Literature Review:
Hybrid Water Mist Fire Extinguishment Systems

Michael J. Gollner
Assistant Professor, University of Maryland

Peter Raia
Undergraduate Student, University of Maryland

Project Supported By:
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?

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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

• 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

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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

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.

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 inering
  – 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

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

## FM Fire Test Results

<table>
<thead>
<tr>
<th>Test</th>
<th>Reported Fire Extinction Time (s)</th>
<th>Predicted Fire Extinction Time (s)</th>
<th>Measured O₂ Concentration at Fire Extinction</th>
<th>Predicted O₂ Concentration at Fire Extinction (%)</th>
<th>Predicted Fire Extinction Time (s)</th>
<th>Predicted Concentration At Fire Extinction (%)</th>
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<td>14.9 (dry based)</td>
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<td>100</td>
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<td>12.8 (wet based)</td>
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</tbody>
</table>

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

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

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 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

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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

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Hybrid systems differ from traditional systems

- Suggested Agent Safety Factor
- Extinguishment Time
- Discharge Time

<table>
<thead>
<tr>
<th>Agent</th>
<th>Extinguishment Time</th>
<th>Agent Safety Factor</th>
<th>Discharge/Hold Time</th>
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</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>60 seconds</td>
<td>20%</td>
<td>10 minutes</td>
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<tr>
<td>Inert Gas</td>
<td>60 seconds</td>
<td>20-30%</td>
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<td>No requirement</td>
<td>2X’s extinguishment time or 10 minutes</td>
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<td>5 to 8 minutes</td>
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<td>10 minutes</td>
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<tr>
<td></td>
<td>Greater than 8 minutes</td>
<td></td>
<td>Not permitted</td>
</tr>
</tbody>
</table>
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
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.

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

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
Technical Panel

George Laverick (UL)
Bob Kasiski (FM Global)
Zachary Magnone (Tyco)
Peter Thomas (Victaulic)
Sandra Stanek (NFPA)

Special Thanks

Bert Yu (FM Global)
Amanda Kimball (FPRF)

Student Project Support