SAFESPILL

Test Report
Wing Tank Drop Test with Heat Flux Data

October 2020

Prepared by:
Kyle Giubbini
R&D Test Engineer
Safespill
Houston, TX 77054

Testing Witnessed and Verified by
3rd Party Fire Protection Engineer

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1 Introduction

1.1 Purpose

The following report details the test procedures, equipment, and results of a simulated wing tank drop fire test conducted on a Safespill floor (an FM Approved liquid drainage floor assembly) on October 6th, 2020. This test was conducted by Safespill and witnessed by a 3rd party fire protection engineering group.

Heat flux sensors were installed inside of the test facility to validate previous estimates of radiant heat flux during wing tank drop tests on Safespill floors. Two cameras were placed inside of the test facility and recorded the entirety of the fire test from two different angles.

The 3rd party served as witness of the test, inspected all aspects of the Safespill floor before and after the test, and confirms that the equipment, heat flux sensors, and fuel used in this test match what is described in this test report.

The Safespill floor used in testing received an FM Approval under Class 6090, Ignitable Liquid Drainage Floor Assemblies, on August 11th, 2020.

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1.2 Testing Facility

Testing was conducted indoors at the Safespill Testing Facility.

The test facility is a metal clad building with internal dimensions of 10.7 meters (35 feet) wide by 13.7 meters (45 feet) deep and a sloped ceiling with a minimum height of 18 ft and a maximum height of 23 ft. The internal walls are composed of 2 layers of fire-resistant drywall.

A roll-up door, 3.7 m (12 ft) wide is located at the front of the building. During the test, the door was opened to a height of 3 m (9.8 ft) to allow for entrance of personnel.

Blueprints of the facility are provided in Appendix A.

Figure 1-1: Safespill Test Facility outside of Houston, TX, USA

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1.3 Testing Floor Design

This section details the design and dimensions of the flooring system used for testing. A detailed piping and instrumentation diagram for the flooring system used in testing is included in Appendix B.

1.3.1 Test Floor Sizing

The testing floor used had dimensions of 6 meters (19.7 feet) floor profile length by 6 meters (19.7 feet) section width. The trench drain used had a length of 6 meters (19.7 feet) and was positioned as shown in Figure 1-1. The floor profiles will have a 0.5 percent slope toward the trench drain to encourage flow.

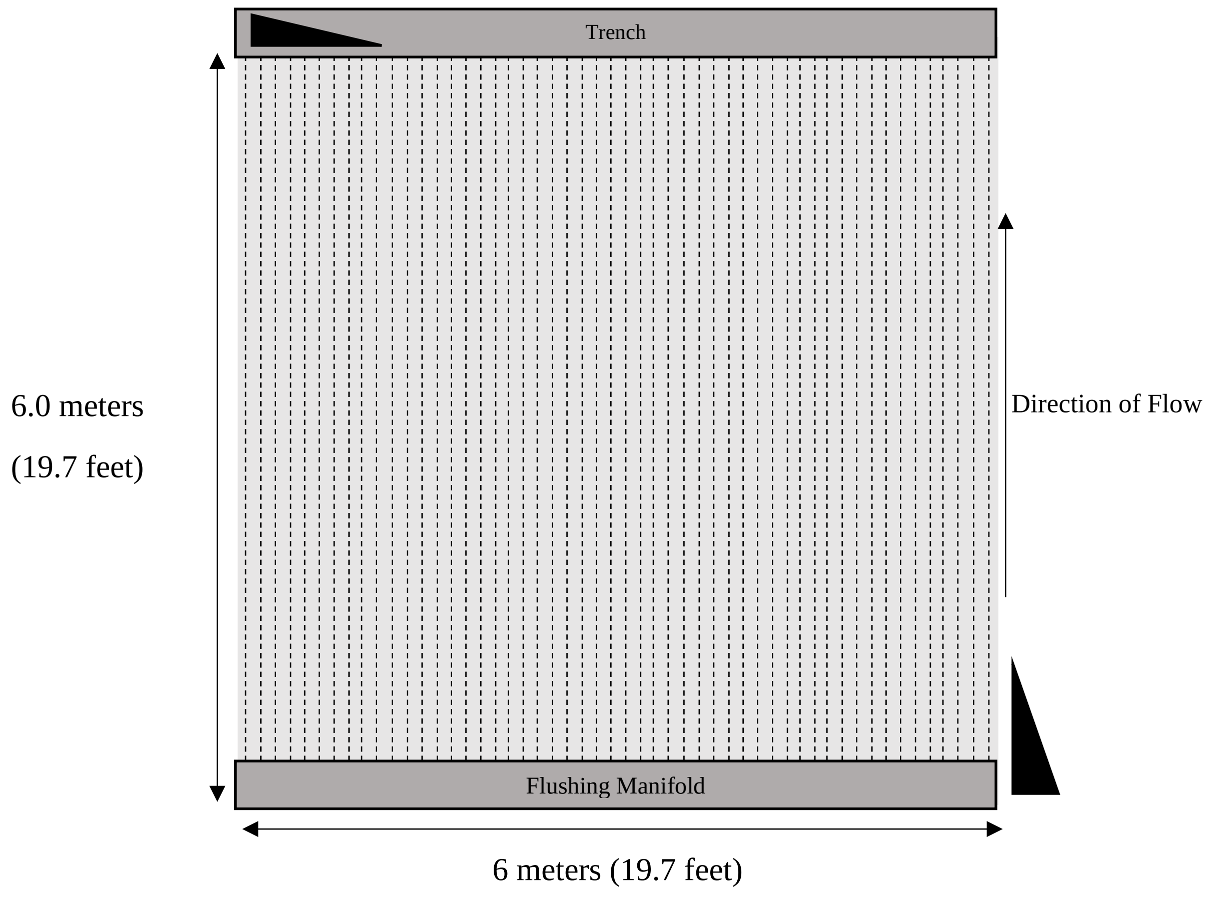

Figure 1-2: Dimensions of test floor

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1.3.2 Profiles

The primary component of the Safespill floor is the floor profiles. The profiles are made from extruded aluminum (6005-T5 Alloy) approximately 150 mm (6 inches) wide and 50 mm (2 inches) high. Each profile contains three separate channels that run along the length of the profile. A line of holes is provided above each of the three channels on approximately a 50 mm (2 inch) spacing, allowing liquid to drain from the profile surface into the channels. The profiles lock together with a tongue and groove style connection to create the desired width of the floor assembly. Viton seals are installed between the profiles to prevent liquid from leaking between each profile. A flushing manifold is attached at one end of the profiles, and a trench is attached at the opposite end. Viton seals are used at the ends of the profiles to prevent liquid from leaking under the floor at these connections.

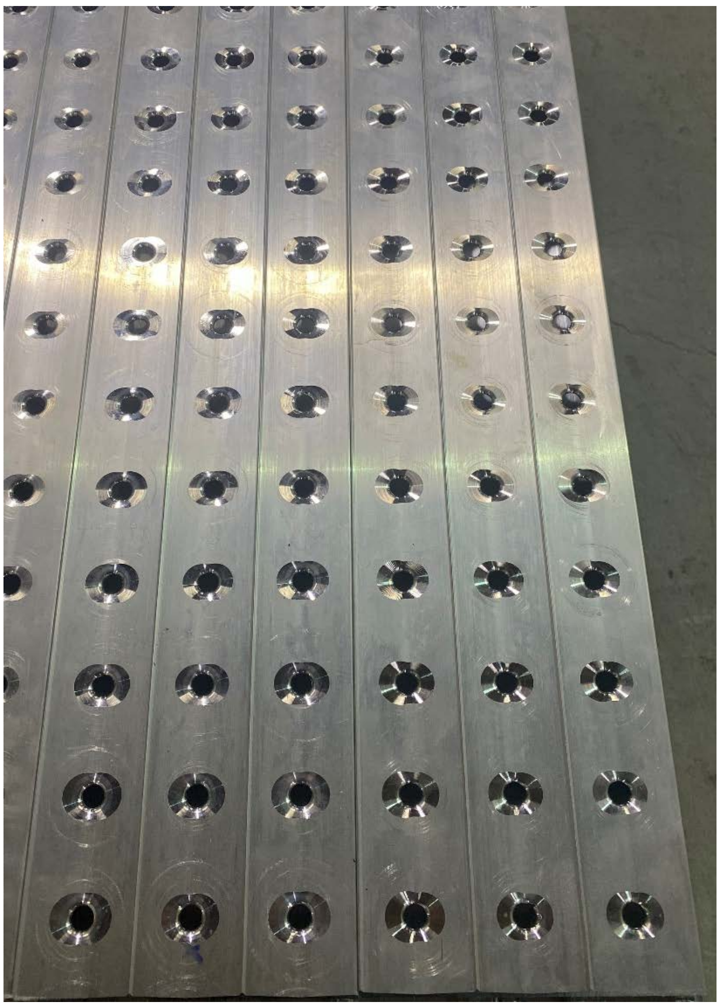

Figure 1-3: Top View of Floor Profile with Drainage Holes

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1.3.3 Trench

Spilled fuel and water from the flushing manifold flows down the length of the profiles and into the trench drain. The trench drain was made of stainless steel and had a width of 300 mm (12 inches) and depths of 410 mm (16 inches) at the deepest point and 380 mm (15 inches) at the shallowest point. At the end of the trench drain, a sump with a square cross-sectional dimension of 300 mm (12 inches) and a depth of 1 meter (3.1 feet) collects spilled liquids. Two suction inlets located at the base of the sump are connected to two 100 mm (4 inch) centrifugal pumps to remove liquid from the trench and pump it into a containment tank located outside of the hazard area. The trench drain had a 0.5 percent slope toward the sump to encourage flow of liquid.

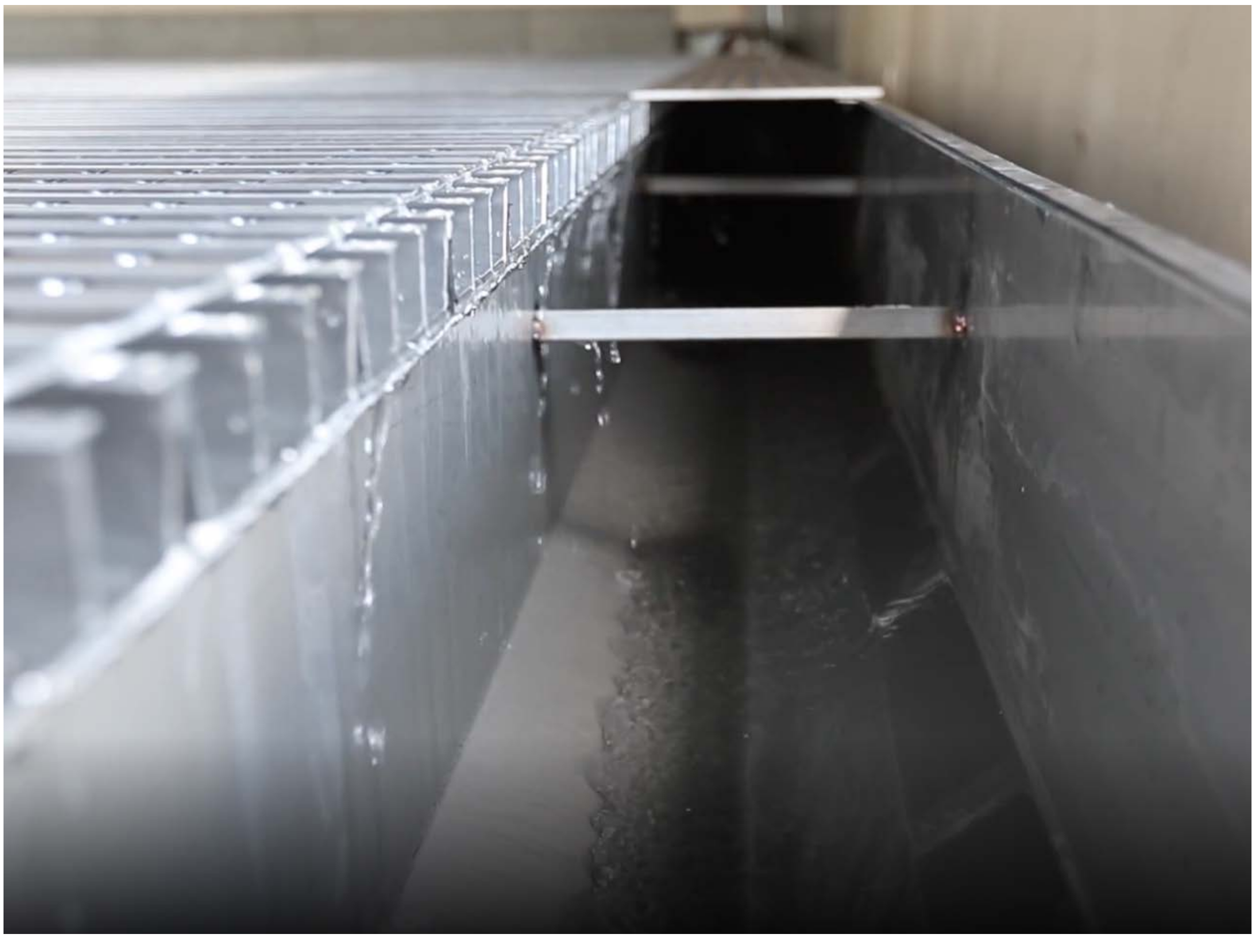

Figure 1-4: Trench shown with connection to floor profiles.

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1.3.4 Flushing Manifold

The flushing system used in this flooring system consists of a 50.8 mm (2 inch) square tube with a series of 1 mm (0.04 inch) diameter holes along its face. The flushing manifold is attached to the end of the floor profiles with a viton seal installed to prevent leaks at the connection point. When the cover plate is removed, an opening in the top surface of the profile near the flushing manifold allows access to the flushing manifold for maintenance and inspection. When pressurized with water, the manifold sprays a stream of water down each channel of the flooring system, encouraging flow of the spilled liquid toward the trench drain. The flow rate of the flushing manifold is 1.0 L/min (0.25 GPM) per channel.

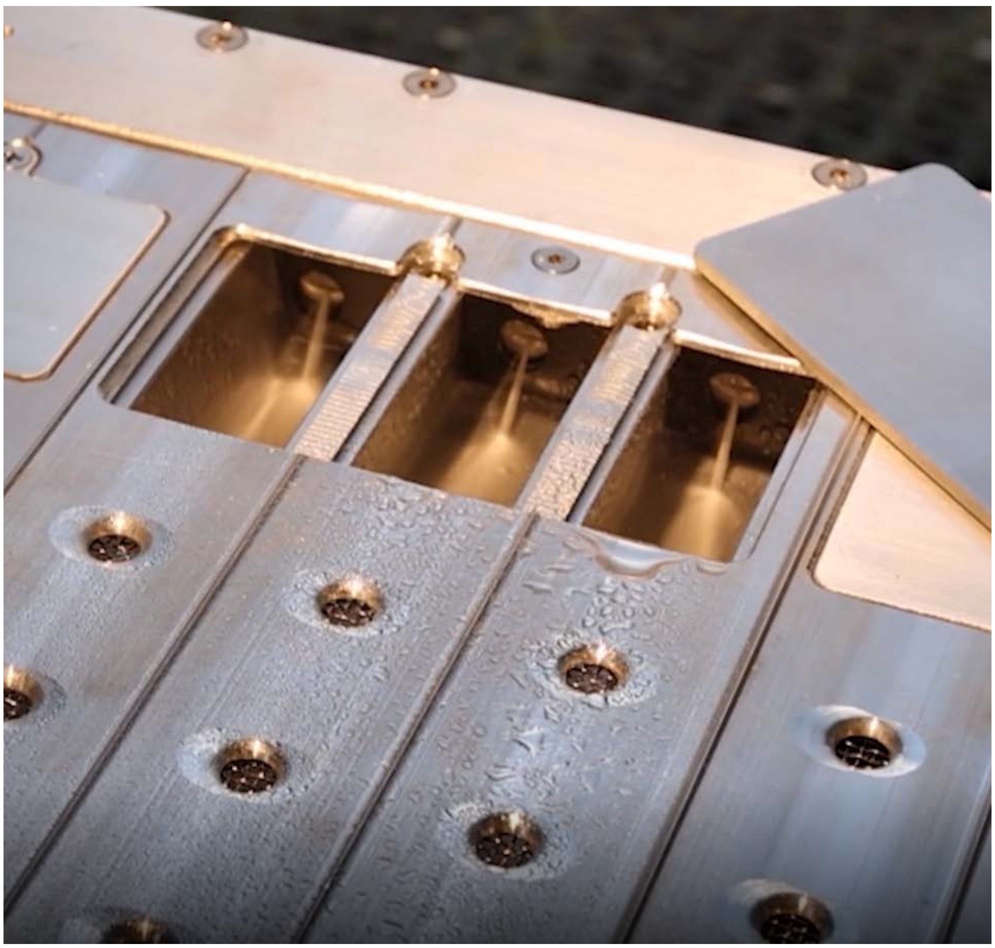

Figure 1-5: Flushing Manifold shown through access hatch with high pressure water flowing.

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1.3.5 Pumps

For all testing, two 100 mm (4 inch) centrifugal pumps connected to the base of the sump were used to evacuate liquids from the trench drain. Pump curves and specifications for these pumps can be found in Appendix D. For both water and fire tests, discharge lines on the pumps were composed of 100 mm (4 inch) rubber hose with a length of 15.25 meter (50 feet) discharging into an atmospheric pressure tank.

1.3.6 Ramps

In a real-world application, ramps can be installed along all sides of the flooring system to allow movement of aircraft on and off the floor. In some applications, the floor may be installed flush with the hangar floor and ramps will not be needed. For testing purposes, ramps were not installed as part of the flooring assembly.

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2 Wing Tank Drop Fire Test

2.1 Test Design and Procedure

In place of JP-4, a fuel mixture consisting of one-part gasoline (33.3%) and two parts kerosene (66.7%) was used for testing. 625 liters (165 gallons) of this fuel mixture was contained in a steel trash hopper with a volume of 757 liters (1 cubic yard, 200 gallons) shown in Figure 2-1. A stainless-steel lid was installed on top of the trash hopper to reduce expelled vapors in the testing area.

Figure 2-1: Steel trash hopper (0.76 m^3, 1 yd^3) used to contain and dump JP-4 fuel analog

The fuel was ignited inside of the trash hopper using a propane torch. The hopper was then dumped after a 5 second pre-burn. A controlled dump was accomplished using a winch and pulley system. The dumping motion was completed, and the entire fuel contents of the hopper were expelled in 37 seconds. Based on the dump rate, the fuel spill rate is approximately 1,025 L/min (270 gal/min). The layout of the flooring system and location of the hopper and igniter is shown in Figure 2-2.

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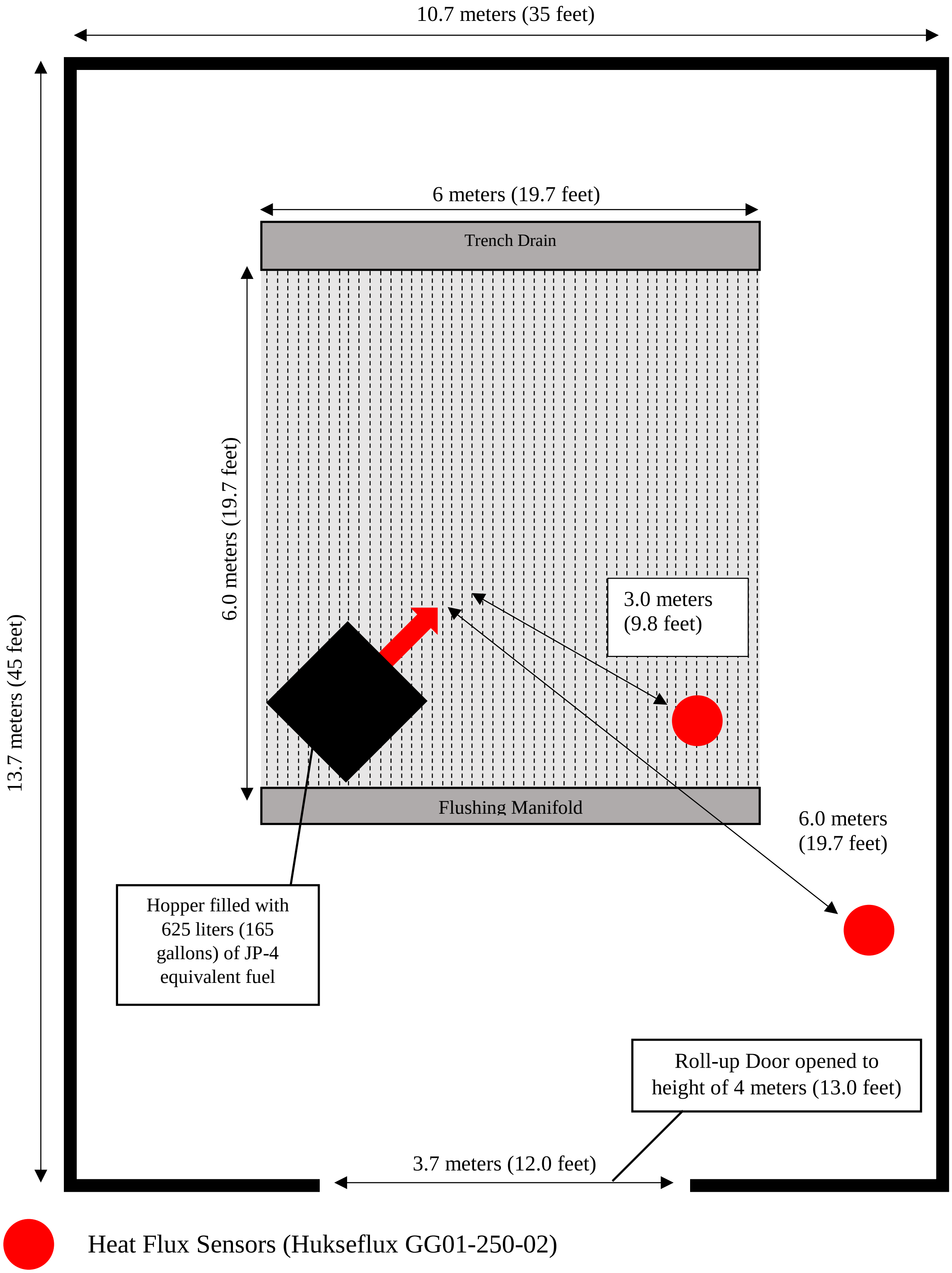

Figure 2-2: Testing layout with hopper and heat flux sensors shown in position. Heat flux sensor positioned at 3 meters (9.8 feet) and 6 meters (19.7 feet) from the center of the fire. Contents of hopper spill at 45-degree angle toward trench drain. Overall building dimensions are 10.7 meters (35 feet) by 13.7 meters (45 feet), with a roll-up door that is 4 meters (13 feet) wide and opened to a height of 3 meters (9.8 feet).

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2.2 Heat Flux Sensors

Two Hukseflux GG01-250-02 heat flux sensors were installed inside of the test facility as shown in Figures 2-2, 2-3, and 2-4. One was placed 3.0 meters (9.8 feet) from the center line of the hopper and a second was placed 6.0 meters (19.7 feet) from the center line of the hopper. Both sensors were positioned 0.3 meters (1 foot) above the top surface of the floor. The heat flux sensors were connected to a Graphtec GL240 data logger. Cooling water was provided to each of the sensors throughout the test. Calibration certificates for all data collection equipment can be found in Appendix C.

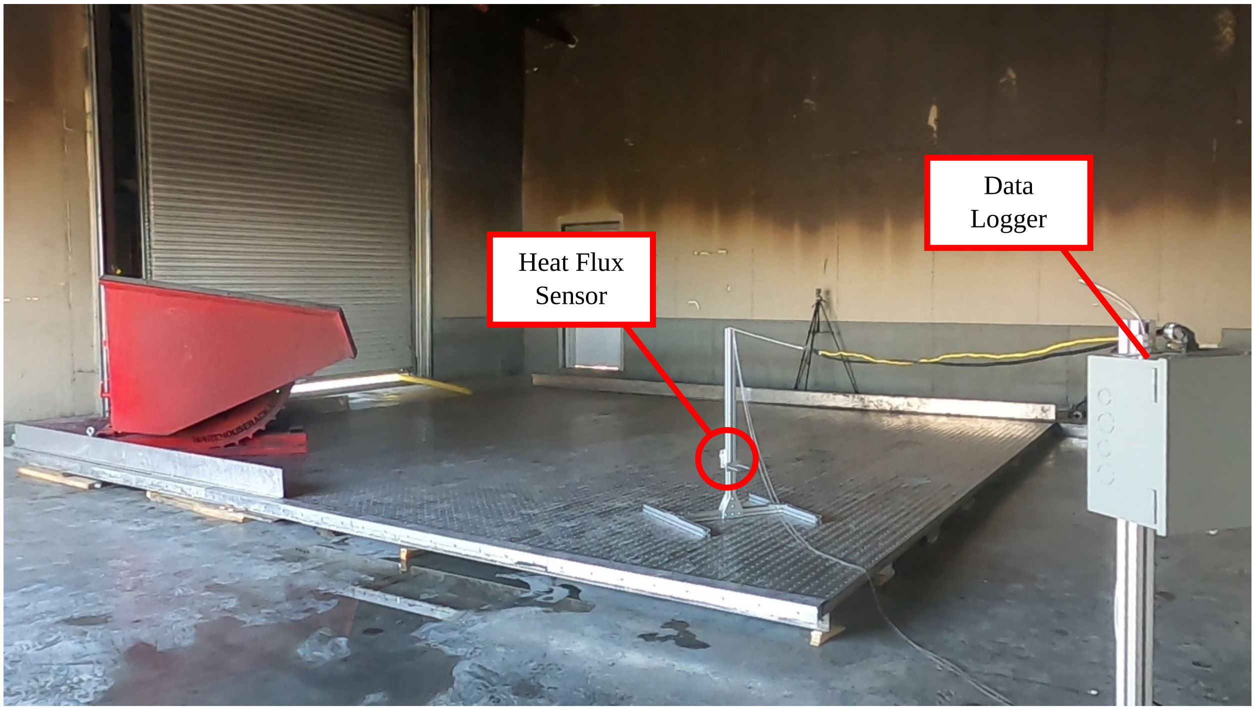

Figure 2-3: Position of heat flux sensor shown from camera next to sensor stand at 6.0 meters (19.7 feet) Aluminum stands used to position sensors at various positions and heights. Junction box at 6.0 meters (19.7 feet) holds data logger.

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Figure 2-4: Test layout shown from trench side of floor. Heat flux sensors mounted to stands on left side of frame.

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2.3 Results

2.3.1 Visual Summary of Testing

Video footage of the test is available at the following links:

Camera 1 - https://jwp.io/s/CgZoAsyx

Camera 2 - https://jwp.io/s/JG6f9U5K

Timer for the test begins when the fuel spill was completed. The following table shows the measured heat flux and fire size at critical moments during the fire test. Each moment highlighted in the table is also included in the visual summary.

Time	Description	Heat Flux (kW/m^2) at 6.0 meters	Heat Flux (kW/m^2) at 3.0 meters	Pool Size, m^2 (ft^2)	Mean Flame Height, m (ft)
0:37 before dump completion	Spill Initiated	0.16	0.22		
0:26 before dump completion	Peak Heat Flux	2.39	7.04	9 (100)	2.2 (7.2)
0:00	Spill Complete	0.41	0.94	7.5 (81)	0.6 (2)
0:53		0.16	0.18	4.3 (46)	0.25 (0.8)
1:20	Heat Flux Undetectable	0.00	0.00	0.8 (8.6)	0.25 (0.8)
2:33	Fire Extinguished				

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Preburn - Fuel is ignited using propane torch and allowed to burn inside enclosed hopper for 5 seconds before dump begins.

Spill initiated - As hopper begins to dump, fuel flows onto floor creating a large flare-up.

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Peak Heat Flux – The maximum recorded heat flux occurs at this point, 7.04 kW/m^2 at 3.0 meters (10 ft) from the center of the fire. Flames cover approximately 9.0 m^2 (100 ft^2) and reach a maximum height of approximately 4.3 m (14 ft).

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0:00 – Hopper dump is complete and full volume of fuel has spilled onto the floor. Approximate area covered by fire is 7.5 m^2 (81 m^2). Mean flame height is approximately 0.6 m (2 ft).

0:53– Fire continues to burn across most of spill area, but flame height and intensity is greatly reduced. Primarily appearing as small, candle-like flames that come up out of holes on top surface of floor.

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1:20 – Area of fire is reduced to approximately 0.8 m^2 (9 ft^2). Heat flux is undetectable to both sensors at this point.

2:33 – Fire is extinguished without intervention, supervising fire fighter gives "all clear" and the floor is cool to touch.

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2.3.2 Heat Flux Data

Summary of Key Data	
Peak Heat Flux	7.04 kW/m^2 at 3.0 meters (10 ft)
Time to Undetectable Heat Flux	1 minute, 20 seconds
Time to Fire Extinguishment	2 minutes, 33 seconds

The maximum recorded heat flux recorded during the test was 7.04 kW/m^2 at 3.0 meters (10 ft). This occurred before the spill was completed, approximately 11 seconds after the spill began.

The maximum temperature recorded by the water-cooled heat flux sensors during the test was 32.9 °C. The maximum recorded ceiling temperature was 121°C at a height of 6 meters (19.7 feet). The ambient temperature inside the test facility before the test was 27.3 °C. The water temperature used for cooling the heat flux sensors was 30.5 °C.

The baseline voltage measurement for the heat flux sensors was 0.003 mV for both sensor 3033 and 3034. Heat flux readings less than 0.003 mV indicate that no additional heat flux is created by the fire. Both sensors fall below this threshold 1 minute and 35 seconds after the spill is completed.

The fire is fully extinguished, and the floor is cool to the touch 2 minutes and 48 seconds after the spill has been completed.

Figure 2-5 shows a comparison of the recorded heat flux during the test compared with previous estimates submitted to the Airport Facilities Technical Committee in a November 2019 test report.

The actual data shows that heat flux peaks are much lower than was previously estimated. The decay in heat flux for both the recorded data and the estimates mirrors the diminishing fire size shown in the Visual Summary above.

Figure 2-6 shows the recorded heat flux from this test, compared to a previously used "delamination curve". This curve represents the threshold, factoring in both heat flux value and exposure time, at which composite aircraft components begin to delaminate. Details for delamination data are provided in the November 2019 test report.

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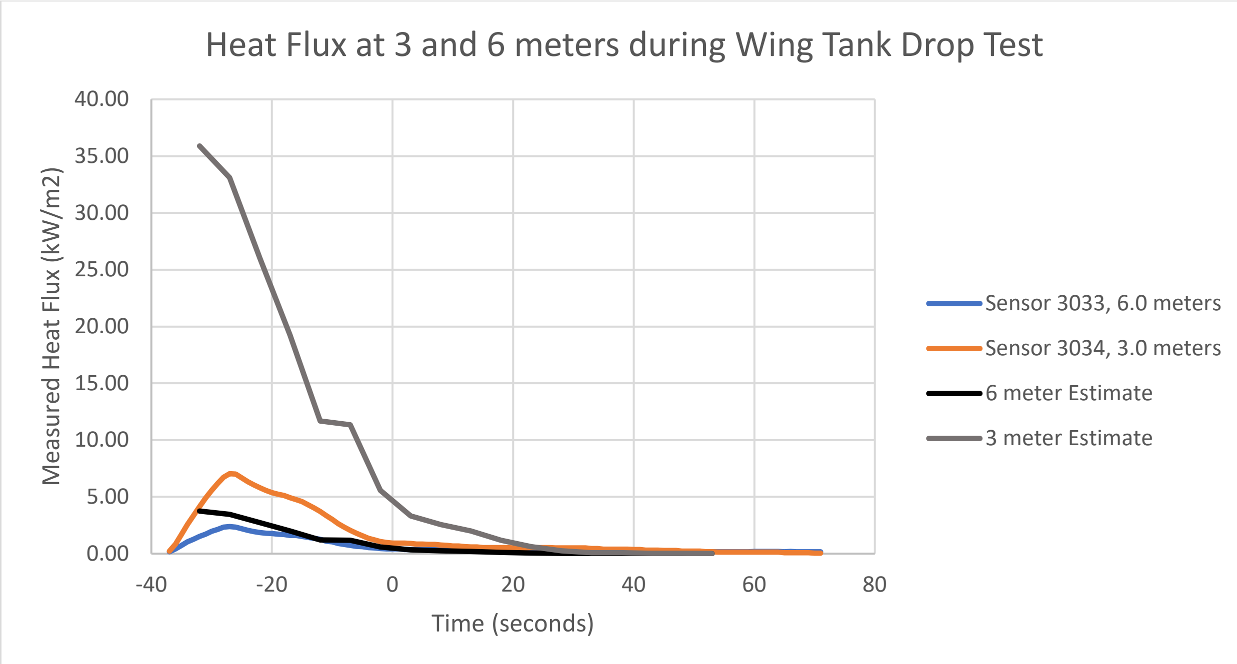

Figure 2-5: Comparison of measured vs estimated heat flux values at 3 meters and 6 meters from wing tank drop test.

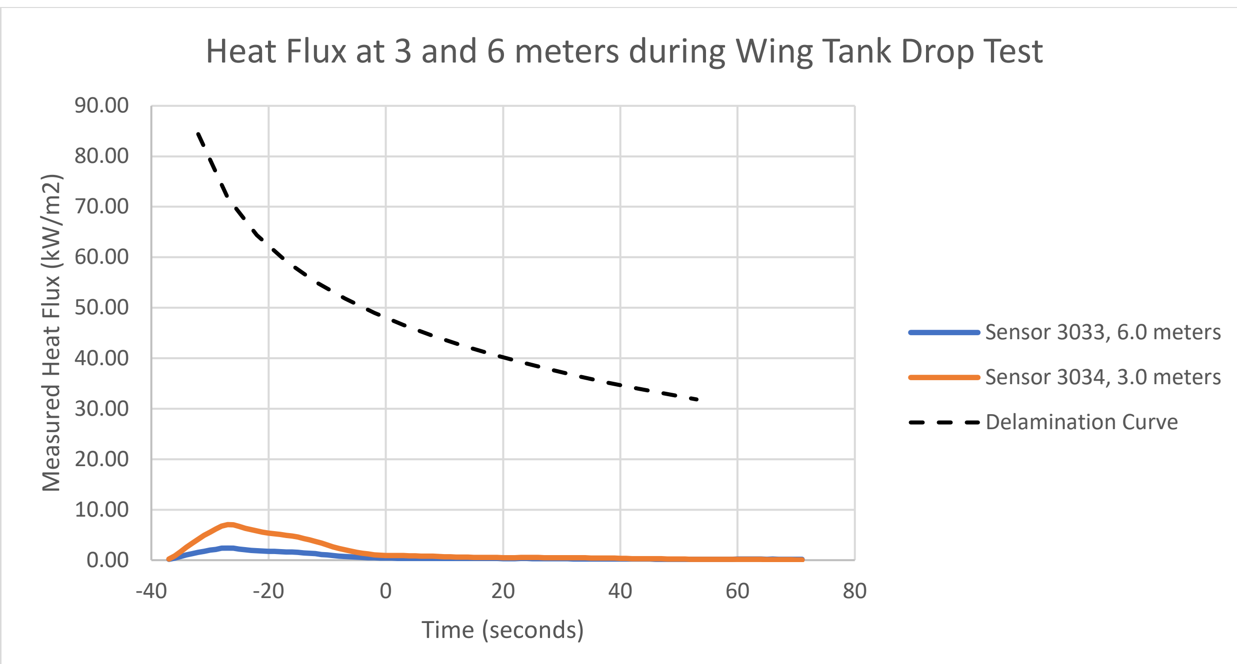

Figure 2-6: Measured heat flux values at 3 meters and 6 meters from wing tank drop test shown in comparison to delamination threshold for composite aircraft components.

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Appendix A: Safespill Test Facility

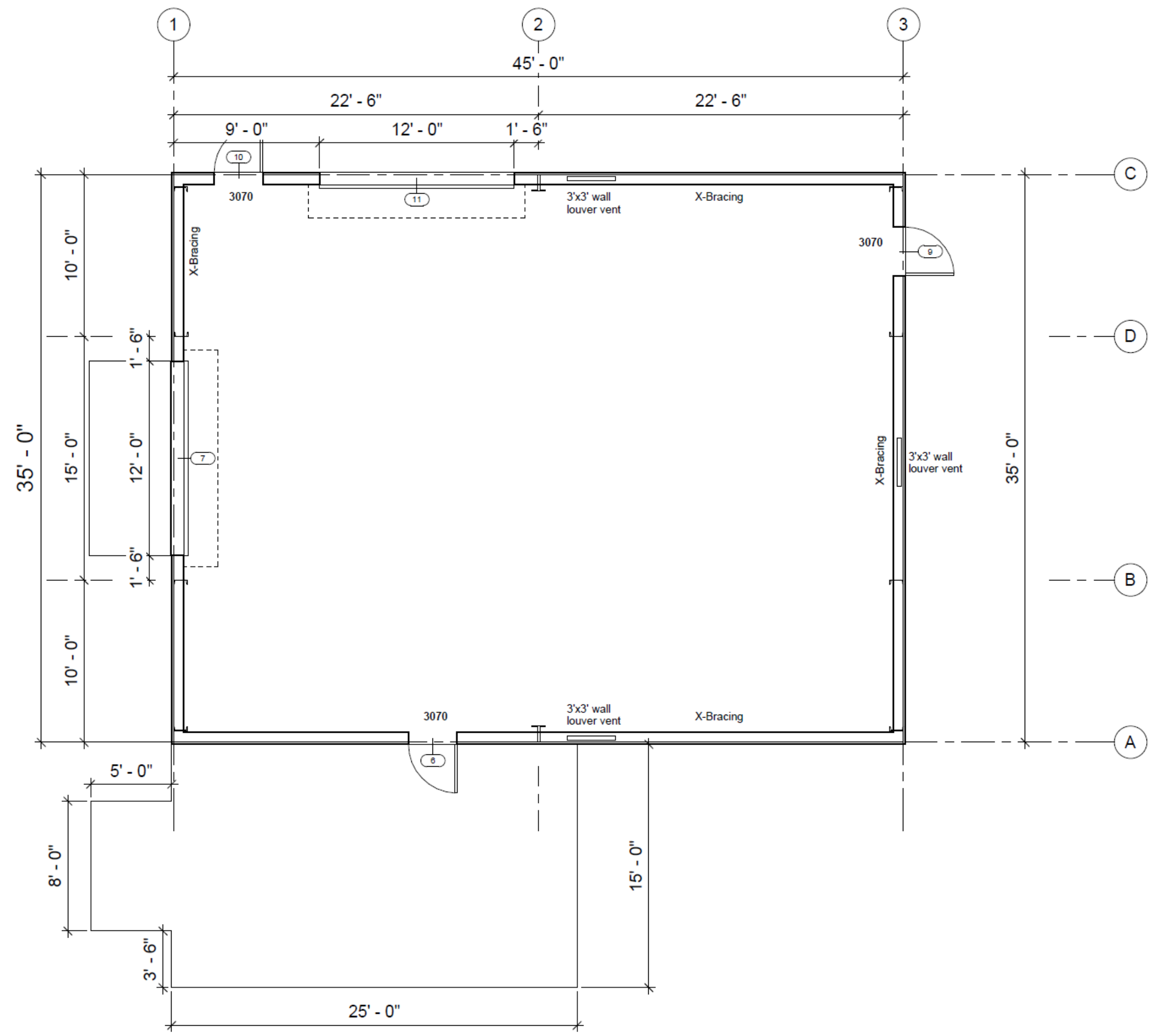

Figure A-1: Bird's Eye View of Test Facility

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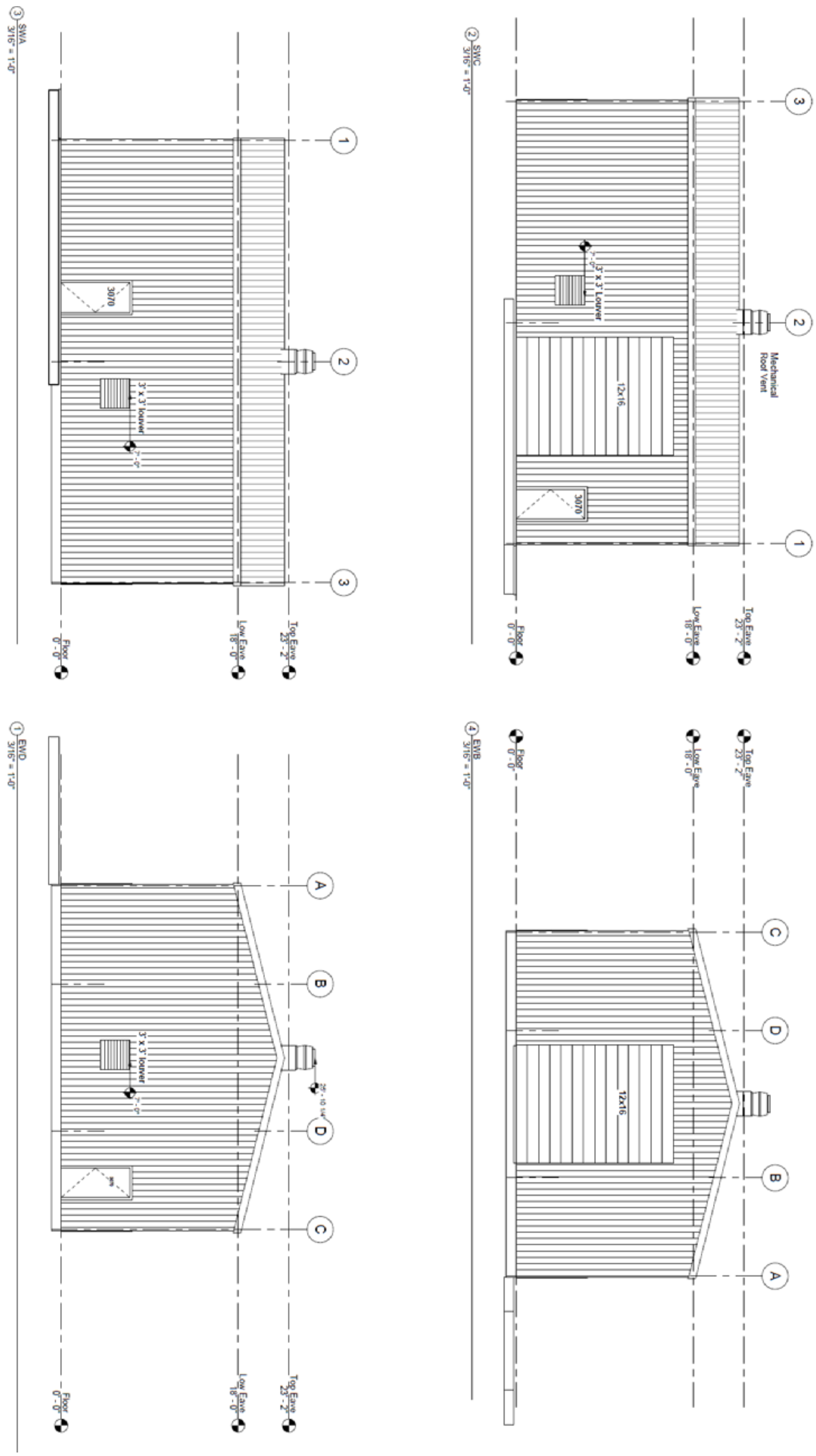

Figure A-2: Side view of testing facility with roof heights

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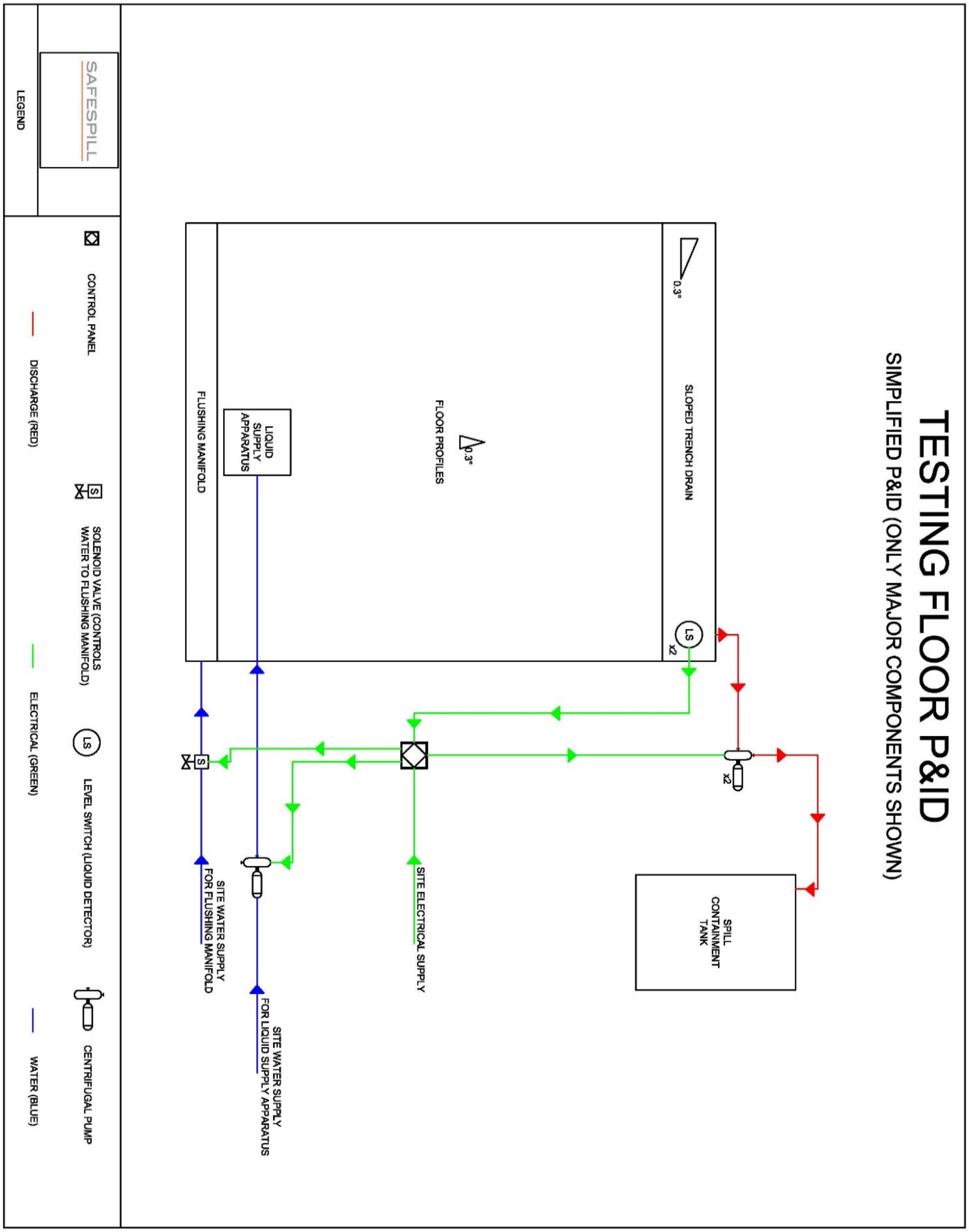
Appendix B: P&ID for Flooring System and Test Equipment



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Appendix C: Calibration Certificates

Hukseflux Thermal Sensors

Hukseflux Thermal Sensors B.V.
www.hukseflux.com
info@hukseflux.com

Product certificate

Pages: 1
Release date: 01 MAY, 2020

Product code	**GG01-250-02**
Product identification	**serial number 3033**
Product type	water cooled heat flux sensor
Measurand	heat flux

Calibration result

Sensitivity	**$S = 24.3 \times 10^{-9}$ V/(W/m^2)**
Calibration uncertainty	**$\pm 1.6 \times 10^{-9}$ V/(W/m^2)**
Reference conditions	$\Phi_0 = 100 \times 10^3$ W/m^2

the number following the ± symbol is the expanded uncertainty with a coverage factor k = 2, and defines an interval estimated to have a level of confidence of 95 percent

Measurement function: $\Phi = U/S$
With Φ heat flux in [W/m^2], U voltage output in [V]

Product specifications

1:	resistance	**1.2 Ω**
2:	rated measurement range	**250×10^3 W/m^2**
3:	cable length	**2 m**
4:	thermocouple	**type K**

Table 0.1 *connections*

WIRE	
Red	signal [+]
Black	signal [−]
Green	thermocouple [+]
White	thermocouple [−]
Grey	shield

Calibration procedure according to Hukseflux SBGC01. Traceability of calibration is to ITS-90.

Please consult the user manual for information on measurement uncertainty during actual use and for product set up, operation and maintenance instructions.

Calibration performed by: M.M.H. Donkers — **Date:** 09 MAR, 2020

Person authorising acceptance and release of product: J.M. Konings — **Date:** 01 MAY, 2020

GG01-250 product certificate — page 1/2

Hukseflux Thermal Sensors

Hukseflux Thermal Sensors B.V.
www.hukseflux.com
info@hukseflux.com

Measurement range test

Pages: 2
Release date: 01 MAY, 2020

Product code	**GG01-250-02**
Product identification	**serial number 3033**
Product type	water cooled heat flux sensor
Measurand	heat flux

Characterisation result

Heat flux **[x 10^3 W/m^2]**	Voltage output **[x 10^{-3} V]**
133.4	3.16
256.8	5.94

Measurement process

Measurement method	Hukseflux Gardon Gauge Characterisation
Measurement equipment	GGC01
Measurement process	Heat flux from a heated graphite plate is measured by a reference instrument and the test instrument simultaneously. Heat flux is increased in steps of about 100 kW/m² till the rated measurement range.
Reference instrument	64-100-20 168973

Conformity assessment

Description of assessment	The ratio between test instrument voltage output and heat flux is calculated for each setpoint. Variation is defined as the maximum difference in ratio from the average
Acceptance interval	The maximum allowed variation is specified at ± 5 %
Conclusion	Conformity verified

Person performing measurement range test: M.M.H. Donkers — **Date:** 09 MAR, 2020

GG01-250 product certificate — page 2/2

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Hukseflux
Thermal Sensors

Hukseflux Thermal Sensors B.V.
www.hukseflux.com
info@hukseflux.com

Product certificate

Pages: 1
Release date: 01 MAY, 2020

Product code	**GG01-250-02**
Product identification	**serial number 3034**
Product type	water cooled heat flux sensor
Measurand	heat flux

Calibration result

Sensitivity	**$S = 22.3 \times 10^{-9}$ V/(W/m²)**
Calibration uncertainty	**$\pm 1.5 \times 10^{-9}$ V/(W/m²)**
Reference conditions	$\Phi_c = 100 \times 10^3$ W/m²
	the number following the ± symbol is the expanded uncertainty with a coverage factor k = 2, and defines an interval estimated to have a level of confidence of 95 percent
Measurement function	$\Phi = U/S$ With Φ heat flux in [W/m²], U voltage output in [V]

Product specifications

1:	resistance	**1.2 Ω**
2:	rated measurement range	**250×10^3 W/m²**
3:	cable length	**2 m**
4:	thermocouple	**type K**

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WIRE	
Red	signal [+]
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Calibration procedure according to Hukseflux SBGC01. Traceability of calibration is to ITS-90.

Please consult the user manual for information on measurement uncertainty during actual use and for product set up, operation and maintenance instructions.

Calibration performed by:
M.M.H. Donkers
Date:
09 MAR, 2020

Person authorising acceptance and release of product:
J.M. Konings
Date:
01 MAY, 2020

GG01-250 product certificate page 1/2

Hukseflux
Thermal Sensors

Hukseflux Thermal Sensors B.V.
www.hukseflux.com
info@hukseflux.com

Measurement range test

Pages: 2
Release date: 01 MAY, 2020

Product code	**GG01-250-02**
Product identification	**serial number 3034**
Product type	water cooled heat flux sensor
Measurand	heat flux

Characterisation result

Heat flux [x 10^3 W/m²]	Voltage output [x 10^{-3} V]
130.9	2.89
248.2	5.32

Measurement process

Measurement method	Hukseflux Gardon Gauge Characterisation
Measurement equipment	GGC01
Measurement process	Heat flux from a heated graphite plate is measured by a reference instrument and the test instrument simultaneously. Heat flux is increased in steps of about 100 kW/m² till the rated measurement range.
Reference instrument	64-100-20 168973

Conformity assessment

Description of assessment	The ratio between test instrument voltage output and heat flux is calculated for each setpoint. Variation is defined as the maximum difference in ratio from the average
Acceptance interval	The maximum allowed variation is specified at ± 5 %
Conclusion	Conformity verified

Person performing measurement range test:
M.M.H. Donkers
Date:
09 MAR, 2020

GG01-250 product certificate page 2/2

Graphtec America, Inc.
17462 Armstrong Ave, Irvine, CA 92606
INST.SUPPORT@GRAPHTECAMERICA.COM
TELEPHONE: 888-378-3247

Certificate No.: NASO # 119336

Certificate Of Calibration
For
SAFESPILL SYSTEMS
8733 KNIGHT RD
HOUSTON TX 77054

Model No.: GL240 **Type:** MIDILOGGER
S/N: C91234507

Calibration Date: 5/7/2020 **Calibration Interval:** 12 MONTHS **Recall Date:** 5/7/2021

Arrival Condition: NEW PRODUCT **Returned Condition:**

Temperature: 74 **Degrees F** **Humidity:** 45 **Percent**

Procedure Manufacturer Service Manual: GL240_UM25101

Standards Used

DC Standard:	330	**S/N**	12867	**Calibration Date**	12/4/2019
Temperaure Sim	1120	**S/N**	25548	**Calibration Date**	12/4/2019

Detail of Work Performed:

The results contained herin relate only to item calibrated. This certificate shall not be reproduced, except in full, without the written approval of Graphtec America, Inc.

The standards used to perform this calibration are traceable to the National Institute of Standards and Technology.

Work Performed By: YEN DANG x Yen Dang

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Appendix D: Pump Curve for AMT 4", 15 HP Centrifugal

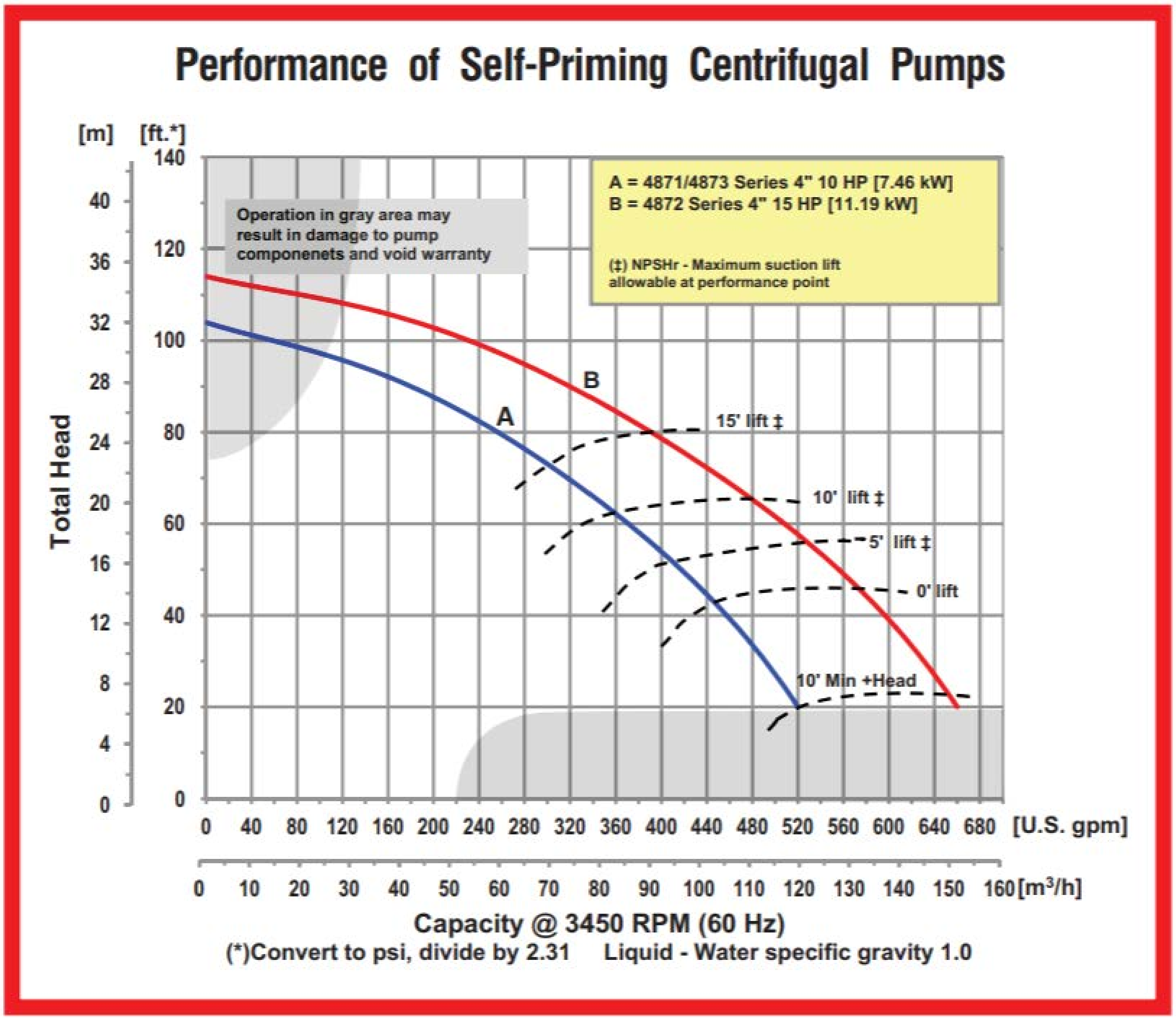

Figure B-1: Pump curve for pumps used in testing is pump curve "B". Testing conducted with Model # 4872, 15 HP.

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