Temporary Thermocouple Attachment for Thermal/Vacuum Testing at Non-Extreme Temperatures

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Post-test examination and data analysis that followed a two week long vacuum test showed that numerous self-stick thermocouples became detached from the test article. The thermocouples were reattached with thermally conductive epoxy and the test was repeated to obtain the required data.

Because the thermocouple detachment resulted in significant expense and rework, it was decided to investigate the temporary attachment methods used around NASA and to perform a test to assess their efficacy.

The present work describes the original test and the analysis that showed that the thermocouples had become detached, temporary thermocouple attachment methods assessed in the retest and in the thermocouple attachment test, and makes a recommendation for attachment methods for future tests.

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THERMAL AND FLUIDS ANALYSIS WORKSHOP

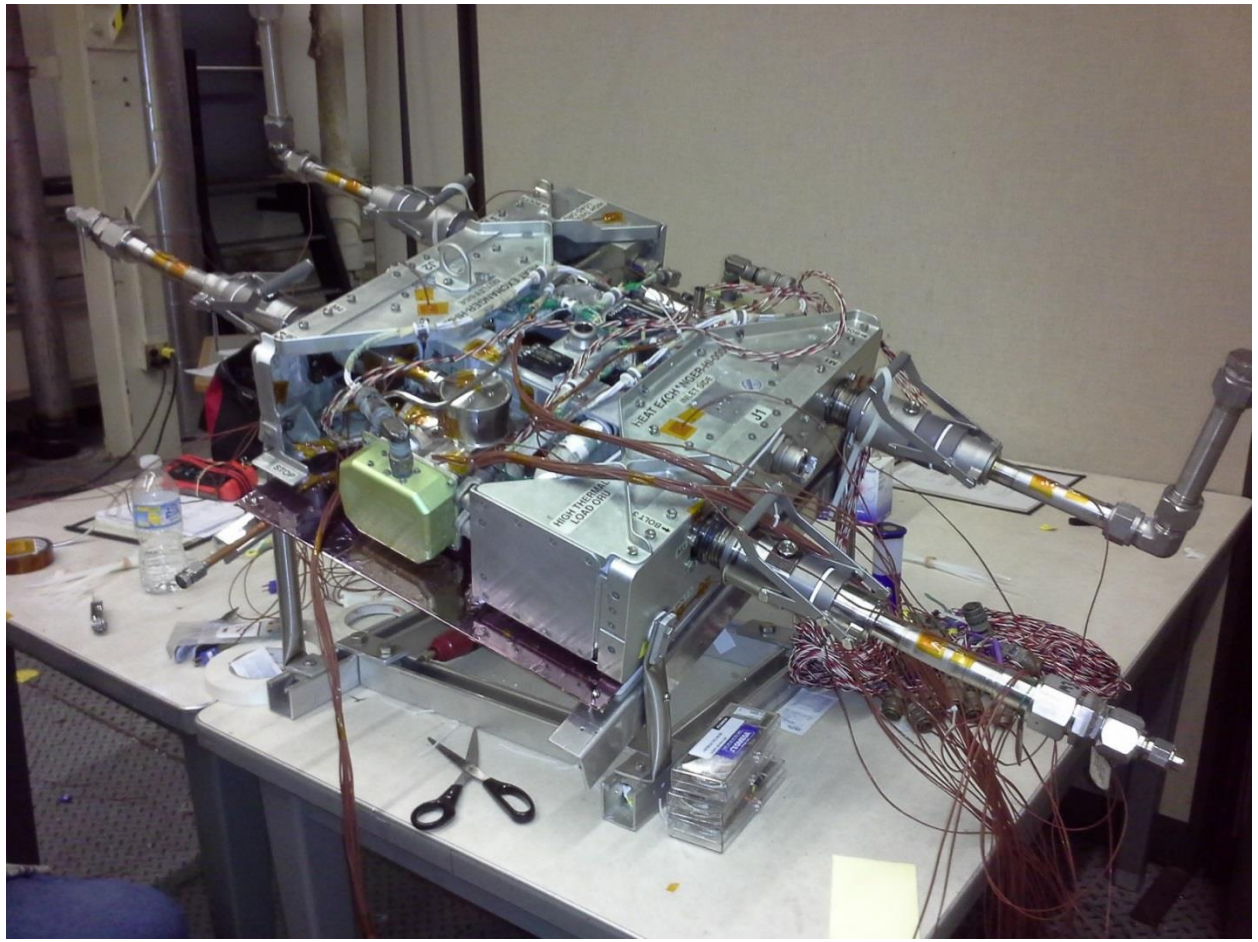
Overview

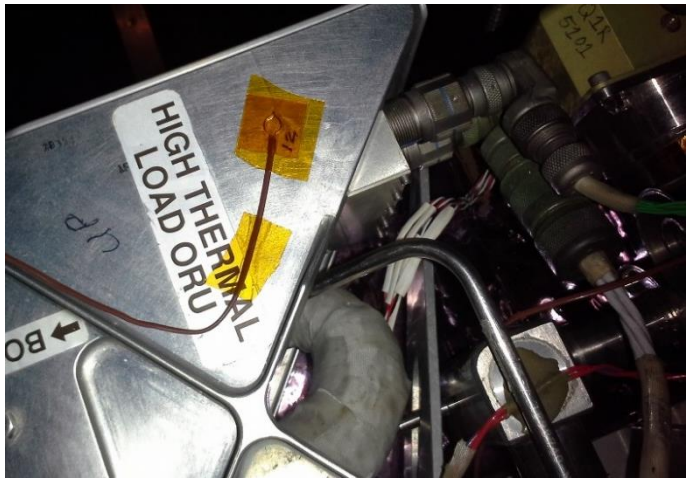
- Post-test inspection of a thermal vacuum test article and analysis of test data showed that many test thermocouples had become detached
- The Interface Heat Exchanger test article was re-instrumented and the test repeated, yielding much different results
- Effort was begun by the NASA Engineering and Safety Center (NESC) to assess and test methods used around the agency to temporarily attach thermocouples
- Thermocouple adhesion test will be performed in the near future

Interface Heat Exchanger Test

- Thermal/vacuum test was performed to assess the thermal response of an International Space Station Interface Heat Exchanger (IFHX) Orbital Replacement Unit
- Qualification unit was instrumented with stick-on type T thermocouples
  - A layer of Kapton tape was overlaid to secure the junctions
- Post-test inspection showed that some of the thermocouples had loosened

Interface Heat Exchanger Test Set-Up





The Heat Exchanger Core

443 mm long, 101 mm wide

63 mm thick

Water Fins are 0.05 mm nickel

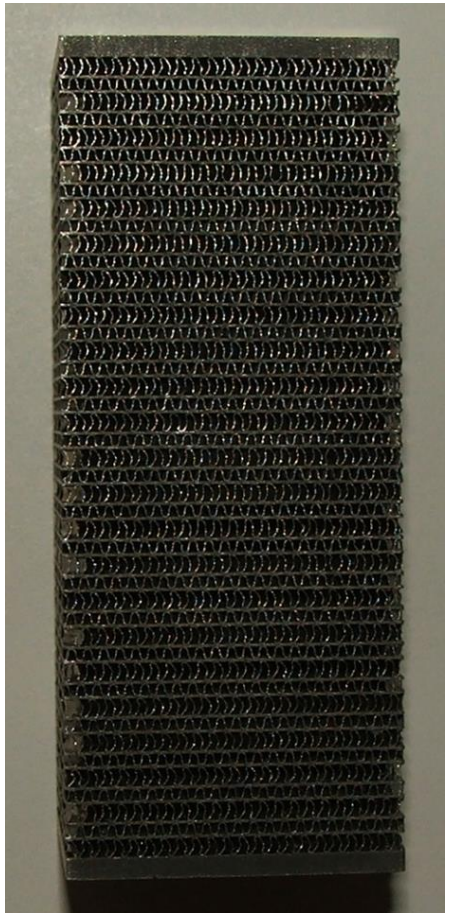
NH3 fins are 0.05 CRES 347

Parting sheet is 0.18 mm CRES 347

End sheet is 2.67 mm Inconel 625

23 water passages
- Each 1.32 mm high
- 0.58 mm fin spacing

22 ammonia passages
- Each 0.81 mm high
- 44 fins/inch



Post IFHX Test Assessment

- Post-test inspection showed that some of the thermocouples had obviously lifted
  - When pressed down they felt springy

Post IFHX Test Assessment

- Test data indicated a 6.7°C temperature gradient from the top to the bottom of the heat exchanger
  - bottoms up estimate of effective thermal conductivity is 4 W/m K
  - 300 W/m^2 by conduction
  - Cold plate underneath at 20°C with measured ε=0.62
  - Bottom of heat exchanger with measured ε=0.21
  - 19 W/m^2 by radiation
- Something was clearly wrong
- Test article was re-instrumented with epoxied thermocouples and test was rerun
  - 0.5°C temperature gradient from the top to the bottom of the heat exchanger

NESC Canvass

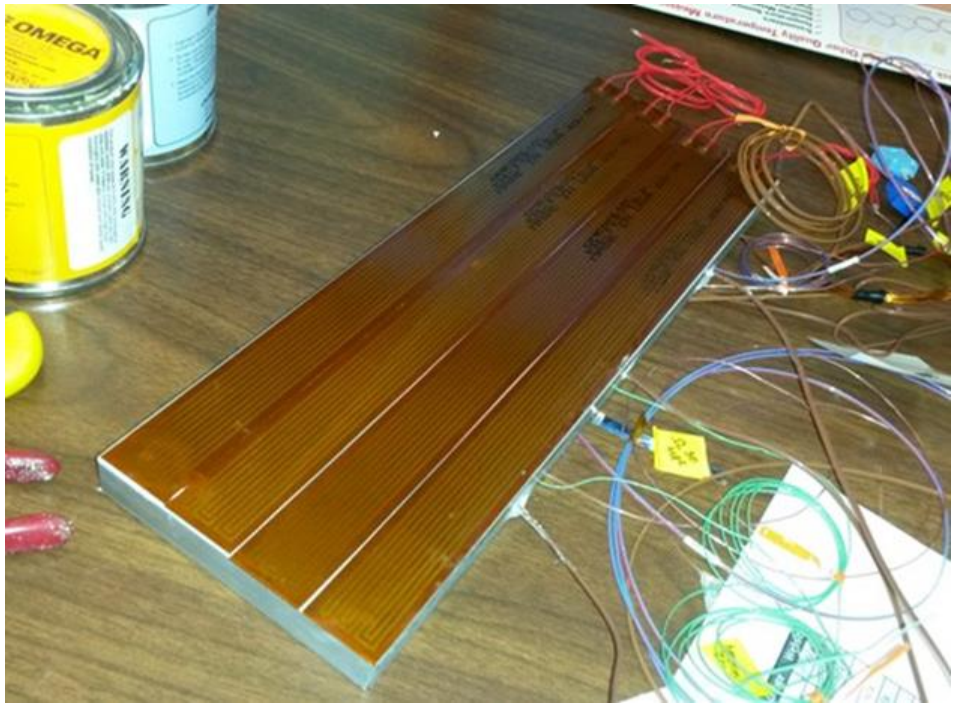
- NESC canvassed the centers to identify preferred thermocouple mounting techniques
  - Johnson Space Center
    - Commercial 24 ga thermocouples with self-adhesive
      - On occasion use a bare bead held with Kapton tape
      - Or sometimes a bare bead held with 3M 425 aluminum tape
  - Jet Propulsion Laboratory
    - fabricates 26 ga self-stick thermocouples
  - Goddard Space Flight Center
    - Commercial 30 ga thermocouples
    - Aluminum tape
      - 3M #425
      - Tape is worked with a wooden stick

NESC Canvass - *continued*

- Kennedy Space Center
  - Aluminum tape
    - Either GSA spec tape or 3M #425
    - Tape is worked with a wooden stick
- Langley Research Center
  - Aluminum tape
    - 3M #425
    - Tape is worked with a wooden stick
- Glenn research Center
  - no standard
- Marshall Space Flight Center
  - Aluminum tape
    - Nominally uses 3M #425
  - Also emphasize strain relief
    - Either bend TC wire into a U-shape under the tape
    - Or tape the wire nearby

Thermocouple Assessment Test Plan

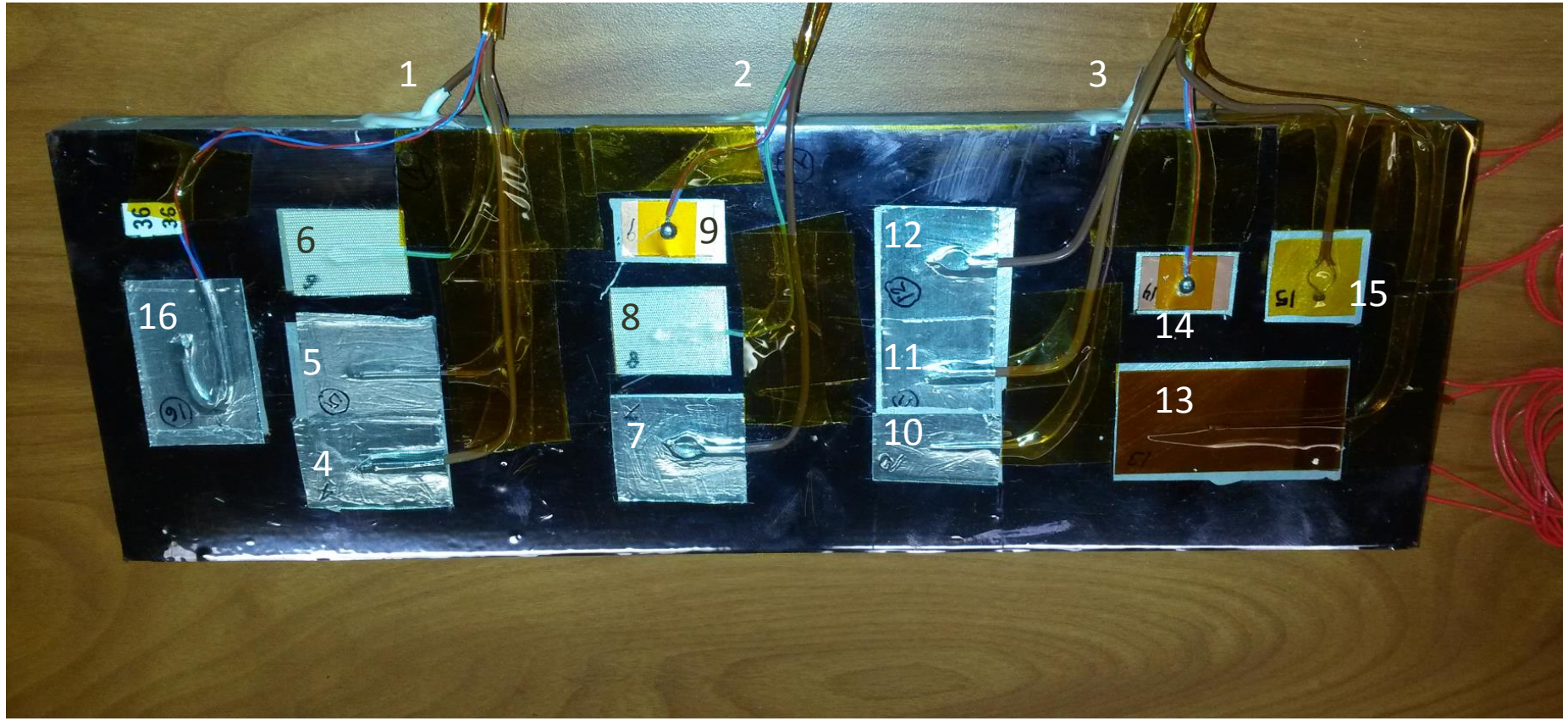
- 305 x 101 x 15.9 mm 6061-T6 aluminum plate suspended in Chamber G
- The back side of the plate is covered with four 305 x 25 mm 120 V 120 W Omega Kapton® heaters with pressure sensitive adhesive
- The heaters are covered with aluminum tape, then insulated with Nomex felt and Mylar sheet



Thermocouple Assessment Test Plan - *continued*

- Three 24 gauge type T RTK control thermocouples are potted into the plate using Omegabond 101 thermally conductive epoxy
- The front surface of the plate is covered with 0.025-mm adhesive-backed aluminized Kapton® film with emissivity of 0.63
- The Kapton® was removed from small areas to allow the test thermocouples to be mounted directly to the aluminum surface

Thermocouple Assessment Test Article

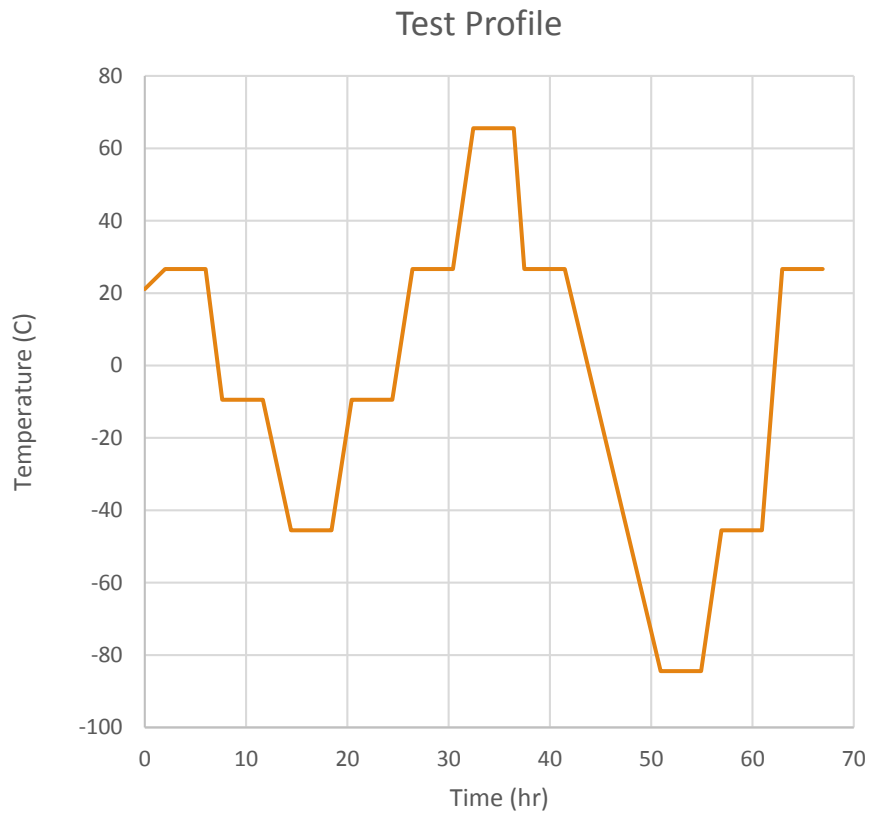


Thermocouple Assessment Legend

TC #	Gauge	Description
1	24	RDF 26895 in 1/4" hole drilled <1" deep. Potted with Omega Bond thermally conductive epoxy.
2	24	RDF 26895 in 1/4" hole drilled <1" deep. Potted with Omega Bond thermally conductive epoxy.
3	24	RDF 26895 in 1/4" hole drilled <1" deep. Potted with Omega Bond thermally conductive epoxy.
4	24	Omega 5TC-TT-T-24-36 T/C on bare aluminum. Covered with GSA aluminum tape.
5	30	Omega 5TC-TT-T-30-36 3on bare aluminum. Covered with 3M #425 aluminum tape.
6	36	Omega SA1-tl-1M self adhesive thermocouple.
7	24	RDF 26895 placed on bare aluminum. Covered with GSA aluminum tape.
8	36	Omega SA1-tl-1M self adhesive thermocouple.
9	26	JPL-2 thermocouple.
10	30	Omega 5TC-TT-T-30-36 T/C on bare aluminum. Covered with GSA aluminum tape.
11	24	Omega 5TC-TT-T-24-36 T/C on bare aluminum. Covered with 3M #425 aluminum tape.
12	24	RDF 26895 placed on bare aluminum. Covered with 3M #425 aluminum tape.
13		Digisense GH-08519-54 self adhesive thermocouple.
14	26	JPL-5 thermocouple.
15	32	RDF 26895-36 self adhesive thermocouple.
16	30	GSFC 30 gauge with strain relief. Covered with 3M #425 aluminum tape.

Thermocouple Assessment Test Plan

Test Point	Temperature (C)	Notes
Cal 1	21 ± 5	Steady-state at vacuum before coldwalls are applied
1	27 ±5	Temperature drift less than 0.05°C/hr
2	-9 ±5	Temperature drift less than 0.05°C/hr
3	-46 ±5	Temperature drift less than 0.05°C/hr
4	-9 ±5	Temperature drift less than 0.05°C/hr
5	27 ±5	Temperature drift less than 0.05°C/hr
6	66 +5/-0	Temperature drift less than 0.05°C/hr
7	27 ±5	Temperature drift less than 0.05°C/hr
8	-84 +0/-5	Temperature drift less than 0.05°C/hr
9	-46 ±5	Temperature drift less than 0.05°C/hr
10	27 ±5	Temperature drift less than 0.05°C/hr
11	66 +5/-0	If time allows
12	-84 +0/-5	If time allows
Cal 2	21 ±5	Steady-state at vacuum after coldwall heatup



Expected Outcome

- We expect to obtain sufficient data to allow us to recommend one or more methods of temporary thermocouple attachment