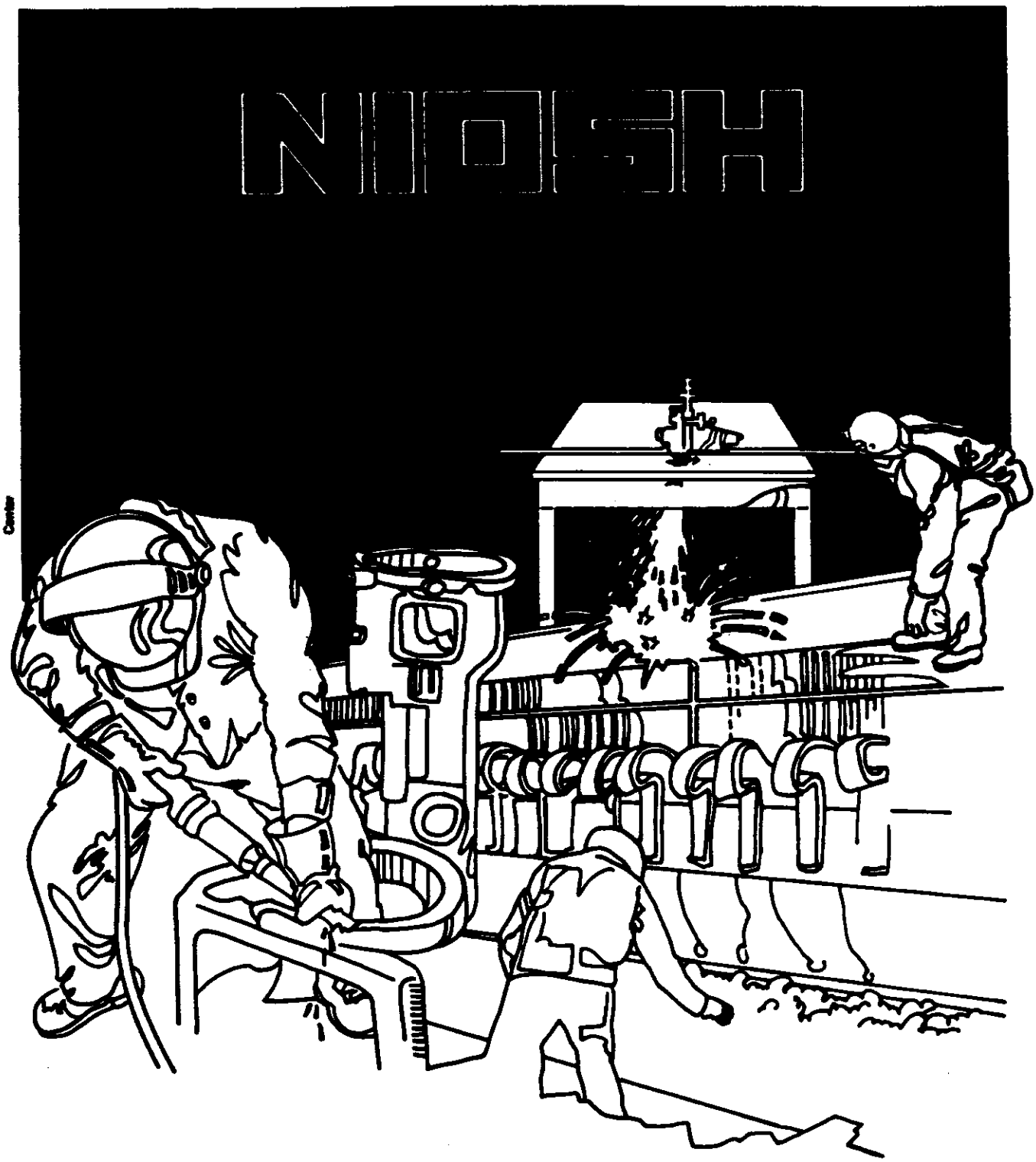
This Health Hazard Evaluation (HHE) report and any recommendations made herein are for the specific facility evaluated and may not be universally applicable. Any recommendations made are not to be considered as final statements of NIOSH policy or of any agency or individual involved. Additional HHE reports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



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Health Hazard Evaluation Report

HETA 87-109-1950
NORTH RIVERSIDE FIRE DEPARTMENT
NORTH RIVERSIDE, ILLINOIS

PREFACE

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

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

HETA 87-109-1950
MARCH 1989
NORTH RIVERSIDE FIRE DEPARTMENT
NORTH RIVERSIDE, ILLINOIS

NIOSH INVESTIGATORS:
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I. Summary

In January 1987 the National Institute for Occupational Safety and Health (NIOSH) received a request from the International Association of Fire Fighters (IAFF) to evaluate the toxicity of smoke clouds produced by a zinc chloride ($ZnCl_2$) smoke generating device (5D smoke bomb) used for smoke training drills at the North Riverside Fire Department, North Riverside, Illinois. During the second of two exercises in October, 1986, fire fighters reportedly experienced adverse health effects including fever, chills and soreness of joints.

On February 17, 1987 NIOSH investigators conducted an assessment of the smoke cloud components generated by the 5D smoke bomb at the North Riverside Fire Department's fire training facility. During each of two tests, three 5D smoke bombs were used in the same manner as in the October 1986 exercise. Based on findings of a previous NIOSH study, air samples were collected for HCl, zinc compounds, and chlorinated hydrocarbons.

HCl concentrations ranged from a trace to 44 milligrams per cubic meter (mg/m^3). The HCl concentrations on the 2nd floor of the training facility which ranged from 20 to 44 mg/m^3 were measured in 15 to 20 minute samples and all exceeded the OSHA and ACGIH ceiling level criteria of 7 mg/m^3. Zinc chloride concentrations ranging from 63 to 172 mg/m^3 were found on the second floor and from 21 to 42 mg/m^3 on the third floor. The zinc chloride concentrations in these 15 to 20 minute samples exceeded the ACGIH short-term exposure limit of 2 mg/m^3. Five chlorinated hydrocarbons were measured at quantifiable concentrations on the second floor. Perchloroethylene was present at the highest relative amounts (up to 62 mg/m^3). The rest were present at less than 10 mg/m^3. Several of the chlorinated hydrocarbons detected are suspect human carcinogens. It should be noted that the measured concentrations constitute an exposure only when the proper respirator is not worn.

The amount of smoke generated during the exercise was far in excess of the amount currently recommended by the manufacturer. However, prior to April 1987, the manufacturer's literature did not specify how many smoke generating devices to use for a given volume of space.

The medical investigation consisted of interviews conducted over the telephone to assess the employees symptoms. Five of the six participants experienced symptoms including breathing difficulty, joint pain, fever and chills, and general fatigue. One training participant continued to be bothered by joint pain and exertional shortness of breath (in excess of that perceived as normal) for two weeks following the exercise. All of those interviewed were asymptomatic at the time of the interviews. These fire fighters were either not wearing a respirator or had removed it as part of the drill.

Dense clouds generated by Zn Cl_2 smoke generating devices should be considered hazardous. While a properly operating SCBA worn by a well-trained individual offers adequate protection against the smoke, even short-term exposure to the dense smoke without respiratory protection presents a health hazard. Recommendations for precautionary measures to minimize potential inhalation health hazards are presented in Section VIII.

Keywords: SIC 9224 (Fire Protection), smoke-generating devices, smoke bomb, zinc-chloride, hydrochloric acid, chlorinated hydrocarbons.

II. INTRODUCTION

On January 9, 1987, the National Institute for Occupational Safety and Health (NIOSH) received a request from the International Association of Fire Fighters (IAFF) to assess the toxicity of smoke clouds produced by a smoke generating device (5D smoke bomb). The requestor stated that during an October 1986 smoke training exercise at the North Riverside Fire Department's Fire Training facility, North Riverside, Illinois, fire fighters experienced adverse health effects when using these devices. The components of smoke clouds produced by $Zn\ Cl_2$ type smoke bomb devices have been found to include hydrochloric acid (HCl), zinc compounds, and a number of chlorinated hydrocarbons.[1]

NIOSH investigators visited the North Riverside Fire Department on February 17, 1987 to assess the smoke cloud components. Concurrently, a NIOSH physician interviewed the participants of the October, 1986 training exercise by telephone.

Preliminary results of the investigation, and recommendations, were distributed by letter in April 1987.

III. Background

Superior Signal Company has sold zinc-based smoke generating devices for approximately 30 years. The 5D smoke bomb is one of several devices the company currently sells. These devices differ primarily in their size and amount of smoke produced. These devices have commonly been used to generate smoke for fire training, disaster drills, and air flow studies. Until about the early 1980s, advertising literature stated that these devices were medically proven to be non-toxic. However, zinc chloride smoke generating devices have been implicated in a number of smoke training accidents.[2-11]

The North Riverside Fire Department has 15 full-time fire fighters and 13 additional fire fighters on call. The fire department's fire training facility is located in one corner of the fire house (Figures 1-2) which was built in the late 1970s. The training facility has three floors and a basement. Each of the three upper floors has a landing with an adjacent stairway, a window, and at least one door. Fire drills have been conducted in the facility approximately four times per year since it was built. The total estimated volume of this training facility is 6700 cubic feet.

During October 1986, two drills were conducted using 5D smoke bombs to simulate a smoke-filled burning building. The October 1986 drills represented the first use of the 5D smoke bombs at this location. Materials previously used to create smoke included straw, wood, and on one occasion a smoke device of unknown identity which had been obtained from the National Guard.

During the second October drill, six fire fighters were involved in a high rope rescue training exercise. Those affected by the smoke were not wearing a respirator or took it off to participate in the drill (e.g. yelling for help).

IV. METHODS

A. Environmental

NIOSH investigators evaluated two separate training exercises on February 17, 1987. North Riverside fire training personnel were asked to position three 5D smoke bombs (the number used during the October drills) in the same locations used in the October 1986 drill. One bomb was placed on each of the 1st, 2nd and 3rd floors (Figure 2). For each training exercise, air samples were collected for chlorinated hydrocarbons, HCl, and metals, including zinc. These chemicals were determined to be the primary smoke cloud components in a previous NIOSH investigation.[1] Area air samples were collected on the 2nd floor, where the highest exposures were anticipated, on the 3rd floor where one employee had been standing during the previous drill, on the roof, and at an outside location. Additional air samples were collected in the basement of the adjacent living space for the second test because smoke had infiltrated into the fire truck bay and adjacent living spaces during the first test.

Battery-operated pumps, with the appropriate sampling media attached via flexible tubing were suspended at breathing height (5 1/2 ft.) at the inside sampling locations. All sampling pumps were started when the smoke devices were ignited. After 15 minutes, all pumps were turned off. A 15-minute sampling period was chosen after consideration of the burn time of the smoke device (5-minutes), analytical limits of detection and sampling pump flow rates. More details on the sampling and analytical techniques are presented in Table 1.

B. Medical

All six firefighters who participated in the October 1986 high rope rescue training exercise were interviewed by telephone.

V. Evaluation Criteria

A. Environmental Exposure Criteria

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff usually employ environmental evaluation criteria for assessment of a number of chemical and physical agents.

Some of 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. Since fire training exercises are of short duration these long-term exposure are not as relevant. They are presented in this report as points of reference. Short-term criteria, [15 minute short-term exposure criteria, ceiling level criteria and concentrations that are considered to be immediately dangerous to life or health (IDLH)], are more relevant for evaluating the acute health effects of exposures to these smoke clouds.

When exposure occurs to a mixture of substances it is usual practice to consider the effects of those that elicit similar responses to be at least additive. That is, if one is exposed to 5 mg/m^3 of chemical A and 5 mg/m^3 of chemical B, and both are respiratory irritants, then from the standpoint of potential health effects, the exposure, in a general sense, is often thought of as an exposure to 10 mg/m^3 of a respiratory irritant. There can also be a synergistic effect. That is, the overall effect is greater than each singular effect or, in some cases, an additive effect.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), and 3) the U.S. Department of Labor (OSHA) occupational health standards.[12-16] Often, the NIOSH recommendations and ACGIH TLVs are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLVs usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended exposure limits, by contrast, are based primarily on concerns relating to the prevention of occupational disease.

B. Toxicity of Chemicals Detected in the Smoke Clouds

Inhalation is the most significant route of exposure to the smoke constituents. The primary smoke cloud components are zinc chloride, hydrochloric acid, and a mixture of chlorinated hydrocarbons.

The primary effects of acute exposure to aerosolized HCL are due to its corrosive properties. Exposure to HCL has been shown to be associated with pulmonary, laryngeal, oral, nasal and conjunctival irritation; the magnitude of effect is in proportion to the dose.[17,18] The irritant effect of the vapors on the respiratory tract may produce bronchitis, pulmonary edema, and death. The OSHAstandard and ACGIH TLV for HCl is 7 mg/m^3 as a ceiling value not to be exceeded. The concentration of HCl listed in the NIOSH Pocket Guide to be immediately dangerous to life and health (IDLH) is 140 mg/m^3.[19]

Zinc chloride, which reacts with water to produce HCl, is an irritant to eyes, mucous membranes, and skin. Inhalation exposure may precipitate a cough (with or without sputum production), stridor, a sensation of chest tightness, dyspnea, pulmonary edema, cyanosis, and in case of very high exposure, death.[17-20] The OSHA standard for zinc chloride is 1 mg/m^3 (8 hour TWA) The ACGIH TLV is 2 mg/m^3 as a short-term exposure level (STEL) for a 15-minute period. The concentration listed in the NIOSH Pocket Guide to be IDLH is 2000 mg/m^3.[19]

The chlorinated hydrocarbons detected in this evaluation may be responsible for numerous symptoms. Table 2 presents the health effects of overexposure. Several of the chlorinated hydrocarbons detected are suspect human carcinogens; however, the potential acute respiratory effects from exposure to the zinc compounds and HCl are of more immediate concern considering how these devices are used during training exercises. The carcinogen issue is complex, especially when the exposure is to a mixture of compounds.[21-26]

VI. RESULTS AND DISCUSSION

A. Environmental

Figure 3 presents the results of a qualitative analysis of a bulk air sample collected during the NIOSH tests. Over 10 chlorinated hydrocarbons were qualitatively identified, including perchloroethylene, carbon tetrachloride, trichloroethylene, hexachloroethane, hexachlorobutadiene, and several chlorobenzenes.

Table 3 presents the air concentrations of the smoke cloud components measured in both tests. Air concentrations for HCl ranged from 20 to 44 mg/m^3 on the second floor and from 1.9 to 6.9 mg/m^3 on the third floor. All values measured on the second floor are above the OSHA AND ACGIH ceiling value of 7 mg/m^3 for HCl.

Zinc was measured in the range of 30 to 82 mg/m^3 on the second floor and from 10 to 20 mg/m^3 on the third floor. Corresponding values for zinc chloride, assuming the zinc was present as zinc chloride, are 63 to 172 mg/m^3 and 21 to 42 mg/m^3, respectively. Thus, the current ACGIH STEL (2 mg/m^3) was exceeded by up to 86 times.

Five chlorinated hydrocarbons (see Table 3) were detected at quantifiable concentrations on the second floor and three of the five were detected on the third floor. Perchloroethylene was measured at the highest relative amounts (up to 62 ppm). The presence of suspect human carcinogens in the smoke clouds constitute a potential long term risk to someone exposed while not wearing a respirator, however, the potential acute health effects from exposure to the zinc compounds and the HCl are of more immediate concern considering how these devices are used.

During the first NIOSH test, smoke infiltrated the fire truck bay and the lower floor of the living spaces. Fire Department personnel reported that smoke was visibly heavy during the first part of the test. Heavy smoke was observed in the truck bay by the NIOSH survey team during the second test. Samples that were collected in the billards room on the lower floor for the second test detected trace amounts of HCl and zinc.

There were no written standard operating procedures (SOP) for the fire training exercises. Such documents are one method to insure consistency and quality control of training activities.

A limitation of this study is the lack of instantaneous, or "grab" samples. Since the 5D smoke bombs have a burn time of about 5 minutes and were ignited at the start of the sampling period, one can assume that air concentrations were highest during the first five minutes of the 15-minute sampling time. The smoke cloud was visibly most dense during the early stages of sampling. Airborne contaminant levels are governed by the number and type of smoke devices used, the volume of the training facility, and the air leakage out of the facility during the test. Use of the same number and type of device under different training conditions could result in lower or higher exposures. A previous NIOSH investigation of an airport disaster drill documented minimal exposures to training participants when one 5D smoke bomb was used outdoors.[21]

Manufacturer's literature, at the time the field data was collected, did not specify what type, or how many, zinc chloride smoke generating devices should be used in a given size area. One of the most important criteria, from the standpoint of the fire training officials, was that vision be effectively obscured. Updated manufacturer's information, available in 1987, does include this information, and, by the 1987 usage criteria, far more smoke was generated than recommended. Additionally, the smoke generating devices are often obtained without the material safety data (MSDS) and other supplemental manufacturers' information.

This study did not evaluate alternative smoke generating methods. The atmosphere produced by another common method of generating fire training smoke, actual burning of combustible materials, although not studied by NIOSH, should also be considered hazardous and warrants the use of an SCBA.

B. Medical

Six fire-fighting personnel were involved in the training exercise in October, 1986. Medical information concerning these individuals was obtained in February 1987 by telephone interview. Five of the six participants reported development of symptoms either immediately post-exercise or within a few hours of exercise. These fire fighters were either not wearing a respirator or had removed it as part of the drill.

Symptoms reported included:

1. Sore throats (3 persons).
2. Difficulty breathing (2).
3. Joint (upper and lower extremities) stiffness and pain (2).
4. Chills and fever (2).
5. Headaches (1).
6. Generalized fatigue (1).

One training participant, who reported being exposed to dense smoke, continued to be bothered by joint pain and exertional shortness of breath (in excess of that perceived as normal) for two weeks following the exercise. This was the only individual who received a medical evaluation at the time of the event; no exposure-specific biological monitoring tests were performed at that time. All of those interviewed were asymptomatic at the time of the medical interviews.

VII. CONCLUSIONS

Based on the data collected, dense clouds produced from $ZnCl_2$ smoke generating devices should be considered hazardous. Chemicals measured in the 5D smoke bomb clouds are consistent with the results of a previous NIOSH investigation of smoke bomb type devices[1] and symptoms reported by the North Riverside fire fighters are consistent with those reported in previous episodes (Table 4).[2-11]

A well trained individual wearing a properly operating SCBA will be adequately protected while in the atmospheres generated by the devices evaluated as part of this study; however, even a short-term unprotected exposure to the components of a dense smoke cloud could result in serious health effects.

VIII. RECOMMENDATIONS

1. No smoke generating device should be considered "absolutely safe" or "non-toxic". Additionally, product literature should be obtained and manufacturer's guidelines followed when using any smoke generating device.

2. If zinc chloride smoke generating devices are used to generate dense clouds, the smoke should be considered hazardous and participants who enter the smoke should wear a self contained breathing apparatus (SCBA). Practices like "buddy breathing" should not be conducted in these dense smoke clouds.

3. Anyone who enters any type of smoke cloud should be instructed to leave the area immediately if they notice any problem (such as a leak in the SCBA). If such individuals experience any breathing difficulties, they should receive medical evaluation as soon as possible.

4. Standard operating procedures should be implemented for training to test new devices and for actions to take should anyone experience problems during a training exercise.

5. While an SCBA, worn by a trained individual will eliminate the inhalation hazard associated with the zinc chloride smoke generating devices, thought should be given to what the real goals of fire training exercises are and what atmospheric characteristics are required to fulfill those goals. For example, is it necessary to generate a dense smoke to obscure vision, or can the face shield of the SCBA be darkened to simulate smoky conditions? Once goals are delineated, a decision can be made as to whether the use of the zinc chloride devices are indicated or whether alternative methods should be evaluated. Whatever method is chosen should be based on the risks and benefits associated with each.

6. Warning labels on individual smoke generating devices should be modified to include information on the principal smoke cloud components.

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XI. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are temporarily available upon request from NIOSH, Hazard Evaluations and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. North Riverside Fire Department
   International Association of Fire Fighters (IAFF),
   Local #2714, North Riverside, Illinois
2. IAFF, Washington, D.C.
3. Superior Signal Company

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

TABLE 1

Sampling and Analytical Techniques
North Riverside Fire Department
North Riverside Illinois
HETA 87-109
Febraury 17, 1987

Material Evaluated	Media	Flow Rate (LPM)	Analytical Techniques
Hydrochloric Acid	ORBO-53 tubes	0.5	Samples were analyzed for hydrochloric acid by ion chromatography according to NIOSH Method 7903. The A and B sections of the silica gel tubes and the fiber end plugs were each separately desorbed in 10 ml of eluant and heated in a boiling water bath for 10 minutes. The resulting solutions were filtered through a 0.45 micron filter, and an aliquot of each solution was analyzed via a Dionex 2010 ion chromatograph utilizing a WISP 710B auto sampler.
Chlorinated Hydrocarbons qualitative and quantitative samples	Charcoal Tubes	0.2 and 0.5	Qualitative samples were desorbed with 1 ml of CS_2 and screened by gas chromatography (FID) The sample with the higher concentrations was further analyzed by GC/MSD to identity components. Quantitative samples were desorbed as above and then analyzed using a GC-FID
Metals	Mixed Cellulose Ester Membrane Filter	2.5	Samples were digested with nitric and perchloric acids. The residues were dissolved in a dilute solution of the same acids and the resulting sample solutions were analyzed for trace metal content using Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES).
Zinc Compound Identification	Mixed cellulose Ester Filter	2.5	Analysis via Transmission Electron Microscopy via Zumwalde-Dement procedure outlined in NIOSH publication no. 77-204. Each preparation was examined 230x and 18,000x magnification. Elemental spectra were obtained during the analysis.

TABLE 2

Health Effects of Identified Smoke Cloud Components
North Riverside Fire Department - Fire Training Facility
North Riverside Illinois

HETA 87-109
February 17, 1987

Chemical	IDLH	Medical Outcome	Reference
Zinc Chloride Fume ($ZnCl_2$)	2000 mg/m^3	fever, cyanosis, tachypnea, burning skin and eyes, conjunctivitis, irritation of nose and throat, cough, copious sputum, chest pain, pneumonia, pulmonary fibrosis	12,16,19
Hydrochloric Acid (HCl)	100 ppm (140 mg/m^3)	burning eyes and skin, dermatitis, inflammation and ulceration of nose, and throat, cough, choking	12,16,19
Tetrachloroethylene (Perchloroethylene) ($CCl_2=CCl_2$)	500 ppm	irritation of eyes, nose, throat, nausea, flushing of face and neck, vertigo, dizziness, incoordination, headache, sommolence, erythema, liver damages, cancer	12,13,16,19,22,23
Hexachloroethane (CCl_3-CCl_3)	300 ppm	eye irritation and cancer	12,13,16,19
Trichloroethylene ($CHCl=CCl_2$)	1000 ppm	headache, vertigo, visual disturbances, tremors, somnolence, nausea, vomiting, irritation of eyes, dermatitis, cardiac arrhythmias, cancer	12,13,16,19,24,26
Carbon Tetrachloride (CCl_4)	300 ppm	skin irritation, central nervous system, depression, nausea, vomiting, liver and kidney damage, liver cancer	13,16,19,25,26
Hexachlorobutadiene ($CCl_2=CCl-CCl=CCl_2$)		eye and nose irritation, kidney tumors	16,26

IDLH = Concentration of subject chemical reported to be immediately dangerous to life and/or health of individual exposed without adequate protective equipment. IDLH values are listed in the NIOSH Pocket Guide (Reference 19).

Table 3

Results of Environmental Sampling in Smoke Clouds from 5D Smoke Bombs
North Riverside Fire Department
North Riverside, Illinois

HETA 87-109
February 17, 1987

Sample Location	No. of Samples	Test	Range of Concentrations for Chemicals Measured in Smoke Cloud (mg/m^3)								
			HCl	Perchloro-ethylene*	CCl_4*	hexachloro-butadiene*	hexachloro-ethane*	Trichloro-ethylene	Zn	$ZnCl_2$**	lead
Second floor	2	T1	20-28	46-47	3.1-3.2	(0.5)	9.6-9.7	(1.2-1.3)	55-82	116-172	0.1-0.13
"	2	T2	34-44	54-62	5.6-6.4	(0.7-0.8)	16-18	1.5-1.7	30-38	63-80	0.05-0.07
Third floor, near window	2	T1	1.9-4.3	3.6-4.1	(ND-0.5)	ND	(1.2-1.3)	ND	10-11	21-23	ND
	2	T2	6.4-6.9	5.5-6.3	(0.4-0.5)	ND	(1.4-1.6)	ND	19-20	40-42	ND
Basement, billiards room	1	T2	(0.4)	(0.49)	ND	ND	ND	ND	2	4.2	ND
Roof, outside	1	T1	(0.3)	ND	ND	ND	ND	ND	0.31	0.65	ND
"	1	T2	(0.5)	ND	ND	ND	ND	ND	0.39	0.82	ND
Ground level, outside	1	T1	ND	-	-	-	-	-	ND	ND	ND
	1	T2	ND	-	-	-	-	-	ND	ND	ND
ACGIH =			7-C	1340-STEL	125-STEL	0.24-T	100-T	None	2-STEL	2-STEL	0.15-T
NIOSH =			None	MWEL	12.6-C	None	LFL	None	None	None	0.10-T
OSHA =			7-C	2010-C	150-C	None	10-T	None	1-T	1-T	0.05-T

One sample from each test, evaluated to determine the zinc compounds present, measured 75-80% $ZnCl_2$, and 15-20% ZnO.
Sample times were ranged from 15-20 minutes for all samples. Chemical was present in the air sample at a level below the laboratory limit of detection, but below the laboratory limit of quantitation, the numbers listed are estimates.

T = Time-weighted Average
STEL = Short-term exposure limit
C = Ceiling value not to be exceeded
MWEL = Minimize workplace exposure level
LFL = Lowest feasible level
ND = None detected

HCl = Hydrochloric acid
CCl_4 = Carbon tetrachloride
Zn = Zinc
$ZnCl_2$ = Zinc chloride
Pb = Lead

* = Chemical considered to be a carcinogen by NIOSH, and/or OSHA and/or ACGIH
** = Values for zinc chloride are calculated by multiplying the total zinc measured by a factor of 2.1. This assumes all zinc measured is zinc chloride.

Table 4

Partial Listing Of Reported Episodes
Involving Smoke Bomb ($ZnCl_2$) Devices

Reference/ Date/ Location	Event	Summary of Reported Health Effect
Ref-8 Feb 83 Malta	Zinc chloride smoke device devices caught fire and filled tunnel with estimated volume of 100,000 ft^3 of smoke. Two of 10 deaths occurred as late as the 14th day after the accident. Six weeks after the accident, two people were still adversely affected.	10 deaths; dyspnea, chest tight; episternal and epigastric pain, red & tearing eyes, cough with copious expectoration; blood stained sputum, nausea & vomiting, cyanosis, headache, high fever. Two autopsies showed red & oedematous lungs & mucous membranes; ulceration at the bifrication of the trachea. Liver, kidney & cerebral congestion.
Ref-4 1959; Texas	In three separate incidents, 17-19 year old airmen were accidently overexposed to smoke during routine survival training.	Burning throat, paroxysmal coughing, nausea & retching during first 48 hours, dyspnea, fever & malaise. Fever up to 105 F, developement of tachypnea and cyanosis. Xray showed infiltrate in both lungs. Symptoms negative after 2-4 month.
Ref-9 Pre-1963 Ontario, Canada	35 year old fireman participated in a fire exercise. Smoke generator placed at the bottom of a depression - buildings on three sides. Patient tried to extinguish bomb. A colleague withdrew almost immediately.	Both subjects reported nausea, sore throat, and chest thightness. Primary subject had a fever, Xray showed diffuse infiltrates 30 hours after exposure, cyanosis, and confusion. Died on the 18th day.
Ref-7 Pre-1964 England?	19 year old was exposed to smoke during a civil defense training exercise, exposure time estimated to be 4 minutes.	Immediate complaints were retrosternal pain, abdominal cramps, anxiety, cyanosis, and high fever. X-ray showed lung edema, necrosis, hemorrhage and an infarct of the upper left lung.

Table 4
(continued)
Partial Listing Of Reported Episodes
Involving Smoke Bomb ($ZnCl_2$) Devices

Reference/ Date/ Location	Event	Summary of Reported Health Effect
Ref-6 Mar 81	22 year old male during fire fighting exercise on ship, respirator facepiece come apart. Stayed in smoke for 5 minutes for "fear" of "messing up" exercise. Device chosen because it was advertised as non-toxic. Welded galvanized pipe during previous few days.	Cough, sore throat, shortness of breath over next 4 days complained of cough and was lethargic, died on 5th day. Autopsy showed bilateral severe necrotizing pneumonitis and dilatation of right atrium and ventricle.
Ref-2 Apr 81 Mo	During buddy breathing exercise a fire fighter was overcome. Participants noted that device were marketed as "medically proven safe and non-toxic". Bombs had been used for years.	Respiratory and intestinal inflammation, swollen lymph nodes, chills, headache, nausea, fatigue and sore throat.
Ref-10	82 "victims" and 28 medical personal were exposed to smoke during an airport disaster drill	Immediate cough, hoarse, sore throat, later symptoms were nausea, fatigue and headache.
Ref-3 Jun 83 ND	Fire chief developed problem with smoke pac during a "buddy breathing" exercise in a garage. Bombs warned of irritation. Chief inhaled a "breath" of smoke. NFPA in letter recommended not using toxic smoke.	Difficult breathing, chest pains, hot and and cold flashes, and nervousness. At hospital emergency room. temperature = 101 F , oxygen administered followed by recovery within 24 hours
Oct 86 IL	5 of 6 fire fighters were affected while conducting smoke training	Symptoms included headache, chills and fever, breathing difficulty, joint pain and sore throats

*Smoke device or exposure are as described in the article or abstract for the reported episode.

FIGURE I

Diagram of North Riverside Fire Department Building

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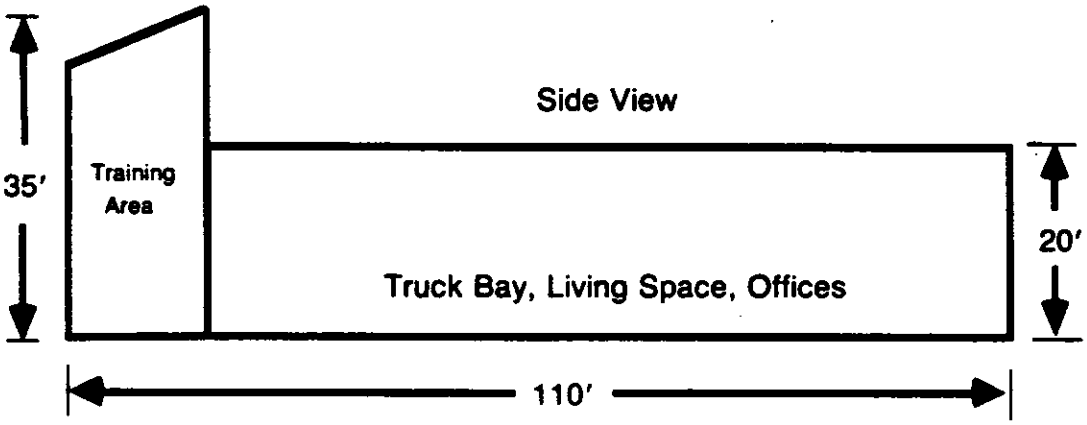
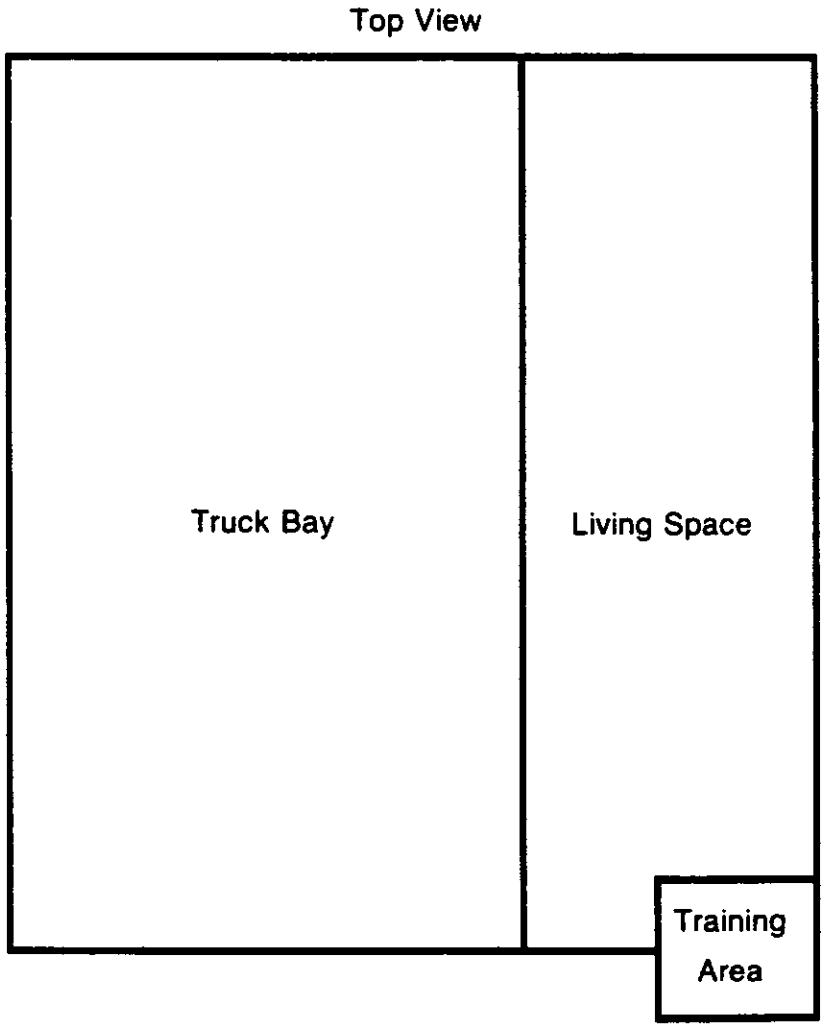




Note: Dimensions and Locations are approximate

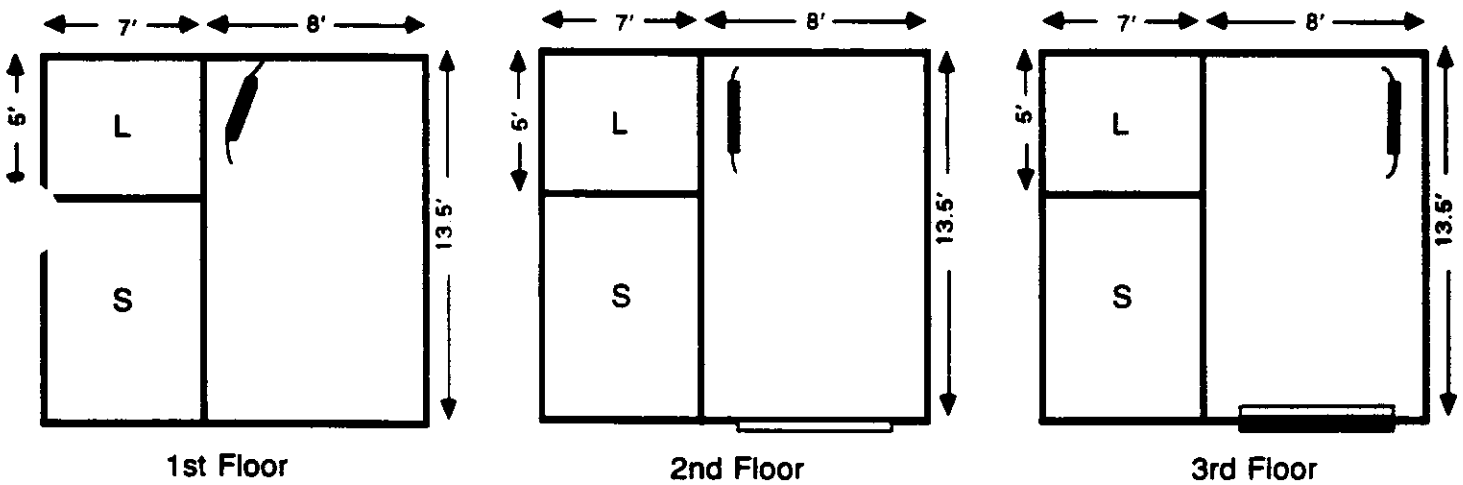
FIGURE II

Location of 5D Smoke Bombs

During NIOSH testing in North Riverside Fire Dept – Training Facility

February 17,1987

HETA 87 – 109



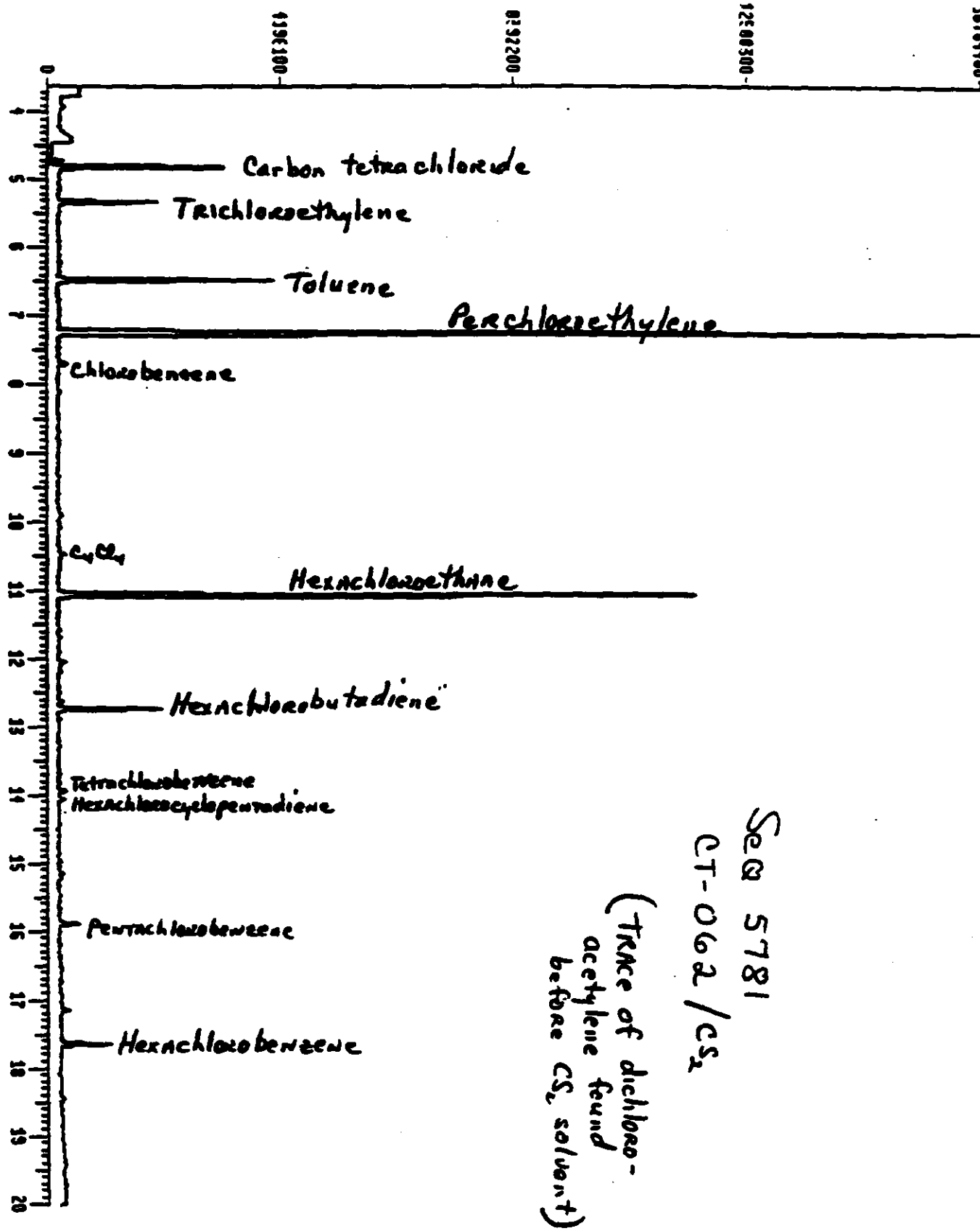
= 5D Smoke Bombs

L = Landing

S = Stairs

Note: Dimensions and Locations are approximate

1: TIC of DATA:SE57818.D



End of plot. Time = 3.63 to 20.03 minutes Chart speed = 1.22 cm/min

FIGURE III

Chlorinated Hydrocarbons Ide[illegible]ed In The 5D Smoke Bomb Cloud