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Sandia National Laboratories

Project Accomplishment Summary

Sandia National Laboratories

Operated for the U.S. Department of Energy by
Sandia Corporation
Albuquerque, New Mexico

PROJECT ACCOMPLISHMENTS SUMMARY

Cooperative Research and Development Agreement (#1733)

between **Sandia National Labs** and Ultramet

Note: This Project Accomplishments Summary will serve to meet the requirements for a final abstract and final report as specified in Article XI of the CRADA.

Title: Ultrahigh Heat Flux Plasma-Facing Components for Magnetic Fusion Energy

Final Abstract:

Sandia and Ultramet partnered to design and test refractory metal plasma-facing components and heat exchangers for advanced, high-temperature power conversion systems. These devices consisted of high-temperature helium-to-helium and lithium-to-helium heat exchangers that operate with high efficiency due to the porous foam inserts used in the gas stream, which promote turbulence and provide extended surface area for enhanced convection. Single- and multi-channel helium panels and the Li-He heat exchanger were fabricated from either pure molybdenum, TZM, or tungsten. The design was carried out through an Ultramet subcontractor. The flow path was carefully tailored to minimize the pressure drop while maximizing the heat transfer. The single- and multi-channel helium panels were tested at Sandia's PMTF using an electron beam system and the closed helium flow loop. In 2006, a single-channel tungsten tube was successfully tested to an average heat flux of 14 MW/m^2 with a localized peak of 22 MW/m^2 along the axial centerline at the outer radius. Under this CRADA, multiple square-channel molybdenum components were successfully tested to heat flux levels approaching 8.5 MW/m^2. The three multi-channel prototypes experienced mechanical failure due to issues related to the design of the large unsupported span of the heated faceplates in combination with prototype material and braze selection. The Li-He heat exchanger was both designed and partially tested at the PMTF for helium and lithium flow.

Background:

DOE and NASA funded multiple projects with Ultramet starting in 2006 to investigate the development of high temperature heat exchangers using their refractory foam technology for application to fusion and fission power conversion. Ultramet is an advanced materials business that turned to Sandia to provide the expertise in fluid dynamics and heat transfer to design such components and provide the unique high heat flux test facilities required to characterize their operation.

Description:

Sandia National Laboratories (Sandia) and Ultramet collaborated on this project to develop single- and multi-channel, large area (20 cm x 20 cm) helium-cooled high temperature refractory metal plasma facing components (PFCs) that can absorb heat fluxes greater than 20 MW/m^2. A similar heat flux had been demonstrated at Sandia in previous work using small, foam-filled tungsten tubes fabricated by Ultramet. The technical scope of the existing CRADA (SC07/01733.00) was amended to include a natural extension of the He-He heat exchanger to a Li-He heat exchanger that can be used for plasma-facing components as well as heat exchangers in small liquid metal fission reactors.

Sandia is unique in the U.S. because it operates a closed helium cooling loop, a closed lithium liquid metal loop, and has the necessary electron beam power required for high heat flux testing. Ultramet has unique expertise in the fabrication of refractory foams for heat exchanger applications. Their foam technology would enable the Li-He heat exchangers to operate at temperatures never before demonstrated. This motivated the cooperation in the technology development.

The primary technical objective of this project was to design, fabricate and test a multi-channel (6 to 8), large area (20 cm X 20 cm) refractory metal heat exchanger that can reliably operate at inlet temperature exceeding 600 °C and remove surface heat fluxes greater than 20 MW/m^2. The original objective was later extended to incorporate this technology to the helium side of a high temperature refractory Li-He heat exchanger and test it with lithium temperatures to 900 K and helium temperatures to 750 K.

Benefits to the Department of Energy:

The development of the heat exchangers revealed important issues regarding design and refractory alloy selection for components. It utilized advanced fabrication technologies that produced devices capable of operating at 900 ^{o}C and allowing efficient heat transfer to exploit Brayton cycle and liquid metal cooled fast reactor technology.

Economic Impact:

The project may have some economic impact should Ultramet decide to commercialize this class of heat exchanger. Such high-temperature heat exchangers are required for a multitude of high power density advanced energy systems and are necessary for Brayton cycle power conversion or hydrogen production.

Project Status:

Multiple single-channel components were successfully tested at the midpoint of the project at heat flux levels approaching 8.5 MW/m^2. The three multi-channel helium panels failed during testing because of a combination of issues involving component design (unsupported faceplate area) and prototype materials (TZM and tungsten faceplates, molybdenum main body) and braze selection. None of the three test articles could withstand 4 MPa of internal pressurization. The TZM and tungsten faceplates and molybdenum main body experienced laminate failure under pressure resulting in their destruction. A Li-He heat exchanger prototype was successfully flow tested at the PMTF using both helium and lithium.

Upon resolution of the component design and material selection issues, the refractory foam heat exchangers would be a good replacement for plate-type heat exchangers, especially for high-temperature applications because they are easier to fabricate, robust and provide higher thermal performance.

ADDITIONAL INFORMATION

Laboratory/Department of Energy Facility Point of Contact for Information on Project

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Company Size and Points of Contact

Company Size: less than 500.

Point of Contact: Brian E. Williams

CRADA Intellectual Property

SD-11896

Technology Commercialization

Potential exists for Ultramet to commercialize the technology and introduce a new product line of high-temperature heat exchangers

Project Examples

Helium-helium heat exchangers and heat sink panels
Lithium-helium heat exchangers

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This summary has been approved for public release by Sandia and Ultramet

Sandia National Laboratories

By________________ Digitally signed by Dennis Youchison DN: cn=Dennis Youchison, o=Sandia National Labs, ou=1658, email=dlyouch@sandia.gov, c=US Date: 2012.01.03 10:06:57 -07'00' ________________
Dennis Youchison — Date
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Sandia National Laboratories

By________________ 9/13/2011
Manager — Date
WFO/CRADA Agreements

Ultramet

By Craig N. Ward — 1/16/12
Title: Engineering Administrative Mgr. — Date

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