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I. SUMMARY

On June l3, l988, the National Institute for Occupational Safety and Health (NIOSH) received a request from a union representative of the Aerospace Machinists Industrial District Lodge 751 who represent workers at the Boeing Company in Auburn, Washington. This request stated that workers were experiencing problems such as headache, nausea, nose bleeds, dizziness, and associated flu-like symptoms. The manufacturing process that was suspect and was the focal point of this evaluation included the hand lay-up of formaldehyde and phenol impregnated fiberglass.

On July 5-8, l988, a preliminary environmental and medical evaluation was conducted. A return visit with a more detailed environmental and medical evaluation was conducted on August l6-l9, l988. During the time of these visits, breathing zone and general area air samples were collected and analyzed for formaldehyde concentrations, phenol, total particulate, antimony, and aliphatic and aromatic amines.

Personal and area formaldehyde concentrations ranged from below the limit of detection to a high of 0.073 mg/m^3. NIOSH recommends formaldehyde levels be kept as low as feasible. Phenol ranged from below the limit of detection to a high of 1.5 mg/m^3. The NIOSH recommended exposure level (REL) for phenol is 19 mg/m^3. Small amounts of antimony (up to 0.001mg/m^3) were detected in two of four samples. The REL for antimony is 0.5 mg/m^3. No amines were detected in any sample. In addition, trace quantities of styrene, various C9-C12 alkanes and C9-C10 aromatics such as trimethylbenzenes, diethylbenzenes, salicylaldehyde, and methanol were found.

A self-administered questionnaire was distributed to all available workers in Building 17-02 (including workers with & without exposure to phenol-formaldehyde) and Building 17-05, where phenol-formaldehyde resin was not used. Workers in the phenolic resin lay-up areas of Building 17-02 reported a statistically significant increased prevalence of cough, chest tightness and pain, sore throat, and nausea when compared to non-lay-up workers in the same building and/or compared to the workers in the referent Building 17-05. Within Building 17-02, phenolic resin lay-up workers reported a statistically significant increased number of hand rashes than non-lay-up workers.

Results showed an increased prevalence of self-reported respiratory tract symptoms and hand rashes among phenolic lay-up workers. However, the environmental results indicated no environmental conditions at the time of our investigation that would explain the reported adverse health effects. Recommendations for further reducing potential exposures are included in this report.

KEYWORDS SIC code: 3728 (Aircraft Parts and Auxiliary Equipment) Phenol, Formaldehyde, Antimony, Amines, Total Particulates.

II. INTRODUCTION

On June l3, l988, NIOSH received a request from a representative of the Aerospace Machinists Industrial District Lodge 751 to evaluate potential exposures in Building 17-02 at the Boeing Company in Auburn, Washington. Employees working with a fiberglass wrap that is impregnated with a phenol-formaldehyde resin had complaints of headache, nausea, nosebleeds, dizziness and skin rashes. Most of the parts made in this department are for the interior of airplanes.

III. BACKGROUND

In July l986, the Federal Aviation Administration (FAA) mandated an increase in the fire retardant properties of aircraft interior materials. FAA examined many materials and a phenolic resin system was chosen. Although it was not possible to predict contaminant exposure levels, the company anticipated an odor problem with the use of these new resins. The Material Safety Data Sheets (MSDS) obtained from the supplier identified the following compounds as the total ingredients of the phenolic resin system: l) Polymers (phenolic and formaldehyde), 2) Silica, 3) Brominated Bisphenol A, 4) Ethyl Alcohol, 5) Antimony Trioxide, and 6) Fibrous glass. In August l987, the Boeing plant in Auburn, Washington started production using the phenol-formaldehyde resin system in Building 17-02. Air samples taken by the Boeing Company revealed levels of phenol less than 0.0l parts per million (ppm) and formaldehyde less than 0.l ppm. Most of the phenolic lay-up work is done in the 17-02 building. During the installation of the new ventilation system in July 1988, many of the lay-up workers were temporarily moved into the 17-54 building. Building 17-05 contains a similar lay-up area, although phenolic resins were not used. On July 5-8, NIOSH conducted a preliminary environmental and medical walk-through evaluation. During this walk-through, environmental sampling was performed in both Building 17-02 and 17-54. On August 16-19, 1988, NIOSH conducted a more detailed evaluation, at which time environmental sampling and a questionnaire survey were performed in Building 17-02 and Building 17-05.

Process Description

Frozen rolls of phenol-formaldehyde resin-impregnated fiberglass are taken from a deep-freeze and thawed. Strips of this material are cut, baking film is removed, and the material is laid up by hand and tools in multiple layers. Vacuum bags are applied over the lay-up and the air is evacuated from the layers. Under vacuum, the parts are oven cured at 250ºF for 90 minutes. The parts are then cooled, debagged, and moved through trimming, deburring, sanding, and inspection stations. The surfaces of the parts are prepared, and the parts are painted, wrapped, and shipped (Figures 1 and 2).

Phenol-formaldehyde resins obtain their commercially useful structural properties as a result of a polycondensation type of chemical reaction. "In polycondensation, two or more starting materials react with each other to build up the molecular structure. The initial polycondensation reaction is interrupted at a stage in which the prepolymer possesses properties that are desirable for further processing in the molding phase."[1] The resins are sometimes referred to as "prepreg" materials at this stage of the process. The phenolic resins that were in use at Boeing are a class of resins known as thermosets, which means that they harden when heated and cannot be reformed after obtaining their desired shape. Because these resins are a "prepreg" material which has already gone through partial polymerization prior to being brought into the lay-up area, off-gassing from some of the unreacted starting materials may occur. Particulate exposures, however, are not of concern based on the physical properties of the material at this point. Particulate exposure may occur after the material has been cured and operations such as trimming and sanding begin. Chemical cartridge respirators, white cotton gloves and latex surgical type gloves were available to all workers. Use of all personal protective equipment was optional, and was minimal in all lay-up areas.

IV. Methods

A. Environmental

Bulk Sample - In order to know what materials might be present during the handling and curing of the phenol resin, a frozen bulk sample of the resin was obtained from Boeing. In the NIOSH laboratory, the frozen bulk material was heated first to a temperature of 20-40°C and then to 120°C in a tube furnace. The resulting effluent was then sampled for organics.

Phenol - Phenol samples were collected on XAD-7 tubes using calibrated vacuum pumps at a flow rate of 100 cubic centimeters per minute (cc/min). These samples were analyzed by high performance liquid chromatography according to OSHA Method No. 32 with modifications.

Formaldehyde - Formaldehyde and total aldehyde samples were collected using either Orbo-23 sampling tubes or impingers containing sodium bisulfite solution. Vacuum pumps were utilized operating at 100 cc/minute for the Orbo-23 tubes and 1 liter a minute for the impingers. The Orbo-23 tubes were analyzed for total aldehydes (which consisted only of formaldehyde in this evaluation) by gas chromatography (FID), using a method similar to Method 2501 (Acrolein). The impinger samples were analyzed for formaldehyde by visible spectroscopy according to NIOSH method 3500.
Amines - Amine samples were collected on silica gel tubes using vacuum pumps operated at 100 cc/minute. An amine scan was performed on these samples. The silica gel tubes were desorbed using 1N H_2S0_4; a small portion of this sample was made basic with NaOH. The basic sample was analyzed for aliphatic amines by gas chromatography. The acidic samples were analyzed for aromatic amines also using gas chromatography.

Total Particulate - Total particulate samples were collected on pre-weighed FWSB filters using vacuum pumps operated at 2 liters/minute. These samples were analyzed for total particulate weight by gravimetric analysis according to NIOSH method 0500 with modifications.

Antimony - Antimony samples were collected on AA filters using vacuum pumps operated at 2 liters/minute. These samples were analyzed by graphite furnace atomic absorption spectroscopy.

B. Medical

A self-administered questionnaire was distributed to employees in two buildings on August 17-18, 1988. This questionnaire was developed to assess the prevalence of self-reported symptoms occurring at work over the preceding 30 days. All available employees (3 shifts) in Building 17-02 (fabrication building) were asked to complete the questionnaire. All available first-shift employees in a second building (Building 17-05), in which phenol-formaldehyde resins were not used, were also asked to complete the questionnaire.

Within Building 17-02, employees who worked with or in close proximity to the uncured phenol-formaldehyde resins were located in Areas 2 and 4 (lay-up). The symptom prevalence of workers in these areas was compared with those who worked in a similar lay-up operation in Building 17-05, except that no phenolic resins are used. Other resins, are used in both buildings, depending upon production needs.

In addition, to evaluate differences within Building 17-02, the symptom prevalence among workers in the lay-up area was compared to the rest of the areas in the building. Sixteen workers who did not clearly indicate the area in which they work, or indicated in the work history that they sometimes worked in Area 2 or 4, were excluded from the analysis.

V. Environmental Criteria

A. Environmental

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

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 evaluation 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 Criteria Documents and Recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLV's), and 3) the U.S. Department of Labor (OSHA) Occupational Health Standards. Often, the NIOSH recommendations and ACGIH TLV's are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLV's usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended exposure limits (RELs), by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet those levels specified by an OSHA standard.

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 or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

Environmental Exposure Limits
8-Hour Time-Weighted Average (TWA) as mg/m3

	NIOSH	OSHA	OSHA(Ceiling)
Phenol	20	20	
Formaldehyde	LFL*	1.2	2.4
Total Particulate (containing formaldehyde)	LFL	15	
Antimony	0.5	0.5	

*LFL Lowest Feasible Level - See Toxicology section for details

B. Toxicology

Phenol - Exposure to phenol above the evaluation criterion of 20 mg/m^3 can cause headaches, dizziness, visual disturbances, weakness, sweating, tremors and convulsions, and unconsciousness. Chronic exposures may cause oliguria and anuria, red and white blood cells in the urine. Chronic exposures may also cause headaches, coughing, fatigue and weakness, anorexia, nausea, vomiting, insomnia, nervousness, loss of weight, and albuminuria and cells in urine. Exposures can be prevented by proper ventilation. If ventilation is not provided, adequate respiratory protection must be provided. The odor threshold for phenol, for most individuals, is far below its evaluation criteria.[2] Phenol is well absorbed through the skin, therefore, adequate dermal protection is necessary.

Formaldehyde - Formaldehyde and other aldehydes may be released from foam plastics, carbonless paper, particle board, plywood, phenol-formaldehyde resins systems, and textile fabrics. Formaldehyde is an irritant to the eyes, nose, mouth, and throat. These symptoms can occur at concentrations as low as 0.l ppm. Formaldehyde vapor has been found to cause a rare form of nasal cancer in rats. These results have prompted NIOSH to recommend that formaldehyde be handled as a potential occupational carcinogen. NIOSH recommends that workplace exposures be reduced to the lowest feasible limit.[3]

The fact that formaldehyde is found in so many home products, appliances, furnishings, and construction materials, including phenol-formaldehyde resins, has prompted several agencies to set standards or guidelines for residential formaldehyde exposure. ASHRAE has recommended, based on personal comfort, that exposure to formaldehyde be limited to 0.1 ppm. This guideline has also been adopted by NASA, and the federal governments of Canada, West Germany, and the United Kingdom.

Appendix A summarizes data from many studies of formaldehyde levels in homes in different parts of the United States, Canada, and the United Kingdom. Mobile homes, due to the large amount of pressed wood products in their construction, have the highest formaldehyde concentrations. A mean of 0.4 ppm has been found in most of the studies conducted in mobile homes. Most other types of homes have average formaldehyde levels less than 0.1 ppm. The older (l5 years) conventional homes have a mean formaldehyde level of 0.03 ppm and they represent the class of dwellings with the lowest levels of formaldehyde.[4] Indoor formaldehyde concentrations, in general, are directly related to temperature and humidity in indoor environments. Variability in indoor concentrations of formaldehyde may be present under these different environmental conditions.[5]

The following information is excerpted from the OSHA formaldehyde standard.[6]

Acute Effects of Exposure

(1) Inhalation (breathing): Formaldehyde is highly irritating to the upper airways. The concentration of formaldehyde that is immediately dangerous to life and health is 100 ppm. Concentrations above 50 ppm can cause severe pulmonary reactions within minutes. These include pulmonary edema, pneumonia, and bronchial irritation which can result in death. Concentrations above 5 ppm readily cause lower airway irritation characterized by cough, chest tightness, and wheezing (Health Hazard Evaluation Report No. 88-298, page 7). There is some controversy regarding whether formaldehyde gas is a pulmonary sensitizer which can cause occupational asthma in a previously normal individual.

The effect of formaldehyde on pulmonary function has also been an issue of considerable debate. Several studies have shown cross-shift decreases in pulmonary function among formaldehyde exposed workers, while others, including controlled chamber studies, failed to support the notion that formaldehyde causes bronchoconstriction.[7,8,9] Formaldehyde can produce symptoms of bronchial asthma in humans.

Exposure to gaseous formaldehyde results in irritation of the mucous membranes and upper-respiratory tract. Upper airway irritation is the most common respiratory effect reported by workers and can occur over a wide range of concentrations, most frequently above 1 ppm. Tolerance to this level of exposure may develop within 1-2 hours. This tolerance can permit workers remaining in an environment of gradually increasing formaldehyde concentrations to be unaware of their increasingly hazardous exposure.
Symptoms of upper airway irritation include dry or sore throat, itching and burning sensations of the nose, and nasal congestion. These irritant effects are generally considered to be dose dependent. Of considerable controversy, however, is the lowest dose at which the threshold for irritation occurs. Many previous studies occur in environments where other chemical exposures are present and thus caution must be used in interpreting the results since synergistic effects may be present. The Department of Labor, in the final ruling for the new revised standard, reports that irritation may occur as low as 0.1 ppm.[6]
Formaldehyde is extremely water soluble and, on this basis, would be expected to be absorbed in the upper-respiratory tract with resultant mucous membrane irritation.

Deposition of formaldehyde lower in the respiratory tract would not usually be expected to occur. However, Gamble and Imbus have proposed that formaldehyde might adhere to dust particles and then be carried further down the bronchial tree, where lower respiratory tract irritation could occur.[10,11] Further studies may help clarify these suggestions.

Odor thresholds for detection of formaldehyde vary greatly in the population. Various reports suggest that odors may be detected at levels between 0.05 and 0.5 ppm.[12] A recent environmental chamber study demonstrated a parallel between odor discrimination and irritation levels.[13]

Recent studies linked olfactory detection of several chemicals, including formaldehyde, to the development of a multitude of recurrent symptoms in several individuals.[14,15] In these models, workers previously exposed to higher levels of a substance, continue to experience similar symptoms even after exposures are reduced to lower levels. Association of the odor with the expected symptoms is the proposed mechanism. These interpretations are based on classical operant conditioning theory and are not considered synonymous with concepts of psychogenic illness. Odors have also been described as a triggering factor for asthma, although the physiologic bases of these observations have not yet been elucidated. [16,17]

(2) Eye contact: Concentrations of formaldehyde between 0.05 ppm and 0.5 ppm produce a sensation or irritation in the eyes with burning, itching, redness, and tearing. Increased rate of blinking and eye closure generally

protects the eye from damage at these low levels but, these protective mechanisms may interfere with some workers' work abilities. Tolerance can occur in workers continuously exposed to concentrations of formaldehyde in this range. Accidental splash injuries of human eyes to aqueous solutions of formaldehyde (formalin) have resulted in a wide range of ocular injuries including corneal opacities and blindness. The severity of the reactions have been directly dependent on the concentration of formaldehyde in solution and the amount of time lapsed before emergency and medical intervention.

(3) Skin contact: Exposure to formaldehyde solutions can cause imitation of this skin and allergic contact dermatitis. The immunological mechanisms by which formaldehyde is believed to cause allergic sensitization have not been adequately described to date. These skin diseases and disorders can occur at levels well below those encountered by many formaldehyde workers. Symptoms include erythema, edema, and vesiculation or hives. Exposure to liquid formalin or formaldehyde vapor can provoke skin reactions in sensitized individuals even when airborne concentrations of formaldehyde are well below 1 ppm.

(4) Ingestion: Ingestion of as little as 30 ml of a 37 percent solution of formaldehyde (formalin) can result in death. Gastrointestinal toxicity after ingestion is most severe in the stomach and results in symptoms which can include nausea, vomiting, and severe abdominal pain. Diverse damage to other organ systems including the liver, kidney, spleen, pancreas, brain, and central nervous systems can occur from the acute response to ingestion of formaldehyde.

(5) Metabolism: Formaldehyde is produced endogenously in human beings and is oxidized to formic acid by at least three known ezymatic pathways. It disappears rapidly from the plasma in about 1-1.5 minutes.[18] Such rapid conversion in the plasma makes the use of serum formaldehyde a poor indicator of either current or past exposure. Attempts to find a good biological marker for formaldehyde exposure have proven largely unsuccessful. Urine formic acid has been proposed as a biological exposure but good correlations between air exposures and excretion of formic acid have not been achieved.[19] Formaldehyde is poorly absorbed through the skin so most control measures focus upon airborne monitoring to provide criteria for workplace exposure limits.

Chronic Effects of Exposure

Long term exposure to formaldehyde has been shown to be associated with an increased risk of cancer of the nose and accessory sinuses, nasopharyngeal and oropharyngeal cancer, and lung cancer in humans. Animal experiments provide conclusive evidence of a causal relationship between nasal cancer in rats and formaldehyde exposure. Concordant evidence of carcinogenicity includes DNA binding, genotoxicity in short-term tests, and cytotoxic changes in the cells of the target organ suggesting both preneoplastic changes and a dose-response effect. Formaldehyde is a complete carcinogen and appears to exert an effect on at least two stages of the carcinogenic process. Formaldehyde can react with hydrochloric acid (HCl) to form bis-chloromethyl ether (BCE), a lung carcinogen. However, BCE was not detected on GCMS analysis in the animal experiments where nasal cancer was observed.

Total Particulate - The particulate resulting from the mechanical sanding and deburring of the cured phenolic resin could have a formaldehyde surface component. Although the analytical techniques needed to evaluate the formaldehyde content are only in the developmental stages, making a quantitative evaluation of exposure difficult, it is prudent to treat such exposures differently than nuisance dust exposures. In this situation, it is recommended that particulate levels be reduced to the lowest levels feasible with engineering controls and respiratory protection based on their potential formaldehyde content.

Antimony - An extremely small amount of antimony was present in the raw material. The antimony was added as a anti-mildew and fire-retardant. Antimony may enter the body by ingestion, inhalation, or by percutaneous absorption. It is a local irritant and may produce liver and kidney damage, and can cause a pneumoconiosis. The first sign of antimony exposure is dermatitis. It may leave a bitter taste and cause nausea, vomiting, diarrhea, and abdominal cramps.

VI. Results

A. Environmental

The results of the bulk analyses of the resin material indicate essentially the same compounds were present at the two temperatures to which the material was subjected. Major compounds identified were formaldehyde and phenol. Low levels of other organics identified included isopropanol, salicylaldehyde, ethyl acetate, and toluene. (See Appendices B, C, and D for additional details.)
Formaldehyde - A total of 52 personal breathing zone (PBZ) and area samples for formaldehyde were collected in Buildings 17-54, 17-02, and 17-05 during the initial July and follow-up August surveys (Tables 1-4). Of the 52 samples, 35 were reported by the laboratory to have non-detectable (N.D.) or trace levels. Trace concentrations are reported when the level falls between the analytical limit of detection and the limit of quantitation. In other words, the material being measured is present but at a level which is too low to be accurately quantified. PBZ formaldehyde samples collected on workers in Building 17-54 during the July survey ranged from N.D. to 0.073 mg/m^3 (0.05 ppm). Area samples collected for formaldehyde in Building 17-54 ranged from N.D. to 0.01 mg/m^3 (0.007 ppm). Area samples collected during the July survey in in Building 17-02 ranged from N.D. to 0.038 mg/m^3 (0.025 ppm). During the follow-up survey in August, PBZ samples for formaldehyde collected in Building 17-02 ranged from N.D. to 0.056 mg/m^3 (0.04 ppm). Area samples collected in Building 17-02 ranged from N.D. to 0.01 mg/m^3 (0.007 ppm). Area samples in Building 17-05 ranged from trace levels to 0.008 mg/m^3 (0.005 ppm). A single process sample (a sample collected as close to the material as possible) from Building 17-02, Station 4 - Batwing, showed a formaldehyde level of 0.285 mg/m^3 (0.19 ppm). This value represents a value of formaldehyde in the immediate vicinity of the resin and should not be confused with an exposure level.

The concentrations of formaldehyde were essentially the same during the initial and follow-up surveys with respect to both personal and area levels and from building to building.

Phenol - A total of 23 PBZ and area air samples were collected for phenol during the initial July and follow-up August surveys (Tables 5-6). The PBZ samples collected in Building 17-54 during the July survey ranged from N.D. to 0.18 mg/m^3, with five of the seven samples containing trace levels. Of the seven personal breathing zone samples collected in Building 17-02, only one sample (0.19 mg/m^3) contained concentrations above the limit of detection. PBZ samples were collected in Building 17-02 during the August follow-up survey. Phenol concentrations ranged from N.D. to 1.5 mg/m^3. An area sample collected for phenol in Building 17-05 contained no detectable levels.

Particulates - Total particulate concentrations were measured in the area of Building 17-02 where the cured resin parts are trimmed, deburred, and sanded. This area of the building was physically isolated from the other production areas.

Three PBZ samples of total particulate levels ranged from 0.89 to 7.7 mg/m^3 (Table 7). Four area samples ranged from 0.14 to 0.51 mg/m^3. Workers in this area wore respirators, so the levels measured do not represent true exposure levels.

Antimony - We sampled for antimony, which was a trace constituent of the raw materials used in this department, because it can be both a pulmonary and skin irritant. Only four samples were collected (Table 8). Although antimony was not expected to be an environmental problem during this survey, samples were taken to confirm that there was no significant antimony exposure. No antimony was found in two of the samples and was in low concentrations (0.0008 and 0.001 mg/m^3) in the other two samples. These concentrations are well below the NIOSH REL and OSHA PEL of 0.5 mg/m^3.

Amines - Review of the materials used in Building l7-02 in the phenol-formaldehyde resin area and in the joining areas, indicated that amines could be formed from some of the compounds. Therefore, 14 samples were collected and screened for aromatic and aliphatic amines. No amines were found in these samples.

B. Medical

1. Study Participants

Within Building 17-02, 382 participants completed the questionnaire. The computation of participation rates by area is not possible because of the organizational grouping of employees, loan of employees from one department to another, and similarity of job descriptions and job locations among several different departments. However, to estimate the overall participation rate, we determined that, of the 382 participants, 326 (85%) identified themselves as belonging to Department A3210. An employee roster supplied by the company indicates that 489 individuals were assigned to A3210, the main organizational department of Building 17-02. Thus, 67% of the known A3210 employees participated in this survey.

Since work area was felt to be a better indicator of potential exposures than organizational department, we grouped participants by work area to test the hypothesis that exposure to the uncured resins was a risk factor for the development of symptoms. The non-lay-up workers in Building 17-02 were chosen as a comparison group since they share a common building and management structure as the lay-up workers. Table 9 shows the distribution of Building 17-02 respondents by work area. Figure 1 is a graphic representation of the building and type of work done in the building.

A review of company-provided interdepartment transfer information for Department A3210, reveals that over 220 permanent and temporary transfers took place between August 1, 1987 and July 28, 1988. Reasons for these transfers included termination, return to school, other employment, promotions, personnel changes, and disciplinary actions. Of the transfers, 17 (8%) were listed as due to medical reasons, medical placement reasons, or management request (medical). There are no specific data that indicate rates of interdepartment transfers as a result of medical restrictions or medical placements. Thus, recent transfers of employees from the lay-up area to another, such as re-work or assembly within Building 17-02, could not be analyzed. For each symptom, workers were asked to indicate if they experienced the symptom at any time during the preceding 30 days.

Forty-four first-shift employees in the Building 17-05 completed the questionnaire. This group was chosen as a second comparison group since it is the work area most closely matched to the Building 17-02 lay-up area. The chief differences between this area and the 17-02 lay-up area are that the 17-05 lay-up area is climate-controlled and does not process phenolic resins. The location of the lay-up area in Building 17-05 can be seen in Figure 2.

Company information indicates that 152 employees work in the lay-up area of Building 17-05, 73 of whom work on the first-shift, yielding a response rate of 60% for first-shift employees. The transfer data and individual job histories were reviewed to identify individuals who were moved to Building 17-05 as a result of medical transfer. No employees who were transferred into Building 17-05 from 17-02 in the past 60 days were identified. However, some individuals did not place their name or work information on the questionnaire so misclassification of some workers is possible. It is also possible that some 17-05 lay-up workers may have had brief assignments in the 17-02 lay-up area that were not reported on the questionnaire. Sixteen workers were excluded from further analysis because of ambiguous work area information or work in both potential exposure and comparison areas.

2. Demographics

Demographic information about workers in Buildings 17-02 and 17-05 is presented in Table 10. Workers in Building 17-02 are divided into lay-up (Areas 2 and 4) and non-lay-up (all other work areas). Compared to workers in Building 17-05 and in Building 17-02 non-lay-up, workers in Building 17-02 lay-up showed a shorter mean duration of employment at Boeing (3.8 yrs vs 6.1 yrs; pooled t-test: $p=0.05$) and (3.8 yrs. vs 6.1 yrs; pooled t: $p=0.003$) respectively.

In comparison to the rest of Building 17-02, lay-up workers in 17-02 were found to have a higher number of females (88% vs. 32%; chi-square: $p<0.001$) and a shorter duration of employment in their current work area (1.6 yrs vs 3.0 yrs; pooled t: $p=0.006$). With respect to other characteristics, the Building 17-02 lay up group was comparable to the other 2 groups.

3. Symptoms

The number and percentage of employee responses for the three study groups are shown in Tables 11 and 12. Responses are considered positive if the symptom reported by the employee occurred any time at work during the preceding 30 days. Missing responses were coded as negative responses. The symptom prevalence ratios ("relative risk" or RR) and 95% confidence intervals were computed.

Table 11 shows the comparison of reported symptoms between Building 17-02 lay-up workers, who are potentially exposed to phenol-formaldehyde resins, and those in 17-05 lay-up, where phenol-formaldehyde resins are not used. Overall, 17-02 lay-up workers had a mean of 7.0 symptoms, compared to 5.3 symptoms for 17-05 lay-up workers (pooled t: $p<0.03$).

For most symptoms, workers in 17-02 lay-up had a higher prevalence of symptoms than workers in the 17-05 lay-up area. These differences were statistically significant ($p<0.05$) for cough, chest tightness, chest pain, sore throat, and nausea.

The relative risks (RR) comparing these two groups were adjusted by current smoking status, gender, and prior mobile home residence, a possible surrogate measure of non-occupational formaldehyde exposure. No significant differences between the crude and adjusted RR's were observed. Therefore, only the unadjusted RR's are reported.

There were no differences in the seemingly high prevalences of self-reported dermatoses between the two lay-up areas as defined by the response to the question, "Have you had a skin rash at work within the past two months?" This was true for general reporting of a rash and for the site specific questions. An explanation for this observation might be that multiple agents are responsible for the dermatologic complaints. In view of the known dermatologic effects of the different resins, this possibility appears plausible. For example, fibrous glass by itself is a known skin irritant and is a component of several different resins used in both buildings.

Reported symptoms among workers in Building 17-02 lay-up were also compared with those among workers in non-lay-up departments within Building 17-02. The results are presented in Table 12. Overall, 17-02 lay-up workers reported a mean of 7.0 symptoms, compared to 6.0 symptoms for non-lay-up workers

(pooled t: $p<0.05$). Lay-up workers reported significantly ($p<0.05$) more headaches, eye irritation, runny nose, chest tightness, nausea, chest pain, and sore throat than did non-lay-up workers in the same building. Again, adjustment of relative risks by gender, mobile home residence, and current smoking status revealed no major differences between the two groups; therefore, only unadjusted RR's are reported.

There was no statistically significant difference in the overall reported prevalence of skin rash between the two groups. However, the prevalence of hand rash in the lay-up workers was significantly greater (RR=1.80, $p=0.007$) than the non-lay-up group. Contact with uncured resins might be a likely explanation for this difference.

Table 13 shows the comparison of self-reported physician diagnoses for the three study groups. Overall, there were no significant differences among the three groups in the proportion of persons with physician-diagnosed conditions. To evaluate whether self-reported illnesses diagnosed prior to 1987 may have been a confounding factor, an attempt was made to adjust the symptom prevalences for the year of diagnosis. However, the large number of individuals who did not report the year in which the condition was diagnosed made this analysis infeasible. In addition, the fact that the resins were introduced in late 1987 made it impossible to discriminate those workers who were diagnosed with a specific condition in early 1987 (i.e. between January and July), prior to the introduction of the new resins. Diagnostic criteria for many of these medical conditions can vary widely among individual physicians and both over-diagnosis and under-diagnosis can be expected.

Table 14 shows the number and percentage of responses to the subjective question of whether a worker felt he/she had a phenol-formaldehyde resin-related illness. One worker from Building 17-02 (lay-up) was identified as having been transferred into Building 17-05 during the past year and the responses were excluded from analysis. Respondents were grouped into two categories: 1) those who felt that they had a resin-related illness and 2) those who responded "no" or "don't know". Significantly more workers from the 17-02 lay-up area believed that they were experiencing health effects from the resins than either the 17-02 non-lay-up workers (RR=1.75, $p<0.01$) or the 17-05 lay-up workers (RR=5.5, $p<0.01$). When individuals who responded "don't know" were excluded from the analysis, 17-02 lay up workers continued to demonstrate a greater proportion of workers who felt that they had a phenolic resin-associated illness than either of the two groups.

Positive respondents were asked whether or not they had received a physician diagnosis for any illness due to the resins. The percentage of workers who reported a physician diagnosed medical condition as a result of the phenol-formaldehyde resins is similar among 17-02 lay-up and non-lay-up workers. Reasons for this may include different diagnostic criteria, referral patterns to specific providers, and transfer of workers from the lay-up area into other job categories outside of lay-up.

Within the lay-up area of 17-02, workers who felt they had a resin-associated illness also showed a greater number of symptoms than lay-up workers who felt they had no resin-associated illness (8.9 vs 3.7; pooled t: $p<0.001$).

The responses to the question, "How often can you smell irritating odors in your work environment?" are shown in Table 13.

VII. Discussion and Conclusions

A. Environmental

Environmental results and observation of the work environment indicated no environmental conditions at the time of this investigation that would explain the reported adverse health effects. The most suspect compound, formaldehyde, was only quantitated on 6 of 19 personal breathing zone samples, with all of these levels being approximately 0.05 ppm. It should be noted, however, it is impossible for the investigators to determine if exposure levels were greater prior to the time of the NIOSH evaluation, which coincided with ventilation improvements. As all use of phenolic resins has been discontinued at Boeing, further evaluation of this substance is also impossible.

B. Medical

1. There is an increased prevalence of self-reported respiratory tract symptoms among workers in the lay-up area of Building 17-02 when compared to either 17-05 or the rest of the workers in 17-02. These differences are not readily explained by the airborne sampling results for phenol, formaldehyde, amines, or total particulates that were obtained during the NIOSH study. Since the questionnaire data were not obtained during the period when the resins were first introduced, or before changes in ventilation and wearing of protective gloves were incorporated, it is not possible to speculate about a definitive association between prior air samples and symptom prevalence.

2. The use of other resin systems in the same area would impair efforts to attribute the reported respiratory complaints to a single agent. Interpretation of objective measurements such as cross-shift pulmonary function testing and serial peak flow measurements would also be impeded. The low air levels of formaldehyde and phenol levels observed during the NIOSH visit make classification by exposure groups difficult, if not impossible.

3. The medical literature suggests that uncured resin material adherent to dust particulate may be carried into the lower respiratory tract. Since the phenolic resins are no longer in use, this hypothesis cannot be tested further in the lay-up area.

4. A review of questionnaire data suggests a similar prevalence of self-reported dermatitis among both the 17-02 lay-up areas and 17-05 lay-up areas. A review of OSHA 101B forms and company medical records also revealed cases of dermatitis that could be due to working with the resins. Workers in 17-02 lay-up area had a higher prevalence of self-reported hand rashes than non-lay-up workers. This suggests that contact with one of the materials may be responsible for some cases of dermatoses. A higher prevalence of hand rashes was reported in the lay-up areas. A likely explanation is that the rashes reflect both irritant and allergic contact dermatoses, and further, that these skin conditions may represent reactions to more than one agent.

   Dermatoses due to phenol-formaldehyde resins have been described as early as 1936.[20] Weichardt notes that finished polymerized plastics are rare causes of harmful skin effects and further explains that it is mostly monomers, hardeners, and other additives that are responsible for the dermatitis.[21]

   There are multiple agents in the resins capable of causing both allergic contact and irritant dermatoses in the lay-up workers. The Material Safety Data Sheets for several of the resins confirm the presence of several chemicals that are known to cause dermatitis. In addition to free formaldehyde, salicylaldehyde, a reaction by-product detected by our environmental sampling of the uncured phenolic resin, has been reported to cause contact sensitization.[22] Depolycondensation and self-condensation reactions have been described by Bruze as responsible for the generation of other intermediate compounds which that act as contact sensitizers.[23] Even protective gloves have been implicated in the development of such skin disorders as itching, irritation, eczema, and hand sweat.[24]

5. Because the questionnaire was administered shortly after the new ventilation system was installed, the results presented here may not adequately reflect the current or previous prevalence of symptoms.

6. Certain features of the current situation in the 17-02 building have been described by Cullen in his discussion of the syndrome of multiple chemical sensitivity.[25] He defines this syndrome as "an acquired disorder characterized by recurrent symptoms, referable to multiple organ systems, occurring in response to demonstrable exposures to many chemically unrelated compounds at doses far below those established in the general population to cause harmful effects." He further outlines seven major diagnostic features:

   a) The disorder is acquired in relation to some documentable environmental exposure(s), insult(s), or illness(es);

   b) Symptoms involve more than one organ system;

   c) Symptoms recur and abate in response to predictable stimuli;

   d) Symptoms are elicited by exposures to chemicals of diverse structures and toxicologic modes of action;

   e) Symptoms are elicited by exposures that are demonstrable (albeit of low level);

   f) Exposures that elicit symptoms must be very low, by which we mean many standard deviations below "average" exposures known to cause adverse human responses;

   g. No single widely available test of organ system function can explain symptoms.

While there is no evidence in this evaluation that conclusively demonstrates the occurrence of this controversial syndrome, it is nevertheless important to consider this as a possibility. Therapeutic intervention must take into consideration the very real psychosocial stressors involved in a situation characterized by anxiety, fear, and uncertainty. These are discussed in detail in several articles.[26,27] The role of occupational stress in the worksite has been the subject of a recent NIOSH publication.[28]

VIII. Recommendations

1. Prior to introducing new chemicals into the work environment, workers should be briefed by newsletter and orally about the health effects of these chemicals.
2. The ventilation system in Building 17-02 should be adjusted so that workers can use it without discomfort. The discomfort includes excessive cold and drying out of eyes.
3. Industrial hygiene data collected on workers should be provided to the workers with an explanation of the results.
4. The Boeing physicians and industrial hygienist should do periodic walk-through surveys through all areas of the facility and answer questions workers have about their work environment.
5. Efforts should be made to ensure that the respirator program remains effective. Workers should be made aware that they can have a respirator even though they are not being exposed to chemicals in concentrations exceeding the OSHA limits. This is a current policy and should be stressed.
6. Although recent changes in the personal protection program have taken place, the findings of increased prevalences of self-reported dermatoses among lay-up workers underscore the need for continued evaluation of dermatologic conditions among the work-force. Protective gloves should be evaluated for permeability to the resins systems in use, as recommended during the previous site visit.
7. It is important both for diagnostic and prognostic purposes to differentiate between irritant dermatitis and true allergic contact dermatitis. The development of a standardized protocol for evaluating individuals with possible allergic contact dermatitis would be an appropriate method for determining the etiology of suspected work-related dermatoses. Such testing should be performed under the guidance of an experienced dermatologist.
8. The finding of a higher prevalence of respiratory tract complaints among the 17-02 lay-up workers may serve as a basis for increased surveillance of employees in this work area. Since health screening procedures are not always helpful in evaluating low-level or mixed exposures, individualized evaluation of employees with suspected occupational illnesses may be more appropriate. If pulmonary function testing is performed, it should be done in accordance with the technical guidelines established by the American Thoracic Society.[29]

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XI. Distribution and Availability of Report:

Copies of this report are temporarily available upon request from NIOSH, Hazard Evaluation and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. Aerospace Machinist International District Lodge 751.
2. Boeing Company
3. U.S. Dept. of Labor/OSHA - Region X
4. NIOSH - Denver Region
5. Washington State Health Dept.

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1

Boeing Company
Auburn, Washington
July 6-7, 1988

Personal Breathing Zone and Area Concentrations of
Formaldehyde in Building 17-54

PERSONAL SAMPLES

Collection Method	**Job**	**Sample Time**	**Formaldehyde (mg/m3**
Orbo 23 Tubes	PBM	6:50 - 11:12	Trace
		11:48 - 2:42	N.D.*
Orbo 23 Tubes	PBM	6:53 - 11:10	Trace**
		11:47 - 2:36	Trace
Orbo 23 Tubes	PBM	6:55 - 11:12	0.073
		11:46 - 2:32	0.066
Orbo 23 Tubes	PBM	6:58 - 11:13	0.049
		11:50 - 2:45	Trace

AREA SAMPLES

Collection Method	Location	Sample Time	Formaldehyde (mg/m^3)
Orbo 23 Tubes	Dispensing Rack	7:10 - 11:13	N.D.
		11:42 - 2:18	N.D.
Impingers		7:30 - 2:15	0.007
		7:30 - 2:15	Trace
Orbo 23 Tubes	Area 5 - Oven	7:02 - 1:31	N.D.
Orbo 23 Tube	Area 5 - Debagger	7:07 - 1:15	N.D.
Impingers	Area 83 - Back	7:20 - 2:10	0.010
	Corner	7:20 - 2:10	Trace
Impingers	BAT Wing	7:25 - 2:18	0.010
		7:25 - 2:18	Trace

*N.D. - Not Detected
**Trace - Between Limit of Detection and Limit of Quantitation

Table 2

Boeing Company
Auburn, Washington
July 6-7, 1988

Area Concentrations of Formaldehyde in Building 17-02

Sample Type	Location	Sampling Time	Formaldehyde (mg/m^3)
Orbo 23 Tube	Spray Booth	7:59 - 1:00	0.038
Orbo 23 Tube	Area 66 - Rework	7:12 - 11:13	N.D.*
		7:30 - 1:20	N.D.
Orbo 23 Tube	Area 4	7:30 - 1:20	Trace**
Orbo 23 Tube	Area 5 - Packaging	7:00 - 1:06	N.D.
Impingers		8:50 - 10:00	0.010
		8:50 - 10:00	Trace
Impingers	Lay-up B-16	8:04 - 1:00	0.005
		8:04 - 1:00	N.D.
Impingers	Oven Area	8:30 - 1:00	Trace
		8:30 - 1:00	N.D.

*N.D. - Not Detected
**Trace - Between Limit of Detection and Limit of Quantitation

Table 3

Boeing Company
Auburn, Washington
August 16-17, 1988

Personal Breathing Zone and Area Concentrations of
Formaldehyde in Building 17-02

PERSONAL SAMPLES

Collection Method	Job	Sampling Time	Formaldehyde (mg/m^3)
Orbo 23 Tubes	PBM Station 4	7:06 - 11:27 11:30 - 2:30	0.056 0.050
Orbo 23 Tubes	PBM Station 4	7:18 - 11:30 11:30 - 2:39	Trace** Trace
Orbo 23 Tubes	PBM Station 4	7:10 - 11:30 11:30 - 2:30	Trace Trace
Orbo 23 Tubes	PBM Station 4	7:10 - 11:20	0.038
Orbo 23 Tube	PBM Station 4	7:10 - 1:08	Trace
Orbo 23 Tube	PBM Station 4	7:17 - 1:03	Trace
Orbo 23 Tubes	Bagging PBM Station 21	8:15 - 2:55 11:30 - 2:42	N.D.* N.D.

AREA SAMPLES

Collection Method	Location	Sample Time	Formaldehyde (mg/m^3)
Impingers	Station 4	7:25 - 1:20 7:25 - 1:20 7:30 - 2:35 7:30 - 2:35 7:25 - 2:38	0.006 Trace 0.012 Trace 0.010
Orbo 23 Tube	Station 21	8:15 - 2:55	N.D.
Orbo 23 Tubes	Area 5 - Bagging	7:15 - 1:06 7:15 - 1:06	Trace Trace

Process Sample

Orbo 23 Tube	Station 4 - Batwing	7:10 - 1:05	0.285

Table 4

Boeing Company
Auburn, Washington
August 17, 1988

Area Concentrations of Formaldehyde in Building 17-05

Collection Method	Location	Sample Time	Formaldehyde (mg/m^3)
Impinger	Area 21	8:10 - 2:55	0.008
Impinger	Area 21	8:10 - 2:55	Trace
Impinger	Area 21	8:10 - 2:55	0.006
Impinger	Area 21	8:10 - 2:55	Trace*

Trace* - Between Limit of Detection and Limit of Quantitation

Table 5

Boeing Company
Auburn, Washington
July 6-7, 1988

Personal Breathing Zone and Area Concentrations of Phenol

Building 17-54

Job	Sample Time	Phenol (mg/m^3)
	Personal Samples	
PBM	6:50 - 11:12	Trace**
	11:48 - 2:42	N.D.*
PBM	6:53 - 11:10	Trace
	11:47 - 2:36	Trace
PBM	6:55 - 11:12	0.18
	11:46 - 2:32	Trace
PBM	6:58 - 11:13	Trace
	Area Samples	
Dispensing Rack	7:10 - 11:13	N.D.
	Building 17-02	
	Personal Samples	
PBM	7:30 - 1:20	N.D.
PBM	7:00 - 1:06	N.D.
Spray Booth	7:59 - 1:00	0.19
Rework	7:12 - 1:12	N.D.
Rework	7:30 - 1:20	N.D.
Debagger - Area 5	7:07 - 1:15	N.D.
Operator - Oven	7:02 - 1:31	N.D.

*N.D. - Not Detected
**Trace - Between Limit of Detection and Limit of Quantitation

Table 6

Boeing Company
Auburn, Washington
August 17, 1988

Personal Breathing Zone and Area Samples for Phenol

Building 17-02 - Personal Samples

Job	Sampling Time	Phenol (mg/m^3)
PBM - Station 4	6:55 - 2:40	0.05
PBM - Station 4	6:55 - 2:38	0.05
PBM - Station 4	7:00 - 2:30	0.12
PBM - Station 4	7:10 - 2:30	0.27
PBM - Station 4	7:10 - 2:30	0.06
PBM - Station 4	7:10 - 1:05	1.5
PBM - Station 4	7:10 - 9:28	N.D.

Building 17-05 - Area Samples

Location	Sampling Time	Phenol (mg/m^3)
Central Box Area	8:17 - 2:30	N.D.

Table 7

Boeing Company
Auburn, Washington
August 16, 1988

Personal Breathing Zone and Area Concentrations
of Total Particulate in Building 17-02

Job/Location	Sampling Time	Total Particulate (mg/m^3)
	Personal Samples	
Knockout - Station 5	6:53 - 12:58	0.89
Knockout - Station 5	7:39 - 2:40	1.69
PBM - Station 67	7:45 - 2:48	7.70
	Area Samples	
Station 5	6:55 - 12:58	0.14
Sand & Fill - Station 67	6:57 - 1:00	0.19
Sand & Fill - Station 67	7:00 - 1:00	0.51
Sand & Fill - Station 67	7:00 - 1:00	0.15

Table 8

Breathing Zone and General Room Air Concentrations
of Antimony
Boeing Company
Auburn, Washington
August 17, 1988

Sample #	Job/Location	Sampling Time	Antimony (mg/m^3)
A-1	Wrapper/Station 4	7:35 - 2:35	ND*
A-2	Rework/Station 66	7:50 - 2:48	0.0008
A-3	Area/Department 21	8:17 - 2:55	ND*
A-4	Area/Sand and Fill	6:58 - 1:00	0.001

Evaluation Criteria 0.5
Laboratory Limit of Detection 0.002 mg/filter

N.D.* = none detected in samples

TABLE 9

HETA 88-294
The Boeing Company
Auburn, Washington

Work areas with at least 10 participants
Building 17-02

Work Area	Job activities	# participants
001	plaster mold makers	13 (3%)
002	plaster wrap	54 (14%)
004	permanent wrap	51 (13%)
005	bagging/curing	36 (9%)
009	plaster fabrication	47 (12%)
065	finish and trim	45 (12%)
066	rework, deburr	32 (8%)
067	vacuum blast	14 (4%)
099	inspection	20 (5%)
Other areas (office areas, dispatch, inspection)		60 (15%)
Unknown or missing		10 (3%)
Total		382

TABLE 10

HETA 88-294
The Boeing Company
Auburn, Washington

Demographics of Study Groups

		Building 17-02*	Building 17-05
	Non-lay-up	Lay-up	Lay-up
number	261	105	44
mean age (s.d.**) 36.0 (10.3)	37.7 (9.8)	37.7 (10.3)	
# females	83 (32%)	92 (88%)	38 (87%)
# mobile home residents	76 (29%)	38 (36%)	12 (27%)
mean # yrs mobile home	4.4 (4.3)	4.2 (4.0)	3.4 (4.3)
smokers	96 (37%)	47 (45%)	15 (34%)
mean pack years smoked	14.4 (13.8)	13.6 (10.6)	12.7 (10.0)
yrs with Boeing	6.1 (6.5)	3.8 (6.0)	6.1 (7.5)
mean # years in current department	3.0 (4.2)	1.6 (2.8)	2.5 (2.3)

* The number of workers in the Building 17-02 (261) excludes 16 individuals whose work area was ambiguous

**Standard Deviation

TABLE 11

HETA 88-294
The Boeing Company
Auburn, Washington

Comparison of Symptoms Rates
of Building 17-02 Lay-up Workers and Building 17-05 Lay-up Workers

	17-02 Lay-up	17-05 Lay-up	RR	C.I.	p value
headache	85 (81%)	34 (77%)	1.1	(0.9, 1.3)	0.60
sneezing	59 (56%)	23 (52%)	1.1	(0.8, 1.5)	0.66
eye irritation	65 (62%)	20 (46%)	1.4	(0.9, 1.9)	0.06
runny nose	62 (59%)	22 (50%)	1.2	(0.8, 1.6)	0.30
cough	45 (43%)	10 (23%)	1.9	(1.1, 3.4)	0.02
sinus congestion	48 (46%)	16 (36%)	1.3	(0.8, 1.9)	0.29
chest tight	45 (42%)	8 (18%)	2.2	(1.1, 4.3)	0.01
short of breath	32 (31%)	8 (18%)	1.7	(0.8, 3.3)	0.12
wheeze	19 (18%)	6 (14%)	1.3	(0.6, 3.1)	0.50
tingling	28 (27%)	11 (25%)	1.1	(0.6, 1.9)	0.83
fever	15 (14%)	7 (16%)	0.9	(0.4, 2.0)	0.80
itching	60 (57%)	23 (52%)	1.1	(0.8, 1.5)	0.59
nausea	46 (44%)	10 (23%)	1.9	(1.1, 3.5)	0.02
muscle pains	27 (26%)	11 (25%)	1.0	(0.6, 1.9)	0.93
chest pain	37 (35%)	6 (14%)	2.6	(1.2, 5.7)	0.007
sore throat	60 (57%)	18 (41%)	1.4	(0.9, 2.1)	0.07

DERMATOSES:

	17-02 Lay-up	17-05 Lay-up	RR	C.I.*	p value
Rash	48 (48%)	20 (47%)	1.03	(0.71, 1.51)	0.87
Hand Rash	33 (33%)	11 (26%)	1.29	(0.72, 2.31)	0.38
Arm Rash	33 (33%)	15 (35%)	.95	(0.58, 1.55)	0.82
Neck Rash	14 (14%)	5 (12%)	1.20	(0.46, 3.13)	0.70
N responding	100	43			

C.I.: 95% Confidence Interval
RR = Relative Risk

TABLE 12

HETA 88-294
The Boeing Company
Auburn, Washington

Comparison of Symptoms Rates
of Building 17-02 Lay-up Workers and Building 17-02 Non-lay-up Workers

	17-02 Lay-up	17-02 Non-lay-up	RR	C.I.	p value
headache	85 (81%)	183 (70%)	1.2	(1.0, 1.3)	0.04
sneezing	59 (56%)	162 (62%)	0.9	(0.7, 1.1)	0.26
eye irritation	65 (62%)	117 (45%)	1.4	(1.1, 1.7)	0.004
runny nose	62 (59%)	122 (47%)	1.3	(1.0, 1.5)	0.03
cough	45 (43%)	100 (38%)	1.1	(0.8, 1.5)	0.48
sinus congestion	48 (46%)	127 (49%)	0.9	(0.7, 1.2)	0.60
chest tight	45 (42%)	76 (29%)	1.4	(1.0, 1.9)	0.04
short of breath	32 (31%)	73 (28%)	1.1	(0.8, 1.5)	0.60
wheeze	19 (18%)	49 (19%)	1.0	(0.6, 1.6)	0.89
tingling	28 (27%)	70 (27%)	1.0	(0.7, 1.4)	0.89
fever	15 (14%)	30 (12%)	1.2	(0.7, 2.2)	0.62
itching	60 (57%)	127 (49%)	1.2	(0.9, 1.4)	0.20
nausea	46 (44%)	74 (28%)	1.5	(1.2, 2.1)	0.004
muscle pains	27 (26%)	80 (31%)	0.8	(0.6, 1.2)	0.31
chest pain	37 (35%)	49 (19%)	1.9	(1.3, 2.7)	0.0005
sore throat	60 57%)	100 (38%)	1.5	(1.2, 1.9)	0.002

DERMATOSES

	17-02 Lay-up	17-02 Non-lay-up	RR	C.I.	p value
Rash	48 (48%)	96 (40%)	1.23	(0.95, 1.59)	0.13
Hand rash	33 (33%)	45 (19%)	1.80	(1.23, 2.64)	0.003
Arm rash	33 (33%)	60 (25%)	1.35	(0.95, 1.92)	0.10
Neck rash	14 (14%)	20 (8%)	1.72	(0.90, 3.26)	0.10
Face rash	14 (14%)	27 (11%)	1.27	(0.70, 2.32)	0.43
N responding	99	243			

TABLE 13

HETA 88-294
The Boeing Company
Auburn, Washington

Self-Reported Feelings of Illness - Responses to Questions:

A. "Are you experiencing any ill health effects that you feel may be due to the Phenol-Formaldehyde Resins?"

	17-02 Lay-up	17-02 (Non-Lay-up)	17-05 Lay-up
Number	102	258	40
Yes	56 (53%)	81 (31%)[a]	4 (9%)[b]
No	23 (22%)	95 (36%)	24 (56%)
Don't Know	23 (22%)	82 (31%)	12 (28%)

a. Comparison of 17-02 lay-up and non-lay-up: RR (Yes vs no or don't know) = 1.75 (1.36, 2.25)

b. Comparison of 17-02 lay-up and 17-05 lay-up: RR = 5.49 (2.13, 14.14).

B. Of those responding yes above, "Have you been diagnosed by a physician as having a medical condition that you were told is due to the phenol-formaldehyde resins?"

	17-02 Lay-up	17-02 (Non-Lay-up)	17-05 Lay-up
Number	56	81	4
Yes	11 (20%)	17 (21%)	1 (25%)
No	41 (73%)	61 (78%)	3 (75%)

C. "How often can you smell irritating odors in your work environment?"

	17-02 Lay-up	17-02 (Non-Lay-up)	17-05 Lay-up
Number	105	261	44
Never	1 (1%)	7 (3%)	1 (2%)
A Little	29 (28%)	104 (40%)	19 (46%)
A Lot	66 (63%)	141 (54%)	21 (51%)
No Response	9 (7%)	9 (3%)	3 (1%)

TABLE 14

HETA 88-294
The Boeing Company
Auburn, Washington

Self-Reported Physician Diagnosed Illnesses

BUILDING 17-02 Lay-up: N = 105

DIAGNOSIS	Number	Onset before 1987	1987-88	
Unknown				
Allergy	27 (26%)	18 (17%)	2 (2%)	7 (7%)
Asthma	5 (4%)	4 (4%)	1 (1%)	
Bronchitis	17 (16%)	8 (8%)	6 (6%)	3 (3%)
Sinusitis	15 (14%)	7 (7%)	5 (5%)	3 (3%)
Hay fever	15 (14%)	11 (10%)	1 (1%)	3 (3%)

BUILDING 17-05 Lay-up : N = 44

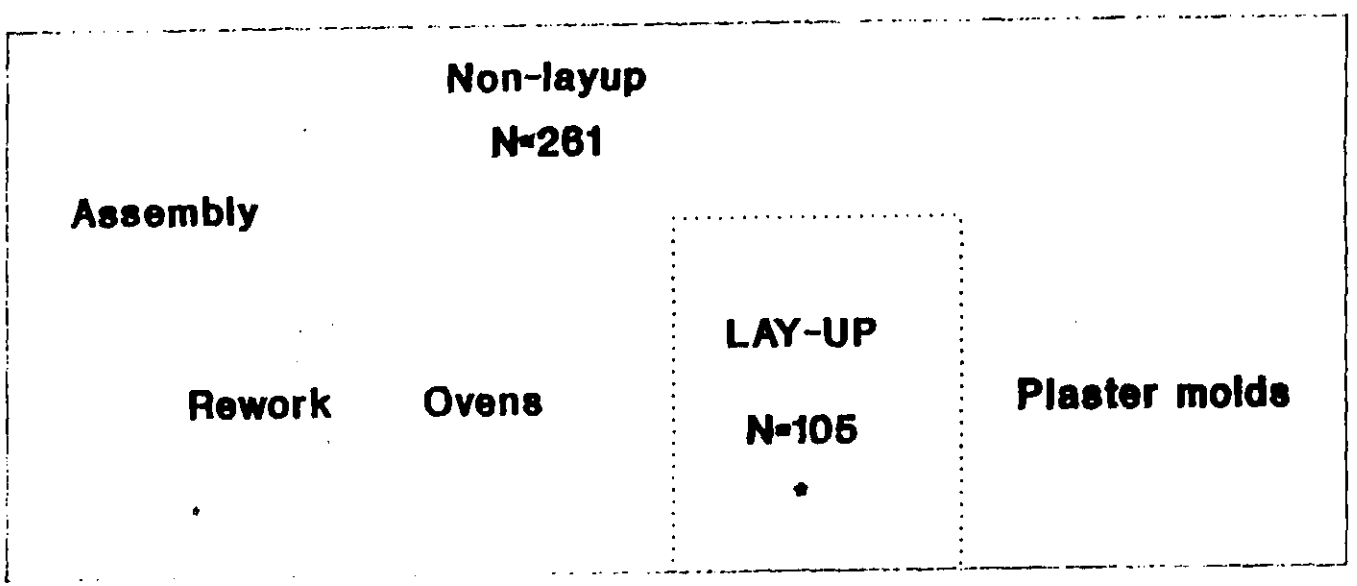
DIAGNOSIS	Number	Onset before 1987	1987-88	
Unknown				
Allergy	14 (32%)	8 (18%)	2 (5%)	4 (10%)
Asthma	5 (11%)	3 (7%)	1 (2%)	1 (2%)
Bronchitis	9 (20%)	4 (10%)	3 (7%)	2 (5%)
Sinusitis	6 (14%)	3 (7%)	2 (5%)	1 (2%)
Hay fever	4 (10%)	1 (2%)	3 (7%)	0

BUILDING 17-02: Non-Lay-up N= 261

DIAGNOSIS	Number	Onset before 1987	1987-88	
Unknown				
Allergy	62 (25%)	37 (14%)	12 (5%)	13 (5%)
Asthma	13 (5%)	6 (3%)	5 (2%)	2 (0%)
Bronchitis	37 (14%)	17 (7%)	13 (5%)	7 (3%)
Sinusitis	17 (7%)	3 (1%)	9 (3%)	5 (2%)
Hay fever	35 (13%)	21 (8%)	6 (3%)	8 (3%)

FIGURE 1

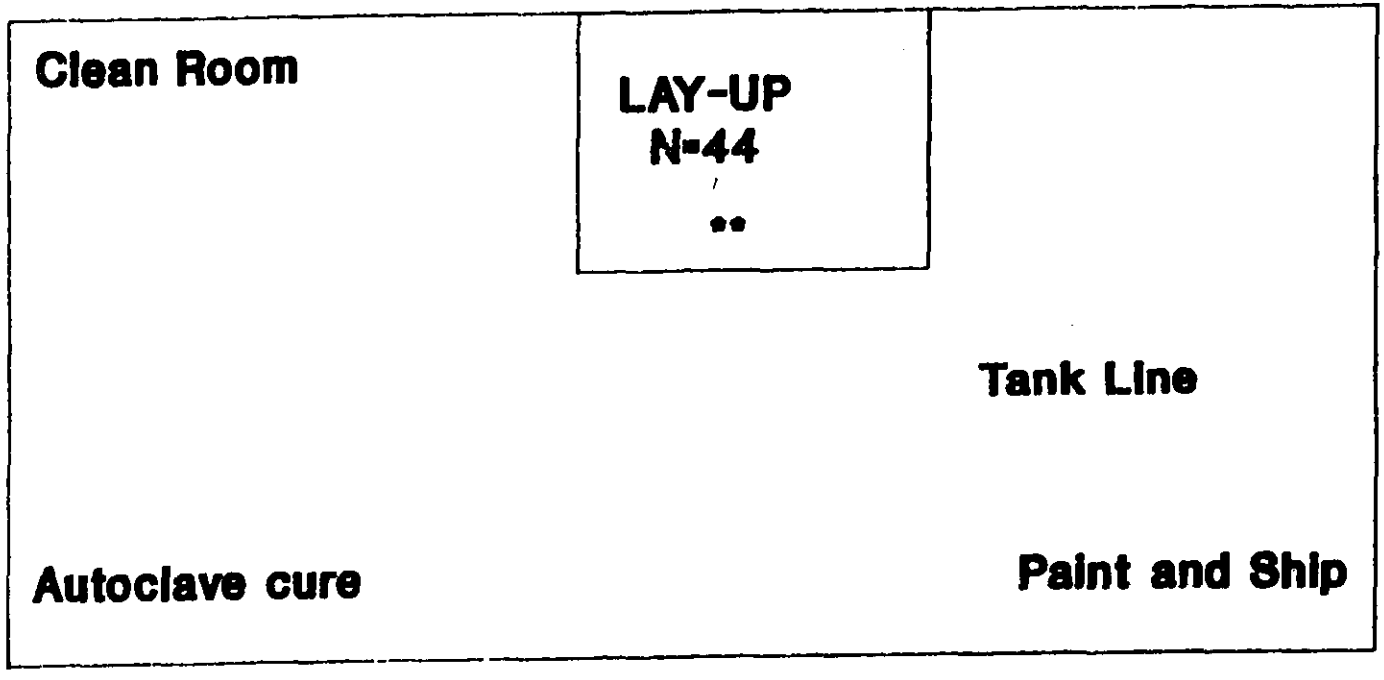
BOEING BUILDINGS
Building 17-02



* uncured phenolics in use

FIGURE 2

BUILDING 17-05



** uncured phenolics minimally in use

APPENDIX A*

Reported Levels of Formaldehyde in the Indoor Air Classes of Private Residences

Type of Residence	No. of Residences	Formaldehyde (ppm) Range	Mean
U.S. homes without urea-formaldehyde foam insulation (UFFI)	41	0.01-0.1	0.03
U.S. homes with UFFI (complaint and non-complaint)	636	0.01-3.4	0.12
U.S. Mobile homes	431	0.01-3.5	0.38
Canadian houses without UFFI	383	(3%>0.1ppm)	0.036
Canadian houses with UFFI	1850	(10%>0.1ppm)	0.054
U.S. houses without UFFI and without particle board	17	-	0.025
U.S. houses without UFFI and without particle board subfloors	600	-	0.050
U.S. mobile homes	several hundred		0.12
U.K. buildings without UFFI	50	<0.03->0.3	0.047 (3% >0.1ppm)
U.K. buildings with UFFI	128	0.01->1	0.093 (7% >0.1ppm)
U.S. houses without UFFI	42	0.03-0.17	0.06
U.S. houses without UFFI	31	-	0.07
U.S. houses with UFFI	-	-	0.06

continued

APPENDIX A

(continued)

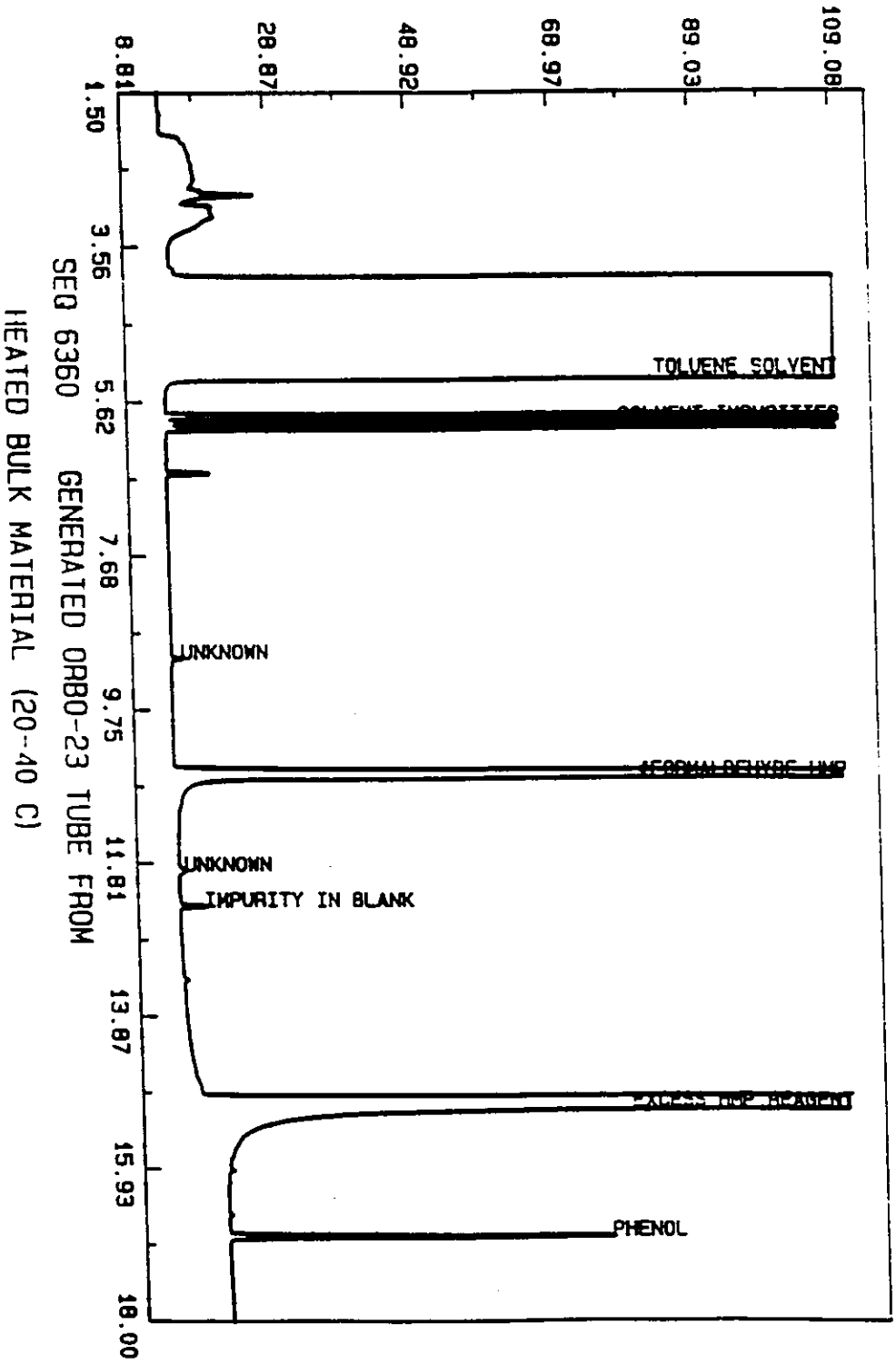
Reported Levels of Formaldehyde in the Indoor Air Classes of Private Residences

Type of Residence	No. of Residences	Formaldehyde (ppm) Range	Mean
Mobile homes (Minnesota complaints)	100	0-3.0	0.4
Mobile homes (Wisconsin complaints)	-	0.02-4.2	0.9
Mobile homes (Wisconsin)	65	<0.10-3.68	0.47
Mobile homes (Washington complaint)	-	0-1.77	0.1-0.44
U.S. Mobile homes			
Never occupied	260	-	0.86
Older occupied			0.25
East Tennessee homes	40	<0.02-0.4	0.06
Age 0-5 years	18	-	0.08
Age 5-15 years	11	-	0.04
Age >15 years	11	-	0.03
Conventional California, Colorado, and S. Dakota homes	64	0.02-0.11	0.05
Specialized housing	52	0.03-0.3	0.1

*Gammage R.B., Hawthorne A.R. "Current Status of Measurement Techniques and Concentration of Formaldehyde in Residences." Turoski V. Formaldehyde: Analytical Chemistry and Toxicology. Page 125. "Developed from a symposium sponsored by the Division of Environmental Chemistry at the 187th Meeting of the American Chemical Society, St. Louis, Missouri, April 8-13, 1984."

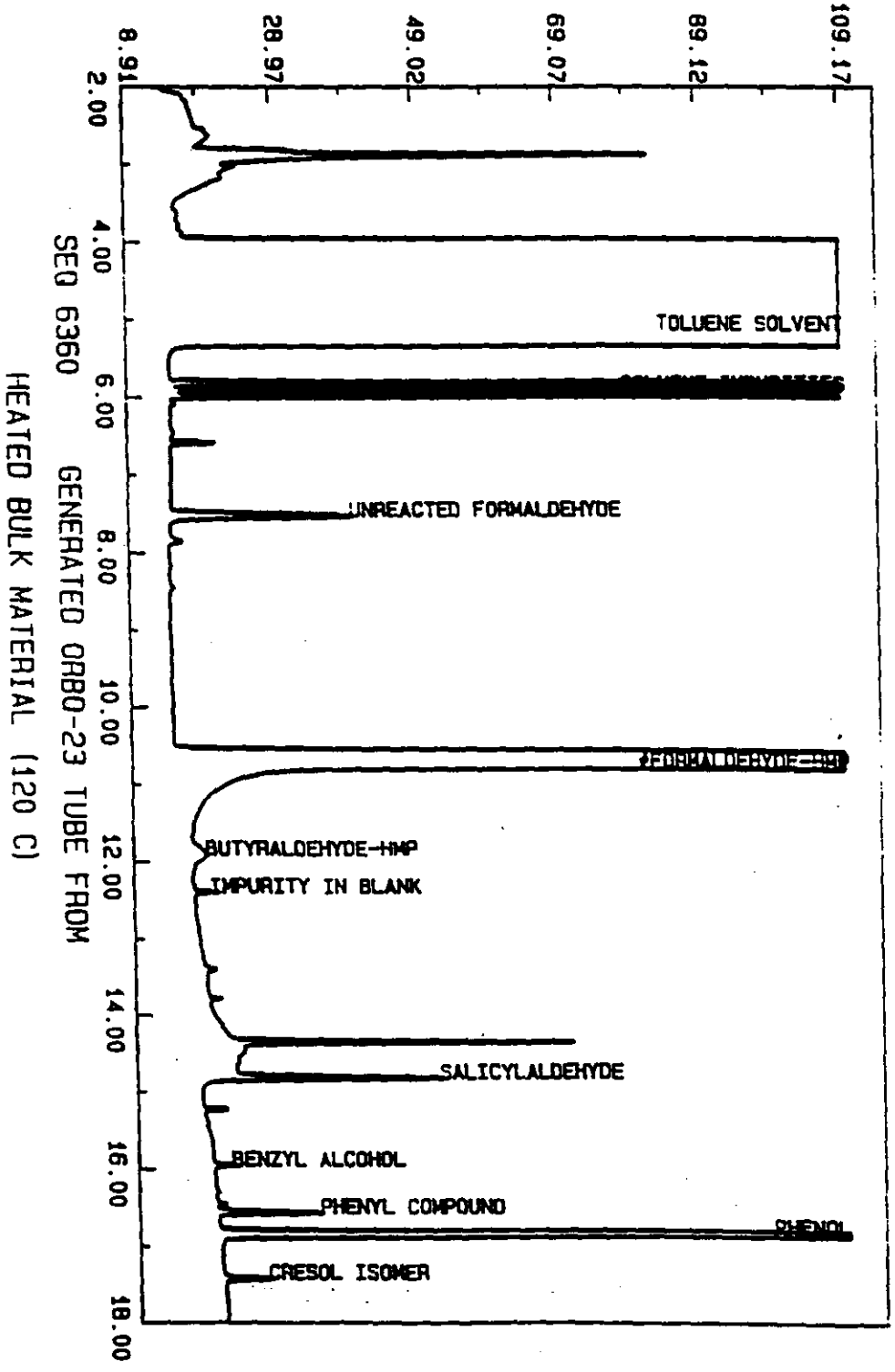
APPENDIX B

GAS CHROMATOGRAPH



APPENDIX C

GAS CHROMATOGRAPH



APPENDIX D

GAS CHROMATOGRAPH