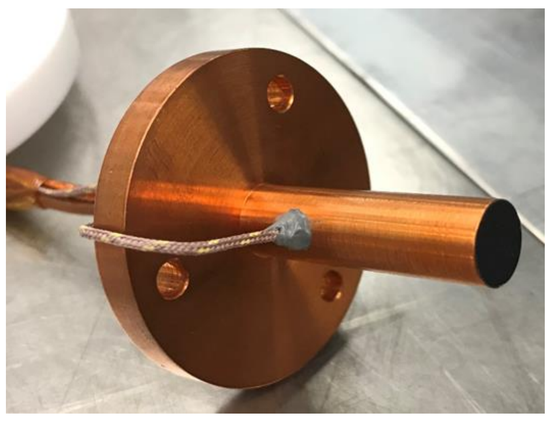
16th International Planetary Probe Workshop, Oxford, UK, 2019 Poster No.: A2

Laboratory-Based Thermal Shock Investigation of Heat Flux Sensors for the Mars 2020 Backshell

R. A. Miller[1], G. T. Swanson[2], J. A. Santos[3], and T. R. White[2]

[1]AMA Incorporated at NASA Ames Research Center, [2]NASA Ames Research Center, [3]Sierra Lobo, Inc. at NASA Ames Research Center

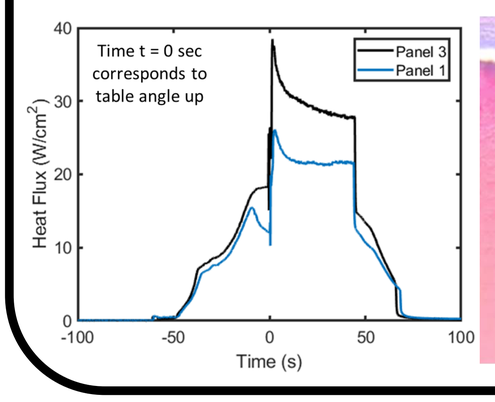
MEDLI2 Heat Flux Sensor

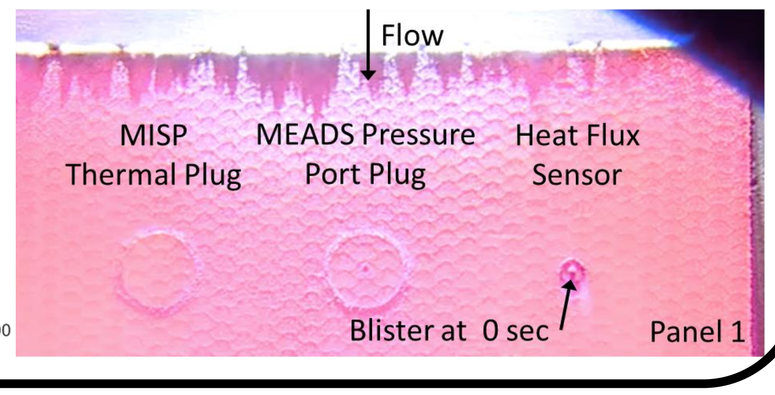


The Mars Entry, Descent, and Landing Instrumentation 2 (MEDLI2) sensor suite on the aeroshell of the Mars 2020 mission will be taking measurements during entry into Mars' atmosphere which will enable reconstruction of atmospheric conditions, vehicle aerodynamics, aerothermal heating, and Thermal Protection System (TPS) performance. MEDLI2 includes two heat flux sensors on the backshell which will directly measure the total (convective + radiative) incident heat flux. The MEDLI2 heat flux sensor is a Schmidt-Boelter Gauge with a range of 0 - 15 W/cm^2 and includes a Type K near surface thermocouple.

Do No Harm Arc Jet Testing

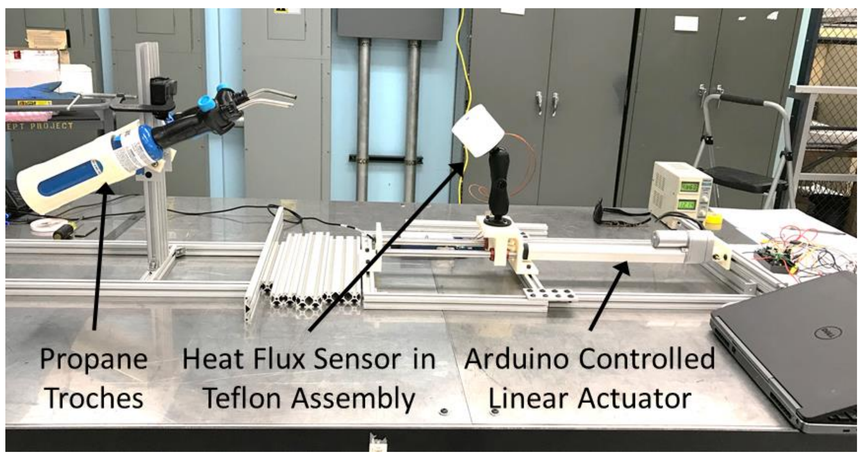
During Do No Harm (DNH) arc jet testing of instrumented backshell TPS panels, the heat flux sensors exhibited an unexpected reduction in the sensor temperature and response as well as a blister in the thermal coating. This unexpected result was confined to the heat flux sensors that experienced the greatest thermal shock condition consisting of a liquid nitrogen bath (-190°C), and then a transition to an arc jet test at a heat rate of ~21 W/cm^2.

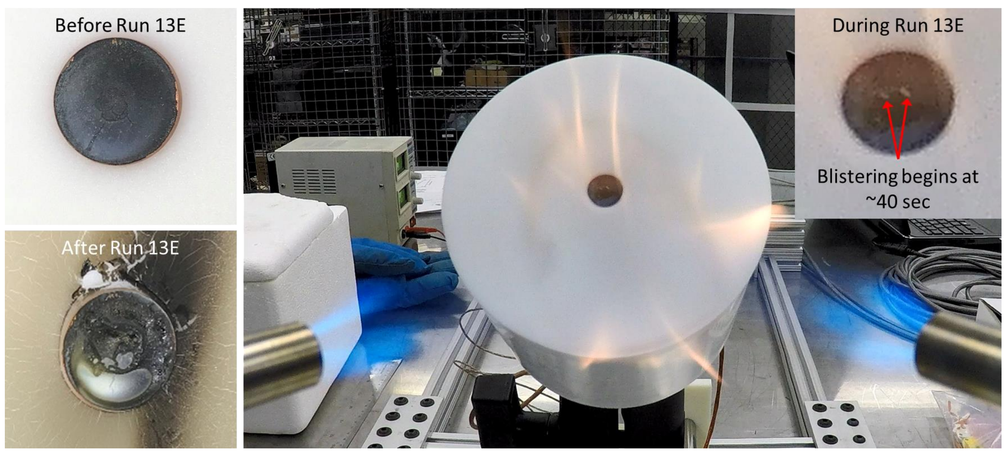




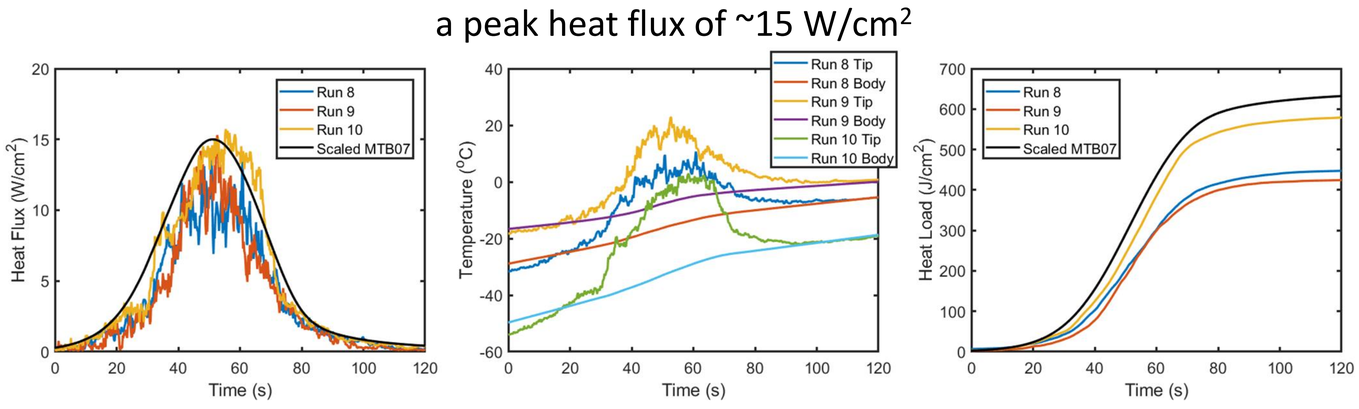
Laboratory-Based Thermal Shock Testing

Laboratory-based thermal shock testing was performed to investigate the cause of the heat flux sensor blistering and subsequent energy release. The heat flux sensor was first cold soaked and then thermally shocked using two propane torches. A linear actuator was used to simulate a flight-like time-varying heat pulse at the sensor location with highest predicted heating (MTB07) as well as replicate the square heat pulse seen during arc jet testing.

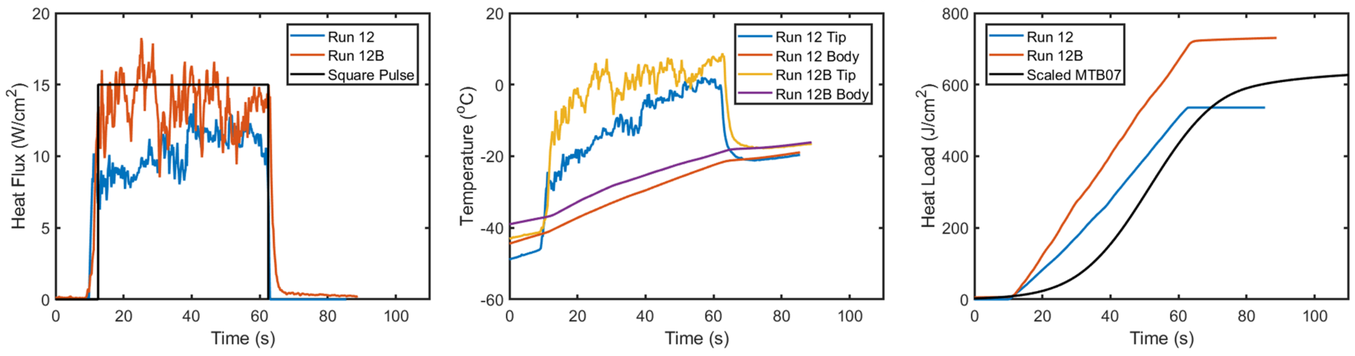




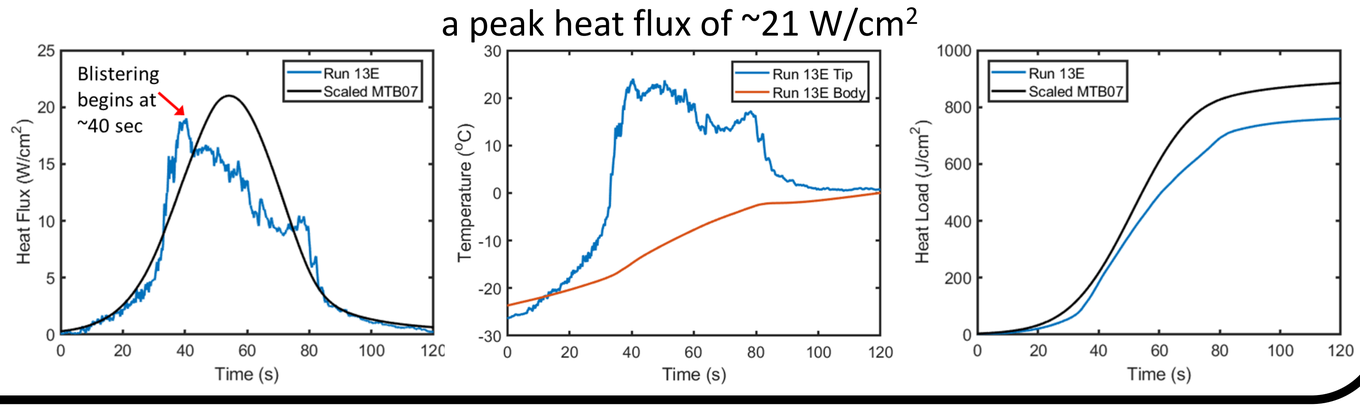
Heat flux sensor cold-soaked to -78°C then exposed to a time-varying heat pulse with a peak heat flux of ~15 W/cm^2



Heat flux sensor cold-soaked to -78°C then exposed to a square ~15 W/cm^2 heat pulse



Heat flux sensor cold-soaked to -78°C then exposed to a time-varying heat pulse with a peak heat flux of ~21 W/cm^2



Results Summary

Test Article	Cold-Soak	Target Heat Flux [W/cm^2]	Profile	Blistering
DNH Arc Jet - Heat Flux Sensor	No	8	Square	No
DNH Arc Jet - Heat Flux Sensor	-190°C	21	Square	Yes
Thermal Coating on Copper Slug	-190°C	21	Square	No
Heat Flux Sensor, No Thermal Coating	-190°C	21	Square	Yes
Heat Flux Sensor, No Thermal Coating	-190°C	8	Square	No
Heat Flux Sensor, No Thermal Coating	0°C	21	Square	No
Heat Flux Sensor, No Thermal Coating	-78°C	21	Square	Yes
Heat Flux Sensor	-78°C	15	Time-Varying	No
Heat Flux Sensor	-78°C	15	Square	No
Heat Flux Sensor	-78°C	21	Time-Varying	Yes

Key Findings

- Test setup with linear actuator and propane torches was able to apply a square or a flight-like time-varying heat pulse
- Blistering observed in arc jet testing was replicated in laboratory test setup
- Copper slugs with thermal coating did not blister. Blistering appears to be due to the epoxy that encapsulates the sensor thermopile
- There is a correlation between thermal shock and blistering. Blistering was only observed with cold-soaks of -78°C or -190°C and heat fluxes of ~21 W/cm^2
- Blistering was not observed at the maximum expected Mars 2020 backshell entry conditions at the heat flux sensor locations (-78°C , ~15 W/cm^2)