HETA 97-0185-2675
McGregor Loudspeaker Manufacturing Company
Prairie du Chien, Wisconsin

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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 Max Kiefer and Richard Driscoll of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Christine Kasting. Analytical support was provided by Larry Jaycox, ACS, Division of Physical Sciences and Engineering. Desktop publishing was performed by Pat Lovell. Review and preparation for printing was performed by Penny Arthur.

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Health Hazard Evaluation Report 97-0185-2675
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February 1998

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SUMMARY

On July 14-16, 1997, investigators from the National Institute for Occupational Safety and Health (NIOSH) conducted a site visit at the McGregor Loudspeaker Manufacturing Company (MLM) in Prairie du Chien, Wisconsin. The site visit was conducted in response to a management request for a health hazard evaluation (HHE) that asked NIOSH to determine if exposures to contaminants in the manufacturing area may be related to health problems; specifically sinus infections, sinus congestion and headaches, reported by some employees.

On July 15, 1997, environmental monitoring was conducted to assess airborne personal breathing zone (PBZ) exposures to various compounds used at MLM. PBZ monitoring was conducted on eight Manual Line employees, three Automatic Line employees, and the one employee working in the Teardown department. Eleven air samples were collected for acetone, hexane, toluene, methylene chloride, and tetrahydrofuran analysis, 11 samples were collected for acetone and methyl-ethyl-ketone (MEK) analysis, and 5 air samples were collected for hydroxyalkyl methacrylate (HMA) analysis. Five area air samples were collected using a broad spectrum sampling and analytical technique (thermal desorption tubes with gas chromatography/mass spectroscopy analysis [TD-GC/MS]). Five surface samples were collected in the employee cafeteria for metal analysis.

To determine whether work-related exposures could be responsible for a cluster of sinus infections, nasal congestion, and headaches, informal confidential interviews were conducted with first shift employees at MLM. Addition information was gathered from company Occupational Safety and Health Administration (OSHA) 200 logs and the log book of employment exit interviews.

The monitoring results showed that PBZ air concentrations of the contaminants sampled were below applicable occupational exposure limits during the sampling period. However, two of the activities monitored had concentrations of 50% or more of the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) for combined exposures, and there appear to be opportunities to reduce exposures at these stations. No measurable quantities of HMA were detected during the survey. Although the results are not quantitative, the TD-GC/MS monitoring showed that many compounds identified in the manufacturing area are also present in the office administrative department, indicating that air from the manufacturing area is infiltrating into the office area either by means of a pressure differential or inadequate separation of the air handling systems. Conditions may also be affected by seasonal differences (e.g., winter) when there is less air exchange in the manufacturing area.

Various concentrations of zinc and copper, and only trace or non-detectable levels of lead, cadmium, tin, and chromium were detected on surfaces in the employee cafeteria. It was not determined if the production area was the source of the detected metals. Standards for surface contamination have not been established.

Housekeeping and chemical handling practices observed during the site visit included the use of improper and unlabeled containers, failure to keep containers closed, excessive clutter, and the blocking of aisles and egress paths in some areas. In both the production and reclaim area, the use of protective gloves when handling chemicals appeared to be sporadic - instances were observed where no protective gloves were worn during dispensing of chemicals. In some areas, gloves are re-used repeatedly without proper decontamination and inspection, which could result in additional exposure to the solvents. Some employees indicated they routinely use solvents (acetone) to clean glue off of their hands.

In addition to exposure concerns, the use of acetone in the Teardown department presents a potential fire hazard. Excessive volumes of acetone in improper and uncovered containers are used in this area.

A limited assessment of the local and general ventilation systems indicated that their effectiveness was hampered from turbulence created by the use of comfort fans, inadequate proximity of local exhaust to the contaminant source, or by failure to detect when the system was inadvertently turned off.

Eight workers volunteered for informal confidential interviews. Two of the eight workers described having recurring sinus infections and headaches. Six of the eight workers described frequent episodes of fatigue and headaches that they attributed to acetone exposure and fumes from the soldering stations. Additionally, one worker described shortness of breath and a dry nose and throat.

Sinus infections are not generally considered to be work related, although upper respiratory tract irritation caused by workplace chemicals might be erroneously attributed to sinus infection. Headaches and fatigue are symptoms that are commonly described by workers exposed to solvents and may be the result of exposure to solvents and acrylic glues used in loudspeaker assembly.

No occupational source could be identified for the cluster of sinus infections reported by employees. Exposures to the airborne contaminants sampled were below applicable occupational exposure limits during the sampling period. However, conditions may be different during times of the year (e.g., winter) when there may be less air exchange in the manufacturing area. Opportunities exist to further reduce exposures at some stations. Recommendations to improve housekeeping, chemical handling practices, the efficacy of the ventilation systems, and to reduce the fire and exposure risk from the use of acetone in the Teardown department are provided in the Recommendations section of this report.

Keywords: SIC 3651 (Household Audio and Video Equipment); Automotive Loudspeaker Manufacturing, acetone, tetrahydrofuran, methyl ethyl ketone, hydroxyalkyl methacrylate, toluene, hexane, methylene chloride, sinus irritation, sinusitis, surface contamination.

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INTRODUCTION

On May 12, 1997, the National Institute for Occupational Safety and Health (NIOSH) received a request from management at the McGregor Loudspeaker Manufacturing Company in Prairie du Chien, Wisconsin, for a health hazard evaluation (HHE) to assess exposure to substances used or generated during the manufacture of automotive speakers. The request indicated some employees had reported health problems (sinus infection, congestion, headaches) possibly associated with their work environment.

On July 14-16, 1997, NIOSH investigators conducted a site visit at the McGregor facility. Personal and area air sampling was conducted to evaluate worker exposures in the manufacturing area, and confidential interviews were held with employees. Various work practices were evaluated, including chemical handling procedures and the use of personal protective equipment. At the conclusion of the site visit, a closing conference was held with management and employee representatives to review the actions taken by NIOSH, and provide preliminary findings and recommendations.

BACKGROUND

McGregor Loudspeaker Manufacturing Company (MLM) assembles automotive speakers and is located in a 52,000 ft^2 single-story (20 ft ceiling) building that was occupied in 1990. The plant employs approximately 160 non-union workers on 2 production shifts (6 a.m. - 2:30 p.m., 2:30 p.m. - 12 a.m.) with a smaller third shift for conducting maintenance activities. The facility operates in this manner Monday through Thursday (the plant closes at 6:30 p.m. on Friday and reopens at 6 a.m. on Monday). Employees are given a 10-minute break every two hours and there is a 30-minute lunch period. The front of the building contains administrative offices, and a production management/engineering center is located in the center of the assembly area. The employee lunch room is located between the administrative offices and the production lines. The shipping/receiving department contains a stockroom and a finished-goods area. Smoking and food/beverage consumption are not permitted on the factory floor.

There are two manual (day shift) and automated (second shift) production lines at the plant, with similar production processes on both lines. The manual line requires 35 workers, while the automated line requires approximately 26 workers. During the NIOSH visit, a third automated line was being installed, which will eventually replace the manual line. Only assembly activities are conducted at the facility; there are no extrusion, formulating, painting, or welding tasks. Each assembly line has a "building" side and a "finish" side, with the center serving as a carryover/heat curing line. Assembly operators perform their tasks sitting down, and there is considerable handling and manipulation of small parts. It is company policy to give line operators the option of changing stations every two hours to reduce the potential for developing musculoskeletal disorders. Production stations include applying adhesives, primers, and activators, needle gun operation, soldering, and testing of the assembled components. A variety of glues and solvents are used on the assembly lines. There are no production tasks requiring the use of respiratory protection. Local exhaust ventilation is provided at the soldering stations and activator application stations. Maintenance personnel are responsible for replenishing chemicals used in the assembly process.

A chemical storage area (Adhesive Room) is located at the back of the facility adjacent the Teardown department. Reject speakers are reclaimed at Teardown. This activity entails soaking parts in open containers of acetone, and spot cleaning with tetrahydrofuran.

In December 1996, and January-February 1997, several employees experienced sinus infections and there was increasing employee concern about exposure to contaminants at work. Other than a 1993 survey conducted to assess airborne levels of lead, there was no workplace exposure information available. Because of the employee concerns and lack of exposure data, NIOSH was asked to conduct the HHE.

METHODS

On July 14, 1997, an opening conference was held with management and employee representatives. During this meeting, information about NIOSH was provided and the HHE request was discussed. Following the opening conference, a walkthrough inspection to review the production processes, chemical handling practices, and finalize the NIOSH environmental sampling strategy was conducted. This process review included the Manual and Automatic Line, Teardown, and the chemical storage (Adhesive Room) area.

Industrial Hygiene

Prior to the site visit, additional information regarding the reported health problems and suspect environmental contaminants was obtained. Information provided by the company included material safety data sheets (MSDS's) for certain process chemicals, a facility layout, and the results of a previous industrial hygiene survey to assess exposure to lead.

On July 15, 1997, environmental monitoring was conducted to assess airborne personal breathing zone (PBZ) exposures to various compounds used at McGregor Manufacturing company. Area air samples were also collected. Processes selected for monitoring were based on an assessment of the chemicals in use, employee work practices, and controls utilized. Activities of concern noted by the HHE requestors were also targeted for sampling. Job titles/processes monitored, and the contaminants sampled, are noted in Table 1.

PBZ monitoring was conducted on eight Manual Line employees, three Automatic Line employees, and the one employee working in Teardown. Eleven air samples were collected for acetone, hexane, toluene, methylene chloride, and tetrahydrofuran analysis, 11 samples were collected for acetone and methyl-ethyl-ketone (MEK) analysis, and 5 air samples were collected for hydroxyalkyl methacrylate (HMA) analysis. Additionally, five area air samples were collected using a broad spectrum sampling and analytical technique (thermal desorption tubes with gas chromatography/mass spectroscopy analysis [TD-GC/MS]). Two TD-GC/MS samples were collected on the manual line, one sample in the automatic line, one sample in the office area, and one sample from outside. The results from this sampling helped identify specific compounds for analysis on the personal samples. A bulk sample of material containing HMA was obtained, and five surface samples were collected in the employee cafeteria for metal analysis.

When available, the monitoring was conducted utilizing established analytical protocols (NIOSH analytical methods).[1] The pumps were calibrated with a BIOS® primary standard prior to collecting the samples. The air sampling pumps were attached to selected workers and connected, via tubing, to sample collection media placed in the employees' breathing zone. Monitoring was conducted throughout the employees' work-shift, or the duration of the activity of interest. After sample collection, the pumps were post-calibrated and the samples submitted to either the NIOSH Measurement Support Branch, or the NIOSH contract laboratory (Data Chem, Salt Lake City, Utah) for analysis. Field blanks were submitted with the samples. Specific sampling and analytical methods used during this survey were as follows:

Thermal Desorption Tubes

Area air samples were obtained utilizing reusable Carbotrap® 300 multi-bed thermal desorption (TD) tubes as collection media. These tubes are designed to trap a wide range of organic compounds for subsequent qualitative analysis via thermal desorption and gas chromatography/mass spectrometry (GC/MS). Each stainless steel tube contained three beds of sorbent material.

Low-flow air sampling pumps (SKC model 223, SKC Pocket Pump™) were used to collect the air samples. Nominal flow rates of 50 cubic centimeters per minute (cc/min) and sample times of approximately 150 minutes resulted in total sample volumes of 7-8 liters of air. The SKC model 223 constant-volume pumps are equipped with a pump stroke counter and the number of strokes necessary to pull a known volume of air was determined. This information was used to calculate a volume of air per pump stroke "K" factor. The pump stroke count was recorded before and after sampling and the difference used to calculate the total volume of air sampled. The SKC model Pocket Pump™ is a constant-flow sampling pump that was pre- and post-calibrated using the BIOS® primary standard to verify the flow rate. The total volume of air sampled is the product of flow rate and time sampled.

After collection, the samples were shipped via overnight delivery to the NIOSH laboratory for analysis. At the NIOSH laboratory, each sample was analyzed by directly inserting the tube into a thermal desorber unit (Perkin Elmer ATD 400 thermal desorption system) with no other sample preparation. A desorption time of 10 minutes at 350°C was used. The thermal desorber was directly connected to the GC and MS detector. Reconstructed total ion chromatograms were obtained for each sample, and all were scaled the same for comparison. Each peak in the chromatogram was identified.

These area TD samples were analyzed prior to any other samples to identify specific compounds for subsequent quantitative analysis on the personal samples.

Solvents

Integrated air samples for solvents were collected using both SKC model 223, and SKC model Pocket Pump™ low-flow sampling pumps. Nominal flow rates of 50-100 cc/min were used to collect the samples.

Samples for methyl-ethyl-ketone and acetone were obtained using carbon molecular sieve (ORBO®-90) tubes (160 milligrams front section/80 milligrams backup) as the collection medium, and analysis was conducted according to NIOSH 4th edition methods 1300 and 2500. Standard charcoal tubes (100 milligrams front section/50 milligrams backup) were used for the other solvents sampled (acetone, hexane, toluene, methylene chloride, and tetrahydrofuran). Analysis of these samples was conducted according to NIOSH 4th edition methods 1300, 1500, 1005, 1609, and 1501, with certain laboratory modifications. After collection, the samples were placed on ice and shipped via overnight delivery to the NIOSH contract laboratory. As previously noted, these samples were held at the laboratory until the results of the TD tube analysis were available. The major compounds identified on the TD samples were selected for quantitative analysis on the charcoal tubes.

Hydroxyalkyl methacrylate

Because the HHE requestor reported some employees had health concerns regarding the use of adhesives and activators containing hydroxyalkyl methacrylate (HMA), air sampling was conducted for this compound. An air sampling method for this compound had not been established, and NIOSH chemists initiated a short term method development project to identify an appropriate sampling technique. Based on this development effort, it was determined that air samples for HMA should be collected on treated charcoal tubes (SKC® 226-73) and, following desorption with a 95% methylene chloride/5% methanol solution, analyzed by gas chromatography equipped with a flame ionization detector.

PBZ samples for HMA were collected using SKC® low flow sampling pumps at a nominal flow rate of 50 cc/min. After collection, the samples were placed on ice and shipped via overnight delivery to the NIOSH analytical laboratory for analysis. A bulk sample was collected in a shielded glass vial (to prevent the adhesive from curing in the presence of light) with a Teflon® cap and shipped separately to the NIOSH analytical laboratory.

Surface Samples

Surface wipe samples were collected to determine the extent of metal dust surface contamination in the employee lunchroom. The samples were collected with commercially-available pre-moistened Wash & Dri® towlettes. One hundred square centimeters (100 cm^2) of surface area were wiped with each towlette. The samples were collected according to the surface sampling protocol described in the Occupational Safety and Health Administration (OSHA) Industrial Hygiene Technical Manual, and NIOSH 4th edition method 7300. After collection, the samples were sent to the NIOSH contract laboratory for analysis.

In addition to the environmental monitoring, work practices, including the use of personal protective equipment (PPE) and chemical handling procedures, were observed.

Epidemiologic Evaluation

According to the management at MLM at least five workers had been diagnosed with a work related sinus infection by their physician. To determine whether work related exposures could be responsible for the reported sinus infections, nasal congestion, and headaches, informal confidential interviews were conducted with first shift employees at MLM. Workers who were interviewed were those who wished to be interviewed (self selected) and those who were systematically selected from the assembly area. Additional information was gathered from company OSHA 200 logs and the log book of employment exit interviews.

EVALUATION CRITERIA

General

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)[2], (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®)[3] and (3) the U.S. Department of Labor, OSHA Permissible Exposure Limits (PELs)[4]. 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.

Organic Solvents

Exposure to organic solvents can occur through inhalation of the vapors, skin contact with the liquid, or ingestion. As many organic solvents have relatively high vapor pressures and readily evaporate, inhalation of vapors is a primary route of occupational exposure. Overexposure to many organic solvents can result in irritation, central nervous system depression, headache, nausea, and possible effects on the liver, kidney or other organs.[5,6,7] Many industrial solvents are primary irritants and can cause defatting of the skin and dermatitis. Solvents are among the leading causes of occupational skin disease.[6] Biological effects of exposure can range from practically non-toxic (e.g. some fluorocarbons) to highly toxic or carcinogenic (e.g. carbon tetrachloride, benzene).[7] The ability to detect the presence of a solvent by the sense of smell will vary widely depending on the specific substance and individual olfactory sensitivity. Substances are considered to have good warning properties if an average person with normal sensory perception can detect the presence of the chemical at a level below the recommended exposure limit. The following table summarizes the principle health effects associated with the solvents evaluated, and lists the NIOSH RELs and odor detection thresholds for these compounds.

Chemical	NIOSH REL[2]	Mean Odor Threshold & Description[8]	Principal Health Effects [(8,9,10)]
tetrahydrofuran	200 ppm TWA 250 ppm STEL	31 ppm: ether like - similar to acetone	Anesthetic effects, upper respiratory tract irritation
methyl-ethyl ketone (2-butanone)	200 ppm TWA 300 ppm STEL	17 ppm: sweet, sharp	Headache, dizziness, numbness of extremities Skin and eye irritation
toluene	100 ppm TWA 150 ppm STEL	1.6 ppm: sour, burnt	Eye/respiratory irritation, fatigue, headache, central nervous system depression
hexane	50 ppm TWA	65-248 ppm: gasoline	Skin and nervous system effects, upper respiratory irritation, central nervous system depression
acetone	250 ppm TWA	62 ppm: sweet, fruity	Eye irritation, nausea, headache, central nervous system depression.
methylene chloride	LFL	160-230 ppm: sweet	Eye, skin, respiratory irritant, central nervous system depression, suspect human carcinogen

Note: *TWA = time-weighted average concentration for up to 10 hours/day*
C = ceiling limit not to be exceeded
STEL = short-term exposure limit - 15 minute average
LFL = lowest feasible limit
PPM = parts of gas or vapor per million parts air

Many solvents have similar toxic effects, and when there are exposures to two or more substances that act upon the same organ system, their combined exposure is often evaluated according to a formula developed by the ACGIH.[3] Unless there is scientific evidence to the contrary, the effects are considered to be additive (as opposed to potentiating, synergistic, or antagonistic), and exposure is evaluated as follows:

$$\text{Combined REL} = \frac{C_1}{EL_1} + \frac{C_2}{EL_2} + \ldots \frac{C_n}{EL_n}$$

Where: C = measured atmospheric concentration
EL = corresponding exposure limit

If the sum of the above fractions exceed unity, the combined EL is considered to be exceeded.

Methylene Chloride

Methylene chloride (MC) is a clear, non-flammable, volatile liquid used primarily as a solvent in paint removers. NIOSH considers MC (also known as dichloromethane) to be a potential occupational carcinogen and recommends controlling exposure to the lowest feasible concentration.[10,11] The National Toxicology Program has concluded that there is sufficient evidence for the carcinogenicity of MC in experimental animals based on studies that have shown the compound can produce lung and liver tumors in mice and female rats when administered by inhalation.[12] Carbon monoxide is a metabolic byproduct of MC, and exposure to this solvent can result in elevated carboxyhemoglobin levels.[10] OSHA recently promulgated a comprehensive standard for MC, which lowered the PEL to 25 ppm as an 8-hour TWA, with an Action Level of 12.5 ppm.[13] Exposure at or above the Action Level requires the implementation of a number of requirements, including exposure control, medical surveillance, establishment of regulated areas, etc.

Hydroxyalkyl Methacrylate

Methacrylate compounds are derivatives of acrylic esters and are used in industry as bases for acrylic resins, plastic production, and medical and dental products such as surgical cement.[14] Methacrylate compounds are considered mild to moderate irritants, and some have been shown to be skin sensitizers.[14] Exposure primarily occurs via the skin and respiratory routes. NIOSH has not established an REL for hydroxyalkyl methacrylate compounds.

Surface Contamination

Occupational exposure standards defining "acceptable" levels of surface contamination have not been established. However, wipe samples can provide information regarding the effectiveness of housekeeping practices, the potential for exposure to contaminants from other exposure routes (e.g., surface contamination on a table that is also used for food consumption), the potential for contamination of worker clothing and subsequent transport of the contaminant, and the potential for non-process related activities to generate airborne contaminants (e.g., custodial sweeping).

RESULTS

Industrial Hygiene

Workplace Observations

Housekeeping was in need of improvement in certain sections of the manufacturing area. In the Teardown department, aisles were not clear and there were numerous used gloves, containers, speakers, parts, etc. that were not properly stored. Housekeeping was also poor in the Adhesive Room. Several unattended open containers of solvent and glue were noted, and the exit door from this chemical storage area was blocked by 55-gallon drums and other containers. The door of a flammable storage cabinet located in this room was missing, invalidating the effectiveness of the cabinet.

Acetone is used extensively in the Teardown area for reclaiming speakers. Acetone is dispensed into 5-gallon plastic containers and speakers are loaded into the containers and soaked. During the NIOSH survey, approximately 10 uncovered containers of acetone were in use in the Teardown department. No local exhaust ventilation or other controls are present in the Teardown area to control acetone emissions. Tetrahydrofuran, dispensed from a squeeze bottle, is also used for reclaiming speakers in this area. Rubber gloves were available for use; however, the worker in this area was observed handling chemicals without wearing protective gloves. Although the activity was not observed, employees indicated that acetone is also used to clean the floor in this department. The emergency eyewash station had not been inspected for sometime; when operated, rust-colored water came out of the eyewash.

During the monitoring period on July 15, one employee was working in the Teardown department while speaker parts were soaking in 5-gallon containers of acetone. During the environmental monitoring some of the containers were covered. On July 16, prior to the closing meeting, an additional employee was observed sitting by the 5-gallon containers manually cleaning the parts. The manual brushing and cleaning of parts was not observed on July 15, and thus, was not monitored.

In both the Production, Speaker Reclaim, and chemical storage areas, chemicals were observed in improper containers, uncovered, improperly labeled, or unlabeled. For example, in the Spider Assembly area, an unidentified solvent was stored in a coffee can. Other improper containers containing chemicals included a soft-drink bottle and a breakfast syrup plastic bottle. Food containers are not appropriate for chemical storage. On the solder line in the production area, small containers of acetone are difficult to distinguish from containers of water that are used to moisten sponges.

In both the production and reclaim area, the use of protective gloves when handling chemicals appeared to be sporadic - instances were observed where no protective gloves were worn when dispensing chemicals. Gloves are available in the workplace for use; in some areas, used gloves were found improperly stored. Some employees indicated they routinely use solvents (acetone) to clean glue off their hands.

The ventilation system for the solder lines appeared to be well designed and operating effectively. In the manufacturing area, however, there is considerable use of comfort fans that create turbulence and often negates the effectiveness of the local exhaust ventilation. On one side of the Spider Assembly station, a wall-mounted exhaust fan was installed to control emissions from this operation. The distance of the fan from the assembly station and the lack of baffles or shields appeared to inhibit the effectiveness of this system. During the ventilation inspection, one of the exhaust systems was found to be turned off.

There appeared to be good adherence to the prohibition on food and beverage consumption, and smoking in the production area. Most employees took breaks outside (weather conditions were pleasant) or in the employee cafeteria. Material Safety Data Sheets were available for chemicals in the production area.

Thermal Desorption Tube Monitoring

The reconstructed total ion chromatograms from the qualitative TD monitoring are shown in Appendix A, Figures 1-6. A separate table is also included in Appendix A listing each peak number with its corresponding identification. As previously noted, all chromatograms were scaled the same for comparison and these samples were analyzed prior to the other air samples to determine the most appropriate compounds to quantify. Major compounds identified on the samples were acetone, toluene, MEK, and hexane. Other compounds detected included sulfur dioxide, methylene chloride (MC), tetrahydrofuran (THF), benzene, acetic acid, ethyl acetate, and isobutylacetate. Based on the results of this monitoring, it was decided to analyze the quantitative air samples for acetone, hexane, toluene, MC, THF, and MEK.

It is important to note that the TD sampling results are not quantitative (the actual concentrations of the compounds detected are not determined), but they do provide useful information regarding the identity of compounds present, as well as signal-strength comparisons between control and target areas. For example, all three samples obtained from different locations in the manufacturing areas identified many of the same compounds. Comparing this data with the office control sample shows that some of the compounds present on the manufacturing floor (e.g., acetone, hexane, MEK, toluene) are also detectable in the administrative office area.

Organic Solvents

The TD monitoring identified the following major organic solvent compounds for quantitative analysis on the charcoal tube or carbon molecular sieve sampling tubes: MEK, acetone, THF, hexane, toluene, and MC. The results of the personal breathing zone air samples collected on July 15, 1997, are shown in Table 2. No exposures exceeding the NIOSH REL or other applicable exposure limits were detected during the monitoring period. Table 2 identifies the task sampled, the sample time, and the concentration of solvent detected in parts per million (ppm) for both the charcoal tube and carbon molecular sieve sampling technique. For each task monitored, the TWA concentration for each contaminant was calculated, as well as the combined REL. In some cases both sampling methods were used to monitor the same task and acetone concentrations were determined by both monitoring techniques. The acetone concentrations determined by the molecular sieve method were used for calculating the TWA concentrations and combined REL because the levels were generally higher than the comparable concentrations determined by the charcoal tube technique, and this would provide a more conservative estimate of exposure.

The highest acetone (116 ppm, REL = 250 ppm) and MEK (19.7 ppm, REL = 200 ppm) concentrations were detected on a 233 minute PBZ sample from the Wire Tier Operator on the Automatic Line. The combined REL for this sample was determined to be 0.56 (if the calculation is greater than unity, the REL is considered to be exceeded). The highest acetone concentration determined on the Manual Line was 107 ppm, found on a 412 minute PBZ sample from the operator at the Glue Pad Ring on Gasket station on the Finish side of the line. The combined REL for this task was determined to be 0.50. The highest hexane concentration (15.6 ppm, REL = 50 ppm) was detected on a 235 minute sample from the Spider and Coil Assembler on the Assembly Line. The combined REL for this task was 0.48, and the hexane concentration was the greatest contributor to the combined REL.

All samples showed relatively low concentrations of toluene (range = 2.4-6.7 ppm, REL = 100 ppm) and THF (range = 0.1-0.21 ppm, REL = 200 ppm). All methylene chloride concentrations were either less than detectable or between the analytical limit of detection (LOD) and analytical limit of quantification (LOQ).

Hydroxyalkyl Methacrylate

Four PBZ samples were collected from workers on the Manual Line who used a material (Loctite 326, Primer X) containing approximately 35% hydroxyalkyl methacrylate (HMA). The results are shown in Table 3. No HMA was detected on any of the air samples. As previously noted, NIOSH has not established a REL for HMA. Because the Material Safety Data Sheet from another HMA-containing product indicated that methacrylic acid may be present, the chromatograms obtained from the HMA analysis were used to determine if this compound was detected. No methacrylic acid was detected on any of the samples.

Surface Samples

Four wipe samples were collected from various surfaces in the employee cafeteria and analyzed for the following elements: cadmium, lead, copper, zinc, chromium, and tin. The results of the surface sampling are shown in Table 4. With the exception of zinc (57-117 micrograms per 100 square centimeter surface area [µg/100cm^2]) only very low levels (or below detectable limits) of metals were detected in the cafeteria. Copper was the second most predominant element detected; only trace or undetectable levels of lead, cadmium, chromium, and tin were found.

Epidemiologic Evaluation

One hundred and fifty-five workers were listed on the personnel roster supplied to us by the company. Of the 155 employees, 129 are considered full time first shift workers and 109 (70%) are female.

Employee Interviews

A total of eight workers volunteered for informal confidential interviews. Workers were asked to describe any health concerns or symptoms that they perceived to be work related. Two of the eight workers described having recurring sinus infections and headaches. Six of the eight workers described frequent episodes of fatigue and headaches that they attributed to acetone exposure and fumes from the soldering stations. Additionally, one worker described shortness of breath and a dry nose and throat. It should be noted that confidential interviews with the employees were restricted to the morning of the first shift on July 15, 1997. An early afternoon equipment malfunction on the 'manual' assembly line resulted in a production backup and we were unable to continue interviewing the workers without further delaying production. Because there were no apparent work related exposures that could account for reports of sinus conditions and the headaches and irritant symptoms described by workers were likely the result of exposure to solvent, we elected to discontinue worker interviews after the equipment malfunction.

Employer Records

The OSHA 200 log had no listings describing sinus infections or headaches. However, over 65% of the OSHA illness and injury listings for the last 3 years were for musculoskeletal strain or injury. A record of exit interviews conducted by the Human Resources Director indicated a limited number of workers who terminated employement for reasons of health; however, none of the listings indicated health conditions that could be related to sinus infections.

DISCUSSION

Although the personal air sampling results during this survey did not identify any exposures exceeding NIOSH criteria or other occupational exposure limits, improvements in chemical handling and housekeeping practices could be made. These improvements would better control solvent loss and worker exposure to these chemicals, and reduce the potential for spills, mishaps, or inadvertent use of the wrong materials. For example, numerous open containers of solvents were present throughout the facility, and many of the containers were improper and unlabeled. Implementing the use of proper (NFPA approved, self-closing lids) labeled containers will reduce evaporative loss and improve safety.

Skin contact can be a significant route of exposure to many of the solvents in use at McGregor Loudspeaker. The skin-protection program is ineffective primarily because the use of protective gloves is not uniformly enforced at the facility. In some areas, gloves are re-used repeatedly without proper decontamination and inspection, which could result in additional exposure to the solvents handled.

The practice of soaking parts in 5-gallon open plastic containers of acetone in the Teardown area presents a potential fire and exposure hazard. Acetone has a flashpoint of 0° F and is considered a Class 1A flammable liquid.[15] Because it is a highly volatile and flammable solvent, acetone should be stored in and dispensed from approved (NFPA) safety containers, and covered as much as possible to reduce evaporative loss. Although the sampling results from the Teardown Operator collected on July 15, 1997, found acetone concentrations below the NIOSH REL, manual cleaning of speakers with acetone (sitting by the container and scrubbing parts) and cleaning the floor with acetone was not conducted during this monitoring period. As such, the monitoring results do not reflect activities that could be expected to result in higher exposures.

The results of the thermal desorption tube monitoring indicate that many of the compounds identified in the manufacturing area were also detected in the office administrative department, and a noticeable solvent odor was also present in this area. The results indicate that air from the manufacturing area is infiltrating into the office area either through pressure differential or inadequate separation of the air handling systems.

The PBZ monitoring results found all exposures to be below applicable occupational exposure limits. Analysis of these results, however, indicate there are areas where efforts to further reduce exposures should be focused. Two of the PBZ sample results (Wire Tier, Automatic line, Glue Pad Ring Assembler, Manual line) were at or above 50% of the combined exposure limit for the compounds monitored (methyl ethyl ketone and acetone). The acetone concentrations during these tasks were also considerably higher than those at other monitored activities on the assembly line. The failure to detect measurable quantities of hydroxyalkyl methacrylate was not surprising. Observation of the tasks entailing the use of these materials indicated that only small amounts are dispensed and used.

This survey was conducted during a time when outside conditions were optimum and doors to the outside were open, possibly resulting in greater air exchanges than would occur during colder periods. As such, the air sampling results are only reflective of these conditions and may not be representative of concentrations that could be present during different times of the year.

Surface samples collected in the employee cafeteria found various concentrations of zinc and copper, and only trace or non-detectable levels of lead, tin, cadmium, and chromium. It could not be determined if the production area was the source for the detected metals. Standards regarding surface contamination have not been established and exposure cannot be estimated from these results. Employees should be aware that there is a potential for skin contact with contaminants in the employee cafeteria, and adherence to good personal hygiene (hand washing) prior to food and beverage consumption should be emphasized.

Rotating workers every two hours is a good practice and appeared to be well-received by employees. However, this should not be used as a substitute for identifying and controlling ergonomic hazards.

Sinus Infections

Sinus infections are not generally considered to be work related. Acute sinus infections are caused by bacteria or viruses and, symptoms associated with this condition include fevers, localized pain, stuffy nose, and a purulant discharge. Chronic sinus infections can be related to allergies or to structural abnormalities of the sinuses. Symptoms associated with chronic sinus infections include a chronic nasal discharge, post nasal drip, and facial and/or eye pain. Chronic sinusitis is most often caused by an anaerobic bacteria.[16]

The Human Resources Director noted that five workers had been informed by their physicians that conditions at work were responsible for their sinus infections; however, only two persons indicated having recurrent sinus infections during worker interviews. We observed no occupationally-related source that could account for sinus infections among employees; however, upper respiratory tract irritation caused by workplace chemical exposures might be erroneously attributed to sinus infections. Headaches and fatigue are symptoms that are commonly described by workers exposed to solvents and may be the result of exposure to acetone and the acrylic glues used in loudspeaker assembly.

CONCLUSIONS

The purpose of this health hazard evaluation was to determine whether an apparent cluster of sinus infections among employees was the result of work exposures. After visiting the site, conducting informal interviews with employees, examining conditions on the assembly lines, and reviewing personnel and safety records, we could not establish an occupationally related source for the sinus infections reported by the employees.

Employee exposures to all substances evaluated were below applicable occupational exposure limits during the sampling period. However, conditions may be different during times of the year (e.g., winter) when there may be less air exchange in the manufacturing area. Two of the activities monitored were at or above 50% of the combined exposure limit as determined by the ACGIH formula, and there may be opportunities to reduce exposures at these stations. Contaminants from the manufacturing area are detectable in the office administrative area, likely because of inadequate separation of the air handling systems or pressure differential.

Housekeeping and chemical handling practices were generally inadequate throughout the facility. These included the use of improper and unlabeled containers, failure to keep containers closed, excessive clutter, and the blocking of aisles and egress paths in some areas. Adherence to the proper use of personal protective equipment was sporadic in many areas. The use of acetone in the Teardown department presents a potential fire hazard. The effectiveness of local and general ventilation systems are hampered from turbulence created by the use of comfort fans, inadequate proximity to the contaminant source, or by failure to detect when the system was inadvertently turned off.

RECOMMENDATIONS

1. The practice of soaking parts in open, unapproved containers of acetone, and hand cleaning of parts over containers of acetone in unventilated areas in the Teardown Department should be eliminated. The process should be modified if possible to eliminate the use of highly flammable and volatile solvents. Ensure the use of National Fire Protection Association approved containers and proper ventilation. The volume of acetone stored and used in use should be evaluated and reviewed with the local Fire Marshall to ensure Fire Code limits for Class 1A flammable liquids are not exceeded. The amount of chemical used for cleaning should be minimized as much as possible. Eliminate the practice of cleaning the floor with acetone.

2. Improve housekeeping in the Adhesive Room and Teardown department. Used gloves should be either discarded or cleaned, inspected, and stored properly after use. Ensure aisle-ways and egress paths are not blocked. Repair cabinets used to store hazardous materials.

3. Implement a program to ensure that chemicals are only stored in approved, properly labeled containers. For example, acetone and other solvents should be stored and used in containers with self-closing lids designed for use with these chemicals. The containers should be readily identified with prominent labels to ensure they are distinguishable from other chemicals and water. All chemical containers should be covered when not in use to reduce solvent loss and the subsequent emissions.

4. Glove use should be mandatory for dispensing or using chemicals. The use of solvents to clean skin should be banned. Prevention of skin contact with chemicals should be the focus of these efforts. A comprehensive personal protective equipment program should be implemented. The elements of an effective program include:

Written procedures: Define the necessary PPE and ensure it is properly and consistently used and maintained. The use of PPE should be mandatory.

Proper Selection and Use: There are many gloves available which provide adequate protection and still allow considerable dexterity. PPE should be individually assigned.

Inspection and Maintenance: Gloves should be inspected before and after each use, cleaned prior to removal, and replaced frequently. After cleaning, PPE should be stored properly.

5. Ensure that employees are aware of the impact of comfort fans and turbulence on the effectiveness of local exhaust ventilation control systems. The use of baffles at the soldering station, and enclosures or baffles at the Spider Assembly department, may improve the efficacy of the contaminant control ventilation systems at these work stations by providing a more directed exhaust. A ventilated drying station for the finished parts at the Spider Assembly department should also be implemented. Ensure that a mechanism is in place to prevent the ventilation system from being inadvertently turned off, and that an alarm is signaled if it is turned off. Additions and modification to the ventilation system, particularly increased demands on the system, should be reviewed by a qualified ventilation engineer.

6. Safety/Emergency equipment (eyewash, safety shower) should be inspected and flushed routinely (monthly) to ensure proper operation.

7. Conduct a detailed review of the Wire Tier task (Automatic Line) and the Glue Pad Ring on Gasket Assembler (Manual Line) to identify activities possibly contributing to the higher acetone concentrations at these stations. Open containers, excessive or unnecessary use of solvent, etc., should be included in this assessment. Initiate improvements based on this review.

8. The review of the OSHA 200 logs indicated that 65% of the listings were for musculoskeletal disorders. Job tasks at MaGregor Loudspeaker Company should be reviewed and necessary changes made to reduce the risk of musculoskeletal injury to employees.

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Table 1
Personal Sampling: Processes Sampled
McGregor Loudspeaker Manufacturing
HETA 97-0185-2675
July 15, 1997

Job Description	Process/Area	Compounds Sampled
Magnet to Pole Assembler	Manual Line - build side	Hydroxyalkyl methacrylate
Spider & Coil Assembler	Manual Line - build side	Hydroxyalkyl methacrylate
Loctite & Tie Assembler	Manual Line - build side	Hydroxyalkyl methacrylate, Acetone, Hexane, Toluene, Methylene chloride, Tetrahydrofuran
Eyelet Assembler	Manual Line - finish side	Acetone, Hexane, Toluene, Methylene chloride, Tetrahydrofuran, Methyl ethyl ketone
Glue Pad Ring on Gasket Assembler	Manual Line - finish side	Acetone, Methyl ethyl ketone
Whizzer Assembler	Manual line - finish side	Hydroxyalkyl methacrylate, Acetone, Hexane, Toluene, Methylene chloride, Tetrahydrofuran
Speaker Reclaim Operator	Teardown	Acetone, Hexane, Toluene, Methylene chloride, Tetrahydrofuran, Methyl ethyl ketone
Spider Assembly Operator	Spider Assembly station	Acetone, Hexane, Toluene, Methylene chloride, Tetrahydrofuran, Methyl ethyl ketone
Spider & Coil Assembler	Automatic Line	Acetone, Hexane, Toluene, Methylene chloride, Tetrahydrofuran,
Wire Tier	Automatic Line	Acetone, Methyl ethyl ketone
Eyelet Lead Assembler	Automatic Line	Acetone, Methyl ethyl ketone

Table 2
Personal Air Sampling Results - Organic Solvents
McGregor Loudspeaker Manufacturing
HETA 97-0185-2675
July 15, 1997

Task Monitored	Sample #	Sample Time (min)	Concentration Detected (ppm) Acetone	MEK	Hexane	Toluene	MC	THF	TWA Concentration (ppm)		Combined REL
Speaker Reclaim Operator: Teardown	CT-1	7:17-9:34 (138)	38.4	NA	3.6	3.2	(0.3)	2.3	Acetone	62	**0.43**
	ORB-31		68.1	2.2	NA	NA	NA	NA	MEK	7.7	
	CT-4	9:41-11:51 (130)	50	NA	6.5	4.9	(0.2)	0.26	Hexane	5	
	ORB-34		78.9	12.7	NA	NA	NA	NA	Toluene	4	
	ORB-41	11:54-15:14 (200)	46.8	8.2	NA	NA	NA	NA	MC	(0.25)	
									THF	1.3	
Spider Assembly Operator Side with exhaust fan in place	CT-2	7:01-10:47 (229)	24.9	NA	3.9	3.5	(0.2)	0.21	Acetone	38.7	**0.35**
	ORB-32		39.5	12.2	NA	NA	NA	NA	MEK	11.1	
	CT-7	10:50-1:54 (184)	28.4	NA	4.9	4.6	(0.2)	0.2	Hexane	4.3	
	ORB-36		37.6	9.8	NA	NA	NA	NA	Toluene	4.0	
									MC	(0.2)	
									THF	0.2	
Spider Assembly Operator Opposite side from the exhaust fan	CT-3	6:57-10:52 (235)	21	NA	3.9	3.5	(0.2)	0.17	Acetone	29.2	**0.33**
	ORB-33		25.8	18.5	NA	NA	NA	NA	MEK	18.5	
	CT-6	10:56-12:10 (74)	17.1	NA	4.7	4.2	<0.2	(0.2)	Hexane	4.1	
									Toluene	3.7	
	ORB-35	10:56-13:45 (169)	33.9	18.6	NA	NA	NA	NA	MC	<0.2	
									THF	0.2	
Eyelet Assembler, Manual Line, Finish Side	CT-9	6:44-13:57 (436)	28.2	NA	4.6	4.4	(0.2)	0.2	Concentrations reported in preceding blocks are TWA		**0.35**
	ORB-38		36.4	12.7	NA	NA	NA	NA			
Loctite & Tie Assembler, Manual Line, Build Side	CT-5	6:35-12:45 (370)	9.8	NA	2.1	2.4	<.05	0.1	Concentrations reported in preceding blocks are TWA		**0.11**
Whizzer Assembler, Manual Line, Finish Side	CT-10	6:52-13:56 (424)	25.7	NA	4.0	4.0	(0.3)	0.1	Concentrations reported in preceding blocks are TWA		**0.22**

Table 2 Personal Air Sampling Results - Organic Solvents McGregor Loudspeaker Manufacturing HETA 97-0185-2675 July 15, 1997										
Task Monitored	**Sample #**	**Sample Time (min)**	**Concentration Detected (ppm)**						**TWA Concentration (ppm)**	**Combined REL**
			Acetone	**MEK**	**Hexane**	**Toluene**	**MC**	**THF**		
Glue Pad Ring on Gasket Assembler, Manual Line, Finish Side	ORB-39	7:10-14:02 (412)	107	14.1	NA	NA	NA	NA	Concentrations reported in preceding blocks are TWA	**0.50**
Spider and Coil Assembler, Automatic Line	CT-8	10:11-14:06 (235)	24.5	NA	15.6	6.7	(0.1)	0.1	Concentrations reported in preceding blocks are TWA	**0.48**
Wire Tier, Automatic Line	ORB-37	10:15-14:08 (233)	116	19.7	NA	NA	NA	NA	Concentrations reported in preceding blocks are TWA	**0.56**
Eyelet Lead Assembler, Automatic Line	ORB-40	10:25-14:10 (225)	20.5	11.4	NA	NA	NA	NA	Concentrations reported in preceding blocks are TWA	**0.14**

Sample Notes: TWA Concentrations were calculated as follows:

$$\frac{(C_1)(T_1) + (C_2)(T_2) + (C_n)(T_n)}{T_1 + T_2 + T_n}$$

Where: C = concentration detected during time (T)

The Combined REL was determined using the following formula developed by the ACGIH:[3]

$$\frac{C_1}{REL_1} + \frac{C_2}{REL_2} + \ldots \frac{Cn}{REL_n}$$

Where: C = measured atmospheric concentration and REL = corresponding recommended exposure limit

If the sum of the above fractions exceed unity, the combined REL is considered to be exceeded.

PPM = parts of gas or vapor per million parts air
() = values in parentheses indicate the concentration detected was between the analytical limit of detection (LOD) and the limit of quantification (LOQ)
< = less than
MC = methylene chloride
MEK = methyl ethyl ketone
THF = tetrahydrofuran
CT = charcoal tube
ORB = molecular sieve tube
NA = not analyzed
When available, the acetone concentration determined by the molecular sieve tube sampling method was used to determine the TWA and combined REL.
Sample CT-6: Pump failed after 74 minutes.

Table 3
Personal Air Sampling Results - Hydroxyalkyl Methacrylate
McGregor Loudspeaker Manufacturing
HETA 97-0185-2675
July 15, 1997

Task Monitored	Sample ID	Sample Time (minutes)	Concentration Detected (mg/m^3)
Magnet to Pole Assembler, Manual Line, Build Side	HMA-4	6:20-14:00 (460)	< 2.5
Spider & Coil Assembler, Manual Line, Build Side	HMA-1	6:26-12:29 (363)	< 3.2
Loctite and Tie Assembler, Manual Line, Build Side	HMA-2	6:35-13:33 (418)	< 3.0
Whizzer Assembler, Manual Line, Finish Side	HMA-3	6:52-13:56 (424)	<2.8

Sample Notes: mg/m^3 = milligrams of contaminant per cubic meter of air sampled
The analytical Limit of Detection for HMA was 58 micrograms per sample
< = less than

Table 4
Surface Sampling Results
McGregor LoudspeakerManufacturing
HETA 97-0185-2675
July 15, 1997

Sample Number	Location	Contaminant Monitored	Results, µg/100 cm^2
WS-21	Employee Cafeteria, Table Closest to Factory Floor	Cadmium	0.25
		Lead	<0.5
		Copper	0.97
		Zinc	57
		Chromium	(0.59)
		Tin	<1
WS-22	Employee Cafeteria, Counter Adjacent the Coffee Pot	Cadmium	<0.08
		Lead	<0.5
		Copper	1.8
		Zinc	57
		Chromium	(0.69)
		Tin	(1.7)
WS-23	Refrigerator Door	Cadmium	(0.19)
		Lead	(1.0)
		Copper	0.66
		Zinc	87
		Chromium	(0.92)
		Tin	<1
WS-24	Table Top Adjacent Blood Pressure Monitor	Cadmium	<0.08
		Lead	(0.95)
		Copper	0.32
		Zinc	117
		Chromium	<0.5
		Tin	<1

Notes: All results are blank-corrected
< = less than
µg/100 cm^2 = micrograms of contaminant per 100 square centimeters of surface sampled
() = values in parentheses indicate the concentration detected was between the analytical limit of detection (LOD) and the limit of quantification (LOQ)

Appendix A

Thermal Desorption Tube Air Monitoring Results: McGregor Loudspeaker
Peak Identification Table

1. Air*/Carbon Dioxide*
2. Sulfur Dioxide*/Propane
3. Acetaldehyde
4. Butene
5. Butane
6. Ethanol
7. Acetone
8. Isopropanol
9. Methylene Chloride
10. 2-Butenal
11. 3-Buten-2-one/2-methyl pentane
12. Methyl ethyl ketone*
13. 3-Methyl pentane
14. Hexane*
15. ethyl acetate
16. Tetrahydrofuran
17. Methylcyclopentane
18. Acetic acid
19. Benzene*
20. Cyclohexane
21. Acetic acid anhydride?
22. Methyl isobutyl ketone
23. Toluene*
24. Isobutyl acetate
25. Hexanal*
26. Butyl acetate
27. Hexamethylcyclotrisoloxane*
28. Aliphatic aldehydes*, C_9-C_{12}
29. Benzaldehyde
30. Phenol

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

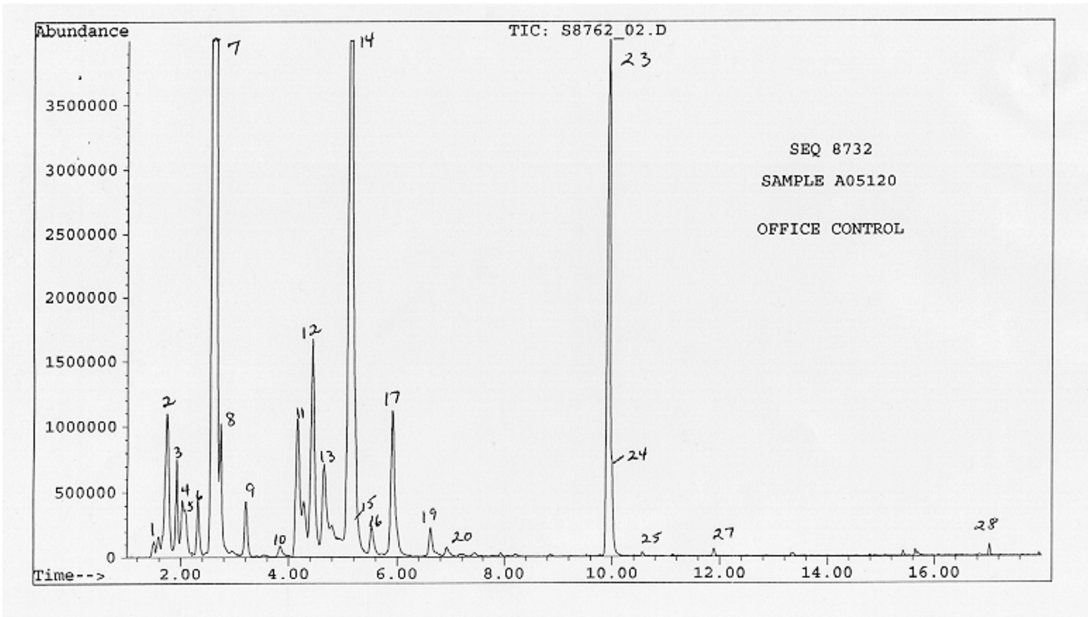


Figure 1 - Office Control

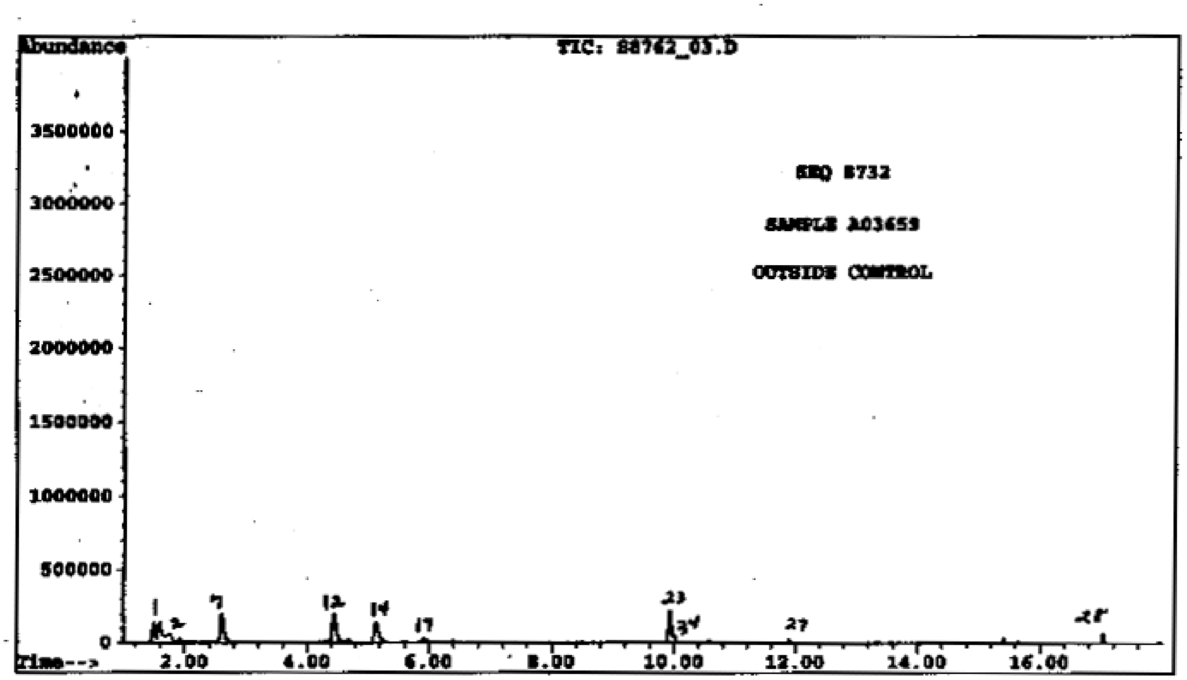


Figure 2 - Office Control

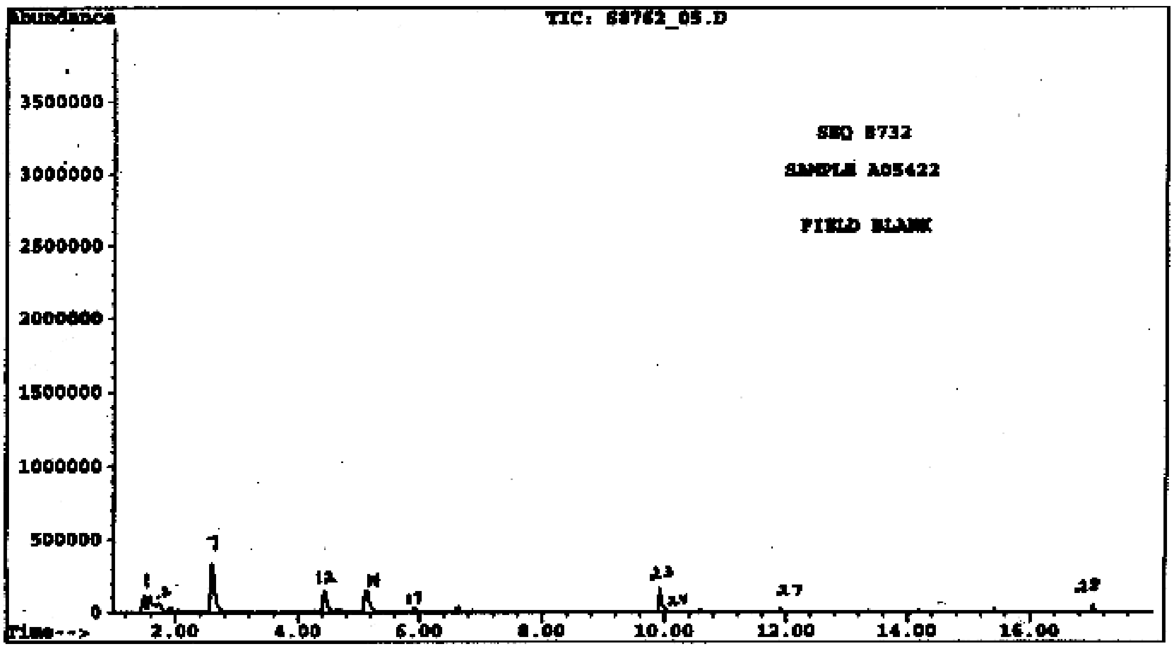


Figure 3 - Field Blank

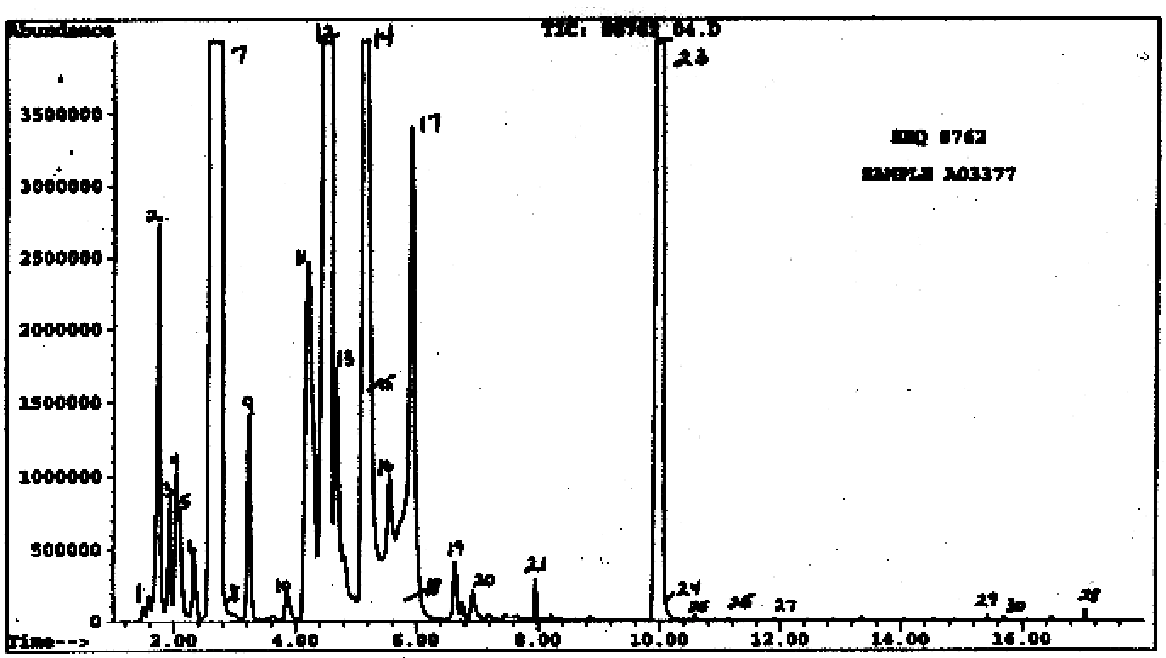
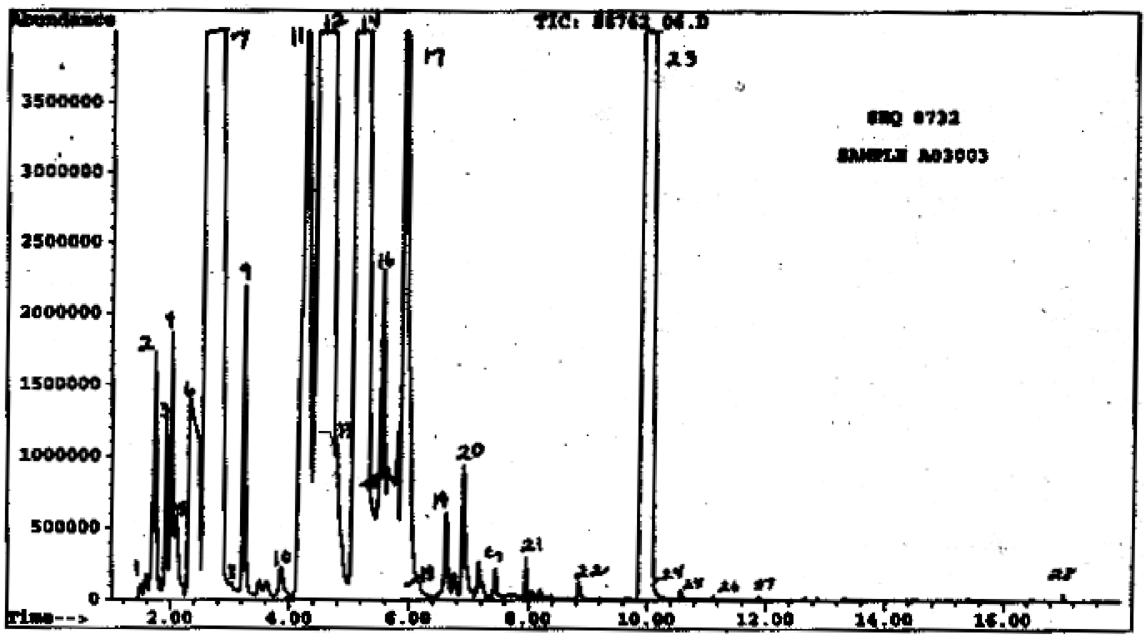


Figure 4- Manual Line, Back End



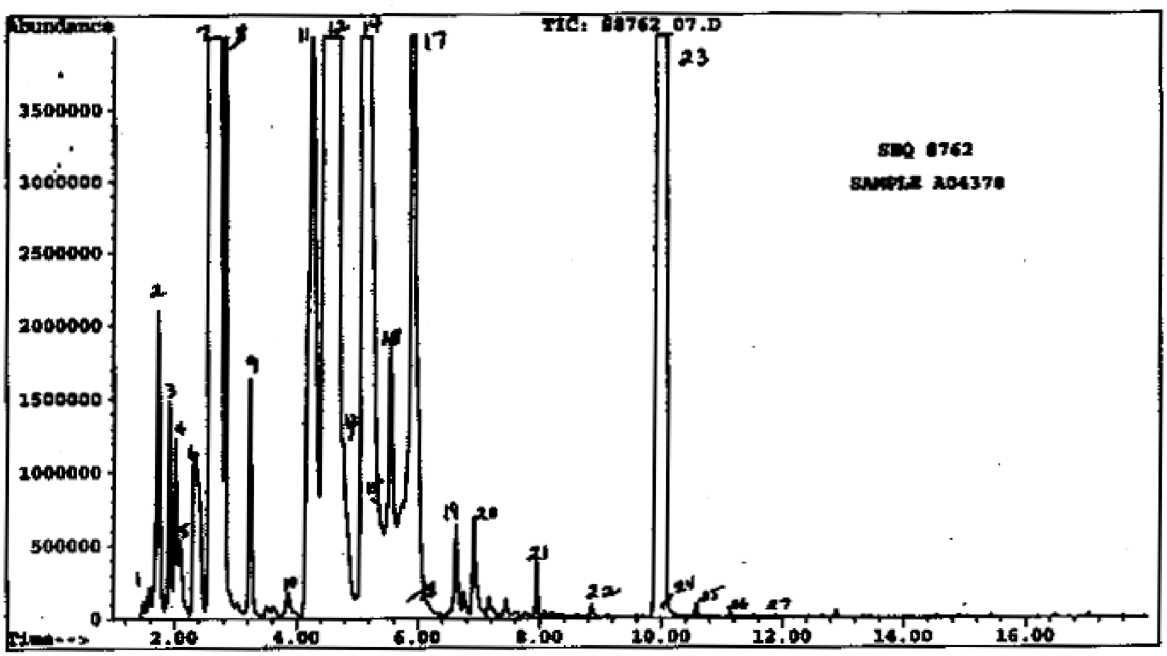


Figure 6 - Automated Line, Assembly Side

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