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NIOSH INVESTIGATORS:
BRUCE W. HILLS, C.I.H.
MELODY M. KAWAMOTO, M.D., M.S.

## I. SUMMARY

In October 1989, the National Institute for Occupational Safety and Health (NIOSH) received an employee request for an assessment of potential exposures to fibrous glass, formaldehyde, phenol, and adhesives, and possible related health effects at two United Technologies Automotive headliner production plants in Port Huron, Michigan.

In August 1990, NIOSH investigators conducted industrial hygiene and medical surveys at the plants. Based on the monitoring conducted by NIOSH, measurable concentrations of formaldehyde were found in both plants, and trichloroethylene was detected at a concentration approaching the NIOSH recommended exposure limit in the plant using adhesives. NIOSH considers formaldehyde and trichloroethylene to be potential occupational carcinogens and, therefore, recommends limiting exposures to the lowest feasible concentrations. The NIOSH recommended exposure limit for fibrous glass was not exceeded, and phenol was not detected. The OSHA permissible exposure limits for fibrous glass, formaldehyde, phenol, and trichloroethylene were not exceeded. Although exposure criteria based on protecting against irritant effects were not exceeded, eye, nose, and throat irritation, and skin rashes were highly prevalent in workers interviewed at both plants. Central nervous system symptoms such as headaches, tiredness, lightheadedness, dizziness, and problems with memory, mood, or personality were also frequently reported by the interviewed workers. It should be noted that air sampling does not account for direct contact, which can be a major route of exposure for some substances.

The high prevalences of symptoms consistent with health effects known to be associated with exposures to fibrous glass, formaldehyde, volatile organic ingredients in adhesives, and decomposition products of heated materials present in both plants indicate that the reported symptoms may be related to workplace exposures. Therefore, exposures should be controlled to decrease the potential for health effects.

NIOSH considers formaldehyde and trichloroethylene to be potential occupational carcinogens. Therefore, exposures to these substances should be reduced to the lowest feasible concentrations. Recommendations to reduce exposures are contained in Section VIII of this report.

KEYWORDS: SIC 3714 (Motor Vehicle Parts and Accessories), fibrous glass, fiberglass, man-made mineral fibers, glass wool, formaldehyde, phenol, trichloroethylene, adhesives, dermatitis.

## II. INTRODUCTION

In October 1989, the National Institute for Occupational Safety and Health (NIOSH) received an employee request for an assessment of potential exposures to fibrous glass, formaldehyde, phenol, and adhesives, and possible related health effects at two United Technologies Automotive headliner production plants in Port Huron, Michigan.

On August 6, 1990, following an opening conference with management representatives, the NIOSH investigators conducted walk-through surveys of the 20th Street plant (plant 1) and the Beard Street plant (plant 2) to become familiar with production processes. NIOSH investigators performed monitoring for airborne fibrous glass, formaldehyde, phenol, trichloroethylene, and volatile organic compounds at plant 2 on August 7, 1990, and at plant 1 on August 8, 1990. A sample of the workers were interviewed for information about health problems attributed to work exposures.

## III. BACKGROUND

United Technologies Automotive manufactures automotive headliners at two facilities in Port Huron. The workforce size parallels that of the American automobile industry, with economic, as well as seasonal, contractions and expansions. One hundred twenty-two hourly workers were employed at plant 1, and 132 at plant 2, at the time of the investigation. The main product is a fibrous glass headliner for automobile interiors. The raw material is uncured fibrous glass wool impregnated with phenol-formaldehyde resin. The supplier reported that, before treatment with resin, fiber diameters of the glass wool in use at the plants range from less than one micron (µm) to 30 µm, with most fibers having diameters of less than 3.5 µm.

In the forming area at the beginning of the fibrous glass headliner production line, uncured fibrous glass is fed from 35-pound rolls into a hot forming press (mold), where the binder system is cured. Formed headliners are cut into individual sections by a guillotine cutter as they exit the forming press. In the pretrim area, individual sections are trimmed by a pretrim press. In the marriage area, sheets of fabric and polyethylene are cut with a hot wire, then bonded to pretrimmed headliners by another hot press. In the final trim area, water jet guns automatically cut and trim headliners. Finally, in the packing area, headliners are hand finished with a hot glue gun. Headliners are transferred by hand from each area to the next. Fibrous glass dust is generated in the forming press and wherever fibrous glass is cut or trimmed. Plant 1 has five fibrous glass headliner production lines and plant 2 has three.

In plant 2, non-fibrous glass headliners are manufactured by cold lamination processes. Adhesives are used to bond paper to foam core, or fabric to cardboard core. Cores are then cold rolled, stacked to air dry, and die cut. According to company Material Safety Data Sheets, the adhesives may contain one or more of the following substances: trichloroethylene, vinyl-acetate ethylene, aliphatic solvent naphtha, carboxylated styrene-butadiene, propylene glycol, styrene maleic anhydride copolymer, styrene, ammonia, naphtha, acetone, acrylic polymer, epichlorohydrin, 4,4'-diphenylmethane diisocyanate,* toluene, and lead-chromate pigment. The specific ingredients of an adhesive depend on the type of headliner produced.

A small amount of visible smoke is generated when headliner fabric is cut by a hot wire. The fabrics can be made from materials such as nylon, polyester, polyethylene, polyolefin, polyurethane foam, or rayon. Depending on the temperature of the hot wire, thermal decomposition products of these materials could include toxic gases such as carbon monoxide, acrolein, formaldehyde and other aldehydes, and hydrogen cyanide [Montgomery, 1982].

## IV. EVALUATION METHODS

A. Industrial Hygiene

During the production of headliners, employees are potentially exposed to fibrous glass, formaldehyde, phenol, solvents in the adhesives, and thermal decomposition products generated from the hot wire cutting of fabric. Personal breathing-zone and area air monitoring was conducted to assess employee inhalation exposures to some of these substances.

1. Fibrous Glass

Airborne fibers were collected on 25-millimeter (mm) cellulose ester membrane filters at a flow rate of 1.0 liter per minute (lpm). Samples were analyzed according to NIOSH Method 7400 for total fiber count and by NIOSH Method 7400/ Modified by Differential Counting for fibrous glass [NIOSH, 1989]. A further restriction was placed on the fibrous glass count in that only fibers having a diameter equal to or less than 3.5 µm and a length greater than 10 µm were counted.

2. Formaldehyde

Formaldehyde samples were collected and analyzed by two methods.

(1) Personal and area samples were collected on Orbo-23 tubes at a flow rate of 0.1 lpm. Samples were

*The company reported that 4,4'-diphenylmethane diisocyanate was used only in research and development.

analyzed by gas chromatography (GC) with a nitrogen-phosphorus detector according to OSHA Method 52 [OSHA, 1987].

(2) Area samples collected in 20 milliliters of 1% sodium bisulfite solution in impingers at a flow rate of 0.5 lpm. The bisulfite solution was analyzed for formaldehyde by visible spectroscopy according to NIOSH Method 3500 [NIOSH, 1984].

This method was used in addition to the first method because it can detect lower air concentrations of formaldehyde. However, the possibility of spills with normal body movement makes it impractical for collecting personal samples.

3. Volatile Organic Compounds

Bulk air samples were collected on charcoal tubes [100/50 milligrams (mg)] at a flow rate of 0.8 lpm.
The samples were desorbed with carbon disulfide and qualitatively analyzed for volatile organic compounds by GC-flame ionization detector (FID).

4. Phenol

Samples were collected on XAD-7 tubes (SKC #226-30-12-07) at a flow rate of 0.1 lpm. The samples were then analyzed for phenol by high performance liquid chromatography according to OSHA Method 32 [OSHA, 1987].

5. Trichloroethylene

Air samples were collected for trichloroethylene on 150 mg charcoal tubes (100/50 mg) at flow rates of 0.1, 0.2, and 0.8 lpm to ensure that breakthrough would not occur. Samples were analyzed for trichloroethylene by GC-FID according to NIOSH Method 1022 [NIOSH, 1984].

B. Medical survey

Nineteen of the 48 day-shift workers (40%) from plant 1 and 17 of the 80 day-shift workers (21%) from plant 2 were randomly selected from each work area on each line for confidential interviews. Five who were not randomly selected were also interviewed either at their request or because they were reported to have possible work-related health effects. The interviewers solicited information on work (e.g., date of hire, usual jobs, and job tasks) and health (e.g., symptoms of eye, nose, or throat irritation, skin rashes, breathing problems, and medical history of allergies or asthma). In addition, Occupational Safety and

Health Administration (OSHA) Form 200 logs (summaries of occupational injuries and illnesses) from January 1989 through April 1990 were reviewed.

## V. EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH investigators employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

Three primary sources of environmental evaluation criteria for the workplace were used: 1) NIOSH Criteria Documents and Recommended Exposure Limits (RELs) [NIOSH, 1988a]; 2) the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs) [ACGIH, 1990]; and 3) the OSHA Permissible Exposure Limits (PELs) [29 CFR 1910 (1989)]*.

A time-weighted average (TWA) exposure refers to the average air concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits (STELs) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures. A "skin" designation indicates that there is a potential for significant exposure by absorption through the skin. If the NIOSH REL is different than the PEL or TLV, the REL is the criteria of choice unless there is information that became available after the REL was set that warrants selecting exposure criteria other than the REL. When appropriate, NIOSH also recommends preventive measures (e.g. protective equipment, medical monitoring) to reduce or eliminate the adverse health effects of work place exposures.

### A. Fibrous Glass

Glass fibers of diameters greater than 3.5 µg are known to cause skin irritation. The risk of dermatitis is increased in warm, humid climates or in the winter when the relative humidity is low. For most workers, symptoms disappear within a week or two of exposure, but may persist in some individuals. Allergic contact

*Code of Federal Regulations. See CFR in references.

dermatitis is not thought to be related to the fibers, but to the resins used in fibrous glass products [Adams, 1990]. Fibrous glass can also cause eye irritation [Adams, 1990] and respiratory irritation [Milby et al., 1969].
Based on experimental studies in animals and epidemiologic studies in humans, the International Agency for Research on Cancer (IARC) concluded that certain man-made mineral fibers (MMMF), including glass wool, are possibly carcinogenic to humans [IARC, 1988].

Several experimental studies in animals have shown that fibrous glass of dimensions similar to that of asbestos fibers (i.e., thin and long) has the potential to induce cancer when implanted into the pleura (lining of the lung) [Stanton and Wrench, 1972; Stanton et al., 1981] or instilled into the trachea (airway between the throat and the lungs) [Mohr et al., 1984, Pott et al., 1987]. In addition to fiber size, durability of fibers and their persistence in tissues are also recognized as important factors in carcinogenesis [Pott, 1987].

Doll [1987] analyzed the combined results of epidemiologic studies conducted in the United States (US), Canada, and Europe, and drew the following conclusions: The risk of lung cancer in workers employed in the early days of both the mineral wool and glass wool sectors of the MMMF industry amounted to some 25% above expected 30 years after first employment; the risk has been greater in the mineral wool sector than in the glass wool sector; and the uncertainty about fiber counts in the early days of the industry and the extent of the contribution of other carcinogens make it impossible to provide a precise quantitative estimate of the likely effect of exposure to current air concentrations of fibers. Doll also postulated that "MMMF are not more carcinogenic than asbestos fibers" and "exposure to current mean levels in the manufacturing industry of 0.2 [fibers/cc] or less is unlikely to produce a measurable risk after another 20 years have passed" [Doll, 1987]. A follow-up study of US MMMF workers showed a continued small excess of respiratory cancer deaths in MMMF workers [Marsh, 1990]. However, when workers were grouped by type of fibrous glass produced (i.e., filament, wool, or both), increasing duration of employment was not associated with increasing excesses in respiratory cancer deaths. This lack of trend could be explained by the fewer than expected respiratory cancer deaths in workers with 30 or more years since first employment in plants that produced only fibrous glass wool. In this study, no exposure factor (e.g., process, plant, duration of employment, average intensity, or cumulative fiber exposure) could be identified as a possible explanation for the excess in respiratory cancer deaths.

Studies have shown that most fibers found in lungs are less than 3.5 µm in diameter [Timbrell, 1976]. Inhaled fibers of greater diameters are deposited primarily in the upper airways (nose, mouth, throat), where they are more readily removed by the clearance mechanisms of the respiratory system.

In 1977, NIOSH proposed a REL of 5 $mg/m^3$ (TWA) for total fibrous glass dust and a 3 fiber/cubic centimeter (cc) limit for fibers having a diameter equal to or less than 3.5 µm and a length equal to or greater than 10 µm, based on evidence that small diameter fibers produce fibrosis in animals and respiratory tract irritation in humans [NIOSH, 1977]. In 1988, as part of the proposed rules on air contaminants, OSHA proposed to adopt the NIOSH recommendation of 5 $µg/m^3$

for total fibrous dust, but not the 3 fiber/cc limit for small diameter fibers. In its testimony to OSHA, NIOSH identified several studies [Stanton et al., 1981; Doll, 1987; Enterline et al., 1987] that suggested a carcinogenic risk in workers exposed to certain types of MMMF, including glass wool. NIOSH concluded that the proposed OSHA PEL of 5 $\mu g/m^3$ for total fibrous dust is unlikely to be protective and that a 3 fiber/cc limit for small diameter fibers is a significantly better alternative [NIOSH, 1988b]. OSHA temporarily delayed a final decision regarding the establishment of a separate PEL for fibrous glass because of the complexity of the issues raised by the extensive evidence submitted to the record [54 Fed. Reg. 2510 (1989)]*.

B. Formaldehyde

Exposure to formaldehyde can occur through inhalation or skin absorption. Low concentrations of formaldehyde in the air have resulted in symptoms such as eye irritation, throat and nose irritation, headaches, nausea, congestion, skin rashes, and, in some individuals who may have developed hypersensitivity (allergy), asthma. It is difficult to ascribe specific health effects to specific concentrations of formaldehyde to which people are exposed, because individuals vary in their subjective responses and complaints. Symptoms of eye, nose, and throat irritation may occur in people exposed to formaldehyde at concentrations as low as 0.1 ppm, but more frequently with exposures of 1.0 ppm and greater. Some individuals who have become sensitized from previous exposure may have symptoms upon exposure to concentrations of formaldehyde between 0.05 and 0.10 ppm. However, cases of formaldehyde-induced asthma and bronchial

*Federal Register. See Fed. Reg. in references.

hyperactivity developed specifically to formaldehyde are relatively uncommon [NRC, 1981]. Dermatitis is more likely to occur as a result of skin contact with formaldehyde-containing materials than from exposure to formaldehyde gas.

In 1981, NIOSH recommended that formaldehyde be handled as a potential occupational carcinogen and that appropriate controls be used to reduce worker exposure to the lowest feasible concentration [NIOSH, 1981]. This recommendation was based primarily on a study in which nasal cancers developed in rats and mice following repeated inhalation exposures of approximately 15 ppm formaldehyde. In 1987, OSHA published an amended formaldehyde standard [29 CFR 1910.1048] that reduced the PEL from 3 ppm to 1 ppm, as an 8-hour TWA. In addition, a 15-minute STEL was set at 2 ppm. During the 1986 public hearings on the proposed standard, NIOSH provided testimony that a PEL of 1 ppm is inadequate to protect against carcinogenic risk and, for a significant proportion of an exposed population, is also inadequate protection against irritation [NIOSH, 1986]. In supplemental comments to OSHA, NIOSH clarified its recommendation that occupational exposure to formaldehyde be controlled to the lowest feasible concentration, with a limit of 0.1 ppm for any 15-minute sampling period and 0.016 ppm as an 8-hr TWA, to protect against carcinogenic and other health effects of peak and chronic exposure [NIOSH, 1987]. The limits were based on the lowest reliably quantifiable concentration of formaldehyde at the time of the recommendation. NIOSH recognizes that, in certain occupational environments, the lowest reliably quantifiable concentration could be lower than ambient background concentrations in environments where industrial processes do not produce or use formaldehyde. In such circumstances, NIOSH recommends that the occupational exposure be reduced to that of the ambient background concentration [NIOSH, 1987].

A Consensus Workshop on Formaldehyde empaneled by the National Center for Toxicological Research reported that outdoor ambient air concentrations of formaldehyde have generally been below 0.010 to 0.015 ppm, except for situations of heavy traffic and/or photochemical smog, when concentrations up to 0.09 to 0.15 ppm have been reported. The workshop also reported that, in specialized residences (mobile homes, urea-formaldehyde foam insulation homes, new houses, energy-efficient and perhaps weatherized homes), mean concentrations of formaldehyde sometimes exceeded 0.1 ppm. In conventional homes more than five years old, mean concentrations of formaldehyde were usually below 0.05 ppm, although concentrations exceeded 0.1 ppm in a small fraction of these homes. [Consensus Workshop, 1984] In studies of workers exposed to formaldehyde, job titles with formaldehyde exposures of less than 0.1 ppm were generally classified into the lowest exposure category for statistical analysis [Blair et al., 1990].

C. Trichloroethylene

Trichloroethylene is a volatile liquid at room temperature and can affect the central nervous system, heart, skin, and possibly the liver and kidney. The most frequently reported symptoms of exposure include headache, nausea, vomiting, dizziness, vertigo, fatigue, mental dullness, sleepiness, lightheadedness, insomnia, and burning eyes [NIOSH, 1978].

Experimental studies in animals have shown that trichloroethylene may be carcinogenic [NCI, 1976]. After a special review of experimental and epidemiologic data, NIOSH concluded that trichloroethylene is a potential occupational carcinogen, although not a potent one [NIOSH, 1978]. The NIOSH REL for trichloroethylene is 25 ppm TWA [NIOSH, 1988b]. NIOSH usually recommends that exposures to potential occupational carcinogens be limited to the lowest feasible concentration [NIOSH, 1990]. This REL was based on the use of engineering control technology feasible at the time of the recommendation, and was not intended to be a final goal [NIOSH, 1978]. The OSHA PEL for trichloroethylene is 50 ppm with a 15-minute STEL of 200 ppm [29 CFR 1910.1000 (1989)].

## VI. RESULTS

### A. Industrial Hygiene

The processes and conditions at the time of the NIOSH industrial hygiene monitoring were reported by employees to be representative of typical work days.

#### 1. Fibrous Glass

Four personal and two area samples in plant 2, and seven personal samples in plant 1, were collected for analysis of total fibers and fibrous glass having a diameter equal to or less than 3.5 µm and a length greater than 10 µm (Table 1). All samples contained a mixture of cellulose and fibrous glass. In plant 2, total fibers ranged from 0.01 to 0.03 fibers/cc and fibrous glass having a diameter equal to or less than 3.5 µm and a length greater than 10 µm ranged from less than 0.01 to 0.03 fibers/cc. In plant 1, total fibers ranged from 0.01 to 0.17 fibers/cc and fibrous glass having a diameter equal to or less than 3.5 µm and a length greater than 10 µm ranged from less than 0.01 to 0.15 fibers/cc.

The highest measurement in plant 1 occurred on an employee who removed forms from the mold (pre-trim and stapler) on line 2. Samples were only analyzed for fiber count and not weight because of the low concentrations of particulates in the workroom air.

#### 2. Formaldehyde

Four area samples for formaldehyde analysis were collected by impingers in each plant (Table 2). In plant 2, formaldehyde concentrations ranged from 0.05 to 0.07 ppm. In plant 1, concentrations ranged from 0.04 to 0.08 ppm.

Fourteen Orbo-23 tubes were also used to collect samples for formaldehyde analysis. Results of nine samples were above the limit of detection (1.0 ug/sample), but all were below the limit of quantitation (3.0 ug/sample) (Table 3). In plant 2, five personal and two area samples were collected. In plant 1, seven personal samples were collected. All of these sample results were equal to or less than 0.02 ppm.

3. Volatile Organic Compounds

Area samples were collected in both plants for qualitative analysis of volatile organic compounds. In plant 2, toluene and trichloroethylene were the main compounds detected (Figure 1). In plant 1, toluene, perchloroethylene, and unspecified aromatic and aliphatic hydrocarbons were present (Figure 2).

4. Phenol

Three area samples for phenol analysis were collected in each plant at each step of the process line. All six sample results were below the limit of detection (1 ug/sample, i.e., less than 0.007 ppm for these samples).

5. Trichloroethylene

Because the cold lamination processes with potential for trichloroethylene exposure occurred only in plant 2, sampling for trichlorethylene was limited to plant 2. Four area samples were collected for analysis. In the area where adhesives were used, concentrations of trichloroethylene ranged from 3.6 to 21.4 ppm (Table 4). The highest concentration was found in the area where an adhesive was used to coat paper with fabric. The trichloroethylene concentration was 2.7 ppm on Line 6, a fibrous glass line in plant 2.

B. Medical

1. Confidential interviews with randomly selected employees

Because of the potential for biasing the results of the medical survey, interviews with employees who were not randomly selected were excluded from the reported results. Three-fourths of the interviewed employees in plant 1, and approximately one-half in plant 2, had worked in the same work area for more than a year. More than 90% of the employees interviewed at both plants had been assigned to their work areas for more than one month.

Table 5 shows the prevalences of reported symptoms by plant. The most prevalent symptom in both plants was irritation of the eyes, nose, or throat. Differences in prevalences of symptoms between the two plants were not statistically significant (by chi square test or Fischer's exact test). Table 6 shows the prevalences of reported symptoms by type of production line (fibrous glass and non-fibrous glass). In almost all cases, symptoms were more prevalent in fibrous glass headliner production than in non-fibrous glass headliner production. However, none of these differences was statistically significant, probably because of the small number (4) of persons interviewed in the latter group.

In the fibrous glass headliner production areas, 75% of those interviewed reported symptoms of irritation to the eye, nose, or throat. Skin rashes,

nonspecific symptoms (headaches, tiredness, lightheadedness, or dizziness), and respiratory symptoms (cough, shortness of breath, wheezing, or chest tightness) were reported by almost 50%. Table 7 shows the prevalences of reported symptoms by work area in fibrous glass headliner production. Although some differences in prevalences among work areas could be explained by differences in exposure, the numbers symptomatic workers in each area were too small to test for statistical significance. In addition, those who had worked in other areas of the plant in the past could have reported symptoms related to those other areas.

Fourteen (39%) of the interviewed workers reported that they sought medical attention for problems such as skin rashes (8), breathing problems (3), and symptoms consistent with cumulative trauma disorders (2).

Hand and wrist problems were reported by several workers and were related to use of hand tools such as scissors and glue guns. One reported a diagnosis of carpal tunnel syndrome and another reported surgical treatment for a problem resulting from use of the glue gun.

2. OSHA Form 200 logs

In 1989, 165 injuries and illnesses were recorded on the OSHA Form 200 logs. Skin rashes and "fiberglass in eye" were reported six times each, eye irritation was reported twice, and particle in eye and nose bleed were reported once each. Ninety one injuries and illnesses were recorded during the first four months of 1990. Skin rashes were reported four times, "fiberglass in eye" was reported once, and "object in eye" was reported once. One case of asthma was reported in 1990.

## VII. DISCUSSION AND CONCLUSIONS

Based on the monitoring conducted by NIOSH, measurable concentrations of formaldehyde were found in both plants, and trichloroethylene was detected at a concentration approaching the NIOSH recommended exposure limit in the plant using adhesives. On the days of the survey, formaldehyde concentrations at the two plants were similar to each other and higher than concentrations expected in unpolluted air. In the plant using adhesives, trichloroethylene was detected at a concentration approaching the NIOSH REL. The air concentration of trichloroethylene was highest in the area where adhesives were used, suggesting that exposures to adhesives might not be adequately controlled. NIOSH considers formaldehyde and trichloroethylene to be potential occupational carcinogens and, therefore, recommends limiting exposures to the lowest feasible concentrations. The NIOSH REL for fibrous glass was not exceeded, and phenol was not detected. The OSHA PELs for fibrous glass, formaldehyde, phenol, and trichloroethylene were not exceeded.

Although exposure criteria based on protecting against irritant effects were not exceeded, eye, nose, and throat irritation, and skin rashes were highly prevalent in workers interviewed at both plants. These symptoms were consistent with health effects related to workplace exposures. The OSHA Form 200 logs provided additional documentation that workplace exposures were responsible for eye and skin irritation (e.g., "fiberglass in eye"

and skin rashes). Although fibrous glass concentrations for fibers having a diameter equal to or less than 3.5 µm and a length greater than 10 µm were below the NIOSH REL, fibers greater than 3.5 µm in diameter can cause skin and mucous membrane irritation. Other workplace exposures (e.g., formaldehyde, smoke from hot wire cutting of fabrics) could also result in irritant symptoms. Central nervous system symptoms such as headaches, tiredness, lightheadedness, dizziness, and changes in memory, mood, or personality are consistent with health effects related to inhalation or skin exposures to formaldehyde, volatile organic ingredients in adhesives, and decomposition products of heated materials.

The high prevalences of symptoms and the consistency of the symptoms with those known to be caused by substances present in both plants indicate that the reported symptoms may be related to workplace exposures. It should be noted that air sampling for fibers or chemicals does not account for direct contact, which can be a major route of exposure for some substances. Therefore, exposures by all routes should be controlled to decrease the potential for health effects.

Repetitive, forceful wrist motions or awkward positions of the hand and wrist in the performance of job tasks are associated with carpal tunnel syndrome and other cumulative trauma disorders. Such wrist movements were observed among employees using hand tools such as scissors and glue guns. These workers and others performing similar tasks may be at increased risk of developing cumulative trauma disorders, some of which could eventually result in irreversible nerve damage. Preventive measures should be undertaken to decrease the risk of developing cumulative trauma disorders.

## VIII. RECOMMENDATIONS

A. All routes of exposure to potentially hazardous materials and substances should be controlled to decrease the potential for health effects.

1. The local ventilation around the hot wire operations, the fibrous glass cutting and trimming operations, and the curing presses should be improved. General ventilation will also reduce air contaminants, but is usually less effective than local ventilation at the source.

a. Where workers are exposed to potential occupational carcinogens (e.g., formaldehyde, trichloroethylene), engineering controls should be improved so that exposures are reduced to the lowest feasible concentrations.

b. Where workers are exposed to fibrous glass, engineering controls should be improved so that no worker is exposed to an air concentration greater than 3 fibers/cc of fibers having a diameter equal to or less than 3.5 µm and a length equal to or greater than 10 µm, determined as a TWA concentration for up to a 10-hr work shift in a 40-hr work week; air concentrations determined as total fibrous glass should be limited to a TWA concentration of 5 $mg/m^3$ of air [NIOSH, 1977].

2. Unless engineering controls can eliminate exposures, substitutes that do not contain suspected carcinogens (e.g., trichloroethylene) should be found for materials (e.g., adhesives) that contain them.

3. Safety glasses, goggles, or face shields should be worn wherever the potential for fibrous glass landing in eyes exists (e.g., a work area from which a case of "fiberglass in eye" has been entered in the OSHA Form 200 logs).

4. The company should provide workers with a daily change of laundered work clothes with long sleeves to protect the arms. Gloves or other types of protective clothing may be helpful. Work clothes should not be worn outside the workplace and contamination of street clothes should be prevented. Showers should be available at work for use before workers change into street clothes.

B. Employees should be educated about the hazards of potential work exposures (including the use of contaminated clothes) and the hazards of not wearing protective equipment or clothing.

C. A program for the prevention of cumulative trauma disorders should be developed. Such a program should include the following [OSHA, 1991]:

1. Worksite analysis to recognize and identify ergonomic hazards.

2. Hazard prevention and control, to include:

a. Selection of tools and handles designed to eliminate or minimize chronic muscle contraction or steady force, extreme or awkward finger/hand/arm positions, repetitive forceful motions, and excessive gripping, pinching, and pressing with the hand and fingers.

b. Work practice controls.

c. Administrative controls.

3. Medical management, to include recordkeeping, early recognition and reporting, systematic evaluation and referral, conservative treatment, conservative return to work, and systematic monitoring.

4. Training and education for employees, supervisors, managers, and health care providers.

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## X. AUTHORSHIP AND ACKNOWLEDGMENTS

Report prepared by:
Bruce W. Hills, C.I.H.
Industrial Hygiene Section

Melody M. Kawamoto, M.D., M.S.
Medical Officer
Medical Section

Survey conducted by:
Bruce W. Hills, C.I.H.
Industrial Hygiene Section

Gregory M. Kinnes, M.S.
Industrial Hygiene Section

Melody M. Kawamoto, M.D., M.S.
Medical Officer
Medical Section

Urs Hinnen, M.D.
Medical Section

Originating office: Hazard Evaluations and Technical Assistance Branch
Division of Surveillance, Hazard Evaluations, and Field Studies

## XI. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Publications Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability can be obtained from NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. United Technologies Automotive
2. Michigan Department of Public Health
   Division of Occupational Health
3. OSHA, Region V
4. Confidential requesters

In order to comply with the NIOSH regulation that affected employees shall be notified about the determination of this health hazard evaluation (CFR, Title 42, Part 85, Section 85.11), the employer shall post copies of this report in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1

United Technologies Automotive
August 7-8, 1990

Fibrous Glass and Total Fibers

| Employee/Location | Glass Sample No. | Total Minutes | Fibers*/cc | Fibers/cc |
|---|---|---|---|---|
| Plant 2 | | | | |
| Line 7 | FG1 | 340 | 0.03 | 0.03 |
| Employee 1 | FG2 | 373 | ND** | 0.01 |
| Employee 2 | FG3 | 417 | ND | 0.01 |
| Employee 3 | FG4 | 433 | ND | 0.01 |
| Employee 4 | FG5 | 448 | ND | 0.01 |
| Line 6 | FG6 | 457 | 0.01 | 0.01 |
| Employee 5 | FG11 | 435 | 0.02 | 0.05 |
| Plant 1 | | | | |
| Employee 6 | FG12 | 437 | 0.02 | 0.02 |
| Employee 7 | FG13 | 435 | 0.01 | 0.01 |
| Employee 8 | FG14 | 436 | ND | 0.01 |
| Employee 9 | FG15 | 426 | 0.01 | 0.02 |
| Employee 10 | FG16 | 428 | 0.01 | 0.02 |
| Employee 11 | FG17 | 427 | 0.15 | 0.17 |

*Glass fibers with diameters having a diameter equal to or less than 3.5 µm and a length greater than 10 µm. For fibrous glass of this size, the NIOSH REL is 3 fibers/cc.
**Not detected. The limit of detection is 3000 fibers per sample.

Table 2

United Technologies Automotive
August 7-8, 1990

Area Samples for Formaldehyde
NIOSH Analytical Method No. 3500

| Location | Sample No. | Minutes | PPM* |
|---|---|---|---|
| Plant 2 | | | |
| Line 7 entrance to mold | FL1 | 298 | 0.07 |
| Line 8 entrance to mold | FL2 | 405 | 0.05 |
| Line 6 entrance to mold | FL3 | 381 | 0.06 |
| Line 6 exit from mold | FL4 | 374 | 0.07 |
| Plant 1 | | | |
| Line 5 loading fibrous glass | FL11 | 394 | 0.04 |
| Line 2 loading fibrous glass | FL12 | 367 | 0.05 |
| Between lines 1 & 2 pre-trim | FL13 | 378 | 0.08 |
| Line 2 after marriage | FL14 | 344 | 0.04 |

*NIOSH recommends that exposure to formaldehyde be reduced to the lowest feasible concentration.

The OSHA PEL and the ACGIH TLV for formaldehyde are 1 ppm as an 8-hour TWA with a 15-minute STEL of 2 ppm.

Table 3

United Technologies Automotive
August 7-8, 1990

Personal and Area Samples for Formaldehyde
OSHA Analytical Method 52

| Employee/Location | Sample no. | Minutes | PPM |
|---|---|---|---|
| Plant 2 | | | |
| Employee 1 | F1 | 364 | ND* |
| Employee 2 | F2 | 390 | (0.02)** |
| Employee 3 | F3 | 366 | ND |
| Employee 4 | F4 | 387 | (0.02) |
| Employee 5 | F5 | 361 | (0.02) |
| Line 8 | F6 | 405 | (0.02) |
| Line 6 | F7 | 379 | (0.02) |
| Plant 1 | | | |
| Employee 6 | F11 | 366 | ND |
| Employee 7 | F12 | 371 | ND |
| Employee 8 | F13 | 400 | (0.02) |
| Employee 9 | F14 | 404 | (0.02) |
| Employee 10 | F15 | 396 | (0.02) |
| Employee 11 | F16 | 402 | ND |
| Employee 12 | F17 | 402 | (0.02) |

*Not detected. The limit of detection is 1.0 ug per sample. The limit of quantitation is 3.0 ug per sample.

**All sample results were less than the limit of quantitation. The results in parentheses should be considered estimated concentrations rather than accurate measurements.

NIOSH recommends that exposure to formaldehyde be reduced to the lowest feasible concentration.

The OSHA PEL and the ACGIH TLV for formaldehyde are 1 ppm as an 8-hour TWA with a 15-minute STEL of 2 ppm.

Table 4

United Technologies Automotive
August 7, 1990

Area Trichloroethylene Samples
Plant 2

| Location | Sample no. | Minutes | Cubic meters | PPM* |
|---|---|---|---|---|
| Hand Lamination<br>Evans-St Clair hot wire | H2 | 302 | .242 | 8.3 |
| Hand Lamination<br>exit to dryer | H4 | 284 | .227 | 3.6 |
| Roll to Sheet<br>next to overhead hood | H8 | 346 | .035 | 21.4 |
| Line 6**<br>on mold | H6 | 352 | .070 | 2.7 |

*NIOSH considers trichloroethylene a potential occupational carcinogen and recommends that occupational exposures be limited to the lowest feasible concentration.

The OSHA PEL and the ACGIH TLV for trichloroethylene are 50 ppm with a 15-minute STEL of 200 ppm.

**Fibrous glass line.

Table 5

United Technologies Automotive
August 7-8, 1990

Symptoms Reported by Plant

| | Plant 1 | Plant 2 |
|---|---|---|
| | Number (%) | Number (%) |
| Number employees interviewed | 19 | 17 |
| Eye, nose, or throat irritation | 15 (80) | 11 (65) |
| Skin rashes | 10 (53) | 6 (35) |
| Headaches, tiredness, lightheadedness, or dizziness | 9 (47) | 7 (41) |
| Cough, shortness of breath, wheezing, or chest tightness | 10 (53) | 5 (29) |
| Nose bleeds | 3 (16) | 4 (24) |
| Chest pain or palpitations | 4 (21) | 2 (12) |
| Changes in memory, mood, or personality | 2 (11) | 3 (18) |
| Nausea, vomiting, or diarrhea | 2 (11) | 1 (6) |

Table 6

United Technologies Automotive
August 7-8, 1990

Symptoms Reported by Type of Production Line
(Plants 1 and 2 combined)

| | Fibrous glass | Non-fibrous glass |
|---|---|---|
| | Number (%) | Number (%) |
| Number employees interviewed | 32 | 4 |
| Eye, nose, or throat irritation | 24 (75) | 2 (50) |
| Skin rashes | 15 (47) | 1 (25) |
| Headaches, tiredness, lightheadedness, or dizziness | 15 (47) | 1 (25) |
| Cough, shortness of breath, wheezing, or chest tightness | 14 (44) | 1 (25) |
| Nose bleeds | 7 (22) | 0 |
| Chest pain or palpitations | 6 (19) | 0 |
| Changes in memory, mood, or personality | 4 (13) | 1 (25) |
| Nausea, vomiting, or diarrhea | 3 (9) | 0 |

Table 7

United Technologies Automotive
August 7-8, 1990

Symptoms Reported by Work Area on Fibrous Glass Production Lines
(Plants 1 and 2 combined)

| | Forming | Pre-trim | Marriage | Final Trim | Packing |
|---|---|---|---|---|---|
| | No. (%) | No. (%) | No. (%) | No. (%) | No. (%) |
| Number employees interviewed | 10 | 5 | 5 | 6 | 6 |
| Eye, nose, or throat irritation | 6 (60) | 3 (60) | 4 (80) | 6 (100) | 5 (83) |
| Skin rashes | 5 (50) | 4 (80) | 2 (40) | 2 (33) | 2 (33) |
| Headaches, tiredness, lightheadedness, or dizziness | 4 (40) | 1 (20) | 3 (60) | 4 (67) | 3 (50) |
| Cough, shortness of breath, wheezing, or chest tightness | 4 (40) | 1 (20) | 1 (20) | 5 (83) | 3 (50) |
| Nose bleeds | 3 (30) | 2 (40) | 0 | 0 | 2 (33) |
| Chest pain or palpitations | 2 (20) | 0 | 0 | 2 (33) | 2 (33) |
| Changes in memory, mood, or personality | 1 (10) | 0 | 1 (20) | 0 | 2 (33) |
| Nausea, vomiting, or diarrhea | 0 | 0 | 1 (20) | 0 | 2 (33) |

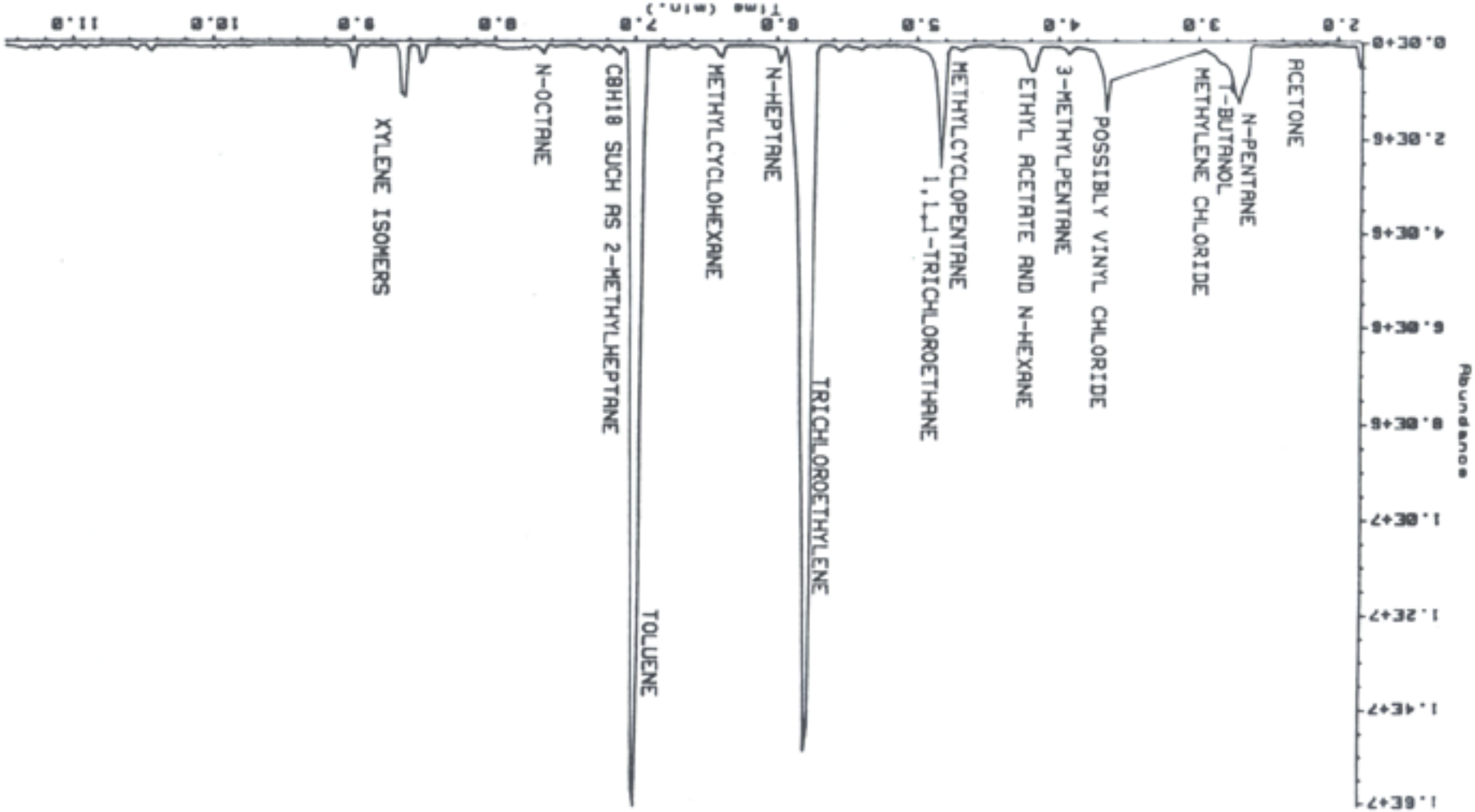


Figure 1

United Technologies Automotive
August 7, 1990

Area Samples for Volatile Organic Compounds
Plant 2

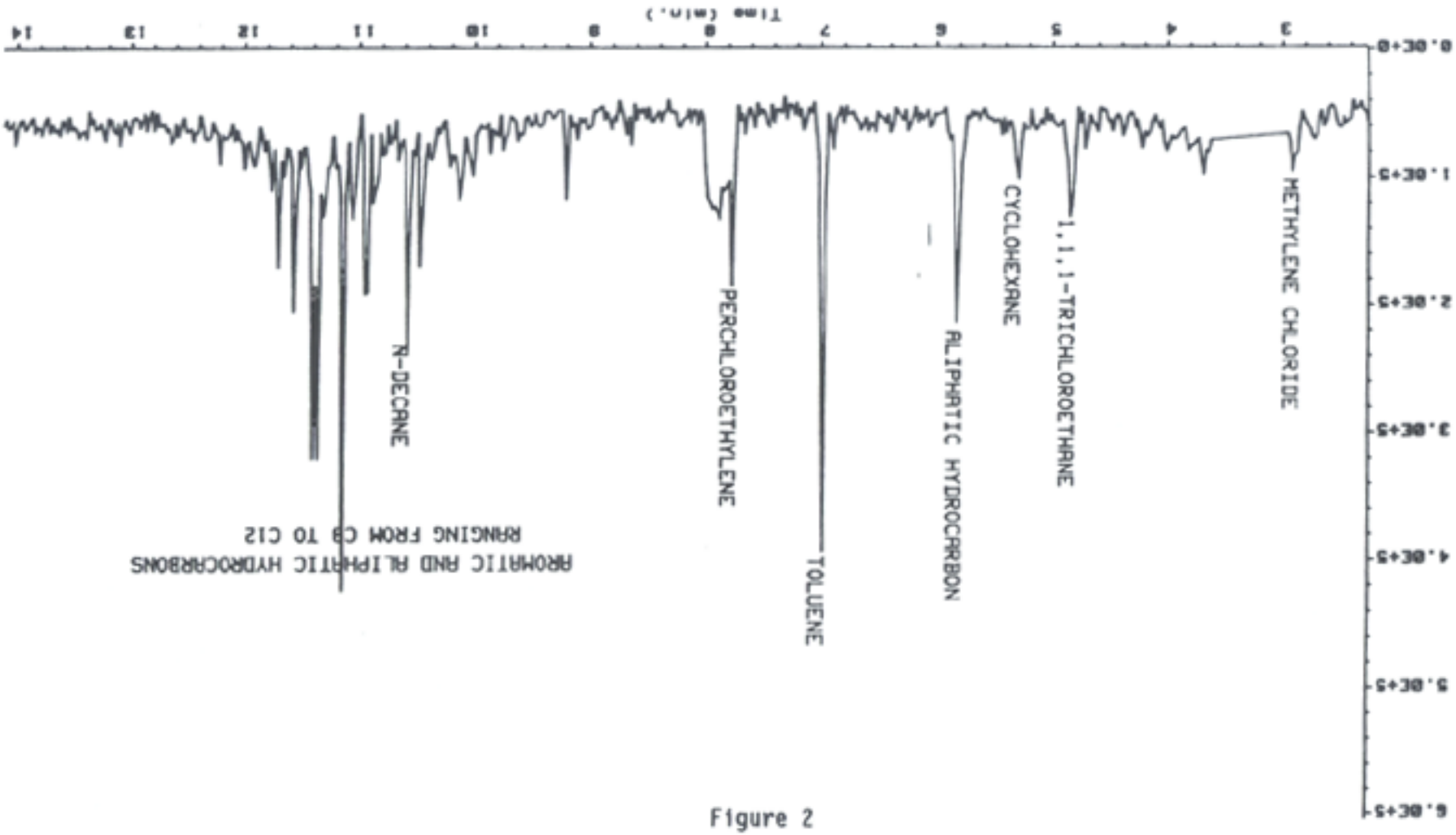


Figure 2

United Technologies Automotive
August 8, 1990

Area Samples for Volatile Organic Compounds
Plant 1