ORDER FOR SUPPLIES OR SERVICES

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

1. DATE OF ORDER	09-04-2007
2. CONTRACT NO. (If any)	**NRC-04-07-094**
3. ORDER NO. / MODIFICATION NO.	**NRC TASK ORDER 001**
4. REQUISITION/REFERENCE NO.	RES-07-094 RES-07-250 (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: Joseph M. Kelly 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
- [X] 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 **OBLIGATE: $20,000.00**
76015111205 N6164 252A 31X0200.760
(This action also administratively transfers $50,000.00 in funds previously obligated upon award of ID/IQ Contract No. NRC-04-07-094) - See **NOTE TO NRC ACCOUNTING** below

10. REQUISITIONING OFFICE RES
RES/DRASP/NRCA

11. BUSINESS CLASSIFICATION (Check appropriate box(es))

- [ ] a. SMALL
- [X] b. OTHER THAN SMALL
- [ ] c. DISADVANTAGED
- [ ] g. SERVICE-DISABLED VETERAN-OWNED
- [ ] d. WOMEN-OWNED
- [ ] e. HUBZone
- [ ] f. EMERGING SMALLBUSINESS

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)	16. DISCOUNT TERMS
			As stated in SOW	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. 001 entitled "**VOID FRACTION IN LARGE DIAMETER PIPES**", under ID/IQ Contract No. NRC-04-07-094

In accordance with Section G.4, Task Order Procedures, this action definitizes TASK ORDER NO. 001. 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. 001 shall be effective 09/04/2007 - 12/31/2009 with a total cost ceiling of $267,737.00.

This order confirms the verbal authorization provided to PURDUE on 9/4/2007 to commence work under this effort, effective September 4, 2007, with a temporary Not-to-Exceed (NTE) amount of $53,000.00.

NOTE TO NRC ACCOUNTING: Request funds in the amount of $50,000.00 previously obligated under ID/IQ Contract No. NRC-04-07-094 be transferred to TASK ORDER NO. 001.

Reference is made to your revised email proposal dated 8/27/07 in response to this effort.

SEE BILLING INSTRUCTIONS ON REVERSE

18. SHIPPING POINT	
19. GROSS SHIPPING WEIGHT	
20. INVOICE NO.	
21. MAIL INVOICE TO: a. NAME	U.S. Nuclear Regulatory Commission Div. of Contracts, Mail Stop T-7-I-2
b. STREET ADDRESS (or P.O. Box)	Attn: (**NRC-04-07-094-T001**)
c. CITY	Washington
d. STATE	DC
e. ZIP CODE	20555
17(h) TOTAL (Cont. pages)	
17(i). GRAND TOTAL	NTE $267,737.00

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

TEMPLATE - ADM001 SUNSI REVIEW COMPLETE SEP 26 2007

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

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 **$267,737.00**.

(b) The amount presently obligated with respect to this Task Order is **$70,000.00***. 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.

**Includes $50,000.00 (Guaranteed Minimum) in FY2007 funds previously obligated under Contract No. NRC-04-07-094, which are hereby administratively transferred to this task order.*

STATEMENT OF WORK FOR TASK ORDER NO. 001
UNDER
CONTRACT NO. NRC-04-07-094 ENTITLED
"THERMAL-HYDRAULIC EXPERIMENTAL AND MODEL DEVELOPMENT SUPPORT FOR TRACE"

Task Order No. 001 Title:	**"Void Fraction in Large Diameter Pipes"**
Contractor:	Purdue University
Site:	Purdue University
Principal Investigators:	M. Ishii (765-494-4587) lth@ecn.purdue.edu T. Hibiki (765-496-9033) hibiki@ecn.purdue.edu
NRC Project Manager:	Joseph M. Kelly (301-415-6852) jmk1@nrc.gov

I. BACKGROUND

The USNRC's system thermal-hydraulic analysis code TRACE (TRAC RELAP Advanced Computational Engine) is being developed to provide a best-estimate accident analysis capability for both operating pressurized and boiling water reactors as well as the next generation of evolutionary water reactor designs. In partnership with the code development, a comprehensive code assessment activity is being conducted. Results from this assessment have identified a code modeling limitation for the prediction of void fraction in large diameter pipes. Remediation of this modeling limitation has a high priority due to its potential impact on calculations for advanced boiling-water reactor (BWR) designs (e.g., SBWR, ESBWR, ABWR).

In most advanced BWR designs, a tall chimney region exists above the reactor core to provide the gravity head necessary to drive the natural circulation two-phase flow through the core. For this chimney region, the TRACE code uses the same interfacial drag models as for 1-D vertical pipes. That is, for the bubbly/slug flow regime, the Kataoka-Ishii drift flux model for large diameter pipes is converted to an interfacial friction correlation. For the annular/mist flow regime, the Wallis annular flow interfacial friction model is used for the liquid film. When entrained droplets are predicted to exist, the drop volume fraction is estimated and the associated interfacial drag is added to that for the liquid film. For the transition region between these two regimes, TRACE uses a simple power-law weighting scheme to provide a continuous and smooth transition.

Two sources of data were identified to assess these models for hydraulic diameters of about the same size as the ESBWR chimney: pool data (Wilson & Carrier bubble rise tests) and the Ontario-Hydro transient upflow tests. In the assessment against the pool data, the TRACE code performed quite well up to void fractions of about 50-60%. This is not surprising as these tests were included in the database used to develop the Kataoka-Ishii drift flux model. However, for the large pipe data, there were a few data points in the void fraction range 60-80% for which TRACE significantly under-predicted the void fraction.

For the Ontario-Hydro transient upflow tests, two possible problems were observed in the TRACE assessment calculation. First, similar to the predictions for the pool data mentioned above, the TRACE calculated void fractions compared well up to a value of about 50%. For higher void fractions, however, TRACE progressively under-predicted the void fraction up to a data value of 78%, the TRACE calculated value was only 67%. To put this into perspective, this means that TRACE over-predicted the liquid inventory in the chimney region by ~50% thereby providing a non-conservative initial condition for a LOCA analysis. Uncertainties in the experimental data, in the boundary conditions or in the void fraction measurements, could make this comparison between TRACE and the Ontario-Hydro tests either better or worse.

A second potential modeling issue was observed at the end of the Ontario-Hydro transient test as the mass flux was decreased and the quality approached 90%. In the data, the void fraction was reported to be near unity, whereas in the TRACE calculation, the value was only 80%. This would appear to indicate that TRACE significantly under-predicted the interfacial shear in the transition region between the bubbly/slug and annular/mist regimes. While this conclusion is consistent with the observation from the pool data comparisons, it is tentative due to the uncertain boundary conditions of the Ontario-Hydro tests for the high quality conditions.

In summary, assessment of the TRACE code has revealed a significant under-prediction for the void fraction in large diameter pipes in the transition region between the bubbly/slug and annular/mist regimes. While the existing data is sufficient to indicate the existence of a limitation in the TRACE interfacial drag model, there is not enough data to permit the selection or development of a new model to address this deficiency. Consequently, this work was initiated in the previous Thermal-Hydraulic Institute (THI) contract. This task will complete the effort to generate the needed data and perform the model selection/development necessary to improve TRACE's ability to predict void fraction in large diameter pipes. In addition, this task will extend the database for interfacial area transport to large diameter pipes.

II. OBJECTIVES

Collect two-phase flow data needed to address a modeling limitation of the TRACE code for the prediction of void fraction in large diameter vertical pipes. Further, this task includes a model development component to produce a model for ready inclusion into TRACE. The ability of TRACE to accurately predict two-phase flow behavior is necessary for any foreseeable audit calculations and in particular for the chimney region of advanced BWR designs. Specific objectives are:

1. To augment the existing void fraction database with new air-water void fraction and void profile data that extends into the transition region between the bubbly/slug and annular/mist regimes;
2. To either select or develop a model for interfacial shear that significantly improves the ability of TRACE to predict void fraction in large diameter pipes;
3. To develop a database of interfacial area concentration, bubble velocity, and bubble size for both pool and upflow conditions for large pipe diameters and for a wide range of flow conditions;
4. To benchmark the existing interfacial area transport equation (IATE) using the above data;
5. To improve the IATE model by developing sink and source term models for interfacial area concentration, and bubble drag models for upwards two-phase flow in large diameter pipes.

III. WORK REQUIREMENTS

Task 1: Generate Void Fraction Data

The contractor shall run air-water experiments to generate void fraction, flow regime, void profile, and pressure drop data for both 15.24 cm (6 in.) and 20.32 cm (8 in.) diameter test sections over a wide range of flow conditions. The test matrix shall include at least two pressure levels, mass fluxes ranging from pool conditions up to 1000 kg/m^2-s and void fractions up to 80%. The test matrix shall be proposed by the contractor in a letter report and concurred upon by the NRC project manager.

Add the new data to the database compiled from the literature in the previous THI contract.

Deliverables	Est. Completion Date
Data in electronic format	10 months after award

Task 2: Interfacial Drag Model Development

Using the void fraction database generated in the previous THI contract and the new air-water data generated in Task 1 of this Task Order, the contractor shall either select or develop an improved model for interfacial drag in vertical pipes for inclusion in the TRACE code. The proposed model must cover the entire void fraction range from bubbly flow to annular flow and be suitable for inclusion in a two-fluid model. Furthermore, the accuracy of the proposed model should be demonstrated to be equal to or superior to the existing TRACE model over all flow regimes and provide a substantial improvement in modeling performance for the transition regime.

Prepare a letter report detailing the proposed interfacial drag model for vertical pipes.

Deliverables	Est. Completion Date
Letter report	12 months after award

Task 3: Generate Interfacial Area Transport Data

The contractor shall run air-water experiments to generate interfacial area concentration, bubble velocity, and bubble size data for both 15.24 cm (6 in.) and 20.32 cm (8 in.) pipe diameter test sections over a wide range of flow conditions. The test matrix shall include at least two pressure levels, mass fluxes ranging from pool conditions up to 1000 kg/m^2-s and void fractions up to 80%. The test matrix shall be proposed by the contractor in a letter report and concurred upon by the NRC project manager.

Add the new data to the database generated in the previous THI contract.

Deliverables	Est. Completion Date
Data in electronic format.	24 months after award

Task 4: Interfacial Area Transport Model Development

Using the interfacial area data generated in Task 3 of this Task Order, the contractor shall benchmark the existing interfacial area transport equation models. Where necessary, mechanistic models for interfacial area concentration source and sink terms, and bubble drag models for two-phase flow in large diameter pipes shall be developed by the contractor. The IAT models developed under this task shall be compatible with the two-phase flow model and numerical scheme employed by the TRACE code.

Prepare a letter report describing the new data and detailing the proposed interfacial area and bubble drag models.

Deliverables	Est. Completion Date
Letter report.	28 months after award

IV. 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.

V. REPORTING REQUIREMENTS

1. Monthly Letter Status Report (MLSR)

   A MLSR should 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:

Project Manager/Technical Monitor (Joseph M. Kelly, Mail Stop T-10K08)
Division Management Analyst, (Sharon Haggerty, Mail Stop T-10E50)
Contracting Officer, (Heriberto Colon, Jr., Mail Stop T-712)

The MLSR shall 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. 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.

VI. DELIVERABLES AND DELIVERY SCHEDULE

1. Void Fraction and flow regime data for both the 15.25 cm (6 in.) and 20.32 cm (8 in.) tests in an electronic format agreed to by the NRC project manager to be delivered 10 months after the award date.

2. Letter report detailing the proposed interfacial drag model for large diameter vertical pipes to be delivered 12 months after the award date.

3. Interfacial area transport data for both the 15.25 cm (6 in.) and 20.32 cm (8 in.) tests in an electronic format agreed to by the NRC project manager to be delivered 24 months after the award date.

4. Letter report describing the interfacial area transport data and detailing the proposed interfacial area and bubble drag models to be delivered 28 months after the award date.

VII. MEETINGS AND TRAVEL REQUIREMENTS

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 have to obtain approval from the NRC project manager in advance.

VIII. TECHNICAL DIRECTION

Technical direction will be provided by the Project Manager (Joseph M. Kelly), who can be reached at:

U.S. Nuclear Regulatory Commission
Mail Stop: (T-10K08)
Washington, D.C. 20555-0001
Phone: (301) 415-6852
Fax: (301) 415-5160
Email: jmk1@nrc.gov