ORNL/HSSI(6953)/MLSR-2000/6

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

Monthly Letter Status Report

March 2000

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HEAVY-SECTION STEEL IRRADIATION PROGRAM

JCN W6953

MONTHLY LETTER STATUS REPORT

FOR

MARCH 2000

Submitted by

T. M. Rosseel
HSSI Project Manager

Compiled by
V. S. Woodward

Submitted to
C. J. Fairbanks
NRC Project Manager

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
managed by
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PREFACE

This report is issued monthly by the staff of the Heavy-Section Steel Irradiation (HSSI) Program 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 fourteen program tasks. The final part of the report normally provides financial status for all tasks and status reports for selected milestones within each task. For the January 1996 report, the earned-value based estimates of performance and the status reports for selected milestones are not included due to their expected changes related to reductions in the FY 1996 budget below that originally included in the applicable 189s. The milestones and individual task budgets addressing the fifteen-month period from October 1995 to December 1996, (thereby covering both the Department of Energy's fiscal year and the second year of the NRC's current performance period for the HSSI Program) will be included once defined in adequate detail by the the NRC.

Beginning in October, 1992, the monthly business calender of the Oak Ridge National Laboratory was changed and no longer coincides with the Julian calendar. The business month now ends earlier than the last day of the calender 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 Program

MONTHLY LETTER STATUS REPORT
March 2000

Job Code Number: W6953
Project Title: Heavy-Section Steel Irradiation Program
Period of Performance: 4/1/98 to 11/30/00
Performing Organization: Oak Ridge National Laboratory
Program Manager: T. M. Rosseel
Address: P.O. Box 2008
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 data bases, 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. Six technical tasks and one for program management are now contained in the HSSI Program.

2. TECHNICAL ACTIVITIES:

<u>Task 1: Program Management</u> (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 1.2.B) Arranged for the shipment of the irradiated MEA specimens, described in subtask 4.5, to the University of Michigan, Ford Nuclear Reactor (FNR) and the return shipment of the remaining KS01 (subtask 2.2) and HAZ (subtask 3.1) specimens from the first HSSI IAR irradiation campaign (HSSI-IAR-01) to the ORNL hot cells. Metler Transport of Knoxville, TN will pick up the cask at ORNL on Monday, April 3, 2000 and guarantee delivery at the University of Michigan Phoenix Memorial Lab (PML) by 8:00 am on Tuesday, April 4, 2000. At the PML, Phil Simpson, FNR manager, will have a crew of riggers on hand to transfer the cask to the Michigan hot cells. After the MEA specimens are unloaded from the cask, the UM team will pack the KS01 and HAZ specimens into the cask for transfer by the riggers to the Metler truck for return shipment to the ORNL hot cells within four to six hours after arrival at the PML. That shipment will be guaranteed for arrival by Wednesday morning, April 6, 2000. Health Physicists will monitor the transfer at both sites. This shipping arrangement was chosen because it allows us to set the exact time that the riggers, HP staff, and hot cell operators at the University of Michigan will be available for the transfer, thus saving “waiting and scheduling” time and therefore total expense.

(Milestone 1.3.D) Preparations were made for the visit of Mr. Shunichi Hatano, Tokyo Research and Development Center, Japan Power Engineering and Inspection Corporation (JAPEIC) and Mr. Yasuhiro Kutomi, Mitsubishi Heavy Industries to ORNL and the Heavy Section Steel Irradiation (HSSI) Program on Tuesday, April 11, 2000, to discuss irradiation embrittlement of RPV steels.

Information for the HSSI web site was collected and vetted. It is planned that the site will contain a description of the program by task, recent HSSI highlights and awards, HSSI publications, staff biographical descriptions with e-mail links as well as links to the US NRC and UM-FNR among many others.

(Milestone 1.3.E) Corrected a minor error in the appendices of the *Evaluation of WF-70 Weld Metal from the Midland Unit 1 Reactor Vessel - Final Report*, by D. E. McCabe, R. K. Nanstad, S. K. Iskander, D. W. Heatherly, and R. L. Swain, NUREG/CR-5736 (ORNL/TM-13748).

Task 2: Fracture-Toughness Transition and Master-Curve Methodology (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. For example, pertinent fracture-toughness data needed to assess the shift and potential change in shape of the fracture-toughness curves due to neutron irradiation will be collected and statistically analyzed. The effects of irradiation on fracture-toughness curve shape for highly embrittled RPV steels, dynamic effects, crack arrest, intergranular fracture, and subsized specimens will also be explored. Finally, guidelines for the application of "surrogate materials" to the assessment of fracture toughness of RPV steels will be evaluated.

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) No activity during this reporting period.

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 submitted to the NRC for publication in May 1999.

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 irradiation of a pressure-vessel steel to a neutron fluence sufficient to produce a fracture-toughness transition-temperature shift (T_0) of about 150 ^{0}C (270 ^{0}F). 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 precracked Charpy V-notch (PCVN) specimens, for both quasi-static and dynamic tests, will be irradiated and tested to investigate the use of more practical surveillance-size specimens. Tensile specimens will also be included to determine the irradiation-induced hardening. A comprehensive test program with unirradiated material will be included to provide the necessary baseline data for comparison.

(Milestone 2.2.A) A group of irradiated specimens of KS-01 weld was transported to ORNL from the Ford Nuclear Reactor (FNR). This group consists of Charpy, PCVN, 0.5 CT, and tensile specimens. The specimens were sorted in the hot cells and are ready to be tested. Most of them will be tested in April 2000 prior to testing 1T C(T) to better estimate irradiated T_o and thus select test temperatures for 1T C(T). Arrangements have been made to transport the remaining 1T C(T) specimens from the FNR to ORNL in early April 2000.

Irradiation of the Midland beltline weld and a high-nickel weld from the Palisades steam generator is under way and proceeding on schedule.

Subtask 2.3: Dynamic Effects, Including Precracked Charpy V-Notch Testing (S. K. Iskander)

As reactors age, the operating window between the startup or shutdown K_a curve, generated from the allowable pressures and temperatures, and the K_{Ia} curve becomes smaller, making it difficult for plants to startup and shut-down. Dynamic testing of relatively small specimens will be evaluated as an alternative method to determine a lower bound to fracture toughness. Results from Subtask 2.5 (crack-arrest), which measures dynamic properties, will also be used in this subtask.

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

Subtask 2.4: Irradiation Effects on Fracture Toughness of Midland RPV Weld (R. K. Nanstad)

The purpose of this subtask is to determine the transition-temperature shift and to evaluate transition-toughness curve shape for a low Charpy upper-shelf weld metal at a relatively high neutron fluence that will produce greater embrittlement damage than previously obtained with irradiations at lower fluences. This subtask will evaluate the assumption of constant shape for the MC with highly embrittled low-upper-shelf RPV steels that exhibit onset of stable ductile tearing at relatively low-fracture toughness. The evaluation will be performed through irradiation of the beltline weld from the Midland Unit 1 RPV to a fluence of about 2.5 to 5 x 10^{19} n/cm^2 (>1 MeV) for which a substantial database of unirradiated and irradiated results to a fluence of 1 x 10^{19} n/cm^2 (>1 MeV) already exists. This research is needed to assess the fracture-toughness behavior of such a weld at high-embrittlement levels. Evaluation of the MC shape will be determined with sufficient numbers of 0.5T C(T) to allow for testing at three temperatures in the transition-temperature region. Additionally, PCVN specimens, for both quasi-static and dynamic tests, will also be irradiated and tested to investigate the use of more typical surveillance-size specimens, and tensile specimens will be included to determine the irradiation-induced hardening. A comprehensive-test program with unirradiated material was previously completed under the first HSSI Program (L1098) 10th Irradiation Series, except for dynamic testing of PCVN specimens, which will be included to provide the necessary baseline data for comparison.

(Milestone 2.4.D) The final report, *Evaluation of WF-70 Weld Metal from the Midland Unit 1 Reactor Vessel - Final Report*, by D. E. McCabe, R. K. Nanstad, S. K. Iskander, D. W. Heatherly, and R. L. Swain, NUREG/CR-5736 (ORNL/TM-13748), was submitted to the NRC for publication in February 1999.

Further evaluation of the Midland beltline weld will be performed under Subtask 2.2.

Subtask 2.5: Crack-Arrest including Midland (S. K. Iskander)

In this subtask, the low-temperature operating pressure regulatory concerns will be addressed through testing of the 15 irradiated, Midland crack-arrest specimens. This evaluation will provide an excellent opportunity to determine whether the lower bounds of crack initiation and arrest toughness coincide for this very important class of irradiated LUS welds. These specimens, which were produced and irradiated as part of the previous HSSI (L1098) program, will be used to evaluate the lower and transition arrest-toughness values.

(Milestone 2.5.A) The 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. HeatherIy, D. E. McCabe, I. Remec, and R. L. Swain, NUREG/CR-6621 (ORNL/TM-13764), is nearing completion. This document will also incorporate a complete report on the dosimetry and irradiation parameters calculated for HSSI Capsule 10.06. The latter capsule contained the 15 crack-arrest specimens of this report. Recent advances in the computer technology have allowed the use of electronic versions of the figures. The figures are being assembled in electronic format to incorporate with the text instead of the “cut and paste” method previously used as it is anticipated that this is a more efficient method for production of reports.

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.

(Milestone 2.6.B) Following review of the draft letter report, discussions were held to consider some amount of additional testing. The median fracture toughness at the lowest test temperature was about 100 MPa√m. Machining eight 0.5T C(T) specimens and testing them at a lower temperature with a target median fracture toughness of about 70 MPa√m would provide additional evidence regarding the application of the Master Curve in that important region of the transition region in the presence of intergranular fracture. The additional specimens can be machined from remaining pieces of previously testing 2T C(T) specimens.

Subtask 2.7: Subsized 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.C) Abstracts are arriving for the ASTM Fourth International Symposium on Small Specimen Techniques. This symposium will be held in January of 2001 with M. A. Sokolov serving as the Chairman of the Symposium.

Subtask 2.8: Quantification of surrogate materials for use in a statistics-based fracture toughness assessment (R. K. Nanstad, J. G. Merkle, and M. A. Sokolov)

The purpose of this subtask is to establish guidelines for the use of "surrogate materials" in the assessment of fracture toughness of RPV steels. A plan will be developed to describe the information acquired and the means of collecting it, the method of evaluating the information, and the methods for using the information. Analyses will be performed to provide a methodology for determining limits for predicting fracture toughness of one material, i.e., a surrogate material, with measured fracture toughness of similar materials.

(Milestone 2.8.B) A NUREG report, *Considerations for Use of Surrogate Materials Data for Reactor Pressure Vessels*, by R. K. Nanstad and J. G. Merkle, has been drafted and sent to the NRC technical monitor for review. A brief summary of the report follows:

The report begins with an introduction which presents a discussion of the surrogate materials issue, with reference to points made by NRC staff (Mayfield, et al.) in a paper published in SmiRT-14 in 1997. The report proposes the following "definition" of a surrogate material relative to RPVs:

> "A surrogate material is a material which is not the 'same' material as that in the RPV, but is deemed appropriate to represent the fracture toughness of the RPV material of interest with prescribed values of uncertainties."

Thus, an important aspect of the surrogate materials issue is the identification of uncertainties, including their origins and eventually their magnitudes.

The report then presents background information and a review of current procedures regarding estimates of reference toughness based on Charpy impact and drop-weight nil-ductility transition (NDT) temperature testing. The review includes discussion of provisions in *Regulatory Guide 1.99*, Revision 2, and 10CFR50, including the ratio method used for adjustment of the embrittlement prediction when surveillance data are available from a material which is known to have different copper or nickel content than the vessel weld. It also presents tables of the critical materials in the 111 currently operating nuclear power plants and a comparison of surveillance materials to those critical materials. The report then presents a potential framework for evaluation of uncertainties, with a view towards development of a procedure to determine and assign a value of uncertainty to a potential surrogate material, based on evaluation of a number of material factors to essentially rate the relationship of the material to the material of interest in the RPV. The result of the evaluation would be the assignment of a "Surrogate Ratio" which could be used to adjust the established uncertainties (i.e., σ values) for the unirradiated and/or irradiated conditions. This section of the report also presents a discussion of the published Kewaunee Plant analysis.

The remainder of the report presents a review of data from the literature regarding variability of specific materials and generic materials in the unirradiated and irradiated conditions. The purpose of such a review is to provide representative data with which decisions can be made regarding values of uncertainties for the various material conditions. It is these values of uncertainties, which could then be adjusted by the Surrogate Ratio noted above.

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

The purpose of this task is to measure and analyze the dosimeters used during the first IAR Campaign in order to obtain accurate fluence determinations.

(Milestone 2.10.A) As soon as the remaining wire dosimeters from the IAR-01 campaign are received during the next reporting period, dosimetry measurements will begin.

Task 3: Irradiation Embrittlement of RPV Steel (S. K. Iskander)

The purpose of this task is to examine two important issues affecting the application of mitigation procedures to RPVs. The first addresses the effects of temper embrittlement on the coarse-grained HAZ in RPV steels. The second examines the effects of reirradiation on K_{Jc} and K_{Ia} 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 using the IAR facility designed, fabricated, and installed as part of the previous HSSI (L1098) program and with a matrix of irradiated and tempered specimens supplied by the Swiss Paul Scherrer Institut (PSI). Further data on reirradiation embrittlement will be obtained through reconstitution and reirradiation of previously irradiated specimens at the RRC-KI.

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

Research conducted to date 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 mitigation of such material resulted in an even greater increase of the transition temperature. Subsequent research at ORNL under the previous HSSI Program (L1098) used five commercial RPV steels to investigate potential temper embrittlement. The first phase 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 ^{0}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.B) As previously reported, the irradiation of specimens has been completed. Three material conditions for evaluation are HAZ material before and after thermal anneal and base metal after irradiation. Specimens were transported to ORNL together with the KS-01 weld (see Subtask 2.2). The specimens are now being sorted in the hot cells with anticipated testing in the April-May time frame.

Subtask 3.2: Embrittlement Rate of Reirradiated Steel (S. K. Iskander, I. Remec, E. D. Blakeman, and C. A. Baldwin)

This subtask will examine the effects of reirradiation on K_{Ic} and K_{Ia} toughness of RPV steel so as to evaluate the relative changes in recovery and reembrittlement between CVN and fracture-toughness properties and to provide a detailed examination of reembrittlement rates. This will be accomplished using the HSSI IAR and the University of California Santa Barbara (UCSB) irradiation facilities at the University of Michigan, Ford Nuclear Reactor (FNR), and through the reirradiation of previously irradiated specimens at RRC-KI, if funding is available. Emphasis will also be placed on completing dosimetry calculations for the new IAR facility.

(Milestone 3.2.B) Neutronics Analysis of the IAR/UCSB Irradiation Capsules (I. Remec, E. D. Blakeman, 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.

(Milestone 3.2.C) No significant activity during this reporting period. Preparation of a paper and abstract by S. K. Iskander, M. A. Sokolov, and R. K. Nanstad, "Reirradiation Response Rate of a High-Copper Reactor Pressure Vessel Weld," for the 20th International Symposium on Effects of Irradiation on Materials, Williamsburg, Virginia, June 6-8, 2000, will begin soon. The subject deals with the response of 73W Charpy specimens reirradiated to three fluence levels. The camera-ready paper, due at ASTM May 1, 2000, will also serve as a part of a NUREG report to document considerable work performed in the HSSI Program over the last few years. Several papers have been published, but no report that includes detailed results and with some preliminary conclusions has been prepared to date.

<u>Subtask 3.3: Evaluation of reirradiated JRQ specimens</u> (R. K. Nanstad, 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, identified as JRQ, will supplied by the Swiss PSI from a terminated research program.

(Milestone 3.3.A) Six drums with two lead pigs each were received at ORNL in January from the Paul Scherrer Institute (PSI) in Switzerland. The PSI also sent a detailed inventory of the contents of each drum and pig, that includes specimens numbers and activities. The total complement is 87 each CVN, 36 each PCVN, six each tensile, and six each 1T three-point bend specimens. The specimens have been removed from the pigs, placed in individually numbered containers, and are ready for testing during the April-May time frame.

<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 feasibility of reconstitution for CVN and 0.5T C(T) and 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: Examination of materials from retired RPVs</u> (S. K. Iskander and J. T. Hutton)

This subtask will examine the issue of neutron-irradiation-induced damage attenuation through the RPV wall. The damage will be related to measurements of received dose, such as displacements per atom (dpa) through the wall. The HSSI program will obtain suitable-size trepans of materials from previously decommissioned RPVs, because these materials would incorporate conditions from actual operating reactors such as the effects of irradiation on stressed material. A sufficient number and size of trepans will be obtained to permit use of the MC approach to relate measures of damage to the fracture toughness. Specimens will be machined on the CNC milling machine located in Cell 6 of the IMET facility. Depending upon availability and appropriateness, trepans from the Japan Power Demonstration Reactor (JPDR) project, Trojan, and Maine Yankee RPVs may be examined.

(Milestone 4.1.2.B) No significant activity during this reporting period.

Subtask 4.2: Reconstitution of irradiated toughness specimens (S. K. Iskander)

Feasibility studies for reconstitution of CVN, PCVN, and 0.5T bend bar specimens will be prepared. To adequately survey the state-of-the-art capabilities, on-site evaluations of US and international facilities will be required. A letter report that includes the estimated costs of either using existing and available facilities or implementing a reconstitution facility at ORNL will be prepared at the completion of this task.

No work is currently funded in this subtask.

Subtask 4.3: Toughness changes in aged stainless steel welds (R. K. Nanstad)

The purpose of this subtask is to evaluate the effects of irradiation and thermal aging on stainless-steel weld metals. Two projects are incorporated in this subtask. The first involves completion of fracture-toughness testing on irradiated stainless-steel weld-overlay cladding specimens at 288 ^{0}C to complete the testing of the matrix from the HSSI (L1089) 7th Irradiation Series. The PCVN specimens were irradiated in HSSI Capsule 10.06. The second project involves completion of a NUREG report on thermal aging of stainless-steel welds for nuclear piping, a project that began before the inception of the HSSI (L1098) Program and involved thermal aging at 343 ^{0}C for up to 50,000 hours.

(Milestone 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 submitted to the NRC for publication in July 1999.

Subtask 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. U.S.-Russia Joint Coordinating Committee for Civilian Nuclear Reactor Safety (JCCCNRS) Working Group on Radiation Embrittlement and Aging of Components.

2. 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.

3. Collaboration with AEA-Technology in the United Kingdom regarding fracture-toughness testing of intergranular embrittlement of RPV HAZs;

4. Collaborative studies on fracture properties of high-copper RPV materials with Korean institutes such as KAERI.

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

6. Collaboration with PSI in Switzerland on re-irradiation.

7. 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.

8. Participation, including membership on the executive committee, in the International Group on Radiation Damage Mechanisms (IGRDM).

9. Participation in the IAEA New CRP on use of PCVN specimens to determine fracture toughness of RPV steels.

(Milestone 4.4.C.) The first meeting of CRP-6 will be held in mid-April at IAEA with R. K. Nanstad attending the meeting. Planning for the next meeting of the IGRDM in Pressure Vessel Steels, IGRDM-9, continues. That meeting will be held in Leuven, Belgium, September 18-23, 2000, and will be hosted by SCK-CEN and Tractebel. R. K. Nanstad, Secretary of the IGRDM, is assisting the local host in the planning. Information has been sent to the members regarding offering of presentations, lodging arrangements, etc. The program on Friday, September 23, will be an open seminar, i.e., open to members of industrial, academic, and research organizations. The topic of the open seminar has not yet been determined.

Subtask 4.5: Technical assistance (R. K. Nanstad, S. K. Iskander, 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 identified activities are incorporated in this subtask, while other activities may be included through modification to the task by the NRC. The currently identified activities involve evaluation of the irradiated specimens contained in capsules previously irradiated at the University of Michigan FNR by Materials Engineering Associates (MEA), evaluation of highly irradiated high-nickel weld surveillance specimens from the Palisades Reactor, evaluation of the effects of post-weld heat treatment (PWHT) on the copper solubility and fracture toughness of unirradiated RPV steels, and compilation of available materials at ORNL and elsewhere for studies of irradiation effects on RPV steels.

A revision of the ASTM Standard E1921 was completed based on recommendations of the ASTM Task Group meeting held in November 1999. The revised version of the standard was sent to the ASTM Committee E8 for E08.08 subcommittee ballot.

(Milestone 4.5 A) Three sets of each 13 irradiated Charpy specimens from the MEA/NRC low-fluence capsule 17A, with codes 24G, F67, and F70, have been repacked with two iron 0.050-in.-diam dosimeter wires to be sent to the FNR to be irradiated an additional 1.2 $x10^{19}$ cm^{-2} (>1 MeV). These specimens have been irradiated to an estimated 0.3 x 10^{19} cm^{-2} (>1 MeV). The location of each specimen and the wire dosimeter identifications have been recorded. This activity requires considerable time and resources from the hot cell staff: P. S. Bishop (hot cell operations supervisor), two chemical operators, and a health physics person. The container was pulled from the cell interior and "flashed" into the shipping cask on top of the hot cells. The cask was closed and placed in an "overpack," which was then readied for shipment. The activity of the container was measured to be 14 R/hr and 1 R/h on contact and at 1 ft, respectively. The container and the overpack were also inspected for contamination and the necessary shipping documents were prepared.

An irradiated empty container, with a capacity of 42 Charpy full-sized specimens, and six half-sized specimens, and which was recently used to irradiate Charpy specimens was reused for this purpose. A 3/16-in. steel spacer with nearly the same dimensions as six half-sized specimens, and three steel dummy specimens have been added to completely fill the container. An aluminum cover with tabs has been manufactured to secure the container contents during shipping, and will be removed on location at the University of Michigan FNR.

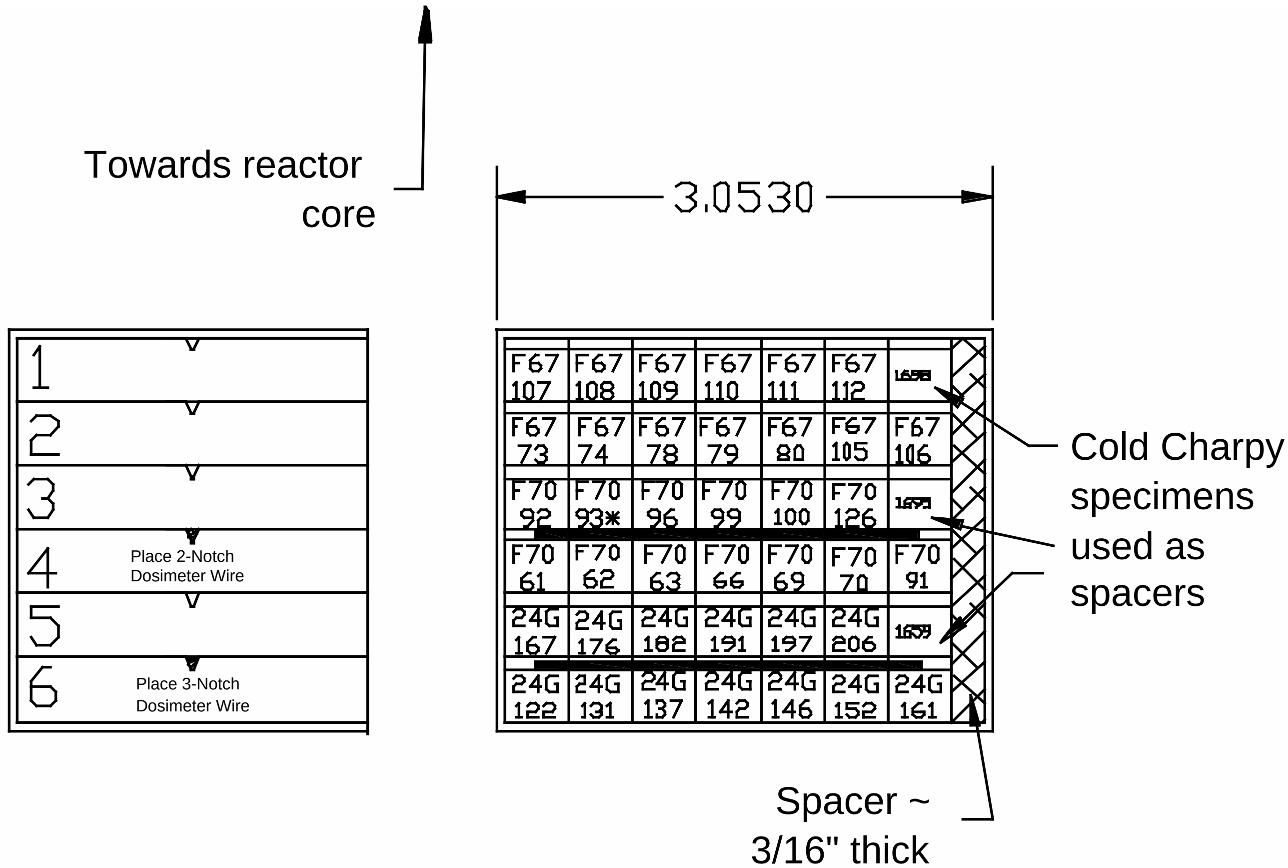
The question of whether to place any dosimeter wires with these specimens has been discussed with Chuck Baldwin and Igor Remec. On the one hand, including the dosimeter wires in the hot cell using manipulators in among the Charpy specimens is difficult especially considering the low dimensional tolerances required by heat transfer considerations. On the other hand, the neutronics of the HSSI IAR capsule have been very well characterized. It was decided that it would be prudent to include the dosimetric wires because over the prolonged irradiation period, estimated to be nearly three years, the reactor core loading cannot be anticipated in advance.

The V-notches of seven each Charpy specimens that occupy a single row were aligned and the dosimeter wires were placed in the grooves of the first and third rows of these specimens. A dosimeter wire was also planned for the fifth row, but could not be placed because of dimensional limitations. When placed in the reactor, the specimen axes will be vertical, with the specimen V-notch towards the reactor core when it is first placed in the capsule. Halfway through the irradiation, the container will be rotated 180˚ about its vertical axis. Thus, the neutrons from the reactor will be streaming parallel to the plane of the Charpy specimen through which fracture will occur during testing (see Figure 1). Because of the presence of the dosimeter wires, packing of the container in the hot cell with manipulators has been a challenge to the operators, particularly since the sheet metal container was warped from being at 300˚C for an extended period of time. In retrospect, it may have been simpler to make a new container.

In the FNR hot cells, the aluminum shipping cover will be removed by bending back the tabs, and the original cover will then be placed in the Charpy container for insertion into either position 2 or position 4 of the HSSI IAR south side capsule. At present, the latter two positions have “dummy” steel blocks to maintain the neutron flux to the configuration in which it was characterized. Since the south side capsule has an average flux of 5×10^{11} cm^{-2} s^{-1} (>1 MeV), there is merit to moving it to the north position, with a flux twice as high, as these become available in the future.

(Milestone 4.5.B) The letter report on RPV materials available for irradiation studies is in progress.

(Milestone 4.5.F) Testing of unirradiated specimens has continued with the high-copper weld given varying time/temperature postweld heat treatments. A Charpy impact energy vs. temperature curve will be obtained for each condition to evaluate toughness as a function of PWHT. If funding can be realized, atom probe tomography will be used to determine the matrix copper contribution as a function of PWHT.



* This specimens was found instead of the F70-95 indicated in MEA report 2553, Fig. 8, row 7.

Dosimeters and Charpy Specimens packed 27 March 2000

Specimens originated from the NRC/MEA low-fluence capsule FNR-17A, irradiated to an estimated 0.3 x 10^{19} cm^{-2} (> 1 MeV). Will be irradiated an additional 1.2 x 10^{19} cm^{-2} in the University of Michigan FNR. To be shipped from ORNL April 3, 2000.

Contents of container to be irradiated in the University of Michigan's Ford Nuclear Reactor.

Task 5: Modeling & Microstructural Analysis (R. E. Stoller)

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 subtasks comprise two major components: (1) theoretical modeling and data analysis, and (2) experimental investigations. The modeling work focuses on 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 consists of special-purpose irradiation experiments to isolate particular irradiation variables (neutron-flux level and energy spectrum), and detailed microstructural characterization of RPV materials in relevant conditions using atom probe and transmission electron microscopy techniques. These conditions include: long-term, thermally-aged, irradiated, post-irradiation mitigation (IA), and reirradiated (IAR). 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 extensive use of the commercial-reactor surveillance data and test-reactor data contained in the NRC-funded Embrittlement Database (EDB), and data generated in other experiments coordinated by this task.

The major areas of inquiry will be: (a) the effects of chemical composition, (b) the role of displacement rate (neutron flux level), (c) the impact of differences in neutron-energy spectrum, (d) potential differences in hardening and embrittlement behavior at very high fluence, and (e) the response of materials that are reirradiated following a post-irradiation mitigation. Damage modeling will also address such questions as attenuation through the RPV wall. 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.

Subtask 5.1: Modeling of damage evolution (R. E. Stoller)

The modeling and analysis work will include completion of the development required to incorporate alloying effects in the embrittlement model. Additional thermodynamic components are needed to account for chemical effects, particularly for the simulation of high-fluence effects and thermal mitigation. Enhancements to the code used for simulating displacement cascades will permit the investigation of the effects of alloying elements on primary damage formation.

(Milestone 5.1.A) No significant activity occurred during this reporting period

Subtask 5.2: Microstructural analysis (R. E. Stoller and M. K. Miller)

Round-Robin studies, using atom probe field-ion microscopy (APFIM), small angle neutron scattering (SANS), and field-emission scanning transmission electron microscopy (FEGSTEM), will be coordinated to resolve the inconsistencies between these techniques that have been used to determine the matrix copper content and the chemical composition of radiation-induced precipitates in RPV materials. Additionally, APFIM characterization will be used to determine whether additional radiation-induced phases are forming.

(Milestone 5.2.A). A paper entitled "Embrittlement of Low Copper VVER 440 Surveillance Samples Neutron Irradiated to High Fluences" by M. K. Miller and K.F. Russell (ORNL) and J. Kocik and E. Keilova (Nuclear Research Institute Rez plc) has been submitted to Journal of Nuclear Materials. This paper describes an atom probe tomography microstructural characterization of low (0.06 at. %) copper surveillance samples from a VVER 440 reactor. The investigation revealed manganese and silicon segregation to dislocations and other ultrafine features in neutron irradiated base and weld materials (fluences $1x10^{21}$ cm^{-2} and $5x10^{20}$ cm^{-2}, E > 0.5 MeV, respectively). The results indicate that there is an additional mechanism of embrittlement during neutron irradiation that manifests itself at high fluences.

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 submitted to the NRC in September.

Subtask 5.3: Experimental verification of neutron flux and energy spectrum effects (R. E. Stoller)

An experimental examination of neutron-flux level (displacement rate) and neutron energy spectrum effects (thermal-to-fast-flux ratio) will be conducted in collaboration with other NRC contractors.

No significant activity occurred in this subtask during this reporting period.

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.

During this reporting period, the reactor operated for the last three days of half-cycle 442B, 10 days of half-cycle 443A, and 5.5 days during half-cycle 443B. Half-cycle 443B started approximately two days late due to reactor instrument problems and it was ended two days early to perform xenon experiments for other experimenters at FNR.
During the last three days of half-cycle 442B, the IAR irradiation facilities received a total of 63 EFPH (effective full power hours). The facilities then received 236 EFPH during half-cycle 443A followed by 129 EFPH during half-cycle 443B, which ended on the last day of this reporting period.

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 746 EFPH. At the end of this reporting period, the second group of specimens had been irradiated for a total of 1174 EFPH. The facilities themselves had been in service for a total of 5502 EFPH

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

This subtask includes supervising the overall operation and provides 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 for during this reporting period.

During this reporting period, the reactor operated for the last three days of half-cycle 442B, 10 days of half-cycle 443A, and 5.5 days during half-cycle 443B. Half-cycle 443B started approximately two days late due to reactor instrument problems and it was ended two days early to perform xenon experiments for other experimenters at FNR.

During the last three days of half-cycle 442B, the UCSB irradiation facility received a total of 63 EFPH (effective full power hours). The facility then received 236 EFPH during half-cycle 443A followed by 129 EFPH during half-cycle 443B, which ended on the last day of this reporting period.

At the beginning of this reporting period, the UCSB facility and original specimen compliment had been irradiated for a total of 12,559 EFPH. At the end of this reporting period the UCSB facility and original specimen compliment had been irradiated for a total of 12,987 EFPH. The latest irradiation plan received from the UCSB experimenters indicates that the final specimens will be removed from the UCSB facility after 13,500 EFPH. At the end of this reporting period, the UCSB irradiation program had obtained 96% of the original desired irradiation time.

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 includes evaluating surveillance reports, entering the data into the EDB, and providing an update to the NRC by the end of the fiscal year.

(Milestone 7.1.A) Work will be reinitiated beginning in the next reporting period.

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 March 14-15, 2000, S. K. Iskander traveled to Nashville, Tenn., to participate in and present a paper at the 129th Annual TMS (The Minerals, Metals, and Materials Society) Meeting.

On March 19-21, 2000, R. K. Nanstad traveled to Rockville, Maryland, for meetings with NRC staff concerning reactor pressure vessels.

4. PRESENTATIONS, REPORTS, PAPERS, AND PUBLICATIONS:

J. R. Hawthorne, M. A. Sokolov, and W. L. Server, "Exploratory Test of 288ºC Radiation Resistance of Two USSR-Produced Reactor Pressure Vessel Steels," *Effects of Radiation on Materials: 19th International Symposium, ASTM STP 1366*, M. L. Hamilton, A. S. Kumar, S. T. Rosinski, M. L. Grossbeck, 2000, pp.16-32.

J. A. Wang, "Analysis of Irradiation Data for A302B and A533B Correlation Monitor Materials," *Effects of Radiation on Materials: 19th International Symposium, ASTM STP 1366*, M. L. Hamilton, A. S. Kumar, S. T. Rosinski, M. L. Grossbeck, 2000, pp. 33-55.

S. K. Iskander, R. K. Nanstad, D. E. McCabe, and R. L. Swain, "Effects of Irradiation on Crack-Arrest Toughness of a Low Upper-Shelf Energy, High-Copper Weld," *Effects of Radiation on Materials: 19th International Symposium, ASTM STP 1366*, M. L. Hamilton, A. S. Kumar, S. T. Rosinski, M. L. Grossbeck, 2000, pp. 245-265.

D. E. McCabe, R. K. Nanstad, and M. A. Sokolov, "Effects of Irradiation and Thermal Annealing on Fracture Toughness of the Midland Reactor Weld WF-70," *Effects of Radiation on Materials: 19th International Symposium, ASTM STP 1366,* M. L. Hamilton, A. S. Kumar, S. T. Rosinski, M. L. Grossbeck, 2000, pp. 306-322.

M. A. Sokolov, A. A. Chernobaeva, R. K. Nanstad, Y. A. Nikolaev, and Y. N. Korolev, "Irradiation, Annealing, and Reirradiation Effects on American and Russian Reactor Pressure Vessel Steels," *Effects of Radiation on Materials: 19th International Symposium, ASTM STP 1366*, M. L. Hamilton, A. S. Kumar, S. T. Rosinski, M. L. Grossbeck, 2000, pp.415-434.

R. E. Stoller and L. R. Greenwood, "an Evaluation of Neutron Energy Spectrum Effects in Iron Based on Molecular Dynamics Displacement Cascade Simulations," *Effects of Radiation on Materials: 19th International Symposium, ASTM STP 1366*, M. L. Hamilton, A. S. Kumar, S. T. Rosinski, M. L. Grossbeck, 2000, pp. 548-559.

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:

None

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: 2/21/00 - 3/26/00

		Current Month (MM)	Fiscal Year to Date (MY)	Cumulative Project to date
I.	Direct Staff Effort	9	4.5	24.4
II.	A. Direct Lab Staff Effort ($)			
	Direct Salaries	71,583	496,443	2,549,682
	Materials and Services	2,374	17,288	338,452
	ADP Support	67	402	1,403
	Subcontracts	48,129	57,338	254,642
	Travel	-1,021	4,527	95,035
	Indirect Labor Costs	0	0	0
	Other: NRC PO Tax	4,000	21,000	114,500
	General and Administrative	33,837	213,291	1,160,141
	Total LMER Costs	158,969	810,289	4,513,855
	B. DOE Added Factor Costs	0	0	0
	TOTAL PROJECT COSTS	158,969	810,289	4,513,855
	Percentage of available cumulative funds costed		80	
	Percentage of available current FY funds costed		43	
	Funds Remaining		1,096,145	

III. Funding Status

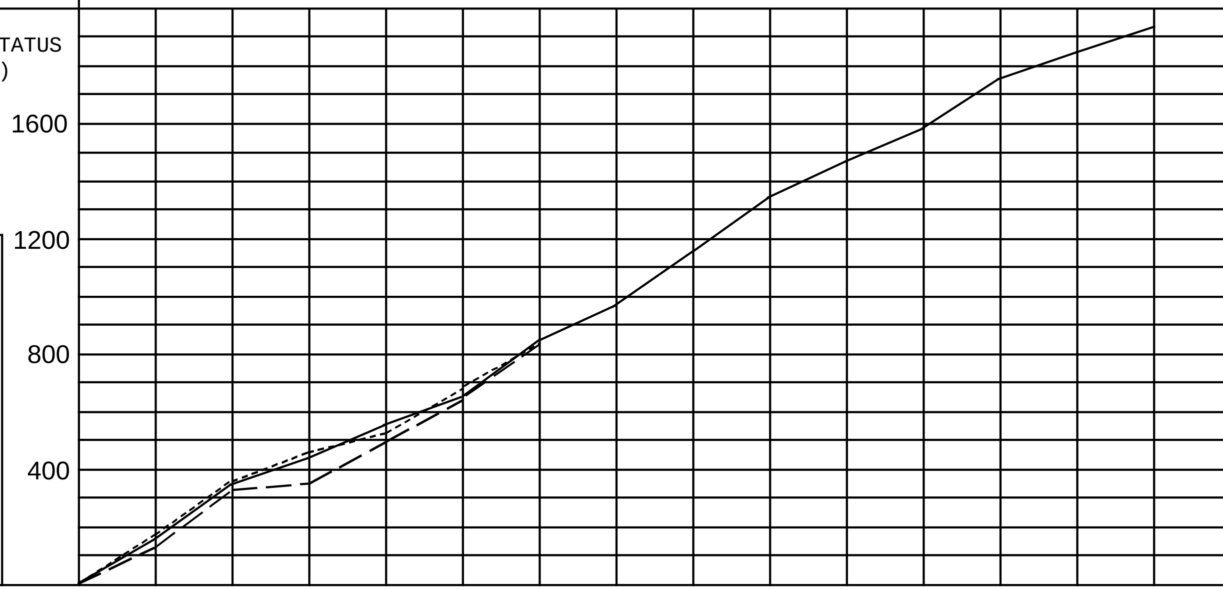
Prior FY Carryover	FY 00 Projected Funding Level	FY 00 Funds Received to Date	FY 00 Funding Balance Needed	Cumulative Amt. Obligated
306,434	1,625,000	1,600,000	25,000	5,610,000

Comments:

1. CONTRACT REPORTING ELEMENT **HSSI - Heavy-Section Steel Irradiation Program**	2. REPORTING PERIOD **2/21/00 - 3/26/00**	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 1999-2000** 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. 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: 1/31/00

PLANNED COSTS FOR ELEMENT ($K): 1,906

ELEMENT COSTS FOR PRIOR FYS ($K): 306

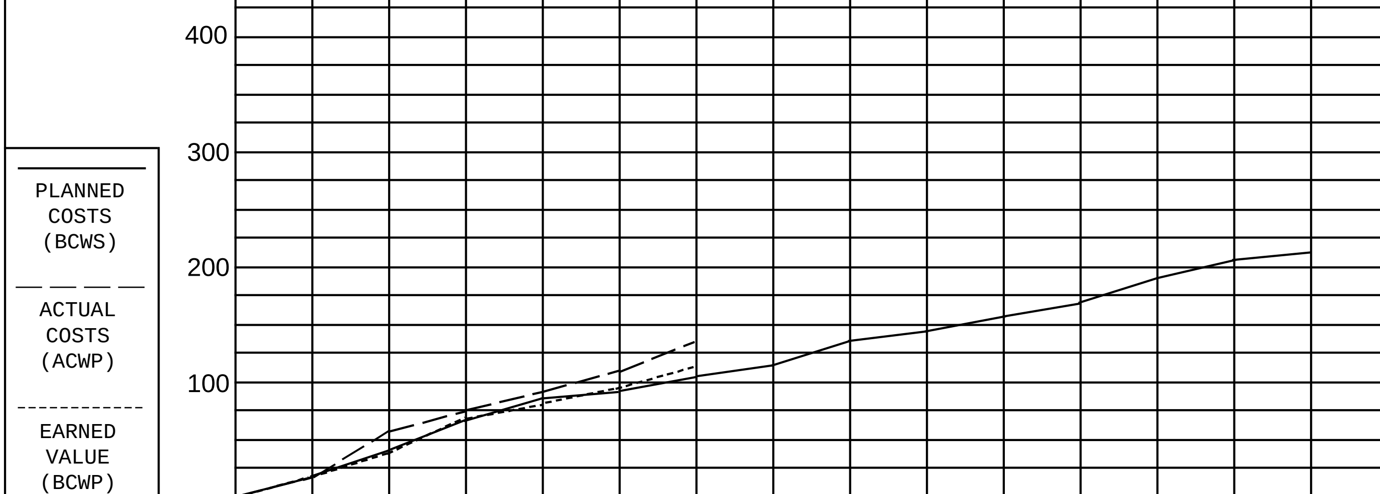
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	168	156	99	115	118	166	163	166	172	142	132	140	100	69	
ACTUAL	113	207	29	149	153	159									
EARNED	140	157	104	107	172	139									
CUM. PLAN.	168	324	423	538	656	822	985	1151	1323	1465	1597	1737	1837	1906	
CUM. ACT.	113	320	349	498	651	810									
CUM. EARN.	177	334	434	508	680	819									

11. REMARKS:

1. CONTRACT REPORTING ELEMENT **HSSI - 1. Program Management**	2. REPORTING PERIOD **2/21/00 - 3/26/00**	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 1999-2000**	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. MONTHS: O N D J F M A M J J A S O N D

10. COST STATUS ($K)



COST PLAN DATES	PLANNED COSTS FOR ELEMENT ($K)	ELEMENT COSTS FOR PRIOR FYS ($K)
1/4/00	219	29

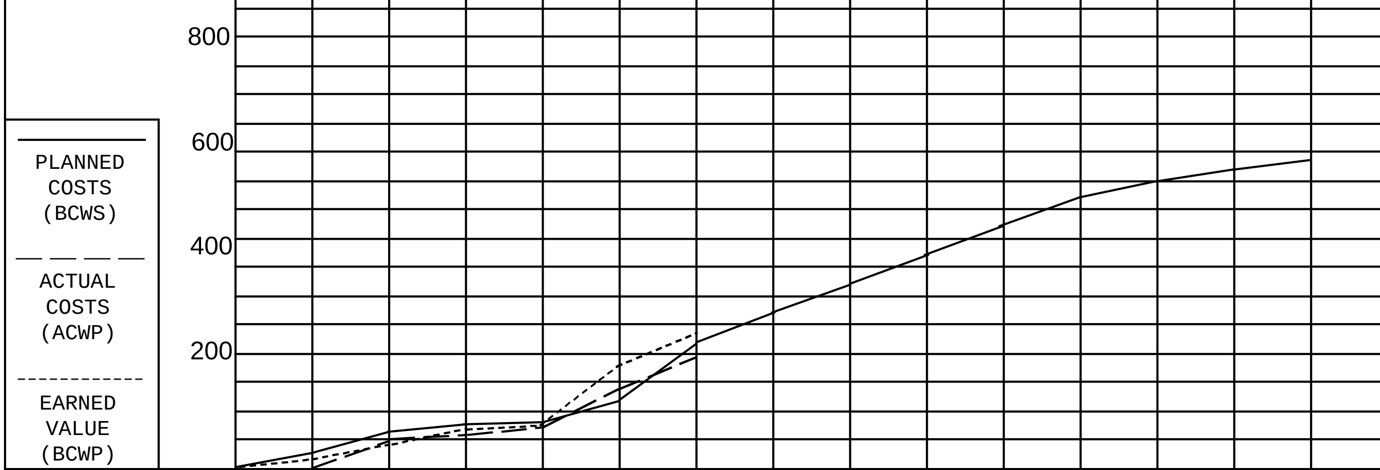
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	18	25	21	17	13	11	12	13	15	12	14	20	13	15	
ACTUAL	18	37	20	17	21	19									
EARNED	18	24	23	14	18	13									
CUM. PLAN.	18	43	64	81	94	105	117	130	145	157	171	191	204	219	
CUM. ACT.	18	55	75	92	113	132									
CUM. EARN.	18	42	65	79	97	110									

11. REMARKS:

1. CONTRACT REPORTING ELEMENT **HSSI - 2. Fracture Toughness Transition and MC Methodology**	2. REPORTING PERIOD **2/21/00 - 3/26/00**	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 1999-2000** 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. MONTHS: O N D J F M A M J J A S O N D

10. COST STATUS ($K)



COST PLAN DATES: 1/31/00

PLANNED COSTS FOR ELEMENT ($K): 539

ELEMENT COSTS FOR PRIOR FYS ($K): 21

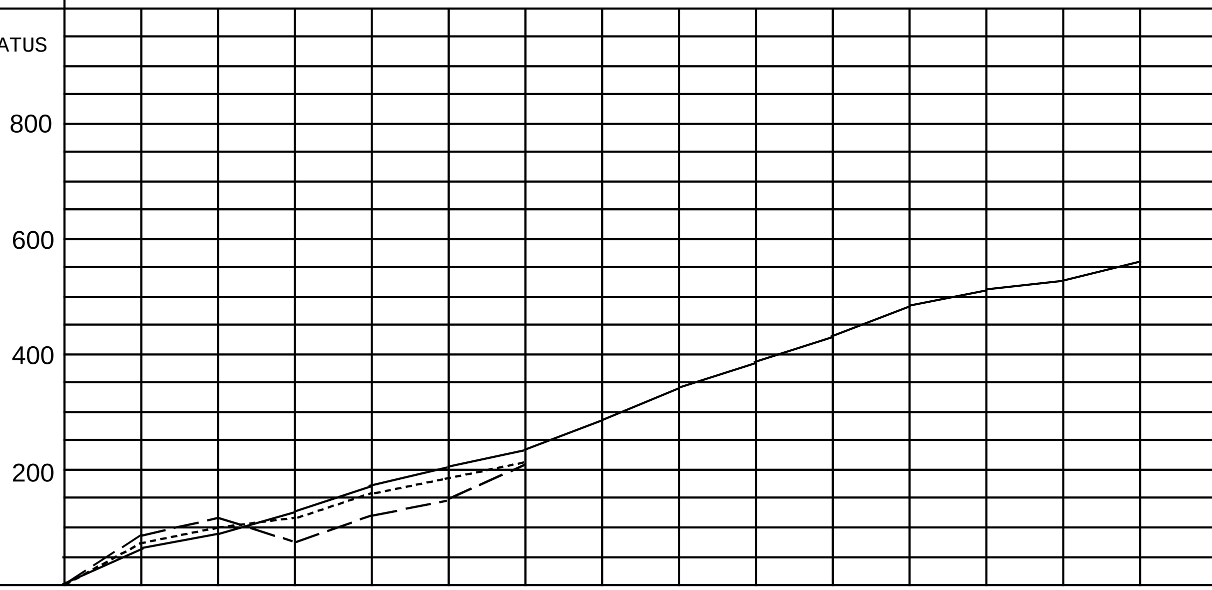
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	29	25	14	20	36	80	57	55	47	52	45	39	25	15	
ACTUAL	-18	43	14	50	53	53									
EARNED	24	24	11	26	89	59									
CUM. PLAN.	29	54	68	88	124	204	261	316	363	415	460	499	524	539	
CUM. ACT.	-18	25	39	89	142	195									
CUM. EARN.	24	48	59	87	174	233									

11. REMARKS:

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 3. Irradiation Embrittlement of RPV Steel	**2/21/00 - 3/26/00**	**W6953**
4. CONTRACTOR (NAME AND ADDRESS)	5. CONTRACT PERIOD	6. ACTIVITY NUMBER
OAK RIDGE NATIONAL LABORATORY	**FY 1999-2000**	**41 W6 95 3W 1**
P.O. BOX 2008	7. NRC B&R NO.	8. DOE B&R NO.
OAK RIDGE, TN 37831	**860 15 21 20 05**	**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) — dashed line

EARNED VALUE (BCWP) — dotted line

COST PLAN DATES: 1/31/00

PLANNED COSTS FOR ELEMENT ($K): 552

ELEMENT COSTS FOR PRIOR FYS ($K): 167

ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	52	43	30	41	35	42	46	52	51	41	41	32	24	22	
ACTUAL	92	31	-50	48	28	62									
EARNED	48	42	29	33	28	33									
CUM. PLAN.	52	95	125	166	201	243	289	341	392	433	474	506	530	552	
CUM. ACT.	92	123	73	121	149	211									
CUM. EARN.	48	90	119	152	180	213									

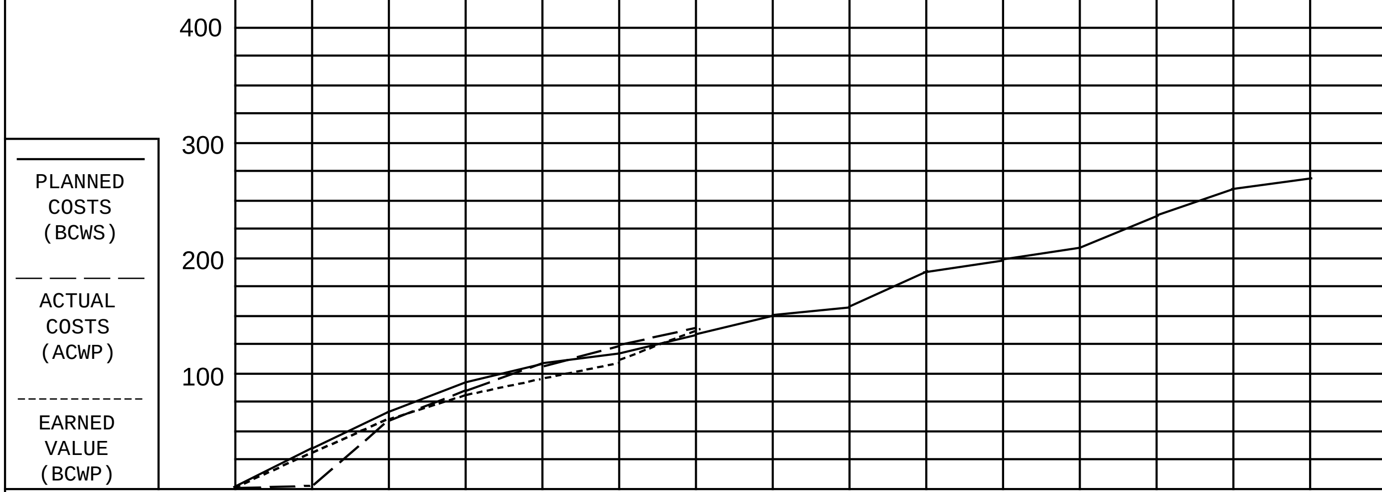
11. REMARKS:

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 4. Validation of Irradiated and Aged Materials	**2/21/00 - 3/26/00**	**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 1999-2000**	**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. MONTHS: O N D J F M A M J J A S O N D

10. COST STATUS ($K)



COST PLAN DATES	PLANNED COSTS FOR ELEMENT ($K)	ELEMENT COSTS FOR PRIOR FYS ($K)
1/31/00	272	30

ACCRUED COSTS ($K)

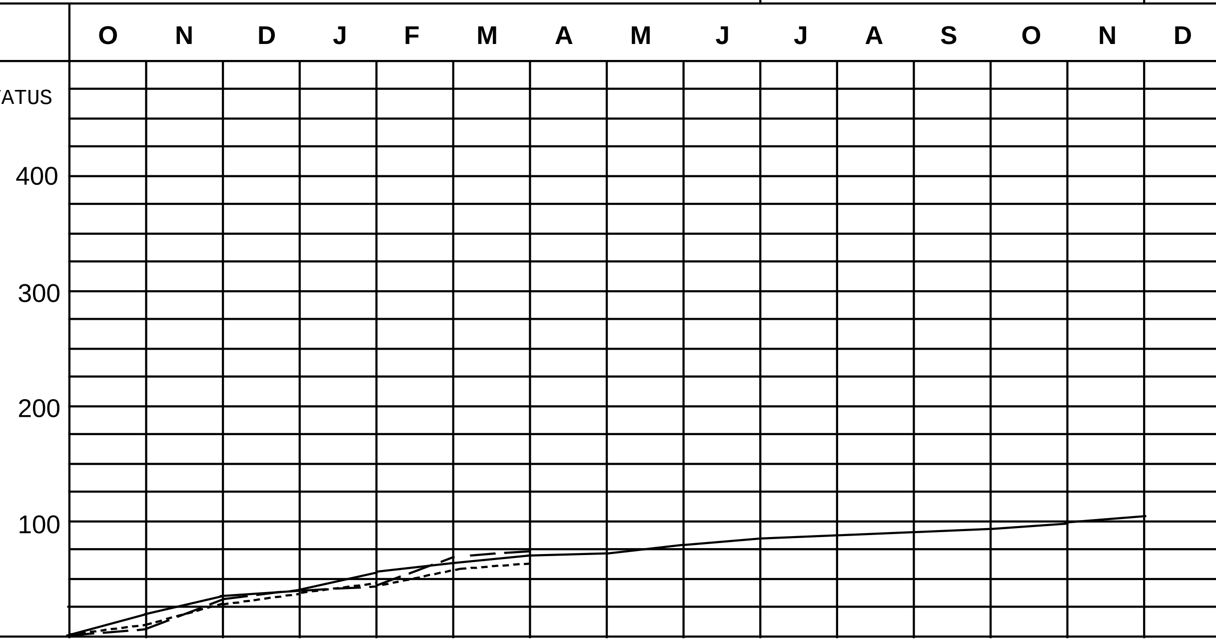
	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	35	37	20	15	11	12	20	15	18	17	13	23	22	14	
ACTUAL	1	57	29	20	17	13									
EARNED	30	31	23	14	15	18									
CUM. PLAN.	35	72	92	107	118	130	150	165	183	200	213	236	258	272	
CUM. ACT.	1	58	87	107	124	137									
CUM. EARN.	30	61	84	98	113	131									

11. REMARKS:

1. CONTRACT REPORTING ELEMENT **HSSI - 5. Modeling and Microstructural Analysis**	2. REPORTING PERIOD **2/21/00 - 3/26/00**	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 1999-2000** 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. 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: 1/4/00

PLANNED COSTS FOR ELEMENT ($K): 102

ELEMENT COSTS FOR PRIOR FYS ($K): 42

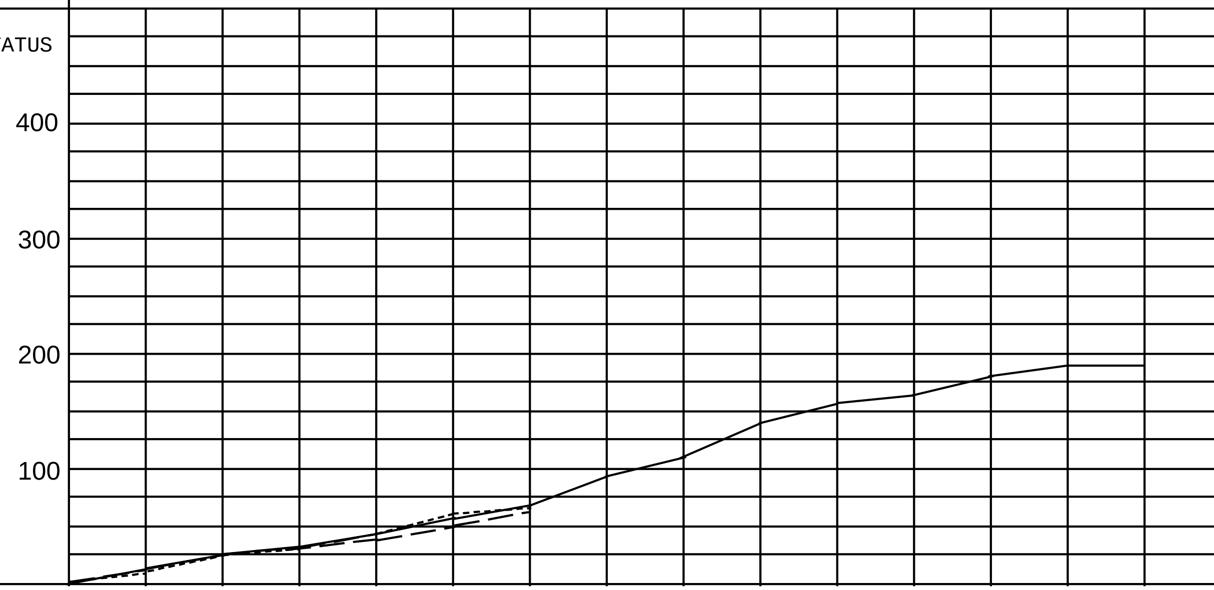
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	20	15	5	12	13	5	3	3	6	4	3	5	5	3	
ACTUAL	4	29	7	5	24	5									
EARNED	5	25	9	9	10	4									
CUM. PLAN.	20	35	40	52	65	70	73	76	82	86	89	94	99	102	
CUM. ACT.	4	33	40	45	69	74									
CUM. EARN.	5	30	39	48	58	62									

11. REMARKS:

1. CONTRACT REPORTING ELEMENT **HSSI - 6. Irradiation Coordination**	2. REPORTING PERIOD **2/21/00 - 3/26/00**	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 1999-2000** 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. 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: 1/4/00

PLANNED COSTS FOR ELEMENT ($K): 187

ELEMENT COSTS FOR PRIOR FYS ($K): 17

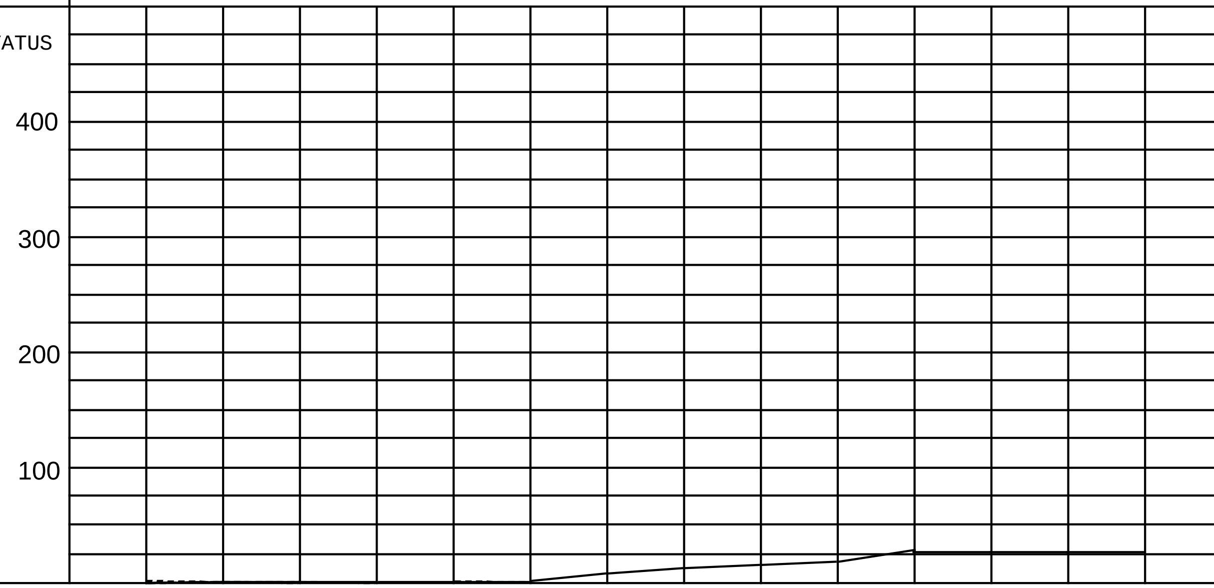
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	10	9	10	10	10	15	20	23	30	11	11	11	11	0	
ACTUAL	16	9	9	9	10	7									
EARNED	15	10	9	11	12	12									
CUM. PLAN.	16	25	35	45	55	70	90	113	143	154	165	176	187	187	
CUM. ACT.	16	25	34	43	53	60									
CUM. EARN.	15	25	34	45	57	69									

11. REMARKS:

1. CONTRACT REPORTING ELEMENT **HSSI - 7. Embrittlement DB & Dosimetry Evaluation**	2. REPORTING PERIOD **2/21/00 - 3/26/00**	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 1999-2000** 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. 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: 1/4/00

PLANNED COSTS FOR ELEMENT ($K): 26

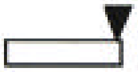
ELEMENT COSTS FOR PRIOR FYS ($K): 1

ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	0	1	0	0	0	0	5	5	5	5	5	0	0	0	
ACTUAL	0	1	0	0	0	0									
EARNED	0	1	0	0	0	0									
CUM. PLAN.	0	1	1	1	1	1	6	11	16	21	26	26	26	26	
CUM. ACT.	0	1	1	1	1	1									
CUM. EARN.	0	1	1	1	1	1									

11. REMARKS:

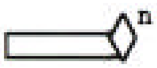
Milestone Symbology


Intermediate milestone planned

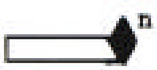

Intermediate milestone completed


Major milestone planned


Major milestone completed



Rescheduled milestone planned

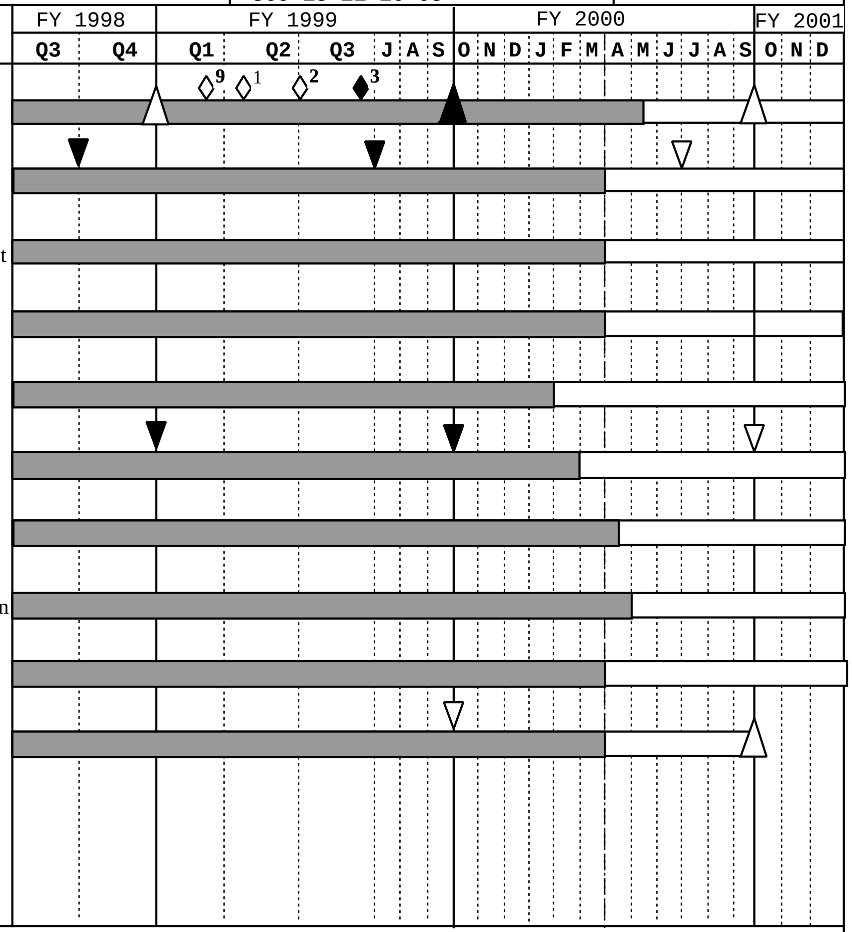


Rescheduled milestone completed

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

1. CONTRACT REPORTING ELEMENT **HSSI - 1. Program Management**	2. REPORTING PERIOD **2/21/00 - 3/26/00**	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 1998-2001** 7. NRC B&R NO. **860 15 21 20 05**	6. ACTIVITY NO. **41 W6 95 3W 1** 8. DOE B&R NO. **40 10 01 06**

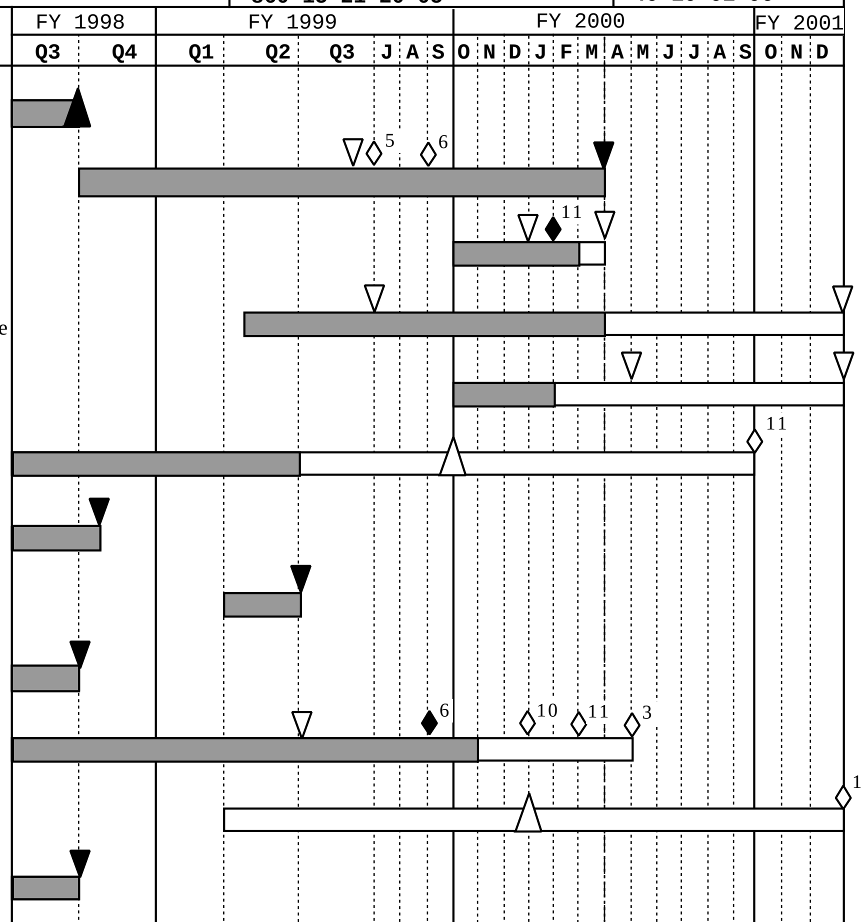
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
1.1.A.	Issue Project & Budget Proposal
1.1.B.	Select and Administer Subcontracts
1.2.A.	Issue Earned Value Based Monthly Management Reports (by the end of subsequent month)
1.2.B.	Ensure QA Requirements are met
1.3.A.	Participate in Appropriate Codes and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



11. REMARKS

1. CONTRACT REPORTING ELEMENT **HSSI - 2. Fracture Toughness Transition & MC Methodology**	2. REPORTING PERIOD **2/21/00 - 3/26/00**
	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 1998-2001**
	6. ACTIVITY NO. **41 W6 95 3W 1**
	7. NRC B&R NO. **860 15 21 20 05**
	8. DOE B&R NO. **40 10 01 06**

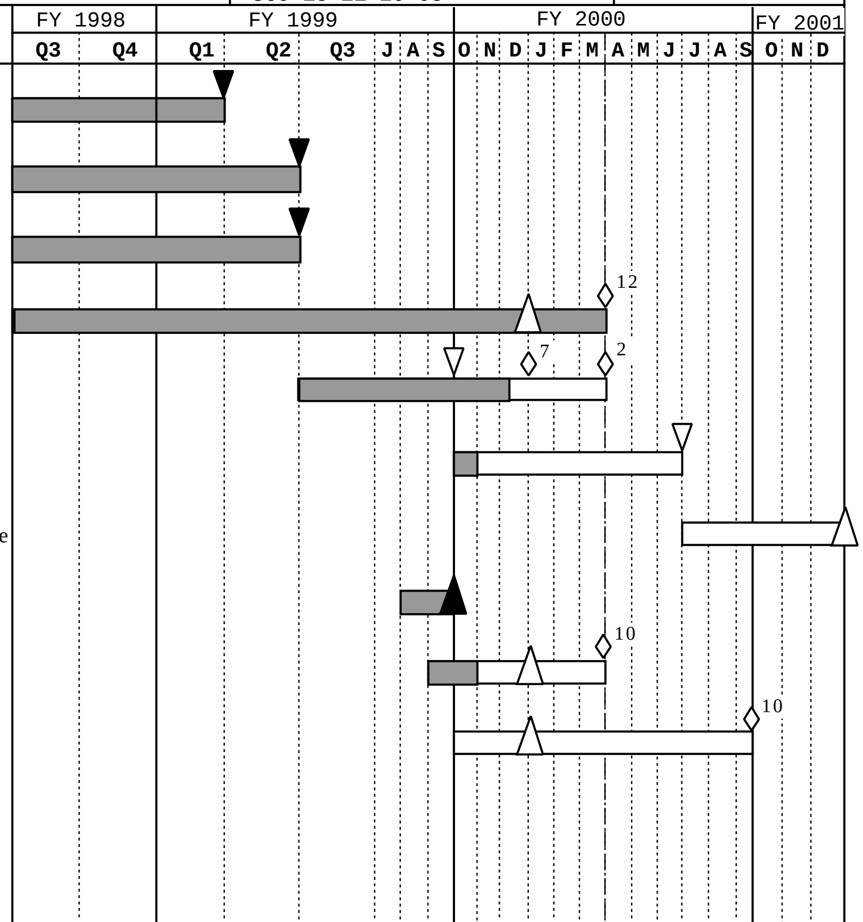
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
2.1.A.	Complete Draft NUREG Report on Comparison of CVN and Fracture Toughness Shifts
2.2.A.	Sample Preparation and Irradiation for Master Curve
2.2.B.	Receive Specimens
2.2.C.	Test Unirradiated & Irradiated Master Curve Specimens
2.2.D.	Draft Letter and NUREG Reports
2.3.A.	Design, Fabrication, Calibration, Evaluation and NUREG Report for Phase I
2.4.A.	Midland Weld Evaluations
2.4.B.	Pressure Vessel and Piping (ASME) Report
2.5.A.1.	Test Midland Crack Arrest Specimens
2.5.A.2.	Analyze Crack Arrest Data & Draft NUREG
2.5.B.	Prepare a Comprehensive NUREG
2.6.A.	IG Fracture Obtain & Machine HT Pieces



11. REMARKS

1. CONTRACT REPORTING ELEMENT **HSSI - 2. Fracture Toughness Transition & MC Methodology**	2. REPORTING PERIOD **2/21/00 - 3/26/00**	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 1998-2001** 7. NRC B&R NO. **860 15 21 20 05**	6. ACTIVITY NO. **41 W6 95 3W 1** 8. DOE B&R NO. **40 10 01 06**

9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
2.6.B.	Age & Evaluate by CVN
2.6.C.	Machine C(T)s and Test
2.6.D.	MC Impact Evaluations
2.6.E.	Reports and Administration
2.7.A.	Complete Fabrication and Preliminary Testing of Subsize Specimen
2.7.B.	Complete Testing of Subsize Specimens
2.7.C.	Complete NUREG Report on Results of Subsize Specimen Fracture Toughness Tests
2.7.D	Fabricate A302B PCVNs from 3 Heats
2.7.E.	Test and Analyze
2.7.F.	Prepare Letter Report



11. REMARKS

1. CONTRACT REPORTING ELEMENT
HSSI - 2. Fracture Toughness Transition & MC Methodology

2. REPORTING PERIOD
2/21/00 - 3/26/00

3. JCN NO.
W6953

4. CONTRACTOR (NAME AND ADDRESS)
OAK RIDGE NATIONAL LABORATORY
P.O. BOX 2008
OAK RIDGE, TN 37831

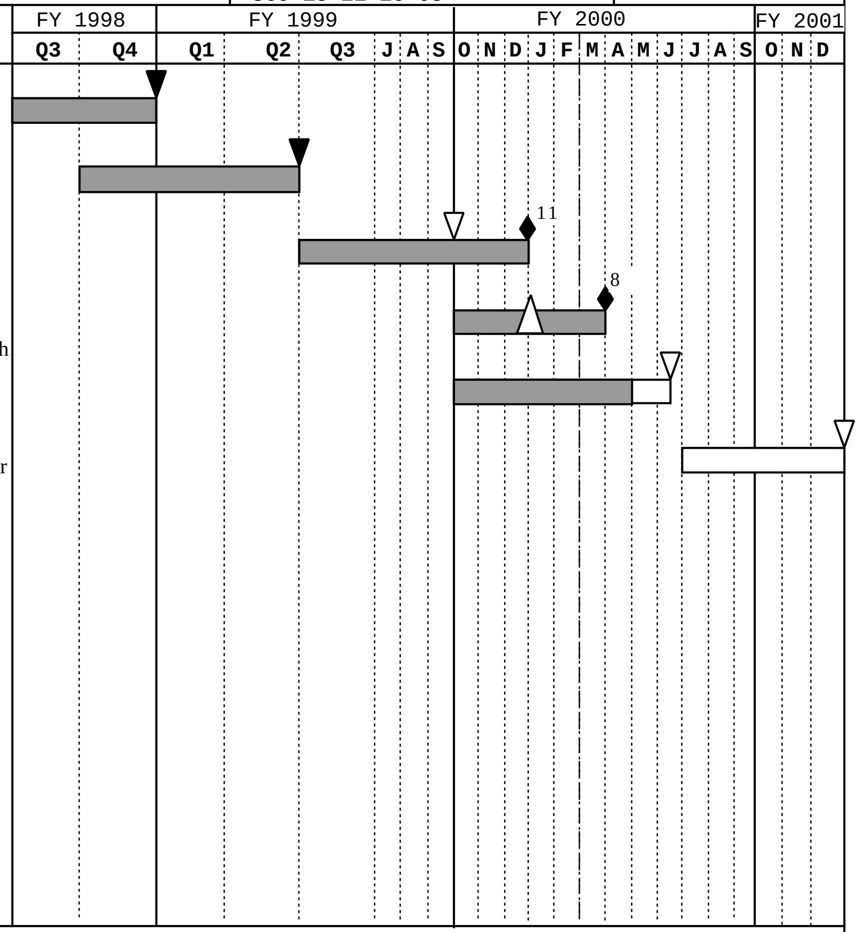
5. CONTRACT PERIOD
FY 1998-2001

6. ACTIVITY NO.
41 W6 95 3W 1

7. NRC B&R NO.
860 15 21 20 05

8. DOE B&R NO.
40 10 01 06

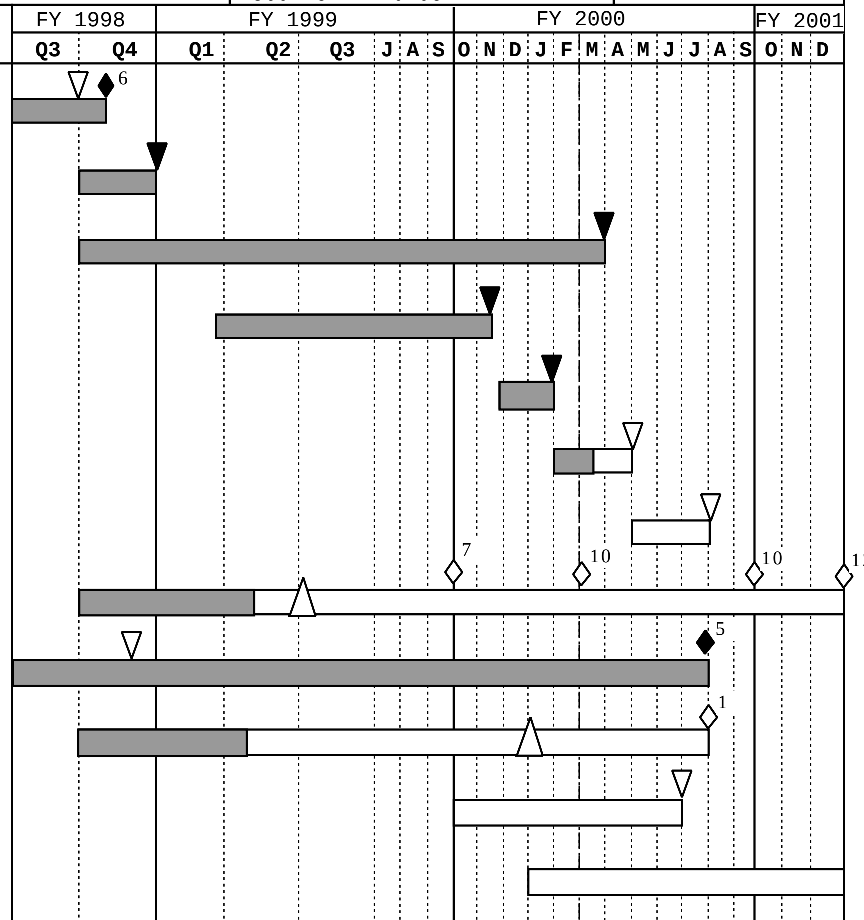
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
2.8.A.	Complete Plan for Assembly and Compilation of Surrogate Materials Data Base
2.8.B.	Complete Assembly and Compilation for Unirradiated Materials
2.8.C.	Complete Statistical Analyses of Data Base for Unirradiated Materials
2.8.D.	Complete Draft NUREG Report on Guidelines for use of Surrogate Materials to Establish
2.8.E.	Complete Assembly and Compilation for Irradiated Materials
2.8.F.	Complete Statical Analysis of Data Base for Irradiated materials



11. REMARKS

1. CONTRACT REPORTING ELEMENT **HSSI - 3. Irradiation Embrittlement of RPV Steel**	2. REPORTING PERIOD **2/21/00 - 3/26/00**	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 1998-2001** 7. NRC B&R NO. **860 15 21 20 05**	6. ACTIVITY NO. **41 W6 95 3W 1** 8. DOE B&R NO. **40 10 01 06**

9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
3.1.A.	Age HAZ Materials
3.1.B.	Machine CVN Specimens
3.1.C.	Evaluate Results and Prepare Letter Report
3.1.D.	Irradiate Capsules
3.1.E.	Ship Specimens
3.1.F.	Test Specimens
3.1.G.	NUREG Report
3.2.A.	NUREG on IA Work to Date
3.2.B.	Dosimetry of 30 CVNs
3.2.C.	NUREG on 30 CVNs (IAR)
3.2.D.	Test Plan for Critical Materials
3.2.E.	IAR of Critical Materials



11. REMARKS

1. CONTRACT REPORTING ELEMENT
HSSI - 3. Irradiation Embrittlement of RPV Steel

2. REPORTING PERIOD
2/21/00 - 3/26/00

3. JCN NO.
W6953

4. CONTRACTOR (NAME AND ADDRESS)
OAK RIDGE NATIONAL LABORATORY
P.O. BOX 2008
OAK RIDGE, TN 37831

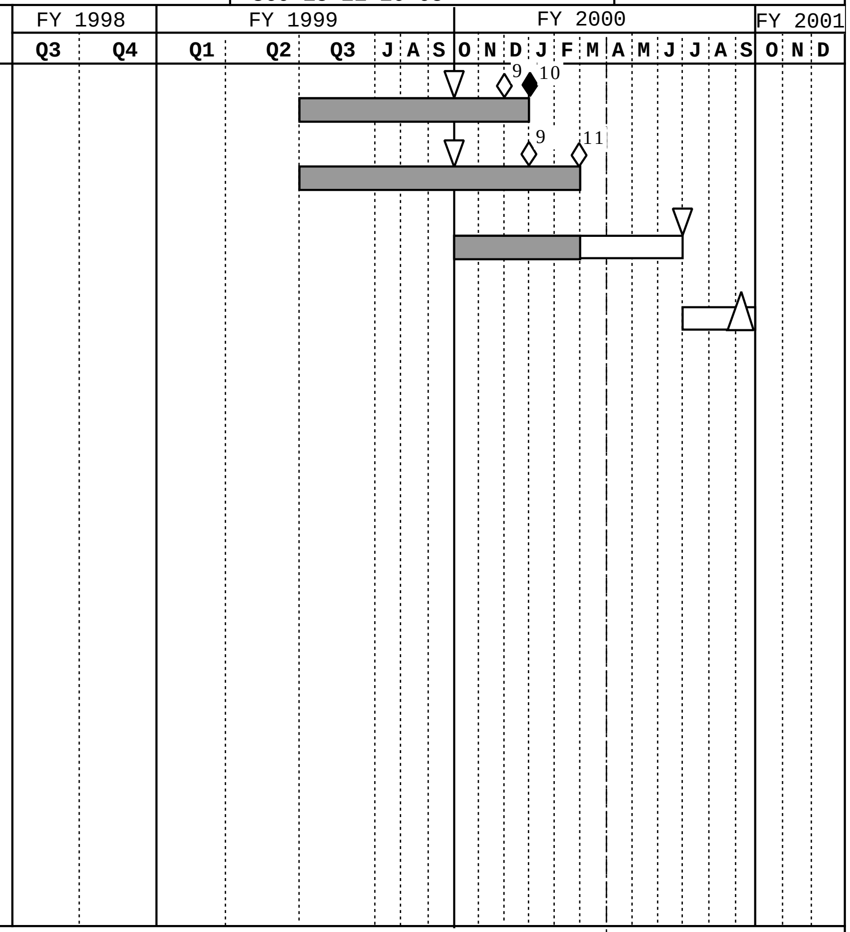
5. CONTRACT PERIOD
FY 1998-2001

6. ACTIVITY NO.
41 W6 95 3W 1

7. NRC B&R NO.
860 15 21 20 05

8. DOE B&R NO.
40 10 01 06

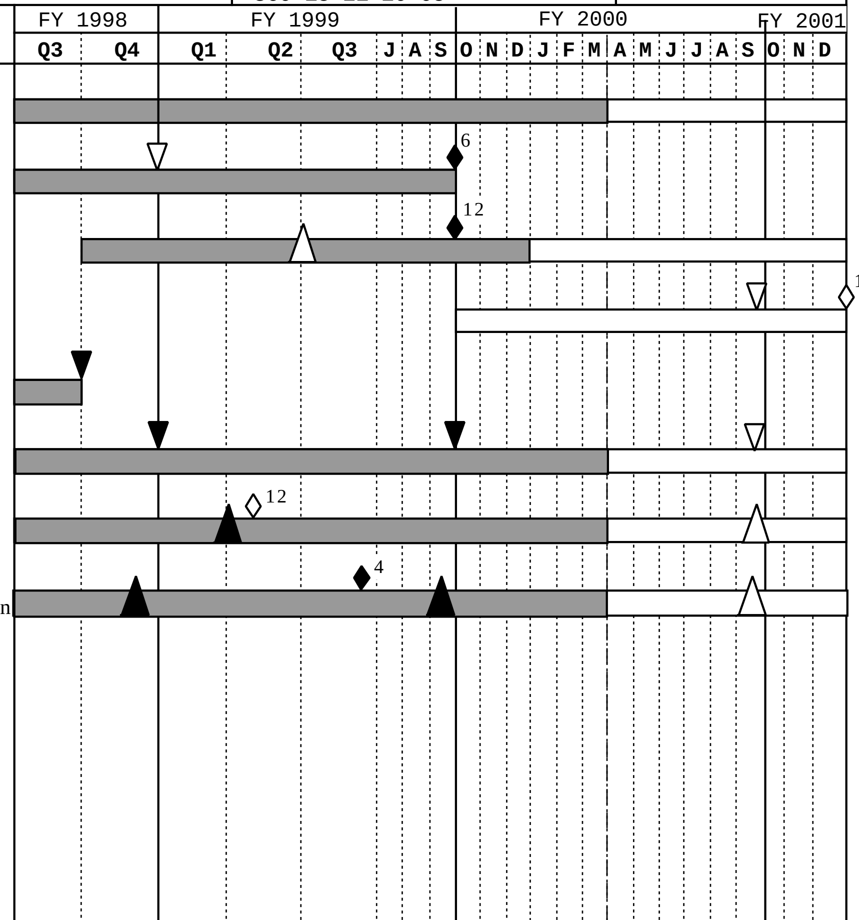
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
3.3.A.	Ship JRQ Specimens From PSI to ORNL
3.3.B.	Complete Test Plan
3.3.C.	Complete JRQ Specimen Testing
3.3.D.	Complete Draft NUREG Report on IAR Results of JRQ



11. REMARKS

1. CONTRACT REPORTING ELEMENT **HSSI - 4. Validation of Irradiated and Aged Materials**	2. REPORTING PERIOD **2/21/00 - 3/26/00**
	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 1998-2001**
	6. ACTIVITY NO. **41 W6 95 3W 1**
	7. NRC B&R NO. **860 15 21 20 05**
	8. DOE B&R NO. **40 10 01 06**

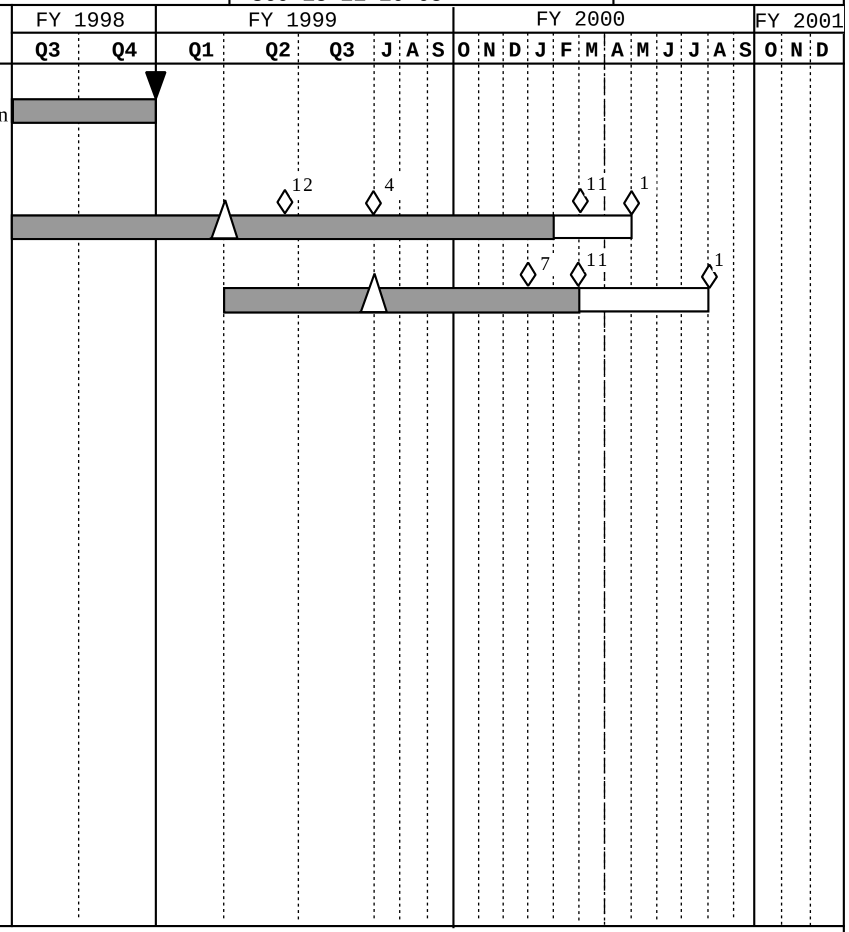
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
4.1.1.A.	JPDR Information Exchange with JAERI
4.1.1.B.	Machining & Inspection of JPDR
4.1.1.C.	Testing, Letter & NUREG Report
4.1.3	Maine Yankee RPV Feasibility Study
4.3.B.	Complete Draft NUREG Report on Thermal Aging of SS Welds
4.4.A.	Complete Preparation of List of Anticipated Foreign Travel
4.4.B.	Participate in Periodic Meetings of IGRDM
4.4.C.	Complete Progress Reports of Collaboration Activities



11. REMARKS

1. CONTRACT REPORTING ELEMENT **HSSI - 4. Validation of Irradiated and Aged Materials**	2. REPORTING PERIOD **2/21/00 - 3/26/00**
	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 1998-2001**
	6. ACTIVITY NO. **41 W6 95 3W 1**
	7. NRC B&R NO. **860 15 21 20 05**
	8. DOE B&R NO. **40 10 01 06**

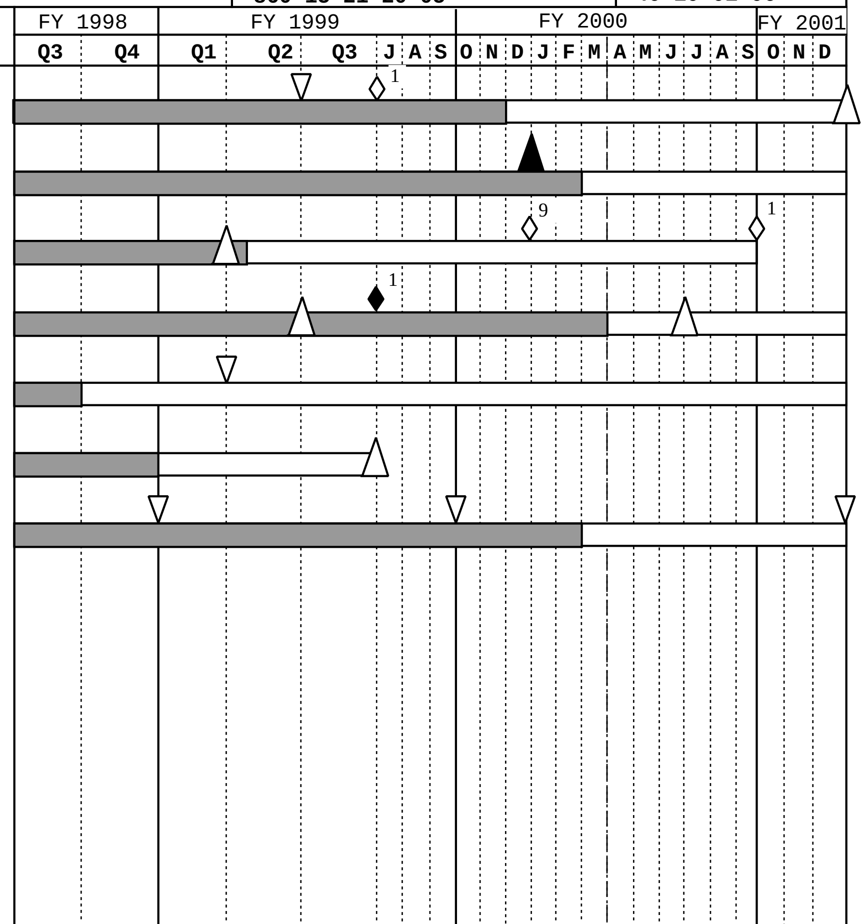
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
4.5.A.	Complete Plans for Testing of Specimens in MEA Capsule, Procurement and Testing of Palisades Capsule & Evaluation of PWHT Sheets
4.5.B.	Complete Letter Report Regarding RPV Materials Available for Irradiation Study
4.5.D.	Complete Letter Report on Test results From MEA Capsule



11. REMARKS

1. CONTRACT REPORTING ELEMENT **HSSI - 5. Modeling & Microstructural Analysis**	2. REPORTING PERIOD **2/21/00 - 3/26/00**	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 1998-2001** 7. NRC B&R NO. **860 15 21 20 05**	6. ACTIVITY NO. **41 W6 95 3W 1** 8. DOE B&R NO. **40 10 01 06**

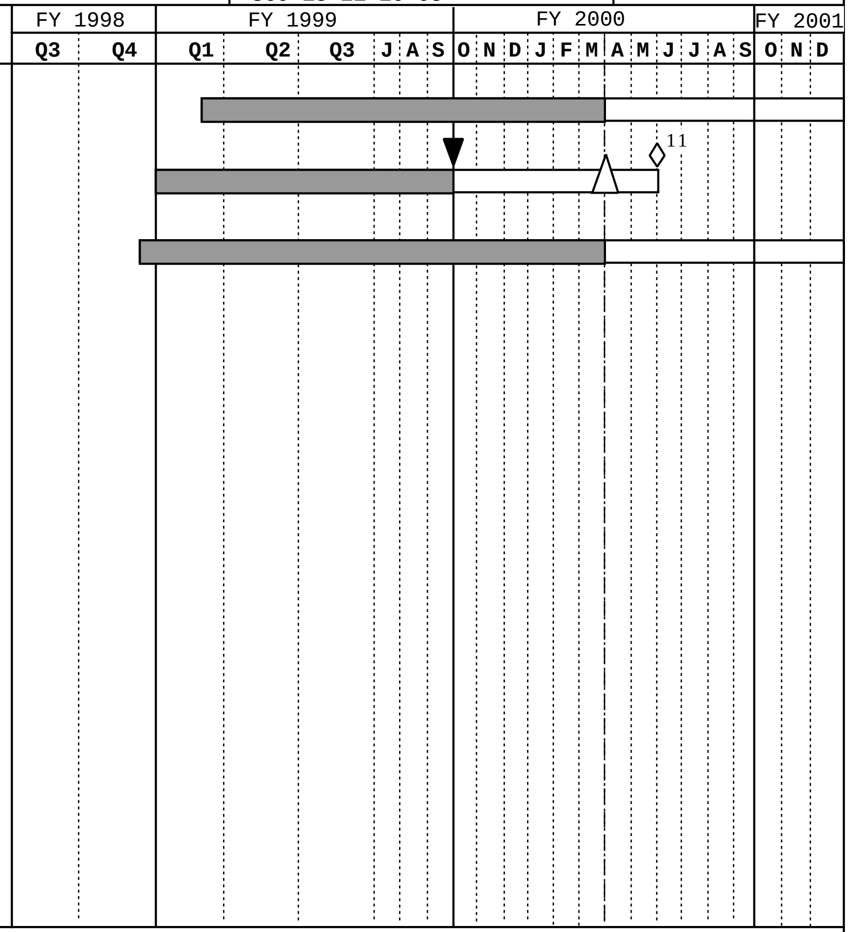
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
5.1.A.	Development and Predictive use of Embrittlement Model
5.1.B.	Model Validation and Data Analysis
5.2.A.	Coordinate and Analyze APFIM/SANS/FEGSTEM Round Robin Experiment
5.2.B.	APFIM Characterization
5.3.A.	Conduct and Coordinate Experiments in HFIR HFBR, and FNR
5.3.B.	High-Flux Irradiation-Annealing-Reirradiation in HFIR
5.4	Administration of Task Activities



11. REMARKS

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 6. Irradiation Coordination	**2/21/00 - 3/26/00**	**W6953**
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P.O. BOX 2008** **OAK RIDGE, TN 37831**	5. CONTRACT PERIOD **FY 1998-2001** 7. NRC B&R NO. **860 15 21 20 05**	6. ACTIVITY NO. **41 W6 95 3W 1** 8. DOE B&R NO. **40 10 01 06**

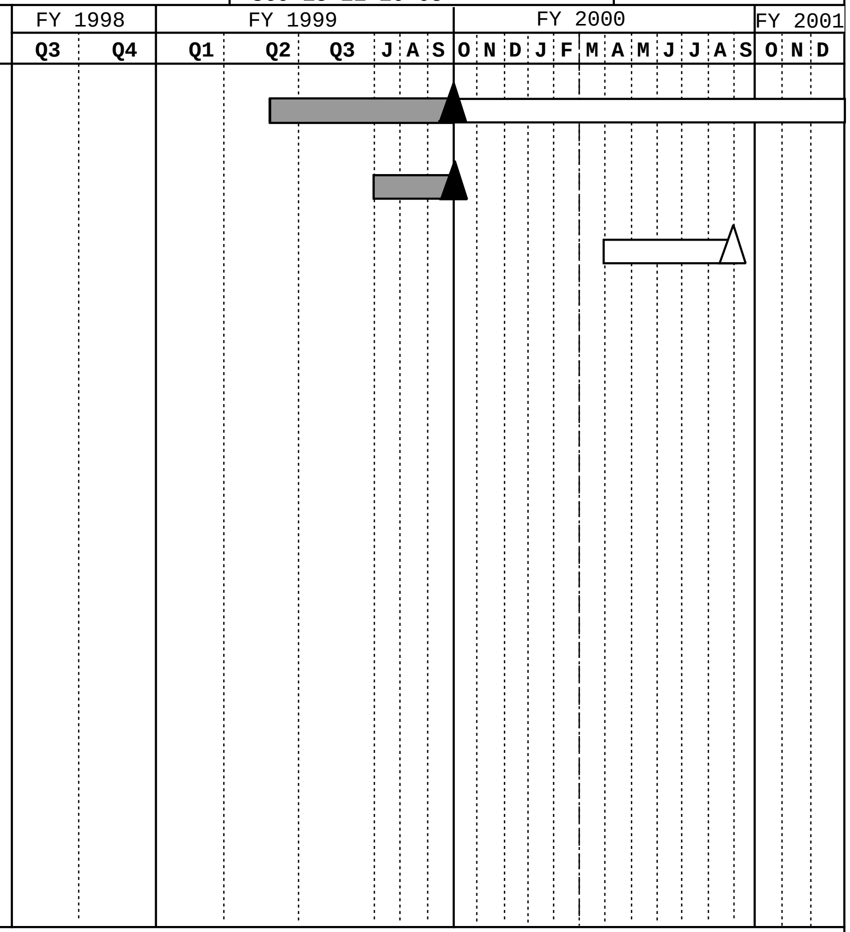
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
6.1.A.	Coordinate the Operation, Data Collection, and Maintenance of the HSSI IAR Facility
6.1.B.	Comprehensive Report on Reusable Irradiation Facilities
6.2.A.	Coordinate the Operation, Data Collection, and Maintenance of the UCSB Irrad.Facility



11. REMARKS

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 7. Embrittlement DB & Dosimetry Evaluation	**2/21/00 - 3/26/00**	**W6953**
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P.O. BOX 2008** **OAK RIDGE, TN 37831**	5. CONTRACT PERIOD **FY 1998-2001** 7. NRC B&R NO. **860 15 21 20 05**	6. ACTIVITY NO. **41 W6 95 3W 1** 8. DOE B&R NO. **40 10 01 06**

9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
7.1.A.	Evaluate and Input Surveillance Reports into Embrittlement Database
7.1.B.	Complete Update 10
7.1.C.	Complete Update 11



11. REMARKS