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January 20, 2004

Mrs. Carolyn J. Fairbanks
U.S. Nuclear Regulatory Commission
Division of Engineering Technology
Electrical, Materials, and Mechanical Engineering Branch
Mail Stop T10-E10
Washington, D.C. 20555-0001

Dear Carolyn:

HSSI Monthly Letter Status Report for JCN W6953

Two copies of the monthly letter status report for the W6953 Heavy-Section Steel Irradiation Program are enclosed for December 2003.

If you have any questions or need any additional information, please contact me.

Sincerely,

Thomas M. Rosseel, Manager
Heavy-Section Steel Irradiation Program

TMR:pjh

Enclosures (MLSR)

cc/encl:	N. Chokshi, NRC	S. N. Malik, NRC	
	P. Cross-Prather, NRC	M. E. Mayfield, NRC	
	A. L. Hiser, NRC	C. G. Santos, NRC	
e-mail/pdf	A. G. Andrews	D. E. McCabe	J. J. Simpson
	C. A. Baldwin	J. G. Merkle	D. L. Slagle
	B. R. Bass	G. E. Michaels	M. A. Sokolov
	E. E. Bloom	M. K. Miller	R. E. Stoller
	D. W. Heatherly	R. K. Nanstad	K. R. Thoms
	L. L. Horton	A. E. Pasto	J. A. Wang
	S. K. Iskander	I. Remec	S. J. Zinkle
	M. T. Kirk, NRC	D. J. Robinson, NRC	File-NoRC
	P. G. Lewis	M. L. Scott, NRC	

ORNL/HSSI (W6953)/MLSR-2004/3

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

Monthly Letter Status Report

December 2003

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ORNL/HSSI (W6953)/MLSR-2004/3

HEAVY-SECTION STEEL IRRADIATION PROGRAM

JCN W6953

MONTHLY LETTER STATUS REPORT

FOR

December 2003

Submitted by

T. M. Rosseel
HSSI Project Manager

Compiled by
P. J. Hadley

Submitted to
C. J. Fairbanks
NRC Project Manager

OAK RIDGE NATIONAL LABORATORY
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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 six program tasks. The six tasks, including a project management task, correspond to the 189, dated August 29, 2003. The final part of the report provides financial status for all tasks and status reports for selected milestones within each task. The task milestones address the period from October 2003 to July 2005, while the individual task budgets address the period from October 2002 to December 2003.

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

Thomas M. Rosseel, Manager
Heavy-Section Steel Irradiation

MONTHLY LETTER STATUS REPORT
December 2003

Job Code Number:	**W6953**
Project Title:	**Heavy-Section Steel Irradiation Program**
Period of Performance:	**4/1/98 to 12/31/05**
Performing Organization:	**Oak Ridge National Laboratory**
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1. PROJECT OBJECTIVE:

The primary goal of the Heavy-Section Steel Irradiation (HSSI) Program is to provide a thorough, quantitative assessment of the effects of neutron irradiation on the material behavior, and in particular the fracture toughness properties, of typical pressure vessel steels as they relate to light-water reactor pressure vessel (RPV) integrity. The program includes studies of the effects of irradiation on the degradation of mechanical and fracture properties of vessel materials\ augmented by enhanced examinations and modeling of the accompanying microstructural changes. Effects of specimen size; material chemistry; product form and microstructure; irradiation fluence, flux, temperature, and spectrum; and post-irradiation mitigation are being examined on a wide range of fracture properties. This program will also maintain and upgrade computerized databases, calculational procedures, and standards relating to RPV fluence-spectra determinations and embrittlement assessments. Results from the HSSI studies will be incorporated into codes and standards directly applicable to resolving major regulatory issues that involve RPV irradiation embrittlement such as pressurized-thermal shock, operating pressure-temperature limits, low-temperature overpressurization, and the specialized problems associated with low upper-shelf welds. Five technical tasks and one for program management are now contained in the HSSI Program.

2. TECHNICAL ACTIVITIES:

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

This task is responsible for managing the program to ensure that the overall objectives are achieved. The management responsibilities include three major activities: (1) program planning and resource allocation; (2) program monitoring and control; and (3) documentation and technology transfer. Program planning and resource allocation includes: (a) developing and preparing annual budgetary proposals and (b) issuing and administrating subcontracts to other contractors and consultants for specialized talents not available at Oak Ridge National Laboratory (ORNL) or that supplement those at ORNL. Program monitoring and control

includes: (a) monitoring and controlling the project through an earned-value, project-management system; (b) ensuring that quality assurance (QA) requirements are satisfied; and (c) issuing monthly management reports. Documentation and technology transfer includes: (a) participating in appropriate codes and standards committees; (b) preparing briefings for the NRC; (c) coordinating NRC and internal ORNL review activities; (d) coordinating domestic and foreign information exchanges approved by NRC; and (e) documenting the activities of the program through letter and NUREG reports.

(Milestone 1.1.A) The first increment of FY 2004 funds that were received at the end of the last reporting period were approved by DOE and transferred to the HSSI Program at the beginning of this reporting period.

(Milestone 1.1.B) During this reporting period, discussions with the staff of the University of Michigan Ford Nuclear Reactor (FNR) continued concerning removal of specimens, return of control panels and disposal of irradiated waste. (See Task 6 for details).

(Milestone 1.3.C) As reported previously, a proposed site evaluation of the Massachusetts Institute of Technology (MIT) 4.9 MW MITR II tank-type reactor as a location for future irradiation experiments on December 11, 2003, was delayed at the request of Dr. Ron Ballard, the MIT contact. It is anticipated that the site visit will be rescheduled for the last week of January.

A late January or early February date is also being considered for a site visit to the University of Missouri, Missouri University Research Reactor (MURR). Professor John Gahl is the point of contact.

Planning for a March site visit and evaluation of the LV-15 reactor at the Nuclear Research Institute (NRI), Rez, Czech Republic remains on hold pending a decision on the number of slots available for foreign travel and possible support from the DOE Generation IV Program. Discussions with Studsvik Nuclear staff concerning the possible use of the R2/0 reactor in Sweden for future irradiation experiments also continued. Based on these discussions, Studsvik has requested that the HSSI Program plan a site visit and evaluation. It is expected that a trip to Sweden would be combined with the trip to Rez.

(Milestone 1.3.D) The NUREG report by M. A. Sokolov, R. K. Nanstad, I. Remec, C. A. Baldwin, and R. L. Swain, "Fracture Toughness of an Irradiated, Highly Embrittled Reactor Pressure Vessel Weld," NUREG/CR- (ORNL/TM-2002/293) was submitted to the US NRC during this reporting period.

The NUREG report, by S. K. Iskander, C. A. Baldwin, D. W. Heatherly, D. E. McCabe, I. Remec, and R. L. Swain, "Detailed Results of Testing Unirradiated and Irradiated Crack-Arrest Toughness Specimens from the Low Upper-Shelf Energy, High Copper Weld, WF-70," NUREG/CR-6621 (ORNL/TM-13764), was submitted to the NRC Program Monitor for review.

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

Fracture-toughness transition and master-curve (MC) methodology will be broadly explored for pressure-vessel applications through a series of experiments, analyses, and evaluations in eight Subtasks. 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. Additionally, the fluence received in the HSSI irradiation experiments will be determined.

<u>Subtask 2.1: Fracture Toughness Transition Temperature Shifts</u> (M. A. Sokolov)

The purpose of this subtask is to collect and statistically analyze pertinent fracture-toughness data to assess the shift and potential change in shape of the fracture-toughness curves due to neutron irradiation. The MC methodology will be applied to provide a statistical analysis of the fracture-toughness data and Charpy data will be fitted by hyperbolic tangent function. The resulting reference fracture-toughness temperature, T_o, shifts are compared with Charpy shifts determined by various indexing methods.

(Milestone 2.1.A) The report by M. A. Sokolov and R. K. Nanstad, *Comparison of Irradiation-Induced Shifts of K_{Jc} and Charpy Impact Toughness for Reactor Pressure Vessel Steels*, NUREG/CR-6609 (ORNL/TM-13755), was published by the NRC in November 2000. There was no significant progress during this reporting period. However, as they become available, additional data sets will be analyzed and a revised database assembled.

<u>Subtask 2.2: Fracture Toughness Characterization of Highly Embrittled Materials</u> (M. A. Sokolov)

The purpose of this subtask is to evaluate the assumption of constant shape for the MC for highly embrittled RPV steels and to determine the effect of the interaction of low-energy ductile crack initiation with cleavage in the transition region for highly embrittled materials. The evaluation will be performed through the testing of pressure-vessel steels that have been irradiated to a neutron fluence sufficient to produce a fracture-toughness transition-temperature shift (T_o) of about 150°C (270°F). Other materials to be irradiated and examined for the curve shape effects study include a highly embrittled low upper-shelf RPV steel that exhibits onset of stable ductile tearing at relatively low fracture toughness and a high-nickel weld.

(1) A specially fabricated, radiation-sensitive, weld was selected to perform a pilot study on the ability of a highly embrittled material to maintain the master-curve shape. This weld, which was fabricated and studied in Germany, was supplied to ORNL by MPA, Stuttgart through a Memorandum of Agreement (MOA). Capsules, loaded with 21 1T compact specimens and a larger number of smaller specimens of Weld KS-01, were irradiated to a target fluence of 8.0×10^{18} n/cm^2 at the FNR during the first HSSI-IAR irradiation campaign. Evaluation of the fracture-toughness transition curve shape has been performed with 1T compact specimens, 1T C(T). Additionally, 0.5T C(T), and pre-cracked Charpy V-notch (PCVN) specimens were tested to investigate the use of more practical surveillance-size specimens. Tensile specimen testing was also completed to determine the irradiation-induced hardening. Evaluation of the

mechanical properties of the unirradiated weld has been completed. Sixteen 0.4T C(T) specimens from the previously irradiated and tested KS01 1T C(T) specimens will be prepared and tested for fracture toughness. These data will be compared with results from small and large compact specimens as well as pre-cracked Charpy specimens from the same material in the unirradiated and irradiated conditions.

(2) Specimens of the Midland belt line weld were fabricated and placed into the IAR facility at the FNR for irradiation to a fluence of at least 3 x 10^{19} n/cm^2 (>1 MeV). This irradiation is being conducted to evaluate the assumption of constant shape for the master curve with highly embrittled low upper-shelf RPV steels that exhibit onset of stable ductile tearing at relatively low fracture toughness.

(3) A high nickel weld from the Palisades steam generator will also be examined. Not only will this material provide additional information on curve shape effects, it will permit experimental validation of an assumption of 1:1 relationship between Charpy 41J and fracture toughness shifts for highly embrittled materials. Eight 0.5C(T) and twelve Charpy specimens were irradiated to the intermediate fluence of 1.6x10^{19} n/cm^2 (>1 MeV) and these specimens shall be tested. These results will be compared to the small specimens data from the UCSB program where this weld was also characterized after a similar dose of irradiation.

(Milestone 2.2.A) Irradiation of the Midland beltline weld and a high-nickel weld from the Palisades steam generator has been completed with shutdown of the University of Michigan FNR on July 3, 2003. Following an appropriate cool-down period, the specimens will be removed from the IAR facility and shipped to the ORNL hot cells for testing. Please also see Task 6.2.

(Milestone 2.2.B) Some of the Palisades steam generator specimens irradiated to an intermediate fluence were removed previously and were received at the ORNL hot cells. These specimens were sorted and identified in preparation for testing, as discussed below (Milestone 2.2.G).

(Milestone 2.2.C) As reported previously, programming of the computer numerically controlled (CNC) milling machine system and the design of fixtures has been completed. Preparations for machining of the 0.4T compact specimens from the broken irradiated 1T compact specimens of KS-01 is under way with evaluation of the CNC machine operational status, design and fabrication of special fixtures for remote change-out of tools, remote lubrication of moving parts, etc. The machine has been exercised, various issues have been identified, and the issues are being resolved. A number of practice specimens have been machined and measured for comparison with established tolerances. This practice machining has identified a number of issues relevant to machining of compact specimens and the issues have been largely resolved, including the machining of new specimen holder fixtures from steel, as opposed to aluminum.

Following machining of the irradiated specimens, these 0.4T specimens will be tested in the same general temperature range as the 1Ts described in Task 2.2 to expand the database further for this material, and will provide for a comparison of compact specimen results with those from the similar size pre-cracked Charpy specimens. This comparison is directed at the bias indicated

in some precracked Charpy data that results in somewhat lower determinations of T_o relative to compact specimens.

(Milestone 2.2.D) As noted previously, 21 1T and six additional 0.5T compact specimens of the submerged-arc weld KS-01, irradiated to ~0.8 $\times 10^{19}$ n/cm^2 (>1 MeV), were successfully tested. The results have been evaluated relative to the shape of the master curve. The occurrence of intergranular fracture in the test specimens was suspected to influence the deviation from MC shape observed. However, for a number of reasons also discussed previously, the contribution of IGF is not clear and the nonconformance of the KS-01 irradiated fracture toughness data may be predominantly due to the high degree of irradiation embrittlement. Further statistical analysis has been performed with these data and have been included in the draft NUREG report. Three additional tensile tests, as noted previously, were expected to shed light on the effects of the intergranular fracture observations relative to expected irradiation-induced hardening. The yield and ultimate strengths for these tests exhibited the expected irradiation-induced strengthening, indicating that intergranular fracture was not the dominant fracture mechanism.

Testing of 12 irradiated precracked Charpy KS-01 specimens has been completed and the results have been analyzed. The draft NUREG report has completed technical review and incorporation of the reviewers' comments, and was submitted to the NRC for publication in December. The KS-01 results were also included in a presentation on nickel effects at the IGRDM-11 meeting in San Diego in September. Please see Section 4.

(Milestone 2.2.G) Charpy impact tests of the Palisades unirradiated specimens and specimens irradiated to ≈1.38 $\times 10^{19}$ n/cm^2 (>1 MeV) were performed. The material exhibited a Charpy 41-J shift of 101ºC. Using the assumed fluence, this is considerably less than the predicted shift of 148ºC by *Regulatory Guide 1.99* (Rev. 2) and the predicted shift of 137ºC by the Eason, Wright, Odette (EWO) equation. Both predictions are, of course, dependent on the chemical composition variables used. The chemical composition used was an average of values available for the weld. Additional analyses will be conducted with the tested specimens to verify those values and will be compared with subsequent results from testing of the specimens irradiated to a higher fluence when they become available.

One broken half of a tested CVN specimen was submitted for atom-probe needle preparation. The fracture surface was cut from the specimen and a 0.5-mm-thick slice was cut from the remainder of the specimen. That slice was then cut into 0.5-mm-thick blanks with approximate dimensions of 0.5 × 0.5 × 10 mm. The blanks were stored in a lead pig and transported to the atom probe preparation facility. Atom probe needles were prepared and atom probe tomography (APT) was conducted. The APT examinations revealed copper-enriched precipitates also enriched with manganese and nickel. This result was also incorporated into the presentation on nickel effects at the IGRDM-11 meeting in San Diego in September.

<u>Subtask 2.3: Dynamic Fracture Toughness</u> (R. K. Nanstad, post doc)

The purpose of this subtask is to evaluate the applicability of the MC to dynamic fracture toughness of RPV steels. There are data available that suggest reasonable applicability of the master curve to dynamic fracture toughness data; however, a review of the available data under

high-rate loading conditions is needed. There are also data available that indicate a significant effect of loading rate within the limits prescribed in ASTM E1921. Previous plans within the HSSI Program included the evaluation of data from precracked Charpy specimens tested under impact conditions. Although the development of such techniques and resulting data are desirable, the first recommended step in evaluation of the master curve will be a review of the available data mentioned above. The conduct of high-rate loading experiments under elastic-plastic conditions with compact specimens under non-impact conditions will be dependent on the results of that review.

(Milestone 2.3.A and 2.3.B) If the review discussed above results in a recommendation for additional testing, compact specimens (either 0.5T or 1.0T) will be machined from a material with a Master Curve pedigree, such as HSST Plate 02, HSST Plate 13A, or HSSI Welds 72W/73W, and tested at a rate consistent with the dynamic elastic-plastic fracture toughness annex in ASTM E-1820-2001. This will allow for a direct comparison between T_o from quasi-static and dynamic tests. As mentioned above, a variation of loading rates within the E-1921 allowable range will also be considered following a review of the recently recommended changes regarding loading rates in the E-1921 standard. This issue has been identified as a potential area of investigation in a proposed Cooperative Research Program at the International Atomic Energy Agency (IAEA). Additionally, a review of instrumented impact testing of precracked Charpy specimens will be conducted to assess the potential inclusion of that technique in the project.

<u>Subtask 2.4: Intergranular Fracture</u> (R. K. Nanstad)

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 To 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 becomes one of understanding the influence of the triggering mechanism on the distribution of K_{Jc} values obtained. This information can be obtained on the lower shelf and, in part, into the transition range.

The proposed approach is to determine if there is an operational weakest-link effect when instability is triggered within an intergranular region. If an effect is observed, there should also be a measurable specimen-size effect on K_{Jc}. It will also be determined if the temper-embrittled materials exhibit a change in the J-R fracture toughness since such steels do not show a significant change in upper-shelf CVN energy.

The modified A302 grade B steel selected to evaluate intergranular-fracture effects on the universal MC shape assumption was specially heat treated to temper embrittle the material, and fracture-toughness testing was performed. In the analysis of the data, however, it became clear

that additional testing was deemed necessary to allow for a more definitive conclusion regarding the relationship between the intergranular fracture results and the Master Curve. A letter report describing this work was submitted in December 2002.

Additional 0.5TC(T) specimens were fabricated and tested, demonstrating that materials that fail with 100% intergranular fracture are not appropriate for MC characterization. This result compares with observations of materials that have failed with 10 to 20% intergranular fracture and which appear to behave in a manner consistent with MC characterization.

(Milestone 2.4.A) A test plan for intergranular fracture (IGF) assessment for conditions that produce less than 100% IGF is being developed.

Subtask 2.5: Sub-sized Specimens (M. A. Sokolov, guest/post doc)

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 test matrix within the New Coordinated Research Program (CRP) of the International Atomic Energy Agency (IAEA).

(Milestone 2.5.A) As reported previously, the testing and analysis of specimens has been completed. These specimens were machined from three blocks of materials into 1TC(T) and precracked Charpy specimens for the size effect study. Two of the blocks are broken halves of 4TC(T) specimens of two A302B plates previously tested by the HSSI Program. The third block of material is the well-characterized Plate 13A. This study is specifically designed as an evaluation of the precracked Charpy specimen.

(Milestone 2.5.B) A series of subsize specimens of JRQ steel has also been completed. The specimens are 0.2TC(T) and 0.4TC(T), and 5□by□5 mm and 5□by□10 mm SE(B) specimens.

(Milestone 2.5.C) A letter report on the results described in Milestones A and B above is in preparation with completion of the draft report anticipated in December.

Subtask 2.6: Dosimetry and Fluence Analysis of the IAR Irradiation Capsules (C. A. Baldwin, I. Remec, and T. M. Rosseel)

The purpose of this task is to measure and analyze the dosimeters used during the HSSI-IAR irradiation campaigns and to obtain accurate fluence determinations.

(Milestone 2.6.A) As reported previously, the set of four Fissionable Radiometric Dosimeters (FRDs), removed from the IAR facilities in April 2001, and shipped to counting lab, will be used

to verify the fluence estimates for the high-Nickel specimens and re-irradiation specimens removed from the FNR in 2001.

(Milestone 2.6.C) – (I. Remec and E. D. Blakeman) Final conversion of the LSL-M2 code package from DOS to Linux will be completed during the second quarter of the new fiscal year. A report, previously prepared under JCN 6164, will be issued as an ORNL technical report.

The report entitled, *Characterization of the Neutron Field in the HSSI/UCSB Irradiation Facility at the Ford Nuclear Reactor*, by I. Remec, E. D. Blakeman, and C. A. Baldwin, NUREG/CR-6646 (ORNL/TM-1999/140) was submitted to the NRC in September 1999.

Subtask 2.7: Investigate the Bias Term Added to T_o Values Determined from Pre-Cracked Charpy Specimens (R. K. Nanstad)

The purpose of this task is to perform a systematic study of the bias term added to T_o values determined from pre-cracked Charpy specimens, such as that used in the Kewaunee evaluation. The approach would utilize both analytical and experimental methods. Either HSST Plate 02 or HSST Plate 13A will be used since extensive C(T) data on these materials are available.

(Milestone 2.7.A) Planning for this task has continued. The experimental phase of the bias term project will tentatively include 1T three-point bend specimens, precracked Charpy specimens with and without side-grooves, Charpy thickness [10 mm (0.394 in.)] compact specimens, some with the standard ligament and some with half the standard ligament to provide a direct comparison with the precracked Charpy specimen. The issue of two different materials is also under consideration. HSST Plate 13A is one material of choice because of the extensive compact specimen-derived fracture toughness database available for that material. One important aspect of such testing is the number of specimens needed to provide a statistically reliable estimate of the difference in T_o for each specimen geometry. There are various methods for such a calculation that will not be discussed here. However, if one desires to know T_o within ±10°C (±2 standard deviations) using the equation provided in E1921, the number of specimens needed is 13. If a two standard deviations variation of 5°C is desired, the number of specimens needed is 52. Thus, statistical considerations will play a strong role in the test matrix. The draft will be discussed with appropriate and interested reviewers outside of ORNL. R. K. Nanstad visited SCK-CEN, Mol, Belgium, in September and discussed this issue with Eric Van Walle and his staff. Additionally, presentations and discussions from the ASTM E-08 Workshop on Constraint are being evaluated relative to planning of the experimental and analytical needs. A literature review is in progress, including a review of linear elastic fracture mechanics (LEFM) results that may provide information regarding specimen configuration differences observed as the result of specimen fractures under predominantly elastic loading. The use of the T-stress based constraint adjustments have received considerable discussions within the technical community and a comparison of such LEFM data may shed light on that specific subject.

Subtask 2.8: Verify the 72W T_o Value (R. K. Nanstad)

The purpose of this subtask is to verify the T_o value for HSSI weld 72W. The ASME Materials Properties Council conducted a round robin testing program a few years ago with pre-cracked

Charpy specimens of two RPV steels, one of which was HSSI Weld 72W. The specimens were machined from the "second batch" of weld 72W. The results showed a disparity in the T_o values of about 20ºC between that determined from the pre-cracked Charpy specimens and that from the extensive base of fracture toughness data using the "first batch" of 72W.

(Milestone 2.8.A) A block of HSSI Weld 72W (second batch) was located, drawings were prepared, and 13 1T compact specimens were machined, fatigue precracked and tested without side-grooves, the same condition as in the HSSI Fifth Irradiation Program. Specimens were tested at –80, -50, and –30°C.

(Milestone 2.8.B) Using the multi-temperature equation in E-1921, the T_o for the group of specimens described above from the "second batch" is –53.4°C. This compares with a T_o from the "first batch" of –56.6°C. The overall T_o for the combined database is –54°C. Thus, the results indicate no significant difference between the first and second batches. Therefore, the T_o result of –75°C from the MPC round robin program with PCVN specimens points to a difference of 21°C between the 1TC(T) and PCVN specimen for HSSI Weld 72W.

(Milestone 2.8.C) A draft letter report, "Comparison of Fracture Toughness Reference Temperatures for the First and Second Batches of HSSI Weld 72W," by R.K. Nanstad, has been prepared and internally reviewed and will be submitted for review in January. Additionally, a summary of the results was prepared and submitted to the MPC for inclusion as an annex in a Welding Research Council (WRC) Bulletin entitled "Indexing Fracture Toughness Data." The WRC Bulletin includes a paper based on the results of the MPC round robin test program with the uncertainty of the T_o value for the second batch of HSSI Weld 72W. Thus, the annex was provided to show resolution of that uncertainty.

Task 3: Irradiation Embrittlement of RPV Steel (R. K. Nanstad)

The issues affecting vessel lifetime extensions including the application of mitigation procedures to RPVs and embrittlement saturation effects at high fluence will be examined. Specifically, (1) the effects of temper embrittlement on the coarse-grained HAZ in RPV steels; (2) the effects of reirradiation on K_{Jc} and J_{Ic} 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; and (3) late-blooming phases in high-nickel steels, will be evaluated.

Subtask 3.1: HAZ embrittlement (R. K. Nanstad)

The purpose of this subtask is to determine the susceptibility of RPV heat-affected-zones (HAZ) to irradiation/thermal aging-induced temper embrittlement. Research conducted to date by ORNL and AEA-Technology (UK) on temper embrittlement of the coarse-grain materials in HAZs of RPV steel multi-pass welds has revealed the potential for substantial embrittlement under some conditions. AEA-Technology discovered that using high-temperature austenitization to produce very coarse grains, followed by thermal aging resulted in large transition-temperature shifts. Further, post-irradiation thermal annealing of such material resulted in an even greater increase of the transition temperature. Subsequent research at ORNL under the previous HSSI

Programs used five commercial RPV steels to investigate potential temper embrittlement. Since the amount of intergranular fracture observed was unexpected following irradiation and thermal annealing, further studies are required to resolve the issue. A letter report on the results of Phase I was published in December 2001.

The objective of this follow-on study is to prepare and test simulated heat-affected-zone (HAZ) material under typical RPV cooling conditions to study the effect of temper embrittlement. This work will be compared to the first HAZ irradiation experiment that was conducted with Gleeble-simulated HAZ material, which used a fast cooling rate after the post-weld heat treatment. Although a fast cooling rate likely enhances the probability of irradiation-induced phosphorus segregation to grain boundaries, it is not prototypic of RPV treatment.

(Milestone 3.1.A) The letter report by R. K. Nanstad, D. E. McCabe, M. A. Sokolov, C. A. English, and S. R. Ortner, *Comparison of Effects of Thermal Aging, Irradiation, and Thermal Annealing on Propensity for Temper Embrittlement on an RPV Submerged-Arc Weld HAZ*, ORNL/NRC/LTR-01/07, was published and distributed.

(Milestone 3.1.B) As noted previously, to investigate the effect of cooling rate following postweld heat treatment, additional material would be treated in the Gleeble system to simulate the coarse-grain HAZ as accomplished previously. This would then be followed by thermal aging, as well as by irradiation and post-irradiation thermal annealing. The A302 grade B (modified) steel in the previous study (designation Z-7) has a phosphorus content of 0.07 wt %. A second steel, A302 grade B (modified) with phosphorus content of 0.14 wt % (designation Z-5) is also included in this study for comparison. Excess material of each heat from the original investigation was identified and Gleeble specimens [(rods of about 75 mm (3 in.) long and 14.3 mm (0.562 in.) in diameter] were machined.

Gleeble treatment was performed with the same procedure used for the previous study and has now been completed for all the specimens. Following Gleeble treatment, the Gleeble specimens were postweld heat treated at 615ºC (1140ºF) for 24 h, then furnace cooled at ~15ºC/h. Charpy and tensile specimens were machined from the Gleeble specimens, notched and some were fatigue precracked for testing as precracked Charpy (PCVN) specimens. A total of 50 CVN (20 of Z-5 and 30 of Z-7), 20 PCVN (all of Z-7), and 16 tensile (4 of Z-5 and 12 of Z-7) specimens were packaged in two specially-fabricated steel boxes and were inserted into the IAR facility at the Ford Reactor in January. The unirradiated/unaged Charpy specimens have been tested and the specimens to be aged were enclosed in glass tubes, evacuated, backfilled with helium, and sealed in preparation for thermal aging. A furnace was identified for the thermal aging exposures and aging began in December. The specimens designated for aging of 168 h have completed aging. Immediately following aging of those specimens, those designated for an aging time of 2000 h were inserted into the furnace and will complete the aging process at the end of March.

(Milestone 3.1.C) The irradiation of these specimens was completed on July 3, 2003, with shutdown of the FNR. Following removal of the specimens from the capsule and after an appropriate cool-down period, the specimens will be shipped to the ORNL hot cells. At that time, a decision will be made regarding testing and thermal annealing of these specimens dependent on

the neutron fluence achieved in the IAR. Consideration is also being given to reirradiation of the remaining specimens from the initial series, dependent on availability of an irradiation facility.

Subtask 3.2 Evaluation of Reirradiated JRQ Specimens (R. K. Nanstad, E. T. Manneschmidt, and T. M. Rosseel)

The purpose of this subtask is to examine the fracture-toughness behavior of an RPV steel that has been irradiated, annealed, and re-irradiated. The specimens, which were fabricated from a heat of A533 grade B class 1 steel identified as JRQ, were prepared by the Paul Scherrer Institute (PSI) as part of the IAEA CRP 3. This steel has been used for several studies sponsored by the IAEA and is under consideration as a reference material for various RPV evaluation projects, including surveillance programs. This subtask is collaboratively conducted under a Memorandum of Agreement (MOA) between ORNL and PSI. Charpy impact, pre-cracked Charpy, and tensile specimens are available in the irradiated, and in the irradiated/annealed/re-irradiated conditions. Thermal annealing and testing of Charpy impact and precracked Charpy specimens has been completed.

(Milestone 3.2.B) During June 2002, the precracked Charpy specimens were tested in the irradiated condition, in the irradiated/annealed condition, and in two different IAR conditions. A presentation on the preliminary results from this work was made by R. K. Nanstad at the ASTM Symposium on Radiation Effects in Materials in Tucson, Arizona, in June. Photographs of specimen fracture surfaces have been made, crack lengths have been measured, and final analyses have been completed. During the hot cell testing, it was discovered that many of the specimens have relatively shallow flaws, with a/W ratios of about 0.3. Results from these specimens do not, of course, satisfy the requirements of E 1921 for valid fracture toughness data. There are some results in the literature indicating no significant effect of a/W ratios as low as 0.3 and this will be further pursued. Thus, the data will be evaluated giving consideration to the potential loss of constraint on the results. An initial comparison of the test results in the irradiated and the irradiated/annealed conditions, both of which included specimens with both short and long cracks, provided mixed results. In one case, the average K_{Jc} values were about the same, while in the other case they were substantially different. Moreover, neither comparison is based on a statistically strong database in that the subsets comprise only 4 or 5 test results.

A paper entitled, "Irradiation and Post-Annealing Reirradiation Effects on Fracture Toughness of RPV Steel Heat JRQ," by R. K. Nanstad, P. Tipping, and R. D. Kalkhof, was submitted to ASTM for review and publication in the STP for the Tucson meeting. The reviewer comments were received and incorporated in the final paper, and the paper has been sent to ASTM for publication. Additionally, R. K. Nanstad made a presentation of the fracture toughness test results and the TEP Seebeck Coefficient results at the IGRDM-11 meeting in San Diego in September.

A work package was prepared for cutting of pieces of selected JRQ specimens to be submitted for atom-probe examination. The same work package included packaging and transport of selected irradiated specimens to PSI for their thermoelectric power (TEP) testing. The selected specimens were retrieved from the storage cans and identified. They were packaged and were shipped to PSI in early September. They were received at PSI in mid-September. The cutting of

specimens for atom-probe examination is scheduled for the second week in January and will be performed in the LAMDA facility of the Metals and Ceramics Division, a low-level radiation zone that will allow for the cutting operations at a much lower cost.

(Milestone 3.2.C) R. K. Nanstad visited PSI during the last week of July to discuss the various aspects and progress of the collaborative project that is conducted under a Memorandum of Agreement between ORNL and PSI. He met with Dr. Dietmar Kalkhof, the lead scientist for the PSI portion of the project, and Dr. Niffenegger of PSI, the researcher responsible for conduct and analysis of the TEP experiments. They have completed TEP measurements with both unirradiated and irradiated CVN specimens that had been previously tested at PSI. Comparison of the results with the Charpy impact results indicates the probability of a reasonable correlation between results from the two tests. Nanstad and Kalkhof discussed and agreed on the selection of broken CVN and PCVN specimens for shipment to PSI for additional TEP testing (see 3.2.B). A joint NUREG report and technical papers will be prepared following completion of all the experiments and analyses. A foreign trip report, ORNL/FTR-200785, *Report of Foreign Travel for R. K. Nanstad*, was prepared and distributed.

Subtask 3.3: Evaluation of reirradiated 73W specimens (R. K. Nanstad)

The purpose of this subtask is to examine the effects of reirradiation on HSSI Weld 73W to a higher fluence than previously obtained. The previous data showed relatively low transition temperature shifts compared with the lateral shift methodology in Regulatory Guide 1.162. Moreover, reirradiation results for Weld 73W from the Kurchatov Institute during the JCCCNRS cooperation were substantially different than those obtained by ORNL.

(Milestone 3.3.A) No significant progress during this reporting period.

Subtask 3.4: Evaluation of High Nickel Steels (R. K. Nanstad/M. A. Sokolov)

The purpose of this subtask is to investigate the effects of high nickel content on irradiation embrittlement of RPV steels at relatively high neutron fluences (above $\sim 2 \times 10^{19}$ n/cm^2 (>1 MeV). A large body of data shows a strong nickel effect and indicates a strong synergistic interaction with copper and manganese. This has been observed with both Western type RPV steels and WWER steels. It is also applicable to concerns of "late-blooming phases" (e.g., MnNi) at high fluences, effects on development of copper-rich precipitates, and effects of post-weld heat treatment. These phases are predicted to nucleate at relatively high fluences with the potential to cause an increase in embrittlement after the onset of the so-called "embrittlement saturation" associated with most embrittlement predictive formulas. There are examples in the surveillance database with such behavior but the materials have not been examined. This subtask will be conducted in close collaboration with UCSB, whose program has developed a large amount of information regarding nickel effects.

(Milestone 3.4.A) No significant progress during this reporting period.

Task 4: Validation of Irradiated and Aged Materials (R. K. Nanstad)

The purpose of this task is to validate the assessment of the effects of neutron irradiation on the fracture-toughness properties of typical RPV materials obtained in the previous HSSI (L1098) Program, Tasks 2 and 3 of this program, and retired RPVs. This will be accomplished through the examination of the effects of neutron irradiation on the fracture toughness (ductile and brittle) of the RPV stainless steel cladding 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. Other issues to be addressed include foreign interactions, thermal aging, evaluation of pressure vessel heads, and technical assistance to the NRC.

Subtask 4.1: Fracture Toughness of Irradiated Stainless Steel Cladding (R. K. Nanstad)

The purpose of this subtask is to evaluate the effects of irradiation on fracture toughness of irradiated stainless-steel weld-overlay cladding specimens at 288°C. This will complete the testing of the matrix from the HSSI (L1098) 7th Irradiation Series. The PCVN specimens were irradiated in HSSI Capsule 10.06.

(Milestone 4.1.A) No significant progress during this reporting period.

Subtask 4.2: 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. Collaboration with MPA-Stuttgart in Germany regarding applicability of the master curve to highly embrittled RPV steels.

2. Collaboration with PSI in Switzerland on evaluation of reirradiation effects.

3. Collaboration with AEA-Technology in the United Kingdom regarding fracture toughness testing, temper embrittlement, and work hardening of RPV steels.

4. Participation in three coordinated research programs (CRPs) sponsored by the International Atomic Energy Agency (IAEA), informally designated CRP-5, CRP-6, and CRP-7. These CRPs will investigate: the use of PCVN specimens to determine fracture toughness of RPV steels, effects of nickel on irradiation-induced embrittlement of RPV steels, and the bias effect on T_0 determined with PCVN specimens, respectively.

5. Participation, including membership on the Executive Committee, in the International Group on Radiation Damage Mechanisms (IGRDM).

6. Collaboration with CIEMAT in Spain on dynamic fracture toughness and subsize specimens in support of MC evaluations.

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

8. 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.

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

10. 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.

(Milestone 4.2.A) The 11th meeting of the International Group on Radiation Damage Mechanisms (IGRDM) was held in San Diego on September 10-16, 2003. R. K. Nanstad, as secretary of the IGRDM, has updated the membership list, prepared a revision of the charter, and worked with the local host for the meeting (R.G. Carter of the Electric Power Research Institute) and the IGRDM Chairman (T.J. Williams of Rolls-Royce, U.K.) to organize the meeting. Presentations were given by HSSI Program staff members, including M. K. Miller, R. K. Nanstad, M. A. Sokolov, and R. E. Stoller.

(Milestone 4.2.B) R. K. Nanstad attended the meeting of the IAEA Cooperative Research Program "Mechanisms of Nickel Content on Irradiation Embrittlement of RPV Steels," in Pamporovo, Bulgaria, 2-4 December 2002. He made a presentation entitled "Comparison of Nickel Effects on Embrittlement Mechanisms in Prototypic WWER-1000 and A533B Steels," by Randy K. Nanstad, Mikhail A. Sokolov, Michael K. Miller, and G. Robert Odette. The presentation included a summary of HSSI Program activities in the area of nickel effects, the test results and atom-probe analysis results of the KS-01 weld, preliminary results of testing of the irradiated [to ~1.6 $\times 10^{19}$ n/cm^2 (>1 MeV)] high-nickel submerged-arc weld from the Palisades steam generator, and the Charpy impact test results for the CRP-supplied high-nickel forging and high-nickel weld (VVER-1000) in the unirradiated condition. The VVER-1000 specimens inserted in the IAR facility in April 2001 were removed in January at the behest of the CRP and transported to ORNL for testing as soon as practicable. A trip report, ORNL/FTR-164584, has been submitted.

The irradiated VVER-1000 Charpy impact specimens were tested in the ORNL hot cells in May. Twelve specimens each of a base metal (forging) and a weld were tested at various temperatures, with lateral expansion measurements and photographs of fracture surfaces made subsequent to testing. The forging contains about 1.2 wt% nickel, while the weld metal contains about 1.7 wt% nickel. The results have been analyzed and are in preparation for transmittal to the IAEA CRP committee members for inclusion in the committee database for those two materials. Following submittal of these data, the committee will complete the final analysis of all the data on the two materials and a final report for the CRP will be prepared.

Slices of the VVER-1000 steels were cut in the ORNL hot cells, put in lead pigs, and shipped to to the LAMDA facility in the Metals and Ceramics Division for cutting of atom probe blanks. Cutting of the blanks has been completed and the blanks will be submitted for atom probe needle preparation and atom probe tomography analysis.

R. K. Nanstad attended the meeting of the IAEA CRP "Surveillance Programmes Results Application to Reactor Pressure Vessel (RPV) Integrity Assessment," and an IAEA consultancy meeting on development of a new CRP on "Bias Terms for Master Curve application," in Vienna, Austria, 24-28 February 2003. R. K Nanstad is an author of a chapter on "Fluence Projection and Attenuation" for the IAEA guidelines document on application of the fracture toughness master curve, now in preparation. A trip report, ORNL/FTR-167446, has been prepared and submitted.

R. K. Nanstad attended a consultancy meeting at the IAEA in Vienna, Austria from July 31 through August 4. The meeting was held to edit and complete the IAEA Technical Report Series (TRS), "Neutron Irradiation Embrittlement of RPV Steels." The book has languished with the death of the previous chief editor (Myrddin Davies) earlier in the year. Also, the former IAEA Technical Secretary responsible for the book, V. Lyssakov, completed his term in April and was replaced as Technical Secretary by Dr. Ki-Sig Kang. Dr. Kang set-up and coordinated the consultancy meeting in Vienna. R. K. Nanstad is the author of Chapter 3, "Irradiation Effects on Mechanical Properties," of the TRS and is also one of the three editors, including Mr. William Server of ATI Consulting in the United States and Dr. Milan Brumovsky of the Nuclear Research Institute in Rez, Czech Republic. All the chapters have now been written and edited with the exception of Chapter 4, "Radiation Damage Mechanisms," primarily authored by Dr. Jean-Claude Van Duysen of EDF in France. Dr. Van Duysen has committed to submit his chapter in mid-October. The meeting in Vienna was very productive in that significant progress was made towards publication of the TRS. Such progress would not have happened without such a meeting.

Additionally, as a result of discussions during the consultancy meeting, the IAEA representative subsequently asked R. K. Nanstad to assume the duties as chairman of the CRP on Nickel Effects discussed earlier. A meeting of selected members of the CRP will be asked to attend a meeting at the IAEA in March, 2004 to prepare the TECDOC report for the CRP.

On November 25-28, R. K. Nanstad attended an IAEA consultancy meeting in Vienna, Austria. The meeting was entitled "Joint Consultant Meeting to Develop the Strategic Plan on Nuclear Power Plant Life Management with European Commission/Institute of Energy." He also met with Dr. Ki-Sig Kang, the IAEA representative, to discuss detailed planning for finalizing the IAEA CRP on Nickel Effects. It was decided to schedule a meeting of selected members of the CRP in Vienna during the week of 15 March 2004, with the goal to finalize the TECDOC (the IAEA report that presents the results of the CRP). Contact was made with the three members, all of whom indicated their willingness to serve and their availability during that week. A foreign trip report, ORNL/FTR-205181, was prepared and distributed on 30 December.

Subtask 4.3: Technical Assistance (R. K. Nanstad and M. A. Sokolov)

The purpose of this subtask is to provide special analytical, experimental, and administrative support to the NRC in resolving various regulatory issues related to irradiation effects. Specific activities will be identified on an as needed basis by the NRC Project Manager. Examples of such activities include: 1) providing support for the NRC on issues related to irradiation effects, 2) evaluation of the effects of post-weld heat treatment (PWHT) on the copper solubility and fracture toughness of unirradiated RPV steels; 3) machining of material removed from retired irradiated RPVs for evaluation of through-thickness attenuation of irradiation embrittlement; 4) reporting on the results of testing crack-arrest toughness specimens; and 5) evaluating embrittlement and 6) identify issues associated with material variability and establish associated uncertainties for use in statistics based fracture toughness assessments.

(Milestone 4.3.A) For the weld previously given a series of postweld heat treatments and irradiated in the University of Michigan Ford Reactor, testing of the irradiated subsize Charpy specimens in the ORNL hot cells has been completed. A letter report will be prepared following completion of all analyses. Additionally, M.A. Sokolov presented a preliminary summary of the results at the IGRDM-11 meeting in San Diego in September. The presentation was authored by M. A. Sokolov, R. K. Nanstad, and M. K. Miller, and was entitled "Effect of Radiation on Embrittlement and Matrix Cu Content of an RPV Weld with Different PWHT Conditions." A paper, for which M. K. Miller was the lead author, including the unirradiated Charpy results and the atom probe tomography results, was presented at the Tenth International Conference on Environmental Degradation of Materials in Nuclear Power Systems - Water Reactors, August 5-9, 2001, in Lake Tahoe, Nevada. R. K. Nanstad attended the meeting and presented the paper. A paper by M. K. Miller, S. S. Babu, M. A. Sokolov, R. K. Nanstad, and S. K. Iskander, "Effect of Stress Relief Temperature and Cooling Rate on Pressure Vessel Steel Welds," *Mater. Sci. Eng. A 327*, 76-79 (2002) was also published. A letter report is in preparation.

(Milestone 4.3.B) The NUREG report, *Detailed Results of Testing Unirradiated and Irradiated Crack-Arrest Toughness Specimens from the Low Upper-Shelf Energy, High Copper Weld, WF-70,* by S. K. Iskander, C. A. Baldwin, D. W. Heatherly, D. E. McCabe, I. Remec, and R. L. Swain, NUREG/CR-6621 (ORNL/TM-13764), was submitted to the NRC Program Monitor for review. It is anticipated that it will be submitted for publication during the next reporting period.

(Milestone 4.3.C) Irradiated, annealed, and reirradiated specimens of HSSI Weld 73W were reinserted into the IAR facility at the FNR to accumulate additional fluence. The results obtained from tests of some of the reirradiated specimens showed a much lower transition temperature shift than expected. The target total fluence for the final group of specimens which was about 4×10^{19} n/cm^2 was obtained. Dosimeters associated with the experiment are waiting to be counted and analyzed (see Task 2.5). The specimens will be scheduled for testing at the ORNL hot cells during the second quarter of 2004.

(Milestone 4.3.E.1) The NUREG report (ORNL/TM-2000/343), *Attenuation of Charpy Impact Toughness Through the Thickness of a JPDR Pressure Vessel Weldment*, by S. K. Iskander, J. T. Hutton, L. E. Creech, M. Suzuki, K. Onizawa, E. T. Manneschmidt, R. K. Nanstad, T. M.

Rosseel, and P. S. Bishop, was submitted to the NRC in January 2001 as part of an Office of Research Operational Milestone.

(Milestone 4.3.E.2) The NUREG report entitled *Evaluation of Neutron Energy Spectrum Effects Based on Primary Damage Simulations in Iron,* NUREG/CR-6643, (ORNL/TM-1999/334) was submitted to the NRC in July 2000.

Subtask 4.4: Review of thermal aging effects in RPVs (R. K. Nanstad and R. E. Stoller)

The purpose of this subtask is to evaluate the role of thermal aging in the potential embrittlement of RPV steels. Although there are data at relatively high aging times in an actual RPV that indicate minimal effects to about 140,000 h, there are other data that do indicate embrittlement due to thermal aging under typical RPV operating conditions. Thus, the existing data provide conflicting results. For life extension of RPVs, the total operating time will exceed 400,000 h. This issue is closely linked to neutron flux and will be performed in collaboration with UCSB.

(Milestone 4.4.A) The report, *The Effect of Aging at 343°C on the Microstructure and Mechanical Properties of Type 308 Stainless Steel Weldments*, by D.□L.□Alexander, K. B. Alexander, M. K. Miller, and R. K. Nanstad, NUREG/CR-6628 (ORNL/TM-13767), was published in November 2000.

Task 5: Modeling & Microstructural Analysis and Embrittlement Data Base (T. M. Rosseel)

This task shall determine the microstructural basis for radiation-induced property changes in RPV materials to aid in understanding and applying the experimental results obtained in Tasks 2 through 4. The two proposed subtasks will comprise: (1) experimental investigations of the microstructure and, (2) maintaining and updating the Embrittlement Data Base (EDB). The experimental component will focus on detailed microstructural characterization of RPV materials in relevant conditions, including long-term, thermally-aged and high-fluence irradiated materials. The information obtained from the experiments and microstructural characterization will be used to support validation of the theoretical models. Further model verification will be carried out through use of the mechanical property data contained in the EDB, and data generated in other experiments coordinated by this task. Updated versions of the EDB will be issued as appropriate.

The modeling and experimental research will be coordinated with complementary activities carried out by other NRC contractors and the international community. Work and milestone schedules will be contingent on available funding.

Subtask 5.1: Microstructural Characterization (M. K. Miller)

APFIM characterization will be used to determine whether additional radiation-induced phases are forming especially at longer times and higher fluence. In addition, the methods of APFIM, SANS, and field-emission scanning transmission electron microscopy (FEGSTEM) have been

used to determine the matrix copper content and the chemical composition of radiation-induced precipitates in RPV materials. Although there is qualitative agreement between the three methods, some significant inconsistencies exist. Comparisons among the techniques will be performed so as to resolve the apparent inconsistencies.

(1) Atom probe tomography (APT) will be used to characterize the thermal surveillance capsule from the EBR-II, if material can be obtained. Attempts were made previously to perform characterization of a sample of the thermal surveillance capsule that was aged at 371°C was for ~18 years. Unfortunately, little data was obtained due to low quality of the specimens that could be prepared from the extremely small size of the sample supplied and the presence of carbides in the A533B material.

(2) APT will be used to study of Mn and high Ni in the so-called late blooming phases. Characterization of model alloys using APT will be compared with the results obtained by University of California-Santa Barbara (UCSB) to determine the influence of manganese on the thermal stability of supersaturated iron-copper alloys.

(3) In collaboration with UCSB, the microstructure of a series of neutron irradiated model (Fe-0.05% Cu-1.6% Mn-1.6% Ni [OV5] and Fe-0.10% Cu-1.6% Mn-1.6% Ni [OV7]) pressure vessel steels will also be characterized by APT to investigate the presence of fine scale phase decomposition.

(4) Palisades high-nickel steel that has been irradiated to fluences of 1.6 and ~4 x 10^{19} n cm^{-2} (E > 1 MeV) will be characterized using APT (see also Task 3.4). Since Ni-rich phases in low Cu steels may contribute to hardening and embrittlement at high fluences, this evaluation is critical to developing an understanding of the so-called late blooming phases that may appear at long irradiation times. When available in FY2003, low fluence broken Charpy specimens will be sliced in the hot cell, prepared for the APT, and examined.

(5) High fluence, broken Charpy specimens will be sliced in the hot cell, prepared for the APT and examined. In addition, the APT will be used to characterize the high fluence ~4 x 10^{19} Midland weld and JRQ specimens in the I, IA, IAR, IARA and possibly IARAR conditions will be initiated. This series of materials is designed to look at extending lifetime issues out to a projected 40-year license time frame.

(Milestone 5.1.C1) Preparation of irradiated, high-nickel Palisades specimens (See Task 2.2) and specimens from the PSI collaboration on the JRQ re-irradiation experiments (See Task 3.2) for APT evaluation in a C-Zone lab has been delayed until the first half of January to due holiday vacation and resource issues. It is anticipated that the APT data will be collected in late January or early February.

<u>Subtask 5.2: Embrittlement Data Base</u> (J.-A. Wang)

Nuclear radiation embrittlement information from radiation embrittlement research on nuclear RPV steels and from power-reactor surveillance reports will be maintained in a database to be published on a periodic basis. The information will assist the Office of Nuclear Reactor

Regulation and the Office of Nuclear Regulatory Research to effectively monitor current procedures and databases used by vendors, utilities, and service laboratories in the pressure vessel irradiation surveillance program.

5.2.A Maintain and update the EDB: This subtask was, until March 1, 1999, part of the Embrittlement Data Base (EDB) and Dosimetry Evaluation Program, JCN: 6164. The objectives of the subtask have been reduced but the focus remains the same. Nuclear radiation embrittlement information from radiation embrittlement research on nuclear RPV steels and from power-reactor surveillance reports will be maintained in a database to be published on a periodic basis. The information will assist the Office of Nuclear Reactor Regulation and the Office of Nuclear Regulatory Research to effectively monitor current procedures and databases used by vendors, utilities, and service laboratories in the pressure vessel irradiation surveillance program. Specifically, this activity will maintain and update the EDB by evaluating surveillance reports, entering the data into the EDB, and providing an update to the NRC by the end of the fiscal year if more than four reports have been received. If there are fewer than four reports, an update will be delayed for another six months.

(Milestone 5.2.B) The comparison of the new (June 2003) EPRI data with that of May 2000 calibration set and PR-EDB Update_12 has been made. In collaboration with Eason, a quality assurance (QA) comparison of the EPRI data presented at the June ASTM meeting to the PR-EDB May 2000 calibration has been completed. This effort included (1) verification of the needed surveillance reports for new EPRI data, (2) identification of the needed references for surveillance data found in the May 2000 calibration data set, which are not currently registered in PR-EDB, (3) validation of the HEAT_ID codes used for the EPRI new data, based on the heat codes developed for PR EDB, (4) verification of the chemistry data consistency for the individual heats, and (5) additional verification for data on "Type of Weld Flux."

5.2.C Move PR-EDB from DOS to Windows: The purpose of this activity is to integrate and transform DOS-base EDB Utility into a WINDOWS operating platform. All fields shall be reconfigured in a user-friendly Windows environment.

The current version of the software package EDB-Utilities has been written in the Clipper language, which allows compilation of dBASE procedures and has facilities for menu and help screens. The dBASE and related software, such as Clipper, lack the ability for extensive mathematics/statistics calculations and scientific graphs. Instead, plotting and Charpy fitting programs are written in FORTRAN using the IMSL and GRAFMATIC libraries and require ASCII files as input. To convert the current EDB utilities from DOS base to WINDOWS base program, three major tasks are needed, (1) converting file manipulation procedures utilizing Visual FoxPro or MS ACCESS program; (2) converting the plotting procedures utilizing WINDOWS compatible plotting package; and (3) converting the Charpy fitting procedures utilizing Visual FORTRAN program. The deliverable products of the proposed EDB-Utilities upgrade will cover the features described below.

1. Converting all the present information into a "windows" type format;
2. Maintaining all search and analysis capabilities;
3. Adding "help" features;

4. Demonstrating a "beta" version;
5. Compiling a final version instruction and demonstration;
6. Developing an installation procedure for PCs;
7. Providing some maintenance and trouble-shooting support; and
8. Preparing a detailed, indexed electronic manual.

The upgrade EDB (Windows version) will pave the way for the future development of the Analytical Program Library for the NRC. The EDB upgrade is an important step in a broader goal to develop an integrated EDB program, which would include "Generate Common Databases and Application Programs," "Build Networks, Intellectual Interfaces, to carry out Data Sharing and Data Exchange," and "Develop Long Term Archive Methodology." Therefore, the continuation of improving EDB methodology on structuring, grouping, linking, and processing data are critical to successfully develop an integrated EDB program.

(Milestone 5.2.C) There was no significant progress during this reporting period, however, it is anticipated that work will begin during the next reporting period.

5.3.D Transfer Surveillance Reports to Electronic Storage: The purpose of the activity is to copy all paper surveillance reports to CDs by October 2004.

(Milestone 5.2.D) There was no significant progress during this reporting period.

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

This task provides the support required to supply and coordinate irradiation services needed by NRC contractors, such as the UCSB and the ORNL HSSI programs at the University of Michigan FNR until it shuts down. 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. For the HSSI irradiation experiment it includes determining the fluence received during a given campaign. This task also provides the support required to coordinate the shut down of irradiation facilities at the FNR following the end of reactor operations on July 3, 2003. All salvageable equipment shall be transported to ORNL. All irradiated and hazardous materials/equipment/supplies shall be disposed of in accordance with Federal, State, and Local laws and regulations.

Subtask 6.1: Investigate Alternative Test Irradiation Facilities (K. R. Thoms. T. M. Rosseel, and D. W. Heatherly)

During fiscal year 2003 and 2004, it is proposed that staff investigate alternative test irradiation facilities including, as necessary and with NRC approval, site visits. The results of these evaluations will be reported to the US NRC.

(Milestone 6.1.A) A proposed site evaluation of the Massachusetts Institute of Technology (MIT) 4.9 MW MITR II tank-type reactor as a location for future irradiation experiments on

December 11, 2003, has been delayed at the request of Dr. Ron Ballard is the MIT contact. It is expected that a site will be rescheduled for late January. A site visit to the University of Missouri, reactor may also be scheduled for late January or early February.

Planning for a March site visit and evaluation of the LV-15 reactor at the Nuclear Research Institute (NRI), Rez, Czech Republic is on hold pending a decision on the number of slots available for foreign travel.

Discussions with staff from Sweden's Studsvik facility concerning the possible use of the R-2 reactor for future irradiation experiments also continued. Based on these discussions, Studsvik has requested that the HSSI Program plan a site visit and evaluation.

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

This subtask provides the necessary monitoring, control, supervision, and maintenance of the HSSI reusable irradiation capsules in the dual-capsule irradiation facilities at the University of Michigan FNR until it shuts down.

(Milestone 6.2.A) As reported previously, all of the irradiated specimens in the IAR-1 and IAR-2 facilities were removed and placed in dry storage in the FNR hot cell. The facilities were shut down and the instrumentation controlling them was shut off. The facilities are currently suspended at the side of the FNR pool. All operating records, specimen-transfer records, and videotapes of specimen transfers have been forwarded to ORNL.

The HSSI instrumentation staff will travel to the University of Michigan in the second quarter so as to prepare the fragile IAR control cabinets and instrumentation for return shipment and storage at ORNL. The instrumentation will be delivered to ORNL for slight modification for use at another reactor site as soon as a suitable site for materials irradiation experiments has been identified. A date for this activity has not been set.

The FNR staff is continuing to monitor the activity of the irradiated specimens to determine the decay rate and schedule a suitable time for shipping the specimens to ORNL. Concurrently, the HSSI staff will be making arrangements to send an empty shielded shipping cask to FNR to retrieve the first of the remaining two groups of irradiated specimens from the FNR hot cells.

(Milestone 6.2.B) The NUREG report, D. W. Heatherly, K. R. Thoms, M. T. Hurst and G. E. Giles, UT-Battelle, LLC, Oak Ridge, Tenn., *Heavy-Section Steel Irradiation Program's Reusable Irradiation Facility,* USNRC NUREG/CR-6779, (ORNL/TM-2002/77) was submitted to the NRC in March 2002.

Subtask 6.3: Operate the HSSI-UCSB Irradiation Facility (K. R. Thoms and D. W. Heatherly)

This subtask includes supervision of the overall operation and provides assistance to the reactor personnel in the routine operation and maintenance of the HSSI-UCSB irradiation facilities at the University of Michigan FNR until it shuts down.

(Milestone 6.3.A) As reported previously, all of the irradiated specimens in the HSSI-UCSB facility were removed and placed in dry storage in the FNR hot cell. The facility was shut down and the instrumentation controlling it was shut off. The facility is currently suspended at the side of the FNR pool. All operating records, specimen-transfer records, and videotapes of specimen transfers have been forwarded to ORNL.

The HSSI instrumentation staff will travel to the University of Michigan in the second quarter of the fiscal year so as to prepare the fragile control cabinets and instrumentation for return shipment and storage at ORNL. The instrumentation will be delivered to ORNL for slight modification for use at another reactor site as soon as a suitable site for materials irradiation experiments has been identified. A date for this activity has not been set.

The activity of the specimens stored in the FNR hot cell is being allowed to decay for a period of time. FNR staff is monitoring the activity of the irradiated specimens to determine the decay rate and schedule a suitable time for shipping the specimens. The staff at UCSB are working with the staff at FNR to ensure that all irradiated specimens are eventually shipped to the experimenters at UCSB.

Subtask 6.4 Shutdown irradiation facilities and dispose of irradiated material from the IAR and IVAR facilities (D. W. Heatherly)

The purpose of this subtask is to coordinate the orderly shutdown of irradiation facilities at the FNR, return the monitoring and control instrumentation to ORNL, and dispose of the irradiated materials generated during the operation of HSSI experiments at the FNR.

(Milestone 6.4.A) The FNR staff in cooperation with the HSSI staff is continuing to develop a plan for the disposal of all the irradiation facilities and irradiation capsules.

3. MEETINGS AND TRIPS:

On November 23-30, R. K. Nanstad traveled to Vienna, Austria, to serve as an invited consultant to the International Atomic Energy Agency (IAEA) on "Joint Consultant Meeting to Develop the Strategic Plan on Nuclear Power Plant Life Management with European Commission/Institute of Energy." He also met with the IAEA representative, Dr. Ki-Sig Kang, to discuss detailed planning for finalizing the IAEA Cooperative Research Project (CRP) on Nickel Effects. Additionally, the IAEA has asked Nanstad to assume the chairmanship of the nearly completed CRP for the purpose of preparing the final TECDOC report.

R. K. Nanstad attend meetings of the ASME Boiler and Pressure Vessel Code in Orlando, Florida, on 9 December, 2003.

4. PRESENTATIONS, REPORTS, PAPERS, AND PUBLICATIONS:

M. A. Sokolov, R. K. Nanstad, I. Remec, C. A. Baldwin, and R. L. Swain, “Fracture Toughness of an Irradiated, Highly Embrittled Reactor Pressure Vessel Weld,” NUREG/CR- (ORNL/TM-2002/293) was submitted to the US NRC.

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.

As reported in the September MLSR, the following items were purchased:

Item	**Cost ($)**
(2) Computers to replace outdated Charpy Machine computers	
Dell Optiplex GX270 (S/N 85C6J31 and 55C6J31)	$ 1,470 ea.
Received 9/24/03	
Fracture machine control and data collection software	
LabView 776670-03 (S/N M61X020243)	
Vision Development Module	$ 1,995
IMAQ Vision Library	$ 2,595
Frame Grabber PXI-1407	$ 895
Received 9/30/03	
Camera system for monitoring remote machining and testing operations:	
(2) MSI Cameras (ME421R/186895 & 180930)	$1,180 ea
35W Halogen remotely controlled light	$ 550
Received 9/25/03	

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 Reporting Period: 11/24/03-12/28/03
for W6953

		Current Month	Fiscal Year to Date	Cumulative Project to date
I.	Direct Staff Effort	3 MM	1.0 MY	43.6 MY
II.	A. Direct Lab Staff Effort ($)			
	Direct Salaries	33,602	190,905	6,065,990
	Materials and Services	730	-602	556,854
	ADP Support	31	93	3,145
	Subcontracts	5,060	13,049	1,148,566
	Travel	1,394	5,871	224,140
	Other: NRC-PO Tax	5,144	9,001	350,047
	General and Administrative	19,292	96,024	2,919,800
	Total UT-Battelle Costs	65,253	314,341	11,268,542
	B. DOE Federal Admin. Costs	1,958	9,430	176,350
	TOTAL PROJECT COSTS	67,211	323,771	11,444,892

Percentage of available cumulative funds costed	94
Percentage of available current FY funds costed	33
Funds Remaining	690,608
Commitments:	23,492
BA Remaining	667,116
BA Remaining Less Projected FAC	647,001

III. Funding Status

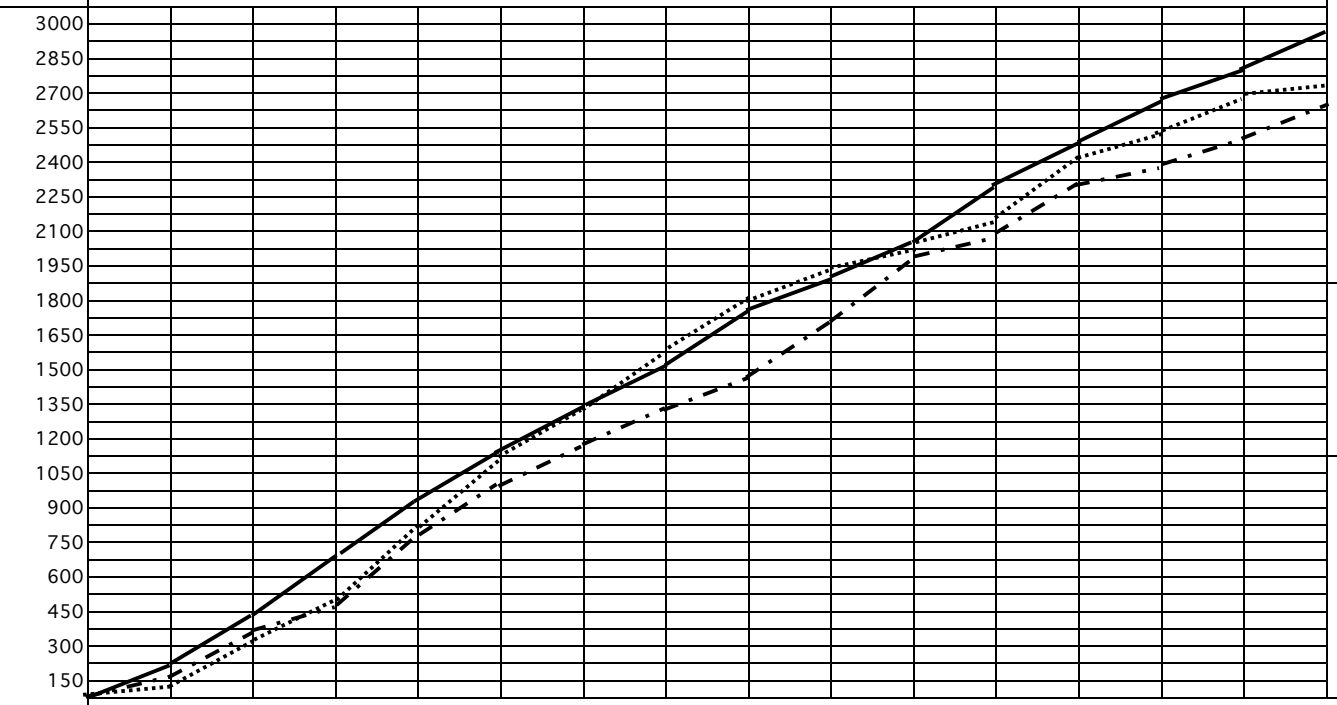
Prior FY Carryover	FY 04 Projected Funding Level	FY 04 Funds Received to Date	FY 04 Funding Balance Needed	Cumulative Amt. Obligated	Cumulative Amt. Costed
693,569	2,430,000	300,000	2,130,000	12,135,500	11,444,892

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

1. CONTRACT REPORTING ELEMENT HSSI - Heavy-Section Steel Irradiation Program	2. REPORTING PERIOD 11/24/2003 - 12/28/2003	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 2003 - 2006	6. ACTIVITY NUMBER W41 W5 85 3W 1
	7. NRC B&R NO. 860 15 21 20 05	8. DOE B&R NO. 40 10 01 06

9. MONTHS

10. COST STATUS ($K)



COST PLAN DATES
07/20/03

PLANNED COSTS FOR ELEMENT ($K)
2965

ELEMENT COSTS FOR PRIOR FYS ($K)
1189

ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	195	247	242	233	218	184	200	168	188	208	194	193	154	165	176
ACTUAL	145	172	198	312	241	248	254	179	132	170	110	261	110	139	65
EARNED	160	169	179	244	179	183	202	176	191	236	158	188	115	124	102
CUM. PLANNED	195	442	684	917	1135	1319	1519	1687	1875	2083	2277	2470	2624	2789	2965
CUM. ACTUAL	145	317	515	827	1068	1316	1570	1749	1881	2051	2161	2422	2532	2671	2736
CUM. EARNED	160	329	508	752	931	1114	1316	1492	1683	1919	2077	2265	2380	2504	2606

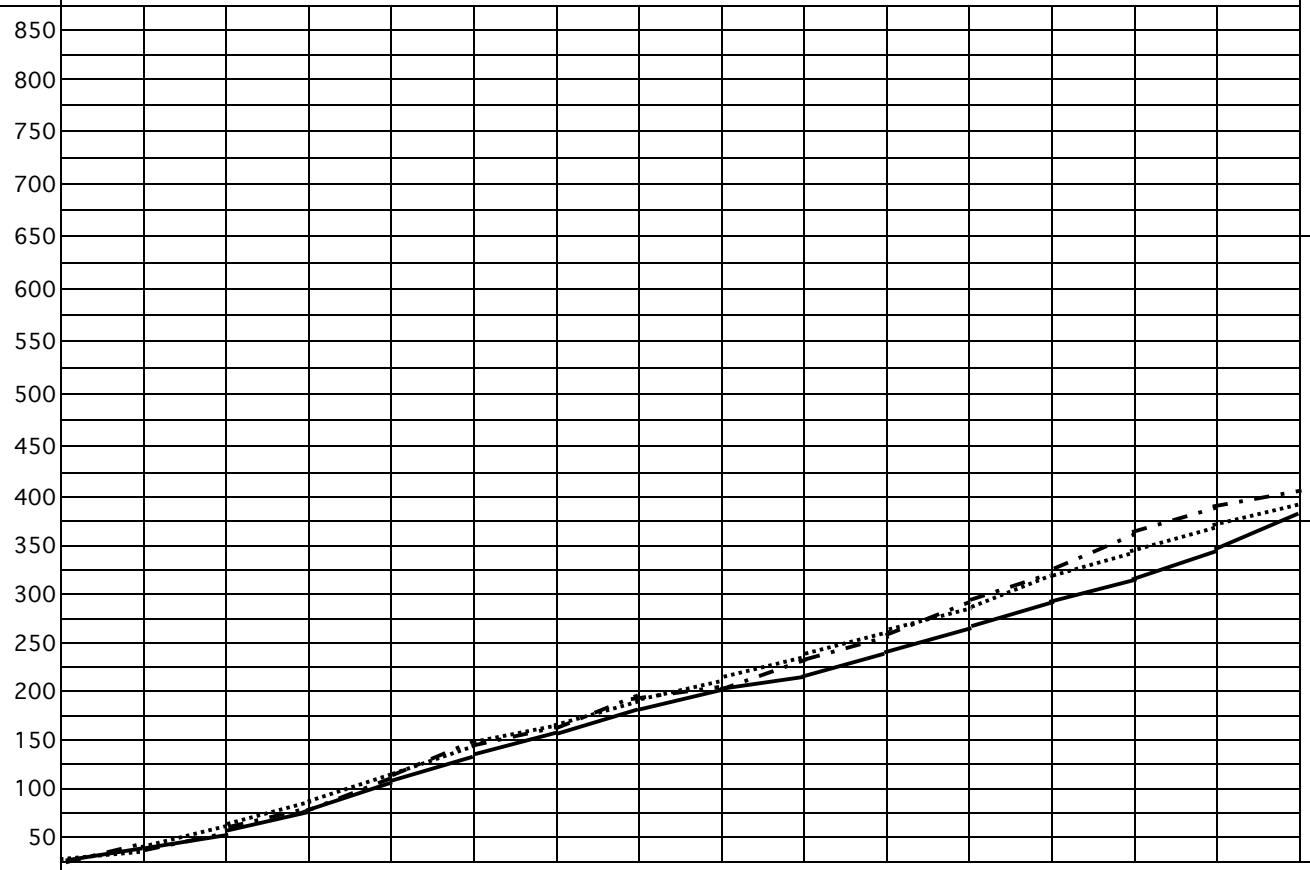
11. REMARKS

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

1. CONTRACT REPORTING ELEMENT HSSI - 1. Program Management	2. REPORTING PERIOD 11/24/2003 - 12/28/2003	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 2003 - 2006	6. ACTIVITY NUMBER W41 W5 85 3W 1
	7. NRC B&R NO. 860 15 21 20 05	8. DOE B&R NO. 40 10 01 06

9. MONTHS

10. COST STATUS ($K)



COST PLAN DATES

07/20/03

PLANNED COSTS FOR ELEMENT ($K)

380

ELEMENT COSTS FOR PRIOR FYS ($K)

124

ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	24	28	23	26	30	25	22	22	18	24	25	27	27	27	32
ACTUAL	30	32	24	24	25	25	28	22	20	32	17	43	22	27	15
EARNED	29	22	16	26	25	29	26	25	40	44	29	26	21	25	24
CUM. PLANNED	24	52	75	101	131	156	178	200	218	242	267	294	321	348	380
CUM. ACTUAL	30	62	86	110	135	160	188	210	230	262	279	322	344	371	386
CUM. EARNED	29	51	67	93	118	147	173	198	238	282	311	337	358	383	407

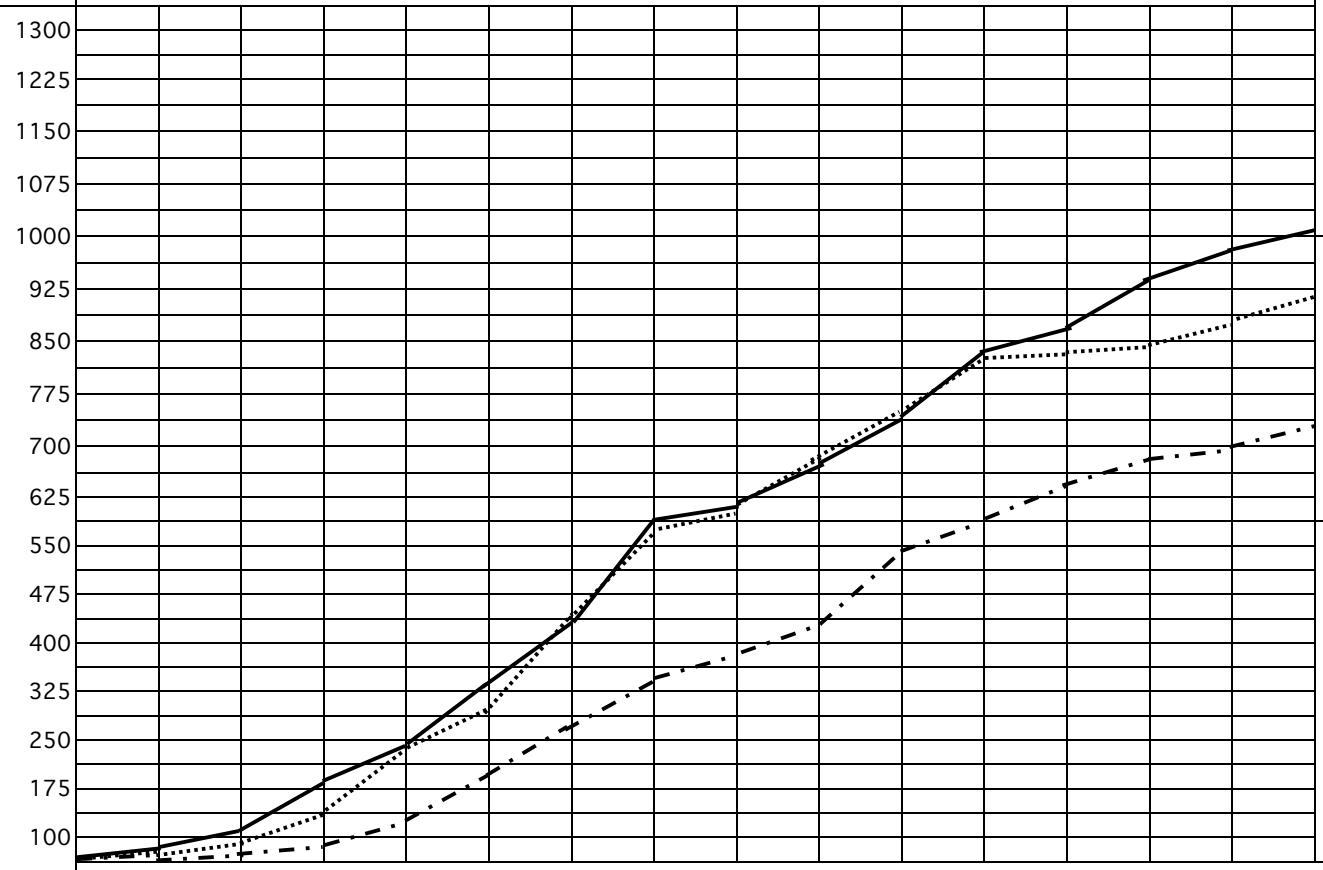
11. REMARKS

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

1. CONTRACT REPORTING ELEMENT HSSI - 2. Fracture Toughness Transition and MC Methodology	2. REPORTING PERIOD 11/24/2003 - 12/28/2003	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 2003 - 2006	6. ACTIVITY NUMBER W41 W5 85 3W 1
	7. NRC B&R NO. 860 15 21 20 05	8. DOE B&R NO. 40 10 01 06

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

10. COST STATUS ($K)



COST PLAN DATES

07/20/03

PLANNED COSTS FOR ELEMENT ($K)

1024

ELEMENT COSTS FOR PRIOR FYS ($K)

402

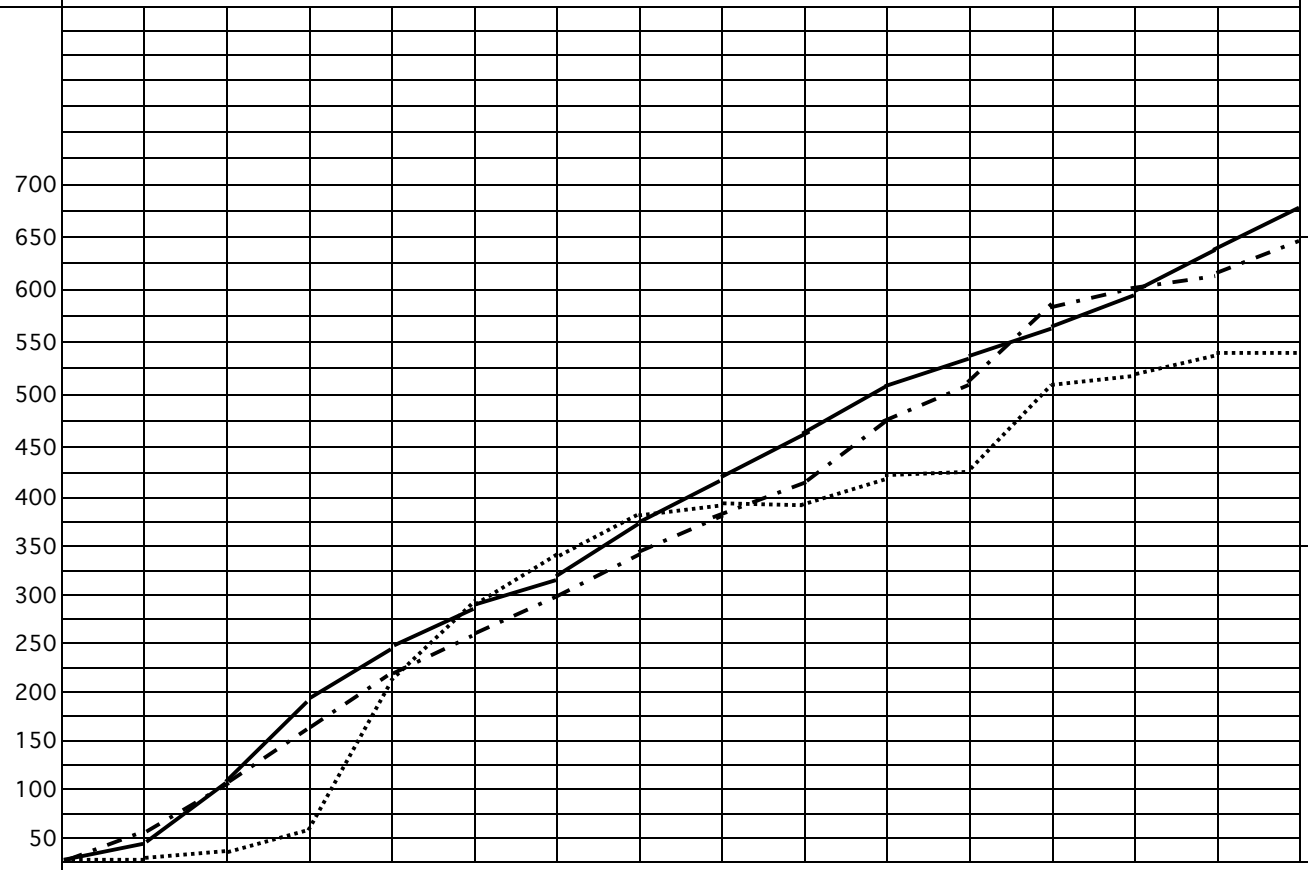
ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	54	62	61	64	89	86	85	70	84	87	67	77	51	42	45
ACTUAL	39	51	52	65	77	142	131	41	72	85	29	31	31	26	31
EARNED	19	16	46	67	59	54	89	36	62	93	51	39	31	28	35
CUM. PLANNED	54	116	177	241	330	416	501	571	655	742	809	886	937	979	1024
CUM. ACTUAL	39	90	142	207	284	426	557	598	670	755	784	815	846	872	903
CUM. EARNED	19	35	81	148	207	261	350	386	448	541	592	631	662	690	725

11. REMARKS

1. CONTRACT REPORTING ELEMENT HSSI - 3. Irradiation Embrittlement of RPV Steel	2. REPORTING PERIOD 11/24/2003 - 12/28/2003	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 2003 - 2006	6. ACTIVITY NUMBER W41 W5 85 3W 1
	7. NRC B&R NO. 860 15 21 20 05	8. DOE B&R NO. 40 10 01 06

9. MONTHS

10. COST STATUS ($K)



COST PLAN DATES

7/20/03

PLANNED COSTS FOR ELEMENT ($K)

676

ELEMENT COSTS FOR PRIOR FYS ($K)

383

ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	39	65	88	57	34	30	60	45	45	40	30	40	23	40	40
ACTUAL	1	15	40	157	77	51	40	8	-7	9	12	108	10	16	-6
EARNED	51	53	55	61	35	44	40	37	44	55	33	78	14	21	24
CUM. PLANNED	39	104	192	249	283	313	373	418	463	503	533	573	596	636	676
CUM. ACTUAL	1	16	56	213	290	341	381	389	382	391	403	511	521	537	531
CUM. EARNED	51	104	159	220	255	299	339	376	420	475	508	586	600	616	640

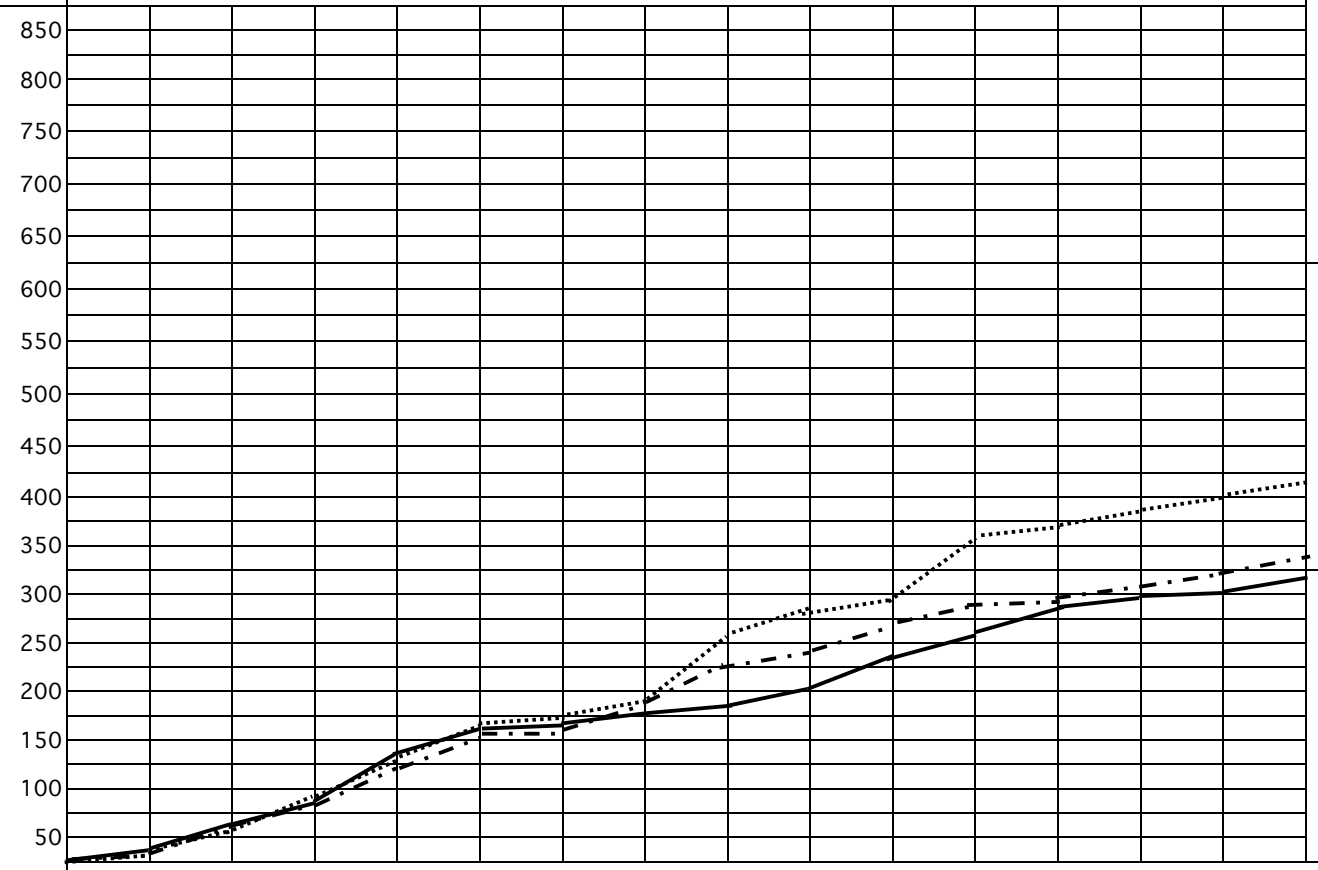
11. REMARKS

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

1. CONTRACT REPORTING ELEMENT HSSI - 4. Validation of Irradiated and Aged Materials	2. REPORTING PERIOD 11/24/2003 - 12/28/2003	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 2003 - 2006	6. ACTIVITY NUMBER W41 W5 85 3W 1
	7. NRC B&R NO. 860 15 21 20 05	8. DOE B&R NO. 40 10 01 06

9. MONTHS

10. COST STATUS ($K)



COST PLAN DATES

07/20/03

PLANNED COSTS FOR ELEMENT ($K)

320

ELEMENT COSTS FOR PRIOR FYS ($K)

152

ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	28	37	21	44	27	11	7	7	20	28	28	28	7	7	20
ACTUAL	27	27	38	36	33	8	24	61	23	22	30	40	15	13	20
EARNED	21	39	17	39	34	12	18	45	18	21	19	10	16	15	18
CUM. PLANNED	28	65	86	130	157	168	175	182	202	230	258	286	293	300	320
CUM. ACTUAL	27	54	92	128	161	169	193	254	277	299	329	369	384	397	417
CUM. EARNED	21	60	77	116	150	162	180	225	243	264	283	293	309	324	342

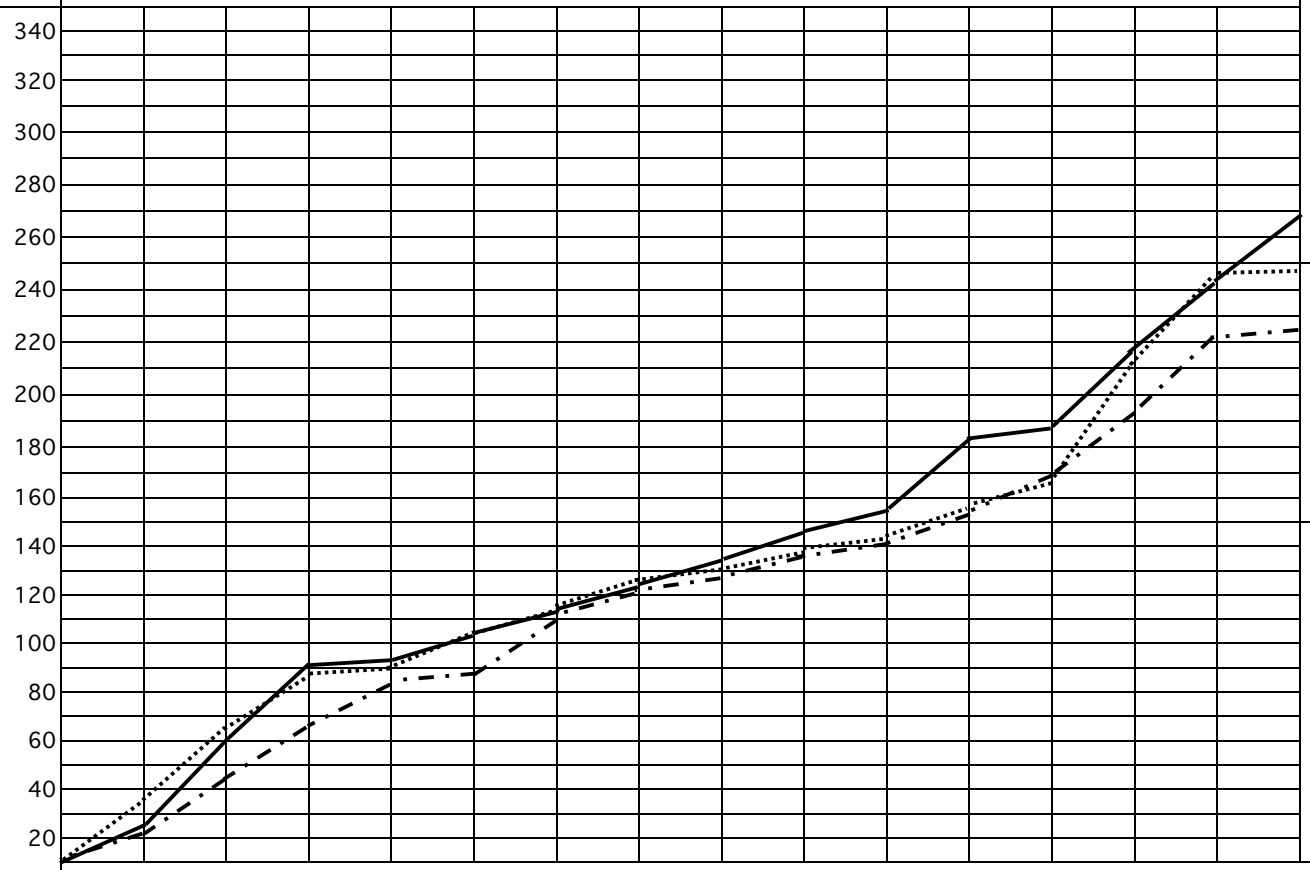
11. REMARKS

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

1. CONTRACT REPORTING ELEMENT HSSI - 5. Modeling and Microstuctural Analysis	2. REPORTING PERIOD 11/24/2003 - 12/28/2003	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 2003 - 2006	6. ACTIVITY NUMBER W41 W5 85 3W 1
	7. NRC B&R NO. 860 15 21 20 05	8. DOE B&R NO. 40 10 01 06

9. MONTHS

10. COST STATUS ($K)



COST PLAN DATES

07/20/03

PLANNED COSTS FOR ELEMENT ($K)

267

ELEMENT COSTS FOR PRIOR FYS ($K)

75

ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	25	35	30	2	10	10	10	10	5	15	30	5	30	25	25
ACTUAL	35	31	22	2	12	10	12	6	7	4	13	31	27	32	2
EARNED	23	20	21	19	4	23	10	7	8	5	13	17	23	28	3
CUM. PLANNED	25	60	90	92	102	112	122	132	137	152	182	187	217	242	267
CUM. ACTUAL	35	66	88	90	102	112	124	130	137	141	154	185	212	244	246
CUM. EARNED	23	43	64	83	87	110	120	127	135	140	153	170	193	221	224

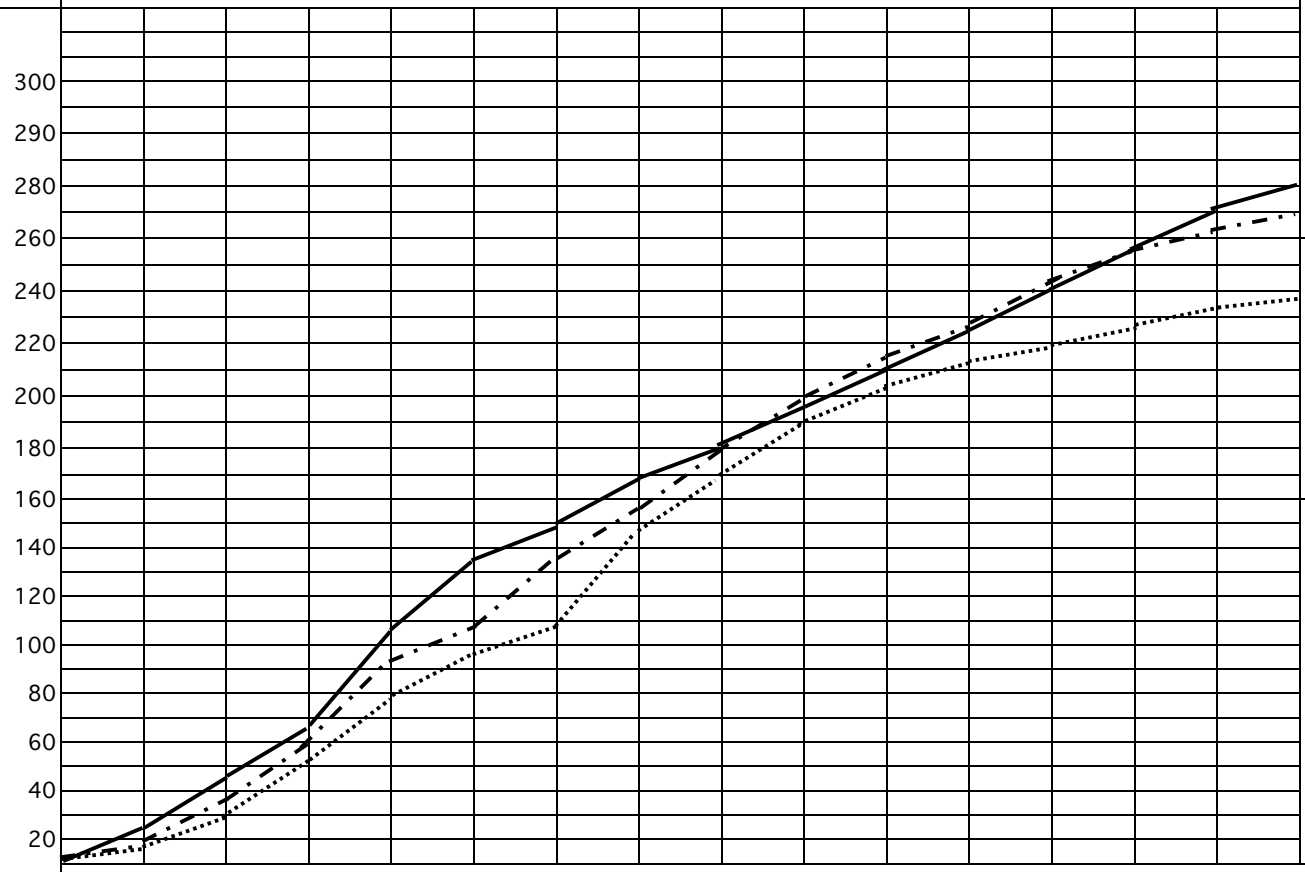
11. REMARKS

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

1. CONTRACT REPORTING ELEMENT HSSI - 6. Irradiation Coordination	2. REPORTING PERIOD 11/24/2003 - 12/28/2003	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 2003 - 2006	6. ACTIVITY NUMBER W41 W5 85 3W 1
	7. NRC B&R NO. 860 15 21 20 05	8. DOE B&R NO. 40 10 01 06

9. MONTHS

10. COST STATUS ($K)



COST PLAN DATES

07/20/03

PLANNED COSTS FOR ELEMENT ($K)

284

ELEMENT COSTS FOR PRIOR FYS ($K)

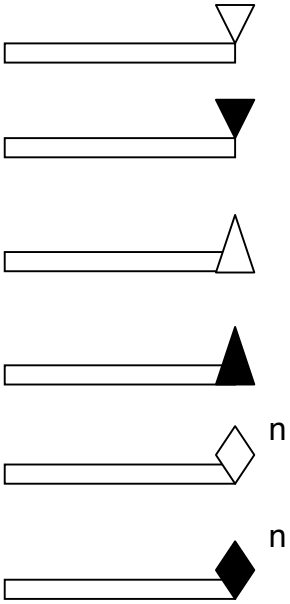
53

ACCRUED COSTS ($K)	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	25	20	19	42	28	16	16	14	16	14	14	16	16	14	14
ACTUAL	13	16	22	28	17	13	19	40	16	18	9	8	6	7	3
EARNED	17	19	24	32	22	21	19	26	19	16	13	18	10	7	6
CUM. PLANNED	25	45	64	106	134	150	166	180	196	210	224	240	256	270	284
CUM. ACTUAL	13	29	51	79	96	109	128	168	184	202	211	219	225	232	235
CUM. EARNED	17	36	60	92	114	135	154	180	199	215	228	246	256	263	269

11. REMARKS

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

Milestone Symbology



Intermediate milestone planned

Intermediate milestone completed

Major milestone planned

Major milestone completed

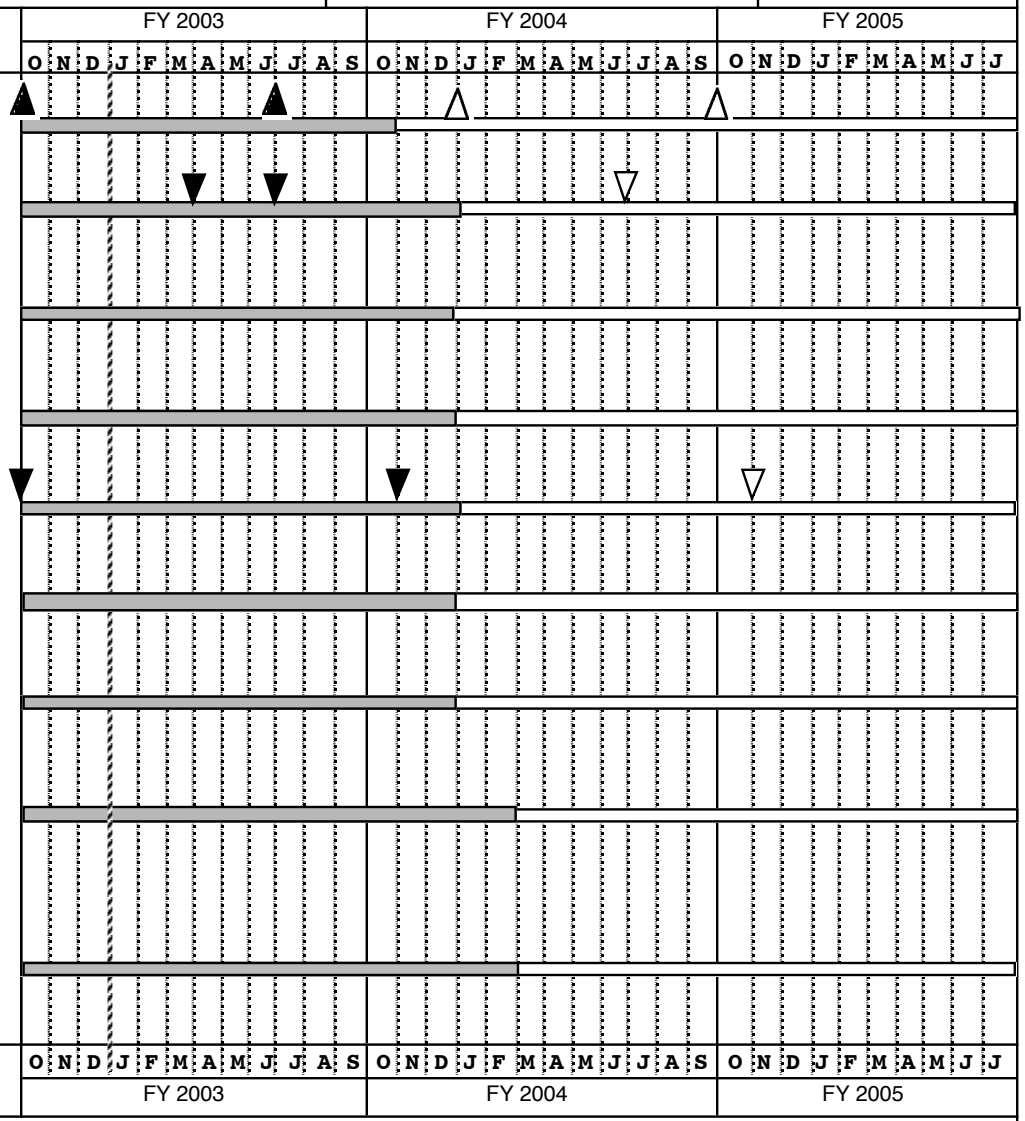
Rescheduled milestone planned

Rescheduled milestone completed

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

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 1. Program Management	**11/24/2003 - 12/28/2003**	**W6953**
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P. O. BOX 2008** **OAK RIDGE, TN 37831**	5. CONTRACT PERIOD **FY 2003--2005**	6. ACTIVITY NUMBER **41 W6 95 3W 1**
	7. NRC B&R NO. **860 15 21 20 05**	8. DOE B&R NO. **40 10 01 06**

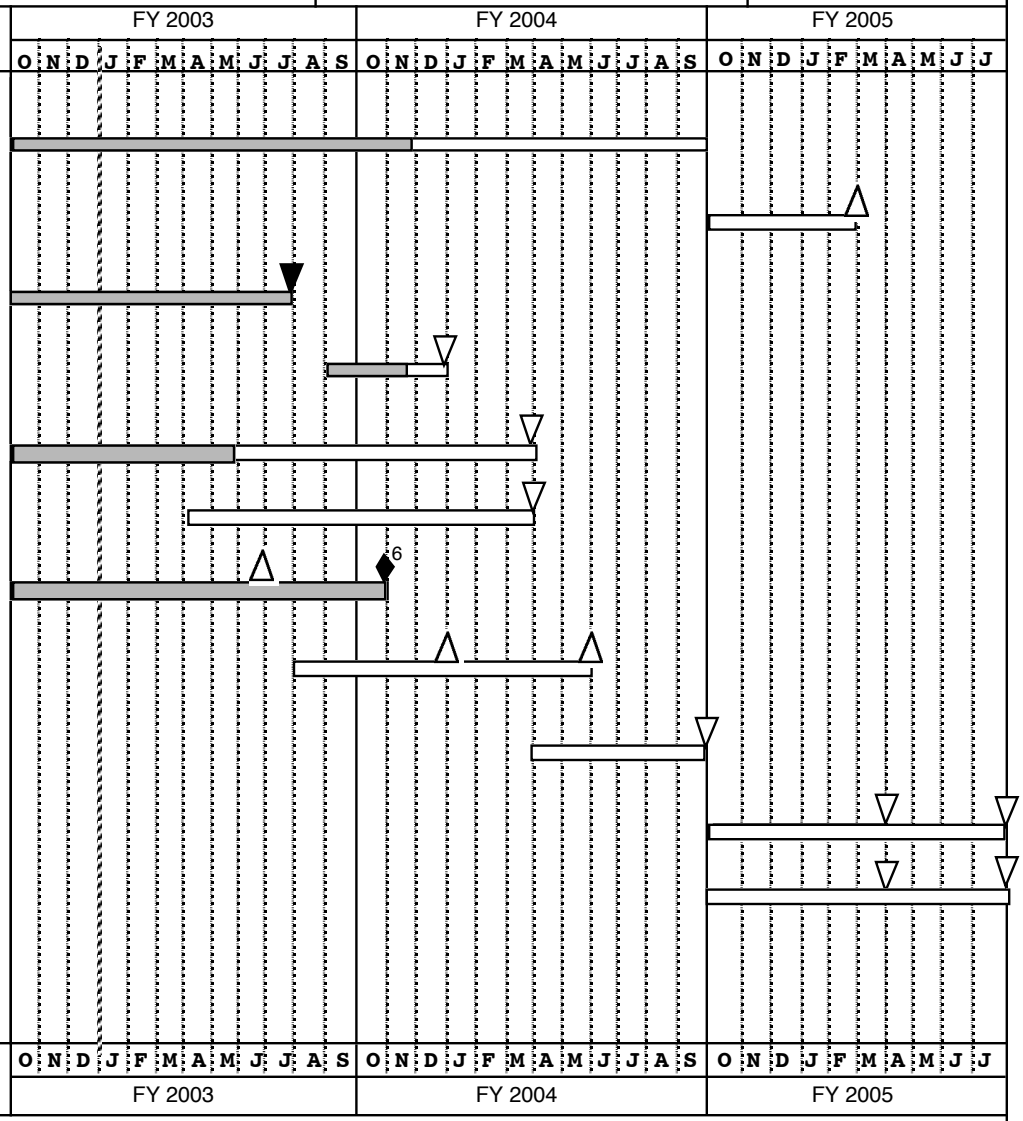
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
1.1.A.	Issue Project & Budget Proposal
1.1.B.	Select and administer subcontracts
1.2.A.	Issue earned value-based monthly reports (by the end of subsequent month)
1.2.B.	Ensure QA requirements are met
1.3.A.	Participate in NRC-sponsored meetings and discussions
1.3.B.	Coordinate NRC and internal reviews
1.3.C.	Coordinate domestic and foreign information exchange as approved by NRC-RES
1.3.D.	Coordinate HSSI Letter and NUREG Reports
1.3.E.	Document the historical information generated by the old HSSI Program



11. REMARKS

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 2. Fracture Toughness Transition & MC Methodology	**11/24/2003 - 12/28/2003**	**W6953**
4. CONTRACTOR (NAME AND ADDRESS)	5. CONTRACT PERIOD	6. ACTIVITY NUMBER
OAK RIDGE NATIONAL LABORATORY P. O. BOX 2008 OAK RIDGE, TN 37831	**FY 2003--2005**	**41 W6 95 3W 1**
	7. NRC B&R NO.	8. DOE B&R NO.
	860 15 21 20 05	**40 10 01 06**

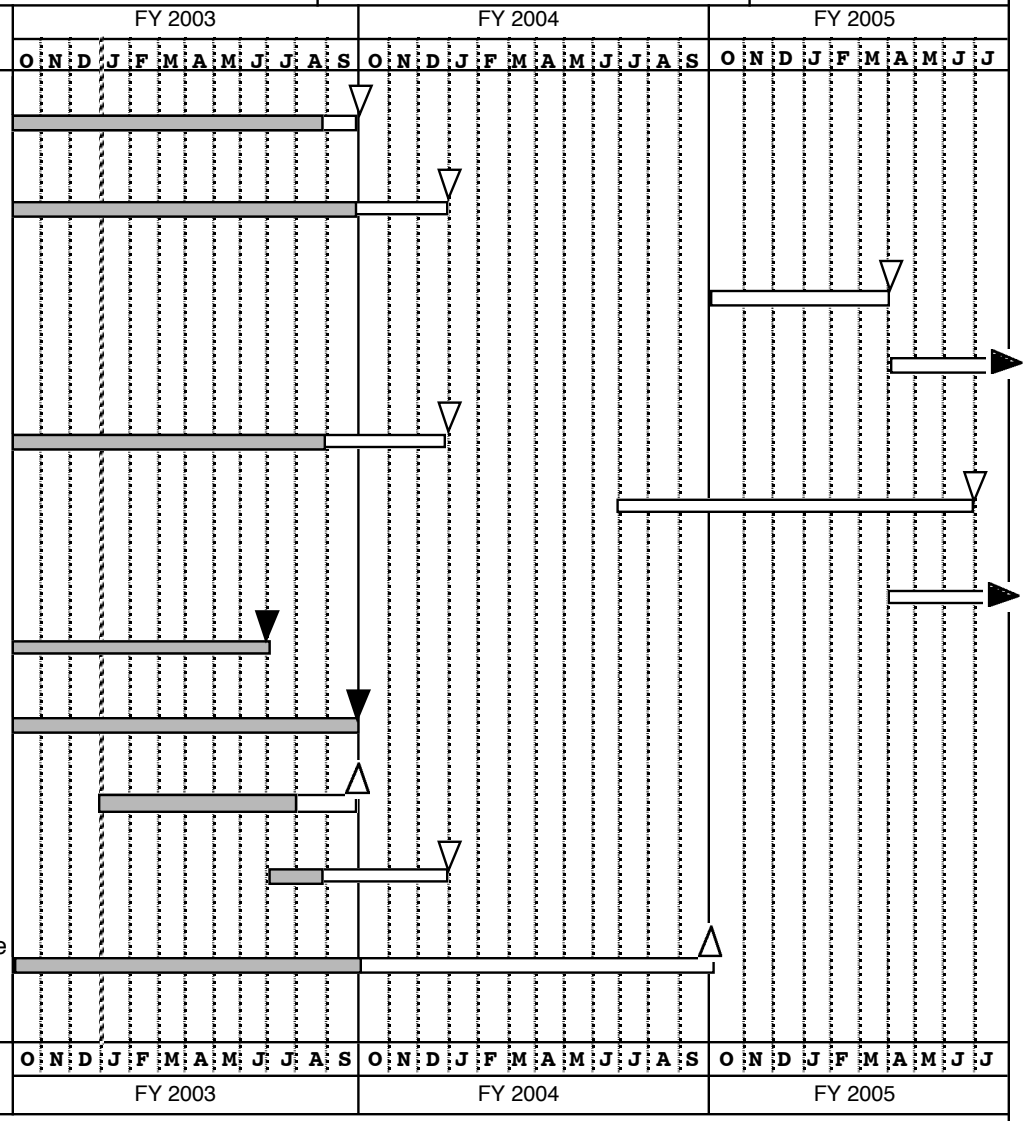
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
2.1.A.	Continue to accumulate data on comparison of CVN and fracture-toughness shifts
2.1.B.	Update NUREG/CR-6009
2.2.A.	Irradiate Midland and Hi-Ni specimens
2.2.B.	Ship and receive specimens
2.2.C.	Machine 0.4 KS-01 specimens and test
2.2.D.	Test subsize PCVN KS-01 specimen
2.2.E.	Submit NUREG Report on KS-01 test results
2.2.F.	Submit letter report on small specimens results from KS-01
2.2.G.	Test unirradiated & irradiated Hi-Ni and Midland weld specimens
2.2.H.	Draft letter/NUREG Report for Midland welds
2.2.I.	Draft letter/NUREG Report for Hi-Ni welds



11. REMARKS

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 2. Fracture Toughness Transition & MC Methodology	**11/24/2003 - 12/28/2003**	**W6953**
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P. O. BOX 2008** **OAK RIDGE, TN 37831**	5. CONTRACT PERIOD **FY 2003--2005**	6. ACTIVITY NUMBER **41 W6 95 3W 1**
	7. NRC B&R NO. **860 15 21 20 05**	8. DOE B&R NO. **40 10 01 06**

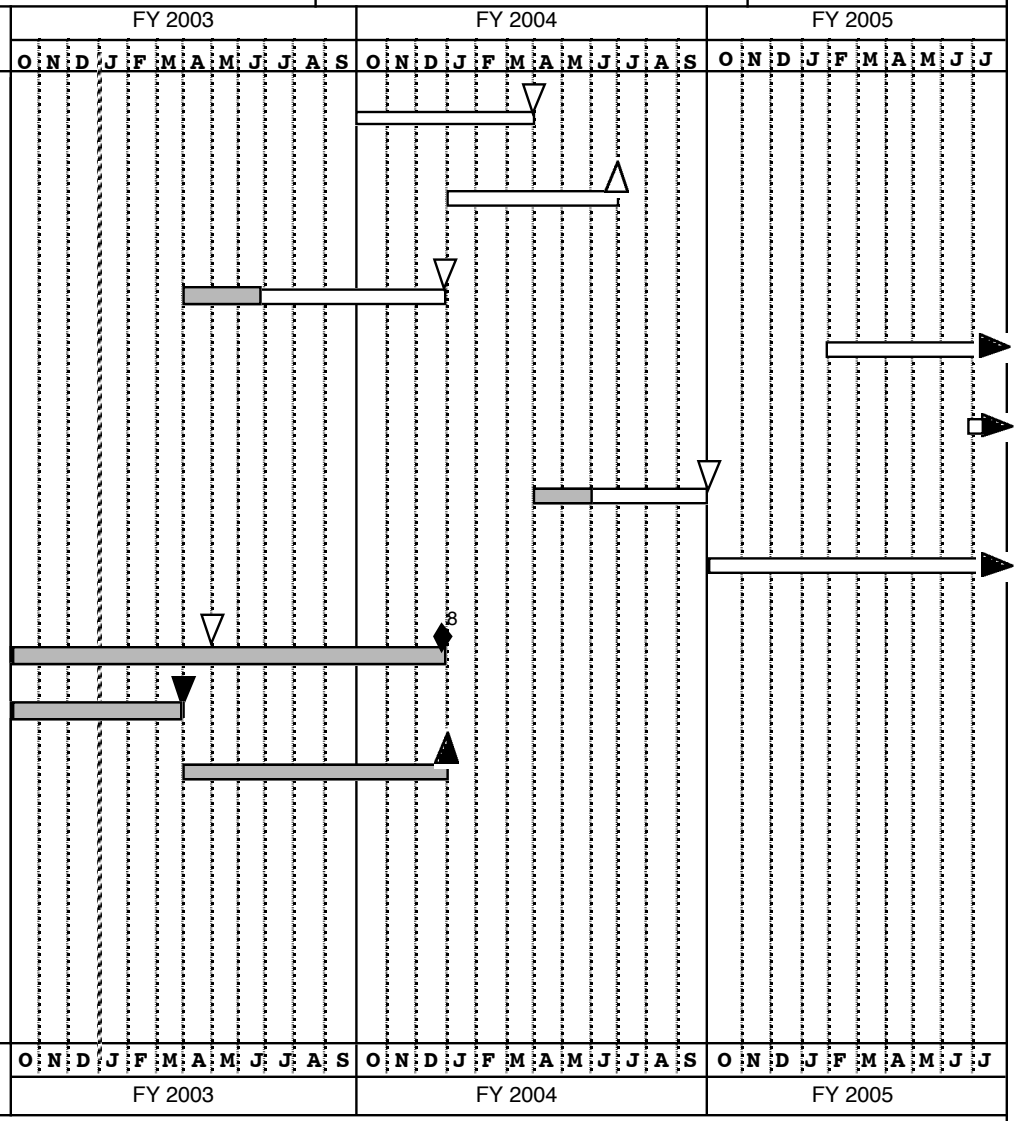
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
2.3.A.	Complete review of dynamic effects
2.3.B.	Develop testing plan for dynamic fracture toughness effects on MC
2.3.C.	Complete dynamic fracture-toughness tests
2.3.D.	Prepare NUREG report
2.4.A.	Develop test plan for IGF assessment with <100% IGF
2.4.B.	Complete testing of all materials
2.4.C.	Submit draft report
2.5.A.	Complete testing and analysis of A302B PCVN
2.5.B.	Initiate testing of JRQ plate sub-size specimen
2.5.C.	Prepare letter report on PCVN and 1(T)CT specimens
2.5.D.	Complete testing of unirradiated and irradiated specimens of JRQ plate
2.5.E.	Submit NUREG Report on assessment of sub-size specimen fracture toughness



11. REMARKS

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 2. Fracture Toughness Transition & MC Methodology	**11/24/2003 - 12/28/2003**	**W6953**
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P. O. BOX 2008** **OAK RIDGE, TN 37831**	5. CONTRACT PERIOD **FY 2003--2005**	6. ACTIVITY NUMBER **41 W6 95 3W 1**
	7. NRC B&R NO. **860 15 21 20 05**	8. DOE B&R NO. **40 10 01 06**

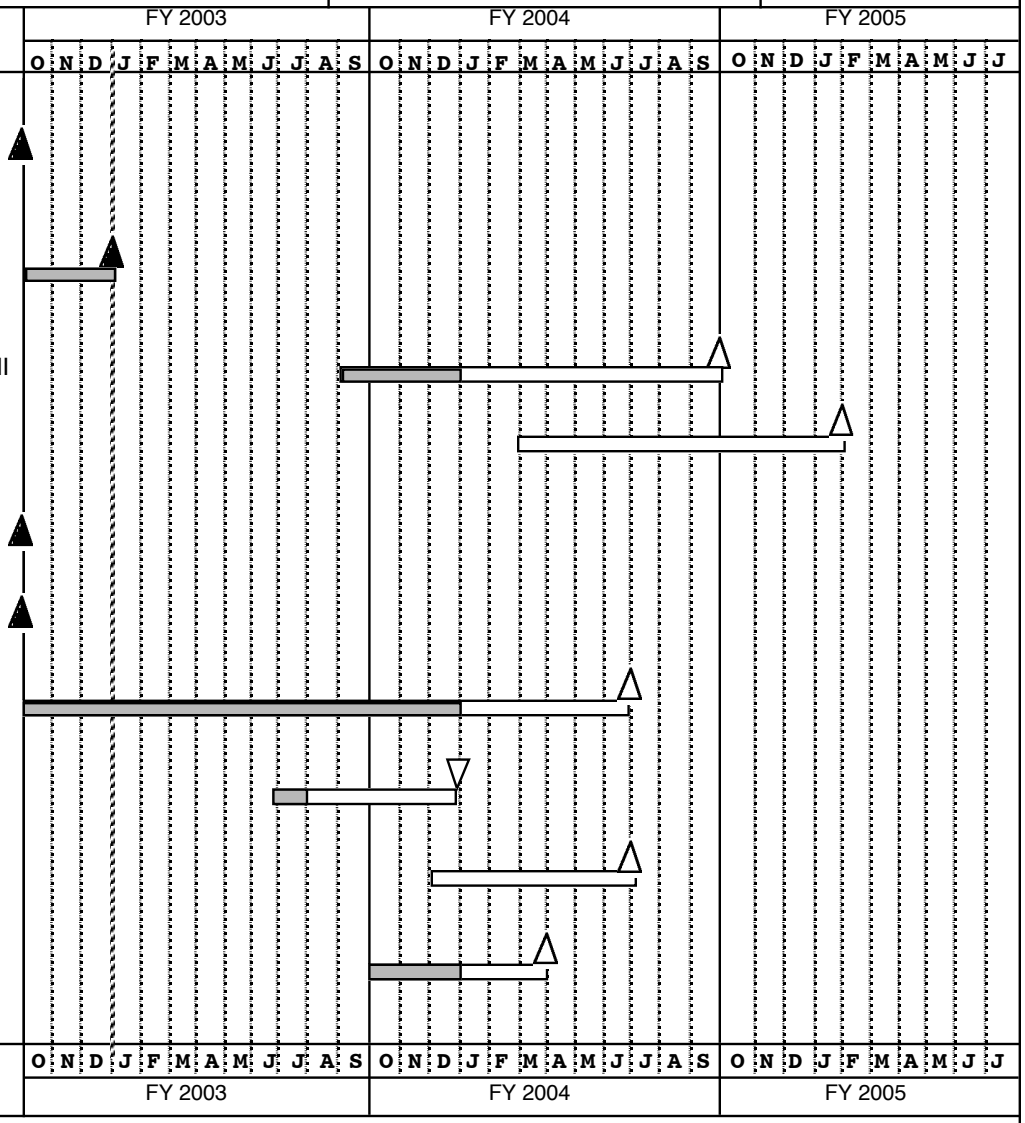
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
2.6.A.	Complete dosimetry/fluence measurements of 2nd IAR Series
2.6.B.	Complete report on 2nd IAR dosimetry/fluence measurements
2.6.C.	Update code to Linux
2.6.D.	Complete dosimetry/fluence measurements for 3rd IAR Series
2.6.E.	Complete letter report on 3rd IAR
2.7.A.	Test 3-point bend and PCVN specimens
2.7.B.	Prepare NUREG Report
2.8.A.	Machine and test second batch 72W specimens
2.8.B.	Compare first and second batch
2.8.C.	Prepare a letter report



11. REMARKS

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 3. Irradiation Embrittlement of RPV Steel	**11/24/2003 - 12/28/2003**	**W6953**
4. CONTRACTOR (NAME AND ADDRESS)	5. CONTRACT PERIOD	6. ACTIVITY NUMBER
OAK RIDGE NATIONAL LABORATORY **P. O. BOX 2008** **OAK RIDGE, TN 37831**	**FY 2003--2005**	**41 W6 95 3W 1**
	7. NRC B&R NO. **860 15 21 20 05**	8. DOE B&R NO. **40 10 01 06**

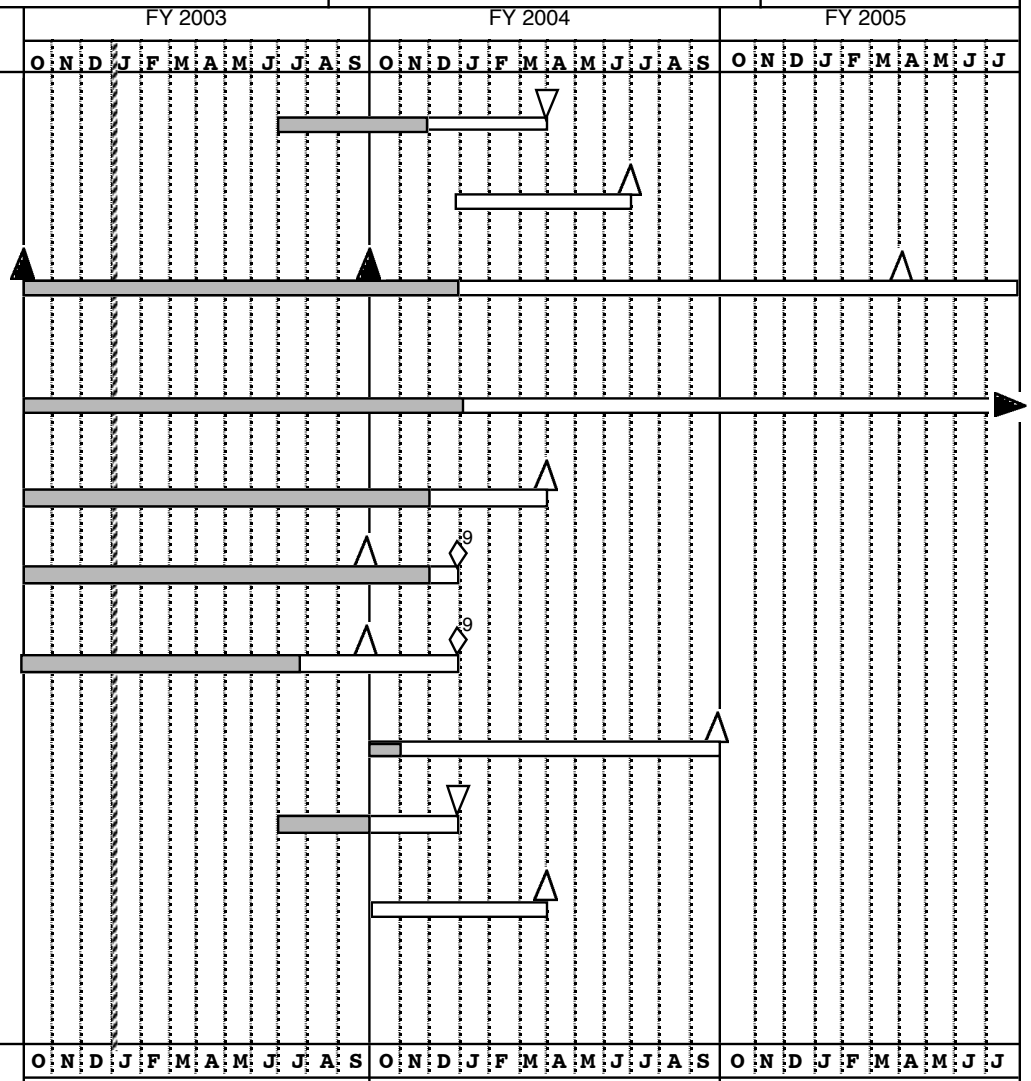
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
3.1.A.	Complete letter report on IA effects on HAZ Phase I
3.1.B.	Fabricate and heat treatment CVN specimens of A302B with slow cool after PWHT. Initiate irradiations in IAR Phase II
3.1.C.	Receive and test IA HAZ specimens from Phase II
3.1.D.	Complete NUREG Report on HAZ irradiation effects
3.2.A.	Complete Charpy testing of PSI-supplied JRQ specimens
3.2.B.	Complete PCVN testing of PSI supplied JRQ specimens
3.2.C.	Submit NUREG Report on results of JRQ testing
3.3.A.	Test and analyze 73W specimens
3.3.B.	Submit a draft NUREG Report
3.4.A.	Complete atom probe and TEM examination of Hi-Ni welds



11. REMARKS

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 4. Validation of Irradiated and Aged Materials	**11/24/2003 - 12/28/2003**	**W6953**
4. CONTRACTOR (NAME AND ADDRESS)	5. CONTRACT PERIOD	6. ACTIVITY NUMBER
OAK RIDGE NATIONAL LABORATORY **P. O. BOX 2008** **OAK RIDGE, TN 37831**	**FY 2003--2005**	**41 W6 95 3W 1**
	7. NRC B&R NO. **860 15 21 20 05**	8. DOE B&R NO. **40 10 01 06**

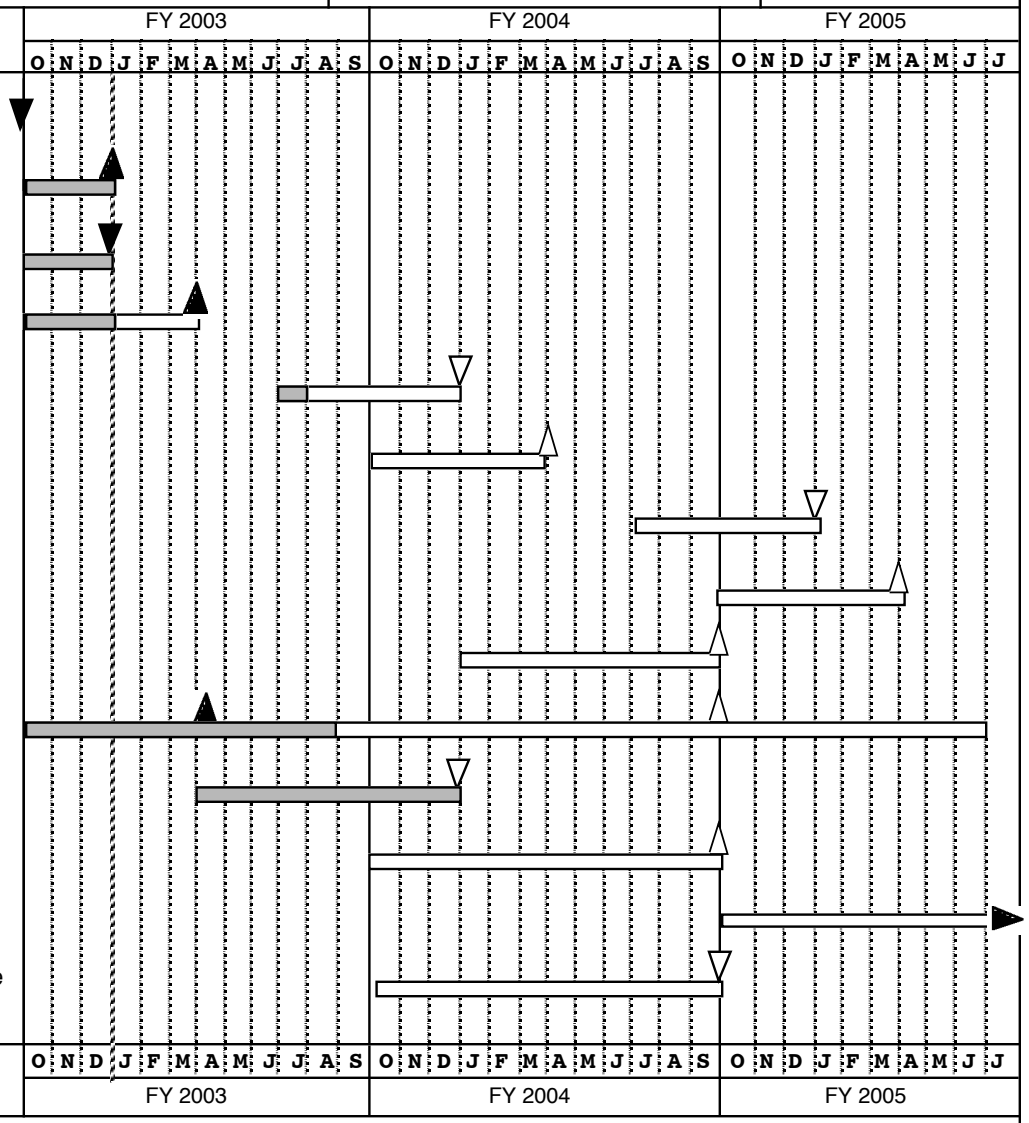
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
4.1.A.	Complete fracture toughness tests of irradiated SS cladding
4.1.B.	Complete letter report on irradiation effects on SS cladding
4.2.A.	Participate in periodic IGRDM meetings
4.2.B.	Participate in international meetings as scheduled
4.3.A.	Draft report on effects of PWHT on copper solubility and toughness of RPV steels
4.3.B.	NUREG Report on crack arrest tests of irradiated Midland Weld WF-70
4.3.C.	NUREG Report on re-embrittlement rate (IAR) of HSSI 73W material
4.3.D.	Draft report on material variability
4.4.A.	Complete literature review
4.4.B.	Submit draft NUREG Report



11. REMARKS

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 5. Modeling & Microstructural Analysis	**11/24/2003 - 12/28/2003**	**W6953**
4. CONTRACTOR (NAME AND ADDRESS) **OAK RIDGE NATIONAL LABORATORY** **P. O. BOX 2008** **OAK RIDGE, TN 37831**	5. CONTRACT PERIOD **FY 2003--2005**	6. ACTIVITY NUMBER **41 W6 95 3W 1**
	7. NRC B&R NO. **860 15 21 20 05**	8. DOE B&R NO. **40 10 01 06**

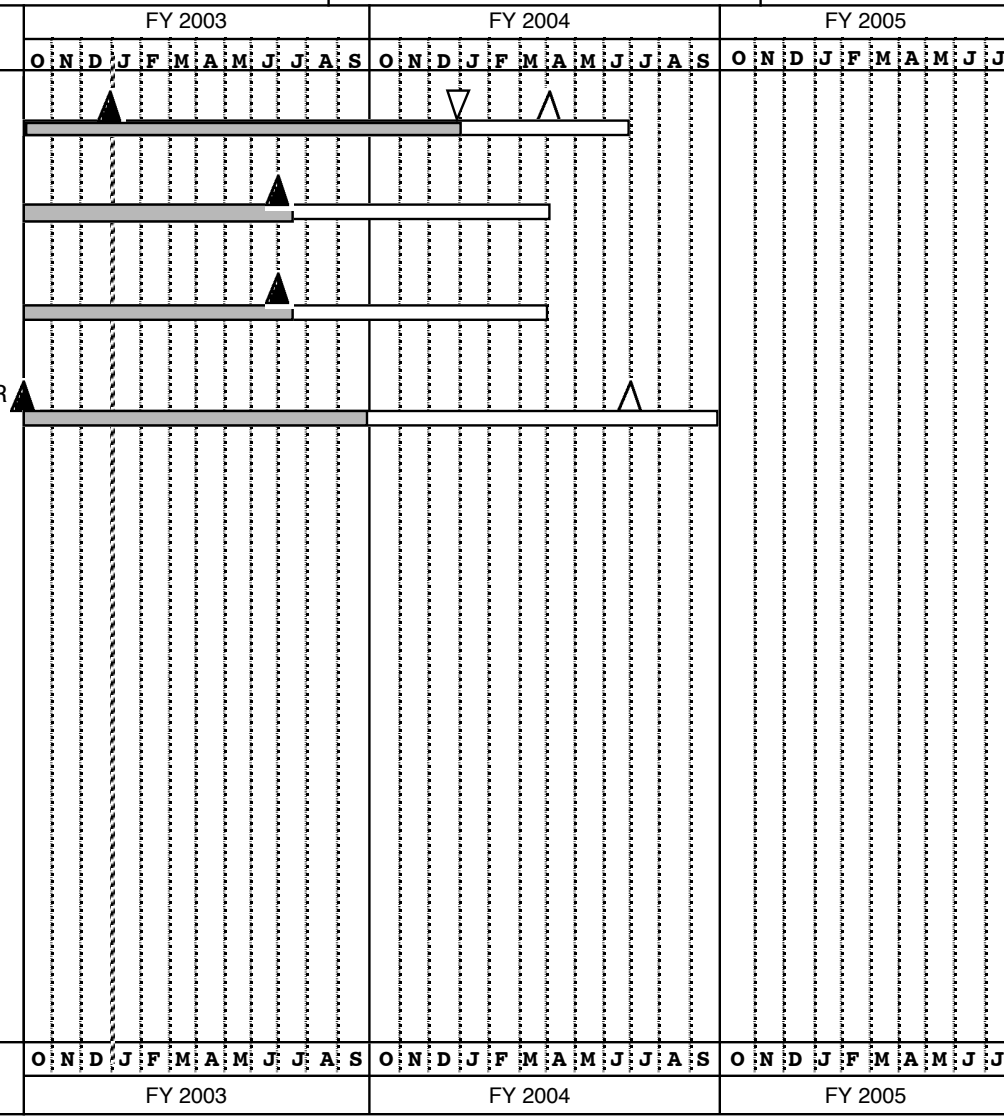
9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
5.1.A.1.	APFIM characterization of late blooming phases
5.1.A.2.	Submit report
5.1.C.1.	APT of model steels to study phase decomposition in collaboration with UCSB
5.1.C.2.	Submit report
5.1.D.1.	APT of Palisades Hi-Ni steel
5.1.D.2.	Submit report
5.1.E.1	APT examination Midland and IARAR conditions
5.1.E.2.	Submit report
5.1.F.	Submit NUREG Report on late blooming phases
5.3.A.	Maintain and update EDB (Update 12 and 13)
5.3.B.	Verify data for embrittlement equation
5.3.C.	Move PR-EDM from DOS to Windows (Alpha)
5.3.D.	Move PR-EDM from DOS to Windows (Beta)
5.3.E.	Transfer surveillance reports to electronic storage



11. REMARKS

1. CONTRACT REPORTING ELEMENT	2. REPORTING PERIOD	3. JCN NO.
HSSI - 6. Irradiation Coordination	**11/24/2003 - 12/28/2003**	**W6953**
4. CONTRACTOR (NAME AND ADDRESS)	5. CONTRACT PERIOD	6. ACTIVITY NUMBER
OAK RIDGE NATIONAL LABORATORY **P. O. BOX 2008** **OAK RIDGE, TN 37831**	**FY 2003--2005**	**41 W6 95 3W 1**
	7. NRC B&R NO. **860 15 21 20 05**	8. DOE B&R NO. **40 10 01 06**

9. MILESTONE IDEN. NO.	10. MILESTONE DESCRIPTION
6.1	Investigate alternative test irradation facilities
6.2.A.	Coordinate the operation, data collection, and maintenance of the HSSI IAR facility through shut down
6.3.A.	Coordinate the operation, data collection, and maintenance of the UCSB irradiation facility
6.4.	Dispose of irradiated materials from the HSSI-IAR and HSSI-IVAR



11. REMARKS