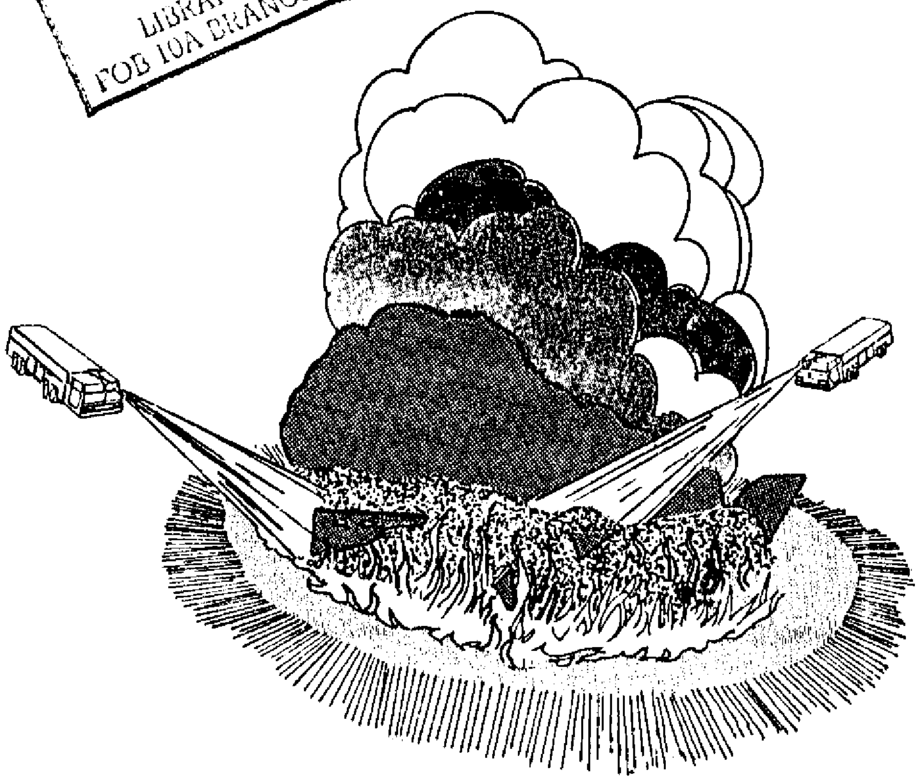
U.S. Department
of Transportation
**Federal Aviation
Administration**

# Design Standards for an Aircraft Rescue and Firefighting Training Facilit

## Advisory Circular 150/5220-17

Date: April 1, 1988





U.S. Department of Transportation
Federal Aviation Administration

# Advisory Circular

Subject: DESIGN STANDARDS FOR AN AIRCRAFT RESCUE AND FIREFIGHTING TRAINING FACILITY

Date: 4/1/88
Initiated by: AAS-120

AC No: 150/5220-17
Change:

1. **PURPOSE.** This advisory circular (AC) contains standards, specifications, and recommendations for the design of an aircraft rescue and firefighting training facility.

2. **APPLICATION.** Conformance with standards and specifications contained in this AC is a prerequisite to receiving Federal grant-in-aid assistance for the design and installation of an aircraft rescue and firefighting training facility. The FAA recommends the use of this document for the design of non-federally assisted projects. ***THE STANDARDS AND SPECIFICATIONS ARE IN LOWER CASE BOLD ITALICS.***

3. **RELATED READING MATERIAL.** Publications referenced within this advisory circular can be obtained by writing to:

**a.** FAA Advisory Circulars (AC), U.S. Department of Transportation, Utilization and Storage Section, M-443.2, Washington, DC 20590.

**b.** American Petroleum Institute (API), 1220 L Street, NW., Washington, DC 20005.

**c.** American Society of Mechanical Engineers (ASME), United Engineering Center, 345 East 47 Street, NY 10017 for ANSI B-31, American National Standard Code for Pressure Piping and ASME publications.

**d.** American Society for Testing and Materials (ASTM), 1916 Race Street, Philadelphia, PA 19103.

**e.** American Water Works Association (AWWA), 6666 W. Quincy Avenue, Denver, CO 80235.

**f.** American Welding Society, Inc. (AWS), 550 N.W. LeJeune Road, P.O.Box 351040, Miami, FL 33135.

**g.** National Association of Corrosion Engineers (NACE), Box 218340 Houston, TX 77218.

**h.** National Fire Protection Association (NFPA), Batterymarch Park, Quincy, MA 02269.

**i.** National Sanitation Foundation (NSF), 3475 Plymouth Road, P.O. Box 1468, Ann Arbor, Michigan 48106.

**j.** Steel Tank Institute (STI), 666 Dundee Road, Suite 705 Northbrook, IL 60062.

**k.** Underwriters Laboratories Incorporated (UL), 333 Pfingsten Road, Northbrook, IL 60062. Underwriters Laboratories Incorporated of Canada (ULC), 7 Crouse Road, Scarborough, Ontario, Canada M1R3A9.

4. **METRIC UNITS.** To promote an orderly transition to metric (SI) units, this AC contains both English and metric dimensions. The metric conversions may not be exact, and pending an official changeover to this system, the English system governs.

Leonard E. Mudd

LEONARD E. MUDD
Director, Office of Airport Standards

# CONTENTS

## CHAPTER 1. PLANNING PHASE

### Section 1. Introduction



### Section 2. Derivation of Design Parameters for Training Fire Size



### Section 3. Burn Area Structural Requirements



### Section 4. Site Selection



### Section 5. Burn Area Fuel Requirements



## CHAPTER 2. DESIGN PHASE



### Section 1. Concrete Design Alternative



### Section 2. Flexible Membrane Liner Design Alternative



### Section 3. Support Components

## Section 4. Support Systems



# CHAPTER 3. CONSTRUCTION PHASE



## APPENDIX



## FIGURES

# TABLES

# CHAPTER 1. PLANNING PHASE

## Section 1. Introduction

**1. THE TRAINING FACILITY.** Aircraft rescue and firefighting (ARFF) service personnel require realistic training in the application of extinguishing agents using the airport's ARFF vehicle(s) and other agent application devices on an appropriately sized fire area. The fire area, termed the burn area structure, is the key element of the training facility. Determining an appropriate size for the burn area structure is the starting point for the design of a training facility. Other basic elements of the training facility are then individually designed to support the burn area structure. Figure 1-1 illustrates the basic elements contained in a typical training facility.

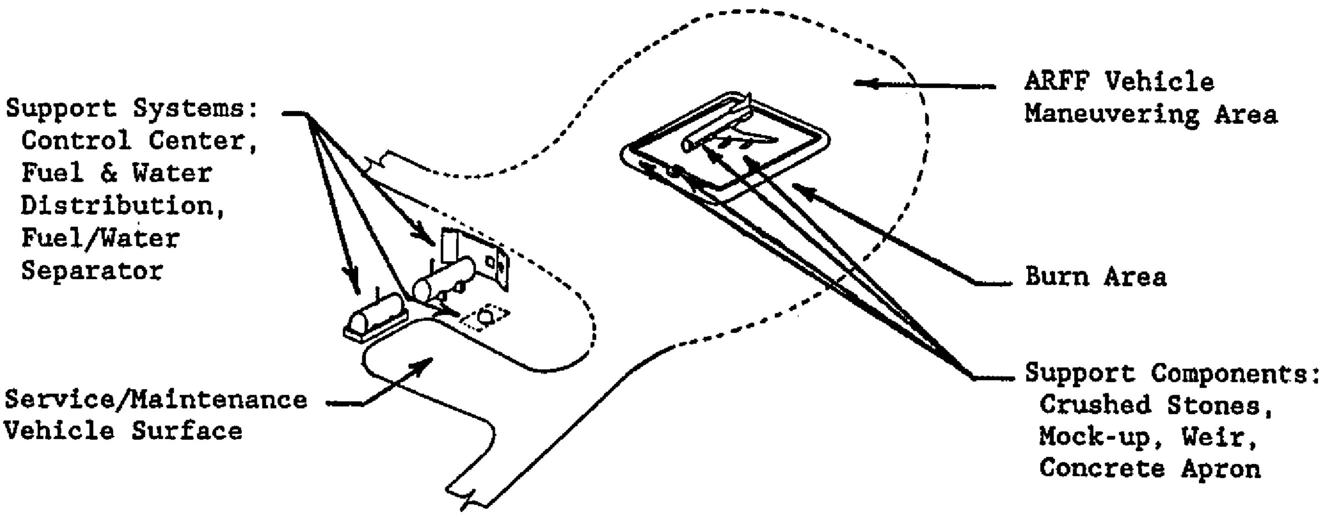



**Figure 1-1. Elements of a training facility**

**2. TERMINOLOGY.**

**a. Training Facility.** The training facility is composed of the ARFF vehicle maneuvering area, burn area structure, support components, and support systems. The areas for these items make up the total area devoted to the training facility.

**b. ARFF Vehicle Maneuvering Area.** This area, which surrounds the burn area structure, allows ARFF vehicles to maneuver within the training facility area and offers different attack approaches to the burn area structure.

**c. Burn Area Structure.** The burn area structure is designed specifically for the creation of a "realistic" aircraft accident environment.

**d. Support Components.** The basic components needed to support the simulation of an aircraft fire and recycle unburned fuel and used water. Included are: an aircraft mock-up, crushed stones, apron and curb or berm, weir, and vented fuel/water separator.

**e. Support Systems.** The basic systems needed to support the training fire and recycle unburned fuel and used water. Included are: the control center and fuel and water distribution systems. Each system is further composed of individual components that makeup the system, e.g., the fuel distribution system consists of a fuel storage tank, pumps, associated piping, etc.

## Section 2. Derivation of Design Parameters for Training Fire Size

**3. TRAINING FACILITY AND FIRE SIZE.** Meaningful aircraft fire suppression training must present the firefighter with a realistic challenging aircraft fire. In addition, this fire must be extinguishable with the fire suppression equipment that a proficient firefighter is expected to use in an actual aircraft emergency. The three interdependent variables which effect these two requirements are discussed below.

**a. Agent Application Rates.** Agent application rate refers to the gallons of foam solution reaching a given square foot of fire in one minute. This variable plays a central role in the design of the training facility's burn area. Each agent has two agent application rates of importance; the "critical application rate" (CAR) and the recommended minimum "operational application rate" (OAR).

**(1) Critical Application Rate (CAR).** For a given foam solution, the CAR is defined as the lowest rate at which that agent can be applied to a given fire area (under a fixed set of fire conditions) and extinguish that fire. The CAR of fire fighting foam agents is used to quantitatively compare relative agent effectiveness. Although not directly used in fire training facility design, it can be used to create a more challenging fire training problem at training sites where a larger burn area is not available. The CAR is also used in determining which foam agent is more cost-effective. For example, if the CAR of a "low priced" foam concentrate requires the use of more agent per square foot of fire extinguished, it may turn out that the "higher priced" foam concentrate with a lower CAR is really cheaper in terms of dollars per square foot of fire suppression capability.

**(2) Operational Application Rate (OAR).** As indicated in Figure 1-2, the recommended OAR is approximately three times the CAR of the agent for a given hazard. This relationship has been established by extensive testing and has been found to be operationally practical in terms of fire control time, average firefighter skills, and the amount of agent required. It can also be seen from this figure that increasing the recommended OAR will generally reduce the fire control time. However, greatly exceeding the recommended OAR will consume agent with no appreciable improvement in fire control time, i.e., more is not necessarily better. On the other hand, as the OAR approaches the CAR, control time is prolonged; hence, a more challenging fire situation can be created in the same sized burn area. However, if it falls below the CAR the fire cannot be extinguished with that agent.

**b. Agent Applicator Discharge Rates.** Agent discharge rates are used to describe or specify the desired capability of a firefighting apparatus to deliver agent from a specified applicator. This differs from agent application rates. The important relationship between these two terms is that if the agent discharge rate, the usable volume of a given firefighting apparatus, and the OAR (for the agent that is to be used) are known, the size of the fire area which this specific combination can be expected to control in one minute can be calculated. In other words, the total fire extinguishing capability in terms of agent volume, time for application and maximum area that can be extinguished is defined. Hence, the maximum "practical critical fire area" (PCA), that can be protected by that vehicle is known.

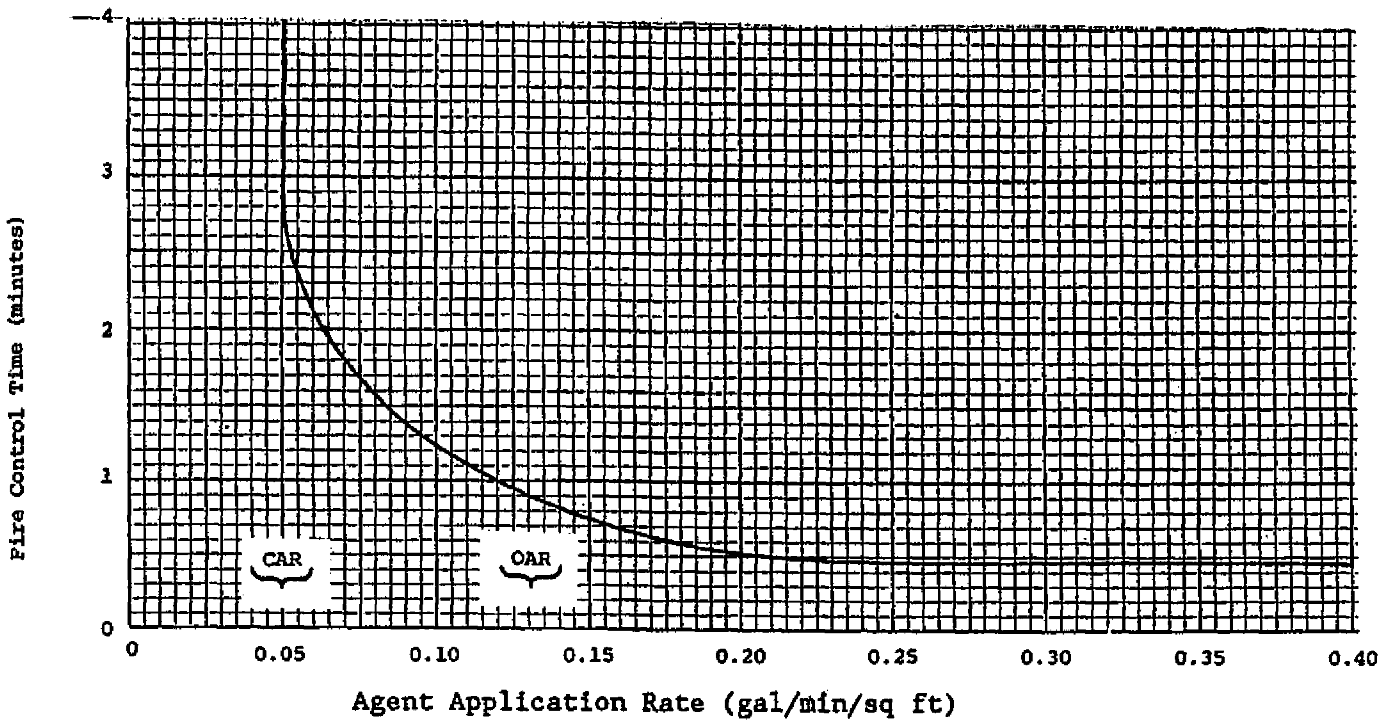



**Figure 1-2. Typical relationship between control time and foam agent application rate for AFFF**

c. **Practical Critical Fire Area (PCA).** Figure 1-3 is a schematic representation of the relationship between the theoretical critical fire area, the PCA, and a large aircraft. Fires outside the theoretical critical area have no immediate impact on the life safety/rescue problem at the aircraft. In contrast, the PCA is very important in that it is used in aircraft rescue and firefighting system planning to quantify the tactical and logistical aspects of the problem. Because the actual size of the PCA is a function of the length and width of the specific aircraft of interest, it is very important in ARFF training facility design.

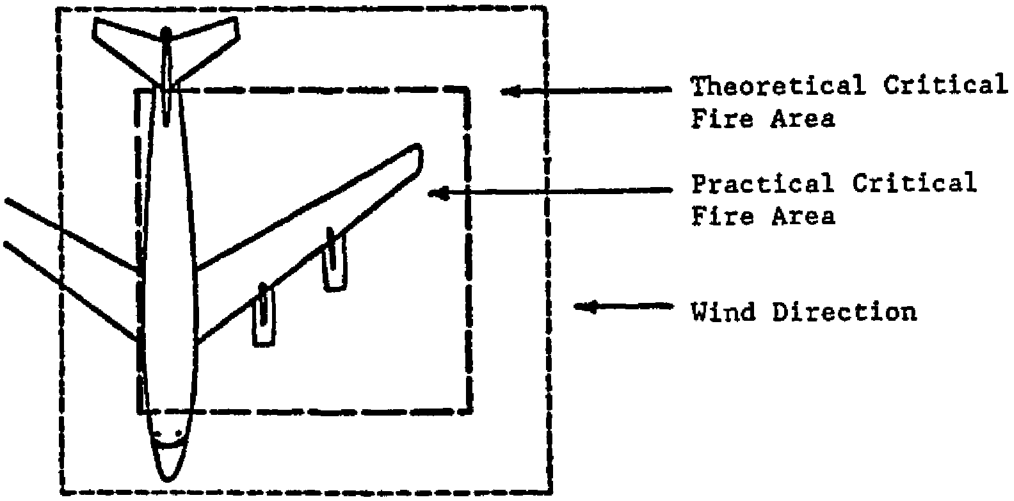



**Figure 1-3. The fire area**

**4. PCA/FIRE SIZE, DISCHARGE RATE AND OAR RELATIONSHIP.**

**a. Logistics and Tactics.** The initial operational objective of the ARFF service is to provide a viable evacuation route for passengers exiting through the PCA. This requires that the ARFF service has the capability to at least control/extinguish fires within this area in one minute or less after the first application of agent. Therefore, there is a need to quantitatively define the logistical and tactical requirements of the PCA, which in effect, defines the minimum ARFF service requirements for a given aircraft size. Drawing on the information developed in the preceding discussions, the means exist to quantify the ARFF service requirements and to relate the results to training facility requirements. For example, Table 1-1 provides the PCA by aircraft size and the literature (manufacturer's or R&D) provides the OAR for generic foam agents, e.g., AFFF and FFFP = O.13 (aqueous film forming foam and film forming fluoroprotein foam), FPF = 0.16 (fluoroprotein foam), and PF = 0.20 (protein foam). With this information, the needed ARFF vehicle(s)' capability can be quantitatively specified. That is, the agent volume to be carried and the optimum discharge rates for the agent applicators can be calculated, assuming efficient application by the operator.

**b. Fire Size for Training.** It is generally accepted that if training is to be meaningful, it must be a practical representation of the operational task. It follows then that the training facility for a given aircraft size should have a burn area structure equal to the PCA of Table 1-1. Unfortunately, available land or other constraints may make it impractical to provide a training facility with such a large burn area structure. However, if the discharge rates of the agent applicators to be used in training are kept in strict proportion to the available burn area, meaningful training can be accomplished. Therefore, a reduced burn area structure can be based on the proportional relationship between fire area, the discharge rate of the agent applicator(s), and the OAR of the agent(s) to be used. In other words, when the available burn area is known (and fixed) and test data or the literature (manufacturer's or R&D) provide the OAR, the appropriate agent applicator discharge rates required for meaningful training can be calculated. This strict applicator discharge rate/burn area relationship must be maintained. Otherwise, if the OAR used in training is too high, the trainee will not be challenged—only led to believe that the needed skills have been acquired. Conversely, if the OAR is too small in relation to the burn area, the fire will go out only after all available fuel has been consumed, not because of the trainee's effort or skill. In either case, no valuable training will have been obtained for the resources expended.

## Section 3. Burn Area Structure Requirements

**5. SIZING METHODS.** Two sizing methods are available. One method, referred to as the Discharge Method, is based on limited land area, and it restricts the discharge rate of the agent applicator (ARFF vehicle turret or handlines) to be used in training. The other method, referred to as the Airport ARFF Index Method, is based on the PCA of an average aircraft size that is common to the airport. The limited discharge rate, which permits a smaller sized burn area structure than the airport ARFF index method, may be employed when land or other constraints are present. The airport ARFF index method sets the upper square footage limits.

**a. Discharge Rate Method.** *A burn area structure using the discharge rate method, based on the proportional relationship between its size and the discharge rate of the agent applicator(s) to be used, shall be in accordance with either figures 1-4 or 1-5.*

(1) This method should be used when available land or other constraints may make it impractical to provide a burn area structure equal to the square footage of the practical critical fire area (PCA) of Table 1 for a given airport ARFF index. This method allows equivalent, effective training on a smaller sized burn area structure by keeping the discharge rates of the agent applicators to be used in training in *strict* proportion to the available burn area.

(2) **Figures 1-4 & 1-5.** A graphic solution for determining the square footage needed under the discharge rate method is presented by Figures 1-4 and 1-5 for known generic foam agents. Normally, the square footage for an appropriate burn area structure is determined by dividing the discharge rate of the agent applicator(s) to be used by the OAR of the agent to be used. Use of Figures 1-4 and 1-5 eliminates the need for these calculations. Note that the square footage presented in these figures is only for the burn

area structure. Additional land area is necessary for the other elements that comprise the training facility. Two examples of how to use these figures are presented below.

(a) **Limited Land Area.** Where the maximum available land for the burn area structure is already fixed, the largest appropriate discharge rate to be used on that structure can be determined by entering either Figure 1-4 or 1-5. First enter along the burn area square footage axis (horizontal) and proceed vertically up to the appropriate generic foam OAR line. Then proceed directly to the left to intersect the discharge rate axis (vertical). For example, trace 1 of Figure 1-4 illustrates that a discharge rate of 195 gpm (738 l/m) is the maximum permissible rate for realistic training for a burn area of 1,500 square feet (139 square meters) using AFFF. This area could be accommodated by a 44 x 33-foot rectangle (13.5 x 10-meter) or a 44-foot diameter circle (13.5-meter).

(b) **Fixed Discharge Rate.** Where the minimum available discharge rate is fixed (as by a vehicle turret), the appropriate square footage can be determined by entering the same figures in reverse. First enter along the discharge rate axis (vertical) and proceed directly to the right to the appropriate generic foam OAR line. Then proceed vertically down to intersect the burn area square footage axis (horizontal). For example, if two vehicles with 750 gpm (2 838 l/m) discharge each are to be used, trace 2 of Figure 1-5 illustrates that a burn area of approximately 11,540 square feet (1 072 square meters) is necessary for a discharge rate of 1,500 gpm (5 676 l/m) using AFFF. This value is acceptable for land limited training facilities at airports with an ARFF D or E index as long as firefighting training operations do not exceed a total discharge rate of 1,500 gpm (5 676 l/m). Similarly, larger or smaller burn areas can be derived for ARFF training operations where larger or smaller discharge rates are expected. However, for economies of construction and operations and maintenance, the upper limit for burn area size is set by Table 1-1.

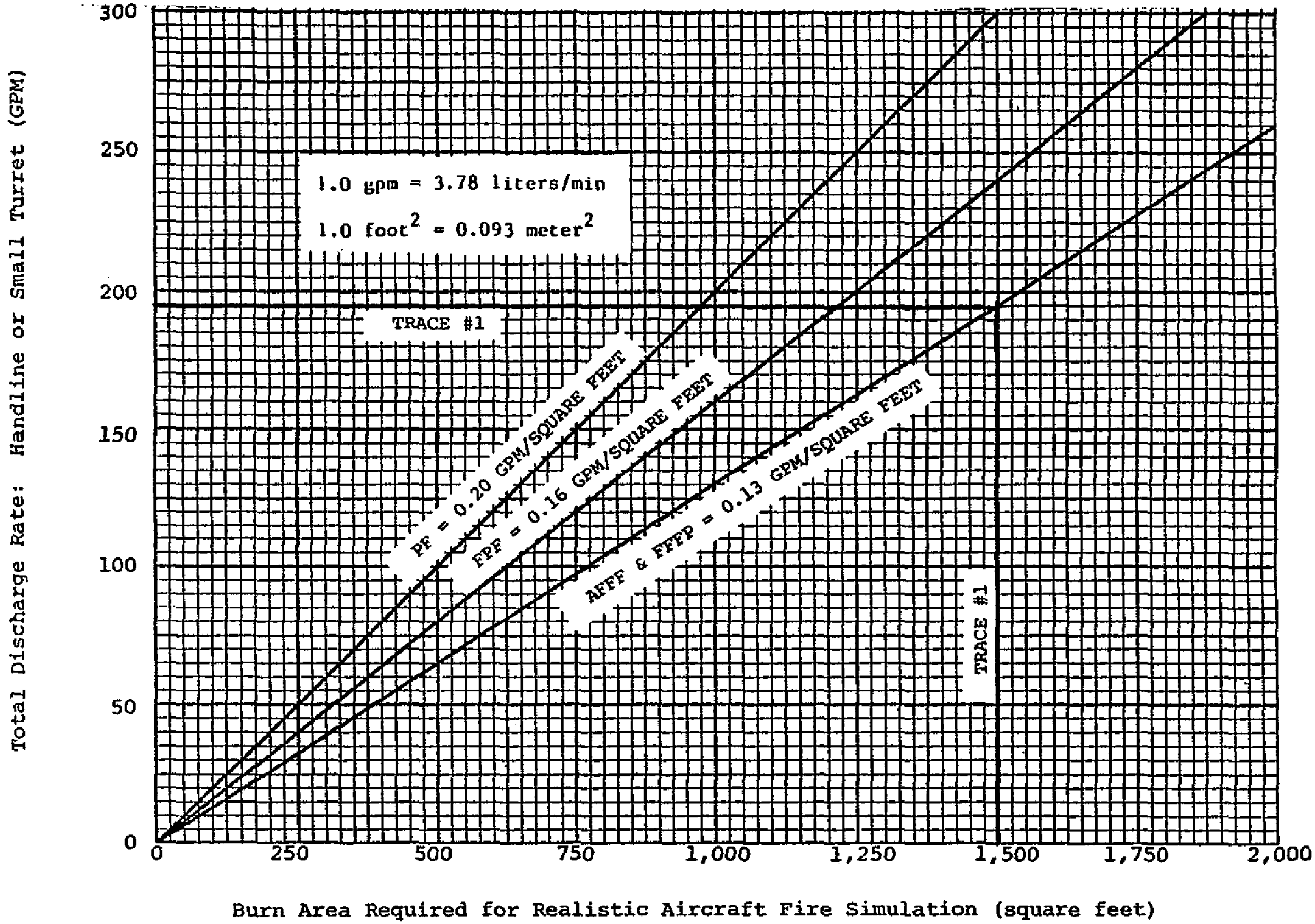



Figure 1-4. Low discharge rates vs training fire area requirements

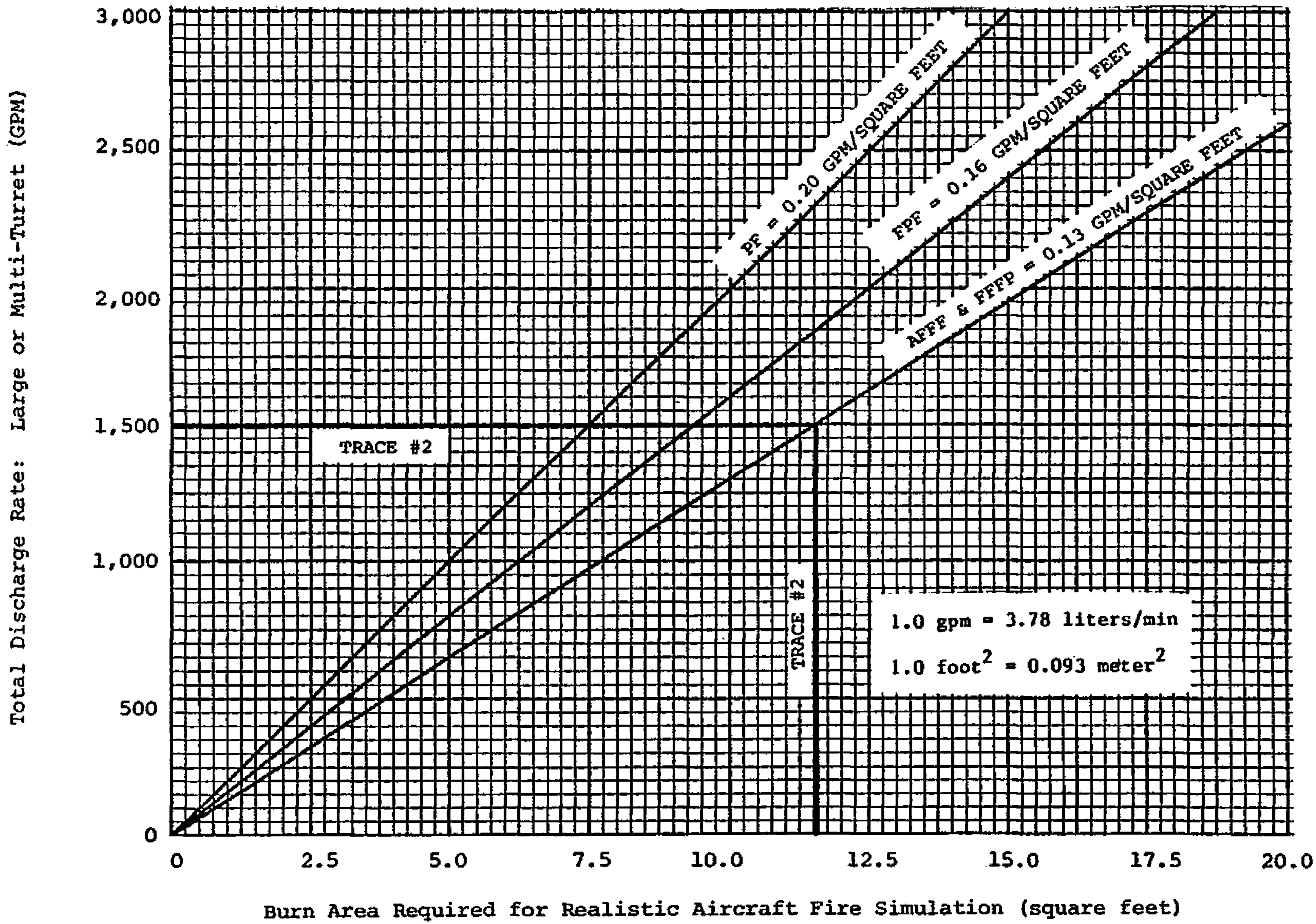



Figure 1-5. High discharge rates vs training fire area requirements

b. Airport ARFF Index Method. *The size of a burn area structure using the airport ARFF index method, shall be in accordance with the practical critical fire area (PCA) of Table 1-1 for a given airport ARFF index.* Although the size of the PCA for a specific aircraft is a function of the fuselage length and width, it has been found that for economies of design, the use of average aircraft dimensions, based on operationally similar groups of aircraft, provides technically acceptable values for airport indexed PCAs. These airplane groupings are commonly referred to as airport ARFF index. Table 1-1, from AC 150/5210-6B, Aircraft Fire and Rescue Facilities and Extinguishing Agents, presents the results of those PCA calculations. The last two columns are added for a quick estimate of the area needed.

### Table 1-1. Burn area structures as a function of airport ARFF index

| Airport ARFF Index [1] | Overall Aircraft Lengths (feet) | | | Average Fuselage Width (feet) | Practical Critical Fire Area (PCA) (square feet) | Rect. Burn Area (L/W=4/3) (feet) | Circular Burn Area Diameter (feet) |
|---|---|---|---|---|---|---|---|
| | Lower Limit | Average | Upper Limit | | | | |
| GA-1 | 30 | 38 | 45 | 6 | 1,171 | 40 x 30 | 39 |
| GA-2 | 45 | 53 | 60 | 10 | 1,775 | 49 x 36 | 48 |
| A | 60 | 75 | 90 | 10 | 5,527 | 86 x 64 | 84 |
| B | 90 | 108 | 126 | 10 | 7,959 | 103 x 77 | 101 |
| C | 126 | 143 | 160 | 10 | 10,539 | 118 x 89 | 116 |
| D | 160 | 180 | 200 | 20 | 14,475 | 139 x 104 | 136 |
| E | 200 | 225 | | 20 | 18,090 | 155 x 116 | 152 |

[1] Airport ARFF index dimensions are defined in AC 150/5210-6B, Aircraft Fire and Rescue Facilities and Extinguishing Agents.

6. THE BURN AREA STRUCTURE. *The burn area structure from either sizing method shall be:*

a. Constructed of materials that retain their material and performance integrity under cyclic thermal, hydraulic, mechanical, and bearing stresses, and long term environmental exposure.

b. In compliance with federal, state, or local environmental standards for groundwater protection (see paragraph 7).

c. Designed so that fuel, water, and ignition can be centrally controlled from an observation area; e.g., a training officer can stop the flow of fuel/water and regulate the location of a fire within the burn area.

d. Capable of creating a variety of fire suppression training scenarios involving forcible entry (panels, doors), fuel spill fires, 3-dimensional or cascading fires, ruptured fuel lines, engine fires, tire/wheel fires, and interior cabin and cargo fires.

e. Capable of rapid recycling of fuel and water.

## Section 4. Site Selection

7. COMPLIANCE WITH ENVIRONMENTAL AND FIRE REGULATIONS. A search should be made of all local, state, and Federal environmental and fire regulations that may impact the design, material selection, and operation of the training facility. Presently, a number of jurisdictions have in place extensive environmental and fire regulations which impact the design, material selection, and operation of such training facilities. Additionally, the use of operating permits and inspection programs is commonplace. Once these requirements are known, the training facility must be developed and designed to satisfy these requirements. All special restrictions or specific laws regarding special fire protection equipment, fuel tank spill and overfill protection equipment or performance criteria for selected construction materials such as flexible mem-

brane liners and single or double walled fuel tanks should be noted. Plans for near-term and long-term land use should also be identified and addressed. The operative words of an environmental and fire regulatory search are review and compliance.

**8. ARFF VEHICLE MANEUVERING AREA.** *The ARFF vehicle maneuvering area shall be compatible with the fire extinguishing performance and mobility characteristics of the ARFF vehicle(s).*

**a. Extinguishing Performance.** Performance items which affect the maneuvering area siting and size requirements are: the turret(s) discharge ranges (minimum and maximum) for discharging foam in dispersed and straight stream patterns for both stationary and pump and roll operations.

**b. Mobility Characteristics.** The size of the maneuvering area should allow for the ARFF vehicle turning radius, backup requirements, and length when parked perpendicular to the burn area structure and still allow the passage of other ARFF vehicles. More than one vehicle approach path to the burn area should be included. This area should also provide room for future expansion for additional or more demanding ARFF vehicle models.

**c. Maneuvering Surface.** Soil type should be of good load bearing capacity or be prepared to withstand fully loaded ARFF vehicles operations without severe rutting damage. Consideration should be given to accelerating and decelerating traction forces and turning actions of wheels. This area should be sloped in one of two ways. Training facilities designed with a berm should slope the entire maneuvering surface away from the burn area. Non-berm training facilities should slope the surface in two directions. The inner most section up to 10 feet (3.3 m) should slope towards the rigid apron where a smooth transition should exist between the two surfaces. The remaining outer portion of this surface should slope away from the burn area, thus reducing the quantity of collected rainfall and snow melt in the recycling system. For airport *operational safety, ARFF vehicles entering the training facility directly from a taxiway or runway should* use access roads that are paved for at least the 500-foot (152-meter) portion leading to/from the taxiway/runway. This lessens the possibility of carrying foreign objects into the those parts of the airport intended for the surface movement of aircraft.

**9. BURN AREA STRUCTURE CLEARANCES.** The burn area structure should be compatible with the surrounding air and land environments.

**a. Air Operations Hazard.** The burn area structure should be located where:

(1) Generated smoke will not become a hazard to aircraft operations or interfere with air traffic control (ATC) tower surveillance of the movement area.

(2) Generated smoke, heat, etc., will not cause physical damage to or interfere with navigational aids.

**b. Protection.** The burn area structure should be:

(1) Accessible only to authorized personnel and secured from unauthorized uses such as chemical dumping, and trash burning.

(2) Accessible only by airport controlled roads. Sites that are fenced should provide a normal entrance located parallel with the prevailing wind. In addition, an emergency exit should be located opposite the normal entrance.

**c. Physical Objects and Boundaries.** The burn area structure should be clear of:

(1) All established restricted areas and designated boundaries such as;

(a) Airport building restriction lines (BRL).

(b) Runway clear zones.

(c) Aircraft parking and/or movement areas for at least 500 feet (152 meters).

(2) Airport buildings or public vehicle parking lots for a distance of 300 feet (90 m) and 1,000 feet (300 m) from occupied residential areas.

(3) All trees and large shrubbery within 300 feet (90 m) of the burn area perimeter.

**10. ENVIRONMENTAL FACTORS.** The following environmental factors should be considered.

**a. Topography.** Relatively flat land offers both improved fuel/water runoff control and lower construction cost.

**b. Proximity to Water Supply Wells.** Water wells in the vicinity should be protected by siting the training facility as far as possible from them. Studies should be conducted of local geological maps to show the extent of the aquifer(s) and hydrogeologic reports obtained to determine the properties of the aquifer(s) such as their direction and depth of flow. In the event that the building materials of the burn area structure become defective, there should be no movement of contaminants into those wells. Coordination with the Environmental Protection Agency (EPA) is required if there is a potential for contamination of a sole or principal drinking water resource aquifer as designated by EPA per the Safe Drinking Water Act. If water wells are present, the training facility should be at least 500 feet (164 m) from the nearest well when sited in low permeability soil types. More separation is desirable in higher permeability soil types.

**c. Permeability of the Local Soil.** The addition of a low permeability confining layer such as clay or slit below the burn area structure and its immediate area (berm, rigid apron and inner sloped surface) will lessen downward migration of contaminants. A confining thick layer of low permeability soil is usually sufficient to lessen downward contamination by the fuel effluent.

**d. Location of Flood Plains.** Training facilities should be sited above the 100-year flood plain as defined in Executive Order 11988. If the area is flooded, fuel and other contaminates can wash out of containment areas and defile the soil and/or groundwater. Additionally, electrical and mechanical equipment can be destroyed.

**e. Mitigation of Effluent Discharge to Nearby Streams.** Containment measures to preclude direct access overland to a perennial stream should be provided. This access creates an environmental risk when burn area effluent is accidentally released under direct low-flow conditions to such a receiver. Any discharge into "navigable waters" as defined by EPA requires a permit under Section 402 of the Clean Water Act (the National Pollution Discharge Elimination System).

**f. Control of Hydrocarbon Fuel Quantities.** The greatest harm to ground water quality during training is attributed to the spillage of hydrocarbon fuels directly onto the soil. Hence, the simplest mitigation measure for maintaining ground water quality is to reduce the amount of expended fuel. An acceptable amount of fuel for a drill is just enough fuel to create a fire of the desired duration and intensity (see paragraph 12b and Figures 1-6 & 1-7). In practice, there should be very little fuel remaining in the burn area structure after fire extinguishment.

**11. UTILITIES.** The availability of water and electric utilities and sewer service should be considered in site selection. Benefits from these services include reduced facility operating costs, improved safety, and enhancement of training activities.

**a. Water Source.** An adequate water source should be readily available that meets the large water quantity required for the operation of the burn area structure. Water replenishment of the training facility's water storage tanks is facilitated by a public water utility. The minimum water quantity should be the quantity needed for the water sublayer, flushing operations, and at least enough water for one additional training exercise. Thorough flushing after the last training exercise of a training session enhances the realism of future training sessions by washing the contaminated surfaces of crushed stones. Completely draining the burn area structure is also recommended to eliminate creation of artificial ponds (bird control). A nearby water main also allows for placement of a fire hydrant for easier vehicle replenishment.

**b. Electrical Service.** Electrical service allows for remote electric fuel igniters, lighted nighttime training exercises, installation of explosive-proof electric fuel/water pumps, and the use of a public address system. Utility light poles should be placed in such a manner to preclude being a hazard to vehicle traffic and aeronautical operations.

**c. Sanitary Sewer Connection.** Eventually both recycled water and fuel will be disposed and replenished with clean counterparts. A sanitary sewer connection provides an environmentally safer and simpler water disposal when permissible. It is noted that contaminated water may be considered a hazardous waste by some local and state jurisdiction and thus prohibited to be released into sanitary sewer lines. ***Fuel disposal***

*shall not to be accomplished by public sewers, drainage systems, or natural waterways, but be either recycled or removed for proper source treatment.*

## Section 5. Burn Area Fuel Requirements

**12. TRAINING FIRE FUEL REQUIREMENTS.** A fuel type and quantity appropriate for the intended aircraft fire simulation, (evenly distributed over the training burn area) is as essential for meaningful training as is the proper applicator discharge rate/burn area relationship.

**a. Individual Quantities.** The total fuel required for each training fire consists of three separate quantities each having a specific purpose. First, the "preburn" quantity of fuel must be sufficient to provide at least a 30 seconds pre-burn over the entire burn area structure before extinguishing operations start. Second, the "control time" quantity must have at least enough fuel to ensure that the established fire can burn beyond the preburn time at full intensity over the entire burn area structure for the training session, usually one minute. Without this second quantity, the fire will self extinguish in less than one minute giving the impression that the trainee was successful. And finally, a "post-burn" quantity to ensure that the trainee was in fact achieving the tactical objective of extinguishing the fire in the practical critical fire area within one minute. This third quantity allows the fire to burn beyond the desired control time when the trainee was unable to successfully extinguish it. Hence, indisputable evidence of trainee failure exists.

**b. Total Quantity.** Figures 1-6 and 1-7 present a convenient means of estimating the fuel requirements for three typical training times for small and large burn area structures. The quantities shown are for a single training fire and are based on the fuel consumption rate of a free-burning fire for Jet-A aviation fuel, (i.e., approximately 0.15 gal/ft $^2$ -min).

**c. Fuel Savings.** All three fuel quantities - preburn, control time, and post-burn - offer fuel savings by the fire ground management skills of the instructors and the proficiency of the trainees. For example, if the preburn fire can be established quickly, the quantity of fuel needed in the burn area structure can approach the 30 second preburn time. As trainees become highly proficient, i.e., consistently extinguishing the fire in less than the desired control time (one minute maximum) both control time and post-burn fuel quantities can also be reduced.

**d. Wind Affects.** Grossly asymmetric burns resulting from the fuel layer being dragged by wind forces can be controlled by crushed stones that protrude partially above the fuel layer. This medium is effective in slowing the rate at which the fuel layer accumulates in the downwind section of the burn area structure; generating unequal burns, varying flame heights, uneven heat, and smoke.

**13. - 15. RESERVED.**

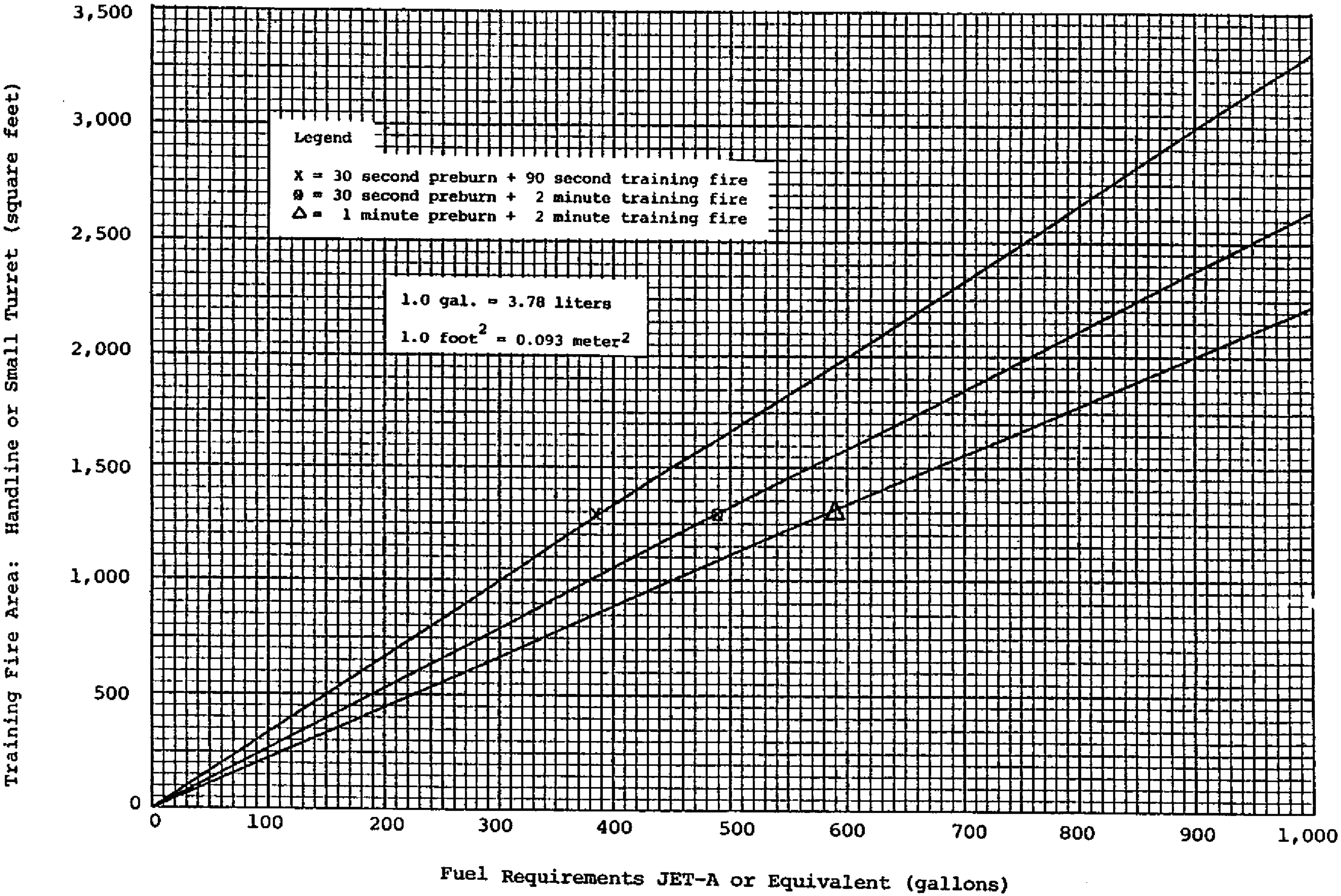



Figure 1-6. Small training fire area vs fuel requirement

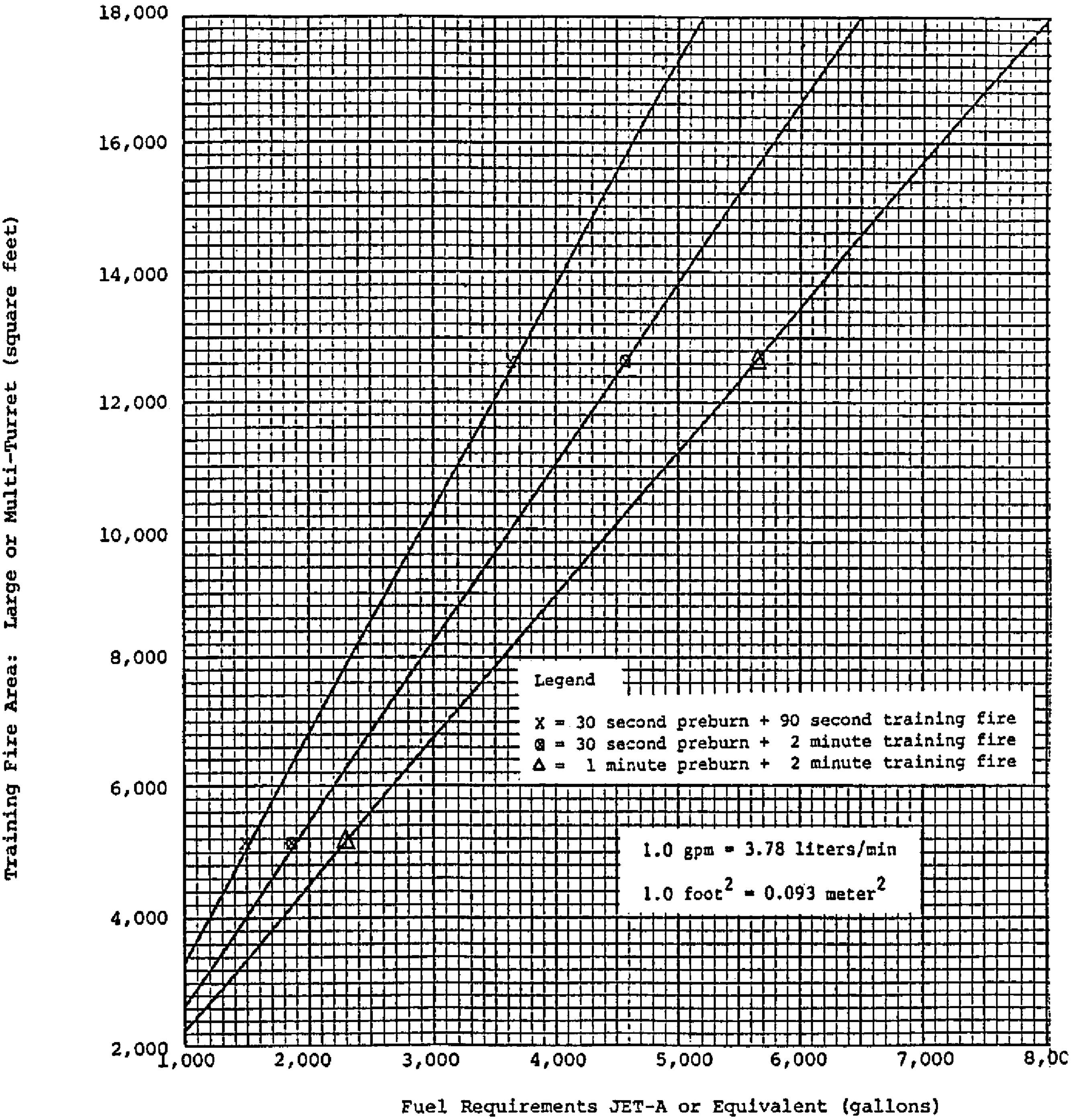



**Figure 1-7. Large training fire area vs fuel requirements**

# CHAPTER 2. DESIGN PHASE

**16. BURN AREA.** The size of the burn area governs the design parameters for most of the training facility elements described in this chapter. These items are individually designed to support the purpose of the burn area, the simulation of a "realistic" aircraft accident environment. Two structural material alternatives for the construction of the burn area are presented. Section 1 describes the use concrete as the primary construction material. Section 2 describes the use of flexible membrane liners (FML) as the primary construction material. These two material alternatives are illustrated in Figures 2-1 and 2-2 with reference paragraphs offering further information on key elements. Sections 3 and 4 are elements of the training facility that are necessary to both material alternatives.

## Section 1. Concrete Design Alternative

**17. CONCRETE BURN AREA.**

**a. Functions.** The primary functions of the burn area structure are to contain all training fluids, withstand fires of varying lengths, radiant heat intensities and repeated thermal shocks resulting from the use of extinguishing agents, withstand bearing, mechanical and hydraulic stresses, and be compatible with the environment. See Figure 2-1 for a burn area based on concrete.

**b. Concrete Structure.**

**(1) Components.** This alternative consists of a rigid floor and wall, the upper portion of the wall being the curb. The illustrated sloped apron, drainage channel, crushed stones, zonal distribution piping networks for fuel and water, weir, and drainage pipes feeding the fuel/water separator are independent of but required to support the functions of the burn area structure.

**(2) Design.**

**(a) Size.** *The size of the burn area structure shall be determined by paragraph 5.*

**(b) Floor/Wall.** The floor and wall should be made of reinforced concrete of a compressive strength to withstand applied stresses. An $f'_5$ of 4,000 psi for water tightness and lower water/cement ratios for chemical resistance and penetration are recommended. Floors should be adequately sloped to channel water towards the weir(s) and any interior drains. Sloped floors offer the weir(s) better leveling control of the fuel/water surface, improved protection of the burn area structure from frost action through total drainage, and safer routine maintenance and inspection. In general, slopes towards the weir should be equal or greater than slopes towards interior drains. For example, slopes may be from 60:1 to 30:1 for weir(s) and 60:1 to 40:1 for interior drains. Interior drains should be provided a screen to preclude the removal of crushed stones. A means of secondary containment of leaked fluids below the floor is recommended, e.g., a flexible membrane liner.

**(c) Heat Protection.**

(i) Protection of the floor from heat energies (fluxes) is performed by the overhead layers of crushed stones and water. The minimum thickness of the dual layer of crushed stones and water should be 6 inches (15 cm), taking into account the sloped floor. Material substitutions for crushed stones should note their insulating properties, e.g., conductivity value. See paragraph 22, Crushed Stones for Burn Area Structural Alternatives, for recommended crushed stone gradation.

(ii) Protection of the upper portion of the wall, namely the curb, from heat energies (fluxes), is found in paragraph 18, Concrete Curb.

**(d) Curb.** See paragraph 18, Concrete Curb, for design.

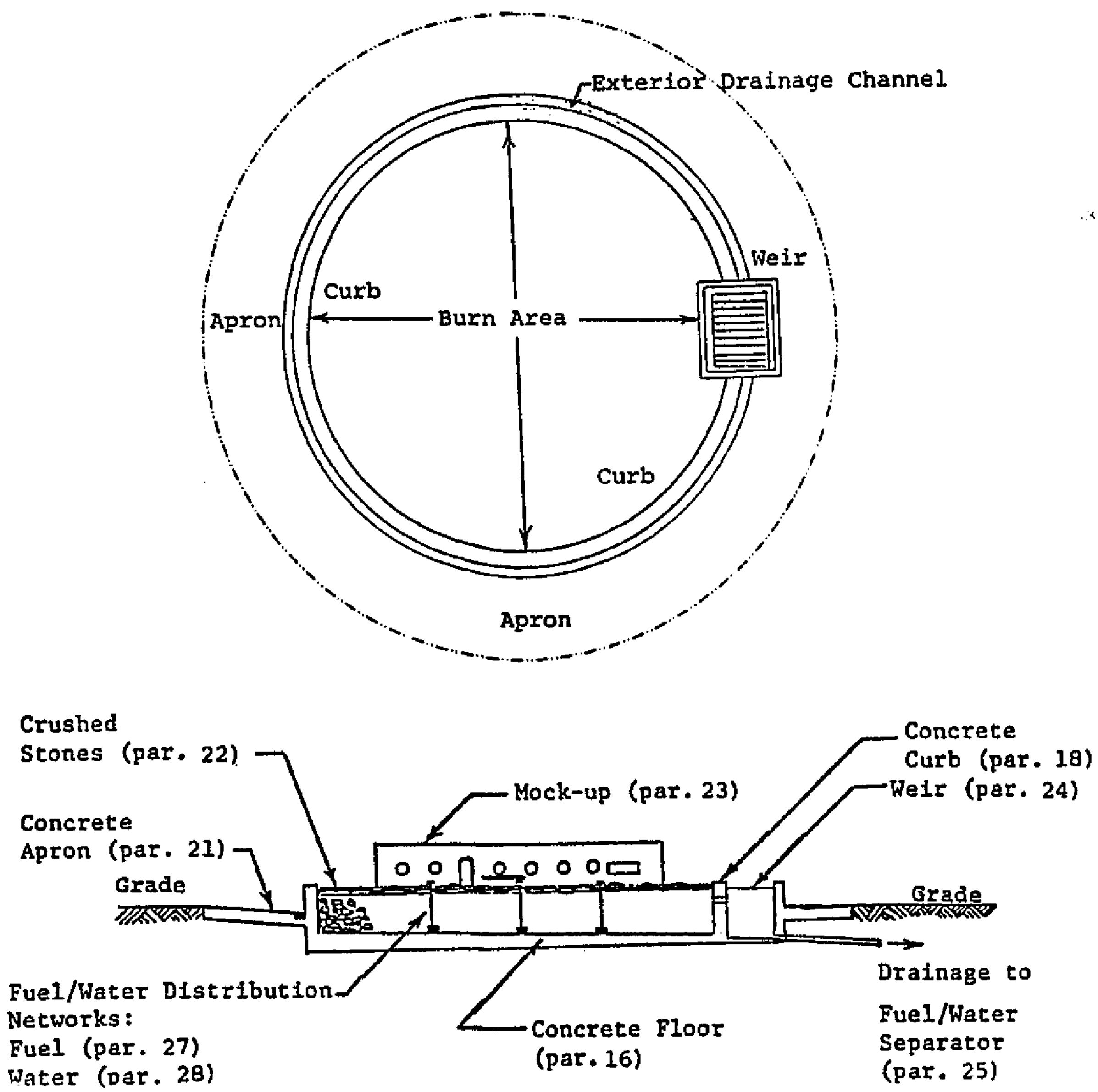



**Figure 2-1. A concrete burn area structure with components and other features**

## 18. CONCRETE CURB.

a. **Functions.** The primary function of both the concrete curb and berm is to contain fluids within the burn area. A secondary function is the separation of the burn area from the ARFF vehicle maneuvering surface.

b. **Concrete Curb Design.**

(1) **Height and Width.** *The maximum difference between the top of any curb and an adjoining surface shall not exceed 8 inches (20 cm). The minimum width of any curb at the top shall not be less than 6 inches (15 cm).* These curb dimensions provide fully clothed fire service personnel a nonhazardous footing when entering or exiting the burn area structure under firefighting conditions.

(2) **Interior Separation Curbs.** To reduce the quantities of expended fuel and water, interior separation curbs constructed for specific zonal training may be included. Curb heights should be at least 2 inches

(5 cm) but not more than 4 inches (10 cm) lower than the exterior perimeter curb. Drainage of zonal areas can be achieved by having individual drainage gates below the fuel/water layers. Drainage gates should be resistant to high temperatures.

**(3) Explosive Concrete Spalling Treatments.** To alleviate explosive spalling of curbs made of portland cement concretes, a refractory concrete is recommended to be used as an insulating cover. The primary function of refractory concretes as defined by ASTM C 401-84, Standard Classification of Castable Refractories, is to provided greater service temperatures, in this case the curb. Either pre-fabricated 4 to 6-foot (1.2 to 1.8 m) sections or field mixes are acceptable. U-shape pre-fabs are recommended for quality control and quicker repairs. Refractory concrete ready field mixes may be either of "castables" that require only clean water prior to placement or of non-castable field mixes that require the addition of aggregates, binder, and clean water. Both pre-fabs and field mixes will adequately receive and absorb the destructive forces of high temperature, thermal shock, and flame impingement for an established service temperature. *Thus, the design service temperature for the burn area structure shall be 2,100° F (1,149° C).* Other properties to be specified by the design should be resistance to abrasion, erosion, physical abuse, and high strength. Refractory concrete manufacturers can either produce pre-fab sections or recommend a type of "castable" or field mix to achieve design specifications. Also, the American Concrete Institute ACI 547R-83, Refractory Concrete: Abstract of State-of-the-Art Report, offers recommendations on the selection of aggregate sizes and types, and specific physical properties of normal and lightweight refractory concretes for this design service temperature. See paragraph 38, Refractory Concretes, for guidance.

## Section 2. Flexible Membrane Liner Design Alternative

### 19. FLEXIBLE MEMBRANE LINER BURN AREA.

**a. Functions.** The primary functions of the burn area structure are to contain all training fluids, withstand fires of varying lengths, radiant heat intensities and repeated thermal shocks resulting from the use of extinguishing agents, withstand bearing, mechanical and hydraulic stresses, and be compatible with the environment. See Figure 2-2 for a burn area based on flexible membrane liners.

**b. Flexible Membrane Liner (FML) Structure.**

**(1) Components.** This alternative consists of a three layer system of two flexible membrane liners that are separated by a compatible interior drainage net and a geotextile filter fabric above the system (see Figure 2-2). The illustrated berm, drainage channel, crushed stone and sand layers, zonal distribution piping networks for fuel and water, weir, drainage pipes feeding the fuel/water separator, and leak detecting monitoring well/trench are independent of but required to support the functions of the burn area structure.

**(2) Design.**

**(a) Size.** *The size of the burn area structure, which excludes the berm and inner ring section, shall be determined by paragraph 5.*

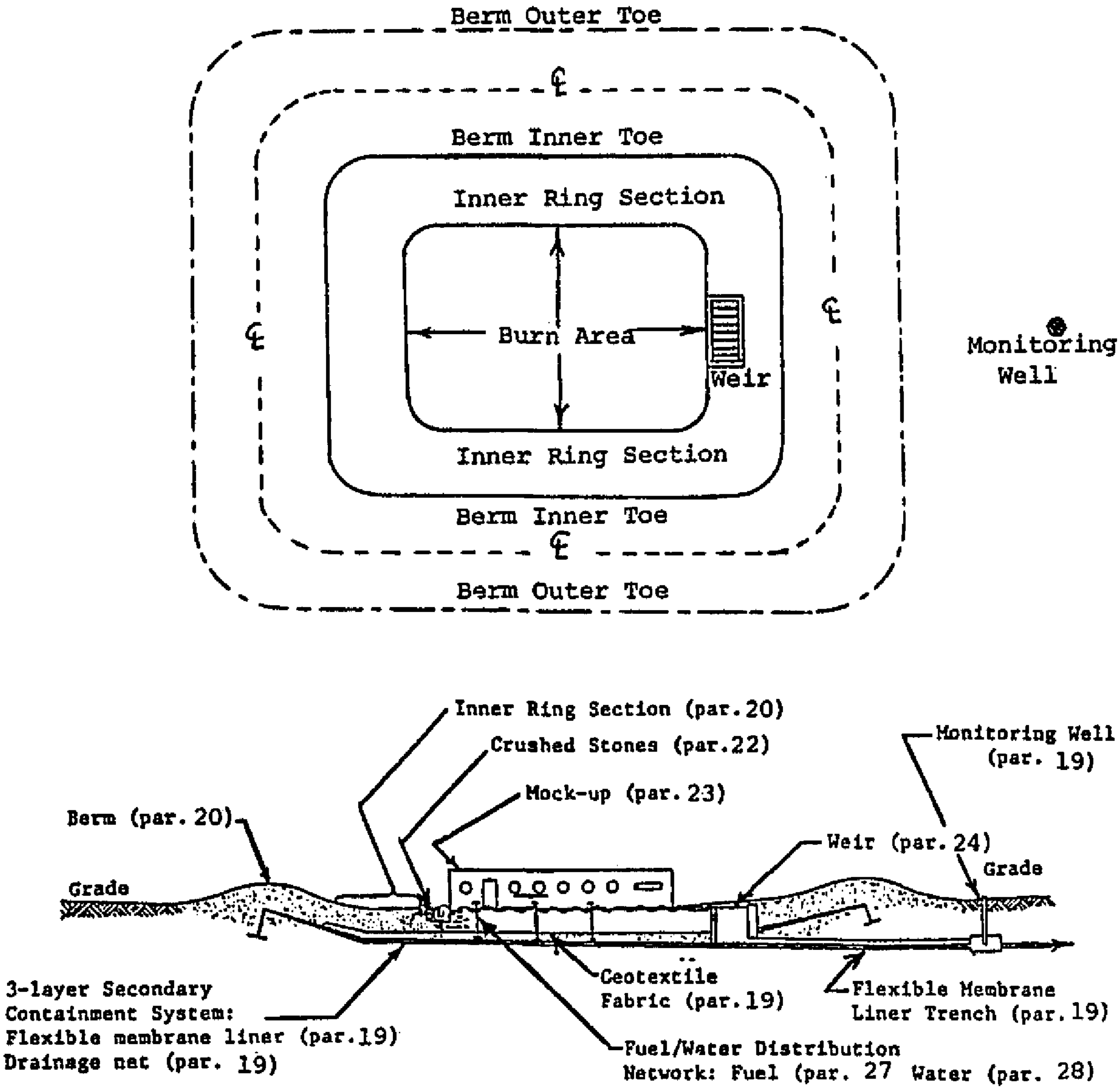



**Figure 2-2. A flexible membrane liner burn area structure with components and other features**

(b) **Floor/Wall.** The floor and wall should be a double layer of flexible membrane liners (FML) that are separated by an interior drainage net. This floor/wall three layer system should slope toward a leak detector/monitoring well that is located outside of the burn area structure. The slope of the "wall" should follow the FML manufacturer's recommendation for wall stability.

(i) **FML.** The upper FML layer acts as the primary containment of fuel while the lower FML layer provides secondary containment of leaked fluids for detection and removal. The lower liner (secondary container) should have the ability to contain at least 100 percent of the volume of the upper liner (primary container). The secondary container shall be equipped with a collection system to accumulate, temporarily store, and permit removal of any fluids leaked by the primary liner. *FMLs shall have the wide range of chemical and weather compatibility and performance specifications as stated in paragraph 39, Flexible Membrane Liners.* FMLs should be anchored below the berm with a minimum of 20 inches (51 cm) of backfill material and be continuous to the monitoring well.

(ii) **Interior Drainage Net.** The interior drainage net separates the primary and secondary FMLs to provide a flow path for the collection and removal of primary FML floor leakage. The material performance of the drainage net should have good hydraulic transmissivity and withstand applied bearing loads. The design pattern of the drainage medium should allow collected fluids multi-directional flow paths to the monitoring device. ***Drainage nets shall have the wide range of chemical compatibility and performance specifications as stated for FML in paragraph 39.*** Drainage nets should end near the perimeter of the double FMLs, e.g., below the berm.

**(c) Heat Protection.** Liner protection from heat energies (fluxes) is performed by the three overhead layers of sand, crushed stones, and water and the inner ring section as defined in paragraph 20b(3). A minimum of 6 inches (15 cm) of sand and a minimum of 12 inches (30 cm) of crushed stones should be placed immediately above the primary FML. Sand also furnishes the primary FML protection from the sharp edges of crushed stones and serves as a buffer zone over the primary FML during maintenance or replacement of crushed stones. Recommended gradation limits for sand aggregates is under "Fine Aggregates" of ASTM C 33-86, Specification for Concrete Aggregates. For crushed stone gradation see paragraph 22, Crushed Stones for Burn Area Structure Alternatives. The drainage system should preclude the removal of sand, e.g., drain covers with filters, perforated drain pipes.

**(d) Geotextile Fabric.** A geotextile fabric should be placed directly above the sand layer to provide a non-intermingling barrier between the sand and crushed stone layers. ***Geotextile filter fabrics shall have the wide range of chemical compatibility and performance specifications as stated in paragraph 41, Geotextile Fabric.*** Foremost, geotextile filter fabrics should be resistant to thermal heats, have adequate filtering capabilities, and withstand imposed bearing loads.

**(e) Berm.** See paragraph 20, Berm, for design.

**(f) Monitoring Well/Trench.** A monitoring well should be contained within a continuous downward sloping trench composed of the same double FML floor and drainage net materials. This trench channels leaked effluent to a monitoring well device that is located in a sump. A recommended slope for the trench towards the sump is 1/2 inch per foot. Additionally, the trench may be designed to provide a non-penetrating entrance of the two layer FMLs and drainage net system for fuel/water supply lines and electrical ignition devices. Conduits within the trench section are recommended for electrical lines. Leaks within the primary FML may be located by the injection of helium as a leak-detection technique at low pressure.

**20. BERM.**

**a. Functions.** The primary function of both the concrete curb and berm is to contain fluids within the burn area. A secondary function is the separation of the burn area from the ARFF vehicle maneuvering surface.

**b. Berm Design.**

**(1) Slopes/Widths.** The slope of the berm should provide a nonhazardous footing when fully clothed fire service personnel enter and exit the burn area structure under firefighting conditions. Recommended slopes are from 4:1 to 2:1 with berm widths ranging from 4 to 8 feet (1.2 to 2.4 m).

**(2) Berm Backfill Material.** Berm backfill material should be of a uniformly graded material of a much *higher* percentage of fines as compared to the crushed stones used in the interior portion of the burn area structure. This higher percentage of fines material serves two functions. First, it will assist in preventing fluids from entering the inner toe of the berm and the "inner ring section" (as defined in item (3) below) by containing the fluids in the more porous crushed stone center of the burn area structure. Second, it provides a protective blanket for the double FML system that is anchored under the berm. A recommended gradation for the backfill material is listed in Table 2-1.

**Table 2-1. Recommended gradation for backfill material for berm and adjoining inner ring section**

| Sieve Size | Percent Passing by Weight |
|---|---|
| 2 inch | 100 |
| 1 inch | 95-100 |
| 3/4 inch | 80-100 |
| 5/8 inch | 75-100 |
| 3/8 inch | 50-85 |
| No. 4 | 35-60 |
| No. 10 | 22-50 |
| No. 16 | 15-35 |
| No. 40 | 15-30 |
| No. 200 | 5-10 |

(3) **Inner Ring Section.** This is a downward sloped area of the burn area that is inward from the inside toe of the berm for a specified horizontal distance. A recommended slope is 12:1 with a maximum horizontal distance of 12 feet (3.7 m). Its dual functions are to contain fluids in the more porous central section of the burn area and to provide a heat protective cover for the underlying double FML system. The lowest point of the sloped ring should be the high fuel/water mark, thus reducing heat energies of fuel burns at the berm. Further, the heat protective cover directly over the upper FML should be a minimum of 18 inches (46 cm) or as recommended by the FML manufacturer. The recommended gradation for the backfill material cover is listed in Table 2-1.

## Section 3. Support Components

### 21. CONCRETE APRON.

**a. Function.** The primary function of the concrete apron is to collect training fluids washed over the exterior curb for their proper disposal.

**b. Design.** The concrete apron should be constructed from materials that are impervious and compatible with fuel and water. Asphalt should not be used because of possible ignition at elevated heat values and its chemical noncompatibility with hydrocarbon fuels. The compressive strength of the concrete should be adequate to support fully loaded RFF vehicles. An $f'_c$ = 4,000 psi for fresh water tightness and lower water/cement ratios for chemical resistance/penetration, and severe weather cónditions are recommended. See ASTM C 318 and ASTM C 173 for recommended air contents for a given maximum aggregate size. The apron surface width should be 10 percent of the square root of the total square footage of the burn area structure with an upper limit of 12 feet (3.6 m) and a lower limit of 6 feet (2 m). For example, a burn area of 12,500 $ft^2$ (1,160 $m^2$) should have an apron width of approximately 11 feet (3.4 m). All apron designs should slope towards the curb with recommended slopes being 24:1 to 10:1. If the apron has a drainage channel adjacent to the perimeter curb, the drainage channel should be properly covered with drain covers that can withstand high temperatures. The transition joint between the apron and the ARFF vehicle maneuvering surface should be as smooth as practical.

**c. Thermal Treatments for Portland Cement Aprons.** Portland Cements of ASTM C 150 types can be improved to lessen the frequency of thermal spalling for elevated temperatures of 500-600° F (260-315° C). Some measures are:

(1) **Binder.** Calcium aluminate cements are recommended as a binder. Greater thermal resistance can be gained by increased contents of Alumina, $Al_2O_3$, and Silica, $SiO_2$. Also, thermal resistance is increased by replacing aggregates with more cement binder to achieve lower thermal conductivity values.

(2) **Aggregate Size.** For normal weight concretes, i.e., unit weights of 135 to 155 pcf (2160 to 2480 kg/m$^3$), thermal improvements are achieved by decreasing the maximum aggregate size.

(3) **Aggregate Type.** Aggregate selection should consider higher compressive strengths and lower Modulus of Elasticity. For example, lower thermal expansion of concrete results from employing carbonate aggregates than siliceous aggregates because of their larger compressive strengths . Aggregates containing quartz such as granite, sandstone, and quartzite, should be avoided since they suffer a large volume change at approximately 1065° F (574° C). Also, the addition of fine siliceous material to react with the calcium hydroxide will alleviate cyclic heating and cooling stresses formed during hydration.

(4) **Fibers.** Introduction of steel or polypropylene fibers improves concrete's resistance to thermal cycling and thermal shock. Steel fibers also increase resistance to cracking, service life, and tensile strengths.

(5) **Unit Weight.** Lightweight concretes, i.e., unit weights of 85 to 115 pcf (1360 to 1840 kg/m$^3$), are recommended since they insulate more than normal or heavy weight concretes. Generally, an increase in thermal insulation (lower conductivity values) is achieved with a decrease in concrete unit weight. Both lightweight and normal weight concretes should be of air-entrained type.

(6) **Free Moisture Content.** Lowering the free moisture content of hardened concrete increases thermal insulation through reduced thermal conductivity values and reduced spalling and cracking of concrete through lower thermal expansion.

(7) **Air Content.** A further increase in the percentage of air content provides greater insulating values, particularly for air contents above 10 percent. Further insulating improvements at this percentage of air content may be achieved for lightweight concrete.

## 22. CRUSHED STONES FOR BURN AREA STRUCTURAL ALTERNATIVES.

a. **Functions.** The crushed stones (or equivalent) function as an effective fuel flow deterrent, a heat shield for the primary FML, a quick drainage medium, and a level walking/training surface.

b. **Design.** A well-graded crushed stone aggregate is recommended for all burn area structure alternatives. Maximum aggregate size should be 1-1/2 inches (4 cm) with 1/2 inch (1.5 cm) being a minimum. The interlocking effect of angular crushed stones provides a stable walking surface for training entry exercises and is sufficiently porous to allow fast drainage. The surface should be as level as possible. Grading of crushed stone aggregates should conform to standard size number 4 (four) of ASTM D 448-86, Standard Classification for Sizes of Aggregate for Road and Bridge Construction. Aggregates containing quartz should be avoided since they have a large volume change at the design service temperature of 2,100° F (1,149° C).

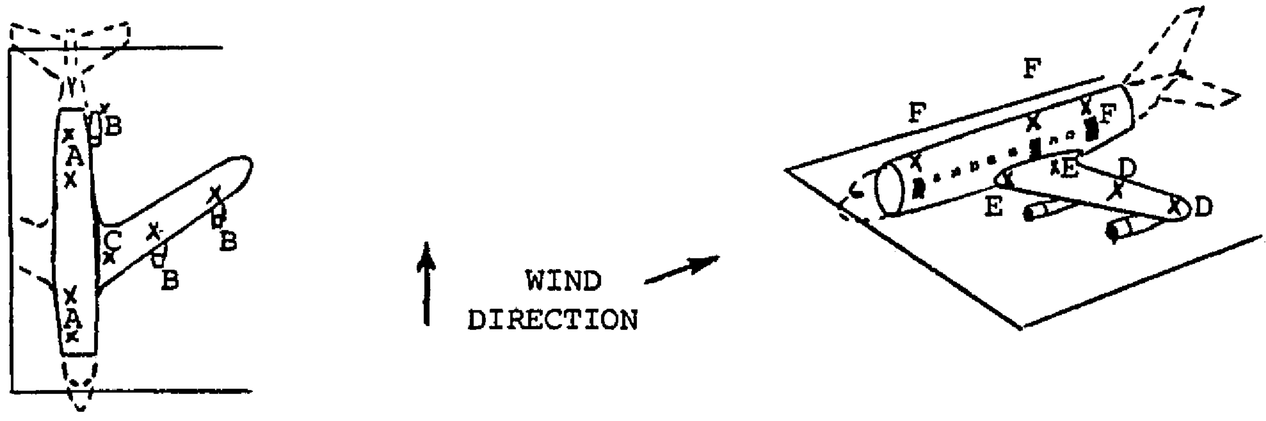
## 23. AIRCRAFT MOCK-UP MODEL.

a. **Functions.** An aircraft mock-up is recommended to add to the complications normally encountered in the suppression of a real aircraft fire. The model should be built with strategically located fuel nozzles and other special devices to simulate a variety of aircraft fires. Figure 2-3 illustrates a single wing, truncated mock-up with an elliptical cross section and fuel nozzles. Categories of fires that the model should provide include:

(1) **Class A Fires.** Baggage compartment and interior cabin fires that can be accessed through replaceable "forced entry" exterior panels or doors and brake/tire fires by an under-the-wing "landing gear" device. A stock of class A combustibles will be required to "refit" the mock-up for interior and brake/tire fire training.

(2) **Class B Fires.** Large pool fires, engine fuel fires, and ruptured aircraft fuel system fires. The last two items provide cascading or 3-dimensional fire training, i.e., cascading and spraying fires.

(3) **Other.** Class C, energized electrical, and Class D, combustible metal fires, are not included in this facility for safety reasons.




View A. View B.

X - Fuel Nozzle Location

A. Compartment Fires
B. Engine Fire Mock-Up
C. Brake/Tires Mock-Up
D. 3-Dimensional Fuel Fires
E. Underwing Difficulties
F. Replaceable "Forced Entry" Panels

**Figure 2-3. An aircraft mock-up**

**b. Design.**

**(1) Shape and Exterior Materials.** The shape of the mock-up aircraft should generally represent an aircraft. For example, the fuselage may take the shape of a long narrow building with vertical walls, circular windows, and a rounded roof. Exterior materials other than metal may be used, such as those found in fire training towers.

**(2) Location.** The mock-up aircraft should be located within the burn area structure with the axis of the model directed towards the control center and the prevailing winds.

**(3) Length.** The length of the mock-up aircraft depends on the sizing method chosen to determine the burn area. If the size of the burn area was selected from Table 1-1, then the length is 67 percent of the length listed in the "Lower Limit" column of Table 1-1 under the heading "Overall Aircraft Length." If the size of the burn area was based on the Discharge Rate Method of paragraph 5a, then the 67-percent length is also proportionally reduced. In addition, all lengths should be further truncated so that it is at least 10 feet (3 m) from the perimeter of the concrete curb or 12 feet (3.6 m) from the inside toe of the berm.

**(4) Height/Width.** The recommended range for widths and heights is 6 to 10 feet (1.8 to 3 m) for mockups with circular/elliptical cross sections and 4 to 7 feet (1.3 to 2.3 m) for rectangular arch roof mock-ups. The upper values offer the capability for aircraft entry training exercises as well as victim removal and interior cabin fire training. Entry exercises, however, should be confined to models that provide a minimum interior height of 7 feet (2.3 m) and a minimum floor width of 5 feet (1.6 m).

**(5) Wing Span.** The wing span (tip to tip) should be at least 50 percent of a representative aircraft for the airport's ARFF index level. Dimensions may be found in the latest edition of AC 150/5325-5, Aircraft Data. If the Discharge Rate Method is used, then the length is also proportionally reduced. In addition, all lengths should also be truncated so that it is not within 10 feet (3 m) from the perimeter of the concrete curb or within 12 feet (3.6 m) from the inside toe of the berm. Wing spans should not be greater than mock-up model lengths. ***All wings shall be attached to the mock-up model to eliminate firetraps.*** The spacing of wing support columns should evenly distribute the weight on to spread footings without damaging the floor of the burn area structure.

(6) **Tail Section.** The mock-up model may include a tail section with or without an engine pod. Dimensions of aircraft tail sections should be at least 50 percent of a selected aircraft from the latest edition of AC 150/5325-5.

(7) **Fuel and Water Nozzles.** Placement of fuel nozzles should be based on a specific type of fire to be simulated (see Figure 2-3). Fuel nozzles located adjacent to the mock-up model should be evenly spaced around its exterior wall. To increase the life of the model, provisions for internally placed water sprays, numerous water drains at all low points, and air vents on the sides and top of the model's main body, wing(s) and, if present, the tail section are recommended. The air vent pattern should provide adequate openings in conjunction with appropriate spacing to prevent the build up of an explosive fuel-air mixture within the model itself.

## 24. WEIR.

**a. Function.** The primary function of the weir is to control the fuel/water level in the burn area. See Figure 2-4 for an example of a weir.

**b. Design.** The size of the weir(s) should hold the fuel/water level in the burn area structure at the level that will permit the bottom of the fuel layer to be kept at or slightly below the protruding edges of the crushed stone surface. Collected flows should then be piped directly to a vented fuel/water separator system for recycling. For total burn area structure drainage and flushing, the weir(s) should have a drain valve opening that feeds the fuel/water separator. One safety feature to consider is the installation of a gas-tight trap in the weir or between the weir and the vented fuel/water separator thereby avoiding possible fuel vapor-air explosions. Weir arrangement(s) may be attached to or near the periphery of the burn area structure.

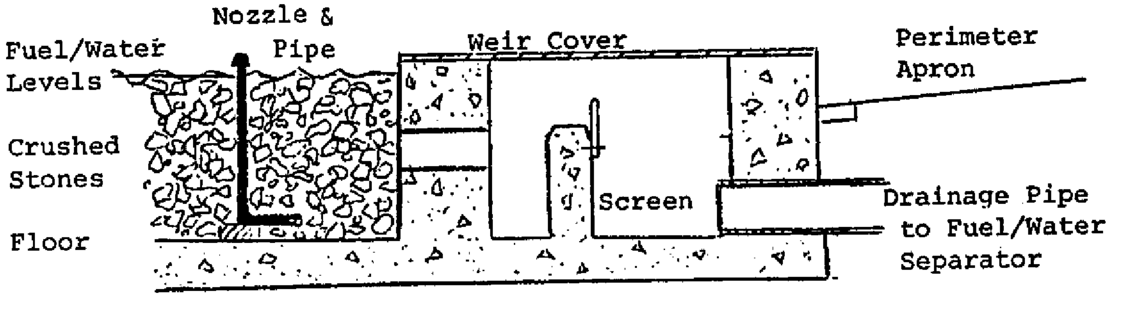



**Figure 2-4. An example of a weir**

## Section 4. Support Systems

## 25. VENTED FUEL/WATER SEPARATOR.

**a. Function.** The primary function of the vented fuel/water separator system is to separate unburned fuel and used water for recycling. The recycling process not only reduces the cost for new fuel and water but also the frequency of contaminated fluids requiring proper disposal.

**b. Design.** ***The fuel/water separator shall be vented.*** The recommended location for the separator is behind the protective wall of the control center (see paragraph 26). If the separator is a tank instead of a rigid concrete vault, aboveground and underground tank placement should follow fuel storage tank practices listed in Appendix 1 and any state, local or Federal (EPA) fuel tank requirements, e.g., aboveground height of the vent pipe. The vented separator should have a capacity to handle the total quantity of fluids generated during training and provide an acceptable separation time to complete the recycling process. ***Re-***

*covery pumps shall be explosive-proof.* Additional capacity considerations should be given to the collection of rainfalls and snow melts.

**26. CONTROL CENTER.** The control center is an area beyond the burn area structure where an instructor or safety officer can safely and visually monitor and control a training exercise from behind a protected wall (see Figure 2-5). Training facility items that should be located behind the protective wall are the control panel, fuel and water vented storage tanks, associated pumps, and the vented fuel/water separator. Also, an appropriate portable fire extinguisher(s) as recommended by NFPA 10-84, Standards for Portable Fire Extinguishers, and "NO SMOKING" signs should be posted.

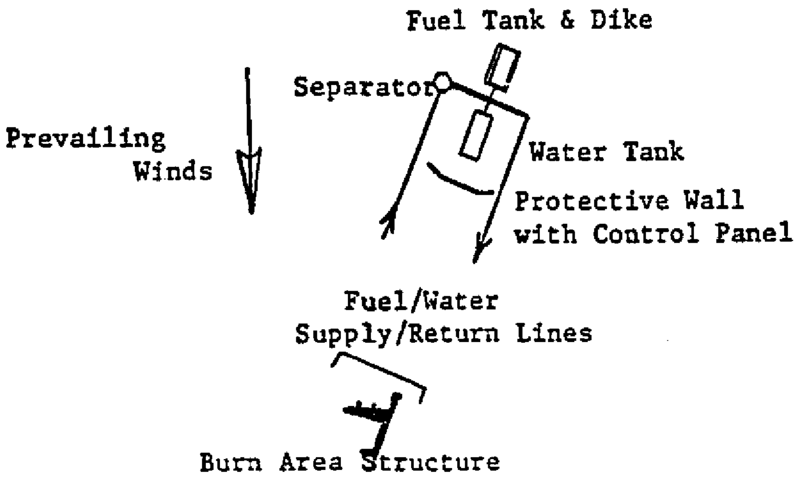



**Figure 2-5. Example of a control center location**

**a. Location.** The distance of the control center's protective wall from the burn area structure should be at least 150 feet (45 m) upwind with respect to the prevailing winds, thus alleviating smoke and flame impingement. Normally, the direction of prevailing winds may be found from a wind rose. Airports with seasonal wind patterns for different seasons of the year and with severe winters or heavy rainfalls, may be restricted to training in a particular season. Such sites should use the prevailing wind during the training season instead of the one indicated on a wind rose.

**b. Protective Wall Construction.** The height of the wall should either equal the height of the tallest aboveground fuel or water tank or be at least 8 feet (2.4 m). The width should be at least 15 feet (4.9 m). Cinder block is recommended as the building material for the protective wall. A window opening that has a complete view of training exercises should be placed within hand reach of the control panel. From this window opening, water and fuel delivery rates, burn area flushing, emergency fuel system shutoff, and electrical fuel ignition (of the burn area) can be monitored.

**c. Electrical Service.** Electrical service is recommended. This allows the use of devices that monitor flow rates such as an emergency fuel pump shutoff, and electrical hookups for items such as a public address system. All wires and cables are recommended to be protected, e.g., the use of conduits. Additionally, a means of safe electric fuel ignition is strongly recommended for the burn area structure. Electric fuel ignition should be effective under all normal weather and operational conditions and should ignite each fuel zone independently and all fuel zones simultaneously. ***The placement of such ignition controls shall permit the operator an unobstructed complete view of the burn area structure.***

**d. Grounds Keeping.** The grounds around the control center should be kept clean of overgrowth, plants, tall grasses, and other fire hazards.

**27. FUEL DISTRIBUTION SYSTEM.** This system consists of the vented fuel storage tank(s), supply piping system, explosive-proof fuel pump(s), independent zonal fuel delivery network, and the burn area fuel delivery network (see Figures 2-6 and 2-7).

a. **General Design of All Vented Fuel Storage Tank.**

(1) **Location.** The preferred location of the vented fuel storage tank is behind the control center wall, either above or below the ground, *aboveground being preferred*, see note [1] below. Local, state, and Federal requirements concerning the installation, maintenance, permissible type of fuel storage tanks, and tank leakage protective measures should be followed. All underground tanks must conform to the Hazardous and Solid Waste Amendments Act of 1984. "NO SMOKING" signs should be posted as appropriate.

(2) **Normal Venting.** ***All fuel tanks shall be vented with the height of the vent pipe opening not less than 12 feet (3.9 m) above the adjoining ground.*** Adequate venting lessens the probability of fires and explosions, e.g., vapor-air mixtures, and the development of a vacuum or pressures that exceed the design pressure of the tank. Vacuum and over pressures are a result of filling or emptying (pump discharge) and atmospheric temperature changes. As a minimum, the recommended nominal inside pipe diameter should be at least 1-1/2 inches (3.2 cm). The required above ground 12 foot (3.9 m) venting pipe should have its outlet(s) protected to minimize the possibility of ingress of foreign materials that may cause blockage such as from weather, dirt, and insect nests. Additionally, there should be no traps or sags in the venting pipe design. Other design considerations such as allowable venting devices, sizes, usage of flame arresters, etc., may be found in Section 2 of Appendix 1. Venting capacity should be designed for the larger of either the filling or the withdrawal rate. This will prevent blow-back of vapor or liquids at the fill opening during filling operations.

(3) **Emergency Relief Venting.** Emergency venting is recommended when there are two or more storage tanks to relieve excessive internal pressures caused by exposure to a neighboring tank fire.

(4) **Tank Capacity.** Tank capacity should be based on the sum of:

(a) the fuel quantities for two successive burns as determined by Figures 1-4 through 1-7.

(b) the volume of the supply piping system and fuel quantities required to maintain the design discharge rate and duration for all systems operating simultaneously.

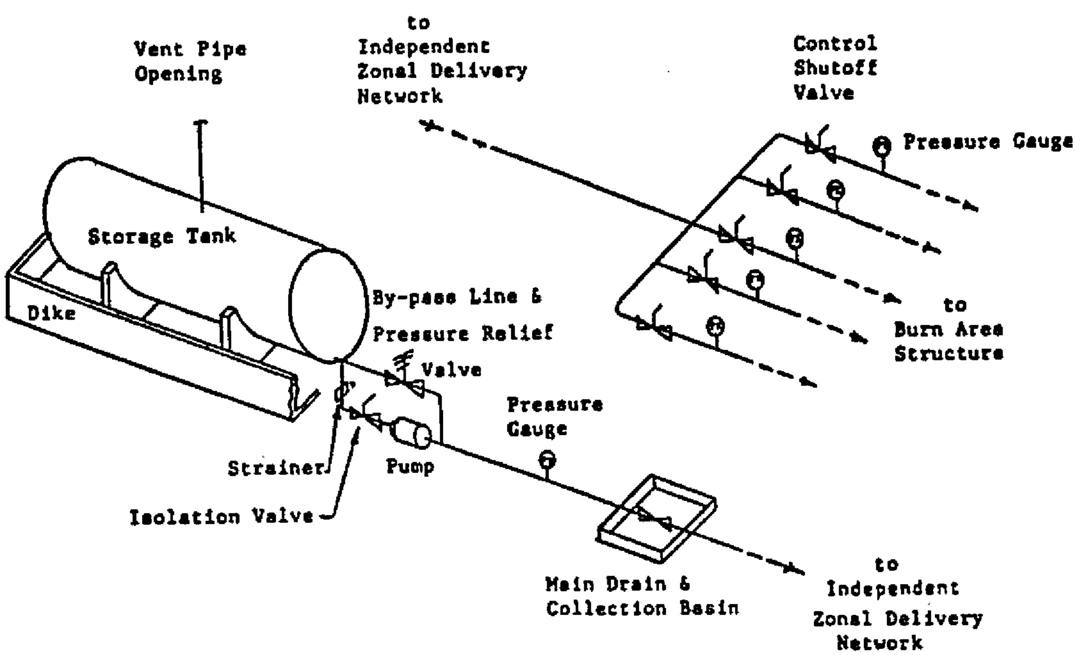



**Figure 2-6. Example of a vented fuel storage tank, pump, supply piping, and independent zonal delivery network**

---

[1] EPA underground fuel storage tank requirements may apply to an aboveground tank having a minimum capacity of 1,100 gallons whose below ground storage capacity is 10 percent or more, including pipes.

(5) **Tank Materials and Fabrication.** The storage tank should be of approved materials, e.g., cathodically protected steel, non-corrosive material (fiberglass-reinforced plastic), or steel coated with a non-corrosive material. Tank design and fabrication should be in accordance with recognized good engineering standards for the materials being used. Prior to the selection of an appropriate tank design and fabrication standards, the following should be decided: single or double walled tanks, type of materials, e.g., steel, fiberglass-reinforced plastic; place of fabrication, i.e., shop or field; internal operating tank pressure, e.g., low pressure tanks; placement of tank, i.e., above or below ground, horizontal or vertical; and type of fabrication, e.g., welded, riveted and caulked, bolted. Once decided, an appropriate design and fabrication reference may then be selected from Section 1 of Appendix 1.

(6) **Tank Fill Connection.** The tank fill connections should be designed to be liquid tight, accessible, and easy to operate. Installation of overfill and/or spill control systems are recommended. Also, for environmental protection, the single walled portions of doubled walled tanks such as the vent pipes or man ways should have an automatic shut-off device to keep fuel from reaching these sections. For safety during fuel transferring operations, observe the latest edition of AC 150/5230-4, Aircraft Fuel Storage, Handling, and Dispensing on Airports, or API Bulletin 1500-76, Storage and Handling of Aviation Fuels at Airports, NFPA Section 11-8, Storage and Handling of Solid Fuels of Fire Protection Handbook, 16th ed., 1986. Fuel level readings should be done by an approved tank reading device. Proper identification of fill connections is recommended.

(7) **Support, Foundations, and Anchorage.** The supports and foundations should be designed to minimize uneven settling of single or double walled tanks and to minimize any corrosive action to contacting tank sections. Tanks should be adequately and properly anchored, weighted or secured to prevent movement when the tank is filled, empty, or submerged by water at the established water table. In areas subjected to earthquakes, the tank supports and connections should be designed to resist damage due to seismic shocks. Tank foundation information may be found in Appendix E of API Standard 650-80, Welded Steel Tanks for Oil Storage and Appendix B of API Standard 620-82, Rules for Design and Construction of Large, Welded, Low Pressure Storage Tanks.

b. **Specific Design of Aboveground Vented Fuel Storage Tanks.**

(1) **Control of Fuel Spillage.** *A dike shall be provided for each tank so that any accidental discharge of fuel will be prevented from endangering other facility components, adjoining property, the groundwater, or from reaching a waterway.* The following design items are either recommendations or standards.

(a) **Slope of Dike Floor.** The slope of a dike floor should be one percent away from the tank to the dike wall.

(b) **Walls/Floor.** *The walls and floor of a dike shall be constructed of either steel, concrete, solid masonry, or a combination of these and shall be designed to be liquid tight with walls withstanding a full hydrostatic head. earthen walls shall not be permitted.* Dike walls and floor should have their surfaces coated to ensure impermeability. Dike walls greater than 6 feet (1.9 m) above the interior dike floor should have a normal and emergency access and safe egress. The minimum distance between the tank and toe of the walls should be 5 feet (1.6 m).

(c) **Capacity.** *The capacity of the dike shall not be less than the greatest volume of the tank when completely full.*

(d) **Penetrating Pipes.** Pipes passing through a dike should be designed to prevent excessive stress as a result of settlement or fire damage.

(e) **Subdivided Dikes.** *Dikes that house two or more fuel tanks shall be subdivided by an intermediate curb forming individual dikes.* This safety measure prevents spills from endangering adjacent tanks within the dike area.

(2) **Tank Openings.** Tank connections that allow flows should be liquid tight if located below the fuel level and be provided with either an internal or external valve located as close as practical to the tank.

(3) **Pollution Control.** Pollution control devices should be installed as required by local, state or Federal authorities.

c. **Specific Design of Underground Vented Fuel Storage Tanks.**

(1) **Burial Depth and Cover.**

(a) **Steel Tanks.** The installation should follow standard engineering practices listed in Section 2 of Appendix 1 such as adequate firm foundations, anchorage and buoyancy requirements, noncorrosive inert blanket materials, etc. The depth of cover placed over a tank is dependent upon whether the tank will or will not be subjected to vehicle traffic. API Publication 1615-79, Installation of Underground Petroleum Storage Systems, and NFPA 30-84, Flammable and Combustible Liquids Code, provide such installation practices.

(b) **Non-Metallic Tanks.** The installation should follow manufacturer's instruction with the minimum cover as specified for steel tanks.

(2) **Corrosion Protection.** It is *highly* recommended, if not required by local, state or the Federal government, that single and double walled tanks made of materials affected by corrosion be protected. Two approaches are:

(a) **Cathodic protection system** with sacrificial anodes or an impressed current designed to provide a minimum of 20 years of protection. Sacrificial anodes system should be electrically insulated from the piping system by di-electric devices or gaskets. Gaskets should be chemically resistant to corrosive soils and stored fuel. It is recommended that each cathodic protection system be provided with a monitor which enables the sponsor to check the adequacy of the system. It is further recommended that a qualified corrosion specialist or qualified engineer supervise their installation. Design, fabrication, and installation should be as prescribed in Section 3 of Appendix 2.

(b) **Approved materials** that are corrosion resistant.

(3) **Secondary Containment.** ***Underground fuel storage tanks shall have an approved local, state, or EPA method of secondary containment with a leak-detection device of primary tank leakage.*** All secondary containers should be both able to contain any unauthorized release of stored fluids to allow detection and recovery and be constructed of materials of adequate thickness, density, and composition to prevent structural weakening of the secondary container as a result of contact with released fluids. Two acceptable secondary containment methods are:

(a) **Double Walled Tanks.** Doubled wall tanks should be of 360 degree secondary containment with monitoring of the annular space. The tank design and installation should allow the annular space to channel leaked fuels to a specific location for collection, detection, and recovery. A vapor pocket elimination system and a top entry man way should also be part of the double walled tank. Installation of a double walled tanks should follow manufacturer's instruction.

(b) **Flexible Membrane Liner (FML).** FMLs should follow the requirements and guidance on FML selection and installation of paragraph 39, Flexible Membrane Liner. The leak-detection device should be properly located to perform its function. A recommended slope for the FML housing the tank is 1/2 inch per foot towards the device. The FML should be capable to contain at least 100 percent of the volume of the tank (primary container). A larger containment volume for sizing purposes should be consider for a FML open to heavy rainfall.

(4) **Tank Fill Lines.** All tank fill lines should be sloped towards the tank with fill and discharge lines entering the tank from the top. ***All tank fill connections shall be lower than the vent pipe opening. Underground storage tanks shall have EPA approved spill/overfill protection devices.*** If possible, the tank fill cap should be in a recessed vault to provide it protection from supply vehicles. If the fill cap is not recessed, it should be distinctly marked or have painted barrier posts for protection. Also, fill caps should have locking capability.

d. **Design Of Fuel Supply Piping System.** The fuel supply piping system should be designed for the structural stresses and the working flow rate and pressure that are capable of maintaining the fuel discharge at the design rate for all zones operating simultaneously. Piping systems consist of pipes, valves, fittings, tubing, bolting, gaskets, pressure containing parts, such as expansion joints and strainers, and devices which serve such functions as regulating flows, metering, distributing, snubbing. The design, fabrication, and assembly of a piping system should follow applicable sections of ANSI B31-73, American National Standard Code for Pressure Piping. Components made of nodular iron such as valves should conform to ASTM A 395-80, Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Uses at Elevated Temperatures. Other design considerations include:

(1) **Corrosion Protection.** It is *highly* recommended, if not required by local, state or the Federal government, that system components used in a corrosive soil or atmosphere, be constructed of materials resistant to corrosion, be covered with protective coatings, or have a cathodic system of either sacrificial anodes or impressed current. See Section 3 of Appendix 1 for cathodic systems. Protection for underground piping may consist of a factory-applied adhesive undercoat and continuously extruded polyethylene coating (see Federal Specification L-C-530C, Type I, Coating, Pipe, Thermoplastic Resin.) Protection for aboveground piping may consist of applied paints such as a zinc-rich primer, one bond or tie coat, followed by two coats of vinyl paint.

(2) **Secondary Containment of Fuel Leaks.** Piping systems are usually the most vulnerable components of a fuel delivery system and generally account for 60 to 80 percent of all underground fuel leaks. Therefore, ***the installation of an approved local, state, or EPA method for secondary containment of pipe fuel leaks shall be provided.*** Two acceptable secondary containment methods are double walled piping and FML trenches.

(3) **Valves and Pipe Joints.** Valves and pipe joints should be liquid tight with threaded pipes having a suitable tread sealant or lubricant. Sections of the piping system that are connected to pumps should have a sufficient number of valves to regulate the flow of fuel during normal operations and in the event of physical damage. Check valves are recommended at all fill connections to automatically protect against backflow if this situation is likely to exist. Drain valves are recommended for low points in both underground and aboveground piping. All valves should be of a type approved for the intended purpose and be readily accessible.

(4) **Identification.** For identification and safety, all exposed fuel elements and components outside the burn area structure should be painted white or aluminum in color and properly identified.

**e. Explosive-Proof Fuel Pump.** ***The installed fuel pump shall be an approved explosive-proof type that delivers the design fuel discharge flow rate.*** Pump size and all piping systems should deliver fuel for a well-developed burn in two minutes or less throughout the whole burn area or zones of the area(s) to be used. Quick delivery is sought to preclude fire hazards (flammable fuel atmosphere inside and outside the burn area structure if ignition is delayed) and for environmental reasons (release of aviation fuel hydrocarbons by delaying ignition). Precautionary measures include properly grounded pumps and hazard free pump surroundings, e.g., away from electrical outlets and panels. To protect the fuel pump and its associated piping (see Figure 2-6), there should be installed:

(1) A line strainer/filter and an isolation valve before the fuel pump. Strainers should be capable of removing from the fuel all solids of sufficient size to obstruct the spray nozzles. The openings of strainer filters should be no greater than 90 percent or less than 50 percent of the smallest nozzle opening within its service area.

(2) A separate fuel return line with a pressure relief bypass valve to safe-guard the fuel pump.

(3) After the fuel pump, a pressure gauge and a drain valve in the line between the fuel pump and the independent zonal delivery network. The drain valve should be placed over a non-asphalt collection basin.

**f. Design of Independent Zonal Fuel Delivery Network.** Each fire zone delivery pipe should have a control valve to regulate the fuel flow within the burn area and a pressure gauge. Zonal control valves should be located for easy emergency access. For protection, the zonal delivery network should be placed below grade.

**g. Design of Burn Area Fuel Delivery Network.** Entrance of the fuel delivery pipes into concrete burn area structures may be through the curb and for FML structures may penetrate the flexible membrane liner system. Upon entrance, each zonal delivery pipe should feed, via a distribution header, into supported branch pipes (risers) with the predetermined number of fuel nozzles (see Figure 2-7). Supports for risers should be heat resistant. Each nozzle riser should be supported below and plumbed for uniform fuel delivery. Correct placement of the nozzle heads is above the crushed stone surface with each nozzle having several horizontal discharging openings. Nozzle coverage should consider nozzles discharge characteristics and its particular objective. Care should be taken in positioning nozzles so that fuel does not miss the target surface, e.g., spray outside the burn area structure. *The standard for the maximum height of a nozzle protruding above the crushed stone surface is 3 inches (7.5 cm).*

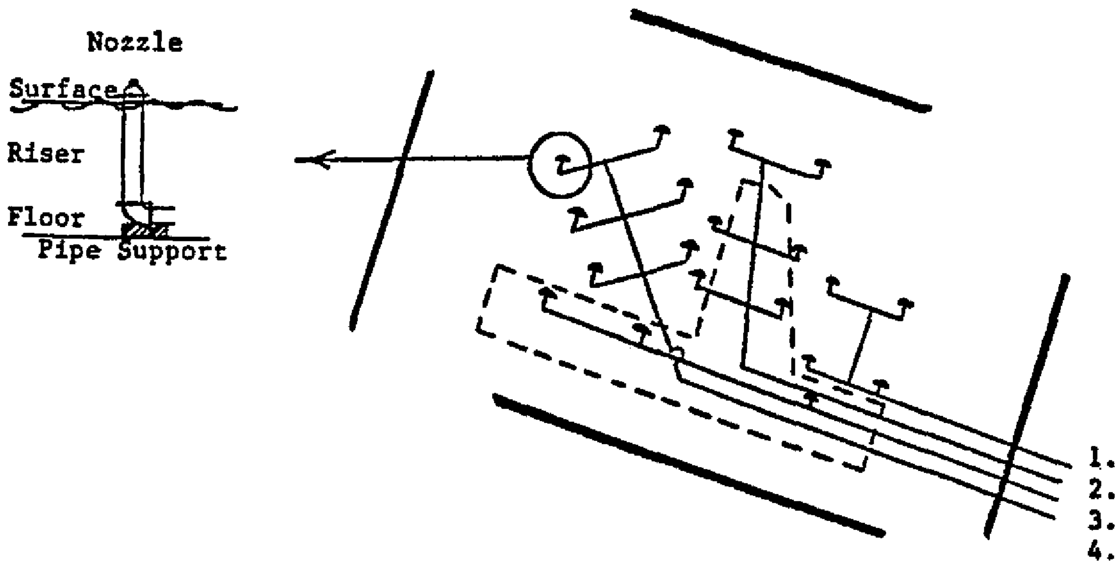



Figure 2-7. Example of a burn area fuel/water delivery network with four independent delivery zones

**28. WATER DISTRIBUTION SYSTEM.** This system consists of a vented water storage tank(s), supply piping system, water pump(s), independent zonal delivery network and, if included, the mock-up water spray network (see Figures 2-6 and 2-7).

**a. Design of All Vented Water Storage Tanks.**

**(1) Location.** The preferred location of a vented water storage tank is behind the control center wall. Aboveground tanks should have their entire outer surface painted a blue color and, with contrasting sizable lettering, have the words "NON POTABLE WATER" printed on both longitudinal sides. For further identification and safety, exposed water pipes and components should also be painted blue in color.

**(2) Normal Venting.** *All water tanks shall be vented above the adjoining ground.* Adequate venting prevents the development of a vacuum or pressures that exceed the design pressure of the tank. Filling or emptying (pump discharge) and atmospheric temperature changes produce vacuums and over pressures. The vent pipe should have its outlet(s) protected to minimize the possibility of ingress of foreign materials that may cause blockage such as from the weather, dirt, and insect nests. Additionally, there should be no traps or sags in the venting pipe design. Venting capacity should be based on the larger of either the filling or withdrawal rate. This will prevent blow-back of liquids at the fill opening during filling operations. As a minimum, the recommended nominal inside pipe diameter should be at least 1-1/2 inches (3.2 cm).

**(3) Tank Materials and Fabrication.** The storage tank should be of approved materials and designed and built in accordance with recognized good engineering standards for the materials being used. Some recommended practices are American Water Works Association (AWWA) D100-84, Welded Steel Tanks for Water Storage, AWWA D103-80, Factory-Coated Bolted Steel Tanks for Water Storage, and AWWA D120-84, Thermosetting Fiberglass-Reinforced Plastic Tanks.

(4) **Tank Capacity.** The tank capacity should be based on the sum of the water sublayer (burn area) for two successive burns, the volume of the supply piping system, the required water flow rate and pressure to maintain the design discharge rate and duration for all systems operating simultaneously, flushing operations (repeated exercises) and, if included, the continuous mock-up water spray treatment.

(5) **Tank Fill Connections.** If the tank is to be refilled by a tank truck, the fill connection needs to be liquid tight, accessible, and easy to operate. The fill connection should be protected from accidental damage from vehicles and should be provided with a cap of locking capability. Water level reading should be done by an approved tank reading device.

(6) ***Support, Foundations, and Anchorage.*** The supports and foundations should be designed to minimize uneven settling of the tank and to minimize any corrosive action to contacting tank sections. Tanks should be adequately and properly anchored, weighted, or secured to prevent movement when the tank is filled, empty, or submerged by water at the established water table. In areas subjected to earthquakes, the tank supports and connections should be designed to resist damage due to seismic shocks.

**b. Design of Water Supply Piping System.** The water supply piping system should be designed for the structural stresses and the working flow rate and pressure that is capable of maintaining water discharge at the design rate and duration for all zones operating simultaneously. Piping systems consist of the same items as listed in paragraph 27d. Other design considerations are:

(1) **Corrosion Protection.** System components installed outdoors or in the presence of a corrosive atmosphere should be constructed of materials which will resist corrosion or be covered with protective coatings.

(2) **Valves.** All valves should be of a type approved for the intended purpose and be readily accessible. For effective drainage, the water tank should be sloped towards the drain valve. Drain valves are recommended for low points in both underground and aboveground piping.

(3) **Identification.** For identification and safety, all exposed water system components outside the burn area should be painted blue in color.

**c. Water Pump.** The installed water pump should be capable of delivering the design water spray discharge rate and duration for all systems operating simultaneously. Pump size considerations are the water discharge rates for spray nozzles, the water sublayer in the burn area, plus, if included, the continuous mock-up water spray treatment and the burn area flushing/turn-around time. ***An approved explosion proof water pump drive is required when the water pump is to be housed with or near a fuel pump.*** To protect the water pump and its associated piping (see Figure 2-6) there should be installed:

(1) A line strainer/filter and an isolation valve before the water pump. Strainers should be capable of removing from the water all solids of sufficient size to obstruct the spray nozzles. The openings of the strainer filter should be no greater than 90 percent or less than 50 percent of the smallest nozzle opening within its service area.

(2) A separate water return line with a pressure relief bypass valve to safe-guard the water pump(s).

(3) After the water pump, a pressure gauge and a drain valve in the line between the water pump and the independent water zonal delivery network. The drain valve should be placed over a collection basin.

**d. Design of Independent Water Zonal Delivery Network.** Each independent zone delivery pipe should have a zonal control valve to regulate the water flow within the burn area and a pressure gauge. Zonal control valves should be located for easy emergency access. For protection, the zonal delivery network should be placed below grade.

**e. Design of Water Spray Network.** The water spray delivery pipes into the burn area of concrete structures may enter through the burn area curb and for FML structures may penetrate the flexible membrane liner system. Upon entrance each zonal delivery pipe should feed, via a distribution header, into supported branch pipes (risers) with the determined number of water spray nozzles (see Figure 2-7). Supports for risers should be heat resistant. Nozzle coverage should consider nozzles discharge characteristics and particular function. ***The design standard for the maximum height of a nozzle protruding above the crushed stone***

*surface is 3 inches (7.6 cm).* Care should be taken in positioning nozzles that water spray does not miss the target surface. Each nozzle riser should be supported below and plumbed for uniform water delivery.

**29. - 32. RESERVED.**

# CHAPTER 3. CONSTRUCTION PHASE

**33. CONSTRUCTION MATERIALS.** The training facility should be constructed with materials that can retain their structural integrity under the unique resulting thermal, hydraulic, mechanical, and bearing stresses imposed by its use. Materials functioning as an assembled unit should be compatible as a whole. Environmentally, materials should, as completely as possible, withstand the degradation effects of the ground (corrosion), air (oxygen), sun light (ultraviolet light), and weather.

**34. TESTING OF OPERATING PARTS.** *All operating parts of a system such as pumps, weir(s), fuel/water separator, etc., shall be fully tested under operating conditions before acceptance.*

**35. STRUCTURAL STEEL.**

a. **Material Quality.** All furnished structural steel, including metal accessories and metal devices necessary for placing, spacing, supporting and fastening reinforcement, should conform to the levels of quality specified to perform the functions intended. Upon delivery, these items should be checked for conformance to specifications and then properly stored from dirt, grease, and the environment.

b. **Practices.** There should be procedures, specifications, and standards that can be followed by contractors and be used to monitor the properties of all finished work. All steel design, fabrication, and erection should be in accordance with the American Institute of Steel Construction (AISC), Specification for Design, Fabrication, and Erection of Structural Steel for Buildings, and with the AISC, Code of Standard Practice for Steel Buildings and Bridges, unless otherwise specified. Steel to be welded should utilize welding procedure that are suitable for the grade of steel and its intended use or service as prescribed by the American Welding Society (AWS) and appropriate AISC welding specifications, unless otherwise specified. Welding practices should be in accordance with the American Welding Society, AWSD 1.1-86, Structural Welding Code - Steel, and appropriate AISC welding specifications, unless otherwise specified.

(1) **Steel Reinforcing Bars and Wire Fabric.** Prior to placement of reinforcements, all dirt, grease, ice, and other coatings should be removed. Tolerances for reinforcing bars and metal devices necessary for placing, spacing, supporting and fastening reinforcement should conform to prescribed specifications. Concrete covers for protecting rebars and wire fabrics may conform to American Concrete Institute ACI 318-83, Building Code Requirements for Reinforced Concrete. Concrete containing structural members that is deposited against the surface of the ground should have adequate concrete between structural members and the ground surface. For corrosion protection of rebars, protective coatings are recommended, such as epoxy coatings.

(2) **Welding.** Prior to construction, a written field welding procedure should be submitted that outlines such items as: welding process; identification of joints to be welded; joint dimensions; details and tolerances. A visual inspection of all finished welds is recommended. The visual inspection should focus on such items as: merged base and weld metals are smooth and free of cracks; pass an established level of porosity, e.g., not exceeding 10 visible pores in any 6-inch (15 cm) length of weld; adequacy of fusion; and a minimal spatter on weld and adjacent surfaces, overlays, and undercut as defined in AWS A 3.0-85, Standard Welding Terms and Definitions. Visual inspection of welds and heat affected zones may be done after cleaning by using magnifying lens (4X), mirrors, or other devices. It is recommended that welders be qualified in accordance with AWSD 1.1-86, Structural Welding Code - Steel. Precautionary measures during welding processes are found in ANSI Z 49.1, Safety in Welding and Cutting.

**36. PORTLAND CEMENT CONCRETE.**

a. **Material Quality.** A system of procedures for selecting the levels of quality required of the concrete to perform the functions intended should be determined. There should be procedures, specifications, and standards that can be followed by contractors and be used to monitor the properties of all finished work. *All types of portland cements shall be in accordance with the chemical and physical requirements of ASTM C 150-85a, Standard Specification for Portland Cement.*

b. **Practices.** Proper construction practices should be specified so that placed concrete satisfies the service requirements and alleviates the adverse effects of temperature, relative humidity, wind velocity, etc., on the properties and serviceability of hardened concrete. Concrete design should adhere to American Concrete Institute (ACI) 318-83, Building Code Requirements for Reinforced Concrete, unless otherwise specified. Regions of moderate or high seismic risks should note Appendix A, Special Provisions for Seismic Design. Recommended hot weather and cold weather concreting practices are: ACI 305R-82, Hot Weather Concreting and ACI 306R-83, Cold Weather Concreting. Air-entrainment is recommended to increase concrete durability and thermal resistance.

(1) **Placement.** Placement of concrete should proceed only after acceptability of concrete cylinder test breaks, e.g., 7-day test breaks. ACI 304-83, Recommended Practices for Measuring, Mixing, Transporting, and Placing Concrete, is recommended.

(2) **Erection of Concrete.** Concrete should be placed in temporary forms except as otherwise indicated or specified on drawings. Where soil permits, earth cuts may be used as forms for walls and footings.

(3) **Form Materials and Construction.** Form construction and erection may be in accordance with ACI 301-84, Specifications for Structural Concrete for Buildings, ACI 318-83, Building Code Requirements for Reinforced Concrete, and ACI 347-84, Recommended Practice for Concrete Formwork. Tolerances for the erection of formwork may be in accordance with ACI 347-84.

c. **Cementitious Waterproofing.** Cementitious waterproofing should be provided on the inside surfaces of all concrete structures used for fluid containment such as a concrete fuel/water separator. Materials used for waterproofing should follow manufacturer's application instructions to ensure proper penetration and closure of concrete capillary tracts to produce waterproofing effects. The cementitious waterproofing system should become permanent, and be non-toxic, inorganic, free of calcium chloride and sodium based compounds. Preparation of surfaces, mixing of compounds, and application should follow manufacturer's instructions.

d. **Aggregates.** See paragraph 37, Aggregates for Portland Cement Concrete.

e. **Admixtures.** Materials used as air-entraining, chemical admixtures, and other mineral admixtures with portland cement concrete should meet the standard specifications set forth by ASTM. For example, air-entraining admixtures should comply with ASTM C 260-86, Standard Specification for Air-Entraining Admixtures for Concrete, water-reducing, retarding, and accelerating admixtures with ASTM C 494-86, Standard Specification for Chemical Admixtures for Concrete, fly ash or natural pozzolans with ASTM C 311-85, Standard Method for Sampling and Testing Fly Ash or Natural Pozzolans for Use as a Mineral Admixture in Portland Cement Concrete.

## 37. AGGREGATES FOR PORTLAND CEMENT CONCRETE.

a. **Material Quality.** The quality of the selected class of aggregate should be based on its soundness and durability, amount of deleterious substances, and suitability for the proposed use. Aggregates containing quartz should be avoided in concrete sections exposed to temperatures over 1,000° F (538° C) such as the apron.

(1) **Fine Aggregates.** May be of natural or manufactured sand conforming to "Fine Aggregate," of ASTM C 33-86, Standard Specification for Concrete Aggregates, and free of injurious amounts of shale, alkali, organic matter, loam, or other deleterious substances.

(2) **Coarse Aggregates.** Should be clean, crushed stone, gravel, crushed gravel, or air-cooled blast furnace slag conforming to "Coarse Aggregate," of ASTM C 33-86. Recommended grading size is 67, unless otherwise specified. The limits of deleterious substances should note the weathering regions noted in Figure 1 of this ASTM standard.

b. **Aggregate Tests.** Soundness of fine and coarse aggregates may be tested in accordance with ASTM C 88-83, Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate, and for weathering exposure by ASTM C 666-84, Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing. Suitability of the aggregates should also be tested, e.g., ASTM C 33-86, Standard Specification for Concrete Aggregates.

**38. REFRACTORY CONCRETE (THERMAL TREATMENT).**

**a. Material Quality.** A system of procedures for selecting the levels of quality required of the refractory concrete to perform the functions intended should be determined. *All refractory concrete castables shall be in accordance with ASTM C 401-84, Standard Classification of Castable Refractories.*

**b. Practices.** There should be procedures, specifications, and standards that can be followed by contractors and be used to monitor the properties of all finished work. To achieve the best refractory concrete lining, contractors should closely follow manufacturer's guidance and/or the American Concrete Institute (ACI) 547R-79, Refractory Concrete: Abstract of State-of-the-Art Report. It is *highly* recommended that the contractor have prior experience with refractory concretes because of the different behaviors between refractory concretes (ASTM C 401 types) and portland cement concretes (ASTM C 150 types).

**(1) Installation.** Maximum service life is not obtained unless the refractory concrete is mixed, installed, cured, and fired-up (initial) properly. For quality control, pre-fabricated sections are recommended over field mixes. Placement of field mixes should proceed within the recommended atmospheric temperature range. Care should be taken to avoid mixing previously hydrated material into fresh refractory concrete. All mixers, tools, and transporting equipment used previously with portland cement, mortar, lime, etc., should be cleaned with clean water prior to mixing refractory concrete. Batch sizes should not be larger than can be installed quickly, e.g., under five minutes. Excess material should never be deposited into newer batches. All forms should be thoroughly waterproofed and removed following the prescribed schedule. Placed refractory concrete should be left in "as-placed" state. That is, scraping, rubbing, or finishing if required should be of the absolute minimum. In all cases, use of steel trowels should be avoided.

**(2) Water/Cement Ratio for Field Mixes.** Since refractory aggregates have a high water absorbency, periodic verification of the water/cement ratio of field mixes should be conducted. ASTM C 860-83, Standard Practices for Determining and Measuring Consistency of Refractory Concretes, should be conducted, e.g., the "ball-in-hand" test.

**(3) Reinforcement.** Positive reinforcement is usually necessary to compensate for the differential of thermal expansion between the hot-face and the cold-face of the refractory concrete used on the curb.

**(a) Anchors.** Anchors may be of refractory types or those made of specific alloy materials that satisfy the design requirements and are able to withstand encountered temperatures. For example, carbon steel can be used up to 1000° F (540° C), Type 304 stainless anchor up to 1800° F (980° C), and Type 310 up to 1900° F (1,038° C). To avoid formation of planes of weaknesses in refractory concrete, anchors free of sharp edges or corners should be placed in a staggered pattern.

**(b) Steel Fiber Reinforcement.** Refractory concrete linings such as castables may be reinforced by the introduction of steel fibers. Steel fibers offer greater resistance to thermal cycling and shock, tensile strength, and physical abuse.

**(c) Precautions.** The use of non-refractory reinforcement should be avoided since usually a differential expansion due to temperature or oxidation results. Likewise, all heavy metal embedments such as pipes, bolts, etc., should not be inserted in refractory concretes.

**(4) Curing and Initial Fire-Up Schedule of Field Mixes.** Prior to the initial fire-up, field mixed refractory concretes should be properly cured as recommended by the manufacturer. Improper initial fire-up schedules will later create excessive internal steam pressures that may lead to explosive concrete spalling.

**c. Selection Parameters.** The type of refractory concrete should meet the design service temperatures and density, the destructive forces of abrasion, erosion, physical abuse, load-bearing stresses, and have for field mixes a quick initial firing schedule. Selection of a refractory concrete that best meets the service requirements should follow manufacturer's recommendations. Items of considerations are:

**(1) Design Service Temperature.** *The specified refractory concrete shall have a minimum design service temperature of 2100° F (1149° C).*

**(2) Binder for Non-Castables Field Mixes.** Binder selection should be based on the required design service temperature of 2,100° F (1,149° C). Binders should be either of "intermediate" or "high purity" classification (i.e., increased Alumina, $Al_2O_3$, and decreased iron content). At this design service temperature, any type of calcium aluminate cement is recommended as the hydraulic binder.

(3) **Abrasion and Erosion Resistance.** Since the binder is the weakest matrix element of refractory concretes, the exposed surfaces of the aggregates should withstand anticipated abrasion and erosion effects. Thus, for good abrasion and erosion resistance a hard aggregate with a high modulus of rupture and high compressive strength should be selected for the hot face of refractory concretes. Coarse aggregates that contain quartz should be avoided since they suffer a large volume change at approximately 1065° F (574° C).

(4) **Graded Aggregate for Non-Castables Field Mixes.** The internal thermal stability of coarse aggregates greatly impacts the design of refractory concretes. Aggregate types recommended for field mixes at specified service temperatures for selected aggregates mixed with calcium aluminate cements are found in Table 3.3a of ACI 547R-79. Also, suggested aggregate gradations are provided by the same table for nominal maximum size aggregates.

(5) **Corrosive Environment.** For refractory concretes subjected to corrosive environments, higher density, higher purity refractory concretes are recommended over lower density, lower purity types.

**39. FLEXIBLE MEMBRANE LINER (FML).**

a. **Material Quality.** The selected flexible membrane liner (FML) materials should be of first quality, virgin materials designed and manufactured specifically for the purpose, properties, and performances required. FMLs should be free of defects that may affect their serviceability such as pinholes, modules, delamination, etc. *All defects shall be corrected prior to delivery or operation of training facility.* All necessary liner anchorage, penetrating hardware, and interface components required for complete installation should be included.

b. **Practices.** The FML should be versatile for easy and cost-effective installation. Installation should closely follow manufacturer's instructions and any unique practices. Contractors *should have* either prior FML installation experience for the type of FML material selected or an experience level of FML installation as approved by the applicable state (e.g., a state department of natural resources).

c. **Material and Performance Properties.** *The selected flexible membrane liner (FML) shall be of a non-extractable plasticizer quality. the FML fabricator shall provide written certification that the full FML and, if included, the piping FML trench meet the material and performance properties required below.*

(1) The specific material property standards including applicable appendices of the National Sanitation Foundation (NSF) Standard #54, Flexible Membrane Liners, revised November 1985.

(2) The material compatibility tests of Environmental Protection Agency (EPA) Test 9090 for the hydrocarbon fuels to be used in training, e.g., Jet A, JP-4.

(3) The maximum permeability rate of either 0.25 oz/ft $^2$ /day (3.3 cm $^3$/m $^3$/m $^2$/hr) for the hydrocarbon fuel to be contained or the established permeability test criteria of the applicable state (e.g., a state department of natural resources), or local government. Permeability tests may be in accordance with ASTM E 96, Standard Test Method for Water Vapor Transmission of Materials, performed with the type of hydrocarbon fuel to be contained.

(4) Chemically compatible with other chemicals that the FML will contact such as those found in the supporting soil.

(5) A low temperature resistance of -40° F (-40° C) and a high temperature resistance of 240° F (115° C) without performance failure.

(6) Highly resistant to abrasion, humidity, rot, mildew, vermin, bacterial deterioration, and sunlight (UV).

(7) A minimum nominal gauge thickness of 30 mils (EPA requirement) or greater as recommended by the manufacturer. Actual FML thickness may be verified by ASTM D 1593-83, Standard Specification for Nonrigid Vinyl Chloride Plastic Sheeting, for unreinforced fabrics and ASTM D 751-79, Standard Method of Testing Coated Fabrics, for reinforced fabrics.

d. **Bonded Seams.** All factory and field seams should be sufficiently strong to withstand installation handling, of seam strengths that exceeds parent material to prevent seams leaks over the service life of the FML, and permanently marked with an identification number. *All factory and field seams shall be made by an approved method such as dielectric, extrusion welding, or thermal methods, and then tested and certified by the manufacturer to be leak free.* Seam integrity may be verified by either a destructive test, a vacuum test or a jet air lance test, e.g., ASTM D 4437-84, Standard Practice for Determining the Integrity of Field Seams Used in Joining Flexible Polymeric Sheet Geomembranes. *Seams shall meet the following:*

(1) **Factory seam joints** the FML physical properties requirements of NSF Standard #54 and the chemical compatibility shear and peel directional tests of Appendix D, part L of NSF Standard #54, revised November 1985.

(2) **Field seaming of joints and of penetrating objects** performed and repaired in accordance with applicable parts of Appendix C, Section VI of NSF Standard #54, revised November 1985.

e. **Interface Components, Liner Tubes, Sleeves, etc.** *All liner penetrations shall be material compatible with the FML and tested for tightness by an acceptable method such as a hydrostatic, vacuum, ultrasonics, or air jet test.*

f. **Installation.** FML installation should closely follow the manufacturer's practices and techniques. Noted precautions during installation are:

(1) The subgrade supporting the FML should be properly prepared. This includes the removal from the subbase of any foreign matter such as vegetation, debris, water, snow, ice. All angular rocks and other protrusions such as broken stones and hard objects in the receiving area should also be removed, particularly, stones larger than 2 inches (5 cm) in diameter, sharp-edged stones, and hard objects within 4 inches (10 cm) of the surface to be lined.

(2) The subbase should be uniformly compacted to ensure against floor settlement and to provide a uniformly sloped surface towards the weir(s), all interior drains, and the FML trench containing the monitoring well. Backfilling should not be accomplished over porous, wet, or spongy subgrade surfaces. Optimum moisture content of backfill materials should be maintained to achieve the required compaction density. Compaction densities should be observed and maintained by conducting a compaction test such as ASTM D 1556-82, Standard Test Method for Density of Soil in Place by the Sand-Cone Method, or ASTM D 2167-84, Standard Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method.

(3) The underside of the secondary FML should be protected by at least 6 inches (15 cm) of sand, pea gravel, or 15 mils (0.015 inch) of geotextile padding with the receiving subgrade not frozen.

(4) There should be no bridging or stressed conditions in the FML.

(5) Concrete or other rigid surfaces adjacent to FMLs should have all rough edges and projections removed. Extruded expansion materials and joint sealers should also be removed and flushed with the concrete surface.

(6) Resulting tears, punctures, or other defects in the FML during installation shall be repaired, tested, and certified to be leak free by the installer at no additional cost to the airport sponsor.

(7) The upper FML (primary containment) inward of the inner ring section should be protected by a minimum of at least 6 inches (15 cm) of sand (see subparagraph 44a(2) for recommended sand gradation).

(8) The outer perimeter of the double layer FML system should be properly anchored below the berm with at least a 20-inch (8 cm) heat protective cover of backfill material (see Table 2-1 of paragraph 20 for gradation).

**40. DRAINAGE NET.**

a. **Material and Performance Properties.** *The drainage net between the double layered FML system shall have the following properties:*

(1) The same material and performance properties of the selected FML stated in subparagraph 39c excluding numbers 3 and 6.

(2) Compatible with all FMLs.

(3) A manufacturer's recommended thickness that withstands overhead applied loads for effective flow characteristics (monitoring well).

**b. Installation.** Installation should follow manufacturer's practices and techniques. Noted precautions during installation are:

(1) There should be no bridging or stressed conditions in the drainage net.

(2) Sloped portions of the drainage net should not exceed manufacturer recommendations.

(3) Draining nets should terminate near the perimeter ends of the double FMLs, e.g., under the berm.

(4) Tears, punctures, or other defects should be repaired by the installer at no additional cost to the airport sponsor.

**41. GEOTEXTILE FABRIC.**

**a. Material and Performance Properties.** *The geotextile fabric shall have the following properties:*

(1) Be compatible with the hydrocarbon fuels used in training.

(2) Withstand elevated temperatures over 212° F (100° C) to maintain its integrity and physical properties such as non-shrinking, softening, or melting.

(3) Have a high water and fuel permeability and filter capabilities to allow adequate drainage and maintain the separation of the upper crushed stone layer from the lower sand layer.

(4) Have high multi-directional tensile strength and high abrasion and puncture resistance as recommended by the manufacturer. Minimum puncture strength may be verified by ASTM D 751-79, Standard Method of Testing Coated Fabrics.

(5) Have excellent load-elongation, creep resistance, and a high coefficient of friction between fabric and separated fill materials.

(6) Be resistant to ultra-violet degradation (UV).

(7) Have a minimum weight equal to or greater as recommended by the manufacturer. The weight, if in $oz/ft^2$, may be verified by ASTM D 3776, Standard Test Method for Mass Per Unit (Weight) of Woven Fabric.

**b. Installation.** Installation should follow manufacturer's practices and techniques. Noted precautions during installation are:

(1) The material upon which the geotextile fabric is to be installed should be properly compacted to specified gradients and elevations.

(2) Geotextile fabric applied to a surface should have sufficient slack to prevent tearing when overhead layer of crushed stone material is placed.

(3) Geotextile fabric edges should be lapped a minimum of 12 inches (30 cm) or as recommended by the manufacturer to prevent separation at overlapped edges when the overhead layer of crushed stone material is placed.

(4) End joints of geotextile fabric should be placed several feet into the inner ring section or as recommended by the manufacturer.

**42. LEAK MONITORING WELL, FML TRENCH.** Prior to the installing of the FML trench leading to the monitoring well, the following should be performed:

**a.** The cut of the FML trench should be sufficiently wide to enable installation of the FML trench material, pipes, utilities if included, and permit inspection.

b. All large stones or other hard materials which could hamper the leak detection function of the monitoring well, penetrate the FML trench, or impede consistent backfilling or compaction to specified elevations and densities should be removed.

c. The location and elevation of the sump housing the monitoring well should receive special attention and be verified.

d. Once the FML trench material has been installed, all trenches should be backfilled by a method that does not disturb elevations or damage the FML trench, pipes, and utility lines. Hand tamping should be preformed in areas inaccessible to compaction equipment.

**43. ELECTRICAL SYSTEMS.** *All electrical equipment and wiring shall be installed in accordance with National Fire Protection Association (NFPA) 70, National Electrical Code, or under stricter governing codes.*

**44. BURN AREA, BERM, AND FML AGGREGATE MATERIALS.**

a. **Burn Area Aggregate Materials.**

(1) **Crushed Stones for Burn Area.** Crushed stones should be angular, crushed, free of shale, clay, friable materials, and debris; graded in accordance with ASTM C 136-84a, Standard Method for Sieve Analysis of Fine and Coarse Aggregates, within the recommended limits of Size No. 4 of ASTM D 448-86, Standard Classification for Sizes of Road and Bridge Construction.

(2) **Sand Cover Over Double FML Liner System.** Sand should be of natural river, bank, or manufactured sand; washed, free of silt, clay, loam, friable, or soluble materials, and organic matter; graded in accordance with ASTM C 136-84a within the recommended limits of "Fine Aggregate" category of ASTM C 33-86, Standard Specification for Concrete Aggregates.

b. **Berm and Inner Ring Section Aggregate Material.** Backfill material should be free of friable or soluble materials, clay, loam, and silt, and other debris; graded and sloped as recommended in Table 2-1 and paragraph 20 and well compacted.

**45. FUEL, WATER STORAGE TANKS.**

a. **Installation.** Storing, handling, and placing of tanks should be performed with care to minimize damages to the surfaces. An aboveground fuel tank is *highly recommended* over an underground fuel tank. Placing of fuel and water tanks should be done with a minimum of handling. Accessible interior portions of tanks should be cleaned and made free of all foreign matter collected during fabrication and placement. Each tank should be furnished with the proper clip angles for grounding purposes. Metals in contact with fuel should be stainless steel; for example types 304 or 316, or aluminum alloys types 3003 or 6061. The tank surface and all ferrous-metal appurtenances which may not withstand corrosive environmental exposure should be cleaned, primed, and painted. All damaged surfaces incurred in tank placement should be repaired. Additional guidance on fuel tank installation is found in NFPA 30-84, Flammable and Combustible Liquids Code.

b. **Testing.** *Fuel tanks shall be suitable for storing jet fuels and shall be fabricated for the intended service in accordance with Appendix 1. All tanks shall be tested before they are placed in service in accordance with the applicable paragraphs of the code under which they were built. All tanks and connections shall be tested for tightness prior to placing the tank in service.* Except for underground tanks, this test shall be performed at the operating pressure with either air, inert gas, or water. Discovered leaks shall be corrected and the tank and connections retested.

**46. FUEL, WATER PIPING SYSTEM.**

a. **Installation.** *Minimum requirements for the materials, design, fabrication installation, and workmanship shall be in accordance with ANSI B-31.3-84, Chemical Plant and Petroleum Refinery Piping, and NFPA 30-84, Flammable and Combustible Liquids Code, unless otherwise specified.* The advisory provisions of NFPA 30 are highly recommended. Some installation items are:

(1) Distribution piping systems and components, including piping, equipment, valves, and accessories should be suitable for minimum design working pressure.

(2) Piping should be installed straight and true and shall bear evenly on supports.

(3) Fittings should be provided for changes in direction of piping and for all connections.

(4) Changes in piping sizes should be achieved through reducing fittings.

(5) Piping adjacent to pump should be supported in such a manner that no weight is carried on pump casings.

(6) Pumps should be checked for proper alignment prior to start-up.

(7) Underground valves should be provided with a valve box and operating wrench. Stems of valves should be installed upright or horizontally, not inverted, unless specified.

(8) Valves should have manufacturer's name and pressure rating clearly marked on outside of body.

(9) To the extent possible, valves should be from the same manufacturer.

**b. Testing.** All piping systems, before being covered, enclosed, or placed in service, should be flushed thoroughly with water (before spray nozzle connection) in order to remove foreign materials which may have entered during the course of installation. Cleanliness of sections where flushing is not practicable should be determined by visual inspection. After cleaning and before being buried, covered, or concealed, *all piping systems shall be tested to demonstrate tightness and conformance with one of the following:*

(1) ANSI B31.3-84, Chemical Plant and Petroleum Refinery Piping, and other applicable sections of ANSI B31, American National Standard Code for Pressure Piping.

(2) NFPA 30-84, Flammable and Combustible Liquids Code.

**47. SECONDARY CONTAINMENT FOR PIPING SYSTEMS.** *All underground fuel piping systems that are connected to a fuel storage tank and supply the burn area with fuel shall have a means of secondary containment with an appropriate leak-detection device.* This may be accomplished by either a piping FML trench or double wall piping.

**a. Piping FML Trench.** *The piping FML trench shall meet all the requirements of paragraph 39, Flexible Membrane Liner. Except for the concrete structure alternative, the FML structure alternative shall use a FML trench of the same material.*

**b. Double Wall Piping.** *Double wall piping shall provide the level of protection as specified by the EPA (Federal), state, or local jurisdiction.*

**c. Leak-Detection System.** *All integrating piping systems shall be equipped with a leak detection system appropriate for the type of secondary containment selected.* For example, a continuously operating mechanical or electronic leak detector between the walls of double walled piping, an observation monitoring well for FML piping trench, or some other means as approved by the state or local government.

# APPENDIX 1. DESIGN AND CONSTRUCTION PRACTICES FOR FUEL STORAGE TANKS

## Section 1. FUEL TANKS

1. AMERICAN PETROLEUM INSTITUTE (API).

a. API Publication 1615-79, Installation of Underground Petroleum Storage Systems.

b. API Standard 620, Rules for Design and Construction of Large, Welded, Low-Pressure Storage Tanks (revised 1985).

c. API Standard 650, Welded Steel Tanks for Oil Storage (revised 1984).

d. API Standard 2000-82, Venting Atmospheric and Low Pressure Storage Tanks.

e. API Standard 2550-65, Methods for Measurement and Calibration of Upright Cylindrical Tanks.

f. API Specification 12B, Specification for Bolted Tanks for Storage of Petroleum Liquids, (supplement 1-1982, supp 2-1985).

g. API Specification 12D, Specification for Field Welded Tanks for Storage of Petroleum Liquids (supp 1-1983).

h. API Specification 12F, Specification for Shop Welded Tanks for Storage of Petroleum Liquids (supp 1-1983, supp 2-1985).

2. AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME), Boiler and Pressure Vessel Code, 1983 edition.

3. AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM).

a. ASTM D 1410-65, Methods for Measurement and Calibration of Stationary Horizontal Tanks (API Standard 2551-65).

b. ASTM D 4021-86, Standard Specification for Glass-Fiber Reinforced Polyester Underground Petroleum Storage Tanks.

4. UNDERWRITERS LABORATORIES INC., (UL).

a. UL 58-76, Standards for Steel Underground Tanks for Flammable and Combustible Liquids.

b. UL 142-81, Standards for Steel Aboveground Tanks for Flammable and Combustible Liquids.

c. UL 1316-83, Standards for Glass-Fiber Reinforced Plastic Underground Storage Tanks for Petroleum Products.

## Section 2. VENTING SYSTEMS

5. AMERICAN PETROLEUM INSTITUTE (API).

a. API Standard 2000-82, Venting Atmosphere and Low Pressure Storage Tanks.

b. API Pub 2021-80, Guide for Fighting Fires in and Around Petroleum Storage Tanks.

6. NATIONAL FIRE PROTECTION ASSOCIATION (NFPA) Appendix A, Emergency Relief Venting for Fire Exposure for Aboveground Tanks (Flammable and Combustible Liquids Code Handbook, 1st ed., 1984).

7. UNDERWRITERS LABORATORIES INC., UL 525-84, Flame Arresters for Use on Vents of Storage Tanks for Petroleum Oil and Gasoline.

## Section 3. CATHODIC SYSTEMS

8. AMERICAN PETROLEUM INSTITUTE (API) Publication 1632-83, Cathodic Protection of Underground Petroleum Storage Tanks and Piping Systems.

9. UNDERWRITERS LABORATORIES INC. (UL).

a. Underwriters Laboratories of Canada (ULC) S603.1-M 1982, Standard for Galvanic Corrosion Protection Systems for Steel underground Tanks for Flammable and Combustible Liquids.

b. UL 58-1981, Standards for Steel Underground Tanks for Flammable and Combustible Liquids.

10. STEEL TANK INSTITUTE No. STIP 3.

11. NATIONAL ASSOCIATION OF CORROSION ENGINEERS STANDARD (NACE), RP-01-69, Recommended Practice - Control of External Corrosion of Underground Submerged Metallic Piping Systems.

_______________ Airport

**DAWN & DUSK**
**Airport Inspection Report**

___:___ A.M.
___:___ P.M.

____ day ____ mo. 19__ year

| | ALL O.K. | Action Taken | Date NOTAM Issued | Date Condition Corrected |
|---|---|---|---|---|
| Runways | | | | |
| | | | | |
| | | | | |
| Taxiways | | | | |
| | | | | |
| | | | | |
| Other Surfaces | | | | |
| | | | | |
| | | | | |
| Runway Lights | | | | |
| | | | | |
| | | | | |
| Other lights & Navaids | | | | |
| | | | | |
| | | | | |
| Airline Loading Areas | | | | |
| | | | | |
| | | | | |
| Terminal Buildings | | | | |
| | | | | |
| | | | | |
| Hangars | | | | |
| | | | | |
| | | | | |
| Other Buildings | | | | |
| | | | | |
| | | | | |
| Miscellaneous | | | | |
| | | | | |
| | | | | |

Sign ____________________

Title ____________________

Date ____________________

NOTE: See reverse side for location data.

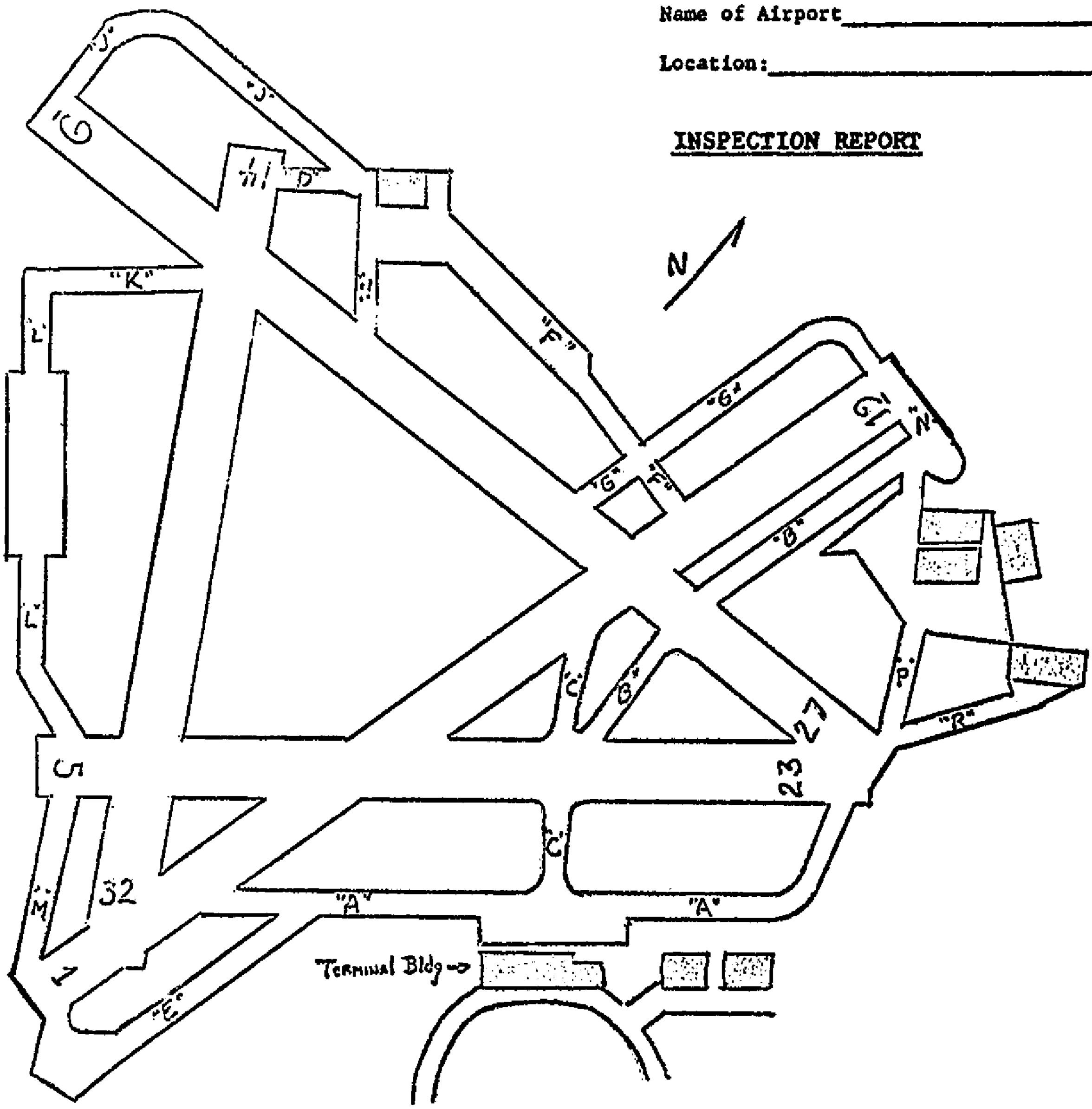
Retain for ____ months from above date.

(On reverse of inspection form)

Name of Airport______________________

Location:__________________________

**INSPECTION REPORT**




Time____________ Date__________ Weather____________

NOTAMS ISSUED:

Conditions Not Noted by NOTAMS:__________________________________________

NOTIFIED: (Initials of Person Notified) Tower____________ Eastern______________

Allegheny______________ Capitol____________________ Del. A.N.G.______________

Inspected by:____________________ Airport Guard

____________________ Airport Superintendent

____________________ Airport Manager

U.S. Department
of Transportation

**Federal Aviation Administration**

800 Independence Ave., S.W.
Washington, D.C. 20591

**BULK MAIL**
POSTAGE & FEES PAID
FEDERAL AVIATION
ADMINISTRATION
PERMIT NO. G-44

**RETURN POSTAGE GUARANTEED**

Official Business
Penalty for Private Use $300