BAO3000

Bonded Assembly Oven - 3000FT^3

Furnace for Final Cure of BETA Technologies Bonded Aircraft Structures Per AMS2750

Disclaimer:

This modified slide deck has been approved for distribution outside of BETA Technologies
All internal links are broken and some images have been removed

Contents

Contents

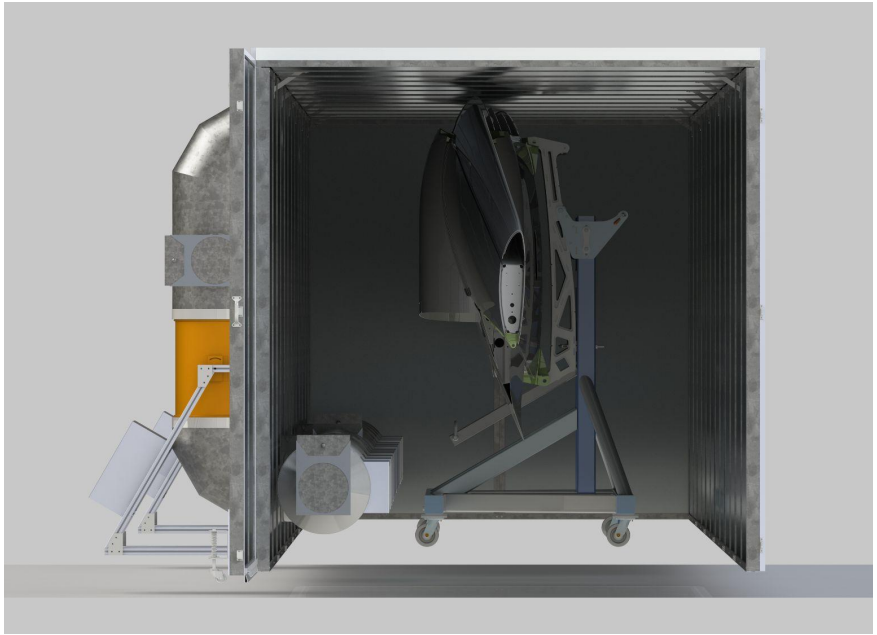
BAO3000

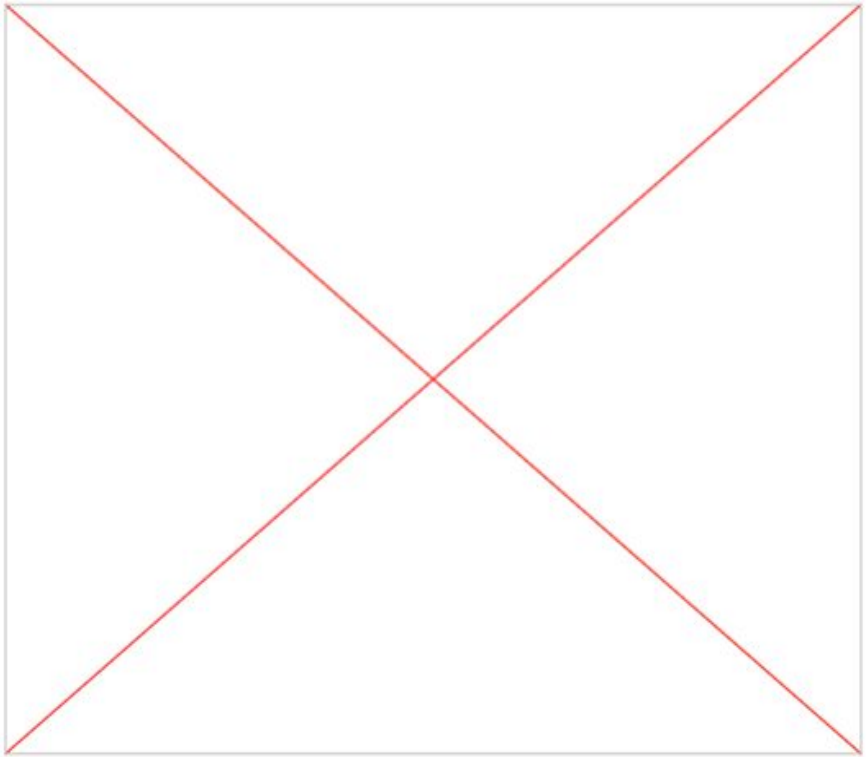
Requirements

Bonded wing utilizes_____which shall be cured per BTPS 45-003:

Designed specifically for the final curing of BETA's Bonded Wing, but is capable of heating any aircraft components to 200+°F

Needed to be able to certify as a Class 2 Type D Furnace Per AMS2750





Dimensions and Characteristics (Overview)

Dimensions

External: 48.9 ft Length, 11.2 ft Width, 8.3 ft Height

Internal: 48.2 ft Length, 7.6 ft Width, 8.1 ft Height

Volume: Internal - 2961 ft^3, Working Area - 2226 ft^3

Heating

Power: 60kW 3 Phase 480V Electrical (2x modified 30kW Resistive Electric Salamander Heaters)

Air flow: 6,200 CFM (3,100 CFM per Heater)

Control

Multifunction Data Acquisition and Control unit: Opto22 Groov EPIC System

Background PID and data loops with Part and Oven mounted K-type thermocouple and user inputs, SCR output

CAD Models

Full Assembly K011320, Structure Assembly A011319, all other Parts and Assemblies Nested

Certification Per AMS2750

3 testing phases must be completed to certify an oven under AMS2750:

- TUS (Temperature Uniformity Survey)
- SAT (System Accuracy Test)
- Instrumentation Accuracy Test (Calibration of Thermocouple Wires)

Cures per BTPS 45-003 must be done in accordance with AMS2750 Class 2 Type D furnace requirements, with different calibration frequencies. This oven must meet the requirements laid out in BTRS 501 which expresses the requirement for AMS2750 compliance with BETA's own calibration schedule

TUS heating requirements to pass AMS2750 as a Class 2 Type D furnace (±10°F tolerance):

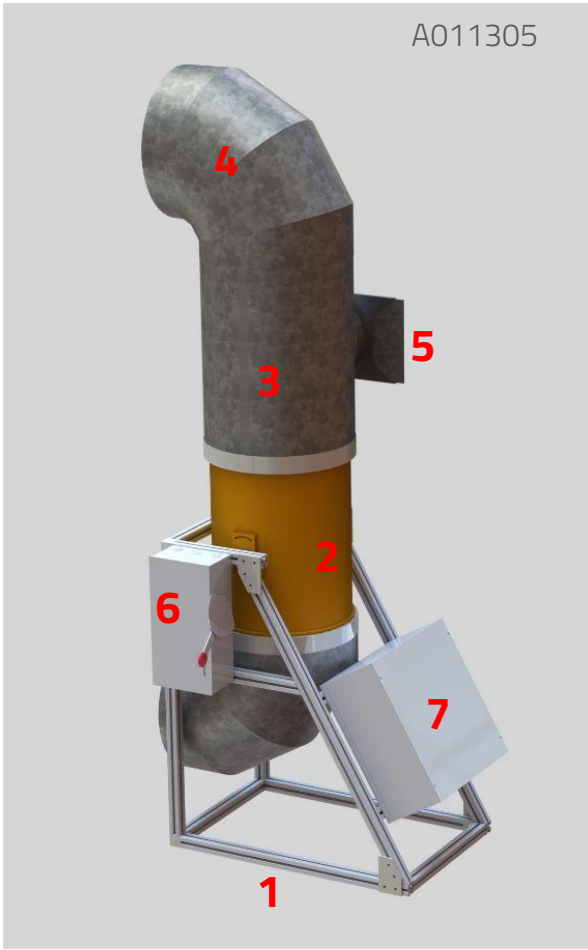
- Furnace must start at entirely room temperature
- During the ramp phase temperature may leave the required maximum range
- At the end of the ramp phase no TC may exceed the upper TUS tolerance limit
- Once temperatures have stabilized, the 30 minute data collection window commences in which no TC may go above OR below the tolerance limit
- Ramping from the coldest TUS temperature to a higher TUS temperature is permitted, but again no TC may exceed the upper TUS tolerance limit during ramp

BA03000

Significant Assemblies

External Heating Structures- A011305

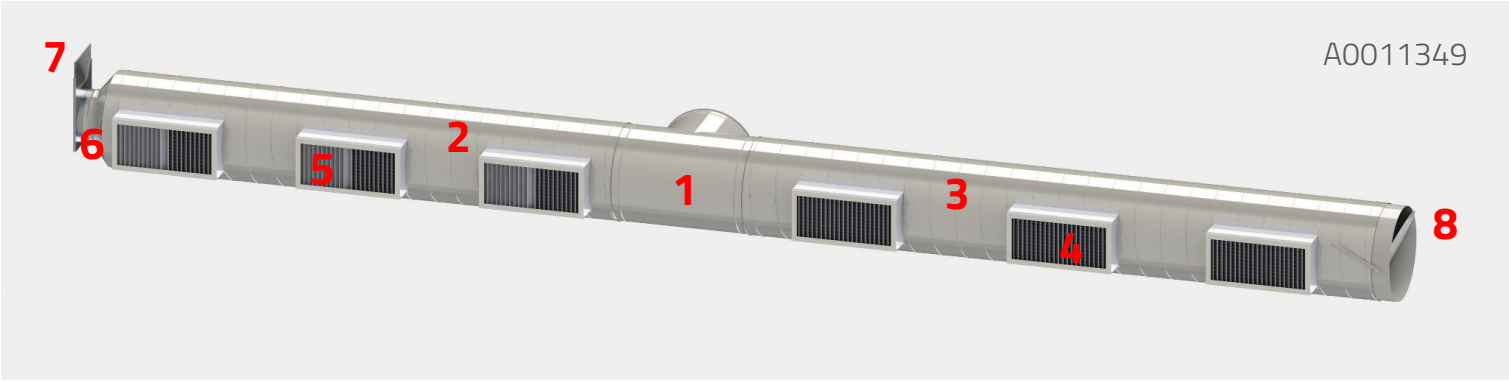
- 80-20 Structural Frame **1**
- 30kW Dayton 784JJ2A Salamander Heater **2**
  - Internal contactors removed
- Straight Duct D18" x 24" **3**
- 2x 90 degree D18" **4**
- Blast Gate **5**
- Single Throw Electrical Disconnect **6**
- Junction Box **7**
  - 1x 3 phase SCRs for variable voltage control



Significant Assemblies

Internal Ducting Trunks - A011349 & A011355

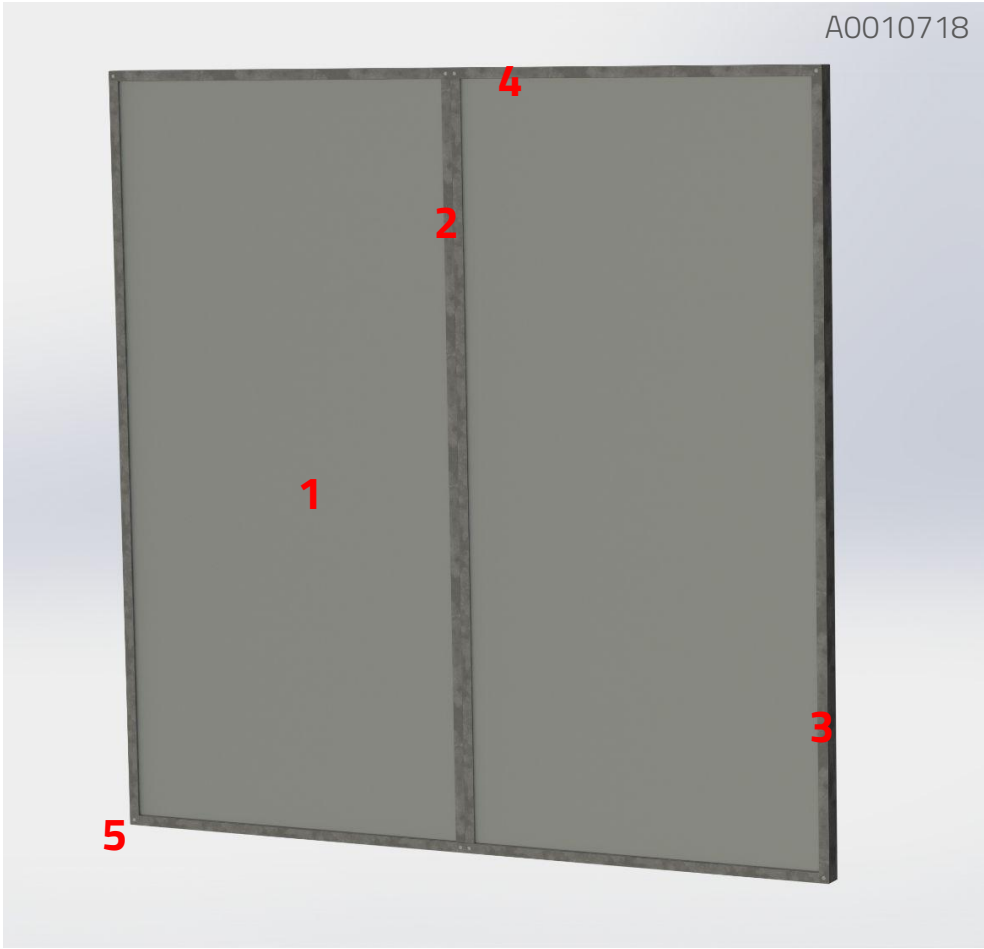
- Ducting Tee **1**
- 8’ D18” Straight Duct **2**
- 10’ D18” Straight Duct **3**
- 3x 10”x20” Louvered Registers (Angled outwards) **4**
- 3x 10”x20” Louvered Registers (Split - Angled Both Ways) **5**
- Straight Reducer (A011349 x2, A011355 x1) **6**
- Blast Gate (A011349 x2, A011355 x1) **7**
- Airflow Damper (A011349 x1) **8**



Significant Assemblies

Wall Panels - A010718 (20 of these consist of the entire oven wall structure)

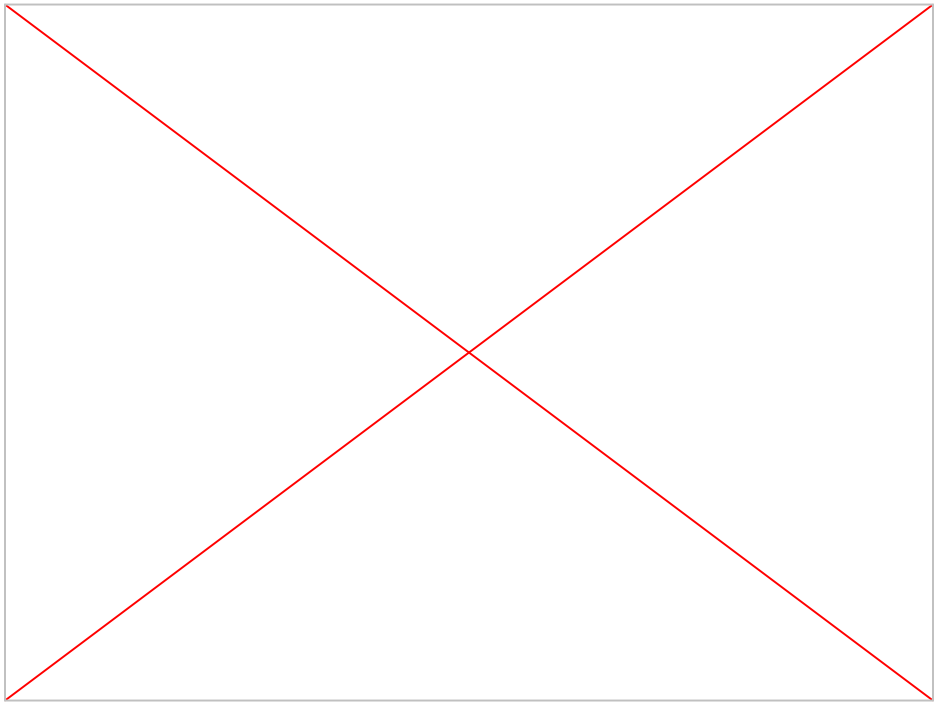
- 2x 2" Thick 48"x96" PolyIsocyanurate Panels **1**
- 6x 8' ProStud Steel Studs **2**
- 2x 8' ProTrack Steel Tracks **3**
- 2x 8' ProTrack Steel Tracks (Snipped) **4**
- 16x ½" Lath Screws **5**



Significant Assemblies

Wall Panels Continued - Construction

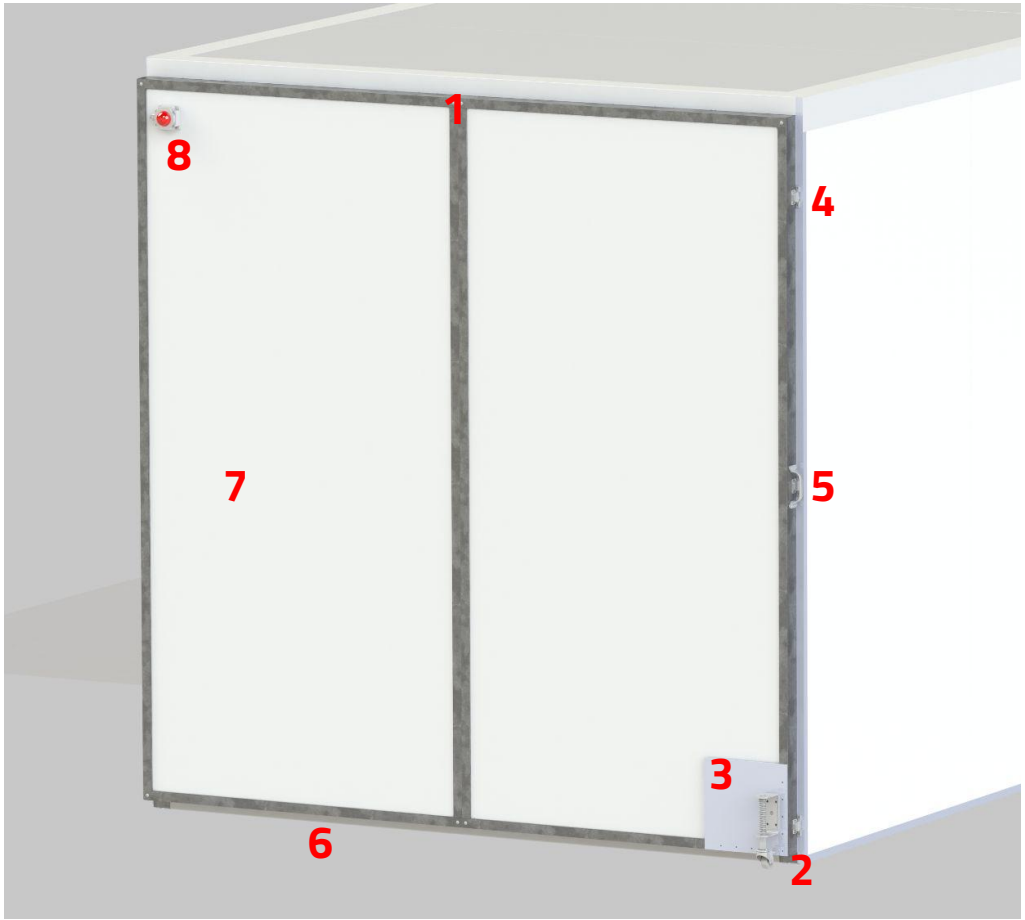
1. ProStud steel studs are attached to the long sides of each of the two Polyisocyanurate panels
2. The two panels are layed next to each other along their long sides
3. Snipped ProStud steel studs are laid along the uncovered sides of the two panels
4. ProTrack steel tracks are laid along the left and right sides of the panel
5. ProTrack steel tracks are laid along the top and bottom sides of the panel
6. ½" sheet metal lath screws are drilled into the steel tracks at each corner of the Polyisocyanurate panels



Significant Assemblies

Door - Part of A011319 and K011320

- Wall Panel **1**
- Swivel Castor Wheel **2**
- Castor Wheel Mounting Plate **3**
- 3x Grab Latches **4**
- Door Handle **5**
- 8’ Heavy Duty Hinge (Not visible but on left edge)
- Bulb Weather Stripping **6**
- Gasket Tape (Not visible but around all edges)
- Sheet Plastic Exterior Panel **7**
- Operation Status Light **8**



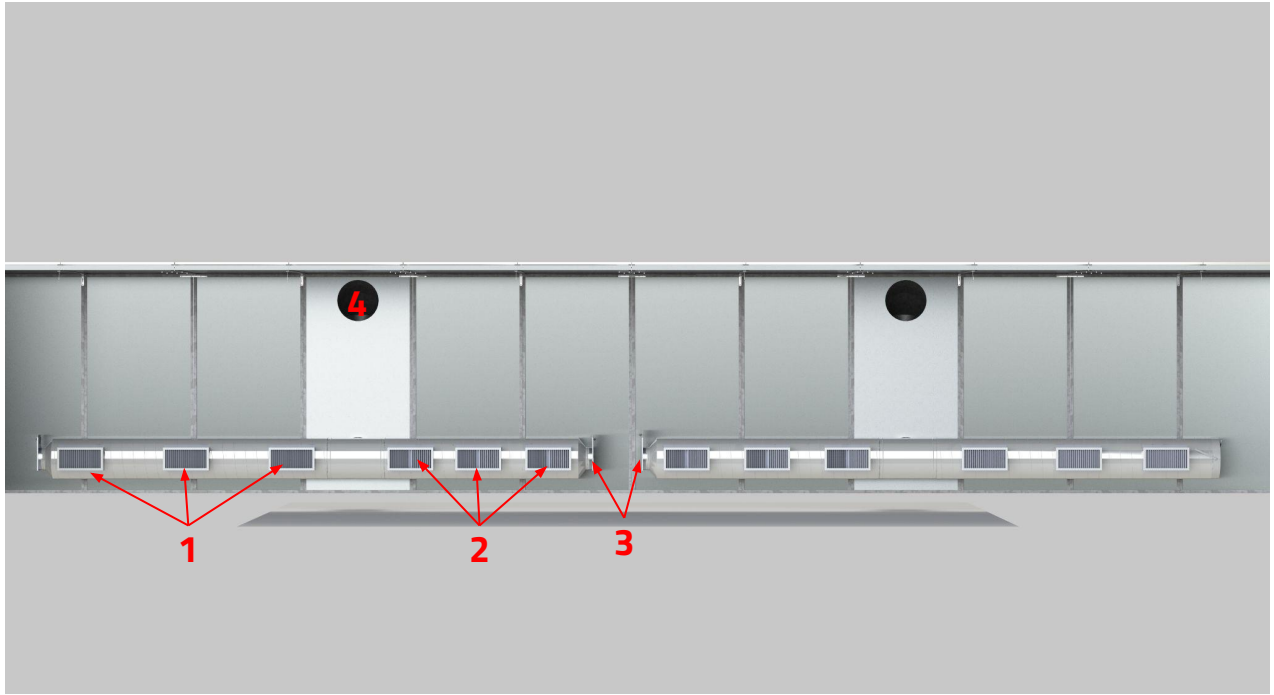
Airflow

Supply Air (Trunk Air Ducting System)

- Louvered registers forcing air towards outer reaches **1**
- Louvered registers forcing air in middle region **2**
- Blast gates and dampers (tuned to control airflow through registers) **3**

Return Air

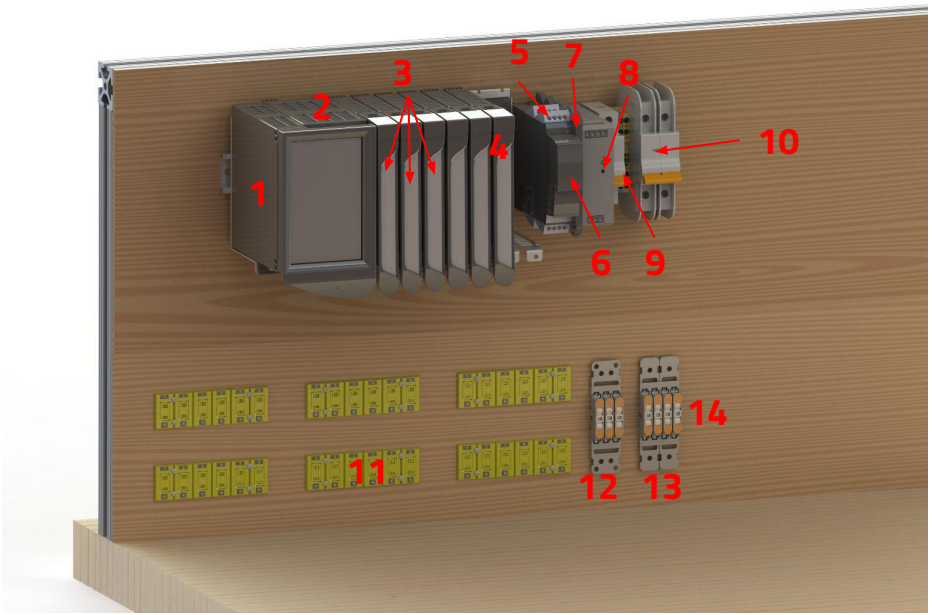
- Sucked through the open ducting holes at the center of each heating zone **4**



Controls

Control Panel

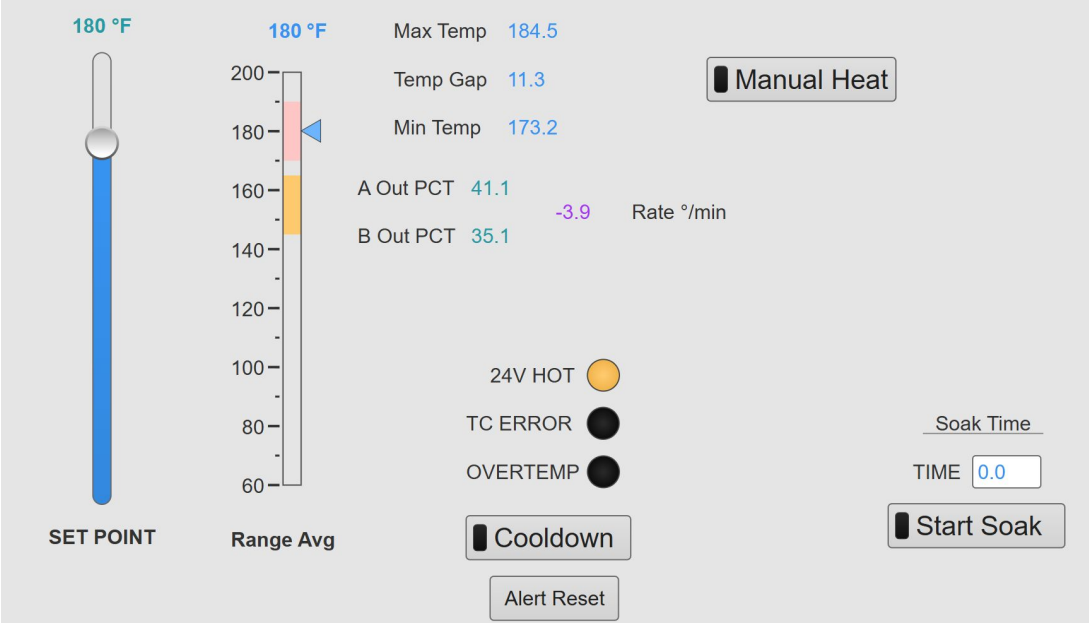
- Opto 22 Groov EPIC PR1 Processor **1**
- Opto 22 Groov EPIC Power Supply (behind touch screen) **2**
- 3x Opto 22 Groov ITM 12 Thermocouple Input Module **3**
- Opto 22 Groov Multifunction Mixed Signal Module **4**
- ProSense SCU-3100 Limit Alarm **5**
- ProSense SCU-PDM2 Programming/Display Module **6**
- ProSense SC6-1112 Signal Conditioner **7**
- Phoenix Contact 1394764 24V Power Supply **8**
- Phoenix Contact 1019919 15A Single Pole Circuit Breaker **9**
- 2 Pole Circuit Breaker **10**
- 6x Panel Mount Thermocouple Connection Strip **11**
- WAGO 221-2503 Mounting Carrier **12**
- 2x WAGO 221-2502 Mounting Carrier **13**
- 7x WAGO 221-22401 Inline Splice **14**



Controls

GROOV VIEW User Interface

- Oven operators may control the oven via this link: [BAO3000 Control Page]
  - If given an option screen, click 'Groov View'
  - Username:
  - Password:
  - *(Note: Your PC may advise that you are using an unsecure connection. Click advanced, then continue to the site)*
- Site displays relevant information regarding the current internal conditions of the oven and current percentage of available power being output to the heaters
- Provides control over the set point
- Provides alerts for Overtemp and TC errors

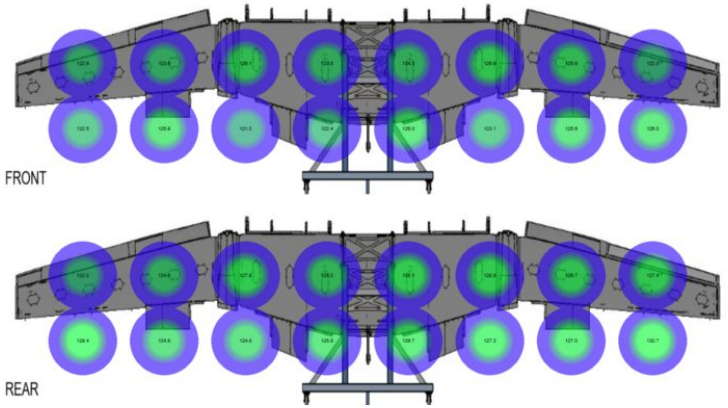


Controls

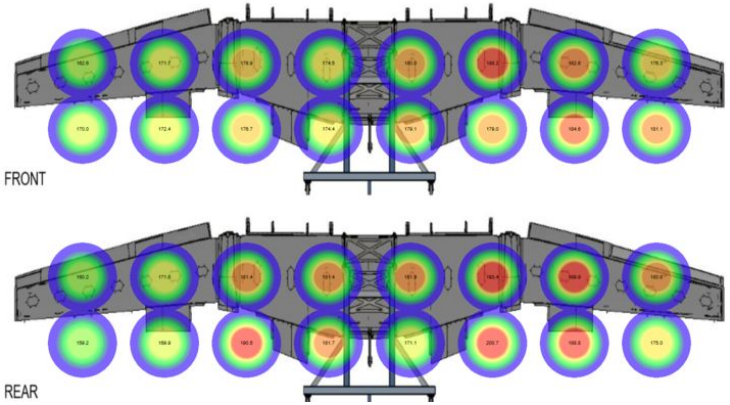
Node-Red User Interface

- Oven operators may monitor temperatures in the oven via this link: BAO3000 Monitoring Page
  - Navigate to “Heat Map” page
- Allows operator to view temperatures throughout the oven, indicating hot and cold spots
- Thermocouples indicated on this screen are oven mounted and positioned in general relation to the wing as displayed on the figures provided

Example 1 : Desired Display of Even Heating



Example 2: Problematically Uneven Heating



Controls

Temperature Sensing (Thermocouples) - Full Map Found Here

Current configuration: (Subject to change for future iterations)

- 32 K type Thermocouples mounted in orientation shown in **Figure 1** to control temperature in the oven
- 26-30 K type Thermocouples mounted in orientation shown in figures 2, 3, 4 to control time of dwell cycles (Based on minimum recorded temperature)
  - **Figure 2** TCs are mounted inside of the wing bays
  - **Figure 3** TCs were omitted on BT30Z as the components they were mounted to were not included in that build

Figure 1.

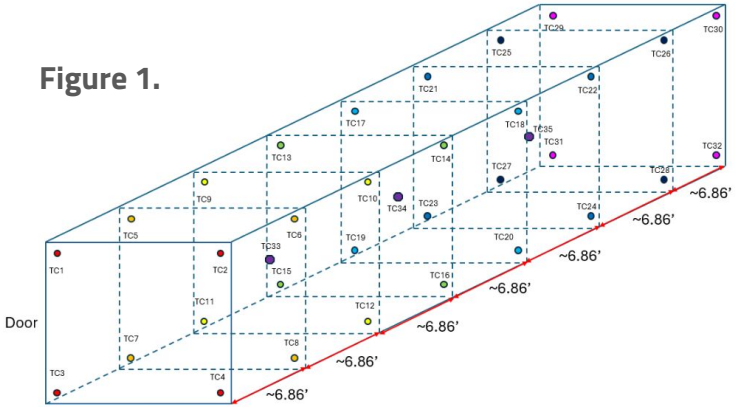


Figure 2.

Figure 3.

Figure 4.

Controls

PID Loop

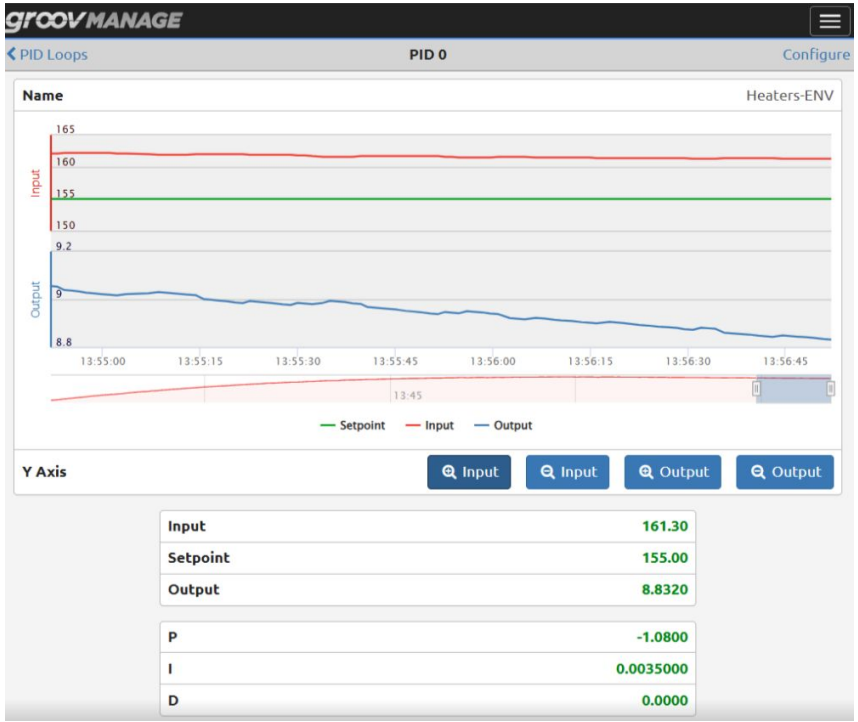
Temperature control in the oven is continuously managed by a PID loop which is checking the Setpoint vs. the Current Temperature (Input) of the oven. Based on the difference between these values, the PID loop determines the appropriate power setting of the heater and adjusts it in real time (Output).

Input - moving weighted temperature average from Oven Thermocouples (neglects 7 lowest and 2 highest)

Setpoint - user input target oven temperature

Output - value determined by the PID in mA on a 4-20 scale (maximum set by designers at 18 mA to prevent runaway heating)

By adjusting P, I, D, or Scan Time values the engineer is able to adjust ramp rates, setpoint overshoot, and temperature spread throughout the oven.



Controls

SCRs (Variable Voltage Control)

What: SCRs, or Silicon Controlled Rectifiers are solid state switching devices that allow a user to continuously control the current flowing through their system to an infinitely variable degree.

Why: By replacing the contactor coils that came stock in the heaters we were able to introduce the PID controller and more actively regulate the temperature in the oven. This decision also mitigates the risk of failure in both our heating coils and switching mechanism during a cure cycle. See link below for more details.

Full reasoning behind the use of SCRs in this system can be found **here**

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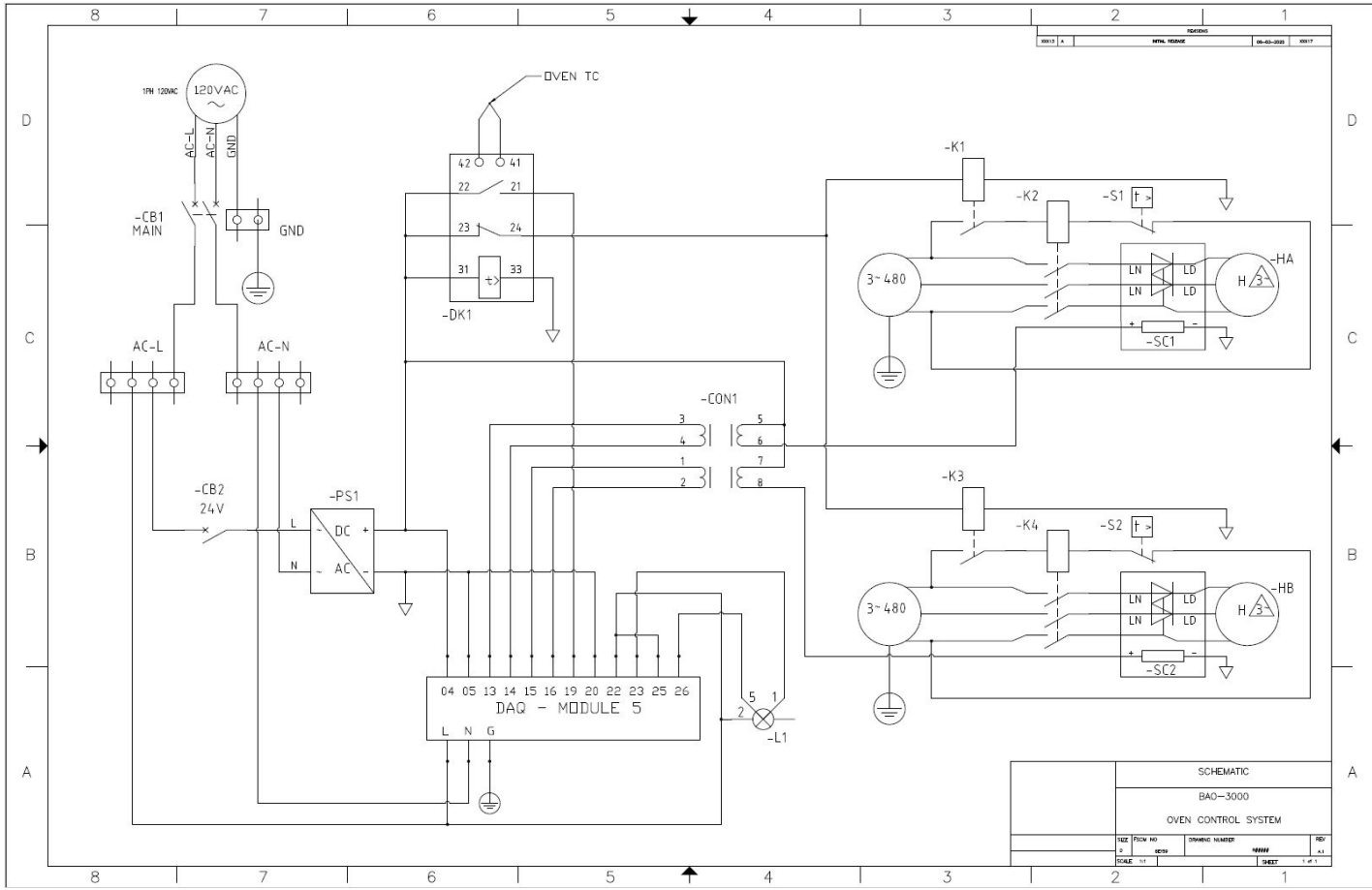
Wiring Diagram

This wiring diagram depicts all control and heating components in the system



Bill of Materials

Full BOM: Link

Significant Components/Materials that Could Need to Be Replaced or Added			
BETA Part Number	Description	Link	Cost
V011322	784JJ2A Salamander Heater (modified for use)	Grainger.com	$775.45
V010713	RMAX Pro Select 2" Thick Polyisocyanurate Panel	HomeDepot.com	$55.78
V011295/ V011296	Grab Latches (10lb strength) used for Front Door of Oven	McMaster.com	$6.67
	SCR39Z-48-040 DwyerOmega SCR Power Controller	DwyerOmega.com	$1,031.23
	K type Male Thermocouple Connector	McMaster.com	$5.21
	K type Female Thermocouple Connector	McMaster.com	$6.50
	K Type Thermocouple Wire (Save 24"+ from both ends of roll for SAT)	McMaster.com	$127.00

Cost

Total Cost: $27,322.50

- **Oven Structure:** $7,286.10
- **Heating System:** $2,551.44
- **Ducting System:** $5,335.84
- **Electronics and Controls:** $12,149.12

Aesthetics: Nothing was bought for this aspect of the project as all aesthetic components were extra stock found at Plattsburgh from discarded paint booth materials

Note: All other commercially purchased alternatives that meet the requirements achieved by this oven would have cost in the range of $250,000 - $500,000 based on quotes and research done at the start of the project

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Work Instructions

Link to detailed work instructions for final wing cure can be found here: Final Curing Process of Bonded Wing

These work instructions are specifically for the Bonded Wing. As more components implement the use of this oven in production, their work instructions should be listed here:

Other Features

- Status Light
  - Mounted on front door
  - **Red** during active heating (**DO NOT ENTER**)
  - **Yellow** during cooling phase (**Caution Upon Entering**)
- Over Temperature Controller
  - Programmable shut down temperature
  - Ensures components will not reach high temperatures which could impact the cure in a negative way
  - Required to be compliant with AMS2750
- Power Dials on Heaters
  - Not connected to anything (Don't worry about them)
  - Left on the heaters after modification

IF OVER TEMP IS TRIGGERED

1. Shut down oven
2. Contact Joe Verdino, Nick Bresnahan, and Kevin Tait
3. Upon restart power cycle 24V switch

Preventative Maintenance

- Keep door closed when not in use
  - This will preserve the integrity of the hinge, door frame, and caster wheel spring
- Keep blast gates closed when unattended to ensure no FOD enters the heaters
  - Shine a light inside of the heaters and look through the blast gate (use a camera if necessary) to ensure that no FOD is present before turning on fans or heaters
- Allow fans to run during cooling phase with blast gates open until the oven temperature is below 100°F

Maintaining Certification Compliance

- SAT (System Accuracy Test): Semi Annually
- TUS (Temperature Uniformity Survey): Annually
- Calibration of Thermocouple Wires: Whenever a new roll of TC wire is used it must be sent out for Calibration (save 24”+ from start and end of TC wire roll)

Troubleshooting

Start Up

- No power to heaters
  - Check circuit breaker and ask Alan Trowell or Ian Roos if they are turned off for a reason
- TC reads cooling when TC is grasped in hand
  - TC is likely wired backwards in one of the connectors
    - Check and correct all connectors on that TC wire between TC tip and data logger

During Cure

- Wing based TC is reading low temperature
  - Check floor temperature by sliding a thermocouple under the door
    - If temperatures are comparable: remove TC channel on data logger and make note in build documentation
    - If floor temperature is significantly lower than low TC: Judgement is up to operator, likely due to poor internal airflow in wing bays and set point can be increased if it will not push any wing based TCs above the maximum allowable temperature
- TC is reading astronomically high or low temperature
  - Likely a poor connection in one of the TC connectors
    - Tug on wire at all points where it plugs in. If it slides out simply set it back in place and tighten set screws

Troubleshooting (Continued)

During Cure (Continued)

- Thermocouples on one side of the oven start reading significantly lower temperatures
  - Contact Kevin Tait to read current running through each 480V line between SCRs and heating coils
    - Could be result of burnt out heating coil or shorted SCR
- Controls page or monitoring page stop updating or do not respond to inputs
  - Check that you are plugged into ethernet cable
  - Contact IT
  - Control from oven is still possible from display screen on DAQ, contact Kevin Tait for further information on how to operate
- Anything catches fire
  - Tell someone to call 911
  - Grab a fire extinguisher
  - Spray and pray