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

Version 6.0
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REVISION LOG

February 2025. Version 6.0 released. The following changes were made.

Global Revisions
References to ITG FY23-02.1 replaced with UFC 4-211-01 due to Change 4 expected release in Summer 2025. UFC 4-211-01, Change 4 supersedes ITG FY23-02.1.

Chapters Revised
Chapter 4: Hangar coverages were revised based on UFC 4-211-01, spill radius updated to be 18 ft (5.5 m) for all aircraft

Chapter 4.2: Maximum profile lengths and recommended trench arrangements were revised based on project experience.

Chapter 5.2: Moved from 6.1, figure revised with updated design for mating strips

Chapter 5.3: Shimming details were updated with new images and additional guidance on spacing and construction materials

Chapter 6: Consolidated to provide guidance for trenches in both retrofit and new build

Chapter 6.1: Structural Considerations for Trenches moved from Chapter 7.5

Chapter 6.2: Additional guidance added for use of existing trenches in hangars.

Chapter 7.2: New Section on Slip Resistance Data added to document with details on Safespill “Omni-slip” design

Chapter 7.3: New Section added with information on FOD screens

Chapter 8.2: Grounding Point design revised and new figures added

Chapter 8.3: New Section on utilities access design added

Chapter 9: Additional guidance on required devices for water supply added

Chapter 9.2: New Chapter Detailing Booster Pump Skid

Chapter 10: Discharge pump size standardized to 6”, 50 HP Pump

Chapter 11: Merged into Chapter 9

Chapter 11.3: Battery Trunk Sizing Updated

Chapter 11.4: Sequence of Operations added in accordance with UFC 4-211-01

Chapter 11.5: Logic Tree revised in accordance with UFC 4-211-01 and split into 2 pages

Chapter 12: Conduit size tables updated

Chapter 12.2: Solenoid Valve enclosure and conduit routing updated based on new design

Chapter 18: Detail added on dry pipe flushing system

Figures Revised

Figure 3-1: Updated
Figure 3-3: Removed
Figure 4-4: Added
Figure 4-5: Updated
Figure 5-1: Updated
Figure 5-2: Added
Figure 6-2: Updated
Figure 6-3: Updated
Figure 6-4: Updated
Figure 6-5: Updated
Figure 6-6: Updated
Figure 6-7: Updated
Figure 7-4: Added
Figure 8-9: Updated
Figure 10-1: Updated
Figure 13-2: Updated
Figure 14-1: Updated
Figure 14-2: Updated
Figure 18-1: Updated

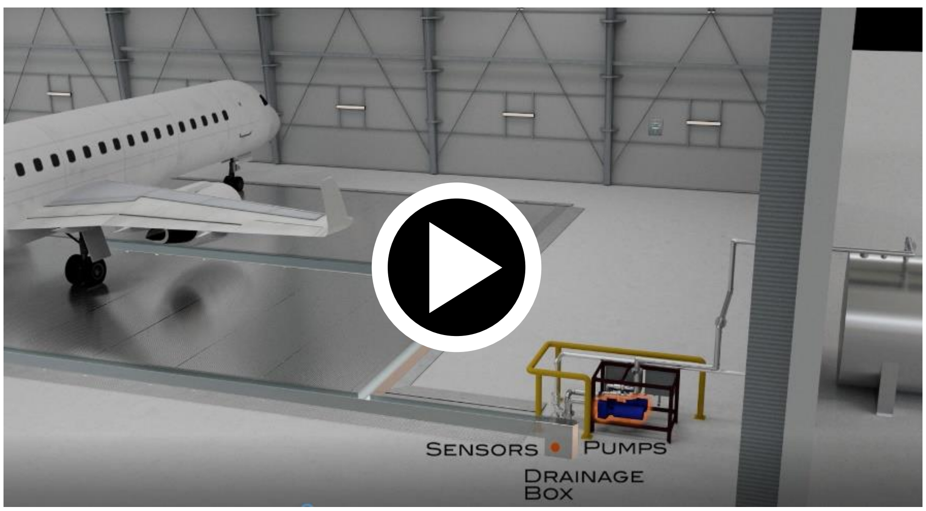
1. Scope of Document

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 for detailed input by the ILDFA manufacturer.

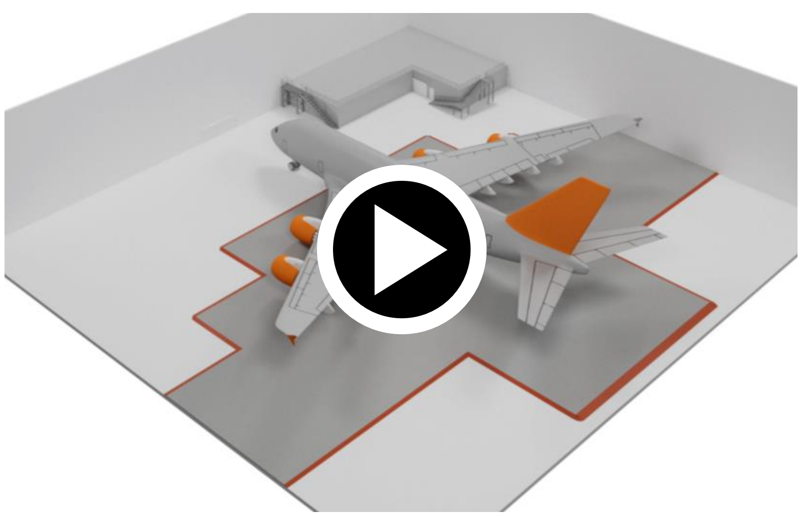
Safespill is committed to continuous improvement; therefore, best practices, installation, and manufacturing improvements continuously evolve. Please check for the latest version of the document at: https://safespill.com/technical-specs-resources/

Before continuing to read this document, please view the following videos which provide background on the working principles of the system and how to approach layouts and sizing of the system.

Explaining the Safespill Floor



Flooring Layout Options



2. ILDFA Purpose

An ILDFA is designed to contain and remove ignitable liquid spills before they develop 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 ignitable 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 and are the preferred method of fire protection for aircraft hangars according to FM Datasheet 7-93.

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. Unified Facilities Criteria (UFC) 4-211-01, “Aircraft Maintenance Hangars” is expected to be revised with Change 4 in 2025 to include guidance on the installation of ILDFA in retrofit and new build hangars. Relevant sections from UFC 4-211-01 are referenced in this document.

In addition, the U.S. Air Force Civil Engineer Center (AFCEC) has independently verified fire test performance of the ILDFA, documented in this test report: https://apps.dtic.mil/sti/pdfs/AD1168510.pdf

3. Piping and Instrumentation

An ILDFA is divided into zones with a standard width of 30 feet (9.2 m) and 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 3-1.

The tie-in points represent what a third-party contractor will be responsible for, but Safespill can include this in the scope of supply upon request.

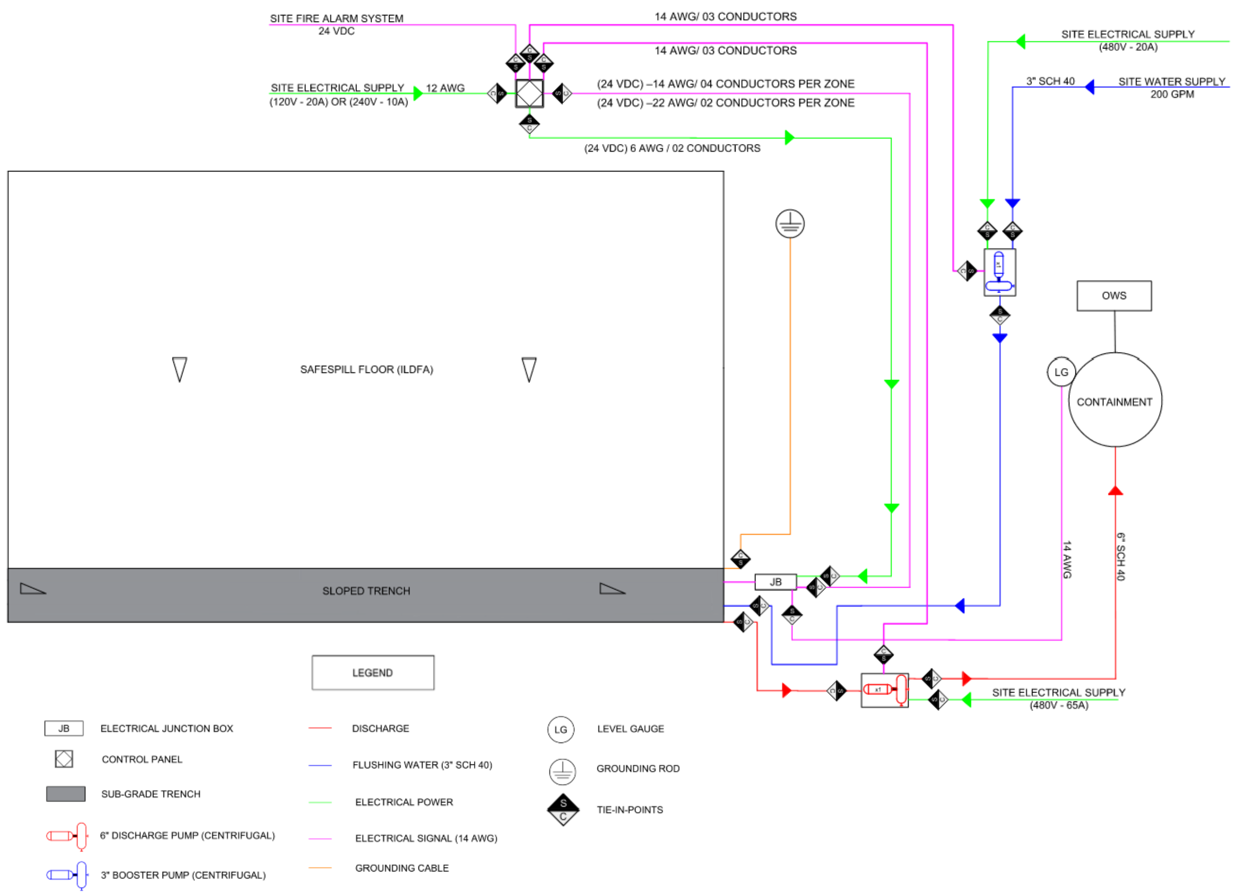


Figure 3-1: Simplified ILDFA Piping and Instrumentation Diagram (P&ID) of one zone

When a spill occurs in a zone, only the flushing manifold dedicated to that zone will activate. Each flushing manifold requires 50 gallons per minute (GPM) (189 liters per minute) of flushing water. In a worst-case scenario, as shown in Figure 3-2, a spill may occur across multiple zones activating adjacent zones in both x and y directions. Up to 4 zones (Zones 1, 2, 6, and 7 in Figure 3-2) could detect a spill and activate all 4 flushing manifolds. In this case, 4 x 50 GPM (189 LPM) will require 200 GPM (757 LPM) as the worst-case scenario.

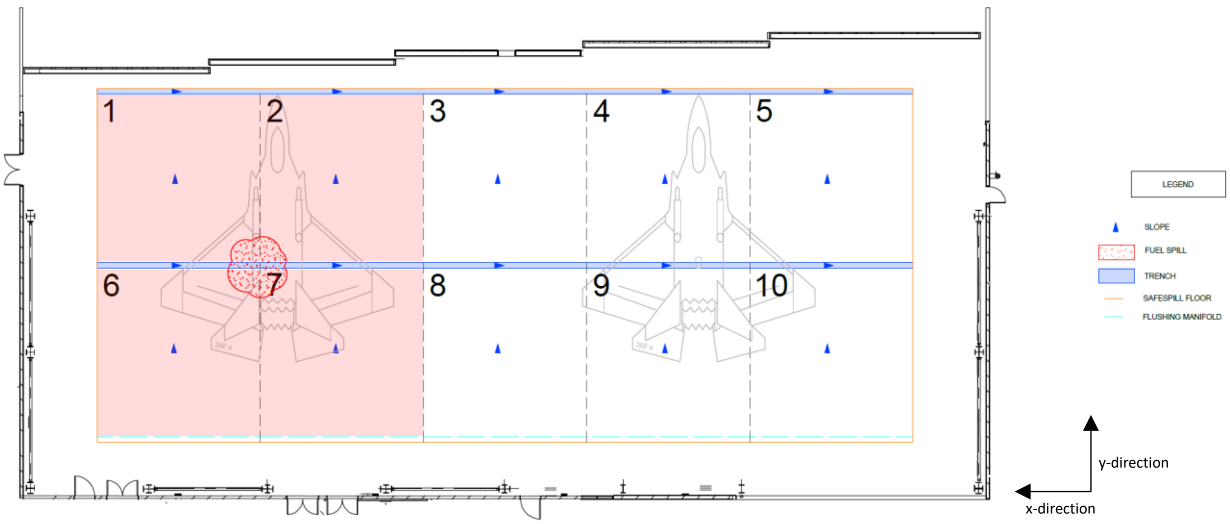


Figure 3-2: ILDFA layout drawing showing 4 zones activated by spill at intersection of 4 zones

4. 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. For ILDFA installations following UFC 4-211-01, partial hangar bay coverage is only permitted when approved by the Component Fire Protection Engineer (CFPE) or Component Technical Representative (CTR).

For all applications, ensure that the ILDFA covers all areas where a fuel spill could occur by drawing an 18 ft (5.5 m) radius from the outer edge of all areas containing fuel in the aircraft, such as fuel tanks and engines as shown in Figure 4-1 through Figure 4-3.

To view the report with spill radius data and scenarios, click here.

4.1. Flooring Layouts

Three examples of an ILDFA hangar coverage are shown below. In Figure 4-1, a parking spot configuration across multiple bays is shown. In Figure 4-2, a wall-to wall ILDFA for multiple aircraft is shown. In Figure 4-3, a parking spot configuration for a single aircraft is shown.

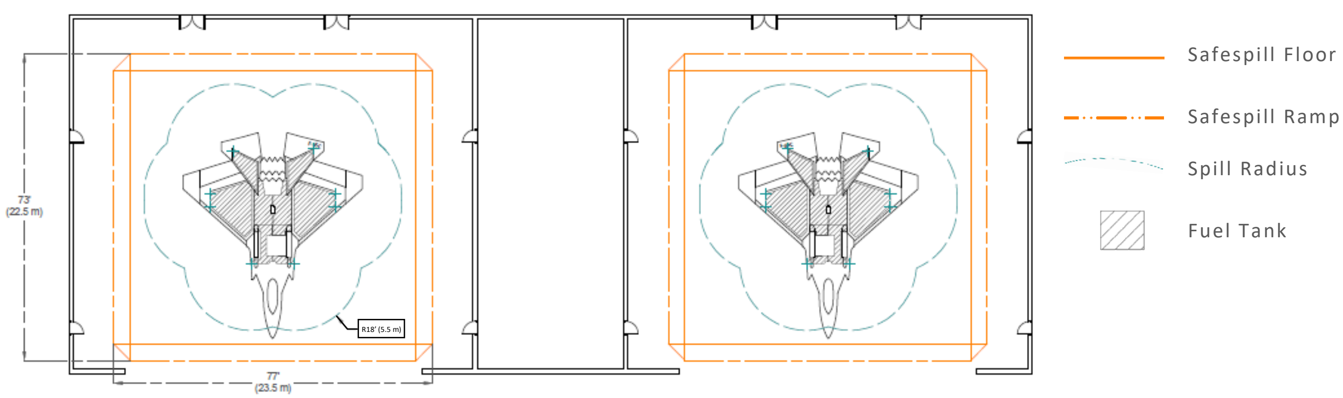


Figure 4-1: Example of a two-bay F-35C hangar with an ILDFA fixed to the spill radius

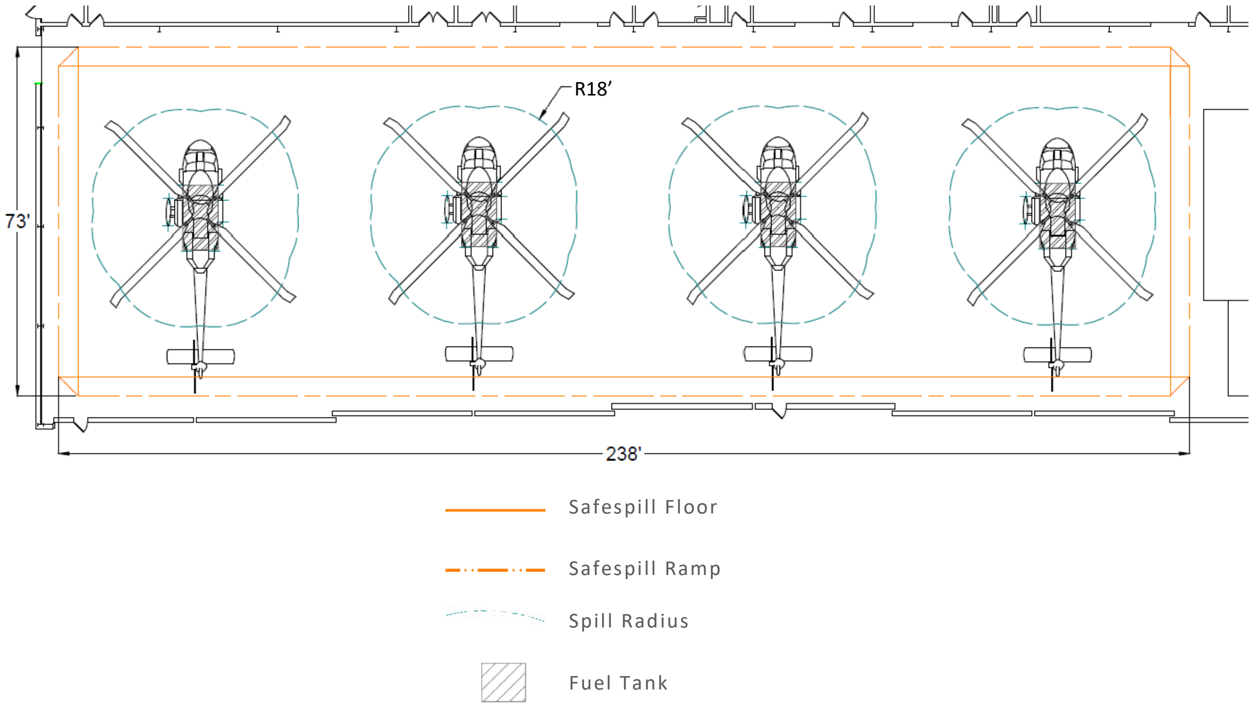


Figure 4-2: Example of a MH-60T Jayhawk hangar designed wall-to-wall, per UFC 4-211-01

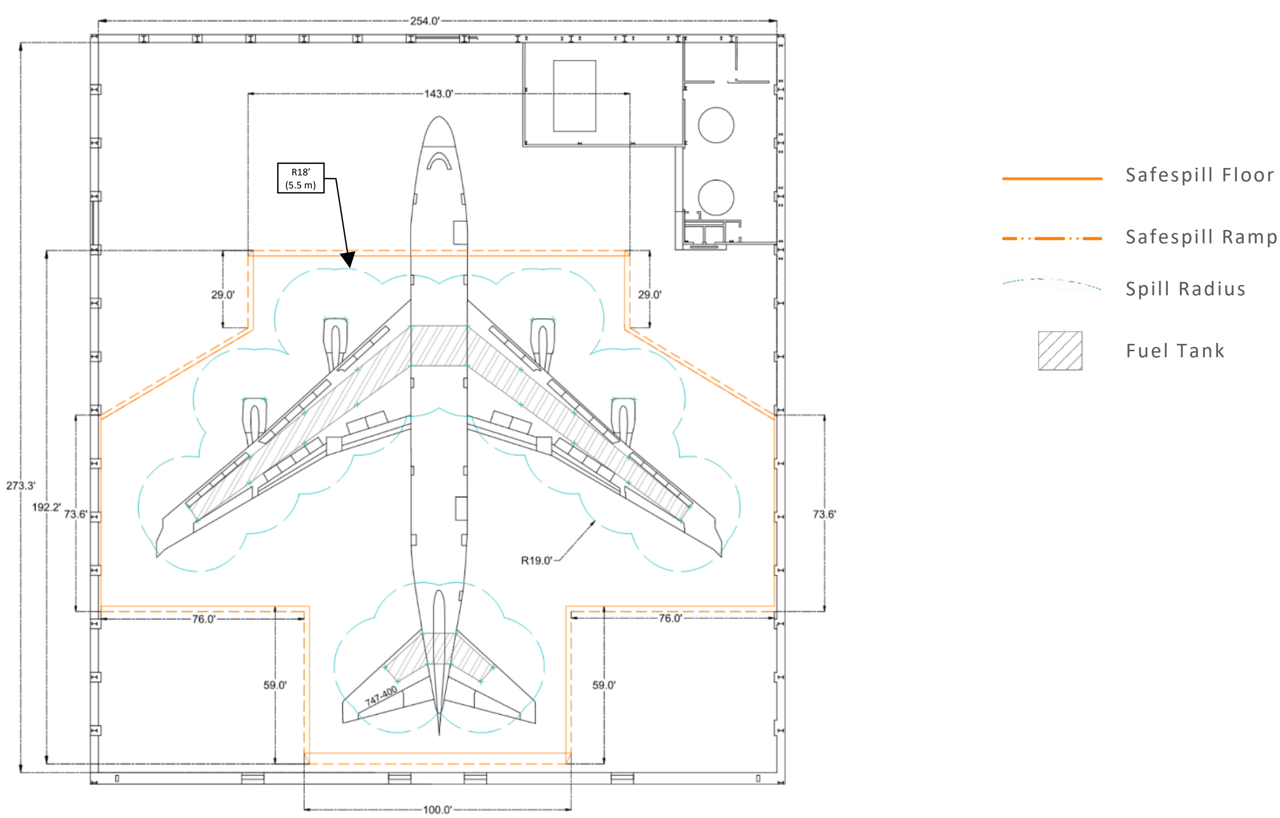


Figure 4-3: Example of a Boeing 747-400 hangar designed with a reduced ILDFA only covering potential spill areas

4.2. Trench Locations

The location of trenches in retrofit applications should be determined based on the slopes of the existing slab. In most cases, trenches are already present at the lowest points within the hangar, designed to align with the existing slopes of the hangar slab (refer to Chapter 6., "Trenches" for guidance on using existing trenches with ILDFA).

If no trenches exist in the hangar, it is common for the hangar slab to feature a monoslope, with its lowest point located near the hangar door(s). In this case, a trench will be installed along the hangar door. This is the preferred arrangement for new build applications.

It is recommended that, when determining trench location, trenches are positioned based on the hangar's parking configuration so that the ILDFA slope runs parallel to the aircraft. This alignment prevents a spill from one aircraft migrating to and exposing adjacent aircraft.

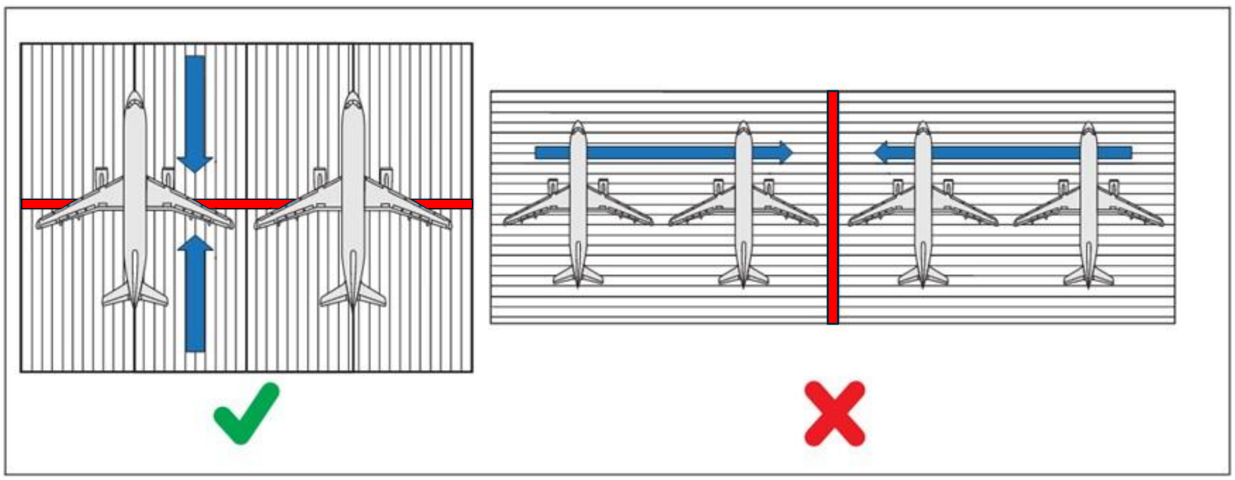


Figure 4-4: Example of recommended trench arrangement relative to aircraft (FM Datasheet 7-93, Fig. 2.2.2.2-1)

Trench spacing depends on the following factors:

1. **Profile Length Restrictions:**

If the hangar location is in an area where road transportation from Safespill's manufacturing facility (Houston, TX) is possible, ILDFA sections can be manufactured in lengths up to 49 ft (14.9 m). If transportation via shipping container (overseas freight) is required, the maximum profile length is reduced to 40 ft (12.2 m).

2. **Reduction of Trench Quantity:**

To reduce production costs, the number of trenches should be minimized and ILDFA sections can be manufactured at different lengths to achieve optimum spacing of trenches.

Profiles are installed directly on the concrete slab and connected to a corresponding trench that is 12 inches (305 mm) wide. This means that the maximum spacing of the trenches needs to be 50 ft (15.2 m) from center to center of each trench.

For example, Figure 4-5 below shows a 100 ft (30.5 m) deep hangar that will require a minimum of two trenches. These trenches should be evenly spaced at 50 ft (15.2 m).

In this case, both rows of profile sections can be standardized to 49 ft (14.9 m), therefore reducing additional design and production cost.

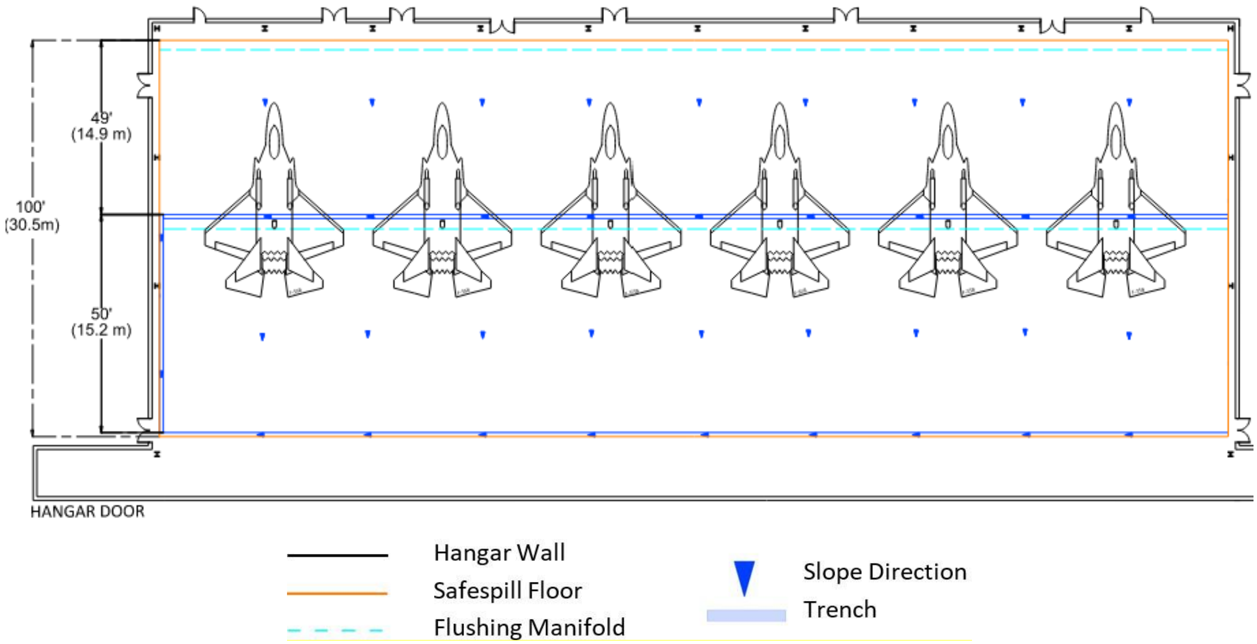


Figure 4-5: Trench spacing example for ILDFA design

5. Concrete Slab Design

5.1. 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 the applicable code:

- NFPA 409 (2022), 7.12.2.5 requires a minimum slope of 0.5% (0.3°)
- When using FM Datasheet guidance, provide a minimum slope of 0.5% (0.3°).
  - FM Datasheet 7-93 does not specify a required slope for ILDFA and refers to the manufacturer's written instructions and the product's listing in the FM Approvals Approval Guide.
  - FM Datasheet 7-93, 2.2.2.3.2.2 is not applicable for ILDFA installations as this section provides requirements for "Emergency Drainage Systems" which are not equivalent to ILDFA.
- UFC 4-211-01, 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.

5.2. New Construction: Recessed Concrete Slab

When designing an ILDFA for a 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.

Recessed concrete must have a consistent slope between 0.5% and 1.5% toward each trench. Consistent flatness ensures that shimming requirements are minimized. “Very flat” finish in accordance with ACI 117 is recommended and slab irregularities should not exceed an elevation delta of 0.125” over 10 feet.

To reinforce the corners of formed or cut concrete, it is recommended that steel or aluminum angle is used as shown in Figure 5-1. Where dissimilar metals are used, fluoroelastomer (FKM, Viton™) seals will be installed to isolate metals and prevent galvanic corrosion.

ILDFA sizing will include a 1” – 2” (25 - 50 mm) gap around the floor perimeter between the edge of the flooring and the concrete recess to allow for construction tolerances. This gap should be coordinated during design and will be **filled** with concrete or equivalent after the ILDFA is installed.

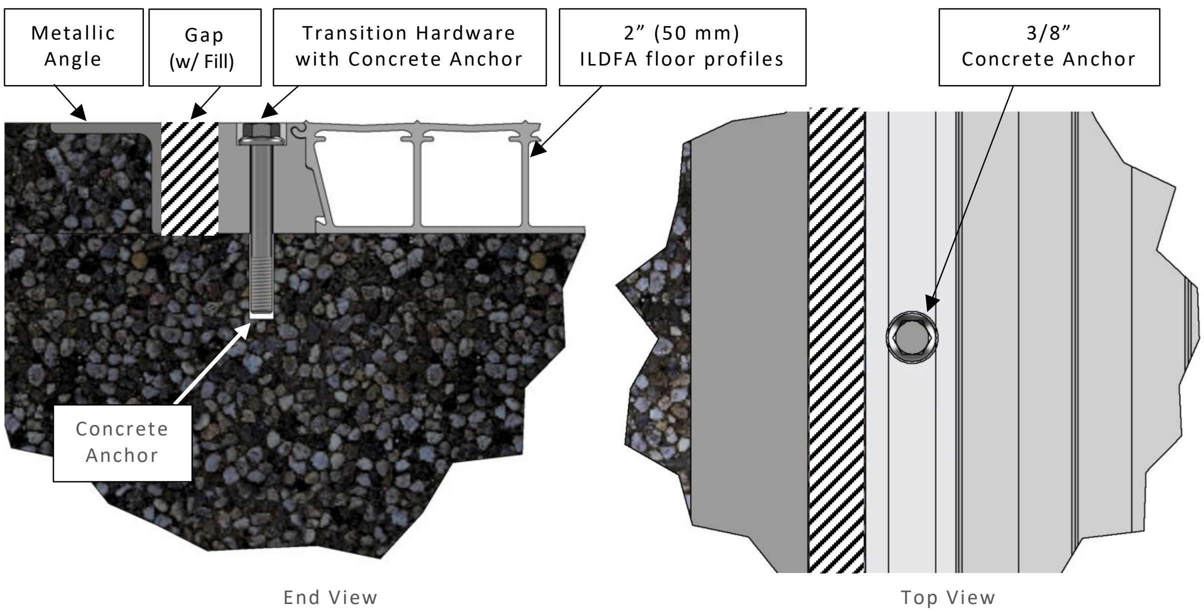


Figure 5-1: Transition from Hangar Slab to ILDFA with Recessed Concrete

When a trench is located at the recessed area, trench girders must extend across the trench and be supported on the concrete between the edge of the trench and the transition hardware. The design for this transition is detailed in Figure 5-2. The required distance from the edge of the trench to the end of the transition hardware is 6-1/2” (140 mm). With a 1” – 2” (25 - 50 mm) gap for construction tolerances, the slab should be designed with a recess located 7-1/2” (165 mm) to 8-1/2” (190 mm) from the edge of the trench.

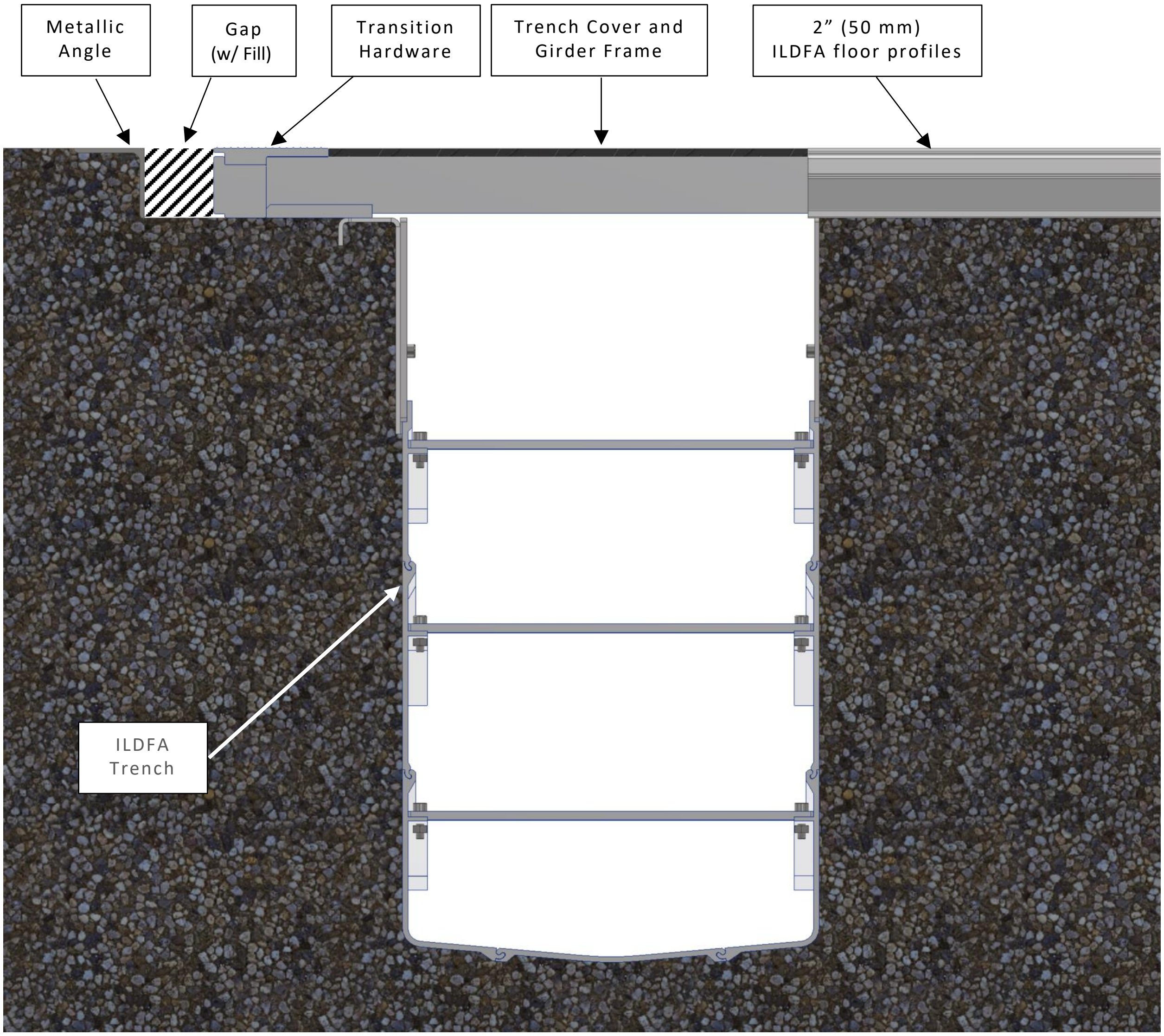


Figure 5-2: Transition from Hangar Slab to ILDFA at trenches

Although some corrosion may occur when aluminum is exposed to concrete, the total corrosion is minimal and occurs only while concrete is wet. Corrosion of aluminum when embedded in dry concrete is non-significant.

(Reference: [“Aluminum in Concrete, Linberg”])

5.3. Existing Slab: Shimming

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 5-3 shows an example of shimming the ILDFA to match the 0.5% slope during an installation.

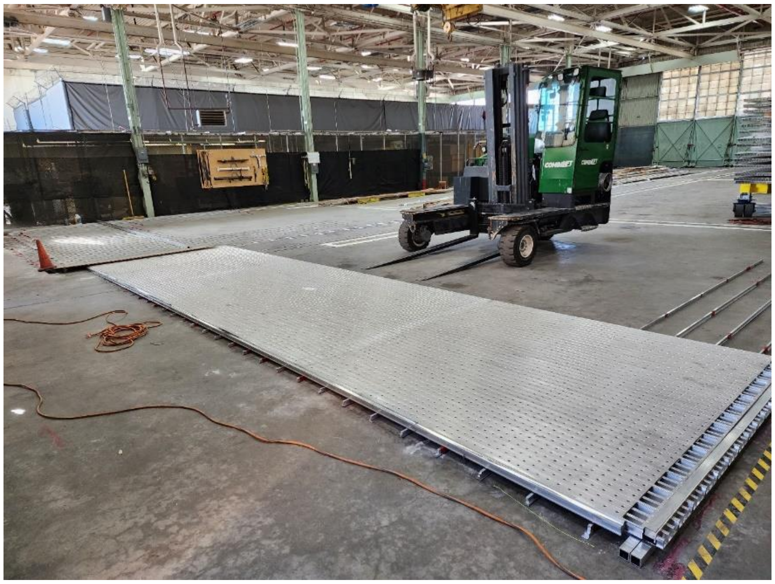


Figure 5-3: Aluminum flat bar used for shimming to proper slope requirements during installation

When shimming is necessary, a structural engineer should confirm that the spacing and shim heights are adequate to support the expected loading scenarios. Typically, when Safespill ILDFA profiles require shims, they are placed every 300 mm (12 in) with shim thicknesses no greater than 50 mm (2 in). Each aluminum shim is secured to the concrete slab using an epoxy resin specified for concrete and metal adhesion (Hilti HIT-RE 500 V3 is one example).

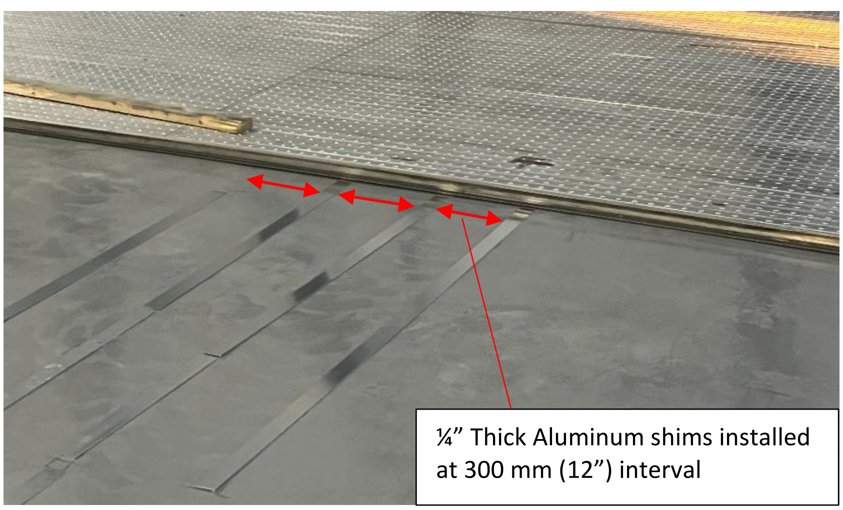


Figure 5-4: Example of shim installation under ILDFA.

5.4. Retrofit Hangar: Ramps

For retrofit installations that require the ILDFA to be installed directly on the hangar slab, ramps will be installed on all sides of the floor. Ramps are anchored to the slab using concrete anchors to restrict movement.

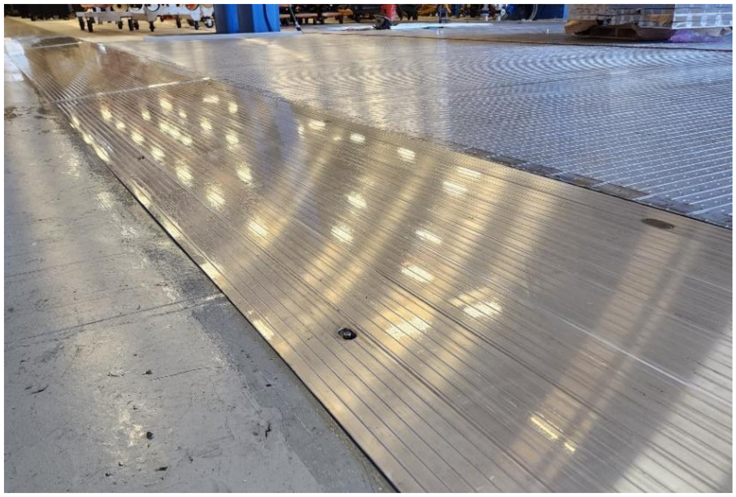


Figure 5-5: ILDFA Standard Sloped Access Ramps

Standard ramps for the ILDFA have a length of 40 in (1.0 m) from the edge of the floor and will be utilized to the maximum extent possible. For all locations where aircraft enter and exit the floor, standard ramps will be utilized.

In areas where only maintenance equipment and personnel will access the floor, it may be acceptable to utilize ramps with a steeper slope. This can maximize the amount of usable floor space and provide clearance around doors, stairways, and other preexisting obstructions within the hangar. Steep ramps have a length of 24 in (0.6 m) from the edge of the floor.

If the hangar will house a rotary aircraft or other aircraft that has a tow-bar or tug with a short elevation clearance, it is recommended to use a 1:48 sloped entrance ramp.

Figure 5-6: ILDFA with 1:48 sloped entrance ramp for helicopter with short elevation clearance

6. Trenches

6.1. Structural Considerations for Trenches

Due to the design of the trenches and trench cover girder frame, the aluminum trench shells do not experience loading from aircraft moving over the trench covers.

All force generated by aircraft movement is distributed through the trench cover to the girder frame and into the concrete slab as shown in Figure 6-1.

For new build projects, the aluminum trench shells serve as formwork for concrete, but are not structural.

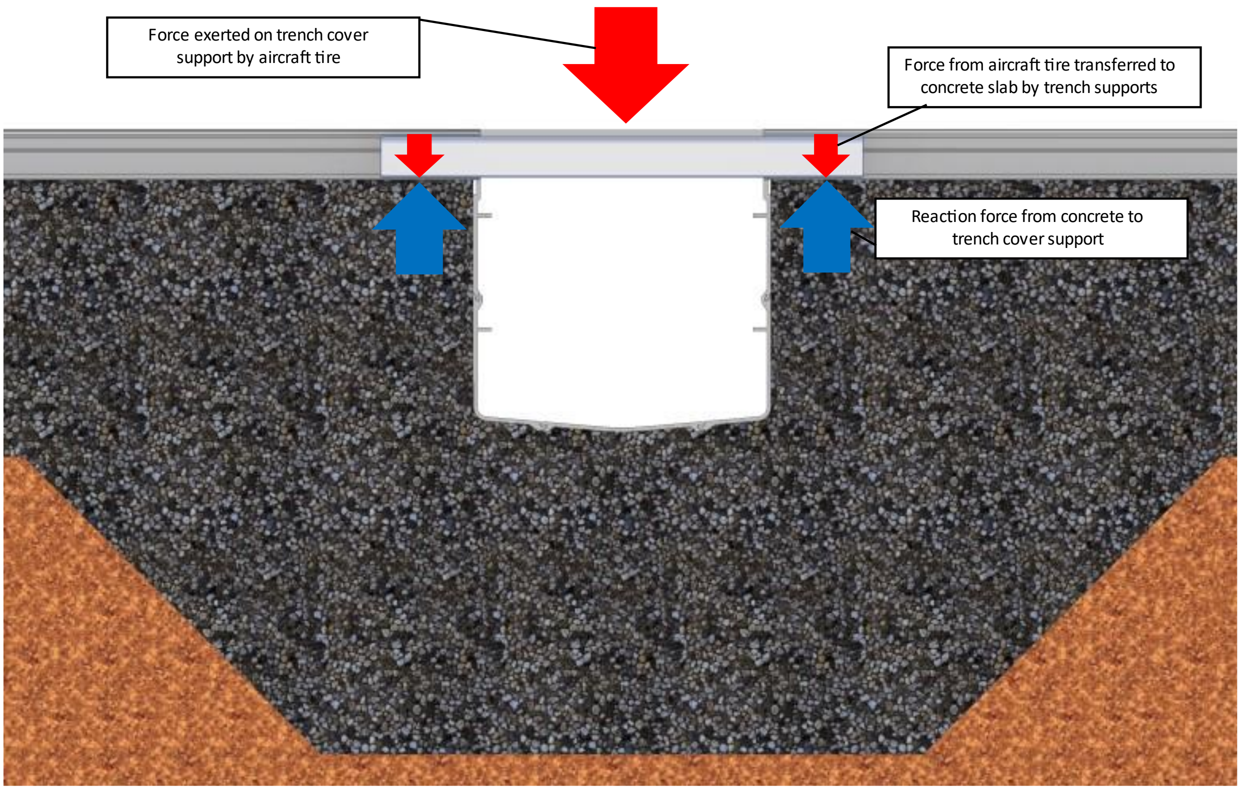


Figure 6-1: Rendering of aluminum trench and concrete slab showing force transferred from aircraft tire to concrete. First profile removed to show girder which spans beyond the width of the trench.

Trench covers and girder frames have been designed using finite element analysis to ensure that supports can handle point load capacity for the Maximum Takeoff Weight (MTOW) of the largest airframe as described in Section 7.1, *Point Load Capacity*.

Girders located under the trench cover lid are fitted into the profile channels and span the width of the trench.

Figure 6-2 shows the girders fit into the profile channels, with the trench cover lid removed and the first profiles removed.

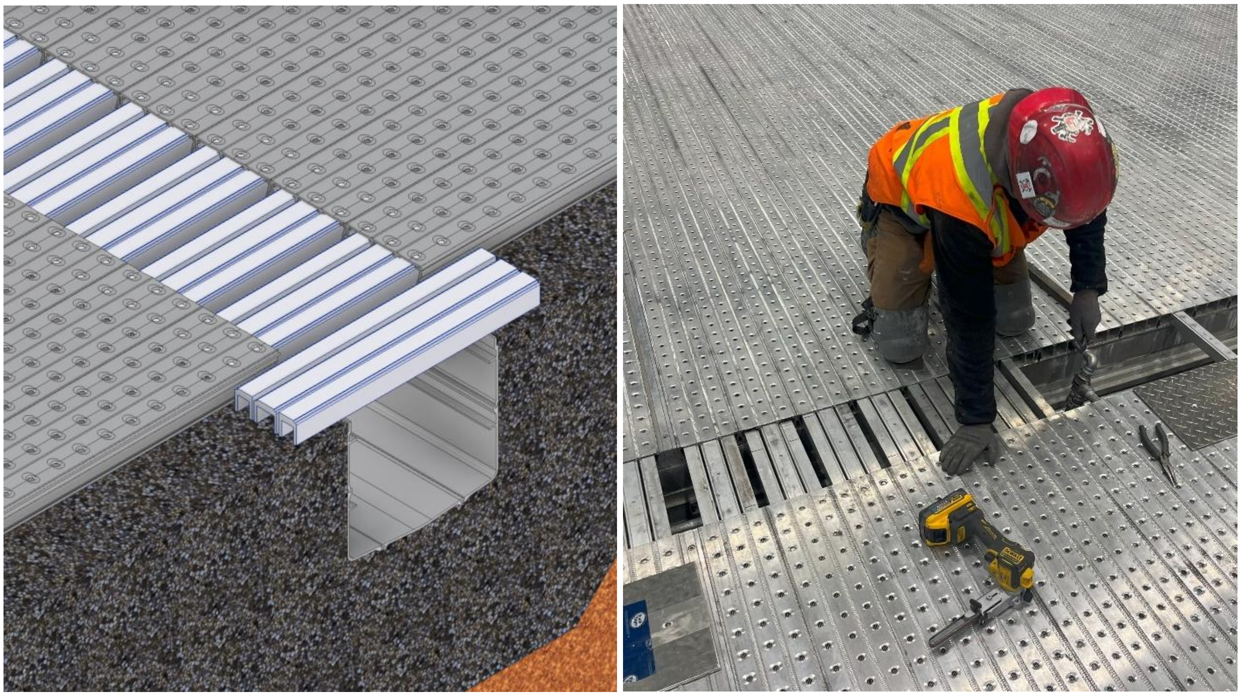


Figure 6-2: (Left) Render showing Trench cover support girders. First profiles and trench lid removed to show girder supports. (Right) Trench support girders installed in the field

Figure 6-3 shows the same arrangement as Figure 6-2 with the trench cover lid and first profiles restored. This figure demonstrates the final installation of the trench cover support.

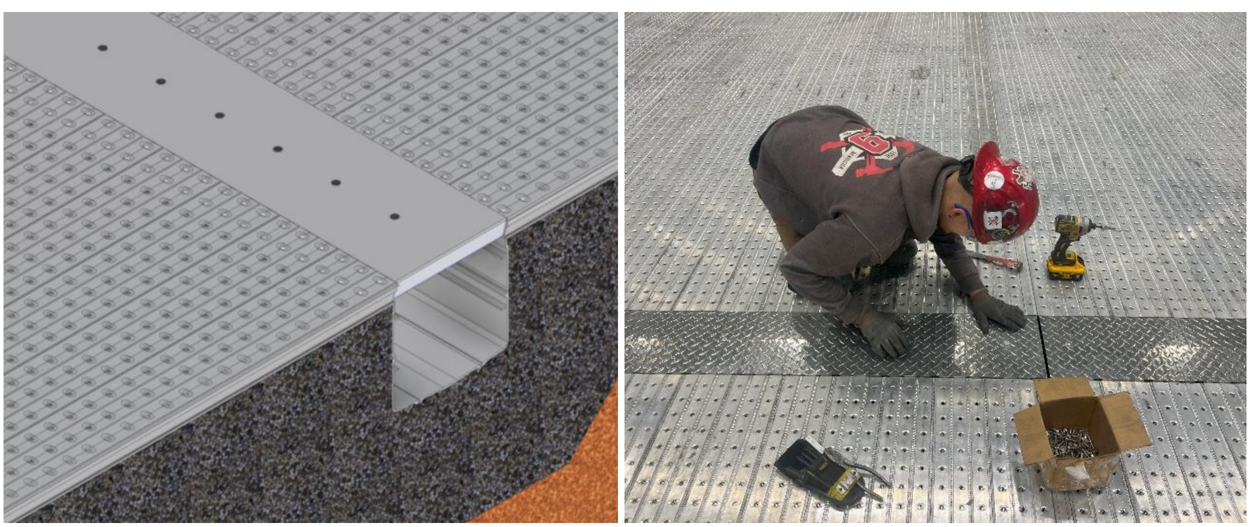


Figure 6-3: (Left) Render showing fully assembled trench cover lid. (Right) Field installation of trench cover lid.

When designing, please note the ILDFA will be installed directly onto the concrete slab but should not be considered in determining the structural strength of the slab.

For example, a 10” (254 mm) slab thickness requirement for a hangar cannot be reduced to 8” (203mm) with an ILDFA (the height of the ILDFA is 2” (51mm)); the slab needs to remain 10” (203mm) thick. The slab plus the ILDFA will be 12” (305mm).

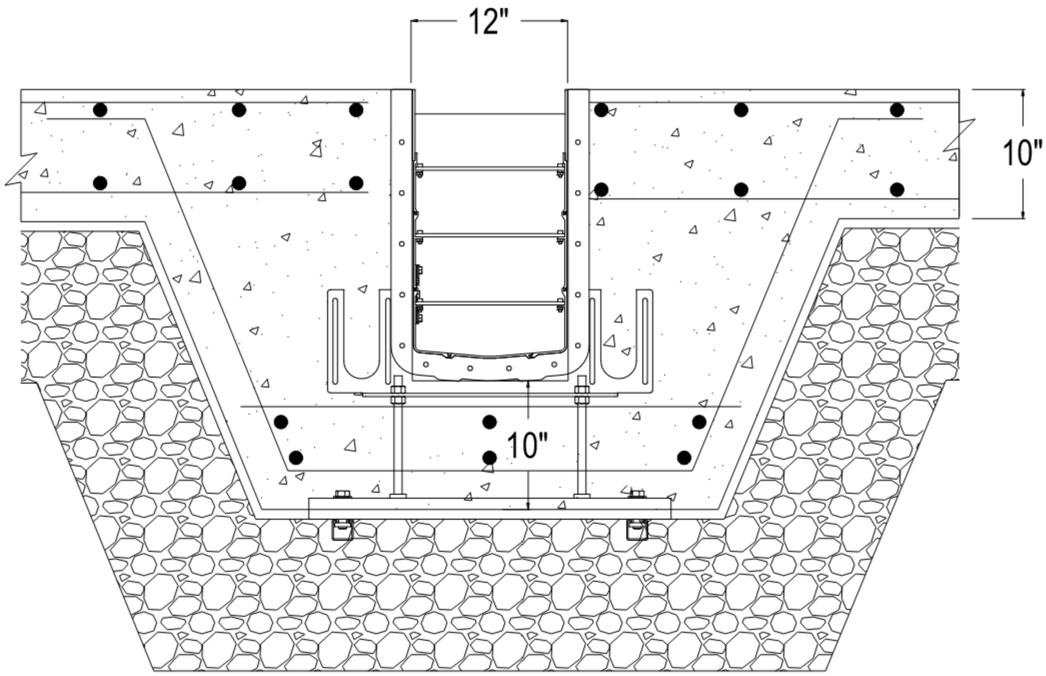


Figure 6-4: Slab design with prefabricated aluminum trenches

6.2. Trench Design

For all installations, Safespill recommends the use of prefabricated aluminum trenches. Prefabricated trenches are used as plumbing conduits and include liquid sensor mounts, electrical conduits, flushing manifold supply piping, and solenoid valves. All electrical cables within the trench are routed in fireproof conduit and solenoid valves are housed in sub-grade enclosures mounted adjacent to the trench. Supplying prefabricated trenches with these components reduces production costs and installation time.

However, if trenches already exist in the hangar, it is possible to utilize these trenches if the following conditions are met:

1. The existing trenches are located in acceptable locations based on the information discussed in Section 4.2, "Trench Locations."
2. The existing trenches meet the volumetric flow requirements and constructability necessary to accommodate plumbing and electrical conduits as described above.

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 19 inches (404 mm) to allow for proper flow of spilled liquid and piping conduit.

For retrofit projects without existing trenches, the existing hangar slab will need to be cut and pre-fabricated aluminum trenches will be installed and back-filled with a cast-in-place concrete (Figure 6-5).

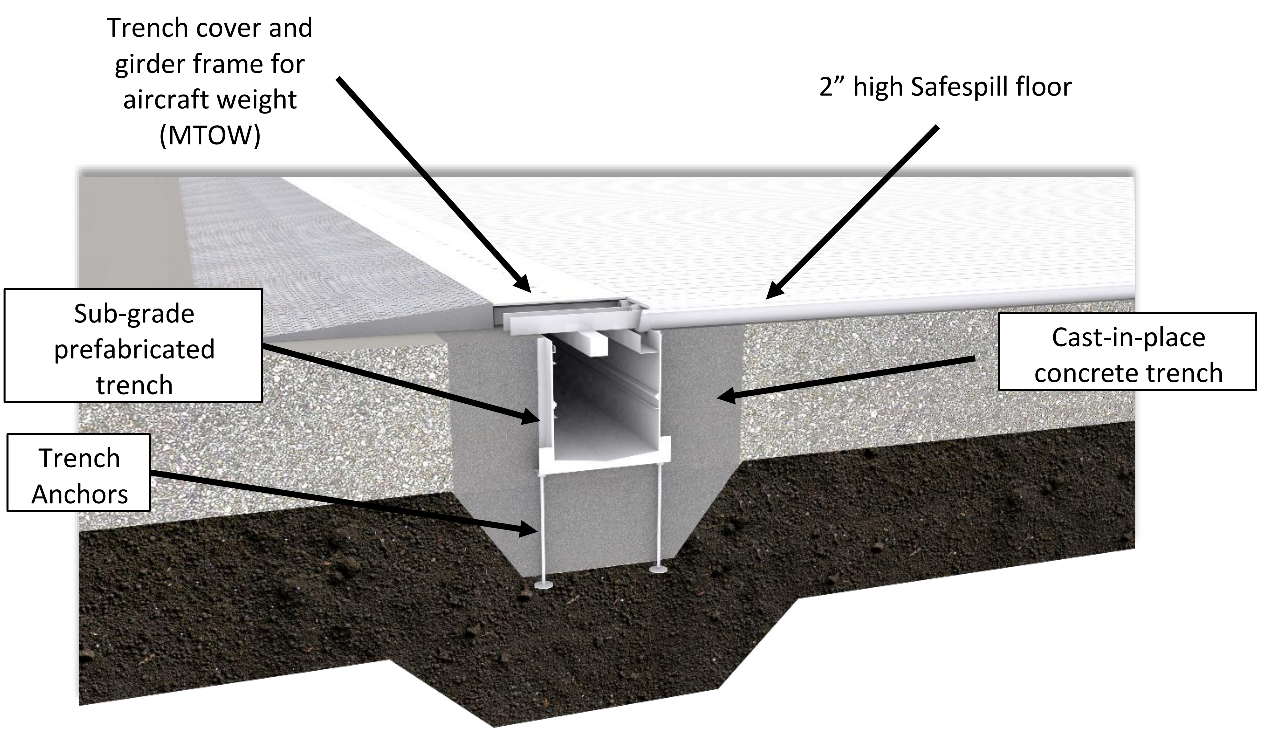


Figure 6-5: Render of ILDFA installed directly on hangar slab with prefabricated trench for retrofit projects

For existing hangars, the necessary trench depth may exceed what is allowed by site conditions. In this case, two trench sections can be mirrored so 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.

For new construction hangars, cast-in-place trenches are not limited to a certain depth and length when concerning the ILDFA. A structural engineer should determine the maximum dimensions of the cast-in-place trenches that the existing soil conditions allow.

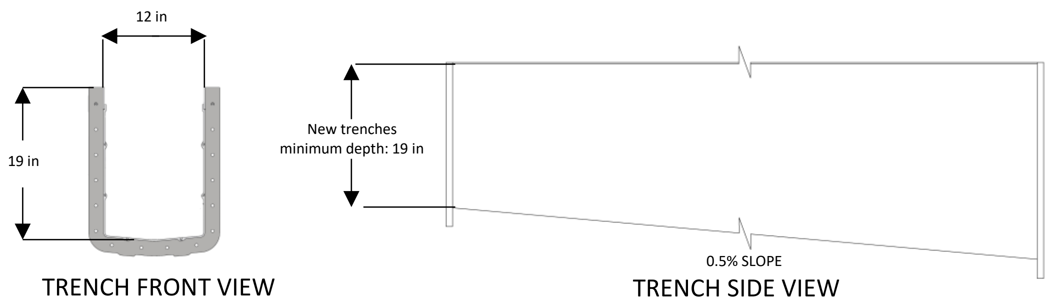


Figure 6-6: Trench dimensions and slope

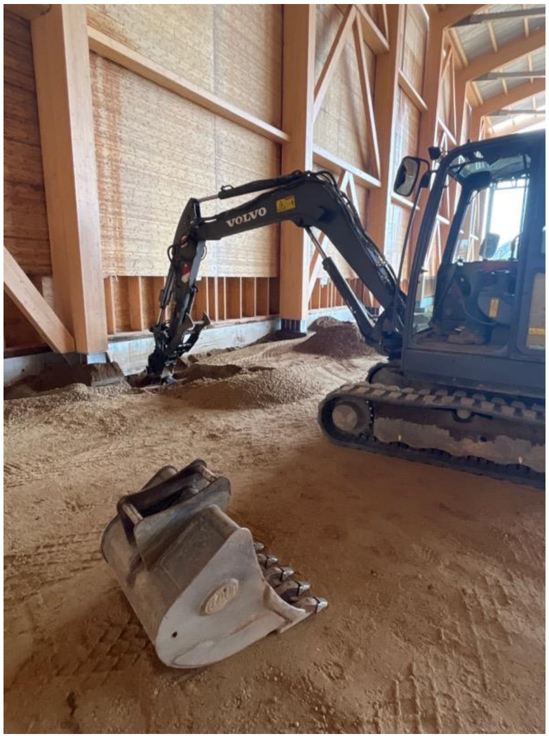
All cast-in-place aluminum trench shells are supplied with adjustable trench supports. Trench supports are welded to the trench shell and connected to a standard 1-5/8” (41 mm) aluminum strut channel using threaded rods and angled struts. The aluminum strut channel is anchored to the mud slab, which should be sloped at a minimum of 0.5% (Figure 6-7). Threaded rods can be adjusted to level the trench and angled struts are secured once the required height is reached to prevent the trench shell from moving and twisting during the slab pour.

A step-by-step process is shown in Figure 6-7 and Figure 6-8 on the following pages of how the ILDFA prefabricated trenches are installed. Non-structural temporary trench covers are provided during the installation only. The ILDFA trench covers are designed with a girder frame (see Figure 6-2) that supports the Maximum Takeoff Weight (MTOW) of the largest airframe. The ILDFA trench covers and girder frame are included within the manufacturer’s scope.

Where a potential exists for aluminum ILDFA components to be in contact with metals such as cast-iron grates, steel rebar, or carbon steel angle, non-conductive isolation materials need to be used to prevent galvanic corrosion. Fluoroelastomer (FKM, Viton^{TM}) or bituminous coatings can be applied to isolate the prefabricated trench from dissimilar metals.

1. Excavate

Excavate trenches to slope and depth required for ILDFA trenches. Grade and compact dirt/gravel.



2. Pour Mud Slab

Sloped at minimum 0.5% to follow ILDFA trench

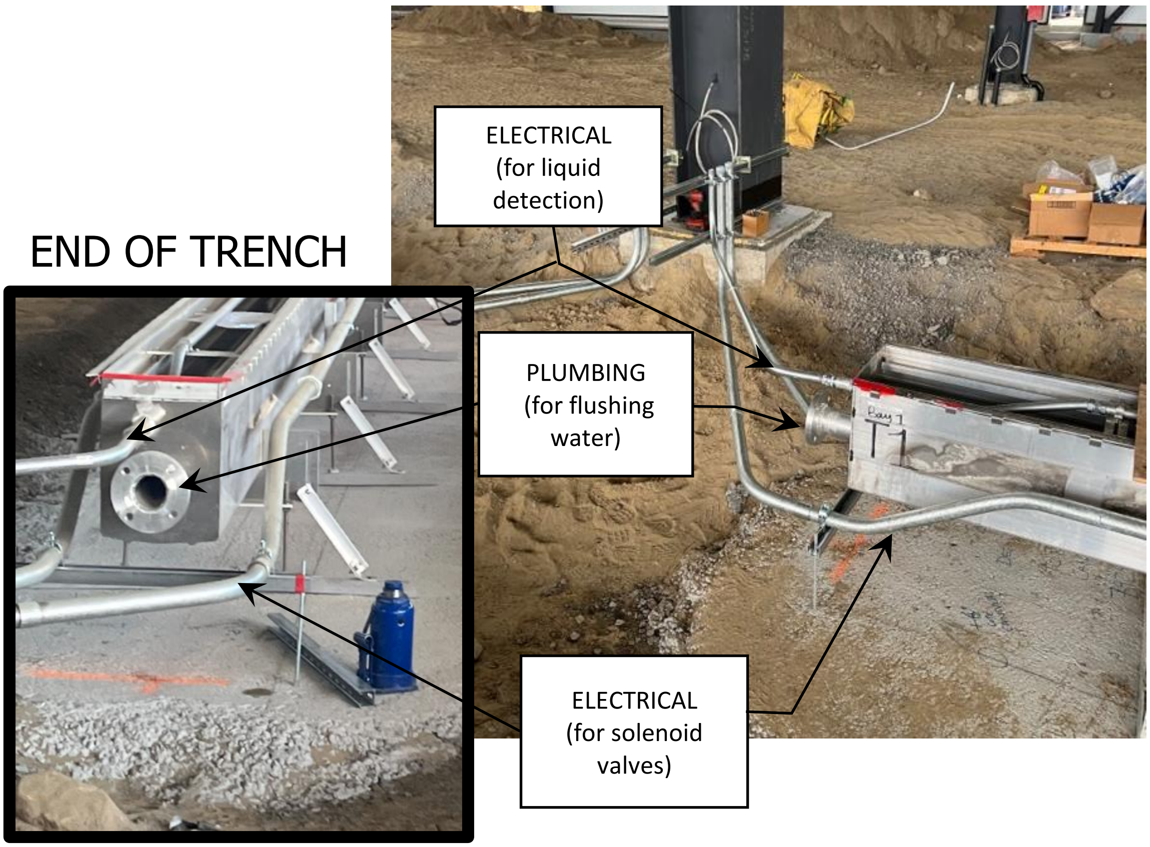
3. Place Trench

Trench slope & squareness must remain consistent.

4. Anchor Trench to Mud Slab

Figure 6-7: Step-by-step process of installing ILDFA prefabricated trenches

5. Connect tie-in points for electrical & plumbing



6. Pour Slab

Slab is poured flush to top of Safespill trench

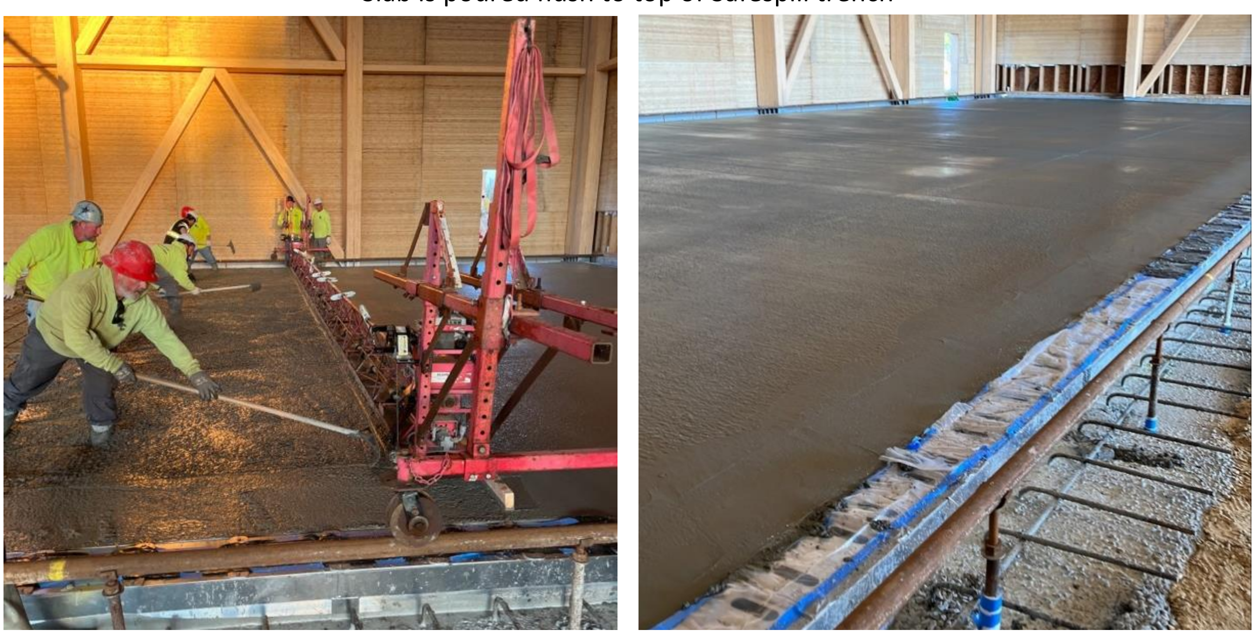


Figure 6-8: Step-by-step process of installing ILDFA prefabricated trenches (Continued)

7. Structural Specifications

7.1. 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 contact area of a fighter jet tire, the ILDFA withstood up to 48 tons (44 MT) of pressure.

48 tons
(96,000 lbs)

Figure 7-1: Point load capacity of a 9” x 16” ILDFA area can handle 96,000 lbs (46 bar)

It should be noted that using aircraft tire pressure to estimate point load is a conservative estimate, as it assumes that all pressure exerted within the tire is transferred directly to the contact area between the tire and the surface below it. However, the elasticity of the tire also absorbs some of this force.

Table 7-1 utilizes the point load capacity demonstrated above to calculate safety factors for various aircraft. Typically, small aircraft such as fighter jets exert the greatest point load.

Table 7-1: Safety factor calculations for the ILDFA point load capacity are as follows:

ILDFA Point Load Capacity:	96,000 lbs / (9 in * 16 in) = 666 psi (46 bar)
KC-135 Stratotanker load per tire*:	170 psi
Safety Factor:	**3.9**
F-35 load per tire*:	250 psi
Safety Factor:	**2.7**

**Reference: Goodyear Aviation Data Book 2022. Section 6C Military Aircraft Application Charts*

7.2. Profile Texture and Slip Resistance

The Safespill floor profile consists of a polished aluminum top surface with shallow slopes to direct flow of liquid into drainage holes. To provide adequate slip resistance, an anti-slip texture is applied to the top surface along the high points of the profile surface as shown in Figure 7-2.

A video demonstrating the slip resistance of the surface is available at the following link: https://www.youtube.com/watch?v=BnpZZ3edwD0

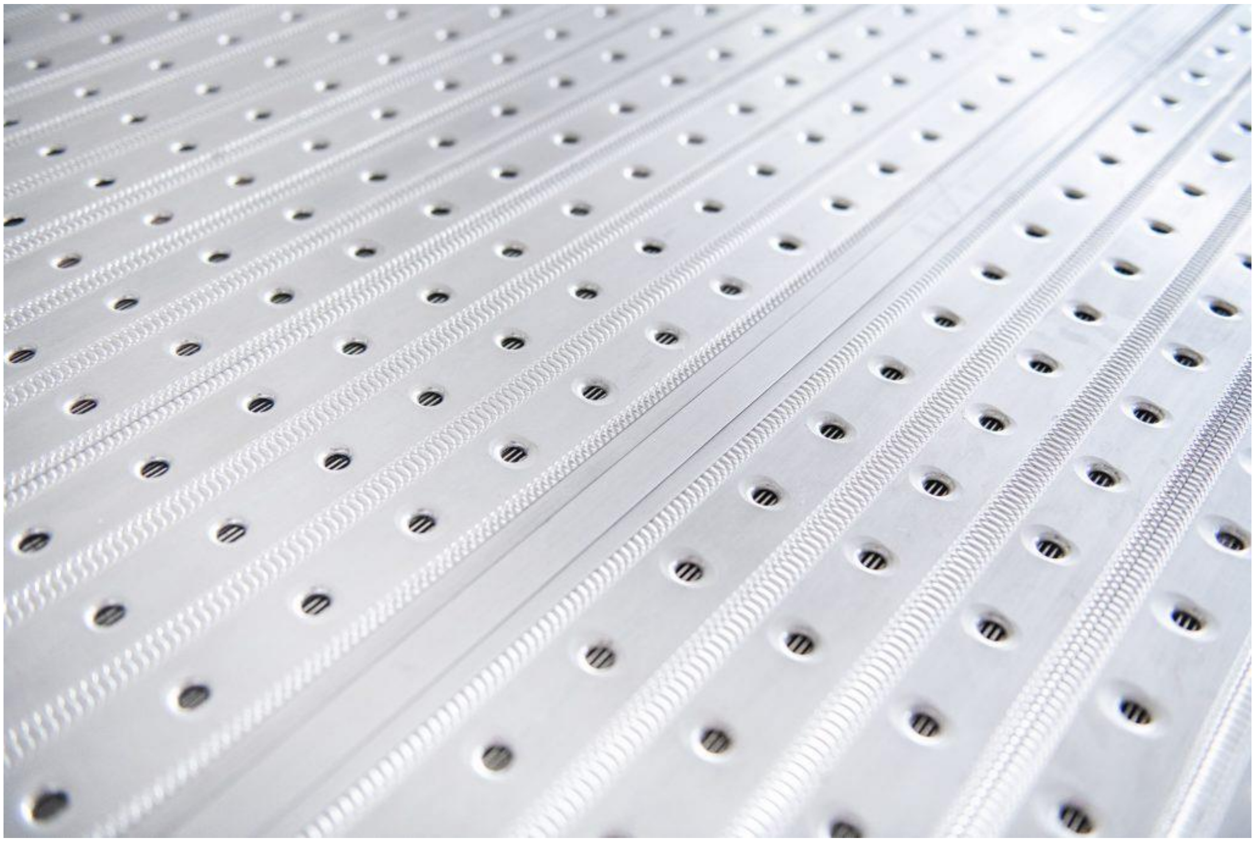


Figure 7-2: Safespill floor profile with anti-slip texture

The Safespill floor is an atypical work surface for most contractors, maintainers, and other personnel working in or walking through an aircraft hangar. Hangar floors are subject to many potential hazards, such as wet surfaces or lubricant spills.

To address concerns regarding potential slip hazards on the Safespill floor, slip resistance testing was conducted on the Safespill floor according to ANSI/NFSI B101.1 using an American Slip Meter 825A Tribometer.

Testing was conducted on 3 different surfaces:

1) Safespill Floor Profile
2) Polished Concrete
3) Flooring Sample from NAVAIR Hangar, 10-year age (VX-30 Point Mugu, Hangar 372)

A comparison of SCOF for each surface under dry, wet, and oily conditions is shown in *Table* 7-2.

Table 7-2: SCOF of Concrete Surfaces vs Safespill (ILDFA) floor

Conditions	Dry	Wet	Oily
Safespill (ILDFA)	0.72 – High Traction	0.78 – High Traction	0.25 – Minimal Traction
Polished Concrete	0.84 – High Traction	0.76 – High Traction	0.16 – Minimal Traction
10-year Hangar Sample (PM-372)	0.73 – High Traction	0.56 – Moderate Traction	0.05 – Minimal Traction

Based on testing conducted with the ASM 825A in accordance with ANSI/NFSI B101.1, the Safespill floor profile provides comparable slip resistance to polished concrete and the PM-372 hangar sample under dry conditions and improved slip resistance under wet and oily conditions.

While the Safespill floor surface provides minimal traction under oily conditions, the expectation for all hangar surfaces is that oil spills and greasy, or dirty, floors are cleaned in a timely manner to eliminate any potential slip hazards.

The PM-372 sample represents a typical hangar floor after 10 years of daily activity. Multiple NAVAIR hangar floors at Point Mugu were inspected to confirm that the tested sample was consistent with a typical hangar floor surface. Values for all surfaces have been color-coded and described according to guidance from the National Floor Safety Institute (NFSI).

Table 7-3: Available Traction and Probability of Slipping based on SCOF

SCOF Value	Available Traction	Slip Probability
≥0.6	High Traction	Lower
0.4 ≤ SCOF < 0.6	Moderate Traction	Increased
<0.4	Minimal Traction	High

7.3. FOD Screens

Below each perforation in the top surface of the ILDFA, a mesh screen is installed to prevent foreign object debris (FOD) from entering the channels of the ILDFA. This reduces the likelihood of blockages with the drainage system and prevents maintainers from losing key components when working atop the ILDFA.

The mesh size is small enough to prevent washers as small as No. 5 or M4 from entering the ILDFA. However, the mesh allows sand and dust to pass through so that these perforations are not blocked by debris.

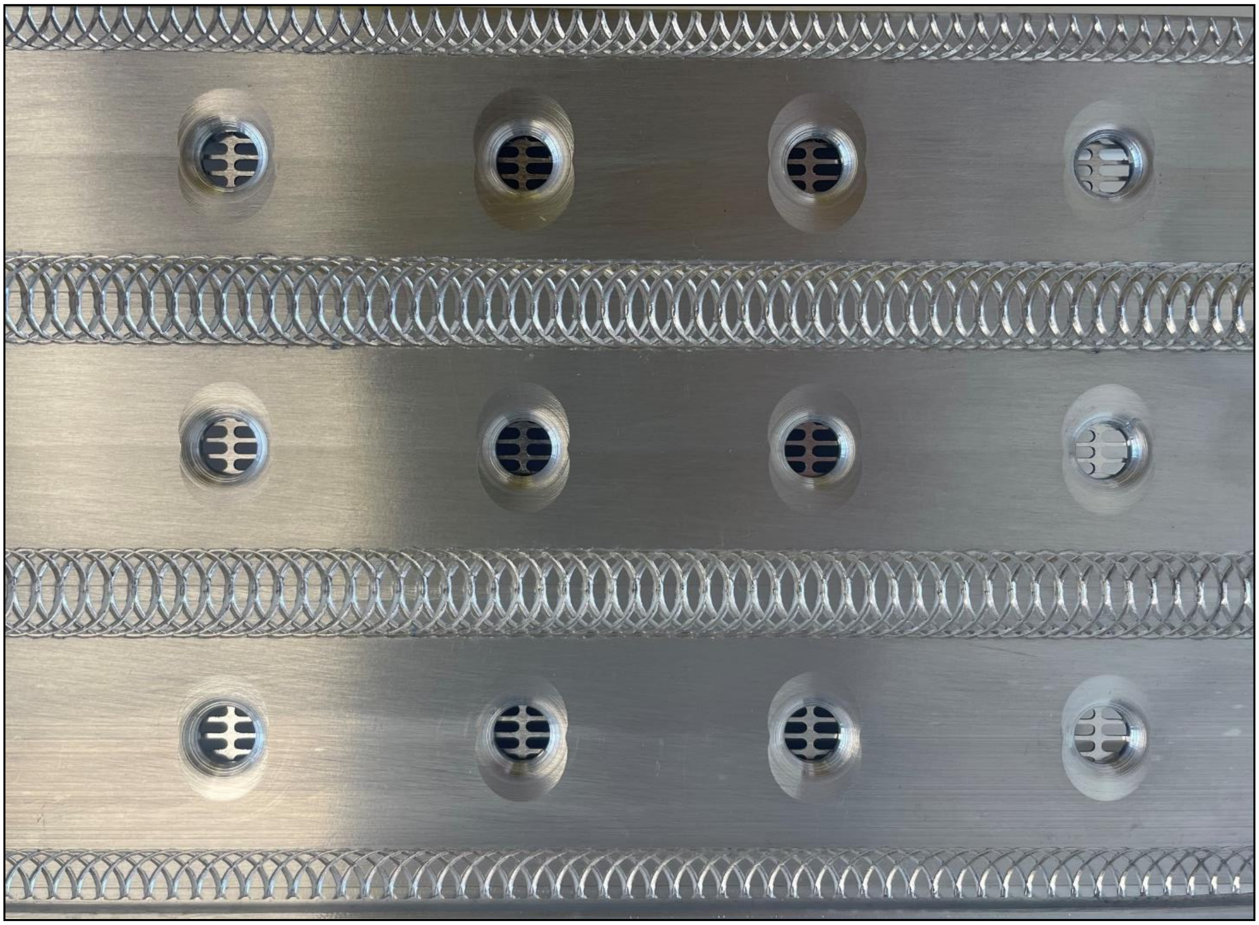


Figure 7-3: ILDFA top surface with FOD screen installed below perforations

7.4. Frictional Force in Stopping Conditions

Since ILDFA floor profiles are placed directly on the hangar slab, movement of aircraft onto and off the floor could cause the profiles to shift. However, in most situations the profiles are bounded either by a recessed slab (as described in Section 5.2) or by anchored ramps (as described in Section 5.4).

In addition, the surface area in contact between the aluminum floor profiles and the concrete slab provide sufficient static friction to prevent movement.

For example, consider the following scenario in which an emergency causes a large aircraft and a tow tractor to suddenly stop while on top of the ILDFA:

Figure 7-4: Example of tug moving an aircraft onto ILDFA.

To move the ILDFA, the horizontal force generated during deacceleration of the tow tractor and aircraft must exceed the static frictional force that exists between the ILDFA and the hangar floor.

The force generated by stopping of the tow tractor is described by the free body diagram below:

F_v = Vertical force due to weight of the aircraft.
F_h= Horizontal force motion of the aircraft.

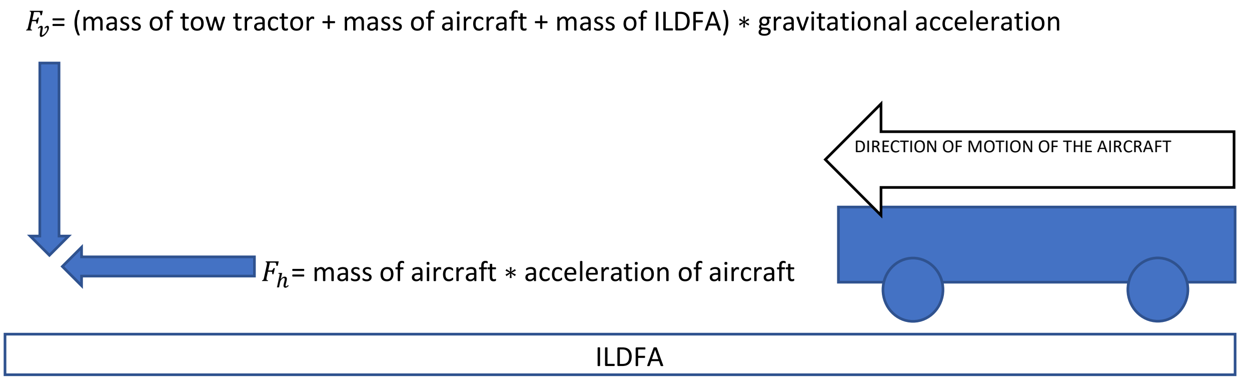


Figure 7-5: Free body diagram demonstrating forces on ILDFA under a moving aircraft

Therefore, the ratio of horizontal force to the normal force must exceed 0.73 to overcome static frictional forces and move the ILDFA relative to the hangar floor.

Static friction force is described by Equation 1.

(1) $F_f = \mu * F_n$

Where F_f is frictional force, μ is the coefficient of friction, and F_n is the normal force of the aircraft and ILDFA in the vertical plane. Normal force is equal and opposite to the Vertical Force (F_v) shown in the free body diagram above.

To overcome the static frictional force and move the ILDFA, the horizontal force generated by the deaccelerating aircraft must exceed the frictional force.

(2) $F_h > F_f$

Combining equations 1 and 2:

(3) $F_h > 0.73 * F_v$

The equations for the horizontal and vertical forces are given in equations 4 and 5:

(4) $F_h = (m_{aircraft} + m_{tractor}) * a$
(5) $F_v = (m_{aircraft} + m_{tractor} + m_{floor}) * g$

Since the mass of the ILDFA is much less than that of the tractor and aircraft, it is neglected and the equation can be simplified to:

(6) $(m_{aircraft} + m_{tractor}) * a > 0.73 * (m_{aircraft} + m_{tractor}) * g$

Simplified further, the condition can be evaluated regardless of the weight of the tractor and the aircraft.

(7) $a > 0.73 * g$ where g = acceleration due to gravity = 9.8 m/s^2

Deceleration can be represented as the product of initial velocity and stopping distance.

(8) $a = V_i * d_s$

Stopping distance can be calculated based on the following equation:

(9) $d_s = \frac{V_i^2}{2*\mu*g}$

The coefficient of friction for a rubber tire on an aluminum surface can be approximated at 0.51. Based on an assumed initial velocity of 5 mph (8 km/h), the stopping distance is 1.74 ft (0.53 m) and the deceleration is approximately 1.2 $^{m}/_{s^2}$.

The frictional force, expressed as the product of acceleration due to gravity and the coefficient of friction between aluminum and the hangar floor, is much greater at 7.2 $^{m}/_{s^2}$.

Therefore, **the ILDFA will not move in this scenario**.

For additional information regarding alternative scenarios, please consult the ILDFA manufacturer.

8. Floor Openings
8.1. Tie Down Points

Openings in the ILDFA to access tie down points can be incorporated. The tie down points shown in Figures 8-1 through 8-4 carry a load rating of 10,000 lbs (4,536 kg). 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 8-1 and 8-2.

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 8-6.

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 8-1: Concrete core drilled out of hangar slab to allow the ILDFA tie down point to be chemically anchored

Figure 8-2: ILDFA tie down point chemically anchored into concrete slab

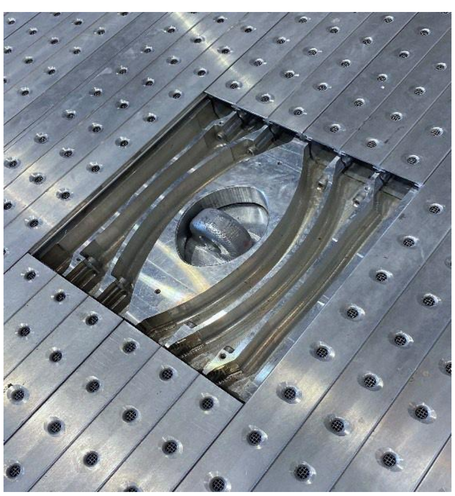


Figure 8-4: ILDFA tie down point without lid

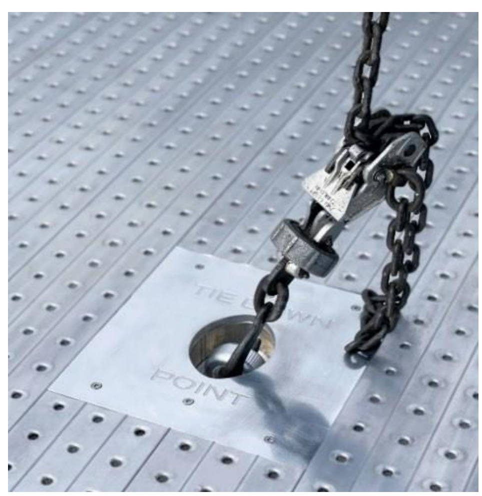


Figure 8-3: ILDFA tie down point example with aircraft chain connection

8.2. Grounding Points

Grounding points for aircraft grounding are integrated in the ILDFA and connected to a grounding bus located in the ILDFA trench using a minimum of 6 AWG jacketed grounding wire. The ILDFA grounding bus is connected to ground rods or building ground. An example of an ILDFA grounding point is shown below in Figure 8-5.

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.

Grounding points may be placed at any location on the ILDFA, except on top of the trenches. Additional grounding points can be added to the ILDFA retroactively if parking configuration or other changes are made to hangar operations.

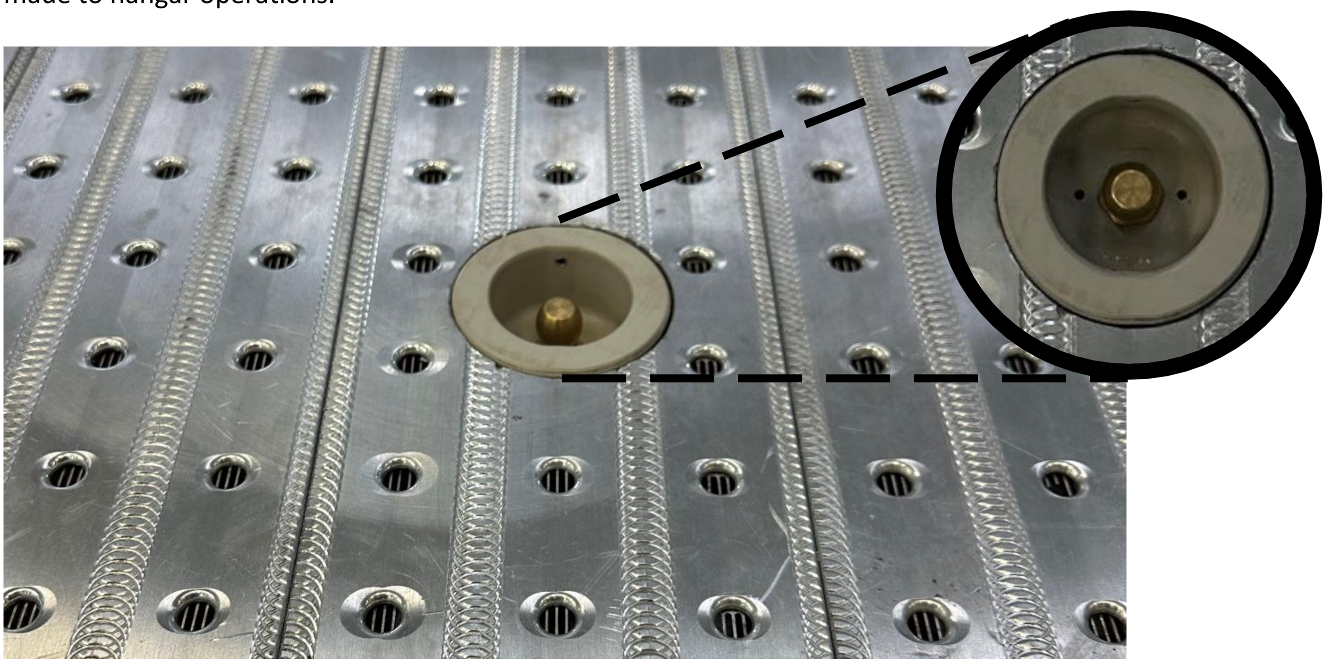


Figure 8-5: Example of ILDFA Grounding Point

Grounding points consist of a high-strength composite (PEEK) cup. When installed in the ILDFA floor profile, these components exceed the point load capacity of the floor profiles. A ball stud (ERICO B165R or equivalent) is fitted to the composite part and provides insulation from the aluminum ILDFA floor profiles (Figure 8-6).

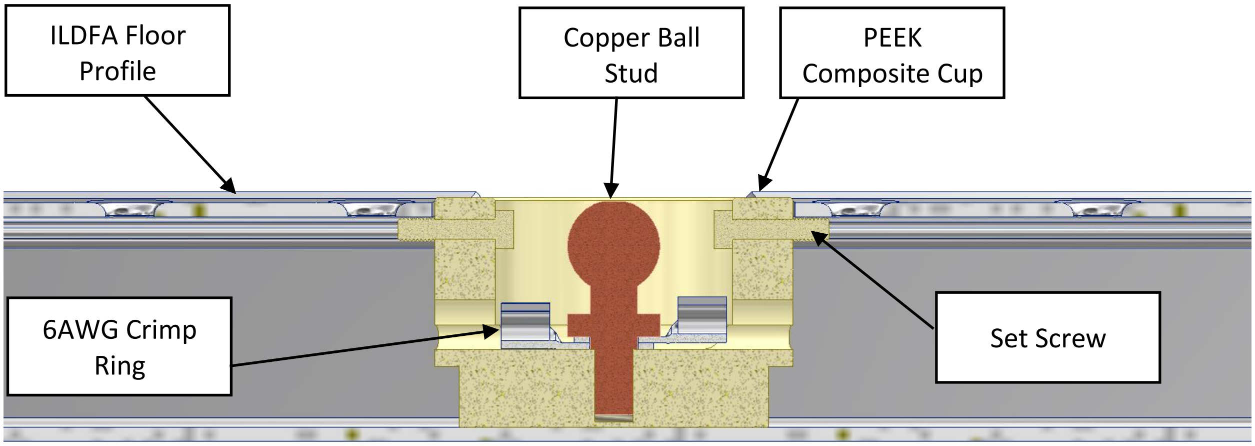


Figure 8-6: Cross section view of ILDFA grounding point embedded in profile

To install the grounding point, a 3" (76 mm) diameter hole is cut through the top surface of the ILDFA floor profile (Figure 8-7) and the grounding point assembly is inserted into the opening (Figure 8-8). Once inserted, set screws hold the grounding point in place and prevent removal.

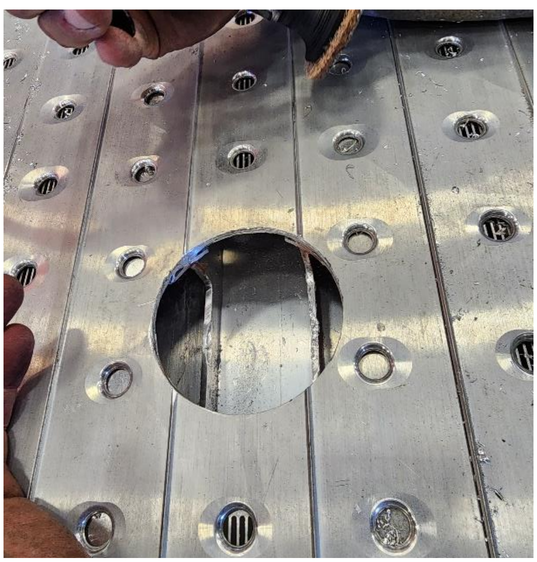


Figure 8-7: 3" Cutout in ILDFA Floor Profile

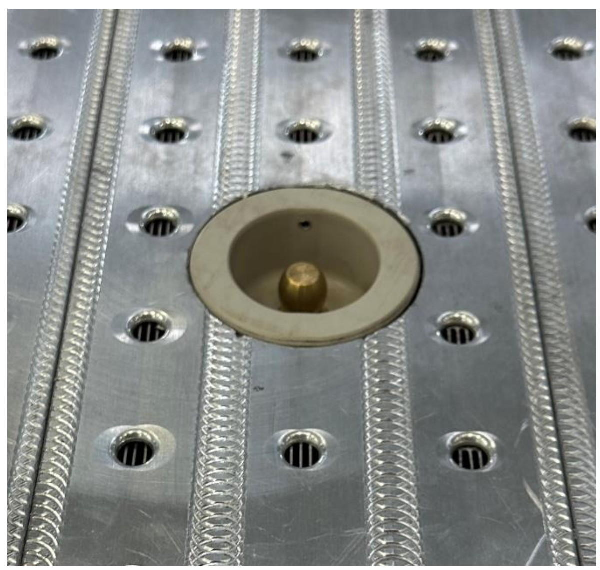


Figure 8-8: Grounding Point Inserted in ILDFA Floor Profile

Grounding points are connected in series using 6 AWG grounding wire with 2 paths to ground. The ground wire is routed through the ILDFA profile to the trench, then through the trench to the edge of the floor assembly, and finally terminated on a grounding bus (Figure 8-9). The grounding bus is connected to a grounding rod or building ground (Figure 8-10).

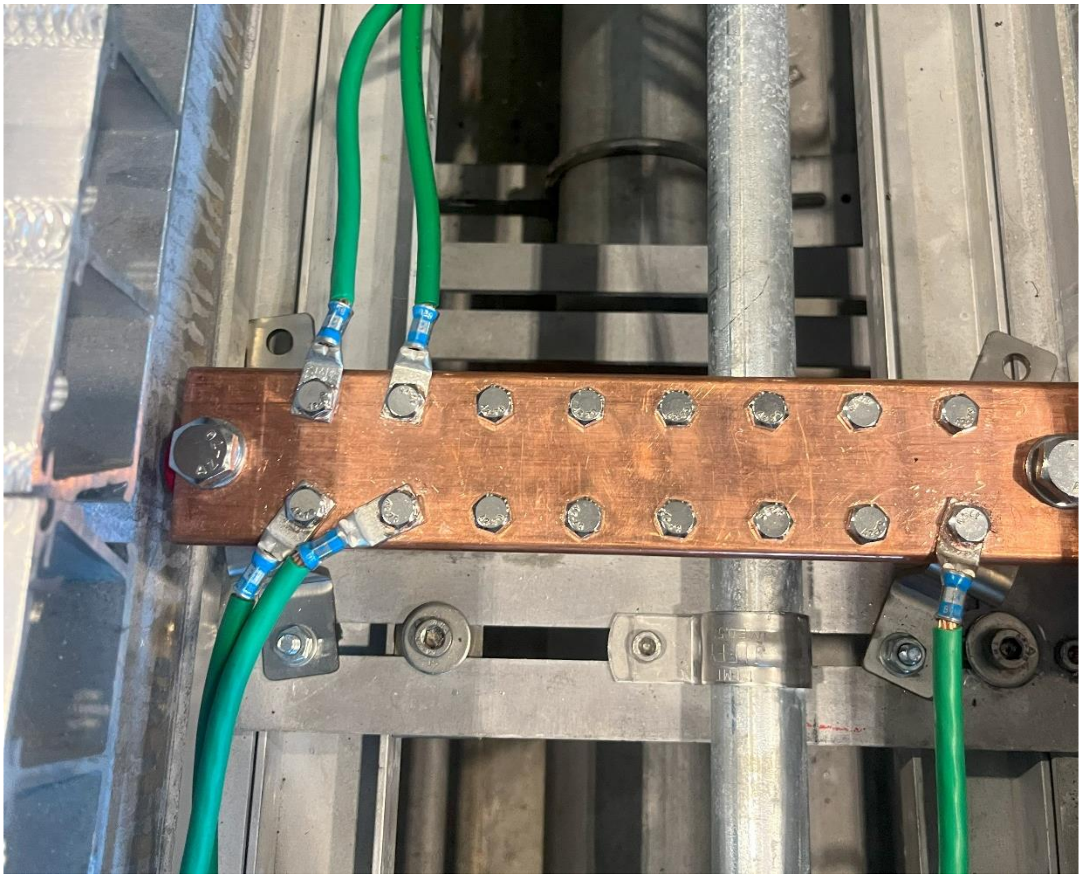


Figure 8-9: Grounding Bus installed in ILDFA prefabricated aluminum trench for termination of grounding points.

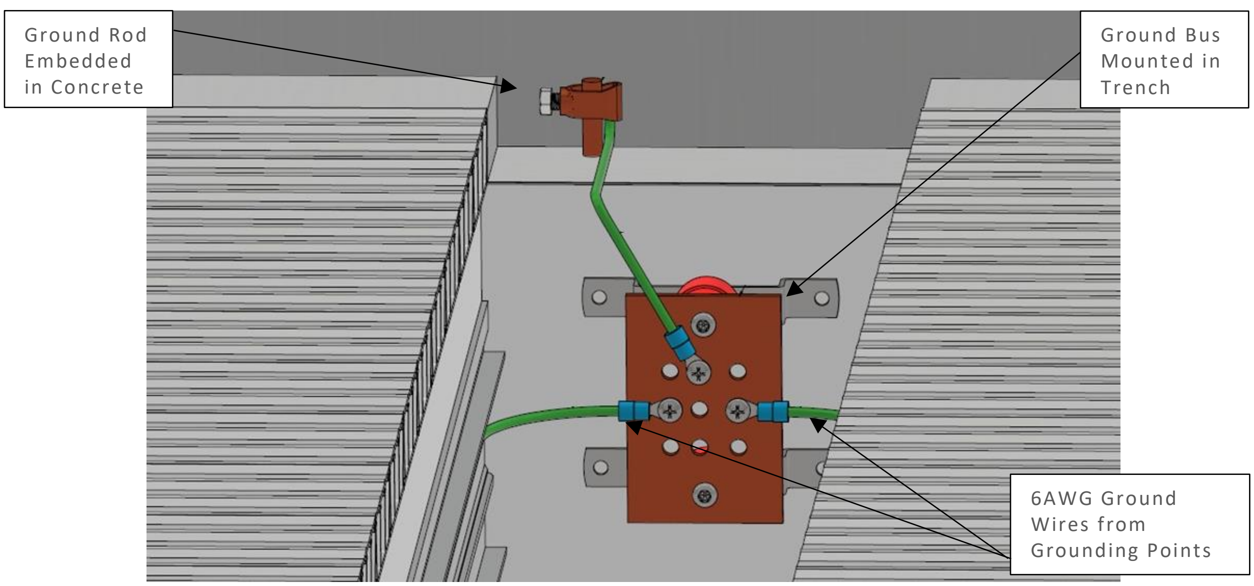


Figure 8-10: Grounding point termination at end of trench. Ground bar may vary in size depending on number of grounding points. Figure shows termination to grounding rod, but termination to building ground may be used in some cases.

8.3. Utilities Access

Openings in the ILDFA allow access to existing utilities in the slab that cannot be relocated, such as sewer drain cleanouts, electrical boxes, and pneumatic connections. The machined aluminum block is incorporated into the design of the floor and directs flow around the opening. Openings are rated for the same loading capacity as the ILDFA floor profiles when the lid is installed. For electrical box access, additional precautions may be necessary to prevent liquid from entering the electrical equipment.

Figures 8-11, 8-12, and 8-13 are examples of possible openings. Exact styles and dimensions needed for each project are determined during the design phase.

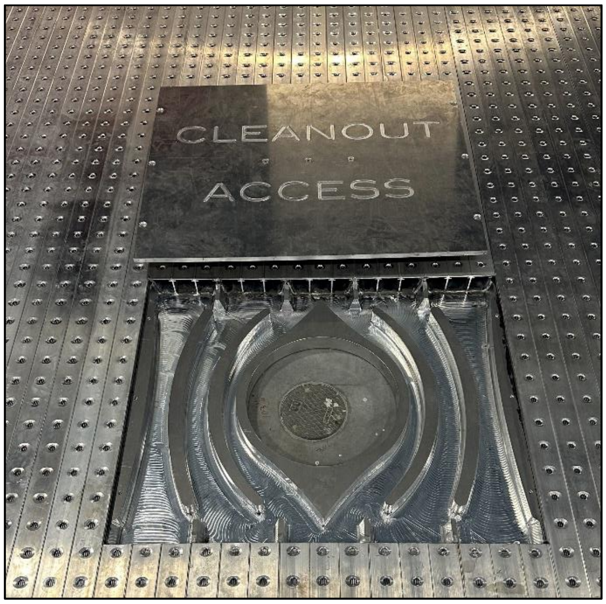


Figure 8-11: Utility Opening with lid removed

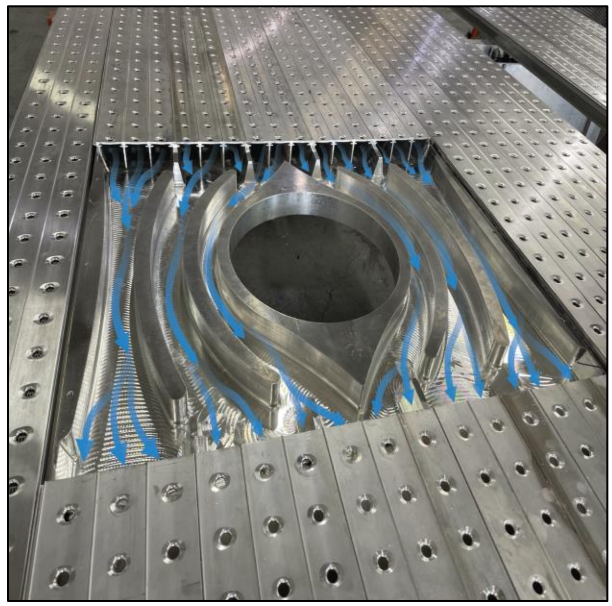


Figure 8-12: Utility Opening with example of flow through channels

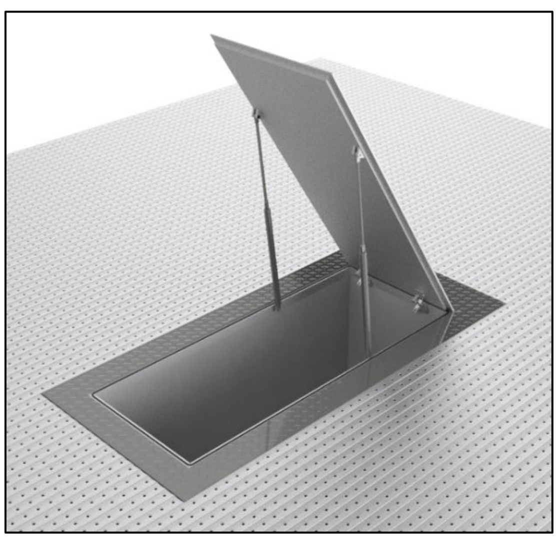


Figure 8-13: Utility Access Door Concept

9. Flushing Water Requirements

An ILDFA requires water to flush the internal drain channels. The ILDFA water requirement is 200 GPM (757 LPM). Each zone requires a water supply of 50 GPM (189 LPM). If a spill occurs on the corner of a zone, the 3 adjacent zones could activate as well.

Therefore, the total water supply required is 4x50 GPM = 200 GPM (757 LPM)

Three options are available for the ILDFA water supply:

1. Domestic Water Supply – Connect upstream of the facility water meter
2. Facility Sprinkler Water Supply – Connect upstream of the sprinkler backflow preventer and flow switch
3. Continuously maintained, dedicated non-potable source – Examples include a flushing supply tank or water recycle system

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. See *Section 9.2, Booster Pump Design* for more details.

If providing a dedicated line to the hangar requires significant plumbing or if water availability is limited, a dedicated flushing water tank can be placed outside the hangar as an alternative. Typically, this would require a tank of 9,000 (34,070 L) to 12,000 gallons (45,425 L). NFPA 409 requires 45 minutes of flushing water at 200 GPM (757 L/min), while UFC 4-211-01 and FM Datasheet 7-93 require 60 minutes of flushing water at 200 GPM (757 L/min).

9.1. Water Supply Devices

When utilizing a domestic water supply, ensure that a backflow preventer is installed ahead of all ILDFA components.

For all water supplies, provide the following:

Valves
Provide water control valves that are indicating type and comply with NFPA 13 requirements, around all components which need to be isolated for service. This includes upstream and downstream of booster pumps, upstream of each connection to the ILDFA, upstream of each strainer, and upstream of each water hammer arrestor or expansion tank.

Water Hammer Arrestor
Provide a water hammer arrestor sized based on manufacturer’s calculations and located as close as possible to the ILDFA inlet connection.

Strainers
Provide a strainer, with opening size less than US Mesh 20 (1/32” or 1 mm), upstream of all ILDFA components. For applications following UFC 4-211-01, the strainer must be chrome-moly simplex basket

conforming to ASTM A217/A217M, with a flanged connection, and stainless steel strainer basket with mesh size 40.

Flow Meter
Provide an ultrasonic flow meter for monitoring of flushing manifold supply piping. The flow rate is monitored and tied into the ILDFA control panel. If flow rates are measured outside of typical parameters during operation, alarms will be displayed on the control panel and a trouble signal will be sent to the FACP.

Figure 9-1 shows an example of a water supply arrangement when a booster pump is not utilized. In this case, a flow meter, water hammer arrestor, and basket strainer are installed upstream of the connection to the ILDFA and located on the back wall of a hangar.

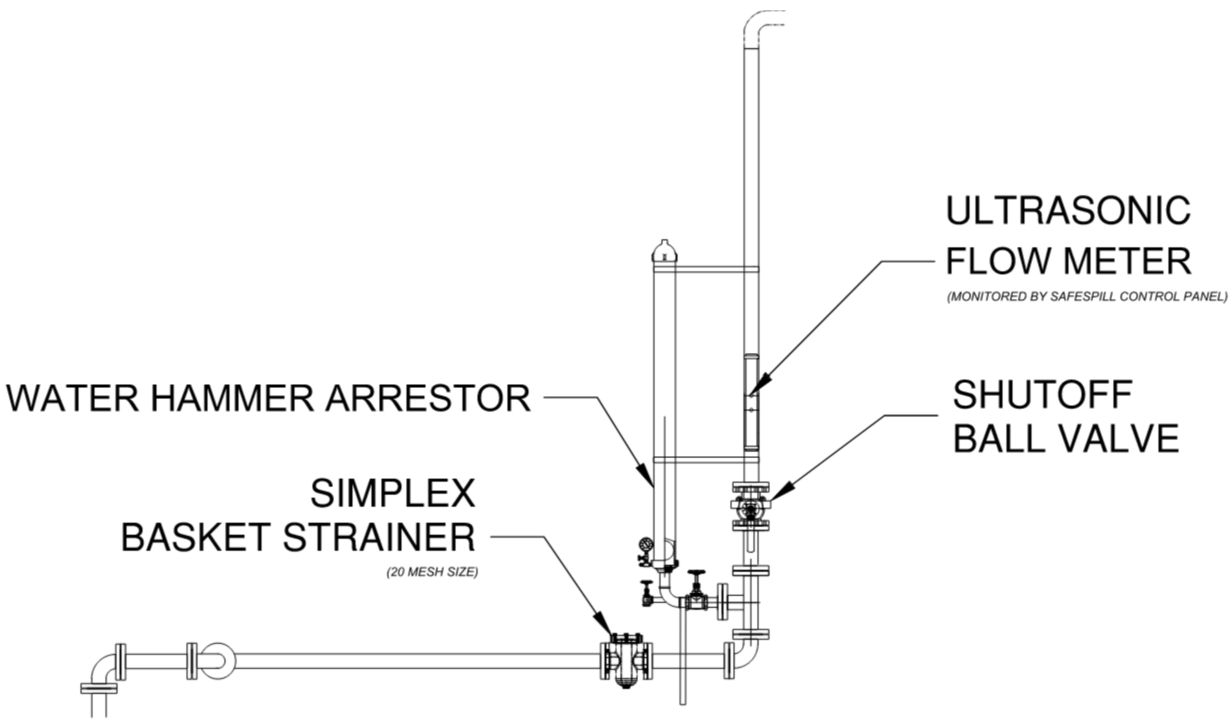


Figure 9-1: Example water supply arrangement with necessary devices.

9.2. Booster Pump Design

To determine whether a booster pump is needed, friction loss calculations through the ILDFA piping must be calculated based on the incoming water supply pressure.

The water supply requirement at the tie-in point is 200 gallons per minute (681 L/min) at 100 psi (6.9 bar). This ensures that the ILDFA flushing system is pressurized to a minimum of 50 psi (3.5 bar) when 4 zones are activated. If the water supply cannot meet the pressure requirements at this flow rate, a booster pump is needed.

Due to variation in water supply location relative to the ILDFA and the overall size of the ILDFA, booster pumps can vary in size. However, booster pumps are typically an end suction centrifugal pump with a 3" diameter inlet and outlet, fitted with a 20 HP motor. Operating power for this pump would be 480 VAC at 20 amps. Alternative motors can be supplied to meet local voltage requirements.

Power is supplied directly from the building to a pump control panel with a motor starter. The start signal can be sent from the main control panel whenever an ILDFA solenoid valve is opened. Alternatively, a pressure switch can be installed on the supply line downstream of the pump to provide a start signal for the pump.

The booster pump and required components will be integrated on a booster pump skid with a footprint of 8 ft (2.4 m) by 4 ft (1.2 m). The skid should be in an area near the ILDFA installation, but should not interrupt the footprint of the ILDFA system. The booster pump skid may be placed in the hangar bay, or in a nearby pump room.

An example of a typical booster pump skid is shown in Figure 9-2 below.

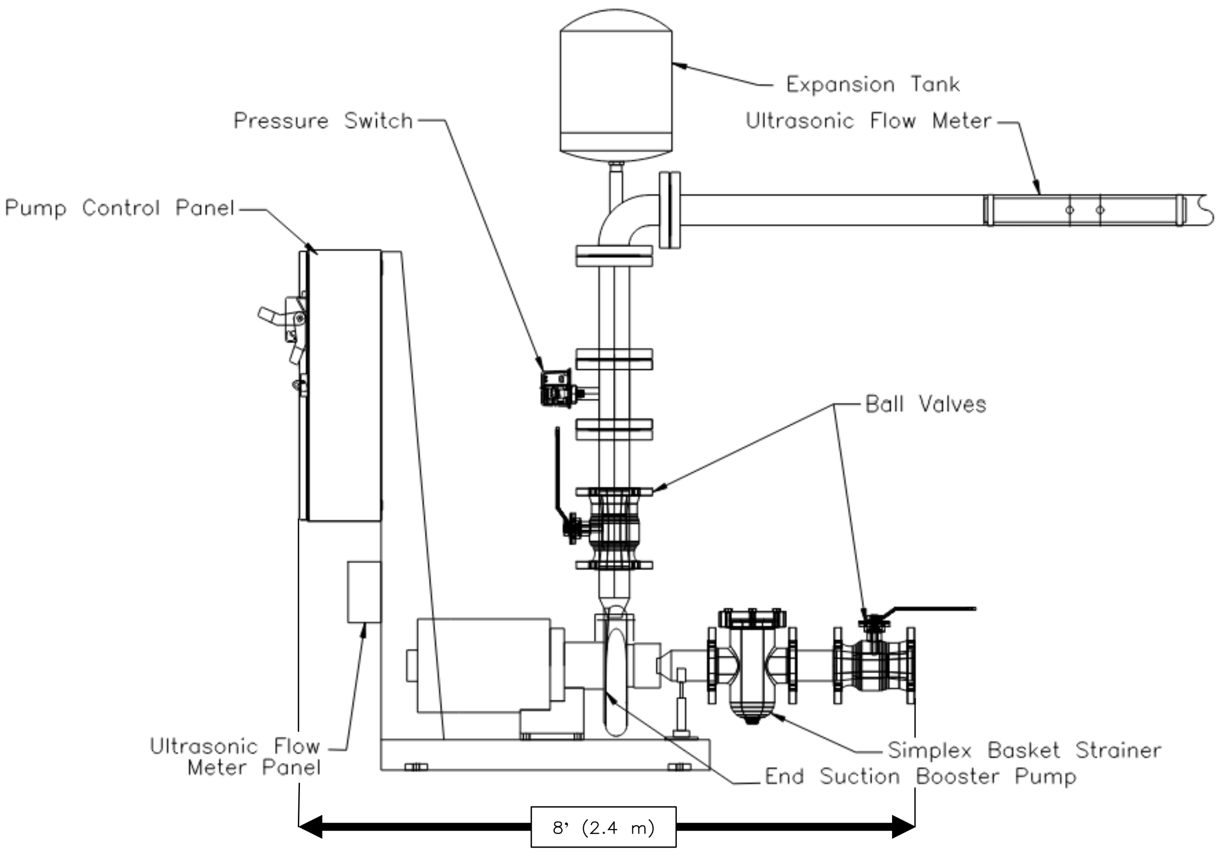


Figure 9-2: Example Booster Pump Skid

10. Discharge Pump Skid

When designing the ILDFA, the pump skid system typically uses an FM Approved 6", 50HP centrifugal pump with a maximum flow rate of 1,500 GPM (5,680 L/min). The discharge pump is controlled by a listed pump controller.

A 460/480VAC, 3 phase power supply with a 65A breaker is required for each pump skid. For hangars outside of the United States, pump motors can be modified to work with local 3 phase voltage supply.

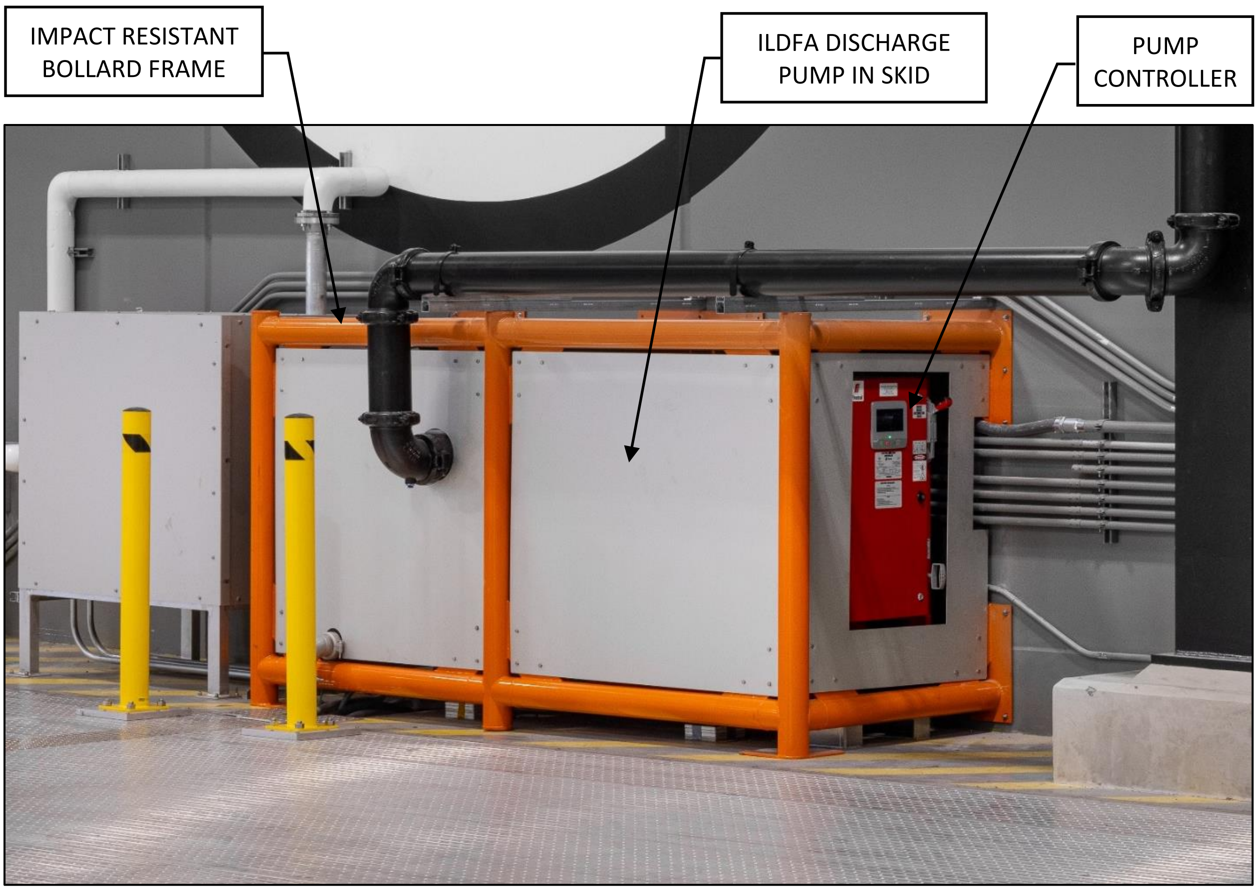


Figure 10-1: Typical pump skid enclosure in ILDFA hangar installation.

The pump and controller are housed inside of a welded aluminum bollard frame, with heavy duty aluminum panels to protect the equipment from collisions, such as forklifts, tugs, or tool carts. The bollard frame has an approximate footprint of 10 ft (2.9 m) by 5 ft (1.5 m) and an approximate height of 5.5 ft (1.6 m).

The hangar layout, width, and number of trenches will determine if one or more pump skids are required.

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 10-2: Render of ILDFA Layout with pump skids on opposite sides of the system

10.1. Discharge Pump Controller

To ensure reliability, all discharge pumps will be connected to a listed fire pump controller. The fire pump controller will be installed inside of the pump skid bollard frame with an opening in the enclosure panels for access. The pump controller will provide signaling to the main control panel to provide alerts when power is lost, pumps are running, or phase reversal occurs. A liquid detection sensor installed in the drainage box will send signal to the pump controller to start the discharge pump whenever liquid is present in the drainage box of the ILDFA. The pump will start upon liquid detection and run for a pre-set duration after the liquid detection sensor is dry.

For most applications, the pump will run for (1) minute after the liquid detection sensor is dry as shown in the example logic tree in Figure 11-5. For applications following FM Datasheet 7-93, the pump will be required to run until it is manually shut off. Changes in run time can be accommodated through on-site programming of the pump controller.

11. Controls System

For all ILDFA installations, a main control panel will be provided in each hangar bay. A controls junction box will be installed near the trenches and act as a cutoff between the main control panel and wiring entering the trench. One controls junction box can accommodate up to 16 ILDFA zones. All ILDFA control panels and junction boxes are UL-508A listed and FM approved and typically require a 2,400 watt (120 VAC, 480 VAC, or other local voltages can be used) power supply. Control panels and junction boxes carrying Intrinsically Safe wiring are UL-698A listed.

11.1. Main Control Panel

The ILDFA control panel consists of a NEMA 4/IP66 enclosure, which should be mounted on a wall within the hangar, in a central location where it is visible to all hangar personnel.

In hangars with multiple bays, one main control panel will be provided for each hangar bay. Figure 11-1 shows an example of an ILDFA main control panel mounted on the inside wall of the hangar. Placement is within view of all ILDFA zones and is accessible to emergency responders and maintenance personnel.

The typical dimensions of the main control panel are 24 in (0.61 m) wide by 30 in (0.76 m) high by 12 in (0.3 m) deep. The main control panel should be installed at least 18 in (0.45 m) above the ground.

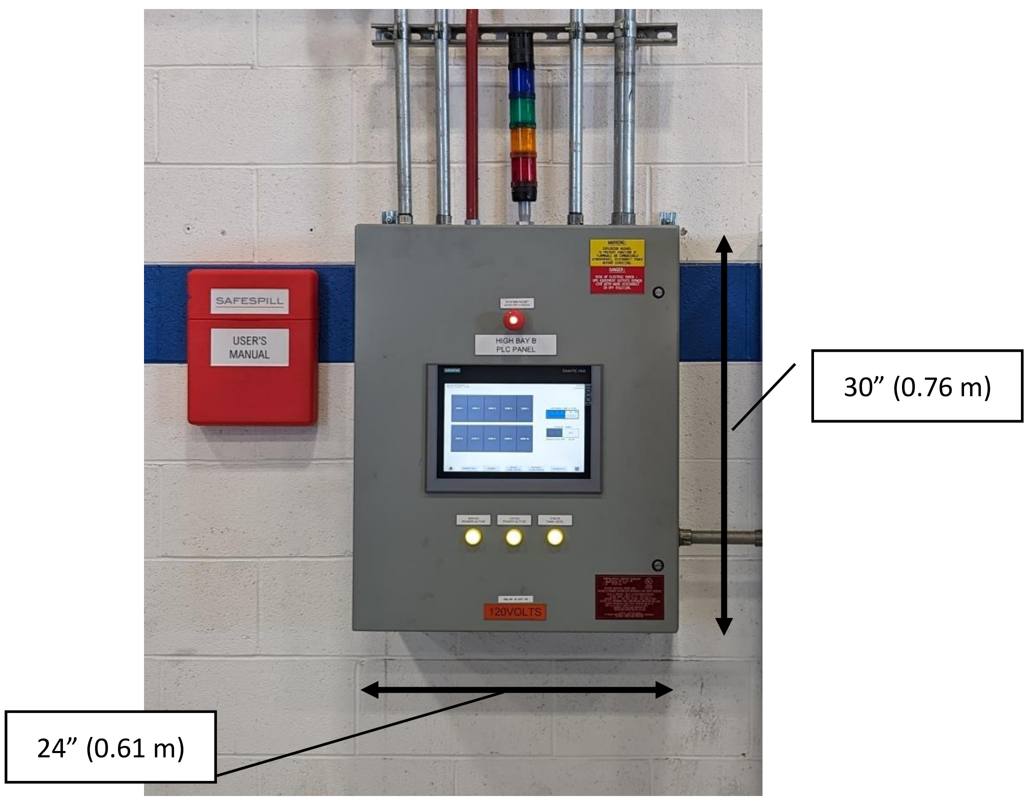


Figure 11-1: ILDFA Control Panel mounted on the interior hangar wall

The main control panel has indicating lights for power loss, system armed, and tank conditions. Audio-visual alarms are initiated at the main control panel. The main control panel has dry contacts for connection to the hangar's Fire Alarm Control Panel (FACP) or Building Management System (BMS). A fire alarm sequence of operation is provided in *Section 11.4, Fire Alarm Sequence of Operation*.
The ILDFA is designed to detect liquid spills only and does not detect fire. Therefore, the ILDFA control panel will not activate "alarm" for an FACP and it is recommended that ILDFA should be installed alongside fire detection systems to activate alarm on the FACP.

UFC 4-211-01 requires the use of Triple Infrared (IR) Optical Flame Detectors in hangars with ILDFA installed. Additional information related to the use of Optical Flame Detectors with ILDFA is discussed in *Section 17, Optical Flame Detectors*.

A Human-Machine Interface (HMI) installed on the main control panel allows the user to activate cleaning cycles, manually activating the system if a spill occurs, observe current conditions of sensors and tank levels, and view alarm logs.

If remote monitoring is permitted, the ILDFA manufacturer can access the control panels' PLC and HMI through a VPN connection to analyze the data and make continuous improvements. This allows the manufacturer to run diagnostic tests. One example is testing liquid detection sensors to diagnose errors within individual zones.

During standard operation, the system is armed and will activate upon three scenarios:

1. Automatic Operation – Activated by liquid detection sensors
2. Emergency Operation – Activated manually, when a spill is observed but not detected, via button on HMI
3. Manual Operation – Activated manually, for cleaning or flushing purposes, via button on HMI

More details on the system operations are provided in *Section 11.5, Logic Tree.*

The HMI displays the zone currently being activated by one of the three scenarios. The example below in Figure 11-2 shows the ILDFA Zone 3 activated for manual operation in green.

Figure 11-2: Example of the ILDFA HMI with Zone 3 cleaning mode activated

11.2. Controls Junction Box

The controls junction box is used as a cutoff point between wiring from the main control panel and wiring entering the trench. These junction boxes are installed near the end of trenches and connect to conduit runs in the trench. Each junction box can be connected to up to 16 zones. The junction box sends input signals for liquid detection sensors and receives output signals for solenoid valves from the main control panel. The method of communication varies based on whether the ILDFA is installed on a military or non-military hangar.

11.2.1. Military Applications

For military applications, the controls junction box will contain the following:

1. Intrinsically safe barriers for wiring liquid detection sensors
2. Terminal blocks for wiring to solenoid valves in the trench.

Due to cybersecurity concerns, all circuits are hardwired from the junction box terminals to the logic controller located in the main control panel.

The following wiring is required between the main control panel and the controls junction box:

- 24VDC for power to IS Barriers: 6AWG, 2 conductors + 1 ground
- Liquid Detection Sensor Signal: 22AWG, 2 conductors per zone (i.e. for 16 zones, 32 conductors are required)
- Solenoid Valve Power: 14AWG, 2 conductors per zone (i.e. for 16 zones, 32 conductors are required)

Additional wiring for tank sensor, flow meter, and other auxiliary devices may be required on a project-by-project basis.

11.2.2. Non-Military Applications

For non-military applications, a secondary logic controller will be installed in the controls junction box. The same intrinsically safe barriers and terminal blocks will be used as in military applications. However, the use of a secondary logic controller greatly reduces the required wiring between the main control panel and controls junction box. Input signals for liquid detection sensors and output signals for solenoid valves are transmitted via ethernet cable.

The following wiring is required between the main control panel and the controls junction box:

- 24VDC for power to IS Barriers and secondary logic controller: 6AWG, 2 conductors + 1 Ground
- Liquid Detection Sensor Signal and Solenoid Valve Power: 1 Cat6 Ethernet cable

11.3. Backup Battery Power

Each main control panel will be connected to backup battery power providing 24VDC power for 48 hours of standby plus 30 minutes of operation. The batteries will be stored in a battery cabinet, which should be installed next to the main control panel, at least 18 inches above the ground.

The dimensions of the battery cabinet will be either:

For applications with **16 zones or less**: 19 in (0.48 m) wide by 40 in (1.02 m) high by 17 in (0.43 m) deep.

For applications with **more than 16 zones**: 26 in (0.66 m) wide by 40 in (1.02 m) high by 17 in (0.43 m) deep.

When building power is lost, the main control panel will automatically switch to battery power and continue to provide power supply to the logic controller, signaling devices, liquid detection sensors, solenoid valves, and tank sensor(s). When building power is lost, the main control panel will display power loss via an indicating light and transmit a supervisory signal to the FACP.

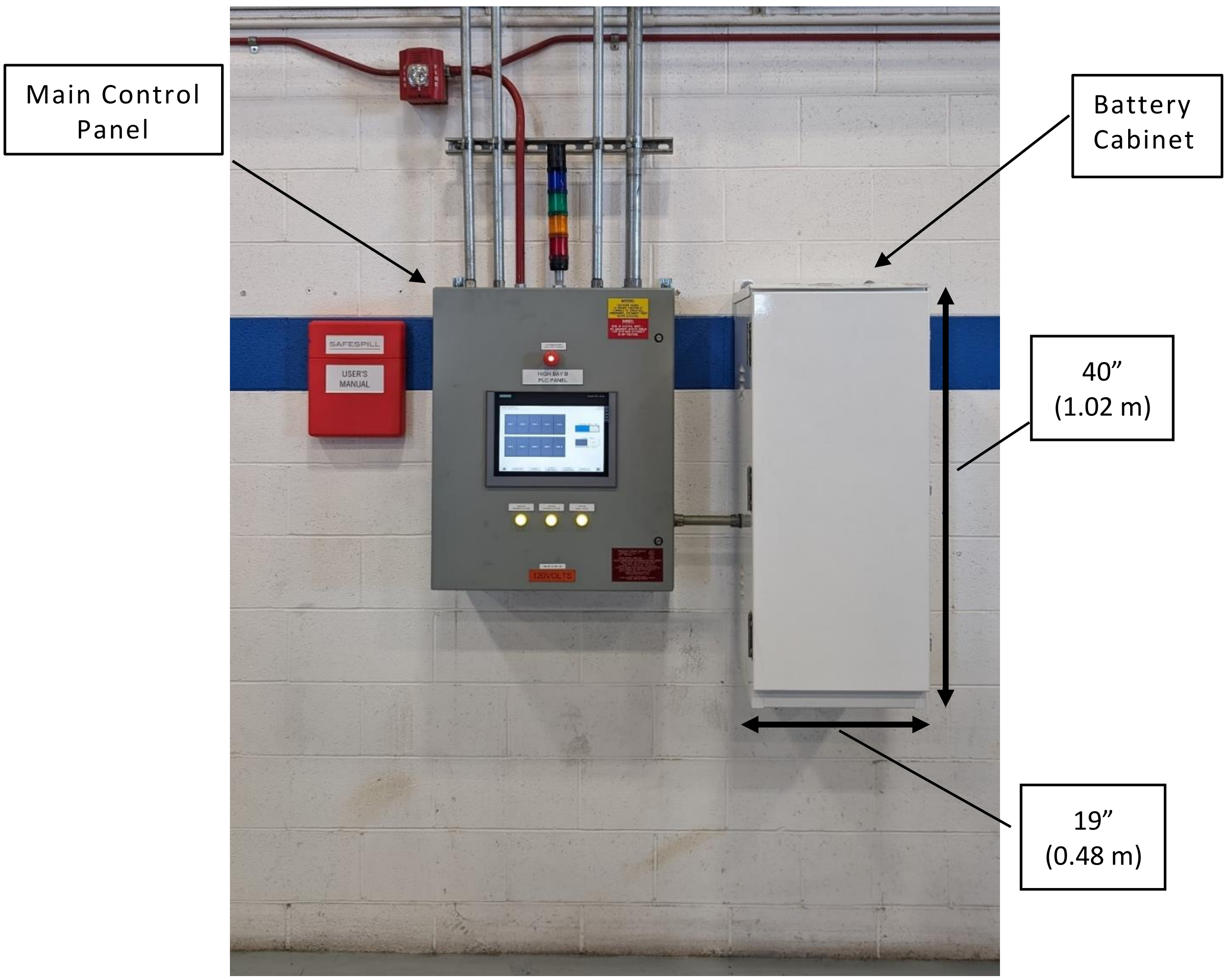


Figure 11-3: Battery cabinet mounted on wall near main control panel

11.4. Fire Alarm Sequence of Operation

Figure 11-4 shows a typical fire alarm sequence of operation meeting the minimum requirements for the sequence of operations in accordance with UFC 4-211-01. This includes signaling between the ILDFA Controls System and the hangar's FACP or BMS

ILDFA SEQUENCE OF OPERATION								
			SYSTEM OUTPUT					
			ANNUNCIATION AT SAFESPILL CONTROL PANEL				SUPERVISORY ANNUCIATION AT LOCAL PANEL (BMS or FACP)
			CONTINUOUS AUDIBLE NOTIFICATION AT SAFESPILL CONTROL PANEL	CONTINUOUS STROBE AT SAFESPILL CONTROL PANEL	CONTINUOUS INDICATING LIGHT AT SAFESPILL CONTROL PANEL	SILENCABLE AUDIBLE NOTIFICATION AT SAFESPILL CONTROL PANEL	
SYSTEM INPUT			A	B	C	D	E
SUPERVISORY CONDITIONS	1	AUTOMATIC ACTIVATION OF ILDFA (SPILL DETECTED)	X	X			X
	2	EMERGENCY ACTIVATION OF ILDFA	X	X			X
	3	ACTIVATION OF SAFESPILL EMERGENCY STOP			X	X	
	4	LOW FLOW DETECTED DURING SOLENOID OPERATION, SAFESPILL FLUSHING SUPPLY				X	
	5	SIGNAL FROM SAFESPILL CONTROL PANEL, DISCHARGE TANK IS ≥95% FULL	X	X	X		X
	6	SIGNAL FROM SAFESPILL CONTROL PANEL, DISCHARGE TANK IS 30-94% FULL	X	X	X		X
	7	SIGNAL FROM SAFESPILL CONTROL PANEL, DISCHARGE TANK IS 20-29% FULL		X	X	X	
	8	SIGNAL FROM SAFESPILL CONTROL PANEL, 120 VOLTAGE SUPPLY IS INTERRUPTED			X	X	
	9	SIGNAL FROM SAFESPILL CONTROL PANEL, 480 VOLTAGE SUPPLY IS INTERRUPTED	X	X	X		

SYSTEM OUTPUT DETAILS		
AUDIBLE CONTINUOUS NOTIFICATION AT SAFESPILL CONTROL PANEL	=	CONTINUOUS HORN AT SAFEPSILL CONTROL PANEL
CONTINUOUS STROBE AT SAFESPILL CONTROL PANEL	=	CONTINUOUS STROBE AT SAFESPILL CONTROL PANEL
CONTINUOUS INDICATING LIGHT AT SAFESPILL CONTROL PANEL	=	CONTINUOUS INDICATING LIGHT AT SAFESPILL CONTROL PANEL
SILENCABLE AUDIBLE NOTIFICATION AT SAFESPILL CONTROL PANEL	=	INTERMITTENT HORN AT SAFEPSILL CONTROL PANEL (SILENCABLE)

Figure 11-4: Sequence of Operations for FACP in accordance with UFC 4-211-01

11.5. Logic Tree

Figure 11-5 and Figure 11-6 are examples of the ILDFA logic tree that explains the flow of operations for all typical and atypical scenarios.

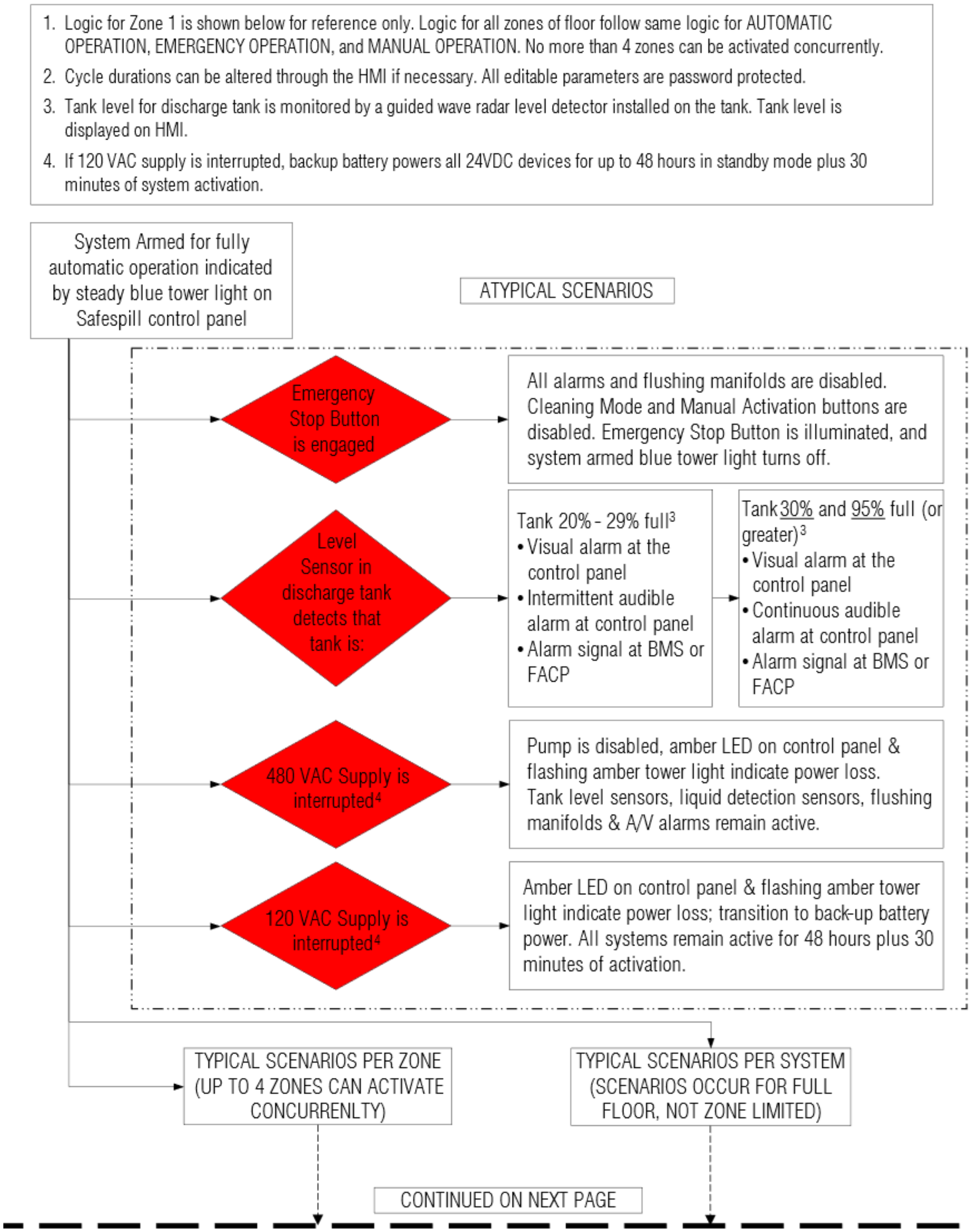


Figure 11-5: ILDFA Logic Tree

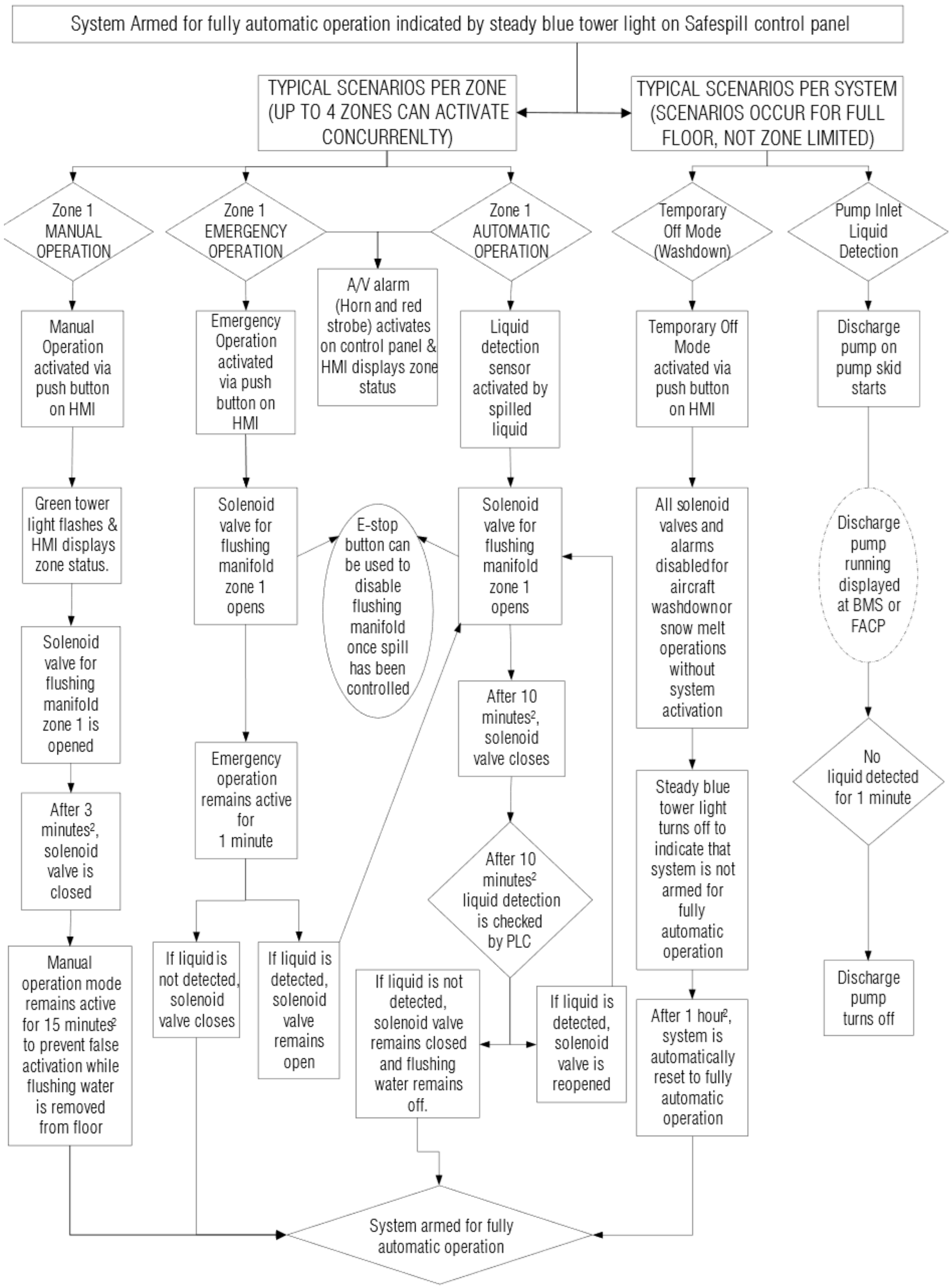


Figure 11-6: ILDFA Logic Tree (Continued)

12. Electrical Components in Trench

Liquid detection sensors, solenoid valves, and wiring for these devices are installed within the trench of the ILDFA and are provided by Safespill.

12.1. Liquid Detection Sensors

For each zone of the ILDFA, (1) liquid detection sensor is installed. The liquid detection sensor is intrinsically safe and FM Approved for use in Class 1, Division 1 locations. The liquid detection sensor consists of a two-wire amplifier which converts intrinsically safe voltages to a visible red light.

Figure 12-1 provides a visual explanation of liquid detection sensor components and operations.

The visible red-light travels through a fiber optic cable to a glass prism and returns via fiber optic cable to a receiver on the sensor. When the glass prism is not submerged in liquid, the red light returns to the sensor uninterrupted. When the glass prism is submerged in liquid, the red light is scattered and does not return to the sensor. The sensor transmits a “light” or “dark” condition to an intrinsically safe barrier located in the controls junction box.

Each liquid detection sensor is connected to the intrinsically safe barrier via (2) 18AWG conductors, with a 4-pin, M12 quick disconnect fitting on the device side.

Liquid detection sensor wiring is routed through the trench in a rigid metallic conduit to prevent abrasion and crushing. Table 12-1 provides recommended conduit sizing based on the number of zones in each conduit run. Please note, conduit sizing remains constant from the controls junction box to each liquid detection sensor on the conduit run.

If a liquid detection sensor component or wiring is damaged, the device registers as activated and signals the control panel that a spill has occurred.

Table 12-1: *Recommended Conduit Size for Liquid Detection Sensor Wiring*

Number of Zones	**Recommended Conduit Size**
12 Zones or Less	1”
13 to 20 Zones	1-1/4”
More than 20 zones	1-1/2”

Glass Prism at end of fiber optic cable

Sensor amplifier and fiber optic cable

DRY fiber optic cable

WET fiber optic cable

Figure 12-1: Liquid detection sensor components and operations

12.2. Solenoid Valves

For each zone of the ILDFA, (1) solenoid valve is installed in an aluminum enclosure mounted adjacent to the trench. The solenoid valve is FM Approved for use in Class 1, Division 1 locations. Water supply piping is routed through the trench and connected to the solenoid valve. Electrical conduit is routed externally and encased in concrete, entering the enclosure through the top or back side of the enclosure. When liquid is detected in a zone, the solenoid valve for that zone opens to provide water flow to the flushing manifold in that zone.

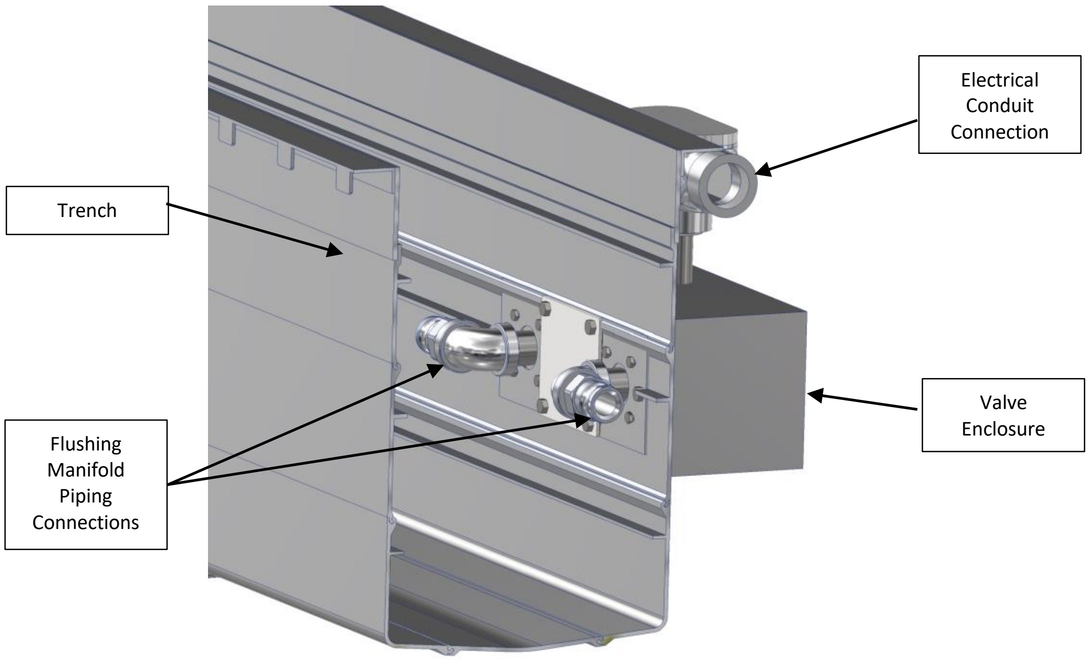


Figure 12-2: Solenoid valve enclosure installed on external wall of trench

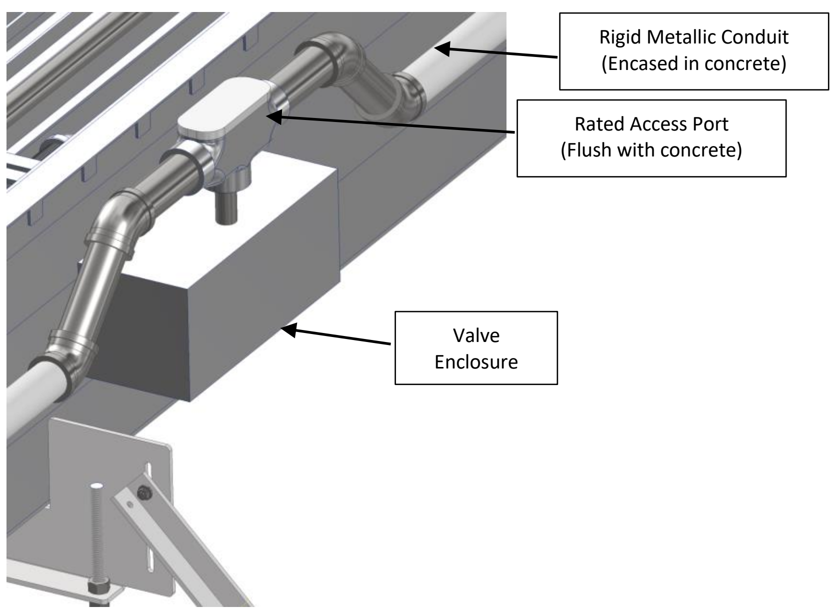


Figure 12-3: Solenoid valve enclosure shown with conduit routed outside of trench

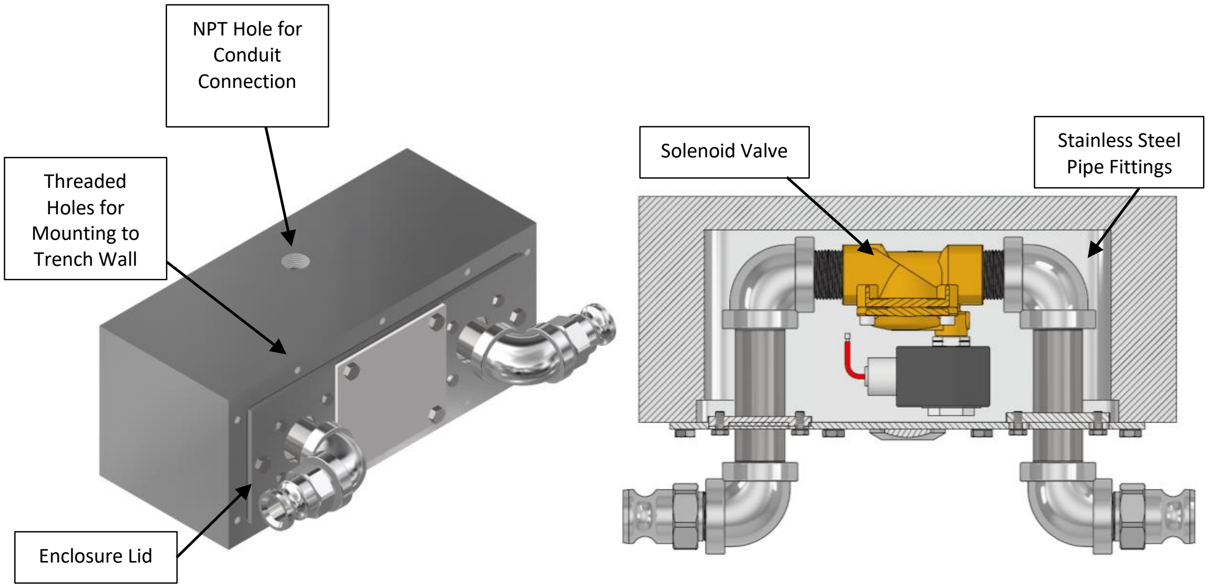


Figure 12-4: Detailed view of solenoid valve enclosure

Solenoid valves fail-closed, so that in the event of a power loss condition, water is not supplied to all zones of the floor. Wiring is routed through rigid metallic conduit with explosion proof fittings.

Table 12-2 provides recommended conduit sizing based on the number of zones in each conduit run. Please note, conduit sizing remains constant from the controls junction box to each valve cabinet on the conduit run.

Table 12-2: Recommended Conduit Size for Solenoid Valve Wiring

Number of Zones	Recommended Conduit Size
10 Zones or Less	1”
11 to 18 Zones	1-1/4”
Up to 24 Zones	1-1/2”
Greater than 24 Zones	2”

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 10 Discharge Pump Skid* for details) will direct the liquid to above ground containment.

Regardless of style or size of tank, liquid containment must be located **outside** of the hangar.

13.1. Tank Styles and Sizing

NFPA 409 (2022 Edition), FM Datasheet 7-93 (July 2022), and UFC 4-211-01 all provide requirements on the style of containment and size requirements; however, each standard varies in its requirements.

A breakdown of style of containment allowed is provided in *Table* 13-1.

Table 13-1: Style of Liquid Containment

	UFC 4-211-01	NFPA 409	FM 7-93
Above Ground Tank	✓	✓	✓
Above Ground Tank w/ Overflow*	X	✓	✓
Underground Tank	✓	✓	✓
Underground OWS	✓	✓	✓
Open Pit	X	✓	✓

* In some cases, a smaller tank volume with overflow to larger containment may be used. This option allows for everyday spills to be captured in the small tank with overflow to a larger containment option for worst-case scenarios

Figure 13-1: Example of 15,000 gallon (56,781 L) UL-142 steel aboveground tank; shown for reference only

13.2. Sizing Considerations

When calculating the required size of the spill containment tank for small aircraft consider the total inboard fuel capacity as the largest potential spill volume.

When calculating the required size of the spill containment tank for large aircraft, the single largest internal fuel cell size for the largest potential spill (LPS) is used.

Figure 13-2 shows the fuel tank layout for a KC-135.

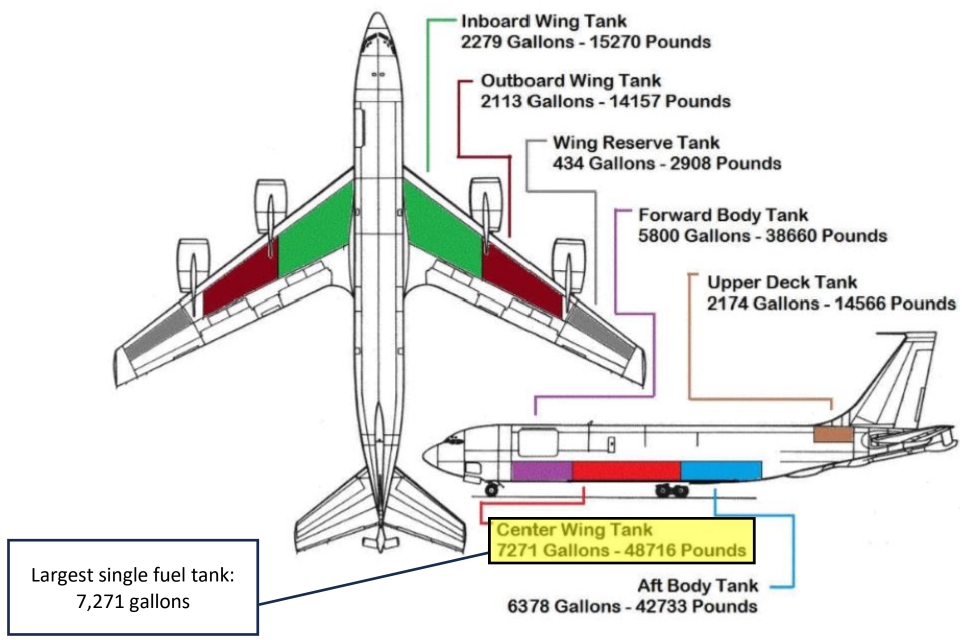


Figure 13-2: KC-135 fuel cell locations

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).

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

13.3. Example Calculations

Table 13-2 provides containment tank sizing requirements based on UFC 4-211-01, NFPA 409, and FM 7-93.

Table 13-2: Containment Sizing Requirements

	UFC 4-211-01	NFPA 409	FM 7-93
Worst-Case Scenario (WCS) Spill Flow Rate	200 GPM (681 LPM) for small* aircraft, 400 GPM (1,514 LPM) for larger aircraft		
WCS Flushing Water	200 GPM (681 LPM)		
Event Duration	30 minutes	Largest potential spill/WCS Spill Flow Rate	60 minutes
Sprinkler Density	N/A	0.17 gal/min/ft^2	600 gal/min
Sprinkler Coverage Area		15,000 ft^2	

**NFPA 409 Chapter 8.2.13.4.1 and FM Datasheet 7-93, Chapter 2.2.2.2 define small aircraft up to 78 ft (24 m) in length with a fuselage width of less than 13 ft (4 m)*

Table 13-3 provides example calculations for containment tank sizing for a hangar housing one KC-135 Stratotanker (Figure 13-2) using requirements from UFC 4-211-01, NFPA 409, and FM 7-93.

Table 13-3: KC-135 Spill Containment Sizing Calculation

	UFC 4-211-01	NFPA 409	FM 7-93
Largest Aircraft Fuel Cell	7,271 gal (27,519 L)	7,271 gal (27,519 L)	7,271 gal (27,519 L)
WCS Flushing Water	6,000 gal (22,712 L)	6,000 gal (22,712 L)	12,000 gal (45,420 L)
Sprinkler Water	N/A	76,500 gal (289,552 L) [1]	36,000 gal (136,260L)
Required Containment Size	15,000 gal (56,775 L) [2]	89,771 gal (339,780 L)	55,271 gal (209,197 L)

1: NFPA 409 Chapter 8.2.4.5 requires a sprinkler density of 0.17 gpm/ft^2 (6.9 LPM/m^2) over 15,000 ft^2 (1,394 m^2)
2: UFC 4-211-01 requires a minimum tank size of 15,000 gallons

14. Safespill Oil Water Separator Package

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) Skid can be included in the tank package of the ILDFA manufacturer's scope.

The OWS Skid will be controlled locally, independent of the ILDFA hangar control panel and will manually or automatically process the tank's liquid content after a spill has occurred.

The OWS Skid consists of an 8' x 10' (2.5m x 3m) fully enclosed skid with an oil water separator, activated carbon filter, and 500 gal (1900L) oil storage tank. The oil storage tank is fitted with a level sensor which alerts the operator when the tank is full. When the tank is full, it can be emptied using a tank mounted fuel pump to the desired disposal vessel.

The OWS Skid is connected to the containment tank and can be configured to draw contaminated fluid manually or automatically from the tank, discharging clean water (<5 mg/L TPH) and sending hydrocarbons to the skid-mounted storage tank.

The OWS Skid requires 120VAC, 25A electrical connection to power the OWS control panel. This includes the required power for the pumps on board the OWS Skid. Motor starters for each pump are housed within the OWS control panel. No other utilities are required.

The end-user, AHJ, or local environmental team will be responsible for determining the clean water disposal location or whether water can be recycled to the ILDFA water supply tank. The hangar operator will be responsible for emptying the oil storage tank and replacing the carbon filter when needed.

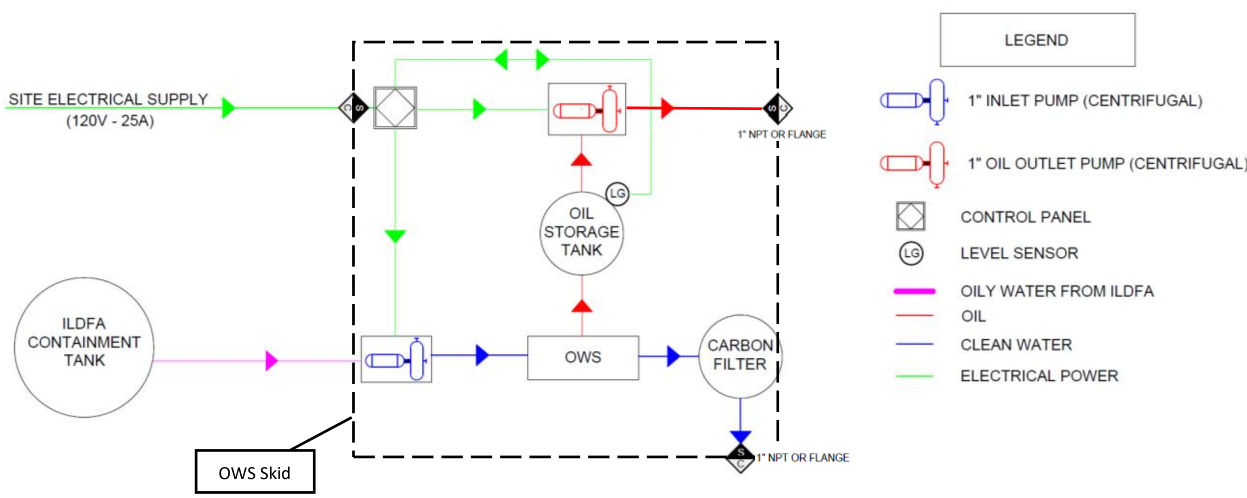


Figure 14-1: P&ID of Oil Water Separator Skid

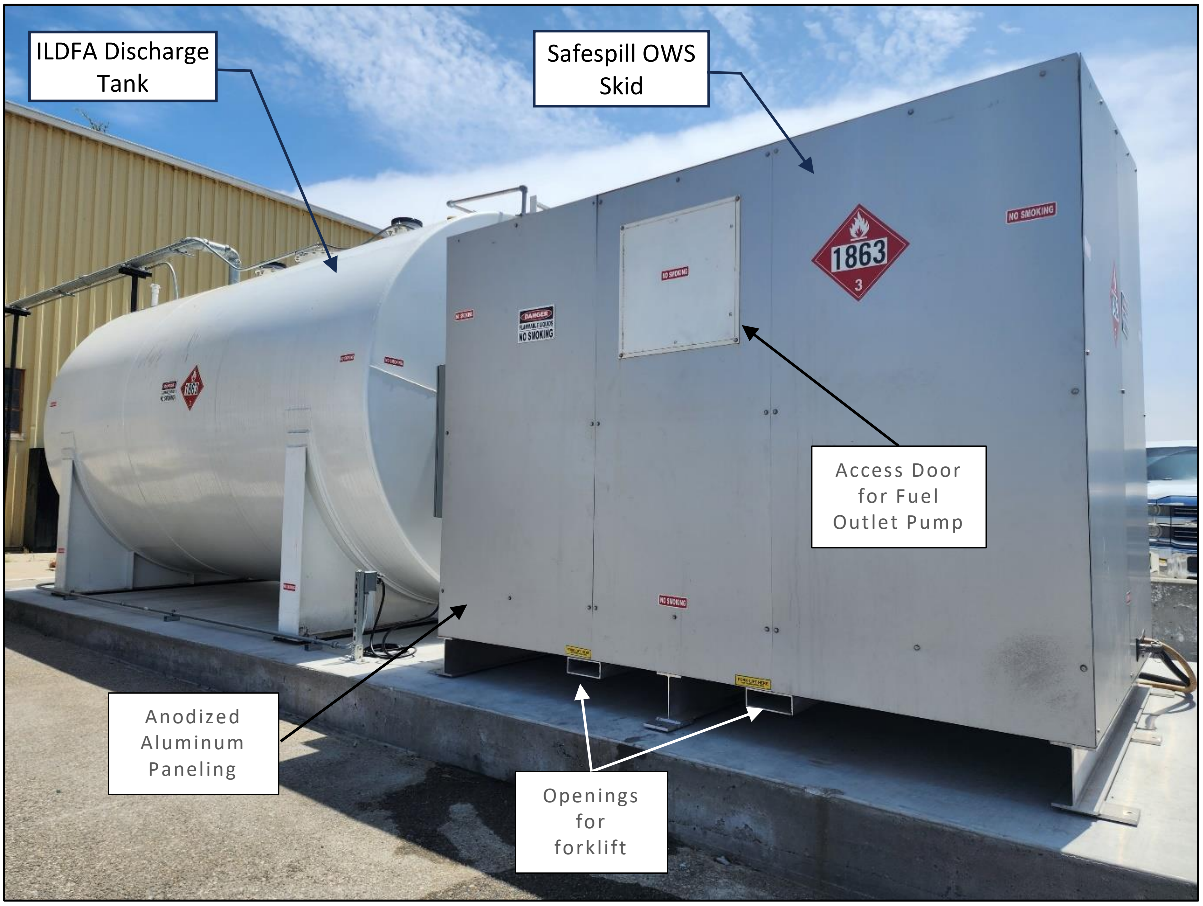


Figure 14-2: OWS Skid External View

Clean water can be discharged via gravity to a storm drain or retention pond based on local environmental requirements (Figure 14-3) or be recycled via pump to a water supply tank for the ILDFA (Figure 14-4).

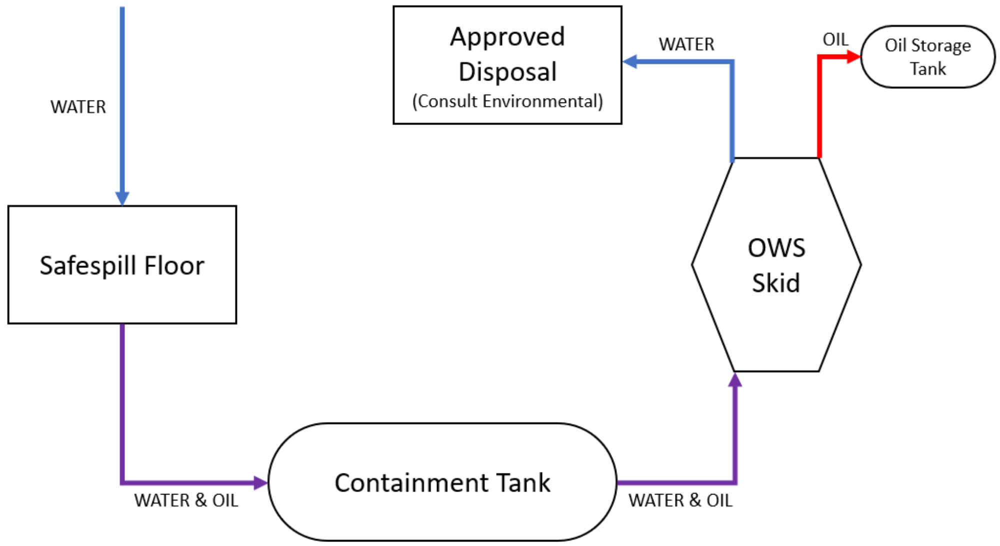


Figure 14-3: Flow Diagram of OWS Skid when discharging clean water

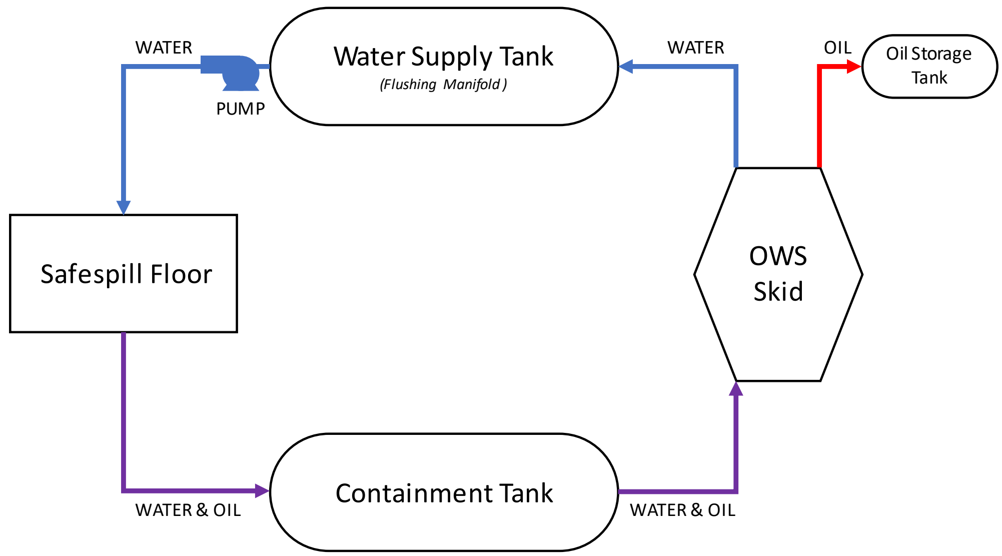


Figure 14-4: Flow Diagram of OWS when reusing water for ILDFA

15. Pre-Conditioned Air (PCA) Trenches

The installation of the Safespill ILDFA is compatible with hangars using pre-conditioned air (PCA) trenches. The following design has been submitted and approved by NAVFAC.

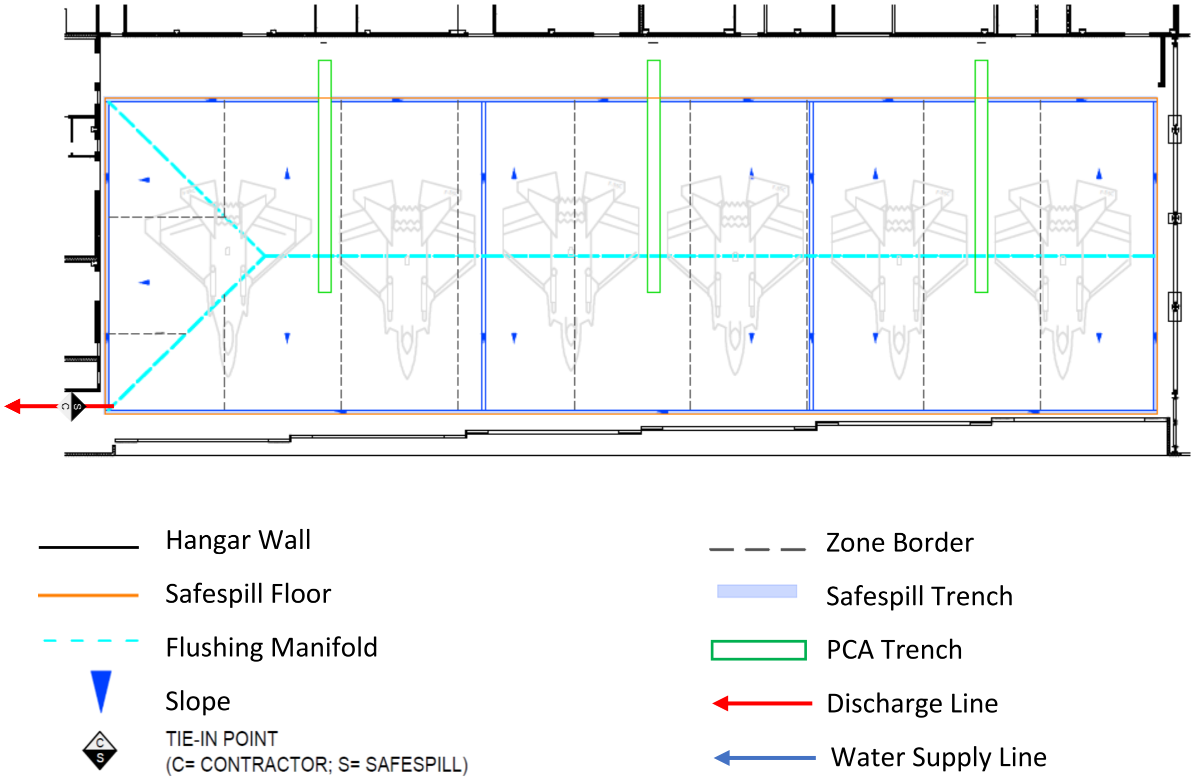


Figure 15-1: Approved layout for ILDFA in hangars using PCA trenches

In this design, there is no intersection between PCA trenches and ILDFA trenches. Air ducts do not enter the ILDFA trenches and no liquid from the ILDFA will enter PCA trenches. PCA trenches are fully isolated from ILDFA trenches.

PCA trenches begin near the back wall of the hangar and travel below the floor profiles of the ILDFA. ILDFA trenches always slope away from PCA trenches.

16. Overhead Sprinkler System

Provide a sprinkler system as required by NFPA 409, FM Datasheet 7-93, 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.

17. Optical Flame Detectors

UFC 4-211-01 requires the installation of Triple Infrared (IR) Optical Flame Detectors in hangars where ILDFA is installed. Optical flame detectors are utilized to detect fires within the hangar, while ILDFA detects liquid spills. Flame detection activates the FACP alarm, while ILDFA liquid detection activates the FACP supervisory.

Due to concerns related to the reflectiveness of ILDFA, 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 17-1: Flame detector testing was conducted on the ILDFA shown.

18. Dry Pipe Flushing System

The ILDFA flushing manifold requires water supply, which is typically wet pipe and pressurized in all conditions. When ILDFA is used in cold weather environments, the flushing manifold supply piping can be designed as a dry pipe system.

A "dry-pipe" valve, which is slow-closing, motor-driven, and electrically operated, is added upstream of the ILDFA near the supply header. At the lowest point in the flushing manifold supply piping, a solenoid valve, designated as a "drain valve", is added to allow all water to drain from the system.

The system may be designed to be always dry or when temperatures drop to freezing conditions, the dry-pipe valve is closed and the drain valve is opened to remove all water from the system. The water is drained directly into the trench of the ILDFA and removed like any other spill.

If a spill occurs while the piping is dry, the drain valve closes and the dry pipe valve opens along with the solenoid valve(s) for the appropriate zones to provide flushing water.

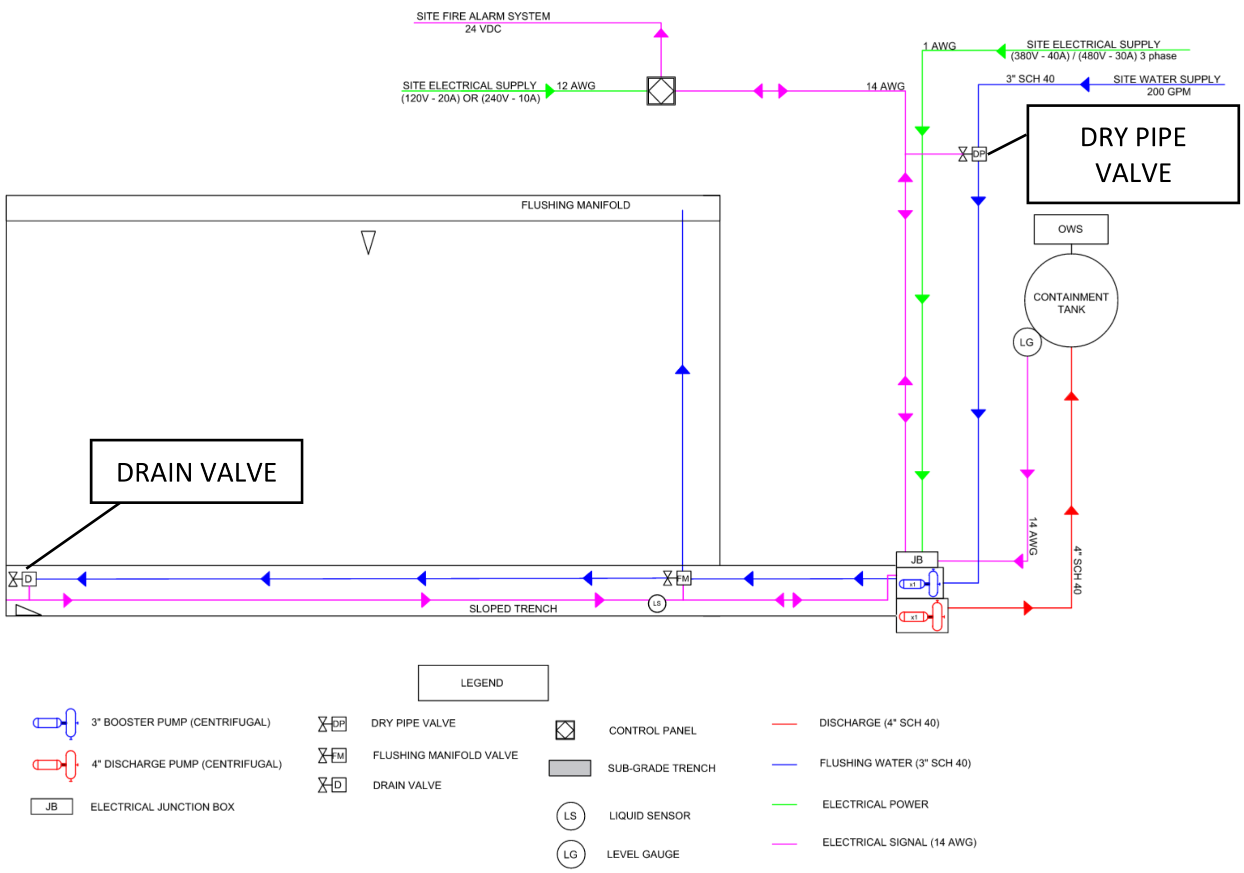


Figure 18-1: P&ID of ILDFA with addition of supply valve and drain valve for dry pipe capability