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HEALTH HAZARD EVALUATION
DETERMINATION REPORT 72-21-91

NOVEMBER 1973

Establishment: American Viscose Division
F M C Corporation
Nitro, West Virginia

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HEALTH HAZARD EVALUATION DETERMINATION REPORT 72-21
FMC CORPORATION
AMERICAN VISCOSE DIVISION
NITRO, WEST VIRGINIA

NOVEMBER 1973

I. SUMMARY DETERMINATION

A. Introduction

Section 20 (a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669 (a)(6), authorizes the Secretary of Health, Education, and Welfare, following a written request by 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 National Institute for Occupational Safety and Health (NIOSH) received such a request from an authorized representative of employees to evaluate the potential hazards associated with the alleged exposure to carbon disulfide (CS₂) vapors evolved during the manufacture of rayon staple in the spinning and cutting areas of a viscose rayon manufacturing plant of The American Viscose Division, FMC Corporation, located at Nitro, West Virginia.

B. Federal Standards

The Occupational Health Standards as promulgated by the U.S. Department of Labor (Title 29, Chapter XVII, Part 1910, Subpart G, Section 1910.93, Table G-2) applicable to substances for this evaluation are:

Substance	8-Hour Time Weighted Average	Acceptable Ceiling Concentration	Acceptable Maximum Peak Above the Acceptable Ceiling Concentration for an 8-Hour Shift	
			Concentration	Maximum Duration
Carbon Disulfide	20 ppm ^a	30 ppm	100 ppm	30 Minutes
Hydrogen sulfide	-	20 ppm	50 ppm	10 Minutes once only if no other measurable exposure occurs

^aParts of vapor or gas per million parts of contaminated air by volume.

C. Environmental Evaluation Results

Hydrogen sulfide samples were obtained in workers' breathing zones during a survey conducted June 15-17, 1972. These tests resulted in hydrogen sulfide levels of 0.72 ppm to 1.25 ppm being measured. A total of fifteen detector tubes were used to measure hydrogen sulfide levels in several areas of the Staple Department during a survey conducted September 26-28, 1972. Hydrogen sulfide was detected in only two of these tubes at 1 ppm and 5 ppm respectively with no detectable level of hydrogen sulfide resulting from the remaining thirteen tubes.

A total of 36 air samples to determine carbon disulfide concentrations were obtained in workers' breathing zones utilizing short term sampling periods during the September 26-28, 1972 visit. Twelve of these samples were in excess of the 8-hour time-weighted average exposure limit of 20 ppm, but more importantly, seven determinations were in excess of the maximum peak exposure limit of 100 ppm which should never be exceeded.

A follow-up Environmental Evaluation was conducted December 11-18, 1972 during which a comprehensive study of the exposure of 8 Cuttermen and 6 Spinnermen to carbon disulfide was made. The results of this environmental study may be summarized:

1. Carbon Disulfide Air Concentrations in Cuttermen's Breathing Zones

(A) Acute Exposures: Acute exposures for cuttermen are those times during the work shift when work is performed with the cutter-house hood open, stretch section hood open, or loaded tow buggies are pushed or emptied. Carbon disulfide concentrations are considerably higher than general room concentrations in the cutting area during these work periods. Two hundred and thirty individual short-term air samples of approximately four and one-fourth minutes duration were obtained.

(1) Two measurements were made which resulted in air concentration levels in excess of 2000 ppm of CS₂.

(2) Fifteen per cent of the acute measurements were in excess of 300 ppm.

(3) Fifty-two per cent of the acute measurements were in excess of 100 ppm. The maximum peak exposure standard is 100 ppm which should never be exceeded.

(4) The average length of total work shift acute exposure was 140 minutes per shift.

(B) Time-Weighted Average (TWA) Exposures: Computed exposure averages calculated from both acute and 52 general room air sample levels.

(1) Six of eight Cuttermen's TWA-acute exposures were in excess of 100 ppm.

(2) The TWA-acute exposure for all samples collected in Cuttermen's breathing zones was 186 ppm.

(3) Seven of eight Cuttermen had work shift-TWA exposures in excess of the 20 ppm TWA exposure standard for an eight-hour shift. The maximum TWA-shift exposure was more than six times greater than the 20 ppm eight-hour TWA exposure standard.

(4) Five of eight general room-TWA exposures were in excess of 20 ppm while one was equal to the 20 ppm standard.

(5) Four of eight work shift-TWA exposures are in excess of 20 ppm even when complete respiratory protection during all acute exposures is assumed.

2. Carbon Disulfide Air Concentrations in Spinnermen's Breathing Zones

(A) Acute Exposures: Acute exposures for spinnermen are primarily at the spinning machine with the hood open performing a variety of tasks such as lacing up a machine, cleaning hooks from the machine, changing jets, or washing the machine. Carbon disulfide concentrations are generally higher than general room concentrations in the spinning area during these work periods. Eighty-nine individual short-term air samples of approximately 11 minutes duration were obtained.

(1) Only one measurement was in excess of 100 ppm.

(2) The average length of total work shift acute exposure was 167 minutes per shift.

(B) Time-Weighted Average Exposures: Computed exposure averages calculated from acute and 44 general room air sample levels.

(1) The TWA-acute exposure for all samples collected in Spinnermen's breathing zones was 11.2 ppm.

(2) All TWA-work shift exposures are below 20 ppm. The maximum TWA-work shift exposure was 11.1 ppm.

D. Medical Evaluation Results

A total of four visits were made to evaluate the toxic effects of workers' exposure to CS₂. During the May 31 and June 15, 1972 evaluations, 25 workers in the Staple Department were questioned and it was considered that a majority were having symptoms consistent with overexposure to CS₂. A more extensive study was conducted during the period of August 9-16, 1972, during which almost all Cuttermen and Spinnermen were interviewed and their urines tested by the iodine azide test for exposure to CS₂. Again a majority of Cuttermen and many Spinnermen had evidence of overexposure to CS₂. A final medical study was conducted during the period December 11-18, 1972, similar to the August study. During this study air measurements were performed and were correlated with medical findings. The medical conclusions

of the December study were that a serious safety and health hazard exists to all Cuttermen and chargehands and other workers working in the immediate area of the cutterhouse due to excessive exposure to CS₂. Spinnermen, N-10 men, patrolmen, fittermen and pumptesters on occasion may be exposed to hazardous levels of CS₂.

E. Toxicity Determination

Based upon the results of environmental-medical studies reported above, it is determined by the NIOSH investigators that the exposure to carbon disulfide vapors at the concentrations found in this work environment is toxic to cuttermen, chargehands, or others working in the cutter area. The overall respirator program in effect for Cuttermen was believed to be ineffective in protecting this group. Spinnermen, N-10 men, patrolmen, fittermen, and pumptesters may occasionally be exposed to levels of carbon disulfide potentially toxic to them. These findings are based upon (1) medical interviews, (2) iodine azide test results, (3) acute exposure air measurements, (4) shift, time-weighted average exposure air measurements, (5) general room exposure air measurements. It is also determined that a potentially toxic condition to workers in the Staple Department does not exist from the exposure to hydrogen sulfide vapors at concentrations found in this work environment. This finding is based upon (1) air measurements of hydrogen sulfide well below those levels reported to cause abnormal effects in exposed workers, (2) medical interviews in which no complaints of symptoms specifically related to exposure to hydrogen sulfide were noted.

F. Recommendations

A suitable supplied air respirator should be furnished to all cuttermen to wear during the entire work period. This measure would be temporary until proper engineering controls have been instituted to control carbon disulfide levels within safe limits.

All cuttermen and chargehands should be given a complete physical exam as soon as is feasible (certainly within 3 months) to establish the extent of symptomatology and physical disability which may have been caused by exposure to CS₂. Areas of concern should be the cardiac, renal, and nervous systems.

Additional recommendations, environmental and medical, are made to management in the complete report to obviate the observed hazards of carbon disulfide exposure to affected employees.

G. Distribution

Copies of this Summary Determination as well as the forthcoming Full Report of the evaluation will be available upon request from the Hazard Evaluation Services Branch, NIOSH, U. S. Post Office Building, Room 508, 5th and Walnut Streets, Cincinnati, Ohio 45202. Copies of this Summary Determination have been sent to:

- a) FMC Corporation, American Viscose Division, Nitro, West Virginia
- b) Authorized Representative of Employees
- c) U. S. Department of Labor - Region III
- d) NIOSH - Region III

For purposes of informing approximately ninety (90) exposed employees, the employer will promptly "post" the Summary Determination in a prominent place(s) near where affected employees work for a period of 30 calendar days.

II. INTRODUCTION

Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6), authorizes the Secretary of Health, Education, and Welfare, following a written request by 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 National Institute for Occupational Safety and Health (NIOSH) received such a request from an authorized representative of employees of the American Viscose Division, FMC Corporation, Nitro, West Virginia.

The plant is engaged in the manufacture of rayon staple fiber by the viscose process. The operations performed in the areas of the request are spinning of the cellulose into an acid bath, stretching of the fiber, and cutting of the fiber tow into staple. In similar settings exposure to excessive carbon disulfide and hydrogen sulfide has been commonly reported.

The request states seven (7) cuttermen per shift are exposed to carbon disulfide vapors when working at the cutter machines in the Staple Department. The activities which workers perform when exposed to carbon disulfide are described as pulling tow, unjamming cutter blades, cutting wraps off drums, unstopping sluice stopups, and removing tow from the work area. A number of employee symptoms are also described: intoxication, loss of strength, faintness, nervous tremors, blurred vision, headaches, and reports of cuttermen requiring admission to mental institutions.

There are a total of twenty-eight (28) cuttermen normally employed at the plant, and thirty-two (32) spinnermen work in the same room as the one in which cuttermen are located.

Process Description^{1,2}

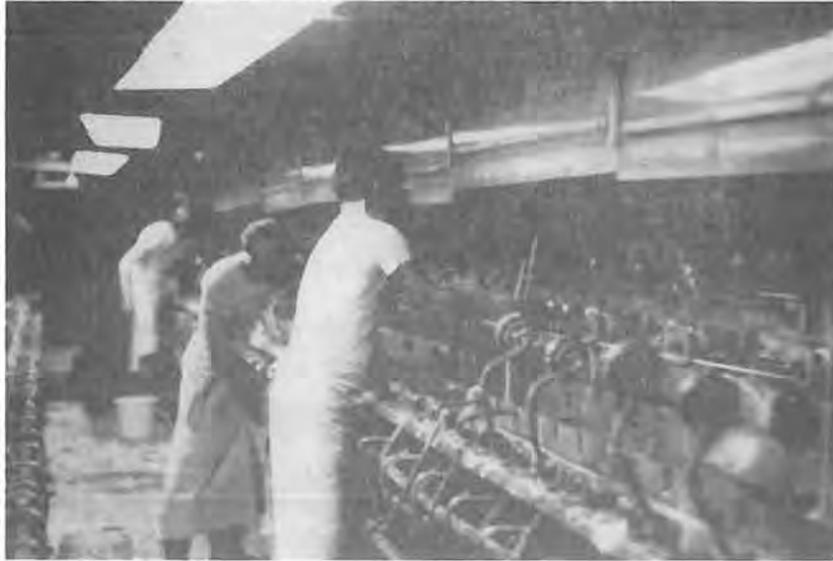
The operations which precipitated the initiation of a Request for Health Hazard Evaluation were the cutting and spinning areas of a viscose rayon plant. The viscose process is the most widely used rayon process due to its versatility and the wide range of fiber properties produced by it. The spinning part of the process is also referred to as regeneration and begins by pumping the viscose solution to headers on each side of the spinning bath. Metering pumps are located along each side of the spinning bath, one metering pump for each jet. The viscose is pumped through the metering pumps to the jets which are submerged in the acid solution of the spinning bath.



CLOSEUP VIEW OF JET PULLED FROM ACID BATH

Reaction between viscose and sulfuric acid causes the release of carbon disulfide and salt cake (sodium sulfate). The initial action of the bath is to form a skin on the outside of the filament with eventual penetration to the interior resulting in complete regeneration, i.e., a change back to cellulose.

Carbon disulfide released during regeneration resulted in environmental conditions which precipitated the initiation of the hazard evaluation. The bundle of fibers, called tow, which has been spun into the acid bath is wrapped around a driven wheel called a Godet which serves as a holding point for the application of stretch to the fiber bundle. Spinnermen perform a variety of jobs in the spinning area consisting of lacing up machines, cleaning scraps of rayon from drains in the bath (cleaning hooks), changing jets, washing salt off machine parts, or performing routine process checks.



VIEW OF SPINNERMEN LACING UP SPINNING MACHINE

The amount of stretch used depends upon the product being produced. Tow is then fed over a reel at the cutting end of the machine and into a cutter which chops it into short lengths of staple. Cuttermen are responsible for patrolling their assigned machines, checking machine stretch sections, cutting wraps off takeup reels, clearing plugged cutters, pulling tow, cleaning cutter sluice plugs, loading and emptying tow buggies.



TYPICAL CUTTERHOUSE SHOWING TAKEUP REELS AND CUTTERS

III. BACKGROUND HAZARD INFORMATION

A. Federal Standards

The Occupational Health Standards as promulgated by the U.S. Department of Labor (Title 29, Chapter XVII, Part 1910, Subpart 1910.93, Table G-2) applicable to substances of this evaluation are:

Substance	8-hour time weighted average	Acceptable ceiling concentration	Acceptable maximum peak above the acceptable ceiling concentration for an 8-hour shift	
			Concentration	Maximum duration
Carbon disulfide	20 ppm ^a	30 ppm	100 ppm	30 Minutes
Hydrogen Sulfide	-	20 ppm	50 ppm	10 Minutes once only if no other measurable exposure occurs

Occupational health standards are established at levels designed to protect workers occupationally exposed to a substance on a 8-hour per day, 40-hour per week basis over a normal working lifetime.

^aParts of vapor or gas per million parts of contaminated air by volume.

B. Toxic Effects

Carbon Disulfide (CS₂)

Industrial poisoning from CS₂ has been known for over 100 years. An excellent review of the literature has recently been published by Davidson and Feinleib.²

The major route of absorption of CS₂ is inhalation³ and the standards have been established to limit high air levels. Absorption through intact skin is uncertain.²

Single high dose exposures result in headache, dizziness and narcosis. Repeated exposures may lead to nervousness, irritability, indigestion, insomnia, excessive fatigue, loss of appetite⁵, peripheral nerve damage and psychoses⁶, which may be permanent.

The machine for producing rayon in the staple department contains three general areas: spinning, stretching, and cutting. The photograph below shows a view taken from the cutting area of a machine.



VIEW OF TYPICAL MACHINE FROM CUTTING AREA

The spinning area is the background beyond the operator. The operator is standing at the stretch area while the cutterhouse containing cutting machines is in the foreground. The final steps in the process are washing followed by bleaching and drying. The staple is then baled for shipment.

A number of various maintenance and cleanup activities must be performed in the spinning and cutting areas during normal operations. N-10 men among other responsibilities are responsible for keeping the basement below the spinning and cutting machines clean of waste material. Fittermen, pump testers, and patrolmen are responsible for checking the spinning equipment and are in the spinning department some time each day.

Davidson and Feinbeib² also cite reports of CS₂ causing skin irritation, vision damage, hearing abnormalities, intestinal problems, blood abnormalities, and abnormalities of the adrenal glands and the testes. Of particular importance is the association of kidney, heart, and blood vessel damage in workers exposed to CS₂. Kidney damage may be secondary to a general atherosclerotic process possibly induced by CS₂, according to Attenger.⁷ As a result of a number of studies which noted an association of CS₂ exposure with atherosclerosis of cerebral, myocardial and renal tissue, high blood pressure disease and abnormal electrocardiograms, Tiller, Schilling and Morris⁸ studied deaths from cardiovascular diseases among employees of three British viscose rayon factories. They found a significant increase in death in CS₂ workers during the years 1943-1957 but no increase since 1958. However calculating mortality rates for men working over ten years in the factory and dying between 1945 and 1964, the investigators noted that these workers at the viscose rayon factory exposed to CS₂ had a two-fold increase in the number of deaths due to heart disease. One other study has also reported an association of CS₂ exposure and excess deaths or increased incidence of coronary heart disease.⁹

Teisinger and Soucek¹⁰ report that continuous high exposure to CS₂ (17 to 30 ppm) results in at least 80% of inhaled vapors being absorbed during the first 15 minutes of exposure with equilibrium, total body saturation, reached in about two hours for nonviscose workers. Experiments conducted with viscose workers exposed at 31 to 63 ppm resulted in slightly less CS₂ retention, but equilibrium was reached in approximately 45 minutes. Gordy and Trumper¹¹ have reported long term poisoning effects occurring after only brief acute exposures to CS₂ fumes.

Paluch¹² has investigated the poisoning of workers at a viscose rayon plant in Poland during the period from December 1945 to March 1946. Carbon disulfide measurements in the spinning room were in a range of 55 to 125 ppm, and measurements made at the desulfuring baths were at levels from 283 to 370 ppm. Paluch investigated past CS₂ poisoning occurrences and examined 83 workers employed in the spinning area where the greatest exposure to CS₂ existed. He concluded, "From the toxicological point of view the second outbreak which as in a stage of development shows that a concentration of about 300 ppm of carbon disulfide is the amount which exceeds almost everybody's tolerance in a comparatively short period of time and can produce serious pathological changes within a few days."

Vigliani¹³ reported some conclusions concerning CS₂ exposures based on observations made on Italian workers in two large rayon staple fiber factories. He concluded: "It was observed concentrations of more than 500 mg/m³ (160 ppm) up to 2500 mg/m³ (800 ppm) may cause serious intoxication in a few months time, 350 mg/m³ (112 ppm) to

500 mg/m³ (160 ppm) may cause the appearance of symptoms after more than one year of work; 180 mg/m³ (58 ppm) to 350 mg/m³ (112 ppm) only rarely are causes of mild intoxication and concentrations under 150 mg/m³ (48 ppm) have never produced symptoms."

In summary the Documentation of the TLV³ notes that air levels 60 to 120 ppm and higher have been associated with chronic symptoms of CS₂ overexposure e.g., mental fatigue, sleepiness and headaches. Milder cases are seen at 30-45 ppm. In an attempt to establish an average 8 hour exposure various authors have recommended a TLV of 45 ppm¹³, 30 ppm¹⁴ or 10 ppm^{4,11,15}. The American Conference of Governmental Industrial Hygienists has established a TLV of 20 ppm as that level which will protect against serious systemic effects but appears to allow little margin for safety.

Hydrogen Sulfide

Hydrogen sulfide at low concentrations (about 20 ppm) acts primarily as an irritant to the eyes, producing conjunctivitis. At higher concentrations (50-100 ppm) it may irritate the respiratory tract.

IV. HEALTH HAZARD EVALUATION

A. Initial Visit - Observational Survey

On May 31, 1972 a NIOSH industrial hygienist and a physician met with plant personnel to discuss alleged hazard of exposure to carbon disulfide.

A walk-through inspection was made in the company of employer and employee representatives. It was noted that the spinning and cutting rooms were hot and humid. All spinning and cutting frames or machines were enclosed and ventilated. Plexiglass windows were provided to open vertically when required to make adjustments or perform work. No odor was apparent unless the windows of the hood were open. However, when the cuttermen were "pulling tow", the odor of carbon disulfide was rather strong.

Interviews were conducted with many of the exposed workers. Symptoms of carbon disulfide exposure were prevalent.

B. Environmental Evaluation

Sampling-analytical methods to determine air level concentrations of CS₂ and H₂S were tested during a survey conducted June 15-17, 1972. The results of this survey for CS₂ indicated the need for different methodology to define the problem. Hydrogen sulfide samples were obtained using a midget impinger containing absorbing solution. The sample time varied from 20 to 176 minutes for these samples. Two general area samples revealed concentrations of 0.74 to 3.37 ppm concentrations respectively. Breathing zone samples for hydrogen

sulfide were also obtained: one cutterman's sample resulted in a 0.72 ppm level where two spinnermen's levels were 1.12 and 1.25 ppm respectively. A 30 minute sample taken six inches inside a spinning hood at head height revealed 6.47 ppm.

During a follow-up survey September 26-28, 1972, various methodologies under development by NIOSH's Cincinnati laboratory were field tested with some degree of success. Although personal exposure concentration data on an 8-hour time-weighted average (TWA) basis were not obtained, measurements of short-term samples demonstrated air concentrations well in excess of the Federal standards for CS₂ (8 hour TWA - 20 ppm, maximum peak - 100 ppm). Results are summarized in Table I.

TABLE I
Summary of Results - Environmental CS₂ Concentration Data

Type Sample	Number of Samples	CS ₂ Range
General Area		
Spinning Room	5	2.7-X ≤ 6.8
Cutting Room	7	15.7-X ≤ 121
Breathing Zone		
Spinnerman - Lacing	13	2.8-X ≤ 19.1
Cuttermen - Pulling Tow	11	14.3-X ≤ 606

Hydrogen sulfide samples were obtained using detector tubes in the machine aisles in the cutting area as well as in the spinning area. Hydrogen sulfide was measured at 1 and 5 ppm on two tubes with no H₂S measured on the remaining six in the cutting area. Seven tubes were used in the spinning area with no measurable level of H₂S (1 ppm) resulting. In view of the relatively low hydrogen sulfide levels in comparison to the TLV of 10 ppm for an eight hour TWA, it was decided H₂S measurements could be eliminated from further consideration in the hazard evaluation.

Environmental Evaluation, December 11-18, 1972

1. Procedure

The last day of a shift sequence was selected as the day upon which to characterize the atmospheric concentrations to which cuttermen are exposed. This decision was predicated upon the need to obtain biological samples reflecting the maximum total exposure and retention of carbon disulfide which normally coincides with the last day of a shift sequence. Spinnermen being exposed to lower air concentrations were sampled on the next to last day of the shift sequence.

Two types of personal samples were obtained for both the spinnermen and cuttermen reflecting either "acute" or "general air" (room) exposures. "Acute" exposures for cuttermen occur when work is performed with the cutterhouse hood open, stretch section hood open, pulling tow, and emptying or pushing loaded tow buggies. Cuttermen have instructions to wear respirators during any of these acute exposure periods, but on a number of occasions men were observed working without this protection.



CUTTERMEN WORKING IN CUTTERHOUSE ACUTE EXPOSURE
NOTE: INDUSTRIAL HYGIENIST OBTAINING BREATHING ZONE SAMPLE

For spinnermen, "acute" exposures occur primarily at the spinning machine when the hood is opened to perform a variety of tasks such as lacing up a machine, cleaning hooks from the machine, changing spinnerets, or washing the machine.



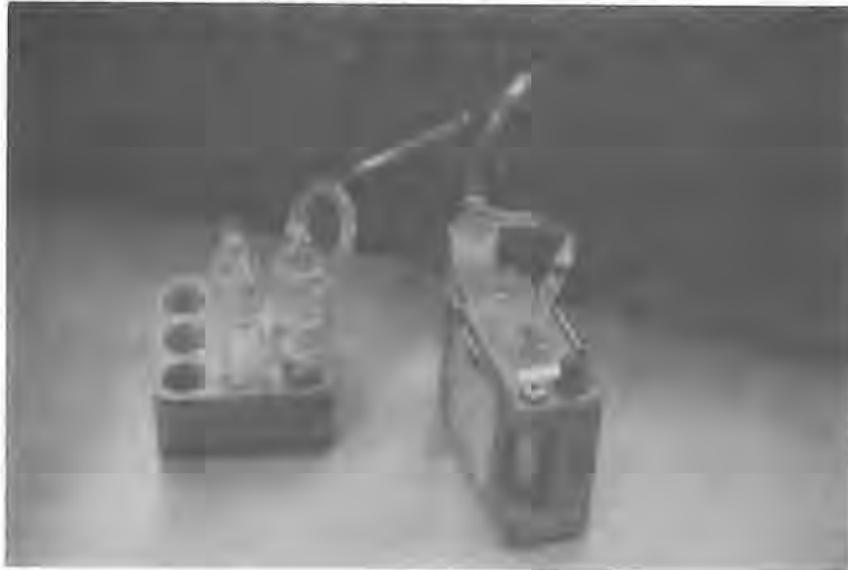
INDUSTRIAL HYGIENIST OBTAINS BREATHING ZONE SAMPLE AS SPINNERMAN LACES MACHINE

2. Sampling Methods, Equipment

The acute exposures were measured by holding the inlet to the midget bubbler-impinger sampling train in the breathing zone of the cuttermen or spinnermen who were being exposed at the time. The sampling technique used can be seen in the two preceding pictures. The general air (room) exposures were measured by the NIOSH industrial hygienists carrying a midget-bubbler-impinger sampling train on their person while accompanying operators not being acutely exposed. A ten to twenty minute sampling time was typical for the general air samples although at times shorter sampling periods were necessary due to the atmospheric carbon disulfide levels.

A sampling train composed of midget bubbler, midget impinger, tygon tubing, empty impinger at the pump to serve as a liquid trap, and MSA Model G battery operated personal sampling pump (flowrate of

1 liter per minute) was utilized. No tubing was attached to the inlet of the midget bubbler and the tygon tubing connector between midget bubbler and midget impinger was kept as short as possible. The tubing between the exhaust of the midget impinger and trap was kept long to facilitate rapid movement as required to follow the operator's movements for acute sampling.



SAMPLING TRAIN FOR OBTAINING ACUTE OR GENERAL ROOM CS₂ SAMPLES

3. Analytical Methods

Each of 423 environmental samples was collected in an absorption solution consisting of 0.5% (v/v) diethylamine, 0.5% (v/v) triethanolamine, and 0.001% (w/v) cupric acetate in 95% ethanol-water contained in a bubbler and impinger connected in series. The solutions from the bubblers and impingers were analyzed individually by the procedure of McKee.¹⁶

The method involves the immediate stabilization of carbon disulfide as the yellow cupric diethyldithiocarbamate. The color of the solution is directly proportional to the concentration of carbon disulfide. The absorbance of the solution at 420 nm was determined by a Spectronic 20 spectrophotometer. Further dilutions are required if the absorbance is greater than 0.500 and can be done using fresh absorption solution. The CS₂ concentration is determined from a calibration curve prepared from known quantities and reported in micrograms CS₂ per 20 ml sample.

4. Results and Discussions

a. "Acute" Exposure of Cuttermen to Atmospheric Carbon Disulfide

Table II. Contains the distribution of all acute CS₂ measurements made in the breathing zones of the eight cuttermen studies in December.

TABLE II - Distribution of "Acute" CS₂ Measurements from Cuttermen's Breathing Zones

<u>Cumulative Number Samples</u>	<u>Concentration of of CS₂ ppm</u>	<u>Per Cent Above Indicated Concentration</u>
2	2000	0.4
5	1000	1.4
11	700	2.9
21	500	6.7
45	300	14.5
77	200	30.6
117	100	51.7
196	20	83.0

There are several points which stand out when reviewing this data, keeping in mind the literature sources outlined in the Toxic Effect Section.

(1) The acute exposure data covered a very wide concentration range with a minimum less than 20 ppm and a maximum greater than 2000 ppm.

(2) The acute exposure levels measured during the environmental survey exceed by far the limits which various investigators have suggested such as the 160 ppm to 800 ppm high range outlined by Vigliani¹³ or the 300 ppm level suggested by Paluch¹⁴ which he states exceeds almost everyone's tolerance. Nearly 15% of the data collected during the acute exposure periods exceeds 300 ppm.

(3) The peak exposures exceeding 1000 ppm are higher than levels previously reported for industrial exposure.

(4) The acceptable maximum peak above the acceptable ceiling concentration for an eight hour shift is 100 ppm promulgated by the U.S. Department of Labor. Acute exposures 20 times greater than this level were measured. For any given acute exposure to which a cutterman is exposed, chances are slightly greater than 50% he will be exposed to a level greater than the acceptable maximum peak exposure.

All of these points emphasize the seriousness of the exposure potential for cuttermen under the acute exposure conditions which exist at this plant.

Even though cuttermen wear respiratory protection during the majority of acute exposures, the potential for considerable unprotected exposures exist. When machine operating conditions require pulling tow for extended periods (longer than a few minutes), cuttermen were observed to take rest breaks during such periods. Cuttermen were also observed to take off their respirators during such breaks in areas close to the acute exposure area.



CUTTERMEN LOADING TOW INTO BUGGY
NOTE: CUTTERMEN IN BACKGROUND NOT WEARING RESPIRATOR

In fact when cutterhouse hoods are open for extended periods of time the CS₂ concentration is increased in a large part of the cutting area. The potential for exposure can then be quite high especially when large amounts of tow are on the floor, loaded tow buggies are in the area, and fans blow air containing CS₂ into the breathing zone of the workers.

Such conditions were observed during the December environmental survey under operating conditions in which the cutter sluice became plugged with tow, cutters on a line required replacement, or bleaching plant problems stopped the flow of rayon staple from the cutting operation and tow pulling was necessary until the bleaching problem was corrected.



LOADED TOW BUGGY IN CUTTER AREA
NOTE: CUTTERMEN NOT WEARING RESPIRATOR



LARGE PILES OF TOW CONTRIBUTE TO
ELEVATED GENERAL ROOM CS₂ LEVELS

Distribution of acute concentrations for individual cuttermen are contained in the Appendix.

b. "Acute" Exposures of Spinnermen to Atmospheric Carbon Disulfide

Acute exposure of CS₂ by spinnermen were at much lower levels than those of cuttermen. Spinnermen may be exposed around the spinning bath with the hood open during a large part of the work shift. The spinnermen perform a variety of tasks with the machine hoods open, such as checking machines, cleaning hooks, lacing machines, making jet changes, and taking up machines. However, spinnermen do infrequently get acutely exposed in the cutting area of the room and the potential for high acute exposure levels does exist. Only one sample from a spinnermen's breathing zone exceeded 100 ppm and the worker was exposed for part of the sample time around the open hood of a machine stretch section.

The acute exposure levels for all spinnermen varied from 0.9 to 127.0 ppm. The time-weighted average for all spinnermen's acute exposures was 11.2ppm. A significant portion of the shift is spent exposed to acute levels since average length of exposure was 167 minutes per shift.

c. Time-Weighted Average Exposures to Carbon Disulfide

The environmental data from acute and general room exposures was combined by time weighting the data to obtain a shift time weighted average exposure to CS₂. Although the majority of acute exposures were sampled, in a few instances due to lack of fresh bubblers and impingers it was not possible to sample an entire acute exposure. In those cases the length of exposure was accurately recorded along with the circumstances of exposure. When the calculations were performed, the concentration for the sample which most nearly fitted the circumstances of the unsampled exposure was used to complete the acute exposure calculations. An outline of the procedure for calculating the time weighted average exposures for each cuttermen is contained in Appendix A.

Total length of all exposure, acute plus general room, is less than the total length of the shift since operations took a break for lunch and also were out of the operating area for a medical interview. The total length of exposure is probably less than the normal work period exposure and can vary among operators on the same shift. The results obtained by calculating TWA exposures for cuttermen and spinnermen are contained in Table III. The iodine azide urine analyses which were obtained at the start of the shift and end of shift are also shown for each of the operators.

TABLE III
 SUMMARY OF ENVIRONMENTAL - MEDICAL SURVEY - DECEMBER 11-18, 1972

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Date	Job	Operator	Length of Exposure (Minutes)		Concentration (ppm) Time-Weighted Average			Iodine Azide Tests		Symptoms	
			Acute	General Room	Acute	General Room	Shift	Shift Start	Shift End	Day Surveyed	Past History
12/11	C	1	165	263	199	20.0	89.2	Norm	6.1	-	-
12/11	C	2	85	365	23.2	6.3	9.5	Norm	Norm	-	-
12/13	C	3	184	266	160	12.6	72.9	Norm	6.5	-	+
12/13	C	4	151	290	183	41.1	89.8	Norm	1.1	-	+
12/15	C	5	185	204	179	46.5	110	5.4	1.8	+	+
12/15	C	6	82	283	378	41.5	117	5.1	1.4	-	+
12/18	C	7	111	263	357	33.0	129	5.2	1.0	+	+
12/18	C	8	154	239	77.5	25.0	45.5	Norm	2.8	-	+
12/12	S	1	167	288	7.9	3.7	5.2	7.6	5.4	-	+
12/12	S	2	195	245	5.5	3.4	4.3	Norm	7.0	-	+
12/14	S	3	142	233	22.4	4.2	11.1	7.9	Norm	-	-
12/14	S	4	33	247	10.9	5.5	6.1	Norm	Norm	-	-
12/17	S	5	298	176	12.4	3.0	8.9	Norm	6.5	-	-
12/17	S	6	170	286	9.2	3.9	5.9	7.5	6.3	-	+

The TWA acute exposure for cuttermen varied from a minimum of 23.2 ppm to a maximum of 378 ppm. All except one of the TWA acute exposures for cuttermen exceeded the Department of Labor's maximum peak of 100 ppm for CS₂ exposure as well as the 30 ppm ceiling and 30 minute maximum duration per shift criteria. The time weighted average acute exposure for all cuttermen was found to be 186 ppm. These results serve to re-emphasize the very serious nature of the acute CS₂ exposures existing at this plant especially for cuttermen. The TWA acute exposure of spinnerman did not exceed Department of Labor standards for CS₂ exposure.

The range of general room exposure for cuttermen was from 6.3 to 46.5 ppm. Four of the general room exposures of cuttermen were higher than the upper limit of 30 ppm which more liberal investigators would suggest as a safe TWA shift exposure, and these four levels are also in excess of the 30 ppm ceiling - 30 minutes duration standard of the Department of Labor. Two of the remaining general room levels, 20.0 and 25.0 ppm, would be considered as borderline safe while the other values of 6.3 and 12.6 ppm are considered to be safe. The level of the general room exposure leads one to consider seriously the necessity for protection of cuttermen during the entire shift until adequate engineering controls are operating which will provide a safe environment in the cutting area. The general room TWA obtained in the spinning areas show values in a range of 3.0 to 5.5 ppm which would all be considered well within safe limits.

When the acute and general exposures are combined to obtain shift TWAs, the seriousness of the situation measured during the survey becomes even more apparent. All of the cuttermen's shift TWA except one far exceed the level which needs to be maintained to protect worker health. Seven of the eight exposures were in a range from 45.5 to 129 ppm which is approximately two to six times as great as the 20 ppm shift TWA promulgated by the Department of Labor. Prior to NIOSH investigation exposures of this type were being experienced by cuttermen without benefit of any protection whatsoever save the ability to hold their breath during the worst of short term exposures. The shift TWA results for spinnermen are all below 10 ppm except for one operator exposed to a level of 11.1 ppm; and all these exposures are well within safe limits. Cuttermen normally wear a protective respirator during acute exposures, but spinnermen did not wear respirators at any time so environmental and medical results can be correlated without question of respirator effectiveness for this latter group.

Since the cuttermen did wear respirators during periods of acute CS₂ exposure, it is of interest to look at the data while trying to take into account the effect of the respirators. The purpose of this conversion is to obtain TWA CS₂ exposures which correlate

with the biological samples. The results obtained after converting the general room TWA to shift TWA are contained in Table IV. A number of assumptions must be made in order to make this conversion:

- (1) The respirator cartridges remove all CS₂ vapors from air which is breathed through them.
- (2) Cuttermen maintain a good seal around mouth and nose at all times while wearing the respirator.
- (3) Cuttermen do not get exposed to acute levels while not wearing their respirators.
- (4) The relatively short term general room samples, usually ten minutes in length, adequately characterize the general room CS₂ levels for the entire hour in which sampled.

The TWA in Table IV were obtained by converting the general room TWA to shift TWA as shown:

$$\bar{C} \text{ Actual} = \bar{C} \text{ Shift} \times \frac{T_{\text{General Room}}}{T_{\text{Acute}} + T_{\text{General Room}}}$$

- shift TWA exposure

\bar{C} Shift

\bar{C} Actual - Average shift TWA assuming general room as only exposure during the shift

T_{Acute} - Total length of acute exposures during shift

$T_{\text{General Room}}$ - Total length of general room exposures during the shift

The results which are obtained in this manner tend to be biased toward minimal values. All assumptions which are made except (4) would result in the calculation of TWA (actual) exposures which are less than the actual exposure to which the cuttermen are exposed. The last assumption might explain variation in the data but it should not cause a bias resulting in either consistently high or low values. As was found in the preceding examinations of the environmental average exposure values, the average exposure results referred to as TWA (Actual) values were found to be excessive. Four of the cuttermen were exposed to CS₂ levels in excess of 20 ppm.

TABLE IV

TIME-WEIGHTED EXPOSURE TO CUTTERMEN TO CS₂* DECEMBER 11-18, 1972

Date	Operator	Time in Minutes		Time-Weighted Average (Actual)	Iodine Azide	
		Total-Shift	General Room		Start	End
12/11	1	428	263	12.3	Norm	6.1
12/11	2	450	365	5.1	Norm	Norm
12/13	3	450	266	7.4	Norm	6.5
12/13	4	441	290	27.0	Norm	1.1
12/15	5	389	204	24.4	5.4	1.8
12/15	6	365	283	32.2	5.1	1.4
12/18	7	374	263	23.2	5.2	1.0
12/18	8	393	239	15.2	Norm	2.8

* Assumes only General Room exposure

C. Medical Evaluation

A total of four visits were made to evaluate the alleged hazard to workers from carbon disulfide (CS₂). The first two visits on May 31, 1972 and June 15, 1972 consisted of walk-through tours of the Viscose and Staple Departments, the latter department being the area of concern. Personal interviews with 25 workers (about one-half of the workers exposed) were conducted during these two visits. It was apparent from interviews that most workers, especially those who were cuttermen were having symptoms consistent with CS₂ overexposure. Because of this finding, a more intensive study was conducted during the period of August 9-16, 1972. During this third visit, a medical questionnaire was administered, the questionnaire being based upon the most common symptoms noted by Alice Hamilton in her classic study of CS₂ exposure and also the symptom lists presented in various papers appearing in Toxicology of Carbon Disulfide.¹⁸ The questionnaire is presented in Appendix B. Furthermore, in order to correlate symptoms elicited from workers with an objective test of exposure, urine samples were taken on the last day of a work week and were analyzed using the iodine azide test originally described by Yoshida¹⁹ and developed further as a field test for CS₂ exposure by Vasak^{20,21} which correlates CS₂ levels with test results. Djuric²² successfully used the iodine azide test for workers exposed to high levels of CS₂ in a European viscose factory. Djuric²³ reported that end of day exposure coefficients (E_F values) could be used as a reliable index of the average CS₂ exposure during the day, and beginning of day exposure coefficients (E_S values) would indicate whether workers had recovered from the previous day's exposure. He further noted²⁴ that "workers with recovery [normal E_S] did not show any objective or subjective symptoms of poisoning" and that these workers were, "in no danger in spite of duration and severity of exposure." Workers showing non-recovery (abnormal E_S) were in most cases symptomatic and thus an abnormal E_S is a reliable sign of some biochemical disorder."

The results of the medical questionnaire and urine tests from the August study can be briefly summarized. The cuttermen group contained the greatest number of symptomatic individuals, followed by spinnermen, charge hands and Viscose personnel serving as controls. These percentages are consistent with the observed work activities.

TABLE V
SUMMARY OF RESULTS - WORKERS INTERVIEWS (AUGUST 1972)

Job Group	Symptomatic	Percent
Cuttermen	20 of 28	71%
Spinnermen	13 of 27	48%
Charge Hands	2 of 6	33%
Viscose	1 of 20	5%

Symptoms for most cuttermen included headaches, dizziness, insomnia, nervousness, excessive sleep, loss of appetite, weight and initiative. Spinnermen reported a somewhat less extensive list of symptoms and usually symptoms associated with a more acute, high dose exposure (i.e., headaches and dizziness). Chargehands, at times, have exposure similar to cuttermen and their symptoms were similar. The control group, with no obvious exposure to CS₂ contained a few individuals who noted some sleep difficulties and nervousness but did not give the same symptom complex as the exposed group.

The iodine azide test also showed good correlation with anticipated exposure and symptoms, as seen in Table VI. Cuttermen had the greatest number of abnormal results, followed by spinnermen, chargehands and controls.

TABLE VI
SUMMARY OF RESULTS - IODINE AZIDE TESTS (E_E) (AUGUST 1972)

Job Group	Total	Borderline Abnormal 6.0 > E ≥ 5.0	Abnormal E < 5
Cuttermen	28	4	10
Spinnermen	27	4	2
Chargehands	6	2	0
Viscose	20	2	0

On the basis of the medical evaluation done in May, June, and August studies and the environmental studies of September 1972, both indicating high levels of CS₂, a preliminary report²⁵ was sent to the requesters of the hazard evaluation and management summarizing the results and making the following conclusions and recommendations:

"On the basis of substantial medical findings presently available and preliminary environmental concentrations of carbon disulfide measured, it is concluded that a definite and serious hazard to the health of workers, especially cuttermen, exists in operations conducted in the Staple Department.

1. Specifically, respirators should be issued and worn by all cuttermen when glass hoods are open near cutting machines, when they are pulling tow, and at other times when the company has termed exposure to be significant.

2. It is recommended that spinnermen and chargehands be issued appropriate respirators to be used, at present, at their discretion when fumes are heavy or when workers become symptomatic.

3. Immediate attention be directed to both the inadequate ventilation existing in the cutting machines and general area. Specifically, a professional consultant ventilation engineering firm should be employed to plan and implement a comprehensive program for ventilation control of all operations in question.

4. Institute an adequate environmental - medical program to monitor air levels for CS₂ and worker symptomatology, medical examinations and biological tests, as necessary.

It was noted in the preliminary report that a final medical environmental study would be conducted on December 11-18, 1972, to correlate the medical and environmental data.

Since August and September studies, the company has begun a respirator program consisting of the issuing of respirators for all cuttermen and instructions that must be worn when hoods are open, when working in the stretch area, pulling tow and when carting away tow. It is also understood that chargehands were issued respirators, but spinnermen were not. Iodine azide tests were begun on cuttermen, spinnermen and some other workers. Some ventilation changes were also instituted and major changes were planned.

The December 11-18, 1972, study was designed to correlate symptomatology with iodine azide test results and these indicators of exposure with actual air levels. Furthermore, the effectiveness of the respirator program in reducing symptoms and yielding negative iodine azide test results was to be evaluated.

METHOD: (December Study)

Medical questionnaires were administered and urine samples were collected before and after the 7th day of a work week, as was done during the previous study. Urine specimens were preserved with thymol and were analyzed at the plant site by NIOSH personnel. Samples were observed for five hours. If they did not convert during this period of time they were considered "normal." Exposure coefficients (E values) are reported either as "Normal" or $E \geq 6.0$; Borderline Abnormal $6.0 > E \geq 5.0$ Abnormal $E < 5.0$.

All cuttermen and spinnermen were involved in the evaluation. A special group of workers whose exposure was unknown but who were working in the spinning area were also similarly tested. They included the job classifications of N-10 men, patrolmen, pumpsters, and filtermen. Controls were used for standardization of the iodine azide tests but no questionnaires were given these individuals. Chargehands were not evaluated, but can be assumed to have similar types of exposure as cuttermen, although probably less total exposure, since they are in a supervisory capacity.

RESULTS:

As can be seen in Table VII, there was no significant change in the percentage of symptomatic individuals among the cuttermen or spinnermen group since the institution of respirators.

TABLE VII
SYMPTOMATIC INDIVIDUALS

	<u>Total</u>	<u>August</u>	<u>December</u>
Cuttermen	(28)	71%	78%
Spinnermen	(27)	48%	42%
Special Group	(15)	(not done)	20%

Comparing the spinnerman group with the special group (known to have less work time in CS₂ atmospheres) the special group has a smaller percentage of symptomatic individuals.

Workers were considered symptomatic if they admitted to at least symptoms of headaches, and dizziness on occasion. In most instances symptomatic spinnerman and workers in the special group, complained only of headaches and dizziness (the typical symptoms of acute high dose CS exposure). The men easily predicted when symptoms would occur, e.g., on "bad days" when fumes were "heavy"; when ventilation was poor; when spinnermen would come to the aid of cuttermen and thereby be exposed to the cuttermen's area. Symptomatic cuttermen, on the other hand, rarely complained only about headaches and dizziness, but often had associated sleep disturbances, fatigue, nervousness and poor appetite.

Table VIII illustrates that there has been no significant change (p .05) from August to December in the percentage of abnormal E_E values in cuttermen despite the respirator program. Spinnermen E_E values have not changed, and the special group had no one with abnormal E_E values.

TABLE VIII
PERCENTAGE OF VARIOUS GROUPS HAVING ABNORMAL OR BORDERLINE ABNORMAL E VALUES

	<u>Total</u>	<u>E_E < 5</u> (Abnormal)		<u>6.0 > E_E ≥ 5.0</u> (Borderline abnormal)	
		<u>August</u>	<u>December</u>	<u>August</u>	<u>December</u>
Cuttermen	28	(16) 57%	(21) 75%	(3) 10%	(2) 7%
Spinnermen	27	(2) 7%	(1) 3%	(2) 7%	(5) 18%
Special Group	15	not done	0%	not done	0%
Controls	28	0%	0%	(2) 7%	(1) 3%

Examination of cuttermen E values (Table IX) shows that although the percentage of abnormal values has not changed significantly, the number of values less than 3 has actually increased to a preponderance of E values in a range from 1 to 2; suggesting continued over-exposure, or a worsening of the over-exposure.

TABLE IX
NUMBER OF $E_E < 3$ FOR CUTTERMEN
(RANGE IN PARENTHESIS)

<u>August</u>	<u>December</u>
4 (2.0-2.8)	13 (0.9-2.8)

In Table III one may compare a worker's exposure to CS_2 and with his iodine azide results and also with his symptoms.

Since spinnermen were not wearing respirators their TWA represents in all cases a full day's exposure and may be compared directly to their iodine azide values. In only one case, #1, did a spinnermen have a borderline abnormal E_E with a TWA well below the Federal Standard of 20 ppm. Of interest is that he was the only one of two monitored who had two excursions above 30 ppm during the day. These two mild excursions above the ceiling level may explain the E value. All other spinnermen had normal E_E and TWAs below the Federal Standard.

Table IV reveals the TWA for cuttermen who were environmentally monitored and assumes exposure to only general room air and further assumes that the worker is not exposed to unfiltered air during the acute exposure period. We note that TWAs calculated place four of the eight cuttermen only slightly above the Federal Standard of 20 ppm (23.2-32.2), while E values are markedly abnormal in five of the eight.

We may predict average CS_2 exposure from actual E values. Djuric²⁸ notes that his E values and active measured air exposures to CS_2 showed good correlation with those obtained from calculations using the graph in Figure 1.¹¹

FIGURE 1

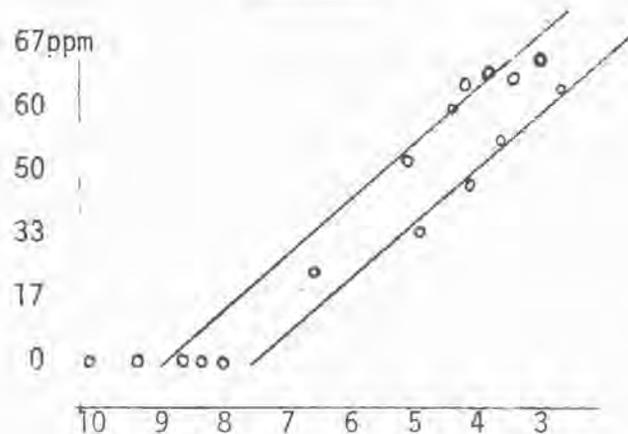


Fig. 1 Demonstrates the relation between the concentration of CS₂ in the inhaled air and the exposure coefficients in different experimental persons in a laboratory situation.

If we look at all E_E values from cuttermen who were monitored environmentally, the five which are abnormal all have an E value of 3. Using Fig. 1, this would place all exposure levels at greater than 60 ppm. Furthermore, a total of 13 cuttermen not monitored environmentally also had E_E values less than 3, indicating average exposure to not less than 60 ppm.

In a comparison of symptoms and the iodine azide test, non-tabulated data shows that 23 cuttermen had abnormal E_E values, and of the 23, 18 had symptoms of an acute (day of testing) nature (4) or chronic nature (14). This would suggest that E_E is a good indicator (18 of 23 - 78%) of workers who are or have been symptomatic. The false positive rate i.e., workers having an abnormal E_E but denying symptoms past or present is 5 of 23 (21%). The false negative rate i.e., workers having normal E_E but having suggestive symptoms was 3 of 23 (13%).

Of all cuttermen only five (#5 and #7 of Table III and three not tabulated) had both abnormal E_S and E_E values. Three of these five had symptoms on the day of testing and all reported past symptoms.

DISCUSSION:

The hazards due to acute high doses or chronic low dose exposure to CS₂ have been long recognized. Over-exposure to CS₂ may cause damage to a number of organs and systems of the body. The present study has served to uncover numerous cases of symptomatic over-exposure, but other possibly harmful and permanent effects were not evaluated in this limited medical survey. The December study documented the high exposures, symptomatic individuals and abnormal iodine azide tests found in the August and September evaluations.

As can be seen in Table VII, the fact that there is no change in the percent of cuttermen who are symptomatic despite the respirator program means that further steps to alleviate the hazard are required. The iodine azide tests in Table VIII further confirms heavy dose exposure for monitored and non-monitored cuttermen.

Although the data in Table III (shift TWA) where cuttermen were monitored, cannot be used directly to correlate air concentrations and iodine azide tests with symptoms, since respirators were not employed before August 1972, it can be assumed that the shift TWA resembles the probable exposure of cuttermen prior to that time. These shift TWAs are markedly above the maximum level for CS₂.

Making the assumption that cuttermen are exposed only to general room air (and not to acute exposures because of respirator use) (Table IV) exposure averages which are slightly above the Federal Standard (23-32ppm) were calculated while corresponding E_g values are markedly abnormal. Using Figure 1 to calculate average CS₂ concentrations from E values suggests concentrations above 60 ppm. The difference between the actual calculated TWAs (Table IV) and these predicted from E values (Fig. 1) suggests that cuttermen were in fact exposed to high levels of CS₂ when standing near an "acute exposure operation" without respirators. These exposures were not monitored.

It would appear therefore that as part of the respirator program respirators need to be worn after acute exposures when cuttermen remain in the same area.

As further evidence of the ineffectiveness of the current respirator program the iodine azide test results may be cited. Adequate respirator protection causes values to revert to normal. In fact, the opposite was shown in Table IX and values of less than 3 suggest even greater exposure. This may be explained by hypothesizing poorer ventilation in December (winter condition) as compared with August ventilation (summer condition).

The only evidence of respirator effectiveness is the subjective finding that cuttermen report that they can pull tow for longer periods of time without getting headaches or feeling high. To fully determine whether the respirators are ineffective or insufficiently used they should be worn all day and the iodine azide tests repeated.

Spinnermen and the special group are not routinely exposed to hazardous CS₂ environments. High dose exposures are often predictable by the worker and at present most symptoms are of an acute nature. Borderline abnormal iodine azide tests in these workmen can be explained on the basis of unusual situations or activities outside the normal job description. For example, spinnermen may work in the stretch area and may even help pull tow in order to save their own line. The special group may have difficulties during days in which there are mechanical

problems and the basement is filled with CS₂ saturated waste material. It is probable that all of these men can identify times when there will be heavy exposure and they should be issued respirators for these occasions. Chargehands also should be wearing respirators since their exposures are often similar to the cuttermen although not of the same duration. Furthermore, any other personnel e.g., electricians, engineers, etc. who are performing repairs in the cutting area should be wearing respirators. The dizziness and feeling of being "high" poses a serious safety hazard in an area where heavy machinery and cutting blades are moving.

Because the iodine azide test is beginning to be widely used as an objective test of excessive exposure to CS₂ and because the test alone with occasional air monitoring can be used to determine if men are over-exposed, it should be noted that NIOSH findings differ somewhat from those reported by Djuric²⁴. He felt that workers with a normal E_F were in danger of experiencing objective or subjective symptoms (and that of significance were only those men who showed non-recovery, i.e., abnormal E_S). Our data suggests otherwise of 18 of 23 cuttermen (78%) who had symptoms of an acute (4) or chronic nature (14), only 4 of these workers would have been picked up by Djuric's criteria since only 4 had abnormal E_S. Thus, relying solely on the E_S as an indicator one would have missed 14 workers who were symptomatic and had only an abnormal E_F. It seems advisable, therefore to use the E_F value as the indicator of symptomatic over-exposure. Workers with abnormal E_S should be viewed as having over-exposure. The data of monitored cuttermen (Table III) show that the 3 men with E_S <6, all had histories of chronic symptoms and 2 noted headaches and dizziness on the day of testing.

Workers may also be chronically symptomatic yet have normal E_F values. This can occur easily since the E_F will only be abnormal if the CS₂ exposure that day is excessive. Because some individuals may be symptomatic and not have an abnormal iodine azide test (because of low dose exposure on the day of testing), there is no substitute for periodic medical interview and examination. One should not rely solely on an objective test such as the iodine azide test to determine over-exposure to CS₂.

Finally it should be stressed that this study only elicited symptoms of CS₂ over-exposure. Subclinical effects which have been associated with CS₂ over-exposure such as kidney and heart disease and possible glandular dysfunctions were not evaluated. Efforts by management must be made to evaluate such possible health problems.

Persistence of symptoms and the abnormal iodine azide test results in cuttermen raise serious doubt as to the adequacy of the respirator program. Pending engineering modification, it is recommended that respirators continuously be worn by all personnel in the cutterhouse area. Efforts should be made to insure proper respirator use (e.g. respirator causes shortness of breath, or irritates workers' face and therefore is taken off as soon as possible).

The best objective confirmation of excessive CS₂ exposure is the end of shift E values (E_E). If abnormal this should be regarded as sufficient evidence of excessive exposure. All men with abnormal E_S values should be regarded as having experienced excessive CS₂ exposure.

V. CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations which follow are based upon comprehensive environmental-medical studies conducted at the FMC Corporation, American Viscose Division, Nitro, West Virginia plants.

A. Conclusions

1. It has been determined that exposures to carbon disulfide vapors at the concentrations found in this work environment are toxic to cuttermen, chargehands, or others working in the cutter area. This finding is based upon:

a) Environmental studies which showed carbon disulfide air levels greater than the highest levels recommended by numerous investigators to protect the health of workers as well as occupational health standards established by the Department of Labor. Types of measurements showing excessive exposures are:

- (1) Acute
- (2) Shift time-weighted average
- (3) General room air
- (4) Shift time-weighted average assuming complete protection during acute exposure

b) Medical findings of symptomatic cuttermen and abnormal iodine azide tests.

2. Spinnermen are exposed to levels of carbon disulfide within limits recommended by numerous investigators to protect health and also within standards established by the Department of Labor. Types of measurements indicating allowable exposures are:

- a) Acute
- b) Shift time-weighted average
- c) General room

However, because of evidence of symptomatic spinners and borderline abnormal iodine azide test results, spinners, N-10 men, patrolmen, filtermen, and pump testers may on occasion be exposed to levels of carbon disulfide potentially toxic to them.

3. A serious safety hazard also exists to any worker exposed to excessive levels of carbon disulfide because of the dizziness which may result.

B. Recommendations

Since it has not been clearly defined as to how long workers may be overexposed to CS₂ without permanent damage occurring, significant efforts should be made as soon as possible to reduce levels of CS₂ to Federal Standards or below and to provide sufficient protection from over-exposure until such time.

Environmental and medical recommendations are made to control and monitor the excessive exposure to carbon disulfide occurring at this plant:

Environmental

1. Since high environmental levels of carbon disulfide exist even in general room samples resulting in symptomatic workers and abnormal iodine azide tests despite respirator use, it is strongly recommended that all personnel, whether normally assigned there or not including maintenance workers, wear respirators on a continuous basis in the stretch and cutting areas.
2. A suitable supplied air respirator should be considered for all cuttermen to wear during the entire work period. This measure would be temporary until proper engineering controls have been instituted to bring the carbon disulfide levels within safe limits.
3. Other personnel (e.g., spinners, N-10 men, pump testers, and filtermen) in the spinning area should wear respirators when the ventilation system is not operating properly or when they begin developing symptoms of dizziness and/or headaches.
4. Extended acute exposures can occur when maintenance work is performed while the machine is operating. Only personnel required to safely perform the job should be permitted in the area.
5. A program needs to be instituted to provide a work environment in the stretch and cutting areas which will protect the health of workers. Such a program will necessarily require several steps.

- a. Environmental data as necessary to augment that contained in this report for establishing thoroughly the control problems.
- b. Engineering of a suitable control system which will maintain CS₂ levels at standards or below.
- c. Installation of the control system(s)
- d. Environmental testing to insure the control system(s) are providing the necessary environmental control.
- e. Environmental monitoring to ensure the control system is maintaining safe conditions or to spot problems at the earliest stage possible.

Medical

6. All cuttermen and chargehands should be given a complete physical exam as soon as is feasible (certainly within 3 months) to establish the extent of symptomatology and physical disability which may have been caused by exposure to CS₂. Areas of concern should be the cardiac, renal and nervous systems.
7. In general, any worker having suspicious symptoms, an abnormal E_S or E_F should receive an appropriate medical exam and should return only when urine results are negative and symptoms (if any) disappear.
8. Until the respirator program and ventilation changes have decreased symptoms and iodine azide tests revert to normal, all workers working in the cutterhouse, primarily cuttermen and charge hands should have rotation of the cutterhouse responsibilities for periods of time (perhaps every other week) to lessen exposure to areas where high levels of CS₂ exist. The period of rotation may be determined by monitoring symptoms and E values.
9. All workers in the Staple Department should receive periodic iodine azide tests. Cuttermen and chargehands should be tested on the first, fourth, and seventh days of a work week, with beginning and end of shift urine - every third week; spinnermen and other personnel not normally near the cutterhouse for prolonged periods of time should be tested every month of the last day of a work week with beginning and end of shift urines. This urine screening program should be done until sufficient evidence is obtained by the responsible physician that there is no health hazard to workers. Thereafter, periodic medical exam and urine screening should be maintained for all personnel exposed to the Staple Department with special consideration for cuttermen and chargehands.

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VII - APPENDIX A

APPENDIX A

Method for Calculating Time-Weighted Average Exposures

$$\bar{C}_{Acute} = \frac{\sum_{i=1}^n C_i t_i}{\sum_{i=1}^n t_i}$$

\bar{C}_{Acute} time weighted average acute exposure

n total number of acute samples during the shift

C_i concentration of i th acute sample

t_i length of time for the i th acute sample

$$\bar{C}_{General Room} = \frac{\sum_{j=1}^m C_j t_j}{\sum_{j=1}^m t_j}$$

$\bar{C}_{General Room}$ time-weighted average general room exposure

m total number general room samples during shift

C_j concentration of j th general room sample

t_j length of time for the j th general room sample

The two average time-weighted average exposure were then used to calculate a shift time-weighted average:

$$\bar{C}_{shift} = \frac{\bar{C}_{Acute} T_{Acute} + \bar{C}_{General Room} T_{General Room}}{T_{Acute} + T_{General Room}}$$

T_{Acute} total length of time for all acute exposures during the day

$T_{General Room}$ total length of time of general room exposure during the day

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VII - APPENDIX B

CARBON DISULFIDE STUDY

Name _____
Last First Middle

2. Age _____ 3. Sex _____ 4. Race _____

5. Occupational History: (List present job first)

JOB TITLE	HOW LONG	
(1)		1. Cutterman 2. Spinnerman 3. Supervisor 4. Charge Hand 5. Other
(2)		A. Staple Department B. Viscose Department

6. Have you had any alcohol in last 24 hours? _____

Have you had to seek medical attention since the last study in August for a problem from Carbon Disulfide or any other type of fume, gas, or chemical?

A. When? _____

B. Symptoms? _____

C. Doctor or Clinic? _____

D. Treatment? _____

8. Are you wearing a respirator now? Yes _____ No _____

9. How long have you worn the respirator? _____

10. Any difficulty using it? _____

11. Is there any difference as far as symptoms, since you've used respirator

(1) Decreased but still there occasionally (note most common symptom)

SX _____

(2) No more symptoms _____

(3) No difference--still have them _____

(4) No difference--never had any symptoms _____

	Since Respirator		Symptoms Today
	YES	NO	
1. Headache			
2. Dizziness or feeling "high"			
3. Fainting			
4. Difficulty sleeping			
5. Irritable			
6. Nervous			
7. Numbness or tingling in hands or feet			
8. More tired than usual			
9. Muscle aches or weakness			
10. Short of breath			
11. Loss of appetite			
12. Weight loss? How much?			
13. Nausea			