HETA 97–0217–2667
Design Evolution 4, Inc.
Lebanon, Ohio

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PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Nancy Clark Burton, Robert Malkin, and Ali Lopez of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Robert McCleery. Desktop publishing was provided by Juanita Nelson. Analytical support was provided by Data Chem Laboratories, Inc., Salt Lake City, Utah.

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Health Hazard Evaluation Report 97–0217–2667
Design Evolution 4, Inc.
Lebanon, Ohio
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SUMMARY

In May 1997, the National Institute for Occupational Safety and Health (NIOSH) received a health hazard evaluation (HHE) request from the management at Design Evolution 4, Inc., in Lebanon, Ohio. The request described concern for workers' exposures and symptoms, including dizziness and sleepiness, that workers believed were related to a hot melt adhesive process used in the production of residential doors since March 1997. In response to this request, an initial site visit was conducted on June 23, 1997, and a second site visit was conducted on August 21, 1997. Confidential medical interviews were conducted during the first survey with six employees in the door assembly area. Thermal desorption tubes were used to characterize the volatile organic compounds (VOCs) present in the door assembly area. A bulk sample of the hot melt adhesive was also analyzed for VOCs. Personal breathing zone (PBZ) and area air samples were collected for acetone, methylene bisphenyl diisocyante (MDI), methylene chloride, toluene, styrene, and methyl methacrylate.

Sleepiness and dizziness were reported by three of the interviewed workers; one worker also referred to slow movements and disorientation that lasted a few seconds and improved once he inhaled fresh air; and two workers reported weakness and tiredness. Five workers believed that their symptoms were due to hot adhesive exposure. Two employees reported headaches on the morning of the second survey. According to employees, symptoms appeared only on certain days and increased in frequency when the temperature and relative humidity in the plant were high.

Qualitative air sampling for VOCs detected a wide range of compounds which can affect the central nervous system (CNS) and cause symptoms similar to those reported by the employees. However, concentrations of acetone, MDI, methylene chloride, toluene, styrene, and methyl methacrylate were below current occupational exposure limits. The local exhaust ventilation of the roller machine was operating. There was very little air movement in the door assembly area, and the fans that were used were blowing directly toward the assembly employees. In addition, air containing solvents from the adjacent production area was entering the door assembly area.

The industrial hygiene sampling data indicate that several different VOCs were present in the door assembly area. These exposures could cause CNS effects similar to those reported by the employees, although on the day of the evaluation, none of the sampled compounds were present in concentrations that exceeded occupational exposure limits. The potential synergistic or additive effects of exposure to such a chemical mixture is not known. Recommendations to improve ventilation in the door assembly area are provided in the Recommendations section of this report.

Keywords: SIC Code 2431 (Millwork), door manufacturing, hot adhesive, acetone, methylene bisphenyl diisocyante (MDI), methylene chloride, toluene, styrene, methyl methacrylate, sleepiness, dizziness, ventilation.

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INTRODUCTION

In May 1997, the National Institute for Occupational Safety and Health (NIOSH) received a health hazard evaluation (HHE) request from the management at Design Evolution 4, Inc. in Lebanon, Ohio. The HHE request described concern for workers' exposures and symptoms, including dizziness and sleepiness, which workers believed were related to a hot melt adhesive process used in the production of residential doors. In response to this request, an initial site visit was conducted on June 23, 1997, and a second site visit was conducted on August 21, 1997.

BACKGROUND

The plant started operating the door assembly process, consisting of a hot melt adhesive roller machine, a table, and a pinch press, in late March 1997. Prior to that time, a hot melt adhesive spray process was used, and no adverse health effects were reported. The hot melt adhesive used in both assembly processes is PUR–FECT LOK 34–9014, manufactured by National Starch and Chemical Company, Bridgewater, New Jersey. The active ingredients are 2% methylene bisphenyl diisocyanate (MDI) and various acrylates. One worker feeds the pieces of wood for the door frame into the roller machine, which applies the adhesive, while two assemblers place a door skin (made of fiberglass coated with a methyl methacrylate resin) on the assembly table. The two assemblers then take the four pieces of wood and place them over the door skin to form the frame. Rubber hammers are used to fit the pieces together. The assemblers take another door skin from the pile located on top of the pinch press and affix it to the other side of the completed frame. The door is immediately pushed into the pinch press to seal the door skins to the frame, then stacked on a skid for shipment. The process is run once a week, and the production rate is about 200 doors over one 10–hour shift. There are three to five employees in the door assembly area, depending on production needs. The employees use rubber gloves for protection from the heat and chemicals in the hot melt adhesive. The roller machine has local exhaust ventilation and is exhausted directly to the outside. The rest of the door assembly area relies on open doors for ventilation. A ceiling fan and cooling fans are used to circulate air. Acetone and methylene chloride are used in the facility to clean machinery.

METHODS

A walk–through inspection of the plant was conducted during the June site visit. To evaluate the components of the adhesive, the hot melt adhesive manufacturer was contacted for additional information on the hot melt adhesive components and all material safety data sheets (MSDS) were reviewed for products used in the door assembly area.

Industrial Hygiene Evaluation

Volatile Organic Compounds (VOCs)

During the first site visit, three thermal desorption tube air samples were collected and analyzed by gas chromatography/mass spectroscopy (GC/MS) to characterize the VOCs present in the door assembly area. A bulk sample of the hot melt adhesive was also submitted for analysis by GC/MS. Based on the thermal tube and bulk sample analysis, additional air sampling was conducted for acetone, methylene chloride, toluene, styrene, and methyl methacrylate, during the second site visit.

Acetone

Five area air samples for acetone were collected in the door assembly and adjacent production areas.

The area air samples were collected at a flowrate of 0.05 liters per minute (L/min) using charcoal tubes and analyzed for acetone according to NIOSH Method 1300 using gas chromatography with a flame ionization detector (GC/FID).[1] The analytical limit of detection (LOD) was 0.001 milligrams (mg), which is equivalent to a minimum detectable concentration (MDC) of 0.016 parts per million (ppm), assuming a sample volume of 26 liters. The limit of quantitation (LOQ) was 0.0033 mg, which is equivalent to a minimum quantifiable concentration (MQC) of 0.052 ppm, assuming a sample volume of 26 liters.

Methylene Bisphenyl Diisocyante (MDI)

Two area air samples were collected in the door assembly area for MDI using midget impingers containing a tryptamine and dimethyl sulfoxide solution, at a flowrate of 1.5 L/min. The area samples were analyzed for MDI according to NIOSH Method 5522 using high performance liquid chromatography.[2] The analytical LOD was 0.003 mg, which is equivalent to a MDC of 0.0005 ppm, assuming a sample volume of 578 liters. The LOQ was 0.011 mg, which is equivalent to a MQC of 0.0018 ppm, assuming a sample volume of 578 liters.

Methylene Chloride

Five area air samples for methylene chloride were collected in the door assembly and adjacent production areas. The area air samples were collected at a flowrate of 0.05 L/min using two charcoal tubes in series. The samples were analyzed for methylene chloride according to NIOSH Method 1005 using GC/FID.[3] The analytical LOD was 0.001 mg, which is equivalent to a MDC of 0.011 ppm, assuming a sample volume of 26.5 liters. The LOQ was 0.0033 mg, which is equivalent to a MQC of 0.035 ppm, assuming a sample volume of 26.5 liters.

Toluene/Styrene

One PBZ and four area air samples for toluene and styrene were collected in the door assembly and adjacent production areas of the plant. The samples were collected at a flowrate of 0.05 L/min using charcoal tubes and analyzed for toluene and styrene according to NIOSH Method 1501 using GC/FID.[4] The analytical LODs were 0.001 mg and 0.004 mg for toluene and styrene, respectively, which are equivalent to MDCs of 0.011 ppm and 0.038 ppm, assuming a sample volume of 24.6 liters. The LOQs were 0.0033 mg and 0.012 mg for toluene and styrene, respectively, which are equivalent to MQCs of 0.035 ppm and 0.113 ppm, assuming a sample volume of 24.6 liters.

Methyl Methacrylate (MMA)

One PBZ and four area air samples for MMA were collected in the door assembly and adjacent production areas. The samples were collected at a flowrate of 0.02 L/min using silica gel tubes and analyzed for MMA according to NIOSH Method 2537 using GC/FID.[5] The analytical LOD was 0.001 mg, which is equivalent to a MDC of 0.025 ppm, assuming a sample volume of 9.8 liters. The LOQ was 0.0033 mg, which is equivalent to a MQC of 0.081 ppm, assuming a sample volume of 9.8 liters.

Ventilation Evaluation

Smoke tubes were used to determine the airflow pattern in the door assembly area and to assess the hot melt adhesive machine's local exhaust ventilation system.

Medical Investigation

During the site visit on June 23, two NIOSH medical personnel participated in a walk–through inspection of the facility and conducted confidential medical interviews with the six employees working with the hot melt adhesive machine.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the 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 even though 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). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[6] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[7] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[8] In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard and that the OSHA PELs included in this report reflect the 1971 values.

A time–weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8–to–10–hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

Acetone

Acetone is used as a solvent for various compounds, including fats, oils, waxes, resins, rubber, and plastics; as a paint and varnish remover; and as a chemical intermediate in the chemical, lacquer, paint, dyeing, and celluloid industries.[9,10] The principal route of exposure is inhalation.[10] It is an irritant of the eyes and mucous membranes and, at high concentrations, can cause central nervous system (CNS) effects which can result in symptoms such as headache and fatigue.[9,10]

OSHA has established an 8–hr TWA PEL of 1000 ppm for acetone.[8] ACGIH has established an 8–hr TWA TLV for acetone of 500 ppm.[7] NIOSH has established a 10–hr TWA–REL of 250 ppm for acetone.[6]

Methylene Bisphenyl Diisocyante (MDI)

Methylene bisphenyl diisocyanate (MDI) is used in the manufacture of polyurethane foams, adhesives, and solid urethane elastomers.[9] It is also used in certain spray applications. The exposure routes for MDI are inhalation, ingestion, and skin or eye contact.[10] The main toxic effect is the development of respiratory sensitization. Exposure to MDI has been associated with cough, wheezing, pulmonary secretions, chest pain, dyspnea (shortness of breath), and asthma.[9]

OSHA has established a ceiling level for MDI of 0.02 ppm.[8] ACGIH has established an 8–hr TWA TLV for MDI of 0.005 ppm.[7] NIOSH has established a 10–hr TWA–REL of 0.005 ppm for MDI.[6]

Methylene Chloride

Methylene chloride is used as a solvent in a variety of industries, as a paint remover, in polyurethane foam manufacturing, and as a degreaser.[10] The major routes of occupational exposure are inhalation and skin absorption. Methylene chloride exposure can cause CNS effects (including symptoms such as headaches, disorientation, dizziness, fatigue, and decreased attention span); skin chapping, erythema (redness), and cracking skin; skin burns; eye irritation; chest pain; and shortness of breath.[9,11] It is an animal carcinogen.

OSHA has established an 8–hr TWA PEL of 25 ppm for methylene chloride.[12] ACGIH has established an 8–hr TWA TLV for methylene chloride of 50 ppm.[7] NIOSH has classified methylene chloride as a potential occupational carcinogen, but has not yet established a REL.[6]

Toluene

Toluene is a solvent found in paints and other coatings and used as a raw material in the synthesis of organic chemicals, dyes, detergents, and pharmaceuticals.[10] Inhalation and skin absorption are the major occupational routes of entry. Toluene can cause acute irritation of the eyes, respiratory tract, and skin. Since it is a defatting solvent, repeated or prolonged skin contact will remove the natural lipids from the skin, which can cause drying, fissuring, and dermatitis.[11]

The main effect reported with excessive inhalation exposure to toluene is CNS depression.[10] Studies have shown that subjects exposed to 100 ppm of toluene for six hours complained of eye and nose irritation, and in some cases, headache, dizziness, and a feeling of intoxication.[13,14,15] No symptoms were noted below 100 ppm in these studies. Exposure to extremely high concentrations of toluene may cause mental confusion, loss of coordination, and unconsciousness.[16,17]

The NIOSH REL for toluene is 100 ppm for an 8–hour TWA and 150 ppm for a 15–minute sampling period.[6] The OSHA PEL for toluene is 200 ppm for an 8–hour TWA.[8] The ACGIH TLV is 50 ppm for an 8–hour exposure level with a skin notation, indicating that cutaneous exposure contributes to the overall absorbed dose and potential systemic effects.[7]

Styrene

Styrene is used as a solvent in the plastics industry and as a monomer for plastics, fiberglass resins, and synthetic rubber elastomers.[10] Styrene is readily absorbed by inhalation and can be stored in fat tissue. Prolonged skin exposure can result in rash or dermatitis.[11] It can cause eye, nose, and throat irritation.[18] Styrene causes CNS effects, such as headache, listlessness, and drowsiness.[10] Several studies have documented weakness, increased reaction times, and abnormal electroencephalograms in workers exposed to styrene.[9,10,19,20] Air concentrations of styrene were either undocumented or at times exceeded 100 ppm for some of the employees. OSHA has established an 8–hr TWA PEL of 50 ppm for styrene.[8] ACGIH has established an 8–hr TWA TLV for styrene of 20 ppm.[7] NIOSH has established a 10–hr TWA–REL of 100 ppm for styrene.[6]

Methyl Methacrylate (MMA)

Simple acrylic compounds (methyl, ethyl, ethylhexy, and butyl acrylates and the respective methacrylates and their mixtures) are widely used in adhesives and glues.[11] Exposure to methyl methacrylate can cause irritation in the eyes, skin, throat, and respiratory tract; gastrointestinal irritation (nausea, vomiting, and diarrhea); and CNS effects (dizziness, drowsiness, weakness, fatigue, and unconsciousness).[10,21] Workers who were exposed to air concentrations between 0.5 ppm and 50 ppm reported a high incidence of headache, pain in the extremities, irritability, loss of memory, excessive fatigue, and sleep disturbances.[11]

Allergic contact dermatitis has been reported in workers handling methacrylate sealants. Exposure to MMA and cyanoacrylates has been shown to result in asthma. OSHA, ACGIH, and NIOSH have established occupational exposure criteria of 100 ppm for MMA.[6,7,8]

RESULTS

Industrial Hygiene Evaluation

Volatile Organic Compounds (VOCs)

Major compounds identified on the thermal desorption tubes collected in the door assembly area were acetone, methylene chloride, methyl methacrylate, styrene, butyl methacrylate, and limonene. Other compounds detected included decane, p–dichlorobenzene, various aliphatic hydrocarbons, xylene cyclohexane, cyclopentanone, acetic acid, toluene, and naphtalene. Copies of the chromatograms are included in Appendix A.

Compounds detected in the bulk sample of heated adhesive included methyl methacrylate, butyl methacrylate, azobisisobutyronitrile, butylated hydroxy toluene (BHT), cyclopentanone, an unidentified acrylate compound, and possibly a morpholine compound. Most of these compounds correspond to the product components listed on the MSDS. A copy of the chromatogram is included in Appendix A.

Acetone

The results of the acetone environmental sampling are presented in Table 1. Air concentrations for the five area samples ranged from 2.7 to 5.6 ppm, well below existing occupational exposure limits.

Methylene Bisphenyl Diisocyante (MDI)

The results for the MDI area air sampling are shown in Table 2. The MDI concentrations were 0.002 and 0.003 ppm, which were below the occupational exposure limit of 0.005 ppm established by NIOSH and ACGIH.

Methylene Chloride

The results for the methylene chloride monitoring are given in Table 3. The area air concentrations ranged from 0.42 to 0.68 ppm in the door assembly area. The air concentration for the sample collected in the other portion of the building, where methylene chloride is used more frequently for general machine cleaning, was 17.4 ppm. These results were below the OSHA and ACGIH occupational exposure limits.

Toluene/Styrene

The toluene and styrene environmental sampling results are presented in Table 4. The PBZ concentrations measured on a door assembler for toluene and styrene were 0.09 ppm and 0.46 ppm, respectively. The area air concentrations ranged from trace levels to 0.07 ppm for toluene and 0.24 to 0.43 ppm for styrene. All of these concentrations are well below their current occupational exposure limits.

Methyl Methacrylate

The results from the methyl methacrylate sampling are shown in Table 5. The PBZ concentration measured on a door assembler was 1.4 ppm. The area air concentrations ranged from 1.5 to 2.7 ppm. All of these concentrations are well below the current occupational exposure limits for methyl methacrylate.

Observations

The local exhaust ventilation for the hot adhesive machine was operating during the site visits. Smoke tubes showed very little airflow in the area surrounding the door assembly process. The fan near the door assembly process blew directly into the space occupied by the door assemblers. There was very little airflow into the work area from the outside door (the source of outside air) located near the door assembly process. Air also flowed from the other production area into the door assembly area. The lack of air movement could lead to a build–up of contaminants in that area. Gasoline powered forklifts were used inside the facility which could lead to worker exposures to carbon monoxide and incomplete combustion products if there is not sufficient dilution ventilation.

Medical Evaluation

Some common concerns about the work environment were raised by the interviewed employees, and specific problem areas in the plant were identified. Sleepiness and dizziness were reported by three of the interviewed workers. One worker also referred to slow movements and disorientation that lasted a few seconds and improved once he inhaled fresh air. Two workers reported weakness and tiredness. Five workers believed that their symptoms were due to hot adhesive exposure, the remaining worker did not express his opinion in this matter. Three of the interviewed workers mentioned that symptoms appeared only on certain days and increased in frequency when the environmental temperature and humidity were high.

All interviewed workers agreed that these symptoms started to appear after the March 1997 implementation of the new process using the roller machine. After that time production increased from approximately 30 to 200 doors for the weekly 10–hour shift. This section is where the adhesive–coated wood exits the machine, is placed in a jig to form the outline of a door frame, and the second fiberglass skin is placed on top of the frame, and where the PBZ and majority of area air samples were collected. Two employees reported headaches on the morning of the second site visit that resolved after their lunch break.

DISCUSSION AND CONCLUSIONS

Employees at this facility began reporting symptoms, including dizziness and sleepiness, after the March 1997 implementation of a new process using a hot melt adhesive roller machine and increased door production. The hot adhesive formulation and process temperature remained the same. The employees working on the door assembly process reported the majority of the symptoms. Employees reported more symptoms when there was an increase in relative humidity and temperature in the facility and stagnant air in the door assembly area. Relative humidity (55%) and temperature (76°F) were moderate during the second site visit (no measurements were made during the first visit).

Qualitative air sampling for VOCs detected several compounds which can effect the CNS and result in symptoms similar to those reported by the employees. Concentrations of acetone, MDI, methylene chloride, toluene, styrene, and methyl methacrylate were all below occupational exposure limits during the site visit. Several of these compounds can be absorbed through the skin, but the employees wore rubber gloves to protect themselves from the chemicals and heat from the hot melt adhesive. The potential synergistic effects of such a complex mixture of chemicals are unknown. Exhaust from gasoline powered forklifts could also contribute to employee symptoms of headache and dizziness.

NIOSH investigators measured VOCs on one day and it is possible that exposures vary at different times depending on environmental conditions (temperature and relative humidity were low on the day of the sampling), production rate (about three–fourths of maximum production during sampling), and the amount of chemicals used in other parts of the facility. In any case, there was very little air movement into the door assembly area from the outside door which is the source of fresh air for that part of the facility. Even though the local exhaust ventilation of the roller machine was operating, the fans that were used for air circulation were blowing the chemicals generated during the hot melt adhesive process directly toward the door assembly employees. Air was also moving from the other production area, which used several different VOCs, into the door assembly area. Exposures from these areas may vary in intensity, depending on the chemical and amount being used at the time.

RECOMMENDATIONS

(1) Ventilation

a) Because of continued health complaints among employees in the door assembly area, Design Evolution 4, Inc. should consider adding local exhaust ventilation to the door assembly work station.[22] This could be in the form of a downdraft bench which would pull contaminants away from the workers' breathing zones.

b) Replacement air from a clean area or from outside (not the other production area) should be added to compensate for the air being exhausted and to provide additional ventilation in the door assembly area.

c) Until the changes detailed above can be implemented, the existing fans should be adjusted so that potentially contaminated air is not blown directly into the employees' faces.

(2) Gasoline powered forklifts should not be used inside due to the potential for exposures to carbon monoxide and other exhaust components.

REFERENCES

1. NIOSH [1994]. Ketones I: method no. 1300, issue 2. In: Eller PM and Cassinelli ME, eds. NIOSH manual of analytical methods (NMAM). 4th. ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public

Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94–113.

2. NIOSH [1996]. Isocyanates: method no. 5522, issue 1. In: Eller PM and Cassinelli ME, eds. NIOSH manual of analytical methods (NMAM). 4th. ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94–113.

3. NIOSH [1994]. Methylene chloride: method no. 1005, issue 3. In: Eller PM and Cassinelli ME, eds. NIOSH manual of analytical methods (NMAM). 4th. ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94–113.

4. NIOSH [1994]. Hydrocarbons, aromatic: method no. 1501, issue 2. In: Eller PM and Cassinelli ME, eds. NIOSH manual of analytical methods (NMAM). 4th. ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94–113.

5. NIOSH [1994]. Methyl methacrylate: method no. 2537, issue 2. In: Eller PM and Cassinelli ME, eds. NIOSH manual of analytical methods (NMAM). 4th. ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public
Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94–113.

6. NIOSH [1992]. Recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92–100.

7. ACGIH [1997]. 1997 TLVs® and BEIs®: Threshold limit values for chemical substances and physical agents; Biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

8. Code of Federal Regulations [1993]. 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Federal Register.

9. Rosenstock L, Cullen M [1994]. Textbook of Clinical Occupational and Environmental Medicine. Philadelphia, PA: W.B. Saunders Company.

10. Hathway GJ, Proctor NH, Hughes JP, Fischman ML [1991]. Chemical hazards of the workplace. 3rd ed. New York, NY: Van Nostrand Reinhold.

11. Zenz C, Dickerson O, Horvath E [1994]. Occupational Medicine. 3rd. Edition. Chicago, IL: Mosby–Year Books, Inc.

12. Code of Federal Regulations [1997]. Methylene chloride. 29 CFR 1910.1052. Washington, DC: U.S. Government Printing Office, Federal Register.

13. WHO [1981]. Recommended health–based limits in occupational exposure to select organic solvents. Geneva: World Health Organization, Technical Report Series No. 664.

14. Benignus VA [1981]. Health effects of toluene: a review. Neurotoxicology *2*:567–568.

15. Anderson I, et al. [1983]. Human response to controlled levels of toluene in

six–hour exposures. Scand J Work Environ Health 9:405–418.

16. Bruckner JV, Peterson RG [1981]. Evaluation of toluene and acetone inhalant abuse I. Pharmacology and pharmacodynamics. Toxicol Appl Pharmacol *61*:27–38.

17. Bruckner JV, Peterson RG [1981]. Evaluation of toluene and acetone inhalant abuse II. Model development and toxicology. Toxicol Appl Pharmacol *61*:302–312.

18. Lewis R [1992]. Sax's dangerous properties of industrial materials. Eighth Edition, Volume III. New York, NY: Van Nostrand Reinhold.

19. Härkönen H, Lindström K, Seppäläinene AM, Asp S, Hernberg S [1978]. Exposure–response relationship between styrene exposure and central nervous system functions. Scand J Work Environ Health 4:53–59.

20. Lilis R, Lorimer WV, Diamond S, Selikoff IJ [1978]. Neurotoxicity of styrene in production and polymerization workers. Environ Res 15(1):133–138.

21. Blagodatin VM, Golova IA, Bladokatkina NK, Ramyantseva YP, Goryacheva LA, Aliyeva NK, Gronsberg YS [1976]. Establishing the maximum permissible concentration of the methyl ester of methacrylic acid in the air of a work area. Gig Tr Prof Zabol 6: 5–8.

22. ACGIH [1992]. Industrial Ventilation, 21st Edition. A manual of recommended practice. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

Table 1
Acetone Air Sampling Results
Design Evolution 4, Inc.
Lebanon, Ohio
HETA 97–0217
August 21, 1997

Job Description/ Area	Sample Time	Sample Volume (liters)	Acetone Concentration (ppm)*
Area			
Beside Adhesive Machine Loader	7:55 a.m. – 4:35 p.m.	26.00	2.7
Side of Adhesive Machine	7:28 a.m. – 4:33 p.m.	27.25	4.1
On Top of Press	7:32 a.m. – 4:31 p.m.	26.95	3.8
Table Next to Press	7:39 a.m. – 4:29 p.m.	26.50	3.3
Other Production Area	7:50 a.m. – 4:50 p.m.	26.55	5.6
OSHA PEL			1000
ACGIH TLV			500
NIOSH REL			250
Minimum Detectable Concentration (MDC)		26	0.016
Minimum Quantifiable Concentration (MQC)		26	0.052

* – ppm = parts per million

Table 2
Methylene Bisphenyl Diisocyanate (MDI) Air Sampling Results
Design Evolution 4, Inc.
Lebanon, Ohio
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August 21, 1997

Job Description/ Area	Sample Time	Sample Volume (liters)	MDI Concentration (ppm)*
Area			
Side of Adhesive Machine	8:40 a.m. – 3:05 p.m.	578	0.003
Table Next to Press	8:40 a.m. – 3:05 p.m.	578	0.002
OSHA PEL			0.02 (Ceiling)
ACGIH TLV			0.005
NIOSH REL			0.005
Minimum Detectable Concentration (MDC)		578	0.0005
Minimum Quantifiable Concentration (MQC)		578	0.0018

* – ppm = parts per million

Table 3
Methylene Chloride Air Sampling Results
Design Evolution 4, Inc.
Lebanon, Ohio
HETA 97–0217
August 21, 1997

Job Description/ Area	Sample Time	Sample Volume (liters)	Methylene Chloride Concentration (ppm)*
Area			
Beside Adhesive Machine Loader	7:55 a.m. – 4:47 p.m.	26.6	0.68
Side of Adhesive Machine	7:28 a.m. – 4:45 p.m.	27.85	0.42
On Top of Press	7:32 a.m. – 4:42 p.m.	27.5	0.66
Table Next to Press	7:39 a.m. – 4:31 p.m.	26.6	0.62
Other Production Area	7:59 a.m. – 4:49 p.m.	26.5	17.42
OSHA PEL			25
ACGIH TLV			50
NIOSH REL			Carcinogen
Minimum Detectable Concentration (MDC)		26.5	0.011
Minimum Quantifiable Concentration (MQC)		26.5	0.035

* – ppm = parts per million

Table 4
Toluene/Styrene Air Sampling Results
Design Evolution 4, Inc.
Lebanon, Ohio
HETA 97–0217
August 21, 1997

Job Description/ Area	Sample Time	Sample Volume (liters)	Styrene Concentration (ppm)*	Toluene Concentration (ppm)*
Personal				
Door Assembler	7:50 a.m. – 11:02 p.m. 11:35 a.m. – 4:35 p.m.	24.6	0.46	0.09
Area				
Side of Adhesive Machine	8:20 a.m. – 2:26 p.m.	27.8	0.28	0.07
On Top of Press	8:20 a.m. – 2:26 p.m.	27.4	0.28	0.06
Table Next to Press	8:20 a.m. – 2:26 p.m.	26.4	0.24	0.06
Other Production Area	8:20 a.m. – 2:26 p.m.	26.55	0.43	Trace**
OSHA PEL			50	200
ACGIH TLV			20	50 (skin)
NIOSH REL			100	100
Minimum Detectable Concentration (MDC)		24.6	0.038	0.011
Minimum Quantifiable Concentration (MQC)		24.6	0.113	0.035

* – ppm = parts per million
** = Between MDC and MQC

Table 5
Methyl Methacrylate Air Sampling Results
Design Evolution 4, Inc.
Lebanon, Ohio
HETA 97–0217
August 21, 1997

Job Description/ Area	Sample Time	Sample Volume (liters)	Methyl Methacrylate Concentration (ppm)*
Personal			
Door Assembler	7:52 a.m. – 11:02 p.m. 11:37 a.m. – 4:37 p.m.	9.8	1.4
Area			
Side of Adhesive Machine	7:28 a.m. – 4:45 p.m.	11.14	1.6
On Top of Press	7:32 a.m. – 4:41 p.m.	10.98	1.6
Table Next to Press	7:39 a.m. – 4:25 p.m.	10.52	1.5
Other Production Area	7:59 a.m. – 4:49 p.m.	10.6	2.7
OSHA PEL			100
ACGIH TLV			100
NIOSH REL			100
Minimum Detectable Concentration (MDC)		9.8	0.025
Minimum Quantifiable Concentration (MQC)		9.8	0.081

* – ppm = parts per million

Appendix A

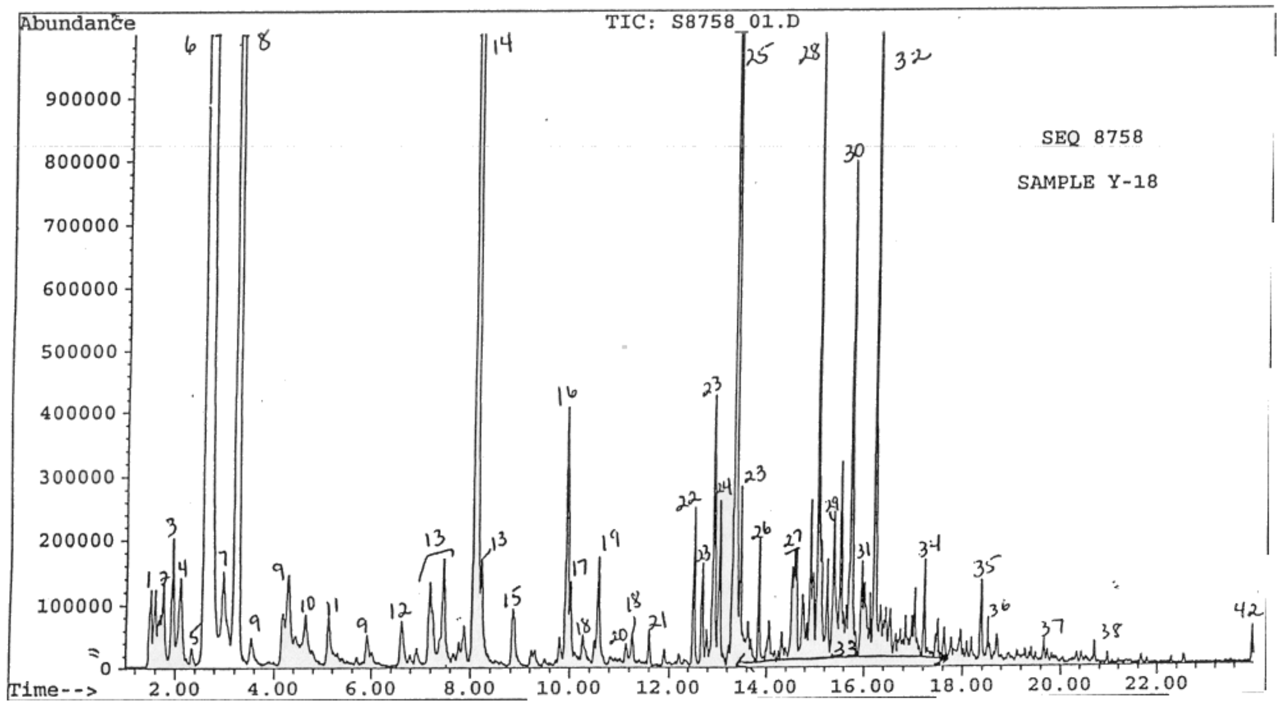
Chromatographs

SEQ 8758
THERMAL DESORPTION TUBES and HEATED BULK SAMPLE
PEAK IDENTIFICATION

1) Air*/CO_2*
2) Propane
3) Methanol*/isobutane/acetaldehyde*
4) Butane
5) Ethanol
6) Acetone*
7) Pentane
8) Methylene chloride
9) C_6 aliphatics
10) Acetic acid
11) Hexane
12) Benzene*
13) C_7 aliphatics
14) Methyl methacrylate
15) Methyl isobutyl ketone (MIBK)/methylcyclohexane
16) Toluene
17) Cyclopentanone/isobutyl acetate
17A) Cyclopentanone
18) C_8 aliphatics
19) Hexanal*
20) Butyl acetate
21) Diacetone alcohol
22) Propylene glycol methyl ether acetate (PGMEA)
23) Xylene/ethyl benzene isomers
24) Cyclohexanone
25) Styrene
26) Nonane
27) Benzaldehyde/α-pinene
28) Butyl methacrylate
29) 2,2'-Azobisisobutyronitrile?
30) Decane/p-dichlorobenzene
31) Terpene (pinene/carene)
32) Limonene
33) Mixture of C_9-C_{12} aliphatics/C_9-C_{10} alkyl benzenes
34) Dimethyl glutarate
35) Naphthalene
36) Dodecane
37) Tridecane
38) Tetradecane
39) Aliphatic, nitro- compound?
40) Dodecene
41) Butylated hydroxytoluene (BHT)
42) Acrylate compound (in bulk)
43) Possible morpholine compound (based on MSDS, possibly the dimorpholino diethyl ether)
44) Aliphatic aldehydes*, C_9-C_{12}

*Also present on some media and/or field blanks.

File : C:\HPCHEM\1\DATA\S8758\S8758_01.D
Operator : AAG
Acquired : 24 Jun 97 8:22 am using AcqMethod ATD
Instrument : 5970 - In
Sample Name: SAMPLE Y-18
Misc Info : 30 M DB-1 SC20-300 TP35-300
Vial Number: 1



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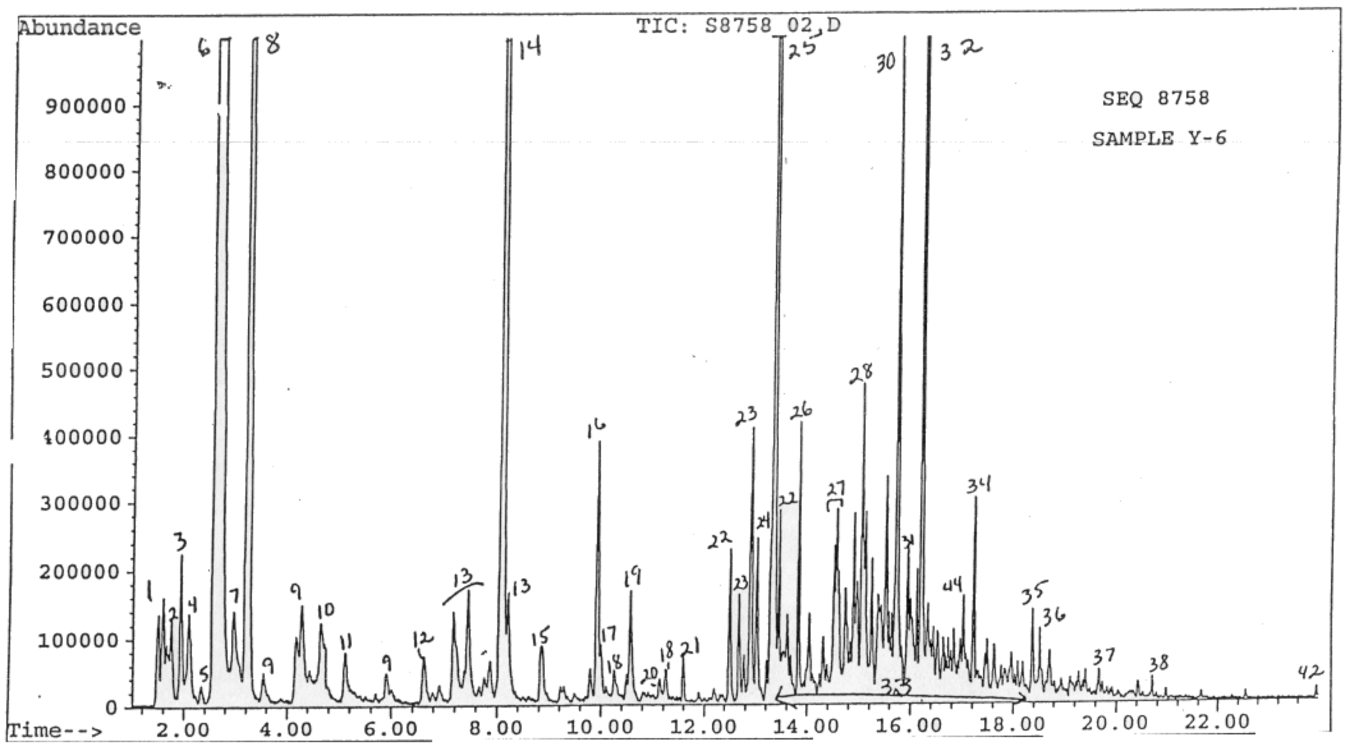
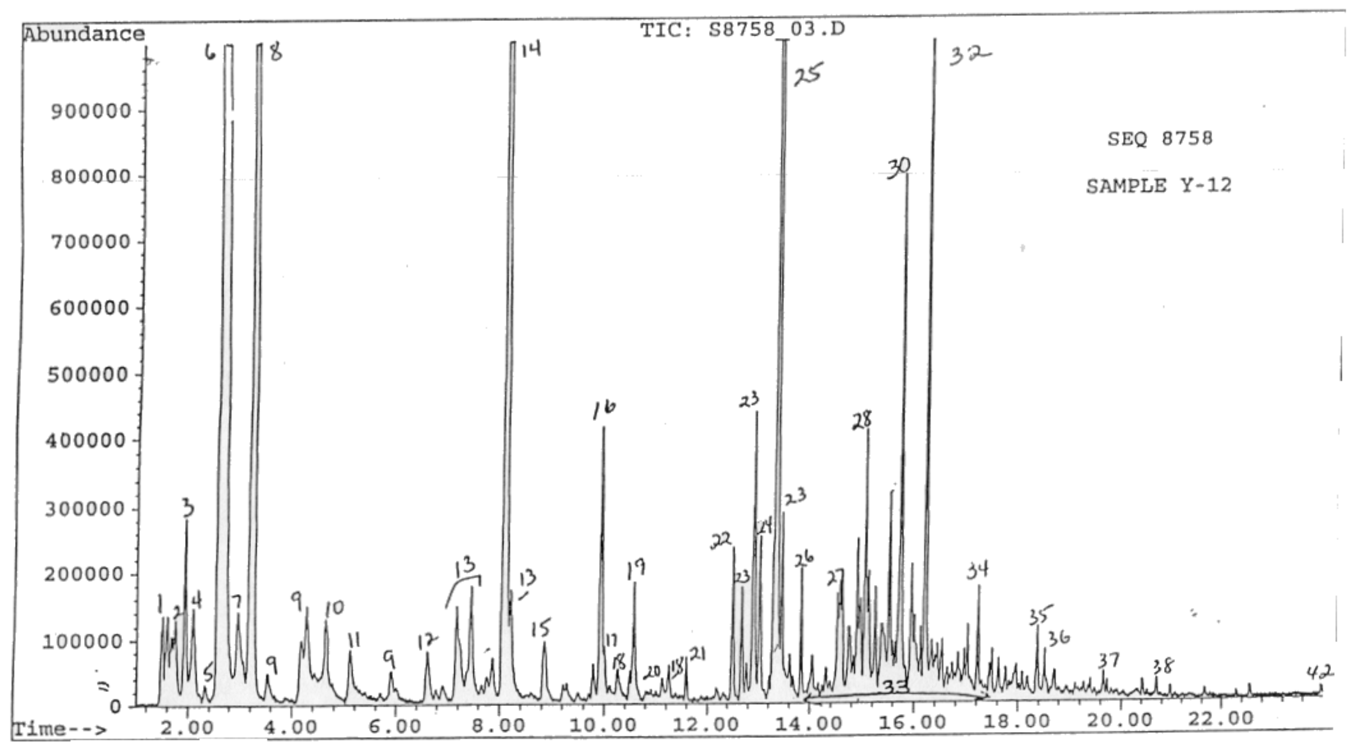
File        : C:\HPCHEM\1\DATA\S8758\S8758_02.D
Operator    : AAG
Acquired    : 24 Jun 97   9:12 am using AcqMethod ATD
Instrument  :   5970 - In
Sample Name: SAMPLE Y-6
Misc Info   : 30 M DB-1   SC20-300   TP35-300
Vial Number: 2
```



File : C:\HPCHEM\1\DATA\S8758\S8758_03.D
Operator : AAG
Acquired : 24 Jun 97 10:02 am using AcqMethod ATD
Instrument : 5970 - In
Sample Name: SAMPLE Y-12
Misc Info : 30 M DB-1 SC20-300 TP35-300
Vial Number: 3



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File        : C:\HPCHEM\1\DATA\S8758\S8758_04.D
Operator    : AAG
Acquired    : 24 Jun 97  10:51 am using AcqMethod ATD
Instrument  :   5970 - In
Sample Name: SAMPLE Y-1 FIELD BLANK
Misc Info   : 30 M DB-1   SC20-300   TP35-300
Vial Number: 4
```
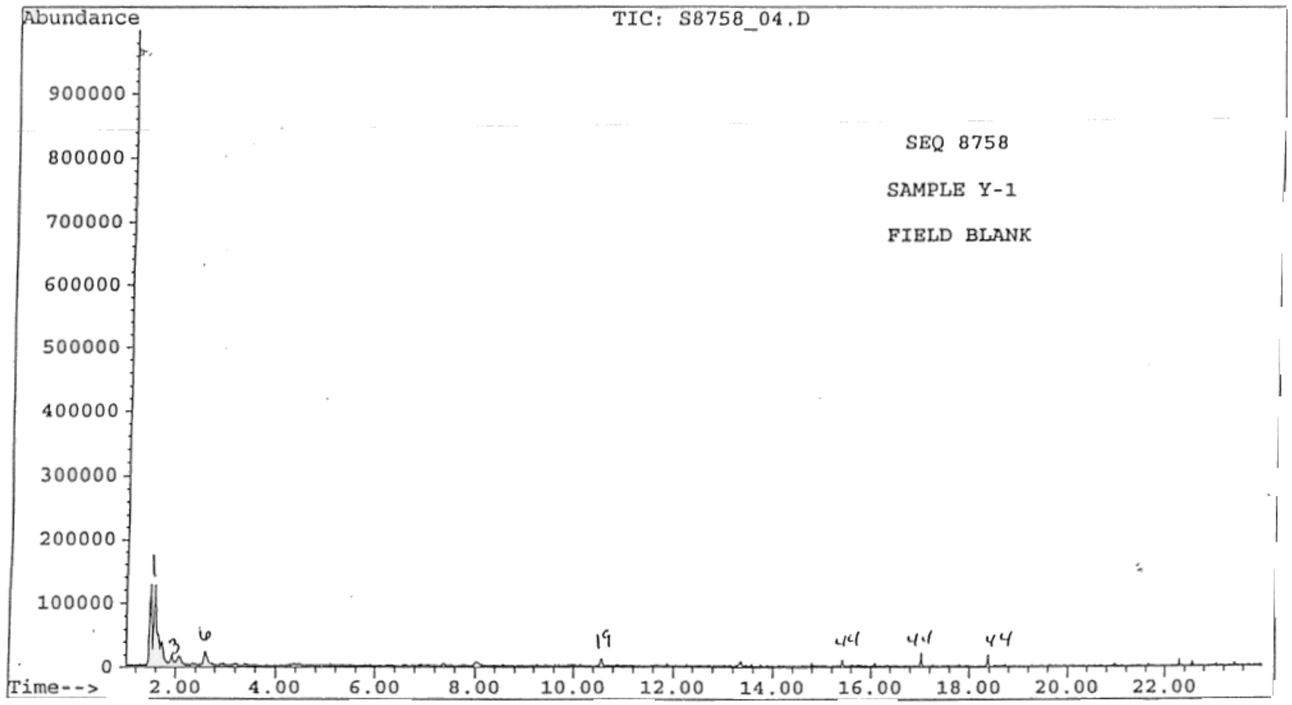
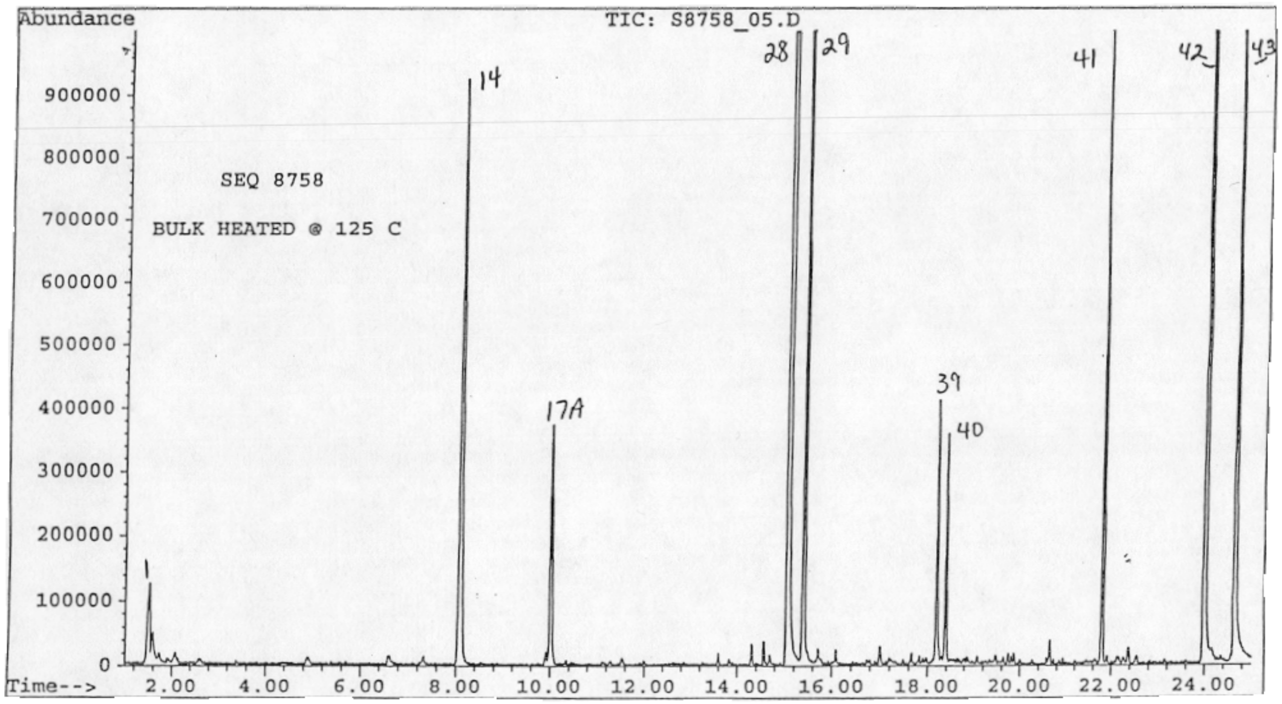



File : C:\HPCHEM\1\DATA\S8758\S8758_05.D
Operator : AAG
Acquired : 24 Jun 97 2:04 pm using AcqMethod PLASTIC
Instrument : 5970 - In
Sample Name: BULK SAMPLE HEATED @ 125C 10 MIN
Misc Info : 30 M DB-1 SC20-400 TP35-300
Vial Number: 6



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