ORDER FOR SUPPLIES OR SERVICES

PAGE 1 OF PAGES

IMPORTANT: Mark all packages and papers with contract and/or order numbers.

BPA NO.

1. DATE OF ORDER: 07-01-2004
2. CONTRACT NO. (if any): NRC-04-02-054
3. ORDER NO.: T014
MODIFICATION NO.:
4. REQUISITION/REFERENCE NO.: RES-02-054
5. ISSUING OFFICE (Address correspondence to):
U.S. Nuclear Regulatory Commission
Division of Contracts
Attn: T-7-I-2
Contract Management Center No. 2
Washington DC 20555

6. SHIP TO:
a. NAME OF CONSIGNEE: U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research
b. STREET ADDRESS: MS-10-K-8
c. CITY: Washington
d. STATE: DC
e. ZIP CODE: 20555
f. SHIP VIA:

7. TO:
a. NAME OF CONTRACTOR: Information Systems Laboratory, Inc
b. COMPANY NAME: 11140 Rockville Pike, Suite 500
c. STREET ADDRESS:
d. CITY: Rockville
e. STATE: MD
f. ZIP CODE: 20852

8. TYPE OF ORDER

[ ] a. PURCHASE ORDER
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/TASK ORDER
Except for billing instructions on the reverse, this delivery/task 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: RES-C04-426 46015115105 Y6748 252A $200,000

10. REQUISITIONING OFFICE: 04 Office of Nuclear Regulatory Research

11. BUSINESS CLASSIFICATION (Check appropriate box(es))
[ ] a. SMALL [X] b. OTHER THAN SMALL [ ] c. DISADVANTAGED [ ] d. WOMEN-OWNED

12. F.O.B. POINT: Destination
14. GOVERNMENT B/L NO.:
15. DELIVER TO F.O.B. POINT ON OR BEFORE: see SOW
16. DISCOUNT TERMS: net 30

13. PLACE OF
a. INSPECTION: Destination
b. ACCEPTANCE: Destination

FOR INFORMATION CALL: (No collect calls)
Stephen M. Pool
301-415-8168

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)
0001	Estimated cost for full performance of the work outlined in attached SOW	[redacted]			$369,353.00	
0002	Fixed Fee for full performance of the work outlined in the attached SOW				$24,490.00	
	Incrementally funded see block 9					

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

$393,843.00 ceiling SUBTOTAL

SEE BILLING INSTRUCTIONS ON REVERSE

21. MAIL INVOICE TO:
a. NAME: U.S. Nuclear Regulatory Commission, Division of Contracts
b. STREET ADDRESS (or P.O. Box): MS T-7-I-2
c. CITY: Washington
d. STATE: DC
e. ZIP CODE: 20555

17(h) TOTAL (Cont. pages)

obligatio $200,000.00

17(i). ~~GRAND TOTAL~~ funds

22. UNITED STATES OF AMERICA BY (Signature): Stephen Pool

23. NAME (Typed): Stephen M. Pool
TITLE: CONTRACTING/ORDERING OFFICER

CONTINUATION PAGE

Accepted TO#14: [signature]

Signature

V.P.

Title

7/6/04

Date

STATEMENT OF WORK
NRC-04-02-054 TASK ORDER 14

TITLE: **Scaling of AECL Test Facilities Used to Support ACR-700 Design Certification**

I. BACKGROUND

The NRC staff must determine the adequacy of major experimental facilities and the experimental database that AECL intends to use in support of ACR-700 Design Certification. Thermal-hydraulic codes such as TRACE contain numerous models and correlations that are empirically based and may be geometry and scale dependent. As a result, codes must be assessed for new applications when code applicability has not been established. The ACR-700 design differs significantly from reactor designs that have been previously analyzed using TRACE. In order to insure that TRACE, following model development and assessment, provides accurate predictions of ACR-700 hypothetical transients, a well scaled experimental database must be identified for the code assessment effort. New experiments may be also required to validate the codes and models for ACR-700.

Recognition of these needs led to incorporation of the licensing requirement for an adequate experimental data base as a prerequisite for design certification. This requirement, which is codified in 10 CFR 52.47(b)(2)(i)A, expresses the considered view that an adequate experimental data base must be established prior to design certification. Part 52 states,

> "The performance of each safety feature of the design has been demonstrated through either analysis, appropriate test programs, experience, or a combination thereof;
>
> Interdependent effects among safety features of the design have been found acceptable by analysis, appropriate test programs, experience, or a combination thereof;
>
> Sufficient data exist on the safety features of the design to assess the analytical tools used for safety analysis over a sufficient range of normal operating conditions, transient conditions, and specified accident sequences, ... "

The ACR-700 is characterized by more than 100 parallel flow paths for core cooling. Coolant flows in such a geometry are inherently unstable and difficult to predict or analyze. AECL has an integral test facility located at Whiteshell, Manitoba, to study the reactor coolant system behavior. The integral facility was designed and scaled by AECL as a full height, full pressure facility representing a typical CANDU reactor. There are several variations of the facility, designated RD-14, RD-14M, and RD-14/ACR, and experimental data from each of these variations may be used to support code validation for the ACR-700 design. As with other scaled experimental facilities, these facilities may have scaling distortions which limit their applicability to the full scale prototype. The integral facility data is supplemented by separate effects information from facilities such as CWIT and LASH.

Major thermal hydraulic issues with regards to scaling and data adequacy for ACR-700 include:

1. Large Scale System Interactions. Flow phenomena for a geometry that features multiple, competing parallel flow paths is complex, and can be stochastic and unstable. Compared to conventional CANDU plants, the ACR-700 design includes an inlet to outlet header interconnect pipe that re-distributes coolant during some accident scenarios. There may also be interactions between safety and non-safety systems in "crash-cooling" of the steam generators is assumed, and the plant behavior may be strongly influenced by ACR-700 control systems.

2. Multidimensional Flow in Headers and Supply of Flow from Headers to Feeders. In the ACR-700 design, the reactor coolant pumps supply water to horizontal inlet headers. Feeder pipes are connected at numerous locations along the header, both axially and azimuthally. Emergency core cooling is introduced into the headers horizontally at one end. Thus, flow distribution and two-phase conditions develop in a header, and cooling of an individual fuel channel will be influenced by the location and orientation of its feeder connection on the header. Phase separation at the header connections are expected to have an important influence on fuel channel coolability during an accident.

3. Heat Transfer and Flow Patterns in Horizontal Fuel Bundles. Some accidents lead to dryout of the fuel and rapid heatup until flow from the headers is reestablished. The flow pattern in a partially filled fuel channel is also expected to influence heat transfer from various fuel rods. Fuel rods above the mixture level reside in steam and radiate much of their heat to the pressure tube wall and in turn to the calandria tube, which is itself cooled by the moderator water in the calandria tank. Thus, the temperature distribution around the pressure/ calandria tubes and heat transfer to the moderator plays an important role in fuel channel cooling.

4. Energy Transfer from Pressure Tube to Calandria Tube. During normal reactor operation, the gas gap between the pressure tube and the calandria tube insulates the hot primary fluid from the cold, low-pressure water in the moderator (calandria) tank. A heat exchanger is connected to the calandria vessel to provide moderator cooling. During some accidents, the moderator can act as an important heat sink when the pressure tube balloons and/or sags making contact with the calandria tube.

5. Natural Circulation Flow and Heat Transfer. Natural circulation flow and heat transfer around the primary loop and on the secondary side of the steam generator are difficult to model. Flow between an inlet header and an outlet header has dozens of parallel flow paths to take. When the reactor is in a cool-down mode, with the primary pumps off and

ECC on, the flow may be forward in one fuel channel while reversed in an adjacent fuel channel. This has been observed in several RD-14M experiments.

6. Thermal-Hydraulic Phenomena in the Calandria Vessel. During steady-state operation, a detailed model of the calandria tank is probably not necessary because the energy transfer process is slow enough that the moderator heavy water can stay fairly well mixed. However, if a pressure tube should rupture, an accurate model is needed to determine the course of the accident. Complete condensation of the break effluent steam may occur if the pressure tube is sufficiently submerged. If a tube near the top of the moderator tank ruptures, thermal stratification could lead to incomplete condensation and over-pressurization of the tank. Rupture discs will then break, allowing the tank to blow down.

7. Break Spectrum and Break Location. The effects of breaks in various parts of the reactor coolant system must be understood. including breaks in feeder lines and pressure tubes.

8. Limited Core Damage Accidents: Initiating events must include consideration of accidents that potentially lead to fuel element and fuel channel distortion, and fuel melt. Analysis of these accidents require an understanding of single channel thermal-hydraulics at full power, critical heat flux (CHF) and rapid dryout of the rod bundle.

II. OBJECTIVE OF PROPOSED WORK

The main objective of the proposed work is to perform an independent scaling evaluation of the major test facilities intended for ACR-700 thermal-hydraulic code validation. This scaling evaluation is to consider the RD-14, RD-14M, and RD-14/ACR facilities and identify any important scaling distortions that may prevent data from these facilities from being applied to ACR-700. Scaling of separate effects test facilities that address highly ranked phenomena as identified by the ACR-700 PIRT is also to be performed. Therefore, the scaling analysis should consider the support facilities for headers and channel heat transfer, namely, Cold Water Injection Tests and Large Scale Header Facility. Both the integral and separate effects test scaling evaluations are to concentrate on the highly ranked (and medium ranked, as appropriate) phenomena from the PIRT (Phenomena Identification and Ranking Table).

III. SCOPE OF WORK:

1. Scaling

The geometry of the CANDU reactors may make it impossible to apply a single scaling approach consistently throughout the reactor coolant system and ECCS systems. The RD-14 facility and its various configurations employs engineering judgement in many cases to arrive at a scaled design. Only a single break location has been studied (header break), and break flow measurements have not been made.

The PIRT development was performed in a related project at Brookhaven National Laboratory. Input deck development for TRACE for ACR-700, RD14M, and the Cold Water Injection Facility was performed through a related project at ISL. The scaling evaluation for the integral facilities should include both "top-down" and "bottom-up" approaches, and quantify the phenomena in terms of non-dimensional parameters derived from mass, momentum and energy equations representing active regions of the system.

From the PIRT, prioritize scaling requirements and perform scaling analysis to preserve important phenomena (the scaling approach is to first identify and rank the dominant phenomena and set priorities for preservation in a scaled facility). The scaling analysis should consider:

- Power-to-volume scaling. This includes the system as a whole (single node model) as well as distributed volume, that is, each major tank component should be evaluated for local power-to-volume. The objective is to ensure depressurization during LOCA is represented in terms of mass and enthalpy flows. Volume versus elevation must be examined as well to help determine the scaling of gravity driving heads.

- Preservation of flow regimes. Determine whether the piping diameters are sufficient to preserve flow regime transitions as well as CCFL. This includes consideration of Froude and Kutateladze numbers.

- Facility heat structures. Full height, full temperature facilities less than 1:100 volume scale suffer from significant distortions due to heat loss or heat flux. Fast transients may be distorted by excessive heat flux from structures to the fluid. Slow transients may have the opposite problem of excessive heat loss to the environment. Determine the scaling of heat addition from the metal structures to fluid in terms of heat capacity and area to determine the extent of heat flux distortions. Determine as well the distortions caused by heat loss to the environment.

- Preservation of geometric similitude. Determine how closely the isometric layout to the ACR-700 will be maintained.

- Preservation of loop flow. Determine how well the facility preserves the combination of gravity driving forces and loop flow resistance for single and two phase conditions. Particular emphasis should be given to the competing parallel flow paths between headers, and the differential pressures between inlet and outlet headers. Following late phase depressurization, these differential pressures become very small. Each flow path can respond differently due to their different elevations and different channel powers. Two-phase conditions in the channels act as individual amplifiers to flow resistance, resulting in different two phase multipliers. This feedback may reduce or prevent flow from entering the channels, resulting in considerable channel-to-channel variations. Note that the RD-14 and RD-14/ACR facilities allow only one pass though the core.

The scaling analysis for the RD-14 and RD-14M facilities should include consideration of the various periods of a hypothetical accident. A large header break for example, would consider separately the important scaling groups during the blowdown, refill and long-term cooling periods. The scaling analysis should consider all active components of the system. The scaling work should be based the ACR 700 thermal hydraulic PIRT and past work done on scaling, such as:

a. Banerjee, S., Ortiz., M.G., Larson, T.K., Reeder, D.L., "Top-Down Scaling Analyses Methodology for AP600 Integral Tests," INEL-96/0040, May 1997

b. "System Scaling for the Westinghouse AP600 Pressurized Water Reactor and Related Test Facilities," Wulff, W., Rohatgi, U.S., NUREG/CR-5541, September 1999

c. "An Integrated Structure and Scaling Methodology for Severe Accident Technical Issue Resolution," Technical Program Group, NUREG/CR-5809, November 1991

d. Reyes, J.N., Scaling Analysis Report for the OSU APEX-CE Integral System Test Facility, NUREG/CR-6731, U.S. Nuclear Regulatory Commission, June 2002.

Estimated Completion Date: April 30, 2005
Estimated Level of Effort: 20 staff-months

IV REPORTING REQUIREMENTS

NUREG/CR report documenting the work performed.

V. Deliverables and Delivery Schedule

1. A forecast milestone chart is required 2 months after contract award.

2. Draft NUREG/CR report describing the work performed should be submitted by April 30, 2005.

3. A Monthly Letter Status Report is to be submitted to the NRC Project Manager by the 20th of the month with copies provided to the following:

   Office of Nuclear Regulatory Research Project Manager and Technical Monitor

   Division of Contracts and Property Management, Office of Administration (Mail Stop T-7I2)

   The Monthly Letter Status Report 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. 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.

Note:

(1) NRC has implemented a new document management system, Agencywide Documents Access and Management System (ADAMS). For the present, contractors' mail will not be placed in ADAMS. All documents mailed to NRC (e.g., letters, technical reports, monthly letter reports, and other mail) should have "Addressee Only" on the envelope to keep it from being entered into ADAMS. Send mail for the addressee and cc's as separate mailings.

(2) NEW STANDARDS FOR CONTRACTORS WHO PREPARE NUREG-SERIES MANUSCRIPTS

The U.S. Nuclear Regulatory Commission (NRC) is capturing its official records electronically. These records will be saved electronically in the Agency-wide Documents Access and Management System, known as ADAMS. The NRC is currently scanning each final NUREG-series publication from the printed copy. Therefore, 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 report number (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 NRC project manager will forward a copy of the cover and title page so the contractor can prepare an image file to include in the electronic manuscript. For the electronic manuscript, convert the file to Portable Document Format (pdf).

II MEETINGS AND TRAVEL REQUIREMENTS

Total of four trips for three staff, each trip. One 1-week trip for three staff to Canada to include visits to: Whiteshell Laboratories, Pinawa, Manitoba; Stern Laboratories, Hamilton Ontario; Chalk River Laboratories, Chalk River, Ontario. Three trips within the U.S. as working meetings. One trip to NRC to present work to the ACRS. Other travel such as technical professional society meetings to present papers may be considered if needed, but must be approved by the NRC Project Manager. Foreign travel must be approved by processing NRC Form 445, in addition to being provided as part of the approved proposal.

VII. ESTIMATED LEVEL OF EFFORT

The estimated level of effort is 20 staff months

VIII. PERIOD OF PERFORMANCE

The period of performance of this task order is ~~May 24, 2004~~ 7/1/04 SP through April 30, 2005.

IX. QUALITY ASSURANCE

Section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001 (Public Law 106-554) directs the Office of Management and Budget (OMB) to issue government-wide guidelines (FR Vol. 67, No. 36, pp. 8452-8460) that "provide policy and procedural guidance to federal agencies for ensuring and maximizing the quality, objectivity, utility, and integrity of information (including statistical information) disseminated by federal agencies." NRC Information Quality Guidelines are provided in FR Vol. 67, No. 190, pp. 61695-61699.

The Contractor shall cite contractor quality assurance procedures used in the conduct of this work that provide for compliance with OMB and NRC guidelines.

X. NRC-FURNISHED MATERIAL

NRC will obtain AECL proprietary reports and experimental data to support this task.

XI. TECHNICAL AND OTHER SPECIAL QUALIFICATIONS REQUIRED

The contractor shall provide one to three thermal hydraulic senior code development engineers skilled in use of a thermal-hydraulic code such as CATHENA, TRACE and/or RELAP5. At least one of the engineers shall have prior experience in evaluation of CANDU type reactors. The engineers should have had experience performing the specific tasks detailed in this SOW. The NRC will rely on representations made by the contractor concerning the qualifications of the personnel assigned to the task order including assurance that all information contained in the technical and cost proposal, including resumes, is accurate and truthful.