HETA 90-375-2334
JULY 1993
CHAMPION INTERNATIONAL CORPORATION
BUCKSPORT, MAINE

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SUMMARY

In August 1990, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from employees at Champion International Corporation in Bucksport, Maine. The requestors expressed concern over chemical exposures at the plant and indicated that two mill employees had died and other employees had worsening medical conditions.

In November 1990, NIOSH staff conducted an initial site visit to collect background information concerning the request and to perform a walk-through survey of the plant. At a second site visit in March 1991, additional information was gathered, and interviews with employees regarding health concerns were conducted. A third site visit was made in July 1991, to conduct additional medical interviews and to address potential employee exposures to bioaerosols, contaminants in drinking water, noise, and heat. Medical records of 30 employees were subsequently reviewed.

Medical records reviews included those of two deceased Champion employees. These deaths were carefully evaluated as potential occupational sentinel health events, that is, illnesses that signal the potential for grave ongoing exposure hazards for co-workers. One individual had worked in the pulp lab for nearly 2 years. The other was a carpenter in kraft plants and pulp mills since 1977. Both had autopsies; one died of coronary artery disease and the other of systemic vasculitis.

Two employees developed acute respiratory symptoms while working in Tower #3 on October 2, 1990. They were evaluated in a local emergency room and discharged with a diagnosis of toxic inhalation. Subsequent pulmonary function testing has been normal. The source of the exposure was not identified.

The bioaerosol sampling indicated an amplification in the concentration of thermophilic actinomycetes (TA) traced to the bark of the wood used in the paper-making process. The highest concentrations of TAs were found in Tower #3 and in the A-frame building. While these bacteria are the most common organisms involved in the development of hypersensitivity pneumonitis (HP), a type of non-infectious inflammatory lung disease, cases of HP were not identified from the medical record reviews.

Water samples from the drinking water system and the potable water system were analyzed for volatile organic chemicals (VOCs) and trace elements in response to employee concerns regarding the potential for water contamination. None of the samples detected the presence of VOCs or trace elements in concentrations exceeding the maximum contaminant levels (MCLs) specified in the Safe Drinking Water Act.

The area noise measurements made near paper machines #4 and #5 indicated that the three control booths are very efficient in reducing potentially hazardous noise levels. Thus, the booths offer a place for workers to remove hearing protection devices during the work shift without risking noise overexposure. Environmental heat measurements were made in work areas surrounding the paper machines. Wet bulb globe temperature (WBGT) measurements revealed that, with the exception of one booth which was not adequately ventilated, the control booths provided a substantial reduction in heat exposures.   WBGT levels in other areas indicate the need for developing appropriate work/rest regimens to reduce heat exposures.

The two Champion employee deaths in 1989 and 1990, are not felt to represent occupational sentinel health events. Review of the other medical records identified a variety of illnesses among employees throughout the plant. However, this HHE did not identify a specific health outcome which would suggest the need for an epidemiologic study. We did, however, identify potential exposures to noise, heat and thermophillic actinomycetes (TAs). Recommendations are made in the report to develop a comprehensive heat stress management program, to improve specific elements of the hearing conservation program, and to reduce exposures to TAs.

KEYWORDS: SIC 2621 (Paper mills), paper making, paper mill, wood, magazine, noise, heat, bioaerosol, thermophilic actinomycetes.

INTRODUCTION

In August 1990, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from employees at Champion International Corporation in Bucksport, Maine. The requestors expressed concern over chemical exposures at the plant and indicated that two mill employees had died and that other employees had worsening medical conditions. After the initial HHE request was received, the United Paperworkers International Union (UPIU) expressed their support for NIOSH involvement and the Occupational Safety and Health Administration (OSHA) Region I office requested an "in-depth study."

In November 1990, an initial site visit was made to the facility to obtain background information concerning the request and to conduct a walk-through survey of the plant. A decision was made at that time to delay future visits to the plant until an ongoing OSHA investigation was completed. A second visit was made to the plant in March 1991, to obtain additional information and to conduct interviews with employees regarding health concerns. A third visit was made to the plant in July 1991, to address potential employee exposures to contaminants in drinking water, and to noise, heat, and bioaerosols. Additional medical interviews were conducted with employees at that time. The NIOSH evaluations have also included a review of material safety data sheets, a review of air sampling and noise monitoring data, a review of OSHA 200 illness and injury logs, and a review of available medical records. An interim report summarizing the findings from the water analyses and noise monitoring survey was issued in September 1992.

FACILITY DESCRIPTION AND BACKGROUND

Champion International Corporation is a paper manufacturing company. The Bucksport, Maine facility manufactures lightweight coated magazine stock, and at the time of the NIOSH survey employed approximately 1250 workers. The plant is operated 24 hours per day, seven days per week.

Spruce, fir and poplar logs are used to manufacture the magazine stock. The paper making process begins with debarking, where the bark is removed by friction in a drum debarker. The bark is then moved via conveyors and mixed with waste wood and wood chips from this and other plants for use as fuel in the power plant. The Bucksport mill utilizes both groundwood and thermomechanical pulping processes. The pulp wood is blended with kraft pulp (purchased bleached pulp), waste paper, biocides, and various dispersants in the stock prep area. Sulfite pulp was produced at this mill until 1966, at which time, because of environmental concerns, a decision was made to purchase kraft pulp. Four paper machines are used to produce the rolls of paper which are then coated with a mixture containing clay, latex, titanium dioxide and starch before undergoing a calendering process to produce a shine.

There are several labs within the plant, including the analytical lab, the pulp lab and the super calender lab. In the analytical lab, there is a small printing press which is used a few times per shift as a quality control check on the paper. Wastewater analyses are also performed in this lab (there is on-site wastewater treatment at Champion) along with a variety of physical tests of the paper. The super calendar lab also has a small printing press which is used a few times per shift. This lab is responsible for testing the optical properties of the paper such as brightness, opacity, and gloss. Various physical tests are also performed in the pulp lab along with tests for pH, chlorine and ash content. Changes were made in early 1990, to the pulp lab's ventilation system, and improvements were made to minimize the potential for entrainment of potentially-contaminated mill air. The changes reportedly include the following: the lab was placed under positive pressure with respect to surrounding areas; doors, windows and walls were sealed in an effort to minimize inward flow of air from the plant; a ducted source of outside air was provided; a fresh air heat transfer unit was installed; the chlorine injector system located outside the lab was modified to prevent chlorine release; and the machine chest top entries (containing stock prep chemicals) also located outside the lab, were sealed.

At the time of the NIOSH survey there were two separate water systems within the plant: the potable water system and the mill water system. While the source of the water is the same (Silver Lake), and both systems are filtered and chlorinated, there are separate supply lines for these two water systems, and only the potable water source is tested by the Bucksport Water Company for adherence to the federal drinking water standards. The mill water supply is used for process water and at the time of our survey had been used in sinks, eyewashes, toilets and showers.

On October 25, 1990, OSHA noted the potential for chemical contamination of the mill water system when paper coating contaminated the mill system resulting in the discharge of a white, milky substance.[1] The coating consisted of clays and starch, with small amounts of biocide. It was subsequently determined that conditions existed such that coating backed up into the warm water reclaim tank causing the contamination; however, it is unclear if this situation occurred at other times, or at other locations, and if so, with what frequency. In February 1991, OSHA issued a citation to Champion regarding the fact that "Open or potential cross connections existed between a system furnishing potable water and a system furnishing non potable water." Other citations were issued for failure to adequately-label some non-potable water outlets to indicate clearly that the water is "unsafe and is not to be used for drinking, washing, or cooking purposes," and failure to provide emergency eyewash and shower facilities with water meeting the requirements of potable water.[2] All citations were reportedly-abated as of August 1991, and in April 1992, a project to replace the use of mill water with potable water in all sinks, eyewashes, showers, and toilets was completed.

METHODS

Medical Evaluation

Plant employees were invited to meet on site or off site with NIOSH staff for individual, confidential medical interviews. These employees were self selected and many were identified by union representatives. Employees were also invited to present medical records for review or to identify medical providers from whom NIOSH investigators could obtain them. The medical records from 30 workers, including those of the two deceased workers, were thus obtained and reviewed. The medical evaluation also included a review of the illness reports from the medical department (OSHA 200 logs).

Environmental Evaluation

Bioaerosol Sampling

Bioaerosol sampling was conducted based on a review of the literature which described respiratory illnesses, including hypersensitivity pneumonitis, among workers in the pulp and paper industry exposed to contaminated wood pulp, dust, and chips. This sampling was also performed because of reports of respiratory symptoms among workers assigned to Tower #3.

The purpose of the bioaerosol monitoring was to determine the concentrations of airborne microorganisms, specifically bacteria and fungi, at selected process locations. Sampling locations included Tower #3 (where the wood chip and treatment plant biomass conveyor systems converge); the A-frame building (on the catwalk at the top of the building); the debarking building (on the catwalk next to the rotating cylinders); the pulp room (stationed between the far side machinery); and outside the old training building (used as a control).

The Andersen 2-stage viable cascade impactor was used to obtain the bioaerosol samples at a flow rate of 28.3 liters per minute (Lpm). The 50% effective cutoff diameter for the Andersen sampler is 8 microns (µm); hence, larger, non-respirable particles are collected on the top stage and smaller, respirable particles are collected on the bottom stage. Trypticase soy and malt extract agars were used for the enumeration of bacteria and fungi, respectively. The sample plates for bacteria were incubated at 50°C to promote the growth of thermotolerant bacteria, specifically thermophilic actinomycetes (TAs). The sample plates for fungi were incubated at 30°C. Sample times varied according to the estimated load on the sample plates at different process locations. For example, sampling times of 1 to 5 minutes were used in the A-frame building; whereas, sampling times of 5 to 10 minutes were used for the control samples collected outside. For each location, two samples were collected for bacteria and four samples were collected for fungi. Temperature and relative humidity were recorded for each sample run.

All sample plates were counted at 24 and 48 hours; fungal sample plates were also counted at 72 hours. Results are reported as colony forming units per cubic meter of air sampled (CFU/m^3), and percentage of TAs (for the bacterial plates). Species identification for TAs were based on colony morphology as determined from Bergey's Manual of Determinative Bacteriology.[3]

Water Sample Analyses

In response to concerns regarding the potential for water contamination, on July 31, 1991, water samples were collected from various locations throughout the plant for analysis of volatile organic chemicals (VOCs) and trace elements. Samples were collected from the mill water system (eyewash and laboratory sinks) as well as from the potable water system (drinking water in nurse's station).

The water samples were analyzed for VOCs according to the Environmental Protection Agency (EPA) Method 502.2.[4] This method utilizes gas chromatography with photoionization and electrolytic conductivity detection. A list of the 58 VOCs quantitated and their respective analytical limits of detection (LODs) are shown in Table 1. The water samples were also analyzed using gas chromatography with mass spectrometry detection (GC/MS) for confirmation of VOCs detected. EPA Method 200.7 was used in the analysis of the water samples for trace element content.[5] This method uses inductively coupled plasma emission spectrometry. A list of the 25 elements quantitated

Table 1

Detection Limits for 58 VOCs quantitated in
Water Samples Collected at Champion International*

July 31, 1991

VOC†	LOD (µg/ℓ)Δ	VOC†	LOD (µg/ℓ)Δ
Bromobenzene	2	Dichlorodifluoromethane	1
Bromodichloromethane	2	Fluorotrichlromethane	1
Bromform	1	Carbon Tetrachloride	1
Bromomethane	1	1,2-Dichloroethane	1
Chlorobenzene	1	Trichloroethylene	1
Chlorodibromomethane	1	p-Dichlorobenzene	1
Chloroethane	1	1,1-Dichloroethylene	1
Chloroform	3	1,1,1-Trichloroethane	1
Chloromethane	1	Vinyl Chloride	1
o-Chlorotoluene	1	cis-1,3-Dichloropropene	1
p-Chlorotouluene	1	Ethyl Benzene	1
Dibromomethane	1	m-Xylene and p-Xylene	1
m-Dichlorobenzene	1	o-Xylene and Styrene	1
o-Dichlorobenzene	1	Toluene	1
trans-1,2-Dichloroethylene	1	n-Butylbenzene	1
cis-1,2-Dichloroethylene	1	Hexachlorobutadiene	1
Dichloromethane	1	Isopropylbenzene	1
1,1-Dichloroethane	1	p-Isopropyltoluene	1
1,1-Dichloropropene	1	Naphthalene	1
1,2-Dichloropropane	1	n-Propylbenzene	1
1,3-Dichloropropane	1	sec-Butylbenzene	1
trans-1,3-Dichloropropene	1	tert-Butylbenzene	1
2,2-Dichloropropane	1	1,2,3-Trichlorobenzene	1
1,1,2-Trichloroethane	1	1,2,4-Trichlorobenzene	1
1,1,1,2-Tetrachloroethane	1	1,2,4-Trimethylbenzene	1
1,1,2,2,-Tetrachloroethane	1	1,3,5-Trimethylbenzene	1
Tetrachloroethylene	1	Benzene	1
1,2,3-Trichloropropane	1	1,2-Dibromoethane	1
Bromochloromethane	1	1,2-Dibromo-3-Chloropropane	1

* Water samples were analyzed according to EPA Method 502.2.
† VOC = volatile organic chemical.
Δ Limit of detection (LOD) reported in micrograms per liter of water (µg/ℓ).

and their respective analytical LODs are shown in Table 2. The water was allowed to run for several minutes before samples were collected from each source. In addition, all water samples were brought to a pH of two or less using nitric acid and hydrochloric acid solutions for the elemental and VOC analyses, respectively. Sample containers were selected and cleaned as specified in the EPA methods.

Table 2

Detection Limits for 25 Elements
Quantitated in Water Samples
Collected at Champion International*

July 31, 1991

Element	LOD (µg/ℓ)†
Aluminum	200
Antimony	60
Arsenic	100
Barium	200
Beryllium	5
Calcium	500
Cadmium	5
Cobalt	50
Chromium	10
Copper	20
Iron	100
Lithium	20
Magnesium	500
Manganese	20
Molybdenum	40
Nickel	40
Lead	50
Phosphorus	100
Selenium	100
Silver	10
Sodium	200
Strontium	20
Thallium	200
Vandium	50
Zinc	20

* Analyses performed using EPA Method 200.7.
† LOD = Limit of Detection; LODs are reported in micrograms per liter (µg/ℓ) of water.

Noise Monitoring

Area noise measurements were made by the paper machines at the locations where noise attenuating booths had been placed, in the basement under one of the paper machines, and in the drum debarking building. A Larson-Davis Laboratories Model 800B Precision Integrating Sound Level Meter was used. Octave band measurements were made at the above locations in the mill at consecutive center frequencies of 31.5 Hertz (Hz) to 16 kilohertz (kHz) along with A-weighted and C-weighted scales. All measurements were made with the sound level meter integrating the sound energy over a 1-minute period with a 3 decibel (dB) exchange rate. Values are reported as 1-minute equivalent levels (L_{eq}) at each measurement band or scale. In addition, a review of Champion's hearing conservation program was conducted.

Heat Stress Evaluation

Environmental heat measurements were made in areas typically considered hot environments in paper mills: the paper machines, coaters, and driers. A Reuter Stokes Wibget heat stress meter was used to obtain the measurements. This direct reading instrument electronically calculates the wet bulb globe temperature (WBGT) index using direct readings from the wet bulb (WB), dry bulb (DB), and globe temperature (GT) thermometers. Measurements were collected approximately four feet above the floor, after the meter was allowed to stabilize. The measurements were made to obtain information concerning potential heat exposures in these work areas and to assess the efficacy of the control booths in minimizing heat exposure. No attempt was made in this limited survey to follow individual workers throughout the course of the day to obtain time weighted average (TWA) WBGTs.

EVALUATION CRITERIA

Bioaerosols

The term bioaerosol refers to airborne particles, volatile organic compounds, or large molecules that are either living or were released from a living organism.[6] Sources of bioaerosols include bacteria, fungi, protozoa, viruses, algae, and mammals. In this evaluation the bioaerosol assessment focused on assessing bacteria and fungi present in selected areas of the mill. Literature reports have documented cases of hypersensitivity pneumonitis, a type of non-infectious inflammatory lung disease, among workers in the paper manufacturing industry exposed to raw wood products contaminated with bacterial and fungal spores.

Hypersensitivity pneumonitis (HP), also called extrinsic allergic alveolitis, can result from sensitization and repeated exposure to inhaled organic dusts (antigens). The most common organisms involved in the development of HP are the bacteria, thermophilic actinomycetes (*Micropolyspora faeni*, *Thermoactinomyces vulgaris*, *Thermoactinomyces saccharin*, and *Thermoactinomyces candidus*).[7] Thermophilic actinomycetes have been implicated in the development of the hypersensitivity disease "farmers lung," as a result of its presence in moldy fodder. Hypersensitivity to wood dust, pulp, and chips has been described in the literature.[8,9,10] The offending agents have included thermophilic actinomycetes as well as various fungi, including *Aspergillus fumigatus*, *Cryptostroma corticale*, *Alternaria sp*., *Pullularia sp*., and *Penicillium frequentans*.[11]

While up to 50% of similarly-exposed yet asymptomatic individuals may have humoral or cellular immune responses to the antigen, the number of individuals in a given population with detectable disease has ranged from only 3 to 15%.[12,13] Development of HP, like all allergic diseases, depends on individual or host factors, history of prior exposure to the antigen, and duration and dose of antigen exposure. Some studies have suggested that other factors may also be involved in the development of HP, such as concomitant exposure to certain chemicals[14] or to infectious agents which stimulate or enhance the immune response.[15]

There are two clinical forms of HP. The acute form generally occurs in individuals intermittently exposed to a high dose of the antigen. Symptoms of fever, chills, malaise, dry cough, and dyspnea begin from 4 to 8 hours after inhalation of the antigen, gradually subsiding over the next 18 hours. Fatigue may persist for several weeks, and with repeated exposure, anorexia and weight loss is common.[16] The chronic form of the disease can occur with continuous exposure to low levels of the antigen. The onset of symptoms is more insidious, and chills and fever occur less commonly.

With continued exposure to the antigen, symptoms can progressively worsen, leading to pulmonary disability and, in some cases, death.[16] In some patients the disease may progress even after exposure to the offending antigen has stopped. For this reason, once HP has been diagnosed the following medical management is recommended: (1) identification of probable antigen, (2) avoidance of antigen exposure, and (3) medical follow-up, using pulmonary function tests and carbon monoxide diffusing capacity tests to chart the patient's recovery.

Environmental evaluation criteria for airborne microorganisms do not currently exist.

Drinking Water

There are 83 contaminants which are regulated under the Safe Drinking Water Act of 1986.[17] These contaminants fall under the categories of VOCs, microbiology and turbidity, inorganics, organics, and radionuclides. The samples analyzed in this survey include those in the VOC, organics and inorganics categories only. Of the 25 elements analyzed by NIOSH, 17 are on the list of regulated inorganics. All 14 of the regulated VOCs were quantitated in the water samples analyzed by NIOSH along with six additional contaminants which are regulated under the organics section of the Act. In the Results and Discussion section of this report, the results from the water analyses are compared with the maximum contaminant levels (MCLs) specified in the Act, where appropriate.

Noise

Occupational deafness was first documented among metalworkers in the sixteenth century.[18] Since then, it has been shown that workers have experienced excessive hearing loss in many occupations associated with noise. Noise-induced loss of hearing is an irreversible, sensorineural condition that progresses with exposure. Although hearing ability declines with age (presbycusis) in all populations, exposure to noise produces hearing loss greater than that resulting from the natural aging process. This noise-induced loss is caused by damage to nerve cells of the inner ear (cochlea) and, unlike some conductive hearing disorders, cannot be treated medically.[19]

While loss of hearing may result from a single exposure to a very brief impulse noise or explosion, such traumatic losses are rare. In most cases, noise-induced hearing loss is insidious. Typically, it begins to develop at 4000 or 6000 Hz (the hearing range is 20 Hz to 20,000 Hz) and spreads to lower and higher frequencies. Often, material impairment has occurred before the condition is clearly recognized. Such impairment is usually severe enough to permanently affect a person's ability to hear and understand speech under everyday conditions. Although the primary frequencies of human speech range from 200 Hz to 2000 Hz, research has shown that the consonant sounds, which enable people to distinguish words such as "fish" from "fist," have still higher frequency components.[20]

The OSHA standard for occupational exposure to noise (29 CFR 1910.95)[21] specifies a maximum permissible exposure level (PEL) of 90 dB(A)-slow response for a duration of 8 hours per day. The regulation, in calculating the PEL, uses a 5 dB time/intensity trading relationship. This means that in order for a person to be exposed to noise levels of 95 dB(A), the amount of time allowed at this exposure level must be cut in half in order to be within the OSHA PEL. Conversely, a person exposed to 85 dB(A) is allowed twice as much time at this level (16 hours) and is within his daily PEL. Both NIOSH, in its Criteria for a Recommended Standard,[22] and the American Conference of Governmental Industrial Hygienists (ACGIH), in their Threshold Limit Values (TLVs),[23] propose an exposure limit of 85 dB(A) for 8 hours, 5 dB less than the OSHA standard. Both of these latter two criteria also use a 5 dB time/intensity trading relationship in calculating exposure limits.

Time-weighted average (TWA) noise limits as a function of exposure duration are shown as follows:

Duration of Exposure (hrs/day)	Sound Level [dB(A)] NIOSH/ACGIH	OSHA
16	80	85
8	85	90
4	90	95
2	95	100
1	100	105
1/2	105	110
1/4	110	115*
1/8	115*	---
		**

* No exposure to continuous or intermittent noise in excess of 115 dB(A).

** Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

The OSHA regulation has an additional action level (AL) of 85 dB(A) which stipulates that an employer shall administer a continuing, effective hearing conservation program when the TWA value exceeds the AL. The program must include monitoring, employee notification, observation, an audiometric testing program, hearing protectors, training programs, and recordkeeping requirements. All of these stipulations are included in 29 CFR 1910.95, paragraphs (c) through (o).[21]

The OSHA noise standard also states that when workers are exposed to noise levels in excess of the OSHA PEL of 90 dB(A), feasible engineering or administrative controls shall be implemented to reduce the workers' exposure levels. Also, a continuing, effective hearing conservation program shall be implemented.

Heat Stress

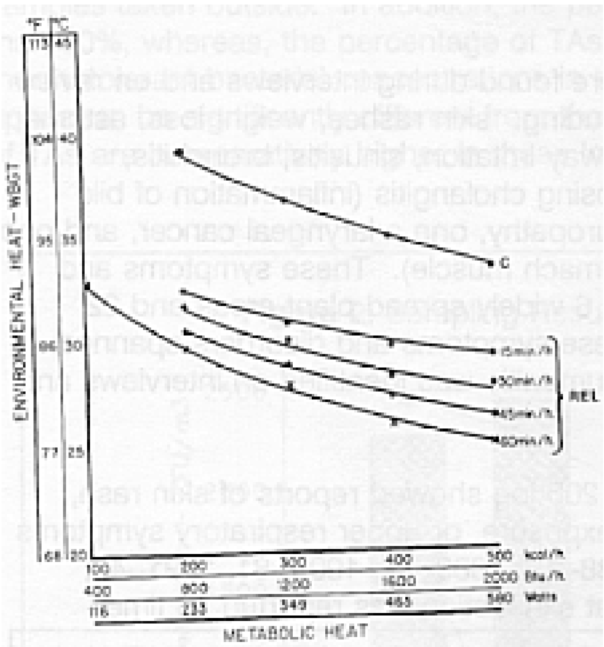
The body maintains a natural heat load resulting from metabolic processes, muscular activity, and various environmental sources such as the sun, heated surfaces, and the air. When the body's natural regulatory mechanisms fail to cope with the total heat load (environmental and metabolic), a variety of conditions may develop.[24] Heat syncope (fainting) and heat edema (swelling due to body fluid accumulation) may occur in employees standing erect and immobile in a hot environment. Heat cramps may occur when salt, naturally lost in sweating, is not adequately replaced. Heat exhaustion, due either from salt or water depletion, may lead to weakness, nausea, headache, and fainting. The most serious complication, heat stroke, represents a complete breakdown of the body's heat regulating systems and may be fatal if prompt treatment is not obtained.

Both NIOSH and the ACGIH recommend the use of the WBGT index to measure environmental heat because of its simplicity and suitability with regard to heat stress. Both recommendations use a maximum core body temperature of 38°C (100.4°F) as the basis for the environmental criterion.[23,24]

The WBGT index takes into account environmental conditions such as air velocity, humidity, radiant heat and air temperature. The calculation of WBGT is as follows:

$WBGT_{in} = 0.7(WB) + 0.3(GT)$ (indoors or outdoors without solar load)
$WBGT_{out} = 0.7(WB) + 0.2(GT) + 0.1(DB)$ (outdoors with solar load)

Figure 1. NIOSH Recommended Heat Exposure Limits -- Heat Acclimatized Workers



NIOSH has developed two sets of recommended limits: one for acclimatized workers [recommended exposure limit (REL)], and one for unacclimatized workers [recommended alert limit (RAL)], The NIOSH RELs are shown in Figure 1.

Similarly, ACGIH recommends Threshold Limit Values (TLVs) for environmental heat exposure permissible for different work-rest regimens and work loads.[25] The NIOSH REL and ACGIH TLV criteria assume that the workers are heat acclimatized, are fully clothed in summer-weight clothing, are physically fit, have good nutrition, and have adequate salt and water intake. Modification of the evaluation criteria are needed if the worker or conditions do not meet these assumptions. Selection of a protective NIOSH WBGT exposure limit is contingent upon identifying the appropriate work-rest schedule and the metabolic heat produced by the work. The ACGIH heat exposure TLVs are published for light (up to 200 kcal/hr), moderate (200 to 350 kcal/hr), and heavy (350 to 500 kcal/hr)work load categories.

RESULTS AND DISCUSSION

Medical Evaluation

The medical records provided and requested, by or on 30 employees were reviewed. These medical records included those of 2 deceased Champion employees.

One death was of a 34-year old worker from complications of coronary artery disease. This individual worked in the pulp lab for nearly 2 years. Symptoms of exertional chest pain and dyspnea were first reported in March of 1989, and his death was in December 1989. His clinical course was consistent with severe ischemic heart disease, and included clinical diagnostic evaluation by cardiac catheterization and therapeutic intervention with coronary bypass graft surgery. He died several days after his bypass surgery, and the post-mortem examination showed extensive multi-vessel coronary artery disease, including previous myocardial infarctions.

The other death was of a 58 year old employee, a carpenter--employed in kraft plants and pulp mills since 1977, with a systemic vasculitis. Flu-like symptoms and a 30 pound weight loss was evaluated in July 1989, without a definitive diagnosis. Multiple organ system symptoms, including the gastrointestinal tract, the respiratory system, and the joints, preceded a final hospitalization and death in July 1990. His autopsy showed a systemic small vessel vasculitis with widespread disease including renal, splenic, skin, and pulmonary involvement.

Two employees developed acute respiratory symptoms while working in the Tower #3 area (where the woodchip and treatment plant biomass conveyor systems converge) on October 2, 1990. They were evaluated in a local emergency room for severe respiratory symptoms. The findings were consistent with a toxic inhalation exposure. Initial NIOSH evaluation entertained the working diagnosis of hypersensitivity pneumonitis, and prompted environmental evaluation for thermophilic organisms, however, final review of the records did not confirm HP and subsequent pulmonary function testing has been normal.

A variety of other symptoms and disorders were found during interviews and on review of personal medical records of employees including: skin rashes, weight loss, asthma, pneumonia, sore throat, depression, upper airway irritation, sinusitis, bronchitis, headache, carpal tunnel syndrome, and sclerosing cholangitis (inflammation of bile duct). One worker had a multifocal motor neuropathy, one a laryngeal cancer, and one a gastric leiomyosarcoma (a cancer of the stomach muscle). These symptoms and disorders have been reported in workers from 6 widely spread plant areas and 22 different job assignments, and the onset of these symptoms and disorders spanned several years in time. No hypersensitivity pneumonitis was identified on interviews and medical record reviews.

A review of the illness reports from the OSHA 200 log showed reports of skin rash, headache, heat exhaustion, "chemical/fume" exposure, or upper respiratory symptoms or complaints by year: 1986--5, 1987--16, 1988--16, 1989--37, 1990--81, 1991--43, 1992--10, and through mid-June 1993--4. Heat exhaustion was reported 18 times in 1991, 3 times in 1992, and 3 times through mid-June 1993.

Table 3

Concentration of Thermotolerant Bacteria and Fungi in Air Samples

Location	Type	Concentration (CFU/m^3)★		% Respirable		% TAs†	
		Mean	STD△	Mean	STD	Mean	STD
Tower #3	Bacteria	2265	235	77	15	99	2
A-Frame	Bacteria	2456	1294	36	14	93	5
De-barking	Bacteria	131	45	45	23	82	5
Pulp Room	Bacteria	41	22	29	40	66	13
Control	Bacteria	21	25	45	64	45	64
Tower #3	Fungi	32	22	0	0		
A-Frame	Fungi	329	502	11	22		
De-barking	Fungi	817	701	13	16		
Pulp Room	Fungi	92	25	75	24		
Control	Fungi	581	370	16	7		

★ Concentration reported in colony forming units per cubic meter of air sampled (CFU/m^3).

Environmental Evaluation

Bioaerosols

Table 3 includes the summary data from the bioaerosol monitoring. The mean bacterial and fungal concentrations are reported along with the percentage of respirable organisms, and for bacterial samples, the percentage of TAs. This information is graphically presented in Figures 2 and 3. Figure 2 includes the bacterial results and Figure 3, the fungal sampling results. Observation of Figure 2 clearly indicates that the highest bacterial concentrations occurred in Tower #3 and the A-frame building. These concentrations are two orders of magnitude greater than those observed in the control samples taken outside. In addition, the percentage of TAs in these samples is greater than 90%, whereas, the percentage of TAs in the control samples falls to 45%. The thermotolerant bacterial concentrations in the debarking area and the pulp room do not appear to be significantly different from the control samples. However, the percentages of TAs are comparatively higher in these locations as compared to the controls.

Figure 2. Sampling Results for Thermotolerant Bacteria

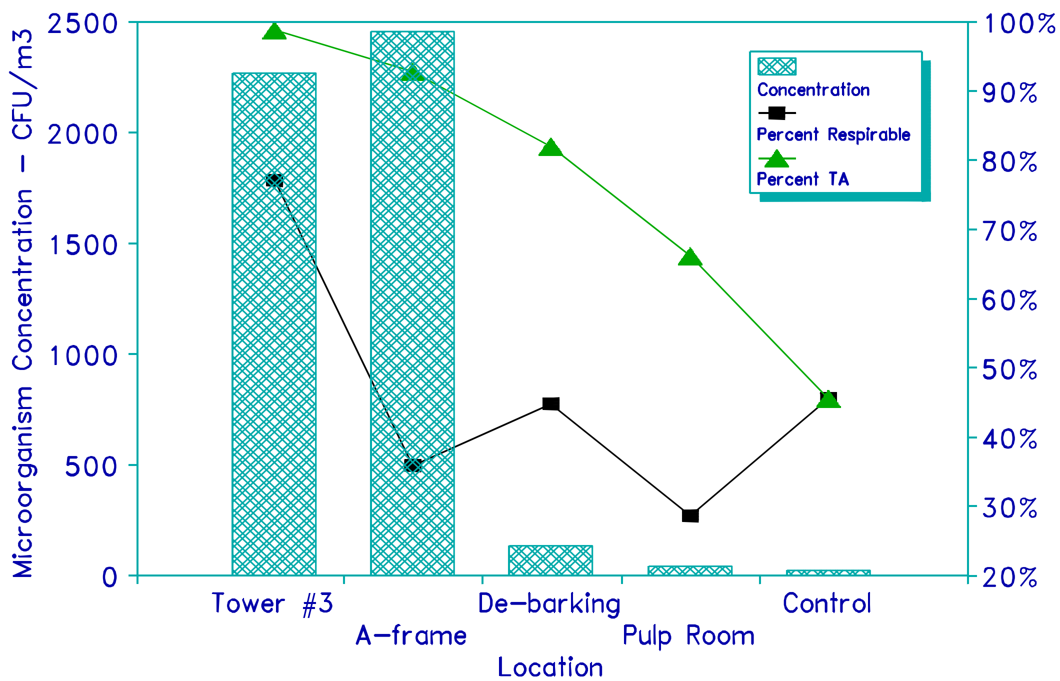
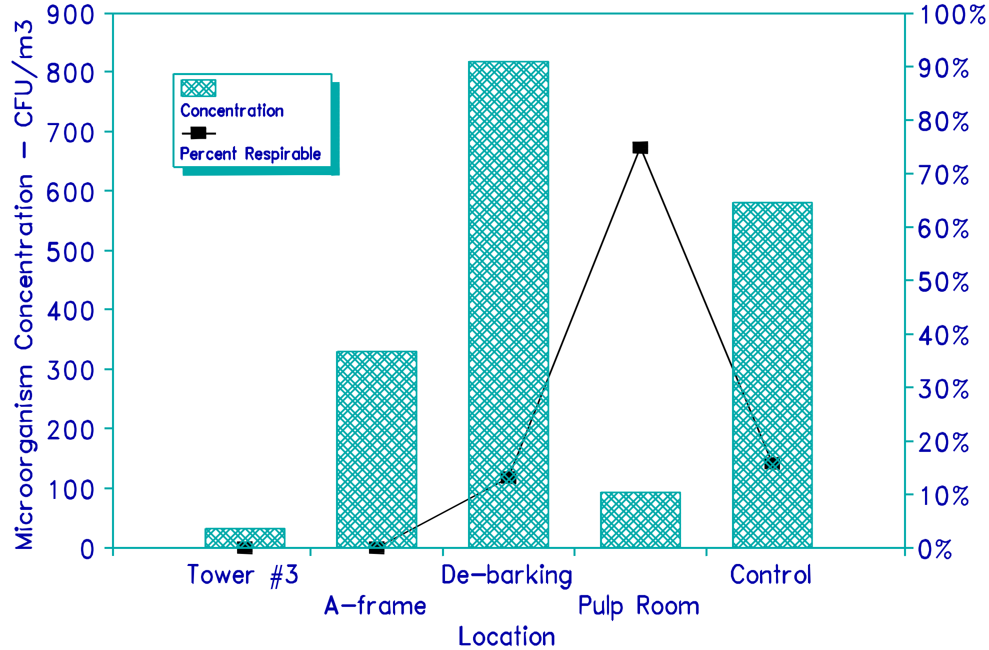


Figure 3. Sampling Results for Fungi



The degree of amplification in the concentration of TAs in Tower #3 and the A-frame building compared to the control samples support the conclusion of a viable source traced to the bark of the wood used for the paper milling process. The absence of similar concentrations in the debarking area can be directly attributed to the application of water to the wood logs during the bark removal operation. This "wetting" action reduces the potential for bacterial entrained dust or wood particulates to become airborne.

Observation of Figure 3 does not indicate the existence of fungi around process operations at concentrations significantly different from those observed in the control samples. However, the predominance of TAs on some of the fungal sample plates may have adversely affected the ability of fungi to grow, therefore, observed counts may have been underestimated. In addition, many of the sampling plates having lengthier sampling times were overgrown, decreasing the reliability of the counts.

Water Samples

Table 4

Locations and Sources of Water Samples Analyzed for VOCs and Elements

LOCATION	SOURCE
Wet End Eyewash Between 1 & 2 Paper Machines	Mill Water
Ground Wood Lab	Mill Water
Analytical Lab Sink Near Computers	Mill Water
Kraft Lab Sink	Mill Water
Supply Room Nurse's Station Sink	Potable Water

Table 4 lists the locations and sources of water samples analyzed for VOCs and elements. A total of nine water samples were collected for VOC analysis, including duplicate samples for all but the water sample obtained in the nurse's station; the sample container for this duplicate had been contaminated prior to sample collection. Of the 58 VOCs quantitated in the water samples, only 3 were present in any of the samples. Bromodichloromethane and chloroform were present in concentrations of 4.1 and 61 micrograms per liter (µg/L), respectively in the water samples obtained in the nurse's station. While chloroform and traces of bromodichloromethane were later detected in all other water samples by GC/MS, the concentrations found were below the analytic LODs of 3 µg/L and 2 µg/L, respectively. The Safe Drinking Water Act specifies a MCL for total trihalomethanes of 100 µg/L, which includes bromodichloromethane, chloroform, dibromochloromethane, and tribromochloromethane.[4] The water sample obtained in the nurse's station did not exceed this level.

The only other VOC detected in some water samples was dichlorodifluoro-methane (DCDFM). While this substance was noted in samples obtained from the wet end eyewash, analytical lab sink, and the kraft lab sink, the levels detected were considered artificially elevated due to contamination from a peak which was later determined by GC/MS to be sulfur dioxide. Matrix spikes and calibration standard duplicates analyzed after the samples also exhibited higher than expected levels for DCDFM, therefore, the results for DCDFM are inconclusive. No other analytes were detected in any of the samples using GC/MS.

A total of five water samples were collected for elemental analysis as shown in Table 4. Duplicate samples were then obtained in the lab by taking two aliquots from each sample container. Of the 25 elements quantitated, only calcium (Ca), copper (Cu), iron (Fe), magnesium (Mg), manganese (Mn), sodium (Na), and zinc (Zn) were present in any of the samples. The mean concentrations of the two duplicate samples from the five locations are as follows:

Ca = 4.4 to 8.45 milligrams per liter (mg/L)
Cu = none detected (ND)(<0.02) to 0.06 mg/L
Fe = ND (<0.1) to 0.3 mg/L
Mg = 0.7 to 0.8 mg/L
Mn = ND (<0.02) to 0.02 mg/L
Na = 4.25 to 4.45 mg/L
Zn = ND (<0.02) to 0.05 mg/L

Of the elements detected, National Secondary Drinking Water Regulations exist for Cu, Fe, Mn, and Zn. The concentrations detected in the water samples obtained at Champion were below the respective secondary MCLs (for public water systems) with the exception of the sample obtained at the wet end eyewash which had an iron concentration at the MCL (0.3 mg/L).

While the potential existed for contamination of water with process chemicals due to a lack of adequate backflow prevention devices (see discussion in Facility Description and Background Section), such conditions do not always exist and cannot be predicted. In some cases, several failures within the system would have to occur before contamination could occur. Therefore, the possibility of the water being contaminated at any given time (such as when the NIOSH water samples were collected) is low. In addition, the analytical methods used in the NIOSH investigation are limited in the scope of the analytes which can be detected. In order to successfully quantitate contaminants in water samples, the identity of the contaminant must be known, an appropriate analytical method must be available, and appropriate sample collection, preservation and storage conditions must exist to maintain sample integrity prior to analysis. Even then, if a contaminant is successfully identified, sufficient toxicological data may not be available for that contaminant to assess the potential hazard posed by the contamination. Further, information would then be needed regarding the quantity ingested, to enable a hazard determination.

The samples collected by NIOSH were collected at a single point in time and were analyzed for common VOC and trace element contaminants which may be present in drinking water. While no contaminants analyzed were present above safe levels (as specified in the Safe Drinking Water Act), the limitations discussed above do not allow us to generalize that the water samples were completely free of all potentially hazardous contaminants on the day of sampling, or in past years. It should be noted, however, that at the time of our evaluation, signs were posted above the lab sinks and at other locations noting that these sources did not contain potable water. In addition, a project to replace the use of mill water with potable water in sinks, eyewashes, showers, and toilets was begun in June 1991, and has reportedly been completed as of April 1992. Bottled drinking water was also supplied at many locations within the plant during the interim period. These changes should eliminate the potential hazard presented by the previous lack of adequate backflow prevention devices.

Noise

The area noise measurements were made in the paper mill in the aisle between paper machines #4 and #5 at the locations where noise attenuating booths had been placed. Complete readings were made inside and outside of the booths to determine the noise levels emitted by the machinery and the amount of attenuation of the noise afforded by the booths. The measurements made outside of the booths were also used to determine the effectiveness of the E-A-R® Plugs used almost exclusively on the work floor. The effectiveness of the plugs was calculated using NIOSH Method #1[25] for estimating the adequacy of hearing protector attenuation. Additional area noise measurements were made in the basement under paper machine #4 and at the sorting line of the drum debarking building.

Graphs of the area noise measurements are given in Figures 4-9. The data are presented as bar graphs where inside and outside enclosure measurements were conducted. Both the inside and outside measurements are presented together to visually show the amount of attenuation given by the enclosure. In areas where only the outside measurements were made, the data are presented as a line graph with the extreme root-mean-square (rms) noise values measured during the 1-minute integration period plotted along with the L_{eq} values. This method of presentation gives an indication of the variability of the noise in the area. Relatively steady-state noise areas will have minimal distance between the L_{eq} curve and the extreme rms curves. Conversely, highly variable noise sources will have larger distances between the average and extreme values.

The noise measurements made inside of the three enclosures revealed that these booths are very efficient in reducing the noise levels. The enclosures offered 19 to 28 dB(A) of attenuation. These areas thus offer a place for workers to remove hearing protection devices (HPDs) during the work shift without risking noise overexposure. The noise levels measured outside of the booths also point to the need for continued use of HPDs outside of the enclosures. Noise levels on the floor between paper machines #4 and #5 ranged from 86 dB(A) to 94 dB(A).

Two other areas, the basement under paper machines #4 and #5 and the drum debarking sorting line, were monitored for noise. These two locations were found to have noise levels of 103 dB(A) and 94 dB(A), respectively. The effectiveness of an E-A-R® Plug in these two areas, as well as the areas around the paper machines were calculated by the above referenced NIOSH Method #1. The results of these calculations are given in Table 5.

Table 5

Effectiveness of E-A-R® Plugs in Surveyed Areas of the Mill

Mill Area	Level (dB[A])	Reduction Factor (dB[A])	Effective Level (dB[A])
Wet End #5	94.0	31.9	62.1
1st Coater #5	91.9	32.8	59.1
Winder #5	85.9	32.2	53.7
Rewinder #5	87.9	31.5	56.4
Vacuum Pump in Basement	102.6	31.6	71.0
Drum Debarking - Sorting Line	93.8	31.1	62.7

The output from a spreadsheet program which was used to calculate these values according to the NIOSH Method #1 is included as Appendix 1. The earplug effectiveness calculations show that the E-A-R® plugs will offer adequate protection in all of the surveyed areas as long as they are worn properly, i.e., deeply inserted into the ear canal. The requirement for double protection at the sorting line in the drum debarking area is not warranted. The noise levels measured at this location were equal to areas found in the mill near the paper machines. A properly used earplug will work equally well in all of these areas. Even the highest noise levels found near the vacuum pump under paper machine #4 will be adequately attenuated with an E-A-R® Plug. The training programs on the use of HPDs has succeeded in informing workers on the proper insertion of the earplugs as is evidenced by good insertion techniques noted during the survey period.

Table 6

Environmental Heat Measurements
July 31, 1991

Location	Time	DB	WB	GT	WBGT	Comments
		(°F)				
#5 Machine Tender Station inside control booth	08:30	76.0	70.9	79.7	73.6	
#5 Machine Tender Station outside control booth	08:30	95.9	81.8	96.9	86.5	adjusting machines
Backside of #5 Fordrainer	08:55	111.8	105.2	107.2	106.1	a few minutes at a time spent here
#4 Machine Tender Station outside control booth	09:05	95.6	83.2	97.4	87.4	
#4 Machine Tender Station inside control booth	09:30	77.7	75.4	78.7	73.0	
#5 Machine Tender outside booth on picnic table	09:25	96.6	83.8	98.2	88.2	
#5 Coating outside booth	09:42	103.8	83.0	105.7	90.1	
Middle of Run #5 coating by spray area	09:47	106.5	89.6	109.5	96.1	operators spend little time here
Outside coating booth #4	09:55	99.7	80.6	102.0	86.9	
Inside coating booth #4	10:00	68.5	62.3	68.1	64.3	
Inside coating booth #2	10:15	62.5	53.1	68.5	57.8	
Outside coating booth #2	10:20	97.9	80.6	100.0	86.3	
Back Tender #4 inside booth	10:35	70.3	62.2	72.8	65.7	
Back Tender #4 outside booth	10:30	85.7	72.6	88.8	77.4	
Winder #4 inside booth	10:40	72.8	64.5	72.3	66.9	
Winder #4 outside booth	10:45	86.0	72.0	89.1	77.2	
Back Tender station #5	10:55	89.9	73.7	89.6	78.7	booth open on two sides no A/C (outside air in winter)
Inside Winder booth #5	11:15	69.5	59.1	71.6	62.6	
Outside by training area	12:00	72.0	64.7	79.8	68.3	cool, partly sunny
Crane above booth	15:05	112.7	89.7	100.0	93.2	
Mezzanine wet end #1 and #2	15:16	97.6	82.9	96.1	86.5	
Between #1 and #2 outside wet end booth	16:30	94.5	81.7	94.6	85.6	

Heat Stress

Environmental heat measurements made in work areas near the paper machines are shown in Table 6. These measurements were made throughout the day on July 31, 1991, on a day when the outside air temperature was relatively mild (72°F at 12:00 noon).

While efforts were not made in this screening survey to obtain TWA-WBGTs for individual workers, the environmental measurements document some particularly hot areas as well as the benefits of the control booths in reducing the workers' heat exposures. The WBGT levels measured during this survey ranged from 57.8°F (inside a coating booth) to 106.1°F (at the backside of the Fordrainer). The WBGT of 106.1 exceeds the ceiling level recommended by NIOSH for even the lowest metabolic heat load. Workers performing preventive or corrective maintenance in this area would need body cooling and/or heat protective clothing to safely work for extended times (beyond a few minutes).

Relatively high WBGT levels were measured by the coaters and driers (85.4 to 91.1°F), as expected. Assuming a moderate heat load of approximately 300 kcal/hr, the appropriate work/rest regimen recommended by NIOSH would range from 15 to 30 minutes of work per hour at these WBGT levels (see Figure 1). The WBGT levels measured inside the air-conditioned machine tender, coating and winder booths measured 10 to 28°F lower than outside the booths, indicating that these booths provide a substantial benefit in reducing heat exposures in addition to their documented benefit in reducing noise exposures. The extent of the reduction in heat exposure for a given worker is obviously dependent on the amount of time spent in the booth as compared with the time spent in other areas of the mill, and will vary from day to day. A WBGT of 78.7 was obtained inside the back tender station #5 booth. This station is not completely enclosed and does not have a supply of conditioned air. Further reductions in heat exposure could be achieved by enclosing this booth and providing conditioned air to the booth as is done for the other booths.

CONCLUSIONS

The plant site visits and employee interviews identified several areas of concern, including the deaths of two Champion employees, one from coronary artery disease and one from systemic vasculitis, an apparent exposure to an unknown agent in Tower #3 which resulted in acute respiratory symptoms in two employees, the potential for contamination of mill water with process chemicals, and a variety of other health symptoms reported by Champion employees.

The two deaths of Champion employees were evaluated carefully by NIOSH staff for their potential to represent occupational sentinel health events.

Coronary artery disease is a common illness in the United States. The non-occupational risk factors for the development of ischemic heart disease are well described, these include, smoking, hypertension, family history, diabetes, and lipid abnormalities. The best known occupational associations with adverse outcomes from ischemic heart disease are carbon monoxide and carbon disulfide. The potential for chronic exposures to these substances, including exposure to carbon disulfide was not identified at the pulp laboratory worksite. Workplace exposures to fluorinated hydrocarbons or fluorocarbons have been associated with serious and fatal arrhythmias, but these exposures have not been linked to the development of coronary artery disease.

A "systemic vasculitis" is a clinical syndrome of inflammation of blood vessels. This group of diseases are uncommon. Many organ systems are often involved, such as the lungs, kidneys, liver, skin, muscles, brain, and gastrointestinal tract. In most of these conditions the cause or etiology is unknown, an exception is a specific type of systemic vasculitis, polyarteritis nodosa, and chronic infection with the Hepatitis B virus. In many of these syndromes a history of a respiratory illness or infection may precede the diagnosis. It is noteworthy that occupational associations are not well described as causes for these syndromes.

The NIOSH evaluation has concluded that these deaths do not represent occupational sentinel health events, that is, illnesses that signal the potential for grave ongoing exposure hazards for co-workers.

With regard to the Tower #3 incident, a cause for the respiratory symptoms has not been identified. On the day of the incident, an unusual odor was noted by the employees prior to the initiation of respiratory symptoms. While it is possible that contaminated groundwood material was being processed, this can not be concluded with certainty. To our knowledge, further incidents of this nature have not been reported. In addition, while this evaluation identified the presence of elevated levels of thermophilic actinomycetes in Tower #3 (as well as in the A-frame), and these bacteria have been associated with the development of hypersensitivity pneumonitis, this respiratory illness was not identified among employees whose medical records were reviewed, including the two diagnosed with "toxic inhalation."

Various other symptoms and disorders were found on review of medical records of employees from 6 plant areas and 22 job assignments as discussed in the Results section. The onset of these symptoms and disorders spanned several years in time and were not temporally or geographically clustered.

While contamination of the mill water system with process chemicals (clay, starch, biocides) was documented during an OSHA inspection and attributed to a lack of adequate backflow prevention devices, it is unclear if this situation occurred at other times or locations, and if so, with what frequency. It should be noted, however, that the conditions which caused the potential for cross-contamination have since been corrected.

This health hazard evaluation did not identify a specific health outcome which would suggest the need for an epidemiologic study. However, we did identify potential exposure hazards which should be addressed. Recommendations are made below.

RECOMMENDATIONS

1.Over the course of the NIOSH investigation a number of changes have been made with respect to the identification of potential occupational hazards at Champion and education of employees with regard to these potential hazards. The industrial hygiene capabilities have been expanded greatly and Chemical Awareness Training of workers has been completed. These activities are important in the early recognition and identification of suspected hazards. Efforts should be continued in this area so that workplace concerns can be addressed and corrected in a timely fashion. Effective communication between management and employees should be facilitated through the health and safety committees. Employees should be made aware of problems which are idenfitied and should be involved in and informed of the decisions made by management to address those problems. In addition, periodic hazard communication training should be performed, as required by 29 CFR 1910.1200, the OSHA Hazard Communication Standard.

2.A comprehensive heat stress management program should be implemented which includes periodic environmental monitoring, medical examinations, emergency procedures, and worker training.[24] Time-weighted average WBGTs for individual workers exposed to hot environments should be obtained during anticipated hot spells (as forecasted by the National Weather Service), as well as during times when extended maintenance activities are performed, to further quantify heat exposures and the reduction in exposure achieved by the use of the booths on a given day. Heat stress evaluations similar to the one performed by a consultant in August/September 1989, are appropriate. The consultant's report (dated November 7, 1989) documented TWA-WBGTs for various jobs performed on paper machines 4 and 5. The TWA-WBGT levels obtained from such surveys can be compared with the NIOSH and ACGIH evaluation critera to enable the selection of appropriate engineering and administrative controls.

3.A review of the hearing conservation program revealed a few areas which need to be addressed by the company. The monitoring of workers' noise exposures needs to be continued in a systematic fashion. At the time of the NIOSH evaluation, the Environment, Health and Safety Department had 4 personal noise dosimeters in their possession. These meters should be used to survey worker noise exposures throughout the mill. A program that routinely checks exposures at various locations in the mill should be initiated to periodically update the worker noise exposure data. These checks can also be conducted whenever a change in the process is completed, when new equipment is brought into the facility, or when workers have complaints about an area.

4.The medical department, which is in charge of the audiometric test phase of the hearing conservation program, tests all employees on site and then sends copies of the audiograms to a consultant for evaluation. This procedure seems to work well for this company. However, a great deal of nursing staff time is spent transcribing the audiometric data onto other forms for the evaluation. The purchase of an audiometer with microprocessor capabilities would eliminate this time-consuming step and also assure that no transcription errors occur. The microprocessor audiometer would also store the hearing data in a format that would allow a worker's audiometric history to be directly loaded into the patient information program currently in use in the department. Finally, audiometric data stored in a computer format is readily available for further analysis which will give feedback on the effectiveness of the hearing conservation program. New methods of audiometric database analysis are being developed in order to accomplish this kind of feedback on how well the program is working.[26,27,28,29] The American National Standards Institute currently has a working group (ANSI S12.12) preparing a consensus standard for the audiometric database analysis techniques.

5.The review of the hearing conservation program revealed that the medical department did not have readily available a list of TWA noise levels for workers in the mill which would help in the evaluation of the hearing tests. These TWA values were estimated by a member of the medical staff who relied on her memory of areas of the mill to determine those areas greater than 85 dB(A). This procedure is unacceptable. The results of a dosimeter study need to be forwarded to the medical department so that this determination is based on current industrial hygiene information. Also, if the medical department's analysis of the audiometric database finds an area of the plant with less than acceptable nosie exposure control performance, then the industrial hygiene personnel can be directed to the area to reevaluate the use of hearing protection devices or remeasure the workers' noise exposures for possible noise-attenuating engineering controls. In order for these things to happen, one individual should supervise all aspects of the hearing conservation program in order for it to work smoothly and efficiently.

6.Due to the presence of elevated concentrations of thermophilic actinomycetes, access to the A-frame and Tower #3 should be restricted to employees required to be in those areas. These organisms originate from the wood bark and have been implicated in the development of hypersensitivity pneumonitis in sensitized individuals. In addition, Champion should search for feasible engineering controls to minimize worker exposures and should ensure that medical care providers are aware of the potential for HP in certain groups of workers since HP is sometimes difficult to diagnose.

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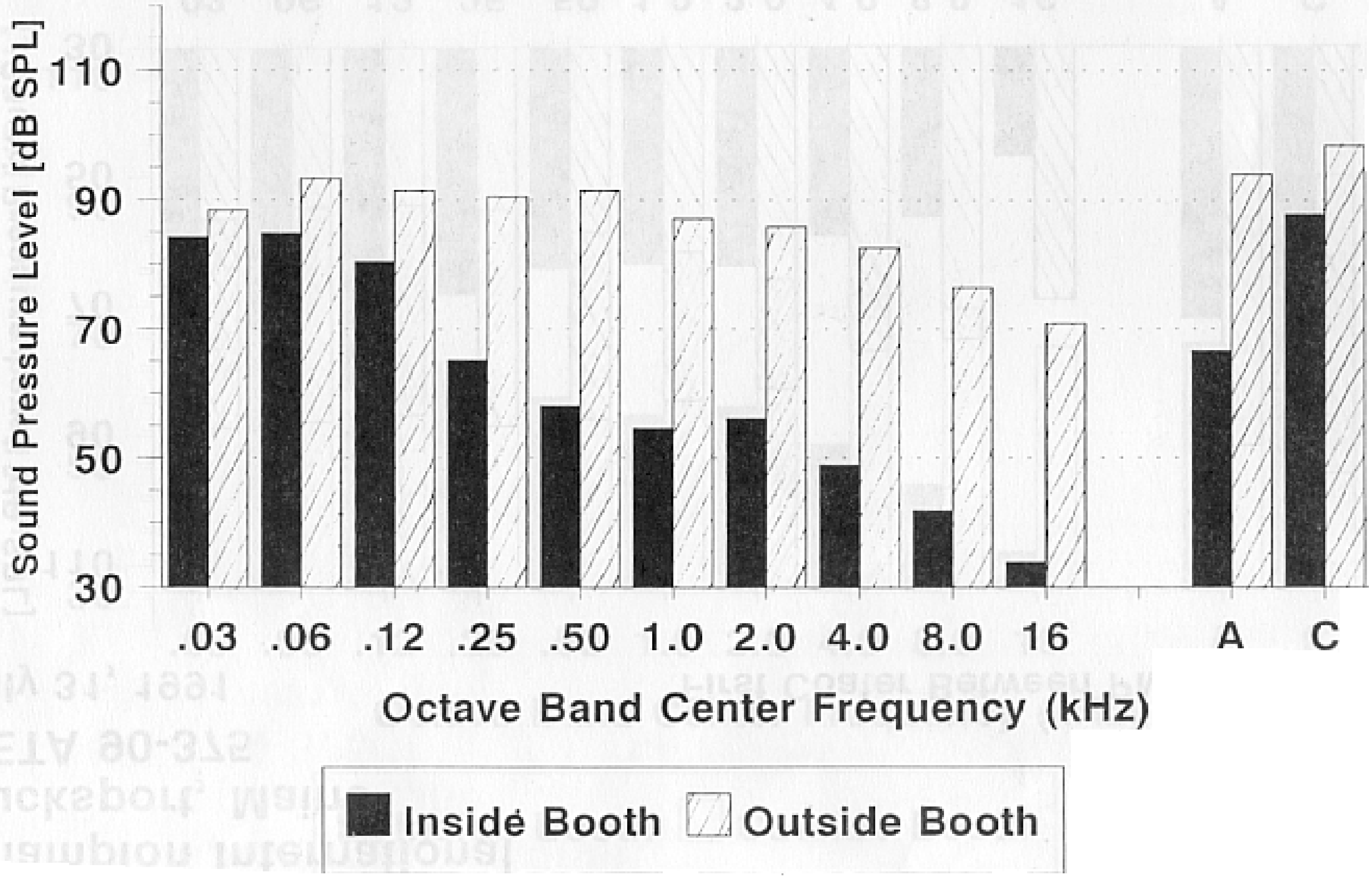
Champion International
Buckport, Maine
HETA 90-375
July 31, 1991

Figure 4

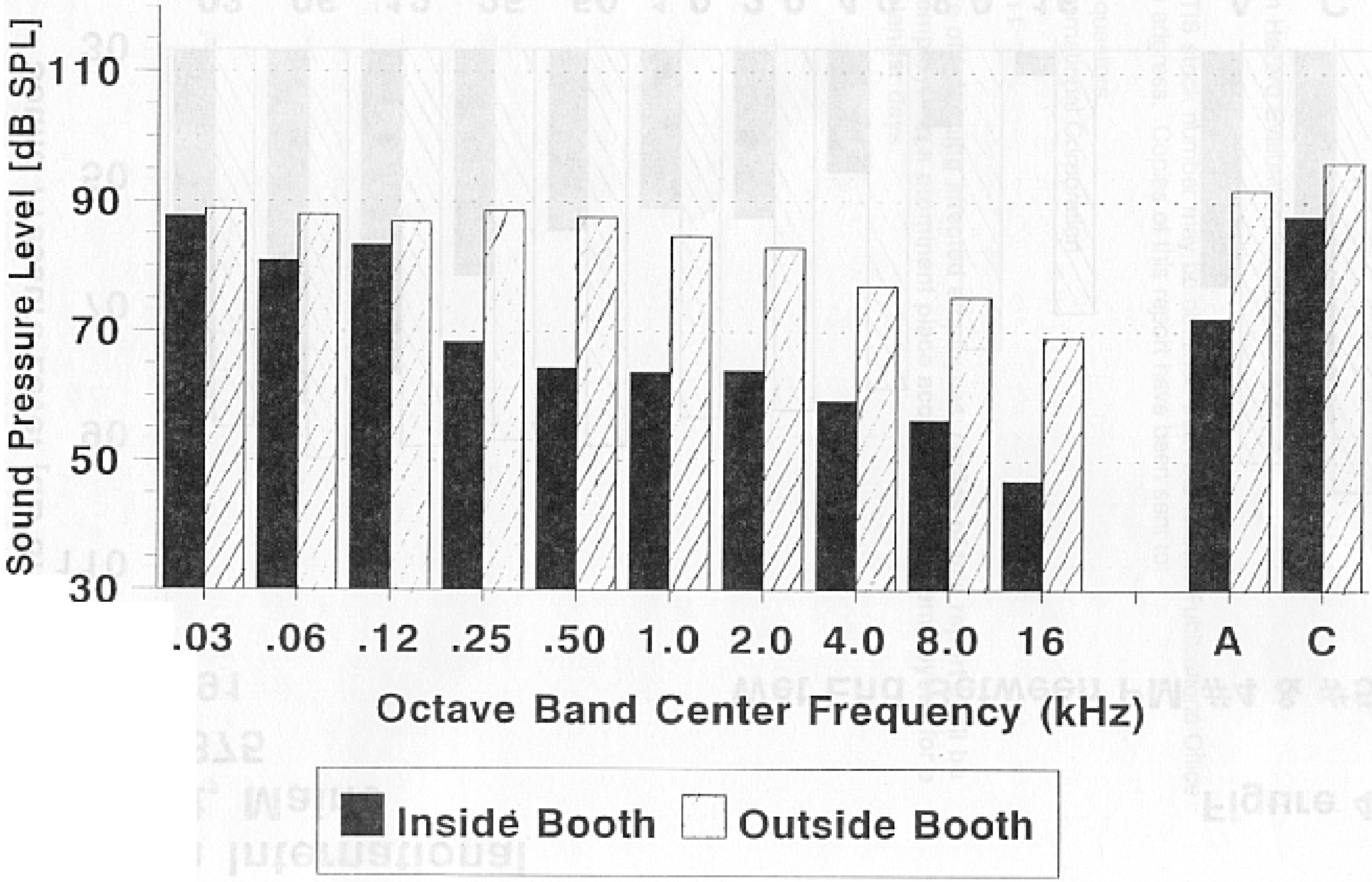
Wet End Between PM #4 & #5



Champion International
Buckspot, Maine
HETA 90-375
July 31, 1991

Figure 5

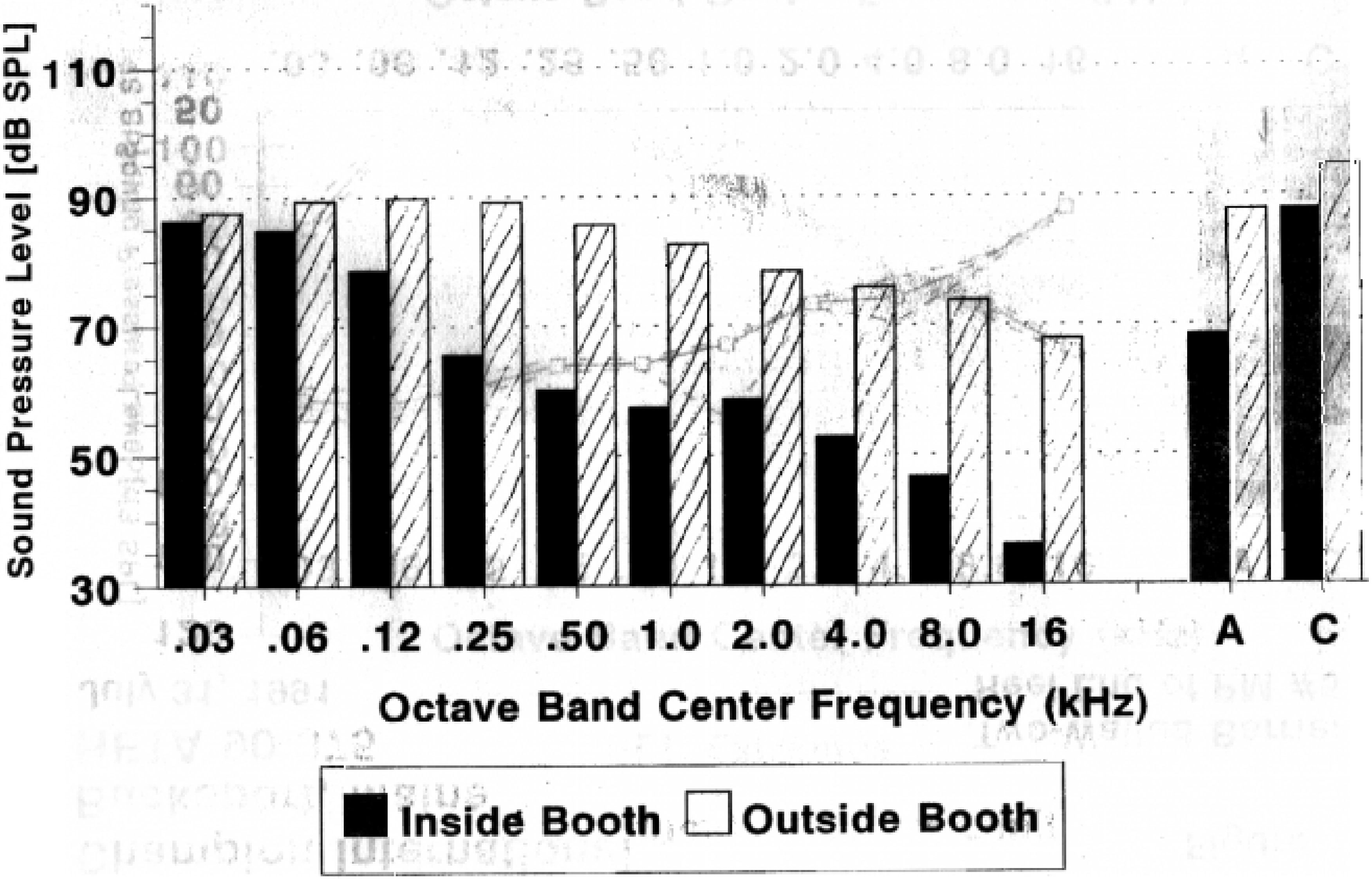
First Coater Between PM #4 & #5



Champion I.
Bucksport, Maine
HETA 90-375
July 31, 1991

Figure 6

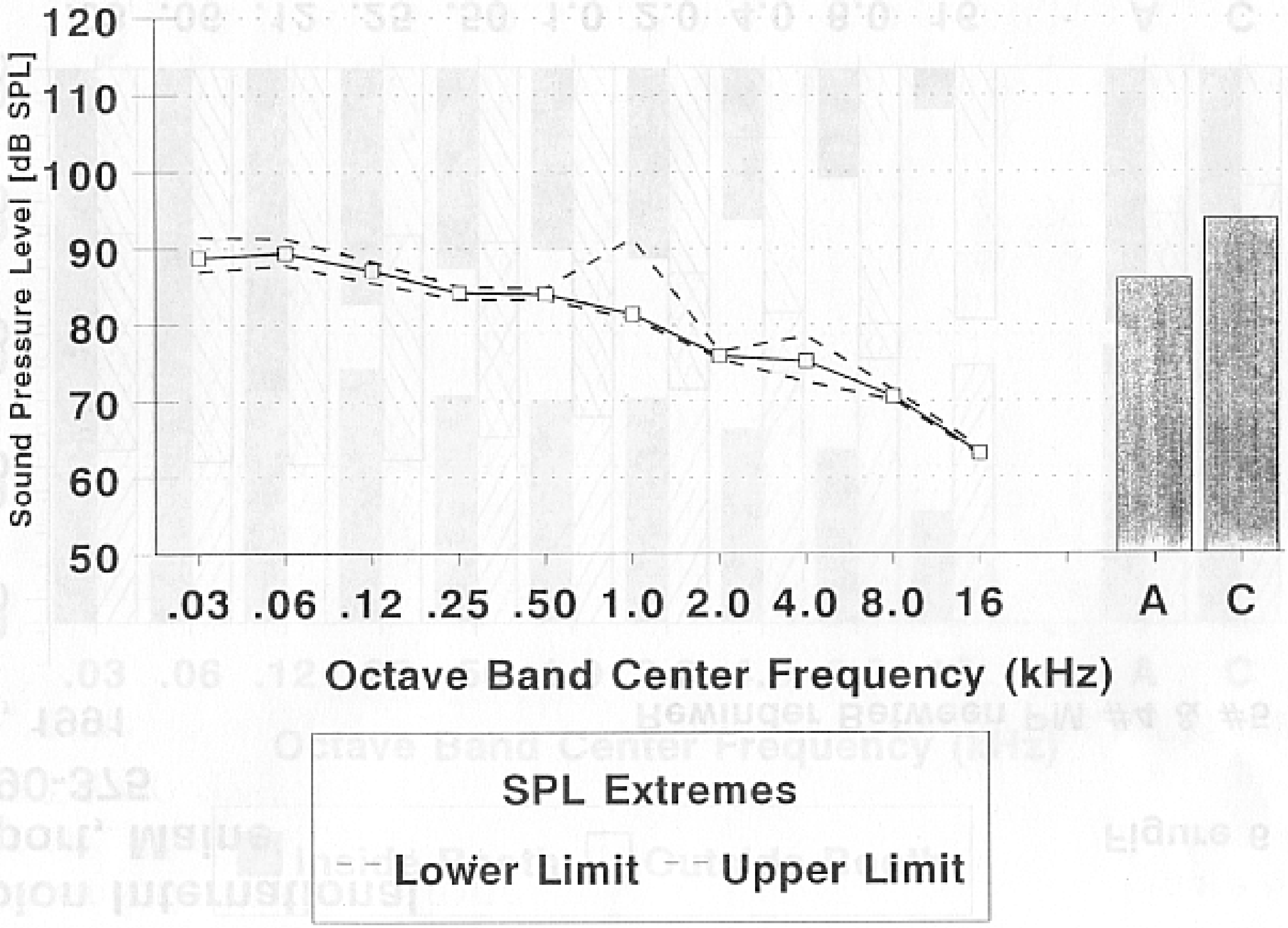
Rewinder Between PM #4 & #5



Champion International
Bucksport, Maine
HETA 90-375
July 31, 1991

Figure 7

Two-Walled Barrier
Reel End of PM #5



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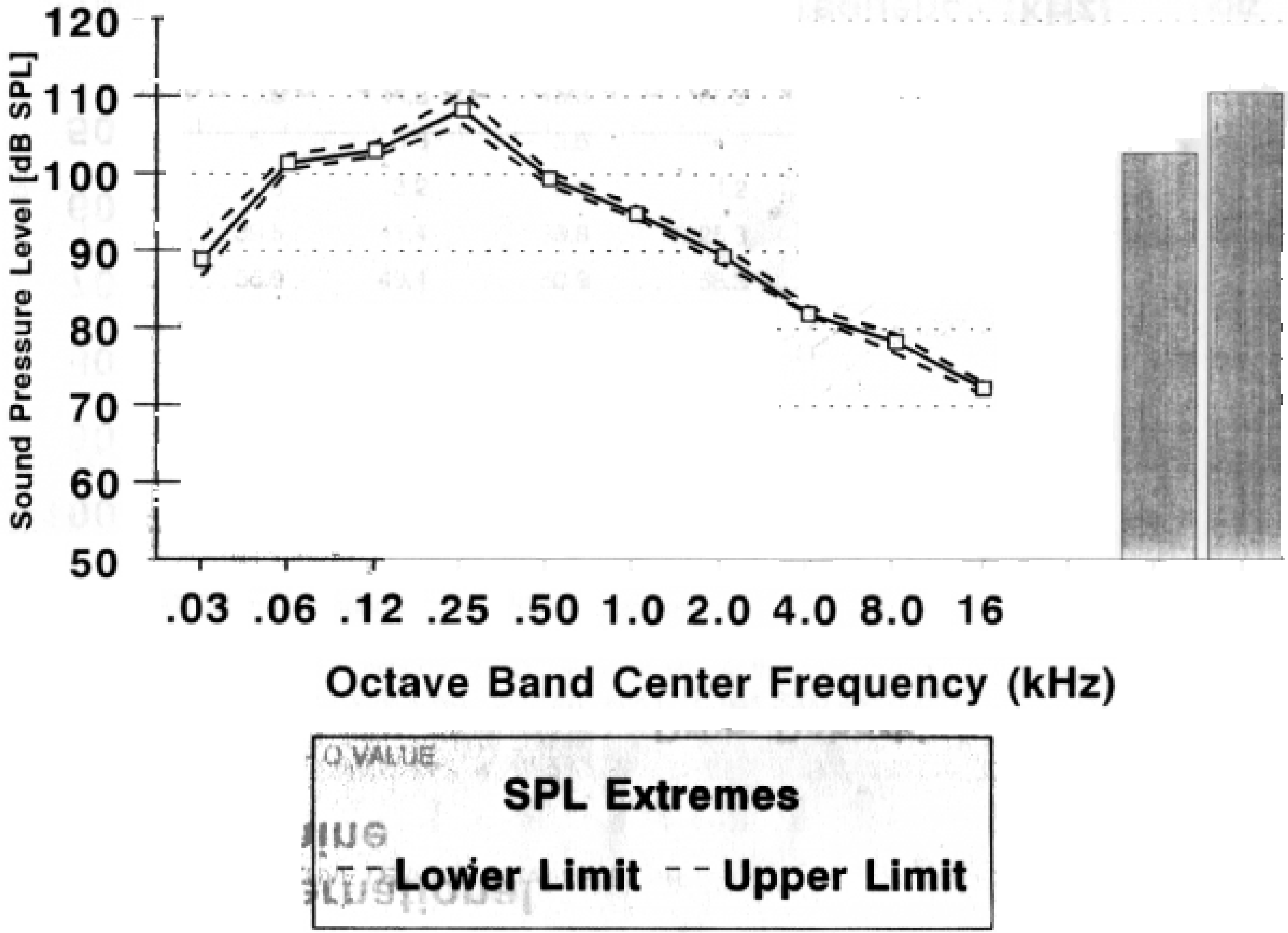
Buckspport, Maine
HETA 90-375
July 31, 1991

Figure 8

Vacumm Pump #10250
Basement Below PM #4



CHAMPION INTERNATIONAL   DRUM DEBARKING SORTING LINE, E-A-R PLUGS

OCTAVE BANDS	125 HZ	250 HZ	500 HZ	1 KHZ	2 KHZ	3.2 KHZ	4 KHZ	6.3 KHZ	8 KHZ
NOISE LEVELS	98.1	96.4	90.8	87.7	84.1		78.5		70.1
HPD ATTENUATION	37.4	40.9	44.8	43.8	36.3	41.9	42.6	46.1	47.3
STD. DEVIATION	5.7	5	3.3	3.5	4.9	3	3.1	3.5	2.7
A-WEIGHTING	16.1	8.6	3.2	0.0	-1.2		-1.0		1.1
Q VALUES	42.1	39.5	41.4	36.8	25.3		35.15		41.6
LEVEL - Q	56	56.9	49.4	50.9	58.8		43.35		28.5
S VALUES	398107.1	489778.8	87096.35	123026.8	758577.5		21627.18		707.9457
dB[A] LEVEL	93.8								
SUM OF S	1878921.								
R	31.06091								
EFFECTIVE LEVEL	62.73908								

HPD ATTENUATION and STD. DEVIATION are provided by the HPD manufacturer.

Q VALUE = HPD ATTENUATION + A-Weighting Correction - 2(STD. DEVIATION). At the 4 kHz band, average 3150 and 4000 Hz and then use the sum of the two respective STD. DEVIATIONS. Similarly, at 8 kHZ, use 6300 and 8000 Hz.

LEVEL - Q = Octave band sound pressure level - Q VALUE

S VALUE = antilog [(0.1)(LEVEL - Q)

R = dB[A] LEVEL - 10 log (SUM OF S)   EFFECTIVE LEVEL = dB[A] LEVEL - R