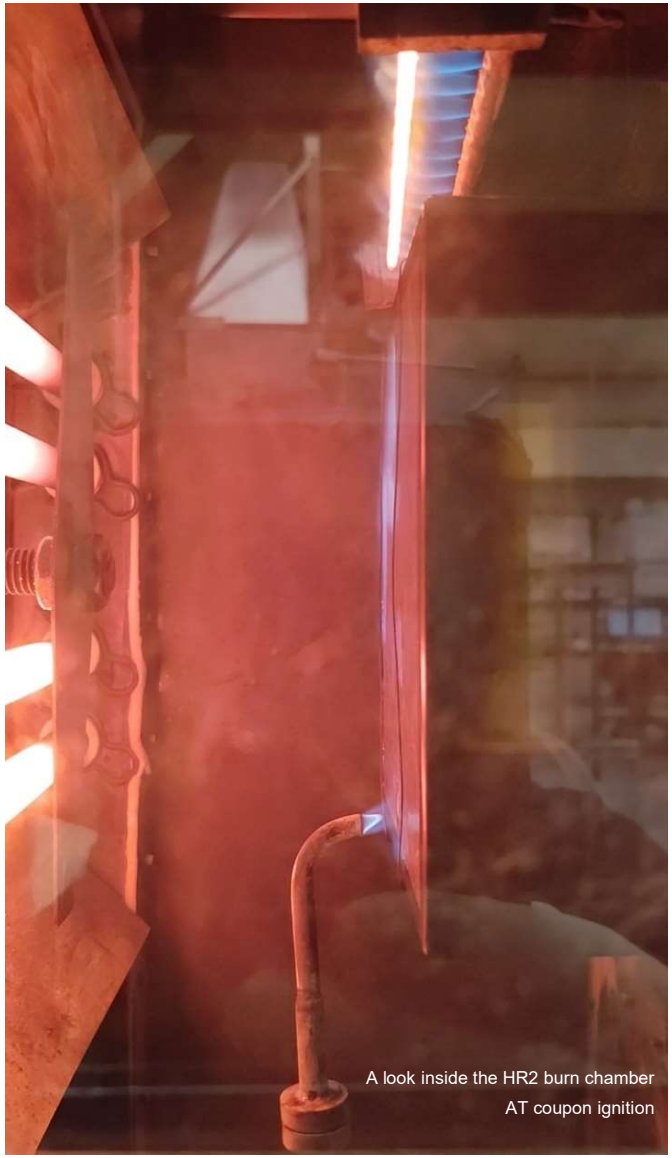
HR2 Development – TRL 6 Testing and Planning



A look inside the HR2 burn chamber
AT coupon ignition

Presented by: Brian Johnson, BCA Flammability

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

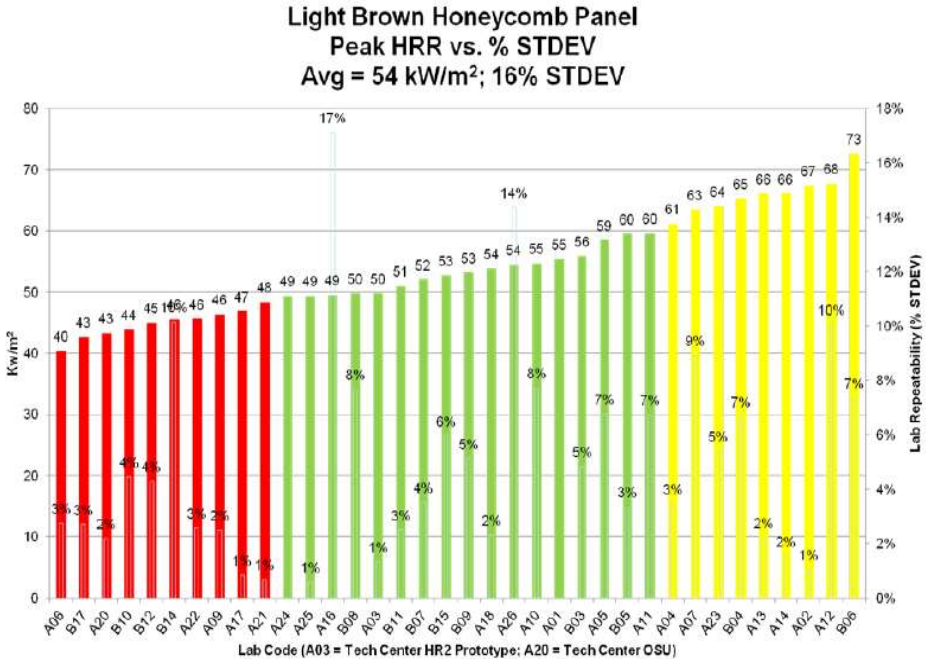
June 2023 MFTF – Köln

OSU Test Method

14CFR25.853(d)

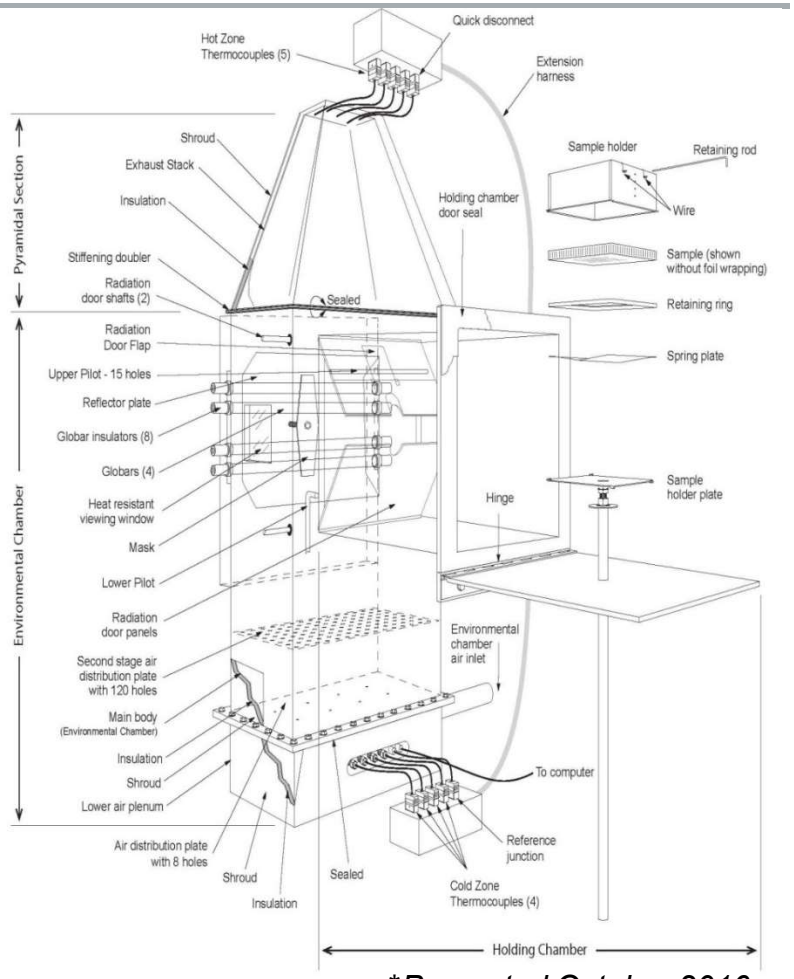
- Added in 1986
- Current FAR - Appendix F Part IV
- Applicable to interior exposed surfaces greater than 144 square inches
- Measures heat release as a function of time
- Test code: HR

- 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

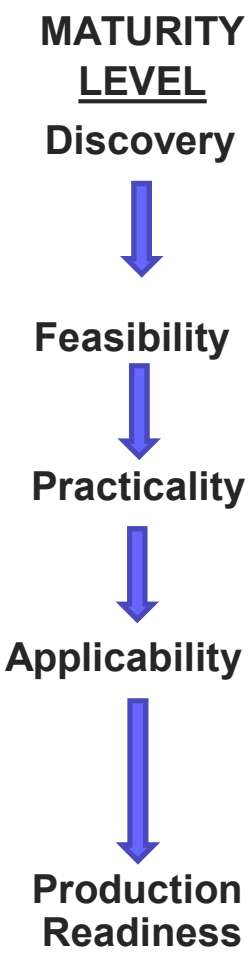
History / Status

- 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)



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 7 – Notional Plan

SPECIMEN FAMILIES

Honeycomb Core (Standard) Panels

Thin Core	0.125" core, 2 ply/2ply with dec lam on one side
Thick Core	0.75" core, 4 ply/4ply with dec lam on both sides
Honeycomb Core / Al plys	0.40" core, 1 ply/1ply Al sheets, both sides dec lam
Aluminum Core & Plys	1.75" Al core, 1 ply/1ply Al sheets, both sides dec lam

Thermoplastic Panels

Boltaron 9815	PVC 0.06" thick, one side dec lam
Polyphenyl Sulphone	PPSF 0.08" thick, one side primed and painted
Ultem 9085	PEI 0.25" thick, both sides primed and painted
Lexan XHR	PC 0.125" thick

Laminate

Decorative Laminate	BAC 5596 TY XXXIII 401U3500-53784 BAC 7176
Phenolic Glass Laminate	6 ply pre-preg, primed and painted

Specialty Panels

Carpeted Honeycomb	0.75" core, 3 ply/3 ply, carpet one side, dec lam one side

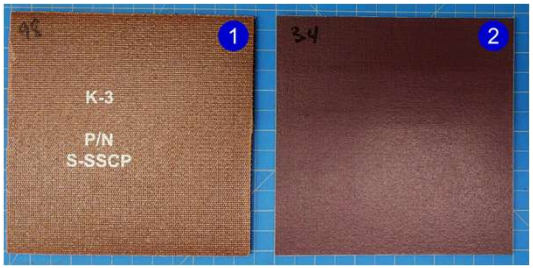
- Test 10 (?) coupons each on OSU ('golden unit') and HR2 unit
- Input and coupon support appreciated – discussion at breakout session

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

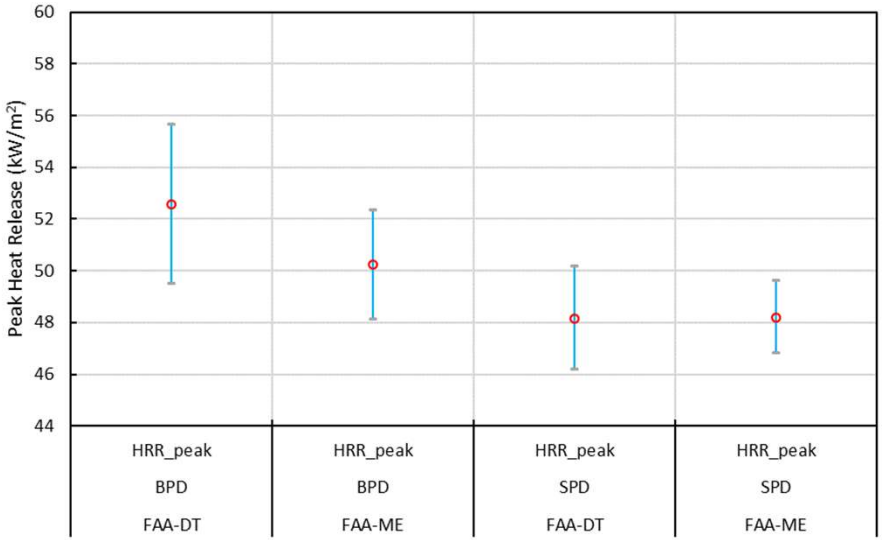
Future Implementation

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

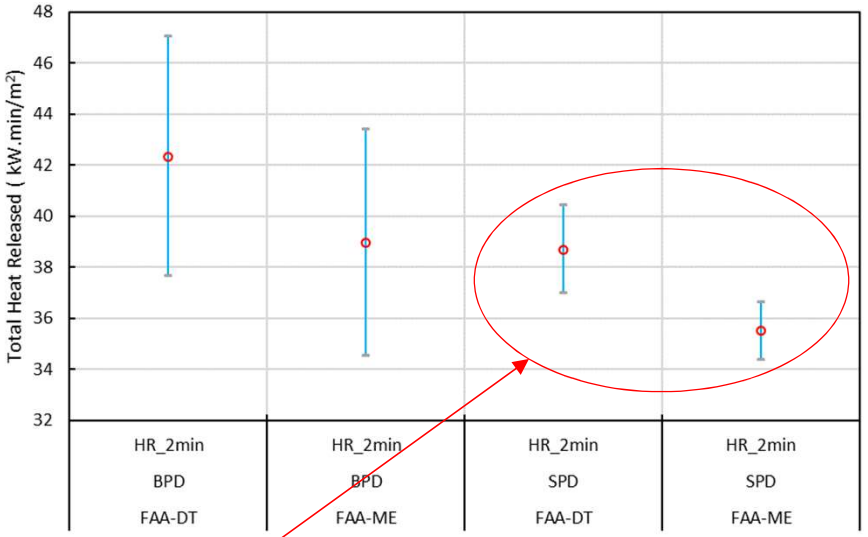
Note: Final TRL 6 Decision Requires Data from More Instruments

TRL 6 Test – Part 2 – Results

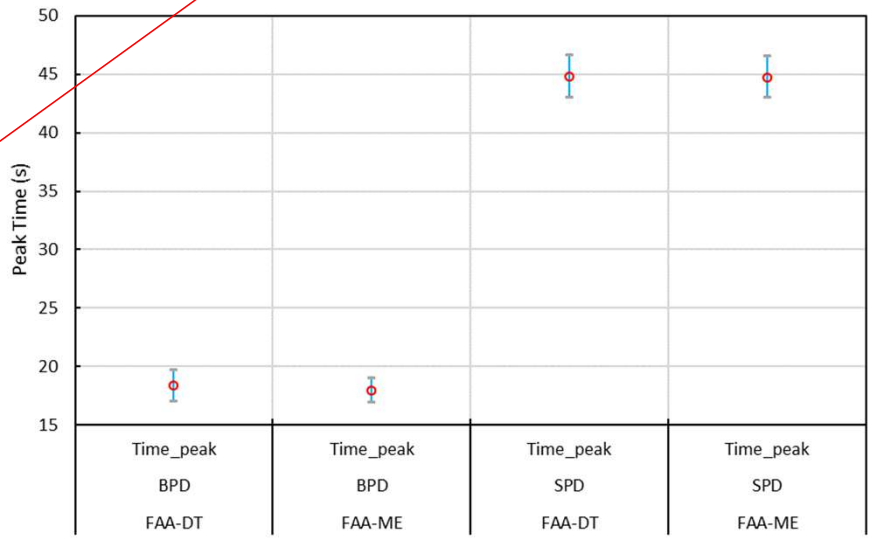
Peak Heat Release



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 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

270 – 290 °C

15 – 19 W / °C

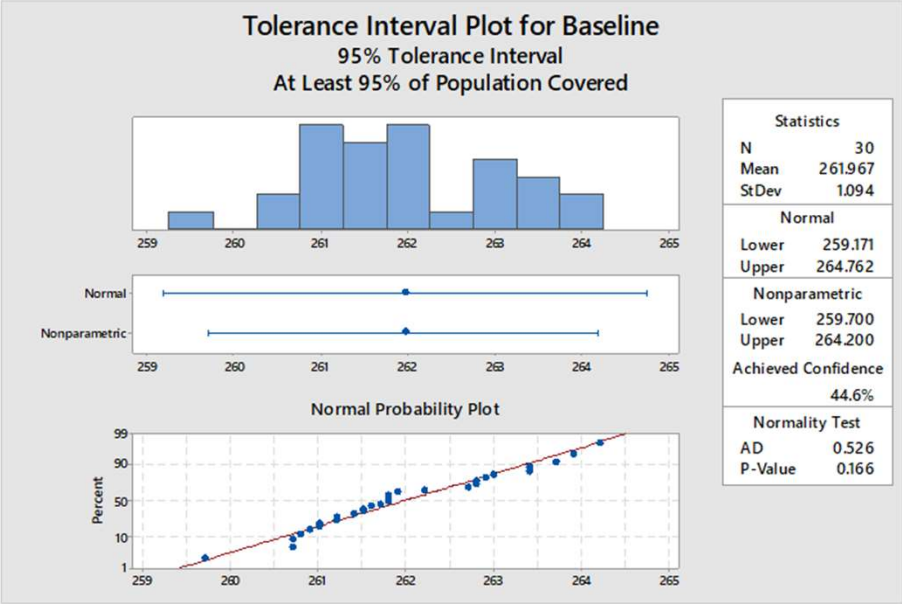
365 – 395 °C

All based on observations

Boeing HR2 Status

30 data points gathered prior to control unit / Sierra MFC malfunction (current state)

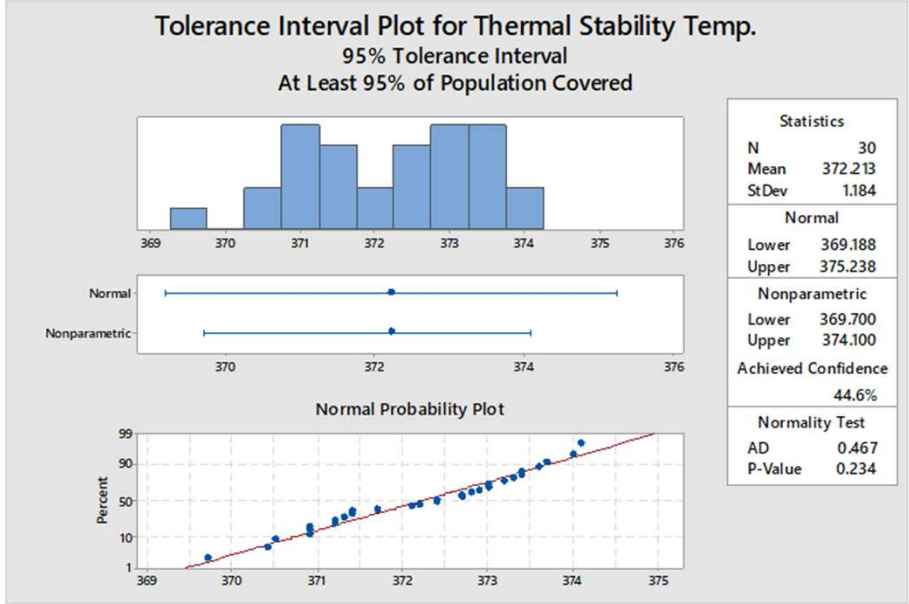
Baseline, Thermal Stability Temperature (BOEING-ME-30 Data Points)



Baseline = 259.2 – 264.8 °C

Range = 5.6 (2.1% of mean)

270 – 290 °C Observation



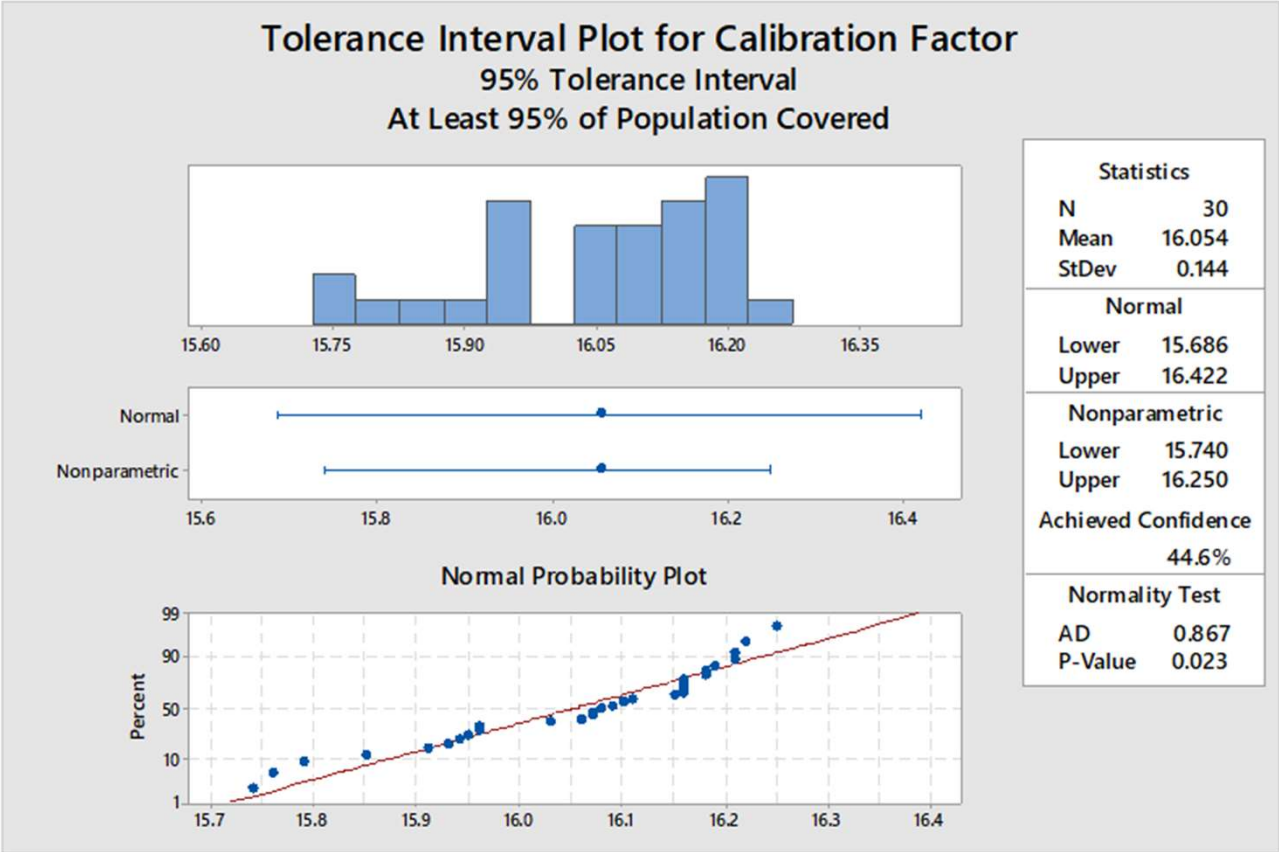
TST = 369.2 – 375.2 °C

Range = 6.0 (1.6% of mean)

365 – 395 °C Observation

Boeing HR2 Status

Calibration Factor (BOEING-ME-30 Data Points)



Calibration Factor = 15.7 – 16.3 W/°C

Range = 0.6 (3.7% of mean)

15 – 19 W / °C
Observation

Boeing HR2 Status

Initial results are lower than expected based on FAA TC instrument behavior

- Low end of range for Calibration Factor and TST
- Below range for Baseline

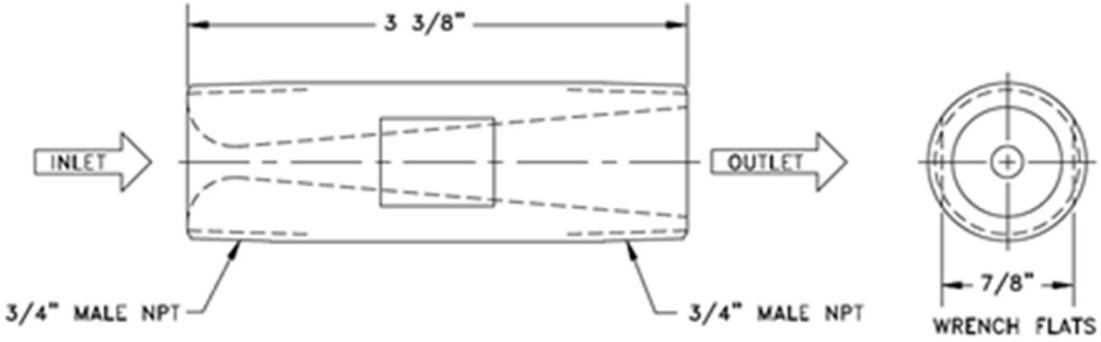
Discussion Topics

- Airflow – control unit / Sierra MFC malfunctioned after 30 data points gathered
- Heat flux gauge calibration – repaired / recalibrated Medtherm gauges
- Medtherm corner HFG calibration may be ‘cold’, resulting lower baseline and TST

	FAA Calibration Values		Medtherm Calibration Values		
	W/cm2	BTU(s*ft2)	W/cm2	BTU(s*ft2)	% Delta
Center HFG	0.4898	0.4313	0.4907	0.4322	-0.2%
Corner HFG	0.4986	0.4391	0.5326	0.4690	-6.4%

Boeing HR2 Status

- 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



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	Aug 2023
TRL 7 Notional Coupon Definition	Complete
TRL 7 Material Test Plan Complete	Oct 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	In Progress
Chemitox TRL 6 Testing and Data Analysis Complete	TBD

Questions?