ORDER FOR SUPPLIES OR SERVICES

PAGE OF PAGES: 1 | 2

IMPORTANT: Mark all packages and papers with contract and/or order numbers. BPA NO.

1. DATE OF ORDER: 09-29-2008
2. CONTRACT NO. (If any): NRC-04-07-094
3. ORDER NO. / MODIFICATION NO.: NRC TASK ORDER 005
4. REQUISITION/REFERENCE NO.: RES-07-094; RES-C08-171 (FFS Commitment #)

5. ISSUING OFFICE (Address correspondence to):
U.S. Nuclear Regulatory Commission
Div. of Contracts
Attn: H. (Eddie) Colón, Jr.
Mail Stop T-7-I-2
Washington, DC 20555

6. SHIP TO:
a. NAME OF CONSIGNEE: U.S. Nuclear Regulatory Commission
b. STREET ADDRESS: Office of Nuclear Regulatory Research
Attn: Andrew Ireland, Mail Stop: T10-K8
c. CITY: Washington | d. STATE: DC | e. ZIP CODE: 20555
f. SHIP VIA:

7. TO:
a. NAME OF CONTRACTOR: PURDUE UNIVERSITY (DUNS #: 072051394)
b. COMPANY NAME: ATTN: KENNETH W. SUTER
YOUNG HALL
c. STREET ADDRESS: 302 WOOD STREET
d. CITY: WEST LAFAYETTE | e. STATE: IN | f. ZIP CODE: 479072108

8. TYPE OF ORDER
☐ a. PURCHASE — REFERENCE YOUR _____ Please furnish the following on the terms and conditions specified on both sides of this order and on the attached sheet, if any, including delivery as indicated.
☒ b. DELIVERY — Except for billing instructions on the reverse, this delivery order is subject to instructions contained on this side only of this form and is issued subject to the terms and conditions of the above-numbered contract.

9. ACCOUNTING AND APPROPRIATION DATA: 86015171277 N6678 252A 31X0200.860
OBLIGATE: $100,000.00
10. REQUISITIONING OFFICE: RES
RES/DRASP/NRCA

11. BUSINESS CLASSIFICATION (Check appropriate box(es))
☐ a. SMALL ☒ b. OTHER THAN SMALL ☐ c. DISADVANTAGED ☐ g. SERVICE-DISABLED VETERAN-OWNED
☐ d. WOMEN-OWNED ☐ e. HUBZone ☐ f. EMERGING SMALL BUSINESS

12. F.O.B. POINT: Destination

13. PLACE OF: a. INSPECTION | b. ACCEPTANCE
14. GOVERNMENT B/L NO.:
15. DELIVER TO F.O.B. POINT ON OR BEFORE (Date): As stated in SOW
16. DISCOUNT TERMS: NET 30

17. SCHEDULE (See reverse for Rejections)

ITEM NO. (a)	SUPPLIES OR SERVICES (b)	QUANTITY ORDERED (c)	UNIT (d)	UNIT PRICE (e)	AMOUNT (f)	QUANTITY ACCEPTED (g)
	TASK ORDER NO. 005 entitled "**AIR EXCHANGE AND AIR INGRESS EXPERIMENTAL DATA**", under ID/IQ Contract No. NRC-04-07-094 In accordance with Section G.4, Task Order Procedures, this action definitizes TASK ORDER NO. 005. This effort shall be performed in accordance with the **Statement of Work** (Enclosure 1) and the terms and conditions of Contract No. NRC-04-07-094. TASK ORDER NO. 005 shall be effective **09/30/2008 - 12/29/2010** Reference is made to your revised proposal dated 8/26/2008, (Purdue SPS Development number 00014906) and sent via email dated 8/29/2008. Please indicate your acceptance of this Task Order. **ACCEPTED**: NAME/TITLE: Mark Pearson Sr. Contract Analyst SIGNATURE: Mark Pearson DATE: SEP 30 2008					

18. SHIPPING POINT:
19. GROSS SHIPPING WEIGHT:
20. INVOICE NO.:

SEE BILLING INSTRUCTIONS ON REVERSE

21. MAIL INVOICE TO:
a. NAME: Department of Interior
National Business Center
b. STREET ADDRESS (or P.O. Box): Attn: Fiscal Services Branch - D2270, 7301 W. Mansfield Avenue
c. CITY: Denver | d. STATE: CO | e. ZIP CODE: 80235-2230

17(h) TOTAL (Cont. pages)
17(i). GRAND TOTAL
NOT-TO-EXCEED $363,125.00

22. UNITED STATES OF AMERICA BY (Signature)
23. NAME (Typed): Heriberto Colón, Jr.
Contracting Officer
TITLE: CONTRACTING/ORDERING OFFICER

AUTHORIZED FOR LOCAL REPRODUCTION
PREVIOUS EDITION NOT USABLE

OPTIONAL FORM 347 (REV. 4/2006)
PRESCRIBED BY GSA/FAR 48 CFR 53.213(f)

ADM002 DATE - ADM002

SUNSI REVIEW COMPLETE

OCT 22 2008

ADM002

ADDITIONAL TASK ORDER TERMS AND CONDITIONS

A.1 CONSIDERATION AND OBLIGATION--TASK ORDER

(a) The total estimated amount of this Task Order (ceiling) for the products/services ordered, delivered, and accepted under this contract is **$363,125.00**.

(b) The amount presently obligated with respect to this Task Order is **$100,000.00**. This obligated amount may be unilaterally increased from time to time by the Contracting Officer by written modification to this contract. The obligated amount shall, at no time, exceed the Task Order ceiling as specified in paragraph (a) above. When and if the amount(s) paid and payable to the Contractor hereunder shall equal the obligated amount, the Contractor shall not be obligated to continue performance of the work unless and until the Contracting Officer shall increase the amount obligated with respect to this contract. **Any work undertaken by the Contractor in excess of the obligated amount specified above is done so at the Contractor's sole risk.**

NRC-04-04-094, Task Order No. 005 (Enclosure 1)

STATEMENT OF WORK

TITLE: **AIR EXCHANGE AND AIR INGRESS EXPERIMENTAL DATA**

BACKGROUND

Depressurized Loss of Forced Circulation (D-LOFC) is one of the most important events that must be considered for a Very High Temperature gas-cooled Reactor (VHTR). Following the initial blowdown and depressurization, air can enter the vessel through the break causing oxidation of graphite support structures and possibly fuel. Oxidation of the fuel may cause rapid release of fission products that can then be transported to the surrounding containment. There are several processes by which air can enter the reactor vessel. For breaks at the bottom of the vessel, hot helium in the vessel sits on top of the relatively cold air/helium mixture in containment and transport occurs by molecular diffusion. This process is slow, and can take many hours to transport significant amounts of air into the vessel eventually leading to natural convection and oxidation of the in-vessel graphite.

A double-ended break of the horizontal cross-connection duct results in a break plane that is vertical. Following blowdown, an "air-exchange" process can occur in which the hot helium and cold containment air counter-flow past each other through the break. Cold air enters the bottom of the duct and rapidly fills the lower plenum of the vessel as helium escapes at the top of the duct. The lower plenum quickly stratifies with air filling the plenum below the top of the cross-connect duct where it can oxidize graphite support structures. This process is described by Reyes et al. [1] and was recognized as important in the NRC's PIRT [2] for thermal-fluid and accident analysis. The flow is initially buoyancy driven, with cold air in the containment providing the driving head. After the bottom of the lower plenum is flooded with air, diffusion becomes important as a means of transport to higher elevations in the core and reactor vessel.

Air-exchange can also be an important transport process for breaks on the top of the vessel, such as at a control rod drive. Work by Hishida et al. [3], and Fumizawa et al. [4] showed that air ingress can occur following rupture of a stand pipe, which is a vertical pipe extending from the top of a gas-cooled reactor upper plenum in the High Temperature Engineering Test Reactor (HTTR) [5]. In this geometry, the hot helium in the vessel sits below the break and the relatively cold air/helium gas mixture above it. Air enters the vessel by natural convection. Both calculations and experimental information confirmed air-exchange and natural circulation resulting in air ingress to the plenum. Tilting the break plane was found to increase the air ingress rate.

Because of its importance in oxidation rates of fuel and structural graphite in the vessel, and the possibility of increasing fission product release rates, air-exchange processes and natural convection transport of air through small openings is of significant interest to the staff in its review of gas-cooled reactors. Therefore, an experimental data collection is desired in order to improve understanding of these processes and to provide information for model development and code assessment.

NRC-04-04-094, Task Order No. 005 (Enclosure 1)

STATEMENT OF WORK

OBJECTIVE

The primary objective of this Task Order is the generation of an experimental data collection sufficient to develop models and assess thermal-fluid codes, such as MELCOR and CFD codes, for gas-cooled reactor evaluation. In particular, the data collection is to include air ingress rates into helium filled enclosures through simulated breaks for a range of sizes and orientation.

Specific objectives are:

1. Design a test apparatus appropriate for determination of the countercurrent flow of air and air/helium mixtures past helium through a duct. The test apparatus is to either operate at prototypical pressures and temperatures expected in a gas-cooled reactor Depressurized Loss of Force Cooling (D-LOFC) event, or be suitably scaled to those conditions.

2. Determine the instrumentation and measurement techniques to be used. The measurements need to provide temperature, velocity and species distributions within the test apparatus, as well as the flow rate of air through a duct.

3. Develop an experimental data collection of air ingress rates through an opening representing a break in a gas-cooled reactor vessel. The effect of duct area, the duct length to diameter ratio (L/D), orientation, initial helium temperature, and geometry are to be included in the data collection.

SCOPE OF WORK

This work consists of the following four tasks: Tests Apparatus Design and Instrumentation, Construction and Calibration of Test Apparatus, Air-Exchange Experimental Tests and Final Documentation. Tasks 1 and 2 are associated with development of the test apparatus, its construction and initial testing to insure high quality measurements. Tasks 3 and 4 obtain the data collection, evaluate the results and document all aspects of the project.

Task 1: Test Apparatus Design and Instrumentation

The contractor shall develop a conceptual design and present to the NRC plans for the test apparatus with sufficient details on scale, overall dimensions, materials, and instrumentation for review by the Project Manager and Technical Monitor. The basic design of the apparatus is expected to consist of two relatively large enclosures connected by a duct through which air – helium exchange would occur and be measured. The initial temperature of the helium is to be elevated relative to the air (or air/helium mixture) in the other enclosure. The base and sides of at least one enclosure are to have heaters to maintain a constant wall temperature and set up an initial circulation pattern in the helium. To examine the effect of orientation, the test section(s) shall be able to take experimental data at several angles from vertical to horizontal. Instrumentation shall be capable of determining the temperature distributions within the

enclosure, and species compositions in each enclosure, fluid velocities at several locations, and the air ingress rate. Measurement uncertainties are to be determined and reported. Documentation for this Task shall include a report describing the apparatus and instrumentation and a presentation to NRC staff on the design.

Deliverables	Completion Date
Letter report on proposed test apparatus	3 months after award

Task 2: Construction and Calibration of the Test Apparatus

The contractor shall complete design, construction and shakedown testing of the test apparatus following resolution of NRC comments on the Task 1 report. Instrumentation is shall be calibrated and shake-down testing shall be performed to insure high quality data.

A letter report shall be prepared documenting the as-built test facility, the shakedown tests, instrumentation, and data acquisition tools.

Deliverables	Est. Completion Date*
Letter report documenting the test facility	12 months after award

* *Actual dates to be coordinated with and approved by the NRC Project Officer*

Task 3: Air-Exchange Experimental Tests

The contractor shall conduct a series of experiments to determine air ingress and thermal-fluid conditions in the enclosures. The data are to include the effects of duct area, duct geometry (circular as opposed to a slot with the same equivalent area), orientation, duct L/D, and initial helium temperature. The test matrix shall include tests in which the duct is vertical, horizontal, and at a sufficient number of inclined angles to determine the inclination with the maximum air ingress rate. A range of duct L/D ratios are to be investigated, and at least one non-circular duct is to be tested in order to examine flow through a longitudinal slot. The test matrix and test procedures shall be proposed in a letter report and concurred upon by the NRC Project Manager. Data generated from these matrix tests shall be provided to the NRC in electronic format to facilitate model development and code assessment.

A Quick-Look Report shall be prepared and submitted to the NRC Project Manager following each test describing the experimental results and the data transferred to the NRC in the electronic format.

Deliverables	**Est. Completion Date***
Letter report on proposed test matrix.	12 months after award
Experimental testing.	24 months after award

* *Actual dates to be coordinated with and approved by the NRC Project Officer*

Task 4: Final Documentation

The contractor shall prepare a final report, formatted as an NRC NUREG document, that describes the test facility, instrumentation, test procedures, and experimental results. Evaluations of the data shall be included so that major sensitivities exhibited by the data are determined and so that the data can be compared to tests involving similar phenomena. All experimental data shall be collected and transferred to the NRC in electronic format.

Deliverables	**Est. Completion Date***
Final report and final data collection.	27 months after award

* *Actual dates to be coordinated with and approved by the NRC Project Officer*

RESEARCH QUALITY

The quality of NRC research programs are assessed each year by the Advisory Committee on Reactor Safeguards. Within the context of their reviews of RES programs, the definition of quality research is based upon several major characteristics:

Results meet the objectives (75% of overall score)
- Justification of major assumptions (12%)
- Soundness of technical approach and results (52%)
- Uncertainties and sensitivities addressed (11%)

Documentation of research results and methods is adequate (25% of overall score)
- Clarity of presentation (16%)
- Identification of major assumptions (9%)

It is the responsibility of the contractor to ensure that these quality criteria are adequately addressed throughout the course of the research that is performed. The NRC project manager and technical monitor will review all research products with these criteria in mind.

NRC-04-04-094, Task Order No. 005 (Enclosure 1)

STATEMENT OF WORK

TECHNICAL AND OTHER SPECIAL QUALIFICATIONS REQUIRED

None.

REPORTING REQUIREMENTS

Monthly Letter Status Report.

A Monthly Letter Status Report (MLSR) is to be submitted to the NRC Project Manager by the 20th of the month following the month to be reported with copies provided to the following:

Andrew Ireland, Project Manager, Mail Stop: T-10K08
Stephen M. Bajorek, Technical Monitor, Mail Stop: T-10K08
Management Analyst, Peggy Bennett, Mail Stop T-10D5
Chris Hoxie, Branch Chief, Mailstop: T-10D5

The MLSR will identify the title of the project, the job code, the Principal Investigator, the period of performance, the reporting period, summarize each month's technical progress, list monthly spending, total spending to date, and the remaining funds and will contain information as directed in NRC Management Directive 11.1. Any administrative or technical difficulties which may affect the schedule or costs of the project shall be immediately brought to the attention of the NRC project manager.

PUBLICATIONS NOTE

RES encourages the publication of the scientific results from RES sponsored programs in refereed scientific and engineering journals as appropriate. If the laboratory proposes to publish in the open literature or present the information at meeting in addition to submitting the required technical reports, approval of the proposed article or presentation should be obtained from the NRC Project Manager. The RES Project Manager shall either approve the material as submitted, approve it subject to NRC suggested revisions, or disapprove it. In any event, the RES Project Manager may disapprove or delay presentation or publication of papers on information that is subject to Commission approval that has not been ruled upon or which has been disapproved. Additional information regarding the publication of NRC sponsored research is contained in NRC Management Directives 3.7, "NUREG Series Publications," and 3.9, "NRC Staff and Contractor Speeches, Papers, and Journal Articles on Regulatory and Technical Subjects."

If the presentation or paper is in addition to the required technical reports and the RES Project Manager determines that it will benefit the RES project, the Project Manager may authorize payment of travel and publishing costs, if any, from the project funds. If the Project Manager determines that the article or presentation would not benefit the RES project, the costs

associated with the preparation, presentation, or publication will be borne by the contractor. For any publication or presentations falling into this category, the NRC reserves the right to require that such presentation or publication will not identify the NRC's sponsorship of the work.

NEW STANDARDS FOR CONTRACTORS WHO PREPARE NUREG-SERIES MANUSCRIPTS
The U.S. Nuclear Regulatory Commission (NRC) began to capture most of its official records electronically on January 1, 2000. The NRC will capture each final NUREG-series publication in its native application. Therefore, please submit your final manuscript that has been approved by your NRC Project Manager in both electronic and camera-ready copy.

All format guidance, as specified in NUREG-0650, Revision 2, will remain the same with one exception. You will no longer be required to include the NUREG-series designator on the bottom of each page of the manuscript. The NRC will assign this designator when we send the camera-ready copy to the printer and will place the designator on the cover, title page, and spine. The designator for each report will no longer be assigned when the decision to prepare a publication is made. The NRC's Publishing Services Branch will inform the NRC Project Manager for the publication of the assigned designator when the final manuscript is sent to the printer.

For the electronic manuscript, the Contractor shall prepare the text in Microsoft Word, and use any of the following file types for charts, spreadsheets, and the like.

File Types to be Used for NUREG-Series Publications	
File Type	File Extension
Microsoft®Word®	.doc
Microsoft® PowerPoint®	.ppt
Microsoft®Excel	.xls
Microsoft®Access	.mdb
Portable Document Format	.pdf

This list is subject to change if new software packages come into common use at NRC or by our licensees or other stakeholders that participate in the electronic submission process. If a portion of your manuscript is from another source and you cannot obtain an acceptable electronic file type for this portion (e.g., an appendix from an old publication), the NRC can, if necessary, create a tagged image file format (file extension.tif) for that portion of your report. Note that you should continue to submit original photographs, which will be scanned, since digitized photographs do not print well.

If you choose to publish a compact disk (CD) of your publication, place on the CD copies of the manuscript in both (1) a portable document format (PDF); (2) a Microsoft Word file format, and

(3) an Adobe Acrobat Reader, or, alternatively, print instructions for obtaining a free copy of Adobe Acrobat Reader on the back cover insert of the jewel box.

DELIVERABLES/SCHEDULES AND/OR MILESTONES

1. A Monthly Letter Status Report (MLSR) is to be submitted to the NRC Project Manager by the 20th of the month following the month to be reported.

2. Letter report describing the proposed test apparatus and instrumentation (Task #1) to be delivered three months following the award date.

3. Letter report detailing the as-built facility to be delivered 12 months following the award date.

4. Letter report proposing the test matrix is to be delivered 12 months after the award date.

5. Quick-Look Reports (QLRs) are to be submitted within one week following test completion.

6. Final report describing the facility, test procedures, and experimental results in addition to the test data in electronic format to be delivered 27 months following the award date.

MEETINGS AND TRAVEL

For domestic travel, the contractor is expected to attend an annual meeting at the NRC in Rockville, MD, for research review and a national conference. The trips will be of approximately two days duration. All trips must be approved by the NRC project manager in advance.

NRC-FURNISHED MATERIAL

None.

NRC-04-04-094, Task Order No. 005 (Enclosure 1)

STATEMENT OF WORK

TECHNICAL DIRECTION

Technical direction will be provided by the Project Manager (Andrew Ireland), who can be reached at:

Mail Stop: (T-10K08)
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001
Phone: (301) 415-6061
Fax: (301) 415-5160
Email: (Andrew.Ireland@nrc.gov)

Alternatively, technical direction may also be provided by William Macon.

Mail Stop: (T-10K08)
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001
Phone: (301) 415-3965
Fax: (301) 415-5160
Email: (William.Macon@nrc.gov)

Background References:

[1] Reyes, J. N. Jr., Groome, J. T., Woods, B. W., Jackson, B., and Marshall, T. D., "Scaling Analysis for the High Temperature Gas Reactor Test Section (GRTS)," NURETH-12 Proceedings, Pittsburgh, PA, October 2007.

[2] Ball, S. J. et al., "Next-Generation Nuclear Plant Phenomena Identification and Ranking Tables (PIRTs) Volume 1—Thermofluids and Accident Analysis PIRTs," NUREG/CR-6944, Vol. 1, to be published.

[3] Hishida, M., Fumizawa, M., Takeda, T., Ogawa, M., and Takenaka, S., "Researches of Air Ingress Accidents of the HTTR," Nucl. Eng. and Design, 144, 1993.

[4] Fumizawa, M., Kunugi, T., Hishida, M., Akamatsu, M., Fujii, S., and Igarashi, M., "Numerical Analysis of Buoyancy-Driven Exchange Flow with Regard to an HTTR Air Ingress Accident," Nucl. Technology, Vol. 110, 1995.

[5] Saito, S., "Design of High Temperature Engineering Test Reactor (HTTR) and Associated Research and Development," J. At. Energy Soc., Japan 32-9 (1990).