U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
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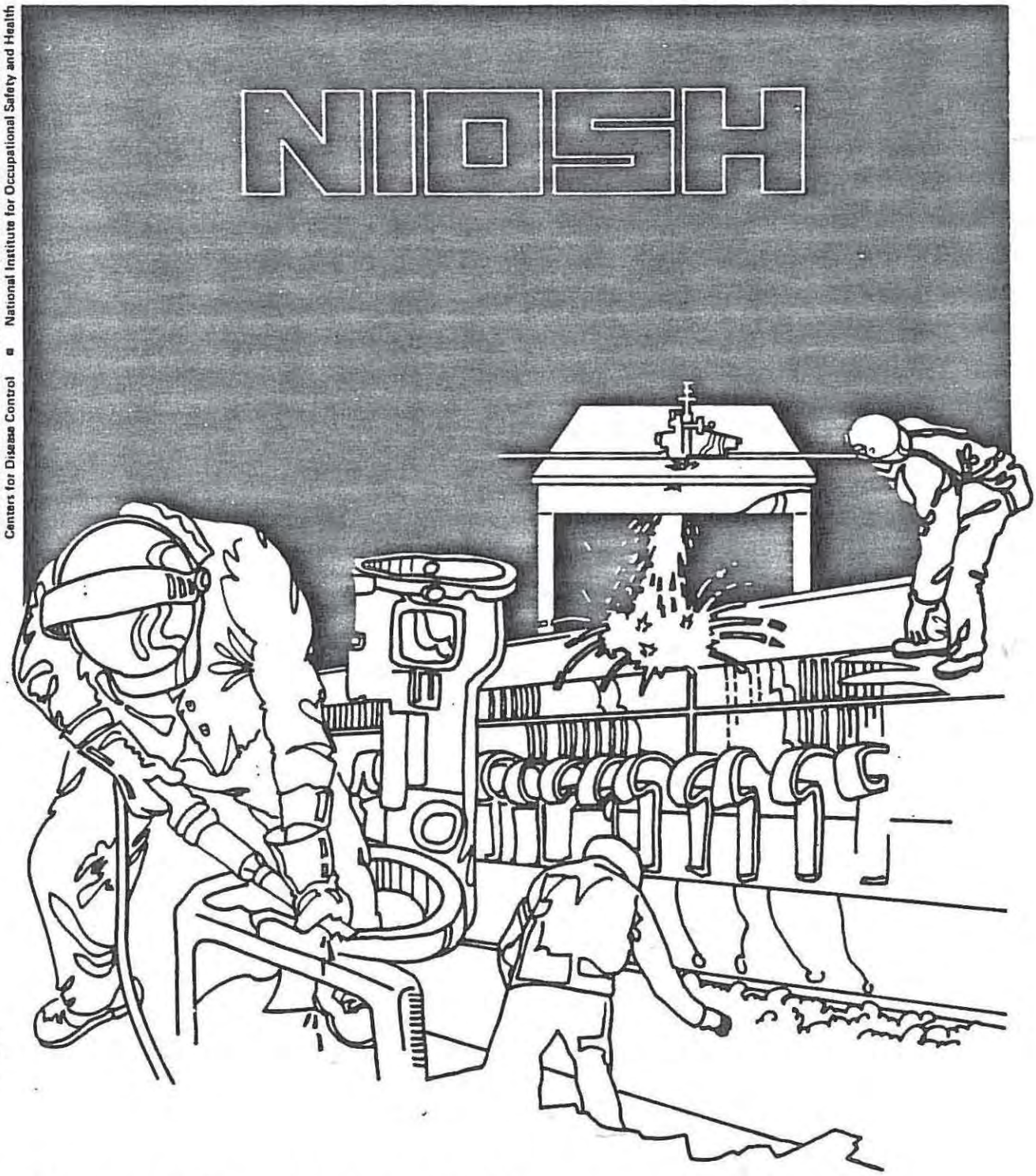

Health Hazard Evaluation Report

HETA 83-451-1547
ARMSTRONG WORLD INDUSTRIES
LANCASTER, PENNSYLVANIA

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.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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ARMSTRONG WORLD INDUSTRIES
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I. SUMMARY

On October 18, 1983, the National Institute for Occupational Safety and Health (NIOSH) was requested to evaluate the health effects of working with a powdered chemical blowing agent, azodicarbonamide, at Armstrong World Industries Floor Plant, Lancaster, Pennsylvania. The request reported the occurrence of nose bleeds, skin rashes, and mucous membrane irritation among workers handling powdered azodicarbonamide. A review of the literature raised the question of possible pulmonary sensitization associated with exposures to azodicarbonamide. Two areas of the plant use this material in the formulation of pastes or paints, which are subsequently used in the production of resilient flooring. The material is used intermittently, on a batch basis.

NIOSH conducted an initial survey November 30 - December 1, 1983, and an in-depth follow-up survey January 8-11, 1984. The environmental evaluation included personal exposure monitoring (both short- and long-term) of workers for azodicarbonamide exposures. Observation of work practices and engineering controls were also undertaken. The medical evaluation included a confidential, structured interview; pre- and post-shift chest auscultation; pre- and post-shift pulmonary function tests; and serologic testing for azodicarbonamide antibodies.

Worker exposures were divided into three categories: direct (i.e. short-term while handling the compound); indirect (full-shift, working in the vicinity where the compound was used); and unexposed (full-shift, no expected exposures). Arithmetic means and ranges for the three groups are respectively: 3.6 mg/m^3 (0.59-12 mg/m^3); 0.01 mg/m^3 (none detected - 0.04 mg/m^3); and 0.001 mg/m^3 (none detected - trace). No evaluation criterion currently exists for azodicarbonamide. (The OSHA total nuisance dust standard of 15 mg/m^3 is not appropriate because azodicarbonamide is biologically active.).

The prevalence of reported asthmatic and nose/eye symptoms was significantly greater among workers who had potential exposure to azodicarbonamide than among workers who had not worked in areas with potential for direct exposure. No evidence of chronic (i.e. baseline) effect of exposure on pulmonary function tests was found. Small intrashift decreases in FEV_1 and FVC were observed, but these were not statistically significantly different from those who were not exposed. There was a suggestion that the change in FEV_1 was greater among those with higher personal exposure than among those with trace or nondetectable exposures. Immunologic findings were indeterminate.

Based on the results of this investigation, the NIOSH investigators conclude that exposure to particulate azodicarbonamide presents a potential respiratory health hazard. Recommendations addressing ventilation, work practices, hazard communication, and personal protective equipment are presented in Section VIII.

KEYWORDS: SIC 3079 (Miscellaneous Plastics Products), paste and plastisol formulation, azodicarbonamide, CAS # 123-77-3, irritation, asthma, pulmonary sensitization

II. INTRODUCTION

On October 18, 1983 the National Institute for Occupational Safety and Health (NIOSH) received a confidential Health Hazard Evaluation (HETA) request from workers at Armstrong World Industries Floor Plant in Lancaster, Pennsylvania. The request concerned worker exposure to a powdered chemical blowing agent, azodicarbonamide (CAS #123-77-3, 1, 1'-azobisformamide here after referred to as ABFA). Paints, Oils, and Plastisols (Building 67b) and the Paint Room of Building 98 - were identified by NIOSH investigators and management as the only two locations where this material was handled. The request reported the occurrence of nose bleeds, skin rashes, and mucous membrane irritation among workers handling the material in powder form.

NIOSH investigators conducted an initial survey November 30-December 1, 1983. A walk-through survey focused on the areas mentioned above and included limited sampling for ABFA and interviews of employees from both departments. A follow-up medical and environmental survey was conducted January 8-11, 1984. This latter survey included full-shift and short-term exposure monitoring for ABFA, administration of interviews and medical questionnaires of all current workers in Buildings 67b and 98, collection of blood samples for immunologic testing, and pre- and post-shift pulmonary function testing of workers handling ABFA on January 9, 1984 (Monday). The variables affecting the usage of ABFA made scheduling of the surveys difficult and extensive coordination of activities with the company was required in order to conduct the follow-up survey. Worker representation was provided by members of the United Rubber Workers of America, Local 202. Industrial hygiene exposure data to ABFA obtained during the HETA surveys was sent to both management and labor representatives August 1, 1984.

III. BACKGROUND

Armstrong World Industries Inc.'s Lancaster Floor Plant, located in Lancaster, Pennsylvania, has been manufacturing resilient flooring at this site since 1908. The current facility covering 250 acres and housed in over 300 buildings, is the largest resilient flooring plant in the world. The two areas involved in this study are Building 67b Paints, Oils, and Plastisols, and the Paint Room for the Coating and Fusion Department lines located in Building 98. The number of workers in these two areas is approximately 41. There are two workshifts per day in Building 67b and three per day in Building 98.

A. History of Use:

Azodicarbonamide (in this case Kempore® AF, manufactured by Olin Corporation) became an "official" specification raw material in August of 1970. Prior to this time there had been some small usage of the material in test runs, process trials, prototype product

production, etc. Paints, Plastisols and Inks (Building 67b) has used ABFA in a powdered form since that time. In Coating and Fusion (Building 98 - Paint Room) this material has been used in powdered form since July 1982, coinciding with the introduction of a new production line in Coating and Fusion. The paste form (into which ABFA is incorporated), along with some sporadic, short-term usage of powder, dates officially back to 1970. A review of all the material safety data sheets for substances used in Buildings 67b and 98 did not result in the identification of any other compounds known to be pulmonary sensitizers. Appendix A presents background information on the compound ABFA itself.

B. Process Description:

Both Building 67b and 98 are involved in the formulation of pastes and plastisols containing varying amounts of resins, plasticizers, blowing agent, pigments, stabilizers, fillers, and miscellaneous other materials. The primary raw materials used (in greatest quantity) are powdered polyvinyl chloride resins, titanuim dioxide, limestone, and plasticizers such as dioctyl phthalate. The use of ABFA (a chemical blowing agent) varied with the material being formulated. Larger quantities per batch of the blowing agent are used in Building 67b (10 or more times the quantity used in a batch formulated in Building 98). However, the frequency with which ABFA containing batches are made in Building 98 is greater than in Building 67b.

The production of the pastes and plastisols generally involves measuring out prescribed quantities of liquid and powdered raw materials into a mixer or blender. Powdered materials are dumped into the mixers in unit quantities (bags or drums), except for partial amounts obtained from partially filled drums (called stumps) which must be manually measured into a container located on a scale. Potential exposures to ABFA occurred during the weighing and dumping of the powdered form of this compound.

C. Engineering Controls, Personal Protective Equipment:

Local exhaust ventilation equipment was present at points where the dry material is charged into the mixers. Disposable respiratory protection (3M 8710™) was provided to workers upon request, with their use strongly encouraged by the company during the weighing and dumping of powdered ABFA. A policy of mandatory dust respirator use when handling powdered ABFA had been recently introduced (after 12/83). Shower and locker facilities are provided for the workers. Several workers handling ABFA used disposable coveralls and gloves.

D. NIOSH Surveys:

The initial survey, conducted November 30 and December 1, 1983 involved a walk-through of areas using ABFA. Limited industrial hygiene sampling (short-term) was taken during the production of several batches of paints and plastisols using ABFA in building 67b and 98. The use of this material was reduced due to the installation of new equipment and renovation of a primary ABFA using production line as well as product development occurring on production lines in the area.

As a result of these developments the amount of exposure monitoring which initially had been anticipated could not be completed. Eighteen employees, from both Building 67b and Building 98 - Paint Room were interviewed. In general, these interviews revealed a high prevalence of symptoms that needed further investigation. Additionally, medical records were reviewed and medical department personnel were interviewed.

A follow-up environmental and medical survey was conducted January 8-11, 1984. This survey included full-shift and short-term exposure monitoring for ABFA, pre- and post-shift pulmonary function testing, administration of interviews and medical questionnaires, and drawing of blood samples. A total of 37 workers were monitored for ABFA exposure and 49 presently employed in either buildings 67b or 98 participated in the medical study.

IV. EVALUATION DESIGN AND METHODS

A. Environmental:

The industrial hygiene evaluation conducted November 31-December 1, 1983 and January 8-11, 1984 used pre-calibrated battery-operated sampling pumps equipped with sampling trains for the collection of ABFA. During the initial survey only short-term sampling was conducted during the production of batches using ABFA. Both full-shift and short-term sampling for ABFA were conducted during the follow-up surveys. Short-term samples were obtained during the period that the compound was being weighed and dumped (referred to as direct samples). Additionally, exposure samples during a non-ABFA handling period (indirect) were obtained for workers opposite the short-term exposure period. This was undertaken to assess indirect exposures. Workers in the area neither handling nor dumping ABFA were also monitored over the full shift to determine their (indirect) exposure. All workers handling ABFA and participating in the pulmonary function testing (described below) were monitored for exposure, at least during the first three

workshifts of the week. Observation of work practices and limited ventilation measurements using a Kurz® thermoanemometer were also obtained. Lists of all materials generally used in the two areas were obtained. This was to determine if any other materials associated with sensitization were or potentially could be present.

1. Azodicarbonamide:

Sampling was conducted using FALP Fluoropore filters in two piece cassettes at a flow rate of two liters per minute (Lpm). These filters consist of polytetrafluoroethylene with a polyethylene backing and have a pore size of 1.0 micrometer (um).

The analytical procedure calls for desorption with 2 milliliters (ml) of dimethylsulfoxide (DMSO) and analysis by high performance liquid chromatography (HPLC). Separation is achieved on a 10 um silica Radial Compression Column in a Radial Compression Module. The mobile phase is 15 per cent DMSO/85 per cent methylene chloride isocratic. Quantitation and detection was achieved by an ultraviolet detector at 276 um and a visible wavelength detector at 405 um in series.

The results of the ABFA analyses for all filters were quantitated at 276 nanometers (nm). A limit of quantitation (LOQ) of 5 micrograms (ug) per sample and a limit of detection (LOD) of 1 ug per sample was attained. If a sample concentration was large enough, quantitation at 405 nm was also obtained.

Azodicarbonamide exposures are grouped by areas and sample types. Three categories of ABFA exposure were determined for the purposes of data evaluation: 1. "direct", which involved actual handling of ABFA; 2. "indirect", i.e. working in the same room where ABFA was being weighed and dumped or the exposure of workers in these areas outside of the periods when ABFA was not being weighed and dumped; and 3. "controls", which are considered unexposed workers on processes where ABFA was no longer present in the original dry powder form. Arithmetic means and standard deviations are given for environmental data.

No omission of nondetectable data has been made. The value for nondetectable concentrations used in the calculations was obtained by dividing the analytical limit of detection (1 ug) by the sample volume and then dividing this resulting environmental limit of detection for the sample by two.

2. Ventilation Assessment:

Local exhaust ventilation present in the two production areas was evaluated using smoke tubes (to visualize air flow patterns) and a Kurz® thermoanemometer.

B. Medical:

During the initial survey, NIOSH investigators conducted brief interviews with employees from the Paints, Plastisols and Inks Department (Building 67b) and from Coatings and Fusions (Building 98); reviewed medical records of employees from Coatings and Fusions; and interviewed a company physician and nursing supervisor. After this survey, the company safety department provided personnel lists for employees from the two departments.

Employees in Building 98 were categorized by the company, on the basis of potential exposure to ABFA (in powdered form), into regularly, often, seldom or never exposed; that is, on the basis of work in the paint room for Coating and Fusion lines where ABFA barrels were opened and dumped. (The accuracy of the exposure categorization was verified by the work history portion of the questionnaire.) NIOSH investigators offered a medical evaluation to all Building 67b employees; to all employees who had worked regularly or often in the Building 98 paint room since the introduction of ABFA; and to a random sample of those who had never worked in the paint room for Coating and Fusion (i.e. had not worked directly with ABFA).

The medical evaluation was designed to assess whether health effects were associated with work in departments where potential exposure to ABFA existed. The medical evaluation included: a confidential, structured questionnaire interview; pre- and post-shift auscultation (listening with stethoscope) of the chest; pre- and post-shift pulmonary function tests; and venipuncture to obtain blood to analyze for antibodies to ABFA. The clinical interview was administered privately and included assessment of occupational history, smoking status, symptoms associated with disease of the upper and lower respiratory tract and with hypersensitivity pneumonitis, and a determination of the probable work-relatedness of symptoms elicited. The latter was assessed after consideration of factors including the effect on symptoms of weekends and vacations and the time to onset after starting work at Armstrong. Symptoms were considered ABFA-related if they were temporally work-related and appeared to occur at times when the material was being handled or when there was work in areas with potential for exposure to dry ABFA.

During performance of spirometry, forced vital capacity (FVC), one-second forced expiratory volume (FEV_1), and the average rate of flow over the middle two quarters of the expiratory effort (FEF_{25-75}) were measured, and the FEV_1/FVC ratio was calculated. Investigators used an Ohio Medical Products Model 822® dry-rolling seal spirometer connected to a Spirotech dedicated computer, which records the flow curves and calculates expected values based on age, height, sex and race. A test was considered adequate for interpretation only if there were three acceptable trials, and the best two curves differed by no more than 5% with respect to FVC and FEV_1. Predicted normal values were calculated according to the method of Knudson.[4] Pulmonary function data were analyzed first for all participants and then for all except those reporting that they had smoked within an hour of testing or had had an upper respiratory infection in the three weeks prior to study. Personal air sampling was performed at times coinciding with pulmonary function testing.

The sera were coded so that the laboratory personnel performing the serological tests had no knowledge of exposures or symptoms. The serological tests included specific IgE antibody to ABFA conjugated to human serum albumin (ABFA-HSA) by the radioallergosorbent test (RAST);[5,6] and specific IgG antibody to ABFA-HSA by the enzyme-linked immunosorbent assay (ELISA).[7,8]

Investigators also interviewed and reviewed medical records for one employee who had worked in Building 67b and was transfered out of Building 67b in 1974 because of occupational asthma.

V. EVALUATION CRITERIA

A. Environmental Criteria

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 standards, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In reviewing the exposure levels, and the recommendations for reducing those levels found in this report, it should be noted that industry is required by the Occupational Safety and Health Act of 1970 to meet those levels specified by OSHA standards.

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.

B. Azodicarbonamide

Animal feeding studies addressing the safety of azodicarbonamide have been conducted to assess the compound's toxicity when used as a flour-maturing agent in baked goods.[2,10] The use of ABFA in baked goods was authorized by the Food and Drug Administration in 1962. Azodicarbonamide is hydrolyzed in the digestive system to an inert biurea. Azodicarbonamide, when ingested, has very low acute toxicity.

Toxicity studies addressing the health effects associated with the inhalation of azodicarbonamide are lacking. Two reports in the literature suggest the occurrence of occupational asthma among workers handling the powdered ABFA.[11,12] and one discusses a decrease in pulmonary function[11]. The exposure levels reported in these two articles ranged from 700 ug/m^3 to 5000 ug/m^3.

Slovak[12] reports that of the workers diagnosed as having asthma due to exposure to ABFA, none had had asthma or any other significant chest disease before exposure to the chemical. History of atopy (diseases of an allergic nature) is not considered predictive of a predisposition to ABFA sensitivity. In the case of ABFA, the characteristic clinical presentation, as reported by Slovak, consists of a latent period preceeding onset followed by an abrupt onset and frequently rapid worsening of symptoms if exposures continue. He suggests that azodicarbonamide be considered a potent lung sensitizer of the small molecular weight type, the characteristics being a predominance of severe and worsening late onset asthmatic symptoms. These symptoms usually occur within the first year of exposure and have been associated with negative skin prick tests to the causative agent.[12]

The National Toxicology Program initiated the pre-chronic phase toxicity testing for ABFA in fiscal year 1984.[13] Long-term toxicity testing will be initiated in early 1985. An additional test species (guinea pigs) will be used in addressing the question of respiratory sensitivity associated with ABFA exposure. Invitro cytogenetic testing of azodicarbonamide was conducted during fiscal year 1984. The data from this study is currently undergoing statistical analysis (Personal communication).

Currently no environmental exposure limit criteria in any of the previously mentioned sources for azodicarbonamide. Extensive searches of the literature have not revealed any domestic or foreign mandatory or advisory limits for this compound. One approach has been to treat ABFA as a nuisance dust thus applying a total dust TWA exposure limit over an eight hour workshift of 15 milligrams per cubic meter (mg/m^3) under the OSHA standard. The OSHA permissible exposure limit for respirable nuisance dust is a 5 mg/m^3 TWA. The ACGIH recommends nuisance dust exposures be kept below 10 mg/m^3 total and 5 mg/m^3 respirable dust over an eight hour workshift.

Nuisance dust evaluation criteria will not be applied to ABFA in this study because the compound in question does not meet the ACGIH

definition of a nuisance particulate (dust), i.e. a dust that "has little adverse effect on lungs and does not produce significant organic disease or toxic effect when exposures are kept under reasonable control."[9] The ACGIH TLV documentation states that these (nuisance dust) limits do not apply to those substances which may cause physiologic impairment at lower concentrations, and for which threshold limits have not yet been recommended.[9]

VI. RESULTS

A. Environmental

The results of personal exposure monitoring for ABFA are presented in Tables I and II. Table I contains short-term sampling data obtained during the initial survey conducted December 1, 1983. Table II presents the results from sampling conducted January 8-11, 1984.

1. Azodicarbonamide sampling

a). Initial Survey:

Four of seven short-term air samples had no detectable ABFA, one other had a non-quantifiable "trace" amount, and the remaining two, both from a Building 67 worker had 3.1 and 2.1 mg/m^3. All samples were of limited duration since these batches of material were not a part of the normally scheduled production.

b). Follow-up Survey:

The highest exposures to ABFA were observed during the weighing and dumping of this compound in both Building 67b and Building 98. The median direct exposure value for ABFA was 2.7 mg/m^3 of all direct exposures evaluated. The range of exposure values in Building 67b was 0.15 to 12 mg/m^3 (3 samples), median 3.8 mg/m^3. The range of exposure values in Building 98 was 0.59 mg/m^3 to 4.8 mg/m^3 (5 samples), with a median value of 1.6 mg/m^3.

Indirect exposures to ABFA (i.e. exposures of workers in the same room that ABFA was being weighted and dumped, or the exposure of workers in these areas outside of the period when they weighed and dumped this material) had trace exposures for the median value (range N.D. to 0.1 mg/m^3, 25 samples) of all such samples in Buildings 67b and 98. The range of values for Building 67b alone was N.D. to 0.03 mg/m^3 (11 samples) with a trace median value. The range of values for Building 98 was N.D. to 0.10 mg/m^3 (14 samples) with a trace median value.

Combined eight hour TWA's for the workers having ABFA weighing and charging responsibilities for both Buildings 67b and 98 had a median value of 0.08 mg/m^3 (range N.D. to 0.91 mg/m^3, 8 samples). Combined exposure values for this same group obtained by using the direct and indirect exposure values for ABFA had a median of 0.36 mg/m^3 (range 0.04 to 1.7 mg/m^3, 6 samples). See Table II.

Control exposures were negligible. Of the 12 samples collected, 9 were below detectable levels and 3 had trace quantities present. This confirmed that the investigators' control group on the production lines was encountering no significant ABFA exposure associated with the use of this material in an exclusively liquid form.

Thus, workers directly weighing and dumping ABFA had the greatest exposure during their workshift. Workers in Buildings 67b and 98 not involved with the direct handling of ABFA still had significant exposures to ABFA when compared to the workers whose exposures were measured outside of these two areas (controls).

Table III presents the arithmatic means, standard deviations, ranges, and sample sizes of the exposure sampling subgroups.

2. Ventilation Measurements and Observations

Table IV presents the results of ventilation measurements obtained for local exhaust hoods present on equipment using ABFA in powdered form. The effectiveness of the exhaust ventilation appeared to be marginal at best, especially at observed work distances from the hoods. Work practices and the presence of cross drafts and air turbulence (especially in Building 98) further reduced the effectiveness of the exhaust ventilation.

3. Personal Protective Equipment

Workers in both areas (Building 67b and 98) wore 3M 8710® disposable dust respirators during the period they handled ABFA. The company had recently instituted a mandatory respirator use policy during the handling of ABFA (between the time of our initial and follow-up surveys). The degree of protection provided by these respirators is questionable since some of the workers had beards. Respirators were also

observed lying around the area when they were not in use. Respirator use by other workers in the immediate vicinity during the time ABFA was being handled was discretionary. Many workers in Building 98 wore respirators due to the general dustiness in the area.

All workers directly handling ABFA wore gloves, and in Building 67b one worker was observed wearing a pair of disposable coveralls. This personal protective equipment use was intended to reduce the degree of skin contact with the material. Locker and shower facilities are also provided for the workers' use. The NIOSH investigators did not encounter much reporting of skin problems during the investigation.

B. Medical

The interviews during the initial survey revealed a high prevalence of symptoms reported by workers that were referable to the upper and lower respiratory tract. Of 11 exposed workers interviewed, eye irritation was reported by nine, nose irritation by seven, cough by six, cough at night by five, shortness of breath by four, wheeze by four, and chest tightness by three. This appeared to confirm the spectrum of health problems noted on the request and indicated the need for a follow-up study.

Forty-nine workers in Buildings 67b and 98 participated in the medical evaluation during the follow-up survey: 33 who had worked with ABFA (based on work assignment and use of ABFA), and 16 who had never worked with ABFA. As our initial intention had been to recruit only regularly or frequently exposed workers, two workers included as exposed who had inadvertently worked for very short periods with ABFA were excluded from further analysis, as was one exposed worker previously known to be asthmatic and who had audible pre-shift wheezing. Of the 30 remaining exposed workers, eight were from Building 67b and 22 from Building 98. Fifteen of the 30 ever exposed workers who were currently working with ABFA (seven from building 67b, eight from Building 98) and 11 of the 16 who had never worked with ABFA underwent pulmonary function testing (PFT).

a). Demographic Data

The ever-exposed group was comparable to the never-exposed group (Table V) with respect to proportion of older individuals; racial composition; proportion of individuals completing school and mean years of school; mean duration of employment at the plant; proportion of never-smokers and mean pack-years among current smokers; and proportion of

individuals reporting allergies. However, the ever-exposed group appeared to be, on average, slightly younger, and there seemed to be a lower proportion of current (and greater proportion of ex-) smokers, with current smokers having smoked for fewer years. None of these differences reached statistical significance at the conventional 0.05 level.

There were considerable differences in smoking status among the subgroup having PFTs. Seven (47%) of 15 exposed and three (27%) of 11 never-exposed had never smoked; five (33%) and one (9%) respectively were ex-smokers; and three (20%) and seven (64%) respectively were current smokers. Current smokers among the exposed workers having PFTs had smoked for fewer years and had fewer pack-years than the corresponding non-exposed workers having PFTs (Table VI).

b). Symptoms

Lower respiratory tract symptoms (cough, wheezing, or shortness of breath) were reported by 18 (60%) of 30 ever-exposed workers and by one (6%) of 16 never-exposed workers, a statistically significant difference (Table VII). The onset of symptoms is shown in Figure I. Among the exposed, 15 (68%) of 22 in Building 98 compared to three (38%) of eight in Building 67b, were symptomatic ($p=0.21$, Fisher's exact test, two-tailed). Of the 18 with asthmatic symptoms, the cause of the symptoms were believed (on the basis of their temporal characteristics) by the investigators to be nonoccupational for three, occupational but not ABFA-related for seven, and occupational and ABFA-related for eight. The symptoms of the one symptomatic never-exposed worker were believed to be occupational. The reported time to onset of symptoms among the symptomatic was immediate (within one hour of entry to the work area) in eight cases, late (more than one hour) in seven, dual in one, and not answered by two.

Ten (56%) of 18 with symptoms and three (25%) of 12 without symptoms had a prior history of allergies ($X^2=2.7$, $p=0.098$). The prevalence of symptoms was high among all smoking groups: seven (50%) of 14 smokers, eight (89%) of nine ex-smokers, and five (56%) of nine never-smokers. Indices of exposure to ABFA were considered for each building separately. There were no significant differences between symptomatic and asymptomatic exposed workers with respect to number of weeks assigned to ABFA department,

average number of batches per week, or estimated cumulative number of batches.

Eye and/or upper respiratory tract symptoms (nasal stuffiness, itchy or irritated eyes, runny nose) were reported by 26 (87%) of 30 ever-exposed and by five (31%) of 16 never-exposed workers, a statistically significant difference (Table VII). Of the 26 symptomatic exposed individuals, the origin of the symptoms was considered by the investigators to be nonoccupational in three, occupational but not ABFA-related in five, and occupational and ABFA-related in 18. Of the five symptomatic never-exposed workers, the symptoms were considered to be nonoccupational in one and occupational in four.

No systemic symptoms suggestive of hypersensitivity pneumonitis (fever, chills, muscle aches) were reported.

Symptoms recorded before and after the shift at the time of spirometry were infrequent and were not markedly different between the same workers pre- and post-shift or between exposure groups. Wheezing on examination was also infrequent, and there were no apparent differences between groups or over the shift.

c). Pulmonary Function Data

Baseline spirometry findings, by smoking status and exposure group, are displayed in Table VI. Inferences about comparisons between the groups may not be meaningful due to the small numbers. However, with this in mind, none of the comparisons between exposure groups, considering comparable smoking groups, except one, showed exposed workers to have worse pulmonary function than unexposed workers. Among current smokers, the exposed group had a lower FEV_1/FVC and FEF_{25-75} than the unexposed group, but the difference was not statistically significant. However, the FVC percent of predicted was significantly greater among the currently exposed (mean $\pm$ S.D.: 107 $\pm$ 9) than among the never-exposed workers (94 $\pm$ 7) (Table VI). It should be noted that the mean duration of smoking (24 vs 16 years) and mean pack-years (27 vs 18) were greater among the never-exposed group, potentially counterbalancing any effect of ABFA exposure on pulmonary function.

Abnormal baseline spirometry was defined as FEV_1 <80% predicted or FEV_1/FVC <70% = obstructive; FVC <80% predicted with $FEV_1/FVC \geq 70\%$ = restrictive; or mixed. Of the nonexposed workers undergoing spirometry, abnormal results were noted in two (a smoker who had an FEV_1 90% of predicted, an FVC of 104% predicted, an FEV_1/FVC ratio of 68%; and a nonsmoker with an FEV_1 78% of predicted, an FVC 76% of predicted, and an FEV_1/FVC ratio of 81%). Abnormal results were noted in three currently exposed workers undergoing spirometry including one who was previously known to be asthmatic, had audible pre-shift wheezing and was excluded from all PFT analyses above. Of the other two, one was a smoker with mild obstruction (FEV_1 79% of predicted, FVC 97% of predicted, and FEV_1/FVC 60%), and the other was a nonsmoker with an FEV_1 95% of predicted, an FVC 112% of predicted, and an FEV_1/FVC ratio of 68%.

The mean pre- to post-shift changes in FEV_1 and FVC were decreases in both the exposed and non-exposed groups (Table VIII). Although this was greater among the exposed for both FEV_1 (-0.087 vs -0.048 liters) and for FVC (-0.116 vs -0.043 liters), these differences were not statistically significant. The decrease in FEV_1 among the exposed was significantly different from zero (t=-2.27, p=0.040 by paired t-test). The pre- to post-shift decreases in the exposed group are equivalent to 2.3% of FEV_1 and 2.2% of FVC. Among the exposed, these declines were confined largely to nonsmokers and appeared greater (but not statistically significantly so) among those in Building 98 than among those in Building 67b. By paired t-test analysis, the change in FEV_1 in Building 98 was statistically significantly different from zero (t=-2.48; p=0.042) while the changes in FEV_1 in Building 67b and in FVC for both buildings were not (all p>0.182). For FEV_1, the declines were smaller among the symptomatic than among the asymptomatic workers (-0.082L vs -0.098 liters (L); p>0.8); for FVC, the decline was limited to the symptomatic workers (-0.182L vs +0.016L; p=0.125). The mean changes in FEV_1 among the asymptomatic and in FVC among the symptomatic workers were different from zero (t=-3.64, p=0.022; t=-2.64, p=0.027, respectively).

d). Relation Between Change in FEV_1 and Exposure to ABFA

Fourteen participants in the medical survey had breathing zone exposure sampling for ABFA: eight had quantifiable exposures, four had trace exposures, and two had no

detectable exposure. The mean changes for these groups were -0.123 L, -0.018 L, and +0.02 L, respectively, for FEV_1; and -0.210 L, -0.023 L, and 0.0 L, respectively, for FVC (Figure II). This is suggestive of a trend of increasing effect (decrease in pulmonary function) with increasing exposure, but one must be aware of limitations addressed in the discussion (Section VII).

e). Antibody Studies

No positive results for specific IgE antibody to ABFA-HSA by RAST were observed. For IgG ELISA, medically significant results are usually defined as a value three times the mean of the unexposed controls at a serum dilution of at least 1:50. No significant values were observed at this dilution. Values obtained with a 1:10 dilution are shown in Table IX. Values greater than three times the mean of the unexposed controls (O.D. 0.045) were observed in 10 (43%) of 23 ABFA-exposed workers in Building 98, one (17%) of eight ABFA-exposed workers in Building 67b, and three (20%) of 15 nonexposed workers. Values exceeding 0.07 (the highest of the laboratory controls) were observed in seven (23%), none, and two (13%) of these three groups, respectively. All seven from Building 98 were symptomatic (six had cough, wheeze and/or shortness of breath and all seven had nose and/or eye symptoms). Neither of the nonexposed had symptoms.

VII. DISCUSSION AND CONCLUSIONS

The NIOSH investigators found personal exposures to ABFA to be significantly greater for workers in Building 67b and Building 98 than for workers on production lines in the Coating and Fusion department. Exposures to ABFA during direct handling of the material are the greatest. The frequency of handling this material also varies greatly, thus short-term samples are important in assessing worker exposure in addition to full shift sampling. The data for Building 98 generally reflects the weighing and dumping of material for two batches in each short-term sample. In Building 67b each short-term sample represents exposures during the handling of ABFA for one batch of material. The greatest number of batches containing ABFA in any one shift during our survey was six; this occurred in Building 98. Company data and worker accounts of production indicate that usage can range from zero to several times this amount in a workshift. Usage of ABFA in Building 98 appears to occur more frequently than in Building 67b even though Building 67b will use more for any one batch.

Work practices varied widely among the workers observed. Since the plant operates on an incentive work system, efforts at reducing spillage and handling materials in a manner which releases less particulate into the workroom appear to suffer. Crushing of empty bags, pounding on ABFA weighing containers to dislodge residual material, and scooping out raw material (including ABFA) from stumps (partially full bulk containers) all contributed to generating visible particulate in the workroom. In addition workers were observed to use compressed air to blow dust off of themselves. The manner in which materials were added to the mixers also generated dust which escaped from the local exhaust systems on the equipment. In Building 98 the weighing station had spilled ABFA on and around the scale and floor, along an aisle which was used by workers enroute to and from locker rooms.

The effectiveness of the local exhaust systems in Building 98 appeared very limited since there were severe cross drafts across the face of the hoods. Additionally, the design of the scale hood in Building 98 was very poor. This, in combination with the cross drafts from heating equipment, made it essentially nonfunctional. Workers would add materials to the ribbon blenders in such quantities that the exhaust ventilation system was overwhelmed. Capture velocities at observed working distances for all hoods measured less than 150 feet per minute. (The company industrial hygienist informed us that modifications to improve the exhaust system present in Building 67b were scheduled.)

The NIOSH medical investigators found that the prevalence of reported asthma-like and nose/eye symptoms were significantly greater among workers who had potential exposure to ABFA than among workers who had not worked in areas with potential for direct exposure. The reporting of both lower and upper respiratory tract symptoms substantially increased in the time period when ABFA was introduced to Building 98. About one-half of the symptoms appeared to the investigators to be work-related, but this was a subjective interpretation with the possibility of observer bias. The prevalence of asthma-like symptoms was about twice as great in Building 98 as in Building 67b. In the two previous reported studies of occupational exposure to ABFA, asthmatic symptoms were also reported.

Ferris et al.[11] reported the results of a study at a company where grinding of ABFA occurred. The material was used as a foaming agent for thermoplastic resins and rubbers. All but one of the 11 employees in the production area had cough, especially at night. Interviews with seven indicated that six had productive cough, five had shortness of breath, and five had nocturnal cough. A British study[12] examined 151 workers who had been, or were currently, exposed to ABFA dust in the process of its manufacture. The prevalence of workers diagnosed as

having developed asthma because of ABFA was 18.5% (predominantly shortness of breath, chest tightness and wheezing). It should be noted that this prevalence figure represents only those whose symptoms were related to ABFA and is not strictly comparable to the total 60% prevalence we observed. Over half of the patients developed asthma within three months of first exposure, and 75% developed it within the first year. With respect to the pattern of onset, 56% had late-onset asthma, 22% immediate, and 22% dual. Additional symptoms reported in that study were cough (39%), rhinitis (29%), conjunctivitis (25%) and rash (4%).

The investigators found no evidence of chronic (i.e. baseline) effect on PFTs. We observed small intrashift decreases in FEV_1 and FVC, but these were not statistically significantly different from those who were not exposed. The mean changes appeared 2-3 times greater in Building 98 than in Building 67b, but perhaps because of the small number of workers, the differences were not statistically significant. There was a suggestion that the change in FEV_1 was greater among those with higher personal exposure than among those with trace or nondetectable exposure. This is interesting given the use of respirators by all individuals dumping ABFA on this occasion. However, any conclusions based on this finding are limited by the small numbers, and by the fact that the comparison group (never exposed) demonstrated a mean decrease of magnitude between that found in the "trace" and "quantifiable" exposed groups. The study by Ferris et al[11] observed changes over the shift, on three different days, of 16.6, 5.0, and 5.2% in FEV_1, and 20.8, 8.3, and 10.4% in FVC, respectively. The British study[12] documented "nothing but the small improvement in daytime performance to be expected from diurnal variations". The decreases we observed of 2-3% lie between the findings of the other two studies and, since they are similar to the unexposed group, suggest that any acute ABFA effect on pulmonary function on the exposed workforce, as a group, is minimal.

The significance of the immunologic findings in this investigation should be interpreted with considerable caution, as there were no positive ABFA-HSA specific IgE determinations found, and the specific IgG results were not positive in the usual dilution of greater than 1:50. "Positive" values were noted in both exposed and nonexposed workers. A previous study[12] reported that prick tests with ABFA solutions in all ABFA-sensitized and asymptomatic exposed workers were negative.

VIII. RECOMMENDATIONS

Recommendations have been grouped in the following categories: Engineering Controls, Work Practices, Hazard Communication, and Personal Protective Equipment. Some such as Engineering Controls and Work Practices are interdependent.

A. Engineering Controls:

Building 98

Air distribution in Building 98 from space heaters should be modified to eliminate cross drafts across exhaust hood faces. Redesign of the scale hood should be undertaken. Adequacy of the existing system to provide effective capture of contaminants in the work area, as well as the system's capability for handling additional systems, such as the scale hood, should be evaluated.

Building 67b

Hoods should be flanged, and the weighing scale hood should be sized to accomodate the containers being used. (This recommendation may not be applicable due to modifications planned for the system.)

Raw Materials

Azodicarbonamide should be obtained and/or used in pre-weighed incremental amounts thereby reducing or eliminating "stumps" (partially full containers) in the work area. This would reduce measuring and weighing procedures which require handling the loose material.

Empty ABFA drums should be free of any residual material before they are used for other purposes and workers should be properly informed and precautions taken in handling the drums.

Future production equipment modifications should include provisions for bulk handling of dry materials. This should reduce the overall dustiness and spillage in the area and eliminate most lifting tasks.

B. Work Practices:

Greater care should be taken when handling loose ABFA. This includes scooping, weighing, dumping, replacing lids, and knocking residual material loose from drums and buckets. Dry sweeping of spilled ABFA should not be permitted. Raw materials, including azodicarbonamide, should be added more carefully to the process equipment in order to avoid generating quantities of dust either exceeding the exhaust ventilation removal capacity or occuring beyond the effective capture zone of the hood.

Compressed air should not be used to remove dust from oneself. Provisions for vacuuming dust from work clothes should be made.

Empty bags, drums, and weighing buckets should not be crushed, shaken, or dropped unnecessarily. The practice of compressing empty bags by stepping down on them should be discontinued.

Vacuuming or wet cleanup of ABFA should be done at the time the material is spilled. A high efficiency particulate air (HEPA) filter may be necessary on the vacuum due to the small particle size (2 to 20 microns).

C. Hazard Communication:

A uniform procedure should be established for informing workers of the hazards associated with new materials introduced in the process of product development and manufacture of new product lines. This would include discussion of health effects, proper handling of the material, appropriate use of existing or new engineering controls, necessary work practices, and appropriate personal protective equipment.

D. Personal Protective Equipment:

The company should clarify periodically the personal protective equipment required for certain tasks or when handling certain substances when engineering controls and work practice alone are known to be insufficient to control the hazard. Limitations of personal protective equipment also needs to be discussed, such as facial hair, which interferes with the seal of the respirator facepiece. Since this severely compromises the protection provided by the respirator, workers who wear or are required to wear respirators should be clean shaven.

Unused respirators should be stored properly, in a clean, uncontaminated area. Workers should have provisions for storage of their respirator during the workshift when it is not needed.

Half mask respirators equipped with high-efficiency cartridges are recommended while directly handling ABFA. This type of respirator would provide better protection than the currently used disposable nuisance dust masks. Uncertainty regarding the biological activity of ABFA through inhalation exposure supports this recommendation.

In order to minimize exposure due to contamination of regular work clothes, and to reduce direct contact with ABFA, workers should use gloves and disposable coveralls when handling ABFA.

E. Medical Recommendations

Although the potential for ABFA to produce sensitization, and whether this is mediated through an immune mechanism, is not clear, a program for medical surveillance of workers potentially exposed to ABFA should be instituted because of this compound's potential for respiratory problems. Such a program has a number of components: an example could be similar to that outlined previously by NIOSH.[16]

New employees should have medical histories to seek pre-existing respiratory symptoms and disease, especially asthma, and occupational histories to seek evidence of previous exposures to asthmogens, such as isocyanates. They should have baseline PFT's including at least FEV_1 and FVC (and a calculation of the FEV_1/FVC ratio). Worker education concerning possible effects of ABFA and work practices to minimize exposure should be instituted (see B. Work Practices, C. Hazard Communication, D. Personal Protective Equipment).

Any worker reporting symptoms such as persistent cough, cough at night, wheezing, shortness of breath, or difficulty breathing should be further evaluated, including pre- and post-shift PFT's. Those with greater than a 10% decrease in FEV_1 over the shift should be referred to a pulmonary physician for determination of sensitization.

Current employees should have pre- and post-shift PFT's performed (after two consecutive work days, if possible) at the beginning of the program and should be questioned about respiratory symptoms. All workers potentially exposed should be interviewed and undergo PFT's at least annually. Again, symptoms compatible with "sensitization" should be investigated and significant pre- and post-shift decrements in FEV_1 or loss of FEV_1 greater than about 10% from one year to the next should be evaluated. Anyone shown on evaluation to have a decrease or "sensitivity" related to ABFA should not have a work assignment involving exposure to the compound.

For proper performance of spirometry, a number of technical considerations should be addressed, including the use of a spirometer meeting American Thoracic Society (ATS) specifications[17], employing a trained and enthusiastic technician, and, to the extent feasible, doing the tests with the same machine, technician, and time of day from year to year.

Other features of an occupational pulmonary disease surveillance program include education of workers, maintenance of medical records and records of environmental exposure, and epidemiologist evaluation of data.

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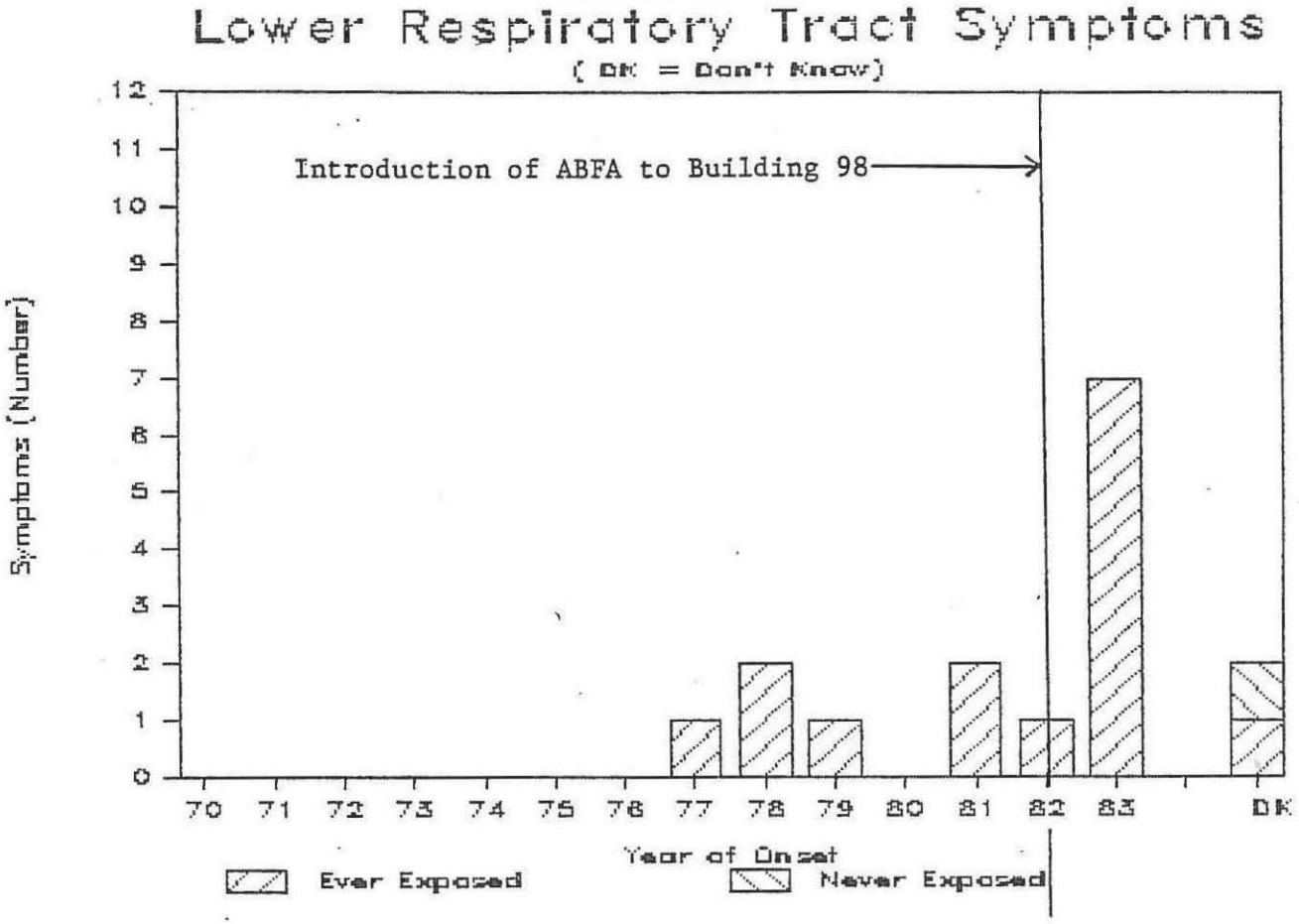
Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Publications Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service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

1. Confidential Requestors
2. Local 202, United Rubber Workers of America
3. Armstrong World Industries
4. National Toxicology Program
5. NIOSH, Region III
6. OSHA, Region III

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.

Figure I

Time of Onset of Symptoms
Armstrong World Industries
Lancaster, Pennsylvania
HETA 83-451



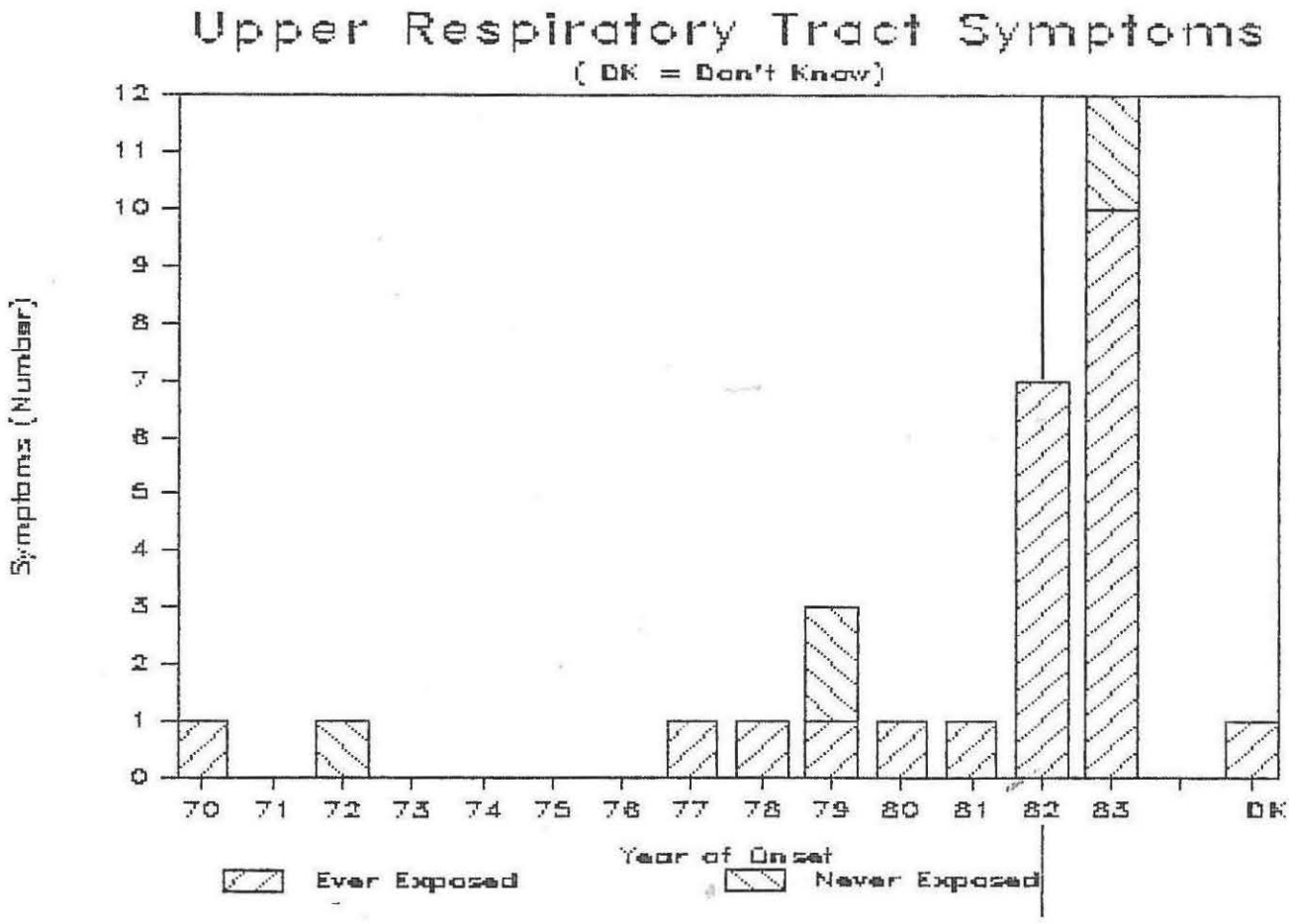


Figure II

Change in FEV_1 and FVC over the shift and results of air sampling for personal exposure to Azodicarbonamide

ARMSTRONG WORLD INDUSTRIES
LANCASTER, Pennsylvania
HETA 83-451

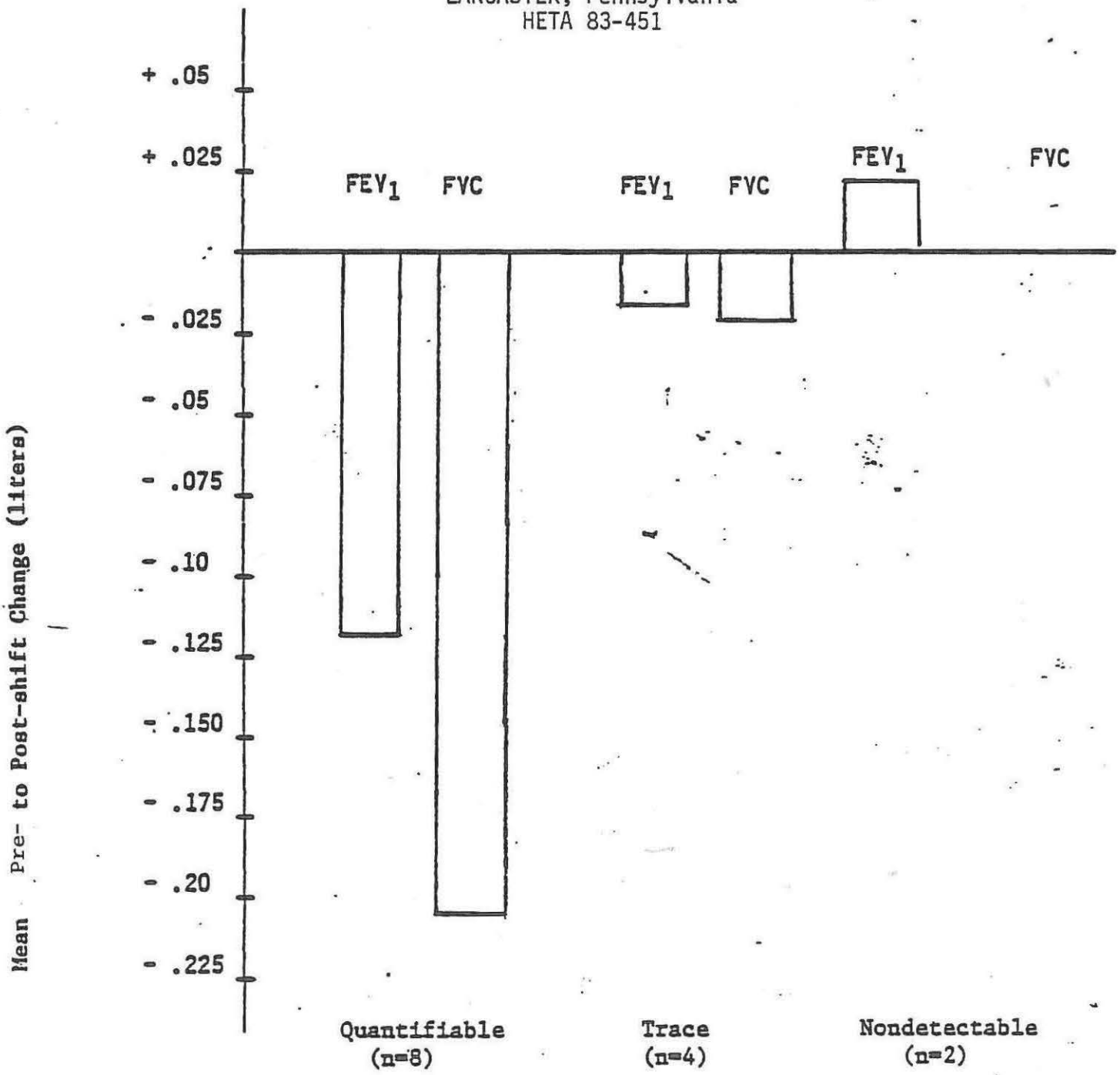


Table II

Exposure Concentrations for Azodicarbonamide
Armstrong World Industries
Lancaster, Pennsylvania
HETA 83-451

January 8-11, 1984

Sample Description*					Azodicarbonamide Concentration in mg/m^3**		
Date	Shift	Job Title	Respirator	Duration	Indirect	Direct	Combined
Bldg. 67 Paints, Oils, Plastisols							
1/8	10:30-7	Leader	N	346	0.01	-	-
1/8	10:30-7	Helper	N	344	0.02	-	-
1/8	10:30-7	Grinder	N/Y	340	-	-	0.91
			N	308	0.03	-	]-0.38
			Y	32	-	3.8	
1/9	7-3:30	Leader	N	396	ND	-	-
1/9	7-3:30	Helper	N	419	Trace	-	-
1/9	7-3:30	Grinder	N/Y	410	-	-	ND
			N	354	ND	-	]-1.7
			Y	56	-	12	
1/9	7-3:30	Grinder	N	406	Trace	-	-
1/11	7-3:30	Grinder	N	305	ND	-	-
1/11	7-3:30	Helper	N	311	ND	-	-
1/11	7-3:30	Leader	N	304	0.02	-	-
1/11	7-3:30	Grinder	N/Y	309	-	-	0.66
			N	257	0.02	-	]-0.04
			Y	53	-	0.15	
Bldg. 98 Paint Room- Coating & Fusion							
1/8	11-7	Leader	N	354	0.01	-	-
1/8	11-7	Helper	N/Y	418	-	-	0.36
			N	391	0.02	-	]-0.34
			Y	27	-	4.8	

Table 1

Exposure Concentrations for Azodicarbonamide
Armstrong World Industries
Lancaster, Pennsylvania
HETA 83-451

December 1, 1983

Sample Description* Job Title	Respirator	Duration	Azodicarbonamide Concentration in mg/m^3**	Comments
Bldg. 67: Paints, Oils, Plastisols				
Leader	Y	12	3.1	Weighing and charging azodicarbonamide.
	N	53	2.1	Sample obtained during the remainder of batch component weighing and charging. Produced 1 batch
Grinder	N	58	ND	Working downstairs, not in immediate area of azodicarbonamide use.
Area sample	-	50	ND	Located across the room from azodicarbonamide weighing, handling and charging
Bldg. 98: Paint Room-Coatings & Fusion				
Leader	Y	68	ND	Weighed up oils, dumped other dry ingredients into blenders. Wore respirator.
Helper	Y	55	ND	Weighed azodicarbonamide, dumps it into blender. Produced 3 batches.
Helper	N	40	Trace	Opened and dumped other dry materials into blenders.

Analytical Limit of Detection ug/sample: 1 ug/sample
Analytical Limit of Quantitation ug/sample: 5 ug/sample

Evaluation Criteria: None specific for azodicarbonamide

*Sample Description provides the worker's job title, use of disposable dust masks during task (Y=yes, N=no), and duration in minutes.
**Concentrations calculated over sample period only and given in milligrams per meter cubed (mg/m^3).
ND denotes no azodicarbonamide was detected in the sample. Trace denotes that azodicarbonamide was identified in the sample but was below a quantifiable concentration level.

Table II (continued)

Sample Description*					Azodicarbonamide Concentration in mg/m^3**		
Date	Shift	Job Title	Respirator	Duration	Indirect	Direct	Combined
1/9	7-3	Leader	N	397	0.01	-	-
1/9	7-3	Helper	Y	401	0.04	-	-
1/9	7-3	Helper	N/Y	403	-	-	0.08
			N/Y	373	0.10	-	]-0.46
			Y	31	-	4.8	
1/9	3-11	Leader	N	388	Trace	-	-
1/9	3/11	Helper	N	385	Trace	-	-
1/9	3/11	Helper	N/Y	364	-	-	0.01
			N	353	Trace	-	]-Note a
			Y	11	-	0.59	
1/10	3-11	Leader	N	418	ND	-	-
1/10	3/11	Helper	N	415	ND	-	-
1/10	3/11	Helper	N/Y	416	-	-	Trace
			N	409	Trace	-	]-Note a
			Y	7	-	0.63	
1/11	7-3	Leader	N	426	Trace	-	-
1/11	7-3	Helper	Y	414	ND	-	-
1/11	7-3	Helper	N/Y	412	-	-	0.08
			N	330	0.03	-	]-0.12
			Y	21	-	1.6	

Table II (continued)

Sample Description*					Azodicarbonamide Concentration in mg/m^3**		
Date	Shift	Job Title	Respirator	Duration	Indirect	Direct	Combined
Coating and Fusion Dept: "Unexposed" Workers							
1/9	Line 7-3	Coater Operator	N	423	ND	-	-
1/9	Line 7-3	Roll-up Operator	N	430	Trace	-	-
1/9	Line 7-3	Unroll Operator	N	415	Trace	-	-
1/9	Line 7-3	Roll-up Operator	N	421	ND	-	-
1/9	Line 3-11	Line Operator	N	380	Trace	-	-
1/9	Line 3-11	Laborer	N	368	ND	-	-
1/9	Line 3-11	Roll-up Operator	N	363	ND	-	-
1/9	Line 3-11	Leader	N	369	ND	-	-
1/10	Line 3-11	Coater Operator	N	414	ND	-	-
1/10	Line 3-11	Coater Operator	N	403	ND	-	-
1/10	Line 3-11	Unroll Operator	N	401	ND	-	-
1/10	Line 3-11	Roll-up Operator	N	397	ND	-	-

Analytical Limit of Detection: 1 ug/sample
Analytical Limit of Quantitation: 5 ug/sample

Evaluation Criteria: None specific for azodicarbonamide

*Sample Description: Disposable NIOSH approved dust masks in use by workers during weighing and dumping of azodicarbonamide and by some during other periods: N=no; Y=yes; NY=combined sample obtained over entire period. Duration in minutes. Underlined indicates pump failure.

**Exposure concentration is given in milligrams per cubic meter (mg/m^3).

- "Indirect" denotes sample obtained when no weighing or dumping of azodicarbonamide was being performed by worker and for workers in the area but not weighing and dumping azadicarbonamide.
- "Direct" denotes sample obtained during the period that worker was weighing up and dumping azodicarbonamide.
- "Combined" denotes the sample obtained separately from the previous two for workers weighing and dumping azodicarbonamide. This sample ran the entire work shift. Values with the bracket were obtained by combining the indirect and direct samples.

ND: None detected, contaminant below analytical detection capabilities. Trace denotes azodicarbonamide present in the sample but at concentrations below the limit of quantitation. Calculated trace environmental levels average less than 0.006 mg/m^3.

Note a: No time weighted average (TWA) is calculated for situations requiring the use of a sample with azodicarbonamide present between quantifiable and detectable limits.

Table III

Exposure Concentration Statistics for Azodicarbonamide
Armstrong World Industries
Lancaster, Pennsylvania
HETA 83-451

Location	Exposure Type*	Sample size (n)	Mean	Standard Diviation	Range (mg/m^3)
Building 67	Indirect	11	0.01	0.01	N.D.**-0.03
Building 67	Direct	3	5.3	6.1	0.15-12
Building 67	Combined	3	0.52	0.47	N.D.-0.91
Building 98	Indirect	14	0.02	0.03	N.D.-
Building 98	Direct	5	2.5	2.2	0.59-4.8
Building 98	Combined	5	0.11	0.15	Trace**-0.36
Production Lines	Controls	12	0.001	0.001	N.D.-Trace
Buildings 67 and 98	Pooled Direct	8	3.6	3.9	0.59-12
Buildings 67 and 98	Pooled Indirect	25	0.01	0.02	N.D.-0.04

*Indirect = workers in Buildings 67b and 98 where ABFA was handled in powdered form, but not handling it directly; also non-ABFA handling periods.
Direct = worker weighing and dumping powdered ABFA
Combined = fullshift exposure sample for worker incorporating both weighing and dumping of ABFA as well as working in area for the work shift. Combined TWA samples (Table II) obtained by adding together direct and indirect exposure samples are not included in with the full-shift samples.

**N.D. = non-detectable
Trace = denotes a concentration that was analytically detectable but insufficient to quantify (below the limit of quantitation).

Table IV
Local Exhaust Ventilation Measurements
Armstrong World Industries
Lancaster, Pennsylvania

HETA 83-451
January 9, 1984

Building	Hood Identification and Description	Average Face Velocity in fpm* (# sample points)	Capture Velocity** at (x inches) in fpm	Observation/Comments
67b	weighing scale hood, 2 vertical slots	222,270 (4/slot)	50-70 (30" above floor, 12" from hood face) 15-20 (24" from face)	Drums of azodicarbonaide from which material is weighed in front of scale are 33" tall. Height of hood is 33.5"
67b	Charging hood, closest to scale. 2 horizontal openings	662 (2/opening)	160-180 (12" from hood face, over charging part) 40-60 (24" from face)	Speed of dumping dry materials influences particulate escapes collection at sides. No flange, material accumulation in hood.
67b	Charging hood, second from scale. 3 horizontal slots	925,800,675 (top to bottom, 2/slot)	80-140 (12" from hood face over charging port) 20-30 (24" from face)	Same as other charging hood.
98	Weighing station hood partially enclosed canopy hood with 90° take off, solid back, curtained sides.	Could not be obtained due to cross drafts	Could not be obtained due to cross drafts	Appeared to be ineffective. Heating units created room air currents of 100-200 fpm, interference from cross drafts prevented obtaining meaningful measurements. Poor design.
98	Ribbon blender slot hood with upward plenum and dual takeoff closest to scale.	370 (6)	Not obtained. Due to cross drafts, turbulence.	Material accumulation in hood; speed of material additionally affects hood effectiveness; operation of blender during dry material addition can result in material being kicked up, out of blender.
	Middle ribbon blender	560 (6)	Not obtained	Workers crush empty bags in pile on floor. Cross drafts and turbulence noted from operation of heating units. Lids are present on the units and used during initial mixing of dry and liquid materials after additions are completed.
	Blender nearest outside exit	620 (6)	Not obtained	

* fpm = linear feet per minute measured air flow.
** Measured velocities are given at heights and or distances in front of the exhaust hood based on observation of where the work was performed or, in the care of measuring raw materials, at the height of containers in use. "denotes inches.
Note: In situations where multiple hoods were connected to the same exhaust system and which could be regulated with a blast gate, all blast gates were opened for the hoods of interest before measurements were taken.

TABLE V

DEMOGRAPHIC DATA

Armstrong World Industries
Lancaster, Pennsylvania
HETA 83-451

January, 1984

CHARACTERISTIC		Exposure Group EVER	Exposure Group NEVER
Categorical Data			
Number of partcipants		30	16
Age:	< 40	19 (63) *	9 (56)
	≥ 40	11 (37)	7 (44)
Race:	White	28 (93)	15 (94)
	Black	2 (7)	1 (6)
School:	5 - 11	13 (43)	6 (38)
	12 +	17 (57)	10 (62)
Smoking Status:	Current	13 (43)	11 (69)
	Ex	9 (30)	1 (6)
	Never	8 (27)	4 (25)
Allergies Excluding Hayfever	Yes	7 (23)	3 (19)
Seasonal Rhinitis	Yes	6 (20)	3 (19)

TABLE V (continued)

DEMOGRAPHIC DATA

Armstrong World Industries
Lancaster, Pennsylvania
HETA 83-451

January, 1984

	Exposure Group	
	EVER	NEVER
Continuous data (Mean ± S.D.)		
Age, Yrs. (Range)	39 ± 10 (28 - 61)	44 ± 11 (30 - 61)
School, Yrs. (Range)	11 ± 2 (7 - 13)	11 ± 2 (5 - 12)
Duration of Employment (months)	75 ± 57 (1 - 168)	75 ± 69 (5 - 180)
Pack-Yrs., Current Smokers (Range)	32 ± 28 (3.5 - 100)	36 ± 20 (4.0 - 80)
Pack-Yrs., Ex Smokers (Range)	18 ± 13 (1 - 40)	- 3.5
Years Smoked, Current Smokers (Range)	21 ± 13 (4 - 40)	28 ± 11 (8 - 45)
Years Smoked, Ex-Smokers (Range)	15 ± 12 (2 - 40)	- 7.0

* Numbers in parenthesis represent percentages.

TABLE VI

Baseline Pulmonary Function by Exposure Group and Smoking Status

Armstrong World Industries
Lancaster, Pennsylvania
HETA 83-451

January 1984

	Currently Exposed			Never Exposed		
	Never Smokers	Ex Smokers	Current Smokers	Never Smokers	Ex Smokers	Current Smokers
Participants	7	5	3	3	1	7
FEV_1, % of Predicted	94 ± 6 *	95 ± 10	103 ± 21	91 ± 14	94	95 ± 7
FVC, % of Predicted	95 ± 9	98 ± 11	107 ± 9 A	93 ± 16	97	94 ± 7 A
FEV_1/FVC	81 ± 8	78 ± 6	74 ± 13 B	79 ± 3	78	81 ± 6 B
FEF_{25-75}, % of Predicted	78 ± 27	67 ± 20	68 ± 23 B	66 ± 10	69	81 ± 24 B
Pack-Yr.	-	17 ± 13	18 ± 12 B	-	3.5	27 ± 16 B
Years Smoked	-	13 ± 11	16 ± 13 B	-	7.0	24 ± 10 B

* Mean ± S.D.

A p = 0.037
B p > 0.3
=

TABLE VII

Reported Symptoms, by Exposure Group

Armstrong World Industries
Lancaster, Pennsylvania
HETA 83-451

January, 1984

Symptoms	Exposure Group: Ever (N = 30) # (%)	Exposure Group: Never (N = 16) # (%)	Risk Ratio	X^2***	p-value
Lower Respiratory Tract *	18 (60)	1 (6)	10	12.4	0.0004
Eye and Upper Respiratory Tract **	26 (87)	5 (31)	2.8	14.6	0.0001

* Wheezing, cough or shortness of breath
** Nasal stuffiness/sneeze, itchy or irritated eyes, runny nose
*** Chi-square

TABLE VIII

Pulmonary Function Changes Over the Shift, by Exposure Group

Armstrong World Industries
Lancaster, Pennsylvania
HETA 83-451

January 1984

Parameter	Exposure Group: Currently Exposed (N = 15)	Exposure Group: Never Exposed (N = 11)	p value **
FEV_1 (post-pre) liters	-0.087 ± 0.149 *	-0.049 ± 0.155	0.531
	Smokers (N = 3) +0.003 Non/ ex-smokers (N = 12) -0.110	Smokers (N = 7) -0.070 Non/ ex-smokers (N = 4) -0.013	
FVC (post-pre) liters	-0.116 ± 0.233	-0.044 ± 0.104	0.299
	Smokers (N = 3) -0.007 Non/ ex-smokers (N = 12) -0.143	Smokers (N = 7) -0.010 Non/ ex-smokers (N = 4) -0.103	

Among the Currently Exposed

Parameter	Building 98 (N = 8)	Building 67 (N = 7)	
FEV_1 (post-pre) liters	-0.134 ± 0.153	-0.034 ± 0.136	0.208
FVC (post-pre)	-0.146 ± 0.279	-0.081 ± 0.184	0.610

* Mean ± S.D.
** Pooled t-test, two-tailed

TABLE IX

Measurement of Specific IgG to Azodicarbonamide by ELISA Using Azodicarbonamide-Human Serum Albumin (Az-HSA) Conjugates

Armstrong World Industries
Lancaster, Pennsylvania
HETA 83-451

January 1984

Worker #	Optical Density @ 405 mu (1:10 Serum Dilution)
No exposure	
7	0
8	0
9	0
14	0
29	0
31	0
35	0
36	0
46	0
47	0
53	.002
38	.010
34	.068
13	.264
33	.266
Building 67b	
1	0
3	0
17	0
18	0
19	0
41	0
16	.036
10	.053
Building 98	
11	0
24	0
25	0
30	0
37	0
45	0
51	0
52	0
23	.014
44	.016
5	.023
43	.032
6	.033
20	.048
26	.052
42	.062
40	.071
27	.101
12	.108
4	.130
2	.136
21	.202
22	.439

Laboratory Controls: 0, 0, 0, .005, and .070; $\bar{X}$ = .015

Note: A medically significant IgG ELISA would be a value 2 x the mean of the laboratory controls @ a serum dilution of at least 1:50. Since these values were obtained with a 1:10 dilution, values need to be correlated to clinical symptoms to determine significance.

Appendix A

Azodicarbonamide Fact Sheet
Armstrong World Industries
Lancaster Pennsylvania
HETA 83-451

Introduction

Azodicarbonamide is an organic chemical foaming agent which liberates gases when heated by means of decomposition. An organic foaming agent releases gas over a specific, narrow temperature range. Azodicarbonamide is found among the medium-temperature foaming agents. This processing range is 320 to 450°F (160-232°C). Fine particle-size azodicarbonamide decomposes at a lower temperature than a more coarse form. In low-pressure atmospheric applications, such as polyvinyl chloride plastisols, the particle size has a large effect upon the final cell structure.

Physical Appearance:

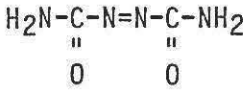
Yellow-orange crystalline solid with an average particle diameter ranging from 2 to 20 microns.

Chemical Name: 1,1'-azobisformamide

Chemical Name: $C_2H_4N_4O_2$

Molecular Weight: 116.10

Chemical Structure:



CAS Numbers: 123-77-3

Synonyms:

1,1'-azobiscarbamide*
azobicarbonamide* azobiscarboxamide*
1,1'-azobis(formamide)* azodicarbamide*
azodicarboamide* azodicarbonamide*
azodicarboxamide* azodicarboxylic acid diamide
*delta (1,1')-biurea *Celosen AZ *ChKhZ21*
ChKhZ 21R *Diazencdicarboxamide *Genitrow AC *
Genitrow AC2* Genitrow AC 4
Kempore 125 Kempore R 125 *Lucel ADA
*NCI-C55981 *Pinhole AK2 *Porofor 505
Porafor ADC/R Porofor ChKhZ 21*
Porafor ChKhZ 21R * Unifoam AZ*
Uniform AZ* Yunihomu AZ

(Continued)

Trade Names and Supplies

Celogen AZ®(Uniroyal)
Ficel AC® (BFC)
Kempore® (Olin)
Porofor ADC® (Mobay)

Decomposition Products:

About 220 cubic centimeters of gas is released per gram of material. The gas is a mixture with 65% of it nitrogen. A white, nonstaining solid residue contains hydrazobisformamide, cyanuric acid, urazol, and under specific conditions, oxamide. The composition of the gaseous and solid decomposition products vary, depending upon the conditions under which decomposition occurs and the additives present in the system.

Polymers Utilyzing Azodicarbonamide:

ethylene-vinyl acetate copolymer, polyvinyl chloride, low density polyethylene, high density polyethylene, high-impact polystyrene, polypropylene, acrylonitrile butadiene styrene, acetal, acrylic, and modified polyphenylene oxide.

Other Uses:

Azodicarbonamide is regulated by the Food and Drug Administration as a food additive.
(Source of physical properties, use, and decomposition products: Modern Plastics Encylopedia 1982-1983, ref 1; Name, formula, CAS#, synonyms: RTECS 1981-1982, ref 2)