AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

1. CONTRACT ID CODE: RES-97-052 — PAGE 1 OF PAGES 2

2. AMENDMENT/MODIFICATION NO.: M009

3. EFFECTIVE DATE: MAY 0 3 2001

4. REQUISITION/PURCHASE REQ. NO.: RES-C01-038 RES-C01-383

5. PROJECT NO. (If applicable)

6. ISSUED BY — CODE

U.S. Nuclear Regulatory Commission
Division of Contracts and Property Mgt.
Attn: T-7-I-2
Contract Management Branch
Washington DC 20555

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

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

Battelle Memorial Institute
Columbus Operations

550 King Avenue
Columbus OH 43201-2693

CODE — FACILITY CODE

(X) 9A. AMENDMENT OF SOLICITATION NO.

9B. DATED (SEE ITEM 11)

10A. MODIFICATION OF CONTRACT/ORDER NO.: NRC-04-97-052

X 10B. DATED (SEE ITEM 13): 10-01-1997

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 of 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)

B&R No.: 16015110110; Job Code: W6775; BOC: 252A;
Appn. No.: 31X0200.160; Amount Obligated: $123,052.00

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 By mutual agreement of the parties.

D. OTHER (Specify type of modification and authority)

E. IMPORTANT: Contractor ___ is not, X is required to sign this document and return 2 copies to the issuing office.

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

Please see the attached page.

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): ULES P. JACKSON, CONTRACTING OFFICER

15B. CONTRACTOR/OFFEROR: Ules P. Jackson (Signature of person authorized to sign)

15C. DATE SIGNED: 5/3/01

16A. NAME AND TITLE OF CONTRACTING OFFICER (Type or print): Mary H. Mace, Contracting Officer

16B. UNITED STATES OF AMERICA BY Mary H. Mace (Signature of Contracting Officer)

16C. DATE SIGNED: 4-27-01

TEMPLATE-ADM-002 ADM-01

This modification is issued to: (1) add within scope tasks 8.3, 8.4 and 8.5 as described in the contractor's proposal dated 04/10/01and attached herein; (2) increase the contract ceiling by $84,940 from $505,312 to $590,252; and (3) increase the obligated amount by $123,052 from $467,200 to $590,252. The contract is therefore modified as follows:

1. Paragraphs (a), (c) and (d) of Section B.4, CONSIDERATION AND OBLIGATION–COST PLUS FIXED FEE - ALTERNATE I, are hereby deleted in their entirety and replaced with the following:

"(a) The total estimated cost to the Government for full performance of this contract is $590,252, of which the sum of $547,757 represents the estimated reimbursable costs, and of which $42,495 represents the fixed fee.

(c) The amount currently obligated by the Government with respect to this contract is $590,252, of which the sum of $547,757 represents the estimated reimbursable costs, and of which $42,495 represents the fixed fee.

(d) It is estimated that the amount currently allotted will cover performance through 09/30/01."

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

FY97 for Job Code W6775:	$ 72,200
FY98 for Job Code W6775:	$100,000
FY00 for Job Code W6775:	$ 70,000
FY01 for Job Code W6775:	$170,052
Cumulative NRC Total for W6775:	$412,252
FY97 for Job Code W6779:	$ 55,000
FY98 for Job Code W6779:	$ 53,000
FY99 for Job Code W6779:	$ 70,000
Cumulative NRC Total for W6779:	$178,000
Cumulative NRC Total Obligations	$590,252

This modification obligates FY01 funds in the amount of $123,052.

All other terms and conditions remain the same.

US NUCLEAR REGULATORY COMMISSION

Modification No. 9 Under Contract No. NRC-04-97-052

EVALUATION OF HOT-LEG NOZZLE TO PIPING BI-METALLIC WELD JOINT INTEGRITY FOR V. C. SUMMER NUCLEAR POWER PLANT

Part of Task 8 of the BINP Program
(Contract Number – NRC-04-97-052, Job Code W6775)

1.0 INTRODUCTION

The work plan outlined here is to help support the NRC's assessment of the cracking found in the 'A' hot leg nozzle to pipe weld in the Virgil C. Summer nuclear plant. The hot leg weld is a bimetallic weld joining a SA-508 (Class 2) reactor vessel nozzle with a 304 stainless steel pipe using an inconel weld procedure. The analysis is broken into three tasks. The first task is to model the residual stresses that develop from welding. This analysis will include the effects of selected repair weld analyses. The second is to validate the model by performing measurements on a similar bi-metallic welded pipe that was obtained during an earlier NRC program at Battelle (Short Cracks in Piping and Piping Welds). The final task involves evaluating stress intensity factors and crack opening displacements within the welded pipe along with performing simple pressurized water stress corrosion cracking (PWSCC) analyses of the cracks. All work is to be performed as part of Task 8 of the BINP Program.

2.0 WORK PLAN AND TASK STRUCTURE

Task 8.3 Bi-metallic Weld and Repair Weld Residual Stress Analyses..

Three separate sets of weld analyses are planned. These include: (i) analysis of a cold leg bimetallic weld used in an experiment conducted by Battelle in an earlier NRC sponsored program, (ii) analysis of a typical design bimetallic weld in the V. C. Summer plant for V. C. Summer hot legs 'B' and 'C', and (iii) Repair weld analyses of several typical repairs. The first analysis is planned for model validation purposes (support of Task 8.4) while (ii) is planned to predict the crack growth response within residual stress fields for a typical hot or cold leg plant weld. Analysis set (iii) will quantify the important effect that weld repairs have on weld induced residual stresses and on the corresponding crack growth through the repair residual stress fields.

The analyses in sets (i) and (ii) will be performed using both axis-symmetric analysis and full 3D analysis. The analysis set (iii) will be performed using full 3D analysis. It is noted that 3D welding considerations can have an important effect on the residual stresses, especially in the region of the weld start/stop locations and for considering the effects of weld repairs. The axis-symmetric analyses of (i) and (ii) will provide an initial 'general' overview of the residual stress fields in this bi-metallic weld. However, as discussed below, full 3D effects will be included in the fracture assessment even for the axis-symmetric weld modeling case.

- **Case 1.** A weld analysis of a bimetallic weld from a cold leg that was tested as part of the NRC program 'Short Cracks in Piping and Piping Welds' program is planned first. This pipe test was an A516 Grade 70 carbon steel pipe welded to a 316 SS safe end using an inconel weld. The pipe diameter was 36-inch with a thickness of 3.4 inches. The materials and geometry of this case are similar to the hot and cold leg welds in the V. C. Summer plant. The purpose of this analysis is to validate the weld models for the bimetallic weld case. It should be noted that Battelle's weld models have extensive validation from other programs in industry, US Government, and overseas utilities, but validation for this bimetallic case should further provide confidence in the advanced models.

- **Case 2.** Weld analysis of the 'B' and 'C' design hot leg bimetallic welds in the V. C. Summer plant will be conducted. This analysis will predict the residual stresses for use in a fracture assessment in Task 3. Weld joint specifications and material properties available through the licensee will be provided by NRC so as to accurately model the residual stresses.

- **Case 3.** Repair weld assessments will be made of the typical hot and cold leg analyses for the Case 2 condition. The analyses will proceed as follows. First, a special 'composite shell' solution (Reference [1]) will be employed to obtain a general overview of the weld repair stresses. Because the composite shell solution is quite rapid several quick analyses can be performed in order to define the location and size of the weld repairs for the complicated full 3D solutions. This composite shell solution has been used extensively by Battelle to provide assistance to a European utility on design of weld repairs and to quantify the effect of repairs on leak rates. After locations and weld repair designs have been agreed upon by cognizant NRC and Battelle staff (from the results of the approximate composite shell solutions and from V. C. Summer plant experience) full 3D weld repair analyses will be performed. These are complex and computer intensive solutions, but due to the need for local region accuracy, are considered necessary. Two separate repair lengths and two depths (a total of four repair analyses) will be performed, as specified and approved by NRC staff. The repair solution procedure consists of first modeling the original bi-metallic weld. This is a computationally intense solution since there are so many passes involved. Next, the material removal in preparation for the repair will be modeled. Finally, the repair passes will be modeled. For all repair cases, the predicted residual stresses will be used to predict SCC crack growth in task 3.

Some of the information necessary to perform the analyses described above includes weld geometry and weld parameters. It is tacitly assumed that NRC can provide this information from discussions with the licensee. Tensile and thermal properties are necessary for all materials of interest up to *near melting temperature*. The NRC through the licensee will also provide these material properties. Due to time constraints, Battelle does not plan to perform the necessary tests to obtain the tensile data.

Finally, all analyses will be performed using the STARWELD© weld analysis code (Reference [2]), which was developed jointly by Battelle and Caterpillar. This code has an extensive database of validation for complex welded structures and is considered to be the best available weld analysis code.

Task 8.4 Weld Residual Stress Measurements.

This task involves determining the residual stresses from the Battelle bimetallic test case (Reference [3] – from the Short Cracks in Piping and Piping Welds program) to further validate the models for bimetallic welds. Battelle still has sections of the original pipes that were taken from a canceled plant, and several were tested (Reference [3]) but several sections still remain undamaged. Battelle plans to use a trepanning technique to obtain surface measurements of the residual stresses.

Task 8.5 Fracture Mechanics and PWSCC Analysis.

Stress intensity factors will be determined by first mapping the results obtained from the weld analyses to a full three-dimensional finite element model. The stress intensity factors will be determined from the residual stress fields using the finite element alternating method (FEAM) code developed by Battelle (Reference [4]). FEAM is an extremely efficient method for fracture analysis that was developed recently in the aerospace community and has FAA and Air Force acceptance. In addition, Battelle has been using FEAM for weld fracture analyses for Argonne National Laboratory (as part of another NRC program), as part of a DOE weld fracture analysis program for Savannah River, and for European utilities. It is accepted as accurate and has been extensively validated. The effect of weld residual stress redistribution during crack growth is accurately accounted for with FEAM. The efficiency of FEAM is because a special crack mesh is not needed – rather the mesh for the *uncracked* geometry is all that is required, and K solutions can be obtained for many crack sizes, shapes, and locations with this one mesh.

Both circumferential and axial crack solutions will be obtained for both surface and through-wall cracks. From the recent documentation of the V C Summer cracking it is clear that both types of cracking have been observed. Flaw indications have been identified using ultrasonic testing (UT) and eddy current testing (ECT) in hot legs A, B, and C as reported in 12/20/2000 and 01/18/2001 licensee public meeting presentations. The NRC and Battelle will jointly determine the number, sizes, and locations of the cracks. It is assumed that K will be determined for about 20 cracks of various sizes and locations. In addition, one 'old fashioned' full 3D finite element analysis will be performed using ABAQUS for validation purposes. It is emphasized that the full 3D analysis using ABAQUS is time consuming and costly compared with FEAM solutions.

Finally, PWSCC predictions will be made using the K solution results. The analyses of PWSCC include the effect of residual stress redistribution caused by crack growth. NRC will provide pertinent material properties for the PWSCC analyses.

3.0 SCHEDULE

Work is expected to begin on 05/15/01 and to be completed by 02/28/02. A draft final letter report will be submitted by 12/28/01 and a final report will be submitted within 45 days after receiving NRC comments.

4.0 DELIVERABLES

A report describing the results of the study will be provided at the end of the project along with several PowerPoint presentations that detail the results. In addition, due to the need to obtain results quickly we will provide bi-monthly progress reports.

5.0 REFERENCES

[1] F. W. Brust, P. Dong, J. Zhang, "Influence of Residual Stresses and Weld Repairs on Pipe Fracture", Approximate Methods in the Design and Analysis of Pressure Vessels and Piping Components, W. J. Bees, Ed., PVP-Vol. 347, pp. 173-191, 1997.

[2] STARWELD©- (Simulation Tool for Advanced Rapid WELding-process Development), Version 1, Developed Jointly by Battelle and Caterpillar (Caterpillar owned), Exclusively distributed by Battelle, December, 1999.

[3] Scott, P. M., et al., "Fracture Evaluations of Fusion Line Cracks in Nuclear Pipe Bimetallic Welds", NUREG/CR-6297, January, 1995.

[4] FRAC@ALT© (FRacture Analysis Code via ALTernating method), Version 2.0, January, 1999, Battelle Memorial Institute.