Fuel Cell Flammability

Fuel Cartridge Assessment

Federal Aviation Administration

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BACKGROUND

- **Fuel cells are an alternate power source used in lieu of or in conjunction with batteries to power electronic equipment.**
- **Fuel cells use a hydrocarbon fuel source to generate electrical power, with water as the byproduct**
- **Fuel sources range from highly flammable to relatively inert**

FUEL CELLS

- **Definition: An electrochemical cell in which the energy of a reaction between a fuel, such as liquid hydrogen, and an oxidant, such as liquid oxygen, is converted directly and continuously into electrical energy**
- **FAA Concerns**
  - In-flight use and operation
  - Carry on luggage
  - Checked luggage
  - Bulk Shipment

Micro Fuel Cell Fuels

- **Methanol**
  - Methanol is oxidized directly in the Direct Methanol Fuel Cell (DMFC) system.
  - Reformed methanol fuel cells (RMFC) produce hydrogen “on demand” and consume the hydrogen immediately within the fuel cell.

- **Formic Acid**
  - Fuel (formic acid) concentration: < 85% wt (Not Flammable).
  - Formic acid is oxidized directly in the Formic Acid Fuel.

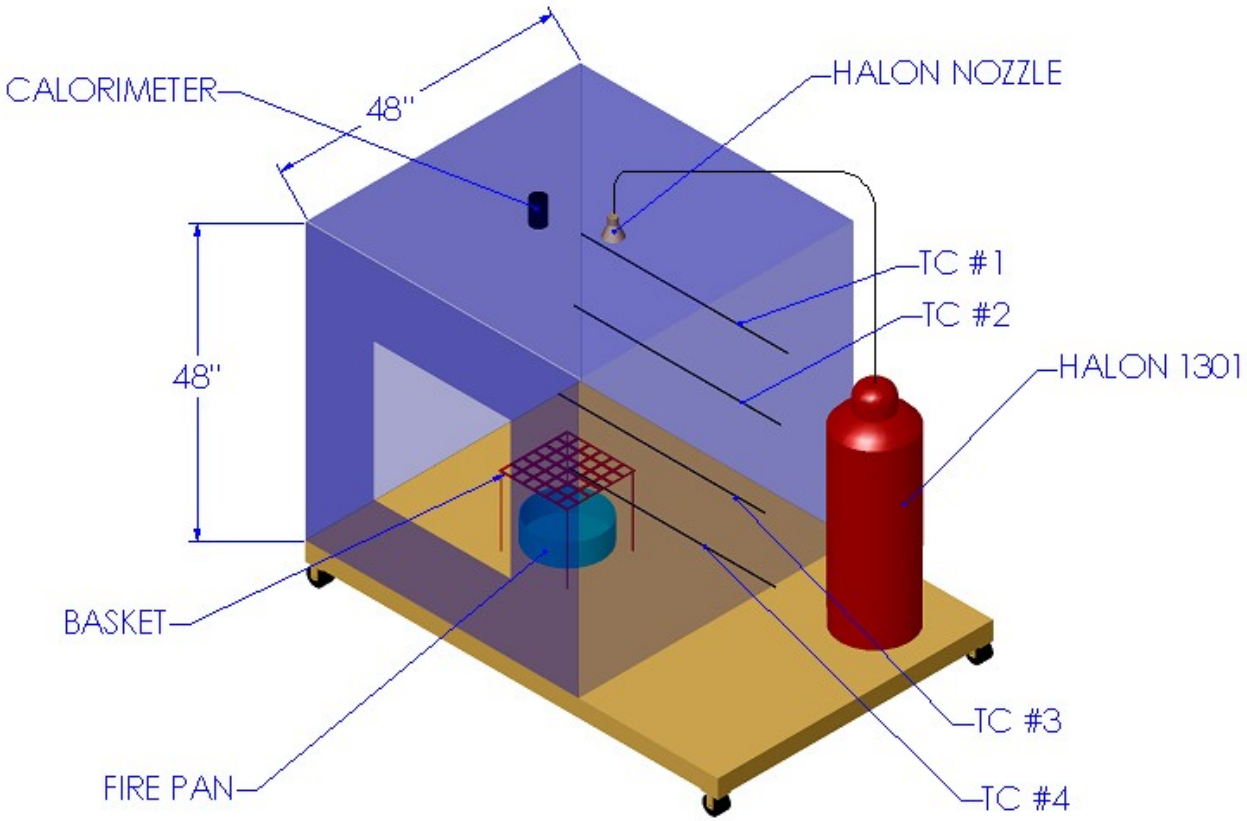
Micro Fuel Cell Fuels

- **Borohydride**
  - Direct liquid Borohydride (Class 8) is oxidized directly in the Direct Borohydride Fuel Cell (DBFC) system.
  - Indirect Borohydride (Class 8 or 4.3) produce hydrogen “on demand” and consume the hydrogen immediately within the fuel cell.
- **Butane**
  - A Butane or a Butane/Propane mix is oxidized directly by a solid oxide fuel cell system.
- **Hydrogen Stored in Metal Hydrides**
  - Hydrogen gas is chemically stored in metal powder under low pressure.
  - Hydrogen is produced “on demand” and consumed immediately within the fuel cell.

FUEL CELL CARTRIDGE FLAMMABILITY TESTS

- **The fuel cell industry has made available a number of different types of fuel cell refill cartridges. These are not complete fuel cells, but contain the fuel used to power the cells**
- **Tests were conducted in the same 64 cubic foot test chamber used to test lithium batteries and the same low level alcohol fire exposure.**

64 CUBIC FOOT TEST CHAMBER



TEST ARTICLE

- **Medis 24/7 Power Pack**
  - This is a complete fuel cell
- **Fuel Type:**
  - Sodium/potassium borohydride
  - Potassium hydroxide
  - Water
- **Shipping Class**
  - Class 8
- **Plastic enclosure**

MEDIS FUEL CELL

MEDIS FLAMMABILITY RESULTS

- **Plastic case is flammable**
- **Unit vented some material which added to the fire**
- **No explosion or rapid burning**
- **Easily extinguished with Halon 1211**

ULTRACELL

TEST ARTICLE

- **Ultracell**
  - Fuel cartridge
- **250 CC**
  - 67% methanol
  - 33% water
- **Shipping Class**
  - Class 3

- **Metal fuel enclosure, plastic mounting**

ULTRACELL FLAMMABILITY RESULTS

- **The contents vented through end fitting after approximately 3.5 minutes of fire exposure**
- **The vented material was flammable, burned with a reddish flame.**
- **Plastic parts flammable.**
- **Easily extinguished with Halon 1211**

Protonex C720 Fuel Cartridge

TEST ARTICLE

- **Protonex C720**
  - Fuel Cartridge
- **Fuel Type**
  - Sodium Borohydride
  - Sodium Hydroxide
- **Shipping Class**
  - Class 8
- **Plastic enclosure**

PROTONEX FLAMMABILITY RESULTS

- Vented non-flammable fumes
- Plastic case was penetrated
- At 7:00, small flame visible on side of unit
- Fume buildup extinguished the alcohol fire at 11:00 minutes
- At 12:00, small flame self extinguished
- White paste oozed from cracked plastic case
- 15:00 No visible flames at test termination

JADOO POWER SYSTEMS TYPE C5

TEST ARTICLE

- **Jadoo Power Systems, Type C5**
  - Fuel cartridge
- **Fuel Type**
  - Hydrogen in a metal hydride
- **Shipping Class**
  - Class 2.1
- **Metal enclosure**

JADOO FLAMMABILITY RESULTS

- **At 9:30, vented gas from end cap fitting**
  - Relatively large reddish blow torch type flame
  - Flame gradually diminished in pressure and size
- **At 15:00 test was terminated**
- **Halon 1211 easily extinguished remaining flame**
- **Metal enclosure not penetrated except at end fitting**

TEKION

TEST ARTICLE

- **Tekion Inc.**
  - Fuel Cartridge
- **Fuel Type**
  - Formic Acid
- **Shipping Class**
  - Class 8
- **Plastic enclosure**

TEKION FLAMMABILITY RESULTS

- **At 1:00, sprayed liquid from the fill port, 2-3’ stream**
- **Liquid did not ignite**
- **Plastic case deformed, but did not burn**
- **Case was not penetrated except at the fill port**

ANGSTROM


ANGSTROM
www.angstrompower.com
Micro Hydrogen™
FUEL CARTRIDGE
Patents Pending - Prototype Only

TEST ARTICLE

- **Angstrom Softank**
  - Fuel cartridge
- **Fuel Type**
  - Hydrogen in a metal matrix
- **Shipping Class**
  - Class 2.1
- **Plastic enclosure**

ANGSTROM FLAMMABILITY RESULTS

- **At 1:30, edges glowed red**
- **Red glow continued for 4 minutes**
- **Plastic case charred but did not burn with an open flame**

LILLIPUTIAN SYSTEMS

TEST ARTICLE

- **Butane**
  - Fuel cartridge
- **Fuel Type**
  - Butane
- **Shipping Class**
  - Class 2.1
- **Plastic enclosure**

LILLIPUTIAN FLAMMABILITY TEST RESULTS

- **At 0:45, contents of container released and ignited**
- **Entire test enclosure filled with fire**
- **Fire duration: 20 seconds**

Millennium Cell

- **Fuel Type**
  - Loose chemical mixture
  - Sodium Hydroxide / Sodium Borohydride
- **Shipping Class**
  - Class 8
- **Enclosure**
  - Placed in 2” metal pipe cap

Millennium Cell Flammability Results

- **0:32, Ignited with small flame on surface**
- **12:00, flame momentarily extinguished with halon 1211**
- **15:00 material reignited, pipe cap extremely hot**
- **Material allowed to self extinguish, pipe cap cooled after 2 hours**

Interim Conclusions

- **All of the technologies present some fire hazard**
- **The flammable liquids and gases are easily controlled by normally available hand held fire extinguishers**
- **The corrosives (class 8) are flammable solids that are not easily ignited**
  - However, once ignited, difficult to extinguish and require specialized metals extinguishers

Additional Work

- **Flammability tests will be conducted on the different technologies as production units become available:**
  - Individual units
  - Bulk shipments
  - Fuel cells in use powering electronic equipment
  - Fuel cells charging batteries