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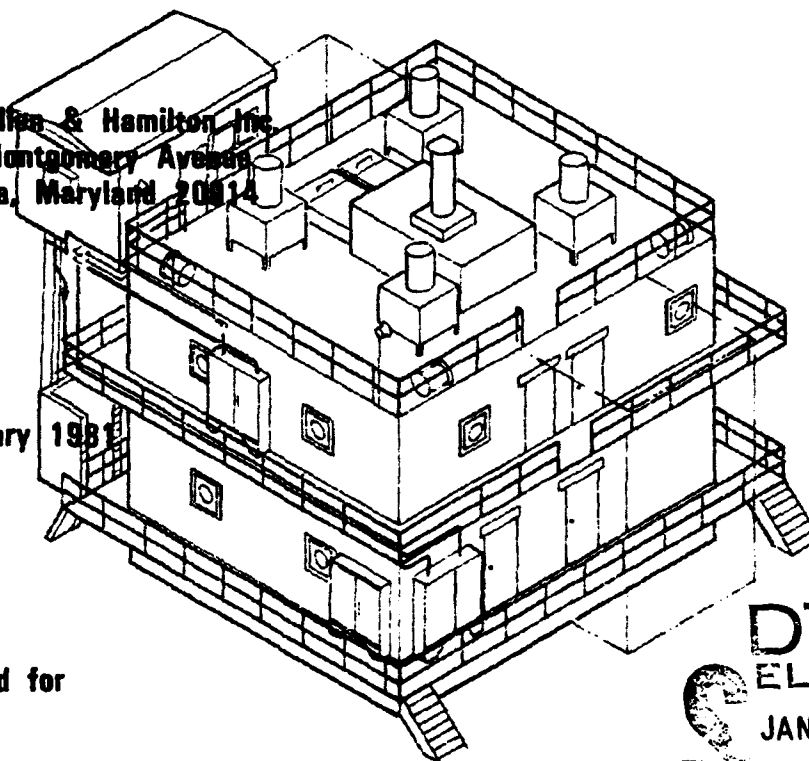
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## **FIRE FIGHTER TRAINER ENVIRONMENTAL CONSIDERATIONS**

Booz, Allen & Hamilton, Inc.  
4550 Montgomery Avenue  
Bethesda, Maryland 20814

8 January 1981



Prepared for

**ADVANCED TECHNOLOGY SYSTEMS**  
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P.O. Box 950  
Fair Lawn, New Jersey 07410

**NAVAL TRAINING EQUIPMENT CENTER**  
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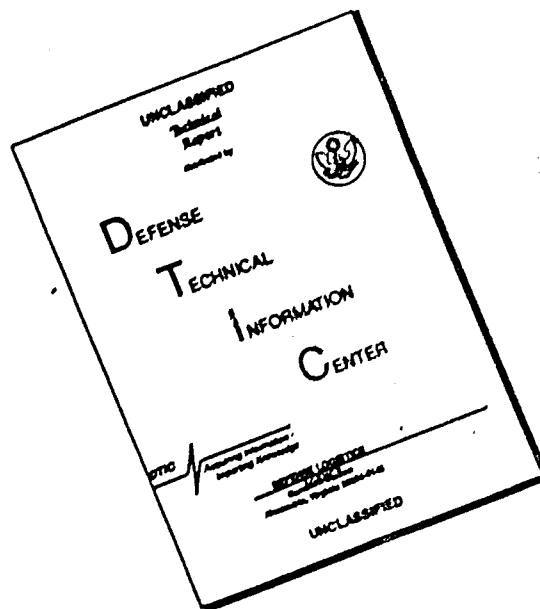
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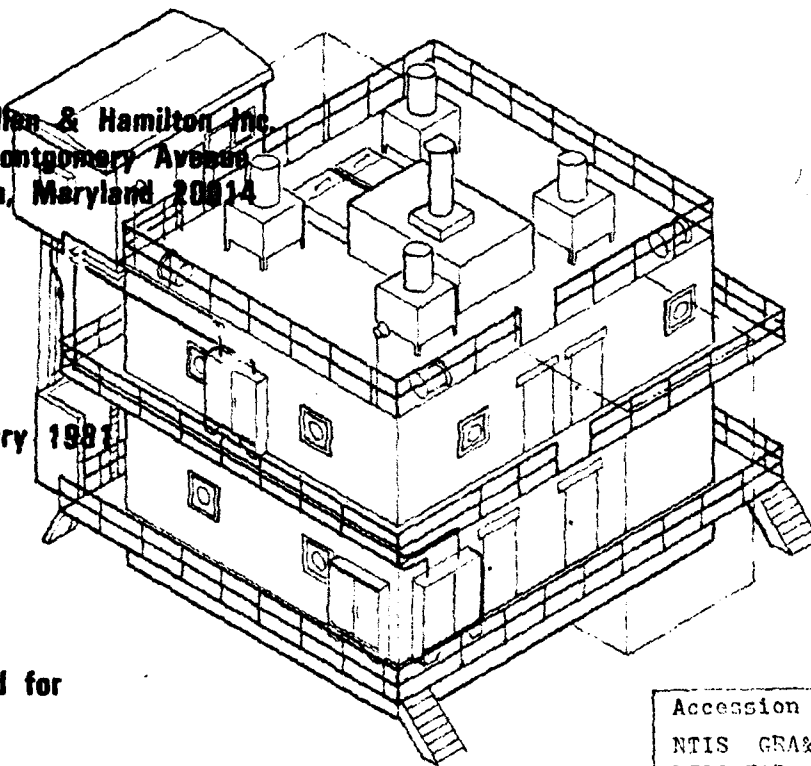
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## 1 INTRODUCTION

The U. S. Navy has contracted with ~~Advanced Technology Systems (ATS)~~, a division of the Austin Company, to provide the fire simulators and control system to be used in the Advanced Fire Fighter Simulator 19F1. The simulator was designed by the Naval Training Equipment Center for use in Naval fire-fighting training activities. A Phase I prototype trainer has been installed and is undergoing final testing at the Naval Fire-Fighting School of the Fleet Training Center at Norfolk, Virginia (NORVA).

The 19F1 will simulate Class A, B, and C fires under different, but controlled, conditions in a training environment resembling shipboard conditions. The simulator must meet ambient air quality standards for combustion products of burning fuel, byproducts from heating fire-extinguishing agents, and artificially generated smoke; and water pollution-control requirements for industrial discharges of expended extinguishing agents. In addition, it must provide a working environment free of hazards such as potentially toxic-extinguishing agents and their byproducts, smoke, or an oxygen-deficient atmosphere. This report provides the results of a preliminary assessment of the environmental, health and safety acceptability of the trainer, and contains recommendations for moderating the deficiencies found.

1.1 Background. Shipboard fires represent a constant threat to the safety of personnel, shipboard equipment, and ultimately, combat readiness of Naval forces. Accordingly, the Navy requires that all personnel serving aboard ship receive training in fire-fighting techniques. This training is conducted at shore-based facilities by burning fossil fuels with the associated adverse environmental impacts. In an effort to upgrade their training techniques, the Naval Education and Training Command, through the Naval Training Equipment Center, conducted a program to provide more effective fire fighter training and to address the problems imposed by environmental restrictions and the shortage of fossil fuels.

Current training is deficient in that practical instruction in combating fires for advanced trainees generally involves using water as the only extinguishing agent. Although this technique builds self-confidence, the degree of overall skill development is limited. Because of the safety hazards involved, training in some fire situations, such as the deep fat fryer and oil spray, can only be accomplished by demonstration in

place of participation. Furthermore, the existing training facilities are high-energy consumers (using fossil fuels), pollution contributors, and hazardous owing to the time required to secure the training fire and clear the smoke in emergency situations.

In addition to the need to provide more effective fire fighter training, current regulations on air pollution emissions require the development of a nontoxic, nonpolluting fire fighter training environment that is consistent with the criteria for clean air and clean water as established by the Environmental Protection Agency and various state and local ordinances. At present, the Navy's fire fighter training facilities use gasoline-impregnated lumber and rubber materials to simulate Class A fires and diesel fuel to simulate Class B hangar deck and bilge fires. Burning of these fuels results in the emissions of large volumes of thick black smoke particulate and a multitude of gaseous pollutants.

The current methods of reducing smoke emissions from oil-fired trainers include afterburner and water-spray systems. Costly afterburner systems have been installed in a few fire-fighting schools to provide smoke abatement for forecandle, boiler room, engine room, and flight deck fire simulators, but they are not used in open-fire trainers. The use of an afterburner results in the effective oxidation of carbon compounds, as well as in the undesirable byproducts of nitrogen and sulfur oxides. The water-spray method, developed by the Illinois Institute of Technology Research Institute, is also installed in some fire-fighting schools. Use of the water-spray smoke-abatement technique effectively removes visible particles from the effluent; however, large amounts of invisible, toxic combustion byproducts are emitted.

Although both methods reduce visible smoke, neither of these smoke-suppression techniques cleans smoke effectively. In addition, both methods have limited application to training situations that use open fires or liquid foam as an extinguisher. Current facilities that use diesel oil as a primary source of fuel will probably fail to meet future environmental emissions standards, even when equipped with an afterburner or water-spray system.

The use of a gaseous fuel in conjunction with a logic-control circuit in the Advanced Fire Fighter Trainer has been developed as an alternate method of reducing pollution. In addition to providing a clean burning fuel with relatively few gaseous products, this system is capable of quick start-up and shut-down, flexible control of extinguishment and reflash rates, and monitoring of trainee performance. Hence, this system makes it possible to provide adaptive-type training and features such as temporarily stopping a training session for detailed corrective instruction.



The extinguishment of a gaseous fuel fire in this type of system will not be accomplished by the direct application of an extinguishing agent. Sensors will detect the quantity and location of the applied agent. Signals from these sensors and the solenoid gas valves will feed into a digital control unit that determines the degree of extinguishment for a particular burner. Realism will depend on how the burners and sensors are arrayed and the time delays for extinguishment and reflash. These characteristics should be responsive to the various actions of sweeping the extinguishing agent over the simulated area of fire.

1.2 Purpose of the Study. This study of the AFFT addresses the aforementioned issues of environmental pollution, health, and safety. The general requirements of the study are:

- . Define the acceptable use of the Advanced Fire Fighter Trainer (AFFT) as its operations and use relate to environmental, health, and safety considerations in specific planned locations
- . Develop preliminary data on the modifications and redesign that may be necessary for the acceptable environmental and occupational operation of the AFFT
- . Perform limited laboratory tests and analyses as necessary to estimate the degree of environmental hazard.

Meeting these requirements involved the systematic identification, analysis, and integration of data pertaining to the following:

- . Extinguishing agents and possible substitutes
- . Characteristic behaviors of materials under fire conditions
- . Quantification, where possible, of the expected effects related to health, safety, and the environment
- . Performance of the modified oxygen-breathing apparatus under fire conditions
- . Regulatory and Navy requirements as they relate to health, safety, and the environment.

## 2. 19F1 TRAINING SYSTEM DESCRIPTION

The 19F1 system consists of eight major components or subsystems: training structure, fire simulators, extinguishing agents, extinguishment sensors, environmental monitor, system controller, communications, and oxygen-breathing apparatus. Each component is described in the following sections.

2.1 Training Structure. Building No. 8 at NORVA, which will serve as the 19F1 training structure, is shown in Figure 1. During Phase I of the prototype program, 4 of approximately 15 planned shipboard fire simulators or fireplaces will be installed and tested in actual training exercises.

The structure is divided into four quadrants. Each quadrant is exhausted by a 5,000-cfm axial fan that draws air from beneath the building and up through steel gratings that comprise the decks of both levels. The four prototype fire simulators will be installed on the upper deck of Quadrant 2 and on the lower deck of Quadrant 1, as shown in Figure 2.

The trainer is designed and programmed to activate the exhaust fans during the 3-minute building preventilation period following turn-on. After 3 minutes, the fans automatically stop except in the case of manual or gas-detection shutdown:

A manual shutdown occurs when any emergency shutdown switch is activated. The fans will run for 3 minutes in the compartment in which the switch is activated.

A gas-detection shutdown occurs when a concentration of fuel (propane) in an active quadrant (I or II) is greater than 10 percent of that which could ignite from any free gas within the quadrant. In this event, the fans will be controller programmed to automatically start and operate for a minimum of 3 minutes or until the gas concentration is at an acceptable level.

As shown in Figures 1 and 2, the instructor control station is located on the top deck of the training structure. The station contains the fire-simulator control panel, structure control panel, communication and alarm controls, environmental and audiomonitoring controls, and instructor communications system.

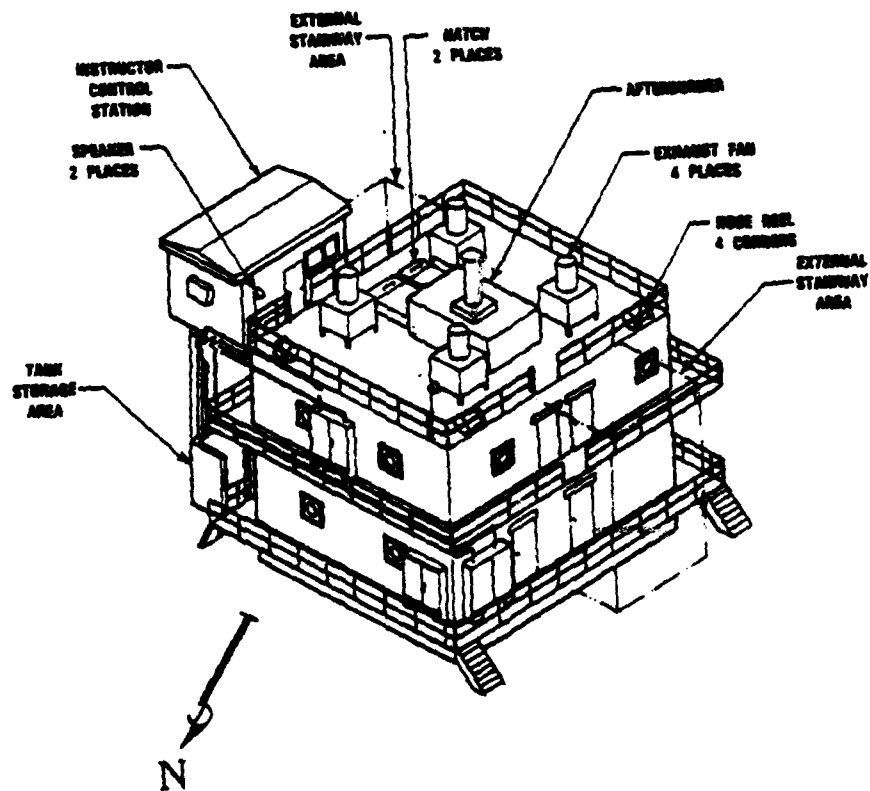


FIGURE 1. 19F1 TRAINING STRUCTURE

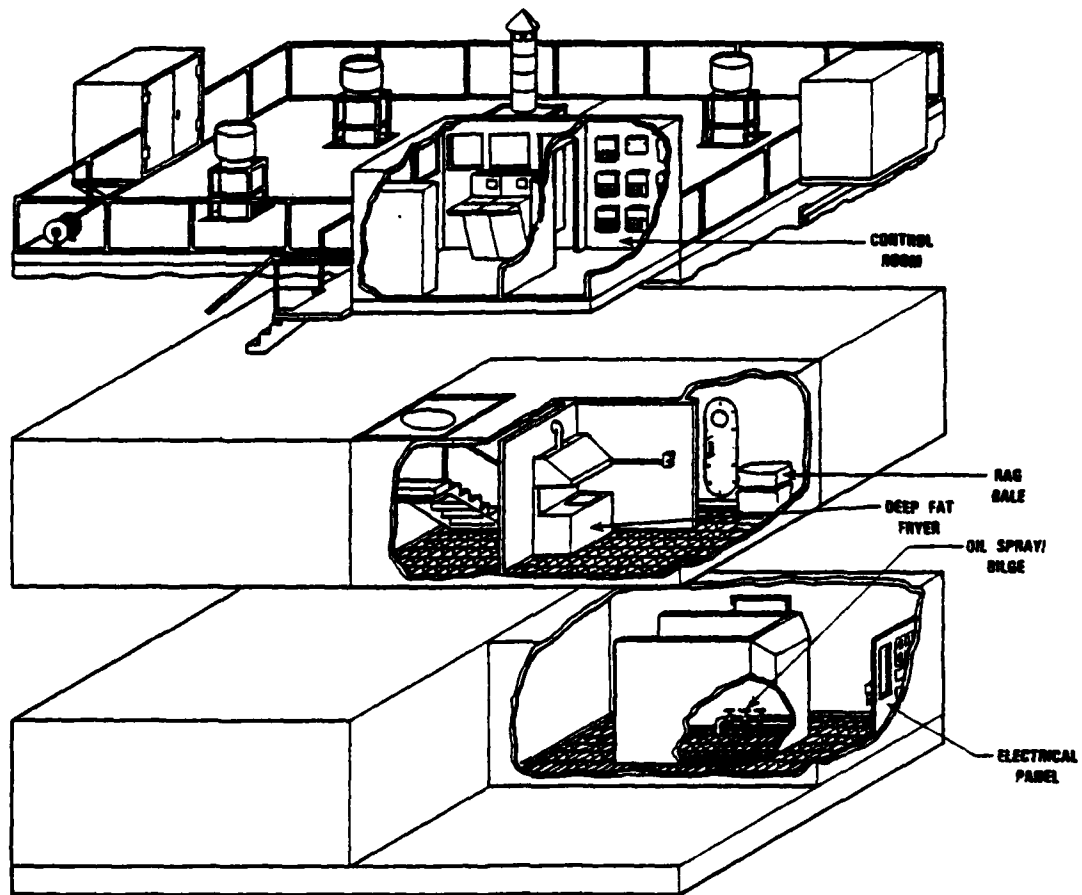


FIGURE 2. ADVANCED FIRE FIGHTER TRAINER

2.2 Shipboard Fireplace Simulators. Four fireplace simulators used to ignite shipboard fires include oil spray and bilge fire, electrical fire, rag bale fire, and deep fat fryer and stack hood fire. These four simulators, which are presented in Figures 3 through 6, are equipped with propane burners to simulate each type of fire.

Different fireplaces require different size flames, and these flames must be varied in size to give the appearance of growing and spreading. The controller provides this function through modulated valves on each burner. Nonextinguishable pilot flames are on at all times during the exercises.

To simulate a natural fire, the air/propane ratio in the burners is normally maintained at 10:1 to provide a yellow flame. The temperature of this flame ranges from 1095°C to 1210°C (2003°F to 2210°F).

The rag bale and electrical panel fireplaces have smoke generators that are under the manual control of the instructor. Smoke is generated by heating propylene glycol in a Steammaster 7.5-kW Model HPJ-3A steam boiler and exhausting the resulting vapors through an adjustable needle valve. The pressure of the vapor in the boiler can be varied from 20- to 40 lb/in<sup>2</sup>-gauge pressure.

2.3 Extinguishing Agents and Smoke-Generating Materials. The Simulator 19F1 will use four extinguishing agents - water, CO<sub>2</sub>, PKP, and aqueous film-forming foam (AFFF). PKP, which is primarily KHCO<sub>3</sub> in a fine powder form, will be applied at a rate of 2 lb/min. AFFF will be used in a water solution of approximately 3-percent concentration with a water-flow rate of approximately 50 gal/min. At this rate, approximately 5 gallons of AFFF will be used every 3 to 4 minutes. AFFF, PKP, and the propylene glycol used to generate smoke are discussed in more detail in the following subsections. Table 1 shows the agents used in each fireplace.

2.3.1 Aqueous Film-Forming Foam. AFFF is supplied to the Navy as a military-specified material (MIL-F-24385B) and as a nonspec material by the 3M Company (FC-780 B and FC-206 A) and the Ansul Company (AFC-3). It is sold as a liquid in three concentrations, which when used are diluted with water to a 6-percent, 3-percent, or 1-percent concentrate. The concentrated solutions are commonly referred to as 6-percent concentrate, 3-percent concentrate, or 1-percent concentrate.

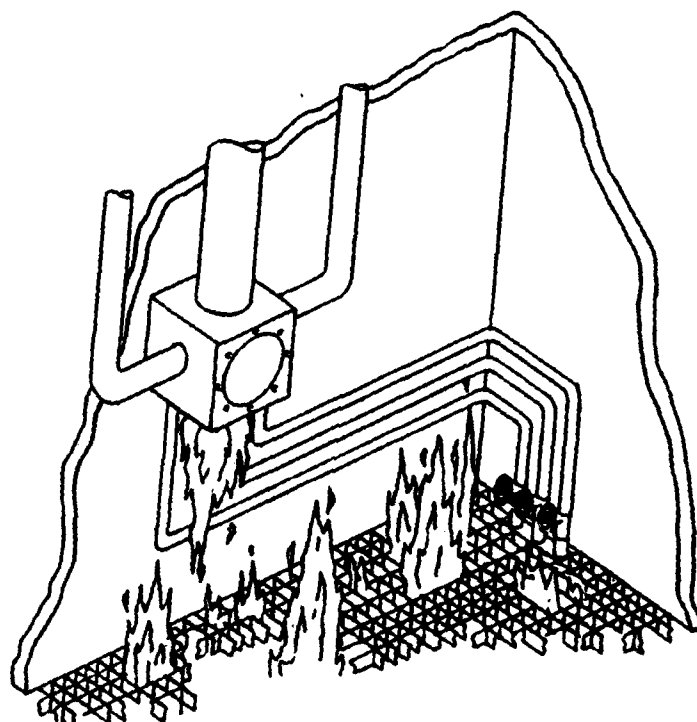


FIGURE 3. OIL SPRAY/BIDGE FIREPLACE

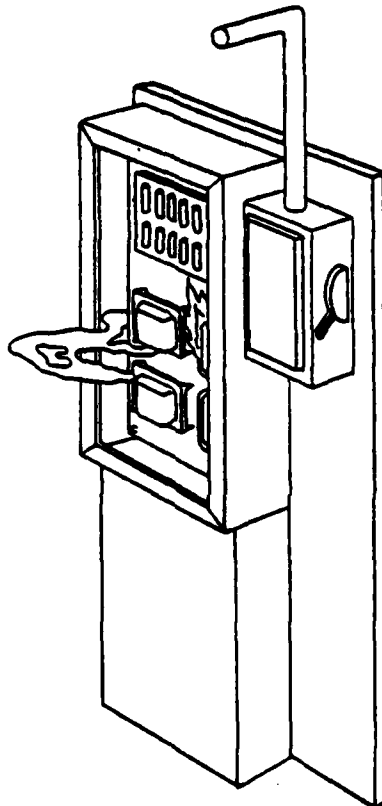


FIGURE 4. ELECTRICAL PANEL FIREPLACE

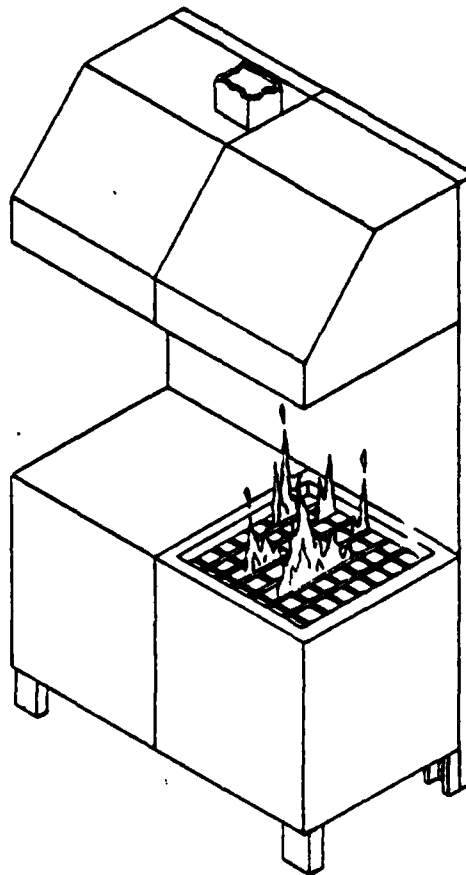


FIGURE 5. DEEP FAT/STACK HOOD FRYER FIREPLACE



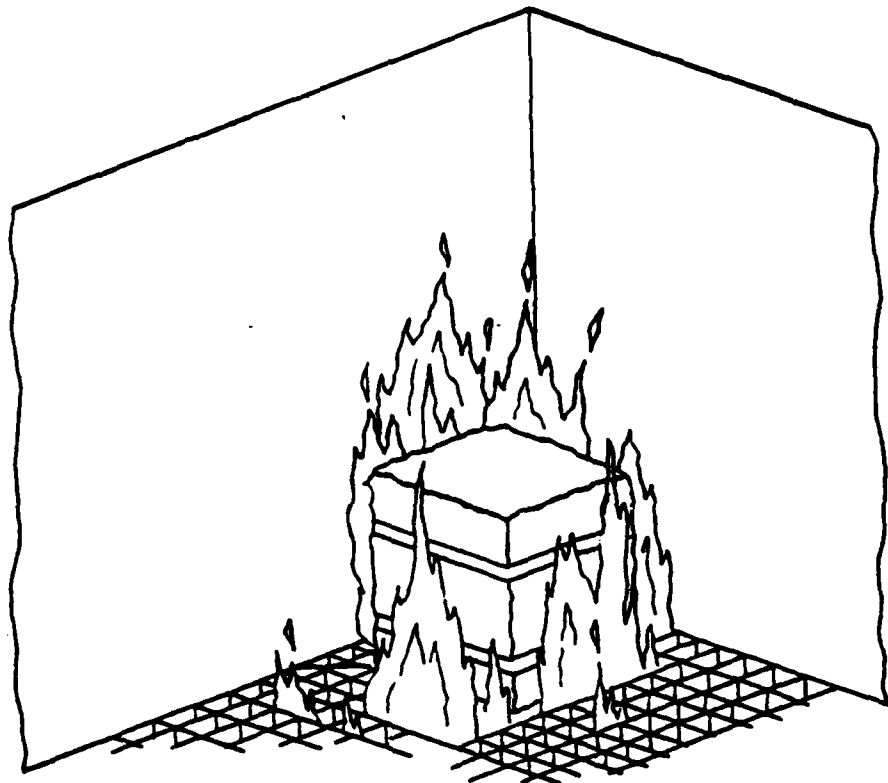


FIGURE 6. RAG BALE FIREPLACE

TABLE 1. EXTINGUISHING AGENTS USED IN EACH FIREPLACE

Fireplace	Water	AFFF	PKP	CO <sub>2</sub>	Smoke
Bilge	X	X	X		
Oil Spray	X	X	X		
Rag Bale	X	X			X
Electrical Panel				X	X
Deep Fat Fryer	X		X		
Stack Hood	X		X		
Deep Fat Fryer/ Stack Hood	X		X		

The AFFF suppliers provided the following information on their products:

- . 3M FC-780 B 6 percent concentrate (mil. spec. type)
  - 75 percent water
  - 14 percent butyl carbitol
  - 5 percent urea
  - <5 percent synthetic detergents
  - <5 percent fluoroalkyl surfactants
- . Ansul AFC-3
  - 70 percent water
  - 20 percent higher glycols
  - Mixture of fluorocarbon compounds
  - Mixture of surfactants.

Patent literature is available on both products; however, no definite statements can be made from this information.

2.3.2 PKP. PKP must meet the requirements of Federal Specification 0-0-1407 "Dry Chemical, Fire Extinguishing, Potassium Bicarbonate." Information supplied by the Pyro Chemical Company, a manufacturer of PKP, indicates that PKP is formulated as follows:

- . 95 percent potassium bicarbonate
- . 5 percent flow improver (either Cab-0-Sil M500 or precipitated silica finely ground and blended).

The potassium bicarbonate particles are coated with DC 1107 Silicone Fluid. Because of the silicone coating, the PKP floats on water but agitation will break the coating and cause the potassium bicarbonate to dissolve.

The particles distribution has a Count Median Diameter of approximately 30 $\mu$ m with a geometric standard deviation of approximately 1.25. The Count Median Diameter represents the midpoint size of the particle population (50 percent larger/50 percent smaller). The geometric standard deviation indicates the dispersion around that median diameter. The value given represents a relatively narrow dispersion of sizes. These values were obtained using a coulter counter in a liquid media.

The PKP powder is discharged as a cloud from a hose nozzle by carbon dioxide or compressed air. The cloud is very diffuse and penetrating and does not readily settle.

2.3.3 Propylene Glycol. Propylene glycol is used to generate artificial smoke in the 19F1 trainer. Smoke is generated by heating the propylene glycol after it has replaced the water in an electrical steam boiler. The temperature in the boiler is 380°F to 420°F, with a pressure of not more than 40 psig. The vapor is released through a nozzle and is conducted through heated piping to the appropriate fireplace.

The dimensions of each quadrant are approximately 14 x 14 x 9 feet, equivalent to 1,764 ft<sup>3</sup>. At ATS, trials have shown that in a 50-m<sup>3</sup> area (1,754 ft<sup>3</sup>), an average of 190 grams of propylene glycol produced a dense smoke equivalent to about 1-foot visibility in 1.5 minutes. Average particle size of the smoke was 2.2 μm. It is assumed that each smoke-producing event will require about 200 grams of propylene glycol to produce a satisfactory smoke.

2.4 Extinguishment Sensing System. To achieve the appearance of extinguishing the fire, each fireplace is equipped with a system to detect flame height and quantity, and location and type of the extinguishing agent. The system will differentiate between the application of water, PKP, and AFFF directly on the fire through liquid level sensors, ultraviolet flame detectors, and retroreflective-pulsed LED photodetectors. These sensors respond to the various actions of sweeping the extinguishing agent over the simulated area of fire. Signals from the sensors are fed into the digital controller that determines the degree of extinguishment for a particular burner and adjusts the modulation rate of the solenoid valves appropriately.

Realism is achieved through placement of the burners and sensors and through the time delays for reaction to extinguishments, reflash (the interaction of adjacent burners to produce flame spread over an area), and torching (a rapid flame growth resulting from applying a solid stream of water in a "digging" fashion).

2.5 Environmental Monitoring System. An air quality/fire effluent-monitoring system is used to detect unacceptable levels of O<sub>2</sub>, CO<sub>2</sub>, CO, NO, and HC. A fire-effluent air sampling intake is located at ceiling level at the entrance to each of the two roof exhaust fans in the training facility. An air-quality sampling intake is also located in each compartment.

Operation of the training structure's exhaust system is governed by start-up procedures, manual shutdown, and gas detection. Start-up procedures and manual shutdown functions of the exhaust system are programmed into the controller. Function of the exhaust system for gas detection requires that unacceptable gas levels be detected by the air-quality analyzer.

2.6 System Controller. Activation and control of the 19F1 trainer is initiated at the instructor console. The control-system interface is shown in the schematic presented in Figure 7. The system contains all of the controls and indicators necessary to initiate a fire and establish the growth, spread, and reflash rates, as well as the soaking and extinguishment time periods, for the fire. By adjusting these parameters, the instructor can simulate various fuel types, the amount of fuel available, and the fire temperature. Alarms and indicators are provided to monitor fire status and alert the instructor to any hazardous conditions in the fire simulator or training area.

All fire-generation and control signals from the instructor console are routed through a programmable controller. The controller scans all inputs from the console and establishes whether the input status meets the circuit conditions stored in memory. Based on the input status and stored circuit conditions, the controller generates the appropriate output signals to the various trainer units. The output signals control the motorized valves, solenoids, relays, and electronic units used to simulate the appropriate fire conditions. As the training exercise progresses and trainee interaction occurs (the application of extinguishment), the extinguishment sensor system detects the extinguishment application and feeds such data back to the Square D controller. The Square D controller then processes the feedback data with the entered parameter data and appropriately varies the flame output of the fireplace burners. Thus, the flames seen by the trainees appear to vary as they would if encountered in a real world shipboard fire emergency.

2.7 Communications. Communications equipment meets military standards where possible and has been modified to work with high-grade commercial equipment where necessary. All operational capabilities for military communications equipment have been retained. Each training compartment has a local communications station with damage-control communications equipment consisting of compartment audiomonitoring microphones, microphone communication links to the instructor station and other trainee compartments, and a sound-powered telephone.

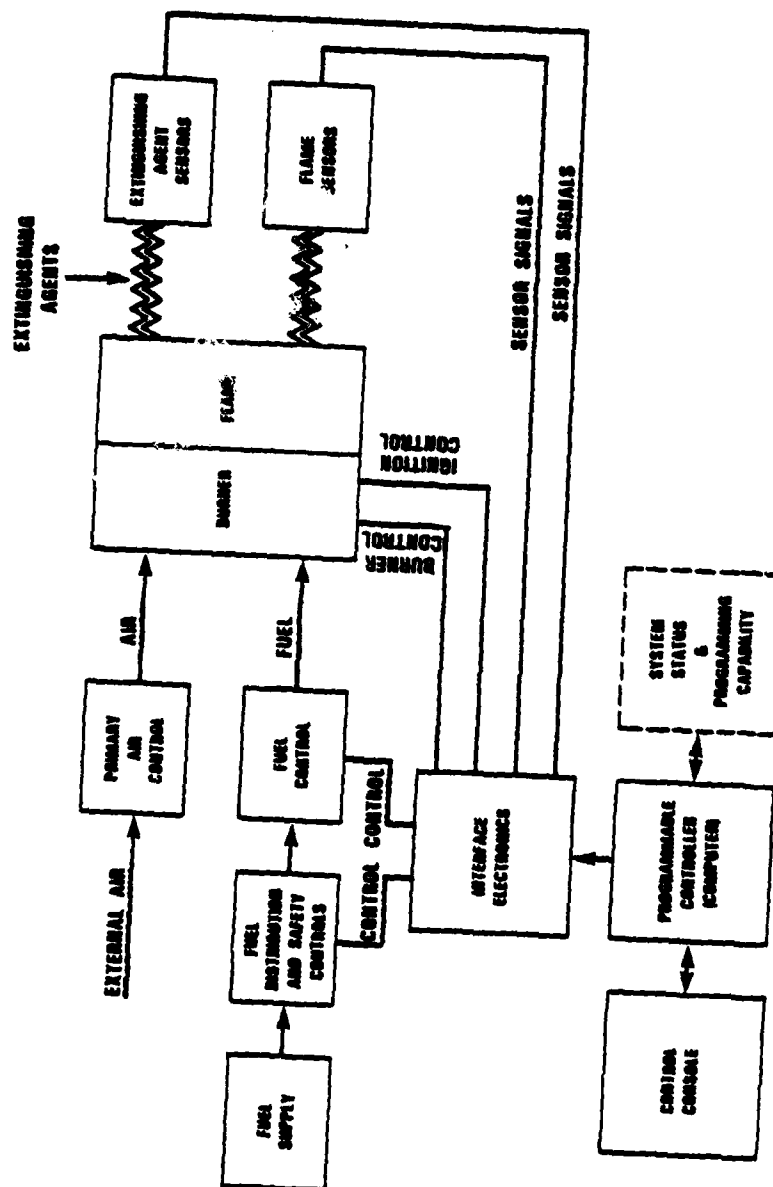


FIGURE 7. CONTROL SYSTEM INTERFACE SCHEMATIC

2.8 Oxygen-Breathing Apparatus. Respiratory protective equipment is an integral component of the fire-fighting scenario. In fire situations, high levels of toxic smokes, fumes, gases, and vapors are generated as well as oxygen-deficient atmospheres. To protect themselves against these substances, fire fighters use a self-contained breathing apparatus. Such a device provides complete breathing protection for various periods of time based on the amount of breathing air, or oxygen, supplied and the breathing demand of the wearer.

The basic types of self-contained breathing apparatus are the oxygen cylinder rebreathing, demand and pressure demand, and chemical oxygen rebreathing (self-generating). The first two types have fire-fighting uses, but they are not logistically feasible for shipboard fire-fighting situations, because wearing air tanks restricts maneuverability through narrow passages. Hence, the Navy uses the chemical oxygen-rebreathing (self-generating) apparatus because of its compact size.

2.8.1 Standard Oxygen-Breathing Apparatus. The chemical oxygen-rebreathing type of oxygen-breathing apparatus (OBA) has been used by the Navy for several decades. The currently accepted OBA model is the A-4, which will shortly replace the A-3 models on all ships. The A-4 evolved under the direction of the Naval Ship Engineering Center and was designed to improve the A-3 model.

The OBA differs from conventional cylinder rebreathing apparatus in that it uses a chemical canister that evolves oxygen and removes the exhaled carbon dioxide in accordance with physiological breathing requirements. It eliminates the need for high-pressure cylinders, regulating valves, and other mechanical components.

The replacable canister, which contains potassium oxide ( $KO_2$ ), evolves oxygen when contacted by the moisture and carbon dioxide in the exhaled breath and retains the carbon dioxide and moisture. Retaining moisture is important as it aids in preventing lens fogging.

In use, the self-generating unit operates as other OBAs except that the wearer using the canister makes his own oxygen instead of drawing from a compressed gas cylinder. The self-generating apparatus has a protection period of 1 hour, but a shorter or longer protection period may result based on the user and his level of exertion. The outstanding features of this type of apparatus are its simplicity of construction and use and low maintenance needs when compared with a high-pressure apparatus.

NORVA currently uses A-4 model OBAs for its Naval training but still uses A-3 model OBAs for Coast Guard trainees because the Coast Guard ships have not yet been refitted with the A-4 models.

2.8.2 Simulated Oxygen-Breathing Apparatus. The Navy requested ATS to construct a modified OBA for use in the 19F1 AFFT. ATS constructed the simulated OBA based on the design recommendations of NTEC. The major changes are designed to significantly reduce the high-replacement cost of the canisters. The modified canister uses standard Navy gas mask filters for removing particulates, hydrocarbon gases, and gases requiring catalytic removal.

The operation of the simulated activator is similar to that of the standard OBA activator in several ways. Both activators reduce breathing difficulty and require the same amount of breathing effort. The breathing bags of both activators inflate with air. In addition, the weight of both OBAs is approximately the same. Figure 8 illustrates the standard OBA, and Figure 9 illustrates the simulated OBA.

The simulated OBA will be artificially operated to ensure that use during fire-fighting exercises will not impair trainee breathing after lanyard activation and will not impart any hazardous condition such as airflow blockage during operation. The tests include induced airflow that simulates maximum stress-induced breathing, enabling detection of any "breathing" impairments.

The simulated OBA will be used only by individuals entering the inner structures of 19F1 AFFT and not by those remaining on the outside. In addition, the instructors may use the OBAs as alternate respiratory protection to the "Biomarine Pacs."

### 3. 19F1 PLANNED UTILIZATION

This chapter describes the Navy's requirements for fire fighter training and the curricula proposed for training exercises in the 19F1.



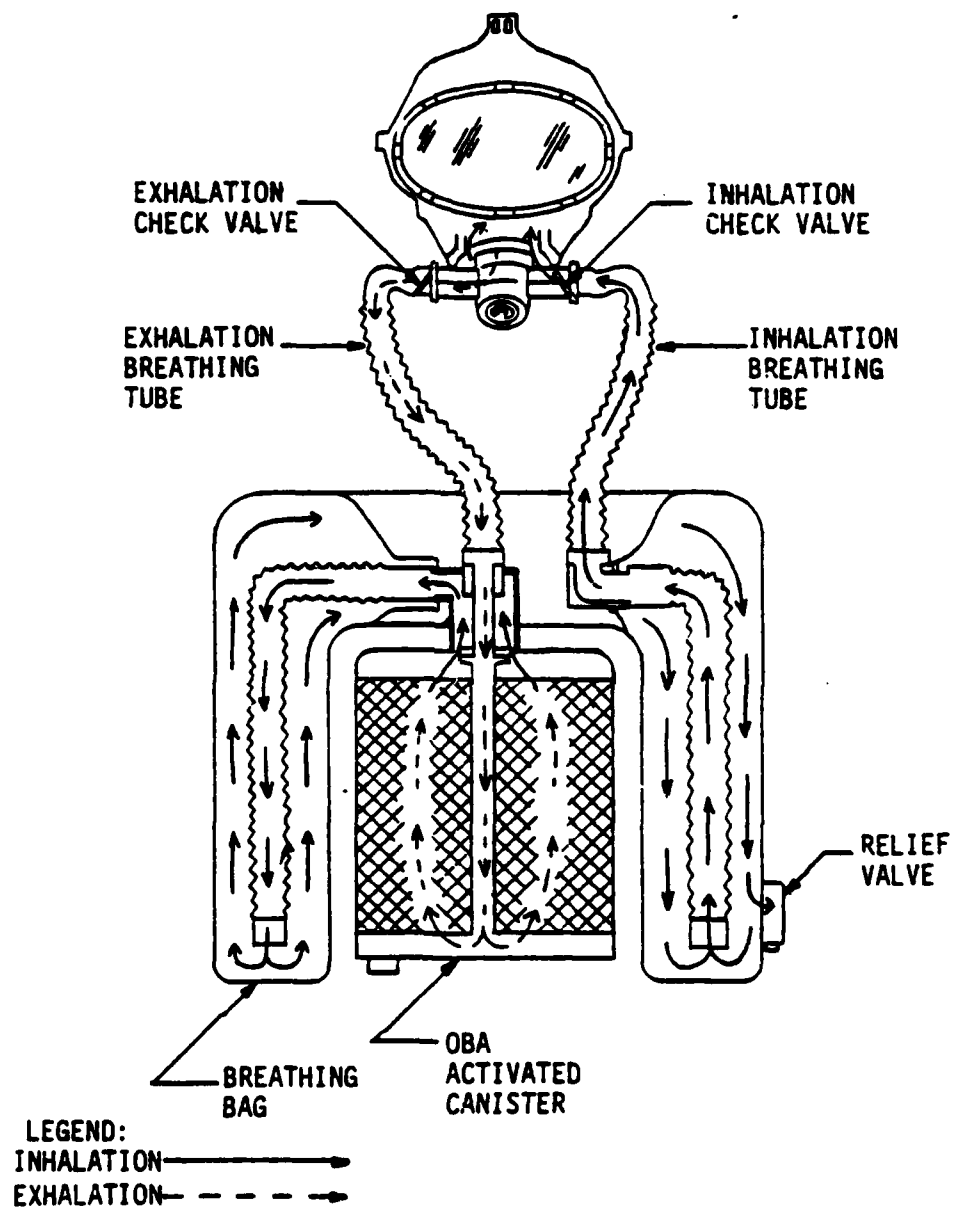


FIGURE 8. STANDARD OBA

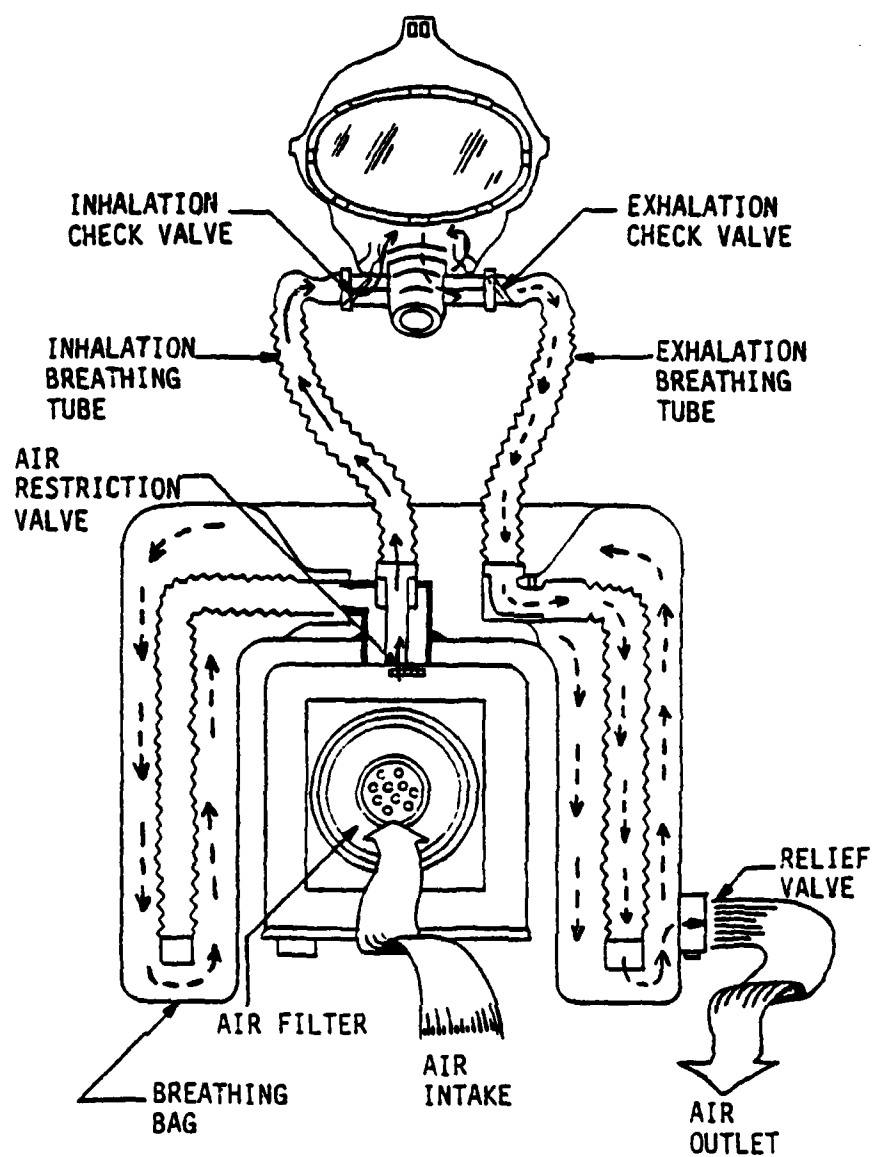


FIGURE 9. SIMULATED OBA

3.1 U.S. Navy Fire Fighter Training Program. Other than OPNAVISNT 3541.1B, Damage Control Training Requirements of May 29, 1973 and CINCLANTFLTINST 3541.1B, Damage Control Training Program of April 12, 1979, the Navy has minimum damage-control training requirements and few formal damage-control courses. Damage control includes the functional combination of all equipment, material devices, and techniques designed to prevent, minimize, or repair damage that occurs in wartime or peacetime or during fire-fighting.

Navy policy states that each commanding officer is required to attain and maintain a level of damage-control proficiency that will enable his ship to carry out its assigned mission when operating in any environment.

Responsibilities for formal and functional fire-fighting training follow:

- . Chief of Naval Operations
  - Provides overall policy guidance for damage-control training and coordinates efforts for such training
  - Provides general and specific operational requirements for new and improved damage-control equipment and techniques
- . Fleet Commanders in Chief
  - Specify scope and nature of on-board training and the training materials and equipment required for its support
  - Exercise a continuing review of shipboard damage-control proficiency and provide feedback information to the Chief of Naval Operations, Chief of Naval Material, Chief of Naval Training, and Chief of Naval Reserve
- . Chief of Naval Material
  - Serves as a central source for obtaining operational and technical damage-control information pertaining to damage-control incidents, responsibilities, performance, and equipment

- Provides training support for new or extensively modified damage-control equipment, systems, and techniques
- Provides training equipment to training activities and forces afloat
- Initiates and funds the development of damage-control training devices and aids, as required
- Provides, on a continuing basis, technical information and reports upon which damage-control curricula, course materials, and NEC review may be used to training activities and bureaus
- Provides a continuing review of damage-control training to ensure technical accuracy and currency

. Chief of Naval Training

- Provides damage-control training for individuals and teams to meet the needs of the forces afloat
- Develops and maintains current personnel qualification standards for applicable damage-control billets and ratings and all other shipboard personnel so minimum standards for damage-control proficiency, knowledge, and skill level can be attained
- Provides for the development of training films and other training materials required to support damage-control training
- Initiates and funds the development of damage-control training devices and aids, as required
- Provides initial indoctrination training for aviation-rating trainee personnel and for all other personnel involved in flight (helo) deck operations

. Chief of Naval Reserve

- Specifies scope and nature of training, training materials, and equipment required for support of cognizant Naval Reserve personnel, making maximum use of active Navy establishment resources

- Conducts a vigorous program of damage-control training for all reservists

. Chief, Bureau of Medicine and Surgery

- Provides a continuing review of damage-control curricula and course material to ensure adequacy of instruction in techniques and procedures for care or prevention of personnel casualties
- Provides, on a continuing basis, technical information and reports in cognizant areas upon which damage-control curricula, course materials, and NEC review may be used to training activities and BUPERS
- Initiates and funds the development of related training aids in cognizant areas
- Provides indoctrinational training to trainee personnel under cognizance.

The minimum requirements for fire-fighting training for Atlantic Fleet personnel are as follows:

- . All officers and enlisted personnel prior to reporting to their first duty station afloat will receive training in fighting and reporting Class A, B, C, and D fires. This includes the demonstrated ability to operate or use hoses, nozzles, applicators, and portable extinguishers.
- . All officers and enlisted personnel will receive operational training in the use of an OBA..
- . All officers and enlisted personnel must receive live fire-fighting training every 4 years at a specialized fire-fighting course incident to specific shipboard assignments.
- . Personnel assigned to repair fire-fighting squads and in-port damage-control parties will receive damage-control or fire-fighting training incident to such an assignment.
- . Personnel assigned to carriers, LHAs, LPHs, and LPDs, including personnel in embarked units whose flight quarters or general quarters station places them in the vicinity of the flight deck or hangar deck, must have received training in fighting shipboard aircraft fires within the past 24 months.

- . Personnel on board nonaviation facility ships who are assigned to a helicopter fire-fighting team or to a billet that places them on or adjacent to the helicopter deck during flight quarters must have received helicopter fire-fighting team training within the past 24 months.
- . Personnel whose watches or duty stations are in engineering spaces and personnel who are routinely involved in the handling of ordnance or the storage of flammable or explosive materials must receive additional fire-fighting or damage-control training, both practical and theoretical. This training must be commensurate with their responsibilities to ensure qualifications for assignment where advanced knowledge and expertise are required.
- . Prospective commanding, executive, air, and engineering officers of afloat commands will receive appropriate training in fire-fighting prior to assuming their duties.

3.2 Proposed Curricula Outline. In the controlled environment of the 19F1 trainer, repeated training exercises in fighting Class A, B, and C fires are provided for key members of shipboard fire-fighting teams. Each exercise requires the participation of a 15-man team--11 key members and 4 additional hands to serve as hose handlers. The key members who will be graded are the scene leader, two nozzlemen, two hosemen, two plugmen, two investigators, an accessman, and a phone talker/messenger. Support personnel functions, such as Damage-Control Central, electrician, and corpsman, will be provided by the team of instructors.

The proposed curricula outline for the AFFT course is presented in Figure 10. Training objectives for the key team members are presented in Appendix A. The first day of the 2-day AFFT course consists of 3 hours of classroom exercises and 5 hours of laboratory exercises. The classroom exercises involve introductory and review materials related to the school, the OBA, fire investigation and reporting, and basic fire-fighting procedures.

The first-day laboratory sessions are also concerned with introductory and review exercises. These exercises are used to familiarize the fire-fighting team members with the training structure and to review fire-fighting procedures.

UNIT 1.0 REVIEW OF FIRE-FIGHTING FUNDAMENTALS

3 Hours Classroom

LESSON TOPIC 1.1 INTRODUCTION TO SCHOOL AND COURSE

1 Hour Classroom

LESSON TOPIC 1.2 REVIEW OF OXYGEN-BREATHING  
APPARATUS (OBA), TYPES A-3  
AND A-4, USAGE

1 Hour Classroom

LESSON TOPIC 1.3 REVIEW OF INVESTIGATION AND  
REPORT OF FIRE

1/2 Hour Classroom

LESSON TOPIC 1.4 BASIC FIRE-FIGHTING PROCEDURES  
REVIEW

1/2 Hour Classroom

UNIT 2.0 INSTRUCTIONAL EXERCISES

5 Hours Laboratory

LESSON TOPIC 2.1 INTRODUCTION TO TRAINING  
STRUCTURE

1 Hour Laboratory

LESSON TOPIC 2.2 INSTRUCTIONAL EXERCISE ON A  
CLASS A FIRE AND PERSONNEL  
CASUALTY

1 Hour Laboratory

FIGURE 10. PROPOSED CURRICULA OUTLINE FOR THE ADVANCED  
FIRE FIGHTER TRAINING COURSE

LESSON TOPIC 2.3      INSTRUCTIONAL EXERCISE ON A CLASS  
B FIRE AND RUPTURED HOSE RECOVERY

1 Hour Laboratory

LESSON TOPIC 2.4      INSTRUCTIONAL EXERCISE ON A  
CLASS B OIL SPRAY FIRE AND TWIN  
AGENT SYSTEM INDOCTRINATION

1 Hour Laboratory

LESSON TOPIC 2.5      INSTRUCTIONAL EXERCISE ON A  
CLASS C FIRE AND RUPTURED FIRE-  
MAIN RECOVERY

1/2 Hour Laboratory

LESSON TOPIC 2.6      INSTRUCTIONAL EXERCISE ON A CLASS  
B DEEP FAT FRYER FIRE

1/2 Hour Laboratory

UNIT 3.0    PERFORMANCE EXERCISES:    TEST AND EVALUATION

8 Hours Laboratory

LESSON TOPIC 3.1      EIGHT PERFORMANCE EXERCISES

8 Hours Laboratory

FIGURE 10 (Continued)



The second-day laboratory sessions consist of testing and evaluating team members in a minimum of eight performance exercises. The student must receive a grade of satisfactory on at least six of the exercises. For those students that do not achieve this score, the exercises are repeated until the required performance is achieved. Scenarios for each of the training exercises with the four prototype fire simulators are given in Appendix B.

To determine how much time is spent actually fighting fires in the 19F1 trainer, the following assumptions are used:

- . Each exercise takes a maximum of 30 minutes--9 minutes for investigation and preparation, 14 minutes for fire fighting, and 7 minutes for regrouping and critiquing.
- . Three exercises are done on the first day.
- . A maximum of 15 exercises can be accommodated during normal hours on the second day.

Therefore, for those students/teams that require repeated exercises up to the maximum of 15 on the second day:

- . 135 minutes are spent investigating
- . 210 minutes are spent fighting fires
- . 105 minutes are spent regrouping and critiquing.

#### 4. ENVIRONMENTAL, HEALTH, AND SAFETY CONSTRAINTS

This chapter presents a discussion of the environmental, health, and safety constraints that will be placed on the 19F1 AFFT. The trainer must comply with air and water pollution requirements established by EPA and/or by the state within which the facility functions, and it must be operationally safe. Candidate locations for use of the trainer are Bangor, WA; Charleston, SC; Great Lakes, IL; Mayport and Orlando, FL; Norfolk, VA; Newport, RI; New London, CT; Pearl Harbor, HI; San Diego and Treasure Island, CA; and Yokosuka, Japan. To meet the safety requirements, the 19F1 must comply with safety and health standards and criteria that, in some cases, are more severe than those required of the commercial sector. In addition to these constraints, problems concerning materials compatibility must be addressed. Each issue is discussed in greater detail in the following sections.

4.1 Health and Safety Constraints. Under the authority of Executive Order 12196, Occupational Safety and Health Programs for Federal Employees (effective October 1, 1980), and revised 29 CFR 1960, Basic Program Elements for Federal Employee Occupational Safety and Health Programs (effective October 15, 1980), the 19F1 AFFT will be subject to the same health and safety constraints as the private sector. In addition, because of the Navy's long-standing concern with safety and health matters, all Naval commands, under the direct order of OPNAV, are required to comply with the most stringent health standards and/or recommendations that are used by OSHA, NIOSH, ANSI, ACGIH, or other standard-setting organizations. This rule is excepted when there is a "uniquely military" justification for not complying. In that situation, separate NAVOSH standards may be developed by the Bureau of Medicine and Surgery.

Enforcement of all safety and health criteria is solely the Navy's responsibility and is carried out by the Naval Environmental Health Center and the Environmental Preventive Medicine Unit. States with individual occupational safety and health programs will exempt Federal facilities from state inspections.

Specific guidelines are set for many of the potentially toxic materials used in the 19F1 AFFT. Those materials that do not have standards require evaluation for potentially hazardous exposures. The operating parameters of the 19F1 AFFT require consideration of the recommended guidelines for confined spaces. In addition, there are standards regarding hazards from physical agents such as noise and nonionizing radiation from hot environments causing burns and heat stress.

The Naval Safety Center is responsible for Naval onshore personnel safety. Navy policy is to follow good safety practices as outlined by OSHA, the National Electrical Code (NEC), the National Fire Prevention Association (NFPA), and the International Fire Service Training Association. The Navy's safety standards are outlined in a manual entitled "Safety Precautions," NAVMAT P-5100. The Navy has also adopted the Fire Fighting Occupational Safety Standards of the International Fire Service Training Association and follows the recommended practices for tank testing concerning gas-free engineering and confined spaces.<sup>1</sup>

<sup>1</sup>U.S. Navy, "Gas-Free Engineering," Naval Ship Technical Manual, NAVSEA 5908CH STM-030, Vol. 3, Chpt. 074, 1979.

Guidelines for exposure to chemical contaminants and physical agents and the minimum internal environmental oxygen requirement as well as the sources of these guidelines are presented in Table 2. These guidelines reflect the original materials to be used in the 19Fl, as well as the various decomposition and combustion products. In general, these guidelines are more stringent than previous ones.

Several of the chemical agents used in the AFFT (i.e., propane and propylene glycol) may also have a significant safety hazard potential. Safety requirements for these agents are included in explosion-related guidelines. In specific applications, however, these requirements may need modification.

The confined space condition of the 19Fl further requires consideration of the specific potential safety hazards associated with burning in a confined atmosphere. These guidelines relate to oxygen deficiencies, exhaust ventilation, flammable parameters, dilution ventilation, and NEC and NFPA requirements for electrical equipment. Some of the key guidelines are presented in Table 3. In addition to these guidelines, there are other guidelines that cover general safety, proper working/walking surfaces, ladders, means of egress, and fire protection.

4.2 Constraints Related to Air Pollution. Air pollution control requirements for a particular facility may be governed by the applicable emissions standards or by the state ambient air quality standards, depending on the type and amount of emissions from the facility and the existing air quality at the facility site. These two sets of regulations as well as Japanese air pollution-control regulations are discussed in the following subsections.

4.2.1 U.S. Ambient Air Quality Standards. Ambient air quality standards exist at both the federal and state levels. Many states have adopted the federal ambient standards, but some states have promulgated more stringent standards or added other pollutants to those regulated at the national level. National ambient air quality standards have been established for seven criteria pollutants.

Of the nine states designated as AFFT sites, only Connecticut, Rhode Island, and Virginia have completely adopted the federal standards. The other states have adopted more stringent standards for one or more of the seven pollutants. In addition, several of the states have promulgated standards for pollutants not regulated at the federal level. The regulatory status of each state is summarized in Table 4.

TABLE 2. GUIDELINES FOR EXPOSURE TO CHEMICAL CONTAMINANTS AND PHYSICAL AGENTS  
AND THE MINIMUM INTERNAL ENVIRONMENTAL OXYGEN REQUIREMENT

	Guidelines		Source
	TWA <sup>1</sup>	STEL <sup>2</sup>	
<u>Chemical Contaminant</u>			
Propane	1,000 ppm	-	3
Propylene Glycol	-	-	
PKP	5 mg/m <sup>3</sup>	-	4
AFFF	-	-	
HF	3 ppm	-	4
Polytetrafluoroethylene	As low as possible	As low as possible	4
Decomposition Products	3 ppm	5 ppm	4
NOx	1 ppm	-	4
NO <sub>2</sub>	25 ppm	-	4
NO	-	-	4
HC	-	-	4
CO <sub>2</sub>	5,000 ppm	15,000 ppm	4
CO	50 ppm	400 ppm	4
Silica (Amorphous)	3 mg/m <sup>3</sup>	-	4
<u>Physical Agent</u>			
Heat	Maximum body temperature of 100.4° F or 27.9° C (TWA)		5
Noise	90dBA <sup>6</sup>		3
<u>Minimum Internal Environmental Oxygen Requirement</u>			
O <sub>2</sub>	20%		7
	18%		4

See notes on following page.

Notes

- <sup>1</sup> Threshold limit value - time-weighted average.
- <sup>2</sup> Threshold limit value - short-term exposure limit.
- <sup>3</sup> 29 CFR Part 1910 - Occupational Safety and Health Standards.
- <sup>4</sup> Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment as adapted by the American Conference of Governmental Industrial Hygienists (ACGIH).
- <sup>5</sup> Criteria Document on Occupational Exposures to Hot Environments, National Institute of Occupational Safety and Health (NIOSH), 1972.
- <sup>6</sup> A-Weighted Sound Pressure Level - 8-hour exposure limit.
- <sup>7</sup> Naval Ship Technical Manual, "Gas Free Engineering," NAVSEA 5908CH STM-030, Vol. 3, Chpt. 074, 1979.

TABLE 3. SAFETY GUIDELINES RELATED TO 19F1 AFFT

NIOSH criteria for working in confined spaces recommends:

- Prohibited entry for hot work if 10 percent of the lower flammable limit (LFL) is exceeded.
- Continuous general ventilation where a toxic atmosphere is being produced.
- All electrical equipment must comply with NEC and NFPA #70.
- Exhaust stream must be diluted below the permissible exposure level (PEL) or 10 percent of the LFL, whichever is lower.
- Where PELs are exceeded, respirator protection is recommended.

NAVSEA Gas Free Engineering Office recommends:

- Internal environmental O<sub>2</sub> supply should be the same as outside atmosphere.
- Entrance into confined space for hot work requires that 10 percent of the lower explosive limit (LEL) not be exceeded.

TABLE 4. AMBIENT AIR QUALITY STANDARDS

	Carbon Monoxide (ppm)	Hydrocarbons (ppm)	Lead (ppm)	Ozone (ppm)	Nitrogen Dioxide (ppm)	Sulfur Dioxide (ppm)	Total Suspended Particulates (ppm)
Federal <sup>1</sup>	10 8 hrs. 40 1 hr.	160 3 hrs.	1.5 3 mos.	235 1 hr.	100 annual	80 annual 165 24 hrs. 1,300 3 hrs.	75 annual 260 24 hrs.
California <sup>2</sup>	10 12 hrs. 40 1 hr.	Federal	1.5 30 days	200 1 hr.	500 1 hr.	0.05 ppm 24 hrs. 0.5 ppm 1 hr.	60 annual 100 24 hrs.
Florida	Federal	Federal	Federal	Federal	Federal	60 annual 260 24 hrs. 1,300 3 hrs.	60 annual 150 24 hrs.
Hawaii	5 8 hrs. 10 1 hr.	100 3 hrs.	Federal	100 1 hr.	70 annual 150 1 hr.	20 annual 80 24 hrs. 400 3 hrs.	55 annual 150 24 hrs.
Illinois <sup>3</sup>	Federal	Federal	Federal	Federal	Federal	Federal	73 annual 260 24 hrs.
South Carolina <sup>4</sup>	Federal	Federal	Federal	Federal	Federal	Federal	60 annual 250 24 hrs.
Washington <sup>5</sup>	Federal	Federal	Federal	0.08 ppm 1 hr.	Federal	0.02 ppm annual 0.1 ppm 24 hrs. 0.4 ppm 1 hr.	150 24 hrs.
Japan <sup>6</sup>	10 ppm 24 hrs. 20 ppm 8 hrs.	-	-	-	0.04-0.06 ppm 24 hrs.	0.04 ppm 24 hrs. 0.1 ppm 1 hr.	100 24 hrs. 200 1 hr.

<sup>1</sup> Connecticut, Rhode Island, and Virginia have adopted the federal standards.

<sup>2</sup> California also has the following standard:  $\text{H}_2\text{S}$ , 0.03 ppm (1 hr.); sulfates, 25  $\text{mg}/\text{m}^3$  (24 hrs.).

<sup>3</sup> Illinois also has the following standard: photochemical oxidants, 160  $\text{ppm}/\text{m}^3$  (1 hr.).

<sup>4</sup> South Carolina also has the following standards: gaseous fluorides, 0.8 ppm (10 days), 1.6 ppm (7 days), 2.9 ppm (24 hrs.), and 3.7 ppm (12 hrs.).

<sup>5</sup> Washington also has the following standard: fluorides (as  $\text{HF}$ ), 2.9  $\text{ppm}/\text{m}^3$  (24 hrs.), 1.7  $\text{ppm}/\text{m}^3$  (7 days), and 0.84  $\text{ppm}/\text{m}^3$  (30 days).

<sup>6</sup> Japan also has the following standard: photochemical oxidants, 0.06 ppm (1 hr.).

<sup>7</sup> Rhode Island also has the following standard:  $\text{H}_2\text{S}$ , 0.01 ppm (1 hr.).

4.2.2 U.S. Emission Limitation Standards. In some areas, the ambient standards for one or more pollutants are currently being violated, while in other areas, the ambient air quality is better than the set limitations. The Clean Air Act requires those areas exceeding standard values to control emissions from both existing and new sources. Those areas that fall within the air quality standards must prevent significant deterioration of the air quality by requiring controls on new sources of emissions.

EPA has established emission standards for total suspended particulates,  $\text{NO}_x$ ,  $\text{SO}_2$ , CO, and volatile organic compounds from certain classes or types of new stationary sources. Most states have adopted EPA regulations with minor modifications. The proposed fire fighter training facility is not included in any particular class or category of sources for which emission standards have been established. Therefore, it must meet general emission-control requirements, the most notable of which are the limitations placed on visible emissions.

Most states have established an opacity standard for controlling visible emissions. Table 5 summarizes the opacity standards for the nine states under consideration and lists possible exemptions for fire-fighting facilities. Currently, only three of the states have any exemption provisions, and these are specific for open-burning facilities. It is doubtful, however, that these exemptions will pertain to the AFFT, as it is not classified as an open-burning facility.

4.2.3 Other U.S. Regulations. Another general requirement at each AFFT site will be to obtain an air pollution permit to construct and operate the proposed facility. Some states have established a minimum threshold, such that any source with emissions above the threshold must obtain a permit and comply with the emission-control requirements stipulated in the permit. In San Diego, a source emitting any pollutant over 10 pounds per hour must use the Best Available Control Technology (BACT). The BACT is determined on the basis of energy, environmental, and economic impacts of alternative control strategies. The other states will require a case-by-case review.

In addition to these requirements, EPA has established national emission standards for four pollutants that are considered to be carcinogenic or mutagenic hazards. These pollutants include asbestos, mercury, beryllium, and vinyl chloride. Three substances that are considered potential pollutants include benzene, radionuclides, and inorganic arsenic.



TABLE 5. VISIBLE EMISSION STANDARDS

<u>State</u>	<u>Opacity Standard</u>	<u>Exemptions for Fire-Fighting Training</u>
California (San Diego)	Not to exceed 20 percent any time.	None.
Connecticut	Not to exceed 20 percent, except for 5 minutes in any 1 hour up to 40 percent opacity is allowed.	Fire-fighting training under open-burning conditions is exempted.
Florida	Not to exceed 20 percent.	None.
Hawaii	Not to exceed 40 percent, except for 3 minutes in any 1 hour up to 60 percent is allowed.	None.
Illinois	Not to exceed 20 percent, except for 3 minutes in any 1 hour up to 40 percent is allowed. <sup>1</sup> Not to exceed 30 percent, ex- cept for 8 minutes in any 1 hour up to 60 percent is allowed. <sup>2</sup>	None.
Rhode Island	Not to exceed 20 percent, except for 3 minutes in any 1 hour.	None.
South Carolina	Not to exceed 20 percent, except for 6 minutes in any 1 hour but no more than 24 minutes per day up to 60 percent is allowed.	Fire-fighting training exempted from open-burning regulation.
Virginia	Not to exceed 20 percent, except for two 6-minute periods in any 1 hour.	Fire-fighting training exempted from open-burning regulation.
Washington	Not to exceed 20 percent, except for 15 minutes in any 8-hour period.	None.

<sup>1</sup> New fuel combustion sources with actual heat input > 250 million  
Btu/hr.

<sup>2</sup> All other sources.

Pollutants other than those discussed may be subject to control requirements established by the state or local air pollution-control agencies on a case-by-case basis.

4.2.4 Japanese Air Pollution-Control Regulations. The Japanese Air Quality Bureau is in charge of establishing and enforcing air pollution, noise and odor pollution, and automotive pollution-control regulations. The Air Pollution Control Law was promulgated in 1968 to give the Japanese government authority to set environmental quality and emission standards, regulate soot and dust emissions, and establish a system of air pollution monitoring and surveillance.

The AFFT proposed for Japan must conform with Japanese environmental quality standards presented in Table 4. These standard values are comparable to the U.S. ambient air quality standards.

Emission standards regulate the emissions from a particular type of facility and are specific to the particular type of operation performed at the facility. Because none of the present emission standards are specific to the AFFT, the fire fighter trainer and other similar facilities will most likely be regulated on a case-by-case basis.

4.3 Constraints Related to Wastewater Discharges. The effluent generated by the AFFT will be discharged into natural waters and sewage treatment plants at locations across the country. This discharge of industrial wastewater is regulated by the Clean Water Act, which gives state and local governments jurisdiction in establishing water pollution-control programs. Industrial wastewater such as the AFFT effluent may be disposed of by direct discharge into local receiving waters or by discharge into a publicly owned treatment works (POTW) or municipal sewage treatment plant. Each option is regulated under separate but interrelated laws at the federal, state, and local levels.

4.3.1 Direct Discharge. Direct discharge of industrial wastewater into receiving waters is regulated at the federal and state level. States have promulgated water-quality standards that specify maximum pollutant concentrations in bodies of water, depending on the designated use of receiving water (i.e., boating, wildlife habitat, commerce, etc.). Both EPA and the individual states use these water-quality standards as a basis for a second regulatory approach--the issuance of discharge permits.

Regional offices of EPA have had the initial responsibility for establishing the major permit program--the National Pollutant Discharge Elimination System (NPDES). Subsequently, many states have applied for and received approval to operate their own NPDES programs and have assumed the permit functions from EPA. Many states, however, do not have NPDES authority and do not intend to obtain it. Instead, they work with EPA by certifying NPDES permits before they are issued. In some cases, states without NPDES authority operate independent permit programs. Both NPDES and independent state permits are issued based on the water-quality standards for the site in question, the identity and concentration of pollutants in the discharge, and an engineering assessment of technically feasible control measures.

4.3.2 Discharge Into a POTW. States may establish controls on discharges into POTWs through their permit programs if the programs cover discharges into sewer systems as well as into waters of the state. Although some state permit programs have this authority, this type of discharge is usually regulated by either effluent standards or pretreatment standards promulgated at the local level.

Effluent standards, the most commonly used regulatory tools, specify maximum concentrations of pollutants allowable in industrial discharges. Pretreatment standards are specific to industrial processes and their discharges and must be approved by EPA. Many states are presently in the process of developing pretreatment programs for specific industries, but few, if any, are expected to apply to the AFFT operations.

4.3.3 Regulatory Status of AFFT Sites. Table 6 summarizes the regulatory status of each AFFT site. It presents general requirements at state and local levels for both direct discharge and discharge into a POTW.

4.3.3.1 Direct Discharge. At most AFFT sites, direct discharges are regulated by either a state NPDES program or an independent state permit program. Bangor, Washington, on the other hand, has no state-regulated permit program for federal facilities and relies completely on the regional EPA NPDES programs. Direct discharge is not permitted in Newport, Rhode Island, San Diego, California, and Pearl Harbor, Hawaii. In Norfolk, Virginia, the state has deferred its permit authority to EPA, but EPA will not accept it. Virginia is, therefore, temporarily without any regulation on direct discharges.

TABLE 6. APTT WASTEWATER DISPOSAL OPTIONS - APPLICABLE STATE  
AND LOCAL REGULATORY REQUIREMENTS

APTT Sites	Direct Discharge		Discharge into POTW		
	State NPDES Permit Required	Other State Permit Required	State Permit Required	Pretreatment Regulations	Industrial Effluent Standards
Bangor, MA	X <sup>2</sup>		N/A <sup>3</sup>	N/A <sup>3</sup>	N/A <sup>3</sup>
Charleston, SC	X		X		X
Great Lakes, IL	X				X
Mayport, FL		X	N/A <sup>4</sup>	N/A <sup>4</sup>	N/A <sup>4</sup>
Orlando, FL		X	X		X
Norfolk, VA	X <sup>5</sup>			X	X
Newport, RI	N/A <sup>6</sup>	N/A <sup>6</sup>			X
New London, CT	X		X	X	X
Pearl Harbor, HI	N/A <sup>6</sup>	N/A <sup>6</sup>	N/A <sup>7</sup>	N/A <sup>7</sup>	N/A <sup>7</sup>
San Diego, CA	N/A <sup>6</sup>	N/A <sup>6</sup>			X
Treasure Island, CA	X		N/A <sup>7</sup>	N/A <sup>7</sup>	N/A <sup>7</sup>

<sup>1</sup> Includes state permits under NPDES or other authority.

<sup>2</sup> Washington has not yet taken over authority for Federal facilities from EPA.

<sup>3</sup> Not applicable; Bangor does not have sewage treatment facilities.

<sup>4</sup> Not applicable; POTW will not accept industrial wastewater.

<sup>5</sup> Virginia has deferred permit authority for Federal facilities until further notice.

<sup>6</sup> Not applicable; direct discharge into receiving waters not permissible.

<sup>7</sup> Not applicable; permitted Naval wastewater facility available.

Table 7 presents water quality standards for specific AFFT sites where direct discharge is an option. Facilities wishing to use the direct discharge option must comply with these standards prior to issuance of either a state or NPDES discharge permit. The standards shown include those possibly relating to AFFT discharges as well as common standards that may serve as indications of the relative regulatory stringency of each state.

4.3.3.2 Discharge Into a POTW. Most AFFT sites using this wastewater disposal option must comply with industrial effluent standards imposed by local governments to ensure that wastewater entering their municipal sewage plant does not contain material that might damage the system. Effluent standards have been developed for most municipalities; however, there are some exceptions. Mayport, Florida, for example, is a site where the municipal sewage plant will not accept any industrial discharges. AFFT sites at Treasure Island, California, and Pearl Harbor, Hawaii, are not subject to local effluent standards as each has a permitted Naval treatment facility onsite. Relevant local effluent standards are summarized in Table 8.

In addition to effluent standards, several AFFT sites are subject to further state or local regulation. In Charleston, Orlando, and New London, the state requires an NPDES permit to discharge into a POTW. Pretreatment regulations have also been approved for Norfolk and New London, but as they were written for specific industrial situations, they are not expected to apply to the AFFT facilities.

4.3.4 Japanese Requirements. The Water Quality Bureau of the Japanese Environmental Agency is responsible for controlling potentially harmful substances that might be discharged into Japanese waters. The Water Pollution Control Law, enacted in 1971, enforces Japan's water pollution regulations and standards. These regulations consist of environmental quality standards and effluent standards.

Japanese effluent standards limit the concentration of pollutants discharged into Japan's natural waters, whereas U.S. effluent standards focus on pollutants discharged into POTWs. The Japanese effluent standards set maximum permissible levels for more than a dozen pollutants that can be emitted from any source into Japanese waters. These standards are summarized in Table 9.

Japan has also promulgated water quality standards to ensure that the pollutant concentrations of a particular

TABLE 7  
Selected Water Quality Standards for Receiving Waters  
Where Direct Discharge Is Possible

AFFY SITES	CLASS OF RECEIVING WATERS <sup>1</sup>	DISSOLVED OXYGEN	OIL AND GREASE	pH	PHOSPHOROUS	FLUORIDES	CHLORIDES	COLIFORMS
BANGOR, WA	AA	> 7 mg/l		7.0-8.5				FECAL: < 14/100 ml MEDIAN; NO MORE THAN 10% > 43/100 ml
CHARLESTON, SC	SA	> 5 mg/l	NONE	± 0.33 NATURAL WATERS	< 0.05 mg/l			TOTAL: < 70/100 ml MEDIAN; NO MORE THAN 10% > 230/100 ml
GREAT LAKES, IL	GENERAL	> 6 mg/l FOR 18 HOURS; 5 mg/l MIN		6.5-9.0	< 0.05 mg/l	< 1.4 mg/l	500 mg/l	FECAL: < 200/100 ml MEAN; NO MORE THAN 10% > 400/100 ml
MAYPORT, FL	III	> 5 mg/l; 4 mg/l MIN	5.0 mg/l	6.5-8.5	< 0.10 mg/l	< 5.0 mg/l	< 0.01 mg/l (TOTAL RESIDUAL CHLORINE)	TOTAL: < 1000/100 ml AVG.; 2,400/100 ml MAXIMUM
ORLANDO, FL	III	SAME AS ABOVE	SAME AS ABOVE	SAME AS ABOVE	SAME AS ABOVE	SAME AS ABOVE	SAME AS ABOVE	SAME AS ABOVE
NORFOLK, VA	N	> 5 mg/l; 4 mg/l MIN		6.0-8.5		< 1.7 mg/l <sup>2</sup>	< 250 mg/l <sup>2</sup>	
NEW LONDON, CT	B	> 5 mg/l	NONE	6.5-8.0	< 0.03 mg/l			TOTAL: < 1,000/100 ml MEDIAN; NO MORE THAN 20% > 2,400/100 ml
TREASURE ISLAND, CA	NONE <sup>3</sup>							

<sup>1</sup>Each state individually sets criteria for its receiving waters and similarly uses its own grading systems.

<sup>2</sup>At raw water intake.

<sup>3</sup>Treasure Island and San Francisco have no water quality standards.

TABLE 8. POTW INDUSTRIAL EFFLUENT STANDARDS POTENTIALLY APPLICABLE TO AFPT

AFPT Sites	pH	BOD <sup>1</sup>	Oil and Grease	Ammonia Nitrogen	Suspended Solids
Charleston, SC	6.5-8.5	300 ppm	100 ppm		300 ppm
Great Lakes, IL	6.0-9.0	300 ppm	75 ppm	50 ppm	350 ppm
Orlando, FL	6.5-9.5	300 mg/l	100 mg/l		300 mg/l
Norfolk, VA	6.0-9.0	250 mg/l	100 mg/l		250 mg/l
Newport, RI	≤ 10.0	230 mg/l	25 mg/l <sup>2</sup>		285 mg/l
New London, CT	6.5-9.0		100 mg/l		100 mg/l
San Diego, CA	5.0-9.0	50 mg/l	40 ppm weekly avg.; 25 ppm monthly avg.	325 ppm	50 mg/l

<sup>1</sup> Biochemical oxygen demand.

<sup>2</sup> Floatable oil, fat, or grease not permitted.

TABLE 9. JAPANESE EFFLUENT STANDARDS

<u>Pollutant</u>	<u>Permissible Limit</u>
Cadmium	0.1 mg/l
Cyanide	1 mg/l
Organic phosphorus	1 mg/l
Lead	1 mg/l
Chromium (VI)	0.5 mg/l
Arsenic	0.5 mg/l
Total mercury	0.005 mg/l
PCB	0.003 mg/l
pH	5.8-8.6 (water other than coastal)
	5.0-9.0 (coastal waters)
BOD, COD <sup>1</sup>	160 mg/l (daily average 120 mg/l)
Suspended solids	200 mg/l (daily average 150 mg/l)
Phenols	5 mg/l
Copper	3 mg/l
Zinc	5 mg/l
Dissolved iron	10 mg/l
Dissolved manganese	10 mg/l
Fluorine	15 mg/l
Coliforms	3,000 per cc <sup>2</sup>

<sup>1</sup>BOD is for waters other than coastal and lakes; COD (chemical oxygen demand) is for coastal and lakes only.

<sup>2</sup>Daily average.



body of water do not exceed certain levels. These standards are similar to U.S. water quality standards in that they specify the level of pollutants in a general class of receiving waters. In areas that exceed their prescribed water quality standards, the Japanese government may place more stringent control on local industrial effluents on a temporary or permanent basis.

4.4 Materials Compatibility. A critical part of this investigation concerns the compatibility of extinguishing agents, smoke-generating chemicals, combustion byproducts, and materials used in the construction of the trainer itself. Incompatibility of these materials could result in the following conditions:

- . Chemical reactions of individual fire-extinguishing and smoke-generating chemicals in mixtures and among themselves
- . Decomposition of individual fire-extinguishing and smoke-generating chemicals in the presence of heat
- . Decomposition of mixtures composed of fire-extinguishing and smoke-generating chemicals in the presence of heat
- . Chemical reactions of individual fire-extinguishing and smoke-generating chemicals with byproducts of combustion.

Compounds resulting from such decomposition or chemical reactions may be toxic or otherwise hazardous to health; combustible; environmentally undesirable; or corrosive, causing clogging, obscuration, or harming the trainer itself. Therefore, certain constraints should be placed on the specific materials used in the 19F1.

4.5 Solid Waste Disposal. Three key elements of the solid waste generated from the 19F1 AFFT include spent OBA canisters, AFFF sludge from the treatment facility, and PKP. These elements need to be evaluated as potentially hazardous wastes to assess the Navy's responsibility under the Hazardous Waste Provisions of the Resource Conservation and Recovery Act. These provisions set guidelines for the proper disposal of hazardous materials. These elements are addressed in more detail in Section 6.7.

## 5. CHEMICAL ANALYSES

A series of chemical analyses were performed as part of the overall evaluation of the 19F1 AFFT at the Norfolk Naval Base. Samples taken of stack effluent air, test room atmosphere, and wastewater volume were characterized. A number of actual fire trials were made in the oil bilge fire module, enabling dynamic samples to be obtained.

5.1 Measurement Criteria. Measurement parameters for the chemical analyses performed are summarized in the following subsections.

### 5.1.1 Stack Effluent.

- . Concentration of particulate material during operation
- . Rough characterization of materials collected
- . Concentration profiles of gaseous effluents (CO, CO<sub>2</sub>, O<sub>2</sub>, NO, hydrocarbons, percent of the lower explosive limit (LEL)).

### 5.1.2 Room Atmosphere.

- . Determine the concentration of particulate dust during dry chemical discharge in the personnel space of the fire-test cell
- . Determine the concentration of any solvent extractable organic material
- . Monitor the test cell atmosphere for indications of propane presence and changes in oxygen concentration during fire-test scenarios
- . Obtain concentrations of total fluorides and propylene glycol in the atmosphere under conditions of synthetic smoke generation and during the use of the AFFF extinguishing agent
- . Monitor gaseous contaminant levels within the oil bilge module (CO, CO<sub>2</sub>, O<sub>2</sub>, NO, hydrocarbons).

### 5.1.3 Water Effluent. From collected runoff wastewater determine:

- . Butyl carbitol concentration
- . Total amount of fluoride

- . Controlled pollutants listed in Table 10
- . General attributes of the collected water sample.

A limited inspection of the AFFF concentrate was conducted to establish the usefulness of IR, UV, or thin layer as analytical approaches to measure the foam concentrate directly in water effluents.

5.2 Methodology. The following methodologies were used to conduct the chemical analyses during the fire-test scenarios.

5.2.1 Stack Effluent. EPA Method 5, "Determination of Particulate Emissions From Stationary Sources," was used to measure the concentrations of dust discharged into the atmosphere during fire tests. The cross-section of the 24-inch stack was profiled during powder discharges and subsequent ventilation times. Two-minute samples at each of four points were taken cumulatively.

The air stream from the stack was isokinetically sampled, and the weight of solid or condensable material was determined gravimetrically after removal of the uncombined water. After weighing the residue, the filter element was extracted with hexane to estimate the organic fraction that might have been present. In addition, gaseous stack effluents (CO, CO<sub>2</sub>, O<sub>2</sub>, NO, hydrocarbons, percent LEL) were monitored with direct reading instruments supplied by ATS as an integral component of the monitoring system.

5.2.2 Room Atmosphere. Ambient sampling of airborne dust or particles was accomplished with high-volume (hi-vol) samplers. Up-draft air was taken from the atmosphere and pulled through a fiberglass filter capable of removing 99.7 percent of all particles larger than 0.3  $\mu$ m. The air volume was sampled at the rate of 45 to 70 cfm, and the amount deposited on the paper was weighed and then calculated in milligrams per cubic foot or cubic meter of air.

Sampling time was started when the dry chemical discharges began, and collection continued for 2 minutes. At this point, the dust had been well ventilated from the room.

The sampling was cumulative for the number of fire trials made, and the concentrations calculated represented the average for the runs. Separate samples were taken for the series of runs made with the ventilator fan on and for a series of trial fires made with the fan off.

TABLE 10. WATER EFFLUENT PARAMETERS

Color (Platinum Cobalt Units)

Total Solids

Total Volatile Solids

Total Mineral Solids

Total Suspended Solids

Volatile Suspended Solids

Mineral Suspended Solids

Turbidity

Chlorides

Sulfates

Biochemical Oxygen Demand (BOD)

Chemical Oxygen Demand (COD)

Total Organic Carbon (TOC)

Source: Case Consulting Laboratories, Inc.

A teledyne combination oxygen meter and combustible gas meter were used to monitor the test cell atmosphere. Lengths of 1/4-inch copper tubing were placed along the floor of the test cell at three locations and were connected to the pump intake manifold of the meter. A filter to remove particulate matter was placed in the manifold to avoid contamination of the sensor system. Each line was numbered, and the air sampled through each during fire runs was monitored for meter-reading changes in oxygen and combustibles.

Figure 11 shows a schematic location of the hi-vol sampler and the sampling tubes. Attached to the hi-vol units, two impinger systems with pumps were arranged to take samples of the room atmosphere so that the presence of fluorides and propylene glycol could be detected. Two bubbler impingers were used in series for each detection. Each fluoride detection impinger contained 100 ml of 0.1N NaOH in accordance with NIOSH procedure. The impingers used for the capture of the propylene glycol each contained 100 ml of distilled water. Air flows of 7 liters per minute were used to collect these samples.

The presence of fluoride was determined by using a specification electrode procedure capable of detecting concentrations of 0.2 ppm. The propylene glycol was measured using gas chromatography methods having detection limits of 80 ppm.

Levels of gaseous contaminants (CO, CO<sub>2</sub>, O<sub>2</sub>, NO, hydrocarbons, percent LEL) were recorded using the direct reading instrumentation provided by ATS as an integral component of the monitoring system.

5.2.3 Water Effluent. Water from the fires using foam was collected in a blocked sump area under the test cells. It was estimated by operating personnel that about 150 gallons of 6-percent foam were used in the fires that had water-based foam applied. The supply water used for all tests was fresh potable water.

The pH of the water as collected was measured on-site, and two 1-gallon plastic containers of the water mixture were collected for laboratory analysis. Through wet chemical methods and instrumentation procedures, the water samples were examined for the properties and contents outlined in the objectives.

5.3 Findings. This section presents the results of the sampling as well as a discussion of the subsequent tabulated determinations relative to test objectives. The impact of these findings with respect to existing standards or guidelines is discussed in Chapter 6.

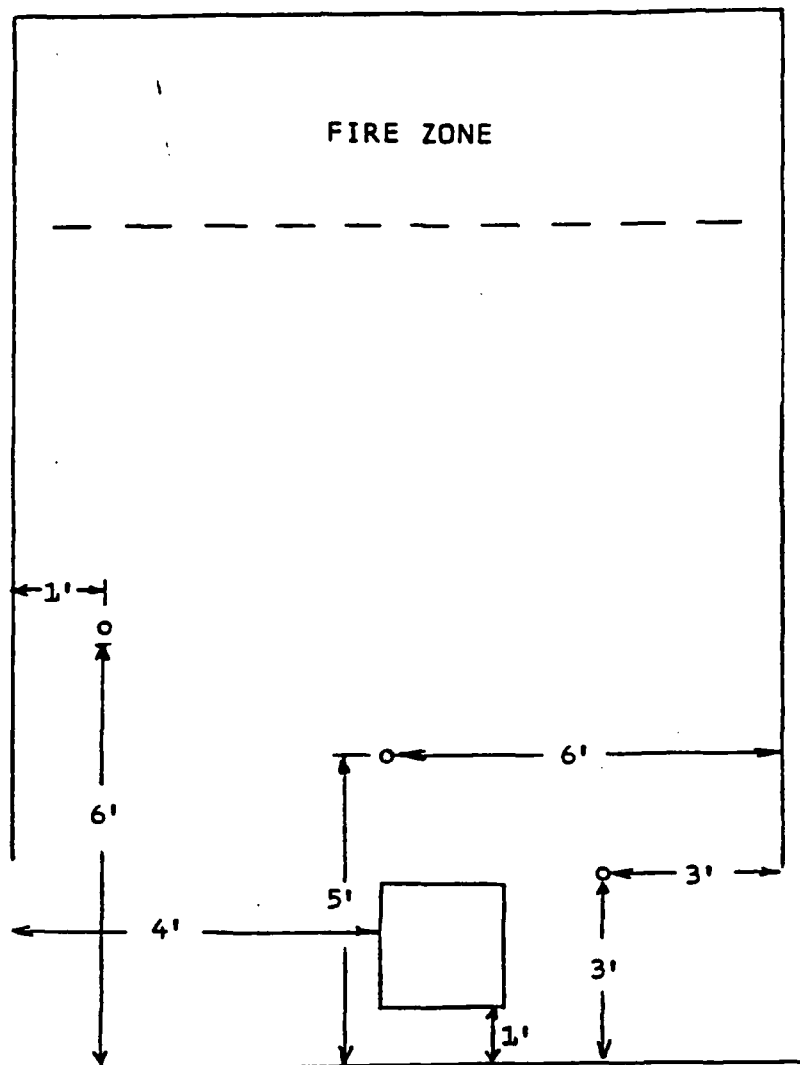


DIAGRAM NOT TO SCALE.

○ OXYGEN/COMBUSTIBLE GAS SAMPLE POINTS.

□ HI-VOL, GLYCOL AND FLUORIDE SAMPLING UNIT.

Source: Case Consulting Laboratories, Inc.

FIGURE 11. SCHEMATIC LOCATION OF SAMPLE POINTS  
WITHIN THE FIRE CELL

5.3.1 Stack Effluent. Samples were taken during the discharge of the PKP dry chemical extinguishing agent and during the period of exhausting the room of the suspended dust. The effluent from the stack was quite homogeneous and evenly distributed over the cross-section. Pressure drop readings at various locations across the stack opening confirmed that a uniform flow was prevalent.

To conserve the amount of dry chemical on-hand for these range-finding trials, it was agreed that one-half of a 20-lb unit would be discharged each time, and the stack would be sampled for a 2-minute interval during and after each discharge.

The December 5, 1980 trial findings are as follows:

. Stack velocity	1,200 ft/min
. Gas volume	3,203 ft <sup>3</sup> /min
. Stack temperature	167°F
. Emission rate	6.5 lb/hr.

The collected material was a very uniform, slightly tan deposit on the filter paper and was essentially water insoluble. No organic residue was found upon extraction.

Monitored stack gas samples were observed to approximate gaseous contaminant levels within the room as illustrated in Table 11.

5.3.2 Room Atmosphere. Hi-vol sample results were calculated for a series of runs with the exhaust fan running and for a series of runs with the fan off during powder-extinguishing discharge. Comparison of the values for each condition is shown in the following tabulation:

<u>Test Conditions</u>	<u>Atmospheric Particulate Concentrations in the Test Cell</u>
With Continuous Exhaust	0.015 g/ft <sup>3</sup> or 529 mg/m <sup>3</sup>
Without Continuous Exhaust	0.024 g/ft <sup>3</sup> or 845 mg/m <sup>3</sup>

Monitoring for changes at floor level in oxygen concentration or in the presence of combustible gases did not indicate response on either parameter. The circumstances of operation would probably prevent any local changes as air is pulled up through the grating floor of the test cell with the exhaust fan in operation. However, an oxygen-deficient atmosphere was detected with the direct reading monitors in

TABLE 11. MAXIMUM OBSERVED GASEOUS CONTAMINANT LEVEL  
IN THE 19FI AFFT

Test Conditions	Contaminant (Minimum)				
	CO <sub>2</sub>	CO	HC	NO	O <sub>2</sub>
	PPM				Minimum Percent
PKP Alone - Vents On	20,000 <sup>1</sup>	1,000 <sup>1</sup>	850	28	15.5
AFFF Alone - Vents On	20,000 <sup>1</sup>	1,000 <sup>1</sup>	300	20	17.0
Dual Agents - Vents On	20,000 <sup>1</sup>	1,000 <sup>1</sup>	300	30	14.5
Dual Agents - Vents Off	20,000 <sup>1</sup>	1,000 <sup>1</sup>	200	34	13.5

<sup>1</sup> These values represent the calibrated maximum of the monitoring equipment. The actual concentrations are above these stated levels.



the control room. This detector was strategically placed at a higher point in the room, causing a discrepancy between the two detectors. This discrepancy is caused by each sensor detecting different microenvironments within the compartment.

Table 11 outlines the maximum observed concentrations of gaseous contaminants monitored during the various fire-test scenarios.

No organic residue was found by solvent extraction of the hi-vol filters.

Temperature monitoring from the rear wall of the test cell (opposite the fire), at the communications conduit height (approximately 7 feet above the grating), recorded peak temperatures of about 550°F as successive fires were run with only 5 to 10 minutes between trials.

Air samples taken for the presence of propylene glycol, and total fluorides were analyzed:

- . Total fluorides - (0.2 ppm
- . Propylene glycol - (500 ppm.

The propylene glycol sampling was done for only 1 minute due to the short duration of smoke-generator operation. The values obtained indicated that retesting was necessary.

Figures 12, 13, and 14 characterize the changes in gaseous contaminant levels during several fire-test scenarios. Figure 12 illustrates gaseous contaminant levels in both stack and oil bilge quadrants during a test scenario where only PKP was applied to the fire with the exhaust vents in operation.

In comparison, Figures 13 and 14 illustrate the observed gas concentrations when both PKP and AFFF were applied with the exhaust vents not operating. Both figures represent the same fire-test scenario repeated. The similarities in concentrations can be seen between the two figures.

5.3.3 Water Effluent. Samples taken were analyzed for the items listed in the objectives and in Table 10. Values measured are recorded in Table 12. Tests confirm the presence of an anionic surfactant in the water sample.

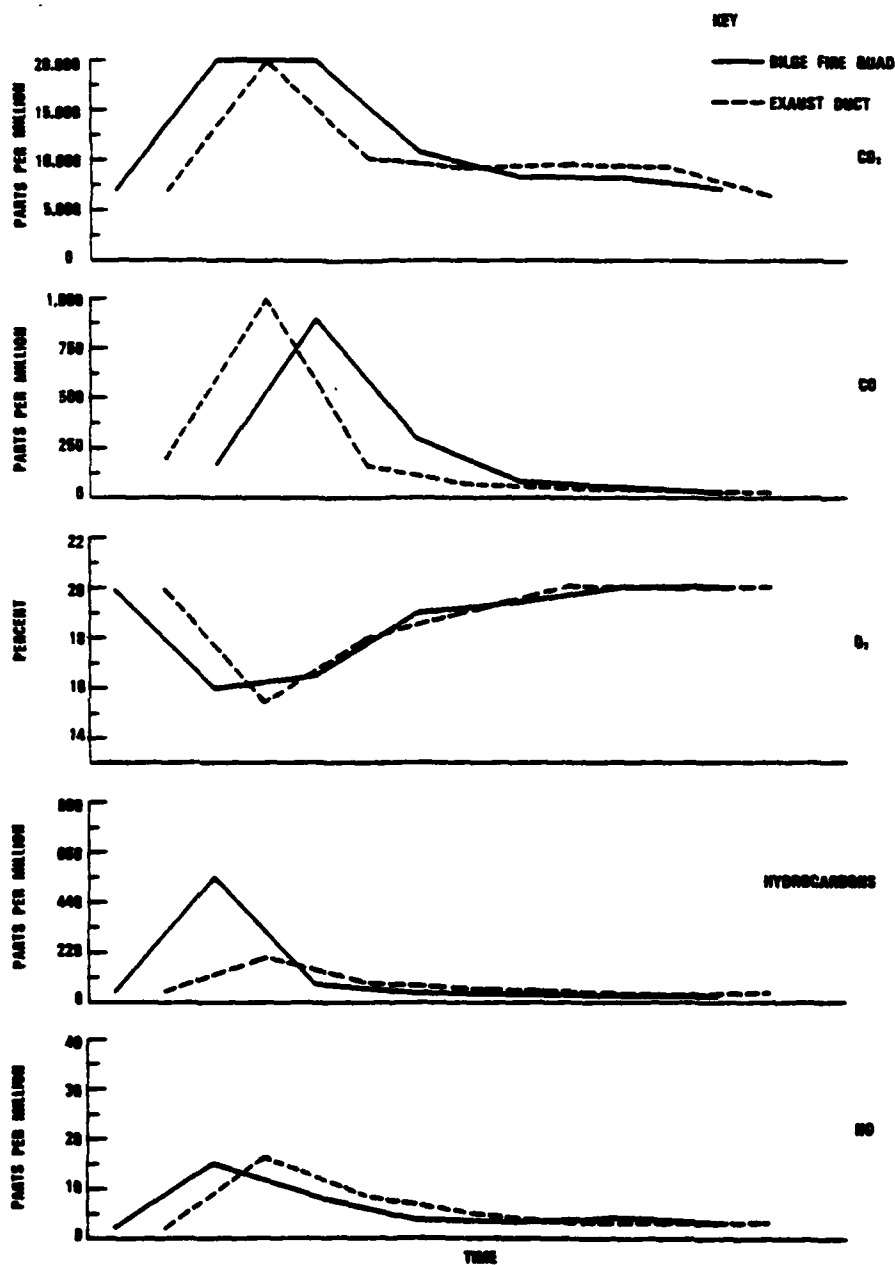
TABLE 12. WATER EFFLUENT RESULTS

<u>Parameter</u>	<u>Concentrations Determined</u>
Total Flouride	3.3 ppm
Chloride	63 ppm
Color	120 Color Units
Sulfate	130 ppm
Total Solids @ 105°C	14,300 mg/l
Total Solids @ 550°C	12,000 mg/l
Mineral Volatiles	2,300 mg/l
Filterable Solids @ 105°C	14,600 mg/l
Filterable Solids @ 550°C	12,000 mg/l
Suspended Solids @ 105°C	473 mg/l
Suspended Solids @ 550°C	392 mg/l
Mineral Volatiles	81 mg/l
Turbidity	300 NTU <sup>1</sup>
Butyl Carbitol	0.24 Percent
Total Organic Carbon	1,800 mg/l
BOD	2,200 ppm
COD	5,950 ppm
pH	9.2 on-site

Note: The water sample is turbid, grayish brown in color, with some visible sediment. Foam is produced when the sample is stirred. After settling, about 5 percent of the volume is solid sediment.

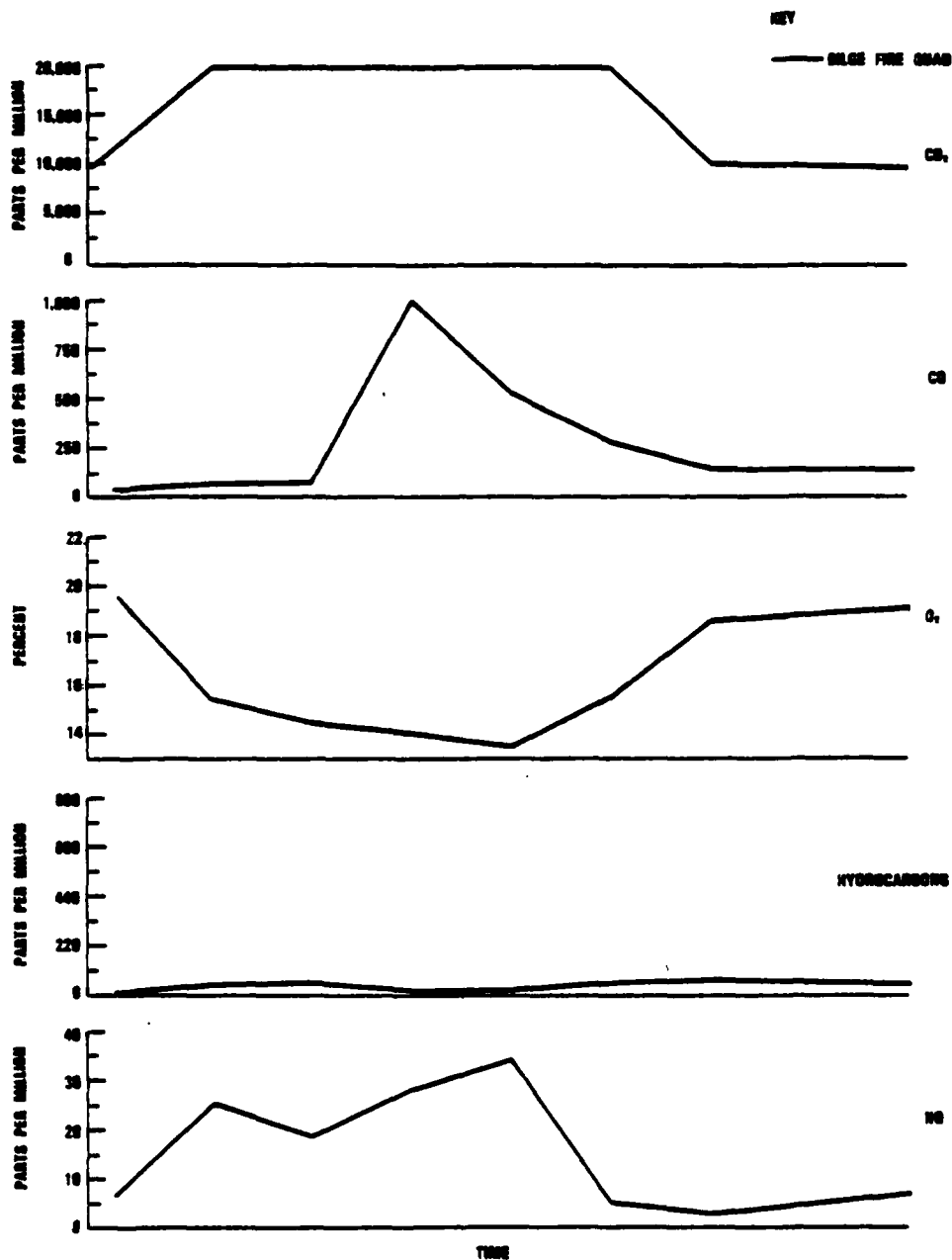
<sup>1</sup>NTU - nephelometer turbidity units.

Source: Case Consulting Laboratories, Inc.



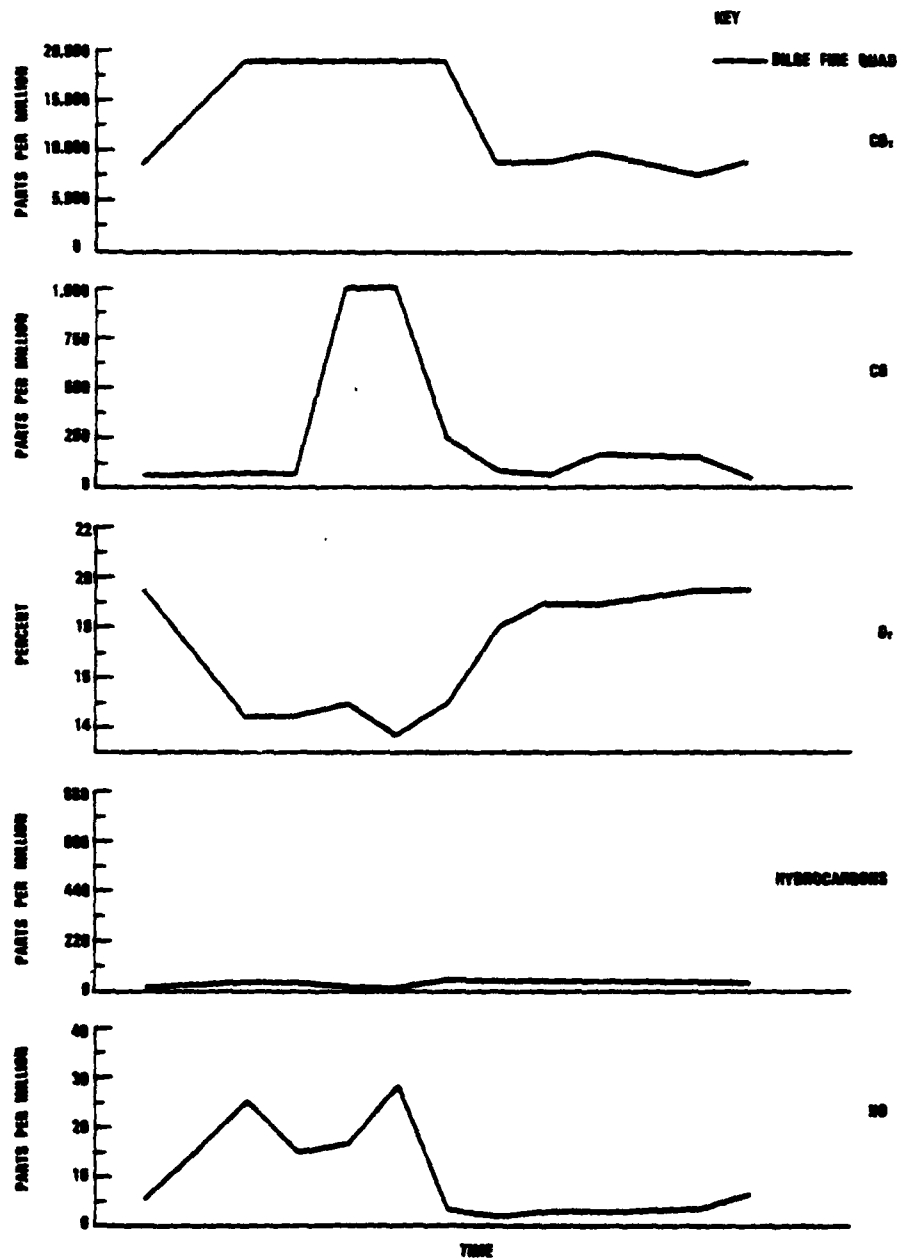
NOTE: FIGURE STARTS WITH A SINGLE 5-SECOND BURN OF PKP ONLY/VENTS ON. ENTIRE TIME FRAME IS APPROXIMATELY 10 MINUTES. TIME SCALE IS NONLINEAR.

FIGURE 12. GASEOUS CONTAMINANT LEVELS -  
 PKP ONLY/VENTS ON



NOTE: FIGURE STARTS AT SCENARIO INITIATION (6 SECONDS FROM 10 SECONDS AFTER) AND EXTENDS OVER A 10-MINUTE TIME PERIOD. TIME SCALE IS NONLINEAR.

FIGURE 13. GASEOUS CONTAMINANT LEVELS - DUAL AGENTS/VENT OFF (RUN 1)



NOTE: FIGURE STARTS AT SCENARIO INITIATION 10 SECONDS PRIOR TO SCENARIO START AND EXTENDS OVER A 10-MINUTE TIME PERIOD. TIME SCALE IS NONLINEAR.

FIGURE 14. GASEOUS CONTAMINANT LEVELS - DUAL AGENTS/VENT OFF (RUN 2)

## 6. PRELIMINARY ENVIRONMENTAL, HEALTH, AND SAFETY ASSESSMENT

Based on a review of applicable literature, interviews with knowledgeable individuals in government and industry, environmental and chemical sampling and analysis and a review of the AFFT design, a preliminary assessment has been made of the environmental, health, and safety aspects of the 19F1. This assessment, discussed in this section, covers the following topics:

- . Health effects
- . Safety factors
- . Internal atmospheres and materials compatibility
- . Oxygen-breathing apparatus (OBA)
- . Air emissions
- . Wastewater discharges
- . Solid waste disposal
- . Oncogenic potentials.

6.1 Health Effects. An assessment of the potential health effects to personnel from the 19F1 AFFT involves consideration of the specific groups at risk and the potential for acute and chronic exposures and effects. Acute exposures are those situations where an individual is exposed to a contaminant for relatively short periods of time at intermittent intervals. Chronic exposures refer to those situations where the individual is exposed to a contaminant for long periods of time (e.g., years). An acute effect is the short-term response from an acute exposure. A chronic effect is the long-term organism response from either a short-term or chronic exposure.

6.1.1 Acute Exposure. Any assessment of the health of personnel involved with the 19F1 AFFT is based on the assumption that all personnel entering the AFFT will have adequate respiratory protection (an OBA or a comparable self-contained respirator). It is clear from our preliminary testing data that the internal atmosphere of the 19F1 AFFT during operation contains sufficient toxic materials that are "immediately dangerous to life or health." This criterium, as established by OSHA, requires all personnel entering the trainer facility to use respiratory protection.

Proper use of appropriate respiratory protection will protect personnel from acute inhalation exposures to potentially toxic materials including possible asphyxiation from CO or CO<sub>2</sub>, dyspnea from NO, or anoxia from oxygen deficiency. Specific assessments based on the analytical testing are further detailed in Section 6.3.1.

Another potential health effect is skin absorption and ingestion of toxic materials. This can be prevented by using appropriate protective apparel as is currently used. Protection from acute health effects from the fire itself (i.e., burns) will also require the use of protective apparel. This protective apparel coupled with proper personal hygiene is expected to sufficiently protect the personnel involved with the fire-fighting exercises to the greatest extent possible while maintaining adequate mobility for training exercises.

The heat generated by the fireplaces during the training exercise is necessary to simulate actual conditions for the trainees. However, heat stress represents a potentially acute response from unacclimatized personnel working in the intense heat environment of the 19F1. Caution must be exercised during training activities.

Two major physical conditions of the 19F1 AFFT include the extensive flames and the associated intense heat. A theoretical analysis of the largest fireplace (bilge fire) based upon the operating parameters of the fireplace and the associated physical constraints yields the following data.

Data on the amounts of propane consumed in the 6-inch burners and in the accompanying pilot flame were supplied by ATS. Omitting the pilot flame figures, which seem rather high, the fuel and primary air consumption is:

- . Air - 59 ft<sup>3</sup>/min
- . Propane - 9 ft<sup>3</sup>/min.

The relevant physical constants are:

- . One ft<sup>3</sup> propane equals 2,465 Btu
- . One Btu will raise the temperature of 55 ft<sup>3</sup> of air 1°F.

The volume of the quadrant is 1,765 ft<sup>3</sup>, and the heat generated by six of the 6-inch burners in the quadrant is 133,110 Btu/min. Operating these burners for 1 minute will theoretically raise the quadrant's temperature to extremely hot conditions. These conditions are only approximations as they do not consider heat loss, air exchange, or incomplete combustion. However, they are significant because the heat generated from these burners must be dissipated very rapidly.

Booz, Allen recorded actual temperature levels of up to 550°F under high-flame conditions in the oil bilge compartment during the chemical-testing exercises.

The application of water during various fire-fighting exercises will create an extremely humid atmosphere. This may be a contributing parameter to interior compartment temperatures as well as a fogging factor from the steam generated. In addition, high humidity will have an effect on the physiological thermoregulatory processes (i.e., reduced evaporative cooling and increased conductive heat loss) of the exposed personnel.

Although heat and humidity may not be of prime concern from a regulatory compliance standpoint (however, there are recommendations by both ACGIH and NIOSH), continual attention must be paid to this potential health effect.

6.1.2 Chronic Exposure. The instructors at the training facilities must be considered as a separate group of individuals because they are chronically exposed to the adverse conditions of the fire fighter. The instructors are considered to be the greatest group at risk. In addition to being exposed to these adverse conditions on a daily basis, the work practices of the instructors were observed to be extremely poor. Improper or no respiratory protective equipment was used during related fire-fighting scenarios observed during a site visit. These poor practices will be reflected in both an increased risk of adverse chronic health effects as well as a great risk of acute effects. These instructors will be entering areas that may be immediately dangerous to life and health.

Assuming there will be an improvement in the practices of the instructors as a group, and appropriate respiratory protective equipment is used, the risk of a health hazard will be drastically reduced. However, it would be advantageous to maintain an active medical follow-up program for these individuals and to remain aware of chronic health effects.

Heat stress should be less of a concern for the instructors because they will be acclimatized. However, the potential for heat stress remains an area for additional interest.

6.2 Safety Factors. The ultimate safety of the 19F1 AFFT will be a major factor in its overall success as a training tool. Several key issues have been raised concerning the safety of the trainer. These issues include the following:



- . Does the 19Fl AFFT comply with current OSHA safety standards regarding:
  - Walking/working surfaces?
  - Means of egress?
  - Approved NEC equipment?
  - NFPA guidelines?
- . Does the 19Fl AFFT require consideration as a confined work space and does it conform to NIOSH criteria?
- . Is there a real potential for an uncontrolled fire and/or explosion within the fire fighter trainer during operation?

Based on site visits, data compilation, literature reviews, initial chemical analyses, and related interviews with safety experts, a number of potentially hazardous safety situations have been identified and safety criteria have been evaluated.

6.2.1 General OSHA Safety Standards. The Naval Safety Center follows and evaluates guidelines set by OSHA.

6.2.1.1 Walking/Working Surfaces. In general, the trainer and facility appear to be in compliance with safety standards regarding walking/working surfaces, guarding on floors, wall openings, and ladders. However, some specific noncompliance situations exist, such as the following:

- . There appeared to be lack of protection for the hinged-floor openings on the third level of the trainer. These openings require proper guarding (29 CFR 1910.23). (This is expected to be corrected before the Navy takes over the AFFT.)
- . There appeared to be inadequate vertical clearance above the fixed stair treads to an overhead obstruction at the third level of the trainer (29 CFR 1910.24). (This is expected to be corrected before the Navy takes over the AFFT.)
- . The first tread on the third-level stairways was not wide enough to accommodate individuals stepping over the toeboard (29 CFR 1910.24). (This is expected to be corrected before the Navy takes over the AFFT.)

- . A fixed ladder did not have proper clearance in relation to the ceiling opening (29 CFR 1910.27). (This is expected to be corrected before the Navy takes over the AFFT).

Attention should be given to the possible safety problem of wet foam-covered floors during trainer operation.

6.2.1.2 Means of Egress. There appeared to be a sufficient number of exits in the 19F1 AFFT for prompt escape in case of emergency. Information was obtained during the site visit that the majority of exits would be locked, preventing prompt escape. This is in direct noncompliance with OSHA guidelines (29 CFR 1910.36). In addition, these exits were not properly marked (29 CFR 1910.37).

If it is necessary for the access doors on the trainer to be locked for security reasons, the doors should only be locked from the outside while maintaining a free exit from the inside of the structure.

6.2.1.3 Approved NEC Equipment. Appropriate NEC electrical equipment (explosion-proof lights and switches) was observed to be installed and properly functioning (29 CFR 1910.309).

6.2.1.4 NFPA Guidelines. It is expected that the recommended practices outlined by the NFPA and the International Fire Service Training Association and adopted by the Naval Safety Center will be followed to provide protection for the fire fighter trainees. In addition, it is expected that Navy safety precautions (NAVMAT P-5100) will be properly complied with.

6.3 Internal Atmospheres and Materials Compatibility. Consideration of both the materials in use and the physical conditions under which they are used permits the estimation of the internal atmospheres of the 19F1 AFFT. The internal atmosphere determines the potential exposure parameters of the personnel as well as the potential effluents and emissions to the environment. The predicted composition of the internal atmospheres outlined below are based on both our on-site chemical sampling and other laboratory and theoretical evaluations.

6.3.1 Gases and Vapors. A number of gases and vapors are expected to be present in the internal environment of the 19F1 AFFT. In addition to the extinguishing agents propylene glycol and propane, the decomposition products of these materials will be present. The predicted byproducts of each of these materials are as follows:

- Propane: Carbon dioxide, carbon monoxide, oxides of nitrogen, and unburned hydrocarbons (mostly propane due to incomplete combustion)
- AFFF: Hydrogen fluoride and fluorochlorocarbon decomposition products, including hydrogen fluoride. (Specific product information is included in Appendix D.)
- Propylene glycol: Methane, ethylene, propane, acetaldehyde, isobutane, ethanol, propionaldehyde, acetone, propanol, 2-butanone, crotonaldehyde, butanol, allyl acetate, 4-methyl-1,3-dioxane, 4-methyl-2-ethyl-1,3-dioxane, carbon monoxide, carbon dioxide, tribenzopyrene, caronene, anthraquinone, pyrenequinone, pentacene, fluoranthrene, phenanthrene, and benzo(a)pyrene.

The concentrations of each of these materials will vary with flame temperatures and the ratios of flame to room volumes.

As outlined in Chapter 5, the on-site sampling has identified a number of contaminants that require consideration of their potential exposure hazards. Specifically, the following assessments can be made based on these sampling results:

- Carbon monoxide levels (> 1,000 ppm) are significantly higher (unable to quantify actual values) than the permissible ACGIH Short-Term Exposure Level (STEL) of 400 ppm. It is important to note that the STEL, as defined by ACGIH, should be considered the Maximum Acceptable Concentration, or ceiling and not to be exceeded at any time during the 15-minute excursion period.
- Carbon dioxide levels (> 20,000 ppm) exceed the current acceptable STEL of 15,000 ppm.
- Nitric oxide concentrations (maximum of 35 ppm) exceed the current acceptable STEL of 25 ppm.
- Oxygen levels (observed minimum of 13.5 percent) in the trainer during the test scenarios should be considered inadequate for human entry as determined by both ACGIH and NAVSEA.

The low propylene glycol concentrations detected during the test run reflect the absence of heat in the quadrant. Therefore, vaporization was not a critical parameter in obtaining and maintaining obscuration as it would be at normal operating temperatures.

These gaseous contaminants must further be assessed in terms of their reaction products. This may result in further lowering the acceptable exposure level for each individual contaminant.

It is important that the detection equipment for both CO and CO<sub>2</sub> be recalibrated to reflect a broader detection range so that accurate quantitation is obtainable through the entire scenario.

6.3.2 Aerosols (Dusts, Smokes, and Fogs). The aerosols present in the internal atmosphere of the 19F1 AFFT during operation consist primarily of PKP and silicates, propylene glycol, and some organic particulates. In addition, an intense water fog is present during several of the fire-fighting scenarios.

PKP and associated silicates (5 percent of initial product) create a dense, dusty atmosphere upon discharge in a compartment. This will be in addition to the obscuration from the propylene glycol fog. Smoke can be expected from the combustion of the propane, the propylene glycol, and the extinguishing agents.

A major factor in determining the total internal environment is the potential reaction of these materials with heat. For example: PKP consists of KHCO<sub>3</sub> with 5 percent of an inert silica filler and a silicone coating. The reaction with heat yields K<sub>2</sub>CO<sub>3</sub> ( $2 \text{ KHCO}_3 \xrightarrow{\text{heat}} \text{K}_2\text{CO}_3 + \text{CO}_2 + \text{H}_2\text{O}$ ) and with stronger heating of K<sub>2</sub>CO<sub>3</sub>, it yields K<sub>2</sub>O ( $\text{K}_2\text{CO}_3 \xrightarrow{\text{heat}} \text{K}_2\text{O} + \text{CO}_2$ ).

This reaction is reversible. In the presence of water, K<sub>2</sub>O forms KOH. The possibility of the formation of K<sub>2</sub>O is rather remote. KHCO<sub>3</sub> or K<sub>2</sub>CO<sub>3</sub> will not react with propylene glycol. Because we do not know the precise composition of AFFF, we cannot predict possible chemical reactions with any degree of certainty.

The nuisance dust concentrations of 845 mg/m<sup>3</sup> (which is primarily PKP) detected in the room atmosphere exceed recommended threshold limits of 10 mg/m<sup>3</sup> for an 8-hour time weighted average.

6.3.3 AFFT as a Confined Workplace Environment. The 19F1 AFFT will operate as a confined space. Therefore, it should be assessed for its safety compliance based on Navy criteria for confined workplace environment (NAVSEA gas-free engineering and NIOSH criteria). A number of major concerns relate to potential health hazards as outlined in Section 7.3; however, as a confined workplace environment, specific attention must be given to imminent safety hazards involved with a hot/open flame in a confined space, such as oxygen deficiencies, uncontrolled fires, and explosions as outlined in the following subsection.

6.3.4 Uncontrolled Fire and Explosion Potential. Two major material constituents of the 19F1 AFFT appear to present a significant potential hazard for creating uncontrolled fires and/or explosions. These materials, in the presence of an open flame, include the following:

- . Propane
- . Propylene glycol fog
- . Propane and propylene glycol mixture.

Each material is discussed below as to its inherent flammability properties as well as to its specific hazard potential during operation of the AFFT.

6.3.4.1 Propane. Due to the inherent characteristics of the material, propane is readily usable as a fuel source for the fire fighter fireplaces. Under normal operating conditions, the propane is expected to be used in the fire with minimal release of unburned product to the surrounding environment.

Analysis of the predicted training scenarios revealed a potential for the release of significant amounts of propane into the training compartments. The specific training event relates to the use of PKP on the oil spray/bilge fire. Although PKP will not generally extinguish the propane fire, it does dramatically suppress the flames. During this period of flame suppression, quantities of unburned propane are released into the compartment because the fuel flow remains at a predetermined level. At this point, an explosive situation may occur in the scenario, with the flames still quite active. Critical attention is required to assure that the lower explosive limit (LEL-2.2 percent) is not exceeded, even in small pockets within the trainer. Furthermore, NIOSH recommends that no one be permitted entry to a confined space for hot work with an excess of 10 percent of the LEL. NAVSEA (gas-free engineering) recommends entrance

only at near atmospheric conditions. The initial analytical tests reflected relatively small propane-level buildups in the quadrants during the simulated scenario runs. Special attention will be required to closely monitor this potential problem as the trial testing continues.

Specific engineering controls may be required to lower the risk of explosion from excess propane during the training scenarios.

6.3.4.2 Propylene Glycol Fog. Propylene glycol is a relatively innocuous material. Its inherently low toxicity makes it a prime candidate as a relatively nontoxic training smoke. However, a question arose concerning a potential safety hazard related to the propylene glycol fog and the open flames of the 19Fl AFFT fireplaces. We have proceeded to look in some depth at the interactions of the material with an open fire and the potential for uncontrolled combustion and/or explosion.

Based on our compilation of available data and the extensive work of the Naval Research Laboratories (NRL) on propylene glycol fog, we have advised ATS that the fog-generation and fireplace-operation tests should not be conducted simultaneously because of a significant potential for layering of the propylene glycol and subsequent ignition. It is reasonable to expect that, under open flame and heat conditions (greater than 140°F to 150°F), propylene glycol fog will vaporize, layer, and reach its lower explosive limits (2.6 percent). NRL also suggests that several decomposition products from the propylene glycol are more flammable than the original material, further increasing the risk of uncontrolled combustion. We estimate that at predicted levels of obscuration (3 to 4 feet or less), a significant risk of ignition may exist. The chemical analyses performed revealed ambient concentrations of less than 500 ppm. Because these concentrations were determined without any flame sources to cause vaporization, they are not representative of the actual fog scenario.

We would recommend that, at this time, a great degree of caution be exerted in any testing where both the propylene glycol fog and open flames are involved. We would also recommend that the fog, if tested, be used cautiously at the lowest possible concentrations.

6.3.4.3 Propane and Propylene Glycol Mixture. In considering the potential risks of uncontrolled combustion or explosion in a mixed atmosphere of gases and vapors, the

potential flammability closely follows an additive function. For example, the potential for ignition in a mixed atmosphere may be greater even if the LEL of any individual material has not been exceeded and thus, can rapidly create an explosive situation.

6.3.5 Combustible Gas Indicators. It is important to realize that in the fire fighter trainer the internal atmospheric conditions can have a considerable effect on the accurate response of the combustible gas indicators. Varying gas and vapor mixtures in the atmosphere can dramatically affect the indicator's response.

The sensitivity and accuracy of combustible gas indicators are affected by a wide range of conditions. These include the presence of dust, high humidity, and temperature extremes. In addition, the sensor catalyst can be expected to be "poisoned" after exposures to atmospheres containing both fluorine and silicone, both of which are present in the 19F1 AFPT. Recalibration of the detection equipment should be performed on a regular basis.

6.3.6 Confined Space Exhaust Ventilation. NIOSH recommends an exhaust ventilation rate based on a maximum value of the permissible exposure level (PEL) and/or 10 percent of the lower flammable limit (LFL), whichever is lower. This is approximately 1,000 ppm of propane (PEL) as a maximum exhaust concentration. This value may be exceeded at various times during the training operations. Further evaluation may require ventilation modifications.

6.4 Oxygen-Breathing Apparatus (OBA). The modified OBA unit as built by ATS on the Navy's request is totally inadequate for use in a fire-fighting (simulated or real) situation. The OBA, as modified, will not provide an oxygen-sufficient atmosphere for the fire fighter if there is a deficiency in the 19F1 AFPT during operation. This fact alone is sufficient grounds for not permitting the use of this OBA during the fire-fighting exercises.

Although the OBA could be modified for collection of aerosols and organics and for CO-conversion, the unit would still be totally inadequate for oxygen-deficient atmospheres, other potentially toxic materials (i.e., HF), or simple asphyxiants (i.e., CO<sub>2</sub>). Under these potentially hazardous conditions, the modified OBA should not be considered as appropriate respiratory protection with a sufficient factor of safety.

The modified OBA unit could be used to demonstrate the canister loading and starting procedure as well as breathing-resistance simulation. However, it should not be used in all fire-fighting exercises.

The mechanism for resistance in the modified OBA operates in reverse to the original unit. The standard OBA has a breathing resistance on exhalation whereas the modified unit has a breathing resistance on inhalation. There are commercially available OBA units made specifically for training purposes. These provide a far better simulation of the standard OBA.

The OBA is used routinely several times a day. The unit is rated to operate sufficiently for approximately 70 minutes continuously. Therefore, this practice of reuse is not an acceptable one from the standpoint of oxygen delivery and respiratory protection from toxic materials.

6.5 Air Pollution Assessment. The data collected during preliminary chemical testing reveal that the proposed facility will emit an average of 6.5 lb/hr of particulate matter from one quadrant. Since there are four quadrants in the facility, all of which may operate simultaneously, the maximum emission rate for particulate material will be approximately 26 lb/hr.

If the facility were considered an industrial batch-processing plant, the allowable emission rate corresponding to the process rate (see Appendix E) may be used to determine the emission control requirements. The process weight in this case would be the amount of PKP injected into the building, or approximately 120 lb/hr for all four quadrants. Using the table in Appendix E, the maximum permissible emission rate for the facility will be 0.62 lb/hr. The required emission reduction will then be 25.38 lb/hr, or a 97.6-percent reduction from the current emission rate of 26 lb/hr. This will be a very stringent emission-control requirement, necessitating the use of an electrostatic precipitator. However, because of the special nature of this facility, individual states may require less stringent emission control.

Because CO levels were observed to be high for short periods of time but not readily quantifiable, further testing and evaluation of this contaminant is indicated to adequately assess it for regulatory compliance.



Because there is a lack of facility-specific emission-control regulations governing the other pollutants, it is not possible to determine emission-control requirements for those pollutants. Should individual states choose to require control of these pollutants for the proposed facility, such requirements will be specified in the permit for the facility. These permits will be issued by each state in question on a case-by-case basis; thus, it is not possible to state at this time the degree to which the proposed facility will comply with each state's control requirements. The exception to this is San Diego, where any emission more than 10 lb/hr must apply the Best Available Control Technology (BACT) for this type of facility. The BACT must, therefore, be applied in the case of the AFFT, unless a method is developed to significantly reduce the facility's emission rate.

The Japanese emission standards, as mentioned previously, are specific to certain types of operations. The proposed AFFT facility does not fall under any of the operational categories presently set forth by the Japanese Environment Agency; therefore, such a facility will most likely be regulated on an individual case-by-case basis.

6.6 Wastewater Assessment. The results of preliminary effluent sampling, as described in Chapter 5, serve as a basis for assessing compliance of the proposed facility with established industrial effluent standards in Norfolk, Virginia, the site of the prototype AFFT. The following serves as a comparison:

<u>Parameter</u>	<u>Analytical Results</u>	<u>Norfolk Standards</u>
pH	9.2	6.0-9.0
BOD	2,200 ppm	230 ppm
Suspended Solids	473 mg/l at 105°C 392 mg/l at 550°C	250 mg/l

The major digression of the AFFT wastewater from the required effluent standards is in the area of solids content. The high solids content of the effluent is most likely due primarily to PKP that is not solubilized due to its treatment with silicone. The solids content exceeds effluent limitations in each state that has established these limitations. Many state officials mentioned this as the major roadblock to obtaining a permit. This may become less of an issue as the fire fighter trainer is further developed and as data are reviewed in more depth by state and local officials; however, reduction of the solids content will probably be necessary prior to approval of most state permit applications.

EPA usually judges each source of wastewater by area load and treatment plant capability. Some treatment may be needed to reduce the values found. Various control options are further discussed in Section 7.4.2.

As noted in Section 5.3.3, foaming occurred when the effluent sample was agitated. This is a general indication that the concentration of AFFF is above recommended (by the 3M Company) levels for proper disposal. Further dilution or treatment is indicated to reduce the AFFF concentration in the effluent.

As cited earlier, judgment on effluent permits is handled on an individual basis, and the need to submit data to the permitting agency is critical.

**6.7 Solid Waste Disposal.** Solid waste will come from two sources: the used OBA canisters and the sludge generated by AFFF waste treatment. Disposal of these wastes is discussed in the following subsections.

**6.7.1 Disposal of Used OBA Canisters.** According to the Mine Safety Appliances Company, the OBA canisters are neutralized by punching them with holes and soaking them in water. Based on additional information supplied by MSA and on data taken from the military specification pertinent to the OBA (MIL-0-15633C and MIL-C-17671C), a spent OBA canister, after soaking in water, will release the following compounds:

- . KOH, 448 g
- . NaOH, 193 g
- . NaCl, 37.8 g
- . KCl, 0.57 g
- . Ba(OH)<sub>2</sub>, 3.5 g
- . Fiberglass, 4.0 g
- . Iron oxides, 8.2 g
- . Nickel, 0.075 g
- . Titanium, 0.050 g
- . Infusiorial earth, 0.012 g.

The last five items will be suspended solids. The empty canisters may be disposed of with ordinary solid waste. The remaining solution can be discharged through POTW, provided it is pH controlled. Any change in the disposal procedures should be assessed separately by the because of the wide-scale use of the OBAs throughout the service.

6.7.2 Disposal of AFFF Sludge. It would be extremely difficult to predict the composition of this sludge without complete evaluation of the treatment process as well as operational testing and characterization of the sludge generated. Although compliance may be a function of the total amount generated (the Resource Conservation and Recovery Act currently has a 1,000-kg/mo exemption), it is critical that the sludge be evaluated for its potential as a hazardous waste so appropriate disposal procedures are followed.

6.8 Oncogenic Potential. Oncogenic potential refers to the ability of an agent to produce tumors. The disease process may involve the production of either benign or malignant tumors (neoplasms). A neoplasm, or tumor, is a new growth of cells or tissue masses that are abnormal and which may be limited to the tissue or organ of origin (benign) or may spread to other organs (malignant).

The decomposition products of propylene glycol may be associated with the potential for inducing oncogenic (neoplastic) effects. It is not clear, at the present time, if these substances are formed in the fire fighter trainer, nor, if they are formed, what the concentrations of these substances may be. The evidence regarding the oncogenic potential of the decomposition products is based on surveys of the NIOSH Registry of Toxic Effects of Chemical Substances (1978) and the Toxic Substances List (USDHEW/NIOSH, 1973). The primary references that describe the oncogenicity studies were not reviewed. Therefore, evaluation of the validity of those studies and the conclusions regarding oncogenic potential can not be adequately assessed at this time. It can only be suggested that these decomposition products may have an oncogenic potential pending a more detailed review of the evidence presented in the primary references.

Based on a survey of the two references cited above, the following decomposition products of propylene glycol may have an oncogenic potential:

- . 3,4-benzopyrene
- . Coronene
- . Phenanthrene
- . Pyrene quinone
- . Tribenzopyrene
- . Anthraquinone.

Additional chemical analyses will provide greater insight into the presence and hazard associated with these compounds.

## 7. POTENTIAL MODIFICATIONS TO THE 19F1 TRAINER

The results of the chemical and environmental sampling and the environmental health and safety assessment presented in Chapters 5 and 6 indicated a need for modifying certain aspects of the 19F1 design and/or operation. This chapter discusses these potential modifications.

7.1 Substitute Extinguishing Agents. Because of corrosion, pollution, possible toxicity problems, and high cost, more suitable materials should be substituted for the existing extinguishing agents AFFF and PKP. Possible substitutes are discussed in the following subsections.

7.1.1 Fire Extinguishing Foams. AFFF, the foam currently planned for use as an extinguishing agent in the 19F1, exhibits several undesirable characteristics:

- . Relatively high cost
- . Requires controlled discharge into POTWs
- . Possible toxicity of heat-reaction products.

Because of the nature of the extinguishing foam sensors (activated by opacity of the applied foam) and the flame-control logic of the trainer, a suitable substitute for AFFF must have similar physical properties although it need not have actual extinguishing ability. A possible AFFF substitute would be a commercial surfactant produced in quantity and with background data on toxicity, biodegradability, stability, and foaming properties. Both current AFFF manufacturers, the Ansul Corporation (licensed by Ciba-Geigy) and the 3M Company, have patents on formulation and employ surfactants as foam enhancers or foam stabilizers. The types of surfactants used by these manufacturers and considered as suitable substitutes for AFFF include the following:

- . Polyox WSR-N10 -- a polyethylene glycol
- . Pluronic P94 -- an ethylene oxide/propylene copolymer
- . Triton X100 -- an ethoxylated nonyl phenol.

A Navy Training Equipment Center preliminary study found sodium lauryl sulfate, an anionic detergent, to be a satisfactory AFFF replacement. However, a subsequent literature search disclosed that heat decomposition products of this compound are toxic. In addition, because sodium lauryl sulfate is an ester of lauryl alcohol and sulfuric acid, heat could yield either sulfuric acid or sulfur trioxide, although it would require rather unusual conditions.

The following types of surfactants are not considered suitable AFFF substitutes:

- . Alka metal soaps
- . Phosphorus containing compounds
- . Amines, amine oxides, or other nitrogen compounds
- . Cationic compounds
- . Amphoteric compounds
- . Sulfate esters
- . Sulfate ester ethers
- . Lignin sulfonates.

Proteinaceous foams, which are partially hydrolyzed proteins such as chicken feathers or fish scales, are also considered unsuitable candidates.

The areas in which likely candidates will be found include nonionic surfactants and alkylbenzene sulfonates. Nonionic surfactants embrace a wide variety of materials. For fire fighter trainer purposes, the following four types appear promising:

- . Ethoxylated octyl or nonyl phenols
- . Ethoxylated straight-chain aliphatic alcohols in the C<sub>11</sub> to C<sub>14</sub> range
- . Linear alkylbenzene sulfonates
- . Polyethylene glycols.

These types of surfactants exhibit good foaming properties, low toxicity, biodegradability, and ready availability at low cost.

Promising commercial candidates and their manufacturers include the following:

- . Ethoxylated straight-chain alcohols
  - Neodol 25-7 (Shell Oil Company)
  - Neodol 25-12 (Shell Oil Company)
  - Tergitol 15-5-7 (Union Carbide)
  - Tergitol 15-5-12 (Union Carbide)
- . Ethoxylated nonyl phenols
  - Triton X100 (Rohm and Haas)

- . Linear alkylbenzene sulfonates
  - Ultrawet K (ARCO)
  - Nacconol 35 SL (Stepan)
- . Polyethylene glycols
  - Polyox WSR N10 (Union Carbide)
  - Pluronic P94 (BASF-Wyandotte).

The most promising candidates appear to be the ethoxylated straight-chain alcohols, which are widely used in shampoos and laundry detergents. The action of heat or hot metal surfaces upon these compounds is not known or available at present but could be determined by simple experiments.

The polyethylene glycols are good wetting agents, film formers, and foam stabilizers rather than foam producers, hence their possible presence in AFFF. They could serve a useful purpose in admixture with another foaming agent.

Although all of these surfactants appear promising at this time, there is a wide variety of compounds with differing properties that might be suitable as an AFFF replacement.

7.1.2 Fire Extinguishing Powder. Like AFFF, PKP, a powdered extinguishing agent, exhibits several undesirable characteristics:

- . Is extremely diffusive and difficult to control
- . Causes skin irritation
- . Causes deterioration of painted surfaces
- . Is corrosive to metal surfaces
- . Penetrates electronics and controls
- . Causes white plume when exhausted from trainer.

Unlike AFFF, an important requirement of a substitute powdered material is its ability to suppress flame. This characteristic is necessary because both the bilge and electrical panel fireplaces use sensors during PKP application that are activated when the flames are suppressed below line of sight. This requirement limits the number of potential PKP substitutes to the following:

- . Sodium bicarbonate
- . Potassium bicarbonate
- . Monoammonium phosphate
- . Diammonium phosphate.

These products are used in commercial extinguishers, as fine powders, which is a disadvantage because of the diffusiveness problem. Monoammonium phosphate is effective against Class A, B, and C fires, but it has an acid pH that makes its solutions corrosive to metals. Sodium bicarbonate is the most promising substitute regarding toxicity, biodegradability, and lack of corrosiveness.

The problem of diffusiveness is related to particle size. The mean particle size of PKP powder is 30 to 35 $\mu$ m. As can be seen from the data on particle size and settling in air presented below, a particle size of about 80 $\mu$ m, or about 200 mesh, has a faster settling velocity in air than one with a particle size of 35 $\mu$ m. (These data are not for potassium bicarbonate, but should be representative.)

Particle Size ( $\mu$ m)	Settling Velocity Air (cm/sec)	Screen Mesh
35	0.1	400
80	1.0	200
100	3.0	150
150	8.0	100
400	20.0	50

One might consider conducting a test by preparing sodium bicarbonate or potassium bicarbonate extinguishments with the customary formulation but only with a particle size of about 80 $\mu$ m. It would be necessary to balance particle size against flowability in the extinguisher system, which can be done only by trial. This approach may not completely solve the PKP diffusiveness problem. However, if the product selected is sodium bicarbonate, there are other advantages such as lower cost, less alkalinity, and easy disposability.

7.2 Substitute Fogs/Smokes. Propylene glycol, currently used to produce an artificial smoke in the prototype 19F1, appears to be an ideal product because of its low cost, low toxicity, and biodegradability. However, according to recent studies conducted by the Naval Research Laboratory (NRL), there is a chance of flammability of the propylene glycol droplets or vapor due to heat decomposition. This work, however, was done using an unstabilized material.

The material suggested for use in the 19F1 is Union Carbide Experimental Fluid No. 7454-25 stabilized with a proprietary stabilizing agent. This agent is a food-grade antioxidant in less than 1 percent concentration. Additional work by NRL has shown that the flash point of the stabilized

material is slightly higher than that of the unstabilized material. However, the significance of this is not clear at this time. The addition of 10 percent water to a stabilized propylene glycol might reduce the flammability of the fog although it should simultaneously dilute the fog generated.

Aberdeen Proving Ground has generated fogs using mixtures of water and certain long-chain aliphatic alcohols. The alcohols used are hexadecyl or, for a longer lasting fog, a mixture of lauryl and eicosanyl alcohols. Such materials have been used in Florida to offset effects of frost on orange groves. One fog-generating system currently in use, the Frostop system manufactured by the Applied Technology Company, a subsidiary of Boeing Aerospace Company, uses an emulsified hexadecyl alcohol. Currently, there are no data on the effect of heat or flames on these fogs.

Other methods of smoke production that may be considered include, commercial smoke producers or smoke bombs. However, these methods usually involve a metal salt such as zinc chloride that may introduce a possible hazard because of its potentially toxic nature.

7.3 Ventilation. Ventilation is the widely accepted engineering control for reducing potentially toxic and/or flammable internal atmospheres. Ventilation requirements for the fire fighter trainer necessitate both control of the internal atmosphere by general and/or local exhaust ventilation and dilution ventilation for the purposes of fire prevention. Concentrations within the exhaust ventilation system can readily exceed the LEL even if the room atmosphere is considerably lower than the LEL due to concentrating. Additional ventilation could reduce the potential for an oxygen-deficient microenvironment within the compartments. Therefore, careful scrutiny of emission concentrations is necessary to properly evaluate the current system.

7.3.1 Exhaust Ventilation. NIOSH recommends that the concentration of Hazardous contaminants in the exhaust from a confined space be no more than the PEL and/or 10 percent of the LEL, whichever is lower. More detailed analyses of both the internal atmospheric conditions and exhaust ventilation concentrations will determine whether redesign of the ventilation system is necessary. Obviously, in the redesign of the ventilation system, the total output of material remains constant, but the concentration is reduced. NIOSH also recommends that continuous general ventilation be maintained where toxic atmospheres are produced or may develop due to the nature of the confined space. Furthermore, NIOSH suggests local exhaust ventilation be provided where general ventilation is not effective.



7.3.2 Dilution Ventilation. Dilution ventilation can be used to reduce the explosion potentials by reducing internal atmospheric concentration of the highly flammable materials propane and propylene glycol. Dilution ventilation for reducing concentrations below the LEL is never applied where personnel health might be affected. If OBAs are used, then human exposure is not the determining criteria. Dilution ventilation requirements can be estimated based on the sample chemical analyses performed.

7.4 Pollution Control. Any pollution-control modification will be based on the individual state's assessment of the fire fighter and on the stringency of the required permit.

7.4.1 Air Pollution Control. Preliminary assessment indicated that the primary air contaminant is particulate emissions. Should emission reductions of up to 97 percent be required, sophisticated control equipment such as electrostatic precipitators may be necessary. However, individual states may not require this high control level, permitting other emissions-control options such as cyclone separators and baghouse filters.

7.4.2 Water Pollution Control. To resolve the problem of disposal of wastewater containing AFFF, modifications to the system may be necessary. This subsection describes several potential modifications.

In areas where industrial effluent standards or pretreatment standards prevent release of an AFFF effluent into a POTW, one alternative might be the construction or modification of an on-site treatment facility capable of handling this AFFF effluent. Several of the planned sites will be equipped with such EPA-approved treatment plants. The presence of such an on-site facility would exempt the trainer from most state and local regulations.

Where the high solid content of the AFFF effluent poses a regulatory problem, another possible alternative might be construction of holding tanks for gradual release and/or dilution of the wastewater. However, because of the large quantities of water used for each training exercise and cost factors associated with construction of such tanks, the feasibility of this alternative may be limited.

A third possible alternative would be the replacement of AFFF and PKP with extinguishing substances, which would produce an effluent that could comply with water quality and effluent limitation standards. Further testing of the

present effluent, however, will be necessary to completely characterize the nature and quantity of pollutants prior to consideration of any of these alternatives.

7.5 Modified Training Exercises. To enhance the safety of the 19F1 AFFT, all personnel in or on the trainer should be required to use an OBA. This extends protection beyond those directly in the fire compartment and to others being exposed to potentially toxic materials at the trainer perimeter.

7.6 Training Structure Modifications. Modifications that would greatly improve the trainer from the standpoint of general OSHA safety regulations would include stair and ladder modifications, guardings on openings, maintaining appropriate means of egress, and ventilation- and pollution-control equipment made more suitable to the actual operating conditions of the trainer.

An additional modification to the training structure includes installing large holding tanks for water effluents to permit the slow dilution of the effluent (to reduce the AFFF concentration) prior to treatment at the facility. The feasibility of this modification requires further investigation.

Another possible modification to the training structure as a preventative measure against explosions involves the use of an explosion suppression system. These systems are designed to rapidly extinguish (in milliseconds) and suppress an explosion. The system is triggered by pressure detectors that cause the rapid release of a heavy spray of water or halogenated hydrocarbon under very high pressures. This will also extinguish the flames in the trainer fireplaces. Further evolution of this explosion-control practice should be investigated in more depth in the next phase of the study.

Construction materials, such as PVC pipes and conduits, under intense heat conditions may be an important factor for possible emissions of toxics. Appropriately approved high temperature-resistant materials should be used.

7.7 Corrosion Reduction/Prevention. To reduce or prevent corrosion (primarily due to the PKP and AFFF), a high-grade epoxy-based paint would be used. These paints are far superior to the currently used alkyl-based paints in resisting corrosion. Additional protection might be achieved by using various available chlorofluorocarbon coatings. These substitutes will also reduce the potential for trace metals from the alkyl-based paints in both air emissions and water effluents.

The use of corrosion-resistant air handling equipment could reduce problems in the ventilation system.

To reduce corrosion in the electronic circuit boxes, these units should be maintained under positive pressure with filtered air. This avoids the problems of sealing the units under vacuum conditions and eliminates the chance for the fine powders to enter the units.

## 8. CONCLUSIONS AND RECOMMENDATIONS

The 19F1 Advanced Fire Fighter Trainer will be operationally feasible once appropriate modifications are made and a data base is developed that is sufficient to satisfy the regulatory constraints and permitting requirements.

In order to focus on the major issues identified in this study, this chapter is structured to summarize and highlight our key conclusions with our recommendations immediately following.

8.1 Regulatory Constraints. The regulatory constraints affecting the 19F1 include those of the Environmental Protection Agency (EPA), the National Institute of Occupational Safety and Health (NIOSH), the Occupational Safety and Health Administration (OSHA), the Naval Environmental Health Center (NEHC), and the Naval Safety Center (NSC). We recommend the following:

- . Complete compliance to the strictest recommended criteria
- . The Navy provide a liaison with the regulatory bodies listed above to monitor changes in recommended constraint guidelines.

8.2 Modified OBA. The modified OBA does not provide adequate respiratory protection within an operating AFFT. Therefore, we recommend the following:

- . Continued use of the standard OBA
- . Each OBA canister be used only for its rated life expectancy (about 1 hour)

- . Establishment of specific operating rules and procedures
- . Review of canister disposal needs and techniques
- . Further consideration of modified OBA use during certain training activities.

8.3 Health and Safety. The internal conditions of the 19F1 operation are deleterious to human health from inhalation exposure to toxic materials and extreme heat. We recommend:

- . All personnel in or on the operating trainer wear an OBA or a supplied-air respirator to protect against toxic materials and oxygen deficiency
- . All personnel in an operating trainer wear appropriate apparel to protect against burns and skin absorption of toxic materials
- . Supervisors be alert to episodes of heat stress during training activities and to the fact that protective apparel will exacerbate the problem and that trainees will be more susceptible than instructors
- . Special attention be given to health hazards of instructors who will generally be at greatest risk
  - Instructors' work practices need significant improvement and enforcement
  - Medical surveillance should be provided
- . The oncogenic potential of propylene glycol thermal decomposition products be further investigated.

There are several safety concerns related to the trainer. We recommend the following:

- . Violations of OSHA safety criteria be corrected by modifications to the structure as outlined in Section 7.6, including
  - Guarding of hinged floor openings on third level
  - Vertical clearance above stair treads
  - Clearance for fixed ladder
- . Assured egress in emergency situations be maintained at all times by properly marked exits and by exit doors that are operable from the inside
- . Propylene glycol fog not be used with open flames or, at the minimum, to closely control propylene glycol concentrations and to evaluate the effectiveness of adding water to the stock material to be generated
- . Investigation of feasibility and cost of explosion-suppression systems
- . Investigation of the potential for propane buildups and consideration of engineering controls
- . Validation of the effectiveness of the currently installed environmental monitoring system
- . Consideration of the need for redesigning the exhaust ventilation system to meet NIOSH criteria for confined spaces
- . Adequate maintenance procedures be followed to reduce slipping hazards from wet surfaces that become coated with foam extinguishments.

8.4 Potential Uncontrolled Combustion and Explosions.  
The propylene glycol fog has a high potential for uncontrolled combustion or explosion under open flame conditions. We recommend the following:

- . Propylene glycol not be used as a smoke simulator in the 19F1
- . Use of a less flammable smoke, possibly a solid particulate.

There is a potential for an explosion of excess propane accumulated during the trainer operation. We recommend the following:

- . Further testing to determine the extent of this explosion potential under varied conditions
- . Further evaluation of a redesigned ventilation system incorporating the principles of general, local, and dilution ventilation.

8.5 Materials Compatibility. The materials currently used in the AFFT have exhibited considerable incompatibility. We recommend that substitutes for AFFF and PKP should be vigorously pursued.

- . AFFF is costly, requires controlled discharge, and has potentially toxic decomposition products. There are many candidate substitutes, the most promising being in the following chemical groups:
  - Nonionic surfactants
  - Alkylbenzene sulfonates
- . PKP is diffusive, is a skin irritant, can deteriorate painted surfaces, corrodes some metals, and produces opaque air emissions. The prime candidate for a substitute is sodium bicarbonate with an increased particle size.

- . Until less corrosive agents are incorporated into the AFFT, interim measures to reduce corrosion should be considered. These measures include the use of:
  - Epoxy-based paints instead of alkyd-based paints
  - Chlorofluorocarbon coatings
  - Corrosion-resistant air-handling equipment
  - Positive pressure filtered air to electronic circuit enclosures.

8.6 Environment. Major concerns exist for air emissions, wastewater effluents, and solid waste disposal. We recommend the following:

- . Detailed characterization of air emissions with orientation directed toward appropriate courses of action for each site, such as installing air pollution-control devices, obtaining special permit exemptions, and substituting a more acceptable material for PKP.
- . Detailed characterization of liquid effluents and determination of an acceptable disposal technique for AFFF wastewater. Disposal options include pretreatment, controlled release, special permitting, and identifying an acceptable substitute.
- . Characterization of wastewater from OBA canister disposal and determination of an appropriate disposal technique (pH control as a minimum).

Although the recycling of the gray water would reduce operating costs, it would also cause problems such as chemically changing the recycled water concentrating contaminants, resulting in malfunctions and misreadings by 19F1 sensors. We recommend the following:

- . No attempt be made to recycle gray water
- . Proper procedures for treatment and disposal be followed
- . Further evaluation of recycling where water supplies are critical.

The generation of solid wastes occurs during normal operations. These wastes may require special handling. We recommend the following:

- . Sludge from a selected AFFF wastewater treatment process be assessed to determine its potential as a hazardous waste
- . Current Navy technique for disposing of OBA canisters be reviewed for applicability to AFFT needs.



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## REFERENCES

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APPENDIX A

KEY TEAM MEMBER TRAINING OBJECTIVES



## APPENDIX A

### KEY TEAM MEMBER TRAINING OBJECTIVES

One terminal objective and a set of enabling objectives have been developed for each key member of the fire fighting team. The key members are scene leader, nozzleman, hosemen, plugmen, investigators, accessmen, and phone talker/messenger. The student will achieve of terminal the objective by attaining a grade of SAT on at least six exercises under the following conditions:

- . While performing as a member of a shipboard fire fighting team engaged in combatting Class A, B, and C fires in the training structure
- . Without sustaining personal injury, violating safety precautions, and, if applicable, without violating material conditions of readiness
- . When given a minimum of eight separate team exercises.

#### A.1 Objectives for the Scene Leader.

A.1.1 Terminal Objective. Direct activities of the fire-fighting party by initiating fire-fighting activities coordinating the attacking party, overseeing extinguishment, handling casualties, and postfire activities, and securing. For satisfactory performance, the scene leader must ensure that the following events occur:

- . The fire-fighting party must be manned and ready within 9 minutes after the alarm is sounded.
- . The fire-fighting party must extinguish the fire within the time limit prescribed for the exercise.
- . The scene leader must report progress to Damage Control Central in accordance with Shipboard Damage Control NWIP 50-3 (A), to include, as a minimum, location and class of fire, action taken to combat, fire under control, and fire out.

A.1.2 Enabling Objectives. Respond to a fire alarm, given an oral announcement of fire forward or aft, following a designated route and arriving on the scene within 7 minutes after the alarm is sounded. The scene leader must:

- . Muster the fire party
- . Designate the route to the scene
- . Draw from the repair locker and take to the scene the clipboard, message blanks, pencil, and helmet with head lantern.

Initiate fire-fighting activities, given the fire party on the scene. For satisfactory performance, the scene leader must achieve the following:

- . Direct the investigation
- . Direct isolation of the fire
- . Order power and ventilation secured
- . Order hoses rigged and charged
- . Order telephones set up and tested
- . Report status to Damage Control Central
- . Report manned and ready within 9 minutes after alarm is sounded.

Coordinate the attacking party, given a report by the investigator as to the class of fire. For satisfactory performance, the scene leader must achieve the following:

- . Select agent to be used
- . Direct compartment entry
- . Report progress to Damage Control Central.

Oversee extinguishment, given access to the fire. For satisfactory performance, the scene leader must achieve the following:

- . Ensure safe, effective progress
- . Change agents, if necessary
- . Supervise hose handlers
- . Report progress to Damage Control Central.

Direct casualty recovery, given an actual or simulated equipment casualty or a simulated personnel casualty. For satisfactory performance, the scene leader must direct personnel and equipment casualty recovery.

Direct postfire activities, given a report from the No. 1 nozzleman that the fire is out. For satisfactory performance, the scene leader must order the reflash watch set and report progress to Damage Control Central.

Supervise the securing of the fire party, given directions to secure from Damage Control Central. For satisfactory performance, the scene leader must direct team members in equipment stowage, ensuring that all equipment is properly stowed in the repair locker.

#### A.2 Objectives for the No. 1 Nozzleman.

A.2.1 Terminal Objective. Extinguish Class A, B, and C fires by applying the correct agents, using the method prescribed in NAVSEA Technical Manual Chapter 555, Volume I. For satisfactory performance, the No. 1 nozzleman, wearing a Type A-3 or A-4 oxygen-breathing apparatus (OBA), must extinguish the fire within the 14-minute time limit prescribed for each exercise.

A.2.2 Enabling Objectives. Respond to a fire alarm, given an oral announcement of fire forward or aft, following a designated route and arriving on the scene within 7 minutes after the alarm is sounded. The No. 1 nozzleman must draw from the repair locker and take to the scene the following equipment:

- . OBA
- . Canister
- . Asbestos gloves
- . Helmet with head lantern.

Operate a Type A-3 or A-4 OBA and a quick-starting canister. For satisfactory performance, the No. 1 nozzleman must achieve the following as outlined in NAVSEA Technical Manual 079, Volume 2:

- . Don and activate the OBA
- . Upon completion of fire-fighting, remove and dispose of the canister and clean and stow the OBA.

Assist the accessman, given direction from the scene leader. For satisfactory performance, the No. 1 nozzleman must apply a high-velocity fog pattern to the access fitting until the fitting is cool enough to approach.

Identify a fire as a Class A, B, or C fire, given a fire in a compartment with burning material that simulates Class A, B, or C matter. For satisfactory performance, the No. 1 nozzleman must orally report the correct class of fire to the scene leader.

Extinguish a Class A fire, given burning material simulating an A-type fire, within 14 minutes after the alarm is sounded. For satisfactory performance, the No. 1 nozzleman must achieve the following:

- . High-velocity fog pattern in circular or horizontal motions to beat down flames
- . Solid stream pattern to break up smoldering material.

Extinguish a Class B fire, given a simulated Class B fire in a compartment, within 14 minutes after the alarm is sounded. For satisfactory performance, the No. 1 nozzleman must apply aqueous film-forming foam (AFFF) supplied from an FP-180 until 1/2 inch layer has been applied to the fire area.

Activate the twin agent fire extinguishing system, given a simulated oil spray or bilge fire, when directed by the scene leader, and follow the procedural steps as outlined in NAVSEA Technical Manual 0993-LP-023-6010. For satisfactory performance, the No. 1 nozzleman must achieve the following:

- . Activate AFFF system from the damage control desk
- . Activate AFFF PKP (dry chemical) system from the engine room or fire room.

Extinguish an engine room or fire room fire, given a simulated oil spray or bilge fire, within 14 minutes after the alarm is sounded. For satisfactory performance, the No. 1 nozzleman must use the twin agent fire extinguishing system, applying both PKP and AFFF as prescribed in NAVSEA Technical Manual 0993-LP-023-6010.

Extinguish a Class C fire, given a simulated electrical fire, within 14 minutes after the alarm is sounded. The No. 1 nozzleman must follow standard fire fighting procedures as outlined in NAVSHIPS Technical Manual 9930.

Extinguish a deep fat fryer fire, given a simulated deep fat fryer fire and a No. 2 nozzleman to assist, within 14 minutes after the alarm is sounded. For satisfactory performance, the No. 1 nozzleman must achieve the following:

- . Using a portable PKP bottle, apply PKP to knock down the flames
- . Secure PKP after the No. 2 nozzleman has secured the low-velocity fog spray.

Report progress to the scene leader, given a simulated Class A, B, or C fire, using standard damage-control terminology. For satisfactory performance, the No. 1 nozzleman must complete the following reports without error:

- . Location of fire
- . Class of fire
- . Fire under control
- . Fire out
- . Reflash watch set.

Set the reflash watch, given the command from the scene leader, by remaining in the compartment with the agent readily available. For satisfactory performance, the No. 1 nozzleman will maintain the reflash watch until secured by the scene leader.

#### A.3 Objectives for the No. 2 Nozzleman.

A.3.1 Terminal Objective. Provide a heat shield to protect both the Nos. 1 and 2 nozzlemen by maintaining a low-velocity fog pattern between the nozzlemen and the fire. For satisfactory performance, the No. 2 nozzleman, wearing a Type A-3 or A-4 OBA, must maintain a continuous heat shield until directed otherwise by the No. 1 nozzleman.

A.3.2 Enabling Objectives. Respond to a fire alarm, given an oral announcement of fire forward or aft, following a designated route and arriving on the scene within 7 minutes after the alarm is sounded. The No. 1 nozzleman must draw from the repair locker and take to the scene the following equipment:

- . OBA
- . Canister
- . Asbestos gloves
- . Helmet with head lantern.

Operate Type A-3 or A-4 OBA and a quick-starting canister. For satisfactory performance, the No. 2 nozzleman must achieve the following as outlined in NAVSEA Technical Manual 079, Volume 2:

- . Don and activate the OBA, and upon completion of fire fighting
- . Upon completion of fire-fighting, remove and dispose of the canister and clean and stow the OBA.

Assist the accessman, given a hot access fitting, under the direction of the scene leader. For satisfactory performance, the No. 2 nozzleman must apply a high/low velocity fog pattern from a 4-ft applicator to the access fitting until the fitting is cool enough to approach.

Provide a heat shield to protect both the Nos. 1 and 2 nozzlemen, given a simulated Class A fire. For satisfactory performance, the No. 2 nozzleman must maintain a low-velocity fog pattern from a 4-ft applicator between the nozzlemen and the fire and maintain a continuous heat shield until otherwise directed by the No. 1 nozzleman.

Provide a heat shield to protect both the Nos. 1 and 2 nozzlemen, given a simulated Class B fire. For satisfactory performance, the No. 2 nozzleman must maintain a low-velocity fog pattern from a 4-ft applicator between the nozzlemen and the fire and maintain a continuous heat shield until otherwise directed by the No. 1 nozzleman.

Provide a heat shield to protect both the Nos. 1 and 2 nozzlemen, given a simulated oil spray or bilge fire. For satisfactory performance, the No. 2 nozzleman must maintain a low-velocity fog pattern from a 4-ft applicator between the nozzlemen and the fire and maintain a continuous heat shield until otherwise directed by the No. 2 nozzleman.

Extinguish a deep simulated fat fryer fire, given a No. 1 nozzleman with a portable PKP bottle, within 14 minutes after the alarm is sounded. For satisfactory performance, the No. 2 nozzleman must apply low-velocity fog pattern from a 4-ft applicator. The low-velocity fog pattern includes:

- . Above the fire
- . Immediately after PKP is applied
- . For 3 seconds
- . Secure.

Set the reflash watch, given the command from the scene leader. For satisfactory performance, the No. 2 nozzleman must achieve the following:

- . Slowly back out of the space
- . Keep the agent readily available
- . Maintain the reflash watch until secured by the scene leader.

#### A.4 Objective for the Hoseman.

A.4.1 Terminal Objective. Rig and tend a fire hose as specified in NAVSEA Technical Manual, Chapter 555, Volume I. For satisfactory performance, the hoseman wearing a Type A-3 or A-4 OBA, must rig the hose with the correct nozzle, including an applicator if needed, within 9 minutes after the alarm is sounded. He must maneuver the hose so as to avoid pushing, pulling, or holding the nozzleman back, and he must restow the fire hose in accordance with MRC A-634 W-1.

A.4.2 Enabling Objectives. Respond to a fire alarm, given an oral announcement of fire forward or aft, following a designated route and arriving on scene within 7 minutes after the alarm is sounded. The hoseman must draw from the repair locker and take to the scene the following equipment:

- . OBA
- . Canister
- . Asbestos gloves
- . Helmet with head lantern.

Operate a Type A-3 or A-4 OBA and a quick-starting canister. For satisfactory performance, the hoseman must achieve the following as outlined in NAVSEA Technical Manual 079, Volume 2:

- . Don and activate the OBA
- . Upon completion of the fire-fighting, remove and dispose of the canister and clean and stow the OBA.

Rig both the Nos. 1 and 2 hoses at the scene of the fire, given a complete shipboard fire station, under the direction of the scene leader. For satisfactory performance, the hoseman must achieve the following within 9 minutes after the alarm is sounded. Attach correct nozzles to each hose, hand tighten all hose fittings, and fake out free of kinks and rig hoses to the proper side of access fitting.

Tend a fire hose by manning a charged 1½ inch fire hose, with an instructor acting as the nozzleman. For satisfactory performance, the hoseman must, during a sustained period of 2 minutes, maintain a distance of approximately 4 feet behind the nozzleman without pushing, pulling, or holding him back.

Restow the fire hoses, given directions by the scene leader to secure, in accordance with MRC A-634 W-1.

Rig a jumper hose, given a ruptured firemain with a loss of pressure to the plug in use. For satisfactory performance, the hoseman must achieve the following within 4 minutes:

- . Secure isolation valves correctly
- . Rig hose to restore firemain pressure to the plug in use without leaks to the fittings.

#### A.5 Objectives for the Plugman.

A.5.1 Terminal Objectives. Operate a shipboard-type fire station by opening and closing the fireplug, Y-gate, and marine strainer as directed by the scene leader. For satisfactory performance, the plugman must charge the hose fully but slowly, secure the hose within 3 to 5 seconds in case of hose casualty, and secure the station completely and properly in accordance with MRC A-634 W-1.

A.5.2 Enabling Objectives. Respond to a fire alarm, given an oral announcement of fire forward or aft, following a designated route and arriving on the scene within 7 minutes after the alarm is sounded. The plugman must draw from the repair locker and take to the scene the following equipment:

- . Helmet
- . Flashlight.



Charge a firehose, given a shipboard-type fire station having a marine strainer and Y-gate, with the hose faked out and free of kinks. For satisfactory performance, the plugman must achieve the following:

- . Open fireplug fully and back off one-quarter turn
- . Open Y-gate fully
- . Charge hose slowly.

Dump and close a marine strainer, given a shipboard-type fire station with an open fire plug and a closed marine strainer and Y-gate. For satisfactory performance, the plugman must achieve the following:

- . Dump strainer quickly, with handle at right angle to strainer housing
- . Close strainer slowly until handle is in line with strainer housing and no water is spraying from the dump outlet.

Secure a shipboard-type fire station, given an open fire plug and a charged hose. For satisfactory performance, the plugman must achieve the following:

- . Close the Y-gate with the lever at a right angle with the hose
- . Close the fireplug until snug.

Secure a simulated or actual ruptured or wild hose, given a shipboard-type fire station with a hose faked out and charged, within 3 to 5 seconds.

Restow the fire station, given directions by the scene leader to secure in accordance with MRC A-634 W-1.

#### A.6 Objectives for the Accessman.

A.6.1 Terminal Objective. Gain access to a compartment on fire by opening the access fitting when directed by the scene leader. For satisfactory performance, the accessman must undog the hinge side first, open the fitting slowly, and stand by to close the fitting as needed.

A.6.2 Enabling Objectives. Respond to a fire alarm, given an oral announcement of fire forward or aft, following a designated route and arriving on scene within 7 minutes after the alarm is sounded. The accessman must draw from the repair locker and take to the scene the following equipment:

- . Pry bar
- . Sledge
- . Helmet
- . Asbestos gloves.

Open the access fitting to a compartment on fire, given directions by the scene leader. For satisfactory performance, the accessman must undog the access fitting from the hinge side first and open slowly.

Close the access fitting to a compartment on fire, given an attacking party retreating from the compartment on fire. For satisfactory performance, the accessman must dog the door closed with the knife edge sealed against the gasket.

Report progress to the scene leader, given the type and number of access fitting to open or close. For satisfactory performance, the accessman must report the number, type, and status of the access fitting.

#### A.7 Objectives for the Investigator.

A.7.1 Terminal Objective. Locate a fire and determine its class. For satisfactory performance, the investigator, wearing a Type A-3 or A-4 OBA, must locate without exception any flame or excessively warm surface, determine the class of fire, and report his findings, including a statement of extent, using a standard damage-control message blank.

A.7.2 Enabling Objectives. Respond to a fire alarm, given an oral announcement of a fire forward or aft. The investigator must draw from the repair locker and take to the scene the following equipment:

- . OBA
- . Canister
- . Asbestos gloves
- . Helmet with head lantern
- . Message blanks
- . Pencil
- . Investigator's kit.

Operate Type A-3 or A-4 OBA and a quick-starting canister. For satisfactory performance, the investigator must achieve the following as outlined in NAVSEA Technical Manual 079, Volume 2:

- . Don and activate the OBA
- . Upon completion of fire-fighting, remove and dispose of the canister and clean and stow the OBA.

Locate a compartment on fire, given burning material in a compartment, within 5 minutes after the alarm is sounded. For satisfactory performance, the investigator must check bulkheads, decks, overheads, and compartment interiors.

Identify a fire as a Class A, B, or C fire, given a fire in a compartment with burning materials that simulate Class A, B, or C matter, without error.

Report the status of a fire, given a simulated Class A, B, or C fire in a compartment, within 6 minutes after the alarm is sounded. For satisfactory performance, the investigator must achieve the following:

- . Report location, class, and extent of fire
- . Use standard damage-control message blanks and symbology.

#### A.8 Objectives for the Phone Talker/Messenger.

A.8.1 Terminal Objective. Relay messages between the scene leader and Damage Control Central, by setting up and operating a sound-powered telephone. For satisfactory performance, the phone talker/ messenger must relay each message without error, in the order received, and properly secure and restow the telephone.

A.8.2 Enabling Objectives. Respond to a fire alarm, given an oral announcement of fire forward or aft, following a designated route and arriving on the scene within 7 minutes after the alarm is sounded. The phone talker/messenger must draw from the repair locker and take to the scene the following equipment:

- . Sound-powered telephone
- . Lighted clipboard
- . Message blanks
- . Pencil
- . Phone talker's helmet.

Set up and operate a sound-powered telephone, given the proper circuit, message blanks, pencil, and instructors in Damage Control Central and on scene. For satisfactory performance, the phone talker/messenger must achieve the following without error:

- . Use standard telephone talking procedures
- . Connect the telephone to the correct circuit
- . Send, receive, and relay reports, converting written reports to oral and oral reports to written.

Secure and restow the sound-powered telephone, given directions by the scene leader, by restowing the telephone in the correct manner and in the correct place.

APPENDIX B  
TRAINING SCENARIO

APPENDIX B  
TRAINING SCENARIO

BILGE SEQUENCE  
(1) Without Oil Spray

<u>Control</u>	<u>Trainee</u>
Pilot light on	
Bilge flames on:	Apply water in "digging" fashion. Flames will "torch" five feet Cease application of water. Flames will return to maximum height.  Apply water less than required extinction time. Flames will recede. Discontinue water. Flames will return.  Apply water for greater than required extinction time. Flames will recede and reflash in 15 seconds.  Elapsed burn time will be displayed
Bilge flames on:	Apply water for greater than required time. Flames will recede and not reflash.  Apply PKP for 2 seconds. Flames will recede, then grow again.  Apply PKP for greater than five seconds. Flames will recede. Reflash in five seconds.  Apply PKP for greater than five seconds. Flames will extinguish.
Bilge flames on:	Apply AFFF uniformly over flames for less than required time. Flames will recede. When AFFF application is stopped, flames will grow again.  Apply AFFF uniformly over flames for greater than required time. Flames will recede and extinguish.

BILGE SEQUENCE  
(1) Without Oil Spray  
(Continued)

<u>Control</u>	<u>Trainee</u>
Bilge flames on:	Apply AFFF to the bilge bulkhead for greater than the required time. Flames will recede and extinguish.
Burn time will be displayed	

BILGE SEQUENCE  
(2) With Oil Spray

Control	Trainee
Open simulated oil supply valves	
Oil spray/bilge on:	Apply PKP for two seconds. Oil spray fire will not extinguish.
	Apply PKP for greater than five seconds. Oil spray fire will extinguish and reflash in 15 seconds.
	Apply water to the oil spray fire. Oil spray fire will not extinguish.
	Secure the simulated oil supply valves. The oil spray fire will extinguish.
	Apply AFFF uniformly over the bilge fire for greater than the required time flames will recede and extinguish.
Burn time will be displayed	

Note: No smoke is required for oil spray/bilge fires.



RAG BALE

<u>Control</u>	<u>Trainee</u>
Pilot light on	
Smoke on rag bale flame on:	Apply water for less than required time flames will recede. Smoke will emanate from fireplace. When water application ceases flames will grow and spread. Smoke will cease.
	Apply water for greater than required time. Flames will recede. No smoke will emanate. Flames will reflash. Apply water until flames are ex- tinguished.
Burn time will display	Continue water for required soak time. Fire will not reflash.
Flame on:	Apply AFFF for less than required time. Flames will recede. When AFFF application ceases, flames will grow again. Apply AFFF for greater than required time.
Burn time will display	Flames will extinguish. No smoke will emanate.

ELECTRICAL PANEL

<u>Control</u>	<u>Trainee</u>
Pilot light on	
Smoke on:	Smoke will emanate from fireplace.
Smoke off:	Smoke emanation will cease.
Flame on:	Apply CO <sub>2</sub> for less than required Time. Flames will recede. When CO <sub>2</sub> application ceases, flames will grow again. Apply CO <sub>2</sub> for greater than required reflash.
Secure simulated power source to electrical panel	Apply CO <sub>2</sub> for greater than required time. Flames will extinguish. Burn time will be displayed.

DEEP FAT FRYER

<u>Control</u>	<u>Trainee</u>
Remove cover Pilot light on	Deep fat fryer circuit breaker on.
Flame on:	Direct a spray of water into the fryer for more than two seconds. Bell will ring, flames will torch. When water application ceases, bell will stop ringing, flames will return to maximum height.
	Apply a combination of PKP and low velocity water fog over the fryer edge for greater than three seconds.
	Bell will ring, fire will extinguish and reflash in 15 seconds.
	Deep fat fryer circuit breaker set to "off" and apply a combination of PKP and low velocity water fog.
Burn time will display	Fog over the fryer edge for greater than three seconds. Fire will extinguish and not reflash.
Flame on:	Circuit breaker on. Place fryer cover over the deep fat fryer. Fire will extinguish. Burn time will display.

## STACK HOOD

<u>Control</u>	<u>Trainee</u>
Pilot light on	Deep fat fryer circuit breaker "on" on ventilation stack, open damper.
Flame on:	Apply water fog less than required time. Bell will ring, flames will recede, when water application is stopped, flame will grow again.  Deep fat fryer circuit breaker set to "off". Apply water to the fire for greater than required time. Flames will extinguish. Then reflash in 15 seconds.  Close damper on ventilation stack.  Apply water for greater than required time; flames will extinguish and not reflash.  Burn time will display.
Flame on:	Apply PKP for less than two seconds. Flames will recede. When application ceases, flames will grow again.  Apply PKP for a period greater than five seconds.  Flames will extinguish and not reflash. Burn time will display.

FRYER/HOOD

Control

Trainee

Pilot light on

Ventilation stack damper open  
deep fat fryer circuit breaker  
"on".

Flame on:

Fires will start in the fryer  
and hood. Apply PKP for time  
greater than five seconds  
to hood. Flames will extinguish  
and reflash in 15 seconds.

Ventilation stack damper closed.  
Apply PKP to stack hood for  
greater than five seconds.  
Flames will extinguish and  
reflash in 15 seconds.

Apply a combination of PKP  
and low velocity water over the  
fryer edge for greater than  
three seconds. Bell will  
ring. Fryer fire will  
extinguish and reflash in 15  
seconds.

Deep fat fryer circuit breaker  
to "off" place cover on deep  
fat fryer. Fire will extinguish.  
Apply PKP to the stack hood  
fire for more than five seconds.

Fire will extinguish and not  
reflash. Burn time will display.

APPENDIX C  
PERSONS CONTACTED

APPENDIX C  
PERSONS CONTACTED

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MSA  
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(412) 325-1313
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26. John Simiack  
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27. Carl Spence  
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30. Mr. W. Walls  
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31. F. W. Williams  
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Combustion & Fuels Branch  
Chemistry Division  
Washington, DC  
(202) 767-2476

APPENDIX D

AFFF PRODUCT INFORMATION

# Product Environmental Data



Environmental Laboratory  
Environmental Engineering and Pollution Control

900 Bush Avenue  
PO Box 33331  
St Paul, MN 55133  
612/778 5104

COMMERCIAL CHEMICALS DIVISION  
MILITARY SPEC. TYPE AFFF 6% CONCENTRATE  
FC-780B

DESCRIPTION: Fire extinguishing agent.

APPEARANCE: Clear amber liquid.

USAGE: FC-780B is employed at a 6% level (i.e., 94 parts water to 6 parts FC-780B) to extinguish fires involving liquid fuels and other liquid organic compounds.

WASTE DISCHARGE: Facilities which use FC-780B in actual or simulated firefighting activities usually direct the resulting wastes to wastewater treatment systems. Whenever possible, 3M recommends disposing of FC-780B wastes in this manner. However, aquatic and soil environments sometimes receive these wastes untreated.

DISPOSAL: May be bled to wastewater system with a treatment plant in accordance with local regulations.

## AQUATIC TOXICITY:

<u>Test Organism</u>	<u>96-Hr. LC<sub>50</sub></u>
Bluegill sunfish ( <u>Lepomis macrochirus</u> )	1,600 mg/l (1,300-1,800)*
Common Mummichog or Kille Fish ( <u>Fundulus heteroclitus</u> )	3,900 mg/l (3,400-4,600)*

TREATABILITY: Neither foaming nor sludge settling problems developed as a result of aeration in laboratory scale activated sludge reactors containing 100 mg/l of FC-780B. Based on these results, no serious foaming or settling problems are anticipated in waste treatment systems containing less than 100 mg/l of FC-780B.

Date: 1/8/80

Page 1 of 2

All statements, technical information and recommendations contained herein are of a general nature and are based on laboratory tests or literature information we believe to be reliable, but the accuracy, completeness or applicability to particular circumstances is not guaranteed. 3M makes no representation that the customer's use and disposal of the product will comply with all applicable environmental laws, regulations and local requirements.

Form 1475-B PWC

# Product Environmental Data



Environmental Laboratory  
Environmental Engineering and Pollution Control

900 Bush Avenue  
PO Box 33331  
St. Paul, MN 55133  
612/778 5104

COMMERCIAL CHEMICALS DIVISION  
MILITARY SPEC. TYPE AFFF 6% CONCENTRATE  
FC-780B

(continued)

## BIODEGRADATION: \*\*

Chemical Oxygen Demand (COD)	387,000 mg/l
Ratio of Twenty-Day Biochemical Oxygen Demand to Chemical Oxygen Demand (BOD <sub>20</sub> /COD)	0.96

\* 95% confidence interval.

\*\* As reported by the Naval Research Laboratory, Fire Suppression  
Section, Washington, DC.

Date: 1/8/80

Page 2 of 2

All statements, technical information and recommendations contained herein are of a general nature and are based on laboratory tests of literature information we believe to be reliable, but the accuracy, completeness or applicability to particular circumstances is not guaranteed. 3M makes no representation that the customer's use and disposal of the product will comply with all applicable environmental laws, regulations and rules.



# MATERIAL SAFETY DATA SHEET

3M  
3M Center  
St. Paul, Minnesota 55144  
(612) 733-1110

Form 15593-C PWO

DUNS NO.: 00-617-3082

Chemical Family	Fire Control Agent	Trade Name	FC-780 B Mil-Spec Type AFFF 6% Concentrate
3M I. D. Number	98-0211-0778-8 (5 gallon)	Commercial Chemicals Division	

1. INGREDIENTS	CAS. #	%	TLV® (unit)
Water	7732-18-5	75	
Butyl Carbitol	112-34-5	15	Not Established
Synthetic Detergents		<5	Not Established
Fluoroalkyl Surfactants		<5	Not Established
Urea	57-13-6	5	

2. PHYSICAL DATA				
Boiling Point	Initial	212°F	Solubility in Water	Miscible
Vapor Pressure			Specific Gravity (H <sub>2</sub> O=1)	1.01
Vapor Density (Air = 1)			Percent Volatile	~90
Evaporation Rate ( B. A. =1)		<1	pH	7-8.5
Appearance and Odor	Clear, amber colored liquid.			

3. FIRE AND EXPLOSION HAZARD DATA			
Flash Point (Test Method)	None	Flammable Limits:	LEL = UEL =
Extinguishing Media	FC-780 B is a fire extinguishing agent.		
Special Fire Fighting Procedures	None		
Unusual Fire and Explosion Hazards	Toxic by-products including HF may be formed.		

4. ENVIRONMENTAL INFORMATION
Spill Response
Collect spilled material. Wash residue to wastewater treatment system.

## Recommended Disposal

Bleed to wastewater treatment system in accordance with local regulations. Diluting 1 gallon of FC-780 B in > 10,000 gallons of sewage prevents serious foaming in aeration basins and prevents sludge settling problems in clarifiers.

## Environmental Data

96-Hr. LC<sub>50</sub> Bluegill Sunfish (*Lepomis macrochirus*) - 1,600 mg/l  
96-Hr. LC<sub>50</sub> Common Mummichog or Killie Fish (*Fundulus heteroclitus*) - 3,900 mg/l  
Chemical Oxygen Demand (COD) - 387,000 mg/l  
20-Day Biochemical Oxygen Demand (BOD<sub>20</sub>) - 370,000 mg/l

Threshold Limit Values listed above are current to 1980. Because they are reviewed yearly by ACGIH and subject to change (usually to a lower value) it is necessary for the user of this Material Safety Data Sheet to maintain a list of current values.

TRADE NAME: FC-780 B Mil-Spec Type AFFF 6% Concentrate

#### 5. HEALTH HAZARD DATA

**Eye Contact** FC-780 B concentrate was found to be minimally irritating to the eyes of test animals. Persons coming in contact with the concentrate would be expected to experience slight transient irritation.

**Skin Contact** Animal studies indicate FC-780 B is non-irritating dermally. The skin irritation potential to individuals handling the concentrate or the diluted solution should be quite low.

**Inhalation** The inhalation hazard associated with FC-780 B use is low. Aspiration of the concentrate may be hazardous. Avoid prolonged inhalation of the spray or mist.

**Ingestion** Undiluted FC-780 B has an acute oral LD<sub>50</sub> (rat) greater than 5 gm/kg. This classifies the product as being practically non-toxic orally.

#### Suggested First Aid

**EYE CONTACT:** Flush eyes with water. Call a physician.

**SKIN CONTACT:** Wash affected area with water and soap.

**INHALATION:** Remove person to fresh air.

**INGESTION:** DO NOT INDUCE VOMITING. Call a physician.

#### 6. REACTIVITY DATA

##### STABILITY

☐ Unstable  
☒ Stable

Conditions to Avoid

##### INCOMPATIBILITY

Materials to Avoid

##### HAZARDOUS

##### POLYMERIZATION

☐ May Occur  
☒ May Not Occur

Conditions to Avoid

#### Hazardous Decomposition Products

Thermal decomposition may produce toxic materials including HF.

#### 7. SPECIAL PROTECTION INFORMATION

##### Eye Protection

Safety Glasses

##### Skin Protection

Rubber Gloves

##### Ventilation

General ventilation is adequate.

##### Respiratory and Special Protection

##### Other Protection

#### 8. PRECAUTIONARY INFORMATION

#### 9. DEPARTMENT OF TRANSPORTATION

##### DOT Proper Shipping Name

Not Applicable

##### DOT Hazard Class

Not Applicable

##### Issue Date

Sept., 1980

##### Supersedes

Aug., 1979

The information on this Data Sheet represents our current data and best opinion as to the proper use in handling of this product under normal conditions. Any use of the product which is not in conformance with this Data Sheet or which involves using the product in combination with any other product or any process

**PRODUCT  
TOXICITY  
SUMMARY**

**3M**

Product Name

MIL-SPEC Type Aqueous Film Forming Foam 6% Concentrate FC-780B

Issue Date

May, 1979

Below is a summary of the study data giving an indication of the relative toxicity of the product. (Definitions of test procedures are found on the reverse side of this sheet.)

Relative toxicity of a material is only one factor that is important in determining the degree of hazard in handling a chemical or product. Other considerations to include are physical properties of the chemical, extent and frequency of use or exposure, intended use, and possible misuse of the product. For additional information regarding safe handling of the product, please reference the Material or Product Safety Data Sheet.

**PRIMARY SKIN IRRITATION:** Undiluted FC-780B was found to be non-irritating when tested according to conventional (Draize) procedures using albino rabbits as the test animals. No signs of dermal irritation were observed in any of the test animals. These results suggest that the skin irritation potential to individuals handling the concentrate or the diluted solutions should be quite low.

**EYE IRRITATION:** Undiluted FC-780B was found to be minimally irritating to the eyes of albino rabbits when tested according to conventional (Draize) procedures. The irritation was limited to conjunctival irritation characterized by moderate to maximal reddening, swelling and discharge. These effects were apparent at one and twenty-four hours post-instillation. At 48 hours all readings were zero and remained so throughout the remainder of the study. Flushing the eyes with plenty of water immediately following contact with FC-780B should arrest/reverse the irritation process.

**ACUTE ORAL TOXICITY:** FC-780B was found to have an acute oral LD<sub>50</sub> greater than five grams per kilogram of body weight when administered to ten albino rats. The material produced no deaths, no unusual behavioral or pharmacotoxic signs and no adverse weight effects during the study. FC-780B is considered practically non-toxic orally.

**COMMERCIAL CHEMICALS DIVISION**

Inquiries regarding this information are to be referred to Toxicology Services, Medical Department, 3M Center, 220-2E, St. Paul, MN 55101, (612) 733-2882. The above information is based upon studies conducted by 3M Company and/or by recognized professional testing laboratories. It is believed to be correct, and it is supplied to others upon the condition that the person receiving it shall make their own determination of its suitability for their purposes.



## ANIMAL TEST DESCRIPTIONS

Below are described animal studies commonly used in testing 3M products. Variations from these routine tests are described in the space below the test descriptions. Results of the data of the various studies that were performed may be found in the table below.

**LD<sub>50</sub>** — refers to the quantity of chemical that kills 50% of the exposed animals. Dosage is expressed in grams, milligrams or milliliters per kilogram of animal body weight.

**LC<sub>50</sub>** — refers to that quantity of chemical that kills 50% of the exposed animals. Dosage is expressed in parts per million (ppm) or milligrams per liter (mg/l) of chamber concentration for a stated period of time.

1. **Acute Oral** — refers to a test of a single dose of a chemical with \_\_\_\_ grams or \_\_\_\_ milliliters per kilogram of body weight administered orally. A 14-day observation period following dosing is used. The toxicity of the chemical is classified according to the system of Hodge and Sterner (expressed as an oral LD<sub>50</sub> per kg of body weight): Extremely toxic: 1 mg or less; Highly toxic: 1 to 50 mg; Moderately toxic: 50-500 mg; Slightly toxic: 500 mg to 5 gms; Practically non-toxic: 5-15 gms; Relatively harmless: > 15 gms.
2. **Acute Dermal** — refers to a test of a single dose of a chemical with \_\_\_\_ milligrams or \_\_\_\_ milliliters per kilogram of body weight administered by continuous contact for 24 hours or less with the bare skin of albino rabbits weighing between 2 and 3 kg each. A 14-day post-administration observation period is used. The dermal toxicity of a chemical is categorized by the American National Standards Institute (ANSI) as being highly toxic if the LD<sub>50</sub> is 200 milligrams or less per kilogram of body weight and toxic if the LD<sub>50</sub> is greater than 200 mg per kilogram but less than 1000 mg per kilogram of body weight.
3. **Acute Inhalation** — refers to a test of a single continuous inhalation exposure of a \_\_\_\_ concentration of a chemical for a given period of time. ANSI defines a highly toxic chemical by inhalation as one that has an LC<sub>50</sub> in air of less than or equal to 200 parts per million by volume of gas or vapor, or less than or equal to 2 milligrams per liter of mist, fume, or dust administered for 1 hour or less to albino rats weighing between 200-300 grams each. A toxic chemical by inhalation is defined as having an LC<sub>50</sub> of 200-2000 parts per million by volume of gas or vapor or 2-20 milligrams per liter of mist, fume or dust under the above mentioned conditions.
4. **Primary Skin Irritation** — refers to a single application of \_\_\_\_ grams or \_\_\_\_ milliliters of a chemical to albino rabbits on intact and abraded skin test sites. The material is occluded and held in contact for 24 hours. Observations are made at 24 and 72 hours post-application and scored for dermal irritation according to the procedure of Draize.
5. **Eye Irritation** — refers to a test of a single dose of a chemical with \_\_\_\_ grams or \_\_\_\_ milliliters into the conjunctival sac of the eye of the test animals (usually albino rabbits). Observations are made at 24, 48, 72 hours, 5 and 7 days, post-application and scored according to the procedure of Draize.
6. **Additional or Modified Tests:**

QUALITY CONTROL TEST METHOD, CHEMICAL RESOURCES DIVISION, 3M COMPANY

ISSUED: 10-6-78

QCM # 53.14

TITLE: PERCENT FLUORINE IN AQUEOUS FILM FORMING FOAM CONCENTRATES BY SCHÖNIGER COMBUSTION

SCOPE:

This procedure is used to quantitatively determine the fluorine concentration in AFFF concentrates. A sample is concentrated and then burned in pure oxygen, transforming the fluorine into hydrofluoric acid. The acid is neutralized to free fluoride ions and direct fluoride ion concentration is determined by the specific ion electrode.

APPARATUS:

1. Flask, oxygen combustion, borosilicate glass, 500 ml, A.S.T.M. E205
2. Stopper, borosilicate glass with fixed platinum sample holder, A.S.T.M. E205
3. Wire, platinum, 0.6 - 0.8 mm diameter
4. Filter paper, Whatman No. 40 or equivalent, 4 x 1.5 cm strips with hole punched in one end (use standard hole puncher)
5. Dessicator
6. Weighing dish, ground glass, 50 x 33 mm
7. Balance, analytical, accurate to five places
8. Flask, volumetric 100 and 500 ml
9. Cylinder, graduated, 25 ml
10. Regulator, oxygen cylinder, 0-1000 psi
11. Tape, vinyl, 2 inch
12. Wrist - action shaker or equivalent
13. Digital pH/MV meter, Orion Model 901 or equivalent, Orion Research, Inc.
14. Manual electrode switch, Orion Model 605 or equivalent, Orion Research, Inc.
15. Specific ion electrode, No. 94-09, Orion Research, Inc.
16. Reference electrode, No. 90-01, Orion Research, Inc.
17. Beakers, polyethylene, 50 ml
18. Magnetic stirrer and stirring bars
19. Funnel, 50 mm fluted
20. Wash bottle for TISAB/DI water solution
21. Oven, Forced Air set to 105°C
22. Oven, convection set to 100°C
23. Polyethylene bottle, 16 ounce

REAGENTS:

1. Dionized water
2. Oxygen (99% pure)
3. Orion TISAB solution No. 94-09-09A, Orion Research, Inc.
4. TISAB/DI water solution (50/50): Place 1500 ml TISAB in gallon plastic jug. Add 1500 ml DI water and mix thoroughly.
5. Orion reference electrode filling solution No. 90-00-01
6. Stock fluoride standard solution (100 ppm), Orion No. 94-09-07. Orion Research, Inc.
7. 10 ppm Standard fluoride solution - pipet 50 ml of 100 ppm standard stock solution into a 500 ml volumetric flask, dilute to the mark with 50/50 TISAB/DI water solution and mix thoroughly. Store the solution in a labeled 16 ounce polyethylene bottle.

SAFETY PRECAUTIONS:

1. Though oxygen is not combustible, it supports combustion; flow should be controlled and shut off when not in use.
2. Orion TISAB solution and fluoride standard solutions are irritating to eyes and mucous membranes. Wash all contacts with water. Avoid prolonged inhalation.

PROCEDURE:

I. Concentrating Sample

1. Obtain tare weight of a ground glass weighing dish on the analytical balance to 0.0001 g. ( $W_1$ ).
2. Add about 10 grams (10 droppers) sample to the weighing dish, cover dish and reweigh ( $W_2$ ).
3. Place dish uncovered in forced air oven set to 105°C. for 45 minutes.
4. Allow dish to cool in desiccator and reweigh ( $W_3$ ). Sample should remain fluid after cooling. If solids are visible repeat steps 1 thru 4 using less drying time.

II. Combustion

Note: Sample should be prepared in duplicate in case of incomplete combustion.

1. Fold filter paper strips as shown and pre-dry (at 105°C.) convection oven.
2. Allow paper strips to cool in desiccator. A supply of preconditioned papers should be kept on hand.
3. Using a gem clip for a hook, weigh the paper strip to 0.00001 ( $W_4$ ).
4. With paper folded as shown, dip folded portion in product, so that each end is free of product. Touch last drop off on dish and reweigh to 0.00001 g. ( $W_5$ ).
5. Place paper on gem clip hanger and dry for one hour in 100°C convection oven.
6. Attach paper to platinum wire screen by tying platinum wire through screen and hole in end of paper.
7. Place 25 ml of DI water in combustion flask and fill with oxygen by blowing oxygen (moderate flow) into flask for at least 30 seconds.
8. Light the filter paper on lower edge (opposite hole) and quickly insert the paper closing the flask immediately. Discard sample if some of product burns before flask is completely closed.
9. Tilt the flask about 45° to keep a burning piece of paper from falling into the water. Be certain sample burns completely.
10. Shake the closed flask vigorously. A white smoke will form in the flask.

fold  
line

sample

PERCENT FLUORINE IN AQUEOUS FILM FORMING FOAM CONCENTRATES BY SCHONIGER COMBUSTION

Page 3

QCM # 53.14

PROCEDURE: continued....

11. With stopper taped securely, place on wrist-action shaker. Allow to shake until flask is clear of smoke (5-10 minutes).
12. Open the flask by placing 5 ml of DI water around the stopper and lifting it carefully so that the water is sucked into the flask.
13. Rinse stopper and wire screen into the flask with 50/50 TISAB/DI water solution using a wash bottle.
14. Transfer flask contents to a 100 ml volumetric flask using a funnel.
15. Rinse flask three times with 50/50 TISAB/DI water solution. Transfer rinses to volumetric flask.
16. Rinse funnel and dilute to 100 ml mark with TISAB/DI water solution.
17. Mix flask contents thoroughly.

III. Sample Analysis

**CAUTION:** Refer to QCM-87.8.3.2 for operation of the Orion model 901 ionalyzer.  
**USE CARE IN HANDLING ELECTRODES.**

1. Fill the reference electrode with Orion Reference Electrode Filling Solution No. 90-00-01. The filling solution level must always be visible 1 inch above the surface of the sample.
2. Wipe the electrodes with a clean dry tissue, being careful not to scratch the electrode tips.
3. Pour 20-30 ml of the ppm standard into a 50 ml polyethylene beaker. Agitate slowly with magnetic stirrer.
4. Immerse electrodes. Do not allow stirring bar to strike the electrodes.
5. Set the "STD VALUE" scale to 10.0 (standard concentration, ppm).
6. Set the slope of the electrode (from electrode calibration chart) on the "SLOPE" scale.
7. Place the electrodes in the standard, agitate slowly and set the "MODE" selector to "CONCN".
8. Press the "CLEAR/READ MV" button and allow the millivolt reading to stabilize. (Compare reading to calibration chart to verify integrity of the standard.)
9. Press the "SET CONCN" button. The value on the "STD VALUE" scale will be displayed.

PERCENT FLUORINE IN AQUEOUS FILM FORMING FOAM CONCENTRATES BY SCHONIGER COMBUSTION

Page 4

QCM-53.14

PROCEDURE: continued.....

10. Remove the electrodes from the standard, rinse and blot, and place in the unknown sample.
11. Agitate slowly and allow reading to stabilize. Reading obtained will be ppm fluorine (F).
12. If more than one sample is to be analyzed, DO NOT press CLEAR/READ MV or change the MODE selector.

CALCULATIONS:

$$\text{Concentration (C)} = \frac{W_3 - W_1}{W_2 - W_1}$$

$$\% \text{ Fluorine} = \left[ \frac{(F)(V)}{W_5 - W_4} \times 100 \right] \times C$$

Where: C = Sample concentration factor  
W<sub>1</sub> = Tare wt. of drying dish  
W<sub>2</sub> = Wt. of dish and sample  
W<sub>3</sub> = Wt. of dish and concentrated sample  
W<sub>4</sub> = Wt. of paper strip in milligrams  
W<sub>5</sub> = Wt. of paper strip and sample in milligrams  
F = Concentration of fluorine in sample in parts per million (milligrams per liter)  
V = Volume of diluted sample in liters (0.100)

AVERAGE TEST TIME: 1.0 hours

REFERENCE:

1. Mil-F-24385B, dated 31 May 1978 requirement, Section 3.3.4.
2. QCM #53.13 dated 7-27-78, J. M. Stovall
3. Memo, J. T. Speake to T. W. Hill, dated 9-26-78, "Fluorine Content of AFFF Concentrates".

BY:

J. T. SPEAKE

REVIEWED:

T. W. HILL

APPROVED:

H. W. KELLEY

APPENDIX E  
TYPICAL STATE EMISSION-CONTROL REGULATIONS

APPENDIX E  
TYPICAL STATE EMISSION-CONTROL REGULATIONS

This appendix provides a summary of Connecticut regulations which are typical of state emission control requirements for carbon monoxide, nitrogen oxides, total suspended particulates, and volatile organic compounds emissions.

1. CONTROL OF CARBON MONOXIDE (CO)

According to Connecticut regulations for the emissions of CO from steel or petroleum processing facilities, the waste gas containing CO must be incinerated in a direct flame afterburner, boiler, or equivalent device at a temperature of 1300° F for a period of not less than 0.3 seconds.

2. CONTROL OF NITROGEN OXIDES (NO<sub>x</sub>)

For gas fired fuel burning equipment, the Connecticut regulations stipulate that the NO<sub>x</sub> emissions calculated as nitrogen dioxide must not exceed 0.2 pounds per million Btu of heat input. This requirement applies to all equipment with a maximum capacity rating above 250 million Btu per hour. For equipment rated between 5 and 250 million Btu/hr., these regulations shall apply unless the Commissioner is satisfied that it is not technically or economically feasible for a unit of the size considered.

3. CONTROL OF PARTICULATE MATTER

Connecticut has separate sets of emission standards for particulate matter emissions from fuel burning equipment and process industries. For fuel burning equipment, no person shall cause or permit the emission from fuel burning equipment of particulate matter in excess of 0.20 pounds per million Btu of heat input for existing sources and 0.10 pounds per million Btu of heat input for new sources.

For process industries, the emission of particulate matter must not exceed the amount shown below for the process weight allocated to the source.

Process Weight Rate	Emission Rate	Process Weight Rate	Emission Rate
lbs./hr.	lbs./hr.	lbs./hr.	lbs./hr.
50	0.36	60,000	29.60
100	0.55	80,000	31.19
500	1.53	120,000	33.28
1,000	2.25	160,000	34.85
5,000	6.34	200,000	36.11
10,000	9.73	400,000	40.35
20,000	14.99	1,000,000	46.72

For the purpose of this regulation, process weight per hour is the total weight of all materials introduced into any specific process that may cause any emission of particulate matter. Solid fuels charged will be considered as part of the process weight, but liquid and gaseous fuels and combustion air will not. For a cyclical or batch operation, the process weight per hour will be derived by dividing the total process weight by the number of hours in one complete operation from the beginning of any given process to the completion thereof, excluding any time during which the equipment is idle. For a continuous operation, the process weight per hour will be derived by dividing the process weight for a typical period of time by the length of that period of time.

#### 4. CONTROL OF VOLATILE ORGANIC COMPOUNDS (VOC)

Connecticut has established stringent emission limitations on photochemically reactive volatile organic compounds and less stringent limitations on non-photochemically reactive VOC. According to the regulations the discharge of photochemical reactive organic compounds is generally limited to 40 pounds per day or 8 pounds per hour unless the discharge has been reduced by at least 85 percent. For non-photochemically reactive species, the general limitation is 800 pounds per day or 160 pounds per hour unless the discharge has been reduced by at least 85 percent. Photochemically reactive organic compounds are defined as follows:

- . Group R1: Any hydrocarbons, alcohols; aldehydes, esters, ethers, or ketones, having an olefinic or cyclo-olefinic type of unsaturation.
- . Group R2: Any aromatic compounds with eight or more carbon atoms to the molecule except ethylbenzene, phenyl acetate, and methyl benzoate.



- . Group R3: Any ketones having branched hydrocarbon structures, and ethylbenzene, trichloroethylene, and toluene.

Any solvent mixture will be considered photochemically reactive if the composition of such mixture exceeds any of the following limits by volume:

- . 5 percent of any combination of chemical compounds in group R1.
- . 8 percent of any combination of chemical compounds in group R2.
- . 20 percent of any combination of chemical compounds in group R3.
- . 20 percent of any combination of chemical compounds in groups R1, R2, and R3.

Whenever any organic solvent or any constituent of any organic solvent may be classified from its chemical structure into more than one of the above groups of organic compounds, it shall be considered a member of the most reactive chemical group, which is that group having the least allowable percent of the total volume of solvents.

Any solvent not classified above and any solvent mixture which does not exceed any of the above limits shall be considered photochemically nonreactive.

APPENDIX F

CROSS-REFERENCE WITH NTEC STATEMENTS  
OF WORK

## APPENDIX F

### CROSS-REFERENCE WITH NTEC STATEMENTS OF WORK

The following index cross-references the Phase I report contents with the major objectives outlined in the Statements of Work for Phases I and II. The key point is that these objectives have been addressed with the most rational and reasonable level of effort within the constraints of the current contract. Any divergence from due course is a direct result of experience gained during the assignment. For example, there was no need for further modification of the OBA once its applicability was not considered adequate for fire fighting.

<u>Statement of Work Number</u>	<u>Brief Summary</u>	<u>Report Section(s)</u>	<u>Page(s)</u>
224-1188	Analysis of Stabilized Propylene Glycol for 19F1 Fire-Fighting Trainer Flame Environment	2.3.3	14
		4.4	43
		6.3	60-65
		7.2	73-74
		8.4	80
224-1189	Analysis of AFFF Fire Extinguishing Agent	2.3.1	7,13
		4.4	43
		6.3	60-65
		6.5-6.6	66-68
		6.7.2	69
		7.4	75
		8.5	81
224-1190	Analysis of PKP Fire Extinguishing Agent	8.6	82
		Appendix D	
		2.3.2	13
		4.4	43
		6.3	60-65
		6.5-6.6	66-68
224-1191	Analysis of Substitute AFFF Fire Extinguishing Agent	7.4	75
		8.5	81
		7.1.1	70-72

<u>Statement of Work Number</u>	<u>Brief Summary</u>	<u>Report Section(s)</u>	<u>Page(s)</u>
224-1192	Analysis of Substitute PKP Fire Extinguishing Agent	7.1.2	72-73
224-1193	Analysis of Gray Water Recycling	8.6	82
224-1194	Analysis and Modification of Simulated OBA for Fire- Fighting Training	2.8.2 6.4 6.7.1 8.2 8.6	18 65-66 68 78 82