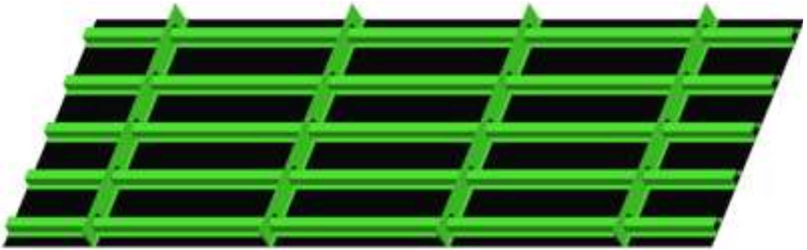
Inaccessible Area Fire Tests on Composite Structure - Update

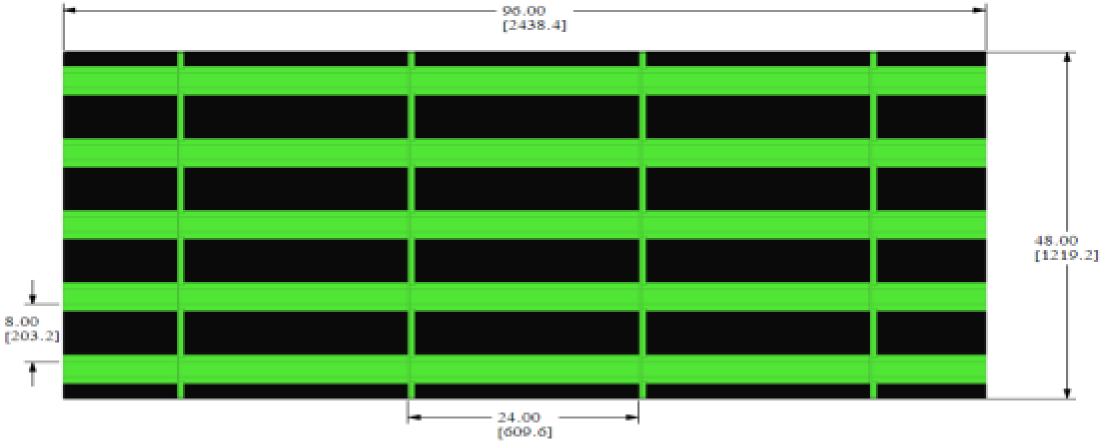
Presented to: IAMFTWG

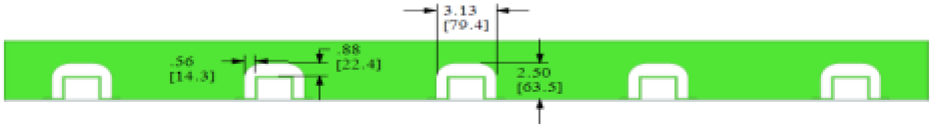
By: Robert I Ochs

Date: March 7 2017

Large Scale CFRP Skin & Structure Tests



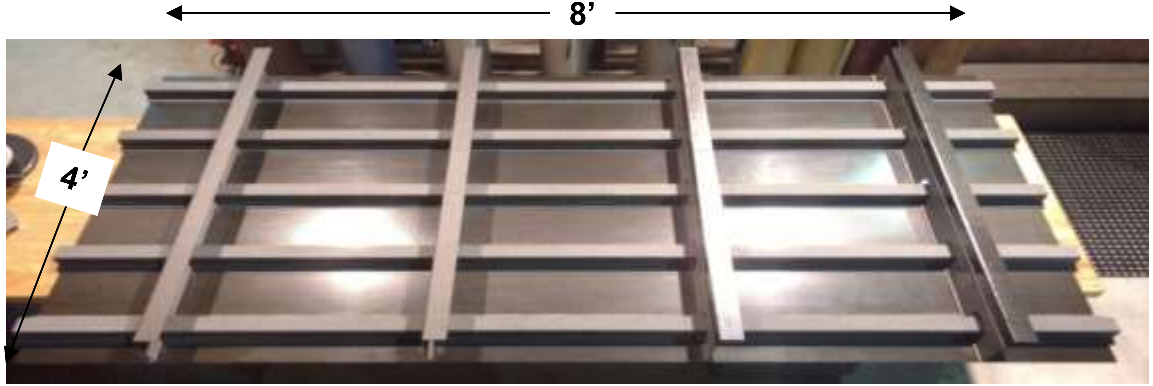


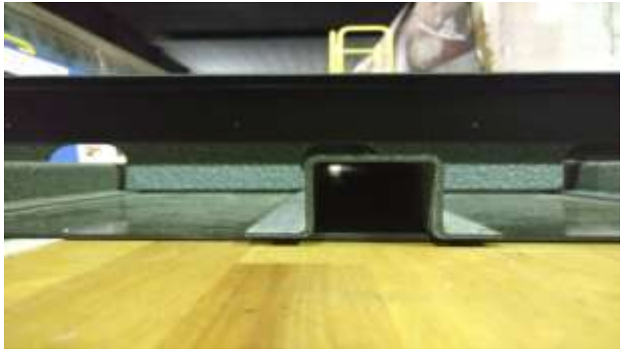


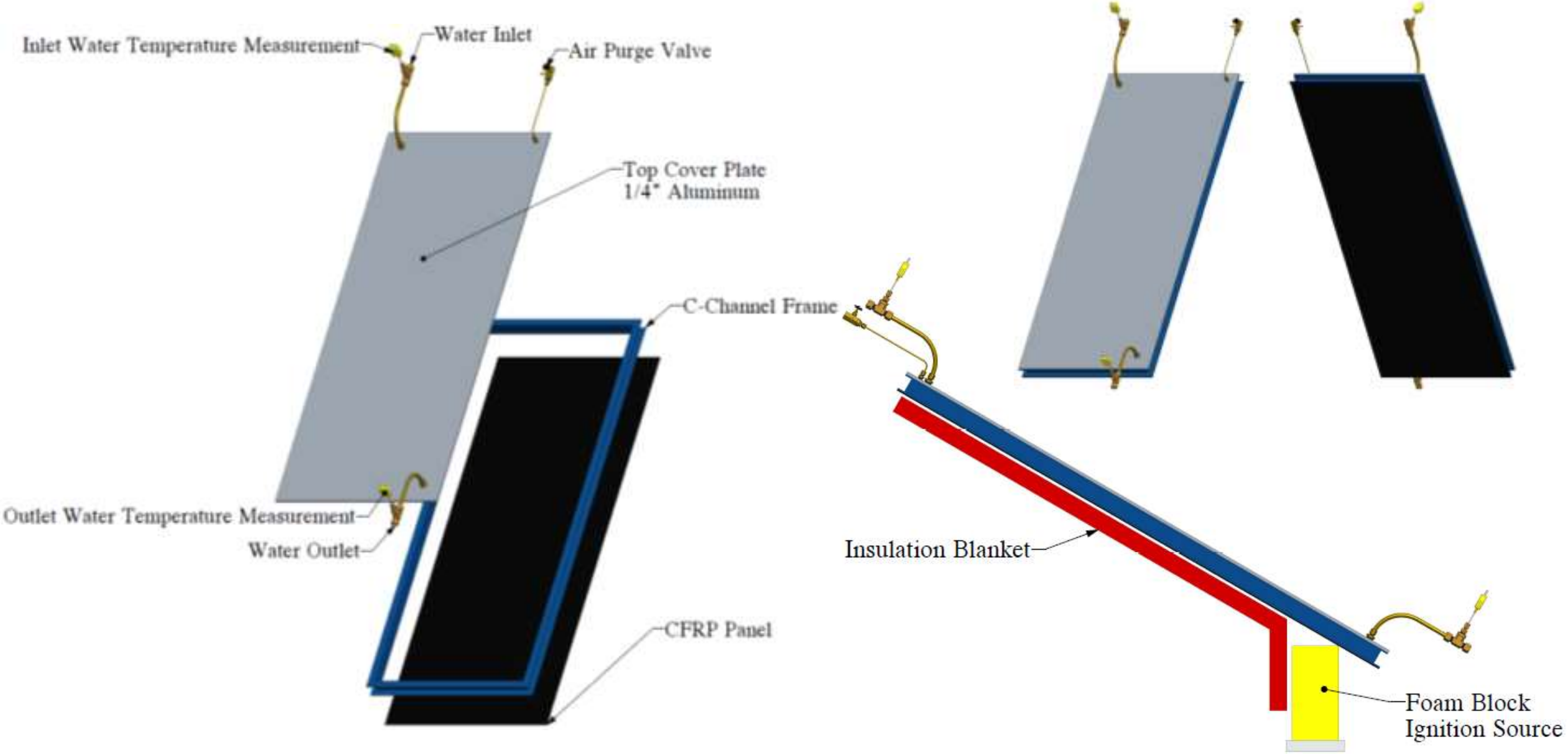
- Large scale CFRP skin and structure test fixture
- Study propagation of fire from bay-to-bay with and without cooling

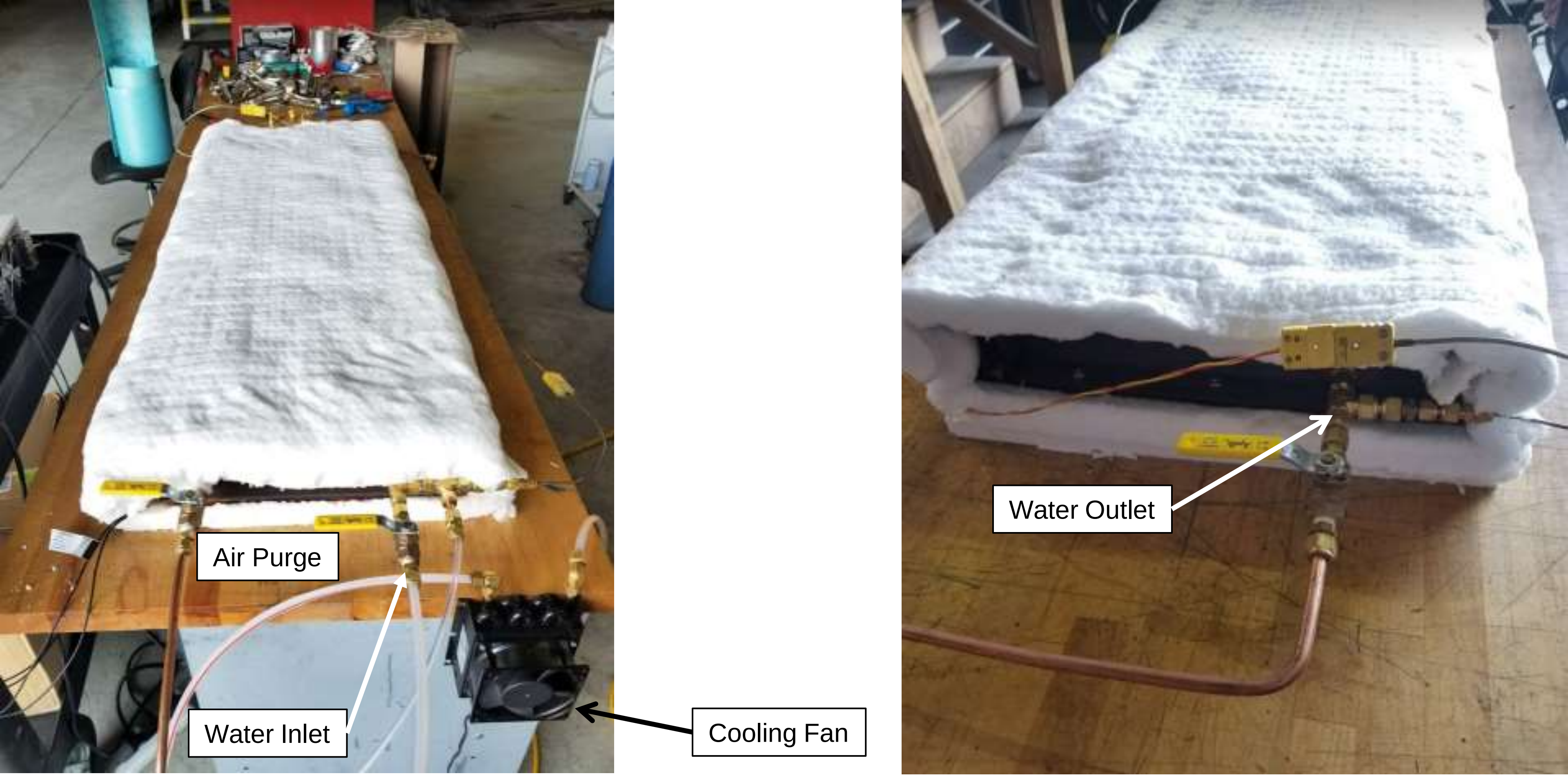
CFRP Structure Tests

Simulated CFRP Aircraft Structure



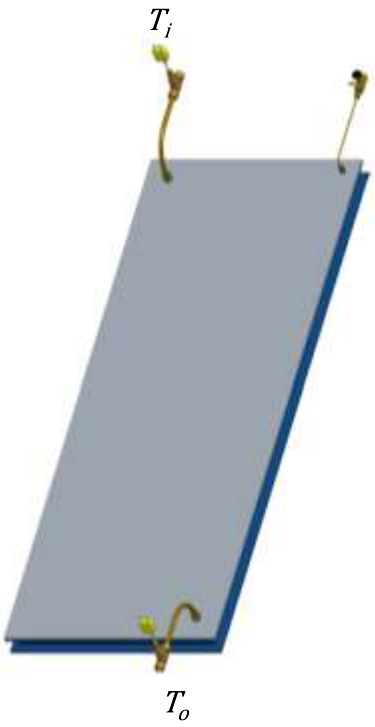



Inlet Water Temperature Measurement
Water Inlet
Air Purge Valve
Top Cover Plate
1/4" Aluminum
C-Channel Frame
Outlet Water Temperature Measurement
Water Outlet
CFRP Panel
Insulation Blanket
Foam Block
Ignition Source

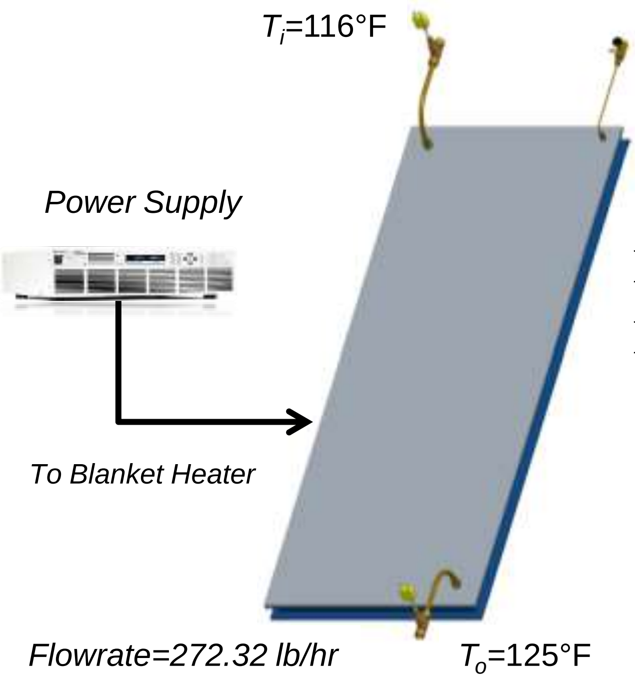

Air Purge
Water Inlet
Cooling Fan
Water Outlet

Heat Transfer Calculation

- Energy required for water heating
  - $Q = mc_p\Delta T$
    - Q is heat, BTU
    - m is mass of water heated, lb.
    - c_p is heat capacity of water, $1\,\frac{BTU}{lb\ °F}$
    - ΔT is temperature difference, °F
- Heat Flux $Q'' = \frac{Q}{At}$
  - Q'' is heat flux, $\frac{BTU}{ft^2 s}$
  - A is area, ft^2
  - t is time, sec



Outlet Temp [°F]	Inlet Temp [°F]	ΔT [°F]	Flowrate [mL/min]	Flowrate [GPH]	Flowrate [lb/hr]	Q [BTU/hr]	Q'' [BTU/ft2s]	Q'' [W/m2]
125	116	9	2070.00	32.81	272.32	2477.25	0.15	1666.53



$$Q = mc_p\Delta T$$

$$Q = 272.32\frac{lb}{hr} \times 1\frac{BTU}{lb°F} \times (125°F - 116°F) = 2477.25\frac{BTU}{hr}$$

$$\text{Heater Power Input} = 843 \text{ Watts} = 2876\frac{BTU}{hr}$$

$$\text{Heat Transfer Calculation Error} =$$

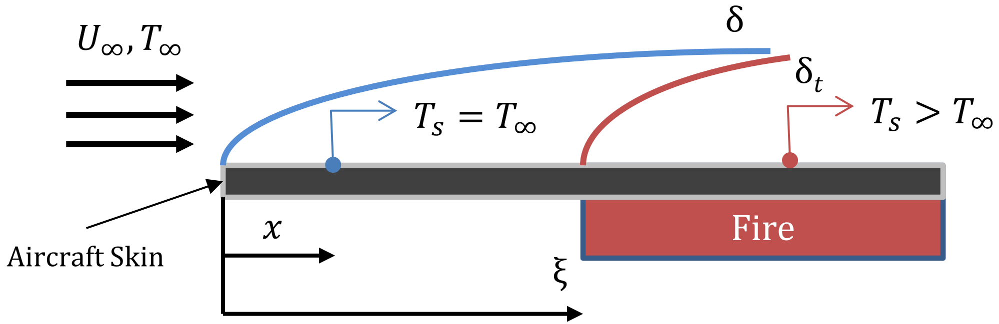
$$\frac{\left(2876\frac{BTU}{hr} - 2477\frac{BTU}{hr}\right)}{2876\frac{BTU}{hr}} = 0.14$$

- In flight conditions:
  - M=0.85
  - Velocity $U = 903 \frac{Km}{hr} = 250.8 \frac{m}{s}$
  - Altitude=40,000'=12,192m
    - Density $\rho = 0.302 \frac{kg}{m^3}$
    - Dynamic Viscosity[1] $\mu = 14.27 \times 10^{-6} Pa \cdot s = \left(\frac{N}{m^2}\right) \cdot s = \left(\frac{\frac{kg \cdot m}{s^2}}{m^2}\right) \cdot s = 14.27 \times 10^{-6} \frac{kg}{m \cdot s}$
    - Temperature $T = -69.7°\text{F} = 216.65K$
    - Pressure $P = 2.72\ psi = 18{,}753.9\ \frac{N}{m^2}$
- Reynolds Number $Re = \frac{\rho U \delta}{\mu}$
  - Characteristic Length $\delta = 62m$ (fuselage length)
  - $Re = \frac{0.302 \frac{kg}{m^3} \cdot 250.8 \frac{m}{s} \cdot 62m}{14.27 \times 10^{-6} \frac{kg}{m \cdot s}} = 3.29 \times 10^8$

- $Nu = \frac{hx}{k}$
  - Thermal Conductivity[1]
    - $k \approx 0.01965\ \frac{W}{m \cdot K}$
- $Pr = \frac{\nu}{\alpha} = \frac{\mu C_p}{k}$
  - Dynamic Viscosity[1]
    - $\mu = 14.27 \times 10^{-6} Pa \cdot s = \left(\frac{N}{m^2}\right) \cdot s = \left(\frac{\frac{kg \cdot m}{s^2}}{m^2}\right) \cdot s = 14.27 \times 10^{-6} \frac{kg}{m \cdot s}$
  - Specific Heat Capacity
    - $c_p = 1.005 \frac{kJ}{kg \cdot K}$
  - Thermal Conductivity[1]
    - $k = 0.01965\ \frac{W}{m \cdot K}$
- $Pr = \frac{\nu}{\alpha} = \frac{\mu C_p}{k} = \frac{14.27 \times 10^{-6} \frac{kg}{m \cdot s} \cdot 1005 \frac{J}{kg \cdot K}}{0.01965 \frac{W}{m \cdot K}} = 0.72984$

[1] Viscosity and Thermal Conductivity of Dry Air in the Gaseous Phase
K. Kadoya, N. Matsunaga, A. Nagashima, J. Phys. Chem. Ref. Data, Vol. 14, No. 4, 1985

Flat Plate in Parallel Flow with Unheated Starting Length



- Uniform surface heat flux, turbulent flow, unheated starting length
  - $Nu_x = 0.0308 \cdot {Re_x}^{4/5} \cdot Pr^{1/3}, 0.6 \lesssim Pr \lesssim 60$

    $$Nu_x = \frac{hx}{k} = 0.0308 \cdot {Re_x}^{4/5} \cdot Pr^{\frac{1}{3}}$$

    $$h = \frac{1}{62\ m} \cdot 0.01965\ \frac{W}{m \cdot K} \cdot 0.0308 \cdot (3.29 \times 10^8)^{\frac{4}{5}} \cdot (0.72984)^{\frac{1}{3}}$$

    $$h = 57.24\ \frac{W}{m^2 K}$$

  - $q'' = h(T_s - T_\infty) = 57.24 \frac{W}{m^2 K} \times (T_s - T_\infty) K = \frac{W}{m^2}$

Ambient air temperature of -70°F (216K)
Need outside surface temperature

~500°F (533K) – observed during CFRP burn tests with FLIR
70°F (294K) – inside cabin temperature

$$q'' = 57.24\frac{W}{m^2K} \times (T_s - 216)K$$

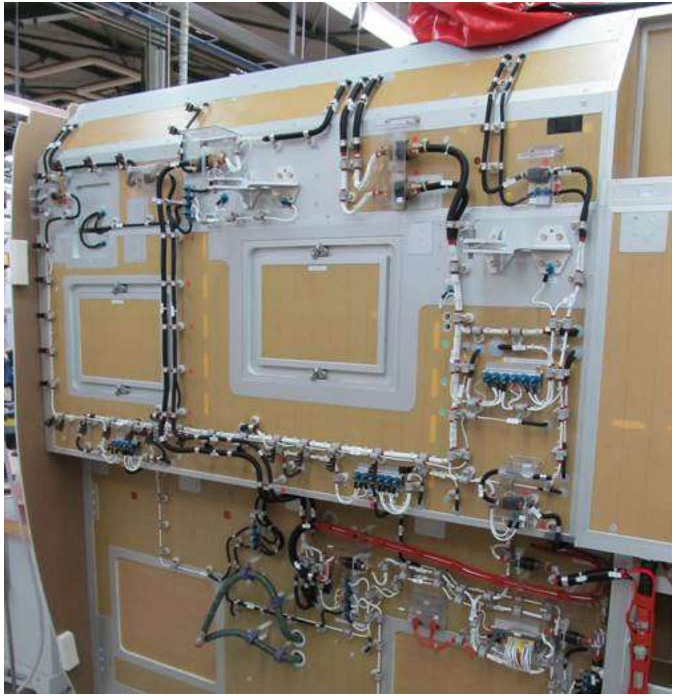
For T_s of 500°F (533K), q''=18,145 W/m^2
For T_s of 70°F (294K), q''=4,464 W/m^2

Heat Transfer Rig Only Reaches q''=1,666 W/m^2
With current configuration
Corresponds to a T_s of 245K=-18.67°F

Next Steps

- Continue testing on heat transfer apparatus
- Perform burn test with set external heat transfer rate
- If successful, scale up to large panel

Inaccessible Area Wire Task Group



Inaccessible Area Wire Task Group

- Task group will meet to discuss examples of design configurations of small or non-extensively used wires
- These wires, if determined to be non-extensively used, would not pose a significant flame propagation threat

- For Instance
  - A wire insulation material that is used in small quantities or short lengths in an inaccessible area of the airplane
  - It might be considered a “small part” and could potentially not be required to meet VFP
  - That same wire insulation material is not used extensively anywhere else in the airplane





Contact:
Robert I. Ochs
Fire Safety Branch
William J. Hughes Technical Center
ANG-E212; Bldg 287
Atlantic City, NJ 08405
T 609 485 4651
E robert.ochs@faa.gov

Federal Aviation Administration