Aerospace Applications of NanoMist Ultra Fine Fog

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NanoMist Vs. Clean Gas Agents and Regular Water Mist

- NanoMist Ultra Fine Fog (UFF) resembles gaseous agents such FM-200, CO_2 or Nitrogen - it is a "microfluid dispersion"
  - NanoMist flow mimics gaseous agents in convoluted space
  - Because of its extremely small diameter (1-10 micron), droplet fall out rate is very low (stable aerosol)
  - Can be transported to remote locations from a central production site
- UFF mass loading can be as high as 45% (wt) in a carrier gases such as air or nitrogen - UFF is a truly a fire extinguishing as well as an inerting agent
- UFF discharge velocity can be varied to simulate either a low momentum, self-entraining agent or a high momentum, gaseous agent discharge
- UFF has ~2.5 x 10^6 j/kg heat extraction capability - highest amongst any agents known today (clean gas agents not close to this)
- Unlike regular water mist, UFF has the highest vaporization rate and large surface/volume ratio of droplets for efficient heat absorption

NanoMist Vs. Clean Gas Agents and Regular Water Mist

- Self entrainment behavior: because NanoMist is a microfluid, it can mimic air - fire can entrain it like air surrounding the fire base. Regular mist cannot be positioned around the firebase because of droplet fallout
- UFF has multiple fire protection capabilities that are not exhibited by other agents:
  1. Excellent fire extinguishment agent with a suitable discharge method
  2. Preemptive cooling, inerting and securing agent
  3. Hybrid system with : a) co-mist with clean gas agent : b) nitrogen as a carrier
- Environmentally benign water-fog-based permanent solution

NanoMist Device Technology Progress

NanoMist, UFF generation rate

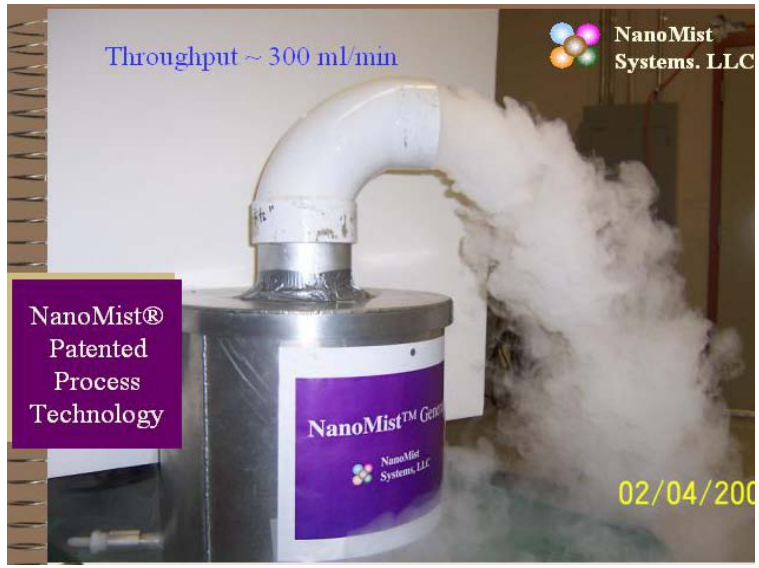
- Current : modular units 250-300 ml/min
- Projected : 0.5-1.0 liter/min

Prototypes are assembled out of off-the-shelf parts (i.e., large appearance)

Current prototype generator size of 250 ml/min: 13 x 13 x 18”

Projected : 6 x 6 x 6 ”

New technologies being explored for further reduction of size and efficiency of fog production rate



Cup Burner, Propane (lbs. agt./lbs. air)			
NanoMist (8 micron mist)	**N_2**	**HFC-227ea**	**Halon 1301**
14[1] (0.2 kg/m^3)	28-32[1,2]	33[2]	18[2]

[1] 2005 HOTWC paper Navy data

[2] 1994 NIST SP 861 report data

Aerospace Applications of NanoMist Ultra Fine Fog

Ultra Fine Fog Fire Suppression agent (UFF)

- Local flooding and total flooding
- UFF can be co-fogged with gaseous agents and dissolved chemical agents (patent pending)
- NanoMist Portable Fire Extinguishers

Ultra Fine Inerting Fog (UFIF)

- Water-based inerting fog for securing fuel spills from re-ignition
- Fuel-based inerting fog for fuel tank inerting (patent pending) - **O**nboard **F**uel Fog Inerting System (OFFIS)

OFFIS Fuel Tank Inerting System

- Generates Atomized Fuel Fog, Discharges Into Fuel Tank Ullage – Fuel-Rich Mixture
- Prior Fuel-Rich Approach Shown Feasible (Quenching or Pre-Inerting)
  - Pentane fuel used to quench in-tank explosions in aircraft (1950s) - detection technology limitation
  - "Fuel Fogging" in 1960s/70s w/high pressure nozzles – could only discharge 0.13 lbm fuel/air – limited range

NanoMist Technology: 0.3+ lbm fuel/air

- >0.22 lbm fuel/air covers all tank temperature ranges
- Unit fills ullage quickly with no pressure, nozzles
- Generates fog just outside of tank or internal, floating system – can also transport fog (lightweight)

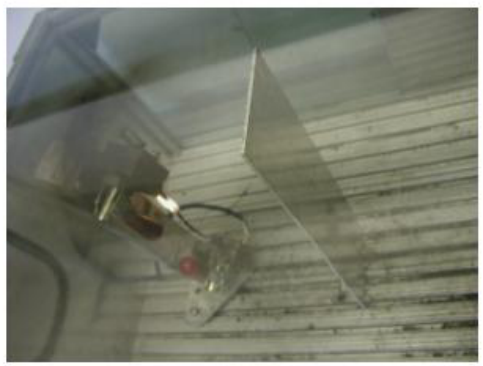
Fog Resides for Extended Period Without "Wash Out" – No Consumables, Simple System at Low Cost, Weight – Easy to Retrofit, Practical for Applications Like UAVs, Military and Small Commercial A/C, As Well as Major Airliners

UFF Extinguishing/UFIF Inerting – Cargo Bay

- NanoMist UFF Extinguishes With Low Extinguishing Mass (a few lbs. est. for typical cargo bay), Lightweight Hardware (no pressure)
  - Demonstrated in Navy, NASA, industry Class A,B fire tests
  - Shown to effectively disperse around corners, through tight clutter spaces
- Water-Based UFIF Can Suppress, Prevent Re-Ignition
  - Mated to other fast discharge systems - sustained suppression post-knockdown
  - Can suppress or extinguish deep-seated fires until OBIGGS N_2 buildup

Controlling Fire Growth By NanoMist

Controlled Class A flame in wind tunnel (Nadubizu et al. NRL)



Controlled Class A flame in space shuttle mid-deck locker (Abbud-Madrid et al. Colorado School of Mines, CSM)

Passenger Cabin Cooling for Post-Crash Evacuation

- NanoMist May Meet FAA Goal of Efficient Cooling of Cabin To Extend Flashover and Evacuation Time After Post-Crash Fire
- Fog Uses Very Small Water Quantities for Significant Cooling, Can be Transported Through Ducts, Cavities and Plumbing
  - Can even be centrally generated from galley, or portable units
- Safe for Exposure, Minimal Obscuration or Slip Hazard, No Water Damage if False Discharge, No Pressure/Nozzle Reliability

SUMMARY

- NanoMist Creates A Novel State of Material With Unique Fire Safety Properties
  - All the environmental and safety benefits of water – consistent with evolution of FAA, aircraft industry research, preferences
  - Flows like a gas through clutter, around corners
  - Extracts heat much better than water mists, other extinguishants – requires far less extinguishant due to efficiency, entrainment behavior into fire
  - Non-pressurized, no-nozzle units safer, more reliable
- Novel Derivatives Exist - Address Special Aircraft Requirements
  - Fuel fog device technology overcomes limitations of prior derivatives
    - Less weight, retrofit and flyaway costs, greater reliability anticipated
  - Fire suppression, re-ignition prevention in addition to extinguishing
    - Provides extra protection at minimal weight, can use on-board water if desired
  - May offer a feasible and cost effective way to cool cabins for evacuation
  - Partners being sought for further development, demonstration