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OAK RIDGE
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LOCKHEED MARTIN

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

MONTHLY LETTER STATUS REPORT

FOR

MARCH 1999

Oak Ridge National Laboratory
Oak Ridge, Tennessee

MANAGED AND OPERATED BY
LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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HEAVY-SECTION STEEL IRRADIATION PROGRAM

JCN W6953

MONTHLY LETTER STATUS REPORT FOR MARCH 1999

Submitted by

T. M. Rosseel
HSSI Project Manager

Compiled by
R. A. Raschke

Submitted to
C. J. Fairbanks
NRC Project Manager

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
managed by
LOCKHEED MARTIN ENERGY RESEARCH CORP.
for the
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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. 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 1998 to November 1999, thereby covering both the Department of Energy's fiscal year 1999 and the second year of the NRC's current performance period for the W6953 HSSI Program.

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 (W6953) Program

MONTHLY LETTER STATUS REPORT
March 1999

Job Code Number: W6953
Project Title: Heavy-Section Steel Irradiation Program
Period of Performance: 4/1/98 to 12/30/00
Performing Organization: Oak Ridge National Laboratory
Program Manager: T. M. Rosseel
Address: P.O. Box 2008
Oak Ridge, Tennessee 37831-6158
Telephone: (423) 574-5380
Telefax: (423) 574-5118
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 annealing 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). A modified SOEW, which included minor modifications to the annealing Task 3 and foreign interactions Subtask 4.4 as well as the work incorporated from the "Embrittlement Data Base and Dosimetry Evaluation Program (EDB &DE)," JCN 6164, into a new HSSI Task 7, was received and has been incorporated in to the budget plan. Additional discussions with the former EDB & DE ORNL program manager and the NRC program monitor concerning the future of this work and the ability of the NRC to maintain these critical capabilities are expected during the next reporting period.

(Milestone 1.1.B) An incremental funding modification to the University of Michigan subcontract was submitted to the ORNL procurement office for the trolley and gear replacement system (see Figure 3). This FNR-compatible trolley replacement will result in a right-angle-drive attachment that can be readily removed and attached to a new factory-supplied linear-motion system. Since the mechanical mechanism is anticipated to fail during the lifetime of the irradiation experiments and subcontract, the University of Michigan FNR staff, when authorized, will procure materials and services to fabricate a suitable replacement mechanism in order to minimize the impact that a failure would have on the conduct of NRC-sponsored HSSI and UCSB irradiation experiments.

As reflected in the March cost, invoices have now been received from the University of Michigan and costed for the period through December 1998. The assistance of the FNR staff in expediting these invoices is appreciated.

During this reporting period, it was learned that the University of California Santa Barbara (UCSB) change-out schedule has altered substantially since last fall. Based on a review of the revised change-out schedule, it was ascertained that the UCSB has planned five (5) additional change outs in FY 1999 and two (2) additional change outs in FY 2000. Since each change out will cost an estimated $ 4,500, including University Michigan hot cell and technician time and ORNL oversight and overhead, it is estimated that the additional cost of these unplanned change outs will be at least $ 22,500 in FY1999 and $ 9,000 in FY 2000. It is important to note that the HSSI Program has neither budgeted nor requested funds for these additional change outs in our University of Michigan subcontract. It is recommended that the NRC, ORNL, and UCSB discuss these plans and costs, and our collective options, in greater detail. For example:

(1) What are the revised or possible plans/uses for the IVAR facility? How can they be accommodated? The original change-out plan is what was used to develop the ORNL budget for the University of Michigan subcontract.

(2) What funding will be required to operate the IAR and IVAR facilities at their maximum/optimum potential? What funding will be available for these facilities in FY 2000; FY 2001; and beyond?

(Milestone 1.2.B) At the end of the second quarter of FY 1999, the HSSI program has used 22 hot cell days. This number is expected to increase significantly in the next quarter as the machining of the Japan Power Demonstration Reactor (JPDR) specimens (subtask 4.1.1) is completed. Based on the initial test results of the reirradiated Charpy specimens (subtask 3.2) that showed little damage, no further testing was performed during this quarter.

(Milestone 1.3.D) A revised Memorandum of Agreement for the materials characterization study of the Japan Power Demonstration Reactor (JPDR) between ORNL and the Japan Atomic Energy Research Institute (JAERI) was submitted by JAERI to ORNL for review.

(Milestone 1.3.E) The following NUREG report was submitted to the NRC during this reporting period.

D. E. McCabe, et al., Lockheed Martin Energy Research, Inc., Oak Ridge Natl. Lab., Oak Ridge, TN., *Evaluation of WF-70 Weld Metal from the Midland Unit 1 Reactor Vessel,* NUREG/CR-5736, (submitted March 1999)

Listed below are the Letter and NUREG reports that are scheduled for submission during the next three months (April - June).

NUREG Reports:

1. M. A. Sokolov, et al., Lockheed Martin Energy Research, Inc., Oak Ridge Natl. Lab., Oak Ridge, TN., *Comparison of Radiation-Induced Fracture Toughness and Charpy Curve Shifts*, NUREG/CR-6609, April 1999. STATUS: Final corrections are being made and preparation for transmittal will begin in the next reporting period.

2. S. K. Iskander, et al., Lockheed Martin Energy Research, Inc., Oak Ridge Natl. Lab., Oak Ridge, TN., *Results of Crack-Arrest Tests of Irradiated Midland Weld WF-70*, NUREG/CR-6621, April 1999. STATUS: In preparation

4. R. K. Nanstad, et al., Lockheed Martin Energy Research, Inc., Oak Ridge Natl. Lab., Oak Ridge, TN., *Thermal Aging of Stainless Steel Welds*, NUREG/CR-6628, April 1999. STATUS: Finalizing figures

5. M. K. Miller, et al., Lockheed Martin Energy Research, Inc., Oak Ridge Natl. Lab., Oak Ridge, TN, *APFIM Examination of High-fluence Irradiated RPV Reference Materials*, NUREG/CR-6629, May 1999. STATUS: Finalizing figures

6. S. K. Iskander, et al., Lockheed Martin Energy Research, Inc., Oak Ridge Natl. Lab., Oak Ridge, TN., *Effects of Annealing Irradiated Reactor Pressure Vessel-Steels*, NUREG/CR-XXXX, June 1999. STATUS: In preparation

7. R. K. Nanstad, et al., Lockheed Martin Energy Research, Inc., Oak Ridge Natl. Lab., Oak Ridge, TN., *RPV Materials Available for Irradiation Studies*, NUREG/CR-XXXX, June 1999. STATUS: Draft preparation

8. R. E. Stoller, et al., Lockheed Martin Energy Research, Inc., Oak Ridge Natl. Lab., Oak Ridge, TN, *Model-based Evaluation of RPV Material Behavior at High Fluence and Following Annealing*, NUREG/CR-XXXX, June 1999. STATUS: Draft preparation

Letter Reports:

1. R. K. Nanstad, et al., Lockheed Martin Energy Research, Inc., Oak Ridge Natl. Lab., Oak Ridge, TN., *RPV Materials Available for Irradiation Studies*, Letter Report, April 1999. STATUS: In preparation

2. D. W. Heatherly et al., Lockheed Martin Energy Research, Inc., Oak Ridge Natl. Lab., Oak Ridge, Tenn., *Design and Fabrication of an Irradiation, Anneal, Reirradiation Facility at the University of Michigan's Ford Nuclear Reactor,* Letter Report, May 1999. STATUS: In preparation

3. R. E. Stoller, et al., Lockheed Martin Energy Research, Inc., Oak Ridge Natl. Lab., Oak Ridge, TN, *Comparison of Chemical Composition Measurements by APFIM, FEGSTEM, and SANS*, Letter Report, June 1999. STATUS: In preparation

4. M. A. Sokolov, et al., Lockheed Martin Energy Research, Inc., Oak Ridge Natl. Lab., Oak Ridge, TN., *Mechanical Properties of KS01 Material*, Letter Report, June 1999. STATUS: Data collected

5. D. E. McCabe, et al., Lockheed Martin Energy Research, Inc., Oak Ridge Natl. Lab., Oak Ridge, TN., *Mechanical Properties of RPV Submerged-Arc Weld HAZ*, Letter Report, June 1999. STATUS: Data collected

(Milestone 1.3.F) Listed below are reports associated with work performed under the L1098 program and the date the report was submitted to the NRC:

T. M. Rosseel, Lockheed Martin Energy Research, Inc., Oak Ridge Natl. Lab., Oak Ridge, TN., *HSSI (L1098) Semiannual Progress Report, V8 N2,* NUREG/CR-5591, (submitted July 1998)

J. Giovanola and J. E. Crocker, SRI, International, *Fracture Toughness Testing with Cracked Round Bars: Feasibility Study* NUREG/CR-6342 (ORNL/SUB/94-DHK60), (submitted September 1998)

The L1098 project closeout is continuing, as cost and property issues are slowly resolved.

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) The NUREG report based on the currently available data is completed, underwent review, and is in final preparation for publication.

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

The purpose of this subtask is to evaluate the assumption of constant shape for the MC even for highly embrittled RPV steels. The evaluation will be performed through irradiation of a pressure-vessel steel to a neutron fluence sufficient to produce a fracture-toughness transition-temperature shift (T_0) of about 150 ^{0}C (270 ^{0}F). Evaluation of the MC shape will be determined with sufficient numbers of 1T compact specimens, 1T C(T), to allow for testing at three temperatures in the transition-temperature region. Additionally, 0.5T C(T), and precracked Charpy V-notch (PCVN) specimens, for both quasi-static and dynamic tests, will be irradiated and tested to investigate the use of more practical surveillance-size specimens. Tensile specimens will also be included to determine the irradiation-induced hardening. A comprehensive test program with unirradiated material will be included to provide the necessary baseline data for comparison.

(Milestone 2.2.A) Irradiation of two IAR capsules is under way. Capsules are loaded with 21 1T compact specimens and a larger number of smaller specimens of weld KS-01. The high-flux capsule (IAR-1) has achieved half of the target fluence. The capsule was retrieved from its position, moved into a hot cell at the Ford reactor, and opened. Specimens within the capsule were shuffled to smooth the total average flux distribution between different cells of the capsule. The capsule was closed and moved back into position. The low-flux capsule (IAR-2) was only rotated and placed in the same position. Irradiation of the specimens was restored and testing of unirradiated specimens was initiated. Six 1T C(T) specimens of unirradiated KS-01 were tested at room temperature and several specimens were tested at -35 C. Testing of the remaining unirradiated 1T and tensile specimens will be continued in the next month. Charpy impact tests were also performed and provided Charpy impact data practically the same as from MPA, Stuttgart.

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) Several strikers used in the ORNL 240-ft-lb Charpy-impact tester have been statically calibrated in a specially fabricated fixture. These include several 8-mm radius strikers that have been used in most of the testing performed at ORNL as well as a 2-mm radius striker. Note that the 8-mm striker was referred to as the "ASTM E-23 striker," but since the addition of the 2-mm striker to ASTM E-23, the 8-mm striker should now be referred to by its size. The 2-mm striker is one used in much of Europe and Japan. The special fixture was designed to calibrate the strikers in the ORNL 240-ft-lb Charpy machine by loading them in the ORNL 20-kip MTS testing machine. The load cell used in the calibration is one used to calibrate other load cells to ASTM E-8 requirements. The strikers had an error in their load indication of less than 5%. An interesting observation from this task is that the load indication of the strikers is sensitive to the location at which the Charpy specimen impacts the striker. The gain factors of all the strikers was normalized to 2,500 lb/V, which would allow the maximum anticipated load of 10,000 lb to produce 4-V output. Preliminary testing did not give a satisfactory agreement between the two methods of determining the load/volt conversion factor. The sources of this discrepancy are being pursued. This does not affect the results of Charpy impact testing since the dial energy is unaffected by the load indicated by the striker. However, the load/volt conversion is necessary in dynamic fracture toughness computations since they use the load-time trace from the instrumented striker. The other purpose of static calibration is to check the current method of determining the force-voltage conversion factor. This topic has been discussed in the January 1999 and December 1998 monthly reports. There are several components in the chain between the tup and the recorder that are being individually recalibrated to determine the source of the discrepancy mentioned above.

A presentation on this topic is being prepared for the ASTM Symposium on Pendulum Impact Testing: A Century of Progress, May 19-20, 1999, Seattle, Washington: "A Comparison Between Charpy Instrumented Response of 8-mm- and 2-mm-Radius Strikers for Measurement of Toughness," by S. K. Iskander, R. K. Nanstad, D. E. McCabe, J. T. Hutton and D. L. Thomas.

Subtask 2.4: Irradiation Effects on Fracture Toughness of Midland RPV Weld (D. E. McCabe)

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 on the Tenth Irradiation Series has been submitted to the NRC: *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). This project has met the intended objectives. The report contains new information on low upper-shelf steels with regard to the fracture-mechanics-based properties and an evaluation of how well the ASME Code practices represent these properties. The methodology behind the ASME Code that relies upon drop-weight NDT and Charpy tests could not differentiate between the fracture toughness of nozzle course and beltline weld metals. The master curve method of data evaluation provided higher precision of transition-temperature definition that showed that nozzle course and beltline WF-70 welds were different materials from a fracture toughness perspective.

A paper, "A Summary of Experimental Validation Work to Prove the Master Curve Concept," by D. E. McCabe and M. A. Sokolov, has been prepared for the 1999 Pressure Vessels and Piping Meeting in Boston. The paper gives evidence in support of (1) the specimen-size effect relationship as defined by the weakest-link model, (2) the master curve shape for both unirradiated and irradiated steels, and (3) a progress report on the ability of the precracked Charpy specimens to perform as a legitimate fracture-mechanics specimen.

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) Preparation of the NUREG on MW crack-arrest test results, *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, is progressing. The fracture surfaces and the corresponding charts from the X-Y plotter from both unirradiated and irradiated specimens will be reproduced in the report. It is believed that this is important since crack-arrest testing differs in many respects from other fracture-toughness testing. One important difference is that the crack-mouth opening displacement (CMOD) and the length of the remaining unbroken ligament are evaluated together in order that a crack-arrest toughness value, K_a, can be estimated. The estimation of the length of the remaining ligament is complicated by the uneven crack front and the many unbroken ligaments. The CMOD is obtained from the X-Y plotter chart. Thus, it is important to document these two key items, particularly since less than 100 irradiated crack-arrest toughness values are known to have been published in the world.

Subtask 2.6: Intergranular Fracture (D. E. McCabe)

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) The testing of the steel that was heat treated to increase its propensity for intergranular fracture is currently under way. Testing of 1/2T compact specimens at -100, -25, and +25°C has been completed. All transition-range data fit well to a Weibull slope of four. Testing of 1T specimens has just been started. Analyses of the test records is currently in progress. The fracture surfaces show that the material has been properly prepared to make the steel susceptible to intergranular fracture after embrittlement aging. Intergranular fracture has been identified using low-magnification optics. Exact information on the percent of intergranular versus cleavage fracture facets will be the final task undertaken in this subtask. All specimens, including 2T specimens, are now available for testing.

Subtask 2.7: Subsized specimens (M. A. Sokolov)

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

(Milestone 2.7.A) Work on this subtask is now under way. The initial effort will focus on analysis of existing fracture-toughness results for specimens with thicknesses of 0.5 in. and smaller. These specimens, both compact and three-point bend, have different ligament/thickness ratios.

Subtask 2.8: Quantification of surrogate materials for use in a statistics-based fracture toughness assessment (R. K. Nanstad)

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.A) The review of surveillance program materials in the Reactor Vessel Integrity Database and the Power Reactor Embrittlement Database continued. The current regulatory framework is based on experience developed with drop-weight and Charpy V-notch (CVN) impact tests with various margins applied at several steps in the process. Concern has been expressed that the current framework may not be entirely appropriate in the case of fracture-toughness tests and the master-curve approach (MCA), especially as regards surrogate materials.

In the previous progress report, a "definition" of a surrogate material relative to RPVs was proposed and it was discussed that the current guidelines involve "descriptions" of material conditions that are allowed for surrogacy with specified uncertainties. As noted in that progress report, one step should be to outline the existing accepted procedures and evaluate their use with respect to the use of fracture-toughness specimens. Some of the items to be considered include :

1. Variability of fracture toughness and Charpy-impact toughness, e.g., within a heat of material as well as within a "class" of materials.

2. Current margins applied to the determination of RT_{NDT} for generic materials, i.e., for a "class" of materials.

3. Current margins applied to the determination of the adjusted reference temperature for irradiated conditions and applicability to fracture toughness, both for the predictive models and surveillance tests.

4. Comparisons of irradiation-induced, transition-temperature shifts for Charpy impact and fracture toughness for plates, welds, and forgings.

Task 3: Thermal Annealing of RPV Steel (S. K. Iskander)

The purpose of this task is to examine two important issues affecting the application of thermal-annealing procedures to RPVs. The first will address the effects of temper embrittlement on the coarse-grained HAZ in RPV steels. The second will examine the effects of thermal annealing and reirradiation on K_{Jc} and K_{Ia} in order to evaluate the relative changes in the recovery and reembrittlement between CVN and fracture-toughness properties and a detailed examination of reembrittlement rates. These questions will be addressed using the irradiation-anneal-reirradiation (IAR) facility designed, fabricated, and installed as part of the previous HSSI (L1098) program and with a matrix of irradiated and annealed specimens supplied by the Swiss HSK and 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 from annealing (D. E. McCabe)

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 thermal annealing of such material resulted in an even greater increase of the transition temperature. Subsequent research at ORNL under the previous HSSI Program (L1098) used five commercial RPV steels to investigate potential temper embrittlement. The first phase simulated the AEA-Technology heat treatment and observed large transition-temperature shifts, although not as large as those from AEA-Technology. The second phase of the ORNL study used the same five RPV steels, but used the Gleeble system (an electrical-resistance heating device) to produce material deemed representative of the coarse-grain region in RPV welds. These materials revealed very high toughness in the initial condition (i.e., from the Gleeble). After thermal aging at about 454 ^{0}C for 168 hours the materials exhibited only modest transition temperature increases, however, after aging at the same temperature for 2000 hours, significant transition temperature increases were observed. Of course, 2000 hours is much in excess of the time that RPV steels would be exposed to thermal annealing 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 thermal annealing at somewhat lower or higher temperatures.

(Milestone 3.1.B) The draft of the final report on heat-affected-zone embrittlement from local-brittle-zone (LBZ) microstructure has been started despite the fact that the irradiation exposure phase is not complete. The report will first review the information available on the LBZ phenomenon reported in the literature. All of this information focuses on problems with the welding of offshore platforms, specifically, a petroleum industry problem. The objective of the present report is to determine if this LBZ problem is relevant to weldments in reactor pressure vessels. The differences in base metals, welding practices, heat treatments, and in-service environment conditions are discussed. This information explains the rationale used to prepare the experimental plan for this subtask.

Several commercially made RPV welds have been evaluated for grain-coarsened material that is generally present along the weld fusion line. These grains are identified as material that has LBZ potential. The available welds were SNUPPS longitudinal and transverse, Midland beltline and nozzle course, and HSSI Fifth Irradiation Series Welds 72W and 73W. SNUPPS welds had coarse-grain zone material with ASTM grain size of 6 to 6.5. The Midland weld coarse grains were on the order of 6 to 7. Coarse-grain zone could not be found in Weld 73W. In all cases, coarse-grain material does not form a continuous network along the heat-affected zone. The inspection of commercial welds is only preliminary at this point and more effort is planned.

Subtask 3.2: Embrittlement Rate of Annealed and Reirradiated Steel (S. K. Iskander and I. Remec)

This subtask will examine the effects of thermal annealing and 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 irradiation-anneal-reirradiation (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)

During this reporting period, the counting of the ORNL dosimeters from the top and middle Charpy packets in the UCSB high-fluence capsule was completed. Each Charpy packet contained three iron and two Co-Al dosimeters. These dosimeters will be used for the overall characterization of the combined HSSI-IAR/UCSB facility at the University of Michigan FNR, and, of course, for the determination of the irradiation parameters of the Charpy specimens in which the dosimeters were included. Preliminary comparisons indicate the results are consistent with the previous measurements.

The measurements performed for the UCSB irradiation facility characterization experiment were re-analyzed with the neutron fluxes from the three-dimensional TORT calculations. The fast neutron fluxes ($E > 1MeV$) obtained agree with the previous analysis typically within a few percent at all the 23 locations of the dosimeters used in the analysis. On average, the new fluxes are 6.5% lower than the fluxes from the previous analysis, with the maximum difference of 20% observed at one location. Note that in the previous analysis the fluxes from the transport calculation were not available. Based on a request from G. R. Odette and G. E. Lucas, the spectrum-averaged cross sections for the Ni58(n, p) and Fe54(n, p) were generated for the 23 dosimeter locations and forwarded to them for their calculations. The results for the irradiation parameters throughout the HSSI-IAR/UCSB facility will be finalized when the dosimetry measurements from the IAR capsules are integrated into the analysis. In next reporting period, it is expected that the dosimetry measurements from IAR dosimetry experiment will become available and work on the analysis will continue.

To better understand the necessity of performing a three-dimensional TORT calculation of the HSSI-IAR/UCSB facility to determine the fluence for the specimens within the facility, Figure 1 shows the complete TORT model. The pool of water in which the reactor core and capsules are sitting in is not shown. The "large box" in the center is the FNR core. In the periodic green-red structure, the green areas show the fuel element side plates (made of aluminum) while the red areas are the homogenized zones of fuel plates and coolant. On the east side the reactor, the core guard plate as well as the thermal shield of the irradiation facility are shown as the thin blue plates. The green box to the east of the core is the water surrounding the capsules, which are shown in red. Only the top of the capsules can be seen with the IAR north and south capsules sandwiched between the taller UCSB capsules. The two blue bodies on the bottom represent the support structure. The blue body to the north of the core is the D_2O tank, and to the north of it another body of water is shown.

This figure was prepared with a new visualization code that is being developed to facilitate the preparation of the TORT models and may be compared with a photograph of the facilities shown in Figure 3, subtask 6.1. Note that the code development is not funded by the HSSI program. This code allows one to display the model on the screen, add or withdraw a body or zone of the model and change the viewpoint, i.e., the model can be rotated to allow views from the top, sides or bottom.

(Milestone 3.2.C) As mentioned previously, accurate fluence determinations are being performed before any of the ten remaining Charpy specimens from HSSI Weld 73W that were irradiated, annealed, and reirradiated (IAR) will be tested. Preliminary estimates of the fluences for the low and medium flux positions are 0.5 and 1×10^{19} n/cm^2 (>1 MeV). However, the Charpy results of testing two sets of five specimens each gave almost identical results although estimates of their fluences are substantially different as mentioned above. Thus the need for more accurate fluence exposures. These two sets, each of 10 Charpy specimens, had been irradiated, annealed, and reirradiated in the Ford Nuclear Reactor UCSB Facility. A third set of 10 specimens is still being reirradiated, and will be withdrawn at a time guided by the results of the tests from these two sets.

<u>Subtask 3.3: Evaluation of annealed and reirradiated JRQ specimens</u> (M. A. Sokolov)

The purpose of this subtask is to examine the fracture-toughness behavior of a model steel that has been irradiated, annealed, and re-irradiated. The specimens, identified as JRQ, will supplied by the Swiss HSK and PSI from a terminated research program.

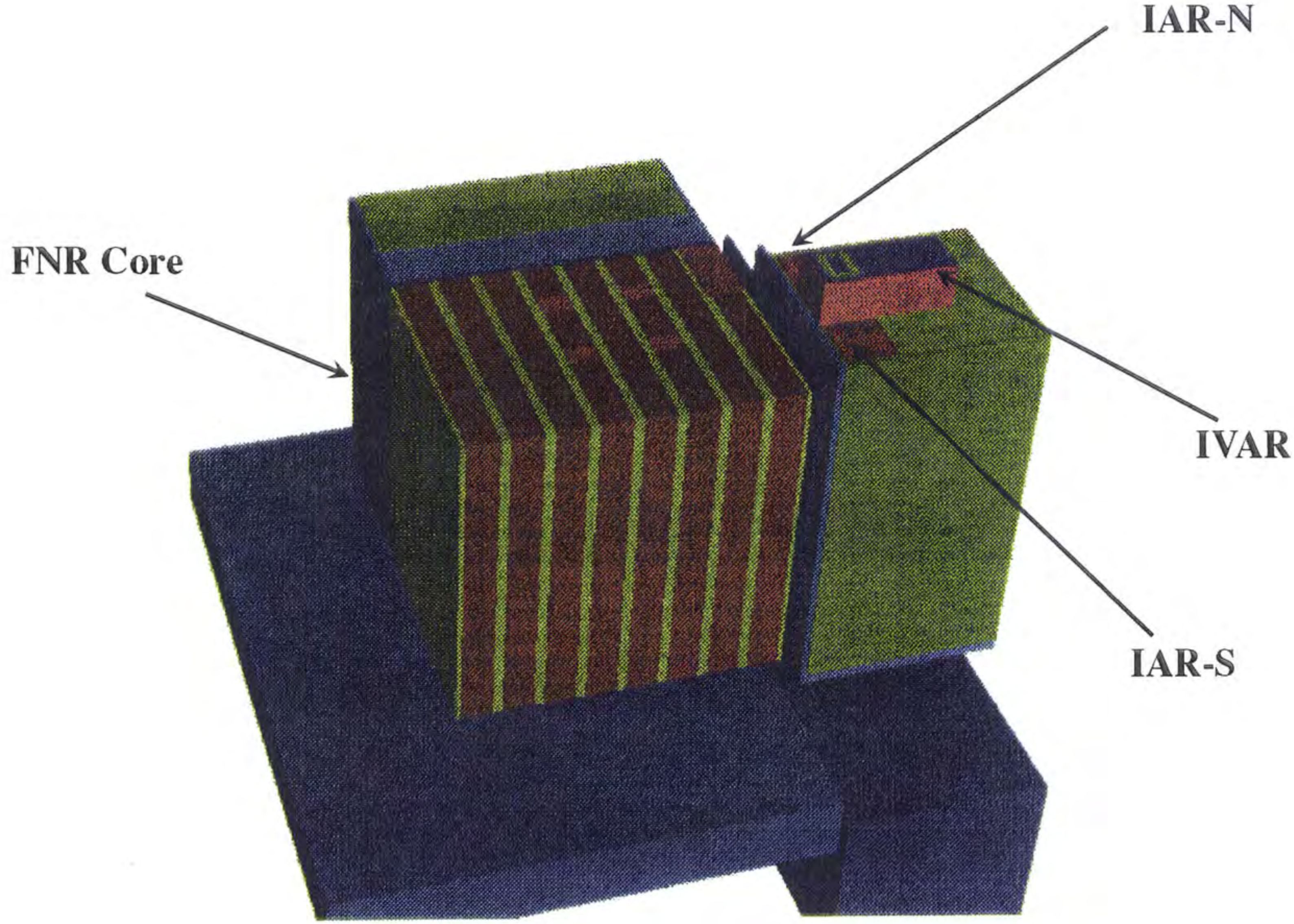


Figure 1

(Milestone 3.3.A) No work is currently funded for this subtask. However, R. K. Nanstad will visit with Dr. Phillip Tipping of the Swiss Federal Nuclear Safety Inspectorate (HSK) and the Paul Scherrer Institute (PSI) in May to discuss a potential collaborative effort under a Memorandum of Agreement under development.

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

The purpose of this task is to validate the assessment of the effects of neutron irradiation on the fracture-toughness properties of typical RPV materials obtained in the previous HSSI (L1098) Program, tasks 2 and 3 of this program, and RPVs retired. This will be accomplished through the examination of the effects of neutron irradiation on the fracture toughness (ductile and brittle) of the HAZ of welds and of typical plate materials used in RPVs. The irradiated materials from retired RPVs will be machined and tested in the Irradiated Materials Examination and Testing (IMET) hot cells. The feasibility of reconstitution for CVN and 0.5T C(T) and aging of stainless steel welds will also be explored in this task. Other issues to be address include foreign interactions and technical assistance to the NRC.

<u>Subtask 4.1: Examination of materials from retired RPVs</u> (S. K. Iskander)

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 design of a clamp to hold the round JPDR trepans while they are being sawed into disks was completed, fabricated, and installed in the hot cell. Unirradiated cylindrical trepans are being sawed into disks to gain experience in using the hot-cell saw.

The process to obtain spare parts for the CNC Mill is back on track, and the parts are expected soon. The replacement parts are for a defective electronic board that powers the spindle motor on the prototype milling machine and was ordered in late December. ORNL has obtained a free replacement board that will be used. The purpose of the parts is to repair the defective board and keep it as a spare. This matter is receiving top-priority attention from the highest levels of management of the U.S. distributor.

<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.

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

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

(Milestone 4.3.B) The draft NUREG report on thermal aging of stainless steel welds is currently under internal review in preparation for publication.

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 Annealing, and Aging of Components..

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

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

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

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

6. Collaboration with PSI in Switzerland on re-irradiation after thermal annealing.

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

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

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

(Milestone 4.4.C) A foreign travel request was submitted to the NRC for R. K. Nanstad to travel to Europe in April for participation in the IAEA meeting on Irradiation Embrittlement and Mitigation (Madrid, Spain), and to hold meetings with representatives of various organizations with which the HSSI Program has ongoing or potential collaborative projects. Meetings will be held with researchers from SCK-CEN (Belgium) and NRI (Czech Republic) in Spain, while site visits will be made to AEA-Technology (United Kingdom), MPA-Stuttgart (Germany), and HSK/PSI (Switzerland).

Subtask 4.5: Technical assistance (R. K. Nanstad)

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.A) Planning is under way for testing of the specimens contained in the MEA capsule which was irradiated in the Ford Nuclear Reactor and subsequently shipped to ORNL for disassembly and testing. We anticipate testing the specimens during the next two months, depending on the crane installation scheduled in our hot-cell facility.

(Milestone 4.5.B) The letter report on RPV materials available for irradiation studies has been initiated.

(Milestone 4.5.E) A discussion was held with Mr. John Kneeland of Consumers Power Company Palisades Nuclear Plant regarding availability of a high-nickel weld for potential irradiation in the IAR facility of the Ford Nuclear Reactor. He agreed to ship any available material to us for our use.

(Milestone 4.5.F) The high-copper weld referred to in the previous monthly report continues to undergo various aging treatments.

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 three subtasks will comprise two major components: (1) theoretical modeling and data analysis, and (2) experimental investigations. The modeling work will focus 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 will consist 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. These conditions include: long-term, thermally-aged, irradiated, post-irradiation annealed (IA), and irradiated-annealed-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 anneal. 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 annealing. 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.B) A model-based analysis of neutron-flux effects and review of relevant data was performed in order to prepare a document describing the technical basis for including the effects of neutron-flux level in the ASTM Standard Guide E900 on embrittlement. This standard incorporates a new embrittlement correlation developed under NRC funding. The analysis supports the use of a flux or time-at-temperature term at low fluxes. The magnitude of the predicted flux effect is generally small, in agreement with the weak effect observed in the power-reactor embrittlement database. The technical basis document will be presented to and discussed at an ASTM subcommittee meeting in April.

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) Final data analysis of high-fluence RPV materials examined by APFIM was carried out and preparation of a NUREG report summarizing the data was begun. This report will include data from the new ORNL position-sensitive atom probe (ECOPoSAP), and will focus on neutron irradiated Weld 73W (2.0×10^{19} n/cm^2; E> 1 MeV) and on neutron irradiated material that had been annealed for 0.5, 1 and 168 h at 454°C.

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 will provide 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, Anneal, and Reirradiation (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 without incident during this reporting period.

During this reporting period, the reactor operated for the last five days of half-cycle 429B, ten days of half-cycle 430A, and five days of half-cycle 430B. During the last five days of half-cycle 429B, the IAR irradiation facilities received a total of 105.7 EFPH (effective full power hours). The facilities then received 221.4 EFPH during half-cycle 430A, which was followed by 154 EFPH during the first five days of half-cycle 430B. A specimen change out and capsule rotation was performed during this reporting period at the request of the subtask 2.2 experimenters. The change out and capsule rotation was performed at the end of half-cycle 430A after a total of 1233 EFPH irradiation time. A description of the operations that were performed during the requested change out follows.

The IAR-1 capsule was removed from the IAR-1 facility and transferred to the hot cells where the specimens were shuffled within the capsule. The specimen compliment originally in cell 1 (top position) was moved to cell 3(middle position). The specimen compliment originally in cell 3 was placed in cell 1. The specimen compliment in cell 2 (second from top) was left in place. The specimen compliment originally in cell 4 (second from bottom) was moved to cell 5 (bottom position) and the specimen compliment originally in cell 5 was moved to cell 4. The flux monitors in the specimen groups were not disturbed. The two-each fission radiometric set (FRDS) monitors were placed back into their original locations in the capsule. After the specimen shuffle was completed in the hot cell, the capsule was placed back into the IAR-1 facility and rotated 180 degrees from the original orientation so that the orientation pointer and capsule lid are now facing toward the FNR core (reverse position). This procedure was performed to provide a more uniform irradiation of the metallurgical specimens.

The IAR-2 capsule was raised in the IAR-2 facility, rotated 180 degrees, and reinserted into the facility to provide a more uniform irradiation of the metallurgical specimens. No specimen exchange or shuffle was performed. After this rotation the capsule was placed into the facility with the orientation pointer and lid toward the FNR core (reverse position).

At the beginning of this reporting period, the first metallurgical specimens in the new IAR facilities had been irradiated at the desired temperature of 288 degrees C for a total of 906 EFPH. At the end of this reporting period the specimens had been irradiated for a total of 1387 EFPH. The next specimen exchanges and/or rotations are scheduled to occur after 2000 EFPH of irradiation time.

Shown in Figure 2 are the six instrument panels used for controlling and monitoring the IAR (three on the left) and the UCSB (three on the right) experiments at the FNR. Figure 3 shows a view of the UCSB IVAR high- and low-flux capsules being removed from the Irradiation Facility to the special transfer rack in preparation for a sample change out. The IAR North and IAR South capsules and the thermal shield remain on the trolley at a pool depth of 26 feet. The trolley is always pulled away from the reactor core during change outs. This figure provides a useful reference to the TORT model shown in Figure 1, Subtask 3.2.

Subtask 6.1 Operate the HSSI Irradiation, Anneal, and Reirradiation (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 (UM) completed as part of the previous (FY 1998) HSSI program, the new tasks 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 without incident during this reporting period.

During this reporting period, the reactor operated for the last five days of half cycle 429B, ten days of half-cycle 430A, and five days of half-cycle 430B. During the last five days of half-cycle 429B, the IAR irradiation facilities received a total of 105.7 EFPH (effective full power hours). The facilities then received 221.1 EFPH during half cycle 430A, which was followed by 104 EFPH during the first five days of half-cycle 430B. A specimen change out and capsule rotation was performed during this reporting period at the request of the subtask 2.2 experimenter. The change out and capsule rotation was performed at the end of half-cycle 430A after a total of 1293 EFPH irradiation time. A description of the operations that were performed during the requested change out follows.

The IAR-1 capsule was removed from the IAR-1 facility and transferred to the hot cells where the specimens were shuffled within the capsule. The specimen compartment originally in cell 1 (top position) was moved to cell 3 (middle position). The specimen compartment originally in cell 3 was placed in cell 1. The specimen compartment in cell 2 (second from top) was left in place. The specimen compartment originally in cell 4 (second from bottom) was moved to cell 5 (bottom position) and the specimen compartment originally in cell 5 was moved to cell 4. The flux monitors in the specimen groups were not disturbed. The two-each fission radiometric sets (FRSS) monitors were placed back into their original locations in the capsule. After the specimen shuffle was completed in the hot cells, the capsule was placed back into the IAR-1 facility and rotated 180 degrees from its original orientation so that the orientation pointer and capsule ID are now facing toward the FNR core (reverse position). This procedure was performed to provide a more uniform irradiation of the metallurgical specimens.

The IAR-2 capsule was raised in the IAR-2 facility, rotated 180 degrees, and reinserted into the facility to provide a more uniform irradiation of the metallurgical specimens. No specimen exchange or shuffle was performed. After this rotation the capsule was placed into the facility with the orientation pointer and ID toward the FNR core (reverse position).

At the beginning of this reporting period, the first metallurgical specimens in the new IAR facilities had been irradiated at the designed temperature of 288 degrees C for a total of 968 EFPH. At the end of this reporting period the specimens had been irradiated for a total of 1399 EFPH. The next specimen exchanges and/or rotations are scheduled to occur after 2000 EFPH of irradiation time.

Shown in Figure 2 are the six instrument panels used for controlling and monitoring the IAR (three on the left) and the UCSB (three on the right) experiments at the FNR. Figure 3 shows a view of the UCSB IVAR high and low-flux capsules being removed from the irradiation facility to the special transfer rack in preparation for a sample change out. The IAR North and IAR South capsules and the thermal shield remain on the trolley at a pool depth of 26 feet. The trolley is always pulled away from the reactor core during change outs. This figure provides a visual reference to the TOCF model shown in Figure 1, Subtask 5.2.

IAR Monitor & Control Instrumentation

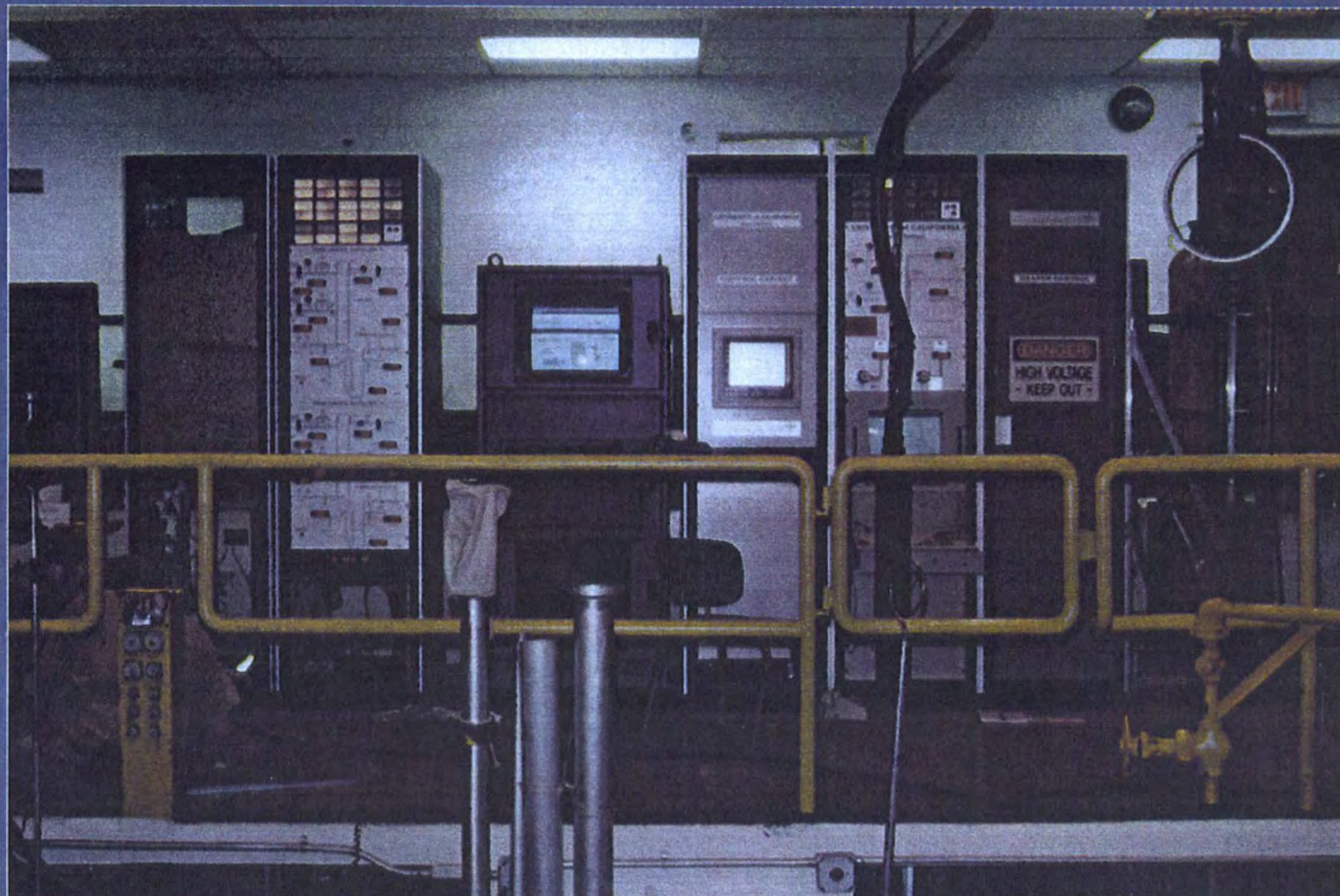


Figure 2

Figure 3

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

This subtask includes supervising the overall operation and provide assistance to the reactor personnel in the routine operation and maintenance of the UCSB irradiation facilities. 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 and ORNL specimens in the UCSB irradiation facility continued without incident during this reporting period

During this reporting period, the reactor operated for the last five days of half-cycle 429B, ten days of half-cycle 430A, and five days of half-cycle 430B. During the last five days of half-cycle 429B, the UCSB irradiation facility received a total of 105.7 EFPH (effective full power hours). The UCSB facility then received 221.4 EFPH during half-cycle 430A, which was followed by 154 EFPH during the first five days of half-cycle 430B. Two specimen change outs were performed during this reporting period at the request of the UCSB experimenters. The first change out was performed at the end of half-cycle 429B and the second was performed two weeks later at the end of half-cycle 430A.

At the beginning of this reporting period, the UCSB facility and original specimen compliment had been irradiated for a total of 8438 EFPH. At the end of this reporting period the UCSB facility and original specimen compliment had been irradiated for a total of 8919 EFPH. The latest irradiation plan received from the UCSB experimenters indicates that the final specimens will be removed from the UCSB facility after 13,500 EFPH. At the end of this reporting period, the UCSB irradiation program had obtained 66% of the desired irradiation time.

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

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

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

The purpose of the subtask is to maintain and update the EDB. This includes evaluating surveillance reports, entering the data into the EDB, and providing an update to the NRC by the end of the fiscal year.

(Milestone 7.1.A) The following surveillance report was integrated into EDB format,

M. E. Sauby, G. L. Stevens, "Review of the Test Results of two Surveillance Capsules, and Recommendations for the Materials Properties and Pressure- Temperature Curves to be used for the Monticello Reactor Pressure Vessel," SIR-97-003/R2, October 1998.

One typographical error was found in this report. The Capsule G-1 tensile data identified as being from base metal was actually from weld metal. While the plots of tensile properties vs. fluence factor change slightly, this correction does not change any of the conclusions in the report. The author was notified who then alerted the client and made the appropriate changes to tables and plots in the report.

The QA for the EDB input was completed for the following reports,

E. C. Biemiller, G. M. Solan, "Analysis of Seabrook Station Unit 1 Reactor Vessel Surveillance Capsules U and Y," DES-NFQA-98-01, May 1998.

T. L. Laubham, J. D. Perock, R. P. Shogan, "Analysis of Capsule V from Southern Nuclear Vogtle Electric Generating Plant Unit 1 Reactor Vessel Radiation Surveillance Program," WCAP-15067, September 1998.

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.

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

3. MEETINGS AND TRIPS:

None

4. PRESENTATIONS, REPORTS, PAPERS, AND PUBLICATIONS:

R. E. Stoller, "*The Impact of Mobile Point Defect Clusters in a Kinetic Model of Pressure Vessel Embrittlement,*" Effect of Radiation on Materials: 18th International Symposium, ASTM 1325, R. K. Nanstad, M. L. Hamilton, F. A. Garner, and A. S. Kumar, American Society for Testing and Materials, 1999, pp. 14-29.

R. K. Nanstad, D. E. McCabe, and R. L. Swain, "*Evaluation of Variability in Material Properties and Chemical Composition for Midland Reactor Weld WF-70,*" Effect of Radiation on Materials: 18th International Symposium, ASTM 1325, R. K. Nanstad, M. L. Hamilton, F. A. Garner, and A. S. Kumar, American Society for Testing and Materials, 1999, pp. 125-156.

M. A. Sokolov and R. K. Nanstad, "*Comparison of Irradiation-Induced Shifts of K_{JC} and Charpy Impact Toughness for Reactor Pressure Vessel Steels,*" Effect of Radiation on Materials: 18th International Symposium, ASTM 1325, R. K. Nanstad, M. L. Hamilton, F. A. Garner, and A. S. Kumar, American Society for Testing and Materials, 1999, pp. 167-190.

S. K. Iskander, R. K. Nanstad, M. A. Sokolov, D. E. McCabe, J. T. Hutton, and D. L. Thomas, "*Use of Forces From Instrumented Charpy V-Notch Testing of Determine Crack-Arrest Toughness,*" Effect of Radiation on Materials: 18th International Symposium, ASTM 1325, R. K. Nanstad, M. L. Hamilton, F. A. Garner, and A. S. Kumar, American Society for Testing and Materials, 1999, pp. 204-222.

M. A. Sokolov, S. Spooner, G. R. Odette, B. D. Wirth, and G. E. Lucas, "*Sans Study of High-Copper RPV Welds in Irradiated and Annealed Conditions,*" Effect of Radiation on Materials: 18th International Symposium, ASTM 1325, R. K. Nanstad, M. L. Hamilton, F. A. Garner, and A. S. Kumar, American Society for Testing and Materials, 1999, pp. 333-345.

S. K. Iskander, M. A. Sokolov, and R. K. Nanstad, "*Comparison of Different Experimental and Analytical Measures of the Thermal Annealing Response of Neutron-Irradiated RPV Steels,*" Effect of Radiation on Materials: 18th International Symposium, ASTM 1325, R. K. Nanstad, M. L.

Hamilton, F. A. Garner, and A. S. Kumar, American Society for Testing and Materials, 1999, pp. 403-420.

5. PROPERTY ACQUIRED:

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

Item	Cost ($)

None

6. PROBLEM AREAS:

None

7. PLANS FOR THE NEXT REPORTING PERIOD:

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

FINANCIAL STATUS for W6953 — Reporting Period: 2/22/99-3/28/99

		Current Month (MM)	Fiscal Year to Date (MY)	Cumulative Project to date (MY)
I.	Direct Staff Effort	26	8.1	11.7
II.	A. Direct Lab Staff Effort ($)			
	Direct Salaries	184,927	784,342	1,242,275
	Materials and Services	10,460	59,974	269,125
	ADP Support	83	491	502
	Subcontracts	57,478	71,796	71,796
	Travel	730	19,268	37,128
	Indirect Labor Costs	0	0	0
	Other	0	0	0
	General and Administrative	84,599	354,224	631,699
	Total LMER Costs	338,277	1,290,095	2,252,525
	B. DOE Added Factor Costs	0	0	0
	TOTAL PROJECT COSTS	338,277	1,290,095	2,252,525

Percentage of available cumulative funds costed	59
Percentage of available current FY funds costed	43
Funds Remaining	1,540,475

III. Funding Status

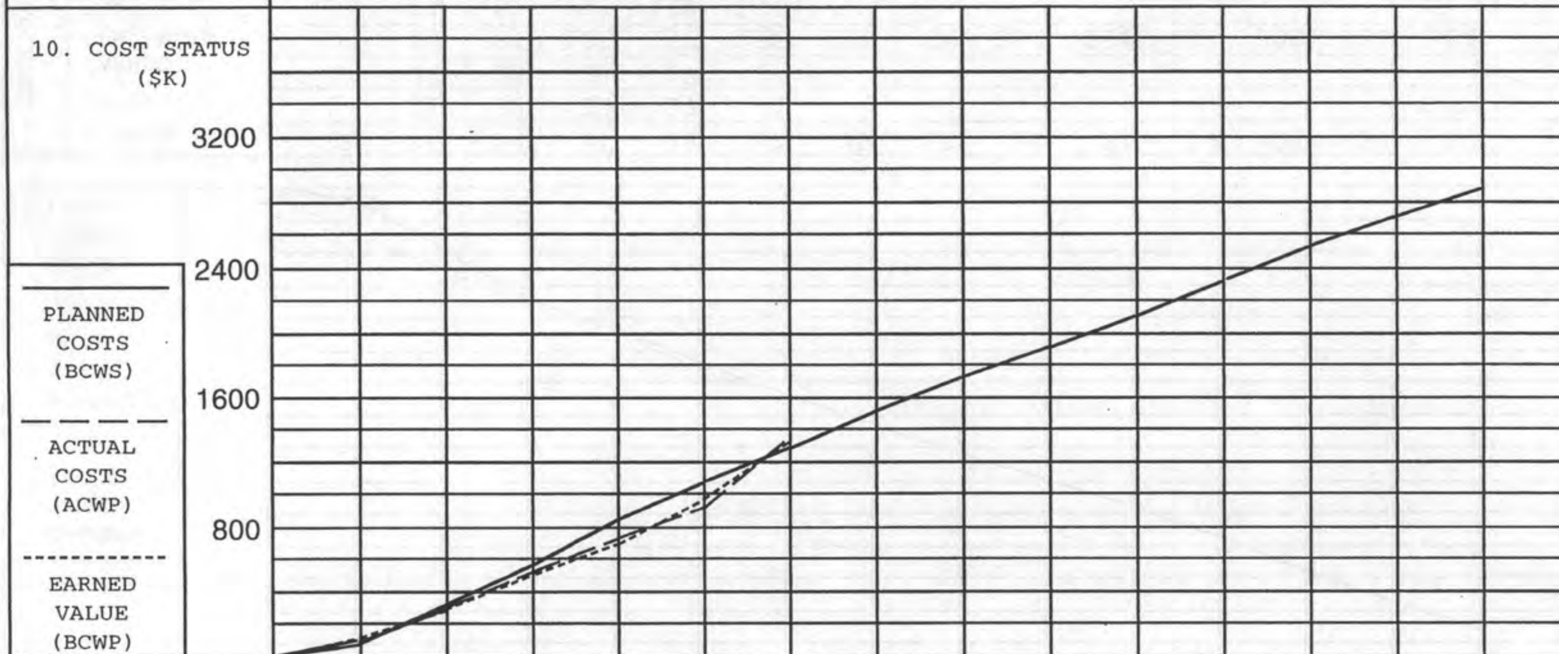
Prior FY Carryover	FY 99 Projected Funding Level	FY 99 Funds Received to Date	FY 99 Funding Balance Needed	Cumulative Amt. Obligated	Cumulative Amt. Costed
890,570	2,134,000	2,082,000	52,000	3,793,000	2,252,525

Comments:

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - Heavy-Section Steel Irradiation Program	**2/22/99-3/28/99**	**W6953**
4. CONTRACTOR (NAME AND ADDRESS)	5. CONTRACT PERIOD	6. ACTIVITY NUMBER
OAK RIDGE NATIONAL LABORATORY	**FY 1998-1999**	**41 W6 95 3W 1**
P.O. BOX 2008	7. NRC B&R NO.	8. DOE B&R NO.
OAK RIDGE, TN 37831	**860 15 21 20 05**	**40 10 01 06**

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

10. COST STATUS ($K)



COST PLAN DATES

3/22/99

PLANNED COSTS FOR ELEMENT ($K)

2,973

ELEMENT COSTS FOR PRIOR FYS ($K)

962

ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	135	241	220	211	209	236	278	234	239	201	201	204	186	178	
ACTUAL	142	209	209	189	203	338									
EARNED	159	187	196	200	252	261									
CUM. PLAN.	135	376	596	807	1016	1252	1530	1764	2003	2204	2405	2609	2795	2973	
CUM. ACT.	142	351	560	749	952	1290									
CUM. EARN.	159	346	542	742	994	1255									

11. REMARKS:

1. CONTRACT REPORTING ELEMENT **HSSI - 1. Program Management**		2. REPORTING PERIOD **2/22/99-3/28/99**	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 1998-1999**	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: 3/22/99

PLANNED COSTS FOR ELEMENT ($K): 354

ELEMENT COSTS FOR PRIOR FYS ($K): 184

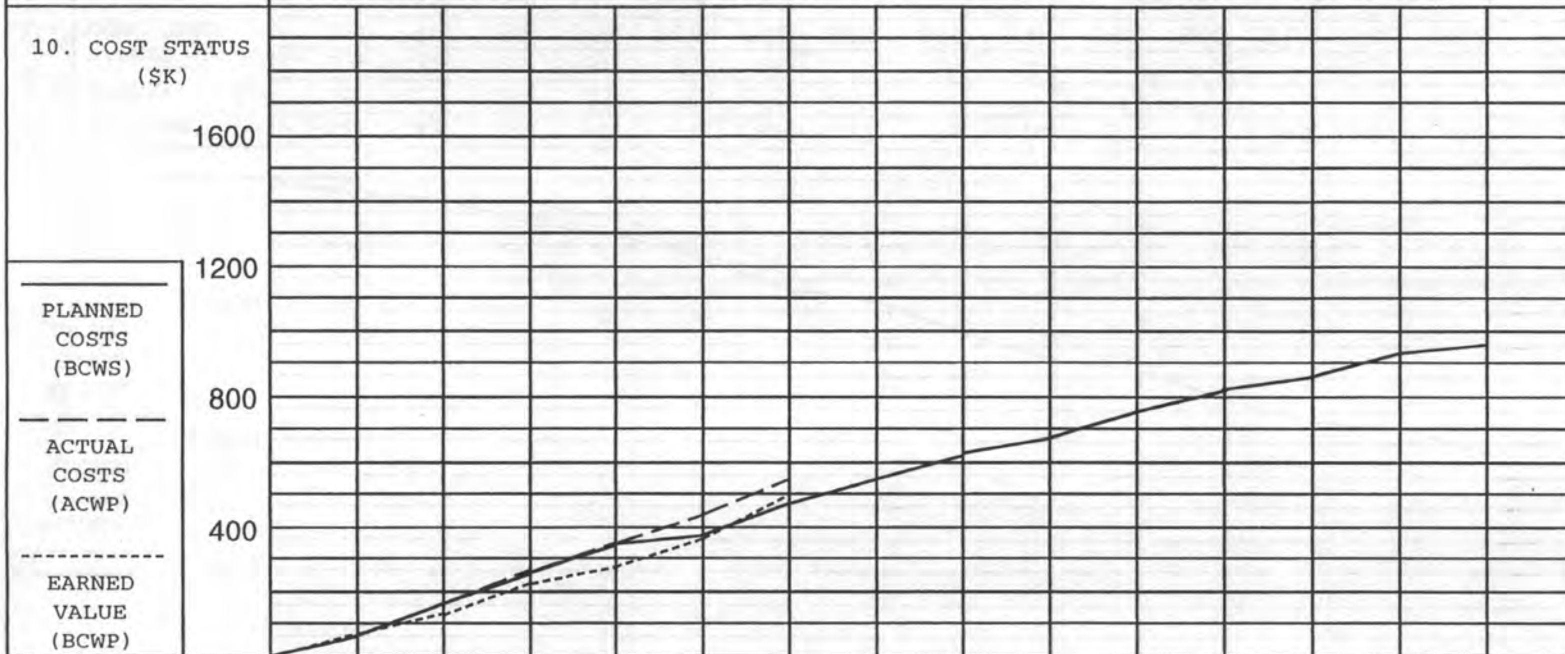
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	18	31	32	24	25	27	25	24	24	24	24	27	27	22	
ACTUAL	18	31	32	22	27	34									
EARNED	32	28	25	23	27	29									
CUM. PLAN.	18	49	81	105	130	157	182	206	230	254	278	305	332	354	
CUM. ACT.	18	49	81	103	130	164									
CUM. EARN.	32	60	85	108	135	164									

11. REMARKS:

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 2. Fracture Toughness Transition and MC Methodology	**2/22/99-3/28/99**	**W6953**
4. CONTRACTOR (NAME AND ADDRESS)	5. CONTRACT PERIOD	6. ACTIVITY NUMBER
OAK RIDGE NATIONAL LABORATORY	**FY 1998-1999**	**41 W6 95 3W 1**
P.O. BOX 2008	7. NRC B&R NO.	8. DOE B&R NO.
OAK RIDGE, TN 37831	**860 15 21 20 05**	**40 10 01 06**

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

10. COST STATUS ($K)



COST PLAN DATES: 1/22/99

PLANNED COSTS FOR ELEMENT ($K): 960

ELEMENT COSTS FOR PRIOR FYS ($K): 342

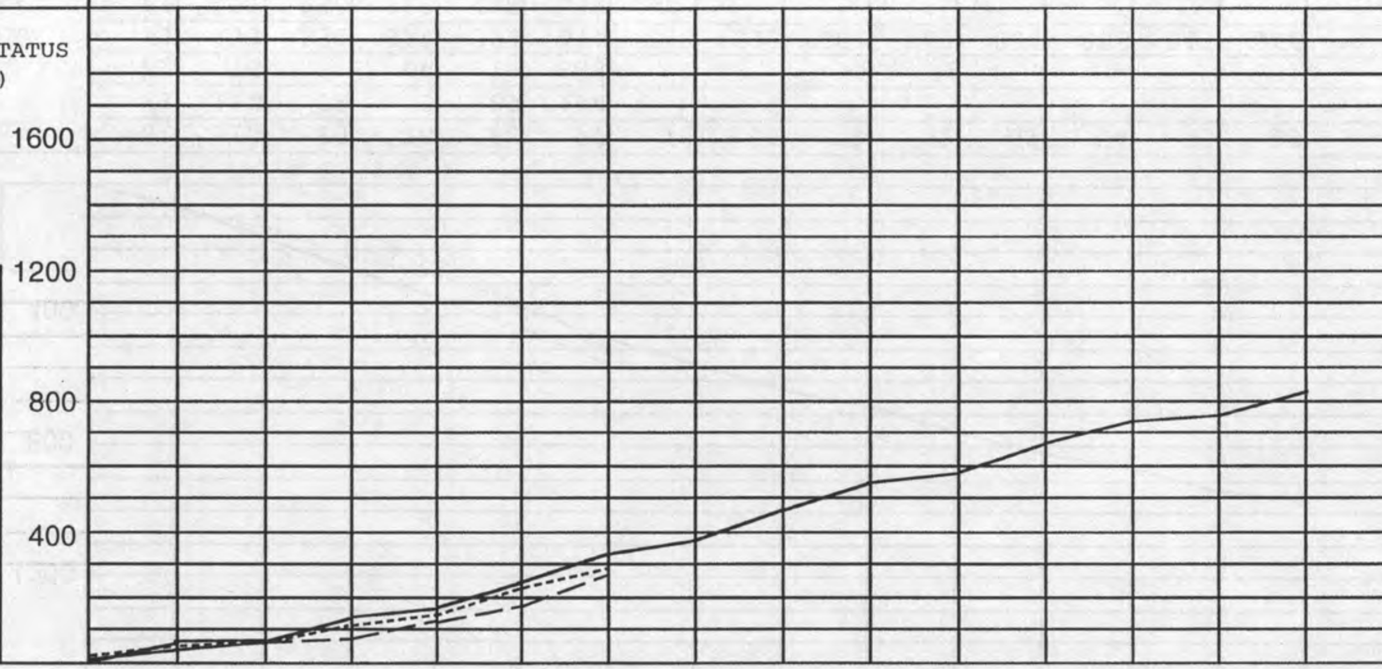
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	61	110	80	76	66	77	76	65	70	62	61	54	53	49	
ACTUAL	61	110	79	79	89	114									
EARNED	62	76	71	66	116	108									
CUM. PLAN.	61	171	251	327	393	470	546	611	681	743	804	858	911	960	
CUM. ACT.	61	171	250	329	418	532									
CUM. EARN.	62	138	209	275	391	499									

11. REMARKS:

1. CONTRACT REPORTING ELEMENT **HSSI - 3. Thermal Annealing of RPV Steel**	2. REPORTING PERIOD **2/22/99-3/28/99**	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 1998-1999** 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: 3/22/99

PLANNED COSTS FOR ELEMENT ($K): 823

ELEMENT COSTS FOR PRIOR FYS ($K): 187

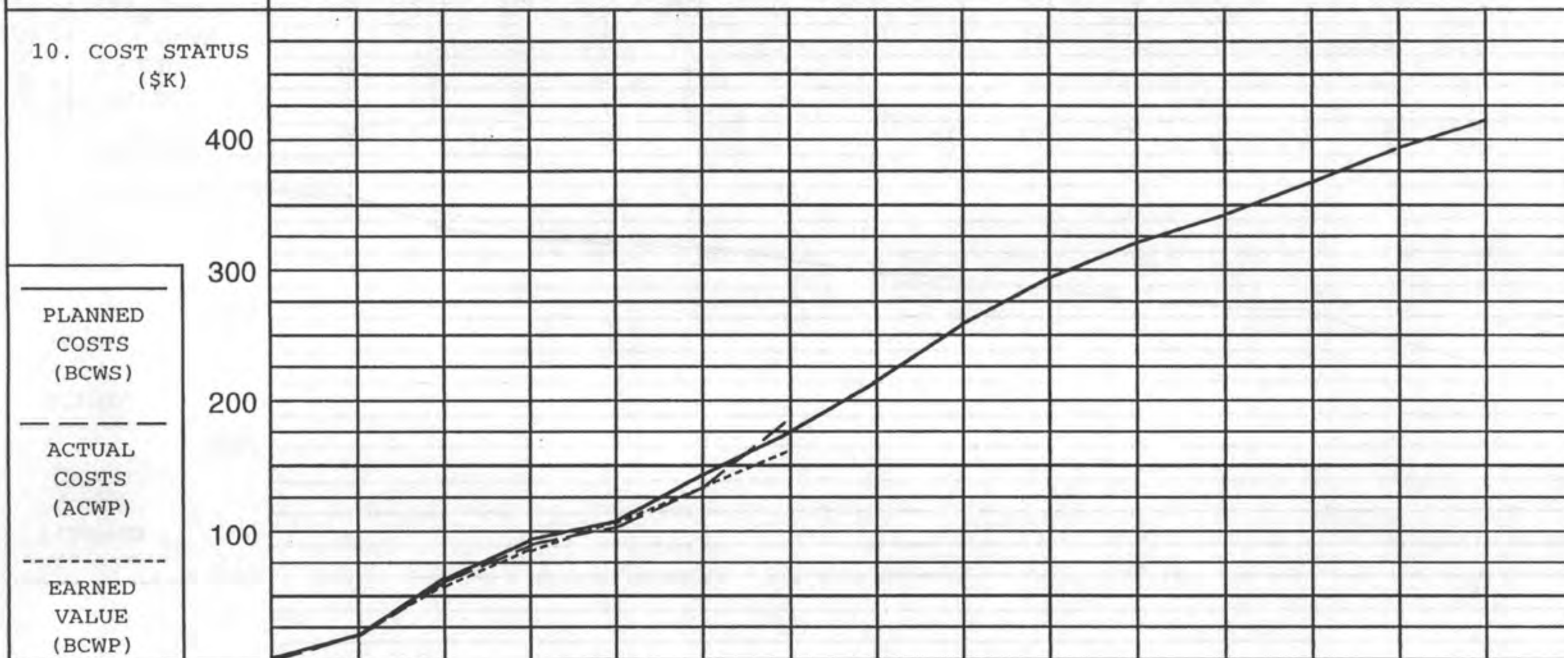
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	28	42	47	60	61	66	87	74	70	57	68	73	47	43	
ACTUAL	35	11	37	41	50	116									
EARNED	32	32	39	60	67	66									
CUM. PLAN.	28	70	117	177	238	304	391	465	535	592	660	733	780	823	
CUM. ACT.	35	46	83	124	174	290									
CUM. EARN.	32	64	103	163	230	296									

11. REMARKS:

1. CONTRACT REPORTING ELEMENT **HSSI - 4. Validation of Irradiated and Aged Materials**		2. REPORTING PERIOD **2/22/99-3/28/99**	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 1998-1999**	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: 3/22/99

PLANNED COSTS FOR ELEMENT ($K): 418

ELEMENT COSTS FOR PRIOR FYS ($K): 188

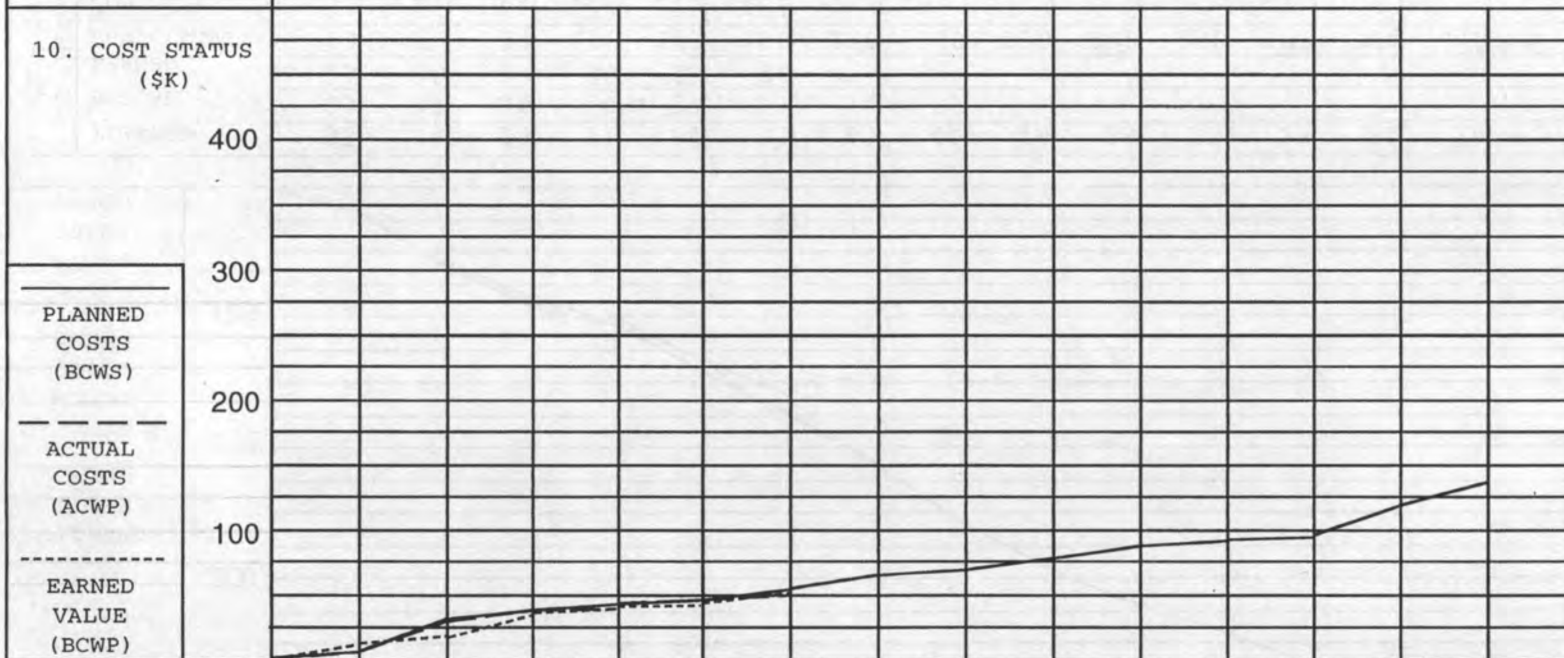
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	23	34	30	21	34	33	43	42	40	28	22	23	21	24	
ACTUAL	23	33	30	18	27	53									
EARNED	23	30	27	28	23	26									
CUM. PLAN.	23	57	87	108	142	175	218	260	300	328	350	373	394	418	
CUM. ACT.	23	56	86	104	131	184									
CUM. EARN.	23	53	80	108	131	157									

11. REMARKS:

1. CONTRACT REPORTING ELEMENT **HSSI - 5. Modeling and Microstructural Analysis**	2. REPORTING PERIOD **2/22/99-3/28/99**	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 1998-1999**	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: 1/22/99

PLANNED COSTS FOR ELEMENT ($K): 136

ELEMENT COSTS FOR PRIOR FYS ($K): 59

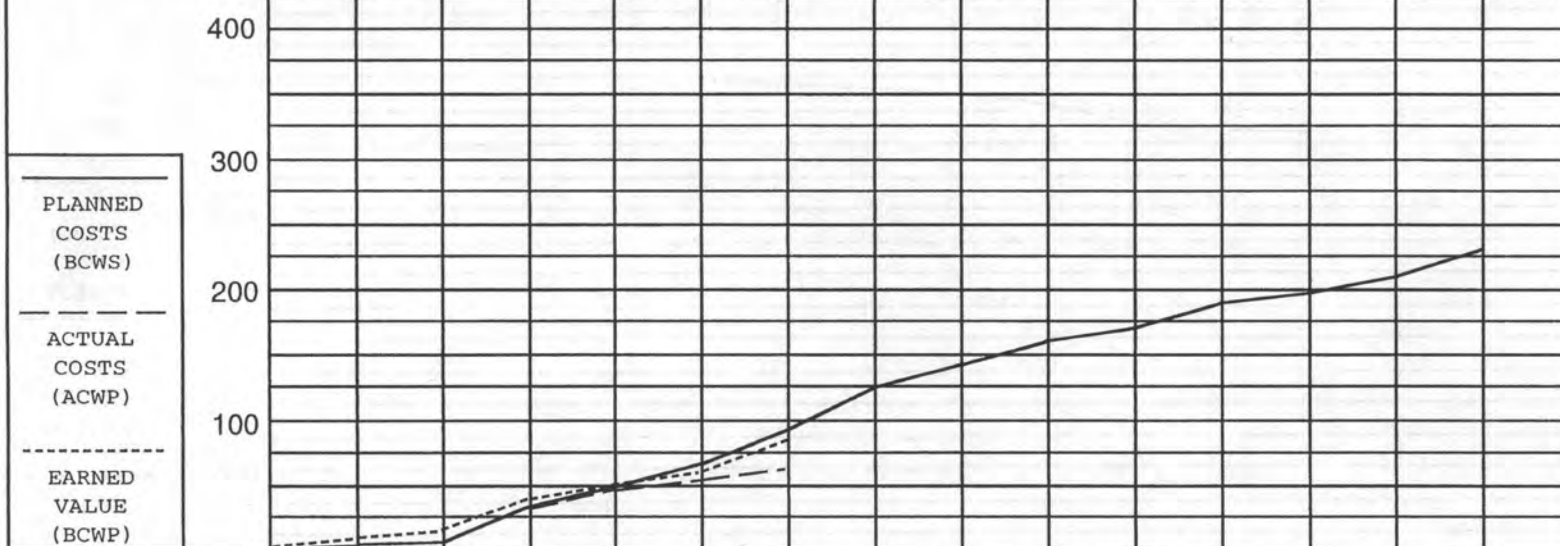
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	4	23	5	8	5	7	7	6	11	5	5	10	24	16	
ACTUAL	4	23	5	7	6	5									
EARNED	6	16	10	6	4	9									
CUM. PLAN.	4	27	32	40	45	52	59	65	76	81	86	96	120	136	
CUM. ACT.	4	27	32	39	45	50									
CUM. EARN.	6	22	32	38	42	51									

11. REMARKS:

1. CONTRACT REPORTING ELEMENT **HSSI - 6. Irradiation Coordination**	2. REPORTING PERIOD **2/22/99-3/28/99**	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 1998-1999**	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: 1/22/99

PLANNED COSTS FOR ELEMENT ($K): 227

ELEMENT COSTS FOR PRIOR FYS ($K): 1

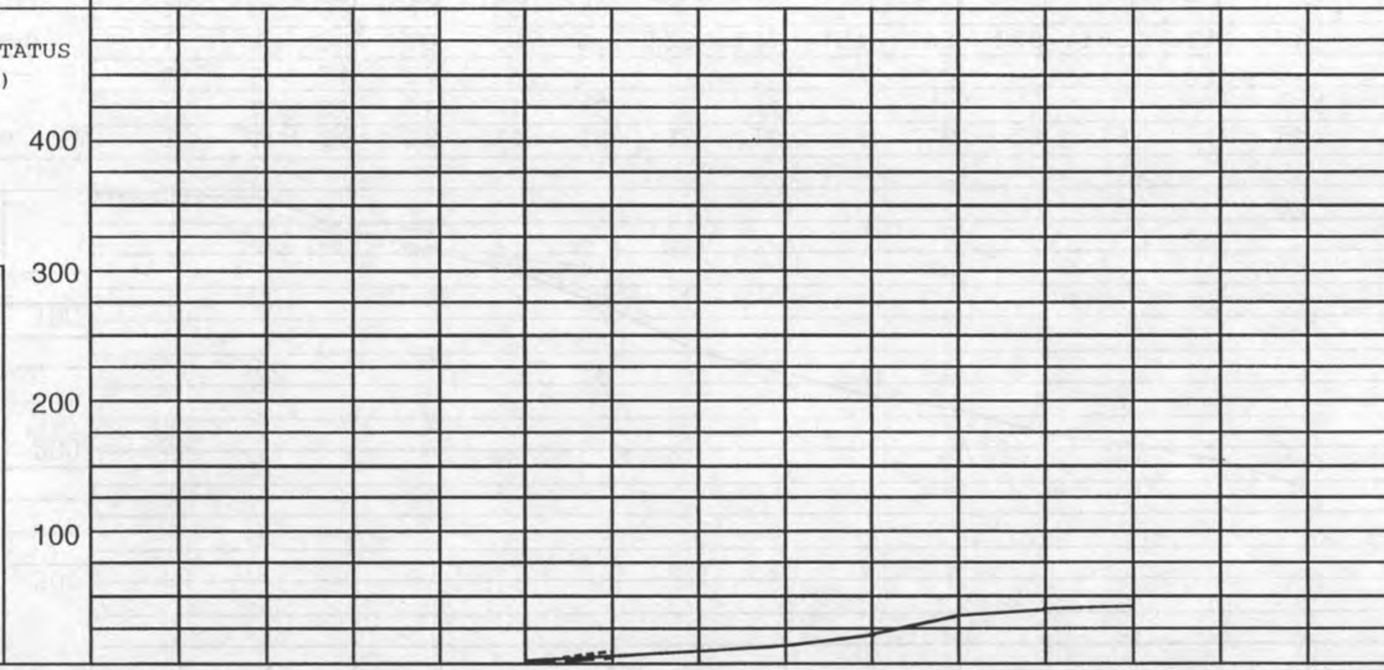
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	1	1	26	22	18	22	35	16	16	16	13	13	14	14	
ACTUAL	1	1	26	21	3	16									
EARNED	4	5	24	17	15	17									
CUM. PLAN.	1	2	28	50	68	90	125	141	157	173	186	199	213	227	
CUM. ACT.	1	2	28	49	52	68									
CUM. EARN.	4	9	33	50	65	82									

11. REMARKS:

1. CONTRACT REPORTING ELEMENT **HSSI - 7. Embrittlement DB & Dosimetry Evaluation**	2. REPORTING PERIOD **2/22/99-3/28/99**	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 1998-1999** 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: 3/22/99

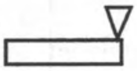
PLANNED COSTS FOR ELEMENT ($K): 45

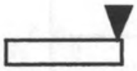
ELEMENT COSTS FOR PRIOR FYS ($K): 0

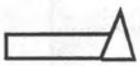
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED						4	5	7	8	9	8	4			
ACTUAL						3									
EARNED						6									
CUM. PLAN.						4	9	16	24	33	41	45			
CUM. ACT.						3									
CUM. EARN.						6									

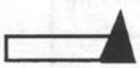
11. REMARKS:

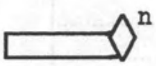
Milestone Symbology


Intermediate milestone planned

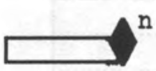

Intermediate milestone completed


Major milestone planned


Major milestone completed



Rescheduled milestone planned

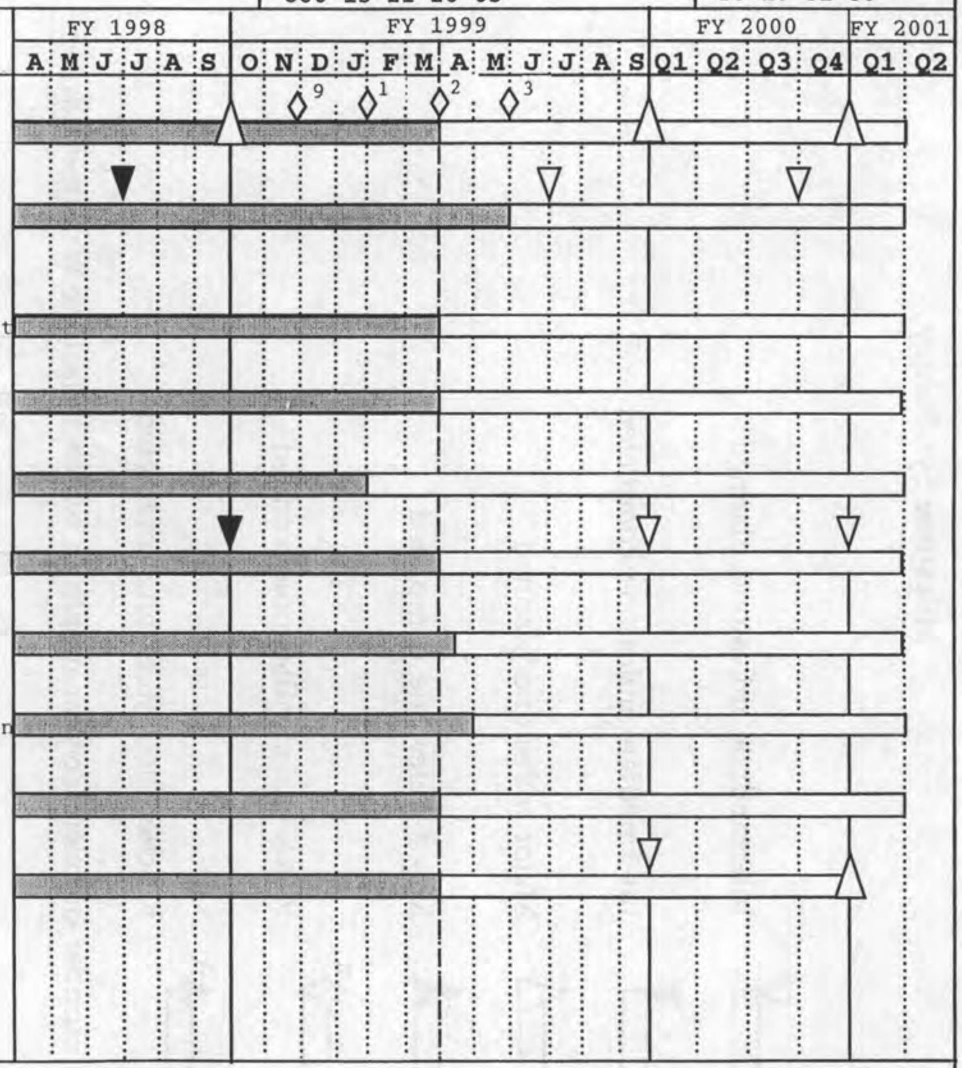


Rescheduled milestone completed

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

1. CONTRACT REPORTING ELEMENT **HSSI - 1. Program Management**	2. REPORTING PERIOD **2/22/99 - 3/28/99**	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**

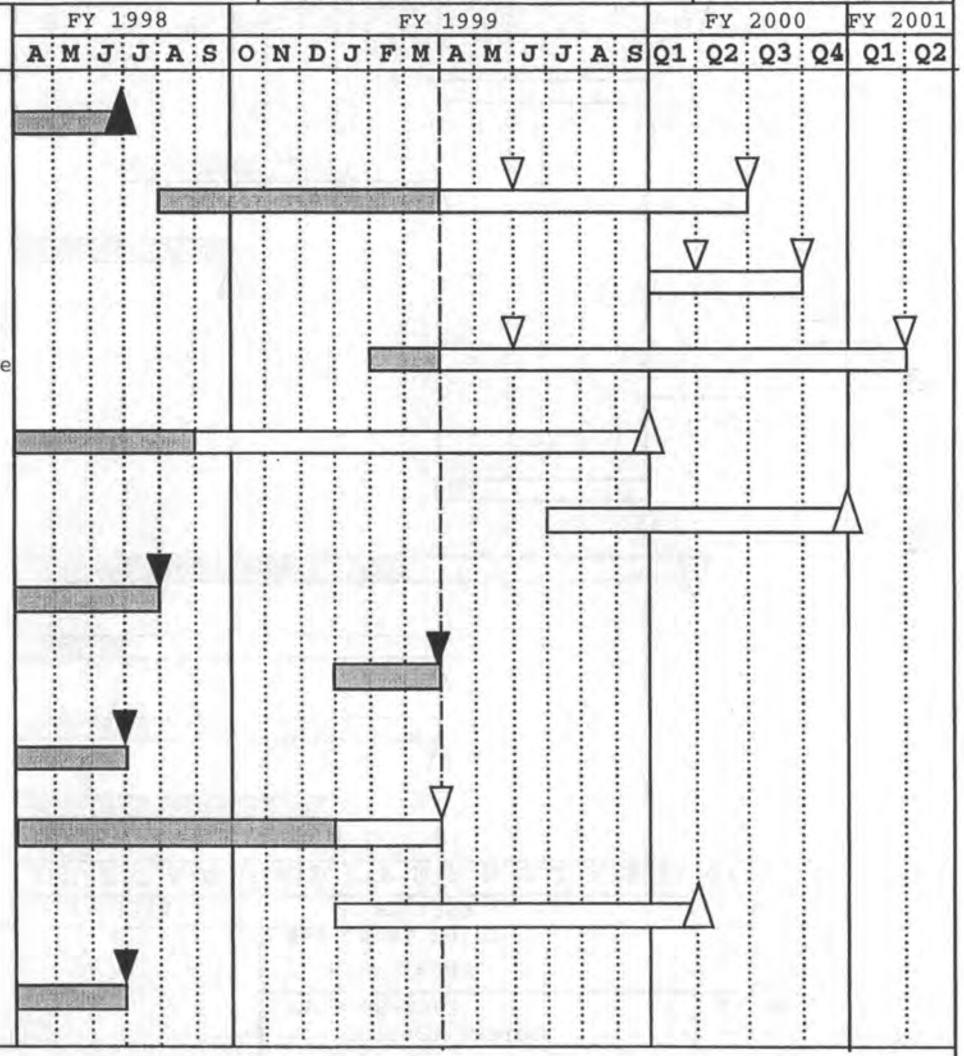
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
1.1.A.	Issue Project & Budget Proposal
1.1.B.	Select and Administer Subcontracts
1.2.A.	Issue Earned Value Based Monthly Management Reports (by the end of subsequent month)
1.2.B.	Ensure QA Requirements are met
1.3.A.	Participate in Appropriate Codes and 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 **2/22/99 - 3/28/99**	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**

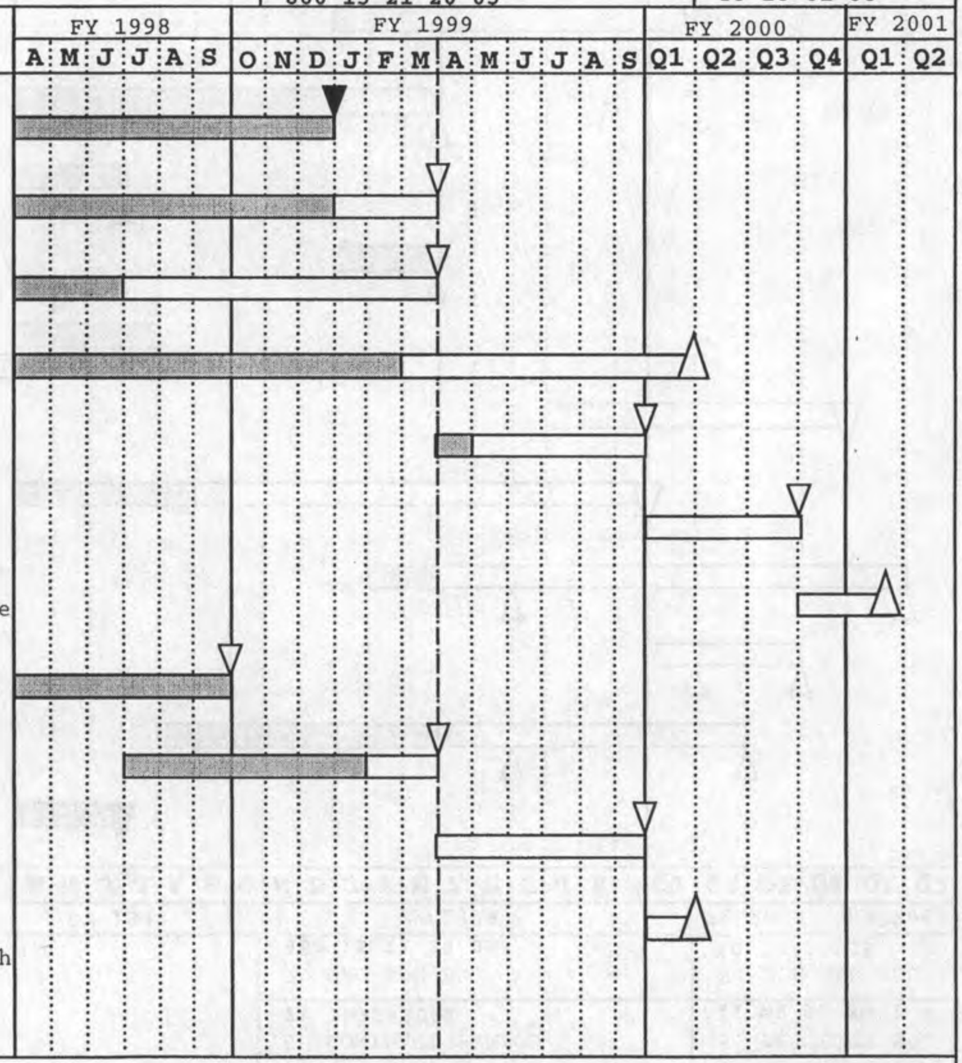
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
2.1.A.	Complete Draft NUREG Report on Comparison of CVN and Fracture Toughness Shifts
2.2.A.	Sample Preparation and Irradiation for Master Curve
2.2.B.	Receive Specimens
2.2.C.	Test Unirradiated & Irradiated Master Curve Specimens
2.3.A.	Design, Fabrication, Calibration, Evaluation and NUREG Report for Phase I
2.3.B.	Phase II: NUREG on MC Evaluation
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	2. REPORTING PERIOD	3. JCN NO.
HSSI - 2. Fracture Toughness Transition & MC Methodology	**2/22/99 - 3/28/99**	**W6953**
4. CONTRACTOR (NAME AND ADDRESS)	5. CONTRACT PERIOD	6. ACTIVITY NO.
OAK RIDGE NATIONAL LABORATORY **P.O. BOX 2008** **OAK RIDGE, TN 37831**	**FY 1998-2001**	**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. 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
2.8.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



11. REMARKS

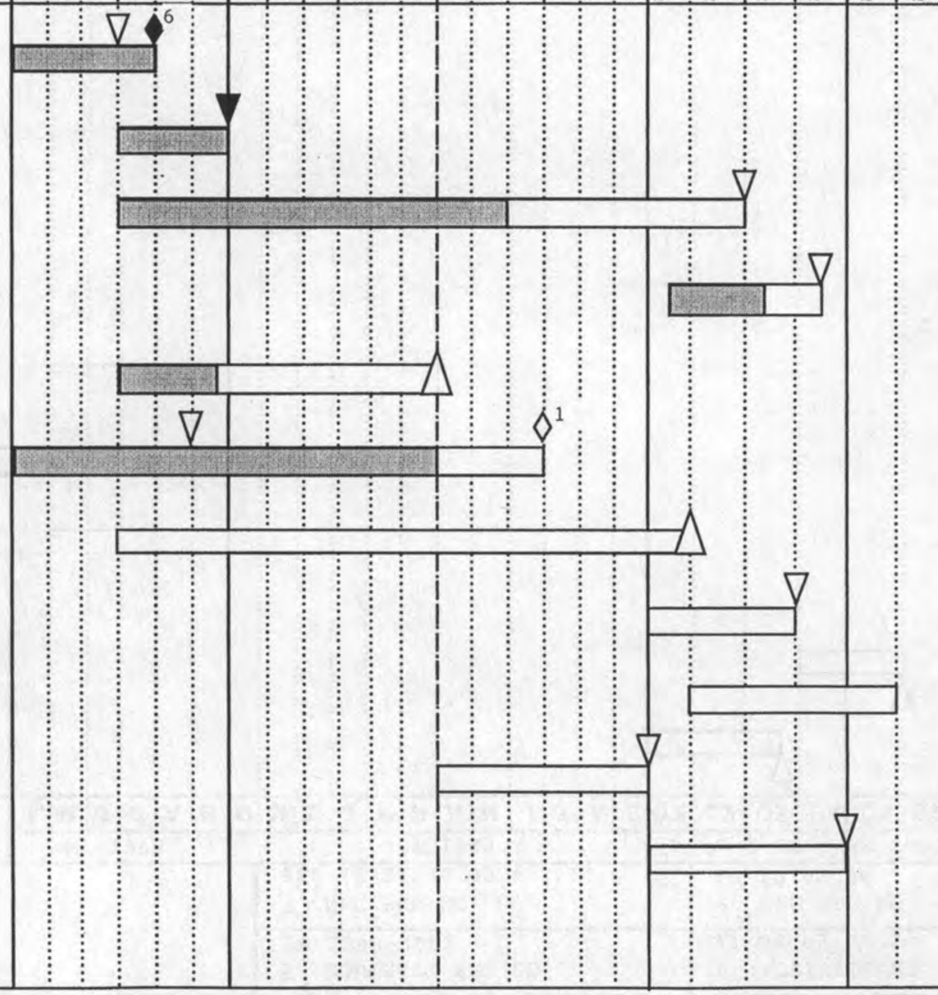
1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 2. Fracture Toughness Transition & MC Methodology	**2/22/99 - 3/28/99**	**W6953**
4. CONTRACTOR (NAME AND ADDRESS)	5. CONTRACT PERIOD	6. ACTIVITY NO.
OAK RIDGE NATIONAL LABORATORY	**FY 1998-2001**	**41 W6 95 3W 1**
P.O. BOX 2008	7. NRC 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	FY 1998						FY 1999												FY 2000				FY 2001	
		A	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**
2.8.E.	Complete Assembly and Compilation for Irradiated Materials																								
2.8.F.	Complete Statical Analysis of Data Base for Irradiated materials																								

11. REMARKS

1. CONTRACT REPORTING ELEMENT **HSSI - 3. Thermal Annealing of RPV Steel**	2. REPORTING PERIOD **2/22/99 - 3/28/99**	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	FY 1998	FY 1999	FY 2000	FY 2001
		A M J J A S	O N D J F M A M J J A S	Q1 Q2 Q3 Q4	Q1 Q2
3.1.A.	Heat-Treat HAZ Materials and Age				
3.1.B.	Machine CVN Specimens				
3.1.C.	Evaluate Results and Report				
3.1.D.	Irradiate Capsules				
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				
3.2.G.	Complete Reconstitution of Irradiated CVN Specimens				
3.2.H.	Reirradiation of HSST Plate 02				

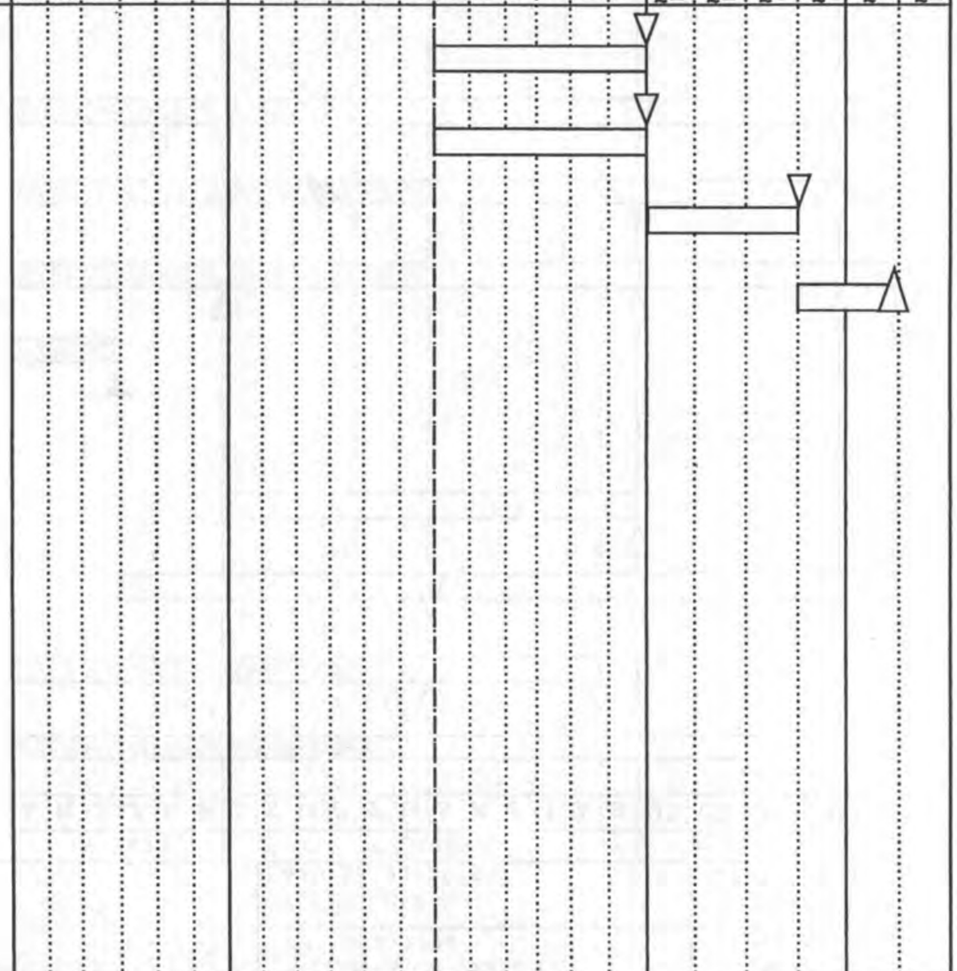


11. REMARKS

1. CONTRACT REPORTING ELEMENT **HSSI - 3. Thermal Annealing of RPV Steel**	2. REPORTING PERIOD **2/22/99 - 3/28/99**	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

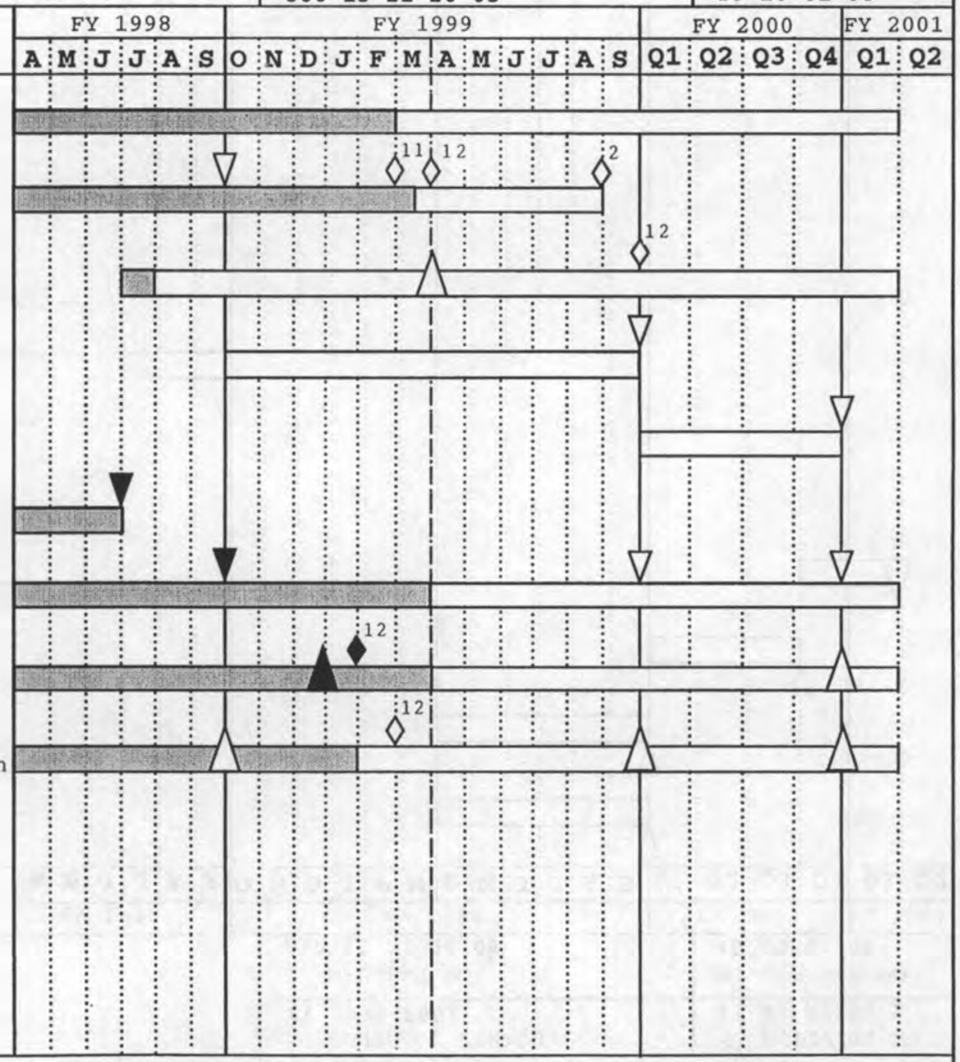
FY 1998: A M J J A S — FY 1999: O N D J F M A M J J A S — FY 2000: Q1 Q2 Q3 Q4 — FY 2001: Q1 Q2



11. REMARKS

1. CONTRACT REPORTING ELEMENT **HSSI - 4. Validation of Irradiated and Aged Materials**	2. REPORTING PERIOD **2/22/99 - 3/28/99**	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**

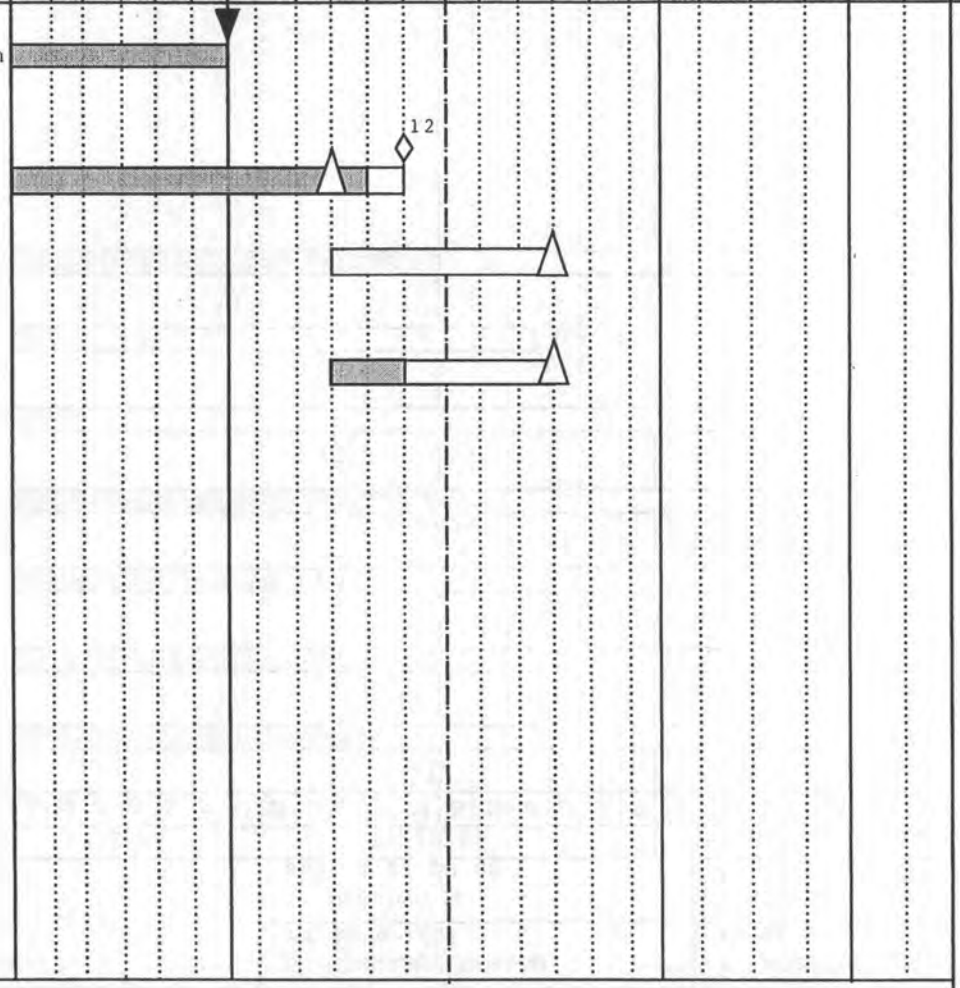
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
4.1.1.A.	JPDR Information Exchange with JAERI
4.1.1.B.	Machining & Inspection of JPDR
4.1.1.C.	Testing & NUREG Report
4.1.2	Trojan RPV Feasibility Study
4.1.3	Maine Yankee RPV Feasibility Study
4.3.B.	Complete Draft NUREG Report on Thermal Aging of SS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



11. REMARKS

1. CONTRACT REPORTING ELEMENT **HSSI - 4. Validation of Irradiated and Aged Materials**	2. REPORTING PERIOD **2/22/99 - 3/28/99**	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**

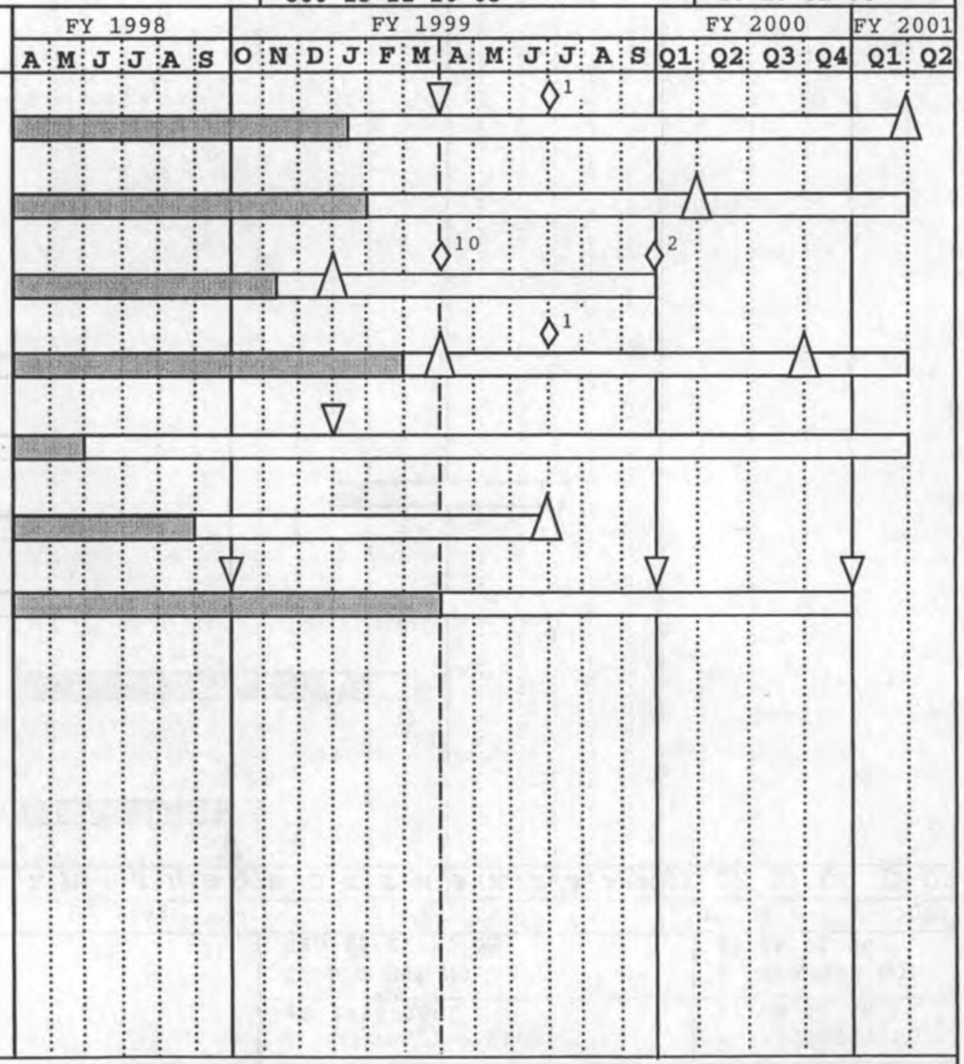
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION	FY 1998: A M J J A S — FY 1999: O N D J F M A M J J A S — FY 2000: Q1 Q2 Q3 Q4 — FY 2001: Q1 Q2
4.5.A.	Complete Plans for Testing of Specimens in MEA Capsule, Procurement and Testing of Palisades Capsule & Evaluation of PWHT Sheets	
4.5.B.	Complete Letter Report Regarding RPV Materials Available for Irradiation Study	
4.5.C.	Complete NUREG Report Regarding RPV Materials Available for Irradiation Studies	
4.5.D.	Complete Letter Report on Test results From MEA Capsule	



11. REMARKS

1. CONTRACT REPORTING ELEMENT **HSSI - 5. Modeling & Microstructural Analysis**	2. REPORTING PERIOD **2/22/99 - 3/28/99**	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

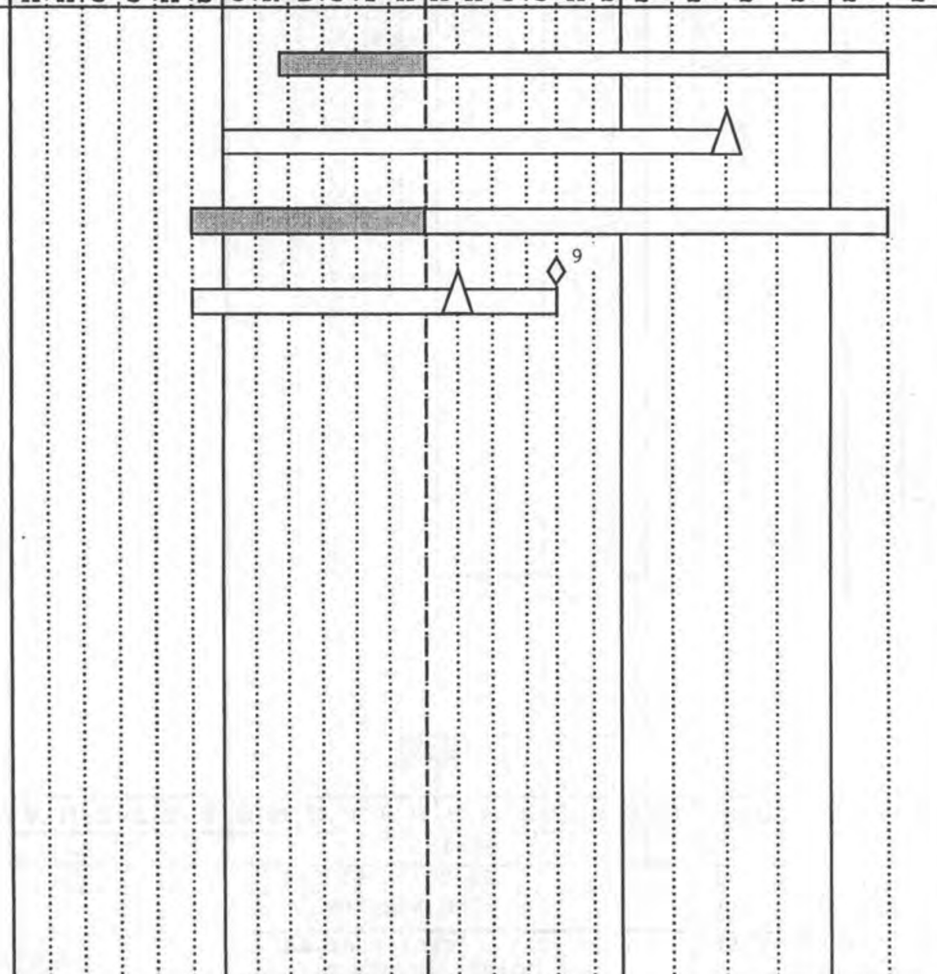


11. REMARKS

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 6. Irradiation Coordination	**2/22/99 - 3/28/99**	**W6953**
4. CONTRACTOR (NAME AND ADDRESS)	5. CONTRACT PERIOD	6. ACTIVITY NO.
OAK RIDGE NATIONAL LABORATORY **P.O. BOX 2008** **OAK RIDGE, TN 37831**	**FY 1998-2001**	**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. 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 the IAR Facility
6.2.A.	Coordinate the Operation, Data Collection, and Maintenance of the UCSB Irrad.Facility
6.2.B.	Comprehensive Report on the UCSB Irradiation Facility

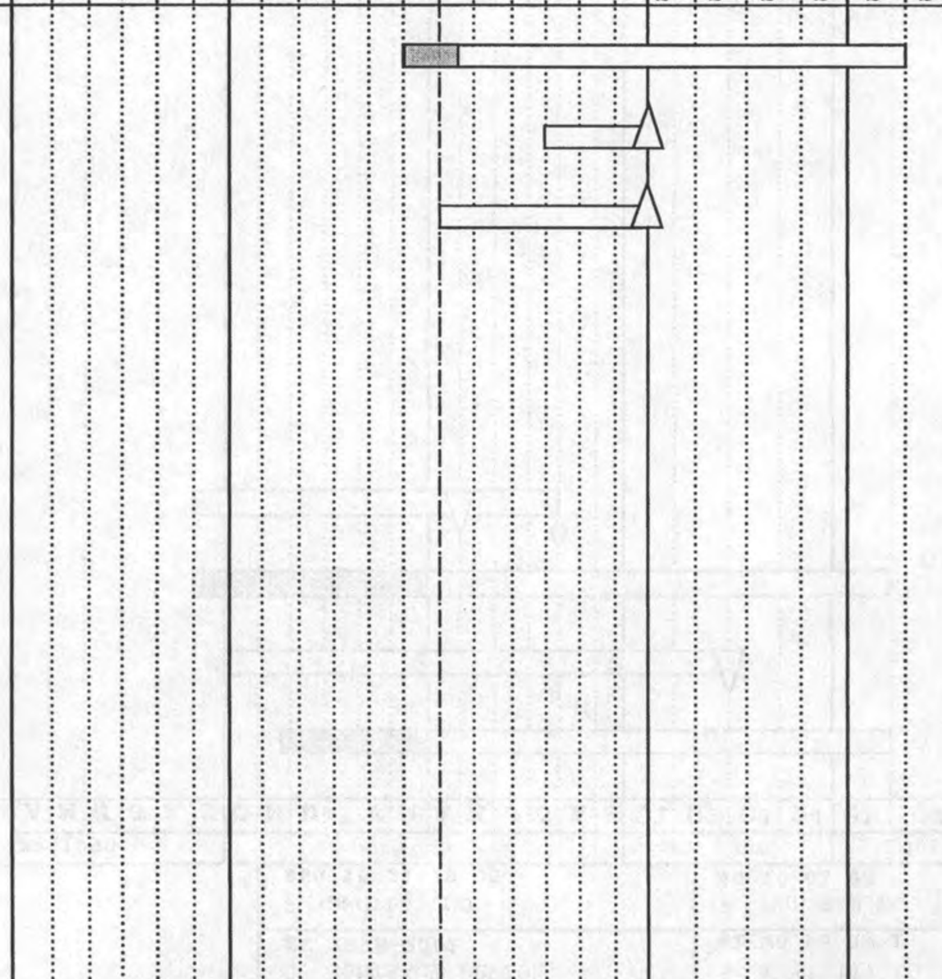
FY 1998: A M J J A S | FY 1999: O N D J F M A M J J A S | FY 2000: Q1 Q2 Q3 Q4 | FY 2001: Q1 Q2



11. REMARKS

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 7. Embrittlement DB & Dosimetry Evaluation	**2/22/99 - 3/28/99**	**W6953**
4. CONTRACTOR (NAME AND ADDRESS)	5. CONTRACT PERIOD	6. ACTIVITY NO.
OAK RIDGE NATIONAL LABORATORY **P.O. BOX 2008** **OAK RIDGE, TN 37831**	**FY 1998-2001**	**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. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION	FY 1998	FY 1999	FY 2000	FY 2001
		A M J J A S	O N D J F M A M J J A S	Q1 Q2 Q3 Q4	Q1 Q2
7.1.A.	Evaluate and Input Surveillance Reports into Embrittlement Database				
7.1.B.	Complete Update 10				
7.2.A.	Complete DG-1053 Report				



11. REMARKS