

Ceramic/Metallic Heat Exchanger Development

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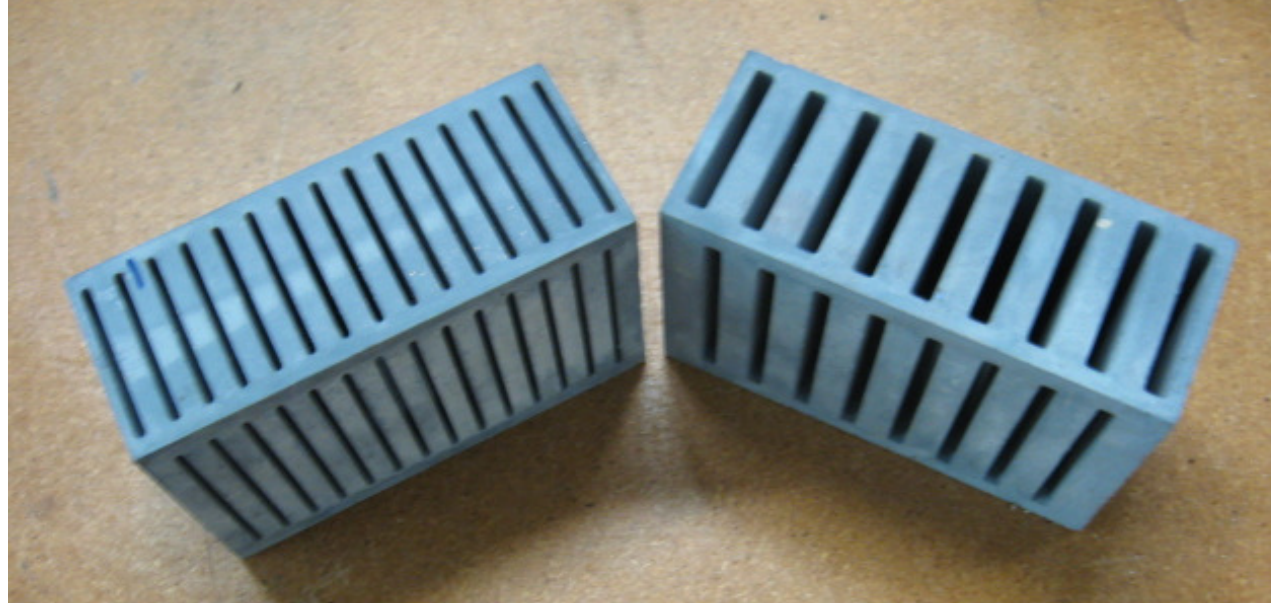
| Metallic | | Ceramic | |
|---|------------------------------------|---|-----------------|
| Advantages | Disadvantages | Advantages | Disadvantages |
| • Manufacturability • Extended Surface • Compactness • Thermal Shock | • High Cost • Fouling/Oxidation | • Low Cost Materials • High Temp Stability • Single Casting | • Thermal Shock |

Hybrid

Advantages

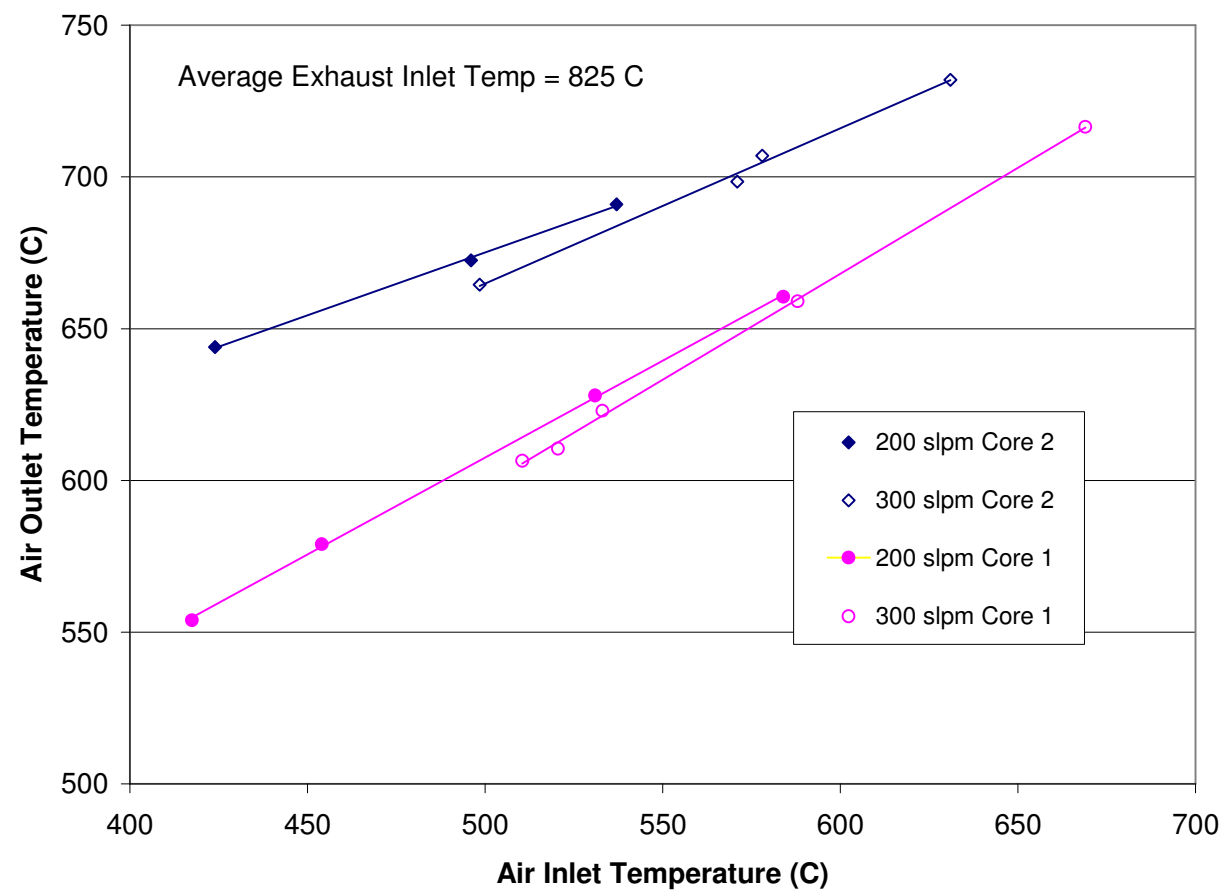
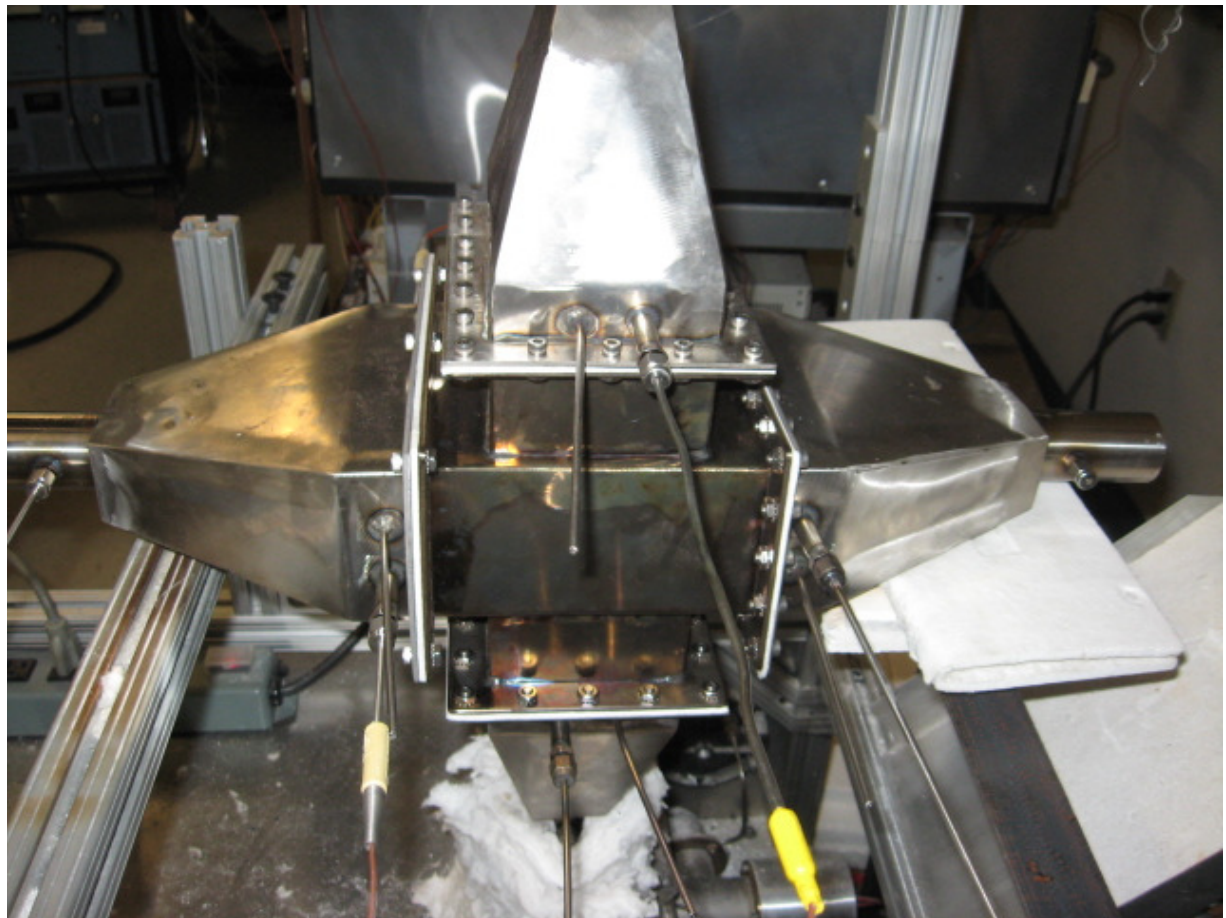
- Low Cost Materials Throughout
- Modular Manufacture
- Temperature Gradients on Ceramic are Reduced
- Materials Optimized for Temperature
- Thermal Expansion Unrestrained

Ceramic Cores Manufactured by Blasch Precision Ceramics



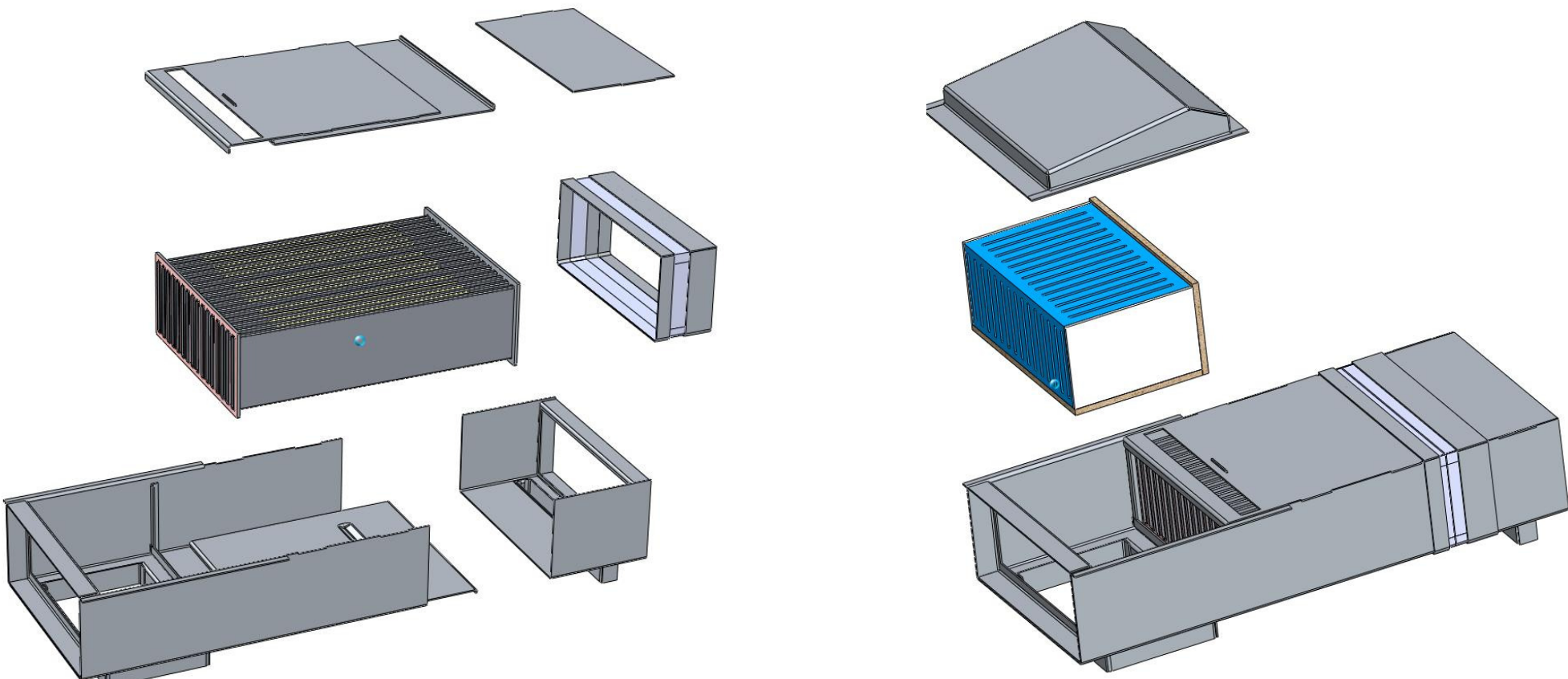
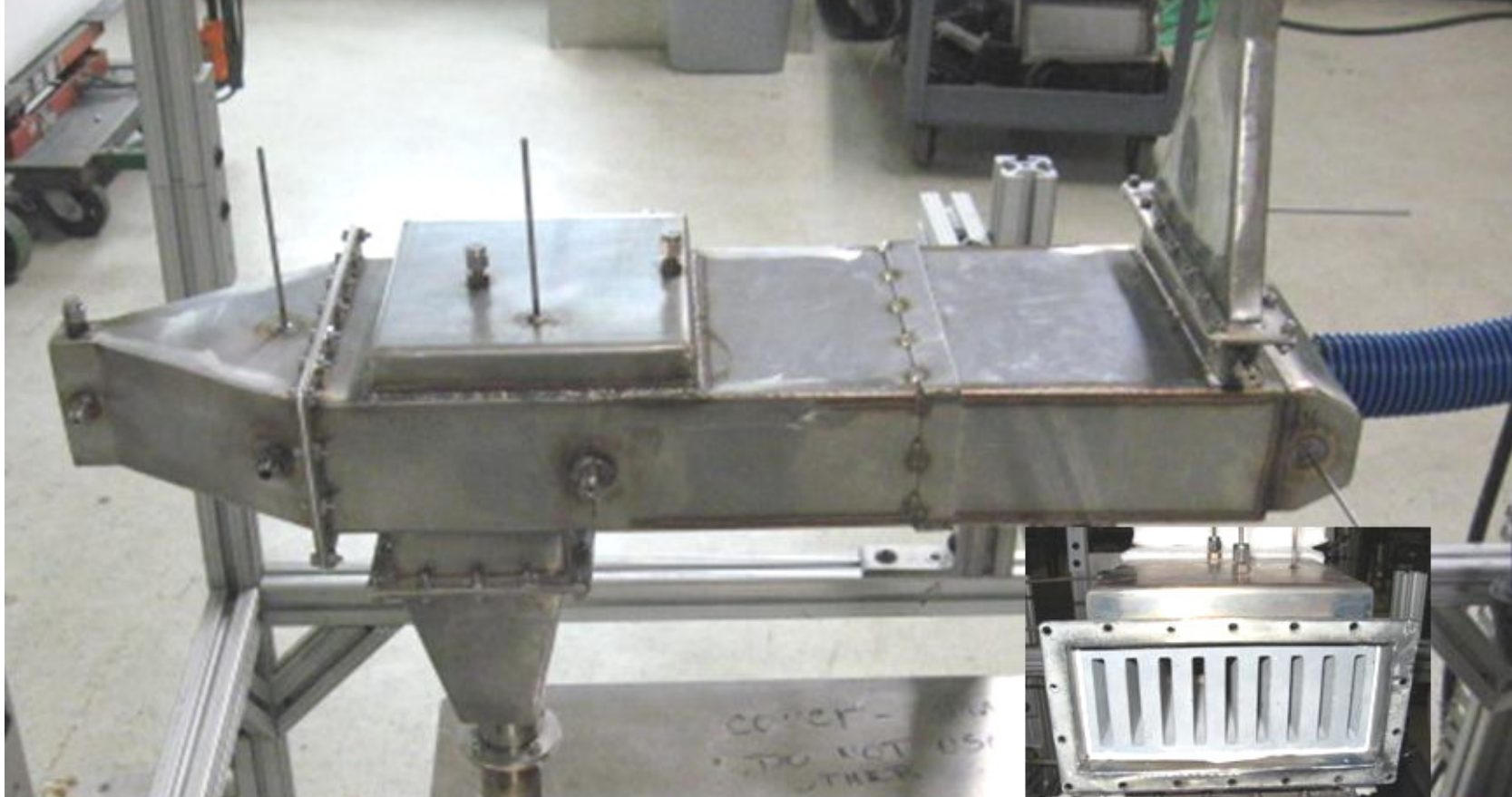
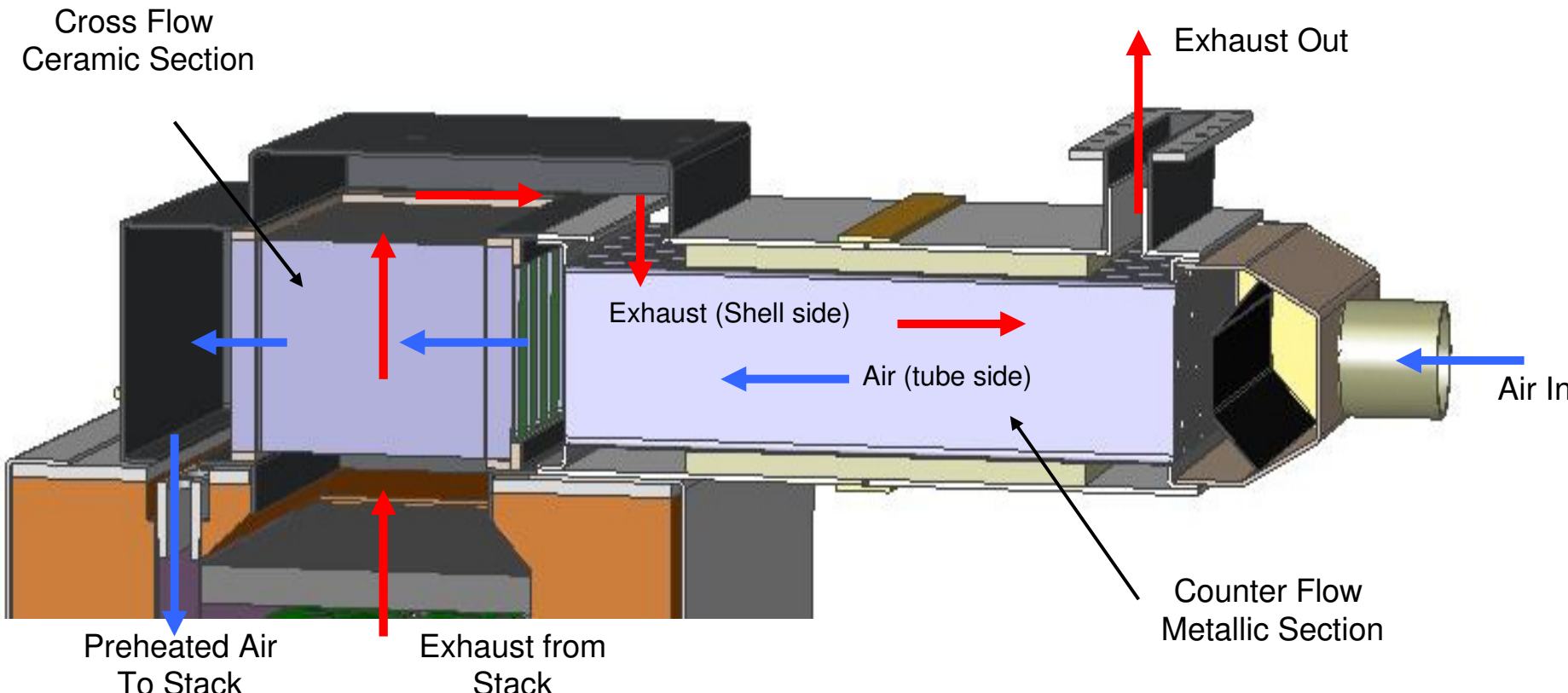
| | Passage Width (mm) | Heat Transfer Area (cm ²) |
|--------|--------------------|---------------------------------------|
| Core 1 | 7.0 | 810 |
| Core 2 | 3.3 | 1425 |

Ceramic Section Testing



Project Objective

Combine ceramic and metallic heat exchanger cores to produce a low cost, high effectiveness, recuperator for cathode air preheating



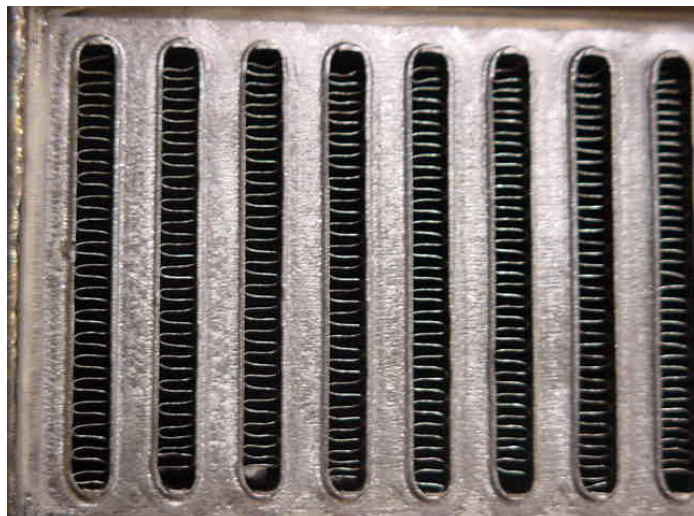
Accomplishments

- Designed, manufactured and tested ceramic heat transfer cores
- Designed, manufactured and tested various metallic heat exchanger cores
- Completed the detailed design of a cross flow ceramic / counter flow metallic hybrid recuperator
- Manufactured and tested prototype 1 kW hybrid recuperators
- Developed heat exchanger models
- Evaluated recuperator designs which are compatible with a "replaceable" cell bundle design
- Developed manufacturing techniques and tested heat exchangers capable of integrated stack cooling and cathode air recuperation

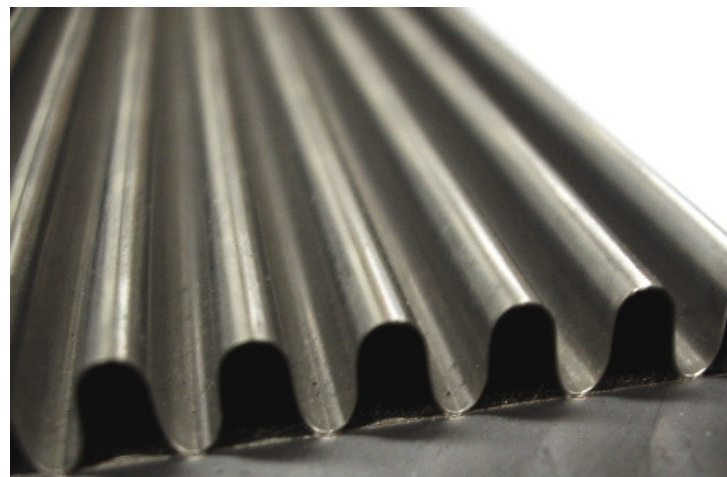
Recuperator Specification

- Exhaust Inlet Temperature – 800 - 950 C
- Air Outlet Temperature – 725 - 800 C
- Effectiveness – >85%
- Total Pressure Drop – 1250 Pa
- Equal Air and Exhaust Flowrates
- Air Flow – 150 lpm per kW

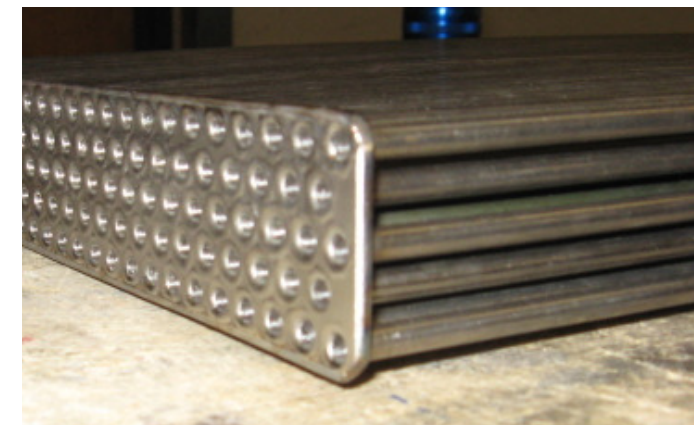
Metallic Sections Tested



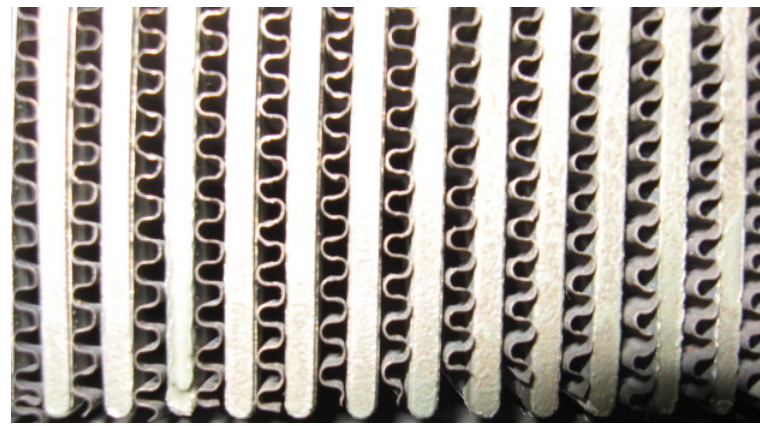
Fin Core



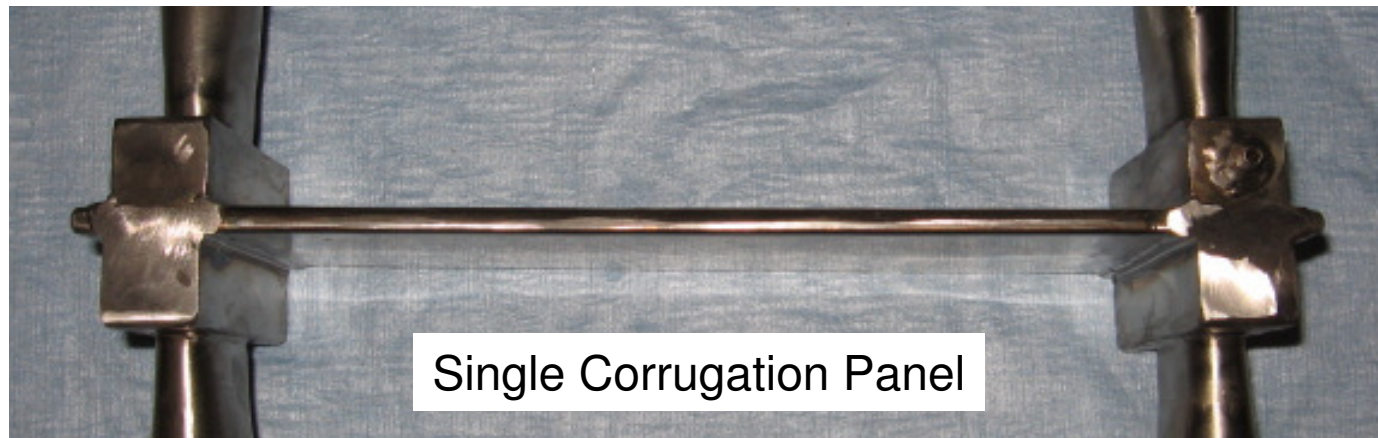
Panel



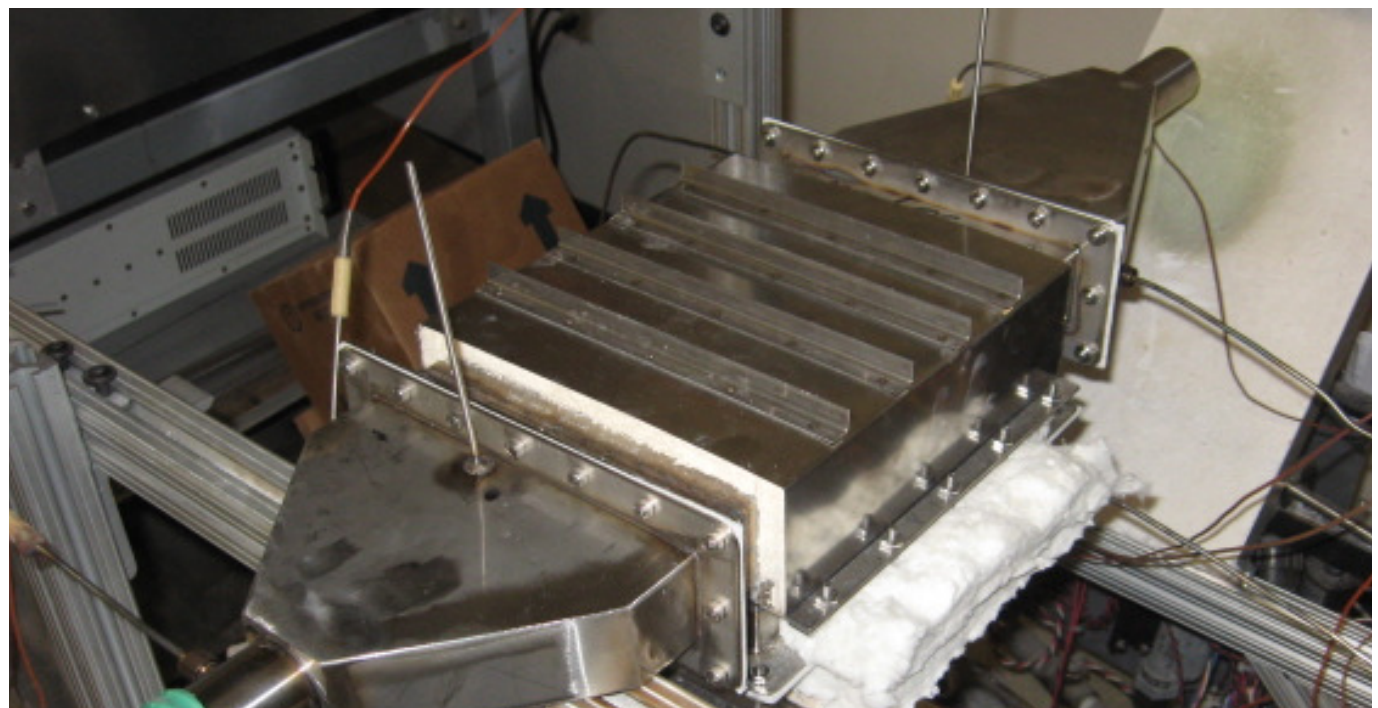
Shell & Tube



Foil



Metallic Section Testing



Foil Recuperator Manufactured by Catacel

| Test Point | Exh Flow slpm | Air Flow slpm | Exhaust Diff Press Pa | Air Diff Press Pa | Exhaust Inlet Temp C | Exhaust Outlet Temp C | Air Inlet Temp C | Air Outlet Temp C | Effectiveness |
|------------|---------------|---------------|-----------------------|-------------------|----------------------|-----------------------|------------------|-------------------|---------------|
| 1 | 229 | 221 | 475 | 350 | 787 | 210 | 591 | 22 | 0.901 |
| 2 | 229 | 213 | 488 | 345 | 803 | 206 | 567 | 22 | 0.901 |
| 3 | 237 | 328 | 363 | 363 | 781 | 92 | 544 | 21 | 0.811 |
| 4 | 330 | 318 | 713 | 450 | 785 | 200 | 506 | 21 | 0.871 |
| 5 | 316 | 312 | 735 | 450 | 794 | 206 | 500 | 21 | 0.869 |
| 6 | 229 | 221 | 500 | 345 | 813 | 196 | 510 | 21 | 0.867 |
| 7 | 145 | 140 | 194 | 200 | 787 | 126 | 544 | 22 | 0.874 |
| 8 | 229 | 221 | 393 | 283 | 642 | 157 | 499 | 21 | 0.902 |
| 9 | 222 | 221 | 500 | 363 | 864 | 206 | 614 | 21 | 0.874 |
| 10 | 284 | 265 | 563 | 388 | 741 | 166 | 499 | 21 | 0.884 |
| 11 | 284 | 274 | 563 | 425 | 833 | 239 | 491 | 22 | 0.862 |
| 12 | 284 | 342 | 588 | 468 | 828 | 155 | 482 | 20 | 0.832 |
| 13 | 284 | 291 | 638 | 450 | 828 | 192 | 503 | 21 | 0.869 |
| 14 | 284 | 288 | 638 | 455 | 831 | 192 | 489 | 21 | 0.857 |
| 15 | 281 | 274 | 538 | 388 | 730 | 170 | 529 | 20 | 0.876 |
| 16 | 233 | 228 | 200 | 200 | 322 | 62 | 250 | 19 | 0.881 |

Acknowledgements

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- Thanks to the staff at Blasch Precision Ceramics and Catacel

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