AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

BPA NO.

1. CONTRACT ID CODE

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2. AMENDMENT/MODIFICATION NO. M003

3. EFFECTIVE DATE 08/21/2006

4. REQUISITION/PURCHASE REQ. NO. RES-03-048

5. PROJECT NO. (If applicable)

6. ISSUED BY CODE

U.S. Nuclear Regulatory Commission
Division of Contracts
Attn: T-7-I-2
Contract Management Branch No. 2
Washington DC 20555

7. ADMINISTERED BY (If other than Item 6) CODE

U.S. Nuclear Regulatory Commission
Div of Contracts
Mail Stop: T-7-I-2

Washington, DC 20555

8. NAME AND ADDRESS OF CONTRACTOR (No., street, county, State and ZIP Code)

PURDUE UNIVERSITY

SPONSORED PROGRAM SERVICES
302 WOOD ST. (YOUNG HALL)
W LAFAYETTE IN 479072108

CODE 072051394 FACILITY CODE

(X) 9A. AMENDMENT OF SOLICITATION NO.

9B. DATED (SEE ITEM 11)

10A. MODIFICATION OF CONTRACT/ORDER NO. NRC-04-03-048 T004

X 10B. DATED (SEE ITEM 13) 09-24-2003

11. THIS ITEM ONLY APPLIES TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in Item 14. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.
Offers must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation or as amended, by one of the following methods:
(a) By completing Items 8 and 15, and returning ________ copies of the amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGMENT TO BE RECEIVED AT THE PLACE DESIGNATED FOR THE RECEIPT OF OFFERS PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided each telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

12. ACCOUNTING AND APPROPRIATION DATA (If required) 660-15-111-205 Y6589 252A 31X0200.660
FFS: RES-C06-616 OBLIGATE: $125,129.00

13. THIS ITEM APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS, IT MODIFIES THE CONTRACT/ORDER NO. AS DESCRIBED IN ITEM 14.

(X)	
	A. THIS CHANGE ORDER IS ISSUED PURSUANT TO: (Specify authority) THE CHANGES SET FORTH IN ITEM 14 ARE MADE IN THE CONTRACT ORDER NO. IN ITEM 10A.
	B. THE ABOVE NUMBERED CONTRACT/ORDER IS MODIFIED TO REFLECT THE ADMINISTRATIVE CHANGES (such as changes in paying office, appropriation date, etc.) SET FORTH IN ITEM 14, PURSUANT TO THE AUTHORITY OF FAR 43.103(b).
	C. THIS SUPPLEMENTAL AGREEMENT IS ENTERED INTO PURSUANT TO AUTHORITY OF:
X	D. OTHER (Specify type of modification and authority) Bilateral Mutual Agreement Between the Parties

E. IMPORTANT: Contractor ☐ is not, ☒ is required to sign this document and return two (2) copies to the issuing office.

14. DESCRIPTION OF AMENDMENT/MODIFICATION. (Organized by UCF section headings, including solicitation/contract subject matter where feasible.)

This confirms the verbal authorization that was given on 8/21/06, with a temporary ceiling of $25,000.00. This also confirms the 9/22/06 verbal that extended the period of performance through 9/30/06. The purpose of this modification is to:(1) revise the level of effort in accordance with the enclosed SOW, at no additional cost to NRC; (2)provide incremental funding in the amount of $125,129.00; and (3)extend the period of performance through 7/31/07. There is no change in the estimated ceiling amount of the task order. A summary of obligations, from the award date through the date of this action, is given below:
Total FY 2003 Obligated Amount: $187,717.24; Total FY 2004 Obligated Amount: $243,000.00.
Total FY 2005 Obligated Amount: $35,000.00; Total FY 2006 Obligated Amount: $125,129.00.
Cumulative Total of NRC Obligations: $590,846.24. All other terms and conditions of this task order remain the same, including the task order ceiling amount of $659,174.24.

Except as provided herein, all terms and conditions of the document referenced in Item 9A or 10A, as heretofore changed, remains unchanged and in full force and effect.

15A. NAME AND TITLE OF SIGNER (Type or print) Rick Evans Assistant Director

16A. NAME AND TITLE OF CONTRACTING OFFICER (Type or print) Mona C. Selden Contracting Officer

15B. CONTRACTOR/OFFEROR (Signature of person authorized to sign)

15C. DATE SIGNED SEP 28 2006

16B. UNITED STATES OF AMERICA BY Mona C. Selden (Signature of Contracting Officer)

16C. DATE SIGNED 9/27/06

STANDARD FORM 30 (REV. 10-83)

TEMPLATE - ADM001 SUNSI REVIEW COMPLETE ADM002

P.03 SEP-27-2006 22:50

STATEMENT OF WORK

MODIFICATION NO. 3 TO TASK ORDER NO. 4
UNDER CONTRACT NO. NRC-04-03-048

Task Order Title:	Interfacial Area Transport
Principal Investigator:	M. Ishii (765-494-4587) lth@ecn.purdue.edu
Period of Performance:	Date of Award through 7/31/07
NRC project Manager:	Shawn O. Marshall (301-415-5861) Som@nrc.gov

The purpose of this modification is to: (1) revise the level of effort in accordance with this Statement of Work, at no additional cost to the Government, (2) provide incremental funding, and (3) extend the period of performance from September 23, 2006, to July 31, 2007. There is no increase in the ceiling amount of the task order.

I. BACKGROUND

Numerical treatments of two-phase flow are generally represented by macroscopic field equations and constitutive relations using the continuous Eulerian formulation. A two-fluid model, such as that employed by the TRACE code, is formulated by considering each phase separately in terms of two sets of conservation equations governing the mass, momentum and energy for each phase. The phasic interaction terms, which couple the transport of mass, momentum and energy across the interface, appear on the right hand side of the field equations. These interfacial transfer terms are strongly related to the interfacial area and to the local transfer mechanisms for momentum and heat. Therefore, an accurate model for the interfacial area is essential for the two-fluid model formulation.

In the current TRACE code, the interfacial area concentrations are calculated with the flow regime-dependent correlations that do not dynamically represent the changes in interfacial structure and are often ad hoc in nature. The flow regime maps are based on the assumptions of steady-state and fully developed flows. These flow regime maps produce discontinuous changes in the interfacial transfer because very small changes in fluid conditions can lead to a very different steady-state flow regime. The flow regime transitions represent bifurcation phenomena in the two-fluid model. Also, since the maps are static, they cannot resolve the time or length scales over which flow regime transitions occur.

The two-fluid model, with static flow regime transition criteria and flow regime-dependent constitutive relations, represents a conceptual inconsistency in modeling the dynamic phase interactions. A better modeling approach employing the interfacial area transport equation has been recommended (Ishii, 1975; Kocamustafaogullari and Ishii, 1995). The interfacial area transport equation is formulated by mechanistically modeling the physical processes that govern the creation and destruction of interfacial area. Therefore, it dynamically models the changes in the flow structure. In 1997, the US Nuclear Regulatory Commission (NRC) launched a research project, entitled " Thermal-hydraulic Research (Contract No. RS-RES-97-046)" to establish a dramatic improvement to the existing ability to accurately simulate the behavior of Advance Light Water Reactors under all conceivable regimes of operation. Among the various tasks, the team at Purdue University developed the interfacial area transport equation to minimize the undesirable effects of the current flow regime-based empirical correlation approach. As a result, the one-group and two-group interfacial area transport equations have been successfully developed. In the model evaluation study based on the extensive database acquired in various experimental conditions, the interfacial area transport equation demonstrated that it can predict the interfacial structures dynamically along the flow field.

The previous research was mainly focused on establishing the foundation of the interfacial area transport equation and developing the models for the adiabatic air-water two-phase flow conditions in vertical upward two-phase flows. Neither the effect of phase change nor complicated geometry transitions was included in the model. In order to apply the transport equations to the thermal-hydraulic analysis for the nuclear reactors, however, the phase change effects should be accurately taken into account. In particular, the subcooled boiling flow phenomenon should be studied in detail, because it provides the boundary condition for the initiation of the vapor generation and the initial bubble diameters for the two-phase region. To address this need, a heated annular test section was designed and constructed. The generation of a two-phase boiling data base and the development of the associated models for the interfacial area transport remain to be done.

The two-phase flow in rod bundles occur in the reactor core and the steam generator. Conventionally, as the 1st order approximation, the experimental results from a pipe flow are employed to study the subchannel in the rod bundles. When the two-phase flow is dispersed uniformly and fully developed, this is a reasonable approximation. However, in flow regimes such as slug or churn-turbulent flow regimes, the lateral distribution of the flow parameters have been found to be significantly different from the ones in the pipe flow due to the open boundary between the subchannels. To address this, an air/water two-phase flow rod bundle test loop was constructed. The generation of a two-phase rod bundle data base and the development of the associated models for the interfacial area transport remain to be done.

To date, efforts have focused on the bubbly-slug or bubbly-churn flow regime transitions. To complete the description for pre-CHF flow regimes, the annular flow regime and its associated transition need to be considered. To address this need a task on annular flow that utilizes an existing test section will be added in the future. Similarly, for horizontal flow and area changes, experimental work was previously conducted at the University of Wisconsin-Milwaukee. This task has been transferred to the University of Missouri-Rolla to establish a data base for horizontal flow and develop the needed models for interfacial area transfer.

II. OBJECTIVES

This modification will allow the contractor, Purdue University (PU), to collect data needed for the substantial update of two-phase heat transfer and flow modeling in the TRACE code. The ability of TRACE to accurately predict two-phase flow behavior is essential in nearly any foreseeable audit calculations. Specific objectives are:

1. To establish detailed local database for air-water flow in rod bundle geometry, for a steam-water boiling flow, and for horizontal flow through various flow restrictions.
2. To develop mechanistic models for the necessary constitutive relations to complete the interfacial area transport equation for applications in Objective 1;

3. To evaluate the interfacial area transport equation together with the developed constitutive models against the acquired database;
4. To address the issues related to the implementation of the developed interfacial area transport equation into the TRACE code.
5. Provide data for the assessment of two-phase CFD codes such as NPHASE.

III. WORK REQUIREMENTS

The work scope for the existing tasks 2, 3 and 5 is as follows:

Task 2: Two-Phase Flow Structure in a Rod Bundle Geometry

Using the 8x8 rod bundle test section, being the work of generating a database for co-current upflow in the bubbly and churn turbulent regimes. To the degree possible, the range of mass flow rates investigated should encompass that of BWR operating conditions to nearly stagnant flow associated with boil-off conditions expected in a SBLOCA or during long term cooling in an advanced passive design. Detailed data for the effects of spacer grids on the void fraction and interfacial area shall be made.

Future work will complete the generation of this database, identify the differences of bubble behavior between tubes and rod bundles and develop models for the consequent interfacial area source/sink terms. Prepare a letter report upon the completion of the task.

Deliverables	Level of Effort	Completion Date
Letter report and data in electronic format	4 Staff Months (30% PI, 70% graduate assistant)	On, or about 7/31/07

Task 3: Steam-Water Boiling Flow in a Vertical Pipe

Using the heated annular test section, a database shall be generated for co-current upflow in subcooled and saturated nucleate boiling and for bulk condensation. Models for the source and sink terms of interfacial area for the effects of subcooled and saturated nucleate boiling and condensation shall be developed.

Prepare a letter report upon the completion of the task.

Deliverables	Level of Effort	Completion Date
Letter report and data in electronic format	5 Staff Months (30% PI, 70% graduate assistant)	On, or about 7/31/07

Task 5: Horizontal Two-Phase Flow through Various Flow Restrictions

The contractor shall obtain the experimental data generated under the previous contract by the University of Wisconsin-Milwaukee and document it in both a letter report and an electronic data base. Using this data base, mechanistic models to describe the interfacial area transition in horizontal flow and through flow restrictions for 90 and 45 degree elbows in a horizontal configuration and for the scaled downcomer.

Deliverables	Level of Effort	Completion Date
Letter report and data in electronic format	3 Staff Months (30% PI, 70% graduate assistant)	On, or about 7/31/07

IV. REPORTING REQUIREMENTS

As stated in the basic contract award.

V. MEETINGS AND TRAVEL

For domestic travel, the contractor is expected to attend one meeting for one person at the NRC in Rockville, MD for research review. The trip will be of approximately two day's duration. The contractor will also attend one meeting for one person to the ANS/ASME technical meeting. All trips have to obtain approval from the NRC project manager in advance.

VI. TECHNICAL DIRECTION

Technical Direction will be provided by the Technical Monitor, Joseph Kelly who can be reached at:
Phone: (301) 415-6852
Fax: (301) 415-5160
Email: jmk1@nrc.gov