| INTERAGENCY AGREEMENT | 1. IAA NO<br>NRC-HQ-20-14-T-0025/M0005 | PAGE 1 OF 2 |
|---|---|---|

| 2. ORDER NO | 3. REQUISITION NO. | 4. SOLICITATION NO |
|---|---|---|
| | | |

| 5. EFFECTIVE DATE | 6. AWARD DATE | 7. PERIOD OF PERFORMANCE |
|---|---|---|
| 09/30/2015 | 09/30/2015 | 08/11/2014 TO 02/15/2019 |

**8. SERVICING AGENCY**
PACIFIC NORTHWEST NAT LAB
ALC:
DUNS: +4:
US DEPARTMENT OF ENERGY
PACIFIC NORTHWEST SITE OFFICE
PO BOX 350 MS K9-42
RICHLAND WA 99352

POC Genice Madera
TELEPHONE NO 509-372-4010

**9. DELIVER TO**
JAY COLLINS
US NUCLEAR REGULATORY COMMISSION
ONE WHITE FLINT NORTH BUILDING
11555 ROCKVILLE PIKE
MAIL STOP O-9H4
ROCKVILLE MD 20852

**10. REQUESTING AGENCY**
ACQUISITION MANAGEMENT DIVISION
ALC: 3100001
DUNS: 040535809 +4:
US NUCLEAR REGULATORY COMMISSION
TWO WHITE FLINT NORTH
11545 ROCKVILLE PIKE
MAIL STOP T-5E3
ROCKVILLE MD 20852-2738

POC Carolyn A. Cooper
TELEPHONE NO. 301-415-6734

**11. INVOICE OFFICE**
US NUCLEAR REGULATORY COMMISSION
ONE WHITE FLINT NORTH
11555 ROCKVILLE PIKE
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ROCKVILLE MD 20852-2738

**12. ISSUING OFFICE**
US NRC - HQ
ACQUISITION MANAGEMENT DIVISION
MAIL STOP TWFN-5E03
WASHINGTON DC 20555-0001

**13. LEGISLATIVE AUTHORITY**
Energy Reorganization Act of 1974

**14. PROJECT ID**

**15. PROJECT TITLE**
SEE BOX 18

**16. ACCOUNTING DATA**
N/A

| 17. ITEM NO | 18. SUPPLIES/SERVICES | 19. QUANTITY | 20. UNIT | 21. UNIT PRICE | 22. AMOUNT |
|---|---|---|---|---|---|
| | NRC-HQ-25-14-D-0001/NRC-HQ-20-14-T-0025<br><br>Master IAA: NRCHQ2514D0001<br>The purpose of this modification is to incorporate a within scope change to the Statement of Work (SOW) thereby increasing the authorized ceiling amount of the Agreement and extending the period of performance from September 30, 2017 through February 15, 2019. The NRC accepts modified Tasks 3, 4, 5, 7, 14, and Optional Task 16 as reflected in the revised SOW (Attachment 1). Optional Tasks 5C, 7a, 11a,<br>Continued ... | | | | |

**23. PAYMENT PROVISIONS**

**24. TOTAL AMOUNT**
$0.00

**25a. SIGNATURE OF GOVERNMENT REPRESENTATIVE (SERVICING)**

**26a. SIGNATURE OF GOVERNMENT REPRESENTATIVE (REQUESTING)**

**25b. NAME AND TITLE**

**25c. DATE**

**26b. CONTRACTING OFFICER**
CAROLYN A. COOPER

**26c. DATE**
9/30/2015

TEMPLATE - ADM001

SUNSI REVIEW COMPLETE

OCT 22 2015

ADM002

11b, and 12c will not be exercised at this time. It should be noted that Tasks 10 and 11 are no longer required, therefore, these tasks will be descoped from the SOW. As a result, the original ceiling amount of the Agreement is being reduced by $134,226.00 from $1,849,839.00 to $1,715,613.00.

Accordingly, the Agreement is hereby modified:

AUTHORIZED COST CEILING: $2,223,423.00 (changed)
TOTAL AMOUNT OBLIGATED: $1,400,000.00 (unchanged)
PERIOD OF PERFORMANCE: August 11, 2014 through February 15, 2019 (changed)

The following document is hereby made apart of this Agreement modification:

Attachment 1, Revised Statement of Work

All other terms and conditions of the subject agreement remain unchanged.

REFERENCE: ZEROREQ-NRR-15-0215

**STATEMENT OF WORK**

| **NRC Agreement Number**<br><br>NRC-HQ-25-14-D-0001 | **NRC Agreement Modification Number**<br><br>N/A | **NRC Task Order Number (If Applicable)**<br><br>NRC-HQ-20-14-T-0025 | **NRC Task Order Modification Number (If Applicable)** |
|---|---|---|---|
| **Project Title**<br><br>Technical Assistance for Topical Report Review of MRP-335, Peening Mitigation of PWSCC | | | |
| **Job Code Number** | **B&R Number** | **DOE Laboratory**<br><br>Pacific Northwest National Lab | |
| **NRC Requisitioning Office**<br><br>NRR | | | |
| **NRC Form 187, Contract Security and Classification Requirements**<br>☐ Applicable<br>☒ Not Applicable | ☐ Involves Proprietary Information<br>☐ Involves Sensitive Unclassified | | |
| ☒ Non Fee-Recoverable | ☐ Fee-Recoverable (If checked, complete all applicable sections below) | | |
| **Docket Number (If Fee-Recoverable/Applicable)** | **Inspection Report Number (If Fee Recoverable/Applicable)** | | |
| **Technical Assignment Control Number (If Fee-Recoverable/Applicable)** | **Technical Assignment Control Number Description (If Fee- Recoverable/Applicable)** | | |

## 1.0 BACKGROUND

Primary water stress corrosion cracking (PWSCC) of nickel-base alloy components and welds in the reactor coolant system of pressurized water reactors is a significant regulatory concern due to the potential for cracking or boric acid corrosion that could lead to a loss of coolant accident. Regulatory requirements have been established over the past 10-years to develop an inspection program that tries to proactively address this potential degradation mechanism to provide reasonable assurance of leak-tightness and structural integrity of the reactor coolant pressure boundary. Several mitigation techniques have been authorized by the NRC to allow relaxation of these inspection requirements due to the evaluated effectiveness of the mitigation to address PWSCC. Similarly these mitigation programs with

the associated modified inspection program provide defense in depth to meet the NRC goals of protecting public health and safety.

The Materials Reliability Program (MRP) of Electric Power Research Institute (EPRI) submitted a topical report for review to the NRC entitled, "Primary Water Stress Corrosion Cracking Mitigation by Surface Stress Improvement (MRP-335, Revision I)." This report summarizes a technical basis to allow the NRC to review the effectiveness of three types of surface stress improvement; water jet peening, underwater laser peening and air laser peening. The purpose of the report is to provide a basis for licensees of pressurized water reactors to proactively mitigate their nickel-alloy components and welds and then modify their inspection programs for the mitigated components or welds.

In order to complete an effective evaluation of the peening processes identified, NRC staff requires the use of laboratory resources to perform testing on realistic plant components under as close as possible in-service operational conditions. Further, the NRC staff is focusing this testing on surfaces for which access is limited or the surface condition is rough to ensure effective application of the peening process is possible for the range of components identified in MRP-335.

In February 2015, the NRC re-evaluated the path forward for the review of MRP-335. After a series of public meetings with stakeholders, the NRC determined that the review would consist of three distinct parts. The first part would be to determine if peening for the purpose of surface stress improvement would be allowed to be implemented. The second part would be the determination of the regulatory examination frequency relief that should be provided given a certain level of stress improvement, as generically defined in MRP-335. The third part would be the verification process necessary to ensure a licensee's peening process was effective at obtaining the necessary level of stress improvement, as generically defined in MRP-335. This three-part approach significantly changed the way MRP-335 was to be reviewed for approval.

Hence the three part approach to review peening and MRP-335 has a significant impact on this task order's scope of work. This revised statement of work is provided to transition the old program into the scope of the new NRC objectives. **It should be noted that while the scope of the original work has changed, it is not envisioned that the agreement ceiling will increase as the result of this modification.**

## 2.0 OBJECTIVE

The objective of the new verification project is to provide the NRC staff the tools necessary to ensure the effectiveness of any peening process to meet the levels of stress improvement defined in MRP-335. The tools will be DOE findings of the tasks outlined in this statement of work that have been developed to support NRC identified limitations of peening processes. The NRC will use these tools to evaluate each licensee's specific peening process through their quality assurance programs in the third part of the review process. This work is not to be

considered a comprehensive research project to evaluate the full and complete effectiveness of each peening process; it is instead a verification of known limiting cases to provide reasonable assurance that each process meets the levels of stress improvement defined in MRP-335.

## 3.1 SCOPE OF WORK

The DOE Laboratory must provide all resources necessary to accomplish the tasks and deliverables described in this statement of work (SOW). The following items should be considered;

1. Upper head penetration nozzles with at least three different incident angles (0-10 degrees, 15- 25 degrees, and > 30 degrees) including partial penetration weld. No grinding should be performed on the weld surfaces.

2. Alloy 182/82 butt welds representative of reactor coolant system piping butt welds with surface roughness at the limits allowed by MRP-335.

3. Alloy 600 plate
    a. Without flaws as a baseline for initiation testing
    b. Without flaws to be peened for initiation testing
    c. With surface stress corrosion cracks to be peened for crack arrest testing

4. Alloy 182 weld on plate, surface cleaned but left in the "as-welded" condition.
    a. Without flaws as a baseline for initiation testing
    b. Without flaws to be peened for initiation testing
    c. With fabrication defects both surface breaking and very near-surface (5mm to 0.2mm in depth from surface) for initiation testing
    d. With surface stress corrosion cracks to be peened for crack arrest testing

The DOE Laboratory must be able to perform eddy current and ultrasonic testing of items above. The DOE Laboratory must be able to add sufficient indications in items above to determine the surface and subsurface depth detection capability of the eddy current inspection technique. The DOE laboratory must be able to provide expert recommendations for the implementation of examination techniques to provide inspection coverage for the depth of compression identified in MRP-335.

The DOE Laboratory must be able to mathematically predict the weld residual stresses in items 1 and 2 above to identify the areas of higher weld residual surface and near surface stresses.
The DOE Laboratory must be able to use multiple weld residual stress measurement techniques (including, but not limited to, surface incremental hole drilling, slotting and x-ray diffraction) to evaluate the predicted weld residual surface and near surface stress conditions

up to 1 millimeter in depth of items 1 and 2 above, both pre and post peening. The DOE laboratory must provide their expert opinion on the effectiveness of this process to validate peening depth of compression in individual licensee mockups, and provide any recommendations for requirements to provide adequate assurance of an effective validation test.

The DOE Laboratory must be able to perform in-situ PWSCC initiation testing on baseline cold worked alloy 600/182/82 specimens in the pre and post peened conditions to determine if there is reasonable assurance that a minimum improvement factor of 5 is applicable to crack initiation for these materials.
The DOE Laboratory must be able to perform in-situ PWSCC crack arrest testing on peened cold worked alloy 600/182/82 specimens with pre-existing stress corrosion cracks of multiple depths to provide reasonable assurance of depth of compression required in MRP-335 is adequate to arrest flaw growth.

The DOE Laboratory will provide documentation of their results and participate in monthly status calls throughout the period of performance. Additionally, DOE Laboratory staff will support public meeting discussions with the authors of the topical report to address any needed additional information and discuss final results of the project. Finally, DOE Laboratory will provide a technical letter report summarizing the effort and providing all details of the findings for use in NRC written safety evaluations.

The DOE Laboratory may need to travel to supervise any subcontracts that are necessary such as manufacture or processing of samples or measurement of weld residual stress.

The DOE Laboratory will be responsible for shipment of all specimens to and from designated sites for the application of the peening process.

## 4.1 SPECIFIC TASKS

The DOE Laboratory must perform the following tasks:

**Task 1** – The NRC will provide to the DOE Laboratory all submitted documentation associated with the review of MRP-335 to include the original submittal, any supporting technical document basis, and any additional documentation provided due to requests for additional information, as available. The DOE Laboratory will be familiar with the information provided and control proprietary information in accordance with standardized agreements between the NRC and DOE Laboratory.

**DOE Laboratory (PNNL) Task 1 Response:**

**PNNL will obtain any necessary literature or pertinent documentation as reviews and technical expertise are requested from the Sponsor (NRC). PNNL will become familiar**

**with the documents and any additional supporting technical documents provided by the NRC, and PNNL will handle the information appropriately (and in accordance with agreed protocols) with regard to any proprietary or business sensitive information contained therein. PNNL understands that the NRC may request technical support in the form of reviews or technical comments as requests for relief are submitted and as requests for additional information (RAIs) are generated. PNNL will support these requests on an asneeded basis, and understands that these requests will likely be supported via written reviews, and verbal discussions (telephone calls or teleconferences). However, some situations may develop that require PNNL travel to Rockville, MD, (or other destination) to support a discussion or request for a technical opinion, via a face-to-face meeting, and these situations will be handled on a case-by-case basis as the project evolves, directly with the NRC Contracting Officer's Representative (COR).**

**PNNL notes that during the last round of RAI discussions, MRP specified that ID peening was required to support their risk analysis. While PNNL does not agree with this position, if ID peening becomes an important aspect to this work, an additional modification to the workscope will become necessary, as the work defined in this SOW is solely focused on OD peening applications.**

**Task 2** – The DOE Laboratory must acquire the following types of samples in sufficient quantity to meet the needs of the remaining tasks of this statement of work.

1. Upper head penetration nozzles with at least three different incident angles (0-10 degrees, 15- 25 degrees, and > 30 degrees) including partial penetration weld. No grinding should be performed on the weld surfaces.

2. Alloy 182/82 butt welds representative of reactor coolant system piping butt welds with surface roughness at the limits allowed by MRP-335.

3. Alloy 600 plate
    a. Without flaws as a baseline for initiation testing
    b. Without flaws to be peened for initiation testing
    c. With surface stress corrosion cracks to be peened for crack arrest testing

4. Alloy 182 weld on plate, surface cleaned but left in the "as-welded" condition.
    a. Without flaws as a baseline for initiation testing
    b. Without flaws to be peened for initiation testing
    c. With fabrication defects both surface breaking and very near-surface (5mm to 0.2mm in depth from surface) for initiation testing
    d. With surface stress corrosion cracks to be peened for crack arrest testing

DOE Laboratory (PNNL) Task 2 Response:

PNNL will identify, locate and configure the necessary materials/samples for fabrication of the required specimens identified in Task 2 above, (1-4). Many of the specimens have already been located at PNNL and prepared for use on the project. Some specimens may need to be cut out (extracted) from larger component configurations. In addition, some specimens may require reduction in size (and weight) for more improved handling and manipulation in the Lab. This Task includes acquisition and configuration of the necessary NDE data acquisition systems and scanning setups.

Items 1 and 2 above:

For the DMW mockups, in particular the nozzles provided to PNNL by Engineering Mechanics Corporation of Columbus ($EMC^2$), it may be necessary to cut (reduce) the carbon steel back-end of the mockup, by cutting off some amount of the nozzle (away from the DMW of interest) to allow ease of handling, manipulation and rotation for ET scanning. The existing PNNL rotational scanner platform (for conducting outside surface ET exams on cylindrical components) has a maximum weight capacity of 500 lbs. If the owner's of the mockups will not allow for some carbon steel nozzle material reduction, PNNL will need to obtain a rotational scanning platform (under Task 3) that has a higher weight capacity and also procure motors and motor drivers to couple the motion control to both existing PNNL data acquisition/control systems and the new WesDyne ET data acquisition system. The material costs associated with this option are approximately $15K, and will provide the capability to conduct rotational ET scans on very heavy, large components without the need to cut them down in size. There will also be some labor associated with writing up the driver code to couple the motor pulses from the DAS to the motor controller, but this is anticipated to be on the order of 40-60 hours. PNNL believes these nozzles could be reduced in size (via cutting), without significantly affecting the stresses on the targeted DMWs.

PNNL will subcontract this work out to a trusted and proven 3rd party for any required fabrication, cold spray or welding processes. These specimens will be appropriately marked and sectioned for specific activities (two stages of NDE, peening, and two stages of WRS measurements) throughout the effort. Baseline markings for development of a scanning coordinate system will be etched onto the surfaces of the mockups. Sufficient surface areas on each specimen will be made available for effective peening and for both NDE and WRS measurements. Specimens will contain areas designated for "no-peening" and "peening-only" processes. Some of this work has already been completed in numbers 1 and 2 above, however, the addition of a small (0° to 10°) incident angle upper head penetration nozzle will require some additional work. Originally, all CRDM nozzles for potential use on this project had been identified, extracted from the vessel and machined/prepared for characterization and NDE. This CRDM nozzle may need to be extracted from the remaining cluster of 3 upper head

**penetrations still residing in the vessel head material. If this is the case, an identical process as conducted on the other CRDM nozzles over the past many months, will be conducted to extract the one remaining nozzle from the vessel head, machine, cut and condition the mockup, for more manageable NDE, WRS and peening activities. This part of the effort will include Teamster costs associated with the use of a crane, flatbed truck and transportation costs, CRDM extraction/cutting, additional sample specimen conditioning and machining for reduction of unnecessary material and nozzle length, and associated in-lab configurations for handling and management of these large and heavy specimens. Work at PNNL to cut, machine or otherwise configure, handle and ship specimens out, will require the use of Service Requests through the Laborer's Union contract currently in operation at the Hanford Site. These requests typically take more time and can be more costly than anticipated. The schedule and costing information associated with this Task have taken this into consideration.**

**Item 3 above:**

**PNNL agrees with this, and the material for Items 3a and 3b have already been obtained as part of the originally accepted SOW. Item 3c will be obtained by starting with the same material used for Items 3a and 3b. As part of Task 5, SCC cracks will be grown into oversize specimens using SCC testing methods that have been developed at PNNL for CT specimen crack growth rate testing.**

**Item 4 above:**

**Regarding 4a and 4b, PNNL agrees with this, and the material was obtained as part of the originally accepted SOW. Regarding item 4c, this material was not in the originally accepted SOW and represents significant additional time and cost to produce. The time available to respond to this SOW was insufficient to determine a feasible means to produce such a material. An optional task (16) has been added to determine a cost to obtain this material and test it. Regarding 4d, PNNL agrees with this, and the material will be obtained by starting with the same material used for Items 4a and 4b. As part of Task 5, SCC cracks will be grown into oversize specimens using SCC testing methods that have been developed at PNNL for CT specimen crack growth rate testing.**

**Task 2a (optional)** – The DOE Laboratory will implant flaws, stress corrosion crack like indications, in one or more of the items in Task 2, Items 1 and 2, as directed by the NRC. If Task 2a is implemented, NRC understands it may delay the completion of Task 3 by two months.

**DOE Laboratory (PNNL) Task 2a Response:**

**As directed by the NRC COR, PNNL will support this activity to identify a suitable vendor and direct the introduction of flaws into specimens identified in Items #1 and #2 of Task 2. There are numerous ways to introduce flaws or stress corrosion crack-**

**like indications into these specimens. These may include implantation techniques, thermally induced crack initiation, cold-spray techniques, or other methods. The cost and time to complete these various flaw introduction approaches vary as a function of the flaw-type, flaw dimensions, flaw locations, and component-material configuration and characteristics. If the NRC COR directs PNNL to investigate insertion of flaws/cracks into these mockups, a cost assessment will need to be conducted, and a determination can be made at that time, to pursue or not pursue this activity.**

**If this Task is initiated, PNNL recommends adding some simulated voids/inclusions for near surface flaws based on the destructive testing (DT) results from South Texas Project (STP) and the Arizona Public Service (APS) leaking bottom mounted nozzles. Even though BMIs are not components currently specified in this evaluation, it is essentially the same disease. Both the NRC and PNNL have copious amounts of information on these efforts, to support a basis for including these.**

Task 3 – The DOE Laboratory will perform eddy current and ultrasonic examinations of the areas to be peened of items 1 & 2 of Task 2. The DOE Laboratory can perform eddy current examination of items 3 and 4 as necessary to evaluate the examination process on these materials. The DOE Laboratory will document, in a procedure, the steps taken to develop the most effective eddy current examination for surface and subsurface flaw of the items of Task 2.

DOE Laboratory (PNNL) Task 3 Response:

**PNNL will conduct a best-effort for obtaining effective baseline NDE (including ET and PA-UT examinations) on pre-peened areas of the sample specimens identified in items #1 and #2 above in Task 2. There may exist as-welded surface conditions and geometry on some specimens that may impede access or otherwise degrade NDE data quality (for example due to liftoff of the ET probe). PNNL will conduct the most effective NDE assessments available for these measurements. In addition, all NDE approaches and scanning protocols employed in this work will be documented appropriately. A detailed procedure, defining the steps performed for an assessment of ET detection performance (to determine maximum detection capabilities for near/sub surface flaws) will also be developed. Specimens identified for these measurements may employ a well-controlled cold-spray technique, iteratively applied over the surface of the specimens to provide step-wise changes in thickness of the surface coating as a function of each ET test. This will provide an effective means to determine probe depth of penetration as a function of frequency and flaw characteristics. Additionally, PNNL suggests considering the use of time-of-flight diffraction ultrasonic testing (TOFD-UT) as a complementary technique for characterizing the J-groove welds and DMWs identified in Task 2.**

**The specific probes desired to conduct the NDE assessments have been obtained. The Eddy Current data acquisition and signal conditioning system will be procured as part of this activity. Once obtained, a scan plan and protocol will be developed and ET will be conducted on all J-groove welds and DMWs identified in items #1 and #2 above in Task 2. For the CRDM specimens, 0° phased array ultrasonic (PA-UT) examinations will also be conducted for detection and localization of weld fabrication defects and slag inclusions at the J-groove weld/tube-wall boundary. It is critical that PNNL assess whether or not the CRDM specimens contain this condition or not. Much of this NDE work has already been conducted on the CRDM nozzle mockups, with the exception of the small (0° to 10°) incident angle upper head penetration nozzle. For the DMW specimens, PA-UT examinations *may* be conducted to baseline the welds prior to WRS and peening activities, but only with guidance from the NRC COR.**

**If the owner's of the mockups in Task 2 (item 2) will not allow for some carbon steel nozzle material reduction, PNNL will need to obtain a rotational scanning platform (under Task 3) that has a higher weight capacity and also procure motors and motor drivers to couple the motion control to both existing PNNL data acquisition/control systems and the new WesDyne ET data acquisition system. The material costs associated with this option are approximately $15K, and will provide the capability to conduct rotational ET scans on very heavy, large components without the need to cut them down in size. There will also be some labor associated with writing up the driver code to couple the motor pulses from the DAS to the motor controller, but this is anticipated to be on the order of 40-60 hours. PNNL believes these nozzles could be reduced in size (via cutting), without significantly affecting the stresses on the targeted DMWs.**

**PNNL will make every effort to expedite the schedule and compress the time for conducting and reporting NDE measurements. The PNNL team will encounter a time-lag between the time the ET data acquisition system is procured (immediately upon acceptance and authorization of this modified SOW by the NRC) and the time the system has been received at PNNL, and configured for laboratory data acquisition work. Current lag-time is anticipated to be approximately 10 weeks.**

**The NDE data obtained in Task 3 will be used as baseline data to compare/contrast with post-peened mockups. This subsequent work will be conducted under Task 10.**

**Task 4** – The DOE Laboratory will engineer, procure and evaluate through testing, a crack initiation testing rig and a crack arrest testing rig capable of in-situ testing of each sample under pressurized water reactor conditions with increased environmental susceptibility due to temperature only. The DOE Laboratory will provide a technical letter report (TLR) documenting the assembly, evaluation and verification of the equipment prior to use on specimens. The NRC will review and approve the TLR prior to testing.

**DOE Laboratory (PNNL) Task 4 Response:**

**PNNL proposes to add an additional task to develop and qualify an appropriate test specimen to evaluate the effectiveness of peening on SCC crack initiation and SCC crack arrest. PNNL also proposes changes to this task description to add more detail.**

**Task 4a:** ***Design and Evaluate a Specimen for Assessing The Effect of Peening on SCC***

**A new test specimen will be designed and evaluated to establish its effectiveness to assess the effect of peening on SCC initiation and SCC crack arrest. This task will begin with finite element modeling of specimen concepts with a goal of producing a specimen that can be fitted with DCPD instrumentation to monitor for cracking and can be peened. A key aspect of specimen design will be to produce peak stresses in the region where SCC initiation is desired to occur. Several specimens will then be fabricated and tested to demonstrate initiation response using an available PNNLowned or NRC-owned test system. In addition, both FEA and CGR testing on a relevant material will likely be conducted on cold-worked Alloy 600.**

**Through ongoing work started under the original SOW, a 4-point bend specimen has been selected. Specimen design is complete, and a test fixture design is nearly complete that maintains load on the specimen through the peening process and the entire test period. This ability to maintain load is vital to effectively simulate a service environment where the completed reactor structure with its residual stresses and strains is peened.**

**While only a few short steps are needed to produce a peened specimen for crack initiation testing, several more steps that take a substantial length of time are needed to produce a peened crack arrest specimen. The additional steps needed to prepare such a specimen are: 1) Grow an intergranular SCC crack into an oversized, notched 4-pt bend specimen. [~3.5 months] 2) Remove excess material from the specimen to produce a surface crack of desired depth. [~0.5 months] 3) Confirm SCC response of this modified specimen. [~1 month]. The total additional time is expected to be ~5 months. Due to the variability in SCC response for a given material, especially for weld metals, it is challenging to grow SCC cracks to a particular length in multiple specimens simultaneously in one autoclave. It is envisioned that this can be done with only 3 specimens at a time. These steps to produce SCC cracked specimens for peening adds substantial time to the process and will limit the number of crack arrest specimens that can be produced during the program lifetime.**

**The level of effort estimated to complete this task has grown beyond expectation due to the selection of a brand new specimen concept and also due to the realization that in order to properly evaluate the effects of peening, the fixture must be able to maintain load on the specimen before, during, and after the peening process. Careful consideration was needed to determine a design that cannot only maintain load as**

**described, but also allows the specimen surface to be peened. Effects of thermal expansion on load relaxation during fixture heating also had to be considered for the design. And at the same time, the goal of a 27-specimen fixture had to be maintained.**

**Task 4b:** ***Fabrication of One Test System for Peening SCC Initiation Research***

**An SCC initiation test system will be engineered, components will be procured, and the system operation will be validated through testing. The completed system will enable simultaneous testing of not less than 27 specimens under PWR primary water conditions at 360°C with in-situ crack detection.**

**Task 4c:** ***Fabrication of Test System for Peening SCC Crack Arrest Study***

**A test system to evaluate the effect of peening on SCC crack arrest will be engineered, parts will be procured, and the system will be constructed. The system will be capable of in-situ testing of not less than 6 specimens simultaneously under 360°C PWR primary water conditions, and it will have the capability to easily be later retrofitted with a 27-36 specimen SCC initiation load train.**

**Task 4d:** ***Technical Letter Report on Specimen Design and System Construction***

**A technical letter report (TLR) will be provided documenting peening specimen design and validation, and the assembly, evaluation and verification of the equipment prior to use for evaluating the effect of peening on SCC initiation and SCC crack arrest. The NRC will review and approve the TLR prior to testing to evaluate the effectiveness of peening.**

**Task 5** – The DOE Laboratory will produce specimens for the crack initiation and crack arrest testing rigs from items 3 and 4 of Task 2. The samples will include the following at a minimum,

1. 15% cold worked alloy 600,
2. Item 1 with stress corrosion cracks with depths between 0.005 to 0.01 inches,
3. Item 1 with stress corrosion cracks with depths between 0.02 to 0.05 inches,
4. 15% cold worked alloy 182 with dendrites in line with the cracking plane,
5. Item 4 with fabrication defects as much as possible in line with the cracking plane,
6. Item 4 with stress corrosion cracks with depths between 0.02 to 0.04 inches,
7. Item 4 with stress corrosion cracks with depths between 0.05 to 0.08 inches,

The total number of specimens will be determined by the size of the testing rigs. Items 1, 4 and 5 are provided for the crack initiation testing rig. Items 2, 3, 6 and 7 are provided for the

crack arrest testing rig. An even distribution of each item for each rig should be produced. Variation in crack depth can be allowed provided it is approved by NRC staff.

**DOE Laboratory (PNNL) Task 5 Response:**

**PNNL concurs with obtaining 15% cold worked alloy 600 and alloy 182 for this program. As part of the original SOW, appropriate material in the non-CW condition has already been obtained but still needs to be 15% cold worked. In order to provide better detail of the proposed work, this task is being broken into two different sections, one for initiation specimens and one for crack arrest specimens.**

**Item 5.5 (alloy 182 specimens with built-in defects) is outside of the originally accepted scope and will require extended investigation to determine how the material could be produced. An optional task (16) has been added to determine a cost to obtain this material and test it.**

**Task 5a:** ***Production of Specimens for Evaluating Effect of Peening on Crack Initiation***

**4-point bend SCC initiation test specimens will be produced to fill the initiation test system and, as possible, enable a statistical evaluation of time for crack nucleation. Assuming a 27-specimen test system, it is proposed to test 9 alloy 600 specimens and 18 alloy 182 specimens. Two rounds of testing will be required - one for baseline response of unpeened specimens and one to evaluate peening. Six extra specimens each of alloy 600 and alloy 182 will be produced. This leads to the following specimen quantities:**

- **Twenty-four (9+9+6=24) 15% cold worked alloy 600 specimens**
- **Forty-two (18+18+6=42) 15% cold worked alloy 182 specimens with the weld aligned in the most susceptible orientation**

**Task 5b:** ***Production of Specimens for Evaluating The Effect of Peening on SCC Crack Arrest***

**The originally accepted SOW only provided time and funding to produce three 15% CF alloy 600 specimens and three 15% CF alloy 182 specimens for crack arrest testing. To adhere to the originally accepted SOW time and cost structure, either Items 5.2 and 5.6 (specimens with shorter SCC cracks) or Items 5.3 and 5.7 (specimens with longer SCC cracks) can be produced and evaluated. PNNL proposes that the NRC choose which of these two sets of specimens are to be produced and evaluated.**

Task 5c (Optional): ***Additional Production of Specimens with SCC Cracks for Evaluating The Effect of Peening on SCC Crack Arrest***

**PNNL will produce an additional 3 specimens each of 15% CF alloy 600 and 15% CF alloy
182 with either short SCC cracks or long SCC cracks. This will require additional funding, and completion of testing of these specimens would require extending the project end date to April 30, 2019.**

**While it is highly desirable to produce extra crack arrest specimens of each type to be evaluated, the balance between available time and the desire to test as many different conditions as possible precludes this. If any specimens become damaged during the production process or do not turn out as intended, the number of specimens for crack arrest testing will be reduced by that amount.**

Task 6 – The DOE Laboratory will perform baseline crack initiation testing of samples from Items 1, 4 and 5 of Task 5.

DOE Laboratory (PNNL) Task 6 Response:

**Nine 15% CF alloy 600 and eighteen 15% CF alloy 182 specimens will be tested in the unpeened condition. All will be instrumented for SCC initiation. These specimens will be loaded such that the outer surface will be at or above the yield strength of the 15% CF material. While it is likely that all specimens will initiation within four months, six months are being set aside for the testing and another month is set aside for startup and shutdown activities.**

**As discussed in the PNNL response to Tasks 2, 4, and 5, materials with built-in defects are outside of the originally accepted SOW and represent significant additional effort to procure and test. An optional task (16) has been added to determine a cost to obtain this material and test it.**

Task 7 – The DOE laboratory will provide an assessment on the effectiveness of the licensee's proposed process to validate peening depth of compression in individual licensee mockups. The DOE laboratory will use a section of weld from Item 4 of Task 2. The DOE laboratory will take surface residual stress measurements (including, but not limited to, surface incremental hole drilling, slotting and x-ray diffraction) of the weld and near plate material surfaces. Each measurement type should be performed three times. The DOE laboratory will then provide the data with any notes to the NRC.

The DOE laboratory will also provide any recommendations for requirements to provide adequate assurance of an effective validation test through the following steps.

**Task 7a** - The DOE Laboratory will mathematically predict the weld residual surface and near surface stresses in items 1 and 2 of Task 2. The DOE Laboratory will then submit these analyses for NRC review.

**Task 7b** – The NRC will identify up to 3 areas of high tensile stress to be evaluated by the DOE Laboratory.

**Task 7c** - The DOE Laboratory will use weld residual stress measurement techniques (including, but not limited to, surface incremental hole drilling, slotting and x-ray diffraction) to evaluate the predicted weld residual surface and near surface stress conditions up to 1 millimeter in depth of the locations identified in Task 7b.

**Task 7d** – The DOE Laboratory will provide a technical letter report documenting this task and providing assessment of this technique to choose locations to validate the effectiveness of peening.

**DOE Laboratory (PNNL) Task 7 Response:**

**PNNL will manage this effort via a modified subcontract to EMC$^2$ for all weld residual stress measurements and analysis. With input from the subcontractor, PNNL will generate a TLR documenting the locations and values of the stress profiles for each specimen. EMC$^2$ and its senior staff have conducted extensive analytical, computation, experimental and confirmatory research work for the US NRC for several decades. These efforts recently have included weld modeling, weld residual stress mitigation and fracture mechanics of surface and through wall flaws in Class 1, 2 and 3 safety-related components in nuclear power plants – which are directly related to the proposed efforts in this modified SOW. EMC$^2$ will conduct the research on this Task and will engage subcontractors of their own on an as-needed basis, to include (but not limited to) companies that have unique and significant expertise in the area of residual stress measurement such as, Hill Engineering, Rancho Cordova, CA.**

**The goal of the weld-on-plate WRSM task is to validate the accuracy of the various residual stress measurement techniques using a simple specimen such as a stainless steel plate with a weld. Emc2 will first work with PNNL to determine the size of the stainless steel plate as well as the number of weld passes needed to prepare this sample plate specimen. Three areas on this specimen in the parent (plate) material and three areas in the weld region will then be selected for measuring residual stresses using at least three techniques including: hole-drilling, slotting and x-ray diffraction. These plate specimens shall then be fabricated by PNNL and shipped to Emc2 or its subcontractor to make these WRSM measurements.**

**Upon receiving the results from the residual stress measurements, Emc2 will compile the results for comparison and then make recommendations to PNNL and NRC about effective validation methods for the CRDM specimens in the subsequent Tasks below.**

**Emc2 will, in accordance with the RFP, provide monthly letter summary reports, coordinate meetings and conference calls with all participating entities as necessary and provide technical assistance and support, including participating in meetings at NRC, vendors, or PNNL as required to successfully complete these efforts. Two "optional" trips to NRC for 2 staff members for 2 days per trip will be scheduled for progress meetings and reviews as described in the specific task discussions. We have also budgeted for "optional" trips to the vendors and to PNNL for face-to-face meetings with technical personnel, where needed.**

**In addition, and if needed, Emc2 will provide any technical support for public meetings, such as ACRS hearings related to these efforts. The required resources for this support has been identified as "optional".**

**<u>DOE Laboratory (PNNL) Task 7a Response:</u>**

**With regard to FE Analyses of CRDMs, the work proposed in this task was not in the original scope of the on-going project at Emc2. This additional scope described below is deemed necessary based on the progress to date and will therefore increase the cost ceiling of the existing effort.**

**Emc2 will support PNNL in its efforts to predict weld residual surface and near surface stresses along with full field stresses identified in Items 1 and 2 of Task 2 via computational methods supported by physical data developed for both the upper head penetration nozzles and the Alloy 182/82 butt welds of interest. Task 7 will focus on characterizing these properties in the 'as received' samples, prior to any optional 'peening' processing that may be selected during this project (See Optional Task 11 later in this document for Post-Peening discussions). Emc2 will use the VFT© code along with ABAQUS for these solutions. Specifically related to these efforts:**

**Emc2, in consultation with PNNL, will select three (3) representative Control Rod Drive Mechanism (CRDM's) specimens with upper head penetration nozzle geometries in the ranges of:**

- **0-10 Degree**
- **15-25 Degree**
- **> 30 Degree**

**PNNL will measure the geometry of each of the CRDM specimens adequately and provide the input needed to Emc2 to develop a full 3-dimensional finite element model for each of the CRDM specimens above. Once the 3D FE Model has been constructed and appropriately checked for completeness, Emc2 will conduct a full scale 3D FE**

**Analysis of each of the models to determine stress profiles across the CRDMs. The FEA results will be used to identify critical areas of high tensile residual stresses for each model. These results will be submitted to PNNL for forwarding to NRC-NRR in conjunction with parallel efforts at PNNL.**

**The "Optional" portion of this subtask encompasses work associated with FEA of dissimilar metal butt welds (item #2 of Task 2). In addition to the WRSM on the CRDM specimens, a similar methodology will be used to evaluate WRS on an Alloy 182/82 butt weld that is representative of reactor coolant system butt welds. The weld evaluated will be selected and generated by PNNL and delivered to Emc2 or its subcontractor for inclusion in the various studies with the CRDM samples.**

**This task is currently optional and will only be undertaken if deemed necessary by the NRC and PNNL in consultation with Emc2 staff.**

**<u>DOE Laboratory (PNNL) Task 7b Response:</u>**

**Upon review of the results from Task 7a, NRC-NRR will, in consultation with appropriate
PNNL and Emc2 technical staff, identify up to three (3) areas of high tensile residual stress determined through the FE Analysis (FEA) to be experimentally confirmed by the PNNL/Emc2 team. This work will require a conference call with PNNL, NRC and Emc2 staff in order to critically review the FEA results of Task 7a to insure that sufficient detail was available in the initial analyses to be able to select appropriate high stress areas. If necessary, after this initial review and with direction and approval from PNNL, Emc2 will conduct additional scoping FEA to provide more fidelity in the models to provide greater clarity in defining the three (3) best areas for Weld Residual Stress Measurement (WRSM) in each CRDM.**

**<u>DOE Laboratory (PNNL) Task 7c Response:</u>**

**The work proposed in this task was not in the original scope of the on-going project at Emc2. This additional scope described below is deemed necessary based on the progress to date and will therefore increase the cost ceiling of the existing effort.**

**Currently, a 'practice' CRDM resides at Hill Engineering in Sacramento, CA which conducted deep hole drilling (DHD) WRSMs in earlier tasks on this effort to determine comparability of experimentally determined WRS with those predicted using FEA. An objective of Task 7c is to develop complementary experimental techniques to DHD as a quality assurance (QA) check of the primary analysis and test methodologies.**

**For Task 7c, Emc2 has identified two (2) potential vendors of X-ray diffraction analyses that have the capabilities to evaluate WRS in both the CRDM and butt weld sample specimens. These vendors, Lambda Technologies of Cincinnati, OH and America**

**Stress Technologies of Pittsburgh, PA, will be asked to analyze the 'practice' CRDM in similar locations as Hill Engineering has to confirm Hill's WRSM findings using the complementary x-ray diffraction technology. Based on discussions with Hill Engineering, Lambda Technologies has developed their own proprietary process for mitigating weld residual stresses. During discussions with Lambda staff, additional information will be obtained about their process and provided to PNNL and NRC for further consideration as part of this task.**

**Thus, Emc2 will arrange to have the 'practice' CRDM returned from Hill to Emc2 laboratories. Upon return of this specimen, Emc2 will inspect visually to make sure no evident damage occurred during shipment. Following this internal inspection, Emc2 will then ship the sample to Lambda for WRSM via x-ray diffraction. Following Lambda's testing, the specimen will be returned to Emc2 for forwarding to American Stress Technologies (AST) for similar x-ray diffraction WRSM testing.**

**After both Lambda and AST have completed their measurements and provided a report on their findings, Emc2, PNNL and NRC-NRR staff will review the results and select one vendor for conducting additional x-ray diffraction work on the three (3) CRDMs selected in Task 7a along with the butt weld specimen prepared for these exercises. Once the CRDMs selected in Task 7a and the butt weld have been received by the selected x–ray diffraction vendor, they will be asked to conduct analyses at three locations on each CRDM that was identified from the Task 7b effort along with the location(s) identified for the butt weld sample.**

**Once the x-ray diffraction measurements on these CRDMs and the butt weld have been completed the samples will be shipped to Hill Engineering for DHD analyses using both hole and slotting techniques that have been conducted on the 'practice' CRDM previously. The x-ray diffraction vendor will supply a report of their results on each of the separate CRDMs and the butt welded specimen to forward to Emc2 for comparison the DHD results of Hill. Likewise, Hill will provide a report of results of their WRSM.**

**Based on discussions between NRC and PNNL, there may be another vendor available to conduct X-ray diffraction measurements that is currently used by the industry (Westinghouse). If a third vendor is available, they will be engaged for this effort after approval by NRC staff.**

**<u>DOE Laboratory (PNNL) Task 7d Response:</u>**

**Some of the work proposed in this task was not in the original scope of the on-going project at Emc2. This additional scope described below is deemed necessary based on the progress to date and will therefore increase the cost ceiling of the existing effort.**

**Task 7d will focus on preparing a technical letter report comparing the results of the computational FEA with those of the experimental methods, x-ray diffraction, hole drilling and slotting efforts. The report will provide recommendations and conclusions regarding the confidence levels when comparing computational WRS prediction results with those determined experimentally and will identify the preferred experimental technique for efforts of this type.**

**Emc2 will prepare draft technical reports for PNNL to review and forward to NRC-NRR for review and comments.**

**Task 8** - The DOE Laboratory will provide a TLR documenting each sample. The TLR will clearly identify the surfaces of each sample that can be peened. The NRC will review this document and provide comments to the DOE Laboratory. The DOE Laboratory will address any comments in a reasonable time period to support schedule. The NRC will use this document to have each sample peened as necessary to support the review process.

**DOE Laboratory (PNNL) Task 8 Response:**

**PNNL will provide detailed specimen information including photographs and specimen maps defining specific areas for peening, and outlining these areas where NDE baseline and post-peening measurements, WRS baseline and post-peening measurements and any other measurements or processes are to be applied. This TLR will be written and submitted to the NRC for use in vendor discussions and guidance for peening. This effort will focus on the specimens identified for peening in Task 2. This work includes writing the TLR, performing PNNL's internal ERICA review processes and iterating with the client and subcontractors on TLR content/modifications. The TLR will clearly identify the three regions for each sample type for items 1-4 of Task 2 that can be peened. The NRC will use this document to have each sample peened using the appropriate techniques identified in MRP-335 R1. Therefore, the NRC will review this document and provide comments to the DOE Laboratory. The DOE Laboratory will address any comments in a reasonable time period to support schedule.**

**Task 9** – The DOE Laboratory will ship the specimens as described by written letter from the NRC. The NRC will provide shipping order letters based on the NRC relief request evaluation schedule and vendor ability to peen items. The shipping orders will be based on information provided by the Task 8 TLR. The NRC will be responsible to ensure that each sample is peened in accordance with the Task 8 TLR. Once a specimen is peened, the DOE Laboratory will be responsible to ship it back to the DOE Laboratory facilities. NRC understands that a cost estimate of this shipping task is highly variable, as all specimens many not be required to be peened or peened at the same location. NRC requests a cost estimate of shipping all specimens, in shipments to contain all specimens of the same type, to the AREVA facilities in Lynchburg, VA.

DOE Laboratory (PNNL) Task 9 Response:

PNNL concurs with the NRC guidance defined in Task 9. Since some specimens to be peened are linked to crack arrest and crack initiation activities while others are associated with the NDE/WRS activities, PNNL acknowledges that specimen shipments may not be coordinated in time (scheduling) as these two sets of specimens are programmatically decoupled. PNNL will coordinate logistics and ship the specimens to the vendor(s) of choice, as per guidance from the NRC COR. Shipping/freight costs will be attributed to this Task for this activity. The DOE Laboratory will ship the Task 2 specimens as directed, to the AREVA facilities in Lynchburg, VA, as described by written letter from the NRC. The NRC shipping order letter will be based (in part) on information provided by the Task 8 TLR. The NRC will be responsible to ensure that each sample is peened in accordance with the Task 8 TLR. Once peened, the DOE Laboratory will be responsible for shipping all of the peened specimens back to the DOE Laboratory facilities for additional NDE and WRS assessments, to be conducted in Tasks 10 and 11.

DOE Laboratory (PNNL) Task 11a Response:

Subtask 11a is deemed "optional". Depending on decisions made in Task 2 regarding potential peening of any of the specimens, Emc2 will support PNNL in developing stress profiles of the peened specimens. Similar to the Task 7 efforts, Emc2 will ship for analysis up to three (3) CRDMs and one butt welded specimen post-peening to the selected x-ray diffraction vendor chosen in Task 7. This vendor will then develop WRSM at the locations determined from Task 7b. Following these measurements, the same CRDM and butt weld specimens will be shipped to Hill Engineering for WRSM using hole drilling and slotting techniques in a manner similar to Task 7c.

DOE Laboratory (PNNL) Task 11b Response:

This subtask is deemed "optional", and will also focus on preparing a draft technical report for PNNL to forward to NRC-NRR which will compare the results from all above tasks, i.e., FEA vs x-ray vs hole drilling and slotting techniques. Results from both pre- and post-peening measurements will be analyzed separately to determine if the peening process creates any different relationships amongst the analysis methods. Results, recommendations and conclusions from these evaluations will be incorporated in to the volume to be delivered to PNNL for review and forwarding to NRC-NRR for review and comments.

Emc2 will, in accordance with the RFP, provide monthly letter summary reports, coordinate meetings and conference calls with all participating entities as necessary and provide technical assistance and support, including participating in meetings at NRC, vendors, or PNNL as required to successfully complete these efforts. Two

**"optional" trips to NRC for 2 staff members for 2 days per trip will be scheduled for progress meetings and reviews as described in the specific task discussions. We have also budgeted for "optional" trips to the vendors and to PNNL for face-to-face meetings with technical personnel, where needed.**

**In addition, and if needed, Emc2 will provide any technical support for public meetings, such as ACRS hearings related to these efforts. The required resources for this support has been identified as "optional".**

Task 12 – The DOE Laboratory will perform crack initiation and crack arrest testing of the peened specimens of Task 5. The DOE Laboratory may interrupt the crack initiation test to monitor and maintain the test specimens, but the full test length shall continue until either all specimens have initiated cracks or until five times the time required for the 75th percentile of the crack initiation time of the specimens in Task 6. If any peened specimens develop indications of cracking, the DOE Laboratory will be expected to perform additional metallurgical analysis as authorized by the NRC.

DOE Laboratory (PNNL) Task 12 Response:

**Item 5.5 (alloy 182 specimens with built-in defects) is outside of the originally accepted scope and will require some investigation to determine how it could be produced. Therefore, it is not under consideration for testing in this revised SOW.**

Task 12a: ***Crack Initiation Testing of Peened Materials***

**Nine 15% CF alloy 600 specimens (Item 5.1) and eighteen 15% CF alloy 182 specimens (Item 5.4) will be tested in the peened condition. All will be instrumented for SCC initiation. These specimens will be loaded such that the outer surface will be at or above the yield strength of the 15% CF material. 12 months are being set aside for testing and another 1 month has been set aside for startup and shutdown activities.**

Task 12b: ***Crack Arrest Testing of Peened Specimens with SCC Cracks***

**Three 15% CF alloy 600 crack arrest specimens of Item 5.2 or Item 5.3 and three 15% CF alloy 182 crack arrest specimens of Item 5.6 or Item 5.7 will be SCC tested in the peened condition. Specimens will be loaded to a stress intensity roughly equivalent to that used to confirm SCC crack growth before peening. All six specimens will be instrumented to observe SCC crack growth of the small crack. Testing is expected to last 6 months.**

Task 12c (Optional): ***Additional Crack Arrest Testing of Peened Specimens with SCC Cracks***

**A second evaluation of SCC cracked specimens is outside the original scope, and therefore is being offered as an optional task. Three 15% CF alloy 600 crack arrest specimens of Item 5.2 or Item 5.3 and three 15% CF alloy 182 crack arrest specimens of Item 5.6 or Item 5.7 will be SCC tested in the peened condition. Testing would take up to 8 months. Because it takes considerable time to prepare these specimens, not only is additional funding required, but the project end date must also be extended. This optional additional work can be completed by April 30, 2019.**

Task 13 – At the conclusion of the crack initiation testing, the DOE Laboratory will develop a TLR documenting all testing results. The NRC will review this document and provide comments to the DOE Laboratory. The DOE Laboratory will address any comments in a reasonable time period.

DOE Laboratory (PNNL) Task 13 Response:

**PNNL concurs with this Task. It is suggested that this TLR be completed within 2 months of the completion of all tests and specimen examinations.**

Task 14 – DOE Laboratory will provide monthly letter status reports (MLSRs) to the contracting officer's representative (COR), alternate COR, and the Division of Contracts at ContractsPOT.Resource@nrc.gov. The MLSRs will be reviewed by the NRC and DOE Laboratory during monthly phone calls.

DOE Laboratory (PNNL) Task 14 Response:

**PNNL identifies this Task as the Management Task for this project. PNNL concurs with the NRC guidance for monthly letter reporting. The Task manager will be responsible for overseeing the work being performed, including developing detailed project plans, tracking all project deliverables, ensuring they are delivered on time and within planned budgets, and coordinating weekly or monthly teleconference calls with the NRC. In addition, this Task includes preparing integrated monthly business letter reports and semi-annual reports (as needed), organizing and conducting any project reviews as directed by NRC, coordinating and supporting project modifications and re-direction based on emergent issues, and supporting other NRC requests. PNNL will conduct the work defined in the NRC SOW guidance and provide specified deliverables within the time and budget provided. Due to the number and complexity of deliverables defined here, and based on discussions with the NRC COR, this task has been determined to be important and necessary for PNNL project task coordination. The costs/level-of-effort defined in Task 14 cover much more than writing of MLSRs. These costs cover all other PM functions as well, including PNNL**

**required Project Management Office and Sector reviews, monthly teleconferences, and all other required PM activities over the life of the project.**

**This task is also focused on providing support to activities where PNNL's expertise is required through consultation or engagement. On an as-needed basis, PNNL will provide NRC with technical assistance in resolving high priority, fast track issues related to NDE to support the NRC-NRR program offices related to peening. The NRC COR must approve technical assistance to the program offices prior to initiation of any effort. This task includes the monitoring of technologies being developed and applied in the field for specific NDE inspection problems related to mitigation/peening techniques, support for public meetings, video teleconferences, consultation-focused phone calls, and other support activities related to this Task. This Task does not require the performance of specific research but involves tracking relevant publications and possibly attending important meetings and/or conferences. PNNL should identify any meetings deemed to be important and discuss them with the NRC COR, who will grant formal approval before PNNL staff attend any meeting/conference or activity. PNNL will provide letter reports on this task as requested by the NRC COR. PNNL will provide technical assistance and consultation as directed by NRC guidance and complete specified deliverables within the time and budget provided. Since consulting is on an as-needed basis and driven by unplanned and unexpected events, it is not possible to assess these activities in advance; thus, each request made by the NRC will be addressed by defining the scope of work, time frame to accomplish the work, level of effort required, and deliverables. This information will be provided in the monthly report to document the activities on this Task.**

**In addition, it is necessary for PNNL to capture efforts conducted by EMC$^2$, in accordance with PNNL's subcontract with EMC$^2$, and define PM activities conducted by the EMC$^2$. It is expected that EMC$^2$ will provide PNNL with monthly letter summary reports, coordinate meetings and conference calls with all participating entities as necessary and provide technical assistance and support, including participating in meetings at NRC, vendors, or PNNL as required to successfully complete these efforts. For EMC$^2$, a minimum of two trips to NRC for 2 staff members for 2 days per trip will be scheduled for progress meetings and reviews as described in the specific task discussions. It is also necessary to engage EMC$^2$ at various stages of the project, and therefore travel to the vendors and to PNNL for face-to-face meetings with technical personnel have been captured here for eventual inclusion in the subcontract to EMC$^2$. Finally, it is expected that EMC$^2$ will provide all technical support along with attendance and testimony at public meetings such as ACRS hearings related to these efforts.**

**Task 15** (optional) – Should concerns be raised about the adequacy of the peening process, NRC reserves the option to discuss additional scope of testing with the mutual agreement of the DOE Laboratory and modifications to the SOW, as necessary.

**DOE Laboratory (PNNL) Task 15 Response:**

**PNNL concurs with the NRC guidance in Optional Task 15. Note: this optional task is not included as part of this cost proposal. If this task is authorized, a revised cost proposal will need to be generated.**

**Task 16 (Optional): Determine Time and Cost to Produce and Test Alloy 182 with Built-in Defects**

**Methods to produce alloy 182 with surface-breaking and subsurface defects will be investigated. Associated costs and time to obtain such a material will be reported along with the cost to perform initiation testing on unpeened and peened material.**

## 5.0 DELIVERABLES AND/OR MILESTONES SCHEDULE

The following table provides NRC concept on the timeline goals to meet milestone completion dates, which are the ***bold italic*** listings in the table. With the multiple numbers of tasks in this SOW, some must be completed in series, while others can be done in parallel. This table is provided as a tool for communication with only the ***bold italic*** line items to be considered contract requested requirements.

| **Potential Timeline With Recommended *Milestones in Bold Italic*** | | |
|---|---|---|
| **Task Number(s)** | Task Description or ***Deliverable/Milestone Description*** | Goal Completion or ***Milestone Completion*** |
| 1a | NRC provide MRP-335 and initial supporting documentation to DOE Laboratory | Completed |
| 1b | NRC provide additional resources to support the peening review | Within 5 working days of receipt at the NRC |
| 2 | DOE acquires all samples | 1 month after modification of contract |
| 2a | Optional, DOE shall implant flaws in specimens as directed by NRC | 2 months after completion of Task 2 |
| 3 | DOE completes NDE on Task 2 samples | 3 months after completion of Task 2 or 2a if implemented |
| 4a | DOE crack arrest and initiation testing rigs completed | 3 months after modification of contract |

| | | |
|---|---|---|
| 4b | Final TLR on testing rig verification | 30 days after Task 4a completed |
| 5 | DOE acquires all crack arrest specimens | 4 months after Task 4 completed |
| 6 | DOE completes crack initiation testing of non-peened mini-tensile specimens | 4 months after Task 4 completed |
| 7 | DOE completes surface stress measurement technique evaluation | 1 month after the completion of Task 2. |
| 7a | DOE completes all stress profiles on non-peened specimens | 2 months after completion of Task 2 or 2a if implemented |
| 7b | NRC and DOE agree on testing locations | 10 days after Task 7a completed |
| 7c | DOE completes stress measurements | 2 months after Task 7b completed |
| 7d | Final TLR on stress analysis | 30 days after Task 7c completed |
| **8** | **Final TLR documenting specimens and areas to be peened** | **8 months after modification of contract** |
| **Potential Timeline With Recommended *Milestones in Bold Italic*** | | |
| **Task Number(s)** | Task Description or ***Deliverable/Milestone Description*** | Goal Completion or ***Milestone Completion*** |
| 9 | DOE Ship/ NRC Peen/DOE Ship | As required by NRC |
| 10a | Optional, DOE completes NDE on peened specimens | 1 month after completion of Task 9 |
| 10b | Optional, DOE completes final TLR on NDE | 30 days after Task 10a completed |
| 11a | Optional, DOE completes stress profiles on peened specimens | 2 months after completion of Task 10a |
| 11b | Optional, DOE completes final TLR on peening stress profile improvement | 30 days after Task 11a |

| | | |
|---|---|---|
| 12 | DOE completes crack arrest and initiation testing on peened specimens | 15 months after the completion of Task 9 |
| **13** | **DOE completes final TLR on crack arrest and initiation** | **30 days after completion of Task 12** |
| ***14*** | ***Monthly MLSRs*** | ***Every month*** |

**DOE Laboratory (PNNL) Deliverables and/or Milestones Schedule Response:**

**It is unclear as to why there is a milestone 1b. This appears to be an NRC action and not a PNNL milestone or deliverable. From a review of this Milestones/Deliverables Table, PNNL understands that there exist six (6) tangible deliverables for this project (excluding MLSRs) including:**

1. **Final TLR on Testing Rig Verification (Task 4)**
2. **Final TLR on Stress Analysis (Task 7)**
3. **Final TLR on Specimen Documentation and Peening Areas (Task 8)**
4. **Final TLR on Post-Peening NDE Assessments (Task 10)**
5. **Final TLR on Peening Stress Profile Improvement (Task 11)**
6. **Final TLR on Crack Arrest And Initiation (Task 13)**

**PNNL concurs with these tangible deliverables. It is acknowledged, that the NDE and WRS measurement activities that focus on Task 2 (items #1 and #2) sample specimens are essentially decoupled from the materials crack initiation and crack arrest Task activities. However, in order to expedite schedule and minimize the level of duplicate efforts, PNNL will make every attempt to coordinate and synchronize activities that can leverage each other between NDE/WRS activities and crack initiation/arrest activities.**

**An updated version of the activity/milestone table is provided here to match the DOE (PNNL) laboratory outlook on timing for the activities and milestones.**

| **Potential Timeline With Recommended *Milestones in Bold Italic*** | | |
|---|---|---|
| **Task Number(s)** | Task Description or ***Deliverable/Milestone Description*** | Goal Completion or ***Milestone Completion*** |
| 1a | NRC provide MRP-335 and initial supporting documentation to DOE Laboratory | Completed |

| | | |
|---|---|---|
| 1b | NRC provide additional resources to support the peening review | Within 5 working days of receipt at the NRC |
| 2 | DOE acquires all materials | 1 month after modification of contract |
| 2a | Optional, DOE shall implant flaws in specimens as directed by NRC | 2 months after completion of Task 2 |
| 3 | DOE completes NDE on Task 2 samples | 3 months after completion of Task 2 or 2a if implemented |
| 4a,b,c | DOE crack arrest and initiation testing rigs completed | 8 months after modification of contract |
| 4d | Final TLR on testing rig verification | 30 days after Task 4a,b,c completed |
| 5a | DOE acquires all crack initiation specimens | 5 months after modification of contract |
| 5b | DOE acquires crack arrest specimens | 11 months after completion of Task 4c |
| 5c (optional) | DOE acquires additional crack arrest specimens | 11 month after completion of Task 5b |
| 6 | DOE completes crack initiation testing of non-peened specimens | 9 months after Task 4b completed |
| 7 | DOE completes surface stress measurement technique evaluation | 1 month after the completion of Task 2. |
| 7a | DOE completes all stress profiles on non-peened specimens | 2 months after completion of Task 2 or 2a if implemented |
| 7b | NRC and DOE agree on testing locations | 10 days after Task 7a completed |
| 7c | DOE completes stress measurements | 2 months after Task 7b completed |
| 7d | Final TLR on stress analysis | 30 days after Task 7c completed |
| **8** | **Final TLR documenting specimens and areas to be peened** | **8 months after modification of contract** |
| 9 | DOE Ship/ NRC Peen/DOE Ship | As required by NRC |

| | | |
|---|---|---|
| 10a | Optional, DOE completes NDE on peened specimens | 1 month after completion of Task 9 |
| **Potential Timeline With Recommended *Milestones in Bold Italic*** | | |
| **Task Number(s)** | Task Description or ***Deliverable/Milestone Description*** | Goal Completion or ***Milestone Completion*** |
| 10b | Optional, DOE completes final TLR on NDE | 30 days after Task 10a completed |
| 11a | Optional, DOE completes stress profiles on peened specimens | 2 months after completion of Task 10a |
| 11b | Optional, DOE completes final TLR on peening stress profile improvement | 30 days after Task 11a |
| 12a | DOE completes initiation testing on peened specimens | 16 months after the completion of Task 9 |
| 12b | DOE completes crack arrest testing of peened specimens with SCC cracks | 8 months after completion of Task 9, or if Task 5c is accepted, 8 months after that |
| 12c (optional) | DOE completes crack arrest testing of additional peened specimens with SCC cracks | 11 months after completion of Task 12b |
| **13** | **DOE completes final TLR on crack arrest and initiation** | **30 days after completion of Task 12** |
| ***14*** | ***Monthly MLSRs*** | ***Every month*** |
| Task 16 (optional) | Develop cost and timeline to fabricate and assess welds with defects | 3 months after modification of contract |

## 6.0 TECHNICAL AND OTHER SPECIAL QUALIFICATIONS REQUIRED

Specialized experience must include expertise in such areas as (1) ultrasonic inspection, (2) eddy current inspection, (3) surface and near surface stress profile measurement, (4) material sample manufacturing and processing, (5) material sample testing, and (6) metallurgical analysis. Additional expertise is desired regarding American Society of Mechanical Engineer's Boiler and Pressure Vessel Code activities regarding the construction and inspection of upper and lower reactor pressure vessel heads and various sized dissimilar

metal butt welds. Specialized expertise is requested in addressing each of these areas with the application of alloy 600/182/82 materials.

## 7.0 MEETINGS AND TRAVEL

All travel requires written Government approval from the CO, unless otherwise delegated to the COR.

Foreign travel for the DOE laboratory personnel requires a 60-day lead time for NRC approval.
For prior approval of foreign travel, the DOE laboratory shall submit an NRC Form 445, "Request for Approval of Official Foreign Travel." NRC Form 445 is available in the MD 11.7 Documents library and on the NRC Web site at: http://www.nrc.gov/reading-rm/doccollections/forms/. Foreign travel is approved by the NRC Executive Director for Operations (EDO).

**DOE Laboratory (PNNL) Meetings and Travel Response:**

**Travel, to support technical activities defined in this SOW, to support public meetings, engage in face-to-face discussions or conduct technical reviews of subcontractor work, are anticipated and required. The information in Table 7.1 defines (at a minimum) the proposed travel by PNNL staff in the conduct of work defined in this SOW.**

| Task | Description of Travel | Staff/Duration | Destination | FY |
|---|---|---|---|---|
| 3 | Technical Data Acquisition Planning and ET System Configuration | Two trips, 1 person, 5 days | Hartford, CT to Richland, WA | 16 |

## 8.0 REPORTING REQUIREMENTS

The DOE Laboratory is responsible for structuring the deliverable to follow agency standards. The current agency standard is Microsoft Office Suite 2010. The current agency Portable Document Format (PDF) standard is Adobe Acrobat 9 Professional. Deliverables must be submitted free of spelling and grammatical errors and conform to requirements stated in this section.

### *Technical Letter Reports*

DOE Laboratory shall provide technical letter reports (TLR) as described in the SOW. TLRs are expected to be concise reports that provide data results and additional analysis as required. Additional analysis is defined in the SOW above, but could consist of procedure to

perform eddy current to achieve maximum detection of sub-surface defects or additional metallurgical analysis of indications of cracking in crack initiation test specimens. Each TLR is expected to have a short introduction including the requested information, a short discussion on the data collection process and finally the results. One expectation is the TLR for Task 8. The Task 8 TLR will list all samples and identify areas of peening for each sample.

***Monthly Letter Status Reports***

In accordance with Management Directive 11.7, NRC Procedures for Placement and Monitoring of Work with the U.S. Department of Energy, the DOE Laboratory must electronically submit a

Monthly Letter Status Report (MLSR) by the 20th day of each month to the Contracting Officer
Representative (COR) with copies to the Contracting Officer (CO) and the Office Administration/Division of Contracts to ContractsPOT.Resource@nrc.gov. If a project is a task ordering agreement, a separate MLSR must be submitted for each task order with a summary project MLSR, even if no work has been performed during a reporting period. Once NRC has determined that all work on a task order is completed and that final costs are acceptable, a task order may be omitted from the MLSR.

The MLSR must include the following: agreement number; task order number, if applicable; job code number; title of the project; project period of performance; task order period of performance, if applicable; COR's name, telephone number, and e-mail address; full name and address of the performing organization; principal investigator's name, telephone number, and e- mail address; and reporting period. At a minimum, the MLSR must include the information discussed in Attachment 1. The preferred format can also be found in Attachment 1.

## 9.0 PERIOD OF PERFORMANCE

The estimated period of performance for this agreement is August 11, 2014 through February, 2019.

## 10.0 CONTRACTING OFFICER'S REPRESENTATIVE

The COR monitors all technical aspects of the agreement/task order and assists in its administration. The COR is authorized to perform the following functions: assure that the DOE Laboratory performs the technical requirements of the agreement/task order; perform inspections necessary in connection with agreement/task order performance; maintain written and oral communications with the DOE Laboratory concerning technical aspects of the agreement/task order; issue written interpretations of technical requirements, including

Government drawings, designs, specifications; monitor the DOE Laboratory's performance and notify the DOE Laboratory of any deficiencies; coordinate availability of NRC-furnished material and/or GFP; and provide site entry of DOE Laboratory personnel.

Contracting Officer's Representative

Name: Jay Collins
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Mail Stop: OWFN-9H4
Washington, DC 20555-0001
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Alternate Contracting Officer's Representative

Name: Stephen Cumblidge
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## 11.0 MATERIALS REQUIRED

| Materials Property/Material | Quantity | Associated Task | Estimated Cost |
|---|---|---|---|
| Alloy 600 plate | 1 | Task 2 | $ 10,000 Material |
| Rotational Bore Scanning Tool for UT Scans | 1 | Task 3/10 | $ 35,000 Material |
| ET and UT Probes | 6 | Task 3/10 | $166,000 Material |
| Crack initiation test rig | 1 | Task 4 | $220,000 Material |
| Crack arrest test rig | 1 | Task 4 | $175,000 Material |
| TOTAL ITEMS/COST: | 12 | n/a | $606,000 TOTAL COST |

**DOE Laboratory (PNNL) Materials Required Response:**

**See revised material required:**

| Materials Property/Material | Quantity | Associated Task | Estimated Cost |
|---|---|---|---|
| Alloy 600 plate | 1 | Task 2 | $ 10,000 Material |
| Rotational Bore Scanning Tool for UT Scans | 1 | Task 3/10 | $ 35,000 Material |
| ET and UT Probes | 6 | Task 3/10 | $3,000 Material |
| Crack initiation test rig | 1 | Task 4 | $220,000 Material |
| Crack arrest test rig | 1 | Task 4 | $175,000 Material |
| ECT Equipment | 1 | Task 3 | $100,000 Material |
| Rotating Table and motor drives/controls | 1 | Task 3 | $15,009 Material |
| Test System overhaul parts | 1 | Task 12C | $1,500 Material |
| TOTAL ITEMS/COST: | | | $559,009 TOTAL COST |

**PNNL concurs with the materials required list in Section 11.0 with a few additions. If however, the NRC COR requests that PNNL employ a complementary NDE technique other than PA-UT or ET for evaluation of the J-groove welds and DMWs identified in Task 2, procurement of additional probes may be required. In particular, if TOFD-UT is requested, probe-wedge combinations may need to be procured for this application. This revised list includes a rotational scanning platform that has a higher weight capacity than the existing PNNL platform, and motors and motor drivers to couple the motion control of this platform to both existing PNNL data acquisition/control systems estimated at $15K and the new WesDyne ET data acquisition system estimated at $100K. (See discussion under Tasks 2 and 3).**

## 12.0 SUBCONTRACTOR/CONSULTANT INFORMATION

Task 2a: Some specimens may require fabrication, welding and/or introduction of flaws. PNNL will subcontract this work out to a trusted and proven 3rd party for any required fabrication processes. See Task Section above for more detail. Estimated cost is $24.7K.

FlawTech is the likely vendor to conduct this work based upon their past performance and experience in providing these types of services to PNNL on other NRC JCNs.

In addition, the extraction (cutting) of the three (13) CRDMs from the vessel head cannot be performed by PNNL crafts services, and this will require a subcontract. This subcontract will include transportation of the vessel head from PNNL to the subcontractor (metal fabricator/machining organization) and back, as well as cutting of the CRDM nozzles from the head and any conditioning/machining for reduction of unnecessary material from the 4 or 5 CRDMs to be identified for this work. Estimated cost is $37K

Task 7: PNNL will manage these efforts via a subcontract to $EMC^2$ for all weld residual stress measurements and analysis. See Task Section above for more detail. Estimated cost is $175.4K.

**DOE Laboratory (PNNL) Response:**

**As a result of the increased scope in Task 7, additional support is required from EMC2 (see Task 7 of SOW. Increased subcontracting value is estimated at $142,500.**

**As part of Task 5 and Optional Task 5c additional material forging services will be necessary. Estimated cost is $20K.**

## 13.0 NRC-FURNISHED PROPERTY/MATERIALS

| NRC-Furnished Property/Material | Quantity | Date provided to DOE Laboratory | Method of Shipment |
|---|---|---|---|
| Upper head penetration nozzle and associated J-groove weld | 4-5 | On site | On site |
| Dissimilar Metal Butt Weld | 1 | On site | On site |
| Alloy 600/182/82 materials for testing | As needed | On site | On site |

## 14.0 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 DOE Laboratory to ensure that these quality criteria are adequately addressed throughout the course of the research that is performed. The NRC COR will review all research products with these criteria in mind.

## 15.0 STANDARDS FOR CONTRACTORS WHO PREPARE NUREG-SERIES MANUSCRIPTS (TYPE N/A IF NOT APPLICABLE)

The U.S. Nuclear Regulatory Commission (NRC) began to capture most of its official records electronically on January 1, 2000. The NRC will capture each final NUREG-series publication in its native application. Therefore, please submit your final manuscript that has been approved by your NRC Project Manager in both electronic and camera-ready copy.

The final manuscript shall be of archival quality and comply with the requirements of NRC Management Directive 3.7 "NUREG-Series Publications." The document shall be technically edited consistent with NUREG–1379, Rev. 2 (May 2009) "NRC Editorial Style Guide." The goals of the "NRC Editorial Style Guide" are readability and consistency for all agency documents.

All format guidance, as specified in NUREG-0650, "Preparing NUREG-Series Publications," Rev. 2 (January 1999), will remain the same with one exception. You will no longer be required to include the NUREG-series 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 designator for each report will no longer be assigned when the decision to prepare a publication is made. The NRC's Publishing Services Branch will inform the NRC Project Manager for the publication of the assigned designator when the final manuscript is sent to the printer.

For the electronic manuscript, the Contractor shall prepare the text in Microsoft Word, and use any of the following file types for charts, spreadsheets, and the like.

| File Types to be Used for NUREG-Series Publications | |
|---|---|
| File Type | File Extension |
| Microsoft®Word® | .doc |
| Microsoft® PowerPoint® | .ppt |
| Microsoft®Excel | .xls |
| Microsoft®Access | .mdb |
| Portable Document Format | .pdf |

This list is subject to change if new software packages come into common use at NRC or by our licensees or other stakeholders that participate in the electronic submission process. If a portion of your manuscript is from another source and you cannot obtain an acceptable electronic file type for this portion (e.g., an appendix from an old publication), the NRC can, if necessary, create a tagged image file format (file extension.tif) for that portion of your report. Note that you should continue to submit original photographs, which will be scanned, since digitized photographs do not print well.

If you choose to publish a compact disk (CD) of your publication, place on the CD copies of the manuscript in both (1) a portable document format (PDF); (2) a Microsoft Word file format, and (3) an Adobe Acrobat Reader, or, alternatively, print instructions for obtaining a free copy of Adobe Acrobat Reader on the back cover insert of the jewel box.