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TECHNICAL REPORT

Industrial Hygiene Characterization of Urea Formaldehyde and Polyurethane Foam Insulation

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health

INDUSTRIAL HYGIENE CHARACTERIZATION OF UREA FORMALDEHYDE AND POLYURETHANE FOAM INSULATION

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ABSTRACT

Industrial hygiene surveys were conducted at urea formaldehyde and polyurethane foam thermal insulation manufacturing and application facilities as part of a NIOSH industrywide study of foam insulation materials. In all, eight sites were surveyed--two sets of manufacturers and applicators for each of the two types of foams. Personal and area monitoring were conducted to determine exposure levels to chemical substances and physical agents.

Within the urea formaldehyde industries surveyed formaldehyde exposures at the manufacturing facilities ranged from a TWA value of 0.18 ppm to peak values of 5-10 ppm; exposures at the application sites ranged from <0.08 to 2.4 ppm. The NIOSH and ACGIH recommended limits were exceeded and the potential for an excursion to the OSHA standard for formaldehyde was shown to exist. In addition ammonia, furfuryl alcohol, acetaldehyde, phenol, nitrosamines, and respirable dust were measured. Ammonia sample results were less than established workplace limits, except during ammonia drum pump stem removal when the measured concentration of 300 ppm exceeded the ACGIH STEL of 35 ppm. All other chemical contaminant levels were below the lower limits of detection. Noise levels in excess of established limits were measured at one of the manufacturing facilities.

Within the polyurethane industries surveyed MDI exposures ranged from <0.0008 to peaks of 0.002-0.005 ppm at the manufacturing facilities and <0.001 to peaks of 0.002-0.068 ppm at the application sites. The NIOSH, ACGIH and OSHA limits for MDI were exceeded at one of the application sites. In addition, exposure levels for TDI (not a component of polyurethane thermal insulation systems) were exceeded at a manufacturing facility. Measurements for fluorotrichloromethane, *alpha*-methyl stryene, tertiary amine compounds, organotin compounds, 2-ethoxyethanol, carbon monoxide and methylene chloride were taken; these compounds were not detected at levels which exceeded either the NIOSH and ACGIH recommended limits or the OSHA standards. Exposure to noise in excess of established limits would not occur under routine conditions.

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INTRODUCTION

AUTHORITY

The Williams-Steiger "Occupational Safety and Health Act of 1970" was passed into law "to assure safe and healthful working conditions for working men and women...." This Act established the National Institute for Occupational Safety and Health (NIOSH) in the Department of Health, Education and Welfare (presently the Department of Health and Human Services) and the Occupational Safety and Health Administration (OSHA) in the Department of Labor. The Act provides for research, informational programs, education, and training in the field of occupational safety and health and authorizes the enforcement of standards.

NIOSH has been given the authority and responsibility under the Act to conduct field research studies in industry, evaluate findings, and report on these findings. Section 20(a)(1) of the Act mandates NIOSH to "conduct (directly or by grants or contracts) research, experiments, and demonstrations relating to occupational safety and health...." Section 20(c) provides the authority to enter into contracts, agreements, or other arrangements with appropriate public agencies or private organizations for the purpose of conducting studies relating to responsibilities under the Act. For this purpose, NIOSH has established a contractual agreement with Enviro Control, Inc. (Enviro) to study worker exposures at eight urea formaldehyde and polyurethane foam insulation manufacturers and applicators.

PURPOSE AND NEED FOR STUDY

Members of the insulation trade have long been noted to experience excess mortality due to malignant and nonmalignant respiratory diseases (Fleisher 1946, Marr 1964, Selikoff et al 1964, Keane et al 1966). Much of this observed disease has been attributed to exposures to asbestos fiber.

However, the hazards associated with many of the other thermal insulation materials used remain unknown. With the great increase in the use of thermal insulation and the proliferation of insulation materials, there is need for a study to identify hazards associated with these materials.

The purpose of this study is to determine the types and quantities of thermal insulation materials commonly used in the United States, the end use categories of these materials, and information regarding past worker exposure data. In addition, current occupational exposure levels of workers engaged in the production and application of two commonly used thermal insulation materials have been determined by industrial hygiene surveys.

MATERIAL SELECTION

Insulation sales were shown, in an economic analysis performed by a major stock brokerage firm, to be distributed as presented in Table 1.

TABLE 1. 1977 Insulation Market Shares (dollar value)

Material	Residential Insulation*	Total Insulation
Fibrous Glass	68%	52%
Mineral Wool	12	23
Cellulose	15	10
Foams, Other	5	15
TOTAL	100%	100%

* Residential insulation accounts for about 65% of total insulation.

To select the thermal insulation materials most appropriate for study within the resources available for this contract, the following selection criteria were applied to the more than two dozen materials currently being commonly used:

- Number of potentially exposed workers
- Present extent of use
- Projections of future extent of use
- Toxicity
- Purity of material in use
- Length of time material has been used
- Availability of worker exposure data

Based primarily on these factors, each material was placed in one of three categories as shown in Table 2.

TABLE 2.

CATEGORIZATION OF THERMAL INSULATION MATERIALS

A. Materials Most Appropriate for this Study

- Polyurethane
- Urea formaldehyde

B. Materials Appropriate for Further Consideration

- Calcium silicate
- Cellulose
  - Cotton fiber
  - Macerated paper
  - Wood fiber
- Ceramic fiber
  - Aluminum oxide, Al_2O_3
  - Aluminum silicate, Al_2O_3-SiO_2
  - Zirconium oxide, ZrO_2
- Diatomaceous earth
- Gypsum
- Isocyanurates
- Magnesium carbonate
- Perlite
- Polystyrene
- Vermiculite

C. Materials Less Appropriate for this Study

- Aluminum foil
- Asbestos
- Carbon black
- Carbon fibers
- Castable-ceramic insulating refractories
- Cork
- Cork-filled mastic
- Felt board
- Fibrous glass
- Foam glass
- Mineral fibers
- Polyester film
- Polyvinyl acetate
- Refractory brick
- Rubber and resin
- Silica aerogel
- Vinyl chloride foam

Category A Materials

Polyurethane

The consumption of plastic foams for building insulation has been growing at a rate between 10-15% annually. This consists primarily of polyurethane, polyisocyanurate, polystyrene, and urea formaldehyde foams. The Society of Plastics Industry, Inc. (SPI), 1978 Edition of Facts and Figures of the Plastics Industry provides extensive information on production for the various types of plastic foams used as thermal insulation. Plastics consumption in insulation is expected to increase more than 10% per year and by 1985, this end use will consume the largest volume of plastics. The following table compiled from SPI information shows general data for all types of plastics used as insulation in the interior construction market:

TABLE 3. Production of Plastic Foams Used as Thermal Insulation in the Interior Construction Market

Application	1972/1974	1980	1985
Insulation* (in millions of pounds)	257	500	840

*These figures do not specify the insulation application to be "thermal" insulation

The diisocyanate addition polymerization used for the preparation of polyurethane was discovered in 1937. Since then the area of polyurethane chemistry and applications has continuously grown. Urethane foam has generally replaced polystyrene foam and fibrous glass the as thermal insulation material in such applications as refrigerated trucks, railroad cars, and cold rooms (1). These are insulated by pour-in-place or froth-in-place urethane systems. Foams are also power-sprayed on surfaces using a two-component spray gun. The isocyanate and polyol components are metered volumetrically to the gun head, where they are mixed and ejected as a fine spray. This process is particularly convenient for the application of insulation on roofs, ceiling, and walls, as well as such curved substrates as tanks and pipes.

Between 1955 and 1972, the average growth rate of urethane foam was in excess of 20% per year. The thermal conductivity of a low-density urethane foam is lower than any of the commonly-used insulations now on the market. The growth potential of rigid polyurethane foam in the construction area is anticipated to be the highest among all the applications for urethanes, even though there have been significant problems associated with fire retardancy and toxic smoke generation.

NIOSH estimated that production of polyurethane in 1974 was 1520 million pounds, with an estimated 1900 workers potentially exposed (2). The amount used as thermal insulation was not specified.

In a literature review performed in 1978 for this study, 45 manufacturers of rigid and foamed plastic insulations were identified. A typical company indicated that they had six persons engaged in supplying polyurethane foam products to about 100 installation contractors. They did not have an estimate of the average number of insulation workers per contractor. However, at least several hundred workers were potentially exposed to polyurethane foam components provided by just one distributor. Although there are several reports related to occupational exposure to isocyanates used in the production of polyurethane foam (3-9), no report was found identifying worker exposure to total polyurethane foam production systems; therefore, polyurethane was placed in Category A.

A NIOSH Criteria Document (10) citing 156 references, summarizes the literature available on diisocyanates. Some worker exposure data associated with the manufacture of diisocyanates are given. Also, some data related to foaming operations are presented. However, the activities monitored were generally not identified as being associated with thermal insulation. Due to noted severe respiratory reactions associated with worker exposure to diisocyanates, NIOSH recommended an environmental limit of 5 ppb with a 10-minute ceiling of 20 ppb. Generation of data showing the exposure of thermal insulation workers relative to the NIOSH-recommended standard is desirable. In addition to potential exposure to isocyanates which have been shown to present significant toxic hazards, worker exposure to some of the halogen-containing blowing agents is appropriate to evaluate. Therefore, polyurethane foam systems were considered to be appropriate materials to select for this study.

Urea Formaldehyde

Urea formaldehyde foam is a thermosetting plastic composed of urea formaldehyde resin, air, and a foaming agent which contains an acid catalyst (11). Typically, urea formaldehyde resins are condensation products to which various additives are added to impart desired characteristics to the finished foam. The foam is generated either continuously or in batches. An aqueous detergent containing the acid catalyst is foamed up in a continuous stream or in a vessel, after which the urea formaldehyde resin is added. Once generated, it takes from 5 to 120 seconds for the foam to set. During this time, it is fluid and can be injected into spaces such as hollow walls. The condensation and drying take from a day or two to a month or more, depending on ambient temerature, relative humidity, and permeability of the containing walls.

Urea formaldehyde-based foam is one of the oldest of the cellular plastics, having been known since 1933. Although it has been commercially available in the United States since the 1950s, its use has been limited. However, with the increased necessity to conserve energy, the use of urea formaldehyde foam systems has grown. Its greatest use as thermal insulation has been for retrofitting residential wall cavities. It is used to a lesser extent as an insulation in commercial and industrial buildings for both new construction and retrofit, and in residential new construction (12). The 1978 production capabilities of the industry were 125-130 million pounds per year, and the 1980 industry capacity was projected to be 450-500 million pounds per year (13).

The Consumer Products Safety Commission, Economic Analysis Division indicated that the 1977 consumption of urea formaldehyde insulation was 60 million pounds. They also indicated that there are about 25 domestic manufacturers and 3000 to 5000 installers of urea formaldehyude insulation, based on information obtained by Battelle for a CPSC report, "Product/Industry Profile and Related Analysis on Formaldehyde."

To provide additional information regarding the number of workers potentially exposed to urea formaldehyde materials some the largest manufacturers of urea formaldehyde foam were contacted. One manufacturer had about 25 persons engaged in the manufacture of urea formaldehyde foam. Another large manufacturer had 18 persons engaged in the manufacture of urea formaldehyde foam products which it shipped to 39 states. This manufacturer estimated that there were from 1500 to 2000 insulation workers engaged in the installation of its urea formaldehyde thermal insulation products.

A NIOSH Criteria Document on formaldehyde (14), citing 222 references, summarized the literature available on formaldehyde as of 1976. No report of worker exposure to formaldehyde in urea formaldehyde foaming operations was identified, indicating that these exposures probably have not been very extensively documented. Also, in a study being conducted under the supervision of the Chemcial Industry Institute of Toxicology (15), nasal carcinomas have been diagnosed in rats exposed to formaldehyde. This information was not available when urea formaldehyde foam was selected for study. The NIOSH recommendation in the Criteria Document to lower the standard indicates that exposures to formaldehyde may pose a hazard to workers, thus demonstrating a need to determine whether worker exposures at urea formaldehyde foaming operations are within acceptable limits. Therefore, urea formaldehyde was placed in Category A, and urea formaldehyde foam systems were considered to be appropriate materials to select for this study.

Category B and Category C Materials

Generally, materials placed in Category B were those which may present some hazard to exposed workers, but which present only limited potential for worker exposure. Category C materials include both those considered to present only minimal hazards to exposed workers, and those which have already been extensively studied. To further study this latter group within the resources available for this study would result in only an incremental addition to a large body of existing information.

Fibrous glass and mineral wool were placed in Category C largely due to the extensive amount of worker exposure information that has already been generated. Even though these materials are very widely used, indicating that there is a large number of potentilly exposed workers in both manufacturing and application, hazards to these workers have been evaluated in numerous studies. In a 1975 study (16), Dement presented the results of a NIOSH industrywide study of the fibrous glass industry. A NIOSH Criteria Document (17) citing 108 references summarizes the available literature. For control purposes, NIOSH uses a fiber diameter of 3.5 micrometers as the division between two categories of fibrous glass. However, on the basis of currently available information, NIOSH does not consider fibrous glass to be a substance that produces cancers as a result of occupational exposure. Also, although this criteria document addresses occupational exposure to fibrous glass, NIOSH considers that, until more information is available, the recommended standard can also be applied to other man-made fibers.

The Thermal Insulation Manufacturers Association has funded several extensive industrial hygiene and epidemiology studies of man-made fibers. Industrial hygiene studies in 16 fibrous glass and mineral wool plants and in three ceramic fiber plants have just been completed. Corn reported exposure to mineral wool production workers. Several representative pertinent studies related to man-made fibers have been identified (18-32). An industrywide study (33) of occupational exposures to mineral wool is currently being prepared for publication by NIOSH.

Predominant unanswered questions are not in the area of worker exposure, but are largely in the area of toxicology, which this study does not address. Therefore, even though additional worker exposure information in selected areas is desirable, fibrous glass and mineral wool were not considered to be the most appropriate materials to select for this study.

Similarly, exposures to ceramic fibers have been recently studied (24, 27, 28, 31), although not as extensively as fibrous glass. Also, ceramic fibers are used for limited high-temperature applications with considerably fewer potentially exposed workers than are associated with fibrous glass or mineral wool. Since less worker exposure information is available about ceramic fibers than fibrous glass or mineral wool, ceramic fibers were placed in Category B; however, due to the worker exposure information already available and the smaller number of potentially exposed workers, ceramic fibers were not considered to be the most appropriate materials to select for this study.

Asbestos has been extensively studied (34-43). In December 1976, NIOSH published a thoroughly documented "Revised Recommended Asbestos Standard" (43). Stringent exposure standards for asbestos have resulted in the phasing out of asbestos for many thermal insulation applications. For these reasons, even though additional studies of some specific activities may be desirable, asbestos is not considered to be the most appropriate material to select for this study, and was accordingly placed in Category C.

Cellulose

- cotton fiber
- macerated paper
- wood fiber

Cellulose thermal insulation is made by converting used newsprint, other paper feedstock, cotton, or virgin wood to fiber form and incorporating various chemicals to provide flame retardancy. Typically used at a loading of about 20% by weight are borax, boric acid, and aluminum sulfate.

In an economic impact analysis performed for the Consumer Product Safety Commission (CPSC) (44), there were estimated to be about 540 cellulose insulation manufacturing facilities in operation in June 1978 and about

435 firms near the end of 1978. The data imply that there were about 3500 workers engaged in the production of cellulose insulation. Several times that number are engaged in its installation.

The Insulation Contractors Association of America estimated in 1978 that there were about 3,000 insulation contractors operating in the United States. No data were reported that revealed what percentage of the contractors installed cellulose insulation, but industry comments indicated that most of the contractors had installed or were installing the material. An average number of installers per contractor was not given, but a limited survey of contractors in the metropolitan Washington, DC area indicated that contractors commonly had from 20 to 50 workers.

The cellulose insulation industry in 1978 was experiencing insufficient demand relative to industry capacity. The industry experienced steady growth in production from 1973 through 1976 and a surge in 1977. However, by January 1978 there had been a large increase in industry capacity followed closely by a sharp decrease in production. Cellulose insulation production decreased 66% from 1977 (1600 million pounds) to 1978 (550 million pounds). This decrease appeared to be related largely to an overall drop in demand for all major insulation materials in 1978. For instance, mineral wool demand decreased about 20%. Also, an estimated 30% fewer housing units were retrofitted with all types of insulation in 1978 than in 1977. Cellulose insulation production during the next decade is estimated to decrease rapidly from the 1977 peak of 1600 million pounds to 400 million pounds annually through the middle 1980s.

The relatively large potentially exposed worker population and the lack of identified studies of worker exposure indicated that cellulose insulation was an appropriate material to study; therefore, cellulose was placed in Category B. However, the lack of identified significant health hazards associated with the substances to which cellulose thermal insulation production workers and applicators were potentially exposed indicated that cellulose was not the most appropriate material to select for this study.

Isocyanurates are second-generation isocyanate-based foams which are chemically distinct from urethanes. As a result, they have different properties, the most significant being superior thermal stability and improved flammability characteristics. Urethanes are made by reaction of a polyol with an isocyanate, while isocyanurates are formed by catalytic cyclization of three isocyanate molecular groups to a six-membered ring. Isocyanurates can be prepared using diphenylmethane diisocyanate (MDI) or more generally polymethylenepolyphenyl isocyanate (PMPPI). Suitable catalysts for effecting trimerization of PMPPI include amines (generally in combination with some other material), carboxylates, acids, and organometallic compounds. Recent important uses of polyisocyanurate foams have been in insulating conduits for superheated water and heated refinery storage tanks. Some isocyanurate foams also are used for building insulation. Major application areas for low-density, closed-cell insulating foam are construction, refrigeration, transportation, industrial storage tanks, and marine usage. Isocyanate components for production of either polyurethanes or polyisocyanurates are sometimes similar or the same; therefore, separate production figures for components used in isocyanurates were not available. However, at present polyurethanes are considerably more widely used than are isocyanurates. Even though worker exposures to isocyanurate components are desirable to define, isocyanurate foam is not the most appropriate material to select for this study since many of the same components are used in polyurethane foams and since a considerably larger potentially exposed population is associated with polyurethane foams.

Magnesium carbonate is a major constituent of magnesia which contains about 15% asbestos fiber. Magnesia was widely used in the chemical process industries and in commercial buildings in thermal insulation applications such as those involving ovens, boilers, stills, steam lines, and pipe wrapping. The predominant hazard associated with magnesia was potential exposure of workers to asbestos fibers rather than to magnesium carbonate; therefore, magnesium carbonate was not considered to be the most appropriate material to select for this study.

Carbon fibers were placed in Category C due to the very limited use of this material as thermal insulation in specialized high-temperature applications, indicating that few workers are potentially exposed to carbon fibers. Also, toxicologic information indicating particular hazards due to exposure to carbon fibers was not observed. Although not in the same form as carbon fibers, carbon black was the subject of a NIOSH criteria document (45) in which 86 references are cited summarizing the available literature. Although worker exposure data related to the use of carbon fibers and carbon black as thermal insulation may be desirable to generate, these materials are not considered to be the most appropriate selections for this study, due largely to the lack of identified hazards related to exposure and the limited worker population potentially exposed.

There are several specialized industrial applications of thermal insulation materials and techniques in which generally a more closely controlled and a smaller exposed population are involved than are associated with residential insulation applications. Many of the materials are considered to be essentially inert. Also, toxicologic information defining the potential hazard to workers exposed to some insulation materials used in specialized applications is not available. For these reasons, each of these materials was placed in Category B or C, and applications rather than individual insulation types are discussed.

Insulations used in the cryogenic temperature range fall within two types: vacuum and massive, the latter consisting of one or more solid phases distributed with a gas such as dry air to produce a very low thermal conductivity. Vacuum insulation systems, consisting typically of highly polished metal supporting walls with a vacuum space between them, sometimes with multiple metal reflective foils or opacified powders inside, are usually custom-designed and installed by the insulation vendors. Vacuum cryogenic insulation relies in part on vacuum between the walls, and in part on reflection of radiant heat. Coating the inside hot surface facing the evacuated area reduces heat transfer to a level proportional to the emissivity of the coating (0.01 for silver, for example).

A thermal insulation technique referred to as the floating-shield approach takes advantage of the fact that thermal radiation can often be cut in half by floating a radiation shield between the cold and warm surfaces. Powders such as expanded perlite, silica aerogel, carbon black, calcium silicate, diatomaceous earth and fiber are used. The material is packed in before the air is pumped out.

Less costly than these evacuated forms are the foam-type insulations. Polyurethane and polystyrene in flexible sheets, foamed in place, or foamed in rigid insulation sections, initially showed great promise, but deterioration from permeation by water vapor and air has caused problems. Foamed glass stands up better to drying-out processes and is less permeable.

In the higher part of the low-temperature range, from about -20°F to 212°F, a variety of organic and inorganic massive insulations are used, sometimes in loose-fill form. These include:

- Compressed and granulated cork
- Sandwiched cellular glass and felt board
- Glass fibers bonded with organic resins
- Expanded and cellular forms of polystyrene
- Polyurethane foams
- Rubber and resin combinations
- Vinyl chloride cellular foams
- Wood fibers with suitable binders
- Polyvinyl acetate
- Cork-filled mastic
- Expanded vermiculite and perlite
- Aluminum foil on paper

Fibrous glass is the insulation most used for applications ranging from the temperature of chilled water up to 212°F. Lower temperature cryogenic systems generally employ either massive solid insulations or vacuum types. In the latter, highly polished metal supporting walls have a vacuum space, reflective foils, and various inorganic or organic materials coated with metals between them.

The material applications described for use in the cryogenic temperature range and in the higher part of the low-temerature range are associated largely with the chemical process industries. Since systems using these materials are usually custom-designed and installed by the insulation vendors for limited applications, a much smaller and more closely supervised worker population is involved than is the case with materials generally used in the building trades. Of the materials identified for these low-temperature applications, several are considered to present minimal hazards to the health of workers or to involve very specialized applications when these materials are used as thermal insulation materials:

- Aluminum foil
- Calcium silicate
- Cork
- Cork-filled mastic
- Diatomaceous earth
- Felt board
- Foam (cellular) glass
- Perlite
- Polystyrene
- Polyvinyl acetate
- Rubber and resin
- Silica aerogel
- Vermiculite
- Vinyl chloride foam

Due largely to limited potentially exposed worker populations or minimal health hazards associated with the materials, these materials were not considered to be the most appropriate to select for this study.

Polyester film is used in some limited, very specialized applications, particularly in the low-temperature thermal insulation area. A multilayer series of reflective shields consists of a number of aluminum-coated layers of polyester film, crinkled to reduce heat transfer by conduction from layer to layer. This withstands high acceleration loads without loss of insulating effectiveness. Since significant health hazards have not been identified with this use of polyester film and since the very limited usage indicates a very limited potentially exposed worker population, polyester film is not the most appropriate material to select for this study.

Many of the materials used as thermal insulation in the cryogenic range are also utilized in the high-temperature range. Major materials in the high-temperature range are (listed in ascending order of temperature resistance):

- Mineral fiber: 1000 to 1900^oF
- Calcium silicate: 1200 to 2000^oF
- Multiple-metal-foil systems for vacuum applications: to 2500^oF
- Ceramic fibers based on the Al_2O_3-SiO_2 systems: 1600 to 2600^oF
- Castable-ceramic insulating refractories: 2000 to 3000^oF
- Oxide fibers, primarily Al_2O_3 or ZrO_2: 2800 to 3000^oF
- Rigid ceramic insulating brick: 2000 to 3200^oF
- Carbon fibers: to 3600^oF

The refractory materials, castable-ceramic insulating refractories, and rigid ceramic insulating brick, have long been associated with silicosis hazards, both among workers engaged in the manufacture of refractory brick and among workers such as bricklayers installing these materials. Particularly, several years ago, significant hazards were associated with activities such as the removal of firebrick linings in open-hearth furnaces and in relining these furnaces with new refractory brick. Free silica exposures have been identified and at present are largely controlled through combinations of specific removal and replacement techniques and through the use of personal protective equipment. These materials are generally used in large organizations such as steel companies that have medical and industrial hygiene surveillance programs. Although additional worker exposure data may be desirable, these ceramic refractory materials are not considered to be the most appropriate selections for this study.

Gypsum boards are used largely for roof deck applications. Although widely used for many years in both residential and commercial construction, health hazards associated with the use of this material have not been identified; therefore, gypsum is not considered to be the most appropriate material to select for this study.

Rationale for Selection of Materials

Considering the increasing use of polyurethane and urea formaldehyde foams, the severe respiratory reaction associated with worker exposure to diisocyanates, as well as the increasing use of and the recent information regarding possible carcinogenic effects of exposure to formaldehyde, selection of polyurethane and urea formaldehyde foam thermal insulation systems for study is appropriate and timely.

SITE SELECTION

Two manufacturers and two applicators of urea formaldehyde foam insulation systems and two manufacturers and two applicators of polyurethane foam insulation systems were selected for study. Two sets were selected for each material, each set consisting of a manufacturer and an applicator of that manufacturer's materials. This concept as well as several additional factors were considered in selecting for study manufacturers and applicators of the two foam insulation systems. Although not necessarily of equal weight in the selection process, the additional criteria considered in the selection of the eight facilities for study included:

- Representativeness of the facility to the industry
- Number of potentially exposed workers
- Turnover rate
- Use of engineering controls
- History of production
- Whether potential exposure is mixed with other exposures
- Availability of data regarding past exposure levels and work practices

Also, where selection using these criteria resulted in nearly equally acceptable choices, consideration was given to the producer marketing over the wider geographic area.

The literature review performed for this study provided major listings of producers and applicators. Contact with trade associations identified in the literature search provided additional specific information regarding producers and applicators of polyurethane and urea formaldehyde thermal insulation. Also of particular assistance were the Urethane Foam Contractors Association and the National Association of Urea Foam Insulation Manufacturers. The Society of the Plastics Industry, Inc., provided a list of their Urethane Division Membership. In addition, literature sources such as the Thomas Register's Thomcat Directory and the SRI Directory of Chemical Producers were searched relative to identifying producers of polyurethane and urea formaldehyde thermal insulation materials.

PRODUCERS

Information necessary to apply the selection criteria to producers was obtained in 1979 by telephone conversations with appropriate company representatives. This information is summarized in Tables 4 and 5. Since urea formaldehyde and polyurethane are completely separate materials produced by different companies, appropriate additional information relative to the producers is discussed separately.

TABLE 4. Urea Formaldehyde Component Producers

FACILITY	YEARS OF PRODUCTION	NUMBER OF WORKERS	AVERAGE YEARS OF EMPLOYMENT	OTHER CHEMICAL ACTIVITIES	ENGINEERING CONTROLS	EXPOSURE & WORK PRACTICE DATA	REPRESENTATIVENESS TO INDUSTRY
1	2	6		No	Yes	No	Small
2	(No manufacturing; distribution only)						
3	(No UF thermal insulation products)						
4	(Has withdrawn from UF market)						
5	8	1	8	No	Yes	No	Average
6	(Information only through NAUFIM)						
7(B)[a]	6	3	5	No	Yes	No	Typical
8	(UF foam equipment manufacturer; UF distributor)						
9	(Wholesale distributor)						
10	(No manufacturing; distributor only)						
11	1	2	1	No	Yes	No	Typical
12(A)[a]	4	3			Yes	No	Typical
13	1	2	1	No	No	No	Similar
14	8	1			Yes		Modern
15	(No UF thermal insulation manufacturing)						

[a] Facility selected for study

TABLE 5. Polyurethane Component Producers

FACILITY	YEARS OF PRODUCTION	NUMBER OF WORKERS	AVERAGE YEARS OF EMPLOYMENT	OTHER CHEMICAL ACTIVITIES	ENGINEERING CONTROLS	EXPOSURE & WORK PRACTICE DATA	REPRESENTATIVENESS TO INDUSTRY
1	(No polyurethane thermal insulation products)						
2	(Compounds and sells to applicators in North Carolina)						
3	10	8	S[a]	No	Yes	Yes	Typical
4(C)[b]	17	8	S[a]	No	Yes	Yes	Clean
5	(Only supplies raw materials)						
6	(No thermal insulation; only flexible foam)						
7	4	6		Yes	Yes	Yes	Better
8	20	(Not in home insulation market)					
9	(Only supplies raw materials)						
10	11	4	2	Yes	Yes	Yes	Typical
11	12	6	S[a]	No			
12	(For industrial applications only)						
13	9	(For heated storage & reroofing only)					
14	(Supplies some amines & blowing agents)						
15	7	6		Yes		No	
16	10	14	S[a]	Yes	Yes	No	Typical
17	8	12	4	Yes	Yes	Yes	Typical
18	8	8	S[a]	Yes	Yes	Yes	
19	14	15	5	No	Yes	Yes	
20	8	3	8	No			
21(D)[b]	25	8	15	No	Yes	Yes	

[a] Stable
[b] Facility selected for study

UREA FORMALDEHYDE

The summary of information obtained from contacts with urea formaldehyde component producers, as presented in Table 4, identifies three producers with at least three workers directly associated with the production of urea formaldehyde two-component systems. Facility Number 1 is a significant producer of urea formaldehyde (UF) materials, marketing largely in the midwest. Although it meets the selection criteria, study of a producer of a more widely distributed product was desirable.

The largest producers of urea formaldehyde systems for foam applications are, according to various industry statements, Facility Numbers 7 and 12. Each of these producers meets the selection criteria and was considered to be appropriate to select for this study. Facility Number 7 is Producer B and Facility Number 12 is Producer A in this study.

POLYURETHANE

The summary of information obtained from contacts with polyurethane component producers, as presented in Table 5, identifies seven producers with at least six workers directly associated with the production of polyurethane two-component systems. Facility Number 3 is a significant producer, marketing in the midwest and south. It is more suitable to select a producer marketing over a larger geographic area if all other selection factors are similar. Facility Number 4 is a major producer of polyurethane systems, with nationwide product distribution. It produces only materials related to polyurethane systems in the polyurethane production areas. Since the other selection criteria also were met and since it is among the largest polyurethane systems producers, Facility Number 4 (Producer C) was selected for this study.

Facility Number 7 has been in business for 4 years, considerably less than the 17 years of Facility Number 4. Facility Number 7 is a significant manufacturer, marketing mainly in the west. Due largely to the fewer persons engaged in the production of polyurethane systems and to the limited marketing areas, Facility Number 7 was not considered to be the most appropriate facility to select for this study, although it was an acceptable alternate selection.

Facility Number 11 is a significant producer marketing in the southeast. Little detailed information was provided. Due primarily to the lack of exposure and work practice information, this facility was not considered to be the most appropriate to select for this study.

Facility Numbers 15, 16, 17, and 18 are major manufacturers of polyols as well as major formulators of polyurethane systems. The predominant reason for not selecting any of these facilities as being most appropriate for this study was the mixed exposures due to the production of other resins and adhesives by the workers associated with the production of the polyurethane systems.

Facility Number 19 is a major manufacturer of isocyanates and polyols. It also manufactures rigid foamed polyurethane products. However, it does not make systems sold to applicators or distributors. Therefore, this facility was not considered to be the most appropriate to select for this study.

Facility Number 21 is a major producer of polyurethane foam systems, with a production history of about 25 years. About half of the workers in the polyurethane area have been employed in this area for more than 15 years. Since this facility was used for the production of polyurethane systems for 25 years, the workers were not engaged in other chemical activities, and since the other selection criteria were met, this facility (Producer D) was selected for this study.

APPLICATORS

In selecting applicators for either polyurethane or urea formaldehyde systems, some producers identified applicators of their products in the Washington, DC, metropolitan area. Additionally, these names were augmented with applicators identified in area telephone directories. For example, about 20 applicators advertising the application of either polyurethane or urea formaldehyde were listed in the DC Yellow Pages.

There appears to be little consistent training associated with the application of polyurethane foam. Therefore, most applicators of polyurethane foams were found to switch from supplier to supplier rather than always to use the same brand.

Conversely, for the application of urea formaldehyde foam, the applicator received, as a minimum, 40 hours of training at the producer's facility. These applicators were certified by the producer as meeting certain proficiency requirements, and used that producer's urea formaldehyde foam products exclusively, although they also applied other types of thermal insulation materials.

Applicators selected were those organizations which had at least three employees who were engaged nearly full time in the application of the types of foam of interest. For polyurethane foam, the applicators selected frequently apply the specific producer's material. For urea formaldehyde foam, each applicator exclusively applied the material of the producer identified with the applicator. Information regarding the selected applicators is presented in Table 6:

TABLE 6

Urea Formaldehyde and Polyurethane Applicator Information

Urea Formaldehyde

Applicator A

- Two years applying foam
- Fifteen applicators
- Only apply Producer A's UF foam materials

Applicator B

- One year applying foam
- Four applicators
- Only apply Produder B's UF foam materials

Polyurethane

Applicator C

- Four years applying foam
- Three applicators
- Apply Producer C's and other producer's polyurethane materials

Applicator D

- Twelve years applying foam
- Ten applicators
- Apply Producer D's and other producer's polyurethane materials

UREA FORMALDEHYDE FOAM INSULATION

I. DESCRIPTION OF FACILITIES SURVEYED

A. MANUFACTURERS

Plant Description and History

- Manufacturer A

This manufacturer's plant is a one-story, free-standing steel structure with approximately 14,000 square feet of space. Except for the office area, the ceiling height is 16 feet at the eaves and 18 feet at the peak. Manufacturer A has occupied this facility for about 4½ years. The urea formaldehyde foam insulation system has been the only product manufactured.

The building is divided into five basic sections: offices, quality control laboratory, parts room, application test area, and production area. Viscosity and pH determinations on batch samples are performed in the quality control lab. During the survey, the lab was not utilized. The parts room is used for equipment storage and as a repair area for production and application equipment. Urea formaldehyde foam insulation is applied to the prefabricated wall cavities in the application test area. The production area, approximately 12,000 square feet, contains a reaction vessel, storage and blending tanks, container-filling equipment, drum-washing equipment, and storage space for raw materials and finished goods.

- Manufacturer B

This manufacturer occupies space in two adjacent buildings. Included are a foam manufacturing area, a storage and baling area for newspapers to be used in cellulose insulation production at another company facility, a training area where installers are instructed in the application of the foam insulation, a workshop where application guns and pumps are assembled, an office area, and a laboratory. The form manufacturing area is divided into two sections: an area approximately 25 feet by 27 feet with a 20-foot ceiling where the reaction vessel is located; and an area approximately 50 feet by 37 feet with a 14-foot ceiling where the foaming agent mixing tank is located, and finished product, raw materials and empty drums are stored.

Manufacturer B has been manufacturing a urea formaldehyde-based thermal insulation system since 1972. From 1972 until 1974, the company made the product with urea and formaldehyde. In 1974, the company began using methylolurea in place of formaldehyde; however, test batches using methylolurea were made prior to 1974 in a 30-gallon reactor.

Description of Operations and Existing Controls

The Urea Formaldehyde Foam Insulation System Manufacturing Process

A two-component urea formaldehyde foam insulation system, consisting of a resin and a foaming agent, is made at each of these facilities. The manufacturing process and the chemical components of the urea formaldehyde-based system at Manufacturer B have recently been patented; however, the patent number is not yet available.

- Manufacturer A

Two batches of urea formaldehyde resin are made daily in a 1500-gallon rectangular stainless steel reactor. The bottom of the reactor is heated directly with open propane gas burners. The reactor is vented through a stack equipped with a double-reflux condenser at its base. There is a small rectangular access door on the top side of the reactor for batch sampling. Formalin (37 percent formaldehyde in water inhibited with a maximum of 1 percent methanol) is piped directly to the reactor from a large storage tank located in the west end of the production area. The pH of the formalin is then adjusted with sodium hydroxide. Simultaneously, prilled urea is augered into a cylindrical stainless steel kettle and dissolved in warm water. This vessel, known as the addition tank, is also gas-heated and is located near the reactor. Water and aqueous ammonia are added to the reactor and the pH of the solution is adjusted with sodium hydroxide. The reaction proceeds until a predetermined degree of condensation has been reached; at that time, the urea solution is pumped from the addition tank into the reactor. After an additional required degree of condensation has been reached, the pH of the resin is adjusted with sodium hydroxide and the resin allowed to cool. When the resin has cooled to a specified temperature, a fire retardant, an anti-shrinking agent and a humectant are added; these are proprietary materials. In addition, a cross-linking agent (furfuryl alcohol) is added. The batch of resin is then piped from the reactor into a 2000-gallon holding tank. A hose attached to the holding tank is used to convey the resin from the tank into 55-gallon plastic drums. The drums are either filled with the lid off or, more frequently, through the lid opening.

The foaming agent, or "B" component, is blended in the southwest section of the production area. The main ingredient is a proprietary blend of "cross-linking and emulsifying agents" purchased by the company; it is received in large plastic drums and pumped into a 2000-gallon tank. Proprietary hardeners, a proprietary catalyst, and water are added and blended to form the foaming agent "concentrate". The foaming agent is dispensed through a hose into 55-gallon drums and through a spigot into 5-gallon plastic pails. One of the hardeners is added directly to the 5-gallon pails.

- Manufacturer B

Batches of resin are made in a 2750-gallon reactor. The production schedule varies with demand for the product from the installers, ranging from two to ten batches per week. The reactor, which is heated and cooled by piping water through a system of coils, vents through a reflux condensor. The reactor is charged with base materials consisting of a methylolurea prepolymer, small amounts of acetaldehyde, urea, and phenol in an aqueous solution. The base materials are piped directly to the reactor from storage tanks in the production area. Small amounts of phenol and prilled urea are added to adjust the composition of the reaction mixture and the mixture is heated with constant agitation. Formic acid solution is added and the reaction proceeds until the proper degree of condensation is reached. The reaction is stopped with sodium hydroxide and cooled, and additives including fructose and urea solution are introduced. The finished resin is piped through a hose from the bottom of the reactor into 55-gallon metal drums. The drums are filled through the lid openings.

The foaming agent is manufactured in batches of approximately 2300 gallons. Generally, one batch of foaming agent is made for each batch of resin produced. Foaming agent is manufactured by mixing a sulfonic acid emulsifier containing small amounts of sulfuric acid, and oxalic or phosphoric acid with water. The emulsifier is a proprietary compound purchased by Manufacturer B, and the use of oxalic or phosphoric acid is determined by the ambient temperature at the location where the product will be applied. Mixing continues at room temperature for approximately 6 hours, after which the foaming agent is transferred to 55-gallon drums.

Description of Worker Activity, Occupational Titles, and Job Descriptions

Operations at both manufacturing facilities were limited to the day shift. Work days were Monday through Friday; however, Manufacturer B's facility may not produce foam on all 5 days. The number of employees involved in production was small--seven employees were involved in production at Manufacturer A while three were involved in production at Manufacturer B. These numbers of employees are representative of the industry.

Job classifications have been identified which have a potential for chemical or physical agent exposure during the manufacturing process of the urea formaldehyde foam insulation systems. These job classifications have been divided into two general categories on the basis of the types of duties that are performed:

- Resin Batchmakers (Cook and Research and Development Chemist) are involved in preparing batches of resin and monitoring the resin reaction.
- Production Assistants include those employees who assist in resin production, blend the foaming agent, handle and store material, and perform other duties as required.

A description of the duties of these job classifications is presented below.

Resin Batchmakers

- Cook (Manufacturer A)

  The Cook has the major responsibility for the production of a satisfactory batch of urea formaldehyde resin. His duties include: adding raw materials to the reactor, monitoring the reaction, and collecting samples. The Cook also performs quality control tests such as pH, temperature, degree of condensation, and viscosity determinations. Normally there are two Cooks; each makes one batch of resin during the day. While not making a batch of resin, the Cook performs other duties such as operating the forklift, assisting in filling containers with foaming agent, and washing drums.

- Research and Development Chemist (Manufacturer B)

  The Research and Development Chemist is primarily responsible for production of the resin component of the foam system. His duties include: making additions to the reaction mixture, monitoring the progress of the reaction, collecting samples and performing tests to determine the end point of the reaction, and terminating the reaction. During the survey period, the Chemist typically spent approximately 2 hours per day in the vicinity of the reaction vessel. The Chemist also has overall responsibility for the formulation of the foaming agent, although the foaming agent production is generally performed by the Laborer. The Chemist performs a variety of other functions in the company, including research and development on foam insulation systems.

Production Assistants

- Floorworkers (Manufacturer A)

  The Floorworkers at Manufacturer A were broken down into three distinct job classifications as follows:

  Cook's Assistant--

  The employee's duties include: collecting drummed and bagged raw material for resin manufacturing; assisting in adding raw materials to the addition tank; setting up empty resin drums for filling; labeling resin drums and lids; and filling the resin drums. There are two Cook's Assistants; each normally performs the duties described during the production of one batch only.

Other duties performed include: forklift operation, assisting the drum filler by placing lids on the drums, filling orders for application equipment, and repairing application and production equipment.

Foaming Agent Blender--

There is one Foaming Agent Blender. This individual is responsible for blending and drumming the foaming agent. The raw foaming agent is pumped from plastic drums into a blending tank. The Blender then adds small amounts of hardeners and a catalyst. When blending is complete, the Blender fills containers with the foaming agent.

The foaming agent is blended about once a week. When not blending or drumming the foaming agent, this employee may operate the forklift, scrape labels off lids, or perform other duties as required.

Drum Washer--

The plastic resin drum is a reusable item that is returned to the plant for cleaning. There is one full-time Drum Washer. There is also a part-time Drum Washer who works from 1:00 p.m. to 6:00 p.m.

The Drum Washer removes the lids from the returned drums and dumps the small amount of resin that remains into a trench. The washer then sprays the drums with high-pressure hot water. The water is heated in a kerosene-fired, portable steam and hot water generator. The used plastic lids are placed in a kettle of warm water which is located near the reactor. After soaking for a period of time, the Drum Washer removes the lids and scrapes the labels off with a knife. The Drum Washer spends about 10 minutes per day removing labels.

- Laborer (Manufacturer B)

The Laborer's duties include metering ingredients into the reaction vessel, making certain additions to the reaction mixture, drumming the finished resin, mixing and drumming the foaming agent, and performing general cleanup activities.

- Plant Foreman (Manufacturer B)

The Plant Foreman is primarly involved in shipping and receiving, and in general mechanical work in the plant. He assists in the production of the foaming agent, and operates the forklift to move finished drums of resin and catalyst to the shipping area. With the exception of shipping and receiving, this employee does not supervise foam manufacturing activities.

In order to produce two batches of resin in a day at Manufacturer A's facility, an operating period of about 11 hours is necessary. A Cook arrives about 6:15 a.m. to start the first batch. About 7:00 a.m., one Assistant arrives. The other production workers, with the exception of a part-time Drum Washer, arrive at 8:00 a.m. The workday ends at 5:00 p.m. for those arriving at 8:00 a.m. The early Cook and Assistant do not necessarily leave after 9 hours. They may stay until drums have been filled with the second batch of resin, which could be as late as 5:00 p.m. The only formal break is lunch, which lasts for about 45 minutes. Other breaks are informal and do not necessarily involve leaving the work area.

Under production conditions when one batch of resin is produced per day at Manufacturer B's facility, the Laborer arrives about 6:00 a.m. to begin the day's production run. The Plant Foreman also arrives early in the morning and may be involved in the preparations of resin and foaming agent production. The Research and Development Chemist arrives about 8:00 a.m. and takes charge of the resin production run. Typically, the production of a batch of resin and foaming agent is completed by about 3:00 p.m. There are no formal breaks during the workday, with the exception of lunch which the workers usually eat in the office area of the plant. Due to the small number of workers involved in the production process, the work schedule is very flexible and the employees generally identify and perform tasks which need to be done with a minimum of supervision.

Exposure Control Measures

- Manufacturer A

Respirators, hearing protectors, gloves, safety glasses, goggles, and rubber boots and aprons are provided for employee use. There is a company policy that all employees working with raw materials wear safety glasses and gloves. During the survey the Cook wore safety glasses and gloves; the Drum Washer wore rubber boots and a rubber apron; and the Foaming Agent Blender wore rubber gloves and goggles. An eyewash and shower are located near the foaming agent area.

A lunchroom is available for employee use. Handwashing is required prior to eating. There are no restrictions on smoking in the production area.

Respirators were not used during the survey. A Welsch 7500-30 facepiece with 7500-1 cartridges and 7500-6 filters (NIOSH certification number TC-23C-73) had been used in the past when handling one of the hardeners that caused irritation. This respirator is certified for protection against not more than 1000 ppm organic vapors, dusts and mists having a time-weighted average not less than 0.05 mg/m^3 or 2 mppcf, and asbestos-containing dusts and mists. Recently, the company replaced that hardener with one of a coarser grade which, when handled, does not generate dust in irritating levels. 3M 8500 disposable respirators are also available. They were also used when handling the irritating hardener. The 3M 8500 respirator is not NIOSH certified. About once a year, the formalin storage tank is entered for cleaning. The tank is not purged prior to entry. A Willson Model 1860 full-facepiece air line respirator (NIOSH certification number TC-19C-94) is used by the employee entering the tank. The employee is lowered into, and hoisted from, the tank by means of block and tackle. The hoisting and lowering apparatus are homemade. There is a standby employee who also wears the same type of respiratory device. The company does not have a respiratory protection program, and neither qualitative nor quantitative fit testing has been performed.

Only natural and some general mechanical ventilation exist in the plant. Open loading dock and entrance/exit doors serve as portals for natural ventilation. There are two 48-inch exhaust propeller fans on the west wall in the production area, one of which is located above the labaoratory. These fans each exhaust 22,700 cfm. A portable 48-inch-diameter propeller fan is available to move air in the drum-washing area. During a visit in August, the fan was located about 25 feet from the Drum Washer. Air velocity in the drum-washing area was 150-300 fpm. The fan was not in use during a visit in September. There is a 19-inch propeller fan on a table in the reactor area and a 27-inch propeller fan on a pedestal in the drum-filling area. These fans are used when the Cook and Cook's Assistant feel they are needed. Ventilation methods in the past were similar to those in existence today (i.e., wall exhaust and portable fans).

Some improvements in hygiene have been made since production began. The lunchroom was provided for employee use about one year ago. Prior to that time, employees ate in the production area. Mandatory handwashing prior to eating became a company policy about the time that the lunchroom was provided.

- Manufacturer B

Respirators, boots, chemical goggles, and full faceshields are provided by the company. The use of these protective devices is at the discretion of each employee. During the survey, the Chemist and the Plant Foreman did not wear protective equipment. The Laborer wore gloves and rubber boots during the drumming and cleanup operations.

Ventilation in the area of the reactor is provided by a 24-inch propeller fan which moves air from the top of the reaction vessel above the operator's position, and exhausts through the plant roof. Mechanical ventilation is not used in other production areas. The mixing and drumming of foaming agent are performed near a large overhead door which is kept open, providing natural ventilation through the area. Ventilation in the past was not significantly different from that in use today.

Respirators were not used during the period of the survey. Norton half-mask, Model 7100, respirators were available. These respirators are NIOSH approved for dusts and mists (approval number TC-21C-175).

The reaction vessel is cleaned approximately every six months. Prior to cleaning, the tank is flushed several times with water, then the tank is entered by two workers who remove hardened resin from the interior surfaces by manually chipping and flushing the surface with running water. Respiratory protection is not used during the cleaning process. The storage tanks and the foaming agent mixing tank have not yet required cleaning during their period of use.

- Manufacturer A

Standard first aid supplies are available at the plant. One nonproduction employee has been trained in first aid by the local rescue squad. Physical examinations are not provided for employees engaged in the urea formaldehyde foam insulation manufacturing process. Medical treatment is provided at a local hospital, which is located about seven miles from the plant.

Approximately every two months, the plant manager measures concentrations of formaldehyde in air in the production and office areas with Draeger 0.002 and 0.5/a formaldehyde detector tubes. No written records of formaldehyde levels, sampling conditions, or measurement locations are maintained. The levels were described as being below the OSHA standards. The detector tube surveys have been conducted since production began. There has never been a comprehensive industrial hygiene survey conducted at this facility.

There is no formal safety and health program. The general practice is to follow the procedures recommended by the vendors of the raw materials.

- Manufacturer B

Two employees are trained in first aid and first aid supplies are available at the plant. Emergencies requiring medical attention would be treated at the emergency room of a hospital approximately two minutes driving time from the plant. The plant does not maintain a formal medical program.

Industrial hygiene measurements, consisting of airborne formaldehyde determinations using detector tubes, have been made by the Research and Development Chemist. The company does not maintain a formal industrial hygiene program, and a comprehensive industrial hygiene survey has never been performed at the plant.

The company's safety program is generally based upon the supplier's recommendations for safe handling and use of the compounds used as raw material in the manufacturing process.

B. APPLICATORS

Plant Description and History

- Applicator A

Applicator A is an applicator of thermal insulation for the residential and commercial market. The company has been in business since January 1978.

The company applies the following types of thermal insulation:

- urea formaldehyde foam
- rigid polyurethane foam
- fiberglass batting and mats
- cotton

Applicator A has been applying Manufacturer A's second generation urea formaldehyde foam insulation since November 1978. Prior to that time, the company applied Manufacturer A's original urea formaldehyde foam. Other urea formaldehyde foams have been used, but only on a trial basis. The company began insulating attics with cotton fiber in about March 1979. Prior to that time, other cellulose was used. Fiberglass has been used by Applicator A as an insulation material since the company began operations in 1978. Polyurethane applications began in May 1979.

About 60-70% of the applications involve urea formaldehyde foam. This is injected into the building's wall cavity in a semisolid state. Application to an existing structure is known as a retrofit. About 85% of the urea formaldehyde foam applications are made to existing structures from the exterior; about 5% of the applications are made to existing structures from the interior. About 10% of the applications involve urea formaldehyde foam application between the studs of a building under construction. This is known as open-bay application.

- Applicator B

Applicator B is a family owned and operated applicator of thermal insulation, specializing in the residential market. The company has been in business since June 16, 1978. The company maintains an office in the home of the president and also maintains a small warehouse in another location.

Applicator B applies urea formaldehyde foam and cellulose insulation. Manufacturer B's urea formaldehyde-based foam is, and has been, the only urea formaldehyde foam applied. The company has been blowing and spraying cellulose for about 1 year.

About 90% of the applications involve urea formaldehyde foam. About 90% of the urea formaldehyde applications are made from the outside of the structure and involve retrofitting. The other 10% are made from the inside. Some of the inside application involves open-bay insulating.

Description of Operations and Existing Controls

The Urea Formaldehyde Foam Insulation System Application Process

- Applicator A

Exterior Retrofit Applications

Manufacturer A's foaming agent is received in 5-gallon plastic pails (2.5 gallons per pail) and the resin in 55-gallon plastic drums. Prior to use, the foaming agent is diluted with water to 55 gallons. The resin and foaming agent are stored in the warehouse along with other insulation materials, mortar mix, and application equipment. The warehouse is a one-story, 2500-square foot structure situated adjacent to the office. It also serves as a vehicle storage garage and as a location for rebuilding application equipment. Application equipment is rebuilt as time permits.

Applicator A has three urea formaldehyde foam application crews. The urea formaldehyde foam application crew usually consists of five individuals--one Foam Mechanic and four Laborers. The Foam Mechanics are certified applicators of Manufacturer A's urea formaldehyde foam. Certification is awarded by Manufacturer A after a 1-week foam application training course. The crew members arrive at the office at 7:00 a.m. Job sites are designated by the production manager. The crews leave the warehouse area between 7:15 a.m. and 7:45 a.m. in three 12-foot step vans. There is a partition between the front and back sections of one of the vans. The vans are stocked with the necessary supplies and equipment on the preceding evening. Upon arriving at the job site, a determination is made of the appropriate method for gaining access to the wall cavity, which is generally referred to as "opening" the structure. Masonry is drilled, aluminum siding and shingles are removed, and weatherboard is knocked through with a hammer. The holes are made between studs and fire-stops. The resulting openings are relatively small--3/4 inch in masonry and 2-3 inches in weatherboard. The building is opened by the four Laborers and, when he is not performing other duties, by the Foam Mechanic.

While the building is being opened, the Foam Mechanic cleans the application gun and hose, and starts circulating resin and foaming agent. The resin and foaming agent circulate from storage drums through plastic tubing and a pump and back into the drums. This is done to assure a uniform product. Application equipment components downstream of the foaming chamber usually cake with dried foam. The components are disassembled with a wrench and cleaned with hot water and a rag or by scraping with a tool such as a screwdriver. Some Foam Mechanics choose to clean their equipment in the afternoon, following completion of foam application for the day.

Foaming begins after the structure has been opened to a point where foam application can proceed without interruption, the application equipment has been cleaned and reassembled, and the resin and foaming agent have been properly circulated. Before the foam is applied, a density determination is made. This is accomplished by filling a standard volume with foam and weighing. Resin, foaming agent, or nitrogen adjustments are made until the foam density is within an acceptable range. Foam is also discharged onto the ground so that foam body can be evaluated. This is known as making "beehives" due to the appearance of the resulting pile of foam. Occasionally, a piece of the foam is tasted as part of the qualitative testing.

After the foam has passed the qualitative and quantitative tests, application begins. Figure 1 is a drawing of the foam application system. The application gun is suspended from the Foam Mechanic's shoulder by a strap. The application hose, located on the end of the application gun, is inserted into the wall opening. A lever on the gun is depressed, and proper amounts of nitrogen and foaming agent mix in a chamber with plastic beads. The nitrogen serves as a blowing agent. Downstream of the mixing chamber, resin is introduced. The resulting foam, similar in appearance to shaving cream, leaves the application hose and fills the wall cavity. After the space has been filled, a Laborer removes the excess foam from the wall with water from a garden hose. The hole is then "closed" (i.e., covered, plugged, or filled) by another Laborer. For example, shingles are nailed back into place, masonry is filled with a small amount of mortar, and aluminum siding is put back into place. On occasion, one employee is stationed in the house to listen for structural stress caused by overfilling the wall cavities. After all the cavities have been filled, the Foam Mechanic cleans the application equipment (if that is his preference) and stores it in the van. He then sketches and measures the square footage of the structure to check the measurements previously made by the salesman. In the meantime, the Laborers finish closing and clean waste material from the area. The trash is placed in the back of the van in plastic bags. The crew's workday ends when they return to the warehouse.

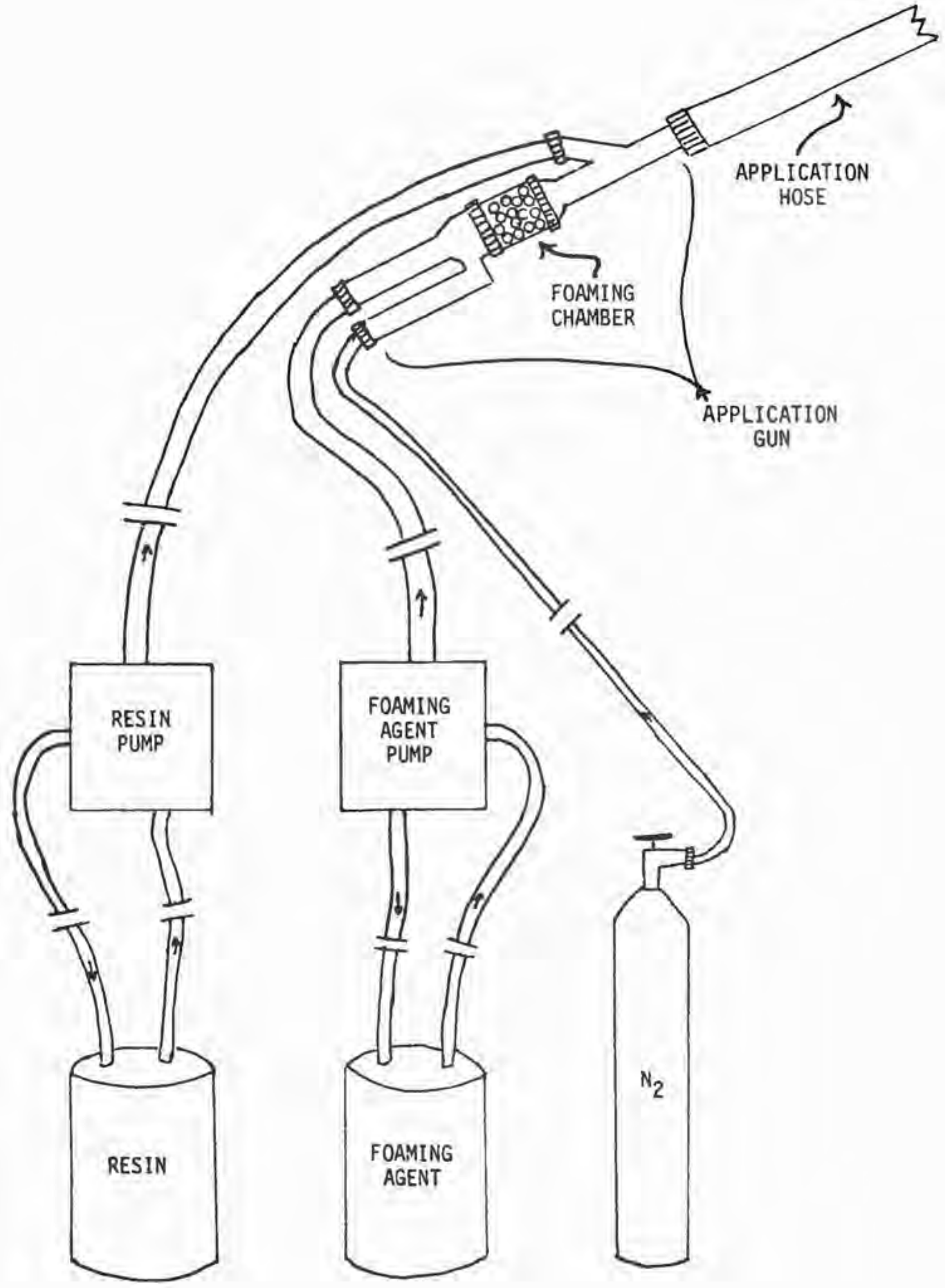
At the warehouse, waste material is disposed of into a dumpster, and the van is stocked with adequate foaming agent and resin for the next day. This is done by the Warehouseman.

Open-Bay Application

In this procedure, the urea formaldehyde foam is applied between exposed studs before the wallboard is put into place. Usually, small amounts of the foam are first "splattered" onto the surface. This is accomplished by increasing the nitrogen pressure and pinching the end of the application hose. After the form has been splattered, the nitrogen pressure is reduced and a rectangular, transparent piece of plastic is placed on the end of the application hose. There is a hole in the plastic to allow foam to flow through it. The plastic bridges the two adjacent studs and serves as a trowel as the foam is applied from floor to ceiling in the cavity. Good foam body prevents the foam from falling out of the cavity. The foam slightly overfills the cavity. A flat-edged shovel is used to bridge two adjacent studs and scrape the excess foam off and onto the floor. This is done by a Laborer approximately 15 minutes after the cavity has been filled with foam. Normally, a third Laborer nails a polyethylene sheet over the insulation. Other aspects of open-bay application activities are similar to exterior retrofit application activities.

Figure 1

Urea Formaldehyde Foam Application System



- Applicator B

Exterior Retrofit Application

The resin and foaming agent are stored in the warehouse, which is an 11,000-square foot, one-story stone structure. Other items stored in the warehouse include: cellulose insulation, cellulose insulation adhesive, commercial mortar mix, muriatic acid, and application equipment. In addition to being a storage area, the warehouse also serves as a shop for performing light maintenance on equipment. Occasionally, foam is tested by discharging foam onto the warehouse floor.

Generally, the application team consists of the company president's two sons; both have been certified by Manufacturer B as foam applicators. A third individual is utilized for large jobs.

The application team arrives at the warehouse about 8 a.m. and loads a 12-foot step van with the application equipment and insulation components. About 8:15 a.m., the application team leaves the warehouse for the job site.

Applicator B's opening, circulating, equipment cleaning, and foam application processes are similar to Applicator A's with a few exceptions. Applicator B uses air compressed by a gasoline-powered compressor instead of compressed nitrogen. The application gun used by Applicator B differs from Applicator A's in that the blowing agent and foaming agent do not mix in a chamber containing plastic beads.

After all the cavities have been filled, the application equipment is put away. The applicator then assists in closing operations. At the end of the day, trash foam is put into plastic bags and placed in the van. The application team then returns to the warehouse to store equipment, dispose of trash, and perform maintenance on equipment if necessary.

Open-Bay Application

Initially, the air pressure is increased and a scratch coat of foam (approximately 1 inch thick) is applied to the wall surface. After the scratch coat has been applied, the air pressure is reduced and the cavities between adjacent studs are filled with foam. The foam is immediately troweled by the assistant. In some cases, a trowel is attached to the end of the application hose. Polyethylene or polyvinyl chloride sheeting is hung first. A hole is made in the sheeting between adjacent studs. The application hose is inserted into the hole and the cavity is filled with foam insulation. The foam is then leveled by passing the trowel over the plastic sheeting.

There are 20 individuals involved with the application of urea formaldehyde foam insulation at Applicator A and two (occasionally three) individuals at Applicator B. Both Applicator A and B work Monday through Saturday when work is available.

Job classifications have been identified which have a potential for chemical substance or physical agent exposure during the application of urea formaldehyde foam insulation and the activities associated with it. These job classifications have been divided into two general categories on the basis of the types of duties that are performed:

- Foam Applicators apply the foam to the wall cavity and oversee the application process.
- Application Assistants prepare the structure for foam application, refinish the structure after application, and perform other duties as required.

A description of the duties within these job classifications is presented below.

Foam Applicators

- Foam Mechanic (Applicator A)

  The Foam Mechanic has the major responsibility for providing a satisfactory insulation job. His duties include: determining the method and strategy for opening the structure, application equipment cleaning and assembly, proper conditioning of resin and foaming agent, assuring adequate foam quality, foam application, assisting in opening and, on accasion, closing the structure, cleanup, measuring and sketching the building being insulated, and application equipment maintenance. The Foam Mechanic also serves as the crew chief.

  Application equipment cleaning and assembly usually takes less than ½ an hour. Resin and foaming agent circulation usually begins about 1 hour before foam application starts. Density testing consists of weighing foam that is shaped into a cube of pre-determined volume. The cube is formed on a bench top in the back of the van. Foam quality testing consists of applying foam onto a plastic sheet. The test is conducted out-of-doors and usually takes a few minutes. For the 5 days of the study during which exterior application was conducted, foam application time varied from 1-3/4 to 3 hours. The Foam Mechanic assists in opening, closing, and cleanup when time permits. The house can be measured and sketched in about ½ an hour.

- Applicator (Applicator B)

  The Applicator has the major responsibility for applying the insulation satisfactorily. His duties include: determining the method and strategy for opening the structure, cleaning and assembling application equipment, proper conditioning of resin and foaming agent, assuring adequate foam quality, foam application, assisting in opening and closing the structure, cleanup, and light maintenance of equipment.

  The Applicator spends about 1 hour cleaning and assembling the foam application equipment. The foam quality check usually takes less than 10 minutes but may take longer, depending upon conditions. The actual time spent applying foam varies daily; for example, on some days foam is not applied. Conditioning resin and foaming agent involves starting the circulating pump and, if necessary, placing a band heater around the drums or circulating the components through a line heater to raise temperatures. The time spent opening varies; the amount of time spend closing is also variable and will depend on the progress that the Assistant has made in closing the house during the application process. Cleanup operations usually take less than 1 hour. Equipment maintenance is performed as needed.

Application Assistants

- Laborer (Applicator A)

  The Laborers' duties include: opening, washing excess foam from the walls, monitoring for structural stress during foam application, closing, cleanup, scraping foam (open-bay procedure), hanging polyethylene film (open-bay procedure), and performing other duties as required. The Laborers spend most of their time opening and closing during exterior retrofit operations. On occasion, a Laborer will be stationed in the house to monitor for structural stress. Wiping excess foam from an opening can be accomplished in a matter of seconds. Cleanup operations usually last about ½ an hour. Foam-scraping operations can proceed faster than the application process.

- Assistant (Applicator B)

  The Assistant's duties include: opening, closing, cleaning excess foam from the wall after application, cleanup, and light maintenance of equipment.

  The Assistant may spend a workday or longer performing opening operations. The closing operation usually ends a short time after foam application has been completed; an exception to this is when wood must be filled, sanded, and painted. In many cases, the closing operation is less time-consuming than is foam application. The Assistant spends about the same amount of time performing cleanup and equipment maintenance operations as does the Applicator.

- Warehouseman (Applicator B)

  The warehouseman usually works from 4 p.m. until 7 p.m. He is responsible for cleaning trash from the vans and stocking them for the next jobs. His duties include: removing trash from the vans and placing it into a dumpster outside the warehouse, consolidation of resin and foaming agent where more than one drum of each is present on a van, and preparing fresh foaming agent by diluting the 2.5 gallons of concentrate with 52.5 gallons of water. In all, three vans are serviced.

Exposure Control Measures

- Applicator A

Personal protective equipment consists of respirators, goggles, and gloves. 3M 8500 disposable respirators are used, at times, when insulating with cotton fiber and when drilling masonry. This respirator is not NIOSH certified. Tight-fitting, soft plastic goggles are sometimes used when drilling masonry. Rubber gloves are frequently used by the Foam Mechanic to prevent contamination of his hands with urea formaldehyde foam. Other than the gloves worn by the Foam Mechanic, no other personal protective equipment was observed in use during the course of the study. There is no mechanical ventilation used in association with the application process.

- Applicator B

Rubber gloves are used during foaming operations and subsequent wall-surface cleaning to prevent contamination of the hands. Respiratory protective devices are not used during the urea formaldehyde foam application process. A wind-driven propeller fan provides ventilation for the van. There is no mechanical ventilation used in association with the application process.

Medical, Industrial Hygiene, and Safety Programs

- Applicator A

First aid supplies on the van and in the office consist of adhesive bandages, iodine, insect repellant, and a commercial antidote for bee stings which occur frequently. Medical treatment would be rendered at the hospital nearest to the application site. Physical examinations are not provided for employees.

The production manager meets frequently with the application crew to discuss safety. There has never been an industrial hygiene survey.

- Applicator B

First aid supplies on the van consist of gauze and adhesive bandages. Medical treatment would be rendered at the hospital nearest to the application site.

An industrial hygiene survey has not been performed previously. The company does not have a formal safety program. The company's safety policy is to use common sense. Physical examinations are not provided for employees.

II. DESCRIPTION OF SURVEY METHODS

PROCEDURES

The survey procedures involved a discussion with appropriate company personnel to obtain general information regarding each activity associated with the manufacture and application of urea formaldehyde foam insulation. A walk-through observation of the manufacturing and application process was then made. Detailed information about processes, production or application activities, raw materials, and each job classification was obtained from appropriate company personnel. All apparent potential chemical and physical hazards were evaluated. Sampling was limited to those agents considered to be capable of causing significant exposures under existing conditions.

Sampling procedures for chemical substances and physical agents monitored varied from facility to facility. Atmospheric sampling for formaldehyde, ammonia, and furfuryl alcohol was conducted during the production of the urea formaldehyde foam insulation system at Manufacturer A. Personal monitoring was performed on the Cook, Cook's Assistant, Drum Washer, and Foaming Agent Blender. Some area sampling was also conducted. Direct-reading instrumentation was used to measure noise levels and wet bulb globe temperatures. Short-term and long-term personal samples were collected for formaldehyde and ammonia. Personal sampling was not conducted during the lunch break, during the sampling equipment setup period at the beginning of the workday, or during the cleanup period at the end of the workday. Sampling was conducted during informal breaks.

At Manufacturer B's plant, atmospheric sampling for formaldehyde, acetaldehyde, and phenol was performed during the production of the resin component of the urea formaldehyde resin-based thermal insulation system. Personal samples were collected on the Research and Development Chemist and the Laborer during the resin manufacturing process, and area samples were collected during resin and foaming agent production. A sound level meter was used to measure noise levels.

Short period samples to measure peak exposures, and long term samples were collected and analyzed for formaldehyde, acetaldehyde and phenol. Personal samples were collected during periods when the workers were directly engaged in resin production; area samples were taken in locations where workers performed tasks such as monitoring the reaction, making additions, performing quality control tests, and drumming the resin and foaming agent. Area samples were also collected for nitrosamines, utilizing Thermosorb/N solid sorbent samplers.

Atmospheric sampling for formaldehyde, ammonia, respirable dust, and furfuryl alcohol was conducted during urea formaldehyde foam application activities performed by Applicator A. Personal monitoring for formaldehyde was conducted in the breathing zones of the Foam Mechanic, Laborers, and Warehouseman. Personal monitoring for furfuryl alcohol was conducted in the breathing zones of the Foam Mechanic and Laborers. Personal sampling for respirable dust was conducted in the breathing zone of a Laborer while drilling through the mortar. Direct-reading instrumentation was used to measure ammonia concentrations and noise levels.

During Applicator B's activities atmospheric sampling for formaldehyde and respirable dust was conducted. In all, personal monitoring was performed on three individuals--one applicator and two assistants. Some area sampling for formaldehyde was conducted in the van and warehouse. A sound level meter was used to measure noise levels.

LIMITATIONS

This industrial hygiene study represents an evaluation of conditions present on the days during which the study was conducted in each facility. Plant conditions during the study were described by company personnel as being typical of day-to-day operations with the exception of two study days (November 27 and 29, 1979) with Applicator B. On November 27, foam application was discontinued due to coagulated resin and on November 29, foam application was limited because minimum foaming agent and resin temperatures could not be maintained. Applicator B's applications were limited to exterior retrofit and open bay. Applicator B's exterior retrofit applications were limited to aluminum-sided and clapboard-faced houses while Applicator A's exterior retrofit applications were limited to houses with bricks, cedar shakes, asbestos shingles and aluminum facing.

SAMPLING AND ANALYTICAL METHODS

All analyses were performed by laboratories accredited under the Laboratory Accreditation Program of the American Industrial Hygiene Association. The laboratories used participate in all six analysis categories of the NIOSH Proficiency Analytical Testing Program.

Formaldehyde

NIOSH Method No. P&CAM 125 (46) was the chosen method for sampling and analysis of formaldehyde. Air was drawn through two Bendix midget impingers (Catalog #7202), each containing 20 ml of a 1% sodium bisulfite solution. At Manufacturer A's facility the procedure was modified by the use of two Daco Model SI-14 impingers and an empty third Daco Model SI-14 impinger serving as a backup to capture spill over, in place of the two Bendix impingers. At Manufacturer B's facility the procedure was modified by using 15 ml of 1% sodium bisulfite per impinger instead of 20 ml. The sampling rate was approximately 1 liter per minute. The impingers were connected in series to a calibrated MSA Model G or S pump. After sampling, the impinger contents were transferred to Teflon or polypropylene capped glass vials. The samples were refrigerated until analysis was performed. The contents of each of the impingers were analyzed separately and the results were added together to calculate the concentration for each sample set. 0.4 ml of 0.5% chromotropic acid reagent and 5 ml of concentrated sulfuric acid were added to a 2-ml aliquot of the sample. The aliquot was then brought up to 10 ml with distilled water. Absorbance was then read at 580 nm on a Norelco SP-500 spectrophotometer using a 1-cm cell. Absorbing solution from the same batch as the samples was handled in the same manner as the samples, except that no air was drawn through it. Portions were submitted as field blanks. 0.1 ml of 1.0% chromotropic acid and 6 ml of concentrated sulfuric acid were added to 4 ml of each sample collected at Manufacturer B's facility. The absorbance was read at 580 nm on a spectrophotometer.

In addition, formaldehyde concentrations were measured with Draeger 0.5/a and 0.002 detector tubes. The measurement range for the 0.5/a tubes is 0.5-10 ppm and for the 0.002 tubes is 1.6-40 ppm. These tubes are not certified by NIOSH.

Ammonia

NIOSH Method No. P&CAM 205 (47) was the chosen method for sampling and analysis. Air was drawn through a Daco Model SI-14 impinger containing 15 ml of 0.1 N H_2SO_4 at a rate of approximately 1 liter per minute. The NIOSH method recommends use of 10 ml of absorbing solution. Fifteen ml was used to accommodate the long sampling periods. The impinger was preceded by a Millipore cellulose ester 0.8-μm filter to remove particulate ammonium salts. The impinger and an empty second impinger serving as a trap to capture spillover were connected in series to a calibrated MSA Model G or S pump. After sampling, the impinger contents were transferred to teflon capped glass vials. The samples were refrigerated until analysis was performed.

At the laboratory, each sample was diluted to 50 ml with distilled water. One ml of this diluted solution was again diluted to 50 ml with distilled water; 2 ml of Nessler reagent was then added. Absorbance was determined using a Norelco SP-500 spectrophotometer with a 1-cm cell.

Absorbing solution from the same batch as the samples was handled in the same manner as the samples, except that no air was drawn through it. Portions were submitted as field blanks.

In addition, ammonia concentrations were measured with Draeger 5/a detector tubes. The measurement range for these tubes is 5-70 ppm. The 5/a tubes are certified by NIOSH (TC-84-031).

Furfuryl Alcohol

NIOSH Method No. S365 (48) was the chosen method for sampling and analysis. Sampling was accomplished by drawing air at a rate of between 0.01 and 0.05 liter per minute through a glass tube (8.5-cm long with a 6-mm O.D. and a 4-mm I.D.) containing 225 mg of 50/80 mesh Porapak Q. The Porapak Q was separated into a 150-mg front section and a 75-mg backup section. The tube was connected to an MSA Model C-200 pump. After sampling, the tube was capped, refrigerated, and air-shipped on ice to the laboratory for analysis. Field blanks were submitted with the samples. Analysis was performed by gas chromatography using a column packed with 10% FFAP on Chromosorb WAW, and a flame ionization detector.

Acetaldehyde

Measurement of airborne acetaldehyde levels was made by analysis of the impinger solutions used for collection of airborne formaldehyde. The impinger solutions were analyzed by gas chromatography, utilizing a glass column packed with 4% Carbowax 20M and 1% PPI on 60/80 mesh Carbopack B. Temperature was programmed at a rate of 8°C per minute from 120°C to 150°C and flame ionization was the detection method.

Phenol

Samples for measurement of phenol in air were collected and analyzed utilizing NIOSH Method No. S330 (49). Samples were collected in midget glass bubblers, run at a flow rate of 1 liter per minute with MSA Model G pumps. The bubblers contained 15 ml of 0.1 N sodium hydroxide. After sampling, the contents of each bubbler were transferred to polypropylene-capped glass vials. Field blanks were submitted with the samples. Analysis was performed by gas chromotography utilizing a Chromosorb 102-packed column and a flame ionization detector.

Nitrosamines

Samples for measurement of nitrosamines were collected on Thermosorb/N solid sorbent samplers at a rate of 1 liter per minute with calibrated MSA Model G pumps for approximately 4 hours per sample. Analysis was performed by a method utilizing a gas chromatograph or a high-pressure liquid chromatograph coupled with a thermal energy analyzer. This analyzer is a nitrosamine-specific detector.

Respirable Dust

Air was drawn at a rate of 1.7 liters per minute through a Millipore 5-μm pore size PVC filter mounted in a plastic cassette. Calibrated MSA Model G or S pumps were used. The air was first passed through a Bendix 10-mm cyclone. After sampling, the cassette was plugged and air-shipped to the laboratory for analysis.

At the laboratory, the filter was removed from the cassette, vacuum-desiccated for 1 hour, equilibrated for 1 hour in the balance room, and weighed on a Mettler balance. The procedure was repeated until two successive weights were within ±0.1 mg. Filters in cassettes from the same batch as the sample were handled in the same manner as the sample, except that no air was drawn through them. These filters were submitted for analysis as blanks.

Noise and WBGT

Noise level readings were made with a GenRad Type 1565B sound level meter at both Applicators' worksites and at Manufacturer A's facility. A Quest Electronics Model 215 sound level meter was used at Manufacturer B's facility. Measurements were made at head level.

WBGT was measured with the Weksler Catalog No. 218 unit. Measurements were made at about waist level in the reactor and drum washing areas of Manufacturer A's facility.

EVALUATION CRITERIA

Formaldehyde

The American Conference of Governmental Industrial Hygienists (ACGIH) established for formaldehyde a time-weighted average (TWA) limit of 10 ppm in 1946. This was changed to 5 ppm in 1948. In 1963, the ACGIH introduced a ceiling limit concept. At that time, the ceiling limit for formaldehyde was set at 5 ppm. In 1973, it was decreased to the present ceiling limit of 2 ppm (50).

The present OSHA standard (29 CFR 1910.1000) (51) for occupational exposures to formaldehyde was adopted from the American National Standards Institute limit (52). This formaldehyde standard specifies an 8-hour TWA limit of 3 ppm, an acceptable ceiling concentration of 5 ppm, and an acceptable maximum peak above the acceptable ceiling concentration of 10 ppm for no more than 30 minutes during an 8-hour shift.

NIOSH has proposed a ceiling value of 1 ppm for formaldehyde in air for any 30-minute sampling period. This is based on reports of irritation, objectionable odor, and sleep disturbances for some employees who were exposed to formaldehyde at 0.3 ppm and due to complaints of a more general nature at concentrations exceeding 1 ppm. NIOSH has also proposed an action level of 0.5 ppm for formaldehyde in air for any 30-minute sampling period (53).

A recent study conducted under the supervision of the Chemical Industry Institute of Toxicology has shown that in the 18th month of a 24-month study 37 nasal carcinomas have been diagnosed in rats exposed to formaldehyde at 15 ppm. One nasal carcinoma has been diagnosed in the group of rats exposed to formaldehyde at 6 ppm. One hundred twenty rats of each sex were exposed at each level in the study. One hundred twenty mice of each sex were also exposed at the same levels. No nasal carcinomas have been observed in the mice (15).

Ammonia

In 1943, the U.S. Public Health Service published toxic limits for various substances. The maximum allowable concentration (MAC) for ammonia was listed as 100 ppm (54).

The ACGIH established a MAC for ammonia of 100 ppm in 1946 (55); in 1948, this became a threshold limit value (TLV) (56). In 1963, the TLV was reduced to 50 ppm (57). In 1970, the ACGIH recommended (58), and in 1973, adopted (59), a TLV of 25 ppm as a time-weighted average. The ACGIH currently recommends an 8-hour TWA of 25 ppm and a short-term exposure limit (STEL) of 35 ppm (50).

An 8-hour TWA of 50 ppm is the current OSHA standard for ammonia (51). This is based on the 1968 ACGIH recommendation (60) which was unchanged from the 1963 ACGIH TLV (57).

A standard of 50 ppm, expressed as a ceiling and determined by a 5-minute sampling period, has been recommended by NIOSH. NIOSH considers that this limit would protect the worker from all adverse effects of long-term ammonia exposures. NIOSH advises that epidemiological and experimental studies are needed for verification (61).

Furfuryl Alcohol

The ACGIH proposed a TLV of 50 ppm for furfuryl alcohol as an 8-hour TWA concentration in 1960 (62). A tentative change to a TLV of 5 ppm was proposed in 1971 (63); this was adopted in 1974 (64). In 1976, the ACGIH recommended a STEL of 10 ppm for furfuryl alcohol (65).

The current OSHA standard for furfuryl alcohol is 50 ppm as a TWA concentration for an 8-hour workday (51). NIOSH does not recommend a change from the OSHA standard at this time since there is no information showing that 50 ppm does not provide adequate worker protection or that there is a more appropriate value (66).

Acetaldehyde

The ACGIH TLV for acetaldehyde was 200 ppm as a TWA limit until 1973 when the TLV was lowered to 100 ppm. The current TLV is recommended to prevent excessive eye irritation and potential injury to the respiratory tract (67). The current OSHA standard for acetaldehyde is 200 ppm as an 8-hour TWA (51). NIOSH has not recommended a standard for exposure to acetaldehyde.

Phenol

The ACGIH TLV for phenol was first established at 5 ppm in 1952. A notation that skin may be a significant route of exposure was made in 1961, and the TLV has not changed since that time (67). The current TLV is recommended to prevent systemic poisoning if skin absorption is avoided. The current OSHA standard for phenol, 5 ppm with a skin notation adopted from the 1968 TLV (51). NIOSH has recommended exposure limits of 20 mg/m^3 (approximately 5 ppm) as a TWA and a 15-minute ceiling concentration of 60 mg/m^3 (approximately 15 ppm) (68).

Nitrosamines

Nitrosamines are a group of compounds which can be formed by a variety of reaction mechanisms, including the reaction of a secondary amine such as urea, with an oxide of nitrogen (NO, NO_2, N_2O_3, or N_2O_4) or nitrite (NO_3). Formaldehyde is capable of catalyzing the reaction which forms nitrosamines. Nitrosamines are regarded as potent animal carcinogens; however, they have not been directly associated with cancer in humans.

Continuous Noise

Currently the federal government (OSHA) allows employees to be exposed to noise at an average level of 90 decibels, as measured on the A scale of a standard sound level meter at slow response (dBA), for an 8-hour period. For every 5-dBA increase in the average noise level, the allowable exposure time period is reduced by a factor of 0.5. Exposure to levels in excess of 115 dBA is not permitted (51).

The ACGIH recommends that sound levels not exceed an average of 80 dBA for a 16-hour workday. For every 5-dBA increase in the average exposure, the allowable exposure time period is reduced by a factor of 0.5. Exposures to levels in excess of 115 dBA are not recommended (50).

The NIOSH recommended permissible sound level exposures (69) are identical to the ACGIH levels. The criteria document recommends that these sound levels become effective for existing places of employment after an extensive feasibility study.

Heat Stress

When the wet bulb globe temperature (WBGT) TWA exceeds 26.1°C (24.4°C for women) for a continuous exposure of 1 hour or greater, or for an intermittent exposure of 2 hours or greater, NIOSH recommends the following to insure that the employee's body core temperature does not exceed 38°C: acclimatization; work-rest regimens, even work distribution; proper scheduling times for hot jobs; regular breaks; adequate water and salt; appropriate protective clothing; engineering controls; medical monitoring; adequate first aid; training; environmental monitoring; and recordkeeping (70).

The ACGIH recommends WBGT TWAs that are dependent upon the hourly work-rest regimen and the employee's metabolic rate. The limits cannot be exceeded for a continuous exposure of 1 hour or greater, or for an intermittent exposure of 2 hours or greater. The limit values are considered to be valid for acclimated workers who are physically fit (50). OSHA has not adopted a heat stress standard.

III. RESULTS AND DISCUSSION

FORMALDEHYDE

Personal exposure concentration ranges for selected individual tasks have been presented in Table 7. Where similar tasks were performed among the facilities, comparisons have been made. All sampling data are presented in the Appendix. The highest exposures occurred during resin drum filling, open-bay insulation activites, and exterior retrofit foam application.

Formaldehyde measurements were made during resin drum filling at both manufacturers' facilities. These measurements were made during a number of drum filling cycles, i.e., inserting the filling hose into the drum, opening the valve to allow the flow of resin, closing the valve, and moving to the next drum. Resin drums were filled at Manufacturer A with the lids off and, in one case, through lid openings. Personal formaldehyde exposures during open top filling were 2.6 ppm and 5.4 ppm. A personal exposure concentration of 2.1 ppm was measured while filling drums through the lid openings. The lower exposure observed while filling through lid openings was most likely due to the decreased resin surface area present. Personal formaldehyde exposures during resin drum filling operations at Manufacturer B ranged from 0.18-1.28 ppm. Drums were being filled through lid openings. The differences in formaldehyde concentrations between the two manufacturers while filling drums through lid openings may have been due to the presence of more free formaldehyde in Manufacturer A's resin.

Additional measurements were made with Draeger detector tubes for formaldehyde, Part Number 0.002, in the breathing zone of the Cook's Assistant at Manufacturer A during the period of time that resin was flowing from the hose and into the drum. Formaldehyde concentrations were measured at 5-10 ppm.

Personal samples collected for formaldehyde during activities on the reactor platform (cooking, testing, or sampling) showed similar exposure levels at both facilities--0.35 and 0.37 ppm at Manufacturer A and 0.34 and 0.45 ppm at Manufacturer B.

Formaldehyde exposures during exterior retrofit foam application by Applicator A (0.14-1.2 ppm) were similar to Applicator B (<0.08-1.3 ppm). Exposure concentrations during open-bay foam application (1.1-2.4 ppm) were higher than during exterior retrofit foam application.

TABLE 7. Personal Formaldehyde Concentration Ranges During the Performance of Selected Tasks in the Urea Formaldehyde Foam Thermal Insulation Manufacturing and Application Processes

TASK	FACILITY	SAMPLES COLLECTED	CONCENTRATION RANGE (PPM)
Resin Drum Filling	Manufacturer A	3	2.1-5.4
	Manufacturer B	4	0.18-1.28
Cooking (reactor deck activities) -- resin sampling, testing, and cooking	Manufacturer A	2	0.35 & 0.37
	Manufacturer B	2	0.34 & 0.45
Exterior Retrofit Foam Application	Applicator A	7	0.14-1.2
	Applicator B	9	<0.08-1.3
Exterior Retrofit Closing Operations	Applicator A	4	0.12-0.73
	Applicator B	3	<0.08-0.13
Trash Foam Cleanup	Applicator A	2	0.15 & 0.65
	Applicator B	2	<0.09[a] & 0.26
Monitoring for Structural Stress	Applicator A	2	0.32 & 0.40
Resin Drum Washing	Manufacturer A	2	0.23 & 0.32
Cleaning Out and Stocking Van	Applicator A	2	0.60 & 0.61
Open-Bay Foam Application	Applicator A	4	1.1-2.4
Open-Bay Foam Scraping	Applicator A	4	0.86-2.3

[a] Some time was spent closing.

Exposures during open-bay foam scraping (0.86-2.3 ppm) were very similar to open-bay application exposures. Exposure to formaldehyde during exterior retrofit closing operations for Applicator A (0.12-0.73 ppm) ranged higher than Applicator B (<0.08-0.13); however, three of the four values for Applicator A were less than or equal to 0.20 ppm. Formaldehyde exposure during trash foam cleanup for Applicator A (0.15 and 0.65 ppm) ranged higher than for Applicator B (<0.09 and 0.26 ppm) even though trash foam was being cleaned from the inside of a house during the 0.26 ppm exposure.

Formaldehyde concentrations in selected areas have been presented in Table 8. Formaldehyde concentrations in the step vans during trips to the application site were higher for Applicator A (0.23 and 0.48 ppm) than for Applicator B (0.18 and 0.18 ppm); however, in each case the concentrations during the return trips were higher -- 0.66 and 1.0 ppm for Applicator A and 0.23 and 0.33 ppm for Applicator B. Concentrations in Applicator A's warehouse were found to be higher when the vans were being stocked and cleaned (0.22 - 0.85 ppm) than in the morning prior to departure (0.17 and 0.19 ppm). The Warehouseman's formaldehyde exposure concentration during the stocking and cleaning was measured at 0.60 and 0.61 ppm -- within the range observed in the warehouse during that activity.

TABLE 8. Formaldehyde Concentration Ranges in Selected Areas During Manufacturing and Application Processes of Urea Formaldehyde Foam Thermal Insulation

TASK	FACILITY	SAMPLES COLLECTED	CONCENTRATION RANGE (PPM)
Inside van while traveling to application site	Applicator A	2	0.23[a] & 0.48
	Applicator B	2	0.18 & 0.18
Inside van while traveling from application site	Applicator A	2	0.66 & 1.0
	Applicator B	2	0.23 & 0.33
Back of van during foam application	Applicator A	3	0.14-2.0
	Applicator B	3	<0.03-0.16
Reactor area	Manufacturer A	1	0.27
	Manufacturer B	8	0.14-5.17
Near center of room during open-bay foam application	Applicator A	4	0.57-1.2
Warehouse prior to departure	Applicator A	2	0.17 & 0.19
	Applicator B	1	0.35[b]
Warehouse during cleaning and stocking of vans	Applicator A	3	0.22-0.85

[a] Van was at jobsite for about ½ hour before sample collection was terminated.

[b] Taken in the drum storage area.

Area samples for formaldehyde taken in the reactor area during resin production at Manufacturer B ranged from 0.14-5.17 ppm. Measurements were made on the upper left and right handside of the reactor deck and, in one case, over the temperature readout. Concentrations on the upper left side ranged from 0.26-0.75 ppm while those on the upper right side ranged from 0.14-3.58 ppm. The concentration over the temperature readout was 5.17 ppm. A formaldehyde measurement was made on the reactor platform at Manufacturer A during the production of a batch of resin with the exception of the time during which formaldehyde was added to the reactor. The formaldehyde concentration was 0.27 ppm.

OTHER AIR CONTAMINANTS

A concentration of 300 ppm of ammonia was measured in the Cook's breathing zone during removal of the drum pump stem from an aqueous ammonia drum, after the ammonia was transferred to the reactor at Manufacturer A's facility. The measurement was made with a Draeger 5/a detector tube. The Cook's average exposure concentration during the entire transfer operation was 15 ppm as measured by the 0.1 N H_2SO_4 collection method. Ammonia concentrations for other activities at Manufacturer A's facility, measured by the 0.1 N H_2SO_4 collection method, were well below this 15 ppm value. Ammonia concentrations measured during Applicator A's activities were not detectable (<5 ppm) as measured with Draeger 5/a detector tubes. Tables 7 through 10 in the Appendix contain ammonia sample results.

Furfuryl alcohol measurements were made in Manufacturer A's facility during resin preparation, drumming, drum washing, and during the course of some of the Foaming Agent Blender's activities. All results were below detectable limits (<0.3-<3.3 ppm). Measurements were also made during periods encompassing urea formaldehyde foam exterior retrofit application, closing operations, cleanup and travel from the job sites for Applicator A. Again, values were below detectable limits (<0.3-<0.6 ppm).

All samples collected for acetaldehyde, phenol, and nitrosamines, at Manufacturer B's facility, during resin and foaming agent production were below levels of detection -- 1.3 ppm, 0.3 ppm, and 0.03 $\mu g/m^3$, respectively.

The respirable dust concentration while drilling through mortar during Applicator A's activities was reported as less than the limit of detection based on the sample volume--<0.1 mg or <0.4 mg/m^3. A weight increase of 0.1 mg was reported for the blank submitted. The respirable dust concentration while drilling through pine wood during Applicator B's activities was less than the lower limit of detection for the volume of air sampled (<0.30 mg/m^3). No detectable weight increase (<0.1 mg) was reported for the two blanks submitted.

PHYSICAL AGENTS

Noise

Noise level readings were taken during the manufacture and application of urea formaldehyde foam insulation. Levels that exceeded 85 dBA are discussed below.

Noise level readings exceeding 85 dBA at Manufacturer A's facility occurred during resin batch making, drum washing, resin drum lid retainer screwing, and foaming agent drum filling. Noise level readings taken on the reactor platform while the impeller was operating at high speed were 83-94 dBA and 74 dBA when operating at low speed. The impeller operated at high speed for about 3 hours per batch. With the exception of breaks and duties of a higher priority, the drum-washing operation was continuous. The full-time Washer took about 12 minutes to wash a drum -- 8 minutes inside, 3 minutes outside, and 1 minute for the lid. Noise levels ranged from 84-92 dBA and exceeded 90 dBA only when the inside of each drum was washed. The part-time Drum Washer cleaned the outside of the drums only. The drum was inverted on the floor and sprayed. This is in contrast to the full-time Washer who placed the drums on an inclined rack. Levels while cleaning the outsides of the drums were 88-97 dBA. After filling, metal circular lid fasteners were screwed onto the resin drums with an electric-powered screwdriver. The operating time for the screwdriver was only a few minutes per batch of resin. Noise levels were 93-96 dBA. Noise levels during foaming agent drum filling were 95-99 dBA. The source of high noise levels during this operation was the electric pump being used. Drum-filling is not a daily operation. On days that drums are filled, the exposure time to the high noise levels is 1 to 1½ hours.

The highest noise level observed in Manufacturer B's facility was 86 dBA. This occurred on the reactor deck during resin cooling prior to drumming. At that time, cooling water was circulating through the reactor and the agitator was running to mix the resin. The cooling process takes less than 1 hour, during which time the Chemist spends only brief periods on the reactor deck to monitor the cooling process. Noise levels measured during other phases of resin and foaming agent production ranged from 81-84 dBA.

Noise level readings were taken while drilling through mortar at Applicator A's worksite. Noise levels of 100-105 dBA were measured while drilling with a Milwaukee No. 5310 drill. It took 7-10 seconds to drill a hole. Noise levels of 92-96 dBA were measured while drilling with a Ramset No. 640 drill. It took approximately 20 seconds to drill a hole. Approximately 200-250 holes are drilled in a typical brick house. Usually at least two individuals share the drilling.

Noise level readings were taken while drilling through aluminum, plywood, and pine clapboard with a Rockwell No. 7556 drill at Applicator B's worksite. Sound levels were 87-93 dBA, 86-94 dBA, and 92-96 dBA, respectively. Approximately 300 holes are drilled per house and it usually takes 10-15 seconds to drill a hole.

Heat Stress

WBGT measurements were made at Manufacturer A's facility. Locations of elevated heat are the drum-washing and reactor areas. WBGT measurements taken on August 29, 1979, in the reactor area were in excess of 27°C and as high as 29°C. Outdoor temperatures were high on that day. Using ACGIH criteria, the Cook's work-rest regimen would be classified as continuous and the workload light to moderate when performing duties on the reactor platform.

WBGT measurements were taken on a relatively cool day in the drum-washing area (dry bulb 21°C about 12 feet from the washing area). The washing area WBGT was 26°C at 10:30 a.m. as opposed to 19°C taken about ½ an hour later approximately 12 feet from the site. Using ACGIH criteria, the Drum Washer's work-rest regimen would be classified as continuous and the workload as moderate.

IV. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Formaldehyde

Exposure to Formaldehyde During Urea Formaldehyde Foam Insulation Manufacturing Activities

Personal samples taken during resin drumming show formaldehyde exposures can exceed the NIOSH recommended limit of 1 ppm for a 30-minute sampling period and the ACGIH ceiling value of 2 ppm. The total coefficient of variation (C_T) for formaldehyde samples collected at Manufacturer A's facility was 0.13. Although the lower confidence limit (95%) of the highest formaldehyde exposure concentration during resin drumming (5.4 ppm) does not exceed the OSHA acceptable ceiling concentration of 5 ppm for a 30-minute sampling period, the potential for an excursion exists. Calculation of the LCL and total coefficient of variation is discussed in the Appendix. Detector tube measurements of 5-10 ppm formaldehyde in the Cook's Assistant's breathing zone of Manufacturer A while the drum was filling with resin suggest concentrations at or near the OSHA acceptable maximum peak above the acceptable ceiling concentration (10 ppm).

Exposures during the reactor deck activities were found to be below the NIOSH and ACGIH recommended limit and the OSHA standard; however, a level of 5 ppm detected over the reactor charging port at Manufacturer B's facility indicates that a potential for increased exposures exists due to changes in operator position or air currents on the reactor deck.

In addition to those samples previously discussed, 14 additional sample values were found to exceed the NIOSH action level of 0.5 ppm. During the sampling periods when these excursions occurred, affected employees were engaged in various activities, including resin drum washing, scraping labels from resin drum lids, unloading empty resin drums from trucks, working in the drum fill areas, handling material, assisting in capping filled resin drums, and cooking a batch of resin. Of the four categories of employees monitored at Manufacturer A's facility, only the Foaming Agent Blender was not found to be exposed to formaldehyde at levels in excess of the NIOSH action level. Since many of the types of activities being conducted when excursions to the action level occurred are performed by all the employees, employees in all job categories can be expected to be exposed to formaldehyde at concentrations in excess of the 0.5 ppm action level on occasion.

Exposure to Formaldehyde During Urea Formaldehyde Foam Insulation Application Activities

Personal samples taken during exterior retrofit foam insulation application show that formaldehyde exposures can exceed the NIOSH recommended limit. Of 16 samples taken between the two Applicators for this activity, two exceeded 1 ppm -- the highest being 1.3 ppm. Foam Applicators from both companies were found to be exposed to formaldehyde at concentrations in excess of the NIOSH recommended limit.

Exposure concentrations can exceed the NIOSH recommended limit of 1 ppm for a 30-minute sampling period and the ACGIH ceiling limit of 2 ppm during open-bay urea formaldehyde foam application activities. Both the Applicator and the Laborer were shown to be exposed at levels in excess of either of these limits for 7 out of 8 measurements that were made. Area concentrations of 0.57-1.2 ppm indicate the potential for exposures in excess of the NIOSH limit of 1 ppm and certainly the NIOSH action level of 0.5 ppm for all application team members during this activity. Higher exposures may result during open-bay insulation of larger structures. The second personal samples taken in the breathing zone of the Foam Mechanic on both floors were greater than the first samples taken (2.4 ppm versus 1.1 ppm, and 1.6 ppm versus 1.1 ppm). This trend is also apparent with the Laborer's personal samples and the area samples taken. This increase can be attributed to a corresponding increase in exposed urea formaldehyde foam surface area.

The potential exists for formaldehyde levels to exceed the NIOSH and ACGIH limits while in transit from the job site to the warehouse, and while cleaning out and stocking (servicing) the vans. All area samples taken in Applicator B's van were below the ACGIH and NIOSH limits; however, this was not the case with Applicator A, where levels in the van were generally below 0.5 ppm until the return trips were made. An exception to this was an exposure concentration of 0.73 ppm measured while the Foam Mechanic was checking the resin level in the drum. This involved inserting and removing a dipstick. Another exception occurred during a period of exterior retrofit application. No reason is apparent for the resultant 2.0 ppm concentration during that activity. Two other samples taken during exterior retrofit application under similar conditions resulted in concentrations of 0.14 and 0.15 ppm. Samples taken in the van during return trips by Applicator A showed formaldehyde concentrations of 0.66 and 1.0 ppm. Formaldehyde concentrations of 4-7 ppm were measured with a Draeger 0.5/a detector tube on one occasion when a van had arrived at the warehouse. This demonstrates the potential for an excursion of the ACGIH limit of 2 ppm and the OSHA acceptable ceiling concentration of 5 ppm. On another occasion levels of 2-5 ppm were measured with detector tubes in the van upon its return to the warehouse. The result of a 24-minute sample taken in a van during servicing was 1.2 ppm while the personal sample taken in the Warehouseman's breathing zone during the same period was 0.60 ppm. Concentrations of 0.7-1.0 ppm of formaldehyde were measured with detector tubes after that particular van had been completely serviced.

This buildup in formaldehyde concentrations in Applicator A's vans is apparently due to the presence of trash foam which is heated indirectly by the exhaust system as it lays in bags on the floor of the van during return trips to the warehouse. The subsequent decrease in concentration is apparently due to the removal of the trash foam. Manufacturer B's employees also brought trash foam back to the warehouse in plastic bags. The lower formaldehyde concentrations during their return trip may have been due to better ventilation (Manufacturer B's van was equipped with a wind driven ventilator), and to less free formaldehyde in their foam.

Area formaldehyde levels in Manufacturer A's warehouse did not exceed the NIOSH limit of 1 ppm; however, the action level of 0.5 ppm was exceeded in one instance. This occurred when vans were being serviced.

Other Chemical Substances

With the exception of ammonia the concentrations of all other chemical substances monitored were below limits of detection. The resultant ammonia concentration of 300 ppm during removal of the drum pump stem from the drum of aqueous ammonia at Manufacturer A's facility exceeded the ACGIH STEL of 35 ppm. An airborne ammonia hazard does not appear to exist during other activities.

Physical Agents

Noise

Projected noise exposures based on sound level readings made during urea formaldehyde foam application are not expected to exceed the NIOSH and ACGIH recommended limits or the OSHA standard under normal conditions. Although exposures exceed 85 dBA during drilling operations, the exposure time is not sufficient to result in an overexposure.

Noise levels during foam insulation manufacturing may exceed NIOSH and ACGIH recommended limits or the OSHA standard. Projected potential noise exposures to the Cook at Manufacturer A's facility during the operation of the reactor impeller at high speed are 28-130% of the NIOSH/ACGIH recommended limits and up to 65% of the OSHA standard. These values are based on a full 3 hours of exposure at the minimum and maximum sound level readings (83 and 94 dBA, respectively). At Manufacturer B's facility the Chemist's exposure would be approximately 62% of the NIOSH/ACGIH recommended limits if the entire 5 hours of resin production time would have been spent on the reactor deck.

The full-time Drum Washer at Manufacturer A's facility is exposed to sound levels in excess of the NIOSH/ACGIH recommended limits. This is based on exposure time and to average sound levels being in excess of 85 dBA. The projected maximum exposure is 88% of the OSHA standard. This is based on an exposure of 92 dBA for 8 minutes of the 12-minute drum-cleaning cycle throughout the work shift.

The part-time Drum Washer's (at Manufacturer A's facility) projected exposure is 94-333% of the NIOSH/ACGIH recommended limits, and 47-167% of the OSHA standard. This is based on 5 hours of exposure to sound levels of 88-97 dBA. The difference in sound levels between the part-time and full-time Drum Washers when washing the outside of the drums (88-92 dBA versus 84-87 dBA) appeared to be due to the position of the drum and the angle at which the spray struck the drum. The part-time Washer inverted the drum on a wooden pallet; the resulting spray angle was about 90°. The spray angle for the full-time Washer's rack-mounted drum was much less, thus resulting in less impact. In addition, the rack may have served as a damping body.

The Foaming Agent Blender's (at Manufacturer A's facility) projected noise exposure is 75-125% of the NIOSH/ACGIH recommended limits and 37.5-65.0% of the OSHA standard. These values are based on exposure times of 1 and 1½ hours and on sound levels of 95-99 dBA.

Heat Stress

Drum washing and working in the area of the reactor may pose a heat stress hazard. WBGT readings taken in the reactor area at Manufacturer A's facility on August 29, 1979, exceeded the NIOSH recommended limit of 26.1°C as a 1-hour (or greater) TWA. Since only one reading was taken in the drum-washing area on September 26, 1979, an excursion cannot be demonstrated; however, the reading was in the permissible limit range. Higher values can be expected during warmer weather.

The ACGIH recommends a WBGT TWA of 26.7°C for moderate work that is continuous and 30.0°C for light work that is continuous. WBGT levels in the reactor and drum-washing area were in the permissible limit range for the type of work performed.

Other Considerations

Urea formaldehyde foam insulation manufacturing and application present a number of opportunities for employee exposure to irritating and corrosive materials. Formaldehyde, phenol, acetaldehyde and furfuryl alcohol are irritating while ammonia and foaming agent acids are corrosive. Phenol and furfuryl alcohol can also be absorbed through the skin.

Confined space entry is another potential hazard in the urea formaldehyde foam insulation manufacturing industry. Reactor and storage tank cleaning are performed periodically.

RECOMMENDATIONS

Formaldehyde and ammonia concentrations and noise and WBGT levels in excess of NIOSH, ACGIH and OSHA limits require the implementation of control measures. In addition, control measures are necessary to prevent exposure to materials that could cause a hazard by direct contact or through skin absorption. Control measures should consist of engineering controls and acceptable work practices. Where engineering controls are not feasible, adequate personal protective equipment should be used. Improvements should include the following:

1. Install local exhaust ventilation to reduce formaldehyde exposure levels to below the NIOSH/ACGIH recommended limits during urea formaldehyde drum fill operations.

2. Provide local exhaust ventilation or an enclosed transfer system to prevent an exposure to ammonia in excess of the ACGIH STEL of 35 ppm when removing the drum pump stem from the aqueous ammonia drum. Provide a small booth, with local exhaust ventilation, large enough to contain the ammonia drum and a container of water suitable for rinsing the drum pump stem to reduce exposures.

3. Use a full-face gas mask, chin type, with an ammonia canister during the interim period when engineering controls are being installed to reduce air contaminant levels below acceptable limits.

4. Modify reactor charging and sampling ports to be kept tightly closed or equip them with local exhaust ventilation to capture emissions so as to reduce unnecessary formaldehyde concentrations in the reactor area during resin production.

5. Require the use of full-facepiece respirators with organic vapor cartridges by the Applicator during exterior retrofit urea formaldehyde foam insulation application. This type of respiratory protective device should also be worn by employees engaged in open-bay application activities. Methods for reducing formaldehyde exposures during foam application should be investigated. Maximum usage should be made of natural ventilation, such as working upwind. General mechanical ventilation should be utilized where possible.

6. Store waste foam in a container on the roof of the vehicle until disposal. This material should not be placed in the van. Install a wind driven ventilator on the wall or roof of the van for general ventilation.

7. Conduct periodic personal monitoring for formaldehyde for employees engaged in activities that result in formaldehyde exposures in excess of 0.5 ppm for a 30-minute sampling period. Activities to be monitored should include all phases of urea formaldehyde foam insulation manufacturing, exterior retrofit foam application, resin level checking, test foaming in enclosed spaces, open-bay insulation activities, exterior retrofit closing operations, waste foam cleanup, traveling from the jobsite to the warehouse, and cleaning and stocking vans.

8. Institute an effective respiratory protection program in all cases where respiratory protection is used. The following should be a part of the program: standard

written operating procedures, fit testing, training in usage and limitations, medical evaluation of the employee's ability to wear a respirator, and maintenance and storage procedures. Respiratory protection program details are presented in the NIOSH publication, "A Guide to Industrial Respiratory Protection" (71).

9. Provide engineering Controls to prevent employees from being exposed to sound levels in excess of NIOSH/ACGIH recommended criteria, and OSHA standards during urea formaldehyde foam insulation manufacturing activities. In the interim, all employees exposed to excessive levels of noise should wear properly-fitted hearing protective devices capable of providing adequate noise attenuation. Audiometric testing should be performed on those employees on an annual basis.

10. Conduct WBGT monitoring during the winter and summer to establish a WBGT profile during urea formaldehyde foam insulation manufacturing. This is to serve as a guide for deciding when appropriate action, as recommended by NIOSH, should be initiated.

11. Employees engaged in resin reactor operations, foaming agent blending, foaming agent and resin drumming, raw material handling, and foam application should wear chemical goggles and protective gloves. Install suitable eye washes and safety showers in resin and foaming agent drum fill areas, resin reactor areas, raw material storage areas, and applicator warehouses. A suitable eye wash should be taken into the field by the application crew. In addition, eye protection should be worn by application team members during drilling operations.

12. Confined-space entry poses serious potential hazards. Develop adequate procedures, including provisions for proper personal protective equipment, for reactor and storage tank cleaning operations. Provide a rescue procedure that includes hoisting and removal of a simulated "unconscious individual" and provisions for adequate medical attention. At least one employee stationed outside of the confined space should be competent in administering cardio pulmonary resuscitation (CPR).

13. Discontinue the practice of tasting urea formaldehyde foam.

V. SUMMARY

The manufacture and application of urea formaldehyde foam insulation has been investigated from an industrial hygiene perspective. Several potential health hazards have been identified. Formaldehyde concentrations during resin drumming and foam application activities have been shown to exceed NIOSH and ACGIH recommended limits. Noise, heat stress and confined space hazards have been shown to exist in manufacturing activities. Hazards associated with skin contact and skin absorption of harmful chemical substances exist in both the manufacturing and application activities. Where necessary, a regimen of engineering control measures, good work practices and personal hygiene, and adequate personal protection will help to minimize exposure to health hazards.

The facilities of Producers A and B are considered to be representative of the industry. Even though two of the largest producers were selected for this study, there are only a few employees involved at any of the producers, and the general production activities are similar. Some differences in ingredients used by Producers A and B were noted. Applicators A and B are considered to be representative of urea formaldehyde foam applicators.

POLYURETHANE FOAM INSULATION

I. DESCRIPTION OF FACILITIES SURVEYED

A. MANUFACTURERS

Plant Description and History

- Manufacturer C

Products manufactured at this facility include rigid polyurethane foam systems (used in the thermal insulation industry), flexible foams and foam systems, and elastomers.

Of the some 235,000 square feet of plant area, only a portion is used for the production of polyurethane foam systems. The remainder of the facility is used for the manufacture of the other products, as well as quality control and research and development laboratories, sales and administrative offices, and warehouses. This plant began production of polyurethane products in 1960. There are approximately 80 non-union employees.

- Manufacturer D

Products manufactured at this plant include rigid polyurethane foam systems and flexible and elastomer systems. The production operations are enclosed in two separate one-story brick buildings. The main production area consists of several blend tanks and adjacent drum-fill stations. Also located within the plant are: a research and development laboratory, a test-foaming demonstration laboratory, a raw materials storage area, warehouses, and sales and administrative offices. Polyurethane products were first produced in this facility in 1954. There are 14 production employees at this facility.

Description of Operations and Existing Controls

Major components of urethane foam systems include:

Isocyanates. One of the two major portions of a urethane foam formulation is an isocyanate. The two most widely used isocyanates are toluene diisocyanate (TDI) and diphenylmethane diisocyanate (MDI), with MDI being the isocyanate used in thermal insulation.

Polyols. The other major portion of a urethane foam formulation is a polyol. Since the variety of isocyanates is limited, polyols are the main constituents used for changing and adjusting foam properties. Some polyols are based on OH-terminated polyesters, amines, and highly halogenated substrates.

Surfactants. Most surfactants for urethane foams are based on silicone block copolymers of silicon tetrachloride. The major role of the surfactant is to make compatible the ingredients of the mixed blend, and to stabilize the cells by preventing drainage and collapse before the polymer growth has reached the gel stage. Some surfactants are additive (nonreactive) while others are reacted into the polymeric structure.

Catalysts. Most urethane catalysts are tertiary amines or organometallics. In rigid foams, organotin catalysts and some amine catalysts are used to promote maximum cross-linking by formation of biuret and allophanate. In flexible foams, the rate of reaction between water and isocyanate is controlled by tertiary amine catalysts.

Blowing Agents. The reaction of water with isocyanate results in an unstable intermediate carbamic acid which decomposes to an amine and carbon dioxide. The amine reacts further with isocyanate to form a urea linkage. With low-density foams, the blowing is frequently accomplished with fluorocarbons. These low-boiling liquids perform similarly to carbon dioxide except that they enhance firmness and insulation properties.

The Polyurethane Foam Insulation System Manufacturing Process

Rigid polyurethane foam systems for thermal insulation consist of an "A" and a "B" component which, when mixed, form a rigid foam. The "A" component consists of a mixture of polymeric (50%) and monomeric (50%) methylene bisphenyl isocyanate (MDI), which is purchased in bulk and repackaged into drums. Alternately MDI may be blended with a flame retardant and then drummed.

The "B" component, or resin, is a mixture of ingredients which are prepared by a blending process. The process does not involve a chemical reaction. The formulation of a resin may vary depending upon the end use of that product. Resins produced by both manufacturers are intended for a variety of uses, including thermal insulation.

The resins used for thermal insulation contain one or more polyols (polyhydroxy compounds), a silicone oil copolymer, one or more tertiary amine catalysts, an organotin catalyst, fluorotrichloromethane (used as a blowing agent), and *alpha*-methyl styrene (used as a stabilizer). A phosphate ester-based flame-retarding agent may also be added.

- Manufacturer C

The MDI repackaging process at this facility is conducted several times per week, as needed, and usually involves only one employee. Twenty to fifty thousand pounds (40-100 drums) may be drummed per day. This operation takes place inside a 100' x 290' building which also serves as a warehouse. The bulk MDI tank car is located adjacent to this building; there is a permanent pipe connection to the MDI loading area.

In the resin manufacturing process any one of several various sized vessels may be used. All of the vessels are located inside the 40' x 50' compounding room. Raw materials, including polyols, silicone oil copolymers, and fluorotrichloromethane, are poured from drums into the top opening of the vessel using an electric drum lifter. Ingredients are measured by weighing each drum before and after pouring. Ingredients are mechanically stirred until homogeneous and then sampled for quality control. After manufacture, the resin is pumped into 55-gallon drums. Drum loading takes place in an open area adjacent to the vessels using a 3-inch feeder hose connecting the vessel with the drum. There are five production days per week in the compounding room. Each employee generally compounds several products per day.

Various resins are also produced in blending operations at Manufacturer C. The various ingredients are thoroughly mixed and the finished resin is transferred to 55-gallon drums. Essentially no spillage of resin occurs during this blending process. The employees in the blending operation routinely wear chemical splash goggles and rubber gloves. Eighty to 100 drums may be filled on an average blending day.

Until mid-1979, another polyurethane insulation product, bun (board) stock, was produced at this plant. This process has been moved to a different Manufacturer C plant.

TDI is used in the compounding room in the production of TDI prepolymers (polyurethane systems intended for uses other than thermal insulation). Drum-sized batches are usually produced. Production takes place inside a walk-in booth. TDI in a drum, which has been heated, is placed in the booth. Raw materials (usually polyols and stabilizers) are added to the drum by hand. The ingredients may be mixed for an hour or longer.

- Manufacturer D

MDI drumming is conducted at the MDI drum-fill station where it is pumped directly into drums from a permanent pipe connection with the bulk storage tank. The MDI-flame retardant blends are produced in two blend tanks within the main production area. This process involves a "cold" blending step in which MDI is pumped into the blend tanks from bulk storage and flame retardant is added. The blend tanks rest on scales; the flow is monitored until the desired weight has been added. The product is then drummed at the adjacent drum-fill station. Potential employee exposure to the "A" component is expected only during drum-filling operations.

Toluene diisocyanate (TDI) is a common "A" component in many polyurethane systems intended for uses other than thermal insulation. TDI may also be either drummed or blended with other materials in the main production area; however, it was not used during this survey.

Three blend tanks are normally used in the production of resins at this facility. The tanks range in capacity from 9000 to 40,000 pounds (900 - 4000 gallons). Each tank rests on a scale and is equipped with electric mixers and permanent pipe connections to the raw materials storage tanks. Certain raw materials, such as the catalysts, are pumped into the blend tank from drums. The Chemical Operator monitors the flow until the desired weight of each material including various polyols, fluorotrichloromethane, and silicone oil, has been added, then blends the materials for 30-60 minutes. The blend process does not involve a chemical reaction.

The finished resin is pumped into drums at the drum-fill station which is equipped with a scale and weight-sensitive automatic shutoff switch that stops the resin flow when the drum is filled to the proper weight. A screened funnel, which is inserted into the large drum opening, is used in the filling of both the "A" and the "B" components.

Another blend tank, which is located in a building separate from the main production areas, is not equipped with a pump for filling the blend tank. This tank is used for the blending of products other than those used for thermal insulation. Raw materials, with the exception of fluorotrichloromethane, are poured from the drum into the tank opening using an electric hoist. This operation involves increased worker contact with raw materials compared with the blend process in the main production area.

Worker exposure during the production of "B" components may occur during the addition of raw materials, during drum filling, while withdrawing samples, and while conducting routine laboratory tests.

Description of Worker Activity, Occupational Titles, and Job Descriptions

Operations at the two manufacturing sites ran 1 shift (8 hours) per day, 5 days per week. Crew members at both plants may be involved in the manufacture of a variety of polyurethane products in addition to those used for thermal insulation. At Manufacturer C, seven to eight persons may work on insulation systems. At Manufacturer D, seven persons may work on insulation systems.

Job classifications have been identified which have a potential for chemical exposure during the manufacturing process of the polyurethane foam insulation system. The activities assigned to each job classification vary within each category with some overlap between categories. Consequently, a precise comparison of exposure by job categories between the two manufacturing plants cannot be performed.

- Compounder (Manufacturer C)

  The Compounder is responsible for the compounding of polyurethane products including the compounding of drum-sized batches of TDI prepolymers. Work activites are similar for the production of both thermal and other polyurethane products. Specifically, the Compounder adds raw materials to the compounding vessels by following a product formulation sheet. The Compounder weighs each drum of raw material and pours the contents into the top opening of the vessel using an electric drum lifter. He then reweighs each drum. (Due to the high viscosity of many of the raw materials, residue may be left in the drum after pouring.) Certain raw materials, such as the catalysts which are used in small quantities, are first poured into smaller containers for more precise weighing, and then poured by hand into the compounding vessels. After the materials have been compounded, the Compounder collects a sample for quality control by dipping a paper container into the top opening of the vessel; the then takes the sample to the laboratory for a quality control check. Adjustments to the resin may be made depending upon the laboratory results. If the sample is acceptable, the Compounder transfers the finished resin into drums. This is performed by lining up the drums on the compounding area floor, making a hose connection to the vessel, and filling the drums one at a time. Exposures may occur when ingredients are poured into the vessels, during the drum loading, and when a sample is collected. The Compounders spend more than 90 percent of their time in the compounding room.

- Blender (Manufacturer C)

  The Blender maintains the levels of raw materials in the supply tanks, monitors the flow of finished resin during drum filling, takes periodic samples for laboratory tests, and performs required maintenance and cleaning on the equipment. The Blender spends 100 percent of his time at the blending fill station when the equipment is in operation. When the operation is finished, the Blender may be involved in maintenance and repair, cleanup, filling the tanks, or ordering materials. His assigned tasks generally do not require him to enter other areas of production except for the "A" component drumming area which is located next to the blending operation in the same room. The blending process affords little opportunity for exposure to the ingredients of the B component.

- Chemical Operator (Manufacturer D)

  The Chemical Operator is responsible for all of the activities associated with the blending of polyurethane products including quality control tests and drumming the finished product. Job duties include adding raw materials to the blend tanks by following a product formulation sheet. Raw materials for which there is a permanent pipe connection with the blend tank involve little or no worker contact with the materials. The Operator inserts the pump stem into the drum, turns on the pump, and monitors the flow until the desired weight of material has been added to the blend tanks.

  After blending is completed, the Operator withdraws a sample by pumping a small amount of product into a container. Each Operator conducts the quality control laboratory tests for the blend product which include a test for water content and a test-foam (mixing the "A" with the "B" component) to determine foam rise time. Adjustments to the blend may be made based on laboratory results. The Operator then pumps the product into 55-gallon drums at the drum-fill stations, and seals each drum.

MDI Loading

- Drum Handler/Drum Loader (Manufacturer C)

  During the survey, the Drum Handler for the blending operation also served as a Drum Loader for "A" component drum loading. During the blending operation, he assists the Blender by supplying empty drums at the fill station and by removing and sealing the full drums. During the filling operation he spends all of his time in close proximity to the fill station. When the blending process is not in operation he may be loading "A" component (MDI) into 55-gallon drums. Drum loading involves lining up the drums in an open area adjacent to the blending operation, making a hose connection to the MDI pipe, filling drums one at a time, and then sealing each drum. Employee exposure may occur during the filling of either resin or MDI drums.

  At Manufacturer D the Chemical Operators conduct MDI and TDI repackaging.

Quality Control

- Quality Control Technician (Manufacturer C)

  The Quality Control Technician is responsible for conducting quality control testing of the resin at the blending operation. He picks up samples of the current run of resin from the Blender and performs a test foaming operation by mixing the resin with MDI and observing various foam characteristics. He then sections and weighs the foam to determine the foam (end product) density. He conducts all testing at an open table located about 25 feet from the fill station. The Technician takes about 5 minutes to complete each test. While the blending process is in operation, the Technician spends about 70 percent of his time at or near the table.

Exposure Control Measures

- Manufacturer C

Safety glasses are required at all times in the plant and laboratory areas. Chemical goggles are required in the vicinity of the compounding vessels during compounding. Employees engaged in the transfer and compounding of TDI wear full-facepiece, chin-style gas masks approved for pesticides (NIOSH Approval No. TC-14G-86). Gas masks are not worn during the production of thermal insulation systems.

Exposure control at the blending operation is accomplished through the use of a local exhaust ventilation system, maintenance of the integrity of the components, and use of beveled couplings which insert directly into the drums during filling and prevent spillage. The local exhaust ventilation system vents the displaced air from the drum during filling. The system has branch ducts which lead to the drum locations at the fill station. The ducts terminate in a 3-inch circular, plain (nonflanged) opening located above the open pressure relief bungs. Another branch duct terminates in a flanged canopy hood located over an overflow drum. The distance from the drum opening to the hood opening is about 4 inches; the hood openings were not positioned directly above the drum openings. Air flow measurements indicate an average face velocity of 660 fpm at the face of the first duct and 840 fpm at the face of the second duct (located upstream from the first duct). However, the calculated air velocities at each of the drum openings (based on measured air flows) are only 29 fpm and 37 fpm, respectively.

Other controls include a walk-in booth (15' x 18') located in the compounding area which is used for the transfer of TDI and for the mixing of polyurethane products containing TDI. The airflow into the booth was measured using an Alnor Thermo-Anemometer Type 8500. The flowrate was approximately 3300 cubic feet per minute. Located within the booth are flexible hose air ducts which can be placed at the top of a drum during mixing. However, the capture velocity of the air ducts as indicated by use of a smoke tube was insufficient to provide control. This booth has been in operation for 3 years. A walk-in oven, also located in the compounding area, was equipped with a slot hood in 1977. This oven is used to heat drums of raw materials including TDI. Two of the larger compounding vessels are equipped with local exhaust ventilation ducts which vent vapors generated while filling and mixing. The ventilation systems of the oven and the compounding vessels were not evaluated.

- Manufacturer D

Exposure control in the production areas is accomplished through the use of a local exhaust ventilation system at the drum-fill stations and at a blend tank lid. The drum-fill stations are equipped with metal or metal and plastic canopy hoods measuring 18 inches in diameter and 25 inches high. Each hood is connected by a 6-inch diameter, flexible duct to an exhaust fan which is located inside the building. In some cases, the fans exhaust into a common duct before discharging contaminated air to the outside. The hoods, which rest on swivel stands and are equipped with access doors, provide nearly complete enclosure of the funnel and spout. The smaller drum vent opening, which remains open during filling to allow escape of the displaced air, is not covered by the hood. Consequently, vapors present in the displaced air may not be captured by the hood. Only three of the six hoods were used during the survey.

The air velocities of the hoods were measured using an Alnor Thermo-Anemometer Type 8500. Results are shown in the Appendix. (see Table 44, Manufacturer D)

One of the blend tanks is equipped with a slot hood around the outer edge of the tank lid. This hood is generally operating while raw materials are being added to the tank. The ventilation system of the vessel was not evaluated.

Process controls exist which may indirectly provide exposure controls. These include automatic flow shutoff devices, which interrupt the flow of product when the drum is full, lessening the chance of overflow, and permanent connections between the blend tanks and certain raw materials storage tanks which reduce employee contact with these materials.

Medical, Industrial Hygiene and Safety Programs

- Manufacturer C

The medical program at this facility includes preemployment physical examinations for all employees, including administrative employees. The program is administered by a consulting physician at the plant's clinic. Parameters included in the examination are: height, weight, blood pressure, temperature, and respiratory function. In addition, comprehensive medical and work histories are taken with emphasis on preexisting respiratory conditions. Yearly physical examinations are required for each employee with emphasis on the condition and performance of the respiratory tract. A medical examination is required following an exposure to a hazardous chemical. The clinic, located inside the plant, is staffed by a part-time nurse. Records have been maintained since the medical program was initiated approximately 20 years ago.

An important aspect of the medical program is the surveillance for employees who may have become sensitized to isocyanate compounds. As part of this surveillance, employees are required to report all colds and cold-like symptoms to the nurse or doctor. If conditions warrant it, the employee may be relocated.

The safety program was initiated in 1960; an industrial hygiene program was added in 1976. Both programs are under the supervision of the plant's Administrator of Safety and Occupational Health, with some direction being provided by the Corporate Occupational Health and Safety Unit.

As part of the safety program, all personnel entering the production area are required to wear safety shoes and safety glasses. With regard to the compounding or blending of polyurethane products, safety procedures have been developed for the handling of the materials during specific tasks. These tasks, including the sampling, handling, and drum loading of both the "A" and "B" components, require the use of rubber gloves and chemical splash goggles.

Area and personal monitoring surveys have been conducted at the plant; however, only one survey has been conducted in thermal insulation product manufacturing areas. Many of the surveys were conducted to determine exposure to toluene diisocyanate (TDI). Area monitoring for TDI vapor is presently being conducted using an MDA No. 7005 Isocyanate Continuous Monitor (MDA Scientific, Inc., Park Ridge, Illinois). TDI, which is not used in the blending of thermal insulation products, has a much higher vapor pressure than MDI; consequently, its potential for exposure is considered to be greater than that for MDI. Recently, personal and area samples for *alpha*-methyl styrene were taken by a corporate industrial hygienist at the blending operation. *alpha*-Methyl styrene was not detected in any of the five samples taken.

- Manufacturer D

The medical program at the facility includes preemployment and annual physical examinations for production and laboratory employees. The program, which is administered by a consulting physician, includes an SMA-12 test (blood chemistry), general physical examination, chest X-ray, and a vision test. Pulmonary function tests are administered during the annual physical examination only. The program was initiated in 1965; however, annual physical examinations were not initiated until 1978. Medical records which include previous work history are maintained by the consulting physician.

The Plant Manager is responsible for industrial hygiene and safety at the plant. Guidance in health and safety is provided by the Corporate Safety Department. An industrial hygiene program has been in effect since 1978. Area monitoring for TDI vapor has been conducted since 1974 using MDA No. 700 or No. 7005 Isocyanate Continuous Monitors (MDA Scientific, Inc., Park Ridge, Illinois). Personal monitoring for TDI vapor has also been conducted at the plant. Monitoring for chemical agents other than TDI has not been conducted.

A general safety program has been in operation since 1969 when the company took over the ownership of the plant. A formalized safety program was initiated in 1977. As part of the safety program, all employees are supplied with safety glasses, safety shoes, Nomex flame-retardant work clothes, and hardhats. Rubber gloves are worn when handling raw materials. MSA full-facepiece gas masks approved for use with organic vapors (NIOSH approval No. TC-14G-97) are worn by the Chemical Operators when filling drums with TDI.

B. APPLICATORS

Plant Description and History

- Applicator C

This company operates out of a small warehouse containing both office and storage space. The company applies polyurethane foam and urea formaldehyde foam insulation, with limited application of cellulose and fiberglass insulation materials.

Typical polyurethane foam applications performed by this company include roof exteriors, refrigerated warehouses, and industrial water tanks. The company, which serves a nine state area, has been in business since 1975. There are 12 employees, 3 of whom are generally involved in polyurethane application.

- Applicator D

The insulation division of this company, which has 10 employees, is involved in the full-time application of polyurethane foam insulation. The pipe coverings division installs fiberglass and calcium silicate pipe coverings. Both divisions operate out of a warehouse having both office and storage space.

Typical polyurethane foam applications include refrigerated warehouses, industrial water tanks, and residential and commercial buildings. The company has been applying polyurethane foam insulation since 1967-1968; the company generally serves areas within a 100-mile radius of its office.

Description of Operations and Existing Controls

The Polyurethane Foam Insulation System Application Process

- Applicator C

The "A" and "B" components from Manufacturer C are received in 55-gallon metal drums. The components are stored in the warehouse along with other insulation materials and application equipment. The warehouse also serves as a vehicle storage garage and has adjacent office space.

The "A" and "B" components are mixed in the internal mixing chamber of a spray gun, atomized, and sprayed onto a substrate, where the foam mixture expands and hardens in less than 1 minute. The foaming process involves an exothermic polymerization reaction; the heat evolved helps to expand and cure the foam.

At Applicator C the application team, consisting of an Applicator and a Helper, arrived at the warehouse at about 8:00 a.m. and loaded the polyurethane products onto a 20-foot truck. The cab of the truck is separated from the bed; therefore, exposure while in transit to and from the jobsite was not evaluated. The truck also contained the application equipment and a desk.

The application site during this survey was a church for which polyurethane foam insulation was applied to the flat portion of the roof. The application team had previously cleaned some portions of the roof of dirt and loose gravel.

The application equipment consists of: a gasoline engine-powered air compressor, pneumatic transfer pumps, a Gussmer H-2 proportioning pump, hoses and an airless spray gun. The air compressor drives the transfer pumps which supply the "A" and "B" components to the proportioning pump. The proportioning pump heats the components to 60°C, pressurizes and meters each component to the spray gun. A line heater (electrical resistance) wrapped around the hoses maintains the temperature.

The foam is applied to the roof in 4-foot-wide paths from a standing/walking position. The foam is built up to a thickness of an inch or more by applying the foam in layers. Periodically, the Applicator cleans the spray gun by squirting "gun cleaner" (Cellosolve acetate or 2-ethoxyethyl acetate) into the mixing chamber. When spraying is completed for that day, the equipment is put back onto the truck, the spray gun is cleaned with "gun cleaner", and the application team returns to the warehouse.

The application team spent about 7 hours each day at the application site; however, only about 4-4½ hours each day were spent spraying foam. Other activity at the application site included downtime due to equipment malfunction, downtime while waiting for the roof to dry, setting up and taking down application equipment, and lunch breaks.

- Applicator D

The application team arrived at the warehouse at 7:00 a.m. and loaded the application equipment and the polyurethane products onto a pickup truck. The application site for this survey was a refrigerated room which was being constructed inside an existing food warehouse. Polyurethane foam was applied to the interior walls of the room to a thickness of 3 inches. The room measured 35 x 70 feet and had a 14-foot-high ceiling. An asphalt-based vapor barrier had been applied to the walls several days earlier by other company employees.

Applicator D's foam application equipment and process are similar to Applicator C's with two exceptions. Applicator D used an electric air compressor to drive the transfer pumps instead of a gasoline engine-powered air compressor. The Gussmer H-2 pump used by Applicator D was customized so that it was portable. The application equipment was located outside the refrigerated room during the application process. A portable oil-fired heater located at the entrance to the room was used to increase the wall (substrate) temperature so that the foam would expand properly. The foam was applied to the walls in 4-foot-wide sections from a standing position; the spray gun was held approximatey 3 feet from the walls. A scaffold was used for spraying the upper sections of the walls. Periodically, the spray gun was cleaned with "gun cleaner" (Cellosolve, or 2-ethyoxyethanol) by squirting a few drops into the mixing chamber. When spraying was completed for the day, the application team returned to the warehouse.

Foam was applied over a 2½-day period; considerable downtime occurred on the second day due to a heater malfunction which caused the "A" component to harden. The team applied foam for 5 hours on the first day, 1 hour on the second day, and 2½ hours on the third day.

Description of Worker Activity, Occupational Titles, and Job Descriptions

Operations at both applicators ran one shift, 8-10 hours per day, 5-7 days per week.

Job classifications have been identified which have a potential for chemical or physical agent exposure during the application of polyurethane foam insulation and the activities associated with it. These job classifications have been divided into two general categories on the basis of the type of duties that are performed:

- Foam Applicators apply the foam to the surface and oversee the application process.
- Application Assistants prepare the surface for application, set up the application equipment, and perform other duties as required.

A description of the duties within these job classifications is presented below by job category:

Foam Application

- Applicator (Applicator C)

  The Applicator, who is also the vice president of this company, has the responsibility for applying the polyurethane insulation. His duties include: maintenance, cleaning and assembly of the application equipment, assuring foam quality, foam application, and general cleanup. On days when foam is not applied, he may be involved in preparation and cleaning of the surface/area to be foamed, applying a weatherproof sealant to a foamed surface, or applying another type of thermal insulation material.

  The Applicator spends about 1 hour inside the truck each day cleaning, assembling, and performing maintenance on the application equipment. The actual time spent performing maintenance may vary; during the survey, there were delays due to equipment malfunction. End-of-day cleanup generally takes less than 1 hour.

- Mechanic (Applicator D)

  The Mechanic's duties include: applying the foam, assuring foam quality, and cleaning and maintenance of the application equipment. The mechanic spends about 1 hour each day cleaning, assembling and performing maintenance on the application equipment.

  The actual time spent performing maintenance varies; during the survey there were delays due to equipment malfunction.

Application Assistant

- Helper (Applicator C)

  The Helper's duties include: setting up equipment, moving the hoses from the path as the Applicator sprays the foam; making adjustments to the proportioning pump; changing over the MDI and resin drums when empty; and general cleanup. Occasionally the Helper may spray foam. The Helper spent less than half of his time on the roof helping the Applicator during the survey.

- Helper (Applicator D)

  While the Mechanic is spraying foam, the Helper assists by: moving the hoses, pushing the scaffold, making adjustments on the pumps, and changing over the drums of components when empty. At other times, the Helper may be setting up or cleaning equipment. The Helper spends about 75% of his time behind or near the Mechanic during spraying.

Exposure Control Measures

- Applicator C

Personal protective equipment consisted of respirators and gloves. The respirators (Norton half-mask respirator, NIOSH Approval No. TC-23C-74, approved for pesticides) were used when foam was applied under the overhang of the steeple. Rubber gloves were used by the Applicator while spraying foam. There is no mechanical ventilation used with the polyurethane foam application process. The foam is applied outdoors; the operator generally stands upwind of the spray taking advantage of natural ventilation.

- Applicator D

The company supplies respirators (Willson Model No. 1221 with R-21 organic vapor cartridges, NIOSH certification No. TC-23C-50) for employees. Company policy requires the use of respirators; however, some workers were observed not wearing respirators while spraying polyurethane foam.

The Mechanic used the respirator while spraying foam from the floor level. While on the scaffold, the respirator was generally not used because the spray was directed mostly downward. (The helper stands near the base of the scaffold, but clear of the overspray.) Spraying from the floor level involved directing the spray upwards, and the resulting overspray settled on the employee. There is no mechanical ventilation associated with the foam application process, and the natural ventilation was limited in the indoor application.

Medical, Industrial Hygiene and Safety Programs

- Applicator C

Applicator C has no formalized medical, industrial hygiene, or safety programs. Medical examinations are not provided for employees. First aid supplies on the truck consist of a first aid kit. There has never been an industrial hygiene survey conducted at this company. The use of safety equipment is optional.

- Applicator D

Applicator B has no formalized medical, industrial hygiene, or safety programs. Employee safety is stressed by the company's Personnel Director who is also the Safety Coordinator. Yearly physical examinations are encouraged by the Vice-President and covered under the company's employee medical plan. There has never been an industrial hygiene survey at this company.

II. DESCRIPTION OF SURVEY METHODS

PROCEDURES

The survey procedures involved a discussion with appropriate company personnel to obtain detailed information on the manufacture and application of polyurethane insulation products and the associated job classifications. A walk-through observation of the manufacturing sites was made. A personal monitoring schedule was developed to obtain data for an evaluation of worker exposure to selected raw materials associated with production and application of polyurethane insulation products. Sampling procedures for chemical and physical agents varied at each facility. At Manufacturer C, atmospheric sampling for fluorotrichloromethane, *alpha*-methyl styrene, dimethylethanolamine and dimethylcyclohexylamine was conducted during the resin manufacturing process. Sampling for MDI was conducted during the MDI repackaging process. Samples were also taken for methylene chloride during routine cleaning. Personal and area sampling for TDI were conducted during the production of a TDI prepolymer. Personal sampling was not conducted during lunch breaks.

At Manufacturer D, atmospheric sampling for fluorotrichloromethane, *alpha*-methyl styrene, dimethylcyctohexylamine, dimethylanolamine, triethylene diamine and tetramethyl butanediamine was conducted during the resin manufacturing process. Sampling for MDI was conducted during the MDI repackaging process.

At Applicator C, atmospheric sampling for MDI, fluorotrichloromethane, *alpha*-methyl styrene, dimethylethanolamine, dimethylcyclohexylamine and dimethyltin dicarboxylate was conducted. Direct reading instruments were used to measure carbon monoxide and noise levels.

During Applicator D's activities atmospheric sampling for the following compounds was conducted: MDI, fluorotrichloromethane, *alpha*-methyl styrene, dimethylcyclohexylamine, triethylene diamine, 2-ethoxyethanol and an organotin compound (proprietary). A sound level meter was used to measure noise levels. Short period samples to measure peak exposures and long-term samples were collected for MDI in both the manufacturing and application processes. Personal samples were collected during periods when workers were engaged in manufacture or application of the polyurethane products; area samples were collected in locations where workers performed tasks such as monitoring equipment, adding raw materials, drumming finished products or performing maintenance.

LIMITATIONS

In each of the four site visits, this industrial hygiene survey represents an evaluation of conditions present during the days of sampling. All apparent chemical and physical hazards were evaluated. Sampling was limited to those agents capable of causing significant exposures under existing conditions.

Conditions monitored during this study are considered to be representative of typical plant conditions except as noted. In Manufacturer C's facility, the "A" component drum-loading operation was limited in duration due to a short supply of bulk MDI. In Manufacturer D's facility, the only activity noted that deviated from the normal routine was the TDI blending/drumming operation. TDI, commonly used as the "A" component in many polyurethane products other than thermal insulation, was not used during the survey.

SAMPLING AND ANALYTICAL METHODS

All samples were shipped by air to a laboratory which is accredited under the Laboratory Accreditation Program of the American Industrial Hygiene Association. The laboratory used participates in all six analysis categories of the NIOSH Proficiency Analytical Testing Program.

TDI and MDI

NIOSH Method No. P&CAM 141 (72) and Method No. P&CAM 142 (73) were selected for sampling and analysis of TDI and MDI, respectively. The two methods have identical sampling procedures. Sampling was conducted by drawing a known volume of air through a Bendix midget impinger containing 15 ml of absorbing solution (hydrochloric acid and glacial acetic acid in distilled water). The sampling rate was 1 liter per minute. Calibrated MSA Model G or S sampling pumps were used. After each sampling period, the impinger contents were transferred to glass vials with Teflon-lined caps. Impingers, each containing 15 ml of absorbing solution, were handled in the same manner as the samples, except that no air was drawn through them. The contents of these were analyzed by the laboratory as field blanks.

Analysis of TDI and MDI involves the formation of a colored complex which is subsequently quantified utilizing a spectrophotometer. The analytical method cannot be used to differentiate between polymeric and monomeric forms; consequently, the sample results may reflect concentrations of both forms. The limit of detection for this analytical method was 0.5 μg per sample for TDI and 0.2 μg per sample for MDI.

Amine Compounds

Currently, NIOSH and OSHA do not have sampling and analytical methods specific for any of the four amine compounds: dimethylethanolamine (DMEA), dimethylcyclohexylamine (DMCHA), triethylene diamine (TEDA), and tetramethyl butanediamine (TMBD). NIOSH Method No. P&CAM 270 (74) was selected for this survey based on chemical similarity between DMEA and other amino-ethanol compounds which are covered in this method. This method was followed for all amine compounds with a slight variation in the sampling phase. The method recommends stabilization of the amine by adding hydrochloric acid (with a microliter syringe) to the collection tube immediately after sampling is completed. However, shelf-life stability studies conducted by the analytical laboratory indicated that the compounds were stable for up to two weeks; consequently, the stabilization procedure was not performed.

Sampling was conducted by drawing a known volume of air at about 100 ml per minute through a silica gel tube to trap the amine compounds. Calibrated MSA Model C-200 and SKC Model 222-3 personal sampling pumps were used. The silica gel tubes consist of glass tubes, 7 cm long, packed with 150 mg of silica gel in two sections. The absorbing section contains 100 mg of silica gel and the backup section contains 50 mg. Tubes containing silica gel were handled in the same manner as the samples, except that no air was drawn through them. These tubes were submitted for analysis as field blanks.

At the laboratory, the samples were desorbed with methanol:water (4:1). An aliquot was taken, made basic ($pH > 8$) with 0.5 ml of a 0.2 N NaOH-methanol:water (4:1) solution, and then analyzed by gas chromatography. Desorption efficiency tests were also conducted by the laboratory for the amines by spiking silica gel tubes with known amounts of the four compounds, and then analyzing in the same manner as that used for the samples. The desorption efficiencies for the compounds ranged from 38% to 92%; results were efficiency corrected. The silica gel tube-loading range for the desorption efficiency tests was several orders of magnitude greater than the field samples. Consequently, the reported desorption efficiencies may not be an accurate reflection of the sample desorption efficiencies.

Fluorotrichloromethane

Sampling and analysis for fluorotrichloromethane were conducted in accordance with NIOSH Method No. S102 (75). A known volume of air was drawn through a charcoal tube at 30 ml per minute to trap the fluorotrichloromethane vapor present. Calibrated MSA Model C-200 and SKC Model 222-3 personal sampling pumps were used. The charcoal tubes consist of glass tubes, 10 cm long, packed with two sections of 20/40 mesh activated coconut charcoal. The front section contains 400 mg of charcoal, and the backup section contains 200 mg. Analysis involves desorbing the fluorotrichloromethane with carbon disulfide and subsequent analysis by gas chromatography. Tubes from the same batch as the samples were handled in the same manner as the samples, except that no air was drawn through them. These tubes were submitted for analysis as field blanks.

alpha-Methyl Styrene and Methylene Chloride

NIOSH Method Nos. S26 (76) and S329 (77) were selected for sampling of *alpha*-methyl styrene and methylene chloride, respectively. Sampling methods for both compounds are similar, and both are compatible with the sampling method for fluorotrichloromethane. Consequently, one collection tube was generally used for sampling and analysis for all three compounds. The analytical methods for *alpha*-methyl styrene and methylene chloride involve desorption with carbon disulfide and injection of an aliquot into a gas chromatograph. Tubes from the same batch as the samples were handled in the same manner as the samples, except that no air was drawn through them. These tubes were submitted for analysis as field blanks.

Dimethyltin Dicarboxylate

Sampling for dimethyltin dicarboxylate was conducted according to NIOSH Method No. P&CAM 176 (78). Sampling was conducted by drawing a known volume of air through a Millipore 37-mm Type AA 0.8 um pore size filter, mounted in a cassette, to trap the tin compound. MSA Model G or S sampling pumps were used. The sampling rate was 1.5 liters per minute. Cassettes with filters from the same batch as the samples were handled in the same manner as the samples, except that no air was drawn through them. These were submitted for analysis as field blanks.

Samples were analyzed according to a method developed by the analytical laboratory and based on published methods (79, 80). Analysis involves refluxing with nitric acid to dissolve the membrane filter, treating with concentrated hydrochloric acid, and analyzing on an atomic absorption spectrophotometer with an air-acetylene flame. Results are reported as elemental tin.

2-Ethoxyethanol

The sampling and analytical methods for 2-ethoxyethanol were similar to those for fluorotrichloromethane. Analysis involves desorption with carbon disulfide and injection of an aliquot into a gas chromatograph. Two charcoal tubes from the same batch as the samples were handled in the same manner as the samples, except that no air was drawn through them. These tubes were submitted for analysis as field blanks.

EVALUATION CRITERIA

TDI and MDI

The American Conference of Governmental Industrial Hygienists (ACGIH) in 1959 adopted a Threshold Limit Value (TLV) for TDI of 0.1 ppm as an 8-hour TWA concentration limit. In 1962, the ACGIH reduced the TLV to 0.02 ppm based upon a study which demonstrated respiratory irritation and asthma-like symptoms in workers in several plants where TDI concentrations were considerably below 0.1 ppm. In 1963, the TLV for TDI which remained at 0.02 ppm was changed to a ceiling value (67). The current ACGIH TLV (50) is a ceiling value of 0.02 ppm. In 1978, a notice of intended change for TDI was proposed by the ACGIH (81). The change, if adopted, would reduce the current TLV of 0.02 ppm to 0.005 ppm as an 8-hour TWA with a short-term exposure limit (STEL) of 0.02 ppm.

The ACGIH adopted a TLV for MDI of 0.02 ppm as a ceiling value in 1965. Although the vapor pressure of MDI is relatively low, significant vapor concentrations were reported in the workplace. Available data indicated that MDI was similar to TDI in its irritant and sensitizing properties, suggesting that a similar ceiling value of 0.02 ppm was warranted (67).

In 1973, NIOSH published criteria for a recommended standard for occupational exposure to TDI, recommending a TWA limit of 5 ppb and a ceiling limit of 20 ppb. In 1978, this recommended standard was extended to include all diisocyanates including MDI. Exposure to diisocyanates should be controlled so that no employee is exposed at concentrations in excess of 5 ppb as a TWA for a 10-hour workshift, 40-hour workweek, and a ceiling limit of 20 ppb for a 10-minute sampling period (82). The current OSHA standards (29 CFR 1910.1000) for occupational exposure to TDI and MDI are ceiling limits of 0.02 ppm for each compound.

Fluorotrichloromethane

The current ACGIH TLV for fluorotrichloromethane is 1000 ppm (50). Fluorotrichloromethane is a central nervous system depressant in animals; however, there are no reported effects in humans. The current OSHA standard for fluorotrichloromethane is 1000 ppm. There is no NIOSH recommendation for occupational exposure to this compound.

alpha-Methyl Styrene

The current ACGIH TLV for *alpha*-methyl styrene is 100 ppm (50) expressed as a ceiling concentration. This TLV was set to prevent eye irritation (67). The present OSHA standard for *alpha*-methyl styrene is 100 ppm, expressed as a ceiling concentration. There is no NIOSH recommendation for occupational exposure to this compound.

Methylene Chloride

The ACGIH TLV for methylene chloride is 200 ppm (50) with a STEL of 250 ppm. A notice of intended change has been published which, if adopted, will reduce the TLV to 100 ppm with a STEL of 500 ppm. The current TLV was established to prevent interference with delivery of oxygen to tissues and to prevent depression of the central nervous system (67).

The NIOSH recommendation for a standard for occupational exposure to methylene chloride is 75 ppm averaged over a work shift up to 10 hours per day, 40 hours per week, with a ceiling exposure limit of 500 ppm averaged over 15 minutes. The basis for this recommendation is prevention of significant interference with delivery of oxygen to tissues and abnormalities in central nervous system function. Methylene chloride has been shown to be metabolized to carbon monoxide in the body (83).

The current OSHA standard for methylene chloride is 500 ppm averaged over an 8-hour work shift, with an acceptable ceiling level of 1000 ppm and a maximum peak concentration of 2000 ppm for 5 minutes in any 2-hour period.

Amine Compounds

There are currently no standards or recommended limits for occupational exposure to dimethylethanolamine, dimethylcyclohexylamine, tetramethyl butanediamine, or triethylene diamine.

Dimethyltin Dicarboxylate

The current OSHA standard for organotin compounds (including dimethyltin dicarboxylate) is 0.1 mg/m^3, as tin. NIOSH (84) recommends that the current OSHA standard be retained until more definitive information can be obtained. The current ACGIH TLV for organotin compounds is also 0.1 mg/m^3, as tin (50). The TLV was established in view of lack of pertinent data and by analogy with mercury, thallium and selenium compounds (67).

Carbon Monoxide

The current OSHA standard for carbon monoxide is 50 ppm as a TWA limit. The NIOSH recommended limit (85) for exposure to carbon monoxide is 35 ppm as a TWA limit for a 10-hour work shift. The ACGIH TLV (50) for carbon monoxide is an 8-hour TWA limit of 50 ppm. The TLV is based on an air concentration that should not result in blood carbon monoxide levels above 10%, a level that is just below the development of signs of asphyxiation (67).

2-Ethoxyethanol (Cellosolve)

The current OSHA standard for occupational exposure to 2-ethoxyethanol is 200 ppm, expressed as an 8-hour TWA. The ACGIH-TLV for this compound is 100 ppm (50) expressed as an 8-hour TWA. The TLV was set at this level to prevent eye and nose irritation; at much higher levels, the compound caused lung and kidney damage in animals (67). A notice of intended change has been presented which, if adopted, would reduce the recommended limit to 50 ppm. Currently, NIOSH does not have a recommended limit for occupational exposure to this compound.

Noise

Currently, the OSHA standard allows employees to be exposed to an average of 90 dBA, as measured on the A-scale of a standard sound level meter at slow response, for an 8-hour period. For every 5-dBA increase in the average exposure, the allowable exposure time period is reduced by a factor of 0.5. Exposures to levels in excess of 115 dBA are not permitted (51). The ACGIH recommends that noise levels not exceed an average of 80 dBA for a 16-hour workday. For every 5-dBA increase in the average exposure, the allowable exposure time period is reduced by a factor of 0.5. Exposures to levels in excess of 115 dBA are not recommended (50).

The NIOSH-recommended permissible noise level exposures (69) are identical to the ACGIH levels. The criteria document recommends that these sound levels become effective for existing places of employment after an extensive feasibility study.

III. RESULTS AND DISCUSSION

Exposure concentration ranges for selected individual tasks have been presented in Tables 9 and 10. Where similar tasks have been performed among the facilities, comparisons have been made. A complete record of sampling results is presented in the Appendix.

MDI

Repackaging of bulk MDI was conducted at both manufacturing facilities in a generally comparable procedure, the main difference being that local exhaust ventilation was employed at certain locations at Manufacturer D. Personal exposures during MDI drum loading (see Table 9) were similar at both of the manufacturing facilities. The NIOSH recommended standard was not exceeded at either facility.

The foam was applied in a similar manner at both application sites. The duties assigned within each job classification were generally similar. The concentration range reported for Applicator C (1.0-9.0 ppb) is representative of employee exposure during an outdoor application whereas the range reported for Applicator D (<2.3-68.0 ppb) is representative of employee exposure during an indoor foam application process. Since no mechanical ventilation is associated with the process at either location the difference in concentration ranges may reflect the presence of natural ventilation at the outdoor site or differences in chemical composition between the two systems. A comparison of the concentration ranges for the Helpers at each location also shows a higher concentation range at the indoor application site. Both the OSHA standard and the NIOSH recommended standard for exposure to MDI were exceeded at Applicator D's site.

Area sample results (see Table 10) were generally similar to personal sample results for both drum fill and foam application tasks.

TABLE 9
Employee's Exposure to MDI

TASK	FACILITY	SAMPLES COLLECTED	CONCENTRATION RANGE (ppm)
Filling drums with MDI	Manufacturer C	5	<0.0008-0.0020
Filling drums with MDI	Manufacturer D	15	<0.0002-0.0050
Applying foam (outdoors)	Applicator C	15	0.0010-0.0090
Cleaning application equipment	Applicator C	1	<0.0017
Setting up application equipment	Applicator C	1	<0.0010
Cleaning surface to be foamed	Applicator C	3	<0.0010-<0.0016
Helper--assisting Applicator	Applicator C	4	<0.0010-0.005
Monitoring application equipment (inside truck)	Applicator C	3	<0.0010-<0.0050
Applying foam (indoors)	Applicator D	16	<0.0023-0.068
Helper--assisting Applicator	Applicator D	12	0.0047-0.028
Equipment maintenance during downtime	Applicator D	1	0.0018

TABLE 10
Area Samples for MDI

TASK	COMPOUND	FACILITY	SAMPLES COLLECTED	CONCENTRATION RANGE (ppm)
Filling drums	MDI	Manufacturer C	1	0.0005
Filling drums	MDI	Manufacturer D	11	0.0002-0.0039
Applying foam	MDI	Applicator D	4	0.0200-0.0690

TDI

At Manufacturer C's facility, a TDI prepolymer (a component of a polyurethane system not used for thermal insulation) was prepared in a process which involved handling and mixing TDI. The concentrations ranged from 22 to 310 ppb for three samples taken. TDI was not used at any of the other facilities.

OTHER AIR CONTAMINANTS

The exposure concentration range of fluorotrichloromethane obtained for workers engaged in resin production by compounding at Manufacturer C's facility (35-96 ppm) was much higher than that obtained for resin production by blending (3.6 ppm) at that facility (see Table 11). The difference may be attributed to the observed increase in employee contact with raw materials in the compounding process at Manufacturer C's facility. The compounding process involves pouring raw materials including fluorotrichloromethane from drums into open vessels, whereas those engaged in the resin blending process have little contact with raw materials. At Manufacturer D's facility the blending vessels are equipped with pipe connections to bulk fluorotrichloromethane tanks. However, one of these vessels was open at the top. Visible amounts of vapor were released from the open vessel while fluorotrichloromethane was being added. The highest concentration detected at this facility (193 ppm) was obtained in the personal sample on the operator of this open vessel.

Concentrations of fluorotrichloromethane during foam application were higher for Applicator D (105-180 ppm) than for Applicator C (1.6-13 ppm). The differences may be attributed to the natural ventilation associated with the outdoor application process for Applicator C, or to the differences in composition between the two systems being used.

Exposure to *alpha*-methyl styrene is generally expected to parallel that of fluorotrichloromethane because it is present in (or added to) fluorotrichloromethane at 0.4% (by weight). *alpha*-Methyl styrene was not detected at any of the facilities with the exception of personal samples on the employee applying foam for Applicator D. The concentrations ranged from 0.17 to 0.21 ppm. This employee was also exposed to fluorotrichloromethane at a relatively high concentration.

TABLE 11

Employee's Exposure to Fluorotrichloromethane

TASK	FACILITY	SAMPLES COLLECTED	CONCENTRATION RANGE (ppm)
Resin manufacture (compounding)	Manufacturer C	3	35.0-96.0
Resin manufacture (blending)	Manufacturer C	1	3.6
Maintenance of blend equipment	Manufacturer C	1	0.95
Quality control testing	Manufacturer C	1	6.4
Handling & sealing drums at blending operation	Manufacturer C	1	6.8
Resin manufacture	Manufacturer D	5	4.4-193.0
Applying foam	Applicator C	2	1.6-13.0
Assisting Applicator	Applicator C	2	2.5-5.6
Applying foam	Applicator D	2	105-180
Assisting Applicator	Applicator D	2	33-77

The exposure concentration ranges of amine compounds are presented in Table 12. Amine compounds were detected in personal samples at both the manufacturing facilities and the application sites. Concentrations during resin production were higher at Manufacturer C's facility than at Manufacturer D's facility. The addition of amine compounds in the resin manufacturing process is not performed by similar methods. At Manufacturer D's facility the compounds are added by inserting the pipe stem into a drum and pumping the desired amount into the vessel. At Manufacturer C's facility the process presents greater potential exposure because it involves additional steps including weighing the compounds in a separate container and pouring the compounds into the top of the vessel.

Generally higher concentrations of amine compounds were obtained in the personal samples for Applicator D. This may be attributed to the difference in formulation of the resins used at the two different sites or the effects of natural ventilation (discussed previously).

TABLE 12

Employee's Exposure to Amine Compounds

TASK	FACILITY	SAMPLES COLLECTED	CONCENTRATION RANGE (ppm)			
			DMEA[1]	DMCHA[2]	TEDA[3]	TMBD[4]
Resin manufacture (compounding)	Manufacturer C	2	<0.020-<0.140	<0.007-0.620		
Resin manufacture (blending)	Manufacturer C	2	0.11-0.17	0.45-0.81		
Quality control testing	Manufacturer C	2	<0.064-<0.130	0.061-0.110		
Handling & sealing drums at blending operation	Manufacturer C	2	<0.073-<0.15	0.054-0.20		
Maintenance of blend equipment	Manufacturer C	2	<0.095-<0.220	<0.077-0.056		
Resin Manufacture	Manufacturer D	5	<0.017-<0.033	<0.005-0.063	<0.015- 0.026	<0.056
Applying foam	Applicator C	2	<0.008-<0.016	0.025-0.170		
Assisting Applicator	Applicator C	2	<0.011-<0.025	<0.017-0.017		
Applying foam	Applicator D	3		<0.016-0.48	<0.045-0.07	
Assisting Applicator	Applicator D	3		<0.008-0.130	<0.020- 0.10	

[1] Dimethylethanolamine
[2] Dimethylcyclohexylamine
[3] Triethylene diamine
[4] Tetramethyl butanediamine

The employee exposure to 2-ethoxyethanol (used to clean the spray gun and application equipment) was measured for Applicator D. The measured concentration was 129 ppm for the Applicator and 62 ppm for the Helper.

Carbon monoxide measurements were made inside the truck for Applicator C and near the portable heating unit for Applicator D. The concentration for Applicator C ranged from 30 to 50 ppm with the gasoline powered compressor running. Normally, however, employees spend less than ½ an hour inside the truck. The carbon monoxide level in the foam application area of Applicator D was 5 ppm.

NOISE

Noise level measurements were taken during the manufacture and application of polyurethane foam insulation. All values were below 85 dBA except for Applicator C where an equipment malfunction resulted in the Helper remaining inside the truck near an air compressor for an extended period. The noise level measured near this employee's ear was 96-97 dBA; the duration of the exposure was 2 hours. The projected 8-hour noise exposure is 57% to 66% of the OSHA standard and 115% to 132% of the NIOSH and ACGIH recommended limits.

IV. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Exposure to Chemical Substances During Polyurethane Foam Insulation Manufacturing Activities

Existing engineering controls at the manufacturing facilities were found to be adequate to maintain vapor concentrations of materials associated with the manufacture of polyurethane thermal insulation systems within the limits established by NIOSH and ACGIH, and the OSHA standards. The amine compounds detected in the personal samples of employees have no standards or recommended limits; the highest observed amine concentration was 0.81 ppm. Personal samples taken during the manufacture of TDI prepolymer (not used in thermal insulation systems) at Manufacturer C show that the airborne concentration of TDI can exceed the NIOSH and ACGIH recommended limits and OSHA standard. Personal protective equipment including respiratory protection (described previously) was used during the manufacture of the TDI prepolymer.

Exposure to Chemical Substances During Polyurethane Foam Insulation Application Activities

Employees were not exposed to airborne contaminants in excess of the NIOSH and ACGIH recommended limits or the OSHA standards during the outdoor application process. Personal samples taken during the indoor application process show that MDI exposures can exceed the NIOSH and ACGIH recommended limits and the OSHA standard. Both the Mechanic and the Helper were shown to be exposed at levels in excess of the recommended limits and the OSHA standard during indoor application. Generally, higher concentrations of MDI were obtained in the samples taken on the Mechanic, whose activities involved a much closer association with the spraying operation than did the activities of the Helper. Exposure to other chemical substances associated with the indoor application process in excess of NIOSH and ACGIH recommended limits or the OSHA standard did not occur.

Exposure to Physical Agents

Projected noise exposures based on sound level readings made during polyurethane foam application are not expected to exceed NIOSH and ACGIH limits or OSHA standards under normal conditions. Although the Helper's exposures exceeded the NIOSH and ACGIH limits near an air compressor on one of the sampling days, the activity associated with this exposure is not considered to be routine. The OSHA standard was not exceeded during that activity.

RECOMMENDATIONS

Those operations at which MDI and TDI concentrations exceeded the NIOSH and ACGIH limits and the OSHA standards require the implementation of control measures. These should consist of engineering controls and acceptable work practices. Where engineering controls are not feasible, adequate personal protective equipment should be used. Improvements should include the following:

1. Apply additional local exhaust ventilation to the TDI mixing drum to reduce TDI airborne concentrations to below the NIOSH and ACGIH recommended limits during the manufacture of TDI prepolymers at Plant C.
2. Use adequate respiratory protective devices during the interim period while existing ventilation systems are being modified to reduce airborne TDI concentrations. NIOSH recommends Type C supplied-air respirators with full-facepiece, operated in the positive-pressure mode, for use with diisocyanates (82).
3. Engineering controls to reduce MDI levels during indoor foam application would be desirable. The highly mobile nature of the spraying operation, however, makes the application of exhaust ventilation impractical. The tendency of foam particles to adhere to surfaces makes the use of conventional fans and ducting impractical. In view of the difficulties of applying engineering controls to the foam application process, use adequate respiratory protective devices (described previously for TDI) during indoor foam spraying.
4. Institute an effective respiratory protection program in all cases where respiratory protection is used. The essential elements of such a program have been described previously and are also presented in the NIOSH publication, "A Guide to Industrial Respiratory Protection" (71).
5. Use work practice modifications or engineering controls to prevent employee exposure to sound levels in excess of the NIOSH and ACGIH recommended criteria during occasions which require an employee's pesence inside the truck (near the

air compressor) for extended periods of time. The compressor should be removed from the truck on such occasions. Both NIOSH and ACGIH recommend that an effective hearing conservation program with audiometric testing be implemented for workers who are exposed to noise at or above the recommended limits.

6. MDI, TDI and the components of the resin can cause irritation or corrosive damage to the eye. Wear snug-fitting goggles whenever there is a possibility of contact with these chemicals. Install fixed safety showers and eyewash stations in the production areas.

V. SUMMARY

The manufacture and application of polyurethane foam insulation has been investigated from an industrial hygiene perspective. Existing controls at the manufacturing facilities were found to be adequate to maintain vapor concentrations within NIOSH and ACGIH recommended limits and the OSHA standards. However, during indoor application activities MDI concentrations have been shown to exceed NIOSH and ACGIH recommended limits and the OSHA standards. Noise levels in excess of NIOSH and ACGIH recommended limits and the OSHA standards have been shown to exist at an applicator's site. Engineering control measures, improved work practices and use of adequate personal protective equipment will help to minimize worker exposure.

The facilities of Producers C and D are considered to be representative of the industry to the extent that similar materials are used and generally the same types of production activities are performed. There are some differences between Producers C and D regarding the labor-intensiveness and degree of automation of various of their activities, but these variations are probably reflected throughout the industry. Producers A and B were selected for this study largely because they were major producers without substantially mixed exposures; throughout most of the industy the workers producing polyurethane foam systems also produced various other chemical systems. Applicators C and D are considered to be representatie of polyurethane foam applicators.

RECOMMENDATIONS FOR FURTHER STUDY

1. The chemistry of formaldehyde is complex, and reactions of formaldehyde in air or solutions, including polymerization, degradation, and combinations with other substances, require continued investigation. Development of a sampling and analytical technique suitable for personal monitoring and rapid analysis in the field would be particularly useful. Such a technique would allow specific identification and quantitative determination of formaldehyde and substances acting as sources of formaldehyde.

2. Detailed epidemiologic studies are needed to determine the long-term health effects of occupational exposure to formaldehyde and safe levels for such exposures. This information is particularly relevent to identifying the significance for workers of the recent carcinogenic implications associated with exposures of rats to formaldehyde.

3. A sampling and analytical method should be developed for MDI which will differentiate between monomeric and polymeric forms.

4. The consequences of exposure to the aerosols produced during MDI spraying applications should be investigated. The reactive diisocyanate in aerosol form has been considered to produce the same biologic consequences as diisocyanate vapor at an equivalent concentration. This assumption should be experimentally verified.

5. Detailed epidemiologic studies are needed to determine the long-term health effect of occupational exposure to diisocyanates and safe levels for such exposures. The studies should relate respiratory symptoms, pulmonary function data, and other health effects to actual individual exposures and should include long-term followup of persons leaving the workforce for health reasons.

6. A worker education program should be developed and implemented in which workers are provided information including job hazards, proper application techniques to minimize exposures, proper maintenance and cleanup methods, and proper respirator use.

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APPENDIXES

Appendix 1. CALCULATION OF STATISTICAL MEASURES

LCL Calculation

Where samples were taken for the entire period for which the standard is defined, the lower confidence limit (95%) was determined using the following formula.

$$LCL = X-[(1.645)(C.V.)(Standard)]$$

where

X = measurement being tested

1.645 = critical standard normal deviate for 95% confidence

C.V. = total coefficient of variation

standard = occupation health standard to which the comparison is being made

Example calculation:

A personal formaldehyde sample was collected for 33 minutes. The concentration was 5.4 ppm. The total coefficient of variation was 0.13. Does the lower confidence limit (95%) exceed the acceptable ceiling concentration of 5 ppm which is allowed for 30 minutes; thus showing, with 95% confidence, that the true average concentration exceeds the standard?

Answer:

$$\begin{aligned} LCL &= X - [(1.543)(C.V.)(Standard)] \\ &= 5.4 \text{ ppm} - [(1.645)(0.13)(5 \text{ ppm})] \\ &= 5.4 \text{ ppm} - [1.1 \text{ ppm}] \\ &= 4.3 \text{ ppm} \end{aligned}$$

The LCL (4.3 ppm) does not exceed the standard (5 ppm); therefore, we cannot be 95% confident that the true average concentration exceeds the standard.

Reference:

NIOSH Technical Information: Statistical Methods for the Determination of Noncompliance with Occupational Health Standards. April 1975.

Coefficient of Variation

The total coefficient of variation (CV_T) was determined using the formula $CV_T = \sqrt{(CV_P)^2 + (CV_A)^2}$

CV_P is an average of the coefficients of variation for all pumps used that collected with identical sampling trains at the same intended flow rates. CV_A is the analytical coefficient of variation, which was reported as 0.05 or less.

Example Calculation of CV_T

Five pumps were used over the course of a study to collect formaldehyde at 1 liter per minute. Each pump received multiple calibrations. The coefficient of variations (standard deviation of calibration flow rates/ arithmetic mean of calibration flow rates) for the 5 pumps were as follows:

Pump 1: 0.06
Pump 2: 0.03
Pump 3: 0.05
Pump 4: 0.06
Pump 5: 0.05

Calculate CV_P:

$CV_P = 0.06 + 0.03 + 0.05 + 0.06 + 0.05 / 5$
$CV_P = 0.05$

Given that the CV_A is 0.05, calculate the CV_T

$$CV_T = \sqrt{(CV_P)^2 + (CV_A)^2}$$

$$= \sqrt{(0.05)^2 + (0.05)^2}$$

$$= \sqrt{0.005^2}$$

$$= 0.07$$

Reference:

NIOSH Occupational Exposure Sampling Strategy Manual. January 1977.

Appendix 2.

UREA FORMALDEHYDE THERMAL INSULATION

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POLYURETHANE THERMAL INSULATION

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UREA FORMALDEHYDE THERMAL INSULATION

Manufacturer A

Table 1. Cumulative Daily Sampling Period Time-Weighted Averages of Formaldehyde in parts per million (ppm)

Job Classification	Concentrations	
	9/25/79	9/26/79
Cook	0.27	0.36
Cook's Assistant	0.47	0.78
Drum Washer	0.52	0.30
Foaming Agent Blender	0.24	0.18

Table 2. Exposure to Formadlehyde in ppm -- Cook

Sample #	Date	Sampling Period (min)	Activities	Concentration
1	9/25 a.m.	30	Working on the floor while reactor was being filled with formalin	0.35
2	9/25 a.m.	178	Cooking first batch of urea formaldehyde resin	0.37
3	9/25 a.m.	78	Cooking first batch of urea formaldehyde resin; washing resin drums	0.22
4	9/25 a.m.	232	Washing resin drums; removing lids from used resin drums	0.20
5	9/26 a.m.	15	Operating forklift while reactor was being filled with formalin	0.12
6	9/26 a.m.	178	Cooking first batch of urea formaldehyde resin	0.35
7	9/26 a.m.	125	Cooking first batch of urea formaldehyde resin; material handling; assisting in capping filled resin drums	0.55
8	9/26 p.m.	99	Operating forklift; assisting the Foaming Agent Blender	0.23
9	9/26 p.m.	89	Operating forklift	0.29

Table 3. Exposure to Formaldehyde in ppm -- Cook's Assistant

Sample #	Date	Sampling Period (min)	Activities	Concentration
1	9/25 a.m.	218	Gathering raw materials for first batch of resin; operating forklift; setting up resin drums for filling	0.17
2	9/25 a.m.	62	Open-top filling of drums with urea formaldehyde resin; some time spent in other activities	1.8[a]
3	9/25 p.m.	226	Operating forklift; setting up resin drums for filling; gathering raw materials for resin production; placing lids on filled resin drums	0.39
4	9/26 a.m.	222	Gathering raw materials for first batch of resin; labeling resin drum tops	0.29
5	9/26 a.m.	30	Open-top filling of drums with urea formaldehyde resin	5.4
6	9/26 p.m.	113	Operating forklift; various duties in the reactor area	0.31
7	9/26 p.m.	40	Unloading empty resin drums from truck; working in drum-filling area	0.52
8	9/26 p.m.	25	Filling drums with urea formaldehyde resin through lid opening	2.1
9	9/25 p.m.	30	Open-top filling of drums with urea formaldehyde resin	2.6

[a] This value may be a slight underestimation for the activity described since sampling started about 8 minutes before filling operations began.

Table 4. Exposure to Formaldehyde in ppm -- Drum-Washer

Sample #	Date	Sampling Period (min)	Activities	Concentration
1	9/25 a.m.	177	Washing used resin drums	0.23
2	9/25 p.m.	230	Washing used resin drums; scraping labels off lids	0.74
3	9/26 a.m.	198	Washing used resin drums; unloading new resin drums from truck	0.20
4	9/26 p.m.	115	Washing used resin drums	0.32
5	9/26 p.m.	98	Washing used resin drums; stacking new resin drums	0.47

Table 5. Exposure to Formaldehyde in ppm -- Foaming Agent Blender

Sample #	Date	Sampling Period (min)	Activities	Concentration
1	9/25 a.m.	204	Operating forklift; pumping foaming agent into drums	0.15
2	9/25 p.m.	207	Pumping raw foaming agent into holding tank; handling foaming agent drums; cleaning foaming agent area	0.34
3	9/26 a.m.	199	Operating forklift; unloading truck; setting up foaming agent pails for filling	0.26
4	9/26 p.m.	101	Setting up foaming agent pails for filling; filling pails with foaming agent	0.06
5	9/26 p.m.	96	Scraping labels off resin drum lids; unloading truck	0.13

Table 6. Formaldehyde Measurements Using Draeger Detector Tubes

Sample #	Date	Tube	Location/Activity	Concentration (ppm)
1	8/29	0.002	Cook's Assistant's breathing zone while filling drums with resin	10
2	8/29	0.002	Cook's Assistant's breathing zone while filling drums with resin	10
3	8/29	0.002	Drum Washer's breathing zone while washing drums	N.D.[a]
4	8/29	0.002	Drum Washer's breathing zone while washing drums	N.D.[a]
5	9/25	0.5/a	Reactor platform while reactor was being filled with formalin	2
6	9/25	0.5/a	Lid kettle area while reactor was being filled with formalin	1
7	9/25	0.5/a	Center of plant while reactor was being filled with formalin	N.D.[b]
8	9/25	0.002	Cook's Assistant's breathing zone while filling drums with resin	5-10

[a] Non-detectable: <1.6 ppm; the manufacturer states this value is the lower limit of reliable detection.

[b] Non-detectable: <0.5 ppm; the manufacturer states this value is the lower limit of reliable detection.

Table 7. Exposure to Ammonia in ppm on September 27, 1979 -- Cook

Sample #	Sampling Period (min)		Activities	Concentration
1	13	a.m.	Pumping ammonia into reactor	15
2	205	a.m.	Cooking first batch of urea formaldehyde resin	1.1
3	73	a.m.	Cooking first batch of urea formaldehyde resin	1.3
4	186	p.m.	Working in foaming agent area; removing tops from used resin drums	0.96
Cumulative sampling period TWA				1.5

Table 8. Exposure to Ammonia in ppm on September 27, 1979 -- Cook's Assistant

Sample #	Sampling Period (min)		Activities	Concentration
1	218	a.m.	Handling drummed and bagged resin raw materials	0.13
2	55	a.m.	Filling drums with resin	N.D.[a]
3	182	p.m.	Operating forklift; setting up resin drums for filling	0.16
4	52	p.m.	Filling drums with resin	1.6
Cumulative sampling period TWA				0.28

[a] Non-detectable: <50 μg (<1.2 ppm).

Table 9. Ammonia Concentrations (ppm) on the Reactor Platform -- September 27, 1979

Sample #	Sampling Period (min)		Activities	Concentration
1	13	a.m.	Ammonia being pumped into reactor	24
2	178	a.m.	First resin batch cooking	0.69
3	106	a.m./ p.m.	Resin cooking; ammonia being pumped into reactor	3.8
4	211	p.m.	Resin cooking; drums being filled with resin	0.45
Cumulative sampling period TWA				1.8

Table 10. Ammonia Measurements Using 5/a Draeger Detector Tubes

Sample #	Date	Location/Activity	Concentration (ppm)
1	8/29	Breathing zone of Cook while pumping ammonia	N.D.[a]
2	8/29	Reactor platform while pumping ammonia	5-10
3	8/29	Cook's breathing zone while pulling pump stem from ammonia drum	300
4	8/29	Breathing zone of Drum Washer while washing drums	N.D.[a]
5	9/27	Reactor platform while pumping ammonia into reactor	N.D.[a]
6	9/27	Reactor platform while pump stem was pulled from ammonia drum	40-50
7	9/27	Reactor area during cooking of resin	N.D.[a]
8	9/27	Reactor platform during cooking of resin	N.D.[a]
9	9/27	Drum-washing area during cooking of resin	N.D.[a]
10	9/27	Breathing zone of Cook's Assistant while filling drums with resin	N.D.[a]
11	9/27	Breathing zone of Drum Washer while washing drums	N.D.[a]
12	9/27	Reactor platform while ammonia was being pumped into the reactor	N.D.[a]

[a] Non-detectable: <5 ppm; the manufacturer states this value is the lower limit of reliable detection.

Table 11. Furfuryl Alcohol Exposures

Sample #	Sampling Period (min)	Employee or Location/Activity	Concentration (ppm)
1	336	Reactor area/Cooking and drumming resin	<0.3
2	32	Drum Washer/Washing drums	<3.3
3	187	Foaming Agent Blender/Working in foaming agent area	<0.6
4	52	Cook's Assistant/Filling drums with resin	<0.9

Table 12. Sound Level Readings for Various Operations

Location/Activity	dBA
Center of reactor platform with impeller running at low speed	74
Reactor platform with impeller running at high speed	83-94
Drum-Washer washing drums (using Landa steam generator)	85-92
Drum-Washer washing outside of drums (using Landa steam generator)	84-87
Part-time Drum Washer cleaning outside of drums, drums inverted	88-97
Screwing lid retainers on resin drums	93-96
Foaming Agent Blender filling drums with foaming agent	95-99

Table 13. WBGT Readings on the Reactor Platform -- August 29, 1979

Time	Wet Bulb	Globe Temperature	WBGT[a]
8:17 a.m.	26	32	28
8:47 a.m.	26	33	28
9:30 a.m.	27	34	29
10:23 a.m.	26	32	28
11:08 a.m.	26	31	28
11:45 a.m.	27	33	29
12:49 p.m.	27	34	29
1:52 p.m.	27	36	30
2:53 p.m.	27	33	29

[a] WBGT = 0.7 WB + 0.3 GT.

Manufacturer B

Table 14. Formaldehyde Concentrations -- Area Samples

Sample Number	Date	Sampling Period (min)	Sample Location	Concentration (ppm)
301	3/3	253	reactor deck, upper left side	0.32
306	3/3	102	reactor deck, upper left side	0.26
402	3/4	124	reactor deck, upper left side	0.29
403	3/4	120	reactor deck, upper left side	0.75
302	3/3	118	reactor deck, upper right side	0.14
303	3/3	119	reactor deck, upper right side	3.58
305	3/3	98	reactor deck, upper right side	1.04
401	3/4	190	reactor deck, over temperature readout	5.17
307	3/3	70	near resin drumming	0.21
406	3/4	45	near resin drumming	0.22
407	3/4	46	near resin drumming	0.16
404	3/4	140	near foaming agent drumming	0.07
408	3/4	57	near foaming agent drumming	0.04

Table 15. Formaldehyde Concentrations -- Personal Samples

Sample Number	Date	Sampling Period (min)	Activity	Concentration (ppm)
304	3/3	54	resin sampling and testing **(chemist)**	0.34
405	3/4	60	resin sampling and testing **(chemist)**	0.45
308	3/3	11	resin drumming **(laborer)**	0.18
309	3/3	28	resin drumming **(laborer)**	0.69
409	3/4	31	resin drumming **(laborer)**	1.28
410	3/4	12	resin drumming **(laborer)**	0.80

Applicator A

Table 16. Formaldehyde Exposure During Urea Formaldehyde Foam Application -- Exterior Retrofit Foam Mechanic

Sample #	Date	Sampling Period (On-Off)	Sampling Period (min)	Concentration (ppm)
1	12/6/79	1329-1406	37	1.2[a]
2	12/6/79	1406-1508	62	0.50
3	12/10/79	1205-1233	28	0.24
4	12/10/79	1235-1305	30	1.1
5	12/10/79	1308-1350	42	0.40
6	12/11/79	1229-1302	33	0.24
7	12/11/79	1337-1417	40	0.14

[a] Vial containing contents of second impinger reported broken at laboratory; result reflects concentration in first impinger.

Table 17. Exposures to Formaldehyde During Additional Urea Formaldehyde Exterior Retrofit Activities -- Foam Mechanic

Sample #	Date	Sampling Period (On-Off)	Sampling Period (min)	Activity	Concentration (ppm)
1	12/6/79	1032-1235	123	Opening house	0.16
2	12/6/79	1245-1324	39	In truck while resin and foaming agent were circulating	0.34
3	12/10/79	0907-1058	111	Opening; observing progress	0.11
4	12/10/79	1408-1446	38	Checking resin level in drum; storing application equipment	0.73
5	12/11/79	1110-1222	72	Cleaning application gun in truck; begin circulation of foaming agent and resin	0.35

Table 18. Exposure to Formaldehyde During Urea Formaldehyde Foam Exterior Retrofit Activities -- Laborers

Sample #	Date	Sampling Period (On-Off)	Sampling Period (min)	Activity	Concentration (ppm)
1	12/6/79	0844-1018	94	Opening (removing shingles)	0.09
2	12/6/79	1411-1529	78	Closing (replacing shingles)	0.15
3	12/10/79	0839-1109	150	Opening (drilling mortar)	0.11
4	12/10/79	1214-1315	61	Closing (with mortar)	0.12
5	12/10/79	1322-1409	47	Closing (with mortar)	0.73
6	12/10/79	1344-1402	20	In house monitoring for structural stress	0.40
7	12/10/79	1418-1452	34	Cleaning up trash foam	0.65
8	12/11/79	1315-1413	58	Closing (replacing aluminum siding)	0.20
9	12/11/79	1208-1418	10	In house monitoring for structural stress	0.32
10	12/11/79	1446-1508	22	Cleaning up trash foam	0.15

Table 19. Exposure to Formaldehyde -- Warehouseman

Sample #	Date	Sampling Period (On-Off)	Sampling Period (min)	Activity	Concentration (ppm)
1	12/10/79	1603-1722	79	Cleaning out and stocking two urea formaldehyde vans	0.27
2	12/11/79	1623-1648	25	Cleaning out and stocking urea formaldehyde van #14	0.60
3	12/11/79	1737-1824	47	Cleaning out and stocking urea formaldehyde van #15	0.61

Table 20. Formaldehyde Concentrations in the Step Van During Urea Formaldehyde Exterior Retrofit Activities

Sample #	Date	Sampling Period (On-Off)	(min)	Activity	Concentration (ppm)
1	12/6/79	0846-1042	116	During opening operations	0.27
2	12/6/79	1055-1511	256	During opening and application operations	0.33
3	12/6/79	1513-1532	19	During application operations	2.0
4	12/10/79	0723-0800	37	During trip to site	0.48
5	12/10/79	0815-1058	163	During opening operations	0.10[a]
6	12/10/79	1107-1211	64	During foaming agent and resin circulation	0.25
7	12/10/79	1211-1413	122	During foam application	0.14
8	12/10/79	1431-1448	17	During cleanup	0.31
9	12/10/79	1523-1534	11	During trip back to warehouse	0.66
10	12/10/79	1632-1703	31	During clean out and stocking at warehouse	0.37
11	12/11/79	0743-0920	97	During trip to site[b]	0.23
12	12/11/79	0930-1110	100	During opening operations	0.32
13	12/11/79	1117-1223	66	During gun cleaning and resin and foaming agent circulation	0.14
14	12/11/79	1223-1425	122	During foam application	0.15
15	12/11/79	1448-1505	17	During cleanup	0.39
16	12/11/79	1509-1545	36	During trip back to warehouse, van #14	1.0
17	12/11/79	1624-1648	24	During clean out and stocking at warehouse, van #14	1.2
18	12/11/79	1737-1824	46	During clean out and stocking at warehouse, van #15	0.55

[a] Results reflect concentration in first impinger only.

[b] Van was at site for about ½ hour before sample collection was terminated.

Table 21. Formaldehyde Concentrations in the Warehouse[a]

Sample #	Date	Sampling Period		Activity	Concentration (ppm)
		(On-Off)	(min)		
1	12/10/79	0706-0730	24	Employees waiting to leave	0.19[b]
2	12/10/79	1624-1722	58	Cleaning and stocking vans	0.22
3	12/11/79	0711-0743	32	Employees waiting to leave	0.17
4	12/11/79	1633-1647	14	Cleaning and stocking vans	0.43
5	12/11/79	1746-1825	39	Cleaning and stocking vans	0.85

[a] Taken on shelf near restrooms.

[b] Results reflect concentration in first impinger only.

Table 22. Formaldehyde Exposure During Open-Bay Urea Formaldehyde Foam Insulation Application on December 12, 1979 -- Foam Mechanic

Sample #	Sampling Period		Concentration (ppm)	Floor
	(On-Off)	(min)		
1	1152-1226	34	1.1	Second
2	1226-1257	31	2.4	Second
3	1346-1416	30	1.1	First
4	1416-1443	27	1.6	First

Table 23. Formaldehyde Exposure During Open-Bay Scraping Operations on December 12, 1979 -- Laborer

Sample #	Sampling Period (On-Off)	(min)	Concentration (ppm)	Floor
1	1208-1242	34	0.86	Second
2	1242-1317	35	2.3	Second
3	1404-1435	31	1.6	First
4	1437-1449	12	2.3	First

Table 24. Area Samples for Formaldehyde During Open-Bay Urea Formaldehyde Foam Insulation Application on December 12, 1979[a]

Sample #	Sampling Period (On-Off)	(min)	Concentration (ppm)	Floor
1	1237-1309	32	0.89	Second
2	1310-1340	30	1.1	Second
3	1347-1427	40	0.57	First
4	1427-1449	22	1.2	First

[a] Taken near room center.

Table 25. Formaldehyde Measurements Using Draeger Detector Tubes

Sample #	Date	Tube	Location/Activity	Concentration (ppm)
1	9/17/79	0.5/a	Front of van prior to leaving warehouse	N.D.[a]
2	9/17/79	0.002	Back of van while resin and foaming agent were circulating	N.D.[b]
3	9/17/79	0.5/a	Back of van while resin and foaming agent were circulating	N.D.[a]
4	9/17/79	0.002	Foam Mechanic's breathing zone while forming a foam cube for density test	N.D.[b]
5	9/17/79	0.002	Foam Mechanic's breathing zone during urea formaldehyde foam application – exterior retrofit	N.D.[b]
6	9/17/79	0.5/a	In house during urea formaldehyde foam application	N.D.[a]
7	9/18/79	0.5/a	Back of van while resin and foaming agent were circulating	N.D.[a]
8	9/18/79	0.002	Back of van during foam application	N.D.[b]
9	9/18/79	0.002	Foam Mechanic's breathing zone during urea formaldehyde foam application – exterior retrofit	N.D.[b]
10	9/18/79	0.002	Back of van upon returning to warehouse	2-5
11	12/6/79	0.5/a	Foam Mechanic's breathing zone while cleaning application gun in back of van	[c]
12	12/10/79	0.5/a	Foam Mechanic's breathing zone during urea formaldehyde foam application – exterior retrofit	N.D.[a]
13	12/10/79	0.5/a	Back of van shortly after density test	N.D.[a]
14	12/10/79	0.002	Resin drum air space	2
15	12/11/79	0.5/a	Back of van upon return to warehouse prior to removal of trash	4-7
16	12/11/79	0.5/a	Back of van after servicing by Warehouseman	0.7-1
17	12/11/79	0.5/a	Back of truck while Warehouseman removed trash	0.7-1
18	12/11/79	0.5/a	Back of van after servicing by Warehouseman	0.7-1
19	12/12/79	0.5/a	Foam Mechanic's breathing zone during open-bay urea formaldehyde foam application – measurement was made near the time of completion of the second floor	4
20	12/12/79	0.5/a	Foam Mechanic's breathing zone during open-bay urea formaldehyde foam application – measurement was made near the time of completion of the first floor	0.7-1

[a] <0.5 ppm - the manufacturer states that this value is the lower limit of reliable detection.

[b] <1.6 ppm - the manufacturer states that this value is the lower limit of reliable detection.

[c] **A pink stain, not as intense as the standard, developed after 16 strokes.**

Table 26. Ammonia Measurements Using Draeger 5/a Detector Tubes

Sample #	Date	Location/Activity	Concentration (ppm)
1	9/17/79	Back of van during formation of a cube for foam density determination	N.D.[a]
2	9/17/79	Foam Mechanic's breathing zone during urea formaldehyde foam application – exterior retrofit	N.D.[a]
3	12/10/79	Back of van while resin and foaming agent were circulating	N.D.[a]
4	12/11/79	Back of van upon return to warehouse	N.D.[a]
5	12/12/79	Foam Mechanic's breathing zone during open-bay application of urea formaldehyde foam	N.D.[a]

[a] < 5 ppm - the manufacturer states that this value is the lower limit of reliable detection.

Table 27. Furfuryl Alcohol Exposures on September 18, 1979

Sample #	Sampling Period (On-Off)	Sampling Period (min)	Employee or Location	Activity	Concentration (ppm)
1	1237-1536	179	Laborer	Replacing aluminum siding	<0.3
2	1657-1835	98	Step van	Cleanup period and during trip back to warehouse	<0.6
3	1222-1532	190	Foam Mechanic	Applying urea formaldehyde foam during exterior retrofit	<0.3

Applicator B

Table 28. Exposure to Formaldehyde During Urea Formaldehyde Foam Insulation Application -- Applicator

Sample #	Date	Sampling Period Time		Concentration (ppm)
		(On-Off)	(min)	
1	11/28/79	1037-1116	39	0.10
2	11/28/79	1124-1155	31	0.80
3	11/28/79	1231-1331	60	0.58
4	11/29/79	1226-1258	32	0.45
5	11/30/79	1036-1120	44	<0.08
6	11/30/79	1150-1254	64	0.43
7	11/30/79	1305-1331	26	0.75
8	11/30/79	1450-1549	59	1.0
9	11/30/79	1608-1645	37	1.3

Table 29. Exposure to Formaldehyde During Other Activities -- Applicator

Sample #	Date	Sampling Period		Activity	Concentration (ppm)
		(On-Off)	(min)		
1	11/27/79	0946-1020	34	Cleaning application equipment; begin circulation of resin and foaming agent	0.18
2	11/27/79	1020-1103	43	Painting hole plugs in truck, while resin and foaming agent were circulating	0.18
3	11/27/79	1121-1216	55	Test-foaming; cleaning application equipment	0.07
4	11/27/79	1612-1712	60	Cleaning resin pump at shop	0.18
5	11/27/79	1837-1919	42	Test-foaming on shop floor	0.52
6	11/28/79	0915-1031	76	Cleaning application equipment; begin circulation of resin and foaming agent; on break in van	0.11
7	11/28/79	1340-1505	85	Foaming and cleanup operations	0.26
8	11/30/79	0905-1014	69	Cleaning and assembling application equipment; begin circulation of resin and foaming agent	0.06

Table 30. Exposure to Formaldehyde -- Assistant

Sample #	Date	Sampling Period		Activity	Concentration (ppm)
		(On-Off)	(min)		
1	11/27/79	1008-1104	56	Opening; asssisting in equipment preparation	0.06
2	11/27/79	1837-1920	43	Assisting Applicator during test-foaming in shop	0.37
3	11/28/79	0912-1030	78	On break in van	0.09
4	11/28/79	1124-1156	32	Closing and cleaning area	<0.09
5	11/28/79	1413-1505	52	Cleaning excess foam from inside of house; cleaning exterior area	0.26
6	11/29/79	1040-1222	102	Opening	<0.03
7	11/29/79	1234-1358	84	Opening (foaming in progress)	0.13
8	11/30/79	0903-1014	71	Opening	<0.04
9	11/30/79	1030-1240	130	Opening and wiping excess foam from wall	0.03
10	11/30/79	1304-1421	77	Assisting in foaming operation; break	0.10[a]
11	11/30/79	1450-1549	59	Assisting Applicator	<0.04
12	11/30/79	1606-1620	14	Assisting Applicator	0.50

[a] A small amount of the second impinger's contents was lost in transferring from impinger to vial; thus, true value may be slightly higher.

Table 31. Exposure to Formaldehyde During Closing Operations

Sample #	Date	Sampling Period		Concentration (ppm)
		(On-Off)	(min)	
1	11/28/79	1037-1116	39	<0.08
2	11/28/79	1248-1406	78	0.06
3	11/30/79	1459-1600	61	0.13

Table 32. Formaldehyde Concentrations in the Step Van

Sample #	Date	Sampling Period		Activity	Concentration (ppm)
		(On-Off)	(min)		
1	11/27/79	0827-0917	50	During trip to site	0.18
2	11/27/79	1144-1207	23	During foam application	0.16
3	11/27/79	1425-1509	44	Return trip from site	0.23
4	11/28/79	1043-1549	306	During foam application	0.02
5	11/29/79	0920-1242	202	While resin and foaming agent were circulating and being brought up to operating temperature	0.02
6	11/29/79	1252-1415	83	While resin and foaming agent were circulating and being brought up to operating temperature; some foam application in progress	<0.08
7	11/30/79	0808-0850	42	During trip to site	0.18
8	11/30/79	0908-1233	205	During foaming agent and resin circulation; during foam application	<0.02
9	11/30/79	1247-1437	110	During foam application	<0.03
10	11/30/79	1709-1741	32	Return trip from site	0.33

Table 33. Formaldehyde Measurements Using Draeger Detector Tubes

Sample #	Date	Tube	Location/Activity	Concentration (ppm)
1	11/27/79	0.5/a	Applicator's breathing zone while foaming in shop	[a]
2	11/27/79	0.002	Applicator's breathing zone while foaming in shop	N.D.[b]
3	11/28/79	0.5/a	Applicator's breathing zone	N.D.[c]
4	11/28/79	0.002	Applicator's breathing zone	N.D.[b]
5	11/28/79	0.5/a	Back of van during foam application	N.D.[c]
6	11/28/79	0.002	Back of van during foam application	N.D.[b]
7	11/29/79	0.5/a	Applicator's breathing zone	N.D.[c]
8	11/30/79	0.5/a	Airspace of C.P. resin drum	2

[a] A pink stain, less intense than the reference standard, developed after 16 strokes.

[b] <1.6 ppm - the manufacturer states that this value is the lower limit of reliable detection.

[c] <0.5 ppm - the manufacturer states that this value is the lower limit of reliable detection.

Table 34. Ammonia Measurements Using 5/a Draeger Detector Tubes

Sample #	Date	Location/Activity	Concentration (ppm)
1	11/27/79	Front of van during trip to site	N.D.[a]
2	11/28/79	Back of van during foam application	N.D.[a]
3	11/28/79	Applicator's breathing zone while applying foam	N.D.[a]
4	11/29/79	Applicator's breathing zone while applying foam	N.D.[a]

[a] **Non-detectable: <5 ppm; the manufacturer states that this value is the lower limit of reliable detection.**

Table 35. Survey Sound Level Readings

Location/Activity	dBA
Drilling through aluminum with a Rockwell #7556 drill	87-93
Drilling through plywood with a Rockwell #7556 drill	86-94
Drilling through pine clapboard with a Rockwell #7556 drill	92-96

Manufacturer C

Table 36. MDI Exposure for Drum Loader

Sample #	Date	Sampling Period (min)	Activities	Concentration (ppm)
1	10/24	21	Filling drums with MDI	<0.001
2	10/24	11	Filling drums with MDI	<0.002
3	10/25	16	Filling drums with MDI	<0.001
4	10/25	25	Filling drums with MDI	<0.0008
5	10/25	20	Filling drums with MDI	0.002

Table 37. Results of Area Sampling for MDI and TDI

Sample #	Date	Sampling Period (min)	Compound	Location	Concentration (ppm)
1	10/24	27	MDI	In drum-loading area	<0.0005
2	10/24	33	TDI	Inside walk-in booth	0.19
3	10/25	16	TDI	Inside walk-in booth	0.014

Table 38. TDI Exposure for Compounder B During the Compounding of a TDI Prepolymer

Sample #	Date	Sampling Period (min)	Activities	Concentration (ppm)
1	10/24	37	Adds raw materials to TDI	0.022
2	10/25	12	Adds raw materials to TDI (TDI at 50°C)	0.31
3	10/25	10	Adds raw materials to TDI (TDI at 50°C)	0.14

Table 39. Employees' Time-Weighted Average Exposure to Fluorotrichloromethane and *alpha*-Methyl Styrene

Sample #	Employee	Date	Sampling Period (min)	Activity	Concentration (ppm)	
					[a]	*alpha*-Methyl Styrene
1	Compounder A	10/24	438	Compounds Product A (a non-thermal product), withdraws sample, does paperwork at desk	96.0	<0.084
2	Compounder A	10/25	428	Compounds and drums two non-thermal products (contains no fluorotrichloromethane or *alpha*-methyl styrene	35.0	<0.085
3	Compounder B	10/25	96	Compounds Product B (a thermal insulation product)	94.0	<0.52
4	Blender	10/25	357	Operates blending equipment (Product B)	3.5	<0.78
5	Blender	10/25	344	Maintenance of equipment, general cleanup, paperwork	0.95	<0.13
6	Quality Control Tecn'ian.	10/24	312	Conducts quality control tests at blending operation	6.4	<0.15
7	Drum Handler	10/24	92	Supplies drums to blending operation fill station, seals and weighs drums	6.8	<0.37

[a]Fluorotrichloromethane

Table 40. Results of Area Samples for Fluorotrichloromethane and *alpha*-Methyl Styrene

Sample #	Date	Sampling Period (min)	Location	Concentration (ppm)	
				[a]	*alpha*-Methyl Styrene
1	10/24	286	In compounding room on loading platform adjacent to compounding vessel	113.0	<0.16
2	10/24	415	Near drum fill station at blending operation	3.9	<0.67
3	10/25	89	In compounding room near compounding vessel	110.0	<0.52
4	10/25	94	In compounding room near compounding vessel	321.0	<0.37

[a]Fluorotrichloromethane

Table 41. Employees' Time-Weighted Average Exposure to Dimethylethanolamine (DMEA) and Dimethylcyclohexylamine (DMCHA)

Sample #	Employee	Date	Sampling Period (min)	Activity	Concentration (ppm)	
					DMEA	DMCHA
1	Compounder A	10/24	289	Compounds Product A (does not contain amines) withdraws sample, does paperwork at desk	<0.02	<0.007
2	Compounder B	10/25	96	Compounds Product B	<0.14	0.62
3	Blender	10/24	262	Operates blending equipment (Product B)	0.17	0.45
4	Blender	10/24	93	Operates blending equipment (Product B)	0.11	0.81
5	Quality Control Tech'ian.	10/24	215	Conducts quality control tests at the blending operation	<0.064	0.061
6	Quality Control Tech'ian.	10/24	99	Conducts quality control tests at the blending operation	<0.13	0.11
7	Drum Handler	10/24	195	Supplies drums to the blending operation fill station, seals and weighs drums	<0.073	0.054
8	Drum Handler	10/24	99	Supplies drums to the blending operation fill station, seals and weighs drums	<0.15	0.20
9	Blender	10/25	259	Maintenance of equipment, general cleanup	<0.095	0.056
10	Blender	10/25	95	General cleanup in blending equipment area, paperwork	<0.22	<0.077

Table 42. Results of Area Samples for DMEA and DMCHA

Sample #	Date	Sampling Period (min)	Location	Concentration (ppm)	
				DMEA	DMCHA
1	10/24	286	In compounding room near compounding vessel	<0.075	<0.026
2	10/24	94	In compounding room near compounding vessel	<0.085	0.20
3	10/24	250	Near drum fill station at blending operation	0.31	0.57
4	10/24	111	Near drum fill station at blending operation	0.25	0.11

Table 43. Blender -- Time-Weighted Average Exposure to Methylene Chloride

Sample #	Date	Sampling Period (min)	Activity	Concentration (ppm)
1	10/25	344	Maintenance of equipment, general cleanup (including washing floor with solvent), paperwork	11.0

Manufacturer D

Table 44. Air Velocity of Hoods

Drum-Fill Station	Velocity (fpm)	Air Flow (cfm)
#1[a]	150	265
#2[a]	160	280
#3[a]	120	210
#4	130	230
#5[a]	130	230
MDI-TDI	125	220

[a] Hood used for drum-filling operations during the survey.

Table 45. Chemical Operator's Exposure to MDI During Drum-Filling Operations

Sample #	Date	Drum-Fill Station	Product	Sampling Period (min)	Comment	Concentration (ppm)	Sampling Period TWA[a]
1	10/31	MDI	MDI	21	LEV[b] not used	<0.0008	0.0023
2	"	"	"	24	"	<0.0008	
3	"	"	"	30	"	0.0029	
4	"	"	"	31	"	0.0028	
5	"	"	"	37	"	0.0050	
6	"	"	"	63	"	0.0014	
7	10/31	#5	MDI blend	25	LEV used	<0.0007	0.0011
8	"	"	"	41	"	0.0018	
9	"	"	"	33	"	<0.0006	
10	11/1	#3	MDI blend	60	LEV used	<0.0003	0.0005
11	"	"	"	60		<0.0003	
12	"	"	"	32	"	0.0023	
13	"	"	"	111	"	<0.0002	
14	11/1	MDI	MDI	73	LEV not used	<0.0003	0.0004
15	"	"	"	104	"	0.0006	

[a] TWA includes sample concentrations have (<) designations.

[b] LEV = Local Exhaust Ventilation.

Table 46. Results of Area Samples for MDI During Drum-Filling Operations

Sample #	Date	Sampling Period (min)	Location	Concentration (ppm)
1	10/31	24	Near MDI fill station	<0.0008
2	"	24	"	<0.0008
3	"	30	"	0.0015
4	"	31	"	0.0028
5	"	40	"	0.0039
6	"	62	"	0.0007
7	10/31	42	Near #5 fill station	0.0011
8	"	27	"	0.0011
9	11/1	57	Near #3 fill station	0.0008
10	"	128	"	0.0002
11	11/1	51	Near MDI fill station	0.0009

Table 47. Chemical Operator's Exposure to Amine Compounds During Resin-Blending Operations

Sample #	Date	Drum-Fill Station	Sampling Period (min)	Activity	Concentration (ppm)			
					Tetramethyl-butane-diamine	Triethylene-diamine	Dimethyl-ethanolamine	Dimethyl-cyclohexyl-amine
1	10/31	#2	374	Operator blends and drums resin #1[a] and blends resin #2 (both are nonthermal products) LEV was used during filling of drums	[b]	[b]	<0.017	0.018
2	10/31	#4	337	Operator blends and drums resin #1, starts blending resin #3 (a thermal insulation product)	[b]	<0.026	[b]	<0.009
3	11/1	#6	306	Operator blends, then drums resin #4, starts blending resin #5 (both are nonthermal products)	<0.056	[b]	<0.021	0.063
4	11/1	#4	315	Operator finishes blending resin #3, then drums finished product	[b]	<0.015	[b]	<0.005
5	11/1	#2	258	Operator drums resin #2	[b]	[b]	<0.033	<0.012

[a] Product numbers have been arbitrarily assigned to the resin, due to the proprietary nature of these products.

[b] Amine compound not present in the products being blended at this location.

Table 48. Results of Area Samples for Amine Compounds During Resin-Blending Operations

Sample #	Date	Sampling Period (min)	Location	Concentration (ppm)			
				Tetramethyl-butane-diamine	Triethylene-diamine	Dimethyl-ethanolamine	Dimethyl-cyclohexyl-amine
1	10/31	270	Near #4 blend/drum station	*a*	<0.024	*a*	0.021
2	11/1	326	Near #4 blend/drum station	*a*	<0.026	*a*	<0.009

[a] Compound not in use at this location.

Table 49. Chemical Operator's Exposure to Fluorotrichloromethane and *alpha*-Methyl Styrene

Sample #	Date	Drum-Fill Station	Sampling Period (min)	Activity	Concentration (ppm)	
					Fluorotri-chloromethane	*alpha*-Methyl Styrene
1	10/31	#1	374	Operator blends and drums resin #1 and blends resin #2 (both are non-thermal products), LEV was used during filling of drums	4.4	<0.088
2	10/31	#4	337	Operator blends, then drums resin #1, starts blending resin #3 (a thermal insulation product)	15.0	<0.160
3	11/1	#6	306	Operator blends, then drums resin #4, starts blending resin #5 (both are nonthermal products)	193.0	<0.120
4	11/1	#4	315	Operator finishes blending, then drums resin #3	6.6	<0.200
5	11/1	#2	258	Operator finishes blending, then drums resin #2, LEV was used	7.5	<0.220

Table 50. Results of Area Samples for Fluorotrichloromethane and *alpha*-Methyl Styrene

Sample #	Date	Sampling Period (min)	Location	Concentration (ppm)	
				Fluorotri-chloromethane	*alpha*-Methyl Styrene
1	10/31	270	Near #4 blend/drum fill station	46.0	<0.13
2	11/1	326	Near #4 blend/drum fill station	5.5	<0.14

Applicator C

Table 51. Exposure to MDI -- Applicator

Sample #	Date	Sampling Period (On-Off)	(min)	Activity	Concentration (ppm)	Sampling Period TWA (ppm)[a]
1	11/19/79	0952-1103	65	Cleaning/assembling spray gun and spraying foam	0.0010	
2	11/19/79	1103-1124	21	Spraying foam	0.0090	
3	11/19/79	1124-1210	46	Spraying foam	0.0015	
4	11/19/79	1329-1501	92	Spraying foam (includes 50-min downtime)	0.0010	
5	11/19/79	1501-1521	20	Spraying foam under gutter	<0.0025	
6	11/19/79	1606-1617	11	Spraying foam under gutter	<0.0045	0.0020
7	11/20/79	1100-1129	29	Cleaning/assembling spray gun and waiting for roof to dry--no spraying	<0.0017	
8	11/20/79	1155-1230	35	Spraying foam	<0.0013	
9	11/20/79	1324-1354	30	Spraying foam	<0.0017	
10	11/20/79	1354-1420	26	Spraying foam	0.0022	
11	11/20/79	1420-1430	10	Spraying foam	<0.0050	
12	11/20/79	1430-1441	11	Spraying foam	<0.0045	
13	11/20/79	1441-1452	11	Spraying foam	<0.0045	
14	11/20/79	1452-1502	10	Spraying foam	<0.0050	
15	11/20/79	1502-1513	11	Spraying foam	<0.0045	
16	11/20/79	1532-1618	46	Spraying foam (includes cleanup)	0.0053	0.0031

[a] TWA includes sample concentrations having (<) designations.

Table 52. Exposure to MDI -- Helper

Sample #	Date	Sampling Period (On-Off)	(min)	Activity/Location	Concentration (ppm)	Sampling Period TWA (ppm)[a]
1	11/19/79	1003-1105	62	Setting up hoses and helping Applicator on the roof	<0.0010	
2	11/19/79	1105-1214	69	Cleaning roof (distant to spraying operation)	<0.0010	
3	11/19/79	1358-1455	57	Cleaning roof and general cleanup on the ground	<0.0010	
4	11/19/79	1455-1617	82	Helping Applicator on roof and applying foam	0.0015	0.0011
5	11/20/79	1101-1131	30	Cleaning roof (distant to spraying operation	<0.0016	
6	11/20/79	1152-1235	43	Helping Applicator on roof	<0.0010	
7	11/20/79	1324-1353	29	Inside truck monitoring equipment	0.0019	
8	11/20/79	1353-1440	47	Inside truck monitoring equipment	<0.0010	
9	11/20/79	1440-1450	10	Inside truck monitoring equipment	<0.0050	
10	11/20/79	1450-1500	10	Helping Applicator on roof	<0.0050	
11	11/20/79	1532-1617	45	Helping Applicator and cleanup	<0.0011	0.0016

[a] TWA includes sample concentrations having (<) designations.

Table 53. Employee Exposure to Fluorotrichloromethane and *alpha*-Methyl Styrene

Sample #	Employee	Date	Sampling Period (min)	Concentration (ppm)	
				fluoro-trichloro-methane	*alpha*-methyl styrene
1	Applicator	11/19/79	312	13.0	<0.17
2	Helper	11/19/79	314	2.5	<0.24
3	Applicator	11/20/79	281	1.6	<0.15
4	Helper	11/20/79	283	5.6	<0.49

Table 54. Employee Exposure to Amine Compounds

Sample #	Employee	Date	Sampling Period (min)	Concentration (ppm)	
				dimethyl-ethanolamine	dimethyl-cyclohexylamine
1	Applicator	11/19/79	209	<0.016	0.17
2	Helper	11/19/79	314	<0.011	0.017
3	Applicator	11/20/79	281	<0.008	0.025
4	Helper	11/20/79	283	<0.025	<0.017

Table 55. Applicator's Exposure to Dimethyltin Dicarboxylate[a]

Sample #	Date	Sampling Period (min)	Concentration (mg/m^3)
1	11/19/79	244	<0.027
2	11/20/79	281	<0.023

[a] Reported as tin.

Table 56. Sound Level Readings -- November 20, 1979

Time	Location	Sound Level (dBA)
1230	Inside truck at the desk	93-94
1230	Inside truck, approximately 2½' from the compressor	101-102
1400	Inside truck at the employee's ear	96-97

Table 57. Results of Detector Tube Sampling for Carbon Monoxide -- November 20, 1979

Time	Location	Concentration (ppm)
1215	Inside truck at the desk	30
1220	Inside truck near the compressor	50

Applicator D

Table 58. Exposure to MDI During Foam Application Process -- Mechanic

Sample #	Date	Sampling Period (On-Off)	Sampling Period (min)	Concentration (ppm)	Sample Period TWA (ppm)[a]	Total Work Shift (hr)
1	12/19/79	1014-1102	43	<0.0023		
2	12/19/79	1102-1137	35	0.0200		
3	12/19/79	1210-1220	10	0.0680		
4	12/19/79	1220-1232	12	0.0410		
5	12/19/79	1334-1404	35	0.0530		
6	12/19/79	1409-1447	38	0.0440		
7	12/19/79	1447-1515	28	0.0630	0.0361	9
8	12/20/79	0801-0840	39	0.0150		
9	12/20/79	1522-1601	39	0.0550		
10	12/20/79	1601-1611	10	0.0390		
11	12/20/79	1611-1619	8	<0.0120	0.0335	10
12	12/21/79	0732-0808	36	0.0300		
13	12/21/79	0808-0819	11	<0.0089		
14	12/21/79	0819-0900	41	0.0140		
15	12/21/79	0900-0912	12	<0.0081		
16	12/21/79	0912-0946	34	0.0430	0.0247	6

[a] TWA includes sample concentrations having (<) designations.

Table 59. Exposure to MDI During Foam Application Process -- Helper

Sample #	Date	Sampling Period (On-Off)	Sampling Period (min)	Concentration (ppm)	Sample Period TWA (ppm)[a]	Total Work Shift (hr)
1	12/19/79	1016-1058	42	0.0047		
2	12/19/79	1058-1137	39	0.0075		
3	12/19/79	1137-1220	43	0.0091		
4	12/19/79	1220-1231	11	<0.0089		
5	12/19/79	1334-1409	35	0.0200		
6	12/19/79	1409-1447	38	0.0280		
7	12/19/79	1447-1515	28	0.0240	0.0144	9
8	12/20/79	0801-0842	41	0.0048		
9	12/20/79	1113-1259	106	0.0018[b]		
10	12/20/79	1541-1553	12	<0.0081	0.0030	10
11	12/21/79	0738-0830	52	0.0056		
12	12/21/79	0830-0900	30	0.0065		
13	12/21/79	0900-0932	32	0.0092	0.0068	6

[a] TWA includes sample concentrations having (<) designations.

[b] Helper's exposure during downtime.

Table 60. Area Samples for MDI -- December 19, 1979

Sample #	Sampling Period (On-Off)	Sampling Period (min)	Location	Concentration (ppm)
1	1038-1136	58	Attached to scaffold underneath spraying operation; includes 20 minutes of downtime	0.045
2	1136-1221	45	Attached to scaffold during spraying	0.069
3	1221-1338	77	Attached to scaffold; 20 to 25 feet from spraying operation	0.062
4	1338-1513	95	Attached to scaffold; 20 to 50 feet from spraying operation	0.020

Table 61. Employee Exposure to Amine Compounds

Sample #	Employee	Date	Sampling Period (On-Off)	Sampling Period (min)	Concentration (ppm) Dimethylcyclohexylamine	Concentration (ppm) Triethylenediamine
1	Helper	12/19/79	1003-1520	317	0.13	<0.030
2	Mechanic	12/19/79	1005-1515	310	0.38	0.070
3	Helper	12/20/79	0749-1540	472	<0.008	<0.020
4	Mechanic	12/20/79	0801-0840/ 1050-1520	309	<0.016	<0.045
5	Helper	12/21/79	0808-0932	84	0.13	<0.10
6	Mechanic	12/21/79	0726-0946	140	0.48	<0.25

Table 62. Employee Exposure to Fluorotrichloromethane and *alpha*-Methyl Styrene

Sample #	Employee	Date	Sampling Period (On-Off)	Sampling Period (min)	Concentration (ppm) Fluorotrichloromethane	Concentration (ppm) *alpha*-Methyl Styrene
1	Helper	12/19/79	1003-1520	317	33	<0.062
2	Mechanic	12/19/79	1005-1515	310	105	0.17
3	Helper	12/21/79	0731-0932	121	77	<0.17
4	Mechanic	12/21/79	0726-0946	140	180	0.21

Table 63. Employee Exposure to 2-Ethoxyethanol -- December 29, 1979

Sample #	Employee	Sampling Period (On-Off)	Sampling Period (min)	Concentration (ppm)	8-hr TWA (ppm)
1	Helper	0749-1540	471	62	61
2	Mechanic	0801-0849/ 1050-1520	309	129	83

Table 64. Mechanic's Exposure to Proprietary Organotin Compound

Sample #	Date	Sampling Period		Concentration (mg/m^3, as Sn)
		(On-Off)	(min)	
1	12/19/79	1102-1513	252	<5.2
2	12/21/79	0912-0946	34	<38.0

Table 65. Mechanic's Exposure to Total Particulate

Sample #	Date	Sampling Period		Concentration (mg/m^3)
		(On-Off)	(min)	
1	12/19/79	1137-1206	29	6.9
2	12/19/79	1210-1515	185	5.4
3	12/20/79	1522-1620	58	6.9
4	12/21/79	0735-0912	97	4.1

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