Handheld Fire Extinguisher Optimization Final Update

Systems Working Group Meeting
Bremen Germany

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Date: May 14 - 15, 2014

Background

Civil aviation has seen an increase in Halon 1211 hand-held fire extinguisher (HHFE) in-use restrictions since the 1989 Montreal Protocol.

- Most recent cut-off dates for aviation
  - International Civil Aviation Organization(ICAO)
    - ICAO resolution A37-9 and amendments to Annexes 6 and 8 of the Chicago Convention require the use of Halon replacements for new designs and new production aircraft by December 31, 2016
  - European Aviation Safety Agency (EASA)
    - All Halon 1211 removed from service by January 2025
  - Underwriters Laboratories (UL)
    - UL 1093 Certification extended to January 2025

Background

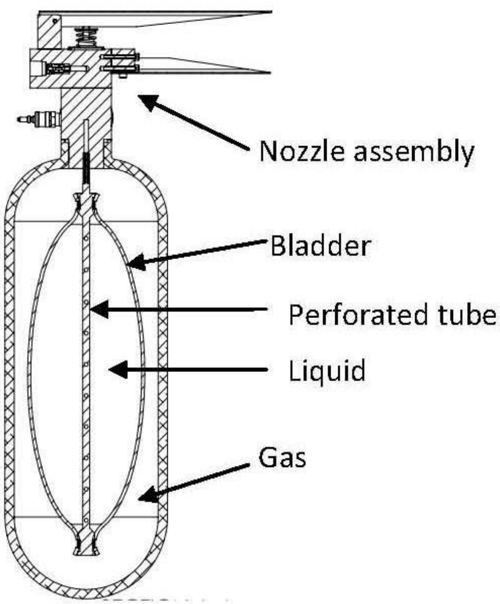
The FAA went out with a solicitation for the redesign or optimization of an aircraft HHFE to replace the Halon 1211 5BC unit currently on civilian transport aircraft that will contain an Environmental Protection Agency (EPA) approved streaming agent on the Significant New Alternatives Policy (SNAP) list

After reviewing many proposals, the FAA was interested in developed research that was already being used inside the NASA International Space Station in the form of a fine water mist extinguisher created and patented by ADA Technologies.

The FAA decided in September 2012 to continue NASA's previous work and awarded a Phase III Small Business Innovative Research (SBIR) contract to ADA Technologies.

Accepted Design

The design called for Novec 1230, a fluoroketone (FK) known as FK 5-1-12, stored in a pressurized elastomeric bladder, pressurized to 500 psi with nitrogen, and discharged through a fine-mist delivery system. This design generates a fine halocarbon mist with droplets averaging 30 – 50 μm in diameter and can be operated upside down with no loss of performance thus offering excellent firefighting capability.



Test Results

Aberdeen Test Center

- 30 fire tests performed in March 2013 using 3B and 5B fire pans
- 2 propellants were used; Carbon Dioxide and Nitrogen
- All tests used 4 lbs Novec 1230 and propellant charged to 500 psi

Initial Burst

3.8 seconds

7 seconds

Successful example of a 5B Pan fire
JP8 Fuel, 4 lbs Novec 1230, CO_2

Test Results

Aberdeen Test Center Successful Tests

- 5B fire pan, JP8 fuel
  - 4 lbs Novec 1230, CO_2 propellant charged at 500 psi
- 3B fire pan, Heptane fuel
  - 4 lbs Novec 1230, CO_2 propellant charged at 500 psi
- Test Summary
  - Fire fighter technique is very important and hard to repeat
  - 4 lbs Novec 1230 & CO2 are very close to achieving MPS 5B (heptane) requirement
  - Nozzle redesign for more initial flow for next round of testing

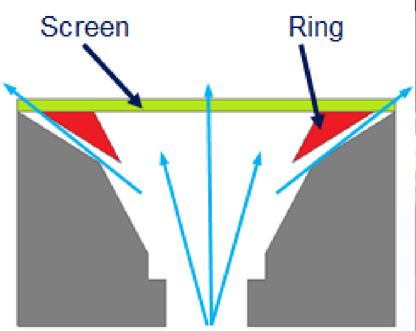
FAA Technical Center

- 18 fire tests performed in August 2013 using 5B fire pans
- 3 propellants were used; Argon, Carbon Dioxide, and Nitrogen
- 3 different nozzle prototypes
- All tests used 4 lbs Novec 1230 and propellant charged to 500 psi
- Interferometric Particle Imaging (IPI) droplet size measurements

Test Results

FAA Technical Center Successful Tests

- 5B fire pan, JP8 fuel
  - 4 lbs Novec 1230, N_2 propellant charged at 500 psi, 30°cone/screen1/ring2



  - 4 lbs Novec 1230, N_2 propellant charged at 500 psi, 3xS6x30/screen1

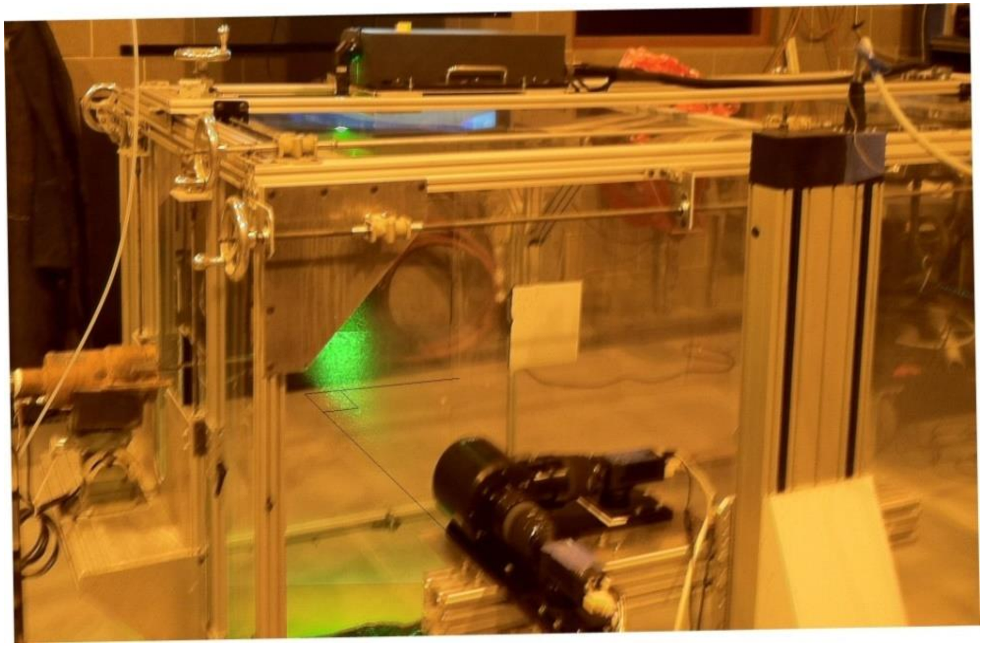
Test Results

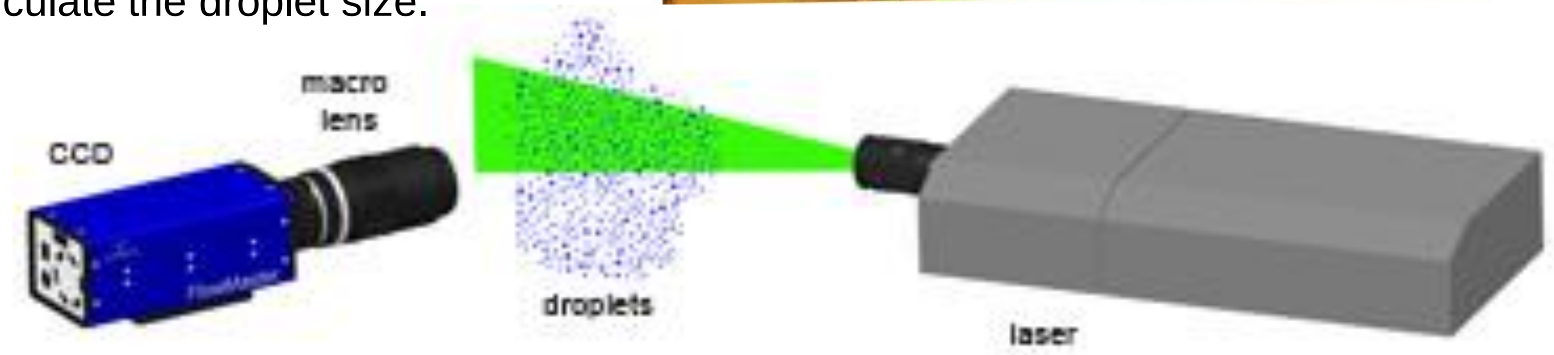
FAA Technical Center Successful Tests

- 5B fire pan, JP8 fuel
  - 4 lbs Novec 1230, Ar propellant charged at 500 psi, 30°cone/screen1
  - 4 lbs Novec 1230, N_2 propellant charged at 500 psi, 30°cone/screen1
  - 4 lbs Novec 1230, CO_2 propellant charged at 500 psi, 30°cone/screen1
  - 4 lbs Novec 1230, N_2 propellant charged at 500 psi, 30°cone/screen1/ring2
  - 4 lbs Novec 1230, N_2 propellant charged at 500 psi, 3xS6x30/screen1
- Test Summary
  - Fire fighter technique is very important and needs to be perfected
  - JP8 fuel is easily handled by new nozzle design type
  - More nozzle optimization is needed to meet the 5B heptane pan fire MPS requirement
- Interferometric Particle Imaging (IPI)
  - Test method used to measure the size of our fire extinguisher prototype nozzle droplets. The process uses a laser light sheet and (2) digital cameras; one camera setup sharply focused on the laser light sheet and the other camera setup slightly out of focus on the laser light sheet. The unfocused image reveals the droplet fringes and is used by the system software to calculate the droplet size.

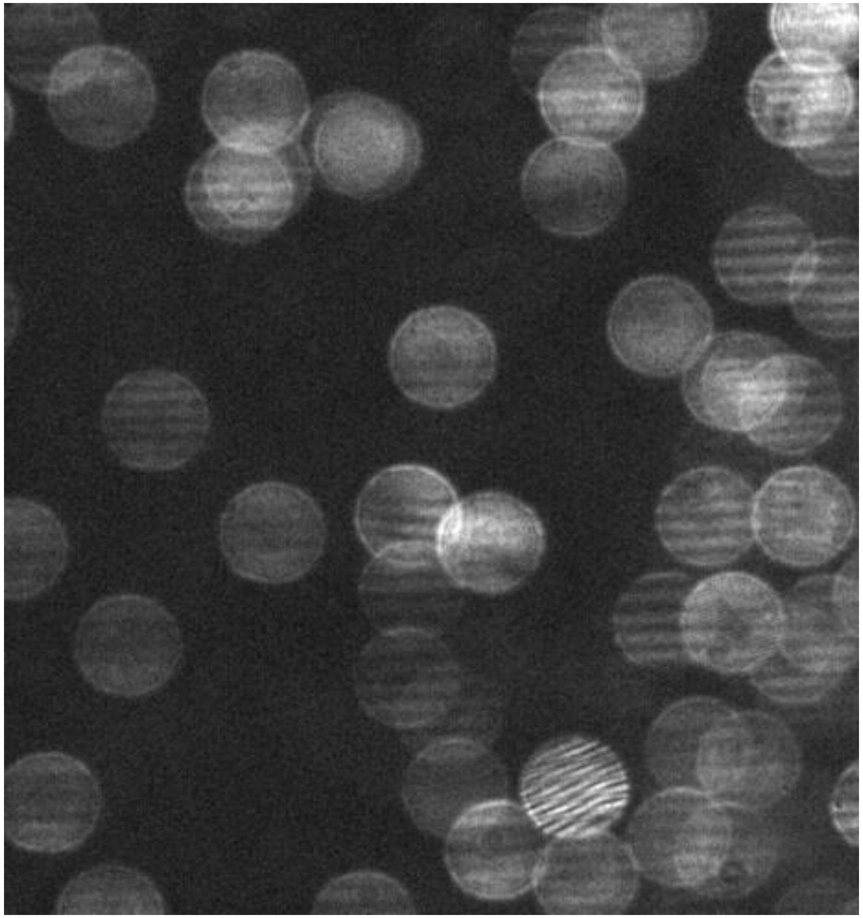
Interferometric Particle Imaging Setup

- Test method used to measure the size of our fire extinguisher prototype nozzle droplets.
- The process uses a laser light sheet and (2) digital cameras.
- One camera is setup sharply focused on the laser light sheet and the other camera is setup slightly out of focus on the laser light sheet. The unfocused image reveals fringes on the droplet and is used by the system software to calculate the droplet size.

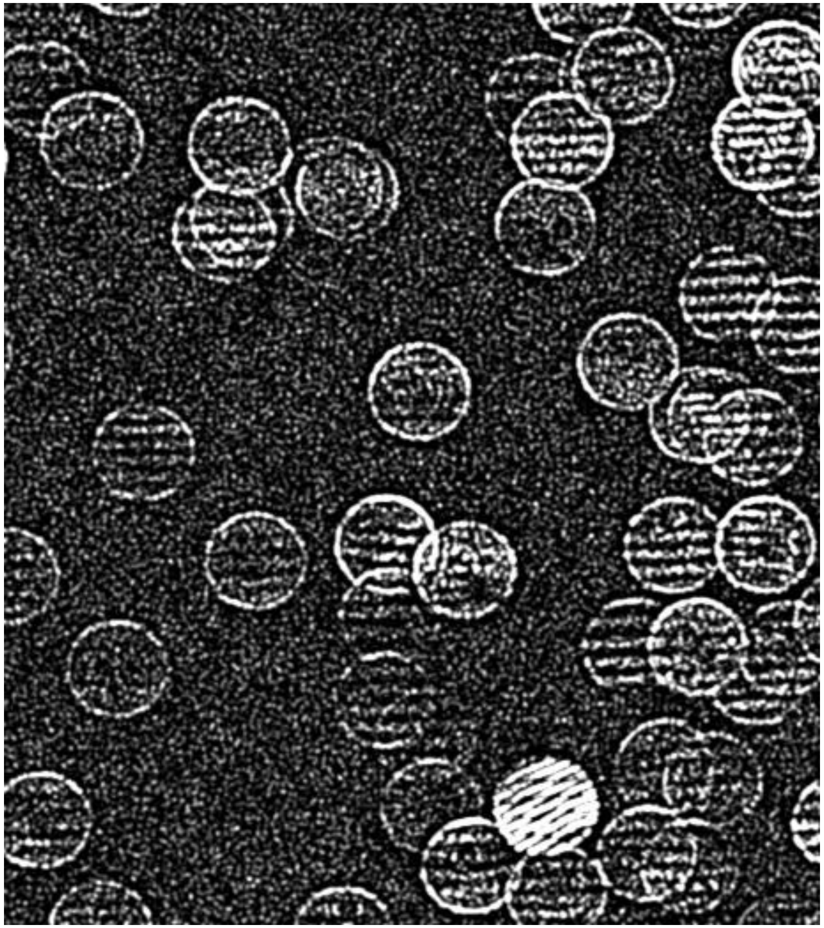




Test Results



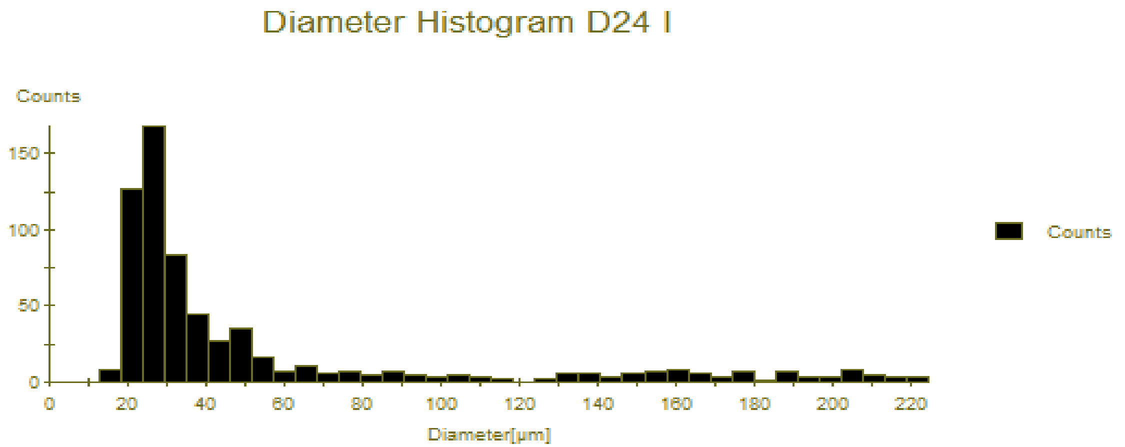
Defocused IPI Image before filtering



IPI Image after software filtering

Test Results

Interferometric Particle Imaging

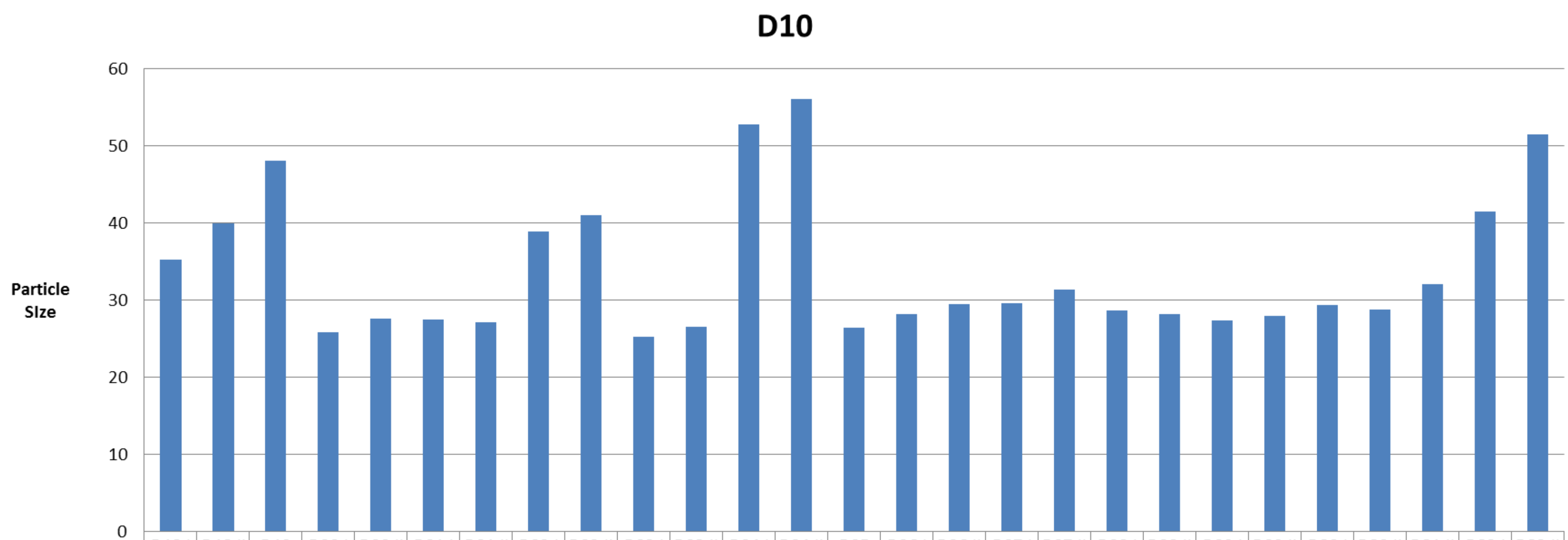


Index: 1
Statistic:
Counts = 667
D StdDev = 53.02um
D10 = 52.78um
D20 = 74.78um
D30 = 95.18um
D32 = 154.19um
D43 = 176.16um

Typical Histogram - notice a high D10 & D32 value on run #22 & #24 on the next 2 slides. We experimented with a venturi change and lowered N2 charge pressure from 500 psi to 125 psi; thus forming larger droplets

Test Results

Interferometric Particle Imaging

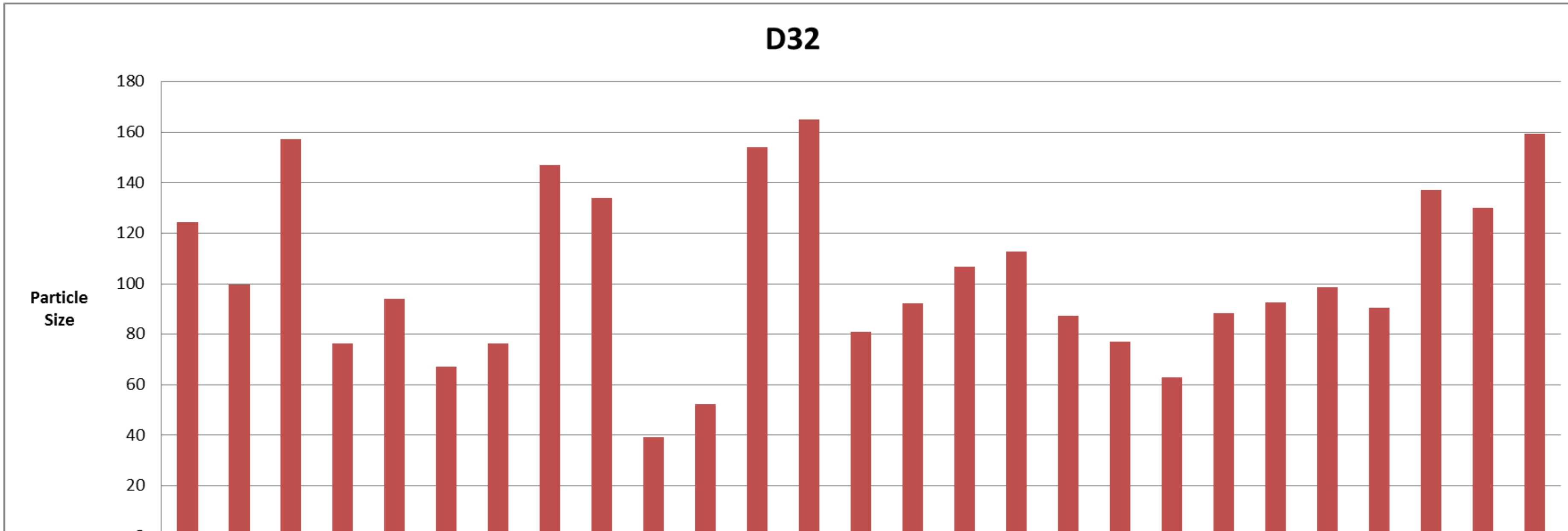


	D18 I	D18 II	D19	D20 I	D20 II	D21 I	D21 II	D22 I	D22 II	D23 I	D23 II	D24 I	D24 II	D25	D26 I	D26 II	D27 I	D27 II	D28 I	D28 II	D29 I	D29 II	D30 I	D30 II	D31 II	D32 I	D32 II
D10, microns	35.22	39.96	48.05	25.81	27.54	27.43	27.07	38.91	41.02	25.18	26.5	52.78	56.07	26.4	28.17	29.5	29.52	31.32	28.65	28.15	27.31	27.92	29.33	28.7	32.08	41.49	51.53

D10:
Arithmetic mean diameter. Is most important where the number of particles is of interest.

Test Results

Interferometric Particle Imaging



	D18 I	D18 II	D19	D20 I	D20 II	D21 I	D21 II	D22 I	D22 II	D23 I	D23 II	D24 I	D24 II	D25	D26 I	D26 II	D27 I	D27 II	D28 I	D28 II	D29 I	D29 II	D30 I	D30 II	D31 II	D32 I	D32 II
D32, microns	124.5	99.73	157.2	76.42	94.06	67.05	76.49	147	134	39.29	52.35	154.2	165.1	80.8	92.25	106.6	112.6	87.3	77.2	62.83	88.33	92.45	98.63	90.43	137.3	130	159.5

D32:
Sauter Mean Diameter (SMD) is a means of expressing the fineness of a spray in terms of the surface area produced by the spray. SMD is the diameter of a drop having the same volume to surface area ratio as the total volume of all the drops to the total surface area of all the drops.

Test Results

Interferometric Particle Imaging Summary

- The droplet sizing is hopeful in analyzing why certain nozzle configurations and agent combinations work best
- We observed improved performance when a 60 mesh screen (0.0092” opening, 30.5% open area) was mounted to the nozzle and determined that this screen reduces the momentum of the spray
- Conversely, we observed decreased performance when a finer 200 mesh screen (0.0029” opening, 33.6% open area) was mounted to the nozzle which increased momentum of the spray
- There is an optimal combination of droplet size and spray momentum so the Novec evaporates in the fire maximizing the agent’s effectiveness

Project Final Results

Requirement	Description	Proposed Design
UL Approved	At least 5B:C per UL 711 standards	Class C requirement met Class 5B requirement not met
EPA SNAP Approval	Listed by EPA	Requirement met
FAA Hidden Fire Test	Extinguish at least 9 out of 20 heptane cups	Requirement met
FAA Seat Toxicity Test	Extinguish fire and limit toxic by-products formation	Not tested. Must meet 5B requirement first
Temperature Envelope	-65°F to 120°F	Requirement met
Minimum Throw	8 feet or more	Requirement met
Corrosivity	Not corrosive	Requirement met

Conclusions

- CO2 is a more effective propellant compared to N_2 and Ar.
- Higher flow rate increases effectiveness.
- A nozzle that produces a peripheral plume around a focused center plume increases effectiveness (30° Cone/Screen 1/Ring 2 & 3xS6x30/Screen 1)
- A 60 mesh screen increases performance and lowers momentum compared to finer mesh screens and no screen at all.
- Firefighter technique specific to a Novec 1230 extinguisher needs to be developed.
- Droplet size data will enable further optimization of the delivery hardware (nozzle, Venturi).
- With a further improved delivery system (driven by droplet size and momentum data) and a well-trained firefighter, we believe that a handheld extinguisher containing less than 4 lb of Novec 1230 could meet the 5B pan requirement.
- Phase III contract completed – No further work planned