

Evaluation of Test Criteria for the G124 Standard Test Method for Determining the Combustion Behavior of Metallic Materials in Oxygen-Enriched Atmospheres (Valid Ignition Criteria and Sample Holder Affected Zones)

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G124 - Determining the Combustion Behavior of Metallic Materials in Oxygen-Enriched Atmospheres

- G124 is a key test method for materials evaluation and selection for both spacecraft and industry applications.
- As spacecraft and industry designs push the boundaries of materials selection, it is important to clearly define test method criteria.
 - **Valid Test Criteria**
 - **Sample holder affects on regression rate analysis**
- Presenting data from WSTF test campaign.
- Proposed refinements to the existing G124 standard.



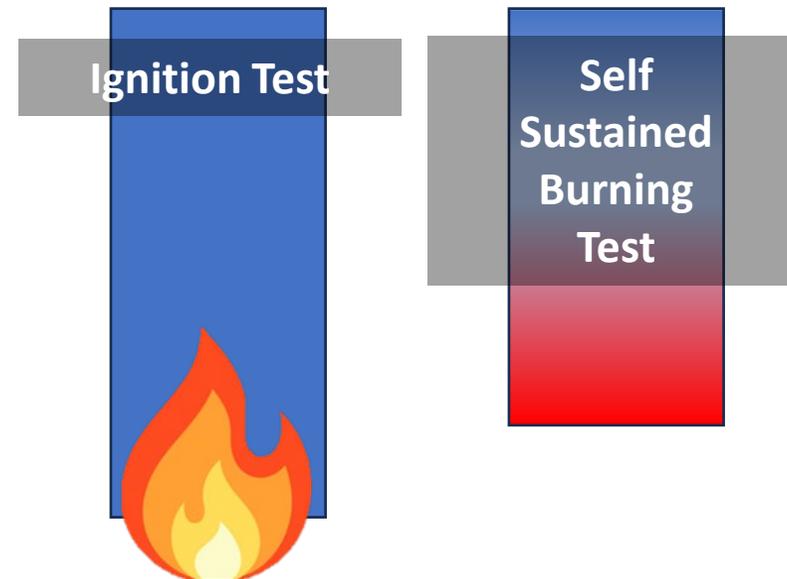
Valid Test Criteria



G124-18 Scope

Section 1.1 states: *This test method covers test apparatus and techniques to determine the minimum test gas pressure and sample temperature that **supports self-sustained burning** and the regression rate of the melting surface of a standardized sample of a metallic material that has been ignited using a promoter.*

- Evaluates how much input energy is required to ignite a material.
- G124 is NOT an ignition test.

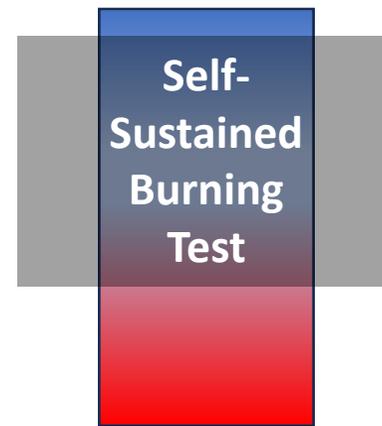


- “Overwhelming” ignition source
- Once ignition is confirmed & you exit ignitor-affected area, now you can evaluate self-sustained burning.
- **How do you verify material was ignited sufficiently to achieve self-sustained burning?**

G-124-18 Igniter and Promoter Definitions

3.1.5 igniter, *n*—a material used to ignite the promoter that can burn under an electrical influence, such as a small-diameter wire.

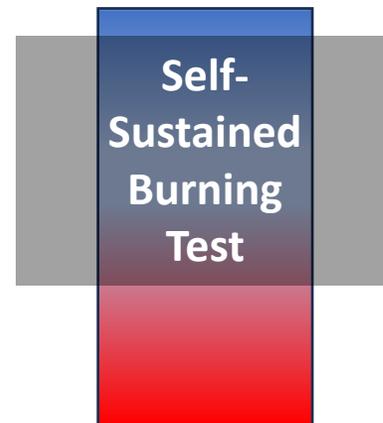
3.1.8 promoter, *n*—an optional material that can add supplemental heat and increase the temperature to **start burning of the metallic material** being tested.



- How do you verify material burning has started?

G124-18 Valid Test Criteria

Section 3.1.13 defines: *valid test, n*—a test in which the igniter and/or promoter combination **has melted** the **bottom section** of the test sample where the igniter and/or promoter is located.

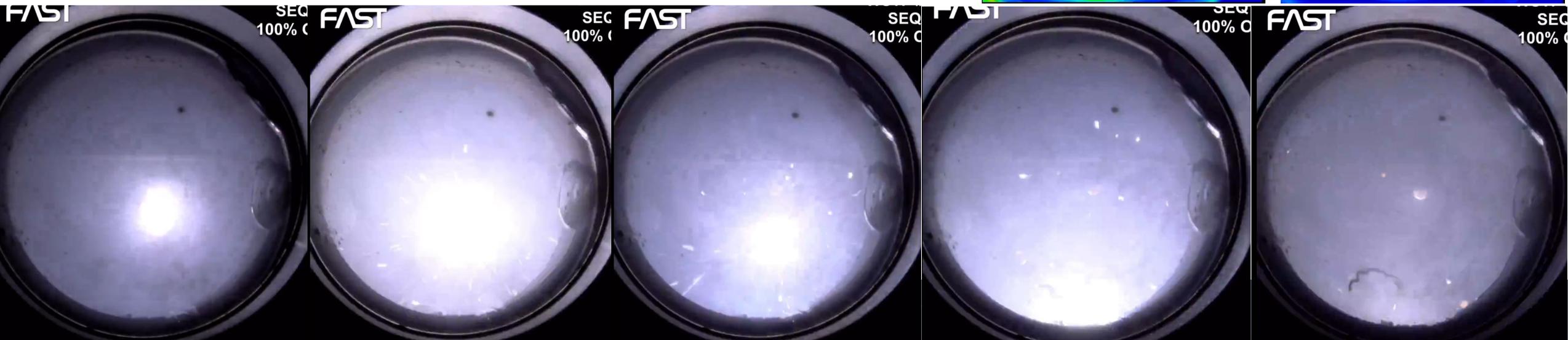
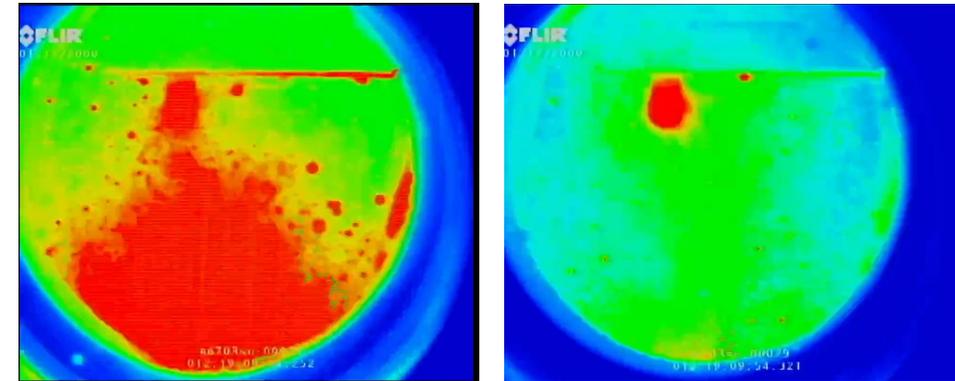


- What constitutes melt?
- What constitutes bottom section?

Melt and Drip

“valid test, n—a test in which the igniter and/or promoter combination has melted the bottom section of the test sample where the igniter and/or promoter is located.”

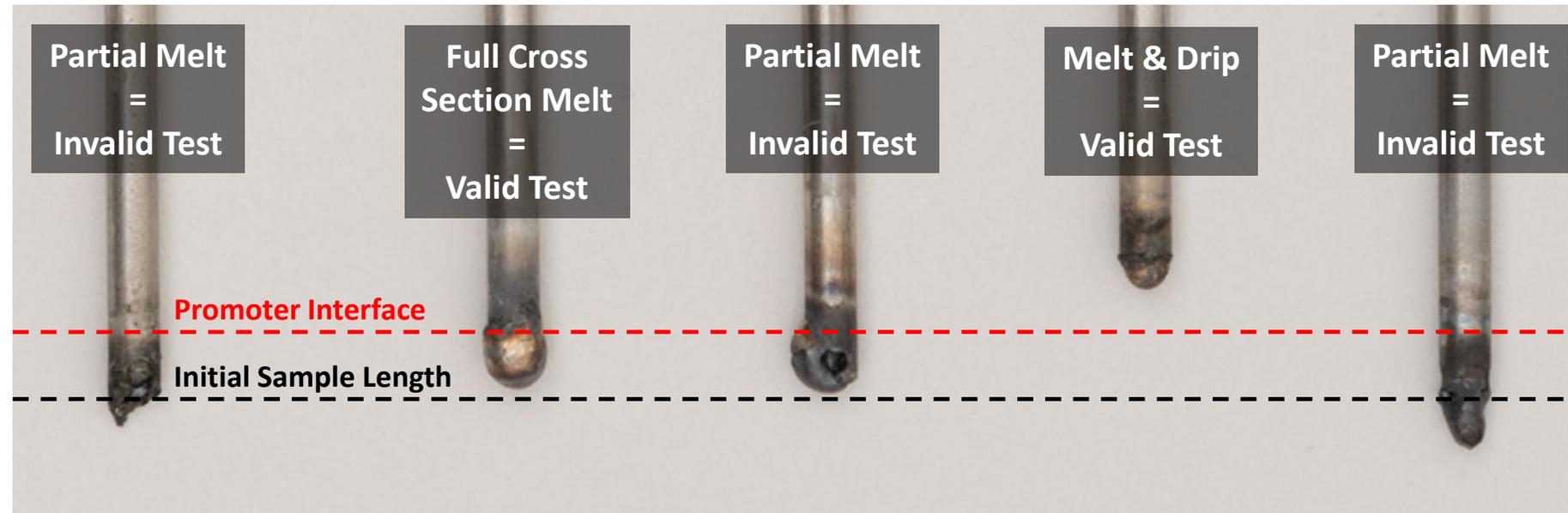
- Melt and Drip is preferred way to confirm full melt of bottom section of material.



Ensuring Valid Test in Challenging Conditions

“*valid test, n*—a test in which the igniter and/or promoter combination **has melted** the **bottom section** of the test sample where the igniter and/or promoter is located.”

- Depending on material and conditions, achieving full drip can be challenging.
- Clarification needed for “Bottom Section.”
 - Full Cross Section
 - Full Promoter Area



Ensuring Valid Test in Challenging Conditions

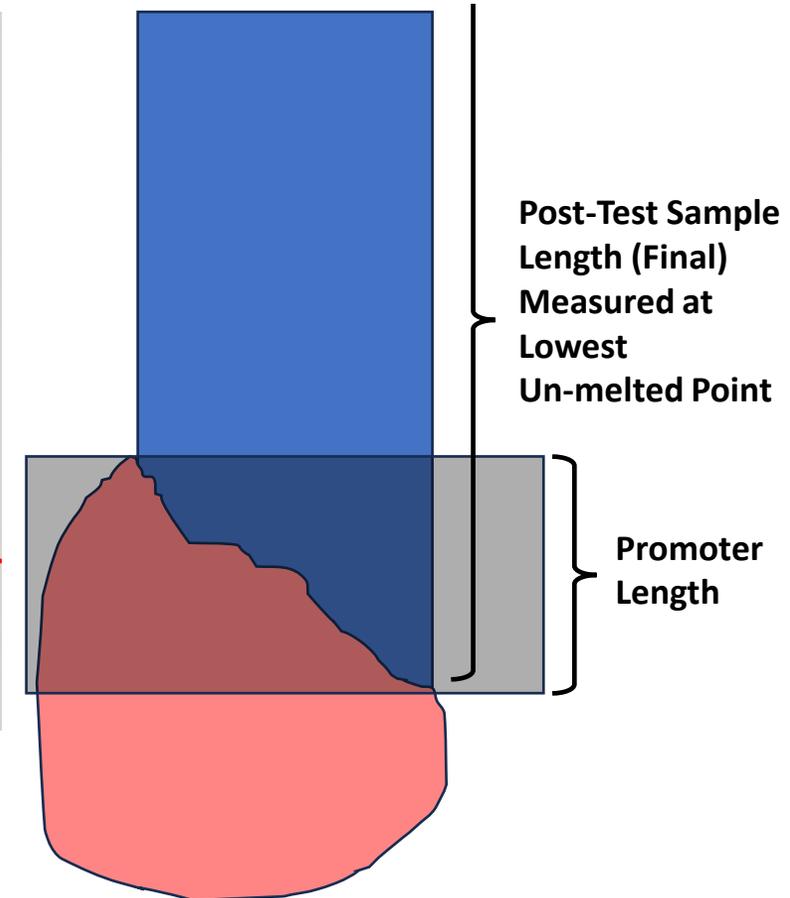
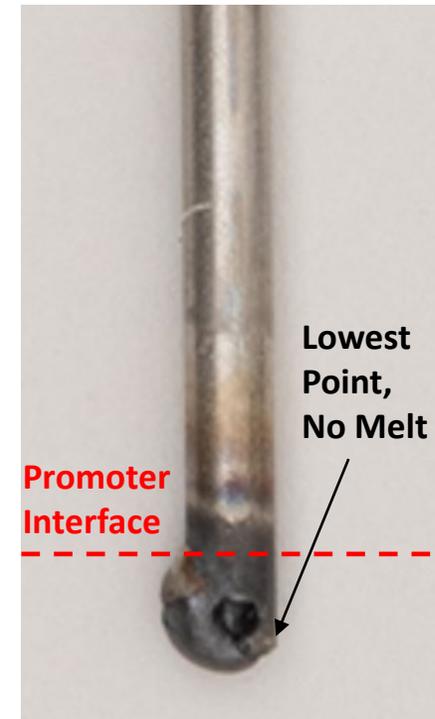
- Clarification needed for “Bottom Section.”
 - Full Cross Section
 - Full Promoter Area
- Can be evaluated via pre- & post-test measurements.
- Evaluate post-test sample length at lowest point with no melt.

$$SL_i - SL_f \geq PL$$

SL_i = Initial Sample Length (pretest)

SL_f = Final Sample Length (posttest)

PL = Promoter Length



Example:

$$14 - 13.5 = 0.5 \leq 1.0\text{cm } PL = \text{Invalid Test}$$

$$14 - 12.9 = 1.1 \geq 1.0\text{cm } PL = \text{Valid Test}$$

G124-18 Recommended Clarifications

Current:

Section 3.1.13 defines: *valid test, n*—a test in which the igniter and/or promoter combination has melted the bottom section of the test sample where the igniter and/or promoter is located.

Proposed Clarification:

Section 3.1.13 defines: *valid test, n*—a test in which the igniter and/or promoter combination has melted the bottom section of **the full cross section** of the test sample where the igniter and/or promoter is located, **ideally sufficiently to induce melt and drip. (SLi-SLf ≥ PL, Sample Length Initial (SLi), Sample Length Final (SLf), Promoter Length(PL))**

G124-18 Recommended Clarifications

Current:

- 3.1.1 *burn length, n*—the burn length is the length of the sample that has been consumed by combustion.
 - 3.1.1.1 *Discussion*—The burn length is determined by subtracting the post-test sample length from the pre-test sample length (which does not include the promoter length or region used by the test sample support).

Proposed Clarification:

- 3.1.1 *burn length, n*—the burn length is the length of the sample that has been consumed by combustion.
 - 3.1.1.1 *Discussion*—The burn length is determined by subtracting the post-test sample length from the pre-test sample length (which does not include the promoter length or region used by the test sample support). **As sample melt fronts are often uneven, this measurement should be taken at the furthest point (undisturbed/un-melted point) away from the test sample support.**



Sample Holder Effects on Regression Rate Analysis

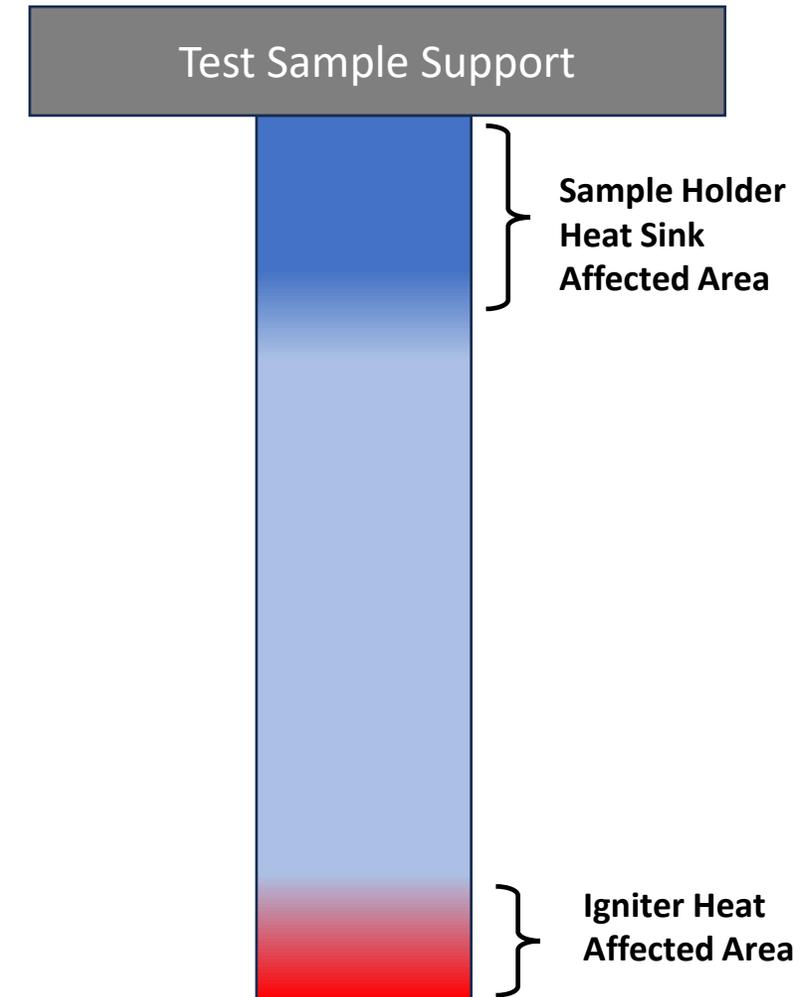
G124-18 Scope

Section 1.1 states: *This test method covers test apparatus and techniques to determine the minimum test gas pressure and sample temperature that supports self-sustained burning and **the regression rate of the melting surface** of a standardized sample of a metallic material that has been ignited using a promoter.*

- **What is the minimum sample length required to accurately evaluate regression rate?**

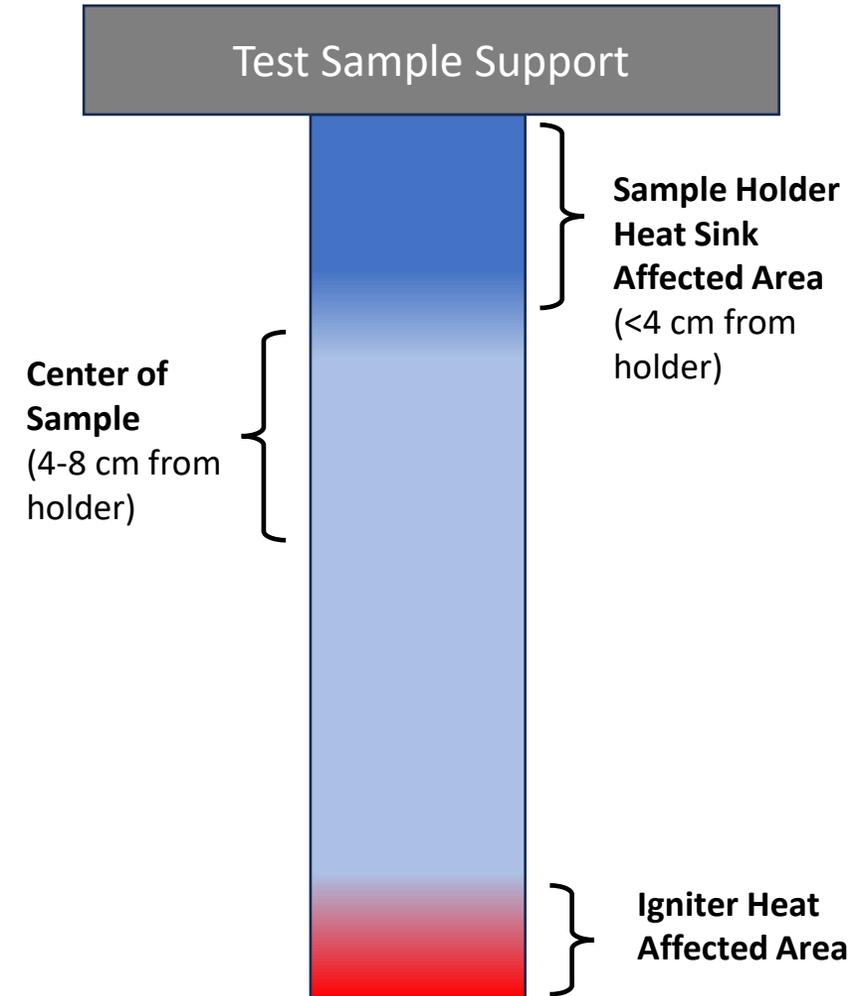
Sample Holder Impacts on Regression Rate

- Igniter heat affected was previously evaluated and determined to be <3 cm (1.2").
 - Used to define current G124-18 failure criteria
- WSTF performed characterization to evaluate if regression rate impacts would be observed from in-sample support heat sink area.
 - 6061-T6 Aluminum 1/8" Rod
 - 100% O₂
 - ~50 psi
 - Ensure flammable but minimize burn rate for better accuracy.
 - Evaluated from post-drip to post-drip.



Sample Holder Impacts on Regression Rate

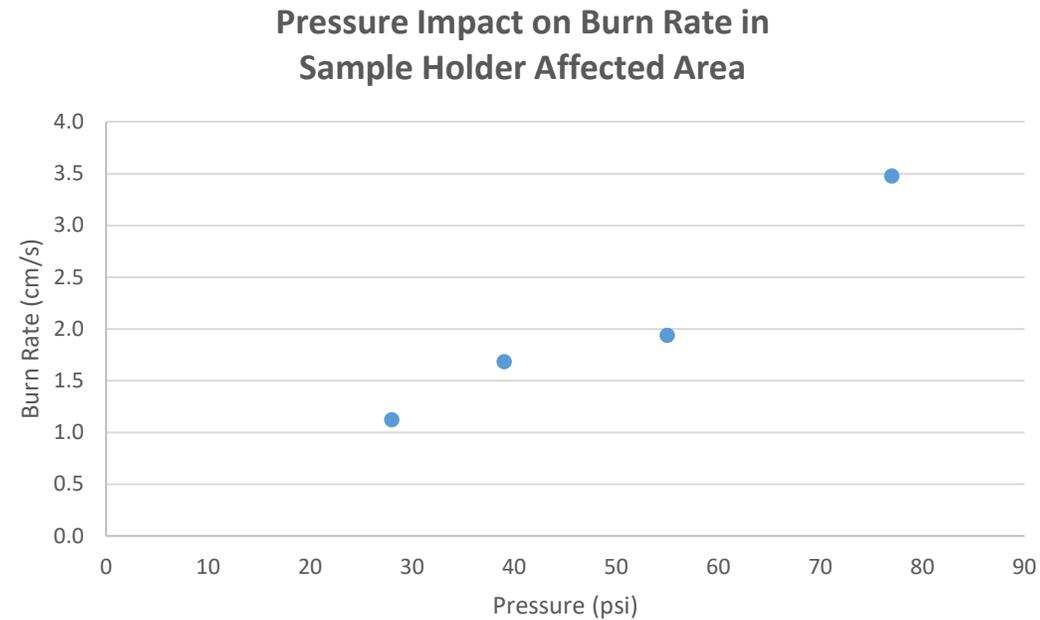
- Evaluated 2 Ranges
 - Sample Holder Affected Area (<4 cm from holder)
 - Center of Sample (4-8 cm from holder)



Sample Holder Affected Area Data

WSTF#	Material Name	Recorded Pressure (psi)	Range of Sample Evaluted	Visible Burn Length Actual (cm)	Visible Distance from Sample Holder (cm)	Burn Rate (cm/s)
23-48405	6061-T6 Aluminum, 1/8" Rod	77	Sample Holder Affected	3.1	<4cm	3.5
		55	Sample Holder Affected	2.7	<4cm	1.9
		28	Sample Holder Affected	1.5	<4cm	1.1
		39	Sample Holder Affected	2.8	<4cm	1.7
		51	Center of Sample	3.7	4-8cm	2.7
		49	Center of Sample	3.9	4-8cm	2.3
		50	Center of Sample	2.6	4-8cm	2.2

Pressure Impacts on Sample Holder Affected Area

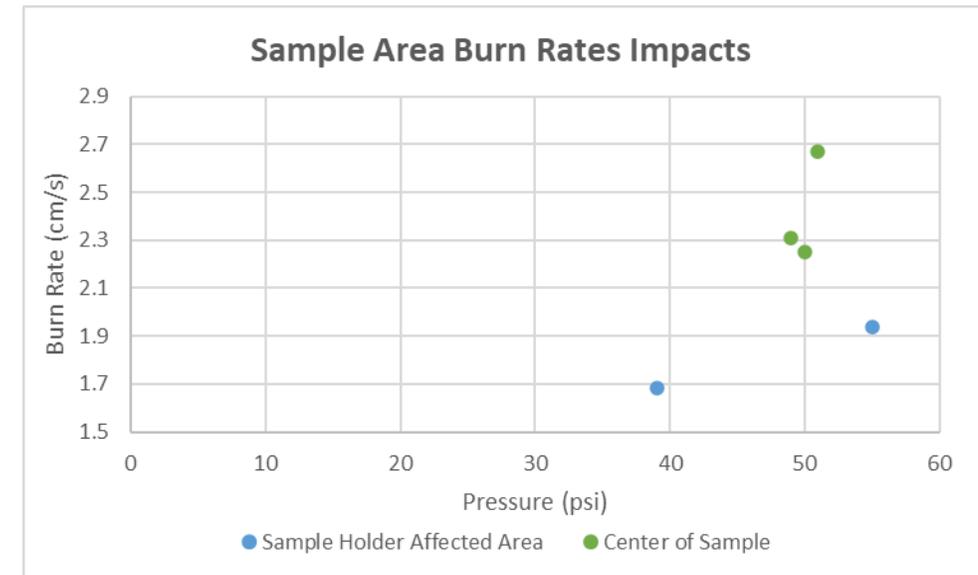


- Pressure impact observed on burn rate
- Focused on ~40-50 psi range for sample holder evaluation

Sample Holder Impact Burn Rate Comparisons

WSTF#	Material Name	Recorded Pressure (psi)	Range of Sample Evaluted	Visible Burn Length Actual (cm)	Visible Distance from Sample Holder (cm)	Burn Rate (cm/s)
23-48405	6061-T6 Aluminum, 1/8" Rod	55	Sample Holder Affected	2.7	<4cm	1.9
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Average Burn Rate in 40-50 psi range for Al 6061-T6 in 100% Oxygen		
Sample Holder Affected Area (<4cm from Holder)	Center of Sample (4-8cm from holder)	BR % Increase in sample center
1.8	2.4	33%



- Burn rate was found to be ~33% higher in center of sample vs in area closest to sample holder.
- This suggests that regression rate evaluations should be performed >4 cm away from the sample holder.

G124-18 Minimum Sample Length Impacts: Recommended Clarifications

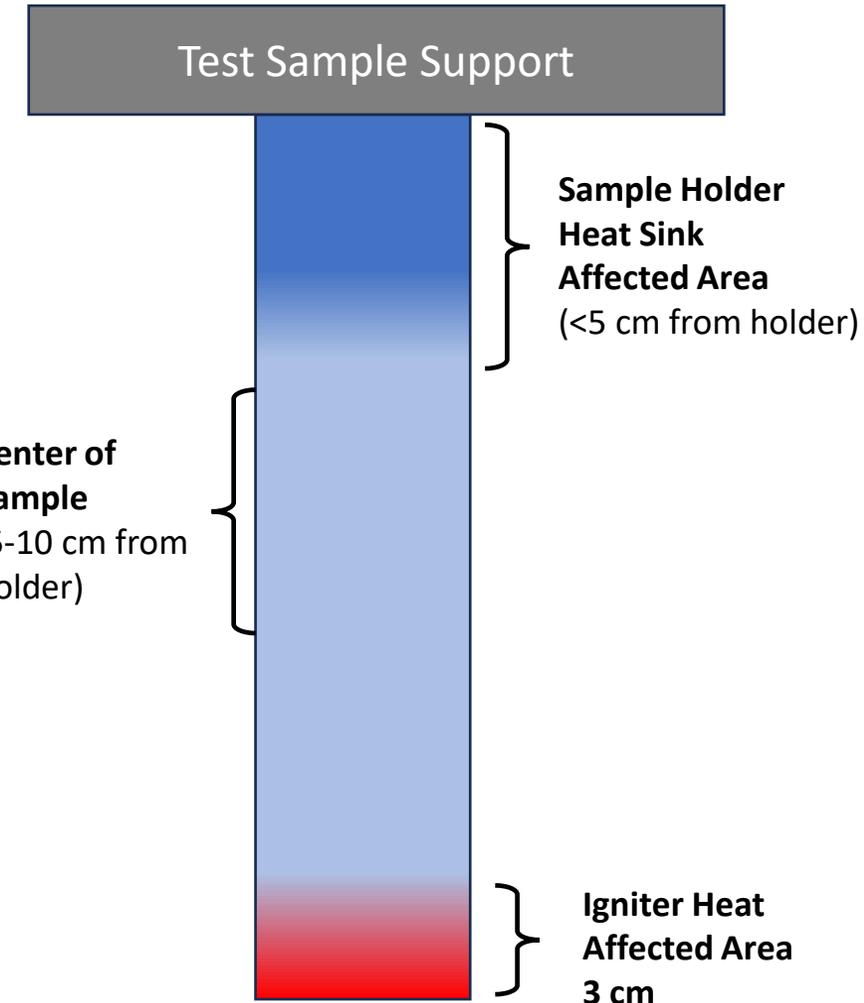
- Data suggests that for regression rate analysis, minimum sample lengths may need to be longer than the 101 mm currently required.
- Additional margin (1 cm) added to recommend heat affected sample holder area compared to evaluated (4 cm).

Current:

3.1.11 *standard rod test sample, n*—a 3.2 mm (0.125 in.) diameter rod with a minimum length of 101.6 mm (4 in.).

Proposed Clarification:

3.1.11 *standard rod test sample, n*—a 3.2 mm (0.125 in.) diameter rod with a minimum length of 101.6 mm (4 in.). **For regression rate analysis, a minimum length of 130 mm (5 in.) is recommended to provide sufficient length to avoid performing regression rate analysis in <5 cm range closest to sample support and in <3 cm range closest to igniter/ promoter.**



Conclusions

- Valid Ignition/ Sustained Propagation Criteria
 - Evaluations at WSTF suggest that ambiguity exists in how to apply G124-18 valid test and burn length criteria.
 - Recommendation to clarify “valid test” definition to include:
 - Full cross-section melt as part of criteria
 - Post-test burn length verification to ensure promoter length area was fully melted or consumed
 - Recommendation to clarify “Burn Length” definition:
 - To clarify the furthest point of undisturbed/un-melted material as the point to be used for post-test burn length evaluation
- Sample Holder Heat Affected Area
 - Testing at WSTF showed that sample holder heat sink effects can impact regression rates in <4 cm range.
 - Recommendation provided to update G124 to increase minimum sample length to 130 mm (5 in.) when being used for regression rate analysis and for data <5 cm of the sample holder to be avoided.

National Aeronautics and
Space Administration



Questions?