ORNL/HSSI (W6953)/MLSR-2001/8

# HEAVY-SECTION STEEL IRRADIATION (HSSI) PROGRAM (W6953)

## Monthly Letter Status Report

**May 2001**

ORNL/HSSI (W6953)/MLSR-2001/8

# HEAVY-SECTION STEEL IRRADIATION PROGRAM

JCN W6953

# MONTHLY LETTER STATUS REPORT FOR MAY 2001


Submitted by

T. M. Rosseel
HSSI Project Manager

Compiled by
R. D. Godfrey

Submitted to
C. J. Fairbanks
NRC Project Manager



OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
managed by
UT-Battelle, LLC.
for the
U. S. DEPARTMENT OF ENERGY
Under DOE Contract No. DE-AC05-00OR22725

# PREFACE

This report is issued monthly by the staff of the Heavy-Section Steel Irradiation (HSSI) Program (JCN:W6953) to provide the Nuclear Regulatory Commission (NRC) staff with summaries of technical highlights, important issues, and financial and milestone status within the program.

This report gives information on several topics corresponding to events during the reporting month: (1) overall project objective, (2) technical activities, (3) meetings and trips, (4) publications and presentations, (5) property acquired, (6) problem areas, and (7) plans for the next reporting period. Next the report gives a breakdown of overall program costs as well as cost summaries and earned-value-based estimates for performance for the total program and for each of the six program tasks. The six tasks, including a project management task, correspond to the 189, dated March 7, 2001. The final part of the report provides financial status for all tasks and status reports for selected milestones within each task. The task milestones address the period from October 2000 to March 2003, while the individual task budgets address the period from October 2000 to November 2001.

Beginning in October 1992, the monthly business calendar of the Oak Ridge National Laboratory was changed and no longer coincides with the Gregorian/Julian calendar. The business month now ends earlier than the last day of the calendar month to allow adequate time for processing required financial reports to the Department of Energy. The precise reporting period for each month is indicated on the financial and milestone charts by including the exact start and finish dates for the current business month.

Thomas M. Rosseel

Thomas M. Rosseel, Manager
Heavy-Section Steel Irradiation

**MONTHLY LETTER STATUS REPORT**
**May 2001**

| | |
|---|---|
| **Job Code Number:** | **W6953** |
| **Project Title:** | **Heavy-Section Steel Irradiation Program** |
| **Period of Performance:** | **4/1/98 to 4/1/03** |
| **Performing Organization:** | **Oak Ridge National Laboratory** |
| **Program Manager:** | **T. M. Rosseel** |
| **Address:** | **P.O. Box 2008<br>Oak Ridge, Tennessee 37831-6138** |
| **Telephone:** | **(865) 574-5380** |
| **Telefax:** | **(865) 241-3650** |
| **Email:** | **rosseeltm@ornl.gov** |

## 1. PROJECT OBJECTIVE:

The primary goal of the Heavy-Section Steel Irradiation (HSSI) Program is to provide a thorough, quantitative assessment of the effects of neutron irradiation on the material behavior, and in particular the fracture toughness properties, of typical pressure vessel steels as they relate to light-water reactor pressure vessel (RPV) integrity. The program includes studies of the effects of irradiation on the degradation of mechanical and fracture properties of vessel materials augmented by enhanced examinations and modeling of the accompanying microstructural changes. Effects of specimen size; material chemistry; product form and microstructure; irradiation fluence, flux, temperature, and spectrum; and post-irradiation mitigation are being examined on a wide range of fracture properties. This program will also maintain and upgrade computerized databases, calculational procedures, and standards relating to RPV fluence-spectra determinations and embrittlement assessments. Results from the HSSI studies will be incorporated into codes and standards directly applicable to resolving major regulatory issues that involve RPV irradiation embrittlement such as pressurized-thermal shock, operating pressure-temperature limits, low-temperature overpressurization, and the specialized problems associated with low upper-shelf welds. Five technical tasks and one for program management are now contained in the HSSI Program.

## 2. TECHNICAL ACTIVITIES:

### TASK 1: Program Management (T. M. Rosseel)

This task is responsible for managing the program to ensure that the overall objectives are achieved. The management responsibilities include three major activities: (1) program planning and resource allocation; (2) program monitoring and control; and (3) documentation and technology transfer. Program planning and resource allocation includes: (a) developing and preparing annual budgetary proposals and (b) issuing and administrating subcontracts to other contractors and consultants for specialized talents not available at Oak Ridge National

Laboratory (ORNL) or that supplement those at ORNL. Program monitoring and control includes: (a) monitoring and controlling the project through an earned-value, project-management system; (b) ensuring that quality assurance (QA) requirements are satisfied; and (c) issuing monthly management reports. Documentation and technology transfer includes: (a) participating in appropriate codes and standards committees; (b) preparing briefings for the NRC; (c) coordinating NRC and internal ORNL review activities; (d) coordinating domestic and foreign information exchanges approved by NRC; and (e) documenting the activities of the program through letter and NUREG reports.

(Milestone 1.1 A) Discussions were held with the NRC Program Monitor concerning additional work if funding becomes available this fiscal year. These topics include:

1. Evaluate the effects of dynamic fracture-toughness on the master curve.

Proposed effort: Develop a test plan for dynamic fracture-toughness testing and analysis of unirradiated materials. Begin testing of pre-cracked Charpy specimens according to ASTM E 1921 including the complete the range of allowable loading rates in the standard. This effort would accelerate the plan for Task 2.3. Results will be discussed with the NRC and other organizations to determine the path forward. The issue was raised previously by Bill Server in an IAEA CRP meeting in which he presented some data that indicated an effect. The main interest, however, would be the testing of RPV steels at rates as high as practically achievable.

Deliverable: Test plan and initial test results of high-rate loading of Charpy specimens.

2. Prepare HAZ material

Proposed effort: Machine and heat treat additional specimens of the HAZ material used in the previous test program, but use a slow cooling rate following post-weld heat treatment. This would accelerate the date for completion of irradiation and testing now in the 189.

Deliverable: Gleeble-treated specimens prepared for irradiation and testing

3. Finite element analysis to verify that plane stress should be used when converting J to K in ASTM E 1921 (Master Curve)

Proposed effort: Perform finite element (FE) analysis of elastic constraint in compact and bend specimens. This relates to the ASTM E 1921 issue of whether the plane-strain or plane-stress modulus adjustment should be used to convert from J to K. This item is under discussion at the ASTM E08 committee meetings. Although some have suggested a change in the current standard from the plane stress to the plane strain equation, John Merkle has prepared a detailed negative ballot. A definitive answer would be possible if FE analyses, with a much-refined mesh near the crack tip, were performed.

Deliverable: Finite element analysis of crack tip to verify that plane stress modulus is appropriate when adjusting from J to K.

4. Initiate analysis of irradiated materials for inclusion in Surrogate Materials table of uncertainties.

Proposed effort: Collect additional irradiated surrogate material data and perform analyses. These analyzed data will be used to begin the process of formulating a table of uncertainties for irradiated surrogate materials. This would accelerate the effort on Task 2.8 Surrogate Materials.

Deliverable: Analyzed irradiated material data that will eventually be incorporated into a table of uncertainties.

Acquisition of RPV trepans from the San Onofre Unit 1 (SONGS-1) Reactor.

Proposed effort: Coordinate the acquisition of trepans from the (SONGS-1) reactor with Southern California Edison and EPRI. Since opportunities to obtain domestic service-irradiated materials have previously been unsuccessful (Trojan, Maine Yankee, etc.), due to the unavailability of resources and/or the relatively short "window of opportunity" to obtain such components from the time a plant is shutdown to the time it is sent for disposal at a waste storage site or otherwise rendered inaccessible, it is critical that the effects of aging previously simulated and tested in the laboratory environment be benchmarked against components and materials that have aged under prototypical service conditions in nuclear power plants.

Deliverable: Coordination plan to ensure that trepans are obtained from SONGS-1

(Milestone 1.1.B) The subcontract with the University of Michigan for collaborative irradiation work at the Ford Nuclear Reactor (FNR) was extended through June 30, 2001 to permit sufficient time for the University to respond to the statement of work that will extend the collaboration to 4/01/03 and incrementally fund the work through 11/30/01.

(Milestone 1.3.C) Discussions were held with the NRC at the DOE-EPRI Nuclear Plant Optimization (NEPO) workshop in Charlotte, NC, concerning the acquisition of RPV trepans from the San Onofre Unit 1 (SONGS-1) Reactor. This work (see 1.1.A-5) would be coordinated with Southern California Edison, and EPRI.

## **Task 2: Fracture-Toughness Transition Issue and Master-Curve Methodology - (M. A. Sokolov)**

Fracture-toughness transition and MC methodology will be broadly explored for pressure-vessel applications through a series of experiments, analyses, and evaluations in eight subtasks. Specifically, the effects of irradiation on fracture-toughness curve shape for highly embrittled RPV steels, dynamic effects, crack arrest, intergranular fracture, and subsized specimens will be explored; guidelines for the application of "surrogate" materials to the assessment of fracture toughness of RPV steels will be evaluated; and the fluence received in the HSSI irradiation experiments will be determined.

Subtask 2.1: Fracture-Toughness Transition-Temperature Shifts (M. A. Sokolov)

The purpose of this subtask is to collect and statistically analyze pertinent fracture-toughness data to assess the shift and potential change in shape of the fracture-toughness curves due to neutron irradiation. The MC methodology will be applied to provide a statistical analysis of the fracture-toughness data and Charpy data will be fitted by hyperbolic tangent functions. The resulting reference fracture-toughness temperature, $T_0$, shifts will be compared with Charpy shifts determined by various indexing methods.

(Milestone 2.1.A) The report by M. A. Sokolov and R. K. Nanstad, *Comparison of Irradiation-Induced Shifts of $K_{Jc}$ and Charpy Impact Toughness for Reactor Pressure Vessel Steels,* NUREG/CR-6609 (ORNL/TM-13755), was published by the NRC in November.

As they become available, additional data are added to the database.

Subtask 2.2: Irradiation Effects on Fracture-Toughness Curve Shape (M. A. Sokolov)

The purpose of this subtask is to evaluate the assumption of constant shape for the MC even for highly embrittled RPV steels. The evaluation will be performed through the testing of a pressure-vessel steel weld that has been irradiated to a neutron fluence sufficient to produce a fracture-toughness transition-temperature shift ($T_0$) of about 150°C (270°F). A specially fabricated radiation-sensitive weld was selected to perform a pilot study on the ability of highly embrittled material to maintain the master curve shape. This weld had been fabricated and studied in Germany and supplied to ORNL by MPA, Stuttgart through a Memorandum of Agreement (MOA). The capsules, loaded with 21 1T compact specimens and a larger number of smaller specimens of Weld KS-01, were irradiated to a target fluence of 8.4 x $10^{18}$ n/cm$^2$ at the FNR during the first HSSI-IAR irradiation campaign. Evaluation of the MC shape will be determined with sufficient numbers of 1T compact specimens, 1T C(T), to allow for testing at three temperatures in the transition-temperature region. Additionally, 0.5T C(T), and pre-cracked Charpy V-notch (PCVN) specimens, using both quasi-static and dynamic methods, will be tested to investigate the use of more practical surveillance-size specimens. Tensile specimens will also be tested to determine the irradiation-induced hardening. Testing of irradiated specimens is dependent upon the availability of suitable hot-cell facilities. Evaluation of the mechanical properties of the unirradiated weld has been completed.

Specimens of the Midland beltline weld were fabricated and placed into the IAR facility at the FNR for irradiation to a fluence of at least 2.5 x $10^{19}$ n/cm$^2$ (>1 MeV). This irradiation is being conducted to evaluate the assumption of constant shape for the master curve with highly embrittled low upper-shelf RPV steels that exhibit onset of stable ductile tearing at relatively low fracture toughness.

Irradiated high-nickel welds from the Palisades steam generator will also be examined. Not only will this material provide additional information on curve shape effects, but it will permit experimental validation of an assumption of linear relationship between Charpy 41J and fracture toughness shifts for highly-embrittled materials.

(Milestone 2.2.A) Irradiation of the Midland beltline weld and a high-nickel weld from the Palisades steam generator is under way and proceeding on schedule in the University of Michigan FNR. Please also see Task 6.1.

(Milestone 2.2.C) As noted in the last report, 21 1T compact specimens of the submerged-arc weld KS-01, irradiated to ~0.8 x $10^{19}$ n/$cm^2$ (>1 MeV), were successfully tested as follows: six at 125 °C, six at 150°C, five at 175°C, and four at 200°C. Following testing, the unbroken specimens were broken open and photographs were made of the fracture surfaces. The photographs were used to document the fracture surface appearance and used to measure the crack length parameters needed for analysis of the tests. Analysis of the test records were completed and the results were combined with those from the previously tested 0.5T specimens to provide a basis for a decision regarding testing of the remaining six 0.5T specimens. Following this evaluation, and discussions with other national and international experts, the decision was made to test the 0.5T specimens at 100°C.

All of those specimens have now been tested. Photographs of the broken 0.5T specimens have also been taken and crack length measurements are under way. Additional scanning electron fractography of the 0.5T specimens has been performed, and analyses of all the data will be completed during the following two months.

(Milestone 2.2.G formerly 2.4.D) The final report, *Evaluation of WF-70 Weld Metal from the Midland Unit 1 Reactor Vessel*, by D. E. McCabe, R. K. Nanstad, S. K. Iskander, D. W. Heatherly, and R. L. Swain, NUREG/CR-5736 (ORNL/TM-13748), was published by the NRC in November.

Subtask 2.3: Dynamic Fracture Toughness [Combines previous subtasks 2.3 and 2.5] (R. K. Nanstad)

The purpose of this subtask is to evaluate the applicability of the master curve to dynamic fracture toughness of RPV steels. There are limited data available that suggest reasonable applicability of the master curve to such data, however, sufficient data under high-rate loading conditions for a reliable statistical assessment are not available. Previous plans within the HSSI Program included the evaluation of data from precracked Charpy specimens tested under impact conditions. Although the development of such techniques and resulting data are desirable, the first recommended step in evaluation of the master curve is high-rate loading of standard bend or compact specimens under non-impact conditions.

(Milestone 2.3.A) No significant activity during this reporting period

Subtask 2.4 - Statistical Representation of Valid $K_{Ic}$ Data for Irradiated RPV Steels (R. K. Nanstad and J. G. Merkle)

The purpose of this subtask is to develop a statistical representation of valid $K_{Ic}$ data for irradiated RPV steels from available elastic-plastic fracture toughness data. In the estimation of failure probabilities for RPVs subjected to postulated pressurized thermal-shock loadings, it is necessary to employ realistic statistical representations of both flaw size and fracture toughness. The rationally based statistical model of weak-link behavior incorporated in ASTM Standard

E1921 and available large-scale experimental fracture mechanics data, are the potential bases for developing an improved representation of the statistical behavior of valid $K_{Ic}$ data, with the expectation that uncertainties will be less than those resulting from the present method.

(Milestone 2.4.A) A subcontract was implemented so as to initiate activity on this task.

Subtask 2.5 (formerly 2.10): Dosimetry and Fluence Analysis of the IAR Irradiation Capsules (C. A. Baldwin, I. Remec, T. M. Rosseel)

The purpose of this task is to measure and analyze the dosimeters used during the HSSI-IAR irradiation campaigns and to obtain accurate fluence determinations.

(Milestone 2.5.A formerly 2.10.A) Data files containing the activity information calculated from the analyzed, HSSI-IAR, first-series dosimeters were prepared in the format used in all past HSS-IAR experiments, including the use of the previously defined coordinate system. From this data, the 3-D model, fuel changes and reshuffling, and the original dosimetry experiment results, the exposure parameters for these metallurgical specimens will be calculated. Calculations have not been initiated due to unavailability of staff.

(Milestone 2.5.B formerly 3.2.B) Neutronics Analysis of the IAR/UCSB Irradiation Capsules - (I. Remec, E. D. Blakeman, and C. A. Baldwin). The report entitled, *Characterization of the Neutron Field in the HSSI/UCSB Irradiation Facility at the Ford Nuclear Reactor*, by I. Remec, E. D. Blakeman, and C. A. Baldwin, NUREG/CR-6646 (ORNL/TM-1999/140) was submitted to the NRC in September 1999.

Subtask 2.6: Intergranular Fracture (R. K. Nanstad and J. G. Merkle)

This subtask will address the issue of whether the MC technique can be applied to materials that experience brittle fracture by an intergranular mechanism. Specifically, it will be determined whether steels that experience intergranular fracture can be correctly characterized by the MC $T_o$ temperature and whether the transition-curve shape can be changed by different fracture modes. Complete intergranular fracture from temper embrittlement occurs only at lower-shelf temperatures. As it is with transgranular cleavage, the transition to upper shelf is marked by an increased volume percentage of ductile rupture mixed with the lower-shelf, brittle-fracture mechanism. Since the onset of crack instability is most likely triggered in the brittle zones, the critical issue is understanding the influence of the triggering mechanism on the distribution of $K_{JC}$ values obtained. This information can be obtained on the lower shelf and, in part, into the transition range.

The proposed approach is to determine if there is an operational weakest-link effect when instability is triggered within an intergranular region. If an effect is observed, there should also be a measurable specimen-size effect on $K_{JC}$. It will also be determined if the temper-embrittled materials exhibit a change in the J-R fracture toughness since such steels do not show a significant change in upper-shelf CVN energy.

The modified A302 grade B steel selected to evaluate intergranular-fracture effects on the universal MC shape assumption was specially heat treated to temper embrittle the material, and fracture-toughness testing was performed. In the analysis of the data, however, it became clear that additional testing was deemed necessary to allow for a more definitive conclusion regarding the relationship between the intergranular fracture results and the Master Curve. Additional 0.5 TC(T) specimens have been fabricated and testing is underway.

(Milestone 2.6.A) The five remaining 0.5T compact specimens will be tested at a higher temperature than the previously tested specimens during the next reporting period, and a multi-temperature master curve analysis will be conducted and included in the final letter report.

(Miletstone 2.6.B) Additional scanning electron fractography will also be performed to evaluate the fracture mode of the specimens previously tested at the highest temperatures (room temperature and above). This fractographic evaluation will specifically evaluate the presence of so-called ductile intergranular fracture. This is an important aspect of the evaluation as it relates to the relationship between the master curve shape, which is used to describe unstable cleavage fracture in the ductile-brittle transition region, and unstable fracture by intergranular fracture. It is anticipated this SEM examination will also be conducted in July.

(Milestone 2.6.C) The draft letter report has already been completed except for the inclusion of the five additional test results as discussed in 2.6.A.

<u>Subtask 2.7: Sub-sized Specimens</u> (M. A. Sokolov)

The purpose of this subtask is to evaluate the applicability of the weakest-link theory-based size-adjustment procedure in the MC methodology to specimen sizes that are the most likely to be present in surveillance capsules. The MC methodology will be applied using precracked Charpy-size or smaller specimens to test the lower-size limit applicability. Testing will be performed at two or more temperatures with at least six specimens at each temperature. The exact number of temperatures and specimens will be determined following analysis of initial results. The testing of these subsize specimens will also satisfy the HSSI Program suggested testing matrix within the New Coordinated Research Program (CRP) of the International Atomic Energy Agency (IAEA). Subsized specimens will be fabricated from previously characterized materials within the HSSI Program, such as HSST Plate 02, HSSI Welds 68W through 73W, the Midland beltline weld and plate JRQ.

(Milestone 2.7.A) The testing of specimens is well under way, although delayed over the last few months due to priority testing in the hot cell while it remains open. Completion is expected in July. These specimens were machined from three blocks of materials into 1T C(T) and precracked Charpy specimens for the size effect study. Two of the blocks are broken halves of 4T C(T) specimens of two A302B plates previously tested by the HSSI Program. The third block of material is the well-characterized Plate 13A. This study is specifically designed as an evaluation of the precracked Charpy specimen.

<u>Subtask 2.8: Quantification of Surrogate Materials for use in a Statistics-Based Fracture Toughness Assessment</u> (R. K. Nanstad and J. G. Merkle)

The purpose of this subtask is to identify issues and make recommendations for the use of surrogate or non-identical materials in the assessment of fracture toughness of RPV steels. In many cases, surveillance programs for RPVs include specimens of a material that are not identical to the critical material in the RPV and test results from those surveillance specimens are used to represent the critical material in RPV analysis. This issue has been identified as an overarching issue in that a more complete understanding of most other issues are needed in order to reduce the uncertainties associated with material variability.

(Milestone 2.8.A) Further review of data, both unirradiated and irradiated, is continuing, which will eventually result in the preparation a table of uncertainties that could be utilized for evaluating the application of surrogate materials. This work is intended to be included in the final NUREG report on this subject.

(Milestone 2.8.B) A draft NUREG report, *Considerations for Use of Surrogate Materials Data for Reactor Pressure Vessels*, by R. K. Nanstad, J. G. Merkle, and J. Galt, was previously prepared and sent to the NRC technical monitor for review.

## Task 3: Irradiation Embrittlement of RPV Steel - (R. K. Nanstad)

The purpose of this task is to examine two important issues affecting the application of mitigation procedures to RPVs. The first will address the effects of temper embrittlement on the coarse-grained HAZ in RPV steels. The second will examine the effects of reirradiation on $K_{Jc}$ and $K_{Ja}$ in order to evaluate the relative changes in the recovery and reembrittlement between CVN and fracture-toughness properties and a detailed examination of reembrittlement rates. These questions will be addressed in-part using specimens supplied by the Swiss HSK and PSI.

### Subtask 3.1: HAZ Embrittlement (M. A. Sokolov and R. K. Nanstad)

The purpose of this subtask is to determine the susceptibility of RPV heat affected zones (HAZ) to irradiation/thermal aging-induced temper embrittlement. Research conducted to date by ORNL and AEA-Technology on temper embrittlement of the coarse-grain materials in HAZs of RPV steel multi-pass welds has revealed the potential for such embrittlement under some conditions. AEA-Technology discovered that using high-temperature austenitization to produce very coarse grains, followed by thermal aging resulted in large transition-temperature shifts. Further, post-irradiation thermal annealing of such material resulted in an even greater increase of the transition temperature. Subsequent research at ORNL under the previous HSSI Programs used five commercial RPV steels to investigate potential temper embrittlement. Since the amount of intergranular fracture observed was unexpected, further studies are required to resolve the issue.

The first phase of this project simulated the AEA-Technology heat treatment and observed large transition-temperature shifts, although not as large as those from AEA-Technology. The second phase of the ORNL study used the same five RPV steels, but used the Gleeble system (an electrical-resistance heating device) to produce material deemed representative of the coarse-grain region in RPV welds. These materials revealed very high toughness in the initial condition (i.e., from the Gleeble). After thermal aging at about 454°C for 168 hours the materials exhibited only modest transition temperature increases, however, after aging at the same temperature for 2000 hours, significant transition temperature increases were observed. Of course, 2000 hours is much in excess of the time that RPV steels would be exposed to mitigation cycles, but potential synergistic effects of irradiation and thermal aging are unknown. Moreover, questions also remain regarding other time-temperature effects, such as post-irradiation mitigation at somewhat lower or higher temperatures.

(Milestone 3.1.A) The letter report, by R. K. Nanstad, D. E. McCabe, M. A. Sokolov, C. A. English, and S. R. Ortner, "Preliminary Investigation of Temper Embrittlement in Reactor Pressure Vessel Steels Following Thermal Aging, Irradiation, and Thermal Annealing," is in preparation.

(Milestone 3.1.B) As noted in the previous progress report, to investigate the effect of cooling rate following postweld heat treatment, additional material would be treated in the Gleeble system to simulate the coarse-grain HAZ as accomplished previously. This would then be followed by thermal aging, as well as by irradiation and thermal annealing. Excess material from the original investigation has been identified, and the proposed study will be discussed with the NRC technical monitor with consideration of funding needs. Consideration is also being given to reirradiation of the remaining specimens from the initial series.

<u>Subtask 3.2 (formerly 3.3): Evaluation of Reirradiated JRQ Specimens</u> (R. K. Nanstad, E. T. Manneschmidt, and T. M. Rosseel)

The purpose of this subtask is to examine the fracture-toughness behavior of a model steel that has been irradiated, tempered, and re-irradiated. The specimens, which were fabricated from a heat of A533 grade B class 1 steel identified as JRQ, were prepared by the Paul Scherrer Institute (PSI) as part of the IAEA CRP 3. This steel has been used for various studies sponsored by the IAEA and is under consideration as a reference material for various other RPV studies, including surveillance programs. This subtask is collaboratively conducted under a Memorandum of Agreement (MOA) between ORNL and PSI. Charpy impact, pre-cracked Charpy, and tensile specimens are available in the irradiated, and in the irradiated/annealed/re-irradiated conditions. Testing of irradiated specimens is dependent upon the availability of suitable hot-cell facilities.

(Milestone 3.2.A formerly 3.3.A) The testing of the JRQ specimens from the Paul Scherrer Institute, previously placed on hold primarily due to time required to repair the servohydraulic machine, was initiated in March. A total of 46 Charpy V-notch impact specimens were tested:

> 15 specimens irradiated at 290°C to 5.0 x $10^{19}$ n/cm$^2$ (>1 MeV),
>
> 14 specimens in the condition IAR (0.50): Irradiated-Annealed-Reirradiated to the target total fluence of 0.50 x $10^{19}$ n/cm$^2$ (>1 MeV). This means that the specimens thermally annealed at 460°C for 18 h when 50% of their target fluence had been reached. The procedure was irradiation to 0.25 x $10^{19}$ n/cm$^2$ (>1 MeV), followed by annealing, followed by reirradiation to the end fluence of 0.50 x $10^{19}$ n/cm$^2$ (>1 MeV), and
>
> 17 specimens in the condition IAR (1.70), with the same procedure as above, except annealing was conducted at 0.85 x $10^{19}$ n/cm$^2$ (>1 MeV).

The absorbed energy data were analyzed and hyperbolic tangent curve fits were performed to determine various transition temperatures and the upper-shelf energy. The results were compared relative to the unirradiated results provided by PSI. For the specimens irradiated to 5.0 x $10^{19}$ n/cm$^2$ (>1 MeV), the 41-J shift was 97°C. For the IAR (0.5) and IAR (1.70) conditions, the 41-J shifts were 27 and 56°C, respectively. These results have been provided to the researchers at PSI and compare favorably with results obtained previously. When completed, these Charpy impact results will allow for completion of a series of experiments with the JRQ plate comprising four different fluence levels and four different IAR conditions. During April, lateral expansion measurements were completed on the tested specimens and discussions were held with the PSI researchers regarding testing of the remaining specimens. For the remaining specimens of the two IAR groups, it was agreed that some specimens will be thermally annealed and some reirradiated. This will then provide two datasets to evaluate the effectiveness of IARA and two datasets to evaluate the response of the material to IARAR conditions. Due to hot cell scheduling issues, a testing schedule for the precracked Charpy specimens is unknown at this time.

A presentation on this work, to include previous work by PSI, was presented by R. K. Nanstad at the International Atomic Energy Agency (IAEA) Specialists' Meeting on Radiation Embrittlement and Mitigation in Gloucester, U.K., 14-17 May 2001. The presentation was co-authored by Ph. Tipping (Swiss HSK), G. Waeber (PSI), and Kalkhof (PSI). Figure 1 shows that the post-irradiation annealing and reirradiation cycles resulted in significantly lower yield strengths relative to those following irradiation.

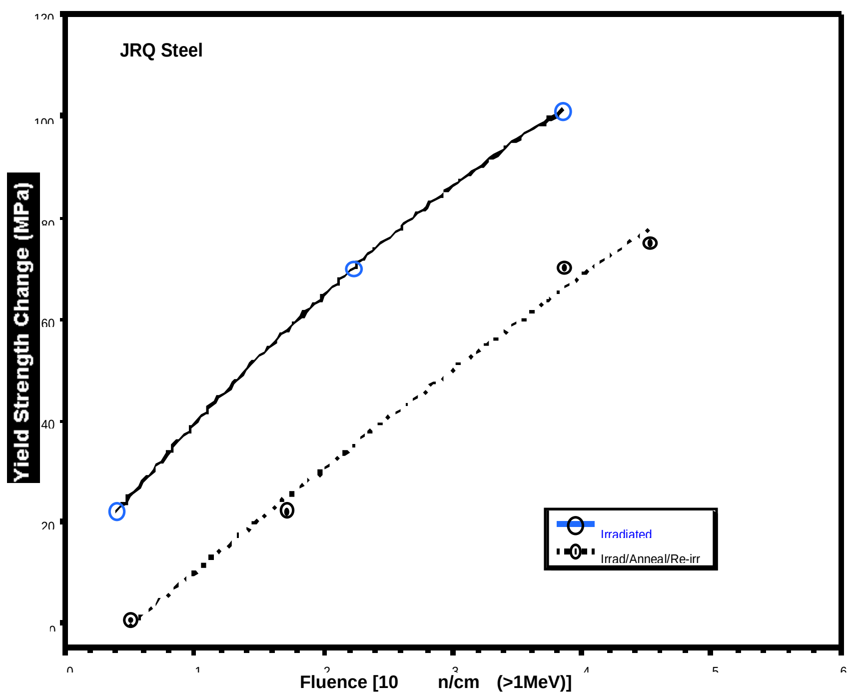



Figure 1. Room temperature tensile tests conducted by PSI reveal the mitigating effect of thermal annealing on irradiation-induced hardening.

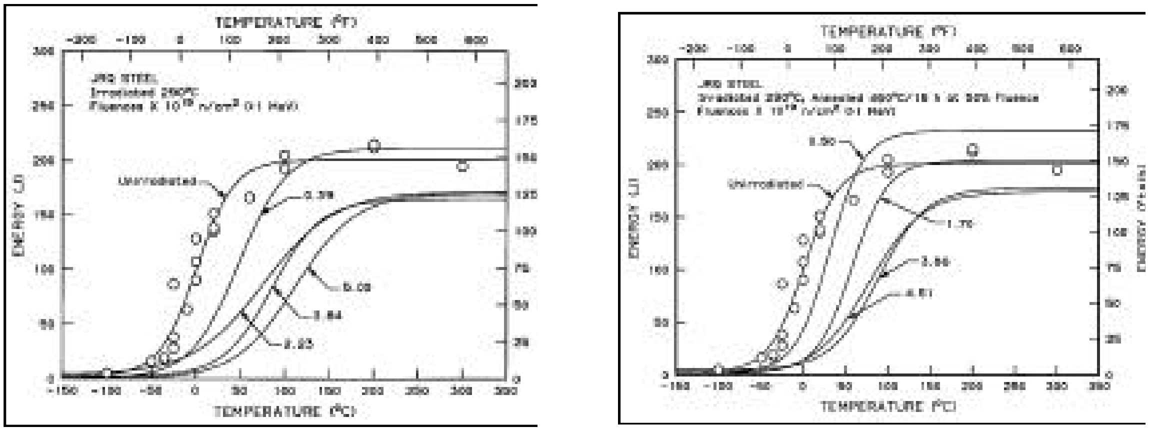
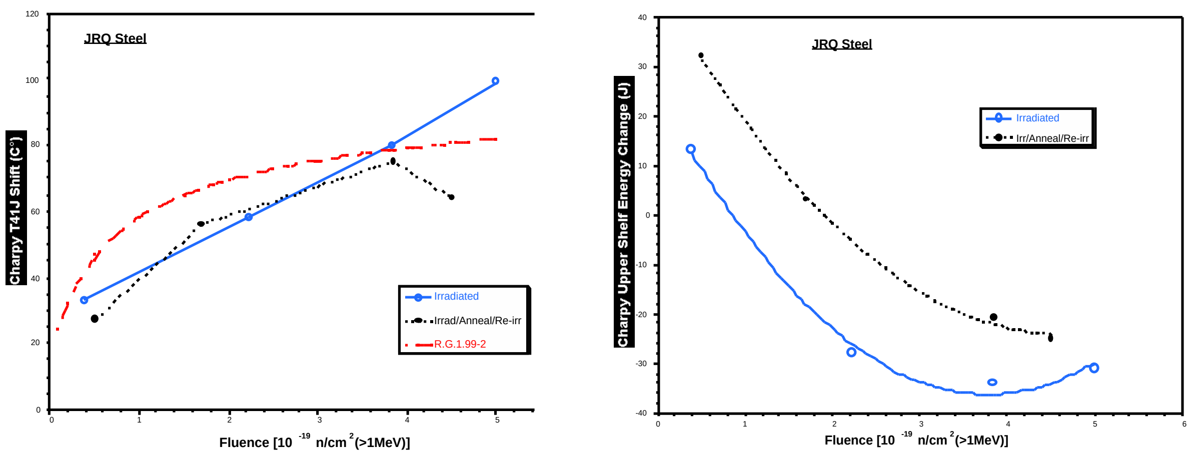



Figure 2. Charpy impact results by PSI and ORNL show (a) typical irradiation-induced behavior with fluence and, (b) an influence of the intermediate thermal anneal.

Figure 3. Charpy impact results by PSI and ORNL show mixed benefits of the intermediate thermal anneal on (a) Charpy 41-J temperature, and (b) Charpy upper-shelf energy. In contrast with the tensile results, the intermediate anneal had little effect on impact toughness**.**




The tensile strengths for the IAR specimens were at least 30% lower at a given total fluence compared to those only irradiated, demonstrating effectiveness of the intermediate anneal treatment on hardening. However, except at the highest fluence [5 x $10^{19}$ n/$cm^2$ (>1 MeV ]), the IAR specimens exhibited about the same Charpy shifts as those only irradiated, although upper-shelf energy decreases were less for the IAR specimens. Thus, in contrast with tensile results, the intermediate anneal had little effect on impact toughness. That result is unusual and further evaluation of the data and the tested specimens, to include scanning electron fractography, will be performed.

**<u>Task 4: Validation of Irradiated and Aged Materials</u> (R. K. Nanstad)**

The purpose of this task is to validate the assessment of the effects of neutron irradiation on the fracture-toughness properties of typical RPV materials obtained in the previous HSSI (L1098) Program, Tasks 2 and 3 of this program, and retired RPVs. This will be accomplished through the examination of the effects of neutron irradiation on the fracture toughness (ductile and brittle) of the HAZ of welds and of typical plate materials used in RPVs. The irradiated materials from retired RPVs will be machined and tested in the Irradiated Materials Examination and Testing (IMET) hot cells. The aging of stainless steel welds will also be explored in this task. Other issues to be address include foreign interactions and technical assistance to the NRC.

<u>Subtask 4.1: (formerly 4.3) Toughness Changes in Aged Stainless Steel Welds</u> (R. K. Nanstad)

The purpose of this subtask is to evaluate the effects of irradiation on fracture-toughness testing of irradiated stainless-steel weld-overlay cladding specimens at 288°C. This will complete the testing of the matrix from the HSSI (L1098) 7th Irradiation Series. The PCVN specimens were irradiated in HSSI Capsule 10.06.

(Milestone 4.1.B formerly 4.3.B) The report, *The Effect of Aging at 343°C on the Microstructure and Mechanical Properties of Type 308 Stainless Steel Weldments*, by D. J. Alexander, K. B. Alexander, M. K. Miller, and R. K. Nanstad, NUREG/CR-6628 (ORNL/TM-13767), was published in November 2000.

<u>Subtask 4.2: (formerly 4.4) Foreign Interactions</u> (R. K. Nanstad)

The purpose of this subtask is to provide technical support and continued collaboration for a number of cooperative relationships with foreign institutions in the area of radiation effects on RPV steels. Collaborative relationships may be developed during the course of this program and will be developed with the cognizance of NRC. Current relationships are:

1. Cooperation with SCK-CEN in Belgium regarding the supply of well-characterized materials and comparison of test results, including dynamic PCVN testing for development of RPV testing standards.

2. Collaboration with AEA-Technology in the United Kingdom regarding fracture toughness testing and temper embrittlement of RPV HAZs.

3. Collaboration with institutes in the Czech Republic, Germany, and Finland on fracture toughness with small specimens in support of MC evaluations.

4. Collaboration with PSI in Switzerland on evaluation of reirradiation effects.

5. Information and data exchange with all of the above and other countries, especially regarding RPV surveillance data and comparisons of fracture toughness and Charpy impact data.

6. Participation, including membership on the Executive Committee, in the International Group on Radiation Damage Mechanisms (IGRDM).

7. Participation in two coordinated research programs (CRPs) sponsored by the International Atomic Energy Agency (IAEA), informally designated CRP-5 and CRP-6. These CRPs will investigate: the use of PCVN specimens to determine fracture toughness of RPV steels, and effects of nickel on irradiation-induced embrittlement of RPV steels, respectively.

8. Collaboration with NRI, Rez (Czech Republic) in the area of microstructural evolution in RPV steels as a consequence of reirradiation.

9. Collaboration with MPA-Stuttgart in Germany regarding applicability of the master curve to highly embrittled RPV steels.

10. Collaboration with researchers at the University of Lille, France, in the area of primary radiation damage simulation.

(Milestone 4.2.A, formerly 4.4.B) R. K. Nanstad, as secretary of the International Group on Radiation Damage Mechanisms (IGRDM) in Pressure Vessel Steels, is updating the IGRDM membership list and (with assistance from R. E. Stoller) is revising the IGRDM charter. The next meeting of the IGRDM will be held in Japan in the Spring of 2002, most probably during the first half of May.

<u>Subtask 4.3: (formerly 4.5) Technical Assistance</u> (R. K. Nanstad and M. A. Sokolov)

The purpose of this subtask is to provide special analytical, experimental, and administrative support to the NRC in resolving various regulatory issues related to irradiation effects. Specific activities will be identified, on an as-needed basis, by the NRC Project Manager. Examples of such activities include: 1) evaluation of the effects of post-weld heat treatment (PWHT) on the copper solubility and fracture toughness of unirradiated RPV steels and 2) machining of material removed from retired irradiated RPVs for evaluation of through-thickness attenuation of irradiation embrittlement.

(Milestone 4.3.B formerly 4.5.F) Testing of unirradiated specimens has continued with the high-copper weld given varying time/temperature postweld heat treatments. A series of specimens in the as-welded condition were completed during this reported period. A Charpy impact energy versus temperature curve has now been obtained for each condition to evaluate toughness as a function of PWHT. Some Atom Probe Tomography has been conducted by Dr. Michael K. Miller through Department of Energy Basic Energy Sciences funding and will be used to determine the matrix copper contribution as a function of PWHT. A presentation of progress on this study was made at the IGRDM meeting in September in Leuven, Belgium, and was also be made at the IAEA Specialists' Meeting on Radiation Embrittlement and Mitigation in Gloucester, U.K., 14-17 May 2001. Depending on hot cell scheduling, testing of the irradiated sub-size Charpy specimens is anticipated for May. A letter report will be prepared following completion of all testing and evaluation. An abstract has been submitted and accepted for the

Tenth International Conference on Environmental Degradation of Materials in Nuclear Power Systems - Water Reactors, to be held August 5-9, 2001, in Lake Tahoe, Nevada.

(Milestone 4.3.C, formerly 2.5.A) The draft NUREG report, *Detailed Results of Testing Unirradiated and Irradiated Crack-Arrest Toughness Specimens from the Low Upper-Shelf Energy, High Copper Weld, WF-70*, by S. K. Iskander, C. A. Baldwin, D. W. Heatherly, D. E. McCabe, I. Remec, and R. L. Swain, NUREG/CR-6621 (ORNL/TM-13764), is finished, but completion of the final report and submission to the NRC for publication will be delayed until about September due to personnel reductions.

(Milestone 4.3.D formerly 3.2.C) Irradiated, annealed, and reirradiated specimens of HSSI Weld 73W were reinserted into the IAR facility at the FNR to accumulate additional fluence. The results obtained from tests of some of the reirradiated specimens showed a much lower transition temperature shift than expected. The target total fluence for the specimens is about $4 \times 10^{19}$ n/cm$^2$.

(Milestone 4.3.E formerly 4.1.2.B) The NUREG report (ORNL/TM-2000/343), *Attenuation of Charpy Impact Toughness Through the Thickness of a JPDR Pressure Vessel Weldment*, by S. K. Iskander, J. T. Hutton, L. E. Creech, M. Suzuki, K. Onizawa, E. T. Manneschmidt, R. K. Nanstad, T. M. Rosseel, and P. S. Bishop, was submitted to the NRC in January as part of an Office of Research Operational Milestone.

**Task 5: Modeling & Microstructural Analysis and Embrittlement Data Base - (T. M. Rosseel)**

This task shall determine the microstructural basis for radiation-induced property changes in RPV materials to aid in understanding and applying the experimental results obtained in Tasks 2 through 4. The three subtasks will comprise: (1) theoretical modeling and data analysis; (2) experimental investigations; and, (3) maintaining and updating the Embrittlement Data Base (EDB). The modeling work will include the development of an improved description of primary-damage formation in irradiated materials, and the further development and use of predictive models of radiation-induced microstructural evolution and its impact on the mechanical behavior of RPV materials. The experimental component will focus on detailed microstructural characterization of RPV materials in relevant conditions, including long-term, thermally-aged and high-fluence irradiated materials. The information obtained from the experiments and microstructural characterization will be used to support validation of the theoretical models. Further model verification will be carried out through use of the mechanical property data contained in the EDB, and data generated in other experiments coordinated by this task. Updated versions of the EDB will be issued as appropriate.

The major areas of inquiry include: (a) the effects of chemical composition; (b) the role of displacement rate (neutron flux); (c) damage attenuation through the RPV wall; and, (d) potential new hardening mechanisms and embrittlement behavior at very high fluence. The overall goal of the task is to provide an embrittlement model that can be used in a predictive way to anticipate the response of RPV materials at high fluences near or slightly beyond their nominal end-of-life, and to provide support to the NRC for related safety or licensing questions. The tools developed in this task will also be used to support the analysis of experimental results obtained in other program tasks. Both the modeling and experimental research will be coordinated with complementary activities carried out by other NRC contractors and the international community.

The nature of the modeling and data analysis carried out under this task requires that it extend over the lifetime of the program. Model development and validation is coordinated with the experimental activities in an iterative fashion. Work and milestone schedules will be contingent on available funding.

Subtask 5.1: Modeling of Damage Evolution (R. E. Stoller)

The modeling of damage evolution will focus on the development of an integrated microstructural model that includes components developed at ORNL and by other NRC contractors and will provide the basis of an improved embrittlement model. The integrated model may include thermodynamic components to account for chemical effects that may be particularly important at high-fluence and in low-copper steels. A more detailed treatment of point defect and solute clustering will also be pursued.

(Milestone 5.1.B) The NUREG report entitled *Evaluation of Neutron Energy Spectrum Effects Based on Primary Damage Simulations in Iron*, NUREG/CR-6670, (ORNL/TM-1999/334) was submitted to the NRC in July, 2000.

Subtask 5.2: Microstructural Analysis (M. K. Miller)

APFIM characterization will be used to determine whether additional radiation-induced phases are forming. In addition, the methods of APFIM, SANS, and field-emission scanning transmission electron microscopy (FEGSTEM) have been used to determine the matrix copper content and the chemical composition of radiation-induced precipitates in RPV materials. Although there is qualitative agreement between the three methods, some significant inconsistencies exist. Comparisons among the techniques will be performed so as to resolve the apparent inconsistencies.

(Milestone 5.2.A) Atom probe analyses were performed on five baseline materials. Two alloys, LA and LC, are Laval commercial model alloys while VB, VD and VH are simple model alloys. A copper precipitate adjacent to a carbide was found in the LA baseline alloy.

The NUREG report entitled, *Atom Probe Tomography Characterization of the Solute Distributions in a Neutron-Irradiated and Annealed Pressure Vessel Steel Weld*, NUREG/CR-6629, (ORNL/TM-13768), was published by the NRC in November, 2000.

A draft NUREG report entitled, *Effect of Reirradiation Rate on The Charpy Properties of an Irradiated/Annealed High Copper Reactor Pressure Vessel Weld HSSI 73W*, that incorporates the atom probe tomography results on weld 73W specimens, has been prepared in draft form.

Subtask 5.3: Modeling and Embrittlement Data Base (formerly 7.1) (J.-A. Wang)

This subtask was, until March 1, 1999, part of the Embrittlement Data Base (EDB) and Dosimetry Evaluation Program, JCN: 6164. The objectives of the subtask have been reduced but the focus remains the same. Nuclear radiation embrittlement information from radiation embrittlement research on nuclear RPV steels and from power-reactor surveillance reports will be maintained in a data base to be published on a periodic basis. The information will assist the Office of Nuclear Reactor Regulation and the Office of Nuclear Regulatory Research to effectively monitor current procedures and data bases used by vendors, utilities, and service laboratories in the pressure vessel irradiation surveillance program. The specific activity of the subtask is to maintain and update the EDB. Additional work on statistical analysis of toughness data bases will also be performed. The purpose of this effort is to design a new data fitting procedure to generate a new multi-space trend surface that can properly reflect the inhomogeneity of the surveillance materials, and utilize this multi-space trend surface to link and to project the surveillance test results to that of reactor pressure vessel steels.

(Milestone 5.3.A) The completed UPDATE-11 of PR-EDB was transmitted to the US NRC technical program monitor in July 2000. No new surveillance reports have been received.

(Milestone 5.3.B) Sorting of the chemistry data from raw Charpy data listed in PR-EDB for base and weld materials was begun. Additionally a method to determine how many surveillance test sets have completed chemistry data available from the broken Charpy test samples was initiated.

## Task 6: Test Reactor Irradiation Coordination (K. R. Thoms)

This task provides the support required to supply and coordinate irradiation services needed by NRC contractors (such as the UCSB and the ORNL HSSI Program) at the University of Michigan FNR. These services include the design and assembly of irradiation facilities (and/or capsules), as well as arranging for their exposure, periodic monitoring by remote computer access and interaction with the FNR staff, and return of specimens to the originating research organization.

Subtask 6.1: Operate the HSSI Irradiation (IAR) Facility (K. R Thoms and D. W. Heatherly)

With the fabrication, installation, and initial testing of the HSSI IAR facility at the University of Michigan FNR completed as part of the previous (L1098) HSSI program, the activities associated with the new program include supervising the irradiation of the reusable irradiation capsules in the dual-capsule irradiation facility at FNR. A NUREG report on the design, assembly, installation, and operation of the HSSI IAR facility will be prepared.

(Milestone 6.1.A) Irradiation of the ORNL specimens in the HSSI-IAR 1 and 2 irradiation facilities continued during this reporting period.

The HSSI-IAR irradiation facilities operated without incident during this reporting period. During this period, the HSSI-IAR facilities were irradiated for 10 days of reactor half-cycle 458A, 10 days of half-cycle 458B, and the first 1.2 days of half-cycle 459A.

During the 10 days of reactor half-cycle 458A, the IAR irradiation facilities received a total of 241 EFPH (effective full power hours). During reactor half-cycle 458B, the facilities received a total of 235 EFPH, followed by an additional 30 EFPH during the first 1.2 days of half-cycle 459A. During this reporting period, the HSSI-IAR irradiation facilities received a total of 506 EFPH.

At the beginning of this reporting period, the second group of specimens to be irradiated in the new IAR facilities had been irradiated for a total of 5859 EFPH. At the end of this reporting period, the second group of specimens had been irradiated for a total of 6365 EFPH. The facilities have been in service for a total of 10,693 EFPH.

(Milestone 6.1.B) The draft NUREG report on the reusable irradiation facilities has been delayed until August due to efforts to complete the draft white paper entitled, “Options Regarding Facilities for Irradiation of Reactor Pressure Vessel Steels,” by K. R. Thoms. As described in the previous report, this manuscript provides a detailed description of the current HSSI IAR and UCSB IVAR reusable irradiation facilities at the University of Michigan Ford Nuclear Reactor (FNR), including the issues that led to the design of these facilities. Potential North American and European reactor options were also reviewed and summarized in a series of tables that will permit a comparison of the costs and advantages and disadvantages of each facility option.

<u>Subtask 6.2: Operate the HSSI/UCSB Irradiation Facility</u> (K. R. Thoms and D. W. Heatherly)

This subtask includes supervising the overall operation and providing assistance to the reactor personnel in the routine operation and maintenance of the HSSI-UCSB irradiation facility. A NUREG report on the design, assembly, installation, and operation of the UCSB facility will be prepared.

(Milestone 6.2.A) Irradiation of the UCSB specimens in the HSSI-UCSB irradiation facility continued during this reporting period

The HSSI-UCSB irradiation facility operated without incident during this reporting period. During this period, the facility was irradiated for 10 days of reactor half-cycle 458A, 10 days of half-cycle 458B, and the first 1.2 days of half-cycle 459A.

During the 10 days of reactor half-cycle 458A, the HSSI-UCSB irradiation facility received a total of 241 EFPH (effective full power hours). During reactor half-cycle 458B, the facility received a total of 235 EFPH, followed by an additional 30 EFPH during the first 1.2 days of half-cycle 459A. During this reporting period, the HSSI-UCSB irradiation facility received a total of 506 EFPH.

At the beginning of this reporting period, the HSSI-UCSB facility and original specimen compliment had been irradiated for a total of 17,672 EFPH. At the end of this reporting period, the facility and original specimen compliment had been irradiated for a total of 18,178 EFPH.

The latest irradiation plan received from the UCSB experimenters indicated that the final specimens would be removed from the facility after 13,500 EFPH. Additional specimen irradiations have been added to the original plan and at the end of this reporting period, the UCSB irradiation program had obtained 135% of the original desired irradiation time.

**Former Task 7: Embrittlement Data Base and Dosimetry Evaluation (T. M. Rosseel)**

This task was until March 1, 1999, the Embrittlement Data Base (EDB) and Dosimetry Evaluation Program, JCN: 6164. The objectives of the two subtasks listed below have been reduced but the focus remains the same. Nuclear radiation embrittlement information from radiation embrittlement research on nuclear RPV steels and from power-reactor surveillance reports will be maintained in a data base to be published on a periodic basis. The information will assist the Office of Nuclear Reactor Regulation and the Office of Nuclear Regulatory Research to effectively monitor current procedures and data bases used by vendors, utilities, and service laboratories in the pressure vessel irradiation surveillance program. It will also provide technical expertise and analysis to the NRC regarding dosimetry and transport calculations and methodologies.

Subtask 7.1: Embrittlement Data Base (J.-A. Wang)

The purpose of the subtask is to maintain and update the EDB.

This task has been incorporated into Task 5.3

Subtask 7.2: Dosimetry Evaluation (I. Remec)

Technical expertise and analysis regarding dosimetry and transport calculations and methodologies will be provided as needed to the US NRC. Specifically, work will be performed to complete the review of, and hold final discussions with the NRC concerning, the dosimetry guide, DG-1053.

This activity was eliminated as directed by SOEW 60-99-356.

## 3. MEETINGS AND TRIPS:

On May 6-9, M. A. Sokolov traveled to Phoenix to participate in ASTM committee meetings.

On May 7-18, R. K. Nanstad traveled to London and Gloucester, United Kingdom, to participate in the International Atomic Energy Agency Consulting Meeting and Specialists' Meeting on Radiation Embrittlement Mitigation.

On May 15-17, T. M. Rosseel traveled to Charlotte, NC to participate in the EPRI-DOE NEPO (Nuclear Plant Optimization) fiscal year 2002 planning meeting. Discussions were held regarding obtaining irradiated material, including RPV trepans from the San Onofre Unit-1 (SONGS-1) reactor. This trip was sponsored by DOE.

On May 25-June 2, R. K. Nanstad traveled to Sazopol, Bulgaria, to participate in the International Atomic Energy Agency Research Coordination Meeting on Effects of Nickel in Irradiation Embrittlement of Reactor Pressure Vessel Steels.

## 4. PRESENTATIONS, REPORTS, PAPERS, AND PUBLICATIONS:

J. A Wang, Pace, J. V. III, and Rosseel, T. M, "U.S. NRC Embrittlement Data Base (EDB), "Reactor Dosimetry:Radiation Metrology and Assessment, ASTM STP 1398, John G. Williams, David W. Vehar, Frank H. Ruddy, and David Gilliam, Eds., American Society for Testing and Materials, West Conshohocken, PA, pp. 657-664, 2001.

M. A. Sokolov, *Report of Foreign Travel to Belgium and Germany,* ORNL/FTR-125480, May 14, 2001.

M. K. Miller, M. A. Sokolov, S. S. Babu, and R. K. Nanstad, “Effect of Post-Weld Heat Treatment Temperature on Matrix Copper Level and Charpy Toughness of Reactor Pressure Vessel Welds,” presented by R. K. Nanstad at the International Atomic Energy Agency Specialists’ Meeting on Irradiation Embrittlement and Mitigation, Gloucester, United Kingdom, May 14-17, 2001.

R. K. Nanstad, Ph. Tipping, W. Waeber, and R. D. Kalkhof, “Effects of Irradiation and Post-Annealing Reirradiation on RPV Steel Plate JRQ,” presented by R. K. Nanstad at the International Atomic Energy Agency Specialists’ Meeting on Irradiation Embrittlement and Mitigation, Gloucester, United Kingdom, May 14-17, 2001.

## 5. PROPERTY ACQUIRED:

Items listed in this section include all nonconsumable project purchases that were actually paid for during this reporting period. They do not include either accruals or accrual reversals and hence may not accurately reflect total material procurement charges within this period.

| Item | Cost ($) |
|---|---|
| None | |

## 6. PROBLEM AREAS:

The IMET hot cell facility is currently scheduled for standby from June 1, 2001, until the end of the fiscal year to perform maintenance, including the installation of the new crane.

During testing of the final group of irradiated 0.5T compact specimens, excessive electrical noise from the machine actuator displacement transducer was observed. Preliminary diagnostic examination of the machine has not determined the exact reasons for the noise problem.

However, movement of the machine crosshead and actuator position reduced the noise sufficiently to allow completion of the testing of the remaining 0.5T specimens.  Further evaluation of the system will be conducted prior to any additional testing.

## 7.  PLANS FOR THE NEXT REPORTING PERIOD:

The plans for the next reporting period are described in Section 2.

FINANCIAL STATUS for W6953 — Reporting Period: 4/23/01-5/27/01

| | | Current Month | Fiscal Year to Date | Cumulative Project to date |
|---|---|---|---|---|
| I. | Direct Staff Effort | 10 MM | 6.1 MY | 35.9 MY |
| II. A. | Direct Lab Staff Effort ($) | | | |
| | Direct Salaries | 87,717 | 595,692 | 3,611,397 |
| | Materials and Services | 1,632 | 7,396 | 383,352 |
| | ADP Support | 21 | 335 | 2,120 |
| | Subcontracts | 14,570 | 33,023 | 395,441 |
| | Travel | 4,682 | 17,175 | 133,784 |
| | Indirect Labor Costs | 0 | 0 | 0 |
| | Other: NRC-PO Tax | 4,000 | 24,000 | 162,500 |
| | General and Administrative | 37,960 | 250,199 | 1,629,421 |
| | Total UT-Battelle Costs | 150,582 | 927,820 | 6,318,015 |
| B. | DOE Federal Access Costs | 4,517 | 27,835 | 27,835 |
| | TOTAL PROJECT COSTS | 155,099 | 955,655 | 6,345,850 |

| | |
|---|---|
| Percentage of available cumulative funds costed | 89 |
| Percentage of available current FY funds costed | 56 |
| Funds Remaining | 759,150 |
| Commitments: | 174,988 |
| BA Remaining | 584,162 |
| BA Remaining Less Projected FAC | 562,051 |

III. Funding Status

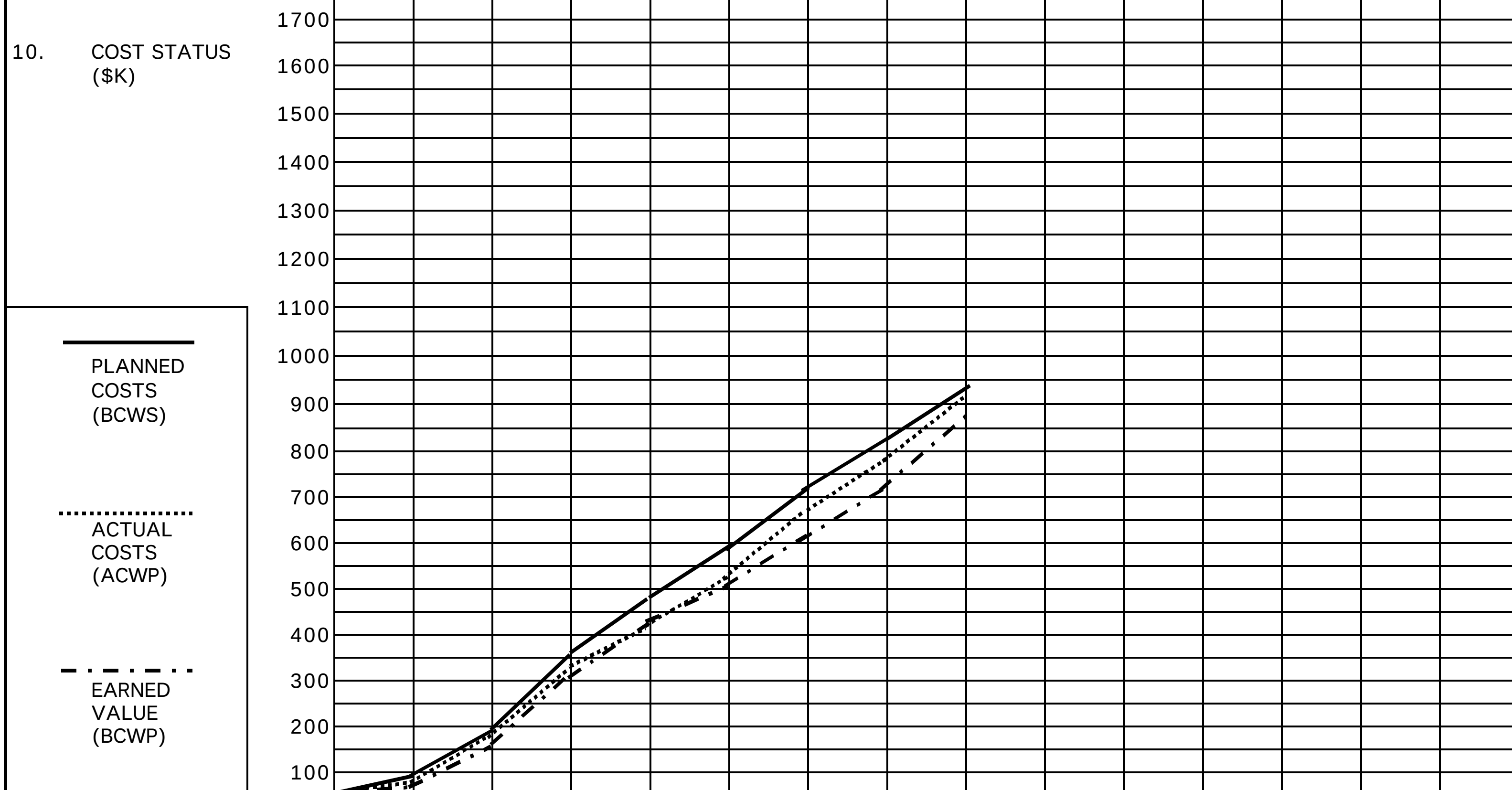
| Prior FY Carryover | FY 01 Projected Funding Level | FY 01 Funds Received to Date | FY 01 Funding Balance Needed | Cumulative Amt. Obligated | Cumulative Amt. Costed |
|---|---|---|---|---|---|
| 279,802 | 1,460,000 | 1,435,000 | 25,000 | 7,105,000 | 6,345,850 |

Comments: The Federal Access Charge of 3% is applied to monthly costs.

| | | |
|---|---|---|
| 1. CONTRACT REPORTING ELEMENT<br>**HSSI - Heavy-Section Steel Irradiation Program** | 2. REPORTING PERIOD<br>**04/23/01 - 05/27/01** | 3. JCN NO.<br>**W6953** |
| 4. CONTRACTOR (NAME AND ADDRESS)<br>**OAK RIDGE NATIONAL LABORATORY**<br>**P. O. BOX 2008**<br>**OAK RIDGE, TN 37831** | 5. CONTRACT PERIOD<br>**FY 1998 - 2003** | 6. ACTIVITY NUMBER<br>**W41 W5 85 3W 1** |
| | 7. NRC B&R NO.<br>**860 15 21 20 05** | 8. DOE B&R NO.<br>**40 10 01 06** |

9. MONTHS: O N D J F M A M J J A S O N D

10. COST STATUS ($K)




COST PLAN DATES: 04/20/01

PLANNED COSTS FOR ELEMENT ($K): 1546

ELEMENT COSTS FOR PRIOR FYS ($K): 280

| ACCRUED COSTS ($K) | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PLANNED | 98 | 98 | 155 | 119 | 128 | 129 | 103 | 112 | 107 | 97 | 82 | 117 | 113 | 93 | |
| ACTUAL | 77 | 113 | 134 | 85 | 110 | 145 | 113 | 151 | | | | | | | |
| EARNED | 74 | 78 | 156 | 105 | 93 | 110 | 88 | 174 | | | | | | | |
| CUM. PLANNED | 98 | 196 | 351 | 470 | 598 | 722 | 825 | 937 | 1044 | 1141 | 1223 | 1340 | 1453 | 1546 | |
| CUM. ACTUAL | 77 | 190 | 324 | 409 | 519 | 664 | 777 | 928 | | | | | | | |
| CUM. EARNED | 74 | 152 | 308 | 413 | 506 | 616 | 706 | 880 | | | | | | | |

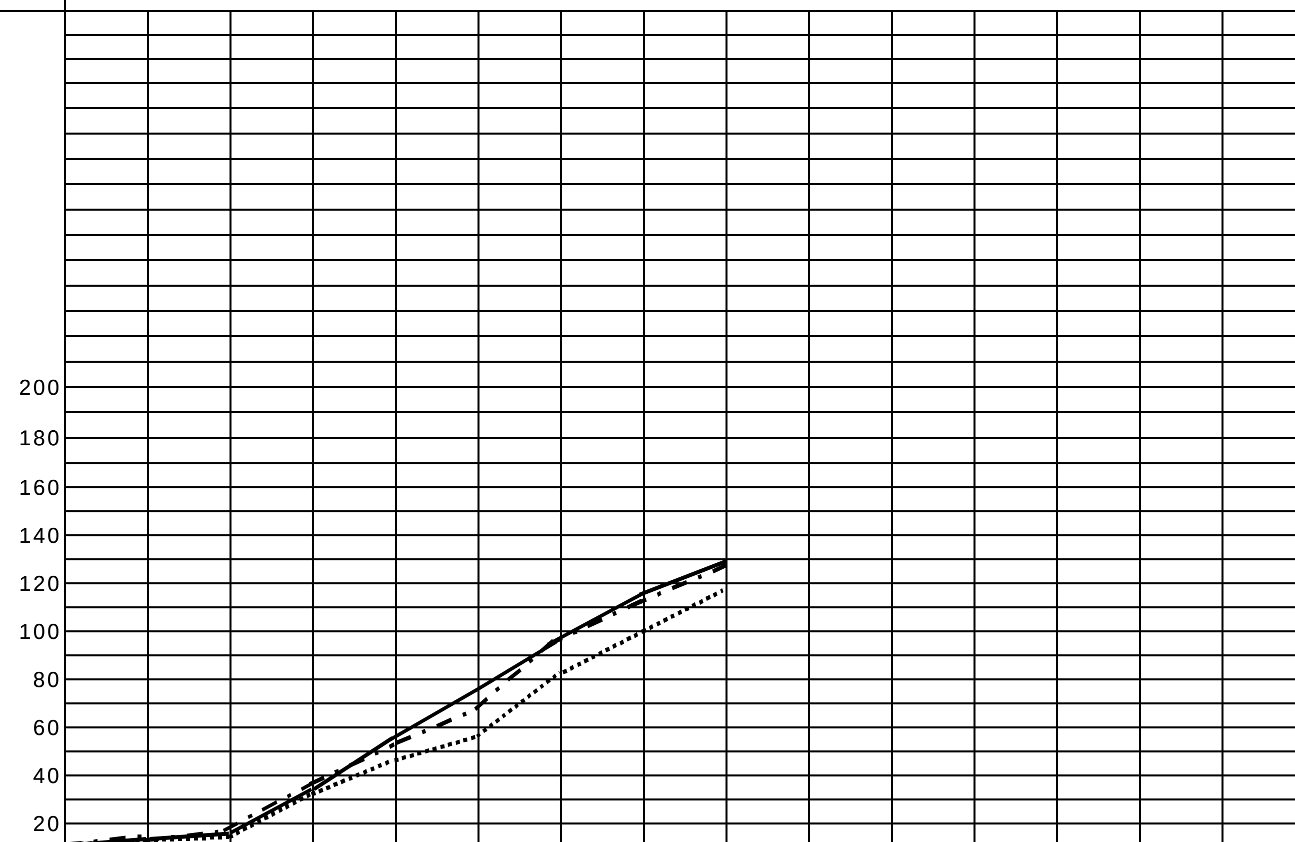
11. REMARKS

Total/Planned Cost reflects reduction in funds received due to FAC.

| | | |
|---|---|---|
| 1. CONTRACT REPORTING ELEMENT<br>**HSSI - 1. Program Management** | 2. REPORTING PERIOD<br>**04/23/01 - 05/27/01** | 3. JCN NO.<br>**W6953** |
| 4. CONTRACTOR (NAME AND ADDRESS)<br>**OAK RIDGE NATIONAL LABORATORY**<br>**P. O. BOX 2008**<br>**OAK RIDGE, TN 37831** | 5. CONTRACT PERIOD<br>**FY 1998 - 2003**<br>7. NRC B&R NO.<br>**860 15 21 20 05** | 6. ACTIVITY NUMBER<br>**W41 W5 85 3W 1**<br>8. DOE B&R NO.<br>**40 10 01 06** |

9. MONTHS: O N D J F M A M J J A S O N D

10. COST STATUS ($K)




PLANNED COSTS (BCWS) — solid line

ACTUAL COSTS (ACWP) — dotted line

EARNED VALUE (BCWP) — dash-dot line

COST PLAN DATES: 04/20/01

PLANNED COSTS FOR ELEMENT ($K): 189

ELEMENT COSTS FOR PRIOR FYS ($K): 10

| ACCRUED COSTS ($K) | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PLANNED | 4 | 10 | 20 | 20 | 22 | 19 | 13 | 13 | 15 | 14 | 15 | 20 | 15 | 10 | |
| ACTUAL | 4 | 10 | 20 | 11 | 10 | 26 | 19 | 18 | | | | | | | |
| EARNED | 5 | 9 | 20 | 17 | 16 | 31 | 14 | 13 | | | | | | | |
| CUM. PLANNED | 4 | 14 | 34 | 54 | 76 | 95 | 108 | 121 | 136 | 150 | 165 | 185 | 200 | 210 | |
| CUM. ACTUAL | 4 | 14 | 34 | 45 | 55 | 81 | 100 | 118 | | | | | | | |
| CUM. EARNED | 5 | 14 | 34 | 51 | 67 | 98 | 112 | 125 | | | | | | | |

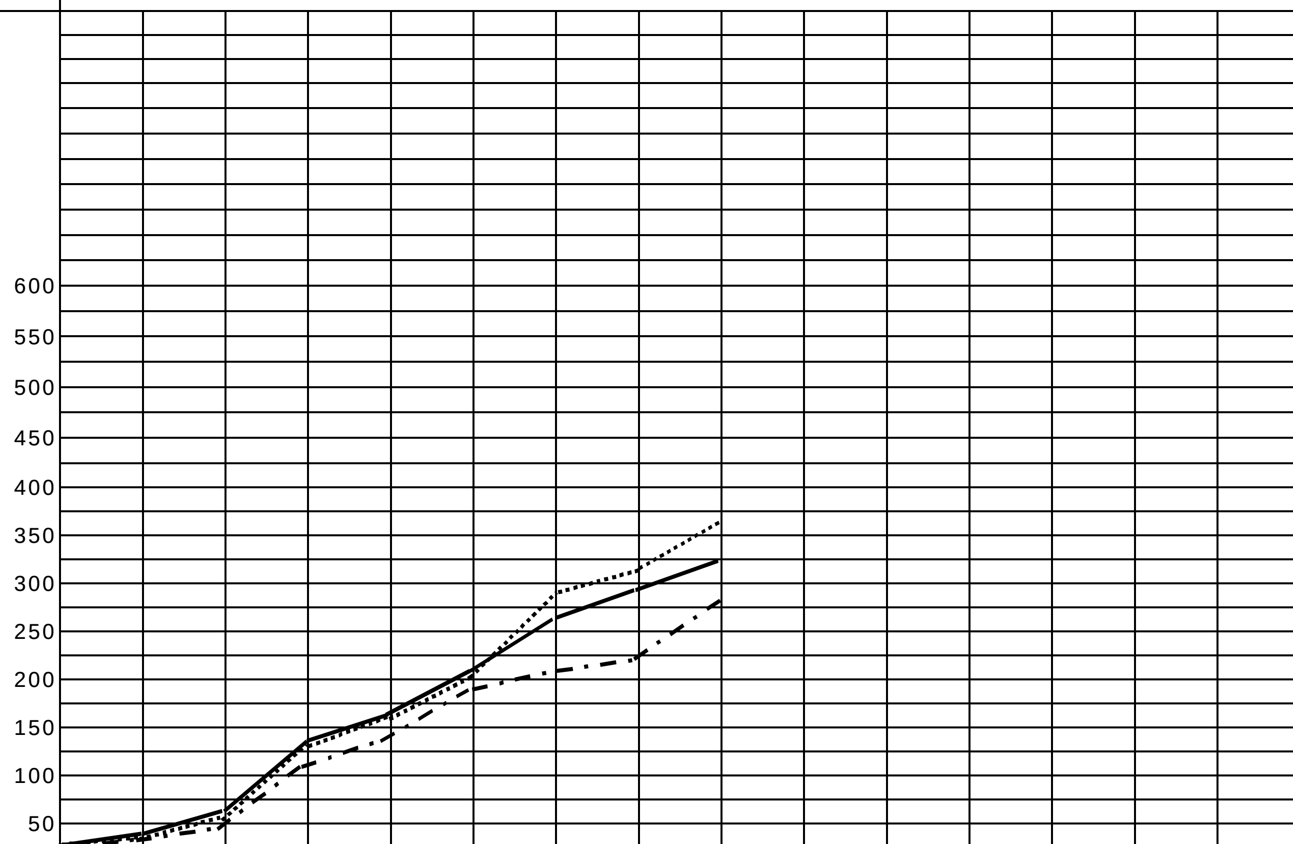
11. REMARKS

Total/Planned Cost reflects reduction in funds received due to FAC.

| | | |
|---|---|---|
| 1. CONTRACT REPORTING ELEMENT<br>**HSSI - 2. Fracture Toughness Transition and MC Methodology** | 2. REPORTING PERIOD<br>**04/23/01 - 05/27/01** | 3. JCN NO.<br>**W6953** |
| 4. CONTRACTOR (NAME AND ADDRESS)<br>**OAK RIDGE NATIONAL LABORATORY**<br>**P. O. BOX 2008**<br>**OAK RIDGE, TN 37831** | 5. CONTRACT PERIOD<br>**FY 1998 - 2003**<br>7. NRC B&R NO.<br>**860 15 21 20 05** | 6. ACTIVITY NUMBER<br>**W41 W5 85 3W 1**<br>8. DOE B&R NO.<br>**40 10 01 06** |

9. MONTHS: O N D J F M A M J J A S O N D

10. COST STATUS ($K)




PLANNED COSTS (BCWS)

ACTUAL COSTS (ACWP)

EARNED VALUE (BCWP)

COST PLAN DATES
04/20/01

PLANNED COSTS FOR ELEMENT ($K)
509

ELEMENT COSTS FOR PRIOR FYS ($K)
117

| ACCRUED COSTS ($K) | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PLANNED | 25 | 33 | 73 | 37 | 47 | 46 | 28 | 35 | 32 | 29 | 27 | 33 | 32 | 30 | |
| ACTUAL | 20 | 33 | 75 | 40 | 47 | 78 | 13 | 56 | | | | | | | |
| EARNED | 19 | 22 | 74 | 27 | 29 | 35 | 17 | 56 | 56 | | | | | | |
| CUM. PLANNED | 25 | 58 | 131 | 168 | 215 | 261 | 289 | 324 | 356 | 385 | 412 | 447 | 479 | 509 | |
| CUM. ACTUAL | 20 | 53 | 128 | 168 | 215 | 293 | 306 | 362 | | | | | | | |
| CUM. EARNED | 19 | 41 | 115 | 142 | 171 | 206 | 223 | 279 | | | | | | | |

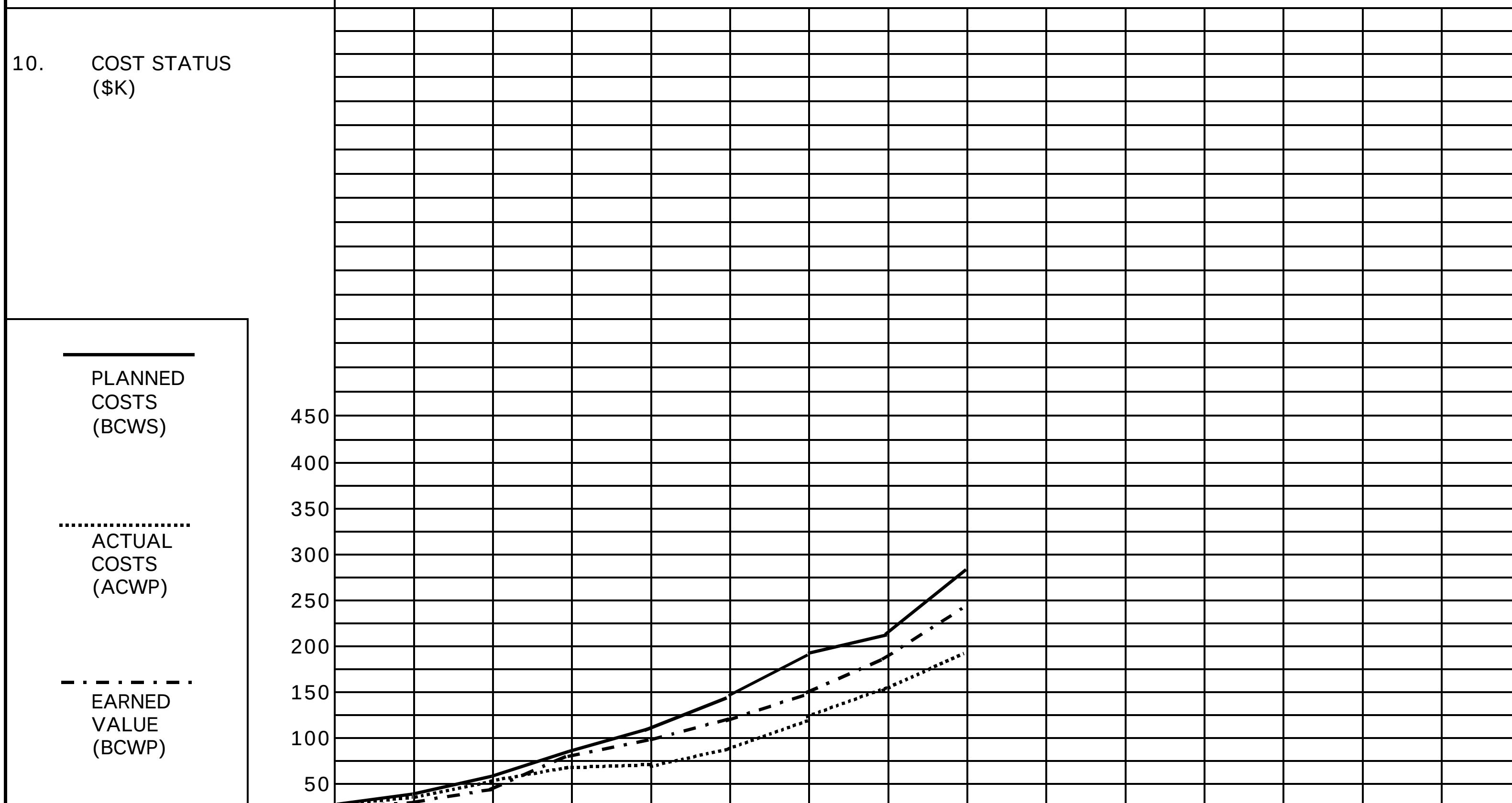
11. REMARKS

Total/Planned Cost reflects reduction in funds received due to FAC.

| | | |
|---|---|---|
| 1. CONTRACT REPORTING ELEMENT<br>**HSSI - 3. Irradiation Embrittlement of RPV Steel** | 2. REPORTING PERIOD<br>**04/23/01 - 05/27/01** | 3. JCN NO.<br>**W6953** |
| 4. CONTRACTOR (NAME AND ADDRESS)<br>**OAK RIDGE NATIONAL LABORATORY**<br>**P. O. BOX 2008**<br>**OAK RIDGE, TN 37831** | 5. CONTRACT PERIOD<br>**FY 1998 - 2003**<br>7. NRC B&R NO.<br>**860 15 21 20 05** | 6. ACTIVITY NUMBER<br>**W41 W5 85 3W 1**<br>8. DOE B&R NO.<br>**40 10 01 06** |

9. MONTHS: O N D J F M A M J J A S O N D

10. COST STATUS ($K)




COST PLAN DATES

4/20/01

PLANNED COSTS FOR ELEMENT ($K)

443

ELEMENT COSTS FOR PRIOR FYS ($K)

98

| ACCRUED COSTS ($K) | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PLANNED | 33 | 26 | 24 | 26 | 37 | 39 | 25 | 67 | 26 | 31 | 40 | 27 | 22 | 20 | |
| ACTUAL | 32 | 26 | 9 | 2 | 22 | 23 | 37 | 35 | | | | | | | |
| EARNED | 24 | 24 | 30 | 20 | 22 | 29 | 30 | 62 | | | | | | | |
| CUM. PLANNED | 33 | 59 | 83 | 109 | 146 | 185 | 210 | 277 | 303 | 334 | 374 | 401 | 423 | 443 | |
| CUM. ACTUAL | 32 | 58 | 67 | 69 | 91 | 114 | 151 | 186 | | | | | | | |
| CUM. EARNED | 24 | 48 | 78 | 98 | 120 | 149 | 179 | 241 | | | | | | | |

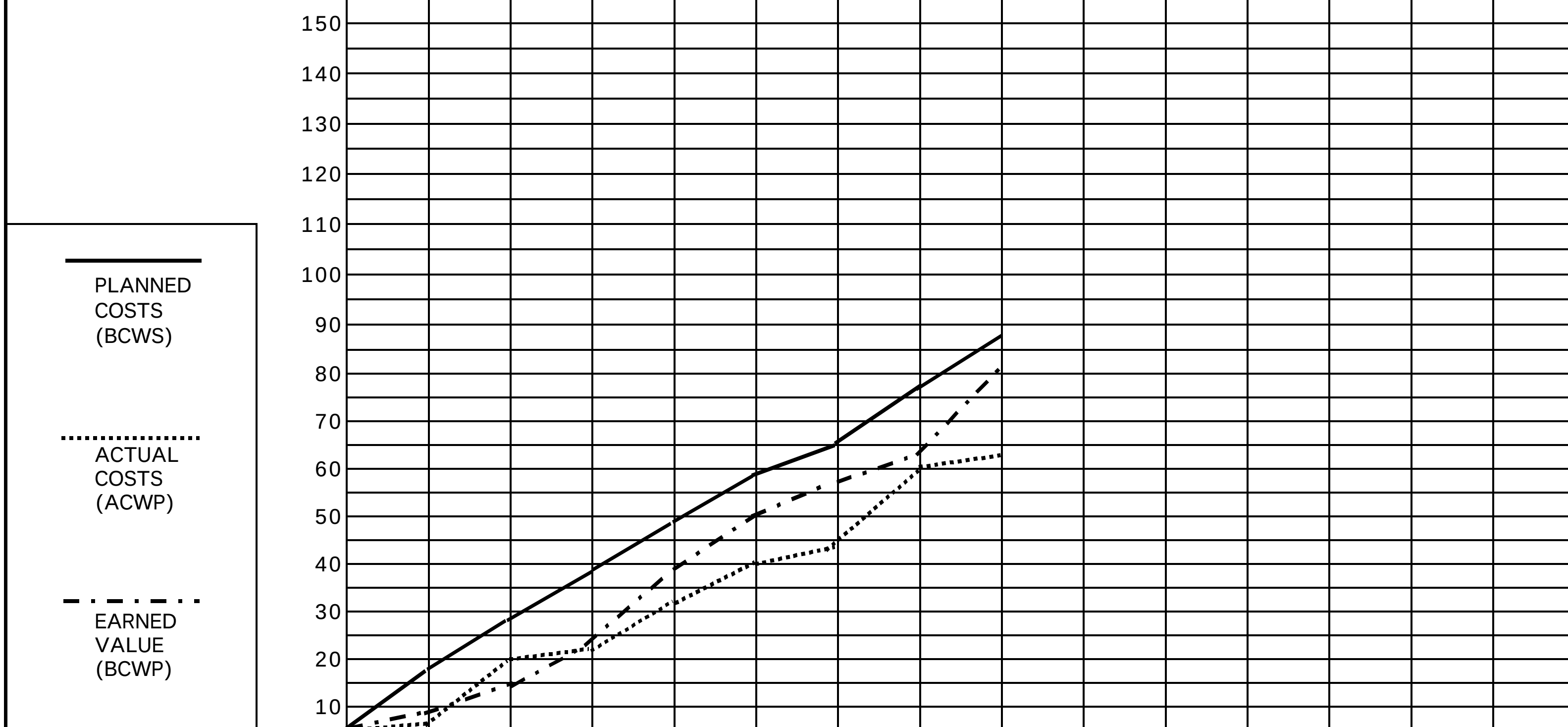
11. REMARKS

Total/Planned Cost reflects reduction in funds received due to FAC.

| | | |
|---|---|---|
| 1. CONTRACT REPORTING ELEMENT<br>**HSSI - 4. Validation of Irradiated and Aged Materials** | 2. REPORTING PERIOD<br>**04/23/01 - 05/27/01** | 3. JCN NO.<br>**W6953** |
| 4. CONTRACTOR (NAME AND ADDRESS)<br>**OAK RIDGE NATIONAL LABORATORY**<br>**P. O. BOX 2008**<br>**OAK RIDGE, TN 37831** | 5. CONTRACT PERIOD<br>**FY 1998 - 2003**<br>7. NRC B&R NO.<br>**860 15 21 20 05** | 6. ACTIVITY NUMBER<br>**W41 W5 85 3W 1**<br>8. DOE B&R NO.<br>**40 10 01 06** |

9. MONTHS: O N D J F M A M J J A S O N D

10. COST STATUS ($K)




COST PLAN DATES: 04/20/01

PLANNED COSTS FOR ELEMENT ($K): 133

ELEMENT COSTS FOR PRIOR FYS ($K): 18

| ACCRUED COSTS ($K) | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PLANNED | 16 | 13 | 10 | 10 | 9 | 7 | 12 | 9 | 8 | 7 | 6 | 9 | 8 | 9 | |
| ACTUAL | 2 | 18 | 3 | 9 | 8 | 3 | 17 | 3 | | | | | | | |
| EARNED | 7 | 7 | 9 | 16 | 11 | 6 | 7 | 18 | | | | | | | |
| CUM. PLANNED | 16 | 29 | 39 | 49 | 58 | 65 | 77 | 86 | 94 | 101 | 107 | 116 | 124 | 133 | |
| CUM. ACTUAL | 2 | 20 | 23 | 32 | 40 | 43 | 60 | 63 | | | | | | | |
| CUM. EARNED | 7 | 14 | 23 | 39 | 50 | 56 | 63 | 81 | | | | | | | |

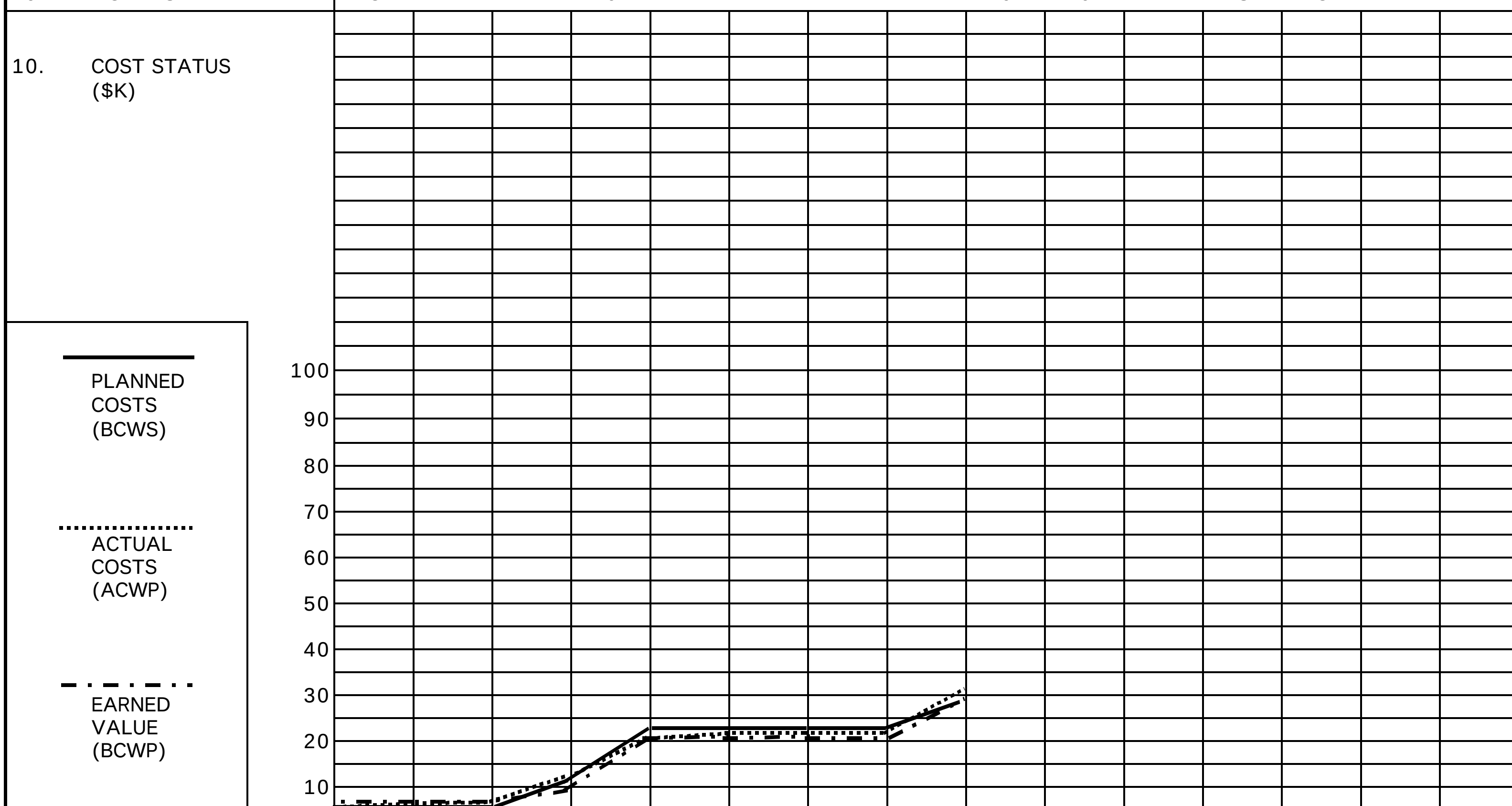
11. REMARKS

Total/Planned Cost reflects reduction in funds received due to FAC.

| | | |
|---|---|---|
| 1. CONTRACT REPORTING ELEMENT<br>**HSSI - 5. Modeling and Microstuctural Analysis** | 2. REPORTING PERIOD<br>**04/23/01 - 05/27/01** | 3. JCN NO.<br>**W6953** |
| 4. CONTRACTOR (NAME AND ADDRESS)<br>**OAK RIDGE NATIONAL LABORATORY**<br>**P. O. BOX 2008**<br>**OAK RIDGE, TN 37831** | 5. CONTRACT PERIOD<br>**FY 1998 - 2003**<br>7. NRC B&R NO.<br>**860 15 21 20 05** | 6. ACTIVITY NUMBER<br>**W41 W5 85 3W 1**<br>8. DOE B&R NO.<br>**40 10 01 06** |

9. MONTHS: O N D J F M A M J J A S O N D

10. COST STATUS ($K)




COST PLAN DATES

04/20/01

PLANNED COSTS FOR ELEMENT ($K)

58

ELEMENT COSTS FOR PRIOR FYS ($K)

2

| ACCRUED COSTS ($K) | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PLANNED | 0 | 0 | 12 | 11 | 0 | 0 | 0 | 6 | 10 | 5 | 4 | 6 | 4 | 0 | |
| ACTUAL | 0 | 0 | 12 | 9 | 1 | 0 | 0 | 9 | | | | | | | |
| EARNED | 0 | 0 | 8 | 13 | 0 | 0 | 0 | 8 | | | | | | | |
| CUM. PLANNED | 0 | 0 | 12 | 23 | 23 | 23 | 23 | 29 | 39 | 44 | 48 | 54 | 58 | 58 | |
| CUM. ACTUAL | 0 | 0 | 12 | 21 | 22 | 22 | 22 | 31 | | | | | | | |
| CUM. EARNED | 0 | 0 | 8 | 21 | 21 | 21 | 21 | 29 | | | | | | | |

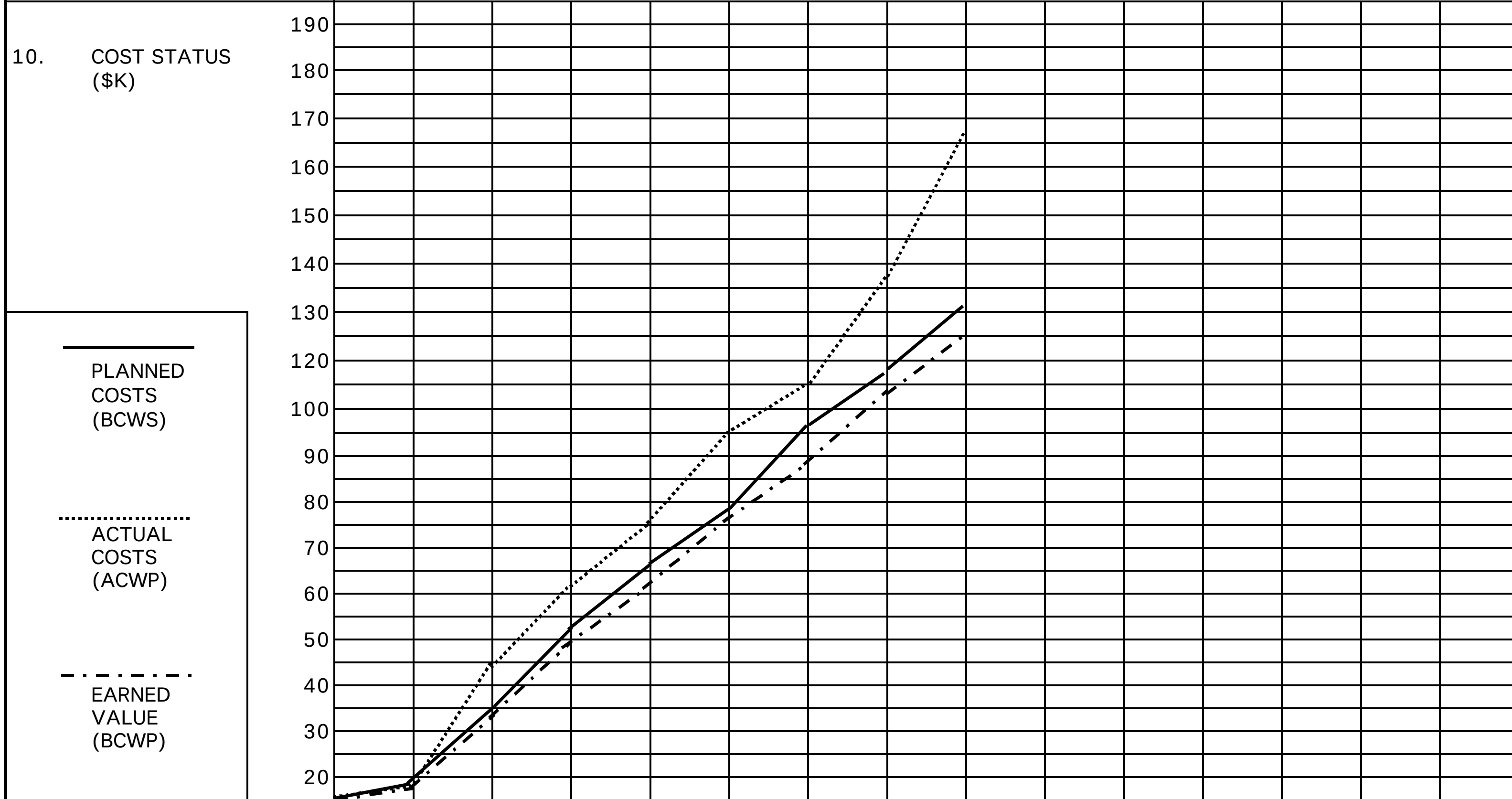
11. REMARKS

Total/Planned Cost reflects reduction in funds received due to FAC.

| | | | |
|---|---|---|---|
| 1. CONTRACT REPORTING ELEMENT<br>**HSSI - 6. Irradiation Coordination** | | 2. REPORTING PERIOD<br>**04/23/01 - 05/27/01** | 3. JCN NO.<br>**W6953** |
| 4. CONTRACTOR (NAME AND ADDRESS)<br>**OAK RIDGE NATIONAL LABORATORY**<br>**P. O. BOX 2008**<br>**OAK RIDGE, TN 37831** | | 5. CONTRACT PERIOD<br>**FY 1998 - 2003** | 6. ACTIVITY NUMBER<br>**W41 W5 85 3W 1** |
| | | 7. NRC B&R NO.<br>**860 15 21 20 05** | 8. DOE B&R NO.<br>**40 10 01 06** |

9. MONTHS: O N D J F M A M J J A S O N D

10. COST STATUS ($K)




COST PLAN DATES

04/20/01

PLANNED COSTS FOR ELEMENT ($K)

208

ELEMENT COSTS FOR PRIOR FYS ($K)

38

| ACCRUED COSTS ($K) | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PLANNED | 19 | 16 | 16 | 15 | 13 | 18 | 20 | 14 | 12 | 12 | 8 | 15 | 16 | 14 | |
| ACTUAL | 19 | 26 | 16 | 14 | 20 | 15 | 28 | 29 | | | | | | | |
| EARNED | 19 | 16 | 14 | 12 | 15 | 11 | 20 | 18 | | | | | | | |
| CUM. PLANNED | 19 | 35 | 51 | 66 | 79 | 97 | 117 | 131 | 143 | 155 | 163 | 178 | 194 | 208 | |
| CUM. ACTUAL | 19 | 45 | 61 | 75 | 95 | 110 | 138 | 167 | | | | | | | |
| CUM. EARNED | 19 | 35 | 49 | 61 | 76 | 87 | 107 | 125 | | | | | | | |

11. REMARKS

Total/Planned Cost reflects reduction in funds received due to FAC.

| | | | |
|---|---|---|---|
| 1. CONTRACT REPORTING ELEMENT<br>**HSSI - 7. Embrittlement DB & Dosimetry Evaluation** | 2. REPORTING PERIOD<br>**04/23/01 - 05/27/01** | 3. JCN NO.<br>**W6953** |
| 4. CONTRACTOR (NAME AND ADDRESS)<br>**OAK RIDGE NATIONAL LABORATORY**<br>**P. O. BOX 2008**<br>**OAK RIDGE, TN 37831** | 5. CONTRACT PERIOD<br>**FY 1998 - 2003**<br>7. NRC B&R NO.<br>**860 15 21 20 05** | 6. ACTIVITY NUMBER<br>**W41 W5 85 3W 1**<br>8. DOE B&R NO.<br>**40 10 01 06** |

9. MONTHS: O N D J F M A M J J A S O N D

10. COST STATUS ($K)

Legend: PLANNED COSTS (BCWS); ACTUAL COSTS (ACWP); EARNED VALUE (BCWP)

Chart scale: 100, 90, 80, 70, 60, 50, 40, 30, 20, 10

COST PLAN DATES: 04/20/01

PLANNED COSTS FOR ELEMENT ($K): 0

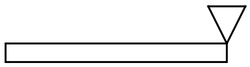
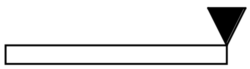
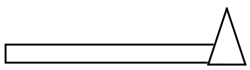
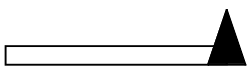
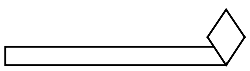
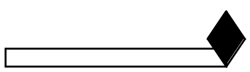
ELEMENT COSTS FOR PRIOR FYS ($K): 0

| ACCRUED COSTS ($K) | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PLANNED | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | |
| ACTUAL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | |
| EARNED | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | |
| CUM. PLANNED | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | |
| CUM. ACTUAL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | |
| CUM. EARNED | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | |

11. REMARKS

Total/Planned Cost reflects reduction in funds received due to FAC. **This task is now part of Task 5.**

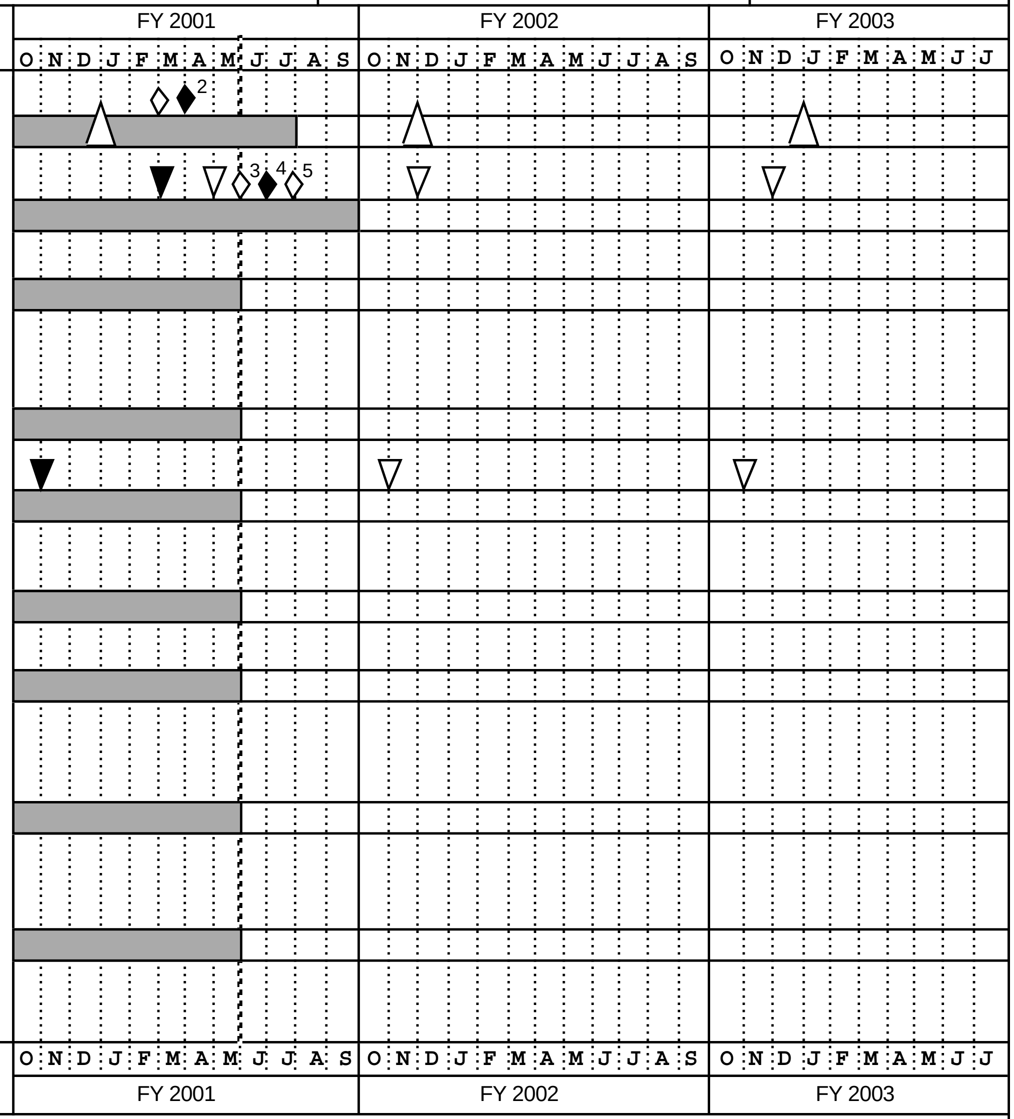
Milestone Symbology

| Symbol | Meaning |
|---|---|
|  | Intermediate milestone planned |
|  | Intermediate milestone completed |
|  | Major milestone planned |
|  | Major milestone completed |
|  n | Rescheduled milestone planned |
|  n | Rescheduled milestone completed |

n = number of calendar-year month in which milestone was rescheduled

| | | |
|---|---|---|
| 1. CONTRACT REPORTING ELEMENT<br>**HSSI - 1. Program Management** | 2. REPORTING PERIOD<br>**04/23/01 - 05/27/01** | 3. JCN NO.<br>**W6953** |
| 4. CONTRACTOR (NAME AND ADDRESS)<br>**OAK RIDGE NATIONAL LABORATORY**<br>**P. O. BOX 2008**<br>**OAK RIDGE, TN 37831** | 5. CONTRACT PERIOD<br>**FY 1998-2003** | 6. ACTIVITY NUMBER<br>**41 W6 95 3W 1** |
| | 7. NRC B&R NO.<br>**860 15 21 20 05** | 8. DOE B&R NO.<br>**40 10 01 06** |

| 9. MILESTONE IDEN. NO. | 10. MILESTONE DESCRIPTION |
|---|---|
| 1.1.A. | Issue Project & Budget Proposal |
| 1.1.B. | Select and Administer Subcontracts |
| 1.2.A. | Issue Earned Value Based Monthly Management Reports (by the end of subsequent month) |
| 1.2.B. | Ensure QA Requirements are met |
| 1.3.A. | Participate in NRC-Sponsored Meeting and Discussions |
| 1.3.B. | Coordinate NRC and Internal Reviews |
| 1.3.C. | Coordinate Domestic and Foreign Information Exchange as Approved by NRC-RES |
| 1.3.D. | Coordinate HSSI Letter and NUREG Reports |
| 1.3.E. | Document the Historical Information Generated by the Old HSSI Program |

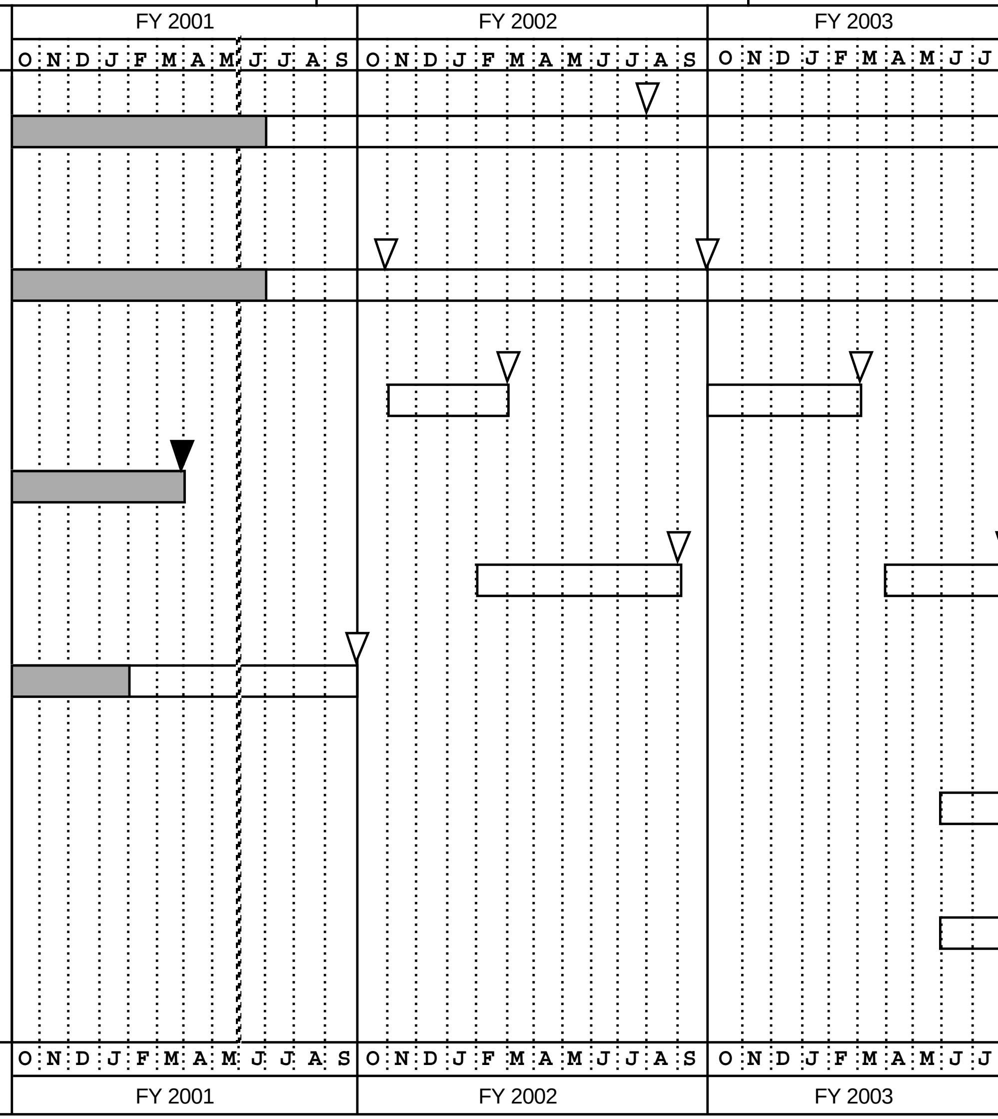



11. REMARKS

| 1. CONTRACT REPORTING ELEMENT | 2. REPORTING PERIOD | 3. JCN NO. |
|---|---|---|
| **HSSI - 2. Fracture Toughness Transition & MC Methodology** | **04/23/01 - 05/27/01** | **W6953** |

| 4. CONTRACTOR (NAME AND ADDRESS) | 5. CONTRACT PERIOD | 6. ACTIVITY NUMBER |
|---|---|---|
| **OAK RIDGE NATIONAL LABORATORY**<br>**P. O. BOX 2008**<br>**OAK RIDGE, TN 37831** | **FY 1998-2003** | **41 W6 95 3W 1** |
| | 7. NRC B&R NO.<br>**860 15 21 20 05** | 8. DOE B&R NO.<br>**40 10 01 06** |

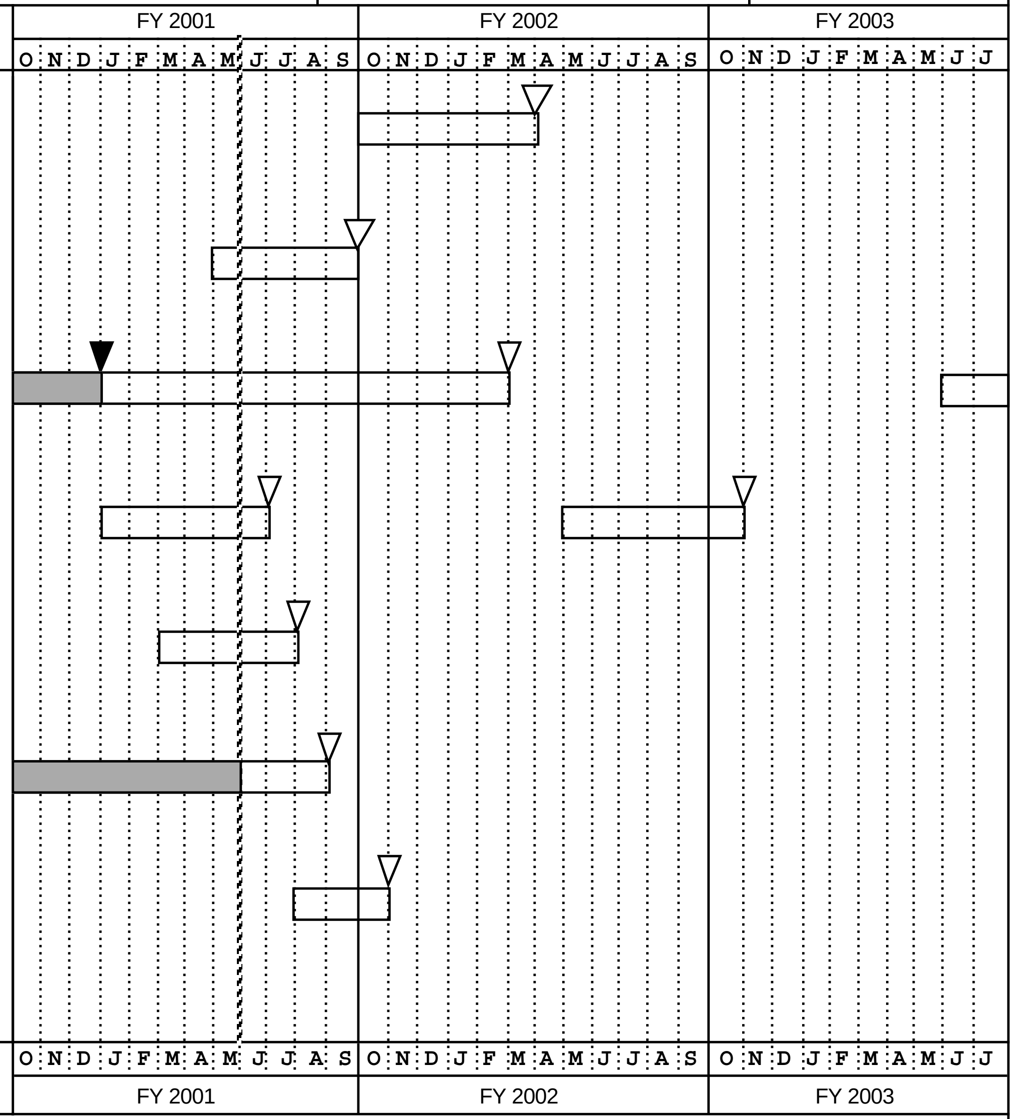
| 9. MILESTONE IDEN. NO. | 10. MILESTONE DESCRIPTION |
|---|---|
| 2.1.A. | Continue to accumulate data on Comparison of CVN and Fracture Tougness Shifts |
| 2.2.A. | IIrradiate Midland and Hi-Ni Speciments |
| 2.2.B. | Receive Specimens |
| 2.2.C. | Test Unirradiated & Irradiated KSØ1 for Master Curve |
| 2.2.D. | Test Unirradiated & Irradiated Hi-Ni Midland Weld Specimens |
| 2.2.E. | Draft Letter and NUREG Report for KSØ1 |
| 2.2.F. | Draft Letter and NUREG Report for Midland Weld |
| 2.2.G. | Draft Letter and NUREG Report for High Ni |




11. REMARKS

| | | |
|---|---|---|
| 1. CONTRACT REPORTING ELEMENT<br>**HSSI - 2. Fracture Toughness Transition & MC Methodology** | 2. REPORTING PERIOD<br>**04/23/01 - 05/27/01** | 3. JCN NO.<br>**W6953** |
| 4. CONTRACTOR (NAME AND ADDRESS)<br>**OAK RIDGE NATIONAL LABORATORY**<br>**P. O. BOX 2008**<br>**OAK RIDGE, TN 37831** | 5. CONTRACT PERIOD<br>**FY 1998-2003**<br>7. NRC B&R NO.<br>**860 15 21 20 05** | 6. ACTIVITY NUMBER<br>**41 W6 95 3W 1**<br>8. DOE B&R NO.<br>**40 10 01 06** |

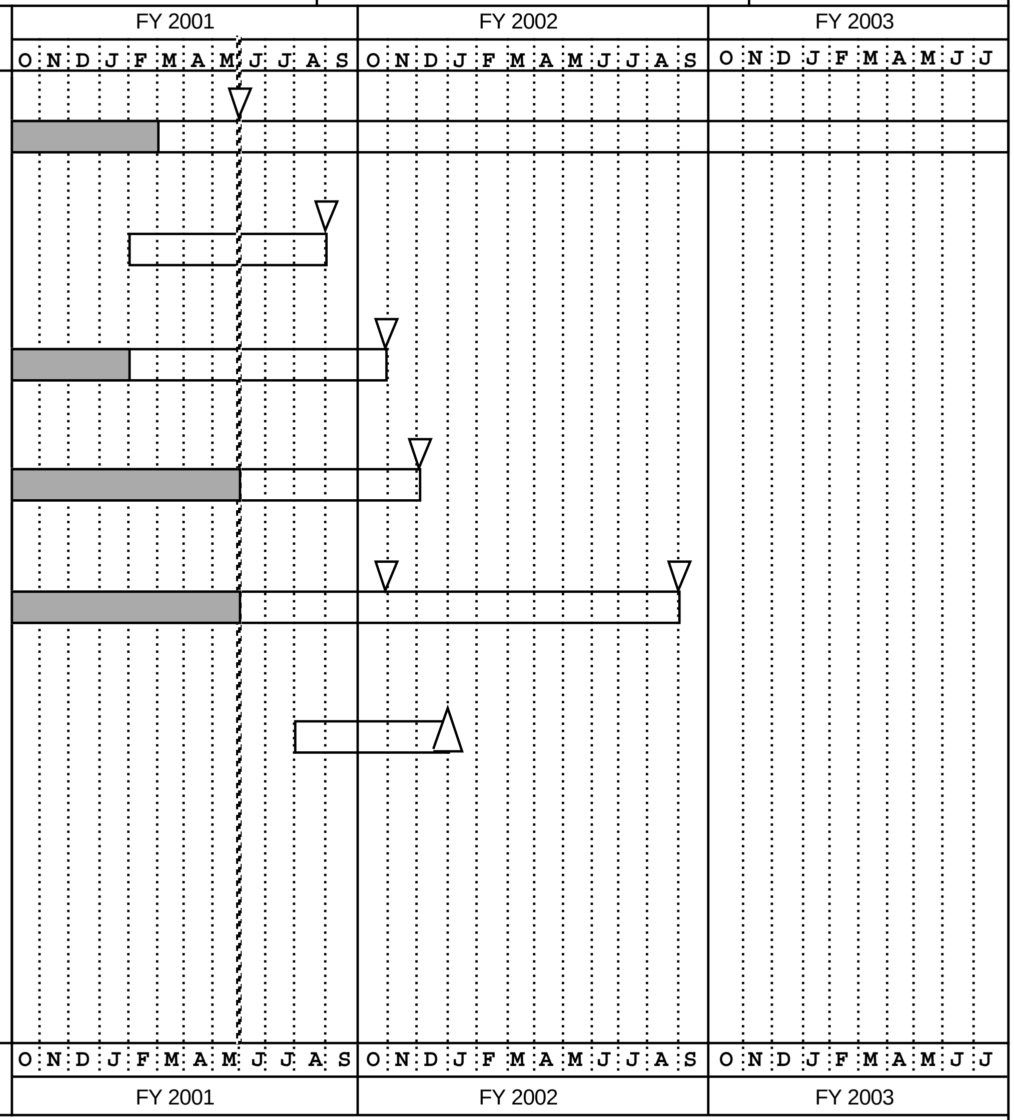
| 9. MILESTONE IDEN. NO. | 10. MILESTONE DESCRIPTION |
|---|---|
| 2.3.A. | Develop Testing Plan for Dynamic Fracture Toughness Effects on MC |
| 2.4.A. | Letter Report on Statistical Representation of Valid $K_{JC}$ Data |
| 2.5.A. | Measure Activity and Prepare Report |
| 2.5.B. | Calculate Fluence and Prepare Report |
| 2.6.A. | Complete Testing of 0.5C(T) |
| 2.6.B. | Fractography Specimens |
| 2.6.C. | Final IGF Report |




11. REMARKS

| | | |
|---|---|---|
| 1. CONTRACT REPORTING ELEMENT<br>**HSSI - 2. Fracture Toughness Transition & MC Methodology** | 2. REPORTING PERIOD<br>**04/23/01 - 05/27/01** | 3. JCN NO.<br>**W6953** |
| 4. CONTRACTOR (NAME AND ADDRESS)<br>**OAK RIDGE NATIONAL LABORATORY**<br>**P. O. BOX 2008**<br>**OAK RIDGE, TN 37831** | 5. CONTRACT PERIOD<br>**FY 1998-2003** | 6. ACTIVITY NUMBER<br>**41 W6 95 3W 1** |
| | 7. NRC B&R NO.<br>**860 15 21 20 05** | 8. DOE B&R NO.<br>**40 10 01 06** |

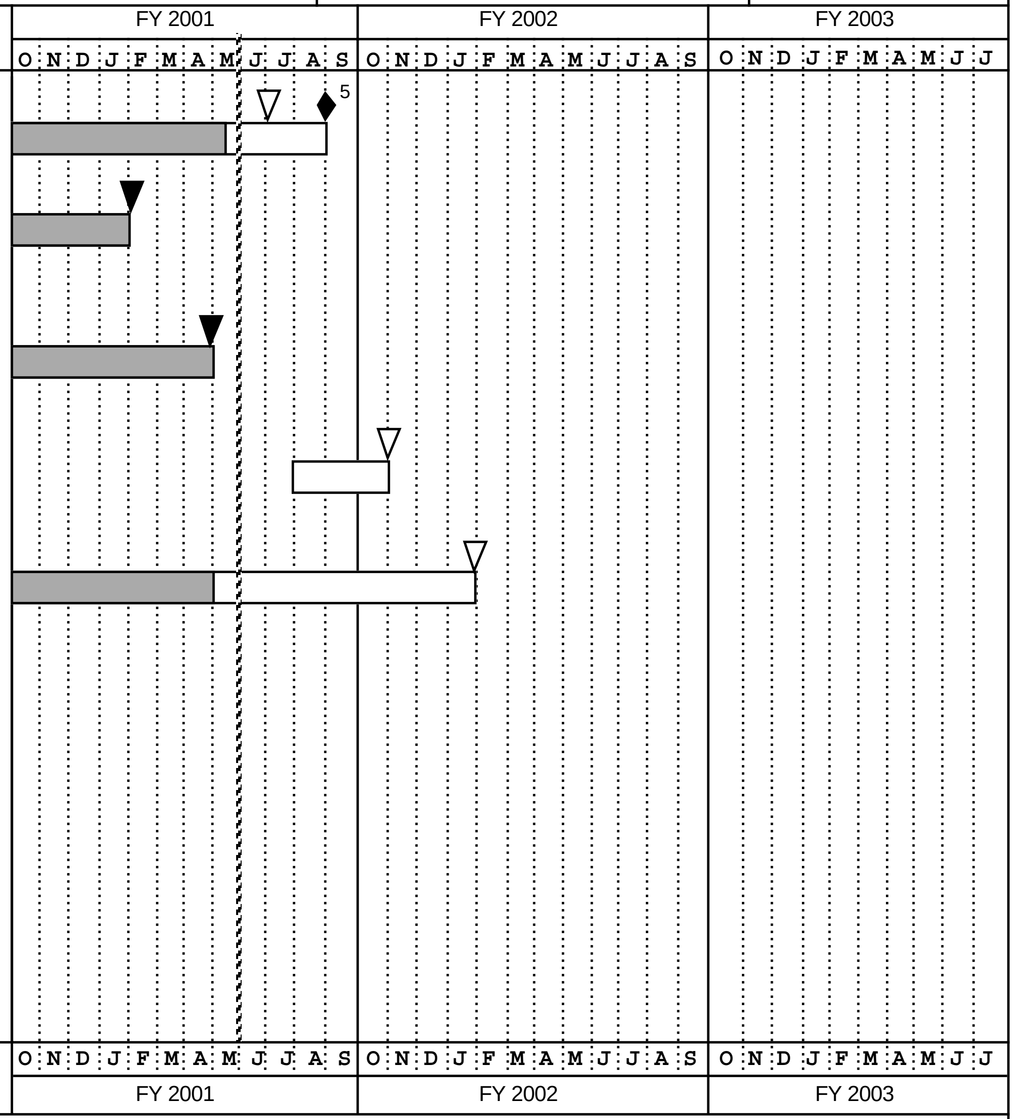
| 9. MILESTONE IDEN. NO. | 10. MILESTONE DESCRIPTION |
|---|---|
| 2.7.A. | Complete Testing of Subsize Specimens |
| 2.7.B. | Testing of JRQ Plate |
| 2.7.C. | Complete Letter Report on Results of Subsize Specimen Fracture Toughness Tests |
| 2.8.A.1 | Complete Assembly and Compilation for Irradiated Materials for Surrogate Materials DB |
| 2.8.A.2 | Complete Statistical Analysis of Data Base for Irradiated Materials |
| 2.8.B. | Submit NUREG Report |




11. REMARKS

| 1. CONTRACT REPORTING ELEMENT | 2. REPORTING PERIOD | 3. JCN NO. |
|---|---|---|
| **HSSI - 3. Irradiation Embrittlement of RPV Steel** | **04/23/01 - 05/27/01** | **W6953** |
| 4. CONTRACTOR (NAME AND ADDRESS) | 5. CONTRACT PERIOD | 6. ACTIVITY NUMBER |
| **OAK RIDGE NATIONAL LABORATORY**<br>**P. O. BOX 2008**<br>**OAK RIDGE, TN 37831** | **FY 1998-2003** | **41 W6 95 3W 1** |
| | 7. NRC B&R NO. | 8. DOE B&R NO. |
| | **860 15 21 20 05** | **40 10 01 06** |

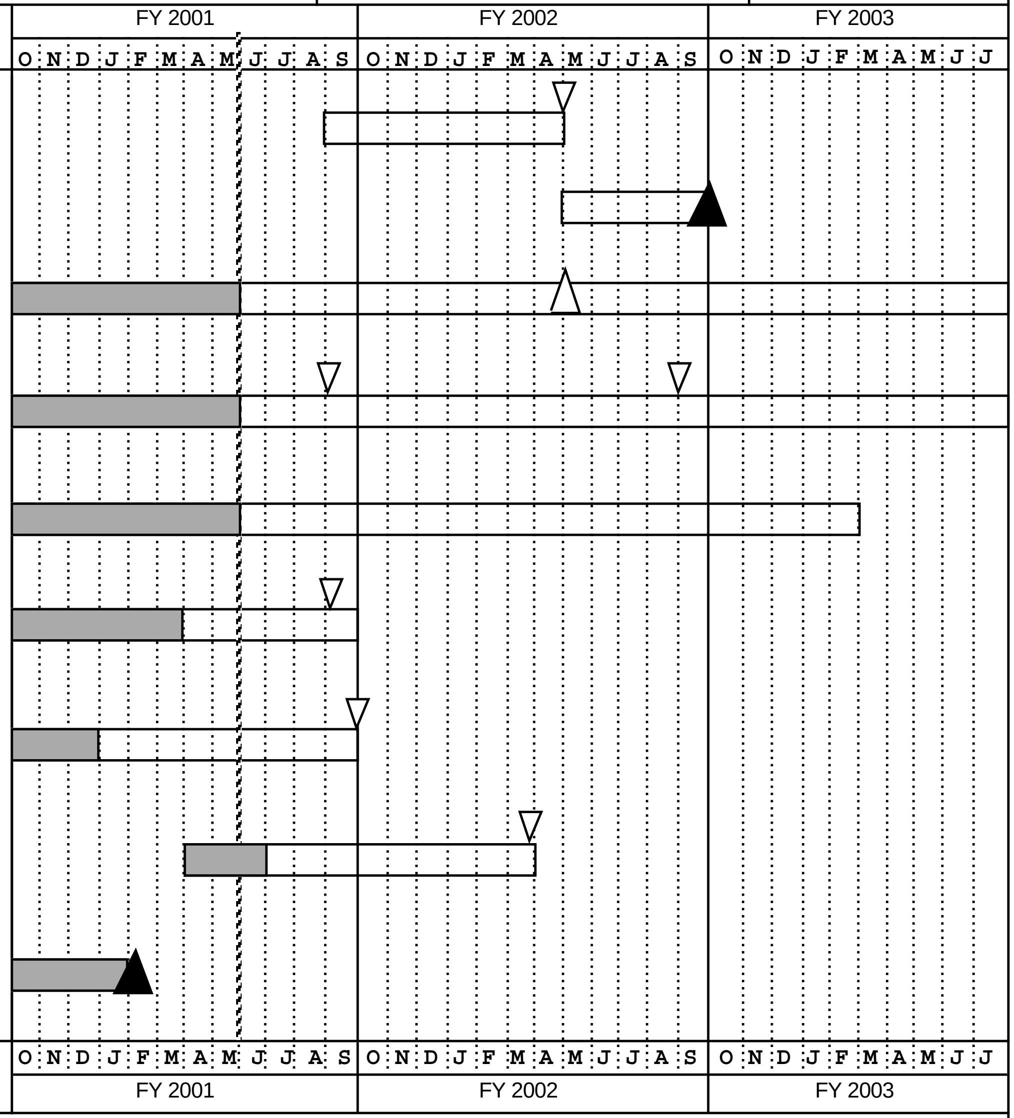
| 9. MILESTONE IDEN. NO. | 10. MILESTONE DESCRIPTION |
|---|---|
| 3.1.G. | HAZ NUREG Report |
| 3.1.H. | Evaluate Need for Additional Specimen Testing |
| 3.2.A. | Complete JRQ Charpy Testing |
| 3.2.B. | Complete PCVN Testing |
| 3.2.C. | Complete Draft NUREG Report on IAR Results of JRQ |




11. REMARKS

| | | |
|---|---|---|
| 1. CONTRACT REPORTING ELEMENT<br>**HSSI - 4. Validation of Irradiated and Aged Materials** | 2. REPORTING PERIOD<br>**04/23/01 - 05/27/01** | 3. JCN NO.<br>**W6953** |
| 4. CONTRACTOR (NAME AND ADDRESS)<br>**OAK RIDGE NATIONAL LABORATORY**<br>**P. O. BOX 2008**<br>**OAK RIDGE, TN 37831** | 5. CONTRACT PERIOD<br>**FY 1998-2003**<br>7. NRC B&R NO.<br>**860 15 21 20 05** | 6. ACTIVITY NUMBER<br>**41 W6 95 3W 1**<br>8. DOE B&R NO.<br>**40 10 01 06** |

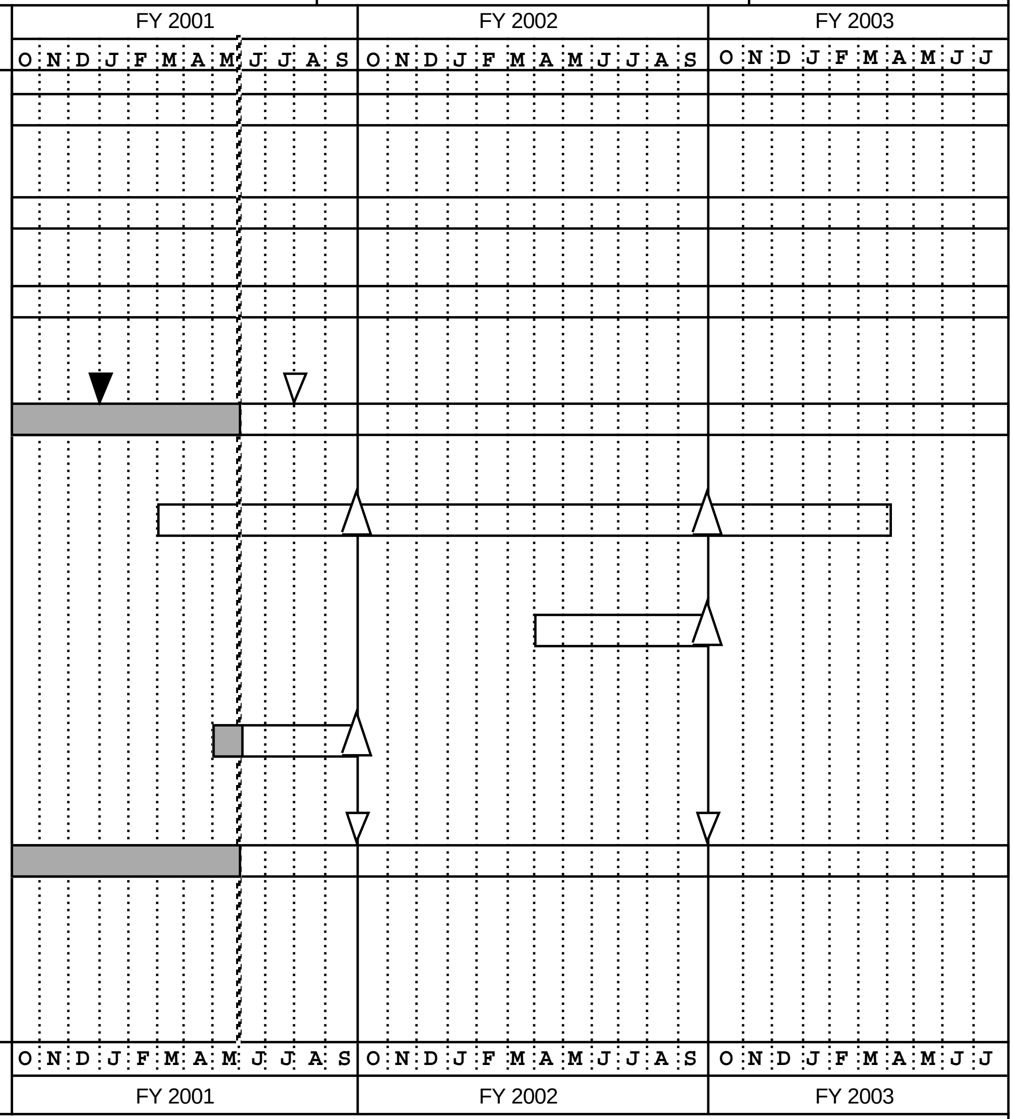
| 9. MILESTONE IDEN. NO. | 10. MILESTONE DESCRIPTION |
|---|---|
| 4.1.A. | Toughness Tests on SS Cladding |
| 4.1.B. | Letter Report |
| 4.2.A. | Participate in Periodic Meetings of IGRDM |
| 4.2.B. | Complete Progress Reports of Collaboration Activities |
| 4.3.A. | Letter Report on PWHT and Copper |
| 4.3.B. | Complete Letter Report Regarding RPV Materials Available for Irradiation Study |
| 4.3.C. | Complete Crack Arrest NUREG Report |
| 4.3.D. | Complete Letter Report on IA of 73W |
| 4.3.E. | NUREG Report on JPDR Attenuation Effect |




11. REMARKS

| | | |
|---|---|---|
| 1. CONTRACT REPORTING ELEMENT<br>**HSSI - 5. Modeling & Microstructural Analysis** | 2. REPORTING PERIOD<br>**04/23/01 - 05/27/01** | 3. JCN NO.<br>**W6953** |
| 4. CONTRACTOR (NAME AND ADDRESS)<br>**OAK RIDGE NATIONAL LABORATORY**<br>**P. O. BOX 2008**<br>**OAK RIDGE, TN 37831** | 5. CONTRACT PERIOD<br>**FY 1998-2003**<br>7. NRC B&R NO.<br>**860 15 21 20 05** | 6. ACTIVITY NUMBER<br>**41 W6 95 3W 1**<br>8. DOE B&R NO.<br>**40 10 01 06** |

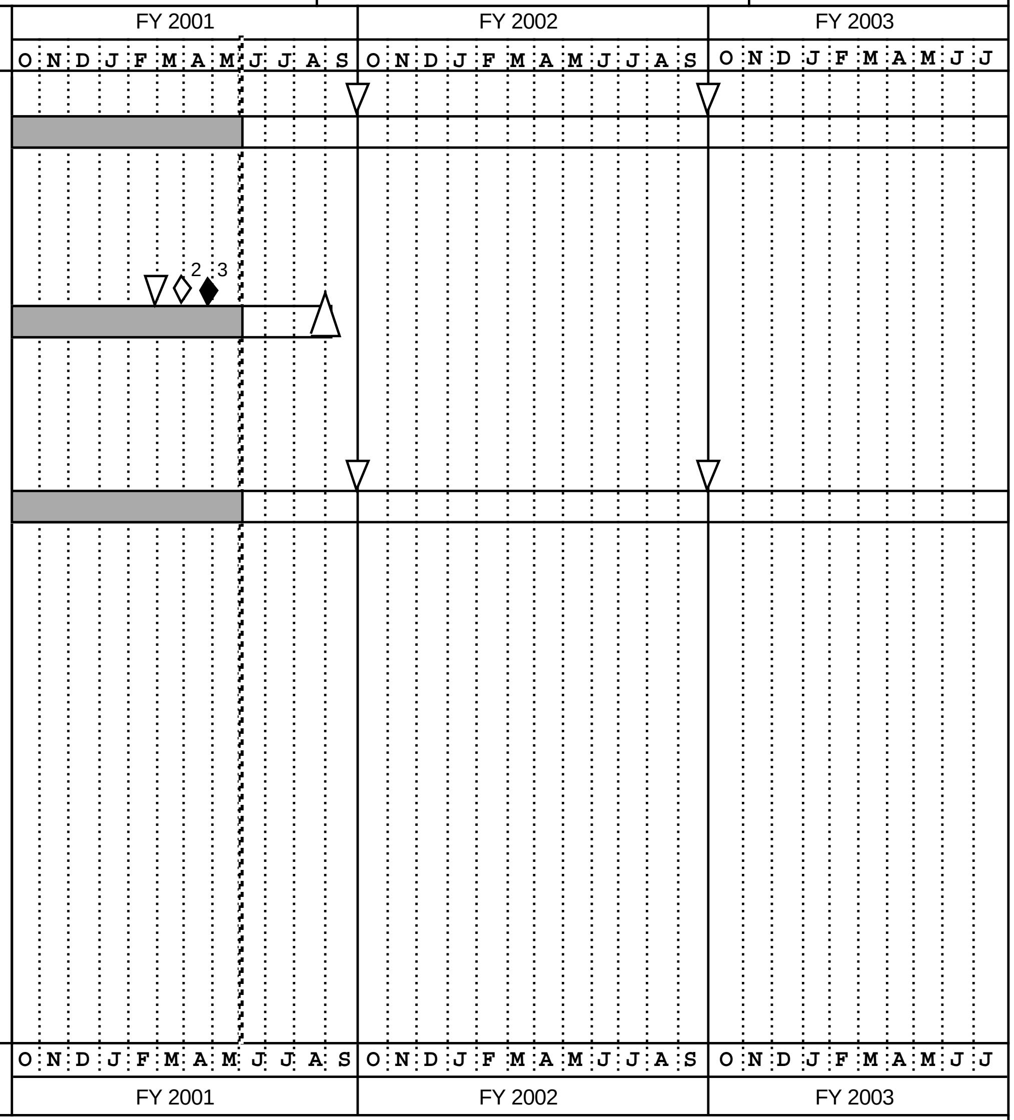
| 9. MILESTONE IDEN. NO. | 10. MILESTONE DESCRIPTION |
|---|---|
| 5.1.A. | Development and Predictive use of Embrittlement Model |
| 5.1.B. | Model Validation and Data Analysis |
| 5.2.A. | Coordinate and Analyze APFIM/SANS/FEGSTEM Round Robin Experiment |
| 5.2.B. | APFIM Characterization |
| 5.3.A.1 | Evaluate and Input Surveillance Reports into Embrittlement Database |
| 5.3.A.2 | Complete Update 12 |
| 5.3.B. | Database Modeling Studies |
| 5.4. | Administration of Task Activities |




11. REMARKS

| 1. CONTRACT REPORTING ELEMENT | 2. REPORTING PERIOD | 3. JCN NO. |
|---|---|---|
| **HSSI - 6. Irradiation Coordination** | **04/23/01 - 05/27/01** | **W6953** |
| 4. CONTRACTOR (NAME AND ADDRESS) | 5. CONTRACT PERIOD | 6. ACTIVITY NUMBER |
| **OAK RIDGE NATIONAL LABORATORY**<br>**P. O. BOX 2008**<br>**OAK RIDGE, TN 37831** | **FY 1998-2003** | **41 W6 95 3W 1** |
| | 7. NRC B&R NO. | 8. DOE B&R NO. |
| | **860 15 21 20 05** | **40 10 01 06** |

| 9. MILESTONE IDEN. NO. | 10. MILESTONE DESCRIPTION |
|---|---|
| 6.1.A. | Coordinate the Operation, Data Collection, and Maintenance of the HSSI IAR Facility |
| 6.1.B. | Comprehensive Report on Reusable Irradiation Facilities and Report on Facility Options |
| 6.2.A. | Coordinate the Operation, Data Collection, and Maintenance of the UCSB Irrad. Facility |




11. REMARKS