Engine Nacelle, Halon Replacement

Reconsidering Carbon Dioxide as a Fire Extinguishant ~ Status

Presented to:
FAA International Aircraft Systems Fire Protection Working Group,
Cologne, Germany

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Date:
10 May 2017
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Brief Project Overview

A. Why revisit carbon dioxide (CO$_2$)?
   1. An existing fire extinguishing agent with history
   2. Past and current use in ground-based systems, and aviation
   3. Currently recognized as acceptable by the FAA
      a. Advisory Circular 20-100/1977 (1)
      b. Must satisfy 37%v/v CO$_2$ for ½ sec in the powerplant fire zone
   4. Thinking existing concentration requirement can be reduced…
      a. Will put CO$_2$ through testing similar to MPSHRe rev04 (2)
      b. Will report outcomes when finished, regardless of outcome
Project Goals/Status

A. Goals
   1. Assess CO$_2$ via MPSHRe rev04
   2. Present results

B. Aspect(s) in progress...
   1. Establishing CO$_2$ storage & usage techniques
      a. Investigating/refining the cyclical-use process
         1) Pre- & post-test storage vessel handling/transport
         2) CO$_2$ servicing & thermal-conditioning
         3) CO$_2$ injection during a test
      b. Addressing a pressure-integrity problem with the storage vessel

C. Aspect(s) not yet started...
   1. MPSHRe rev04 testing with CO$_2$ ...
Current Challenges

VV02 & CO₂ Heating

A. Creating a variable-volume storage vessel (VV02)

1. Needs to be “easily” & “reliably” serviced; i.e. hand-portable
2. Current design has pressure-integrity weakness at its neck seal
   a. VV02 will require repeated handling/transport during testing
   b. An o-ring seal is repeatedly failing after pressurizing 3-4 times
   c. Repair requires full dis- & reassembly after each o-ring failure
   d. Reviewing/reworking design to eliminate this o-ring seal…
3. Will not N₂-pressurize CO₂ in VV02 during MPSHRe testing

B. Learning about thermally-conditioning CO₂ in VV02

1. Modified & using an existing electrical heating system
2. Have 3 recent trials to characterize heating VV02 & CO₂
Current Challenges

- THERMOCOUPLE (TC), CO₂-SENSING SERVICING (SVC) VALVE
- VV02 BAND-HEATER ASSEMBLY, 3 kW HYDRAULIC ACCUMULATOR, 1 U.S. GAL MANUALLY-DISCHARGED BALL VALVE

REPEATEDLY-FAILING O-RING LOCATED HERE (at the neck seal)

Date: 04/26/2020
Current Challenges

VV02 installed...

- TC, CO$_2$-SENSING
- SVC VALVE
- PRESSURE TRANSUDER, CO$_2$-SENSING
- VV02 BAND HEATERS
- TC, VV02 SHELL
- MANUALLY-DISCHARGED BALL VALVE
Current Challenges

Preparation of 2.90 kg CO₂ in 3.46 L (839 kg/m³)...
[6.4 lbm CO₂ in 211 cubic inches]

USEFUL NOTES:
1. 2.9 kg CO₂ is near VV02’s full capacity.
2. Summer-time, pre-test CO₂ heating likely 30 minutes or less (need to attain 38°C).
3. CO₂ discharge duration similar to halon/HFC-125.
4. CO₂ discharge pressure ≈ 2-3X halon or HFC-125.
Summary

A. In the near-term, will:
   1. Prevent occasional VV02 faulty pressure integrity
   2. Further refine CO$_2$ heating in VV02
   3. Commence testing with CO$_2$ per MPSHRRe rev04
Thank you.
Appendix


Appendix

Explain the Change in Testing from CO₂ & N₂ to CO₂ alone

A. VV02 experiencing pressure integrity issues
   1. Want to reduce its internal storage pressure
   2. Doing so to reduce impact on VV02 seals

B. Check if CO₂ P-v-T behavior at 38°C/100°F presents a disconnect with prior MPSHRe-test experience
   1. For halon 1301 & HFC-125, “benchmark” configurations required storage pressures ≈ 4.96 MPa/720 psig

<table>
<thead>
<tr>
<th>Bottle Fill</th>
<th>Density</th>
<th>Pressure @ 38°C/100°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ &amp; N₂</td>
<td>786.5 kg/m³</td>
<td>20.5 MPa (~2970 psig)</td>
</tr>
<tr>
<td></td>
<td>(49.1 lb/ft³)</td>
<td></td>
</tr>
<tr>
<td>CO₂</td>
<td></td>
<td>14.3 MPa (~2080 psig)</td>
</tr>
</tbody>
</table>

2. Pressure-insult from injecting pure CO₂ still exceeds experience, so CO₂ alone it is…

(a) BASED ON A SERVICE POINT OF 600 psig/4.14 MPa @ 70°F/21°F
   (which for this closed system includes a P-T point of 292 psig @ -65°F)
(b) BASED ON A P-T POINT OF 292 psig/2.01 MPa @ -65°F/-54°C
Appendix

Explain the Change in Testing from CO₂ & N₂ to CO₂ alone

- 3.6 lb h1301 & N₂, 59.8 lb/ft³
- 2.5 lb h1301 & N₂, 66.5 lb/ft³
- 8.0 lb HFC-125 & N₂, 58.6 lb/ft³
- 7.0 lbf CO₂ & N₂, 57.3 lb/ft³
- 6.4 lbf CO₂ & N₂, 52.4 lb/ft³
- 6.0 lbf CO₂ & N₂, 49.1 lb/ft³
- 5.0 lbf CO₂ & N₂, 40.9 lb/ft³

Pressure [psig]

6.895 MPa = 1000 psig

T(°C) = 5/9 * [T(°F) - 32]

16.018 kg/m³ = 1 lb/ft³

Temperature [°F]