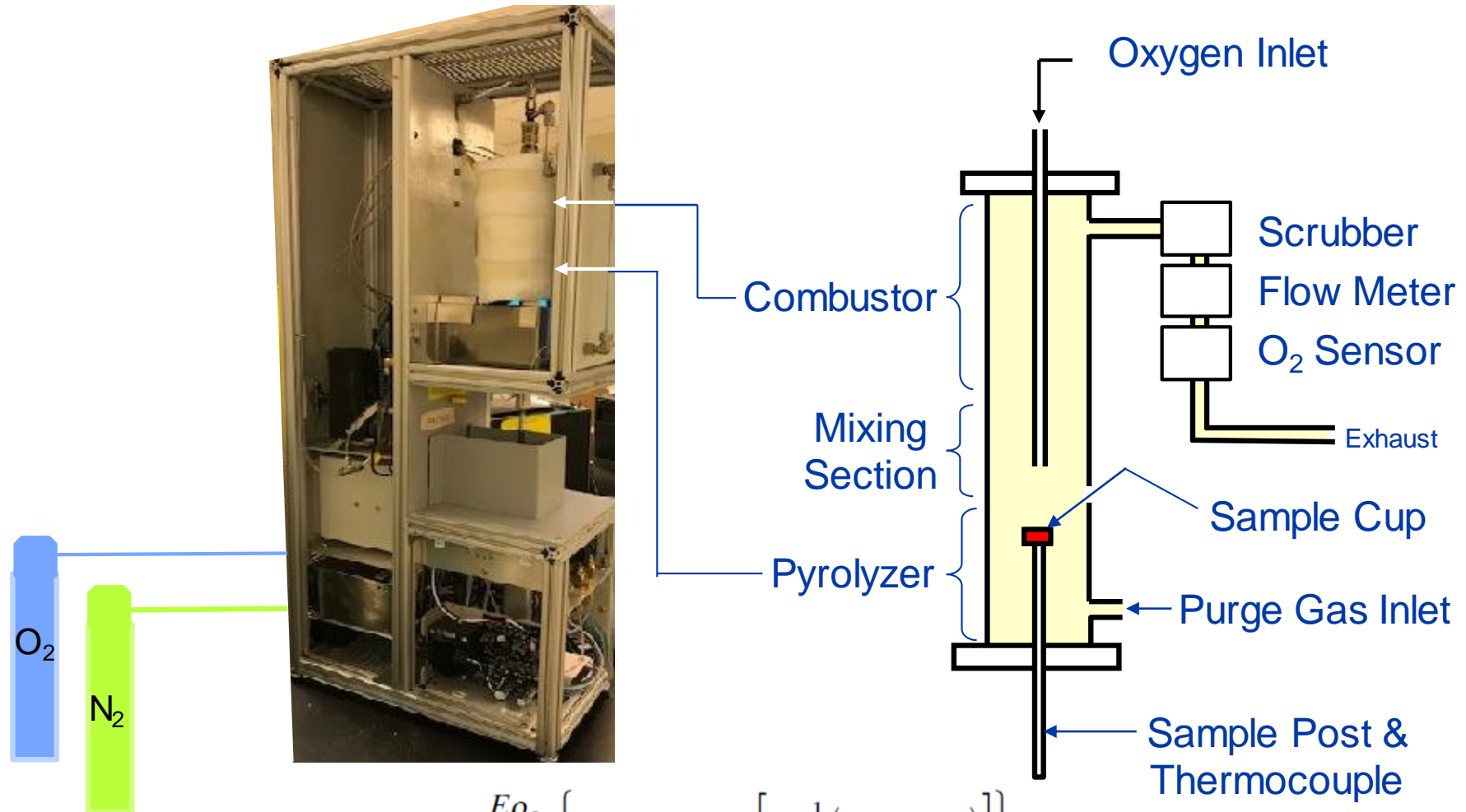


Future State: How the Micro-scale Combustion Calorimeter is Changing How Industry Characterizes Heat Release

- **John Harris, Greg Hooker, Jeff Mentel, William Ferng, and Mike Cloud**

Micro-scale Combustion Calorimeter (MCC)



$$Q(T) = \frac{E\rho_{O_2}}{m_0} \left\{ F^0 X_{O_2}^0 - F X_{O_2} \left[1 - \frac{1}{3} (X_{O_2}^0 - X_{O_2}) \right] \right\}$$

MCC Test Method Fully Documented

ASTM D 7309-18: “Standard Test Method for Determining Flammability Characteristics of Plastics and Other Solid Materials Using Micro-scale Combustion Calorimetry

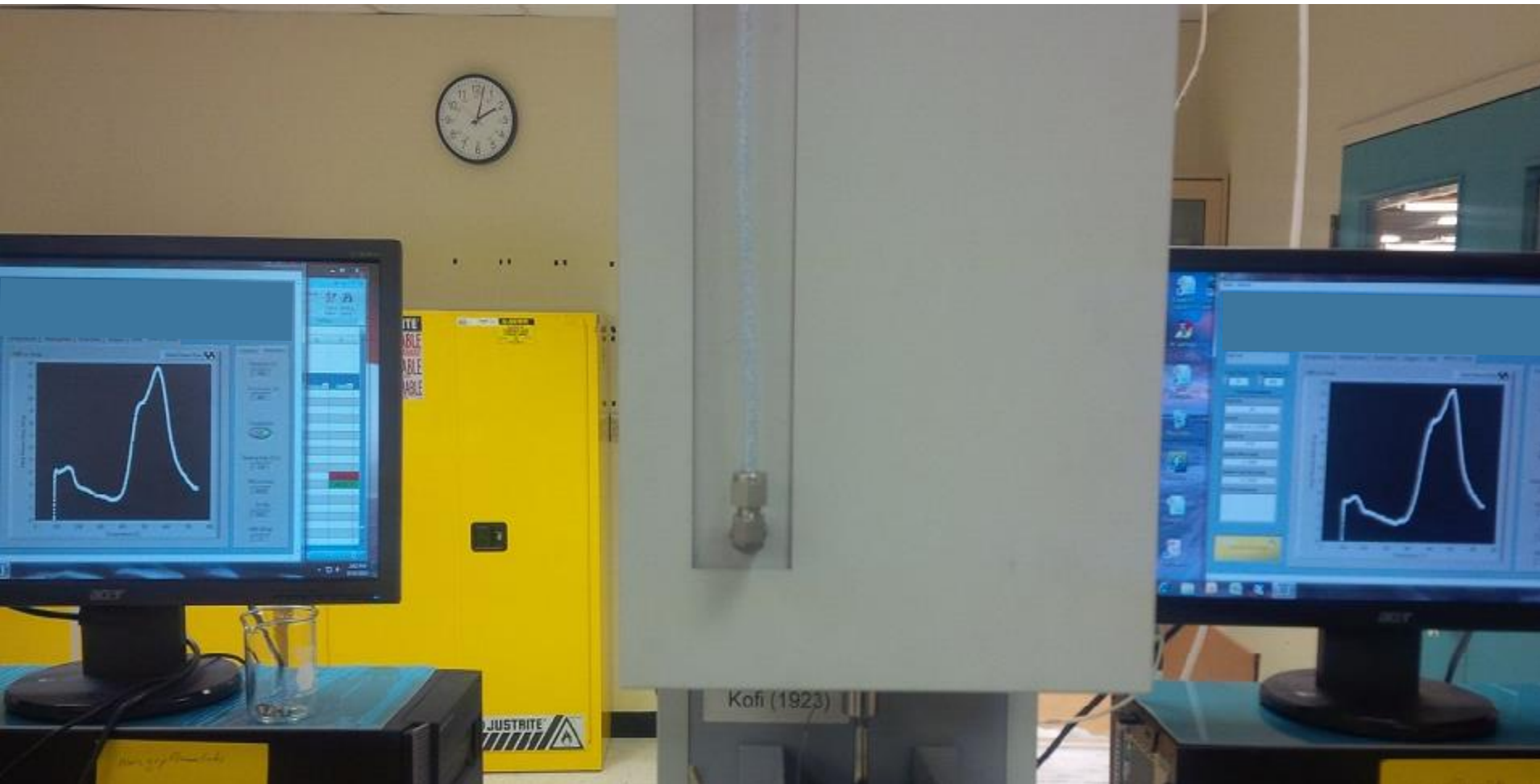
BSS7450 Determination of Heat Release of Plastics and Other Solid Materials Using Micro-scale Combustion Calorimetry

- Operations/Maintenance manual drafted and ready for publication
 - Provides detail and helps to standardize MCC calibration process

Checklist also prepared for in-lab use

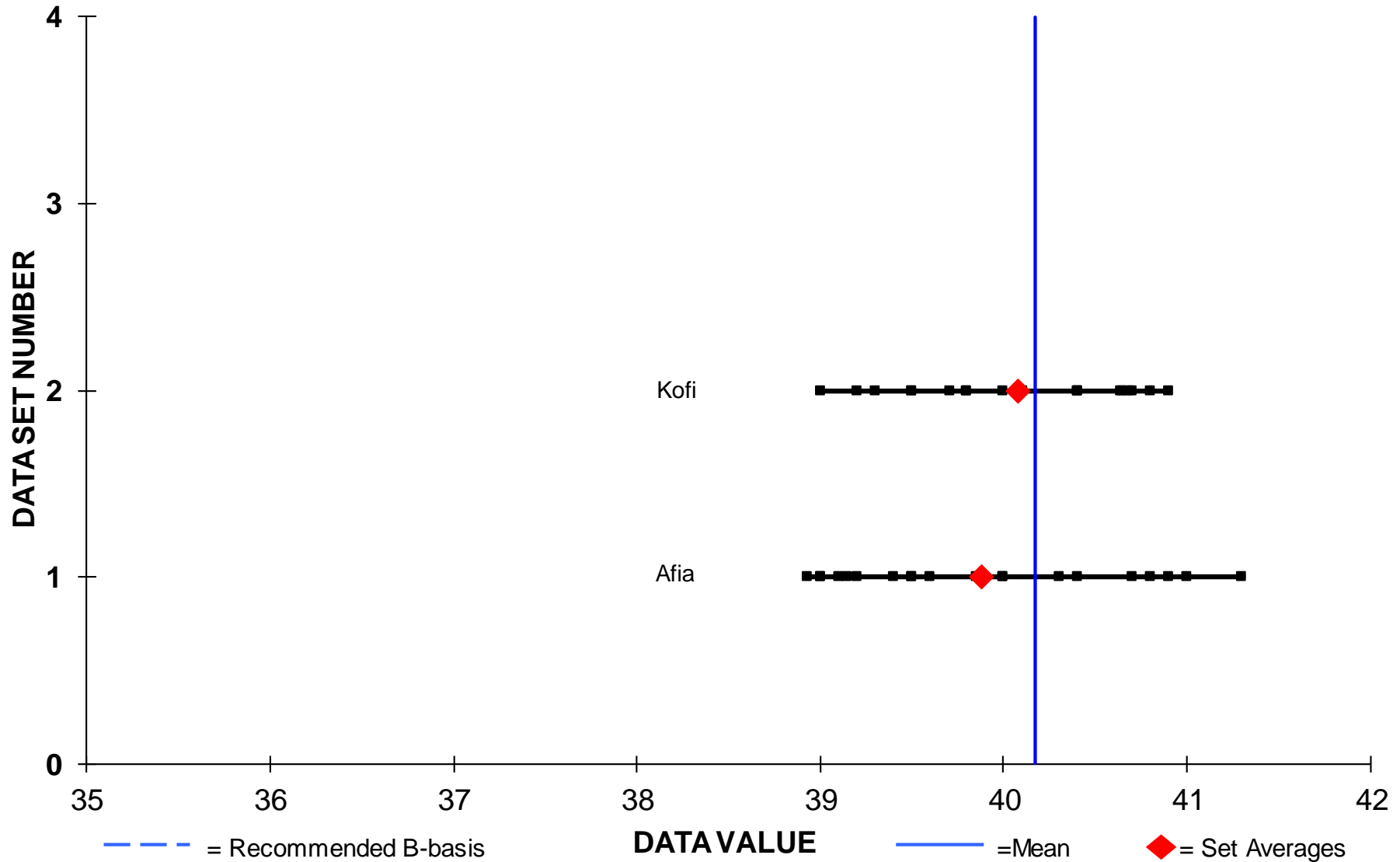
Good Agreement Among Multiple MCC Units

MCC testing run concurrently in two separate units



Good Agreement Among Multiple MCC Units

DATA SET RANGE PLOT



MCC Applications: How They Can Help The Aerospace Industry

Supplier Delegation of heat release testing

- Low cost/low maintenance MCC method supports in-process testing at supplier facility (cost reduction)
- Certificate of Conformance (CoC) receipt provides Boeing upstream look ahead at raw materials (risk reduction)

High throughput engineering tests

- Rapid screening of candidate raw materials
 - MCC sample sizes are small and don't normally need conditioning

QA Root Cause

- MCC testing parameters (THR, HRC, FGC, IGC, Char) provide insight to material heat release properties

Support of modeling studies

- MCC test parameters also support modeling studies of flammability properties

Example: Supplier Delegated Heat Release Testing

- **QA heat release testing for prepreg adds cost and is not ideal**
 - Test coupons contain core in addition to prepreg – core adds variation to results
 - Heat release testing occurs after Boeing receipt of raw material putting risk on Boeing
- **Target: Reducing costs associated with QA heat release data while managing risk**
- **Proposal: Supplier delegation of heat release testing using MCC method as preferred option to heat release.**

Phasing in Supplier-Delegated Heat Release Testing

- **Phase I: Generate requirements from multi-batch MCC testing for all raw materials qualified to prepreg classifications**
 - Reduce costs associated with OSU sample fabrication
 - BMS8-222, BMS8-226, BMS8-274, BMS8-260, BMS8-151, BMS8-143

Phase I complete except for 3 low volume prepreg materials

- **Phase II: Delegate heat release testing to supplier**
 - Supplier procurement: MCC unit with Boeing data reduction software
 - Supplier trained by Boeing on MCC operations/data reduction
 - Delegation granted only after successful side by side testing and review by Boeing (QA and BR&T)
 - Supplier furnishes Boeing with CoC with each batch

QA Heat Release Data Transfer & Storage

Phase III: Database development for receipt of supplier MCC data

Prototype Database Ready

- Contains all key MCC parameter results (THR, HRC, FGC, IGC, Char)
- Adequate storage capability
- Limited access to supplier MCC data (QA)
- Allows for data transfer:
 - PC/Disk to database
 - Database to PC/disk
- Allows for data analysis
 - MCC analysis
 - Additive analysis
- Allow for storage of Boeing engineering data (Greater access needed)

QA Heat Release Testing: Future State

Boeing
Data Base
(MCC)



Test
Results



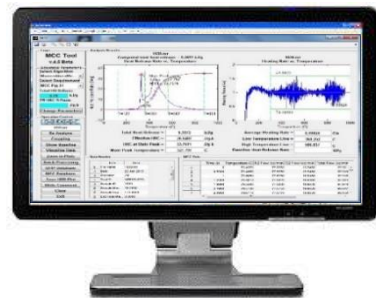
Supplier
Testing



Cure prepreg
Cut samples



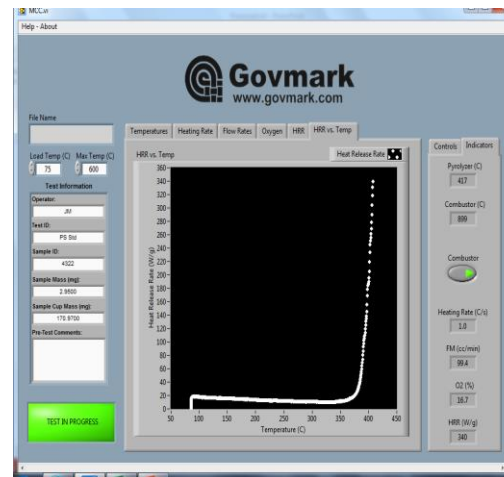
Weigh sample



Data Reduction

MCC Tool data reduction
software

Raw data



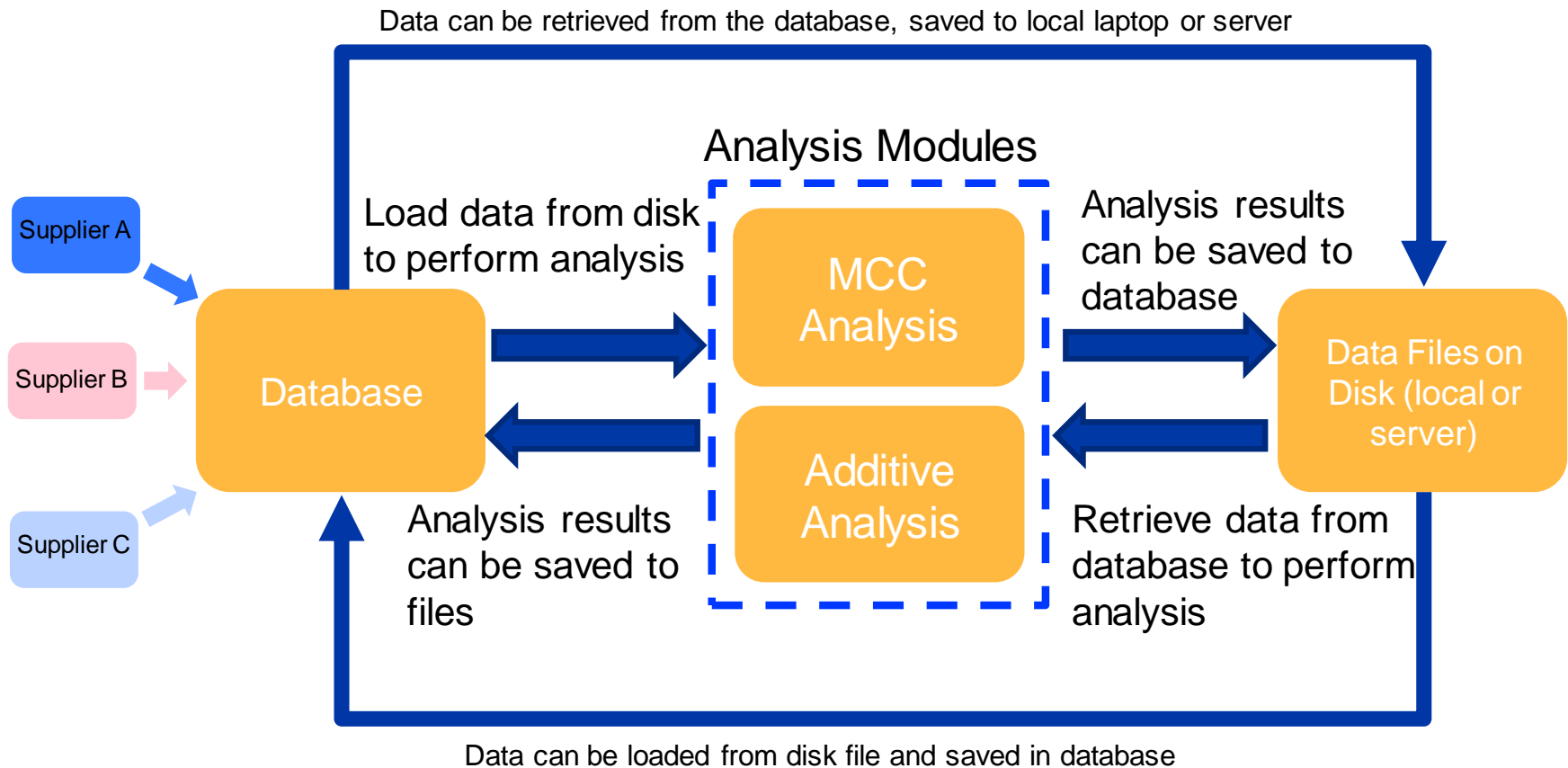
Data Collection



Sample Load

MCC Database Flow

- Targeting MCC data flows from suppliers to Boeing database



Digital flow of MCC data provides Boeing with upstream heat release information

Database User Interface Overview

- User interface with the main window and additive analysis window

Specify sample ID for query

Access database or disk files

Data to be submitted to or retrieved from the database

Access analysis modules

The screenshot displays the MccDatabase application interface. On the left is a sidebar with a 'Logo' section containing 'MCC Tool' and 'MCC Database'. Below this is an 'Operations' section with buttons: 'Configuration', 'Test Connection', 'DB Connected' (highlighted in green), 'Lookup Database', 'Load File(s)', 'Submit to DB', 'Retrieve from DB', 'Save to File(s)', 'MCC Analysis', 'Additive Analysis', 'Batch Analysis', 'Run Report', 'Clear', and 'Close'. The main window is titled 'Query' and contains fields for 'Sample ID =', 'Campus ID = 2. Everett', 'Test ID =', and 'Analyst BEMSID ='. Below these are date pickers for 'Test Date - From' and 'To'. A 'Data' section shows 'Total Number of Data = 1' and buttons for 'Previous', 'Next', and 'Remove from List'. The 'Data Header' table lists fields like File Name, Date, Operator, Test ID, Sample ID, Sample Mass, and Sample Cup Mass. The 'Analysis Results' table lists measurements like Total Heat Release THR, HRR at Peak, Heat Release Capacity, IGC, FGC, Heating Rate, and Temperature at Peak. At the bottom, a 'Data' table shows a time-series of measurements including Time (s), Temperature (C), N2 Flow (cc/min), O2 Flow (cc/min), Total Flow (cc/min), Oxygen (%), HRR (W/g), and H.

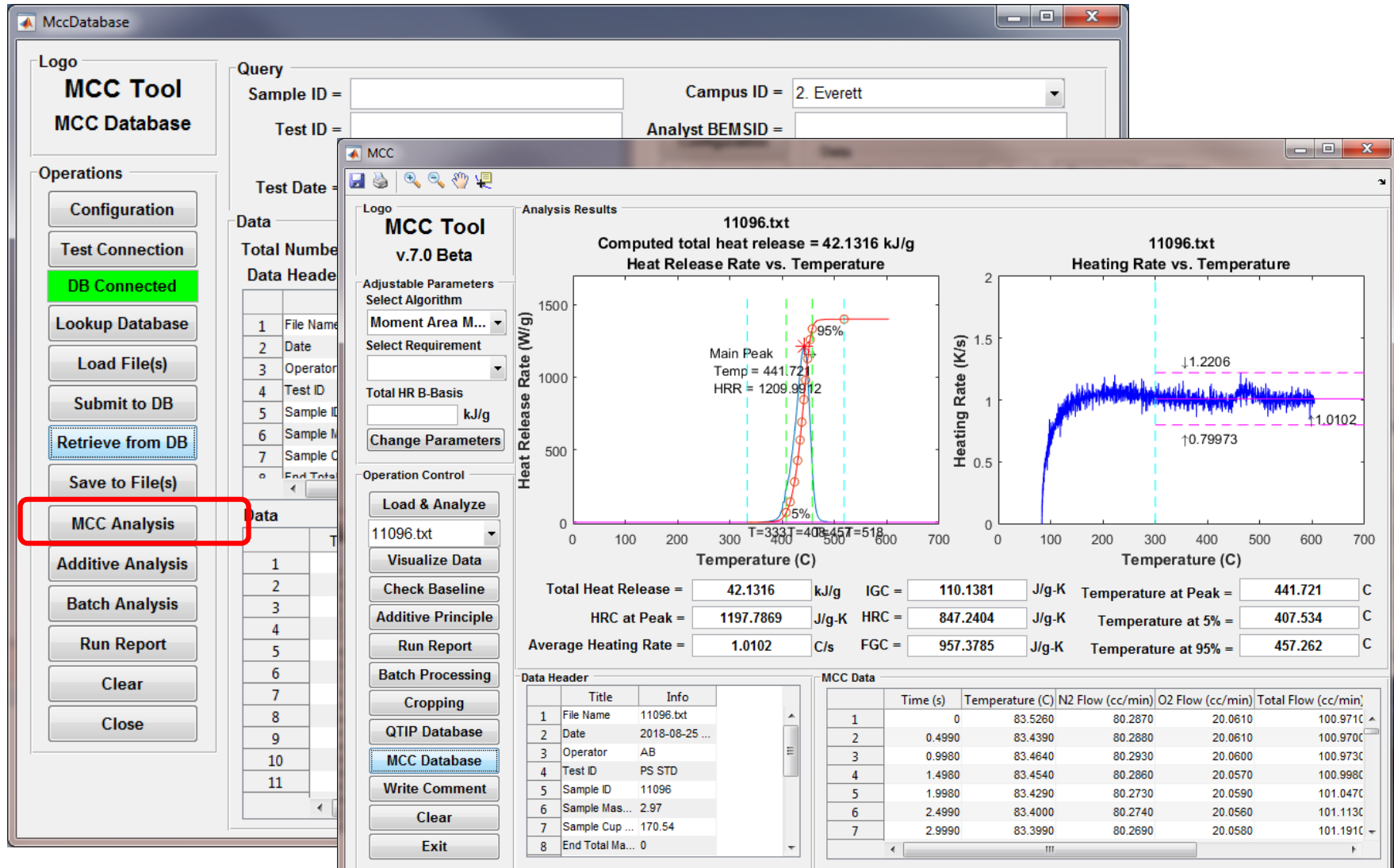
	Title	Info
1	File Name	10218.txt
2	Date	04 May 2018
3	Operator	JM
4	Test ID	MSIS 27
5	Sample ID	10218
6	Sample Mass (mg)	8.3000
7	Sample Cup Mass (mg)	173.0300
8	End Total Mass (mg)	0.0000

	Measurement	Result
1	Total Heat Release THR (kJ/g)	9.6516
2	HRR at Peak (W/g)	67.5900
3	Heat Release Capacity at Peak (J/g-K)	67.6159
4	Heat Release Capacity HRC (J/g-K)	35.1229
5	IGC (J/g-K)	43.3336
6	FGC (J/g-K)	78.4565
7	Heating Rate (C/s)	0.9996
8	Temperature at Peak (C)	475.0810
9	Temperature at 5% (C)	247.7270

	Time (s)	Temperature (C)	N2 Flow (cc/min)	O2 Flow (cc/min)	Total Flow (cc/min)	Oxygen (%)	HRR (W/g)	H
1	0	80.8190	80.3820	20	101.2030	20.1810	0.8720	
2	0.5000	80.8390	80.3870	20.0010	101.2060	20.1670	1.3850	
3	1	80.8300	80.3820	20	101.2110	20.1490	2.0360	
4	1.4980	80.8650	80.3910	19.9970	101.2500	20.1240	2.9010	
5	1.9980	80.9370	80.3820	19.9970	101.3170	20.1080	3.4790	
6	2.4980	80.9280	80.3840	19.9960	101.4070	20.0940	3.9690	
7	2.9980	80.9030	80.3760	19.9980	101.5150	20.0840	4.3300	
8	3.4980	80.9460	80.3780	20	101.6290	20.0730	4.7360	
9	3.9980	80.9830	80.3800	20	101.7230	20.0640	5.0410	
10	4.4980	81.0220	80.3720	19.9980	101.8000	20.0570	5.2860	
11	4.9980	81.0460	80.3880	19.9980	101.8580	20.0550	5.3880	

Display MCC Analysis Results

- Analysis results are displayed



Retrieve Data From Database for Additive Analysis

- Multiple datasets can be retrieved from database, and perform adaptive analysis

Multiple datasets
retrieved from
database

The screenshot shows the MccDatabase application window. On the left is a sidebar with a 'Logo' section containing 'MCC Tool' and 'MCC Database'. Below this is an 'Operations' section with buttons: 'Configuration', 'Test Connection', 'DB Connected' (highlighted in green), 'Lookup Database', 'Load File(s)', 'Submit to DB', 'Retrieve from DB' (highlighted in blue), 'Save to File(s)', 'MCC Analysis', 'Additive Analysis' (highlighted with a red box), 'Batch Analysis', 'Run Report', 'Clear', and 'Close'. A blue arrow points from the text 'Multiple datasets retrieved from database' to the 'Retrieve from DB' button. Another blue arrow points from the text 'Perform additive analysis' to the 'Additive Analysis' button. The main area is titled 'Query' and contains input fields for 'Sample ID', 'Test ID', 'Campus ID' (set to '2. Everett'), and 'Analyst BEMSID'. Below these are date pickers for 'Test Date = From' and 'To'. A 'Data' section shows 'Total Number of Data = 5' and a list of files with '1848.txt' selected. The 'Analysis Results' section has a table with 'Measurement' and 'Result' columns. At the bottom is a large 'Data' table with columns: Time (s), Temperature (C), N2 Flow (cc/min), O2 Flow (cc/min), Total Flow (cc/min), Oxygen (%), HRR (W/g), and H.

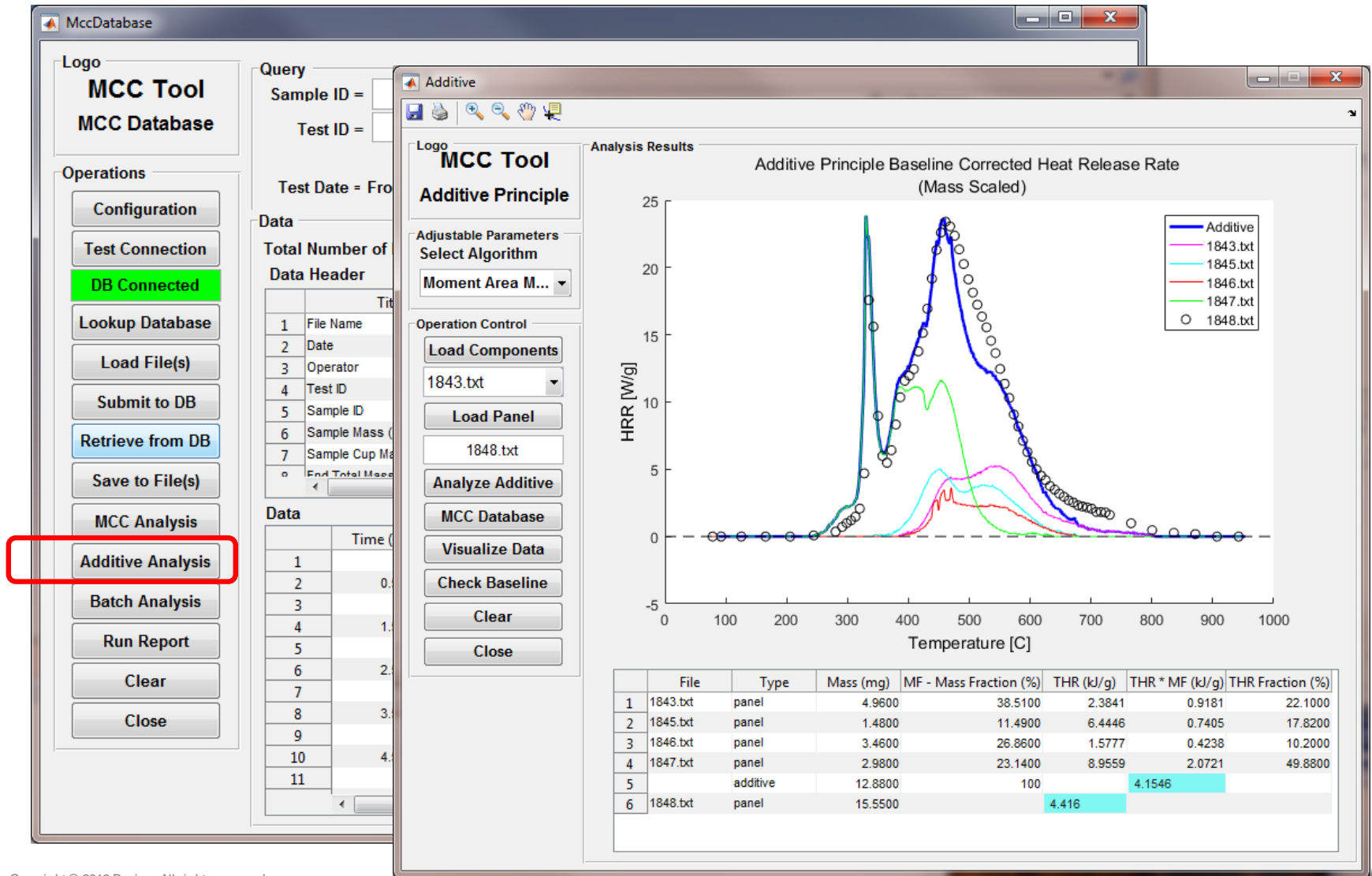
	Title	Info
1	File Name	1848.txt
2	Date	2014-12-08 00:00:00.0
3	Operator	JM
4	Test ID	A2-Fig31
5	Sample ID	1848
6	Sample Mass (mg)	15.55
7	Sample Cup Mass (mg)	169.66
8	End Total Mass (mg)	0

	Time (s)	Temperature (C)	N2 Flow (cc/min)	O2 Flow (cc/min)	Total Flow (cc/min)	Oxygen (%)	HRR (W/g)	H
1	0	78.4090	78.5880	19.9010	103.2140	19.7450	0.0950	
2	0.5000	78.4160	78.5810	19.8990	103.2080	19.7420	0.1580	
3	1	78.4960	78.5820	19.9030	103.2060	19.7300	0.3830	
4	1.5000	78.5030	78.5830	19.9050	103.2290	19.7230	0.5300	
5	2	78.5340	78.5820	19.9010	103.2770	19.7140	0.7000	
6	2.5000	78.5980	78.5820	19.9050	103.3400	19.7010	0.9410	
7	3	78.6480	78.5820	19.9030	103.4250	19.6870	1.2250	
8	3.5000	78.6400	78.5800	19.9010	103.5190	19.6740	1.4650	
9	4	78.7520	78.5840	19.8990	103.6010	19.6630	1.6780	
10	4.5000	78.8040	78.5770	19.9060	103.6740	19.6520	1.9080	
11	5	78.8030	78.5800	19.8990	103.7370	19.6440	2.0450	

Perform additive
analysis

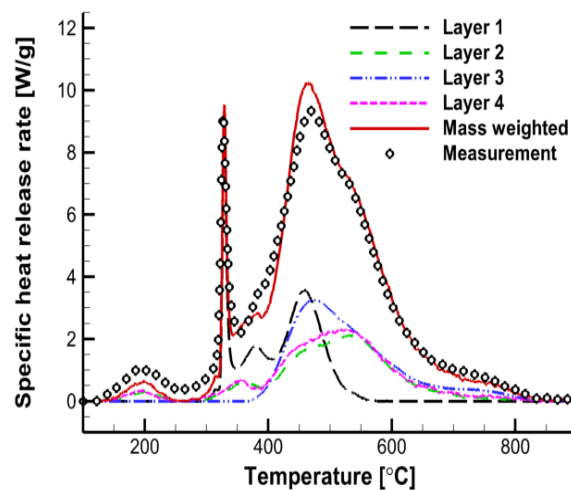
Display Additive Analysis Results

- Results of additive analysis are displayed

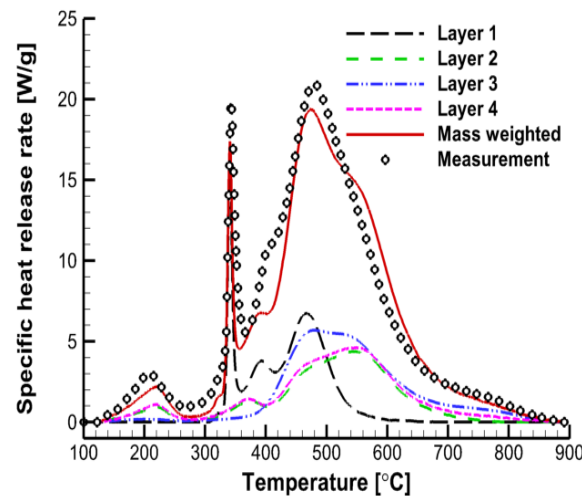


Additive Heat Release Properties of Thin Composites

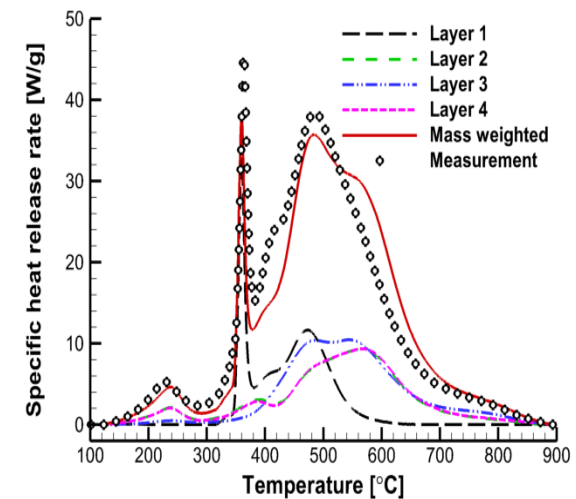
- Raw material heat release can be tested separately in the MCC
- Heat release is additive and can be summed based on mass fraction in panel
- Raw material heat release is data based to support new material evaluations for new constructions



0.5 °C/s heating rate



1.0 °C/s heating rate



2.0 °C/s heating rate

MCC plot overlay of composite panel (integral decorative)

Heat Release Testing Technology Roadmap

Key Enablers

Electronic transfer of data from Supplier to OEM-owned MCC database

MCC baseline correction algorithm (FAA)

Pre-coordination with key raw material suppliers

License agreement for Boeing software

Searchable MCC database for Boeing/Supplier data

Boeing-developed MCC data reduction software

Additive principle of heat release

FUTURE STATE

Supplier Delegated Flam testing
Digitized QA Heat Release Data
(KPI-based QA diagnostics)

2020

2019

MCC technology implemented at supplier

2018

Boeing software license agreement

2017

MCC option for heat release testing
added to interior prepreg specs

2016

MCC data base development begun

2015

MCC requirements developed

2014

Boeing-developed MCC data
reduction software

2012 - 2013

Boeing-developed MCC operation
and maintenance procedures

CURRENT STATE

Heat release testing (often redundant)
performed primarily by Boeing

- Completed project milestones
- In-progress
- Future project milestones

Key Impacts/Benefits

1. Flow of supplier MCC data/KPIs to Boeing QA
2. Benchtop flam analysis of composite constructions
3. KPI-based process control for interior components

