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IN-DEPTH SURVEY REPORT:

CONTROL TECHNOLOGY FOR NEW PLASTICS PROCESSES

AT

HERMAN MILLER COMPANY

HOLLAND, MICHIGAN

REPORT WRITTEN BY:

William F. Todd
Dennis M. O'Brien

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

PLANT SURVEYED: Herman Miller Company

SIC CODE: Furniture, Metal Office (2522)

SURVEY DATE: May 1, 1984

SURVEY CONDUCTED BY:
William F. Todd
Dennis M. O'Brien
John C. Frede

EMPLOYER REPRESENTATIVES CONTACTED:
Dale Bilby, Maintainence Supervisor
Lloyd Budnick, Safety Supervisor
Larry Howard, Manager, Manufacturing Engineering
Jim Huisingh, Manager, Operation Services
Fred Gordon, Industrial Hygiene Technician
David Nestle, Urethane Technical Supervisor

EMPLOYEE REPRESENTATIVES CONTACTED: None

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I. INTRODUCTION

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

Since 1976, ECTB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial processes, or specific control techniques. The objective of each of these studies has been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures.

These studies involve a number of steps or phases. Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concepts or techniques. Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures. Ultimately, the information from these research activities builds the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury.

This survey report covers an in-depth survey of a manufacturing plant. This survey was conducted to familiarize the investigators with the reaction injection molding process, to understand the potential of these operations for exposure to air contaminants, and to observe and evaluate the control measures employed to prevent the overexposure of workers to toluene-2, 4-diisocyanate (TDI) and methylene bisphenyl isocyanate (MDI).

II. PLANT AND PROCESS DESCRIPTION

Plant Description:

This is a modern facility about 5 years old. The plant is designed to utilize modern production methods which result in a smooth flow of materials. The products have two components which are composed of polyurethane polymers. Some models are metal covered with a hard polyurethane foam and parts are made of a soft polyurethane foam formed on plywood. The plant is well lighted to create a pleasant and comfortable work environment.

Process Description:

The polyurethane molding operations were of interest in this survey. There are two resin molding areas which are contained in an area of the plant measuring about 60' by 100'. The area is open except for a room designed to contain resin mixing and pumping operations.

One molding area contains the reaction injection molding operation which forms hard polyurethane resin foam onto "s" shaped metal components and is contained in a semicircular area about 15 to 20 feet across. It contains 6 mold presses and 8 molds. This area is shown in Figure 1. The presses have high pressure self-cleaning heads for the mixing and injection of the polyol and isocyanate components and operate on a 4 minute cycle. After molding, the parts are deflashed and trimmed. This area has ventilation hoods which are for the purpose of removing light hydrocarbon vapors released from the mold release compound when it is sprayed on the molds. The pump and mixing apparatus are located adjacent to the molding head area which is not enclosed. Area samples were obtained as located in Figure 1.

The soft resin (foam) area is about 60 feet from the hard resin foam area. Parts are molded around plywood support structures. This area uses two types of resin mixing heads: an airless, high-pressure impingement mixing, self-cleaning cylinder head, which generates little isocyanate emissions. The Henneke, high-pressure air, spin-disk, impingement mixer in which injection is initiated with pressure-activated needle valves. The cleaning of the air nozzle generates considerable blow-off of isocyanate contaminated air when the head is purged of resin by "shooting" into a waste container. These work areas are shown in Figure 2.

The resin for the foaming area is mixed and pumped from the Pump Room. This room is a potential source of isocyanate exposure so an area sample was obtained at this location, shown in Figure 2.

Potential Hazards:

The use of polyurethane resins in this plant creates a hazard of potential exposure to methylene bisphenyl isocyanate (MDI) and toluene-2, 4-diisocyanate (TDI). These two compounds fall in a category of diisocyanate compounds that can irritate the respiratory tract and can act as respiratory sensitizers to produce asthma-like symptoms in individuals with exposure at very low concentrations well below the permissible exposure limit (PEL) of 0.02 ppm. Exposure to diisocyanates may also result in chronic impairment of pulmonary function.[1] The summary of the legal and recommended levels for diisocyanates and their health effects appear in Table I.

Table I. Summary of hazards associated with the production of polyurethane chair components

Materials or Agents	PEL[1] (ppm)	TLV[2] (ppm)	NIOSH[3] Recommended Level (ppm)	Major[1,2,3] Health Effects
TDI	0.02	0.02	0.005	Respiratory sensitizers: asthma and bronchitis
MDI	0.02	0.02	0.005	"

1. Permissible Exposure Limit; this is the legally enforceable standard
2. Threshold Limit Value, 8 hour TWA; This is a level recommended by the American Conference of Governmental Industrial Hygienists
3. Occupational Exposure to Diisocyanates, Criteria for a Recommended Standard, DHEW (NIOSH) Publication No. 78-215

Ref. 1.: United States Department of Health, Education and Welfare, NIOSH, Occupational Exposure to Diisocyanates, DEWH (NIOSH) publication # 78-215, September 1978

III. METHODOLOGY

MEASUREMENT OF CONTROL PARAMETERS

Hood control velocities and spray booth face velocities were measured using a Kurz hot wire anemometer. Volumetric airflow was determined from the average face velocity multiplied by the open area of the hood.

SAMPLING PROCEDURES

To evaluate potential exposures, samples for MDI, TDI, and total isocyanate were collected in locations of possible escape or leakage. Samples were collected for a nominal four hour period using personal sampling pumps operated at 1 lpm and midget impingers filled with 15 ml of sampling reagent. The reagent consisted of a solution of 1-(2-methoxyphenyl)-piperazine in toluene. To minimize evaporation of the toluene the impinger was place in ice. A second impinger was filled with charcoal and placed between the first impinger and the sampling pump to prevent solvent escape. At the conclusion of sampling the reagent was transfered to 20 ml scintillation vials for transport to the NIOSH laboratory. The samples were analyzed using NIOSH method 5505. This method is used to determine the total concentration of the isocyanate group, regardless of the molecule to which it is attached, by measuring the consumption of 1-(2-methoxyphenyl)-piperazine. Monomeric isocyanate can be individually determined with this sampling reagent. The concentration of the urea derivative and the 1-(2-methoxyphenyl)-piperazine are determined using high pressure liquid chromatography (HPLC). Initial analysis of the samples was performed to determine total reactive isocyanates and screen for the presence of TDI or MDI. Samples which contained peaks matching retention times of the TDI or MDI urea derivatives were then quantitated using standards of the appropriate urea derivative.

Seven samples were collected using a filter which had been coated with 1-(2-methoxyphenyl)-piperazine. The primary purpose of this set of samples was to compare this procedure with the standard impinger technique. Six of these samples were collected in parallel with the impinger samples. Plant sampling data had indicated that the foam fill operator's exposure was significantly higher than the area samples for that location. Thus, a single treated filter sample was collected as a personal sample on the foam fill operator. The treated filter samples were collected at a flowrate of 200 cc/m for a period of one hour. The analytical procedure was similar to that reported for the impinger samples.

IV. CONTROL TECHNOLOGY

INTRODUCTION - PRINCIPLES OF CONTROL

Occupational exposures can be controlled by the application of a number of well-known principles, including engineering measures, work practices, personal protection, and monitoring. In general, a system comprised of the above control measures is required to provide worker protection under normal operating conditions as well as under conditions of process upset, failure and/or maintenance. These principles of control apply to all situations, but their optimum application varies from case-to-case. The application of these principles are discussed below.

LOCAL EXHAUST VENTILATION

Foam fill booth--

Foam cushions were filled with a TDI-based polyurethane foam in a conventional spray booth exhausted at approximately 9500 cfm. The booth measured 7 feet high, 12 feet wide, and 4.5 feet deep.

Crush and glue table--

After removal from the molds, the cushions are manually crushed to alter the foam cell structure, and an isocyanate-based adhesive applied to critical areas. Isocyanate vapors are controlled by ventilating the table area by a six inch wide slot hood running the full length of the table. The hood was exhausted at a rate of approximately 2900 cfm.

Mold machine hoods--

The reaction injection molding machines were ventilated primarily to contain mist produced during the spraying of mold release agent (a proprietary blend of waxes in an aliphatic hydrocarbon solvent). Three canopy hoods ventilated this process. The hoods were arranged in a "U" pattern, above the molding machines. The canopy hoods were tilted at an angle of 45° from the horizontal, with mist eliminating filters mounted in the hood face to capture the mold release agent. Each hood had a face area of about 28 square feet. Total airflow from the three hoods was 18,700 cfm, which resulted in air velocities at the front of the mold machines (a point about 3 feet from the hood face) ranging from 40 to 100 fpm.

ISOLATION

Pumps and mix tanks for the foam cushion line were isolated in a 24 x 28 ft room designated by the plant as a limited access area. The room was ventilated with 100% outside air at a rate reported by the plant of 30 air changes/hour (about 3300 cfm).

PERSONAL PROTECTIVE EQUIPMENT

Due to the nature of the mold filling task, the foam fill operator is required to work within the confines of the booth. The foaming equipment produces a visible foam aerosol which is released from the mold cavity with a considerable velocity. This necessitates the use of an air supplied helmet by this operator, as is the current practice in this plant.

CONTROL MONITORING

TDI vapors are monitored near the foam fill booth and in the pump room by two MDA Scientific Model 7005 Tape Monitors connected to chart recorders. Carbon monoxide in the breathing air supplied to the foam fill operator is monitored by a Dynamation CO Monitor.

The company has extensive sampling data on TDI dating to 1981. The samples have been collected by their staff industrial hygienist (with the analytical work performed by an AIHA accredited laboratory), their insurance carrier, and the State Department of Public Health. The bulk of the data is from 1981. Early that year airborne TDI concentrations exceeded 0.02 ppm in 4 of the 5 operations studied. A program was initiated to increase the plant make-up air and raise the exhaust stacks. This resulted in a reduction in airborne TDI to the range of 0.005 to 0.010 ppm. A January, 1984 survey of the plant found high levels of TDI (0.09 and 0.05 ppm) in the breathing zone of the foam fill operator, outside of the air supplied respirator. No MDI was was detected in the reaction injection molding (RIM) operations. In April, 1984, after the face velocity was increased at the point of operation, a study by the Department of Health found levels of TDI at .0032 and .0137 ppm in the breathing zone of the foam fill operator, both of which are below the P.E.L.

V. SAMPLING RESULTS

The results of the area air sampling are presented in Table II. All but one of the samples were below the limits of quantitation (LOQ) for TDI. The single quantifiable sample was located in the pump room. Even in this case the concentrations was about one half the maximum concentration recommended by NIOSH and by the ACGIH, and less than twenty percent of the OSHA PEL. No MDI was detected in any of the samples collected in this plant. Measurable levels of total unreacted isocyanate were found in the foam filling and mold opening operations. There are no U. S. standards for exposure to total unreacted isocyanate (NCO); 20 ug (NCO)/m^3 is recommended in the United Kingdom.

TDI was detected in the personal filter sample, but instrument detector problems precluded quantification. For the purpose of method development, the filter samples are being stored for later analysis after the detector is repaired. Because of the unknown shelf life of these samples, the data will not be included in this report.

VI. CONCLUSIONS AND RECOMMENDATIONS

1. In the course of normal operations, the RIM molding operation appears to be inherently free from isocyanate hazard due to the use of MDI and the relatively closed nature of the process. The ventilation provided for the mold release agent should minimize exposure in the unlikely event of a process upset.

2. The foam filling processes used have a hazardous potential. While the spray booth appears to contain the hazard to the actual filling area, it may be inadequate in protection of the filling operator. An airless foam filling system used on another line produced no visible aerosol, and would appear to present a logical choice for new installations. Installation of such a system on the other line would be desirable, but, according to plant officials, would require retooling to provide for adequate filling of the molds.

3. Ventilation of the modular line could be improved in two areas. The plenum on the gluing table does not distribute air properly. Guidelines for plenum design can be found in <u>Industrial Ventilation: A Manual of Recommended Practice</u>. They suggest that for proper air distribution that the slot velocity should be twice that of the plenum velocity. The odor of amines, presumably from the curing cushions, was evident in the demolding area. One of two samples containing quantifiable levels of unreacted isocyanate were collected in this area. A sheet metal tunnel could be constructed to contain the molds until they are ready for opening. If this tunnel were connected to the spray booth exit, it is possible that no additional exhaust to the tunnel would be required.

4. Because the foam filling operator works with the emission point in his hands, the monitoring of this operation using area samples underestimates the worker's exposure. Unfortunately, the use of solvent filled impingers is not very practical for personal sampling of long term exposures. The use of the coated filters is convenient, but these filters may underestimate concentrations if the isocyanate is contained in a complex aerosol matrix. NIOSH should consider developing a gel-filled impinger holster, which could be frozen to minimize evaporation of the volatile solvents.

5. The airborne concentration corresponding to the limit of quantitation (LOQ) of the NIOSH method for total unreacted isocyanate is well above the standard recommended for total isocyanates in the United Kingdom. This procedure needs additional refinement to reduce the LOQ by a factor of at least three.

TABLE II
RESULTS OF AIR SAMPLES (IMPINGER) FOR TDI, MDI, AND TOTAL ISOCYANATE

May, 1984

AREA	LOCATION	SAMPLE		PERIOD		RATE	VOLUME	TDI	TDI	MDI	MDI	TOTAL ISOCYANATE	
		No.	DATE	START	STOP	(lpm)	(liters)	(ug)	ug/m^3	(ug)	ug/m^3	(umoles)	ugNCO/m^3
RIM	Machine D2193	01	5/2	0730	1434	1.02	432	N.Q.	1.9*	N.D.	1.5*	N.Q.	60*
RIM	Machine D2180	02	5/2	0732	1433	1.03	434	N.Q.	1.9*	N.D.	1.5*	N.Q.	60*
RIM	Operator table	03	5/2	0737	1435	1.03	431	N.Q.	1.9*	N.D.	1.5*	N.Q.	60*
RIM	Pump area	04	5/2	0739	1436	1.05	438	N.Q.	1.9*	N.D.	1.5*	N.Q.	60*
RIM	Operator table	11	5/3	0720	1407	1.02	415	N.Q.	1.9*	N.D.	1.5*	N.Q.	60*
RIM	Machine D2193	12	5/3	0721	1407	1.03	418	N.Q.	1.9*	N.D.	1.5*	N.Q.	60*
RIM	Machine D2180	13	5/3	0722	1407	1.04	421	N.Q.	1.9*	N.D.	1.5*	N.Q.	60*
RIM	Pump area	14	5/3	0725	1406	1.01	405	N.Q.	1.9*	N.D.	1.5*	N.Q.	60*
FOAM	Pump room	05	5/2	0743	1439	1.04	433	N.Q.	1.9*	N.D.	1.5*	N.Q.	60*
FOAM	Foam fill (L)	06	5/2	0746	1440	1.03	426	N.Q.	1.9*	N.D.	1.5*	0.98	92
FOAM	Mold opening	07	5/2	0749	1438	1.01	413	N.Q.	1.9*	N.D.	1.5*	1.02	99
FOAM	Glue table	08	5/2	0751	1438	1.04	423	N.Q.	1.9*	N.D.	1.5*	N.Q.	60*
FOAM	Modular area	09	5/2	0755	1439	1.02	412	N.Q.	1.9*	N.D.	1.5*	N.Q.	60*
FOAM	Foam fill (R)	10	5/2	0759	1440	1.02	409	N.Q.	1.9*	N.D.	1.5*	N.Q.	60*
FOAM	Mold opening	15	5/3	0728	1405	1.03	409	N.Q.	1.9*	N.D.	1.5*	N.Q.	60*
FOAM	Glue table	16	5/3	0729	1406	1.05	417	N.Q.	1.9*	N.D.	1.5*	N.Q.	60*
FOAM	Modular area	17	5/3	0730	1404	1.03	406	N.Q.	1.9*	N.D.	1.5*	N.Q.	60*
FOAM	Pump room	18	5/3	0731	1403	1.04	408	8.36	20.5	N.D.	1.5*	N.Q.	60*
FOAM	Foam fill (R)	19	5/3	0733	1404	1.02	399	N.Q.	1.9*	N.D.	1.5*	N.Q.	60*
FOAM	Foam fill (L)	20	5/3	0733	1404	1.02	399	N.Q.	1.9*	N.D.	1.5*	N.Q.	60*
NIOSH Recommendation (1978)									35		50		#
OSHA PEL (CFR 1910.1000)									140		200		#
ACGIH TLV (1983-84)									40		200		#

N.Q.: Analysis was below the limit of quantitation (LOQ), quantifiable results are underlined.
N.D.: Analysis was below the limit of detection (LOD).
* indicates "less than" the stated concentration, based on the applicable LOQ (LOD) and a sample volume of 400 l.
# there are no U. S. standards for exposure to total unreacted isocyanate; 20 ug(NCO)/m^3 is recommended in the U. K.

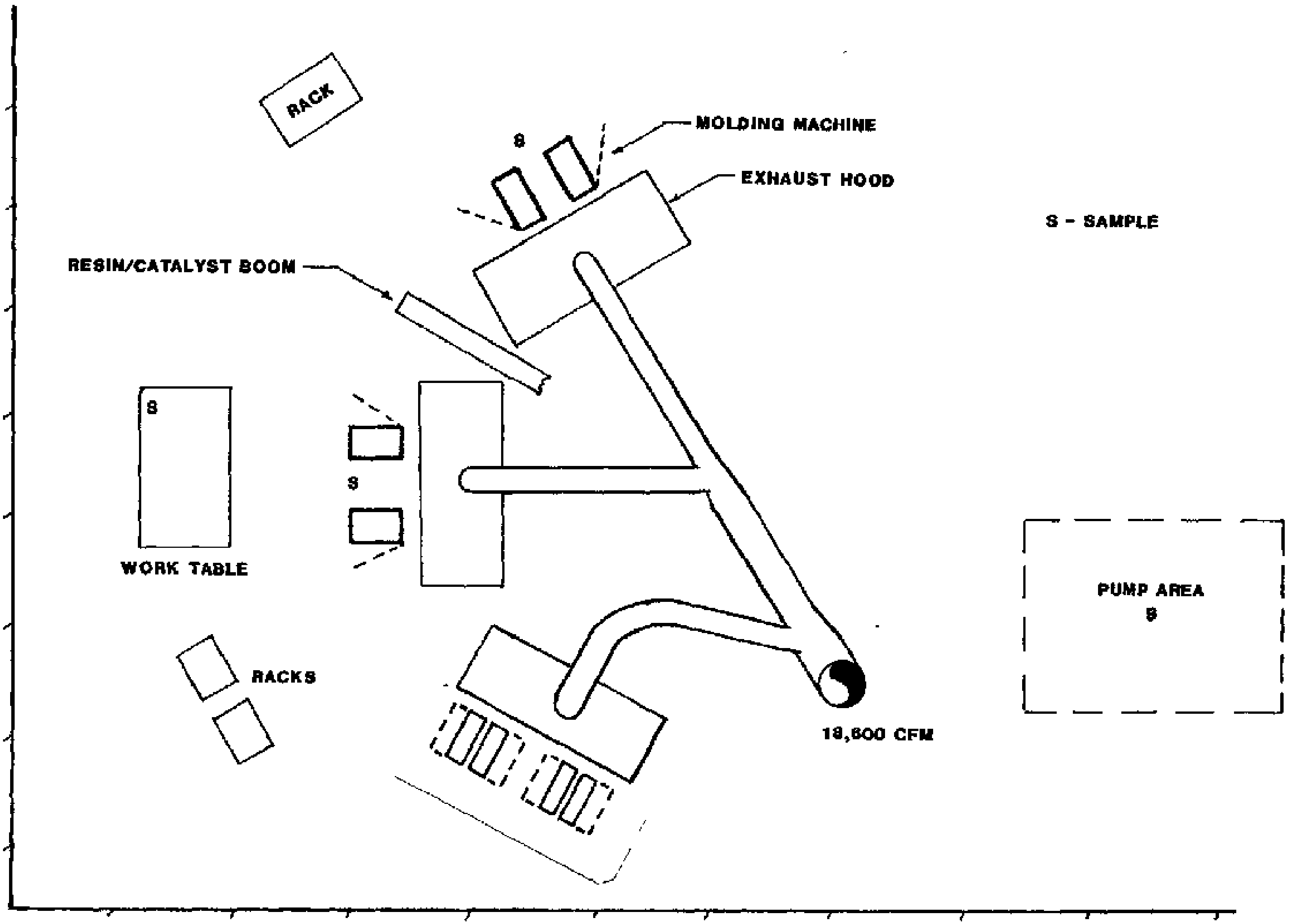

FIGURE 1. INTEGRAL SKIN FOAM MOLDING AREA

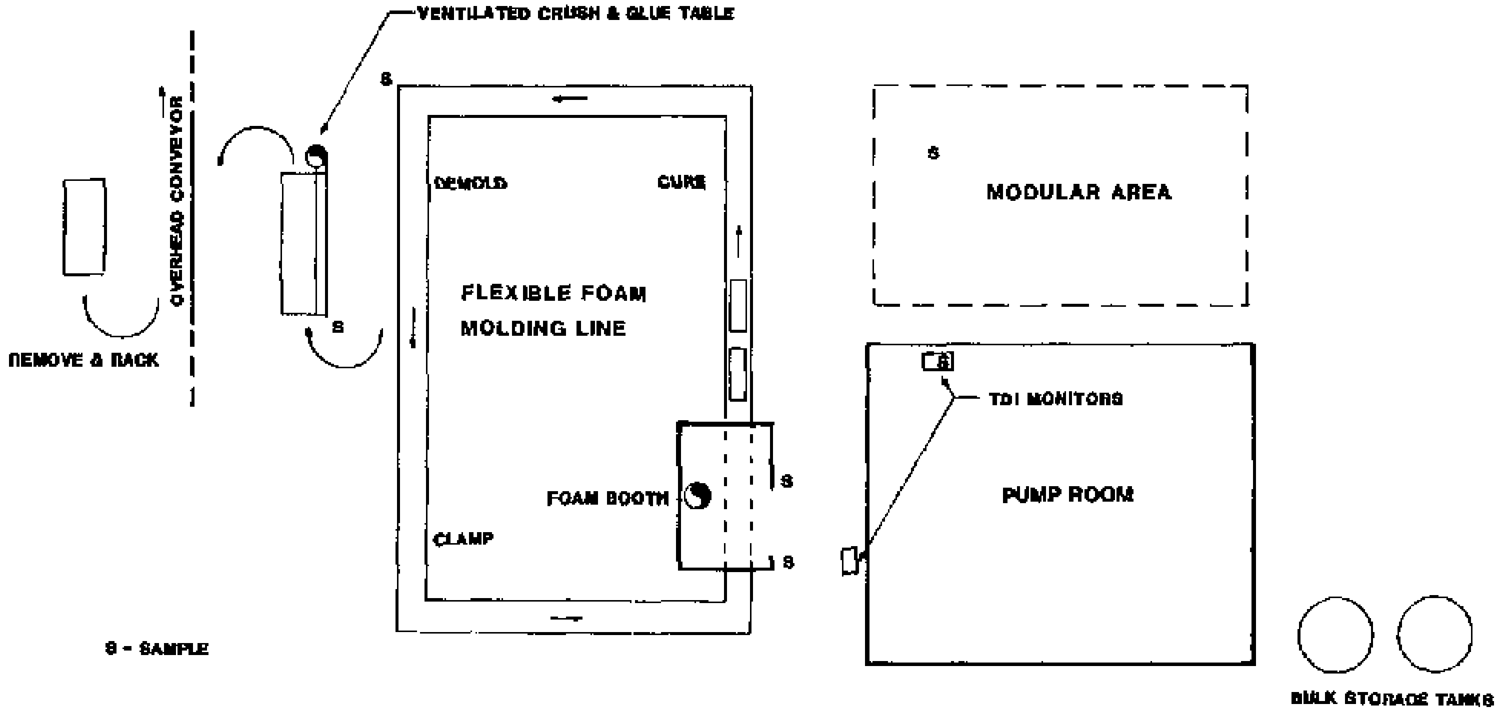

FIGURE 2. FLEXIBLE FOAM MOLDING AREA