ORNL/HSSI (W6953)/MLSR-2001/10

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

Monthly
Letter Status
Report

July 2001

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HEAVY-SECTION STEEL IRRADIATION

PROGRAM

JCN W6953

MONTHLY LETTER STATUS REPORT

FOR

JULY 2001

Submitted by

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Submitted to
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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, Manager
Heavy-Section Steel Irradiation

MONTHLY LETTER STATUS REPORT
July 2001

Job Code Number:	**W6953**
Project Title:	**Heavy-Section Steel Irradiation Program**
Period of Performance:	**4/1/98 to 4/1/03**
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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 1.3.B) Participated in the ASTM E-10 and E-10.02 committee meetings. The revision of the embrittlement equation and the terms that should be included were discussed at length and a decision was made to ballot a version of that equation.

(Milestone 1.3.C) Discussions continued with the NRC concerning the acquisition of RPV trepans from the San Onofre Unit 1 (SONGS-1) Reactor. Funding was received during this reporting period (see Task 4.4) to make contacts and express interest with Southern California Edison, the owner of SONGS-1, this summer and to provide a preliminary estimate of the potential problems that could be encountered. This effort, which would permit the evaluation of through-thickness attenuation of irradiation embrittlement of service irradiated RPVs, would be coordinated with EPRI. A letter report will be prepared that describes the progress and status of that effort.

<u>Task 2: Fracture-Toughness Transition Issue and Master-Curve Methodology</u> - (M. A. Sokolov)

Fracture-toughness transition and Master Curve (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.

<u>Subtask 2.1: Fracture-Toughness Transition-Temperature Shifts</u> (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, 2000.

As they become available, additional data are added to the database. Recently, some additional data became available, 5 data sets for weld metal and 24 data sets for base metal. These data have not been analyzed in the same fashion as those in the NUREG, and are considered very preliminary. Nonetheless, they were added to the database and a preliminary analysis was performed.

The results showed a slight change from the comparison for base metals reported in the above published NUREG, with the preliminary analysis showing a ratio of fracture toughness to Charpy impact shift of about 1.10, compared with the previous result of about 1.16. For weld metal, the revised ratio is about the same as the previous ratio of 1.0. All the data taken together give a ratio of about 1.04. These preliminary results may be incorporated into the FAVOR code for the pressurized thermal shock reanalysis. More detailed analysis of the new data will be performed for qualification and a new database will be assembled in preparation for a new overall analysis.

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 ~0.8×10^{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 been tested. Photographs of the broken 0.5T specimens have also been taken and crack length measurements have been completed. Additional scanning electron fractography of the 0.5T specimens has been performed, and analysis of all the data has also been completed. The results are now being evaluated relative to the shape of the master curve.

(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 due to funding limitations.

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 during the previous month and work has begun on this task. The initial efforts are focused on background and defining of objectives.

Subtask 2.5 (formerly 2.10): Dosimetry and Fluence Analysis of the IAR Irradiation Capsules (C. A. Baldwin, I. Remec, and 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 will be initiated this fall with availability of staff. In addition, radiometric dosimeter sets will be prepared for more accurate characterization of the fluence as specimens are shuffled with the irradiation facility.

(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 T C(T) specimens have been fabricated and testing is underway.

(Milestone 2.6.A) The five remaining 0.5T compact specimens to be tested at a higher temperature than the previously tested specimens have been fatigue precracked and test temperatures have been selected. Following testing, a multitemperature master curve analysis will be conducted, scanning electron fractography will be conducted, and the final letter report will be published.

(Milestone 2.6.B) Additional scanning electron fractography has been performed to evaluate the fracture mode of the specimens previously tested at the highest temperatures (room temperature and above). The results have confirmed the failure by intergranular fracture and has also confirmed 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.

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

Subtask 2.7: Sub-sized Specimens (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.

Subtask 2.8: Quantification of Surrogate Materials for use in a Statistics-Based Fracture Toughness Assessment (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 is 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. A different methodology is being evaluated for potential application to this issue. The methodology involves a combination of non-linear estimators including domain models, neural networks, vector space methods, and nearest neighbor regressions. The evaluation will examine in a very preliminary manner, whether the methodology appears applicable to the issue and whether it can be implemented in a relatively straightforward manner. This effort began in July and will continue into August.

(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 previously, 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 previously proposed. This would 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.

Subtask 3.2 (formerly 3.3): Evaluation of Reirradiated JRQ Specimens (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 was initiated in March. A total of 46 Charpy V-notch impact specimens were tested and the results were presented in the previous progress report.

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). The previous progress report graphically showed the results.

Task 4: Validation of Irradiated and Aged Materials (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.

Subtask 4.1: (formerly 4.3) Toughness Changes in Aged Stainless Steel Welds (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.

Subtask 4.2: (formerly 4.4) Foreign Interactions (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 middle part of May. R. K. Nanstad and M. A. Sokolov have submitted and had accepted abstracts for presentation at the IAEA Specialists' Meeting on Master Curve Fracture Toughness, to be held in Prague, Czech Republic in September 2001.

Subtask 4.3: (formerly 4.5) Technical Assistance (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, including the as-welded 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 has been 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 made at the IAEA Specialists' Meeting on Radiation Embrittlement and Mitigation in Gloucester, U.K., 14-17 May 2001. Because of hot cell scheduling issues, testing of the irradiated subsize Charpy specimens has not been conducted. A letter report will be prepared following completion of all testing and evaluation. A paper has been submitted 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. R. K. Nanstad will attend the meeting and present the paper.

(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 December 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 4×10^{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.

<u>Subtask 4.4: Obtaining RPV material for SONGS-1</u> (R. K. Nanstad, R. E. Stoller, and T. M. Rosseel)

The purpose of this subtask is to obtain Southern California Edison's, the owner of San Onofre Unit 1 (SONGS-1) Reactor, consent and assistance in obtaining trepans from the SONGS-1 RPV and to provide a preliminary estimate of the potential problems that could be encountered during this operation. This effort, which would permit the evaluation of through-thickness attenuation of irradiation embrittlement of service irradiated RPVs, will be coordinated with EPRI. A letter report will also be prepared that describes the progress and status of that effort.

(Milestone 4.4.A) Funding was received during this reporting period to make contacts and express interest with Southern California Edison this summer and to provide a preliminary estimate of the potential problems that could be encountered in the process of obtaining RPV trapans.

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) Analysis of atom probe data on five baseline materials continued.

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.

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 DataBase (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 database 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 databases 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 continued.

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

This task provides the support required to supply and co-ordinate 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 continued to operate without incident during this reporting period. Recently, while viewing historical data, the Task Leader noticed that a slight upset in facility temperatures had occurred during off-shift hours. The slight upset lasted less than two minutes, after which, everything returned to normal. The slight upset was also seen in the HSSI-UCSB facilities at FNR. Following discussions with FNR staff and a review of the reactor operator's logbook, it was discovered that a short electrical power outage occurred at the time in question. During the short power outage, the un-interruptible power supply (UPS) for the HSSI-IAR facility performed as designed, which allowed the system to return to normal in less than two minutes. The only reason the slight temperature upset was observed was that the control system called for electrical heater power but was available. Shortly after the momentary electrical power outage everything returned to normal. The lack of problems associated with this brief outage is a testament to the design, modifications, and repairs performed over the last year by the ORNL Instrumentation and Controls personnel.

During this period, the HSSI-IAR facilities were irradiated for the last 4.6 days of reactor half-cycle 460A, 10 days of half-cycle 460B, and the first 7.4 days of half-cycle 461A. In the last 4.6 days of reactor half-cycle 460A the IAR irradiation facilities received a total of 111 EFPH (effective full power hours). During reactor half-cycle 460B, the facilities received a total of 236 EFPH, followed by an additional 177 EFPH during the first 7.4 days of half-cycle 461A. During this reporting period the HSSI-IAR irradiation facilities received a total of 524 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 6865 EFPH. At the end of this reporting period the second group of specimens had been irradiated for a total of 7389 EFPH. The facilities themselves had been in service for a total of 11,293 EFPH

(Milestone 6.1.B) The draft NUREG report on the reusable irradiation facilities is scheduled to be completed in August.

Subtask 6.2: Operate the HSSI/UCSB Irradiation Facility (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 UCSB irradiation facility continued during this reporting period

The HSSI-UCSB irradiation facility continued to operate without incident during this reporting period. Recently, while viewing historical data, the Task Leader noticed that a slight upset in facility temperatures had occurred during off-shift hours. The slight upset lasted less than two minutes, after which, everything returned to normal. The slight upset was also seen in the ORNL facilities at FNR. Following discussions with FNR staff and a review of the reactor operator's logbook, it was discovered that a short electrical power outage occurred at the time in question. During the short power outage, the un-interruptible power supply (UPS) for the HSSI-UCSB facility performed as designed, which allowed the system to return to normal in less than two minutes. The only reason the slight temperature upset was observed was that the control system called for electrical heater power but was available. Shortly after the momentary electrical power outage everything returned to normal. The lack of problems associated with this brief outage is a testament to the design, modifications, and repairs performed over the last year by the ORNL Instrumentation and Controls personnel.

During this period, the HSSI-UCSB facility was irradiated for the last 4.6 days of reactor half-cycle 460A, 10 days of half-cycle 460B, and the first 7.4 days of half-cycle 461A. In the last 4.6 days of reactor half-cycle 460A, the irradiation facility received a total of 111 EFPH (effective full power hours). During reactor half-cycle 460B, the facility received a total of 236 EFPH, followed by an additional 177 EFPH during the first 7.4 days of half-cycle 461A. During this reporting period, the HSSI-UCSB irradiation facility received a total of 524 EFPH.

At the beginning of this reporting period, the HSSI-UCSB facility and original specimen compliment had been irradiated for a total of 18,678 EFPH. At the end of this reporting period, the facility and original specimen compliment had been irradiated for a total of 19,202 EFPH. The latest irradiation plan received from the UCSB experimenters indicated that the final specimens would be removed from the HSSI-UCSB 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 142% 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 DataBase (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 database 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:

R. K. Nanstad, *Report of Foreign Travel to the United Kingdom*, ORNL/FTR-137146, July 30, 2001.

R. K. Nanstad, *Report of Foreign Travel to Bulgaria*, ORNL/FTR-138237, July 26, 2001.

4. PRESENTATIONS, REPORTS, PAPERS, AND PUBLICATIONS:

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:

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: 6/24/01-7/22/01

		Current Month	Fiscal Year to Date	Cumulative Project to date
I.	Direct Staff Effort	6 MM	7.1 MY	36.9 MY
II.	A. Direct Lab Staff Effort ($)			
	Direct Salaries	46,786	700,004	3,715,709
	Materials and Services	495	9,187	385,143
	ADP Support	21	377	2,162
	Subcontracts	743	33,766	396,184
	Travel	776	20,155	136,764
	Indirect Labor Costs	0	0	0
	Other: NRC-PO Tax	4,000	32,000	170,500
	General and Administrative	20,470	295,547	1,674,769
	Total UT-Battelle Costs	73,291	1,091,036	6,481,231
	B. DOE Federal Access Costs	2,199	32,731	32,731
	TOTAL PROJECT COSTS	75,490	1,123,767	6,513,962

Percentage of available cumulative funds costed	89
Percentage of available current FY funds costed	59
Funds Remaining	766,038
Commitments:	167,783
BA Remaining	598,255
BA Remaining Less Projected FAC	575,943

III. Funding Status

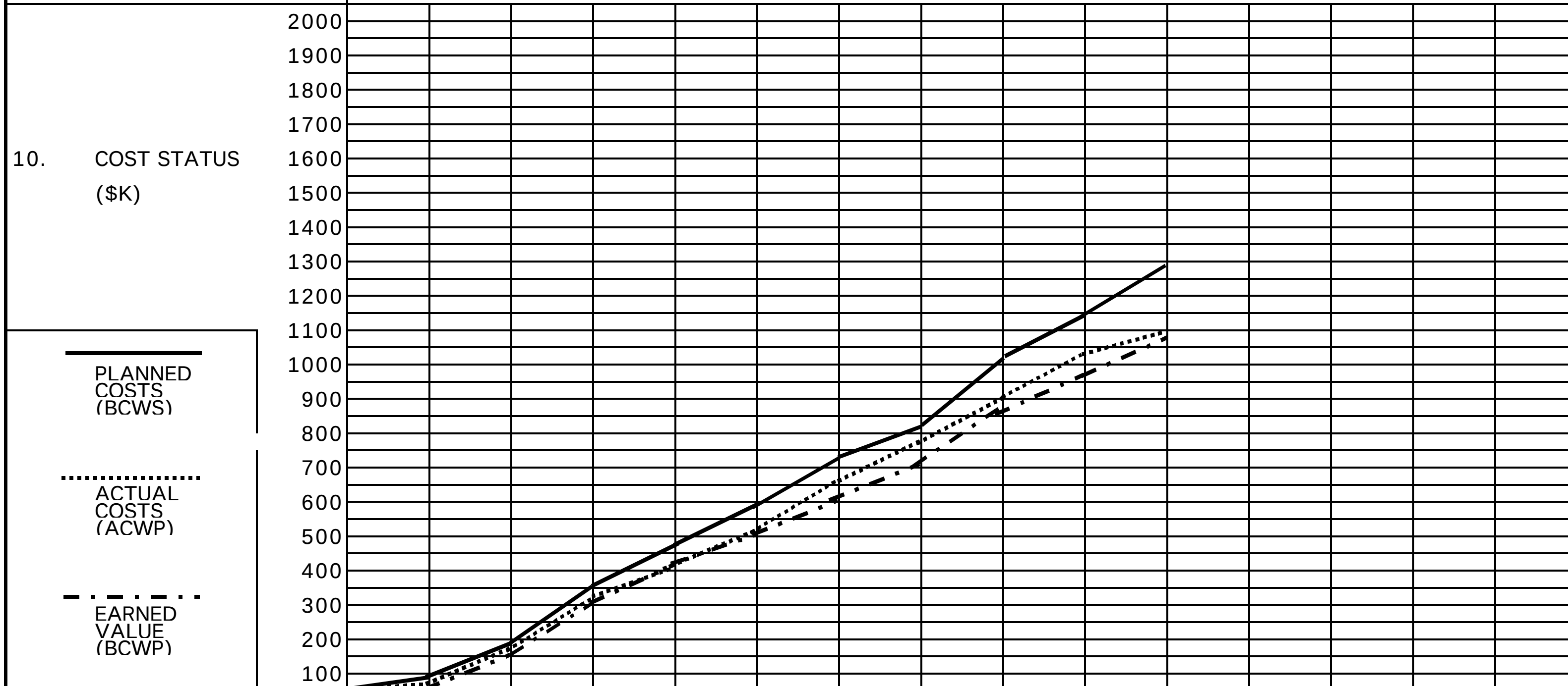
Prior FY Carryover	FY 01 Projected Funding Level	FY 01 Funds Received to Date	FY 01 Funding Balance Needed	Cumulative Amt. Obligated	Cumulative Amt. Costed
279,802	1,610,000	1,610,000	0	7,280,000	6,513,962

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

1. CONTRACT REPORTING ELEMENT **HSSI - Heavy-Section Steel Irradiation Program**	2. REPORTING PERIOD **06/25/01 - 07/22/01**	3. JCN NO. **W6953**
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P. O. BOX 2008** **OAK RIDGE, TN 37831**	5. CONTRACT PERIOD **FY 1998 - 2003**	6. ACTIVITY NUMBER **W41 W5 85 3W 1**
	7. NRC B&R NO. **860 15 21 20 05**	8. DOE B&R NO. **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 07/20/01

PLANNED COSTS FOR ELEMENT ($K) 1760

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	133	98	183	132	142	147	124	109	94	
ACTUAL	77	113	134	85	110	145	113	151	90	73					
EARNED	74	78	156	105	93	110	88	174	89	100					
CUM. PLANNED	98	196	351	470	598	731	829	1012	1144	1286	1433	1557	1666	1760	
CUM. ACTUAL	77	190	324	409	519	664	777	928	1018	1091					
CUM. EARNED	74	152	308	413	506	616	706	880	969	1069					

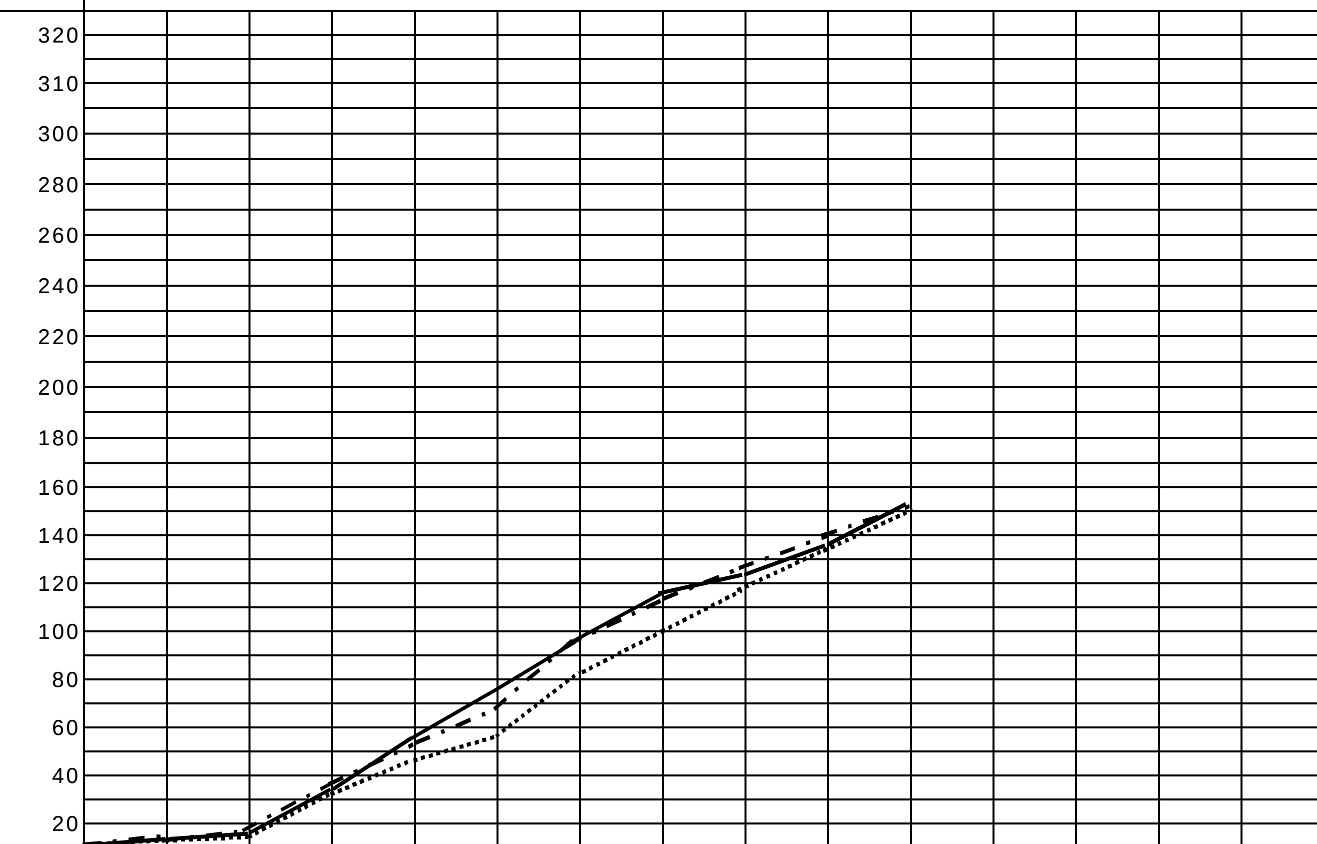
11. REMARKS

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

1. CONTRACT REPORTING ELEMENT **HSSI - 1. Program Management**	2. REPORTING PERIOD **06/25/01 - 07/22/01**	3. JCN NO. **W6953**
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P. O. BOX 2008** **OAK RIDGE, TN 37831**	5. CONTRACT PERIOD **FY 1998 - 2003** 7. NRC B&R NO. **860 15 21 20 05**	6. ACTIVITY NUMBER **W41 W5 85 3W 1** 8. DOE B&R NO. **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

07/20/01

PLANNED COSTS FOR ELEMENT ($K)

219

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	17	15	20	17	14	
ACTUAL	4	10	20	11	10	26	19	18	17	15					
EARNED	5	9	20	17	16	31	14	13	14	14					
CUM. PLANNED	4	14	34	54	76	95	108	121	136	153	168	188	205	219	
CUM. ACTUAL	4	14	34	45	55	81	100	118	135	150					
CUM. EARNED	5	14	34	51	67	98	112	125	139	153					

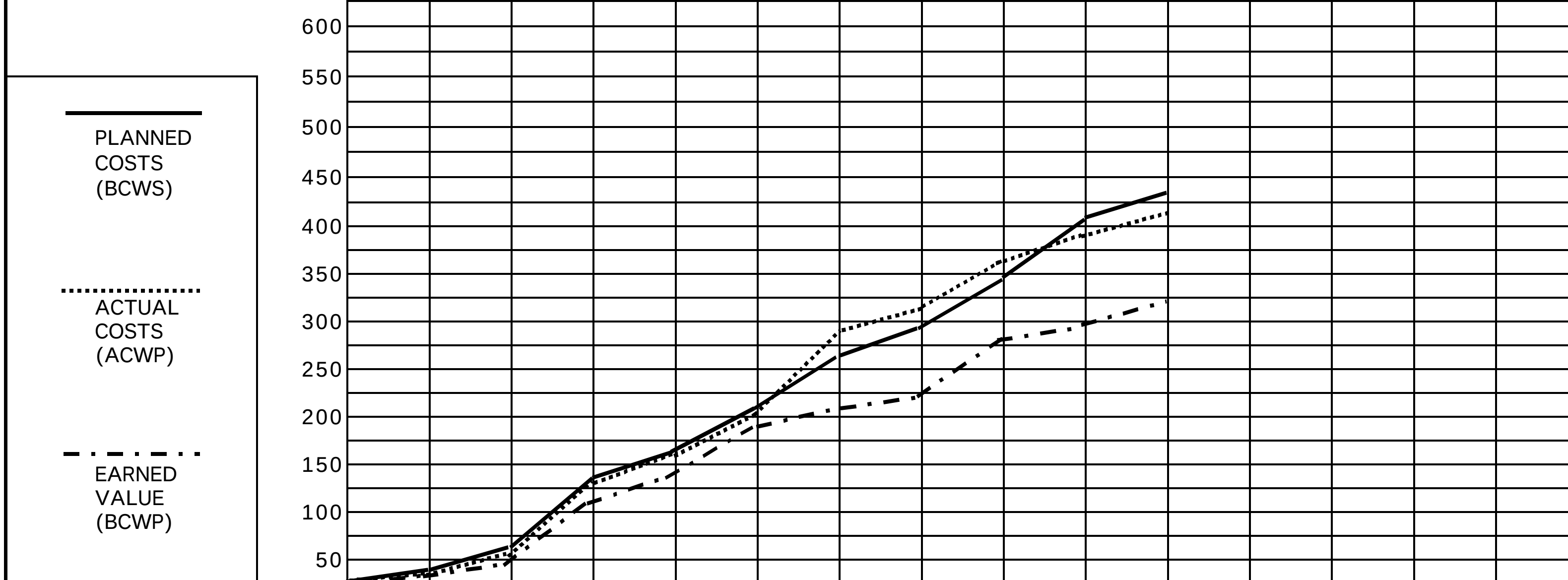
11. REMARKS

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

1. CONTRACT REPORTING ELEMENT **HSSI - 2. Fracture Toughness Transition and MC Methodology**		2. REPORTING PERIOD **06/25/01 - 07/22/01**	3. JCN NO. **W6953**
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P. O. BOX 2008** **OAK RIDGE, TN 37831**		5. CONTRACT PERIOD **FY 1998 - 2003**	6. ACTIVITY NUMBER **W41 W5 85 3W 1**
		7. NRC B&R NO. **860 15 21 20 05**	8. DOE B&R NO. **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
07/20/01

PLANNED COSTS FOR ELEMENT ($K)
599

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	60	55	50	46	35	36	28	
ACTUAL	20	33	75	40	47	78	13	56	21	24					
EARNED	19	22	74	27	29	35	17	56	19	26					
CUM. PLANNED	25	58	131	168	215	261	289	349	404	454	500	535	571	599	
CUM. ACTUAL	20	53	128	168	215	293	306	362	383	407					
CUM. EARNED	19	41	115	142	171	206	223	279	298	324					

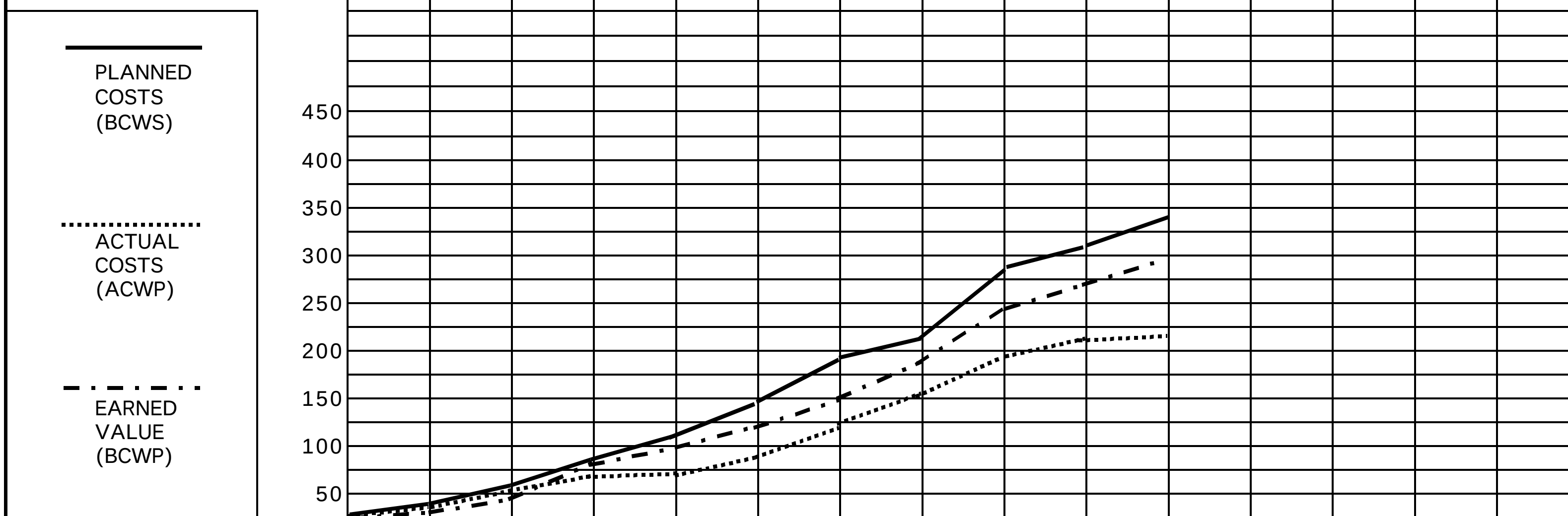
11. REMARKS

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

1. CONTRACT REPORTING ELEMENT **HSSI - 3. Irradiation Embrittlement of RPV Steel**	2. REPORTING PERIOD **06/25/01 - 07/22/01**	3. JCN NO. **W6953**
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P. O. BOX 2008** **OAK RIDGE, TN 37831**	5. CONTRACT PERIOD **FY 1998 - 2003** 7. NRC B&R NO. **860 15 21 20 05**	6. ACTIVITY NUMBER **W41 W5 85 3W 1** 8. DOE B&R NO. **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

7/20/01

PLANNED COSTS FOR ELEMENT ($K)

464

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	26	67	27	33	42	28	28	28	
ACTUAL	32	26	9	2	22	23	37	35	19	9					
EARNED	24	24	30	20	22	29	30	62	27	25					
CUM. PLANNED	33	59	83	109	146	185	211	278	305	338	380	408	436	464	
CUM. ACTUAL	32	58	67	69	91	114	151	186	205	214					
CUM. EARNED	24	48	78	98	120	149	179	241	268	293					

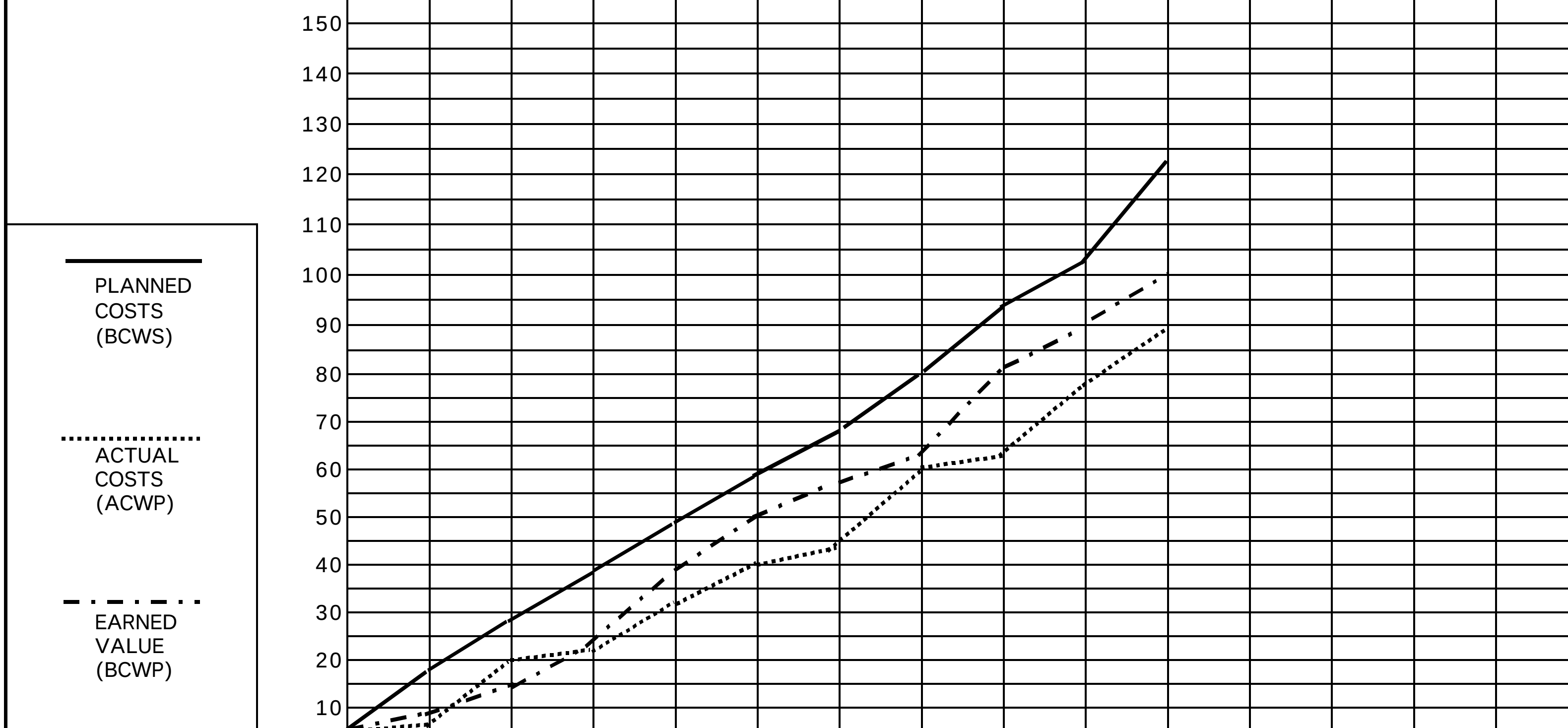
11. REMARKS

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

1. CONTRACT REPORTING ELEMENT **HSSI - 4. Validation of Irradiated and Aged Materials**		2. REPORTING PERIOD **06/25/01 - 07/22/01**	3. JCN NO. **W6953**
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P. O. BOX 2008** **OAK RIDGE, TN 37831**		5. CONTRACT PERIOD **FY 1998 - 2003**	6. ACTIVITY NUMBER **W41 W5 85 3W 1**
		7. NRC B&R NO. **860 15 21 20 05**	8. DOE B&R NO. **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

07/20/01

PLANNED COSTS FOR ELEMENT ($K)

192

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	11	11	13	11	19	23	22	14	10	
ACTUAL	2	18	3	9	8	3	17	3	14	11					
EARNED	7	7	9	16	11	6	7	18	7	11					
CUM. PLANNED	16	29	39	49	58	69	80	93	104	123	146	168	182	192	
CUM. ACTUAL	2	20	23	32	40	43	60	63	77	88					
CUM. EARNED	7	14	23	39	50	56	63	81	88	99					

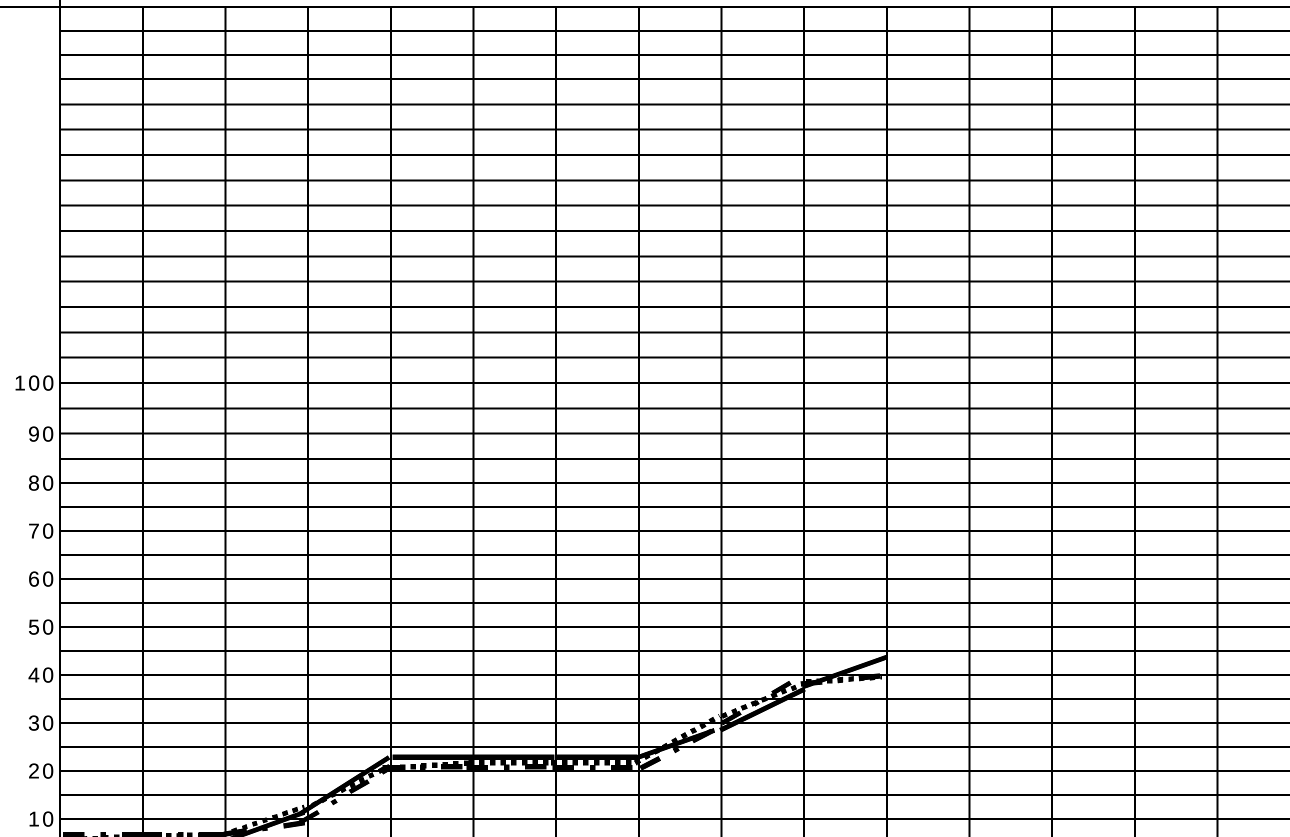
11. REMARKS

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

1. CONTRACT REPORTING ELEMENT **HSSI - 5. Modeling and Microstuctural Analysis**	2. REPORTING PERIOD **06/25/01 - 07/22/01**	3. JCN NO. **W6953**
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P. O. BOX 2008** **OAK RIDGE, TN 37831**	5. CONTRACT PERIOD **FY 1998 - 2003**	6. ACTIVITY NUMBER **W41 W5 85 3W 1**
	7. NRC B&R NO. **860 15 21 20 05**	8. DOE B&R NO. **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)

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	7	2					
EARNED	0	0	8	13	0	0	0	8	8	3					
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	38	40					
CUM. EARNED	0	0	8	21	21	21	21	29	37	40					

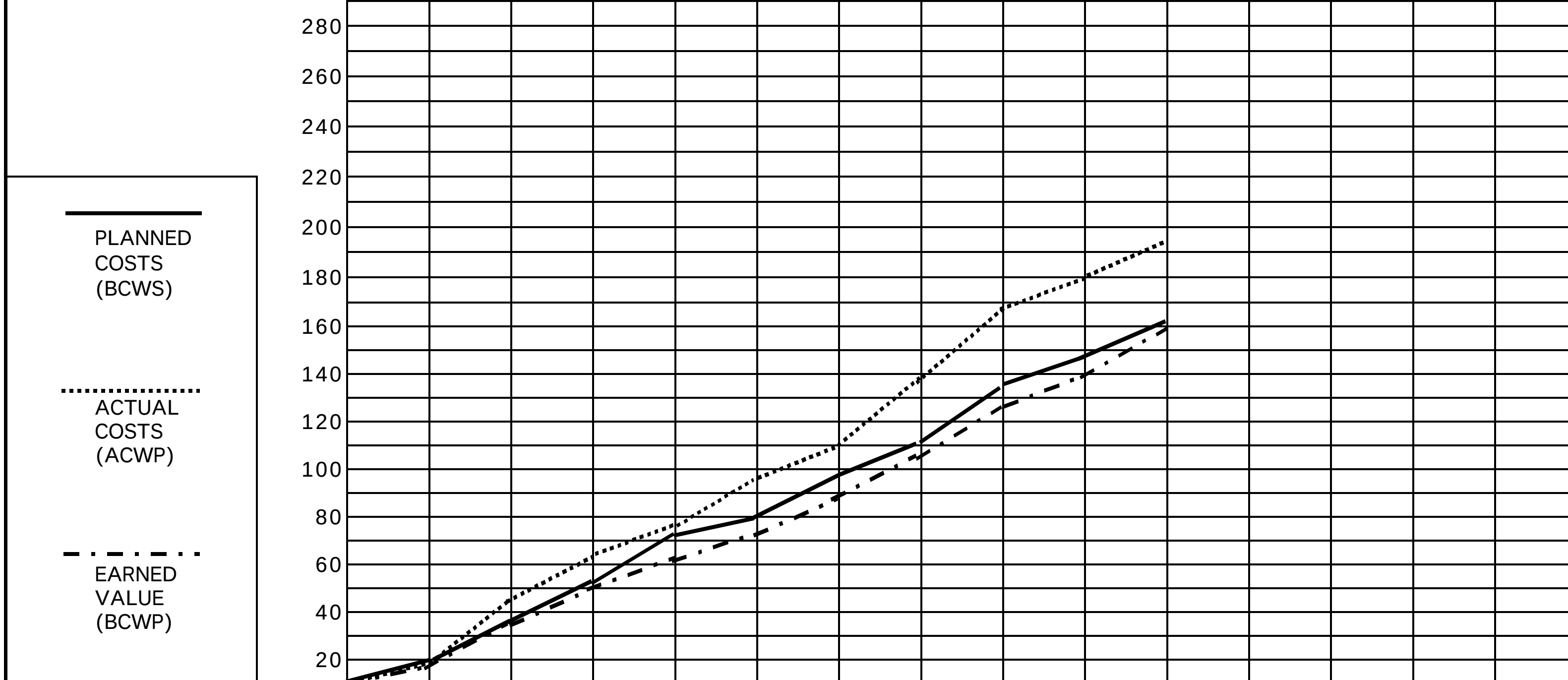
11. REMARKS

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

1. CONTRACT REPORTING ELEMENT **HSSI - 6. Irradiation Coordination**	2. REPORTING PERIOD **06/25/01 - 07/22/01**	3. JCN NO. **W6953**
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P. O. BOX 2008** **OAK RIDGE, TN 37831**	5. CONTRACT PERIOD **FY 1998 - 2003** 7. NRC B&R NO. **860 15 21 20 05**	6. ACTIVITY NUMBER **W41 W5 85 3W 1** 8. DOE B&R NO. **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

07/20/01

PLANNED COSTS FOR ELEMENT ($K)

228

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	18	18	12	16	21	18	14	14	
ACTUAL	19	26	16	14	20	15	28	29	13	12					
EARNED	19	16	14	12	15	11	20	18	14	20					
CUM. PLANNED	19	35	51	66	79	97	115	133	145	161	182	209	214	228	
CUM. ACTUAL	19	45	61	75	95	110	138	167	180	192					
CUM. EARNED	19	35	49	61	76	87	107	125	139	159					

11. REMARKS

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

1. CONTRACT REPORTING ELEMENT **HSSI - 7. Embrittlement DB & Dosimetry Evaluation**	2. REPORTING PERIOD **06/25/01 - 07/22/01**	3. JCN NO. **W6953**	
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P. O. BOX 2008** **OAK RIDGE, TN 37831**	5. CONTRACT PERIOD **FY 1998 - 2003** 7. NRC B&R NO. **860 15 21 20 05**	6. ACTIVITY NUMBER **W41 W5 85 3W 1** 8. DOE B&R NO. **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) — solid line; ACTUAL COSTS (ACWP) — dotted line; EARNED VALUE (BCWP) — dash-dot line

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

COST PLAN DATES: 04/20/01

PLANNED COSTS FOR ELEMENT ($K): 0

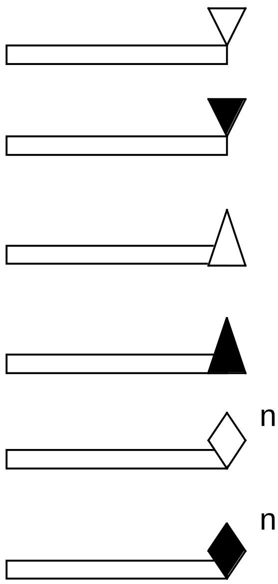
ELEMENT COSTS FOR PRIOR FYS ($K): 0

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	0						
ACTUAL	0	0	0	0	0	0	0	0	0						
EARNED	0	0	0	0	0	0	0	0	0						
CUM. PLANNED	0	0	0	0	0	0	0	0	0						
CUM. ACTUAL	0	0	0	0	0	0	0	0	0						
CUM. EARNED	0	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



Intermediate milestone planned

Intermediate milestone completed

Major milestone planned

Major milestone completed

Rescheduled milestone planned

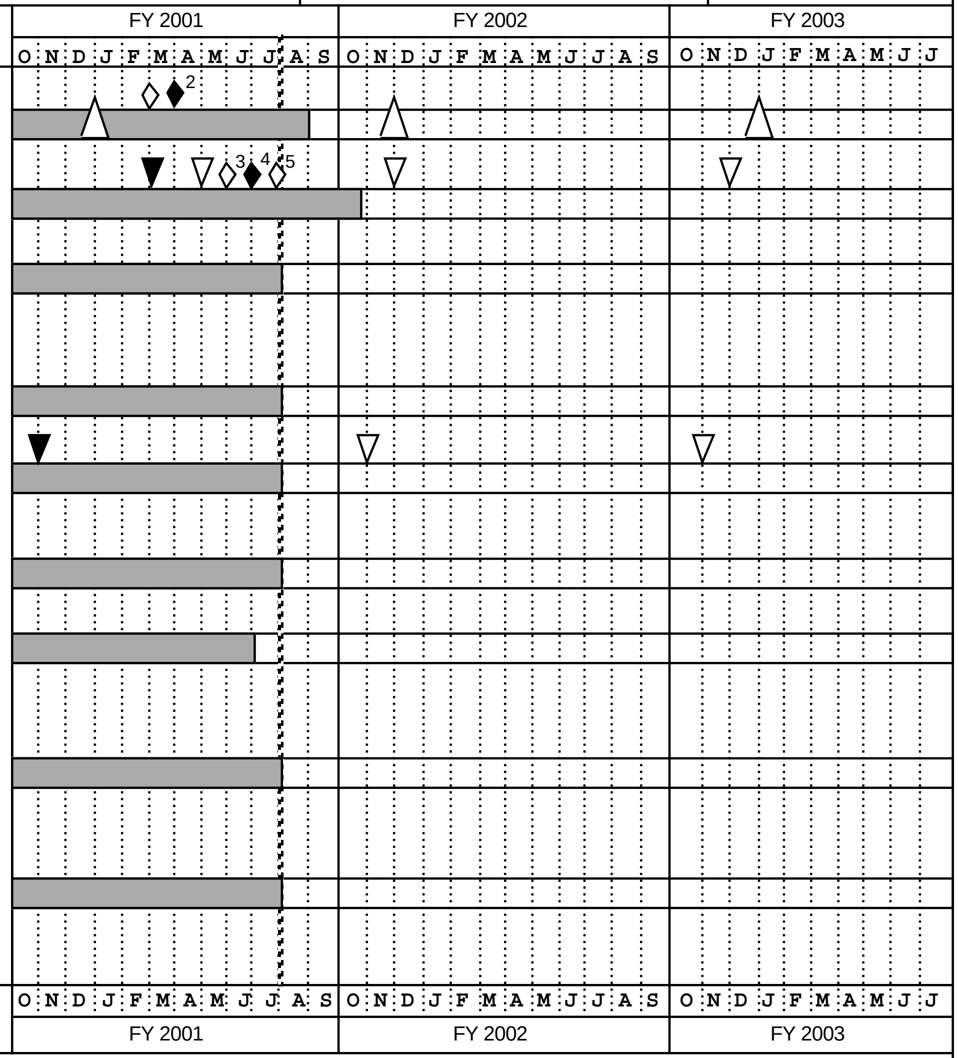
Rescheduled milestone completed

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

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 1. Program Management	**06/25/01 - 07/22/01**	**W6953**

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

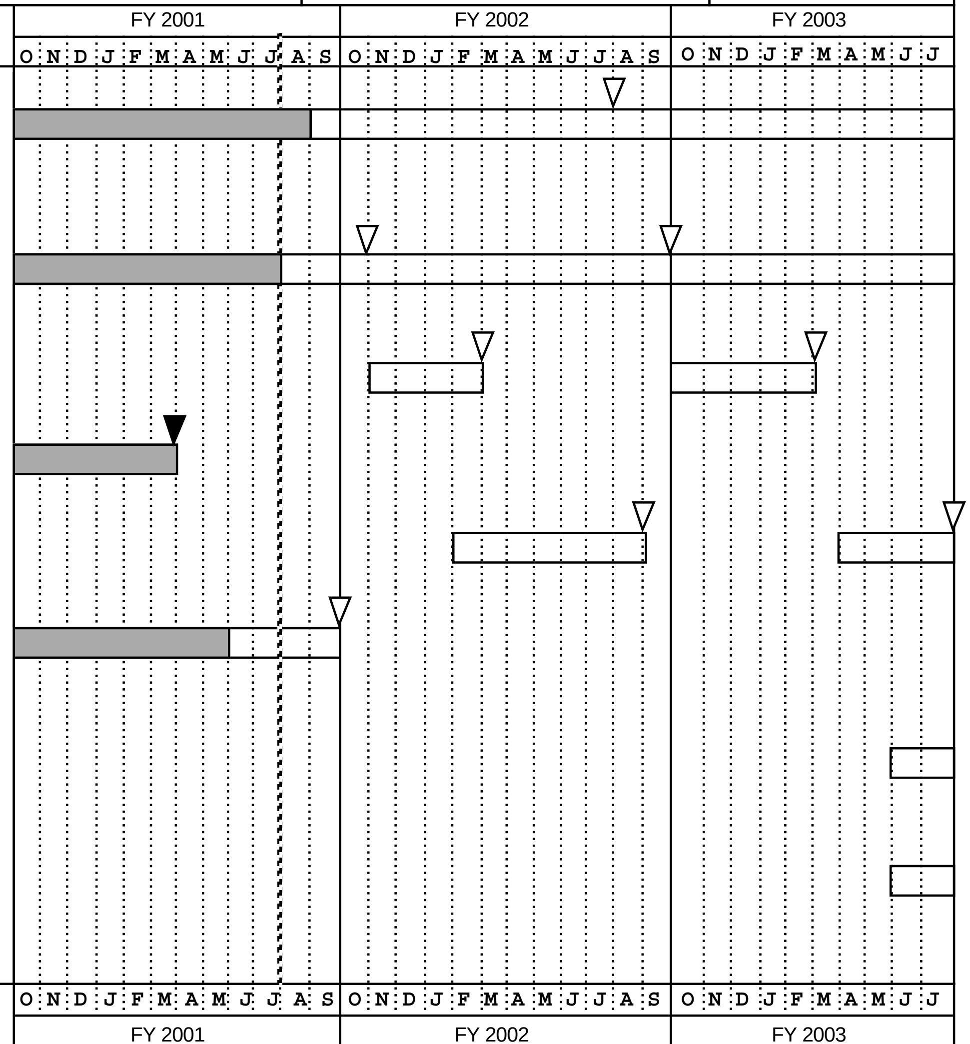
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
1.1.A.	Issue Project & Budget Proposal
1.1.B.	Select and Administer Subcontracts
1.2.A.	Issue Earned Value Based Monthly Management Reports (by the end of subsequent month)
1.2.B.	Ensure QA Requirements are met
1.3.A.	Participate in NRC-Sponsored Meeting 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	**06/25/01 - 07/22/01**	**W6953**
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P. O. BOX 2008** **OAK RIDGE, TN 37831**	5. CONTRACT PERIOD **FY 1998-2003** 7. NRC B&R NO. **860 15 21 20 05**	6. ACTIVITY NUMBER **41 W6 95 3W 1** 8. DOE B&R NO. **40 10 01 06**

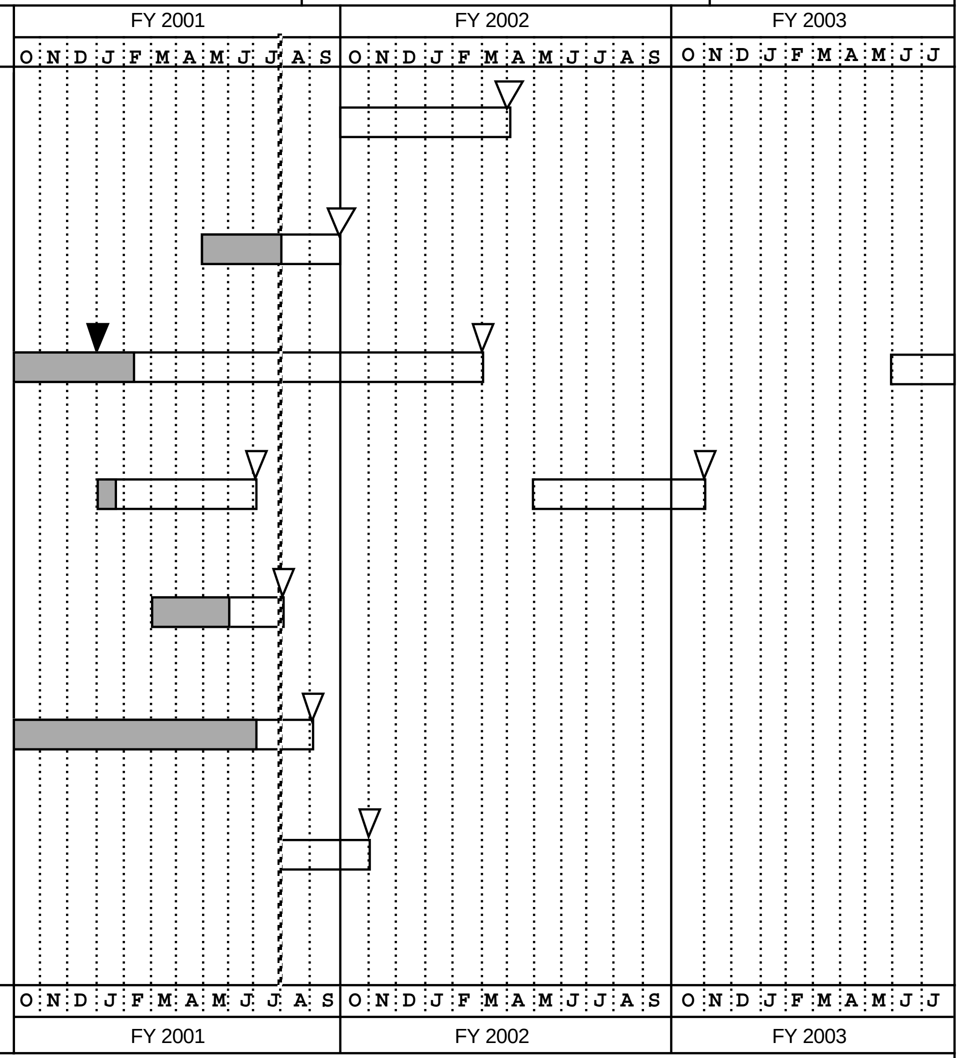
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
2.1.A.	Continue to accumulate data on Comparison of CVN and Fracture Tougness Shifts
2.2.A.	IIrradiate Midland and Hi-Ni Speciments
2.2.B.	Receive Specimens
2.2.C.	Test Unirradiated & Irradiated KSØ1 for Master Curve
2.2.D.	Test Unirradiated & Irradiated 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 **HSSI - 2. Fracture Toughness Transition & MC Methodology**	2. REPORTING PERIOD **06/25/01 - 07/22/01**	3. JCN NO. **W6953**
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P. O. BOX 2008** **OAK RIDGE, TN 37831**	5. CONTRACT PERIOD **FY 1998-2003** 7. NRC B&R NO. **860 15 21 20 05**	6. ACTIVITY NUMBER **41 W6 95 3W 1** 8. DOE B&R NO. **40 10 01 06**

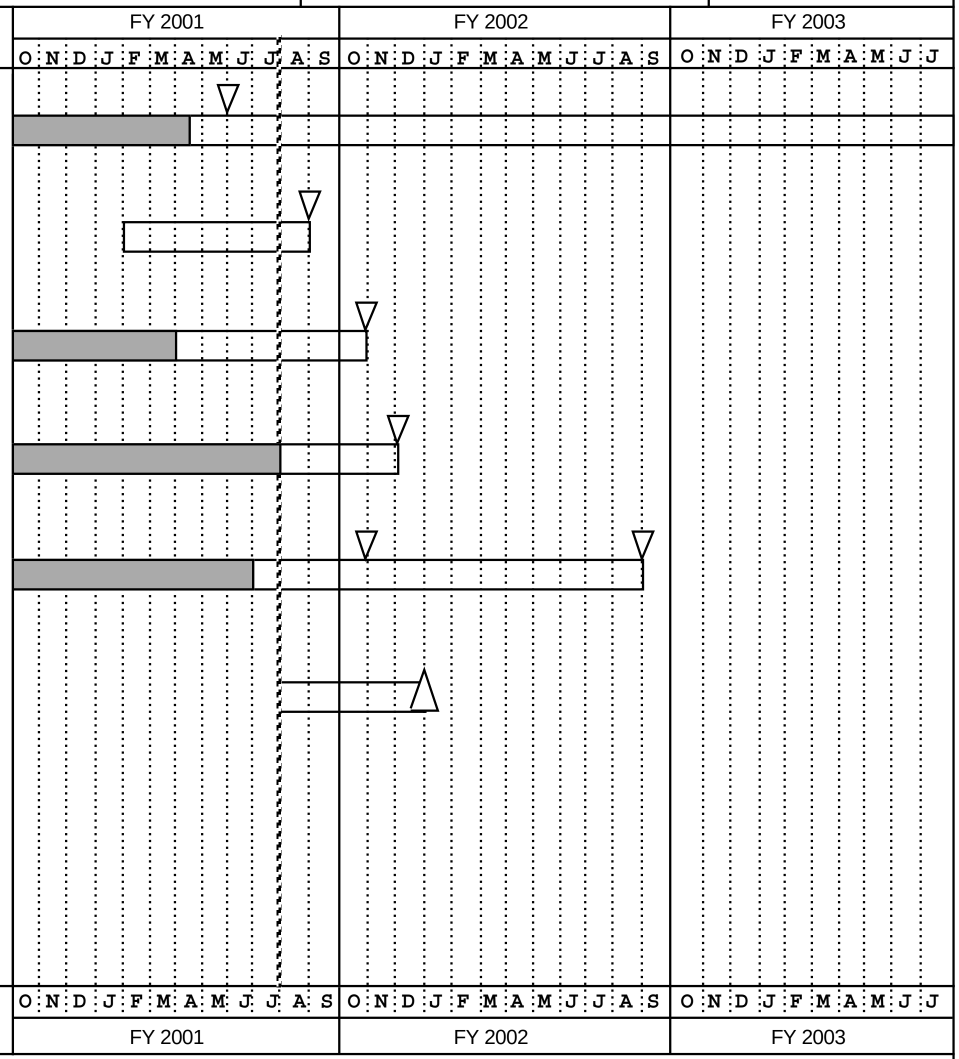
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
2.3.A.	Develop Testing Plan for Dynamic Fracture Toughness Effects on MC
2.4.A.	Letter Report on Statistical Representation of Valid K_{JC} Data
2.5.A.	Measure Activity and Prepare Report
2.5.B.	Calculate Fluence and Prepare Report
2.6.A.	Complete Testing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



11. REMARKS

1. CONTRACT REPORTING ELEMENT **HSSI - 2. Fracture Toughness Transition & MC Methodology**	2. REPORTING PERIOD **06/25/01 - 07/22/01**	3. JCN NO. **W6953**
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P. O. BOX 2008** **OAK RIDGE, TN 37831**	5. CONTRACT PERIOD **FY 1998-2003**	6. ACTIVITY NUMBER **41 W6 95 3W 1**
	7. NRC B&R NO. **860 15 21 20 05**	8. DOE B&R NO. **40 10 01 06**

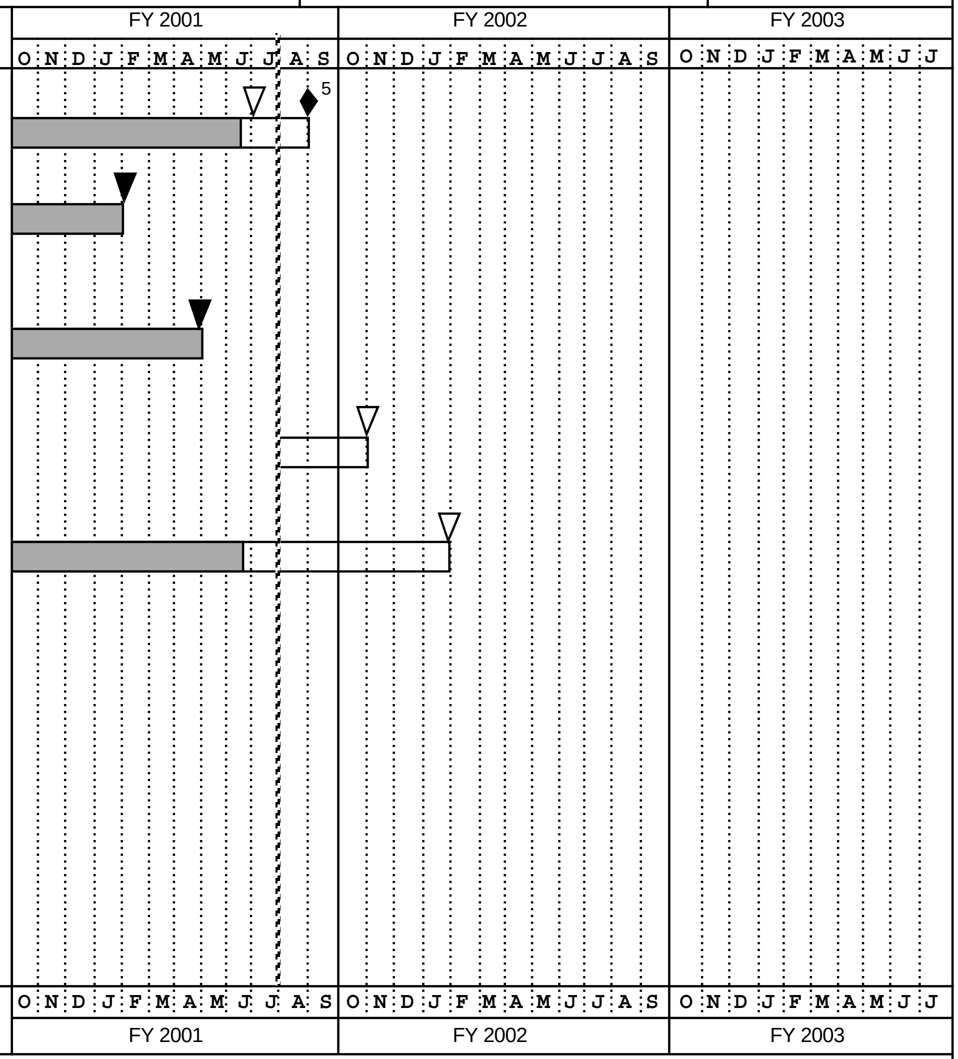
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
2.7.A.	Complete Testing of Subsize Specimens
2.7.B.	Testing of JRQ Plate
2.7.C.	Complete Letter Report on Results of Subsize Specimen Fracture Toughness Tests
2.8.A.1	Complete Assembly and Compilation for Irradiated Materials for Surrogate Materials DB
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 **HSSI - 3. Irradiation Embrittlement of RPV Steel**	2. REPORTING PERIOD **06/25/01 - 07/22/01**	3. JCN NO. **W6953**
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P. O. BOX 2008** **OAK RIDGE, TN 37831**	5. CONTRACT PERIOD **FY 1998-2003** 7. NRC B&R NO. **860 15 21 20 05**	6. ACTIVITY NUMBER **41 W6 95 3W 1** 8. DOE B&R NO. **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

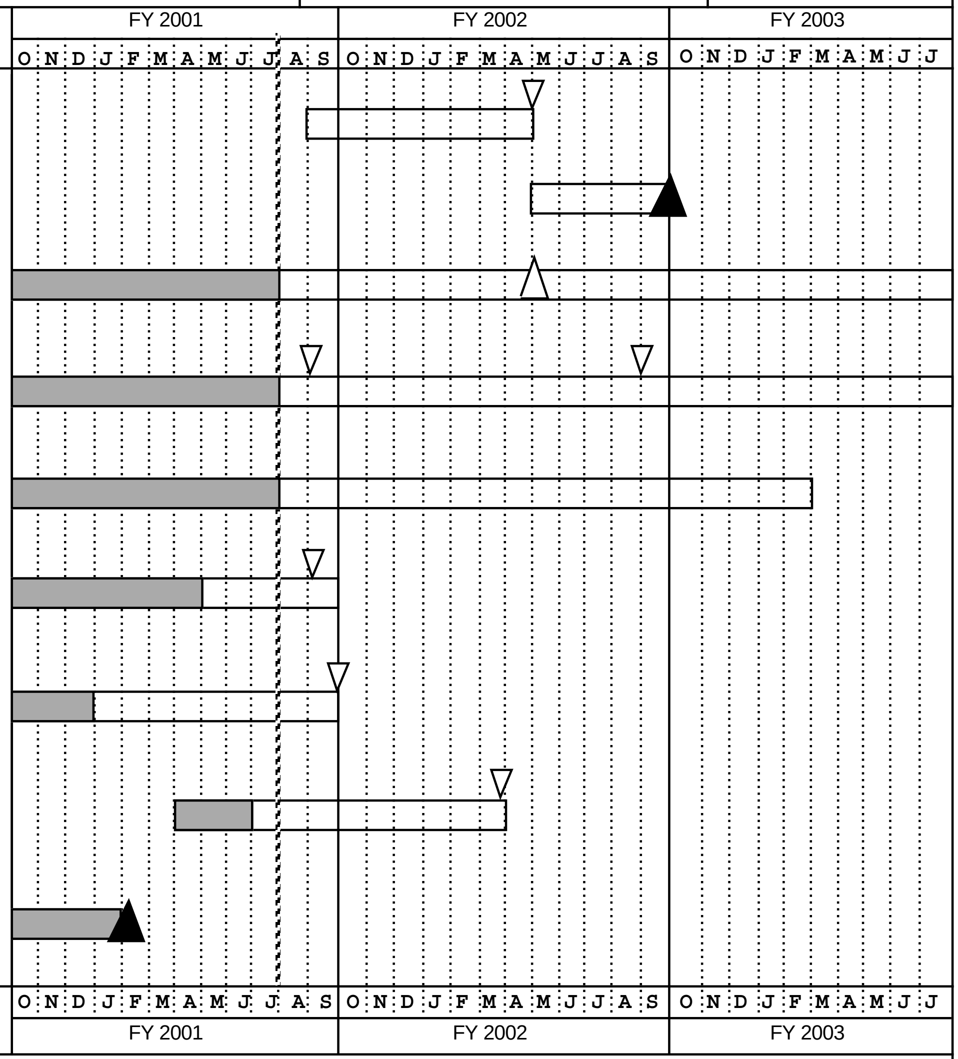


11. REMARKS

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 4. Validation of Irradiated and Aged Materials	**06/25/01 - 07/22/01**	**W6953**

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

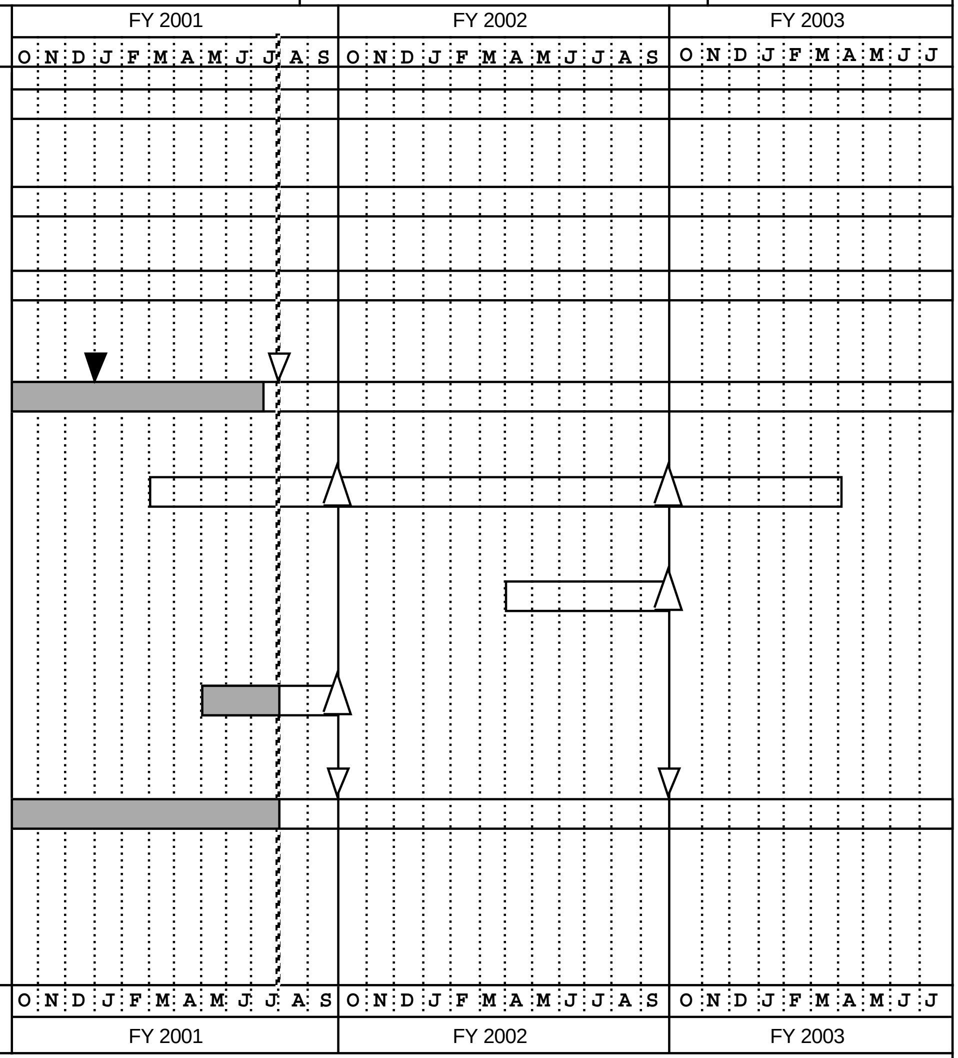
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
4.1.A.	Toughness Tests on SS Cladding
4.1.B.	Letter Report
4.2.A.	Participate in Periodic Meetings of IGRDM
4.2.B.	Complete Progress Reports of Collaboration Activities
4.3.A.	Letter Report on PWHT and Copper
4.3.B.	Complete Letter Report Regarding RPV 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 **HSSI - 5. Modeling & Microstructural Analysis**	2. REPORTING PERIOD **06/25/01 - 07/22/01**	3. JCN NO. **W6953**
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P. O. BOX 2008** **OAK RIDGE, TN 37831**	5. CONTRACT PERIOD **FY 1998-2003**	6. ACTIVITY NUMBER **41 W6 95 3W 1**
	7. NRC B&R NO. **860 15 21 20 05**	8. DOE B&R NO. **40 10 01 06**

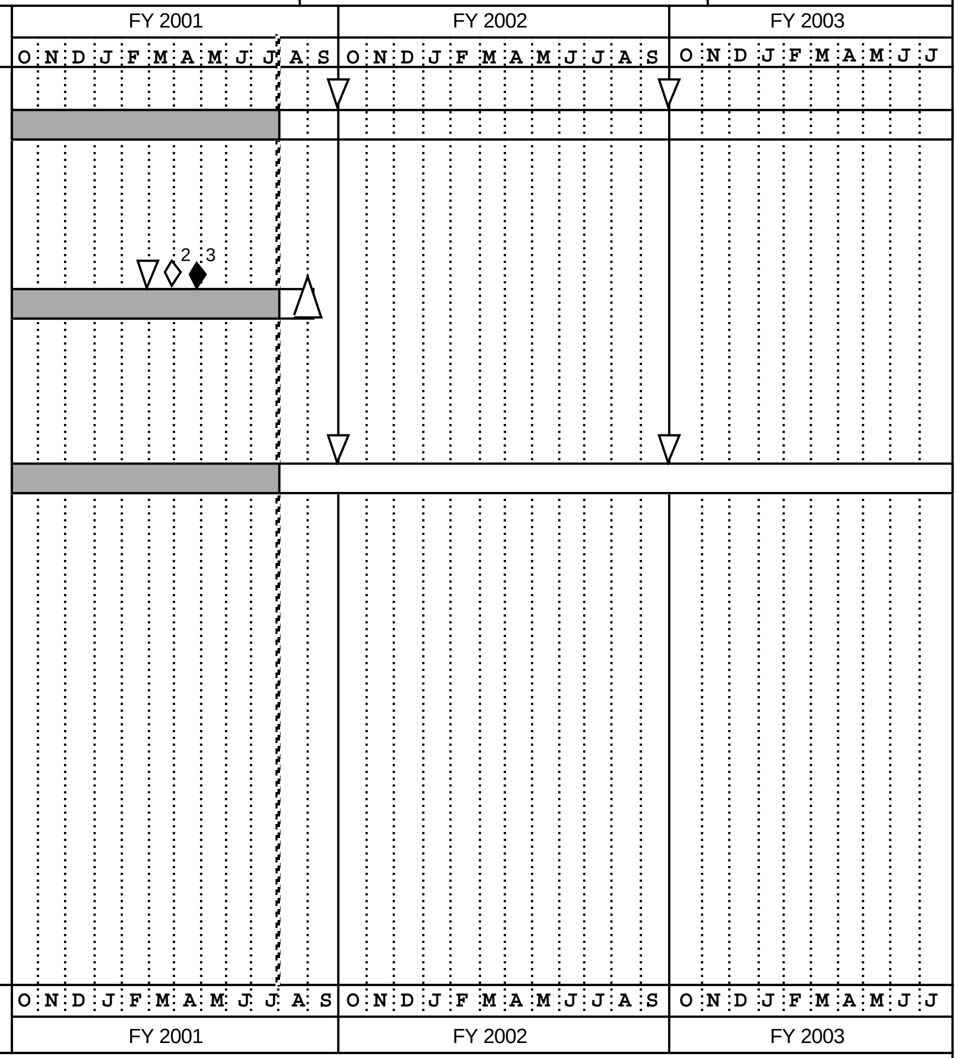
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
5.1.A.	Development and Predictive use of Embrittlement Model
5.1.B.	Model Validation and Data Analysis
5.2.A.	Coordinate and Analyze APFIM/SANS/FEGSTEM Round Robin Experiment
5.2.B.	APFIM Characterization
5.3.A.1	Evaluate and Input Surveillance Reports 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 **HSSI - 6. Irradiation Coordination**	2. REPORTING PERIOD **06/25/01 - 07/22/01**	3. JCN NO. **W6953**
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P. O. BOX 2008** **OAK RIDGE, TN 37831**	5. CONTRACT PERIOD **FY 1998-2003** 7. NRC B&R NO. **860 15 21 20 05**	6. ACTIVITY NUMBER **41 W6 95 3W 1** 8. DOE B&R NO. **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