# SURVEY REPORT

# CONTROL TECHNOLOGY FOR FRP TANK MANUFACTURE

AT

FMC Corporation
Jonesboro, Arkansas

REPORT WRITTEN BY:
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NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
Division of Physical Sciences and Engineering
Engineering Control Technology Branch
4676 Columbia Parkway
Cincinnati, Ohio 45226

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| PLANT SURVEYED: | Agricultural Machinery Division<br>FMC Corporation<br>Jonesboro, Arkansas |
| SIC CODE: | 3522 |
| SURVEY DATE: | June 17, 1985 |
| SURVEY CONDUCTED BY: | Dennis O'Brien<br>William Todd<br>Gary Swinehart |
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# I. INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency engaged in occupational safety and health research. Located in the Department of Health and Human Services (formerly DHEW), it was established by the Occupational Safety and Health Act of 1970. This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards. The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering has been given the lead within NIOSH to study the engineering aspects of health hazard prevention and control.

Since 1976, ECTB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques. Examples of these completed studies include the foundry industry; various chemical manufacturing or processing operations; spray painting, and the recirculation of exhaust air. The objective of each of these studies has been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest.

This particular study was initiated by a request for assistance from FMC Corp. in suggesting controls for styrene exposures during a tank joining process. The survey measured styrene exposures under the current control technology conditions. Several suggestions for reducing the high styrene exposures were proposed at the time of the survey and are detailed in the Conclusions and Recommendations of this report.

## II. PLANT AND PROCESS DESCRIPTION

### PLANT DESCRIPTION:

The Agricultural Machinery Division of FMC Corp. is located in Jonesboro, Arkansas. This facility produces agricultural spray and oil field equipment. The agricultural sprayers employ tanks made of stainless steel or reinforced fiberglass plastic manufactured in the fiberglass shop, a building separated from the main plant. The sprayers and metal supports for the tanks are also machined at the plant. Approximately 200 people are presently employed at the Jonesboro plant. Fifteen of these people work in the fiberglass shop.

### PROCESS DESCRIPTION:

The agricultural sprayers incorporate fiberglass reinforced plastic tanks of 300, 500, and 1200 gallon capacities. These tanks are produced in two halves (top and bottom) by conventional spray-up/hand lay-up techniques. First, a layer of pigmented polyester resin, the gel coat, is applied to the mold. This is followed by mechanical spray application of chopped fiberglass and resin to the tank forms. A roller is used to saturate the fiberglass with resin and to expel air bubbles.

The process studied was the joining of the top and bottom tank halves. A worker enters the tank through a single 15 or 17 inch diameter opening on top. A flexible exhaust hose is then inserted into the tank. In addition to a single opening on top, some tanks have six inch diameter openings on each end, depending on the hardware to be attached later. The tank is sealed from inside by first filling the space between the two halves with a polyester resin/amorphous silica putty, then covering the filled space with three layers of resin-soaked glass cloth. The glass cloth is prepared outside the tank by a second worker who hands it through the opening to the worker inside. The resin, which contains styrene as reactant and diluent, is rolled out to remove air bubbles and achieve a secure fiberglass/resin seal. The operation requires 20 to 45 minutes depending on the size of the tank. An average set-up time for the resin is approximately 30 minutes but varies depending on the ambient temperature and the amount of catalyst added to the resin mixture. After the seal has hardened, the tanks are sent to the finishing area, where grinding, patching, and attachment of hardware are completed.

The 1200 gallon tank is divided into two sections (200 and 1000 gallons) each of which has an opening on top. The perimeter of the smaller section is sealed, followed by sealing of the larger section. Finally, the barrier between the two sections is sealed. One, two or three tanks may be sealed in a typical day.

### POTENTIAL HAZARDS.

The most serious potential hazard in this operation is styrene exposure during bonding of the top and bottom tank halves. Styrene evaporates along the entire length of the seam while the worker inside the tank is completing the fiberglass/resin application. Without adequate mechanical exhaust ventilation, the confined space nature of the tank would not allow general room ventilation to dilute the styrene to safe levels.

Styrene levels of less than the eight-hour PEL (100 ppm), do not produce subjective symptoms when the exposure time is short, however, mild eye and throat irritation may develop if exposure continues. At higher concentrations (600-800 ppm), nasal, eye, and throat irritation are more noticeable. In addition, symptoms of headache and nausea, extreme fatigue, and a feeling of somnolence or intoxication have also been reported in the literature. Workers were not questioned regarding any adverse health effects; however, no overt symptoms of intoxication were observed. To minimize the risk of these effects, NIOSH has recommended that worker exposure to styrene should not exceed 50 ppm as a time weighted average (TWA) concentration for up to a 10 hour workshift. To minimize irritation from styrene, NIOSH has recommended that worker exposure should not exceed 100 ppm, as determined for any 15 minute period.

Although not as serious a problem, acetone is used for hand and tool cleaning. It is contained in a five gallon container close to the workstation.

# III. METHODOLOGY

LIST OF EQUIPMENT:

Dupont P-125 pumps calibrated at 50 cc/min
Dupont P-200 pumps calibrated at 200 cc/min
Charcoal tubes-150 mg
Kurz Air Velocity Meter
Smoke tubes
Styrene monomer Drager tubes

MEASUREMENT OF CONTROL PARAMETERS:

The ventilation systems were evaluated using an air velocity meter and smoke tubes. Smoke tubes were used to visualize the airflow inside the tank and in the spray-up area. A smoke tube was also used in determining the capture distance of the exhaust duct. The airflow into the duct and into the large wall fans were measured using the air velocity meter.

SAMPLING PROCEDURES:

Breathing zone samples for the determination of airborne concentrations of styrene vapor were obtained with charcoal tubes using a 50 cc/min sampling rate for long term samples and a 200 cc/min rate for 10-20 minute samples. The short-term charcoal tubes were exchanged every 10-20 minutes while the worker was inside the tank to obtain ceiling concentrations. Drager tube samples were taken in the workers breathing zone to obtain instantaneous concentrations while the resin was being applied. Long-term styrene samples were obtained from one of the spray-up operators, the worker inside the tank, and his helper outside the tank. None of the long-term samples were of a duration so as to permit the calculation of an 8-hour TWA. Two area samples were obtained at the wall exhaust fan which ventilates the spray-up area. The charcoal tubes were analyzed by gas chromatography according to NIOSH Method No. 1501 with modifications.

## IV. CONTROL TECHNOLOGY

### INTRODUCTION - PRINCIPLES OF CONTROL

Occupational exposures can be controlled by the application of a number of well-known principles, including engineering measures, work practices, personal protection, and monitoring. These principles may be applied at or near the hazard source, to the general workplace environment, or at the point of occupational exposure to individuals. Controls applied at the source of the hazard, including engineering measures (material substitution, process/equipment modification, isolation or automation, local ventilation) and work practices, are generally the preferred and most effective means of control. Controls which may be applied to hazards that have escaped into the workplace environment include dilution ventilation, dust suppression, and housekeeping. Control measures may also be applied near individual workers, including the use of remote control rooms, isolation booths, supplied-air cabs, work practices, and personal protective equipment. Ongoing monitoring and maintenance of controls to insure proper use and operating conditions, and the education and commitment of both workers and management to occupational health are also important ingredients of a complete, effective, and durable control system.

These principles of control apply to all situations, but their optimum application varies from case to case. The evaluation and application of these principles are discussed below.

### ENGINEERING CONTROLS:

The current engineering control for the tank bonding process consists of inserting a flexible duct exhausting 350 cfm from the tank. This duct was designed to capture styrene vapors at the point of evaporation while also drawing in fresh replacement air. However, since styrene evaporates from the entire surface of the fiberglass/resin bond, the exhaust duct should be viewed primarily as pulling fresh air into the tank, thereby diluting the styrene concentration.

The spray-up area was ventilated by two, four foot by four foot propeller type wall fans. A wall separated the spray-up area from the gel coat area which was similarly ventilated. The resin used in spray-up and hand lay-up is a conventional mixture which allows approximately 100 grams of styrene to evaporate per square meter of application area (0.022 pint per square foot).[1]

### WORK PRACTICES:

During bonding of the divided 1200 gallon tank, the exhaust duct was placed in the unoccupied side of the tank. This practice allowed unobstructed access through the opening and easier movement within the compartment. The flexible exhaust duct was cumbersome and difficult to move. A small amount of air is exhausted from the occupied compartment through the unsealed barrier.

The spray-up operators were often observed standing between the exhaust fans and the mold. In this situation, styrene is pulled directly through their breathing zone. The matted fiberglass/resin mixture was removed from the fans at the end of each workday.

## PERSONAL PROTECTION:

Gloves were worn by all employees handling styrene. The worker who entered the tanks also wore coveralls over his clothes. No employee was required to wear respiratory protection, based on the results of previous sampling data (FMC and OSHA).

## EVALUATION OF CONTROLS:

Drager tube results presented in Table 1 indicate that styrene concentrations in the tank increase as the hand lay-up proceeds. Concentrations are initially less than 130 ppm and rise to more than 800 ppm. The charcoal tube data in Table 2 indicate a similar trend. Styrene concentrations in the large end of the 1200 gallon tank increased from an initial level of 160 ppm to 860 ppm during the final application. The measured concentration of 860 ppm may be unrepresentative of the process however. During this sample, the exhaust duct was inadvertently placed against the bottom of the tank, effectively cutting off the exhaust. The long-term personal samples (132 - 154 minutes) may not be accurate estimates of typical of 8-hour exposures, as they may represent periods of higher (or lower) work activity.

The average velocity at the opening of the flexible exhaust duct was 1250 fpm. The volume of air exhausted through the four inch by 10 inch opening was 350 cfm. Smoke tubes indicated a strong air current into the tank when air was being exhausted.

The four foot by four foot wall fans in the spray-up area were exhausting approximately 13,000 cfm at a velocity of 800 fpm. One diameter from the fan surface, the velocity fell to 120 fpm. The efficiency of the fans decreased when the chopped fiberglass/resin stuck to the fan screen. Spray-up and roll-out operations took place at least two diameters from the fan. The smoke tubes indicated a general air movement toward the wall fans in the spray-up area. However, charcoal tube results indicate the spray-up operator was exposed to a styrene concentration of 94 ppm.

## V. CONCLUSIONS AND RECOMMENDATIONS

A combination of increased exhaust volume, low styrene evaporation (LSE) resin, and proper work practices should lower the styrene concentration to safe levels inside the tank. To increase the exhaust volume, a larger diameter duct and fan capable of working against a large resistance need to be installed. The employee working inside the tank should wear respiratory protection while the improved controls are implemented. After evaluation of the styrene concentration in the tank, the respiratory protection may be discontinued.

The employee working outside the tank should have constant communication with the worker inside the tank. Since the tank is a confined space, appropriate precautions must be observed.

The volume of dilution air needed to maintain a 50 ppm styrene concentration was calculated from the formula given in the Industrial Ventilation manual.[2] A safety factor of three produced a value of 209,000 cubic feet per pint of styrene evaporated. When this value is multiplied by the evaporation rate of styrene the answer is given in cfm. The evaporation rate of styrene was determined to be approximately 0.015 pint/minute (see Appendix) corresponding to an airflow of 3100 cfm. The air flow should be exhausted through a duct no larger than 11 inches in diameter. This duct size will allow fresh air to enter the tank at approximately the same velocity it is exhausted.

The air velocity of 4700 feet per minute through an 11 inch duct would cause a substantial resistance to air flow. This resistance will be greater for a flexible duct than for a smooth fixed duct. The smooth duct should be extended further down to reduce the length of flexible duct needed and also its weight and unwieldiness. A straight bladed centrifugal or vane-axial exhaust fan is needed to work against the large static pressure loss while maintaining the required air flow.

Use of a LSE resin could reduce the amount of dilution air needed to maintain safe exposure levels. The use of styrene suppressed resins is reported to reduce styrene evaporation from 100 grams per square meter (0.022 pint per square foot) for conventional resins to 20 grams per square meter (0.0044 pint per square foot).[1] The LSE resins are most effective when the worker does not disturb the resin surface after roll-out and is least effective when the spray-up technique is used. The use of LSE resins may reduce the styrene concentration inside the tank by 50%.[1]

Good work practices during bonding of the tank halves should significantly reduce the styrene concentration. When the 1200 gallon tank is bonded, it is necessary to place the exhaust duct in the worker's compartment. Exhausting contaminated air from the unoccupied compartment has little or no beneficial effect for the worker. The orientation of the duct should also be checked periodically. A much smaller volume of air will be drawn into the exhaust duct if the opening is against the wall. This defeats the purpose of providing dilution ventilation.

The ventilation in the spray-up area can be improved by simply cleaning the wall fans more often. The fans work more efficiently when the chopped fiberglass/resin mixture is removed from the fan screen. The measured air velocity at the wall fans reflect the added resistance after a day's spray-up. The fan housing on the outside of the building also reduces fan efficiency. Modifications of this structure to allow unobstructed airflow may increase the amount of air exhausted. The spray-up operators should always orient themselves with the mold between themselves and the fan and as close as possible to the fan. This position will make maximum use of the ventilation system.

The spray-up and roll-out process appears to present more of an exposure hazard than previously thought. Styrene concentrations could be reduced in this area by more effective use of the existing wall fans. Addition of a wall and low ceiling would create a spray booth type enclosure. This would cause more air to flow past the mold, lowering the styrene concentration.

# VI. REFERENCES

1. Kalliokoski,P., Koistinen,T. and Jaaskelainen,M.: "Prevention of Styrene Hazards - Hygienic Approaches", in Industrial Hazards of Plastics and Synthetic Elastomers, Ed. by J. Jarvisalo, P. Pfaffli and H. Vainio, Alan Liss, Inc., pp. 279-286, 1984.

2. American Conference of Governmental and Industrial Hygienists: Industrial Ventilation, 18th Edition, Edwards Brothers, Inc., Ann Arbor, Michigan, pp. 2-1 through 2-4, 1984.

3. Kalliokoski,P., "Production and Uses of Styrene Containing Polymers": in Industrial Hazards of Plastics and Synthetic Elastomers, Ed. by J. Jarvisalo, P. Pfaffli and H. Vainio, Alan Liss, Inc., pp 193-202, 1984.

# APPENDIX

Evaporation rate calculations for large end of 1200 gallon tank:

| | |
|---|---|
| Application time | 20 minutes |
| Gel time | + 30 minutes |
| Evaporation time | 50 minutes |

| | |
|---|---|
| Amount of resin used | 16 pints (2 gallons) |
| Amount of styrene in resin (40%)[3] | 7.2 pints |
| Amount of styrene evaporated (10%)[3] | 0.72 pints |

0.72 pints/50 minutes = 0.014 pint/minute

Alternate method:
The amount of styrene which evaporates from a fiberglass/resin surface is 100 grams per square meter (0.0218 pint/square foot).

Perimeter of tank X Width of bond = Area of resin application

24.5 ft. X 1.5 ft. = 37 ft$^2$

0.0218 pint/ft$^2$ X 37 ft$^2$ = 0.80 pint

0.80 pint/50 minutes = 0.016 pint/minute

Table 1. Styrene concentrations (ppm) of air samples estimated with Drager tubes at FMC Corp., June 17, 1985.

| Operation | Sample No. | Styrene Conc. (ppm) |
|---|---|---|
| <u>500 gallon tank</u> | | |
| After 5 min. of lamination with exhaust | 1 | 160 |
| After 8 min. of lamination with exhaust | 2 | 160 |
| After 15 min. of lamination with exhaust | 3 | 400-800 |
| <u>Small end of 1200 gallon tank</u> | | |
| Starting lamination, exhaust in other side | 4 | 300-400 |
| Finishing lamination, exhaust in other side | 5 | 800 |
| <u>Large end of 1200 gallon tank</u> | | |
| Before lamination begins, duct in small side | 6 | 130 |
| Start lamination, exhaust duct in small side | 7 | 800 |
| After 10 min. break with no exhaust | 8 | 800 |
| Laminating center partition, duct was cut off | 9 | 400-800 |

Table 2. Styrene concentrations (ppm) of air samples obtained with charcoal tubes at FMC Corp., June 17, 1985.

| Location | Tube No. | Sample Time (minutes) | Styrene Conc. (ppm) |
|---|---|---|---|
| <u>Long term personal samples</u> | | | |
| Hand lay-up inside tank | 1 | 154 | 130 |
| Spray-up and roll-out of tank halves | 2 | 132 | 94 |
| Finish work outside tank (soak fiberglass in resin) | 5 | 146 | 21 |
| <u>Short term personal samples</u> | | | |
| Inside 500 gallon tank during lay-up | 7 | 10 | 170 |
| Small end of 1200 gallon tank | 10 | 20 | 90 |
| Large end Start of lay-up | 11 | 15 | 160 |
| Large end Continuation of lay-up | 12 | 15 | 260 |
| Large end Final lay-up of center division* | 13 | 10 | 860 |
| <u>Area samples</u> | | | |
| At wall fan in spray-up area | 6 | 51 | 25 |
| At wall fan in spray-up area | 8 | 22 | 25 |

* The exhaust hose was sealed off on the bottom of the tank.