

Electronic Space Fire Protection: Scale up False Deck Fire Testing of Ultra Fine Mist

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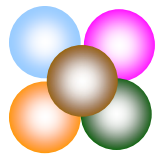
Paper presentation at the SFPE *Advances in Fire Suppression Technologies, San Diego, CA*
October 18-19, 2005

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Capabilities (FNC), Advanced Damage Countermeasures (ADC) program



Outline

- Background of NanoMist® water mist technology
- Objective of this Work
- Description of test scenario/experiments
- Results of NanoMist® Fire Suppression Behavior
 - Telltales
 - Flow blockage and additional surface area via tube bundles
 - Floor leaks (missing floor tiles)
 - Cable fires
 - Electronics exposure
- Conclusions
- Next Step



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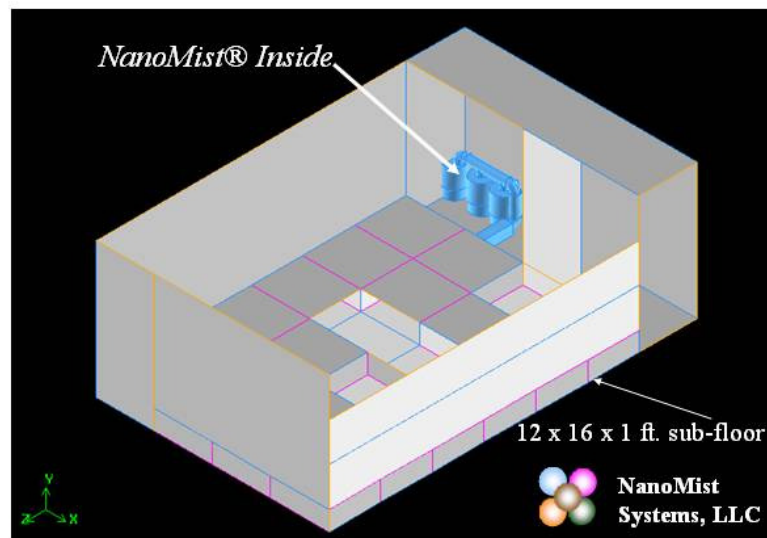
Background: NanoMist®

Background (1): NanoMist® Technology



**NanoMist®
Generator**

Layout of NanoMist® to be Engineered into Electronics Space
Sub-floor for Navy's ex-USS Shadwell (Mobile, AL) Demonstration, Sept 2005



Patented
Technology

NanoMist Systems, LLC

Background (2): NanoMist Fire Suppression Areas

1

Electronic Space Fire Protection **(Data Center Protection)**

- * Navy Sponsored False-Deck
Scaling Tests for Shipboard
Applications

2

Commercial Kitchen Protection **In-House Study**

- * NanoMist®
Deep fat fryer cooking oil fire
suppression and post fire cooling
and securing

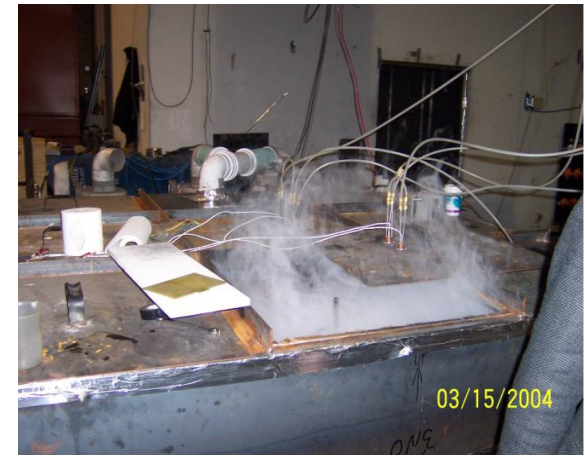
3

Research on NanoMist®

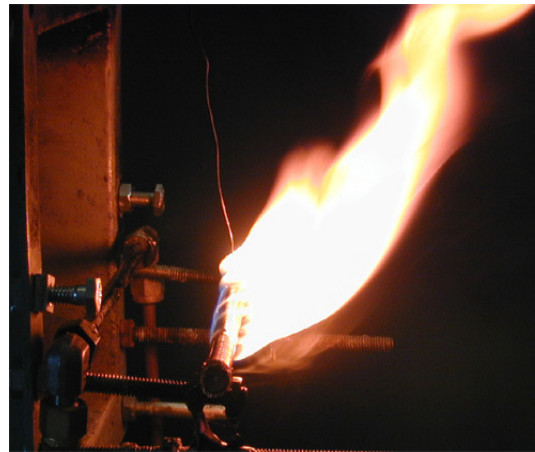
- * NRL Boundary layer fires
- * Cable fires in Space Shuttle mid-
deck locker mockup Colorado
School Mines (CCACS)
- * In-house R&D work

Background (3) :NanoMist Fire Suppression Areas

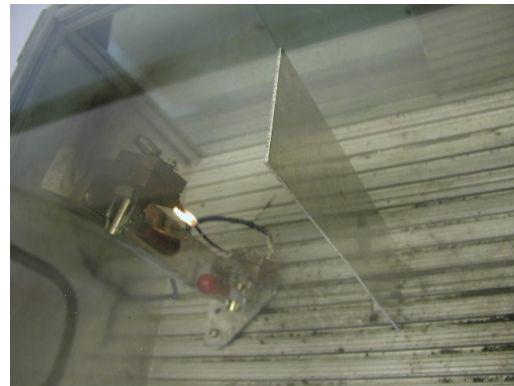
1.
Sub-floor Study:
Forssell et al., Hughes Associates
(NRL Sponsored Projects)



2.
Cable Flame Study of
NanoMist®: Courtesy of Ndubizu
et al.(NRL)



3.
NanoMist® Cable Flame
in Space Shuttle mid-deck
locker mockup
Courtesy of Abbud-Madrid et al
(CSM-CCACS)



Background (4): NanoMist Fire Suppression Areas

4. In-House Research & Development

NanoMist® Deep Fat Fryer : Cooking Oil Fire. Fryer Mockup : 18 x 19 inch



5. In-House Research & Development

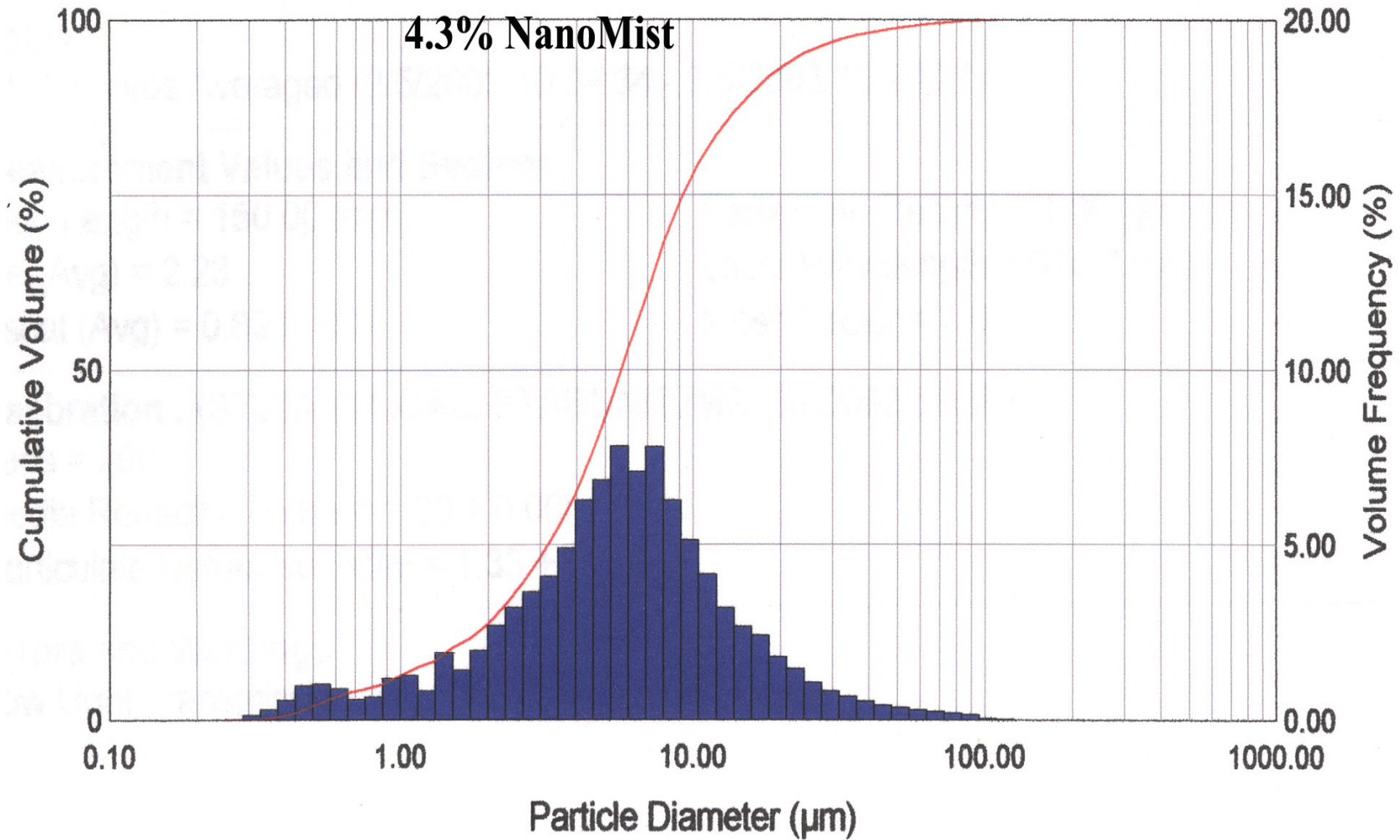
Local flooding Heptane Pool Fire (0.3 m)



Background (5): NanoMist® Electronic Space Protection

- Search for a gas-like water mist system continued for electronic space fire protection --data center/sub-floor
- NanoMist®, ultra fine water mist (< 10 micron) resembles a dense gaseous medium -- microfluid
- NanoMist® comes close to a gaseous medium and is environmentally friendly
- NRL sponsored projects at Hughes Associates, Inc. investigated 2.3-m² sub-floor mockup ; tests were successful
- Scale up test in a 25-m² area March 2005 to confirm scalability and system design parameters for implementation
- Demonstration of technology in ex-USS Shadwell, Mobile, AL, FY 2006
- Implementation of technology in shipboard application scenarios

NanoMist ® Droplet Characterization



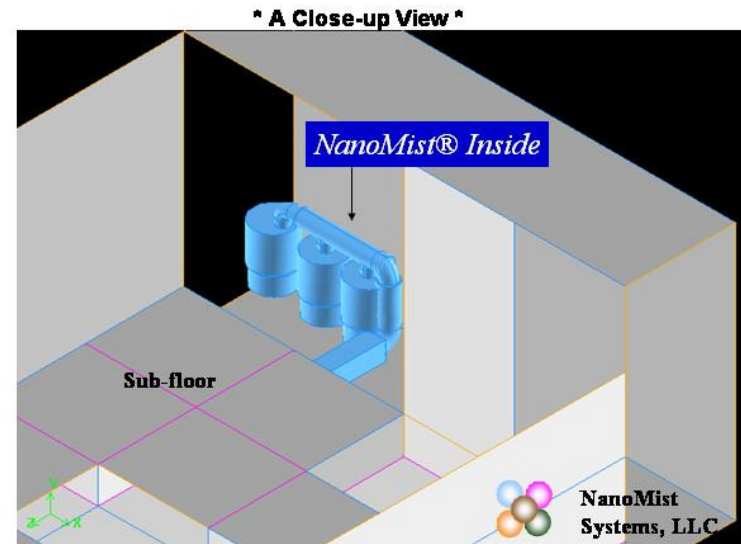
Courtesy : Ndubizu et al.

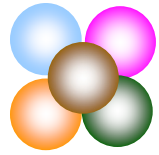
Objectives of this Study

- Evaluate the scalability of the previously performed reduced scale (2.5 m²) testing at a larger scale (25 m²)
- Develop/refine system design parameters
- Evaluate effects of water mist exposure on electronics in a configuration consistent with installation practice.
- Evaluations for real-scale shipboard testing onboard the Ex-USS Shadwell --FY 2006



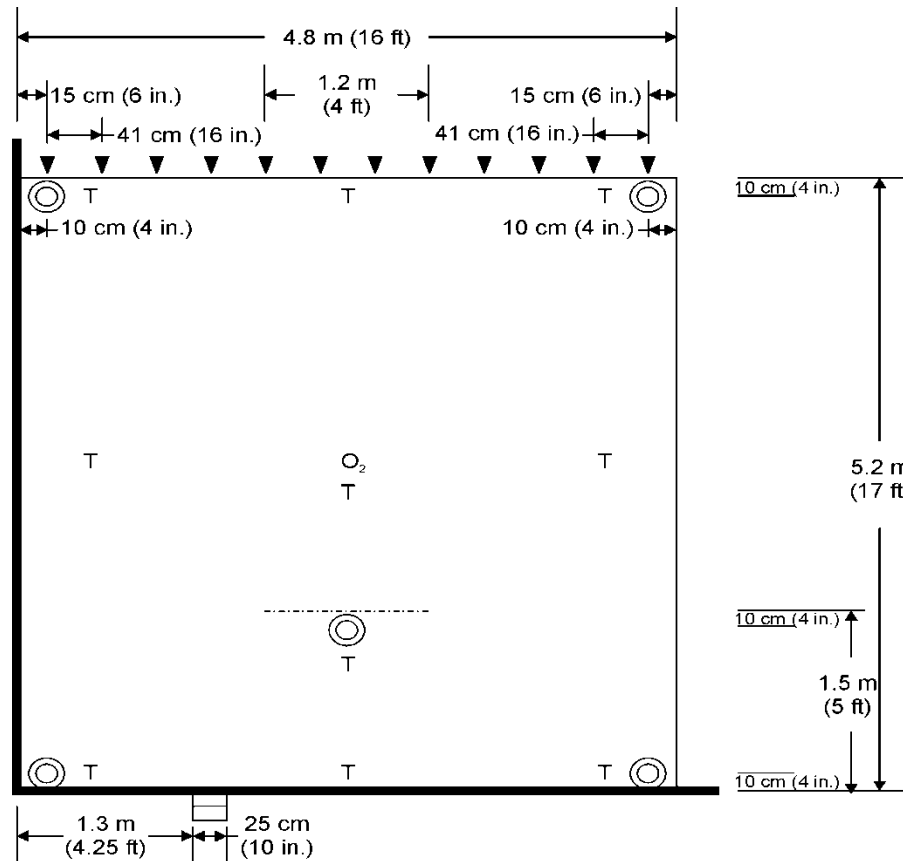
Layout of NanoMist® to be Engineered into Electronics Space
Sub-floor for Navy's ex-USS Shadwell (Mobile, AL) Demonstration, Sept 2005





Sub-floor test scenarios and description of test layout

Electronic Space Mockup Layout



▲ Mister Outlet Location – 30 cm (1 ft) above floor

⊙ Tell-tale or other Fire Location

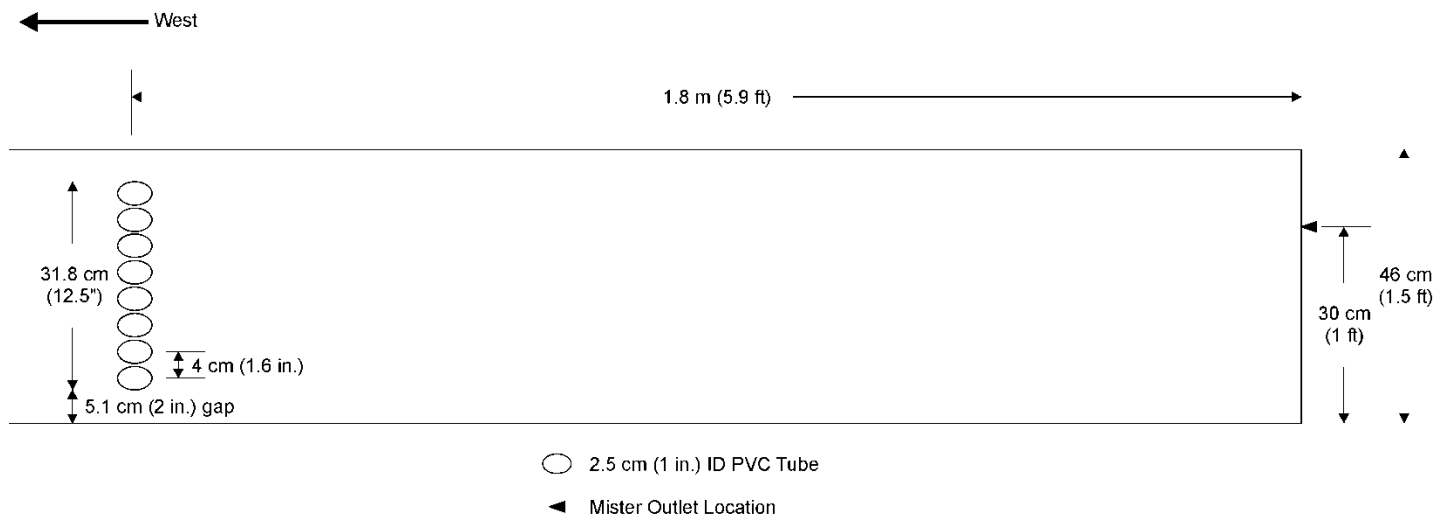
----- Baffle Location

O₂ Gas Sampling Location (Oxygen, Carbon Monoxide, Carbon Dioxide)

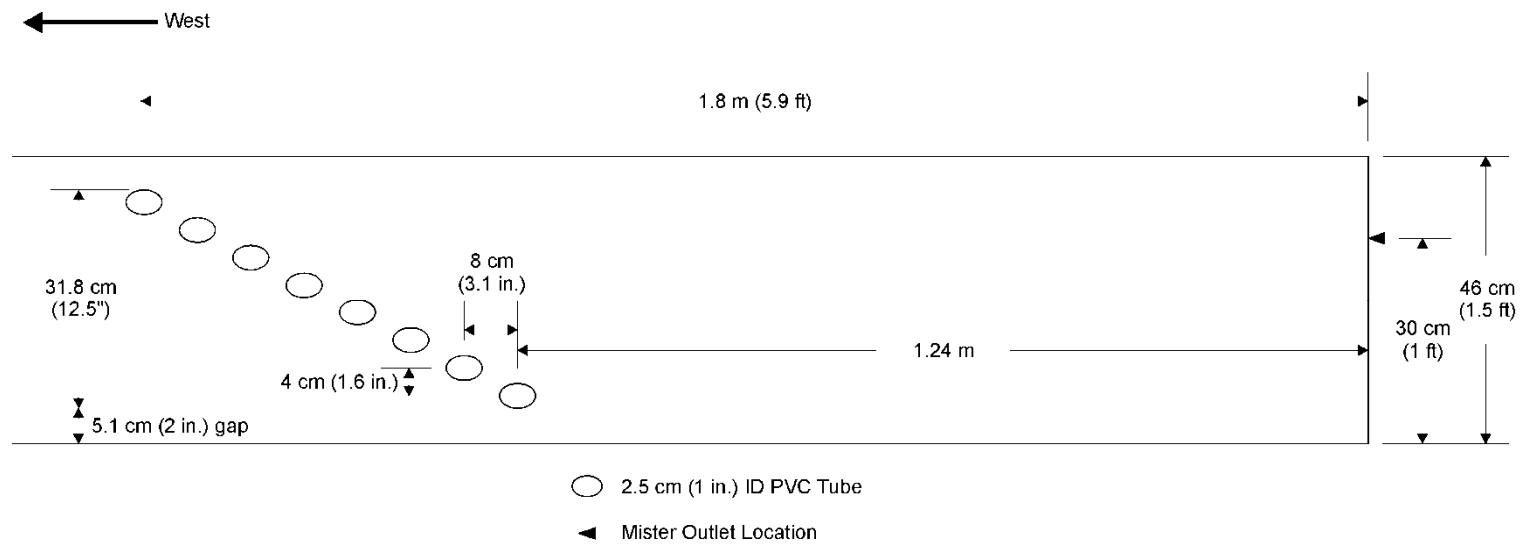
T Thermocouple Location

□ 25 x 25 cm (10 x 10 in.) Vent with Motorized Damper

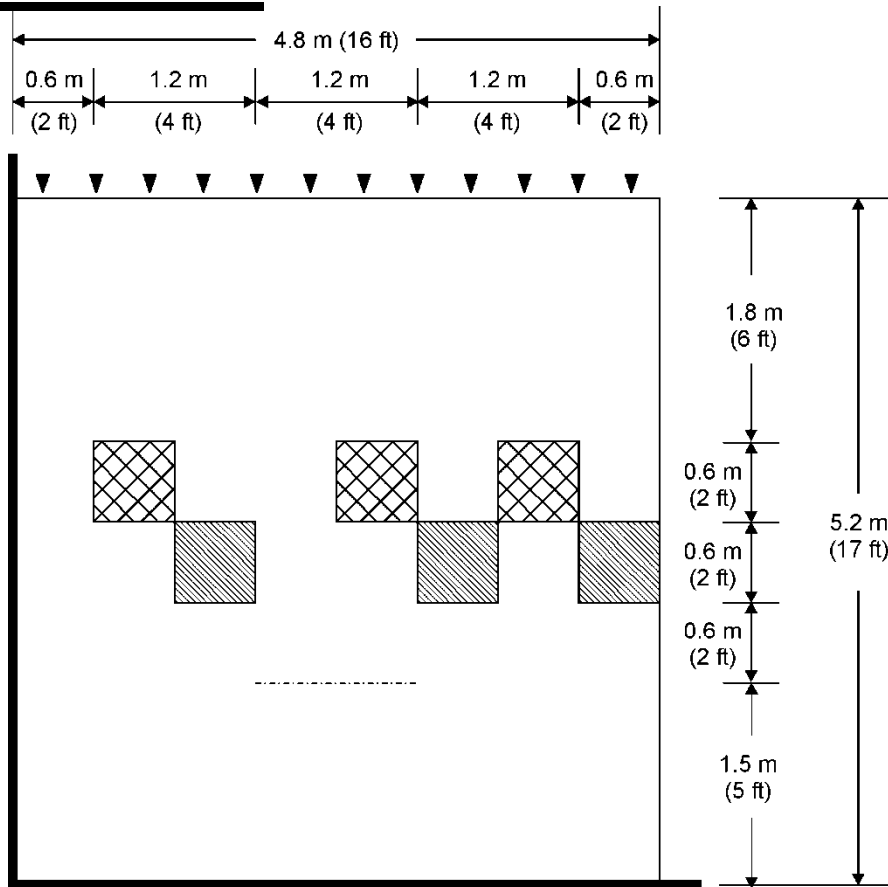
Removable obstruction to cross-sectional flow area – section view



Removable obstruction providing additional surface area – section view



Leaks in Floor (Tiles removed)



▲ Mister Outlet Location – 30 cm (1 ft) above floor

----- Baffle Location



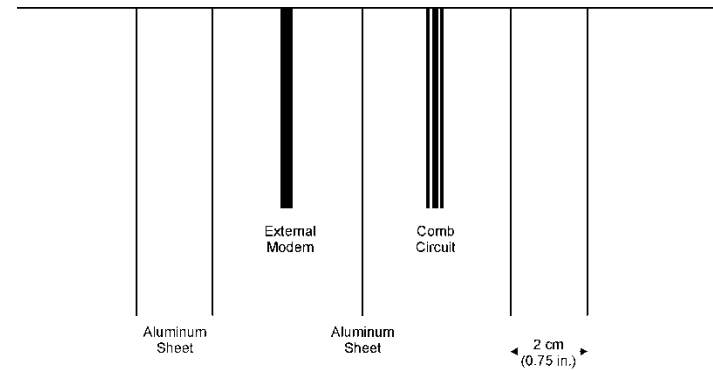
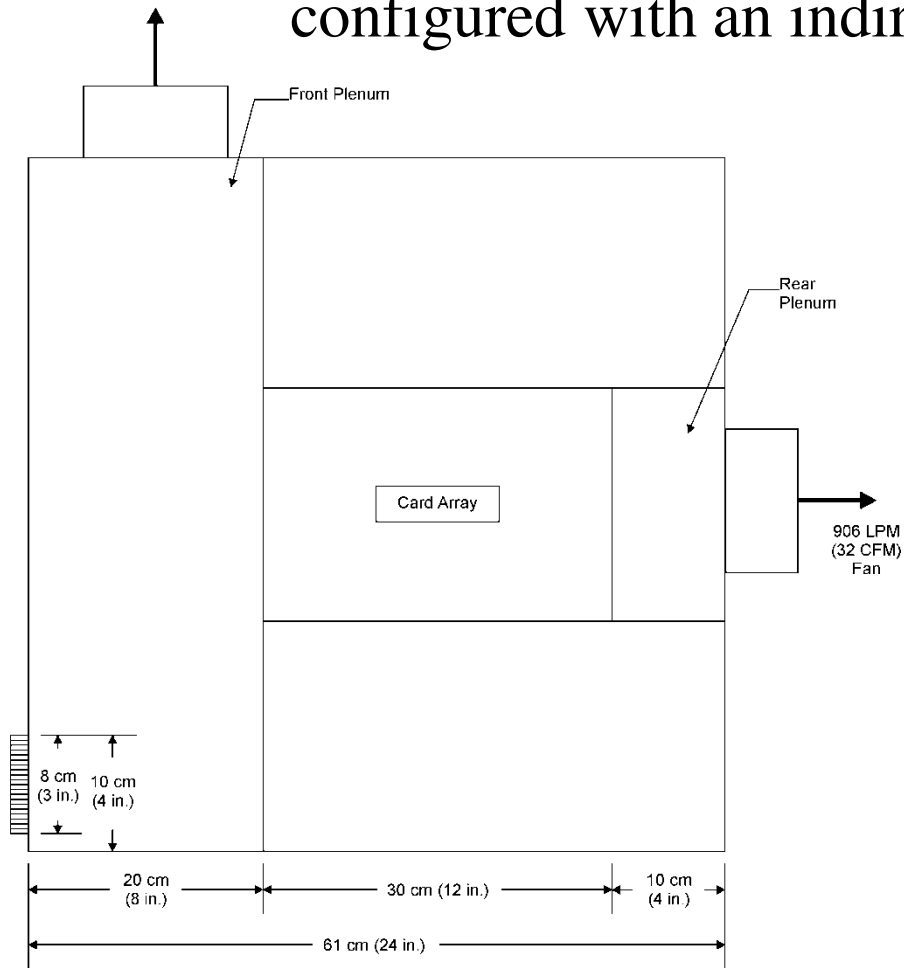
Floor Tile Removed during (4.4% and 8.8%) Floor Open Area Tests



Floor Tile Removed during (8.8%) Floor Open Area Tests



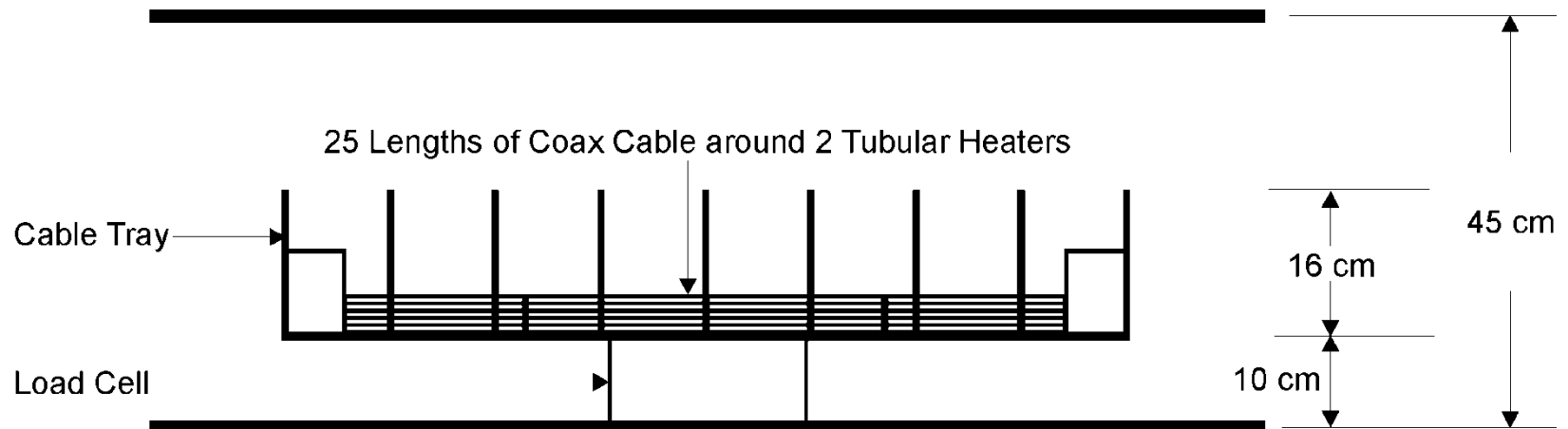
Photograph of simulated electronic cabinet configured with an indirect connection to sub-floor

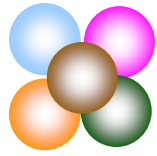


Photographs of Electronics Cabinet Exposed to NanoMist® In Sub-floor



Cable bundle fire scenario setup – elevation view





Test Results of NanoMist® Application to 25 m² sub-floor area Mockup

* Telltale Fires *

NanoMist water mist system installed in sub-floor



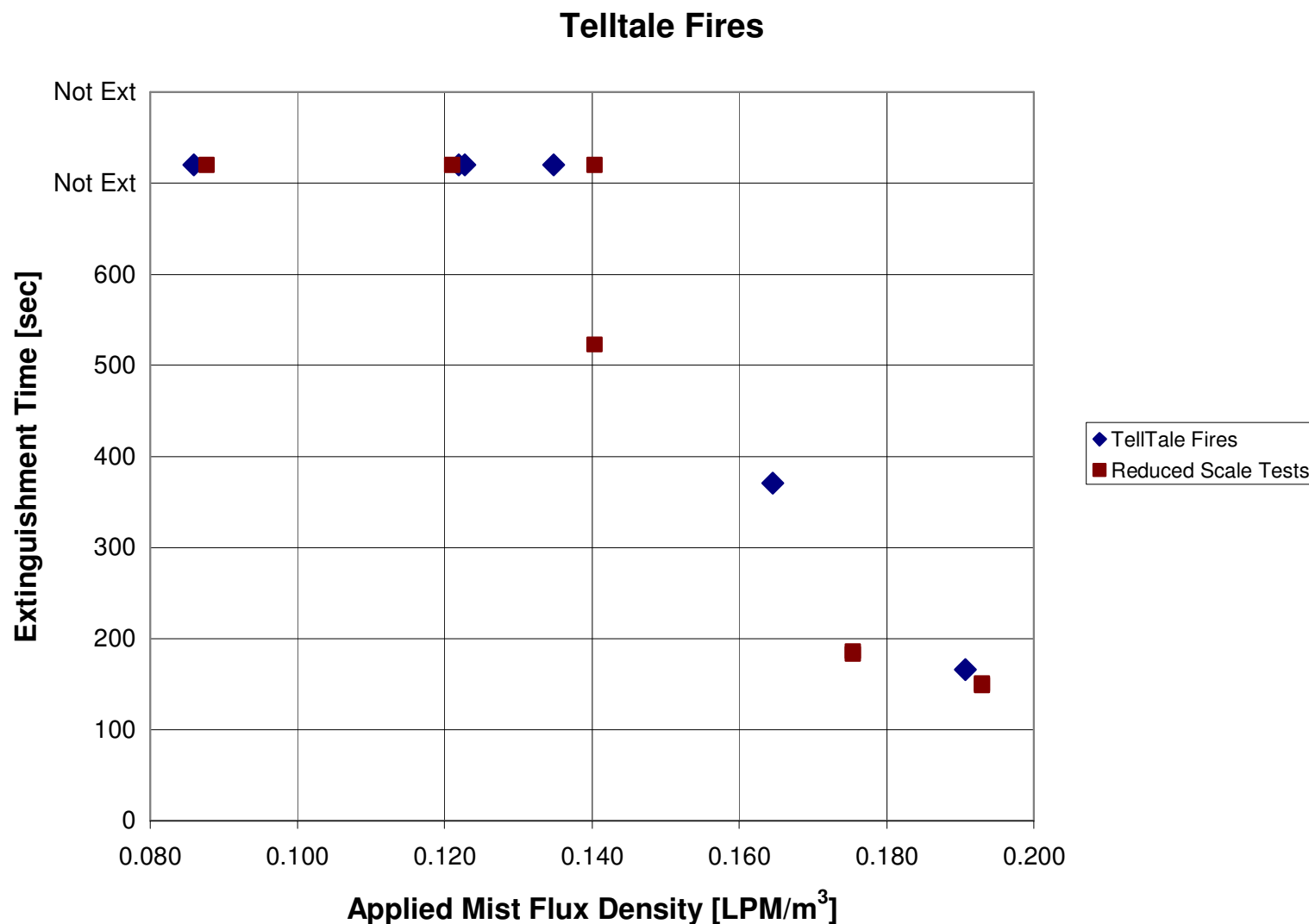
NanoMist Water Mist System Parameters

Number of Misters	Flow Rate		Air Flow Rate			Application Flux Density		Applied Water Mist Concentration (Outlet of Mister)	
	[Lpm]	[gpm]	[Lpm]	[cfm]	[Changes /hr]	[Lpm/m ³]	[gpm/f t ³]	[% wt]	[g/m ³]
6	1.27	0.33	4078	144.0	21.2	0.110	0.0008	20.5%	310
7	1.48	0.39	4757	168.0	24.7	0.128	0.0010	20.5%	310
8	1.69	0.45	5437	192.0	28.2	0.146	0.0011	20.5%	310
9	1.90	0.50	6116	216.0	31.8	0.164	0.0012	20.5%	310
10	2.11	0.56	6796	240.0	35.3	0.183	0.0014	20.5%	310
11	2.32	0.61	7475	264.0	38.8	0.201	0.0015	20.5%	310
Reduced Scale Test Parameters									
2	0.22	0.06	681	24.1	35.8	0.193	0.0014	21.2%	322

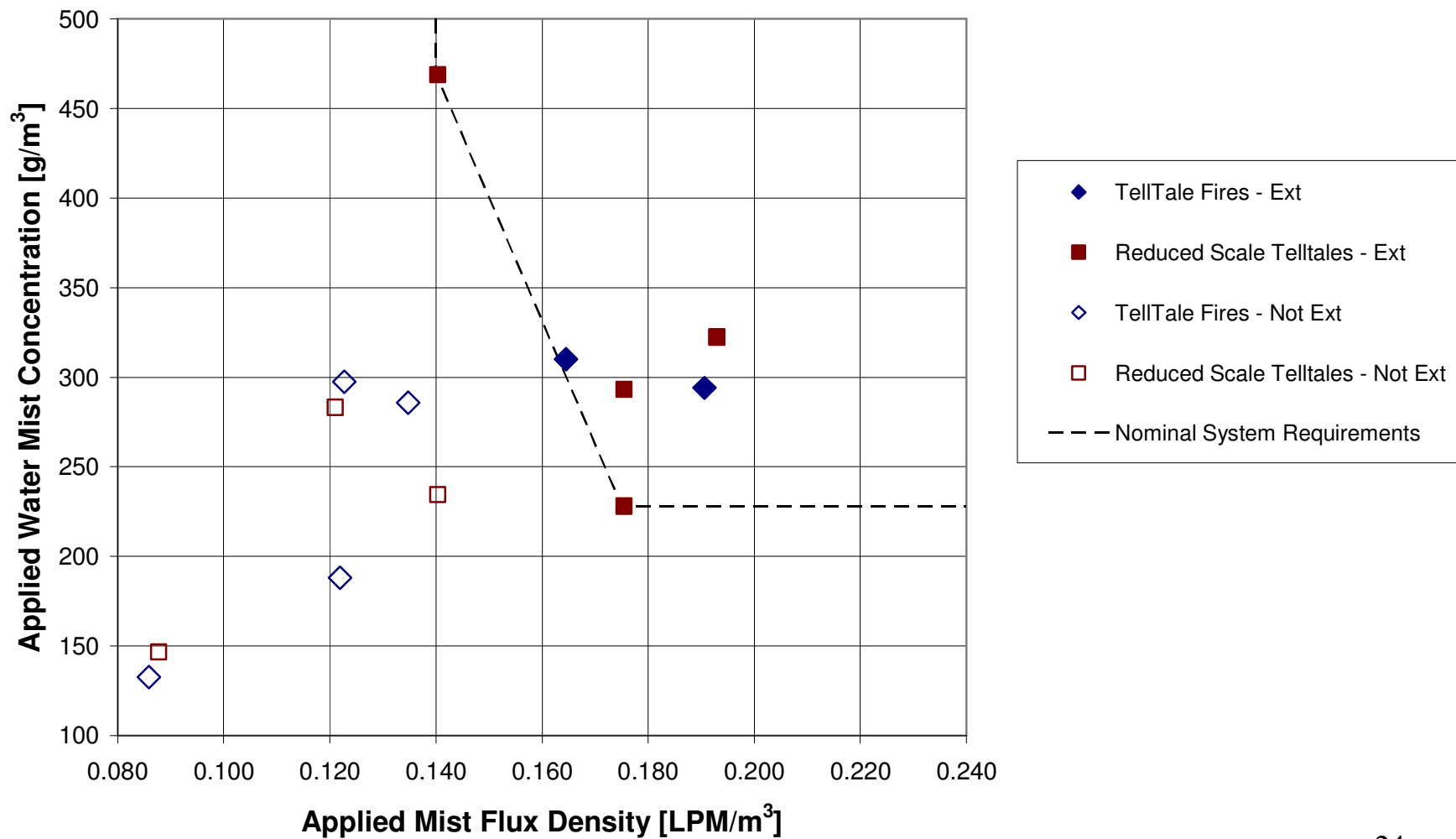
Verification of System Requirements Tests (Telltale Fires)

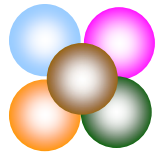
		Water Flow		Air Flow		Applied Mist Water Concentration (Outlet of Mister)		Ext Time	
Test Name	No. of Misters	Rate [LPM]	Flux Density [LPM/m ³]	Rate [LPM]	Changes per hour	[%wt]	[g/m ³]	[sec]	[Changes]
Test22	11	0.99	0.086	7475	38.8	9.9%	133	N/E	N/E
Test25	7	1.41	0.122	7475	38.8	13.5%	188	N/E	N/E
Test26	7	1.42	0.123	4757	24.7	19.9%	298	N/E	N/E
Test27	8	1.56	0.135	5437	28.2	19.2%	286	N/E	N/E
Test24	9	1.90	0.165	6116	31.8	20.5%	310	370	3.27
Test23	11	2.20	0.191	7475	38.8	19.7%	294	166	1.79

Telltale fire scenario extinguishment time comparison between scaled-up and reduced scale testing



NanoMist System Parameters to Cause Extinguishment of Telltale Fires



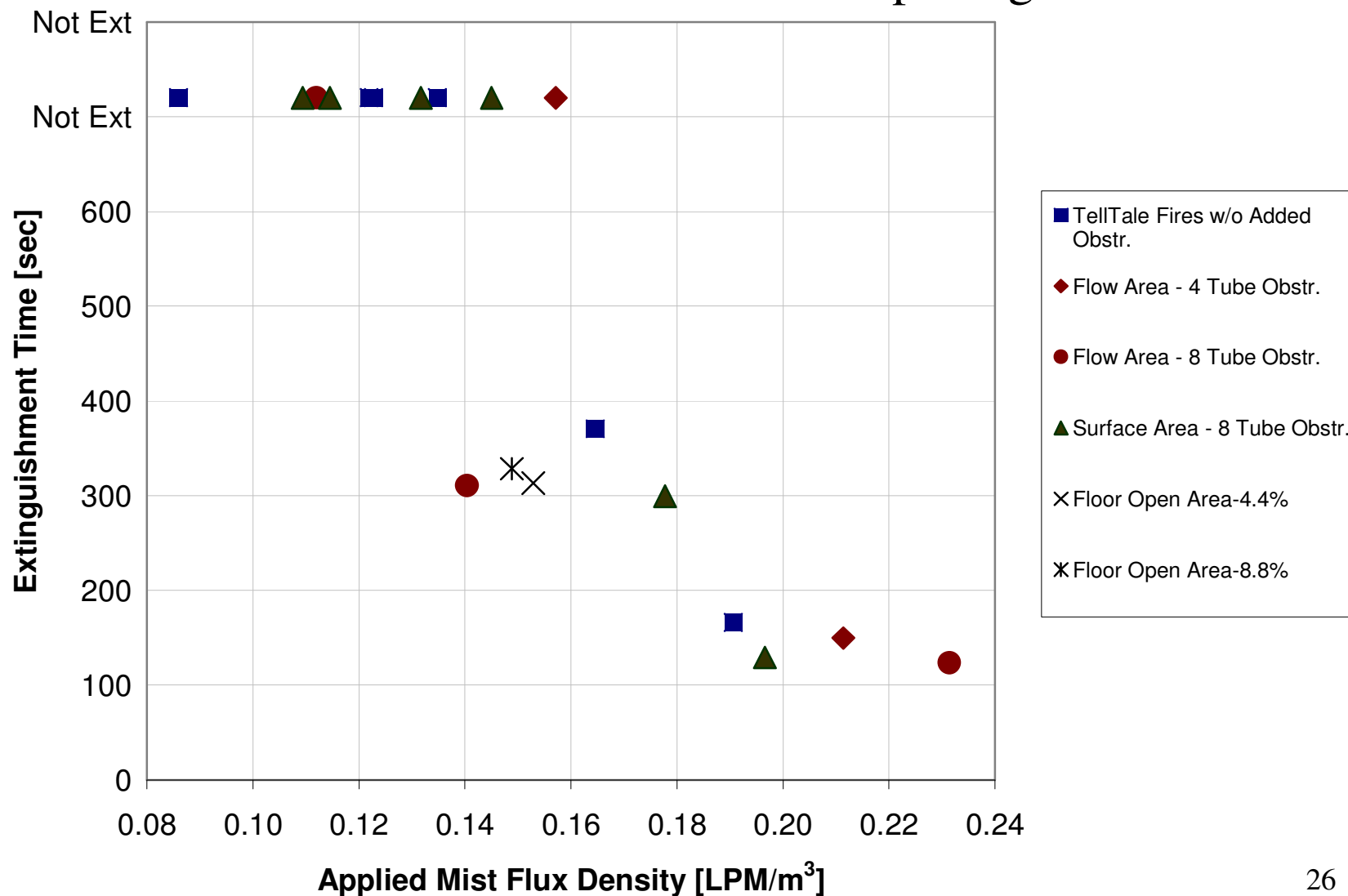


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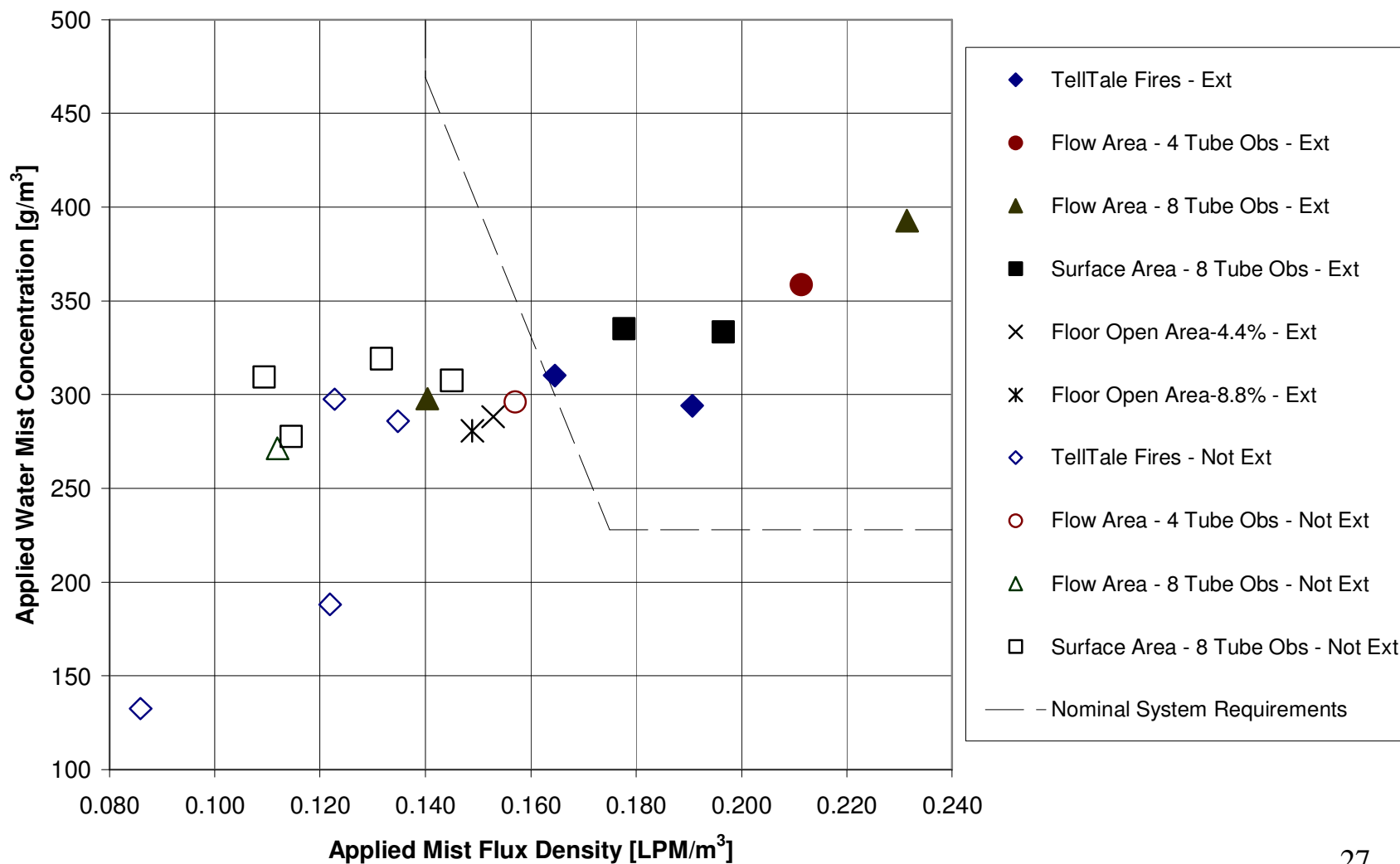
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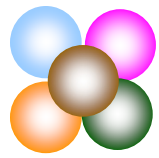
Obstructions and Floor Leaks

Telltale fire scenario: with and without additional obstructions or additional floor openings



Telltale fire scenario : with and without additional obstructions or additional floor openings





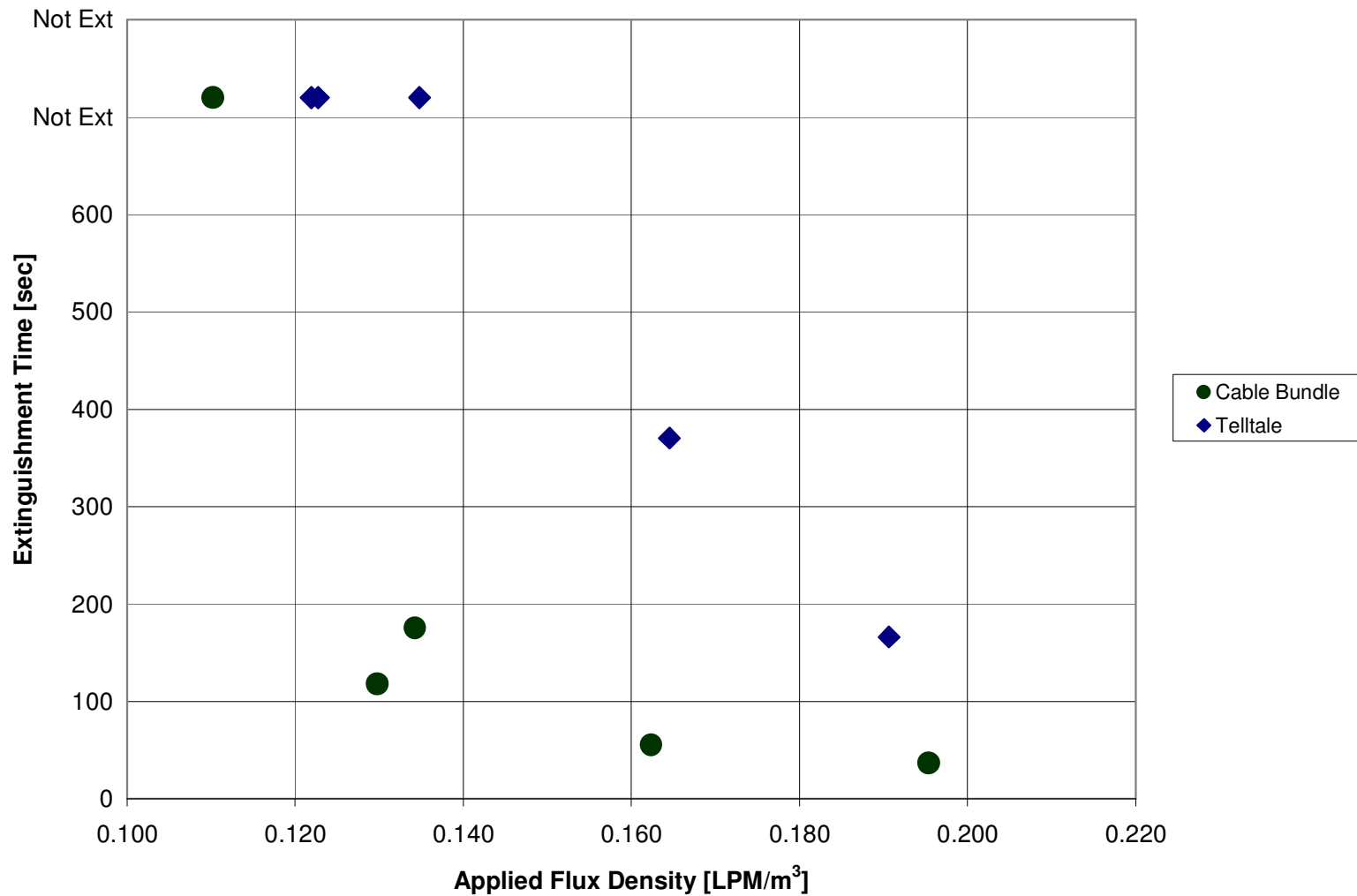
Cable Bundle Fire Tests



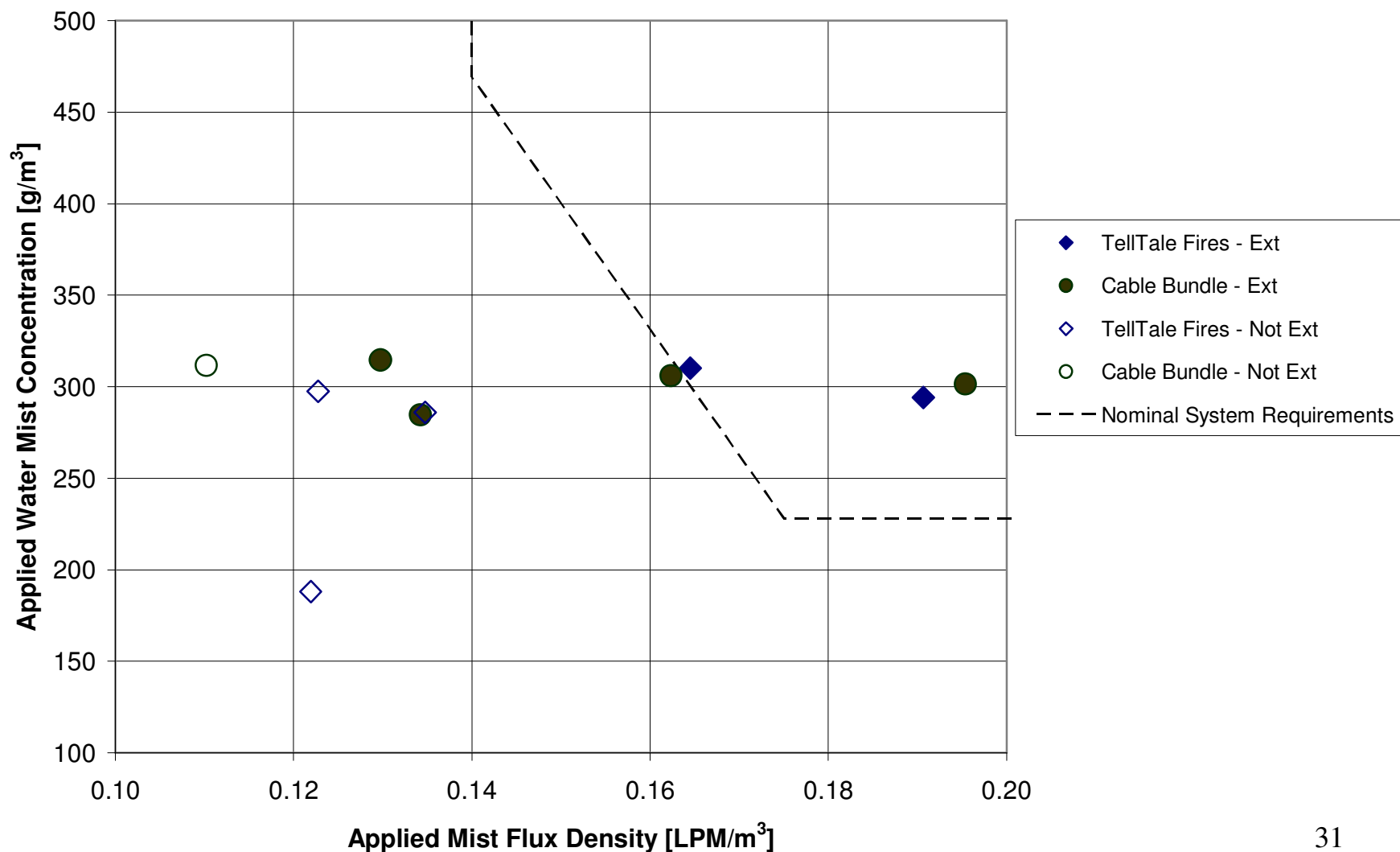
Results of Testing with the Cable Bundle Fire Scenario

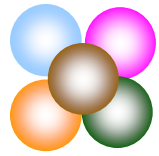
Test Name	No. of Misters	Water Flow		Air Flow		Applied Mist Water Concentration (Mister Outlet)		Extinguishment Time	
		Flow Rate [LPM]	Flux Density [LPM/m ³]	Flow Rate [LPM]	Changes per hour	[%wt]	[g/m ³]	[sec]	[Changes]
Test3 6	6	1.27	0.110	4078	21.2	20.6 %	312	N/E	N/E
Test3 5	8	1.55	0.134	5437	28.2	19.2 %	285	175.5	1.38
Test3 7	7	1.50	0.130	4757	24.7	20.8 %	315	118	0.81
Test3 4	9	1.88	0.162	6116	31.8	20.3 %	306	55.5	0.49
Test3 3	11	2.26	0.195	7475	38.8	20.1 %	301	36.7	0.40

Extinction times for the cable bundle and telltale fire scenarios



Comparison of extinction of cable bundle fire scenario and the telltale fire scenario





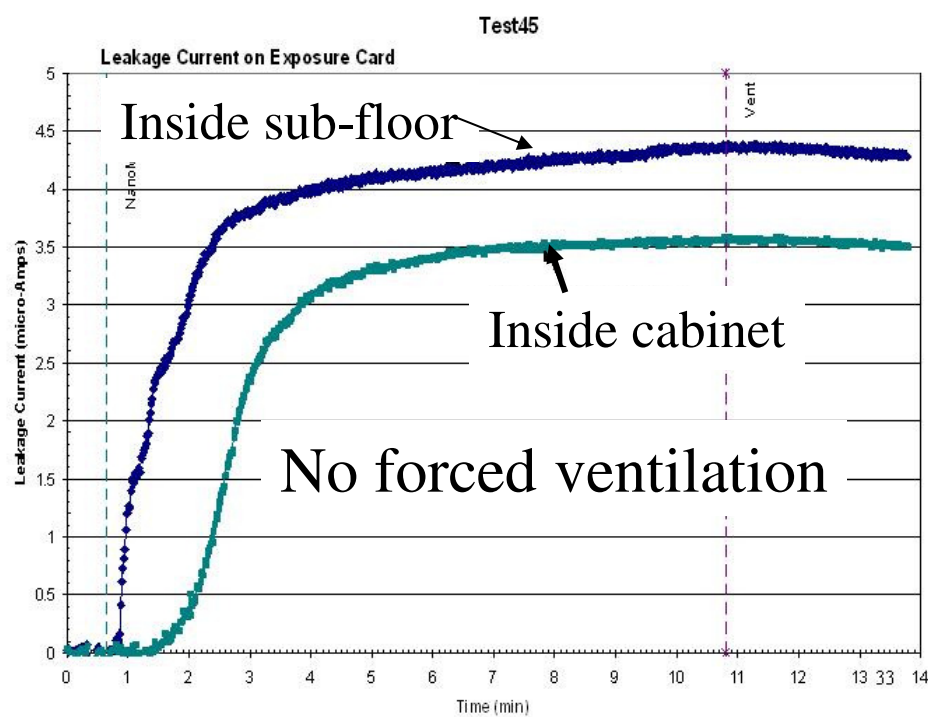
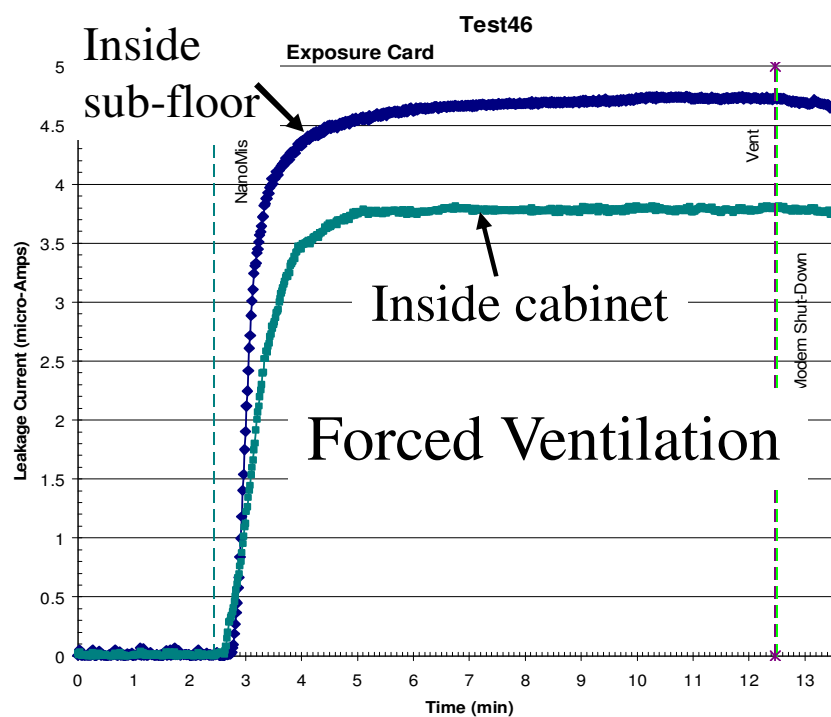
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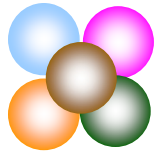
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Electronics Exposure Testing



Leakage current inside cabinet and sub-floor with and without forced ventilation through cabinet



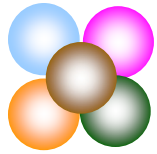


Electronic Exposure Summary

- The exposed operating external modem inside the simulated electronics cabinet continued operating throughout the ten minute exposures to the water mist that emanated from the sub-floor area.
- The measured leakage current was reduced between 15% and 44% depending on the cabinet configuration (compared to cards inside sub-floor)
- The exposure to the water mist experienced during these tests, with the electronics in the cabinet is more reflective of what would be expected in a shipboard electronics space
- The degree of protection afforded by this housing relative to that experienced during these tests would be a direct reflection of these parameters with respect to the simulated electronics cabinet utilized during these tests.

Conclusions (1)

- The NanoMist extinguished the telldales flux density of 0.165 LPM/m³ with mist concentration of 310 g/m³, consistent with previous reduced scale tests
- The NanoMist system was the only water mist system that was able to extinguish all of the test fires without the aid of a complimentary nitrogen system. Additional obstructions up to 60% of the flow area and providing up to 0.62 m² (6.7 ft²) of surface area did not affect extinguishment of the telldale fires
- Removing up to 8.8% of the false deck area/tiles did not affect extinction of the telldale fires
- The cable bundle fire was extinguished with a flux density of 0.130 LPM/m³ and an applied water mist concentration of 315 g/m³ -- reduction of 21% compared to telldale fires.
- The exposed operating external modem inside the simulated electronics cabinet continued operating throughout the ten minutes



Conclusions (2)

- Combining several mist generator's output into one duct and single or reduced mist introduction system -- confirmed to be successful
- Long distance transport of mist from a production shop to protection areas – not evaluated yet

Summary :

NanoMist® water mist behaved like a gaseous system in terms of transport in a cluttered space (overcoming obstructions) and providing protection to teltales as well as cable fires, with a reasonable tolerance to leak (~ 9% area) in the floor. The modem card continued to function for 10 min during the test.

Next Step:

Implementation and demonstration of NanoMist® in ex-USS Shadwell FY 2006

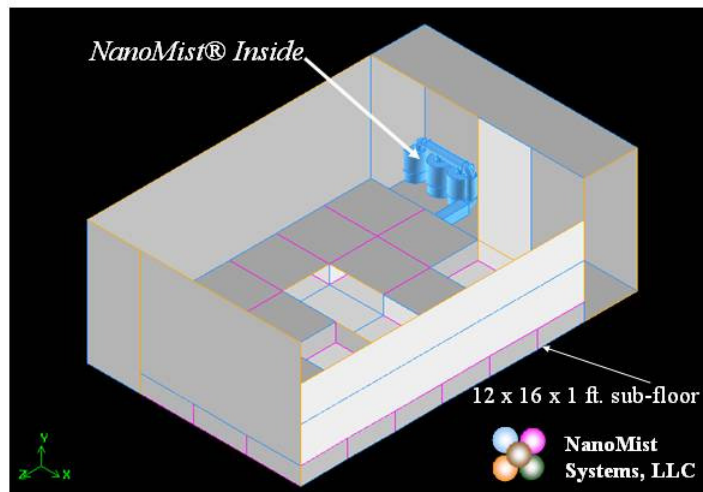
Scope :

Commercialization opportunity for data center fire protection applications

Ex-USS Shadwell Implementation Plan



Layout of NanoMist® to be Engineered into Electronics Space
Sub-floor for Navy's ex-USS Shadwell (Mobile, AL) Demonstration, Sept 2005



Layout of NanoMist® to be Engineered into Electronics Space
Sub-floor for Navy's ex-USS Shadwell (Mobile, AL) Demonstration, Sept 2005

*** A Close-up View ***

