

This Health Hazard Evaluation (HHE) report and any recommendations made herein are for the specific facility evaluated and may not be universally applicable. Any recommendations made are not to be considered as final statements of NIOSH policy or of any agency or individual involved. Additional HHE reports are available at <http://www.cdc.gov/niosh/hhe/reports>

HETA 2001-0043-2844
Madison Fire Department
Madison, Wisconsin

Thomas Hales, MD, MPH
Tommy Baldwin, MS

PREFACE

The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health (OSHA) Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

HETAB also provides, upon request, technical and consultative assistance to Federal, State, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Thomas Hales and Tommy Baldwin of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Desktop publishing was performed by Nichole Herbert and Pat Lovell. Review and preparation for printing were performed by Penny Arthur.

Copies of this report have been sent to employee and management representatives at Madison Fire Department and the Occupational Safety and Health Administration (OSHA) Regional Office. This report is not copyrighted and may be freely reproduced. Single copies of this report will be available for a period of three years from the date of this report. To expedite your request, include a self-addressed mailing label along with your written request to:

NIOSH Publications Office
4676 Columbia Parkway
Cincinnati, Ohio 45226
800-356-4674

After this time, copies may be purchased from the National Technical Information Service (NTIS) at 5825 Port Royal Road, Springfield, Virginia 22161. Information regarding the NTIS stock number may be obtained from the NIOSH Publications Office at the Cincinnati address.

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Highlights of the NIOSH Health Hazard Evaluation

Evaluation of Woodland Plastics Recycling Corporation Incident

In October of 2000, 57 Madison Fire Department (MFD) fire fighters fought a fire at Woodland Plastics Recycling Corporation, a warehouse containing plastic products. Four fire fighters were injured, including one who required hospital treatment. Following the incident, the IAFF requested that NIOSH investigate the effects of this fire on the safety and health of participating fire fighters.

What NIOSH Did

- Surveyed the fire ground.
- Interviewed officers and fire fighters who responded to the fire.
- Reviewed radio dispatch logs, and a number of other Fire Department documents.
- Reviewed the inventory list of the Woodlands Plastics Corp.
- Reviewed rehabilitation, first report of injury, and medical records.

What NIOSH Found

- A staffing shortage occurred while responding to this incident.
- Many crews were on-scene for over six hours.
- Fire fighters were not placed into Rehabilitation after using two SCBA bottles.
- The mobile cascade system ran out of stored compressed air.
- Communication problems compromised the health and safety of fire fighters.
- Many fire fighters were exposed to smoke from burning plastic.
- Symptoms reported by fire fighters were consistent with exposure to burning plastic and smoke in general.

What Madison Fire Department Can Do

- Utilize mutual aid for personnel and equipment during large responses.
- Require rehabilitation for fire fighters who utilize two consecutive SCBA bottles.
- Ensure portable radios are working properly.
- Ensure proper lines of communication.
- Prepare pre-incident plans for commercial structures.
- Enforce use of SCBA in the hazard zone.
- Require the changing of SCBA bottles outside of the smoke environment.
- Institute a comprehensive medical evaluation program for the entire MFD.

What the Madison Fire Fighters Can Do

- Improve communication between various levels of the responding fire fighters regarding the need for rehabilitation and SCBA bottle shortages.
- Remain with their assigned crew during the incident response.
- Observe the use of SCBA in the hazard zone.
- Change SCBA bottles outside of the smoke environment.
- Follow procedures for defensive fire suppression tactics.



What To Do For More Information:
We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513/841-4252 and ask for HETA Report # 2001-0043-2844



Health Hazard Evaluation Report HETA 2001-0043-2844
Madison Fire Department
Madison, Wisconsin
May 2001

Thomas Hales, MD, MPH
Tommy Baldwin, MS

SUMMARY

On October 25, 2000, the National Institute for Occupational Safety and Health (NIOSH) received a request from the International Association of Fire Fighters (IAFF) to conduct a Health Hazard Evaluation (HHE) at the Madison Fire Department (MFD). The request concerned the health and safety of fire fighters who responded to a fire at a plastics recycling plant on October 1, 2000. On December 11-14, 2000, NIOSH investigators traveled to Madison to conduct an incident and medical evaluation.

The incident evaluation consisted of surveying the remaining structures at the fire ground, examining MFD policies and procedures, interviewing fire fighters who responded to the incident, and reviewing the following records: (a) MFD incident reports and witness statements, (b) the Bureau of Alcohol, Tobacco, and Firearms (ATF) report, and (c) material safety data sheets (MSDS) of the primary fuel sources. The medical evaluation consisted of: (a) interviewing fire fighters who responded to the incident, (b) discussing the current health and safety program with the Fire Department's Emergency Medical Services (EMS) Director, (c) reviewing the "first report of injury" forms associated with this incident, (d) reviewing injury reports from the on-scene Rehabilitation (Rehab) unit, (e) reviewing the responding ambulance and medical chart from the one hospitalized fire fighter, and (f) reviewing exposure monitoring conducted two days after the fire.

The investigation revealed the following problems during the fire: staffing shortages, communication problems (radios not working and missed information), material shortages in the Rehab area (air bottles and fluids), procedural deficiencies, lack of a pre-incident plan, and lax observance and enforcement of self-contained breathing apparatus (SCBA) use. One fire fighter suffered a life-threatening emergency (unresponsive, elevated blood pressure, rapid shallow respirations, and sinus tachycardia) and other fire fighters reported mucous membrane irritation and respiratory symptoms consistent with, but not specific for, exposure to burning plastic. Other than one critical case and three less critical cases, no other fire fighters reported persistent symptoms.

A combination of communications problems, staffing and material shortages, and planning and procedural deficiencies, put the health and safety of fire fighters at risk. One fire fighter suffered a life-threatening emergency and other fire fighters reported mucous membrane irritation and respiratory symptoms consistent with exposure to smoke and burning plastic. It cannot be determined if any long-term health effects will result from smoke exposure at this particular fire. Mandatory annual medical evaluations and periodic medical examinations should be implemented for the entire MFD. Analysis of this data over time may allow the department to determine whether this, or other large fires, are associated with adverse long-term health effects. Additional recommendations are included in the Recommendation Section of this report.

Keywords: 9224 (Fire Protection), fire fighters, firefighters, plastics fire, plastic, burning carpet, burning nylon, incident command system, rehabilitation, rehab, respiratory arrest, mucous membrane irritation, respiratory symptoms, constitutional symptoms.

TABLE OF CONTENTS

Preface	ii
Acknowledgments and Availability of Report	ii
HHE Supplement	iii
Summary	iv
Introduction	1
Background	1
Methods	2
Evaluation Criteria	2
Results	3
Exposure Monitoring	3
Incident Description	3
Medical Evaluation	4
Medical Interviews, First Reports of Injury, Physician Evaluations	4
Rehabilitation (Rehab)	5
Ambulance & Hospitalization Report	6
Current Safety and Health Program	7
Discussion	7
Shortage of Fire Fighting Personnel	7
Communication Problems	8
Rehabilitation (Rehab) Problems	8
Procedural Deficiencies	8
Pre-Incident Plan	9
Medical Evaluation of Fire Fighters	9
Conclusions	10
Recommendations	10
Shortage of Fire Fighting Personnel	10
Communications	11
Rehabilitation (Rehab) and SCBA Use	11
Procedural Issues	11
Pre-Incident Plan	12
Medical Screening of Fire Fighters	12
References	12
Appendix	18
Incident Evaluation	18

INTRODUCTION

On October 25, 2001, the National Institute for Occupational Safety and Health (NIOSH) received a request from the International Association of Fire Fighters (IAFF) to conduct a Health Hazard Evaluation (HHE) at the Madison Fire Department (MFD). Specific issues mentioned in the request were the inadequate rehab of fire fighters at the fire ground, heat-related injuries, and one fire fighter hospitalized in critical condition for pulmonary edema and heat stress (reported body temperature of 105° Fahrenheit). On December 11-14, 2000, NIOSH investigators traveled to Madison to conduct an incident and medical evaluation. Additional concerns expressed during the opening conference included whether responding fire fighters would experience any long-term health problems, and what, if any, medical screening would be appropriate for the exposed fire fighters.

BACKGROUND

The MFD employs 292 uniformed fire fighters and serves a geographic area of 68 square miles. The Department maintains 10 fire stations, including nine Engines, four Ladders, six Rescues, and one Command Car. The Department operates three shifts. Each shift works 24 hours, with shift change occurring at 0700 hours, and averages 48 hours of work each week. In response to a working structure fire, the MFD will dispatch two Engines, two Ladder trucks, one Rescue ambulance, and one Command Car to the scene.

On October 1, 2000, the MFD responded to a fire at the Woodland Plastics Recycling Corporation. The building was a combination warehouse and processing facility constructed in a "Quonset Hut" style. Built in the early 1940's, the building consisted of two sections, each approximately 88 feet wide, 523 feet long, and 30 feet high in the center. (Figures 1-4) The two halves shared a common firewall. The floor was a concrete slab, with the exterior wall and roofing combined into a single arch-type design. The arch walls and roofing were constructed of 1½-inch by 7-inch laminated strips of wood. These ribs were curved and connected to form the skeleton of the

building; this was covered by sheet metal to form the roof and exterior walls.

The facility recycled nylon carpet. Used carpet was brought into the facility, cleaned, processed, and transformed into "condux" and pellets for packaging and distribution. The primary fuel sources were:

- Honeywell nylon "6/6 bales" (uncleaned carpet) - 68,328 pounds,
- High Density Polyethylene (HDPE) plastic material - 10,500 pounds,
- Honeywell condux - 19,776 pounds,
- Nylene condux - 55,737 pounds,
- Nylene pellets - 55,829 pounds, and
- Cardboard boxes.

Honeywell nylon "6/6 bales" are also known as "carpet fiber" or "Recycled Nylon 6/6 Resin." This material is composed of nylon 6/6 (75-97% by weight), polypropylene (0-12% by weight), calcium carbonate (0-11% by weight), and styrene butadiene polymer (0-2% by weight). The Material Safety Data Sheets (MSDS) list potential health effects of the dust, fume, or vapor to be skin, eye, and mucous membrane irritation. If these health effects occur, it recommends removing the person to fresh air and flushing the eyes and skin with water. Under its fire fighting precautions/instructions, the MSDS considers, at a minimum, bunker gear and self-contained breathing apparatus (SCBA) be used. "Thermal decomposition products may include a complex mixture of organic and inorganic compounds including but not limited to simple hydrocarbons, aldehydes, ketones, nitriles, inorganic oxides, halides, and probably trace amounts of hydrogen cyanide and other materials depending upon specific temperatures, time of exposure, and other immediate environmental factors."

The Honeywell and Nylene condux and pellets, had the same potential health effects, first aid treatments, and fire fighting precautions/instructions as the Honeywell 6/6 bales.

HDPE was another main fuel source. The primary ingredients listed in the MSDS are a "polyethylene mixture" and carbon black. The MSDS lists irritation to the eyes, skin, and respiratory tract as

a sign or symptom of acute overexposure with nausea, drowsiness, and headache for prolonged exposure at high concentrations. "Individuals with chronic respiratory disorders may be adversely affected by any fume or airborne particulate exposures. Sensitive individuals may be susceptible to allergic reaction from contact with skin, eyes, or respiratory tract." The MSDS adds that fire fighters and others exposed to some products of combustion should wear an SCBA and protective clothing. Hazardous by-products may be formed if material temperature exceeds 250 degrees (C); these may include carbon monoxide, carbon dioxide, hydrogen chloride, and organic vapors.

Another fuel source was the "Nylon 6 Packaging Grade Resin." Nylon 6 (>98% by weight), caprolactam (<1% by weight), and other non-regulated additives are the constituents listed in the MSDS. The MSDS lists the same potential health effects, first aid treatments, and fire fighting precautions/instructions as the MSDS for HDPE.

The MFD utilizes an incident management system (IMS) contained in their policies and procedures manual (PPM). The PPM identifies the following incident management policies: incident command procedures, rehab, emergency response, incident safety officer, accountability, personal safety standards, radio communication system channel designation, alarm dispatching, radio messages, personnel recall, second alarm dispatch, and critical incident stress debriefing.

To assist with determining the origin of the fire, on October 1, 2000, the City of Madison requested assistance from the National Response Team of the Bureau of Alcohol, Tobacco, and Firearms (ATF). On October 2, 2000, the ATF arrived in Madison as a fully operational unit. On October 5, 2000, the ATF completed their report determining the fire was accidental in nature and due to heated conductive material being placed into combustible insulating boxes.

METHODS

The incident evaluation consisted of:

- surveying the remaining structures at the fire ground,
- examining MFD policies and procedures,
- interviewing fire fighters who responded to the incident,
- reviewing radio dispatch logs,
- reviewing MFD incident reports and witness statements,
- reviewing the ATF report, and
- reviewing exposure monitoring performed day two and three after the fire.

The medical evaluation consisted of:

- interviewing fire fighters who responded to the incident,
- reviewing first report of injury forms,
- reviewing injury reports from the on-scene Rehab unit,
- reviewing the responding ambulance and medical chart of the hospitalized fire fighter, and
- discussing the current health and safety program with the Fire Department's EMS medical director.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially

increases the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),¹ (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),² and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).³ Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm.⁴ Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended STEL or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

There are no specific exposure limits for the nylon 6/6, polypropylene, HDPE, polyethylene mixture, or the nylon 6 material. For exposure assessment purposes, these would be considered "particulates not otherwise classified (PNOC)" by ACGIH and "particulates not otherwise regulated (PNOR)" by OSHA. These exposure limits are listed in Table 1. Exposure limits for some of the minor components of the fuels' sources, such as calcium carbonate, styrene, butadiene, carbon black, caprolactam dust, and caprolactam vapor are also listed in Table 1. It should be noted that the exposure limits for these minor components are for the original substance, not their thermal combustion products. Hundreds of thermal

by-products occur during plastic fires.^{5,6,7,8} The exposure limits for some of the most common thermal by-products are also listed in Table 1.

RESULTS

Exposure Monitoring

There was no exposure monitoring during suppression efforts, however two and three days later, exposure monitoring was conducted by the Fire Investigator using direct reading instruments. This sampling for thermal decomposition by-products (carbon monoxide, carbon dioxide, hydrogen chloride, hydrogen cyanide, ammonia) was performed in the general vicinity of clean-up operations and above some smoldering material (Table 2). These results confirm the presence of some thermal by-product.

Incident Description

A complete incident sequence of events is located in the Appendix. The following is a brief synopsis of the MFD response.

At 0859 hours, October 1, 2000, the MFD received a report of a structure fire near the airport. A full structure fire assignment, consisting of two engine companies (Engine 8 and Engine 10), two ladder truck companies (Ladder 1 and Ladder 8), one ambulance (Rescue 10), and one command car (Car 31) were dispatched to the scene and arrived between 0902 hours and 0907 hours. An off-duty Assistant Chief (F-2) and Rescue 6 also responded. Upon arrival, flame was visible from the dock doors on the Sector 4 side, and heavy white smoke was showing toward the Sector 2 direction. F-2 arrived and took command until the on-duty Division Chief (Car 31) arrived. Engine 10 and Rescue 10, who initially fought the fire between Sector 4 and Exposure 4, utilized a defensive fire attack mode (no personnel would enter the structure), while Engine 8 crew members attacked the fire through the front door and ladder companies set up water tower operations.

A second alarm was called and two engine companies (Engine 3 and Engine 5), one ladder company (Ladder 6), and one ambulance (Rescue 5) responded. The second alarm generated an

automatic “all call” of chief officers, including the Fire Chief and the Mayor, to advise them of the incident. F-4 (an Assistant Chief serving as the Duty Chief for that day), F-5 (Division Chief), and F-10 (Division Chief) responded to headquarters (OIC) to call off-duty fire fighters to request their assistance at the fire. Shortly thereafter, F-10 left to assist the Incident Commander (IC) on-scene. The Chief’s Aide, whose sole responsibility is typically on-scene accountability, was also assigned as the Staging Officer, and Car 31 (the IC) also assumed the additional role of Incident Safety Officer (ISO).

Rescue 5 and Rescue 6 (Cascade unit) arrived on-scene between 0915 and 0918 hours and were assigned to Rehab. Dispatch advised the IC that the building was full of plastics and that the building’s owner was en route. Engine 3 advised the IC that there was a fire wall about 100-feet from the front of the structure, and Ladder 8 advised the IC that the fire building was over 100-yards long. The front wall then began to collapse.

Over the next two hours, two fire fighters were injured (see the following Medical Evaluation section). As the fire spread to pallets on the dock in Sector 2, second alarm ladder companies set up water tower operations. The Fire Investigator (I-86) arrived on-scene at 0927 hours and advised the IC that Exposure 4 had smoke showing from the second floor.

Engine 10 and Rescue 10 requested and received rehab, and at 0951 hours, the IC asked F-2 about crew status pertaining to rehab. The IC also spoke with F-4 at headquarters regarding the progress of reaching off-duty fire fighters to relieve suppression crews. Rescue 10, now out of rehab, replaced Engine 3 personnel. The Lieutenant of Engine 3 offered rehab to the Ladder 8 crew; however, the Lieutenant of Ladder 8 stated that his crew did not need rehab. Around this time Ladder 6 had entered the fire building to ascertain the integrity of the fire wall which, at the time, was intact. After this was done, the IC advised them to vacate the building because they were in a defensive operation. Salvation Army, which had been requested to bring fluids and food, arrived on-scene at approximately 1030 hours.

At 1050 hours, F-10 replaced F-2 and became the Rear Sector Officer. Soon after, F-10 requested eight air bottles and an additional portable radio (due to radio problems). A Rescue 5 fire fighter-paramedic loaded the SCBA bottles onto a stretcher and took the bottles to the Rear Sector. Ten full SCBA bottles remained at the scene while Rescue 6 left the scene and traveled to the maintenance facility to refill its cascade system. Rescue 6’s total time away from the fire scene was approximately one hour.

Two call-back crews (Engine 40 and 41) responded at 1113 and 1133 hours, respectively, but did not arrive on-scene until 1207 hours. Ladder 6 advised the IC that they needed another eight SCBA bottles. At approximately 1142 hours, Engine 8 asked the IC if there were any replacement crews and was told that replacements were coming. Ladder 6 then advised the IC that they were due for a replacement. At 1207 hours, Engine 40 and Engine 41 relieved Ladder 6 and Ladder 8, respectively. The Rear Sector Officer requested relief for some of the crews (Engine 8) in his Sector. The Apparatus Engineers on Engine 3 and Engine 8 were soon replaced by Engine 3 crew members. At 1347 hours, the IC advised Dispatch that the fire was knocked down and the crews were doing hot spot overhaul. The time frame of units departing the scene is located in the Appendix.

Medical Evaluation

Medical Interviews, First Reports of Injury, Physician Evaluations

A total of 69 MFD personnel responded in some capacity to this fire. Interviews were conducted with 60 (87%) of the most actively engaged and heavily exposed fire fighters to determine if any health problems resulted from, or had been exacerbated during, suppression activities. The most common symptoms, reported by most responding fire fighters, were throat and eye irritation. Respiratory symptoms (non-productive cough, shortness of breath, and chest tightness) were the second most common, followed by constitutional symptoms (fatigue, lightheadedness, dizziness, nausea, and persistent odor). All these

symptoms (mucous membrane irritation, respiratory, and constitutional) typically began during the suppression efforts and improved over the next 72 hours, with only a couple of fire fighters reporting the symptoms persisting for more than a week. One fire fighter was experiencing persistent symptoms (chest muscle spasms) six weeks later.

Fifty-one fire fighters participating in the suppression effort submitted a first report of injury form. Forty-five fire fighters filed reports exclusively for smoke inhalation injury. Four additional reports were submitted for smoke inhalation plus another injury: dehydration, heat exhaustion, musculoskeletal strain, or eye injury. Two reports were completed for injuries unrelated to smoke inhalation: one laceration and one musculoskeletal strain.

Nine fire fighters sought medical evaluation two to three days after the fire. Eight of these evaluations were for smoke inhalation, while one evaluation was for a musculoskeletal injury. Most of these evaluations were performed at the local emergency department and consisted of a brief history, brief physical examination, and pulse oxygen saturation measurement. In each of these evaluations, no abnormalities were found in the physical examination of the lungs or the pulse oxygen saturation. Although blood was collected from some fire fighters, it was not analyzed due to the low suspicion of carbon monoxide poisoning, the low probability of any electrolyte abnormalities, and the inability to test for exposure to specific chemicals found in smoke.

Rehabilitation (Rehab)

Rescue 5 was assigned to establish the Rehab unit. The unit set up on a grassy area across the street and upwind of the fire building. Rescue 6, carrying supplemental air (75 bottles), fluids (Gatorade®), and a small amount of food (a few pieces of fruit) set up along side of Rescue 5. Rescue 5 personnel helped fire fighters exchange air bottles at Rescue 6, but no record was kept of the number of bottles each fire fighter had used, nor whether their vital signs were checked.

At approximately 1000 hours, one hour into the suppression effort, Rescue 5 notified Car 31 and his Aide that fluids were getting low. Shortly thereafter, the fluids were gone and Rescue 6 began using sterilized water from Rescue 5. This sterilized water was supposed to be for irrigating and cleaning wounds. The sterilized water became depleted at approximately 1030 hours, and for a short time the Rehab unit was out of water. Salvation Army responded with food and fluids at approximately 1030 hours, but the food soon ran out.

At approximately 1030 hours, Rescue 6 departed the fire ground to refill its cascade system at the maintenance facility. The travel and refilling time took approximately one hour. Prior to its departure, Rescue 6 left approximately ten full air bottles on the grassy area next to the Rehab unit. This was communicated to Car 31 (IC) and his Aide, but many fire fighters getting low on air were not informed. Thus, several fire fighters continued defensive fire suppression efforts in light to moderate smoke conditions without supplied air.

During the suppression effort, two fire fighters collapsed at the fire ground. One was transported to the hospital (see below). The other received an extensive evaluation (vital signs, physical exam, pulse oximetry, and electrocardiogram [EKG], all of which were normal except for an elevated heart rate) in the Rehab unit. He never lost consciousness and was treated for heat stress (cooling, hydration, oxygen, and rest). He refused transport to the hospital's emergency department and returned to his crew after 35 minutes. (This episode was well documented in an electronic MFD medical report). For all other fire fighters assigned to the Rehab unit, vital signs were not routinely taken, nor was a log maintained of their visits. A third fire fighter was released from the fire scene late in the afternoon and felt lightheaded on his drive home. He stopped at the nearest fire station, and paramedics performed an extensive evaluation (vital signs, physical exam, pulse oximetry, and EKG all of which were normal). After resting for 30 minutes and being treated with oxygen, his symptoms improved. He also refused transport to the hospital and the episode was well documented in an electronic MFD medical report.

Ambulance & Hospitalization Report

The fire fighter/paramedic (FF-P) who collapsed at the fire ground had a history of asthma, diagnosed approximately four years ago. His asthma attacks were infrequent, typically triggered by pollen, upper respiratory infections, or exercise, but were easily controlled with an inhaler. He had been cleared for duty without restrictions by his private physician.

The morning of the incident, he established and staffed the Rehab unit with his partner. At the fire, he was asked to don his bunker gear and help the utility company employee turn off the gas and electricity supplying the building (Olds Seed Company) next to the fire. This building was upwind of the fire, and SCBA was not needed. He returned to the Rehab unit and was told to bring SCBA air bottles to fire fighters positioned downwind of the fire (Engine 5, Ladder 6, and Ladder 8). These crews were intermittently enveloped in the thick, black, acrid smoke. Although most fire fighters were using their SCBA, some were not, and the paramedic/fire fighter donned his SCBA, but did not turn on the air because, at the time, they were not enveloped in smoke. He delivered eight bottles via a stretcher to crews in the smoke and returned to the Rehab unit.

He then requested the opportunity to assist in the fire suppression effort with the E-5 crew. He was granted this permission by the Rear Sector Chief. After approximately 20 minutes of checking the integrity of the firewall and hitting spot fires with water, the air in his SCBA bottle was getting low. Like other fire fighters, he changed bottles on a ledge of the fire building, where there was light to moderate smoke exposure. Shortly thereafter, he experienced chest tightness and a sensation of being very hot. He informed the officer of Ladder-6 that he did not feel well, became unstable, and fell to his knees.

Several of the nearby FF-P immediately assisted him, finding him in respiratory distress, conscious, but not responsive. His bunker gear and SCBA were removed as he was carried a short distance to Ladder 6, where oxygen and a cardiac monitor (automated external defibrillator [AED]) were

available. At this same time the ambulance in the Rehab and Staging area were informed that a fire fighter was having difficulty breathing, then informed that the fire fighter was "down." Rescue 5, staffed by the Rescue 6 crew, reached the FF-P within one minute and found him conscious, but unresponsive. His skin was red and warm to the touch. Vital signs revealed a fast heart rate, rapid shallow respirations, and a palpable blood pressure. The cardiac monitor revealed sinus tachycardia. Oxygen was being supplied by a non-rebreather mask. He was placed on the cot and loaded into Rescue 5, where a nasal intubation was attempted without success (he was combative and resistant). The responding paramedic was aware of the patient's history of asthma and administered one dose (0.5 milligrams [mg]) of subcutaneous epinephrine and a nebulized albuterol treatment (2.5mg). At this point, an intravenous line was placed and the patient was transported to the hospital's emergency department (ED). He became more responsive en route (he was able to sit up and respond to commands), and one more dose of subcutaneous epinephrine and a nebulized albuterol treatment were administered.

After a 15 minute transport, evaluation in the ED revealed him to be once again unresponsive with shallow, wheezing respirations at a rate of 40/min, a pulse of 102, blood pressure 224/93, and a temperature of 100.5°F. He was intubated, given additional respiratory medications, and transferred to the intensive care unit with a diagnosis of an inhalation injury versus an asthma attack. During the intubation, he was noted to have significant upper airway swelling, but no carbonaceous (black) sputum. He responded well to empiric treatment for asthma, was extubated the next day, and discharged two days later (October 4, 2000). He did not have a heart attack (as noted from normal cardiac enzymes and a normal electrocardiogram), and his carboxyhemoglobin level of 1% suggested he was not exposed to significant amounts of carbon monoxide, even considering that he received 100% oxygen at the fire scene, during transport, and at the hospital by intubation. His discharged diagnosis was respiratory failure. At the time of the NIOSH site visit, he did not report any residual symptoms.

Current Safety and Health Program

The Department requires a pre-employment/pre-placement medical evaluation for all new hires. These evaluations are performed by the contract physician, who makes a determination regarding medical clearance for fire fighting duties and forwards this decision to the Fire Department. Periodic medical evaluations are not required by this Department. If an employee misses work due to an illness or a work-related injury, the employee must be cleared for "return to work" by the employee's personal physician. In 1997, MFD expanded the return-to-work guidelines for off-duty injury or illness. The policy required a functional capacity examination and final medical examination to be completed by the contract physician for seven specific conditions: (1) surgery on the musculoskeletal system; (2) surgery requiring more than four weeks absence; (3) surgery, injury, illness, or pregnancy requiring more than six weeks absence; (4) cardiac surgery; (5) heart attacks; (6) illness affecting joints or muscles severely enough to cause absenteeism or limitations; and (7) illness of the central nervous system.

DISCUSSION

Shortage of Fire Fighting Personnel

The Duty Chief and another Chief Officer were responsible for personnel recall (calling off-duty fire fighters to notify them that their services were needed). Due to the day of the week (Sunday) and the time of day (0859 hours), it took over two hours to staff a full complement of call-back fire fighters. Relegating these Chief Officers to perform an administrative function at headquarters underutilized their extensive fire suppression experience; experience that would have been valuable at the fire ground. Second alarm units staged for a short time, but were soon committed to the extinguishment effort. Thus, for several hours, there was no additional apparatus or personnel available in Staging. This resulted in some fire fighters using up to eight bottles of air before being relieved to enter Rehab.

Due to the shortage of personnel and the defensive fire tactics, the IC assumed the role of Safety Officer. To ensure safe operation throughout all sectors, the Safety Officer should be mobile on the fire ground and be identified by a highly visible vest, helmet, or other indicator.^{9,10,11} However, according to MFD procedures, the IC must remain in the command vehicle. By assigning himself the Safety Officer position, the IC limited the effectiveness of the Safety Officer by being unable to move around the fire ground.

Employees at emergency operations must be accounted for at all times. It is the Company Officer's responsibility to keep an accurate on-duty roster for each in-service apparatus at their station. The roster is carried in a 4" by 6" plastic envelope on the front door of each vehicle. The IC or a designee will be able to check each duty roster to make an accurate list of personnel at an emergency incident. At this incident, the IC's Aide was responsible for personnel accountability via the status board carried on Car 31. While the Chief's Aide was able to account for personnel as they arrived at the fire scene, he was unable to monitor their location as fire suppression activities were initiated due to his dual assignment as Staging Officer. Finally, due to the staffing shortage and the defensive tactics, Rehab and multiple Sector Officers were not assigned.

Communication Problems

A number of communication problems hampered an efficient response to this incident. These included non-functioning pagers (two Chief Officers) and non-functioning portable radios (Rear Sector Officer, Ladder 1, Engine 3 Lieutenant, and Engine 5 Lieutenant). Without the portable radios, companies communicated directly with Dispatch, rather than the IC or the Sector Officer.

Even when the equipment was working, some companies did not utilize the appropriate channels. For example some on-scene units were utilizing radio Channel 3 (full fire response) instead of Channel 4 or 6, and the staging units were utilizing Channel 3 instead of Channel 1. When the equipment was working and the appropriate channels were being used, some units were transmitting at the same time, causing missed

information, and messages were not acknowledged. Thus, some units never received the message that Command was passed from F-2 to Car 31. Finally, some fire fighters and their Company Officers were not communicating with each other regarding their needs for rehab. For example, the IC Aide and the crew from Engine 3 offered Ladder 8 rehab, however; the Officer of Ladder 8, unaware of his crew's rehab needs, declined.

Rehabilitation (Rehab) Problems

The purpose of rehab is to ensure that the physical and mental condition of fire fighters operating at the scene of an emergency or a training exercise does not deteriorate to a point that affects their safety or the safety and integrity of the operation.⁹ Rehab provides rest and rehydration to fire fighters. After two air bottles or 45 minutes of worktime, rehab is recommended.^{10,11,12} The staffing shortage and the communication problems discussed above resulted in rehab delay for many fire fighters engaged in fire suppression efforts. In addition, when rehab was offered, supplies of fluids and food were exhausted in less than two hours into the incident. Although the Salvation Army responded with supplies, their stocks also became depleted. Finally, there were no bathroom facilities at the scene.

The cascade system on Rescue 6 and the extra SCBA air bottles (except for 10) were empty by approximately 1030 hours. Rescue 6 left the scene two times to go to Maintenance, refill its cascade system, and return to the scene. When Rescue 6 departed the fire scene at 1030 hours, 10 full SCBA bottles were left on-scene, but this was not communicated to all personnel. Thus, some fire fighters continued defensive fire suppression efforts in light to moderate smoke conditions without supplied air. Since the incident, the Fire Department has implemented an air bottle system that utilizes color coded tarpaulins, one color marked "EMPTY" and the other color marked "FULL." The tarpaulin is located with either the Rehab ambulance or with Rescue 6 on the scene of an incident.

Due to the personnel shortage, crews from Engine 5 and Ladder 6 were changing their SCBA bottles at their apparatus, which was intermittently enveloped in smoke. The United States Fire Administration (USFA) recommends SCBA bottles be changed outside of the hazardous (smoke) area.¹² Each fire fighter has the responsibility to use SCBA in the hazard zone, and enforcement of this rule rests with the fire fighter's supervisor. However, the personnel and air bottle shortage put fire fighters, and their supervisors, in a dilemma: abandon their positions or continue operations and risk inhaling potentially hazardous smoke. None of the members of the MFD abandoned their positions. If mutual aid or rotating MFD crews were utilized, or a mobile cascade system or portable generator was available, additional air bottles would have been immediately available.

Procedural Deficiencies

Several procedural deficiencies were noted during this incident. (1) Size-up. Size-up allows the IC to appreciate building size, construction, hazards, exposures, and size and extent of the fire. The IC can accomplish this by walking or driving around the fire building. (2) Although a defensive strategy was taken, and this was communicated to fire fighters, several crews performed more than defensive postures. While some offensive operations must be conducted during defensive strategy (i.e., exposure fire extinguishment, fire spread reconnaissance), some fire fighters went beyond the point of defensive tactics. For example, some fire fighters climbed onto the fire building's collapsed roofing grids to extinguish hot spots. (3) The aerial water towers lowered the smoke plume into several pieces of apparatus (Figures 3 & 4). These pieces of apparatus were not re-positioned despite being directly downwind and enveloped in intermittent smoke. (4) Given the opportunity for smoke exposure for the reasons listed in the previous sections, it would have been useful to gauge the smoke's hazard potential. The MSA Atmosphere Testing Device maintained by the MFD Hazmat team can only provide measurements of only a few of the hundreds of constituents of plastic smoke, but this would have been valuable as a screening tool to monitor the carbon monoxide levels. (5) Unless relocated by the IC, crewmembers should remain

together and at their assigned location. At this incident, one Fire Fighter was reassigned from Ladder 6 to Rescue 6, and the injured Rescue 5 FF-P volunteered for fire fighting duties with Engine 5.

(6) Reasons for the long duration of this fire include: the fuel source (plastic) and building construction (the sheet metal roof which collapsed over the plastic, causing water to run off before reaching the fuel). Foam works as an extinguishing agent by cooling and smothering; water works by cooling. Foam applied to the burning plastic would have formed a blanket over the material, smothered the fire, and probably shortened the time for final extinguishment. In addition, a crane could have lifted the sections of metal roofing, thus allowing hose streams to reach the burning plastic. Given the building construction and fuel source, the use of foam and/or a crane could have been considered. (7) Also, Sector Commanders should have completed worksheets to track companies into and out of their sectors, and progress reports should have been given to the IC every 10 to 15 minutes.

Pre-Incident Plan

A pre-incident plan should be developed for large, potentially hazardous structures.¹³ The plan should be used by responding personnel to effectively manage fires and other emergencies in these facilities using available resources. Unlike fire prevention or fire safety inspections, pre-incident planning assumes that an incident will occur. Once completed, the pre-incident plan should be distributed to appropriate responding personnel. The pre-incident plan will assist the IC in developing appropriate strategies and tactics for managing the incident and help responding personnel identify critical factors that will affect the ultimate outcome, including personnel safety. No pre-incident plan was in effect for the Woodland Plastics facility.

Medical Evaluation of Fire Fighters

The FF-P who suffered a life-threatening respiratory disorder had a previous diagnosis of reactive airways disease (asthma). A severe

asthma attack was the most likely diagnosis given that he responded well to treatment for asthma while inhalation injury (chemical pneumonitis) could be ruled out by his chest X-ray, quick recovery, and overall clinical course. Most likely the inhalation of plastic thermal decomposition products triggered his severe airway constriction because he reported no other attacks while being exposed to similar smoke and physical demands conditions during his 21 years of service to the MFD. Prior to, and after this event, this FF-P was cleared for full duty by his private physician, who specialized in pulmonary medicine and was aware of the hazards of firefighting and familiar with the consensus guidelines published by the National Fire Protection Association (NFPA) 1582, Standard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians. NFPA 1582 considers asthma a Category B medical condition (“a medical condition that, based on its severity or degree, could preclude a person from performing as a member in a training or emergency operational environment by presenting a significant risk to the safety and health of the person or others.”)¹⁴

Medical personnel evaluated several of the symptomatic fire fighters two days after the fire. Pulse oximetry was used to assess their oxygen saturation. This device measures oxygen dissolved in the blood, not the status of tissue oxygenation or oxygen-carrying capacity of the red blood cells. Thus, it could detect oxygenation problems due to lung injury (due to smoke), but it cannot detect carbon monoxide poisoning.^{16,17} A carboxyhemoglobin level is needed to detect carbon monoxide poisoning. However, carboxyhemoglobin has a half-life of 12 hours. Since the medical evaluations on the symptomatic fire fighters occurred 48 hours after the fire, a carboxyhemoglobin test was not useful.

It cannot be determined whether any fire fighter will suffer long-term health consequences due to smoke exposure at this, or any other, particular fire. NIOSH investigators agree with the MFD that there was no medical basis to conduct specific blood, lung, or other screening tests on all fire fighters responding to the incident. However, we do suggest a screening program for this cohort of fire fighters, as well as all members of the MFD, be developed. Guidance regarding the content and

scheduling of periodic medical evaluations for fire fighters can be found in NFPA 1582, or the report of the International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC) wellness/fitness initiative.¹⁵ Applying NFPA 1582 involves legal issues, so it should be carried out in a confidential, nondiscriminatory manner. Appendix D of NFPA 1582 provides guidance for Fire Department Administrators regarding legal considerations in applying the standard. Applying NFPA 1582 also involves economic issues. These economic concerns go beyond the costs of administering the medical program; they involve the personal and economic costs of dealing with the medical evaluation results. The success of medical programs hinges on protecting the affected fire fighter. MFD must (1) keep the medical records confidential, (2) provide alternate duty positions for fire fighters in rehab programs, and (3) if the fire fighter is not medically qualified to return to active fire fighting duties, provide permanent alternate duty positions or other supportive and/or compensated alternatives.

CONCLUSIONS

A combination of staffing shortages, communication problems, material shortages in the Rehab area (air bottles and fluids), procedural deficiencies, lack of a pre-incident plan, and lax observance and enforcement of SCBA use, all combined to put the health and safety of fire fighters at risk. One fire fighter suffered a life threatening emergency and other fire fighters reported mucous membrane irritation and respiratory symptoms consistent with, but not specific for, exposure to burning plastic. Other than one critical case, no other fire fighters reported serious acute health problems or persistent symptoms. There are no specific screening tests for exposure or a health effect, however, this cohort could be followed via a mandatory annual medical evaluation and mandatory periodic medical examination program for the entire MFD.

RECOMMENDATIONS

Shortage of Fire Fighting Personnel

Despite the defensive tactics, an incident of this size should have triggered a call for mutual aid from the Airport FD or from the surrounding fire departments. These crews could have assisted with suppression efforts, crew rotation, staging, SCBA refilling, and replenishing the depleted resources at Rehab.

- MFD companies on alert for additional incidents within Madison could have rotated with on-scene crews.
- Given the size of the incident, a Safety Officer, separate from the IC should have been assigned.
- The IC's Aide should have been devoted to personnel accountability. A separate Staging Officer should have been assigned.
- For incidents of this magnitude (a two alarm fire, with over 50 fire fighters and 12 pieces of responding apparatus), assign a Rehab Officer and other Sector Officers.
- Assign the duty of "callbacks" to either Dispatch or the administrative staff within the MFD, thus freeing up experienced officers for fireground duty.
- Implement a call-back plan that would require off-duty Chiefs to call either Dispatch or the OIC within 5 minutes of the page. If no call is received at Dispatch or the OIC, individual notifications should be made to the Chiefs' home.
- Maintain apparatus/personnel in Staging to replace crews requiring rehab.

Communications

1. Ensure that pagers and portable radios are working properly.
2. Apparatus and personnel should utilize the proper radio channel according to their assignment.

3. Ensure a radio channel is clear before transmitting and acknowledge receipt of transmissions.

4. Ensure crew members communicate with their Company Officer, who in turn communicates with the Sector Officer, who in turn communicates with the IC. The IC will communicate with Dispatch.

Rehabilitation (Rehab) and SCBA Use

1. Clearly mark the Rehab unit and its location. Communicate this information to all on-scene personnel.

2. Require fire fighters to check in at Rehab after using two SCBA bottles and/or performing 45 minutes of work. After being assessed by Rehab personnel, fire fighting crews can return to suppression activities.

3. Maintain a log sheet of all fire fighters entering Rehab, including their vital signs and other pertinent information.

4. Increase the stock of fluids and food in Rehab.

5. Fire fighters should observe, and supervisors enforce, the use of SCBA in the hazard zone.

6. Crewmembers should replace their SCBA bottles outside of the hazard (smoke) area.

7. Install portable cascade systems on additional fire apparatus, maintain a larger reserve of SCBA bottles, or utilize a mobile generator capable of refilling SCBA bottles.

8. Take empty SCBA bottles to Maintenance for refilling prior to depleting nearly the entire stored air supply.

9. Ensure that full or empty SCBA bottles are properly identified.

10. When the function of an SCBA is questioned in a fire fighter's injury, NIOSH is available to perform objective, expert testing of

the SCBA. Given the respiratory failure of one fire fighter/paramedic, the Department appropriately secured his SCBA gear for potential testing. If the need to test SCBA gear should arise again, personnel at the NIOSH Division of Respiratory Disease Studies, Air Supplied Respirator Section, (304) 285-5907, are available to perform an objective evaluation at no cost.

Procedural Issues

1. One of the first tasks for the IC to complete is "size-up," by walking or driving around the fire building to appreciate building size, construction, hazards, exposures, and size and extent of the fire.

2. Ensure all personnel on-scene are informed of, and following, the operating strategy (offensive or defensive).

3. Position apparatus upwind, thereby reducing the smoke exposure of fire fighters.

4. Ensure that crewmembers remain together and at their assigned location, unless relocated by the IC.

5. During a plastics fire, utilize the MSA Atmosphere Testing Device maintained by the MFD Hazmat team to ascertain the extent of the hazardous atmospheres.

6. For similar fires, consider the use of foam and/or a crane.

7. The Sector Commanders should complete worksheets to track companies into and out of their sectors.

8. Members of a company should remain under the supervision of their assigned company officer.

9. The IC should be given progress reports every 10 -15 minutes by sector commanders.

Pre-Incident Plan

Prepare pre-incident plans for all major structures (based on size, occupancy type, dollar value) that will identify building size, construction, occupancy, materials stored, hazards, utility disconnects, exposures, hydrant locations, and other pertinent information. The pre-incident plans should be carried both on fire apparatus with responsibility for first response in its district and in the Command Car.

Medical Screening of Fire Fighters

Implement an annual medical evaluation and periodic medical examination program for all fire fighters. Guidance on the content and frequency is provided in NFPA 1582, Medical Requirements for Fire Fighters and Information for Fire Department Physicians.

REFERENCES

1. NIOSH [1992]. Recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100.

2. ACGIH [2001]. 2001 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. CFR [1997]. 29 CFR 1910.1000. Code of Federal regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

4. OSHA [1970]. Occupational Safety and Health Act of 1970, Public Law 95-596, 91st Congress, S.2193, sec. 5.(a)(1).

5. Forrest MJ, Jolly AM, Holding SR, Richards SJ [1995]. Emissions from processing

thermoplastics. *Annals of Occupational Hygiene* 39:35-53.

6. Vainiotalo S, Pfaffli P [1989]. Measurement of depolymerization products in the polyacetyl, polyamide, and polymethylmethacrylate processing industry. *Am Ind Hyg Assoc J* 50:396-9.

7. Alarie Y [1985]. The Toxicity of Smoke from Polymeric Material During Thermal Decomposition. In: R. George and R. Oken (eds) *Annual Review of Pharmacology and Toxicity*. Palo Alto, Annual Reviews Inc., Vol 25, pp325-48.

8. Baxter PJ, Heap BJ, Rowland MGM, Murray VSG [1995]. Thetford plastics fire, October 1991: the role of a preventive medical team in chemical incidents. *Occup Environ Med* 52:694-98.

9. National Fire Protection Association [1997]. NFPA 1521, Standard for Fire Department Safety Officer. NFPA, Quincy, MA.

10. National Fire Protection Association [1997]. NFPA 1500, Standard on Fire Department Occupational Safety and Health Program. NFPA, Quincy MA.

11. National Fire Protection Association [2000]. NFPA 1561, Standard on Emergency Services Incident Management System. NFPA, Quincy, MA.

12. United States Fire Administration [1992]. Emergency Incident Rehabilitation. Washington, DC: Federal Emergency Management Agency, USFA, Publication no. FA-114.

13. National Fire Protection Association [1998]. NFPA 1620, Recommended Practice for Pre-Incident Planning. NFPA, Quincy, MA.

14. National Fire Protection Association [2000]. NFPA 1582, Standard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians. NFPA, Quincy, MA.

15. International Association of Fire Fighters and the International Association of Fire Chiefs

[2000]. The fire service joint labor management wellness/fitness initiative. Washington, DC: International Association of Fire Fighters, Department of Occupational Health and Safety.

16. Buckley RG, Aks SE, Eshom JL, et al. [1994]. The pulse oximetry gap in carbon monoxide intoxication. *Ann Emerg Med* 24:252-5.

17. Vegfors M, Lennmarken C [1991]. Carboxyhaemoglobinaemia and pulse oximetry. *British J of Anaesthesia* 66:625-6.

Table 1
Exposure Criteria for Fuel Sources

Madison Fire Department
HETA 2001-0043-2844
Madison, Wisconsin

Substance	OSHA PEL		NIOSH REL		ACGIH TLV	
	8 hr TWA	STEL	8 hr TWA	STEL	8 hr TWA	STEL
PNOC in mg/m ³	15	-	-	-	10	-
PNOC (respirable) in mg/m ³	5	-	-	-	3	-
Calcium carbonate in mg/m ³	15	-	10	-	15	-
Calcium carbonate (respirable)mg/m ³	5	-	5	-	-	-
Styrene in ppm	100	200	50	100	20	40
Butadiene in ppm	1	5	LFL	-	2	-
Carbon black in mg/m ³	3.5	-	3.5	-	3.5	-
Caprolactam dust in mg/m ³	1	3	1	3	1	3
Caprolactam vapor in ppm	5	10	0.22	0.66	5	10
Thermal Degradation Products						
Carbon monoxide (CO) in ppm	50	-	35	200 (C)	25	-
Carbon dioxide (CO ₂) in ppm	5,000	-	5,000	30,000	5,000	30,000
Hydrogen chloride (HCl) in ppm	5 (C)	-	5 (C)	-	5 (C)	-
Hydrogen cyanide (HCN) in ppm	10	-	-	4.7 (C)	4.7 (C)	-
Ammonia (NH ₃) in ppm	50	-	25	35	25	35

PEL = permissible exposure limit
 REL = recommended exposure limit
 TLV = threshold limit value
 TWA = time weighted average
 STEL = short-term exposure limit
 PNOC = particulates not otherwise classified
 ppm = parts per million
 mg/m³ = milligrams per cubic meter
 LFL = lowest feasible limit
 (C) = ceiling limit

Table 2
Direct Reading Measurements of Selected Chemicals

Madison Fire Department
HETA 2001-0043-2844
Madison, Wisconsin

Date and Time of Sample	Oxygen (%)	Carbon Monoxide (ppm)	Ammonia (ppm)	Hydrogen Sulfide (ppm)	Hydrogen Cyanide (ppm)	Lower Explosion Limit (LEL)
10/3/00-0950 hours	20.6	10	2	0	-	0
10/3/00-1115 hours	20.8	-	-	0	-	0
10/3/00-1515 hours	20.8	4	0		0	0
10/3/00-1635 hours	20.8	-	-	-	0	0
10/4/00-1030 hours Sample taken above smoldering product - east end	-	-	-	-	2	18%
10/4/00-1030 hours Sample taken above smoldering product - west end	-	20	32	-	12	-



Figure

Courtesy of ATF

1.



Figure 2. Courtesy of ATF



Figur

Courtesy of MFD

re 3.



Figur

Courtesy of MFD

e 4.

APPENDIX

Incident Evaluation

At 0859 hours, October 1, 2000, the MFD received a report of a structure fire near the airport. A full structure fire assignment, consisting of two engine companies (Engine 8 and Engine 10), two ladder truck companies (Ladder 1 and Ladder 8), one ambulance (Rescue 10), and one command car (Car 31) was dispatched to the scene. Rescue 10 arrived on-scene at 0902 hours and notified Dispatch of an actual fire, gave the address, and stated that they were going to locate a hydrant. Engine 10 arrived at 0903 hours, assumed command, and gave size-up. Flame was visible from the dock doors on the Sector 4 side and heavy white smoke showing toward the Sector 2 direction. As Engine 8 and Ladder 8 neared the scene, Engine 10's Lieutenant requested that the next arriving Ladder company connect to a hydrant and supply Engine 10 with water. The Lieutenant also requested that Madison Gas and Electric (MG&E) respond due to high voltage equipment directly at the front of the building. Engine 10's Lieutenant assigned Rescue 10 to firefighting functions and directed that the fire fighters operate in a defensive fire attack mode (no personnel would enter the structure).

Rescue 6 responded at 0904 hours. Engine 8 and Ladder 8 arrived at 0906 hours and Engine 8 connected a hydrant supply line to Engine 10. An off-duty Assistant Chief (F-2) arrived on-scene and assumed command until the on-duty Division Chief (Car 31) arrived. Engine 10 and Rescue 10 fire fighters pulled two 2½-inch hoselines and proceeded between the fire building and Exposure 4 (Olds Seed Company) to attack the fire. As Car 31 arrived on-scene at 0907 hours, Engine 10 fire fighters backed out from their position between the buildings. Engine 8 crewmembers utilized a 2½-inch hoseline to attack the fire through the front door but were driven back by the fire. They retrieved a deck gun from Engine 10 and aimed the stream through the front door. Ladder 8 had initially begun to set up a water tower operation near the front of the fire building, but was directed to Sector 2 (left side of the fire building). Engine 8 then supplied water to Ladder 8 and moved the deck gun to Sector 2.

F-2 passed command to Car 31 and a second alarm was called for. Two engine companies (Engine 3 and Engine 5), one ladder company (Ladder 6), and one ambulance (Rescue 5) responded. The second alarm generated an automatic "all call" of chief officers, including the Fire Chief and the Mayor, to advise them of the incident. F-4 (an Assistant Chief serving as the Duty Chief for that day), F-5 (Division Chief), and F-10 (Division Chief) responded to headquarters (OIC). The Chief's Aide, typically responsible for on-scene accountability, was assigned as the Staging Officer and Car 31 (the Incident Commander [IC]) assumed the additional role of Incident Safety Officer (ISO). All second alarm companies were to utilize radio Channel 1 (instead of Channel 3) and to respond to the Staging Area.

Ladder 1 came on-scene at 0911 hours and was positioned at Sector 4 to set up a water tower over Exposure 4 and onto the fire building. Rescue 5 arrived on-scene at 0915 hours and was assigned to Rehabilitation and to document any personnel assessed medically. Dispatch advised the IC that Avis Rental Car Company had several cars stored just north of the fire building and that the wind was blowing in the direction of the cars. Rescue 6 and Ladder 6 arrived at the Staging Area at 0918 hours.

Once at the OIC, F-4 and F-5 began calling off-duty fire fighters to request their assistance at the fire. F-10 volunteered to go to the scene to assist the IC. Dispatch advised the IC that the building owner was enroute and that the building was full of plastics, but no chemicals. Ladder 6 set up a deck gun behind the firewall at Sector 2 and placed a water curtain between the fire building and Exposure 4. Engine 5 connected a hydrant supply line and pumped water to Ladder 6. Engine 5 crewmembers began to extinguish burning pallets. F-2 directed Rescue 6 to perform as Rehabilitation. Rescue 6 is also the cascade unit, capable of refilling 75 empty SCBA bottles (three at once) and carries 25 full bottles. F-2 requested that Dispatch contact Avis and obtain keys to move the vehicles parked near the fire building. Engine 3, arrived on-scene and was initially placed at Sector 3 (rear of the fire building). Engine 3 advised the IC that there was a fire

wall about 100-feet from the front of the structure. Engine 3 then moved to the front and relay pumped into Ladder 1. Ladder 8 advised the IC that the fire building was over 100-yards long. The front wall then began to collapse.

A Fire Fighter from Engine 10 became ill and walked across the street to Rescue 5. Rescue 5 advised the IC that they were treating the Engine 10 Fire Fighter and that another Rehab Rescue would be needed. The IC advised Dispatch to send another Rescue to the scene and Rescue 4 was dispatched. Engine 10 and Rescue 10 requested and received rehabilitation. By now, the fire had spread to pallets on the dock in Sector 2. Ladder 6 had begun to set up near Ladder 8 but was reassigned to set up a water tower on Sector 3, out of the smoke. Engine 5 connected a hydrant supply line at the rear of Sector 2 and pumped into Ladder 6. Ladder 8 advised the IC that the fire building extended an additional 300-feet beyond the fire wall. The power to the high voltage equipment at the front of the building was turned off, but the power to the rear of the building was still on. Rescue 5 advised the IC that the patient they were treating would be OK in about 10 minutes. Rescue 4 was returned to quarters.

A Fire Investigator (I-86) arrived on-scene at 0927 hours and advised the IC that Exposure 4 had smoke showing from the second floor. Police began to evacuate residents living near the fire building at 0948 hours. Rescue 5 advised the IC that they had released their patient. At 0951 hours, Engine 3 was assigned to enter Exposure 4 and ascertain if fire had actually entered the structure. Engine 3 crewmembers entered the building and advised the IC that the fire had not spread into Exposure 4. Soon after this, the IC asked F-2 about crew status pertaining to rehabilitation. The IC advised that he had just talked to F-4 (Assistant Chief) at headquarters (OIC) about the situation.

At 1003 hours, gas service to the fire building was turned off. (The FF-P from Rescue 5 had escorted the MG&E representative). The Fire Marshal arrived on scene. The IC advised Engine 5 to have their crewmembers assist Ladder 6 with their handlines and for Ladder 6 to send one or two crewmembers to assist Rescue 6 in refilling SCBA bottles; Ladder 6 sent one Fire Fighter. Ladder 6 got their water tower set up, pulled a 2½-inch hoseline, and began to extinguish the rental cars that were now burning. The IC advised Rescue 10, now out of Rehab, to replace Engine 3 personnel. Dispatch advised the IC that the Salvation Army had offered to bring rehab supplies to the scene and the IC requested they respond. Ladder 6 advised the IC that they were inside the building and that the fire wall remained intact. The IC advised Ladder 6 to vacate the building, they were going into a defensive operation.

F-2 advised the IC that F-10 (Division Chief) would replace him (1050 hours). The IC advised F-10 that he (F-10) would be the Rear Sector Officer. Soon after, F-10 requested eight air bottles and an additional portable radio. Salvation Army arrived on-scene at approximately 1030 hours. The IC advised F-10 that he could not understand his radio transmission and was sending a runner to gather information in person. Dispatch relayed the information to the IC due to F-10's radio problems. Engine 3 crewmembers were assigned to operate the hoselines from Engine 10 in between the fire building and Olds Seed Company. Engine 3 crewmembers' SCBA's ran out of air, the crew shut down the hoselines, and went to Rescue 6 to change bottles. One Engine 3 FF experienced eye irritation and the FF-P from Rescue 5 flushed the FF's eye. A fire fighter came from Rehab to the IC and related that there were ten full SCBA bottles remaining at the scene and that Rescue 6 was leaving the scene to get its cascade system refilled. A Fire Fighter-Paramedic from Rescue 5 was standing near the IC and stated that he could take the SCBA bottles to the Rear Sector. The Rescue 5 FF-P loaded the SCBA bottles onto a stretcher and took the bottles to the Rear Sector. Engine 40 (call-back crew) responded at 1113 hours. When the FF-P from Rescue 5 delivered the SCBA bottles to Ladder 6, he requested to join Engine 5 crewmembers in extinguishing burning pallets on the dock and to enter the unburned portion of the building to check for fire spread, which he was allowed to do. The Rear Sector Officer had not advised the Engine 5 Lieutenant that the FF-P was assigned to Rescue 5. The FF-P and a FF advanced a 1¾-inch hoseline into the building. F-4 advised the IC that Rescue 6 will soon be enroute to replace Rescue units on scene. The IC requested that Engine 10, if finished with rehab, assist the Rear Sector with entering the rear portion of the fire building to assess any fire spread.

Rescue 6 became enroute back to the scene at 1120 hours. Ladder 6 advised the IC that they needed another eight SCBA bottles, that they were already four short (out of air) and would need an additional four. Rescue 10 was sent back to its fire station. Engine 41 (call-back crew) responded at 1133 hours. Rescue 6 arrived back on-scene at 1137 hours.

The FF-P from Rescue 5 and the FF from Engine 5 exited the building and extinguished a burning pallet. The FF-P walked to the edge of the loading dock, climbed down from the dock, and walked to Ladder 6, where he attempted to take his SCBA mask off. As the Lieutenant of Ladder 6 assisted the FF-P in removing his mask, the FF-P stated that his chest hurt, and collapsed. At 1139 hours, Ladder 6 advised the IC that a Rescue was needed at their location for a fire fighter having breathing difficulties. The IC notified Rescue 6 and advised all personnel working in the rear of the fire building to wear SCBA, even if working outside. Ladder 6 then advised the IC that they had a fire fighter with chest pains at their location. The IC stated that he had sent Rescue 6 to their location. Dispatch asked Ladder 6 if there were two patients. Ladder 6 advised Dispatch that there was one patient with chest pains. Dispatch advised the IC that it sounded like there was one with chest pains and one with difficulty breathing, two different locations, Ladder 8 and Ladder 6. The IC acknowledged the message and stated that Rescue 5 was on-scene also and that he was going to send them over to Ladder 6. Rescue 5 notified the IC that Rescue 6 personnel would take Rescue 5 back to Ladder 6's location.

At 1142 hours, Dispatch notified the IC that fire units were responding to another fire near their location and asked if those units could utilize the intersection near the fire building. Soon afterward, Engine 8 asked the IC if there were any replacement crews. The IC advised that replacements were coming. Ladder 6 then advised the IC that they were due for a replacement also. The IC advised Ladder 6 that he would get back to them. Ladder 6 advised the IC that their Ladder was experiencing mechanical problems on their water tower and had to shut down. The IC notified Dispatch of the mechanical problem and requested assistance from the Maintenance Division.

At 1154 hours, Dispatch notified the IC that Rescue 5 had left the scene and asked if Rescue 6 was with another patient. Dispatch advised the IC that they would send another Rehab Rescue if needed on-scene. The IC stated that they did not have confirmation yet on how many patients there were. Ladder 6 advised the IC that Rescue 6 had left the scene and that it was Rescue 5 personnel who went down. The IC requested Dispatch send another Rescue to the scene. At 1155 hours, Rescue 10 advised that they would return to the scene. The IC advised Engine 3 to ladder Olds Seed building and train a 2½-inch hoseline down onto the fire building, which they did. Engine 5 crewmembers walked to Rehabilitation and rehydrated. An off-duty Lieutenant arrived at the scene and relieved the Engine 3 Lieutenant (a pre-arrangement). Engine 3 crewmembers soon exited the roof of Olds Seed Company and attempted to locate food, but found only sweets and water.

Rescue 10 arrived on-scene at 1200 hours. Engine 5 crewmembers, having completed rehabilitation, changed their SCBA bottles, got an extra bottle, and returned to their assigned area. Engine 40 and Engine 41 arrived on-scene at 1207 hours. The Rear Sector Officer requested relief for some of the crews (Engine 8) in his Sector. The IC advised that he had one relief crew (Engine 41) that would relieve Ladder 8's crew and one crew (Engine 40) that relieve Ladder 6. Soon thereafter, the Apparatus Engineers on Engine 3 and Engine 8 were replaced by Engine 3 crewmembers.

Engine 40 was then positioned beside Ladder 6 and pumped water to Ladder 6's hoselines. Engine 40 and Engine 41 crewmembers began to extinguish hot spots. At 1220 hours, the IC advised Dispatch that the fire wall was intact. Car 32 responded at 1253 hours. Rescue 5 returned to the scene at 1322 hours. Engine 42 (call-back crew) responded to the scene at 1327 hours. Car 32 arrived on scene at 1329 hours. At 1347 hours, the IC advised Dispatch that the fire was knocked down and the crews were doing hot spot overhaul. After using one SCBA bottle, Engine 41 crewmembers exited the smoky area, took a break, and changed their bottles. They extinguished hot spots in an office that protruded onto the loading dock. Engine 41 crewmembers, having used a second SCBA bottle, exited the area again and took another break. Rescue

6 and F-10 departed the scene at 1351 hours. Engine 41 was directed to relocate and its crewmembers take a hoseline onto the roof of Olds Seed Company to extinguish hot spots. Rescue 5 departed the scene at 1452 hours. Rescue 6 returned to the scene after refilling its cascade system a second time. Engine 5 departed the scene at 1534 hours, Ladder 1 and Engine 10 at 1556 hours, and Rescue 10 at 1600 hours. Engine 7 responded to the scene at 1604 hours. Ladder 8 departed the scene at 1608 hours, Engine 8 at 1609 hours, Engine 3 at 1615 hours, and Ladder 6 and Rescue 6 at 1620 hours. Engine 1 responded to the scene at 1622 hours. Engine 7 arrived on-scene at 1630 hours. Engine 1 arrived on-scene at 1632 hours and its crew was directed atop Olds Seed Company to train the 2½-inch hoseline onto the hot spots. The IC departed the scene at 1720 hours and passed command to the Lieutenant of Engine 1. Ladder 6 and Rescue 6 returned to the scene at 1745 hours. Ladder 6 departed the scene at 1822 hours. Engine 9 responded to the scene at 1909 hours; Ladder 2, at 1939 hours. Engine 9 arrived on-scene at 1942 hours. Engine 42 departed the scene at 1952 hours, the Fire Investigator at 1953 hours, and Car 32 at 1954 hours. F-2 returned to the scene at 2000 hours. Engine 7 departed the scene at 2002 hours. Ladder 2 arrived on-scene at 2011 hours. The Fire Investigator returned to the scene at 2020 hours. Engine 41 departed the scene at 2031 hours. Engine 1 departed the scene at 2048 hours and command was passed to the Ladder 2 Lieutenant. F-2 departed the scene at 2200 hours, Engine 9 at 2224 hours, the Fire Investigator at 2234 hours, and Ladder 2 at 2257 hours. Engine 40 and Rescue 6 departed the scene the next day, October 2, at 0638 hours. Engine 10, Engine 3, Engine 9, Engine 5, Engine 8, Ladder 1, and the Fire Investigator returned to the scene on October 2 to maintain scene security and to check for spot fires. Agents from the Bureau of Alcohol, Tobacco, and Fire Arms began to arrive on October 3 to conduct their investigation into the cause of the fire.

**For Information on Other
Occupational Safety and Health Concerns**

**Call NIOSH at:
1-800-35-NIOSH (356-4674)
or visit the NIOSH Web site at:
www.cdc.gov/niosh**



- Delivering on the Nation's promise:**
- **Safety and health at work for all people through research and prevention**

