International Aircraft Systems Fire Protection Forum Meeting

October 18-19, 2023

William J. Hughes Federal Aviation Administration (FAA) Technical Center, New Jersey, USA

Wednesday, October 18, 2023

UN Battery Classification Test Method Development – Steve Rehn (FAATC)

Steve gave an overview of the work done on battery classification and provided a description of the gas volume test and propagation test conducted on the battery cells. Steve presented the Battery Gas Volume Measurement test results for types of batteries tested. The Battery Propagation Tests were described, and photos were shown of the test setup. A video of a battery cell propagation test was shown. A graph showing the number of cells that propagated for the types of batteries tested was presented. The last parameter investigated was the Speed of Propagation. Steve described the test setup. Conclusion and Future Work: battery gas volume increases with battery capacity in lithium-ion and lithium metal cells: different chemistries produce different L/Wh measurements. Battery propagation test works well for testing propagation and flammability. Future work: simply decision tree. B. Colton: Do you have a chart or does your chart have grams allowed for lithium-metal batteries in grams of what is allowed to be brought on airplanes? S. Rehn: This is mainly focused on shipping batteries not batteries carried onboard aircraft. Question: Did you make any effort to correlate the gas volume amount of electrolyte in the cell to the amount of gas generation? S. Rehn: I don't know if we could get the amount of electrolyte information for the cells. D. Dadia: It is something that maybe we can look into for future tests. S. Pugliese: propagation test for pouch cells – what are the criteria of the test setup box, a specific amount of insulation around the cells, etc.? S. Rehn: We had to fit the cells into the insulated metal boxes? Maybe we should try to standardize this better to have the same amount of insulation on all. Question: Test setup: when you tested the battery propagation it was side by side, are you considering a different battery arrangement? S. Rehn: The heat can definitely travel upwards, so maybe we have to look into that for future tests.

SAE G27 Committee Update – Doug Ferguson (Boeing) (SAE G27 Co-chair)

This committee was formed in March 2016 at the ICAO Air Navigation Commission (ANC) request to create a performance-based package standard (AS6413) for safe transport of lithium batteries as cargo by air. There are 200 members on the Committee. We are working on the draft of AS6413 with the intent to address the safety of the cell/battery and the packaging material (box, etc.) together. Doug provided additional details conducting the test and descriptions of various results and what they mean. The baseline test method has been validated in multiple labs with small (18650) cylindrical lithium-ion cells. Many additional "variations" or alternatives still require validation, including cells in batteries: pouch and prismatic types, lithium metal, Benign @ SOC, oversize package, and generic package. We have a lot of activity that has to happen in addition including incorporating responses to latest ballot comments, including results of October/November reduced cell quantity/surrogate cell testing and ballot again before the end the year to release "narrow scope" standard only applicable to small cylindrical lithium-ion cells. Upcoming balloting: November 2023 – AIR 6840, and December 2023 –AS6413. First or Second quarter of 2024 we will ballot two other documents (AS6413/1 Elevated Temperature Test, and AS6413 Direct Flame Test).

Fire Containment Bags for PEDs (Portable Electronic Devices) – Dan Keslar (FAATC)

PEDs: phones, tablets, laptops containing lithium batteries may undergo thermal runaway. There is a 5-minute video on the FAA website - FAA PED Fire Training Video. There is a link to this video in Dan's presentation. Dan showed 96Wh Power Bank at 100% SOC test. Theoretically, passengers could bring a battery that is 60% larger than this on board the aircraft. Dan described the Fire Containment Bag Test

Setup: PEDs are charged to 100% state of charge (SOC). A photo of a mid-sized tablet test set up was shown. We currently have plans to do testing with four (4) manufacturers' fire containment bags. Dan described the tests conducted for Manufacturer A (the first of the four). Photos of this manufacturer's flight deck and cabin fire containment bags tested were shown. All the bags were equipped with a filter that is supposed to release smoke. Dan showed video of one of the tests conducted. Temperature data was presented. A video of a Power Bank Overheating test was shown. A test of the scenario that the Power Bank is already on fire where the PED pad is put over the Power Bank already on fire and later put into the bag. Joe said he felt a significant amount of shrapnel coming from the flaming Power Bank when he was putting on the PED pad, so would a flight attendant be able to do this in flight? Next Steps: we plan to do these tests with three additional manufacturers' fire containment bags. Question: Do you know if any of these products were tested to the UL5800 standard? D. Keslar: They did not. I do not know why they did not. R. Hill: No one has passed the UL standard. There is one bag that is very close to passing the UL standard. E. Canari: In the work we have done so far at EASA, we have tried to experiment with the use of UL5800. The main weak point of all this testing is that it seems that the PED is magically on the floor then it is magically inside the bag. We are working on similar testing. The UL5800 is not the only way to approach this problem. I think we all need to agree there is a single way to perform a test. Question: Have you considered measuring pressure as well? D. Keslar: That is something we can look into for future tests. T. Mallon: How concerned should we be about the ingestion of the smoke/breathing in this smoke in the confined area of the aircraft? D. Keslar: In terms of the actual lethal dose or amount of the smoke, I don't know that information. D. Dadia: We do have a presentation on the toxicity later today. R. Hill: Gaseous agents are for flames, water is for propagation to cool the device, then you can put it in the bag. Water works for everything. Once you have cooled it with water, then you can handle the device to put it in the bag.

<u>Assessing the Spontaneous Combustion Potential of Hazardous Cargo on a Tarmac</u> – Lindsey Anaya (FAATC)

The concern is the auto-ignition of disinfectants in aircraft cargo. The main impetus is the Ethiopian freighter incident in July 2020. The aircraft main deck cargo compartment was severely damaged by the fire. Cause: chlorine dioxide disinfection tablets spontaneously combusted under high temperature and humidity (93 F/34 C). These goods were not properly designated as dangerous goods and were not packaged in hazmat boxing. These chlorine samples were highly concentrated, not like tablets on the market. Testing and Outcome: This study will indicate the probability of the autoignition of chemical disinfectant and/or Lithium-ion battery cargo on a hot tarmac and the results may affect current FAA/IATA/ICAO hazardous goods regulations. Lindsey conducted Phase 1 tests in July 2023. She is currently planning the Phase 2 tests. She described the Phase 1 test setup. The results of the Phase 1 tests. Data was collected every 2 minutes over a period of 30 days. Lindsey described plans for Phase 2, the types of products that will be tested, and the plans for the Phase 2 test setup. Potential Phase 3 – Chemical Spills: It would be the same conditions as Phase 2. Question: Regarding your test conditions, do you have any factor in your tests for the temperature around the tarmac because it is likely higher? L. Anaya: I could get the temperature of the tarmac or asphalt temperature. I think I will increase the temperature inside the box to be more realistic.

<u>Handheld Extinguisher Toxicity Update</u> – Natallia Safronava (FAATC)

Motivation for this project was to evaluate the difference in thermal and toxic hazards of handheld extinguishing agents used on lithium-ion battery fires in small compartments. The agents and batteries tested were reviewed. Natallia described the tests conducted in the Phase 1 and 2 test series and Phase 3 (currently underway). A schematic of the test compartment was shown. The details of the test setup were described. Water pour results (18650 cells) and water pour results (pouch cells) were presented. Results of the halon 1211 and 2BTP tests were presented. Summary: Project scope was expanded to include the water pour and water extinguisher to compare Halon 1211 and Halotron BrX applied for 18650 and pouch cells. G. McEachen: I am curious about the HF production. N. Safronava: There wasn't much difference for the agents for the MPS testing. G. McEachen: It does kind of make sense for the cargo test.

Enhanced Cargo Compartment Fire Detection: Passive Radio Frequency Identification (RFID) – Matt Karp (FAATC)

Background: Unit Load Devices (ULDs) are integral for cargo transportation in aviation. However, their design inadvertently conceals smoke, hindering timely fire detection. Implications: Concealed fires have led to incidents with overwhelmed onboard fire suppression systems, resulting in tragic accidents. Objective: The research aims to create a cost-efficient, fast, and precise fire detection system to significantly enhance aircraft fire safety.

Limitations: These are ground experiments, so there are different temperatures and pressures than in-flight conditions. We tested a single style of ULD, and there are many different kinds.

UHF RFID Overview: Inexpensive: cost-effective solution for various applications; Communication: uses electromagnetic radio waves for communication with readers via antennas; Material Compatibility: reads through composites but not through metal; Passive Tags: integrated circuits (IC) in passive tags are powered solely by received electromagnetic waves; Communication Method: employs backscattered communication to interact with the reader; Non-line of sight: can collect data from multiple tags without requiring a direct line of sight; and Sensor Capabilities: possible to sense physical parameters such as temperature and location. Tag used in study: Axzon (passive wireless sensor IC, on-chip temperature sensor). Matt showed a photo of the test setup and described the setup in a mock cargo compartment. The fuel sources were explained. A photo of the smoldering fire test setup was shown. Matt described the test conducted. The sensor placement/configuration was described (photo shown). Future Tests: In-flight tests: future tests should incorporate in-flight levels and data should be reevaluated to determine if ground test activation thresholds are appropriate during flight; include tests with loaded ULDs and a variety of ULDs. Matt reviewed the timeline for this project. He expects to release the final report in January 2024. L. Anaya: Were you able to determine an optimal air gap between the top of the ULD and the mount for the RFID? M. Karp: You do get a good improvement by increasing the gap. Even with the sensor stuck right on the top of the cargo, you are getting significantly early detection.

EASA Update on Rulemaking and Research – Enzo Canari (EASA)

(Certification Memorandum) CM-CS-011 Guidance on Smoke Propagation and Smoke Penetration Tests issued June 2023. The content of the CM is the result of a coordination effort with the FAA that started with the objective to propose a policy that could address cases in which both EASA and the FAA accepted test conditions different from those specified in FAA AC 25-9A.

PED Battery Fire on the Flight Deck: Enzo provided background and reviewed the Continuing Airworthiness (CAW) activities, Initial Airworthiness (IAW) activities, and the Safety Information Bulletin (SIB) addressed to operators. The SIB was shared with other authorities as informational. (Continuing Airworthiness Review Item) CARI 25-09: Potential Risks due to devices containing Lithium batteries located on the flight deck. The main findings were reviewed: unambiguous information on safe stowage locations available on the flight deck should be provided to operators (through placards and training material), donning fire gloves is essential to safely relocate PEDs, use of fire containment bags (not acceptable for firefighting but may be used as stowage facilities). The purpose of CARI 25-09 is to investigate if potential unsafe conditions associated to lithium battery fires in the flight deck may exist on any specific transport aircraft type that would require corrective actions as a second step. Enzo discussed the Special Condition

SC-G25.1585-01: Mitigation of flight deck fires originating from lithium batteries that are not part of the aircraft design. Enzo discussed fire gloves, fire containment bags, and electronic flight bag (EFB) mounts.

Next Steps: EASA will approach TC holder with the objective to achieve the implementation the SC in the certification basis of already certified aircraft. Make progress in the definition of a standard for FCBs addressing PEDs handling and battery fire containment: ongoing EASA research project LOKI-PED. EASA should define Minimum Performance Standard (MPS) for fire gloves. EFB Mounts: EASA is developing a new CARI that will be sent to design approval holders (including Design Organization Approvals (DOAs) that mounts installation as minor changes). Revision of the Means of Compliance (MOC) to SC-G25.1585-01.

EASA Research: LOKI-PED (https://loki-ped.de): LOKI (named after Nordic god of fire) – PED (portable electronic devices). This work aims to assess the risks associated with lithium batteries in portable electronic devices in case of fire and smoke in cockpit and cabin. Work began in July 2022 and is expected to end July 2025. Are the regulations for PED in the flight deck and cabin appropriate? Do we need to change anything or create additional procedures? The project overview was presented. The Tasks and Timetable were reviewed. Details of these are available in Enzo's presentation. Enzo outlined the expected outcomes of this project. LOKI-PED – Request for Participation: We welcome airlines sending crew members and safety experts to work together with the LOKI-PED consortium on safer handling of PEDs under thermal runaway. Conact Enzo to participate (enzo.canari@easa.europa.eu). Tests will be conducted at the Flight Test Facility (Fraunhafer IBP), Fraunhafer, Germany.

New EASA research project: AirPED (fire risks associated with the presence of PEDs in the cargo hold): PEDs in checked baggage and bulk shipment of lithium batteries. Enzo described this project. The objectives of this project are: to evaluate the effectiveness of cargo fire suppression systems (Halon and Halon free systems) in case of thermal runaway events originating from battery-powered devices in checked baggage; to generate data to support the revision of the MPS for Aircraft Cargo Compartment Halon Replacement Fire Suppression Systems: validation of the definition of a new cargo fire test scenario involving lithium batteries; and to perform additional tests with the same test setup as Task 4 of the Sabatair project (external fire scenario, with fire containment covers (FCCs) protecting the batteries/cells. Project status: Task 1 is completed. Tasks 2 and 3 are ongoing. Tasks 4 and 5 to be completed in Q2 2024. Final report: Q2 2024. Details of the Tasks are available in Enzo's presentation.

Question: At Boeing we are seeing that a lot of the airlines are requesting PED stowage and charging provisions in the galleys. Most of this has been around smoke detection and not so much fire containment. So far most of the discussions have been around flight deck, but we are also seeing it in galleys. E. Canari: In 2017, we published a Special Condition on charging stations in the galleys. Question: We have been contacted by several airlines that cabin crew were admitted to the hospital for toxicity not just the smoke. Is EASA addressing this? E. Canari: The issue of toxicity is very, very complex to address. We follow a very basic logic, if we see smoke that is not good. I think that it is essential that you can move the bag away from the flight deck. We are looking into toxicity to confirm that what we are doing has a sufficient safety margin and are compatible with the safety objectives we have.

<u>AC 20-135 Revision Update</u> – Phil Dang (FAA)

Phil provided an overview of the updates to the (Advisory Circular) AC 20-135 Rev A. There were some industry questions posed during the October 17, 2023, SAE A-22 meeting, so we may include additional clarifications to address those questions. Question: What about how to handle post-test burning and residual flames? P. Dang: The FAA plans to publish this in the FAA Transport Airline Issues List (TAIL). Question: What about 'there shall be no leak'? P. Dang: Post-test leakage of flammable fluids. The FAA's current position is there shall be no leak after a fire test meaning no wetting of surfaces that can form a drop. This is flammable fluid components.

SAE A-22 Committee Update/Status – Daniel Laborie (GE Aviation)

Daniel reviewed the background on the formation of the SAE A-22 committee, its purpose, and work that has been done by the committee and committee participants. The 2023 Significant Accomplishments were reviewed. AS6826 Powerplant Fire Test Standard Significant Changes were presented. Question: ARP 6828: I have reviewed the document. My question is how receptive are the authorities for the use of the ARP 6828 document? P. Dang: It is going to depend on the topics. If it is a one-time only, those will be looked at with more scrutiny. We will look at the safety and economic impact to the industry.

Update For Sonic Burner Coordination for Use of Testing Powerplant Components – Aeon Brown (FAATC)

Burners studied are Park 3400 DPL Burner, Sonic Burner, and Carlin Burner. Aeon described the comparison work he did with the three burners. The Calibration Results – Average Flame Temperature, Calibration Results – Heat Flux, and Calibration Results – Burnthrough times were presented. Image Comparison of Burnthrough between the three burners – camera is recording at the back of the sample. Aeon stopped when he saw burnthrough. Observations: The Sonic burner can be calibrated to replicate performance of the Park burner. Sonic burner calibration temperatures were approx. 15-50 degrees less than prescribed 2000°F. The Carlin burner burned through the aluminum sample faster than the Park and Sonic burners. Park and Sonic burners have similar burnthrough of the aluminum panel. The Carlin burner burns small hole in the lower left quadrant of the sample. Future Study: investigate the flame retention head of the Carlin burner, and investigate other options of heat flux mapping other than single line copper tube. Contact Aeon to join the Burner Coordination group aeon.s.brown@faa.gov. S. Pugliese: For the heat flux calibration, the goal is to lift the copper tube 1" above the center of the burner? A. Brown: Yes. Aeon showed a photo from his presentation. S. Pugliese: The industry is looking for repeatability. Question: Do you plan to do mapping of the flame? A. Brown: I am planning on doing temperature mapping. K. Iqbal: The previous data shows that the sonic burner was hotter, do you know what the main difference is, tuning the nozzle or the way you are doing the test? A. Brown: The Park and Sonic do not have the flame retention head focusing the flame. I had to go with the performance of the Carlin and the Sonic burners because they are not similar. I had to bring down the temperature of the Sonic by 15-50 degrees to replicate the performance. The BTUs I wasn't too concerned about. Regardless of the BTUs, the burner with the lower BTU is burning faster (Carlin). D. Laborie: Heat Flux Calibration – you can either move the tube up and down and do mapping. M. Spencer: When the sonic burner was originally designed it was to eliminate the need to measure heat flux. A. Brown: That is why I went with performance. However, I did record heat flux and temperatures because some might be interested in those. T. Mallon: It would be useful to understand the efficiency of the nozzles. To understand what pressure you are running at for the burners. Aeon showed the Sonic burner settings slide and explained again.

A Brief Status, Current Powerplant Halon Replacement Activity – Doug Ingerson (FAATC)

Fire extinguishing agent in a system dedicated for the powerplant. A brief test process overview: Proposed certification criteria from two (2) revisions. Directly relate to Halon 1301[3a] performance; based on replicate, multi-condition testing; candidate's performance will equal or exceed CF_3Br's. The process is also part of aircraft certification, although passing the MPSHRe does not guarantee certification. Doug provided a brief test process overview. MPSHRe/rev 03: 2003-2008, implicit empiricism. MPSHRe/rev04: 2010 and is currently active, a proof-test. Doug showed a diagram of the generic nacelle fire simulator and explained test operations. Photos of previously used test fixtures FAA-owned 747Sp's #2 JT9D were also shown (see his presentation). Doug spent some time discussing the Candidate Overview Table and explaining the results and observations for each of the candidates in the table (this is included in his presentation).

Background references were provided. Question: You mentioned that CF_3I gave better results, but then it seems you stopped working on it and started testing other agents? Why aren't you focusing more on it? D. Ingerson: I understand your question & there is a very long answer for it. As a result of the toxicological concerns of this agent, there was a pause on it. Then, in 2018-2019 there was renewed interest in this agent.

Combustion Potential – Nature and Behavior of Fire in an Engine Nacelle - Aeon Brown (FAATC)

Objective: To understand the effects that dimensions, fuel flow, and air flow have on combustion inside of an engine nacelle type compartment. The data acquired from this project will be used to provide an expeditious and small-scale validation method for CFD fire modeling. Background: The space between an aircraft's engine and its nacelle houses many lines carrying fluids that are flammable (including fuel, hydraulic fluid, and oil). Engine nacelles are typically vented with forced airflow usually from free stream air outside the aircraft to limit the accumulation of flammable vapors. Fire tests are an integral part of the process of designing a fire safe environment. Fire modeling allows the analysis of specific fire dynamics at a significantly reduced cost. Aeon showed photos of with views of engine components: Photos of left cowling and left side of the engine, bottom of the engine and right side of the engine of one of the FAA Fire Safety aircraft were shown. Compartment design was reviewed schematic, and photo were shown. A Delavan 2.0 GPH nozzle was used. Aeon explained the observable data. Fire Dynamics Simulator (FDS) simulates the behaviors of fires in an enclosed space. Dodecane was used as the surrogate fuel for aviation fuel. The Test Plan was described (see table in Aeon's presentation). The Test Path was reviewed. Experimental vs. Simulated – ½ GPH Fuel Flow videos were shown side by side. Experimental vs. simulated results were discussed. Experimental vs. Simulated – 1 GPH Fuel Flow videos were shown side by side. These results were presented. Experimental vs. Simulated – 1.5 GPH Fuel Flow videos were shown side by side, and these results were presented. Experimental vs. Simulated Physical test – 2 GPH Fuel Flow videos were shown side by side. 2 GPH fuel flow was the highest fuel flow tested. These results were presented. Future Work/Analysis: Acquire and use properties of experimental fuel for modeling; conduct more airflow analysis within the compartment; analyze particle size and velocity out of the nozzle for each fuel flow; utilize ANSYS Fluent for simulation comparison; and experiment with cylindrical geometry. S. Pugliese: How are you going to judge where to stop with the modeling? A. Brown: You are wondering about the Mesh for example? With the Mesh analysis, you can always refine your mesh analysis, but for me I tried to do as best I can to simulate that off the experiment. I did not write the FDS program, so the assumptions are already built into that program.

EPA Updates – Margaret Sheppard (U.S. Environmental Protection Agency - EPA)

This was a recorded presentation that covered the following topics:

EPA SNAP Program

Phasedown of HFCs

The American Innovation & Manufacturing (AIM) Act

HFC Phasedown Schedule

The AIM Act – Current Rulemakings Overview

HFC Allocation Program

Next Steps for Proposed Emissions Reduction and Reclamation Rule signed October 5, 2023, and available on EPA's HFC website @ https://epa.gov/climate-hfcs-reduction/management-certain-hydrofluorocarbons-and-substitutes-under-subsection-h. End of public comment is 60 days after publication in the Federal

Register (FR). The EPA intends to hold a public hearing 15 days after FR publication. See the presentation for websites for additional information.

Hydrogen Flame Characteristics – John Kurtanidze (Rutgers University)

John reviewed the challenges of using hydrogen as aircraft fuel: hard to detect leak, hydrogen embrittlement, difficult to store, easy to ignite, can permeate through metals.

Challenges with Hydrogen Flames: invisible in daylight and have very low quenching limit. The Project Objective was explained: Experimentally imitate tiny hydrogen leak ignition; study hydrogen flame characteristics; and note the effects of: leak size and shape, standard flow rate (SFR), and nozzle exit-plate spacing. A diagram and photo of the test setup were shown. Nozzles used were shown and described. The Experimental Method was described, and a sketch was shown. Infrared videos of the flame during tests were shown. The test data was presented. Summary: SFR was found to be the most influential factor for H2 flame. Leak size is closely correlated with SFR. Future work: Vertical burner over horizontal for future tests; bigger orifices; higher flow rate flames; burnthrough tests for various materials; and more applicable sensors for heat flux & temperature measurements. S. Hariram: Where do you get your hydrogen from? J. Kurtanidze: It can be created. There is a whole market that has to be established. S. Hariram: At the present time it is made from fossil fuels. Attendee comment: there are different sources you can get hydrogen fuel from. You can get it from green energy.

High-Fidelity Modeling and Simulation of the NexGen Burner – Prashant Khare (University of Cincinnati)

Computations: Overall Goals - Identify the detailed flow physics in the current and modified FAA NexGen burner systematically using high-fidelity Large Eddy Simulation (LES) computations. Establish a reference database using high-fidelity LES simulations for cold flow without fuel spray, cold flow with fuel spray, "hot flow" with vaporizing fuel spray, and reacting flow. Next Steps: Complete the investigation to identify the effect of vaporizing fuel spray on flow dynamics. Implement soot and radiation models. Conduct initial studies on the reacting flow dynamics. Compare and contrast the effect of changes in geometry on flow and combustion physics. P. Dang: Is there a part of the plan to also try to vary the fuel flow rate to produce a certain amount of heat transfer? That is a very important point for industry. Is there a way to match that with experimental data? P. Khare: Once we are confident enough, we do plan to change fuel flow rates, airflow rates. We will provide detailed results. I know where you are going with the question. It is challenging to run a lot of cases like this with such detail. We may be able to use our machine learning – we can discuss this in more detail. Question: Are you planning to compare with temperature data, in addition to that do you think you need to compare Co2, O2, etc.? P. Khare: Oh, we would like to compare everything, but that is impractical.

Task Group Reports:

Cargo Smoke Detection Task Group – Matt Karp (FAA)

The Cargo Smoke Detection Task Group reached a consensus on the necessity of a method for measuring smoke generator performance metrics for cargo smoke detection certification. It is agreed that measuring the aerosol density in a control volume effectively captures aerosol production. However, there is a question regarding the appropriate metric for assessing smoke transport.

The current proposal recommends using a cone atop the smoke generator to measure the volumetric flow rate. However, Airbus has proposed using a larger chimney, not connected to the smoke generator, to measure the vertical flow rate using two light obscuration meters at different heights and four vane anemometers at the exit. Additionally, Airbus proposes repeating previous FAA tests using similar smoke generators from the FAA study, to compare aerosol production and smoke transport measurements utilizing their new chimney setup.

Questions regarding the previously proposed thresholds for aerosol production and transport have arisen due to previous agreements between the airframe manufacturers and the air certification offices. The proposed thresholds were derived by averaging data produced from smoke generators used by airframe manufacturers in the past to certify their aircraft smoke detection systems. Further discussions are necessary to address these questions and arrive at standardized metrics for smoke transport and definitive thresholds for aerosol production and transport.

<u>Engine Nacelle Task Group</u> – Doug Ingerson (FAATC)

Lead: Doug Ingerson (douglas.a.ingerson@faa.gov)

- The purposes of the meeting were to :
  - discuss topics relating to :
    - aircraft powerplant halon-1301 replacement
    - aircraft powerplant oil-burner testing/FAA Advisory Circular 20-135
    - fire modeling relating to the aircraft powerplant; i.e. flame behavior to facilitate powerplant legacy/sonic oil-burner standardization, compartmental fire in the powerplant firezone
  - visit the associated test fixtures
    - learn about the local facilities in person
    - promote deeper discussion, as needed
- Meeting details.
  - Meeting occurred Thursday, 19october2023, 0800-1215 EDT
  - Discussions occurred in a table/chair setting in the conference room of building [bldg] 287 on the WJ Hughes FAA Technical Center.
  - The bldg-287 conference room session concluded then transformed into simultaneous tours of the bldg 203 oil-burner test apparatus & bldg 205 generic engine nacelle fire simulator [gNFS].
- General summary.

  The meeting was an in-person meeting & did not have a virtual-meeting component. The meeting started approximately 0830 EDT. A large majority of the group initially participated in the meeting. Discussion occurred about topics relating to powerplant halon-1301 replacement & powerplant oil-burner testing. A participant attendance change occurred around 1045 EDT where a few others joined & fewer left the meeting. Discussion about powerplant-fire modeling did not occur & was postponed to a later date. At roughly 1130 EDT the group began its departure from bldg 287, separating into 2 smaller groups, each walking to its own destination to visit associated test fixtures. Aeon Brown & Tim Salter escorted the larger group to visit & discuss bldg 203's powerplant oil-burner test fixtures. Doug Ingerson escorted the smaller group to bldg 205's gNFS. The group visiting the bldg 205 gNFS concluded activity around 1200 EDT, the powerplant oil-burner group around 1215 EDT, each group subsequently accessed shuttles, & returned to bldg 300 for lunch.

Attendee roster

[derived from the original participant attendance sign-in sheets; originals provided at this file's end].

Name_last	Name_first	Employer
Aimar	Frederic	Airbus Helicopter
Arnaud	Pierre-Emmanuel	Airbus
Ballard	Kent	Collins Aerospace
Birkenheuer	Andrew	FAA
Brown	Aeon	FAA
Ciero	Robert	Honeywell
Colton	Bradford	Extinguish Ltd

Dang	Philip	FAA
Hariram	Sham	Boeing
Ingerson	Doug	FAA
Iqbal	Khalid	Transport Canada
Khare	Prashant	University of Cincinnati
Krause	Thomas	Airbus Operations GmbH
Laborie	Daniel	GE Aviation
Le Docte	Thierry	Safran Nacelle
Le neve	Serge	DGA Aeronautical Systems
Mallon	Tom	The Nacelle Group
Nakane	Hideharu	Japan Civil Aviation Bureau
Ostic	John	Boeing
Parsons	Thomas	Bell Textron
Pugliese	Stephane	Airbus
Salter	Tim	FAA
Sarwar	Naveed	Rolls Royce Deutschland
Wright	Robert	Boeing

Notes.

A. Doug Ingerson began the meeting at approximately 0830 EDT & indicated :

1. the meeting format would be informal to facilitate open discussions about the 3 meeting topics since the format of this task group meeting is new
2. progress would occur as needed to achieve some form of interim conclusion relative to each topic
3. the meeting's activities would allow the baselining of the status for each of the topics for consideration relative to future activities
4. the 3 topics intended for discussion were :
    a. aircraft powerplant halon-1301 replacement
    b. aircraft powerplant oil-burner testing/FAA Advisory Circular 20-135
    c. fire modeling relating to the aircraft powerplant; i.e. flame behavior to facilitate powerplant legacy/sonic oil-burner standardization, compartmental fire in the powerplant firezone

B. Ingerson subsequently began topical discussions, first about the local activity relating to replacing halon 1301 in the fire-extinguishing system for the aircraft powerplant fire zones.

1. He opened up & displayed the presentation he delivered to the full group at the IASFPF meeting in the bldg 300 auditorium during the mid-afternoon of wed/18oct2023, titled "A Brief Status, Current Powerplant Halon Replacement Activity". He provided deeper details about the MPSHRe/rev04 test process[1], mentioning the MPSHRe resulted from prior task group involvement in 1996 & 2009, the test environment's 4 test conditions resulting from 2 ventilation conditions & 2 fire threats[2], worked an example of a "perfect" replicate/multi-condition test count based on a proof-test rationale[3] being 32 tests, & subsequently indicated "perfect" has not yet occurred.

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[1] "Minimum Performance Standards for Halon 1301 Replacement in the Fire Extinguishing Agents/Systems of Civil Aircraft Engine and Auxiliary Power Unit Compartments (MPSHRe rev04)", https://www.fire.tc.faa.gov/pdf/systems/MPSErev04_MPSeRev04doc-02submtd.pdf

[2] a product of 2 ventilation conditions, "high" & "low" ventilation, & 2 fire threats, a spray & a pool fire.

[3] sub-totals : [a] 5 repeated fire-extinguishment tests/test condition * 4 test conditions = 20 tests, [b] 6 additional fire-extinguishment tests to check against 2 other fuel types, & [c] 3 repeated concentration-measurement tests/ventilation condition * 2 ventilation conditions = 6 tests; total of 20 + 6 + 6 = 32 tests]

2. Questions arose wanting to better understand how “cold” & demonstration testing related to the MPSHRe test process; i.e. will “cold” testing be required in the future & clarified some detail about where FK-5-1-12 was “cold” tested, believed in the #2 JT9D. Ingerson explained “cold” testing would not always be a requirement, so a change in the MPSHRe is not expected. Reasoning provided identified anyone testing a candidate per the MPSHRe is obligated to observe everything related to testing, quantitatively & qualitatively, to subsequently report basal test results & any peculiarities, & to address any observed peculiarities. In the case of CF3I, during its MPSHRe/rev03 testing, flame attachment was observed occurring in the FAA Technical Center’s [FAATC’s] gNFS which departed from the behavior of halon 1301 [CF3Br]. This was a qualitative observation, but knowing the thermodynamic & transport properties of the 2 substances differed[4], additional testing was included to further challenge CF3I distribution, by making portions of the test environment somewhat “cold”, while expecting CF3I to unambiguously extinguish the fire threats. Discussion occurred about the “cold” FK-5-1-12 testing. Corrected a belief that this testing occurred in the FAA-owned Boeing 747SP’s #2 JT9D, indicating it actually occurred in the FAATC gNFS. Explained “cold” testing could become a part of MPSHRe testing. In the instance of CF3I, the additional “cold” testing was perceived to address a qualitatively-observed peculiarity about flame attachment, believed to result from dissimilar transport behavior since differences between CF3I & CF3Br properties are plainly observable, where the “cold” testing challenged the candidate exactly where a possible shortcoming might exist. Also explained that demonstration testing in the #2 JT9D came to be because the solid-aerosol candidate being tested was plainly different from the state of the art; i.e. differences exist between a solid aerosol & gaseous CF3Br relative to flame extinction, plus a new concentration analyzer was needed to characterize the aerosol’s dispersion since the legacy gas-concentration analyzer was inappropriate/ineffective for this candidate.
3. Ingerson flipped to p.8 of his 18oct2023 presentation, & talked through the information provided on the slide. He emphasized 2 items on the table.
    a. If future activity were to involve FK-5-1-12, its concentration criterion for a future set of proposed certification will not be 6.1%v/v FK-5-1-12 & discussion on this point will occur at that point in time. This results because a logical conflict exists with the physics-based scenario posed by the FAA certification criteria for CF3Br. The 6%v/v CF3Br portion of its FAA certification criteria quantifies CF3Br near its peak-inertion concentration, where the FK-5-1-12 MPSHRe/rev03 outcome of 6.1%v/v FK-5-1-12 is smaller than any reported FK-5-1-12 peak-inertion concentration found in the literature; i.e. the concentration threshold for a candidate in this realm is currently a peak-inertion concentration & MPSHRe/rev03’s outcome for FK-5-1-12 falls short here.
    b. The equal-mass CO2/FK-5-1-12 blend will require consideration beyond the typical if considered for aircraft certification; i.e. how the blend behaves across an aircraft’s operational flight envelope requires consideration, in terms of :
        A) measurement by legacy Statham-derivative gas-concentration analyzers
        B) its effectivity to extinguish fire.
4. Discussion occurred regarding the momentum profile in the FAATC gNFS ventilation flow-fields, as generated for the testing. Curiosity existed regarding the injection of various candidates into the global ventilation conditions & if anything were done to account for this variability, since injection would affect the pre-existing ventilation condition differently for different injected substances.

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[4] illustrated solely by CF3Br & CF3I atmospheric boiling temperatures & super-heated vapor densities, which are different & affect injection/transport unto themselves; respectively, temperatures of -72°F/-58°C & -8°F/-22°C; at 101.3 kPa, 298 K, & 25°C vapor densities are 6.17 kg/m^3 & 7.92 kg/m^3; density calculations from the U.S. National Fire Protection Association’s standards about halon 1301 via NFPA 12A/1989 edition & for “clean” agents to replace halon 1301 via NFPA 2001/2008 edition.

Ingerson explained nothing was done to the ventilation condition to account for different injected candidates. The global flow field was left as is for each of the 2 conditions for all testing. Explained the 2 ventilation conditions were crucial to the behaviors of the fire threats, where each had a minimum pre-burn duration. Also explained this was ground-based testing, to create a few different conditions to challenge a candidate, where one would select a worst-case result for a final outcome/result, & was NOT intended to replicate flight conditions.

C. At approximately 1000 EDT the topic of discussion changed to aircraft powerplant oil-burner testing & FAA Advisory Circular 20-135. Aeon Brown introduced & began discussions about the topic of local aircraft powerplant oil-burner testing, focused on establishing an operational condition for the sonic oil-burner that equates its performance to legacy powerplant oil-burners. He was additionally supported during discussions by Phil Dang & Tim Salter.

1. Brown opened up & displayed the presentation he delivered to the full group at the IASFPF meeting in the bldg 300 auditorium during the mid-afternoon of wed/18oct2023, titled "Powerplant Oil Burner Testing Update".
2. He generally described the development of the sonic oil-burner & his efforts to determine its operational parameters to establish similarity between it & the legacy [Park, Carlin] aircraft powerplant oil-burners used for component-endurance fire testing.
3. Discussion included commentary & question/answer regarding local installation configuration, calibration procedure, & relationship to the current body of work by the SAE A-22/AS6826 activity. Discussions included the following :
    a. A focus on how to establish similarity between the powerplant legacy & sonic fire-test oil-burners. Brown focused on & used the burn-through time of aluminum [Al] plate test-specimens in his recent work to establish burner similarity. Group discussion indicated this may not be the optimal observation to use, since characteristics of the Al plate used as the test specimens themselves add variability to the test results, in addition to the known variations existing in the burner's flame behavior itself. The consideration of temperature was discussed, but all acknowledged that this measurement was subject to the type of thermocouple used; i.e. acquire a given thermocouple to indicate the temperature wanting to be seen. A suggestion was made to flame-immerse a large metallic plate & map its temperature profile since this appears more reasonable as the plate is largely & directly affected by the flame, is capturing the effects from much of the burner's flame volume, & its thermal mass is relatively insensitive to localized variation. Additional review/discussion occurred stepping through the associated details to identify other possible disconnects; i.e. the group discussion identified that the sonic oil-burner's fuel flow rate in the recent testing reported out 18oct2023 occurred at 2.50 gph, which differed from the fuel flow of approximately 2.0 gph reported in FAA Powerplant Engineering Report 3A, based on work using legacy oil-burners.
    b. A general recognition that work at the FAATC is not procedurally consistent with information from the current SAE A-22 activity, working to generate the AS6826 test standard, in particular, the calibration procedure, i.e., don't disconnect from AS6826 to calibrate the local Park legacy oil-burner, & then establish similarity between the Park & sonic the oil-burners. Brown indicated the local Park & Carlin legacy oil-burners were calibrated consistent with guidance in the current version of FAA AC 20-135.
    c. Industry participants subsequently indicated that the sonic oil-burner has been shown unable to simultaneously achieve powerplant temperature & heat flux calibration points, without one criterion being excessive. Tim Salter confirmed this. Given the preceding, industry identified priority should be given to the heat flux, where it should measure in the range of 4500-5000 BTU/hr, to the detriment of the temperature constraint, although industry preferred to have a

tighter heat flux tolerance of 4500-4700 BTU/hr. However, it was subsequently noted that for certification fire tests today, various industry legacy burners and the FAA Next Gen burner [the sonic oil-burner] have been modified to achieve both minimum 4500 BTU/hour heat flux and 2000-deg minimum flame temperature average for certification fire tests, & any proposed changes to the standard certification burner fire test characteristics will require technical justifications as well as joint certification authorities review and approval.

4. An itemized list of things to incorporate during future work at the FAATC resulted from these discussions. Actions will include :
   a. conducting calibration of burners like what is done in certification testing, i.e., not shutting burners off between calibration stations which influences lab ambient conditions while maintaining the criteria for flame temperature and heat flux produced by legacy burners. Industry mentioned the current AS6826 standardized calibration procedures and test set up will be used for certification testing.
   b. investigating more insightful ways of capturing hot spots produced by the burners during the temperature and heat flux calibrations. Industry mentioned that future update in Phase 2 of the AS6826 standard will consider adding burner mapping procedures for periodic checks of burner characteristics.
   c. details about the nozzle manufacturer in burner performance reports; i.e. manufacturer, flow rating, spray angle specifications.
   d. instantaneous heat flux measurement history during calibration period to capture the rise to the peak and decay as soot builds up over time on the copper tube.
   e. conducting calibration studies in accordance with reviews made in aerospace standards (AS6826) to exclude thermocouple 1 and 7 from the flame temperature calibration.
   f. implementing change in the heat flux measuring device, to install the Resistance Temperature Detector (RTD) probes in parallel with the copper in lieu of the past perpendicular installation. Review and simulate the AS6826 standardized copper tube set up as much as feasible.

D. Ingerson subsequently brought up the topic of discussing fire modeling relating to the aircraft powerplant. He polled the room to find 3 of the 20+ attendees specifically interested in the topic, being separate from many others indicating a secondary interest. He proceeded to postpone the modeling discussion at this time because few in the group showed a primary interest in the topic, indicated the airworthiness authorities continue internal discussions to identify respective postures on the subject, the subject matter's complexity is substantial, & the time to credibly discuss this topic notably exceeded the allotted time remaining for the task group meeting.

E. At approximately 1145 EDT the task grouped moved downstairs & outside bldg 287, split into 2 smaller groups, & walked to 1 of 2 locations to view local test apparatus. The larger group walked with Aeon Brown & Tim Salter to bldg 203 to view & talk about the local aircraft powerplant legacy & sonic oil-burner test fixtures & their associated test processes. The other group walked with Doug Ingerson to bldg 205 to view & talk about the FAATC gNFS & its associated test processes. Those at bldg 205 concluded that tour & boarded a shuttle vehicle to return to bldg 300 for lunch around 1200 EDT. Those at bldg 203 concluded that tour & boarded a shuttle vehicle to return to bldg 300 for lunch around 1215 EDT.

<u>Cargo MPS Task Group</u> – Dhaval Dadia (FAATC)

Lead: Dhaval Dadia (dhaval.dadia@faa.gov)

We talked about finalizing the document until we can get a handle on trying to get the Handbook published. Publish as a report as an update so it is there for official use. We will work to get the Handbook out. We also discussed the differences between the FAA Technical Center acceptance criteria and Boeing acceptance criteria. We have looked at data from both labs in the past. We still need to take closer look at the surface burning fire test VERDAGENT® and water. We believe that at the finalization of that we can get the acceptance criteria into use – the Boeing acceptance criteria.

Handheld Extinguisher Toxicity Task Group – Task Group Report prepared by Tim Marker (FAATC)

Lead: Natallia Safronava (Natallia.i.safronava@faa.gov)

The Task Group was able to tour the Full-Scale test facility, and view the equipment used in the handheld toxicity testing. The test set-up included a rectangular enclosure constructed of plywood with aluminum facings to promote easy clean-up after each test. Also on display were the various battery packs that were forced into thermal runaway, the hand extinguishers used, and the apparatus used to grab gaseous samples from the enclosure. The sample-grabbing apparatus consisted of a pump to draw vacuum through a series of draw tubes, which were individually activated via electrical solenoid valves. The valves were actuated at preset times throughout the tests, and the draw tubes were removed after each test. The contents of the draw tubes were then subsequently removed from the apparatus and analyzed for various constituents, including hydrogen fluoride (HF), hydrogen chloride (HCl), and hydrogen bromide (HBr).

Following the examination of the test equipment, the Task Group leader then restated the intent of the research, which was to compare the toxicity of Halon 1211 to that of stabilized 2-BTP when these agents were used to extinguish a small group of batteries forced into thermal runaway. Two types of battery configurations were tested: a 5-pack of 18650 batteries enclosed in a rectangular container constructed of Ultem™ thermoplastic, and a 3-pack of pouch cells enclosed in an Ultem™ thermoplastic container. In both test configurations, the batteries were forced into thermal runaway using a small cylindrical heater. All tests were conducted inside a 240 ft^3 enclosure, without any forced ventilation, to simulate a worst-case condition. Although no ventilation was added to the enclosure, the contents were mixed using a small electric fan, to minimize the effects of stratification. During the 18650 tests, the extinguishing agent was released once the third of five batteries exhibited thermal runaway. During the pouch cell tests, the agent was released when the first of three batteries went into thermal runaway.

The task group reviewed the data collected during the tests, and questioned why the HF levels varied so widely from test to test. The test conductor explained that each test was somewhat unique, with the release of the agent not striking the target battery pack exactly the same each time. There was also a difference in terms of the agent's ability to cool the thermal runaway event, which also contributed to variation in gas levels measured within the enclosure. Task group participants then questioned what constitutes a "standard" test.

In reviewing the test data, Task Group participants discussed the various charts that plotted the concentrations of gas collected as a function of time, with the AEGL-2 and AEGL-3 (Acute Exposure Guideline Levels) overlayed on each plot. Although the AEGL-2 and AEGL-3 criteria are estimates for the gas concentrations at which point a person would experience health effects, they provided a basis for comparison. However, the Task leader indicated that the use of a fractional effective dose (FED) survivability model would be a more effective tool in comparing the toxicity effects of the agents under these specific conditions. The FED model produces hazard curves as a function of time and is a good indicator of when a person would become incapacitated as a result of the combined gas concentrations inside the enclosure.

<u>HFC Refrigerant Replacement Task Group</u> – Wade Stoelting (Boeing)

Lead: Wade Stoelting (wade.b.stoelting@boeing.com)

The first in-person task group forum commenced on 10/19/2023. Twenty persons were present and nearly equivalent number participated virtually. The participants included representation form FAA, EASA, Transport Canada, JCAB, EPA, airframers, equipment manufacturers and other interested parties. The first order of business was to develop the task group charter/mission statement. Thibault Pelletier, Airbus, proposed the following:

Mission: Regulators, aircraft manufacturers and equipment suppliers require a mutually accepted strategy in showing alternative flammable refrigerants are safe for use on commercial passenger aircraft.

Objectives: Exchange and propose guidelines/refined certification requirements on flammable non-HFC refrigerants for use in aircraft cooling applications that...

- *are compliant to basic industry and regulatory requirements (CFR/CS 25.863)*
- *meet multiple OEM requirements*
- *meet multiple governmental agency regulatory requirements;*
- *provide a viable business solution (obsolescence risk)*
- *are production-ready and industrially feasible (for retrofit)*

This mission statement remains in draft form and will be further refined at an upcoming virtual Task Group meeting. The focus is to determine how the use of A2L or A3 refrigerants can be compliant to CFR/CS 25.863. Some participants wanted to further advocate how replacing existing refrigerants with alternative (non-greenhouse gas) refrigerants will actually result in a greater environmental impact. It was decided this advocacy topic would be better addressed in other forums such as ICCAIA, Cabin Safety Working Group or maybe IAEG (International Aerospace Environmental Group). The FAA Technical Center will evaluate how best to support the task group's effort with flammability testing. The SAE Intl AC-9 group will monitor the task group activities and determine if an industry standard to communicate a common means of compliance strategy is beneficial.

<u>Additional Discussion</u>:

Dhaval noted that this month is the 30^{th} anniversary of the start of the International Halon Replacement Working Group (now named the International Aircraft Systems Fire Protection Forum) meeting. The first meeting was held here in the FAA Technical Center Auditorium in October 1993.

<u>Next Meeting</u>:

The next meeting will be hosted by EASA at its Headquarters in Cologne, Germany, in April 2024. April will send more meeting dates and more details as soon as they are available.