POLLUTION REDUCTION STRATEGIES in the FIBERGLASS BOATBUILDING and OPEN MOLD PLASTICS INDUSTRIES

Prepared by:

Darryl Davis, Chairman
Department of Manufacturing
East Carolina University

Assisted by:

Y. J. Lao, Chairman
Department of Environmental Health
East Carolina University

Copyright © 1987
Reprint with permission

This project was supported by the Pollution Prevention Pays Program
through a grant from the North Carolina Board of Science and Technology

Acknowledgements and Notice

Sincere appreciation is expressed to the following individuals who have provided support in the development of this manual: Lori Rosinus, Lab Technician for the East Carolina University Department of Environmental Health; Nathan Wolfe, Graduate Student, East Carolina University Department of Manufacturing; Phillip Hagan, Graduate Student, East Carolina University Department of Environmental Health; Debbie Hathaway, Project Coordinator for the East Carolina University Center for Applied Technology; Sarah McPherson, proofreader, Greenville, NC.; Dr. William Grossnickle, Industrial Psychologist, East Carolina University; Tim Ross, President of Rimcraft Technologies, Inc.; Roger Schecter and Gary Hunt of the Pollution Prevention Pays Program; Terry Gray, Technical Writer, Flanders Filters, Inc.; W. C. Jones, Student, East Carolina University Department of Manufacturing; Hope Kemp, Secretary, East Carolina University Department of Manufacturing; and the North Carolina Board of Science and Technology.

Every effort has been made to insure that information provided in this manual is accurate. However, neither the Authors or East Carolina University takes responsibility for the information contained in this manual. No endorsements are provided or implied for the services or products provided by any companies or individuals mentioned in this publication. Comments which can improve the accuracy or usefulness of this manual are welcomed by the Senior Author and by the Pollution Prevention Program.

Darryl Davis, Chairman
Department of Manufacturing
East Carolina University
Greenville, NC 27858
(919)-757-6705

Roger N. Schecter, Director
Pollution Prevention Pays Program
Dept. of Natural Resources and Community Development
P. O. Box 27687
Raleigh, NC 27607
(919)-733-7015

TABLE OF CONTENTS

INTRODUCTION

Funding for this project, "Development of Cost-Effective Pollution Reduction Technologies for Open Mold Plastics Processing Industries in North Carolina," has been provided by the North Carolina Board of Science and Technology through the Department of Natural Resources and Community Development, Pollution Prevention Pays Program. Mr. Roger N. Schecter of the Pollution Prevention Pays Program felt that efforts should be undertaken to reduce the generation of waste and other pollutants in North Carolina industries. Mr. Schecter and the Board of Science and Technology agreed that open mold plastics processing industries should be given attention in the development of pollution reduction strategies for the state. Concentration on this industry was considered important since the industry operations require use of large quantities of liquid resins and produce considerable quantities of contaminated solvents.

Open mold fabricators utilize a number of materials and processing strategies which make knowledge of environmental regulations and appropriate waste management strategies essential to the survival of their companies. The materials used include styrene based polyester resins, methyl ethyl ketone peroxides, acetone, as well as other solvents and specialty chemicals. Since resins are often applied through an atomization process, air quality in and outside the facility is a major concern. Special attention must also be focused on proper inventory and controlling of materials which are purchased, stored, used, and disposed of by the firm.

Information presented in this manual is based on a number of sources. Federal and state regulations were reviewed. Interviews with regulatory compliance inspectors were also conducted. Much of the content was developed as result of numerous in-plant visits and observations, as well as telephone interviews with a number of fiberglass fabricators. Firms engaged in production and marketing of processing equipment and supplies for the industry provided valuable information and many useful leads.

CHAPTER I

AN OVERVIEW OF THE INDUSTRY

A. Products

Open molding of thermosetting plastics is carried out in a variety of North Carolina firms. Some of these companies operate facilities which are dedicated almost exclusively to the production and marketing of molded components such as boat hulls, cultured marble bath fixtures, bathtubs, large storage tanks, and vehicle body components. Other firms may accommodate open molding only to the extent of producing accessories or parts for the more complex products which are assembled in their facility.

Open molding firms are an important element of North Carolina's economy. Several thousand residents are employed in jobs that are directly related to the production of open molded plastic products. Facilities may range in size from local one or two man operations to nationally and internationally recognized organizations which employ more than 1,000 people. Most of these firms employ far fewer than 100 people in daily plant operations. Plants are located in all geographic regions of the state. Many facilities are finding the economic climate conducive to expansion and the number of new facilities continues to increase.

North Carolina should continue to attract open molding industries. These firms find that a skilled and unskilled workforce is available. The moderate climate is well suited to the requirements for processing thermosetting plastics such as polyesters. Since many open molding firms are already located in the state, a good network of equipment and materials suppliers is already well established. Transportation systems for delivery of processing materials and shipment of products are good. North Carolina also has an excellent market for many of the goods produced by the industry. The state is geographically situated so that shipment of products to the heavily populated Northeast and the rapidly growing Southeast is relatively fast and inexpensive. The available waterway transportation is particularly important to boat manufacturers who must ship finished yachts that are too large to transport by truck or rail.

Open molded products produced in North Carolina are highly varied in nature. There is a large and very well established group of fiberglass boatbuilders in the state. Their products range from small creek boats to yachts as large as 77 feet. The traditional fine wood and upholstered furniture industry in the state has expanded to include the development of production facilities for molded furnishings ranging from restaurant seating fixtures to lawn and garden furniture. An expanding demand for durable outdoor fixtures and corrosion resistant industrial equipment is contributing to the growth of open molding operations involved in producing such specialty products as architectural panels, heat exchanger components, floating pier modules, machinery housings, and large storage tanks.

Growth in open molding operations will probably continue during the next several years. A wide variety of products can be produced through the process.

These products can be engineered to meet a variety of application demands, particularly when requirements include high strength, low weight, environmental stability, corrosion resistance, weather resistance, or long life. Demand for these types of products is likely to increase. Start-up and product changes for many of these industries is less expensive and less time consuming than for most other basic types of material processing. For small products and limited productivity the investments required for facilities, tooling, and equipment is low enough to attract the interest of large and small firms.

B. Fabrication Processes and Facilities

Although the composition, shape, and size of open molded products can vary significantly, many basic fabrication requirements change very little. For products with a smooth durable finish a mold which is smooth and highly polished is required. A gel coat resin will be applied as the first step in the lay-up. Both male and female molds may be used (see Figure 1.B.1). Polyester resins are used in most gel coats and for most lay-ups. Fillers are generally added in the form of fiberglass reinforcing, and in some cases to thicken and extend the resins. In most production systems delivery of resin is accomplished through spraying. Fiber reinforcing may take the form of roll stock or short chopped fibers which are sprayed in with the resin. Where fiber reinforcing is used, some hand rolling is almost essential for removing voids and insuring proper integration of resin and reinforcing material. Some specific aspects of processing may vary significantly.

Some variation in processing can be expected because of the diversity of products produced. Approaches to molding a cultured marble bathroom counter and sink are different than the approaches used to mold a fiberglass boat hull. Approaches to producing basically similar products can also vary significantly because of differences in facilities and the organization's production concepts. Where high production outputs are required, larger companies can develop facilities which have specific areas for each unique operation. Smaller organizations frequently are forced to perform a variety of operations within the same production area. Resources for equipment, facility improvements, and efficient management of pollution are frequently a problem for smaller firms.

Physical plant arrangements for most producers consists of one or more open production areas. In open areas where resins are sprayed, a number of exhaust fan outlets are normally provided. The application of these resins leads to potential pollution problems in terms of airborne solids and styrene vapor emissions. To remove these materials exhaust fans are used in most facilities. Even where exhaust systems are provided, there may be problems with design strategies as related to control of air flow. In many cases flow patterns are such that relatively clean plant air is inefficiently turned over while a poor job is done in ventilating areas where air contamination is high. Open molders must also deal with other potential pollution and safety problems in terms of hazardous materials storage, contaminated solvents, waste disposal, highly flammable liquids and vapors, and dust.

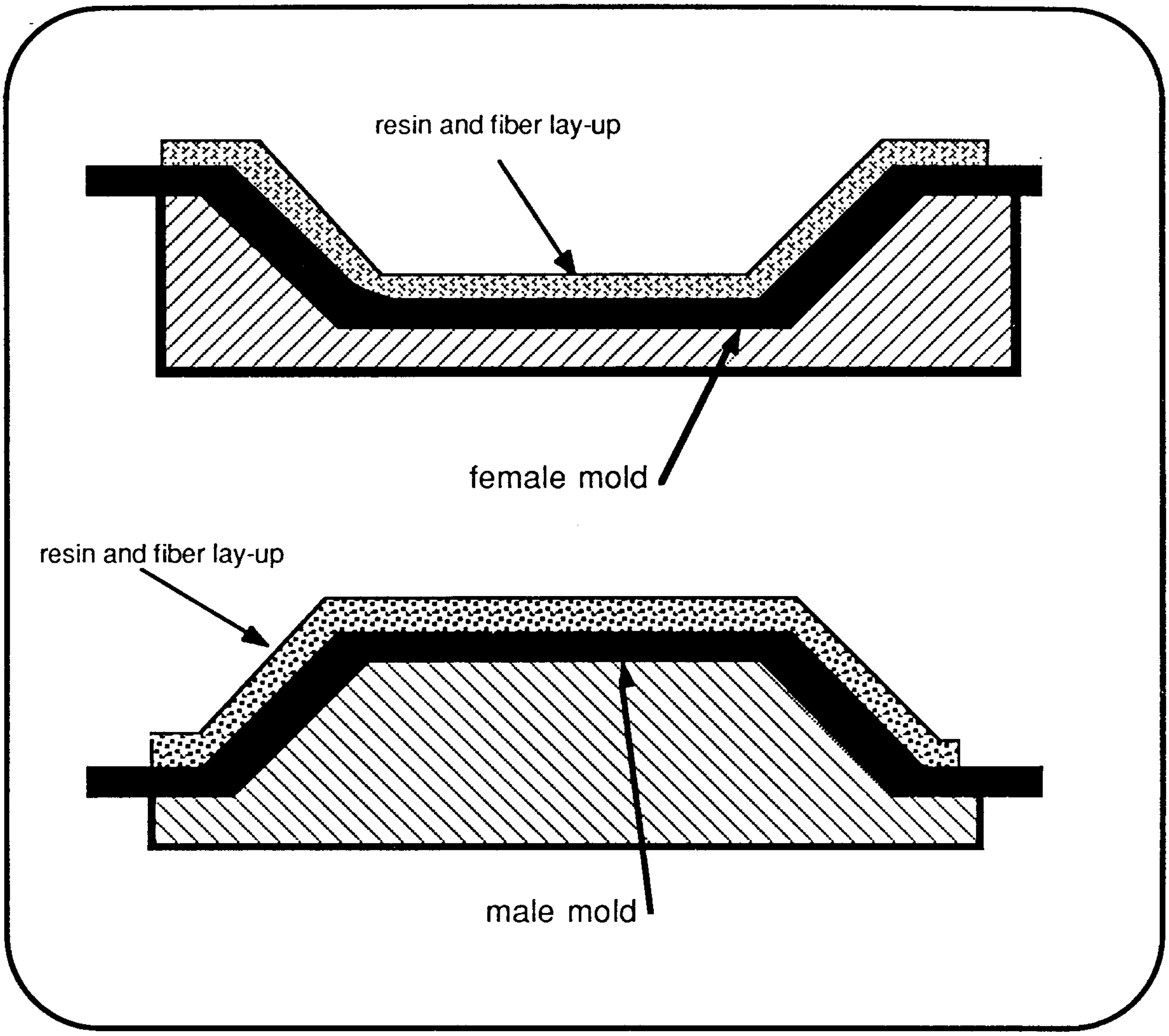


Figure 1.B.1 Open Mold Configurations

C. Establishing Pollution Reduction Strategies

Because of the products used in mold fabrication, the industry can expect increased emphasis on safety and pollution reduction issues. Federal and state regulations are undergoing constant revision in terms of new approaches to managing potentially hazardous materials, atmospheric emissions, and worker safety. Implementation of pollution reduction strategies is often an outgrowth of problems created by these regulatory and enforcement demands. Managers should be aware of these regulations and health standards when they select materials for processing and when they develop production processes. There must also be concern for the health of workers as well as the health of the environment. Producers have also found that some pollution reduction strategies are actually cost effective. A number of these strategies are reviewed in this manual.

In establishing a pollution reduction program a firm must be willing to take a long term view of managing resources. In many cases the approaches to facility and process development in the open molding industry can be categorized as being shortsited. Operations may be set up in open general purpose structures with little regard for anything other than basic lay-up and secondary finishing. Many pollution related problems, created by these approaches, can be minimized through refining basic production and facility design. Profitable pollution reduction approaches are developed when careful attention is paid to refining material flow patterns, conserving materials, conserving utilities, separating incompatible operations, and inventory control.

Planning ahead will be essential to the survival of the industry. The materials used in the open molding process are under constant scrutiny by health and environmental agencies. There seems to be little doubt that future regulations regarding in-plant and out-of-plant air quality, worker exposure, and waste storage will get tougher. Processing equipment and facility designs should be selected with potentially tougher regulations in mind. Where possible, alternate materials and processing approaches should be explored. At a minimum, existing facilities and equipment should be fine tuned to bring potential environmental problems under control.

CHAPTER II
ARE POLLUTION REDUCTION CHANGES NECESSARY?

A. Economic Factors

1. Economics

Profits from investments and operations, along with equity, are major concerns for all businesses and investors. In the open molding industry, the demands of managing a profitable business are complicated by the need to cope with a number of potential worker safety and environmental pollution problems. Management and investor frequently view compliance with pollution regulations and workplace safety requirements as being costly and counterproductive. There is little doubt that strict environmental regulations have resulted in costly changes involving basic production techniques, auxiliary equipment for pollution reduction, and management strategies.

In many cases, environmentally sound approaches to managing processing hazardous materials can lead to cost savings. A number of the case studies and examples included in this manual demonstrate that pollution reduction strategies do not always have a detrimental effect on profits and productivity. In many cases pollution reduction strategies have provided a quick return of investment and have actually increased profits.

When calculating the overall effects of implementing a pollution reduction strategy, it is often difficult to get a clear picture of the actual costs and benefits of all available alternatives. The following factors must be included in order to obtain an accurate analysis: capital equipment, equipment operation, virgin solvent, transportation of virgin solvents and waste solvents, hazardous waste disposal, fees for obtaining any required permits, and legal liability.

2. Governmental Incentives

A number of incentives for implementing pollution reduction strategies are provided by the State of North Carolina, the Federal Government, local governments, and private agencies.

a. Incentives are offered by the State and Federal Government to:

1) Help insure that noncomplying companies do not enjoy a competitive advantage over complying companies;

2) Provide relief to industries forced to implement expensive changes in order to comply with pollution or cleanup requirements; and

3) Encourage compliance with state and federal pollution abatement requirements:

b. Selected North Carolina incentives currently in existence include:

1) Exclusion from local property tax on property used to recycle or provide resource recovery of solid waste;[1]

2) Tax Exempt Industrial Development and Pollution Control Bonds which meet certain criteria and are approved by appropriate local and state authorities;

3) Sixty-month amortization on costs of property used for recovery of solid waste;[1]

4) Reduction of franchise tax for cost of property used for recovery of solid waste;[1] and

5) Matching funds grants available from the Pollution Prevention Pays Program for implementing pollution prevention projects. See Appendix F for additional information.

c. Other potential incentives include:

1) Incentives offered by local governments or industrial development agencies for the purpose of attracting or retaining industries;

2) Payback of investment and/or a satisfactory profit on the investment;

3) The need to maintain and enhance the status of the company in the eyes of the community and customers; and

4) Limiting unforeseen long-term liabilities

Incentives are constantly changing. Information should be sought from local agencies, state governmental agencies, federal agencies, tax specialists, and suppliers of pollution reduction equipment and services.

B. Regulatory Factors

According to the code of federal regulations, all industrial installations are legally obligated to properly handle, ship, store, and dispose of hazardous materials and waste. In addition, there are regulations specifically issued for the protection of employees in the workplace. A few important regulations are listed in Table 2.B.1.

Clean Water Act
Clean Air Act
Resource Conservation and Recovery Act
Toxic Substances Control Act
Occupational Safety and Health Administration-Act
The Occupational Safety Communication Act
Comprehensive Environmental Response Compensation and Liability Act

TABLE 2.B.1 POLLUTION AND SAFETY RELATED REGULATIONS

1. Regulated Materials

In order to know what materials are regulated by governmental agencies, the regulation under which the material is governed should be specified. However, in fiberglass molding industries, since the process only involves a small number of compounds, materials which have the potential to be hazardous either for human health or for the environment can easily be identified. A brief description of the most important ones are:

a. Styrene

Although the bulk of polymer used is styrene-polyester, only the properties of styrene are described here. Styrene is a colorless liquid with a sweet aromatic odor at low concentration. At higher concentration, the odor becomes sharp and disagreeable. Styrene vapor is 3.5 times heavier than air. The flash point of styrene is 90 degrees F. If polymerization inhibitor is not present in sufficient concentration, styrene can polymerize and explode in its container. Styrene will corrode copper and is not compatible with oxidizing agents, strong acid, and catalysts for vinyl polymers. Styrene is known to affect the central nervous system. It has also been implicated with other effects such as peripheral neuropathy, skin disease, and abnormal pulmonary function. It may be considered to have liver toxicity, teratogenicity, and carcinogenicity.

b. Methyl Ethyl Ketone Peroxide

Methyl ethyl ketone peroxide (MEKP) is used as a catalyst and is a potential explosive hazard. It is a clear, colorless liquid with a slightly pungent odor. MEK has a flash point of 185 degrees F. It is incompatible with very strong acids, bases, and oxidizers. It is an irritant for the skin and nose and can cause blindness. It also affects the lungs and central nervous system.

c. Acetone

Acetone is used as a general solvent for cleaning purposes. It is a colorless liquid with a fragrant, mint-like odor. Acetone has a flash point of 1.4 degrees F, and it is incompatible with acids and oxidizing materials. Acetone is an irritant for the eyes, nose, throat, and skin. It is also a central nervous system depressant.

2. Environmental Impact

Application of science and technology in the manufacturing industry can produce wastes and pollutants. Without proper control and treatment, these materials are a threat to the continued survival of the animal and plant communities of the ecosystem. Eventually, they may also threaten the existence of the human community. For a conscientious company, environmental concerns should be addressed with respect to the discharge of pollutants into the air or nearby rivers and streams. In addition, proper disposal of waste on the land should also be assured. Because air pollution, water pollution, and the accumulation of hazardous and toxic waste have created conditions which have adversely affected environmental quality, federal and state governments have promulgated regulations for the prevention of environmental degradation. A severe penalty and possible imprisonment can be imposed under these regulations (State agencies are listed in Figure 2.B.1). The state agency which is responsible for the enforcement of environmental legislation in North Carolina is the North Carolina Division of Environmental Management, Department of Natural Resources and Community Development. The laws are listed in "North Carolina Environmental Management Laws," which was issued by the above mentioned Department (Publisher: The Michie Company, Charlottesville, Va.).

3. Work Environment and Worker Protection:

In addition to the outside environment, which deals with factors related to environmental quality, there is another part of the environment in which people work, i.e., the work environment. Because the emphasis on worker protection is different from that of environmental protection, regulation and standards are also different.

In order to protect workers with compensation if they were injured, worker's compensation laws were passed by many states. The laws not only provide work accident victims with reasonable income and benefits, they also encourage employer interest in reducing work accidents and human suffering. One of the most valuable features of these laws has been the stimulus given for the prevention of occupational diseases and injuries. Since rates charged for worker's compensation insurance coverage usually depend on the accident experience of the company covered, it is financially wise for a company to promote worker safety with a strong safety program.

Departments And Boards Which Currently Regulate Hazardous Materials In North Carolina

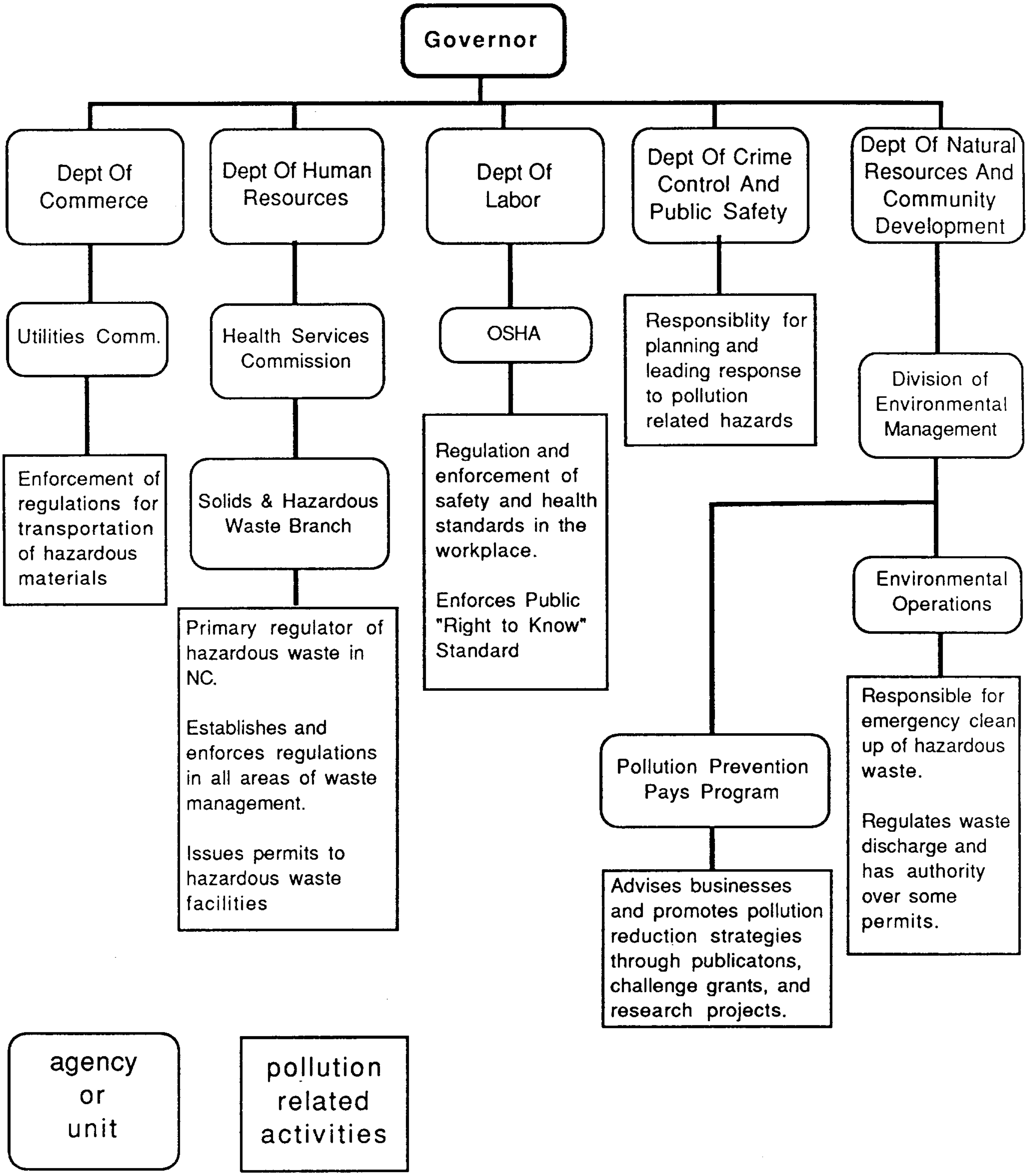


FIGURE 2.B.1

A federal law which has a direct and positive impact on the work environment is the Occupational Safety and Health Administration act (OSHA). In North Carolina OSHA is administered by the North Carolina Department of Labor. Under the act, a company must comply with OSHA standards for the industry, keep records of work related injuries, illnesses, and deaths; and keep records of exposure of employees to toxic materials and harmful physical agents. Furthermore, employers must have a hazard communication program based on the North Carolina Occupational Safety and Health Hazard Communication Standard. The employer can be penalized for failure to comply with these laws.

C. Liabilities

1. Legal Concerns

Long-term liability may be the most important factor in the decision making processes which relate to pollution reduction strategies. This is true when considering worker safety as well as the relationship of materials and processes to the environment. The Resource Conservation and Recovery Act (RCRA) "cradle-to-grave" philosophy, as well as lawsuits being carried out under Comprehensive Environmental Response Compensation and Liability Act (Superfund), should attract the attention of management in the open molded plastics industry. Even companies who legally and properly disposed of hazardous waste in the past are now having to absorb cleanup costs for those materials. Lawsuits have forced companies to pay the cost of removing their wastes from licensed landfills and disposing of them in a manner that meets current standards.

Hazardous materials and processes create a number of concerns regarding worker health and safety. Existing and emerging regulations must be considered when selecting equipment, designing production processes, and choosing materials. Chemicals used in resins and solvents, along with dust created by grinding operations, make the open molding industry a prime target for lawsuits related to long-term worker health.

2. Limiting Legal Liability

Under present state and federal laws the generator of a hazardous waste is never relieved of the responsibility for that material. Obviously, the best approach to limiting long-term liability is to avoid using hazardous materials and generating hazardous waste. Operations which do not use hazardous materials or generate hazardous waste have no liability. Where production of hazardous waste or the use of hazardous materials cannot be avoided, strategies should focus on reducing the volume of those materials. Decreasing the volume will also reduce the magnitude of the long-term liability because environmental effects are frequently related to waste volume.

Processes such as in-house recycling decrease liability when compared to approaches that involve shipment of hazardous wastes. The maximum liability exposure for disposing of waste would appear to be consigning waste to a hazardous waste landfill. Development of production approaches which can eliminate or substantially reduce the quantity of hazardous materials used, or generated as waste, is not always possible. Where hazardous materials cannot be eliminated, an affirmative action approach to waste management, air and water discharge, and worker safety is essential to reduction of long-term legal liabilities.

3. Legal Disincentives

Regulatory agencies and legal statutes provide a number of disincentives for failure to insure worker safety and health and for improper or poor waste management. There are many civil penalties for noncompliance or negligence. In some cases negligent actions or inactions can lead to criminal charges and possible imprisonment. Regulations and penalties as disincentives include policies which prohibit the EPA from approving or recommending to private parties any facilities that have Category 1 violations. North Carolina also follows this procedure. Regulatory policies also require that penalties for noncompliance be large enough to offset any economic gain from noncompliance. Owners or stockholders are directly affected since penalty expenses for violations are not tax deductible.

D. Psychological Factors****

1. The Inevitability of Change

Most people are more comfortable with stability than with change. Yet we exist in a constantly changing environment. There are numerous sources in the environment which require that organizations change. Government regulations constantly exert pressures on managers to deal with issues such as environmental concerns, EEOC guidelines and affirmative action plans, and consumer protectionism. Technological advances, such as the increasing sophistication of microchip technology and the increasing use of robotics and automation, require that workflow processes and jobs be redesigned. The increasing industrialization of the non-western world and the interdependence of the world's banking system influence marketing and distribution patterns. Finally, changing demographics affect the market for products and are changing the nature of the workforce. For example, the United States is undergoing changing migration patterns and the graying of America. Workers are entering industry with different values than those held a generation ago (e.g., they place greater value on achievement and individualism, and they are less willing to accept orders without knowing the reasons for the orders).

Companies must maintain an organization which might be called world class. If not, the organization will fail since for most organizations competition has become worldwide. Industries which have been considered America's exclusive property have now become dominated by foreign firms. Industry leaders and the

---

By William F. Grossnickle, Ph.D., Industrial Psychologist. Professor, East Carolina University, Greenville, North Carolina.

press typically have blamed the loss of business to foreign firms on the high wages of American workers and our often outmoded plants. We believe that this is an incomplete approach and that other major problems include employee motivation, attitudes, and values. To be a world class organization, a firm and its employees must be adaptive, flexible, and constantly improving. This means that one must never be satisfied with results and that goals must constantly be changing. Managing change, therefore, is not a one-time or occasional thing, but is one of the essential ongoing functions of management.

2. Managing the Change Process and Overcoming Resistance

In managing change one needs to know three things: what the present status is, what the proposed goal is, and how to get from here to there. One must carefully assess one's present state. This assessment requires a careful needs analysis, from organization-wide factors such as job skills and attitudes. Future goals should be stated as explicitly as possible and must be clearly communicated to all concerned. If goals are not clear, the probabilities of successful change are diminished.

When one knows the present state and has a clear idea of the goal, it is possible to determine the appropriate techniques for managing the transition. In choosing techniques, it must be remembered that organizations are open systems. The structural, technological, and human systems are all interrelated. If one is changed, the other two subsystems are likely to change regardless of whether or not that was intended.

In assessing these three issues, there is an underlying assumption made by virtually all change agents: organizations need the full cooperation of their employees. This does not mean obedience or superficial compliance, but the wholehearted acceptance of the need for change, the goals to be obtained, and the methods to achieve the goals. The techniques chosen to move the organization from A to B will be to a great extent determined by the source of the resistances (barriers) which the organization expects to encounter with its employees.

Change has been effectively managed if it follows the four criteria suggested by David Nadler: a) the organization has indeed moved to the desired future state; b) the changes have worked as planned; c) the costs to the organization have not been excessive; d) the costs to the employees have not been excessive.

The remainder of this section will address some of the major barriers to change, how to deal with these barriers, how to maintain the changes which have been made, and how to evaluate the effectiveness of the changes.

3. Barriers to Change

Barriers to change may be based on individual factors, organizational factors, environmental factors, or a combination of these.

Some major individual factors include:

a. **Economic concerns**. If the proposed changes are going to materially change employees' jobs, it is only natural for the employees to be apprehensive about job security and future earnings. If reductions in force are necessary, employees should be told how and on what basis such decisions will be made. If the changes will not directly affect earnings or job security, they must be assured of this fact as soon as possible. This assurance should come from various sources since the employees may suspect management of merely trying to maintain productivity.

b. **Obsolescence**. Employees may fear that they do not have the necessary skills or abilities to deal with the changed situation. Management should inform employees that it will conduct job analyses and provide the necessary training so that employees will have the skills to perform successfully.

c. **Insecurity**. Most people fear the unknown. Management must communicate the details of the present change as well as the need for future improvements. Management must help employees realize that their jobs are more secure in an adaptive organization than in a stagnant one.

d. **Conflicting values**. Any change must be consistent with the underlying values of the organization or employees will resist the change either overtly or covertly. For example, if the leaders of an organization try to change to a more participative style of management and the subordinate managers and employees prefer a more autocratic style, the change will probably not be successful. As another example, Quality Circles require that supervisors be willing to share power with subordinates. People in supervisory positions may not wish to share power with subordinates and may undermine these efforts.

e. **Social disruptions**. People get a great deal of satisfaction from interacting with their friends at work. Job or organizational changes which alter interaction patterns may result in dissatisfaction and attempts to block the desired changes.

f. **Inertia**. People become comfortable with the usual ways of doing things. It is inconvenient to learn new ways of doing things, and people often become ingenious at defending the old ways. Management must be careful to reinforce the changes, or employees may revert to the traditional procedures.

A few major organizational and environmental factors are:

g. **Threats to power**. Any change which alters the structural and political patterns within the organization is likely to be threatening, especially to managers, and probably will be strongly resisted.

h. **Relationships with other organizations**. Contracts with suppliers, jobbers, customers, etc. may limit the scope of changes which may be made at a given time.

i. **Environmental turbulence**. When the external environment is uncertain, management may feel that changes are necessary but, at the same time, not know what types of changes are required to meet successfully the challenges of the marketplace. The results of such uncertainty are apparent in the personal computer industry.

4. Overcoming Resistance to Change

There are three broad stages in introducing and managing change:

a. **Create feelings of the need for change**. Kurt Lewin used the term "unfreeze" to imply that the current state or situation is not appropriate or desirable. An organization should attempt to motivate people to change. The major thrust of this stage is to give employees the incentive to change. One way to do this is to give them realistic information about the necessity for change. For example, explain what the economic situation will be if the organization does not change, point out goal discrepancies, and explain the effects of the changes on the employees. Well presented information should give the employees concerned a clear picture of the desired state. This information reduces uncertainty which typically is very troublesome to employees. Communications about the changes should be frequent, accurate, and multi-channelled (written, verbal, group meetings, etc.). Top managers must play a key role in establishing the desired state and in communicating this to the employees. In some instances they may play the role of a visionary, as Lee Iacocca did for Chrysler. Organizations often want early employee participation in the change process to obtain and disseminate information about the future. This accomplishes two purposes: employees often have necessary information for setting future goals and their participation helps them buy into the need for change. Because of time or other pressures, coercion rather than persuasion may seem to be the required strategy. Coercion is faster than participation and persuasion, but the organization runs the risk of creating resentment among its employees. Employees may comply but are unlikely to accept the necessity for change, and compliance requires control systems to monitor employee behavior.

b. **Make the transition**. A transition plan must be developed which involves all concerned as much as possible. The plan should include training programs, both technical and interpersonal, to be conducted at the appropriate times. The broad use of participation during this stage trains people to be problem solvers, improves communication among all members, and increases employee involvement. Participation gives employees a sense of ownership of the change process. Participation, however, can be time consuming, and in some organizations managers may be reluctant to share power. Most experts consider some participation to be very desirable, even if representatives from various units, rather than all employees, must be used in the case of large organizations.

Early successes are especially important because they show progress toward the goal and successes are themselves rewarding. Management should reward all desired behaviors, openly and visibly. Managers, especially top managers, are critical here. It is a well-established principle that an organization gets the behavior that it rewards. These rewards need not necessarily be monetary since praise, recognition, and feelings of control over the job are also potent motivators. Motivation may also be increased by listening, encouraging, supporting, and counseling employees.

One should be prepared for problems during this stage. Organizations must be flexible enough to change their plans. Obtaining feedback on progress being made and problems which are occurring should enable the organization to adjust its behavior accordingly.

c. **Lock-in changes**. Lewin called this stage "refreezing." Evaluation should be an essential component of any change process. Management should arrange to get both performance and attitudinal data. It is essential that managers, especially top managers, continue to reinforce the changed behaviors. As managers move on to new projects, they often ignore the changes which have just been made, and subordinate managers and nonsupervisory personnel revert to old practices. It may be advisable to assign responsibility to a senior manager for maintenance of the changes. Recognize that reward structures may have to changed. When innovation is desired, it must be rewarded.

It is hoped that organizations will make ongoing interventions and evaluations so routine that change will not be so difficult in the future. Paradoxically, change should become routine. To summarize, in all change efforts maintain or enhance employees' sense of self worth, listen openly to their concerns and objections, and ask for their help in solving the organization's problems.

CHAPTER III

PRODUCTON-BASED POLLUTION REDUCTION STRATEGIES

A. Air Assisted Airless Spray Guns

1. Conventional Spray Systems

Use of resin spray applicators has become standard practice for most open mold fabricators of fiberglass products. Conventional gun-type resin application systems use either compressed air or high fluid pressures to atomize resin materials. In air spray systems atomization requires the flow of a large volume of air at high pressure (Figure 3.C.1). These systems offer good control over spray patterns but are not well suited for efficient delivery of thick resins such as those used for gel coats and lamination. Airless spray gun systems are designed so that resins are atomized by being pumped at extremely high pressure through an atomizing nozzle.

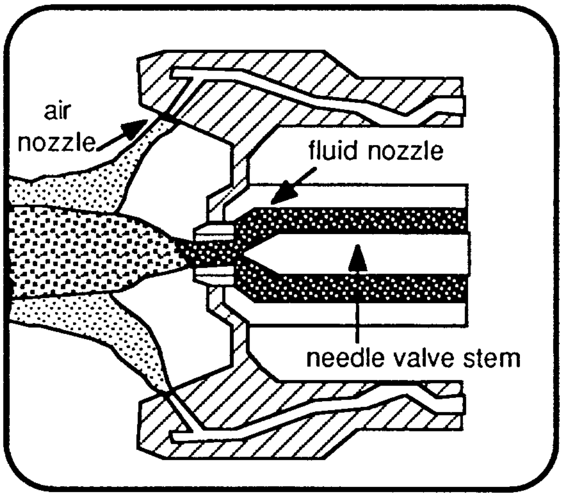


FIGURE 3.A.1 AIR ATOMIZATION

Airless spray guns are considered to be more efficient in delivering resins to the work surface. Large quantities of gel coat and other resins can be rapidly transferred with these systems. For efficient atomization and delivery, pressures in excess of 3,500 psi may be required. These high pressures, while necessary for atomization and spray pattern development, contribute to excessive fogging, overspray, and bounceback during the spray-up process. Recent developments in spray-gun design have resulted in new systems which blend positive characteristics of both air and airless spray guns into one unit.

2. Air Assisted Airless Designs

Air assisted airless guns, like conventional airless guns, utilize high fluid pressures to atomize resins through a spray nozzle. This high pressure nozzle atomization is further augmented by introducing pressurized air into the resin as it exits the pressure nozzle. An example of the nozzle system is pictured in Figure 3.A.2.

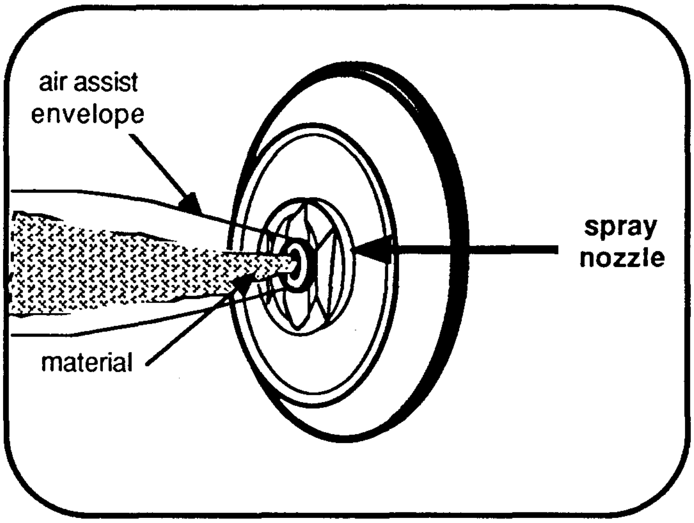


FIGURE 3.A.2 AIR ASSISTED AIRLESS SPRAY NOZZLE

3. Pressure Reduction

Pressures normally used with either air spray guns or airless spray guns may be reduced when using air assisted airless systems. Unlike conventional air spray guns, air assisted airless systems require a very low compressed air pressure at the nozzle. This low air pressure produces an envelope which picks up material dispensed from the pressure nozzle tip. The envelope can be regulated to assist in developing a controllable spray pattern. With low pressure air assist, the fluid pressures required for atomization and delivery pattern development can be reduced by as much as 30%.

4. Potential Benefits

Air assisted airless spray guns can insure that the high volumes of material transfer attainable with airless systems can be maintained while reducing material losses due to excessive fogging, overspray, turbulence, and bounceback. Reduced delivery pressures can help insure that a cleaner, safer, and more comfortable work area is maintained. External emissions and the need for high levels of make-up air may also be reduced.

Quality and productivity need not be sacrificed through the use of air assisted airless spray systems. High volume nozzle and tip designs permit rapid transfer of even thick gel coat resins. The gentle air and pressure atomization allows for the development of spray patterns that offer a high degree of control while greatly reducing the velocity of particles. Application patterns can be made smooth and free of stray tails and fingers.

Lower pressures may help reduce material waste and other expenses. Less energy is required to operate the unit. Lower operating pressures reduce the cost and maintenance of pressure lines and fittings. Lower pressures also reduce wear on pumps, fittings, and controls. Routine cleanup of surfaces in the working environment should be less frequent.

5. Economic Factors

Installation of air assisted airless spray systems does not require extensive modification of the physical facility or the production techniques already in place. Spray guns can frequently be adapted to make use of existing pressure pump and control systems. High capacity air compressors are not required. Attention to nozzle cleaning is essential. Other maintenance and repair procedures differ little from the requirements of other systems. Units are available from a number of suppliers (see Appendix C).

Initial expense may be returned quickly in many applications. Potential for savings is greatest with thicker materials, such as gel coats, where application pressure can be greatly reduced. Payback for lighter materials, such as general purpose resins, will take longer. More of the product will get to and remain on the working area rather than mixing with plant or exhaust air or coming to rest on the floor, walls, and other nearby surfaces.

6. Units in Use

Air assisted airless spray guns have been installed at Grady White Boats in Greenville, North Carolina. Grady White is experimenting with the use of these guns for gel coat applications. The units purchased were installed on existing pump units. The company has noted a reduction in overspray residue in the work area.

Operation of the units did require some operator familiarization. Characteristics of the spray guns were learned quickly by the operators, and no loss in production or quality was noted. Coverage of deep draft, narrow mold openings created some problems. These problems were eliminated through operator training. Overall production performance was judged to be better than conventional airless units with a notable reduction in fogging, overspray, and spray booth build-up.

Case Study No 1

Type:	Air assisted airless spray for gel coat application
Company:	Grady White Boats

Location:	Greenville Blvd. NE P. O. Box 1527 Greenville, North Carolina 27834
Contact:	Jim Hardin, Lamination Coordinator
Phone:	(919)-752-2111
Purpose:	Reduce overspray of resins Reduce cleanup requirements Reduce material consumption Improve gel coat quality
Motivation:	Improvement of air quality Improvement of product quality
Equipment Supplier:	Binks Manufacturing Company 5575 Spalding Drive P. O. Box 920400 Norcross, Georgia 30092 Magnum Industries P. O. Box 1786 Irmo, South Carolina 29063
Payback Period:	Not available
Comments:	Noticeable reduction of overspray and fogging
Source:	Plant visit in June, 1987 and phone conversations with equipment supplier (December, 1986 and March, 1987)

B. RESIN IMPREGNATORS

1. Conventional Material Application Systems

Most open mold fabricators of fiberglass products utilize resin spray applicators for transferring and applying coatings, resins, and fibers to the mold. Conventional gun-type resin application systems use compressed air, high fluid pressures, or combinations of fluid pressure and compressed air to atomize resin materials. Catalysts for the resin systems are normally introduced inside the spray apparatus or as the resins are atomized from the spray nozzle. These systems may also be equipped with glass choppers which chop fiberglass roving into short lengths and propel it onto the molding surface (see Figure 3.B.1).

While spray guns are considered to be efficient in transferring resins to the work surface, extremely high atomization and delivery pressures may be required. These high pressures contribute to excessive fogging, overspray, and bounceback during the the spray-up process. Recent developments in spray gun design have resulted in some improvements, but spray application contributes significantly to the contamination of air in the workplace.

2. Prepreg Fiber Reinforcing

For a number of years fabricators of composite aircraft structures have relied on the use of fiber reinforcements that are presaturated with resins. These materials, referred to as "prepregs," offer a number of advantages over conventional spray techniques. Resin to fiber ratios can be closely controlled; atomization of pollutants is practically eliminated; and cleanup and disposal problems are greatly reduced. These advantages are, however, not enough to make prepregs widely accepted by most fiberglass fabricators.

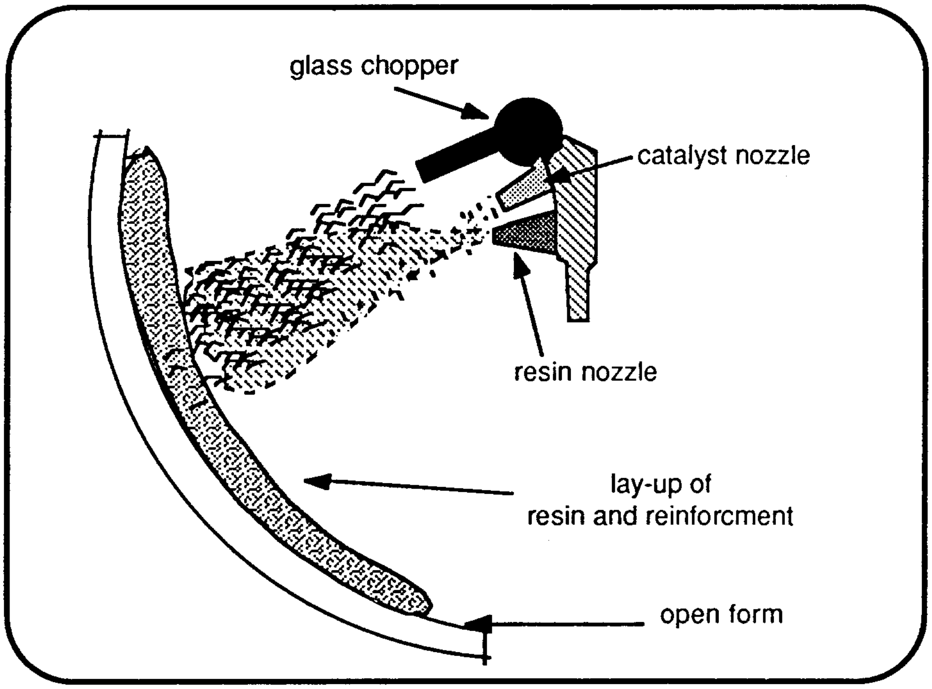


FIGURE 3.B.1 FIBERGLASS SPRAY-UP SYSTEM

Prepregs are generally formulated with more expensive epoxy based resins which require placing the mold in an oven or autoclave to complete the cure cycle. These more expensive resins are normally combined with exotic, high strength reinforcing materials, such as graphite fibers. Storage is also a problem since the materials must remain refrigerated until the lay-up process is begun. Prepregs appear to be best suited for applications where extremely high strength-to-weight-ratios are required and cost factors are secondary.

3. In-House Resin Impregnation

Equipment is now available to provide the fabricator with some of the advantages offered by prepregs while using lower cost polyester resins and fiberglass materials. Impregnators can be placed within the lamination area of a plant and be mounted in such a manner as to feed resin saturated reinforcing materials directly to the molding operation. Conventional resin pumps and catalyst metering devices supply resins to a roller-reservoir system. Woven fiberglass is impregnated as it passes through this reservoir system. A schematic of the system is pictured in Figure 3.B.2.

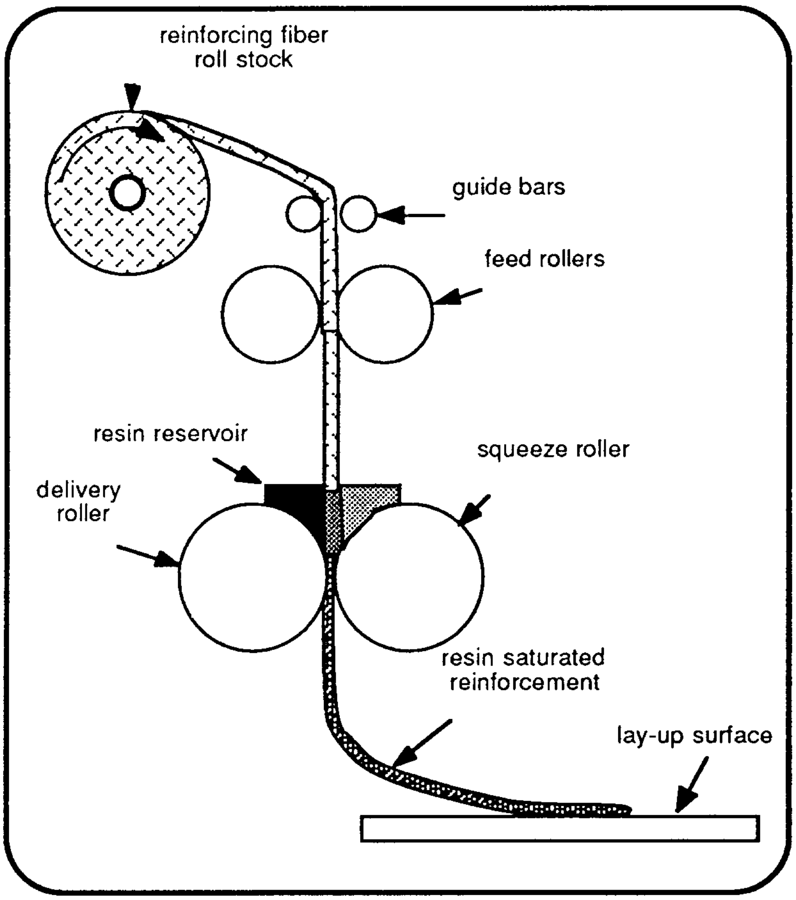


FIGURE 3.B.2 IMPREGNATOR SYSTEM FOR FIBERGLASS

Impregnators can be designed to fit a variety of potential applications. The units can be mounted to overhead track and lift systems, over stationary conveyor fed lines, on bridge cranes, or on portable carts. Conventional resins and roll fiber materials can be used. Machine size and capacity can be engineered to provide a variety of output feed rates and to accommodate a number of roll widths. Units currently available can produce as much as 20 linear feet per minute with resin-to-glass ratios controllable to within $\pm 2\%$. Larger units have an output capacity which can exceed 1,000 pounds of laminate per hour with a 50% glass content.

4. Potential Benefits

Impregnators would appear to have considerable potential for the reduction of pollution associated with open molding operations. Delivery of the resin to the reinforcing laminate by means of an impregnator would help insure that a cleaner, safer, and more comfortable work area would be maintained. Since there would be no spray atomization of resins, the levels of in-plant and external emissions would be minimized. At the same time, requirements for high levels of make-up air and elaborate air handling systems would be minimized.

Application potential for impregnators appears to be highest for users of roll type materials who are either large volume producers or fabricators of large components. Facilities whose molds are widely scattered throughout the plant and are used to produce only one product per day will have difficulty in providing expensive units for a variety of areas or in moving units to a number of locations. Fabricators who can consolidate production lay-up facilities can use a single machine to feed operations on a number of smaller molds, while fabricators of large components can use a single machine to rapidly deliver large quantities of materials.

Quality and productivity may be improved through the use of resin impregnation systems. High volume delivery rates can speed lay-up of large components and lead to the development of an assembly line approach to molding smaller components. Impregnators insure a high degree of control of fiber-to-resin ratios and catalyst-to-resin ratios. Worker productivity may also be expected to improve because strenuous rolling operations are reduced and air within the working environment will be less contaminated.

5. Economic Factors

For many fabricators, installation of impregnator systems may require extensive modification of the physical plant and production techniques. The units are more expensive than existing spray applicators, but their per unit output can be considerably higher. Use of impregnators by builders of small boats would appear to be economically feasible only if the facility could be arranged so that the molds are handled in an assembly line manner, or situated so that one machine could be easily positioned to feed a number of molds. Impregnators merit attention from any company planning new facilities or major changes to existing facilities. Builders of larger components, such as large boat hulls or tanks, may be able to use impregnators with little change in plant facilities. Maintenance and repair requirements would appear to differ little from the requirements of conventional spray systems. Units are available from suppliers identified in Appendix C.

Initial expense may be recovered in many applications. Potential for savings is greatest where operations demand the production of large volumes of resin saturated roll stock. Small volume producers are not likely to find great use for currently available systems. Payback potential lies in five areas: (1) increased output of saturated laminates, (2) more efficient use of materials, (3) improving existing processing strategies, (4) improving laminate quality, and (5) reducing the need for elaborate air filtration and other pollution control systems.

6. Units in Use

Impregnators are in use at Bell Halter Marine in New Orleans, Renaissance Creations in Atlanta, and Syntechnics Inc. in Paducah, Kentucky. Typical applications include the construction of hulls of Navy minesweepers, production of barge covers, and fabrication of large architectural panels. Most impregnator units are used in the production of large components, including some structures with weights of several tons each.

Case Study No 2

Type:	Venus Impregnator
Company:	Syntechnics Inc. .
Location:	700 Terrace Lane Paducah, Kentucky 42003
Contact:	Teddy Hold, Plant Manager
Phone:	(502)-898-7303
Purpose:	Reduce spray-up requirements Reduce plant cleanup requirements Reduce material consumption Improve production of large components
Motivation:	Maintenance of air quality Production improvement
Equipment Supplier:	Venus Products, Inc. 1862 Ives Ave Kent, Washington 98032
Payback Period:	Not available
Comments:	Several units are used in the production of large barge covers
Source:	Phone conversations with plant manager (May,

1987) and with equipment supplier (December, 1986 and March, 1987)

C. Resin Roller Dispensers

1. Sprayless Application Systems

While use of spray delivery of resins has become standard practice for most open mold fabricators of fiberglass products, alternative application processes do exist. Conventional gun-type resin application systems are efficient in delivering large quantities of resins to the work surface. However, even the most efficient spray systems tend to create considerable fogging, overspray, and bounceback of resins during the the delivery process. Other delivery techniques merit consideration. Prepreg materials and in-house impregnators (as discussed in Unit B of Chapter 3) may be useful to some large scale fabricators; however, for the smaller user, resin transfer rollers might prove to be a viable option.

2. Resin Roller Dispenser Designs

Resin roller dispenser units utilize a fluid pumping system to draw resins from drums or bulk distribution lines. This pumping system also includes a separate, fully adjustable catalyst pump. Resin and catalyst are precisely metered and pumped to a gun-type head for mixing. The gun head is essentially an internal mix airless spray gun without an atomization nozzle. The atomization nozzle is replaced by an attachment which directs the catalyzed resin to an attached roller.

Units which attach to existing spray gun heads or other feed systems are available. A flexible material hose is attached to the mixing chamber of the spray gun. This hose will feed resin directly to the roller dispenser. Resin is dispensed directly onto the roller surface through a perforated T-bar. An example of a roller dispenser system is pictured in Figure 3.C.1.

3. Resin Delivery

The high pressures normally associated with the use of either airless spray guns or air assisted airless guns are not required. Since atomization is not required, resin delivery pressures may be well below 100 psi. Pressures are normally regulated for the purpose of controlling the rate of resin delivery. Catalyst flow rates are precisely tied to resin flow to insure a high level of control over catalyst-to-resin ratios and cure rates. Delivery rates for catalyzed resins may be as high as 20 pounds per minute.

When the roller is not required, it can be removed to allow catalyzed resin to be deposited directly in the work area. Units can be mounted to wall fixtures or portable carts. The roller handles are normally adjustable in length to allow for a variety of working requirements. As the operator rolls out the reinforcing materials, he can trigger a gun-type control to distribute resin as needed. The operator will not have to change tools as often when switching from resin application to roll out operations.

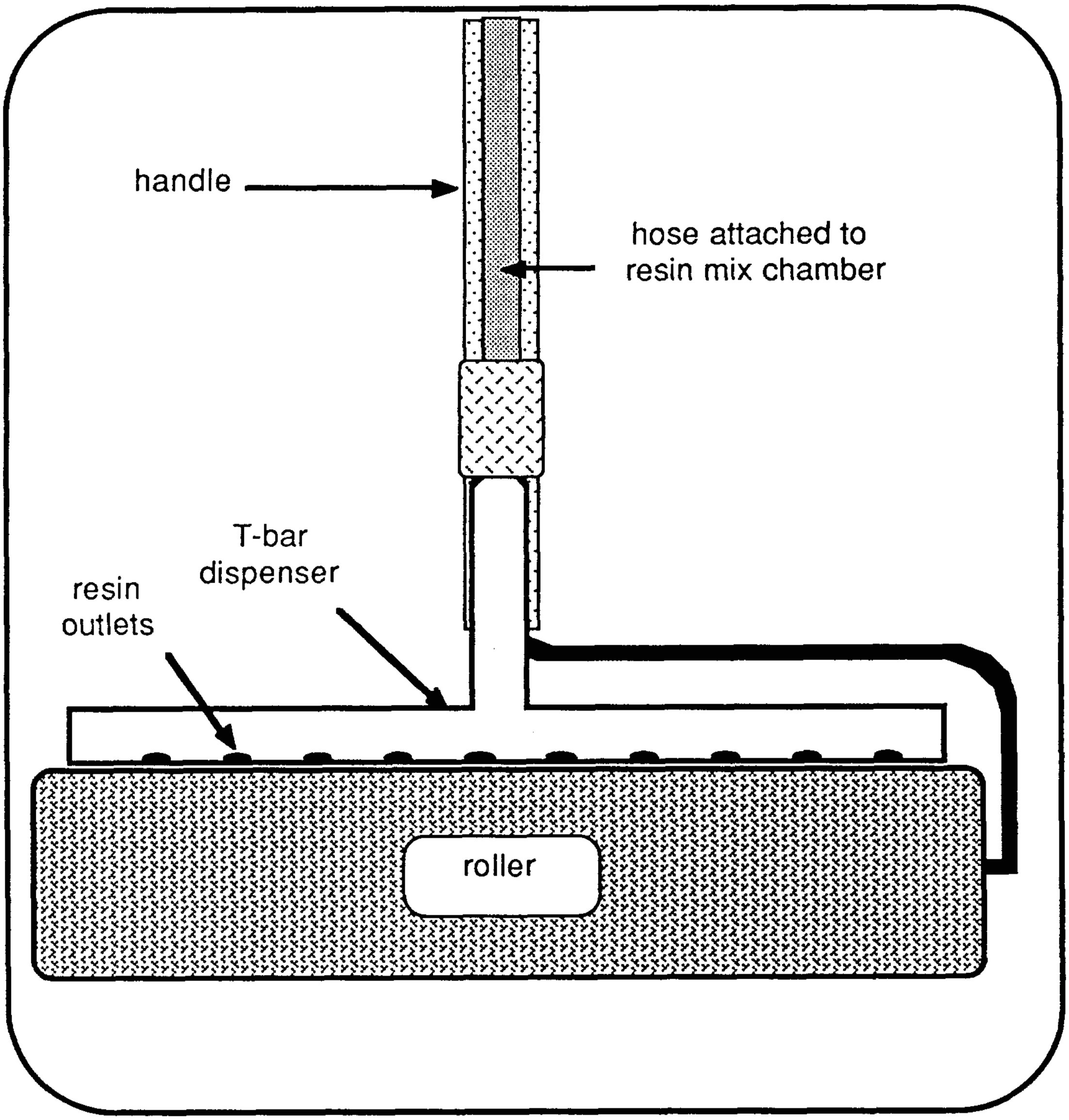


FIGURE 3.C.1 RESIN ROLLER DISPENSER ATTACHMENT

4. Potential Benefits

Resin roller dispensers can transfer catalyzed resins to the molding surface while reducing material losses due to excessive fogging, overspray, turbulence, and bounceback. The low delivery pressures required can help insure maintenance of a cleaner, safer, and more comfortable work area. External emissions and the need for high levels of make-up air may also be reduced.

Quality and productivity needs of the firm must be evaluated. Volume of delivery and area of coverage for these systems may not be as high as for conventional spray units. Speed would appear to be best where lay-ups are typically high in terms of resin content.

Resin delivery without atomization reduces material waste and other expenses. Also, less energy is required to operate the unit. Lower operating pressures reduce the cost and maintenance of pressure lines, pumps, controls, and fittings. Routine cleanup of the laminating area should be reduced in terms of frequency and difficulty.

5. Economic Factors

Installation of resin roller dispenser systems does not require modification of the production facility or the production techniques already in place. Some units readily adapt to existing spray gun systems and may make use of existing pressure pump and control systems. High capacity air compressors are not required. Routine maintenance and repair may differ from the requirements of other conventional spray systems. These units must be thoroughly flushed to prevent curing of catalyzed resins inside hoses, delivery tubes, or the mixing chamber. Suppliers of roller dispenser units are listed in Appendix C.

Where facilities are well equipped to deal with air handling requirements associated with spray-up, initial expense is not likely be returned quickly. Potential for application is greatest where environmental concerns are highly significant. These units would allow work in areas where spray systems would create severe pollution problems. These units may be used to permit lay-up in facilities that are not equipped to exhaust large quantities of air from the working environment. Catalyzed resin will be deposited on the working area rather than mixing with plant or exhaust air or coming to rest on nearby surfaces. Units of this type are frequently used in Sweden and Norway because of highly demanding emission regulations.

D. Vacuum Bag Molding

1. Improving Open Mold Systems

Where fiberglass reinforced polyesters or epoxies offer the performance required for a product, the manufacturer must seek out efficient production methods. Open molding spray-up and hand lay-up production techniques offer a number of advantages for firms that produce limited numbers of units from each mold, require rapid start up, and operate with restricted capital for tooling. Open molding per piece costs are high due to labor intensity and limited daily output. Unit 3.E describes a few of the advantages that closed mold technologies may offer for some companies. Because of limited production requirements and/or unique product designs, many fabricators will continue to rely on open mold fabrication. The basic methods used in open molding fabrication have changed little during the past 30 years. Efforts to change open molding processing techniques appear to have gained momentum during recent years.

These improvement efforts have resulted from a number of pressures. Concerns for worker health and safety and for the environment have resulted in development of improved equipment, materials, and processing techniques. New applications, especially in aviation and other transportation fields, have resulted in the development of new lightweight materials that have incredible strength. These materials require changes in basic molding processes in order to assure product quality. Increased competition has also created a need to modify processes so that productivity, quality, and performance are improved.

Firms engaged in the manufacture of high performance composites, such as aircraft components, have been forced to develop many new approaches to open molding. Use of specialized materials such as carbon fiber reinforced epoxy prepregs, exotic core materials, and unique reinforcing fiber combinations has led to the development of innovative tooling, lay-up strategies, and curing approaches. While most fabricators will have little use for the autoclaves required to work with exotic high strength material, other processing strategies such as vacuum bagging appear to have potential for application.

2. Vacuum Bag Molding Processes

Vacuum bag molding processes can be set up to replace many conventional open molding operations. Molds are produced from the same materials and with the same techniques required for production of conventional molds. Resins and filler materials differ little from those used to produce components in conventional open molds. Conventional gel coating operations can also be utilized.

Vacuum bagging is carried out in a sealed mold at room temperature. Processing begins with the application of a gel coat to the surface of the mold. When a high quality finish is desired, a surfacing layer of glass is carefully placed over the gel coat. Glass reinforcing and other materials, such as core stock, are cut to fit and placed in the mold. Catalyzed resin can be sprayed, pumped, or poured over the lay-up. Where multiple layers of reinforcing and/or core materials are used, the resin should be applied so that proper distribution to all parts of the lay-up can be assured. Once the lay-up materials are in place, the exposed area is covered by special layers of plastics which are sealed to the edges of the mold. Before the resin begins to cure, a vacuum is drawn through one or more strategically located ports in the mold or the plastic cover. A cross section of a vacuum bag molding setup is pictured in Figure 3.D.1.

A number of benefits can be derived through the use of vacuum bag lay-up. With the exception of the gel coat, resin delivery can be accomplished without atomization. Labor involved in rolling out air bubbles and distributing the resin is reduced since the vacuum can be used to insure full distribution of resin to all parts of the lay-up. A high degree of control of resin-to-glass ratios can be maintained by carefully controlling the vacuum and by providing a bleeder material to absorb excess resin. Complicated lay-ups of reinforcing core stock can be accomplished in one operation instead of in steps which require that the resins be cured before new layers are added. Product quality and strength are improved since the vacuum removes trapped air and serves as a clamp to insure tight bonding of all materials in the lay-up. The release film, or ply, applied over the lay-up can be smooth or textured to produce a rough, smooth, or patterned surface.

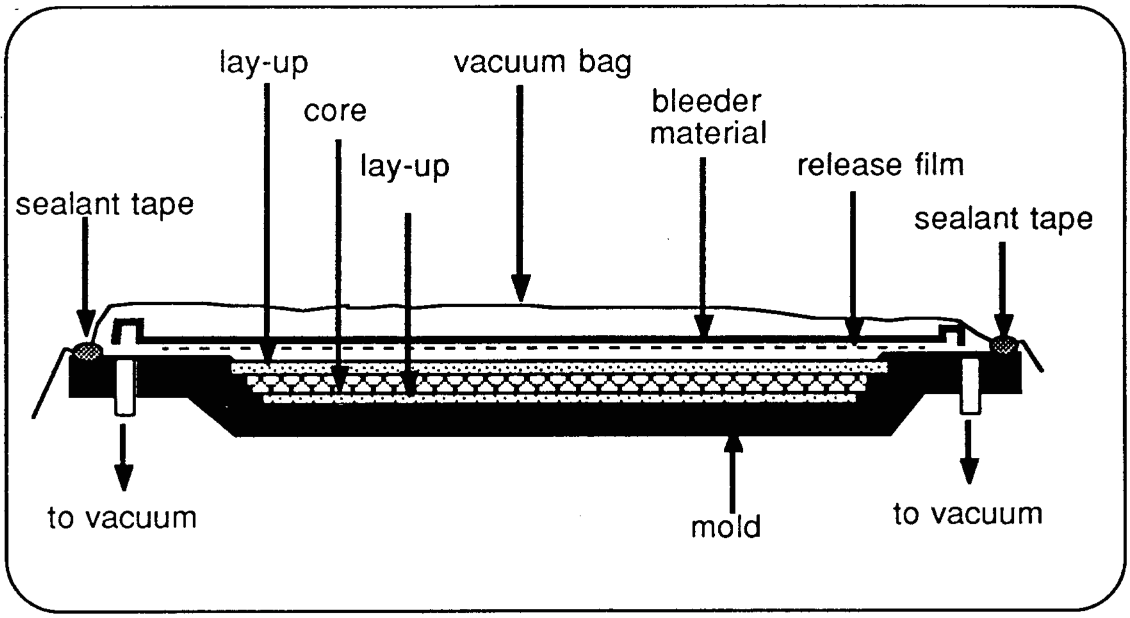


FIGURE 3.D.1 DIAGRAM OF VACUUM BAG MOLDING SETUP

Since vacuum requirements are typically low and curing takes place at ambient temperatures, molds can be made of conventional tooling resins and reinforcements. Molds are laid-up over a pattern in the same manner as those used for open molding. Some specialized tooling may be required in the form of vacuum lines, fittings, and ports. A substantial vacuum pump and manifold system are also required.

3 Potential Benefits

When spray guns are not used to deliver resin to the mold, pollution output can be greatly reduced. Since final distribution of the resin to all areas of the lay-up is largely controlled by the vacuum, gel coating is the only step in vacuum bag molding that requires atomization of resin. Pumping or pouring premixed catalyst and resin into a closed mold eliminates fogging, bounceback, and overspray. Vapor emissions and odor are further reduced by confining the resins in the covered mold until curing is complete. Excess resin can be trapped by bleeder material placed under the vacuum bag. Even dust producing secondary grinding operations are reduced because the closed molding system eliminates most flash removal and edge smoothing requirements.

Quality and productivity may be improved through the use of vacuum bag molding. The molding system produces parts with smooth surfaces and internal structures which are free of voids and excess resin. Open molding may require two or more operations to produce parts with high performance core stock, while vacuum bagging allows the lay-up to be accomplished in one operation. Start up and tooling can be accomplished quickly and economically. . Direct lay-up labor costs may be reduced, and rate of production per mold can be improved. Resins used in in some vacuum bagging operations may have to be designed for the process. With large or complex structures, gel times will need to be extended, and thick lay-ups should use resin systems that will not produce excessive heat. When the application of material can be accomplished within a relatively short period of time, conventional resins may be used.

4. Economic Factors

Vacuum bag molding is probably best suited for intermediate volume production of small to midsize components. Items such as large boat hulls and aircraft wing structures have been produced using vacuum bagging techniques, but large surface areas may be difficulty to cover with lay-up materials before resins begin to gel. Products such as seats, boat hatches, boat deck structures, cored bulkheads, and other items with relatively shallow draft molds are ideal for this type of processing.

Initial investments in vacuum bagging may be returned quickly in some applications. In comparison to open molding, potential payback is greatest where production rates are moderate, high strength and low weight are essential, and the shape of the product is not overly complex. Payback potential is limited when the mold design features deep drafts or complex shapes and demands of quality and strength are only average.

Since most fiberglass processors have limited financing for research and development of new production processes, vacuum bagging is one of the most attractive production alternatives available. The number of vacuum bagging applications is increasing as more processors seek ways to improve productivity, reduce pollution output, and make use of improved materials. Improvements in processing equipment, supplies, and materials are making vacuum bag molding a popular option to conventional lay-up. Suppliers of vacuum bagging supplies are listed in Appendix C.

5. Vacuum Bagging Applications

Vacuum bag molding has been successfully used by Hatteras Yachts in New Bern, North Carolina, and by Fountain Powerboats in Washington, North Carolina. Hatteras uses the process in the production of a number of small parts and for production of floor units and bulkheads for larger yachts. The process is used almost exclusively with high strength-to-weight ratio components which are cored with high performance structural foam. The units produced exhibited outstanding structural integrity and good surface quality.

Floor and deck systems produced by Hatteras are essentially large flat shapes that sandwich several inches of core stock between outer skins of fiberglass reinforced polyester. Many of these units are well over 250 sq. ft. in area. Lay-up of the units is accomplished in one operation, with resin applied both above and below the core stock. Once all materials are in place, they are covered by a release film, a bleeder material, and a vacuum bag which is sealed to the edges of the mold. No gel coat is used on the floor systems since they are covered by finishing materials after installation. For most small parts, molds are gel coated before lay-up is started.

Fountain Powerboats uses vacuum bagging to produce a number of small parts including engine compartment hatch covers. Since boats produced by the company are modeled after high performance offshore racers, careful attention to strength and weight are essential. The engine hatch doors are basically flat panels with rounded edges. They have a high strength structural foam core and a finished thickness of approximately one inch. Each unit is about 12 sq. ft. in area and remarkably stiff, lightweight, and strong.

Case Study No. 3

Type:	Vacuum bag molding Powerboat Engine Compartment Hatches
Company:	Fountain Powerboats
Location:	P. O. Drawer 457 Washington, NC 27889
Contact:	Jeffrey Spear, Director of Quality Control
Phone:	(919)-975-200
Purpose:	Improve product performance Reduce number of operations
Motivation:	Quality assurance Increased production
Equipment Supplier:	Rimcraft Technologies
Payback Period:	Less than one year in comparison to conventional molding and assembly
Comments:	Conventional molding is not well suited for one step lay-up of the high performance materials used.
Source:	Plant visit (May,1987)

E. Resin Transfer Molding

1. Closed Mold Systems

Fabricators who make fiberglass reinforced polyesters the material of choice must carefully consider production methods. Open molding spray-up and hand lay-up production techniques are frequently employed by smaller firms or those who produce limited numbers of units from each mold. Open molding carries a high per piece cost due to labor intensity, limited daily output from each mold, and considerable atomization of resins. Closed mold technologies may offer a practical alternative for some companies. Closed molding operations practically eliminate requirements for atomization of resins and may offer a number of production advantages over conventional approaches to molding. The closed molding technologies most frequently applied to production of fiberglass components are compression molding and resin transfer molding.

Compression molding can reduce high per unit cost, but only if production volume is high enough to sufficiently spread out the high cost of the required matched metal dies. Special molding compounds of resin and reinforcing materials are normally required. The molding compounds are compressed between heated matched molds. Output is high because the molding compounds cure rapidly in the heated mold. Some materials yield a good finish without application of a gel coat. Both surfaces of the molded product will be as smooth as the mold surfaces (see Figure 3.E.1). Compression molding processes have been used successfully in the automotive industry for more than 25 years. Production output requirements for the majority of fiberglass molders do not approach the 150 parts-per-mold-per-shift figure required to reasonably spread out the costs of molds and tooling.

Another closed mold process known as resin transfer molding (RTM) has recently seen a surge of interest. Like compression molding, RTM utilizes matched molds. However, the matched molds do not have to be made of metal, and high pressure mold closing systems are not required. RTM appears to offer many advantages to firms that seek production of 100 to 10,000 parts per year.

2. Resin Transfer Molding Processes

RTM production systems can be set up to replace many conventional open molding processes. Molds can be produced from the same materials and with the same techniques required for production of conventional molds. The molding resins and filler materials differ little from materials used to produce similar components in open molds. Even the gel coat finishes are the same as those produced in open molding.

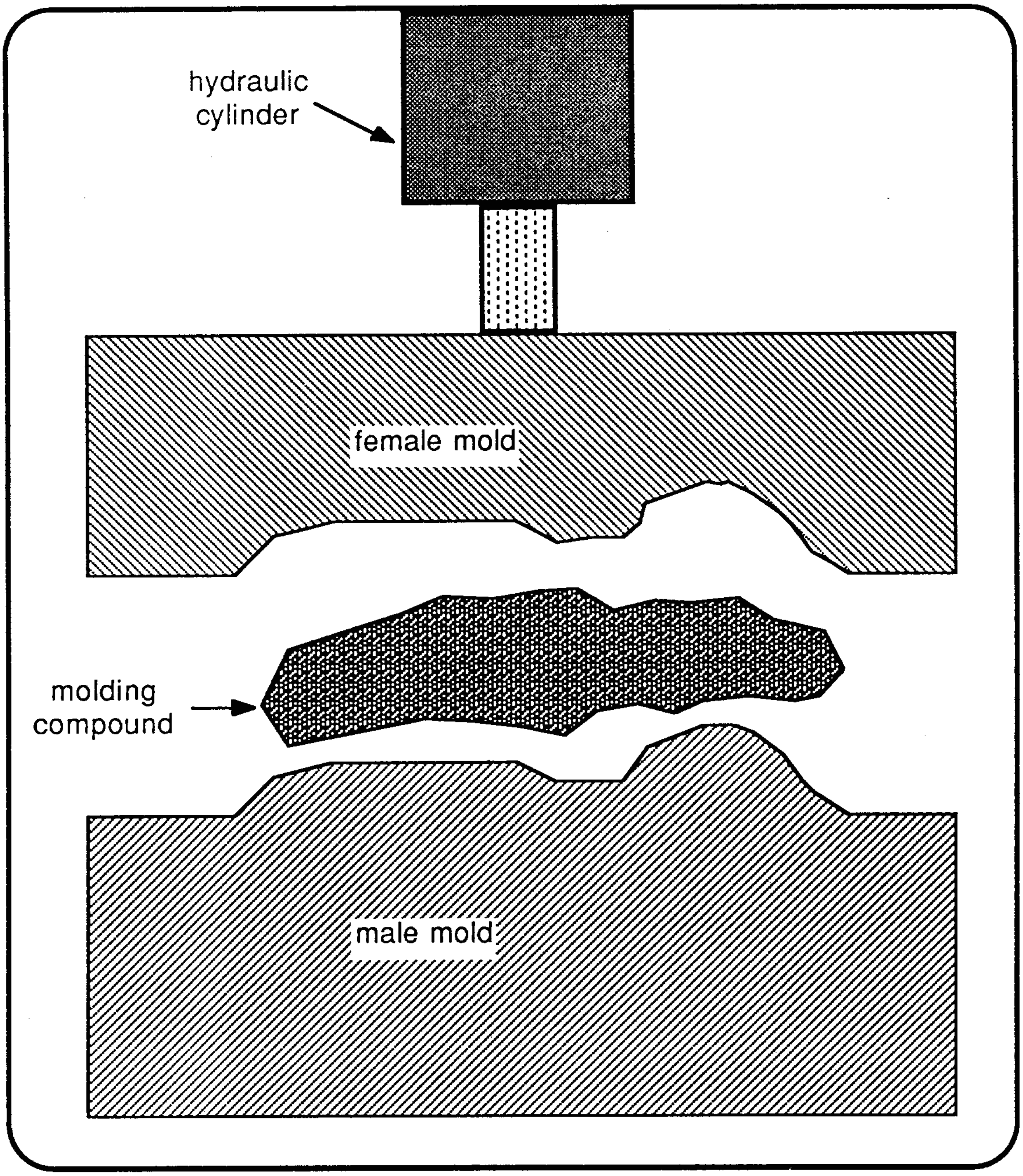


FIGURE 3.E.1 COMPRESSION MOLDING

RTM is carried out in a closed mold at room temperature. Processing begins with the application of a gel coat to one or both sides of the mold, depending on requirements. Glass reinforcing and other materials, such as core stock, are placed in the bottom half of the mold. The mold halves are closed and securely clamped. After the mold is closed, catalyzed resin is injected through one or more strategically located ports. Inlet ports and vents are normally located in the top half of the mold.

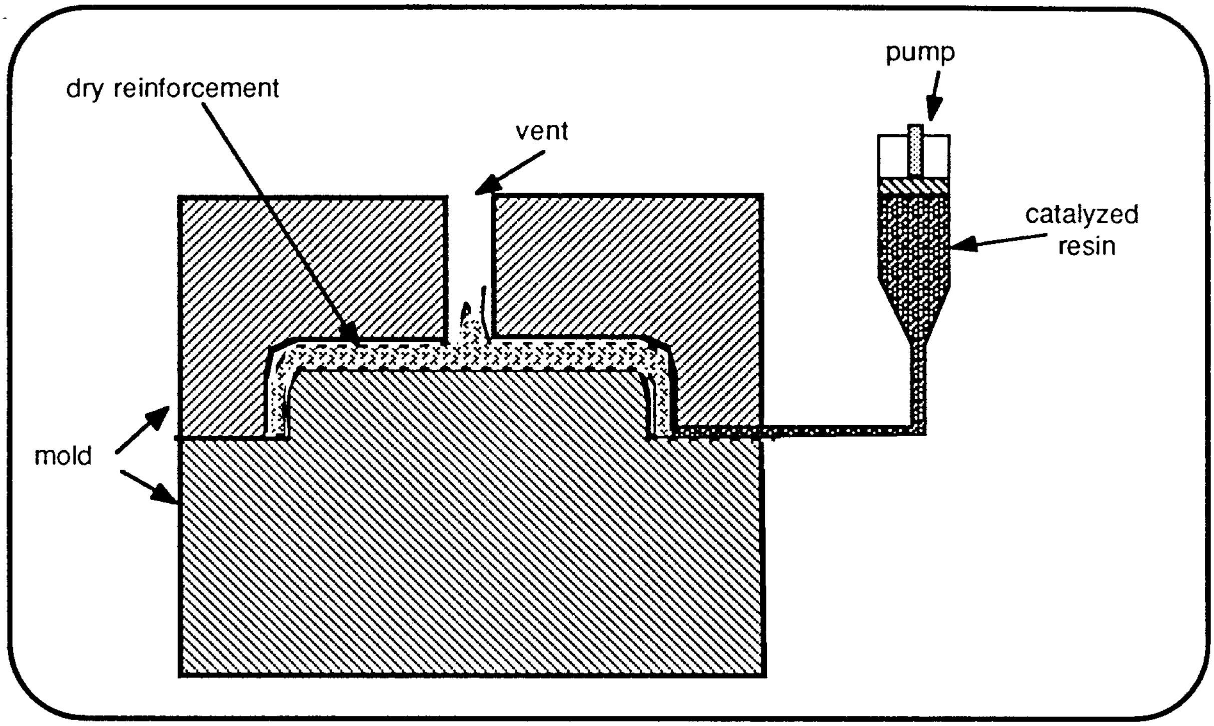


FIGURE 3.E.2 RESIN TRANSFER MOLDING

Since molding pressures typically are between 30 and 75 psi, the molds can be made of plastic based composites rather than metal. The matched molds are laid-up over a pattern in the same manner and with the same types of materials used to produce molds for open molding. Some specialized tooling is required to insure that alignment and clamping pressure are maintained when the molds are closed. The molds must also be properly reinforced to avoid flexing during the injection and curing cycles. Inlet ports and vents must be properly located so that resin is pumped into all parts of the mold. Mold and tooling quality determine the quality of the part. RTM is pictured in Figure 3.E.2.

3. Potential Benefits

Pollution output is greatly reduced since application of the gel coat is the only step in RTM that requires atomization of resin. Pumping catalyzed resin into a closed mold eliminates fogging, bounceback, and overspray. Vapor emissions and odor are further reduced by confining the resins in the mold until curing is complete. There is little, if any, waste of resin. Even dust producing secondary grinding operations are reduced because the closed molding system eliminates most flash removal and edge smoothing requirements.

Quality and productivity may be improved through the use of RTM. The molding system produces parts that can have an excellent finish on both sides. Open molding requires at least two molding operations and secondary assembly work to produce parts with two finished surfaces. Since conventional mold making practices can be employed, start-up and tooling can be accomplished quickly and economically. With complex parts, the lay-up of reinforcing materials, core stock, inserts, and resin can be accomplished in one step.

Low molding pressures required for RTM help reduce many expenses associated with other molding approaches. Less energy is required to operate material delivery units. Lower operating pressures reduce the cost and maintenance of pressure lines and fittings. Wear on pumps, accessories, and controls is also reduced. Routine cleanup of surfaces in the working environment should be needed less frequently.

4. Economic Factors

RTM applications seem best suited for intermediate volume production of small to midsize components. Large items, such as boat hulls, are produced using RTM techniques, but tooling costs per unit are quite high. Items such as restaurant seats, hatches, doors, automotive parts, tubs, and shower units are much better suited to this type of processing. Molds for these products can be kept to a reasonable size and can produce parts that require a minimum of trimming, assembly, and secondary finishing.

Initial investments in RTM may be returned quickly in many applications. In comparison to open molding, potential savings are greatest when production rates are moderately high and the finished component requires assembly of two or more moldings and a good surface on all sides. Payback potential is limited where production is expected to be less than 100 units. In situations where product demands are high enough to require increases in productivity, RTM should be explored.

Since most intermediate volume processors have limited research and development money, RTM applications have increased at a slow pace. The rate of growth is increasing as more processors seek ways to improve productivity and reduce pollution output. Improvements in processing equipment and materials are making RTM more attractive to a broader range of molders. Suppliers of RTM equipment are listed in Appendix C.

5. Units in Use

RTM has been successfully used by Hatteras Yachts in New Bern, North Carolina. The process was applied in the production of the rudder assembly for the company's 65 foot sailing yacht. The rudder assembly has curved surfaces on both sides and is cored with a high strength structural foam. The units produced exhibited good structural integrity and surface finish and required little in the way of secondary finishing and no assembly operations.

Hatteras Yachts also uses RTM in the production of a number of other products including transom door units for large motor yachts. These 4 inch thick curved doors weigh approximately 15 pounds and have a surface area of almost seven square feet on each side. They must fit uniformly with the openings which are molded into the transom. To insure high strength the units are reinforced with roll fiberglass stock and are cored with structural foams. The units are finished on all surfaces so that both mold sides are gel coated. Other applications are included in table 3.E.1.

APPLICATION	COMPANY
TUBS AND SHOWERS	MOLDED FIBERGLASS CO.
RADAR ARCH	VIKING YACHT CO.
ALTERNATOR FAN HOUSING	SHERWOOD PATTERNS
COMPONENTS FOR KIT CARS	EXCALIBER AUTOMOTIVE
SOLAR COLLECTORS	DESIGN EVOLUTION 4
ENGINE ROOM DOORS	HATTERAS YACHTS

TABLE 3.E.1 RTM APPLICATIONS

Case Study No 4

Type:	Resin transfer molding Yacht door and hatch structures
Company:	Hatteras Yachts
Location:	110 N. Glenburnie Road New Bern, NC 28560
Contact:	Kirk Williams
Phone:	(919)-633-3101
Purpose:	Reduce material consumption Insure quality Improve productivity
Motivation:	Reduction of steps required in lay-up Reduction in finishing operations
Equipment Supplier:	Rimcraft Technologies 1914 English Road High Point, North Carolina 27260
Payback Period:	One year
Comments:	Conventional open molding of units which are

finished on both sides requires considerable labor for assembly of components, fairing operations, and finishing.

Source: Plant visits during November, 1986 and April, 1987.

F. Rotational Molding

1. Examining Thermoplastic Options

There are many reasons of the popularity for open molding fabrication processes. Materials such as polyester resins and fiberglass may be combined to manufacture products with outstanding properties. The open molding process can yield a variety of reasonably priced structures with high strength, outstanding corrosion resistance, excellent chemical resistance, light weight, and outstanding appearance. Molds and tooling are simple, and investments in specialty equipment may be considerably below investments associated with other manufacturing processes. Product lead time can be very short, and the process is well suited to the production of prototypes and limited quantity product runs. Production related drawbacks of the process include high labor commitment for each product, long production and curing cycles, limited daily output for each mold, and high pollution potential.

The plastic industry uses far more thermoplastics than thermosetting plastics. Thermoplastics processing offers faster curing cycles, lower emissions during processing, lower costs per pound of raw material, ease of recycling, and lower labor intensity. Open molding of thermosetting plastics is likely to continue as a viable process because of the design constraints associated with many products, limited unit production requirements, performance requirements, and market demands. Recent advances in processing technologies and thermoplastic resin systems are causing many in the industry to examine alternative approaches to the molding process. New engineering grades of thermoplastics can be reinforced with fiberglass or other fibers. These materials can rival the strength of many of the strongest thermosets. Production machinery and tooling costs are still high for thermoplastics forming processes such as injection molding, extrusion, and blow molding. Often thousands of products must be produced in order to provide a reasonable amortization for mold costs alone (large molds machined from stainless steel may cost more than $100,000). Molds for processes such as rotational molding can be produced at costs low enough to warrant the interest of some open molders.

2. Rotational Molding of Small Tanks

Steamex in Raleigh, North Carolina, uses a conventional open molding process to lay-up fiberglass tanks for several models of industrial rug and carpet cleaning equipment. The production facility houses work areas for lay-up as well as assembly of complex machinery and electrical systems. At various times during its history the Company has contracted with outside molders to supply some of its fiberglass tanks. Steamex has recently contracted with a thermoplastics processor to provide rotationally molded tanks for a new line of cleaning equipment.

Rotational molding is a manufacturing process that produces a rigid or semi-rigid hollow part by charging a hollow mold with a measured amount of powder or liquid resin. The charged mold is then rotated simultaneously around two perpendicular axes. While being rotated the mold is subjected to a three phase heating cycle. During this heating cycle the mold is heated to the resin melt and held at that temperature long enough to melt and fuse the resin to the interior of the mold. High temperatures are maintained long enough to allow the resin to cure. Mold rotation is continued through a controlled cooling cycle. After cooling, the mold halves are opened and the part is removed. Cycle times may be as low as five minutes for small products. Cycle times for larger products with thick walls will be considerably longer. Figure 3.F.2 depicts the basic rotational molding process.

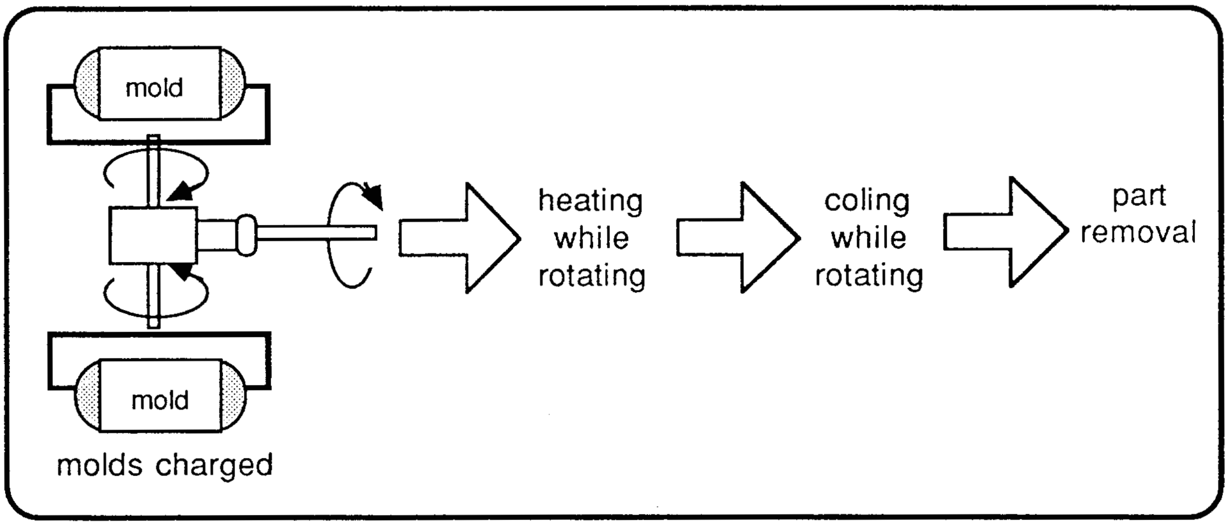


FIGURE 3.F.2 ROTATIONAL MOLDING

Rotational molding provides an attractive alternative to in-plant production of open molded assemblies. Tooling costs for molds are considered to be compatible with tooling costs for conventional molds. Rotation molds for the tanks are produced from inexpensive aluminum castings. Because open molding fabrication and curing cycles are lengthy, a number of conventional molds are required to insure adequate daily output of tanks. Only one rotational mold is required to maintain production. Company officials indicated that the thermoplastic units meet design and performance requirements for strength and durability. Per unit costs are compatible with open molding on low volume runs and less expensive per unit on high volume runs.

Changing from in-plant open molding to contracted rotational molding requires careful study and planning. Steamex has elected to change processes in cases where product redesigns and/or new product designs create a need for new tooling and molds. Chemical and physical properties of thermoplastic tanks are significantly different than those of fiberglass tanks. For this reason basic tank designs were altered, and changes in secondary operations and assembly techniques were necessary.

In electing to go with an outside contractor for tank production, a number of tradeoffs were also considered. Company investment in processing equipment and facilities was limited to the cost of the molds and engineering design work. Plant pollution and cleanup expenses are reduced because use of gel coats, resins, and solvents is eliminated. Potentially negative factors include loss of direct control of production, development of new product assembly techniques, and shipping and storage of molded tanks.

Rotational molding is not an answer for all producers of open molded components. The process is best suited to items which require basically uniform wall thickness and are hollow in structure. Items which are open, relatively shallow in profile, or require inserts and internal structural features are difficult to produce through rotational molding. Replacing in-plant open molding with in-plant rotational molding requires major investments in ovens, materials handling equipment, and specialized processing equipment. Strength and durability properties of many of the plastic materials used for rotational molding may not match properties of materials used in open molding.

G. Low Emission Resins

As preparation of this manual was being completed, Inland Leidy, Inc. of Baltimore, Maryland, in combination with a North Carolina boatbuilder was preparing to conduct a field test of low emission polyester resins. These experimental resins will be used in the production of a large sportfishing boat. All work will be done in the manufacturers' facilities utilizing conventional lay-up practices. The construction phase of the test should be completed during the Summer of 1987.

This is not the first attempt at development of low emission resins which are referred to as "suppressed styrene products". These resins are chemically engineered to reduce emissions which occur while the resins are curing. Styrene monomer makes up approximately 45% of the composition of most general purpose polyester resins. High exposure levels occur during the course of spray-up, lay-up, and curing. Before the cure cycle is completed, about 10% of the styrene can be expected to evaporate. The amount of styrene evolved is dependent on surface area, laminate thickness, ratio of resin to reinforcement, temperature, and duration of processing. Low emission resins will do little to limit emissions created during atomization processes. They can, however, reduce emissions during the curing cycle.

In concept, suppressed styrene resins are designed to limit the outward migration of styrene due to normal evaporation and the exotherm process associated with the reaction of catalysts and resins. Resin producers have experimented with wax type additives which quickly migrate to the surface of the resin and form a barrier to seal in the styrene. Results in terms of emission reduction were positive. Results related to product quality were less than positive. The waxy residue contributed to delamination and separation of the composite lay-up. Current research emphasis has been directed at development of chemical additives which can block excessive styrene migration without interrupting the bonding structure between resin and reinforcing material or various layers of the laminated structure. Resin suppliers should be contacted to keep abreast of new developments related to improved resins.

H. Resin Storage

1. Purchasing and Storing Resins

A number of approaches are utilized for purchasing resins for open molding operations. Many processors elect to purchase all materials in 55 gallon drums while others prefer to purchase resins in bulk quantities. Large firms, such as bath fixture manufacturers, purchase practically all general purpose resins in bulk and store these materials in large storage tanks. Smaller companies usually purchase general purpose resins in drums. Specialty resins such as gel coat colors, tooling resins, and fire retardant resins are almost always purchased in drums.

Both the bulk and drum purchase strategies have positive and negative attributes. Where large quantities of resins are consumed, bulk systems enable companies to purchase resins at lower prices. Lower prices are possible because of quantities purchased, elimination of packaging in the form of barrels, and ease of handling in terms of loading and unloading. Bulk systems are well suited for delivering large quantities of resins to vats for mixing with fillers or other additives. Drum purchases fit the needs of users who need flexibility in terms of quantities purchased. Use of drums does not require installation of expensive storage tanks and resin delivery pumps and piping. Occasional users find that drums eliminate storage tank cleanup and reduce the likelihood of overextending the storage life of large quantities of resin.

Drums do create some problems. A systematic approach to inventory, control, and disposal must be established in order to assure that resins are used before their storage life expires. Drums can collect at a rapid rate, and it may be difficult to dispose of them. Many landfills refuse to accept drums. Disposal of drums containing liquid residue may call for handling the drum as hazardous materials. Landfills will not accept drums containing liquids. Storage of full drums and empty ones is also a problem. Considerable floor space is required for storing large quantities. A management system must be employed to insure that the contents of the oldest drums are used first. Use of drums normally implies a commitment of labor to materials handling. Drums must be transported from the delivery truck to the storage area, from the storage area to the point of use, and then from the point of use to the storage area.

2. Mini-Bulk Resin Storage

Fabricators can consider an approach to resin storage that offers some advantages over both the bulk and barrel strategies. Special containers which are large enough to supply several hundred gallons of resin, but small enough to be handled by a small forklift, form the heart of what are referred to as mini-bulk resin systems. These stainless steel containers are shipped to the user by truck and are stored in one central location. Since the units can be stacked, floor space dedicated to resin storage is reduced by 37%. When new shipments of resin arrive, the empty containers are returned to the supplier. The tanks are steam cleaned and refilled for delivery.

The mini-bulk system offers a number of other positive features. Inventory, product control, and recordkeeping are easier to manage. Products can be tied directly to the resin batch used in their lay-up without resorting to extensive recordkeeping and drum labeling. There is no mixing of different batches from different barrels or mixing batches in a large bulk tank. There are no partially used barrels to dispose of or store. As with bulk storage, there is a need to use a materials distribution system to deliver resins to the work area. This resin distribution system typically consists of a closed loop plumbing system which is used to circulate resin to all areas of the facility. A circulation loop is required to prevent resin from solidifying in pipes used to supply areas where resin is used infrequently. During plant operating hours resin is continually circulated and returned to the storage tank. This action helps keep the resins mixed and prevents settling and the build-up of gel. A low pressure pneumatic pump is ideal for resin delivery. A diagram of a typical approach to mini-bulk storage and delivery is included in Figure 3.G.1.

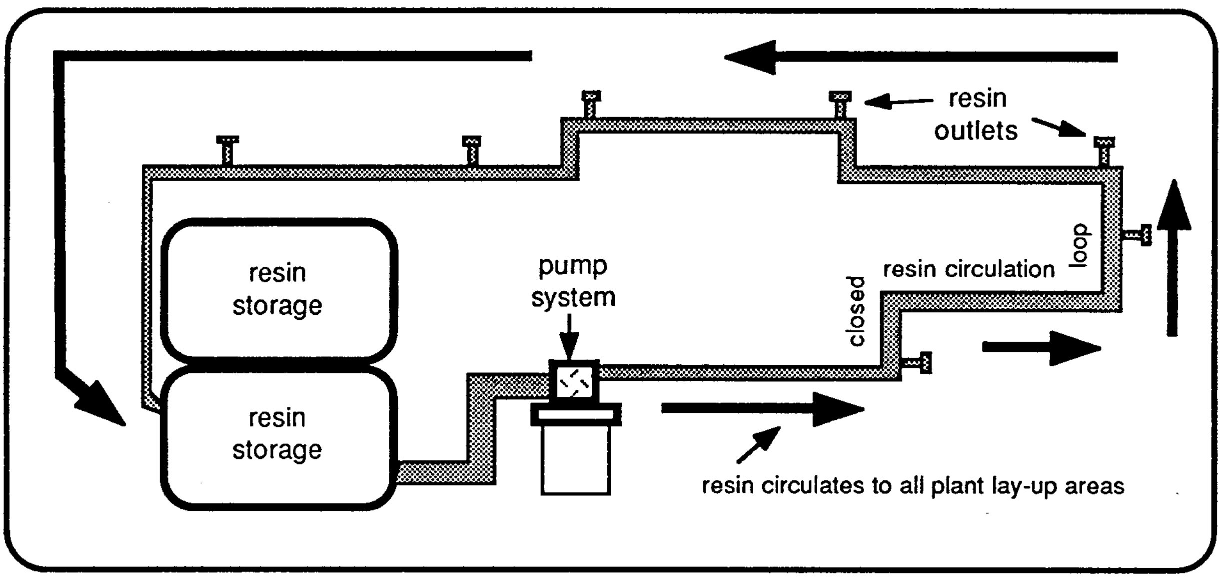


FIGURE 3.G.1 MINI-BULK RESIN STORAGE AND DELIVERY

A mini-bulk system was installed at Privateer Manufacturing, in Chocowinity, North Carolina, in 1986. This system has functioned efficiently in this facility. The stainless steel tanks measure 42 inches X 42 inches X 55 inches and have a capacity of 300 gallons. The resin tanks and resin are supplied and shipped by Inland Leidy, Inc.. Tanks are unloaded with a small forklift and stored inside the main production area. One central resin supply loop and pump are used to distribute resin to a number of outlets in the adjacent lay-up area. On a per pound basis resin prices are the same as for drum shipments. Other cost saving factors have emerged. Since less floor space is required, inside storage of resin is possible. This approach helps keep resins warm in winter and promotes faster and better curing. Time lost to handling resin drums has been greatly reduced, and production interruptions due to empty resin drums are eliminated. There are also fewer drums to dispose of and store. The company owner indicated that installation costs for the resin distribution system were recovered in less than a year.

Case Study No 5

Type:	Mini-Bulk resin storage system
Company:	Privateer Manufacturing, Inc.
Location:	P. O. 69 Chocowinity, North Carolina 27817
Contact:	Warren Wilkerson, President
Phone:	(919)-946-7772
Purpose:	Reduce barrel storage of resins Improve worker productivity
Motivation:	Fewer barrels to dispose of Simplification of recordkeeping Reduction of operating expenses
Equipment Supplier:	*Resin tanks and resin* Inland Leidy, Inc. 900 S. Eutaw Street Baltimore, Maryland 21230 *Resin distribution equipment* Rimcraft Technologies, Inc. 1914 English Road High Point, NC 27260
Payback Period:	Less than one year
Comments:	Drum disposal problems were greatly reduced. Productivity was improved significantly. Reduced the labor required for materials handling

Source: Plant visits in August, 1986 and April, 1987 and phone conversations with plant manager and equipment suppliers (March, 1987)

CHAPTER IV

MANAGING CONTAMINATED SOLVENTS

A. Solvent Use

Use of acetone and other similar solvents for general cleaning is standard practice for most open mold fabricators of fiberglass products. Solvents are used to remove uncured resins from spray equipment, rollers, brushes, tools, finished surfaces, and the hands of employees involved in lay-up operations. Since these solvents become contaminated with residue from resins and catalysts, they fall under strict governmental regulations (see Chapter 1). Precise records must be maintained on the delivery, storage, and disposal of these solvents. Disposal of contaminated solvents represents a major expense in payments for hazardous waste removal and disposal. Prices for transportation and storage can exceed $300 per barrel for moderately contaminated waste. Given the RCRA "cradle-to-grave" philosophy regarding waste generation, the expenses may not end with payment of invoices for shipping and disposal. Long-term liabilities and responsibilities for problems that might evolve from storage of contaminated solvents must also be considered.

In the past some operators have allowed evaporation or spills to take care of much of the disposal of contaminated acetone. Recent developments in regulations and record keeping requirements are making sloppy disposal techniques very risky, even for the smallest producers. In extreme cases, users can be held accountable for disposition of solvents based on records of quantities purchased. On-site storage of contaminated waste is strictly regulated, and severe penalties may be imposed upon violators.

Given the status of current regulations and rising solvent costs, alternative solvent management systems should be considered. Three basic approaches appear to have considerable merit for producers of contaminated solvents associated with fiberglass industries. In-plant recycling, out-of-plant recycling, and incineration have proven to be viable options to conventional secured landfill disposal techniques.

B. In-Plant Solvent Recovery

1. Small Batch Solvent Distillation Equipment

Many fiberglass product fabricators in North Carolina are finding in-plant batch type distillation systems to be a cost efficient approach to dealing with contaminated solvents. Batch type units have proven to be successful in meeting the needs of firms producing small to moderate quantities of contaminated solvents such as acetone. Unit sizes commonly available range from 5 to 55 gallon units.

A basic batch type system should consist of four major components including: a contaminated solvent collection tank, a heated boiling chamber, a condenser, and a clean solvent collection container. A typical low cost system is diagramed in figure 4.B.1. The operating systems for these units are typically contained within a single compact cabinet. Space required to house a unit is generally less than the space required for storage of virgin solvents and contaminated waste.

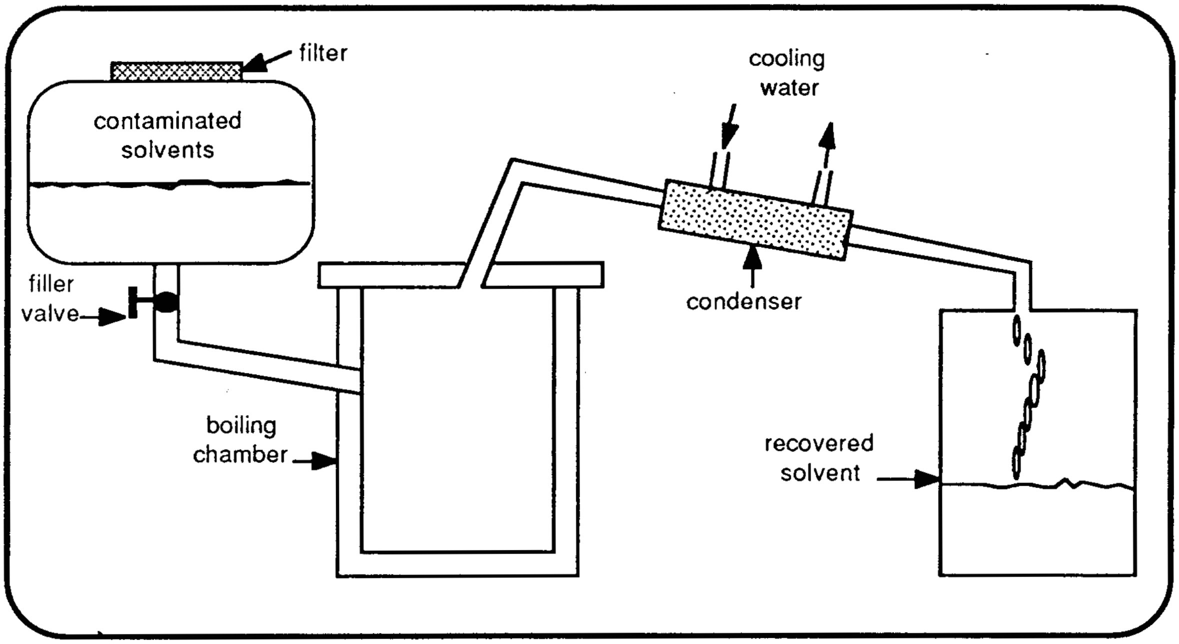


FIGURE 4.B.1 BASIC BATCH SOLVENT DISTILLATION SYSTEM

Small quantities of contaminated solvents are poured into the solvent collection tank during normal employee cleanup operations. The contaminated solvent collection tank should have an inlet that can be properly sealed to prevent evaporation. A filtering screen should also be placed in the inlet collection system to prevent solids and sludge from clogging pumps and/or feed pipes which deliver contaminated resins to the heat chamber. If the collection tank is situated higher than the top of the heat chamber, piping and valves can be permanently installed so that solvent can be gravity fed into the heat chamber. If the collection tank is not located above the heat chamber, a pumping system may be required to transfer solvents for processing.

The heat chamber is designed so that a vapor tight seal can be maintained during heating and cooling cycles. In the chamber contaminated solvents are heated to a predetermined vaporization temperature, and these vapors are channeled out of the container to an external condenser. Heat can be supplied by means of electric elements or by steam bands. Steam units offer some advantages in terms of speed and safety and can be attached to existing plant steam lines or a boiler supplied by the manufacturer of the still. The heat chamber will also be equipped with either a bag or pan to facilitate collection of the unusable residue which has been separated from the reclaimed solvent. This residue is referred to as "distilled bottoms" or "still bottoms".

Depending on design requirements, condenser units may be water cooled or air cooled. Water cooled units are generally more compact and more efficient but require connection of external water inlets and drains. In the condenser, vapors are cooled rapidly in order to promote condensation. This condensate is clean solvent and is drained off and collected in appropriate containers. These collection containers may vary from a single piped in bulk storage unit to conventional barrels. The solvents collected in this manner are generally ready for use without further treatment or additives. The distillation recovery option seems particularly appealing since Federal EPA regulations (Regulation 40 Part 261.6) do not require a permit for this type of solvent treatment. However, the North Carolina Solid and Hazardous Waste Management Branch must be notified when a solvent distillation unit is installed.

There are a number of cost factors affected by the use of batch distillation units. In comparison to conventional disposal techniques, the quantities of solvents which must be disposed of by hazardous waste handlers may be reduced by as much as 90%. Since usable solvents are produced, the outside purchase of virgin solvents can be dramatically reduced. Long-term liabilities for waste disposal are also significantly reduced. The units do require a considerable initial investment. Prices may vary from approximately $3,000 for a basic 5 gallon per batch unit to more than $30,000 for a relatively sophisticated 55 gallon unit with labor saving automatic control systems and pumps. Stills also require energy for heat, some labor for operation, and water for the condenser. These operating costs will generally be less than 50¢ per gallon, with some manufacturers claiming costs under 20¢ per gallon. Other expenses include disposal of distilled bottoms, bags, and maintenance.

Batch type distillation systems do not require full-time operators or extensive operator training. With the most basic design an attendant is normally assigned the duty of filling the heat chamber with contaminated solvents, sealing the unit, activating appropriate controls, deactivating the controls after the cycle is completed, and removing the residue distilled bottoms from the heat chamber. The complete cycle time normally ranges from six to eight hours, but the operator need only be present during start-up, shutdown, and cleanup. Supplies consumed in the processing of solvents are usually limited to disposal bags.

The addition of automatic controls and pumping systems to load waste solvents can greatly reduce labor demands and prove greater assurance that the unit will be shut down if an operational problem occurs. A diagram of a larger unit with automated controls is shown in Figure 4.B.2. Fountain Powerboats in Washington, North Carolina, has used a Recyclene model RX-35, supplied by Southern Recovery Company, for more than two years. The unit features a number of automatic control systems for materials handling, cycle control, and safety. Liner bags are used to collect still bottoms and keep the boiling chamber clean. Total operator time required for each cycle is only 12 minutes.

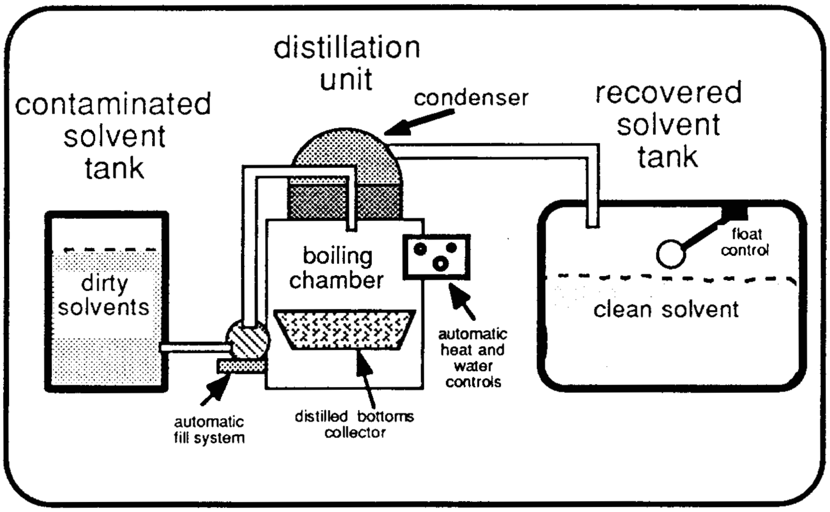


FIGURE 4.B.2 HIGH EFFICIENCY BATCH DISTILLATION SYSTEM

Selection and installation of a batch type distillation system requires careful study and planning. Suppliers listed in Appendix E will normally provide expert advice about the systems they carry. Demonstrations of equipment should be carried out using representative samples of contaminated solvents from your facility. Insurance requirements, safety, and fire codes should be taken into consideration before a system is selected and installed. Vapors produced during distillation can be highly flammable, so units and surrounding equipment should be of an explosion proof design. Results may be disappointing on solvents which have been heavily contaminated with water or other elements with high vaporization temperatures.

Case Study No 6

Type:	Small in-plant batch distillation system
Company:	Steamex
Location:	P. O. Drawer 30800 Raleigh, NC 27622
Contact:	Lewis Perry, Plant Manager
Phone:	(919) 782-5860
Purpose:	Reduce disposal costs of contaminated acetone Reduce storage of waste Reduce storage of materials Reduce consumption of solvents
Motivation:	High disposal costs for contaminated solvents

Equipment Supplier:	Finish Engineering Company 921 Greengarden Road Erie, Pennsylvania 16501-1591 (814)-455-4478
Payback Period:	Six months
Comments:	Unit has been in operation for approximately six months. Purchase of acetone has been reduced by 75% and disposal of drums has been reduced from four per month to two per year.
Source:	Plant visit on May 20, 1987 and phone conversations with equipment supplier (March,1987 and May,1987)

Case Study No. 7

Type:	In-plant batch distillation unit
Company:	Fountain Powerboats
Location:	P. O. Drawer 457 Washington, NC 27889
Contact:	Jeffrey Spear, Director of Quality Control
Phone:	(919)-975-2000
Purpose:	Reduction of waste disposal costs Reduction of solvent costs
Motivation:	Reduced hazardous waste storage and disposal Reduction of expenses
Equipment Supplier:	Southern Recovery Co. P. O. Box 3279 Fort Mill, South Carolina 29715 (803)-548-5740
Payback Period:	Less than one year

Comments:	Unit is cycled at least once per work day. Approximately 90% of the contaminated acetone is recovered. Operator time required is less than 15 minutes per cycle. Hazardous waste shipments and solvent purchases have been reduced by at least 75%.
Source:	Plant visit (May,1987)

---

2. Continuous Feed Distillation Equipment

While batch type solvent recovery units have proven to be successful in meeting the needs of many North Carolina firms, large volume producers of contaminated solvents may find continuous feed distillation equipment better suited to their requirements. Recovery output for continuous feed systems which are commonly available can range from 250 gallons per shift to as much as 200 gallons per hour.

A continuous feed distillation system requires all of the major components included in a batch type distillation unit plus more elaborate controls and materials handling equipment. An automatic pumping system is required to transfer contaminated solvents from the collection tanks or drums to the boiling chamber. Condensers may be either water or air cooled. The clean solvent collection system must be equipped with a monitoring system to avoid dangerous spills created by overflows.

With continuous feed systems contaminated solvents should be collected in a centralized solvent collection tank as a part of normal operational activities. Contaminated solvent collection systems should be equipped with a device to prefilter solids and heavy gels. The collection system should be properly sealed to prevent evaporation. The collection system should be made of conductive materials and properly grounded.

The heat chamber of a continuous feed system will normally be loaded by an automatic pump system. Some designs allow for overriding of automatic loading systems so that batch processing can be carried out. Heat is normally supplied by means of steam elements or steam bands. These steam heating systems can be attached to existing plant steam lines if a central boiler system is available. A boiler system for the unit can supplied for facilities which do not have steam capabilities. As with batch type distillation equipment, the heat chamber will also be equipped with either a bag or pan to facilitate collection of the unusable residue which has been separated from the reclaimed solvent. The units can be equipped with options such as vacuum attachments which allow for recovery of a wide range of solvents.

Just as with batch type units, there are a number of cost factors to be considered in the selection of continuous feed distillation units. In comparison to conventional disposal techniques, the quantities of materials which must be disposed of by hazardous waste handlers may be greatly reduced. Since usable solvents are produced, the outside purchase of materials can be dramatically reduced. Long-term liabilities for waste disposal are also reduced. The units do require an initial investment that is much larger than that for smaller batch type units. Installation costs for large units are likely to exceed $50,000. These types of units are not likely to fit the requirements of firms with recovery needs of less than 100 gallons per day.

Because of the major capital investment required, selection and installation of continuous feed distillation systems requires careful analysis and planning. Suppliers listed in Appendix E will normally provide expert advice about the merits of the systems they carry. Merits of the units available should be evaluated on the basis of compatibility with company needs. Demonstrations of equipment should be requested and carried out using actual samples of contaminated solvents taken from the facility. Insurance requirements, safety, and fire codes should be taken into consideration before a system is selected. Because vapors produced during distillation can be highly flammable, the units and surrounding equipment should be of an explosion proof design and well ventilated.

3. Ongoing Developments

Solvent distillation processes are steadily improving. Equipment manufacturers are highly competitive in research and development as well as marketing approaches. Firms that have experienced poor results with older in-plant distillation processes will find that the newer designs offer more efficient processing, better control systems, improved materials handling systems, and reduced need for operator labor. These units also feature many improved safety features.

Safety should be a primary consideration when selecting, installing, and operating these units. Fire and explosion potential is high since solvent vapors can be highly flammable. Units should be equipped with an explosion proof electrical system, and all electrical fixtures and tools in the surrounding environment should be of an explosion proof design. The insurance carrier for the firm should be also be consulted before installation is begun. All appropriate electrical, fire, and building codes should be carefully observed. Some users have placed units inside the laminating areas, while others have elected to provide remote structures for the installation.

In-plant distillation is likely to gain in popularity during the next few years. Satisfaction rates are very high for newer units. EPA officials have indicated that properly treated distilled bottoms need not be treated as hazardous waste. North Carolina is currently considering changes that would allow fiberglass fabricators some relief from current disposal requirements for acetone distilled bottoms. If these changes are permitted, relief will likely be granted on a case-by-case basis, with routine waste sampling and analysis as a requirement.

C. Out-of-Plant Solvent Recovery

1. Recycling Agreements

Some North Carolina fiberglass fabricators are successfully using supplier based solvent recovery as a cost efficient means of dealing with contaminated solvents. In firms where in-plant-recycling has not proved feasible or gained favor with management, successful arrangements have been made for outside recovery of solvents. Often these arrangements are made with solvent suppliers who can reclaim the contaminated solvents at a cost considerably lower than the cost of producing virgin materials. Contracts and arrangements for these services take a variety of forms.

In some cases "toll" arrangements are made to insure that the waste generator's solvents are handled separately. The reclaimed solvents are then returned to the generator along with virgin stock. This arrangement helps reduce the likelihood of solvents becoming contaminated by undesirable substances produced by other waste generators. Some firms have developed service agreements which do not place restrictions on the source of the reclaimed solvents which they purchase. Other companies may elect to specify the purchase of virgin materials only. Separate arrangements, whereby new solvents are purchased from one source and contaminated solvents shipped to another firm, are also common.

2. Features of Out-of-Plant Recycling

As with in-plant recovery techniques, out-of-plant recycling requires and efficient management and control system. Contaminated solvents must be collected in tanks or drums as a part of normal employee cleanup operations. The contaminated solvent collection system must be carefully monitored. A filtering screen should be placed in the inlet collection system to separate solids and sludge. The collection tank, or drums should be sealed to prevent evaporation and contamination. Water and trash will drive up the cost of recovery.

Where more than one type of solvent is used, special care must be taken to prevent mixing of dissimilar materials. Each container should be clearly marked with a chemical identification label and a permanent tag. The label on the waste container should include composition and the method by which the waste was generated. A record of this information should be produced for each container and maintained in a central location. Containers should not be labeled as waste unless the materials they contain are no longer in use. In order to avoid requirements for special permits, a management system should be developed to assure that containers are not kept in storage for more than 90 days. If drums are used, they must be in good physical condition or they will not be accepted by the waste hauler.

Out-of-plant recovery has a number of drawbacks. Shipment of solvent waste must be carried out by a licensed transportation firm. The waste generator's responsibility for the contaminated solvent does not end when it is loaded on the truck. The RCRA "cradle-to-grave philosophy" places ultimate liability for proper handling and disposal of waste with the generator of that waste. For this reason short term transportation liabilities and long term disposal liabilities have driven up insurance costs.

Selection of a recycler and transportation firm should be done with care. A number of waste management companies have ceased operations due to legal actions or bankruptcy. Failures of this type frequently result in cleanup and dump site management costs being passed on to the waste generator. This may occur years after the waste has been shipped. The waste management firm's financial status and approaches to handling incineration, still bottom, and storage should be thoroughly investigated before any business agreements are reached.

Hatteras Yachts in New Bern, North Carolina, has elected to use supplier base solvent recovery as the primary means of managing and disposing of contaminated solvents. Hatteras buys acetone in bulk and a proprietary non-flammable chlorinated solvent in 55 gallon drums from The Prillaman Company in Martinsville, Virginia. The company also purchases clean drums from Prillaman for the purpose of collecting and shipping contaminated acetone. Contaminated chlorinated solvents are also collected shipped back to Prillaman in drums.

Prillaman charges Hatteras $10.00 for each clean barrel and issues a credit of $6.00 when the solvents are returned for recycling. The net cost to Hatteras for disposal of each drum of contaminated solvent is $4.00. The company does not purchase reclaimed solvents from Prillaman but does have an agreement for purchase of virgin solvents. Hatteras feels that this arrangement provides for satisfactory disposal of waste at a reasonable cost and insures delivery of a good supply of high quality solvents.

Case Study No 8

Type:	Supplier based solvent recovery Acetone and chlorinated solvents
Company:	Hatteras Yachts
Location:	110 N. Glenburnie Road New Bern, NC 28560
Contact:	Andy Misky, Jr., Manager, Facilities Engineering
Phone:	(919)-633-3101
Purpose:	Reduction of waste disposal costs
Motivation:	Limiting long-term liability for waste disposal

Service Supplier:	The Prillaman Company P. O. Box 4024 Martinsville, Virginia 24115
Payback Period:	Immediate in comparison to other out-of-plant methods
Comments:	Cost per drum for disposal is $4.00, including transportation. There is no reduction in the cost of obtaining fresh solvents.
Source:	Plant visits during November, 1986 and April, 1987.

D. Incineration

Incineration is also an option for disposing of contaminated solvents, such as acetone. Acetone can serve as a fuel source for heat recovery because of its high BTU value and low halogen content. In some industries, a number of large companies have installed in-plant incinerators to burn waste solvents. Although in-plant incineration does not appear be particularly suited to the requirements of most open molders, out-of-plant incineration may be attractive to some.

Waste solvents may be sent to cement or light aggregate plants for use as a fuel. This option may be particularly attractive to small producers. Companies such as Oldover Corporation, can send their trucks to the customers facility, to pick up waste solvents. These waste solvents must be pumpable. Collection can be made from large tanks or drums. Cost per gallon for the service is somewhat dependent on the nature of the waste collected. When high BTU value is maintained, costs are reduced. Contaminants that add halogen also adversely affect cost. Still bottoms may also be disposed of by incineration. Burning contaminated solvents and/or still bottoms in an aggregate or cement kiln produces no ash. This effectively relieves the generator from further liability, since no solid or liquid waste remains.

Just as with out-of-plant recycling, out-of-plant incineration requires an efficient management and control system. Contaminated solvents must be collected in tanks or drums as a part of normal employee cleanup operations. The contaminated solvent collection system must be carefully monitored. A filtering screen should be placed in the inlet collection system to separate solids and sludge. The collection tank, or drums should be sealed to prevent loss of BTU value through evaporation and contamination. Water and trash will also drive up the cost of the service.

Record keeping obligations are not relieved simply because solvents are being collected for incineration. Each container of solvent purchased should be accounted for. Containers should be clearly marked with a chemical identification label and a permanent tag. The label on the waste container should include composition and the method by which the waste was generated. A record of this information should be produced for each container and maintained in a central location. Containers should not be labeled as waste unless the materials they contain are no longer in use. In order to avoid requirements for special permits, a management system should be developed to assure that containers are not kept in storage for more than 90 days. If drums are used for shipment of waste, they must be in good physical condition or they will not be accepted by the waste hauler.

Transportation remains a drawback of out-of-plant incineration. Shipment of solvent waste must be carried out by a licensed transportation firm. The waste generator's responsibility for the contaminated solvent does not end when it is loaded on the truck. The RCRA "cradle-to-grave philosophy" places ultimate liability for proper handling and disposal of waste with the generator of that waste. For this reason short term transportation liabilities are not relieved.

Selection of a waste management or transportation firm should be done with care. A number of waste management companies have ceased operations due to legal actions or bankruptcy. Failures of this type frequently result in cleanup and dump site management costs being passed on to the waste generator. This may occur years after the waste has been shipped. The waste management firm's financial status and approaches to handling incineration, still bottom, and storage should be thoroughly investigated before any business agreements are reached. Ideally, the waste generator should inspect the incineration facility and observe the operations carried out there. A system for either reclaiming all barrels shipped or insuring their absolute disposal is desirable. This step may help assure that the waste generator does not bear the expense cleaning up waste placed in these containers, at a later date, by another generator. Records related to collection and disposal of the waste should be maintained forever. A form that would be useful for internal record keeping and tracking of solvents is pictured in Figure 4.D.1.

COMPANY NAME

unit	drum I.D. no.	type waste	date placed	storage area #	date removed	qty.		holding area	date shipped	shipped to	manifest	
						gals.	lbs.				no.	date rec.

FIGURE 4.D.1 FORM FOR TRACKING WASTE STORAGE AND DISPOSAL

CHAPTER V

FACILITY-BASED POLLUTION REDUCTION AND MANAGEMENT STRATEGIES

A. Localizing and Isolating Problem Operations

1. Pollution Sources

Use of spray applicators to facilitate resin transfer to the mold is common practice for most open mold fabricators of fiberglass products and other thermosetting polyester products. Gun-type resin application systems use either compressed air or high fluid pressures or combinations of both to atomize resin materials for efficient delivery to the work surface. As discussed in Chapter 3, airless spray gun systems are considered to be highly effective in delivering resins to the work surface. Gel coat and other resins can easily be transferred in the quantities needed to maintain high levels of productivity. While these application devices yield high resin output, they also tend to produce excessive fogging, overspray, and bounceback of atomized solids and vapors. Recent developments in spray gun design have resulted in new air assisted airless systems which can maintain good material delivery while reducing contamination of air in the workplace. Air assisted airless spray equipment and other equipment and processes which can assist in reduction of pollution are described in Chapter 3.

Factors other than spraying also contribute to pollutants entering the workplace. Even if resins are applied by processes not requiring spraying, the very nature of their chemical curing process will still produce considerable vapor and odor. There are always other environmental and physical dangers such as chemical spills involving resins, catalysts, or solvents. Because of the nature of these chemicals, there is always considerable risk of fire and explosion. Pollution in the form of airborne dust particles is also a potential problem since most products require post-molding grinding and finishing operations.

In the course of preparing this manual more than thirty visits were made to plants where open molding accounted for a sizable part of production activities. All of these processors expressed concern about maintaining a safe plant environment and minimizing pollution. Many had undertaken effective measures for implementing pollution reduction strategies. Some approaches to reduction involved innovative changes in what might be considered typical plant layout and/or major mechanical systems. Just as with some of the production-based approaches to pollution reduction, a number of the facility-based pollution reduction strategies involved relatively simple measures with extremely high payback potential. Other approaches involved equipment outlays and facility developments with very high capital outlays which would be difficult to recover through increased productivity.

2. Isolating Problem Areas

Many firms are producing open molded products in physical facilities that are poorly designed for the production techniques used. Fabricators often perform spray-up in large open structures. This approach normally results in contamination of air throughout the entire facility and necessitates rapid turnover of plant air in order to reduce airborne vapors and solids. Because of this turnover, expenses involved in heating make-up air are increased significantly. When incompatible activities are carried out in these open facilities, there is also considerable potential for cross contamination, such as dust in gel coat finishes or trash in the lay-up. Figure 5.A.1 provides a diagram depicting typical facility problems. A number of benefits can be derived from physically segregating or even isolating some production operations.

3. Confining Gel Coat Applications

Confining spray application of gel coats is not an uncommon practice in the industry. Gel coats carry a relatively high filler content and require high pressures for atomization. Because of these pressures, considerable air contamination occurs in the form of overspray and bounceback. In comparison to other steps in the fabrication process, gel coating is normally considered to be one of the greatest producers of airborne pollutants. Some high volume fabricators, such as bathtub producers, have successfully utilized moving assembly lines to move molds in and out of enclosed spray booths for gel coating and other spray operations. Other fabricators, such as builders of small and medium sized boats, have constructed large spray booths for use in gel coating. These builders use mobile mold fixtures and/or overhead lift systems to move molds in and out of the spray area.

With a relatively confined working area for gel coat applications, a number of pollution, safety, and housekeeping problems become easier to manage. In a confined gel coat area measures to insure worker safety are simplified. Since these units are isolated from other parts of the facility and can be equipped with separate climate control and ventilation systems, only the workers directly involved in the application process need risk exposure to atomized vapors and solids. Potentially explosive vapors are also prevented from entering the plant. Exhaust and make-up air are easily directed to a particular area, thus avoiding unnecessary and inefficient turnover of air throughout the plant. With this approach only the workers in the gel coat room need wear appropriate safety clothing, eye protection, and breathing apparatuses.

Localizing the gel coat application also means that appropriate filtering systems can be placed in the exhaust system in order to reduce the output of airborne pollutants. Where regulations, company policy, or nuisance odor problems create pressures on the fabricators, confining gel coat applications should merit considerable attention. High pollution outputs associated with gel coat application increases the payback potential for filtration or other treatment processes, especially if the spray output can be isolated and confined.

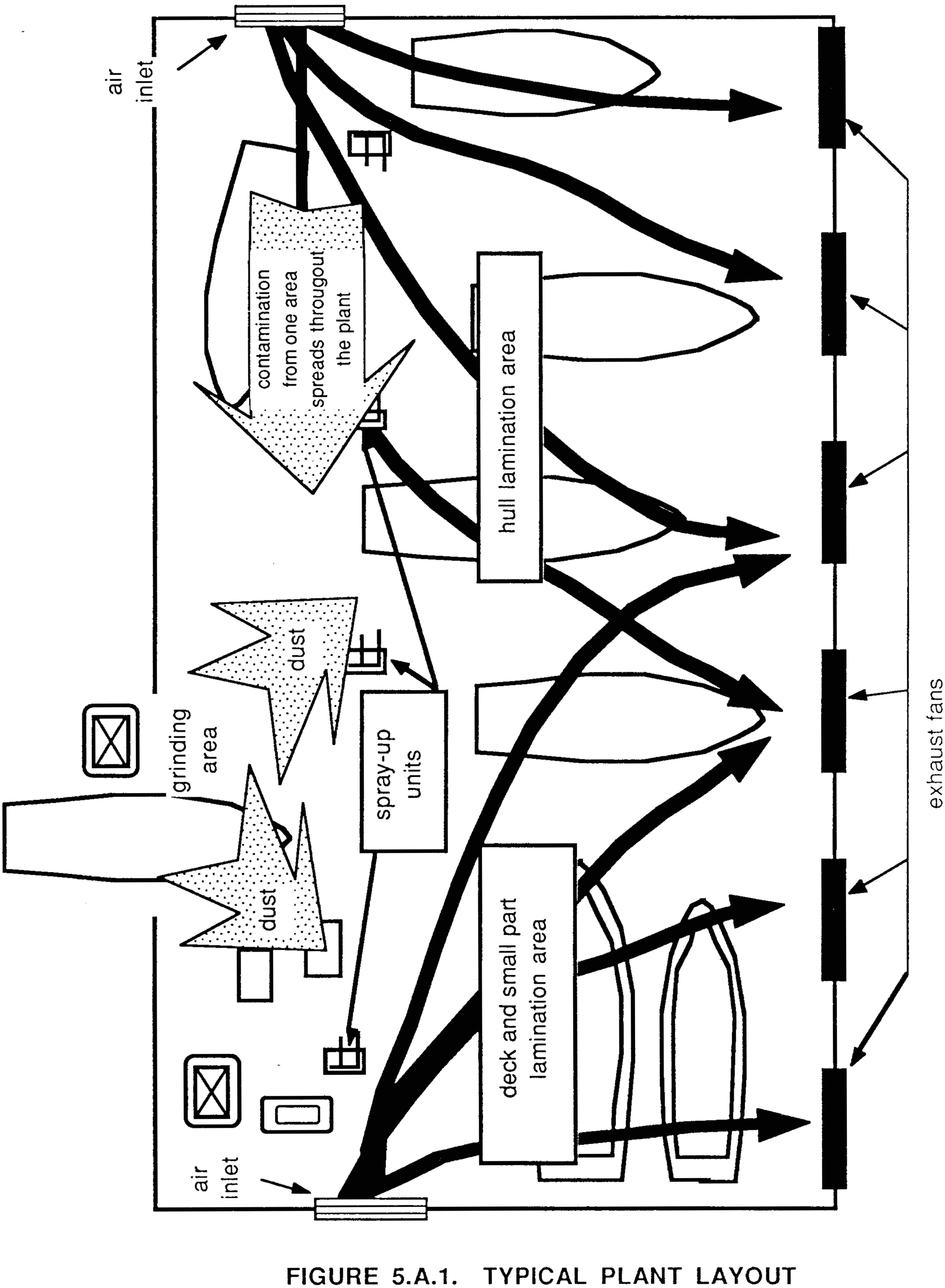


FIGURE 5.A.1. TYPICAL PLANT LAYOUT

Plant maintenance operations and housekeeping can benefit from confining gel coat application to isolated booths or bays. Where application is carried out in the open plant environment, some undesirable output of resins in the form of heavy vapors and solids results. This contamination can affect air throughout the facility. In addition to creating potential respiratory problems and nuisance odors, the contamination causes a number of housekeeping problems. Potential fire problems result because heating, air conditioning, and air handling systems throughout the plant become coated with a build-up of solids. Walls and floors throughout the area also become coated with this build-up. Efforts required to keep equipment and fixtures clean also increased where gel coating applications are not confined. A well designed gel coat application area keeps these contaminants out of the other plant areas. Such units can be easily equipped with disposable wall and floor coverings, filters to protect ventilation systems, and other features which help insure safety and simplify housekeeping chores.

Other benefits gained from isolation of gel coating activities include a number of quality related factors. An isolated spray-up area will not be contaminated by other operations in the plant. Mold surfaces and the resulting product finishes are less likely to be damaged by dust or particles from grinding operations or by fibers and resins from nearby lay-up. The climate in a closed area can be regulated in terms of temperature and humidity in order to insure a proper and consistent chemical cure of resins. Special lighting can also be provided to improve visibility and eliminate shadows that might cause improper application. As long as the mold remains in the spray area, there will be no nearby operations to damage or contaminate the coating before it cures.

4. Approaches to Gel Coat Isolation

Although use of specialized booths or bays for gel coat application is not a new approach, there has been a recent increase in the number and types of operations electing to use this type of facility. Use of spray booths for gel coating is most common with the producers of relatively small items or high volume producers who have incorporated moving assembly lines into their processing operations. A number of firms have elected to use readily available production type spray painting booths. This approach appears to work well when relatively small molds are used. Small mold fixtures are usually moved in and out of the booth by hand. Where high production is necessary, labor requirements can be reduced by using fixtures such an overhead chain conveyors or track systems to move relatively large units like hot tubs or shower enclosures.

The Lasco Bath Fixtures Division of Phillips Industries in South Boston, Virginia, designed their new plant to make use of an overhead chain system to move conventional fiberglass tub molds through various production areas. These production areas include self contained gel coat and spray-up areas, heated curing booths, demolding, and finishing. The system allows Lasco to minimize labor used in materials handling while allowing for easy isolation of areas which generate most airborne pollution. Steamex in Raleigh, North Carolina, uses a conventional paint spray booth for gel and spray-up. Lay-up is required to produce fiberglass tanks for industrial rug and carpet cleaning equipment manufactured by the company. Using the spray booth systems has helped eliminate nuisance odor in other areas of the production facility and has reduced contamination of work areas where assembly of machinery and electrical systems takes place.

Builders of larger products such as boats, custom engineering fixtures, and automotive body structures have been slower in installing self-contained gel coat facilities. Even with relatively small boats in the 18 to 25 foot range, moving a mold in and out of various production areas is difficult. The task is more difficult when mold lengths approach 40 feet or more, it becomes nearly impossible with mold lengths of 50 feet or more. With most of these producers output per mold rarely exceeds one unit a day. This low output means that potential for developing highly mechanized assembly line strategies is limited.

Fountain Powerboats in Washington, North Carolina, has installed a large gel coat spray booth in its recently expanded production facility. The company manufactures high performance offshore speedboats up to 12 meters in length. The new spray booth is completely self-contained and is completely equipped with explosion proof electrical systems and an elaborate lighting system. Molds up to 50 feet in length are mounted on special fixtures which allow them to be rolled to various locations in the facility. These fixtures are designed so that the molds may be rolled from side to side to permit easy worker access for spraying and lay-up. Fountain elected to build and use an isolated booth for a number of reasons. Quality assurance, safety, and air quality were major factors in the decision.

Since the boats produced are very specialized high performance craft with prices that may enter the six figure range, exterior finish quality is extremely critical for customer satisfaction. The company feels that the gel coat finish quality can be more consistently maintained by using a spray booth rather than by spraying in the open plant environment. Trash and other contaminants are practically eliminated. High intensity lighting, required to insure that the operator can deliver a consistent coating, is easier to provide in the booth. Overspray and fogging are reduced since a high volume of air turnover can be easily maintained in the spray booth. The temperature and humidity in the booth can also be maintained at levels which promote proper curing of the gel coat resins.

Other potential benefits have also been noted by the company. There will be a major reduction in contamination of plant air. Overspray build-up on walls, floors, and equipment is reduced. Ventilation and make-up air for the remainder of the facility are also reduced. There will be a lower level of nuisance odor throughout the plant environment.

There seems to be little doubt that the use of an enclosed and environmentally isolated area for gel coating can result in a number of benefits. A highly efficient exhaust and make-up air system can be used to remove contaminated air from the spray area. Odors, vapors, and solids are prevented from contaminating other parts of the facility. Where emission outputs are high enough to require filtration or purification, the treatment systems will be much less expensive and more efficient if they are not required to filter air from the entire facility. Overall requirements for plant ventilation and make-up air will also be greatly reduced. Overall plant safety can be improved and potential fire hazards reduced.

5. Approaches to Isolating Other Operations

Use of conventional gun-type resin application systems to atomize resins and catalysts results in contamination similar to that produced through gel coat application. Not only do these spray-up systems deliver large volumes of resin, but they may also be equipped with glass choppers to chop fiberglass roving into short lengths and spray it onto the molding surface. Some alternative production approaches and equipment are discussed in Chapter 3. Some of these alternative approaches have the potential to reduce pollution output generated during lay-up. Although some of these alternatives are very attractive and will be used by many companies, spray applicators will remain popular. This is true because of their versatility, high efficiency, and relatively low cost. The use of these application systems is not likely to be discontinued in the near future.

Where spraying remains the application technology of choice, efforts should be made to reduce pollution associated with the process. The production line approaches used by Lasco Bath Fixtures Division help eliminate contaminants in the lay-up process as well as gel coating. Steamex, in using spray booths for both gel coating and lay-up, eliminates pollution from other areas of the plant. As with gel coat application, when filtering or treating contaminated air, the task is simplified if the sources of pollution can be isolated. Isolation of the lay-up area can be nearly as beneficial as isolation of gel coating operations. Many of the same pollution, contamination, quality assurance, and maintenance benefits are attained through isolation.

S2 Yachts in Holland, Michigan, has designed and built a well thought out production facility which separates basic production processes. Incompatible operations, such as grinding, finishing, lamination, and gel coating, are confined to different work bays. The company produces a high quality line of power and sail boats in the 18 to 35 foot range. Bay sizes vary for large and small boats. Although the same bays may be used for gel coating, separate bays are maintained for some secondary assembly operations, grinding, and finishing.

In designing its new facility S2 decided to try a total system approach involving improvement of air quality, improvement of materials handling, and reduction of plant air turnover. The filter units and return air units installed are discussed in unit B of this chapter. A design featuring two major first floor production areas and an overhead mezzanine was selected. A basic diagram is pictured in Figure 5.A.2. Each production area features a large center traffic aisle with work bays lining each side. One production area has larger and deeper bays for bigger yachts. The center aisle of each production area is open to the ceiling and equipped with an overhead hoist system to facilitate removal of units from molds, joining subassemblies, and loading components onto mobile fixtures. The aisles are also open at each end to facilitate delivery of raw materials to the work area and transportation of molded units to other areas of the plant for final assembly. Make-up air for the entire facility is forced in through roof mounted heater units and ventilators.

The booths on each side of the aisle have a ceiling height of approximately 12 feet and are covered by a mezzanine. The mezzanine area is used for storage and small part fabrication. Lower ceiling heights reduce the volume of exhaust and make-up air required and improve the air flow over the actual working area. Bay walls are constructed of cement block and are lined with removable plastic film to facilitate cleanup of overspray build-up. The rear of each booth has a false wall which is used as a collection duct for the exhaust units located overhead. Exhaust systems can be turned off, adjusted to exhaust all air from the plant, adjusted to return some air to the plant, or adjusted to return all air to the plant. A diagram of that exhaust system is shown in Figure 5.B.1. Ventilation control systems for each bay are positioned so that they may be adjusted from the work area. Bays used for gel coating and lay-up are equipped with filtration systems that differ from the ones used for grinding bays and other work areas. Each bay used for resin application is connected to a central resin supply system and a contaminated solvent collection basin which is connected to a centralized storage tank.

The facility design has proven to be an efficient one. Turnover of plant air has been reduced. The management team at S2 have indicated that productivity gains were high enough to provide a reasonable payback for extra expenses created by the design. These gains in productivity were attributed to improved ease in moving molds, molded parts, and other materials. Nuisance odor throughout the plant was reduced, and all air recirculated thorough the plant or discharged was dry filtered.

S2's success in developing the new facility can be traced to a willingness to integrate control of plant environment with a workable production scheme. Spraying and lay-up work in the confined bay areas would not be possible if the mold fixtures designed by the company could not be rotated by hand and moved in and out of the bays without an overhead hoist. The plant design also requires a major commitment to aisle space. These large aisles appear to make up for any loss of production space by facilitating rapid movement of molds, hulls, decks, and other structures. Teams in any work area are not interrupted as other workers move molds, remove parts from molds, or join subassemblies. During a plant visit considerable time was spent in direct observation of work in progress. There was little time when the aisle areas were not in use, however, there were no observed bottlenecks in materials movement.

The system used at S2 requires a commitment to performing certain operations only in appropriate areas and adherence to operating policies established by the company. Bays designated for grinding are not used for gel coat or lay-up. Resin coating of plywood components is carried out in only one area. Specific boat models are designated for lay-up in one or two specific bays. Operators must adjust ventilation systems to match the activities

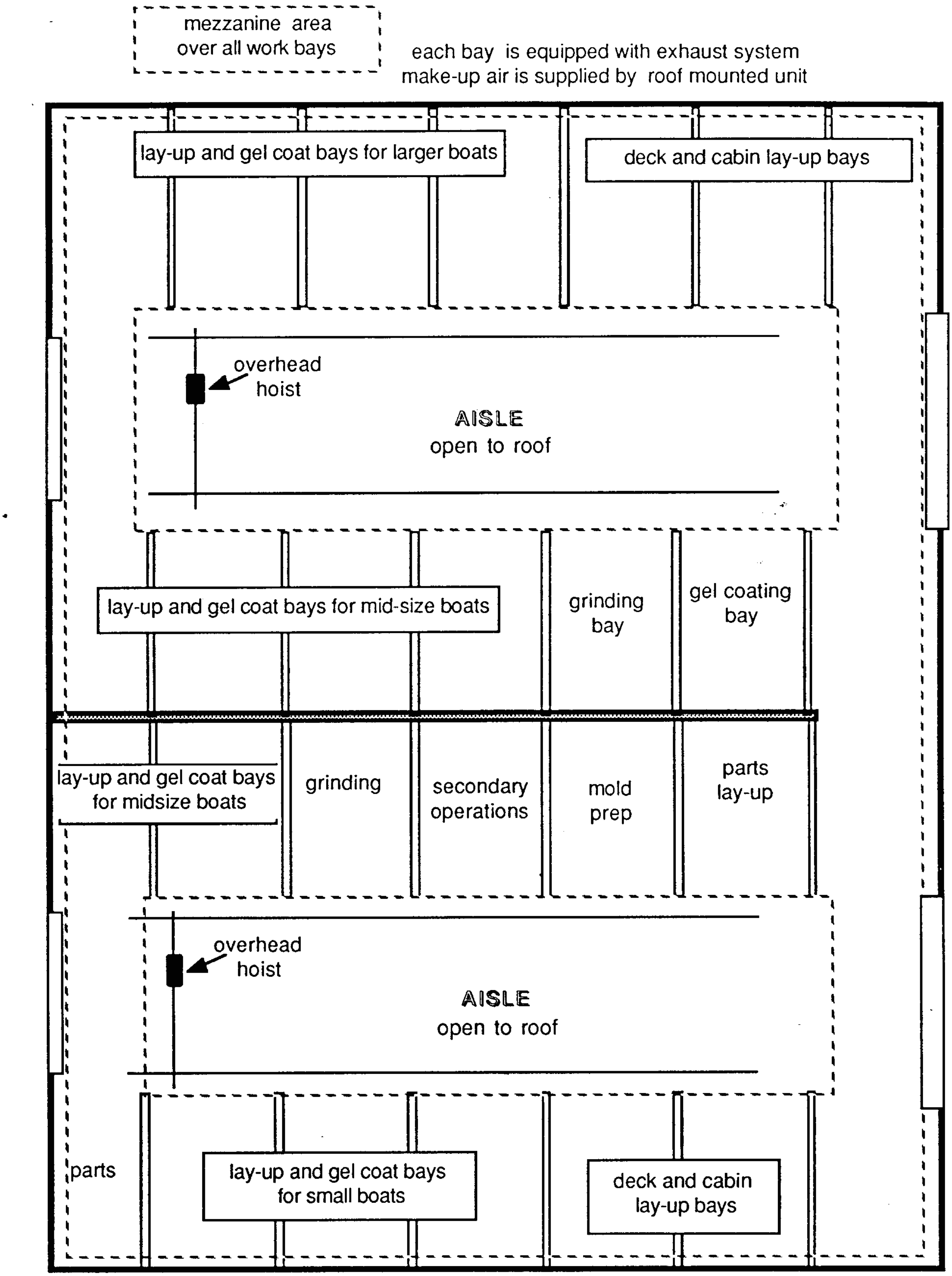


FIGURE 5.A.2. PRODUCTION FACILITY WITH BAYS

being performed in specific bays. Operators must change filters which have become inefficient. Operators must also take responsibility for adjusting the air handling units to match the activities being carried out in the bay.

The bay type facilities and system of air handling used at S2 Yachts have considerable application potential for other boat manufacturers as well as producers of other large fiberglass structures. The very design of a bay type facility helps insure isolation of environmentally troublesome operations such as spraying and grinding. Air turnover can be easily regulated and concentrated where needed. If treatment of emissions is required, the confined bay areas allow expensive filtration systems to be installed only where needed. Unnecessary turnover of plant air is also reduced. Confining work to bays helps keep aisles clear for materials handling and reduces interruption of production activities.

B. Air Filtration and Recirculation Systems

1. Filtering Contaminated Air

Selective filtration of plant air should be given serious consideration by any fiberglass fabricator who seriously wants to reduce pollution output. Heavy vapors and solids can be removed from the plant exhaust flow. Even simple paper or fiberglass filters have some effect on the levels of nuisance odors entering the outside environment. Overspray build-up on plant air handling equipment is reduced along with the build-up of overspray on nearby structures, equipment, cars, vegetation, and the ground. These external deposits often make fiberglass facilities appear to be excessively dirty and high in pollution output. Even when a facility is equipped with simple, through the wall exhaust fan systems, filter units can be fabricated and installed.

Filtering air as it leaves the work area has benefits other than reducing certain emissions. Plant air handling equipment used for exhaust and heating can perform more efficiently when contaminants are removed from the air. Overspray from spray applications and dust from grinding operations can build-up inside ductwork, fan units, motors, and other components. This build-up becomes a potential fire hazard when electricity or heat are involved. Fans and ductwork do not function efficiently when build-up occurs. Excessive build-up reduces air flow and places excessive loads on motors and control systems. This extra load combined with build-up on fan motor cooling vents, frequently leads to overheating and burnout of the motor.

Some firms are left with little choice about filtering plant exhaust. For a few high output facilities, emission cleanup is mandated by regulatory agencies. Where regulations are severe, elaborate filtration and purifications systems are required. For most operations dry filtration can be used to maintain local appearance, protect ventilation equipment, and remove solids in the form of dust or overspray. In some cases dry filtration has been used to remove enough solid contamination to allow the air to be recirculated.

2. Dry Filtration and Recirculation

Many fiberglass fabricators use a dry filtration medium in the plant exhaust system. Protection of expensive air handling equipment is normally sufficient reason to justify expenses for purchasing and changing filters. Dry filters are even used to protect ductwork and fans in facilities which are equipped with elaborate purification systems. Simple dry filter systems can be installed over almost any air intake opening. A number of units, observed in the course of preparing this manual, are simple shop built units constructed of angle iron and/or sheet metal. Large units can also be built in as an integral part of the physical facility.

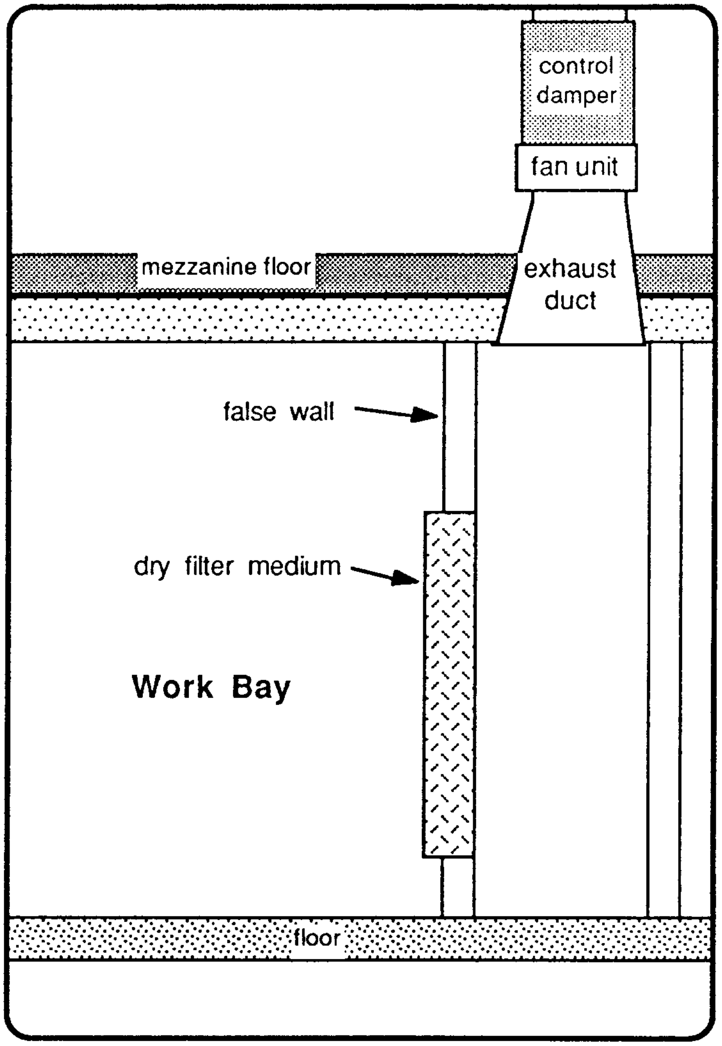


FIGURE 5.B.1 WORK BAY WALL COLLECTOR

S2 Yachts has elected to use built-in air filtration and air handling units in its new facility in Holland, Michigan. Design of this facility is discussed in Unit A of this chapter. All air collection in the S2 plant is filtered through one or more dry filtration units. The air collectors are designed as an integral part of the work bays used for fiberglass production activities. Collectors consist of a false masonry wall built across the rear of the bay. The false wall is placed approximately 18 inches in front of the actual back wall. This wall extends across the width of the bay and from ceiling to floor. An opening extending nearly the full width of the wall is framed up to accept two layers of dry filter material (a cross section of the collection wall is pictured in Figure 5.B.1). Air is pulled through the filter units by an exhaust fan unit located on the mezzanine above the bay. Each bay has its own duct system and fan.

The fan and exhaust ductwork system used by S2 Yachts features some innovative design concepts. Ductwork is provided to exhaust air through the plant roof. An alternate duct provides an outlet for returning air to the plant. A damper system in the ductwork can be regulated to allow all air to be dumped outside the plant or to allow all or part of the air to be returned to the plant environment. This design was selected in an attempt to provide for some filtering of air discharged from the fiberglass production area and to reduce the cost of heating the plant environment. Company officials believed that some air could be returned to the work area, especially if this air were being pulled from areas where pollution output was low. The design selected allows the operator to exhaust all air from a bay when spraying operations are in progress and to return all or part of the air to the plant when pollution output is low. The controls for the system are pictured in diagram5.B.2.

Under operating conditions the units have proven to be efficient in sweeping contaminated air from the workplace. On occasion an operator will forget to switch to outside air discharge when spraying operations are in progress. Odors are immediately noted by workers on the mezzanine, and word is passed to the operator. Air from grinding bays was targeted for full plant recirculation. Problems with this concept were encountered since dust created by grinding proved to be more difficult to remove than expected. Supplemental filters installed on the discharge side of these units were required to make them fully functional. Payback potential for the system has not been determined due to the short time it has been in operation and the relatively mild winter experienced in Michigan during 1986-1987.

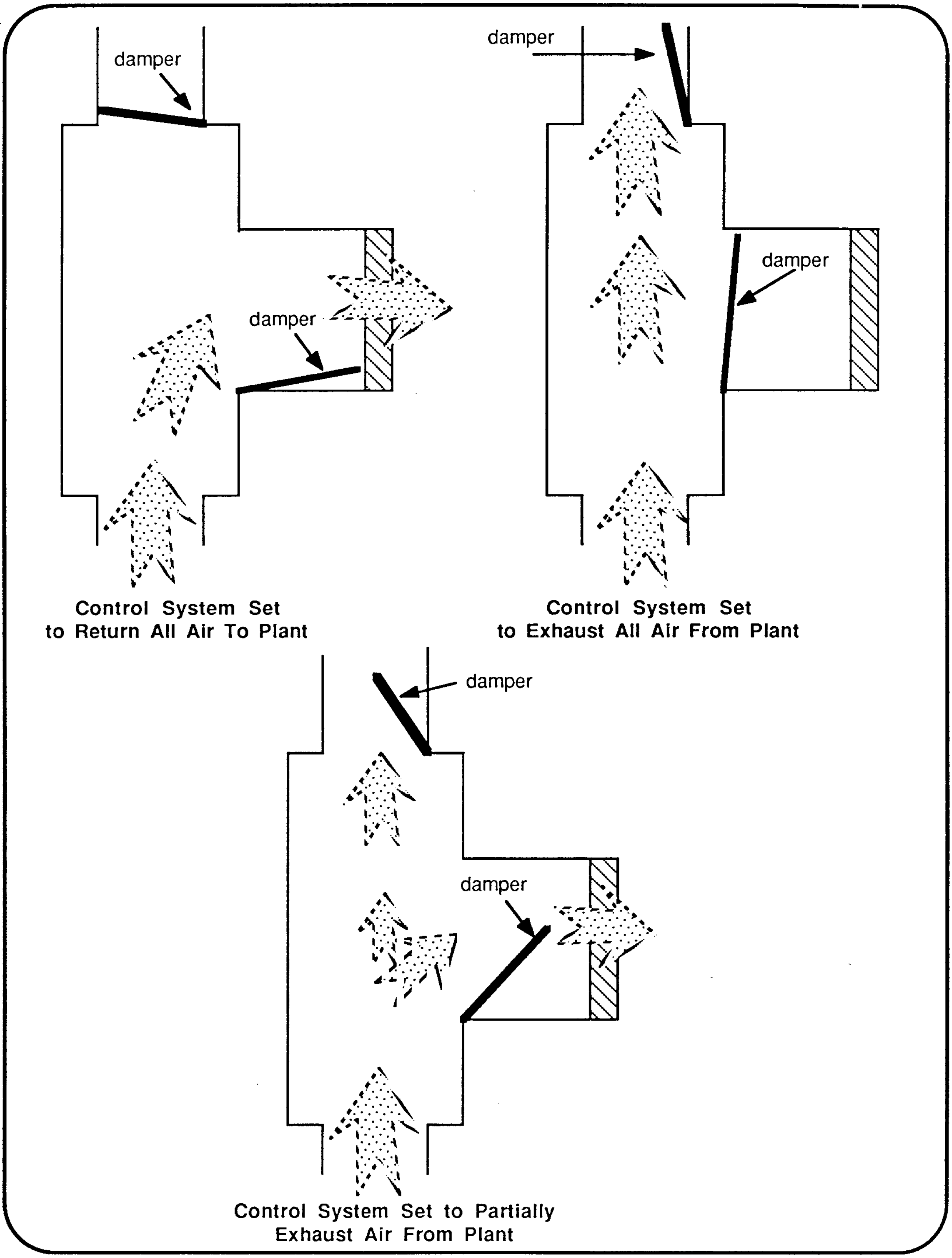


FIGURE 5.B.2 EXHAUST CONTROL SYSTEM

Case Study No 9

Type:	Plant air recirculation system
Company:	S2 Yachts, Inc.
Location:	725 East 40th Street Holland, Michigan 49423
Contact:	Leon Slikkers
Phone:	(810)-292-6171
Purpose:	Filter air exhausted from plant environment Recirculate plant air Reduce requirements for make-up air and heating
Motivation:	Improvement of air quality Reduction of utility costs
Equipment Supplier:	Building contractor for new facility
Payback Period:	Not available
Comments:	All pollution intensive operations are confined to separate work bays. Each bay is equipped with an exhaust and filtration system which allows air to be recirculated or discharged.
Source:	Plant visit in March, 1987 and phone conversations with company president (December, 1986)

3. Wet Filtration Systems

Water wash spray booths have been successfully used to control emissions associated with spray application of industrial finishes. Manufacturers of spray application equipment frequently market conventional and "water wash spray booths." The typical unit features a powerful exhaust system which pulls contaminated air through a mist or spray of water. Most filtration units are designed to provide a water wash by using pumps to spray water in the air passageway. Pumpless designs are also available. Figure 5.B.3 features cross sections of two water wash spray booths. Special chemicals can be added to the water reservoir for the purpose of trapping contaminants. Chemicals added to the water can make contaminants settle to the bottom of a collection tank or float on the surface for collection.

Waterfall units appear to offer some advantages over conventional dry filtration units. Dry filters clog quickly during heavy spray-up and gel coat application. This clogging lowers the surface velocity of air sweeping the work area and replacement of filters drives up maintenance costs. The air passages on waterfall units do not clog, and filtration capacity remains high unless water in the reservoir becomes overloaded with solids. Potential fire hazards are also reduced by the water wash system. Most local codes accept water wash spray booths as the best type of spray booth available. Units can be designed to fit the requirements of almost any production facility. Although use of these units for paint spray operations is widespread, there is little evidence of applications in open molded plastics facilities.

Hatteras Yachts in New Bern, North Carolina, has successfully used water wash booths in two of their production areas. A spray painting area approximately 150 feet long, 40 feet high, and 40 feet wide is equipped with pumpless water wash exhaust units along the full length of each side wall. The units exhaust through the roof and make-up air is forced in from overhead. Make-up air and exhaust air are carefully matched in order to maintain a slightly positive air pressure. These water wash units have enabled the company to efficiently reduce emissions associated with the spray application of large quantities of urethane paints. A smaller area of the main plant is also equipped with a water wash booth. This booth is used to filter dust from grinding and finishing operations carried out on small fiberglass parts.

These water wash units have worked so well that Hatteras has elected to incorporate water wash filtration units in a new production area being added to the New Bern plant. The new facility will be completed during the summer of 1987 and is designed to accommodate production of yachts considerably larger than 75 feet. The building will house three large lay-up areas which will have all exhaust air filtered through pump type water wash exhaust units. The water wash system was selected in an effort to reduce styrene levels in the plant as well as in the surrounding environment.

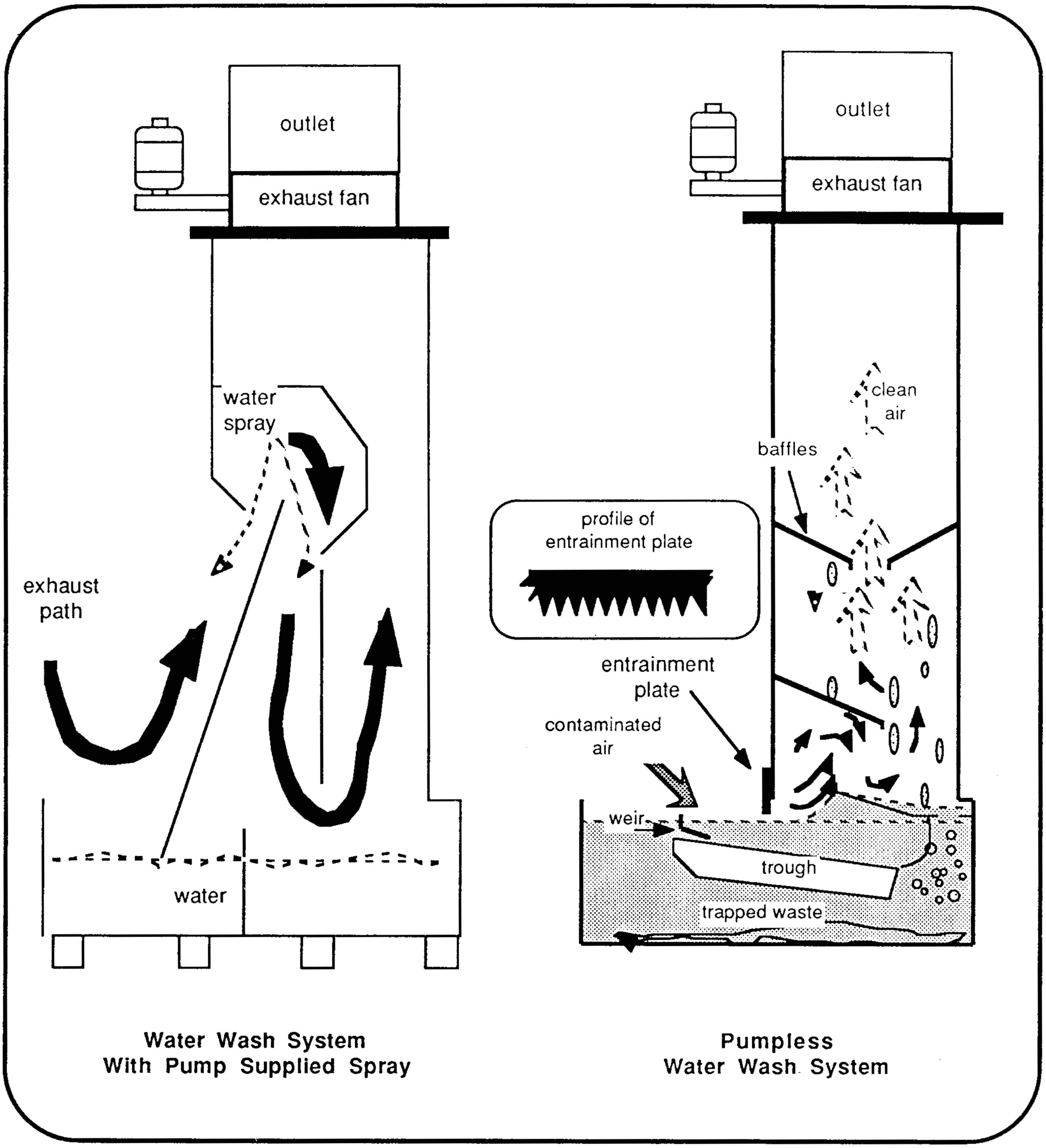


FIGURE 5.B.3 WATER WASH SPRAY BOOTHS

C. Fume Incineration

1. Using Heat to Reduce Styrene Emissions

High heat can be used to eliminate fumes and odors associated with styrene and other polymers. In situations where emissions associated with open molding processes are particularly high or severely restricted by regulation, incineration may prove to be a viable option. Incineration of styrene requires temperatures approaching 1,400° F. These high temperatures mean that any system developed for incineration of styrene must be carefully engineered to insure safety, a reasonable working life, and efficient use of energy.

Designs which provide only a gas fired heat chamber are relatively inexpensive to design and construct. Such designs however will require excessive use of fuel to heat all exhaust air in a relative short period of time. Common afterburner units are designed to rapidly ignite and oxidize the volatile organic compounds (VOC) found in fumes. Efficiency of these units can be improved by adding a tube type "catalytic" converter to hold the VOC's at a high temperature for a longer period of time.

Another design concept features a number of ceramic filled recovery chambers connected to a central burn chamber, the plant exhaust duct, and a discharge stack. These connections are made through a complex manifold system which is connected to a modern computerized monitoring and control system. A simple diagram of a unit depicting the interaction of two recovery chambers with the burn chamber is shown in Figure 5.C.1. Each recovery chamber can alternate between being in the 'inlet" or "outlet" mode.

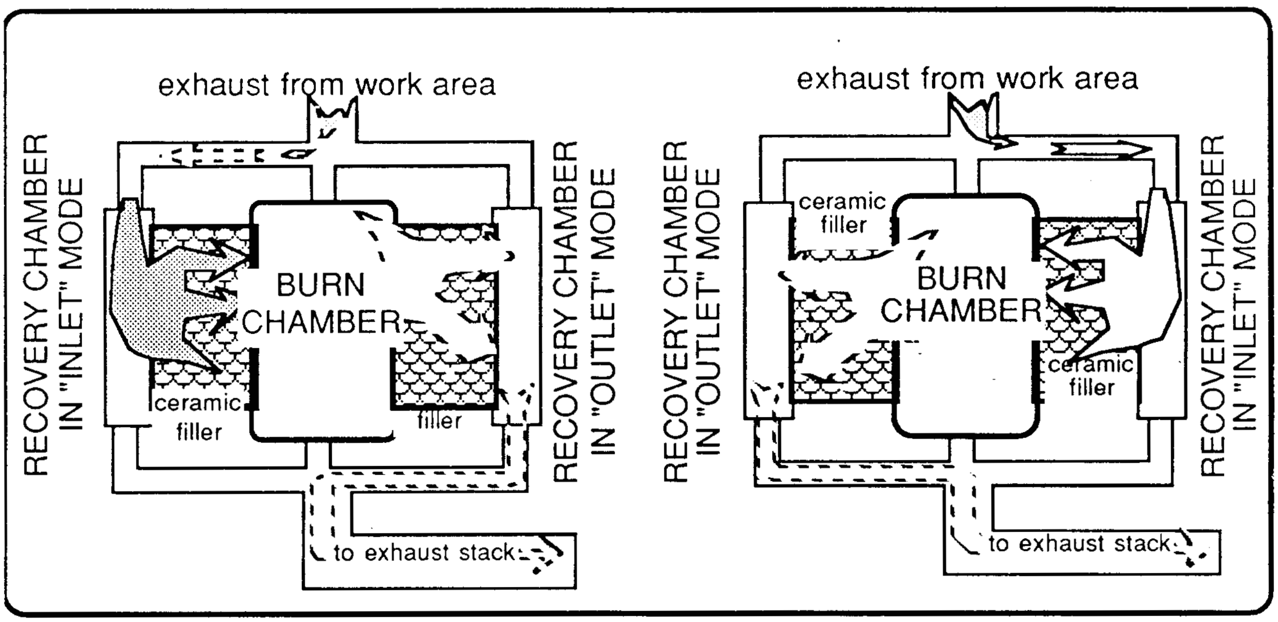


FIGURE 5.C.1 FUME INCINERATION UNIT

When a chamber is in "inlet" mode, plant exhaust is fed over the heated ceramic material in the chamber and out into the burn chamber. As the VOC's leave the chamber, their temperatures are very close to the incineration temperature. Oxidation is completed in the central chamber. The burn chamber is equipped with a burner system in order to maintain a predetermined temperature. Some ignition of the volatiles will occur while they are passing through the ceramic materials in the recovery chamber. When the content of volatiles is high, this auto ignition may provide all of the heat required for recovery, and the burner system will go to the pilot mode.

Purified air is passed from the burn chamber through the ceramic bed in a chamber which is in the "outlet" mode. Heat from this air is absorbed by the ceramic material. As heat is withdrawn, the cooled air exits to an exhaust fan and discharge stack. Most units consist of a central burn chamber and up to seven recovery chambers. Once sufficient exhaust is passed through an 'outlet" chamber, the ceramic bed becomes hot enough to allow the chamber to switch roles and become an "inlet" chamber. The units have to be brought up to temperature before the plant exhaust system can be placed in use.

2. Incineration Unit Application

The Lasco Bath Fixtures Division of Phillips Industries has installed a 20,000 SCFM incineration unit in its bathtub production facility located in South Boston, Virginia. Because of the high volume of resin use anticipated for the operation, installation of a treatment system was required by the State of Virginia. In an effort to attract Lasco to the South Boston location, some local funding was used to assist in the purchase of a treatment unit. The company selected a Re-Therm™ model 20 produced by Regenerative Environmental Equipment Company (see Appendix A). The unit cost was approximately $750,000. All exhaust from the isolated gel coat and spray-up areas are exhausted to the Re-Therm unit.

Performance of the unit is electronically monitored and controlled by a system of sensors and a computer unit. A permanent record of the unit's operation is automatically entered on a paper time chart. All plant equipment is tied to uninterrupted operation of the unit. If the unit is not operational, all spray and resin application systems are automatically shut down. In the event of a system failure, the appropriate state agency must be notified, and all performance charts must be kept on file for review by state inspectors. In two years of operation only one minor failure has occurred. This failure was traced to lightning damage of fuses and electronic components in the control system. The only other maintenance required has been a topping off of the ceramic beds.

Lasco also adds another treatment to air discharged from the plant. An odor masking chemical is misted into the plant discharge vents and stacks. This chemical has a sweet pleasant odor that helps mask the smell of styrene. During the first few months of operation some complaints were received about the smell of the masking chemical. This problem was eliminated by reducing the quantity of masking chemical released.

The company has been pleased with the performance of its incineration unit. Maintenance costs have been low and pollution output is dramatically reduced. There have been few interruptions to production. Neighbor complaints about odor and pollution from this new facility have been minimal. Fuel costs have been estimated to be less than $5.00 per hour. Since location incentives were provided and the unit was deemed essential for plant operation, payback calculations were not available.

Case Study No 10

Type:	Incineration system for styrene emissions Re-Therm™ model 20
Company:	Lasco Bath Fixtures
Location:	P. O. Box 1177 South Boston, Virginia 24592
Contact:	John Davenport, Production Manager
Phone:	(804)-572-1200
Purpose:	Remove styrene emissions from plant exhaust Meet Virginia regulations
Motivation:	Required by State for operating plant Improvement of air quality Lower utility costs when compared to other units
Equipment Supplier:	Regenerative Environmental Equipment Co., Inc. Box 600 520 Speedwell Avenue Morris Plains, New Jersey 07850
Payback Period:	Not available
Comments:	All pollution intensive operations are confined to isolated work booths. Exhaust from booth is fed directly to incinerator.
Source:	Plant visit in April, 1987 and phone conversations with plant manager and equipment supplier (March, 1987)

D. Controlling Air-Flow and Exhaust

1. Introduction

There are many codes and standards that govern the ventilation of commercial and industrial buildings. These may be expressed in terms of natural ventilation, such as the area of window space in a facility as a percentage of its floor area, or in terms of mechanical ventilation, such as the number of cubic feet per minute (CFM) of air required per occupant or unit of space. Because of the complex variables involved, these standards are, at best, approximations. They are primarily concerned with dilution.

Wherever human life or environmental safety is threatened by highly toxic substances, however, the guidelines governing acceptable levels of airborne contaminants are embodied in exacting and comprehensive state and federal regulations. The ventilation of these contaminants may thus require special equipment and administrative and technical measures to achieve compliance.

Most industrial and commercial requirements for ventilation fall somewhere between these two technical extremes. That is, the waste by-product or contaminant is being generated at a rate that is acceptable for immediate exposure, but presents a danger in higher concentrations that cannot be dealt with adequately through simple dilution of the air.

Dilution ventilation can be successfully used to control vapors from some organic liquids, such as the less toxic solvents. In general, it is not successful for the control of dusts, fumes, gases, mists and vapors that can produce an unsafe, unhealthy, or undesirable atmosphere. The control of these substances requires a system of exhaust ventilation designed with the basic principles of airflow in mind.

2. Exhaust Ventilation

The most fundamental principle of airflow is that the flow of air between two points is due to the occurrence of a pressure difference between the two points, with the air flowing from the area of high pressure to the area of low pressure. Simply stated, as an exhaust fan evacuates air from its intake side, it creates and area of low, or negative pressure, causing air to move from all directions toward the area under suction.

3. Maintaining Positive Pressure

Before listing some of the specific guidelines for achieving exhaust control, it should be noted that a complete industrial ventilation system should provide a supply of fresh air to compensate for the air being exhausted from the building. If not enough new air is supplied, the pressure of the building will be negative relative to the surrounding atmospheric pressure. This negative pressure results in the infiltration of air through open doors, windows, cracks, combustion equipment vents, etc. It also increases the total system resistance, making exhaust fans vents, etc. It also increases the total system resistance, making exhaust fans consume more energy than is necessary in a balanced system. There are other potential problems:

"As little as 0.05 inches (water gauge) of negative pressure can cause workers to complain about drafts and might cause downdrafting of combustion vents, creating a potential health hazard...If workers near the plant perimeter complain about cold drafts, unit heaters are often installed. Heat from these units is usually drawn into the plant interior because of the velocity of the infiltration air. This leads to overheating in the area and further complaints.**"

It is therefore recommended that a slight positive pressure be maintained in the facility through the use of sufficient intake fans or air conditioning/heating systems.

4. **General Guidelines**

The propose of exhaust ventilation is to entrain the airborne contaminant or nuisance in the air flow lines created by the system. It is frequently and mistakenly assumed that because of the specific gravity of a contaminant, it is either "heavier-than-air" or "lighter-than-air" and will eventually rise or fall of its won accord. Actually, even relatively heavy dusts, fumes, vapors and gases are truly air-borne, and are not subject to any appreciable migration up or down because of their own weight. This is because the contaminant-air mixture is usually overwhelmingly composed of air. The behavior of this mixture is thus virtually the same as for clean air and should be considered as such when planning an exhaust system.

No two facilities or production processes will be alike, but the following guidelines cover the major points to consider in achieving effective exhaust ventilation.

a. Exhaust fans or outlets should be located at or below the operator work level. They will then tend to pull the contaminant down and away from breathing level.

b. The contaminant-producing process or equipment should be located between the operator and the exhaust outlet. This will pull the contaminant away from the operator area.

c. Outlets should be place as close as possible to the source of contamination. Obviously, the closer the outlet, the more rapidly the contaminant can be entrained and exhausted before it disperses into the room.

d. Consider using a push-pull system, in which the contaminant is directed toward the exhaust outlet(s) by a low velocity airstream produced by

---

** Note: ASHRAE HANDBOOK, 1984 SYSTEMS, p. 20

fans or ducted inlets on the other side of the operation. It is important to keep velocity low to avoid creating eddies and turbulence that would disperse the contaminant.

e. Avoid cross-contamination of "clean" work spaces by arranging the facility so that HVAC inlets, cooling fans, or other exhaust vents do not produce cross-currents of air at the source of contamination.

f. Partitions, lowered ceilings, etc. can be used to advantage to enclose the contaminating process as much as possible. The more complete the enclosure, the more efficiently the exhaust system will evacuate the contaminant.

g. If cost allows, consider the use of an exhaust hood. (See Local Exhaust below).

h. Exterior exhaust outlets should be kept well away from open inlets to the building. Ideally, an exhaust stack above roof level is used. Alternatively, outlets should be placed to take advantage of local prevailing winds and the aerodynamics of the building to avoid re-entry.

An additional recommendation would be to design the provisions for exhaust ventilation with potential future regulatory changes in mind. In terms of environmental safety, the trend is toward ever-greater control of hazardous substances. If possible, the owner should research any governmental initiatives in that direction. The facility might then be deigned for compatibility with the types of containment equipment likely to be used. This is usually less expensive than retrofitting the facility into compliance.

5. Local Exhaust

For certain applications, the most effective method of evacuating a hazardous airborne substance from the workplace is to utilize a truly localized exhaust system. This consists of a ducted hood and an exhaust fan or other air-moving device. It offers optimum contamination control with minimum air volume requirements, and therefore lowers the cost of cleaning the air.

Hoods are either enclosing or non-enclosing types. The enclosing type is obviously more effective and more efficient, but is not always practical because fo the access requirements of the process or machinery. The non-enclosing type can be nearly as effective when placed in very close proximity to the process. This too can be impractical in terms of access to the process or machinery.

Inasmuch as localized exhaust is the most cost-effective method of removing contaminants, it is in the owner's interest to investigate its use wherever possible. The proper design and construction of a hood requires thorough knowledge of the principles of airflow and of the specific application to which it is dedicated, and may require the services of an HVAC engineer.

APPPENDIX A

MATERIALS SAFETY INFORMATION

1. Material Safety Data Sheet Overview

a) The first section of a material safety data sheet **(MSDS)** contains general product identification. The **company** listed (name, address, city, state, zip, phone), should be the backup source of detailed information on the hazards of the materials covered by the MSDS. This section also includes regular product information and emergency telephone numbers. In addition to an **emergency contact number**, many MSDS sheets include **CHEMTREC**, the nation-wide toll-free (1-800-424-9300), 24 hour-a-day, emergency number, of the chemical transportation emergency center. This contact provides response/action information for emergency circumstances. CHEMTREC forwards information to appropriate agencies and provides sufficient information for critical, first steps, in controlling an emergency. CHEMTREC is strictly an emergency operation service.

Additionally, the product should be identified in terms of a **chemical family**, **synonyms,** and **trade names**. A chemical family is a designation of similarity, like alkalis. Synonyms are those names commonly used, especially formal chemical nomenclature, like NaOH, sodium hydroxide. A trade name is a product designation or a common name such as soda lye, caustic soda, and lye. Not all chemicals have trade names or other common names. For some chemicals, it would be impossible to use every name or designation. A simple and standardized identification exists in the use of the **CAS number**. The CAS number is a unique numerical designation, given to every chemical entity by the Chemical Abstracts Service of the American Chemical Society. Its use helps to avoid confusion and ambiguity caused by multiple synonyms, common names, or similar chemical formulas. For example, sodium hydroxide is 1310-73-2. The CAS number is also useful for cross-referencing in different hazard classifications.

b) The materials listed as **hazardous ingredients** are those substances which are a part of the product covered by the MSDS, and individually meet any of the criteria defining a hazardous material (toxicity, ignitability, reactivity, etc). Generally, all ingredients are listed, with their **percent composition** and their toxic hazard data. In the case of proprietary formulas (trade secrets) precise percentages may be substituted by ranges or maximum values. In the case of some undesirable elements, such as fluorocarbons, it may also be useful to know what a product does not contain.

Toxic hazard data is a concept which refers to exposure to substances and conditions in which workers may have repeated and/or continuous exposure, without experiencing adverse affects. Control of the work environment is based on the assumption of a threshold limit, below which, exists a safe or tolerable level of exposure. The **TLV** (threshold limit value) is based on the best information from industrial experience, experimental human and animal studies, or a combination of all three. Emphasis is placed on inhalation exposure because of the rapidity with exposure. The **TLV** (threshold limit value) is based on the best information from industrial experience, experimental human and animal studies, or a combination of all three. Emphasis is placed on inhalation exposure because of the rapidity with which a potentially toxic material can be absorbed into the lungs and passed into the bloodstream, for distribution throughout the body.

The original idea of the TLV is a concept from the American Conference of Governmental Industrial Hygienists (ACGIH); it was intended as a guide in control of health hazards on the job. When OSHA was established, many of the 1968 TLV's were incorporated as legal standards and renamed **PEL**'s for permissible exposure limit. Because substances vary, people have different susceptibilities, work conditions vary, and scientific testing methods become more sensitive, the precision of the TLV and other exposure limits continue to be revised. New TLV's are published annually, but most PEL values are of 1968 vintage. Since the MSDS is required to reflect the most current data, the TLV is taken as an advisory standard. OSHA's PEL is the enforceable limit. The term TLV has come to represent the concept of the safe exposure limit and is expressed in units which reflect the airborne concentration of contaminants: ppm for parts per million; mg/m^3 for milligrams per cubic meter; mppcf for millions of particles per cubic foot of air. Note that for substances which are classified as carcinogens, there is no threshold of safety. Any contact is potentially harmful, and strict control measures are necessary to protect health.

c) The **physical data** contained in section three should reflect the properties of the product. Evaporation rate, appearance, odor are useful for the control of toxic substances. Boiling point, vapor density, volatile composition, and vapor pressure are useful for designing proper ventilation. In a fire situation, knowledge of these properties can help save lives and property.

The **fire and explosion** section should contain as much information as possible about potential product hazards resulting from exposure to fire, sparks, or sources of ignition. A **flashpoint** determination is the lowest temperature at which sufficient vapor is emitted to form an ignitable mixture with air. A standard method, specified by the American Society for Testing and Materials (ASTM), is used for the determination and is usually performed in a Tagliabue closed cup (TCC).

LEL and **UEL** are indicators of the explosive or flammable limits in air, above which or below which combustion does not occur. The lower explosive limit (LEL) is a minimum concentration below which the air-product mix is too "lean" to ignite. The upper limit (UEL) is the maximum concentration above which mixture with air is too "rich" to burn. Results are expressed in percentages by volume of gas or vapor in air. The lower limit is particularly important because the smaller the percentage is, the smaller the amount required to vaporize to form an ignitable mixture.

Any **special procedures** or **precautions** in a fire situation should be fully described. Many situations would require a "self-contained breathing apparatus." Other situations require "special fire extinguishing media" because of low water solubility of a product... an "aerosol can is an explosion hazard" under fire conditions. All considerations should be outlined. If the product is nonflammable or presents no fire hazard, that should be clearly noted.

Chemical components also have properties relating to their inherent stability. This is termed **reactivity** and relates to the degree or susceptibility of materials to release energy. **Stable** materials have a normal capacity to resist changes in their chemical composition, despite exposure to air, water, or heat. **Unstable** materials are those which will undergo chemical changes and vigorously decompose, condense, or become self-reactive. **Reactive** materials are those which readily undergo chemical reaction with other stable or unstable materials. Chemical **incompatibility** may be dangerous or destructive if not noted. Some materials are corrosive to metal and, if dumped down drains, may corrode pipes. A common household incompatibility is chlorine bleach and ammonia.

Polymerization is a chemical reaction which produces large molecules by a process of repetitive addition. Uncontrolled polymerization is a fire and explosion hazard, therefore frequent monitoring of products that may polymerize is a necessity. Storage time of polymerizable materials should be minimized.

d) The **health and safety** data should reflect the combined health hazards of the product, physiological effects of **overexposure** and specific **emergency/first aid** procedures. The TLV for the product should be listed as opposed to the TLV for each individual component, which is often duplicated from the 'hazardous materials' section. A product TLV is not always available since few products are thoroughly evaluated by independent laboratories. Therefore, different types of TLV's are used to help evaluate health and safety hazards.

The most common TLV is the TLV-TWA. This is a threshold limit value based on a time weighted average. The TWA is an exposure level which accounts for day-to-day fluctuations by averaging the exposure over a 40-hour work week, 8 hour shifts. There is also a 12-hour TWA which is based on a 12-hour shift. The TWA more closely approximates a worker's weekly exposure than a flat TLV rate.

The second TLV is the TLV-STEL. This is a short-term-exposure limit which reflects the maximum concentration to which exposure can occur (up to 15 continuous minutes) without ill effects. A worker is allowed 4 excursions with a minimum sixty-minute break between exposures; plus, the daily TLV-TWA (8 hr) must not be exceeded.

The third TLV is the TLV-C. This is a ceiling limit which should not be exceeded, even instantaneously.

The effects of overexposure should be written in lay terms where possible. "Headaches, dizziness, nausea" or "necrosis of the cornea" are examples. Very often, toxic hazard data is included in terms of concentration, mode of exposure, or test: LD_{50}, 25 mg/kg (RAT) or LC, 75 ppm (MAN). An LD_{50} is a lethal dose per kg of body weight which killed 50% of the test animals, 50% of the time. An LC is a lethal concentration, a designation used for airborne contaminants. This type of information is useful for paramedics who may be trying to assess an emergency. For a more thorough explanation of dose-response, consult an occupational toxicology text.

Emergency first aid procedures should also be written in lay terms. These instructions need to be specifically categorized into procedures to perform under different types of accidental contact. Examples are:

EYE:	Flush with water for 15 min. Consult Ophthalmologist...
SKIN:	Wash with a mild soap and water...
INHALATION:	Remove to clear air. Give CPR as needed...
INGESTION:	Do not induce vomiting...
OTHER:	Data as necessary.

Always have a physician monitor an accidental contact or overexposure.

e) Instructions for detailed **spill or leak procedures** for cleanup and disposal should be listed with emphasis on precautions to protect the workers on cleanup duty. Disposal methods, neutralizing chemicals, warnings, and proper tools are a necessary part of the instructions.

f) Special protection information, such as ventilation requirements, respirators, eye protection, and protective clothing, needs to be specified. "Supplied air-positive pressure" for respirator, "chemical splash goggles" for eye/face are examples of specified equipment. An eyewash should be a standard specification.

g) Special precautions are those statements about the product that can affect its safe use, storage, handling, or transportation. "Store below 90^{o}F", "inspect weekly", and "no smoking" are examples.

CONCLUSION

The MSDS is a product information sheet provided by the manufacturer of a chemical product or written by an in-house safety professional. Minimally, it should provide guidelines covering major points associated with methods of handling, controlling, using, and disposing of a substance in a safe manner. Although their primary use is among management representatives, the MSDS is to be accessible to the workers for their perusal.

MATERIAL SAFETY DATA SHEET

DATE ______________________

ACETONE

1 GENERAL		CHEMTREC 800-424-9300
MANUFACTURER'S NAME		EMERGENCY TELEPHONE NUMBER
ADDRESS (Number, Street, City, State, and Zip Code)		
CHEMICAL NAME AND SYNONYMS 2 PROPANONE, DIMETHYL KETONE, KETONE PROPANE		TRADE NAME AND SYNONYMS C_3H_6O
CHEMICAL FAMILY KETONE SOLVENT	FORMULA CH_3COCH_3	CAS # 67-64-1

2. HAZARDOUS INGREDIENTS

PAINTS, PRESERVATIVES, & SOLVENTS	%	TLV (Units)	ALLOYS AND METALLIC COATINGS	%	TLV (Units)
PIGMENTS			BASE METAL		
CATALYST			ALLOYS		
VEHICLE			METALLIC COATING		
SOLVENTS			FILLER METAL		
ADDITIVES			OTHERS		
OTHERS					

HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES	%	TLV (Units)
Acetone (CAS # 67-64-1) PEL (OSHA)	>99	1000ppm
TLV (ACGIH)	>99	750ppm

3. PHYSICAL DATA (at 20°C, 760 mm Hg)

BOILING POINT (F)	133°F	SPECIFIC GRAVITY (H_2O=1)	0.7880 @25°C
VAPOR PRESSURE (mm-Hg.)	266mm	PERCENT VOLATILE BY VOLUME (%)	100
VAPOR DENSITY (AIR=1) @15°C g/cm ^{3}	0.7972	EVAPORATION RATE (WATER)	< 1
SOLUBILITY IN WATER	MISCIBLE	MELTING POINT	-169°F
APPEARANCE AND ODOR	Colorless liquid with a fragrant, sweetish, mint like odor		
OTHERS	Miscible in ether, alcohol		

4. FIRE AND EXPLOSION DATA

FLASH POINT (method used)	1.4°F closed cup	FLAMMABILITY LIMITS	Lel	2.6%
			Uel	12.8%

EXTINGUISHING MEDIA: Alcohol foam, carbon dioxide, and dry chemical. Water can be used to cool exposed containers and disperse vapors and spills

VAPOR DENSITY (AIR=1) @15°C=0.7972 g/cm^3	AUTOIGNITION TEMPERATURE 869°F

SPECIAL FIRE FIGHTING PROCEDURES: Normal protective equipment and positive pressure self-contained breathing apparatus

UNUSUAL FIRE AND EXPLOSION HAZARDS: Dangerous fire hazard from heat, flames, oxidizers, and strong acids

5. HEALTH AND SAFETY DATA

THRESHOLD LIMIT VALUE: OSHA: 1000ppm, ACGIH: 750ppm, NIOSH: 250ppm, 590 mg/m^3 10 hr TWA

EFFECTS OF OVEREXPOSURE: Irritant to eyes, nose, and throat. Dizziness and headaches. Narcotic in high concentration. May cause dermatitis.

EMERGENCY AND FIRST AID PROCEDURES

EYE: Flush immediately with large amounts of water for at least 15 minutes. Contact lenses should not be worn. Obtain emergency medical attention.

SKIN: Immediately remove any contaminated clothing, wash thoroughly with mild soap and water. Seek medical attention if illness or irritation develop. LD_{50} (Rabbits) 20,000 mg/kg

INHALATION: Remove to fresh air immediately. Administer oxygen or artificial respiration as needed. Obtain emergency medical attention.

INGESTION: Obtain emergency medical attention. There is no specific antidote, must give supportive care based on judgement of the physician. Toxicity is low LD_{50} (Rats) >6000 mg/kg.

6. REACTIVITY DATA

STABILITY	UNSTABLE		CONDITIONS TO AVOID: Flames and sources of ignition
	STABLE	X	

INCOMPATABILITY (Materials to avoid): Sodium oxybromide, sulfuric acid plus potassium chromate, nitric acid plus sulfuric acid, hydrogen peroxide, fluorine oxide.

HAZARDOUS DECOMPOSITION PRODUCTS: Carbon dioxide and carbon monxide

HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID
	WILL NOT OCCUR	X	

7. SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

For small spills allow to evaporate (safety permitting). Otherwise soak up with absorbant material. For large spills remove sources of ignition, stop release, keep from entering drains, sewers, and waterways. Use air pump to transfer materials to containers. Report any waterway contact.

WASTE DISPOSAL METHOD

Incinerate in approved, emission monitored facility. Follow all applicable regulations especially where the material becomes contaminated by other waste.

8. SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify type)		For high exposure level a chemical cartridge respirator with organic vapor cartridge should be used.		
VENTILATION	LOCAL EXHAUST	to maintain below exposure guidelines	SPECIAL	Emergency: full faceplate self-contained apparatus
	MECHANICAL (General)		OTHER	
PROTECTIVE GLOVES		Rubber, latex or neoprene as needed	EYE PROTECTION	Splash proof goggles
OTHER PROTECTIVE EQUIPMENT		provide eyewash station		

9. SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING

Store away from heat and sources of ignition. Keep containers tightly closed. Observe no smoking regulations. DOT class: Flammable Liquid

OTHER PRECAUTIONS

Use non sparking tools.

MATERIAL SAFETY DATA SHEET

DATE ______________________

METHYL ETHYL KETONE PEROXIDE

1 GENERAL	CHEMTREC 800-424-9300
MANUFACTURER'S NAME	EMERGENCY TELEPHONE NUMBER
ADDRESS (Number, Street, City, State, and Zip Code)	
CHEMICAL NAME AND SYNONYMS METHYL ETHYL KETONE PEROXIDE (MEKP)	TRADE NAME AND SYNONYMS 2 Butanone Peroxide
CHEMICAL FAMILY ORGANIC PEROXIDE	FORMULA $C_8H_{16}O_4$ — CAS # 1338-23-4

2. HAZARDOUS INGREDIENTS

PAINTS, PRESERVATIVES, & SOLVENTS	%	TLV (Units)	ALLOYS AND METALLIC COATINGS	%	TLV (Units)
PIGMENTS			BASE METAL		
CATALYST			ALLOYS		
VEHICLE			METALLIC COATING:		
SOLVENTS			FILLER METAL		
ADDITIVES			OTHERS		
OTHERS See below					

HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES	%	TLV (Units)
Methyl Ethyl Ketone Peroxide (1338-23-4) ACGH TLV-C (as mixture)	60	0.2 pp
Dimethyl Phthalate (DMP) (131-11-3) OSHA PEL	40	5mg/m^3
Commercially available MEKP 60% with 40% Dilutent, generally DMP		

3. PHYSICAL DATA

~~BOILING POINT (F)~~	N/A	SPECIFIC GRAVITY (H_2O=1)	1.133
VAPOR PRESSURE (mm-Hg.)	N/A	PERCENT VOLATILE BY VOLUME (%)	<3%
VAPOR DENSITY (AIR=1)	N/A	EVAPORATION RATE (-------------=1)	N/A
~~SOLUBILITY IN WATER~~	< 1%		
APPEARANCE AND ODOR	Colorless liquid with pungent odor. May contain color additives.		
OTHERS	Decomposes at 155°F		

4. FIRE AND EXPLOSION DATA

FLASH POINT (method used) 185°F SETA closed cup	FLAMMABILITY LIMITS	lel	N/A	
		uel	N/A	

EXTINGUISHING MEDIA Dry chemical, carbon dioxide, water spray, and foam

VAPOR DENSITY (AIR=1) N/A	AUTOIGNITION TEMPERATURE N/A

SPECIAL FIRE FIGHTING PROCEDURES Fight fire from a distance with large quantities of water. Keep containers cool with spray. Do not attempt clean-up before materials cool to room temperature.

UNUSUAL FIRE AND EXPLOSION HAZARDS Potential explosion hazard. Will burn vigorously.

5. HEALTH AND SAFETY DATA

THRESHOLD LIMIT VALUE 0.2 ppm

EFFECTS OF OVEREXPOSURE Very inflammatory and caustic to skin and eyes. Causes skin necrosis and necrosis of the cornea resulting in loss of eyesite. Vapors are irritating as to cause resiparatory damage. Can cause chemical burns if ingested. An equivocal tumorigenic agent. MEKP is normally diluted with Dimethyl Phthalate which is a potential teratogen, and CNS depressant

EMERGENCY AND FIRST AID PROCEDURES

EYE: Irrigate immediately with large amounts of water for at least 15 minutes. Obtain emergency medical assistance without delay.

SKIN: Immediately remove any contaminated clothing, wash thoroughly with mild soap and water. Contact a physician for further treatment.

INHALATION: Remove to fresh air immediately. Obtain emergency medical attention without delay

INGESTION: Give large quantities of water. Obtain emergency medical attention. Prompt action is essential.

6. REACTIVITY DATA

STABILITY	UNSTABLE		CONDITIONS TO AVOID Sources of heat and ignition
	STABLE	X	

INCOMPATABILITY (Materials to avoid) Strong acids, bases, readily oxidables, accelerators,promoters, and metal salts.

HAZARDOUS DECOMPOSITION PRODUCTS Acrid, smoke, and fumes.

HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID
	WILL NOT OCCUR	X	

7. SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

Absorb spills with inert materials such as Perlite or Vermiculite and then wet with water. Sweep up using non-sparking tools and bag in double polyethylene bags. Isolate leaks and/or contaminated containers. Prevent from entering sewers and waterways. Contact authorities in case of accidental waterway contamination.

WASTE DISPOSAL METHOD

MEKP is a hazardous waste and must be disposed of in accord with RCRA and other state and local regulations.

8. SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify type)	Supplied-air respirator with a tight fitting faceplate operated in continuous flow mode		
VENTILATION	LOCAL EXHAUST To insure lowest possible concentration	SPECIAL	
	MECHANICAL (General)	OTHER	
PROTECTIVE CLOTHING	Polyethelene gloves, apron, sleeves, and boots	EYE PROTECTION	Chemical splash-proof goggles or face shield w/respirator
OTHER PROTECTIVE EQUIPMENT	Eyewash and quick drench shower		

9. SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING

Store in original containers at temperatures below 100°F. Avoid direct sunlight

OTHER PRECAUTIONS

Never mix promoter or accelerator with product. Rapid or explosive decomposition may occur.

4. **MSDS-Styrene**

MATERIAL SAFETY DATA SHEET

DATE ____________________

STYRENE, STYRENE MONONOMER

1 GENERAL	CHEMTREC 1-800-424-9300		
MANUFACTURER'S NAME		EMERGENCY TELEPHONE NUMBER	
ADDRESS (Number, Street, City, State, and Zip Code			
CHEMICAL NAME AND SYNONYMS VINYL BENZENE, CINNAMENE, VINYL BENZOL		TRADE NAME AND SYNONYMS PHENYLETHYLENE, C_8H_8	
CHEMICAL FAMILY AROMATIC HYDROCARBON	FORMULA $C_6H_5CHCH_2$	CAS # 100-42-5	

2. HAZARDOUS INGREDIENTS					
PAINTS, PRESERVATIVES, & SOLVENTS	%	TLV (Units)	ALLOYS AND METALLIC COATINGS	%	TLV (Units)
PIGMENTS			BASE METAL		
CATALYST			ALLOYS		
VEHICLE			METALLIC COATING:		
SOLVENTS			FILLER METAL		
ADDITIVES			OTHERS		
OTHERS (SEE BELOW) INHIBITOR					

HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES	%	TLV (Units)
STYRENE (CAS # 100-42-5) PEL (OSHA) as mixture:	99.9	100 ppm
TLV (ACGIH) as mixture:	99.9	50 ppm
P-TERTIARY BUTYL CATECHOL (CAS # 27213-78-1) (added at rate of 10-15 ppm prevents spontaneous polymerization of styrene)		

3. PHYSICAL DATA (at 25°c 760 mm hg)			
BOILING POINT (F) 145.2°c	293.4	SPECIFIC GRAVITY (H_2O=1)	3.6
VAPOR PRESSURE (mm-Hg.)	6.45	PERCENT VOLATILE BY VOLUME (%)	100
VAPOR DENSITY (AIR=1) g/cm^3	0.9018	EVAPORATION RATE (-------------=1)	
SOLUBILITY IN WATER	25mg/100g	MELTING POINT	-23°F
APPEARANCE AND ODOR	colorless liquid, odor threshold < 1 ppm, sweet aromatic at low concentraions; sharp, penetrating at high concentrations, very		
OTHERS	slightly soluble in water miscible in alcohol, ether		

4. FIRE AND EXPLOSION DATA

FLASH POINT (method used) 94°f (34.4°c) tag closed cup	FLAMMABILITY LIMITS	Lel	1.1%
		Uel	6.1%

EXTINGUISHING MEDIA
dry chemical, CO_2, foam, water spray, water fog (water, for cooling only may be ineffective due to low solubility of styrene in water)

VAPOR DENSITY (AIR=1)	AUTOIGNITION TEMPERATURE
0.9018 g/cm^3	914°F (490°C)

SPECIAL FIRE FIGHTING PROCEDURES
Self-contained breathing apparatus, eye and body protection. Fight fire from safe distanc or protected location. Notify authorities if liquid enters sewer or waterways

UNUSUAL FIRE AND EXPLOSION HAZARDS
Heat, lack of inhibitor,impurities, radiation, sudden exposure to air, may result in spontaneous reacton, may generate heat, build pressure, and rupture containers. Liquid is normally inhibited, but not the vapors. The vapors may condense as solids and plug pressure relief valves, causing rupture of storage containers.

5. HEALTH AND SAFETY DATA

THRESHOLD LIMIT VALUE	OSHA	ACGGIH	NIOSH
	100 ppm 200 ppm ceiling	50 ppm	50 ppm 10 Hr TWA 100 ppm 15 Min Ceiling

EFFECTS OF OVEREXPOSURE Severe eye irritant, drowsiness, weakness, aspiration hazard. Unsteady gait, narcosis, skin irritation,nausea, CNS depression

EMERGENCY AND FIRST AID PROCEDURES

EYE: Irrigate immediately with large amounts of water for at least 15 minutes. Contact lenses should not be worn. Obtain emergency mecical attention.

SKIN: Immediately remove any contaminated clothing, wash thoroughly with mild soap and water. If sticky, a waterless cleaner may be used prior to soap and water wash. Seek medical attention if ill effects or irritation develop

INHALATION: Remove to fresh air immediately. Administer oxygen or artificial respiratio as needed (especially if cyanotic). Obtain emergency medical attention.

INGESTION: Give pint of lukewarm water if victim is conscious and alert. DO NOT INDUCE VOMITING. Obtain emergency medical attention. Prompt action is essential.

OTHER: Styrene is a mutagen and a suspected animal carcinogen

6. REACTIVITY DATA

STABILITY			CONDITIONS TO AVOID
	UNSTABLE		Normally stable with proper maintenance of inhibitor levels. Avoid heat, flame, and contaminants. Corrosive to copper and copper alloys. Dissolves rubber.
	STABLE	X	

INCOMPATABILITY (Materials to avoid) Catalysts for vinyl polymers, oxidizers, peroxides, strong acids, aluminum chloride, pure oxygen.

HAZARDOUS DECOMPOSITION PRODUCTS Acrid fumes, carbon monxide, carbon dioxide.

HAZARDOUS POLYMERIZATION			CONDITIONS TO AVOID
	MAY OCCUR	X	Improperly cleaned containers, inadequate maintenance of inhibitor levels. Improperly vented storage containers. Storage at temperatures above 90°F.
	WILL NOT OCCUR		

7. SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED
Immediate danger of polymerization. Evacuate area and limit access. Stop release and prevent flow into sewers and waterways. Impound large land spills. Soak up small spills with inert absorbent material. On water, spills float; contain dispersion and collect. Report spills as per regulatory requirements.

WASTE DISPOSAL METHOD

May be RCRA/OSHA hazardous. Determine standards that apply.Regulations may require use o registered transporters and permitted landfill sites. Use vented contaniners for storage of waste. Storage must be in accordance with state, EPA, and RCRA/OSHA regulations.

8. SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify type) Any supplied-air respirator with a full facepiece and operated in a positive pressure mode in combination w/ self-contained breathing apparatus o remote air supply. (Required where exposure exceeds PEL/TLV)

VENTILATION	LOCAL EXHAUST	To maintain below TLV	SPECIAL
	MECHANICAL (General)		OTHER

PROTECTIVE CLOTHING Polyethylene gloves, apron, sleeves,and boots	EYE PROTECTION Chemical splash=proof goggles or face shield w/respirator.

OTHER PROTECTIVE EQUIPMENT Standard emergency eye and shower wash facilities in vicinity. Use non-sparking tools. When possibility exists for contact from spraying, splashing airborne solids, or vapors, full protective clothing must be worn.

9. SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING
DOT Hazard: Flammable liquid, store below 90°F. Inspect inhibitor levels bi-weekly. Do no store more than 30 days. Keep containers properly closed and vented. Inspect containers and observe proper cleaning standards.

OTHER PRECAUTIONS
Do not wear contact lenses. Observe good personal hygiene procedures, especially befor eating, drinking, or smoking. Thoroughly clean all equipment after each use

5. RECOMMENDATIONS FOR A STYRENE STANDARD*

The National Institute for Occupational Safety and Health (NIOSH) recommends that worker exposure to styrene in the workplace be controlled by compliance with the following sections. These recommendations are designed to protect the health and provide for the safety of workers for up to a 10-hour workshift, 40-hour workweek, over a working lifetime. Compliance with all sections of the recommended standard should prevent or greatly reduce the risk to exposed workers of adverse effects. NIOSH considers the recommended environmental limits for styrene to be upper boundaries of exposure. Thus, employers should make every effort to maintain exposure concentrations as low as possible. This recommended standard will be subject to review and revision as necessary.

Occupational injury and illness attributed to styrene results from inhalation of the vapor or from skin contact with the readily absorbed liquid. The NIOSH recommended standard is primarily based on reports of effects on the human nervous system, and on irritation of the eyes and respiratory system.

Central nervous system (CNS) effects have been observed among experimental subjects as well as workers exposed to styrene at time-weighted average (TWA) concentrations of about 100 parts per million (ppm). In addition, some investigators have reported observing these effects at concentrations less than 100 ppm, both experimentally and clinically. However, the experimental studies are of limited value in establishing a recommended exposure limit because of the small numbers of subjects studied. Similarly, the clinical studies are difficult to interpret because the exposures occurred over a wide range of concentrations, occasionally in excess of 100 ppm. The most frequently reported effects of exposures at about 100 ppm are subjective symptoms such as fatigue, dizziness, headache, nausea, poor memory, and drowsiness. These subjective symptoms of CNS depression have been substantiated experimentally in human subjects and in clinical studies of workers exposed to styrene who demonstrated slower reaction times and impaired balance; abnormal EEG's have also been noted.

It has been reported in a number of clinical studies that chromosome changes occurred with greater frequency in the lymphocytes of workers exposed to styrene at about 100 ppm than workers not exposed to styrene. Other investigations have reported an increase in the rate of sister chromatid exchanges among styrene-exposed workers. However, the long-term significance of these effects is not clear and requires further elucidation.

Although the evidence is not strong, exposure to styrene has also been implicated with other adverse health effects such as peripheral neuropathy, abnormal pulmonary function, liver toxicity, teratogenicity, and carcinogenicity.

---

* Mazzuckelli LF, Mason RW, and Ludwig HR: **Criteria for a recommended Standard---Occupational Exposure to Styrene,** DHHS (NIOSH) Publication No. 83- 119, Cincinnati, OH, US Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, 1983, pp 1-14.

These health effects need further investigation, and would provide additional evidence for a reduction in the current occupational exposure standard if they were found to be styrene-related.

Although additional research is needed to clarify some of the reported effects, worker exposure to styrene should not exceed 50 ppm as a TWA concentration for up to a 10-hour shift, 40-hour workweek. To prevent CNS depression and irritation of the eyes and respiratory tract, exposures should not exceed 100 ppm, determined as a ceiling concentration by a 15-minute sample.

The "action level" for styrene is defined as one-half the TWA concentration limit for styrene. Due to interday variability of environmental levels, a worker's single TWA exposure measurement over the workshift that is below the recommended standard does not necessarily indicate that exposures on other days would also be below the recommended standard. If a worker's TWA exposure during a workshift is at or above one-half the recommended standard, a sufficient probability exists that on other days exposures could exceed the recommended TWA standard. As such, the concept of an "action level" is needed to ensure adequate protection of the workers. Exposure to styrene below the "action level" will require adherence to all sections of the recommended standard except Sections 2(b), 8 (a) (2), and the monitoring provisions of 8 (b).

Section 1 - Environmental (Workplace Air)

(a) Concentration (Recommended Environmental Limits)

Exposure to styrene in the workplace shall be controlled so that workers are not exposed to styrene at concentrations greater than 50 parts per million (ppm), determined as a time-weighted average (TWA) exposure concentration for up to a 10-hour workshift, 40-hour workweek. A ceiling concentration of 100 ppm, as determined during any 15-minute sampling period, is also recommended.

(b) Sampling and Analysis

Workroom air samples shall be collected and analyzed as described in Appendix I, or by any other methods at least equivalent in accuracy, precision, and sensitivity.

Section 2 - Medical

The employer shall provide the following information to the physician performing or responsible for the medical surveillance program: the requirements of the applicable standard; an estimate of the worker's potential exposure to styrene, including any available workplace sampling results; a description of the worker's duties as they relate to the worker's exposure; and a description of any protective equipment the worker may be required to use.

(a) Preplacement medical examinations shall include at least:

(1) Comprehensive medical and work histories with special emphasis on the nervous system, skin, respiratory tract, liver, and eyes.

(2) A physical examination giving special attention to the nervous system, skin, respiratory tract, liver, and eyes. Additional testing, such as clinical tests of liver function and enzymes, should be considered by the physician responsible for the examination.

(3) A judgement of the worker's ability to use positive and negative pressure respirators.

(b) Periodic medical examinations shall be made available at least annually to all workers occupationally exposed to styrene at airborne concentrations at or above the action level, or who have the potential for significant skin exposure (see paragraph (b) (3) of this section). These examinations shall include at least:

(1) An update of medical and work histories;

(2) A physical examination and tests as outlined in paragraph (a) (2) of this section;

(3) In those instances where there is a potential for elevated or widely varying styrene exposures through inhalation and/or skin absorption, measurement of urinary mandelic acid (a styrene metabolite) may serve as a useful adjunct for characterization of workplace styrene exposures (see Appendix II). If the measurement of a worker's urinary mandelic acid suggests possible overexposure to styrene, an effort should be made to ascertain the cause, such as failure of engineering controls, poor work practices, or nonoccupational exposures.

(c) Monitoring of urinary mandelic acid and a physical examination as outlined in paragraph (a) (2) of this section shall be made available to any worker exposed to unknown concentrations of styrene during a spill or emergency.

(d) Workers and potential workers having medical conditions, such as disorders of the nervous or respiratory systems, or a liver disease that could be directly or indirectly aggravated by exposure to styrene, shall be counseled on the possibility of increased risk of impairment to their health from working with styrene.

(e) Following completion of the examination, the physician shall give to the employer a written statement about whether the worker has any detected medical conditions which would place the worker at increased risk of health impairment from exposure to styrene. The written statement shall include any recommended limitations upon the worker's exposure to styrene or upon the use of respirators. A copy of this written statement obtained by the employer shall not reveal specific findings or diagnoses and shall be provided to the worker.

(f) Pertinent medical records (i.e., the physician's written statement, the results of medical examinations and tests, medical complaints, etc.) for all workers subject to exposure to styrene in the workplace shall be retained for at least 30 years after termination of employment. Copies of environmental monitoring data applicable to a worker shall also be included in that worker's medical records. These records shall be made available to the designated medical representatives of the Secretary of Labor, the Secretary of Health and Human Services, the employer, and the worker or former worker.

(g) The relationship of styrene exposure to adverse reproductive effects has not been thoroughly investigated. Workers shall be made aware of the possibility of such adverse effects.

Section 3 - Labeling and Posting

All labels and warning signs shall be printed both in English and in the predominant language of non-English-reading workers. Workers unable to read the labels and posted signs shall be informed verbally regarding the hazardous areas of the plant or worksite and the instructions printed on labels and signs.

(a) Labeling

Containers of styrene used or stored in the workplace shall carry a permanently attached label that is readily visible. The label shall identify the presence of styrene and give information regarding its effects on human health. The information may be arranged as follows:

STYRENE
CAUTION!
HARMFUL IF INHALED OR IF ABSORBED THROUGH SKIN
IRRITATING TO SKIN, EYES, NOSE, THROAT, MOUTH, AND LUNGS
FLAMMABLE

In case of eye contact, immediately flush eyes with large amounts of water for 15 minutes. If irritation persists, get medical attention. Keep containers closed when not in use. Use only with adequate ventilation. Keep away from heat, sparks, and open flame.

(b) Posting

Readily visible signs containing information on the effects of styrene on human health and emergency measures shall be posted in work areas and at entrances to work areas or building enclosures where there is the likelihood of styrene concentrations above the action level or where the possibility of appreciable spills or skin contact with styrene exists. This information may be arranged as follows:

STYRENE
CAUTION!
HARMFUL IF INHALED OR IF ABSORBED THROUGH SKIN
IRRITATING TO SKIN, EYES, NOSE, THROAT, MOUTH, AND LUNGS
FLAMMABLE

Place cleaning rags and soiled clothing in fireproof containers. Use chemical fire extinguisher.

(c) Respirators

If respirators are needed during the installation or implementation or required engineering controls, the following statement shall be added in large letters to the sign required in paragraph (b) of this section:

RESPIRATORY PROTECTION REQUIRED IN THIS AREA

(d) Emergency Situations

In any area where there is a likelihood of emergency situations arising, signs required by paragraph (b) of this section shall be supplemented with signs giving emergency and first-aid instructions and procedures, the location or first-aid supplies and emergency equipment, and the locations of emergency showers and eyewash fountains.

Section 4 - Protective Clothing and Equipment

Engineering controls and safe work practices shall be used to keep the concentration of airborne styrene at or below the limits specified in Section 1(a) and to minimize skin and eye contact. In addition, protective clothing and equipment shall be provided by the employer to the workers when necessary.

(a) Eye Protection

The employer shall provide safety glasses, chemical safety goggles, or face shields (20-cm minimum) with goggles and shall ensure that workers wear the protective equipment during any operation in which splashes of liquid styrene are likely to occur. Devices for eye and face protection shall be selected, used, and maintained in accordance with 29 CFR 1920.133 (U.S. Department of Labor, Occupational Safety and Health Administration, Occupational Safety and Health Standards, Eye and Face Protection).

(b) Skin Protection

(1) Workers at risk of skin contact with styrene shall be provided with protective clothing such as gloves, boots, overshoes, and bib-type aprons (at least knee-length). The clothing shall be both impervious and resistant to styrene. Material made of polyvinyl alcohol or polyethylene afford good protection.

(2) Clothing contaminated with styrene shall be cleaned before reuse. Anyone who handles contaminated clothing or is responsible for its cleaning shall be informed of the hazards of styrene and the proper precautions for its safe handling and use.

(3) The employer shall ensure that all personal protective clothing and equipment is inspected regularly and maintained in a clean and satisfactory working condition.

(c) Respiratory Protection

(1) The use of a respirator to achieve compliance with the recommended exposure limits is permitted only during the time necessary to install and test required engineering controls, for nonroutine operations such as maintenance or repair activities causing brief exposures at concentrations in excess of the recommended environmental limits, during work in confined spaces, or during emergencies when concentrations of airborne styrene may exceed the recommended environmental limit.

(2) Respirators shall be provided in accordance with Table I-1 by the employer when such equipment is necessary to protect the health of the worker. The worker shall use the provided respiratory protection in accordance with instructions and training received.

(3) The respiratory protective devices provided in conformance with Table I-1 shall comply with the standards jointly approved by NIOSH and the Mine Safety and Health Administration (MSHA) as specified under the provisions of the U.S. Department of the Interior, Bureau of Mines (Respiratory Protective Devices and Tests for Permissibility, 30 CFR Part 11).

(4) The employer shall ensure that respirators are properly fitted and that workers are instructed at least annually in the proper use and testing for leakage of respirators assigned to them.

(5) The employer shall be responsible for the establishment and maintenance of a respiratory protection program meeting or exceeding the requirements established by the Occupational Safety and Health Administration (Respiratory Protection, 29 CFR 1910.134) as summarized below:

(A) Written standard operating procedures governing use of respirators shall be established.

(B) The worker shall be instructed and trained in the proper use of respirators and their limitations.

(C) Where practicable, the respirators should be assigned to individual workers for their exclusive use.

(D) Respirators shall be regularly cleaned and disinfected.

(E) Respirators shall be stored in a convenient, clean, and sanitary location.

(F) Respirators used routinely shall be inspected during cleaning. Worn or deteriorated parts shall be replaced. Respirators for emergency use such as self-contained devices shall be thoroughly inspected at least once a month and after each use.

(G) Workers should not be assigned to tasks requiring use of respirators unless it has been determined that they are physically able to perform the work and use the equipment. The respirator user's medical status should be reviewed periodically (for instance, annually) as recommended by the physician responsible for the physical examination.

(H) Appropriate surveillance of work area conditions and degree of worker exposure or stress shall be maintained.

(I) There shall be regular inspection and evaluation by the employer to determine the continued effectiveness of the program.

Section 5 - Informing Workers of the Hazards of Styrene

(a) All new and current workers in areas where airborne exposures to styrene are at or above the action level, or who have the potential for significant skin exposure, shall be kept informed of the hazards, relevant prenarcotic symptoms, effects of overexposure, and proper conditions and precautions for the safe use and handling of styrene.

TABLE I-1

RESPIRATOR SELECTION GUIDE FOR PROTECTION AGAINST STYRENE

Vapor Concentration	Respirator Type Approved Under Provisions of 30 CFR 11*
400 ppm or less	Any chemical cartridge respirator with organic vapor cartridge(s).**
	Any supplied-air respirator.**
	Any self-contained breathing apparatus.**
1000 ppm or less	A chemical cartridge respirator with a full facepiece and organic vapor cartridge(s).
5000 ppm or less	A gas mask with a chin-style or front-or back-mounted organic vapor canister.
	Any supplied-air respirator with a full facepiece, helmet, or hood.
	Any self-contained breathing apparatus with a full facepiece.
Greater than 5000 ppm or during entry and escape from unknown concentrations.	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
	A combination respirator which includes a Type C supplied-air respirator with a full faceplate operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	Any gas mask providing protection against organic vapors.
	Any escape self-contained breathing apparatus.

*Only NIOSH-approved or MSHA-approved equipment should be used.
**If eye irritation occurs, full-faceplate respiratory protective equipment should be used.

(b) The employer shall institute a continuing education program, conducted by persons qualified by experience or training in occupational safety and health, to ensure that all workers exposed to styrene above the action level have current knowledge of styrene hazards, proper maintenance, cleanup methods, and proper use of protective clothing and equipment, including respirators. The instructional program shall include oral and written descriptions of the environmental and medical surveillance programs and of the advantages to the worker of participating in these surveillance programs. The employer shall maintain a written plan of these training and surveillance programs.

(c) Workers shall also be instructed on their responsibilities for following proper work practices and sanitation procedures to help protect the health and provide for the safety of themselves and their fellow workers.

(d) All new and current workers in areas where exposure to styrene may reasonably be expected to occur during spills or emergencies shall be trained in proper emergency and/or evacuation procedures.

(e) Required information shall be recorded on the "Material Safety Data Sheet" shown in Appendix III, or on a similar form specified by the Occupational Safety and Health Administration (OSHA) describing the relevant toxic, physical, and chemical properties of styrene and of mixtures of styrene that are used or otherwise handled in the workplace. This information shall be kept on file and shall be readily available to workers for examination and copying.

Section 6 - Work Practices

(a) Handling and General Work Practices

(1) Operating instructions for all equipment shall be developed and posted where styrene is handled or used.

(2) Transportation and use of styrene shall comply with all applicable local, State, and Federal regulations.

(3) Styrene shall be stored in tightly closed containers in well-ventilated areas.

(4) Containers shall be moved only with the proper equipment and shall be secured to prevent loss of control or dropping during transport.

(5) Storage facilities shall be designed to contain spills completely within surrounding dikes and to prevent contamination of workroom air.

(6) Ventilation switches and emergency respiratory equipment shall be located outside storage areas in readily accessible locations that will remain only minimally contaminated with styrene in an emergency.

(7) Process valves and pumps shall be readily accessible and shall not be located in pits or congested areas.

(8) Styrene containers and systems shall be handled and opened with care. Approved protective clothing and equipment as specified in Section 4 shall be worn by workers who open, connect, and disconnect styrene containers and systems. Adequate ventilation shall be provided to minimize exposures of such workers to airborne styrene.

(9) Styrene storage equipment and systems shall be inspected daily for signs of leakage. All equipment, including valves, fittings, and connections, shall be checked for leaks immediately after styrene is introduced therein.

(10) When a leak is found, it shall be repaired promptly. Work shall resume normally only after necessary repair or replacement has been completed, and the area has been well ventilated.

(b) Engineering Controls

(1) Engineering controls shall be used when needed to maintain exposure to airborne styrene within the limits prescribed in Section 1 (a). Complete containment of the vapor is the recommended method for control of styrene exposure. Local exhaust ventilation may also be effective when used alone or in combination with process enclosure. When a local exhaust ventilation system is used, it shall be designed and operated so as to prevent accumulation or recirculation of airborne styrene into the workplace environment and to effectively maintain safe levels of styrene in the breathing zones of workers. Exhaust ventilation systems discharging to outside air shall conform with applicable local, State, and Federal air pollution regulations and shall not constitute a hazard to workers or to the general population. Before maintenance work on control equipment begins, the generation of airborne styrene shall be eliminated to the extent feasible.

Enclosures, exhaust hoods, and ductwork shall be kept in good repair so that designed airflows are maintained. Measurements such as capture velocity, duct velocity, or static pressure shall be made at least semiannually, and preferably monthly, to demonstrate the effectiveness of the mechanical ventilation system. The use of continuous airflow indicators, such as water or oil manometers marked to indicate acceptable airflow, is recommended. A log shall be kept showing design airflow and the results of all airflow measurements. Measurements of the effectiveness of the system to control exposures shall also be made as soon as possible after any change in production, process, or control which may result in any increase in airborne concentrations of styrene.

(2) Forced-draft ventilation systems shall be equipped with remote controls and should be designed to shut off automatically in the event of a fire in the styrene work area.

(c) Confined or Enclosed Spaces

(1) Entry into confined or enclosed spaces, such as tanks, pits, tank cars, and process vessels, where there is limited egress, shall be controlled by a permit system. Permits shall be signed by an authorized employer representative and shall certify that preparation of the

confined space, precautionary measures, and personal protective equipment are adequate and that precautions have been taken to ensure that prescribed procedures will be followed.

(2) Confined spaces that have contained styrene shall be thoroughly ventilated, inspected, and tested for oxygen deficiency and for the presence of styrene and any other known or suspected contaminants. Every effort shall be made to prevent inadvertent release of hazardous amounts of styrene into confined spaces in which work is in progress. Styrene supply lines shall be disconnected or blocked off before and while such work is in progress.

(3) No worker shall enter any confined space that does not have an entryway large enough to admit a worker wearing safety harness, lifeline, and appropriate respiratory equipment as specified in Section 4 (c).

(4) Confined spaces shall be ventilated while work is in progress to keep the concentration of styrene at or below the recommended limits, to keep the concentration of other contaminants below dangerous levels, and to prevent oxygen deficiency.

(5) If the concentration of styrene in the confined space exceeds the recommended environmental limit, respiratory protective equipment is required for entry.

(6) Anyone entering a confined space shall be kept under observation from the outside by another properly trained and protected worker. An additional supplied-air or self-contained breathing apparatus with safety harness and lifeline shall be located outside the confined space for emergency use. The person entering the confined space shall maintain continuous communication with the standby worker.

(d) Emergency Procedures

Emergency plans and procedures shall be developed for all work areas where there is a potential for exposure to styrene. They shall include those procedures specified below as well as any others considered appropriate for a specific operation or process. Workers shall be instructed in the effective implementation of these plans and procedures.

(1) If styrene leaks or spills, the following steps shall be taken:

(A) All nonessential personnel shall be evacuated from the leak or spill area.

(B) The area where the leak or spill occurs shall be adequately ventilated to prevent the accumulation of vapor.

(C) The styrene shall be collected for reclamation or be absorbed on vermiculite, dry sand, earth, or similar nonreactive material and be disposed of properly.

(2) Only personnel trained in the emergency procedures and protected against the attendant hazards shall clean up spills, control and repair leaks, and fight fires in areas where styrene is present.

(3) Personnel entering the spill or leak area shall be furnished with appropriate personal protective clothing and equipment. Other personnel shall be prohibited from entering the area.

(4) Safety showers, eyewash fountains, and washroom facilities shall be provided, maintained in working condition, and located so as to be readily accessible to workers in all areas where skin or eye contact with styrene is likely. If styrene is splashed or spilled on a worker, contaminated clothing shall be removed promptly and the skin washed thoroughly with soap and water. Eyes splashed by styrene shall be irrigated immediately with a copious flow of water for 15 minutes. If irritation persists, get medical attention.

(e) Storage

Styrene shall be stored in well-ventilated areas and kept away from ignition sources such as heat or sparks and from oxidizing agents, catalysts, and strong acids. If styrene is stored more than 30 days at 32°C (about 90°F) or above, the inhibitor concentration shall be checked periodically. Large styrene storage containers should be installed with a temperature alarm system to signal interior temperature increases that may result in runaway polymerization, a special concern in hot climates. The rate of polymer formation in storage tanks can be reduced by cooling the tank by means of a water spray, refrigeration, insulation, or reflective painting. In a laboratory, samples of styrene may be stored in refrigerators or cold boxes.

Section 7 - Sanitation

(a) The preparation, storage, dispensing (including vending machines), or consumption of food shall be prohibited in areas where styrene is manufactured, formulated, processed, stored, or otherwise used.

(b) Smoking shall be prohibited in areas where styrene is manufactured, formulated, processed, stored, or otherwise used.

(c) Workers who handle styrene or equipment contaminated with styrene shall be instructed to wash their hands thoroughly with soap or mild detergent and water before eating, smoking, or using toilet facilities.

(d) Facilities such as double lockers should be provided for workers so soiled clothing can be stored separately from clean clothing.

Section 8 - Exposure Monitoring and Recordkeeping Requirements

(a) Exposure Monitoring

(1) The employer shall conduct an industrial hygiene survey to determine whether exposures to airborne concentrations of styrene are in excess of the action level (i.e., 25 ppm determined as a TWA over the workshift). The employer shall keep records of these surveys. If the employer concludes that exposures are below the action level, the records must show the basis for this conclusion. Surveys shall be repeated at least annually and within 30 days of any process change likely to result in an increased concentration of airborne styrene.

(2) If there is exposure to styrene at or above the action level, a program of personal monitoring shall be instituted to identify and measure, or to permit calculation of, the exposure of each worker occupationally exposed to airborne styrene. Source and area monitoring may be a useful supplement to personal monitoring. In all personal monitoring, samples representative of the TWA and ceiling exposures to airborne styrene shall be collected in the breathing zone of the worker. Procedures for sampling and analysis shall be in accordance with Section 1 (b). For each determination of an occupational exposure concentration, a sufficient number of samples shall be collected to characterize each worker's exposure during each workshift. While all workers do not have to be monitored, sufficient samples should be collected to characterize the exposure of all workers. Variations in work and production schedules, as well as worker locations and job functions, shall be considered in decisions on sampling locations, times and frequencies.

If a worker is found to be exposed to styrene at or above the action level but below the recommended environmental limits, the exposure of that worker shall be monitored at least once every 6 months or as otherwise indicated by a professional industrial hygienist. If a worker is found to be exposed to styrene in excess of the recommended environmental limits, controls shall be initiated, the worker shall be notified of the exposure and of the control measures being implemented, and the exposure of that worker shall be evaluated at least once a week. Such monitoring shall continue until two consecutive determinations, at least 1 week apart, indicate that the worker's exposure no longer exceeds the recommended limits. At that point, semiannual monitoring shall then be resumed.

(b) Recordkeeping

Records of the monitoring used to characterize the environmental exposures fo reach worker shall be retained for at least 30 years after the individual's employment has ended. These records shall include the name of the worker being monitored; Social Security number; duties performed and job locations within the worksite; dates and times of measurements; sampling and analytical methods used; number, duration, and results of samples taken; and the type of personal protection used, if any. Workers shall be able to obtain information of their own environmental exposures. Workplace environmental monitoring records shall be made available to designated representatives of the Secretary of Labor, the Secretary of Health and Human Services, and the worker or former worker.

Pertinent medical records (i.e., results of medical examination results, the physician's written opinion, medical complaints, medical and work histories, etc.) for all workers subject to exposure to styrene in the workplace shall be retained by the employer for at least 30 years after termination of employment. Copies of environmental monitoring data applicable to a worker shall be included in that worker's medical records. These medical records shall be made available to the designated medical representatives of the Secretary of Labor, the Secretary of Health and Human Services, the employer, and the worker or former worker.

APPENDIX B

POLLUTION PREVENTION PAYS PROGRAM

Conventional pollution control focuses on "end-of-the-pipe" and "out-the-back-door" approaches--creating waste and then trying to figure out what to do with it. These approaches often serve to remove pollution, such as contaminated air or wastewater, from one place, only to deposit the pollution in another form in another place. Regulations for air, water, toxic materials, and hazardous wastes are becoming increasingly complicated. Industries need to critically examine their current treatment and disposal approaches. Once waste is generated, regulatory costs, disposal costs, and liability costs will continue to increase.

A positive alternative is prevention of pollution at its source. Through prevention, waste minimization, and recovery, many firms can find economic benefits and improved environmental management of their wastewater discharges, air emissions, and hazardous waste generation.

In 1983 the General Assembly authorized and funded the North Carolina Pollution Prevention Program. The goal of the non-regulatory program is to work with industries and local governments to help them identify and apply ways to reduce, recycle, and minimize wastes before they become pollutants. The prevention effort addresses water and air quality, toxic materials, and solid and hazardous wastes. Technical assistance, research and education, and matching grants are provided by the program in cooperation with the Hazardous Waste Management Branch, Waste Management Board, and Board of Science and Technology.

The program has compiled more than 1,500 references on waste reduction and minimization. Additional information is available through customized literature searches and access to public and private research organizations. In-house waste reduction reports are published on a variety of industries and waste streams. Non-regulatory, on-site visits for technical assistance are conducted with waste surveys to identify reduction opportunities for water, air, toxics, and hazardous wastes. In addition to funding research projects and workshops for industries, the Pollution Prevention Program offers matching funds to businesses and communities through Challenge Grants for waste reduction and minimization projects.

For further information or assistance please contact:

Roger N. Schecter, Director
Pollution Prevention Program
N. C. Department of Natural Resources and Community Development
Post Office Box 27687
Raleigh, North Carolina 27611-7687
Telephone: (919) 733-7015

APPENDIX C

PROCESSING EQUIPMENT SUPPLIERS

This list was developed from a review of sales literature, personal interviews, and facility visits. The preparer takes no responsibility for the list's completeness or for the quality of products and services provided by these companies.

Binks Manufacturing Company
9201 West Belmont Avenue
Franklin Park, IL 60131
Mailing Address: P.O. Box 66090
Chicago, IL 60666
(312) 671-3000
Products: Wide range of coating equipment and accessories.

Clean Air Systems, Inc.
P.O. Box 5191
Statesville, NC 28677
Contact: Steve Dagenhart
(704) 873-1717
Product: Spray booth that moves high volume of air to reduce employee VOC exposure. Turbulent water design collects more particles.

The Devilbiss Company (main office)
300 Phillips Avenue
P.O. Box 913
Toledo, OH 43692
(419) 470-2169
Regional Office:
520-A Wharton Circle, S.W.
P.O. Box 43226
Atlanta, GA 30336
(404) 696-4940

Graco, Inc.
P.O. Box 1441
Minneapolis, MN 55440
(612) 378-6000
Contact: Production Systems
Bill Ball, President
(919) 886-5081
Products: Spray guns - airless, air spray, air assisted airless

High Point Pneumatics
P.O. Box 5802
High Point, NC 27262-5802
Contact: Wayne Roach
(919) 889-8416
Product: Supplier of Kremlin, Inc. "Airmix" products. Chemco Spray Booth Filtering Media.

Kremlin, Inc.
211 South Lombard
Addison, Illinois 60101
(312) 543-1177
Products: "Airmix" air-assisted airless spray painting system; "Airmix" electrostatic system; coating heaters; pumps; and assembled portable spray equipment.

Magnum Industries
P O Box 1786
Irmo, SC 29063
Contact: Ron Charette
(803)-732-1251
Products: Spray-up equipment including air assisted airless spray guns.

Nordson Corporation
P.O. Box 7
Matthews, North Carolina 28105
Contact: John Colliet, Finishing
Specialist
(704) 847-8514
Products: Airless spray guns for sealers, lacquers, and stains; airless electrostatic spray guns; automatic versions of the electrostatic guns; and powder coating application and recovery equipment for metal furniture.

Production Systems
P.O. Box 5406
High Point, NC 27262
Contact: Bill Ball, President
(919) 886-5081
Products: Supplier of Ransburg Electrostatic Sprayers, Binks, Graco, Devilbiss, Arrow Products.

Rimcraft Technolgies, Inc.
1914 English Road
High Point, NC 27260
Contact: Tim Ross
(919)-841-7995
Products: All types of lay-up and spray-up equipment. Vacuum bagging supplies and consulting services.

Venus Products, Inc.
1862 Ives St.
Kent, WA 98032
Contact: Ed Marquardt
(206)-854-2660
Products: Impregnators, spray-up equipment, pumps and special rollers.

APPENDIX D

SUPPLIERS OF DISTILLATION EQUIPMENT

The following list was developed from a review of sales literature, personal interviews, telephone conversations, and industrial visits. The preparers of this list take no responsibility for the list's completeness or for the quality of the services or products offered by these firms.

ACTIVATION, INC.
8041-F Arrowridge Blvd.
Charlotte, NC 28210
(800) 558-3127
Contact: Mike Mabry
Equipment: In-house solvent recovery equipment by RECYCLENE Products, Inc., systems from 6 gallons per day to 20 gallons per hour. All equipment is U.L. listed.

AMBRO TECHNOLOGIES
3888 Commerce Street
Riverside, CA 92507
(714) 788-0510
Contact: Anne Probizanski, Pres.
Equipment: Solvent Reclaim Distillation Units, small batch, and continuous batch 150-500 gal/shift.

BARON-BLAKESLEE
1225 Atlando Avenue
Charlotte, NC 28206
(704) 333-9682
Contact: John Sparrow
Equipment: Recovery units for chlorinated and fluorinated solvents by Baron-Blakeslee; also, units and carbon absorption systems for recovering solvents from exhausts.
Recycling Services: See solvent recyclers listing also.

BRIGHTON CORPORATION
11861 Mostellor Road
Cincinatti, OH 45241
(513) 771-2300
Contact: A. Kimpel, Sales Manager

THE CARDINAL CORPORATION
P.O. Box 4234
Wilmington, DE 19807
Contact: Jerold B. Smith
(302) 656-9446
Equipment: user collects spent solvent in empty 55-gallon drum. The cardinal unit evaporates reusable solvent from drum. Residue remains in collection drum.

FINISH ENGINEERING CO., INC.
921 Greengarden Road
Erie, PA 16501
Contact: Mike Snyder, Sales Engineer
(814) 455-4478
Services: Network of distributors that sell and service equipment which distills solvents that boil in the range of 100-500°F. Units available to distill between 15 and 500 gal/day; electrical and steam powered units.

HOFFMAN/DIVISION OF CLARKSON IND.
P.O. Box 548
6035 Corporate Drive
East Syracuse, NY 13057
Contact: Sales
(315) 437-0311
Equipment: Vacuum stills for solvent recovery and emulsion breaking for spent coolants

***Continued on next page**

ROLLINS ENVIRONMENTAL SERVICES, INC.
One Rollins Plaza
Wilmington, DE 19899-2349
(302) 429-2949
Contact: Jack Hornberger
Vice-President of Marketing/Sales
N.C. Office: 2920 South Elm Street
Greensboro, NC 27406
Contact: Gary Seavey
Waste Accepted: All hazardous waste and materials, solids, liquids and gases.
Incineration Services: Three rotary kiln incinerators, with complete emmisions control equipment.
Secure Landfill: No liquids, leachate systems, solidification and stabilization.
Lab Facilities: Complete

OLDOVER CORPORATION
P.O. Box 228
Ashland, Va 23005
(804) 798-7981
Contact: Don Burris, Admin.
Shirley Worsham, Sales
Waste Accepted: Solvents and sludges.
Heat Recovery Services: Used as a fuel in High-temperature (2300 F) rotary kiln used to make light-weight aggregate.
Laboratory Facilities:
Transportation: Provided

STABLEX
P.O. Box 2664 CRS
Rock Hill, SC 29731
(803) 824-5310
Contact: Frank Kelly
Waste Accepted: solids, liquids, sludges, and lab packs.
Incineration Technology: dual-chamber incinerator with liquid, solid and sludge feed.
Lab Facilities: gas chromatograph, infrared spectroscopy atomic absorption, bomb calorimeter, GC/MS, ICP capability. (See listing under Hazardous Waste Services).

STAUFFER CHEMICAL COMPANY
P.O. Box 86
Mt. Pleasant, TN 38474
(615) 379-5813/(800) 521-2289
Contact: Tony Livengood
Wastes Accepted: wastes with 5000 BTU/lb or greater, includes solvents, still bottoms, chemical process wastes and contaminated oil.

SYSTECH
245 North Valley Road
Xenia, OH 45385
(513)-372_8077
Contact: Joe Durcyniski
Wastes Accepted: liquids with a minimum of 80,000 BTU/gal; up to 10% chlorides
Heat Recovery Services: high temperature kiln for the production of portland cement
Lab Facilities:
Transport: bulk
Facility Locations: Ohio, California, Kansas

2. Hazardous Waste Transporters

The following list was compiled through personal interviews, telephone conversations, and sales literature. The preparers of this list take no resposibility of the list's completeness or for the quality of services offered by these firms.

ASHLAND CHEMICAL COMPANY
1415 S. Bloodworth Street
Raleigh, NC 27601
(919) 828-0615
Contact: Rod Henley
Other Locations:
2802 Patterson Street
Greensboro, NC 27407
(919) 299-1101

3930 Glenwood Drive
Charlotte, NC 28208
(704) 392-2121

BRYSON INDUSTRIAL SERVICES, INC.
411 Burton Road
Lexington, SC 29072
(803) 395-7027
(800) 845-5037
Contact: M. Sakwa or Y. Reynolds
Services: Hazardous and industrial waste management, waste transportation of bulk solids and liquids, drums, LTC rates, waste characterization and analysis, lab pack preparation, disposal alternatives, in-plant services, site excavation and clean-up, tank cleaning, lagoon service, sludge forming.

DETREX CHEMICAL INDUSTRIES, INC.
P.O. Box 5287
Charlotte, NC 28225-5278
(704) 372-9280
See listing under Solvent Suppliers.

E.L. DAWSON COMPANY
P.O. Box 2104
Rocky Mount, NC 27802-2104
(919) 446-8700
Contact: Eric L. Dawson
Services: transports waste in 55-gallon drums, will not handle radioactive or carcinogenic wastes.

ECOFLO
P.O. Box 10383
Greensboro, NC 27404
(919) 855-7925
Contact: Micheal Kelly
See listing under Hazardous Waste Services.

ENVIRO-CHEM WASTE MANAGEMENT SERVICES
P.O. Box 12542
Raleigh, NC 27607
(919) 469-8490
Contact: Jerry Deakle
Service: no radioactive, pathological or explosive wastes.

GXS SERVICES, INC.
Route 1, Box 210
Watlington Industries Road
Reidsville, NC 27320
(919) 342-6106
24-Hour Emergency Responce
(919) 272-2222
Contact: Robert D. Steohens
Services: No radioactive waste, poison gas, kepone, sodium azide over 25%, or explosives.

***Continued on next page**

HOYT MANUFACTURING COMPANY
251 Forge Road
Westport, MA 02790-0217
(617) 636-8811
Contact: Sales
Equipment: Stills with capacity of 35 and 60 gallons, for the recovery of perchlorethylene only; SOLVO-SALVAGER, a state-of-the-art distillation system designed to recover both flammable and non-flammable solvents.

JAN ENGINEERING CO.
736 Indian Manor Court
Stone Mountain, GA 30083
(404) 292-1711
Contact: H.A. Janicek
Equipment: Batch style 15 and 55 gallon LITTLE STILLS by Finish Engineering, for solvent recovery. With vacuum option, will distill up to 500 F boiling point.

LUWA CORPORATION
P.O. Box 16348
4404 Chesapeake Drive
Charlotte, NC 28216
(704) 394-8341
Contact: Mic Barnhouse
Equipment: Thin-film evaporation/distillation/drying based equipment and complete systems for recovery of solvents, oils, etc. from non-volatile residues.
Services: Preliminary Evaluation Services (PES), for feasibility screening, and complete pilot plant testing services are available.

PFAUDLER CO./DIVISION OF SYBRON CORPORATION
Rochester, NY 14603
(716) 235-1000
North Carolina Representative:
Bill Gephart
P.O. Box 2427
Charlotte, NC 28211
(704) 541-5953

PHILLIPS MANUFACTURING COMPANY
7334 North Clark Street
Chicago, IL 60626
(312) 338-6200
Contact: Sales

SOUTHERN RECOVERY CO.
P. O. BOX 3279
Fort Mills, SC 29715
(803)-548-5740
Recyclene™ stills

APPENDIX E

HAZARDOUS WASTE SERVICES

1. Heat Recovery and Incineration Services

The following list was compiled through personal interviews, telephone conversations, and sales literature. The preparers of this list take no responsibility for the list's completeness of for the quality of the services offered by these firms.

CALDWELL INDUSTRIAL SERVICES, INC.
P.O. Box 881
Lenoir, NC 28645
(704) 396-2304
Contact: Garry L. Sparks
or Charles Foushee
Services:L Incineration, transports chemical waste bulk solid form, to and from Caldwell and Mitchell Systems and chemical landfills in Pinewood, SC and Emelle, AL,
Pump liquid drums into bulk tankers, clean chemical storage tanks, hazardous waste site clean-ups, emergency spill control, test underground tanks (sonic test), provide bulk container rental service, truck sharing.
Equipment: Vacuum truck, vacuum trailers, roll of bulk sludge container, drum trailers, bulk tankers, emergency equipment.
Note: No radioactive waste.

GSX OF SOUTH CAROLINA, INC
(FORMERLY ABCO INDUSTRIES, INC.)
P.O. Box 335
Roebuck, SC 29376
(803) 576-6821
Contact: Hans Arensburg
Waste Accepted: Organic liquids, aqueous and non-aqueous mixtures, emulsions, and suspensions, organic residues and sludges that are pumpable or capable of being made pumpable.
Incineration Services: Liquid injection, scrubbers bag house filter, waste heat recovery.
Recycling Services: 6000-gallon still for recycling solvents on a toll basis.
Lab Facilities: Atomic absorrption spectrophotometer, microprocessor, ionalyser, gas and liquid chromatography, infrared spectrophotometer, bomb calorimeter.
Transport: Bulk only.

INDUSTRIAL CHEMICALS COMAPNY
Box 2664
Rock Hill, SC 29730
(803) 325-5276
Contact: Walter Neal
Service: Incineration

***Continued on next page**

HIGH RISE SERVICE COMPANY, INC.
Route 1, Box 2000
Leland, NC 28451
(919) 371-2325
Contact: A.J. Simmons, Jr.
Services: Contracts to handle wastes in drums or in an 8000 gallon tank truck. Tank cleaning.

ILT INCORPORATED
4132 Pompano Street
Charlotte, NC 27216
(704) 392-6276
Contact: Fred Haden
Lynn Phillips
Services: Complete pressure vacuum bulk liquid transporter.

M & T DRUM, INC.
Route 4, 1230
Huntersville, NC 28078
(704) 875-6014
Contact: Art Bridges
Services: Trasnports any amount of waste in drums, no radioactive waste, specialize in transportation and disposal of capacitors and transformers and of liquids.

MCLAURIN TRUCKING COMPANY
P.O. Box 26506
Charlotte, NC 28213
(704) 376-1641
Contact: Dana or Leonard McLaurin
Services: Transports waste in drums, no radioactive wastes.

PETROLEUM TANK SERVICE, INC.
P.O. Box 237
Newell, NC 28126
(704) 597-1910
Contact: Steve Smith
Services: Transporter of bulk or drum products, other tank realated services are welding, installation of environmental ptotection systems, tank coating and lining, fiberglassing, calibrating, waterblasting, sandblasting, ultrasonic testing, and mechanical piping.

PHOTO CHEMICAL SYSTEMS
P.O. Box 339
105 Forest Drive
Knightdale, NC 27545
(919) 266-4463
Contact: Kennenth R. Finch
Services: Transports wastes in DOT approved containers to a land disposal site or incinerator. Offer "truck-sharing" for generators of less-than-truckload quantities of wastes.

SOUTHCHEM, INC.
2000 East Pettigrew Street
Durham, NC 27702
(919) 596-0681
Contact: Terry Brown,
Operation Manager
Services: Handles spent solvents, no radioactive wastes.

ST. JOSEPH MOTOR LINES
5724 New Peachtree Road
Chamblee, GA 30341
1-800-241-0423
Contact: Virginia Eastwood
or Bill Oldham

ST. JOSEPH MOTOR LINES (cont.)
Services: Specializes in less-than-truckload quantities of con tainerized waste and serves all 49 states. A brokerage relationship with several major disposal facilities enables them to offer the new community of small quantity generators a complete service package - low cost transportation, help with manifesting, and waste disposal.

*Continued on next page

TRANSFORMER MAINTANENCE & DISPOSAL
P.O. Box 1005
Hildebran, NC 28637
(704) 397-7471
Contact: Larry Austin
Services: PCB specialist, transport any quantity and will do on-site service work.

WASTE INDUSTRIES, INC.
P.O. Box 19026
Raleigh, NC 27619
(919) 876-9250
Contact: Jim Perry
Lonnie C. Poole, Jr.
Other Branches: Oxford, Fayetteville, Henderson, Wilson, Newport, Wilmington, Haw River, and Rocky Mount.
Services: Provides detachable containers for storage, completes all necesssary paperwork, locates an approved disposal site, and tests material if required as well as transports.
Equipment: Straight trucks (50,000 lb GVU class). Enclosed vans for less-than-truckload quantities.

APPENDIX F

REGULATORY INFORMATION RESOURCES

1. RCRA Information Sources

Solid and Hazardous Waste Management Branch
Division of Health Services
P.O. Box 2091
Raleigh, North Carolina 27602
(919) 733-2178

This office is in charge of hazardous waste management for the State of North Carolina and has the responsibility of enforcing all state and federal regulations and issuing permits that apply to hazardous waste. (See p 116 for regional office locations)

DOT--Raleigh
Bill Hawkins
(919) 755-4378.

Local and State Emergency Response: Contact the Emergency Response Coordinator in the local county government (Civil Defense or Civil Preparedness) for assistance with contingency plans or emergencies. The plant emergency coordinator may decide to call in the State Emergency Response Team:

(919) 733-2126 -- 8:00-5:00 p.m. , Monday through Friday
or
(919) 733-3867/(800) 662-7956 All other hours and days

Division of Environmental Management
Department of Natural Resources and Community Development
P. O. Box 27687
Raleigh, NC 27611
(919)-733-5083 (Water Quality)
(919)-733-3340 (Air Quality)

The Division is responsible for regulating toxic emissions and toxic effluents and their impacts upon the environment. The Division works closely with the Solid and Hazardous Waste Management Branch in areas which involve hazardous waste. (See p 116 for regional office locations)

To obtain a copy of the State RCRA Regulations, send $2.00 to the Solid and Hazardous Waste Management Branch, Bath Building, Box 2091, Raleigh, NC 27602.

U.S. Environmental Protection Agency
Office of Solid Waste (WH-565)
Hazardous and Industrial Waste Division
401 M. Street, SW
Washington, DC 20460

RCRA-HOTLINE 800-424-9346
202-382-3000

The RCRA-hotline will answer questions on all sections of RCRA and Superfund and will give interpretations on the regulation. Information regarding EPA publications may be obtained from this office.

Environmental Protection Agency Region IV
James H. Scarbrough
Chief, Residuals
Management Branch
Waste Management Div.
345 Courtland Street, NE
Atlanta, GA 30365
(404) 347-3016 (for general assistance)

Emergency and remedial response unit: (404) 347-4062. Call anytime to report a spill of hazardous material or waste.

EPA Library
(404) 347-4216
services
identification of Regulations
Reference Service
Loan of Agency Reports
Films

National Response Center
Commandant G-TGC-2
400 7th Street S.W.
Washington, DC 20590
800-424-880

The central clearinghouse for the receipt of reports of discharge of oil, hazardous chemicals or hazardous wastes into the environment from anywhere within the continental United States. The Center is tasked with directing these reports to the correct federal on scene (response) coordinator for the area of the discharge. A report to the NRC also satisfies the federal reporting requirements. Staffed by the U.S. Coast Guard, the NRC receives calls 24 hours a day, seven days a week.

To obtain a copy of the Code of Federal Regulations, write to the Superintendent of Documents, U.S. Government Printing Office, Washington, DC , 20402.

2. Assistance from the Chemical Industry

The Chemical Industry is assisting generators of hazardous chemical wastes through the following programs and organizations:

Community Awareness and Emergency Response (CAER) program. CAER brings together chemical companies and local emergency response programs, such as: hospitals, firefighters, and police, to develop a contingency plan for handling chemical waste accidents. Contact:

CAER
c/o Chemical Manufacturers Association
2501 M Street, N.W.
Washington, DC 20037
(202) 887-1265

National Chemical Response and Information Center (NCRIC) offers audio/visual training for employees and local emergency response programs. NCRIC also offers information on suggested chemical companies' emergency plans for handling hazardous chemical accidents. Contact:

NCRIC
c/0 Chemical Manufacturers Association
2501 M Street, N.W.
Washington, DC 20037
(202) 887-1255

CHEMNET is a mutual aid network through which member companies provide help at scene of chemical accident. CHEMNET is used when a company is unable to respond to a chemical accident in a timely manner. Contact:

CHEMNET
c/o Chemical Manufacturers Association
2501 M Street N.W.
Washington, DC 20037
(202) 887-1255

The Chemical Referral Center offers the general public, users of chemicals, and transportation workers health and safety information about chemicals. Call:

(800) 262-8200

Chemical Transportation Emergency Center (CHEMTREC) is a public service of the Chemical Manufacturers Association. For help with Chemical transportation emergencies involving spill, leak, fire or exposure, call toll-free day or night:

(800) 424-9300

3. Division of Environmental Management - Regional Offices
(For water and air quality)

ASHEVILLE

Roy Davis, RS
David Spain, ROM

59 Woodfin Place
P.O. Box 370
Asheville, NC 28802
Courier #681

(704) 253-3341

Avery
Buncombe
Cherokee
Clay
Cleveland
Graham
Haywood
Henderson
Jackson
Macon

Madison
McDowell
Mitchell
Polk
Rutherford
Swain
Transylvania
Watauga
Yancey

FAYETTEVILLE

Marion J. Noland, RS
Richard Bishop, ROM

Wachovia Building
Suite 714
Fayetteville, NC 28301
Courier #106

(919) 486-1541

Anson
Bladen
Cumberland
Harnett
Hoke
Montgomery

Moore
Robeson
Richmond
Sampson
Scotland

MOORESVILLE

Ron McMillan, RS
Al Hilton, ROM

919 North Main Street
P.O. Box 950
Mooresville, NC
Courier #521

(704) 663-1699

Alexander
Burke
Cabarrus
Caldwell
Catawba
Gaston

Iredell
Lincoln
Mecklenburg
Rowan
Stanly
Union

WINSTON-SALEM

Larry Coble, RS
Margaret Plemmons, ROM

8003 Silas Creek Parkway Ext.
Winston-Salem, NC 27103
Courier #227

(919) 761-2351

Alamance
Alleghany
Ashe
Caswell
Davidson
Davie
Guilford
Rockingham
Randolph
Stokes
Surry
Yadkin

RALEIGH

R.W. VanTilburg, RS
Jerry Wall

3800 Barrett Drive
P.O. Box 27687
Raleigh, NC 27611
Courier # Raleigh Regional Office

(919) 733-2314

Chatham
Durham
Edgecombe
Franklin
Granville
Halifax
Johnston
Lee
Nash
Northampton
Orange
Person
Vance
Wake
Warren
Wilson

WASHINGTON

Jim Mulligan, RS
Howard Moye, ROM

1502 North Market Street
Washington, NC 27889
Courier #174

(919) 946-6481

Beaufort
Bertie
Camden
Chowan
Craven
Currituck
Dare
Gates
Greene
Hertford
Hyde
Jones
Lenoir
Martin
Pamlico
Pasquotank
Perquimans
Pitt
Tyrell
Washington
Wayne

WILMINGTON

Chuck Wakild, RS
Bob Jamieson, ROM

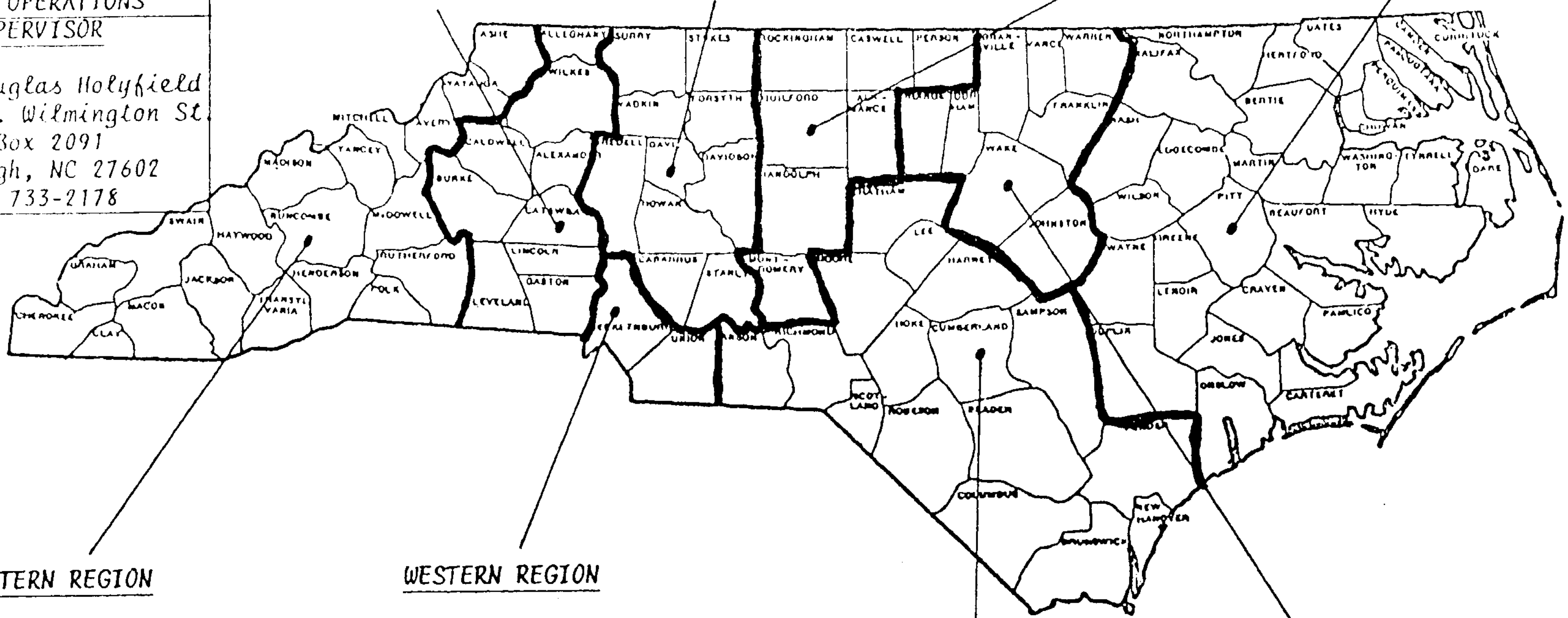
7225 Wrightsville Avenue
Wilmington, NC 28403
Courier #416

(919) 256-4161

Brunswick
Carteret
Columbus
Duplin
New Hanover
Onslow
Pender

NORTH CAROLINA

Hazardous Waste Management Field Operations Team



FIELD OPERATIONS SUPERVISOR

R. Douglas Holyfield
306 N. Wilmington St.
P.O. Box 2091
Raleigh, NC 27602
(919) 733-2178

WESTERN REGION

Larry Fox
P.O. Box 71
907 First St. East
Conover, NC 28613
(704) 464-8103

NORTH CENTRAL REGION

Stephen E. Phibbs
Suit 200
310 East Third St.
Winston-Salem, NC 27106
(919) 761-2390

NORTH CENTRAL REGION

Joseph H. Deakins
1840 Lake Ridge Lane
Mebane, NC 27302
(919)563-1818

EASTERN REGION

Richard Gay
110 Fairview St.
Williamston, NC
27892
(919) 792-1747

WESTERN REGION

D. Keith Masters
Route 1, Box 279
Bakersville, NC 28705
(704) 688-4237

WESTERN REGION

Adam Wipfield
James K. Polk Bldg.
500 W. Trade Street
Charlotte, NC 28202
(704) 374-0584

SOUTH CENTRAL REGION

Flint Worrell
225 Green Street
Wachovia Bank Bldg.
Suite 606
Fayetteville, NC 28301
(919) 486-1191

SOUTH CENTRAL REGION

Larry D. Perry
Route 4, Box 344-E
Zebulon, NC 27597
(919) 269-8358

TECHNICAL SUPPORT

WILLIAM PAIGE
Environmental Engineer
306 N. Wilmington St.
Raleigh, NC 27602-2091
919/733-2178