Fire/Explosion Risk in Transport Category Airplane fuel tank ullages

TANK ULLAGE INERTING ?

Jet A Fuel Vapors' Flammability Limits ?

Limiting Oxygen Concentration (LOC) ?

What if they were flawed ?

ASTM Standard methods must be reviewed under large volume conditions, taking auto-oxidation/ignition into account

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- An ullage atmosphere, composed of fuel vapors/oxygen/inert gas is a reacting**,** « ***explosive atmosphere**** » *,* where reactions start at the instant when fuel and oxidizer are mixed or put in contact, i.e. from time t = 0
- Pre-ignition chain-branching reactions keep rolling from that instant on, usually without any heat release (**globally isothermal**), at a rate which accelerates exponentially when the ambient temperature increases

Spontaneous Self-Ignition of « Explosive Atmospheres * »

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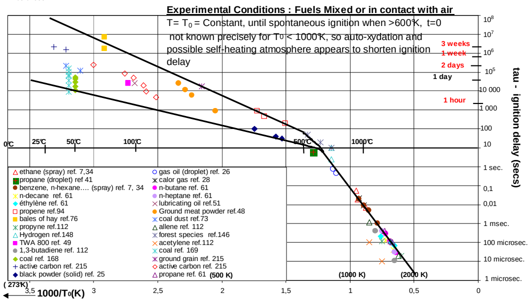

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Spontaneous Self-Ignition entails :

- No need for an « ***ignition source*** », just an « ***ignition cause*** » (which is self-ignition)
- The ***« Triangle of Fire »*** is an obsolete concept
- There is no ***« Auto-Ignition Temperature »*** for jet fuel vapors : mixed with air, they make up an ***« explosive atmosphere*»*** (*****in the EU sense of this term) : **they can self-ignite**, and the flame propagate and burn the entire mixture, even at ambient temperatures of minus 130°Celsius

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1. The **FAA definition** of « *Inerting* » is **flawed and misleading** (it is not « *true inerting* »)
   It does not preclude presence of flammable ullage atmospheres (fuel vapors/oxygen/N2)
2. **LOC** : *« Limiting Oxygen Concentration »,* **arbitrarily defined by FAA** as occuring when [O2] < 12%, **is flawed** : it is not validated by theory, nor by « clean » past experimentation
3. This arbitrary threshold does not guarantee the requested absence of danger and suppression of fire/explosion risk

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- As long as some oxygen is present, merely diluting (enriching) with more nitrogen the mixture of air/Jet A vapors which fill the tank ullages, cannot render such mixtures « *truly inert* », **unless all [O2] is eliminated**
- They will otherwise constitute dangerous, « ***explosive atmospheres**** », in the EU Directive sense of the term, i.e. *ignitable*, incl. by self-ignition, and *flammable* (the flame will propagate and burn the whole mixture)

Fire/Explosion Risk ; in Transport Category Airplane Fuel Tank Ullages

Experimental Validation:no such thing as 12% !

- Oxidation reactions at any [O2], smouldering self-ignition and fire, « cool », hot flames, detonation …
- Combustion, detonation at very high inert gas dilution shock tube experiments (550<T°K<1700)
- oxygen/hydrogen : [O2] < 0.004 in argon
- oxygen/methane : [O2] self-ignites w.>94% N2
- oxygen/iso-octane, n-heptane w.70-90%N2
  at ambient temperatures, self-ignition if [O2]>0%

given **time** : all hydrocarbons and carbohydrates

Fire/Explosion Risk in Transport Category Airplane Fuel Tank Ullages

Theoretical Validation of LOC : None !

- Arrhenius says : Reaction rates accelerate exponentially with rising ambient temperature
- Oxidation reactions take place, from the instant they are created, in all « explosive atmospheres », at any ambient temperature
- The chain–branching reactions lead to self-ignition, often isothermally, for C_nH_m fuels
- Chemical kinetics modeling can now predict the self-ignition delays of hydrocarbon fuels

Fire/Explosion Risk in Transport Category in Airplane Fuel Tank Ullages

Explanation of accidents (Danger)

- Urgent operational guidelines (ground/flight)
- Retrofitting if guidelines insufficient
- Airplanes in production – measures to be taken to suppress danger, to control risk
- What consequences if the present FAA Rules, Regs OK'd? Cost, misrepresentation of safety?
- New design safety (control/monitoring/action)

Fire/Explosion Risk Transport Category Airplane Fuel Tank Ullages

Explanation of airplane fuel tank accidents

- « Warm » days (and nights), AC Units
- « Heated », « empty », fuel tanks
- Self-ignition of « explosive atmosphere », e.g. when « induction period » had elapsed
- Flame kernel, fire, deflagration/explosion
- Self-ignition delay and time –temperature
- Thai Airways and Philippine Airlines on the ground fire start-ups; TWA 800 in flight

Fire/Explosion Risk
Transport Category Airplane Fuel Tank Ullages

Be aware of the Danger:

- Ullage atmospheres are time bombs, will self-ignite w/o warning when their induction period runs out
- They are non-homogeneous and reactive
- *Self-Ignition Delay* (induction period) and *Minimum Ignition Energy* (MIE) both diminish exponentially towards zero with increasing ullage temperature

Fire/Explosion Risk : Transport Category Airplane Fuel Tank Ullages

Urgent Operational Safety Guidelines :

On the ground

1. control of the potential danger of the fuel (chemical and physical specifications) being loaded into the tanks
2. rectify with cooling, cleaning, anti-oxidants

Loading, waiting at gate and in flight

1. monitor fuel and ullage temperatures
2. always flush ullage atmospheres as told

Fire/Explosion of Transport Category Airplane Fuel Tank Ullages

Retrofitting of the existing fleet

- True Inerting (*i.e. ullage containing zero [O2]*)
- Flushing and filling ullages w. pure N2 until at all times presence of only fuel vapors and N2 ?
- Instrumentation (T, t)
- Measuring, monitoring, acting
- Burning oxygen-containing ullage under control ?
- Bladders and Airbags in CWT's, which also offer major improvement of post-crash survivability by reducing/preventing massive fuel spill-off, post crash fires and casualties.

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End of Presentation