# Engine Nacelle, Halon Replacement

## Reconsidering Carbon Dioxide as a Fire Extinguishant ~ Status

Presented to:

FAA International Aircraft Systems Fire Protection Working Group,
Atlantic City, NJ USA

By:

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- Applicable Storage Pressure-Temperature Behaviors

# Project Overview

Basis for this Reconsideration

**A. Carbon dioxide ($CO_2$) = fire extinguishing agent with history**

**B. Used in civilian and military aviation**

1. Used in "early" nacelle fire extinguishment systems
   a. Dating back to the 1940s
   b. Used when applicable aviation rationales were developing
2. $CO_2$ use wanes
3. Currently recognized as acceptable by the FAA(a)
   a. AC(b) 20-100/1977(1)
   b. Must satisfy 37%v/v(c) $CO_2$ for ½ sec in the powerplant fire zone

(a) Federal Aviation Administration
(b) Advisory Circular
(c) volumetric concentration

# Project Overview

Basis for this Reconsideration

**C. Considering $CO_2$ and halon 1301 in this framework**

1. Looking at fire extinguishment design concentrations
   a. Per FAA AC 20-100/1977; resident concentration for ½ second…
      1) 37%v/v $CO_2$
      2) 6%v/v halon 1301
   b. Consider fuel inertion
      1) 6%v/v halon 1301 ≈ inerting concentration, n-heptane(2)
      2) $CO_2$/hydrocarbon inerting; Bulletin 627(3) figs 28 - 35
         a) methane ≈ 22%v/v $CO_2$
         b) ethane ≈ 32%v/v $CO_2$
         c) n-heptane ≈ 28%v/v $CO_2$
   **c. <u>Observations</u> :**
      1) 37%v/v $CO_2$ > 22-32%v/v $CO_2$; FAA AC 20-100 > inertion
      2) 28%v/v $CO_2$ ≈ 6%v/v halon 1301, via n-heptane

# Project Overview

Basis for this Reconsideration

**C. Considering $CO_2$ and halon 1301 in this framework**

2. Simplistic review regarding powerplant use
   a. $CO_2$ design concentration
      1) 37%v/v $CO_2$ => 6.2x larger than halon 1301 (37 / 6)
      2) 28%v/v $CO_2$ => 4.7x larger
   b. Density ratios, halon 1301 / $CO_2$ (T = 25°C)
      1) vapor @ 1 atm = 3.4 = 6.17 kg/m$^3$ / 1.81 kg/m$^3$
      2) liquid = 2.2 =1538 kg/m$^3$ / 710 kg/m$^3$ (different vapor pressures)
   c. Additional $CO_2$ mass needed for halon parity @ room-conditions
      1) 37%v/v $CO_2$ = 1.81; 81% mass increase (0.37*1.81/(0.06*6.17))
      2) 28%v/v $CO_2$ = 1.37; 37% increase
   **d. <u>Observation</u> :** 37-81% $CO_2$ mass increase to approach 1301 behavior

# Project Overview

Basis for this Reconsideration

**C. Considering $CO_2$ and halon 1301 in this framework**

3. If 28%v/v $CO_2$ ≈ 6%v/v halon 1301, what about $CO_2$ storage?
   a. Assume a "cold" point in the typical P-T[(d)] behavior is a design point
      1) working with a stored halon 1301+nitrogen ($N_2$) mixture
      2) the data point is -54°C @ 2110 kPa (-65°F @ 306 psia)
   b. Pure $CO_2$ has insufficient vapor pressure for T ≤ -2°C
      1) compared to halon 1301+$N_2$ typically stored for powerplant use
      2) $CO_2$ also needs $N_2$ to increase "cold" storage pressure
   c. For pressures @ T = -54°C & larger, $CO_2$+$N_2$ > halon 1301+$N_2$
   **d. <u>Observation</u> :** likely a 2[ND] weight penalty to account for P-T increase
      1) Enhancing structure for $CO_2$+$N_2$ storage & delivery systems
      2) Partially offset insult and decrease this weight penalty ?
         a) increasing $CO_2$+$N_2$ volume reduces P-T insult; volume penalty ?
         b) possible delivery system optimization for $CO_2$ ? $CO_2$ ≠ 1301…

(d) pressure-temperature

# Project Overview

## Additional Considerations

**A. Hazards relate to its use**

1. Toxicity, asphyxiation; accidental fatalities have occurred
2. Cryogenic & electrostatic hazards during rapid $CO_2$ injection

**B. Aircraft powerplant fire zones are typically not occupied**

**C. Now available in the open market place**

**D. Does not appear it will be regulated**

# Project Status

**A. Goals**

1. Assess 28%v/v $CO_2$ via MPSHRe rev04[(e)](4) bracketing
2. Present results during 2016 Triennial Conference[(f)]

**B. Aspects in process**

1. MPSHRe rev04 test matrix refinement for $CO_2$ testing
2. Gas analyzer[(g)] maintenance/recalibration
3. Establish $CO_2$ storage, conditioning, & injection systems

**C. Aspects not yet started; will start late-spring, summer**

1. Affirm FAATC NFS[(h)] agrees with MPSHRe rev04
2. Complete MPSHRe rev04 testing with $CO_2$

(e) Minimum Performance Standards for Halon 1301 Replacement in the Fire Extinguishing Agents/Systems of Civil Aircraft Engine and Auxiliary Power Unit Compartments, revision 4
(f) 8TH Triennial International Aircraft Fire and Cabin Safety Research Conference, Oct 2016
(g) FAA-owned/modified Pacific Scientific Halonyzer 2
(h) Federal Aviation Administration nacelle fire simulator

# Thank you.

# Appendix

## References


1) Advisory Circular 20-100, 1977, "General Guidelines for Measuring Fire-Extinguishing Agent Concentrations in Powerplant Compartments," United States Department of Transportation, Federal Aviation Administration, Washington, D.C. http://www.faa.gov/documentLibrary/media/Advisory_Circular/AC20-100.pdf

2) Chamberlain, G., 1970, "Criteria for Aircraft Installation and Utilization of an Extinguishing Agent Recorder," Report No. FAA-DS-70-3, U.S. Department of Transportation, Federal Aviation Administration, National Aviation Facilities Experimental Center, Atlantic City, NJ. http://www.fire.tc.faa.gov/pdf/ds703.pdf

3) Zabetakis, M., 1965, "Flammability Characteristics of Combustible Gases and Vapors," Bulletin 627, United States Department of the Interior, Bureau of Mines, Washington, D.C. http://www.osti.gov/scitech/servlets/purl/7328370

4) Ingerson, D., 2010, "Minimum Performance Standards for Halon 1301 Replacement in the Fire Extinguishing Agents/Systems of Civil Aircraft Engine and Auxiliary Power Unit Compartments, revision 04", draft/working document, United States Department of Transportation, Federal Aviation Administration, W.J. Hughes, Technical Center, Atlantic City, NJ. http://www.fire.tc.faa.gov/pdf/systems/MPSErev04_MPSeRev04doc-02submtd.pdf

5) Yang, J.C., Cleary, T.G., Vázquez, I., Boyer, C.I., King, M.D., Breuel, B.D., Womeldorf, C.A., Grosshandler, W.L., Huber, M.L., Weber, L., and Gmurczyk, G., "Optimization of system discharge," in Gann, R.G., ed., Fire Suppression System Performance of Alternative Agents in Aircraft Engine and Dry Bay Laboratory Simulations, NIST SP 890: vol. I, U.S. Department of Commerce, Washington, DC, November 1995. http://www.nist.gov/customcf/get_pdf.cfm?pub_id=911554

# Appendix

## Flammability of $CO_2$, Air, & Higher Paraffin Hydrocarbons

Bureau of Mines, Bulletin 627, figure 35

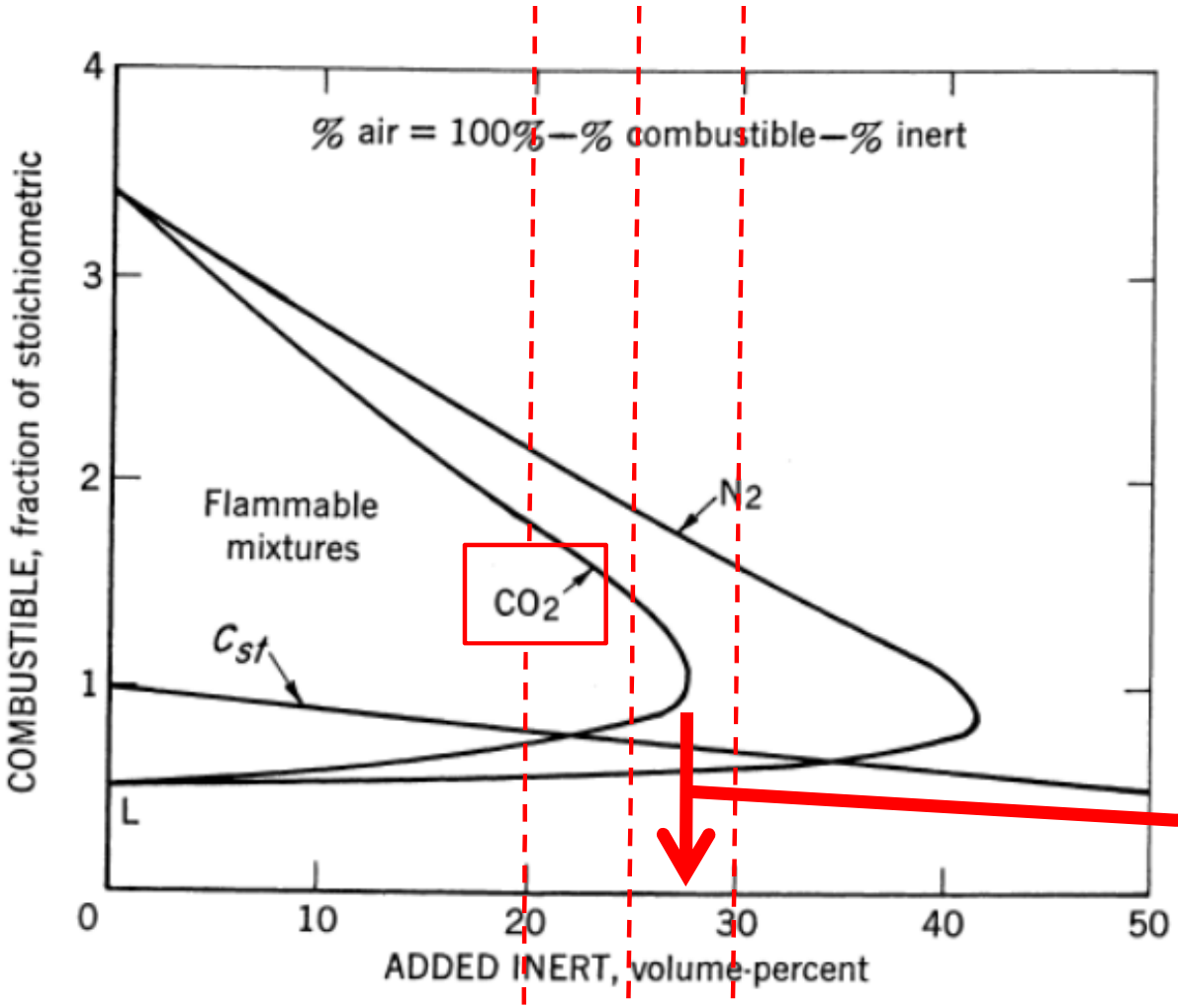



FIGURE 35.—Approximate Limits of Flammability of Higher Paraffin Hydrocarbons ($C_nH_{2n+2}$, $n \geq 5$) in Carbon Dioxide-Air and Nitrogen-Air Mixtures at 25° C and Atmospheric Pressure.

1. **$CO_2$ & n-heptane ($C_7H_{16}$) in air**
2. **$CO_2$ peak ≈ 28% v/v**

# Appendix

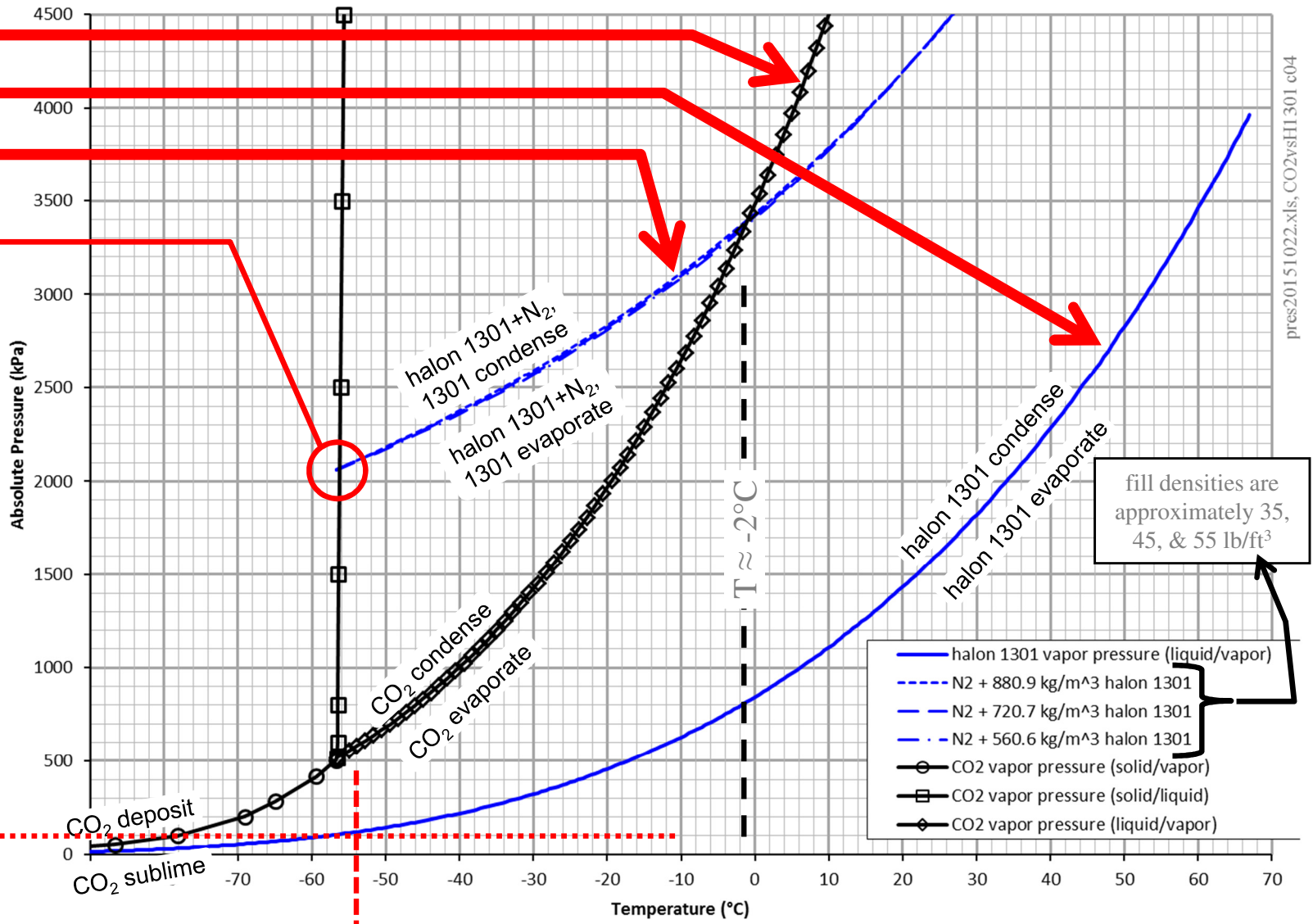
## P-T behaviors, $CO_2$, halon 1301, & 1301+$N_2$, +/-70°C

pure $CO_2$

pure halon 1301

halon 1301 + $N_2$

***assumed*** delivery system design point

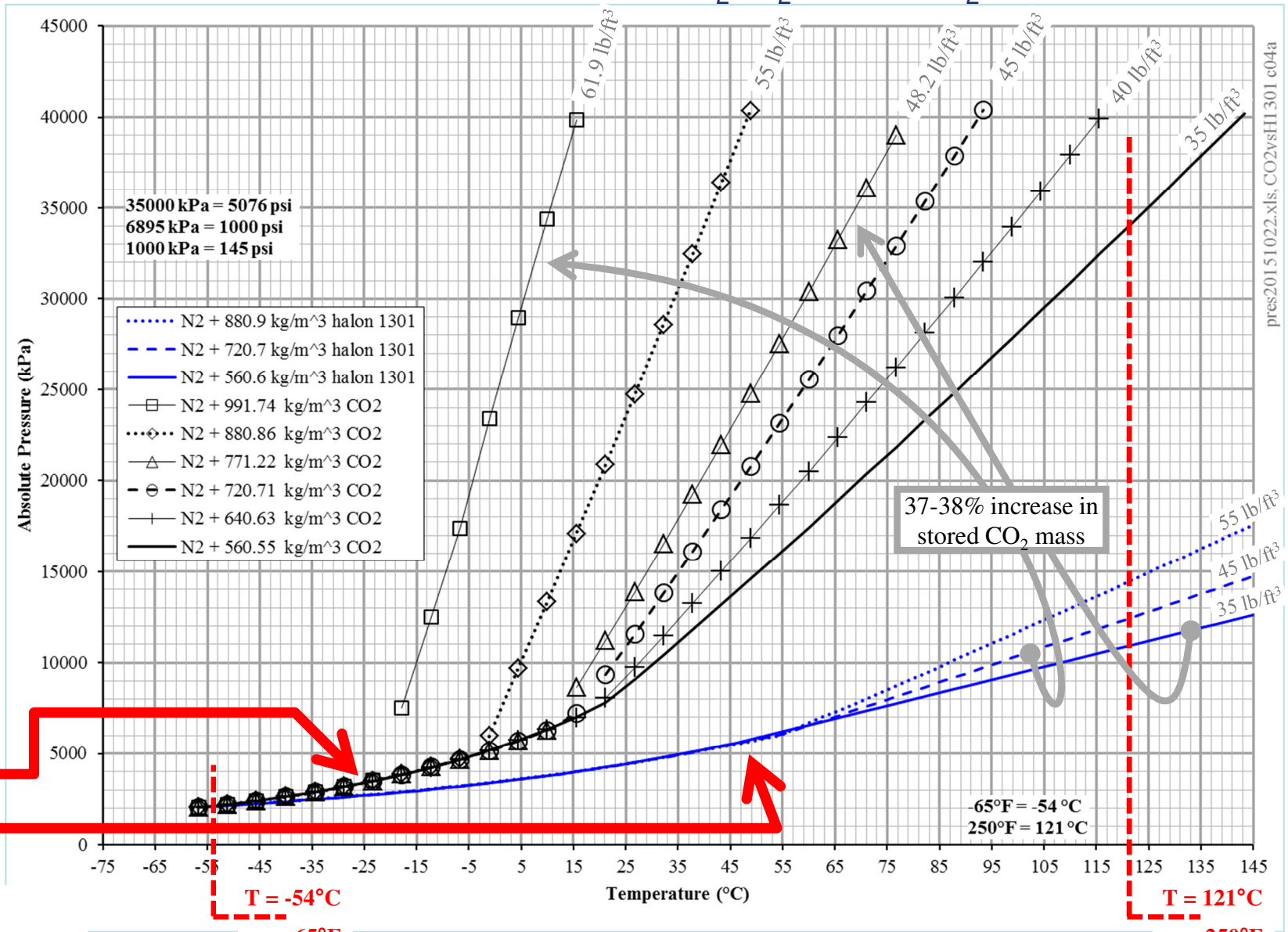



1 atm = 101.3 kPa

All P-T data created from NIST's PROFISSY[5] software

# Appendix

## P-T behaviors, $CO_2$+$N_2$ & 1301+$N_2$, -65° to 145°C




$CO_2$ + $N_2$

halon 1301 + $N_2$

All P-T data created from NIST's PROFISSY[5] software