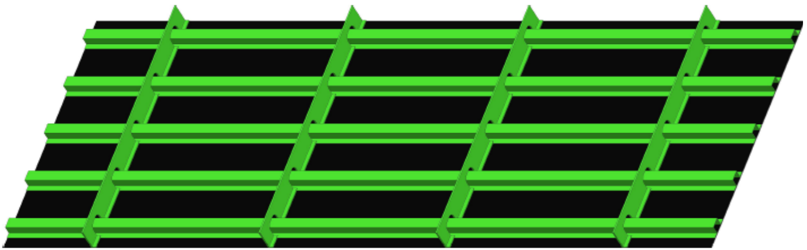
Inaccessible Area Fire Tests on Composite Structure - Update

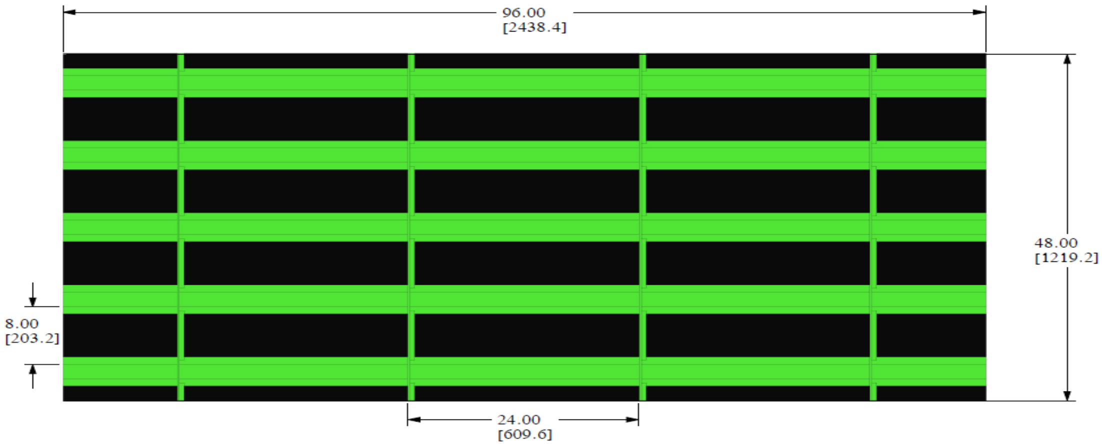
Presented to: IAMFTWG

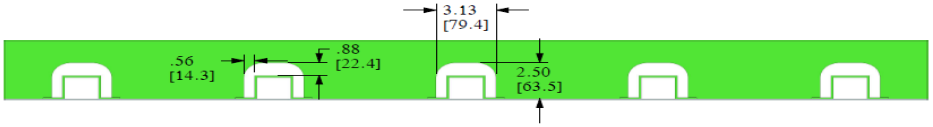
By: Robert I Ochs

Date: March 7 2017

Large Scale CFRP Skin & Structure Tests

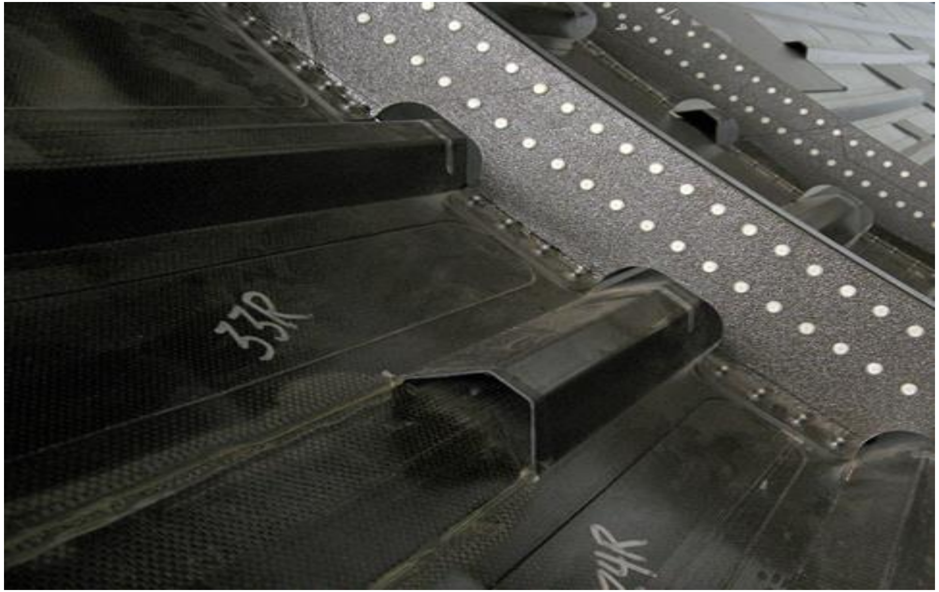


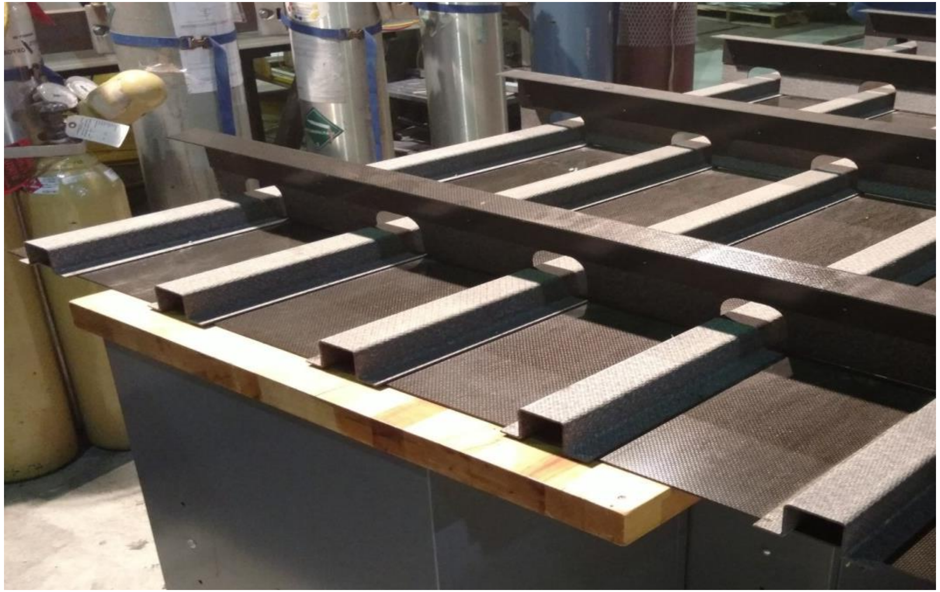




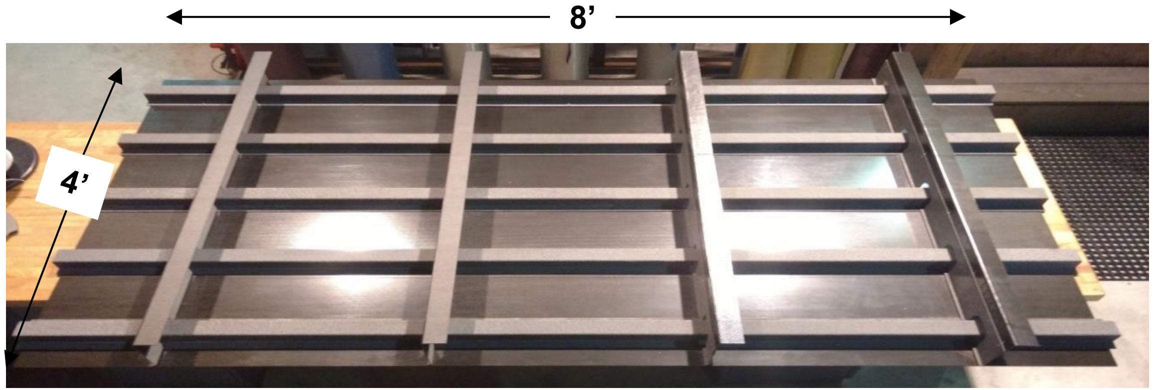
- Large scale CFRP skin and structure test fixture
- Study propagation of fire from bay-to-bay with and without cooling

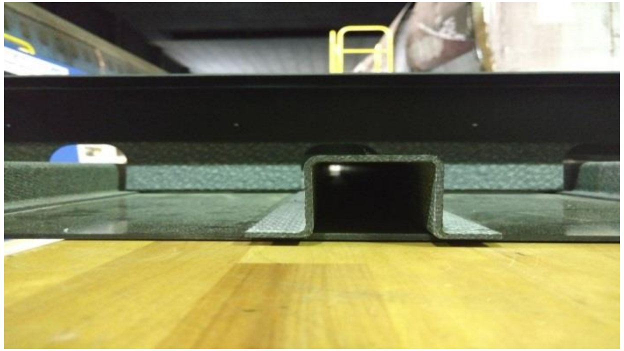
CFRP Structure Tests

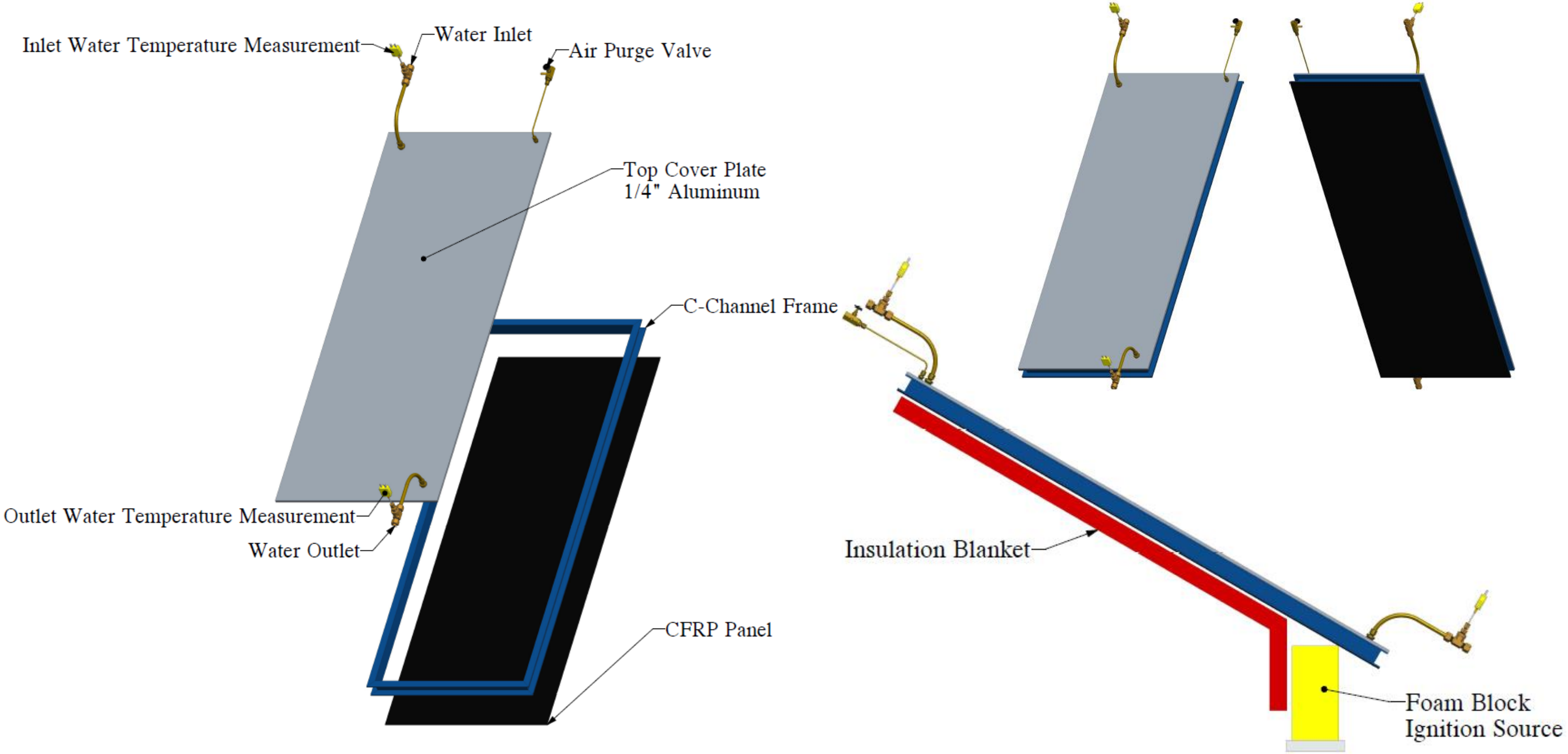




Simulated CFRP Aircraft Structure

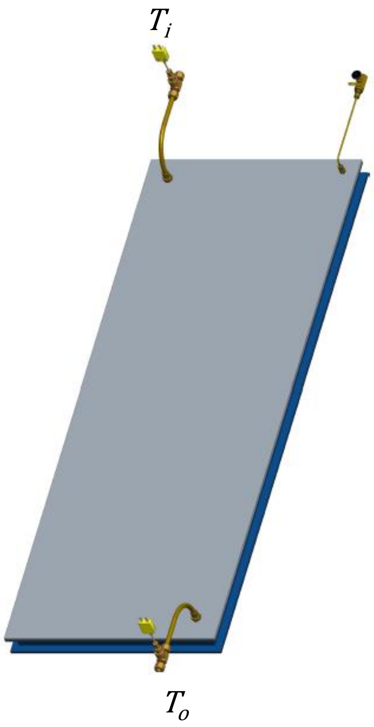





Inlet Water Temperature Measurement
Water Inlet
Air Purge Valve
Top Cover Plate
1/4" Aluminum
C-Channel Frame
Outlet Water Temperature Measurement
Water Outlet
CFRP Panel
Insulation Blanket
Foam Block
Ignition Source

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

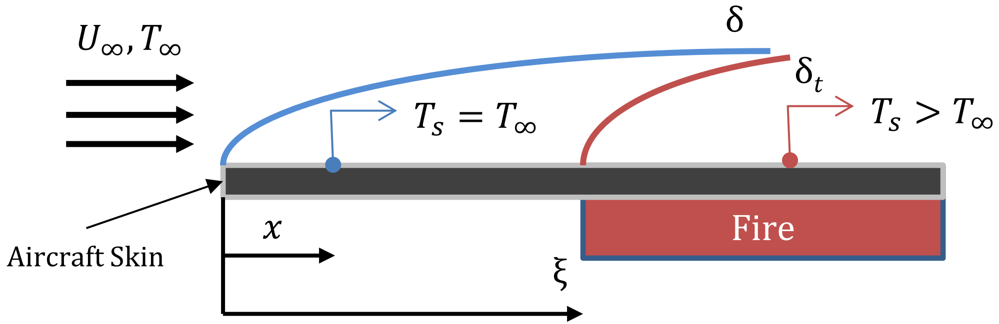


- In flight conditions:
  - M=0.85
  - Velocity $U = 903\,\frac{Km}{hr} = 250.8\,\frac{m}{s}$
  - Altitude=40,000'=12,192m
    - Density $\rho = 0.302\,\frac{kg}{m^3}$
    - Dynamic Viscosity[1] $\mu = 14.27 \times 10^{-6} Pa \cdot s = \left(\frac{N}{m^2}\right) \cdot s = \left(\frac{\frac{kg \cdot m}{s^2}}{m^2}\right) \cdot s = 14.27 \times 10^{-6}\,\frac{kg}{m \cdot s}$
    - 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
  - $Nu_x = 0.0308 \cdot Re_x{}^{4/5} \cdot Pr^{1/3}, 0.6 \lesssim Pr \lesssim 60$

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

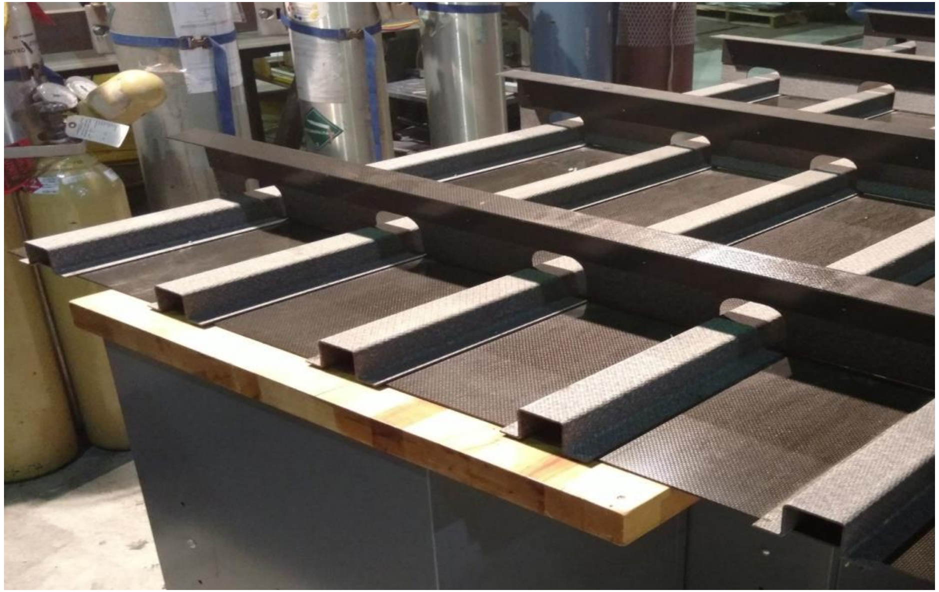
$$h = \frac{1}{62\ m} \cdot 0.01965\ \frac{W}{m \cdot K} \cdot 0.0308 \cdot (3.29 \times 10^8)^{\frac{4}{5}} \cdot (0.72984)^{\frac{1}{3}}$$

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

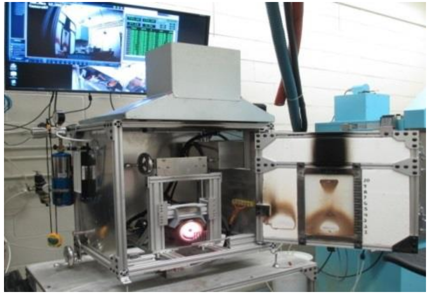
  - $q'' = h(T_s - T_\infty) = 57.24 \frac{W}{m^2 K} \times (T_s - T_\infty) K = \frac{W}{m^2}$

Next Steps

- Begin construction of heat transfer apparatus
- Test theory on small panels first
- If successful, scale up to large panel







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