IGNITABLE LIQUID DRAINAGE FLOOR ASSEMBLY (ILDFA) DESIGN GUIDELINE for NEW BUILD AND RETROFIT AIRCRAFT HANGAR CONSTRUCTION

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1. Scope of Document

The scope of this document is to provide Ignitable Liquid Drainage Floor Assembly (ILDFA) design guidance for Architect & Engineering (A&E) firms in the early design stages of a new build hangar project or a retrofit project of an existing hangar. The goal is to provide sufficient information to specify an ILDFA for a project without the need of detailed input by the ILDFA manufacturer.

ILDFA is a new technology; therefore, best practices, installation, and manufacturing improvements continuously evolve. Please check for the latest version of the document at Safespill.com/Safespill-Design-Guideline.

2. ILDFA Purpose

An ILDFA is designed to contain and remove ignitable liquid spills before developing into a pool fire. In its basics, the ILDFA is a hollow aluminum extruded floor with a perforated top surface, connected to a trench system to remove any spilled liquid to an acceptable location (i.e., containment system, oil water separator, or as directed by the local authority). In the event the spill is ignited, the ILDFA will rapidly control and extinguish the flammable/combustible liquid fuel fire.

One application of an ILDFA is for Class B (fuel) fire protection inside an aircraft hangar, which is accepted under NFPA 409 2022 Edition for Group 1 & 2 hangars in combination with an overhead sprinkler system. ILDFAs are approved under FM Approval Standard 6090. Additionally, the U.S. Air Force Civil Engineer Center (AFCEC) has verified fire test performance of the ILDFA. The U.S. Naval Facilities Engineering Systems Command (NAVFAC) has verified the daily operational use of the system and has various ILDFAs in use today.

3. Piping and Instrumentation

An ILDFA is divided into zones with a maximum area of 1,240 ft^2 (115 m^2) each. Each zone has its own solenoid valve, fiber optic liquid detector sensors, and flushing manifold, as shown in Figure 1. When a spill occurs, only the flushing manifold dedicated in that zone will activate. Each flushing manifold requires 45 gallons per minute (GPM) (170 liters per minute) of flushing water. In case a spill occurs on the corner of a zone, adjacent to a zone in both x and y direction, 4 zones could detect a spill and activate all 4 flushing manifolds. In this case, 4 x 45 GPM (170 LPM) will require 180 GPM (681 LPM) as the worst-case scenario.

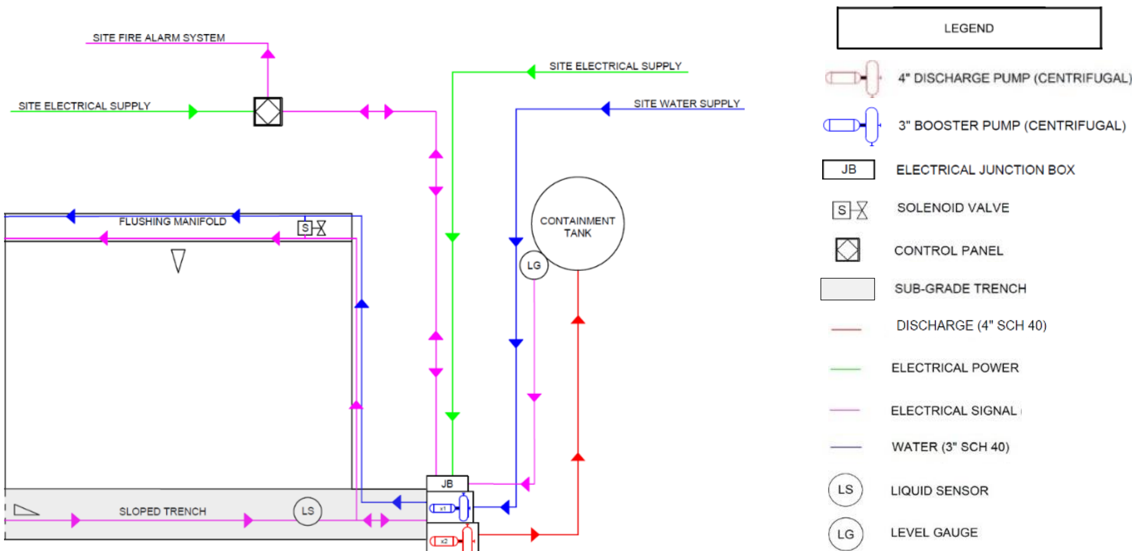


Figure 1: Simplified ILDFA Piping and Instrumentation Diagram (P&ID) of one zone.

The tie-in points represent what a third-party contractor will be responsible for in Figure 2. The ILDFA manufacturer can include this in the scope of supply upon request.

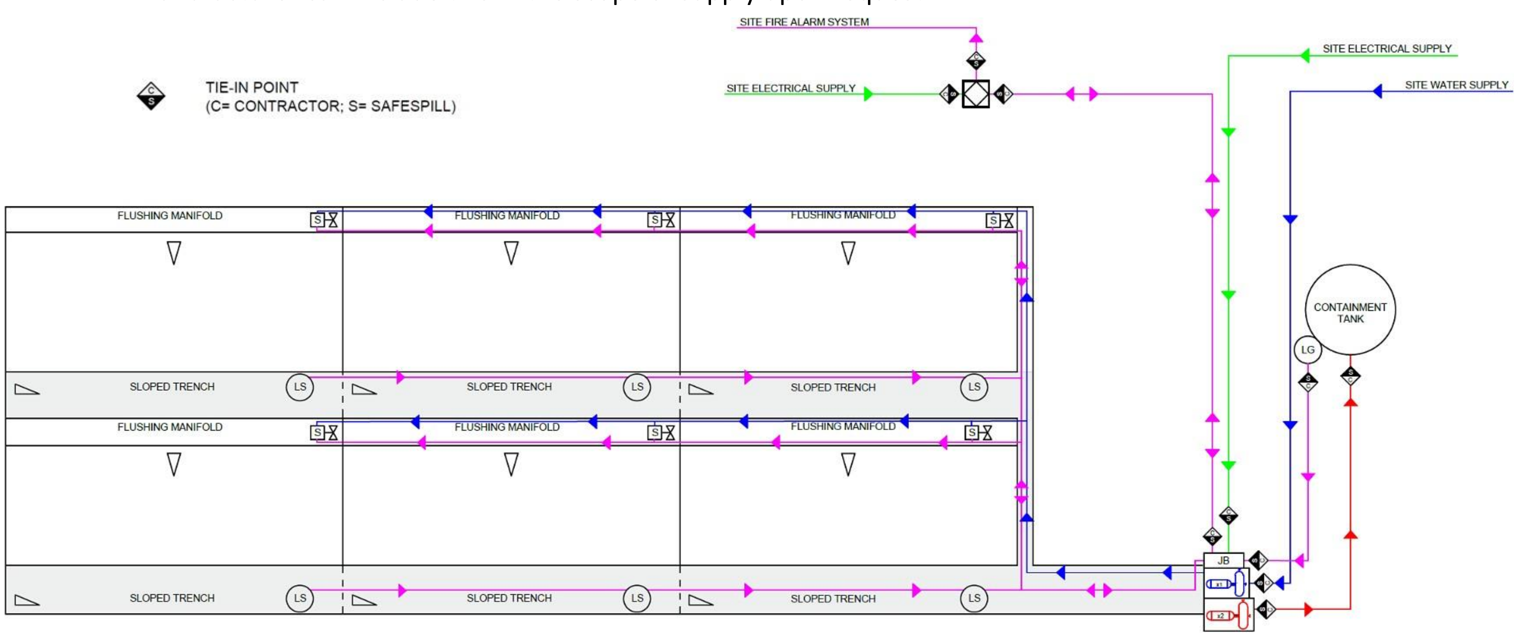


Figure 2: Simplified ILDFA P&ID of six zones.

4. Concrete Slab Requirements

The ILDFA has been designed and tested to support the Maximum Takeoff Weight (MTOW) of any U.S. military or commercial aircraft under a compression load scenario. The slope of the concrete slab should comply with either the UFC code for the Department of Defense or NFPA 409 for all other hangar applications. NFPA 409 Chapter 7.12.2.5 requires a minimum of 0.5% (0.3°), while UFC 4-211-01 Aircraft Maintenance Hangars Chapter 3-4.2.3 requires a slope with a minimum of 0.5% and a maximum of 1.5% (0.3° to 0.85°). An ideal configuration for an ILDFA installation will slope the concrete slab toward the hangar door entrance.

4.1. New Build Hangar: Recessed Concrete Slab

To design a ILDFA for an about to be built (new build) hangar, recessing the slab by 2 inches (51mm) will provide a flush transition between the concrete floor and the ILDFA. In this scenario, no ramps will be required. When designing, please note the ILDFA will be installed directly onto the concrete slab but should be a part of the structural strength of the slab.

> E.g., A 12” (305 mm) slab thickness requirement for a hangar cannot be reduced to 10” (254mm) with an ILDFA (the height of the ILDFA is 2” (51mm)); the slab needs to remain 12” (305mm) thick. The slab plus the ILDFA will be 14” (356mm), as shown in Figure 3.

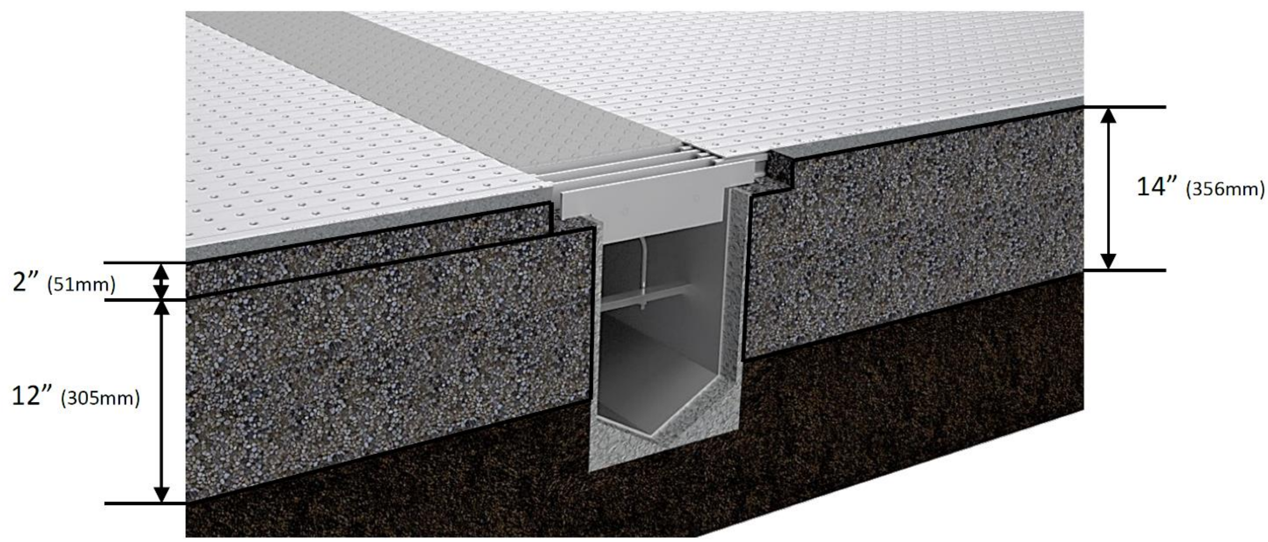


Figure 3: Recessed ILDFA with prefabricated aluminum trenches.

4.2. Retrofit Hangar: Existing Slab

If the existing hangar slab meets the 0.5% to 1.5% slope but has a limited number of inconsistencies or low spots, a flat aluminum bar can be used to shim individual sections to meet the slope requirements. Figure 4 shows an example of shimming the ILDFA to match the 0.5% slope during an installation.

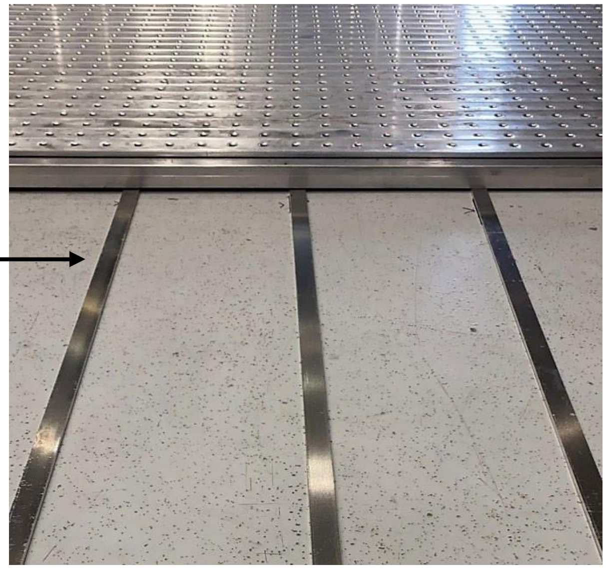


Figure 4: Aluminum flat bar used for shimming to proper slope requirements during installation.

4.2.1 Retrofit Hangar: Ramps

For retrofit installations that require the ILDFA to be installed directly on the hangar slab, a 1:24 sloped aircraft entrance ramp will be installed inside the hangar door. A 1:12 sloped access ramp for all non-aircraft traffic sides of the hangar will be provided. If the hangar will house a helicopter that has a tow tug with a short elevation clearance, please consider a 1:48 sloped entrance ramp.

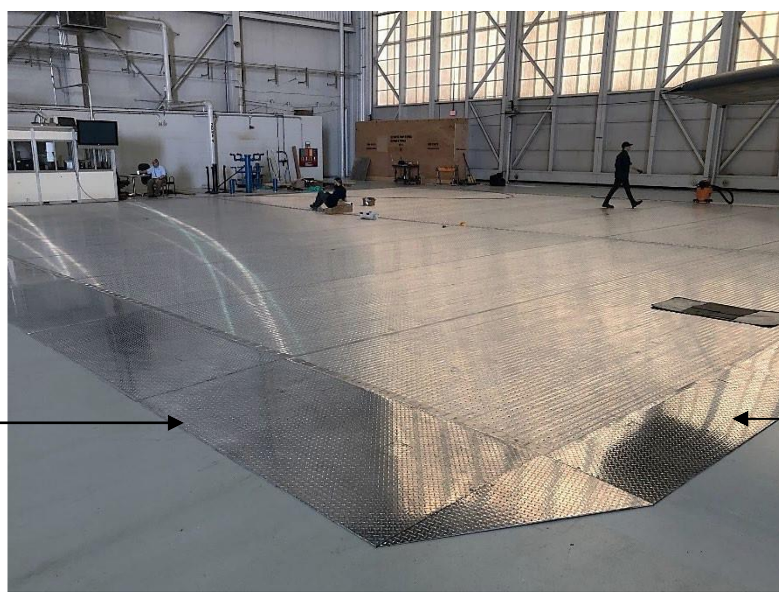


Figure 5: ILDFA sloped entrance and access ramps

4.3. Retrofit Hangar: Milling Existing Slab

Small individual parking spots, such as for helicopters or target drones as shown in Figure 6, are possible by milling the existing slab. Towing, scaffolding, and maintenance can easily transition from the hangar slab to the ILDFA due to no change in elevation. The concrete slab requirements listed in *Section 4.1. New Build Hangar: Recessed Concrete Slab* will be necessary for the individual recessed ILDFAs.

Figure 6: Render of helicopter ILDFAs recessed 2" (51mm) by milling the concrete of the existing hangar slab.

5. Hangar Coverage

A wall-to-wall coverage of the hangar floor will provide the greatest flexibility in an aircraft parking layout. The ILDFA may be able to be offset from the wall if there are aircraft hangar bay clearance requirements established by the owner, i.e., clearances from walls and fixed obstructions. However, in hangars where the aircraft have designated parking spots, wall-to-wall coverage might not be necessary and significant cost can be saved by reducing the floor coverage. In a designated aircraft parking scenario, a 16 ft (4.9 m) to 18 ft (5.5 m) radius should be drawn from the outer edge of any potential area containing fuel in the aircraft, such as fuel tanks and engines. The spill radius requirement is based on the largest lateral distance of a potential spill set by the flow rate. When considering a worst-case scenario spill for smaller aircraft, a 16 ft (4.9 m) lateral distance set by a flow rate of 200 GPM (757 LPM) is required. A worst-case scenario for larger aircraft requires an 18 ft (5.5 m) lateral distance set by a flow rate of 400 GPM (1,514 LPM). This ensures that all spilled liquid will land on the ILDFA. NFPA 409 Chapter 8.2.13.4.1 explains the aircraft size to accurately determine whether a 200 GPM (757 LPM) or 400 GPM (1,514 LPM) spill rate needs to be used for calculations. To view the report with spill radius data and scenarios, click here.

Two examples of an ILDFA hangar coverage are shown in Figure 7 for a 200 GPM (757 LPM) spill and Figure 8 for a 400 GPM (1,514 LPM) spill.

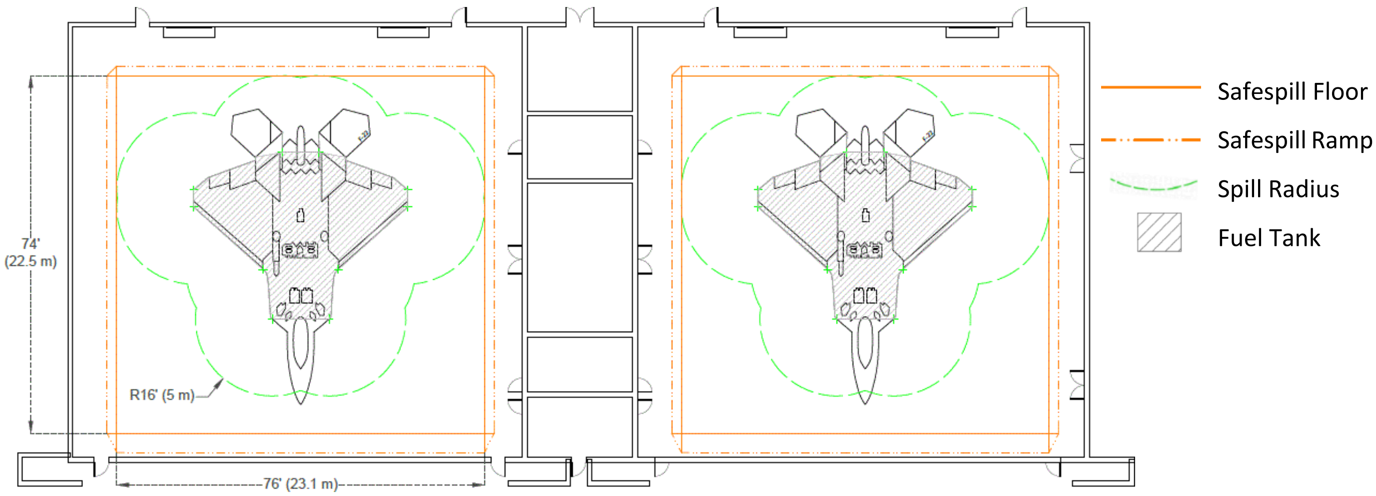


Figure 7: Example of a two-bay F-22 Raptor hangar with an ILDFA fixed to the spill radius.

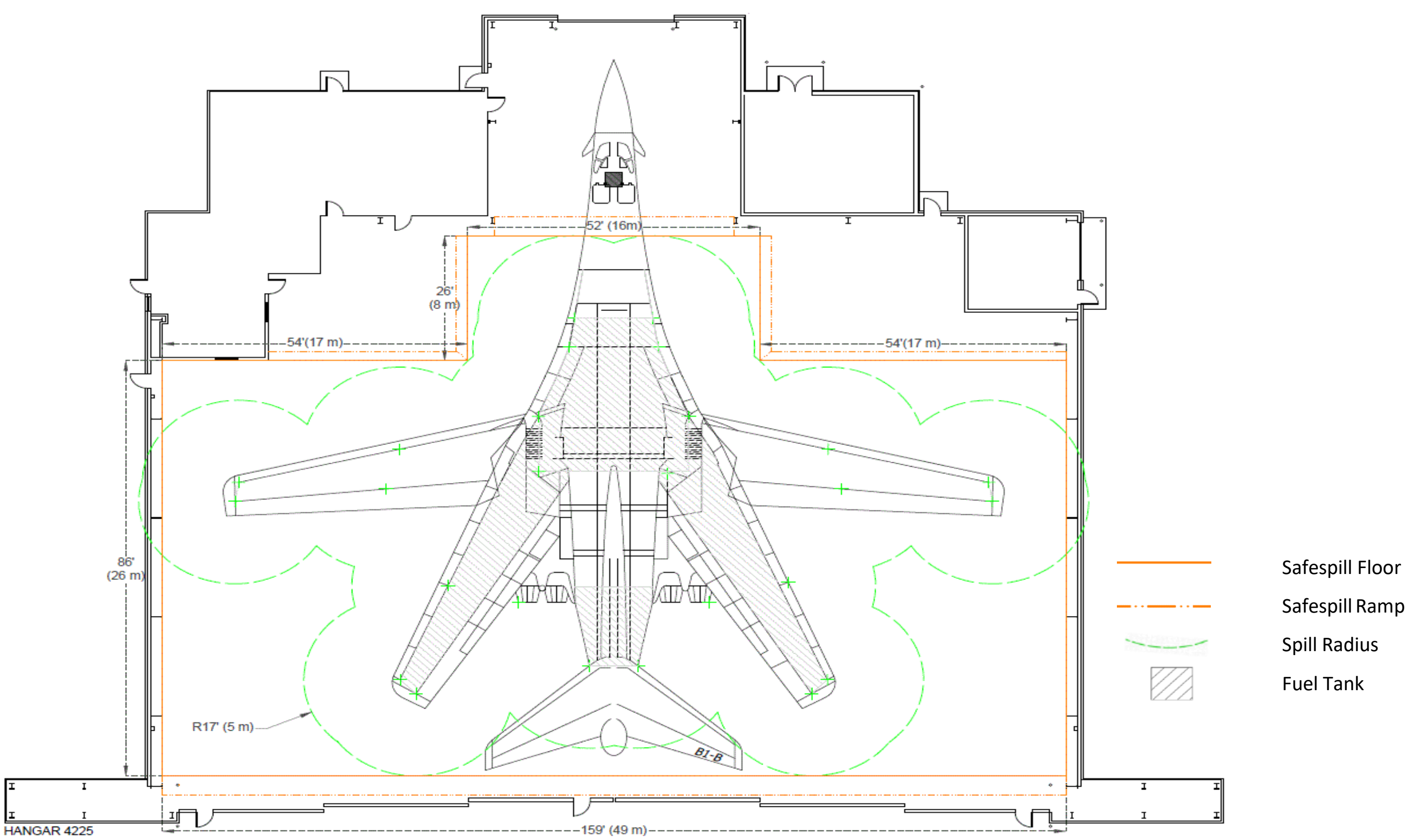


Figure 8: Example of a B1-B Lancer Hangar designed wall-to-wall due to large spill radius.

6. Trench Design

6.1. Cast-In-Place Trenches

6.1.1 New Build Hangar

The ILDFA will require a trench system to drain spilled liquid and flushing water. In a new build construction, the trenches should be designed into the hangar slab as cast-in-place concrete. The concrete slab requirements listed in *Section 4.1. New Build Hangar: Recessed Concrete Slab* will be necessary.

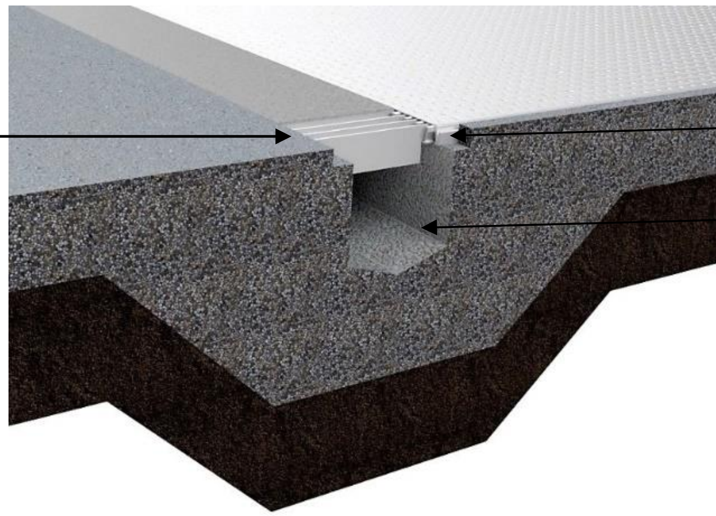


Figure 9: Recessed ILDFA render with cast-in-place trenches for new build projects.

6.1.2. Retrofit Hangar: < 12” (305mm) Concrete Slab Thickness

In the case of thinner slabs that are less than 12 (305mm) inches thick, a cast-in-place solution may be required as for retrofit hangars shown in Figure 9. A structural analysis will need to be conducted to determine whether cast-in-place or prefabricated trenches are the best option.

6.2. Prefabricated Aluminum Trenches

6.2.1 Retrofit Hangar: > 12” (305 mm) Concrete Slab Thickness

For retrofit projects, the existing hangar slab will need to be cut and prefabricated aluminum trenches will be installed. The prefabricated trenches are used as plumbing conduits and include liquid sensor mounts, cable trays, flushing manifold supply piping, and solenoid valves. Supplying trenches with all the components mentioned above reduces production costs and installation time. The ILDFA manufacturer requires prefabricated trenches to be installed for existing hangar scenarios when a structural analysis confirms the hangar slab retains sufficient strength.

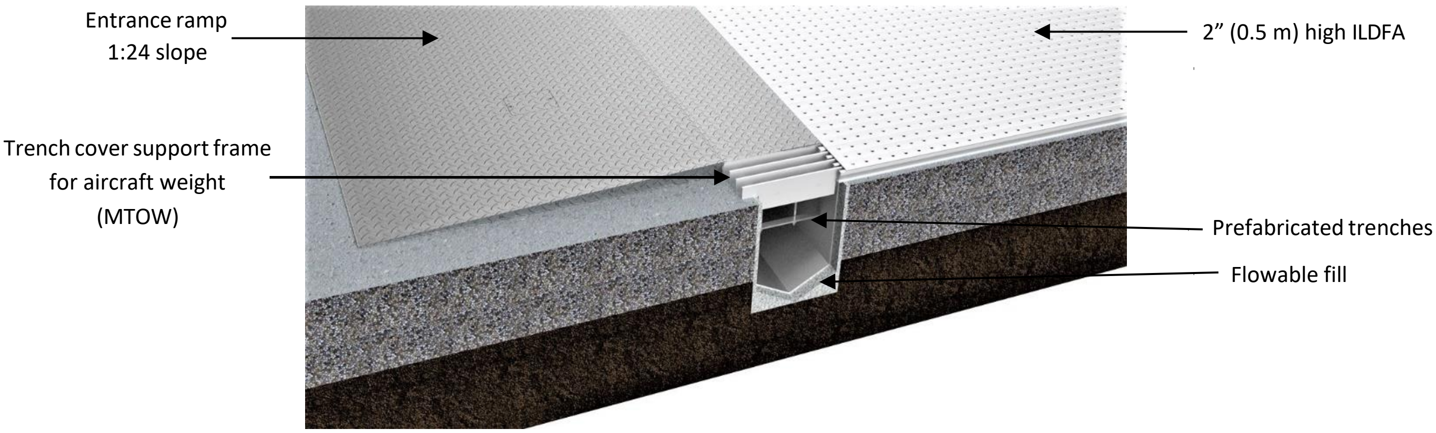


Figure 10: Render of ILDFA installed on hangar slab with prefabricated trenches and entrance ramp for retrofit projects.

A step-by-step process is shown in Figure 11 on the following page of how the ILDFA prefabricated trenches are installed. Shown in Step 4, the ILDFA trench covers are designed with a girder frame that supports the Maximum Takeoff Weight (MTOW) of the largest airframe. The ILDFA trench covers and support frames are included within the manufacturer's scope.

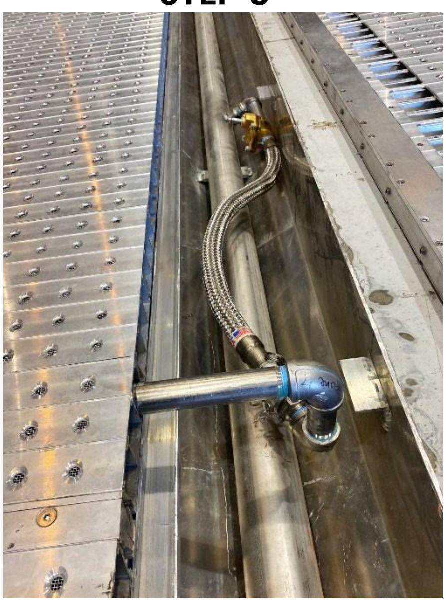
STEP 1

Cutting through existing concrete slab

STEP 2

Excavate and compact soil

STEP 3



Water supply and discharge piping routed in prefabricated aluminum trenches

STEP 4

Trench covers with support frame and profile placement

Figure 11: Step-by-step process of installing ILDFA prefabricated trenches for a retrofit hangar

6.3. Trench Spacing

The spacing of trenches is based on the following:

ILDFA sections are manufactured at standard 39.37 ft (12 m) lengths. They are directly installed on the concrete slab and connected to a corresponding trench that is 12 inches (305 mm) wide. This means the spacing of the trenches needs to be 40.37 ft (12.3 m) from the center of each trench. ILDFA sections can be shortened; however, this should only be done if necessary as it will increase production cost.

> E.g., A 100 ft (30.5 m) deep hangar will have two trenches spaced at 40.37 ft (12.3 m) and a third trench at the remaining length of (100.0’- 40.37’- 40.37') = 19.26’.
> (30.5 m- 12.3 m- 12.3 m) = 5.9 m.

In this case, only one row of ILDFA sections will need to be modified to a custom length instead of three rows to 33.3 ft (10.1 m), therefore reducing additional design and production cost.

6.4. Trench Depth

The internal slope of the trench is required to be a minimum of 0.5% (0.3°) to ensure liquid drains to the lowest point. The minimum depth of a trench should be 9 inches (230mm) to allow for proper flow of spilled liquid and piping conduit.

6.4.1 Cast-In-Place Trenches

Cast-in-place trenches are not limited to a certain depth and length when concerning the ILDFA. Please consult a structural engineer to determine the maximum dimensions of the cast-in-place trenches that the existing soil conditions allow. Cast-in-place trenches are outside of the ILDFA manufacturer’s scope of supply.

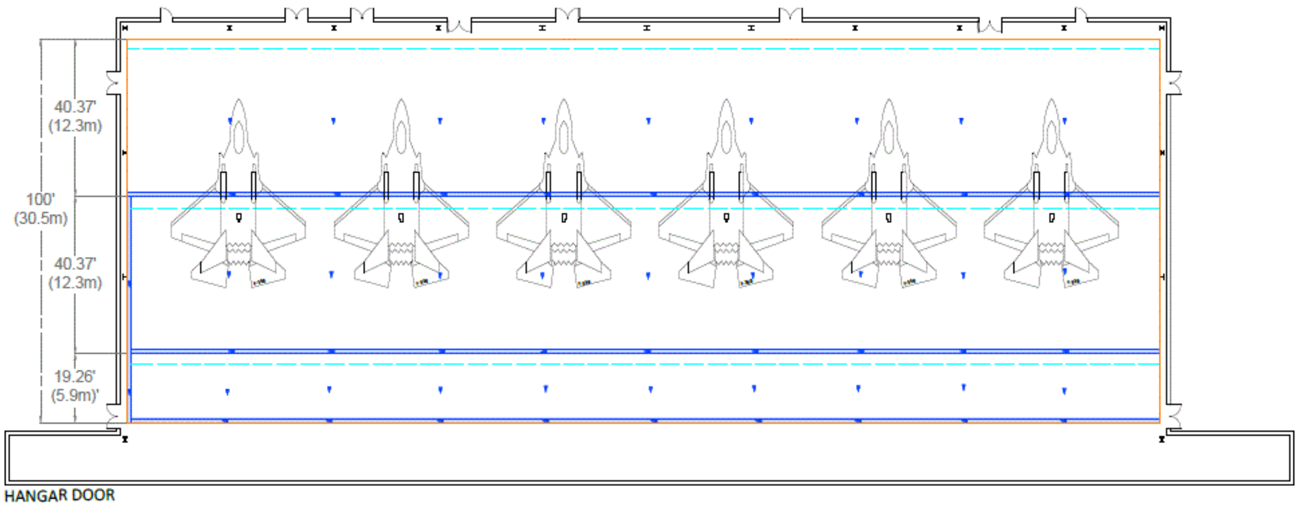
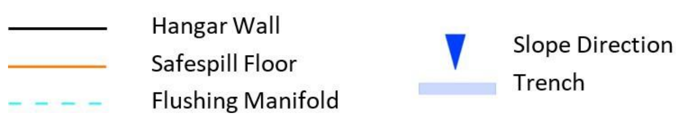


Figure 12: Trench spacing example for ILDFA design.



6.4.2 Prefabricated Aluminum Trenches

For prefabricated trenches, the maximum depth is 19.8 inches (503mm). Based on a 0.5% (0.3°) slope, this results in a maximum trench length of 175 ft (53.3 m). For hangars wider than 175 ft (53.3 m), two trench sections can be mirrored in such way that the shallowest point of the trench is at the center and the deepest end of the trenches are at the outer hangar walls. A structural engineering analysis will need to be conducted to determine if the depth and length can be extended without losing the structural integrity of the concrete slab.

7. Point Load Capacity

The ILDFA floor profiles are manufactured out of 6000 series Marine-Grade Aluminum because of the corrosion resistance and high strength, pushing the life span of the ILDFA to 50 years. Testing was conducted for the point load capacity of the ILDFA floor profiles. Taking a 9" x 16" (229mm x 406mm area, which represents the size of a fighter jet tire, the ILDFA withstood up to 48 tons (44 MT) of pressure.

48 tons
(96,000 lbs)

Figure 13: Point load capacity of a 9" x 16" ILDFA area can handle 96,000 lbs.

Safety Factor calculations for the ILDFA point load capacity are as follows:

ILDFA Point Load Capacity: $\frac{96{,}000 \text{ lbs}}{9 \text{ in} * 16 \text{ in}}$ = 666 psi (46 Bar)

KC-135 Stratotanker load per tire*: 170 psi
Safety Factor: 3.9

F-22 Raptor load per tire*: 275 psi
Safety Factor: 2.4

**Reference: Goodyear Aviation Data Book 2021. SECTION 6C Military Aircraft Application Charts.*

8. Tie Down Points

Openings in the ILDFA to access tie down points can be incorporated. Using a core drill, a 6.5” Ø hole in the concrete is cut. The tie down is installed and then chemically anchored as shown in Figures 14 and 15. The ILDFA access for the tie down point sits flush with the top surface and allows the chain connection to secure the aircraft inside of the hangar as shown in Figure 17.

For new build projects, tie down points should not be included in the hangar slab design to allow the ILDFA manufacturer flexibility of installing the system.

Figure 15: Concrete core drilled out of hangar slab to allow the ILDFA tie down point to be chemically anchored.

Figure 14: ILDFA tie down point chemically anchored into concrete slab.

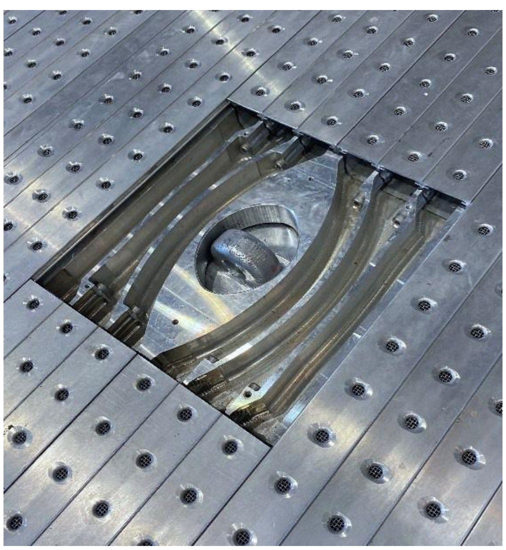


Figure 16: ILDFA tie down point without lid.

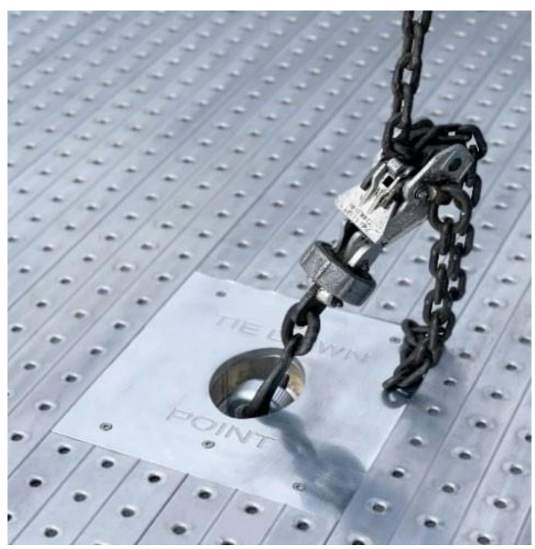


Figure 17: ILDFA tie down point example with aircraft chain connection.

9. Grounding Points

Grounding points for aircraft grounding are integrated in the ILDFA and will be connected to the ILDFAs grounding grid. The ILDFA grounding grid will be connected to ground rods or building ground. An example of an ILDFA grounding point is shown below in Figure 18.

For new build projects, a grounding grid is no longer necessary within the hangar slab when utilizing the ILDFA grounding. For retrofit projects, the existing grounding grid and other utilities will not be used.

Figure 18: ILDFA grounding point example.

10. Water Requirements

An ILDFA requires water to flush the internal drain channels. The ILDFA water requirement is 180 GPM (681 LPM) each zone requires a water supply of 45 GPM (171 LPM). If a spill occurs on the corner of a zone, the 3 adjacent zones could activate as well. Therefore, the total water supply should be 4x45 GPM = 180 GPM (681 LPM).

The flushing manifold will require a minimum of 2" water main connection. For ILDFAs larger than 10,000 ft^2 (929 m^2), the water main connection will need to be increased to 3" due to friction losses created by longer pipe runs. If providing a dedicated line to the hangar requires significant plumbing or water availability is limited, a dedicated flushing water tank placed outside the hangar could be an alternative.

The flushing manifold operates at a minimum pressure of 60 psi (4.1 Bar) and a maximum pressure of 120 psi (8.3 Bar). Depending on the water pressure of the hangar, a booster pump or pressure reducer can ensure the correct pressure will be supplied to the ILDFA.

A domestic water line or a fire water line can provide flushing water for an ILDFA. If a fire water line is providing the water, the tie in point should be upstream of the flow alarm so that flushing activation for cleaning cycles or unignited spill removal will not activate the fire alarm.

11. Power Requirements

11.1. Pump Skid

When designing the ILDFA, the pump skid system typically uses two 4” 15HP centrifugal pumps for the trench discharge. Each pump will be controlled by a FM approved pump controller.

The pump size can potentially be scaled down depending on the ILDFA size, please contact the ILDFA manufacturer for confirmation. The hangar layout, width, and number of trenches will determine if one or more pump skids are required. A 460/480V 3 phase power supply of 50 amps is required per pump skid. Pump motors can be modified to work with local 3 phase voltage supply. The manufacturer recommends designing the ILDFA for 100 amps. Figure 19 is an example of one pump skid with two 4” centrifugal pumps.

Figure 19: ILDFA pump skid installation during construction. External panels not shown.

For a hangar layout that needs two pump skids, the skids will be located at each end of the ILDFA along the hangar wall to pump liquid from the trenches to above-ground external containment. Alternatively, the liquid can gravity drain by individual drain connection points to external containment such as an underground Oil Water Separator (OWS). Please review *Section 13 Liquid Containment Sizing* for more details.

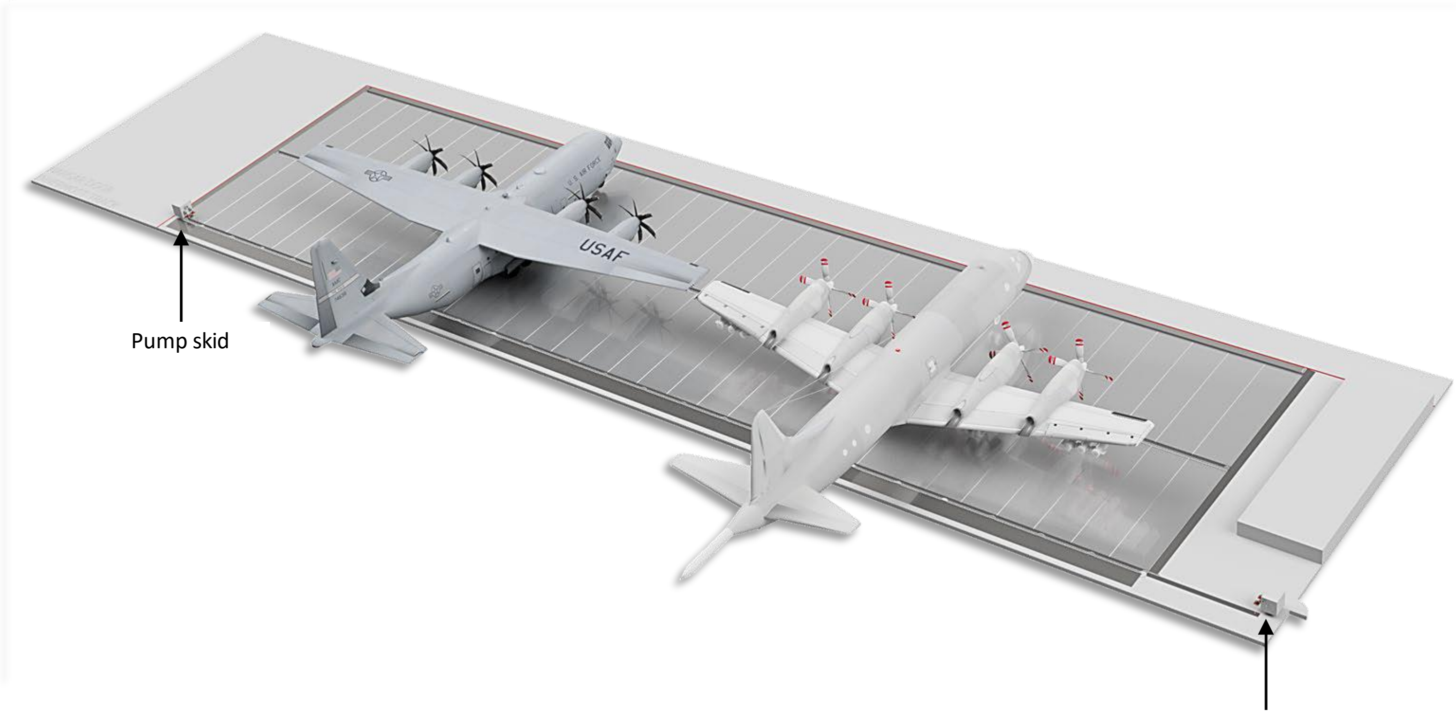


Figure 20: Render of ILDFA layout with pump skids on opposing sides of the system.

11.2. Control Panel

The ILDFA control panel is UL-698A & UL-508A listed, and FM approved with a Human-Machine Interface (HMI) installed to allow the user to observe current and past alarms. A 110VAC power supply of 20 amps is required. During standard operation, the system is armed and will activate upon three scenarios:

1. Liquid detection recognized as a spill
2. Manual system activation by button on HMI
3. Cleaning cycle activation by button on HMI

If remote monitoring is permitted, the ILDFA manufacturer can access the control panels' HMI through a VPN connection to analyze the data and make continuous improvements. This allows the option to override inputs, such as the liquid detection sensors, to diagnose errors within individual zones.

Figure 21 represents an example of the ILDFA control panel mounted on the inside wall of the hangar within view of all ILDFA zones and is accessible to emergency responders and maintenance personnel.

Figure 21: ILDFA Control Panel mounted on the interior hangar wall.

The HMI will display the zone currently being activated by one of the three scenarios. The example below in Figure 22 shows the ILDFA Zone 3 activated by cleaning mode in green.

Figure 22: Example of the ILDFA HMI Zone 3 cleaning mode activated.

12. Logic Tree

Figure 25 is an example of the ILDFA logic tree that explains the flow of operations once one of the three activation scenarios occurs.

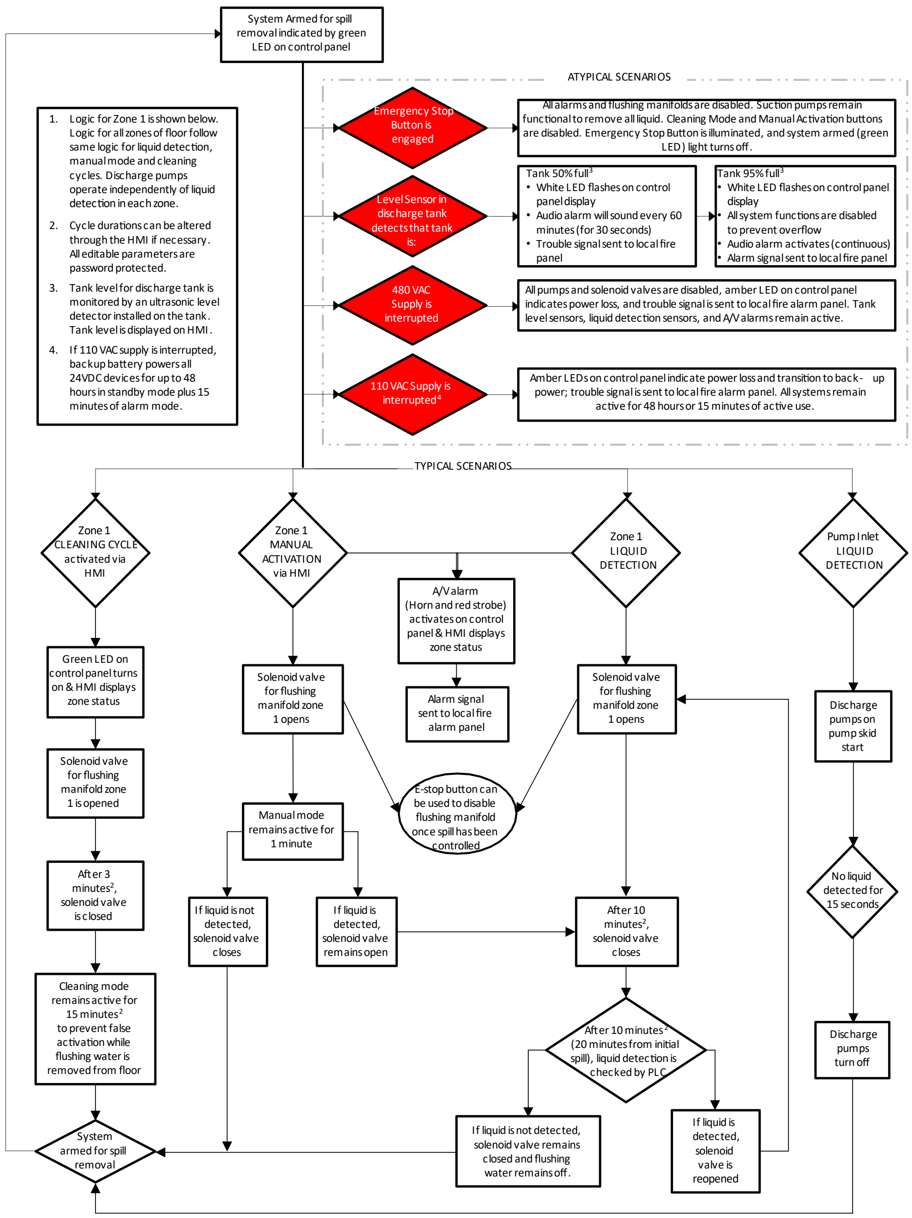


Figure 23: ILDFA Logic Tree.

13. Liquid Containment Sizing

Containment of spilled hydrocarbons is required; there are two typical liquid containment solutions. The first is using gravity-fed drainage to an underground containment tank. In this case, a civil engineer will be responsible for designing the system, which is beyond the scope of this document.

In the event an underground containment tank is not preferred due to cost or environmental concerns, an above ground containment system can be used. This option can be included in the scope of the ILDFA manufacturer. The ILDFA will need to be equipped with pumps to remove spilled liquid and flushing water from the lowest points in the trench system. The discharge pumps (refer to *Section 11.1 Pump Skid* for details) will direct the liquid to a UL-142 Double-Wall steel above ground tank.

Containment tank size calculations are based on the following:

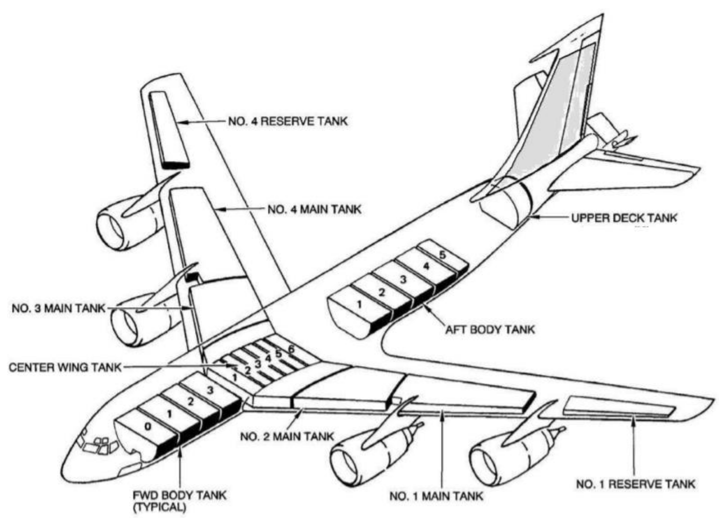


Figure 24: KC-135 Stratotanker fuel cell locations.

*(*Discharge spill rate referenced from Reballasting the KC-135 Fleet for Fuel Efficiency- Military Operations Research Vol.16 No.3 2011)*

When calculating the necessary spill containment tank for a larger aircraft, the largest internal fuel cell size for the largest potential spill (LPS) is used. However, for a smaller aircraft, it is recommended to use the entire fuel capacity of the aircraft.

Example of KC-135 Spill Containment Calculation (Worst Case Scenario – WCS)

Largest Potential Spill	**7,270 gallons (27,519 L)**	Largest Internal Fuel Cell
WCS Spill Flow Rate	400 GPM (1,514 LPM)	Fuel Cell Puncture
Drain Time	7,270 / 400	= 18 min. (round up to 30 min.)
WCS Flushing Water	180 GPM (681 L) x 30 min.	= **5,400 gallons (20,441 L)** *(reference section 3 for 180 GPM calculation)*
Spill Containment Tank	**12,670 gallons (47,961 L)**	**(minimum capacity = LPS + WCS flush)**

For one KC-135 spill calculation, one 20,000-gallon (75,708 L) UL-142 Double-Wall Horizontal steel tank is recommended, based on a conservative assessment in the above calculation. Multiple hangar bays can use one containment tank dependent upon location. The ILDFA manufacturer recommends to account for at least 30% additional capacity.

Based on heat flux data from fire tests and the elimination of a pool fire, it is extremely unlikely that an ignited spill on an ILDFA produces enough heat to activate an overhead sprinkler head. However, based on the relatively low amount of water produced by sprinkler activation and the incremental increase in tank size needed to account for sprinkler water, it could be considered that 1,240 ft^2 (115 m^2) (WCS of one ILDFA zone) would have sprinkler activation. Total sprinkler water amount is calculated by using the sprinkler water density in NFPA 409 Chapter 9.2.5 at 0.17 GPM/ft^2 (6.94 LPM/m^2), or in the case for the Department of Defense, UFC 4-211-01 3-6.15.1 at 0.2 GPM/ft^2 (8.15 LPM/m^2).

E.g., 0.17 GPM/ft^2 * max spill area 1,240 ft^2 * 30 mins = 6,324 gallons
6.94 LPM/m^2 * max spill area 115 m^2 * 30 mins = 23,943 liters

Figure 25: Example of 15,000-gallon (56,781 Liters) UL-142 steel aboveground tank; shown for reference only.

Due to the use of water as a flushing medium, water will be mixed in the spilled volume within the containment tank. To reduce the frequency of emptying the containment tank and to reduce remediation cost, an Oil Water Separator (OWS) can be included in the tank package of the ILDFA manufacturer's scope. The OWS will be controlled by the ILDFA hangar control panel and will manually or automatically process the tank's liquid content after a spill has occurred. More details will be provided in the next revision of this document.

14. Overhead Sprinkler System

Provide a sprinkler system as required by NFPA 409; in the case for the Department of Defense, UFC 4-211-01; or local authority. The sprinkler system is required to protect the hangar against fires other than hydrocarbon-based fires.

Please note that if an ignitable liquid fire occurs with an ILDFA installed, it is extremely unlikely that closed head sprinklers will activate based on reductions in spill size, elimination of a pool fire, and heat release rate.

15. Infrared Flame Detector

Multispectrum infrared flame detectors are not needed for the ILDFA to operate at maximum efficiency and are not a requirement per NFPA 409 2022 Edition. If IR Flame detectors for other reasons unrelated to the ILDFA, the floors reflectiveness does not affect IR detection. Det-Tronics conducted flame detector testing on an ILDFA on December 13, 2021, at the ILDFA manufacturing facility in Houston, TX on a sunny day. The results concluded that the flame detector is not affected by the matte finish of the ILDFA and exhibits less reflection than a typical gloss-finish epoxy floor. The Det-Tronics Flame Detector Testing report can be found Safespill.com/Det-Tronics-Flame-Detector-Safespill-Testing.

Figure 26: The flame detector testing was conducted on the ILDFA shown

SAFESPILL

FOR MORE INFORMATION

Contact the Safespill team for further questions or education on the ILDFA

sales@safespill.com

or visit our website

safespill.com/hangars/