Agenda

Key differentiations in Physical Properties SFFF vs AFFF (AR)

Test Standards and SFFF

NFF 3x3 POG & Aviation Applications

ECHA Limits & Decontamination

Q&A session

Key differences between film forming and non-film forming foam concentrates

Non Fluorinated Foam does not form a film on the fuel surface.

Therefore Non Fluorinated Foam depends on a foam blanket. To create a foam blanket a certain expansion is required.

E

Due to complex new chemistry many Non Fluorinated Foams have a very high viscosity which may cause issues with proportioning

FM has introduced new technical requirements for foam dosing systems taking shear rate into the equation

V

Testing standards that determine the design application rate are not (yet) designed for Non Fluorinated Foam

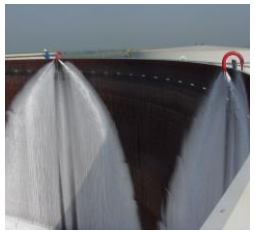
Application Rates found in both UL Listings and FM approvals for sprinkler systems can be significantly higher for Non Fluorinated Foam Concentrates

A

Key differentiations in Physical Properties: Expansion

➔ **Is Foam Expansion Ratio an important Technical criteria for the performance of Non-Fluorinated Foams ?**

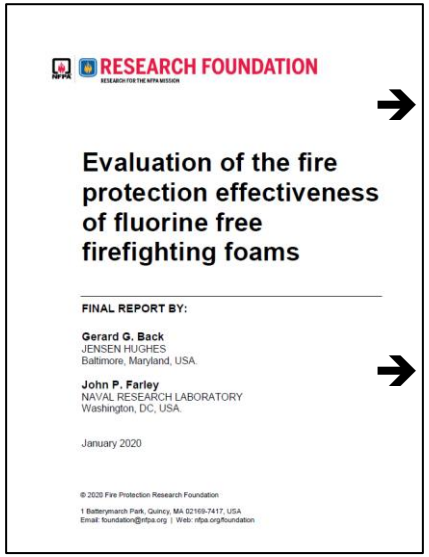

Non-Air Asp Exp


Low Exp (Air-Asp]


Medium Exp


High Exp

➔ **Is my Hardware able to handle it?**
Independent Industry extended testing campaign NFPA Research Foundation] suggests that an increase of Foam expansion ratio from **7:1 up to 10:1** may be needed for many SFFF to perform properly.


RESEARCH FOUNDATION

Evaluation of the fire protection effectiveness of fluorine free firefighting foams

FINAL REPORT BY:

Gerard G. Back
JENSEN HUGHES
Baltimore, Maryland, USA.

John P. Farley
NAVAL RESEARCH LABORATORY
Washington, DC, USA.

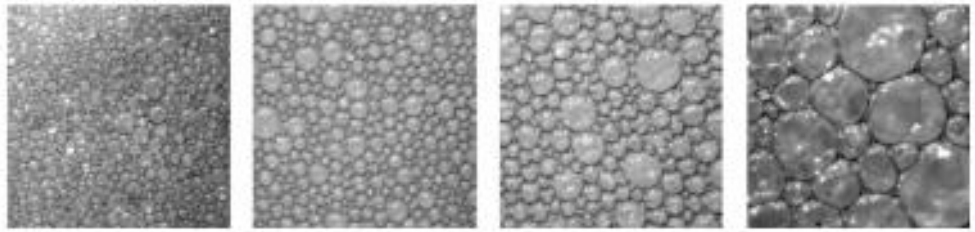
January 2020

1 Batterymarch Park, Quincy, MA 02169-7417, USA
Email: foundation@nfpa.org | Web: nfpa.org/foundation

➔ **Awareness of NFF Agent expansion ratio bracketing is critical to understand if on-site existing equipment can meet the minimum needed foam expansion ratio to maintain fire performance**

➔ **If not … Cost to adapt could be very substantial !**

Key differentiations in Physical Properties: Expansion



Typical Expansion Ratios for Low Expansion devices:	
Foam Chambers	2:1 to 6:1
Floating roof tank pourers	2:1 to 6:1
Dike foam pourers	2:1 to 6:1
Monitor nozzles (non-Air Aspirating)	2:1 to 4:1
Sprinklers	2:1 to 4:1
Foam nozzles (Air aspirating)	6:1 to 12:1

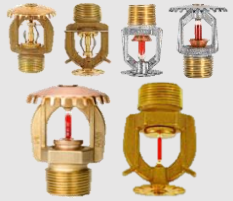
➔JCI SFFFs have been UL tested on Hydrocarbons as low as 3:1 Expansion ratio

Key differentiations in Physical Properties: Expansion

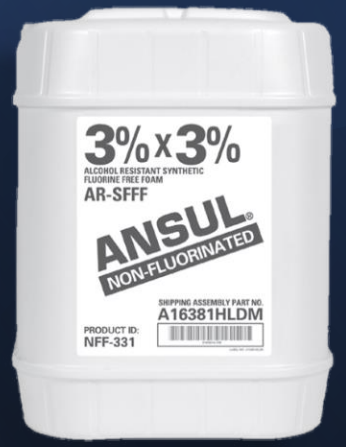
NFF 3x3 UL201

Mix of UL Listed & Validation testing

Foam Discharge Devices

 AFC Foam Chambers	 FLR Dike & Floating Roof Pourers	 OFG Foam Chambers	 MRM Medium Expansion
 Sprinklers K 5.6 - 8.0 - 11.2	 B1 Foam Water Sprinkler	 TF Foam Nozzles	 MLB Foam pourer
 AOM & AFN Monitors	 FJM Monitors	 [Type 3] Foam branchpipe	 Non-Asp. Foam Nozzle Self Ind.

Key differentiations in Physical Properties: Expansion

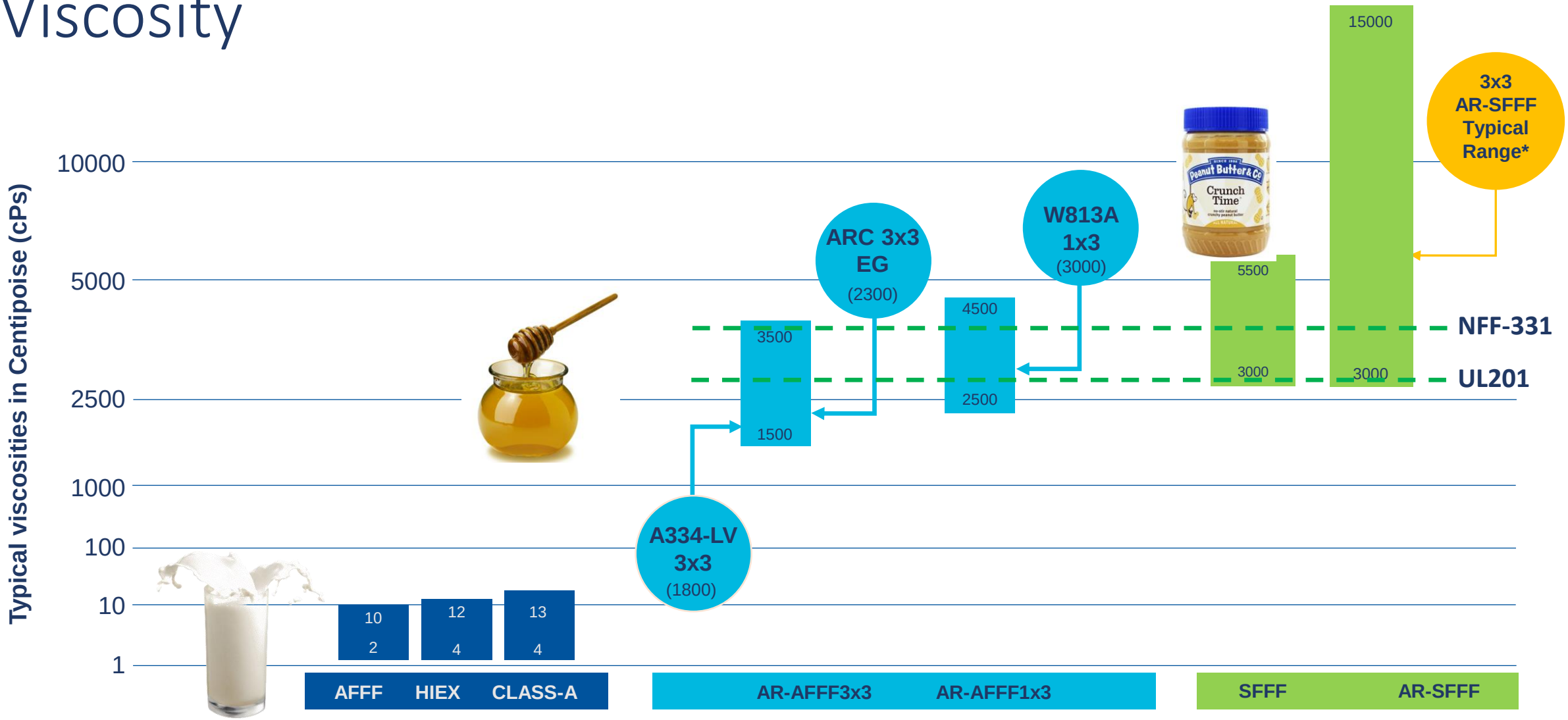


Foam Discharge Devices

NFF 331 3x3
All UL Listed

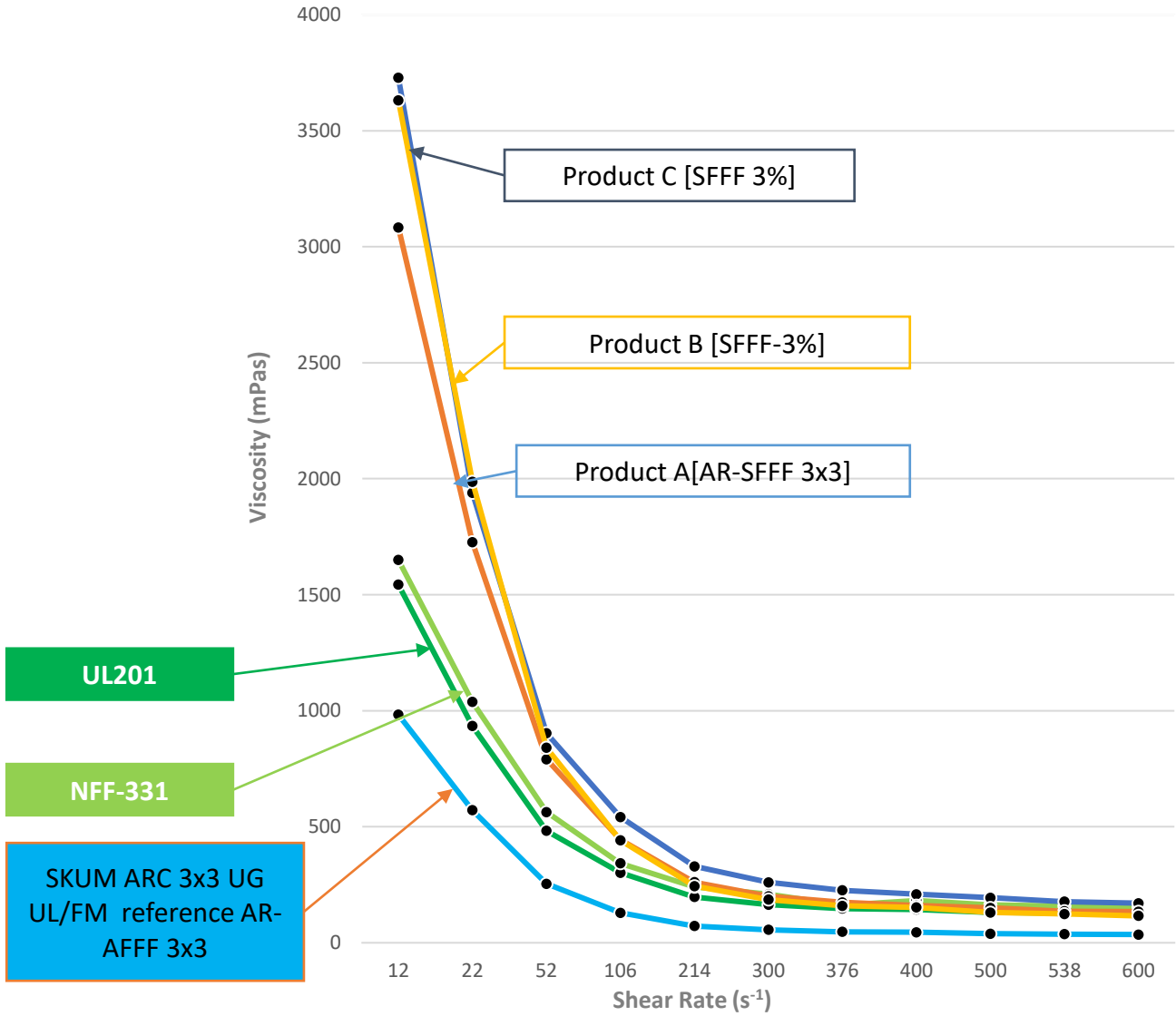
 AFC Foam Chambers	 FLR Dike & Floating Roof Pourers	 B1 Foam Water Sprinkler
 Sprinklers K 5.6 / 80	 Sprinklers K 8.0 / 115	 Sprinklers K 11.2 / 160
 Oscillating AOM Monitors	 Manual Monitors and CMNB nozzles	 Type 3 Foam branchpipe 60-95

Key differentiations in Physical Properties:
Viscosity



Key differentiations in Physical Properties: Viscosity

Dynamic viscosity of foam concentrates with sprinkler approvals

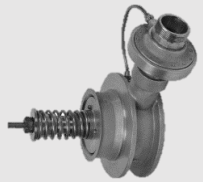


Key differentiations in Physical Properties: Viscosity

Foam Dosing Equipment

NFF 3x3 UL201

Mix of UL Listed & Validation testing

 Bladder tanks	 RFC Proportioners	 Wide Range Proportioners	 TP Mk2 Proportioners
 ILBP Pump Proportioners	 Wide Range Mk3 Proportioners	 PP Mk2 Proportionerd	 Foam Pump
 PL In-Line Proportioners	 ZF In-Line Inductors	 Self Inducting Nozzle	 FireDos Gen 2 & Gen 3 Units

Key differentiations in Physical Properties: Viscosity

Foam Dosing Equipment

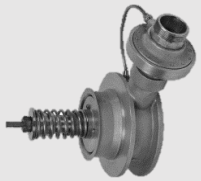
NFF 331 3x3
Mix of UL Listed & Validation testing

Bladder tanks

RFC Proportioners

Wide Range Proportioners

ILBP Pump Proportioners



Wide Range Mk3 Proportioners

Foam Pump

PL In-Line Proportioners

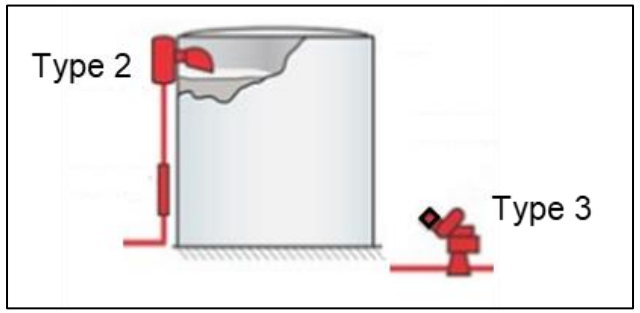
Dosing device	Size	Status	Flow [lpm]
BT Proportioner RFC	2"	UL Listed	799-2865
BT Proportioner RFC	2" 1/2	UL Listed	480-1453
BT Proportioner RFC	3"	UL Listed	768-2925
BT Proportioner RFC	4"	UL Listed	1593-5060
BT Proportioner RFC	6"	UL Listed	3345-10953
BT Proportioner RFC	8"	UL Listed	6896-17047
BT Prop. MK3 Wide Range	6"	UL Listed	193-10389
BT Prop. MK3 Wide Range	8"	UL Listed	Test pending
Pump Prop. MK3 Wide Range	6"	UL Listed	200-11090
Pump Prop. MK3 Wide Range	8"	UL Listed	Test pending
Pump Prop. IBP-2"	2"	UL Listed	200-817
Pump Prop. IBP-2.5"	2" 1/2	UL Listed	700-1340
Pump Prop. IBP-3	3"	UL Listed	1158-2660
Pump Prop. IBP-4	4"	UL Listed	1922-4912
Pump Prop. IBP-6	6"	UL Listed	3168-10851
Pump Prop. IBP-8	8"	UL Listed	5779-17293

Key differentiations in Physical Properties: Application Rate

All standards test SFFF the same way as AFFF ?

Key Points from UL-162 Listings on Hydrocarbons:

- UL-162 classifies SFFF under the Synthetic (**S**) category which has different test criteria and design densities than **AFFF** products.
- Regardless of performance, to qualify for an AFFF category the product must have film forming characteristics, i.e. AFFFs. SFFF products are not film forming and are therefore listed under the Synthetic category with a Type 3 design application density of 6.5 lpm/m^2 whereas for the film forming category it could qualify for a 4.1 lpm/m^2 application density



Key differentiations in Physical Properties: Application Rate

…For reference

EN 1568 — **EN Test Rate** **2.53** Lpm/m2

Listing differences between SFFF and AFFF for monitor application

Table 10.1
Foam application and duration to burnback ignition
Footnote c of Table 10.1 effective July 6,1995

Application	Foam concentrate	Fuel Group	Test application density lpm/m2	Time of foam application, minutes	Duration until burnback ignition, minutes	Minimum design application density, lpm/m2
1. Type III Discharge Outlets	P, FP, S, **SFFF**	Hydrocarbon	**2.4**	**5**	**15**	**6.5**
	AFFF, AR-AFFF	Hydrocarbon	**1.6**	**3**	**9**	**4.1**
2. Type II Discharge Outlets	P, FP, S, **SFFF**	Hydrocarbon	**2.4**	**5**	**15**	**4.1**
	AFFF, AR-AFFF	Hydrocarbon	**1.6**	**3**	**9**	**4.1**
	All	Polar	b	5	15	c
3. Foam Water Sprinklers	P, FP, S, **SFFF**	Hydrocarbon	6.5			6.5
4. Standard Orifice Sprinklers	AFFF, FFFP	Hydrocarbon	4.1	5	15	6.5
		Polar	b	5	15	d
5. Large, nominal 17/32 in, Orifice Sprinklers	AFFF, FFFP	Hydrocarbon	5.7	5	15	9.0
		Polar	b	5	15	d

P - Protein
FP - Fluoroprotein
FFFP - Film Forming Fluoroprotein
AFFF - Aqueous Film Forming Foam
S - Synthetic [HIEX foam]
SFFF - Synthetic Fluorine Free Foam

a - Film-forming fluoroprotein is to be tested at application densities of 2.4 and 1.6 lpm/m2
b - Application rate may vary among polar groups, as specified by the manufacturer.
c - 4.1 or 1.67 times Test Application Rate, whichever is greater
d - 6.5 or 1.6 times test application rate, whichever is greater

Test Standards and NFF's: Expansion

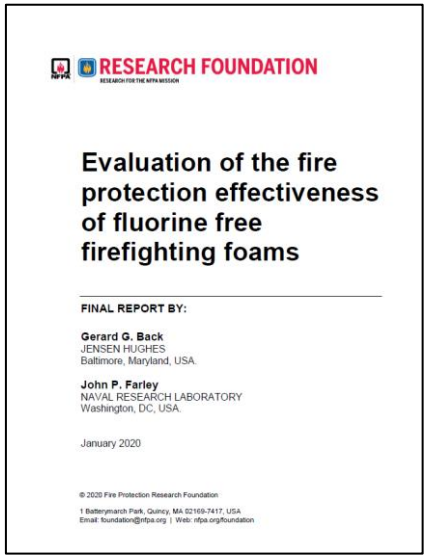
EN1568:2018 Revision ongoing work

Preparing EN1568:2018 revision.

- **Minimum F3 Expansion**
- Minor adjustment on last revision tolerances

WG3 Group research and testing. Impact on Foam Expansion for an SFFF.
Well known product totally failed extinguishing when lowering the Foam Expansion from 8:1 down to 3:1

Foam	Fuel	Proportioning rate [%]	Expansion ratio	Application rate [lpm/m2]	Application type	90% control time	100% extinguishment time
F3-AR	Naphta	3%	8	6	direct	54	58
F3-AR	Naphta	3%	6.5	6	direct	150	180
F3-AR	Naphta	3%	3.1	6	direct	fail	fail



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Evaluation of the fire protection effectiveness of fluorine free firefighting foams

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January 2020

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1 Batterymarch Park, Quincy, MA 02169-7417, USA
Email: foundation@nfpa.org | Web: nfpa.org/foundation

Test Standards and NFF's: Viscosity

New Dynamic Viscosity approach from FM specific for Non-Fluorinated Foams

Viscosity Limitations

Suitable for use with Newtonian foam concentrates and for use with non-Newtonian foam concentrates having viscosity characteristics within (below) the maximum viscosity limitations provided in the viscosity vs. shear rate table shown below.

FM Approvals

ApprovalGuide

My Account

Shear Rate, (1/s)	Viscosity @ 68°F (20°C), (Cp)
5	6392
10	3315
20	1720
50	722
100	375
600	69

Shear Rate	Pipe Diameter	Foam Concentrate flow rate at 3% (LPM)	Velocity (m/s)
5	DN80	16,8	0,052
10	DN80	33,9	0,104
20	DN80	67.5	0,208
50	DN80	168,9	0,519
100	DN80	337,5	1,038
600	DN80	2027,4	6,233

Test Standards and NFF's: Viscosity

Implications for NFF product on FM approved sprinkler Systems:

Dosing system A		JCI NFF201UL	JCI NFF331	Skum 3x3UG	Sprinkler Foam Brand A
Shear Rate (1/s)	Viscosity @ 20C° (Cp)				
5	6392	2987	3272	1687	5532
10	3315	1887	2078	1418	3340
20	1720	1067	1183	658	2017
50	722	500	591	257	1035
100	375	314	371	133	625
600	69	122	153	34	170

Dosing system B		JCI NFF201UL	JCI NFF331	Skum 3x3UG	Sprinkler Foam Brand A
Shear Rate (1/s)	Viscosity @ 20C° (Cp)				
5	2545	2987	3272	1687	5532
10	1505	1887	2078	1418	3340
20	890	1067	1183	658	2017
50	444	500	591	257	1035
100	263	314	371	133	625
600	70	122	153	34	170

Test Standards and SFFF's: Application Rate

UL vs FM main Testing differences on Foam Sprinkler Testing

❶ UL

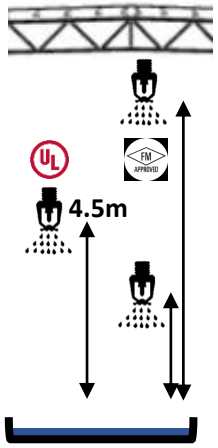
1.6x (60%) Safety Factor applied between Testing and Listing

FM APPROVED

NO safety factor between testing and Approval

K-Factor	Tested Fuel	Spk	Test Rates [lpm.m²]	Approved Rates [lpm.m²]	Test Rates [lpm.m²]	Listed Rates [lpm.m²]
K80	Hydrocarbons	Upright	12,2	12,2	4,1	6,5
		Pendent	12,2	12,2	4,1	6,5
	IPA	Upright	12,2	12,2	8,1	13,0
		Pendent	12,2	12,2	8,1	13,0
	Ethanol	Upright	-	-	4,6	7,3
		Pendent	-	-	4,6	7,3
	Acetone	Upright	12,2	12,2	5,9	9,4
		Pendent	12,2	12,2	5,6	9,0
	75% EtOH 25% Hept	Upright	-	-	5,6	9,0
		Pendent	-	-	5,6	9,0

❷ **FM** impose testing at minimum and Maximum Installation Heights.
UL has fixed sprinkler grid height at 4.5m



❸ **FM** not as demanding as UL for lower Application rates. Minimum application rate applied based on Sprinkler K factors irrespective of Hydrocarbon or Polar fuels :

- K80 App. Rate ≥ 8.2
- K115 App. Rate ≥ 12.2
- K160 App. Rate ≥ 12.2

NFF 3x3 POG & Aviation Applications

Tank Fire Fighting with SFFF*

** Non-Fluorinated Foams*

THUNDERSTORM WNF33A 3%x3% AR-SFFF Non-Fluorinated Foam
Designed for Large Tank Fires Application

NFF 3x3 POG & Aviation Applications

THUNDERSTORM WNF33A 3%x3% Non-Fluorinated Foam

is specifically designed for Tank Fires !

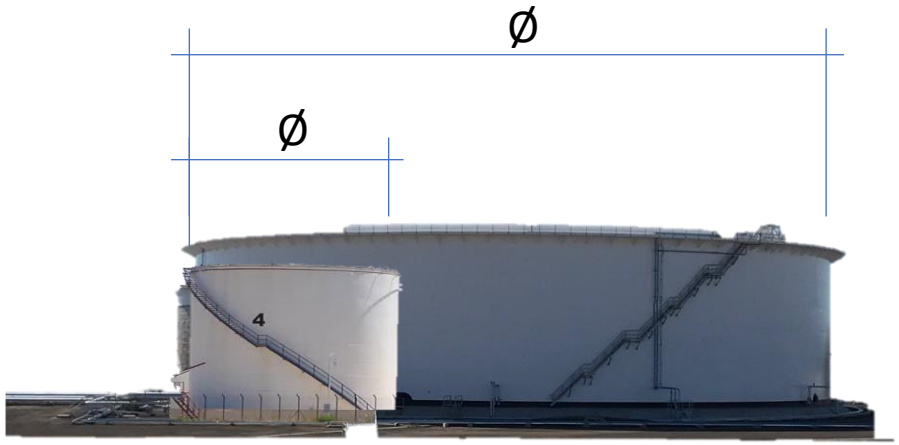
NFF 3x3 POG & Aviation Applications

Scalability of Tank Fire Fighting

WILLIAMS FIRE & HAZARD CONTROL®

Williams Thunderstorm Agent + Equipment proven success with Type III devices :

- Same risk ?
- Same Application Rate ?



NFF 3x3 POG & Aviation Applications

Scalability of Tank Fire Fighting

WILLIAMS FIRE & HAZARD CONTROL®

Williams Thunderstorm Agent + Equipment proven success with Type III devices :

Ø Tank Diameter		Minimum Application rate	
Feet	Meters	gpm/ft²	Lpm/m²
Up to 150 ft	**≤ 45 m**	**0.16**	**6.5**
151 ft - 200 ft	**45 > ≤ 60 m**	**0.18**	**7.3**
201 ft - 250 ft	**60 > ≤ 76 m**	**0.20**	**8.1**
251 ft - 300 ft	**76 > ≤ 91 m**	**0.22**	**9.0**
301 ft +	**> 91 m**	**0.25**	**10.2**

- **WNF33A**
- **W813A**
- **FC-601A**
- **F-601A**

All identically developed and tested with a consistent benchmark method and approach proven over 200+ large industry fire events

NFF 3x3 POG & Aviation Applications

Scalability of Tank Fire Fighting

Developed Test Parameters are a straight mimic of Orion Tank Fire 82m successfully extinguished with a Williams Thunderstorm in 2001 in Louisiana

- 93 Oct Gasoline fuel
- 30 sec Pre-burn
- 2,4 lpm/m^2 App Rate
- **< 3:00 extinguish time**

NFF 3x3 POG & Aviation Applications

Scalability of Tank Fire Fighting: Large scale testing

- **Self aspirating Monitor Nozzle [Non-Air Aspirating]:**

- **Test Rate : 3.2 lpm/m²**
- 419 lpm Nozzle @ 6.9 bar
- Expansion : 3 – 4:1
- Proportioning : ¾” Low Head Jet, 3 – 3.2%

The non-fluorinated foam used in this test was captured and contained
for disposal in accordance with applicable regulations. This test was conducted at a permitted facility.

NFF 3x3 POG & Aviation Applications

Scalability of Tank Fire Fighting: Large scale testing Control Times

THUNDERSTORM Foams Historical Large-scale Benchmark testing at 3.2 lpm/m^2

- 12,8 meter Tank Diameter (129 m^2)
- 415 lpm monitor nozzle
  - [Non-Air Aspirating type]
  - 3-4:1 Expansion

Thunderstorm Test Benchmark history	Control Times
F-601A [C8]	**1 min 45 sec**
F-601B [C8]	**2 min 40 sec**
W813A [C6]	**2 min 55 sec**
WNF33A [NFF]	**1 min 49 sec**

NFF 3x3 POG & Aviation Applications

Aviation Fire Fighting with NFF*

** Non-Fluorinated Foams*

NFF 3x3 POG & Aviation Applications

NFPA 409 - Aircraft Hangar Non-Fluorinated Foam Protection Solutions

AFFF Definition:

3.3.12.2* **Aqueous Film-Forming Foam Concentrate (AFFF).**

A concentrate based on fluorinated surfactants plus foam stabilizers to produce a fluid aqueous film for suppressing hydrocarbon fuel vapors and usually diluted with water to a 1 percent, 3 percent, or 6 percent solution.

3.3.7 Film Formation.

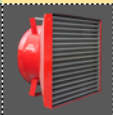
A property of aqueous film-forming foams and film-forming fluoroproteins characterized by a positive (>0.0 dynes/cm) spreading coefficient when measured according to ASTM D1331 using cyclohexane as the hydrocarbon substrate and distilled water to make the foam solution.

…. SFFF ≠ AFFF

NFF 3x3 POG & Aviation Applications

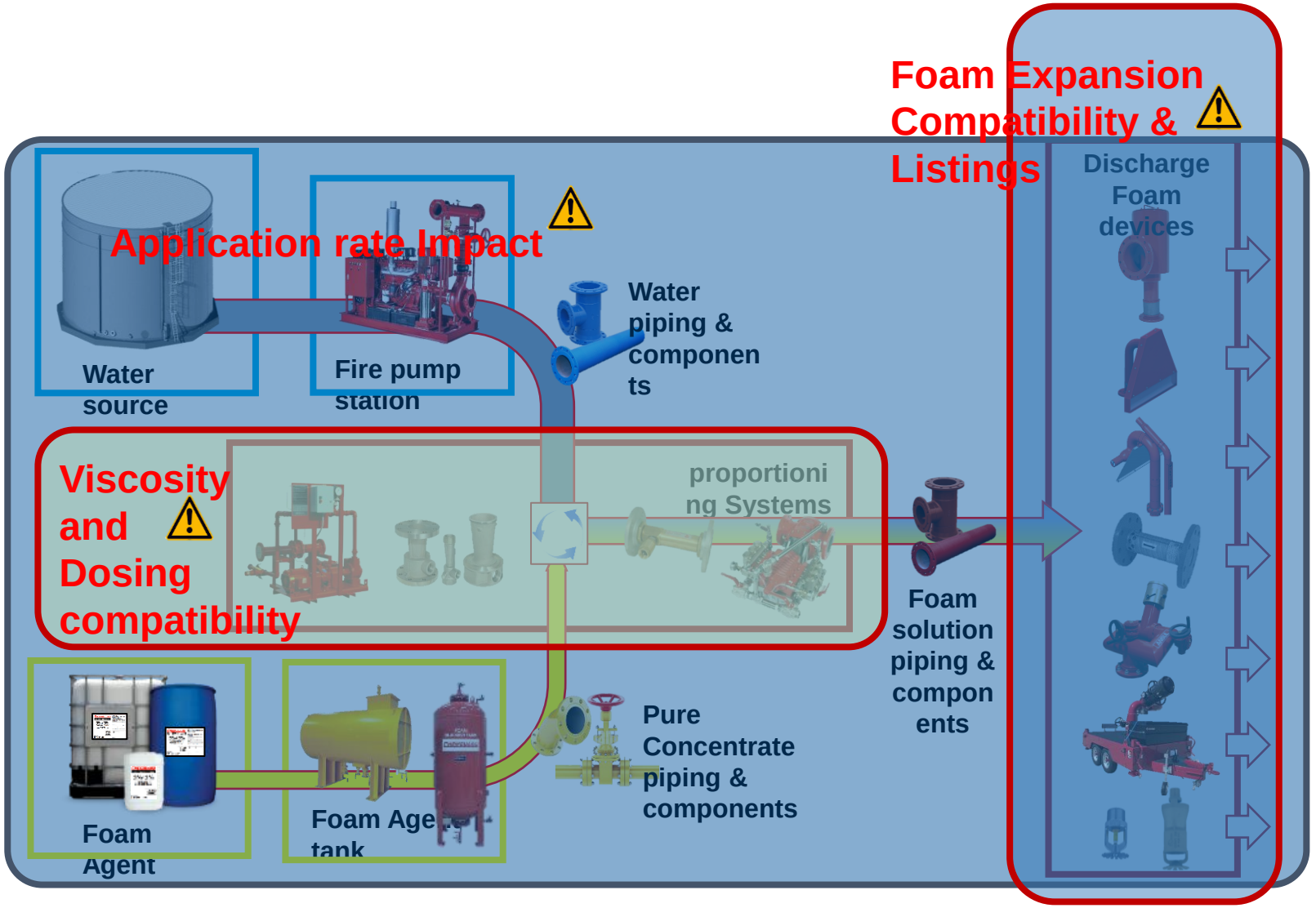
NFPA 409 - Aircraft Hangar Non-Fluorinated Foam Protection Solutions

NFPA 409 Standard on Aircraft Hangars 2022

								Foam Water Deluge			Water Sprinkler	Foam Monitors Low level		Foam - High Expansion	Foam-water Closed-head Sprinkler			
																		
Hangar Group	Option	Foam Water Deluge	Automatic Water Sprinkler Protection	Low level Foam Monitors	Low level High Expansion Foam	Closed-head foam-water Sprinkler	Design Surface Area by system	AFFF Non-Air Aspirating NFF-331	AFFF Air Aspirating	P, FP, SFFF Air Aspirating NFF-331 and UL201	Closed Head Water Sprinkler	AFFF use NFF-331 and UL201 Witness test	P, FP, SFFF use NFF-331 and UL201 use	Low level High Expansion IET-X use	AFFF use only NFF-331 use	Foam Discharge Duration ***	Water Supply Duration	Supplementatry Foam System ****
							m2	lpm/m²	lpm/m²		lpm/m²	lpm/m²		m³/min/m²	lpm/m²	Minutes	Minutes	
1	A	✓					max 1394 m²	6.5	8.1	8.1						10'	60'	For Hangars > 1,115 m2 2x 227 lpm foam hose reels needed foam supply for 20' [2x 136 Litres of Foam]
	B		✓	✓			Oscillation arc ° surface x 30 m				6.9 over 465 m2	4.1*	6.5			10'	45'	
	C		✓		✓		Hangar Floor area over 0.9 m high				6.9 over 465 m2			0.9		12'	45'	
2	A	✓					max 1394 m2	6.5	6.5	6.5						10'	30'	
	B		✓	✓			Oscillation arc ° surface x 30 m				6.9 over 465 m2	4.1*	6.5			10'	≥ 20'	
	C		✓		✓		Hangar Floor area over 0.9 m high				6.9 over 465 m2			0.9		12'	≥ 24'	
	D					✓	max 1394 m2								6.5 over full surface	10'	30'	
3	A	✓					max 1394 m2	6.5	6.5	6.5						10'	30'	
	B		✓	✓			Oscillation arc ° surface x 30 m				6.9 over 465 m2	4.1*	6.5			10'	20'	
	C		✓		✓		Hangar Floor area over 0.9 m high				6.9 over 465 m2			0.9		12'	24'	
	D					✓	max 1394 m2								6.5 over full surface	10'	30'	
4	A			✓			Oscillation arc ° surface x 30 m					4.1*	6.5			10'	45'	
	B				✓		Hangar Floor area over 0.9 m high							0.9		12'	45'	

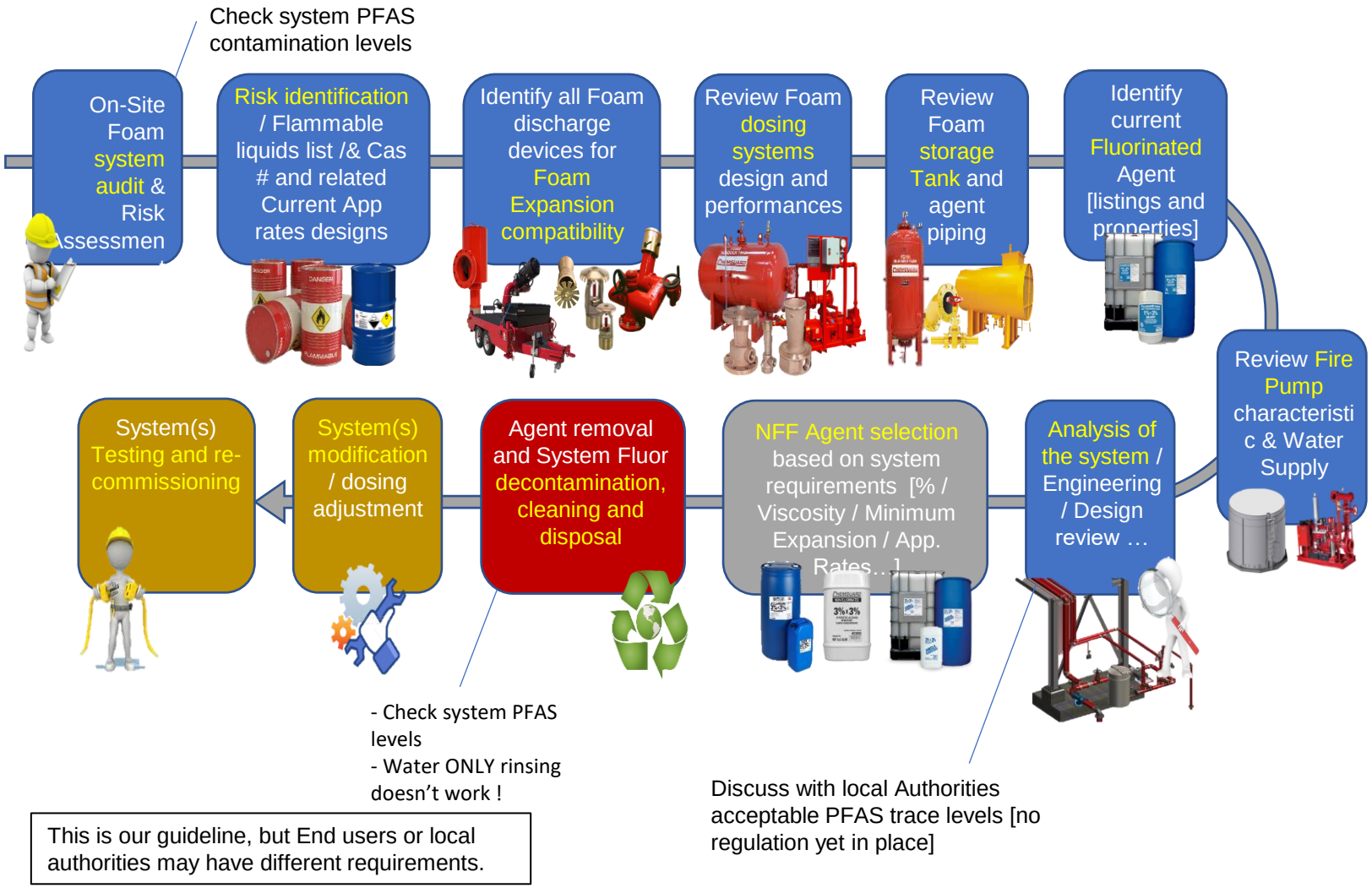
Transition to NFF

Expertise to Transition of Systems from AFFFs to F3s



Transition to NFF

Expertise to Transition of Systems from AFFFs to F3s



Cleaning to conform to ECHA Limits

Why Decontamination?

- PFAS foam creates a **'waterproof' and oil resistant crystalline layers** on the interior of fire suppression systems
- Evidence PFAS **re-contaminates F3 foams** following attempts to decontamination using a double water rinse
  - 1.6 g/L PFASs, significantly higher (x 1600) than the 1mg/L level for total PFAS, recently suggested by ECHA
  - Significantly higher than C8 standards, <25 mg/ L of PFOA and 1 mg/L of it's precursors.

Q&A

Gerard Visser
Business
Development Director
Foam Products

+31 646 199231
Gerard.visser@jci.com

Reading Technical Data Sheets – Sometimes knowing what has been omitted is the most informative.

- High Viscosity? Is there a reason the viscosity data is not readily available?
- Fresh, Salt, and Brackish water? If not mentioned, assume Fresh Water only.
- For sprinkler applications, only use listed & tested Non-Fluorinated Foams.
- We see lots of mistakes of NFPA 11 or 409 application rates assumed wrongly by Engineering, Insurance Co, Foam manufacturers … to be also applicable for NFFs.