HR2 Development – TRL 6 Testing and Planning

A look inside the HR2 burn chamber
AT coupon ignition

Presented by: Brian Johnson, BCA Flammability

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

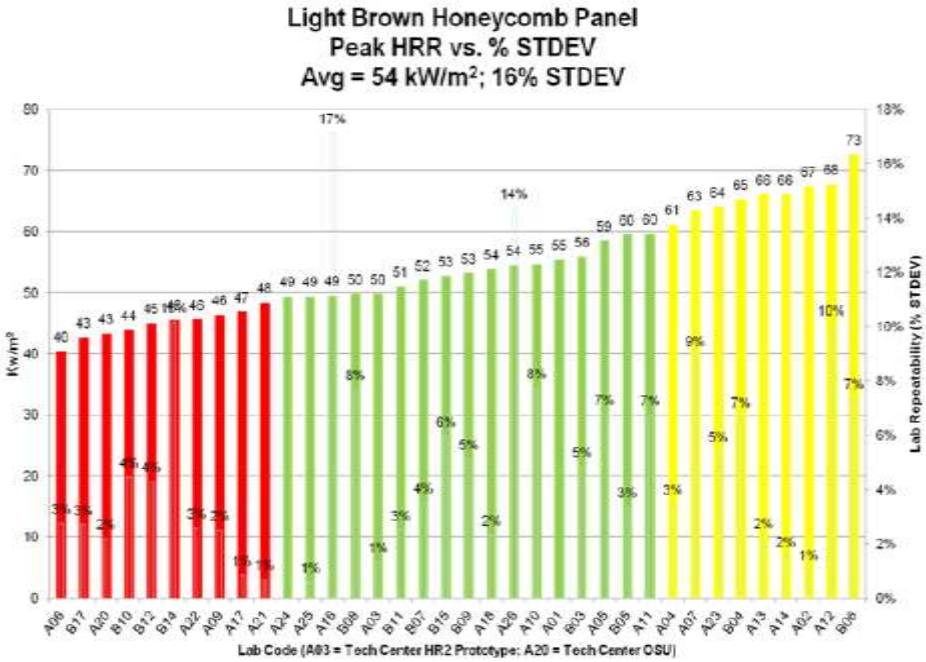
October 2023 MFTF
William J. Hughes FAA Technical Center

OSU Test Method

14CFR25.853(d)

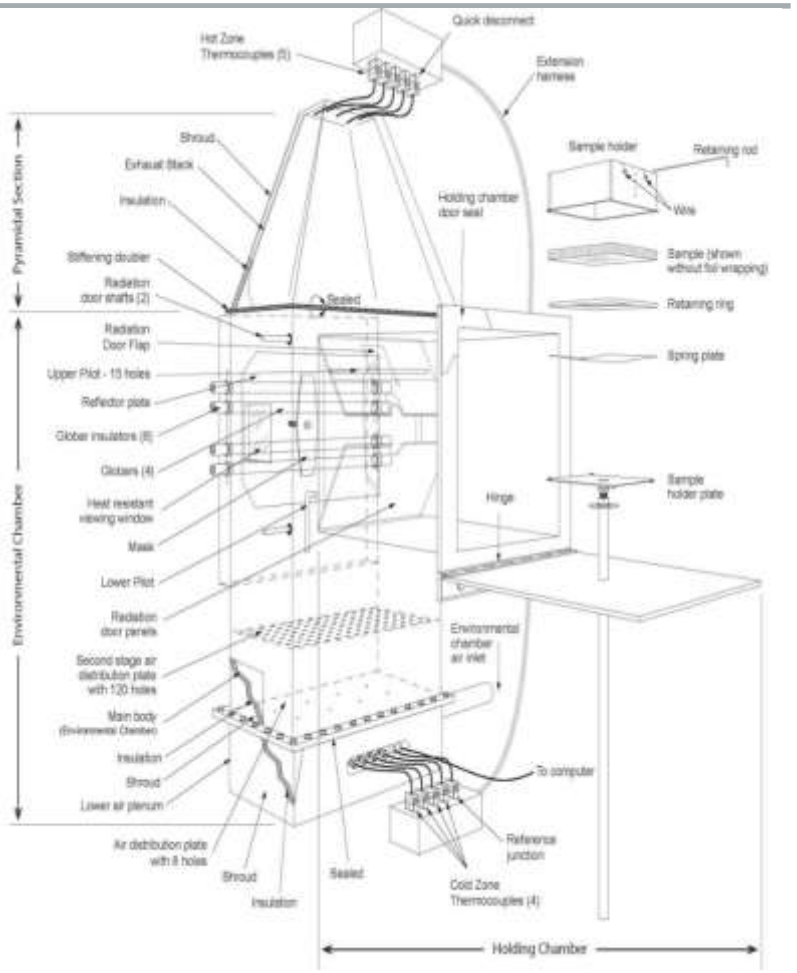
- Added in 1986
- Current FAR - Appendix F Part IV
- Applicable to interior exposed surfaces greater than 144 square inches
- Measures heat release as a function of time
- Test code: HR

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



**Presented June 2012*

HR2 - Next Generation OSU



**Presented October 2016*

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/cm^2)
- Methane calibration and cal factor correction
- Multiple additional procedural changes

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%
- 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)

Developmental Project Technical Readiness

Flammability Test Method/Equipment TRLs (Derived from NASA TRL)

MATURITY LEVEL

Discovery

Feasibility

Practicality

Applicability

Production Readiness

TRL 1	Basic principles/concept of test equipment and procedure defined.
TRL 2	Test method concept formulated and defined by draft standards.
TRL 3	Analytical and experimental critical function and/or characteristic proof-of concept (e.g. by modifying old/existing equipment)
TRL 4	New prototype equipment validation in laboratory environment (robustness)
TRL 5	Updated prototype equipment validation in relevant production environment (repeatability). Documented test guidance framework.
TRL 6	Multiple prototypes validation in relevant environment (reproducibility)
TRL 7	Finalized prototype equipment demonstation on range of production configurations. Documented test guidance defined.
TRL 8	Final test equipment drawings released, equipment built to the standards, and “qualified” through test and demonstration. Documented test guidance finalized.
TRL 9	Multiple production units verified by successful round robin testing.

**Presented in October 2014*

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.

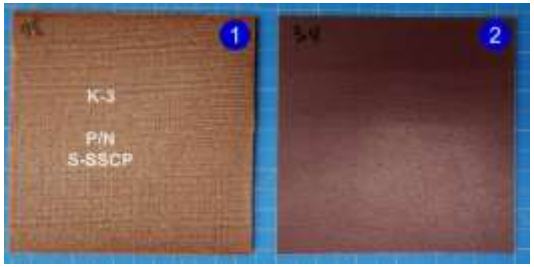
**Updated for this presentation*

TRL 6 Test Plan – Part 2

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 laminate panel (SPD) - provided by Schneller
2. Boeing panel w/ decorative (BPD) - provided by Boeing



Instruments Tested

- Marlin Engineering HR2 (ME) - FAA TC, Egg Harbor Township, New Jersey
- Deatak HR2 (DE) - FAA TC, Egg Harbor Township, New Jersey

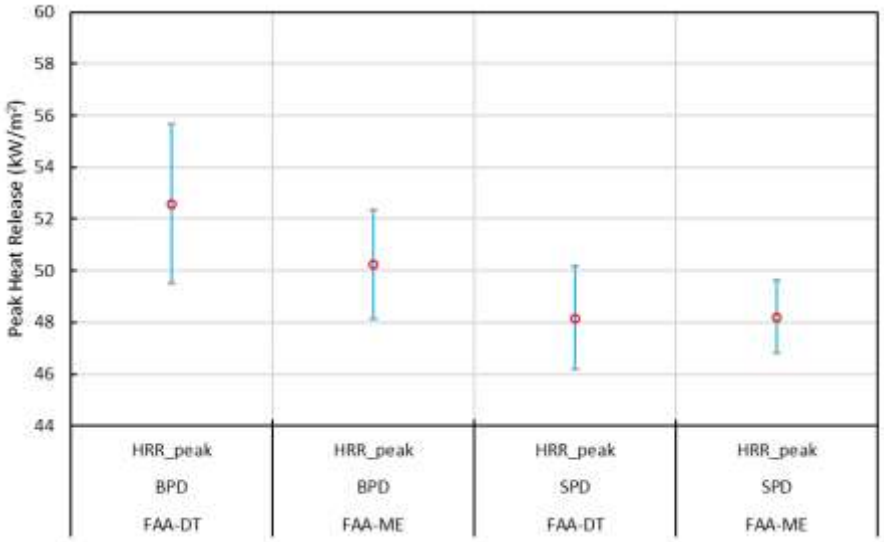
Future Implementation

- Marlin Engineering HR2 - Boeing Test Laboratory, Seattle, Washington
- Marlin Engineering HR2 - Airbus Fire Test Laboratory, Bremen, Germany
- Chemitox HR2 –Test Laboratory, Japan

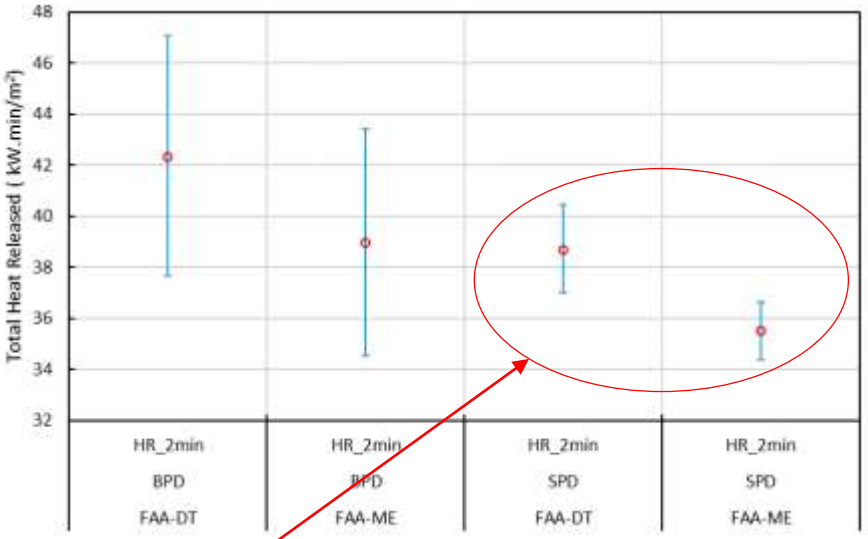
Note: Final TRL 6 Decision Requires Data from More Instruments

TRL 6 Test – Part 2 – Results

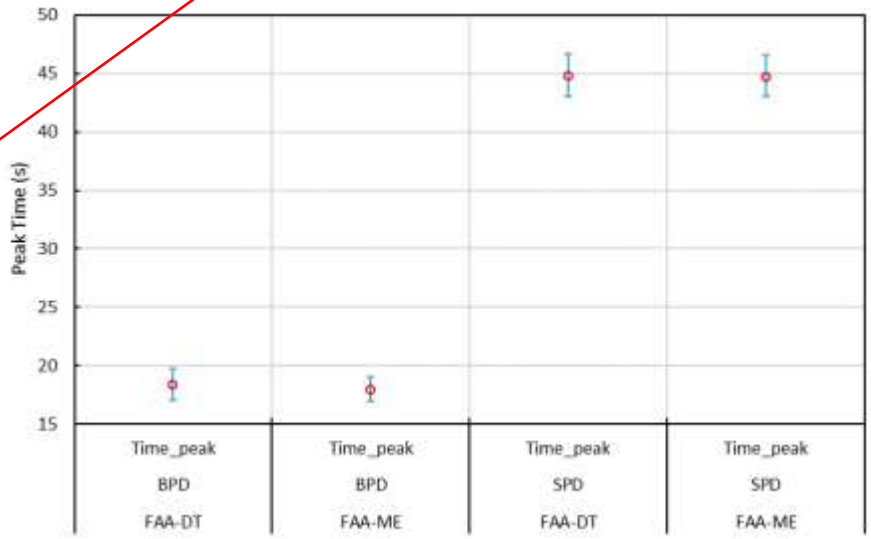
Peak Heat Release



2-Min Total Heat Release



Peak Time



- Plots indicate average (mean) values
- Error bars are +/- 1 standard deviation (σ)
- Means are within 1 std dev of each other with 1 exception:

  2-Min Total HR – Schneller panel

Note: Thanks to Christian Thomas of Airbus for charts and data analysis.

TRL 6 Test – Part 2 – Takeaways (cont.)

The uncertainties in the data presented can be considered reasonable given the complexities in the:

- Combustion processes
- Test environment
- Measurement processes

Discussion topics

- Peak HR is most influenced by the material burning behavior
- 2-Min Total HR is most influenced by the instrument construction, materials and environment

➢ This led to a discovery that the insulation was not the same for both instruments

**Presented in October 2022*

TRL 6 Test – Part 2 – Post-Analysis Actions

- 2-Min Total HR Data Comparison – New Insulation & Tape (ME & DE)

		2-Min Total HR (W/m^2)		
		Mean	Std Dev	CoV
TRL 6 Part 2 Data	**ME 8# no foil**	35.6	1.12	3.15%
	DE 10# w/foil	38.7	1.73	4.47%
New 16 Coupons	**ME 8# w/foil**	34.1	1.19	3.50%
	DE 8# w/foil	34.0	1.71	5.00%

  - Average values very close and within 1 standard deviation

Questions for the HR2 Breakout Session

- Should TRL 6 testing be repeated on the FAA TC units (Schneller only)?
  - This is not an immediate priority given the results above
- How many instruments and locations are required to complete TRL 6?
  - Two in the same location is not sufficient

**Presented in October 2022*

Boeing HR2 – Initial Challenges

- Marlin HR2 unit installed in Seattle Flam lab
- Primary operator is Yonas Behboud
- Initial challenges with low pressure and airflow
- HR2 heater activation caused the Omega MFC to stop airflow (MFC remained powered on)
- Repair attempts resulted in Omega MFC failure
- Mike B. loaned FAA TC Omega MFC to Boeing to facilitate TRL 6 progress

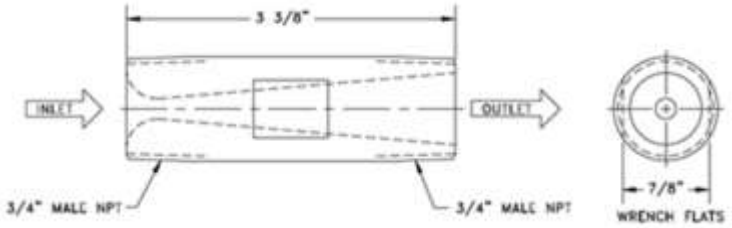
Thank you, Mike!

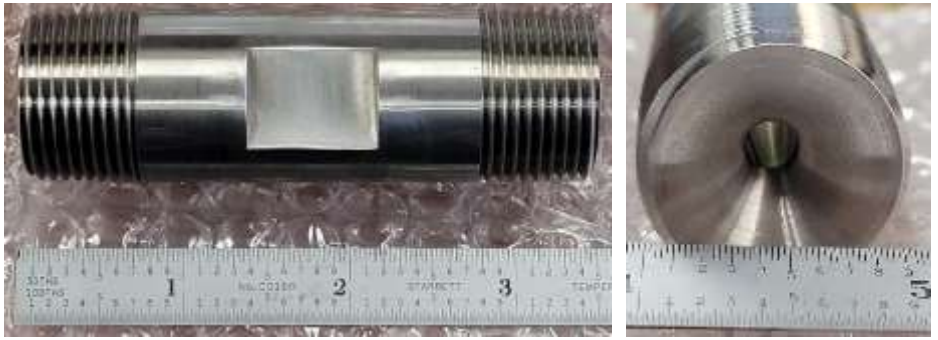
Boeing HR2 – Initial Challenges

- FAA TC MFC installed but lower plenum pressure and observed flow were still lower than expected
  - Lower 8-hole plate was replaced - removed ‘nutsert’ assembly
  - Additional pressure measurement port was added between MFC and plenum
- Repaired Boeing Omega MFC received and installed with new assembly
- Heater activation MFC interference was discovered to be a grounding issue
- Also corrected an issue with lower TC electrical interference – Task Group discussion

Boeing HR2 – Alternate Airflow Strategy

- Sierra indicated they are no longer making an MFC in this range
  - Omega FMA5445 Model - +/- 1.5% full range accuracy
  - Sonic Choke
    - Fox Valve, Inc., Flow Systems (see M. Burns presentation, April 2021)

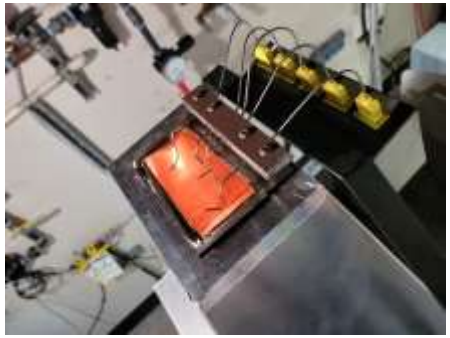




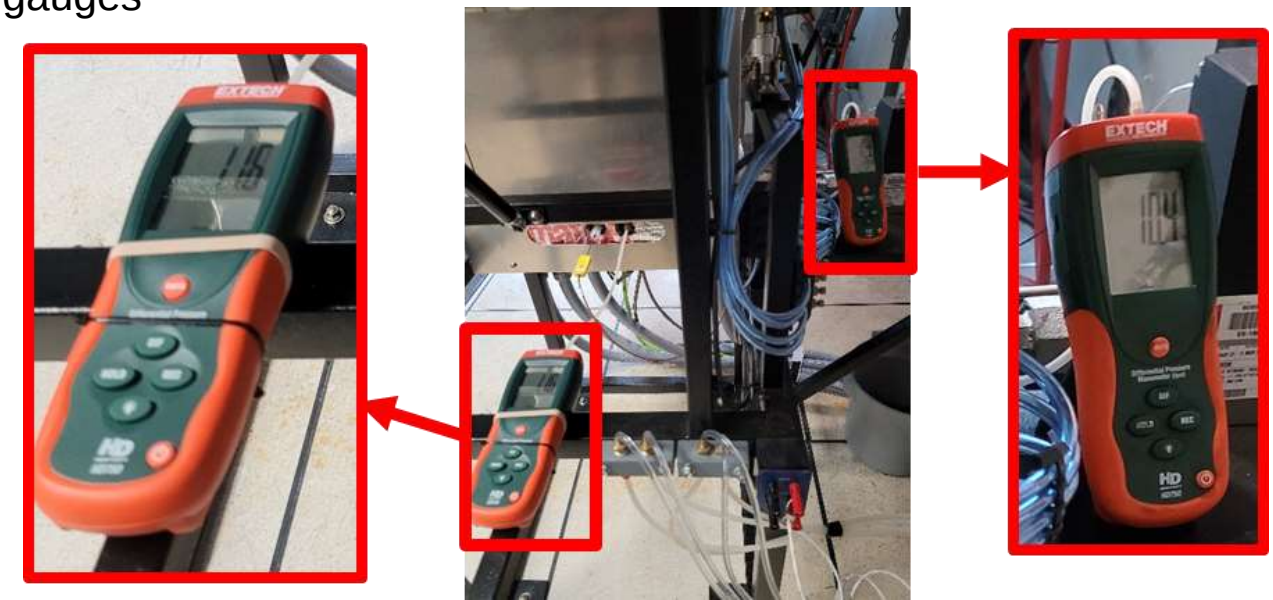
    - ControlAir 7100 Precision Pressure regulator
    - Pressure transducer and thermocouple

- Boeing has acquired sonic choke system components and working with Mike Burns to make this alternate airflow supply viable

Boeing HR2 - Status



- HR2 is functioning normally – no MFC, heater switch or TC issues
- Operating parameter collection has begun
- Plenum pressures continue to be lower than those at the FAA Tech Center (see images below – 11.6, 10.4 in H_2O)
- Next Steps
  - Continue collecting operating parameters
  - Heat flux gauge investigation using Schmidt-Boelter and Gardon gauges



Boeing HR2 Status – Operating Parameters

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	-	-	≤ 65
Heat Flux (W/cm^2)	Center	3.60	3.65	3.70
	Each Corner (4)	3.55	3.65	3.75
Average Baseline Exhaust Gas Temperature	No Flame (°C)	270	280	290
	Slope (L/°C)	0.0255	0.0289	0.0323
Calibration Factor Range	W/°C	15.00	17.00	19.00
	kW/m^2/°C	0.646	0.732	0.818
	3 SLPM ΔT (°C)	92.8	103.7	117.6
Interspace Pressure	inH2O	0.40	0.55	0.70
Lower Plenum Pressure	inH2O	11.0	12.5	14.0
Methane Gas Supply Pressure	PSIG	18	20	22
Main Air Supply Pressure	PSIG	18	20	22
Mixing Air Supply Pressure	PSIG	18	20	22
Thermal Stability Temperature (TST)	20 sec average (°C)	365	380	395
Specimen Conditioning	Temperature (°C)	18	21	24
	Relative Humidity (%)	45	55	65
Upper Pilot Gas Flow	Air (SLPM)	0.98	1.00	1.02
	Methane (SLPM)	1.47	1.50	1.53
Lower Pilot Gas Flow	Air (mL/min)	0.65	0.70	0.75
	Methane (mL/min)	115	120	125

Results Will Be Shared OSU/HR2 Task Group

270 – 290 °C

15 – 19 W / °C

365 – 395 °C

All based on observations

**Presented previously*

TRL 7 – Notional Plan (Updated)

Last Update 13-Oct-23

SPECIMEN FAMILIES

	Honeycomb Core Panels	Description	Provider	Contact	Average Peak	Peak Std Dev	Average Total HR	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				
	Thermoplastic Panels							
4	KYDEX FST	PC copolymer 0.080" thick, integrally colored, opaque	Sekisui KYDEX	Michael Miler				
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
	Laminate							
10	Phenolic Glass Laminate	4 ply pre-preg, with Airbus deco foil	AIRBUS (Diehl, Laubheim)	Christian Thomas				
	Specialty Panels							
11	*Carpeted Honeycomb*	*0.75" core, 3 ply/3 ply, carpet one side, dec lam one side*	Boeing	Yonas Behboud				
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				

* Option to #5 - 9850E

** Option to #5 - Boltaron

Discuss in OSU/HR2 Task Group

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 have agreed to support this activity

Next Steps

Anticipated Schedule

Boeing HR2 Delivery and Installation	Complete
Boeing HR2 Unit Response Experiment	In Progress
Boeing HR2 TRL 6 Testing and Data Analysis Complete	Dec 2023
TRL 7 Notional Coupon Definition	Complete
TRL 7 Material Test Plan Complete	Dec 2023
Airbus HR2 Upgrades	TBD
Airbus HR2 Unit Response Experiment	TBD
Airbus TRL 6 Testing and Data Analysis Complete	TBD
Chemitox HR2 Delivery and Installation	Complete
Chemitox HR2 Unit Response Experiment	Nov 2023
Chemitox TRL 6 Testing and Data Analysis Complete	TBD

Questions?