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NIOSH

Fire Fighter Fatality Investigation and Prevention Program

Death in the line of duty...

A Summary of a NIOSH fire fighter fatality investigation *March 17, 2006*

Life-Fire Training Exercise Claims the Life of One Recruit Fire Fighter and Injures Four Others – Florida

SUMMARY

On August 8, 2003, a 37-year-old male recruit fire fighter (hereafter known as the Recruit) died and four others suffered skin burns and heat exhaustion while participating in their first live-fire training exercise. The training took place in a simulated marine vessel. After completing most of the evolution, the Recruit became separated from his squad as they were returning to the entrance/exit door. All recruits and instructors had exited the structure when the training staff realized a recruit was missing. The structure was "opened up" and the Recruit was found unconscious in cardiopulmonary arrest. Despite cardiopulmonary resuscitation (CPR) and advanced life support (ALS) at the scene, in the ambulance, and in the emergency department of the local hospital, the Recruit died. An autopsy conducted by the County Office of the Medical Examiner concluded the cause of death to be "cardiac arrhythmia" due to "exposure to heat" with "AV node artery stenosis and mild myocarditis" as contributory causes. Findings of the NIOSH investigation support this conclusion. The extreme heat stress could have been avoided if strict compliance with National Fire Protection Association (NFPA) 1403, *Standard on Live Fire Training Evolutions*, had been followed.[1] To reduce the risk of similar occurrences, the fire department (FD) should take the following actions:

Ensure the Fire Department's Occupational Safety and Health Bureau (OSHB) provides oversight on all Recruit Training Bureau (RTB) safety issues, including live-fire training.

Provide the Training Division, and specifically the RTB, with adequate resources, personnel, and equipment to accomplish their training mission safely.

Create a training atmosphere that is free from intimidation and conducive for learning.

***Conduct live-fire training exercises according to the procedures of the most recent edition of NFPA 1403,* Standard on Live Fire Training Evolutions.**

Ensure that Standard Operating Procedures (SOPs) specific to live-fire training are developed, followed, and enforced.

Ensure that team continuity is maintained during training operations.

Ensure that fire command always maintains close accountability for all personnel operating on the fireground.

Ensure coordinated communication between the Incident Commander and fire fighters.

The **Fire Fighter Fatality Investigation and Prevention Program** is conducted by the National Institute for Occupational Safety and Health (NIOSH). The purpose of the program is to determine factors that cause or contribute to fire fighter deaths suffered in the line of duty. Identification of causal and contributing factors enable researchers and safety specialists to develop strategies for preventing future similar incidents. The program does not seek to determine fault or place blame on fire departments or individual fire fighters. To request additional copies of this report (specify the case number shown in the shield above), other fatality investigation reports, or further information, visit the Program Website at

www.cdc.gov/niosh/fire

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Equip all live-fire participants, including recruits, with radios and flashlights.

Establish an on-scene rehabilitation unit consistent with NFPA 1584.

Report and record all work-related injuries and illnesses.

INTRODUCTION & METHODS

On August 8, 2003, a 37-year-old male recruit fire fighter died while participating in his first live-fire training exercise. On August 11, 2003, the U.S. Fire Administration (USFA) notified the National Institute for Occupational Safety and Health (NIOSH) of this fatality. On August 18, 2003, two safety and occupational health specialists, one occupational health physician, and one occupational health nurse from the NIOSH Fire Fighter Fatality Investigation and Prevention Program traveled to Florida to investigate the incident. A NIOSH contract physician and the County's Chief Safety Officer accompanied the NIOSH investigators. The NIOSH team met with and/or interviewed the following people:

- Officials from the affected FD (Fire Chief, Assistant Chief, Training, Safety, etc.)
- Officers from the FD where the training facility was located (Fire Chief, etc.)
- Union officials of the affected FD (President, Vice President, etc.)
- Officers and fire fighters (FF) at the scene of the incident
- Other recruits involved in the evolution
- FD physician
- Officials from the County Medical Examiner's Office
- Recruit's widow with her attorney
- Officials from the State Fire Marshal's Office

During the site visit and subsequent investigation, NIOSH personnel reviewed the following documents:

- FD's training division orientation manual for fire fighter recruits
- FD policies and standard operating guidelines for 1) rapid intervention teams (RIT); 2) passport accountability system at emergency incidents; and 3) safety plans at non-emergency activities
- State fire fighter training and certification requirements
- Blueprints of the live-fire training structure
- Photographs and videotapes taken at the training facility
- Dispatch records for the incident
- Hospital transport records for the recruits
- Hospital emergency department (ED) records of the recruits
- Autopsy report
- FD medical records for the Recruit
- County medical records for the Recruit
- Incident investigation report completed by the FD review panel

- Incident investigation report completed by the County Chief Safety Officer
- Incident investigation report completed by the State Fire Marshal's Office

BACKGROUND

Fire Department Recruit Training. Recruit training is the responsibility of the FD's Recruit Training Bureau (RTB) in the Division of Training. Because the FD is not a State-approved Certified Training Agency (CTA), the FD usually contracts with the neighboring community college (a State-approved CTA). The college provided the written exams, facility, paperwork, and live-burn exercise while the RTB provided the instructors for the classes and the live-fire exercise. Upon completing the training program, the recruits were eligible to take the State Fire Fighter II certification test.

Due to a projected shortage of fire fighters, in 2003 the FD planned to train two "Classes" simultaneously (Class 92 and 93). The local community college could not accommodate the second recruit class (Class 93 with 25 recruits), so the FD sought a second training facility. The FD entered into a Memorandum of Understanding with a neighboring FD that was a State-approved CTA. As with the community college arrangement, the CTA provided the facility, paperwork, and live-burn exercise while RTB provided the instructors.

The need to train two classes simultaneously strained an already depleted instruction staff at the RTB. Although instructor/student ratios were adequate, instructors frequently had to move between classes to ensure proper ratios. This movement resulted in many instructors being unfamiliar with each other. In addition to the shortage of instructors, there were concerns about a shortage of and lack of preventative maintenance on self-contained breathing apparatus (SCBA) and radios. Overall, the inadequate equipment, depleted staff, increased workload, and the tense working environment made it difficult to staff the RTB from other FD divisions.

The RTB was reported to operate in a rigid organizational climate. Recruits reported being threatened with termination if they failed a performance objective, failed a test, failed to participate in physical training, or sustained injuries needing medical care. In the early summer of 2003, the Chief of the FD received an anonymous letter alleging unsafe and inhuman treatment of recruits by staff at the RTB. Although some effort was made to follow-up these allegations, no official investigation was conducted, and no official report was completed.

Live-Burn Facility. State standards require the completion of at least two live-burn exercises for FF II certification. In 2003, neither the local community college nor the neighboring FD had State-approved burn buildings in operation. Both organizations contracted with a local private facility to conduct their live-burn exercises. The facility opened in 1996 to resemble a seagoing vessel (Photo 1). It was designed and intended to train personnel for marine, not structural fire fighting. The simulator had three decks constructed from steel shipping cargo containers. It was about 130 feet long, 60 feet wide, and 28 feet high. The interior was subdivided into many small "cabin-like" spaces typically found on board a ship and contained many marine fixtures including watertight doors, shipboard style chairs, grating, simulated engine compartment, vents, etc. (Figures 1–3).

Ground Level. The ground level of the simulator included several rooms, cabins, and hallways (Figure 1). Two ground level rooms were used during the August 8, 2003, exercise: the simulated engine

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room and simulated crew lounge with its attached "burn box." The burn box was designed as a flashover simulator with an elevated hearth and a 10-foot ceiling. A "fire curtain" was located in the center of the simulated crew lounge. A ceiling damper was located just in front of the burn box and was controlled by a lever located just behind the fire curtain (Figure 3). The ceiling damper was operated via a "dead-man" lever; if someone was not holding the lever down, the lever would rise, the damper would open, and the hot gases would vent above the burn box. This safety mechanism, however, was circumvented by the use of a chain wrapped around the lever and attached to the floor. In addition, due to soot buildup on the pulley system, the damper could only partially open.

Photo 1: *Photograph of the Simulated Seagoing Vessel for live fire training.*

During live-fire exercises, wooden pallets were stacked and ignited in the burn box. The resulting heat and smoke was channeled to different areas of the simulator by the ceiling damper, hatches (doorways), open grid floor grating, open stairways, and ladder wells. The combination of the dense smoke, closed exterior hatches, and lack of windows made visibility extremely limited.

Additional heat was provided by a liquid propane (LP) gas burner placed on a metal grating in the simulated engine room (Figure 1). The metal grating had been heavily damage by fire (Photo 2). A large portable propane tank fed the propane burner whose lines were reported to be without a pressure regulator.

Photo 2: *Heat damaged grating above liquid propane fire in the "engine room."*

Second Deck. The second deck featured several compartments with connecting hatches. Four hatches exited directly onto the open-air portion of the deck (Figure 2). The middle of the second deck contained a small room (compartment 4) with a flue that vented hot gases to the top of the structure.

Third Deck. The third deck consisted of a simulated bridge and several cabins. This deck was not involved in any of the exercises conducted on August 8, 2003.

The simulator did not have any type of fixed temperature sensing system. Fire hose connections were located at several points in the structure and a charged safety backup hose was available in the simulated crew lounge (Figure 3). At the time of the incident, the facility was not certified by the State Bureau of Fire Standards and Training, a fact unknown to both the FD and the two CTA, conducting the training for Class 92 and 93. In addition, according to the facility's building permit and operations manual, the structure was not approved for LP use, or designed for having any type of fire outside the burn box.

Since 2002 the FD's RTB has been using the private marine facility for its recruit live-burn training exercise. In 2003 there were two separate incidents of a recruit becoming lost during live-burn exercises. In both instances the recruit became separated from his squad and was only discovered missing during the personnel accountability report (PAR) at the end of the evolution. Neither incident resulted in changes or a re-examination of the RTB's policies or procedures regarding live-fire exercises.

Days Preceding the Live-Fire Training Evolution. For Class 92, the local community college provided the personnel to operate the prop and safety officers while the RTB provided the instructors. For Class 93, however, the Memorandum of Understanding with the neighboring FD failed to mention any safety coverage for the live-fire. Because the neighboring FD was not providing safety officers for the live-fire exercises, the head of the RTB requested additional FD staff to serve as "safeties." The training division provided a list of four FFs as instructors/safety officers. Only one of the four FFs was a FD-certified Incident Safety Officer, and one FF had not been involved in a live-fire exercise in over 20 years. This lack of experience and certification concerned the head of the RTB. He notified his superiors, who suggested the four FFs familiarize themselves with the facility the day before the exercise. This advice was not followed.

Safety Plan. Although a safety plan was submitted for this exercise, it was cursory and lacked the name of the drill coordinator and the drill date, and was not signed by the drill coordinator or reviewing official.

Recruit Instructions. The day before the live-fire exercise the officer-in-charge (OIC) of the RTB and the Lead Instructor for Class 92 addressed the recruits in Class 93. They reminded the recruits that two live-fire evolutions were required for State certification. They further explained that two live-fire evolutions were scheduled for August 8 and no make-ups were possible. They reportedly explained that anyone who exited the structure prematurely or who received lost-time injuries would be terminated.

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The Live-Fire Training Evolution*. *Weather. For the time period 0700 to 1100 hours, the National Weather Service reported a temperature of 87° Fahrenheit (F) with a relative humidity of 80%.

Rehabilitation Area. Portable tents and canopies for rehabilitation and personal protective equipment (PPE) were erected at the facility about 50 yards from the structure. Ice chests filled with ice and water were readily available.

Personal Protective Equipment. All personnel entering the structure were required to wear a full complement of PPE. This consisted of turnout gear (coat, pants, helmet, hood, gloves, and boots), and a self-contained breathing apparatus (SCBA) with an integrated personal alert safety system (PASS) device. When the squad entered the structure, they donned their turnout gear and SCBA. The recruits were responsible for checking each other's PPE.

Instructors and Training Personnel. Eleven FD instructors, four additional FD training personnel, and two additional "off-duty" FD personnel were present for the live-burn. Of these 17 FD personnel, 11 were State-certified instructors. In addition to the FD personnel the two CTA had approximately seven individuals present, many of whom were experienced with this facility and were State-certified instructors. A few facility employees were also present. Class 93 recruits and most of the instructors arrived between 0615 and 0700 hours.

Evolution Briefing. The instructors gathered to develop and review the training scenario. The plan divided Class 93 into five squads each with five recruits. Each squad would enter the structure with three instructors (lead, middle, and rear) from the west side of deck two (Figure 2).

Due to the complete lack of visibility in the first part of the exercise, instructors and recruits crawled along a charged 1½-inch hose line through compartments 1–3 and then toward a catwalk. The hose was put in a semi-circle in compartment 2 (Figure 2). With the light generated from the LP fire in the simulated engine room, the visibility at the end of the catwalk improved to about 5–10 feet. Although the LP fire increased the visibility, it also markedly increased the heat, particularly to the open steel grate just above the flames. At this point in the exercise, the participants were expected to "duck-walk" across the open steel grating. Duck walking is essentially walking in a squat; it is faster than crawling and can prevent hand and knee burns. Once across the steel grating participants would "back down" the stairs without use of the hand railing. Because of the heat in this area, touching the hand railing would probably result in a hand burn despite the use of gloves.

Once on the floor of the simulated engine room, the squad proceeded into the simulated crew lounge and the burn box. This entire route was approximately 140 feet. Each recruit had a turn handling the nozzle. They were instructed not to extinguish the fire, but to direct their streams of water to the walls around the hearth. After each recruit ran through a series of spray patterns with the nozzle, the entire squad, as a group in reverse order, retraced their steps to exit the structure.

Instructors had the opportunity to walk through the structure and familiarize themselves with the evolution, but not all instructors arrived in time or were included in this overview. In addition, at least one of the instructors who participated

in the walk-through was never told that a LP fire would be burning in the simulated engine room. The recruits were not given the opportunity to walk through the evolution.

Fuel. Three wooden pallets (each weighing about 30–35 pounds, 40–50 pounds if wet) were placed into the burn box. Also several pallets were stacked under the stairway inside the simulated engine room. Between squads the burn box fire was replenished with two or three of the pallets from the simulated engine room. The replenishment occurred from the interior of the burn box to reduce the heat dissipation of the structure. At least one pallet was placed and ignited on the grating alongside the LP simulated engine. This facilitated the ignition of the LP fire between squads, but it also increased the heat and smoke of the exercise. Although the LP fire was supposed to have been stopped and then restarted between squads, NIOSH investigators could not identify which individual performed this function, so it is unclear whether the stop/restart actually occurred.

Accountability System. For each evolution, the accountability officer (AO) stood at the structure's entry point. This individual was also assigned as the incident commander (IC) for that evolution. The AO/IC gave the final check of each recruit's PPE and noted the recruit's name and entry time on the control board as he entered the structure. The AO/IC's control board included neither the FD personnel pre-positioned inside the structure (discussed below) nor the instructors and observer entering with the recruits. The individual assigned as the AO/IC varied with the squad. The AO/IC for Squad D had entered the structure earlier as a Squad A Instructor. While serving as the AO/IC for Squad D he was not wearing turnout gear or SCBA. He was equipped with a radio and control board.

Rapid Intervention Team (RIT). No RIT was assembled for Squad D or any other squad that morning.

Fire Ignition. At approximately 0800 hours three wooden pallets in the burn box were ignited followed by the LP fire in the simulated engine room. The structure filled with heat and smoke before the first squad (A) entered the structure. The squad entry and exit times are as follows:

Squad	Entry (in hours)	Exit (in hours)
A	0820	0835
B	0845	0905
C	0914	0928

Between evolutions, the burn box was replenished with two wooden pallets for squad B and C, and three wooden pallets for squad D.

Pre-Positioned Personnel in the Structure. As Squad D prepared to enter the structure, four personnel positioned themselves inside the structure. The RTC's OIC (acting as an observer for this evolution), the Safety Officer who also could have been considered the Ignition Officer (SO/IO), and an observer (O-1) with a thermal imaging camera placed themselves at the rear of the simulated engine room (Figures 2 and 3). O-1 moved back and forth between the simulated engine room and the burn box. The fourth person was the vent operator (VO) who controlled the damper in the simulated crew lounge (Figures 2 and 3). These four were wearing full PPE and two (OIC, SO/IO) had radios. A fifth person, Observer 2 (O-2), entered the structure with Squad D. O-2 was learning how to operate a thermal imaging camera and his only assignment was to

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prevent anyone from falling into the ladder well in compartment 1.

Squad D. All three squad D Instructors had flashlights, but only the lead instructor (I-1) and the rear instructor (I-3) had radios. I-1's radio had a frayed mouthpiece connection. Both I-1 and I-3 had participated in the evolutions earlier that morning as an instructor and observer, respectively. Both had a chance to cool and hydrate in rehab before beginning another evolution. Once O-2 was in place in compartment 1's ladder well, I-1 entered the structure followed by recruit 1 (R-1) (the victim) at 0939 hours. As mentioned previously, the visibility in compartments 1–3 was essentially nonexistent. The facility lacked a temperature sensor; most individuals rated the heat in this area to be tolerable. Once R-1 began crawling to follow the hose, I-1 followed. The AO/IC spaced the recruits about 3–5 seconds apart so the recruits learned to follow the hose rather than "buddy up."

The recruits and instructors crawled along the hose line through the hatches connecting compartments 1–3. In compartment 3, the hose made a turn toward the catwalk and the open grate above the simulated engine room. Watching as I-1, R-2, and R-3 began duck walking across the open grating, I-2 positioned himself in the well of ladder 2 in compartment 3.

After duck walking across the grate, I-1 waited at the top of the stairs for the recruits. The LP fire below illuminated the area, increasing visibility to about 10 feet, but it also made this area extremely hot. At this point the instructors and recruits were soaked with perspiration inside their turnout gear. I-1 had intended to wait for all the recruits at the top of the stairs, but because of the extreme heat, he had R-1 and R-2 descend, and then followed R-2 down the stairs.

I-2 watched as R-3, R-4, and R-5 passed his ladder 2 position and then followed them as they all duck walked over the catwalk and the open grate. As R-3, R-4, and R-5 descended the stairs, I-2 began having glove problems. When I-2 arrived at the bottom of the stairs, he exited the side of the structure to change gloves. This was noted by the SO/IO in the simulated engine room who notified the AO/IC via radio. I-1 and I-3 were unaware that the middle instructor (I-2) had exited the structure.

Arrival at the Burn Box. The squad continued advancing along the hose line and crawled to the simulated crew lounge where I-1 notified the AO/IC that they had arrived at the burn box (0944 hours). I-1 heard the AO/IC acknowledge the transmission. Once the entire squad assembled in the simulated crew lounge, a "count off" or personnel accountability report (PAR) for the recruits ensued. The squad instructors were not included in this or other PAR count offs.

The recruits knelt along the hose line to begin their nozzle spray patterns (Figure 1). As R-1 began to operate the nozzle, he accidentally sprayed water into the burn box, significantly reducing the fire's intensity. I-1 waited for 2–3 minutes to rebuild the fire's intensity before resuming the nozzle sprays. I-2 returned to the burn box with a new set of gloves, but it is unclear if this information was transmitted to the AO/IC. The visibility in the burn box was about 10 feet, and it was extremely hot at the nozzle area. O-2, with one of the thermal imaging

cameras, had the following temperature readings from the camera: burn box – 900°F, ceiling – 950°F, and floor – 145°F. The accuracy of these measurements, however, is unknown.

After the recruits successfully used the nozzle, I-1 decided that all recruits (1–5) needed one more nozzle rotation. As R-1 started his second nozzle spray, I-1 radioed the AO/IC on at least two separate occasions stating he was overheated and needed relief. This transmission was never acknowledged by the AO/IC, nor heard by other personnel carrying radios. As mentioned earlier, I-1's radio had a frayed mouthpiece connection.

As the squad's second nozzle rotation began, I-2 noted problems with his SCBA. After failing to correct the problems with O-2's assistance, he exited the structure again. It is unclear if this information was transmitted to the AO/IC. After R-1 and R-2 completed their second nozzle rotation, the AO/IC transmitted a 15-minute time stamp. This meant Squad D had been in the structure for more than 15 minutes and it was time to start exiting.

Exit from the Burn Box. At this point only two of the recruits (R-1 and R-2) had taken their second nozzle rotation. Therefore, they were out of order when they turned around and began to exit. The new exiting order was: I-3, R-2, R-1, R-5, R-4, R-3, I-1. I-3 led the recruits as they crawled along the hose line and exited the simulated crew lounge to the simulated engine room.

Lead Instructor's Heat Exhaustion. At this point the VO and O-2 noted something different about I-1's behavior. When asked by the VO if he was all right, I-1 stated he was very hot, but was adamant about staying with his squad. I-3 then started up the stairs, across the open steel grating and the catwalk, and positioned himself in the well of ladder 2 in compartment 3 as he waited for the recruits to follow. As the recruits started up the ladder, the VO noted that I-1 was crouched over with his hands on his knees. The VO suggested he exit the structure immediately and I-1 did so. I-1 and the VO exited the simulated engine room and went directly to the rehabilitation unit. This was not radioed to the AO/IC, and I-3 was still under the assumption that I-1 and I-2 were following the recruits.

Recruits Bunch Up in Compartment #3. Waiting in compartment 3, I-3 watched as the recruits approached. One of the instructors outside the structure (a Chief from a CTA) had noted that multiple personnel (I-1, I-2, VO) had exited the structure, so he donned his SCBA and entered the simulated engine room at the ground level to follow the recruits. He encountered the Training Bureau's OIC, the SO/IO, and O-1. The Chief climbed the simulated engine room's stairs as he maintained visual contact with the squad. He crossed the steel grate and catwalk and encountered the recruits and I-3 in compartment 3. At this point all five recruits were present. In compartment 3, I-3 was having difficulty getting the recruits to exit due to confusion over the proper exit order. The Chief directed I-3 to lead the recruits out of the structure while he brought up the rear. At this time compartment 3 had some visibility due to the LP flame in the simulated engine room. This visibility, however, quickly deteriorated when they followed the hose into compartment 2. I-3 went directly across compartments 2 and

1 to the faint outline of the exit door. He did not follow the hose and the recruits reported doing the same due to their heat stress and exhaustion. Once the squad had exited the structure, the Chief followed the hose with his flashlight in compartments 3, 2, and 1 and then exited the structure.

Missing Recruit. The chief instructor asked the AO/IC if a PAR had been conducted. No PAR had been conducted, and the Chief shouted for a PAR. The recruits counted off. At that point everyone realized that R-1 was missing.

The Chief re-entered the structure and encountered O-1 with his thermal imaging camera in compartment 1. The Chief with a flashlight and O-1 with his camera retraced their steps searching compartments 1, 2, and 3, and the catwalk. The Chief ordered O-1 to continue across the open steel grating and down the stairs while he went down ladder 2 in compartment 3. I-3 quickly reentered with his flashlight and proceeded through compartments 1–3 and across the catwalk to the open steel grate, then returned to the entrance/exit door.

On the outside, the AO/IC alerted staff that a recruit was missing and began opening all the doors of the structure on the second floor (Figure 2). Instructors from the earlier squads donned their SCBAs and entered the structure. One instructor climbed up ladder 2 from the ground level to compartment 3 (Figure 2). This instructor then entered compartment 2 just as I-3 was re-entering from compartment 1. Both saw the missing recruit face down next to the hose in compartment 2 (Figure 2). His PASS device was not discharging.

Resuscitation Efforts. With the assistance of the AO/IC who had just opened compartment 2's outside door, the other instructor and the AO/IC pulled R-1 to the outside deck. As his SCBA mask was removed, compressed air could be heard rushing out of the mask. This indicated that R-1 had not run out of compressed air from his SCBA. R-1's PPE and turnout gear were stripped off and initial assessment revealed him unresponsive with no pulse or respirations and hot to the touch. There was no advanced life support equipment on scene, but a nearby rescue kit provided oxygen by bag and mask. CPR was initiated as a call for 911 was made and cold water and ice were raced to R-1.

An on-duty FF from the neighboring FD noted the victim being pulled from the structure and called his station's Engine Company and Medical Rescue Unit to the scene. Paramedics equipped with ALS equipment arrived on scene and proceeded with intubation, cardiac monitoring, and intravenous medications. The medical rescue unit arrived at the local hospital's emergency department at 1030 hours. ALS procedures continued in the ED until 1054 hours when the victim was pronounced dead, and resuscitation efforts were stopped. R-1's temperature was never taken by the neighboring FD's medical rescue unit, or the hospital's ED.

Medical Evaluations of the Other Squad D Recruits. The other four recruits in Squad D suffered burns and heat-related injuries. After cooling and rehydrating in rehab for 10–15 minutes, all four were taken to the ED. Three recruits had first and second degree burns on their knees and hands, respectively. One recruit suffered severe heat exhaustion resulting in confusion, psychosis, and treatment in the critical care section of

the ED for 30 minutes before being transferred to a step down unit for 3 hours. This recruit had his temperature taken in the EMS unit (101.3º F) and in the ED (100.9º F). It was assumed these temperatures were for oral or tympanic membrane readings. They were taken at least 10 and 15 minutes after the squad had exited from the structure and had removed their turnout gear and been drinking fluids.

NIOSH SCBA Testing. At the request of the County Medical Examiner's office, the Recruit's SCBA was sent for further evaluation to the NIOSH National Personal Protective Technology Laboratory. The purpose of the testing was to determine the SCBA's conformance to the approval performance requirements of *Title 42, Code of Federal Regulations, Part 84 (42 CFR 84)*. Further testing was conducted to determine conformance to the NFPA Air Flow Performance requirements of NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for the Fire Service*.[2] There was no evidence to support malfunctioning of the SCBA. The PASS device was activated and appeared to function normally. These preliminary findings were e-mailed to the FD, the local union, the County Medical Examiner's Office and the State Fire Marshal's Office on October 29, 2003. The full report was mailed to the same contacts on February 18, 2005. A summary of that report is included in Appendix 1.

The full report describes the NIOSH attempt, in conjunction with the SCBA's manufacturer, to examine the unit's "Sentinel" device. The device collects and records the air cylinder pressure, user's breathing rate, and temperature every 20 seconds while the SCBA is in use. When this data is downloaded to a computer, the Sentinel's memory storage is emptied. After installing a new battery, a download link was established. The device was identified as serial number BRPF0496, but no useable data remained, indicating that the device had been downloaded prior to being sent to NIOSH.

Subsequent Inspection of the Structure. When compartment 4 was inspected after the incident, there were hand/glove markings on the walls. This finding suggested that the Recruit lost contact with the curve of the hose in compartment 2 and, given the lack of visibility, crawled into compartment 4. It is believed that he was disoriented in this compartment during the search for the missing recruit. Apparently, he had just crawled out of compartment #4 into compartment #2 when he collapsed. This scenario explains why three personnel (Chief Instructor, I-3, O-1) had inspected compartment 2 at least two times each and not seen the downed Recruit.

MEDICAL FINDINGS

Autopsy Results. Pertinent findings from the autopsy included the following:

- No illicit drugs detected in the urine or blood
- No carbon monoxide (carboxyhemoglobin) detected
- Second degree burns over both hands and both knees
- No evidence of a pulmonary embolus (a blood clot in the lung arteries)
- Heart:
  - Normal size, normal valves
  - No evidence of atherosclerotic coronary artery disease
  - Slight left and right ventricular hypertrophy

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- Microscopic findings of the heart muscle showed the following:
  - Multifocal myocarditis
  - Contraction bands without inflammation
  - Severe focal narrowing of the atrioventricular node artery
  - Mild focal myocyte disarray and myocardial fibrosis
  - Focal hemorrhage of blood in the bundle of His and ventricular septum
- Other cardiac diagnoses included:
  - Pericardial petechiae
  - Dilated right atrial appendage

Cause of Death. The Associate Medical Examiner concluded the cause of death to be "cardiac arrhythmia" due to "exposure to heat" with "AV node artery stenosis and mild myocarditis" as contributory causes.

Past Medical History. In 1994 the Recruit had a pre-employment electrocardiogram (EKG). This showed possible left ventricular hypertrophy (LVH) using "voltage criteria," but was otherwise normal. His second EKG, taken as a job promotion physical exam in 1998, again showed LVH and 1° A-V block (a minor heart conduction abnormality). His FD pre-placement EKG on May 19, 2003, showed only borderline 1° A-V block. On June 2, 2003, his resting EKG before beginning his exercise stress test (EST) did not meet criteria for either 1° A-V block or LVH. During his EST, the Recruit exercised for 13 minutes 30 seconds before being stopped because he had reached 95% of his maximal heart rate. He reached Stage 4 of the Bruce protocol (14.9 METS or a calculated MVO_2 of 48.7 ml/kg/min). He denied any angina-like symptoms, had a good blood pressure response, and no EKG changes suggestive of ischemia.

In 1994 during his pre-employment examination a grade II/VI systolic murmur was found. This was not noted on his physical examination in 1998 or 2003. During his 2003 FD pre-placement medical evaluation, the Recruit reported his history of a heart murmur and made a notation that an echocardiogram was negative. According to his wife, he had never experienced any type of heart problem, syncope, or history of heat stress/exhaustion. On July 15, 2003, the Recruit completed a memorandum to the OIC of the RTB stating that he informed his training officer that he felt "overheated" during the extinguisher drill the previous day. The temperature on July 14, 2003, was 89° F.

DISCUSSION

Based on their findings, the NIOSH investigators agree with the County Medical Examiner's office that the Recruit died from a heart arrhythmia associated with his underlying heart condition. The arrhythmia was triggered by the extreme heat encountered during the live-fire training.

Heat Stroke. There are multiple types of heat illness ranging from heat rash to heat stroke.[3] Heat stroke is the most serious, typically occurring when the core body temperature exceeds 104ºF to 106ºF. Time required to develop heat stroke is variable based on many factors including temperature, humidity, activity level, age, acclimatization, medications, water consumption, clothing, physical condition, obesity, previous history of heat illness, and predisposing medical conditions. Symptoms typically begin as sweating, dizziness, gastrointestinal distress,

and a fast heartbeat then progress to hypotension, hyperventilation, delirium, seizures, and eventually loss of consciousness/coma. Hallmark signs of heat stroke include multi-organ failure, particularly of the nervous system, the circulatory system, and the liver.[3] The lack of a core temperature measurement and the Recruit's rapid death make it difficult to confirm that heat stroke occurred. Environmental conditions, however, were conducive to heat stroke.

Cardiac Abnormalities. The Recruit had two asymptomatic heart abnormalities identified at autopsy. Given his lack of symptoms prior to the incident, normal EKG, and normal EST two months prior to his death, there was no reason for the FD physician to suspect either one of these conditions. The first abnormality, the finding of isolated AV node stenosis (blockage) with the lack of any corresponding atherosclerosis, was unusual. The medical literature includes a few reports of this type of lesion and has associated it with unexplained sudden death.[4,5]

The autopsy also identified microscopic inflammation of the heart muscle (myocarditis). This type of inflammation is typically caused by a viral infection, but can have other etiologies.[6] The clinical course varies, but some individuals with myocarditis progress to a characteristic type of heart failure known as dilated cardiomyopathy. Based on autopsy findings, the Recruit did not have dilated cardiomyopathy. However, myocarditis, by itself, has been associated with sudden death.[6,7] Finally, the Recruit had slight hypertrophy of his left and right ventricles. While some microscopic features of the heart muscle suggested a condition known as hypertrophic cardiomyopathy, the myocyte disarray was not as extensive as typically seen in this diagnosis.[8]

CONCLUSION

The FD did not adhere to NFPA consensus standards, State statutes and codes, and its own policies with respect to live-fire training exercises. This probably contributed to the death of one Recruit and the injury of four others. The FD had inadequate personnel and equipment devoted to the RTB. The decision to train two recruit classes simultaneously strained the already depleted RTB resources. The FD did not allow its Occupational Safety and Health Bureau to provide safety oversight over RTB operations.

RECOMMENDATIONS/DISCUSSION

To reduce the risk of similar occurrences, NIOSH investigators offer the following recommendations:

Recommendation #1: Ensure the Fire Department's Occupational Safety and Health Bureau (OSHB) provides oversight on all Recruit Training Bureau (RTB) safety issues, including live-fire training.

For unclear reasons the OSHB was not involved in safety issues involving the RTB. The RTB, as well as the entire Training Division, should take advantage of the OSHB's experience and expertise.[9]

Recommendation #2: Provide the Training Division, and specifically the RTB, with adequate resources, personnel, and equipment to accomplish their training mission safely.

Several problems identified during the NIOSH investigation were related to inadequate resources devoted to the Division of Training. This includes the shortage of State-certified Instructors, limited number of radios and flashlights, and SCBAs and radios that needed repair.

Recommendation #3: Create a training atmosphere that is free from intimidation and conducive for learning.

The purpose of training is to teach fire fighters proper techniques to accomplish an assignment in a safe environment that supports learning. Training exercises should not take a punitive approach.[10] By fostering a positive learning environment, fire departments can capitalize on each individual's analytical skills to become problem solvers within a team organization.

***Recommendation #4: Conduct live-fire training exercises according to the procedures of the most recent edition of NFPA 1403,* Standard on Live Fire Training Evolutions.**[1]

Fire department policy and State law require compliance with NFPA 1403. The live-fire training exercise described in this report did not follow numerous aspects of this Standard. To comply with NFPA 1403 and other safety measures during live-fire exercises, NIOSH investigators recommend the FD take the following steps:

- Use a structure certified by the State to conduct live-fire exercises.
- Use liquid propane gas only in burn buildings designed for its use.
- Establish an instructor-in-charge at the live-fire training.
- Provide unambiguous assignments to key positions (Instructor-in-Charge, Accountability Control, and Safety Officer).
- Ensure key positions (listed above) do not have other responsibilities or dual assignments.
- Use only State-certified Instructors.
- Use only Instructors and Safety Officers who have live-fire training and who are familiar with the live-fire training structure.
- Ensure that the Safety Officer conducts the final inspection of a recruit's PPE prior to entry into the live-fire structure.
- Ensure the Ignition Officer starts the fire under the supervision of the Safety Officer.
- Ensure that temperature sensing instruments are available and working throughout the structure.
- Conduct pre-burn briefings for ALL participants. This briefing should include emergency evacuation procedures.
- Ensure that the complexity of the planned evolution matches the participant's experience and training.
- Require all participants to conduct a walk-through of the structure to become familiar with the layout, identify hazardous areas, identify trip hazards, and identify emergency exits.
- Establish an evacuation plan and demonstrate an evacuation signal to all participants.
- Ensure fires are not located in any designated exit paths.
- Limit the exercise to only one fire located in the fire box.
- Establish a rapid intervention team (RIT) equipped with a thermal imaging camera.
- Provide on-scene emergency medical services with ALS capability on site.

Recommendation #5: Ensure that Standard Operating Procedures (SOPs) specific to live-fire training are developed, followed, and enforced.[9]

SOPs should be developed specifically for training fires and include areas such as facility inspection, fuel materials, RIT operations, SCBA, water supply, and hoseline operations. The SOP should be in written form and included in the overall risk-management plan for the fire department. If these procedures are changed, provide appropriate training to all affected members. In this incident, the facility used to conduct the live-fire training had operational SOPs for the building that were not followed or enforced. These procedures included the following:

- The structure was designed to have live-fire in the burn box only.
- No more than three pallets were to be used for each burn.
- Fires were not to burn longer than 2 hours without a cool down period.
- Cool down periods were not to be less than 30 minutes with the fire completely extinguished with the vent open and the space was to be cooled down both inside and out with a water spray.
- The lever that operated the vent inside the flashover simulator was chained to the floor to hold it in a closed position. This lever was designed with a counterweight to remain open when unattended.

Recommendation #6: Ensure that team continuity is maintained during training operations.[11,12]

The idea of training is to enforce safe practices for situations that fire fighters may encounter on the fireground. Team continuity relies on the following factors that are instrumental in developing safe fire fighters: knowing who is on your team and the team leader, staying within visual contact at all times (if visibility is obscured then teams should remain within touch or voice distance of each other), communicating your needs and observations to the team leader, rotating to rehab and staging as a team, and watching your team members (practice a strong "buddy-care" approach). These key factors help to reduce serious injury or even death resulting from the risks involved in fire fighting operations and help to discourage freelancing. Teams that enter a hazardous environment together should leave together. In this incident, instructors that were part of the recruit training team left the structure for heat-related safety concerns. This action should have required all team members to exit the structure together as a team through the closest exit as outlined during the walk-through.

Recommendation #7: Ensure that fire command always maintains close accountability for all personnel operating on the fireground.[9,13,14]

Accountability on the fireground is critical; its importance does not diminish during training evolutions. Accountability was never maintained during this training session. The instructors were not accounted for as they entered the structure with the recruits. Other instructors, observers, and "safeties" were entering and exiting the structure through numerous unmonitored entry and exit points. In addition, the Accountability Officer was also assigned the role of Incident Commander.

Recommendation #8: Ensure coordinated communication between the Incident Commander and fire fighters.[9]

Proper communication is critical at any incident site. Use portable radios to keep all personnel on the scene in communication with the Incident Commander. Using a portable radio located in a radio coat or pants pocket impairs the performance of the unit. Portable radios should be held or used with a microphone and speaker attached to the lapel of the coat, which allows the fire fighter to monitor and transmit a clear message. The fire department should provide portable radios operating on the same frequency to ALL participants. These radios should be well maintained and inspected by qualified personnel on a regular basis.

Recommendation #9: Equip all live-fire participants, including recruits, with radios and flashlights.

Providing radios and flashlights to the recruits would increase their safety, and it would make the training exercise more realistic. When conducting interior fire suppression, radios and flashlights are standard equipment.

Recommendation #10: Establish an on-scene rehabilitation unit consistent with NFPA 1584.[15]

The RTB encouraged all participants to increase their hydration the morning of the exercise. In addition, RTB set up a rehab tent with a shaded area to remove turnout gear and drink cold fluids (water and sport drinks). While personnel were available to conduct medical evaluations, these evaluations were not required for all members of the squads, and accountability was not maintained. In addition, there was no intake form on which to record the vital sign measurements (temperature, pulse, respiratory rate, blood pressure, and perceived exertion) taken during the medical evaluation. NIOSH investigators recommend the FD maintain squad accountability at rehab and maintain an encounter form for each participant.

Recommendation #11: Report and record all work-related injuries and illnesses.

Many recruits reported being told by RTB instructors not to report training related injuries or illnesses if they occurred. The Occupational Safety and Health Administration (OSHA) requires private industry employers and public employers in states operating OSHA-approved State plans to record and report work-related fatalities, injuries, and illness.[16] Florida is not a State-plan State, therefore, public sector employers are not required to comply with OSHA standards.[17] However, recording injuries and illness is a good safety and health practice and can help detect ongoing problems. The local community college required the immediate reporting of an injury to the lead instructor, and an accident report completed by college security. NIOSH investigators recommend the FD review their current policies to ensure accurate and complete reporting of work-related injuries and illnesses.

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Live-Fire Training Exercise Claims the Life of One Recruit Fire Fighter and Injures Four Others– Florida

INVESTIGATOR INFORMATION

This incident was investigated and the report written by Thomas Hales, Jay Tarley, Scott Jackson, and Mark McFall of the NIOSH Fire Fighter Fatality Investigation and Prevention Program. The primary author was Thomas Hales. The authors would like to thank Sandy Bogucki, M.D., Ph.D of the Yale Department of Emergency Medicine for accompanying the NIOSH investigators. NIOSH investigators would also like to thank the FD Safety Office, County Safety Official, State Fire Marshal's office, Coroner's office, the Recruit's family, and all personnel of the affected FD who cooperated and assisted with the NIOSH investigation.

Live-Fire Training Exercise Claims the Life of One Recruit Fire Fighter and Injures Four Others– Florida

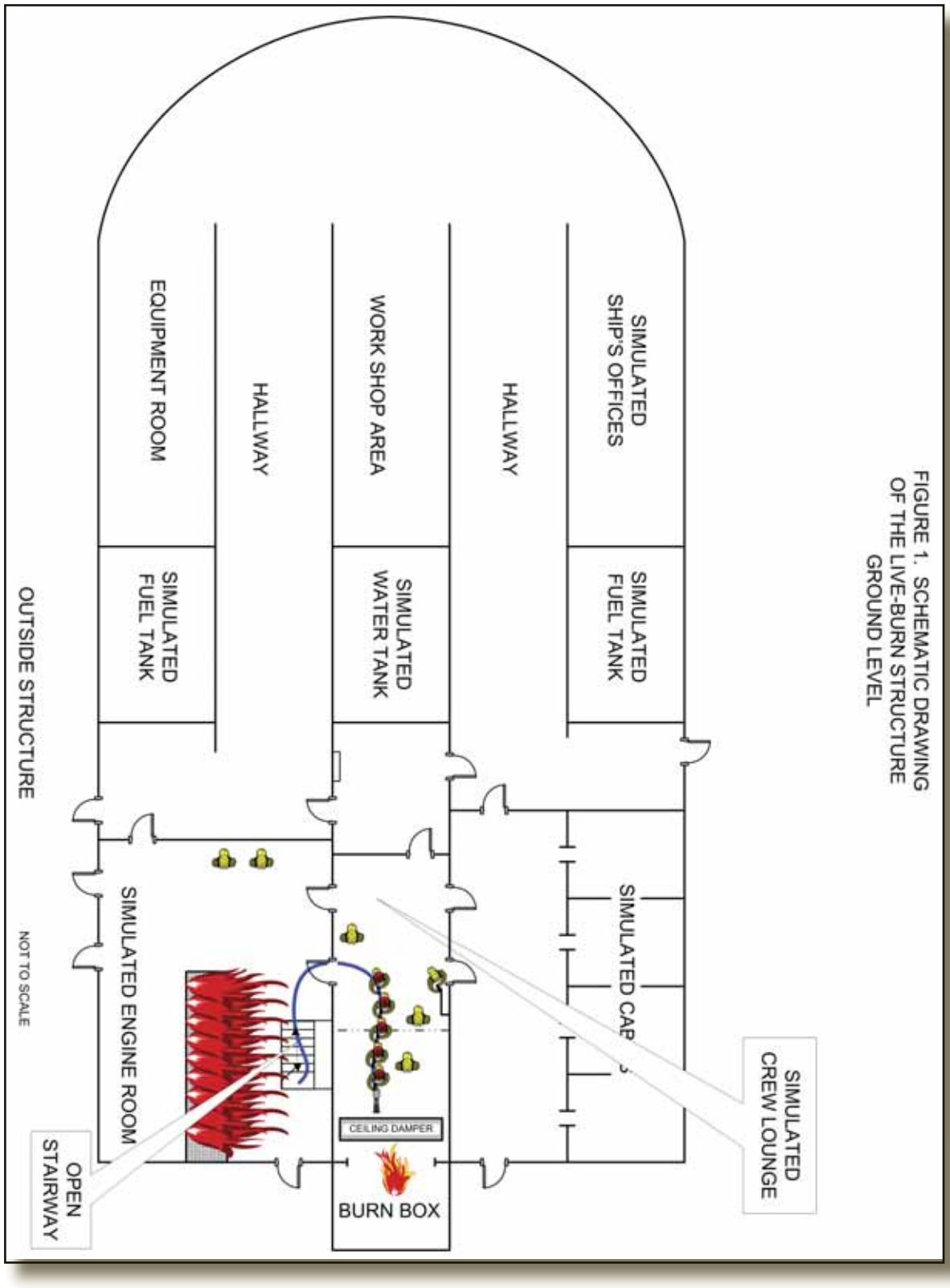


FIGURE 1. SCHEMATIC DRAWING OF THE LIVE-BURN STRUCTURE GROUND LEVEL

Live-Fire Training Exercise Claims the Life of One Recruit Fire Fighter and Injures Four Others– Florida

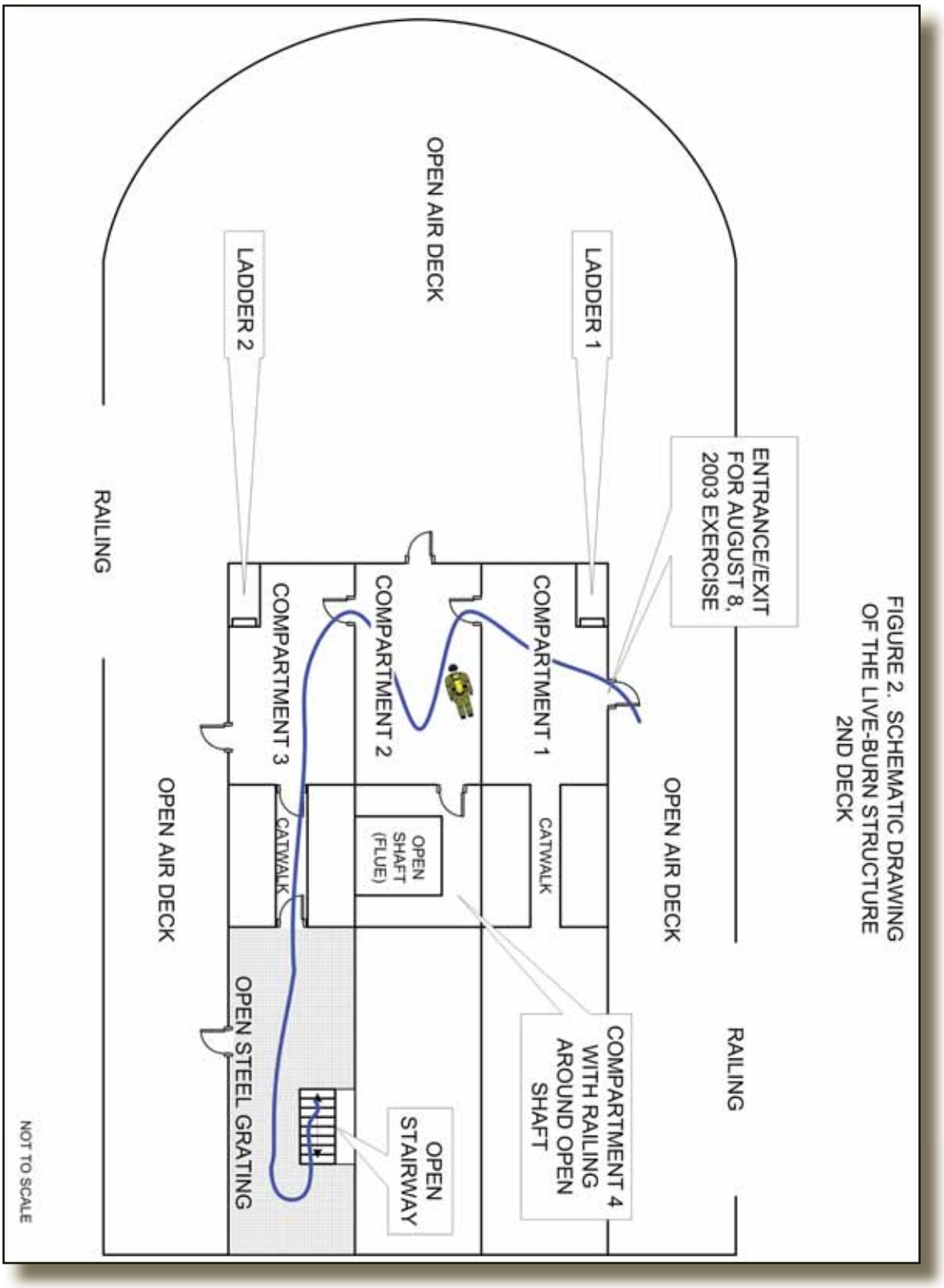
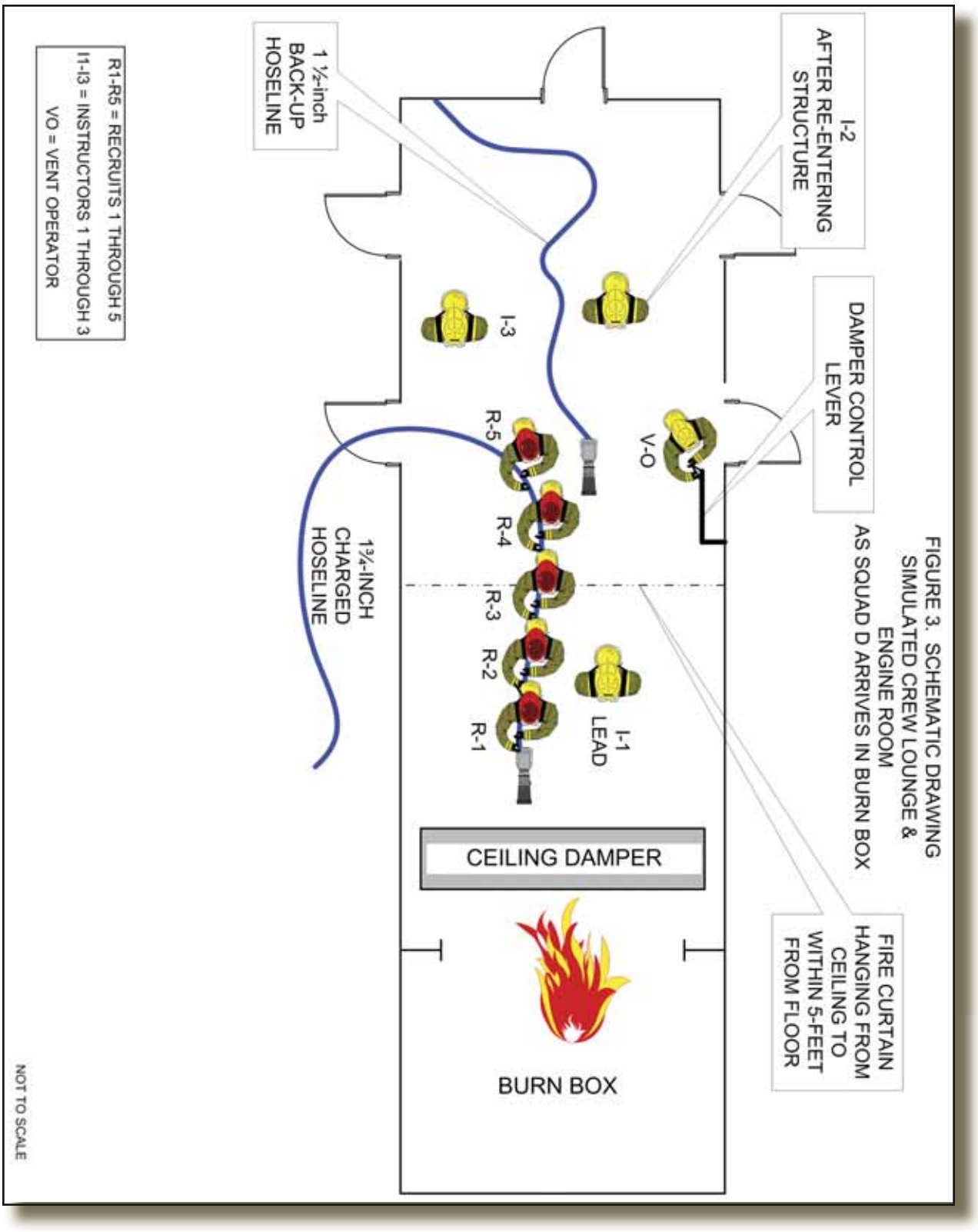


FIGURE 2. SCHEMATIC DRAWING OF THE LIVE-BURN STRUCTURE 2ND DECK

Live-Fire Training Exercise Claims the Life of One Recruit Fire Fighter and Injures Four Others– Florida



Live-Fire Training Exercise Claims the Life of One Recruit Fire Fighter and Injures Four Others– Florida

Appendix 1

Summary of Status Investigation Report NIOSH Task No. 13066

Background

As part of the ***National Institute for Occupational Safety and Health (NIOSH) Fire Fighter Fatality Investigation and Prevention Program***, the Respirator Branch agreed to examine and evaluate one Dräger Safety 4500 psi, 45-minute, self-contained breathing apparatus (SCBA).

This SCBA status investigation was assigned NIOSH task number 13066. The submitter was advised that NIOSH would provide a written report of the inspections and any applicable test results.

The SCBA, sealed in a corrugated cardboard box, was delivered to the NIOSH facility in Bruceton, Pennsylvania on August 27, 2003. Upon arrival, the sealed package was taken to the Firefighter SCBA Evaluation Lab (building 108) and stored under lock until the time of the evaluation.

SCBA Inspection

The package was opened and the SCBA inspection was initiated on September 16, 2003. A complete visual inspection of the SCBA was completed on that day by Vance Kochenderfer, Quality Assurance Specialist, of the Respirator Branch, National Personal Protective Technology Laboratory (NPPTL), NIOSH. The SCBA was examined, component by component, in the condition as received to determine its conformance to the NIOSH-approved configuration. The visual inspection process was videotaped. The SCBA was identified as the Dräger AirBoss model.

Although the SCBA showed signs of wear, particularly the harness, it was overall in very good condition. It was determined that it could be safely pressurized and tested. The cylinder was manufactured in December 1999. According to the exemption under which it was manufactured, it should have undergone a visual inspection and hydrostatic retest within 36 months of that date. After careful inspection, it was judged that the cylinder could safely be used for laboratory testing with appropriate precautions being observed.

Personal Alert Safety System (PASS) Device

A combination Personal Alert Safety System (PASS) and remote air pressure gauge, known as a Sentinel device, was incorporated in the SCBA. On September 17, 2003, representatives of NIOSH and Dräger Safety met at Dräger's Pittsburgh, Pennsylvania facility to examine the Sentinel device and to determine if it contained any stored data. No useful data could be obtained. The PASS device was activated and appeared to function normally. It was not tested against the requirements of NFPA

1982, *Standard on Personal Alert Safety Systems (PASS),* 1998 Edition. Because NIOSH does not certify PASS devices, no further testing or evaluations were conducted on the PASS unit.

SCBA Testing

The purpose of the testing was to determine the SCBA's conformance to the approval performance requirements of Title 42, *Code of Federal Regulations*, Part 84 (42 CFR 84).

The following performance tests were conducted on the SCBA:

NIOSH SCBA Certification Tests (in accordance with the requirements of 42 CFR 84):

1. Positive Pressure Test [§ 84.70(a)(2)(ii)]
2. Rated Service Time Test (duration) [§ 84.95]
3. Static Pressure Test [§ 84.91(d)]
4. Gas Flow Test [§ 84.93]
5. Exhalation Resistance Test [§ 84.91(c)]
6. Remaining Service Life Indicator Test (low-air alarm) [§ 84.83(f)]

National Fire Protection Association (NFPA) Tests (in accordance with NFPA 1981, 1997 Edition):

7. Air Flow Performance Test [Chapter 5, 5-1.1]

Testing was performed on October 10, 2003. All testing was videotaped with the exception of the Exhalation Resistance Tests and Static Pressure Tests.

The SCBA allowed the facepiece pressure to drop below ambient during the Positive Pressure Test. It also had excessive exhalation resistance during the NFPA Air Flow Performance Test, though this condition only existed during the first 30 seconds of the test.

Summary and Conclusions

The SCBA was delivered to NIOSH on August 27, 2003 and inspected on September 16 and 17, 2003. The unit was identified as a Dräger AirBoss 45-minute, 4500 psi SCBA (NIOSH approval number TC-13F-379). The unit was determined to be in a condition safe for testing.

The unit was subjected to a series of seven performance tests. Testing was performed on October 10, 2003. The SCBA was able to meet the requirements of all tests except the Positive Pressure Test and NFPA Air Flow Performance Test. Other than the installation of a new battery in the Sentinel device, no maintenance or repair work was performed on the unit at any time.

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