Low-Pressure Water Mist in Protection of Aircraft Hangers

Jesse Comino

DMA Engineers

Presentation Overview

- Aircraft Hangars & the Hazard
- Limitations of the Traditional Design Approach
- Risk-Based & Performance-Based Approaches
- Low-Pressure Water Mist Principals of Operation
- Suitability of Water Mist System for the Hazard
- System Installation & Design Considerations

About the Speaker

Jesse Comino

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- Master of Fire Safety Engineering, Western Sydney University (2024)
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- Diploma of Fire Systems Design CPC50520

AFFILIATIONS:

- Member of FPAA
- Member of Engineers Australia (MIEAust)
- Chartered Professional Engineer (CPEng)
- Registered Professional Engineer of Queensland (RPEQ) 27168
- FPAS FSD (Qualified) F055626D

About DMA Engineers:

Our Key Services:

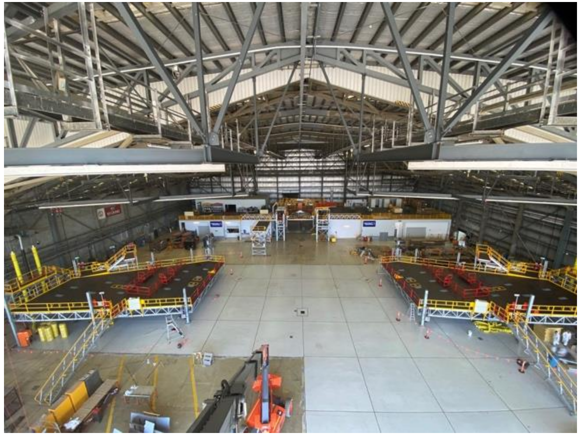
Fire Safety | Hydraulics | Mechanical | Electrical | Vertical Transportation | Fire Protection | ESD

- Master Planning & Advisory
- System Design, Documentation & Certification
- Fire Safety Strategies and Performance Solutions

Aircraft Hangars

- Typically large, open spaces with high ceiling
- Operable external doors (typically open) allow high air movement (esp. in windy conditions)
- Often used for the storage of multiple aircraft of fixed types, quantities & stored locations
- May store fuelled or non-fuelled aircraft depending on hangar use & activities
- Hangar buildings may also incorporate areas of storage or administrative offices

BAC – VirginBlue Hangar *[image courtesy RCP (2006)]*



BAC – Hangar 1
[image courtesy COX Architecture (2022)]

Aircraft Hangars - Authorities

Responding Fire Brigades may include:

- Aviation Rescue Fire Fighting Service (ARFF), and/or
- Local brigade (FRV, CFA, MFS, FRNSW, QFD, etc.)

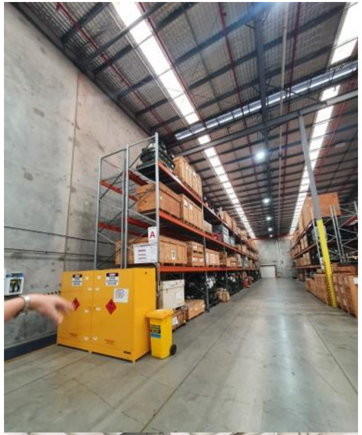
Additional Authorities:

- Airport Building Control (ABC)
- Civil Aviation Safety Authority (CASA)
- Australian Transport Safety Bureau (ATSB)
- Department of Defence

ARFF stations & fleet
[images courtesy AirServices Australia (2026)]

Aircraft Hangars - Hazards

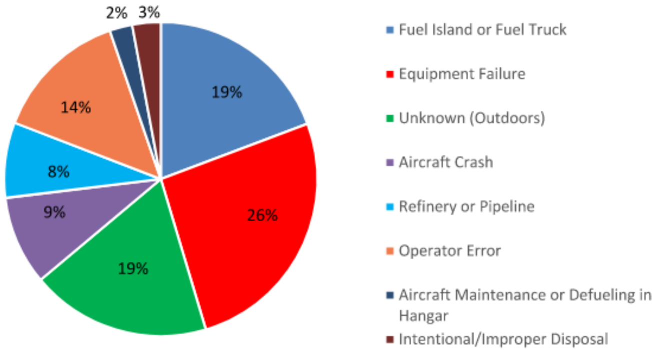
- Class A combustibles
- Aircraft Maintenance activities
- Electrical failures
- Stored Fuels – type is dependent on aircraft, quantities limited where present
- Fuel Spills - Pool Fires (supplied or non-supplied)



Fuel Spills – Cause & Frequency

	Year					
Circumstance	**2016**	**2017**	**2018**	**2019**	**2020**	**Total**
Spills Not in Hangars						
Fuel Island or Fuel Truck	24	32	52	25	31	164
Equipment Failure	77	32	50	41	24	224
Unknown (Outdoors)	50	32	31	24	23	160
Aircraft Crash	17	10	10	23	18	78
Refinery or Pipeline	3	16	20	14	13	66
Operator Error	26	22	28	31	13	120
Intentional/Improper Disposal	6	6	6	1	6	25
Total Spills not in Hangars	**203**	**150**	**197**	**159**	**128**	**837**
Spills in Hangars	**3**	**2**	**4**	**8**	**8**	**25**
Total Spills	**206**	**152**	**201**	**167**	**136**	**862**

Causes and Frequency of Jet Fuel Spills in 2016-2020 (USCG, 2020)



Cause of Jet Fuel Spills in 2016-2020 (USCG, 2020)

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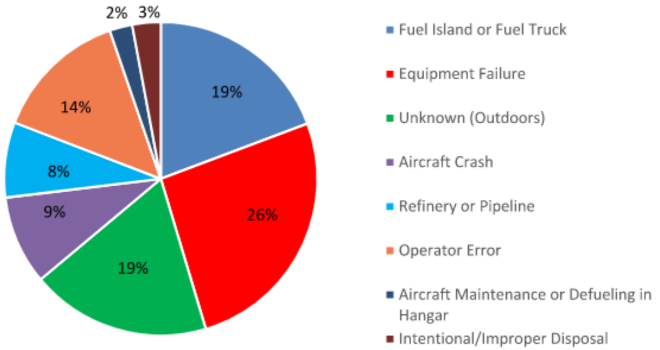

Cause of Jet Fuel Spills in 2016-2020 (USCG, 2020)

~3% of spills 2016-2020 were located within the Hangar

Current Fire Protection Design Approach

- Building Code of Australia (NCC 2022)

  E1D13 dictates when sprinklers are required

  (generally, occupancies of excessive hazard & fire compartments > 2,000m^2 or > 12,000m^3)

- Design Standards:

  → Australian Standard 2118.1-2017

  → High Hazard Occupancy Class

  → Zone Deluge System to AS 2118.3-2010

  → AS 2118.3-2010

  → Table 2.3.2 refers to NFPA standards for design guidance.

  → Clause 2.3 requires Aircraft Hangar Deluge Systems to conform to **NFPA 409** requirements

  → NFPA 409 - Standard on Aircraft Hangars

NFPA 409

- Categorises Hangars into four Groups (Groups I, II, III, IV) based on:
  - Hangar Door Height
  - Floor Area of Largest Single Fire Compartment
  - Construction Type

	Hangar Group			
Fire Suppression System Options	I	II	III	IV
Foam-water deluge system	*[a]	*[a]	*[a,b]	
Combination of automatic sprinkler protection and automatic, low-level, low-expansion foam system	*	*	*[b]	
Combination of automatic sprinkler protection and automatic, high-expansion foam system	*	*	*[b]	
Closed-head foam-water system		*	*[b]	
Water only sprinklers, low-expansion foam or high-expansion foam				*[c]
Combination of automatic sprinkler protection and an ignitable liquid drainage floor assembly	*[a]	*[a]	*[a,b]	*[c]

[a] Where the wing area exceeds 279 m^2 (3,000 ft^2) supplementary protection is required because of concerns of shielding of the fire that may be provided aircraft wings.

[b] Only required if hazardous operations occur in the hangar or required by local codes.

[c] Only required if floor area is greater than 1,115 m^2

Summary of Fire Suppression System Options for Group I-IV Hangars with Fueled Aircraft
(Fire Protection Research Foundation (2022))

NFPA 409

- Categorises Hangars into four Groups (Groups I, II, III, IV) based on:
  - Hangar Door Height
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Primary acceptable fire protection method is the use of a foam or foam-water type system

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Benefits of Foam Firefighting Systems

- Highly effective suppression of Class A & B fires
- Suitable for the fire suppression of liquid hydrocarbon fuels
- Rapid extinguishment and prevention of re-ignition via blanketing

High-Expansion Foam Deluge System Discharge
[image courtesy Global Aerospace (2026)]

Foam Firefighting Systems - Limitations

- Environmental & Health Considerations
    - Handling
    - Containment (bunding & storage)
    - Cleanup & Disposal
- Damage to Stored Aircraft / Equipment
- Accidental Discharge Risk
    - Occupants
    - Downtime
- Foam Sourcing & Supply

KSA Hangar Foam Containment Storage
[image courtesy Atlan Stormwater (2026)]

Accidental vs Intentional Discharge Risks

2021 Survey data:

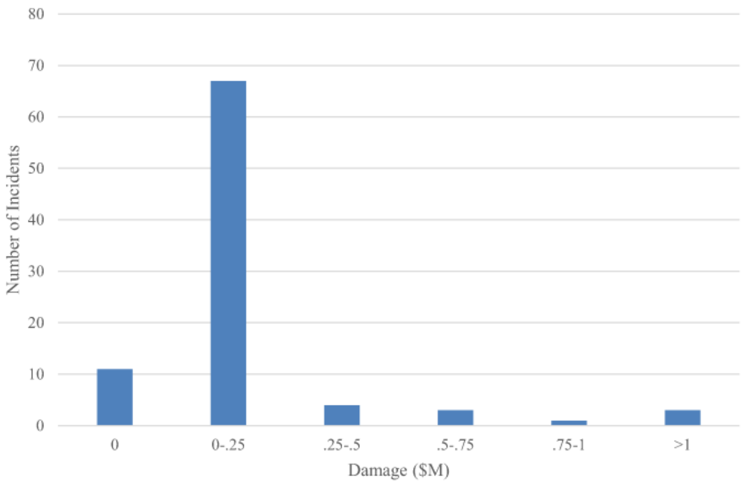
- Number of Discharge Incidents Total: 233
- Number of Accidental Discharges: 201
- Number of Discharge Incidents which involved a fire: 1 Confirmed, 31 unknown
- **Number of Discharge Incidents which were confirmed to involve a pool fire: 0**

Source: Milke, et al., 2021

Data sourced from US DoD, Commercial Airliner, US Coast Guard (USCG) incident databases, dated between 2004-2020.

Damage from Accidental Foam Discharges

Total Damage ($USD, Million)	Number of Incidents
0	11
0 - 0.25	67
0.25 - 0.5	4
0.5 - 0.75	5
0.75 - 1	2
> 1	3

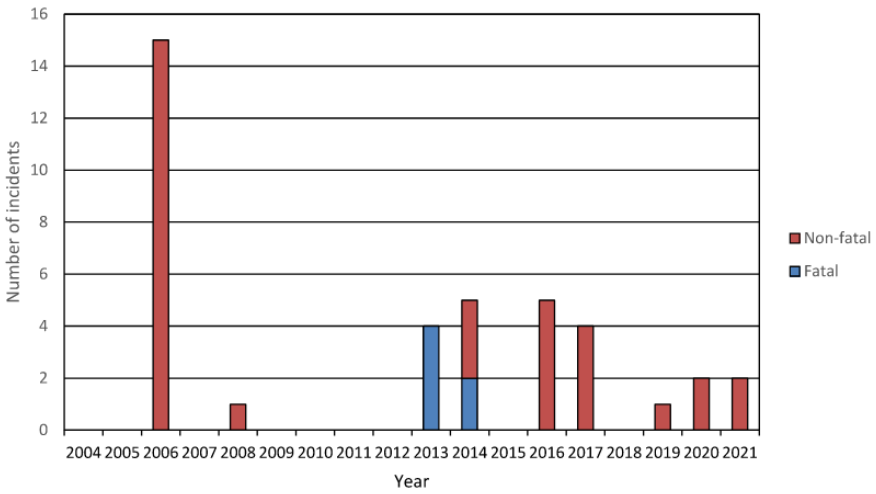


Source: Milke, et al., 2021

Average reported loss: **$110K USD / incident**

Injuries due to Foam Discharges

- 38 casualties 2006-2021
- 50% of casualties **due to accidental foam discharge**
- 2 fatalities **due to accidental foam discharge**



Source: Fire Protection Research Foundation (2022)

NFPA 409 – Risk/Performance-Based Approaches

- NFPA 409 2022 includes consideration for non-prescriptive design approaches:
  - Fire-Risk-Based Approach, or
  - Performance-Based Design Approach

Methodology for both includes:

1. Fire Risk Assessment,
2. Licenced Engineer Documents proposal incl. risk assessment
3. AHJ Review and Approval
4. Optional 3rd-Party Peer Review

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Very similar to the NCC Performance Solution Process!

Benefits of Low-Pressure Water Mist

- Water-based suppression system only
- Low operating pressures require typical PN16 pressure-rated pipework
- Little/no containment/cleanup due to accidental discharge
- No exposure risks
- Rapid system reset after activation
- Simple wet system maintenance regime

Low-Pressure Water Mist

- Water-based suppression system
- Maximum system pressures 1,200kPa
- Nozzles form water droplets between 1000 µm and 10 µm diameter (NFPA 750)
- Droplets penetrate fire plume via droplet momentum
    - High surface area ratio improves evaporation but decreases droplet mass
    - Trade-off exists between plume penetration and surface area

System Type	Typical Droplet Size (µm)
AS2118.1 / NFPA Sprinkler System	~1000 – 3000
Low-Pressure Water Mist	~100 – 1000
High-Pressure Water Mist	~5 – 200

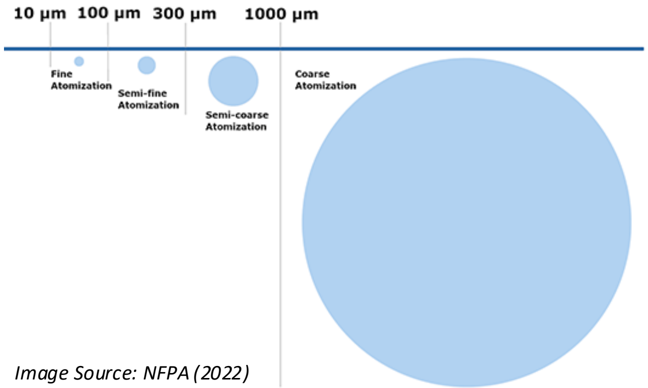


Image Source: NFPA (2022)

Principals of Water Mist Fire Suppression

Primary Mechanisms:

(1) Heat Extraction

- Cooling of fire plume & fire compartment
- Wetting of fuel surface & adjacent combustibles

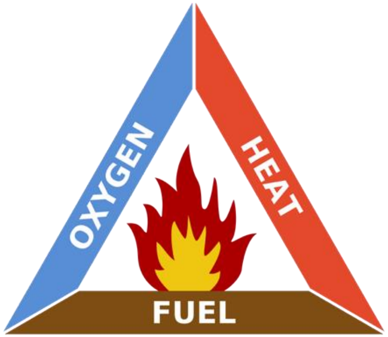
(2) Displacement

- O2 displacement via volume expansion
- Dilution of fuel vapours

Secondary Mechanisms:

(1) Radiation attenuation

(2) Kinetic effects



Liu, Z., & Kim, A. (2000).

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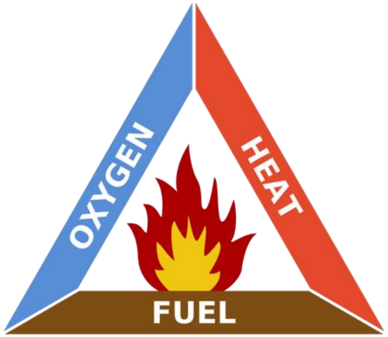


Key mechanisms of water mist in the suppression of fires involving liquid hydrocarbon fuels (B.H. Cong, G.L, 2007)

Effectiveness of Water Mist

- B.H. Cong, G. L. (2007) found **effective water-only fire suppression** of both **diesel and gasoline pool fires** via application of water mist, noting **fuel surface-cooling is key.**
  - Surface temperatures of the fuel were found to be maintained below 120°C experimentally
- Optimum droplet size is a function of fuel, compartment, degree of obstruction
- Superior performance is obtained with an even distribution of both fine and coarse droplet sizes (Liu, Z., & Kim, A., 2000)
- NPFA 750 cites research which has found that fine water droplets (<400 µm) are essential for extinguishment of Class B fires

Previous Testing

Currently, there are no standardised tests for protection of aircraft hangars with water mist to obtain approvals.

However:

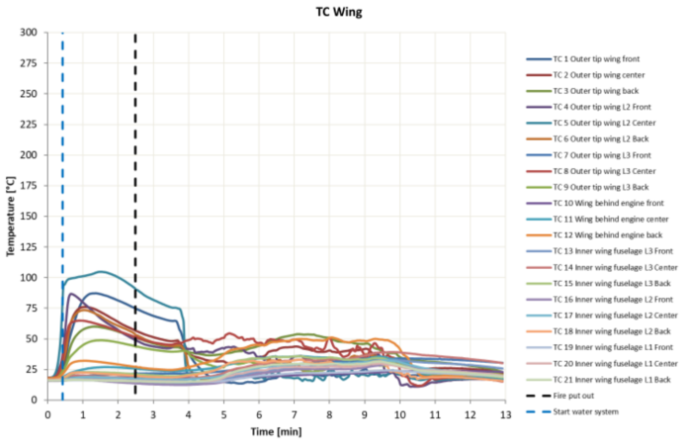
- Several manufacturers have tested low-pressure water mist system designs in aircraft hangars with good extinguishment results
- Water mist nozzles have been tested in large unenclosed spaces, with ceiling heights of up to 15 m (50 ft). (Steranka, 2021)
- FM Global testing and certification of various water mist nozzles has been achieved for the protection of combustible liquid fires in machinery, turbine, and local applications

Previous Testing

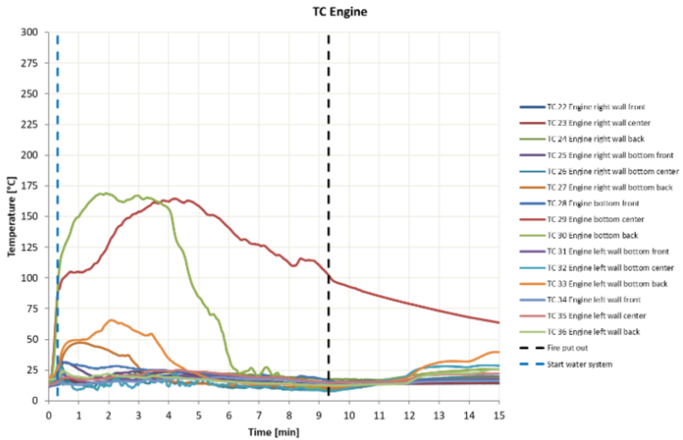
- For hangars with taller ceiling heights, tests have been conducted with nozzles installed at floor level, recessed into hangar flooring.
- Floor nozzles have shown to be useful to provide underwing protection (Steranka, 2021)

Image Source: RISE Fire Research (2021)

Previous Testing



- 1m² 6L Jet Fuel pool fire
- 20 sec pre-burn time
- Fire located under wing, outside engine



- 4m² 20L Jet Fuel pool fire
- 25 sec pre-burn time
- Fire located under engine

Source: RISE Fire Research (2021)

System Installation

Mist System Design Considerations

- Operation of the system
  - Initiation
  - Mist System Zoning
  - Duration of Operation
- Building Use & Nozzle Layout
- Water Supply Sizing & Performance
- Drainage
- Ongoing System Maintenance

Fire Brigade Considerations

Consultation is required with local fire brigade(s), including:

- System suitability
- Brigade response preferences
- System monitoring
- System redundancies
- Brigade boost facilities
- Isolations & Controls

Summary

Through:

- effective stakeholder consultation, and
- a practical design approach,

the use of **low-pressure water mist is a suitable and superior solution** for fire suppression within aircraft hangars

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