ORNL/HSSI (6953)/MLSR-2000/12

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

Monthly Letter Status Report

September 2000

ORNL/HSSI (6953)/MLSR-2000/12

HEAVY-SECTION STEEL IRRADIATION

PROGRAM

JCN W6953

MONTHLY LETTER STATUS REPORT

FOR

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Submitted by

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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 six 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 November 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
September 2000

Job Code Number:	**W6953**
Project Title:	**Heavy-Section Steel Irradiation Program**
Period of Performance:	**4/1/98 to 11/30/00**
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1. PROJECT OBJECTIVE:

The primary goal of the Heavy-Section Steel Irradiation (HSSI) Program is to provide a thorough, quantitative assessment of the effects of neutron irradiation on the material behavior, and in particular the fracture toughness properties, of typical pressure vessel steels as they relate to light-water reactor pressure vessel (RPV) integrity. The program includes studies of the effects of irradiation on the degradation of mechanical and fracture properties of vessel materials augmented by enhanced examinations and modeling of the accompanying microstructural changes. Effects of specimen size; material chemistry; product form and microstructure; irradiation fluence, flux, temperature, and spectrum; and post-irradiation mitigation are being examined on a wide range of fracture properties. This program will also maintain and upgrade computerized 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 1.1 A) Beginning next fiscal year, a three percent federal access charge (FAC) will be applied to the HSSI Program. This tax, which was waived in FY 00, will apply to all uncosted funds including prior year carryover and committed funds as well as new obligations.

(Milestone 1.1.B) The University of Michigan kindly submitted invoices to the HSSI Program for neutrons and services from the Ford Nuclear Reactor (FNR) through late September. This enabled the Program to reduce its FY00 carryover and therefore the FY01 FAC tax.

(Milestone 1.2.B)To address the issue of the repair of the 100-kip MTS servohydraulic machine in the IMET hot cell # 3, a cost growth letter was submitted to the NRC and funding was received. A schedule to complete the repairs will be established by the hot cell staff during the next reporting period. The potential use of another servohydraulic machine in an adjoining hot cell was also investigated, but the load capacity of that machine was found to be insufficient in its current configuration to test the KS01 weld specimens. It is now anticipated 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 November. Testing of the PSI-supplied JRQ specimens (subtask 3.3) should begin during the next calendar year.

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 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°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. Preparations have begun to perform the repairs on the hot cell servohydraulic machine. As soon as the repairs are complete, 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 in the Ford Reactor at the University of Michigan.

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 preparation of 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), has been completed and the manuscript is being edited and prepared for 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) Two broken halves of previously tested compact specimens were sent for machining to obtain 12 0.5T compact specimens for further testing. The 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$\sqrt{}$m using the Master Curve obtained from the previous results. The actual value obtained was 70.4 MPa$\sqrt{}$m, which is 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. Following discussions with our collaborators at AEA-Technology, Harwell, United Kingdom, and with other researchers at the IGRDM meeting in Leuven, Belgium, it was decided that additional scanning electron fractography should be performed to evaluate the fracture mode of the specimens previously tested at the highest temperatures (room temperature and above). At test temperatures from -125°C to -50°C, the K_{Jc} values follow the master curve very well up to about 150 MPa$\sqrt{}$m. At temperatures up to about 50°C, the fracture toughness does not increase significantly, yet unstable fracture occurs. This fractographic evaluation will specifically determine the presence of the 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. Limited results from at least one other study of intergranular fracture in RPV steels have suggested an increase in the temperature range over which unstable fracture occurs. The additional planned fractographic evaluation will allow such a determination for the results of the HSSI tests. Based on planned discussions R. K. Nanstad held with French researchers during the IGRDM meeting (see 4.4) regarding their studies of intergranular fracture, the French will send fracture-toughness data from material that fractured by intergranular fracture for analysis relative to the master curve.

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.

Abstracts have been selected for the ASTM Fourth International Symposium on Small Specimen Techniques and the preliminary program has been developed. This symposium will be held in January 2001 and M. A. Sokolov is serving as the Chairman.

(Milestone 2.7.A) 1T C(T) and precracked Charpy specimens have been machined from three blocks of material and fatigue precracking is underway in preparation for testing as part of the size effects 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.

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

The purpose of this subtask is to 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, J. G. Merkle, and J. Galt, has been 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 that could be utilized for evaluating the application of surrogate materials. This work is intended to be included in the final NUREG report on this subject.

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

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

(Milestone 2.10.A) No significant activity during this reporting period

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_{Ja} in order to evaluate the relative changes in the recovery and reembrittlement between CVN and fracture-toughness properties and a detailed examination of reembrittlement rates. These questions will be addressed 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 reported 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. Moreover, a presentation was delivered at the IGRDM meeting in September in Leuven, Belgium.

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, 1999.

(Milestone 3.2.C) Internal and external reviewers' comments and final revisions were incorporated into the paper, "Reirradiation Response Rate of a High-Copper Reactor Pressure Vessel Weld," by S. K. Iskander, R. K. Nanstad, C. A. Baldwin, D. W. Heatherly, M. K. Miller, and I. Remec, and has been transmitted to ASTM for publication in *Effects of Radiation on Materials, 20th International Symposium*, ASTM STP 1405.

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 has been placed on hold due to scheduling and cost issues in the hot cells, particularly the need for repair of the servohydraulic machine.

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) An operational milestone NUREG report is in preparation: *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. The abstract follows:

> The attenuation of Charpy impact toughness through the wall of a reactor pressure vessel (RPV) was determined from testing 42 irradiated full-size Charpy specimens. The Charpy specimens were machined from eight irradiated trepans from the axial weld of the decommissioned Japan Power Demonstration Reactor (JPDR). Although the results show no attenuation through the 75-mm-thick RPV, the data are not adequate to show significant agreement or disagreement with predictions of U.S. Nuclear Regulatory Commission *Regulatory Guide 1.99*, Revision 2 (RG 1.99-2), because of the relatively small measured Charpy shifts. These small shifts were due to the relatively low exposure of the vessel to neutron irradiation. Thus, although the results are important in the overall context of through-thickness attenuation studies, they cannot be used independently to draw more definitive conclusions regarding the RG 1.99-2 attenuation predictive equation. The irradiation-induced shifts, however, do appear to be reasonable with regards to whether they originated from the core (beltline) or the remote-from-core regions of the vessel, and also whether they were from the inside or outside regions of the vessel wall. This report gives detailed results of testing the 42 JPDR Charpy specimens machined from the irradiated weld metal. An important part of the machining activity is the facilities that enable such machining of irradiated materials. The machining of the Charpy specimens from the JPDR weld trepans is described as an example of the ORNL capabilities to machine irradiated materials.

<u>Subtask 4.2: Reconstitution of Irradiated Toughness Specimens</u> (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.

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

The purpose of this subtask is to evaluate the effects of irradiation 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 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 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.

The International Group on Radiation Damage Mechanisms (IGRDM) in Pressure Vessel Steels held IGRDM-9 in Leuven, Belgium on September 18-22. Approximately 75 presentations were given, with contributions from Europe, Asia, and the United States. The meeting was hosted locally by SCK-CEN and Tractebel. R. K. Nanstad is the Secretary of the IGRDM and assisted the local host and the IGRDM Executive Committee in the planning. Seven presentations were given by ORNL staff from the HSSI Program. The program on Friday, September 22, was open to members of industrial, academic, and research organizations. The topic of the open seminar was lifetime management of RPVs, with invited presentations from various countries. During the executive committee meeting, Mr. Tim Williams of Rolls-Royce was named the new IGRDM chairman and R. K. Nanstad was voted secretary. The vice-chairman is yet to be named.

Prior to the IGRDM meeting, R. K. Nanstad and R. E. Stoller traveled to the United Kingdom and visited with researchers at AEA-Technology, Harwell, regarding ongoing collaborations in the areas of phosphorus segregation, fracture mechanics, and radiation damage modeling. R. K. Nanstad held discussions with French researchers at the IGRDM meeting regarding collaboration on intergranular fracture studies (see 2.6). Following the IGRDM meeting, M. A. Sokolov visited with researchers at SCK-CEN, Mol, Belgium, regarding master curve activities, and then traveled to Stuttgart, Germany, to meet with researchers at MPA to discuss HSSI testing of the KS-01 weld.

<u>Subtask 4.5: Technical assistance</u> (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.

<u>Task 5: Modeling & Microstructural Analysis</u> (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). Atom probe tomography results on weld 73W specimens were incorporated into the NUREG report entitled, “Effect of Reirradiation Rate on The Charpy Properties of an Irradiated/Annealed High Copper Reactor Pressure Vessel Weld HSSI 73W.”

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, 1999.

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 HSSI-IAR facilities were irradiated for 6.7 days during reactor half-cycle 449B and 5.7 days during reactor half-cycle 450A. The FNR was shut down for approximately three days during half-cycle 449B due to instrument problems in the FNR control room. The HSSI-IAR facilities were shut down and cranked away from the reactor early in half-cycle 450A in order for the ORNL Instrumentation and Controls Division to perform the annual maintenance and calibration on the facility instrumentation. During the maintenance work, the thermocouple lead hoses on the IAR-1 and IAR-2 capsules were replaced due to radiation damaged insulation. The new experiment lead hoses were fabricated using electrical leads with a more radiation resistant insulation.

During the 6.7 of days of half-cycle 449B, the IAR irradiation facilities received a total of 161 EFPH (effective full power hours). During the first 5.7 days of reactor half-cycle 450A, the facilities received an additional 138 EFPH. The total irradiation time received by the HSSI-IAR irradiation facilities during this reporting period was 299 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 3073 EFPH. At the end of this reporting period, the second group of specimens had been irradiated for a total of 3372 EFPH. The facilities themselves had been in service for a total of 7700 EFPH.

(Milestone 6.1.B) The draft NUREG report on the reusable irradiation facilities will be completed in October due to limited staff availability .

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.

During this reporting period, the HSSI-UCSB facility was irradiated for 6.7 days during reactor half-cycle 449B and 5.7 days during reactor half-cycle 450A. The FNR was shut down for approximately three days during half-cycle 449B due to instrument problems in the FNR control room. The HSSI-UCSB facility was shut down and cranked away from the reactor early in half-cycle 450A in order for the ORNL Instrumentation and Controls Division to perform the annual maintenance and calibration on the facility instrumentation. During the maintenance work, the computer that controls the HSSI-UCSB facility was replaced with a much faster version. The original computer had been in service since the HSSI program began irradiating specimens at the FNR in the early 1990's. The new computer was not purchased with NRC funds.

During the 6.7 of days of half-cycle 449B, the UCSB irradiation facility received a total of 161 EFPH (effective full power hours). During the first 5.7 days of reactor half-cycle 450A, the facility received an additional 138 EFPH. The total irradiation time received by the HSSI-UCSB irradiation facility during this reporting period was 299 EFPH.

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

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

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

The purpose of the subtask is to maintain and update the EDB. This 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 September 12-16, 2000, R. K. Nanstad and R. E. Stoller traveled to Harwell, United Kingdom, to meet with staff members at AEA-Technology concerning collaborative efforts within the HSSI Program on irradiation effects, fracture mechanics, and phosphorus segregation in reactor vessel steels.

On September 17-23, 2000, M. K. Miller, R. K. Nanstad, M. A. Sokolov, and R. E. Stoller traveled to Leuven, Belgium, to make presentations and participate in the meetings of the International Group on Radiation Damage Mechanisms.

On September 25, M. A. Sokolov traveled to Mol, Belgium, to meet with staff members at SCK-CEN concerning the application of the Master Curve methodology to precracked Charpy V-notch and smaller specimens.

On September 26, M. A. Sokolov traveled to Stuttgart, Germany, to meet with staff at MPA regarding collaborative work on the KS-01 weld, which was supplied to ORNL for irradiation studies.

4. PRESENTATIONS, REPORTS, PAPERS, AND PUBLICATIONS:

R. K. Nanstad, D. E. McCabe, M. A. Sokolov, C. A. English, and S. R. Ortner, "Investigation of Temper Embrittlement in RPV Steels Following Thermal Aging, Irradiation, and Thermal Annealing," presented by R. K. Nanstad, IGRDM, Leuven, Belgium, September 18-22, 2000.

R. K. Nanstad, D. E. McCabe, M. A. Sokolov, and J. G. Merkle, "Relationship of Fracture Toughness from Intergranular Fracture to the Master Curve," presented by R. K. Nanstad, IGRDM, Leuven, Belgium, September 18-22, 2000.

S. K. Iskander, R. K. Nanstad, M. K. Miller, and M. A. Sokolov, "Reirradiation Response of a High-Copper Reactor Pressure Vessel Weld," presented by M. A. Sokolov, IGRDM, Leuven, Belgium, September 18-22, 2000.

M. A. Sokolov and R. K. Nanstad, "Status of Fracture Toughness Characterization of a Highly Embrittled Reactor Pressure Vessel Weld," presented by M. A. Sokolov, IGRDM, Leuven, Belgium, September 18-22, 2000.

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:

Beginning next fiscal year, a three percent federal access charge will be applied to the HSSI Program. This tax will apply to all uncosted funds including prior year carryover and committed funds as well as new obligations.

The servohydraulic machine in the hot cell is still under repair. The replacement actuator has been reconditioned and is ready to install in the hot cell machine. Additional funds have been received from NRC to accomplish this work and a schedule is being established by the hot cell staff. The potential use of another servohydraulic machine in an adjoining cell was investigated, but the load capacity of that machine was insufficient in its current configuration to test the KS-01 weld specimens. This issue has caused a delay in completion of the fracture toughness testing of the highly embrittled KS-01 1T compact specimens to examine shape of the master curve for highly embrittled RPV material. Testing is expected to resume in November.

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: 8/28/00-9/30/00

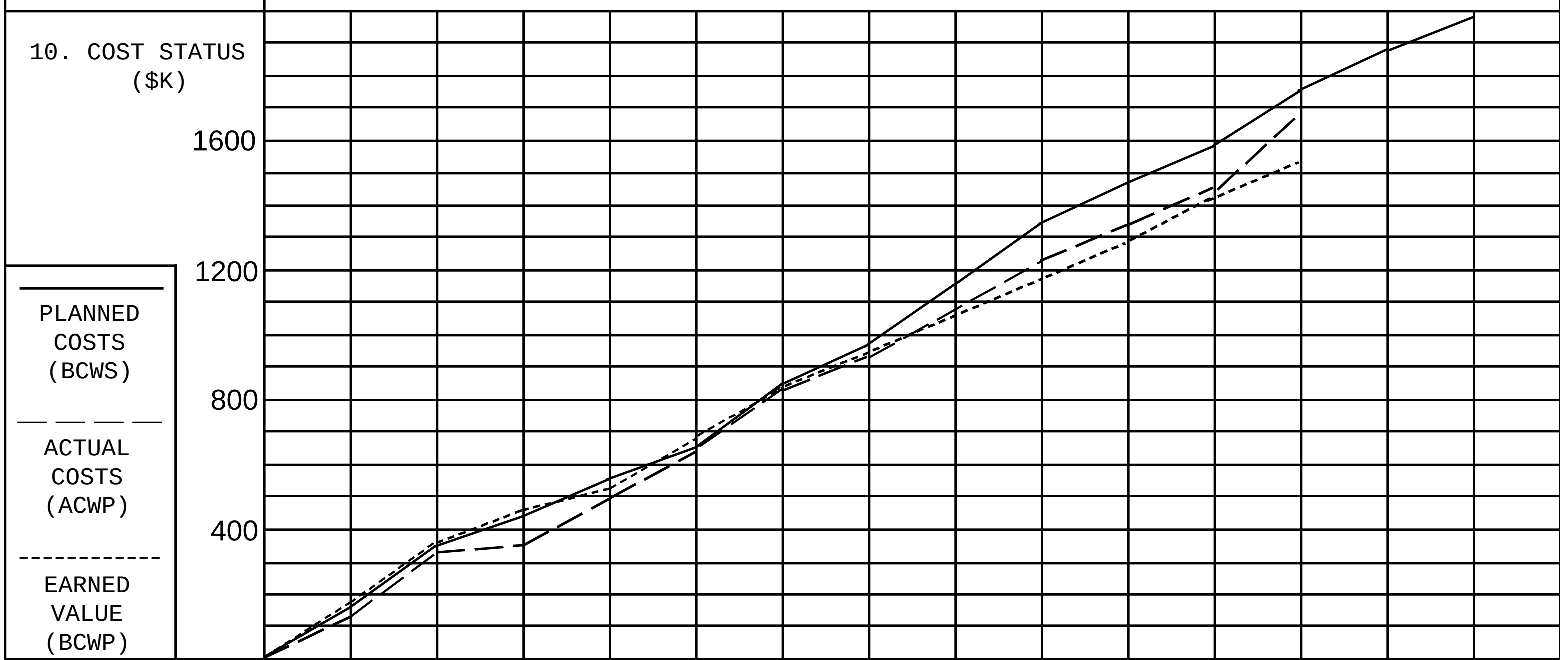
		Current Month	Fiscal Year to Date	Cumulative Project to date
I.	Direct Staff Effort	13 MM	9.9 MY	29.8 MY
II.	A. Direct Lab Staff Effort ($)			
	Direct Salaries	100,742	959,466	3,012,705
	Materials and Services	19,371	54,792	375,956
	ADP Support	61	784	1,785
	Subcontracts	72,715	165,114	362,418
	Travel	1,904	26,101	116,609
	Indirect Labor Costs	0	0	0
	Other: NRC-PO Tax	3,000	48,000	141,500
	General and Administrative	49,039	432,372	1,379,222
	Total UT-Battelle Costs	246,832	1,686,629	5,390,195
	B. DOE Federal Access Costs	0	0	0
	TOTAL PROJECT COSTS	246,832	1,686,629	5,390,195

Percentage of available cumulative funds costed	95
Percentage of available current FY funds costed	86
Funds Remaining	279,805
Commitments:	32,948
BA Remaining	246,857

1. CONTRACT REPORTING ELEMENT **HSSI - Heavy-Section Steel Irradiation Program**	2. REPORTING PERIOD **8/28/00 - 9/30/00**	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: 9/15/00

PLANNED COSTS FOR ELEMENT ($K): 1,966

ELEMENT COSTS FOR PRIOR FYS ($K): 306

ACCRUED COSTS ($K)

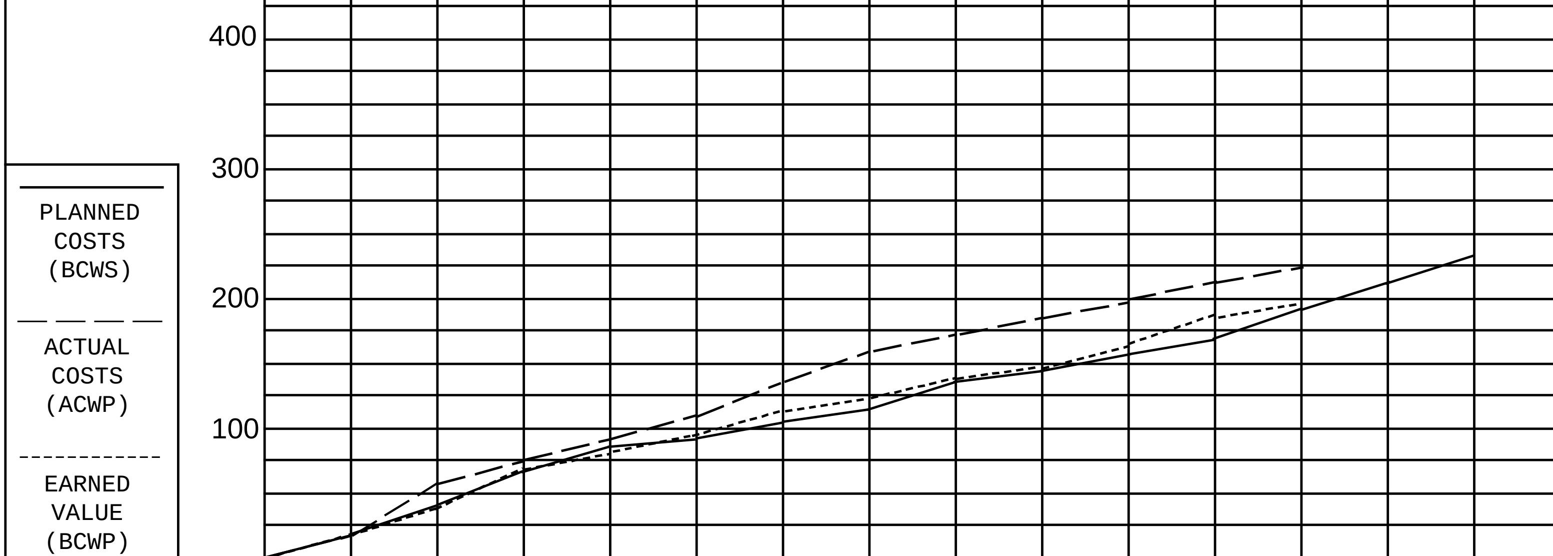
	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	168	156	99	115	118	166	163	166	172	142	132	150	150	69	
ACTUAL	113	207	29	149	153	159	137	147	144	95	107	247			
EARNED	140	157	104	107	172	139	137	112	122	101	119	120			
CUM. PLAN.	168	324	423	538	656	822	985	1151	1323	1465	1597	1747	1897	1966	
CUM. ACT.	113	320	349	498	651	810	947	1094	1238	1333	1440	1687			
CUM. EARN.	177	334	434	508	680	819	956	1068	1190	1291	1410	1530			

11. REMARKS:

1. CONTRACT REPORTING ELEMENT **HSSI - 1. Program Management**	2. REPORTING PERIOD **8/28/00 - 9/30/00**	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: 9/15/00

PLANNED COSTS FOR ELEMENT ($K): 229

ELEMENT COSTS FOR PRIOR FYS ($K): 29

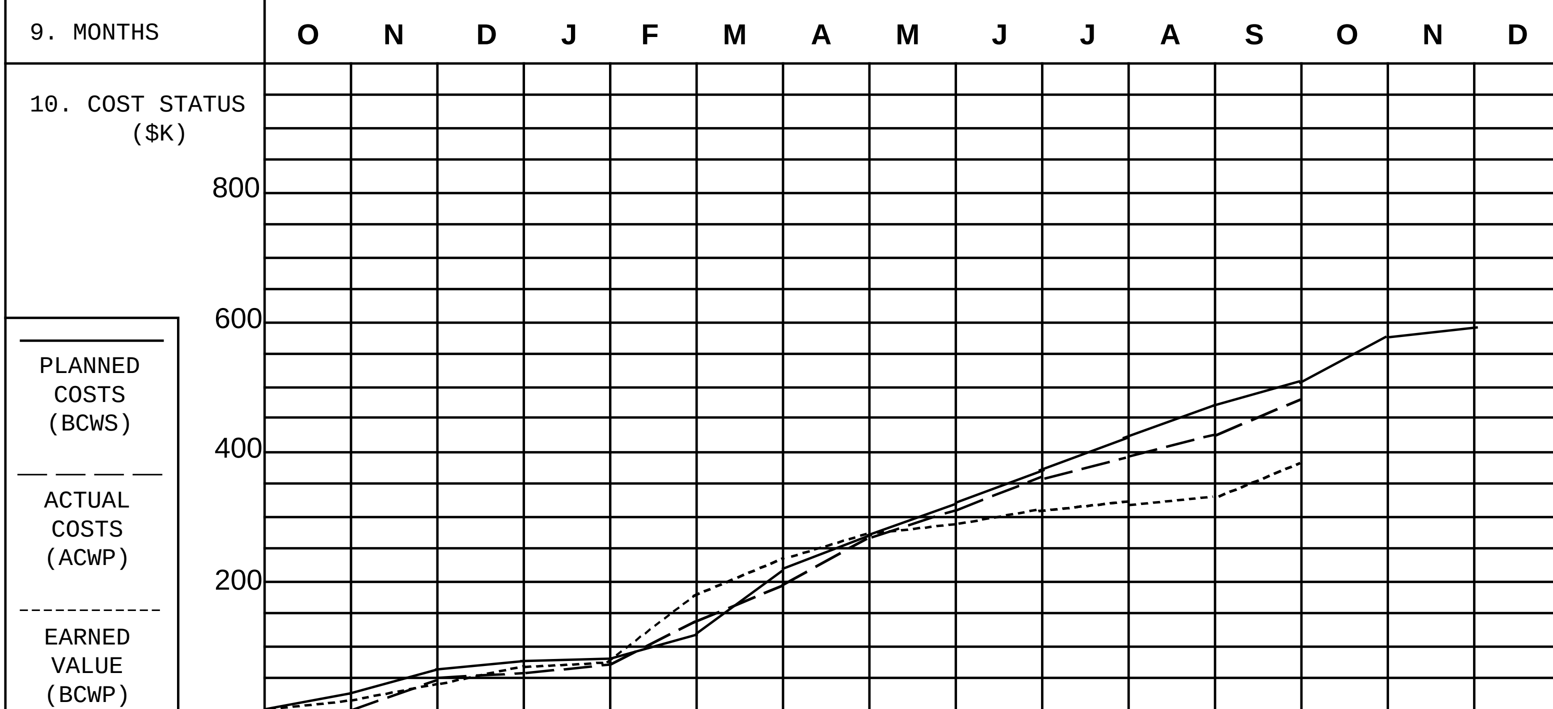
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	18	25	21	17	13	11	12	13	15	12	14	25	18	15	
ACTUAL	18	37	20	17	21	19	25	15	16	11	13	12			
EARNED	18	24	23	14	18	13	14	12	15	13	17	13			
CUM. PLAN.	18	43	64	81	94	105	117	130	145	157	171	196	214	229	
CUM. ACT.	18	55	75	92	113	132	157	172	188	199	212	223			
CUM. EARN.	18	42	65	79	97	110	124	136	151	164	181	194			

11. REMARKS:

1. CONTRACT REPORTING ELEMENT **HSSI - 2. Fracture Toughness Transition and MC Methodology**	2. REPORTING PERIOD **8/28/00 - 9/30/00**	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

10. COST STATUS ($K)



COST PLAN DATES: 9/15/00

PLANNED COSTS FOR ELEMENT ($K): 589

ELEMENT COSTS FOR PRIOR FYS ($K): 21

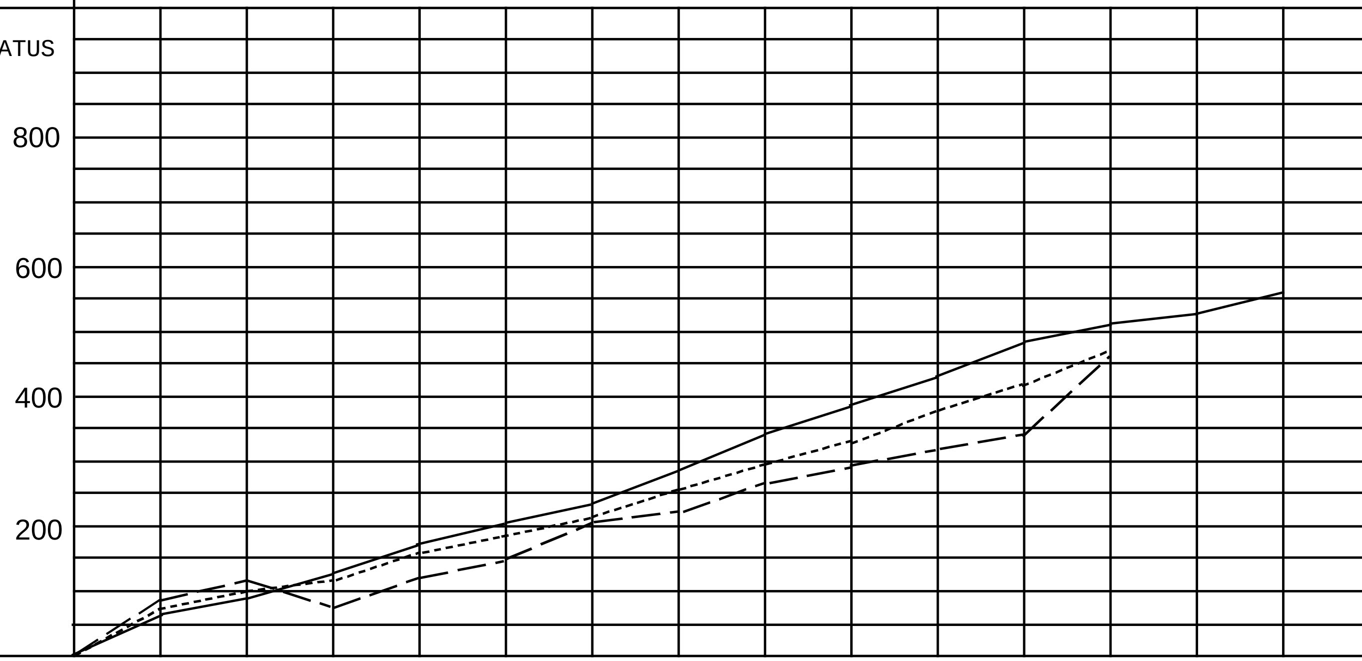
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	29	25	14	20	36	80	57	55	47	52	45	44	70	15	
ACTUAL	-18	43	14	50	53	53	63	51	44	29	43	51			
EARNED	24	24	11	26	89	59	36	20	18	13	23	30			
CUM. PLAN.	29	54	68	88	124	204	261	316	363	415	460	504	574	589	
CUM. ACT.	-18	25	39	89	142	195	258	309	353	382	425	476			
CUM. EARN.	24	48	59	87	174	233	269	289	307	320	343	373			

11. REMARKS:

1. CONTRACT REPORTING ELEMENT **HSSI - 3. Irradiation Embrittlement of RPV Steel**	2. REPORTING PERIOD **8/28/00 - 9/30/00**	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): 552

ELEMENT COSTS FOR PRIOR FYS ($K): 167

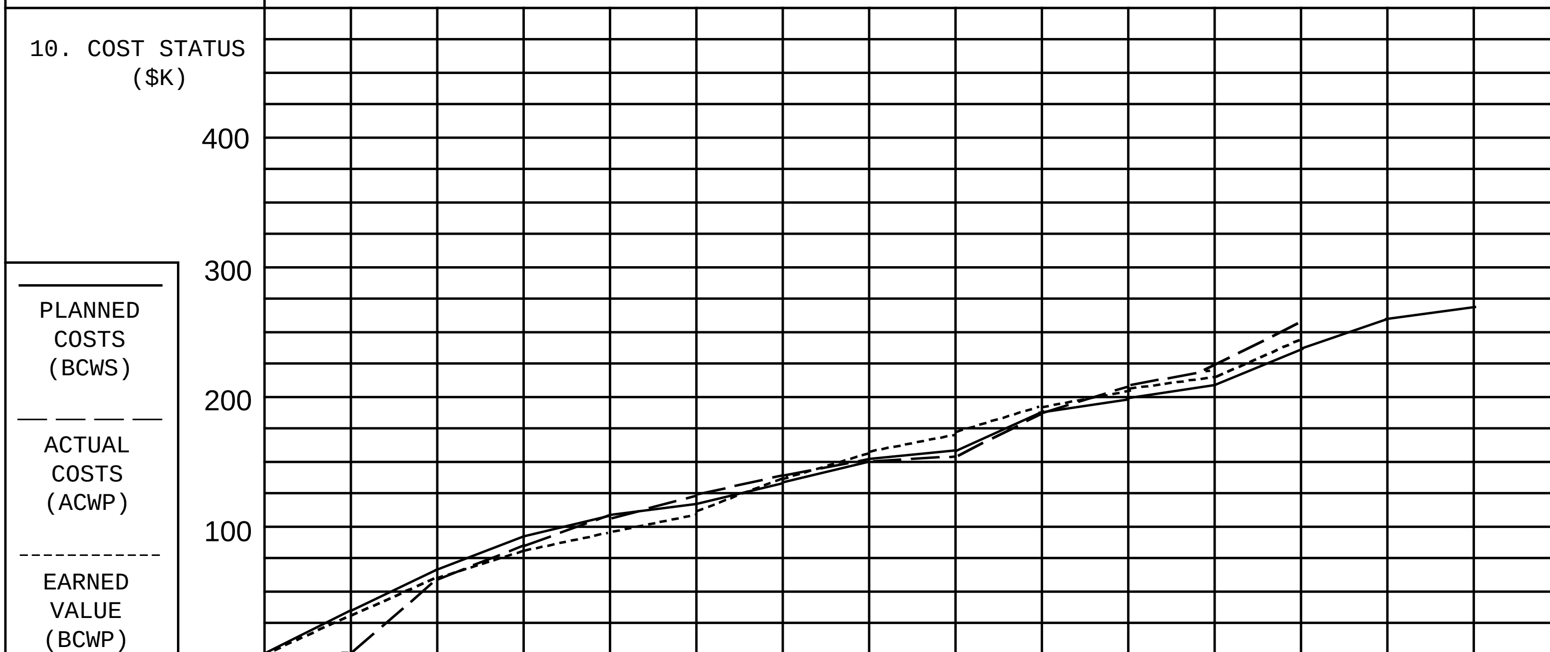
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	52	43	30	41	35	42	46	52	51	41	41	32	24	22	
ACTUAL	92	31	-50	48	28	62	17	32	35	20	25	115			
EARNED	48	42	29	33	28	33	38	40	41	40	47	38			
CUM. PLAN.	52	95	125	166	201	243	289	341	392	433	474	506	530	552	
CUM. ACT.	92	123	73	121	149	211	228	260	295	315	340	455			
CUM. EARN.	48	90	119	152	180	213	251	291	332	372	419	457			

11. REMARKS:

1. CONTRACT REPORTING ELEMENT **HSSI - 4. Validation of Irradiated and Aged Materials**	2. REPORTING PERIOD **8/28/00 - 9/30/00**	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): 272

ELEMENT COSTS FOR PRIOR FYS ($K): 30

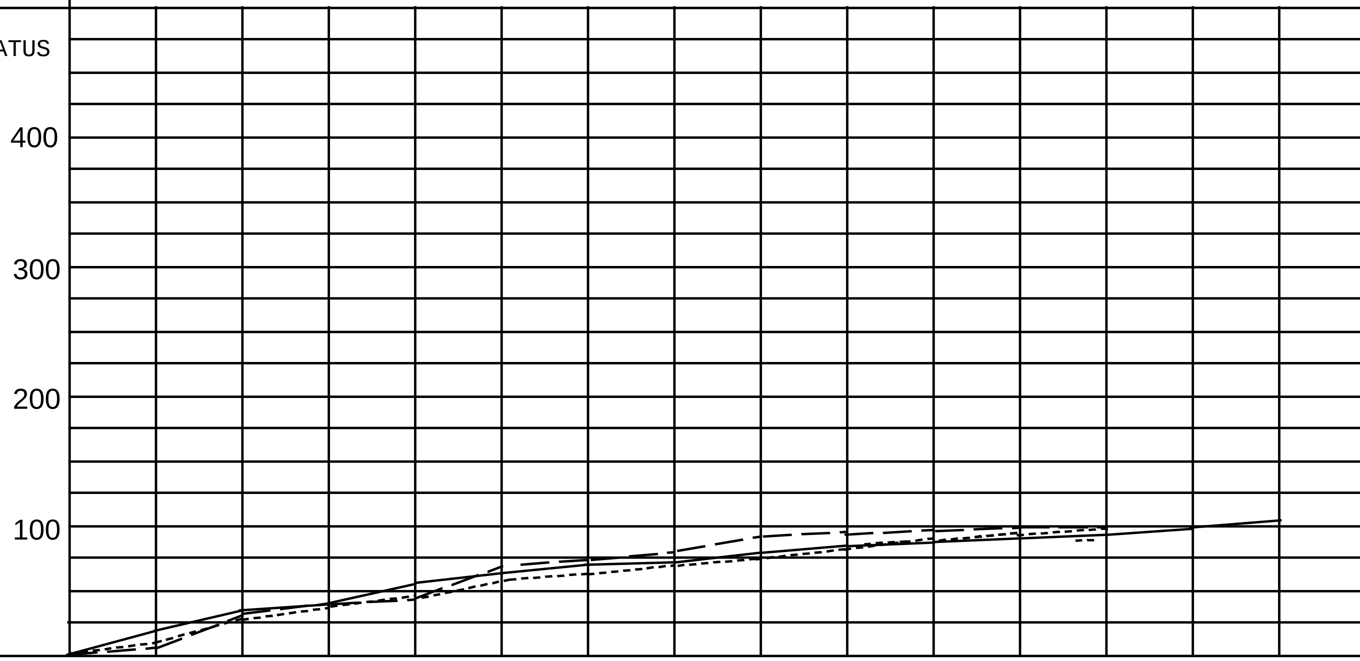
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	35	37	20	15	11	12	20	15	18	17	13	23	22	14	
ACTUAL	1	57	29	20	17	13	14	11	26	29	17	20			
EARNED	30	31	23	14	15	18	23	14	18	20	18	23			
CUM. PLAN.	35	72	92	107	118	130	150	165	183	200	213	236	258	272	
CUM. ACT.	1	58	87	107	124	137	151	162	188	217	234	254			
CUM. EARN.	30	61	84	98	113	131	154	168	186	206	224	247			

11. REMARKS:

1. CONTRACT REPORTING ELEMENT **HSSI - 5. Modeling and Microstructural Analysis**	2. REPORTING PERIOD **8/28/00 - 9/30/00**	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)



Legend:
- PLANNED COSTS (BCWS) — solid line
- ACTUAL COSTS (ACWP) — long-dash line
- EARNED VALUE (BCWP) — dotted line

COST PLAN DATES: 1/4/00

PLANNED COSTS FOR ELEMENT ($K): 102

ELEMENT COSTS FOR PRIOR FYS ($K): 42

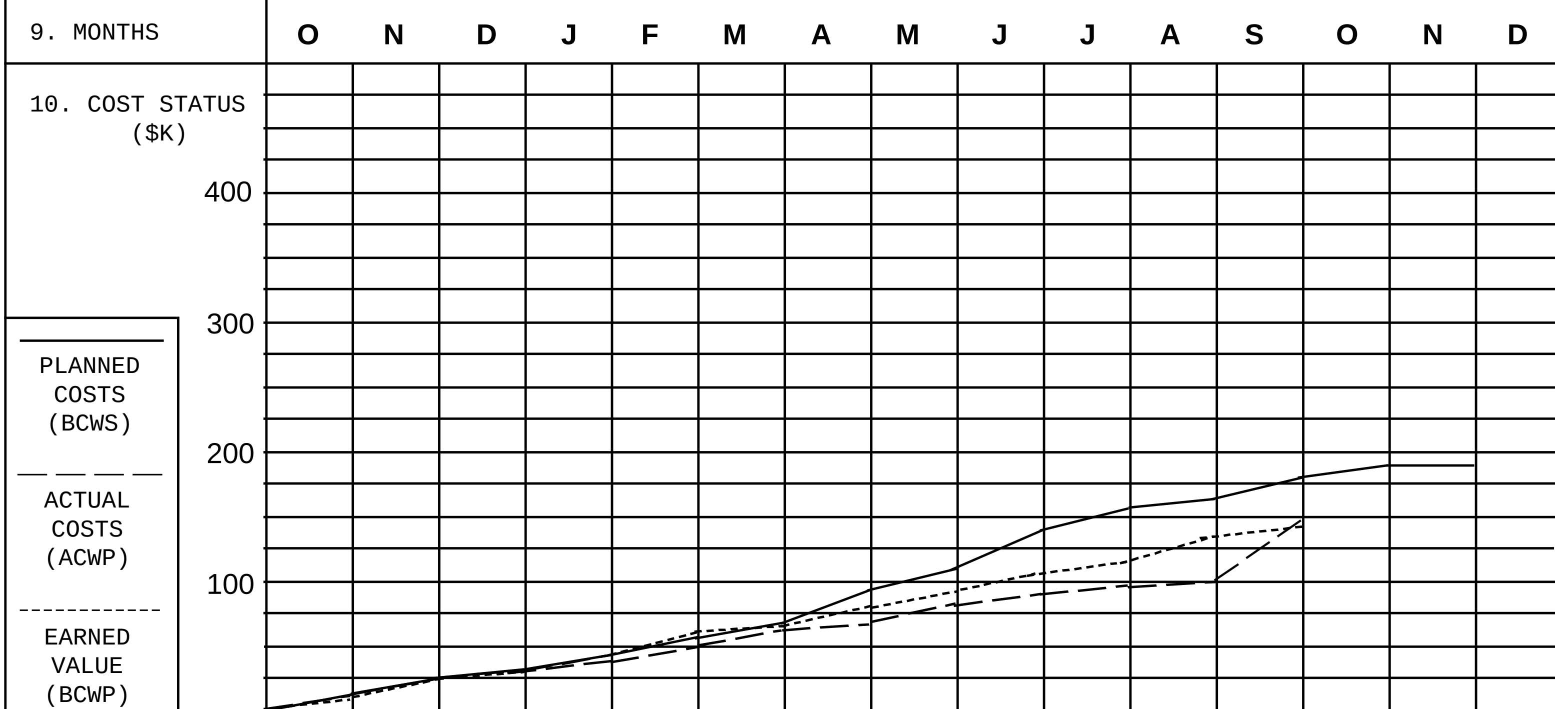
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	20	15	5	12	13	5	3	3	6	4	3	5	5	3	
ACTUAL	4	29	7	5	24	5	6	10	8	1	1	0			
EARNED	5	25	9	9	10	4	7	7	8	3	5	2			
CUM. PLAN.	20	35	40	52	65	70	73	76	82	86	89	94	99	102	
CUM. ACT.	4	33	40	45	69	74	80	90	98	99	100	100			
CUM. EARN.	5	30	39	48	58	62	69	75	84	87	92	94			

11. REMARKS:

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 6. Irradiation Coordination	**8/28/00 - 9/30/00**	**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

10. COST STATUS ($K)



COST PLAN DATES

1/4/00

PLANNED COSTS FOR ELEMENT ($K)

187

ELEMENT COSTS FOR PRIOR FYS ($K)

17

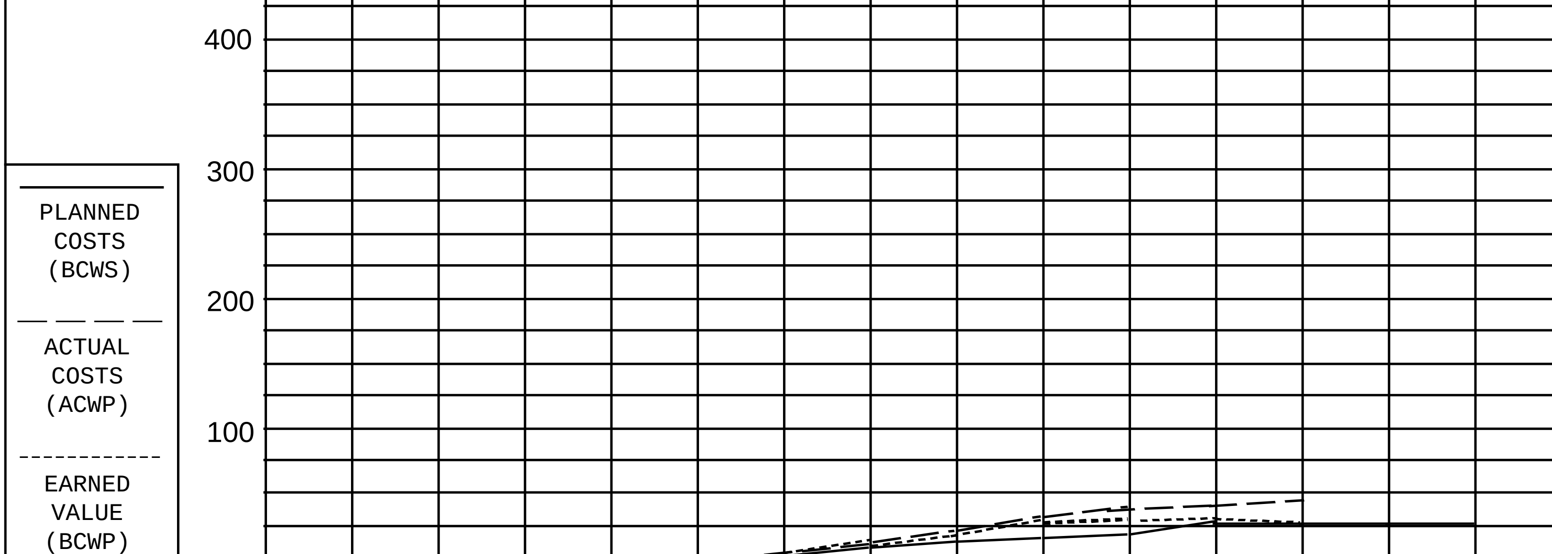
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	10	9	10	10	10	15	20	23	30	11	11	11	11	0	
ACTUAL	16	9	9	9	10	7	4	16	8	3	9	11			
EARNED	15	10	9	11	12	12	11	11	13	12	13	16			
CUM. PLAN.	16	25	35	45	55	70	90	113	143	154	165	176	187	187	
CUM. ACT.	16	25	34	43	53	60	64	80	88	91	100	149			
CUM. EARN.	15	25	34	45	57	69	80	91	104	116	129	145			

11. REMARKS:

1. CONTRACT REPORTING ELEMENT **HSSI - 7. Embrittlement DB & Dosimetry Evaluation**	2. REPORTING PERIOD **8/28/00 - 9/30/00**	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)



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	7	12	7	2	0	1			
EARNED	0	1	0	0	0	0	8	8	9	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	8	20	27	29	29	30			
CUM. EARN.	0	1	1	1	1	1	9	17	26	26	26	26			

COST PLAN DATES: 1/4/00

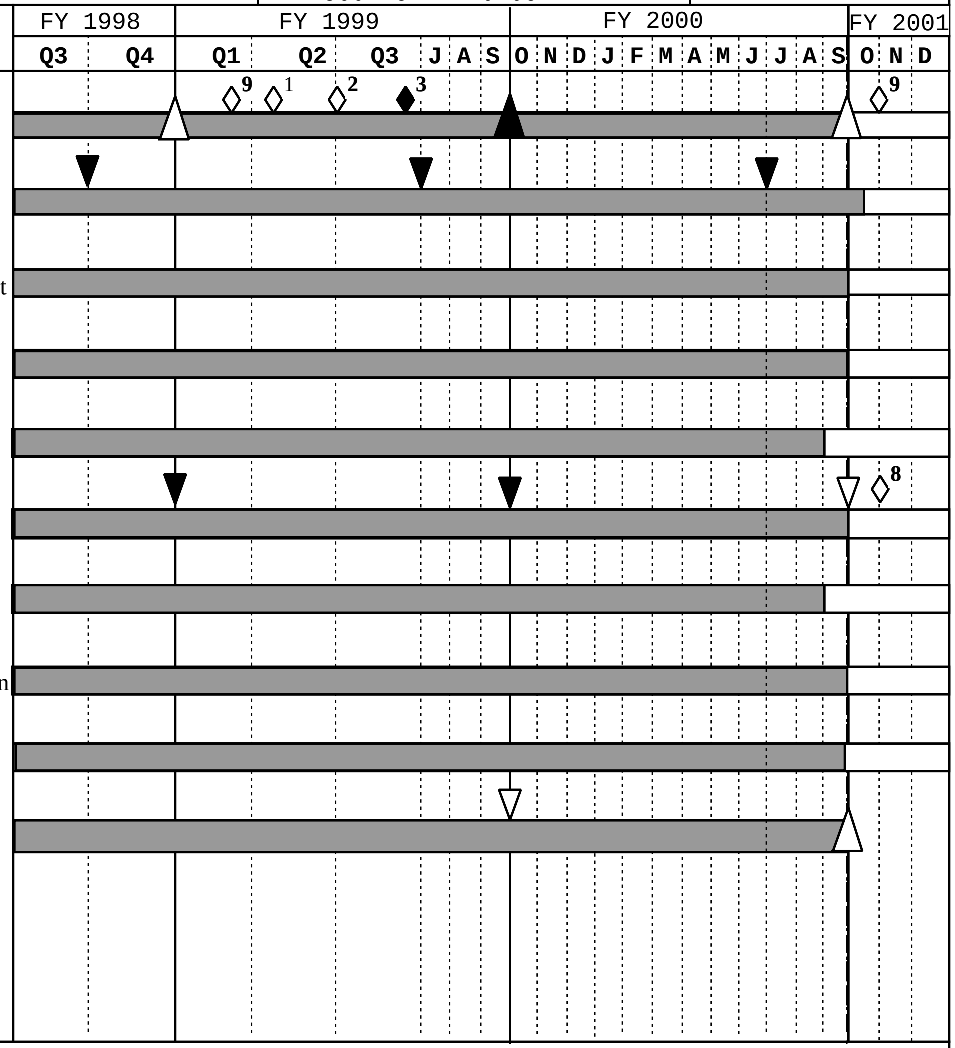
PLANNED COSTS FOR ELEMENT ($K): 26

ELEMENT COSTS FOR PRIOR FYS ($K): 1

11. REMARKS:

1. CONTRACT REPORTING ELEMENT **HSSI - 1. Program Management**	2. REPORTING PERIOD **8/28/00 - 9/30/00**	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**

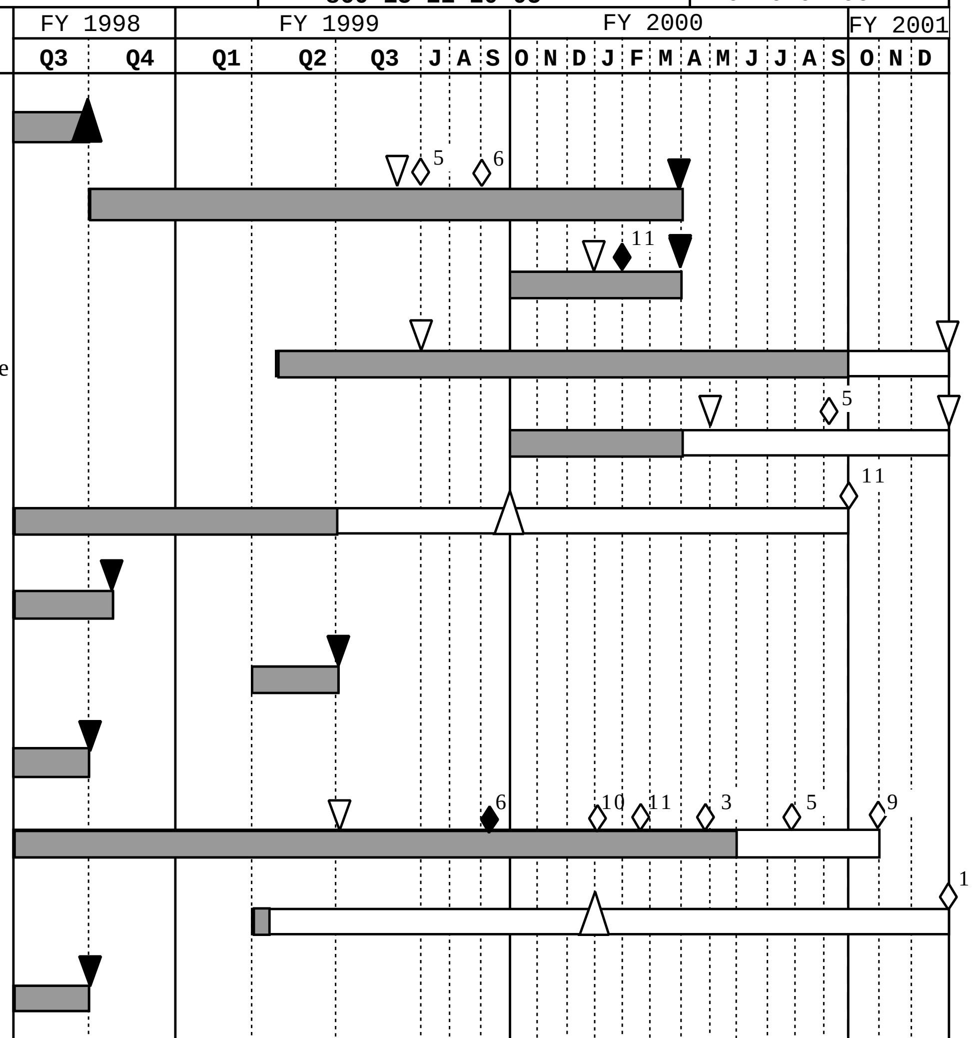
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
1.1.A.	Issue Project & Budget Proposal
1.1.B.	Select and Administer Subcontracts
1.2.A.	Issue Earned Value Based Monthly Management Reports (by the end of subsequent month)
1.2.B.	Ensure QA Requirements are met
1.3.A.	Participate in Appropriate Codes and 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 **8/28/00 - 9/30/00**	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**

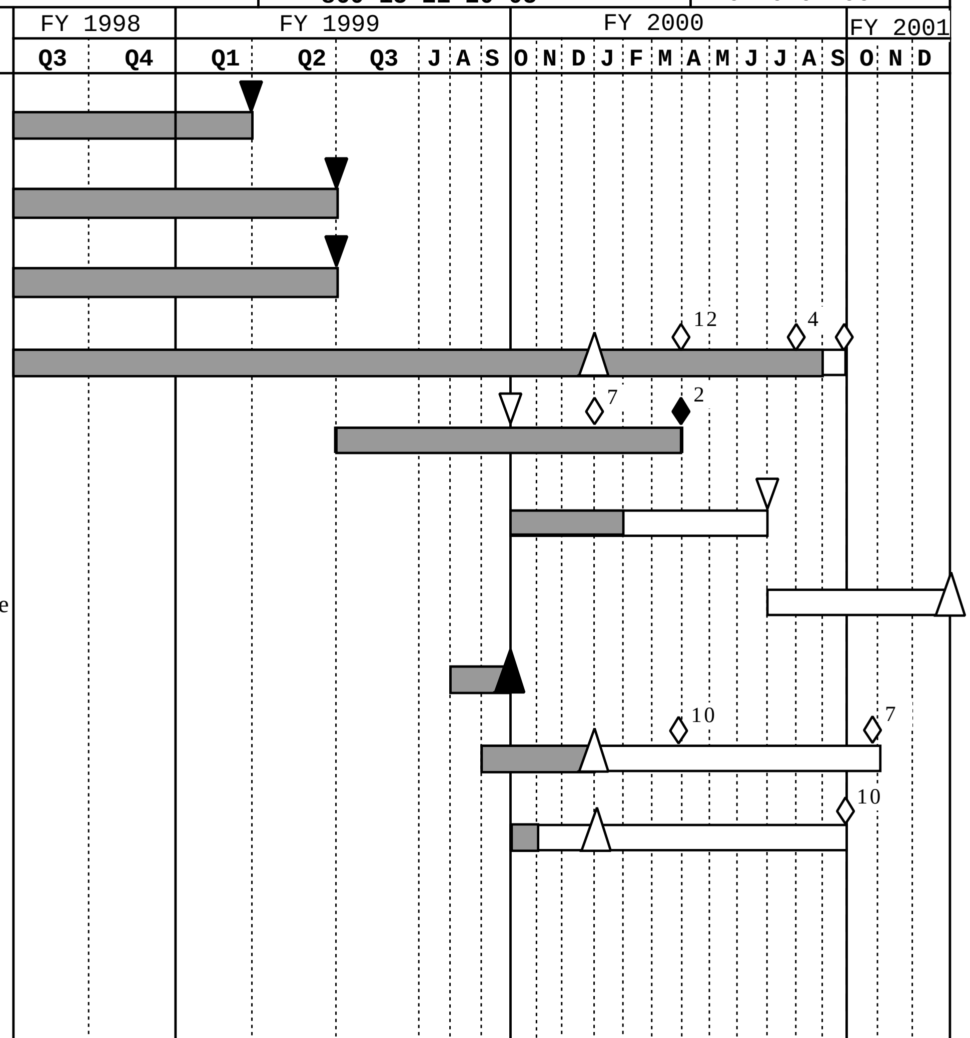
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
2.1.A.	Complete Draft NUREG Report on Comparison of CVN and Fracture Toughness Shifts
2.2.A.	Sample Preparation and Irradiation for Master Curve
2.2.B.	Receive Specimens
2.2.C.	Test Unirradiated & Irradiated Master Curve Specimens
2.2.D.	Draft Letter and 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 **8/28/00 - 9/30/00**
	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**

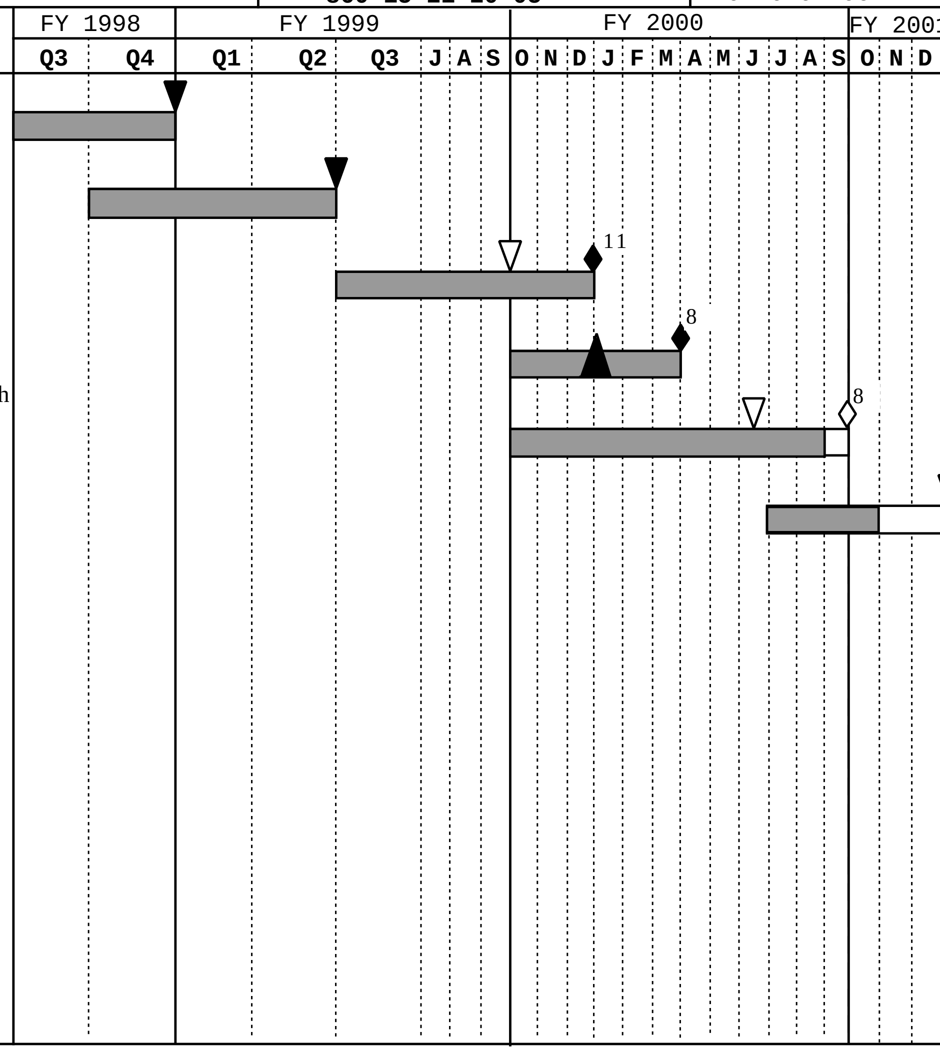
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
2.6.B.	Age & Evaluate by CVN
2.6.C.	Machine C(T)s and Test
2.6.D.	MC Impact Evaluations
2.6.E.	Reports and Administration
2.7.A.	Complete Fabrication and Preliminary Testing of Subsize Specimen
2.7.B.	Complete Testing of Subsize Specimens
2.7.C.	Complete 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 **8/28/00 - 9/30/00**	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**

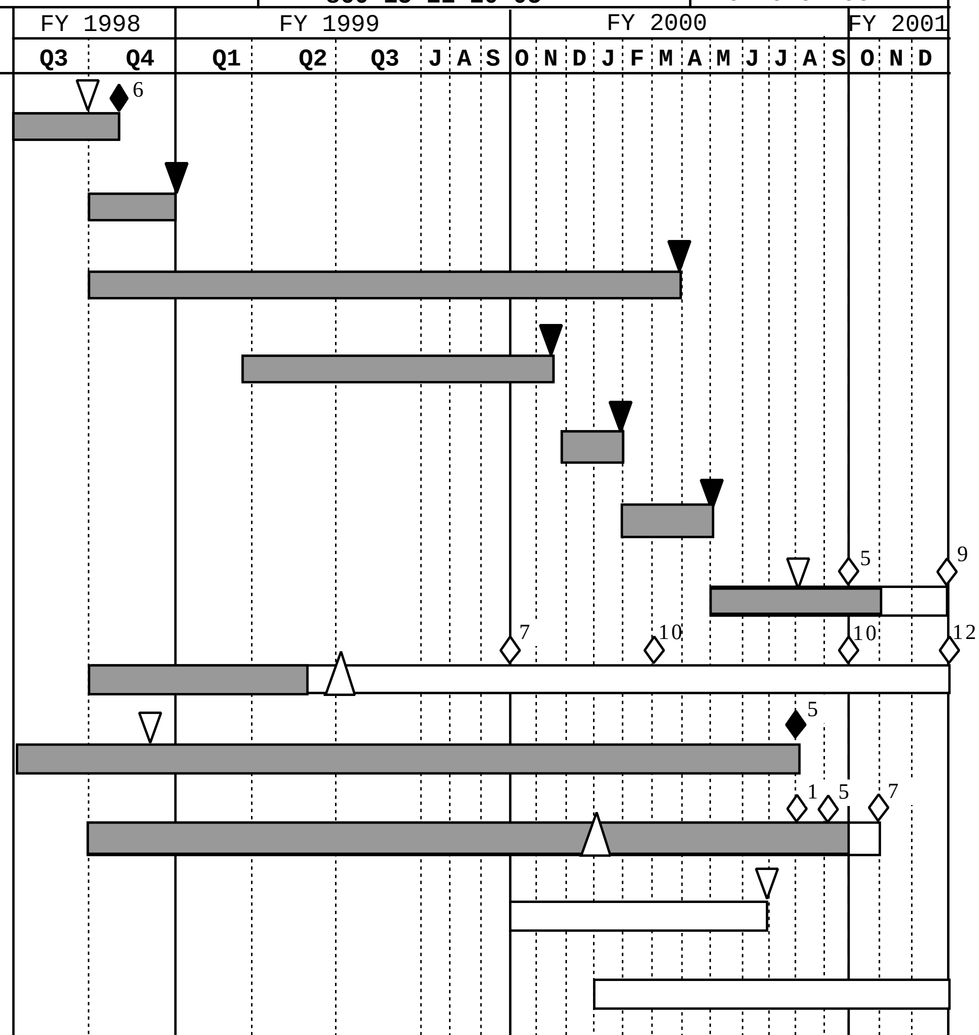
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
2.8.A.	Complete Plan for Assembly and Compilation of Surrogate Materials Data Base
2.8.B.	Complete Assembly and Compilation for Unirradiated Materials
2.8.C.	Complete Statistical Analyses of Data Base for Unirradiated Materials
2.8.D.	Complete Draft NUREG 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



11. REMARKS

1. CONTRACT REPORTING ELEMENT **HSSI - 3. Irradiation Embrittlement of RPV Steel**	2. REPORTING PERIOD **8/28/00 - 9/30/00**	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**

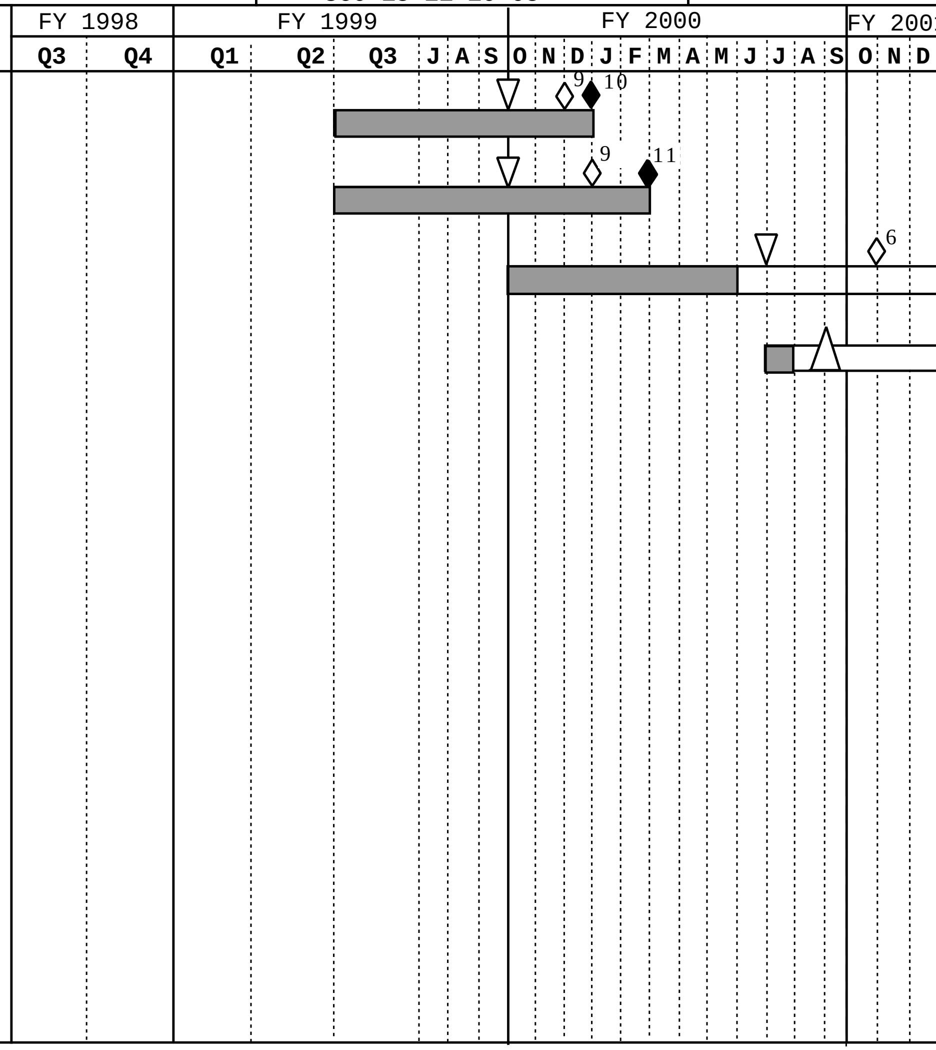
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
3.1.A.	Age HAZ Materials
3.1.B.	Machine CVN Specimens
3.1.C.	Evaluate Results and Prepare Letter Report
3.1.D.	Irradiate Capsules
3.1.E.	Ship Specimens
3.1.F.	Test Specimens
3.1.G.	NUREG Report
3.2.A.	NUREG on IA Work to Date
3.2.B.	Dosimetry of 30 CVNs
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 **8/28/00 - 9/30/00**	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**

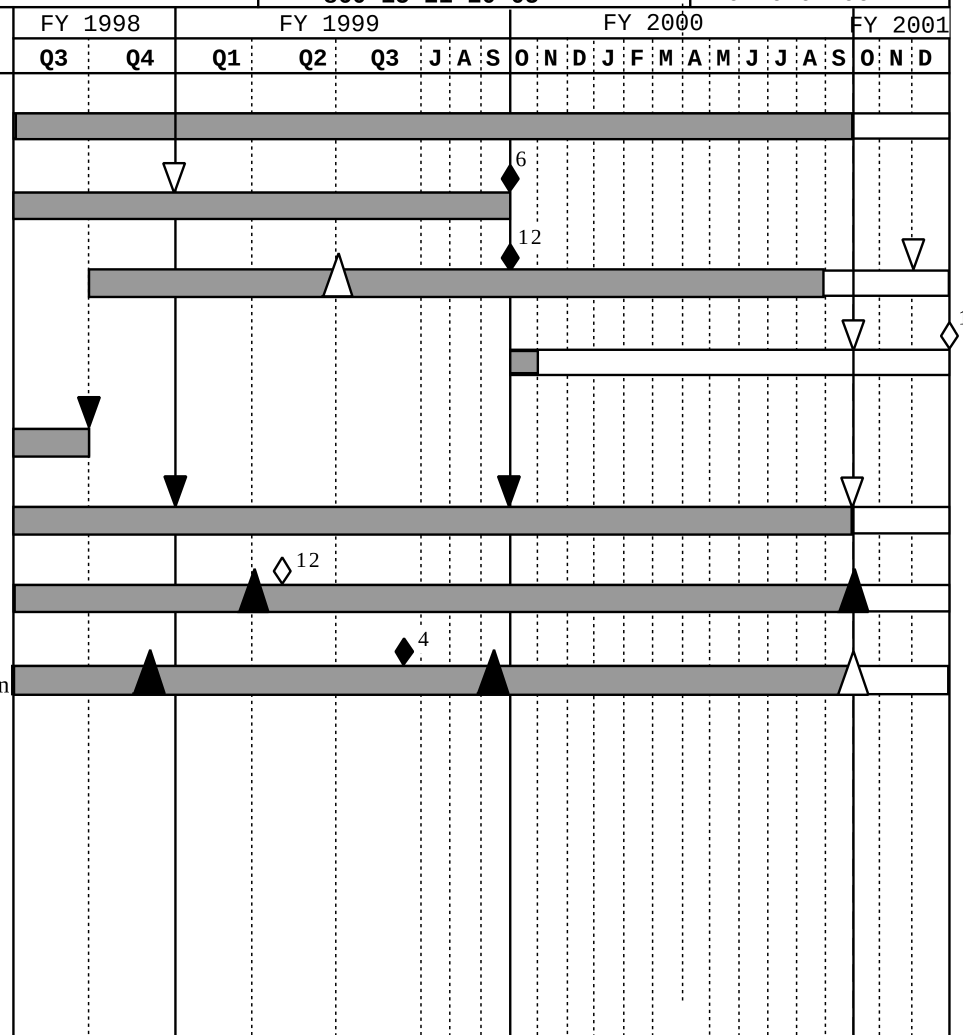
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
3.3.A.	Ship JRQ Specimens From PSI to ORNL
3.3.B.	Complete Test Plan
3.3.C.	Complete JRQ Specimen Testing
3.3.D.	Complete Draft NUREG Report on IAR Results of JRQ



11. REMARKS

1. CONTRACT REPORTING ELEMENT **HSSI - 4. Validation of Irradiated and Aged Materials**	2. REPORTING PERIOD **8/28/00 - 9/30/00**	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**

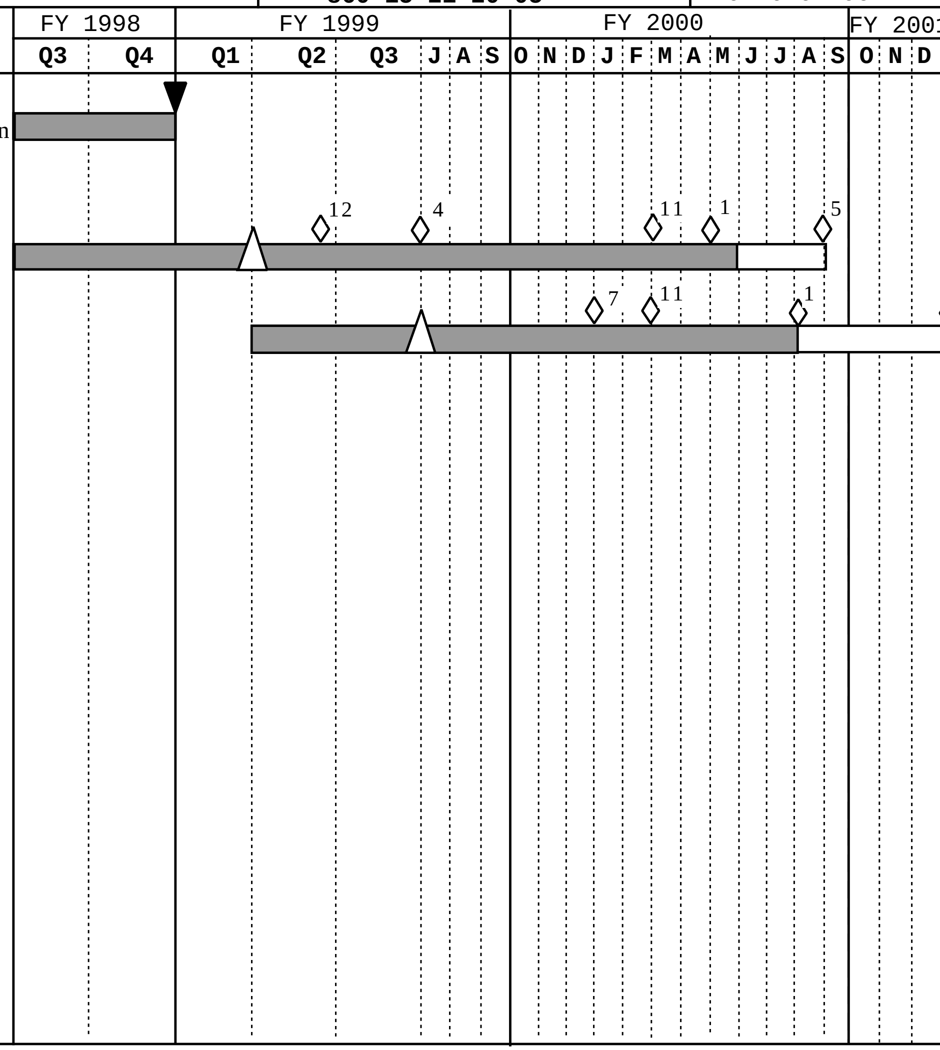
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
4.1.1.A.	JPDR Information Exchange with JAERI
4.1.1.B.	Machining & Inspection of JPDR
4.1.1.C.	Testing, Letter & NUREG Report
4.1.3	Maine Yankee RPV Feasibility Study
4.3.B.	Complete Draft NUREG Report on Thermal Aging of SS Welds
4.4.A.	Complete Preparation 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 **8/28/00 - 9/30/00**	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
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
8/28/00 - 9/30/00

3. JCN NO.
W6953

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

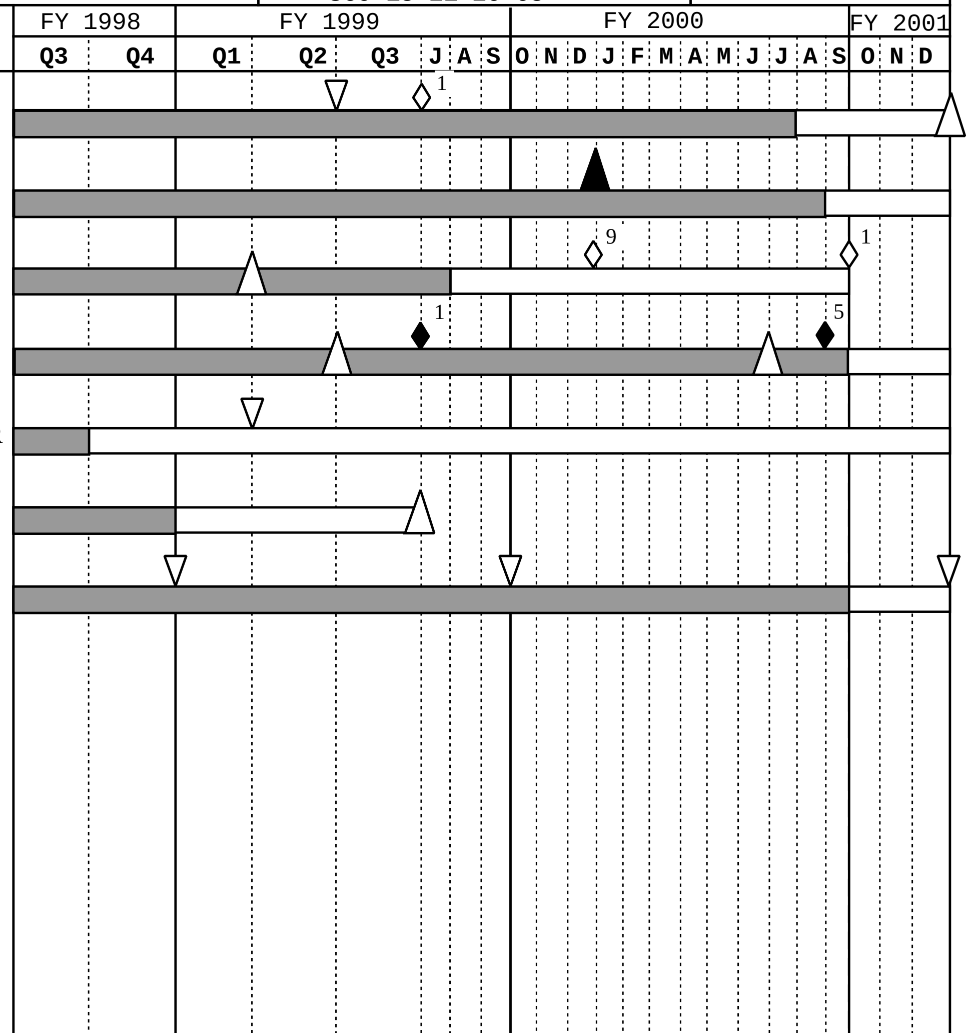
5. CONTRACT PERIOD
FY 1998-2001

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

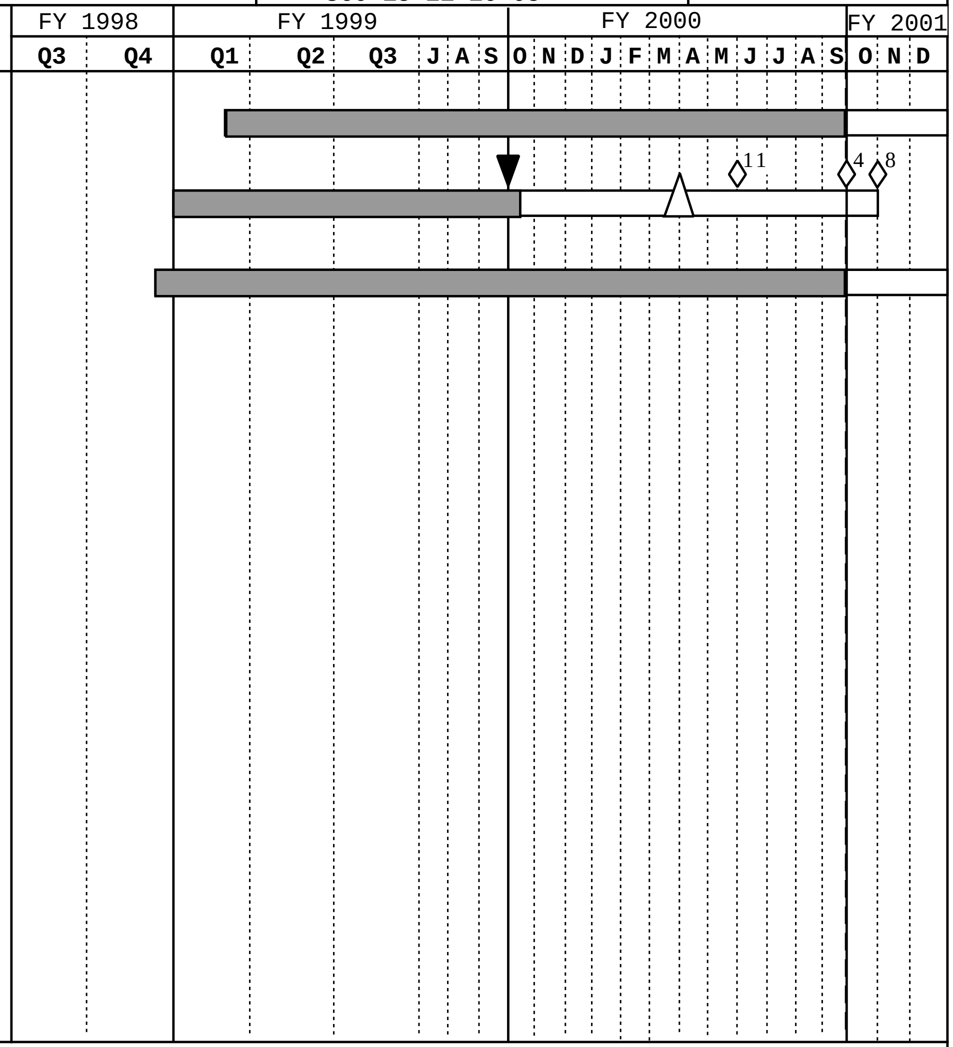
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
5.1.A.	Development and Predictive use of Embrittlement Model
5.1.B.	Model Validation and Data Analysis
5.2.A.	Coordinate and Analyze APFIM/SANS/FEGSTEM Round Robin Experiment
5.2.B.	APFIM Characterization
5.3.A.	Conduct and Coordinate Experiments in HFIR 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 **8/28/00 - 9/30/00**	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**

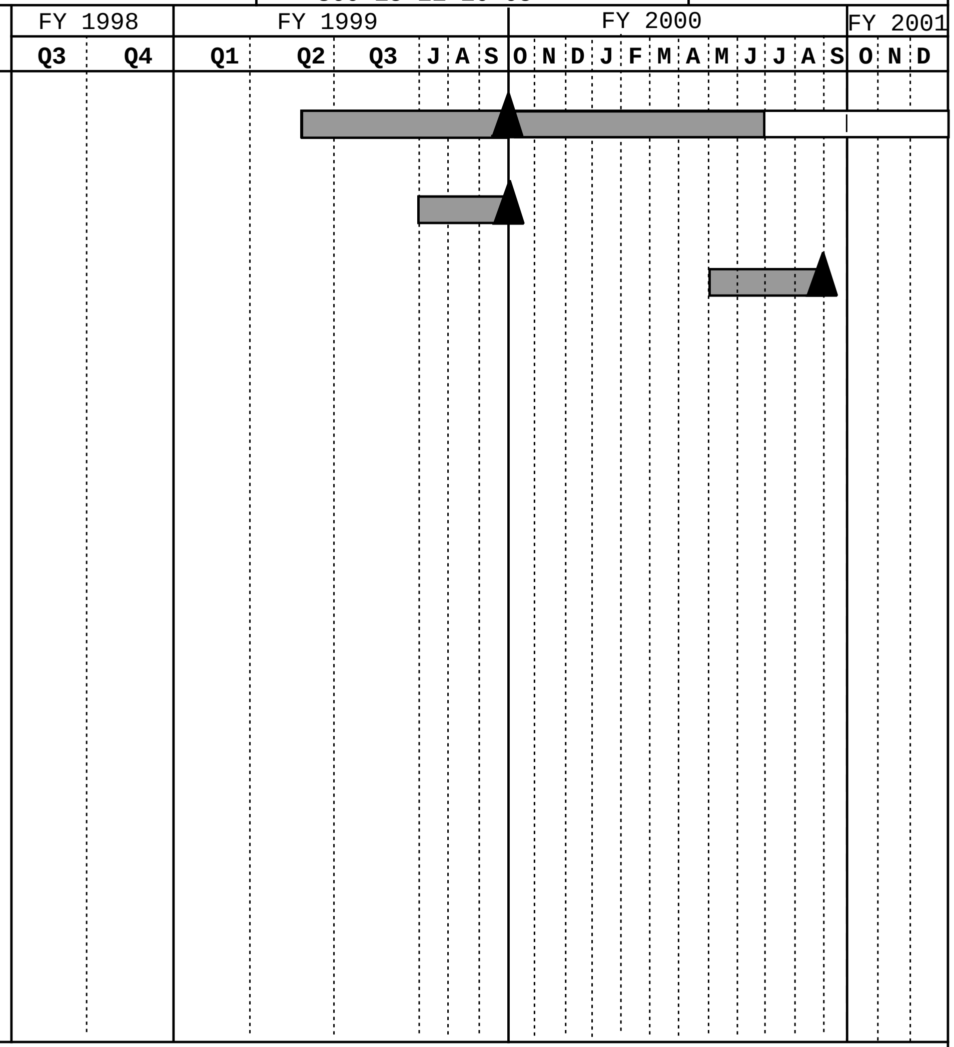
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
6.1.A.	Coordinate the Operation, Data Collection, and Maintenance of the HSSI IAR Facility
6.1.B.	Comprehensive Report on Reusable Irradiation Facilities
6.2.A.	Coordinate the Operation, Data Collection, and Maintenance of the UCSB Irrad.Facility



11. REMARKS

1. CONTRACT REPORTING ELEMENT **HSSI - 7. Embrittlement DB & Dosimetry Evaluation**	2. REPORTING PERIOD **8/28/00 - 9/30/00**	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
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