ORNL/HSSI (6953)/MLSR-2001/3

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

Monthly
Letter Status
Report

December 2000

ORNL/HSSI (6953)/MLSR-2001/3

HEAVY-SECTION STEEL IRRADIATION

PROGRAM

JCN W6953

MONTHLY LETTER STATUS REPORT

FOR

DECEMBER 2000

Submitted by

T. M. Rosseel
HSSI Project Manager

Compiled by
R. D. Godfrey

Submitted to
C. J. Fairbanks
NRC Project Manager

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

Internal Use Only

This document has not been given final patent clearance and is for internal use only. If this document is to be given public release, it must be cleared through the site Technical Information Office which will see that the proper patent and technical information reviews are completed in accordance with UT-Battelle Policy.

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 eight program tasks. The seven tasks correspond to the 189, dated March 23, 1998, and modified by the inclusion of the former "Embrittlement Data Base and Dosimetry Evaluation" Program, JCN 6164 in March, 1999. 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 April 1998 to December 2000, while the individual task budgets address the period from October 1999 to December 2000.

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

Thomas M. Rosseel

Thomas M. Rosseel, Manager
Heavy-Section Steel Irradiation

MONTHLY LETTER STATUS REPORT
December 2000

Job Code Number:	**W6953**
Project Title:	**Heavy-Section Steel Irradiation Program**
Period of Performance:	**4/1/98 to 2/28/01**
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:

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

This task is responsible for managing the program to ensure that the overall objectives are achieved. The management responsibilities include three major activities: (1) program planning and resource allocation; (2) program monitoring and control; and (3) documentation and technology transfer. Program planning and resource allocation includes: (a) developing and preparing annual budgetary proposals and (b) issuing and administrating subcontracts to other contractors and consultants for specialized talents not available at Oak Ridge National Laboratory (ORNL) or that supplement those at ORNL. Program monitoring and control includes: (a) monitoring and controlling the project through an earned-value, project-management system; (b) ensuring that quality assurance (QA) requirements are satisfied; and (c) issuing monthly management reports. Documentation and technology transfer includes: (a) participating in appropriate codes and standards committees; (b) preparing briefings for the NRC; (c) coordinating NRC and internal ORNL review activities; (d) coordinating domestic and foreign information exchanges approved by NRC; and (e) documenting the activities of the program through letter and NUREG reports.

(Milestone 1.1 A) As stated in the previous progress report, due to changes in University of Michigan policy, full-cost recovery requirements for the operation of the Ford Nuclear Reactor (FNR) are expected to increase the cost of FNR services by a factor of two this fiscal year. Additionally, unless long-term support for the facility is identified, the FNR will be shut down within the next two-three years and prepared for decommissioning. Within this framework, discussions were held with the NRC Office of Research staff concerning the future directions of the HSSI Program. It was concluded that two position papers will be prepared concerning research reactor and facility options and the needs and benefits of an NRC-sponsored irradiation program. The first paper will address the options and costs associated performing irradiations at another reactor within the US or in a foreign country. Estimates of the cost of new facilities and disposal of existing facilities will be included in this white paper. The second paper will focus on the compelling issues that an irradiation program can address for the NRC. This will include both anticipatory and confirmatory research.

(Milestone 1.2.B) The Associate Director of the Michigan Memorial Phoenix Project, FNR, informed the HSSI Program manager that a thirty-day notice would be provided before a cost increase in services was enacted.

The repair of the 100-kip MTS servo-hydraulic machine in the Irradiated Materials Examination and Testing (IMET) hot cell # 3 is nearly complete. It is anticipated that efforts to re-route a hydraulic hose will be completed early in the next reporting period and that testing of the KS-01 1T compact specimens, which will be used to examine shape of the master curve for highly-embrittled RPV material (see subtask 2.2), will resume in mid-January.

Due to unexpected reductions in support from several DOE programs as well as continued pressure from the HSSI Program to reduce costs, support for the IMET hot cell facility is insufficient to maintain operation throughout the fiscal year. The facility will be placed in warm standby from March through August. Under this plan, the KS01 material will be tested before the standby and, if sufficient time is available, testing of the PSI-supplied JRQ specimens (subtask 3.3) will also be completed. However, testing of the later specimens could be delayed until the fourth quarter of fiscal year 2001 or the first quarter of fiscal year 2002.

(Milestone 1.3.E) The following NUREG Reports were published and received during this reporting period:

D. E. McCabe, R. K. Nanstad, S. K. Iskander, D. W. Heatherly, and R. L. Swain, *"Evaluation of WF-70 Weld Metal from the Midland Unit 1 Reactor Vessel"*, NUREG/CR-5736 (ORNL/TM-13748), November 2000.

M. K. Miller, K. F. Russell, R. E. Stoller, P. Pareige, *"Atom Probe Tomography Characterization of the Solute Distributions in a Neutron-Irradiated and Annealed Pressure Vessel Steel Weld"*, NUREG/CR-6629, (ORNL/TM-13768), November 2000.

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), November 2000.

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

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 .

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°C (270°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) As previously reported, an actuator has been reconditioned by an outside commercial company to replace the original leaking actuator on the MTS servohydraulic machine in the hot cell. Repairs on the hot cell servohydraulic machine have been completed and the machine is operable. However, a cell entry must be made to re-route one of the hydraulic hoses to increase the space needed for a shield around the base of the machine to keep items from falling into the pit. The machine is scheduled to be back in service about January 9. The oven has also been re-installed on the frame and, as soon as the shield is in place, the testing of 1T C(T) of KS-01 weld will be resumed.

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

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"*, 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 .

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 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 nearly complete and will be submitted for internal technical review.

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 As noted in the previous progress report, twelve 0.5T compact specimens were received, fatigue precracked, and seven specimens were tested at -125°C, the temperature estimated to result in a median K_{Jc} value of about 75 MPa√m using the Master Curve obtained from the previous results. The actual value obtained was very close to the predicted value based on the test results obtained at the higher temperatures. The remaining five specimens will be tested at a different temperature, and a multitemperature master curve analysis will be conducted and included in the final letter report. These tests will be conducted in January. Additional scanning-electron fractography will also be performed to evaluate the fracture mode of the specimens previously tested at the highest temperatures (room temperature and above). This fractographic evaluation will specifically evaluate the presence of so-called ductile intergranular fracture. This is an important aspect of the evaluation as it relates to the relationship between the master curve shape, which is used to describe unstable cleavage fracture in the ductile-brittle transition region, and unstable fracture by intergranular fracture.

<u>Subtask 2.7: Subsized Specimens</u> (M. A. Sokolov)

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

The program for the ASTM Fourth International Symposium on Small Specimen Techniques has been developed and posted on the ASTM web site. This symposium with M. A. Sokolov serving as the Chairman will be held in Reno, Nevada, January 23-25, 2001.

(Milestone 2.7.A) Three blocks of materials were machined into 1T C(T) and precracked Charpy specimens for the size effect study. Two of the blocks are broken halves of 4TC(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 oriented towards an evaluation of the precracked Charpy specimen. The testing of these specimens is well under way and completion is expected in January.

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

The purpose of this subtask is to 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 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. The abstract was included in a previous progress report. Further review of data, both unirradiated and irradiated, is continuing with a view towards eventual preparation of a table of uncertainties which 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.

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

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

(Milestone 2.10.A) Dosimeters included in the first two HSS-IAR metallurgical specimen capsules have been recovered, counted, and analyzed to determine the isotope activities used in calculating damage correlation parameters. Data files containing the activity information were prepared in the format used in all past HSS-IAR experiments. This includes the use of the previously defined coordinate system.

For the two sets of removable dosimeter tubes, analysis is straightforward since the tubes were irradiated in a single location for the duration of the experiment. However, since the metallurgical specimen packets were shuffled and rotated several times during irradiation, each packet has a unique time/position history and for this reason each should be treated as a different experiment. The metallurgical specimen packets have been identified with letters of the alphabet starting with "A" and ending with "J". These designations represent the arrangement of the packets at the start of irradiation. The chronology of the rotations and shuffling for each packet from the start of the irradiation to the end was noted. From this data, the 3-D model, fuel changes and reshuffling, and the original dosimetry experiment results, exposure parameters for these metallurgical specimens will be calculated.

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_{Jac} 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°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 noted in the previous progress report, following the observations of significant intergranular fracture on the irradiated/annealed specimens, further analyses and discussions are under way, with particular attention to the cooling rate following postweld heat treatment of the simulated HAZ material. To investigate the cooling rate effect, additional material would be treated in the Gleeble system to simulate the coarse-grain HAZ as accomplished previously. This would then be followed by thermal aging, as well as by irradiation and thermal annealing. Excess material from the original investigation has been identified, and the proposed study will be discussed with the NRC technical monitor. Consideration is also being given to reirradiation of the remaining specimens from the initial series.

The paper by R. K. Nanstad et al., *"Investigation of Temper Embrittlement in Reactor Pressure Vessel Steels Following Thermal Aging, Irradiation, and Thermal Annealing"*, presented at the ASTM 20th International Symposium on Radiation Effects on Materials, has been reviewed and is being modified for final submission to ASTM.

<u>Subtask 3.2: Embrittlement Rate of Reirradiated Steel</u> (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, 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.

(Milestone 3.2.C) Previously irradiated, annealed, and reirradiated specimens of HSSI Weld 73W were reinserted into the IAR facility at the Ford Nuclear Reactor 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.

Subtask 3.3: Evaluation of Reirradiated JRQ Specimens (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) The testing of the JRQ specimens from the Paul Scherrer Institute, previously placed on hold primarily due to the need for repair of the servohydraulic machine, is now scheduled to begin in mid-January.

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 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.

Subtask 4.1: Examination of Materials from Retired RPVs (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) The NUREG report "*Attenuation of Charpy Impact Toughness Through the Thickness of a JPDR Pressure Vessel Weldment*", by S. K. Iskander with major contributions from J. T. Hutton, L. E. Creech, M. Suzuki, K. Onizawa, E. T. Manneschmidt, R. K. Nanstad, T. M. Rosseel, and P. S. Bishop, has been reviewed and submitted to the ORNL publications office for final preparation and submittal to the NRC for publication.

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 U.S. 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°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°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 for publication to the NRC 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 reirradiation.

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 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.

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

11. Collaboration with the University of Lille (France) in the area of primary radiation damage simulation.

(Milestone 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 likely be held in Japan in the Spring of 2002.

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.

(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 versus temperature curve has been 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. A presentation of progress on this study was made at the IGRDM meeting in September in Leuven, Belgium. A letter report will be prepared following completion of all testing and evaluation. Abstracts are being prepared for offers of presentations at various meetings in 2001.

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) 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.

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). An atom probe tomography characterization has been performed on radiation-sensitive pressure-vessel-steel weld, KS-01. This weld was irradiated in the IAR facility of the UM Ford reactor to a relatively low fluence of 0.8×10^{19} n cm^{-2} (E > 1 MeV) at a temperature of 288°C. This high copper (0.37 wt% Cu) weld exhibited an anomalously high shift in the ductile-to-brittle transition temperature of 170°C. Preliminary analysis of the atom probe data revealed a high number density (> 10^{24} m^{-3}) of ~2-nm-diameter Cu-, Mn-, Ni-, and Si-enriched cluster/precipitates in the matrix. In addition, some phosphorus clusters were observed. The presence of these microstructural features would account for the observed mechanical properties.

With the incorporation of atom probe tomography results on weld 73W specimens the NUREG report entitled, *"Effect of Reirradiation Rate on The Charpy Properties of an Irradiated/Annealed High Copper Reactor Pressure Vessel Weld HSSI 73W"*, is being prepared submission to the NRC.

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.

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.

The HSSI-IAR irradiation facility continued to operate without incident during this reporting period. During this period, the HSSI-IAR facilities were irradiated for the last seven days of reactor half-cycle 452B and ~8.8 days of half-cycle 453A. Reactor half-cycle 453A was shortened to only 8.8 days due to the Christmas holiday. Current plans at the FNR call for the reactor to remain down throughout the Christmas and New Year holidays. The reactor will resume operation at the beginning of half-cycle 453B on January 9, 2001.

During the last seven days of reactor half-cycle 452B, the IAR irradiation facilities received a total of 169 EFPH (effective full power hours). During the holiday shortened 8.8 days reactor half-cycle 453A, the facilities received a total of 211 EFPH. During this reporting period, the HSSI-IAR irradiation facilities received a total of 380 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 4286 EFPH. At the end of this reporting period, the second group of specimens had been irradiated for a total of 4666 EFPH. The facilities themselves had been in service for a total of 8994 EFPH.

(Milestone 6.1.B) The draft NUREG report on the reusable irradiation facilities has been delayed in order to evaluate other test reactor options as substitutes for the FNR.

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 HSSI-UCSB irradiation facility continued during this reporting period.

The HSSI-UCSB irradiation facility continued to operate without incident during this reporting period. During this period, the facility was irradiated for the last seven days of reactor half-cycle 452B and ~8.8 days of half-cycle 453A. Reactor half-cycle 453A was shortened to only 8.8 days due to the Christmas holiday. Current plans at the FNR call for the reactor to remain down throughout the Christmas and New Year holidays. The reactor will resume operation at the beginning of half-cycle 453B on January 9, 2001.

During the last seven days of reactor half-cycle 452B, the HSSI-UCSB irradiation facility received a total of 169 EFPH (effective full power hours). During the holiday shortened 8.8 days reactor half-cycle 453A the facility received a total of 211 EFPH. During this reporting period, the irradiation facility received a total of 380 EFPH.

At the beginning of this reporting period, the UCSB facility and original specimen compliment had been irradiated for a total of 16,099 EFPH. At the end of this reporting period, the UCSB facility and original specimen compliment had been irradiated for a total of 16479 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 122% 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.B) The completed UPDATE-11 of PR-EDB was transmitted to the US NRC technical program monitor in July.

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 December 10-12, 2000, R. K. Nanstad traveled to Nashville, Tennessee, to participate in ASME Boiler and Pressure Vessel Code meetings.

On December 18-19, 2000, R. K. Nanstad traveled to Rockville, Maryland, to give two presentations and participate in the NRC Meeting on RT_{NDT} Uncertainty Characterization. He also participated in a discussion on the future of the HSSI Program.

4. PRESENTATIONS, REPORTS, PAPERS, AND PUBLICATIONS:

D. E. McCabe, R. K. Nanstad, S. K. Iskander, D. W. Heatherly, and R. L. Swain, "*Evaluation of WF-70 Weld Metal from the Midland Unit 1 Reactor Vessel*", NUREG/CR-5736 (ORNL/TM-13748), November 2000.

J. G. Merkle and R. K. Nanstad, "*Master Curve Derived Fracture Toughness and a Statistical Representation of Valid* K_{Ic} *Data*", (presented by R. K. Nanstad), NRC Meeting on RT_{NDT} Uncertainty Characterization, Rockville, Maryland, December 19, 2000.

M. K. Miller, K. F. Russell, R. E. Stoller, P. Pareige, "*Atom Probe Tomography Characterization of the Solute Distributions in a Neutron-Irradiated and Annealed Pressure Vessel Steel Weld*", NUREG/CR-6629, (ORNL/TM-13768), November 2000.

R. K. Nanstad, "*Background of the* RT_{NDT} *Indexing Parameter*", NRC Meeting on RT_{NDT} Uncertainty Characterization, Rockville, Maryland, December 19, 2000.

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), November 2000.

A 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 under preparation.

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:

Due to University of Michigan requirements to obtain full-cost recovery for the operation of the FNR, the cost of FNR services are expected to double during this fiscal year. However, the Associate Director of the Michigan Memorial Phoenix Project, informed the HSSI Program manager that a thirty-day notice would be provided before a cost increase in services was enacted.

Reductions in DOE programmatic support for the IMET hot cell facility are expected to result in a reduced operating schedule during FY 2001.

The repair of the 100-kip MTS servo-hydraulic machine in the IMET hot cell # 3 is nearly complete. It is anticipated that efforts to re-route a hydraulic hose will be completed early in the next reporting period and that testing of the KS01 and possibly the PSI re-irradiated specimens will be initiated.

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: 11/27/00-12/24/00

		Current Month	Fiscal Year to Date	Cumulative Project to date
I.	Direct Staff Effort	16 MM	2.7 MY	32.5 MY
II.	A. Direct Lab Staff Effort ($)			
	Direct Salaries	88,242	205,913	3,221,618
	Materials and Services	1,737	1,624	377,580
	ADP Support	61	183	1,968
	Subcontracts	596	13,702	376,120
	Travel	577	9,974	126,583
	Indirect Labor Costs	0	0	0
	Other: NRC-PO Tax	4,000	4,000	142,500
	General and Administrative	38,753	88,597	1,467,819
	Total UT-Battelle Costs	133,966	323,993	5,714,188
	B. DOE Federal Access Costs	8,154	16,892	16,892
	TOTAL PROJECT COSTS	142,120	340,885	5,731,080

Percentage of available cumulative funds costed	96
Percentage of available current FY funds costed	59
Funds Remaining	238,920
Commitments:	13,339
BA Remaining	225,581

III. Funding Status

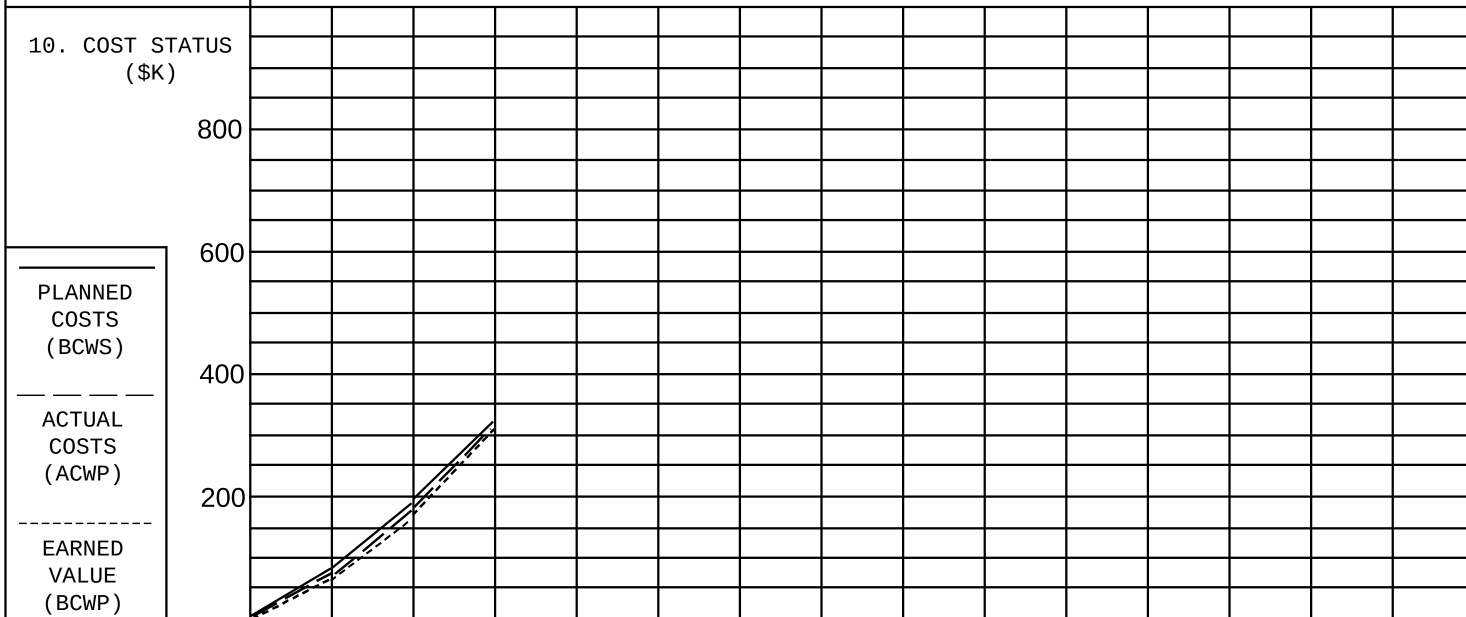
Prior FY Carryover	FY 01 Projected Funding Level	FY 01 Funds Received to Date	FY 01 Funding Balance Needed	Cumulative Amt. Obligated	Cumulative Amt. Costed
279,802	1,450,000	300,000	1,150,000	5,970,000	5,731,080

Comments: Federal Access Charge for FY 00 carryover applied

1. CONTRACT REPORTING ELEMENT **HSSI - Heavy-Section Steel Irradiation Program**	2. REPORTING PERIOD **11/27/00 - 12/24/00**	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 1999-2001** 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: 01/02/01

PLANNED COSTS FOR ELEMENT ($K): 563

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	77	113	134												
ACTUAL	77	113	134												
EARNED	76	87	169												
CUM. PLAN.	77	190	324												
CUM. ACT.	77	190	324												
CUM. EARN.	76	162	321												

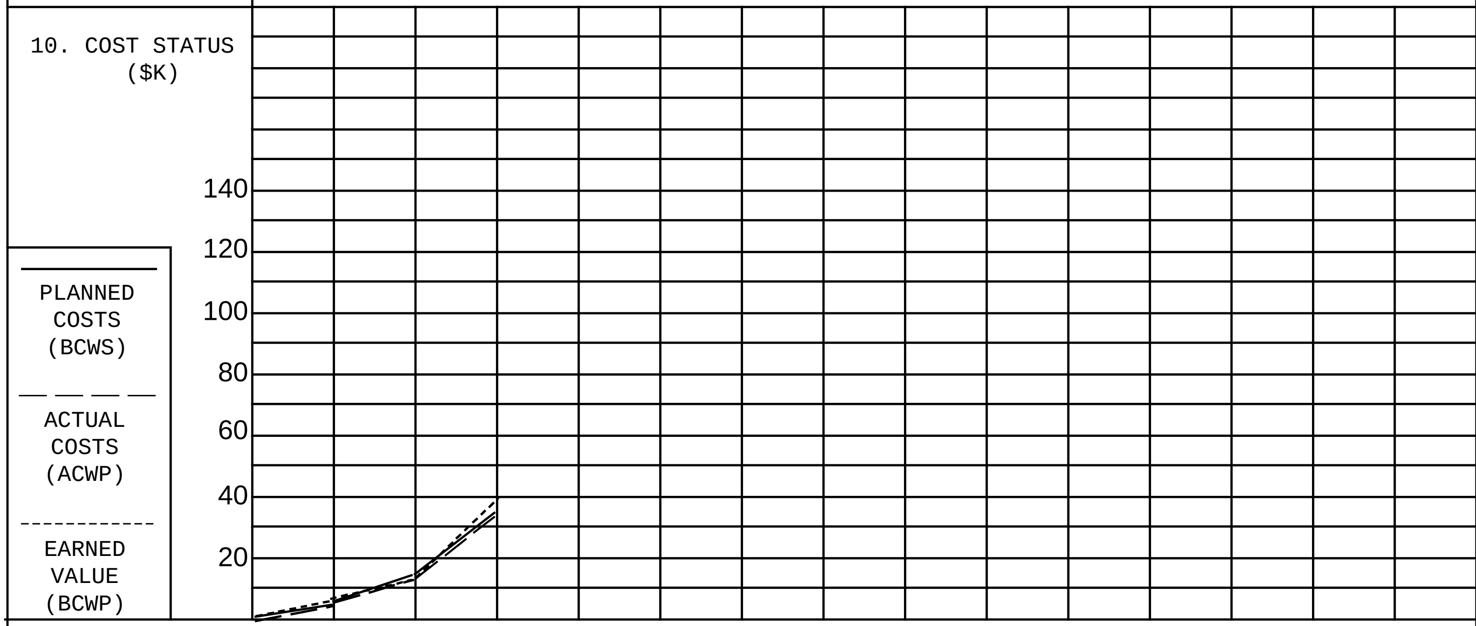
11. REMARKS:

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

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 1. Program Management	**11/27/00 - 12/24/00**	**W6953**
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P.O. BOX 2008** **OAK RIDGE, TN 37831**	5. CONTRACT PERIOD **FY 1999-2001**	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: 01/02/01

PLANNED COSTS FOR ELEMENT ($K): 60

ELEMENT COSTS FOR PRIOR FYS ($K): 10

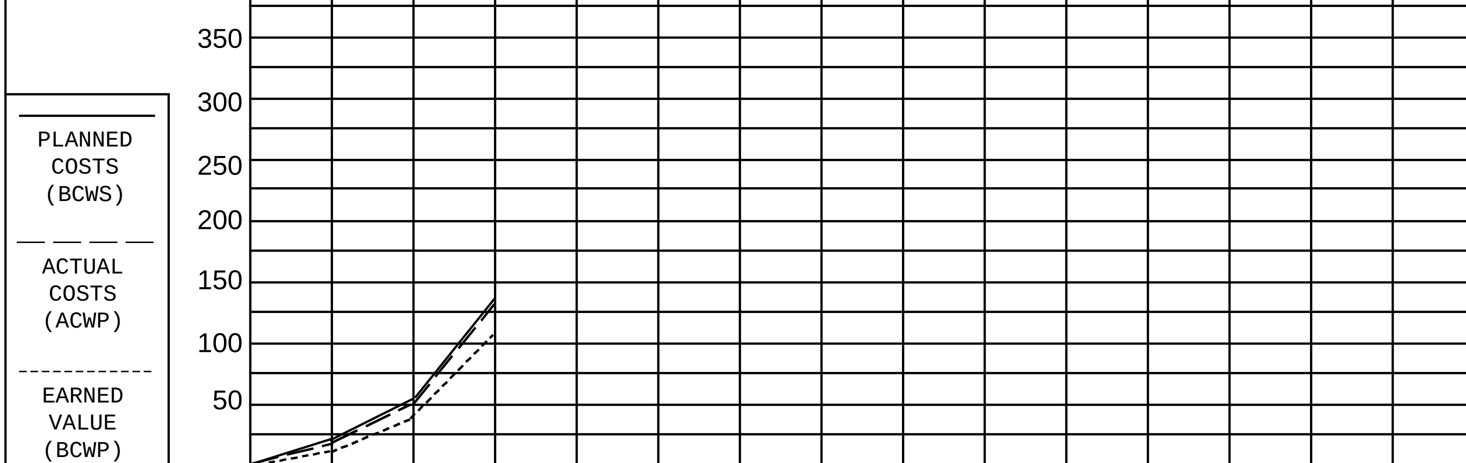
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	4	10	20												
ACTUAL	4	10	20												
EARNED	5	9	25												
CUM. PLAN.	4	14	34												
CUM. ACT.	4	14	34												
CUM. EARN.	5	14	39												

11. REMARKS:

1. CONTRACT REPORTING ELEMENT **HSSI - 2. Fracture Toughness Transition and MC Methodology**	2. REPORTING PERIOD **11/27/00 - 12/24/00**	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 1999-2001**	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)
01/02/01	214	117

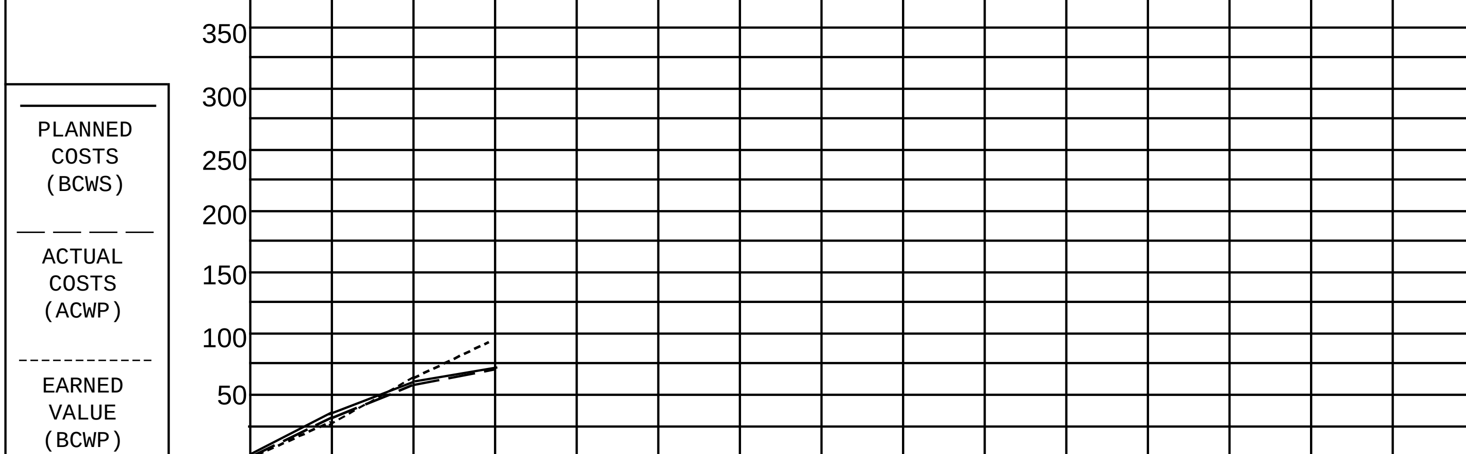
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	20	33	75												
ACTUAL	20	33	75												
EARNED	13	17	73												
CUM. PLAN.	20	53	128												
CUM. ACT.	20	53	128												
CUM. EARN.	13	30	103												

11. REMARKS:

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 3. Irradiation Embrittlement of RPV Steel	**11/27/00 - 12/24/00**	**W6953**
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P.O. BOX 2008** **OAK RIDGE, TN 37831**	5. CONTRACT PERIOD **FY 1999-2001** 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: 01/02/01

PLANNED COSTS FOR ELEMENT ($K): 133

ELEMENT COSTS FOR PRIOR FYS ($K): 98

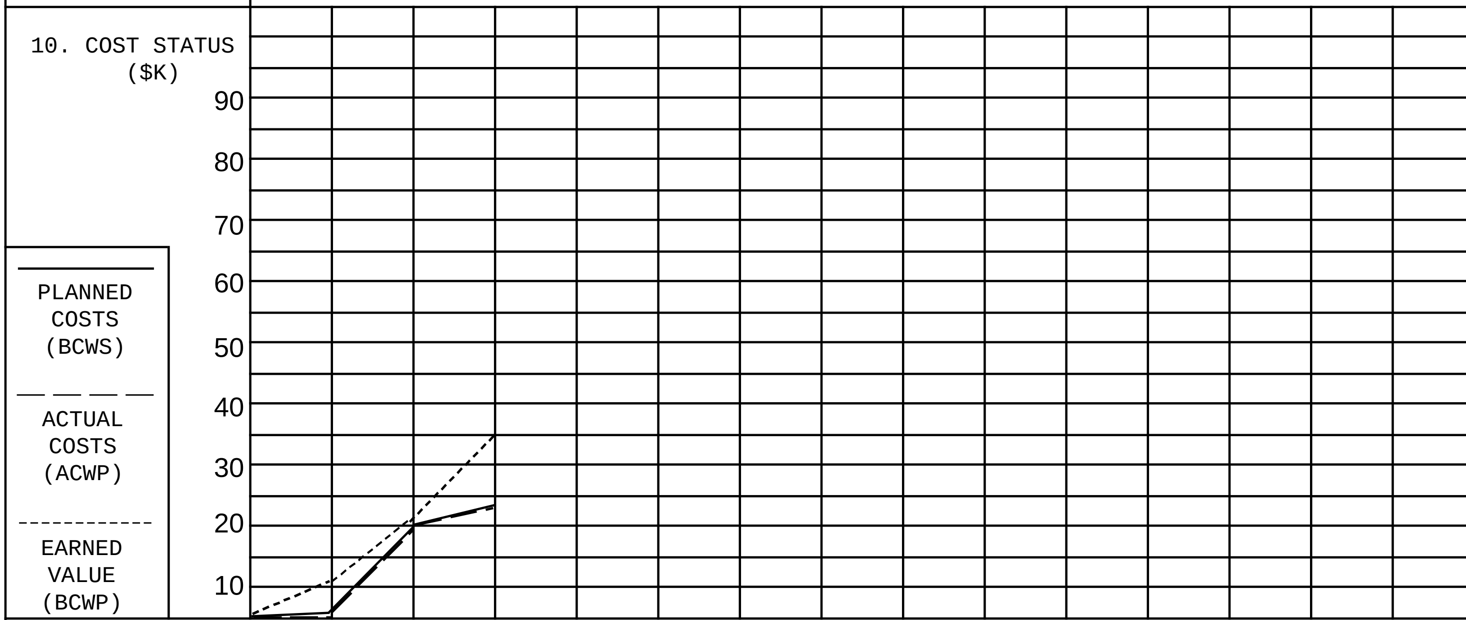
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	32	26	9												
ACTUAL	32	26	9												
EARNED	28	34	35												
CUM. PLAN.	32	58	67												
CUM. ACT.	32	58	67												
CUM. EARN.	28	62	97												

11. REMARKS:

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 4. Validation of Irradiated and Aged Materials	**11/27/00 - 12/24/00**	**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 1999-2001**	**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: 01/02/01

PLANNED COSTS FOR ELEMENT ($K): 63

ELEMENT COSTS FOR PRIOR FYS ($K): 18

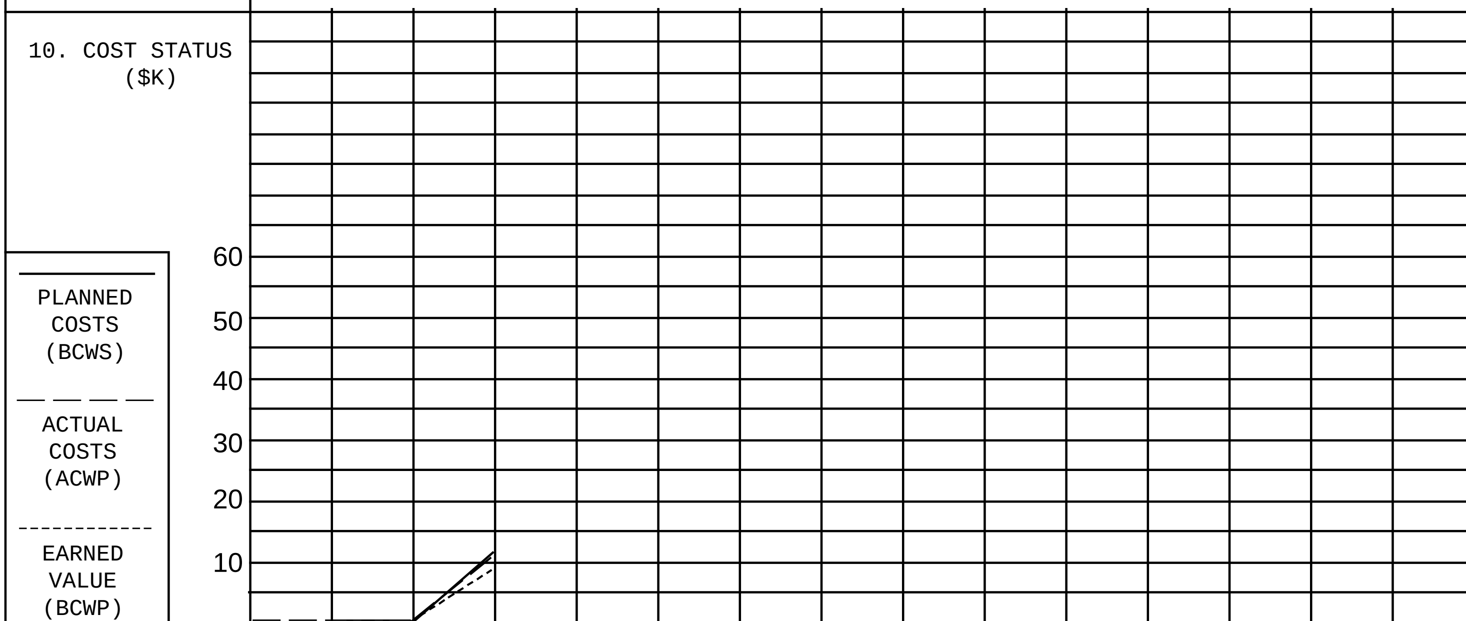
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	2	18	2												
ACTUAL	2	18	3												
EARNED	11	10	14												
CUM. PLAN.	2	20	23												
CUM. ACT.	2	20	23												
CUM. EARN.	11	21	35												

11. REMARKS:

1. CONTRACT REPORTING ELEMENT **HSSI - 5. Modeling and Microstructural Analysis**	2. REPORTING PERIOD **11/27/00 - 12/24/00**	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 1999-2001** 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: 01/02/01

PLANNED COSTS FOR ELEMENT ($K): 22

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												
ACTUAL	0	0	12												
EARNED	0	0	8												
CUM. PLAN.	0	0	12												
CUM. ACT.	0	0	12												
CUM. EARN.	0	0	8												

11. REMARKS:

1. CONTRACT REPORTING ELEMENT
HSSI - 6. Irradiation Coordination

2. REPORTING PERIOD
11/27/00 - 12/24/00

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 1999-2001

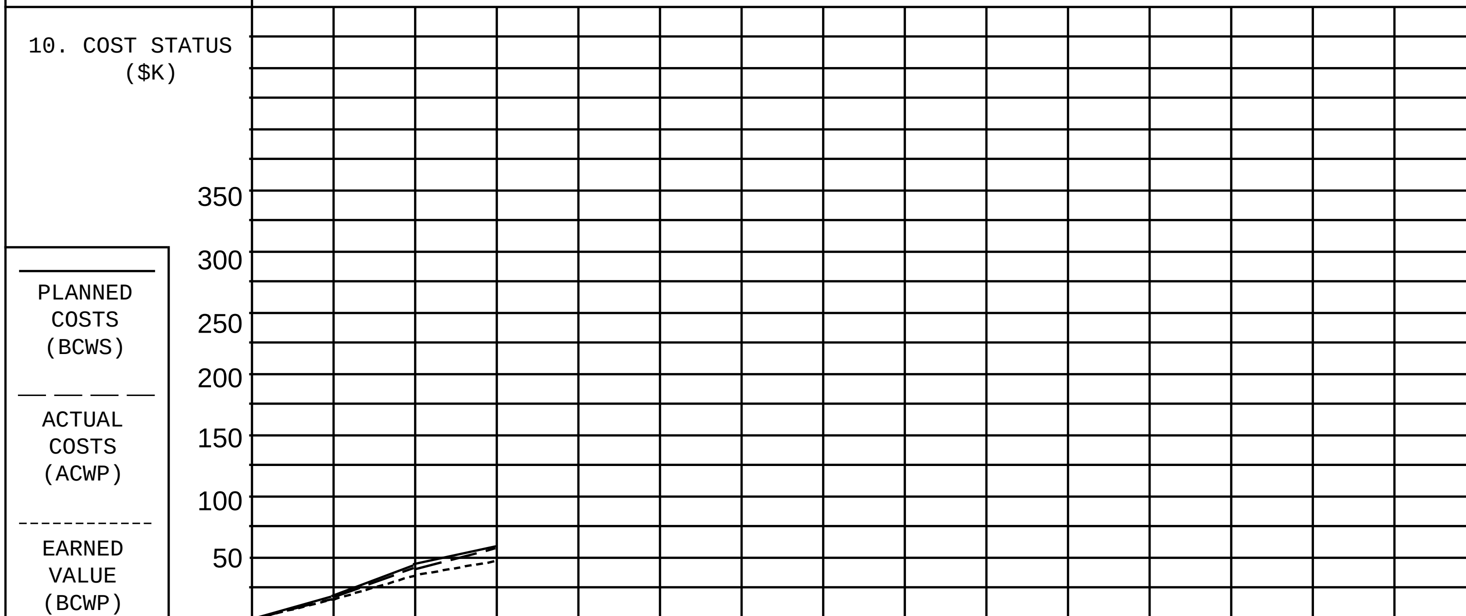
6. ACTIVITY NUMBER
41 W6 95 3W 1

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
01/02/01

PLANNED COSTS FOR ELEMENT ($K)
68

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	26	16												
ACTUAL	19	26	16												
EARNED	19	16	14												
CUM. PLAN.	19	45	61												
CUM. ACT.	19	45	61												
CUM. EARN.	19	35	49												

11. REMARKS:

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 7. Embrittlement DB & Dosimetry Evaluation	**11/27/00 - 12/24/00**	**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 1999-2001**	**41 W6 95 3W 1**
	7. NRC B&R NO.	8. DOE B&R NO.
	860 15 21 20 05	**40 10 01 06**

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

10. COST STATUS ($K)

400

300

200

100

PLANNED COSTS (BCWS)

ACTUAL COSTS (ACWP)

EARNED VALUE (BCWP)

COST PLAN DATES

01/02/01

PLANNED COSTS FOR ELEMENT ($K)

-4

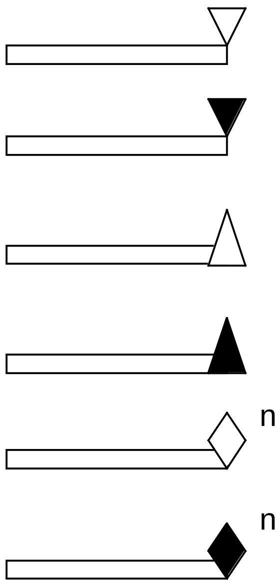
ELEMENT COSTS FOR PRIOR FYS ($K)

-4

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

11. REMARKS:

Milestone Symbology



Intermediate milestone planned

Intermediate milestone completed

Major milestone planned

Major milestone completed

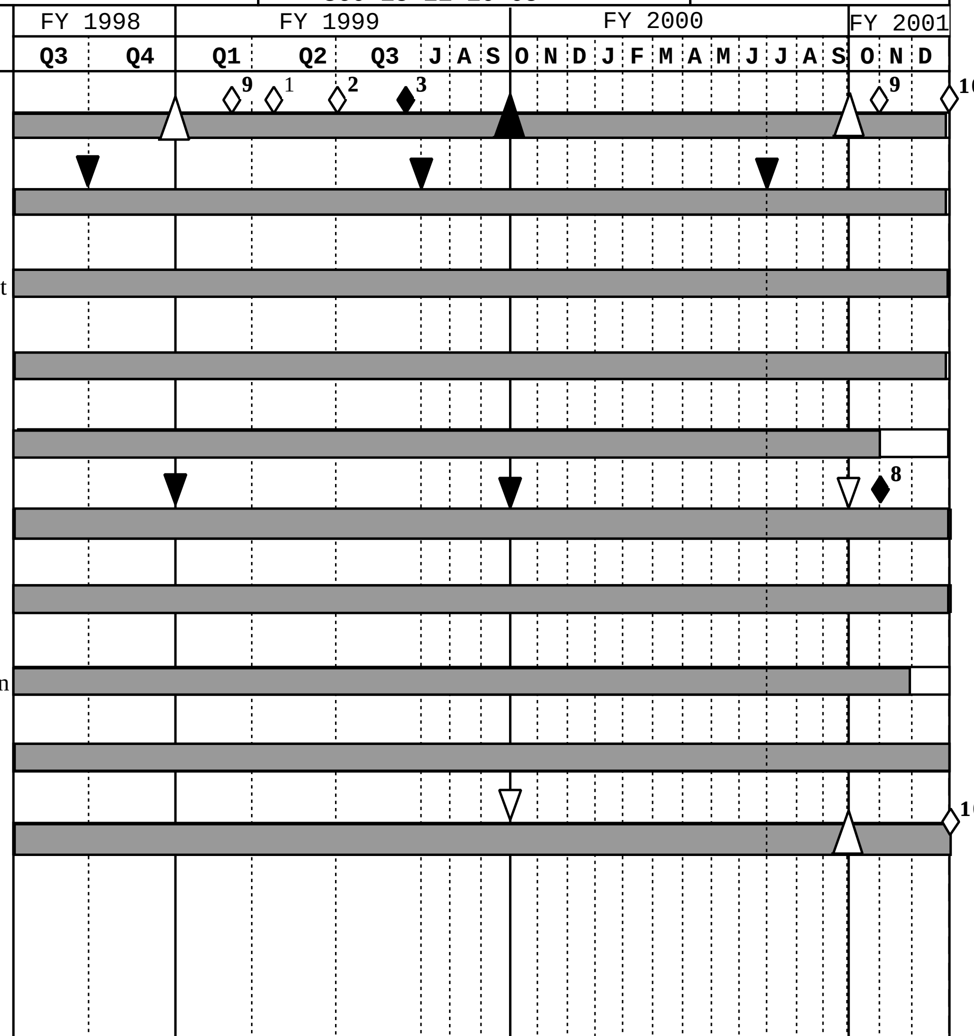
Rescheduled milestone planned

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 **11/27/00 - 12/24/00**	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**

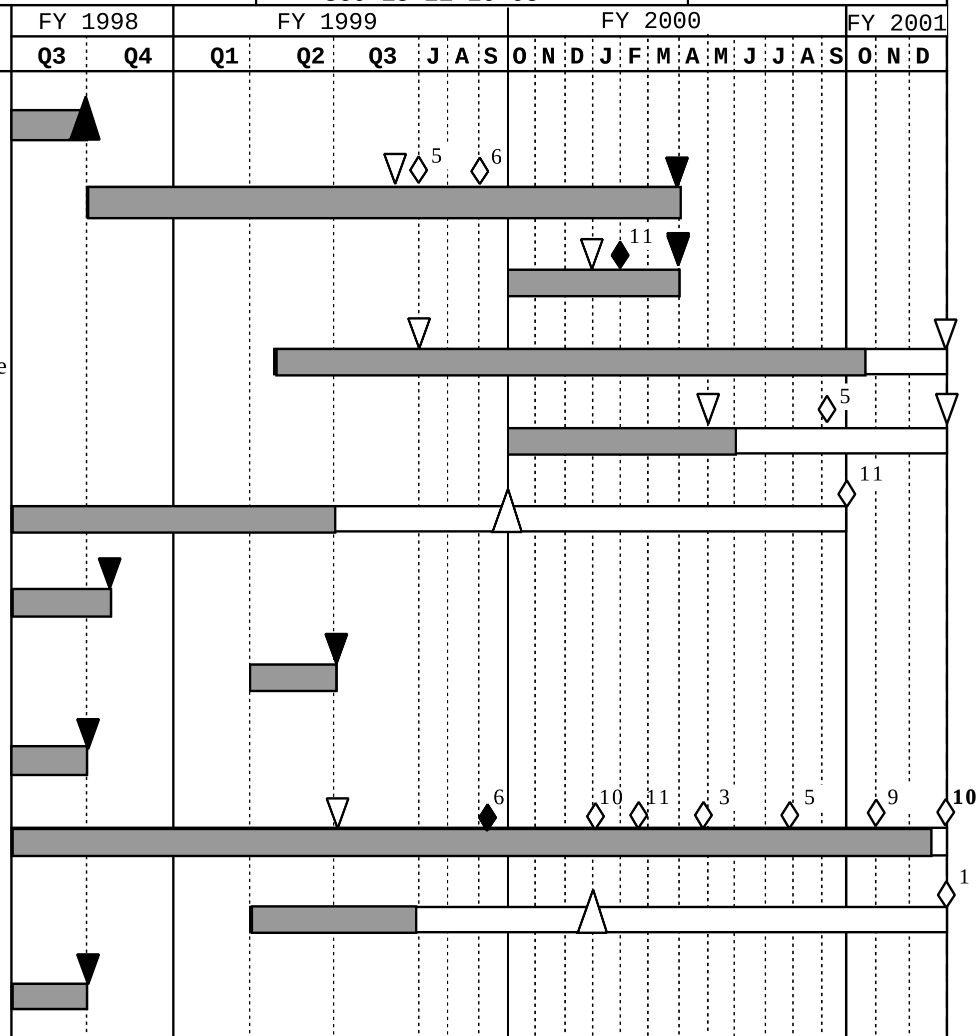
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
1.1.A.	Issue Project & Budget Proposal
1.1.B.	Select and Administer Subcontracts
1.2.A.	Issue Earned Value Based Monthly Management Reports (by the end of subsequent month)
1.2.B.	Ensure QA Requirements are met
1.3.A.	Participate in Appropriate Codes and 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 **11/27/00 - 12/24/00**	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**

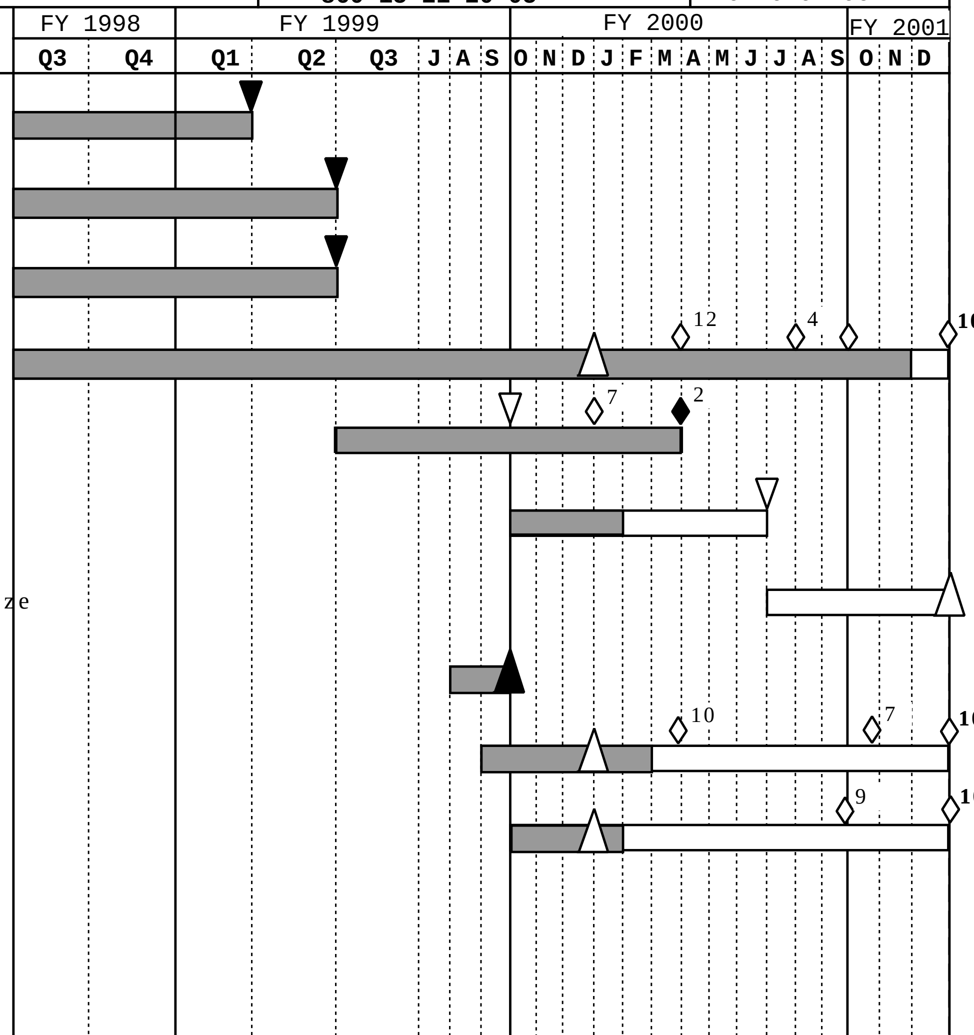
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
2.1.A.	Complete Draft NUREG Report on Comparison of CVN and Fracture Toughness Shifts
2.2.A.	Sample Preparation and Irradiation for Master Curve
2.2.B.	Receive Specimens
2.2.C.	Test Unirradiated & Irradiated Master Curve Specimens
2.2.D.	Draft Letter and 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 **11/27/00 - 12/24/00**	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

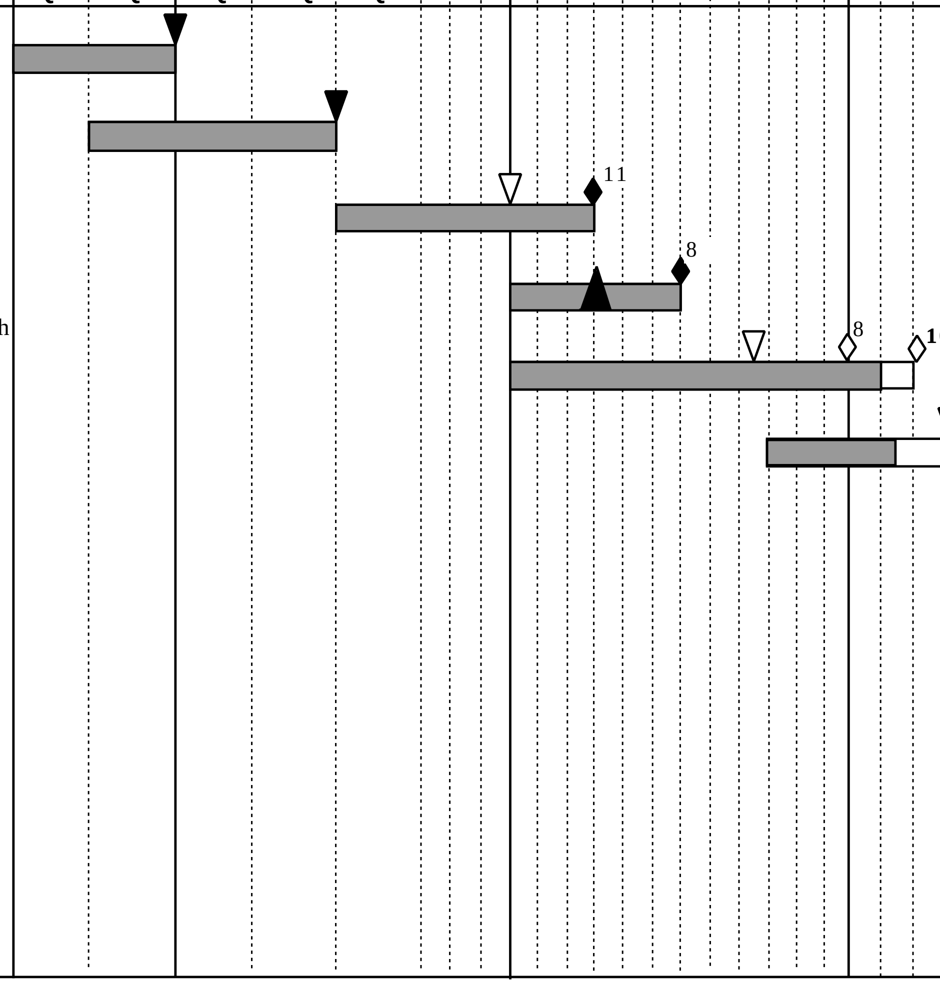


11. REMARKS

1. CONTRACT REPORTING ELEMENT **HSSI - 2. Fracture Toughness Transition & MC Methodology**	2. REPORTING PERIOD **11/27/00 - 12/24/00**	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 Statistical Analysis of Data Base for Irradiated materials

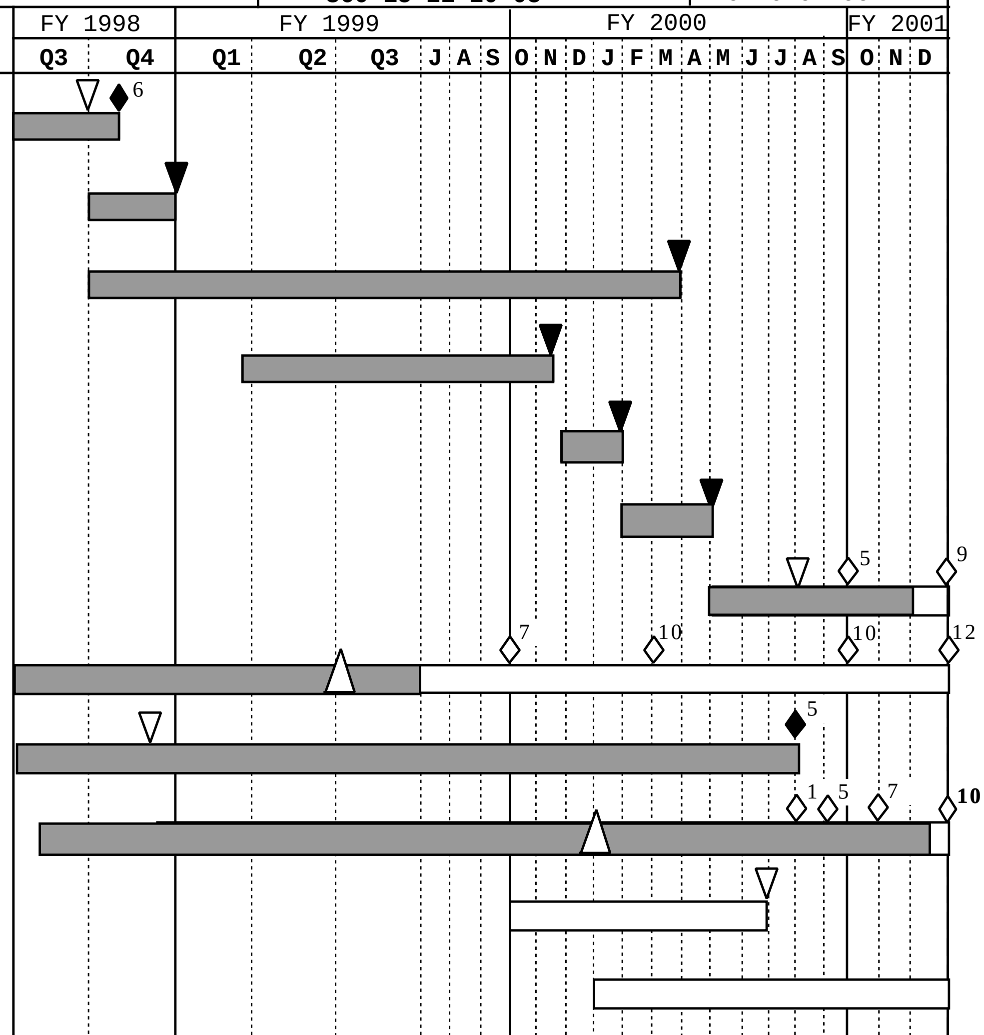
FY 1998: Q3 Q4 | FY 1999: Q1 Q2 Q3 J A S | FY 2000: O N D J F M A M J J A S | FY2001: O N D



11. REMARKS

1. CONTRACT REPORTING ELEMENT **HSSI - 3. Irradiation Embrittlement of RPV Steel**	2. REPORTING PERIOD **11/27/00 - 12/24/00**	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**

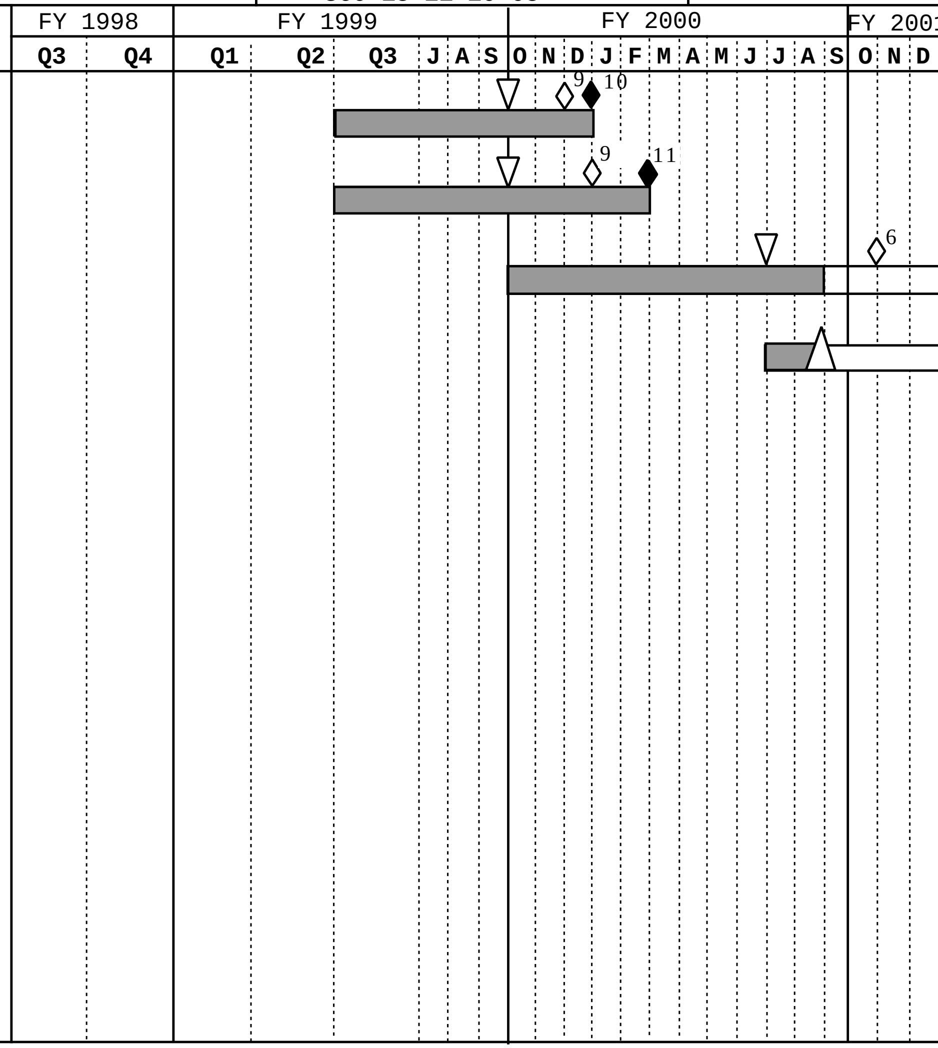
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
3.1.A.	Age HAZ Materials
3.1.B.	Machine CVN Specimens
3.1.C.	Evaluate Results and Prepare Letter Report
3.1.D.	Irradiate Capsules
3.1.E.	Ship Specimens
3.1.F.	Test Specimens
3.1.G.	NUREG Report
3.2.A.	NUREG on IA Work to Date
3.2.B.	Dosimetry of 30 CVNs
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 **11/27/00 - 12/24/00**	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**

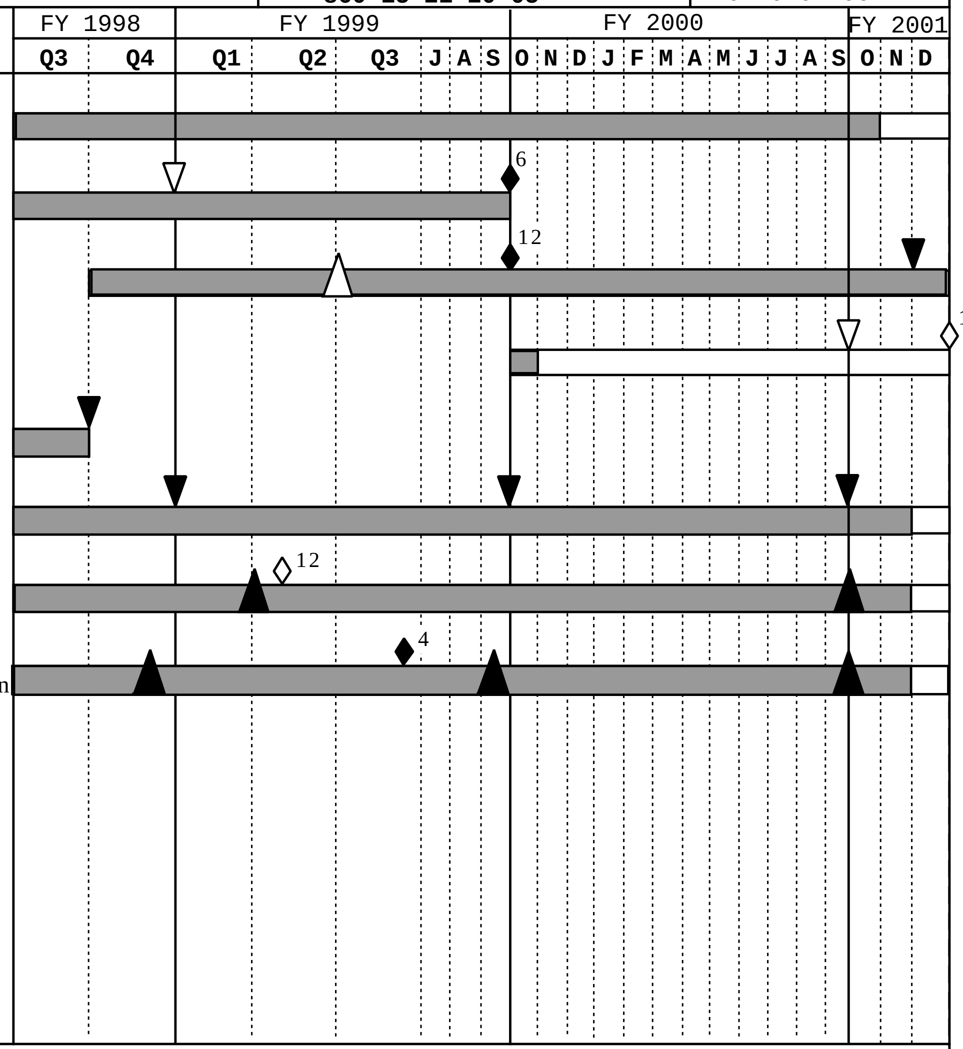
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
3.3.A.	Ship JRQ Specimens From PSI to ORNL
3.3.B.	Complete Test Plan
3.3.C.	Complete JRQ Specimen Testing
3.3.D.	Complete Draft NUREG Report on IAR Results of JRQ



11. REMARKS

1. CONTRACT REPORTING ELEMENT **HSSI - 4. Validation of Irradiated and Aged Materials**	2. REPORTING PERIOD **11/27/00 - 12/24/00**
	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

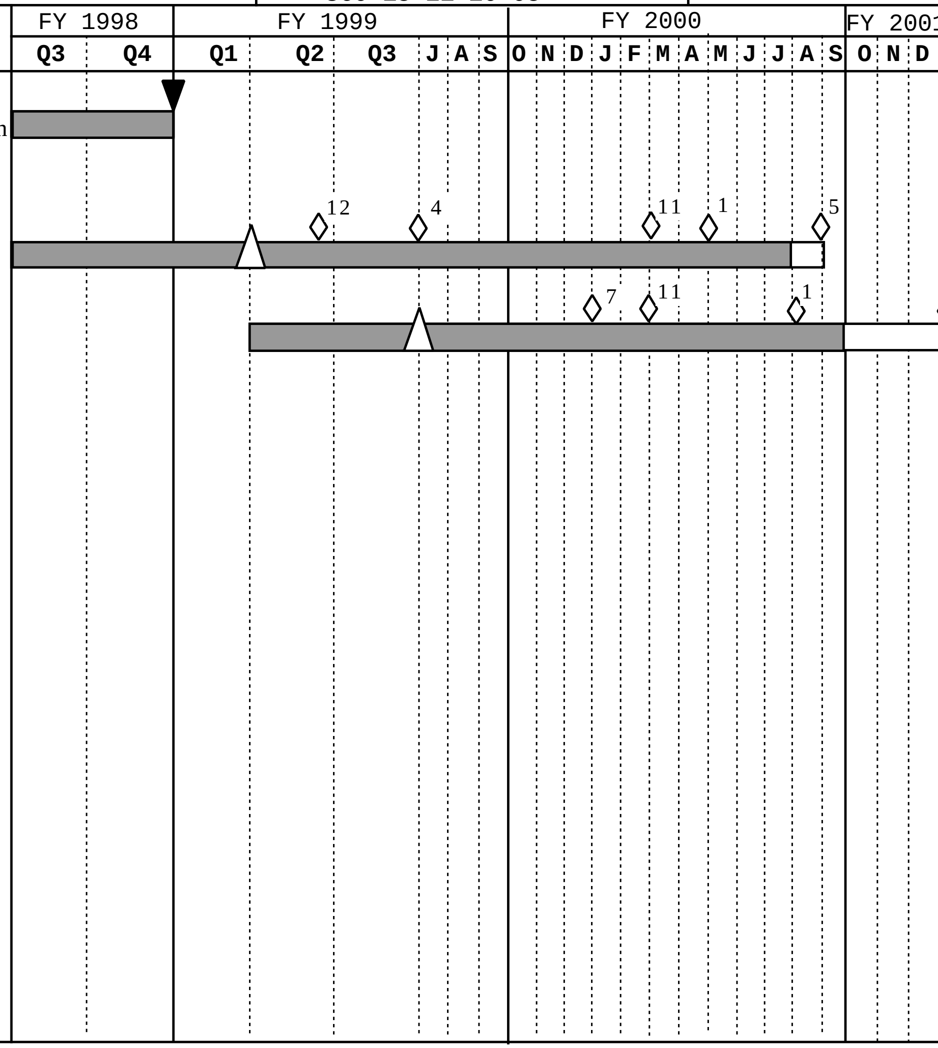


11. REMARKS

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 4. Validation of Irradiated and Aged Materials	**11/27/00 - 12/24/00**	**W6953**

4. CONTRACTOR (NAME AND ADDRESS)	5. CONTRACT PERIOD	6. ACTIVITY NO.
OAK RIDGE NATIONAL LABORATORY	**FY 1998-2001**	**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**

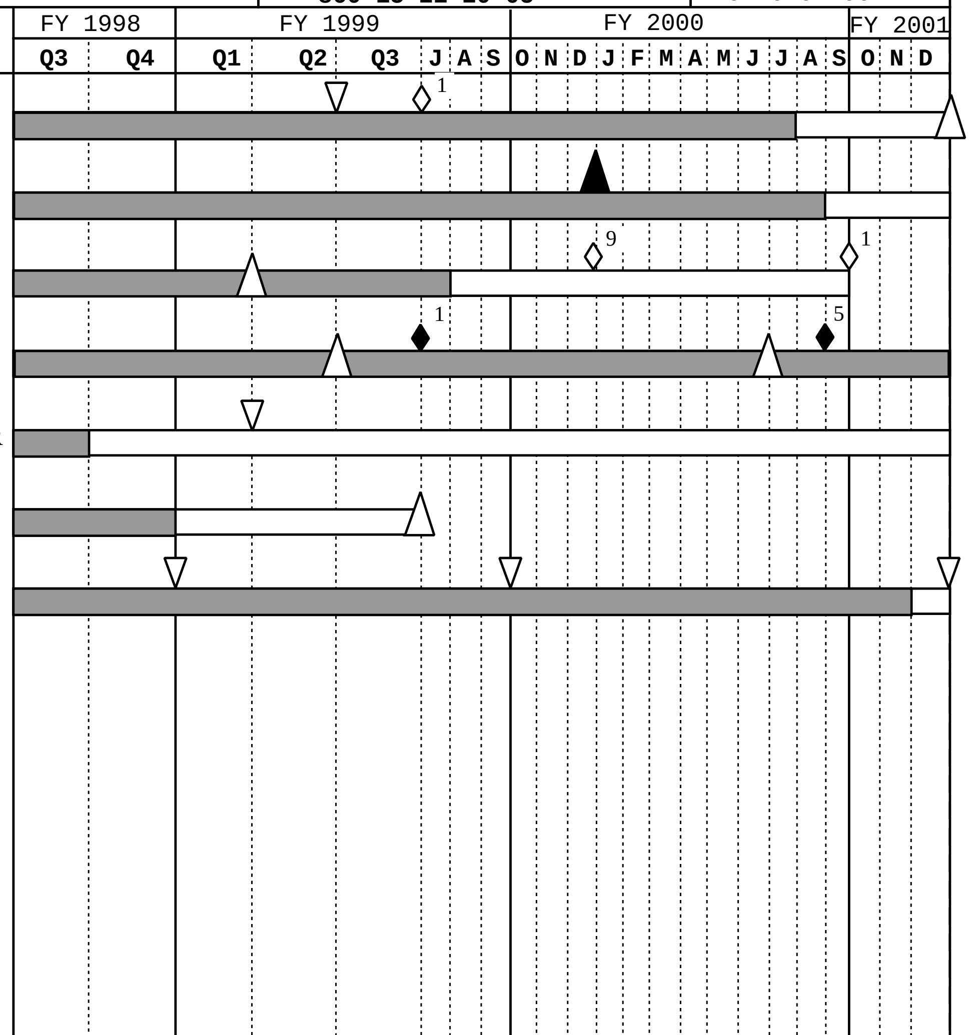
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
4.5.A.	Complete Plans for Testing of Specimens in MEA Capsule, Procurement and Testing of Palisades Capsule & Evaluation of PWHT Sheets
4.5.B.	Complete Letter Report Regarding RPV Materials Available for Irradiation Study
4.5.D.	Complete Letter Report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



11. REMARKS

1. CONTRACT REPORTING ELEMENT **HSSI - 5. Modeling & Microstructural Analysis**	2. REPORTING PERIOD **11/27/00 - 12/24/00**	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
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
HSSI - 6. Irradiation Coordination

2. REPORTING PERIOD
11/27/00 - 12/24/00

3. JCN NO.
W6953

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

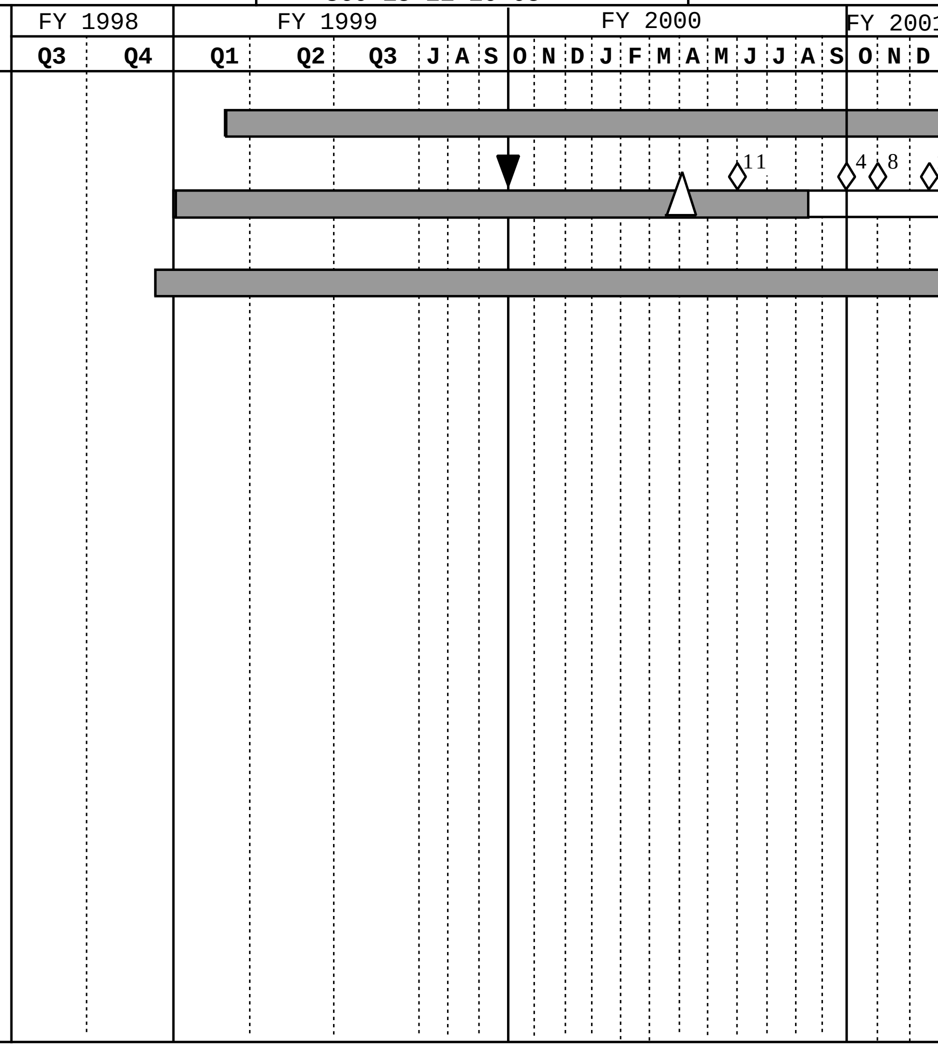
5. CONTRACT PERIOD
FY 1998-2001

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

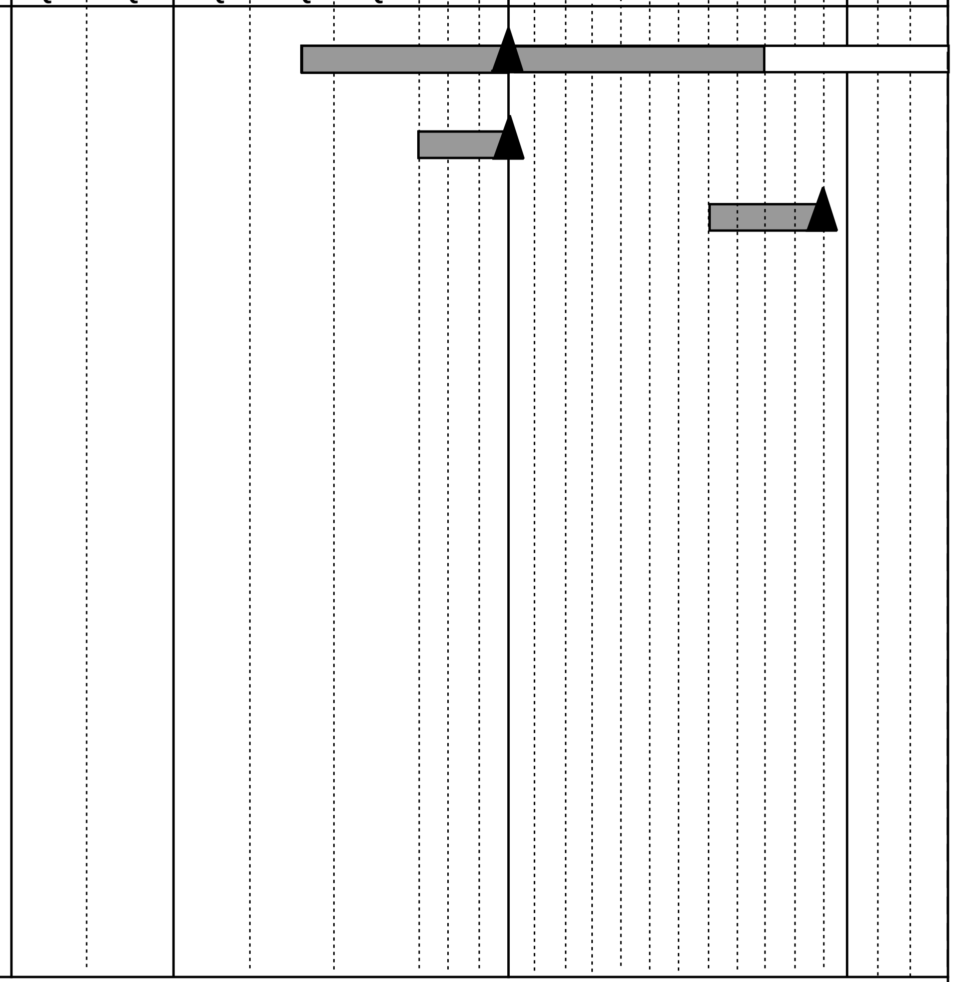
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
6.1.A.	Coordinate the Operation, Data Collection, and Maintenance of the HSSI IAR Facility
6.1.B.	Comprehensive Report on Reusable Irradiation Facilities
6.2.A.	Coordinate the Operation, Data Collection, and Maintenance of the UCSB Irrad.Facility



11. REMARKS

1. CONTRACT REPORTING ELEMENT **HSSI - 7. Embrittlement DB & Dosimetry Evaluation**	2. REPORTING PERIOD **11/27/00 - 12/24/00**	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	FY 1998		FY 1999						FY 2000												FY 2001		
		Q3	**Q4**	**Q1**	**Q2**	**Q3**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
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