

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

Monthly Letter Status Report

January 2002

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HEAVY-SECTION STEEL IRRADIATION
PROGRAM
JCN W6953

MONTHLY LETTER STATUS REPORT
FOR
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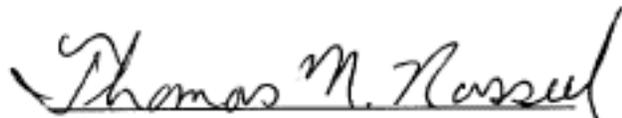
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PREFACE

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 March 7, 2001. 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 2000 to March 2003, while the individual task budgets address the period from October 2001 to December 2002.

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
January 2002

Job Code Number:	W6953
Project Title:	Heavy-Section Steel Irradiation Program
Period of Performance:	4/1/98 to 4/1/03
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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 administering 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 2002 funds, placed in the ORNL financial plan by DOE-ORO in late December, were distributed to the various HSSI Program tasks in accordance with the current version of the HSSI 189 budget and cost proposal. (Please see the financial status section of this report for the six individual tasks and the program summary revisions.)

(Milestone 1.1.B) The ORNL announced that the University of Michigan, Phoenix Memorial Laboratory, Ford Nuclear Reactor (FNR) will be honored as the best subcontractor in the ORNL/SNS Subcontractor Awards Education Category at a luncheon ceremony on March 12, 2002, at the Garden Plaza Hotel, Oak Ridge. This award recognizes the outstanding effort by the FNR staff in support of the HSSI Program. Examples include handling specimen change outs with speed and accuracy, providing extended assistance during urgent situations associated with trouble shooting and repairing/replacing equipment, and providing critical input during planning activities. The University of Michigan technical contacts are Mr. Phil Simpson, Assistant Laboratory Manager, FNR and Mr. Eric Touchberry, Research Administrator / Technical support. The FNR Laboratory Manager is Mr. Chris Becker and the Director of the Phoenix Memorial Laboratory is Professor David K. Wehe.

(Milestone 1.2.B) The annual maintenance and calibration of the control systems for the HSSI Reusable Irradiation Facilities at the University of Michigan, FNR was completed during the first full week in January. HSSI irradiation facilities were operated for the remainder of the half-cycle, which ended on January 18, 2002. During facility startup, after reactor half-cycle 467A had begun, several alarms were received from the HSSI-IAR facilities that required a shut down of the entire facilities control system. After detailed analysis and checking of multiple components it was determined that the faulty component in the system was the micro digital control system (dcs) controller. The controller was removed from the system and shipped to ORNL for repair or replacement. Assistance from the FNR staff was invaluable in this effort to locate and correct the problem. Full estimate of the cost to repair or replace this component and the reason for the failure will be examined during the next reporting period. Additional details may be found in Task 6.1.

(Milestone 1.3.C) On January 16, 2002, Mr. Shunichi Hatano of the Tokyo Research and Development Center, Japan Power Engineering and Inspection Corporation (JAPEIC) and the Nuclear Power Plant Integrated Management Technology (PLIM) Project visited the HSSI Program to discuss embrittlement predictions for low upper-shelf energy pressure vessel steels. HSSI Program capabilities and potential collaborations between JAPEIC and ORNL HSSI Program were also discussed.

On January 24, 2002, Dr. Enrico Lucon of SCK-CEN, Mol, Belgium, visited the ORNL Metals and Ceramics Division and the HSSI Program and provided an overview of current SCK-CEN activities on RPV steels.

(Milestone 1.3.E) A final draft letter report by R. E. Stoller and R. K. Nanstad, entitled *A Proposal for Sampling the SONGS-1 Reactor Pressure Vessel* (ORNL/NRC/LTR-02/12) was submitted to the NRC Program Monitor for review (Task 4.4). It will be released during the next reporting period.

Task 2: Fracture-Toughness Transition Issue and Master-Curve Methodology **(M. A. Sokolov)**

Fracture-toughness transition and Master Curve (MC) methodology will be broadly explored for pressure-vessel applications through a series of experiments, analyses, and evaluations in eight subtasks. Specifically, the effects of irradiation on fracture-toughness curve shape for highly embrittled RPV steels, dynamic effects, crack arrest, intergranular fracture, and subsized specimens will be explored; guidelines for the application of "surrogate" materials to the assessment of fracture toughness of RPV steels will be evaluated; and the fluence received in the HSSI irradiation experiments will be determined.

Subtask 2.1: Fracture-Toughness Transition-Temperature Shifts (M. A. Sokolov)

The purpose of this subtask is to collect and statistically analyze pertinent fracture-toughness data to assess the shift and potential change in shape of the fracture-toughness curves due to neutron irradiation. The MC methodology will be applied to provide a statistical analysis of the fracture-toughness data and Charpy data will be fitted by hyperbolic tangent functions. The resulting reference fracture-toughness temperature, T_0 , shifts will be compared with Charpy shifts determined by various indexing methods.

(Milestone 2.1.A) The 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.

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

The purpose of this subtask is to evaluate the assumption of constant shape for the MC even for highly embrittled RPV steels. The evaluation will be performed through the testing of a pressure-vessel steel weld that has been irradiated to a neutron fluence sufficient to produce a fracture-toughness transition-temperature shift (T_0) of about 150°C (270°F). A specially fabricated radiation-sensitive weld was selected to perform a pilot study on the ability of highly embrittled material to maintain the master curve shape. This weld had been fabricated and studied in Germany and supplied to ORNL by MPA, Stuttgart through a Memorandum of Agreement (MOA). The 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 8.4×10^{18} n/cm² at the FNR during the first HSSI-IAR irradiation campaign. Evaluation of the MC shape will be determined with sufficient numbers of 1T compact specimens, 1T C(T), to allow for testing at

three temperatures in the transition-temperature region. Additionally, 0.5T C(T), and pre-cracked Charpy V-notch (PCVN) specimens, using both quasi-static and dynamic methods, will be tested to investigate the use of more practical surveillance-size specimens. Tensile specimens will also be tested to determine the irradiation-induced hardening. Testing of irradiated specimens is dependent upon the availability of suitable hot-cell facilities. Evaluation of the mechanical properties of the unirradiated weld has been completed.

Specimens of the Midland beltline weld were fabricated and placed into the IAR facility at the FNR for irradiation to a fluence of at least 2.5×10^{19} n/cm² (>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.

Irradiated high-nickel welds from the Palisades steam generator will also be examined. Not only will this material provide additional information on curve shape effects, but it will permit experimental validation of an assumption of linear relationship between Charpy 41J and fracture toughness shifts for highly-embrittled materials.

(Milestone 2.2.A) Irradiation of the Midland beltline weld and a high-nickel weld from the Palisades steam generator is under way and irradiation of the remaining specimens is proceeding on schedule in the University of Michigan FNR. Please also see Task 6.1. Some of the Palisades steam generator specimens irradiated to an intermediate fluence were removed previously and have been received at the ORNL hot cells. They are scheduled for testing in the next two months.

(Milestone 2.2.C) As noted in the last report, 21 1T compact specimens of the submerged-arc weld KS-01, irradiated to $\sim 0.8 \times 10^{19}$ n/cm² (>1 MeV), were successfully tested as follows: six at 125°C, six at 150°C, five at 175°C, and four at 200°C. Following evaluation of the results, six additional 0.5T compact specimens were also at 100°C. The results have been evaluated relative to the shape of the master curve. As a preliminary observation, the fracture toughness data up to a median K_{Jc} value of about 130 MPa√m reasonably follow the shape of the master curve. Above that value, however, the fracture toughness test results deviate substantially from the shape of the curve in a manner indicating a shallower curve shape. For this material, this latter effect is believed to be due, at least in part, to the occurrence of intergranular fracture in the test specimens and shows the same behavior as that observed in the intergranular fracture study performed within subtask 2.6. On the other hand, the unirradiated specimens also exhibited significant intergranular fracture, but the results did not deviate from the shape of the master curve. Further statistical analysis will be performed with these data. Furthermore, tensile tests yet to be performed may shed light on the effects of the intergranular fracture observations relative to expected irradiation-induced hardening. Additionally, an NRC Letter Report is in preparation and an abstract has been submitted for presentation at the ASTM International Symposium on Radiation Effects in Materials in Tucson, Arizona in June, 2002. Results of this project have been incorporated in a presentation at the NRC Workshop on Fracture Mechanics to be held in Rockville on February 20-21.

Moreover, the computer numerically controlled (CNC) milling machine in the hot cell has been exercised recently in preparation for machining of 0.4T compact specimens from the broken

irradiated 1T compact specimens of KS-01 previously tested. These 0.4T specimens will be tested in the same general temperature range as the 1Ts to expand the database for this material.

(Milestone 2.2.G formerly 2.4.D) The final report, *Evaluation of WF-70 Weld Metal from the Midland Unit 1 Reactor Vessel*, by D. E. McCabe, R. K. Nanstad, S. K. Iskander, D. W. Heatherly, and R. L. Swain, NUREG/CR-5736 (ORNL/TM-13748), was published by the NRC in November, 2000.

Subtask 2.3: Dynamic Fracture Toughness [Combines previous subtasks 2.3 and 2.5]
(R. K. Nanstad)

The purpose of this subtask is to evaluate the applicability of the master curve to dynamic fracture toughness of RPV steels. There are limited data available that suggest reasonable applicability of the master curve to such data, however, sufficient data under high-rate loading conditions for a reliable statistical assessment are not available. 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 is high-rate loading of standard bend or compact specimens under non-impact conditions.

(Milestone 2.3.A) No significant progress during this reporting period. However, compact specimens (either 0.5T or 1.0T) will be machined from a material with a Master Curve pedigree, such as HSST Plate 02 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_0 from quasi-static and dynamic tests.

Subtask 2.4 - Statistical Representation of Valid K_{Ic} Data for Irradiated RPV Steels
(R. K. Nanstad and J. G. Merkle)

The purpose of this subtask is to develop a statistical representation of valid K_{Ic} data for irradiated RPV steels from available elastic-plastic fracture toughness data. In the estimation of failure probabilities for RPVs subjected to postulated pressurized thermal-shock loadings, it is necessary to employ realistic statistical representations of both flaw size and fracture toughness. The rationally based statistical model of weak-link behavior incorporated in ASTM Standard E1921 and available large-scale experimental fracture mechanics data, are the potential bases for developing an improved representation of the statistical behavior of valid K_{Ic} data, with the expectation that uncertainties will be less than those resulting from the present method.

(Milestone 2.4.A) The draft letter report has been completed. Initial review resulted in identification of some minor changes as well as the need for preparation of an example calculation to be incorporated in the report. The following statements from the draft abstract of the letter report are provided:

“A statistical representation of valid K_{Ic} data for the ferritic steels typically used in structures, piping, and pressure vessels has been derived by combining the principles of the elastic-plastic Master Curve of American Society for Testing and Materials (ASTM) E 1921 and the criterion for validity under elastic conditions contained in ASTM E 399. By all evidence, the

results obtained agree well with the American Society of Mechanical Engineers (ASME) K_{Ic} database, therefore offering a promising approach for estimating values of K_{Ic} and their statistics based on small specimen fracture toughness data.”

The draft letter report was submitted to the NRC Program Manager in December. It was also sent to three technical experts outside of ORNL for independent review.

Subtask 2.5 (formerly 2.10): 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 2.5.A formerly 2.10.A) With the completion of the exposure parameters calculations for the first metallurgical specimens (KS-01 specimens) irradiated in HSSI IAR facility, a draft report was completed and is undergoing internal review. This report will be either be incorporated as appendices in appropriate NUREG reports or prepared as a separate letter report. Additionally, radiometric dosimeter sets are being prepared for each IAR capsule shelf so as to provide a more accurate characterization of the fluences as specimens are shuffled within the irradiation facility to maximize irradiation efficiency.

(Milestone 2.5.B formerly 3.2.B) Neutronics Analysis of the IAR/UCSB Irradiation Capsules - (I. Remec, E. D. Blakeman, and C. A. Baldwin). The report entitled, *Characterization of the Neutron Field in the HSSI/UCSB Irradiation Facility at the Ford Nuclear Reactor*, by I. Remec, E. D. Blakeman, and C. A. Baldwin, NUREG/CR-6646 (ORNL/TM-1999/140) was submitted to the NRC in September 1999.

Subtask 2.6: Intergranular Fracture (R. K. Nanstad and J. G. Merkle)

This subtask will address the issue of whether the MC technique can be applied to materials that experience brittle fracture by an intergranular mechanism. Specifically, it will be determined whether steels that experience intergranular fracture can be correctly characterized by the MC T_0 temperature and whether the transition-curve shape can be changed by different fracture modes. Complete intergranular fracture from temper embrittlement occurs only at lower-shelf temperatures. As it is with transgranular cleavage, the transition to upper shelf is marked by an increased volume percentage of ductile rupture mixed with the lower-shelf, brittle-fracture mechanism. Since the onset of crack instability is most likely triggered in the brittle zones, the critical issue is understanding the influence of the triggering mechanism on the distribution of K_{Jc} values obtained. This information can be obtained on the lower shelf and, in part, into the transition range.

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

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. Additional 0.5 T C(T) specimens have been fabricated and testing is underway.

(Milestone 2.6.A) Four of the five remaining 0.5T compact specimens to be tested at a higher temperature than the previously tested specimens have been tested, two at 100°C and two at 50°C. The two specimens at 50°C experienced unstable fracture well out on the J-R curve, while the two tested at 100°C exhibited full J-R curves. However, one of the specimens at 100°C did experience an audible pop-in well onto the R-curve. Scanning electron fractography has also been performed. A presentation and paper on this subject were prepared and delivered by R. K. Nanstad at the IAEA Specialists' Meeting on Master Curve in Prague, Czech Republic, in September. The paper will be published in the IAEA meeting proceedings.

(Milestone 2.6.B) Additional scanning electron fractography has been performed to evaluate the fracture mode of the specimens previously tested at the highest temperatures (room temperature and above). The results have confirmed failure by intergranular fracture and have also confirmed the presence of so-called ductile intergranular fracture. This is an important aspect of the evaluation as it relates to the relationship between the master curve shape, which is used to describe unstable cleavage fracture in the ductile-brittle transition region, and unstable fracture by intergranular fracture.

A total of about 50 compact specimens of 0.5T, 1T, and 2T were tested from -125 to 100°C, with brittle intergranular fracture up to 50°C. The fracture toughness vs temperature relationship appears to follow the master curve shape up to about 150 MPa√m. However, the ductile to brittle transition-temperature behavior is significantly different than that observed for cleavage fracture in that brittle intergranular fracture is still observed for this material at test temperatures well above those associated with the master curve. Additionally, the relationship between fracture toughness and Charpy toughness was significantly different from cleavage fracture results.

(Milestone 2.6.C) The draft letter report has been completed and is currently in the review process. It will be submitted to the NRC Program Manager in February. Results of this project have been incorporated in a presentation at the NRC Workshop on Fracture Mechanics to be held in Rockville on February 20-21.

Subtask 2.7: Sub-sized Specimens (M. A. Sokolov)

The purpose of this subtask is to evaluate the applicability of the weakest-link theory-based size-adjustment procedure in the MC methodology to specimen sizes that are the most likely to be present in surveillance capsules. The MC methodology will be applied using precracked Charpy-size or smaller specimens to test the lower-size limit applicability. Testing will be performed at two or more temperatures with at least six specimens at each temperature. The exact number of temperatures and specimens will be determined following analysis of initial results. The testing of these subsize specimens will also satisfy the HSSI Program suggested

testing matrix within the New Coordinated Research Program (CRP) of the International Atomic Energy Agency (IAEA). Subsize specimens will be fabricated from previously characterized materials within the HSSI Program, such as HSST Plate 02, HSSI Welds 68W through 73W, the Midland beltline weld and plate JRQ.

(Milestone 2.7.A) The testing of specimens has been completed; measuring of crack extensions and final analysis are underway. These specimens were machined from three blocks of materials into 1T C(T) and precracked Charpy specimens for the size effect study. Two of the blocks are broken halves of 4TC(T) specimens of two A302B plates previously tested by the HSSI Program. The third block of material is the well-characterized Plate 13A. This study is specifically designed as an evaluation of the precracked Charpy specimen. However, a series of subsize specimens of JRQ steel has also been completed. The specimens are 0.2TC(T) and 0.4TC(T), and 5 × 5 mm and 5 × 10 mm SE(B) specimens. Results of this project have been incorporated in a presentation at the NRC Workshop on Fracture Mechanics to be held in Rockville on February 20-21.

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

The purpose of this subtask is to identify issues and make recommendations for the use of surrogate or non-identical materials in the assessment of fracture toughness of RPV steels. In many cases, surveillance programs for RPVs include specimens of a material that are not identical to the critical material in the RPV and test results from those surveillance specimens are used to represent the critical material in RPV analysis. This issue has been identified as an overarching issue in that a more complete understanding of most other issues is needed in order to reduce the uncertainties associated with material variability.

(Milestone 2.8.A) Further review of data, both unirradiated and irradiated, is continuing, which will eventually result in the preparation a table of uncertainties that could be utilized for evaluating the application of surrogate materials. This work is intended to be included in the final NUREG report on this subject. A different methodology is being evaluated for potential application to this issue. The methodology involves a combination of non-linear estimators including domain models, neural networks, vector space methods, and nearest neighbor regressions. The evaluation will examine in a very preliminary manner, whether the methodology appears applicable to the issue and whether it can be implemented in a relatively straightforward manner. This effort, which began in July, has been completed except for the final report to the HSSI NRC Technical Program Manager.

(Milestone 2.8.B) A draft NUREG report, *Considerations for Use of Surrogate Materials Data for Reactor Pressure Vessels*, by R. K. Nanstad, J. G. Merkle, and J. Galt, was previously prepared and sent to the NRC technical monitor for review.

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

The purpose of this task is to examine two important issues affecting the application of thermal mitigation procedures to irradiated RPVs. The first will address the effects of temper

embrittlement on the coarse-grained HAZ in RPV steels. The second will examine the effects of reirradiation on K_{Jc} and K_{Ja} in order to evaluate the relative changes in the recovery and reembrittlement between CVN and fracture-toughness properties and a detailed examination of reembrittlement rates. These questions will be addressed in-part using specimens supplied by the Swiss HSK and PSI.

Subtask 3.1: HAZ Embrittlement (M. A. Sokolov and 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 on temper embrittlement of the coarse-grain materials in HAZs of RPV steel multi-pass welds has revealed the potential for such embrittlement under some conditions. AEA-Technology discovered that using high-temperature austenitization to produce very coarse grains, followed by thermal aging resulted in large transition-temperature shifts. Further, post-irradiation thermal annealing of such material resulted in an even greater increase of the transition temperature. Subsequent research at ORNL under the previous HSSI Programs used five commercial RPV steels to investigate potential temper embrittlement. Since the amount of intergranular fracture observed was unexpected, further studies are required to resolve the issue.

The first phase of this project simulated the AEA-Technology heat treatment and observed large transition-temperature shifts, although not as large as those from AEA-Technology. The second phase of the ORNL study used the same five RPV steels, but used the Gleeble system (an electrical-resistance heating device) to produce material deemed representative of the coarse-grain region in RPV welds. These materials revealed very high toughness in the initial condition (i.e., from the Gleeble). After thermal aging at about 454°C for 168 hours the materials exhibited only modest transition temperature increases, however, after aging at the same temperature for 2000 hours, significant transition temperature increases were observed. Of course, 2000 hours is much in excess of the time that RPV steels would be exposed to mitigation cycles, but potential synergistic effects of irradiation and thermal aging are unknown. Moreover, questions also remain regarding other time-temperature effects, such as post-irradiation mitigation at somewhat lower or higher temperatures.

(Milestone 3.1.A) The draft 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, has been completed and was sent to the NRC Program Manager in December for review.

(Milestone 3.1.B) As noted in a previous progress report, 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 thermal annealing. Excess material from the original investigation has been identified, and the proposed study will be discussed with the NRC technical monitor with consideration of funding needs. Consideration is also being given to reirradiation of the remaining specimens from the initial series.

Subtask 3.2 (formerly 3.3): Evaluation of Reirradiated JRQ Specimens (R. K. Nanstad, E. T. Manneschildt, and T. M. Rosseel)

The purpose of this subtask is to examine the fracture-toughness behavior of a model steel that has been irradiated, tempered, and re-irradiated. The specimens, 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 various studies sponsored by the IAEA and is under consideration as a reference material for various other RPV studies, 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. Testing of irradiated specimens is dependent upon the availability of suitable hot-cell facilities.

(Milestone 3.2.A formerly 3.3.A) A total of 46 JRQ Charpy V-notch impact specimens from the Paul Scherrer Institute have been tested and the results presented in a previous progress report. Completion of the Charpy impact testing is anticipated for January or February and initiation of the precracked Charpy fracture toughness testing is anticipated for February or March.

A presentation on this work, which included previous work by PSI, was presented by R. K. Nanstad at the International Atomic Energy Agency (IAEA) Specialists' Meeting on Radiation Embrittlement and Mitigation in Gloucester, U.K., 14-17 May 2001. The presentation was co-authored by Ph. Tipping (Swiss HSK), G. Waeber (PSI), and Kalkhof (PSI). A previous progress report graphically showed the results. Completion of the Charpy impact testing is anticipated for February and initiation of the precracked Charpy fracture toughness testing is anticipated for February or March, dependent on hot cell availability.

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

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

Subtask 4.1: (formerly 4.3) Toughness Changes in Aged Stainless Steel Welds (R. K. Nanstad)

The purpose of this subtask is to evaluate the effects of irradiation on fracture-toughness testing 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.B formerly 4.3.B) The report, *The Effect of Aging at 343°C on the Microstructure and Mechanical Properties of Type 308 Stainless Steel Weldments*, by

D. J. Alexander, K. B. Alexander, M. K. Miller, and R. K. Nanstad, NUREG/CR-6628 (ORNL/TM-13767), was published in November 2000.

Subtask 4.2: (formerly 4.4) Foreign Interactions (R. K. Nanstad)

The purpose of this subtask is to provide technical support and continued collaboration for a number of cooperative relationships with foreign institutions in the area of radiation effects on RPV steels. Collaborative relationships may be developed during the course of this program and will be developed with the cognizance of NRC. Current relationships are:

1. 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.
2. Collaboration with AEA-Technology in the United Kingdom regarding fracture toughness testing and temper embrittlement of RPV HAZs.
3. Collaboration with institutes in the Czech Republic, Germany and Finland on fracture toughness with small specimens in support of MC evaluations.
4. Collaboration with PSI in Switzerland on evaluation of reirradiation effects.
5. 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.
6. Participation, including membership on the Executive Committee, in the International Group on Radiation Damage Mechanisms (IGRDM).
7. Participation in two coordinated research programs (CRPs) sponsored by the International Atomic Energy Agency (IAEA), informally designated CRP-5 and CRP-6. These CRPs will investigate: the use of PCVN specimens to determine fracture toughness of RPV steels, and effects of nickel on irradiation-induced embrittlement of RPV steels, respectively.
8. Collaboration with NRI, Rez (Czech Republic) in the area of microstructural evolution in RPV steels as a consequence of reirradiation.
9. Collaboration with MPA-Stuttgart in Germany regarding applicability of the master curve to highly embrittled RPV steels.
10. Collaboration with researchers at the University of Lille, France, in the area of primary radiation damage simulation.

(Milestone 4.2.A, formerly 4.4.B) R. K. Nanstad attended the IAEA Specialists' Meeting on Master Curve Fracture Toughness, held in Prague, Czech Republic, in September 2001.

Additionally, R. K. Nanstad attended a meeting of the IAEA CRP-5 in Prague. A trip report was completed by R. K. Nanstad in January 2002 (ORNL/FTR-142586).

R. K. Nanstad, as secretary of the International Group on Radiation Damage Mechanisms (IGRDM) in Pressure Vessel Steels, has updated the IGRDM membership list and is revising the IGRDM charter. The next meeting of the IGRDM will be held in Awaji Island, Japan, from 20-24 May, 2002; preliminary organization of the meeting is a cooperative effort between the secretary, the chairman (T. J. Williams, Rolls-Royce), and the local host committee (chaired by Dr. Naoki Soneda, CRIEPI). Preliminary information and a call for papers have already been sent to the IGRDM members. R. K. Nanstad, M. A. Sokolov, R. E. Stoller, and M. K. Miller have all sent pre-registration information to the local host committee for the purpose of securing adequate lodging, while all four members have also recently submitted proposed presentation titles as required by the organizers.

Subtask 4.3: (formerly 4.5) 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) evaluation of the effects of post-weld heat treatment (PWHT) on the copper solubility and fracture toughness of unirradiated RPV steels and 2) machining of material removed from retired irradiated RPVs for evaluation of through-thickness attenuation of irradiation embrittlement.

(Milestone 4.3.B formerly 4.5.F) A presentation of progress on this study was made at the IGRDM meeting in September in Leuven, Belgium, and was also made at the IAEA Specialists' Meeting on Radiation Embrittlement and Mitigation in Gloucester, U.K., 14-17 May 2001. Because of hot cell scheduling issues, testing of the irradiated subsize Charpy specimens has not been conducted, but is now anticipated for February. A letter report will be prepared following completion of all testing and evaluation. A paper, for which M. K. Miller was the lead author, with 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.

(Milestone 4.3.C, formerly 2.5.A) The draft NUREG report, *Detailed Results of Testing Unirradiated and Irradiated Crack-Arrest Toughness Specimens from the Low Upper-Shelf Energy, High Copper Weld, WF-70*, by S. K. Iskander, C. A. Baldwin, D. W. Heatherly, D. E. McCabe, I. Remec, and R. L. Swain, NUREG/CR-6621 (ORNL/TM-13764), is finished, but completion of the final report and submission to the NRC for publication will be delayed until about June of 2002 due to personnel reductions.

(Milestone 4.3.D formerly 3.2.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 specimens is about 4×10^{19} n/cm² and the irradiation has been completed. The specimens have been received at the ORNL hot cells and will be scheduled for testing in the near future.

(Milestone 4.3.E formerly 4.1.2.B) 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. Manneschildt, 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.

Subtask 4.4: Obtaining RPV material for SONGS-1 (R. K. Nanstad, R. E. Stoller, and T. M. Rosseel)

The purpose of this subtask is to obtain Southern California Edison's, the owner of San Onofre Nuclear Generating Station (SONGS) Unit 1 Reactor, consent and assistance in obtaining trepans from the SONGS-1 RPV and to provide a preliminary estimate of the potential problems that could be encountered during this operation as well as a preliminary estimate of the cost to obtain the trepans. This effort, which would permit the evaluation of through-thickness attenuation of irradiation embrittlement of a service-irradiated RPV, will be coordinated with EPRI. A letter report will also be prepared that describes the progress and status of that effort.

(Milestone 4.4.A) The draft letter report by R. E. Stoller and R. K. Nanstad, "A Proposal for Sampling the SONGS-1 Reactor Pressure Vessel," (ORNL/NRC/LTR-02/12), which incorporates the conceptual study of the scope and cost estimate to remove up to six, five-inch-diameter through-wall trepan samples from the San Onofre (SONGS) Unit 1 pressure vessel, was completed and submitted to the NRC project manager for review. Unless changes are indicated, it is anticipated that the report will be issued in final form during the next reporting period.

Task 5: Modeling & Microstructural Characterization 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 three subtasks will comprise: (1) theoretical modeling and data analysis; (2) experimental investigations; and, (3) maintaining and updating the Embrittlement Data Base (EDB). The modeling work will include the development of an improved description of primary-damage formation in irradiated materials, and the further development and use of predictive models of radiation-induced microstructural evolution and its impact on the mechanical behavior of RPV materials. The experimental component will 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 major areas of inquiry include: (a) the effects of chemical composition; (b) the role of displacement rate (neutron flux); (c) damage attenuation through the RPV wall; and, (d) potential new hardening mechanisms and embrittlement behavior at very high fluence. The overall goal

of the task is to provide an embrittlement model that can be used in a predictive way to anticipate the response of RPV materials at high fluences near or slightly beyond their nominal end-of-life, and to provide support to the NRC for related safety or licensing questions. The tools developed in this task will also be used to support the analysis of experimental results obtained in other program tasks. Both the modeling and experimental research will be coordinated with complementary activities carried out by other NRC contractors and the international community.

The nature of the modeling and data analysis carried out under this task requires that it extend over the lifetime of the program. Model development and validation is coordinated with the experimental activities in an iterative fashion. Work and milestone schedules will be contingent on available funding.

Subtask 5.1: Modeling of Damage Evolution (R. E. Stoller)

The modeling of damage evolution will focus on the development of an integrated microstructural model that includes components developed at ORNL and by other NRC contractors and will provide the basis of an improved embrittlement model. The integrated model may include thermodynamic components to account for chemical effects that may be particularly important at high-fluence and in low-copper steels. A more detailed treatment of point defect and solute clustering will also be pursued.

(Milestone 5.1.B) The NUREG report entitled *Evaluation of Neutron Energy Spectrum Effects Based on Primary Damage Simulations in Iron*, NUREG/CR-6670, (ORNL/TM-1999/334) was submitted to the NRC in July, 2000.

Subtask 5.2: Microstructural Characterization (M. K. Miller and K. F. Russell)

APFIM characterization will be used to determine whether additional radiation-induced phases are forming. 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.

(Milestone 5.2.A) In order to investigate the influence of manganese on the formation of copper-enriched precipitates, a series of atom probe tomography (APT) characterizations of Fe-0.9% Cu (VH) and Fe-0.9% Cu-1.0% Mn (VD) model alloys that were neutron irradiated at low fluences has been performed. These experiments are a continuation of previous APT and Small Angle Neutron Scattering (SANS) characterizations of these model alloys that were neutron irradiated to higher fluences of 1×10^{19} n cm⁻². In this new series of experiments, the alloys were neutron irradiated to fluences of 4×10^{17} n cm⁻² (VDA5) and 5×10^{18} n cm⁻² (VHK2 and VDK2). The specimens that were neutron irradiated to a fluence of 5×10^{18} n cm⁻² were also examined after a post irradiation anneal of 20 h at 400°C (VHK2A and VDK2A). Small copper-enriched precipitates were observed in all conditions. These APT results, together with SANS results on the same materials obtained from the UCSB group, will be presented at the International Group on Radiation Damage Mechanism (IGRDM) X meeting in Awaji Island, Japan in May 2002.

A draft NUREG report entitled, *Effect of Reirradiation Rate on The Charpy Properties of an Irradiated/Annealed High Copper Reactor Pressure Vessel Weld HSSI 73W*, that incorporates the atom probe tomography results on weld 73W specimens, has been prepared.

The NUREG report entitled, *Atom Probe Tomography Characterization of the Solute Distributions in a Neutron-Irradiated and Annealed Pressure Vessel Steel Weld*, NUREG/CR-6629, (ORNL/TM-13768), was published by the NRC in November, 2000.

Subtask 5.3: Modeling and Embrittlement Data Base (formerly 7.1) (J.-A. Wang)

This subtask was, until March 1, 1999, part of the Embrittlement DataBase (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 data bases used by vendors, utilities, and service laboratories in the pressure vessel irradiation surveillance program. The specific activity of the subtask is to maintain and update the EDB. Additional work on statistical analysis of toughness databases will also be performed. The purpose of this effort is to design a new data fitting procedure to generate a new multi-space trend surface that can properly reflect the inhomogeneity of the surveillance materials, and utilize this multi-space trend surface to link and to project the surveillance test results to that of reactor pressure vessel steels.

(Milestone 5.3.A) The completed UPDATE-11 of PR-EDB was transmitted to the US NRC technical program monitor in July 2000. No new surveillance reports have been received.

(Milestone 5.3.B) The feasibility study for developing a new fitting model is continuing and is expected to be completed by the end of February.

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

This task provides the support required to supply and co-ordinate irradiation services needed by NRC contractors (such as the UCSB and the ORNL HSSI Program) at the University of Michigan FNR. These services include the design and assembly of irradiation facilities (and/or capsules), as well as arranging for their exposure, periodic monitoring by remote computer access and interaction with the FNR staff, and return of specimens to the originating research organization.

Subtask 6.1: Operate the HSSI Irradiation (IAR) Facility (K. R Thoms and D. W. Heatherly)

With the fabrication, installation, and initial testing of the HSSI IAR facility at the University of Michigan FNR completed as part of the previous (L1098) HSSI program, the activities associated with the new program include supervising the irradiation of the reusable irradiation

capsules in the dual-capsule irradiation facility at FNR. A NUREG report on the design, assembly, installation, and operation of the HSSI IAR facility will be prepared.

(Milestone 6.1.A) Irradiation of the ORNL specimens in the HSSI-IAR 1 and 2 irradiation facilities continued for only a short time during this reporting period.

The FNR remained down during the Christmas and New Year's Holidays as scheduled. In order to minimize reactor down time during upcoming 2002 holidays, the FNR operating schedule called for the first reactor half-cycle of 2002 to begin on January 8. The reactor was started up on January 8, 2002, to begin reactor half-cycle 466B. During this period, instrumentation and control experts from the ORNL Engineering Science and Technology Division traveled to the University of Michigan FNR and performed the annual maintenance and calibration of the HSSI-UCSB and IAR control systems. The IAR computer was also replaced using funds associated with contract irradiations. The maintenance was completed during the first week of reactor half-cycle 466B allowing the HSSI-IAR irradiation facilities to be operated for the remainder of the half-cycle, which ended on January 18, 2002.

During facility startup, as half-cycle 467A had begun, several alarms were received from the IAR facilities requiring shut down of the entire facilities control system. These alarms were received from the "Watch Dog" alarm. This alarm is a redundant system that detects any abnormality in the control system. It is programmed to immediately alarm and shut the facilities down whenever it recognizes a problem in the operating system. During these occurrences, however, the alarm was received but did not shut the system down as expected. The Watch Dog system has three components that could produce alarms. These components are two relays that trigger the annunciator and the computer that controls the entire IAR facility. The computer used for control is a micro-dcs (digital control system) plus. It was initially believed that the problems encountered were due to faulty relays in the annunciator system. Replacement relays, sent to Ann Arbor, were installed by the FNR staff and the control system was monitored for 48 hours to determine if the problems had been corrected. However, during the 48-hour test of the system, multiple alarms were received from the Watch Dog system, some of which resulted in total shutdown. At this point it was determined that the faulty component in the system was the micro-dcs controller. The controller was removed from the system and shipped to ORNL for repair or replacement. It is now believe the problems were caused by a computer virus that the HSSI-IAR control system encountered when data was down-loaded through the internet. It is anticipated that the entire system will be repaired and operations of the facilities resumed as soon as possible in the next reporting period.

During the last 3.5 days of reactor half-cycle 466B, the HSSI-IAR irradiation facilities received a total of 82 EFPH (effective full power hours). At the beginning of this reporting period, the second group of specimens to be irradiated in the IAR facilities had been irradiated for a total of 9,605 EFPH. At the end of this reporting period, the second group of specimens had been irradiated for a total of 9,687 EFPH. The facilities have now been in service for a total of 14,396 EFPH.

(Milestone 6.1.B) The draft NUREG report on the reusable irradiation facilities has been prepared and is under final changes prior to submission to the NRC. A final draft copy will be sent to the NRC program monitor before the end of the next reporting period.

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

This subtask includes supervising the overall operation and providing assistance to the reactor personnel in the routine operation and maintenance of the HSSI-UCSB irradiation facility. A NUREG report on the design, assembly, installation, and operation of the UCSB facility will be prepared.

(Milestone 6.2.A) Irradiation of the UCSB specimens in the HSSI-UCSB irradiation facility continued for only a short time during this reporting period.

The FNR remained down during the Christmas and New Year's Holidays as scheduled. In order to minimize reactor down time during upcoming 2002 holidays, the FNR operating schedule called for the first reactor half-cycle of 2002 to begin on January 8. The reactor was started up on January 8, 2002, to begin reactor half-cycle 466B. During this period, instrumentation and control experts from the ORNL Engineering Science and Technology Division traveled to the University of Michigan FNR and performed the annual maintenance and calibration of the HSSI-UCSB and IAR control systems. The maintenance was completed during the first week of reactor half-cycle 466B allowing the HSSI-UCSB irradiation facilities to be operated for the remainder of the half-cycle, which ended on January 18, 2002.

During facility startup, as half-cycle 467A had begun, several alarms were received from the IAR facilities requiring shut down of the entire facilities control system. The system remained shut down at the end of this reporting period while efforts were underway to correct the problems with the companion HSSI-IAR facilities control system. At this time it is believed the problems were caused by a computer virus which the HSSI-IAR control system received from the internet. For more details see Milestone 6.1.A.

During the last 3.5 days of reactor half-cycle 466B, the HSSI-UCSB irradiation facility received a total of 82 EFPH (effective full power hours). The facility remained shut down during the following half-cycle so the total received during this reporting period was 82 EFPH.

At the beginning of this reporting period, the HSSI-UCSB facility and original specimen complement had been irradiated for a total of 21,466 EFPH. At the end of this reporting period, the irradiation facility and original specimen complement had been irradiated for a total of 21,548 EFPH. The latest irradiation plan received from the UCSB experimenters indicated that the final specimens would be removed from the UCSB facility after 13,500 EFPH. Additional specimen irradiations have been added to the original plan and at the end of this reporting period the UCSB irradiation program had obtained 159.6% of the original desired irradiation time.

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

This task was until March 1, 1999, the Embrittlement DataBase (EDB) and Dosimetry Evaluation Program, JCN: 6164. The objectives of the two subtasks listed below have been reduced but the focus remains the same. Nuclear radiation embrittlement information from radiation embrittlement research on nuclear RPV steels and from power-reactor surveillance reports will be maintained in a database to be published on a periodic basis. The information

will assist the Office of Nuclear Reactor Regulation and the Office of Nuclear Regulatory Research to effectively monitor current procedures and data bases used by vendors, utilities, and service laboratories in the pressure vessel irradiation surveillance program. It will also provide technical expertise and analysis to the NRC regarding dosimetry and transport calculations and methodologies.

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

The purpose of the subtask is to maintain and update the EDB.

This task has been incorporated into Task 5.3

Subtask 7.2: Dosimetry Evaluation (I. Remec)

Technical expertise and analysis regarding dosimetry and transport calculations and methodologies will be provided as needed to the US NRC. Specifically, work will be performed to complete the review of, and hold final discussions with the NRC concerning, the dosimetry guide, DG-1053.

This activity was eliminated as directed by SOEW 60-99-356.

• **MEETINGS AND TRIPS:**

On January 16, 2002, Mr. Shunichi Hatano of the Tokyo Research and Development Center, Japan Power Engineering and Inspection Corporation (JAPEIC) and the Nuclear Power Plant Integrated Management Technology (PLIM) Project visited the HSSI Program to discuss embrittlement predictions for low upper-shelf energy pressure vessel steels.

On January 20-23, R. K. Nanstad, M. A. Sokolov, and R. E. Stoller traveled to Dallas, Texas, to participate in ASTM meetings.

On January 24, Enrico Lucon of SCK-CEN, Mol, Belgium, visited ORNL Metals and Ceramics Division staff members and gave an overview on current SCK-CEN activities on RPV steels.

4. PRESENTATIONS, REPORTS, PAPERS, AND PUBLICATIONS:

R. E. Stoller and R. K. Nanstad, *A Proposal for Sampling the SONGS-1 Reactor Pressure Vessel* (ORNL/NRC/LTR-02/12) draft submitted to the 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.

Item

Cost (\$)

None

6. PROBLEM AREAS:

None

7. PLANS FOR THE NEXT REPORTING PERIOD:

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

FINANCIAL STATUS
for W6953

Reporting Period: 12/24/01-1/27/01

	Current Month	Fiscal Year to Date	Cumulative Project to date
I. Direct Staff Effort	12 MM	2.7 MY	41.1 MY
II. A. Direct Lab Staff Effort (\$)			
Direct Salaries	83,626	269,464	4,114,346
Materials and Services	1,658	6,194	393,639
ADP Support	21	116	2,320
Subcontracts	5,971	72,084	572,281
Travel	3,045	9,437	152,305
Other: NRC-PO Tax	3,854	9,351	183,851
General and Administrative	40,167	126,992	1,862,195
 Total UT-Battelle Costs	 138,342	 493,638	 7,280,937
B. DOE Federal Admin. Costs	4,150	14,809	56,722
 TOTAL PROJECT COSTS	 142,492	 508,447	 7,337,659
 Percentage of available cumulative funds costed		88	
Percentage of available current FY funds costed		35	
Funds Remaining		967,341	
Commitments:		166,697	
BA Remaining		800,644	
BA Remaining Less Projected FAC		772,469	

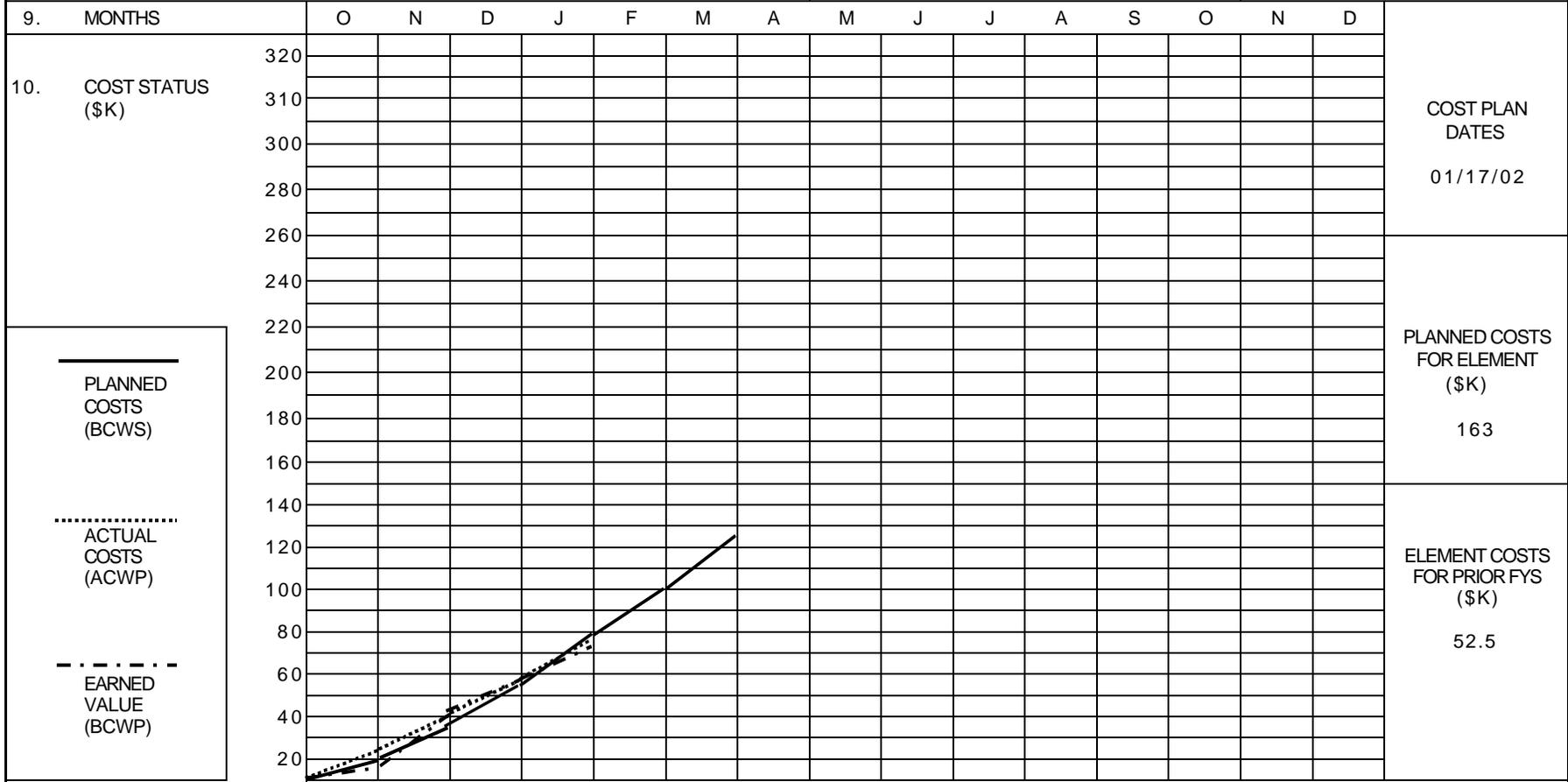
III. Funding Status

Prior FY Carryover	FY 02 Projected Funding Level	FY 02 Funds Received to Date	FY 01 Funding Balance Needed	Cumulative Amt. Obligated	Cumulative Amt. Costed
514,538	2,225,000	946,000	1,279,000	8,305,000	7,337,659

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 12/24/2001 - 1/27/2002					3. JCN NO. W6953						
4. CONTRACTOR (NAME AND ADDRESS) OAK RIDGE NATIONAL LABORATORY P. O. BOX 2008 OAK RIDGE, TN 37831										5. CONTRACT PERIOD FY 1998 - 2003					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 01/17/02 PLANNED COSTS FOR ELEMENT (\$K) 1460 ELEMENT COSTS FOR PRIOR FYS (\$K) 280 514				
2000																					
1900																					
1800																					
1700																					
1600																					
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1200																					
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500																					
400																					
300																					
200																					
100																					
ACCRUED COSTS (\$K)	PLANNED	126	126	129	198	157	152	0	0	0	0	0	0	0	0	0					
	ACTUAL	77	97	181	139	0	0	0	0	0	0	0	0	0	0	0					
	EARNED	105	128	131	143	0	0	0	0	0	0	0	0	0	0	0					
	CUM. PLANNED	126	252	381	579	736	888	0	0	0	0	0	0	0	0	0					
	CUM. ACTUAL	77	174	355	494	0	0	0	0	0	0	0	0	0	0	0					
CUM. EARNED	105	233	364	507	0	0	0	0	0	0	0	0	0	0	0						
11. REMARKS Total/Planned Cost reflects reduction in funds received due to FAC.																					

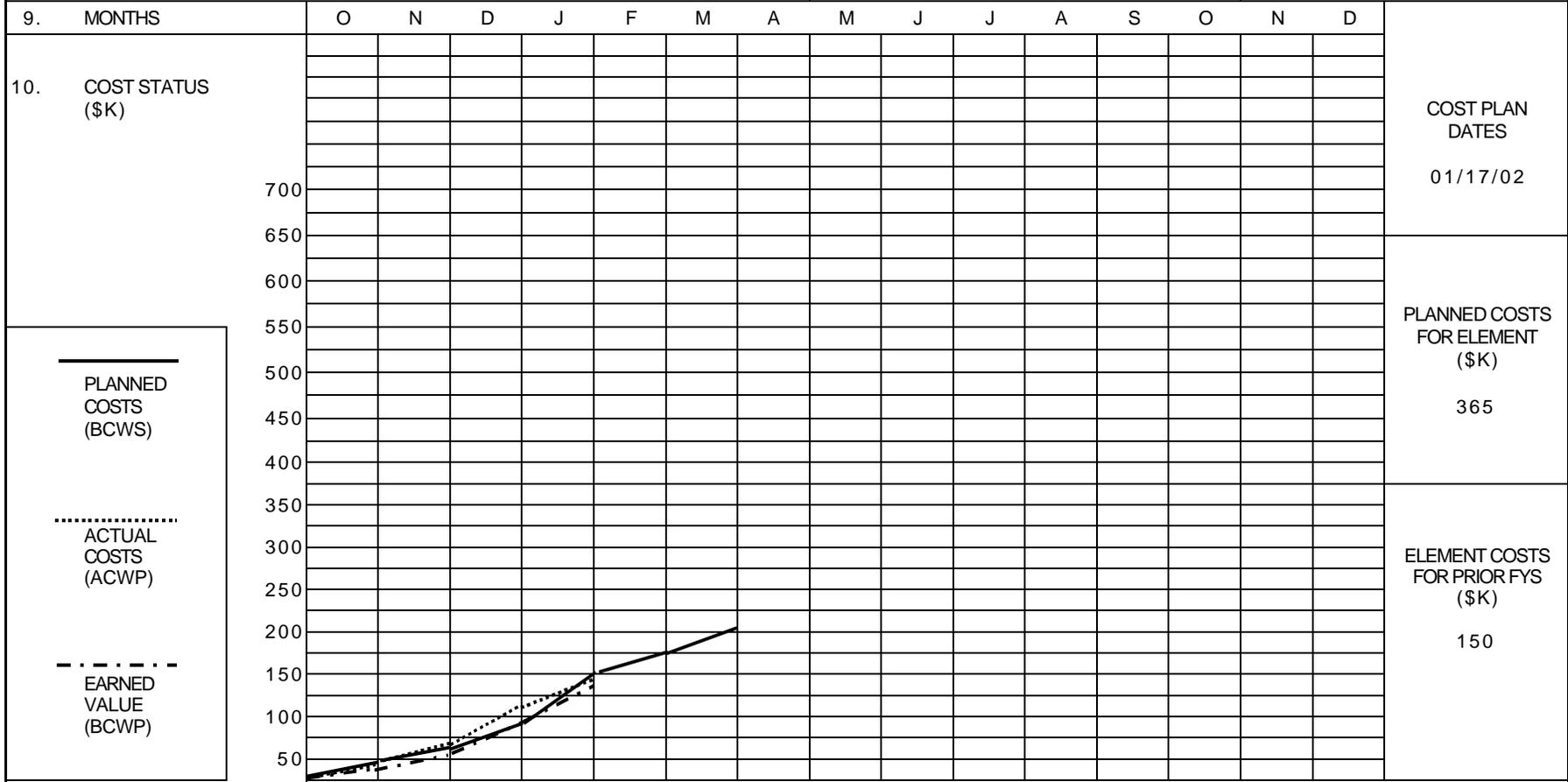
1. CONTRACT REPORTING ELEMENT HSSI - 1. Program Management	2. REPORTING PERIOD 12/24/2001 - 1/27/2002	3. JCN NO. W6953
4. CONTRACTOR (NAME AND ADDRESS) OAK RIDGE NATIONAL LABORATORY P. O. BOX 2008 OAK RIDGE, TN 37831	5. CONTRACT PERIOD FY 1998 - 2003	6. ACTIVITY NUMBER W41 W5 85 3W 1
	7. NRC B&R NO. 860 15 21 20 05	8. DOE B&R NO. 40 10 01 06



ACCRUED COSTS (\$K)	PLANNED	ACTUAL	EARNED	CUM. PLANNED	CUM. ACTUAL	CUM. EARNED										
	18	16	19	24	23	23	0	0	0	0	0	0	0	0	0	0
	22	18	17	21	0	0	0	0	0	0	0	0	0	0	0	0
	15	25	13	18	0	0	0	0	0	0	0	0	0	0	0	0
	18	34	53	77	100	123	0	0	0	0	0	0	0	0	0	0
	22	40	57	78	0	0	0	0	0	0	0	0	0	0	0	0
	15	40	53	71	0	0	0	0	0	0	0	0	0	0	0	0

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

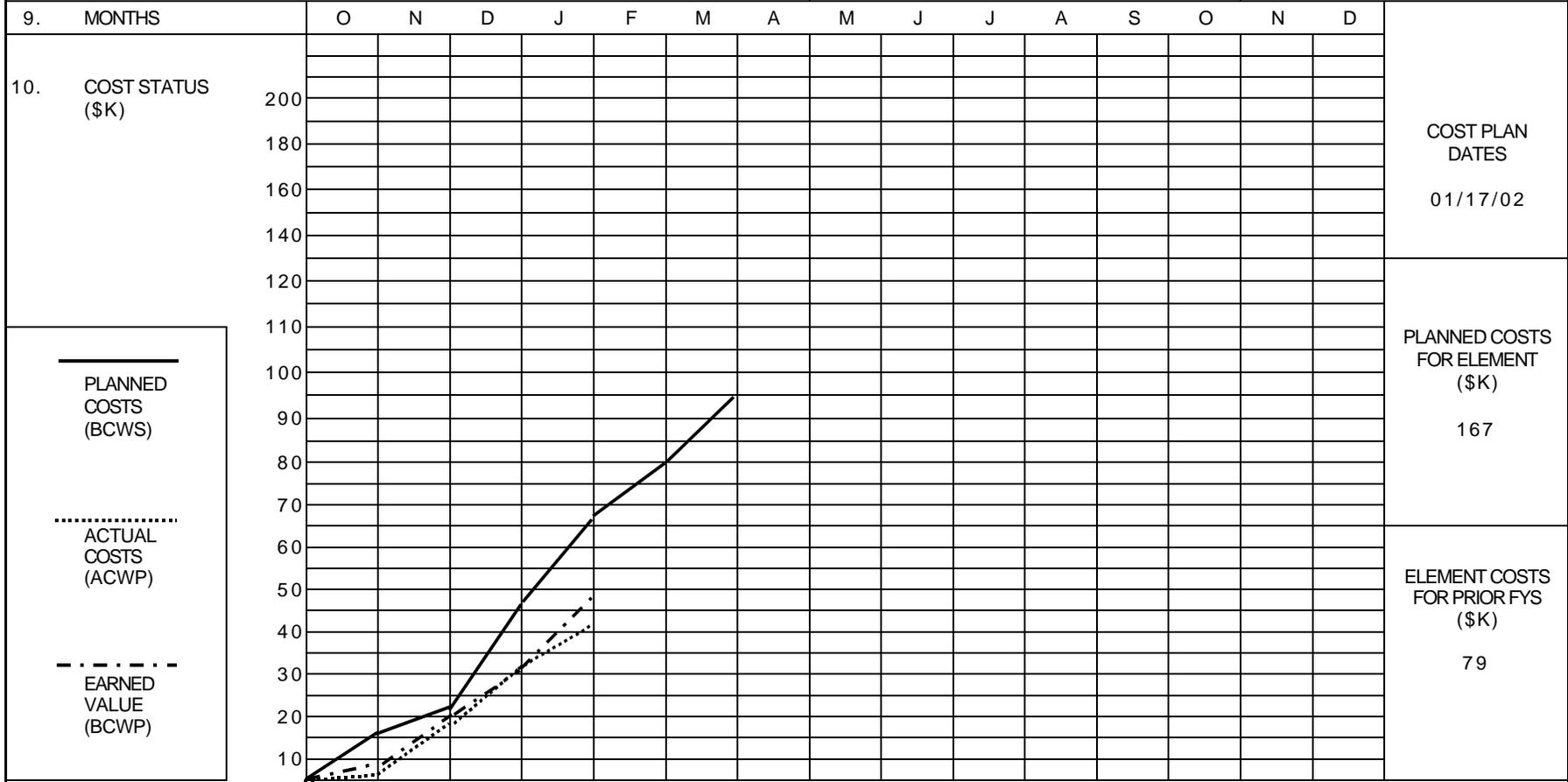
1. CONTRACT REPORTING ELEMENT HSSI - 2. Fracture Toughness Transition and MC Methodology	2. REPORTING PERIOD 12/24/2001 - 1/27/2002	3. JCN NO. W6953
4. CONTRACTOR (NAME AND ADDRESS) OAK RIDGE NATIONAL LABORATORY P. O. BOX 2008 OAK RIDGE, TN 37831	5. CONTRACT PERIOD FY 1998 - 2003	6. ACTIVITY NUMBER W41 W5 85 3W 1
	7. NRC B&R NO. 860 15 21 20 05	8. DOE B&R NO. 40 10 01 06



ACCRUED COSTS (\$K)	PLANNED	ACTUAL	EARNED	CUM. PLANNED	CUM. ACTUAL	CUM. EARNED										
	36	31	31	37	38	38	0	0	0	0	0	0	0	0	0	0
	32	41	28	41	0	0	0	0	0	0	0	0	0	0	0	0
	25	30	41	26	0	0	0	0	0	0	0	0	0	0	0	0
	36	67	98	135	173	211	0	0	0	0	0	0	0	0	0	0
	32	73	101	142	0	0	0	0	0	0	0	0	0	0	0	0
	25	55	96	122	0	0	0	0	0	0	0	0	0	0	0	0

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

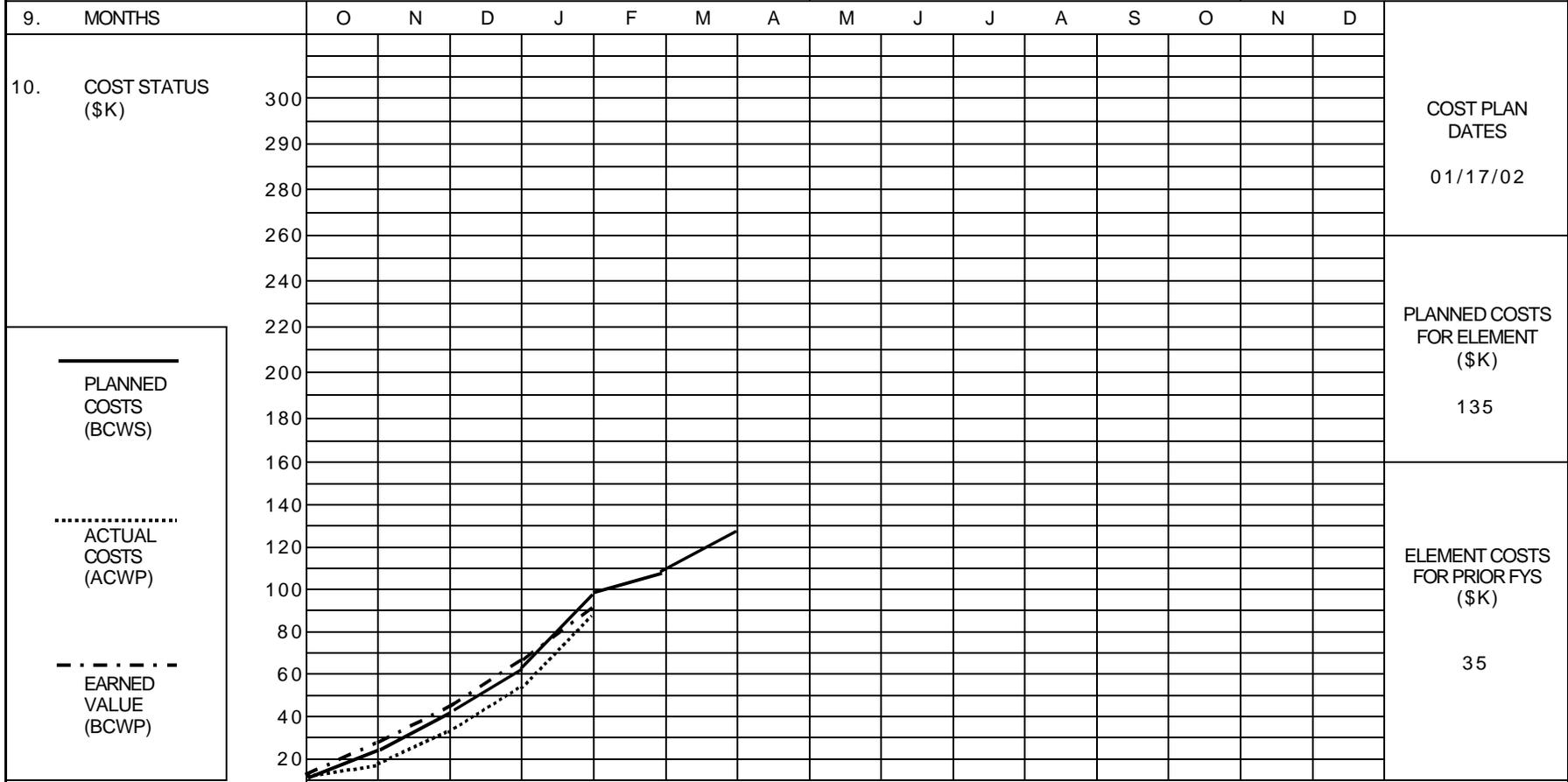
1. CONTRACT REPORTING ELEMENT HSSI - 4. Validation of Irradiated and Aged Materials	2. REPORTING PERIOD 12/26/2001 - 1/27/2002	3. JCN NO. W6953
4. CONTRACTOR (NAME AND ADDRESS) OAK RIDGE NATIONAL LABORATORY P. O. BOX 2008 OAK RIDGE, TN 37831	5. CONTRACT PERIOD FY 1998 - 2003	6. ACTIVITY NUMBER W41 W5 85 3W 1
	7. NRC B&R NO. 860 15 21 20 05	8. DOE B&R NO. 40 10 01 06



ACCRUED COSTS (\$K)	PLANNED	16	16	15	19	14	26	0	0	0	0	0	0	0	0	0	0
	ACTUAL	4	14	14	10	0	0	0	0	0	0	0	0	0	0	0	0
	EARNED	9	11	1	19	0	0	0	0	0	0	0	0	0	0	0	0
	CUM. PLANNED	16	22	47	66	80	95	0	0	0	0	0	0	0	0	0	0
	CUM. ACTUAL	4	18	32	42	0	0	0	0	0	0	0	0	0	0	0	0
	CUM. EARNED	9	20	31	50	0	0	0	0	0	0	0	0	0	0	0	0

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

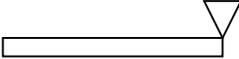
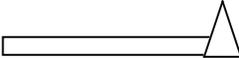
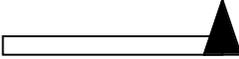
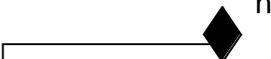
1. CONTRACT REPORTING ELEMENT HSSI - 6. Irradiation Coordination	2. REPORTING PERIOD 12/24/2001 - 1/27/2002	3. JCN NO. W6953
4. CONTRACTOR (NAME AND ADDRESS) OAK RIDGE NATIONAL LABORATORY P. O. BOX 2008 OAK RIDGE, TN 37831	5. CONTRACT PERIOD FY 1998 - 2003	6. ACTIVITY NUMBER W41 W5 85 3W 1
	7. NRC B&R NO. 860 15 21 20 05	8. DOE B&R NO. 40 10 01 06



ACCRUED COSTS (\$K)	PLANNED	23	18	23	35	14	16	0	0	0	0	0	0	0	0	0
	ACTUAL	15	17	20	37	0	0	0	0	0	0	0	0	0	0	0
	EARNED	26	19	22	26	0	0	0	0	0	0	0	0	0	0	0
	CUM. PLANNED	23	41	64	99	113	129	0	0	0	0	0	0	0	0	0
	CUM. ACTUAL	15	32	52	89	0	0	0	0	0	0	0	0	0	0	0
	CUM. EARNED	26	45	67	93	0	0	0	0	0	0	0	0	0	0	0

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 HSSI - 2. Fracture Toughness Transition & MC Methodology		2. REPORTING PERIOD 12/24/2001 - 1/27/02		3. JCN NO. W6953																															
4. CONTRACTOR (NAME AND ADDRESS) OAK RIDGE NATIONAL LABORATORY P. O. BOX 2008 OAK RIDGE, TN 37831		5. CONTRACT PERIOD FY 1998-2003		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	FY 2001		FY 2002		FY 2003																													
		O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
2.1.A.	Continue to accumulate data on Comparison of CVN and Fracture Toughness Shifts	[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]													
2.2.A.	Irradiate Midland and Hi-Ni Specimens	[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]													
2.2.B.	Receive Specimens	[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]													
2.2.C.	Test Unirradiated & Irradiated KSØ1 for Master Curve	[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]													
2.2.D.	Test Unirradiated & Irradiated Hi-Ni Midland Weld Specimens	[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]													
2.2.E.	Draft Letter and NUREG Report for KSØ1	[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]													
2.2.F.	Draft Letter and NUREG Report for Midland Weld	[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]													
2.2.G.	Draft Letter and NUREG Report for High Ni	[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]		[Shaded bar]													
		O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
		FY 2001				FY 2002				FY 2003																									
11. REMARKS																																			

