Ares I-X DFI Lessons Learned

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Presented By
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Outline

- Brief introduction to Ares I-X
- Instrumentation types
- Lessons learned
  - Instrumentation locations
  - Installation
  - Data acquisition techniques
  - Other/general
- Conclusions

Ares I-X

- Demonstrated control of a long, solid-fueled, single-motor flight vehicle with a low fundamental structural frequency.
- Provided an overall assessment of crucial design and induced environments.
- Partially validated selected Ares I thermal environments math models and processes.

Ares I-X

Aerothermal Instrumentation Summary

- 50 Calorimeters with embedded sensor thermocouples
- 6 Radiometers
- 7 Gas temperature probes (GTP)
- 47 Static pressure gauges
- 2 Flow direction probes

Why These Gauges?

- Main measurement is heating rate $(\dot{q})$

$$\dot{q}_{total} = h_c\left(T_{rec} - T_{wall}\right) + \dot{q}_{rad}$$

gaseous convection

radiation

Parameter	Measured by
$\dot{q}_{total}, T_{wall}$	Calorimeter, Thermocouple
T_{rec}	Calculated or Gas temperature probe
$\dot{q}_{rad}$	Radiometer
h_c	Calculated

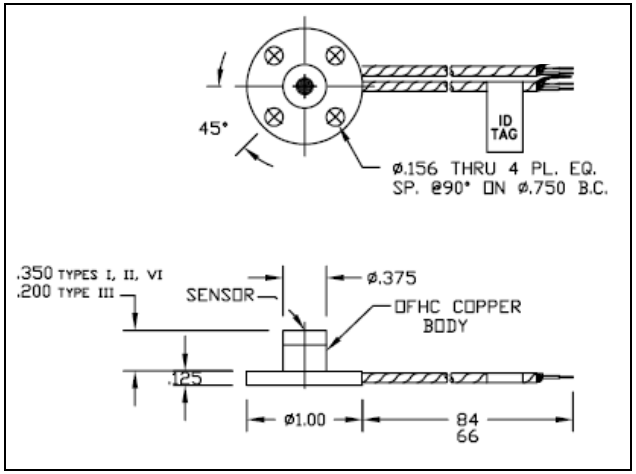
- h_c determined more accurately than in the past
- Flow direction probes characterize plume induced flow separation region
- Static pressures provide local flow conditions and CFD validation data

What Makes Data Unique?

- First NASA launch vehicle to fully utilize calorimeters with embedded sensor temperature measurements
- Ascent
  - Very long vehicle length causes thick boundary layer
  - First Stage (FS) nozzle instrumented for the first time
  - Single Solid Rocket Motor (SRM) plume induced radiation, convection, and gas temperature measured for the first time
- Near-field small motor plume impingement heating data acquired
  - Roll Control System (RoCS) and Booster Deceleration Motor (BDM) plume impingement heating
- FS re-entry data expands Aerothermal database
  - Low altitude tumble is unique
  - Top plate configuration outside Aerothermal database
  - Instrumented thermal curtain in flight for the first time

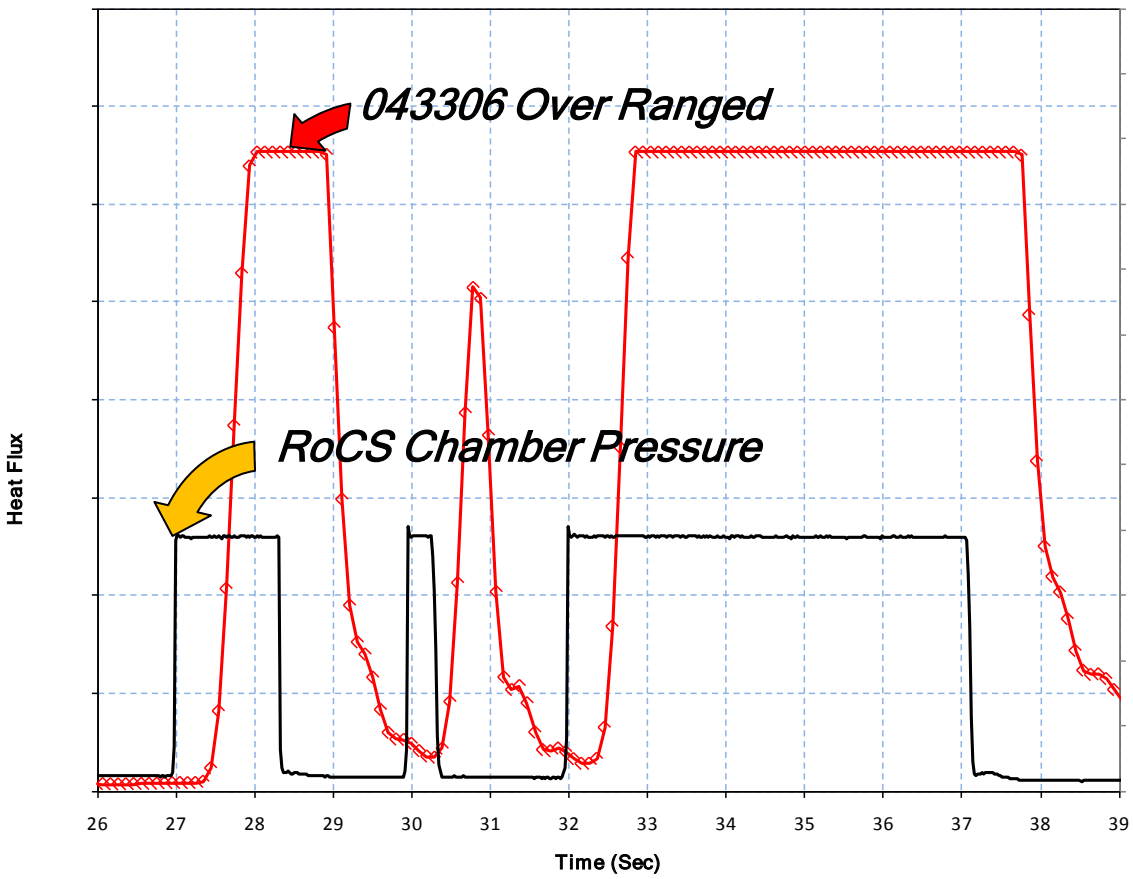
Calorimeters

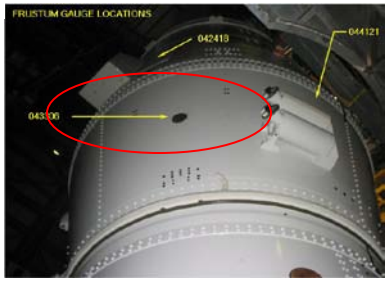
- Schmidt-Boelter type with type K thermocouple mounted next to thermopile
  - Medtherm model 20850
- Performance
  - Sensor temperature measurements worked well (only lost one late in re-entry)
  - Only one high flux gauge failed
- Lessons Learned
  - When in doubt, specify higher range gauge



Calorimeters

RoCS Module B (-Roll) Burns #3-6 Calorimeter Response





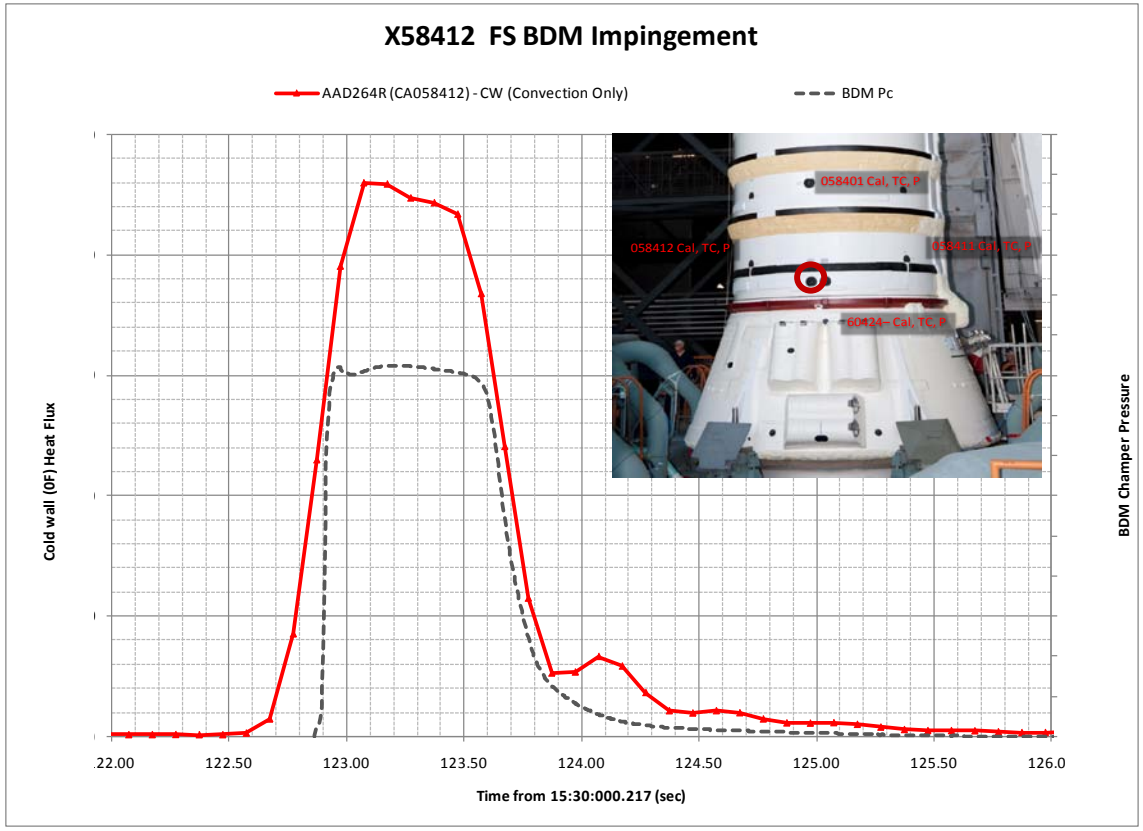
Chamber Pressure

AAD274R (CA043306)

Module B -Roll Motor Pc

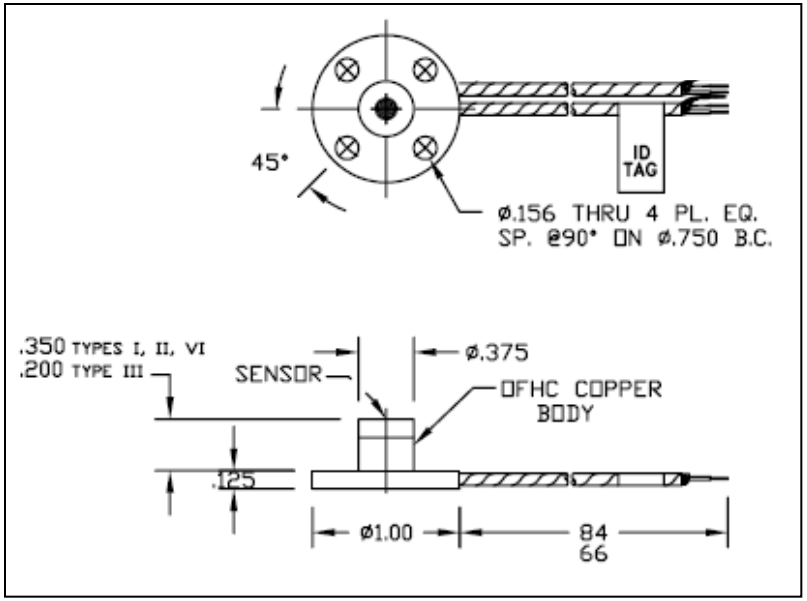
Calorimeters

- In high heat flux areas:
  - Gauges were ranged correctly
  - Most functioned and survived



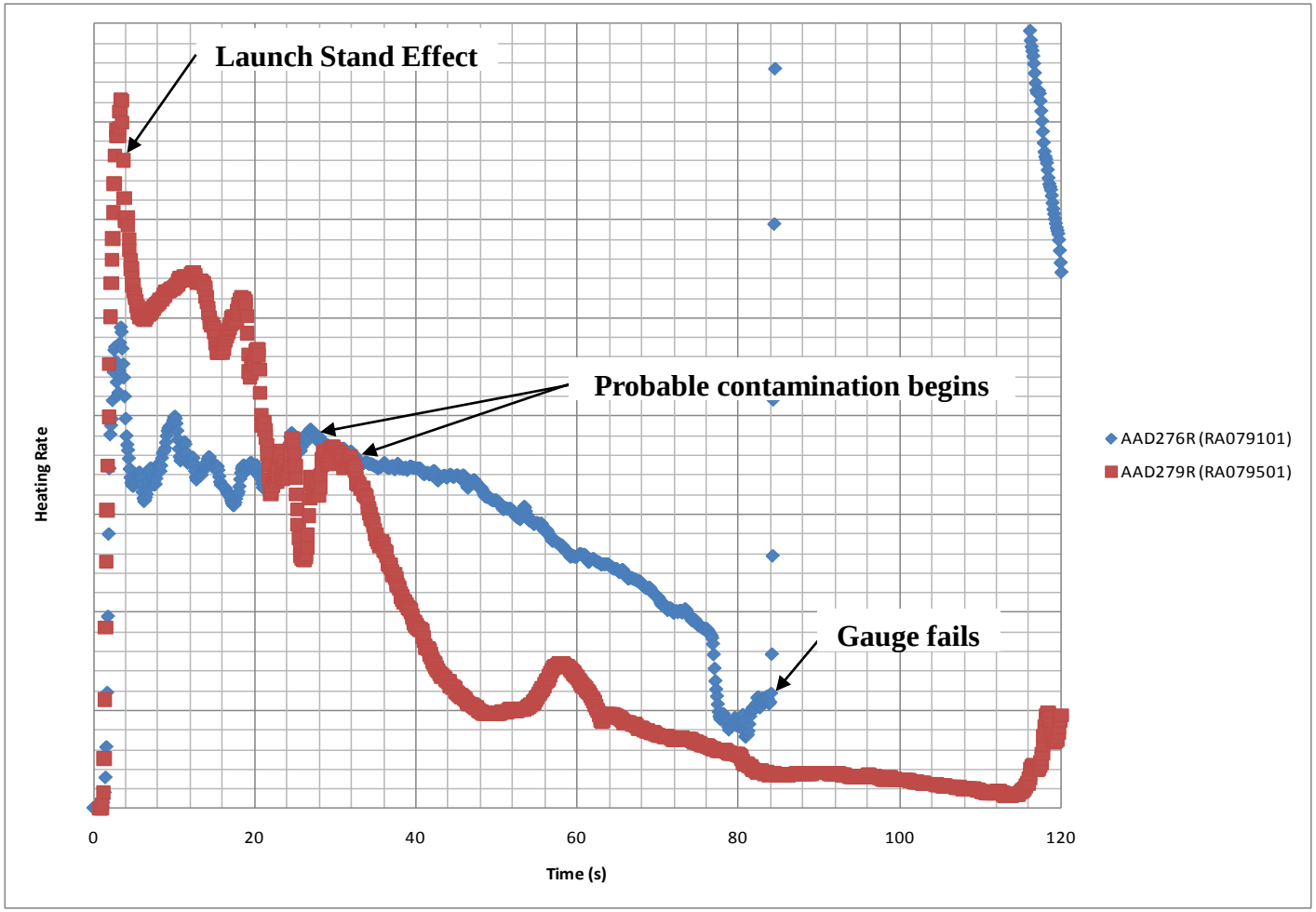
Radiometers

- Calorimeter with a sapphire window
  - Medtherm model 20850
- Performance
  - Mortality rate higher than desirable
- Lessons Learned
  - GN_2 purge required to mitigate contamination (Al_2O_3 or other) and allow acquisition of mid-to-late flight data



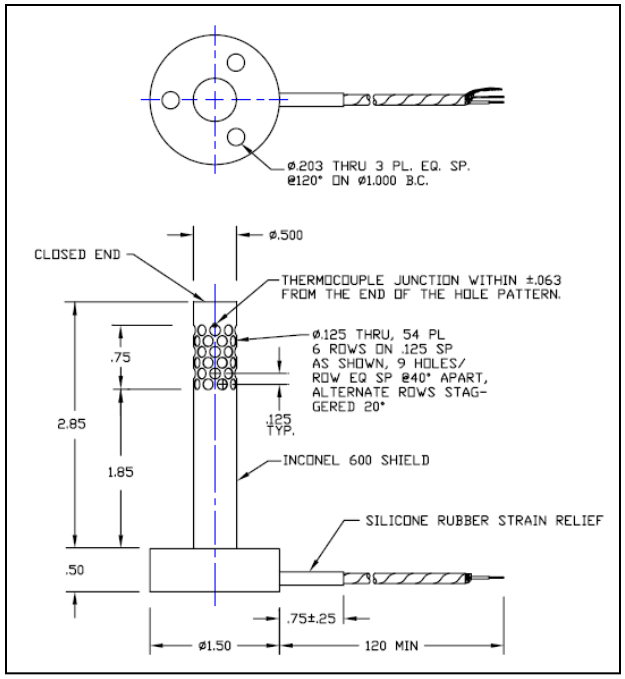
Radiometers

- All radiometers appear to fail eventually



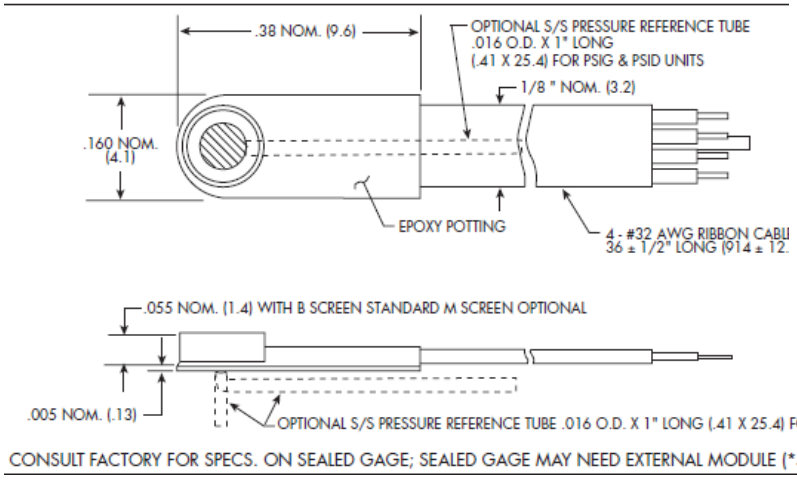
Gas Temperature Probes

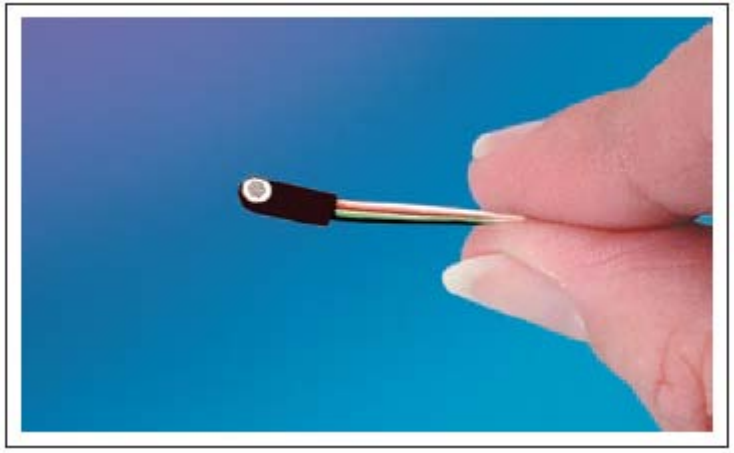
- Base Gas Temperature Transducer
  - Medtherm model 11190
- Performance
  - All gauges functioned
- Lessons Learned
  - Must account for radiation losses



Pressure Gauges

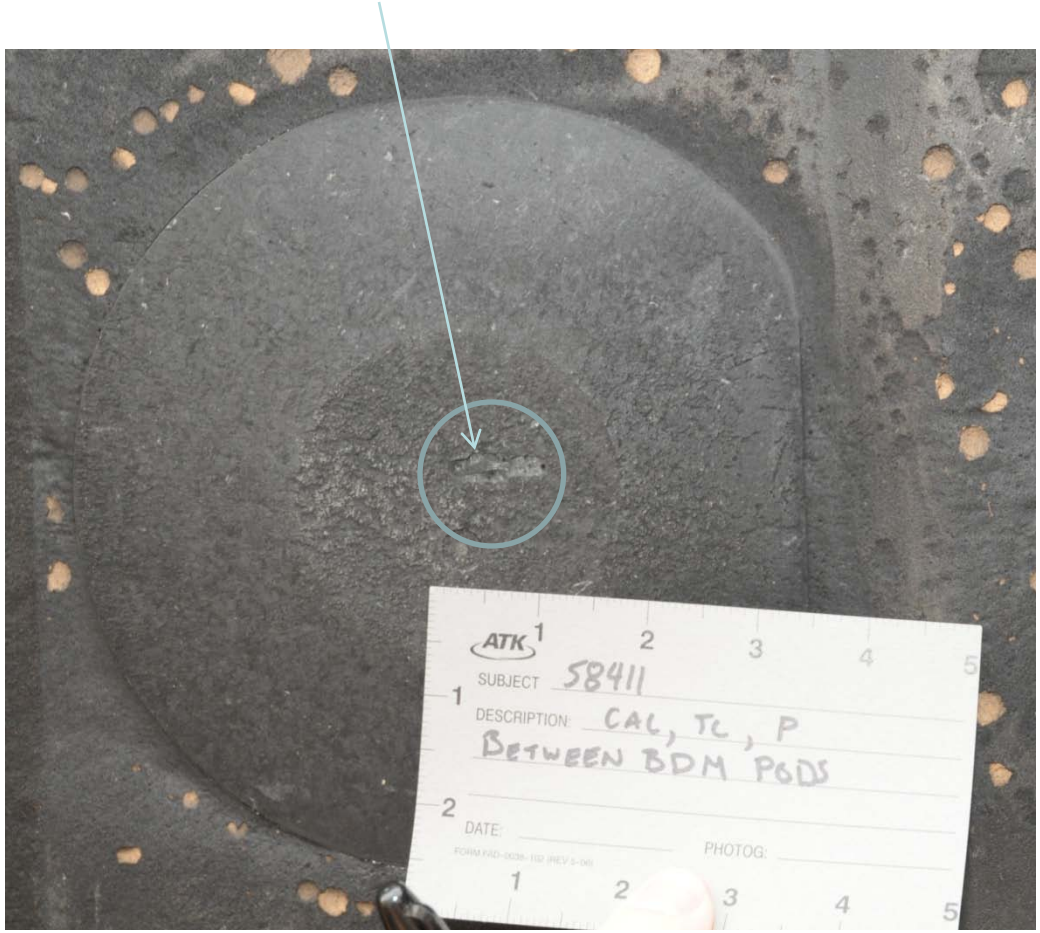
- Thin Line IS Pressure Transducer
  - Kulite LL-080 Series
- Performance
  - Gauge type and installation were not tolerant to significant heating
- Lessons Learned
  - 0-20 psi gauges provided the necessary level of fidelity





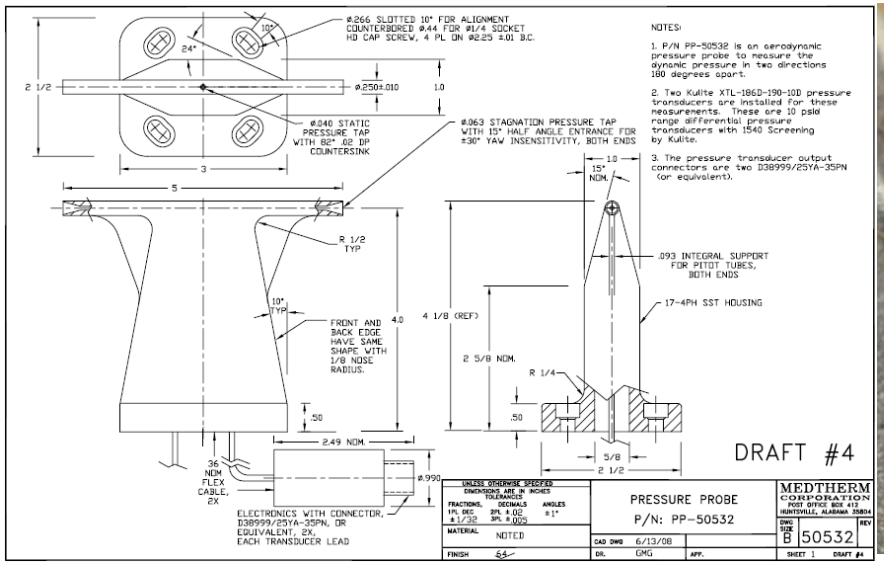
Pressure Gauges

- The gauge was completely burned out by the BDM firing.



Flow Direction Probes

- Flow direction probes
  - Medtherm model 50532
- Performance
  - Newly designed, functioned well
- Lessons Learned
  - May interfere with other gauges: shock heating to nearby calorimeter



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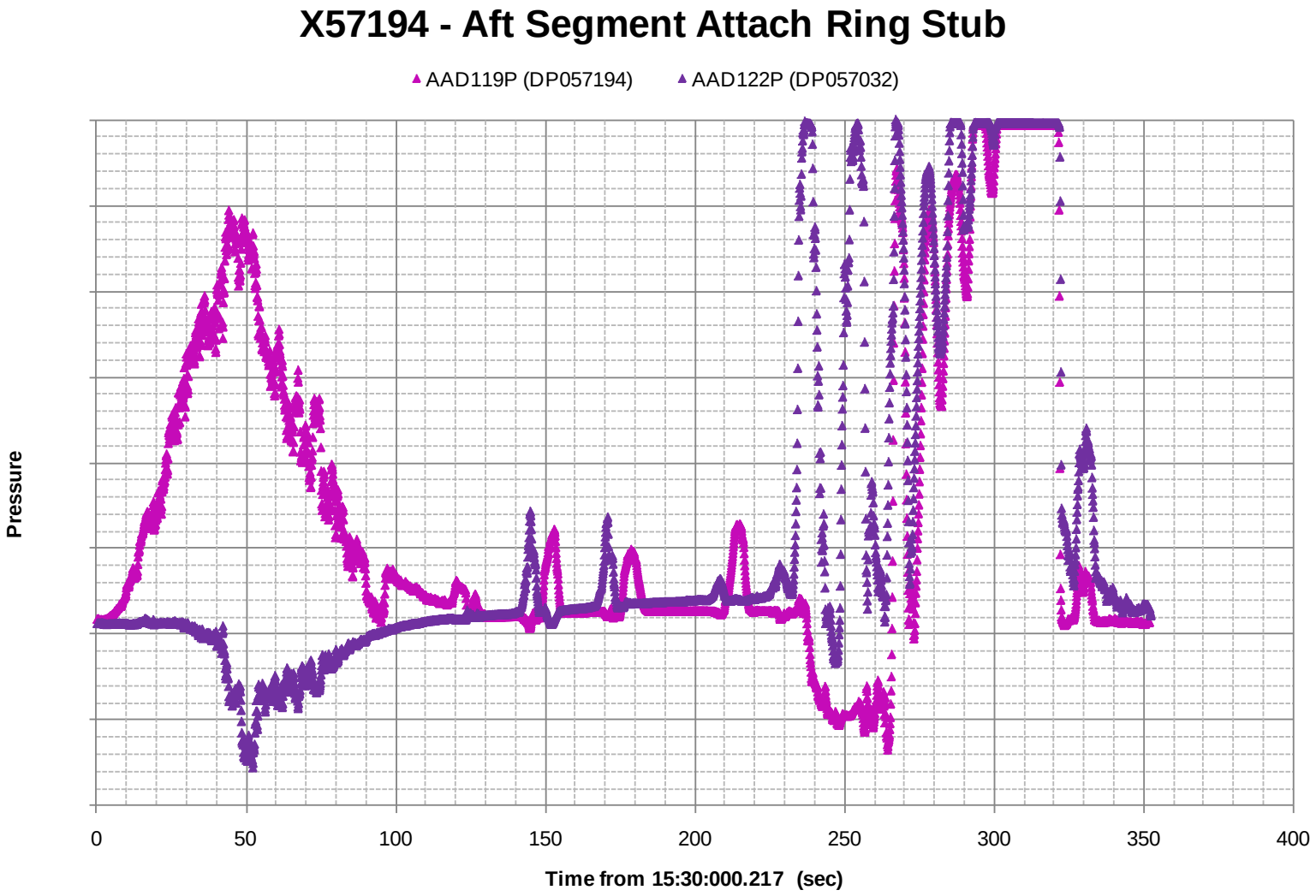


Lessons Learned - Instrument Locations

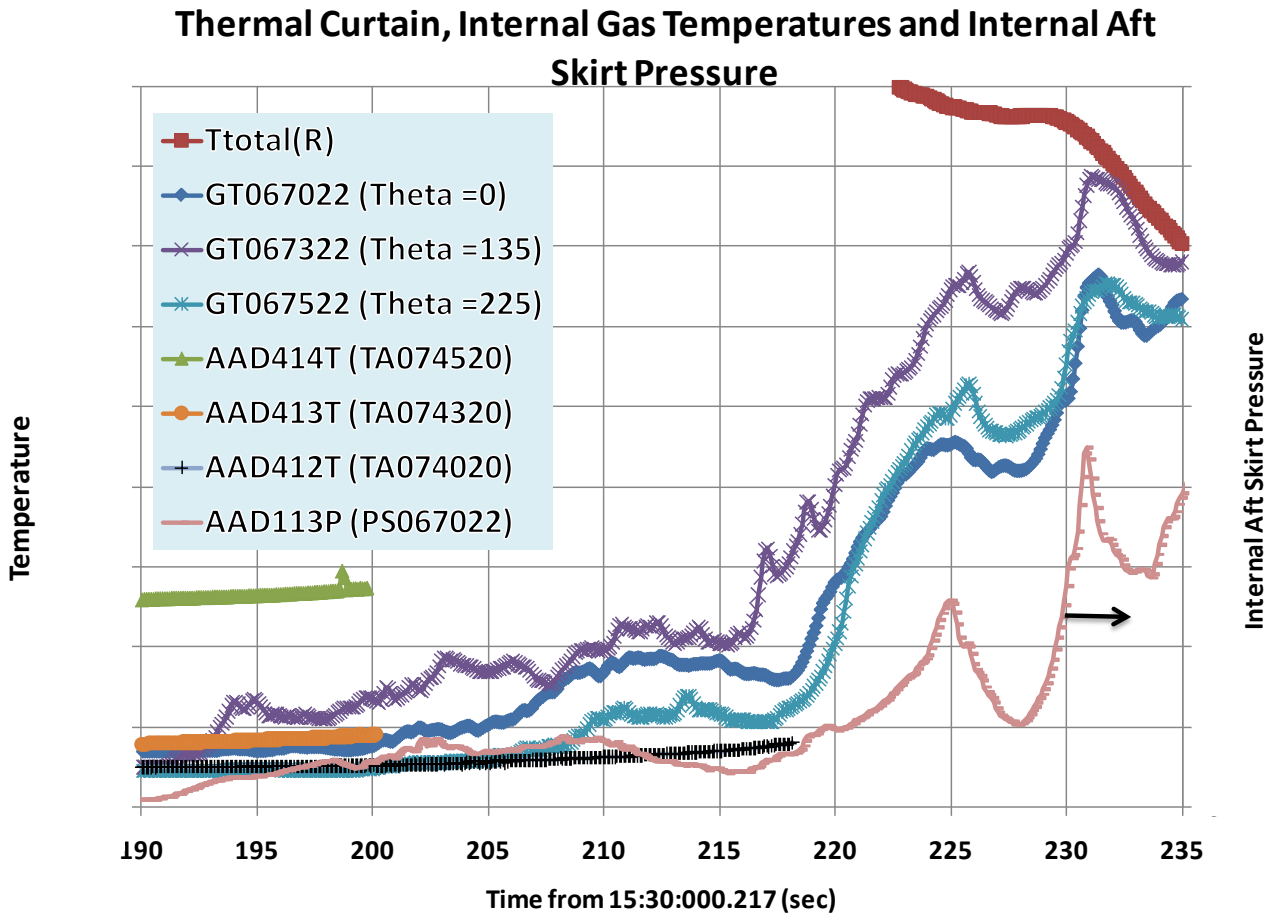
- Ensure there are a few true clean skin calorimeters
  - Measured heating amplifications due to proximity of cork runs near gauges
  - Below, separation occurs over the protuberance due to cork run / antenna

Lessons Learned - Instrument Locations

- Avoid instrument interference/installation effects (e.g. instrument island in the proximity of the flow direction probe)

Lessons Learned - Instrument Locations

- Add internal aft skirt camera for thermal curtain breakup nature and timing



Lessons Learned - Instrument Locations

- Coordinate with other disciplines to avoid redundancy of measurements
- Co-locate external nozzle calorimeters and GTP's

Lessons Learned - Installation

- Clearly specify installation procedures
  - Foam trimming, etc.
  - Need to have person on-site for some critical installation steps such as last minute foam application

  - One of the groups of gauges similar to this set was completely foamed over during close out operations.
    - No data was acquired from those gauges.

Lessons Learned - Data Acquisition

- Pre-flight channelization and calibration constants a must
- 2Hz filter was not good - must specify a higher range next time
- Gauge acquisition ranges
  - Want cooling measured
  - Utilize dual range on high flux if possible
- GTP junction temperatures must be measured

Lessons Learned- Other/General

- Measure one or two chamber pressures from all small motors if possible
  - BDM's, USM's, BTM's, ReCS, RoCS
- Have plan in place to specify T=0.0 ASAP after flight

Conclusions

- The flight test was successful
- Useful data were obtained
- The gauges used were appropriately selected and performed well
- Most problems are understood
  - Failures were few and far between.
  - Relatively simple procedural fixes have already been documented and put into action.