AEM 617

Fuel Inerting

Tank Protection: protection from what?

- Sparks from electrical circuits / shorts. (eg. TWA 800)
- Lightning
- Turbine blades
- External fire (e.g. USS Forrestal in 1967)
- Internal fire
- Enemy projectiles
  - Small arms (holes, maybe incendiary) (See NOVA Zeppelin Terror Attack alternating incendiary + explosive .303, so not easy)
  - Dedicated air defense
    - WW2 ≈ 3000 88mm "Flak" for 1 bomber
    - Now ZSU-23 4000 rpm 23mm HEI
      - Tank O_2 level < 9% to avoid explosion
    - Future Laser heating?
  - Air to Air
  - ...

FLAMMABILITY CHARACTERISTICS OF COMBUSTIBLE GASES AND VAPORS

By Michael G. Zabetakis

Bulletin 627
BUREAU OF MINES

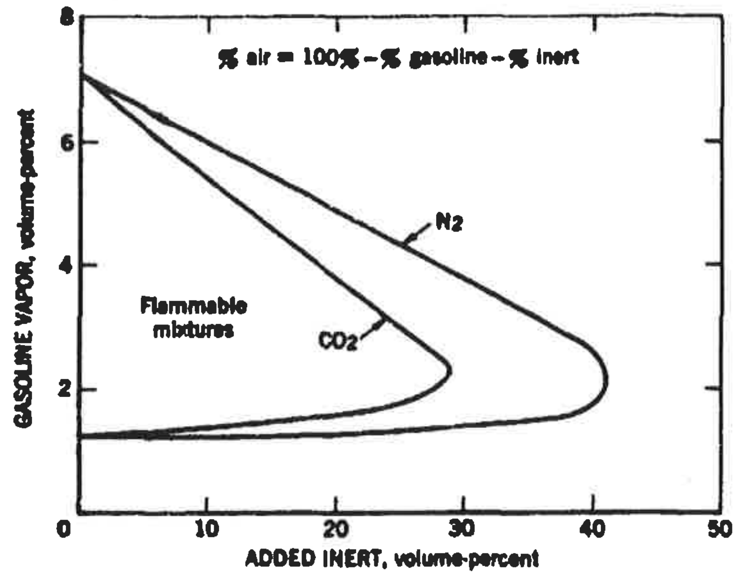


FIGURE 109.—Limits of Flammability of Aviation Gasoline, Grades 115/145 Vapor-Carbon Dioxide-Air and 115/145 Vapor-Nitrogen-Air, at 27° C and Atmospheric Pressure.

Interesting note:

CO_2 is more effective than N_2

Thermodynamics allows CO_2 to "absorb" more thermal energy faster.

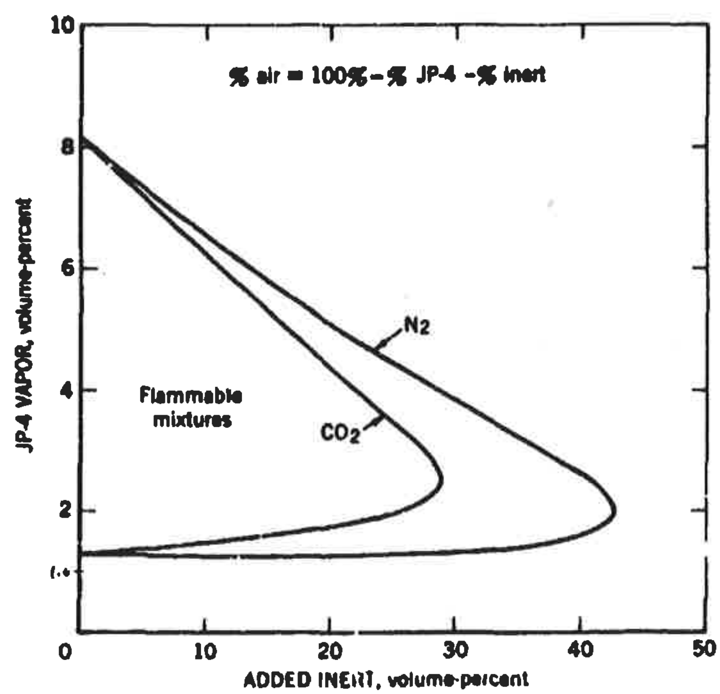


FIGURE 110.—Limits of Flammability of JP-4 Vapor-Carbon Dioxide-Air and JP-4 Vapor-Nitrogen-Air Mixtures at 27° C and Atmospheric Pressure.

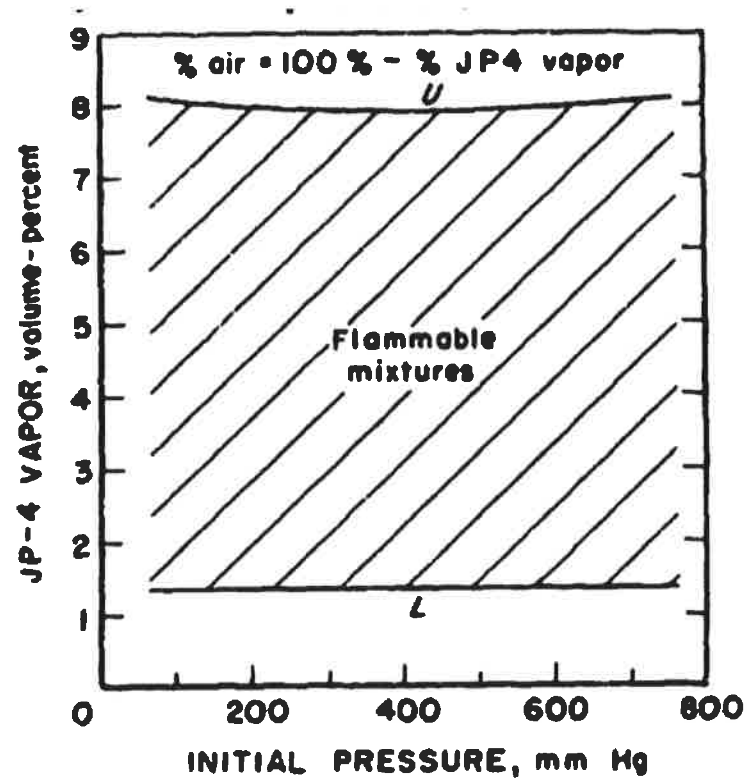


FIGURE 12.—Effect of Initial Pressure on Limits of Flammability of JP-4 (Jet Fuel Vapor) in Air at 26° C.

TABLE 20.—*Autoignition temperature values of various fuels in air at 1 atmosphere*

Fuel:	*AIT, °C*
Aviation gasoline:	
100/130	440
115/145	471
Aviation jet fuel:	
JP-1	228
JP-3	238
JP-4	242
JP-6	232
Diesel fuel:	
41 cetane	233
55 cetane	230
60 cetane	225
68 cetane	226

Flame propagation:

Deflagration ≡ subsonic propagation rate of flame front

Moderate pressure rise ≈ 8

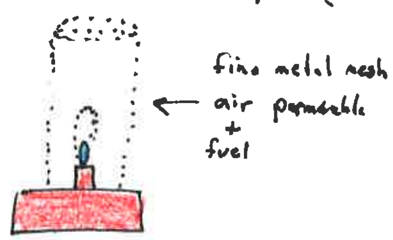
Detonation ≡ Supersonic propagation "

Large pressure rise ≈ 40

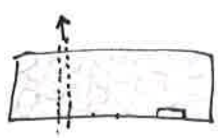
Flame Arrestor

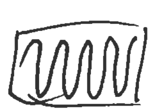
Place a thermal mass across flame front. Reduces heat transfer and stops flame without (severely) interrupting fluid flow

Davy Lamp in coal mining. (1815)



In aircraft,

- foam  A-10 method

- Reticulated Rubber 
  Metal

-

History of inerting (in aircraft)

F-86:

N_2 system, 116 lbs, 9 minutes, not operational

F-100:

N_2, 42 lbs, 35 minutes, not operational

SR-71:

N_2 to prevent spontaneous combustion

C5:

LN_2 ≡ liquid nitrogen stored in a pressurized tank

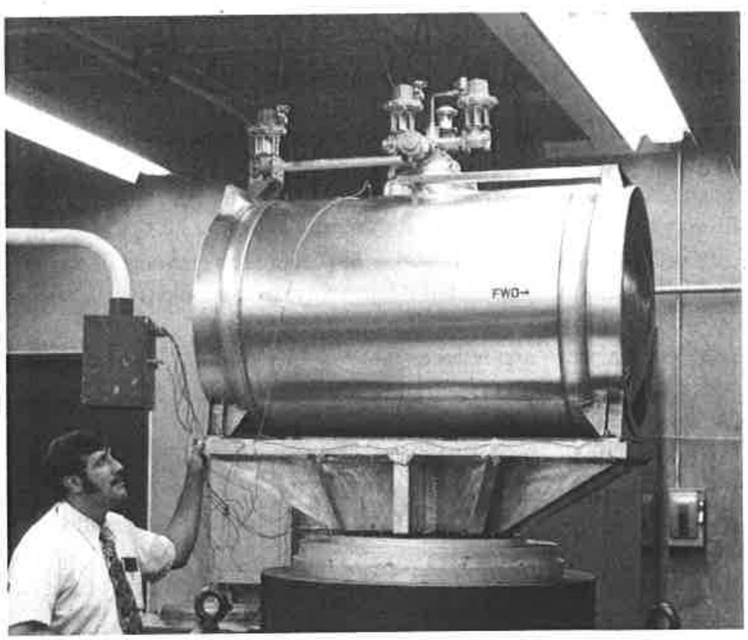
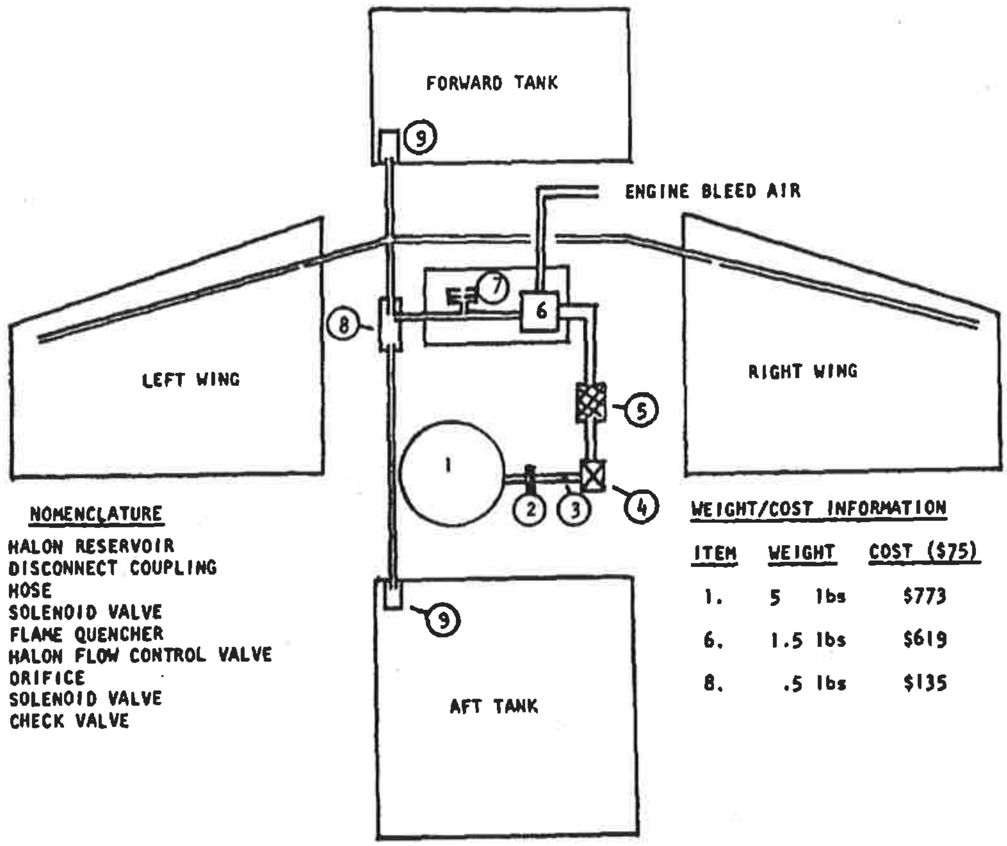


Figure 10.1 The C-5A LN_2 dewar during vibration testing (courtesy of Parker Aerospace).

F-16 INERTING SYSTEM SCHEMATIC



NOMENCLATURE

1. HALON RESERVOIR
2. DISCONNECT COUPLING
3. HOSE
4. SOLENOID VALVE
5. FLAME QUENCHER
6. HALON FLOW CONTROL VALVE
7. ORIFICE
8. SOLENOID VALVE
9. CHECK VALVE

WEIGHT/COST INFORMATION

ITEM	WEIGHT	COST ($75)
1.	5 lbs	$773
6.	1.5 lbs	$619
8.	.5 lbs	$135

FIGURE 2

F-16 TANK EXPLOSION SUPPRESSION TRADES STUDY

CONCEPT	FULLY PACK FOAM	70% PACK FOAM	CHEMICAL EXTINGUISHER AND FOAM	LIQUID NITROGEN	GASEOUS NITROGEN	HALON 1301
Factor						
Weight Increase	166#	116#	84#	55#	93#	25#
Usable Fuel Decrease	341#	238#	51#	0	25#	0
*Performance Ranking	6	5	4	2	3	1
Cost Ranking	3	2	6	5	4	1
Effectiveness Ranking	1	5	6	3	2	4

*Aircraft Performance Penalties (Least Impact to Most Impact)

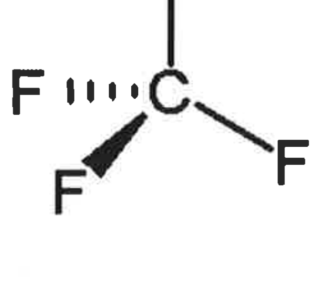
9% Halon effective against .50 API (Armor piercing Incendiary)

20% Halon " 23mm HEI (High Explosive Incendiary)

Properties of Halon 1301. Halon 1301 (bromotrifluoromethane) is a colorless, odorless gas with a chemical formula of $CBrF_3$. The military specification is MIL-B-12218. It is a highly effective fire extinguishing agent with widespread commercial and military application for protection of electrical hazards, engines, ordinary combustibles and liquid and gaseous flammable materials. Normally, Halon 1301 is compressed for convenient storage and shipped as a liquefied gas. The liquid density is 13.1 lbs/gallon at 70°F. It is a low-boiling substance with a freezing point of -270°F and a boiling point of -72°F at 1 atmosphere pressure. The variation of vapor pressure with temperature is shown in Figure 1. The mechanism by which Halon 1301 acts as a fire suppressant is not fully established. One theory is that CF_3Br chemically interferes with the combustion process.[1] As a chemical change to the hydrocarbon/air mixture occurs with the introduction of an ignition source, complex transient combustion products are formed. The Bromine (Br) radical that is freed during thermal decomposition of Halon 1301 is considered to react with these transient products and interfere with the intermediate combustion process to halt the development of an explosion. A relatively small amount of Halon 1301 is needed to produce this effect.

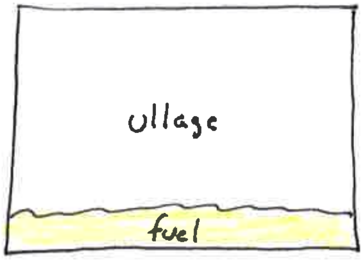
Halon 1301 unfortunately is one of the worst known ozone depleting substances in common use.

Banned since the late 1980s.



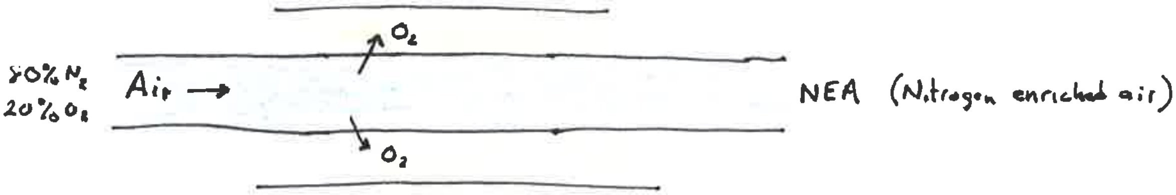
OBIGGS on board inert gas generation system

> Not to be confused with OBOGS which is on oxygen generation system

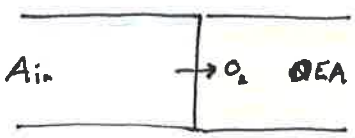


Oculus (Latin eye)
↓
Ullage

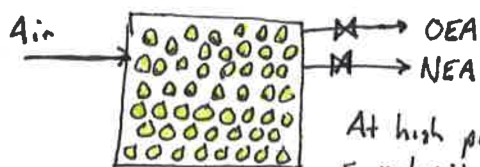
Concept ① Continuous flow



Concept ② Transient flow



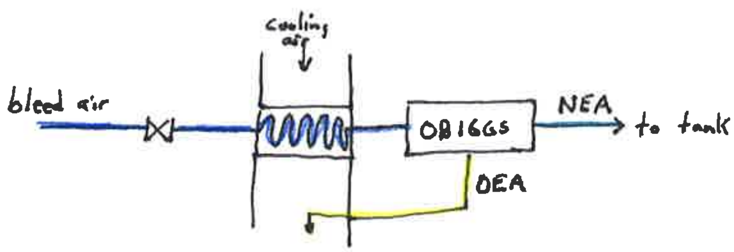
Concept ③ Molecular Sieve (aka. Pressure Swing Absorption)



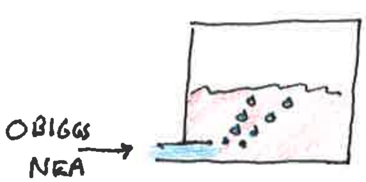
⊙ = Zeolite ultra porous Alumanosilicate mineral

At high pressures, the material absorbs O_2. At low pressures, the O_2 is released. (C17 method)

System Diagram



C17: The fuel contains air dissolved in the fuel. Solution, bubble NEA through fuel to outgas the dissolved O_2.

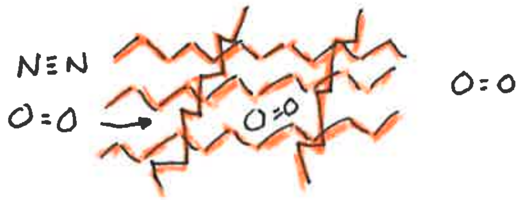


The C17 stores NEA.

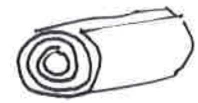
Membrane

- Non Porous

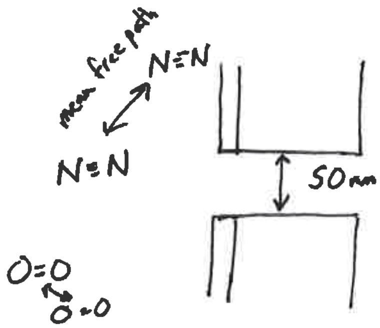
Thin sheet of polymer allows specific molecules to move through the polymer chains. Temperature sensitive.



Must be very thin for even a moderate flow rate.



- Porous



3-5 orders of magnitude more flow rate compared to non-porous!

Knudsen diffusion

$$\text{Diffusivity} = D = \frac{8 r_e}{3}\sqrt{\frac{RT}{2\pi M}}$$

$$D = \frac{\lambda}{3}\sqrt{\frac{8 k_B T}{\pi M}}$$

$$M_{N_2} = 28 \ \frac{kg}{kmol}$$

$$M_{O_2} = 32 \ \frac{kg}{kmol}$$

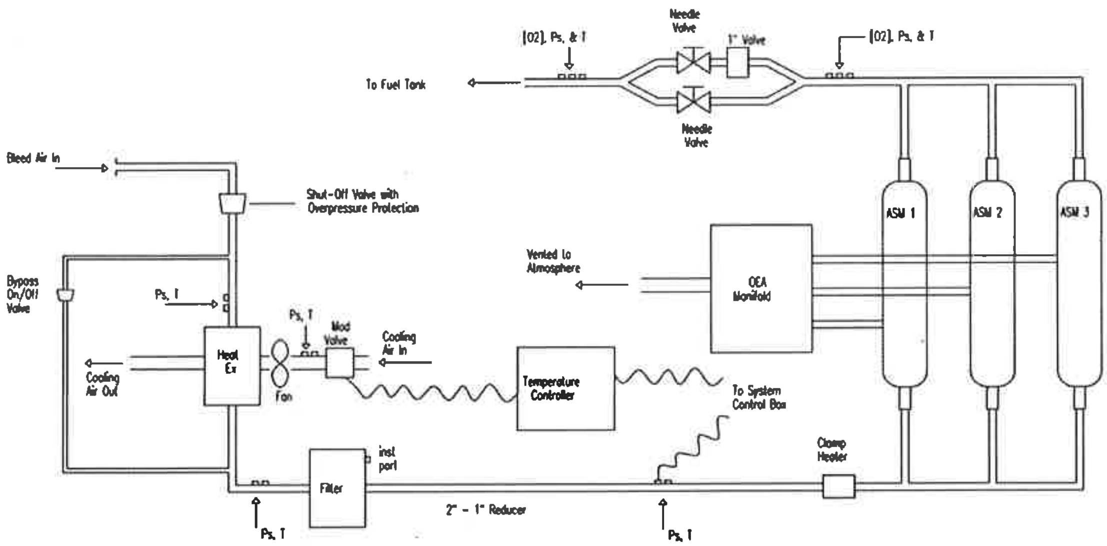


FIGURE 4. SYSTEM BLOCK DIAGRAM

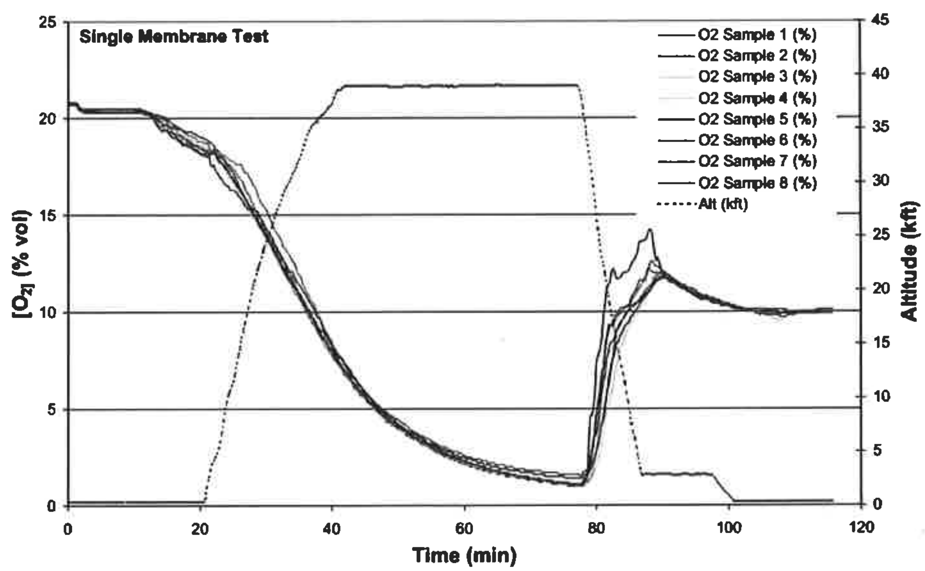


FIGURE 14. OXYGEN CONCENTRATION VARIATION IN THE CWT DURING A TYPICAL FLIGHT TEST