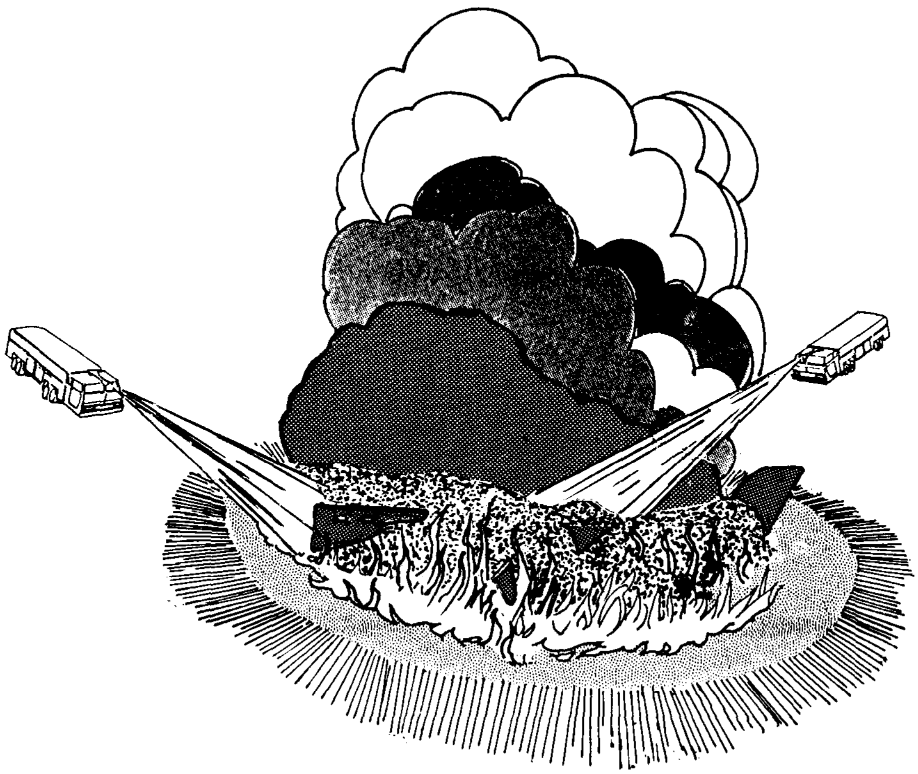
U.S. Department
of Transportation
Federal Aviation Administration

Design Standards for an Aircraft Rescue and Firefighting Training Facility

Advisory Circular 150/5220-17A

Date: January 31, 1992



U.S. Department of Transportation
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Advisory Circular

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

Date: 1/31/92
Initiated by: AAS-120

AC No: 150/5220-17A
Change:

1. PURPOSE. This advisory circular contains standards, specifications, and recommendations for the design of an aircraft rescue and firefighting training facility utilizing either propane or a flammable liquid hydrocarbon (FLH) as the fuel.

2. CANCELLATION. This advisory circular (AC) cancels AC 150/5220-17, dated 4/1/88.

3. 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.

4. RELATED READING MATERIALS. Publications referenced within this advisory circular can be obtained by writing to:

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

b. American Petroleum Institute (API), 1220 L Street, N.W., Washington, DC 20005.

c. American Society of Mechanical Engineers (ASME), United Engineering Center, 345 East 47 Street, New York, NY 10017.

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

American Water Works Association (A&A), 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), 1440 South Creek Drive Houston, TX 77084.

h. National Concrete Masonry Association (NCMA), P.O. Box 781, Herndon, VA 22070.

i. National Fire Protection Association (NFPA), One Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101

j. National Sanitation Foundation (NSF), 3475 Plymouth Road, P.O. Box 1468, Ann Arbor, MI 48106.

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

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

5. 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
Director, Office of Airport Safety and Standards

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CHAPTER 1. PLANNING PHASE

Section 1. INTRODUCTION

1. **GENERAL CRITERIA.** The facility described in this AC is intended to provide aircraft rescue and firefighting (ARFF) service personnel with realistic training in the application of extinguishing agents on an appropriately sized fire area using ARFF vehicle(s) or other agent application devices comparable to those used at their airport. Figure l-l illustrates a generic layout of such a training facility. The major components are discussed in detail in the AC.

2. **THE TRAINING FACILITY.**

a. **General.** The facility is composed of the burn area structure, the ARFF vehicle maneuvering area, the various support components, and the support systems. The physical area needed for each of these items makes up the total land area required to accommodate a realistic training facility.

b. **Burn Area Structure.** The fire area, termed the burn area structure, is the focal point of the training facility. It is designed specifically to create a realistic aircraft accident fire environment and to contain training substances. Its size is a function of the extinguishing agent applicator discharge rates to be used for training exercises.

c. **ARFF Vehicle Maneuvering Area.** This area physically surrounds the burn area structure and shall be large enough to allow for the tactical operation of ARFF vehicles as they approach the burn area structure and the realistic deployment of personnel using hand lines.

d. **Support Components.** These components make up the functional units needed to implement the simulation of various types of aircraft fires and to recycle spent mixtures of chemicals, water, and FLH if necessary. The aircraft mock-up is a basic support component and may be either fixed or mobil.

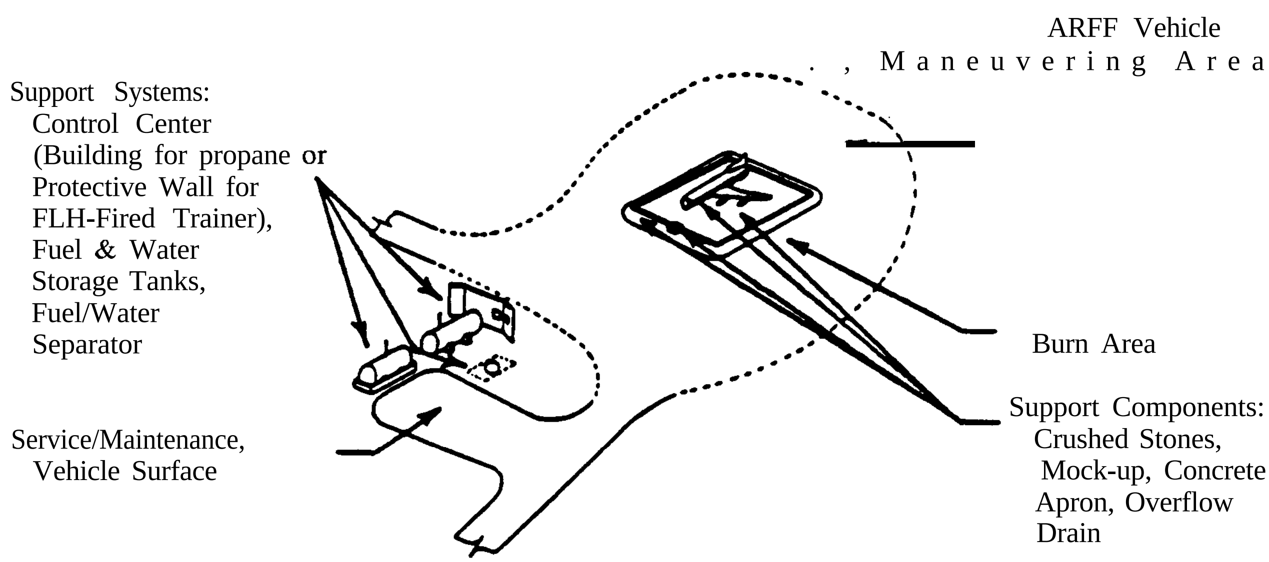


Figure l-l. Example of a training facility

e. **Support Systems. These** systems are the functional units needed to implement the training fire simulation. For example, the control center is a support system. Each support system is composed of individual support components that makeup a system, e.g., the fuel distribution system consists of a storage tank, pumps, associated piping, etc.

Section 2. DERIVATION OF DESIGN PARAMETERS THAT SET TRAINING FIRE SIZE

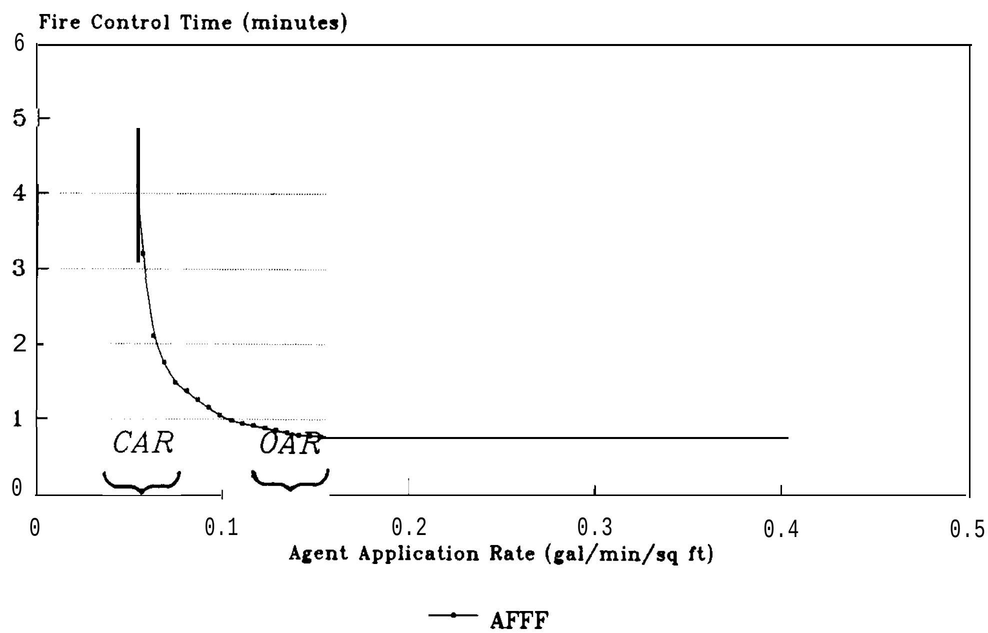
3. TRAINING FIRE SIZE. To be acceptable as well as meaningful, actual or simulated aircraft fire suppression training shall present the firefighter with a realistic, challenging aircraft fire. In addition, the fire shall be, or give the appearance of being, extinguishable with the fire suppression equipment that a proficient firefighter is expected to use in an actual aircraft emergency at the assigned airport. Discussed below are three interdependent variables which effect these two requirements.

a. **Agent Application Rates.** This term 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 burn area structure. As shown in Figure l-2, a typical foam agent has two agent application rates of interest, e.g., the "critical application rate" (CAR) and the recommended "operational application rate" (OAR).

(1) **Critical Application Rate (CAR).** For a given foam solution, the CAR is defined as the lowest rate at which it can be applied to a given fire area (under a fixed set of fire conditions) and extinguish that fire.

(i) The CAR is used principally to quantitatively compare the relative firefighting effectiveness of competing or proposed new agents. 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 structure is not available.

Figure 1-2. Typical relationship between control time & application rate for AFFF



(ii) 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 results in the use of more agent per square foot of fire extinguished than its competitor, 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).

(i) Figure 1-2 also shows that the typical recommended OAR is approximately three times the CAR of a given foam agent for a given fuel fire. This relationship was established by extensive testing. It has also been found to be operationally practical in terms of the uncertainty of the conditions found at a typical fire site, the desired fire control time, the average fire fighter's skill, and the practical amount of agent that can be immediately available at an aircraft accident.

(ii) It can also be seen from Figure 1-2 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 structure by reducing the OAR being used by a trainee. However, if it falls below the CAR the fire cannot be extinguished in a reasonable time with that agent.

b. **Agent Applicator Discharge Rates.** Discharge rates are used to describe or specify the desired capability of a firefighting apparatus to deliver agent from a specified applicator, e.g., turret, hand line, or bumper turret. Hence, there is a notable difference between discharge rates commonly specified for equipment performance and the agent application rates discussed above. There is, however, an important relationship between these two terms. For example, if the agent discharge rate, the usable agent tank 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 equipment and agent 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 fire area that can be extinguished is defined.

c. **Critical Fire** Areas. Figure 1-3 is a representation of the relationship between the theoretical critical fire area (TCA), the practical critical area (PCA), and a large aircraft. The actual size of the TCA is a function of the length and width of the specific aircraft of interest. Fires outside the theoretical critical area have no immediate impact on the life safety and rescue problem at the aircraft. The PCA is defined as an area approximately two-thirds of the TCA for any given aircraft. It is the minimum area that the first responding ARFF units need to keep fire-free during the aircraft evacuation process. Hence, the PCA is used in aircraft rescue and firefighting system planning to quantify the tactical and logistical aspects of the problem. Therefore, it is vital in ARFF training facility design.

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 to exit from the aircraft through the PCA.

(1) This requires the ARFF service to have the capability to at least control/extinguish fires within that 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.

(2) By drawing on the information developed in the preceding paragraphs we have the means to quantify the ARFF service requirements and to relate that result to burn area structure requirements. For example, Table l-l provides a series of calculated PCAs by aircraft size and the literature (manufacturer's or R&D) provides the OAR for generic foam agents, e.g., AFFF = 0.13 (aqueous film forming foam), FPF = 0.16 (fluroprotein foam), and PF = 0.20

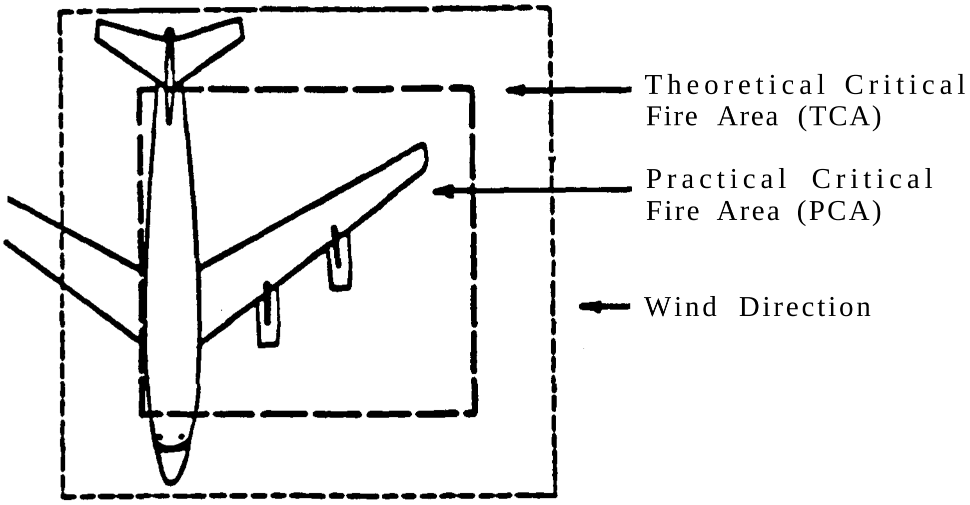


Figure 1-3. The critical fire areas

(protein foam). With this information, the required capability of an ARFF vehicle needed for a specific PCA 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 of course, 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. Hence, it follows that ideally a training facility for a given aircraft size should have a burn area structure equal to the PCA of Table l-l or should be at least able to present a simulated fire extinguishing task that a trainee will perceive as an equal challenge.

(1) Available land or other constraints may make it impractical to provide a training facility with the large burn area structures suggested by Table l-l. However, if the discharge rates of the agent applicators to be used in training are kept in strict proportion to the available burn area structure, meaningful training can be accomplished. Therefore, the size of a burn area structure can also be based on the proportional relationship between the actual or simulated fire area, the total discharge rate of the agent applicator(s), and the OAR of the agent to be used. In other words, when the available burn area structure is known (and fixed) and test data or the literature (manufacturer's or R&D) provide the OAR for the agent to be used, the appropriate agent applicator discharge rates required for meaningful training on the fire area available can be calculated.

(2) This strict applicator discharge rate versus available or simulated fire area relationship shall 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 structure, the fire will go out only after all available fuel has been consumed or turned off, 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. SIZING BURN AREA STRUCTURES

5. SIZING METHODS. Three methods are described in this section to size a burn area structure for aircraft firefighter training. The first two are applicable to burn area structures constructed for the use of FLHs. The first 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 second method, referred to as the Discharge Rate Method, is based on the total discharge rate of the agent applicators, e.g., ARFF vehicle turret and/or handlines, that are going to be used in training. The latter method permits airports with limited land area or environmental constraints on the usable fire size to engage in meaningful training by limiting the agent application rates to that appropriate to the available training fire. The third method, referred to as the Empirical Area Simulator Method, is also based on the agent application rate/fire area relationships governing-the two methods where free burning FLHs are used. However, it takes advantage of the new "fire simulator" technology using propane, that allows control of the apparent fire extinguishing rate. Thus, it permits the use of desired agent application rates on a smaller total fire area than that required where a free burning FLH is used. In all cases the Airport ARFF Index Method sets the upper limits for the square footage of the fundable burn area structure.

a. **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 the given airport ARF'F index.

(1) 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 burn areas which are to represent airport ARFF indexed PCAs.

Airport ARFF Index 1/	Overall Aircraft Lengths			Average Fuselage Width	Practical Critical Fire Area(PCA)	Rectangular Burn Area (L/W=4/3)	Circular Burn Area Diameter
	Lower (feet)	Average (feet)	Upper (feet)	(feet)	(sq. feet)	(feet)	(feet)
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 150/5210-6C, Aircraft Fire and Rescue Facilities and Extinguishing Agents.

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

(2) Table l-l presents the results of the PCA calculations needed in this method. The two columns on the right side of that table provide quick square footage estimates for the appropriate sizing of a FLH burn area.

b. **Discharge Rate Method. The** size of the burn area structure using the Discharge Rate Method shall be in accordance with either figures l-4 or l-5.

(1) Burn area structures sized by this method are acceptable when available land or other constraints make it impractical to provide a burn area equal to the area of the PCA suggested by Table l-l. By keeping the discharge rates of the agent applicators in strict proportion to the available fire area, equivalent and effective training can be performed.

(2) **Figures 1-4 & 1-5.** Figures l-4 and l-5 provide graphic solutions for the burn area structure square footage prescribed under the discharge rate method for known generic foam agents. Alternatively, the appropriate square footage for a burn area structure may be determined by dividing the discharge rate of the agent applicator(s) to be used by the OAR of the agent to be used.

NOTE: The area derived from figure l-4 or l-5 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.

(i) **Limited Land Area.** Where the maximum available land for the installation of a new FLH-fired training facility is smaller than recommended by table l-l, or an existing small facility is being retrofitted, the largest appropriate discharge rate for that burn area structure can be determined from either figure l-4 or l-5. First enter along the burn area structure 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 l-4 illustrates that a discharge rate of 195 gpm (738 L/m) is the maximum permissible rate for realistic training for a burn area structure 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 lo-meter) or a 44-foot diameter circle (13.4-meter).

(ii) **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 structure square footage axis (horizontal). For example, if two vehicles with 750 gpm (2 839 L/min) discharge each are to be used, trace 2 of figure l-5 illustrates that a burn area structure of approximately 11,540 square feet (1 072 square meters) is necessary for the meaningful use of a discharge rate of 1,500 gpm (5 678 L/min) 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 (5 678 L/min). Similarly, larger or smaller burn area structures can be derived for ARFF training operations where larger or smaller discharge rates are expected. However, for economies of construction, operations, and maintenance, the upper limit for burn area size is set by table l-l.

c. **Empirical Area Simulator Method. The** burn area structure for ARFF training facilities using a computer-controlled, propane-fired, FLH fire simulator shall be sized as follows:

(1) For ARFF index A and B simulations, the burn area shall be a circle with a diameter of least 100 feet (-1/+2 ft). A square or a rectangle, which will accommodate the required aircraft mockup, of an approximately equivalent area (7,855 ft^2) is acceptable.

(2) For ARFF index C through E simulations, the burn area shall be a circle with a diameter of least 125 feet (-1/+3 ft). A square or a rectangle, which will accommodate the required aircraft mockup, of an approximately equivalent area (12,273 ft^2) is acceptable.

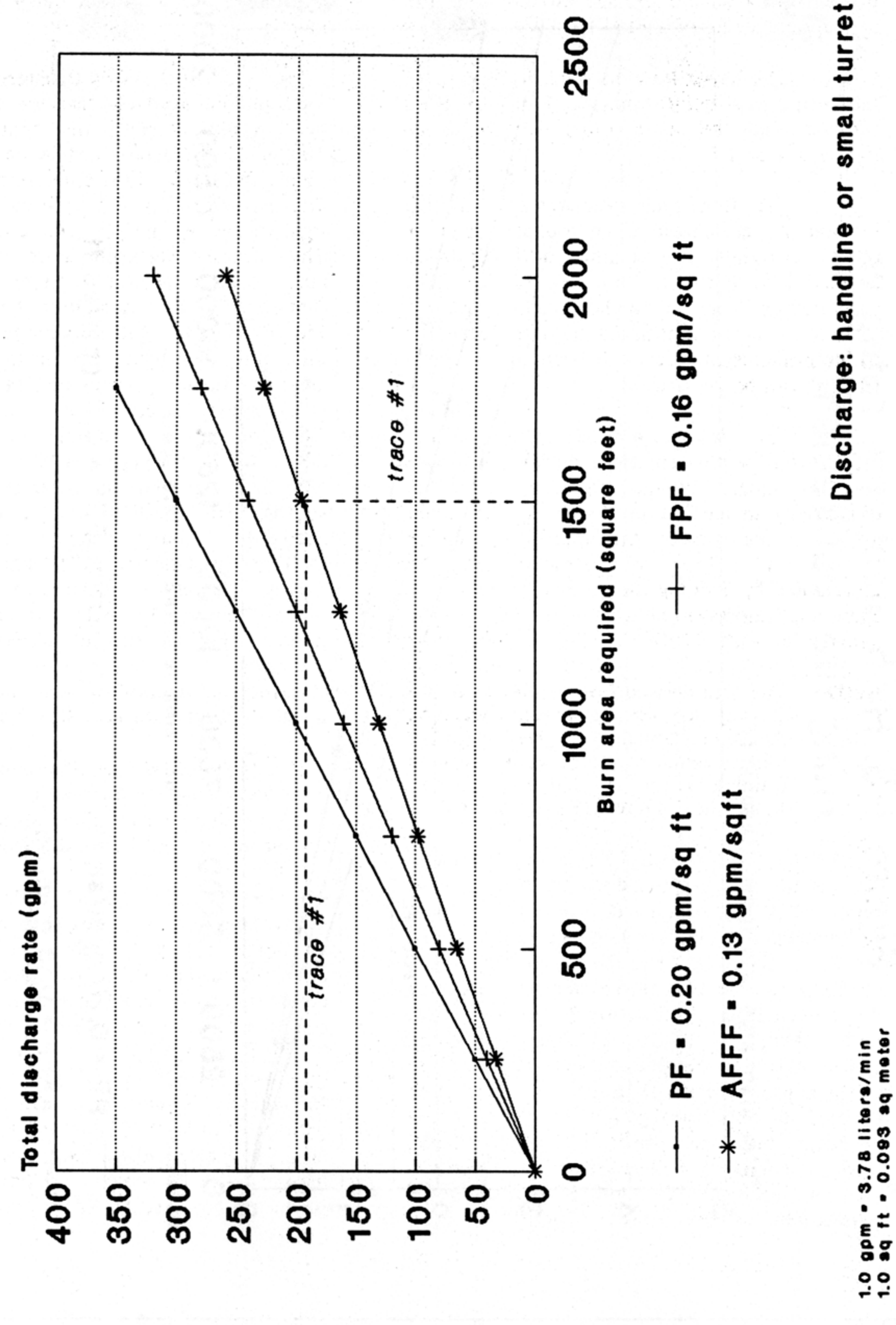
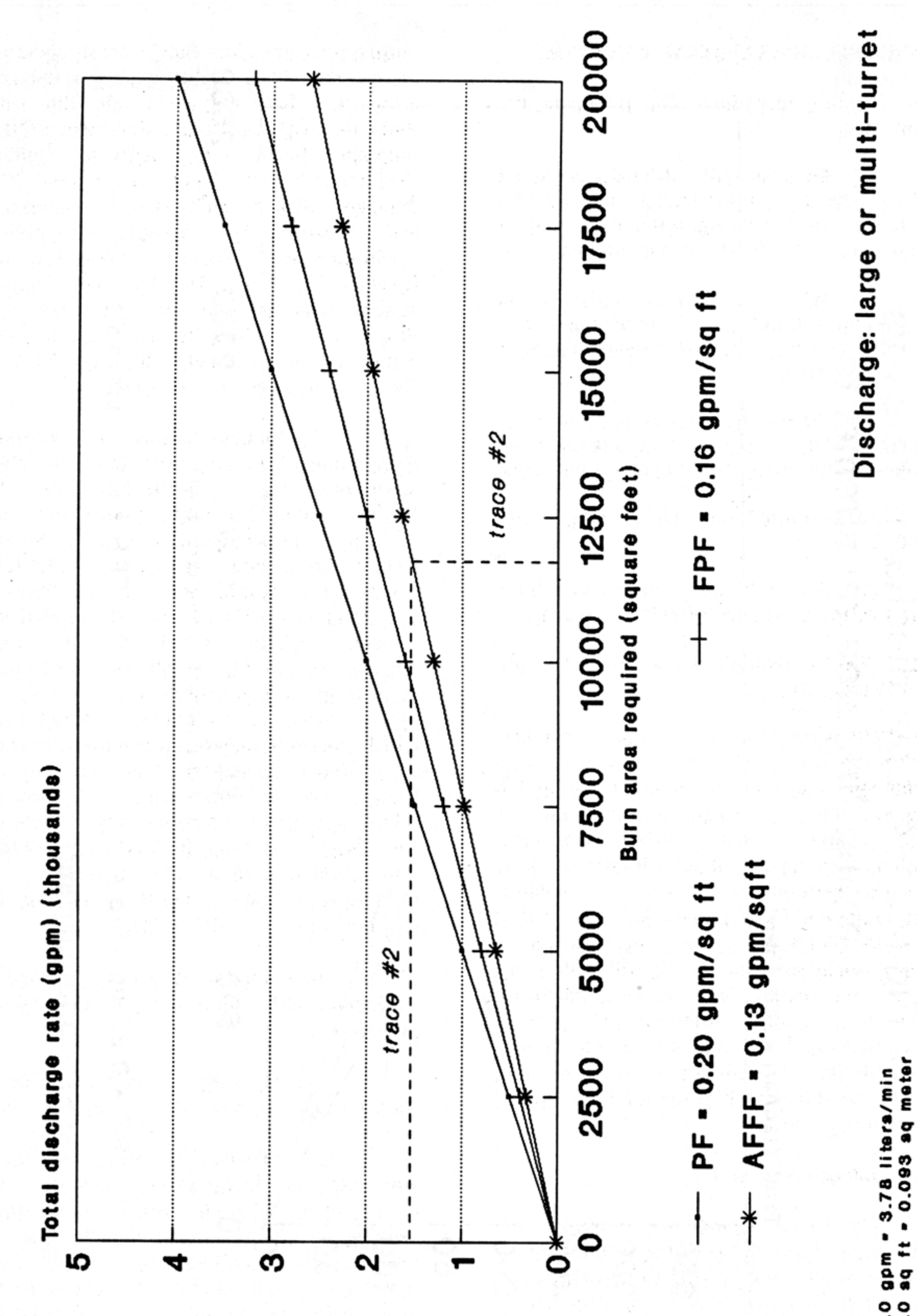


Figure 1-4. Low discharge rates vs training fire area requirements

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



Section 4. SITE SELECTION AND OPERATIONAL CRITERIA

6. AIRPORT OPERATIONAL FACTORS.

a. **Airside Operations.** The training facility shall be sited:

(1) Outside of all restricted areas noted in AC 150/5300-13, Airport Design, and AC 129-29, Criteria for Approving Category I and II Landing Minima for FAR 121 Operations.

(2) Where smoke and the associated thermal plume will not hinder aircraft operations or air traffic control (ATC) tower's surveillance of the movement area.

(3) Where the aircraft mockup (e.g., tail height) and support components (e.g., buildings) will not interfere with navigational aids.

b. **Other Siting Items.** The training facility shall be clear of:

(1) Airport buildings and public vehicle parking lots for a distance of 300 feet (91 m).

(2) Residential areas for at least 1,000 feet (305 m).

7. **ENVIRONMENTAL FACTORS.** A detailed review of applicable Federal, State, and local environmental and fire regulations is necessary for the effective planning, design, and operation of a training facility. Many jurisdictions have regulations that impose effluent discharge limits, air quality operating restrictions, e.g., volatile organic compound (VOC) regulations, and facility fire prevention inspection programs. Advanced knowledge of these requirements will help avoid delays in construction and the curtailment or termination of training. Additionally, both near- and long-term land requirements for the training facility and the intended use of adjacent lands should be identified and addressed early in the site selection process.

a. **Literature Search.**

(1) **Clean Water Act (CWA).** As provided under Section 303 of the CWA, Federal regulations require that all States develop water quality standards which have been approved by the U.S. Environmental Protection Agency (USEPA). Numerous sections of the CWA outline provisions for other Federal regulations to ensure that State water quality standards are achieved. Regulations include the National Pollutant Discharge Elimination System (NPDES) program (Section 402), Effluent Limitations (Section 301), Toxic and Pretreatment Effluent Standards (Section 307), Resource Conservation and Recovery Act (RCRA), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and Superfund Amendments and Reauthorization Act (SARA). Regulations required by the FAA include the National Environmental Policy Act (NEPA) and FAA Orders 5050.4A and 1050.1D.

(2) **Computer Search of Environmental Regulations.** The U.S. Army Corps of Engineers maintains the subscription data base Environmental Technical Information System (ETIS) which summarizes Federal, State, and local environmental regulations. The ETIS is comprised of several subsystems, including the Computer-Aided Environmental Legislative Data System (CELDS), which contains abstracts updated bimonthly of all the environmental regulations of the Federal Government, the 50 States, District of Columbia, and Puerto Rico. CELDS permits an easy but comprehensive search of pertinent regulations that may impact the facility. For assistance using ETIS, contact the ETIS Support Center, University of Illinois, 990 West Nevada, Urbana, IL 61801, (217) 333-1369. For information about ETIS, contact U.S. Army Construction Engineering Research Laboratory, (217) 352-6511, extension 447.

b. **Topography.** Relatively flat land offers both improved runoff control and lower site preparation cost.

c. **Use of FLHs.** Candidate sites for a trainer using FLHs should evaluate the site's:

(1) **Proximity to Water Supply Wells and Wetlands.** Water supply wells and wetlands in the vicinity shall be protected by siting the training facility as far as possible from them. Prior to any construction, the selected site shall first receive approvals by the Federal, State, and local environmental authorities. If sited in the vicinity of a well, the site should be on the downgradient side of the well.

(2) Soil Permeability. The presence of a natural or the addition of a low permeability confining layer such as clay or silt below the burn area structure and its immediate area helps to lessen the downward migration of inadvertent releases of FHL fuels.

(3) Flood Plain. Training facilities should be sited above the 100-year flood plain as defined in FAA Executive Order 11988. This lessens the possibility of washing contaminates out of containment areas and degrading the local soil and groundwater.

(4) Mitigation of Effluent Discharge to Nearby Streams. Training facilities shall include containment measures to preclude overland access to perennial streams by inadvertent release of FHL fuels. This access creates an environmental risk under direct low-flow conditions to such a receiver. Any effluent discharge into "navigable waters" as defined by USEPA requires a permit under section 402 of the Clean Water Act (NPDES).

d. **Mitigation of FLH Quantities. The** greatest harm to groundwater and soil qualities is attributed to FLHs released directly onto the soil during training. Hence, the simplest mitigation measure for maintaining groundwater and soil qualities is to reduce the amount of fuel placed in the burn area. Only that amount of fuel needed to create a training fire of the desired duration and intensity should be placed in the burn area structure for each training session. In practice there should be very little fuel remaining in the burn area structure after fire extinguishment. To assist this effort, a means shall be provided for the training officer to closely monitor the quantity of fuel allowed into the burn structure for training. Paragraph 10(b) and figures l-6 and l-7 provide guidance on estimating fuel quantities.

e. **Use of Propane.** The use of a propane-fired trainer to simulate a FLH fire will eliminate the hydrocarbon/water/agent discharge and disposal problems associated with FLHs. This type of simulator will also minimize air pollution problems. In addition, the rapid automatic or manual shutdown capability offered by the computer system is a significant safety enhancement as well as a versatile tool for the rapid recycling of a given training scenario by the instructor.

8. VEHICLE MANEUVERING AREA.

a. **Sizing.** Facilities intended for vehicle operator and/or turret operator training shall have a vehicle maneuvering area. For long-term cost effectiveness, the area should allow for the operation of future vehicles with more demanding operational characteristics.

(1) **Turret Discharge.** The area shall accommodate the full turret discharge range while discharging dispersed and straight stream patterns during stationary and pump and roll operations.

(2) Vehicle Mobility. The area shall accommodate the ARFF vehicle turning radius, backup requirements, and, with the longest vehicle parked perpendicular to the burn area structure, passage of other ARFF vehicles.

(3) Approach Path. There shall be more than one approach path to the burn area.

b. **Vehicle Maneuvering Surface.**

(1) **Soil Bearing Capacity.** Soil bearing capacity, treated if necessary, shall exhibit good load bearing capacity of fully loaded ARFF vehicles operations and withstand the accelerating and decelerating traction forces and turning actions of wheels without severe rutting damage.

(2) Sloped Surface. To reduce the channelled rainfall and/or snow melt load on the drainage system, the maneuvering surface should sloped as follows:

(i) For facilities with a berm, slope away from the burn area structure to divert runoff.

(ii) For facilities with a concrete curb, slope in two directions. The inner section (apron) up to ten feet (3.0 m) shall slope towards the concrete curb with the outer section sloped away from the burn area. If the apron is paved, a smooth transition shall be provided between it and the outer ground surface.

c. **Paved Access Roads.** If the training facility access road is directly connected to an aircraft operational area, it shall be paved for at least the first 500 feet (152 m) from the edge of the operational area. Paving this strip lessens the chance for foreign object damage (FOD) in areas intended for the movement of aircraft due to "tracking" of objects. Paved access roads shall have signs in accordance with AC 150/5340-18, Standards for Airport Sign Systems, latest edition.

9. **UTILITIES.** The availability of electricity and water utilities within 900 feet (275 m) and access to a sanitary sewer within 300 feet (91 m) should be a component of the site selection process. Their utilization simplifies the operation of a training facility and, if permitted, effluent disposal. Where a mobile mockup is to be used, consideration should be given to the accessibility of utilities for the resupply of consumables and where necessary the disposal of retained effluent.

Section 5. TRAINING FUEL STORAGE, CONSUMPTION, AND CONSERVATION

10. **FLH USE.** The fuel type and quantity appropriate for the intended aircraft fire simulation, (evenly distributed over the burn area structure) is as essential to meaningful training as is the proper applicator discharge rate/fire area relationship.

a. **Fuel Quantities.** The total fuel needed for a meaningful FLH training fire should be viewed as three separate quantities, each having a specific purpose.

(1) Preburn. This quantity should be sufficient to provide a 30-second pre-burn over the entire area before extinguishing operations start. This pre-burn is needed to ensure that the fire area is fully involved and that the fuel surface temperature is sufficiently high to sustain a challenging, stabilized fire.

(2) Control time. This second quantity includes at least enough fuel to ensure that the established fire can burn beyond the pre-burn time, at full intensity, over the unextinguished portions of the fire area for the duration of 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.

(3) Post-burn. Although small, this quantity will ensure that the trainee achieved the training objective, i.e., extinguished 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 is unable to successfully extinguish it. Hence, the instructor has indisputable evidence that additional training is needed.

b. **Estimates of Total Fuel Quantity.** Figures 1-6 and 1-7 are intended only as a convenient means of <u>estimating</u> the fuel quantities for typical FLH training fires. 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 of the fuel components discussed above offer potential fuel savings through the refinement of the training facility operational procedures and the proficiency of the trainees. For example, if the pre-burn fire can be established quickly over the entire fire area, the quantity of fuel used can approach that needed for the 30 second pre-burn time. As trainees become highly proficient, i.e., consistently extinguishing the fire in less than the desired control time, both control time and post-burn fuel quantities can also be reduced.

d. **Wind Effects.** Grossly asymmetric fires are the result of the FLH drifting under the influence of wind forces. This phenomena reduces the fire area, varies flame heights, and causes uneven heats and excessive smoke. To mitigate this problem, a crushed stone surface should be used which will protrude partially above the liquid fuel layer, e.g., 1/2 to 1 inch (1.25 to 2.5 cm).

11. **PROPANE USE.** The quantity of propane appropriate for the simulation of the intended FLH fire (evenly distributed over the burn area structure) is also essential for the creation of a realistic training fire. In addition, as the fire is attacked by the trainee, the appearance of the proper applicator discharge rate/fire area control/control time relationships shall be maintained.

a. **Propane Quantity.** The use of liquid propane effects the planning for fuel quantity requirements in two ways.

Figure 1-6. Small training fire area vs estimated fuel needed

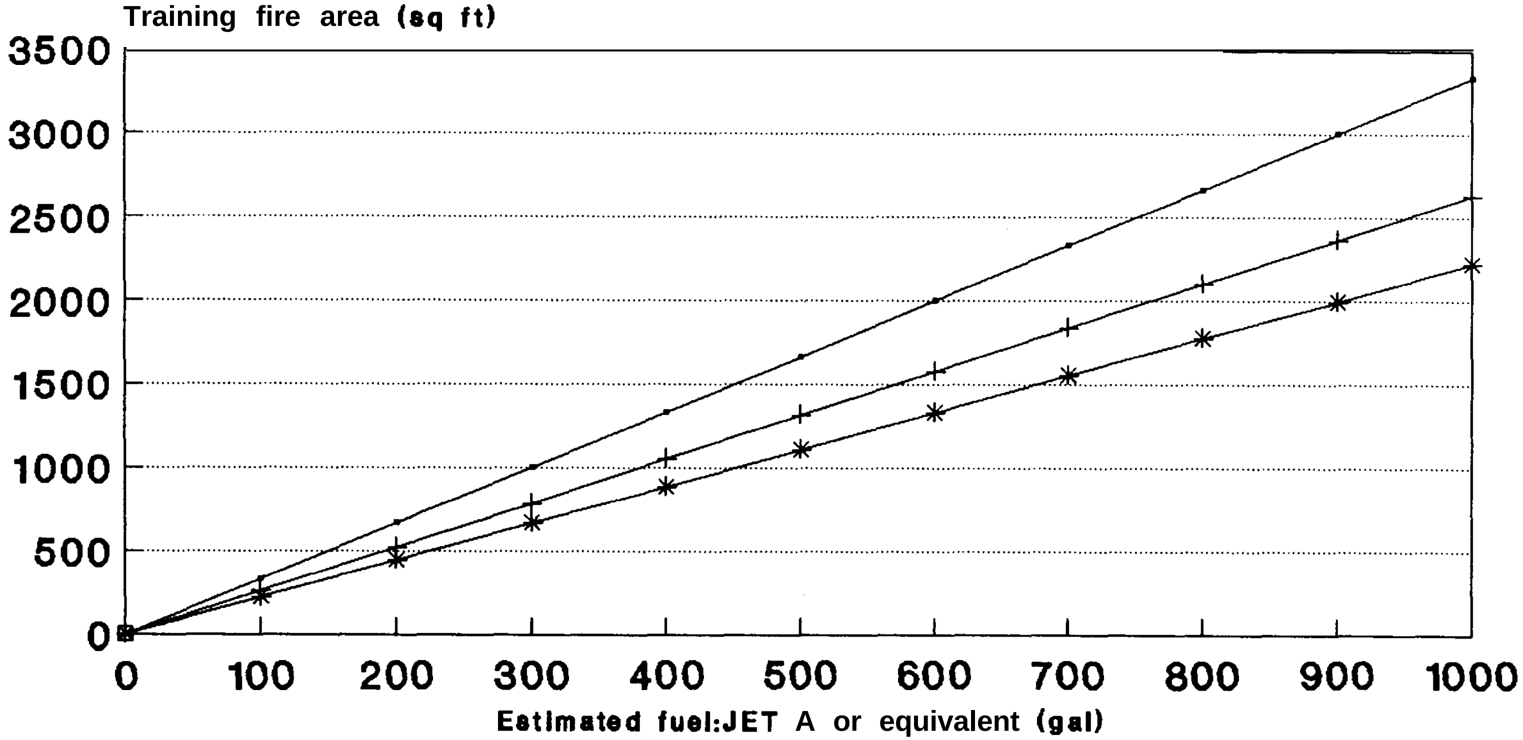


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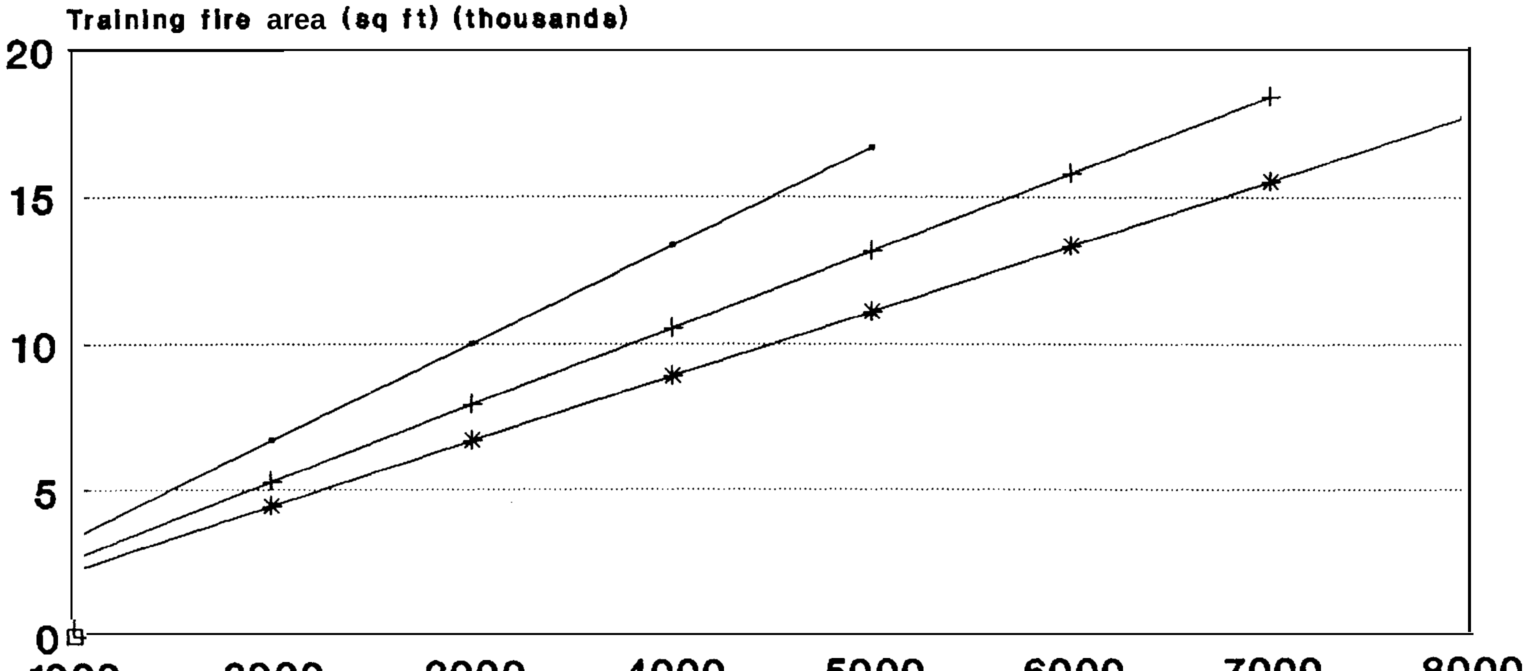
Figure 1-7. Large training fire area vs estimated fuel needed



(1) First, it eliminates the need for the pre-burn and post burn fuel quantities. This is because the propane burner control system will meter propane into the burn area at an adjustable, predetermined rate. Hence, when initiated, the fire will start almost instantly over the entire portion of the burn area selected by the instructor. Thus, there is no pre-burn time required to obtain a stabilized, fully involved scenario. The fire will then continue to burn at the proper intensity over the preselected portion of the burn area until correct extinguishment procedures have been completed, or until stopped by the instructor. Hence, the instructor knows exactly why the fire went out.

(2) The second consideration in planning for the appropriate fuel quantity needed to support the fire area during a training session is a three part problem.

(i) First, the propane storage must have sufficient capacity to support a meaningful amount of training fire burn time between refills. Therefore, the actual tank capacity for this portion of the facility will depend on the expected use rate and the response time of the propane supplier.

(ii) Secondly, the tank must have sufficient working pressure to supply the needed propane flow to the burn area over the ambient temperature range that the training facility is expected to be used.

(iii) And finally, the propane supply line from storage to the multiple burner distribution lines must have sufficient capacity to support the fuel requirements of the maximum number of burners that are needed at one time to generate a given scenario.

c. **Fuel Savings.** The ability to control both the rate of addition and the flow time of the fuel flowing into the fire site, i.e., the total consumption rate offers additional fuel savings over the traditional pre-measured, free burning, FLHs. For example, instructors can completely shutdown all fuel flow immediately as soon as a training session meets the training objective or when additional instructions are needed by a student having trouble during a training burn. In addition, the intensity of the fire can be selected by the instructor in terms of flame height, duration of the extinguishment effort, and the percentage of the burn area utilized for any given exercise; all contribute to fuel savings.

12. OPERATIONAL REQUIREMENTS FOR THE TRAINING FACILITY.

a. **Environmental and Operational Compliance.** Operation of the training facility requires compliance with Federal and State environmental and operational permits.

b. **Controlled Fires.** The training facility shall be designed to:

(1) Centrally control training fires from an observation area, i.e., a training officer can stop and/or regulate the location of the fuel flow to a fire within the burn area structure.

(2) Create a variety of fire suppression training scenarios such as:

(i) A major fuel spill fire around a fuselage mockup.

(ii) Engine fires with and without three dimensional or pressure fed fuel.

(iii) Landing gear, brake and wheel well fires.

(iv) Forcible entry via panels to simulate windows and doors.

(v) Minor fuel spill fires with and without three dimensional or pressure fed fuel.

(vi) Typical interior cabin and cargo bay fires.

(3) Rapidly ignite fuel and, for FLHs, recycle the effluent.

c. **Controlled Access.** All weather access to the training facility shall be provided. A means shall be provided to limit access to authorized personnel and to ensure that there is no unauthorized uses, such as, chemical dumping and trash burning on the burn area.

13 - 19. RESERVED.

CHAPTER 2. TRAINING FACILITY COMPONENTS

Section 1. GENERAL

20. BURN AREA STRUCTURE.

a. **Sizing Alternatives. The** size of the burn area structure is set by the Airport ARFF Index Method, the Discharge Rate Method, or the Empirical Area Simulator Method, described in paragraph 5.

b. **Building Material Alternatives.** This AC specifies two building material alternatives for the bum area structure. Section 2 describes the use of concrete as the primary building material as illustrated in figure 2 - 1. Section 3 describes the use of flexible membrane liners as the primary building material as illustrated in figure 2-2. Section 4 describes a bum area structure designed and suitable for the use of propane fuel.

c. **Fuel Alternatives. This AC** specifies the use of either an appropriate FLH fuel or an appropriately controlled propane fueled system. The use of alternate fuel(s), as yet unspecified, which can be appropriately controlled to provide the simulated affect of the typical FLH fuel spill fire and/or the other required fire scenarios is acceptable.

Section 2. CONCRETE ALTERNATIVE FOR FLH

21. RIGID BURN AREA STRUCTURE.

a. **Basic Design.** The basic design consists of a rigid floor and walls to retain fluids and a secondary means of containment to safeguard the groundwater.

b. **Design Service Temperature. The** design service temperature of the burn area structure shall be 2,100” F (1,149” C).

c. **Floor and Wall.** The floor and walls shall be of an air-entrained, reinforced portland cement concrete in accordance with Paragraph 41, Cast-In-Place Concrete. Floors shall slope to channel water towards interior drains for drainage and to simplify routine maintenance and structural inspections. Interior drains shall be fitted with a screen or a comparable device to preclude the migration of crushed stones into the drain. **A** drain system shall be placed below the floor to relieve the build up of hydraulic pressures beneath the burn area structure. If a perforated drain pipe is placed, it shall be wrapped in a geotextile fabric to prevent migration of foundation materials.

d. **Protection from Heat.**

(1) Protection for building materials from the heat energies is provided by an overlying layer of crushed stones submerged in water. The minimum depth of the crushed stone layer shall be six inches (15 cm) taking into account the sloping floor. Crush stones shall be in accordance with Paragraph 24, Interior Crushed Stones for the Burn Area Structure.

(2) Materials for fabricating the exposed portion of the reinforced wall, i.e., the curb, shall be in accordance with Paragraph 22, Refractory Concrete Curb for FLH-Fired Trainers.

22. REFRACTORY CONCRETE CURB FOR FLH-FIRED TRAINERS. To attain safer service temperature ranges for exposed curbs, thereby reducing the hazards of explosive spalling, refractory concretes shall be specified in lieu of portland cement concretes. Both pre-fabs and ready field mixes, termed “castables,” adequately receive and absorb the destructive forces of thermal shock and flame impingement. Castable refractories shall be in accordance with Paragraph 42, Refractory Concrete. An added benefit in specifying pre-fabs sections is quality control in their manufacturing. Refractory concrete field mixes that require the addition of aggregates, binder, and clean water shall not be allowed.

a. **Perimeter Curb Height and Width. The** difference in height between the top of any curb and an adjoining walking surface shall not exceed **8** inches (20 cm). The minimum width at the top of the curb shall be at least 6 inches (15 cm). These dimensions furnish fully clothed trainees a nonhazardous footing when entering and exiting the burn area structure under firefighting conditions.

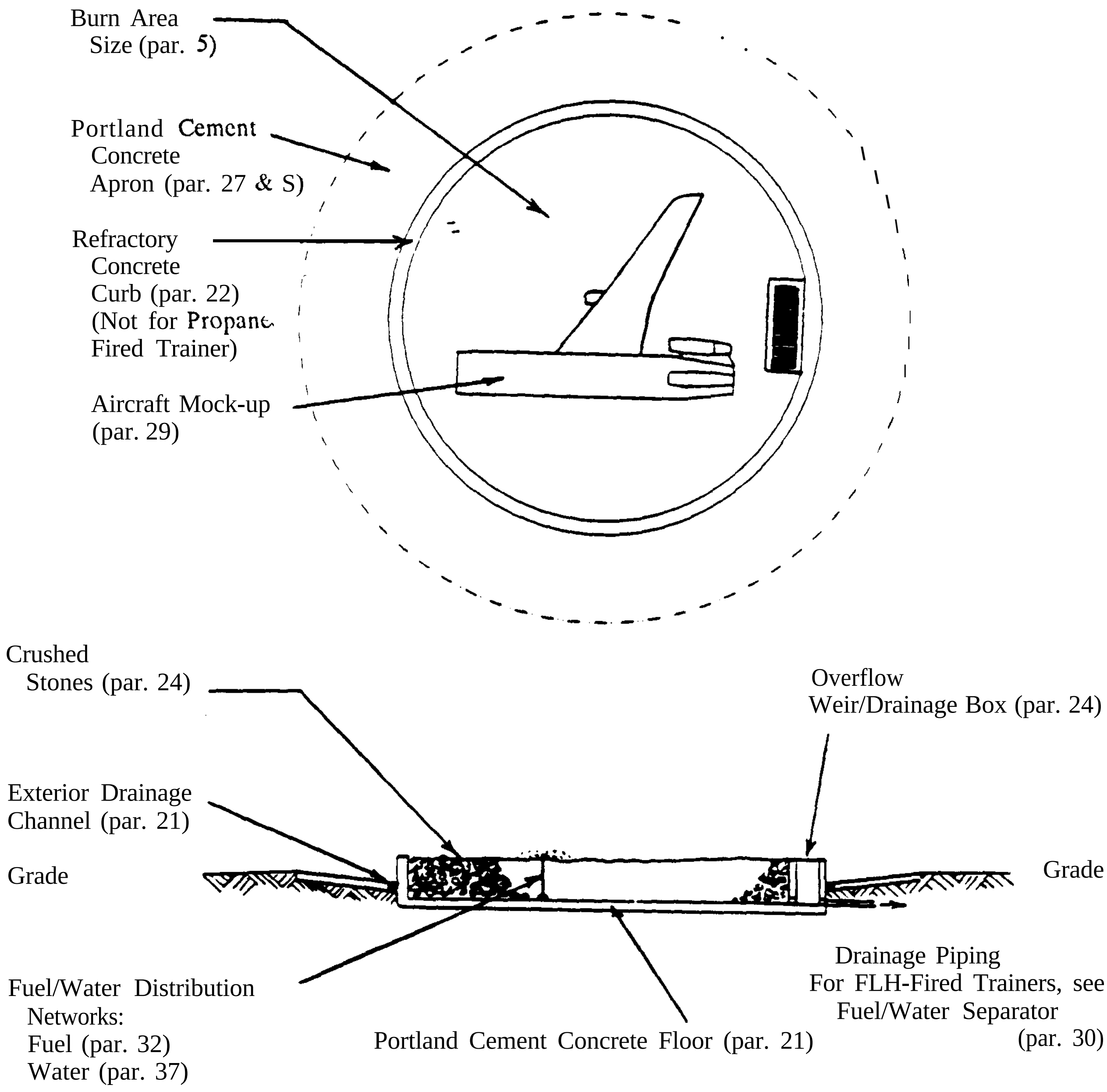


Figure 2-l. Example of a concrete burn area structure (not to scale)

b. **Interior Separation Curbs.** FLH-fired trainers can reduce the quantities of training fuel and water (that immerses the crushed stones) by erecting interior separation curbs to permit specific zonal training. The height and width of such curbs shall comply with perimeter curb standards. The curbs should be lower than the perimeter curb, for example at least 2 inches (5 cm) lower but not more than 4 inches (10 cm). Drainage of zonal areas can be performed by drainage gates located below the top surface of the crushed stones. Drainage gates shall meet the design service temperature of the burn area structure.

Section 3. FLH FLEXIBLE MEMBRANE LINER ALTERNATIVE

23. FLEXIBLE BURN AREA STRUCTURE.

a. **Basic Design. The** basic design consists of a sealed three layer system of two high density polyethylene (HDPE) flexible membrane liners (FML) separated by an interior drainage flow net (see figure 2-2). The system continues downward and beyond the burn area structure to function as a collection system to accumulate, detect, and permit removal of any leaked fluids. FMLs should not to be used as a structural component.

b. **Design Service Temperature. The** design service temperature of the burn area structure shall be 2,100“ F (1,149” C).

c. **Floor and Walls.** The sloped floor and sloped walls shall be fabricated from two layers of HPDE FMLs that are sealed (seamed) and separated by a materially compatible interior drainage flow net. The lowest point of the system shall be located outside of the burn area structure where a monitoring well houses a leak detection device, Side slopes shall follow the HDPE FML manufacturer’s recommendation for wall stability, generally 3:1. The three layer system surrounding the burn area structure shall be mechanically anchored below the berm and covered with backfill material. Berm and backfill material shall be in accordance with Paragraph 25, Berm.

(1) **HDPE FML System.** The upper HDPE FML functions as the primary holding basin of fluids while the lower secondary HDPE FML collects and channels leaked fluids for detection. The secondary liner shall have the ability to contain at least 100 percent of the volume of the upper primary liner and be sealed to the primary liner. A geotextile fabric shall be placed between the secondary liner and foundation material to protect the liner from foundation material. HDPE FMLs shall be in accordance with Paragraph 44, Flexible Membrane Liner.

(2) **Interior Drainage Flow Net. The** interior drainage flow net separates the primary and secondary HDPE FMLs to provide leaked fluids flow paths for detection at the monitoring well. The design pattern of the net shall allow collected fluids multi-directional flow paths to the detection device. Flow nets shall end next to the perimeter of the sealed HDPE FMLs, i.e., below the berm. Interior drainage flow nets shall be in accordance with Paragraph 45, Drainage Flow Net.

(3) **Protection from Heat.** Protection for building materials from heat is provided by an overlying layer of sand and crushed stones submerged in water and an inner ring section (defined in paragraph 25(c)).

(i) **Sand. A** minimum of six inches (15 cm) of sand followed by a minimum of 12 inches (30 cm) of crushed stones shall be placed immediately above the primary liner. Sand shall 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 American Society for Testing & Materials **(ASTM)** C 136, Standard Method for Sieve Analysis of Fine and Coarse Aggregates, within the recommended limits of “Fine Aggregate” category of ASTM C 33, Standard Specification for Concrete Aggregates (optional paragraph 5.2 is acceptable).

(ii) **Crushed Stones.** Crushed stones shall be in accordance with paragraph 24.

(iii) **Drains.** The drainage system above the primary liner shall preclude the migration of sand and crushed stones, e.g., drain covers with filters, use of perforated drain pipes. Drain components subjected to FLHs shall have positive sealed joints as compared to rubber gaskets. Polymer drain components (plastics) shall be compatible with FLHs.

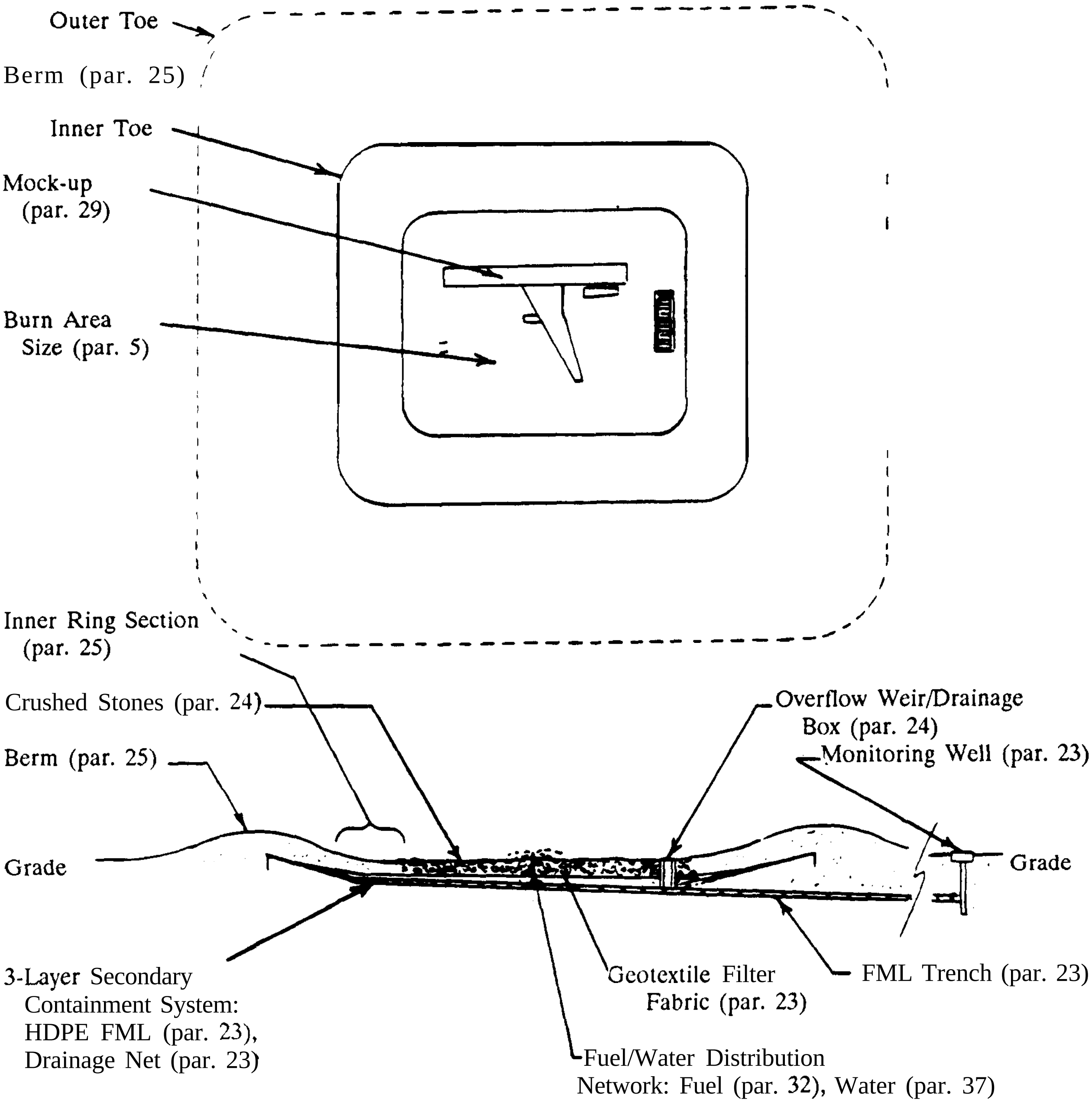


Figure 2-2. Example of a flexible membrane liner burn area structure (not to scale)

(4) Geotextile Filter Fabric. A geotextile filter fabric shall be placed directly above the sand layer to stop the intermingling of crushed stones with the underlying sand layer. The sand layer protects the primary liner from being punctured by intruding crushed stones and exploratory maintenance. The fabric shall end under the inner ring section. Geotextile filter fabrics shall be in accordance with paragraph 46, Geotextile Filter Fabric.

d. **FML Trench and Monitoring Well.** A FML trench shall extend beyond the burn area structure and slope continuously downward to accommodate a monitoring well. The trench shall use the same FML used for the burn area structure. The monitoring well shall have a leak detection device within a sump.

24. INTERIOR CRUSHED STONES FOR THE BURN AREA STRUCTURE. The crushed stones (or another medium known to be suitable for the intended service) placed within the burn area structure function as a quick drainage medium, level walking surface, and a heat absorbent shield. For FLH-fired trainers, crushed stones additionally help to counteract the drifting of fuel by wind forces. The crushed stones shall be angular, well graded, and free of shale, clay, friable materials, and debris with a nominal maximum aggregate size of 1 1/2 inches (3.8 cm) and a nominal minimum size of 1/2 inch (1.3 cm). Standard size number 4 (four) of ASTM D 448, Standard Classification for Sizes of Aggregate for Road and Bridge Construction and standard size numbers 4 (four) and 5 (five) of ASTM C 33 are possibilities. Grading shall be in accordance with ASTM C 136.

<u>NOTE</u>: Aggregates, e.g., those containing quartz, that are prone to fracture when they experience a large volume change at temperatures well below the design service temperature should not be permitted.

25. **BERM.**

a. **Slope.** The slope of the berm shall provide a gentle, nonhazardous footing for fully clothed trainees entering and exiting the burn area structure under firefighting conditions. To provide such footing, slopes shall range from 4:1 to 3:1 (horizontal:vertical).

b. **Backfill Material.** The backfill material specified shall be uniformly graded, free of friable or soluble materials, clay, loam, and silt, and other debris and shall contain a much <u>higher</u> percentage of fines than the crushed stones specified in paragraph 24. The selected covering material should not cause the liner to be punctured and have good erosion resistance. Table 2-l offers one possibility. The higher percentage of fines serves to (1) provide a protective heat absorbing blanket for the primary liner, and (2) limit the fluid/water mixture's downward penetration into the inner toe of the berm by more readily conveying it towards the lower more porous crushed stone layer.

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

Table 2-l. Example gradation of backfill material for berm and adjoining inner ring section

c. **Inner Ring Section.** The Inner Ring Section shall continue downward from the inside toe of the berm for a maximum horizontal length of 9 feet (2.75 m). Besides being composed of the same backfill material and executing the above dual functions, it marks for FLH-fired trainers the upper level of the training fuel and water sublayer mixture. Regardless of the fuel alternative, the backfill cover at the innermost point shall be a minimum of 18 inches (46 cm) to protect the primary liner from heat.

Section 4. PROPANE SYSTEM ALTERNATIVE

26. PROPANE BURN **AREA** STRUCTURE. When compared to a FLH-fueled trainer, an appropriately controlled, propane-fueled system permits significant simplification of the design requirements of the burn area structure. For example, the lack of a water sublayer may reduce the size needed for water storage and the complexity of the distribution system. Also, some State Environmental authorities may not require certain of the protective measures needed to prevent ground water contamination. When appropriately controlled, the propane-fired systems also greatly reduce air pollution problems.

a. **Basic Design.** The basic design for fixed systems shall use either the rigid or the flexible burn area structure alternatives discussed in Sections 2 and 3. Modifications are permitted as may be required by the unique properties and functions of the propane system design.

b. **Design Service Temperature.** Since total exposure to heat is better controlled (as compared to FLHs), construction materials used in the burn area structure shall be materials demonstrated to withstand the exposure temperature. For example, under the rigid alternative refractory material for the curb is not required. Instead, curb material shall be concrete masonry block units or air-entrained portland cement concrete with an f'_c = 3,000 psi. Selection of masonry units shall note National Concrete Masonry Association (NCMA) - TEK STD 117, Evaluation of Concrete Masonry Walls After Being Subjected to Fire. Curb height and width standards of subparagraph 22(a) shall apply.

c. **Floor and Wall.** The floor and wall materials (non-curbs) shall be an air-entrained portland cement concrete with an f'_c = 3,000 psi that is reinforced. Portland cement concrete shall be in accordance with paragraph 41. Floors shall slope to channel water towards drains for drainage and to simplify routine maintenance and structural inspections. Drains shall be fitted with a screen or a comparable device to preclude the migration of crushed stones into the drain. A drain system shall be placed below the floor to relieve the build up of hydraulic pressures beneath the burn area structure. If a perforated drain pipe is placed, it shall be wrapped in a geotextile fabric to prevent migration of foundation materials.

Section 5. SUPPORT COMPONENTS FOR TRAINING FACILITIES

27. CONCRETE APRON.

a. **Building Material.** The apron shall be an air-entrained portland cement concrete. This material, compared to refractory concretes, is acceptable since temperature and energy radiant stresses are less severe than those experienced by the curb. The compressive strength of the concrete shall be adequate to support fully loaded ARFF vehicles.

b. **Slope.** The concrete apron shall slope towards the curb of the burn area structure to collect training spills, rainfall, and snowmelts. If the apron has a drainage channel adjacent to the curb, the drainage channel shall be covered with drain covers that withstand both bearing loads and high temperatures. The transition joint between the upper portion of the concrete apron and the ARFF vehicle maneuvering surface shall be as smooth as practical.

c. **Length.** The length of the concrete apron shall be 10 percent of the square root of the total square footage of the burn area structure, but not less than 6 feet (1.8 m) or more than 12 feet (3.7 m).

d. **Thermal Treatments for Portland Cement Concrete Aprons.** The following items can increase the thermal resistance of ASTM C 150 type portland cement concretes to lessen the frequency of concrete thermal spalling.

(1) **Unit Weight.** Lightweight concretes, i.e., unit weights of 85 to 115 pcf (1360 to 1840 kg/m^3), offer greater thermal insulation than normal or heavy weight concretes. As a rule, a decrease in concrete unit weight results in increased thermal insulation (i.e., lower conductivity values). Structural lightweight aggregates should be in accordance with ASTM C 330, Specification for Lightweight Aggregates for Structural Concrete.

(2) Binder. Greater thermal resistance is possible by using calcium aluminate cements or binders with increased Alumina, Al_2O_3, and Silica, SiO_2 contents. Replacing aggregates with more cement binder also lowers thermal conductivity values.

(3) Aggregate Size. For normal weight concretes of unit weights between 135 to 160 pcf (2 160 to 2 560 kg/m^3), decreasing the maximum aggregate size increases thermal resistance.

(4) Free Moisture Content. Lowering the free moisture content of hardened concrete increases its thermal insulation by an associated reduction in thermal conductivity values (smaller thermal expansions).

(5) Air Content. An increase in the percentage of air content provides greater insulating values, particularly for air contents above 10 percent. Lightweight concretes achieve even greater insulating improvements at this percent air content compared to normal weight concretes.

28. OVERFLOW WEIR/DRAINAGE BOX FOR FLH FIRED TRAINERS. The top of the overflow weir(s) or drainage box should be slightly higher than the fuel level which is kept at or slightly below the protruding edges of the crushed stone surface. Metal grates that withstand the design temperature should rest on "L" iron sections attached to a concrete vault. Collected flows shall have a drain pipe that directly feeds the fuel/water separator system for recycling. A gas-tight trap in the weir or between the weir and the fuel/water separator shall be installed to avoid possible fuel vapor-air explosions. Weir/drainage boxes may be attached to or near the periphery of the burn area structure.

29. AIRCRAFT MOCKUP. An aircraft mock-up shall be provided that can present the complications normally encountered in the suppression of a variety of real exterior and interior aircraft fires. Large pool fires and other training fire scenarios may be supported by either a single multi-purpose training mock-up or a pair of mock-ups.

a. **Single Mockup Model.** The mock-up shall be located within the burn area structure in a manner similar to that shown in figure 2-l. The mock-up shall have strategically located fire devices and other special features to simulate the variety of mandatory aircraft fires described in paragraphs 29c(1)-(3). Figure 2-3 illustrates an example of a single wing, truncated mock-up with an elliptical cross section and FLH fuel nozzle or propane-fired gas burner element locations.

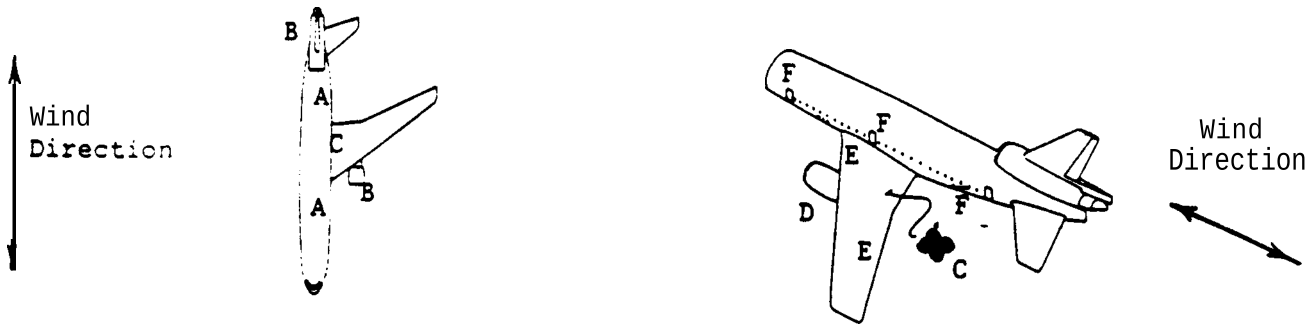
b. **Split Function Mockups.** If this alternative approach is selected, two mockups shall be provided that will permit the separation of the large pool fires from the other training fire scenarios. The major aircraft fuel spill simulator shall be located within the burn area structure in a manner similar to that shown in figure 2-l. The other mockup shall contain all of the other mandatory fire scenarios that cannot be accommodated by the major spill fire simulator. It may be located in any convenient place within the training ground that is compatible with the overall training area layout and may be portable/mobile.

c. **Mandatory Fire Scenarios.**

(1) **Class A Fires.** Baggage compartment and interior cabin fires, such as galleys, cockpit, lavatory, trash containers, that can be accessed through replaceable "forced entry" exterior panels or doors and landing gear, brake/wheel fires by an under-the-wing "landing gear" device. For the simulator using FLHs, a stock of class A combustibles will be required to "refit" the mock-up for cabin and cargo training scenarios. Where this class of fire scenario is being provided by a propane-fired simulator, there is no requirement for a stock of Class A fire consumables.

(2) Class B Fires. Large pool fires, engine nacelle fires, and ruptured wing fuel fires. The last two shall provide cascading or 3-dimensional fire training exercises.

(3) Other. For safety reasons, Class C (energized electrical) and Class D (combustible metal) fires, shall not be part of the FLH-fired mockup. Separate "stand alone" fixtures will be needed for these scenarios. Simulated Class C and D fire scenarios shall be provided as an integral part of the propane-fired mock-up.



View A. View B.

X = fuel nozzle or propane burner element location

A. Galley/Cockpit/Lav/Trash Containers
B. Engine Nacelle Mock-Up
C. Landing Gear Brake/Tires Mock-Up
D. 3-Dimensional Fuel Fires
E. Underwing Difficulties
F. Replaceable "Forced Entry" Panels

Figure 2-3. Example of an aircraft mock-up

d. **Orientation.** As is shown in figure 2-4, any fixed mock-up located within the burn area structure, shall be orientated with its axis directed towards the control center and the prevailing winds.

e. **Shape and Exterior Materials.** The shape of the mock-up shall generally represent an aircraft. For example, the fuselage may take the shape of a long narrow building with vertical walls, circular windows, and an arched roof. Selected materials shall be those with the ability to withstand high radiant energies, direct flame impingement, and repeated thermal cycling stresses. Figure 2-4, reprinted from NFPA 422M, Aircraft Fire and Explosion Investigation, provides thermal performance of metals, such as iron, to fabricate the fuselage and wing. Exterior materials other than metal that meet the design service temperature such as those found in fire training towers are also acceptable. Precautions should be taken to exclude air pollutant generating materials such as plastics (polyurethane can form HCN) and rubber tires.

f. **Sizing.** The primary consideration for the size and shape of the aircraft fuselage mock-up is to provide a viable target for practicing aircraft rescue and firefighting operations. Hence, maintaining a reasonably realistic cross section and using a somewhat truncated length generally fulfills the functional requirements of a mockup. The mock-up structure for ARFF training facilities using either a controlled, propane-fired, or a FLH-fired simulator shall have at least two doorways on each side for rescue training. The fuselage floor in all mock-ups intended for interior aircraft firefighting operations shall be capable of supporting the loads imposed by trainees during rescue and interior firefighting exercises. The mock-up shall be sized as follows:

(1) **Length.** For ARFF index A and B simulation, the fuselage mock-up shall be at least 50 feet (15.25 m) long. For ARFF index C through E simulation, the fuselage mock-up shall be at least 75 feet (23 m) long. If the mock-up is to be a mobil unit, the length of the longest component shall be no longer/heaver than that which meets the legal length/axle weight transportability requirements for public highway transportation.

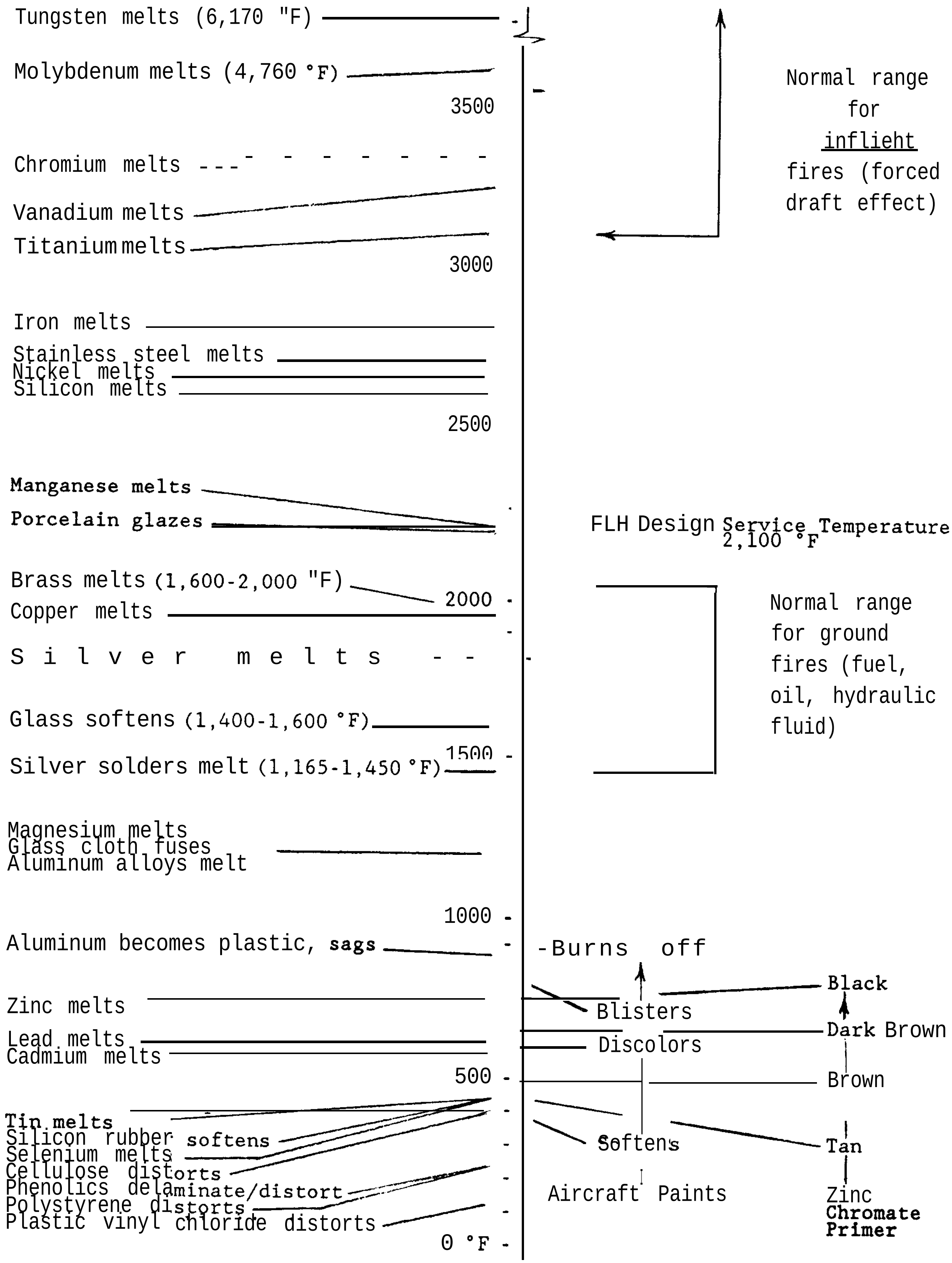


Figure 2-4. Metal material selection guide for mock-ups (reprint from NFPA)

(2) Height and Width. The fuselage diameter shall be at least 10 feet (3.0 m) for mock-ups with round cross sections. If rectangular, it shall be at least 7 feet (2.1 m) wide by 7 feet (2.1 m) high.

(3) Wing Span. The wing span for the SO-foot (15.25 m) long mock-up shall at least 25 feet (7.5 m) from the fuselage centerline to the wingtip. For the 75-foot (23 m) long mock-up, the wing span shall be at least 30 feet (9 m). The spacing of wing support columns should evenly distribute the weight on spread footings to eliminate damage to the concrete or HDPE FML floor. Additional geotextile fabric placed over the primary liner may be necessary to provide required protection in FLH-fired facilities.

g. **Tail Section.** The mock-up may include a tail section with or without an engine pod. If installed, the dimension of the tail sections shall be in approximate proportion to the basic mockup.

h. **Placement of Fuel Nozzles, Propane Burner Elements, and Water Nozzles.** Placement of fuel nozzles or propane burner elements shall be based on the specific type of fire to be simulated (see figure 2-3). Nozzles or elements located adjacent to the mock-up shall be evenly spaced around its exterior wall. To increase the mock-up's service life, provisions for internal water spray, water drains at all low points, and air vents on the sides and top of the mock-up's main body, wing(s) and, if present, the tail section shall be provided. The air vent pattern shall provide adequate openings in conjunction with appropriate spacing to prevent the build up of an explosive fuel-air mixture within the mock-up itself.

i. **Fuel Ignition.** A means of fuel ignition shall be employed that is effective under all normal weather and operational conditions and can reliably ignite all nozzles or elements selected by the instructor for a given exercise.

Section 6. SUPPORT SYSTEMS

30. FUEL/WATER SEPARATOR FOR FLH FIRED TRAINERS. FLH fuel trainers shall have a fuel/water separator to recycle fuel and water quantities for setup and those resulting from training. Besides the financial savings achieved through recycling, the additional cost for frequent disposal of contaminated FLHs and water is eliminated.

a. **Pump Design.** The fuel/water separator shall be equipped with an explosion-proof pump.

b. **Separator Capacity.** The capacity shall handle the total quantity of fluids collected from at least two training sessions, plus ten percent. Depending on operating permits, extra capacity for captured rainfalls and snow melts may need to be provided. For facilities where high volume or frequent use is anticipated, the separator capacity shall be sized to accommodate the anticipated use level, plus ten percent.

c. **Secondary Containment.** The separator shall have a secondary means of containment, for example, a flexible membrane liner.

31. CONTROL CENTER BUILDING AND PROTECTIVE WALL.

a. **FLH-Bred Trainer.** This trainer shall have only a protective wall with a viewing window to provide an instructor or safety officer a complete visual view of the burn area structure for monitoring training exercises (see figure 2-5). Additionally, the wall can provide protection to other training facility items such as, fuel and water storage tanks. The protective wall shall:

(1) Be at least 150 feet (46 m) upwind with respect to the prevailing winds to alleviate blinding smoke and fire hazards caused by wandering gas vapors. Generally, the direction of prevailing winds is identical to the airport's wind rose. However, a different wind orientation is possible. For example, an airport may have a limited training season because of severe winters or heavy seasonal rainfalls. Under these restrictions, a different seasonal wind orientation may exist.

(2) Have a viewing window next to the control console to monitor training exercises.

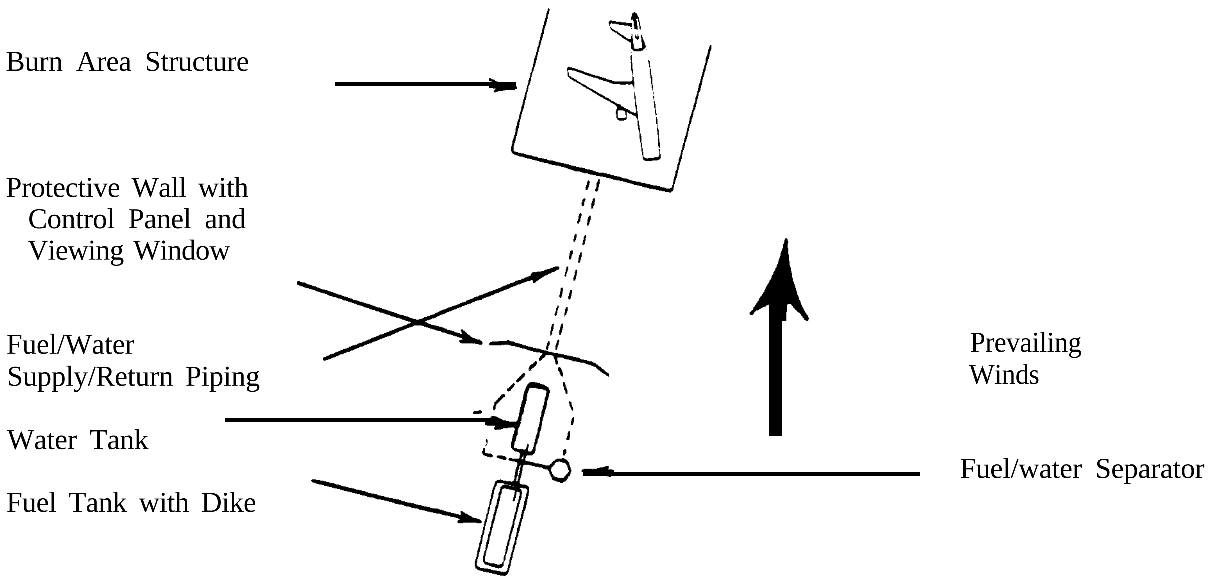


Figure 2-5. Example location of a control center

(3) Have a height equal to the height of the tallest aboveground fuel tank but not over 8 feet (2.4 m) and, if used to protect a fuel tank, a width not less than 15 feet (4.6 m).

b. **Propane-fired Trainer.** This trainer shall have an environmentally regulated, i.e., HVAC, control center building or area to house the equipment (computer, printer, controls, and etc.) and supporting hardware needed to regulate fire simulations and record training exercises. The control center shall provide an instructor or safety officer a complete visual view of the burn area structure for monitoring training exercises. The control center shall be:

(1) Located at least 150 feet (46 m) upwind with respect to the prevailing winds from the burn area structure to alleviate smoke and flame impingement. However, a different orientation is possible as noted in paragraph **31a(1).**

(2) Equipped with the necessary computer hardware or other appropriate means to perform varying degrees and types of training exercises and a hard copy printer or other appropriate means to record training performance and provide permanent reports.

(3) If the propane-fired mobile mock-up option is used, the control center may be an integral part of the overall unit.

c. **Building Housing Propane Containers.** Though a separate building is not required to house LP-gas containers, the construction and ventilation of such a structure shall be in accordance with NFPA 58, Standards for the Storage and Handling of Liquefied Petroleum Gases.

32. FUEL DISTRIBUTION SYSTEM FOR FLHS.

a. **Basic Design.** The system consists of the fuel storage tank(s), metered supply piping system, explosion-proof pump(s), metered independent zonal fuel delivery network, and the burn area fuel delivery network (see figures 2-5 and 2-6).

b. **Emergency Shutoff System.** Each fuel distribution system shall have an emergency shutoff system to quickly and completely stop the flow of fuel in an emergency. Operating controls for emergency shutoff shall be located so as to be readily and safely accessible in the event of an emergency or spill. Location and placarding of shutoff devices shall conform to NFPA 407, Aircraft Fuel Servicing.

c. **General Tank Requirements.**

(1) **Capacity.** Tank capacity shall at least equal the sum of the fuel quantities for (a) two successive burns, which may be based on figures l-4 through l-7, (b) the volume of the supply piping system, and (c) fuel quantities required to maintain the design discharge rate and duration for all systems operating simultaneously.

(2) Tank Fill Cap. The tank's fill cap shall be protected by either a recessed vault or have painted barrier posts. For security, fill caps shall have locking capability.

(3) Fuel Transferring Protection. An adequate means for static electrical discharge protection during fuel transfer shall be installed. For guidance see NFPA 407.

d. **Pumps.**

(1) Type. All pumps shall be an explosion-proof/weatherproof, electrically driven motor design and type that deliver the design discharge flow rate. The design discharge flow rate shall consider the hazardous generation of static electricity that accompanies fuel transfer. Rapid transferring of fuel causes the fuel to be electrostatically charged. If the charge on the fuel is sufficiently high upon being sprayed by the nozzles, a static spark could occur and prematurely ignite the flammable mists and vapors. However, a reasonable delivery time is sought to preclude explosion or fire hazards (flammable fuel atmosphere inside and outside the burn area structure if ignition is delayed) and for environmental reasons (poisonous vapors).

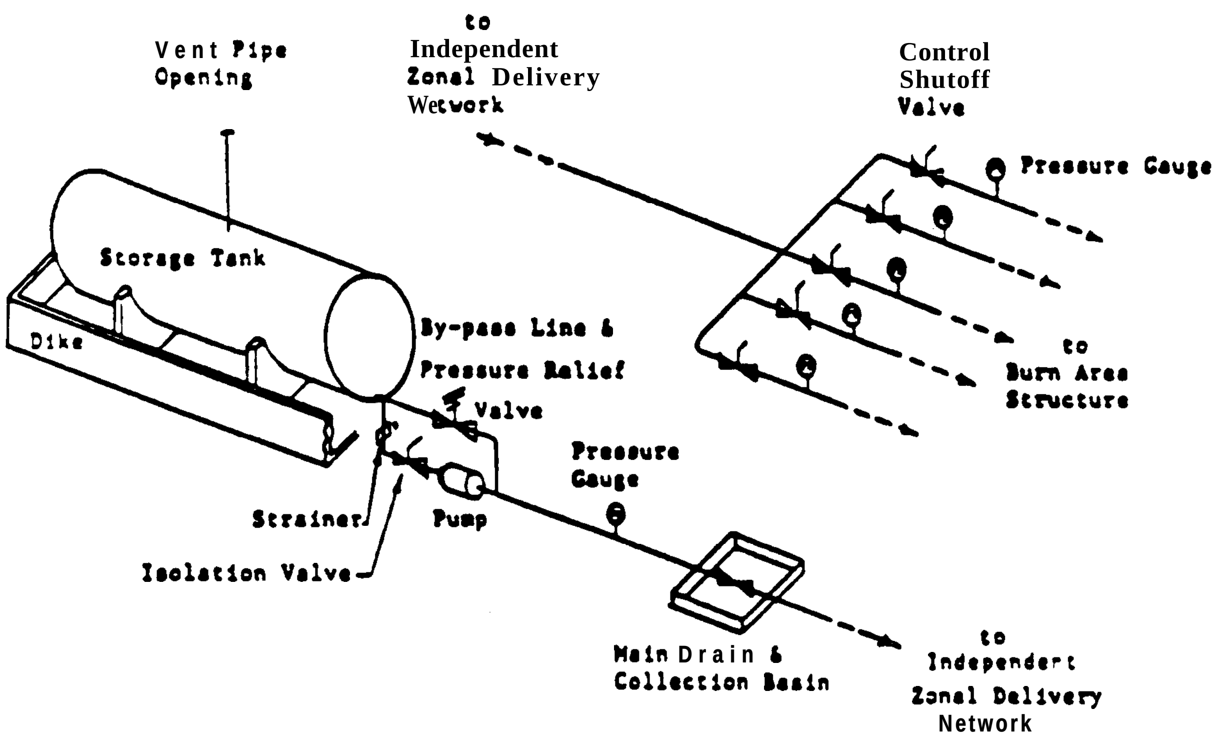


Figure 2-6. Example of an FLH storage tank, pump, supply piping, and independent zonal delivery network

(2) Installation. Pumps installed outside of a shelter shall be located not less than five feet (1.5 m) from any building opening. Pumps installed in a building shall be in a separate room with no opening into other portions of the building. The pump room shall be adequately ventilated to prevent explosive vapors from collecting and posing an explosive or fire hazard. Pumps shall be adequately anchored and protected against physical damage.

33. UNDERGROUND STORAGE TANK (UST) FOR FLHS. The installed UST shall be in accordance with 40 CFR Part 280. These regulations concern proper installation, spill and overfill prevention, corrosion protection, and leak detection. It is important to remember that these regulations apply to the entire UST system, that is both the tanks and underground piping.

a. **Spill and Overfill Prevention.** Many of the leaks at USTs are actually the result of spill and overfill errors, two separate problems. Athough new USTs must be equipped with both spill and overfill protection prevention devices, transfer of fuel should be constantly observed. Fuel transfer practices are found in AC 150/5230-4, Aircraft Fuel Storage, Handling, and Dispensing on Airports, API Publication 1621, Recommended Practices for Bulk Liquid Stock Control at Retail Outlets, NFPA 30, Flammable and Combustible Liquids Code, and NFPA 385, Standard for Tank Vehicles for Flammable and Combustible Liquids."

b. **Burial Depth and Cover for USTs.**

(1) **Steel Tanks.** Section 2 of appendix 1 provides standard engineering installation practices related to 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. Installation practices shall be in accordance with API Publication 1615-79, Installation of Underground Petroleum Storage Systems, or NFPA 30 unless otherwise directed by the engineer.

(2) Non-Metallic Tanks. The installation shall follow manufacturer's instruction with the minimum cover as specified for steel tanks unless otherwise directed by the engineer.

c. **Tank Placement.** Tank placement shall be at a distance that protects the tank from the "radiant" heat loads generated by the burn area structure.

34. ABOVEGROUND STORAGE TANKS FOR FLHS. An aboveground storage tank with a minimum capacity of 1,100 gallons is defined by USEPA as an underground storage tank (UST) when its below ground storage capacity is 10 percent or more, including underground piping.

a. **Overfill Prevention.** Since fuel transferring errors cause most spills and overfills, it is recommended that aboveground tanks, even though not required by EPA, have UST overfill prevention.

b. **Dike Designs. A** dike shall be provided for each aboveground tank to prevent the accidental discharge of fuel from endangering other facility components, adjoining property, the groundwater, or a waterway.

(1) **Capacity.** The capacity of the dike shall equal the sum of the total tank volume and the volume displaced by the tank that is below the height of the dike.

(2) Walls and Floor. Material for the walls and floor shall be of reinforced concrete, solid masonry, or a combination. Walls shall be liquid tight under a full applied hydrostatic head. Normal wall height above the interior dike floor should be less than six feet (1.8 m). If a dike wall is greater than six feet (1.8 m), the wall shall have special provisions for normal and emergency ingress and egress.

(3) Subdivided Dikes. Dikes that house two or more fuel tanks shall contain an intermediate curb to form individual dikes.

(4) FLH Fuel Resistant Concrete Joint Sealer. One of the following FLH-fuel-resistant concrete joint sealers shall be specified: (1) ASTM D 1854, FLH-Fuel-Resistant Concrete Joint Sealer, Hot-Poured Elastic Type, (2) ASTM D 3569, Joint Sealant, Hot-Applied, Elastomeric, FLH-Fuel-Resistant-Type for Portland Cement Concrete Pavements, (3) ASTM D 3581, Joint Sealant, Hot-Poured, FLH-Fuel-Resistant Type, for Portland Cement Concrete and Tar-Concrete Pavements, or (4) Federal Specification ss-s-200, Sealing Compounds, Two-Component, Elastomeric, Polymer Type, FLH-Fuel-Resistant, Cold Applied.

(5) Penetrating Pipes. Pipes passing through a dike shall be designed to prevent excessive stress and leaks as a result of settlement or fire damage.

c. **Support, Foundations, and Anchorage.** The design of tank supports and connections in areas subjected to earthquakes shall be in accordance with Appendix E of API Standard 650, Welded Steel Tanks for Oil Storage, Appendix B of API Standard 620, Rules for Design and Construction of Large, Welded, Low Pressure Storage Tanks, or the jurisdiction having authority.

35. DESIGN OF SUPPLY PIPING SYSTEM FOR FLHS. The metered fuel supply piping system, regardless if it is part of an UST system or not, shall be in accordance with 40 CFR Part 280. These regulations concern proper installation, corrosion protection, and leak detection. The design of the piping system shall meet the mechanical and thermal stresses and the working pressure that are capable of maintaining the fuel discharge at the design rate for all zones operating simultaneously.

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

b. **Design of Burn Area Structure Fuel Delivery Network.** Upon entrance, each zonal delivery pipe may feed, via a distribution header, into supported branch pipes (risers) with the predetermined number of fuel nozzles (see figure 2-7). Supports for risers shall be of heat

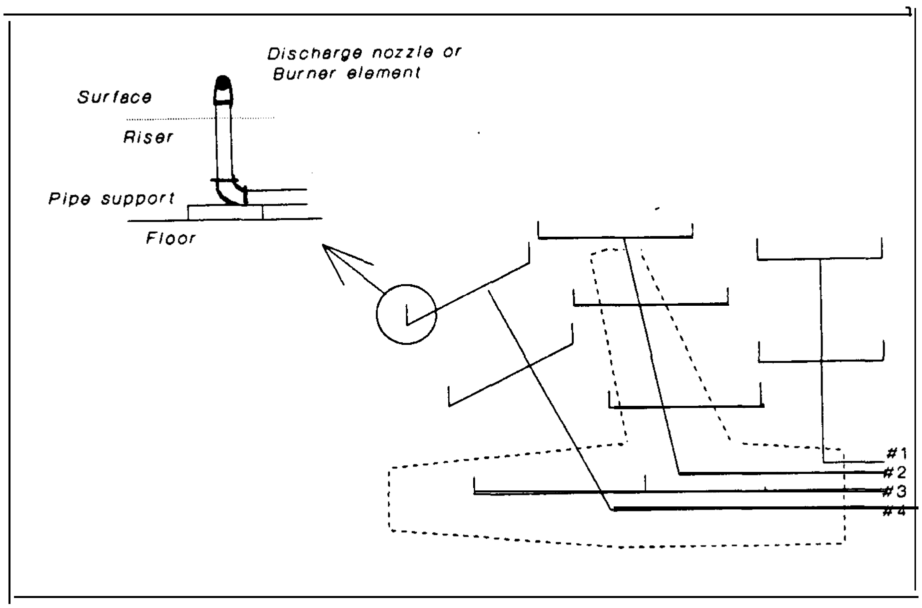


Figure 2-7. Example of a fuel/water delivery network with four independent delivery zones

resistant materials. Each nozzle riser shall 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 discharge openings. The maximum height of a nozzle protruding above the crushed stone surface shall not exceed 3 inches (7.6 cm). Nozzle coverage should consider nozzle discharge characteristics and its particular objective. Care shall be taken in positioning nozzles so that sprayed fuel does not fall outside the burn area structure.

c. **Identification.** All exposed fuel elements and components outside the burn area structure shall be painted and identified according to applicable codes or standards.

36. DESIGN OF COMPUTER CONTROLLED DISTRIBUTION SYSTEM FOR LIQUID PROPANE (LP). An LP-Gas distribution system consists of one or more containers with a means for conveying LP-Gas from the containers to the trainer's fire generation control system which shall interface with agent application detectors and components intended to achieve control of quantity, flow, pressure, or state (either liquid or vapor). The LP-Gas system described shall not use oxygen or contain ammonia.

a. **Control System.**

(1) **A** computer (or other appropriate means capable of providing the required fire simulation performance) shall regulate the flow of LP-Gas to burner elements based on information received from agent application, radiant energy, heat output, or other appropriate detectors that evaluate the appropriateness of the pattern of applied agent and activate a series of control valves that control propane flow to the trainer's burn area.

(2) The control system (computer or other appropriate device) shall be located in an environmentally controlled (HVAC) building/area (Control Center). The console housing the computer shall also include a color monitor and alphanumeric keyboard. A printer to record trainee performance shall complete the system.

b. **Detectors.**

(1) Agent application detectors shall be located in an array within the burn area structure to evaluate the effectiveness of the applied agent's pattern. Gathered information shall then be transmitted to the computer for controlling fire propagation via flow control valves, e.g., to reduce fuel flow and cause the fire to recede and extinguish.

(2) Another means may be used to provide the simulator operator with the feedback necessary to reliably assess student agent application performance if it can be shown that the resulting simulator performance provides safe, realistic, and repeatable training scenarios.

c. **Fire Generation System.** The fire generation system for the fuel spill fire shall consist of a network of main flame burner elements arranged throughout the fuel spill fire burn area, and a number of burner control modules that will control the flow of propane to the burner elements.

(1) **Burner Elements.** The network of burner elements shall be arranged across the fuel spill fire burn area so that each element will distribute propane to a segment of the total area. The arrangement shall be such that control of propane flow to each element shall produce a flame that will realistically grow and spread across the burn area, and then realistically recede and extinguish as the propane flow is manipulated in response to the appropriate agent application. Each element shall be arranged along the surface, or below the surface so as to be protected by the crushed stone. The elements shall be designed and supported to prevent their movement or damage by normal operation of the trainer. If above the surface, their maximum height is 3 inches (7.6 cm).

(2) Burner Control Module. Each burner control module shall provide an ignition source, e.g., a pilot flame, to ignite a portion of the fuel spill fire, a safety shutoff valve that will stop all flow of propane to the elements under that module's control in an emergency or upon loss of electrical power, and a series of control valves that will modulate propane flow to individual burner elements. All burner control modules shall be operable from the fire generation control center and shall reliably control propane flow to individual burner elements according to preset/predetermined parameters that are realistically related to the progress of the extinguishment effort.

d. **Containers.** Containers shall be designed, fabricated, tested, and marked (stamped) in accordance with the (1) Regulations of the U.S. Department of Transportation, the "Rules for the Construction of Unfired Pressure Vessels," Section VIII, Division 1, (2) ASME, "Boiler and Pressure Vessel Code", or (3) the API-ASME 'Code for Untired Pressure Vessels for Petroleum Liquids and Gases" applicable at the date of manufacture.

(1) **Container Appurtenances.** Fabrication and performance provisions shall be in accordance with NFPA 58. Container appurtenances include pressure relief, connections for flow control (filling, withdrawal, equalizing), liquid level gauging devices, and pressure gauges.

(2) Container Markings. Containers shall be marked as provided in the Regulations, Rules, or Code under which they are fabricated or in accordance with chapter 2 of NFPA 58.

(3) Location of Containers. Containers shall be located in accordance with chapter 3 of NFPA 58.

e. **Piping and Piping Systems. The** system shall have pipe, tubing, hose, and flexible rubber or metallic hose connectors and other valves and fittings as required to safely convey LP-gas in either the liquid or vapor state at various pressures from point to point.

f. **Buildings or Structures Housing LP-Gas Distribution Facilities.** LP-Gas distribution facilities that are housed in separate buildings used exclusively for the purpose or in rooms attached to, or located within, buildings used for other purposes, shall be in accordance with Chapter 7 of NFPA 58. This chapter covers the construction, ventilation and heating of structures housing LP-Gas systems referenced in NFPA 58.

37. WATER DISTRIBUTION SYSTEM FOR FLH-FIRED TRAINERS. The system consists of a water storage tank(s), metered supply piping system, water pump(s), independent zonal delivery network and the mock-up water spray network (see figures 2-6 and 2-7).

NOTE: For propane-fired systems, a water spray cooling system utilizing local utility water supply pressure may be required if the mockup structure is not designed to withstand the heat and thermal cycling of the fuel spill fire.

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

(1) Materials and Fabrication. The storage tank shall be designed and built in accordance with recognized engineering standards for the materials being used. Some industry standards are American Water Works Association (AWWA) D 100-84, Welded Steel Tanks for Water Storage, AWWA D 103-80, Factory-Coated Bolted Steel Tanks for Water Storage, and AWWA D 120-84, Thermosetting Fiberglass-Reinforced Plastic Tanks.

(2) Tank Capacity. The tank capacity shall be based on the sum of either the water sublayer for FLH-fired training facilities for two successive burns or operational quantities required for a propane-fired training facility, plus 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.

(3) Support, Foundations, and Anchorage. The design of tank supports and connections in areas subjected to earthquakes shall be in accordance with Appendix E of API Standard 650 or Appendix B of API Standard 620.

(4) Identification. Aboveground tanks shall have the phrase *"CONTAMINATED WATER"* printed on both longitudinal sides. Lettering shall be at least one-foot (30 cm) in height and of a contrasting color.

b. **Design of Metered Water Piping System.** The metered water piping system shall be structurally designed to safely accommodate the flow rate and fluid pressure needed to maintain proper water discharge levels at all zones operating simultaneously. Other design requirements and recommendations are cited below.

(1) **Corrosion Protection.** System components installed in the presence of a corrosive environment shall be of corrosion resistent materials or be covered with protective coatings.

(2) Identification. For identification, all exposed water system components outside the burn area structure should be painted in accordance with applicable codes or standards.

c. **Water Pump.** The water pump shall be sized to meet the water discharge rates for (1) all spray nozzles operating simultaneously, (2) the water sublayer, (3) the continuous mock-up water spray treatment, if necessary, and (4) the burn area flushing/turn-around time for FLH-fired trainers. The water pump shall be of an explosion proof type when it is housed adjacent to a fuel pump.

d. **Design of Independent Water Zonal Delivery Network.** Each independent zonal delivery pipe shall have a control valve with a pressure gauge to regulate the water flow within the burn area. Placement of the zonal control valve shall provide quick and easy access. Placing zonal delivery networks below grade offers piping networks improved protection.

e. Design of Water Spray Network. Upon entrance to the burn area structure, each zonal delivery pipe should feed, via a distribution header, branch pipes (risers) having the determined number of water spray nozzles (see figure 2-7). The maximum height of any nozzle protruding above the crushed stone surface shall be 3 inches (7.6 cm). The number of required nozzles shall be based on the nozzle's discharge characteristics and the particular function to be achieved. Care should be taken in positioning nozzles that water spray does not miss the target surface. Each nozzle riser shall be supported from below and plumbed for uniform water delivery. Supports shall be heat resistant.

38. - 39. RESERVED.

CHAPTER 3. CONSTRUCTION PHASE

40. STRUCTURAL STEEL.

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

b. **Practices.** All steel design, fabrication, and erection shall 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 directed by the engineer.

(1) **Steel Reinforcing Bars and Welded Wire Fabric.** Tolerances and placement for reinforcing bars, welded wire fabric, and metal devices necessary for placing, spacing, supporting, and fastening reinforcement shall conform to the American Concrete Institute (ACI) 318-83, Building Code Requirements for Reinforced Concrete. For corrosion protection of rebars, protective coatings such as epoxy coatings are recommended. If specified, they shall be in accordance with ASTM A 775, Specification for Epoxy-Coated Reinforcing Steel Bars.

(2) Welding. Welding practices shall be in accordance with AWS D 1.1, Structural Welding Code - Steel, and appropriate AISC welding specifications, unless otherwise directed by the engineer. Welders shall be qualified in accordance with AWS D 1.1, Structural Welding Code - Steel.

41. CAST-IN-PLACE CONCRETE.

a. **Material Acceptance.** Portland cement concrete shall be mixed and delivered in accordance with ASTM C 94, Standard Specification for Ready-Mixed Concrete. Cement shall be Type I (normal), II (exposure to sulfate bearing soils and seawater), or III (high early strength) portland cements in accordance with ASTM C 150, Specification for Portland Cement. The minimum 28-day compressive strength shall be 4,000 psi for FLH concrete retaining structures, e.g., burn area structure, concrete fuel/water separator vaults (not the apron or dike) and 3,000 psi for propane-fired trainers. Upon placement, concrete shall have a slump of 1 to 4 inches (ACI 211) and percent air (± 1%) in accordance with paragraph 4.5.1 of ACI 318.

b. **Practices.** Concrete design shall be in accordance with ACI 318 unless otherwise directed by the engineer. Regions subject to moderate or high seismic risks shall note Appendix A, Special Provisions for Seismic Design, of ACI 318. Hot weather and cold weather concreting practices shall be in accordance with ACI 305R, Hot Weather Concreting and ACI 306R, Cold Weather Concreting. Special emphases shall be observed during (1) placement of concrete, i.e., concrete shall be deposited continuously in layers of such thickness that no concrete will be deposited on concrete which has hardened sufficiently to cause seams or planes of weakness, and (2) curing of concrete, i.e., controlled curing is one of the best precautions to make concrete watertight.

c. **Clean Water.** Water shall be clean, potable, and free from pronounced odor.

d. **Aggregates.** The nominal maximum aggregate size shall be 3/4 inch in accordance with ASTM C 33 (e.g., coarse aggregate size number 67). The material shall be free of injurious amounts of shale, alkali, organic matter, loam, or other deleterious substances. Paragraph 5.3.2 of ACI 211 shall be observed, e.g., in no event shall the nominal maximum size exceed 1/5th of the narrowest dimension between sides of forms.

e. **Admixtures.** Air-entrained admixtures shall comply with ASTM C 260, Standard Specification for Air-Entraining Admixtures for Concrete. Calcium chloride shall not be used as an admixture. All other chemical admixtures and mineral admixtures shall meet the appropriate standard specifications set forth by ASTM.

f. **Non-Shrink Grout.** Grout shall be a non-shrink grout in accordance with U.S. Army Corps of Engineers CRD-C-621, Handbook for Concrete and Cement, Specification for Non-Shrink Grout unless otherwise specified by the engineer.

g. **Surface Finish.** Surface finishing shall proceed only after surface water has disappeared and concrete has set sufficiently to support the weight of workers and equipment. The surface shall dry naturally, e.g., do not dust surface with dry cement or sand. A power-driven float machine shall be used to float the surface of the burn area floor to produce a finish true to elevations and slopes with a uniform granular texture. Hand floats shall be used in areas inaccessible to power-driven floats. Surfaces shall be leveled to within 1/4 inch in lo-foot in all directions unless otherwise specified by the engineer. Concrete aprons and other walking surfaces shall be broomed with a flexible bristle broom to produce a non-slip texture in a direction transverse to that of traffic or at right angles to the slope of the surface.

h. **Cementitious Waterproofing.** Cementitious waterproofing shall be provided on the "positive" inside surfaces of FLH fuel concrete retaining structures. Materials used for waterproofing shall follow manufacturer's application instructions to ensure proper penetration and closure of concrete capillary tracts. The selected cementitious waterproofing system shall become permanent and be non-toxic, inorganic, free of calcium chloride and sodium based compounds.

i. **Fuel Resistant Concrete Joint Sealant.** For FLH-fired trainers, the engineer shall specify one of the following fuel-resistant concrete joint sealant: (1) ASTM D 1854, (2) ASTM D 3569, (3) ASTM D 3581, or (4) Federal Specification ss-s-200.

42. REFRACTORY CONCRETE.

a. **Material Acceptance.** Castable refractory concretes shall be a class B or C (regular, not an insulating type castable) in accordance with ASTM C 401, Standard Classification of Castable Refractories. Additional requirements may be specified by the manufacturer to offset the rapid heating and cooling stress cycle, e.g., fast-fire variety castable to offset explosive spalling.

b. **Practices.** All construction practices and materials for placement, anchorage, finishing, curing, drying, firing of refractory castable concrete shall be as specified by the refractory manufacturer. Since refractories behave differently when compared to portland cement concretes, contractor shall have prior construction experience with the product or be properly supervised by the refractory manufacturer.

43. ELECTRICAL SYSTEMS. Electrical systems, equipment, wiring installation, and testing shall comply with latest revisions of NFPA 70, National Electrical Code (NEC), and other applicable State and local regulations. Where codes and/or standards conflict, the more stringent shall apply.

44. FLEXIBLE MEMBRANE LINER.

a. **Material Acceptance.** The liner shall be a high-density polyethylene (HDPE) flexible membrane liner (FML) of a non-extractable plasticizer quality certified by the National Sanitation Foundation (NSF), or equivalent. It shall:

(1) Have a minimum nominal gauge thickness of 80 mils (0.080 inch).

(2) Meet the material property standards for 80-mils noted in table 4, paragraph 3.1, including applicable annexes, of NSF Standard #54, Flexible Membrane Liners, 1991 edition.

(3) Meet the material compatibility tests of the USEPA Test 9090 for the fuels and fire fighting foams used in training. If the solution is not homogenous, i.e., consists of more than one phase, then tests should evaluate each phase.

(4) Be chemically compatible and appropriate for site specific considerations as covered in annexes C and D of NSF 54. Considerations include moist environments, supporting soil environments, constant stress under load at both normal and elevated temperatures.

(5) Not exceed the maximum permeability rate for FLH fuel established by the applicable State (e.g., State Department of Natural Resources) or local authority. 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.

(6) Have a high temperature resistance of 240" F (116° C) without performance failure.

(7) Have a high resistance to abrasion, humidity, rot, mildew, vermin, bacterial deterioration, and sunlight (UV).

b. **Bonded Seams. The** seam is a critical part of the FML system. Seams may be either factory or field constructed in accordance with annexes C and D of NSF Standard 54, 1991 edition, for site specificity and chemical compatibility.

(1) Factory and field seaming techniques shall be as listed in paragraph 4.2.1 of NSF 54.

(2) Factory seams shall meet the 80 mil physical property requirements of table 4, paragraph 3.1 of NSF Standard #54.

(3) Field seams shall be in accoradnce with ASTM D 4437, Standard Practice for Determining the Integrity of Field Seams Used in Joining Flexible Polymetric Sheet Geomembranes, for determining the integrity of field seams.

(4) Field seaming and repairs shall be in accordance with annex C, section VI, part E of NSF Standard #54 at no additional cost to the airport sponsor.

(5) All seams shall be permanently marked with an identification number.

c. **Penetrations: Interface Components, Liner Tubes, Sleeves, etc.** Penetration of FMLs, e.g., by pipes, and FMLs attached to structures shall be in accordance with annex C, section VI, paragraph D of NSF Standard 54. All liner attachments and penetrations shall be verified to be liquid tight. A variety testing methods can be used such as, hydrostatic, vacuum, ultrasonics, or an air jet.

d. **Installation.** Contractors shall have either prior installation experience for the type of liner material selected or an installation experience level approved by the applicable State (e.g., State Department of Natural Resources) or local authority. Prior to liner placement, annexes C and D of NSF Standard 54 shall be addressed, i.e., considerations for chemical compatibility and site specificity. Liner installation shall meet the manufacturer's recommendations and the following.

(1) The subgrade supporting the liner shall be prepared and maintained in accordance with annex C, section VI, paragraph A of NSF Standard 54. If a soil stabilizer to control erosion is used, e.g., chemical binding agent, it shall be chemically compatible with the liner.

(2) Further protection of the secondary FML shall be accomplished by placing on the prepared subgrade either a minimum of six inches (15 cm) of base material (e.g., sand per item 1 above) or a geotextile padding of at least 15 mils (0.015 inch). Placement of either material shall not be accomplished over a porous, wet, spongy, or frozen subgrade.

(3) The base (or the prepared subgrade that is covered only by padding) shall be uniformly compacted to ensure against liner settlement and provide uniformly sloped surface(s) for interior drains and leak monitoring. Compaction shall be 95 percent of that obtained in accordance with Method D, of ASTM D 698, Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb Rammer and 12-inch Drop. Optimum moisture content of backfill materials shall be maintained to achieve the required compaction density. Backfilling shall not be accomplished over a porous, wet, spongy, or frozen base. It is recommended that the site engineer provide visual inspection during compaction operations of areas that support a structure with an attached FML.

(4) Concrete or other rigid surfaces adjacent to the liner shall have all rough edges and projections removed. Extruded expansion materials and joint sealers (compatible with the liner) shall also be removed and flush with the concrete surface.

(5) The perimeter of the sealed double liner system shall be mechanically anchored below the berm (or FML trench) with at least a 20-inch (51 cm) protective cover of backfill material.

(6) Care shall be taken during covering operations to prevent damage to the liner by mechanical equipment.

(7) The cut of the FML trench shall be sufficiently wide to enable installation and inspection of the FLM, and, if included, pipes and utilities.

(8) The location and elevation of the sump housing the leak detection device shall be verified.

(9) Resulting tears, punctures, or other defects in the liner during installation shall be repaired, tested, and certified to be leak free by the installer at no additional cost to the airport sponsor. Repairs to the liner shall be patched using the same type of liner material.

(10) Once the FML trench has been installed, it shall be backfilled by a method that does not disturb elevations or damage the trench FML, leak detection device, pipes, and utility lines. Hand tamping shall be performed in areas inaccessible to compaction equipment.

45. DRAINAGE FLOW NET.

a. **Material Acceptance.** The drainage flow net shall be compatible with the FML and the chemicals used in training, e.g., hydrocarbon fuels, training foams. Also, the net shall withstand bearing loads to maintain effective flow characteristics (i.e., hydraulic transmissivity) towards the leak detection device.

b. **Installation.** Installation of the drainage flow net shall be in accordance with the manufacturer's recommendations. The net shall terminate near the perimeter of the FML system, i.e., under the berm. If tears, punctures, or other defects result from installation, they shall be repaired by the installer at no additional cost to the airport sponsor.

46. GEOTEXTILE FILTER FABRIC.

a. **Material Acceptance.** The geotextile filter fabric shall have the following properties, unless otherwise specified by the engineer:

(1) A woven or nonwoven fabric compatible with the chemicals it contacts.

(2) Minimum puncture strength equal to 120 pounds when tested in accordance with ASTM D 751, Standard Method of Testing Coated Fabrics, modified by using 5/16-inch (0.8-cm) diameter cylinder.

(3) Equivalent opening size in fabric, minimum 100 and maximum 50, as determined by Corps of Engineers Guide, Specification CW-02215, Geotextiles Used as Filters.

(4) Minimum weight of fabric equal to or greater than 8 oz/y^2 (270 g/m^2) determined in accordance with ASTM D 3776, Standard Test Method for Mass Per Unit (Weight) of Woven Fabric.

b. **Installation.** Installation shall be in accordance with manufacturer's recommendations and:

(1) Prior to placing the fabric, the receiving foundation material shall be properly compacted and have surface gradients and elevations verified.

(2) Fabric applied to a surface shall have sufficient slack to prevent tearing when the overhead layer of crushed stones is placed.

(3) Fabric edges shall be lapped a minimum of 12 inches (30 cm) to prevent separation at overlapped edges when the overhead layer of crushed stones is placed.

(4) A minimum 6-inch (15-cm) cover of crushed stones shall be placed over fabric prior to operating equipment on covered area.

(5) End joints of the fabric shall be placed 2 feet (61 cm) into the "inner ring section".

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

47. PIPING DISTRIBUTION SYSTEM FOR FLHS. Since faulty piping installation is a significant cause of UST system failures, proper installation is crucial to ensure their structural integrity of the piping distribution system. To reduce occurrences, the engineer should make sure that installers carefully follow the correct installation procedures called for by industry codes. For example, particular attention should focus on proper layout of piping runs, complete tightening of joints, and adequate cover. It is noted that the airport operator will need to certify on a UST notification form, available from the State, that installation was by a qualified installer.

a. **Acceptance Test.** After cleaning and before being buried, covered, or concealed, the piping system from the storage tank to the discharging nozzles (capped) within the burn area structure shall be proven tight before it is placed in service. The hydrostatic test shall be not less than 150% of the working pressure to demonstrate tightness and conformance in accordance with NFPA 30 unless, otherwise directed by the engineer.

b. **Test for Emergency Shutoff Device. The** emergency shutoff device(s) shall be checked for proper operation prior to placing the system in service.

48. PIPING DISTRIBUTION SYSTEM FOR PROPANE. Field installation of LP-Gas distribution systems utilizing components, subassemblies, container assemblies and container systems shall be in accordance with NFPA 58 or as described by the jurisdiction having authority. Plans of fixed installation shall be submitted to the authority having jurisdiction before the installation is started.

a. **Practices.** The design, construction, installation, and operation of all LP-Gas systems shall be in accordance with NFPA 58 or those portions of LP-Gas systems covered by NFPA 54, National Fuel Gas Code.

b. **Piping (including hose), Fittings, and Values.** Piping (including hose), fittings, and valve designs and material specifications used to connect container appurtenances with the balance of the LP-Gas distribution system shall be in accordance with NFPA 58 and, for those applicable portions, to NFPA 54.

c. **Corrosion Protection.** Underground metallic piping shall be protected against corrosion in accordance with paragraph 3-2.7 of NFPA 58.

d. **LP-Gas Equipment.** Fabrication and performance for pressure containing metal parts of LP-Gas equipment such as pumps, compressors, vaporizers, strainers, meters, sight flow glasses, and regulators, shall be in accordance with NFPA 58. Systems, or individual components assembled to make up systems, shall be approved in accordance with NFPA 58.

e. **Leak Detection Alarm System.** All enclosed spaces containing propane piping or other propane related equipments, shall be adequately furnished with propane leak detectors and an alarm system. On detection of 10 percent or more of the lower explosive level of propane, the alarm system shall be activated. The detection system shall be active at all times when propane is contained in the piping and propane related equipment. If the training facility is active at the time of a leak detection, the system shall automatically shut down the entire propane system and activate all enclosed space ventilating devices.

f. **Testing.** After assembly, piping systems (including hose) shall be tested and proven free of leaks at not less than the normal operating pressure. Piping within the scope of NFPA 54, shall be pressure tested in accordance with that Code. Tests shall not be made with a flame.

g. **Testing of Equipment and Systems.** Systems, or individual components assembled to make up systems, shall be approved in accordance with NFPA 58.

49. STORAGE TANK FOR RECYCLED WATER.

a. **Practices.** Since the recycled water may contain low traces of hydrocarbon fuels or other contaminants, the tank shall be suitable for storing them. Tank installation shall be in accordance with NFPA 30 unless, otherwise directed by the engineer. The tank surface and all ferrous-metal appurtenances shall be cleaned, primed, and painted.

b. **Testing.** Prior to service, the tank shall be tested in service in accordance with the applicable paragraphs of the code under which it was built. Upon fastening tank delivery connections, a tightness test shall be conducted prior to placing the system in service in accordance with NFPA 30. Except for underground tanks, tightness test shall be performed at the operating pressure with either air, inert gas, or water. Leaks shall be corrected and the system retested.

50. PIPING DISTRIBUTION SYSTEM FOR WATER.

a. **Practices.** Requirements for the materials, design, fabrication, installation, and workmanship of the piping system for water shall be in accordance with ANSI B-31.3, Chemical Plant and Petroleum Refinery Piping, or NFPA 30 unless otherwise directed by the engineer.

b. **Testing.** All piping systems, before being covered, enclosed, or placed in service, shall be flushed thoroughly with water (i.e., before spray nozzle connections) 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 water piping systems shall be hydrostatically tested at not less than 150% of the working pressure to demonstrate tightness and conformance in accordance with NFPA 30.

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

Section 1. PETROLEUM FUEL TANKS

1. **AMERICAN PETROLEUM INSTITUTE (API).**

a. API Publication 1615-87, Installation of Underground Petroleum Storage Systems.

b. API Standard 620-90, Rules for Design and Construction of Large, Welded, Low-Pressure Storage Tanks.

c. API Standard 650-88, 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-90, Specification for Bolted Tanks for Storage of Petroleum Liquids.

g. API Specification 12D-82, Specification for Field Welded Tanks for Storage of Production Liquids (supp 1-1983).

h. API Specification 12F-88, Specification for Shop Welded Tanks for Storage of Petroleum Liquids.

2. **AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME),** Boiler and Pressure Vessel Code, 1989 edition.

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

a. ASTM D 1410-84, 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 58-86, Standards for Steel Underground Tanks for Flammable and Combustible Liquids (revised 1990).

b. UL 142-87, 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 (revised 1987).

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 (FCLCH), 3rd ed., 1987).

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 1632-87, Cathodic Protection of Underground Petroleum Storage Tanks and Piping Systems (supplement 1989).

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 58-1986, Standards for Steel Underground Tanks for Flammable and Combustible Liquids (revised 1990).

10. **STEEL TANK INSTITUTE No. STIP3.**

11. **NATIONAL ASSOCIATION OF CORROSION ENGINEERS STANDARD (NACE),** RP-0169-69 (revised 1983), Recommended Practice - Control of External Corrosion of Underground Submerged Metallic Piping Systems.

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