# Literature Review: Hybrid Water Mist Fire Extinguishment Systems

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# Hybrid Water Mist Systems

- Two systems have recently become commercially available
- Systems utilize inert gas and water mist (~100 micron drops) to extinguish fires

*Figure 1: Two examples of hybrid water mist systems currently on the market. (left) Victaulic Vortex system discharging. (right) ANSUL Aquasonic system discharging.*

# Hybrid Water Mist Systems

- No NFPA Standard covers Hybrid Systems
- Only available guidance is FM 5580 – an approval standard for hybrid systems
- NFPA Standards Council asked for a literature review
  - Should Hybrid Systems be a new standard?
  - Added to NFPA 2001?
  - Added to NFPA 750?
  - No action?

*FM Approvals, FM 5580: Approval Standard for Hybrid (Water and Inert Gas) Fire Extinguishing Systems, Factory Mutual Global, 2012.*

# REVIEW OF WATER MIST, CLEAN AGENT & HYBRID SYSTEMS

# Clean Agent Suppression Systems

- Introduced in the 1930's for military aviation/maritime applications
  - Highly toxic agents used
  - US Army Research introduced safer Halons
- 1989 – Montreal Protocol banned Halons
  - Ozone depleting gas
- 1991 – NFPA 2001 was formed to cover a wide range of clean agent suppression systems

*NFPA 2001 Standard on Clean Agent Extinguishing Systems,* Quincy, MA: National Fire Protection Association , 2011.

# NFPA 2001

- Covers the design, installation, maintenance and operation of clean agent systems
- Minimum design specifications provided for Class A, B, C fires as well as safety factors
- Primarily gas-phase extinguishment
  - Extinction mechanism: depleted oxygen levels
  - Oxygen < 15% by displacement of air

*NFPA 2001 Standard on Clean Agent Extinguishing Systems,* Quincy, MA: National Fire Protection Association , 2011.

# Water Mist Systems

- Introduced in 1940's for maritime applications
- New interest after 1989 Montreal Protocol
- Droplets < 1000 micron mean diameter
  - Droplets entrained into fire plume
  - Gas phase cooling achieved by droplet evaporation
  - Secondary effect of oxygen displacement through evaporation
  - Large droplet surface area = very effective operation


- *Z. Liu and A. K. Kim , "A Review of Water Mist Fire Suppression Systems- Fundamental Studies," Journal of Fire Protection Engineering, pp. 1-50, 1999.*
- *J. Mawhinney and J. Richardson , "A Review of Water Mist Fire Suppression Research and Development, 1996," Fire Technology: First Quarter , pp. 54-90, 1996*

# NFPA 750

- Introduced in 1996 after a strong industry demand for a standard
- Provides design objectives, fire test protocols, documentation, system acceptance criteria
- Test protocols designed around the hazard or occupancy of the structure

*Figure 2: Example of Water Mist System Discharge (Marrioff HI-Fog System)*

# NFPA 750

- NFPA 750 covers design objectives, fire test protocols, documentation, system acceptance, system maintenance and marine systems
- 5 performance objectives: fire extinguishment, fire suppression, fire control, temperature control, and exposure control
- Limitations typically due to the reactive properties of water with certain materials

# Hybrid Water Mist Systems

- Combine water mist and inert gas to achieve gas-phase extinguishment
- 1996 – US Navy performed combined halocarbon/mist tests aboard ships
- Very little additional data available except for new FM Approval Standard for Hybrid Water Mist Extinguishing Systems – FM 5580
- Goal of system is combined cooling/inerting extinguishment in the gas phase.

*Forssell, E. W.; Scheffey, J. L.; DiNenno, P. J.; Back, G. G.; Farley, J. P.; Williams, F. W. ,"False Deck Development Testing of Hybrid Nitrogen – Water Mist Fire Suppression Systems" NIST SP 984-2; NIST Special Publication 984-2; Halon Options Technical Working Conference, 14th. Proceedings. May 4-6, 2004, Albuquerque, NM, 1-13 pp, 2004.*

# FIRE TESTING AND FM 5580

FM Approvals Standard for Hybrid (Water and Inert Gas) Fire Extinguishing Systems

# FM 5580

- FM performed tests to determine if Hybrid systems are unique from other listed applications
  - Performed special enclosure fire testing
  - Determined Hybrid deserves separate listing
- Oxygen concentration at extinction was determining factor
- FM 5580 provides 9 applications, each with specific test protocols
  - Approval standard only

# FM Fire Testing

- FM performed tests to distinguish between:
  - Twin-fluid water mist – gas only atomizes
  - Inert gas systems – extinguish due to inerting
  - Hybrid systems – water & gas contribute
- Enclosure fire testing and numerical modeling
  - Well stirred reactor numerical model
  - Applies to total-flooding applications only
- Distinguishing factor needed to classify systems

H.-Z. Yu, "Introducing the New FM Approvals Standard Class 5580 Hybrid (Water and Inert Gas) Fire Extinguishing Systems," 9th International Water Mist Conference, 23rd & 24th September 2009, London, UK, 2009

# FM Enclosure Fire Tests

- a 260 $m^3$ enclosure with a 0.9 m wide by 2.2 m high door opening
  - 1 MW enclosed diesel fire (test D3.2)
  - 2 MW open diesel fire (test D3.4)
  - 1 MW enclosed heptane fire (test E3.2)
  - 2 MW open heptane fire (test E3.4).
- The fires were given an average pre-burn time of around 20 seconds

H.-Z. Yu, "Introducing the New FM Approvals Standard Class 5580 Hybrid (Water and Inert Gas) Fire Extinguishing Systems," 9th International Water Mist Conference, 23rd & 24th September 2009, London, UK, 2009

# FM Fire Test Results

| | Mist & Nitrogen | | | | Hypothetical (N2 Only) | | Hypothetical (Mist Only) | |
|---|---|---|---|---|---|---|---|---|
| **Test** | **Reported Fire Extinction Time (s)** | **Predicted Fire Extinction Time (s)** | **Measured $O_2$ Concentration at Fire Extinction** | **Predicted $O_2$ Concentration at Fire Extinction (%)** | **Predicted Fire Extinction time (s)** | **Predicted $O_2$ Concentration at fire Extinction (%)** | **Predicted Fire Extinction Time (s)** | **Predicted Concentration At Fire Extinction (%)** |
| **D3.2** | 125 | 101 | No data | 14.6 (dry based)<br>12.3 (wet based) | 113 | 12.3 (dry based)<br>12.0 (wet based) | 124 | 16.1 (dry based)<br>12.5 (wet based) |
| **D3.4** | 65 | 73 | No data | 14.0 (dry based)<br>12.2 (wet based) | 84 | 12.5 (dry based)<br>12.0 (wet based) | 88 | 14.9 (dry based)<br>12.4 (wet based) |
| **E3.2** | 173 | 100 | 14.4 (dry based) | 14.6 (dry based)<br>12.3 (wet based) | 112 | 12.4 (dry based)<br>12.0 (wet based) | 122 | 16.2 (dry based)<br>12.6 (wet based) |
| **E3.4** | 86 | 72 | 13.5 (dry based) | 14.1 (dry based)<br>12.3 (wet based) | 83 | 12.6 (dry based)<br>12.1 (wet based) | 87 | 14.9 (dry based)<br>12.4 (wet based) |

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# Fire Test Results

- Traditional Water Mist
  - Dry-based $O_2$ 14.9% – 16.2% at extinguishment
  - Small degree of $O_2$ displacement
- Hybrid Systems
  - Dry-based $O_2$ 12.4% – 12.6%
  - Lowered $O_2$ and water work together
- Gaseous Systems
  - Dry-based $O_2$ 12.3% – 12.6%
  - Low $O_2$ levels provide for extinguishment

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# FM Hybrid Classifying Factor

- Gaseous Extinguishing System
  - Dry Based $O_2$ level below 12.5% for 1 & 2 MW spray fires
- Twin Fluid System
  - Dry Based $O_2$ level below 16% for 1 & 2 MW spray fires
- Hybrid System
  - Dry Based $O_2$ level between 12.5 – 16% for 1 & 2 MW spray fires

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# FM 5580 Fire Tests

- Machinery in Enclosures with Volumes not Exceeding 2825 $ft^3$ (80 $m^3$)
- Combustion Turbines in Enclosures with Volumes not Exceeding 2825 $ft^3$ (80 $m^3$)
- Protection of Machinery in Enclosures with Volumes Exceeding 9175 $ft^3$ (260 $m^3$)
- Combustion Turbines in Enclosures with Volumes not Exceeding 9175 $ft^3$ (260 $m^3$)

*FM Approvals, FM 5580: Appendix B, Approval Standard for Hybrid (Water and Inert Gas) Fire Extinguishing Systems, Factory Mutual Global, 2012.*

# FM 5580 Fire Tests

- Machinery in Enclosures with Volumes Exceeding 9175 $ft^3$ (260 $m^3$)
- Combustion Turbines in Enclosure with Volumes Exceeding 9175 $ft^3$ (260 $m^3$)
- Protection of Computer Room Raised Floors
- Future Applications

*FM Approvals, FM 5580: Appendix B, Approval Standard for Hybrid (Water and Inert Gas) Fire Extinguishing Systems, Factory Mutual Global, 2012.*

# Special Protection System Requirements

- Based on Extinguishment Time
  - 0-5 Minutes – Minimum 10 min discharge Required
  - 5-8 Minutes – Minimum 10 min discharge Required
  - Greater than 8 minutes – 20% safety factor Required
- Approval based upon full evaluation of system

*FM Approvals, FM 5580: Appendix B, Approval Standard for Hybrid (Water and Inert Gas) Fire Extinguishing Systems, Factory Mutual Global, 2012.*

# FM 5580 Design Considerations

- Hybrid systems differ from traditional systems
  - Suggested Agent Safety Factor
  - Extinguishment Time
  - Discharge Time

| Agent | Extinguishment Time | Agent Safety Factor | Discharge/Hold Time |
|---|---|---|---|
| $CO_2$ | 60 seconds | 20% | 10 minutes |
| Inert Gas | 60 seconds | 20-30% | 10 minutes |
| Water Mist | No requirement | No requirement | 2X's extinguishment time or 10 minutes |
| Hybrid Water Mist | 0 to 5 minutes | Not required | 10 minutes |
| | 5 to 8 minutes | 20 % | 10 minutes |
| | Greater than 8 minutes | Not permitted | |

# OTHER CONSIDERATIONS

# Hybrid Water Mist Scalability

- Systems on the market can act like an inert gas, water mist or hybrid system.
- Classification depends on mechanisms responsible for extinguishment, not hardware
- While system may work for local applications, it performs in a water mist configuration
  - Only testing available is for total flooding applications

# CONCLUSIONS AND RECOMMENDATIONS

# Literature Review Conclusions

- A limited amount of work is available on hybrid systems
  - US Navy and others showed Hybrid's potential
  - FM Global has recently shown differentiation between hybrid and traditional systems
  - This work is only available in 1 public presentation
- FM Global testing shows unique combined gas-phase extinguishment mechanism of hybrid water mist systems.

H.-Z. Yu, "Introducing the New FM Approvals Standard Class 5580 Hybrid (Water and Inert Gas) Fire Extinguishing Systems," 9th International Water Mist Conference, 23rd & 24th September 2009, London, UK, 2009

# Literature Review Conclusions

- Hybrid systems may be distinguished by $O_2$%
  - Gaseous Extinguishing $O_2$ < 12.5%
  - Twin Fluid System $O_2$ < 16%
  - Hybrid System $O_2$ 12.5% - 16%
  - Dry-based $O_2$% at extinction for 1 & 2 MW spray fires in a total flooding configuration
- FM Approvals have adopted FM 5580 as a new approval standard in response

H.-Z. Yu, "Introducing the New FM Approvals Standard Class 5580 Hybrid (Water and Inert Gas) Fire Extinguishing Systems," 9th International Water Mist Conference, 23rd & 24th September 2009, London, UK, 2009

# Code Recommendations

- Due to different operating/extinction mechanisms and safety considerations, a new standard/code is necessary
- Options for code adoption
  - New Standalone standard
  - Addendum to NFPA 2001
  - Addendum to NFPA 750
- Note: Before new developments, more data needs to be publicly available

# Code Recommendations

- New code must include separate chapters on system definitions, system design and system inspection, testing, maintenance and training.
  - Currently, these criteria rest only on the manufacturer's specifications, which must be standardized
- Both NFPA 2001 and 750 do not sufficiently provide a standard for a hybrid water mist system without the addition of a dedicated subsection of the existing code

# Code Recommendations

- A standalone code would be cleaner/simpler
  - Addendum would require many stipulations combining total flooding and water mist
  - Approach taken by FM is to create new approval standard
- NFPA 2001 is another possibility for inclusion
  - Simpler than NFPA 750 as it already includes agent safety factor, pressure venting, etc.
  - Water-based considerations would need to be added

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