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Project Summary

Assessment of Styrene Emission Controls for FRP/C and Boat Building Industries

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This study evaluated several conventional and novel emission control technologies that have been used or could be used to treat styrene emissions from open molding processes in fiberglass-reinforced plastics/composites (FRP/C) and fiberglass boat building facilities. Control costs for these conventional and novel technologies were developed and compared for three hypothetical plant sizes. The results of this cost analysis indicate that (1) preconcentration by adsorption followed by desorption for recovery or oxidation appears to reduce the overall cost of styrene control, particularly at the lower styrene concentrations (less than 100 ppm) typically found at these facilities, and (2) increasing the styrene concentration (i.e., lowering flow rate) of the exhaust streams can significantly reduce cost per ton of styrene removed for all technologies examined, because capital and operating costs decrease with decreasing exhaust flow rate. Therefore, a company should evaluate methods to increase concentrations (i.e., reduce flow rates) of the exhaust stream before considering any add-on control devices. This report also presents air flow management practices and enclosure concepts that could be used to create a concentrated exhaust stream while maintaining a safe working environment.

This Project Summary was developed by EPA's National Risk Management Research Laboratory's Air Pollution Prevention and Control Division, Research Triangle Park, NC, to announce key **findings** ***of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).***

Introduction

The fiberglass-reinforced plastics/composites (FRP/C) and fiberglass boat building industries have many alternatives for reducing styrene emissions. Styrene emissions can be reduced by (1) using resin materials and application equipment that generate lower styrene emissions, (2) improving operator techniques to reduce overspray, (3) changing from open- to closed-molding processes, and (4) using add-on emission control devices. The amount of reduction achieved by these alternatives, taken separately or in various combinations, can vary widely.

Lacking the regulatory mandates, add-on pollution control systems are not often used to reduce styrene emissions in the FRP/C and boat building industries. Low concentrations and high air flow rates also have made conventional emission controls very expensive and, in some cases, less efficient in destroying the emissions. The FRP/C and boat building industries need information on the applicabilities and costs of conventional and emerging add-on pollution control technologies so they can make informed decisions about the use of controls to reduce their emissions. To meet this need, the cost and performance of several conventional and emerging add-on pollution control technologies and air flow management practices potentially applicable to these industries were evaluated.

This report summarizes the results of literature reviews and control cost analyses. The report includes background information about the industries and the characteristics of their emissions, assessment of various pollution control technologies, analyses of control costs, and an evaluation of air flow management practices that may reduce worker exposure and control costs. The appendixes include costing procedures for various pollution control technologies and a spreadsheet cost model for these control technologies.

This report provides preliminary technical and cost information to FRP/C and boat building companies for their use in selecting add-on pollution control technologies. Companies should identify those technologies that fit their production processes and contact the vendors of those technologies for more accurate information on equipment costs.

Styrene Emission Control Technologies

This report presents a technical evaluation of conventional, novel, and emerging add-on pollution control technologies that have been used or could be used to reduce styrene emissions from FRP/C and boat building facilities.

Conventional Technologies

Conventional technologies include combustion (i.e., thermal and catalytic oxidation), adsorption, and condensation, which have traditionally been used to treat volatile organic compound (VOC) emissions. The effectiveness and the advantages/disadvantages of their application are presented for each conventional technology.

Novel Technologies

Novel technologies are those that have been applied in the last decade to treat low-concentration emissions. These technologies have been installed in European and Japanese FRP/C or boat building facilities to treat styrene emissions or in the U.S. to treat paint booth emissions or organic vapors from soil remediation. These novel technologies include (1) hybrid systems that preconcentrate VOCs by adsorption, then desorb VOCs for recovery by condensation or for destruction by thermal/catalytic oxidation; (2) a biofiltration process that utilizes biodegradation to remove VOC emissions; and (3) a process that applies ultraviolet (UV) light and ozone in a wet system to disintegrate VOCs into carbon dioxide and water, and removes smaller organics in the exhaust gas by adsorption.

Five preconcentration/recovery/oxidation hybrid systems are evaluated: (1) MIAB system, (2) Thermatrix PADRE system, (3) Polyad system, (4) rotary concentrator system by Durr Industries, and (5) fluidized-bed preconcentration system by REECO/Environmental C&C.

Emerging Technologies

Emerging technologies are those that are just beginning to be explored via field applications and pilot testing after undergoing several years of laboratory evaluations. Two emerging technologies are evaluated: a membrane vapor recovery technology and a photocatalytic oxidation process that treat VOCs in the air at ambient temperatures in the presence of UV light and a catalyst.

Control Cost Analyses

Total annualized costs for all control technologies were calculated using the general procedures outlined in the EPA Office of Air Quality Planning and Standards (OAQPS) Control Cost Manual and cost data collected from equipment vendors and other sources. A computer spreadsheet model was developed to perform cost calculations. Based on the quantity of styrene emitted and the control efficiencies of these technologies, the costs per ton of styrene removed were calculated from annualized costs. Control costs for all control technologies were analyzed for three hypothetical plants, treating 20, 100, and 400 tons* per year of styrene emissions.

The cost analyses show that (1) cost-per-ton of styrene removed decreases as the inlet concentration increases (i.e., exhaust flow rate decreases), and (2) preconcentration technologies appear to reduce the cost of styrene control, particularly at lower styrene inlet concentrations. The results of the cost analyses suggest that reducing the inlet flow rates to control devices is a good approach to making any control technology more economically feasible.

Air Flow Management Practices

Current ventilation systems in FRP/C and boat building facilities are primarily designed to provide an environment that is safe for workers and produces good product quality. General ventilation, also called dilution ventilation, supplies an ample amount of makeup air to dilute the contaminants to an acceptable air quality level in the workplace. This common practice produces high-volume, low-concentration exhaust streams. The cost analysis indicates that these high-volume, low-concentration exhaust streams make emission control systems more expensive. It is also more expensive to heat or cool large volumes of makeup air.

Proper air flow management would capture emissions at the point of generation and prevent mixing contaminated air with clean air. Thus, proper air flow management can maintain a safe environment for operators, while significantly decreasing exhaust flow rates. These reduced exhaust flow rates (increased concentrations) can reduce control costs.

This report presents several air flow management practices and concepts that could be applied to minimize air flow volumes at FRP/C and boat building facilities. These practices and concepts include: local air flow management, spray booth modifications, and enclosures.

Local Air Flow Management

Local air flow management involves capturing air pollutants directly at the emission source; therefore, the amount of air to be ventilated is minimized. In an open space, this can be done by blowing makeup air toward the emission source and capturing the emission with an exhaust hood at the other end (a push/pull ventilation system). Capture efficiency is generally better for a push/pull system than for an exhaust hood alone.

Spray Booth Modifications

Spray booths are commonly used in the FRP/C and boat building industries, especially for gel coat and resin sprayup operations, and for parts (i.e., items being manufactured) that can fit into a spray booth. Using a spray booth can prevent cross-contamination created by general ventilation, because styrene emissions are captured and exhausted directly.

In a typical spray booth, a mold is placed in the center of the booth. Air is drawn into the front opening of the booth, travels past the mold, and exits through a filter bank at the rear of the booth. Dry filter media are used to capture overspray, and the media are replaced frequently to protect the duct work and exhaust system. The captured emissions are vented to the atmosphere or to an emission control device. Several modifications to spray booth design could increase pollutant concentration and decrease exhaust flow, thus making downstream emission controls more cost-effective.

(*) For readers more familiar with metric units, 1 ton = 0.907 tonne.

Recirculation

The concept of recirculation had its origin in the spray painting industry, as a means of lowering exhaust flow rates (and therefore treatment costs) in paint spray booths. Recirculation involves redirecting a portion of the spray booth exhaust stream back into the spray booth. The recirculation stream may be reintroduced at any location in the spray booth (e.g., near the inlet face, or at the center of the booth). For a spray booth with recirculation alone, the increase in inlet concentration to a control device is directly related to the amount of recirculation. The disadvantage of recirculation is the potential for increased worker exposure, unless fresh makeup air is provided to the operator through a duct, or the operator wears a respirator.

Split-Flow Design

In a typical (horizontal-flow) spray booth, the part being sprayed does not extend to the full height of the spray booth. Therefore, most of the spraying and post-spraying emissions occur near the bottom of the booth. A split-flow painting spray booth design takes advantage of this fact. In this design, higher-concentration exhaust air from the bottom of the booth is directed to an emission control device, while lower-concentration air from the top of the booth is recirculated. The main advantage of a split-flow design is that it produces an increase in VOC concentrations going to a control device; however, the area to be split must be specific to each spray booth, based on the actual spraying pattern and concentrations at various locations.

Other Design Modifications

In a typical spray booth in an FRP/C facility, a mold is placed in the center of the booth. The arrangement of the mold within the booth is such that higher concentrations are drawn through the center of the filter bank, rather than through the top or sides of the filter bank. A spray booth can be modified to take advantage of this spatial difference in concentrations. Modification would involve constructing a smaller, centrally located exhaust device. The higher-concentration exhaust collected by this device would be directed to an emission control device. The lower-concentration exhaust could be vented to atmosphere or recirculated in the spray booth.

In addition to spatial differences in emissions within spray booths, temporal (time-related) variations in emissions can be used to increase concentrations to the emission control device. The centrally located exhaust device could be activated to capture high-concentration exhaust during the spraying period. The main exhaust of the spray booth would be operating continuously during the nonspraying or low-concentration period. Periods of high emissions could be determined by concentration measurements, or high emissions could be assumed to occur during any period of spraying (i.e., the small exhaust unit is activated by the spray-gun trigger). Fresh makeup air can be supplied to areas occupied by the operator.

Enclosures

Enclosures provide a physical barrier between the emissions and the surrounding environment, and they can reduce or eliminate the dispersion of styrene vapors from a production process. However, the styrene concentration within the enclosure must be kept below 2,500 ppm (25% of the lower explosive limit) by ventilation. If an enclosure is ventilated, the exhaust concentration is inversely related to the exhaust flow rate. Therefore, an enclosure can be used to confine emissions or to create a low-flow-rate, high-concentration exhaust stream for destruction.

Conclusions and Recommendations

Exhaust streams from open molding processes in the FRP/C and boat building facilities are generally at low styrene concentrations and high air flow rates. General (dilution) ventilation is usually used to ensure that worker exposure is less than that allowed by Occupational Safety and Health Administration (OSHA) standards. Treating this low-concentration, high-air-flow stream is more expensive than treating a low flow rate at higher concentration. Due to the general practice of dilution ventilation and the current lack of specific regulations that require add-on emission controls, these control devices are not commonly used in the FRP/C and boat building industries.

Of the limited number of add-on control devices used in the FRP/C facilities in the U.S., thermal and catalytic oxidation are the most common. Costs of alternative technologies have been compared, including biofiltration and preconcentration followed by recovery or oxidation, with straight thermal and catalytic oxidation. Preconcentration technologies followed by recovery or oxidation appear to reduce the cost of styrene control, particularly at the lower styrene concentrations (less than 100 ppm) typically found at FRP/C and boat building facilities. However, this apparent reduction in cost is significantly affected by the equipment cost assumptions used in this cost analysis. Therefore, FRP/C companies should compare the costs of competing technologies on a case-by-case basis.

The capital and operating costs of all emission control devices are strongly related to the flow rate of the incoming stream. Cost analyses indicate that, for all control devices examined, cost per ton of styrene removed decreases as styrene inlet concentration increases (i.e., as the air flow rate decreases). Therefore, it is probably economical to concentrate the exhaust air stream, using proper air flow management practices or enclosures, before application of add-on emission control devices.

Proper air flow management techniques, which capture emissions at the source, or enclosures, which prevent plant air from diluting styrene emissions, can reduce the exhaust flow rate and increase styrene concentration in the exhaust streams from FRP/C and boat building facilities. These approaches can maintain a safe working environment and produce a high-concentration exhaust stream that makes add-on emission control devices less expensive.

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The complete report, entitled "Assessment of Styrene Emission Controls for FRP/C and Boat Building Industries," (Order No. PB97-104640; Cost: $31.00, subject to change) will be available only from:
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