Review of Foam Fire Suppression System Discharges in Aircraft Hangars

by

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Acknowledgement

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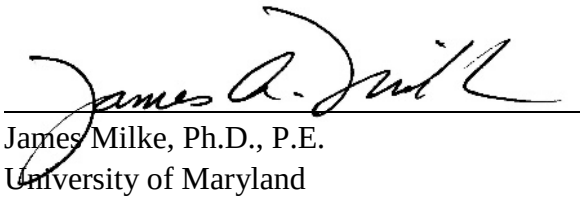
Signatures



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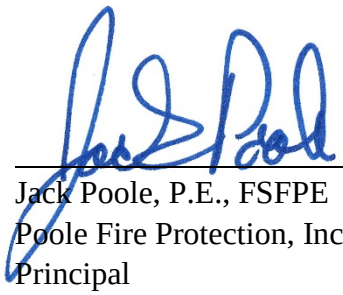

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Executive Summary

This report is a product of a research study on the impacts of low-expansion foam, high-expansion foam and deluge systems in aircraft hangars. A survey was conducted to determine the circumstances and losses associated with incidents involving foam system discharges experienced by commercial airlines and the US Department of Defense (US DoD). A review of fuel spills in the database compiled by the US Coast Guard (USCG) was conducted to determine how many fuel spills occurred in hangars. Finally, a scan of data from fire incidents from 2009-2018 included in the National Fire Incident Reporting System (NFIRS) was conducted to identify fires in hangars.

The review of the NFIRS data resulted in the identification of fourteen incidents that involved an aircraft in a "parking structure." However, no data was available for these incidents on whether an automatic extinguishing system (AES) was present, what type of AES was installed, and if the AES operated, so no further analysis could be done relative to the performance of installed foam systems.

In the review of 5 years of data in the USCG database, 851 incidents were found to involve a fuel spill, though only 5 spills occurred inside a hangar, with a resulting annual rate of 1 incident per year. The 5 spills in hangars represents 0.6% of the total number of spills. The USCG database does not identify if any fires occurred in any of the spill incidents.

From the survey of incidents compiled by the research team, a total of 245 incidents were reported from the commercial airlines and US DoD. A total of three incidents involving fire were included in the incidents reported back to the 1960's. Of the 245 incidents reported, 233 were included in a 17-year window (one database included an incident from the 1960's). In that 17-year window, only one incident where the foam system discharged was in response to a fire while 201 incidents were accidental in nature, with a known cause and no fire was present to motivate the activation (the cause of the activation was unknown in 31 of the incidents). Overall, an average of 11.8 accidental foam discharges occurred per year. The trend of the frequency of accidental hangar foam system discharges is increasing by almost one incident each year. The most common cause of the accidental discharge was a failure of the suppression system of unspecified cause.

1. Background

This report supplements data included a previous report (Milke, et al., 2019). The previous report outlined code requirements for fixed foam fire suppression systems in Group II[1] aircraft hangars and analyzed the performance of the fixed foam fire suppression systems in those applications. The research team requested incident reports of discharges of foam fire suppression systems from several insurance companies and Fixed Base Operators (FBOs) who provide coverage for either the aircraft and/or aircraft hangar. Damage estimates for aircraft and the building/building systems were requested in the form, along with cause of the discharge and cause of the fire.

In the current project, the survey was expanded to include incidents experienced by commercial airlines and the US DoD. In addition, a search of fire incidents in aircraft hangars was conducted in the National Fire Incident Reporting System (NFIRS) and a review was conducted of data on fuel spills compiled by the U.S. Coast Guard (USCG).

2. Survey Methodology to Collect Foam System Field Data

The research team requested incident reports of discharges of foam fire suppression systems from commercial airlines, US DoD and insurance companies. A form to facilitate data reporting, *The Data Collection Form, Foam Suppression System Discharge Analysis*, developed by the University of Maryland (UMD) was provided to each of the participating organizations. The data form is included in the Appendix. Damage estimates for aircraft and the building/building systems were requested in the form, along with cause of the discharge and cause of the fire.

3. Data Analysis

3.1 NFIRS Data

An analysis of the National Fire Incident Reporting System data from the years 2009 through 2018 was conducted. First, this data was sorted for incidents occurring in other vehicle storage, including airplane and boat hangars and excluding parking garages. In order to narrow this field down to incidents occurring in aircraft hangars, a second sort was conducted for incidents involving an aircraft. In the ten years examined, fourteen incidents occurred

[1] A Group II aircraft hangar is classified in NFPA 409 (NFPA 2016) as a hangar with an aircraft access door height of 28 ft or less and a single fire area limited by the type of construction. More details of the definition of Group II hangars are provided in Section 1.1 of this report.

under the circumstances outlined above. However, there was no available data for these incidents on whether an automatic extinguishing system (AES) was present, what type of AES was installed, and if the AES operated, so no further analysis could be done relative to the performance of installed foam systems.

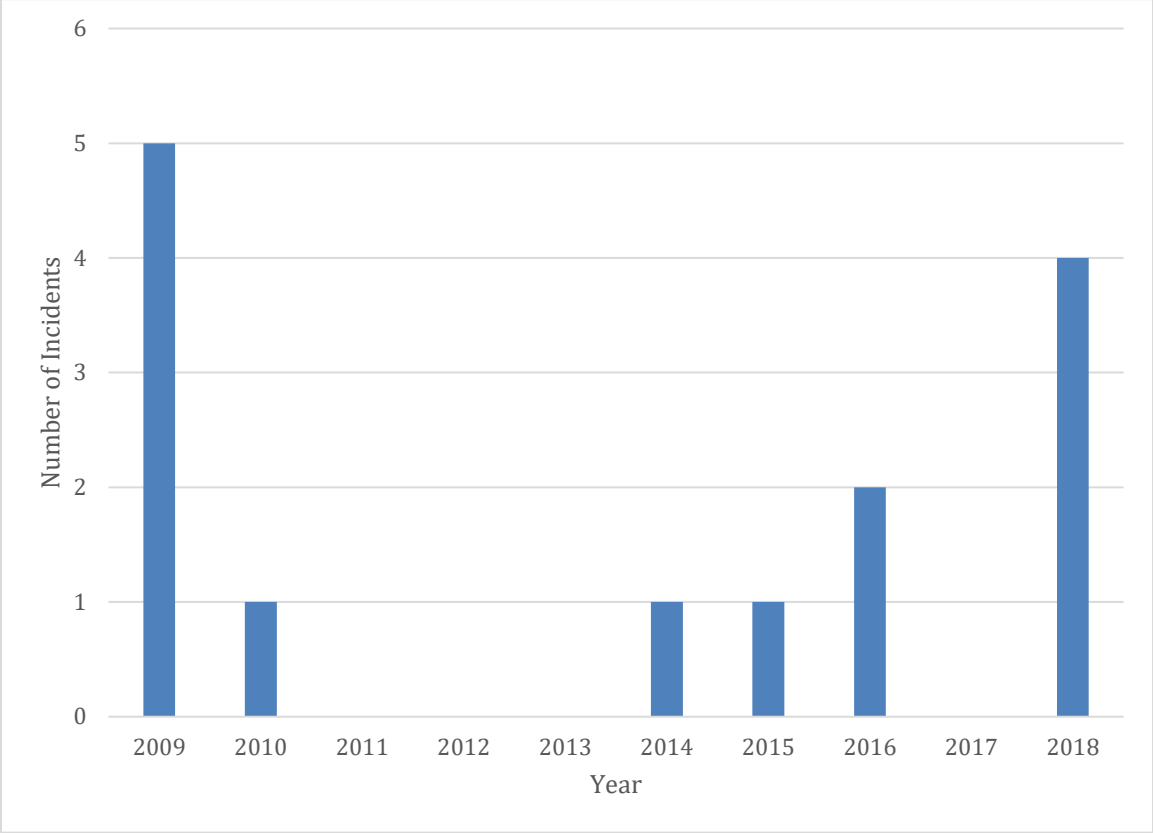

Figure 1. Fire Incidents in Parking Facilities that Included an Aircraft

3.2 U.S. Coast Guard Data

United States Coast Guard collects data on all hazardous liquid spills, including fuel spills, in the U.S. USCG data from January 2016 to November 2020 was reviewed to assess the frequency and location of fuel spills in hangars (as compared to all other locations) (USCG, 2020). The distribution of the cause of the fuel spill by year is presented in Table 1 and Figure 2. Of the 851 incidents observed during almost five full years, only 5 spills have been found to have occurred inside a hangar, resulting in an annual rate of approximately 1 incident per year. The 5 fuel spills in hangars represents 0.6% of the total number of fuel spills. The USCG database does not identify if any fires occurred in any of the incidents involving fuel spills.

Table 1. Causes and Frequency of Jet Fuel Spills in 2016-2020 (USCG 2020)

	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	22	222
Unknown (Outdoors)	50	32	31	24	21	158
Aircraft Crash	17	10	10	23	18	78
Refinery or Pipeline	3	16	20	14	13	66
Operator Error	26	22	28	31	11	118
Aircraft Maintenance or Defueling in Hangar	2	1	2	8	7	20
Intentional/Improper Disposal	6	6	6	1	6	25
Total Spills not in Hangars	**205**	**151**	**199**	**167**	**129**	**851**
Spills in Hangar	**1**	**1**	**2**	**0**	**1**	**5**
Total Spills	**206**	**152**	**201**	**167**	**130**	**856**

As indicated in Table 1 and Figure 2 the leading cause of all 856 jet fuel spills in the U.S. over the last 5 years is equipment failure. The term "equipment failure" refers to a variety of events such as leakage from oil tanks, aircraft fuel tank malfunction, and failure of internal fueling lines.

The descriptions of the five incidents of fuel spills which occurred in hangars are:

- 3 of the incidents occurred when maintenance was being conducted
- 1 incident occurred when an aircraft valve was opened (the reason for the valve being opened was not reported)
- 1 incident occurred when the fuel valve was rotated (the reason for the valve being rotated was not reported)

The next most frequent causes of spills are those caused by activities at a fuel island or fuel truck and then operator error. It is also noteworthy that 18.6% of incidents have an unknown cause.

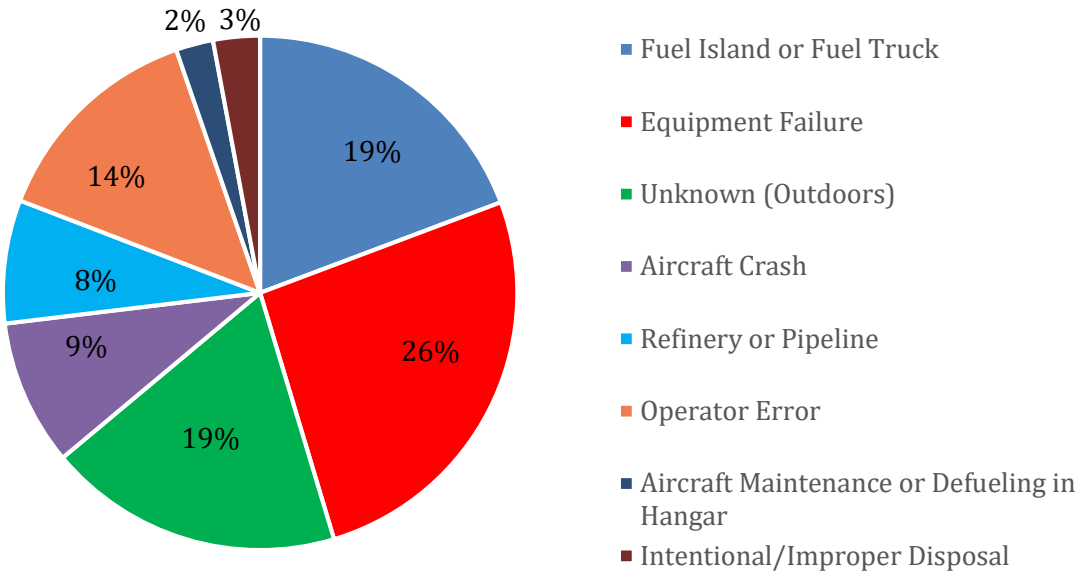

Figure 2. Cause of Jet Fuel Spills in 2016-2020 (USCG, 2020)

3.3 UMD Survey

Analysis of the provided incident report data began with a review to determine if multiple reports were received from two sources for the same incident. In a limited number of cases, using the date and location of the incident, the research team recognized that two incident reports had been filed related to the same incident. These duplicate incidents were thus combined into a single incident.

A total of 245 incidents were reported from the commercial airlines and US Department of Defense (DoD). The DoD compiled information for incidents dating to about 1960. A total of 229 incidents were included in the DoD database. A total of 16 incidents were reported in facilities operated by commercial airlines. The causes for the 245 incidents are summarized as follows:

- 3 incidents include a discharge in response to a fire (all at DoD facilities)
- 214 incidents include a discharge with no fire present, i.e. an accidental discharge
- 31 incidents include a discharge due to an unknown cause[2]

[2] While the presence of a fire would likely have been noteworthy, no information on the cause of these activations is available. Hence, the reason for discharge, i.e. whether in response to a fire or accidental, cannot be stated definitively.

Having received reports of 217 total incidents with a known cause, the 3 incidents that occurred in response to a fire represent 1.4% of the total number of reported incidents.

Reviewing the dates of the incidents included in the DoD database, incidents appear to be reported sporadically from the 1960's until 2004. In 2004 to 2020, there are more regular entries of foam discharges in hangars suggesting that more attention was being given to entering any incident involving a foam discharge in the DoD database. As such, the remainder of the analysis in this report will focus on the 17-year period of 2004 to 2020.

Twelve of the incidents reported among the 245 total number of incidents reported occurred prior to 2004. Eleven of the twelve incidents occurred in DoD facilities, while one was in a hangar operated by commercial airline. A summary of the incident reports of foam system discharges from 2004 to 2020 is included in Table 2. Considering that only one of the 205 incidents with a known cause involved a discharge in response to a fire. That one incident represents only 0.5% of the incidents.

Table 2. Summary of All Incidents Obtained in UMD Survey, 2004-2020

	DoD	Commercial	Total
Discharge due to fire	1	0	1
Accidental discharge	189	12	201
Unknown cause	28	3	31
Total	**218**	**15**	**233**

The annual average number of accidental discharges with a known cause from 2004 to 2020 is 11.8 discharges per year. The trend of the frequency of accidental hangar foam system discharges is increasing by almost one incident each year. The most common cause of the accidental discharge was a failure of the suppression system[3]. A distribution of the year in which incidents involving accidental discharges occurred and the trend line are included in Figure 3. This graph depicts 201 incidents for all 17 years and does not include any incidents of an unknown cause or an unknown year. The trendline provided in Figure 3 has a slope of approximately 0.895 incidents per year, meaning that the frequency of an accidental hangar foam system discharge is increasing by almost one incident each year.

Of the examined incidents, only 89 incidents reported a monetary damage value. The value of damage reported appears to be only the damage to the contents and the hangar itself. In no case was the cost of clean-up included in any of the incident reports provided via the UMD survey. Consequently, the damage estimates presented throughout this report only represent a portion of the loss, rather than the total cost of the incident. Therefore, the total cost is

[3] The cause or nature of the suppression system failures was not identified.

expected to be much greater than the presented damage value in this report, given that neither clean-up nor environmental impact were included. For those incidents that did not report a monetary damage value, it is likely that a cost was at least associated with the cleanup.

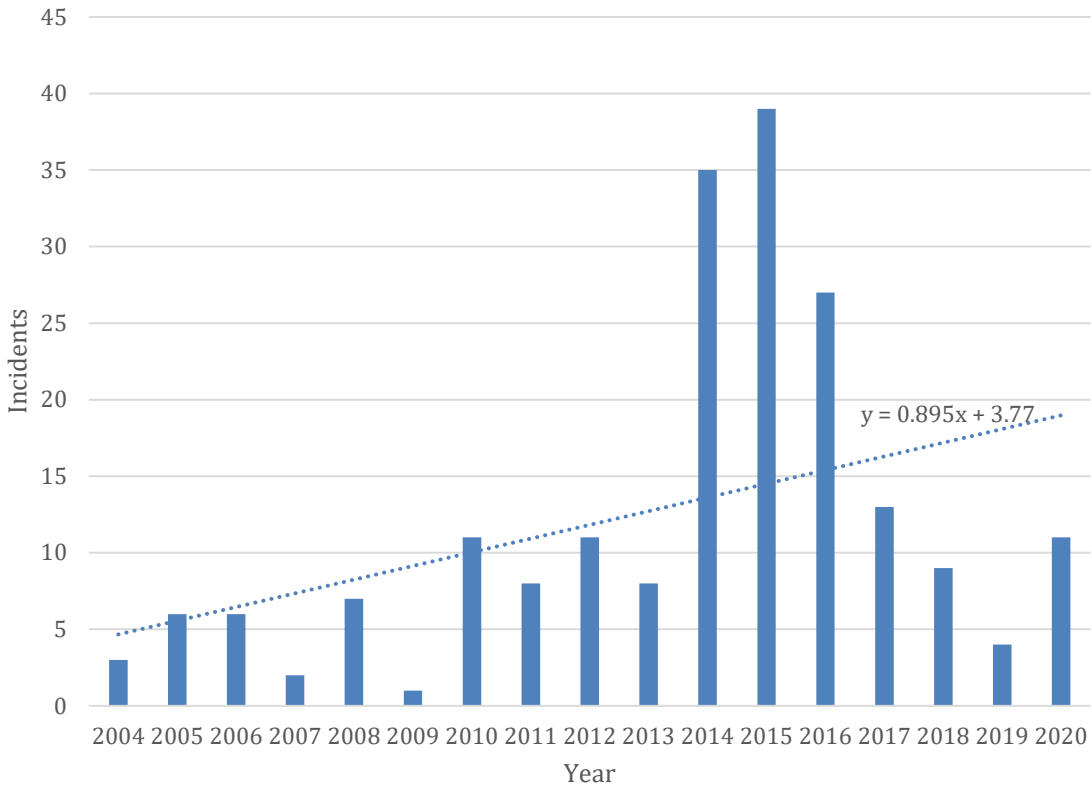

Figure 3: Annual Number of All Incidents of Foam Discharge with Known Causes in UMD Survey

The number of incidents per year involving accidental discharges in DoD versus commercial facilities is included in Table 3 and Figure 4. No information is available to explain the variation in the number of incidents by year in the two sets of facilities. The frequency of the incidents in DoD hangars is increasing at a greater rate than those in hangars for commercial airlines.

Table 3. Total Accidental Discharges by Year

Year	DoD	Commercial	Total
2004	3		3
2005	6		6
2006	6		6
2007	2		2
2008	7		7
2009	1		1
2010	11		11
2011	8		8
2012	11		11
2013	8	1	9
2014	35	0	35
2015	37	1	38
2016	23	3	26
2017	13	0	13
2018	9	0	9
2019	3	1	4
2020	6	6	12
Total	**189**	**12**	**201**

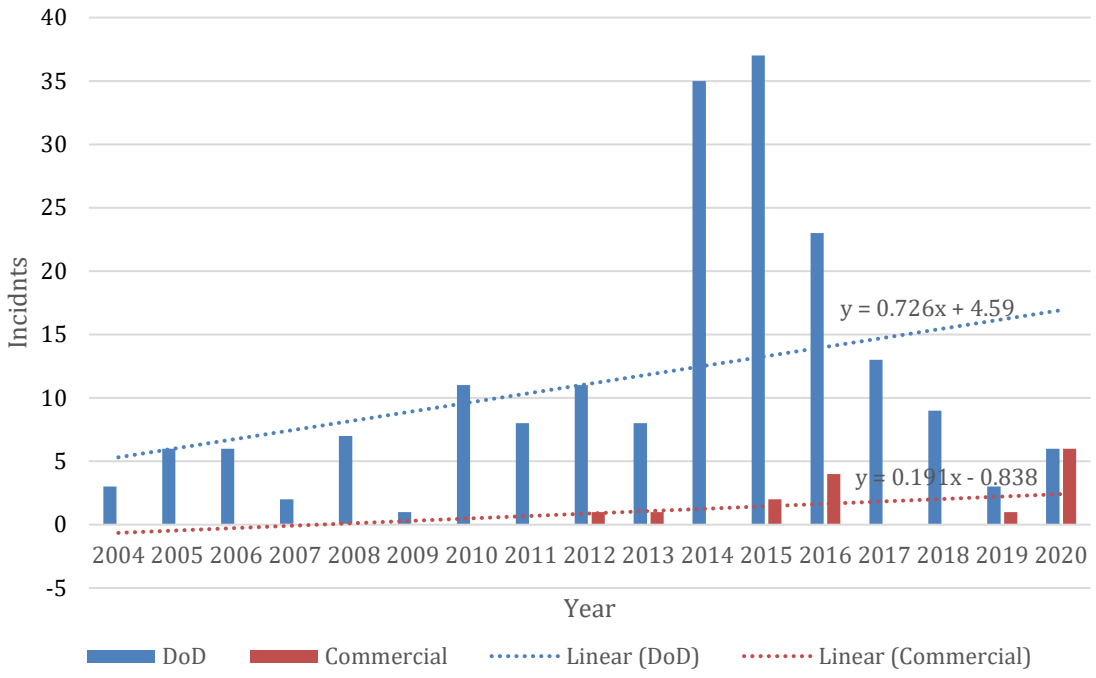

Figure 4. Accidental Discharges by Year in DoD and Commercial Hangars

The distribution of the damage incurred in incidents involving an accidental discharge is shown in Figure 5. The 89 incidents are divided into six categories of monetary loss. The reason for the lower number of incidents recorded in this graph, as compared to the overall total number of incidents is due to a lack of reporting. Most of the incidents reports did not reported the associated cost of damage. The cost incurred by each incident is divided into increments of 0.25 million dollars (USD). The increment with the greatest number of incidents is the 0-0.25-million-dollar category with 67 incidents. The total of all damage estimates for incidents with accidental foam discharges is $9.56 M, for an average loss of $0.107 M per incident.

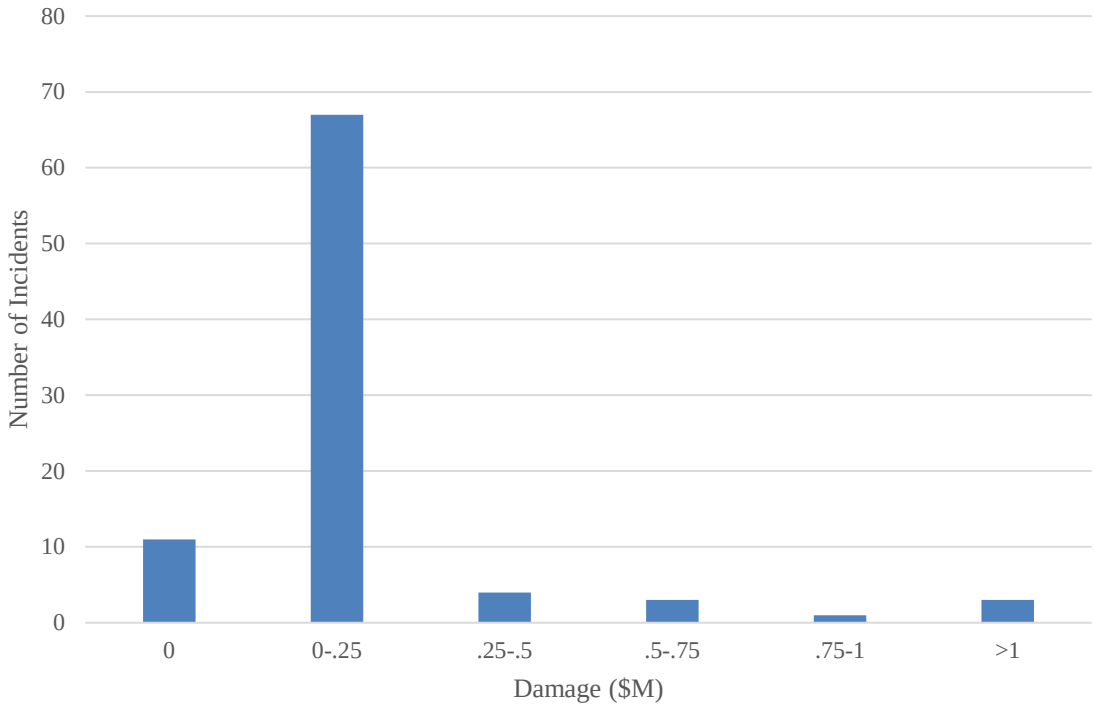

Figure 5: Total Damage of All Incidents

Results of an analysis of the trend in annual total damage in accidental foam discharges is provided in Figure 6. Data from only 2013 through 2020 are included in the graph as no incidents had damage reported from 2004 to 2012. The data from a total of 88 incidents are shown in Figure 5 along with a trendline. The slope of the trendline is -$0.15M/yr slope, which is contrary to the findings from the previous University of Maryland study [Milke, et al., 2019]. In a review of the data, the losses in the incidents that occurred in 2015 to 2017 are significantly larger than those in other years, while losses in 2019 are unusually low.

A comparison of annual monetary damage in DoD versus commercial hangars is presented in Figure 7. The reason for the significant difference in trendlines for the two sets of hangars is unknown.

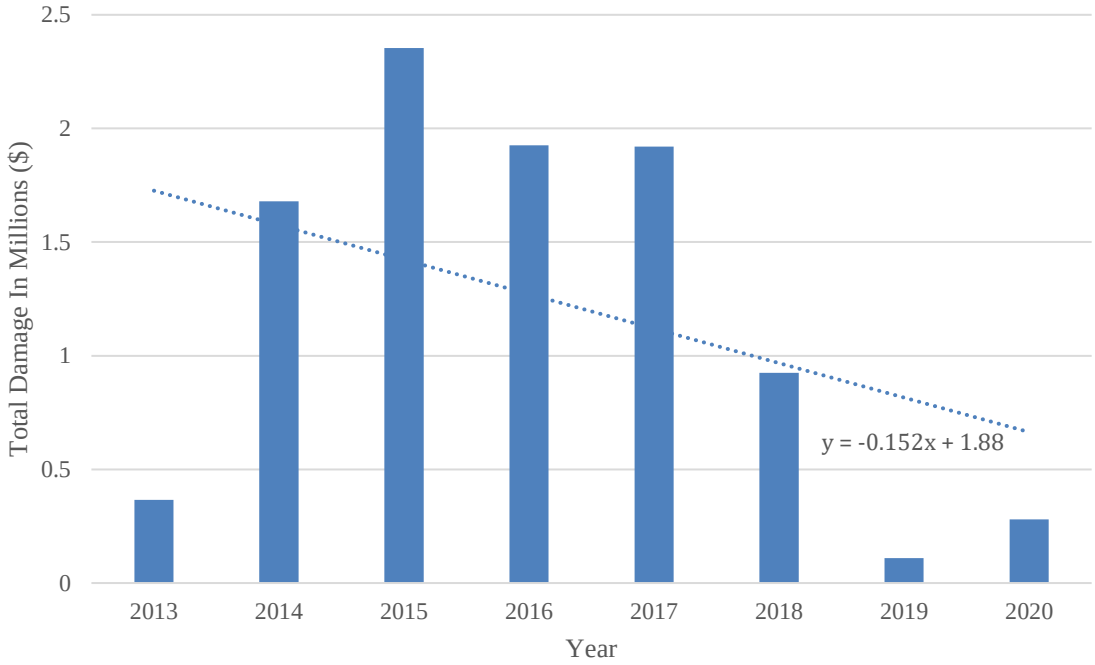

Figure 6: Annual Total Damage, Accidental Discharges

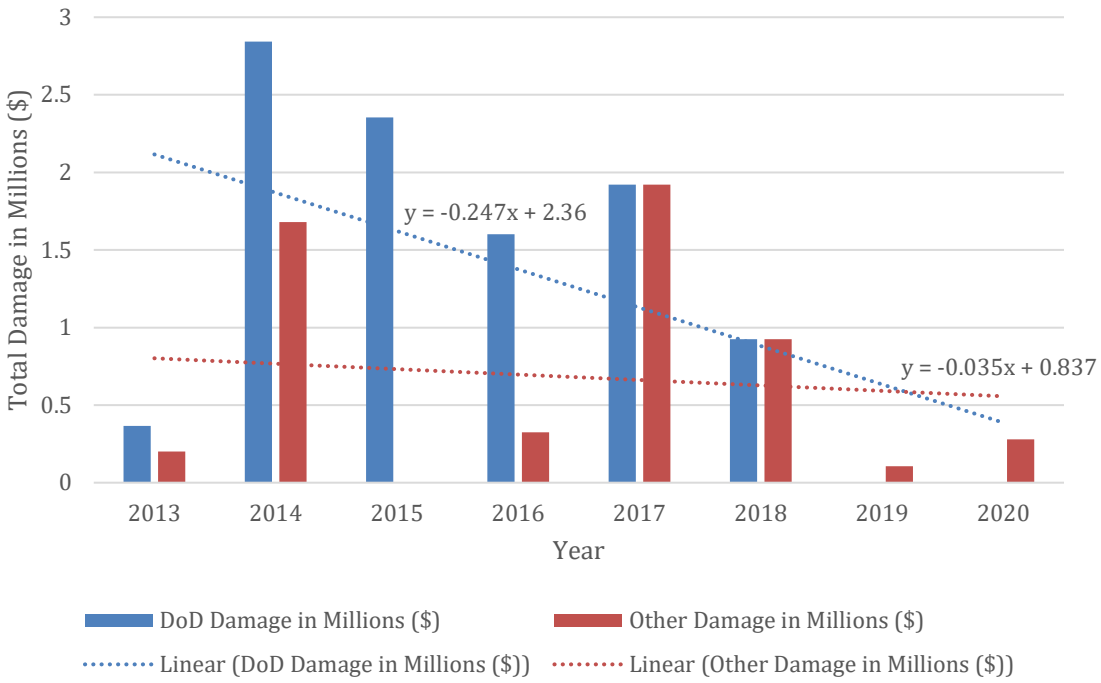

Figure 7: Damage in DoD and Commercial Hangars, Accidental Discharges

An additional explanation for the negative slope trendline in Figures 6 and 7 is presented in Figure 8. The graph in Figure 8 is created by dividing the total amount of damage accumulated by the number of incidents per year that reported damage. While this graph still contains a trendline with a negative slope, the slope is much less than that in Figure 6 and 7.

While this graph is in better agreement to the figure presented in the previous report, it still presents a trendline with a negative slope of -$1720/yr. The graph indicates a low amount of damage in 2019 and a much greater value for 2017. The 2017 data can be explained by a larger number of incidents which reported damage. An average of 44.6% of incidents reported data per year, but the years of 2015, 2016, and 2017 all exceeded this average. The reports of damage from 2013 and 2020 were significantly less than this average. A further depiction of this data is presented in Table 4 which includes the total amount of reported incidents, the number of incidents that reported damage, and the percentage of incidents that reported damage. The reason for the variation in the frequency in reporting monetary loss from year to year is unknown.

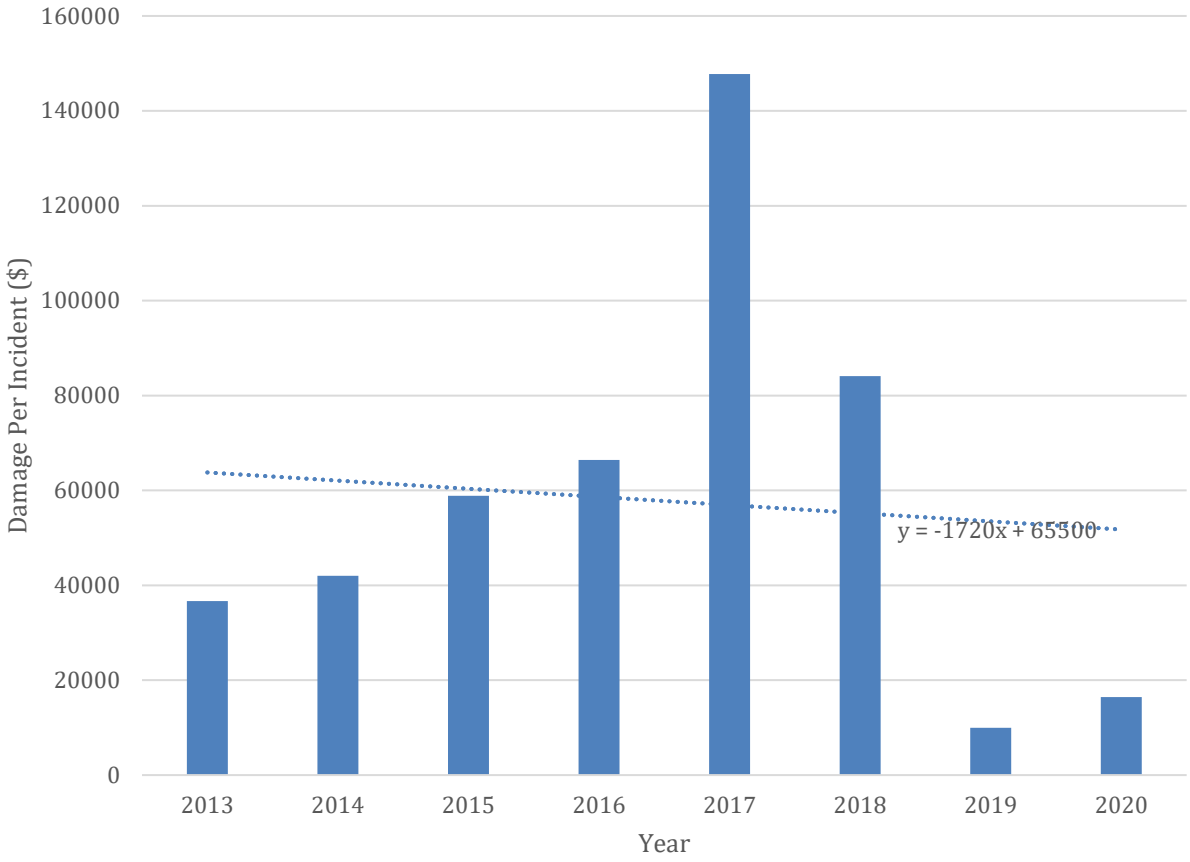

Figure 8: Damage Per Incident Per Year

Table 4: Incidents Reporting Damage

Year	Number of Incidents	Incidents Reporting a Monetary Loss	Percentage
2013	10	2	20.0%
2014	40	15	37.5%
2015	40	30	75.0%
2016	29	22	75.9%
2017	13	8	61.5%
2018	11	4	36.4%
2019	11	3	27.3%
2020	17	4	23.5%

There was a single fatality reported and a minimum of 21 injuries reported through these incidents. A graph of these incidents is presented in Figure 9. Very few of the reported incidents reported any injuries. Furthermore, the injuries and fatalities recorded in 2006, 2014, and 2016 were all the result of one incident in each year. The 2019 and 2020 data are best-case scenarios for each of these years, as 2019 and 2020 years had at least two injuries during each year. Each year had two reported incidents that stated that there were injuries in two different incidents. However, these incidents did not state how many injuries occurred during these incidents.

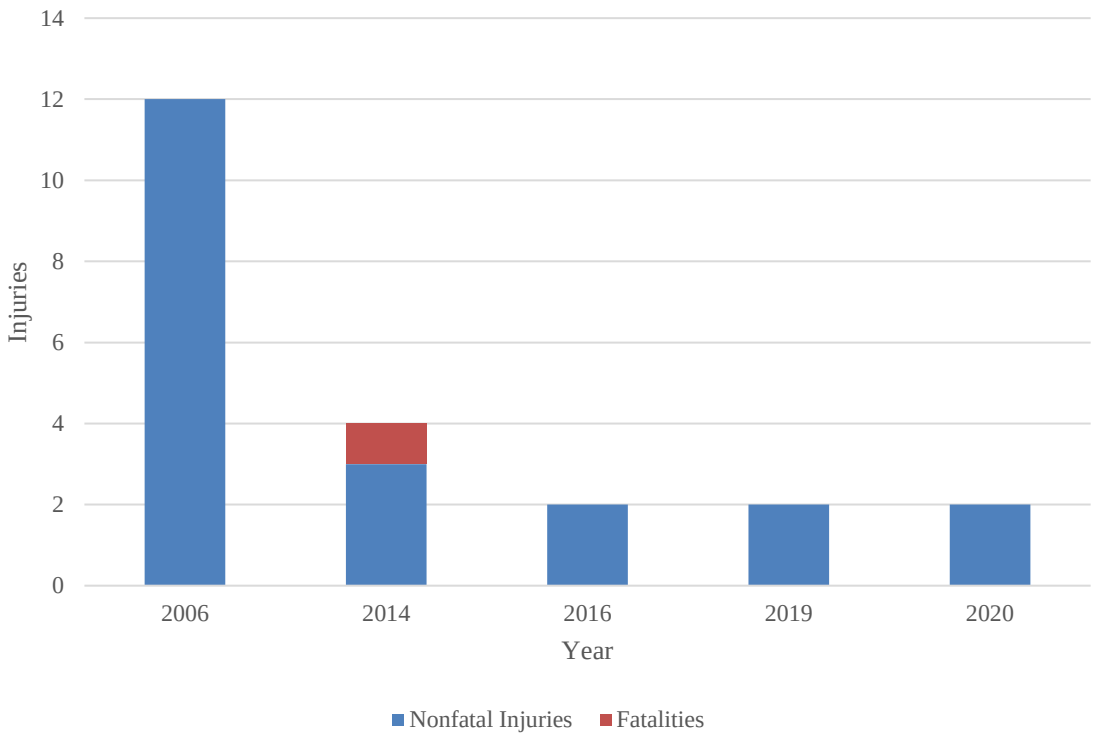

Figure 9: Number of Injuries Resulting from Foam System Discharges

The causes of the accidental discharges are organized into seven categories:

- false detector activation
- suppression system failure[4]
- intentional or malicious activation or human error
- error made during inspection, testing, and maintenance
- weather related causes
- unknown cause, or
- multiple causes.

The causes of the accidental discharges were organized into these categories by the research team based on information provided on the survey form. The cause of accidental foam system discharges was reported in most responses. The distribution of causes is presented in Figures 10 and 11 and Table 5.

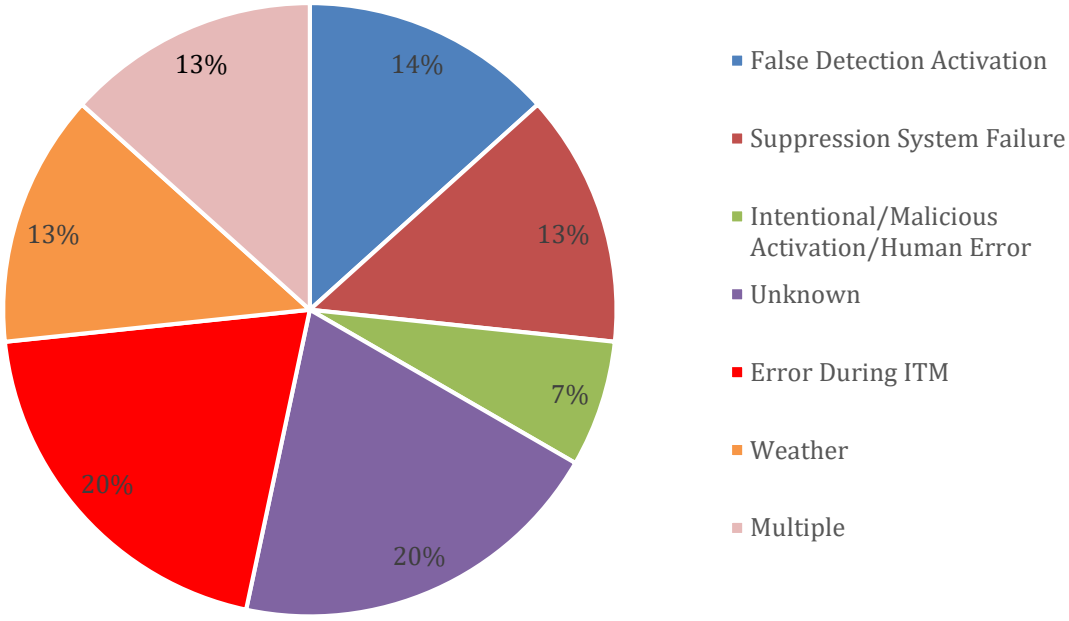

Figure 10. Cause of Accidental Foam Discharge (All incidents)

Comparing the causes in the DoD incidents versus those with commercial airlines, "suppression system failure" was the most frequently cited cause for the DoD facilities at 40% of the incidents, while that cause was noted only in 15% of the incidents for commercial airlines. For incidents reported by commercial airlines, the leading cause of a discharge was

[4] The cause or nature of the failure of a suppression system was not always noted.

for “false detector activation” at 23% of the incidents, while this cause was noted in only 4% of the DoD incidents.

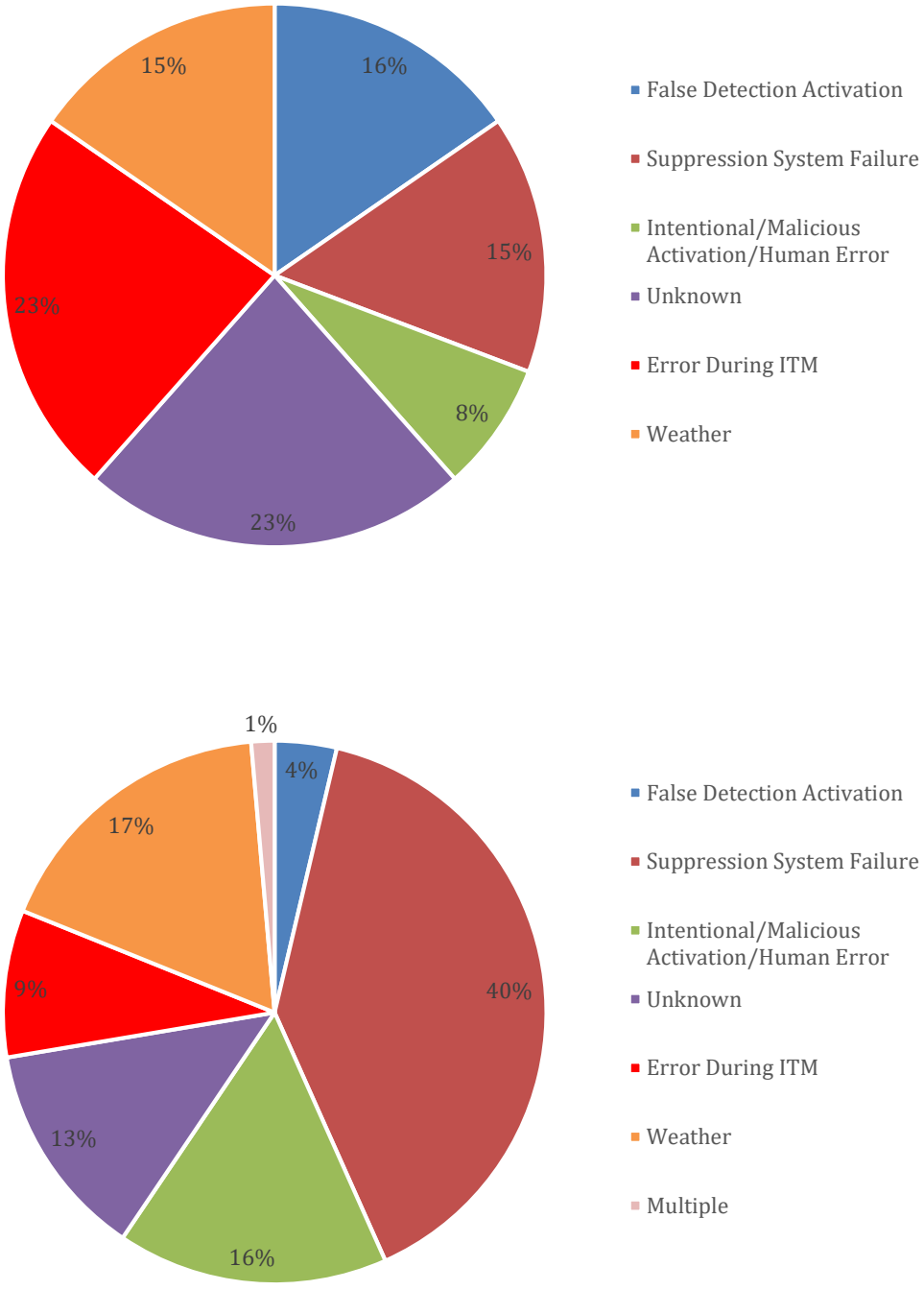

Figure 11. Cause of Accidental Foam Discharge. Top: Commercial, Bottom: DoD

Table 5: Causes of Accidental Foam Discharges

Cause	Commercial	DoD	Total
Error During ITM	3	19	22
False Detection Activation	2	8	10
Intentional/Malicious Activation/Human Error	1	35	36
Multiple	2	3	5
Suppression System Failure	2	86	88
Weather	2	38	40
Unknown	3	28	31
Total	**15**	**217**	**232**

The types of systems that were activated is presented in Figures 12 and 13 and Table 6. The type of system was not reported in all incidents, as indicated by the large proportion of "unknown" cases. Furthermore, not all the activations released foam concentrate. Activations that only released water were also listed in this analysis as an AFFF or High Expansion Foam release. The large proportion of incidents involving AFFF for the incidents in DoD hangars is likely attributed to the policies of the DoD agency which led to the predominance of AFFF systems in those hangars.

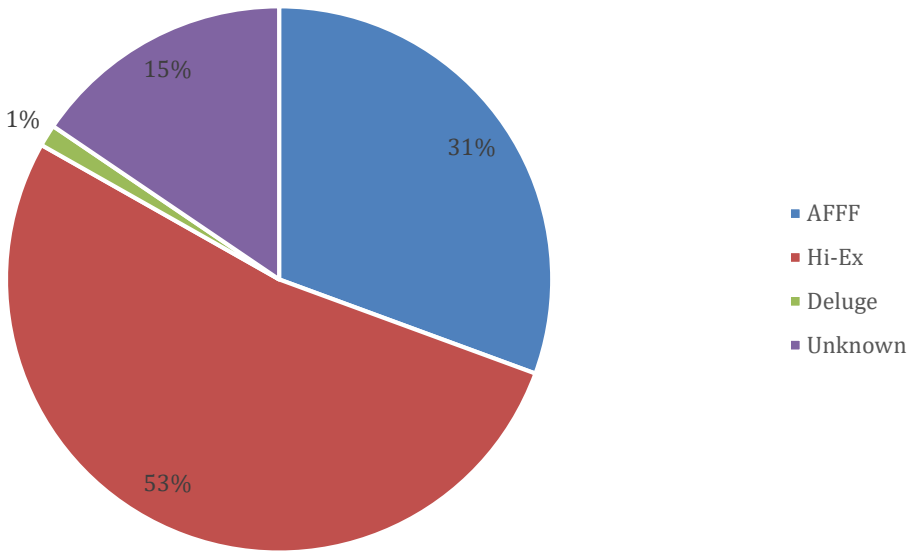

Figure 10: Types of Systems Activated

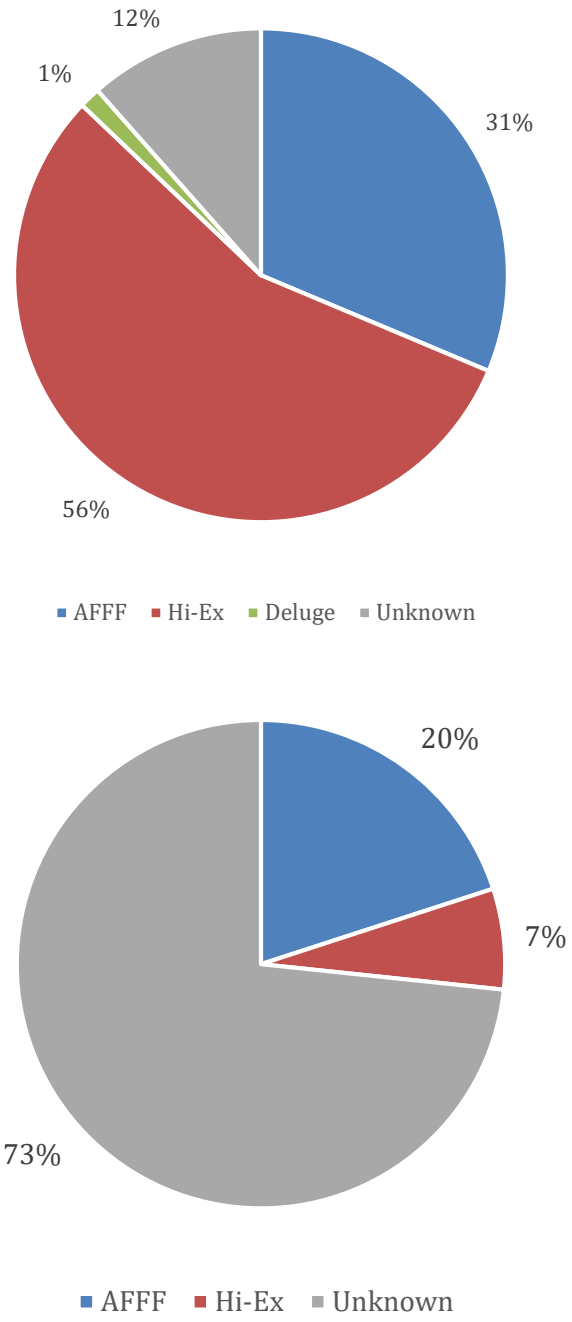

Figure 11: Type of System Activated. Top: DoD, Bottom: Commercial

Table 6: Type of Systems Activated

	Number of Incidents		
System Type	DoD	Commercial	Total
AFFF	68	3	71
High-Expansion Foam	121	1	122
Deluge	3	0	3
Unknown	25	11	36
Total	217	15	232

4. Summary

Requirements for foam fire suppression systems in NFPA 409 were initially justified to provide protection from fires involving fuel spills. However, the occurrence of a fuel spill in a hangar in the U.S. is rare and fires involving such spills even less common. Information in the USCG database indicate only 1 fuel spill occurs each year in the U.S. (no information is available whether any of these spills resulted in a fire). In a survey conducted by the research team to commercial airlines and the US DoD, 242 of 245 incidents of foam discharges that occurred predominantly over a 17 year period occurred despite no fire being present. The discharges without a fire, i.e. “accidental discharges” comprised 98.8% of the total number of discharges. In one of the three incidents that included a foam discharge due to a fire, only one is confirmed to include a fuel spill.

References

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Appendix. Data Collection Form

UNIVERSITY OF MARYLAND

Department of Fire Protection Engineering

Data Collection Form, Foam Suppression System Discharge Analysis

Date of incident _____ Location (city, state) _____

Size hangar (note group or area/door height)

Group (per NFPA 409) _____

Area _____ , Door height _____

Consequences

Injuries

Fatal _____ Nonfatal _____

Damage to building, building systems ($) _____

Damage to aircraft ($) _____

Damage to other building contents ($) _____

Other damage

Business interruption ($ or describe)

_____

Environmental ($ or describe)

_____

Cause for activation (place 'X') (feel free to include brief commentary on incident)

Fire

Fire from fuel spill _____ Fire from other _____

Non-fire

Intentional/malicious activation _____

Suppression system failure _____

Detection false alarm _____

Improper maintenance _____

Error during testing/maintenance _____

Unknown _____

Note: date and location is requested to check for duplicate reports of same incident. Such information will not be conveyed in any reporting.