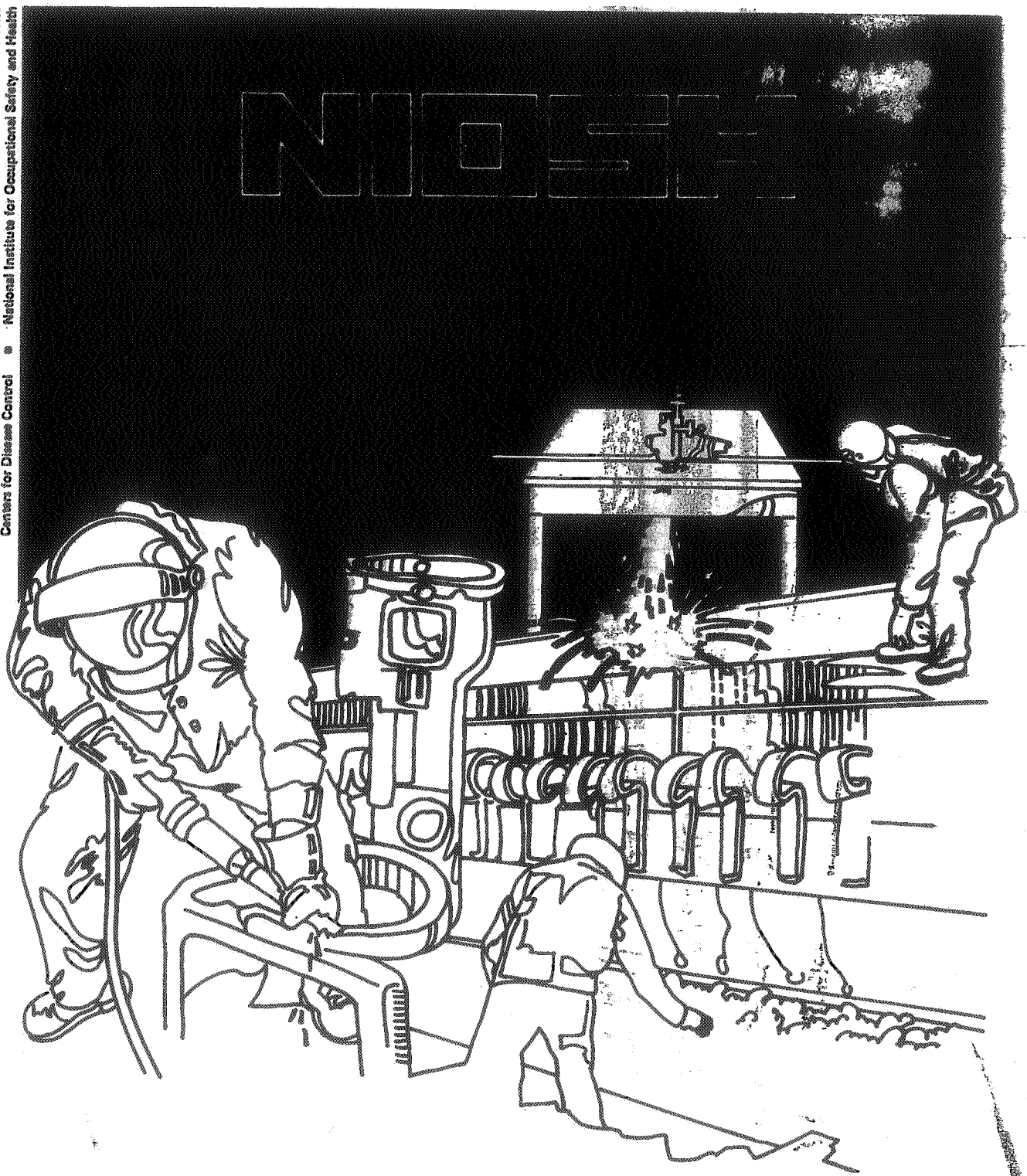
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
Centers for Disease Control ■ National Institute for Occupational Safety and Health

NIOSH



Health Hazard Evaluation Report

HETA 84-108-1821
NIEMAND INDUSTRIES INC.
STATESVILLE, NORTH CAROLINA

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.

HETA 84-108-1821
JULY 1987
NIEMAND INDUSTRIES INC.
STATESVILLE, NORTH CAROLINA

NIOSH INVESTIGATORS:
Stan. Salisbury, CIH
Sara Arnold, M.D.

I. SUMMARY

In December, 1983, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation from the President of Local 919, United Paperworkers International Union (UPIU). The UPIU representative was mainly concerned about the extensive use of solvents and solvent based adhesives in the Film Winding Department of Niemand Industries Inc, in Statesville, North Carolina. A previous inspection by the state OSHA consultation program had not found solvent exposures above the OSHA Permissible Exposure Limits but workers in this department continued to complain of frequent headaches, dizziness, nausea, and other acute symptoms.

On March 28-29, 1984, NIOSH investigators conducted an initial environmental and medical survey, with preliminary findings and recommendations provided in May 1984. During a follow-up survey in June 1984, NIOSH investigators monitored exposures to organic vapors released from solvent based adhesives in the Film Winding Department by collecting personal air samples from 15 film winding machine operators. Specific compounds sampled were methyl ethyl ketone (MEK), toluene, perchloroethylene, 1,1,1-trichloroethane, dioxane, ethylacetate, xylene, Teflon decomposition products (as total fluorides), methylene bisphenyl isocyanate (MDI), and toluene diisocyanate (TDI). Short-term exposures to methylene chloride were monitored for several film winding workers performing end-of-shift cleanup activities. A questionnaire was administered to 16 employees working in the Film Winding Department, and both pre- and post-shift venous blood samples were obtained to determine carboxyhemoglobin levels, a biological index of exposure to methylene chloride. In the Labeling Department, short term (15-minute) personal exposures to organic vapors were monitored at the end of the work shift when operators cleaned a conveyer belt with a "special blend" solvent.

Follow-up survey results were sent to company and union representatives on November 6, 1984. The exposures found in the Film Winding Department were mostly to MEK and dioxane, ranging from 19 to 60 parts per million (ppm) for MEK, and 7 to 14 ppm for dioxane. Methylene chloride exposures during cleanup activities at the close of the work shift ranged from 32 ppm to a high of 211 ppm for exposure durations of 13 to 38 minutes. All of the carboxyhemoglobin values from smokers were within the "normal range" for smokers, but there was a slight increase over the work shift. The mean pre-shift COHb for the non-smokers was slightly above the normal range for non-smokers and rose 143% over the shift. Symptoms reported by workers assigned to the Film Winding Department were consistent with the known effects from many of the

solvents used. There was no evidence of an excess of adverse reproductive outcomes related to occupational exposures for film winders, and no chronic work-related health problems were found in this group. Exposed workers reported no chronic medical conditions such as liver, kidney, lung, heart, or neurologic disorders.

Short-term exposures to the three major components of the solvent blend operators used in the Labeling Department ranged from 28 to 79 ppm for xylene, 6 to 20 ppm for perchloroethylene, and 15 to 18 ppm for 1,1,1-trichloroethane.

Based on the air sampling results, the NIOSH investigators concluded that personal exposures to the mixture of solvent vapors detected in the Film Winding Department presented a potential health risk to exposed workers. Although only one film winder's combined exposure exceeded recommended exposure limits for preventing acute symptom effects (mucous membrane irritation or depression of the central nervous system), NIOSH investigators were concerned by the potential for long-term, low-dose neurotoxic effects. Furthermore, all film winders monitored were exposed to dioxane and methylene chloride which NIOSH regards as potential workplace carcinogens. No exposures to TDI or MDI monomer were detected for workers using adhesives containing polymeric TDI and MDI resins. Thermal breakdown of Teflon polymer films (Kapton F) was not detected and was not considered a health hazard under the conditions evaluated during this survey. In the Labeling Department, solvent vapor exposure times were limited to less than 20 minutes, and short term exposure limits were not exceeded. Recommendations for reducing exposures are contained in Section IX of this report.

KEYWORDS: SIC 2655 (Fiber Cans, Tubes, Drums, and Similar Products), film-winding, solvent-exposure, toluene, dioxane, perchloroethylene, xylene, 1,1,1-trichloroethane, methyl-ethyl-ketone, teflon-decomposition-products, methylene-bisphenyl-isocyanate (MDI), and toluene-diisocyanate (TDI)

II. INTRODUCTION

In December 1983, the National Institute for Occupational Safety and Health (NIOSH) received a request from the United Paperworkers International Union, Local 919 for a health hazard evaluation at Niemand Industries, Statesville, North Carolina. The original request mentioned a large number of potential chemical exposures in a variety of departments. Based on discussions with union representatives, NIOSH investigators focused the evaluation on the Film Winding Department, which had the greatest potential for multiple solvent exposures, and where possible solvent-related adverse health effects had been reported. Solvent exposures in the Labeling Department were also evaluated.

On March 28-29, 1984, a NIOSH industrial hygienist and physician conducted the initial environmental and medical survey and submitted preliminary recommendations for decreasing exposures to solvents in the Film Winding Department. A letter summarizing the initial NIOSH survey was distributed to company and union representatives on May 30, 1984.

On June 26-27, 1984, NIOSH investigators performed a follow-up environmental and medical survey in the Film Winding and Labeling Departments. A letter discussing the environmental results from this survey was distributed on November 6, 1984. Industrial hygiene and medical results were summarized and discussed by the NIOSH physician at a meeting with company and union representatives on November 28, 1984.

III. BACKGROUND

Established in 1956, the Statesville, N.C. plant of Niemand Industries manufactures "spiral wound" tubing from paper or plastic films. The paper wound products are custom designed by Niemand as tubular packaging for items such as cosmetics and toiletries, condiments, and flea powder. Film wound tubing is sold mainly to designers, manufacturers, and rebuilders of electrical and electronic equipment for use as insulation sleeving. At the time of the NIOSH investigation the plant employed 215 production and maintenance workers, plus 20 others who worked in management or clerical jobs.

Most of the plant was devoted to paper winding operations. Adhesives used for paper winding were typical water-based vinyls such as polyvinyl alcohol, or polyvinyl acetate. These processes did not use solvents and no serious exposure hazards were observed.

A. Film Winding Department

The Film Winding Department was located in three adjoining rooms, in a separate area at the rear of the main building. This department was air conditioned. Ventilation was provided by pulling contaminated air through ceiling mounted exhaust fans. Uncontaminated outside make-up air was introduced into the

department through the air-conditioning supply air vents. The air from these vents was about 25% outside air and 75% recirculated air. Management representatives reported that the air exchange rate in this department was about 6-10 air changes per hour. Sixteen film winding machines were operated by the Film Winding Department, with Film Room 1 containing seven machines, Film Room 2 containing three machines, and Film Room 3 containing five machines. Both Film Rooms 2 and 3 had a special purpose machine for making very small diameter tubes. The film winding machines formed plastic sheets into spiral wound plastic tubing.

A variety of solvent based adhesives were used depending on the type of film being wound. Adhesives were blended in the mixing room located in the corner of Film Room 3. Only one employee, who also operated a film winding machine, was assigned to mix adhesives.

Typical ingredients for the most frequently used adhesive mixture were:

1. polyester resins, such as Dupont 56065, Dupont 46956, Bostic 7693, or Bostic 7650;

2. an adhesive additive (EPON 828);

3. and catalysts, such as Mondur MR, Boscodur No. 1, or Boscodur No. 22.

Solvent components in these materials, as identified by manufacturers' material safety data sheets were:

Dupont 56065 - methyl ethyl ketone (MEK) 55%
- toluene diisocyanate (TDI) 2.6%

Dupont 46956 - MEK 40%
- dioxane 35%

Bostic 7650 - toluene 50%
- MEK 20%

Bostic 7693 - MEK 70%

Mondur MR - polymeric isocyanate derived from methylene bisphenyl isocyanate (MDI)

Boscodure No. 1 or 22 - polymeric isocyanate derived from TDI

Other solvents used were tetrahydrofuran for solvent welding of polycarbonate films; 2-ethoxyethanol or 2-ethoxyethanol acetate, also used for solvent welding of special films; and denatured ethyl alcohol, used as an ink solvent.

At each film winding machine, rolls of plastic film (2 or more) were unwound and coated on one side with a solvent based adhesive by running the unrolling strip of film through a "glue stand." The glue stand held an open pan of adhesive and was equipped with a pickup and metering roller for transferring the proper amount of adhesive to one side of the film. Each film strip then passed under a dryer to flash off the residual solvent. Next, the converging film strips were spiral wound around a steel rod (the mandrel) to form a continuous plastic tube held together by the adhesive coating. Tubing was cut into 8 to 10 foot length as it came off the mandrel.

Workers complained about the odor from a special type of tubing called "sticky tube" which was wound on only one machine. Adhesive was coated on both sides of the film used to produce sticky tubing. This double sided coating left some residual undried adhesive inside the finished tubing. To dry the adhesive and flush out any residual solvent, air was blown through a stack of finished tubes placed on a special table. The solvent vapors flushed from the tube stack were directed into a small box shaped exhaust hood attached to a flexible exhaust duct. The vapors flushed off were mostly ethyl acetate and toluene.

Methylene chloride was used to clean out adhesive pans and glue stands. Methylene chloride was also used occasionally to clean up film winding machines.

Spiral winding of Teflon film, known as Kapton F, was accomplished by heat fusion. No adhesive was used, but some film winding workers complained about the odor from this process.

B. Labeling Department

Another area evaluated was the Labeling Department. This operation required operators to manually roll adhesive coated labels onto paper tubes. A solvent called "special blend" was used by the operators to clean the conveyer belts after they became coated with adhesive. This task was normally done at the end of the shift requiring only 15 to 20 minutes.

IV. EVALUATION DESIGN AND METHODS

A. Environmental

To identify the organic vapors released during the film winding processes, bulk air samples were collected on activated charcoal tubes and qualitatively analyzed by gas chromatography / mass spectrometry (GC/MS). These samples were collected in each film winding room and in the mixing area during the initial NIOSH survey. The results from these samples were used in the development of a follow-up environmental survey protocol.

During the follow-up survey, exposures to organic vapors in the Film Winding Department were monitored by collecting personal air samples from the Film Winder Operators and from the worker who mixed adhesives. Battery powered air sampling pumps were used to pull a known quantity of air through the appropriate sample collection media. The collection device was attached to the worker' shirt collar, and connected via a plastic tube to a pump attached to the worker's belt. During cleanup activities at the close of the work shift, short term (13-38 minute) exposures to methylene chloride were also monitored.

In the Labeling Department, the four labeling machine operators were fitted with air sampling equipment to monitor their exposures to solvent vapors when cleaning the labeling machine conveyer belt at the end of the shift. Only short term exposures were measured because the task was completed within 15 minutes.

The specific compounds sampled and the methods used for collection and analysis of the samples are summarized in Table 1. All substances listed in Table 1 were sampled and analyzed according to NIOSH recommended procedures.

B. Medical

During the initial visit, private medical interviews were conducted by the NIOSH physician with six employees from the Film winding Department in order to determine the extent of possible work-related health complaints.

During the follow-up survey, the supervisor and 15 employees in the Film Winding Department participated in the interviews and biological monitoring. Confidential interviews included questions about irritant, neurologic, and dermatologic symptoms associated with mixed solvent exposures. Participants were also asked about reproductive and other medical history, work habits, job history (at Niemand), and smoking history.

Based on direct observations and employee interviews, NIOSH investigators concluded that exposures to methylene chloride were mostly through skin absorption rather than inhalation. Because of concerns that air monitoring for methylene chloride might not accurately reflect individual exposures, pre- and post-shift venous blood samples were obtained from 16 people working in the Film Winding Department for determination of carboxyhemoglobin levels, a biological index of exposure to methylene chloride (and carbon monoxide). Blood was drawn from participants immediately upon their arrival at the plant on Wednesday morning of their Monday through Friday work week.

V. EVALUATION CRITERIA

A. Environmental Criteria

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff use environmental evaluation criteria

for assessment of many 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. However, 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, 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 which could potentially increase the total exposure. Lastly, evaluation criteria may change over the years as new information on the toxic effects of an agent becomes available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH recommended exposure limits (RELs)[1], (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs),[2] and (3) the U.S. Department of Labor (OSHA) occupational safety and health standards.[3] Often, the NIOSH recommendations and ACGIH TLVs are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLVs 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, by contrast, are based primarily on concerns relating to the prevention of occupational disease. When considering the exposure levels and the recommendations for reducing these levels found in this report, employers should note they are legally required to meet those levels specified by an OSHA standard.

For those compounds with established occupational exposure limits, the various criteria proposed by OSHA, ACGIH, and NIOSH for airborne concentrations of the chemical substances measured in this evaluation are listed in Table 2. A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8 to 10-hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

For the purposes of this evaluation, NIOSH has selected the most stringent exposure limits as our evaluation criteria. The major health effects anticipated for workers exposed above these evaluation criteria are summarized in Table 2.

B. Additional Toxicity Information

1. Methylene Chloride

Methylene chloride is a chlorinated organic solvent. Symptoms of overexposure may include mental confusion, light-headedness, nausea, vomiting, and headache. Inhalation of vapors may also cause irritation of the upper respiratory tract. Exposures to methylene chloride may aggravate the symptoms of angina. Direct contact with the liquid may cause skin burns and eye irritation.[4] It is easily absorbed by the lungs (retention: 55-70%) and by direct skin contact with the liquid.[5] Following absorption, methylene chloride is partly metabolized to carbon monoxide (CO) and carbon dioxide. Carbon monoxide in the blood combines with hemoglobin, forming carboxyhemoglobin (COHb) and making the hemoglobin molecule less able to bind with oxygen. Measurements of carboxyhemoglobin or carbon monoxide in expired air correlate with the magnitude of methylene chloride exposure.

The half-life of COHb resulting from methylene chloride exposure is 10-12 hours; that is, after a person absorbs methylene chloride (through skin or inhalation), COHb in the blood will not be eliminated immediately, but will decrease by one-half approximately every 10-12 hours. The COHb level will continue to rise with continued exposure if the rate of absorption is greater than the rate of elimination. Also, the COHb level can continue to rise even after a person is removed from exposure. This most likely results from continued conversion of methylene chloride stored in body tissues to COHb.[6]

Because cigarette smoke contains carbon monoxide, smokers frequently have an average carboxyhemoblobin level of 2 to 10% or sometimes as high as 18%. COHb is generally less than 1% in non-smokers. The combined effects of smoking and exposure to methylene chloride produces an additive increase in blood COHb values.[7] Human male subjects (non-smokers) exposed experimentally to methylene chloride for 7.5 hours daily on 5 consecutive days attained average peak COHb percentages of 2.9% at 50 ppm methylene chloride, 5.7% at 100 ppm methylene chloride, and 9.6% at 250 ppm methylene chloride.[8] In each case, the peaks were attained on the 5th day of exposure.[8] Higher values would be expected if subjects exercised during exposure.

Exposure to methylene chloride sufficient to produce COHb levels of 5% has been shown to produce acute decreases in the speed and precision of psychomotor performance.[9] Chronic methylene chloride exposure has been reported to affect neurologic function in animals,[10] and high exposures have been reported anecdotally to cause chronic brain damage in humans.[11] In 1976 NIOSH recommended a time-weighted average (TWA) exposure limit to methylene chloride of 75 ppm in order to maintain COHb levels below 5% in non-smokers.[12] The reference interval ("normal range") for carboxyhemoglobin is 0.5 - 2.0% for non-smokers and less than 12% for smokers.

Since 1976, the carcinogenicity of methylene chloride has been documented in several studies of chronic effects in animals. Therefore, in 1986, NIOSH identified methylene chloride as a "potential carcinogen", and recommended that exposures be reduced to the lowest feasible level.[13]

2. Dioxane

Neoplastic lesions, most often described as tumors of the liver and nasal cavity, have been produced in experimental animals given drinking water containing approximately 1% dioxane. NIOSH therefore considers dioxane a suspect carcinogen and recommends reducing exposures to the lowest feasible level, not to exceed 1 ppm for a 30-minute exposure duration, the lowest level of detection by current sampling and analytical methods. Dioxane can also penetrate the skin readily causing liver and kidney damage.[14]

VI. RESULTS

A. Environmental

The results for the air samples collected in the Film Winding Department are presented in Table 3. The exposures found were mostly to MEK and dioxane, ranging from 19 to 60 ppm for MEK, and 7 to 14 ppm for dioxane. There was little variation in exposure levels between the three film winding rooms. Because NIOSH considers dioxane a potential workplace carcinogen, any exposure above 1 ppm (30 minute exposure average) exceeds our evaluation criteria. However, when considering only the upper respiratory and central nervous system effects from "combined" exposures to all of the solvent vapors monitored, only the film winder, who also mixed adhesives, was exposed above the evaluation criteria (exposure exceeding 1.0 as determined by the ACGIH combined exposure formula [see Table 3]). A graphic representation of the combined exposure profile for each film winder monitored is presented in Figure 1.

Short-term exposures to methylene chloride during cleanup of film winding machines are shown in Table 4. Individual exposures to film winders ranged from 32 ppm to a high of 211 ppm. Exposure durations ranged from 13 to 38 minutes.

Teflon decomposition products (as total fluorides) were detectable directly above the winding mandrel of machine 02-08, but no personal exposures were detected (see Table 5).

No exposures to TDI monomer (12 personal samples taken) or MDI monomer (4 personal samples taken) were detected in the Film Winding Department.

Table 6 shows the labeling machine operators' exposures to vapors from the special blend solvent used in the Labeling Department for their "end-of-shift" cleanup. Exposures to the three major components of this solvent ranged from 28 to 79 ppm for xylene, 6 to 20 ppm for perchloroethylene, and 15 to 18 ppm for 1,1,1-

trichloroethane. Exposures were below the evaluation criteria for the individual organic vapors monitored and also below the ACGIH combined exposure limit for all organic vapors identifed in this area. Perchloroethylene vapors were consistently detected in the samples collected in this area although the supplier of the "special blend" solvent had not identified perchloroethylene as a component.

B. Medical

The six male film winders interviewed during the initial survey reported experiencing headaches, dizziness, eye irritation, nose and throat irritation (to a lesser extent), nausea, drowsiness, skin irritation, and acute respiratory symptoms (difficulty breathing, coughing, and choking sensation). Every worker interviewed complained of multiple (two to seven) acute symptoms from exposures encountered in the routine performance of their jobs. Some employees reported using methylene chloride and MEK for hand-washing, as well as for cleaning their machines, equipment, and spills.

During the follow-up visit in June, the supervisor and 15 of 16 film winders participated in the medical survey. The one film winder who did not participate was on vacation. They included: 14 men (10 black, 3 white, 1 Hispanic) and 2 white women. The mean duration of employment at Niemand was 9.6 years, with a range of one year to 27.5 years. The mean duration of employment in the film winding area was 4.1 years, with a range of one month to 13.5 years. Table 7 summarizes the frequency of symptoms experienced at work, as reported in the follow-up survey interviews.

No one reported chronic medical conditions such as liver, kidney, lung, heart, or known neurologic disorders. Two men reported having children with birth defects. However, the birth defects were of different organ systems, and the spouse of one of these men was employed in an occupation with possible reproductive hazards.

It was apparent from the medical interviews that work practices were varied. Some employees reported washing their hands in methylene chloride or MEK up to 10 times a day; others stated that they never washed their hands in solvents.

The results of the pre- and post-shift carboxyhemoglobin (COHb) levels are presented in Table 8. The findings for non-smokers (7 people) and smokers (9 people) are presented separately; the reference intervals (normal range) are different since carbon monoxide in cigarette smoke can contribute to the measured COHb levels in smokers. Of the 32 blood samples obtained, 4 could not be analyzed by the laboratory because of small clots that formed in the specimens from handling and transporting the samples.

As shown in Table 8, the pre-shift to post-shift COHb level increased in five of the six non-smokers. The mean COHb level for all the non-smokers (7 people) rose from 2.8% pre-shift to 4.0%

post-shift. One non-smoker had a post-shift level of 4.9%, and another had a post-shift level of 5.3%. The COHb level also rose in five of the six smokers who had both pre-shift and post-shift values. The mean COHb level for all the smokers (9 people) increased from 6.1% pre-shift to 6.8% post-shift. As the values in Table 8 show, there was considerable variability in the COHb levels for smokers. These variable and relatively higher values for the COHb levels in smokers, in contrast to the non-smokers, represent the contribution of an individual's smoking habits to their COHb levels. It was not possible to differentiate between COHb produced by methylene chloride exposure and that produced from cigarette smoking during the work shift.

There was no evidence of an excess of adverse reproductive outcomes related to occupational exposures for the employees in the Film Winding Department. Also, no chronic work-related health problems were apparent among the film winders. However, much remains unknown about the chronic health effects of long-term, low-level exposures to the various chemicals used in this plant.

VII. DISCUSSION

Although TWA exposures to individual organic vapors, for other than suspect carcinogens, were below the OSHA PELs, ACGIH TLVs, and NIOSH RELs, the combined solvent exposures for many film winders approached the limit as defined by the ACGIH combined exposure formula.[1] There is also some evidence of a synergistic effect from exposure to solvent mixtures. That is, mixtures of solvents may be more neurotoxic than the individual components alone, resulting in impaired performance even where exposures are well below the TLV.[15] A case-control study of Scandinavian patients with neuropsychiatric disease suggested that previous solvent exposure may account for up to 3-4% of all such disease.[16] Among solvent-exposed patients, nearly one-half of all neuropsychiatric disease has been estimated to be due to solvent exposure.[17] Based on these studies, among others, clinical neuropsychiatric disorders resulting from solvent exposure are now accepted as an occupational disease by the Swedish National Social Insurance Board.[18]

The reported acute symptoms are consistent with the known effects from many of the solvents used in the Film Winding Department and indicated that exposures should be better controlled. Mucous membrane irritation, evidenced in this group by the eye, nose, throat, and respiratory irritation symptoms reported; and narcosis (drowsiness, sleepiness) are prominent toxic effects of many of the solvents used in film winding.

All of the carboxyhemoglobin values from smokers were within the reference interval ("normal range") for smokers, but if the pre-shift mean is compared to the post-shift mean, there is a very slight trend toward increase over the work shift. For the non-smokers, each of the samples, except one, was higher than the upper limit of normal. The mean pre-shift COHb of the non-smokers was

slightly above the reference interval and rose 143% over the shift. To interpret these results appropriately, it is important to recall that the half-life of carboxyhemoglobin resulting from methylene chloride exposure is 10-12 hours. The pre- and post-shift carboxyhemoglobin samples were drawn on Wednesday, the third day of the working week for the film winders, and might reflect carboxyhemoblobin elevations that had accumulated for two days. If the carboxyhemoglobin levels had been drawn pre-shift on Monday, the non-smokers might have had a mean level less than 2.0%. The mean post-shift carboxyhemoglobin level (4.0%) is still below the NIOSH recommended limit of 5.0%. Also, if the carboxyhemoglobin levels had been drawn on Friday, the non-smokers might have had pre- and post-shift levels higher than those measured on Wednesday. This speculated range of carboxyhemoglobin elevations does not represent an immediate health risk, but is of concern because of the severity of the potential chronic adverse effects on the neurologic and cardiovascular systems from long-term low-level carboxyhemoglobin elevation.

The short term exposures measured for methylene chloride vapors were higher than expected, but exposure durations represented only a small portion of the total work shift period. Therefore, the rise in carboxyhemoglobin levels over the work shift supports our suspicion that film winders may have been getting substantial exposure to methylene chloride through skin absorption. This underscores the important role that careful work practices and personal hygiene can play in minimizing solvent exposures.

VIII. CONCLUSIONS

Based on the air sampling results, personal exposures to the mixture of solvent vapors detected in the Film Winding Department present a potential health risk to exposed workers. Although only one film winder was excessively exposed to solvent vapors, as determined by comparison to recommended exposure limits for preventing acute symptom effects (mucous membrane irritation or depression of the central nervous system), the potential for long-term, low-dose neurotoxic effects remains. NIOSH considers the PELs, RELs, and TLVs for the specific organic solvents found in the workplace as the upper boundaries of exposure and recommends that employers make every effort to keep exposure concentrations below these levels.[19]

All film winders monitored were exposed to dioxane, which NIOSH regards as a potential workplace carcinogen. Exposures to methylene chloride through inhalation of vapors during cleaning operations, and through direct skin contact, were also detected or observed. Because dioxane and methylene chloride exposures were found in the Film Winding Department, the NIOSH investigators must conclude that a health hazard exists for workers using solvents or solvent based adhesives containing these potential carcinogens.

No health hazard from exposures to TDI or MDI monomer were found from the use of adhesives containing polymeric TDI or MDI resins. Thermal breakdown of Teflon polymer films (Kapton F) was not detected and was not considered a health hazard under the conditions evaluated during this survey.

In the Labeling Department, cleaning of the conveyer belt with the special blend solvent did not overexpose workers to solvent vapors because the solvent was used less than 20 minutes during the work shift. Short term exposure limits were not exceeded.

IX. RECOMMENDATIONS

1. Management and union representatives should cooperate in monitoring worker complaints or acute symptoms which could serve as a measure of the effectiveness of progressively instituted improvements in engineering controls and work practices. The goal should be to ultimately eliminate acute adverse effects for workers in the Film Winding Department.

2. Local exhaust ventilation systems should be designed and installed for all film winding machines and glue stands to further reduce solvent vapor exposures. A more effective ventilation system is also needed in the adhesive mixing area.

3. Worker education programs should be instituted to inform workers about the hazards of exposure to organic solvents and to provide information on safe handling practices to minimize their exposures.

4. Direct skin contact with organic solvents should be prevented through the proper use of solvent-resistant gloves, aprons, boots, or entire work suits, depending on the nature and extent of the potential exposure hazard. Face shields or chemical safety goggles should be used wherever the potential for splashing exists. Any clothing that becomes contaminated with organic solvents should be removed and discarded or cleaned before reuse. Areas of the body that come in contact with organic solvents should be thoroughly washed with soap and water. Bathrooms, showers, and change rooms should provide for effective personal hygiene.

5. The use of solvents containing dioxane should be eliminated, since this is the only way to feasibly reduce exposures to below the 1 ppm, 30-minute exposure limit recommended by NIOSH.

6. Adhesive spills should be avoided to minimize the frequency with which solvents are used for cleanup. Because of the potential cancer risk, methlene chloride should not be used as a cleanup solvent.

X. REFERENCES

1. U.S. Dept. of Health and Human Services, Public Health Service, Centers for Disease Control (CDC). NIOSH recommendations for Occupational Safety and Health Standards, Morbidity and Mortality Weekly Report (MMWR), Supplement. July 19, 1985 Vol. 34/No. 1S.

2. American Conference of Governmental Industrial Hygienists (ACGIH). Threshold limit values for chemical substances in the work environment adopted by ACGIH with intended changes for 1986-87. Cincinnati, Ohio: ACGIH, 1986.

3. U.S. Dept. of Labor, Occupational Safety and Health Administration (OSHA). CFR Title 29, Part 1910--Occupational Safety and Health Standards, Subpart Z--Toxic and Hazardous Substances.

4. National Institute for Occupational Safety and Health. NIOSH/OSHA Occupational Health Guidelines for Chemical Hazards. Cincinnati, OH: National Institute for Occupational Safety and Health, 1981. DHHS (NIOSH) Publication No. 81-123.

5. Stewart RD, Dodd HC: Absorption of carbon tetrachloride, trichloroethylene, tetrachloroethylene, methylene chloride, and 1,1,1-trichloroethane through the human skin. Am Ind Hyg Assoc J 25:439-446, 1964.

6. Ratney RS, Wegman DH, Elkins HB: In vivo conversion of methylene chloride to carbon monoxide. Arch Environ Health 28:223-226, 1974

7. Putz VR, Johnson B, Setzer JA: A comparative study of the effects of carbon monoxide and methylene chloride on human performance. J Env Path and Tox 2:97-112, 1978.

8. Clayton GD, Clayton FE (ed): Patty's Industrial Hygiene and Toxicology. New York: John Wiley and Sons, 1981

9. DiVincenzo, GD and Kaplan, CJ. Effect of exercise or smoking on the uptake, metabolism, and excretion of methylene chloride vapor. Tox Appl Pharm, 59, 141 (1981b).

10. Stewart RD, Forster HV, Hake CL, Lebrun AJ, Peterson JE. Human responses to controlled exposures of methylene chloride vapor. Report No. NIOSH-MCOW-ENVM-MC-73-7. Milwaukee, Wis. The Medical College of Wisconsin, Dept of Environmental Medicine, December, 1973, 82 pp.

11. Barrowcliff DF, Knell AJ: Cerebral damage due to endogenous chronic carbon monoxide poisoning caused by exposure to methylene chloride. J Soc Occ Med 29:12-14, 1979.

12. National Institute for Occupational Safety and Health. Criteria for a recommended standard: occupational exposure to methylene chloride, Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1976. DHEW Publication No. (NIOSH) 76-138.

13. National Institute for Occupational Safety and Health. Current intelligence bulletin 46, methylene chloride. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1986. DHHS Publication No. (NIOSH) 86-114.

14. National Institute for Occupational Safety and Health. Criteria for a recommended standard--occupational exposure to dioxane. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1977. DHEW Publication No. (NIOSH) 77-226.

15. Hanninen H, Eskelinen L, Husman K, Nurminen M: Behavioral effects of long-term exposure to a mixture of organic solvents. Scan J Work Env Health 4:240-255, 1976.

16. Lindstrom K: Behavioral changes after long-term exposure to organic solvents and their mixtures. Scan J Work Env Health 7(Suppl 4):48-53, }il981.

17. Axelson O, et. al.: A case-referent study on neuropsychiatric disorders among workers exposed to solvents. Scan J Work Env Health 2: 14-20, 1976.

18. Flodin U, Edline C, Axelson O. Clinical studies of psychorganic syndromes among workers with expsoure to solvents. Am J Ind Med 5:287-295, 1984.

19. National Institute for Occupational Safety and Health. Current intelligence bulletin 48, Organic solvent neurotoxicity. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1987. DHHS Publication No. (NIOSH) 87-104.

XI. AUTHORSHIP AND ACKNOWLEDGMENTS

Evaluation Conducted and Report Prepared By:

Stanley A. Salisbury, CIH
Industrial Hygienist
NIOSH Regional Office
Atlanta, Georgia

Sara Arnold, M.D.
Medical Officer
Medical Section
Hazard Evaluation and Technical Assistance Branch
Cincinnati, Ohio

Environmental Survey Assistance:	Raymond Ruhe Industrial Hygienist Industrial Hygiene Section Hazard Evaluation and Technical Assistance Branch Cincinnati, Ohio
Laboratory Support	Staff Measurements Research Support Branch, NIOSH Cincinnati, Ohio
Originating Office:	Hazard Evaluations and Technical Assistance Branch Division of Surveillance, Hazard Evaluations, and Field Studies NIOSH Cincinnati, Ohio

XII. DISTRIBUTION AND AVAILABILITY

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 ninety (90) days the report will be available through the National Technical Information Service (NTIS), Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from the NIOSH Publications Office at the Cincinnati, Ohio address.

Copies of this report have been sent to:

1. Niemand Industries, Inc.
2. United Paperworkers International Union
3. UPIU, Local 919
4. U.S. Department of Labor, OSHA, Region IV
5. NIOSH Regional Office, Atlanta Region
6. Appropriate agencies of the State of North Carolina

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
AIR SAMPLING METHODS
HETA 87-108

NIEMAND INDUSTRIES
STATESVILLE, NORTH CAROLINA

SUBSTANCE	COLLECTION METHOD	FLOW RATE	NIOSH ANALYTICAL METHOD
Film Winding Department:			
Methyl ethyl ketone	Ambersorb tube	100 cc/min	PCAM 365
Toluene	Charcoal tube	100 cc/min	PCAM 127
Perchloroethylene	"	"	"
111-trichloroethane	"	"	"
Dioxane	"	"	"
Ethylacetate	"	"	"
Xylenes	"	"	"
Teflon decomposition products (as fluorides)	Alkali treated cellulose filter	2.5 Lpm	7902
Methylene chloride	charcoal tube	50 cc/min	S-318
MDI	Impregnated fiber glass filter	1 Lpm	PCAM 347
TDI	Coated glass wool	1 Lpm	PCAM 326
Labeling Department:			
Xylenes	Charcoal tube	200 cc/min	PCAM 127
Perchloroethylene	"	"	"
111-trichloroethane	"	"	"

cc/min = cubic centimeters of air per minute
Lpm = liters of air per minute

TABLE 2
SUMMARY OF EXPOSURE LIMITS* and HEALTH EFFECTS
for SUBSTANCES MEASURED

HETA 84-108
NIEMAND INDUSTRIES, INC.
STATESVILLE, NORTH CAROLINA

SUBSTANCE	OSHA PEL** (ppm)	ACGIH TLV*** (ppm)	NIOSH**** RECOMMENDATION (ppm)	HEALTH EFFECTS CONSIDERED	REFERENCE
Methyl ethyl ketone	200	200 300 STEL	200	Irritation; liver, kidney, and nervous system effects	1
Toluene	200 300 STEL 500 max	100 150 STEL	100 200 ceiling (10 minutes)	Central nervous system depressant	1
Perchloroethylene (tetrachloroethylene)	100 200 STEL 300 maxium	50 200 STEL	LFL	Nervous system, heart respiratory, and liver effects (suspect carcinogen)	1, 4
1,1,1-trichloroethane	350	350	350 ceiling (15 minutes)	Nervous system, liver, and heart effects	1
Dioxane	100	25 (100) STEL	1 ceiling (30 minutes)	Liver and kidney effects, suspect carcinogen	12
Ethyl Acetate	400	400	--	Respiratory and skin irritation, central nervous system depression	8
Xylene	100	100 150 STEL	100 200 ceiling (15 minutes)	Central nervous system depressant, respiratory irritation	1

TABLE 2 (Continued)

SUMMARY OF EXPOSURE LIMITS* and HEALTH EFFECTS
for SUBSTANCES MEASURED at NIEMAND INDUSTRIES

HETA 84-108

SUBSTANCE	OSHA PEL**	ACGIH TLV***	NIOSH**** RECOMMENDATION	HEALTH EFFECTS CONSIDERED	REFERENCE
Methylene chloride	500 1000 STEL 2000 maximum	100 (500) STEL	LFL	Central nervous system effects, carbon monoxide toxicity (suspect carcinogen)	11
Toluene diisocyanate (TDI)	0.02 ceiling	0.005 0.02 STEL	0.005 0.02 ceiling (20 minutes)	Respiratory sensitization	1
Methylenebisphenylisocyanate (MDI)	0.02 ceiling	0.02 ceiling	--	Respiratory sensitization	1

* Limits are 8-hour time-weighted averages (TWA) unless otherwise stated.
** For OSHA standards, see Reference No. 3
*** For ACGIH TLV's, see Reference No. 2
**** For NIOSH Recommended Limits, see Reference No. 1

ppm = parts per million parts of air
LFL = lowest feasible limit

TABLE 3
SOLVENT VAPOR EXPOSURES
HETA 84-108
NIEMAND INDUSTRIES
STATESVILLE, NORTH CAROLINA
Film Winding Department
June 26, 1984

Job Classification	Sample Duration Start	Stop	minutes	Sample Vol liters	Toluene ppm	Dioxane ppm	Perc ppm	Xylene ppm	111-T ppm	MEK ppm	Combined Exposure
Room # 1:											
Machine 02-20 not running											
Film Winder Mch. 02-21	0735	1649	554	55.4	4.55	10.78	0.24	1.42	1.80	51.10	0.76
Film Winder Mch. 03-18	0736	1540	484	48.4	4.14	9.49	0.19	1.18	1.53	52.81	0.70
Film Winder Mch. 02-07	0742	1544	482	48.2	5.34	11.03	0.28	1.67	2.88	67.86	0.86
Film Winder Mch. 02-04	0743	1534	471	47.1	3.61	9.78	0.26	1.51	1.62	60.20	0.75
Film Winder Mch. 02-11	0746	1538	472	47.2	4.29	10.55	0.24	1.59	2.53	50.55	0.74
Film Winder Mch. 02-09	0745	1537	472	47.2	2.78	7.26	0.19	1.20	1.44	52.01	0.60
Room # 2:											
Film Winder Mch. 03-14	0810	1147	217								
"	1254	1533	159	37.6	4.45	10.35	0.49	2.14	5.02	53.18	0.77
Machine 14-17 not running											
Film Winder Mch. 04-07	0749	1438	409	40.9	4.54	11.24	0.33	1.92	2.97	63.73	0.85
Machine 01-02 not running											
Room # 3:											
Film Winder Mch. 03-10	0750	1541	471	47.1	6.84	9.23	0.49	3.32	7.63	41.34	0.71
Film Winder Mch. 02-08	0755	1149	234								
"	1306	1645	219	45.3	6.45	7.97	1.06	4.42	11.65	26.74	0.61
Film Winder Mch. 02-16	0754	1138	224								
"	1303	1548	165	38.9	9.56	10.71	0.53	2.43	8.98	19.07	0.68
Film Winder Mch. 03-15	0800	1145	225								
"	1259	1547	168	39.3	8.79	9.19	0.74	3.32	8.48	46.78	0.76
Film Winder Mch. 03-01	0758	1142	224								
"	1304	1545	161	38.5	21.4	11.55	0.90	4.33	13.71	42.20	0.99
Film Winder Mch. 01-01	0712	1636	564	56.4	5.62	9.09	0.57	3.59	7.07	43.09	0.71
Mixing area and rooms 1,2, & 3:											
Film Winder & Mixer	0705	1547	522	52.2	5.07	14.44	0.38	2.25	3.62	69.26	1.02
Evaluation Criteria (exposure limits in ppm)					100	25	50	100	350	200	1.0

ACGIH Combined Exposure Formula

$$\frac{ppm}{100} + \frac{ppm}{25} + \frac{ppm}{50} + \frac{ppm}{100} + \frac{ppm}{350} + \frac{ppm}{200} = \text{Combined Exposure}$$

ppm = 8-hour time weighted average exposure in parts per million
Note - ethyl acetate was not detected in any of the samples

TABLE 3 (Continued)

SOLVENT VAPOR EXPOSURES
HETA 84-108

Film Winding Department
June 27, 1984

Job Classification	Sample Duration Start	Stop	minutes	Sample Vol liters	Toluene ppm	Dioxane ppm	Perc ppm	Xylene ppm	111-T ppm	MEK ppm	Combined Exposure
Room # 3:											
Film Winder Mch. 01-01	0710	1107	237								
"	1237	1507	150	38.7	4.98	9.62	0.84	3.69	9.62	46.00	0.75
Mixing area and rooms 1,2, & 3:											
Film Winder & Mixer	0709	1103	234								
"	1250	1505	135	36.9	4.30	11.43	0.58	2.52	5.79	58.82	0.93
Evaluation Criteria (exposure limits in ppm)					100	25	50	100	350	200	1.0
ACGIH Combined Exposure Formula					$\frac{ppm}{100} + \frac{ppm}{25} + \frac{ppm}{50} + \frac{ppm}{100} + \frac{ppm}{350} + \frac{ppm}{200} =$						Combined Exposure

ppm = 8-Hour time weighted average exposure in parts per million

Notes 1. Ethyl acetate was not detected in any of the samples

2. Other film winders were not sampled on this day

3. The exposure limit for dioxane (25 ppm), as used to evaluate the combined exposures to solvent vapors in the Film Winding Department does not account for the NIOSH recommendation that dioxane be considered a suspect carcinogen. NIOSH recommends exposures be reduced to the lowest level feasible, not to exceed 1 ppm during 30 minute sampling duration, the lowest level of detection by current sampling and analytical methods.

TABLE 4

METHYLENE CHLORIDE SHORT TERM EXPOSURES

HETA 84-108
NIEMAND INDUSTRIES
STATESVILLE, NORTH CAROLINA

Film Winding Department
June 26-27, 1984

Job Classification	Sample Duration Start-Stop	minutes	Sample Vol liters	Concentration ppm
June 26				
Film Winder-Cleanup	1532 - 1600	28	1.37	210.7
Film Winder-Cleanup	1532 - 1600	28	1.08	79.8
Film Winder-Cleanup	1632 - 1710	38	1.97	46.7
Film Winder-Cleanup	1635 - 1655	20	0.62	32.4
June 27				
Film Winder-Cleanup	1537 - 1554	17	0.15	308.7
Film Winder-Cleanup	1540 - 1553	13	0.80	82.7
Evaluation Criteria (ceiling limit)				500

Limit of Detection = 0.01 mg/sample or about 4 ppm for a 15-minute sample

ppm = average exposure in parts per million for the sampling duration

TABLE 6

SPECIAL BLEND SOLVENT EXPOSURE

HETA 84-108
NIEMAND INDUSTRIES
STATESVILLE, NORTH CAROLINA

Labeling Department
June 27, 1984

Sampling Locations Job Classification	Sample Duration Start	Stop	minutes	Sample Vol liters	Xylene ppm	Perc ppm	111-T ppm	Short Term Combined Exposure
Labeling Opr. Mch 205	1540	1556	16	3.20	79.29	20.25	16.09	0.77
Labeling Opr. Mch 212	1541	1554	13	2.60	83.39	21.53	17.68	0.81
Labeling Opr. Mch 213	1542	1557	15	3.00	27.68	6.38	15.32	0.28

TABLE 5

POLYTETRAFLUOROETHYLENE (TEFLON) DECOMPOSITION PRODUCTS
(as total fluorides)

FROM KAPTON F
HETA 84-108
NIEMAND INDUSTRIES
STATESVILLE, NORTH CAROLINA

Film Winding Department
June 26-27, 1984
Film Winding Machine 02-08

Job Classification	Start Stop	Sample Vol liters	Fluoride Conct mg/M^3
June 26:			
Film Winder Mch. 02-08	1350 - 1657	467.50	<0.01
Film Winder Mch. 03-10	1350 - 1554	310.00	<0.02
Mch 02-08 below mandrel	1350 - 1702	480.00	<0.01
Mch 02-08 above mandrel	1350 - 1702	480.00	0.05
Mch 02-08 at exhaust hood	1350 - 1702	480.00	<0.01
June 27:			
Film Winder Mch. 02-08	0735 - 1155		
"	1240 - 1455	987.50	<0.01
Film Winder Mch. 03-10	0805 - 1155		
"	1248 - 1455	892.50	<0.01
Mch 02-08 below mandrel	0735 - 1457	1105.00	<0.01
Mch 02-08 above mandrel	0740 - 1457	1092.50	<0.01
Evaluation Criteria			None*

Limit of Detection = 0.006 milligrams/sample or 0.01 milligrams per cubic meter of air sampled (mg/M^3) for gaseous and particulate fluoride

*Note Although no evaluation criteria has been established for polytetrafluoroethylene decomposition products, thermal decomposition of the fluorocarbon chain in air leads to the formation of oxidized products containing carbon, fluorine, and oxygen. Pending a determination of the toxicity of these decomposition products, no exposure limit is recommended. Exposures to these products are normally measured by sampling the air for fluorides. The exposure limit for fluorides is 2.5 mg/M^3, monitored as an 8-hour time weighted average.[2]

TABLE 7

WORK-RELATED ACUTE SYMPTOMS REPORTED BY FILM WINDERS

HETA 84-108
NIEMAND INDUSTRIES
STATESVILLE, NORTH CAROLINA

June 1984

Symptom	No. of Film Winders Reporting the Symptom	Percent of Total Group (16 people)
Drowsiness	11	69
Respiratory	10	63
Eye irritation	8	50
Nose irritation	7	44
Throat irritation	5	31
Headache	5	31
Dizziness	5	31
Dry skin	5	31
Nausea	5	31
Sinus congestion and/or pain	3	19

TABLE 8

CARBOXYHEMOGLOBIN (COHb) LEVELS

HETA 84-108
NIEMAND INDUSTRIES
STATESVILLE, NORHT CAROLINA

June 1984

	PERCENT (%) COHb	
	Pre-shift	Post-shift
Non-smokers (7 people)	2.0	4.0
	2.1	4.9
	2.3	3.1
	2.8	4.0
(Reference Interval:	3.0	clotted
0.5-2.0%)	3.3	2.7
	4.2	5.3
Mean:	2.8	4.0
Smokers (9 people)	2.9	3.8
	4.2	6.7
	4.7	7.0
	6.1	clotted
(Reference Interval:	6.4	clotted
less than 12%)	6.5	7.1
	7.1	5.3
	10.5	10.8
	clotted	6.6
Mean:	6.1	6.8

FIGURE 1
HETA 84-108