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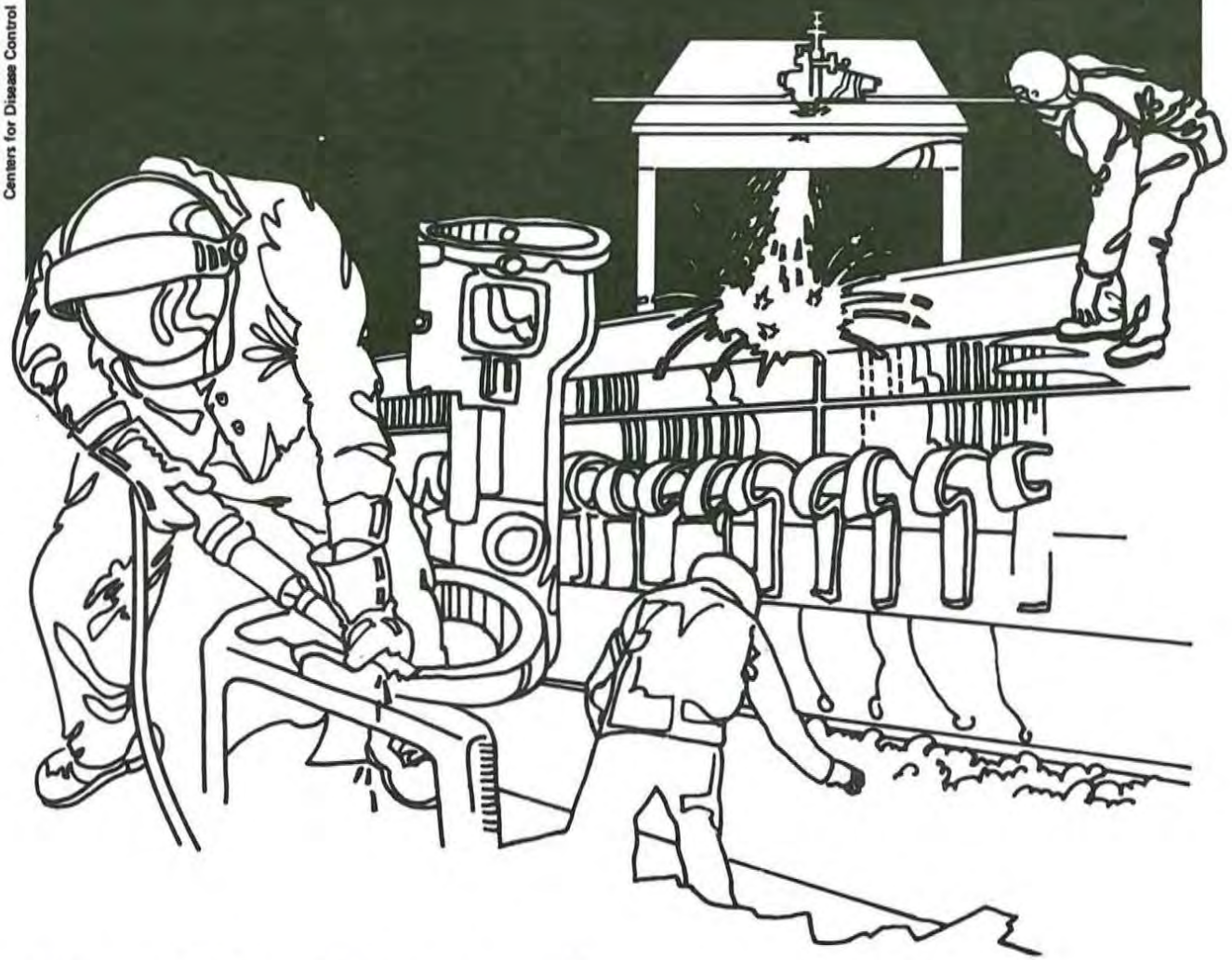
NIOSH



# Health Hazard Evaluation Report

HETA 81-409-1290
THE DONALDSON COMPANY, INC.
DIXON, ILLINOIS

## 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 81-409-1290
APRIL 1983
THE DONALDSON COMPANY, INC.
DIXON, ILLINOIS

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## I. SUMMARY

On August 3, 1981, the National Institute for Occupational Safety and Health (NIOSH) received a request from Teamsters Local Union 455 to evaluate reports of carpal tunnel syndrome (CTS) and of possible sensory polyneuropathy in employees of the Donaldson Co., Inc., Dixon, Illinois. NIOSH conducted an initial walk-through inspection of the plant on August 12-14, 1981. In January 1982, NIOSH conducted a detailed ergonomic evaluation, and in February, performed air sampling for perchloroethylene, vinyl chloride, and Freons.

NIOSH found no detectable vinyl chloride in a personal sample and 0.29 parts per million (ppm) in an area sample (NIOSH recommended 15-minute ceiling: 1 ppm). Air concentrations of individual Freons ranged from 4.2 to 7.4 ppm (OSHA standard: 1000 ppm). Three-hour time-weighted average air concentrations of perchloroethylene ranged from 12.6 to 75.2 ppm; 15-minute ceiling concentrations ranged from 14.2 to 103.1 ppm. (NIOSH recommends perchloroethylene exposure be as low as feasible since it is an animal carcinogen.)

A review of company medical records identified 18 physician-diagnosed cases of carpal tunnel syndrome between 1975 and 1980, of whom NIOSH was able to contact 15 (10 current and five former employees). Seven of the 15 (47%) had worked full- or part-time on the "Slim Vee" line when their symptoms began, a fact determined by Donaldson in its own evaluation in 1980 and which lead to administrative work practice changes directed at correcting the problem. In addition to those former cases, NIOSH identified an additional 15 persons with symptoms suggesting CTS in a medical survey of 92 of the 96 current employees. To better characterize this group, NIOSH sent a more detailed mail questionnaire in January 1982. Thirteen of 16 persons responded, and four of them reported continuing symptoms compatible with CTS symptoms. None of the four worked on the Slim Vee line. However, three of the four worked in departments (Metal Fab, Vent, Engine, and Continental) in which the NIOSH ergonomic evaluation had identified current work practices which might induce or contribute to CTS.

Six of the 97 current or former workers interviewed reported numbness or tingling in the feet. Four of the six had worked on or near the line (Slim Vee) on which large quantities of n-hexane-containing glue had been used until July 1980. In two of the four, the date of symptom onset and other historical information did not suggest an association with workplace exposure.

NIOSH identified work practices in several departments which might induce or exacerbate carpal tunnel syndrome. In addition, NIOSH found a potential health hazard from exposure to airborne perchloroethylene. Recommendations, including changes in work practices and tool design and reduction of exposure to perchloroethylene, are presented in Section VII of this report.

KEYWORDS: SIC 3714 (Motor Vehicle Parts and Accessories Manufacturing), carpal tunnel syndrome, ergonomics, sensory neuropathy, n-hexane, perchloroethylene, vinyl chloride, Freon.

## II. INTRODUCTION

On August 3, 1981, the National Institute for Occupational Safety and Health (NIOSH) received a request from Teamsters Local 455 to evaluate reports of carpal tunnel syndrome (CTS) in employees of the Donaldson Co., Inc., Dixon, Illinois. The request also noted possible cases of polyneuropathy occurring in one or more employees.

On August 12-14, 1981, two NIOSH physicians and an industrial hygienist visited the plant. After an opening conference with management and employee representatives, NIOSH representatives conducted an extensive walk-through inspection, observing all processes and jobs then being performed. Thereafter, the NIOSH physicians interviewed and examined all available personnel from the current seniority list. In January 1982, a NIOSH physician returned to the plant with an ergonomics consultant for a more comprehensive ergonomic evaluation. Following that visit, NIOSH conducted a mail questionnaire survey of persons identified during the August visit as "possible" cases of CTS. A NIOSH industrial hygienist obtained air samples in five departments on February 8-9, 1982. NIOSH sent reports of the investigation, including pertinent recommendations, to the company and union in November 1981 and April 1982 and to the study participants in June 1982.

## III. BACKGROUND

The Dixon plant of the Donaldson Co., Inc., manufactures air filters for a variety of engines and machines, including airplane, truck, railroad, and tank engines, and office machines. In the Metal Fabricating (Metal "Fab") department, the metal cases and supporting structures for the air filters are made. Workers feed metal coil into brake presses, operate the presses, place metal in a "wash" tank to remove cutting oil, and perform spot welding as needed. In the Pleating Operation, rolls of treated paper are heated, pleated, and cooled. Employees operate the machine and transport paper as needed. All other departments transform pleated paper into finished filters. These include Business Machines #1 and #2, Continental, XM1, Aircraft, Slim Vee, Engine, Vent, and Standard Vee. Employees mark, cut, and break paper, assemble filter cases, glue pleated paper filters into end covers with plastisol or contact cement, and place filters in ovens to "cure" plastisol if needed. They then clean the filter cases with a putty knife and solvent, which is most often perchloroethylene. Most of the work is fairly light but involves the use of fingers, hands, and wrists in diverse postures. Portable cooling fans are placed near many oven work stations, but local exhaust ventilation to remove solvent vapors from specific work stations is rare. Plastisol ovens in several departments are furnished with exhaust ventilation.

The plant has been in operation for 9 years. The hourly work force fluctuates in size with the volume of orders for filters, ranging between approximately 55 and 95 employees. According to the plant manager, turnover among the hourly workers is high, and about 200 workers had been hired in the year and a half preceding our visit. Although the hourly work force had consisted of only about 50 workers a year earlier, there were 96 employees on the most recent seniority list at the time of the NIOSH visit in August 1981. Table 1 shows the production departments, the usual number of shifts worked, and the number of employees in each.

In 1979, the plant managers became aware that several employees had reported persistent and recurrent pain, numbness, and tingling in one or both hands. Between 1978 and 1979, the carpal tunnel syndrome was diagnosed in 10 employees, eight of them in 1979. In February and March 1980, both Donaldson corporate safety staff and Donaldson's insurance company conducted surveys of the worksite, including an extensive ergonomic evaluation. A number of recommendations were made, including altered work practices and tool design, the institution of light-work duty, and the replacement of females with male workers on the line on which the heaviest filters were made (Slim Vee) and from which seven of the cases of CTS came.

The issue of polyneuropathy was less clearly defined. According to a union representative, an employee whose symptoms were diagnosed as CTS in 1979 subsequently developed numbness and pain in both feet and was diagnosed in 1981 as having a sensory polyneuropathy. Another worker reportedly also had symptoms compatible with a sensory polyneuropathy. n-hexane-containing cements had been used at the plant between about 1974 and 1980, according to the plant production engineer and manager. Used at the rate of 150-250 gallons per week on the Slim Vee line until July 1980, one cement contained 17% hexane and 9% methyl ethyl ketone (MEK). Another cement containing similar proportions of n-hexane and MEK was used on the Slim Vee line at the rate of 55 gallons per month until July 1980. Other hexane-containing cements are still used in small quantities (10 gallons per year) on the Standard Vee and Aircraft lines. Donaldson's industrial hygiene surveys done between 1975 and 1978, most of which consisted of area sampling, found n-hexane in the range of 5 to 35 ppm (this latter value was the only personal sample for n-hexane), which are all below NIOSH's recommended exposure limit of 100 ppm (time-weighted average over a 10-hour day). Because n-hexane is a known neurotoxin, an employee raised the question of whether the case or cases of neuropathy at the plant bore some relation to hexane exposure.

## IV. METHODS

### A. Environmental

NIOSH conducted an environmental evaluation February 8-9, 1982, in five departments to determine employee exposures to substances used in specific operations. Personal breathing zone samples and area samples near the various work stations were collected to assess airborne concentrations of (1) perchloroethylene, used in all of the departments for dampening rags with the solvent and hand cleaning excess resins and adhesives from metal parts; (2) Freon 11 (a diluent) and Freon 12 (a propellant for a silicone mold release), used in the Continental Department; and (3) vinyl chloride, present in relatively small amounts in vinyl chloride resin, a major component of a plastisol used in the Slim Vee Department.

Samples were collected using battery-powered sampling pumps operating at either 50, 100 or 200 cubic centimeters of air per minute (cc/min) attached via Tygon tubing to charcoal tubes, which served as the collection media. These samples were analyzed using NIOSH methods S-335 for perchloroethylene (1), S-102 for Freon (2), and 178 for vinyl chloride (3).

### B. Medical

During the August 1981 visit, NIOSH medical officers reviewed plant records, noting individuals identified by company insurance records as having CTS. After the records review, we systematically interviewed and examined all available persons among the 96 hourly workers then on the most recent seniority list, including, when possible, those persons on leave (there were two on leave for CTS). One former employee came in and was interviewed during this period. The interviews included a medical questionnaire inquiring about neuropathic symptoms (pain, numbness, tingling, decreased grip, awkwardness or decreased coordination in extremities), night pain in the hands, pregnancy, thyroid disease, diabetes, and whether the individual had been told by a physician that s/he had CTS and whether s/he had undergone surgery for it. We also collected demographic and detailed job history information. The neurological examination included an assessment of gait, station, coordination, strength, sensation in upper and lower extremities, and brachioradialis, biceps, patellar, and Achilles tendon reflexes.

We also mailed questionnaires to the six persons on the seniority list who could not be interviewed and to six persons no longer on the seniority list but who were reported to have had CTS or related symptoms. Finally, we requested copies of medical records on all persons who reported seeing a physician for their hand or foot symptoms.

As a result of the August survey, a number of physician-diagnosed cases of CTS were identified, as were a group of employees designated as "possible" cases on the basis of symptoms. In January 1982, we sent follow-up questionnaires to the 16 persons identified as "possible" cases of CTS. While it was clear that there had been a high prevalence of CTS at the plant, we wished to determine whether new cases were occurring. In the follow-up mail questionnaire survey, we tried to determine whether the "possible" cases were continuing to have symptoms, and to attempt to determine whether those symptoms were likely to be due to carpal tunnel syndrome.

C. Ergonomic

During the January 1982 visit to the Donaldson plant, walk-through ergonomic analyses were performed in the following departments: Metal Fabricating, Continental, Business #1, Engine, Vent, and Slim Vee. Analyses were not performed in the Aircraft department because it was not operating at the time of the visit, or in the XM-1 department because of the long cycle time required to produce a single filter. The purpose of the ergonomic analyses was to identify deficiencies in equipment, tools, and/or work methods which could contribute to the development of carpal tunnel syndrome.

The following basic procedure was used in each department:

1. Management personnel were asked to identify each work station in the department and to give a brief explanation of the task(s) performed at that location.

2. A list was developed of major tasks performed at each work station. In addition, all handtools (manual and power) used at the location were examined.

3. Each task was observed for several cycles. During the observation, special attention was given to the posture of the shoulders, elbows, wrist, and hands, and to the forces exerted by the hands. Photographs were taken to document work postures.

4. Based on the above observations, tasks that required the use of postures associated with increased risk of developing carpal tunnel syndrome were identified.

5. Recommendations were developed to modify certain tasks or to reduce the risk of carpal tunnel syndrome.

## V. EVALUATION CRITERIA

A. Current Potential Exposures: perchloroethylene, Freons, and vinyl chloride monomer.

The environmental criteria described in this section are those airborne concentrations of substances to which workers may be exposed for eight or 10 hours a day, 40 hours per week, for a working lifetime without adverse health effects. Because of wide variation in individual susceptibility, a small percentage of workers may experience discomfort from some substances at concentrations at or below the recommeded criteria. A smaller percentage may be more seriously affected by aggravation of a pre-existing condition or by a hypersensitivity reaction. The time-weighted average (TWA) exposure refers to the average concentration during a normal 8-hour workday. The Short-Term Exposure Limit (STEL) is the maximum allowable concentration, or ceiling, to which workers can be exposed during a period of up to 15 minutes, provided that no more than four excursions per day are permitted, with at least 60 minutes between exposure periods. The STEL should be considered a maximal allowable concentration, or ceiling, not to be exceeded at any time during the 15-minute excursion period, unless otherwise specified (4).

The primary sources of environmental evaluation criteria considered for this study were: (1) NIOSH documents and recommendations, and (2) U.S. Department of Labor (OSHA) Federal occupational health standards (5).

1. Perchloroethylene

Clinical evidence accumulated over the years clearly demonstrates that perchloroethylene is toxic to the liver and kidneys in humans. Liver impairment has been noted in cases of exposure to perchloroethylene, as evidenced by abnormal liver function tests. Also, toxic chemical hepatitis, and enlargement of the liver and spleen have been associated with exposure to high concentrations of perchloroethylene. Perchloroethylene vapor is irritating to the eyes and upper respiratory tract, and may cause nasal congestion and headache. Direct contact with skin can cause burns, blistering, and erythema due to the "degreasing" effect of perchloroethylene on the skin. Over a period of time this can result in extreme skin dryness.

Altered physiological and behavioral responses observed in people exposed to high levels of perchloroethylene include nonspecific complaints generally attributed to central nervous system (CNS) depression. These symptoms include vertigo, impaired memory, confusion, fatigue, drowsiness, irritability, loss of appetite, nausea and vomiting. Motor coordination following excessive perchloroethylene exposure requires additional mental effort which, along with memory impairment and fatigue, have important implications for worker safety. Rare reports of tremors and numbness have been attributed to high-level exposure to perchloroethylene. Excessive absorption of perchloroethylene can cause severe depression of the CNS, leading to coma.

Perchloroethylene is most commonly absorbed through the lungs and can be absorbed from the intestines if ingested. The skin is a less important absorption site. Physical exercise can significantly increase the amount of perchloroethylene absorbed through the lungs because of greater respiration and increased blood flow.

Metabolism and elimination of perchloroethylene is relatively slow. It is deposited in body fat, and the biologic halflife of perchloroethylene in man is estimated at six days (6).

The current OSHA standard for perchloroethylene is 100 ppm for an eight-hour TWA. The acceptable ceiling concentration is 200 ppm for no period greater than five minutes in any three hours, with concentrations above the ceiling limit not to exceed 300 ppm. To prevent the then known toxic effects of perchloroethylene, NIOSH originally recommended a standard for occupational exposure of 50 parts per million (ppm) for a 10-hour day, with a ceiling concentration of 100 ppm as determined by a 15-minute sampling period. Because a subsequent study by the National Cancer Institute found perchloroethylene to cause liver cancer in laboratory mice, NIOSH now recommends that perchloroethylene be treated in the workplace as if it were a human carcinogen; i.e., exposure should be as low as feasible.

2. Freon 11 (Fluorotrichloromethane)
   Freon 12 (Dichlorodifluoromethane)

   Mild central nervous system depression may occur in cases of exposure to very high concentrations of fluorocarbons. Symptoms from acute high level exposure may manifest themselves in occasional tremor and incoordination. It has been reported that dizziness has resulted from an exposure to 5% dichlorodifluoromethane and unconsciousness from exposure to 15%. Typically, fluorocarbons have very low levels of toxicity, and their predominant hazard is from simple asphyxia (7). These compounds may produce mild irritation to the upper respiratory tract. Dermatitis occurs only rarely. Decomposition products may also be the cause of these effects. The OSHA standards for these fluorocarbons are 1000 ppm for an eight-hour TWA.

3. Vinyl Chloride

   Vinyl chloride in high concentrations depresses the central nervous system, causing symptoms which resemble mild alcohol intoxication. Lightheadedness, some nausea, and dulling of visual and auditory responses may develop in acute exposures. Death from severe vinyl chloride exposure has been reported. Vinyl chloride has been identified as a causal agent of angiosarcoma of the liver. Excess cancer of the lung and the lymphatic and nervous systems has also been reported. Experi-

mental evidence of tumor induction in a variety of organs, including liver, lung, brain, and kidney, as well as nonmalignant alterations such as fibrosis and connective tissue deterioration, indicate the multisystem oncogenic and toxicologic effects of vinyl chloride (7).

Vinyl chloride is regulated by OSHA as a demonstrated carcinogen in humans. The OSHA standard for exposure to vinyl chloride is 1 ppm over an 8-hour period, and a ceiling of 5 ppm averaged over any period not exceeding 15 minutes. NIOSH recommends that occupational exposure be reduced to the lowest possible level, not to exceed 1 ppm averaged over any 15 minute sampling period.

B. The Carpal Tunnel Syndrome

The carpal tunnel syndrome (CTS) occurs when the end portion of the median nerve, which supplies strength to the thumb and sensation to most of the palmar surface of the hand, becomes compressed within the narrow channel inside the wrist known as the carpal tunnel (8,9). In addition to the median nerve, the finger flexor tendons and the lubricating sheath surrounding them must pass through this small "tunnel".

In its fully-developed form, CTS has a fairly characteristic pattern of symptoms: tingling, numbness, and pain occur in the distribution of the median nerve, and affected persons are often awakened at night with aching and numbness in the hand. Aching in the forearm and shoulder have also been reported frequently in conjunction with numbness and tingling in the hand (10). CTS is often bilateral (11) and may progress to overt loss of sensation and strength in the affected hand and thumb. Since the advent of nerve conduction tests, slowing of the conduction time of the median nerve across the carpal tunnel has usually been used as a diagnostic criterion by many physicians.

CTS is reported to occur from three to 10 times as often in women as in men, and it may be associated with a host of other diseases and conditions. Some of these predisposing states--including wrist fracture, arthritis, cysts, and acromegaly--can be explained on a purely mechanical basis since, as the tunnel becomes smaller or the contents become larger, compression of the tunnel contents occurs. Other related disease states or conditions, including diabetes, hypothyroidism, dialysis, pregnancy, oral contraceptive use, menopause, and perhaps Vitamin B6 deficiency, appear to predispose individuals to the development of CTS through complex nutritional, vascular, and biochemical, as well as anatomical factors (13-19).

Although CTS is associated with a variety of predisposing disease states and other conditions, it has also been linked prominently to ergonomic factors. There have been several important biomechanical experiments, particularly those by Tanzer and by Smith, which

demonstrated pressure increases within the carpal tunnel when both the wrist and the fingers are flexed (20,21). In several case series--notably those of Tanzer, Hybbinette and Mannerfelt, Birkbeck and Beer, and Gainer and Nugent--the authors noted that occupations "involving considerable use of the hands" appeared to predispose individuals to carpal tunnel syndrome (20,22-24). Examples among Tanzer's patients included persons who performed milking, ladling, and spray painting with the index finger and middle fingers compressing a trigger. In a medical record review of 250 consecutive cases of CTS, Reinstein demonstrated that the dominant hand is affected more often and more severely, suggesting that more frequent and more intense hand use plays a role in the development of CTS (25). In two workplace case control studies, by Armstrong and Chaffin and by Cannon, Bernacki, and Walter (12,26), ergonomic factors were among identified risk factors. These included frequent deviation from neutral wrist position, frequent use of the "pinch" grasping hand position, and repetitive wrist and hand movements. Gynecologic surgery with oophorectomy was also a risk factor. Despite limitations in these studies, they provide suggestive and supporting evidence for ergonomic (as well as hormonal) risk factors. Although CTS is by no means a purely and specifically "occupational" disease, there is little question that hand and tool usage, alone or in combination with other factors, may lead to the development of a compression neuropathy of the median nerve. While the precise mechanism whereby hand use results in CTS is not known, proposed mechanisms include (1) repetitive increases in the intra-tunnel pressure, with consequent trauma to the nerve directly; (2) activity levels which exceed the lubricating capacity of the flexor sheath, resulting in friction, mild inflammation of the flexor sheath, and swelling, with secondary compression of the nerve; or (3) some combination of the two.

C. Possible past exposures: N-hexane

N-hexane has been identified as a cause of peripheral neuropathy since the 1960's, when a group of Japanese workers exposed to n-hexane developed sensorimotor neuropathy (27). Additional outbreaks of neuropathy from hexane exposure, from exposure to compounds (methyl n-butyl betone) with common neurotoxic metabolites, and from hexane combined with methyl ethyl ketone (which has been shown to enhance the neurotoxic effects of n-hexane) have since been reported (28-31). Depending on the severity of exposure, workers have experienced problems ranging from mild sensory symptoms to profound weakness, usually most prominent first in the lower extremities and then, with continued exposure, progressing to the upper extremities. In those reports with follow-up information, milder cases of sensory neuropathy had the earliest and most complete recovery after cessation of exposure, while the more severe cases had slower, and in some cases only partial, recovery (32).

The OSHA standard for n-hexane is an 8-hour TWA of 500 ppm. NIOSH recommends an exposure limit of 100 ppm, with a 15-minute ceiling of 200 ppm. However, a recent study by Sanagi, et al, found that limb dysesthesias were significantly increased and that some nerve conduction parameters and clinical functional parameters (vibration sense, jumping on one foot) were significantly decreased in workers exposed to average air levels of 58 ppm, when compared with an unexposed group (33). The authors note that there was also exposure to acetone, whose effect is unknown.

## V. RESULTS

### A. Environmental

Employee exposures to Freon (Table 2) in the Continental Department and vinyl chloride in the Slim Vee Department (Table 3) were below the environmental criteria used for this study. Personal sample concentrations were 4.2 and 5.8 ppm for Freon 11, and 4.3 and 7.4 ppm for Freon 12, during the period sampled. No vinyl chloride was detected in one personal sample (limit of detection of 0.001 milligrams per sample), and a concentration of 0.29 ppm was found on an area sample taken directly adjacent to an "automated" plastisol dispensing machine.

Short-term environmental samples showed ceiling concentrations of perchloroethylene in the XM-1 Department of 14.2 ppm to 103 ppm. (Table 4). Three-hour TWA concentrations for perchloroethylene ranged from 12.6 ppm in the XM-1 Department to 76.2 ppm in the Ventilation Department. Other samples for perchloroethylene were collected in the Continental (21.5 ppm) and Engine (22.5 ppm) Departments. Due to administrative controls (work rotation), the TWA values represent a work cycle, rather than a workday, but observation of work practices, as well as high short term concentrations, indicate the potential for other employee exposures.

### B. Medical

#### 1. Carpal tunnel syndrome

For epidemiologic purposes, we defined a case of CTS as a Donaldson employee for whom company insurance records showed a diagnosis of carpal tunnel syndrome, or as one who answered yes to the question on the NIOSH questionnaire, "Since you came to work at Donaldson, has a physician told you that you have carpal tunnel syndrome?" (Diagnostic criteria vary among physicians in the community, of course, but as a crude prevalence estimator we judged this to be as valid as a definition based solely on questionnaire data.)

Through our review of the plant medical records, including the OSHA Log of Injuries and Illness (Form 200) from 1978 to 1980, and the NIOSH questionnaire and interview survey in August, we

identified 18 confirmed cases of CTS, of whom we were able to contact 15. The NIOSH medical survey included 97 current or former employees: we interviewed and examined 90 of 96 employees (94%) on the current seniority list and one former employee, and received mail questionnaires from two of the six not interviewed in person and from four former employees.

In addition to the above cases of CTS, we identified 16 "possible" cases. Possible cases were defined as employees who reported numbness, tingling, or pain in one or both hands since coming to work at Donaldson but who had not been told by a physician that they had CTS. To define more precisely the nature of the symptoms, their distribution, frequency, and duration, we sent follow-up mail questionnaires to those 16 "possible" cases in January 1982. Thirteen of the 16 persons (81%) returned the questionnaire. Based on symptom distribution, frequency, and duration, NIOSH estimated that four of the 13 had symptoms consistent with early carpal tunnel syndrome (one of them had since seen a physician, who diagnosed CTS). Of the remaining nine, two persons no longer had symptoms; four persons had seen a physician and been diagnosed as having ulnar nerve dislocation, tendonitis, or ganglion, but not CTS; and three persons had symptoms in such a distribution or of such infrequency and brevity that persistent median nerve compression seemed unlikely.

Of the original 15 interviewed cases of CTS, five (33%) worked full time, and two (13%) part time on the Slim Vee line at the time of their symptom onset. Other cases worked on Engine (2), Vent (1), Metal Fab (1), Fork Lift(1), Metal Fab/Fork Lift (1), or Continental (1). None of the four cases which NIOSH thought were likely to have CTS from among "possible" cases worked on the Slim Vee line at the time their symptoms began: two worked in Engine, one in Metal Fab, and one in Aircraft/Business #1.

Demographic characterization of the 19 diagnosed or possible cases of CTS on whom we were able to collect such information reveals certain differences between cases and non-cases. Cases were all female, all White, with a mean age of 33 years and a range of 21 to 51 years. Seventy-eight non-cases, by contrast, were 52% male. They were similar in age and were largely White, with two Blacks and two Hispanics in the group. In addition to predictable differences in the rate at which carpal tunnel syndrome afflicts men and women, the ratio of males to females in the non-case group was amplified because the Donaldson Co. hired increased numbers of men after the spring of 1980. None of the case group had hypothyroidism, diabetes, or was pregnant at the time of symptom onset. Although we did not directly inquire whether women were menopausal, five of 19 cases were older than 45, compared with four of 37 non-cases. This difference was not statistically significant ($p > 0.10$,

Fisher's exact test, 1-tailed). Regardless of the statistical significance level, the greater prevalence of older-age women in the case group merely supports the notion that menopausal women may be predisposed to the development of the syndrome.

2. Sensory Polyneuropathy

Of the 97 persons interviewed, six (6.1%) reported symptoms compatible with a sensory disturbance of the peripheral nerves, i.e., numbness, tingling, and in some cases pain, in the hands and feet. One of them reported numbness in the feet alone. The other five were all diagnosed (4) or possible (1) cases of CTS as designated by the August survey. Because the presence of CTS is a potentially confusing factor, this description focuses on the development of symptoms in the feet.

Four of the six affected persons worked full- or part-time on the Slim Vee line. Two of the Slim Vee line workers appear to have developed their symptoms prior to July 1980. Both of them have since stopped working at the plant, and both have reported a marked improvement in their sensory symptoms. (Neither of these individuals was interviewed in person by NIOSH). Of the remaining two affected persons who worked on and near the Slim Vee line, one ceased work six months prior to the onset of lower extremity symptoms, and there is contradictory information about the other's medical history. A fifth employee, who worked on Engine line, developed symptoms in January 1980 and did not return the NIOSH follow-up questionnaire sent to "possible" cases of CTS in January 1982. The sixth person, with symptoms in the lower extremities only, worked in Metal Fab.

C. Ergonomic

1. Metal Fabricating Department

Two employees were observed in the metal forming department operating blanking presses to shape the sheet metal used for filter frames. Both employees used vacuum-removal hand tools to lift metal parts after the press has completed its power stroke. This activity could be a contributing factor in the development of carpal tunnel syndrome (CTS) because of:

a. The high frequency of this task (approximately 12 cycles per minute during the observation);

b. The ulnar deviation of the wrist while using the vacuum-removal tool;

c. The relatively large momentum created at the wrist due to the length of the handle of the vacuum-removal tool and the weight of the stamped metal part.

2. Continental Line

   The molding machine operator was the only position on the Continental Line associated with ergonomic stresses which could either cause or aggravate CTS. Specific problems observed on the job were:

   a. The use of an aerosol can to apply mold release compound. The design of this operation required the operator to hold the can with a bent wrist while pressing down on the spray head for a significant portion of the job cycle.

   b. The use of the needle-nose pliers to separate the molds and to remove excess molded material. This resulted in a pronounced ulnar deviation of the wrist while performing this operation.

3. Business Line

   Observation of operations of the Business Line did not reveal any activities that would be significant factors in the development of carpal tunnel syndrome.*

4. Vent Line

   The Vent Line was observed to contain one operation which could be a contributing factor in the development of CTS. Forceful exertions with deviated wrist postures occurred while cleaning excess plastisol from the filter housings with a putty knife.

5. Engine Line

   The following operations on the Engine Line could be contributing factors in the development of CTS:

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*The Business Line was not, however, entirely free from ergonomic problems. The hand-cutting operation (used to separate filter elements) required employees to assume an extended forward reach to initiate the cut. Repetitive motions of this nature could potentially cause musculoskeletal disorders of the back and shoulders.

a. Plastisol Application - Plastisol was applied to filter housings using a pneumatic-type "gun". To perform this operation, it was necessary for the employee to exert a continuous gripping force against a handle trigger while maneuvering the "gun" back and forth above the filter housings. This motion resulted in periodic radial and ulnar deviations of the wrist.

b. Cleaning Filter Housing Prior to Gasket Application - Prior to applying a gasket to the filter housing, it was necessary for employees to remove excess plastisol by mechanical rubbing. This activity required workers to exert relatively high hand forces with deviated wrist postures (extension, ulnar and radial deviations).

## VI. DISCUSSION

The major issue of concern to NIOSH was whether new cases of CTS were occurring at the Donaldson plant, and if they were occurring, whether they appeared to be related to any particular department(s). Before NIOSH began its investigation, a large number of cases of carpal tunnel were diagnosed in 1979, and five of the eight with symptom onset and diagnosis in that year worked on the Slim Vee line. This preponderance of cases in one department was noted by Donaldson's own investigators, and remedial measures were directed largely at that line as a result of the company's March 1980 investigation.

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*A non-CTS ergonomic problem was also observed on the Engine line. The stenciling operation (i.e., painting the words "THIS SIDE IN") required the employees to assume stooped postures when working on a filter element located near the bottom of the pallet. This type of working posture has been associated with the development of low-back pain. A system to deliver filters at a consistent, comfortable height for stenciling (e.g., something similar to spring-operated tray servers often seen in cafeterias) could reduct the ergonomic stresses associated with this operation.

In the group of "possible" cases identified by NIOSH in August 1981, by contrast, only two worked full- or part-time on the Slim Vee line. In fact, in the group of 13 "possible" cases who returned NIOSH's follow-up questionnaire, their work departments and the date of symptom onset were quite different from the original cases: only two of the 13 had symptom onset in 1979, and neither of these appeared likely to have CTS. Six of the 13 worked in the Engine Department (or Engine Pleater), three in Metal Fab, two in Aircraft/Business and Aircraft/ Slim Vee, one in Business, and one in Vent/Sim Vee. Although NIOSH felt that only four of that group were likely to represent cases of persistent or frequently recurring compression of the median nerve, nine of the 13 (69%) in the overall group, and three of four (75%) in the probable-CTS group came from Engine and Metal Fab, two of the departments in which we identified jobs which might contribute to or cause the carpal tunnel syndrome or other ergonomic difficulties. As was true in the original "outbreak" of cases associated with the Slim Vee line, the NIOSH-identified cases have occurred in departments where significant ergonomic stresses were identified. Thus, we felt that new cases appeared to be occurring, with less frequency than in the past, and with a fairly clear relationship to certain work areas.

The etiology(ies) of possible cases of polyneuropathy remains speculative. None of the six affected persons was diabetic or gave a history of heavy alcohol intake. Because n-hexane and MEK in combination have not been used in large quantity at the plant since July 1980, it is not possible for NIOSH to measure or to assess quantititatively past exposures to these compounds. Area and air sampling for n-hexane done by the company between 1975 and 1978 found levels of between 5 and 35 ppm. Although these levels have not been documented to cause neuropathy, experimental toxicological and clinical observations point to the synergistic effects of MEK and hexane. Thus, we cannot dismiss the possibility that workers on or near the Slim Vee line were exposed to air levels of MEK and n-hexane of sufficient intensity to induce a mild sensory neuropathy. That two former employees who worked on that line appear to have developed their symptoms before July 1980 is suggestive evidence, and that those workers appear to have largely improved is entirely compatible with the known course of mild hexane neuropathy. We have no apparent occupational explanation for the symptoms in three other workers, and contradictory medical information on a fourth does not allow NIOSH to comment with any assurance.

Finally, the relationship between cases of CTS on the Slim Vee line and possible exposures to MEK and n-hexane remains moot. Solvent exposure has not been reported to be a contributing cause of CTS, and it seems likely that sufficient ergonomic stress existed on the Slim Vee line prior to Donaldson's interventions (beginning in the spring of 1980) to explain the high prevalence of CTS there solely on an ergonomic basis. However, if exposures to n-hexane in combination with MEK were sufficiently high to compromise the peripheral nerves at what would in

other circumstances have been a "subclinical" level, it is possible that CTS was made manifest at higher rates or in more employees because of the underlying effect of the hexane cement. We recognize that there is no way to prove or disprove this speculation since the company ceased using the hexane-containing cement on the Slim Vee line within a few months of the time it also instituted ergonomic and work practice changes recommended by its own investigation of the carpal tunnel problem.

## VII. RECOMMENDATIONS

1. NIOSH recommends, as it has already done in April 1982 in a letter to the Donaldson Co., that the company implement several ergonomic changes in an effort to reduce hand, arm, and back stresses, which presumably contribute to the occurrence of CTS.

   a. Metal Fabricating

      There are several approaches which might be used to reduce the ergonomic stresses associated with the use of the vacuum-removal hand tools to lift metal parts out of the press:

      (1) The installation of an automatic ejection system on the blanking press to eliminate the need for the vacuum tool;

      (2) Bending the handle of the vacuum-removal tool to reduce the ulnar deviation of the wrist; or

      (3) Reducing the length of the vacuum removal tool to reduce the effective moment about the wrist.

   b. Continental

      The mold release spraying operation may be altered in the following ways to reduce ergonomic stress:

      (1) Automation and enclosure of the mold release spraying operation, and

      (2) Substitution of bent-handled pliers to eliminate ulnar deviation during the separating and cleaning operations.

c. Vent Line

The preferred way of minimizing hand and wrist strain when employees clean excess plastisol from filter cases would be to modify the operation to reduce the amount of excess plastisol remaining on the filter housing. In addition, replacing the existing putty knife with a model that has a larger diameter handle could reduce the level of hand and wrist stresses occurring during the cleaning operation.

d. Engine Line

A possible solution to the problem of the pneumatic gun used on Engine Line to dispense plastisol would be to replace the existing applicator "gun" with a model which incorporates a vertical trigger. This would reduce the frequency and severity of the wrist deviation.

A suggested solution to the problem of cleaning excess plastisol from filter cases with a putty knife and rubbing is better control of the plastisol application process to minimize the excess which must be cleaned from the filter housing.

The relatively large number of employees on the Engine line allows rotation among the various work stations. This reduces the amount of time that an employee is required to perform those tasks which could cause or aggravate CTS. In addition to the controls discussed above, the company should continue to encourage job rotation on the Engine Line.

2. Although there is no evidence that Donaldson employees were exposed to n-hexane levels exceeding either the NIOSH recommended exposure limit or the OSHA PEL, we suggest that the company continue its present substitution of other cements for the large volume of n-hexane and MEK-containing cement used in large quantities on the Slim Vee line until July 1980.

3. Scrupulous efforts should be made to reduce employee exposures to perchloroethylene through a combination of decreased use, improved work and personal hygiene practices, and engineering controls (i.e., local exhaust ventilation).

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1. Donaldson Company, Inc.
2. Teamsters Local 455
3. NIOSH, Region V
4. OSHA, Region V

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

DONALDSON COMPANY
DIXON, ILLINOIS

| | DEPARTMENT | NO. WORKERS/SHIFT | NO. SHIFTS |
|---|---|---|---|
| 1) | Pleater | 3 | 1 |
| 2) | Business machines (office) | | |
| | #1 | 3 | 1 |
| | #2 | 2 | 1 |
| 3) | Aircraft | 4-6 | 1 |
| 4) | XM1 (in operation about 50% of year) | 2 | 1 |
| 5) | Continental (in operation about 30-50% of year) | 2 | 1 |
| 6) | Slim Vee | | |
| | until July 1980 | 8 | 2 |
| | After July 1980 | 6 | 2 |
| 7) | Ventilation | 6-9 | 1+ |
| 8) | Engine | 8-9 | 2 |
| | Plastisol ribbon bonder | 1 | 3 |
| 9) | Standard Vee (in operation 50% of year) | 2 | 1 |

TABLE 2

RESULTS OF ENVIRONMENTAL SAMPLES COLLECTED FOR FREON®
CONTINENTAL DEPARTMENT (2/9/82)

| Sample Type/ Location | Sample Duration (Minutes) | Sample Volume (Liters) | Freon 11 Concentration (ppm)* | Freon 12 Concentration (ppm) |
|---|---|---|---|---|
| Personal/Assembler | 186 | 9.3 | 4.2 | 4.3 |
| Personal/Assembler | 144 | 14.4 | 5.8 | 7.4 |
| OSHA standard (8-hour time-weighted average) | | | 1000 | 1000 |

* ppm = parts of contaminant per million parts of air

TABLE 3

RESULTS OF ENVIRONMENTAL SAMPLES COLLECTED FOR VINYL CHLORIDE
SLIM VEE DEPARTMENT (2/8/82)

| Sample Type/ Location | Sample Duration (Minutes) | Sample Volume (Liters) | Vinyl Chloride Concentration (ppm)[1] |
|---|---|---|---|
| Personal/Assembler (First end-cap) | 101 | 5.0 | ND[2] |
| Area/First end-cap (Plastisol applicator) | 101 | 20.0 | 0.29 |

| | |
|---|---|
| OSHA standard: 8-hour time-weighted average | 1 |
| 15-minute ceiling | 5 |
| NIOSH recommended standard (15-minute ceiling) | 1 |

1. ppm = parts of contaminant per million parts of air
2. ND = not detectable; detection limit for vinyl chloride = 0.001 mg/sample

TABLE 4

RESULTS OF ENVIRONMENTAL SAMPLES COLLECTED FOR PERCHLOROETHYLENE
(2/9/82)

| Personal Samples Department/ Location | Sample Duration (Minutes) | Sample Volume (Liters) | TWA[1] Concentration (ppm)[2] | Ceiling Concentration (ppm) |
|---|---|---|---|---|
| XM-1/Assembler | 180 | 9.0 | 12.6 | |
| " | 15 | 3.0 | | 14.2 |
| " | 15 | 3.0 | | 58.9 |
| Continental/Cleanup & Trim | 180 | 8.9 | 21.5 | |
| Vent./Gasket & Cleanup | 179 | 8.5 | 76.2 | |
| Engine/Cleanup | 177 | 8.5 | 22.5 | |
| XM-1/Assembler | 15 | 3.0 | | 103.1 |
| " | 15 | 3.0 | | 73.6 |
| OSHA standard: 8-hour TWA | | | 100 | |
| 5-minute ceiling | | | | 200 |
| absolute ceiling | | | | 300 |
| NIOSH recommended standard | | | lowest feasible level | |

1. ppm = Parts of contaminant per million parts of air.
2. TWA = Time-weighted average

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