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Literature Review: Hybrid Water Mist Fire Extinguishment Systems

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- 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

- 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

NFPA 750: STANDARD ON WATER MIST FIRE PROTECTION SYSTEMS



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.; DiNunno, 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 m³ 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



Test	Mist & Nitrogen				Hypothetical (N2 Only)		Hypothetical (Mist Only)	
	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) 12.3 (wet based)	113	12.3 (dry based) 12.0 (wet based)	124	16.1 (dry based) 12.5 (wet based)
D3.4	65	73	No data	14.0 (dry based) 12.2 (wet based)	84	12.5 (dry based) 12.0 (wet based)	88	14.9 (dry based) 12.4 (wet based)
E3.2	173	100	14.4 (dry based)	14.6 (dry based) 12.3 (wet based)	112	12.4 (dry based) 12.0 (wet based)	122	16.2 (dry based) 12.6 (wet based)
E3.4	86	72	13.5 (dry based)	14.1 (dry based) 12.3 (wet based)	83	12.6 (dry based) 12.1 (wet based)	87	14.9 (dry based) 12.4 (wet based)

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



Fire Test Results



- Traditional Water Mist
 - Dry-based O₂ 14.9% – 16.2% at extinguishment
 - Small degree of O₂ displacement
- Hybrid Systems
 - Dry-based O₂ 12.4% – 12.6%
 - Lowered O₂ and water work together
- Gaseous Systems
 - Dry-based O₂ 12.3% – 12.6%
 - Low O₂ levels provide for extinguishment

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 Hybrid Classifying Factor



- Gaseous Extinguishing System
 - Dry Based O₂ level below 12.5% for 1 & 2 MW spray fires
- Twin Fluid System
 - Dry Based O₂ level below 16% for 1 & 2 MW spray fires
- Hybrid System
 - Dry Based O₂ level between 12.5 – 16% for 1 & 2 MW spray fires

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 5580 Fire Tests



- Machinery in Enclosures with Volumes not Exceeding 2825 ft³ (80 m³)
- Combustion Turbines in Enclosures with Volumes not Exceeding 2825 ft³ (80 m³)
- Protection of Machinery in Enclosures with Volumes Exceeding 9175 ft³ (260 m³)
- Combustion Turbines in Enclosures with Volumes not Exceeding 9175 ft³ (260 m³)

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 ft³ (260 m³)
- Combustion Turbines in Enclosure with Volumes Exceeding 9175 ft³ (260 m³)
- 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

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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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