

HR2 Development TRL 6 – Status Update



Presented by: Ralph Buoniconti, Sabic

Prepared by: Brian Johnson, BCA Flammability Yonas Behboud, BR&T

September 2024 - Resorts Casino, Atlantic City, NJ

OSU Test Method



14CFR25.853(d)

- Added in 1986
- Current FAR Appendix F Part IV
- Applicable to interior exposed surfaces greater than 144 square inches
- Measures heat release as a function of time
- Test code: HR

- Reproducibility challenges persist
- Specification does not tightly control some key parameters
- Decades of certification data in use



Light Brown Honeycomb Panel

*Presented June 2012

HR2 - Next Generation OSU



Design and Other Changes

- Elimination of cooling flow / inner chimney
- Insulation / metal wall specification changes
- Coupon location in chamber specified
- Air and methane flows controlled via MFCs
- Single lower Tcouple DAQ correction
- HFG calibration / limit changes (3.65 W/cm²)
- Methane calibration and cal factor correction
- Multiple additional procedural changes



*Presented October 2016

Anticipated Improvements

- Repeatability driven by design and cal changes
- Reproducibility increased via spec controls
- Cross industry variation greatly reduced

HR2 Development Goal and Status

 HR2 Goal: Define a robust method to determine peak and total heat release that improves repeatability and reproducibility when compared with OSU

History / Status

- NASA Technical Readiness Level (TRL) model adopted
- TRL 4 Robustness completed calibration factor variation < 5%</p>
- TRL 5 Repeatability completed CoV improvement demonstrated
- HR2 development is in TRL 6 Reproducibility
 - Individual coupon type CoV and ANOVA evaluation
 - Success criteria will be determined by the OSU / HR2 task group*

* Key members: Mike Burns (FAATC), Martin Spencer (MarlinEngineering), Mike Schall (Deatak), Jan Christian Thomas (Airbus), Yaw Agyei (Boeing BR&T), Kent Wenderoth (Herb Curry), Hiroaki Fujioka (Chemitox)

HR2 Tailored TRL Development Model

TRL 6 - *Reproducibility* - variation in measurements taken on the same specimens under the same conditions using different machines.

Gate 6 / Enter **TRL 7**: Individual coupon type CoV and ANOVA evaluation

TRL 7 - *Range* - demonstrated ability to test a range of coupon materials and configurations. Establish pass/fail criteria for HR2 total and peak heat release.

→ Gate 7 / Enter **TRL 8**: Results over a range of specimen types that are consistent with OSU empirical results.

TRL 8 - *Documentation* - Final drawings and methods released, equipment "qualified" through test and demonstration. Documented test guidance finalized.

Gate 8 / Enter **TRL 9**: Final unit drawings and test methods released.

TRL 9 - *Round Robin* - multiple production units performance verified by successful round-robin testing.

Gate 9 / **Completion**: Individual coupon type reproducibility verified on multiple production units.

*Presented October 2023

Boeing HR2 – Seattle Flammability Lab

- Marlin Engineering HR2 unit
- Alicat main airflow mass flow controller
- Operating parameter data shared April 2024
- TRL 6 testing completed Sept 2024
- Primary operator is Yonas Behboud





Chapter A4 - Operating Parameter Updates

PARAMETER	DESCRIPTION	MIN.	NOMINAL.	MAX.
Inlet Airflow Rate	SCFM	19.6	20	20.4
Inlet Air Temperature	°C	21.1	22.5	23.9
Inlet Air Relative Humidity	% RH	-	-	<u>≤65</u>
Heat Floor (W/am ²)	Center	3.60	3.65	3.70
Heat Flux (w/cm ⁻)	Each Corner (4)	3.55	3.65	3.75
Average Baseline Exhaust Gas Temperature	No Flame (°C)	275	285	295
	SLPM	2.85	3.00	3.15
Calibration Factor Ranges	W/°C	19.0	20.0	21.0
	3 SLPM ΔT (°C)	85.3	89.6	94.3
Interspace Pressure	inH2O	0.40	0.55	0.70
Lower Plenum Pressure	inH2O	11.0	12.5	14.0
Methane Gas Supply Pressure	PSIG	20	25	30
Main Air Supply Pressure	PSIG	20	25	30
Mixing Air Supply Pressure	PSIG	20	25	30
Thermal Stability Temperature (TST)	20-sec average (°C)	360	370	380
Sectional Conditioning	Temperature (°C)	18	21	24
Specifien Conditioning	Relative Humidity (%)	45	55	65
Linner Dilet Car Flow	Air (SLPM)	0.98	1.00	1.02
Opper Phot Gas Flow	Methane (SLPM)	1.47	1.50	1.53
Lower Dilot Cos Flow	Air (mL/min)	650	700	750
Lower Phot Gas Flow	Methane (mL/min)	105	120	135

Table A4-2. Nominal Operating Parameters/Ranges



365 – 395 °C

TRL 6 Test Plan

Approach

- Phase 1 Collect 100 operating parameter sets to ensure units fall within set ranges
- Phase 2 Test 30 specimens of 2 coupon types and evaluate reproducibility
- 1. Standard sandwich panel (SP) provided by Schneller
- 2. Boeing sandwich panel (BP) provided by Boeing

Instruments Tested

- Marlin Engineering HR2 Boeing Flam Lab, Seattle, Washington
- Marlin Engineering HR2 FAA TC, Egg Harbor Township, New Jersey

Future Testing

- Deatak HR2 Herb Curry Test Laboratory, Mt. Vernon, Indiana
- Marlin HR2 Chemitox Test Laboratory, Shinjo, Japan

Final TRL 6 Determination Targeted for Early 2025





FAA TRL 6 - Test Data Log (Example)

- Calibration factor determined on each test day for the unit
- Heat flux was measured, calibrated each day prior to testing (center, corners)
- Thermocouples cleaned with misting sprays between runs
- Marlin Unit (ME):
 - 25 SPs tested per unit
 - 30 BPs tested per unit
- Similar testing was conducted on the Boeing (ME) HR2 in Seattle

					Supp	ly Air	Amb	ient	Start	Baseline		Heat Release	•
Day #	Run #	Coupon Type	Number	File Name	Temp (C)	PSIA	Temp (F)	RH (%)	Time	Temp (C)	Peak	Pk Time (s)	2-Min
1	1	BP	39	TRL 6 Set 1	20.59	15.36	27.1	62	10:18	352.6	62.1	45	38.1
1	2	BP	18	TRL 6 Set 1	20.72	15.36	26.8	63	10:30	351.6	58.2	45	37.0
1	3	BP	59	TRL 6 Set 1	20.73	15.36	26.6	63	10:36	351.5	55.5	43	36.8
1	4	SP	10	TRL 6 Set 1	20.83	15.36	26.5	63	10:43	351.0	51.2	44	38.6
1	5	SP	18	TRL 6 Set 1	20.95	15.36	26.3	63	10:49	352.0	49.8	44	37.9
1	6	SP	70	TRL 6 Set 1	20.99	15.36	26.3	63	10:58	351.3	49.2	45.0	37.6
1	7	BP	84	TRL 6 Set 1	21.01	15.36	26.7	63	11:05	351.4	63.4	47	40.4
1	8	BP	118	TRL 6 Set 1	21.11	15.36	26.4	63	11:10	353.0	61.5	45	40.3
1	9	SP	29	TRL 6 Set 1	21.17	15.36	26.1	62	11:17	352.7	48.0	43	36.6
1	10	SP	37	TRL 6 Set 1	21.36	15.36	26.3	62	11:23	352.5	51.4	42	39.6
1	11	BP	104	TRL 6 Set 2	21.31	15.36	26.6	62	11:33	353.1	56.9	41	36.6
1	12	BP	117	TRL 6 Set 2	21.31	15.36	26.7	63	11:39	352.6	57.3	40	37.0
1	13	SP	92	TRL 6 Set 2	21.35	15.36	26.6	62	11:47	352.8	51.1	42	37.2
1	14	SP	42	TRL 6 Set 2	21.41	15.36	26.6	62	11:53	351.5	50.9	48	39.0
1	15	BP	72	TRL 6 Set 2	21.50	15.36	26.7	62	12:00	351.6	57.5	47	38.5
1	16	SP	62	TRL 6 Set 2	21.57	15.36	26.8	61	12:05	350.8	52.7	41	39.9
1	17	BP	51	TRL 6 Set 2	21.57	15.36	27.0	61	12:12	352.1	56.5	45	37.5
1	18	BP	93	TRL 6 Set 2	21.54	15.36	27.2	59	12:18	351.6	56.6	43	38.7
1	19	SP	39	TRL 6 Set 2	21.64	15.35	27.6	60	12:25	352.7	50.4	40	38.0
1	20	BP	47	TRL 6 Set 2	21.49	15.45	28.1	56	1:20	353.6	58.2	23	37.0
1	21	SP	38	TRL 6 Set 3	21.55	15.34	28.1	55	1:29	350.8	48.0	41	37.4
1	22	BP	97	TRL 6 Set 3	21.46	15.35	27.9	55	1:37	353.5	57.3	45	37.7
1	23	SP	82	TRL 6 Set 3	21.68	15.34	27.8	54	1:43	353.1	49.5	43	38.9
1	24	BP	65	TRL 6 Set 3	20.67	15.34	28.1	54	1:50	352.4	59.0	43	39.8
1	25	BP	75	TRL 6 Set 3	21.72	15.34	28.4	53	1:57	353.4	57.0	47	37.3
1	26	BP	16	TRL 6 Set 3	21.69	15.34	28.3	52	2:04	353.0	58.9	45	37.1
1	27	BP	83	TRL 6 Set 3	21.72	15.34	28.7	51	2:10	352.6	57.4	43	38.6
1	28	BP	37	TRL 6 Set 3	21.76	15.34	28.7	51	2:17	352.4	62.0	46	40.5
1	29	SP	78	TRL 6 Day 2	20.13	15.43	25.1	67	8:28	350.4	47.4	45	35.6
1	30	SP	21	TRL 6 Day 2	20.02	15.43	25.0	67	8:34	350.9	45.5	46	35.0
2	31	BP	/1	TRL 6 Day 2	20.02	15.43	25.2	67	8:42	350.8	58.9	46	37.2
2	32	SP	6/	TRL 6 Day 2	19.96	15.43	25.1	6/	8:49	351.3	54.5	44	38.2
2	33	SP	64	TRL 6 Day 2	19.97	15.43	25.1	6/	8:55	350.0	49.9	49	38.6
2	34	BP	0	TRL 6 Day 2	20.00	15.43	25.1	65	9:01	351.1	63.1	45	39.1
2	35	5P	35	TRL 6 Day 2	20.07	15.43	25.1	65	9:08	351.7	50.9	45	37.3
2	27	DP DD	25	TRL 6 Day 2	20.11	15.45	25.1	60	9.10	250.0	50.4	44	20.4
2	20	SP SP	50	TRL 6 Day 2	20.11	15.45	25.0	64	9.20	250.5	49.1	40	20.4
2	39	BP	2	TRI 6 Day 2	20.15	15.44	25.0	63	9.39	350.8	54.4	45	36.7
2	40	BP	114	TRL 6 Day 2	20.00	15 44	25.0	64	9:48	348.9	61.5	46	37.6
2	41	BP	11	TRL 6 Day 2	20.15	15 44	25.2	64	9.55	348.3	61.4	50	39.0
2	42	SP	74	TRL 6 Day 2	20.29	15.44	25.1	62	10:03	348.8	48.4	46	37.9
2	43	SP	45	TRL 6 Day 2	20.40	15 44	25.3	62	10:08	350.4	50.0	44	38.4
2	44	BP	94	TRL 6 Day 2	20.56	15.4	25.8	63	10:16	350.1	58.8	44	37.9
2	45	BP	105	TRL 6 Day 2	20.52	15.45	25.7	62	10:22	350.8	53.2	45	35.4
2	46	BP	48	TRL 6 Day 2	20.53	15.44	25.7	62	10:28	349.4	60.1	45	38.8
2	47	SP	48	TRL 6 Day 2	20.57	15.45	25.9	62	10:35	349.0	50.6	45	39.1
2	48	SP	40	TRL 6 Day 2	20.57	15.45	25.8	62	10:41	349.7	49.1	49	35.5
2	49	BP	113	TRL 6 Day 3	20.57	15.44	25.4	62	10:48	348.9	57.4	45	38.0
2	50	SP	27	TRL 6 Day 3	20.46	15.45	25.4	62	10:54	349.0	52.4	44	37.4
2	51	SP	80	TRL 6 Day 3	20.43	15.44	25.3	62	11:01	349.6	48.2	47	36.8
2	52	BP	68	TRL 6 Day 3	20.46	15.45	25.3	62	11:10	350.1	58.9	45	37.4
2	53	SP	76	TRL 6 Day 3	20.45	15.45	25.6	62	11:15	349.8	51.7	46	38.0
2	54	BP	45	TRL 6 Day 3	20.49	15.45	25.4	62	11:22	349.4	57.6	45	37.2
2	55	SP	8	TRL 6 Day 3	20.62	15.45	25.9	61	11:28	349.2	51.5	45	38.3

Boeing TRL 6 - Statistics

Variable	Coupon	Type Mean	StDev	CoefVar
Peak	SP	52.0	1.5	2.8
Pk Time (s)	SP	48.2	2.4	5.0
2-Min	SP	41.2	1.0	2.5





Variable	Coupon	Type Mean	StDev	CoefVar
Peak	BP	61.4	2.4	3.9
Pk Time (s)	BP	46.6	1.8	3.9
2-Min	BP	41.2	1.5	3.6





FAA TRL 6 – Statistics

Variable	Coupon	Type Mean	StDev	CoefVar
Peak	SP	50.1	1.9	3.8
Pk Time (s)	SP	44.5	2.3	5.2
2-Min	SP	37.8	1.2	3.2





Variable	Coupon	Type Mean	StDev	CoefVar
Peak	BP	58.6	2.5	4.3
Pk Time (s)	BP	44.8	1.9	4.2
2-Min	BP	38.0	1.2	3.2





TRL 6 – Data Comparison – Schneller Panel

Statistics

Variable	Coupon Type	Mean	StDev	CoefVar
Peak	SP-B	52.0	1.5	2.8
	SP-TC	50.1	1.9	3.8
Pk Time (s)	SP-B	48.2	2.4	5.0
	SP-TC	44.5	2.3	5.2
2-Min	SP-B	41.2	1.0	2.5
	SP-TC	37.8	1.2	3.2



Panel variable: Coupon Type





TRL 6 – Data Comparison – Boeing Panel

Statistics

Variable	Coupon	Type Mean	StDev	CoefVar
Peak	BP-B	61.4	2.4	3.9
	BP-TC	58.6	2.5	4.3
Pk Time (s)	BP-B	46.6	1.8	3.9
	BP-TC	44.8	1.9	4.2
2-Min	BP-B	41.2	1.5	3.6
	BP-TC	38.0	1.2	3.2



Panel variable: Coupon Type





TRL 7 – Plan

SPECIMEN FAMILIES

					Average	Peak Std	Average	Total HR
Ho	neycomb Core Panels	Description	Provider	Contact	Peak	Dev	Total HR	Std Dev
1	Thin Core	AerFilm LHR HA211 Adhesive on S-SSCP	Schneller	David Baker	40.2	4.7	45.5	5.4
2	Thick Core	0.75" core, 4 ply/4ply with dec lam on both sides	Boeing	Yonas Behboud				
3	Honeycomb Core / Al plys	0.40" core, 1 ply/1 ply, with Airbus deco foil (or painted)	AIRBUS (Diehl, Laubheim)	C. Thomas/G. Hansen				
The	ermoplastic Panels							
4	KYDEX FST	PC copolymer 0.080" thick, integrally colored, opaque	Sekisui KYDEX	Michael Miler	41	7	36	10
5	Boltaron 9850E	PVC/PMMA 0.08" thick	Boltaron/Simona	Jessica Moore				
6	Polyphenyl Sulphone	PPSU 0.080" thick, one side primed and painted	Solvay/Mankewicz	W. Hamm/G. Hansen				
7	Ultem 9085	PEI 0.080"	Sabic	Ralph Buoniconti				
8	Lexan F6000	PC 0.080" thick, integrally colored (anticipated fail)	Rohm (ex-SABIC)	Ralph Buoniconti				
9	Decorative Laminate	AerForm 0.065"	Schneller	David Baker	50.9	5.3	47.2	10.9
								c
Lar	ninate							
10	Phenolic Glass Laminate	4 ply pre-preg, with Airbus deco foil	AIRBUS (Diehl, Laubheim)	Christian Thomas				

Alternate Thermoplastic Panels								
5a	*Boltaron 9815N	PVC/PMMA 0.08" thick	Boltaron/Simona	Jessica Moore				
5b	**KYDEX 6565	PVC/PMMA 0.08" thick, integrally colored	Sekisui KYDEX	Michael Miler	44	11	26	<mark>1</mark> 5

* Option to #5 - 9850E

** Option to #5 - Boltaron

Number of coupons needed (per row) 10 samples for the OSU, 10 samples for HR2, 10 samples for buffer

Mike B. can store specimens at TC conditioning chamber

30 samples per construction

- Test 10 coupons each on 1 OSU ('golden unit') and 1 HR2 unit
- Thank you to those who are supporting this activity!

Next Steps

Anticipated Schedule

Boeing HR2 Delivery and Installation	Complete
Boeing HR2 Unit Response Experiment	Complete
Boeing HR2 Airflow Evaluation (MFC, Sonic Choke)	Complete
Boeing HR2 TRL 6 Testing and Data Analysis	Complete
Herb Curry Delivery and Installation	Complete
Herb Curry Unit Response Experiment	Sep 2024
Herb Curry TRL 6 Testing and Data Analysis	Oct 2024
Chemitox HR2 Delivery and Installation	Complete
Chemitox HR2 Unit Response Experiment	TBD
Chemitox TRL 6 Testing and Data Analysis Complete	TBD
TRL 7 Testing	Jan 2025

Burning Questions?





