Small-Scale Spacecraft Composite Curing Oven

CESIUMASTRO SPACE & DEFENSE SYSTEMS

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DESIGN CENTER COLORADO

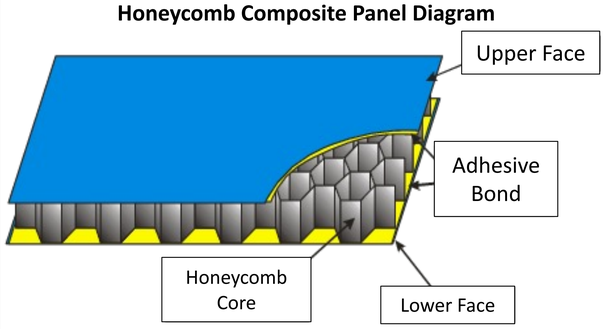
Background & Motivation

- CesiumAstro aims to complete in-house manufacturing of satellite parts
- Spacecraft applications rely on composite materials for their beneficial mechanical properties
- Manufacturing composites requires high-temp, dynamic, and expensive curing in industrial ovens
- The Small-Scale Spacecraft Composite Curing Oven affordably tackles these challenges

Composites

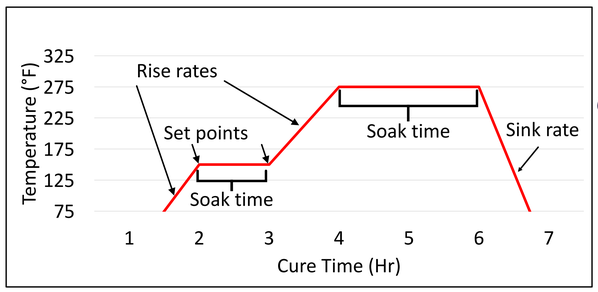
- Key use cases: **satellites**, rocket panel fairings, and solar panels

Honeycomb Composite Panel Diagram



- 2+ materials with different physical properties
- Bound chemically and mechanically by adhesives or **epoxy resins (pre-impregnated)**
- Honeycomb sandwich panels
  - **Lightweight** alternative to metal alloys

Example Composite Curing Profile



- Cure profiles are material and size specific
- Duration: **Few hours to a few days**

Mission Critical Specifications

- Max curing temperature: **350°F**
- Max curing temperature distribution: **±5°F** across heated area
- Max temperature rise/cool rates: **2°F/min**
- Max exterior surface temperature: **<140°F**
- Max oven footprint: **5’ x 5’**

Design Overview

3 Ventilation Ports + Vacuum

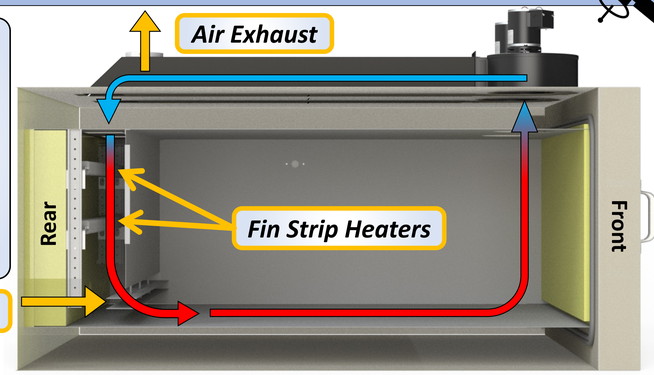
- Top exhaust ports: air expelled from the oven chamber to maintain temperature
- Rear intake port (w/valve): inlet to regulate chamber airflow
- Vacuum port: removes air voids and increases the fiber-to-epoxy ratio

General Information

- Overall Dimensions: 5’ x 4’ x 2’4”
- Weight: 700lbs
- Power: 7,418W
- Cost: **$5,900**; Comparable ovens start at $15,000

HVAC & Airflow

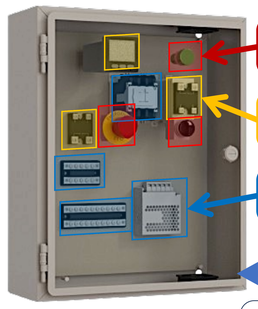
- Single zone heating
- 2x **3450W** rear mounted fin strip heaters
- 2x **300CFM** dorsal mounted blowers

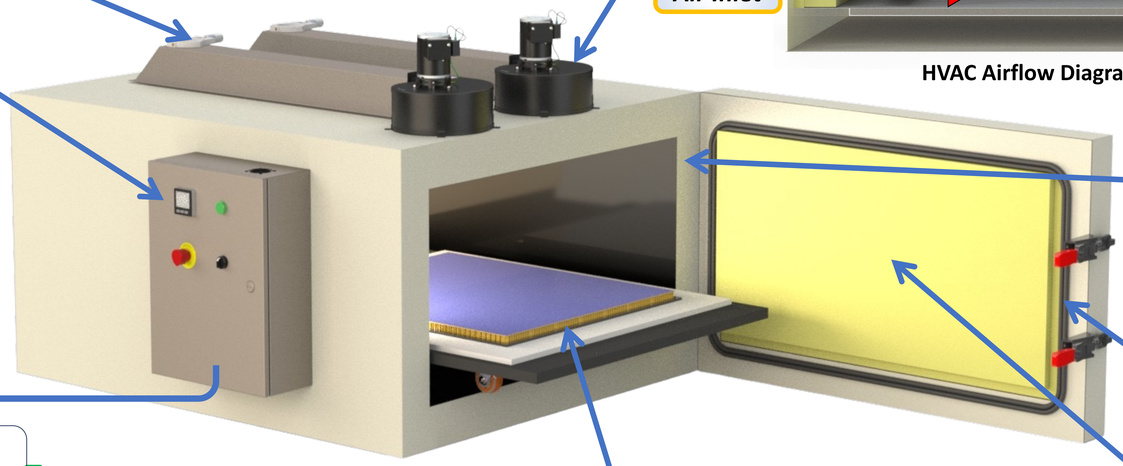


HVAC Airflow Diagram Cross Section

Control Panel

- Operates up to 35.7A @ 240V
- Air-Cooled with emergency stop





Panels

- 17x22 gauge (0.03”) 304 stainless steel

Door

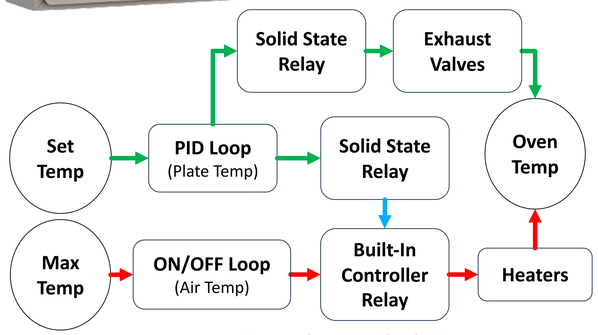
- 2x piano hinge mounted
- 2x compression seal and latch

Insulation

- 4” thick Rockwool
- Combined **R = 16**

Frame

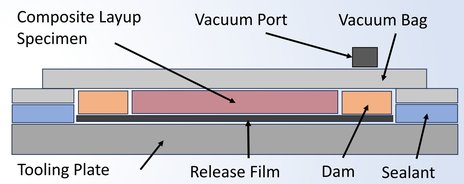
- A500/513 Mild steel
- MIG welded
- Anti-corrosion finish



Temperature Control Loop Block Diagram

Inner Chamber (W/Tooling Plate)

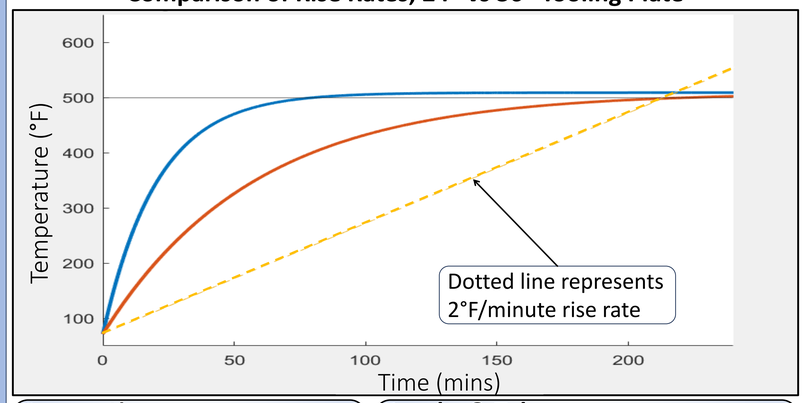
- Chamber Dimensions: 52” x 40” x 20”
- Structural I-beams provide support for tooling plate during transport and use
- Tooling plate ensures flatness for precise composite material placement inside heating chamber



Vacuum Bag Composite Layup Diagram

Design Analysis

Comparison of Rise Rates; 24” vs 36” Tooling Plate



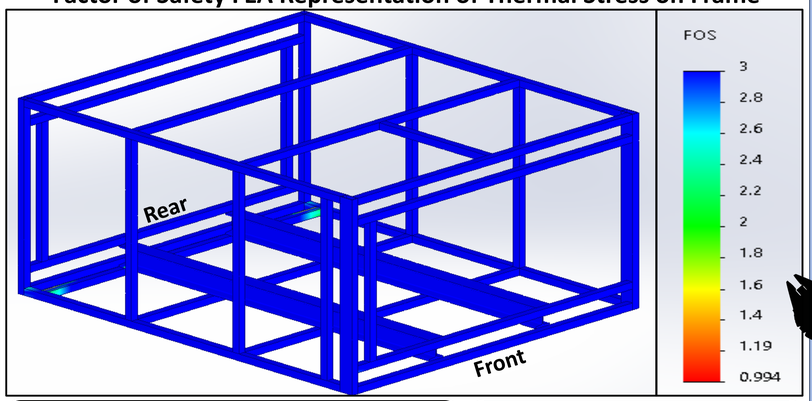
Assumptions

- Uniform, laminar flow over plate
- Biot # calculated **<<0.1** ∴ LC valid
- LC temp profile drives power calc

Results & Takeaways

- 36” long supports more curable material
- 24” long reaches target temps quicker
- Plate spec does not inhibit oven abilities

Factor of Safety FEA Representation of Thermal Stress on Frame



Assumptions

- I-Beams "see" 350°F interior temperature conducting to frame
- Convecting to 72°F ambient temp

Results & Takeaways

- Lowest frame FOS: 2.0 at rear crossmember supports
- Fatigue life est. >10k cycles

Future Work & Testing

- Conduct PID temperature calibration tests
  - Includes: max internal, distribution, and external temperatures
- Simulate cures with pre-preg composite payloads
- Develop material handling system

Special Thanks

Rock West Composites

NoCo Waterjet