PROGRAM EXECUTIVE OFFICE

AVIATION

US Army Handheld Fire Extinguisher Hardware Development for Use with Blended HFC-227ea/Special Sodium Bicarbonate Agent

Dr. J. Douglas Mather – U.S. Army Contractor

CGI Federal (Stanley Associates, Inc.)

HHFE Replacement Project Background

- Tasked to develop and fully test a replacement to the 2.75-lb Halon 1301 handheld fire extinguisher on legacy rotary wing weapon systems
- Goal
  - Replace Halon 1301 (Class I Ozone Depleting Substance-ODS)
  - A more environmentally friendly fire extinguishing agent was desired to eliminate the dependency on ODS in-line with Army ODS Policy.
  - Meet all requirements of the Detailed Test Plan

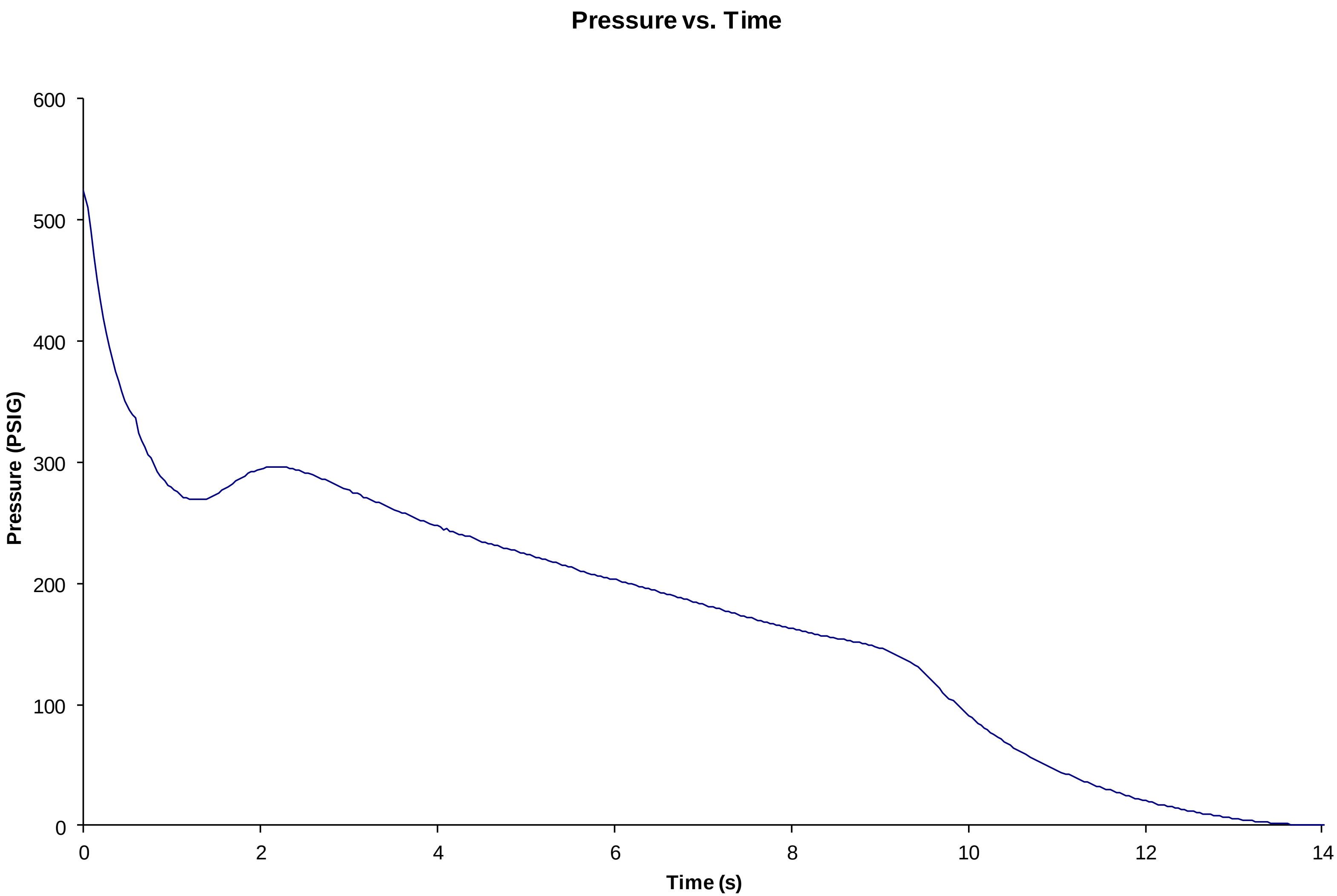
NOTE: The existing Halon 1301 configuration shown served as the baseline

HHFE Development Unique Challenges

- Use of the same cylinder size (Form, Fit, and Function) to eliminate the need for a aircraft redesign
  - Had to increase agent volume
  - Increased agent flow rates
- Agent spray optimization required
- Temperature extremes (Operational and Storage)
  - High storage temperatures: adjusted agent volume to accommodate thermal expansion
  - Low operational temperatures: tailored pressurization to maintain agent flow

NOTE: The replacement configuration shown here during human factors testing

Cylinder Pressure During Discharge (Test 64)



HHFE Nozzle Development and Agent Spray

- Optimized spray for suppression effectiveness
  - Agent droplet size
  - Discharge distance
  - Spray throw and angle characteristics

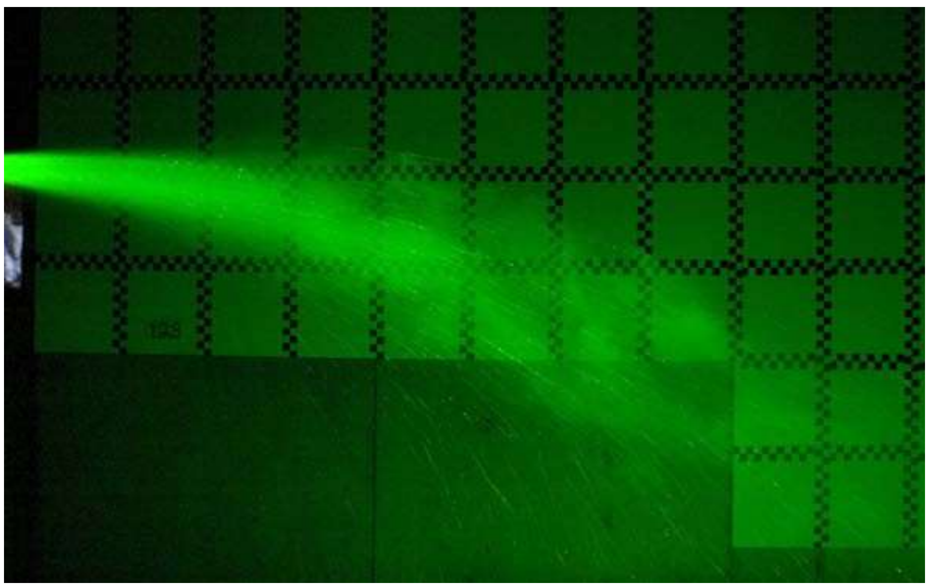
Spray discharge was optimized for each agent under test to take advantage of the heat of vaporization of the agent and to generate an inert blanket over the burning fuel

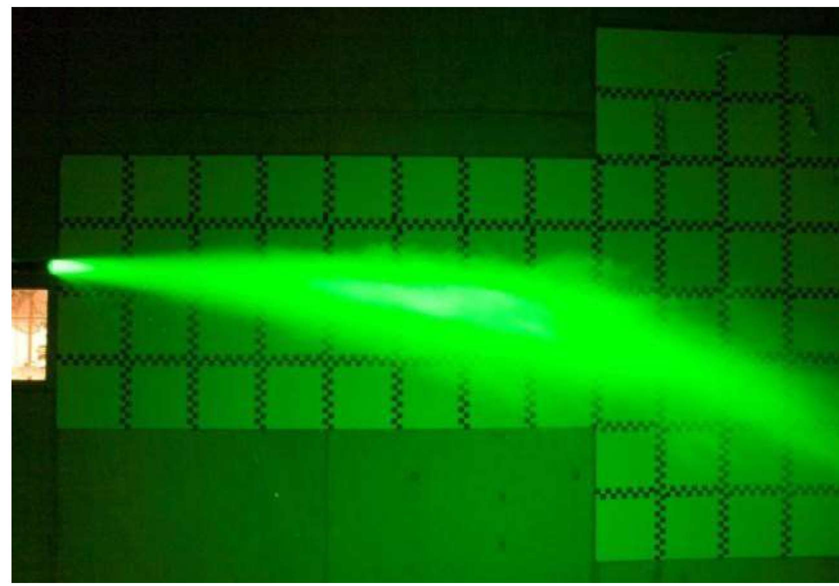
Developmental HHFE Nozzle Examples

Dozens of commercially available nozzle designs were evaluated along with many custom designs

Spray Patterns Evaluated and Optimized

- Multiple Co-Planar Lasers were utilized to show the spray patterns for optimization of agent/hardware
- Droplets shown during these evaluations aided in making design adjustments to the nozzle and pressures

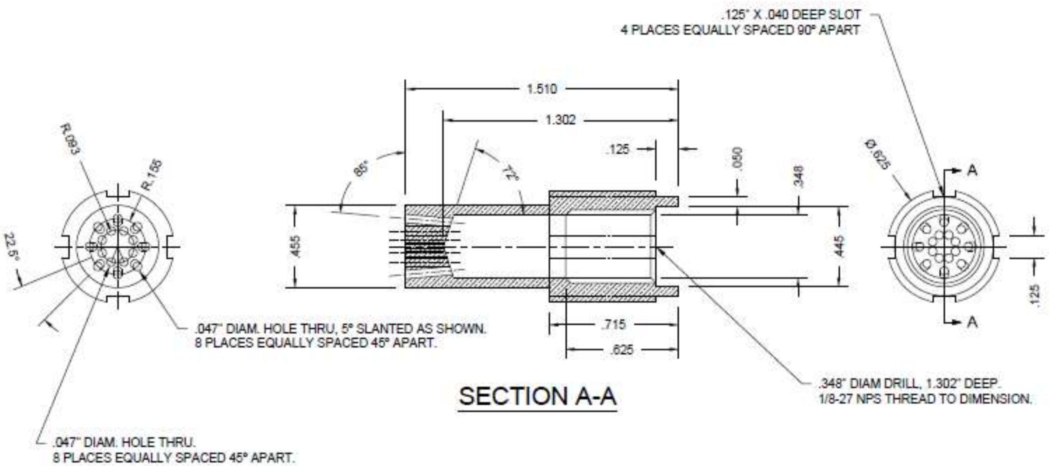




Addition of Sodium Bicarbonate to HFC-227ea

- Fire extinguishment performance of HFC-227ea insufficient.
- Sodium Bicarbonate (SBC) had been previously used to increase agent extinguishing performance in ground vehicles.
  - Total flooding application
  - Fast discharge (all at once, on the front end of discharge)
- Our goal was on a continuous discharge of the SBC HFC agent blend and good dispersion of the discharged agent spray:
  - Greater surface area of a special SBC (SBC_S) is achieved by utilizing smaller particles. Two classes, SBC-1 and SBC-2 were developed.
  - Smaller/Dryer particles increase ability to suspend in HFC-227ea and not cake when subjected temperature cycling
  - Smaller particles are more effective in fire suppression

Selected Nozzle for SBC HFC-227ea agent



- Originally developed for Halotron I and Novec 1230
- Sixteen holes intended to break up the spray
- Effectively disperses SBC_S
- Angled holes to separate droplets to increase range, cover more area

JP-8 Fire Extinguishment

3 FEB 2010
FM-200 w/
SBC-2
12.5 Sq Ft JP-8
Fire Test #29

Obscuration SBC-1 Blend

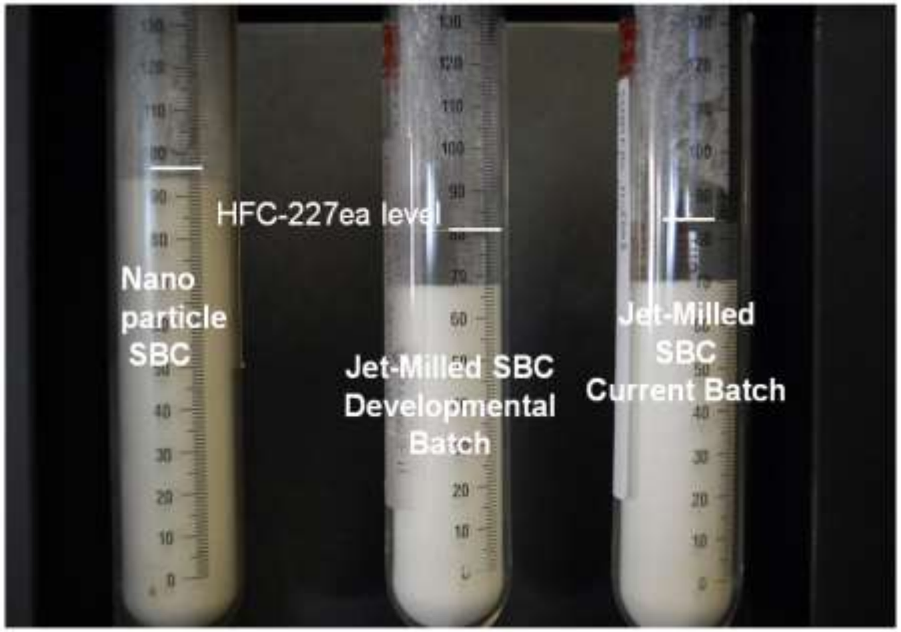
5 MAR 2010
FM-200 w/ SBC-1
Obscuration
Discharge
Test # 11

Obscuration SBC-2 Blend

5 MAR 2010
FM-200 w/ SBC-2
Obscuration
Discharge
Test # 10

Challenge - Filling Extinguishers with Agent Automatically and with a Consistent SBC Wt.%

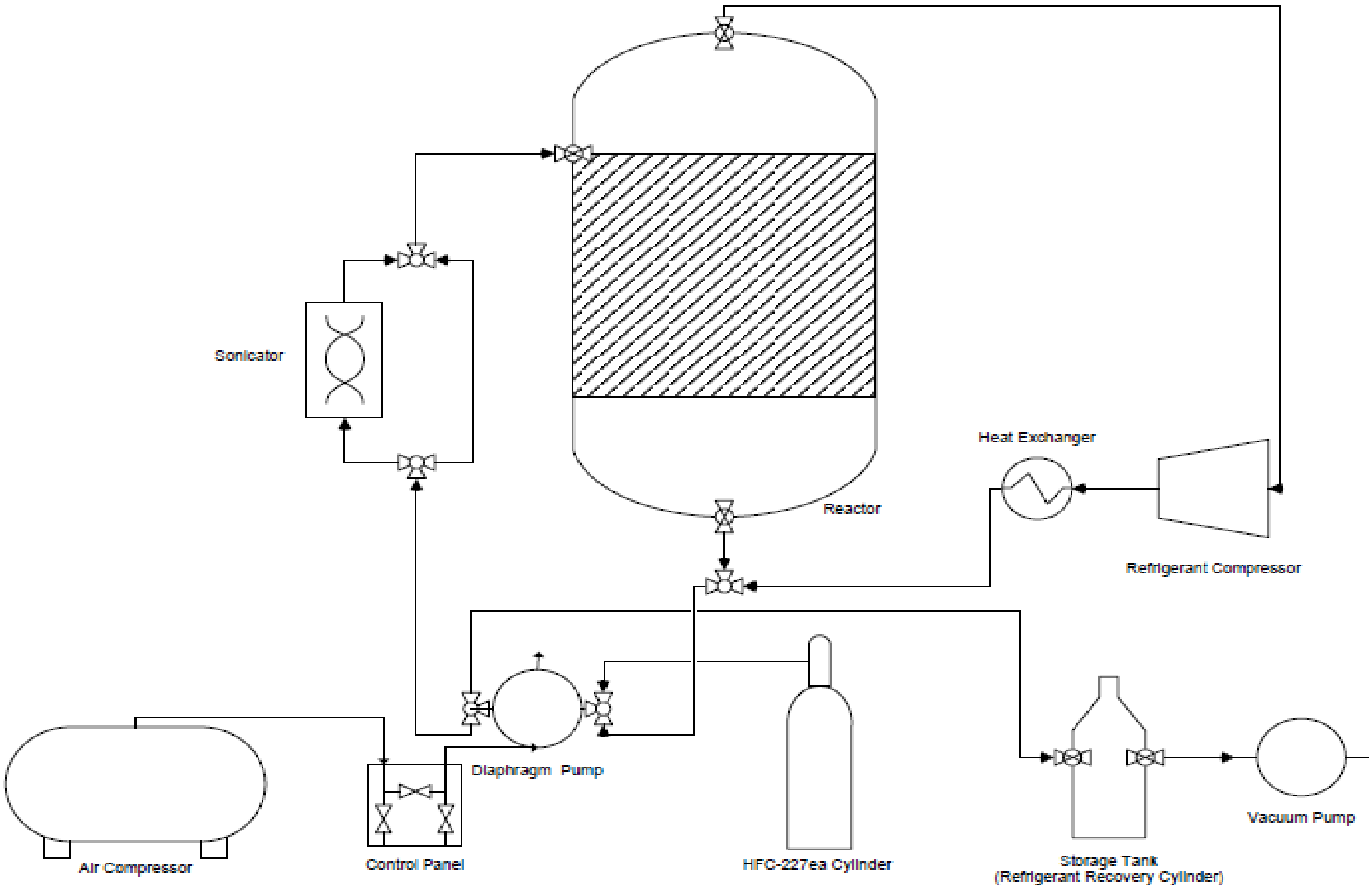
- Early production attempts to fill extinguishers with slurry at a constant weight percent loading of sodium bicarbonate failed
- Solution - keep the SBC HFC-227ea slurry bulk tank well mixed during the filling process
- Note: dry SBCs powder hand filling methods in a glove box were utilized successfully.



HFC-227ea/SBC_S HHFE Filling Station Solution

- Reactor able to withstand high pressure from the HFC-227ea
- Mixer gently keeps agent slurry (HFC-227ea/SBC_S) well mixed
- Capable of sampling HFC-227ea/SBC_S to verify concentration

HFC-227ea/SBC$_S$ Filling Station Process Diagram



Detailed Test Plan Met Requirements for Army Rotary Wing Aircraft

(Production Representative Hardware Development)

Item	Criteria
Initial Inspection (1-18)	
1	Cylinder Shell
2	Cylinder Volume……measure of aluminum cyl = 3 cu in less *
3	Cylinder Contents/Charge
4	Dimensions
5	Mounting Bracket Latch
6	Unlatching Process
7	Removal Interference
9	Pressure indicator Gauge
10	Weight. No more than 3.6 kg (7lbs, 14 oz)
11	Interface with Aircraft
12	Interfacing Materials
13	Agent Release Mechanism
14	Operating Mechanism Locking Device/Safety
15	Valve/Nozzle Assembly
16	Siphon Tube
17	Handle
18	Exterior Surfaces
Safe Design (19-27)	
19	Stress Corrosion
20	Safe to Handle
21	Bracket Test Shock/Vibe
22	Legacy Bracket Test
23	Cylinder Retention on new bracket design
24	Cylinder Fragmentation Resistance (non-shatterability)
25	Hydrogen Embrittlement
26	Immersion Corrosion Properties of Agent
27	Aircraft Personnel Emergency Egress

***** Steel cylinder passed all testing. A new lightweight Aluminum cylinder was evaluated , however failed to meet volume requirements.*

Detailed Test Plan Met Requirements for Army Rotary Wing Aircraft
(Production Representative Hardware Development) Continued

Item	Criteria
Performance (28-31)	
28	Discharge Angle and Range
29	Discharge Time and Amount
30	Class B Fire Extinguishment
31	Discharge Pattern
Operation (32-36)	
32	Method of Operation
33	Bracket Unlatching Effort
34	Discharge Effort
35	Heavy Gloves/Arctic Mitten Operation
36	Operating Mechanism Locking Device/Safety
Environmental Qualifications (37-49)	
37	Temperature Extremes
	High Temperature
	Low Temperature
	Temperature Shock
38	Altitude
39	Humidity Exposure
40	Fungus
41	Salt Fog
42	Sand and Dust Environment
43	Acidic Atmosphere
44	Functional Shock
45	Bench Handling Shock
46	Crash Hazard Shock
47	Vibration Testing
48	Drop Test
49	Accelerated aging for rubber materials

Hardware Problems Discovered/Resolved During Testing

(Production Representative Hardware Development)

- Metal-to-metal contact preventing a proper seal
- Problem identified as overlapping tolerances

Photo of Valve Seat cut to show internal surfaces

Problems Discovered/Resolved During Testing

- Deformation of the burst disc seat led to premature failure during temp cycling
- Resolved by reducing the machining depth

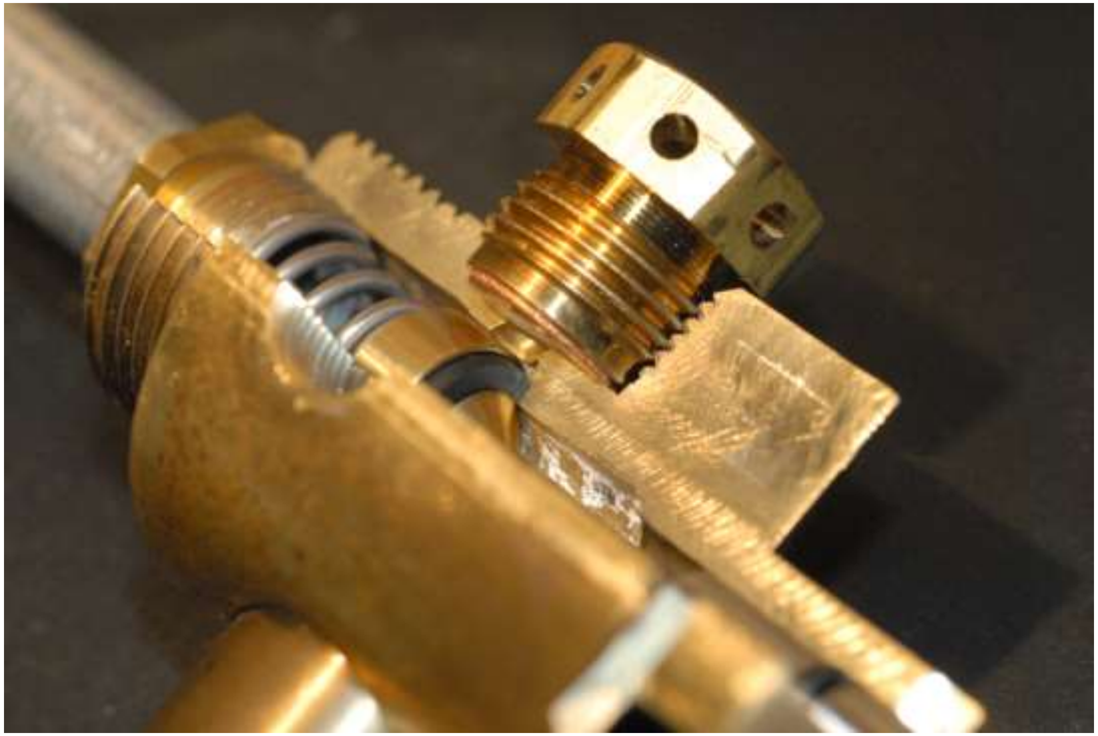


Photo of burst disc with valve cut to show seat deformation

Problems Discovered/Resolved During Testing

- This test is used to help ensure that the HHFE will be operational after a series of drops representative of what it could experience in the field
- This test involves the HHFE being dropped six times from a height of four feet onto the 2-inch plywood shown in the picture which is backed by a concrete floor
- Upgrades to this design resolved issues with the pull pin, rivet and handle material that enabled the HHFE to successfully complete this test

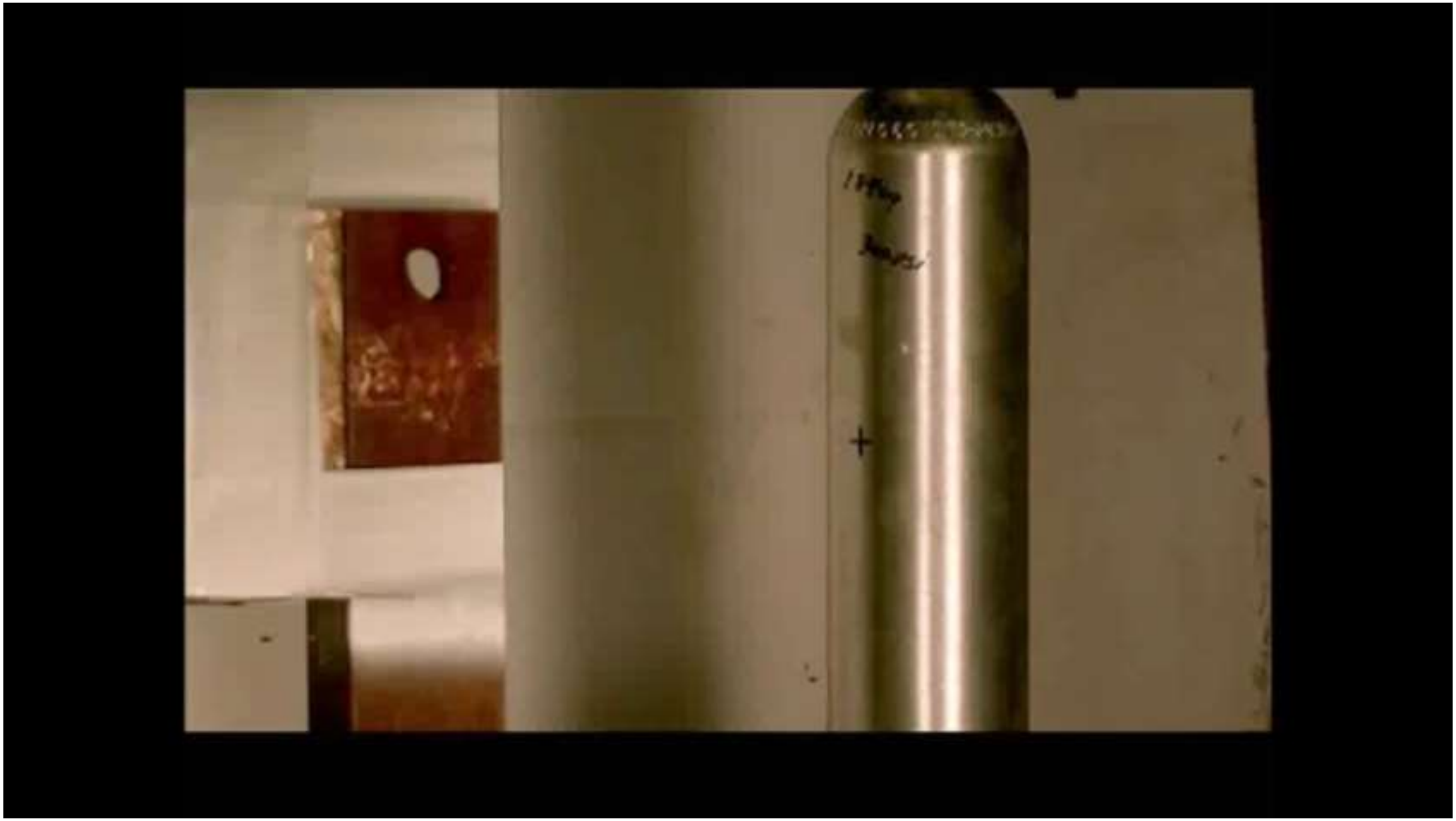
Early Drop Test sample that resulted in a bent pull pin, rivet and handle

Problem Discovered During Testing

- Aluminum cylinder is desired due to reduced weight
- Aluminum cylinder that met the volume requirement was not commercially available for testing
  - Ullage was reduced affecting flow rates
  - When agent volume was reduced to match the fill ratio, flow rate was still affected and there was not enough agent to extinguish the fire
- Aluminum cylinder requirements are part of the specification (MIL-DTL-32403)

NOTE: The steel cylinder configuration passed all requirements within MIL-DTL-32403

Problems Discovered/Resolved During Test

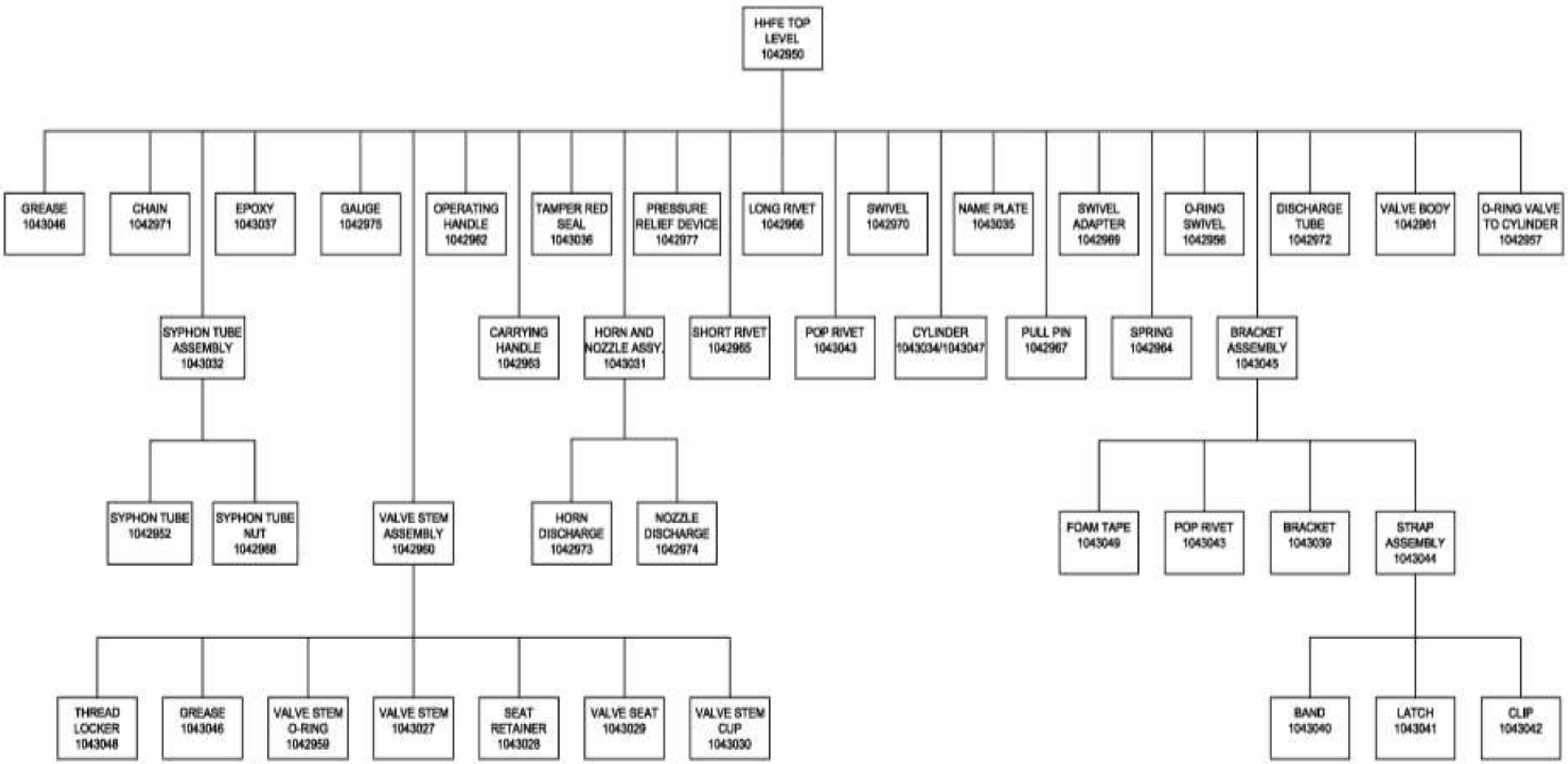


Ballistic testing of aluminum cylinder

PEO Aviation
Cradle to Grave Lethality!

Technical Data Package (TDP)

- Over 40 drawings make up the TDP



Documents that Support Fielding

- Specification for hardware published December 2012
- Safety confirmation released July 2013 from the Army Evaluation Center
- Airworthiness Assessment completed September 2013

INCH-POUND

MIL-DTL-32403
11 December 2012

DETAIL SPECIFICATION
ITEM SPECIFICATION
FOR THE

FIRE EXTINGUISHER, EMPLOYING HFC-227ea AGENT ENHANCED WITH SPECIAL SODIUM BICARBONATE POWDER (HFC-227ea/SBC_5), PORTABLE, WITH BRACKET

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Identification. This document establishes the requirements and verification methods for an HFC-227ea/SBC_5 Hand-held Fire Extinguisher (HHFE) with Bracket. For simplicity, the term 'HHFE system' will be used to describe a fully-charged HFC-227ea/SBC_5 HHFE assembly and its mounting bracket. The term 'HHFE' will most often describe a charged or uncharged HHFE assembly without the bracket. The HHFE can consist of a Steel Pressure Cylinder or an Aluminum Pressure Cylinder (paragraph 3.3.1).

1.2 System Overview. The HFC-227ea/SBC_5 HHFE system is comprised of the following items: a non-refillable, one-time usage HHFE (see paragraph 3.4.2); the fire extinguishing agent (paragraph 3.2.2); the pressurization gas (paragraph 3.2.4); and the point-of-use mounting bracket (paragraph 3.4.4). The fire extinguishing agent HFC-227ea/SBC_5 is comprised of 1, 1, 1, 2, 3, 3, 3-Heptafluoropropane agent (generically named HFC-227ea) having specialized sodium bicarbonate (SBC_5) powder in suspension. The purpose of this HHFE system is to provide Army Aviation weapon systems with an acceptable HHFE that does not employ an extinguishing agent classified as an ozone-depleting substance (ODS).

> Comments, suggestions, or questions on this document should be addressed to: Commander, U.S. Army Research, Development and Engineering Center, ATTN: RDMR-SET, Redstone Arsenal, AL 35898-5000. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.dla.mil.

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Aberdeen Proving Ground

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Quickfire USA – contributed powdered agent for crucial initial HFC227ea and SBC evaluations

3M Corporation – contributed Novec 1230

American Pacific Corporation – contributed Halotron-I

Questions

Any presentation related questions should be addressed to:

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Backup Slides

Discharge Angle and Range

- This test is used to ensure that the HHFE is capable of discharging at least 90 percent of its contents from any orientation ranging from 45 degrees to -45 degrees from the vertical position with a range of four to ten feet for seven to nine seconds


Forward (+45˚) Discharge Test


Reverse (-45˚) Discharge Test

Operational Tests

- Operational testing includes ensuring that most soldiers (5th percentile female to a 95th percentile male) will be able to individually operate the HHFE while wearing their proper personal protective equipment (PPE)

95th Percentile Male Crewmember

5th Percentile Female Crewmember

Blowing Dust Test

- This test is used to help ensure that the HHFE will be operational after it is exposed to wind-blown dust during its life cycle on the aircraft. This test includes the HHFEs being exposed to wind speeds of 1750 feet/minute with a dust concentration of 0.3 grams/cubic foot.


HHFE test samples ready for Blowing Dust Test exposure


Blowing Dust Test Samples after exposure