A STUDY INTO FLAME INGRESSION AND FLAME ARRESTOR PERFORMANCE USING A POWERPLANT STANDARD CALIBRATED FLAME

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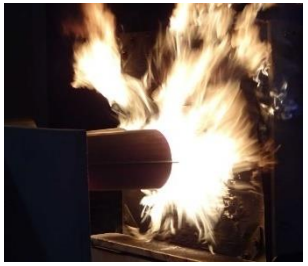

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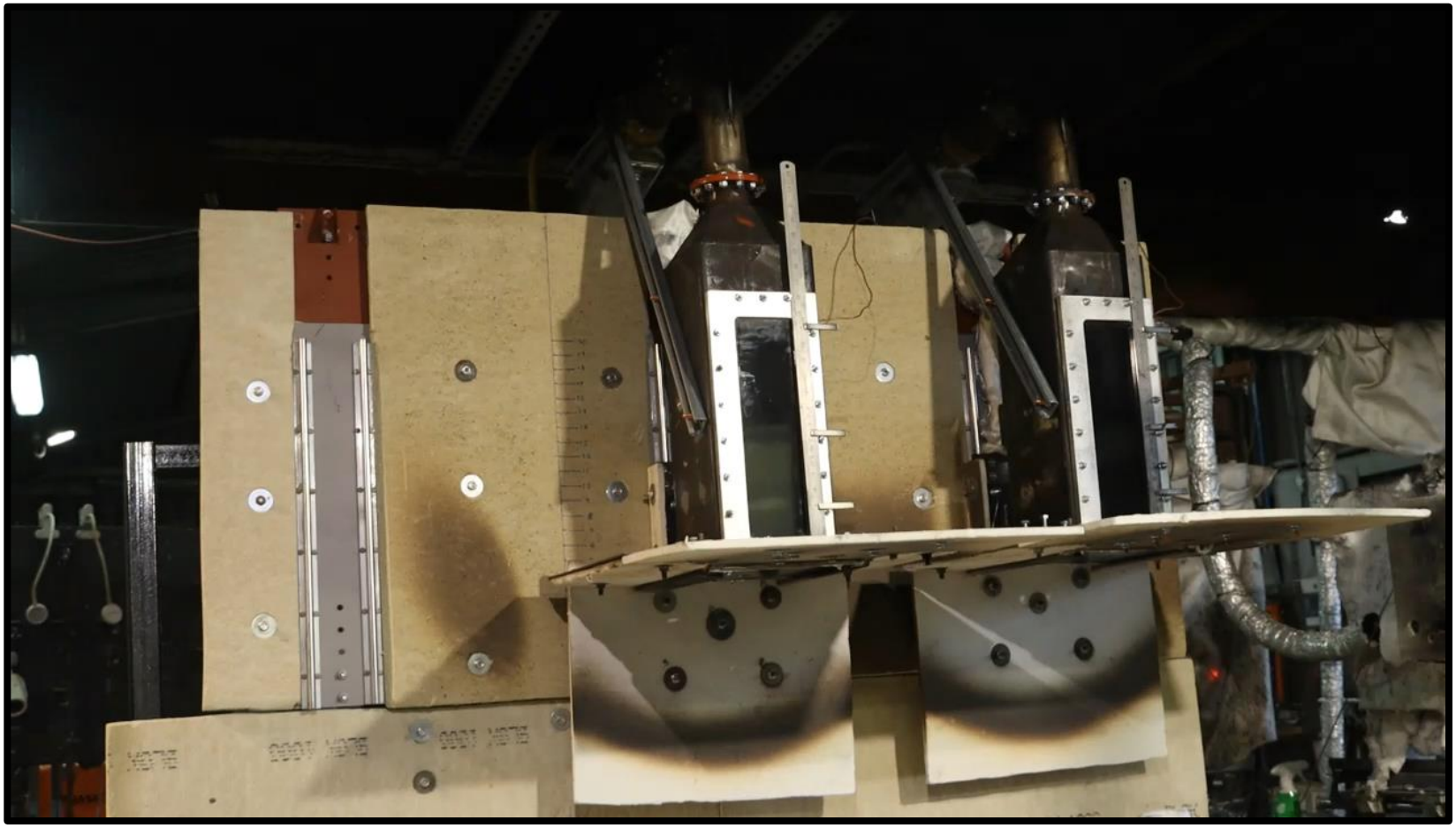
Premise

- There is no available data in the public domain regarding flame ingression and the performance of flame arrestors
- Starting point of this project for Resonate Testing, we recognize improvements can be made to the set up and running of tests – cooling airflow
- Provide data and results to determine if the industry recognized convention, that a straight tube with a length 10 times its diameter (10 L/D) acts as a flame arrestor
- To investigate how much flame ingresses through different size hole/slits/tubes when subject to a powerplant standard calibrated flame, under ambient conditions and pressure differentials
- Investigate how different configurations may affect flame ingression e.g: if the flame is directly impinging or scrubbing
- Consider how far above the flame ingression do the conditions exceed safe temperature limit for fuel

Whilst we are sharing this project, we cannot assume liability, as it is indicative R&D only. We will not be sharing instrumentation used. Data and results cannot be used for commercial gain or validation/certification purposes.

Dynamic Rig



New Rig Design

Horizontal box

Vertical box

Burner can be orientated vertically or horizontally

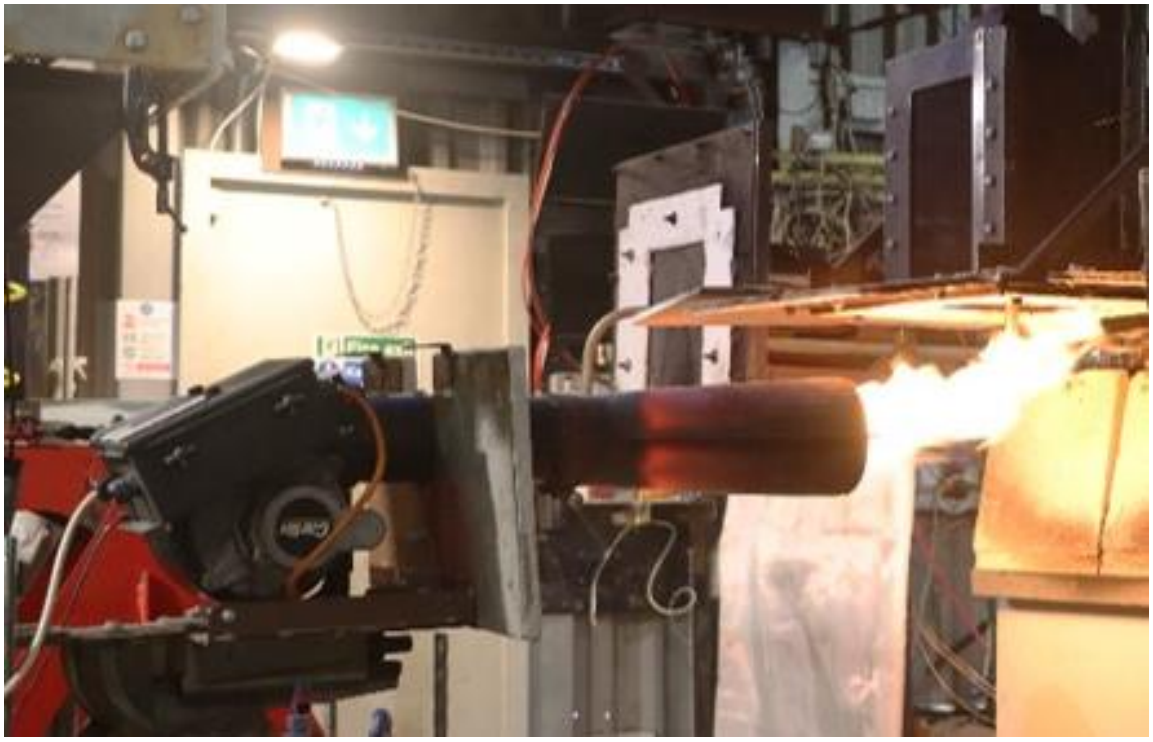
Burner moves in from right to left and stops under each box

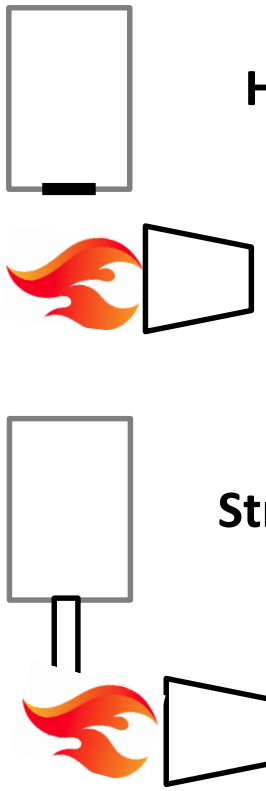
Design allowed the box to be lifted off the plate – investigate ‘no box’ scenario

Setup and Rig Overview

Configurations

Buoyancy





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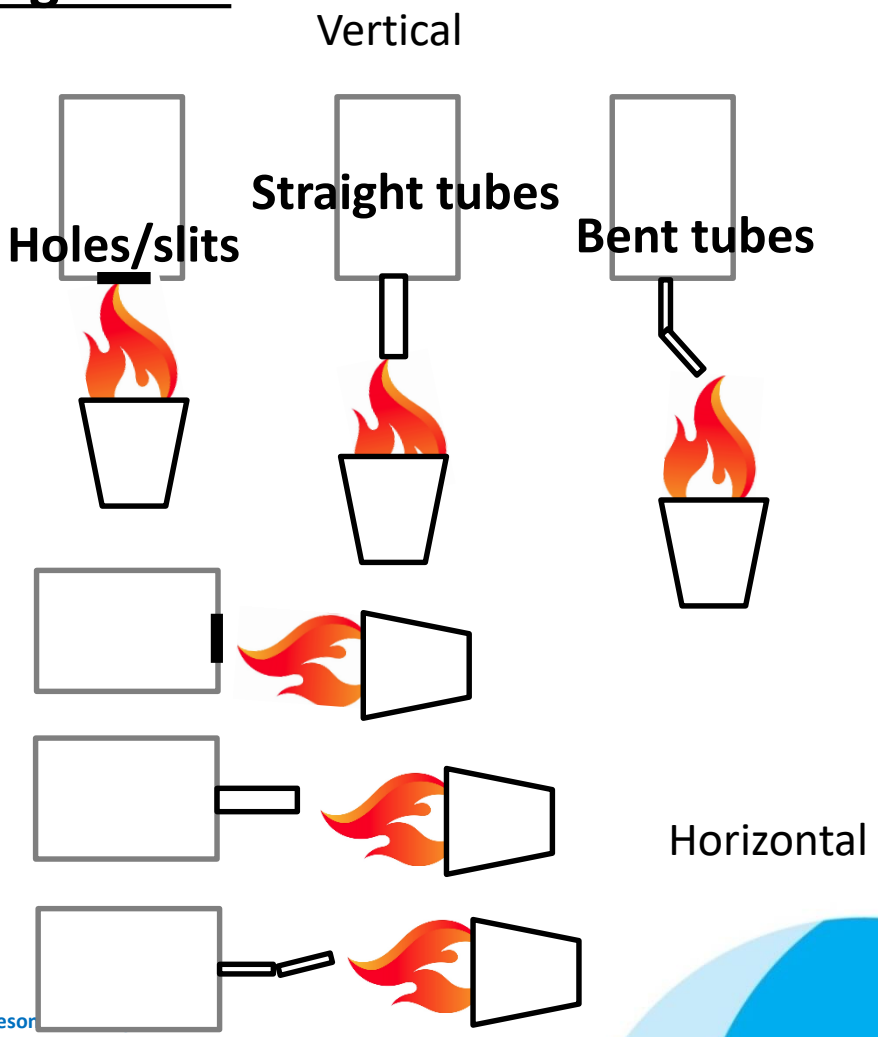
Setup and Rig Overview

Configurations

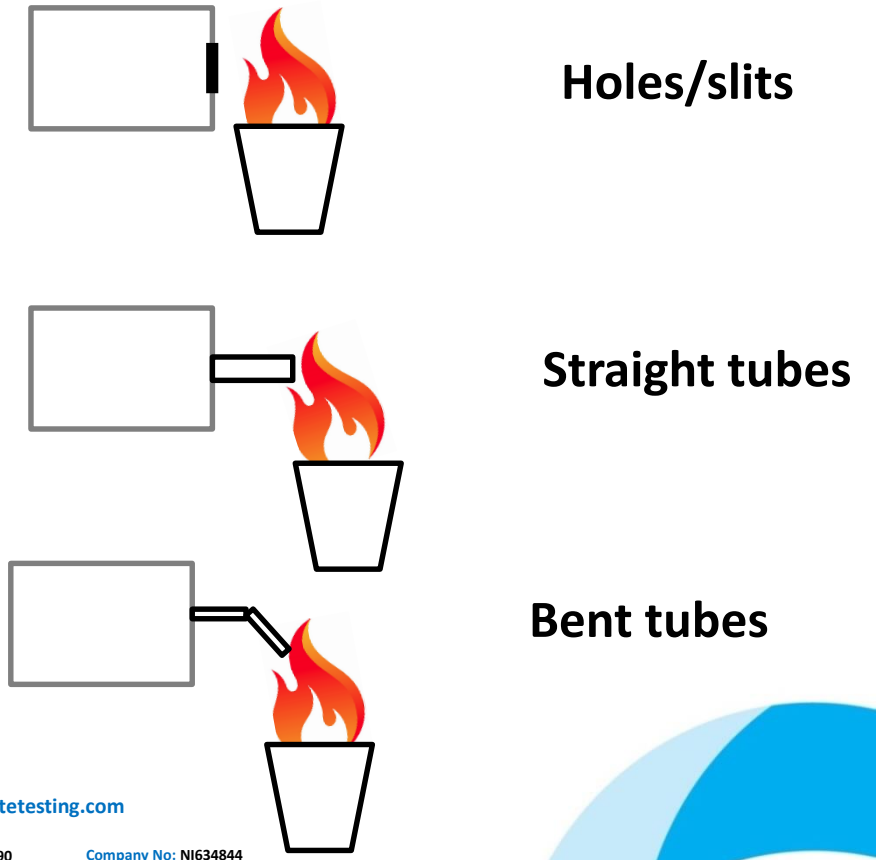
Direct Impingement



Setup and Rig Overview

Configurations

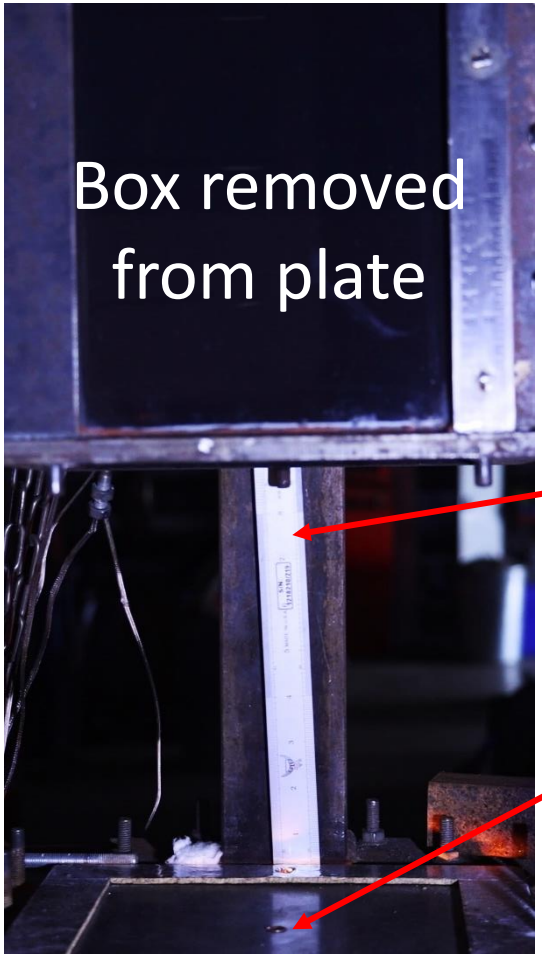
Scrubbing



Setup and Rig Overview

Configurations

‘No box’

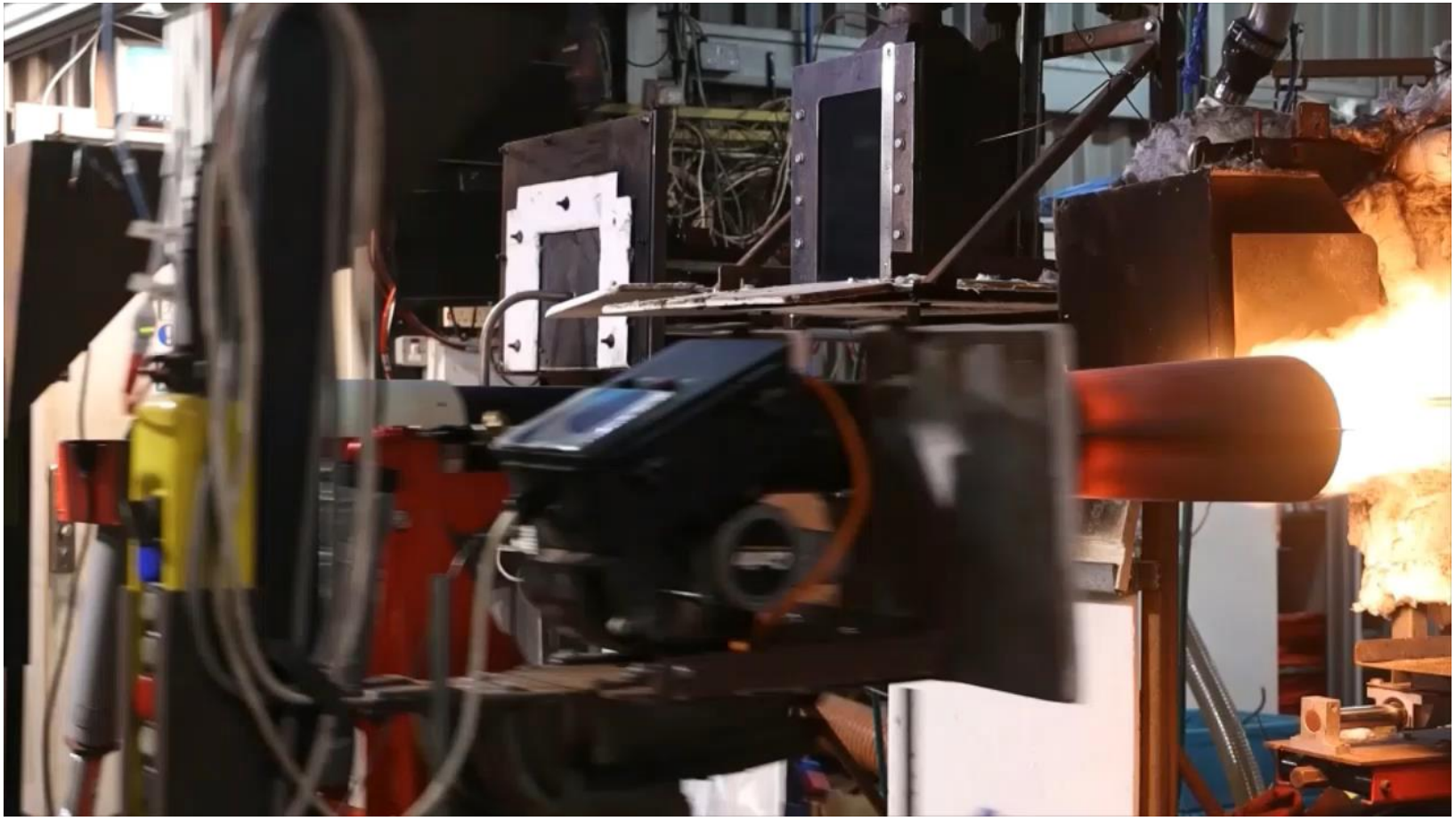


Hole/Slit/Tubes Tested

Holes, Ø in / mm	Slits, width in / mm	Straight tubes	Bent tubes/Tortuous paths
0.2” / 5mm	0.08” / 2mm	-6 5L/D	-6 20L/D 45°
0.6” / 15mm	0.2” / 6mm	-6 10L/D	-6 20L/D 90°
1” / 25mm	0.4” / 10mm	-6 15L/D	-12 10L/D 45°
		-6 20L/D	-12 20L/D 90°
		-12 5L/D	
		-12 10L/D	
		-12 15L/D	
		-12 20L/D	

-6 = 3/8” tube
-12 = 3/4” tube
L/D is defined as the ratio of the length of tube to the diameter
Note: dimensions are approximate

Burner Transition video – -12 (3/4”) 20L/D 90°



Variables considered within the body of testing

Test Setup/Rig Overview	Flame Arrestor	Flame Ingression	Buoyancy/Direct Impingement/Scrubbing
Carlin vs Sonic	Straight Tubes	L/D ratios	Tortuous Paths
Hole and Slit Size	Pressure Differentials	Ambient Conditions	Larger Volume Setups
Flame Calibration Temperature	Flame Height	Pressure Drops	Flame temperature at discrete locations inside the box

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Findings and Results

Straight Tubes

-6ST (3/8”) 10L/D

● Flame observed

● No flame observed

	Vertical DI*	Horizontal DI*	Buoyancy	Scrubbing
Ambient conditions (box)	● ** 2.5” ←	●	●	●
Ambient conditions (no box)	● 0.5” ←	● 0.5” ←	●	●
Pressure differential →	● 3.2”	● 6”	● 5.8”	● 2.1”

*DI = Direct impingement

** flame height observed

Note: Flame was observed in -6ST 20L/D test under pressure differential conditions:

- **4” in horizontal direct impingement configuration**

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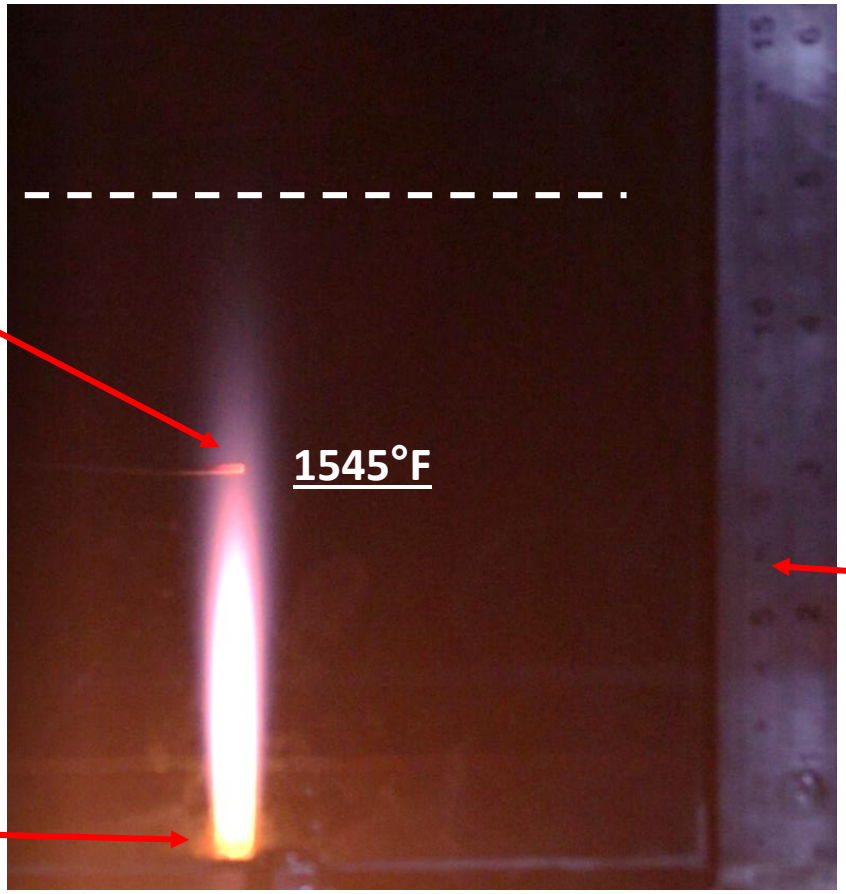
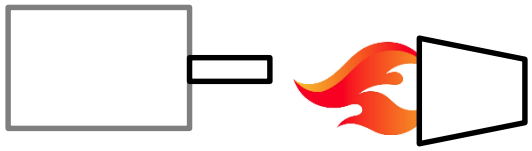
Horizontal Direct Impingement Flame Ingression -6 (3/8”) 10L/D Straight Tube at -0.7psi



Thermocouple

Rule

Tube entrance to box



Horizontal direct impingement

Findings and Results

Straight Tubes

-12ST (3/4”) 10L/D

● Flame observed

● No flame observed

	Vertical DI	Horizontal DI	Buoyancy	Scrubbing
Ambient conditions (box)	● 9”	● 2”	● 5”	● ←
Ambient conditions (no box)	● 4.5”	● 4.5”	● 2.5”	● ←
Pressure differential →	● 10”	● 11”	● 11”	● 3.5”

Note: Flame was observed in -12ST 20L/D test under ambient condition

- **2.6” vertical direct impingement configuration**

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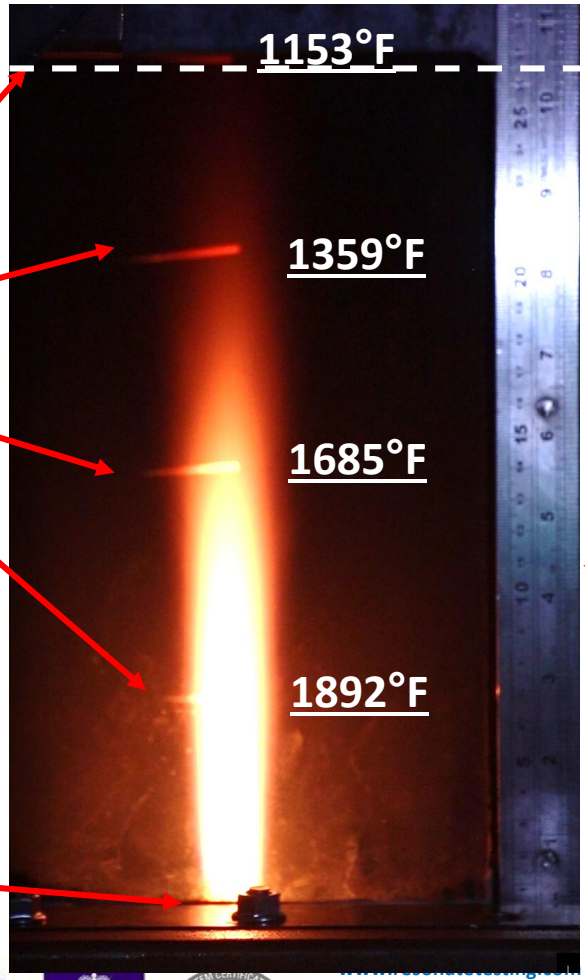
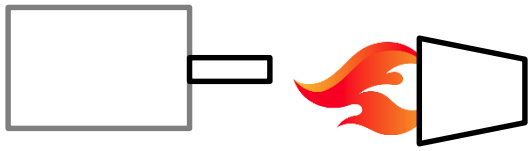
Horizontal Direct Impingement Flame Ingression -12 (3/4”) 10L/D Straight Tube at -0.7psi



Thermocouples

Rule

Tube entrance to box



Horizontal direct impingement

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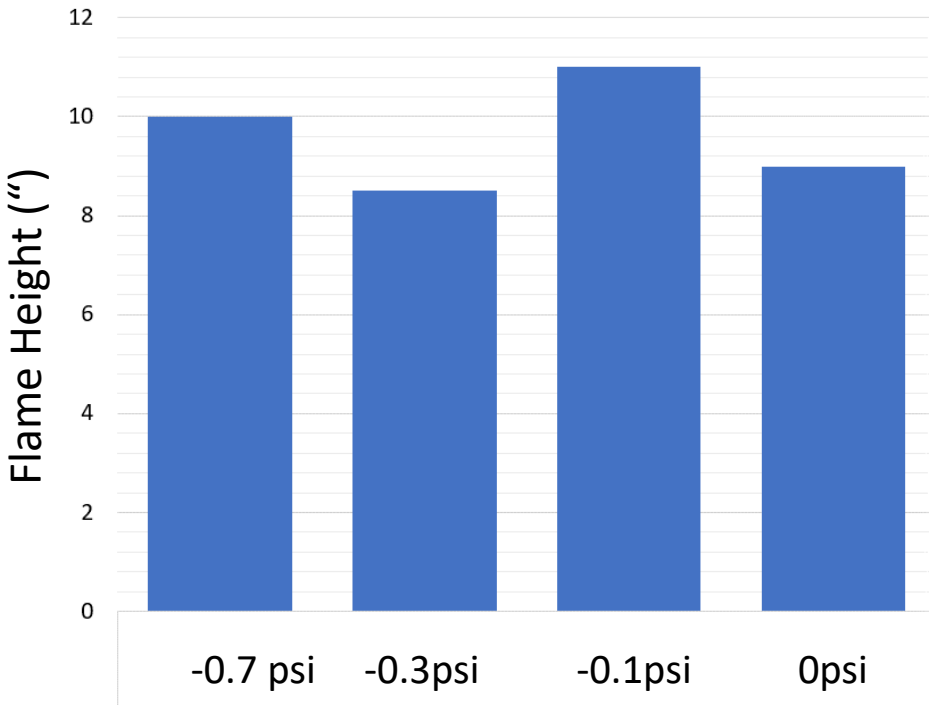
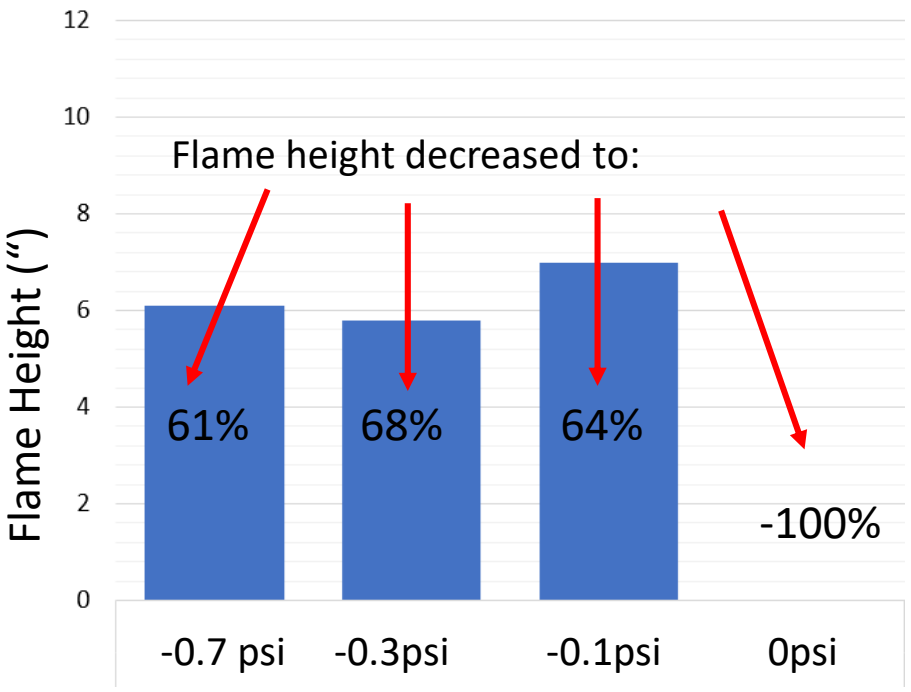
Findings and Results

Tortuous Paths Vertical Direct Impingement - Carlin

-12 (3/4”) 10L/D Straight Tube



-12 (3/4”) 10L/D 45° Bent Tube



Both tests show a decrease in flame height from -0.7psi to -0.3psi but an increase in flame height from -0.3psi to -0.1psi, which is around 1” higher than flame height measured at -0.7psi in both cases

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Findings and Results

🔴 Flame observed

🟢 No flame observed

Holes

	Hole Ø	Vertical DI	Horizontal DI	Buoyancy	Scrubbing
Ambient conditions (box)	0.2” / 5mm	🔴	🔴 1”	🟢	🟢
	0.6” / 15mm	🔴	🔴 4”	🔴	🟢
	1” / 25mm	🔴 5.3”	🔴	🔴	🔴
Ambient conditions (no box)	0.2” / 5mm	n/a – test not carried out			
	0.6” / 15mm	🔴 4”	🔴	🔴	🟢
	1” / 25mm	🔴 5.5”	🔴	🔴	🔴
Pressure differential	0.2” / 5mm	🔴	🔴 3.1”	🔴	🔴
	0.6” / 15mm	🔴	🔴 10”	🔴	🔴
	1” / 25mm	🔴	🔴 10.5”	🔴	🔴

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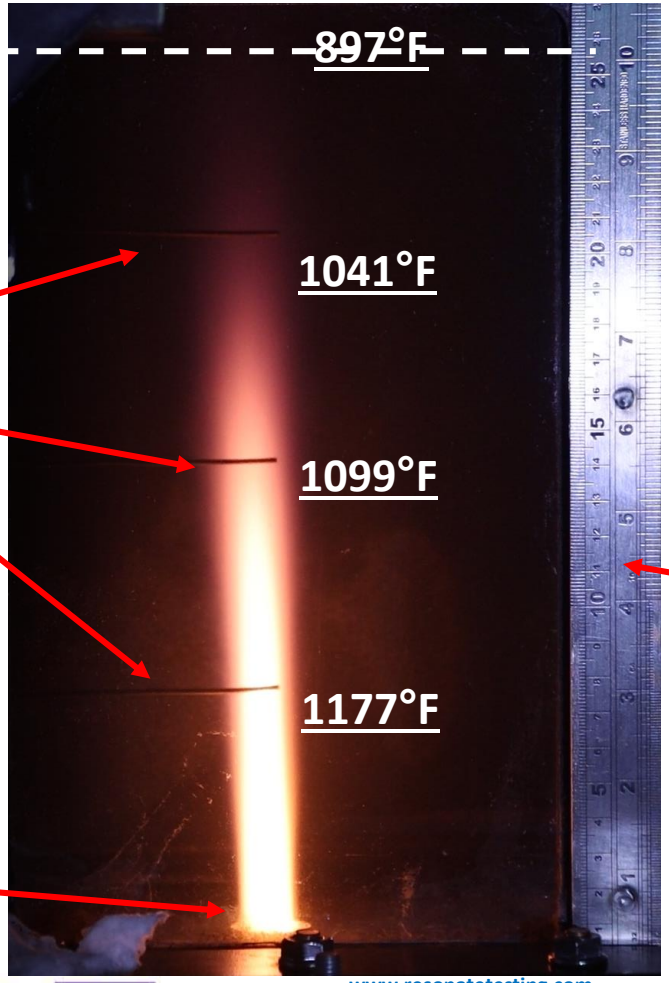
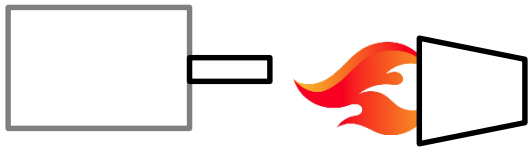
Horizontal Direct Impingement Flame Ingression
1” / 25mm hole at -0.7psi



Thermocouples

Rule

Tube entrance to box



Horizontal direct impingement

Findings and Results

● Flame observed

● No flame observed

Slits

	Slit width	Vertical DI	Horizontal DI	Buoyancy	Scrubbing
Ambient conditions (box)	0.08” / 2mm	● 1.4”	●	●	●
	0.2” / 6mm	● 3.8”	●	●	●
	0.4” / 10mm	● 7.4”	●	●	●
Ambient conditions (no box)	0.08” / 2mm	n/a		● 0.8”	●
	0.2” / 6mm	n/a		● 1.8”	n/a
	0.4” / 10mm	n/a		● 2.5”	n/a
Pressure differential	0.08” / 2mm	●	● 4.3”	●	●
	0.2” / 6mm	●	● 9.5”	●	●
	0.4” / 10mm	●	● 10.5”	●	●

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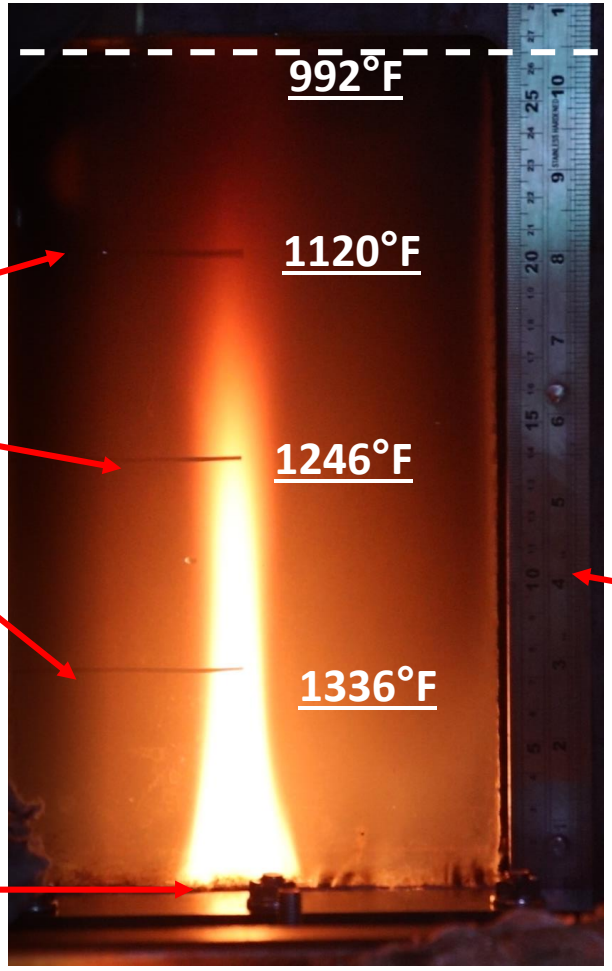
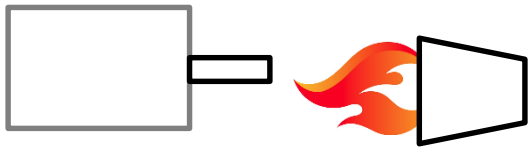
Horizontal Direct Impingement Flame Ingression 0.4” / 10mm slit at -0.7psi



Thermocouples

Rule

Tube entrance to box



Horizontal direct impingement

Summary

- 10L/D convention needs to be treated with caution and on a case-case basis
- Even a small pressure differential results in flame ingression
- Tortuous paths improve flame arrestor properties
- Generally, the larger the tube/gap the larger the flame is drawn through
- Gaps need to be treated with caution (both small and large) – especially where there is a chance of (even a small) pressure differential
- Selected trials were run with both the Carlin and Sonic burner with the aim of distinguishing if one burner caused more flame ingression than the other. Results are inconclusive.
- Generally, temperatures recorded inside the boxes exceeded the safe temperature limit for fuel of ~400°F, unless there was no flame/glow observed

Future Work

- This was a starting point of the R&D project – we know there is room for improvement in the set up.

- Investigate how we can make changes to test set up to make it a more realistic installation – e.g.: add cooling airflow across the tubes to mimic zonal airflows across volumes on other side of firewall.

- Conduct further trials, with different sized holes, slits and tubes and also repeat data points to build upon collected data, with the aim of establishing consistent results and observing trends

- Run more trials with both Carlin and Sonic burners to build on data already collected and to establish if one burner causes more flame ingression than the other – cannot identify from current data

- Understand and process existing thermocouple data. When more trials are run, gather more temperature data from thermocouples inside the box, with the aim to observe trends and examine how far above the flame the safe temperature limit for fuel is.

RESONATE TESTING CAN ACCOMMODATE YOUR FLAME INGRESSION AND FLAME ARRESTOR TESTING REQUIREMENTS

Contact the following email addresses to discuss flame ingression and flame arrestor testing:

OliviaMcAvoy@TheNacelleGroup.com
TomMallon@TheNacelleGroup.com

THANK YOU FOR LISTENING

ANY QUESTIONS?

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