UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

JUN 12 2002

Information Systems Laboratories, Inc.
ATTN: James Meyer
11140 Rockville Pike, Suite 500
Rockville, MD 20852

SUBJECT: MODIFICATION NO. 3 TO TASK ORDER NO. 1 ENTITLED, "PTS ANALYSIS" UNDER CONTRACT NO. NRC-04-02-054

Dear Mr. Meyer:

This letter definitizes Modification No. 3 to Task Order No. 1 in accordance with the enclosed statement of work. The period of performance for Task Order No. 1 is changed to run from December 20, 2001 through September 30, 2002. The task order estimated cost and fixed fee is changed as follows:

	From:	By:	To:
Estimated Costs	$205,053	$188,865	$393,738
Fixed Fee	$ 16,404	$ 14,478	$ 30,882
CPFF	$221,457	$203,163	$ 424,620

$224,620 in incremental funds are hereby allotted to this task order bringing the total funds to $424,620. Accounting Data for Task Order No. 1 Mod ~~X~~ 3 is as follows:

Commitment No.	APPN#	B&R	JCN	BOC	Amount
RES-C02-421	31X0200	26015110191	Y6598	252A	$203,163.00
RES-C02-439	31X0200	26016000000	Y6598	252A	21,457.00
Total Obligated Amount -					$224,620.00

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A summary of obligations for this task order, from award date through the date of this action is given below:

Total FY02 Obligation Amount:	$424,620.00
Cumulative total of NRC obligations:	$424,620.00

TEMPLATE- ADM 001 ADM02

Please indicate your acceptance of Modification No. 3 to Task Order No. 1 by having an official authorized to bind your organization execute three copies of this document, by signing in the space provided, and return two copies to me. You should retain the third copy for your records. All other terms and conditions of this task order remain unchanged.

Should you have any questions, regarding this modification, please contact me on (301) 415-8168.

Sincerely,

Stephen M. Pool, Contracting Officer
Division of Contracts and Property Management
Office of Administration

ACCEPTED:

NAME

V.P.
TITLE

6/14/02
DATE

STATEMENT OF WORK
TASK ORDER NO. 1
MODFICATION NO. 3
PTS ANALYSIS

BACKGROUND

There is currently underway a reevaluation of the issue of pressurized thermal shock (PTS). The purpose is to determine if and how the PTS rule, 10 CFR 50.61 can be revised. It is thought that the current rule and analysis methods, which were developed in the mid-1980s, may be conservative to a significant degree.

The potential benefits to revising the current PTS rule lie with life extension. The use of more accurate analysis methods allows the life of more susceptible reactor vessels to be extended from 40 years to 60 years. There is a very substantial economic benefit to doing so, since the capital costs of the plants were based on a 40 year life.

There are three major parts, or divisions, to the PTS analysis program: 1) fracture mechanics, 2) probabilistic risk assessment, and 3) thermal hydraulic transients. This task is included in part 3.
The purpose of this task is to analyze transients in four specific plants: Oconee-1, Beaver Valley-1, Palisades, and Calvert Cliffs-1. Two of these plants, Oconee-1 and Calvert Cliffs-1, were also the subject of the first PTS studies done in the mid-1980s. Beaver Valley was selected to replace the third plant for the original PTS study (H.B. Robinson). Both are Westinghouse 3-loop plants. Palisades was added because it is a limiting plant in terms of vessel fluence and embrittlement.

The attachment to this Statement of Work provides further background on testing done at the Oregon State University APEX test facility in support of the PTS program.

OBJECTIVE

Prior work was done to update and develop input decks for the four plants and to analyze a large number of transients: approximately 150 for Oconee and approximately 40 each for Palisades, Beaver Valley, and Calvert Cliffs. To complete the Palisades PTS analysis, approximately 40 additional Palisades transients are required. To complete the Beaver Valley PTS analysis, 20 to 40 Beaver Valley transients will be required. This was the subject of Modification #2 to Task Order #1. To date, the Calvert Cliffs analyses were performed by SMSAB staff with consulting assistance from ISL.

Recent presentations to the ACRS on Oconee PTS calculational results indicated the need to provide an assessment and validation case for RELAP5 to support the overall PTS effort. An additional ACRS meeting to address the issue is envisaged during the current fiscal year. To meet this objective, PTS-specific RELAP5 assessment is required.

The objective of this task order modification is twofold: 1) to complete the Calvert Cliffs studies and 2) to perform requisite PTS-specific RELAP5 validation and assessment.

WORK REQUIREMENTS

Task 1: Additional Calvert Cliffs Cases

Approximately 30 additional PTS transients need to be performed for the Calvert Cliffs plant. These will be defined by Probabilistic Risk Assessment staff in the time frame May-June, 2002.

Interact with Calvert Cliffs staff as needed, to present the results of our RELAP5 analyses to utility personnel and obtain comments on our work. This will include joint meetings with utility staff to discuss and review results. It may be necessary to respond to requests for information from Calvert Cliffs staff on results of RELAP5 analyses and their interpretation.

All RELAP5 input and output files that should be retained as defined by the NRC project officer will be archived on the NRC data bank.

Estimated Level of Effort: 4 staff-months
Estimated Completion Date: 9/30/02

Task 2: RELAP5 Validation and Assessment

There are four PTS significant categories:

a. Primary side breach in which HPI flow rate can not compensate the break flow rate

b. Large secondary side depressurization

c. Small primary side breach (HPI can compensate break flow) plus failure and recovery of HPI (causing late repressurization)

d. Multiple system failure (e.g., small primary side breach + secondary side depressurization

Recent presentations to the ACRS of Oconee PTS calculated results indicated the need to provide an assessment and validation case for RELAP5 to support the overall PTS effort. An additional ACRS meeting to address the issue is envisioned during the current fiscal year. To meet this objective, perform a PTS-specific RELAP5 assessment to include the following new developmental assessment cases.

- ROSA-IV Hot Leg Break (SB--HL-03, 05, or 06)
- ROSA-IV Natural Circulation with Stepped Inventory Reduction (ST-NC-09)
- APEX-CE-13 Stuck-Open PZR PORV from Full Power with Subsequent PORV Closure (CE-13)

- MIST 4.4-inch Cold Leg Break (4100B2)
- MIST Feed and Bleed (T360499)

Also assess the following existing RELAP5 developmental assessment cases:

- MIT pressurizer in surge
- Critical flow: MARVIKEN (tests 22 and 24) Saturated Liquid Blowdown
- SEMISCALE Natural Circulation with Stepped Inventory Reduction (S-NC-1 through S-NC-8
- APEX Natural Circulation with Stepped Inventory Reduction (APEX-CE-2 (OSU))
- 1.4-inch MIST Cold Leg Break (ISL)
- ROSA-AP600 1-inch Cold Leg Break (AP-CL-03)
- ROSA-AP600 1-inch Cold Leg Break with Failure of Both CMTs, 50% ADS1-4 failure, ADS1 Opened 30 Minutes After CMT Actuation Signal (AP-CL-09)
- APEX-AP600 1-inch Cold Leg Break with Failure of 3/4 ADS4 Valves to Open. NRC-10
- ROSA-IV 5-inch Cold Leg Break (ISP26)
- LOFT 1-inch Cold Leg Break (L3-7)
- APEX-CE 2.0-Inch Hot Leg Break from Full Power (CE-8 (OSU))
- APEX-CE Combination Stuck Open Pressurizer Safety Relief Valve and Steam Dump Valve (CE-10 (ISL))
- APEX-CE 1.0 ft^2 Main Steam Line Break Inside Containment from Full Power (CE-11 (OSU))
- APEX-CE 1.0 ft^2 Main Steam Line Break Inside Containment from Hot Standby (CE-12 (OSU))

All RELAP5 input and output files that should be retained as defined by the NRC project officer will be archived on the NRC data bank.

RELAP5 may miss a phenomena of possible importance, that is, the backflow of hot water or steam from the upper downcomer into the cold leg, which RELAP5 cannot calculate. In particular, the condensation of steam on the incoming HPI in the sloping part of the cold leg cannot be calculated by RELAP5. For the small breaks (<1.5"), provide information from the upper downcomer ("level", temperature, void fraction) to see when the potential exists for such flow.

The 1-D code problem is of primary concern in the cold leg and downcomer where it was believed that thermal effects may play an important role. We have performed supplemental analysis with REMIX and STAR-CD to address this issue. A summary of this work is shown in a table in the attachment. This addresses the question of volume averaging as well.

RELAP5's ability to calculate certain two-phase flow behavior should be assessed for:

a. Flow interruption by vapor in candy cane

b. Interruption-resumption flow

c. Boiling-condensation mode

d. Mixing of core water in downcomer

e. Reflux condensation

f. Heat sink loss due to secondary-primary liquid level in B&W

g. Heat sink loss due to secondary-primary temperatures

Estimated Level of Effort: 6 staff-months
Estimated Completion Date: 9/30/02

Attachment
Background of APEX Testing and Results

The NRC conducted testing in the APEX facility to support our calculational effort. There were three main objectives:

1. To investigate mixing of the HPI in the cold leg and downcomer. In particular, it was necessary to ensure that strong plumes did not persist into the downcomer region adjacent to the core in order to support the adequacy of the 1-D treatment of the temperature boundary condition in the code FAVOR;

2. To elucidate the onset of loop flow stagnation which is generally necessary to achieve low temperatures in the downcomer;

3. To provide data to validate and assess RELAP5 for PTS-significant transients.

Separate effects tests focused on mixing in the cold leg and plume behavior in the downcomer. Of particular significance was to determine whether the plume would mix and dissipate before reaching the downcomer elevation adjacent to the core. Integral tests have been used to assess RELAP5 for PTS significant transient scenarios. The integral tests were also intended to provide information on the sequential cessation of loop flow in the 4 cold legs of a 2 x 4 geometry. The tests were also intended to determine whether any unexpected phenomena may occur under PTS conditions.

Seven tests were added to the originally planned 13 tests to bring the total number to 20. Thus, far, we have obtained 16 separate effects and integral system tests. All the program objectives have been met.

Table 1 lists the separate effects tests, while Table 2 lists the Integral System tests completed.. A series of flow visualizations tests were also performed to determine the conditions leading to the onset of weir-wall spillover.

Cold Leg Thermal Stratification

Cold leg thermal stratification was observed in all of the natural circulation tests for the CE side injection configuration and Palisades flow rates. The presence of the reactor coolant pump weir wall promoted cold leg fluid thermal stratification and delayed spillover of cold water into the loop seals (i.e., cold leg crossover legs). Significant mixing was observed in the low flow, side injection high pressure safety injection line as a result of buoyant fluid back flow, more than expected from an injection Froude number based model. This phenomenon results in significant warming of the HPSI fluid.

Downcomer Plume Behavior

Downcomer plumes were observed in all of the tests following reactor coolant pump trip. Dissipation of the downcomer plumes occurred very quickly under stagnant loop conditions, typically within 1-2 cold leg diameters for the low flow, side-injection HPSI geometry. The plume had effectively dissipated by the time the downcomer region adjacent to the core had been reached.

A significant amount of plume interactions was seen in the downcomer, with merging of adjacent plumes observed. This merging occurs physically because it minimized the flow resistance of the flowing liquid. For some transients, this changed the location of the coldest downcomer fluid temperatures to between the cold legs rather than directly below the cold legs.

Under natural circulation flow conditions, the plumes remained intact longer and the downcomer fluid became thermally stratified. The plume remains intact longer because the relative velocity between the ambient fluid and the plume is significantly less in the "co-flow" case than in the stagnant ambient case. These results are consistent with the IVO test observations which were not previously explained.

The coldest temperature differences observed axially from the top to the bottom of the downcomer were observed for the small break LOCA cases. These values ranged from 35-40F. Plume behavior in the downcomer was calculated well using a CFD code. The agreement between the analytical and experimental results lends further support to the conclusion that the 1-D treatment of the temperature boundary condition in FAVOR is adequate. This resolved a potentially major issue.

Mechanisms for Primary Loop Stagnation

The four cold legs stop flowing sequentially in transients that lead to flow stagnation. One steam generator (the hotter one) stops flows before the other. During the small break LOCA tests, loop stagnation occurs when steam generator tubes drain. The long tubes drain significantly earlier than the short tubes, as also seen in earlier ROSA tests. Loop stagnation was not observed until the short tubes began to drain.

The remaining 2 cold legs in the colder steam generator may stop flowing separately as one loop seal becomes plugged with cold liquid back flow from the HPI. Spillover of cold water into a loop seal caused the loop seal to become a "cold plug." The negative buoyancy of the cold liquid plug caused stagnation in the affected cold leg. This is an example of a local phenomenon having an integral system effect. This impact of this phenomenon was not recognized in earlier PTS studies.

The onset of loop stagnation as a result of the formation of a cold liquid plug in the loop seal cannot be calculated by RELAP5 because the phenomenon is multidimensional in nature, involving countercurrent flow in the loop seal and cold leg.

During the MSLB tests, loop stagnation was observed to occur in the intact cold legs of the unaffected steam generator. Stagnation occurred after the unaffected steam generator became a heat source for the primary system.

Even in the presence of reverse heat transfer from the steam generators, positive loop natural circulation could occur because of the driving head produced by high pressure safety injection into the downcomer. The steam generator reverse heat transfer acts as a brake to impede natural circulation loop flow.

Current studies using RELAP5 model the steam generators with a single tube. To examine the significance of this modeling simplification, a study was done to compare a one tube model with a three tube model for a 2-inch break in H.B. Robinson [Wang, W., Steam Generator U-Tube

RELAP5 Nodalization Sensitivity Study, June 8, 2001]. For this break size, the difference in timing between the short tube and the long tube was only 10 seconds because the primary system depressurization is reasonably rapid. From this result, it was decided that for other than very small breaks (~1-inch), a single tube model was sufficient.

Table 1 OSU APEX-CE PTS Separate Effects Tests

Test Number	Title	Date	STAR/ REMIX
CE-03	N/C Fluid Mixing Test - (16 Parametric)	11/1/00	STAR
CE-04	Stagnant Loop Fluid Mixing Tests - 1 HPSI	2/8/01	
CE-05	Stagnant Loop Fluid Mixing Tests - 4 HPSI	2/13/01	
CE-06	Stagnant Loop Fluid Mixing Tests - 4 HPSI	2/27/01	
CE-14	Stagnant Loop Fluid Mixing Tests - 2 Adjacent HPSI	11/17/01	
CE-15	Stagnant Loop Fluid Mixing Tests - 2 Opposite HPSI	11/15/01	
CE-16	Stagnant Loop Fluid Mixing Tests - 3 HPSI	11/21/01	
CE-17	Stagnant Loop Fluid Mixing Tests - 1 HPSI Without Upper Plenum/Downcomer Bypass		
CE-18	Stagnant Loop Fluid Mixing Test - 4 HPSI Without Upper Plenum/Downcomer Bypass		
FV-Series	Onset of Weir-Wall Spillover	In Progress	

Table 2 OSU APEX-CE PTS Integral System Tests

Test Number	Title	Date	RELAP
CE-01	N/C Flow Benchmark Test	8/18/00	
CE-02	N/C Stepped-Inventory Reduction Test	10/12/00	Yes
CE-07	1.4 Inch Hot Leg Break from Full Power	5/22/01	
CE-08	1.4 Inch Hot Leg Break from Hot Zero Power	5/24/01	Yes
CE-09	Stuck-Open PZR PORV from Full Power	6/7/01	
CE-10	Stuck-Open PZR SRV and Steam Generator-A ADV from full power	6/15/01	Yes
CE-11	1.0 ft^2 MSLB from Hot Zero Power	5/4/01	Yes
CE-12	1.0 ft^2 MSLB from Full Power	5/11/01	Yes

CE-13	Stuck-Open PZR PORV from Full Power with Subsequent PORV Closure	10/19/01	Planned
CE-19	1.4 inch Hot Leg Break from Full Power with Bypass Closed		
CE-20	1.0 ft^2 MSLB from Full Power with Bypass Closed		