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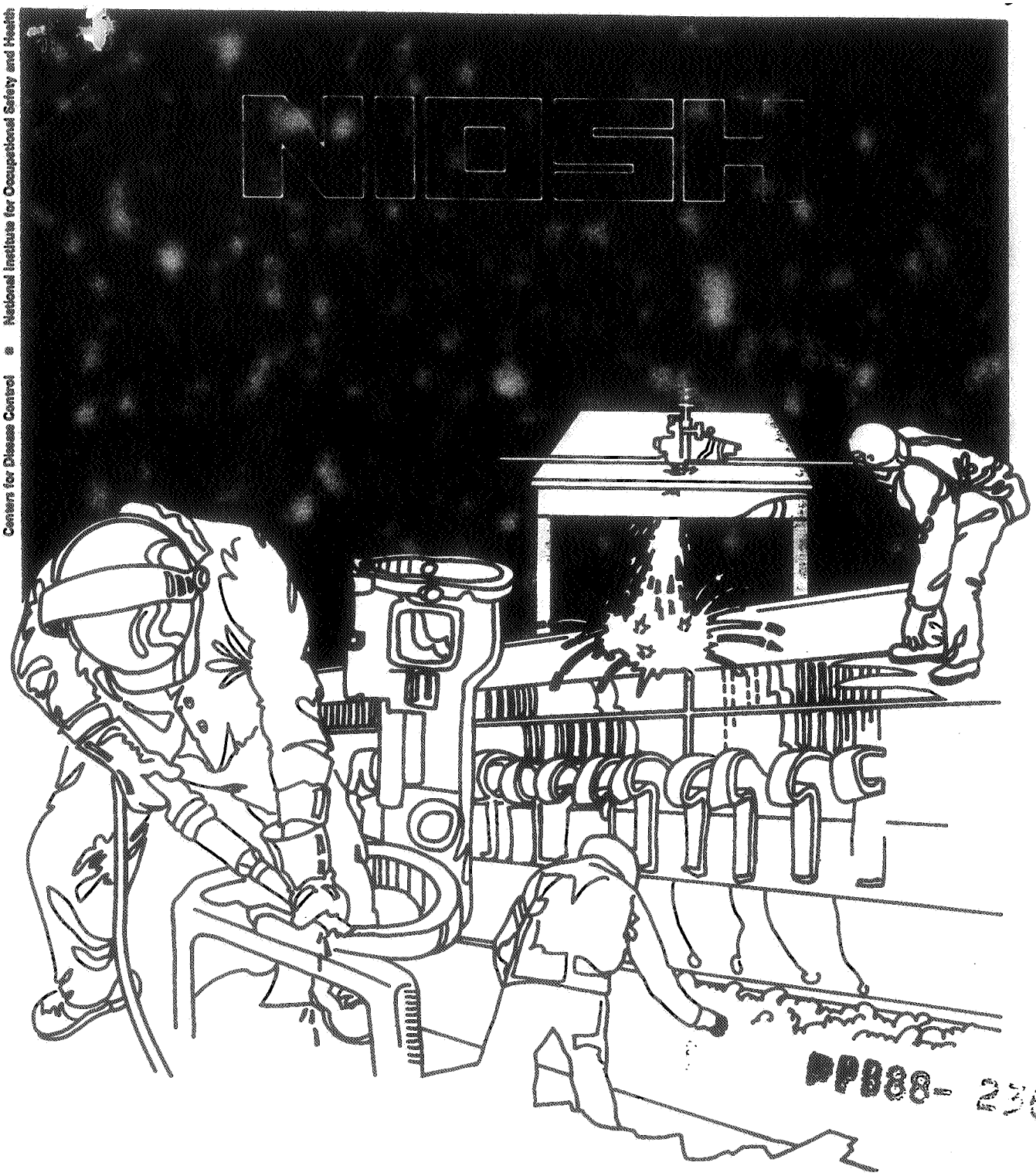

Health Hazard Evaluation Report

HETA 85-274-1879
EVALUATION OF ZINC CHLORIDE
SMOKE GENERATING DEVICES
INTERNATIONAL ASSOCIATION OF
FIRE FIGHTERS
WASHINGTON, D.C.

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 nygiene 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.

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EVALUATION OF ZINC CHLORIDE
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I. SUMMARY

In March 1985 the National Institute for Occupational Safety and Health (NIOSH) received a request from the International Association of Fire Fighters (IAFF) to evaluate the hazard of smoke clouds produced by zinc chloride ($ZnCl_2$) smoke generating devices. The requestor noted that the devices, advertised as "medically proven to be non-toxic", had been implicated in a number of training exercises during which participants experienced adverse health effects, including breathing difficulties, chest pains, joint pains, chills, fever, and death.

A NIOSH literature search indicated that adverse health effects had, in fact, been reported in at least ten episodes; however, those affected were either not wearing a respirator or the respirator had malfunctioned. Literature obtained from the manufacturer in June 1985 reported that the smoke clouds contained $ZnCl_2$, combustion products, and high moisture. Previous investigations had reported finding hydrochloric acid (HCl) and numerous chlorinated hydrocarbons in the smoke clouds. Qualitative tests by NIOSH, as a preliminary effort in this investigation, identified zinc compounds, HCl and over 50 chlorinated hydrocarbons in the smoke cloud. Based on these qualitative data, five separate smoke generating devices were quantitatively evaluated using area sampling techniques during simulated fire training exercises at the Cincinnati Fire Department's fire training facility in December 1985 and April 1986.

Airborne HCl concentrations ranged from 2 to 420 mg/m^3. $ZnCl_2$ concentrations ranged from 11 to 498 mg/m^3. The HCl concentrations documented exceed the OSHA and ACGIH ceiling level criteria of 7 mg/m^3 and the NIOSH IDLH (immediately dangerous to life or health) concentration of 140 mg/m^3. The $ZnCl_2$ concentrations measured exceed the ACGIH short-term exposure limit of 2 mg/m^3.

Numerous chlorinated hydrocarbons, several of which are suspect human carcinogens were also detected. One of these, perchloroethylene, was present in concentrations of 20-540 mg/m^3. Among those chlorinated hydrocarbons detected were carbon tetrachloride, hexachlorobutadiene, hexachloroethane, and chloroform. It should be noted that, from the standpoint of fire training exercises, the acute health risks associated with exposure to the zinc compounds and HCl are of more immediate concern than the carcinogenic risks from the chlorinated hydrocarbons. A properly used SCBA would protect against all of these exposures.

The amount of smoke generated during these exercises was typical of that used in the past to achieve effective vision obscuration, but was far in excess of that currently recommended by the manufacturer. (Prior to 1987 the manufacturer's literature did not specify how many devices were recommended for a given volume of space.)

Results of a telephone survey we conducted in December, 1987 and January, 1988 with fire training personnel at 62 locations throughout the United States revealed that all but one of the fire training organizations that used these devices were using far in excess of that specified in 1987 manufacturer's recommendations.

Dense clouds generated by $ZnCl_2$ smoke generating devices should be considered hazardous. NIOSH sampling documented exposures to HCl which exceed OSHA and ACGIH ceiling levels and the NIOSH IDLH level. While a properly operating self-contained breathing apparatus worn by a well-trained individual offers adequate protection against the smoke, even short-term exposure without respiratory protection to the components of the dense smoke cloud presents a health hazard. Recommendations for precautionary measures to be taken by firefighters to minimize potential inhalation health hazards are presented in Section VIII.

Keywords: SIC 2899 (Miscellaneous chemical preparations) and 9224 (Fire Fighters) smoke bomb, smoke generating devices, zinc chloride, hydrochloric acid, chlorinated hydrocarbons

II. INTRODUCTION

On March 28, 1985, the National Institute for Occupational Safety and Health (NIOSH) received a request from the International Association of Fire Fighters (IAFF) to assess the hazards of using zinc chloride ($ZnCl_2$) producing, smoke generating devices manufactured by the Superior Signal Company, Inc, Spotswood, New Jersey. The requestor noted that although these devices had been advertised as "medically proven to be non-toxic", health problems, including deaths, had been reported during some training exercises in which they were used. The only specific cloud component identified by the manufacturer was zinc chloride.

Information forwarded by the requestor indicated that chlorinated hydrocarbons and HCl were also potential smoke cloud components.[1-3] A Department of the Navy report of a fatality resulting from a training exercise in which a Superior Signal Company 5D smoke bomb was used indicated that a number of chlorinated hydrocarbons were also detected in the smoke cloud (dichloroacetylene, vinylidene chloride, chloroform, carbon tetrachloride, trichloroethylene, tetrachloroethylene, hexachloroethylene). No estimates of either the airborne concentration of these hydrocarbons or percentage of the total cloud they constituted were given.[3]

NIOSH investigators initially conducted a laboratory test of the smallest device sold to assess the chemicals present in a dense smoke cloud. Based on this information two field tests were conducted in a fire training facility to sample smoke clouds produced by five (5) separate devices manufactured by the Superior Signal Company, Inc.

Results, recommendations, and status reports were distributed via letters or interim reports in November 1985, March and June 1986, and April 1987. During the investigation, three meetings were held with Superior Signal Company, Inc. representatives to discuss the NIOSH investigation.

III. BACKGROUND

Superior Signal Company manufactures several different zinc chloride smoke generating devices; they differ primarily in their size and amount of smoke produced. Each device has a rated burn-time and corresponding volume of smoke. Until about the early 1980s, advertising literature stated that these devices were "medically proven to be non-toxic". The smaller devices i.e. the 30 second smoke candle, have been commonly used for ventilation studies. Larger devices have more often been used to generate smoke for training exercises such as fire fighting and airport disaster drills.

The Material Safety Data Sheet (MSDS) dated May, 1972, from the manufacturer (forwarded to NIOSH in June, 1985) stated that smoke generated by these devices could irritate bronchial and nasal passages, that once exposure ceased any irritation would disappear quickly and that affected individuals should be treated for smoke inhalation. The MSDS stated that for other than "casual" exposure, a self-contained breathing apparatus (SCBA) should be used. There was no information on smoke cloud components on the MSDS, but a cover letter stated that the smoke contained zinc chloride, combustion products and high moisture.

The letter also stated that these devices had been used for over 25 years to develop smokey atmospheres for training firefighters in the use of SCBAs.

The five devices NIOSH purchased through a commercial supplier were shipped without MSDS's or supplemental information. Labels on the smoke generating devices contained warnings that all smoke, including smoke produced by these devices, could irritate breathing passages if respiratory protection was not used. The label on the largest device tested (white smoke pot) also stated that the device should not be used in confined spaces without an SCBA because the generated smoke could displace oxygen. None of the labels contained information on the smoke cloud components.

IV. METHODS

A. Literature Search

A comprehensive literature search was conducted to determine the number and types of episodes that have occurred where adverse health effects have been associated with $ZnCl_2$ smoke generating devices.

B. Laboratory Test

To qualitatively determine the probable components of the smoke cloud produced by the zinc chloride smoke generating devices, two 30-second smoke candles (the smallest device sold by Superior Signal Company, Inc.), were ignited inside a cardboard box and the resulting cloud was sampled for gases, vapors, metals, and inorganic acids.

C. Field Tests

December 1985 Test

Based on the laboratory tests, additional testing was done at the Cincinnati Fire Department fire training facility on December 12, 1985. The fire training facility is a three-story brick

structure. The lower floor, which has one room that measured 30 ft x 25 ft x 8 ft (6000 ft^3), was used for this test. A stairway and ceiling/floor grilles connect all three floors. Battery-operated pumps with the appropriate sampling media attached via flexible tubing, were suspended at breathing height (5 1/2 ft.) from the ceiling of the first floor. For each of the two tests conducted, 1-2 samples were collected for identification of HCl, chlorinated hydrocarbons, metals, and zinc compounds. Two 3C smoke bombs were ignited simultaneously for the first test, and one white smoke pot was used in the second test. After 25 minutes, the doors were opened and all pumps were turned off. The building was allowed to clear before the next test was started.

The primary purpose of the December 1985 test was to determine air concentrations of the various decomposition products from the two devices forwarded by the requestor in an actual fire training facility. Due to uncertainties as to the amount of smoke generated, percentage of each component and analytical requirements, the doors and windows were closed. Firefighters present during the test indicated that doors and windows are normally closed during fire training exercises. Area air samples were obtained for total zinc, HCl, and chlorinated hydrocarbons, including chloroform, carbon tetrachloride, trichloroethylene, perchloroethylene, hexachloroethane, and hexachlorobutadiene. Sampling and analytical methods are presented in Table 1.

April 1986 Test

The April 1986 test was conducted at the same facility as the December test with several objectives in mind: (1) to determine if the 3C smoke bomb and white smoke pot generated similar clouds in two separate tests, (2) to test additional Superior Signal smoke generating devices to determine if they produced similar clouds, (3) to determine if the smoke clouds produced were similar in density to those normally used by the Cincinnati Fire Department, which normally burns household furnishings to generate smoke.

To satisfy the first and second objectives, five different smoke generating devices, all manufactured by Superior Signal Company, Inc., were evaluated separately inside the Cincinnati Fire Department's fire training facility. The devices tested were the 30-second candle, 1 minute candle, 3C smoke bomb, smoke grenade, and white smoke pot (Table 2). Each type of device was tested on both April 8 and 9, 1986. For each test, 1-2 samples were collected for identification of HCl, zinc compounds, metals, and chlorinated hydrocarbons. During each test, the oxygen (O_2)

content was determined using an Edmont Oxygen Meter, model 60-625. Additionally, Draeger* gas detector tubes were used to evaluate the O_2 and HCl content of the clouds. Sampling and analytical methods are presented in Table 3.

To evaluate the third objective (smoke cloud density), an official from the Cincinnati Fire Department's fire training staff served as a technical advisor during the tests. This individual was asked to set up the facility as he would for their training exercises, observe the density of each cloud, and state whether or not he believed it to be similar to the clouds produced during their training exercises. Discussions with the technical advisor prior to air sampling indicated for training purposes that heavy clouds were needed to obscure visibility in the training building, thus simulating smoke conditions in an actual building fire.

With doors and windows closed, as during training, four to six units of the three smaller devices and one each of the two larger devices were used. On the second day, the number of 3C smoke bombs and grenades was increased because the technical advisor felt that the smoke clouds generated on the first day were not dense enough. On the first day, the smaller devices were ignited outside and tossed into the fire training facility, per directions on product labels. On the second day, for each test, all devices were placed inside the fire training building and ignited simultaneously. On the second day of testing a white smoke pot was also tested on the second floor to determine air concentrations of HCl and chlorinated hydrocarbon generated in a smaller area.

D. Telephone Survey

In December 1987 and January 1988, fire training personnel at 62 different fire training organizations across the United States were contacted by telephone to obtain information related to the use of smoke bomb type devices. A United States Atlas and city telephone "information" service was used to obtain the phone numbers of fire departments. Those organizations which we knew had experienced problems with the smoke bombs, that had been written about in the literature; or who NIOSH had already spoken with about fire training were omitted from this telephone survey.

Once the fire training organization was contacted, a training offical was questioned to determine if the organization had used smoke bomb type devices. Those indicating that they had used these devices were further questioned as to the number and type of devices used, how long they have been using them, and the manner in which they used the devices.

V. EVALUATION CRITERIA

A. Environmental 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 additive. That is, if one is exposed to 5 milligrams per cubic meter of air (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.[4-7] 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 Measured in the Smoke Clouds

Inhalation is the only significant route of exposure to the smoke constituents relevant to this hazard evaluation. 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 concentration.[8,9] The irritant effect of the vapors on the respiratory tract may produce bronchitis, pulmonary edema and death. The OSHA standard and ACGIH-TLV for HCl is 7 mg/m^3 as a ceiling value not to be exceeded. The concentrations of HCl considered by NIOSH to be IDLH is 140 mg/m^3.[10]

Zinc chloride, which reacts with water to produce HCl is an irritant to eyes, mucous membranes, and skin. Inhalation may precipitate a cough (with or without sputum production), stridor, a sensation of chest tightness, dyspnea, pulmonary edema, and cyanosis, and, in case of very high exposure, death.[8-11] 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 of zinc chloride considered by NIOSH to be IDLH is 2000 mg/m^3.[10]

It should be noted that since zinc chloride and HCl both produce respiratory effects, and, in the absence of scientific data to the contrary, it is prudent to assume that exposure to smoke clouds containing both would result in additive effects.

Chlorinated hydrocarbons, as represented by the substances detected in this evaluation, may be responsible for numerous symptoms. Table 4 presents the target organs affected and signs/symptoms of overexposure. Several of those 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 fire training exercises. The carcinogen issue is complex, especially when the exposure is to a mixture of compounds. For a more detailed discussion on exposure to carcinogens in general, the interested reader is referred to several sources in the literature.[12-17]

VI. RESULTS

A. Literature Review

Reports received from the requestor and a literature review revealed at least ten separate incidents of adverse health effects among individuals exposed to the smoke produced by zinc chloride smoke generating devices.[1-3,18-24] These incidents are summarized in table 5.

The reports reveal that:

1. All but one of the incidents involved the use of zinc chloride smoke generating devices in some type of fire training exercise or disaster drill. The remaining incident resulted from accidental burning of approximately 80 smoke generating devices. Some articles specified the smoke device as a Superior Signal product, but in most cases the device manufacturer was not identified.

2. Some of the incidents resulted from the unintentional inhalation of zinc chloride smoke as a result of problems with respiratory protection devices and/or buddy breathing exercises.

3. In some of the incidents, participants stated that the smoke generating devices were chosen because advertisements indicated the devices were non-toxic or irritation was assumed to be the principle hazard.

4. The health effects that were reported are generally consistent and included: breathing problems, chest pains, hot and cold flashes, headache, fever, fatigue, sore throat, nausea, cough and death. Where autopsies or X-rays were conducted, pulmonary and cardiac abnormalities were reported (Table 5).

5. Reported problems date back to 1943 and involved from one to 70 individuals. Deaths were reported in at least three separate incidents. In one of these, an employee's face mask came apart, but he stayed in the smoke for fear of "messing up" filming of a training exercise.

6. In some of the reports, statements were made that the smoke generating devices had been used previously with no known problems.

7. In one report, measured air concentrations of zinc chloride, were in excess of 4000 mg/m^3. A concentration of 2000 mg/m^3 has been listed by NIOSH as IDLH.

B. Qualitative Air Sampling Results

The results of the laboratory test with the 30-second smoke candles indicated that the principal smoke cloud components were zinc compounds (i.e., zinc chloride, zinc oxide, zinc metal, etc.) and HCl. Over 50 chlorinated hydrocarbons, including several suspected human carcinogens such as carbon tetrachloride, chloroform, and perchloroethylene (Figure 1) were also identified.

C. Quantitative Air Sampling Results

December 1985 test

Table 6 presents the results of sampling conducted at the Cincinnati fire training facility in December 1985 of smoke from both the 3C smoke bomb and the white smoke pot. Materials detected in quantifiable concentrations during one or both tests were HCl, zinc, chloroform, carbon tetrachloride, trichloroethylene, perchloroethylene, hexachloroethane, and hexachlorobutadiene.

HCl was present at concentrations of 7.3 to 10.0 mg/m^3 in the 3C smoke bomb cloud and at 177 to 338 mg/m^3 in the white smoke pot cloud. The current exposure criterion for both OSHA and ACGIH is 7 mg/m^3 as a ceiling value not to be exceeded.[5,6] NIOSH's recommended IDLH level is 140 mg/m^3.[10]

The airborne concentrations of total zinc ranged from 5.1 to 7.1 mg/m^3 in the cloud from the 3C smoke bomb and 8.6 to 17 mg/m^3 in the cloud from the white smoke pot. Assuming these values represent zinc chloride (the principle component reported by the manufacturer), the corresponding zinc chloride concentrations are 11 and 15 mg/m^3 in the cloud from the 3C smoke bomb and 18 and 35 mg/m^3 in the cloud from the white smoke pot. The ACGIH short-term exposure criterion is 2 mg/m^3 for a 15-minute exposure.[6]

Hexachlorobutadiene was not detected in the 3C smoke bomb cloud but was present at 1.72 and 2.78 mg/m^3 in the white smoke pot cloud. The only current exposure criterion is the ACGIH TLV, which is 0.24 mg/m^3 as an 8-hour TWA.[6] ACGIH considers this material to be an industrial substance suspect of carcinogenic potential for man.[6,7]

Octachlorocyclohexadiene and hexachlorobenzene were also detected in area samples used to quantitate the cloud components. The collection media used was not adequate to quantitate these substances; each was present in trace quantities.

April 1986 Test

Table 7 presents the results of air sampling in the smoke clouds produced by the five smoke devices tested. HCl was measured in each cloud at concentrations ranging from 2 to 17 mg/m^3 for the smallest device (30 second candle), and from 12 to 224 mg/m^3 for the largest device (white smoke pot). The additional test conducted in a smaller room on the second level of the fire training facility resulted in HCl concentrations of 24 to 421

mg/m^3 for the white smoke pot. Results from sixteen of 21 samples collected during two days of testing exceeded the current OSHA and ACGIH ceiling value of 7 mg/m^3 for HCl. Results from samples in the smoke clouds generated by the white smoke pot exceeded the ceiling value by up to 60 times, depending on which room was used for the test. NIOSH's recommended IDLH level is 140 mg/m^3.

Perchloroethylene was present in all the smoke clouds. Concentrations ranged from 20 mg/m^3 for the smaller devices to 596 mg/m^3 for the white smoke pot. The air concentrations never exceeded ACGIH or OSHA short-term or TWA criteria. Since NIOSH considers perchloroethylene to be a suspect human carcinogen, NIOSH recommends that workplace exposures be controlled to the lowest feasible level. Carbon tetrachloride, hexachlorobutadiene, and hexachloroethane were also detected in some of the clouds. All three of these materials are considered to be suspect human carcinogens by either NIOSH, OSHA, or ACGIH.[4-7,25-27] The presence of suspect human carcinogens in the smoke clouds should not be ignored, but 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.

Air concentrations of zinc ranged from 16 to 237 mg/m^3. Once again, the highest concentration was measured in clouds produced by the white smoke pot. Calculated zinc chloride ($ZnCl_2$) concentrations from the total zinc measured, assuming all the zinc measured was $ZnCl_2$ (which is consistent with information supplied by the company), ranged from 34 to 498 mg/m^3. The ACGIH STEL (short term exposure limit) is 2 mg/m^3. Thus, the $ZnCl_2$ concentrations exceeded the STEL by as much as 249 times. Additional sampling to identify which zinc compounds were present in the clouds indicated that the percent of zinc chloride ranged from 50% in the 1-minute candle to 90-95% for the white smoke pot. Most of the remaining zinc was present as zinc oxide.

The NIOSH REL for zinc oxide is 15 mg/m^3 as a 15-minute ceiling value [10 hour TWA is 5 mg/m^3] and the ACGIH STEL for zinc oxide is 10 mg/m^3. Therefore even if 50% of the zinc is present as zinc oxide, the short-term exposure criteria for both the chloride and the oxide are exceeded. Lead was also measured in most of the clouds, at concentrations up to 0.54 mg/m^3. The OSHA standard for lead is 0.05 mg/m^3, as an 8 hour TWA. There is no short-term criteria for lead.

Direct reading samples used to assess the percent O_2 indicated that it never dropped below 21% even in the heaviest smoke clouds. The concentration of HCl ranged from 1 to greater than 20 ppm (>28 mg/m^3) measured by gas detector tubes, and was detected in all of the smoke clouds.

As previously stated, the smoke generating devices were used to produce clouds similar in density to clouds used for firefighters training exercises at the Cincinnati fire training facility. According to fire department staff, heavy smoke is needed to simulate building fires. They stated that all of the clouds produced during our tests could have met this need, but the smaller devices produced clouds that were too light to be totally effective from the standpoint of obscuring vision.

D. Telephone Survey

Of the 69 organizations contacted we were able to interview fire training personnel at 62 sites. Personnel at 21 of the 62 locations contacted reported that they had used smoke bomb type devices indoors in their fire training programs. Sixteen of the 21 reported using Superior Signal devices; four of the remaining five described smoke bomb type devices that were probably manufactured by Superior Signal, but this was not confirmed at the time the phone call was made. Information obtained from these telephone interviews is summarized in Table 8.

The number of years that the smoke bomb type devices were used at these 21 locations ranged from 1 to 20. Seven contacts reported that they had used the devices for a least 10 years and seven said they had used them in 1987. It was difficult to always get accurate information on the size of the training area since hotel rooms and rooms in abandoned houses were sometimes used. The size of the training area for the 20 locations that reported dimensions ranged from 900 cubic feet to 36000 cubic feet. The average was about 6000 cubic feet. The majority (14 of 22) of the training areas were under 5000 cubic feet. The facility used to conduct the NIOSH testing measured 6000 cubic feet in the main training area and therefore was representative of a typical sized training area.

All but one location was using far more (from three times (3X) to over 100X) smoke than necessary when compared to the manufacturer's 1987 usage guideline. The rough estimate of how much in excess of the 1987 usage guideline was computed by dividing the volume of space recommended by the manufacturer's 1987 guideline for the number and type device(s) used (recommended volume for each device times the number of devices used) by the volume of space actually available.

For example, if two 3C smoke bombs were used in a 1000 cubic foot space, an estimate of the degree of excess usage can be computed as follows: (2 X 35,000 cubic feet) divided by 1000 cubic feet = 70,000 divided by 1000, or 70 times (70X). The result of this computation for each usage situation appears in the last column of Table 8. This computation for the NIOSH tests ranged from 8X to 83X.

Eleven of the 21 contacts who had used the smoke bomb devices reported that they did not have the manufacturer's literature and several others said they were not sure if they had the literature.

VII. DISCUSSION AND CONCLUSIONS

Information from a literature review indicates that there have been significant adverse health effects, including death, from exposure to a dense smoke cloud produced by zinc chloride smoke generating devices. Those individuals affected were either not wearing respiratory protection (SCBA), or had problems with the SCBA.

The zinc chloride smoke generating devices manufactured by Superior Signal, Inc. have been commonly used during fire training exercises. These devices were used by about 30% of the 62 fire training personnel contacted by telephone. It appears that the primary goal in using these devices is to produce an atmosphere that simulates those conditions which may be experienced in an actual fire and that one important consideration is that vision be effectively obscured. Manufacturers' literature (see Appendix A) which was available at the time of these surveys (1985 and 1986), did not specify how many or which types of smoke generating devices should be used in a given size training area. Updated information (see Appendix B), which was available in 1987, did include information on which devices to use for different sized areas and, by the 1987 criteria, the number of devices used in the NIOSH tests was far in excess of what the manufacturer is now recommending. However, information obtained from several fire training sources suggested that the conditions which were evaluated during this study were representative of the way in which these devices have commonly been used. The telephone interview conducted in December 1987 and January 1988 with fire training personnel at 62 separate locations across the United States also indicated that it has been common practice to generate more smoke than recommended in the manufacturer's 1987 literature. The next most commonly reported method of generating fire training atmospheres was the actual burning of a wide variety of combustible materials (furniture, mattresses, straw, etc.). Other smoke generating techniques (artifical smoke called Roscoe and Pepper Fogger) and blackening the face piece to obscure vision were also mentioned.

The field tests were designed to identify and measure the concentration of the components of the zinc chloride smoke cloud produced during simulated fire training exercises, documented that hazardous atmospheres were produced, and that IDLH atmospheres could be generated depending on the type and number of devices used and the volume of the training facility. The most important components of the smoke cloud are the zinc compounds (primarily zinc chloride but possibly some zinc oxide) and HCl because of the severe respiratory effects which they may cause in a dense cloud exposure situation. A variety of chlorinated hydrocarbons, including several that are suspect human carcinogens, were also identified in the dense smoke clouds. However, while this finding cannot be ignored, the potential respiratory effects from exposure to the zinc compounds and the HCl are of more immediate concern considering how these devices are used during fire training.

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

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.

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

Advertisements suggesting that these smoke generating devices are safe were mentioned in some articles. According to the manufacturer, this was based on a toxicity evaluation conducted by a physician in the 1950s. That assessment was based on the assumption that zinc chloride was the only significant smoke cloud component and there was no sampling of actual $ZnCl_2$ concentrations and no mention of HCl and other substances.

In December 1986, NIOSH was informed of another episode which occurred in October 1986. During a high rope rescue training exercise in which a Superior Signal Company 5D smoke bomb was used to create smoke, 5 of 6 participants experienced adverse health effects. NIOSH is currently investigating this episode.[28] Those experiencing adverse health effects were interviewed by a NIOSH physician. These people were either not wearing an SCBA or had a problem with the SCBA. Reported symptoms and the number of people who reported each symptom included: sore throat (3), difficulty breathing (2), joint (upper and lower extremities) stiffness, pain (2), chills and fever (2), headache (1) and generalized fatigue (1).

The National Fire Protection Association (NFPA) publishes consensus standards for fire fighters. The NFPA recently published a standard on fire training (NFPA 1500). The standard states that smoke generating devices that produce hazardous atmospheres should not be used.[29]

Updated product information was received from Superior Signal Company in early 1987. It contained instructions that "individuals should be urged not to accept exposures that cause minor irritation, but to leave the area". Smoke cloud components identified were hydrated zinc chloride, water condensate and carbon monoxide. There was no mention of HCl or chlorinated hydrocarbons. However, usage guidelines were provided and comments relating to buddy breathing, taking respirators off to "experience the environment" and usage during office type fire drills were omitted.

VIII. RECOMMENDATIONS

These recommendations are directed at the users of zinc chloride smoke generating devices. Other recommendations have been sent to Superior Signal Company concerning labeling, dissemination of usage guidelines and MSDS information.

1. Dense smoke clouds produced by all of the zinc chloride smoke generating devices NIOSH has tested should be considered hazardous. No smoke generating device should be considered safe or non-toxic.

2. Before smoke generating devices are used, technical data sheets and MSDS information should be obtained and reviewed.

3. Practices like "buddy breathing" should not be conducted in "zinc chloride" smoke clouds.

4. No one should enter a zinc chloride smoke cloud without a properly fitted and operating SCBA. Additionally, everyone involved in the training should be made aware of the potential hazards. Anyone who enters a cloud should be instructed to leave the area immediately i

they notice any problem (such as a leak in the SCBA). Anyone experiencing any breathing difficulties should receive a medical evaluation and appropriate medical treatment as soon as possible.

5. While an SCBA, worn by a trained individual will eliminate the inhalation hazard associated with the zinc chloride smoke generating devices, it is recommended that thought 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 modified to obscure vision. 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 finally chosen should be based on the risks and benefits associated with each.

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XI. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Publications Dissemination Section, 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. International Association of Fire Fighters (IAFF)
2. Cincinnati Fire Department
3. Superior Signal Company, Inc.
4. OSHA, Region V
5. National Fire Protection Association (NFPA)

For the purpose of informing affected employees, copies of this report should be distributed through appropriate channels to fire training personnel.

Table 1

Sampling and Analytical Techniques for Air Samples
Collected in Smoke Clouds Generated by Zinc Chloride Smoke Generating Devices

Cincinnati Fire Training Building
Cincinnati, Ohio
HETA 85-274

December 12, 1985

Material Evaluated	Media	Flow Rate (LPM)	Analytical Techniques
Inorganic Acid	ORBO-53 tubes	0.5	Samples were analyzed for chloride by ion chromatography according to NIOSH Method 7903. The A and B sections of the silica gel tubes were each separately desorbed in 10 ml of eluent and heated in a boiling water bath for 10 minutes. The resulting solution was filtered through a 0.45 micron filter, and an aliquot of each solution was analyzed via a Dionex ion chromatograph utilizing a WISP 710B auto sampler.
Chlorinated Hydrocarbons (i.e., carbon tetrachloride, hexachlorobutadiene)	A. Charcoal Tubes B. ORBO-42	0.2 and 0.5 0.2 and 0.5	Two charcoal tubes that were qualitative air samples were desorbed with 1 ml of CS_2 and screened by gas chromatography with a flame ionization detector. One sample was analyzed using gas chromatography/MS for chemical compound identification of detected peaks. Remaining tubes were desorbed and analyzed as above. Two qualitative ORBO-42 samples were analyzed according to NIOSH Method 2518. Samples were desorbed for 1 hour in a sonic bath with 1 ml of hexane and screened by GC/FID as above. Major peaks were the same as a charcoal tube, remaining ORBO-42 samples were not quantitated
Total-Zinc	Mixed Cellulose Ester Membrane Filter	2.5 and 3	Filters were analyzed for zinc using atomic absorption spectroscopy. Samples were ashed with nitric and perchloric acids according to NIOSH Method 7300 and diluted to 25 ml. Analyses were completed using NIOSH Method 7030.

Table 2

Manufacturer's Specifications
for Five Smoke Devices Tested

moke Device Name	Burn Time	Volume of Smoke produced per unit (ft^3)*
0 Second Smoke Candle	0.5 minute	4,000
minute candle	1 minute	8,000
moke Bomb 3C**	2-3 minutes	40,000
moke Grenade	2-3 minutes	115,000
hite Smoke Pot	5-6	500,000

From manufacturer's literature.

* Reported by manufacturer to be their most popular item for firefighter training.

Table 3

Sampling and Analytical Techniques for Air Samples
Collected in Smoke Clouds Generated by Zinc Chloride Smoke Generating Devices

Cincinnati Fire Training Building
Cincinnati, Ohio
HETA 85-274

April 8-9, 1986

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 and A section plugs of the silica gel tubes were each separately desorbed in 10 ml of eluent and heated in a boiling water bath for 10 minutes. The resulting solution was filtered through a 0.45 micron filter, and an aliquot of each solution was analyzed via a Dionex ion chromatograph utilizing a WISP 710B auto sampler.
Chlorinated Hydrocarbons (i.e., carbon tetrachloride, hexachlorobutadiene)	Charcoal Tubes	0.2 and 0.5	Ten charcoal tubes were evaluated qualitatively. Each sample was desorbed with 1 ml of CS_2 and screened by gas chromatography with a flame ionization detector. Since all chromatograms were similar, only two of the ten-samples were further analyzed using gas chromatography/mass spectrometry (GC/MS)for identification of detected peaks. Based on the GC/MS results the remaining tubes were desorbed and with 1 ml CS_2 and quantitated for five chlorinated compounds.
Metals	Mixed Cellulose Ester Membrane Filter	1.5 and 2	Samples were ashed with concentrated 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 GCP-AES).
Zinc Compound Identification	Mixed cellulose Ester Filter	2	Analysis via Transmission Electron microscopy via Zumwalde-Dement procedure outlined in NIOSH publication no. 77-204. Twenty randomly selected grid openings were examined on each sample preparation at 18,000x magnification. Elemental analysis was performed on at least 50 of the various components of each sample preparation.

Health Effects of the Primary Smoke Cloud Components Detected

Cincinnati Fire Training Building
Cincinnati, Ohio
HETA 85-274

Chemical	IDLH	Health Effects	Target Organs	Reference
Tetrachloroethylene ($CCl_2=CCl_2$)	500 ppm	irritation of eyes, nose, and throat; nausea, flushing of face and neck, vertigo, dizziness, incoordination, headache, erythemia, liver tumors in animals	liver, kidneys, eyes, upper respiratory, central nervous system	4,7,10,26,27,30
Hexachloroethane (CCl_3-CCl_3)	300 ppm	eye irritation, liver tumors in animals	eyes	4,7,10,30
Hexachlorobutadiene ($CCl_2=CCl-CCl=CCl_2$)	-	eye and nose irritation, kidney tumors in animals	kidneys	7,31
Zinc Chloride Fume ($ZnCl_2$)	2000 mg/m^3	irritation of nose and throat, conjunctivitis cough, copious sputum, chest pain, pneumonia, pulmonary fibrosis, fever, cyanosis, tachypnea, burning skin	respiratory system, lungs, skin, eyes	7,10,30
Hydrochloric Acid (HCl)	100 ppm (140 mg/m^3)	inflammation and ulceration of nose, throat, cough, burning throat, choking, burning eyes and skin, dermatitis	respiratory system, lungs, skin, eyes	7,10,30
Carbon Tetrachloride (CCl_4)	300 ppm	central nervous system depression, nausea, vomiting, liver and kidney damage, skin irritation, liver cancer	central nervous system, eyes lungs, liver, kidneys, skin	4,7,10,25,30,31
Chloroform ($CHCl_3$)	1000 ppm	dizziness, dullness, nausea, headache, fatigue, hepatomegaly, eye and skin irritation, liver or kidney tumors	liver, kidneys, heart, eyes skin	4,7,10,30,31,32
Trichloroethylene ($CHCl=CCl_2$)	1000 ppm	headache, vertigo, visual disturbances, tremors, somnolence, nausea, vomiting, irritation of eyes, dermatitis, liver tumors in animals	respiratory system, heart, liver, kidney, central nervous system, skin	4,7,10,30,31,33

IDLH = Concentration of subject chemical reported to be immediately dangerous to life and/or health of individual exposed without adequate protective equipment.[10]
- = No IDLH value.

Table 5

Partial Listing of Reported Episodes During Smoke Training
When Smoke Bomb Type Devices Were Used

Author	Date & Location	Type of Device* and/or Exposures	Event	Summary of Report Health Effect
Evans	1943;Malta	Smoke generator; zinc chloride smoke	Smoke generating 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 tightness; 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 bifurcation of the trachea. Liver, kidney & cerebral congestion.
Johnson & Stonehill	1959; Texas (3 separate incidents)	Screening smoke- zinc chloride	17-19 year old airmen were accidentally overexposed to smoke during routine survival training.	Burning throat, paroxysmal coughing, nausea & retching during first 48 hours, dyspnea, fever & malaise. Temperature to 105°F, developement of tachypnea and cyanosis. Xray showed infiltrate in both lungs. Symptoms negative after 2-4 month.
Milliken, Waugh & Kaulsh	Pre-1963 Ontario, Canada	Smoke bomb; zinc chloride	35-year-old fireman participated in fire exercise. Smoke generator was place at bottom of depression - buildings were on three sides. Patient tried to extinguish bomb. A colleague withdrew almost immediately.	Both subjects reported nausea, sore throat, and chest tightness. Primary subject had a fever, Xray showed diffuse infiltrates 30 hours after exposure. Cyanosis, and confusion. died on the 18th day.
Macavly & Mant	Pre-1964 England?	Military smoke canister; zinc chloride	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 5 (continued)

US Navy	3/4/81 On Board Ship,	Superior Signal 5D smoke bomb	22-year-old male during fire-fighting exercise on ship had had respirator facepiece come apart. Stayed in smoke for 5 minutes for of "messing up" exercise. Device chosen because it was advertisement as non-toxic. Welded galvanized pipe during previous 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.
Columbia, Mo. newspaper	April 1981 Columbia, MO.	Superior Signal Company Smoke Bomb	During buddy breathing exercise a fire fighter was overcome. Participants noted that device were marketed as "medically proven safe and non-toxic". Had reportedly used bombs for years.	Respiratory and intestinal inflammation Swollen lymph nodes, chills, headache, nausea, fatigue, and sore throat.
Schenker, Speizer, Taylor	1981	Military smoke canister; zinc chloride smoke	82 "victims" and 28 medical personal personal were exposed to smoke during an airport disaster drill.	Immediate cough, hoarse, sore throat. Later symptoms were nausea, fatigue and headache
Fire department	6/13/83 Medina, ND	Superior Signal Company smoke bomb	Fire chief developed problem with smoke pac during training exercise in a garage. Bombs warned of irritation. Buddy breathing exercise chief inhaled a "breath" of smoke.	Difficult breathing, chest pains, hot and and cold flashes, and nervousness. At hospital emergency room. Temperature = 101°F, Ooxygen administered. Recovery within 24 hours

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

Results of Environmental Sampling in Smoke Clouds from Five Separate Smoke Generating Devices

Cincinnati Fire Training Facility
Cincinnati, Ohio

HETA 85-274
April 8-9, 1986

Smoke Device Tested Pb	No. of Devices Used	Date	Range of Concentrations for Chemicals Measured in Smoke Cloud (mg/m^3) HCl	Perchloro-ethylene*	CCl_4*	hexachloro-butadiene*	hexachloro-ethane*	Zn	$ZnCl_2$**	% of $ZnCl_2$***	
30 Sec candle	6	4/8	2-17	19-29	ND	ND	5-10	16-19	34-40		.05-.07
"	6	4/9	2-5	14-16	ND	ND	(5-11)	22-23	46-48	60-70	ND
1 min candle	6	4/8	3-16	14-20	ND	ND	(4.9-5)	19-23	40-48		ND
"	6	4/9	4-10	17-20	ND	ND	(5-5.7)	29-37	61-75	50	ND
30 smoke bomb	4	4/8	10	67-80	ND	ND	16-20	47-59	99-124		.16-.21
"	6	4/9	27-36	80-96	ND	ND	15-18	57-68	120-143	80-90	.22-.25
Grenades	1	4/8	14-45	48-88	ND	ND	(5-10)	26-30	55-63		.03-.04
Grenades	2	4/9	38-110	145-163	(4.8-5)	ND	16-24	63.7-64	133-134	60-70	.09-.1
White smoke pot	1	4/8	102-224	470-535	29-43	(4.9-5)	29-38	155-237	326-498		.28-.54
"	1	4/9	12-60	347-538	27-29	(4.9-5)	16-39	47-59	99-124	90-95	.12-.13
"	1	4/9	24-421	282-596	22-31	(ND-5)	(5)-16				
ACGIH =			7-C	1340-STEL	125-STEL	.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	0.50-T

Sample times were 25 minutes unless otherwise indicated in table by air concentration being underlined. Sample times are less than 25 minutes for these samples. () indicate that the chemical was present in the air sample at a level above the laboratory limit of detection, but below the laboratory limit of quantitation, the numbers listed are estimates.

HCl = Hydrochloric acid
CCl_4 = Carbon tetrachloride
Zn = Zinc
$ZnCl_2$ = Zinc chloride
Pb = Lead
T = Time-weighted Average, 8 hours for ACGIH and OSHA, 8 or 10 hours for NIOSH
ND = None detected
STEL = Short-term exposure limit
C = Ceiling value not to be exceeded
MWEL = Minimize workplace exposure level
LFL = Lowest feasible level
* = 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.
*** = These values represent percent of zinc chloride for all zinc compounds as identified in an air sample.

Table 8

Telephone Survey
Evaluation of Fire Training Smoke Generation
HETA 85-274
December 1987 & January 1988

Source/State	Number of Years Device Used	Last year Used	Volume (ft^3) of Training Area	Type of Device*	Number Used	Comparison of Usage to Manufacturers 1987 Criteria
Decatur Fire Dept./ Alabama	3	1986	960	3C	1-2	In excess (36X-72X)
Ketchikan Fire Dept./ Alaska	10-12	1983	1250	5D	2-6[a]	In excess (160X-480X)
State Fire Training Serv. Alaska	3	1981	5180	3C	1[b]	In excess (7X)
Anchorage Fire Dept./ Alaska	3	1981	12800	3C	1-2	In excess (3X-5X)
Flagstaff Fire Dept./ Arizona	1	1987	3200	3C	2-3[c]	In excess (22X-33X)
Oakdale Fire Dept./ CAlifornia	7	1982	900	5D	2	In excess (222X)
Boise Fire Dept./ Idaho	10-15	1986	1440	3C**	2-3	In excess (49X-73X)
Garden City Fire Dept./ Kansas	-	1976	Vacant Houses	3C**	-	-
Carson City/ Nevada	10-12	1981	1150	3C	1-2	In excess (30X-61X)
State Fire Standards and Training/ New Hampshire	10	1978	1200	3C**	1-2[d]	In excess (29X-58X)

Table 8 (continued)

Source/State	Number of Years Device Used	Last year Used	Volume (ft^3) of Training Area	Type of Device*	Number Used	Comparison of Usage to Manufacturers 1987 Criteria
Training Institute/ New York	3	1986	6400	5D	1-2[e]	In excess (16X-32X)
Jamestown Fire Dept./ New York	2	1985	12500	3C	3	In excess (8X)
Utica Fire Dept./ New York	1	1983	9000	3C**	1	In excess (4X)
Bend Fire Dept./ Oregon	2	1987	3000	5D	1	In excess (33X)
Corvalis/ Oregon	4	1987	3800 12800	5D 5D	1 1	In excess (26X) In excess (8X)
Pendleton Fire Dept./ Oregon	10-12	1983	9000	3C**	1	In excess (4X)
Aberdeen Rural Fire Dept./ South Dakota	3	1987	1120	3C	1[f]	In excess (31X)
Fernly Vol. Fire Dept./ South Dakota	2	1987	3920	3C	29	In excess (18X)
Pierre Fire Dept./ South Dakota	15-20	1985	1200-2400	3C	4-5[h]	In excess (58X-146X)
Ft. Worth Fire Dept./ Texas	6-7	1987	2400 9000	3C 3C	5-6[i] 2-3[i]	In excess (72X-88X) In excess (9X-12X)

Table 8 (continued)

Source/State	Number of Years Device Used	Last year Used	Volume (ft^3) of Training Area	Type of Device*	Number Used	Comparison of Usage to Manufacturers 1987 Criteria
Charlottesville Municipal Fire Dept./ Virginia	1	1987	11500	3C	8-10[j]	In excess (24X-30X)

NOTES:

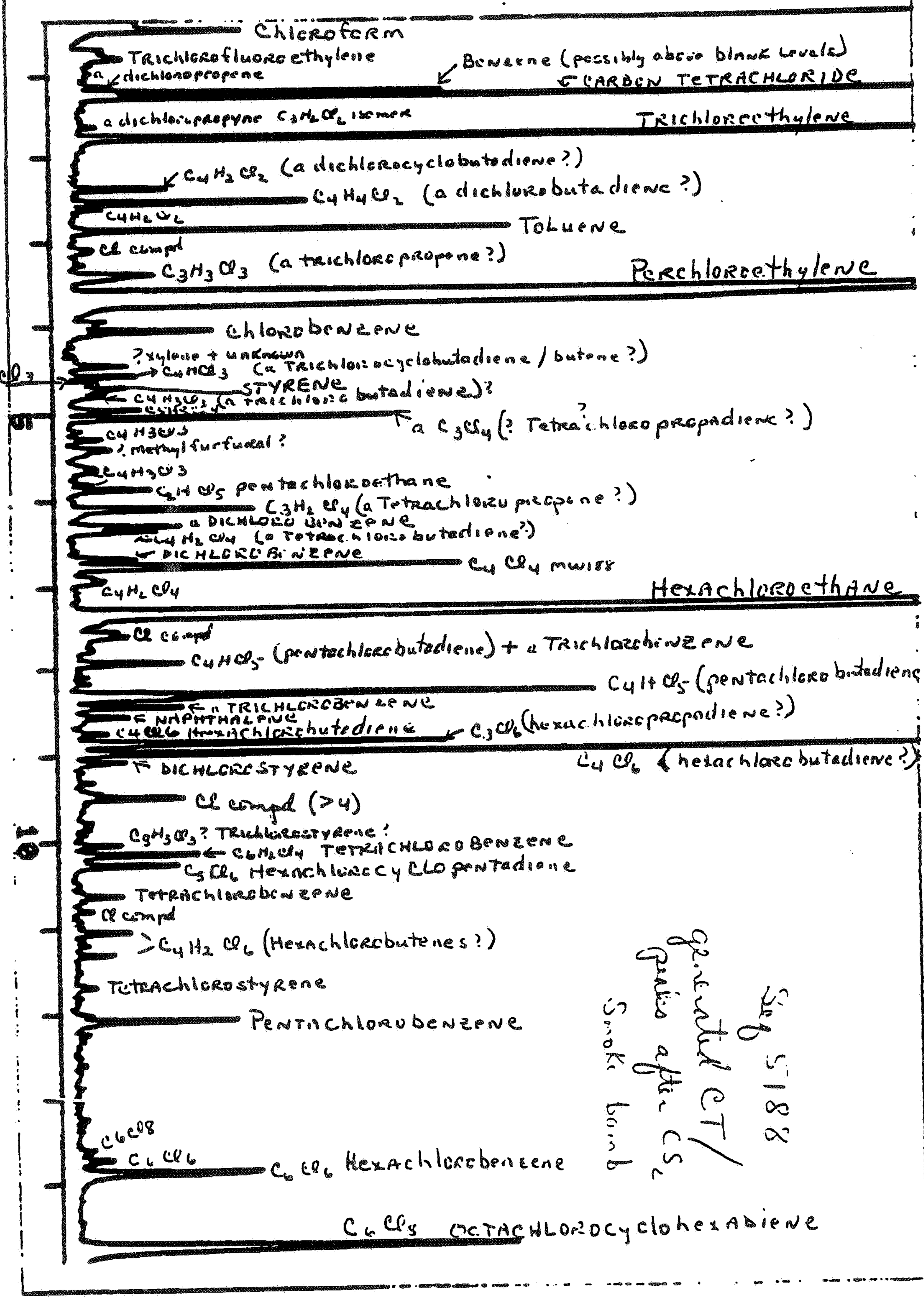
a = Wanted lots of smoke, used rooms in abandoned single family residences.
b = Also used grenade and white smoke pot in larger area of the building.
c = Start with 2-3 then add devices to reduce visibility to zero. When read of potential problem got product literature.
d = Also used yellow grenade in same sized room. Wanted to completely obsure vision.
e = Used in different training facilities, also used abandoned houses. Room size listed is an average.
f = Very heavy smoke.
g = Used small mobile home most often, also used abandoned houses.
h = Used a lot of different facilities (i.e. motel rooms, house, commercial building), also used 5D smoke bomb.
i = Basement training area (2400 ft^3) was tighter - had less leakage, than their training tower (9000 ft^3), thus used fewer devices, even though basement training area was larger than training tower.
j = Used hallway of abandoned school. Used 8-10 bombs at once, then add bombs as needed to heavy smoke, total of 12 dozen bombs used over 8 1/2 hour period.

* = Some contacts identified the manufacturer as Superior Signal Co. but did not know the device ID no., their description was sufficient to indicate which device (usually the 3C smoke bomb) they had used.
** = Contact could not identify smoke bomb manufacturer but the description suggested that the device they had used was a Superior Signal Co. smoke bomb, the device described sounded like a 3C smoke bomb.

Figure 1: 30 Second Smoke Candle (Pre-Test)

** SPECTRUM DISPLAY/EDIT **
SEQ5188 ZEY SMOKE BOMB CT/CS2 AFTER 1ULGS
30M DB-1 SPLITLESS SC35-350 11-21-85

FRN 6908
1ST SC/PG: 16
X= .25 Y= 4.60



Seq 5188
generated CT/
Gases after CS2
Smoke bomb

REPLY MESSAGE
A1 (8½) To Fit Grayarc Window Envelope # EW10P

TO
Mr. John Zey
NIOSH
Mail Stop R-11
4676 Columbia Parkway
Cincinnati, OH 45226

FROM
Superior SIGNAL COMPANY, INC.
P. O. BOX 96
SPOTSWOOD, NEW JERSEY 08884
(201) 251-0800

SUBJECT: Request for Material Safety Data Sheet DATE: June 14, 1985

FOLD

In response to your recent inquiry, we have enclosed literature, cover letter and material safety data sheet. I would welcome the opportunity to be of further service.

SUPERIOR SIGNAL COMPANY, INC.

Barbara Marques

bm
Enclosures

PLEASE REPLY TO → SIGNED Barbara Marques, Secretary

REPLY

DATE: SIGNED

THIS COPY FOR PERSON ADDRESSED

TELEPHONE (201) 251-0800

Superior SIGNAL COMPANY, INC.

P. O. BOX 96 • SPOTSWOOD, N. J. 08884

SEND SHIPMENTS TO:
WEST GREYSTONE ROAD
OLD BRIDGE, N. J. 08857

SUPERIOR SMOKE FOR FIRE TRAINING

For over twenty-five years, Superior Smoke has been successfully used to develop smokey atmospheres for firemen training exercises involving the use of self-contained breathing apparatus. In these drills, an adequate amount of smoke is utilized (1) to obscure vision and (2) to be sufficiently irritating to reveal improper procedures or faulty equipment. Under these simulated fire conditions, instructors have a high degree of confidence in their ability to properly train fire fighters to perform a necessary community service, while minimizing the inherent risks of their occupation.

Smoke drills are developed and performed under the direction of fire training instructors. With proper procedures delivered through clear instructions, firemen would not have any exposure to training smoke; however, circumstances such as leaky masks, equipment failure, incomplete instructions and personnel performance inadequacies do occur. Instructors anticipating these incidents have found these exposures to smoke generally range from thirty seconds to several minutes with either no physiological effects or minor short term effects such as those associated with smoke inhalation.

Normally, the smoke has a particle size of 10^{-4} to 10^{-6} centimeters in diameter; however, thirty seconds after it has been generated, the particle size statistical distribution does not conform to the normal bell-shaped curve. This phenomenon is caused by the smoke being a mist rather than solids suspended in air. Superior Smoke is not a true smoke, but contains a large percentage of atmospheric moisture that provides high visual obscurity at low concentrations. The mist formation is seeded by zinc chloride and some other products of combustion such as free carbon. The toxicity of the materials must be represented relative to the application and brief exposure.

All smokes can be irritating, and normally this telltale sensation encourages personnel to move from areas of heavy concentrations. We recommend the use of self-contained breathing apparatus for dense concentrations or prolonged lighter concentrations.

At times, the users may not participate in a responsible manner caused by incomplete operational instructions for self-contained breathing equipment or less than prudent personal decisions. Our experience in distributing Superior Smoke for fire training exercises reveals that in many instances, excessive volumes of smoke are developed to obscure vision, simulating fire conditions. Low concentrations of smoke allowed to blend in a homogeneous mixture with room air provides obscurity without causing excessive concentrations.

DEPARTMENT OF LABOR
Occupational Safety and Health Administration

Form Approved
OMB No. 44-R1387

MATERIAL SAFETY DATA SHEET

Required under USDL Safety and Health Regulations for Ship Repairing, Shipbuilding, and Shipbreaking (29 CFR 1915, 1916, 1917)

SECTION I

MANUFACTURER'S NAME	EMERGENCY TELEPHONE NO.
Superior Signal Company, Inc.	(201) 251-0800
ADDRESS (Number, Street, City, State, and ZIP Code) W. Greystone Rd., Old Bridge, NJ 08857 - P. O. Box 96, Spotswood, NJ 08884	
CHEMICAL NAME AND SYNONYMS	TRADE NAME AND SYNONYMS
CHEMICAL FAMILY	FORMULA

SECTION II - HAZARDOUS INGREDIENTS

PAINTS, PRESERVATIVES, & SOLVENTS	%	TLV (Units)	ALLOYS AND METALLIC COATINGS	%	TLV (Units)
PIGMENTS Not Applicable			BASE METAL		
CATALYST			ALLOYS		
VEHICLE			METALLIC COATINGS		
SOLVENTS			FILLER METAL PLUS COATING OR CORE FLUX		
ADDITIVES			OTHERS		
OTHERS					

HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES	%	TLV (Units)

SECTION III - PHYSICAL DATA

BOILING POINT (°F.)		SPECIFIC GRAVITY (H_2O=1)	
VAPOR PRESSURE (mm Hg.)		PERCENT, VOLATILE BY VOLUME (%)	
VAPOR DENSITY (AIR=1)		EVAPORATION RATE (_____ =1)	
SOLUBILITY IN WATER			
APPEARANCE AND ODOR Superior Smoke - Color: Gray to White; Odor: Burning Paper			

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used)	FLAMMABLE LIMITS	Lel	Uel
EXTINGUISHING MEDIA			

SPECIAL FIRE FIGHTING PROCEDURES Superior Smoke generating items do not contain any rapid oxidizing materials.

UNUSUAL FIRE AND EXPLOSION HAZARDS

(Continued on reverse side)

SECTION V - HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE	* See Cover Letter
EFFECTS OF OVEREXPOSURE	Smoke can cause irritation of the bronchial and nasal passages.
EMERGENCY AND FIRST AID PROCEDURES	Once exposure has ceased, any irritation quickly disappears. Treat for smoke inhalation.

SECTION VI - REACTIVITY DATA

STABILITY	UNSTABLE		CONDITIONS TO AVOID
STABLE	STABLE	X	

INCOMPATABILITY *(Materials to avoid)*

HAZARDOUS DECOMPOSITION PRODUCTS

HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID
	WILL NOT OCCUR		

SECTION VII - SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

WASTE DISPOSAL METHOD Smoke leaves no visible residue or lingering odors. Unreacted smoke material...Do not allow contact with oils or solvents...Possible reaction causing combustion.

SECTION VIII - SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION *(Specify type)*
For other than casual exposure, use self-contained breathing apparatus.

VENTILATION	LOCAL EXHAUST	SPECIAL
	MECHANICAL *(General)*	OTHER

PROTECTIVE GLOVES	EYE PROTECTION

OTHER PROTECTIVE EQUIPMENT *See Cover Letter

SECTION IX - SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING Temperatures above 33°C, and humidity above 65% may shorten shelf life of Superior Smoke items.

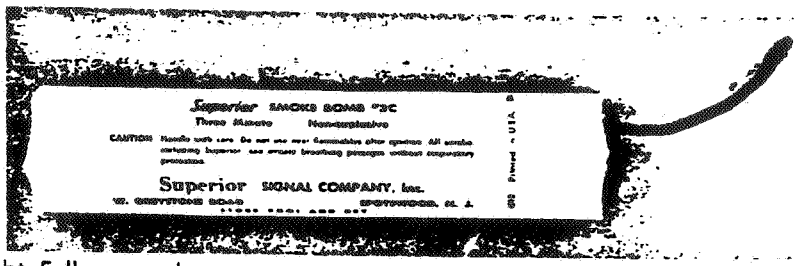
OTHER PRECAUTIONS

Superior

NO RESIDUE NO EXPLOSIVES

Superior SIGNAL COMPANY, INC. W. Greystone Road Spotswood, New Jersey
phone area code 201 251-0800

The revolutionary Superior method of generating smoke by chemical reaction makes previous methods of burning materials to create smoke particles as inefficient and obsolete as the horse drawn fire engine. It leaves no residue to stain the interior of buildings or clothing. Superior Smoke items contain no explosive materials and are the only devices of this nature acceptable in the mails. It has a T. O. P. (total obscuring power) of 2100. T. O. P. is the scientific method of determining the quantity of smoke generated by a given unit of smoke composition. By comparison crude oil has a T. O. P. of 200. More smoke, exclusive safety features, plus low prices make Superior Smoke products your best buy.

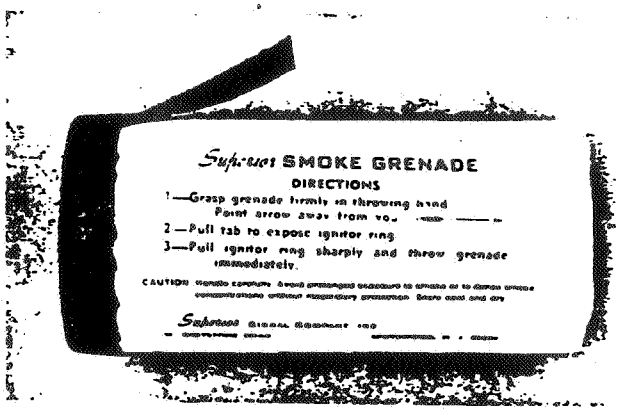


The Superior Smoke Bomb No. 3C generates a big 40,000 cubic feet of whitish gray smoke while burning from two to three minutes. Our most popular item for firemen training.
Shipping weight 5 lbs. per dozen.
Size 1½" x 6". Mailable. Shipping weight 5 lbs. per dozen.

The Superior Smoke Bomb No. 5D (not illustrated) generates 100,000 cubic feet of light gray smoke in five minutes. Long fuses on each end permit mulitple smoke bombs to be tied together for continuous burning to maintain an enormous and sustained volume of smoke. Mailable. Sold in minimum units of six.
Size 1½" x 14". Shipping weight 5¾ lbs. for six.

Superior Smoke Grenades are engineered for use where an instantaneous and exceptionally large volume of smoke is required. They are solidly constructed with a dependable built-in pullwire ignitor and warranted for three years.

Superior Smoke Grenade generates 115,000 cubic feet of smoke during 2-3 minutes burning time, size 2" x 5", weight 14 oz., not mailable.

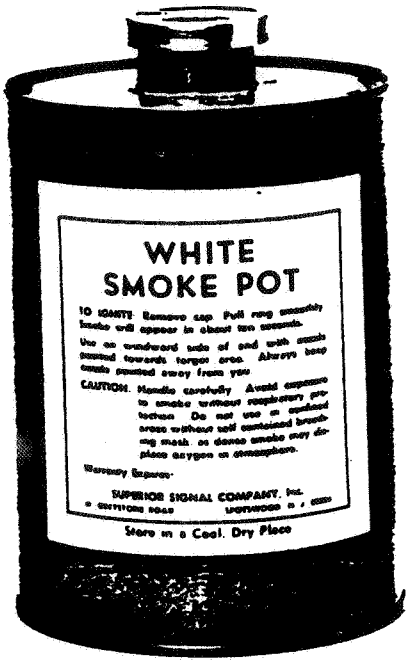


Superior Professional Smoke Grenade generates 130,000 cubic feet of smoke while burning 2-3 minutes, size 2½" x 5" 1 lb.; can be comfortably hand held; not mailable.

Printed in U.S.A. — Effective 12/79
Form S-1

The Superior White Smoke Pot is the ultimate in smoke generators for fire or disaster training. Activated by a sure fire pull wire ignitor, it generates over 500,000 cubic feet of dense white smoke, sufficient to simulate a city block sized disaster area, during a five to six minute burning time. The ignitor and smoke generating materials are enclosed in a sturdy sealed metal container, with an easily removed U-Press-it closure, protecting them from atmospheric changes, the principal cause of ignition failures and unsatisfactory performance. Warranted for three years. 6-¾" x 4", shipping weight 4 lbs. Not mailable.

White Smoke Pot: Handle carefully. Avoid exposure to smoke without respiratory protection. Do not use in confined areas without self contained breathing mask, as dense smoke may displace oxygen in atmosphere.



Superior Smoke items generate a gray or white smoke depending upon density and lighting conditions. It simulates actual fire smoke in appearance and smell without lingering odors or residue to damage clothing and walls. Because of these features, any reasonable size room or building can be used for smoke drills. With a T.O.P. of 2100, Superior Smoke provides maximum obscurity with minimum concentration. It is sufficiently irritating to allow trainees to detect defective mask or improper utilization of same. Fires can be prevented by using Superior Smoke to locate breaks in chimneys and leaks in heating units.

MASK DRILLS: Fire departments, civil defense and rescue units should hold regular drills to maintain the efficiency of smooth operating procedures while wearing masks under difficult and frequently dangerous conditions. Trainees should be instructed thoroughly in the operation of equipment and practice until they can don the equipment, check gauges and adjust valves without hesitation. This gives assurance and may prevent panic or mistakes, with dire circumstances later. The room to be used for drills should contain furniture, rearranged from time to time to prevent familiarity with the layout. Retrieving a can or some easily identifiable object will teach men to feel their way through smoke. Some instructors require trainees to carry sand bags or saw wood to become accustomed to the breathing restrictions encountered while wearing a mask. Frequently trainees are required to remove masks, blow out the smoke and replace to familiarize them with the procedure in event a mask is accidentally torn off in smoke. The glow from a highway flare or the flame and heat from a barricaded fire gives valuable practice in sizing up a fire and its location through the smoke by a faint glow or tell-tale wave of heat. Regular drills teach men to handle themselves and their equipment with a minimum of effort and panic enabling them to concentrate on their assigned jobs of sizing up and fighting fires or making rescues.

FIRE DRILLS: Employees should be instructed on procedure in event of fire. They should know the location of exits, fire extinguishers and fire hoses. Group leaders should be given special assignments and be prepared to supervise speedy evacuation of the building and to close doors to prevent the spread of fire. Training in rudiments of fire fighting are helpful in controlling the fire until firemen arrive. After one or two practice drills, an unannounced drill with Superior smoke simulating a fire, will quickly dispel any lax tendencies towards fire drills and drive home the necessity of preparedness. Lives are needlessly lost every year through lack of adequate fire drills.

Recommendations and product information are believed to be accurate, but the furnishing of it does not constitute the making of a product or process warranty of Seller.

Superior warrants that this product conforms to the Product Description contained in this literature. Superior makes no other warranty, whether expressed or implied, including warranties of merchantability or of fitness for a particular purpose or application. No statements or recommendations contained herein are to be construed as inducements to infringe any relevant patent, now or hereafter in existence. Superior neither assumes nor authorizes any representatives or other person to assume for it any obligation of liability other than such as is expressly set forth herein. Under no circumstances shall Superior be liable for incidental, consequential or other damages from any alleged negligence, breach of warranty, strict liability or any other theory, arising out of the use or handling of this product.

CAUTION: Handle with care. All smoke, including Superior can irritate breathing passages without respiratory protection.

TELEPHONE (201) 251-0800

P. O. BOX 96 • SPOTSWOOD, N. J. 08884

SEND SHIPMENTS TO:
WEST GREYSTONE ROAD
OLD BRIDGE, N. J. 08857

SUPERIOR SMOKE FOR FIRE TRAINING

To develop smokey atmospheres, an adequate amount of smoke is utilized (1) to obscure vision and (2) to be sufficiently irritating to reveal improper procedures or faulty equipment. Under these simulated fire conditions, instructors have a high degree of confidence in their ability to properly train fire fighters to perform a necessary community service, while minimizing the inherent risks of their occupation.

Smoke drills are developed and performed under the direction of fire training instructors. With proper procedures delivered through clear instructions, firemen would not have any exposure to training smoke; however, circumstances such as leaky masks, equipment failure, incomplete instructions and personnel performance inadequacies do occur. Instructors anticipating these incidents have found these exposures to smoke generally range from thirty seconds to several minutes with either no physiological effects or minor short term effects such as those associated with smoke inhalation.

At times, the users may not participate in a responsible manner caused by incomplete operational instructions for self-contained breathing equipment or less than prudent personal decisions. Our experience in distributing Superior Smoke for fire training exercises reveals that in many instances, excessive volumes of smoke are developed to obscure vision, simulating fire conditions.

Low concentrations of smoke allowed to blend in a homogeneous mixture with room air provides obscurity without causing excessive concentrations. Allow the smoke generator to finish generating smoke before entering smokey atmosphere. Superior smoke products produce smoke during stated periods of time; however, the smoke cloud can remain in suspension for 15-30 minutes when not ventilated.

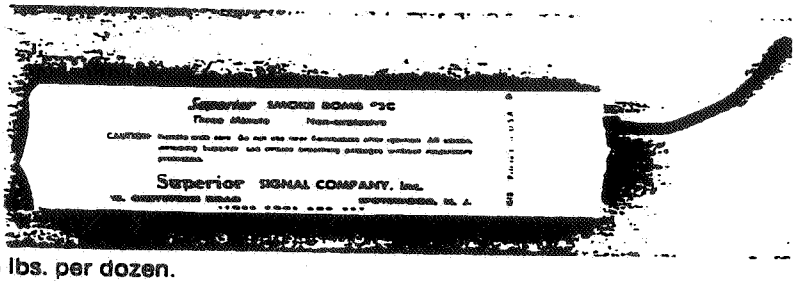
Superior

Inexpensive smoke that's efficient, effective, easy to use!

Superior SIGNAL COMPANY, INC. W. Greystone Road Spotswood, New Jersey
phone area code 201 251-0800

The Superior method of generating smoke by chemical reaction provides smokey atmospheres for training exercises involving the use of self-contained breathing apparatus. The smoke has excellent obscuring power and pungent odor revealing inadequate protection. Superior Smoke items contain no explosive materials and are the only devices of this nature acceptable in the mails. It has a T.O.P. (total obscuring power) of 2100. T.O.P. is the scientific method of determining the relative efficiency of smoke generated by a given unit of smoke composition. By comparison, Superior Smoke has a T.O.P. ten times greater than crude oil. More smoke, exclusive features, plus low prices make Superior Smoke products your best buy.

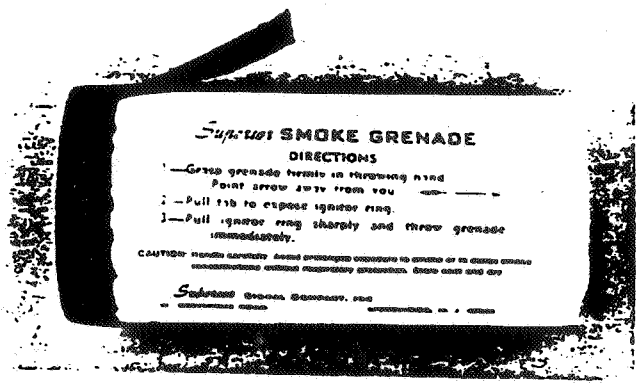
The Superior Smoke No. 3C generates a big 40,000 cubic feet of whitish gray smoke while burning from two to three minutes. Our most popular item for firemen training.
Shipping weight 5 lbs. per dozen.
Size 1½" x 6". Mailable. Shipping weight 5 lbs. per dozen.



The Superior Smoke No. 5D (not illustrated) generates 100,000 cubic feet of light gray smoke in five minutes. Long fuses on each end permit multiple units to be tied together for continuous burning to maintain an enormous and sustained volume of smoke. Mailable. Sold in minimum units of six.
Size 1½" x 14". Shipping weight 5¾ lbs. for six.

Superior Smoke Grenades are engineered for use where an instantaneous and exceptionally large volume of smoke is required. They are solidly constructed with a dependable built-in pull-wire ignitor and warranted for three years.

Superior Smoke Grenade generates 115,000 cubic feet of smoke during 2-3 minutes burning time, size 2" x 5", weight 14 oz., not mailable.



Superior Professional Smoke Grenade generates 130,000 cubic feet of smoke while burning 2-3 minutes, size 2½" x 5" 1 lb.; can be comfortably hand held; not mailable.

Printed in U.S.A. - Effective 3/87
Form S-1

SUPERIOR SIGNAL COMPANY, INC.
MATERIAL SAFETY DATA SHEET

Address: P. O. Box 96, Spotswood, NJ 08884
Phone: (201) 251-0800

SECTION 1: PRODUCT IDENTIFICATION

Chemical Family: Screening Smoke
Trade Name: Superior Smoke for fire fighters smoke drills

SECTION 2: PRODUCT INGREDIENTS (SMOKE)

Neither TLV nor PEL applicable because product is intended for use in short term training exercises.

	TLV	PEL	8-hour time weighted average
Hydrated Zinc Chloride	1 mg/m^3	1 mg/m^3	
Water Condensate	-	-	
Carbon Monoxide	55 mg/m^3	55 mg/m^3	

All other ingredients are present in negligable amounts and/or non-hazardous.

Superior Smoke products are available in various sizes that provide sufficient materials to create obscuring smoke for different sized areas.

Superior #2B	-	8,000 cu. ft.:	227 m^3
Superior #3C	-	35,000 cu. ft.:	1,133 m^3
Superior #5D	-	100,000 cu. ft.:	2,832 m^3
Superior Smoke Grenade	-	115,000 cu. ft.:	3,256 m^3
Superior White Smoke Pot	-	500,000 cu. ft.:	14,158 m^3

SECTION 3: PHYSICAL DATA (SMOKE)

Boiling Point:	N/A
Vapor Pressure:	N/A
Vapor Density:	N/A
Solubility in Water: (Zinc Chloride)	Soluble
pH:	No Data
Appearance and Odor:	Gray to white with an odor of paper.

SECTION 4: FIRE 7 EXPLOSION HAZARD DATA

(SMOKE): Flash Point (method used):	None
Autoignition:	N/A
Flammable limits in air:	N/A

(SOLID PRODUCT): Extinguishing Media: Use media suitable for surrounding fire.

(SMOKE/SOLID PRODUCT): Special fire fighting protective equipment: self-contained breathing apparatus and full protective clothing.

SD/1
1/20/87

Unusual fire and explosion hazards: None Known

SECTION 5: REACTIVITY DATA

Stability: Stable under normal conditions.

Hazardous decomposition products: See Section 2

Hazardous polymerization: None Known

SECTION 6: HEALTH HAZARD ASSESSMENT (SMOKE)

General: Superior Smoke can be used without hazard if applied as directed. Smoke drills with full dress including self-contained breathing apparatus are rigorous tests of respiratory protection equipment and confirm operational competence. Lack of irritation is proof of adequate protection. If protection is not adequate, some irritation may occur. Two major components in the initial undiluted smoke are zinc chloride and water condensate. The main effects of the smoke are irritation of the throat, an awareness of an odd odor, and the appearance of smoke. These effects act as a warning and are desirable to prevent voluntary overexposure. Individuals should be urged not to accept exposures that cause minor irritation, but to leave the area.

Ingestion: Not a significant route of exposure.

Eye Contact: Accute exposure is not likely to induce eye irritation.

Skin Absorption: Not a significant route of exposure.

Inhalation: Acute exposure can cause irritation of the respiratory tract and mucous membranes. Irritation is a warning property of smoke materials; in itself irritation is not usually regarded as a toxic effect unless it is sufficient to cause inflammation and then inflammation, not irritation, is the toxic effect.

Effects of Overexposure: Irritation of the respiratory passages; cough; nausea. Gross overexposure to dense smoke concentrations for periods of ten minutes or more could result in throat irritation and mucous membrane congestion requiring medical treatment. Coughs, chills, fever and pulmonary edema can result from overwhelming exposure. Increasingly sever overexposure is likely to result in increasingly sever irritation and inflammation to all mucous membranes contacted by the smoke with most severe effects usually appearing in the respiratory tract.

Emergency and First Aid Procedures: Remove victim to fresh air. If breathing is difficult, get medical attention.

SD/1
1/20/87

SECTION 7: DISPOSAL METHOD

(SMOKE): Ventilate area: Use local exhaust to keep exposure to a minimum. The length of exposure could be reduced further by opening doors and windows. Push/pull ventilation will speed smoke evacuation.

(SOLID PRODUCT): Disposal Method: Dispose in chemical disposal area in a manner that complies with local, state and federal regulations.

The information herein is given in good faith, but no warranty, expressed or implied, is made.

SD/1
1/20/87