ORNL/TM-12294/V3

OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA

SCALE-4 Analysis of Pressurized Water Reactor Critical Configurations: Volume 3 — Surry Unit 1 Cycle 2

S. M. Bowman
O. W. Hermann

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

ORNL/TM-12294/V3

Computational Physics and Engineering Division

SCALE-4 ANALYSIS OF PRESSURIZED WATER REACTOR CRITICAL CONFIGURATIONS: VOLUME 3 — SURRY UNIT 1 CYCLE 2

S. M. Bowman
O. W. Hermann

Date Completed: January 1995
Date Published: March 1995

Prepared under the direction of
Sandia National Laboratories
under Memorandum Purchase Orders 66-0162 and AD-4072
with Oak Ridge National Laboratory

Prepared by the
OAK RIDGE NATIONAL LABORATORY
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

Table **Page**

ABSTRACT

The requirements of ANSI/ANS 8.1 specify that calculational methods for away-from-reactor criticality safety analyses be validated against experimental measurements. If credit for the negative reactivity of the depleted (or spent) fuel isotopics is desired, it is necessary to benchmark computational methods against spent fuel critical configurations. This report summarizes a portion of the ongoing effort to benchmark away-from-reactor criticality analysis methods using selected critical configurations from commercial pressurized-water reactors.

The analysis methodology selected for all the calculations in this report is based on the codes and data provided in the SCALE-4 code system. The isotopic densities for the spent fuel assemblies in the critical configurations were calculated using the SAS2H analytical sequence of the SCALE-4 system. The sources of data and the procedures for deriving SAS2H input parameters are described in detail. The SNIKR code module was used to extract the necessary isotopic densities from the SAS2H results and to provide the data in the format required by the SCALE criticality analysis modules. The CSASN analytical sequence in SCALE-4 was used to perform resonance processing of the cross sections. The KENO V.a module of SCALE-4 was used to calculate the effective multiplication factor (k_{eff}) of each case. The SCALE-4 27-group burnup library containing ENDF/B-IV (actinides) and ENDF/B-V (fission products) data was used for all the calculations.

This volume of the report documents the SCALE system analysis of two reactor critical configurations for Surry Unit 1 Cycle 2. This unit and cycle were chosen for a previous analysis using a different methodology because detailed isotopics from multidimensional reactor calculations were available from the Virginia Power Company. These data permitted a direct comparison of criticality calculations using the utility-calculated isotopics with those using the isotopics generated by the SCALE-4 SAS2H sequence. These reactor critical benchmarks have been reanalyzed using the methodology described above. The two benchmark critical calculations were the beginning-of-cycle (BOC) startup at hot, zero-power (HZP) and an end-of-cycle (EOC) critical at hot, full-power (HFP) critical conditions. These calculations were used to check for consistency in the calculated results for different burnup, downtime, temperature, xenon, and boron conditions. The k_{eff} results were 1.0014 and 1.0113, respectively, with a standard deviation of 0.0005.

1. INTRODUCTION

In the past, criticality analysis of pressurized-water-reactor (PWR) fuel in storage or transport has assumed that the fuel is fresh with the maximum allowable initial enrichment. This assumption has led to the design of widely spaced and/or highly poisoned storage and transport arrays. If credit is assumed for fuel burnup, more compact and economical arrays can be designed. Such reliance on the reduced reactivity of spent fuel for criticality control is referred to as "burnup credit." If burnup credit is applied in the design of a cask for use in the transport of spent light-water-reactor (LWR) fuel to a repository, a significant reduction both in the cost of transport and in the risk to the public can be realized.[1] These benefits caused the U.S. Department of Energy (DOE) to initiate a program to investigate the technical issues associated with burnup credit in spent fuel cask design. These efforts have been led by Sandia National Laboratories (SNL) and carried out as part of the Cask Systems Development Program within the Office of Civilian Radioactive Waste Management. This four-volume report documents work performed at Oak Ridge National Laboratory (ORNL) as part of a larger effort to demonstrate an acceptable approach for validating computational tools to be used in burnup credit cask design.

The computational tools of interest for burnup credit cask design are initially those currently used and accepted for spent fuel characterization (prediction of isotopics) and criticality safety (prediction of the effective multiplication factor, k_{eff}) in away-from-reactor (AFR) applications. The criticality analysis tools accepted for fresh fuel cask design have typically been validated per the requirements of the ANSI/ANS-8.1 criticality safety standard[2] (i.e., comparison against experimental data). Numerous critical experiments for fresh PWR-type fuel in storage and transport configurations exist and can be used as part of a validation data base. However, there are no critical experiments with burned PWR-type fuel in storage and transport configurations that can be directly used to extend the data base to the realm of burned fuel. Thus, as part of the effort to extend the validation of existing criticality analysis tools to the domain of burned fuel, it was decided to investigate the performance of AFR analysis methods in the prediction of measured reactor critical configurations. Even though elements of a reactor critical analysis do not directly correspond to analyses of spent fuel assemblies in transportation and storage casks (e.g., elevated temperatures in reactor configurations or poison plates in cask designs), comparison against measured critical configurations can be used to validate aspects of spent fuel cask configurations that are not addressed in other experiments (i.e., fission-product interactions and the prediction of time-dependent actinide and fission-product inventories). Reactor critical configurations contain a diverse range of nuclides, including fissile and fertile actinides, fission products, and activation products. Thus, nuclear reactor core criticals can be used to test an analysis methodology's ability to generate accurate burned fuel isotopics and handle the reactivity effects of complex heterogeneous systems containing burned fuel.

This report describes the data and procedures used to predict the multiplication factor for several measured critical core configurations using a select set of AFR analysis codes. The analyses were performed for precise state points at beginning of cycle (BOC) (mixture of fresh and burned fuel) and at measured state points throughout the cycle depletion (all burned fuel). Self-consistency among the reactor criticals in the prediction of k_{eff} will allow the determination of the bias of the approach taken in representing the effect of those materials not present in fresh fuel.

To date, the SCALE code system[3] developed at ORNL has been the primary computational tool used by DOE to investigate technical issues related to burnup credit.[4] SCALE is a well-established code system that has been widely used in AFR applications for spent fuel characterization via the SAS2H/ORIGEN-S analysis sequence[5] and criticality safety analyses via the CSAS/KENO V.a analysis sequence.[6] The isotopic composition of the spent fuel is derived from a SAS2H/ORIGEN-S calculation that simulates two-dimensional (2-D) effects in a one-dimensional (1-D) model of an LWR fuel assembly. The depletion model is a spatially independent point model using cross sections and neutron flux parameters derived from the 1-D fuel assembly model. The KENO V.a Monte Carlo code[7] is used to calculate the neutron multiplication factor for complex multidimensional systems. KENO V.a has a large degree of flexibility in its geometrical modeling capabilities which enables spent fuel arrays and container geometries to be modeled in explicit detail. The SCALE-4 27-group burnup library containing ENDF/B-IV (actinides) and ENDF/B-V (fission products) data was used for all calculations.

Early efforts to analyze reactor criticals[8] using the SCALE modules concentrated on using utility-generated isotopic data, although some analyses were performed using isotopics calculated with SAS2H. Based on this initial work, a consistent SCALE-based analysis methodology that simplifies both the data requirements and the calculational procedure was developed. The criteria used to select the reactor critical configurations were (1) applicability to the PWR fuel to be used in burnup credit cask design (e.g., long downtimes for decay of short-lived isotopes, large percentages of burned fuel in the configuration), the need to verify consistency in calculated results for different reactor conditions, and the need to provide a comparison with the results of ref. 5. Acceptable performance of the SCALE system in the prediction of k_{eff} will be judged relative to established SCALE performance for fresh fuel systems; if agreement is seen within the range typical for fresh fuel systems, then it will be concluded that the methodology described herein is valid in terms of its treatment of depletion and decay calculations and fission-product interactions, within the range of application defined by the reactor conditions.

The purpose of this volume of the report is to describe the reanalysis of two reactor critical configurations from Virginia Power's Surry Unit 1 Cycle 2 that were previously analyzed in ref. 8. These cases were originally selected because of the availability of the operating data and the three-dimensional (3-D) calculated nuclide density distributions from the utility's reactor physics calculations. The revised methodology was first validated by comparison to three reactor critical configurations from Tennessee Valley Authority's Sequoyah Unit 2 Cycle 3 in Vol. 2 of this report. Differences of approximately 1 to 2.5% Δk were observed between the results of the original and revised methodologies. To investigate these differences further, the Surry reactor criticals have been reanalyzed using the revised SCALE methodology. The two benchmark critical calculations were the BOC startup at HZP and EOC operation at HFP critical conditions. These calculations were used to check for consistency in the calculated results for different burnup, downtime, temperature, soluble boron, and xenon conditions.

Section 2 of this volume presents an overview of the methodology employed in the reactor critical analyses. Section 3 provides the details of the analysis performed for Surry 1 Cycle 2. The results and conclusions are discussed in Sect. 4.

2. OVERVIEW OF THE METHODOLOGY

An essential part of any analysis validation effort is to use the same codes, input options, and technical approach for the validation study as that used for the application. To this end, a straightforward calculational strategy was established that minimizes the data required to characterize the spent fuel and is appropriate for use by a cask designer performing criticality analysis for spent fuel assemblies.

The methodology applied in reactor critical analyses can be broken into five steps: (1) grouping of fuel assemblies into similar-content groups and similar-burnup subgroups; (2) calculation of burnup-dependent isotopics for each group; (3) interpolation of decay calculations from results of the previous step to obtain both individual assembly and subgroup isotopics; (4) cross-section processing based on subgroup isotopics; and (5) preparation of a KENO V.a model based on the actual core geometry, individual assembly isotopics, and subgroup-evaluated cross sections. The model developed in step 5 is used to calculate the effective multiplication factor, k_{eff}, for the reactor.

Figure 1 provides a graphical overview of these steps, showing the relationships between the data and codes used in each stage of the calculation. The first step shown in the figure represents the process of collecting assembly information from reactor documentation. Eighth-core symmetry is assumed to reduce the number of unique assemblies models, such that the burnup of each assembly in an eighth-core segment represents the average burnup of all assemblies located in the corresponding symmetric position across the core. Using the reactor information, "groups" of assemblies are identified which are of cognate background (i.e., same initial loading and burn cycles). These assembly groups are then further categorized into "subgroups" consisting of assemblies within a group with similar (±2 GWd/MTU) burnups.

The second step shown in the figure involves the calculation of isotopic contents using the decay and depletion steps of the SAS2H calculational sequence of SCALE. Calculations are performed for each assembly group based on the initial fresh fuel content and operating history of the group. Output consists of calculated isotopic contents for each of a number of user-specified timesteps.

In step three, the SNIKR code package (not a part of the SCALE system) is used to interpolate between isotopics for appropriate timesteps in order to obtain the assembly-specific isotopic contents for each assembly to be used in the KENO V.a core model. (SNIKR is a simple tool used to automate the task of extracting, interpolating, and formatting data; however, this process can be performed manually.) SNIKR is also used to calculate the isotopics for the average burnup of each assembly subgroup.

The results of step three are used in step four to create fuel pin models based on the average composition of an assembly subgroup; the CSASN sequence in SCALE is then used to calculate the problem dependent group-weighted cross sections for each subgroup. the SCALE WAX module is then used to combine all subgroup-based cross sections into a single working library, where cross-section identifiers are assigned such that each numeric identifier indicates both a specific isotope and the subgroup upon which it was based.

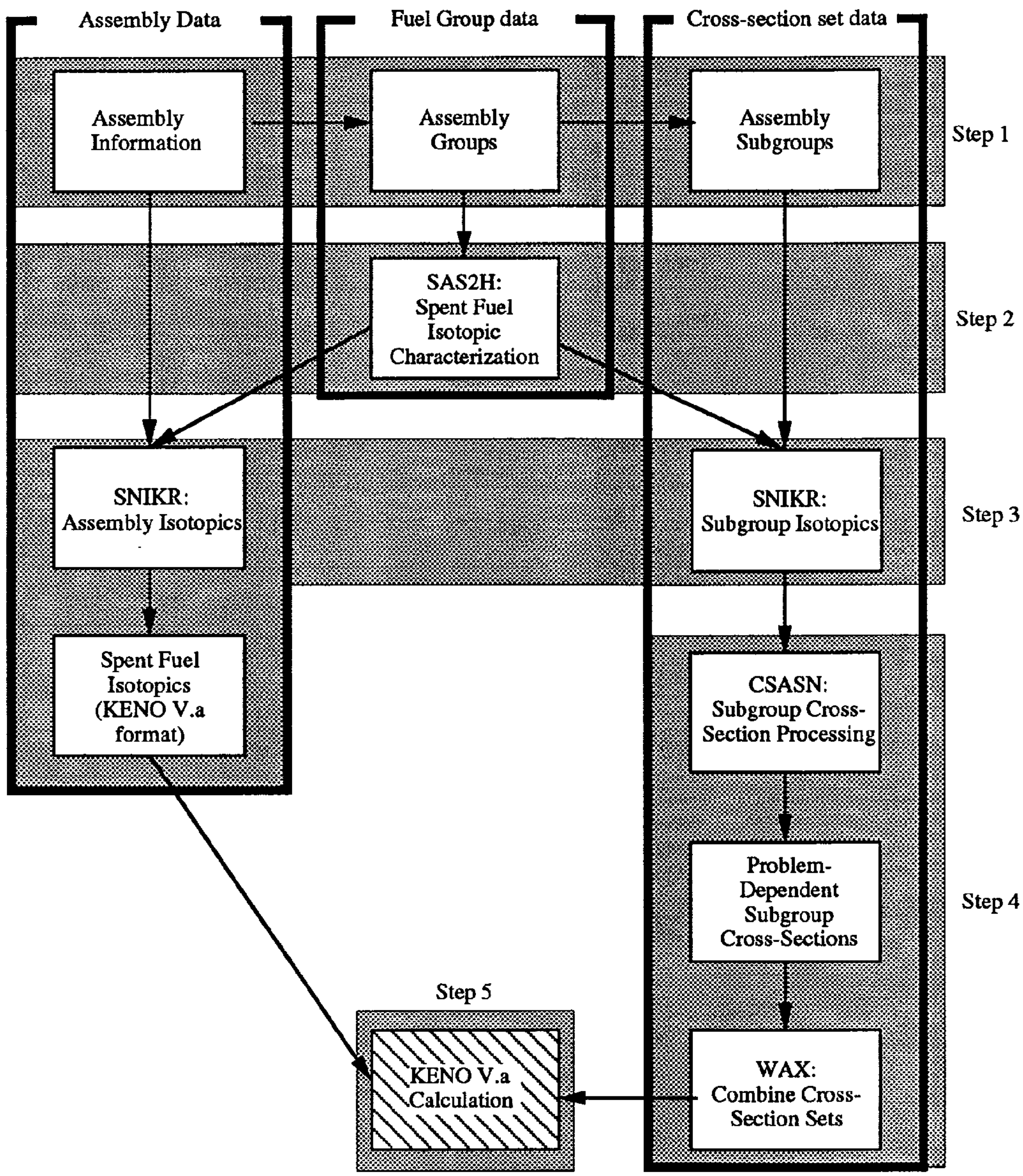

Fig. 1. Overview of the reactor critical calculation procedure.

Finally, in step five a KENO V.a model is created based on the core geometry, again assuming eighth-core symmetry. Thus, while a full-core model is prepared, each eighth-core segment of the core is identical in composition to the other eighth-core segments. (A full-core model in KENO V.a is more computationally efficient than an eighth-core model with reflective boundary conditions.) Fuel assemblies are assumed to be uniform in composition (all fuel pins are comprised of the same material), and isotopics are obtained from the burnup-specific results obtained in step 3. Assembly isotopes are assigned cross-section identifiers corresponding to the appropriate subgroup-based cross sections derived in step 4. Remaining core information is obtained from the reactor documentation. Calculations are then performed to determine the value of k_{eff} for the reactor model and to verify that the solution has converged.

The specifics of each of the steps described above are discussed in detail in each of the following sections.

2.1 FUEL ASSEMBLY GROUPS

Since many assemblies in a reactor begin with identical initial compositions and experience simultaneous operating histories, these similar fuel assemblies can be collected effectively into groups, with one depletion calculation performed for each group. It is assumed that at a given burnup, all assemblies within a group have the same isotopic content. If the isotopic content of a group is known as a function of burnup, then one can interpolate to obtain the specific isotopics for a given assembly burnup. This interpolation is discussed further in Sect. 2.3.

A minimum granularity for grouping is to collect fuel assemblies by reactor fuel batch. In the nomenclature generally applied by commercial PWR core designers, a fuel batch is typically comprised of a single enrichment fuel, all loaded at the same time, and all residing in-core for the same fuel cycles. Three fuel batches (i.e., enrichments) are usually present in the first operating cycle of a reactor. These batches are typically designated by the numbers 1, 2, and 3. Prior to each subsequent cycle of operation, one new batch of fuel is usually added and some of the depleted fuel assemblies are removed. Each new batch of fuel is assigned a number unique to that reactor. If the new fuel assemblies to be loaded consist of more than one enrichment, they may be assigned as a "split batch" using the same number with a different letter appended to each enrichment. For example, if two enrichments were to be added to Cycle 2, the fuel assemblies of one enrichment would be designated as batch 4A, and those of the other enrichment would be designated as batch 4B. Hence, if a given batch of assemblies has experienced identical operating periods, downtimes, and roughly the same power history, the batch meets the minimum requirements for a calculational fuel group. However, within a given fuel batch, additional fuel groups (i.e., separate depletion calculations) may be required when absorber materials [i.e., burnable poison rods (BPRs) or control rods] are present in certain assemblies within the fuel batch.

As discussed, within a fuel group it is possible to interpolate between a series of burnups to determine the isotopic concentrations corresponding to a specific burnup. This interpolation procedure can be used to calculate the contents of each individual assembly. Based on these assembly isotopics, it is possible to generate a content-specific cross-section set for each assembly. However, since nuclide cross sections vary slowly with burnup (after the initial startup of approximately 150 MWd/MTU), the analysis methodology can be accurately simplified by preparing problem-dependent cross sections for a set of similar assemblies with similar burnups. Unfortunately, due to specific power variations related to the assembly locations in the core, it is possible to have a relatively wide range of burnups within a single fuel group. Thus it may be necessary to divide fuel groups into subgroups or cross-section sets based on burnup such that all assemblies included in a cross-section set are within a limited burnup range; the number of cross-section sets will depend on the range of burnups contained in the fuel group. Calculations reported in Sect. 3.8 of this report indicate that cross-section sets with burnup ranges of no more than 2 GWd/MTU can be adequately represented by the average burnup value within the cross-section set.

2.2 DEPLETION CALCULATIONS

Depletion calculations were performed using the SAS2H[5] sequence of the SCALE-4 code system and the 27-group burnup library. The SAS2H sequence invokes the ORIGEN-S[9] code to perform depletion and decay calculations. The SAS2H procedure uses a 1-D, two-part spectrum calculation (part 1 is a pin-cell model, part 2 is an assembly model) at selected times in the irradiation history to generate burnup-dependent cross sections based on the given design and operating parameters. At the end of each burnup step, cross sections for default and any user-specified isotopes are reevaluated based on the new isotopic composition. The purpose of these calculations is to predict the isotopic content of each fuel group as a function of its operating history. For fuel groups comprised of fresh (unburned) fuel at the time of the critical measurements, SAS2H calculations are not necessary; the isotopic content is based on that of the fresh fuel specifications.

Although it is necessary to model the presence of BPRs for the cycle for which the criticality calculation is to be performed, previous studies[10,11] have shown that the history of the assembly with respect to the insertion and removal of BPRs in earlier reactor cycles is small enough to be neglected (<1% $\Delta k/k$). To model the influence of the BPRs in the cycle of interest, an effective cell is derived. This effective cell conserves the mass of the nuclides comprising the BPRs, guide tube, and fuel rods. In this effective cell, the densities of the isotopes remain unchanged, but the rod diameters of the glass and stainless steel in the BPRs are modified appropriately for the 1-D assembly model required by SAS2H.

Since within a fuel group it is assumed that isotopic content is a function only of burnup, it is possible to calculate the content of the fuel at a given burnup by interpolation between SAS2H/ORIGEN-S isotopics provided at each burnup step. The manner of interpolation is discussed in the following subsection. SAS2H provides the capability to obtain the isotopic composition of a fuel at specified burnup intervals given the initial composition of the fuel, clad, and moderator, design parameters of the fuel rod and lattice, and power history. In order to provide sufficient points for interpolation, the burnup history was divided into equal intervals of no more than 5 GWd/MTU. (This interval should not be confused with the 2-GWd/MTU interval used to establish assembly subgroups. The 5-GWd/MTU interval represents an interpolation range over which isotopic concentrations are assumed to vary smoothly.) The fuel groups were depleted at least 1.2 times the maximum burnup (B_{max}) of the fuel group. Note that it is generally sufficient to calculate burnups out to the maximum burnup in a group, as this will bound all burnups in the group. A value of 1.2*B_{max} was used to allow for the capability of modeling axial burnup variations where volume-averaged center region burnups may be up to 1.2 times larger than the assembly average. However, axial burnup variations are not included in the models presented in this report.

To make it possible to interpolate between burnup steps and to account for downtime between cycles, a simplification is made in the burnup model. Since the burnup actually accumulated during each cycle varies for each fuel assembly in a group, the downtime was split and applied at the end of each burnup interval. This practice ensures that the spent fuel isotopics for all fuel assemblies contain the impact of the reactor cycle downtime when interpolation on burnup is performed. The ratio of uptime to downtime for each operating cycle was used to determine the downtime for each burnup interval. Average values for specific power were computed from the fuel group average burnups and the total uptime for the cycle. The average soluble boron concentrations were based on boron letdown curves for each operating cycle. Isotopics for assembly-specific burnups may then be obtained via interpolation between calculated isotopics at the end of each burnup interval (prior to downtime). This approach is illustrated in Fig. 2. The top portion of the picture shows the "actual" burnup histories for two hypothetical assemblies in a fuel group. Note that in this example the number of cycles and downtimes are the same, but that burnup in each assembly is different within each cycle. The lower portion of the figure demonstrates how the burnup of each assembly is represented in a SAS2H depletion, using a single calculation to represent the entire fuel group. Each cycle is broken down into multiple burnup intervals, each followed by a downtime (for the first two cycles). The final cycle is calculated with a sufficient number of burnup intervals to exceed the maximum burnup (31 MWd/MTU in assembly A of Fig. 2) by 20%. The isotopics are then available at fixed time intervals, from which interpolation can be performed for assembly-specific burnups. Note that the burnup in each of the first two cycles is selected to represent average cycle burnups for the group. Any downtime immediately before the reactor critical conditions was not included in the SAS2H depletion, but was explicitly modeled as described in Sect. 2.3.

As discussed earlier, group-weighted cross sections are calculated as a function of burnup within the SAS2H sequence using flux weighting performed by XSDRNPM for each specified burnup step. Cross sections are updated for a default set of isotopes built into the SAS2H sequence, plus any additional nuclides specified by the user. Table 1 shows the default set plus 44 additional actinides and fission products specified for reactor depletion cases. Also included is oxygen, which is present in significant quanties in UO_2 fuel. These nuclides represent a combination of the most important nuclides for burnup credit calculations and for reactor physics calculations. The selection of burnup credit nuclides is based availability of experimentally measured isotopic concentrations and on sensitivity studies performed for a large number of nuclides under various spent fuel transportation/storage conditions, as described in ref. 12. The reactor physics nuclides are additional isotopes that are not important in a transportation sense, but have been determined to be important for depletion, decay, and criticality calculations under reactor operating conditions (e.g., ^{135}Xe builds in rapidly during reactor operation, but decays away with a 9.1-h half-life, and is therefore unimportant in five-year-cooled spent fuel). These nuclides were identified in earlier work.[10,13]

Any additional cross sections required for depletion calculations are obtained from the more than 1000 nuclides available within the ORIGEN-S 1-group LWR library and are adjusted with burnup using the ORIGEN-S spectral parameters (THERM, RES, and FAST)[9] calculated using fluxes calculated by XSDRNPM. The ORIGEN-S 1-group LWR library available in SCALE-4 has been

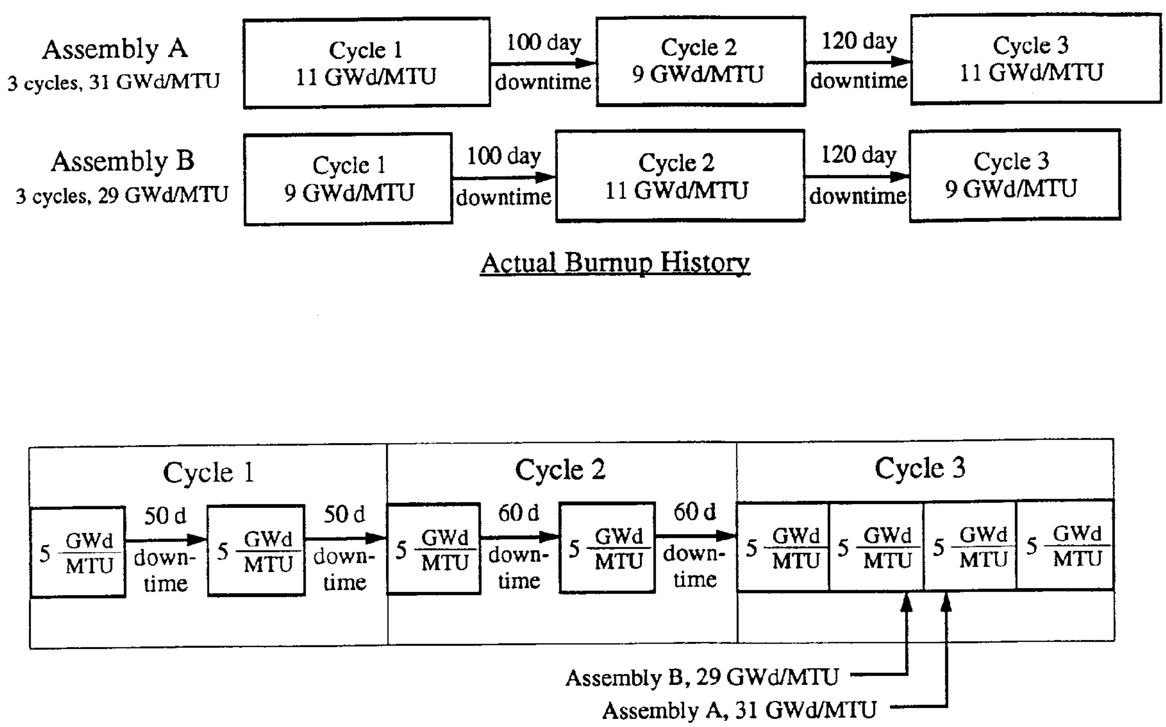

Fig. 2. SAS2H burnup model of assemblies within a fuel group.

Table 1. Nuclides updated by SAS2H

$^{234}U^a$	$^{243}Am^a$	^{94}Nb	^{132}Xe	^{145}Nd
$^{235}U^a$	$^{242}Cm^a$	$^{16}O^b$	$^{135}Xe^a$	^{147}Nd
$^{236}U^a$	$^{243}Cm^a$	^{99}Tc	^{136}Xe	^{147}Pm
$^{238}U^a$	$^{244}Cm^a$	^{101}Ru	$^{133}Cs^a$	^{148}Pm
$^{237}Np^a$	^{83}Kr	^{106}Ru	^{134}Cs	^{147}Sm
$^{238}Pu^a$	^{85}Kr	^{103}Rh	^{135}Cs	^{149}Sm
$^{239}Pu^a$	^{90}Sr	^{105}Rh	^{137}Cs	^{150}Sm
$^{240}Pu^a$	^{89}Y	^{105}Pd	^{136}Ba	^{151}Sm
$^{241}Pu^a$	^{95}Mo	^{108}Pd	^{139}La	^{152}Sm
$^{242}Pu^a$	^{93}Zr	^{109}Ag	^{144}Ce	^{153}Eu
$^{241}Am^a$	^{94}Zr	^{124}Sb	^{141}Pr	^{154}Eu
$^{242m}Am^a$	^{95}Zr	^{131}Xe	^{143}Pr	^{155}Eu
			^{143}Nd	^{155}Gd

^{a} Automatically updated by SAS2H.
^{b} Not an actinide or fission product, but present in UO_2 fuel.

updated to use cross sections from the SCALE-4 27-group burnup library for all 193 nuclides in that library, by extracting 1-group cross sections from the output of a low-burnup LWR-type fuel model using all burnup library nuclides as input.

Note that ORIGEN-S tracks all decay chains and does not account for the loss of volatile isotopes; however, this fact is not felt to have a significant effect on isotopic calculations.

2.3 NUCLIDE CONCENTRATIONS FOR REACTOR CRITICALITY CALCULATIONS

As has been indicated in previous sections, the isotopic content may be determined for each assembly or cross-section set by interpolating between burnups for which SAS2H/ ORIGEN-S depletion calculations have been performed, based on the final burnup of the fuel. The nuclide concentrations output at this point then represents a composition prior to shutdown or discharge. For a criticality condition obtained after the shutdown of the last cycle, it is necessary to perform decay calculations to account for the change in composition caused by radioactive decay during the downtime prior to criticality.

The actual number densities used in the criticality calculations are derived from the SAS2H calculation for a given fuel batch using a newly developed interface module, SAS2H Nuclide Inventories for KENO Runs (SNIKR). This module was developed to enable the user to interpolate number densities from a SAS2H calculation as a function of burnup and to perform the necessary decay calculations to model cooling time for use in spent fuel critical calculations. SNIKR has not been incorporated into SCALE at this time. Thus, input descriptions and code listings have been included in Appendix C.

The current version of SNIKR has been written to be executed as a sequence of computational routines. In the first phase, SNIKR1, burnup-dependent nuclide inventories are read from a dataset produced from a SAS2H calculation. SNIKR1 uses a Lagrangian interpolation scheme to calculate nuclide concentrations for a specified burnup. In the Lagrangian interpolation scheme, a polynomial of degree 1 less than the number of data points to be fit is used to represent the number density for each nuclide as a function of burnup. Comparisons have been made against results using nuclide concentrations calculated directly from SAS2H for a specified burnup to examine the effect of the interpolation procedure on pin-cell k_∞ (i.e., 1-D infinite-lattice calculation) values. The results of these comparisons indicated agreement to within 0.1% Δk in the k_∞ values calculated using isotopics derived from the two methods.

SNIKR1 then sets up the input needed to decay these burnup-specific isotopics to the requested cooling time using the ORIGEN-S point-depletion code. The second phase of SNIKR executes the ORIGEN-S module in the SCALE code system. Phase three, SNIKR3, reads the number densities produced by ORIGEN-S for the requested cooling time and extracts the nuclides to be used in the depleted fuel for the burnup credit criticality analysis. Number densities for these nuclides are then written to output files in the SCALE standard composition input format and the KENO V.a mixing table data format for use in CSASN and KENO V.a calculations, respectively. Typically, the term "SNIKR" is used to refer to the three-step sequence of calculations described above.

SNIKR extracts concentrations for the set of nuclides specified by the user. The set of nuclides selected for the reactor critical benchmark calculations consists of the 48 nuclides listed in Table 2. These nuclides are a subset of those in Table 1, with the exception of ^{103}Ru, ^{135}I, ^{148}Nd, and ^{149}Pm. The cross sections of these four nuclides are small enough or change slowly enough with burnup that omitting them from the cross-section update in SAS2H has a negligible effect and are therefore not needed in the SAS2H calculation. In addition to the 25 nuclides selected for use in burnup credit analysis in ref. 4, the list in Table 2 includes the other nuclides discussed in an earlier burnup credit feasibility study,[1] together with nuclides modeled explicitly in the burnup credit work of refs. 10 and 13.

2.4 CROSS-SECTION PROCESSING BY CROSS-SECTION SET

The CSASN[6] sequence of the SCALE system is used to compute problem-dependent fuel pin cross sections based on the isotopic content and geometry of a lattice fuel cell. Based on a 1-D fuel pin model, CSASN invokes BONAMI-S[14] to perform resonance shielding calculations using Bondarenko factors, followed by NITAWL-II[15] calculations to perform resolved resonance range cross-section processing using the Nordheim Integral Treatment.

CSASN cross-section processing is applied only to cross-section set-averaged nuclide concentrations. As discussed earlier in Sect. 2.1, effective cross sections are not strongly coupled to burnup; hence it is sufficient to compute cross sections for the average burnup of a cross-section set, provided the range of burnups in the cross-section set is not too large (less than 2 GWd/MTU). Nuclide concentrations for use in the CSASN calculation are provided in the SCALE standard composition format in the output from the SNIKR cross-section set calculations.

Table 2. Set of fuel nuclides used in KENO V.a calculations

$^{234}U^{a}$	$^{83}Kr^{d}$	$^{141}Pr^{b}$
$^{235}U^{a}$	$^{93}Zr^{b}$	$^{143}Nd^{a}$
$^{236}U^{a}$	$^{95}Mo^{a}$	$^{145}Nd^{a}$
$^{238}U^{a}$	$^{99}Tc^{a}$	$^{147}Nd^{c}$
$^{237}Np^{b}$	$^{101}Ru^{b}$	$^{148}Nd^{c}$
$^{238}Pu^{a}$	$^{103}Ru^{c}$	$^{147}Pm^{b}$
$^{239}Pu^{a}$	$^{103}Rh^{a}$	$^{148}Pm^{c}$
$^{240}Pu^{a}$	$^{105}Rh^{c}$	$^{149}Pm^{c}$
$^{241}Pu^{a}$	$^{105}Pd^{b}$	$^{147}Sm^{a}$
$^{242}Pu^{a}$	$^{108}Pd^{b}$	$^{149}Sm^{a}$
$^{241}Am^{a}$	$^{109}Ag^{b}$	$^{150}Sm^{a}$
$^{243}Am^{b}$	$^{135}I^{c}$	$^{151}Sm^{a}$
$^{244}Cm^{b}$	$^{131}Xe^{d}$	$^{152}Sm^{a}$
O^{a}	$^{135}Xe^{c}$	$^{153}Eu^{a}$
	$^{133}Cs^{a}$	$^{154}Eu^{b}$
	$^{134}Cs^{d}$	$^{155}Eu^{b}$
	$^{135}Cs^{a}$	$^{155}Gd^{a}$

[a] The 25 nuclides to be used in burnup credit analysis (ref. 4).
[b] Additional burnup credit nuclides from ref. 1.
[c] Additional reactor physics nuclides from Virginia Power's PDQ calculations (ref. 10).
[d] Additional reactor physics nuclides from Yankee Atomic's CASMO-3/SIMULATE-3 calculations (ref. 13).

Because fission-product nuclides represent only a small fraction of the total number density of the fuel, fission-product cross sections are relatively insensitive to the varying isotopic content and need only be calculated for one cross-section set. This situation is also true of many fuel activation products and minor actinides; however, cross sections for seven actinides are known to have a more significant burnup dependence. These isotopes, referred to as the "seven burnup-dependent actinides," are ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{239}Pu, ^{240}Pu, and ^{241}Pu. CSASN cross-section set fuel pin models include the appropriate SNIKR-computed concentrations for each of these isotopes; the remaining nuclides are included only in the highest burnup cross-section set. The highest burnup is chosen because it will result in the lowest resonance absorption, and therefore results in a higher and more conservative k_{eff}; however, the effect is extremely small ($<0.1\%$ $\Delta k/k$).

Once cross sections are computed for each cross-section set, the SCALE utility module WAX[16] is used to combine all CSASN cross-section set working libraries into a single working library for subsequent use by KENO V.a. All cross sections from the highest burnup cross-section set (containing all fission and activation isotopes) are copied into the combined library. For each of the remaining cross-section set libraries, only the seven burnup-dependent actinides are copied. In addition, for each of the seven burnup-dependent actinides in each cross-section set, the cross-section ID number is modified by prefixing the cross-section set number to the cross-section ID so that the KENO V.a core model can reference the appropriate cross section for each cross-section set. The cross sections with modified ID numbers are then copied into the combined library.

2.5 PREPARATION OF THE KENO V.a CORE MODEL

The geometry of the core model is based on the technical specifications of the core geometry; the detailed mechanics of the geometry model are discussed later. Using one-eighth core symmetry, it is possible to build a full-core model using a relatively small number of unique assemblies. For each assembly type, nuclide concentrations are obtained from assembly-specific SNIKR output in KENO V.a mixing table format; thus unique mixture data are available for each assembly type in the model. Within each set of mixing table data, the nuclide ID number of each of the seven burnup-dependent actinides is prefixed by the cross-section set number that represents that assembly (this step can be done automatically by SNIKR) so that the effective cross sections computed for the corresponding cross-section set are utilized. These cross sections are located in the working library prepared as described in the previous subsection.

3. PREPARATION OF THE SURRY 1 CYCLE 2 CORE MODEL

The previous section has given an overview of the technical procedure used in setting up the Surry 1 Cycle 2 reactor critical calculations to provide a broad overview of the entire process before concentrating on the details. This section describes the Surry 1 Cycle 2 core, then details the specifics of each step used to set up a model for this core, based on the geometry, contents, and operating history of the core. Rather than follow the five steps used previously to outline the procedure, this section will describe each distinct aspect of the process, as illustrated by the individual boxes in Fig. 1.

Discussion of the KENO V.a criticality calculation results will be provided in Sect. 4 of this report.

3.1 CORE DESCRIPTION

The Surry 1 Cycle 2 core consisted of 157 Westinghouse fuel assemblies, each comprised of a 15 × 15 lattice containing 204 fuel rods, 20 control rod guide tubes, and one instrument tube. The core configuration is shown in Fig. 3, where each square represents an assembly position. At-power reactivity control is maintained using four control banks and two shutdown banks of full-length Ag-In-Cd control rod clusters, 28 BPR clusters containing a total of 320 fresh and 48 depleted BPRs, and soluble boron. Within each assembly, the lattice positions of guide tubes and/or BPRs are located as illustrated in Fig. 4. The loading of the BPR clusters in Cycle 2 is shown in Fig. 5. Design and operating data were obtained from ref. 17.

The critical conditions modeled in this report are based on HZP conditions at BOC-2 and HFP conditions at EOC-2. The downtime between Cycles 1 and 2 was 99 days (0.271 years).

In the HZP critical at BOC and the HFP critical at EOC the control rod position for each is at or near all rods out (ARO). The ARO condition is advantageous because it reduces the complexity of the calculational model. Partially inserted control rods would require additional axial regions in the KENO V.a model, and the control rods consist of very strong localized neutron absorber materials (silver, indium, cadmium). The advantages of the HZP case are that the temperature is uniform and there is no xenon. In the HFP case, the temperature and xenon distributions are not uniform throughout the core but are a function of the relative power produced by each fuel assembly. Since this information was not available, uniform temperature and xenon distributions were assumed in the HFP KENO V.a model. The critical conditions are given in Table 3.

For BOC-2, six fuel batches were present in the core. Fuel batches 1A and 2 were manufactured with 1.9 and 2.6 wt % ^{235}U, respectively. Both batches were initially loaded in Cycle 1. Batch 4 was split into four batches—4A, 4B, 4C, and 4X—with initial enrichments of 1.9, 2.6, 3.3, and 1.9 wt % ^{235}U, respectively. Batches 4A, 4B, 4C, and 4X were initially loaded in Cycle 2. A full-core loading map and assembly burnup data for Cycle 2 are included in Appendix A. Table 4 provides a physical description of the significant aspects of the fuel design for all assemblies.

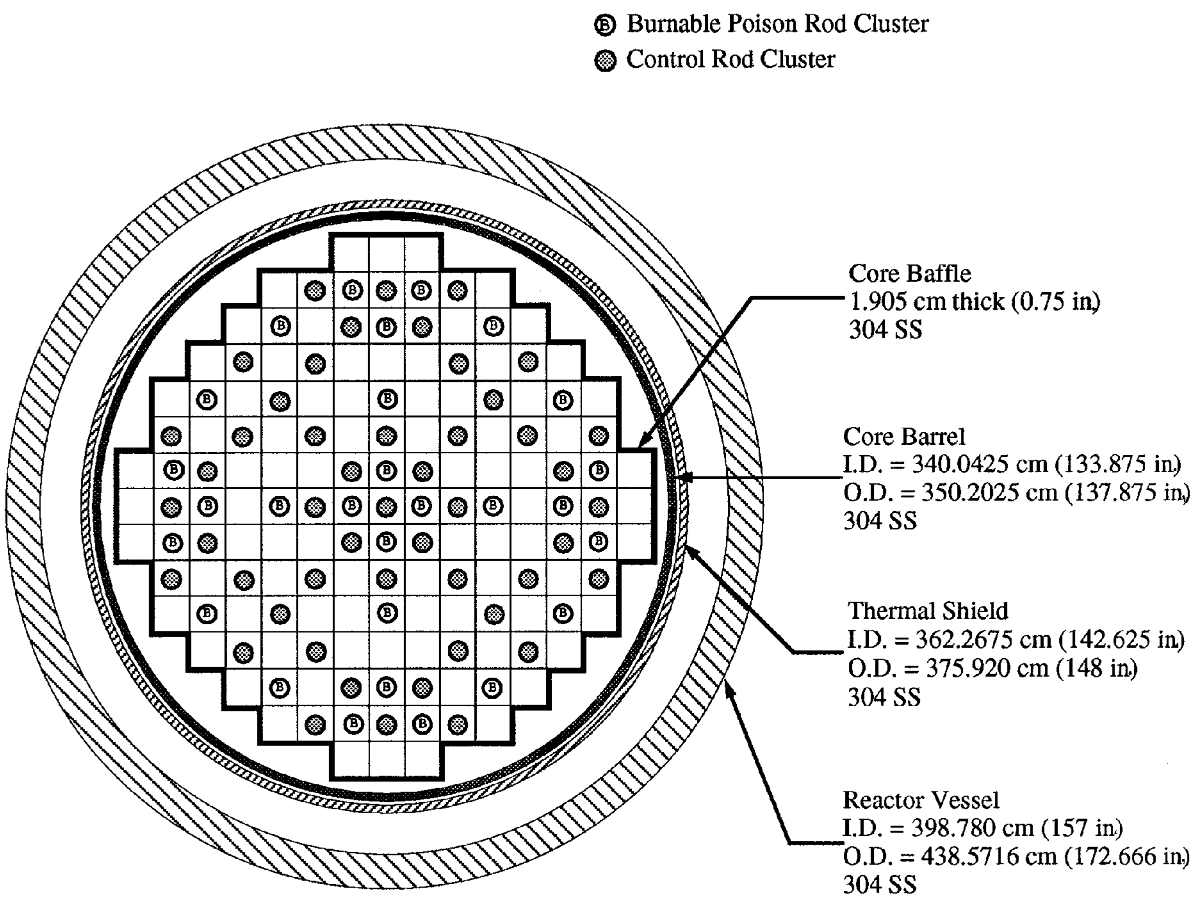

Fig. 3. Surry Unit 1 Cycle 2 core configuration.

ORNL-DWG 93M-9883

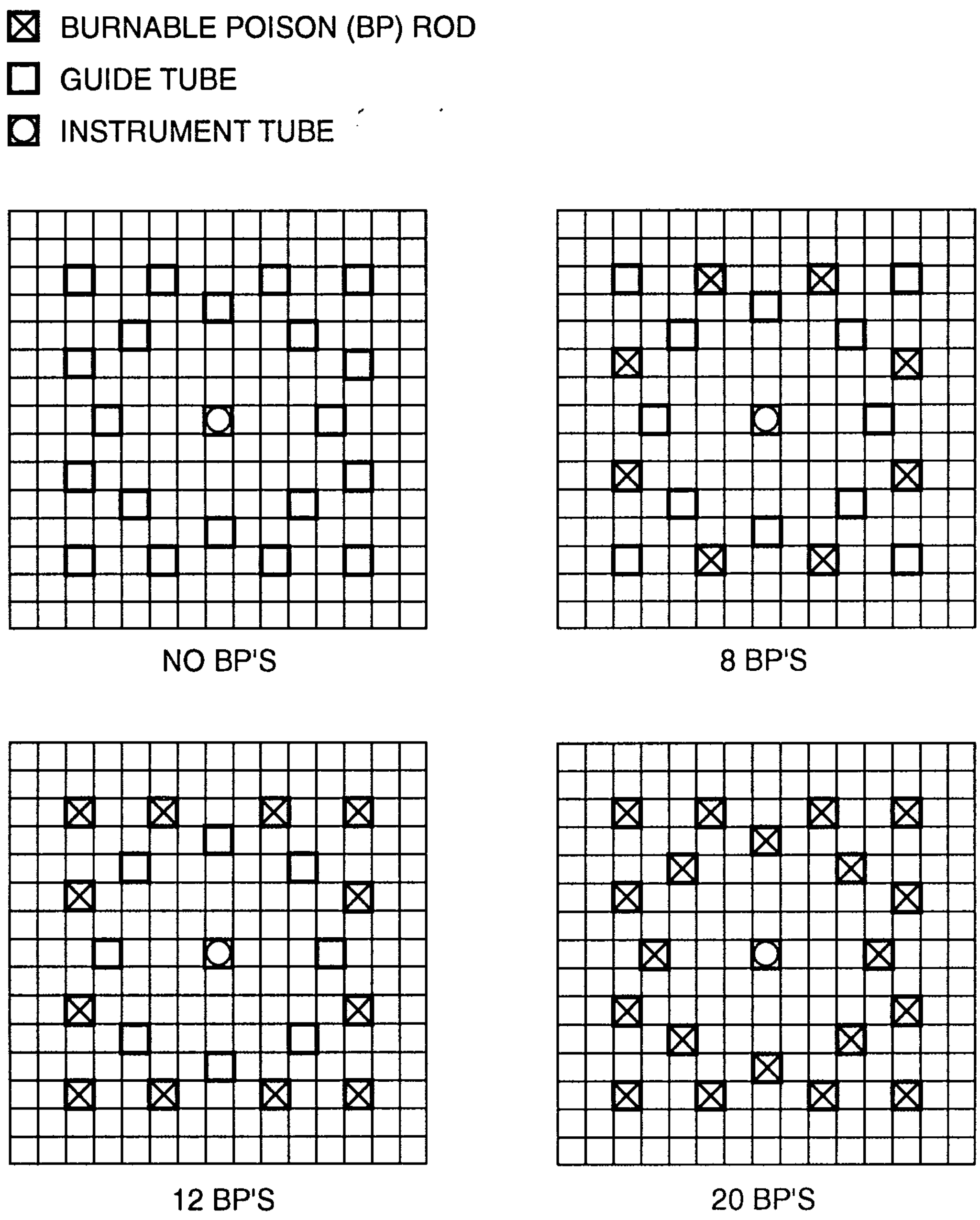

Fig. 4. Fuel assembly lattice arrangements in Surry Unit 1 Cycle 2.

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1															
2							20		20						
3					12			12*			12				
4															
5			12					8					12		
6															
7		20						8						20	
8			12*		8		8		8		8		12*		
9		20						8						20	
10															
11			12					8					12		
12															
13					12			12*			12				
14							20		20						
15															

NO. OF BP RODS
*DEPLETED

368 BP RODS
24 FRESH BP CLUSTERS
4 DEPLETED BP CLUSTERS

Fig. 5. Surry Unit 1 Cycle 2 burnable poison loading configuration.

Table 3. Surry Unit 1 Cycle 2 measured critical conditions at BOC and EOC

Time in cycle	Cycle burnup (MWd/MTU)	Power	Critical boron (ppm)	Average temp. (K)
BOC	0	HZP	1030	559
MOC	6915	HFP	123	569

Table 4. Surry PWR Unit 1 assembly design description

Parameter	Data
Assembly general data	
Number of assemblies	157
Reactor core heat output, MWt	2441
Designer	Westinghouse
Lattice	15 × 15
Number of fuel rods	204
Number of guide tubes	20
Number of instrument tubes	1
Lattice pitch, cm (in.)	21.50364 (8.466)
Fuel rod data	
Type fuel pellet	UO_2
Rod pitch, cm (in.)	1.43002 (0.563)
Rod OD, cm (in.)	1.07188 (0.422)
Rod ID, cm (in.)	0.94844 (0.3734)
Pellet diameter, cm (in.)	0.92939 (0.3659)
Active fuel length, cm (in.)	365.8 (144)
Effective fuel temperature, K (°F)	910 (1178)[a] (ref. 17)
Clad temperature, K (°F)	595 (611)[a]
Clad material	Zircaloy-4
Guide tube data	
ID, cm (in.)	1.3040 (0.5134)
OD, cm (in.)	1.3802 (0.5434)
Tube material	Zircaloy-4

[a] Average HFP value.

To simplify and reduce the volume of input in the KENO V.a model, eighth-core symmetry was assumed in the isotopic input. This assumption reduces the number of unique fuel assemblies to 26 (Fig. 6). The loading pattern for Surry Unit 1 Cycle 2 (Fig. A.1) is eighth-core symmetric.

The assembly burnups were averaged from Table A.1 for BOC and EOC based on the eighth-core symmetry shown in Fig. 6. Assembly burnups listed throughout the remainder of this report are eighth-core average values.

3.2 SAS2H FUEL GROUPS

Assemblies of a given fuel batch are generally relocated within the core between cycles, resulting in a more evenly distributed burnup among assemblies because all fuel assemblies in a batch were loaded in the core during the same operating cycles. Because all fuel assemblies in a batch are loaded in the core during the same operating cycles, each assembly in a batch experiences the same operating (uptime/downtime) history. Thus, a starting point for the process of grouping similar-content assemblies is to begin with fuel batches. As indicated in Fig. 1, assembly group information was used in the preparation of SAS2H input for depletion calculations. For BOC-2, the Surry 1 core was comprised of six fuel batches. Batch 4X, a special test batch of two 17 × 17 fuel assemblies, were included with Batch 4A, which was identical in enrichment and symmetrically loaded. Because BPR clusters were loaded in certain assemblies in batches 4B and 4C, additional subdivision of these batches was necessary. Each of these two batches were divided into two fuel groups. Batch 4B was divided into 4BB which had burned, or depleted, BPRs and 4BF, which was loaded with fresh BPRs. Batch 4C was divided into 4CF and 4CN for fuel assemblies with fresh BPR clusters and for fuel assemblies with no BPR clusters, respectively. The differences between the 1-D fuel cell model for these two types of fuel groups are discussed in Sects. 3.2.1 and 3.2.2. Each fuel group was modeled as a single unit in a SAS2H depletion calculation over the range of burnups represented by the assemblies in the group. Table 5 provides relevant information about each fuel group.

The initial uranium content of each group was determined from the initial ^{235}U enrichment of the associated fuel batch. The following empirical relationship was used to determine relative isotopic content:[18]

$$w_{234} = 0.007731(w_{235})^{1.0837},$$
$$w_{236} = 0.0046 w_{235},$$
$$w_{238} = 100 - w_{234} - w_{235} - w_{236},$$

where w is the weight percentage of the given uranium isotope. Using this formulation, the fresh fuel isotopics for all enrichments were computed. The results are given in Table 6.

In addition to the heavy-metal fuel material, light elements are also present in the fuel assembly in the fuel clad and grid. Elements whose masses are typically found to be in excess of 0.5 g/kgU, plus Mn and Co, are shown in Table 7, along with their estimated masses. These masses are required by SAS2H. They are not used in the neutronics model, but are applied in determining the (n,γ) fraction of energy per fission.

ORNL-DWG 93M-10021

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1							15	8	15						
2					24	20	14	7	14	20	24				
3				26	23	19	13	6	13	19	23	26			
4			26	25	22	18	12	5	12	18	22	25	26		
5		24	23	22	21	17	11	4	11	17	21	22	23	24	
6		20	19	18	17	16	10	3	10	16	17	18	19	20	
7	15	14	13	12	11	10	9	2	9	10	11	12	13	14	15
8	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8
9	15	14	13	12	11	10	9	2	9	10	11	12	13	14	15
10		20	19	18	17	16	10	3	10	16	17	18	19	20	
11		24	23	22	21	17	11	4	11	17	21	22	23	24	
12			26	25	22	18	12	5	12	18	22	25	26		
13				26	23	19	13	6	13	19	23	26			
14					24	20	14	7	14	20	24				
15							15	8	15						

Fig. 6. Surry Unit 1 eighth-core symmetric configuration.

Table 5. Fuel group data for EOC-2

SAS2H fuel group	Surry-1 fuel batch	No. of assemblies	Contain BPRs in Cycle 2	Cycles in-core	Av. B/U (MWd/MTU)	Min. B/U (MWd/MTU)	Max. B/U (MWd/MTU)	Enrichment (wt %)
1A2	1A2	21	No	1,2	19,792	18,501	22,094	1.868
2	2	52	No	1,2	22,584	21,427	24,144	2.573
4A	4A&4X	20	No	2	7,644	6,883	8,070	1.860
4BB	4B	4	Depleted	2	8,428	8,428	8,428	2.610
4BF	4B	8	Fresh	2	8,506	8,372	8,639	2.610
4CN	4C	36	No	2	6,047	5,100	7,334	3.330
4CF	4C	16	Fresh	2	6,958	6,487	7,429	3.330

Table 6. Initial uranium isotopic content of fresh fuel

Fuel batch	Initial U isotopes, wt %			
	^{234}U	^{235}U	^{236}U	^{238}U
1A2	0.015	1.868	0.009	98.108
2	0.022	2.573	0.012	97.393
4A	0.015	1.860	0.009	98.116
4B	0.022	2.610	0.012	97.356
4C	0.028	3.330	0.015	96.627

Each SAS2H calculation also requires specification of the temperature of each material for use in cross-section Doppler broadening corrections. However, since material and, therefore, thermal properties change with exposure, and because an assembly's peak temperature is a function of its linear heat rate, the average temperature in the fuel (and to a lesser extent the average clad temperature) will change with burnup and location. The only thermal data available were average fuel, clad, and moderator temperatures, as given in Table 4. The operating conditions varied from Cycle 1 to 2. Burnup-averaged values of moderator temperature, pressure, and density for each cycle are listed in Table 8.

3.2.1 SAS2H Fuel Cell Without BPRs

The SAS2H fuel cell model input for the four fuel groups without BPR clusters was relatively simple. Requirements included the dimensions of the fuel rod, clad, control-rod guide tube, and lattice pitch and the number of lattice positions in each fuel assembly that are not occupied by fuel rods (i.e., control rod guide tubes or instrumentation tubes). From this basic information included in Table 4, SAS2H constructed a 1-D effective assembly model consisting of a guide tube surrounded by a fuel/moderator region with a volume proportional to the fuel/guide tube volume ratio in the

Table 7. Light-element masses used in SAS2H calculations

Element	Weight (g/kgU)
O	135.0
Cr	5.9
Mn	0.33
Fe	12.9
Co	0.075
Ni	9.9
Zr	221.0
Nb	0.71
Sn	3.6

Table 8. Moderator parameters for Cycles 1 and 2

Parameter	Cycle 1	Cycle 2
Pressure, psia	2090	2250
Temperature, °F	564.8	567
Temperature, K	569	570
Density, g/cm^3	0.7331	0.7327

assembly. Cross sections for the fuel region are obtained from a pin cell calculation. More details of this default SAS2H assembly model can be found in ref. 5.

3.2.2 SAS2H Fuel Cell With BPRs

For the three fuel groups with BPR clusters (fuel groups 4BB, 4BF, and 4CF), an effective fuel cell was derived to incorporate the BPR cell together with the guide tube cell in SAS2H. In the effective cell, the densities of the isotopes or elements remained unchanged from their actual densities, but rod diameters of the glass and stainless steel in the BPRs were reduced to account for their absence in the guide tube positions. The method of deriving the effective cell was such that the various material total masses were conserved.

The composition of the borosilicate glass as modeled is listed in Table 9. The value for B_2O_3 was obtained from Vol. 2 of this report. All other data for typical borosilicate glass were obtained from ref. 19. These data and atomic weights of the elements and isotopic abundance values,[20] were applied in deriving the atomic densities of the borosilicate glass in Table 10. The glass density, 2.23 g/cm^3, was also obtained from ref. 19.

The number of BPR assemblies in fuel groups 4BB, 4BF, and 4CF and the number of assemblies having specific combinations of BPRs and guide tubes are shown in Table 11. The total number of BPRs and guide tubes for each group is also given in the table. Applying these totals and the dimensions of the BPRs, guide tubes, and lattice pitch, a set of effective unit cell dimensions were computed. The radius bounding each material was calculated from the outer to inner zone boundary for each average material volume. For example, the water moderator average volume $\bar{V}_w$ for fuel group 4BB is

$$\bar{V}_w = (48)(V_T - V_{GT} - V_{BP})/80 + (32)(V_T - V_{GT})/80 ,$$

where

V_T = total cell volume = $(\text{pitch})^2 \times (\text{length})$,
V_{GT} = guide tube volume (same as outer tube in BPR cell),
V_{BP} = BP rod total volume.

Then the inner radius of the water or the effective radius of the BP rod is

$$R_{BP} = \sqrt{(V_T - \bar{V}_w - V_{GT})/(\pi L)} ,$$

where L is the active fuel length used in computing the volumes. The guide tube dimensions remain the same because they are identical in both types of cells. Each average volume, V_{ave}, within the effective BP rod is calculated from the corresponding actual BP rod dimensions (and totals for group 4BB from Table 11):

$$V_{ave} = (48\pi L)(B^2 - A^2)/80 , \tag{1}$$

where

A = the material's inner radius in an actual BP rod,
B = the same material zone's outer radius.

Using the prior calculation of the effective outer radius, B_e, the effective inner radius, A_e is

$$A_e = \sqrt{B_e^2 - V_{ave}/(\pi L)} . \tag{2}$$

Equations (1) and (2) are used repeatedly for each material zone for the entire effective cell determination. Applying the above procedure, the effective cell mockup dimensions for the fuel groups with BPRs were computed as listed in Table 12. The densities listed in the table were used only in computing material mass for verification of data.

Table 9. Borosilicate glass composition in BPR assemblies

Compound	Weight fraction
SiO_2	0.805
B_2O_3	0.125
Na_2O	0.038
K_2O	0.004
Al_2O_3	0.022

Table 10. Borosilicate glass input atom densities[a]

Element	Isotope	Weight fraction	Density (atoms/barn·cm)
O		0.5358	0.04497
Na		0.0282	0.00165
Al		0.0116	0.00058
Si		0.3763	0.01799
K		0.0033	0.00011
B		0.03882	
	^{10}B		9.595E-4[b]
	^{10}B (depleted)		2.380E-5
	^{11}B		3.863E-3
Total		0.99402	

[a] Applying weight fractions of compounds in Table 9 and 2.23 g/cm^3 glass density.

[b] Read as 9.595×10^{-4}.

Table 11. Number of BPRs and guide tubes in fuel groups with BPRs

Fuel group	Fuel batch	Number of assemblies	Number/assembly: BP rods	Number/assembly: Guide tubes	Total number: BP rods	Total number: Guide tubes	Total number: Nonfuel[a] locations
4BB	4B	4	12	8	48	32	80
4BF	4B	8	8	12	64	96	160
4CF	4C	8	12	8	96	64	160
4CF	4C	8	20	0	160	0	160
4CF (Total)		16			256	64	320

[a] Excluding instrument tube.

Table 12. Effective fuel cells with BPRs

Zone	Material	Density (g/cm^3)	SAS2H Mixture number	Radius in cell, cm: Fuel group 4BB	Radius in cell, cm: Fuel group 4BF	Radius in cell, cm: Fuel group 4CF
1	Air	1.22E-3[a]	7	0.21457	0.17519	0.24776
2	SS-304	7.92	5	0.22705	0.18538	0.26217
3	Air	1.22E-3	7	0.23329	0.19048	0.26938
4	Glass	2.23	6	0.38017	0.31041	0.43898
5	Air	1.22E-3	7	0.38449	0.31394	0.44397
6	SS-304	7.92	5	0.42001	0.34294	0.48499
7	Mod	0.7149	3	0.65202	0.65202	0.65202
8	Zr-4	6.44	2	0.69012	0.69012	0.69012
9	Mod	0.7149	3	0.80680	0.80680	0.80680
10	Fuel	10.3682	500	2.64088	2.64088	2.64088

[a] Read as 1.22×10^{-3}.

The total material masses of the actual BP rods plus that of the guide tubes were compared with the effective cell total masses. The data were used to verify the cell dimensions. In all cases identical weights were computed for the same materials, verifying that the effective cells conserve mass.

3.3 SIMILAR-BURNUP SUBGROUPING FOR CROSS-SECTION SETS

Although the assemblies of a given fuel group are identical in terms of initial composition, time in core, and operating history, there may be a relatively broad range of burnups within a fuel group. Even though effective cross sections are felt to be insensitive to minor variations in burnups, it is necessary to set a maximum range of burnups for which an average burnup is an acceptable approximation in determining cross sections. As demonstrated in Sect. 3.8, a range of no more than 2 GWd/MTU has been found to be acceptable; this value was used in subdividing fuel groups into similar-burnup cross-section sets. As shown in Fig. 1, cross-section set information is provided to SNIKR for subsequent use in setting up CSASN calculations. CSASN is used to compute effective cross sections for each cross-section set. Since cross sections had to be calculated at BOC-2 and EOC-2, fuel groups had to be subdivided into cross-section sets at both burnups.

To determine cross-section sets for each fuel group, the fuel assembly burnups in each group were sorted and divided into subgroups where the minimum to maximum burnup range was no larger than 2 GWd/MTU. Eighth-core averaged assembly burnups are given in Table 13, along with fuel batch, SAS2H fuel group, and cross-section set information. The cross-section set groupings are shown in Table 14. Tables 15 and 16 show the cross-section sets at BOC and EOC, with the actual burnup ranges for assemblies within each cross-section set, along with the mean average burnup of all assemblies in each cross-section set. Note that except for group 4CN, no subgrouping was necessary for the fuel groups that were fresh fuel when loaded at BOC-2.

3.4 SAS2H DEPLETION CALCULATIONS

SAS2H depletion calculations were required for all fuel groups since all fuel assemblies loaded at the EOC-2 case consisted of spent fuel. In the standard composition section of the SAS2H input for each fuel group, the initial uranium isotopic contents for the UO_2 fuel were as given in Table 6. Although not initially present in the fuel, the additional 44 nuclides from Table 1 were included at an atom density of 1×10^{-20} (^{135}Xe was specified with an initial density on the order of its equilibrium concentration, since it quickly reaches this equilibrium concentration shortly after startup), indicating to SAS2H that cross sections for these isotopes should be updated at the end of each burn cycle, as discussed previously in Sect. 2.2. The remainder of the fuel pin cell was described as Zircaloy clad in water with temperature and geometry data, as specified in Table 4. The active fuel length was divided by the total weight of heavy metal in the assembly. This modification gives results in units of burnup per MTU rather than burnup per assembly. Since SAS2H uses a 1-D assembly cell model, the fuel length is arbitrary and may be used as a conversion factor.

Table 13. Fuel assembly data for eighth-core geometry

			Cross-section set		Average burnup (MWd/MTU)	
Eighth-core location	Surry fuel batch	SAS2H fuel group	BOC	MOC	BOC	MOC
1	1A2	1A2	2	2	15,316	22,094
2	4B	4BF	7	7	0	8,639
3	1A2	1A2	1	1	12,535	19,597
4	4B	4BG	7	7	0	8,373
5	2	2	4	4	15,224	22,670
6	4B	4BB	6	6	0	8,428
7	1A2	1A2	2	1	14,764	20,407
8	4C	4CN	8	9	0	6,398
9	2	2	4	4	16,280	24,144
10	4A	4A	5	5	0	8,070
11	2	2	3	3	14,128	21,879
12	2	2	4	4	15,831	22,793
13	2	2	3	3	14,371	21,427
14	4C	4CF	9	10	0	6,487
15	4C	4CN	8	8	0	5,100
16	1A2	1A2	1	1	11,553	18,501
17	4A	4A	5	5	0	7,599
18	2	2	4	4	15,787	22,535
19	1A2	1A2	2	1	14,187	19,939
20	4C	4CN	8	9	0	7,334
21	2	2	4	4	16,587	23,534
22	2	2	4	4	16,298	22,989
23	4C	4CF	9	10	0	7,429
24	4C	4CN	8	8	0	5,508
25	4A	4A	5	5	0	6,883
26	4C	4CN	8	8	0	6,072

Table 14. Cross-section sets for one-eighth core assemblies

BOC			EOC		
Cross-section set No.	Assembly No.	Burnup (MWd/MTU)	Cross-section set No.	Assembly No.	Burnup (MWd/MTU)
1	3	12,535	1	3	19,597
	16	11,553		7	20,407
	Average	12,044		16	18,501
				19	19,939
2	1	15,316		Average	19,677
	7	14,764			
	19	14,187	2	1	22,094
	Average	14,451		Average	22,094
3	11	14,128	3	11	21,879
	13	14,371		13	21,427
	Average	14,249		Average	21,653
4	5	15,224	4	5	22,670
	9	16,280		9	24,144
	12	15,831		12	22,793
	18	15,787		18	22,535
	21	16,587		21	23,534
	22	16,298		22	22,989
	Average	15,991		Average	22,998
5	10	0	5	10	8,070
	17	0		17	7,599
	25	0		25	6,883
	Average	0		Average	7,644
6	6	0	6	6	8,428
	Average	0		Average	8,428
7	2	0	7	2	8,639
	4	0		4	8,373
	Average	0		Average	8,506
8	14	0	8	14	6,487
	15	0		23	7,429
	23	0		Average	6,958
	24	0			
	26	0	9	15	5,100
	Average	0		24	5,508
				26	6,072
9	8	0		Average	5,560
	20	0			
	Average	0	10	8	6,398
				20	7,334
				Average	7,022

Table 15. Cross-section sets for Surry Unit 1 Cycle 2 BOC

Cross-section set No.	SAS2H fuel group	Enrichment	Burnable poison rods (BPR)	Average burnup	Burnup range	No. of assemblies
1	1A2	1.87	None	12,044	11,553-12,535	2
2	1A2	1.87	None	14,451	14,187-15,316	3
3	2	2.57	None	14,249	14,128-14,371	2
4	2	2.57	None	15,991	15,224-16,587	6
5	4A	1.86	None	0	0	3
6	4BB	2.61	Depleted	0	0	1
7	4BF	2.61	Fresh	0	0	2
8	4CN	3.33	None	0	0	5
9	4CF	3.33	Fresh	0	0	2

Table 16. Cross-section sets for Surry Unit 1 Cycle 2 EOC

Cross-section set No.	SAS2H fuel group	Enrichment	Burnable poison rods (BPR)	Average burnup	Burnup range	No. of assemblies
1	1A2	1.87	None	19,677	18,501-20,407	4
2	1A2	1.87	None	22,094	22,094	1
3	2	2.57	None	21,653	21,427-21,879	2
4	2	2.57	None	22,998	22,535-24,144	6
5	4A	1.86	None	7,644	6,883-8,070	3
6	4BB	2.61	Depleted	8,428	8,428	1
7	4BF	2.61	Fresh	8,506	8,372-8,639	2
8	4CN	3.33	None	5,560	5,100-6,072	3
9	4CN	3.33	None	7,022	6,398-7,334	2
10	4CF	3.33	Fresh	6,958	6,487-7,429	2

Table 17 gives the power history data used for each SAS2H fuel group. Note that a constant burnup per interval was used for each fuel group; this constant spacing is required by SNIKR when interpolating from SAS2H/ORIGEN output. Shorter burnup intervals were used for the fresh fuel loaded in Cycle 2 (batches 4A, 4B, 4C, and 4X) to have a sufficient number of data points for SNIKR to interpolate. The number of intervals for each group was chosen so that the maximum assembly burnup was exceeded by at least 20%. The average specific power for each fuel group was calculated by dividing the group average burnup by the total uptime for each cycle that the fuel was in the core. Calendar days were used for Cycle 1, whereas the effective full-power days (EFPD) were used for Cycle 2. The average power in Cycle 1, during which the reactor operated at reduced power, was appropriate. However, it should be more accurate to apply EFPD during Cycle 2 because the reactor was operating at or near full power most of the cycle (including the end of cycle), and concentrations of some of the short-lived isotopes produced by neutron capture tend to be proportional to the final power. Since the EOC-2 critical is at HFP, equilibrium conditions, these short-lived isotopes are

Table 17. SAS2H operating history data by fuel group and cycle

SAS2H fuel group	Reactor cycles	Average power (MW/MTU)	Fuel length (cm)	Actual uptime (d)	Actual downtime (d)	Number of intervals @ burnup per interval (GWd/MTU)	Modeled burn time per interval (d)	Modeled downtime per interval (d)	Cumulative burnup (GWd/MTU)
1A2	1	19.9034	799.93	680	98[b]	3@5	251.213	37.312	15
1A2	2[a]	30.6293		204[c]	0	3@5	163.242	0	30
2	1	22.7282	805.10	680	98[b]	3@5	219.991	32.675	15
2	2[a]	34.8953		204[c]	0	3@5	143.286	0	30
3	2[a]	37.4187	793.14	204[c]	0	3@4	106.898	0	12
4	2[a]	41.2579	790.63	204[c]	0	3@4	96.951	0	12
5	2[a]	41.6348	790.63	204[c]	0	3@4	96.074	0	12
6	2[a]	29.6003	792.30	204[c]	0	3@4	135.134	0	12
7	2[a]	34.0579	792.30	204[c]	0	3@4	117.477	0	12

[a] To the EOC-2.
[b] For EOC-2 case only. Modeled downtime was zero for BOC-2 case.
[c] EFPD.

important. As explained previously in Sect. 2.2, the ratio of uptime to downtime for Cycle 1 was used to determine the length of downtime following each burnup interval for the fuel in the first cycle. No downtime was applied for any of the fuel groups during Cycle 2, since the EOC-2 case occurs at HFP equilibrium conditions with no prior downtime.

A copy of the SAS2H input for fuel group 4BF is included in Appendix B. With the exception of the uranium isotopics, the burnup steps, and the BPR data, inputs for the other fuel group calculations were identical.

3.5 BURNUP-DEPENDENT INTERPOLATION OF ISOTOPICS

The atom density output files from each of the previous SAS2H calculations contain isotopic concentrations for the associated fuel group at each burnup step. Using the appropriate group output, SNIKR1 was used to interpolate between burnup intervals to estimate the isotopic concentration corresponding to the burnup of each assembly and cross-section set in the Surry 1 models at BOC-2 and EOC-2. This step was the only one necessary for the EOC-2 case, since it occurred at HFP, equilibrium conditions. For the BOC-2 case, SNIKR1 then used these isotopics (which represented nuclide concentrations at the end of the depletion prior to the critical condition at BOC-2) and prepared an ORIGEN-S decay calculation to obtain the concentration of the isotopes after the appropriate downtime of 0.271 years prior to the BOC-2 startup. After ORIGEN-S was executed, SNIKR3 read the ORIGEN-S output and prepared isotopic concentration tables in both SCALE standard composition input format and KENO mixing table format, for the selected set of isotopes listed previously in Table 2.

The SNIKR sequence consists of three codes, as previously described in Sect. 2.3, and requires two files. The first file is a SNIKR input file describing the calculation to be performed for a specific assembly or cross-section set; the second is the SAS2H output file containing the atom density data for the appropriate fuel group. SNIKR calculations are automated in a manner similar to SCALE calculational sequences such that the multistep calling of the individual code packages is transparent to the user. Appendix C lists a user input guide for SNIKR Version 1.0, which was used in these analyses, and FORTRAN listings of SNIKR1 and SNIKR3. The SAS2H and SNIKR calculations were performed on the ORNL IBM/MVS 3090 mainframe computer using SCALE-4.1.

Slightly different approaches are taken between preparation of assembly isotopics and cross-section set isotopics as the results are used in different applications. The following subsections describe each of the two methods.

3.5.1 Assembly Isotopics

In the KENO V.a model of Surry Unit 1 Cycle 2 eighth-core averaged assembly isotopics calculations are used to provide the nuclide concentrations for each assembly position. The assembly isotopics are based on the average burnup for the assembly, and all fuel rods within the assembly are assumed to possess the same isotopic composition. Hence, material numbers for each fuel rod in a given assembly are identical and correspond to a specific KENO V.a mixture number. This mixture is defined based on results of SNIKR calculations for the burnup of the corresponding assembly. In the Surry KENO V.a model, mixture numbers 101 through 126 correspond to SNIKR calculations for assemblies 1 through 26, respectively. Eighth-core averaged assembly burnups are given in Table 13, along with fuel group and cross-section set information.

Sample SNIKR input files for BOC and EOC are listed in Tables D.1 and E.1, respectively. As discussed earlier in Sect. 2.4, cross-section-set-dependent cross sections are required only for the seven burnup-dependent actinides. SNIKR places the cross-section ID modifier in front of the default cross-section ID for each of these isotopes (e.g., ^{238}U, with ID No. 92238, would be described as 292238 for all assemblies located in cross-section set 2). Burnable poison isotopics were similarly generated for each of the five eighth-core fuel assembly locations where BPRs were present in Cycle 2. A sample input file is listed in Table E.2.

The SNIKR output file consists of three sections: a summary of the input and coarsely formatted ORIGEN-S results, isotopic concentrations in SCALE standard composition input format, and isotopic concentrations in KENO V.a mixing table input format. For each assembly calculation, only the latter was of interest; this section was copied and placed directly into KENO V.a input to describe the isotopic composition for the burnup of a specific assembly. A sample SNIKR output is listed in Appendix C.

3.5.2 Cross-Section Set Isotopics

Burnup-dependent cross sections were required for the seven burnup-dependent actinides. As was previously mentioned, cross-section set calculations were performed with CSASN to obtain the cross sections for these actinides for each cross-section set based on the average burnup groupings shown in Table 13; these groupings were selected based on the burnup range criterion of 2 GWd/MTU discussed earlier. SNIKR calculations were required for all cross-section sets, except the fresh fuel sets 5 through 9 at BOC. The seven burnup-dependent actinides were needed for each set of burned fuel at BOC and EOC. In addition, cross-section set 4 also included the other actinides and fission products in the fuel mixture, along with the moderator and structural materials. The microscopic cross-section calculations for cross-section sets 6, 7, 9 (BOC), and 10 (EOC) included the BP nuclides. A sample SNIKR input file is shown in Table D.2.

The SNIKR output file is the same format as was produced for the assembly calculations; however, the region of output data which was of interest was different. The isotopic concentrations in SCALE standard composition input format were copied to a CSASN input file.

3.6 GENERATION OF CROSS SECTIONS USING CSASN

Problem-dependent cross-section libraries were produced using the CSASN sequence of SCALE; the details of this process were described in Sect. 2.4. For each cross-section set, a CSASN input deck containing cross-section set average isotopics was created. Because the physical geometries of all fuel pins were identical, input specifications differed only in the isotopic compositions specified for each set. All cases were set up to use the SCALE ENDF/B-IV and ENDF/B-V based 27-group 27BURNUPLIB cross-section library. All calculations were LATTICECELL-type, with fuel in a Zircaloy clad; dimensions are specified in Table 4. A borated-water moderator was specified, with the appropriate boron concentration as specified in Table 3. For HZP, all components were specified with a temperature of 559 K (547°F), corresponding to HZP conditions. For HFP, appropriate temperatures from Tables 4 and 8 were specified for each component. The example input for HZP and HFP, respectively, are shown in Tables D.3 and E.3.

Isotopic concentrations were obtained from the earlier SNIKR cross-section set calculations. If only the seven burnup-dependent actinides were required, except for set 4, all other actinides and fission products were deleted from the fuel mixture specifications for these cases. Cross-section sets 5 through 9, comprised only of fresh fuel at BOC, HZP, were specified using the fresh isotopic compositions given in Table 6 for that case. The microscopic cross-section calculations for cross-section set 4 also included the other actinides and fission products in the fuel mixture, along with mixtures for the moderator and structural materials. Cross-section set 4 was selected for these calculations because its spent fuel isotopics represented the highest average burnup (16,587 MWd/MTU at BOC and 22,998 MWd/MTU at EOC). The example input for cross-section set 4 is included as Tables D.4 and E.4. The microscopic cross-section calculations for cross-section sets 6, 7, and 9 (BOC) and 10 (EOC) included the BPR nuclides. CSASN calculations were then performed, with the resulting microscopic working format cross-section library saved for each cross-section set.

3.7 COMBINING CROSS-SECTION SET LIBRARIES USING WAX

The WAX program[16] was used to combine the individual working format libraries (one per cross-section set) into a single library for BOC-2 and another for EOC-2 to be used in the KENO V.a core calculations. For cross-section set 4, selected to include the fission products and additional actinides, WAX copied all cross sections into the combined library. For the cross-section sets selected for the BPR cross sections, WAX copied those cross sections in addition to the seven burnup-dependent actinides. For the remaining cross-section sets, WAX copied only the cross sections for the seven burnup-dependent actinides. For each of these actinides, the cross-section ID was modified by adding the cross-section set number as a prefix, to be consistent with the numbering scheme used in the SNIKR-produced KENO V.a mixing-table-format isotopics for each assembly. Sample WAX input listings are provided in Tables D.5 and E.5. All CSASN and WAX calculations were performed with SCALE-4.1 on the ORNL IBM mainframe.

3.8 VALIDATION OF CROSS-SECTION SET ASSUMPTIONS

The methodology of cross-section generation employing cross-section sets resulted in each fuel assembly in the KENO V.a full-core model being modeled with microscopic cross sections generated with isotopics based on the average burnup for a cross-section set (i.e., a subgroup of fuel). In order to validate this methodology, the highest burnup assemblies in cross-section sets 2 (BOC) and 4 (EOC) were analyzed by executing an XSDRNPM[21] eigenvalue calculation in stand-alone mode and via the CSAS1X[6] sequence (BONAMI, NITAWL-II, XSDRNPM). The stand-alone calculations utilized the working format libraries created by WAX that were based on cross-section set averaged isotopics. The CSAS1X calculations generated and used problem-specific microscopic cross sections based on the calculated assembly isotopics. Cross-section sets 2 and 4 were selected for the validation because they represented the highest burnup sets with the largest spans in burnup for their respective enrichments. Individual assembly locations 1 and 9 were selected because they represented the maximum burnup, and, hence, the maximum difference in isotopics from the average, for their respective cross-section sets. These cases should give the poorest agreement since the change in microscopic cross sections should be greatest at higher burnups and for the largest difference in assembly-to-average burnup. The results of these cases are compared in Table 18, which shows a maximum difference of 0.035% $\Delta k/k$ due to the use of the cross sections at subgroup-averaged conditions. Input files are included in Tables D.6 and D.7 and E.6 and E.7.

3.9 PREPARATION OF KENO V.a CORE MODEL

The KENO V.a model used to determine k_{eff} for the Surry 1 BOC-2 and EOC-2 cores consists of four parts. The first section of input contains code parameter specifications. The only significant aspect of this section is the use of 1003 generations of 1000 neutrons per generation; hence, the calculation was based on one million histories (three generations were skipped by KENO V.a). Parameter specifications are followed by mixture specifications, geometry specifications, and plotting specifications. The plotting specifications are unimportant in the criticality calculation and were simply used in debugging and verifying geometry input. The following subsections describe the details of the material and geometry specifications for this model.

3.9.1 KENO V.a Mixture Specifications

In describing the composition of a fuel assembly, it has been assumed that all fuel rods in the assembly are identical and may be represented by the assembly-averaged burnup. No attempt was made to account for burnup asymmetries within an assembly, as this information was not readily available and should have little effect on the computed solution. Thus, only a single fuel rod description is necessary to describe all fuel rods in a given assembly. In addition, in this model, axial power distributions are ignored, and assemblies are represented by a model that assumes a constant (average) power distribution along the length of the assembly. Thus the composition of fuel in an assembly is uniform and is represented by a single material specification. Based on the results of an axial end effects study,[22] this assumption has a minor effect (<0.1% $\Delta k/k$) that is probably conservative for the average burnup in these models. Because it is possible to take advantage of the one-eighth core symmetry of the core, only 26 assemblies are required to represent all 157 assembly positions in the core. Hence, only 26 material mixtures are necessary for the full-core model. These come from the 26 assembly calculations performed earlier using SNIKR for mixtures 101 through 126. The portions of the SNIKR output copied into the KENO V.a input represent complete mixture specifications for each of the 26 materials.

Material specifications were also required for all remaining materials (i.e., clad, borated water, and BPR materials). Concentrations for each isotope were obtained from the output of the CSASN cross-section calculations. Mixture numbers 11 through 15 were used for the burnable poison materials. A unique mixture number was assigned the BPR in each eighth-core fuel assembly that contained BPRs. This designation was necessary for the EOC-2 case where the BPRs were partially depleted and varied with assembly burnup. Table 19 lists all materials included in the core model by mixture number.

Table 18. k_∞ comparison for validation of cross-section methodology

Burnup	Power	Eighth-core assembly location	k_∞ XSDRNPM stand-alone	k_∞ CSAS1X sequence	% Difference
BOC	HZP	1	0.913483	0.913159	0.035
EOC	HFP	9	0.953601	0.953760	−0.017

3.9.2 KENO V.a Geometry Specifications

A fuel rod was defined for each of the 26 one-eighth core fuel assemblies based on the dimensions given in Table 4. Identical dimensions were used for all rod definitions. Fuel rods were assigned to Unit numbers 101 to 126, respectively; the fuel region of each rod was linked to its corresponding material number (e.g., fuel rod 101 used material 101 for the fuel region). All rods were specified with a void gap and Zircaloy clad, centered in a water cuboid. Fuel rods and enclosing cuboids were modeled as having a length equal to that of the active fuel length of the rod (i.e., fuel assembly top and bottom structures were neglected). A 50/50 mixture of borated H_2O and stainless steel was used as a top and bottom reflector (25-cm-thick) to account for structural materials above and below the active fuel region.

Unit 161, representing a control rod guide tube, was created using the dimensions in Table 4, with water inside the tube and centered within a water cuboid. Burnable poison rods were created as Units 162 through 166. Each BPR was put inside a control rod guide tube.

A 17 × 17 array was then defined for each of the 26 fuel assemblies, which were assigned Unit numbers 1 through 26 corresponding to their eighth-core location. The 204 fuel rod locations in each assembly were filled with the fuel rod containing the assembly average isotopics. The remaining array locations were appropriately filled with guide tubes or BPRs according to the full-core BPR loading configuration in Fig. 5 and the fuel assembly lattice arrangements in Fig. 4. Each array was surrounded by a thin layer of moderator to obtain an assembly lattice spacing of 21.50364 cm (8.466 in.).

The core baffle surrounding the outermost assemblies was created as a composite of several smaller segments, comprised of four different cuboid shapes. Units 41 to 46 were used to define these shapes. Figure 7 illustrates the use of these six unit types in modeling the core baffle. The figure also shows assembly position numbers for the full core, based on one-eighth core symmetry and the numbering scheme shown in Fig. 6. Using these position numbers, arrays of assemblies and core baffle segments were used to define larger units, to minimize the number of KENO V.a "holes" placed in the global unit. Figure 8 illustrates the grouping of assemblies used. Global Unit 70 contained the core barrel, thermal shield, and reactor vessel. All other units were placed within Unit 70 using KENO V.a "holes." Note that core baffle components drawn in black in the figure represent

Table 19. Mixtures in KENO V.a model

Mixture No.	Description
1	Clad
2	Stainless steel (BP clad, baffle)
3	Borated moderator
4	50% borated moderator, 50% stainless steel (top and bottom reflector)
5	Stainless steel (core barrel)
6	Borated moderator (outside core barrel)
7	Stainless steel (thermal shield)
8	Borated moderator (outside thermal shield)
9	Stainless steel (reactor vessel)
11–15	Burnable poison, assemblies 2, 4, 6, 14, 23
101–126	Fuel, assemblies 1–26

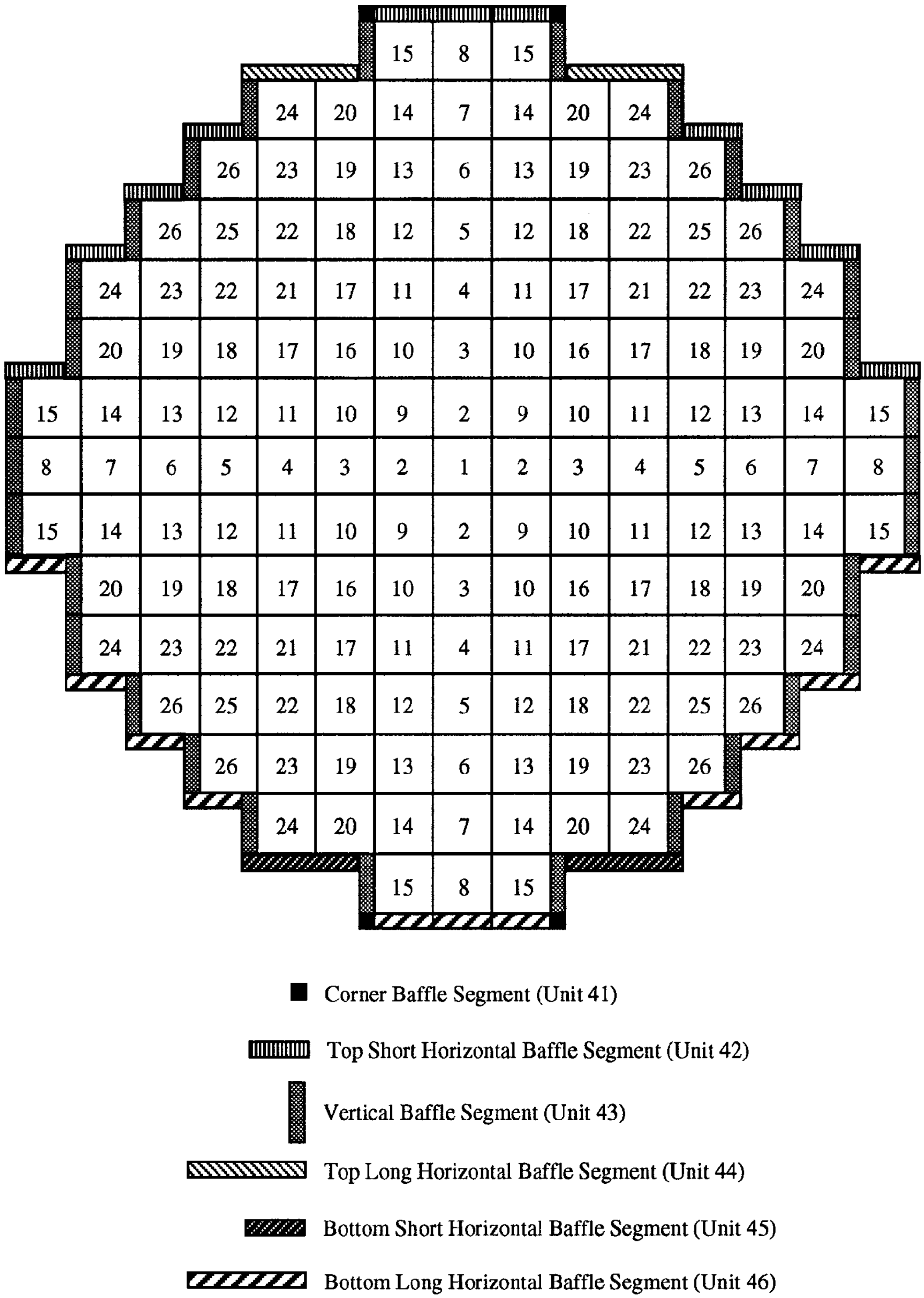

Fig. 7. Full-core assembly positions and core baffle configuration.

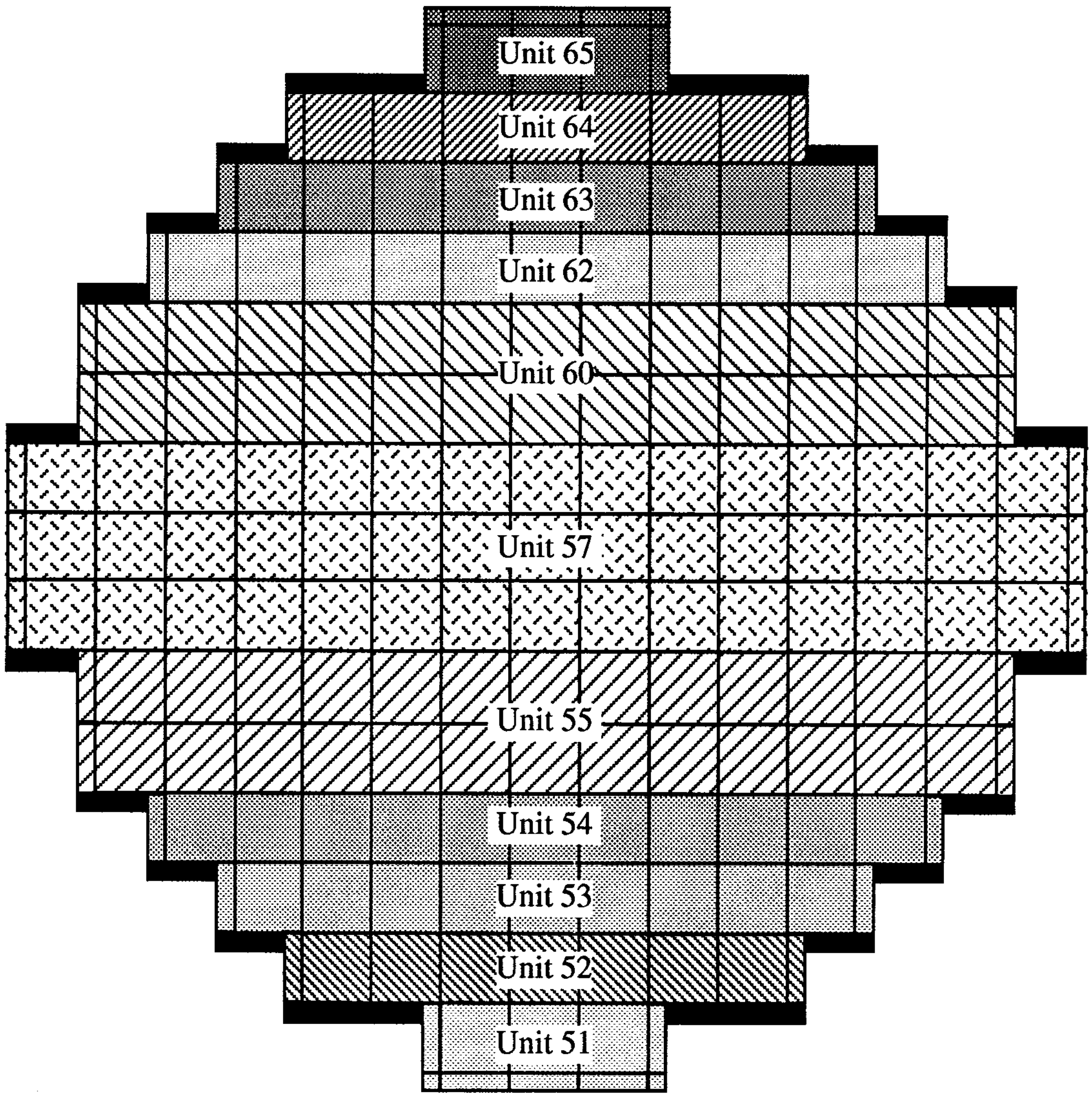

Fig. 8. KENO V.a unit definitions based on component arrays.

individual components not included in these arrays and were entered as individual holes in the global array. Unit number assignments used in the model are given in Table 20.

This discussion completes the geometric description of the core. As a reference, a listing of the entire KENO V.a input for the BOC-2 HZP case and the EOC-2 HFP case are included in Tables D.8 and E.8, respectively. All KENO V.a calculations were performed with SCALE-4.2 on an IBM RS-6000 workstation after the cross-section libraries created with WAX had been transferred from the ORNL IBM mainframe.

Table 20. Unit numbers used in Surry KENO V.a core model

Unit No.	Description
1–26	Fuel assemblies for positions 1 to 26, respectively
41	1.905 × 1.905 cm (corner) segment of core baffle
42	21.50364 × 1.905 cm (horizontal) segment of core baffle
43	1.905 × 21.50364 cm (vertical) segment of core baffle
44	43.00728 × 1.905 cm (horizontal) segment of core baffle
45	21.50364 × 1.905 cm (horizontal) segment of core baffle
46	43.00728 × 1.905 cm (horizontal) segment of core baffle
51	"Bottom" of baffle + row 1 of assemblies + vertical baffle ends
52	Row 2 of assemblies + vertical baffle ends
53	Row 3 of assemblies + vertical baffle ends
54	Row 4 of assemblies + vertical baffle ends
55	Rows 5 and 6 of assemblies + vertical baffle ends
57	Rows 7–9 of assemblies + vertical baffle ends
60	Rows 10 and 11 of assemblies + vertical baffle ends
62	Row 12 of assemblies + vertical baffle ends
63	Row 13 of assemblies + vertical baffle ends
64	Row 14 of assemblies + vertical baffle ends
65	Row 15 of assemblies + vertical baffle ends + "top" of baffle
70 (GLOBAL)	Reactor vessel + thermal shield + core barrel + vertical baffle ends
101–126	Fuel rods for assemblies 1–6, respectively
161	Water-filled control rod guide tube
162–166	BPRs in control rod guide tubes

4. RESULTS AND CONCLUSIONS

The KENO V.a criticality calculations for the Surry 1 Cycle 2 BOC and EOC models described in this report yielded values for k_{eff} from 1.0014 to 1.0113, as shown in Table 21. These results cover different burnup, power, xenon, and temperature conditions. The range of conditions for these reactor criticals are listed in Table 22. The results are based on 1000 generations of 1000 neutrons per generation, for a total of 1×10^6 histories. Included in Table 21 is the average fission group reported by SCALE, which represents the average neutron energy at which fission occurs. Numerical experiments with a different starting random number and different starting source shape and location indicate that these solutions are well converged and adequate source sampling achieved (see ref. 7 for a discussion of what constitutes convergence).

The EOC case contains all spent fuel, but the fuel has experienced no cooling time. Therefore, short-lived fission products are present in this reactor critical that are not present in any of the other criticals. Since the nuclides modeled in the reactor critical calculations are primarily long-lived actinides and fission products, with the exception of ^{135}I and ^{135}Xe, there may be some important short-lived nuclides omitted in the KENO V.a model that account for the higher calculated k_{eff} value for this critical. Another important factor is that the critical boron concentration for the EOC case is not well documented or characterized. The uncertainty of this measured value may also contribute to the higher calculated value.

The results in Table 21 were based on P_3 scattering; however, a test case using (default) P_1 scattering showed no significant change (within 0.1%) in k_{eff}. This result is as would be expected, since angular fluxes throughout a reactor core would be expected to be relatively uniform except near the outer boundary of the core.

Relative fission density distributions (normalized to the core-average value) computed by KENO V.a are shown in Figs. 9 and 10 for a one-eighth core average. These distributions may be interpreted as relative power densities and show the approximate shape expected for an operating PWR core, indicating no major anomalies in the core assembly model. The use of uniform temperature and xenon distributions for the HFP case causes the KENO V.a distributions to be less uniform over the inner-core regions due to the lack of xenon and temperature feedback mechanisms. Note that even though k_{eff}, a total system parameter, is considered to be well converged, individual assembly fission distributions are based on substantially fewer histories, especially in outer-core regions, and therefore are subject to significantly higher uncertainties.

These k_{eff} results are approximately 2% $\Delta k/k$ greater than those reported for the Surry and North Anna reactor critical benchmark calculations[8] performed with the original SCALE scoping calculations. Differences in the earlier analyses that have been identified and their probable order of importance are use of a lumped fission product to account for all nuclides not explicitly modeled, fewer fuel batches and cross-section sets, fewer neutrons per generation and fewer total neutron histories, and use of an earlier version of SAS2H.

The consistency in results for the revised methodology and its straightforward procedure for calculating isotopics provide a high level of confidence in these results. The complexity in the isotopic calculational procedure of the initial methodology, the use of lumped fission products, and

Table 21. KENO V.a calculated results for Surry Unit 1 Cycle 2

Burnup	Power	Boron (ppm)	k_{eff}	Average energy group where fission occurs[a]	Neutron histories
BOC	HZP	1030	1.0014 ± 0.0005	21.0183 ± 0.0036	1,000,000
EOC	HFP	123	1.0113 ± 0.0005	20.9735 ± 0.0035	1,000,000

[a] The energy range for group 20 is 0.8 to 0.4 eV.

Table 22. Range of conditions for Surry reactor criticals

Case	Core avg. burnup (MWd/MTU)	Power (MW)	Mod. temp. (K)	Fuel temp. (K)	Xenon worth (% Δk/k)
BOC,HZP	6,929	0	559	559	0
EOC,HFP	13,845	2441	569	910	2.82

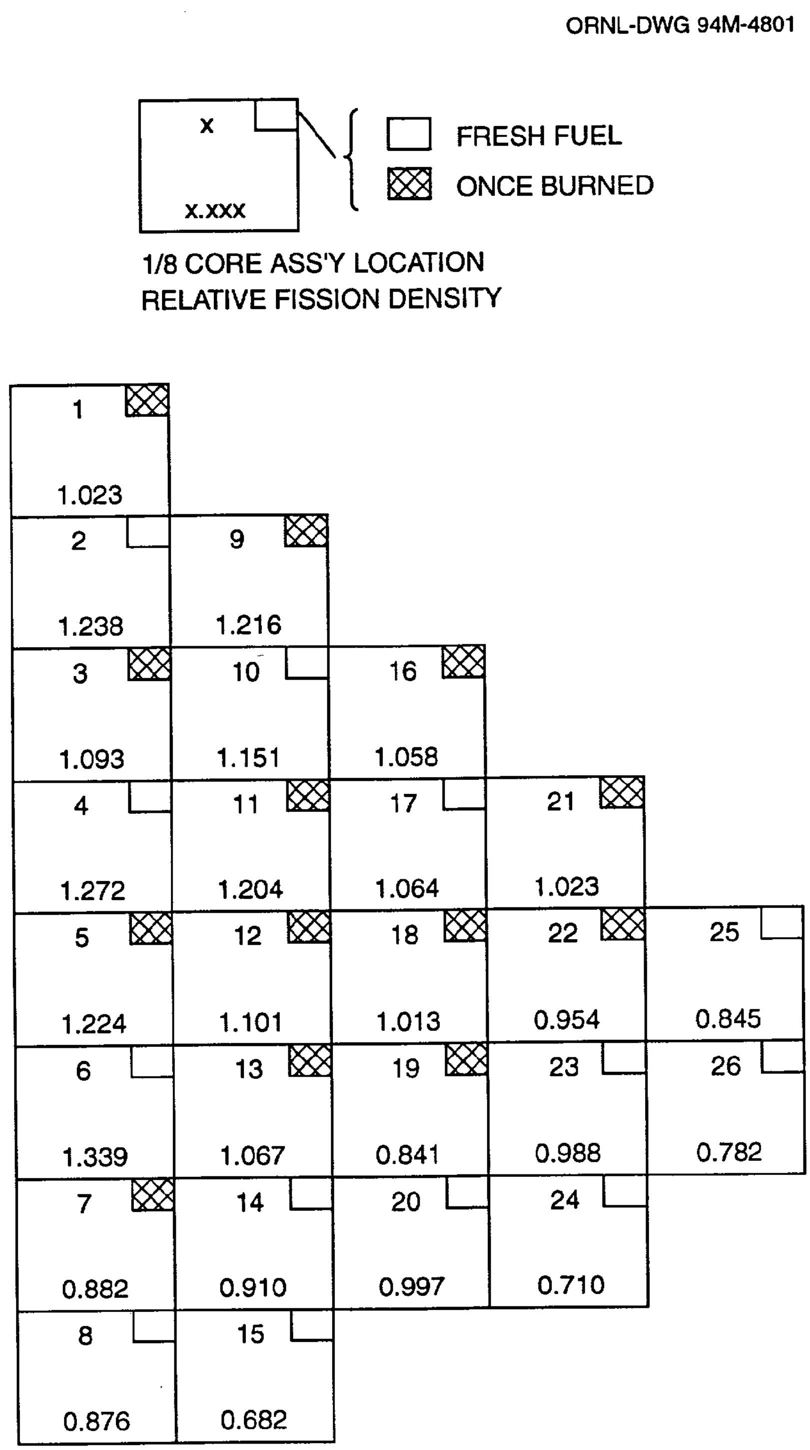

Fig. 9. BOC, HZP eighth-core relative fission density distribution.

ORNL-DWG 94M-4802

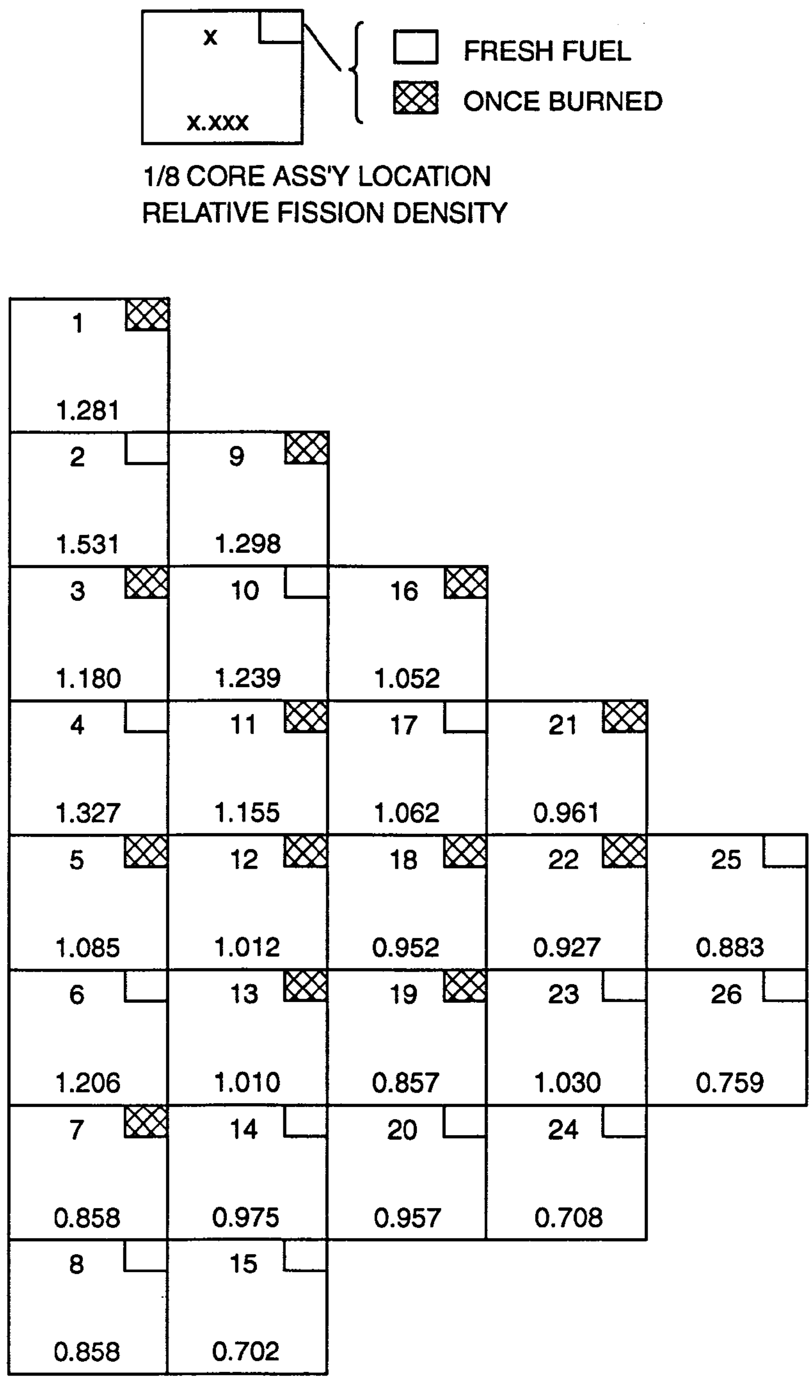

Fig. 10. EOC, HFP eighth-core relative fission density distribution.

the inability to reproduce results caused by the loss of data from the earlier work reduces our confidence in the original calculations.

The results of these calculations demonstrate that even with a relatively simple core model and eighth-core and assembly-averaged burnups, it is possible to closely predict, in a best-estimate fashion, the critical condition after a long decay period for a lattice primarily comprised of spent fuel assemblies. Results are also consistent with SCALE validation calculations performed based on experiments using mixed-oxide fuel rods in square lattice configurations.[23] Hence one may conclude that the methodology applied in performing these reactor critical calculations is valid for performing criticality safety analyses for systems with spent fuel.

REFERENCES

1. T. L. Sanders and R. M. Westfall, "Feasibility and Incentives for Burnup Credit in Spent Fuel Transport Casks," *Nucl. Sci. Eng.* **104** (1990).

2. "American National Standard for Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," ANSI/ANS-8.1-1983.

3. *SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation*, NUREG/CR-0200, Rev. 4 (ORNL/NUREG/CSD-2/R4), Vols. I, II, and III (draft November 1993). Available from Radiation Shielding Information Center as CCC-545.

4. M. C. Brady and T. L. Sanders, "A Validated Methodology for Evaluating Burnup Credit in Spent Fuel Casks," *Proc. of International Conference on Nuclear Criticality Safety*, Christ Church, Oxford, United Kingdom, September 9–31, 1991.

5. O. W. Hermann and C. V. Parks, "SAS2H: A Coupled One-Dimensional Depletion and Shielding Analysis Code," Sect. S2 of *SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation*, NUREG/CR-0200, Rev. 5 (ORNL/NUREG/CSD-2/R5), Vols. 1, 2 and 3 (draft November 1993). Available from Radiation Shielding Information Center as CCC-545.

6. N. F. Landers and L. M. Petrie, "CSAS4: An Enhanced Criticality Safety Analysis Module with an Optimum Pitch Search Option," Sect. C4 of *SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation*, NUREG/CR-0200, Rev. 5 (ORNL/NUREG/CSD-2/R5), Vols. 1, 2 and 3 (draft November 1993). Available from Radiation Shielding Information Center as CCC-545.

7. L. M. Petrie and N. F. Landers, "KENO V.a: An Improved Monte Carlo Criticality Program with Supergrouping," Sect. F11 of *SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation*, NUREG/CR-0200, Rev. 4 (ORNL/NUREG/CSD-2/R4), Vols. I, II, and III (draft November 1993). Available from Radiation Shielding Information Center as CCC-545.

8. J.-P. Renier and C. V. Parks, "Reactor Critical Calculations for Validation of Burnup Credit Analysis Methods," *Trans. Am. Nucl. Soc.* **62**, 308 (1990).

9. O. W. Hermann and R. M. Westfall, "ORIGEN-S: A SCALE System Module to Calculate Fuel Depletion, Actinide Transmutation, Fission Product Buildup and Decay, and Associated Radiation Source Terms," Sect. F7 of *SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation*, NUREG/CR-0200, Rev. 5 (ORNL/NUREG/CSD-2/R5), Vols. 1, 2 and 3 (draft November 1993). Available from Radiation Shielding Information Center as CCC-545.

10. B. H. Wakeman and S. A. Ahmed, *Evaluation of Burnup Credit for Dry Storage Casks*, EPRI NP-6494, Electric Power Research Institute (August 1989).

11. O. W. Hermann and M. C. Brady, *Comparisons of SAS2H and CASMO-3 Benchmark* k_∞ *Calculations for Reactor Fuel With and Without Burnable Poisons*, ORNL/TM-12490, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab. (to be published).

12. B. L. Broadhead et al., *Investigation of Nuclide Importance to Functional Requirements Related to Transport and Long-Term Storage of LWR Spent Fuel*, ORNL/TM-12742, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab. (in press).

13. D. G. Napolitano and D. G. Adli, *Burnup Credit Criticality Analysis Using Advanced Nodal Techniques*, Yankee Atomic Electric Co., March 1992.

14. N. M. Greene, "BONAMI-S: Resonance Self-Shielding by the Bondarenko Method," Sect. F1 of *SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation*, NUREG/CR-0200, Rev. 5 (ORNL/NUREG/ CSD-2/R5), Vols. 1, 2 and 3 (draft November 1993). Available from Radiation Shielding Information Center as CCC-545.

15. N. M. Greene, L. M. Petrie, and R. M. Westfall, "NITAWL-II: SCALE System Module for Performing Resonance Shielding and Working Library Production," Sect. F2 of *SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation*, NUREG/CR-0200, Rev. 5 (ORNL/NUREG/ CSD-2/R5), Vols. 1, 2 and 3 (draft November 1993). Available from Radiation Shielding Information Center as CCC-545.

16. N. M. Greene, "User's Guide for Utility Modules," Sect. M15 of *SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation*, NUREG/CR-0200, Rev. 5 (ORNL/NUREG/ CSD-2/R5), Vols. 1, 2 and 3 (draft November 1993). Available from Radiation Shielding Information Center as CCC-545.

17. R. W. Carlson, *Reactor Core Physics Design and Operating Data for Cycles 1, 2, and 3 of Surry Unit 1 PWR Power Plant*, NP-79-2-LD, Georgia Institute of Technology, March 1979.

18. O. W. Hermann, J-P. Renier, and C. V. Parks, *Technical Support for a Proposed Decay Heat Guide Using SAS2H/ORIGEN-S Data*, NUREG/CR-5625, ORNL/CSD-130, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab. (to be published).

19. G. W. Morey, *The Properties of Glass*, 2nd ed., Reinhold, New York, 1954.

20. F. W. Walker, J. R. Parrington, and F. Feiner (revisors of edition), *Nuclides and Isotopes*, 14th ed., General Electric Co., San Jose, California, 1989.

21. N. M. Greene and L. M. Petrie, "XSDRNPM-S: A One-Dimensional Discrete-Ordinates Code for Transport Analysis," Sect. F3 of *SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation*, NUREG/CR-0200, Rev. 4 (ORNL/NUREG/CSD-2/R4), Vols. I, II, and III (draft November 1993). Available from Radiation Shielding Information Center as CCC-545.

22. S. E. Turner, "An Uncertainty Analysis-Axial Burnup Distribution Effects," *Proc. Workshop Use of Burnup Credit in Spent Fuel Transport Casks*, Washington, D.C., February 21–22, 1988, T. L. Sanders, Ed., SAND89-0018, TTC-0884, UC-820, Sandia National Laboratories, October 1989.

23. S. M. Bowman and M. D. DeHart, "Validation of SCALE-4 for Burnup Credit Applications," Accepted for publication in *Nuclear Technology*.

APPENDIX A

SURRY UNIT 1 CYCLE 2 DATA

The initial core loading pattern of Cycle 2 is shown in Fig. A.1. The initial and final burnup distributions in the core for Cycle 2 are listed in Table A.1. The assemblies are grouped in the table into the eighth-core symmetric sets as loaded in Cycle 2.

ORNL-DWG 94M-6380

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1							D32	D22	D05						
2					D13	D36	D40 20 BP	A08	D52 20 BP	D07	D48				
3				D30	D15 12 BP	A22	B28	E03 12 BP*	B31	A21	D47 12 BP	D23			
4			D20	F04	B07	B19	B52	B35	B03	B25	B34	F05	D38		
5		D27	D09 12 BP	B08	B36	NDI	B10	E10 8 BP	B18	F08	B42	B33	DIB 12 BP	D51	
6		D45	A20	B06	F17	A18	F01	A35	F18	A02	F10	B15	A41	D17	
7	D43	D04 20 BP	B50	B02	B47	F06	B17	E04 8 BP	B21	F14	B24	B11	B23	D06 20 BP	D28
8	D39	A48	E05 12 BP*	B27	E09 8 BP	A38	E01 8 BP	A32	E12 8 BP	A40	E08 8 BP	B01	E11 12 BP*	A19	D41
9	D14	D26 20 BP	B04	B46	B16	F09	B45	E06 8 BP	B49	F07	B40	B37	B43	D50 20 BP	D49
10		D21	A13	B09	F03	A45	F15	A29	F16	A28	F12	B30	A34	D03	
11		D42	D16 12 BP	B44	B26	F11	B51	E02 8 BP	B38	RDI	B14	B29	D34 12 BP	D12	
12			D37	F02	B20	B48	B13	B41	B05	B22	B39	F13	D24		
13				D29	D35 12 BP	A27	B32	E07 12 BP*	B12	A04	D01 12 BP	D11			
14					D44	D08	D46 20 BP	A05	D33 20 BP	D19	D10				
15							D02	D31	D25						

XXX — ASSEMBLY ID
XXX — NO. OF BP RODS
* DEPLETED BP

Fig. A.1. Surry Unit 1 Cycle 2 core loading pattern.

Table A.1. Fuel assembly burnups at BOC and EOC for Surry Unit 1 Cycle 2

Assembly ID	Batch	Burnup (MWd/MTU) BOC	Burnup (MWd/MTU) EOC	Assembly ID	Batch	Burnup (MWd/MTU) BOC	Burnup (MWd/MTU) EOC
A02	1A2	11475	18471	B04	2	14439	21474
A18	1A2	11512	18439	B12	2	14347	21435
A28	1A2	11539	18403	B23	2	13891	21066
A45	1A2	11686	18690	B28	2	14578	21571
				B31	2	14479	21412
A29	1A2	12431	19389	B32	2	14462	21634
A35	1A2	12348	19417	B43	2	14467	21542
A38	1A2	12779	19859	B50	2	14302	21285
A40	1A2	12582	19722				
				B02	2	15479	22472
A04	1A2	14084	19806	B03	2	15972	22922
A13	1A2	14098	19821	B05	2	15833	22725
A20	1A2	14119	19821	B11	2	15870	22932
A21	1A2	14317	20026	B13	2	15849	22847
A22	1A2	14402	20191	B37	2	15749	22668
A27	1A2	14182	19971	B46	2	16039	23043
A34	1A2	14222	19941	B52	2	15855	22732
A41	1A2	14072	19935				
				B06	2	15842	22614
A05	1A2	14439	20165	B09	2	15857	22604
A08	1A2	14688	20192	B15	2	16094	22841
A19	1A2	14997	20667	B19	2	15708	22468
A48	1A2	14933	20602	B22	2	15539	22245
				B25	2	15804	22635
A32	1A2	15316	22094	B30	2	15921	22521
				B48	2	15530	22348
B10	2	14437	21981				
B16	2	13886	21697	B07	2	16403	23111
B18	2	14150	21947	B08	2	16255	22974
B24	2	14069	21956	B20	2	16175	22914
B38	2	14064	21759	B29	2	16178	22848
B40	2	14175	21920	B33	2	16439	22985
B47	2	14173	21920	B34	2	16444	23140
B51	2	14066	21849	B39	2	16136	22857
				B44	2	16354	23080

Table A.1. (continued)

Assembly ID	Batch	Burnup (MWd/MTU) BOC	EOC	Assembly ID	Batch	Burnup (MWd/MTU) BOC	EOC
B01	2	15439	22989	E03	4BB	0	8271
B27	2	15549	23032	E05	4BB	0	8492
B35	2	14992	22344	E07	4BB	0	8349
B41	2	14914	22315	E11	4BB	0	8602
B14	2	16522	23426	E02	4BF	0	8329
B26	2	16610	23550	E08	4BF	0	8499
B36	2	16634	23636	E09	4BF	0	8413
B42	2	16582	23525	E10	4BF	0	8249
B17	2	16315	24286	E01	4BF	0	8734
B21	2	16426	24344	E04	4BF	0	8695
B45	2	16413	24258	E06	4BF	0	8533
B49	2	15965	23686	E12	4BF	0	8592
F02	4A	0	6948	D02	4CN	0	5203
F04	4A	0	6850	D05	4CN	0	4815
F05	4A	0	6789	D14	4CN	0	5163
F13	4A	0	6945	D25	4CN	0	5280
				D32	4CN	0	4998
F03	4A	0	7642	D43	4CN	0	5163
F08	4A	0	7671	D49	4CN	0	5068
F10	4A	0	7622	D28	4CN	0	5108
F11	4A	0	7651				
F12	4A	0	7492	D10	4CN	0	5407
F17	4A	0	7558	D12	4CN	0	5531
ND1	4X	0	7540	D13	4CN	0	5471
RD1	4X	0	7613	D27	4CN	0	5483
				D42	4CN	0	5534
F01	4A	0	8042	D44	4CN	0	5485
F06	4A	0	8112	D48	4CN	0	5377
F07	4A	0	7948	D51	4CN	0	5773
F09	4A	0	8098				
F14	4A	0	8202	D22	4CN	0	6155
F15	4A	0	8093	D31	4CN	0	6572
F16	4A	0	7896	D39	4CN	0	6483
F18	4A	0	8172	D41	4CN	0	6380

Table A.1. (continued)

Assembly ID	Batch	Burnup (MWd/MTU) BOC	EOC	Assembly ID	Batch	Burnup (MWd/MTU) BOC	EOC
D11	4CN	0	6107	D04	4CF	0	6482
D20	4CN	0	6018	D26	4CF	0	6493
D23	4CN	0	6040	D40	4CF	0	6350
D24	4CN	0	6068	D52	4CF	0	6221
D29	4CN	0	6108	D06	4CF	0	6600
D30	4CN	0	6016	D33	4CF	0	6706
D37	4CN	0	6172	D46	4CF	0	6533
D38	4CN	0	6044	D50	4CF	0	6509
D03	4CN	0	7379	D01	4CF	0	7410
D07	4CN	0	7046	D15	4CF	0	7439
D08	4CN	0	7428	D16	4CF	0	7485
D17	4CN	0	7610	D18	4CF	0	7433
D19	4CN	0	7464	D09	4CF	0	7417
D21	4CN	0	7246	D34	4CF	0	7435
D36	4CN	0	7278	D35	4CF	0	7419
D45	4CN	0	7219	D47	4CF	0	7390

APPENDIX B

SAS2H CASE INPUT EXAMPLE

This appendix gives an example of one of the nine SAS2H cases. It gives a list of the JCL and data for SAS2H batch 4BF.

```
//OWHSUR5E JOB (35899),'6011BLDG,X10-HERMANN',MSGCLASS=T,TIME=25
//*
//* **************************************************
//* *                                                *
//* * .FISS-PROD, ACTINIDE ISOTOPICS OF SURRY #1 PWR.  *
//* *                                                *
//* *  FOR A REACTOR CRITICAL CASE AT EOC-2          *
//* *                                                *
//* * CASE FOR BATCH 4BF, SURRY 15X15 PWR, VEPCO     *
//* *                                                *
//* *   THIS PROJECT SPONSORED BY:                   *
//* *                                                *
//* *             M. C. BRADY, ORNL                  *
//* *             T. L. SANDERS, SANDIA NATL LAB     *
//* *                                                *
//* *   COMPUTED BY: O.W. HERMANN, ORNL    APRIL, 1992 *
//* *                                                *
//* **************************************************
//*
//*
//PROCLIB DD DISP=SHR,DSN=TZA.PROCLIB.CNTL
//*
//OUT1 OUTPUT DEFAULT=YES,JESDS=ALL,CHARS=ST15,FCB=10,FORMS=L7BL,
//  DEST=NX10A,COPIES=1
//*UT1 OUTPUT DEFAULT=YES,JESDS=ALL,
//* DEST=RM055,COPIES=1
//*
//*
//*  SAVED ON OWH.SUR5E.BCRED
//*                          PRINT TO BE ON OWH.SUR5E.OUTLIST
//*MAIN LINES=80
//*MAIN CLASS=WHENEVER
//SPDA EXEC SPDASCR
//SYSPRINT DD SYSOUT=*
//SYSIN DD *
  T.OWH35899.SUR5EF55
/*
//POOL EXEC POOLSCR
//SYSPRINT DD SYSOUT=*
//SYSIN DD *
 OWH.SUR5E.WES15F33
 OWH.SUR5E.WES15F34
 OWH.SUR5E.WES15F35
 OWH.SUR5E.WES15F71
 OWH.SUR5E.WES15F72
/*
//S2 EXEC SCALE41,REGION=2000K,H6LIB=NULLFILE,TIME=100
/*
//GO.FT01F001 DD  DCB=(RECFM=VBS,LRECL=X,BLKSIZE=9440,BUFL=10232)
//GO.FT04F001 DD  DCB=(RECFM=VBS,LRECL=X,BLKSIZE=9440,BUFL=10232)
//GO.FT13F001 DD SYSOUT=*,DCB=(RECFM=FA,BLKSIZE=133,BUFL=150)
//GO.FT16F001 DD  SPACE=(TRK,(200,80))                              //GO.FT17F001 DD
DCB=(RECFM=VBS,LRECL=X,BLKSIZE=9440,BUFL=10232)
//GO.FT18F001 DD  DCB=(RECFM=VBS,LRECL=X,BLKSIZE=9440,BUFL=10232)
//GO.FT19F001 DD  DCB=(RECFM=VBS,LRECL=X,BLKSIZE=9440,BUFL=10232)
//GO.FT21F001 DD DSN=OWH.PRESAS.PWR17,DISP=SHR
//GO.FT32F001 DD UNIT=SYSDA,SPACE=(TRK,(30,5)),
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=9440,BUFL=10232)
//GO.FT33F001 DD UNIT=DISK,SPACE=(TRK,(30,5)),
// DISP=(NEW,CATLG),DSN=OWH.SUR5E.WES15F33,
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6136,BUFL=6136)
//GO.FT34F001 DD UNIT=DISK,SPACE=(TRK,(30,5)),
// DISP=(NEW,CATLG),DSN=OWH.SUR5E.WES15F34,
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6136,BUFL=6136)
//GO.FT35F001 DD UNIT=DISK,SPACE=(TRK,(30,5)),
// DISP=(NEW,CATLG),DSN=OWH.SUR5E.WES15F35,
```

```
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6136,BUFL=6136)
//*    NOTE ABOVE BLOCKSIZE/BUFL CHANGED TO SCALE DEFAULT.....
//GO.FT70F001 DD  SPACE=(TRK,(10,8)),UNIT=SYSDA,
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=9440,BUFL=10232)
//GO.FT71F001 DD UNIT=DISK,SPACE=(TRK,(20,5)),
// DISP=(NEW,CATLG),DSN=OWH.SUR5E.WES15F71,
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=9440,BUFL=10232)
//GO.FT72F001 DD UNIT=DISK,SPACE=(TRK,(10,5)),
//  DCB=(RECFM=FB,LRECL=80,BLKSIZE=6400),
// DISP=(NEW,CATLG),DSN=OWH.SUR5E.WES15F72
//GO.FT74F001 DD UNIT=SYSDA,
//   SPACE=(800,(2,2),RLSE),DCB=(RECFM=FB,LRECL=80,BLKSIZE=800)
//GO.FT53F001 DD UNIT=SYSDA,SPACE=(TRK,(90,5)),
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=3664,BUFL=4088)
//GO.FT55F001 DD UNIT=SPDA,SPACE=(TRK,(2,1)),
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=3664,BUFL=4088),
// DISP=(NEW,CATLG),DSN=T.OWH35899.SUR5EF55
//GO.SYSIN DD *
=SAS2     PARM='HALT03,SKIPSHIPDATA'
SAS2H: SURRY CRITICAL ISOTOPICS, BATCH 4BF, 4 GWD/MTU INT, X 3 CYCLES
27BURNUPLIB    LATTICECELL
'
'   MIXTURES OF FUEL-PIN-UNIT-CELL:
'
UO2  1 0.946 910 92234 0.022 92235 2.61 92236 0.012 92238 97.356  END
KR-83    1 0 1-20 910  END
KR-85    1 0 1-20 910  END
SR-90    1 0 1-20 910  END
 Y-89    1 0 1-20 910  END
MO-95    1 0 1-20 910  END
ZR-93    1 0 1-20 910  END
ZR-94    1 0 1-20 910  END
ZR-95    1 0 1-20 910  END
NB-94    1 0 1-20 910  END
TC-99    1 0 1-20 910  END
RH-103   1 0 1-20 910  END
RH-105   1 0 1-20 910  END
RU-101   1 0 1-20 910  END
RU-106   1 0 1-20 910  END
PD-105   1 0 1-20 910  END
PD-108   1 0 1-20 910  END
AG-109   1 0 1-20 910  END
SB-124   1 0 1-20 910  END
I-135    1 0 1-20 910  END
XE-131   1 0 1-20 910  END
XE-132   1 0 1-20 910  END
XE-135   1 0 6-9  910  END
XE-136   1 0 1-20 910  END
CS-134   1 0 1-20 910  END
CS-135   1 0 1-20 910  END
CS-137   1 0 1-20 910  END
BA-136   1 0 1-20 910  END
LA-139   1 0 1-20 910  END
PR-141   1 0 1-20 910  END
PR-143   1 0 1-20 910  END
CE-144   1 0 1-20 910  END
ND-143   1 0 1-20 910  END
ND-145   1 0 1-20 910  END
PM-147   1 0 1-20 910  END
PM-148   1 0 1-20 910  END
PM-149   1 0 1-20 910  END
ND-147   1 0 1-20 910  END
SM-147   1 0 1-20 910  END
SM-149   1 0 1-20 910  END
SM-150   1 0 1-20 910  END
SM-151   1 0 1-20 910  END
```

```
SM-152   1 0 1-20 910  END
GD-155   1 0 1-20 910  END
EU-153   1 0 1-20 910  END
EU-154   1 0 1-20 910  END
EU-155   1 0 1-20 910  END
ZIRCALLOY   2 1  595   END
H2O  3 DEN=0.7327  1  570 END
ARBM-BORMOD  0.7327 1 1 0 0 5000 100 3 423.0E-6  570  END
'
'    423 PM(WT) BORON
' - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
'
'  BURNABLE POISON ROD ATOM DENSITIES:
'
' - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
SS304  5 1 579  END
O      6 0  0.04497   570 END
NA     6 0  0.00165   570 END
AL     6 0  0.00058   570 END
SI     6 0  0.01799   570 END
K      6 0  0.00011   570 END
B-10   6 0  9.595-4   570 END
B-11   6 0  3.863-3   570 END
N      4 0  5-5       570 END

' - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
END COMP
'
' - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
'
'      FUEL-PIN-CELL GEOMETRY:
'
SQUAREPITCH   1.43002 0.92939 1 3 1.07188 2 0.94844 0  END
'
' - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
'
MORE DATA   SZF=0.6  END
'
'    ASSEMBLY AND CYCLE PARAMETERS:
'
NPIN/ASSM=204 FUELNGHT=790.63  NCYCLES=3  NLIB/CYC=1
PRINTLEVEL=4 LIGHTEL=9  INPLEVEL=2   NUMZTOTAL=10
NUMINSTR=1  FACMESH=0.65   END
'
'  MIXTURES (BY MIX-NO.) WITHIN RADII (CM):
'
4 0.17519   5 0.18538   4 0.19048   6 0.31041   4 0.31394
5 0.34294   3 0.65202   2 0.69012   3 0.80680  500 2.64088
'
POWER=41.6348  BURN=96.074   DOWN=0         END
POWER=41.6348  BURN=96.074   DOWN=0         END
POWER=41.6348  BURN=96.074   DOWN=3652.5   END
'
  O 135     CR  5.9     MN  0.33
 FE 12.9    CO 0.075    NI  9.9
  ZR 221    NB  0.71    SN  3.6
'
' - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
'       .....END OF INPUT.....
END
//
```

APPENDIX C

SNIKR VERSION 1.0 DOCUMENTATION

This appendix includes a User's Input Guide, FORTRAN Listings, and Sample Output.

SNIKR VERSION 1.0 USER'S INPUT GUIDE

Each entry below must begin in column 1. Recommended values are given in parentheses.

Line 1	SNIKR1
Line 2	Title card for SNIKR1 (80-character maximum)
Line 3	READ BURNUP
Line 4	N72=ii (I2 format) Unit number for SAS2H atom density file (72)
Line 5	NOUT=ii (I2 format) Unit number for SNIKR1 output file (70)
Line 6	BURN=xxxxxx.x (F8.1 format) Desired burnup in MWd/MTU for interpolation
Line 7	NCYC=ii (I2 format) Number of cycles in SAS2H depletion
Line 8	END BURNUP
Line 9	READ DECAY
Line 10	NORS=ii (I2 format) Unit number for ORIGEN-S input file created by SNIKR1 (74)
Line 11	N71=ii (I2 format) Unit number to which ORIGEN-S will write the restart file containing the isotopic data at the requested cooling times. This file will then be read by SNIKR3 (71)
Line 12	COOLTME=xxx.xx (F6.2 format) Cooling time in years at which isotopics are desired

Line 13 LIGHTEL=ii (I2 format)
Number of light element nuclides for which isotopics are desired. Data will be read after "END DECAY." This option allows the user to extract light element data in addition to actinide and fission-product data and/or to adjust the concentrations of light-element nuclides.

Line 14 END DECAY

If LIGHTEL > 0, enter the following data for each light-element nuclide (free format):

a. Nuclide ID number
b. Atom density of nuclide
c. Option flag
    1= replace SAS2H atom density with value entered above
    2= replace SAS2H atom density only if SAS2H value is zero
    3= add the atom density to the SAS2H value. Using this option and an atom density of zero above will extract data from SAS2H without modification.

Line 15 SNIKR3

Line 16 Title card for SNIKR3 (80-character maximum)

Line 17 READ MXFUEL

Line 18 N71=ii (I2 format)
Unit number from which SNIKR3 will read the ORIGEN-S restart file containing the isotopic data at the requested cooling times (71)

Line 19 NICE=ii (I2 format)
Unit number to which SNIKR3 writes the data for input to ICE (75)

Line 20 NOUT3=ii (I2 format)
Unit number to which SNIKR3 writes the data in SCALE standard composition and KENO V.a mixing table input formats (73)

Line 21 NCOOL=ii (I2 format)
Cooling time step in ORIGEN-S output from which isotopic data are to be extracted

Line 22 FISPROD=iii (I3 format)
Actinide and fission-product nuclides for which isotopic data are to be extracted

0	=	25 burnup credit nuclides from ref. 4
−1	=	37 burnup credit nuclides from ref. 1
−2	=	48 nuclides used in reactor critical calculations (Table 2)
−3	=	193 nuclides (all nuclides in 27-group burnup library)
N	=	Read N nuclides specified by user after "END MXFUEL"

Line 23 MIXF=iiii (I4 format)
Mixture number for SCALE standard composition input

Line 24 IDMOD=ii (I2 format)
Fuel nuclide ID modifier for seven burnup-dependent actinides

Line 25 END MXFUEL

If FISPROD > 0, enter the nuclide IDs here. (Format 10(1X,I5))

SNIKR1 FORTRAN Listing

```
C
C
      PROGRAM SNIKR1
       COMMON /CONST/ BCONV,BURN,COOL,MIXF,IDMOD,SMACT0
       COMMON /INDEX/ NBURN,NCRIT,NLITL,ILE,IACT,IFP,ITOT,NCYC
       COMMON /UNTNOS/ N72,NOUT,N71,NORS,NICE
       COMMON /IDENT/ IDLITL(40),IDCRIT(200),IDDK(2000)
       COMMON /ADENS/ ADLITL(40),LTYP(40),ADCRIT(200),ADDK(2000)
       COMMON /TITLE/ ITTL(20)
       DIMENSION TSTEP(10)
C  READ INPUT TO SNIKR NEEDED TO SET UP ORS RUNS
      DATA TSTEP/0.08,0.25,0.5,1.0,2.0,3.0,5.0,10,15,20/
      CALL RDINPT1
C
C  WRITE INPUT TO NOUT
C
      WRITE(NOUT,120)ITTL
      WRITE(NOUT,130)N72
      WRITE(NOUT,140)NOUT
      WRITE(NOUT,150)BURN
      WRITE(NOUT,160)BCONV
      WRITE(NOUT,170)NCYC
      WRITE(NOUT,140)NORS
      WRITE(NOUT,180)COOL
      WRITE(NOUT,190)NLITL
  120 FORMAT(20A4)
  130 FORMAT(4X,I2)
  140 FORMAT(5X,I2)
  150 FORMAT(5X,F8.1)
  160 FORMAT(6X,F6.4)
  170 FORMAT(5X,I2)
  180 FORMAT(8X,F6.2)
  190 FORMAT(8X,I2)
C
C  RETRIEVE NUMBER DENSITIES FROM SAS2H OUTPUT (N71) FOR BURN
      CALL DENSITY
C     WRITE(NOUT,110)(IDDK(I),ADDK(I),I=1,ITOT)
C 110 FORMAT(4(I8,2X,1P,E10.4))
C
C  IF THE REQUESTED BURNUP OR COOLING TIME IS 0, IT IS NOT NECESSARY
C  TO PERFORM THE ORIGEN-S STEP
      IF(BURN.EQ.0.0.OR.COOL.EQ.0.0)GO TO 1000
C  SET UP ORIGEN-S RUN TO DECAY ISOTOPICS FOR REQUESTED COOL TIME
      CALL TYMSTP(NCOOL,TSTEP)
      WRITE(NOUT,100)NCOOL
 100  FORMAT('****NEEDED FOR PHASE 3 INPUT****    NCOOL= ',I2,'.')
      CALL LITEL(0)
      CALL WRTORS(TSTEP)
      GO TO 2000
C  **********CHECK FILE NOUT FOR MESSAGES
 1000 CONTINUE
      NCOOL=0
      CALL RDINPT3(NCOOL)
      CALL LITEL(0)
      CALL CLECT(1)
      CALL WRTICE
C
C  WRITE NUMBER DENSITIES FOR MIXING IN KENO TO ...NOUT3
      CALL WRTKENO
 2000 STOP
      END
C-------------------------------------------------------------------
C
C  READ INPUT DATA FOR PHASE ONE CALCULATIONS, READING SAS2H OUTPUT
C  AND SETTING UP ORIGEN-S DECAY ONLY CASE
```

```
C
C-------------------------------------------------------------------
      SUBROUTINE RDINPT1
       COMMON /CONST/ BCONV,BURN,COOL,MIXF,IDMOD,SMACT0
       COMMON /INDEX/ NBURN,NCRIT,NLITL,ILE,IACT,IFP,ITOT,NCYC
       COMMON /UNTNOS/ N72,NOUT,N71,NORS,NICE
       COMMON /IDENT/ IDLITL(40),IDCRIT(200),IDDK(2000)
       COMMON /ADENS/ ADLITL(40),LTYP(40),ADCRIT(200),ADDK(2000)
       COMMON /TITLE/ ITTL(20)
      CHARACTER*6 ICHK
      N5=5
      READ(N5,110)ICHK
C  READ AND CHECK IF APPROPRIATE PHASE INPUT - SNIKR1
      IF(ICHK.NE.'SNIKR1')STOP 5101
C  READ TITLE CARD
      READ(N5,120)ITTL
C  READ LABEL AND CHECK TO BE SURE BURN DATA IS NEXT
      READ(N5,110)ICHK
      IF(ICHK.NE.'READ B')STOP 5102
C  READ N72, UNIT NUMBER FOR SAS2H FILE 72 OUTPUT TO BE READ FROM
      READ(N5,130)N72
C  READ NOUT, UNIT NUMBER FOR OUTPUT TO BE WRITTEN TO
      READ(N5,140)NOUT
C  READ BURNUP IN MWD/MTU THAT NUMBER DENSITIES ARE TO BE RETRIEVED FROM N72
      READ(N5,150)BURN
C  READ METAL (MTU/ASSEMBLY), BCONV IS CONVERSION FACTOR FOR BURNUPS
C  READ FROM N72
C     READ(N5,160)BCONV
C   **** MODIFIED SNIKR, NOW READ FROM SAS2H OUTPUT
C
C  READ NCYC, NUMBER OF BURN CYCLES USED TO PRODUCE SAS2H OUTPUT ON N72
      READ(N5,170)NCYC
C  READ AND CHECK THAT THIS IS END OF BURNUP DATA
      READ(N5,110)ICHK
      IF(ICHK.NE.'END BU')STOP 5103
C  READ AND CHECK THAT DECAY DATA BEGINS WITH NEXT CARD
      READ(N5,110)ICHK
      IF(ICHK.NE.'READ D')STOP 5104
C  READ NORS, UNIT NUMBER FOR ORIGEN-S INPUT TO BE WRITTEN
      READ(N5,140)NORS
C  READ N71, UNIT NUMBER FOR ORIGEN-S OUTPUT TO BE WRITTEN FOR PHASE 3
      READ(N5,130)N71
C  READ COOLING TIME IN YEARS TO BE USED TO SET UP ORIGEN-S DECAY CASE
      READ(N5,180)COOL
C  READ THE NUMBER OF LIGHT ELEMENTS TO BE SPECIFIED IN THE DECAY CASE
      READ(N5,190)NLITL
C  READ AND CHECK THAT THIS IS THE END OF DECAY DATA
      READ(N5,110)ICHK
      IF(ICHK.NE.'END DE')STOP 5105
C  IF NLITL IS GREATER THAN ZERO READ IN ID'S OF LIGHT ELEMENTS
      IF(NLITL.EQ.0)GO TO 1000
      READ(N5,*)(IDLITL(I),ADLITL(I),LTYP(I),I=1,NLITL)
 1000 CONTINUE
C
C  WRITE INPUT TO NOUT
C
C     WRITE(NOUT,120)ITTL
C     WRITE(NOUT,130)N72
C     WRITE(NOUT,140)NOUT
C     WRITE(NOUT,150)BURN
C     WRITE(NOUT,160)BCONV
C     WRITE(NOUT,170)NCYC
C     WRITE(NOUT,140)NORS
C     WRITE(NOUT,180)COOL
C     WRITE(NOUT,190)NLITL
      RETURN
  110 FORMAT(A6)
  120 FORMAT(20A4)
```

```
  130 FORMAT(4X,I2)
  140 FORMAT(5X,I2)
  150 FORMAT(5X,F8.1)
  160 FORMAT(6X,F6.4)
  170 FORMAT(5X,I2)
  180 FORMAT(8X,F6.2)
  190 FORMAT(8X,I2)
C 195 FORMAT(1X,I5,E10.4,2X,I1)
      END
C
C  RETURNS IDDK AND ADDK ARRAYS FOR THE APPROPRIATE BURNUP, BURN
C
C---------------------------------------------------------------------
      SUBROUTINE DENSITY
       COMMON /CONST/ BCONV,BURN,COOL,MIXF,IDMOD,SMACT0
       COMMON /INDEX/ NBURN,NCRIT,NLITL,ILE,IACT,IFP,ITOT,NCYC
       COMMON /UNTNOS/ N72,NOUT,N71,NORS,NICE
       COMMON /IDENT/ IDLITL(40),IDCRIT(200),IDDK(2000)
       COMMON /ADENS/ ADLITL(40),LTYP(40),ADCRIT(200),ADDK(2000)
       COMMON /TITLE/ ITTL(20)
       DIMENSION RDBURN(10),IDPLT(26),A(2000),B(2000),AD(2000,10)
      DATA IDPLT/92234,92235,92236,92238,94238,94239,94240,94241,
     &94242,95241,8016,42095,43099,45103,55133,55135,60143,60145,
     &62147,62149,62150,62151,62152,63153,64155,13027/
       NC=-1
       NBN=0
 1000  NC=NC+1
       NBN=NBN+1
       CALL RDF72(NC,AD,RDBRN)
C
C  CONVERT RDBRN FROM MWD/ASSY TO MWD/MTU
C
       RDBRN=RDBRN/BCONV
       WRITE(NOUT,130)RDBRN
       RDBURN(NBN)=RDBRN
       IF(NC.LT.NCYC)GO TO 1000
C  *******************************************************************
C   THIS SECTION TEMPORARY TO PLOT NUMBER DENSITY WITH BURNUP
       DO 3 J=1,26
       WRITE(NOUT,332)IDPLT(J)
       IDPLT(J)=IDPLT(J)*10
       DO 2 I=1,ITOT
       IF(IDDK(I).NE.IDPLT(J)) GO TO 2
       DO 1 K=1,NBN
   1   WRITE(NOUT,333)RDBURN(K),AD(I,K)
   2   CONTINUE
   3   CONTINUE
  333  FORMAT(F8.1,1X,',',1X,1P,E11.3)
  332  FORMAT('PAIRS OF BURNUP(MWD/MTU) AND NUMBER DENSITY FOR ',I10)
C  *******************************************************************
       SMACT0=0.
       I1=ILE+1
       I2=ILE+IACT
       DO 31 I=I1,I2
   31  SMACT0=SMACT0+AD(I,1)
       WRITE(NOUT,105)SMACT0
  105  FORMAT('SMACT0=',1PE10.4)
       IF(BURN.EQ.0.0)THEN
       IBN=0
       GO TO 1500
       END IF
      IF(BURN.GE.RDBURN(2))GO TO 15
      WRITE(NOUT,110)
      WRITE(NOUT,120)BURN,RDBURN(2)
      IBN=2
      GO TO 1500
  15  CONTINUE
      IF(BURN.GT.RDBURN(NBN))THEN
```

```
      IBN=NBN
      WRITE(NOUT,110)
      WRITE(NOUT,140)BURN,RDBURN(NBN)
      GO TO 1500
      END IF
       DO 20 I=1,NBN
      BDIFF=ABS(RDBURN(I)-BURN)/BURN
      IF(BDIFF.LT.0.01)THEN
      IBN=I
      GO TO 1500
      END IF
      IF(RDBURN(I).GT.BURN)GO TO 1250
      ILOW=I
   20 CONTINUE
 1250 CONTINUE
      IHI=ILOW+1
C@@@*********BEGIN LINEAR INTERPOLATION*************************
C     DO 25 K=1,ITOT
C     A(K)=AD(K,ILOW)
C  25 B(K)=AD(K,IHI)
C     CALL INTERP(A,B,RDBURN(ILOW),RDBURN(IHI))
C***************END LINEAR INTERPOLATION*************************
C@@@*********BEGIN LAGRANGIAN INTERPOLATION*************************
      DO 27 I=1,ITOT
      DO 26 J=2,NBN
   26 A(J-1)=AD(I,J)
      DO 28 K=2,NBN
  28  B(K-1)=RDBURN(K)
      NBINT=NBN-1
      CALL LAGINT(B,A,NBINT,BURN,CONC)
   27 ADDK(I)=CONC
C***************END LAGRANGIAN INTERPOLATION*************************
      RETURN
 1500 CONTINUE
C     WRITE(NOUT,160)
C     WRITE(NOUT,150)(IDDK(I),AD(I,IBN),I=1,ITOT)
      DO 30 J=1,ITOT
   30 ADDK(J)=AD(J,IBN)
C     WRITE(NOUT,150)(IDDK(I),ADDK(I),I=1,ITOT)
      RETURN
  110 FORMAT('$$WARNING --------')
  120 FORMAT('REQUESTED BURNUP OF ',F10.3,' GWD/MTU IS LESS THAN FIRST'
     &/'CYCLE BURNUP OF ',F10.3,'.  FIRST CYCLE BURNUP HAS BEEN USED')
  130 FORMAT('RDBRN=',F10.3)
  140 FORMAT('REQUESTED BURNUP OF ',F10.3,' GWD/MTU IS GREATER THAN LAST
     &'/'CYCLE BURNUP OF ',F10.3,'.   FINAL CYCLE BURNUP HAS BEEN USED')
C 150 FORMAT(4(I8,2X,1P,E10.4))
C 160 FORMAT('PAST 1500')
      END
C---------------------------------------------------------------------
       SUBROUTINE RDF72(NC,AD,RDBURN)
       COMMON /CONST/ BCONV,BURN,COOL,MIXF,IDMOD,SMACT0
       COMMON /INDEX/ NBURN,NCRIT,NLITL,ILE,IACT,IFP,ITOT,NCYC
       COMMON /UNTNOS/ N72,NOUT,N71,NORS,NICE
       COMMON /IDENT/ IDLITL(40),IDCRIT(200),IDDK(2000)
       COMMON /ADENS/ ADLITL(40),LTYP(40),ADCRIT(200),ADDK(2000)
       COMMON /TITLE/ ITTL(20)
       DIMENSION AD(2000,10)
       CHARACTER*4 ITEST,TTL72(20)
       NCT=NC+1
       IND=3
C
C  READ THE FOLLOWING QUANTITIES FROM FILE 72 IN ADDITION TO NUCLIDE
C  ID AND NUMBER DENSITY
C     1) LPASS, LIBRARY PASS NO. USED FOR ORIGEN-S CASE
C     2) MTIME, POSITION NO. OF DATA FROM UNIT NO. 71
C     3) TW, TIME FROM START OF ASSEMBLY BURNUP, D
C     4) DUM1
```

```
C      5) RDBURN, ACCUMULATED BURNUP AT TW, MWD/ASSEMBLY
C      6) SPWR, SPECIFIC POWER OF CYCLE, KW/KG U
C      7) DUM3
C      8) BCONV, INITIAL METRIC TON U WEIGHT PER ASSEMBLY
C
       READ(N72,100,END=2000)LPASS,MTIME,TW,DUM1,RDBURN,SPWR,DUM3,BCONV
       IF(NCT.EQ.1)WRITE(NOUT,99)
   99  FORMAT(/,
     &/'1) LPASS, LIBRARY PASS NO. USED FOR ORIGEN-S CASE',
     &/'2) MTIME, POSITION NO. OF DATA FROM UNIT NO. 71',
     &/'3) TW, TIME FROM START OF ASSEMBLY BURNUP, D',
     &/'4) DUM1',
     &/'5) RDBURN, ACCUMULATED BURNUP AT TW, MWD/ASSEMBLY',
     &/'6) SPWR, SPECIFIC POWER OF CYCLE, KW/KG U',
     &/'7) DUM3',
     &/'8) BCONV, INITIAL METRIC TON U WEIGHT PER ASSEMBLY')
       WRITE(NOUT,100) LPASS,MTIME,TW,DUM1,RDBURN,SPWR,DUM3,BCONV
       IF(LPASS.EQ.NCYC)IND=1
       IF(LPASS.NE.NC)THEN
       WRITE(NOUT,101)NC,LPASS,NCYC
  101  FORMAT('NC=',I2,' LPASS=',I2,' NCYC=',I2,' MTIME=',I2,' IND=',I2)
       STOP 7210
       END IF
       IF(MTIME.NE.IND)THEN
       WRITE(NOUT,101)NC,LPASS,NCYC,MTIME,IND
       IF(NC.EQ.NCYC.AND.MTIME.EQ.3)GO TO 5
       STOP 7220
       END IF
    5  CONTINUE
       READ(N72,110) ITOT,ILE,IACT,IFP
       ISUM=ILE+IACT+IFP
       IF(ISUM.NE.ITOT)STOP 7230
       DO 10 I=1,4
   10  READ(N72,140)
       READ(N72,120)(IDDK(I),AD(I,NCT),I=1,ITOT)
C      WRITE(NOUT,102)NCT,LPASS,NCYC
C 102  FORMAT('NCT=',I2,' LPASS=',I2,' NCYC=',I2,'  AD ARRAY')
C      WRITE(NOUT,120)(IDDK(I),AD(I,NCT),I=ILE,ILE+16)
       READ(N72,125)TTL72
       WRITE(NOUT,125)TTL72
C      WRITE(NOUT,160)RDBURN,NCT
 1000  READ(N72,130)ITEST
       IF(ITEST.NE.'----')GO TO 1000
       RETURN
 2000  CONTINUE
       WRITE(NOUT,150)
       RETURN
  100  FORMAT(2I10,6(1X,1P,E9.3))
  110  FORMAT(4I10)
  120  FORMAT(4(I8,2X,1P,E10.4))
  125  FORMAT(20A4)
  130  FORMAT(A4)
  140  FORMAT( )
  150  FORMAT('***EOF ERROR READING FILE 72***')
C 160  FORMAT('RDBURN(F72)=',F10.3,' NCT=',I2)
       END
C-----------------------------------------------------------------------
      SUBROUTINE LAGINT(X,Y,N,XINT,YOUT)
C  THIS SUBROUTINE PERFORMS LAGRANGIAN INTERPOLATION WITHIN A SET OF
C  (X,Y) PAIRS TO GIVE THE Y VALUE CORRESPONDING TO XINT.  THE DEGREE OF
C  THE INTERPOLATING POLYNOMIAL IS ONE LESS THAN THE NUMBER OF POINTS
C  SUPPLIED.  TAKEN FROM GERALD'S "APPLIED NUMERICAL ANALYSIS" PG 181
C  PARAMETERS ARE:
C      X - ARRAY OF VALUES OF THE INDEPENDENT VARIABLE
C      Y - ARRAY OF FUNCTION VALUES CORRESPONDING TO X
C      N - NUMBER OF POINTS
C   XINT - THE X-VALUE FOR WHICH ESTIMATE OF Y IS DESIRED
C   YOUT - THE Y-VALUE RETURNED TO CALLER
```

```
      DIMENSION X(10),Y(10)
C ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
C  8/16/91 - MODIFIED ORIGINAL SUBROUTINE TO CHECK FOR ZERO OR NEAR
C  ZERO NUMBER DENSITIES BEFORE INTERPOLATING
      NC0=0
      NM1=N-1
      DO 5 I=1,N
      IF(Y(I).GT.1.0E-25)GO TO 5
      NC0=NC0+1
  5   CONTINUE
      IF(NC0.LT.NM1)GO TO 8
      YOUT=0.0
      RETURN
  8   CONTINUE
C +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
      YOUT=0.0
      DO 20 I=1,N
       TERM=Y(I)
       DO 10 J=1,N
        IF(I.EQ.J)GO TO 10
        TERM=TERM*(XINT-X(J))/(X(I)-X(J))
   10  CONTINUE
         YOUT=YOUT+TERM
   20  CONTINUE
      IF(YOUT.LE.1.0E-25)YOUT=0.0
       RETURN
       END
C----------------------------------------------------------------------
       SUBROUTINE INTERP(A1,A2,B1,B2)
C
C  THIS ROUTINE LINEARLY INTERPOLATES ATOM DENSITY AS A
C  FUNCTION OF BURNUP
C
       COMMON /CONST/ BCONV,BURN,COOL,MIXF,IDMOD,SMACT0
       COMMON /INDEX/ NBURN,NCRIT,NLITL,ILE,IACT,IFP,ITOT,NCYC
       COMMON /UNTNOS/ N72,NOUT,N71,NORS,NICE
       COMMON /IDENT/ IDLITL(40),IDCRIT(200),IDDK(2000)
       COMMON /ADENS/ ADLITL(40),LTYP(40),ADCRIT(200),ADDK(2000)
       COMMON /TITLE/ ITTL(20)
       DIMENSION A1(2000),A2(2000)
       DB=B2-B1
       DELB=B2-BURN
       DO 10 I=1,ITOT
       SLOPE=(A2(I)-A1(I))/DB
       ADDK(I)=A2(I)-SLOPE*DELB
       IF(ADDK(I).LT.0.0)STOP 7299
       IF(IDDK(I).NE.922350)GO TO 10
       WRITE(NOUT,111)B1,A1(I),B2,A2(I),SLOPE,DELB
       WRITE(NOUT,112)ADDK(I)
 10    CONTINUE
 111   FORMAT('B1=',F8.1,' A1=',E11.4,' B2=',F8.1,' A2=',E11.4,
     &' SLOPE=',E11.4,' DELB=',E11.4)
 112   FORMAT('VALUE FOR LINEAR INTERP FOR 92235',1X,E11.4)
       RETURN
       END
C-------------------------------------------------------------------
      SUBROUTINE TYMSTP(NCOOL,TSTEP)
       COMMON /CONST/ BCONV,BURN,COOL,MIXF,IDMOD,SMACT0
       COMMON /INDEX/ NBURN,NCRIT,NLITL,ILE,IACT,IFP,ITOT,NCYC
       COMMON /UNTNOS/ N72,NOUT,N71,NORS,NICE
       COMMON /IDENT/ IDLITL(40),IDCRIT(200),IDDK(2000)
       COMMON /ADENS/ ADLITL(40),LTYP(40),ADCRIT(200),ADDK(2000)
       COMMON /TITLE/ ITTL(20)
      DIMENSION TSTEP(10)
C
C  THIS ROUTINE WILL CHECK REQUESTED COOLING TIME AGAINST THE
C  DEFAULT TSTEP ARRAY AND MAKE ANY CHANGES THAT ARE NECESSARY
C  TO ACCOMMODATE THE USER'S REQUEST
```

```
C
C  IF THE USER REQUEST A DECAY STEP NOT IN THE DEFAULT LIST,
C  THE TIME STEP NEAREST THE REQUESTED COOLING TIME WILL BE
C  ALTERED.  THE LONGEST COOLING TIME ALLOWED IS 20 YEARS.
C
      COOLMX=20
      DO 10 I=1,10
      IF(COOL.NE.TSTEP(I))GO TO 10
      NCOOL=I
      RETURN
   10 CONTINUE
      IF(COOL.LE.COOLMX)GO TO 20
      WRITE(NOUT,100)COOL,COOLMX
      STOP 801
   20 CONTINUE
      DO 30 J=1,9
      IF(TSTEP(J).LT.COOL.AND.COOL.LT.TSTEP(J+1))THEN
         JCOOL=J
         GO TO 40
         END IF
   30 CONTINUE
      TSTEP(10)=COOL
      NCOOL=10
      RETURN
   40 F1=COOL-TSTEP(JCOOL)
      F2=TSTEP(JCOOL+1)-COOL
      IF(F1.GT.F2)JCOOL=JCOOL+1
         TSTEP(JCOOL)=COOL
         NCOOL=JCOOL
      RETURN
  100 FORMAT('REQUESTED COOLING TIME ',F7.2,' LARGER THAN MAXIMUM OF ',
     &F4.1,' YEARS')
      END
C-------------------------------------------------------------------
       SUBROUTINE LITEL(IFLAG)
C
C  THIS SUBROUTINE CHECKS TO SEE IF ANY
C  LIGHT ELEMENTS ARE REQUESTED BY THE
C  USER, IF OXYGEN IS NOT EXPLICITLY
C  REQUESTED IT IS ADDED.
C
       COMMON /CONST/ BCONV,BURN,COOL,MIXF,IDMOD,SMACT0
       COMMON /INDEX/ NBURN,NCRIT,NLITL,ILE,IACT,IFP,ITOT,NCYC
       COMMON /UNTNOS/ N72,NOUT,N71,NORS,NICE
       COMMON /IDENT/ IDLITL(40),IDCRIT(200),IDDK(2000)
       COMMON /ADENS/ ADLITL(40),LTYP(40),ADCRIT(200),ADDK(2000)
       COMMON /TITLE/ ITTL(20)
C
       IF(NLITL.NE.0)GO TO 10
       NLITL=1
       IDLITL(1)=8016
       LTYP(1)=1
       GO TO 30
    10 CONTINUE
       DO 20 I=1,NLITL
       IF(IDLITL(I).EQ.8016)GO TO 35
    20 CONTINUE
       NLITL=NLITL+1
       IDLITL(NLITL)=8016
       LTYP(NLITL)=1
    30 CONTINUE
       IF(IFLAG.EQ.1)GO TO 45
       ADLITL(NLITL)=2.0*SMACT0
       WRITE(NOUT,110)ADLITL(NLITL)
   110 FORMAT('ADLITL(NLITL)=',1PE10.4)
    35 CONTINUE
       DO 40 I=1,NLITL
       DO 40 J=1,ILE
```

```
      IDLT=IDLITL(I)*10
      IF(IDLT.NE.IDDK(J))GO TO 40
      WRITE(NOUT,150)IDDK(J),ADDK(J)
      IF(LTYP(I).EQ.1)ADDK(J)=ADLITL(I)
      IF(LTYP(I).EQ.2.AND.ADDK(J).EQ.0.)ADDK(J)=ADLITL(I)
      IF(LTYP(I).EQ.3.AND.ADDK(J).NE.0.)ADDK(J)=ADDK(J)+ADLITL(I)
      WRITE(NOUT,140)IDLT,ADLITL(I)
      WRITE(NOUT,150)IDDK(J),ADDK(J)
   40 CONTINUE
   45 CONTINUE
      DO 50 I=1,NLITL
   50 IF(IDLITL(I).EQ.8016)WRITE(NOUT,120)ADLITL(I)
      DO 60 J=1,ITOT
   60 IF(IDDK(J).EQ.80160)WRITE(NOUT,130)J,IDDK(J),ADDK(J)
      RETURN
  120 FORMAT('ADLITL FOR 8016= ',1PE10.4)
  130 FORMAT(I2,I10,' ADDK FOR 8016=',1PE10.4)
  140 FORMAT('LITEL ARRAY',2X,I6,2X,1PE10.4)
  150 FORMAT('DECAY ARRAY',2X,I6,2X,1PE10.4)
      END
C---------------------------------------------------------------------
      SUBROUTINE WRTORS(TSTEP)
C
C  ABURN IS THE ASSEMBLY BURNUP (MWD/ASSEMBLY), N71 IS THE
C  FILE THE BINARY OUTPUT FILE IS TO BE WRITTEN TO, TSTEP
C  IS THE ARRAY CONTAINING THE DECAY TIME INTERVALS, AND
C  TBURN IS THE TOTAL BURNUP (GWD/MTU)
C
C
C  THIS ROUTINE WRITES THE INPUT TO THE ORIGEN-S
C  DECAY CASE - ***PRESENTLY IN CARD IMAGE FORM TO
C  UNIT 'NORS' FOR INPUT TO ORS, WILL CHANGE TO WRITE
C  BINARY INPUT FOR DRIVER TO CALL ORIGEN-S
C
      COMMON /CONST/ BCONV,BURN,COOL,MIXF,IDMOD,SMACT0
      COMMON /INDEX/ NBURN,NCRIT,NLITL,ILE,IACT,IFP,ITOT,NCYC
      COMMON /UNTNOS/ N72,NOUT,N71,NORS,NICE
      COMMON /IDENT/ IDLITL(40),IDCRIT(200),IDDK(2000)
      COMMON /ADENS/ ADLITL(40),LTYP(40),ADCRIT(200),ADDK(2000)
      COMMON /TITLE/ ITTL(20)
      DIMENSION TSTEP(10)
C  CONVERT BURNUP TO GWD/MTU - TBURN
      TBURN=BURN/1000.
C  CONVERT BURNUP TO MWD/ASSEMBLY - ABURN
      ABURN=BURN*BCONV
        WRITE(NORS,203) N71
        WRITE(NORS,204) ABURN
        WRITE(NORS,205)
      WRITE(NORS,206)ITOT
      WRITE(NORS,207)TBURN
      WRITE(NORS,208)
      WRITE(NORS,209)(TSTEP(K),K=1,10)
      WRITE(NORS,211)
      WRITE(NORS,201)
      WRITE(NORS,220)(IDDK(K),ADDK(K),K=1,ITOT)
      WRITE(NORS,202)
      WRITE(NORS,220)(IDDK(K),ADDK(K),K=1,ITOT)
      WRITE(NORS,212)ILE,IACT,IFP
      WRITE(NORS,214)
      WRITE(NORS,213)
      RETURN
  201 FORMAT('73U'/'  (3(I8,12X))')
  202 FORMAT('74U'/'  (3(10X,1P,E10.4))')
  203 FORMAT('#ORIGENS'/'0$$ A11 ',I2,' E  1T')
  204 FORMAT('DECAY ONLY CASES FOR SNIKR AT BURNUP ',1P,E9.3,
     &' MWD/ASSEMBLY')
  205 FORMAT('2T'/'35$$ 0 4T')
  206 FORMAT('56$$  A5 1  1 A13 ',I4,' 5 3 0 4 E 5T')
```

```
  207  FORMAT('BURNUP - ',1P,E9.3,' GWD/MTU')
  208  FORMAT('UNITS - ATOMS/BARN-CM')
  209  FORMAT('60** ',10(1X,F5.2))
  211  FORMAT('65$$ 1 A22 1 A43 1 E')
  212  FORMAT('75$$ ',I3,'R1 ',I3,'R2 ',I3,'R3'/'6T')
  213  FORMAT('56$$ F0 T'/'END')
  214  FORMAT('56$$ 0 -10 A10 0 E T')
  220  FORMAT(3(I8,2X,1P,E10.4))
       END
C-----------------------------------------------------------------------
      SUBROUTINE RDINPT3(NCOOL)
       COMMON /CONST/ BCONV,BURN,COOL,MIXF,IDMOD,SMACT0
       COMMON /INDEX/ NBURN,NCRIT,NLITL,ILE,IACT,IFP,ITOT,NCYC
       COMMON /UNTNOS/ N72,NOUT,N71,NORS,NICE
       COMMON /IDENT/ IDLITL(40),IDCRIT(210),IDDK(2000)
       COMMON /ADENS/ ADLITL(40),LTYP(40),ADCRIT(200),ADDK(2000)
       COMMON /TITLE/ ITTL(20)
      CHARACTER*6 ICHK
      DIMENSION IDAT1(25),IDAT2(37),IDAT3(49),IDAT4(193)
      DATA IDAT1/92234,92235,92236,92238,94238,94239,94240,94241,
     &94242,95241,8016,42095,43099,45103,55133,55135,60143,60145,
     &62147,62149,62150,62151,62152,63153,64155/
      DATA IDAT2/92234,92235,92236,92238,93237,94238,94239,94240,94241,
     &94242,95241,95243,96244,8016,40093,42095,43099,44101,45103,46105,
     &46108,47109,55133,55135,59141,60143,60145,61147,62147,62149,
     &62150,62151,62152,63153,63154,63155,64155/
      DATA IDAT3/92234,92235,92236,92238,93237,94238,94239,94240,94241,
     &94242,95241,95243,96244,8016,36083,40093,42095,43099,
     &44101,44103,45103,45105,46105,46108,47109,53135,54131,54135,
     &55133,55134,55135,59141,60143,60145,60147,60148,61147,61148,
     &61149,62147,62149,62150,62151,62152,63153,63154,63155,64155,
     &99999/
      DATA IDAT4/ 32072,32073,32074,32076,33075,34076,34077,34078,34080,
     &34082,35079,35081,36080,36082,36083,36084,36085,36086,37085,37086,
     &37087,38086,38087,38088,38089,38090,39089,39090,39091,40090,40091,
     &40092,40093,40094,40095,40096,41093,41094,41095, 8016,42095,42096,
     &42097,42098,42099,42100,43099,44099,44100,44101,44102,44104,44105,
     &44106,46104,46105,46106,46107,46108,46110,47107,47109,47111,48108,
     &48110,48111,48112,48113,48114,      48116,49113,49115,50115,50116,
     &50117,50118,50119,50120,50122,50123,50124,50125,50126,51121,51123,
     &51124,51125,51126,52122,52123,52124,52125,52126,      52128,
     &52130,52132,53127,53129,53130,53131,54128,54129,54130,54131,54132,
     &54133,54134,54136,55133,55134,55135,55136,55137,56134,56135,56136,
     &56137,56138,56140,57139,57140,58140,58141,58142,58143,58144,59141,
     &59142,59143,60142,60143,60144,60145,60146,60150,61151,62147,62148,
     &62150,62151,62152,62153,62154,63151,63152,63156,63157,64154,64156,
     &64157,64158,64160,65159,65160,66160,66161,66162,66163,66164,67165,
     &68166,68167,44103,45103,45105,53135,54135,60147,60148,61147,61148,
     &62149,61149,63153,63154,63155,      64155,90232,91233,92233,92234,
     &92235,92236,92238,93237,94238,94239,94240,94241,94242,95241,
     &95243,96244/
      N5=5
      READ(N5,110)ICHK
C  READ AND CHECK IF APPROPRIATE PHASE INPUT - SNIKR3
      IF(ICHK.NE.'SNIKR3')STOP 5301
C  READ TITLE CARD
      READ(N5,120)ITTL
C  READ LABEL AND CHECK TO BE SURE MXFUEL DATA IS NEXT
      READ(N5,110)ICHK
      IF(ICHK.NE.'READ M')STOP 5302
C  READ N72, UNIT NUMBER FOR ORIGEN-S FILE 71 OUTPUT TO BE READ FROM
      READ(N5,130)N71
C  READ NICE, UNIT NUMBER FOR ICE INPUT TO BE WRITTEN TO
      READ(N5,140)NICE
C  READ NOUT, UNIT NUMBER FOR OUTPUT TO BE WRITTEN TO
      READ(N5,140)NOUT
C  READ NCOOL, NUMBER OF COOLING STEP FOR WHICH DENSITIES ARE TO BE READ
      IF(NCOOL.GT.0)READ(N5,110)
```

```
      IF(NCOOL.EQ.0)READ(N5,145)NCOOL
C  READ FLAG NFIS TO DETERMINE WHICH FUEL NUCLIDES WILL BE USED IN
C  KENO CALCULATIONS:
C             =0  USE TTC713 INTERSECTION WITH SID BIERMAN'S NUCS
C             =-1 USE TTC713
C             =-2 USE TTC713 U SID U VEPCO U CASMO
C             =-3 USE ALL 27BURNUPLIB NUCLIDES
C             =N  READ IN USER'S CHOICE OF NUCLIDES
      READ(N5,150)NFIS
      IF(NFIS.EQ.0)THEN
      NCRIT=25
      DO 10 I=1,NCRIT
  10  IDCRIT(I)=IDAT1(I)
      GO TO 500
      END IF
      IF(NFIS.EQ.-1)THEN
      NCRIT=37
      DO 20 I=1,NCRIT
  20  IDCRIT(I)=IDAT2(I)
      GO TO 500
      END IF
      IF(NFIS.EQ.-2)THEN
      NCRIT=49
      DO 21 I=1,NCRIT
  21  IDCRIT(I)=IDAT3(I)
      GO TO 500
      END IF
      IF(NFIS.EQ.-3)THEN
      NCRIT=193
      DO 31 I=1,NCRIT
  31  IDCRIT(I)=IDAT4(I)
      GO TO 500
      END IF
      IF(NFIS.GT.0)NCRIT=NFIS
 500  CONTINUE
C  READ MIXTURE NUMBER TO BE USED FOR FUEL OF THIS BURN IN KENO CALCULATIONS
      READ(N5,160)MIXF
C  READ INTEGER MODIFIER FOR FUEL NUCLIDE ID'S FOR USE IN ICE RUN
      READ(N5,145)IDMOD
C  READ AND CHECK THAT THIS IS END OF FUEL MIX DATA
      READ(N5,110)ICHK
      IF(ICHK.NE.'END MX')STOP 5303
C  IF FISPROD IS GREATER THAN ZERO READ IN ID'S OF ELEMENTS IN FUEL FOR
C  CRITICALITY CALCULATIONS
      IF(NFIS.LE.0)GO TO 1000
      READ(N5,170)(IDCRIT(I),I=1,NCRIT)
 1000 CONTINUE
C
C  WRITE INPUT TO NOUT
C
      WRITE(NOUT,120)ITTL
      WRITE(NOUT,130)N71
      WRITE(NOUT,140)NICE
      WRITE(NOUT,140)NOUT
      WRITE(NOUT,145)NCOOL
      WRITE(NOUT,150)NFIS
      WRITE(NOUT,160)MIXF
      WRITE(NOUT,145)IDMOD
      WRITE(NOUT,170)(IDCRIT(I),I=1,NCRIT)
  110 FORMAT(A6)
  120 FORMAT(20A4)
  130 FORMAT(4X,I2)
  140 FORMAT(5X,I2)
  145 FORMAT(6X,I2)
  150 FORMAT(8X,I3)
  160 FORMAT(5X,I4)
  170 FORMAT(10(1X,I5))
      RETURN
```

```
      END
C-----------------------------------------------------------------------
       SUBROUTINE CLECT(IFLAG)
       COMMON /CONST/ BCONV,BURN,COOL,MIXF,IDMOD,SMACT0
       COMMON /INDEX/ NBURN,NCRIT,NLITL,ILE,IACT,IFP,ITOT,NCYC
       COMMON /UNTNOS/ N72,NOUT,N71,NORS,NICE
       COMMON /IDENT/ IDLITL(40),IDCRIT(200),IDDK(2000)
       COMMON /ADENS/ ADLITL(40),LTYP(40),ADCRIT(200),ADDK(2000)
       COMMON /TITLE/ ITTL(20)
       DIMENSION IDLFP(165)
      DATA IDLFP/ 32072,32073,32074,32076,33075,34076,34077,34078,34080,
     &34082,35079,35081,36080,36082,36083,36084,36085,36086,37085,37086,
     &37087,38086,38087,38088,38089,38090,39089,39090,39091,40090,40091,
     &40092,40093,40094,40095,40096,41093,41094,41095,42094,42095,42096,
     &42097,42098,42099,42100,43099,44099,44100,44101,44102,44104,44105,
     &44106,46104,46105,46106,46107,46108,46110,47107,47109,47111,48108,
     &48110,48111,48112,48113,48114,48115,48116,49113,49115,50115,50116,
     &50117,50118,50119,50120,50122,50123,50124,50125,50126,51121,51123,
     &51124,51125,51126,52122,52123,52124,52125,52126,52127,52128,52129,
     &52130,52132,53127,53129,53130,53131,54128,54129,54130,54131,54132,
     &54133,54134,54136,55133,55134,55135,55136,55137,56134,56135,56136,
     &56137,56138,56140,57139,57140,58140,58141,58142,58143,58144,59141,
     &59142,59143,60142,60143,60144,60145,60146,60150,61151,62147,62148,
     &62150,62151,62152,62153,62154,63151,63152,63156,63157,64154,64156,
     &64157,64158,64160,65159,65160,66160,66161,66162,66163,66164,67165,
     &68166,68167/
      NLFP=165
C
C  EXTRACT NUCLIDES NEEDED FOR CRITICALITY CALCULATIONS FOR THIS
C  BURNUP AND COOLING TIME.  TAKE REQUESTED LIGHT ELEMENTS FROM
C  THE LIGHT ELEMENT LIBRARY (1ST ILE ENTRIES IN IDDK/ADDK),
C  ACTINIDES FROM THE ACTINIDE DATA (NEXT IACT ENTRIES IN IDDK/ADDK),
C  AND FISSION PRODUCTS FROM THE FINAL IFP ENTRIES IN IDDK/ADDK)
C
C  NLITL WILL BE AT LEAST 1, TO ACCOUNT FOR OXYGEN.  THE ONLY
C  SITUATION THAT WILL ALLOW IT TO BE LARGER THAN 1 IS IF THE
C  USER HAS CHOSEN TO INPUT A SET OF ISOTOPICS DIFFERENT FROM
C  THE BURNUP CREDIT NUCLIDES (IE., TTC-0713 OR BIERMAN'S) AND
C  HAS CHOSEN TO ENTER MORE LIGHT ELEMENTS THAN JUST OXYGEN
C
C  IF IFLAG=1 CHANGE ALL IDDK BY FACTOR OF 10 (FROM 72 NOT 71)
       IF(IFLAG.EQ.0)GO TO 20
       DO 10 I=1,ITOT
   10  IDDK(I)=IDDK(I)/10
   20  CONTINUE
       DO 40 I=1,NLITL
       DO 30 J=1,ILE
       IF(IDDK(J).NE.IDLITL(I)) GO TO 30
       ADLITL(I)=ADDK(J)
       GO TO 40
   30  CONTINUE
       WRITE(NOUT,102)IDLITL(I),N71
  102  FORMAT('0'/'****ERROR, NO MATCH FOR LIGHT ELEMENT ',I8,
     &' WAS FOUND ON UNIT ',I2)
       STOP 7102
   40  CONTINUE
       NLP1=ILE+1
       DO 70 I=1,NCRIT
        IF(IDCRIT(I).EQ.99999)GO TO 70
       ADCRIT(I)=0.0
       DO 60 J=NLP1,ITOT
       IF(IDDK(J).NE.IDCRIT(I)) GO TO 60
       ADCRIT(I)=ADDK(J)
       GO TO 70
   60  CONTINUE
       DO 65 K=1,NLITL
       IF(IDCRIT(I).EQ.IDLITL(K))GO TO 70
   65  CONTINUE
```

```
      WRITE(NOUT,103)IDCRIT(I),N71
 103  FORMAT('0'/'****ERROR, NO MATCH FOR NUCLIDE ',I8,
    &' WAS FOUND ON UNIT ',I2)
      STOP 7103
  70  CONTINUE
C  ADD CONTRIBUTION FROM LIGHT ELEMENT AND ACTINIDE/FISSION PRODUCT LIBR
      DO 80 I=1,NLITL
      DO 80 J=1,NCRIT
      IF(IDCRIT(J).NE.IDLITL(I))GO TO 80
      ADCRIT(J)=ADCRIT(J)+ADLITL(I)
  80  CONTINUE
C   COMPUTE NUMBER DENSITY FOR LUMPED-FISSION PRODUCT IF REQUESTED
C   ONLY AVAILABLE FOR NFIS=-2  (FOR MIKEY'S USE ONLY)***
      ADLFP=0.0
      IFP0=ILE+IACT
C  DO WE NEED TO CALCULATE A LUMPED FISSION PRODUCT
C  CHECK TO SEE IF IDCRIT=99999, IF SO CALCULATE LFP
C  ALSO (IF ICKFP=1) CHECK TO SEE IF ANY NUCLIDE IN IDCRIT IS ALSO
C  IN IDLFP, IF SO SET IDLFP TO ZERO
C
C  ICKFP=0 WILL CALCULATE THE VIRGINIA POWER LUMPED FISSION PRODUCT
C  EXPLICITLY
      ICKFP=0
C
C ICKFP=1 CALCULATES VP LFP MINUS FP IN IDCRIT ARRAY ###DON'T USE NOW
C     ICKFP=1
      K99=0
      DO 92 KL=1,NCRIT
      IF(IDCRIT(KL).EQ.99999)K99=KL
      IF(ICKFP.EQ.0)GO TO 92
      DO 90 J=1,NLFP
      IF(IDLFP(J).NE.IDCRIT(KL))GO TO 90
      WRITE(NOUT,110)IDLFP(J)
      IDLFP(J)=0
      GO TO 92
  90  CONTINUE
  92  CONTINUE
 110  FORMAT(I10,' NUCLIDE WAS IN IDLFP AND IDCRIT')
C   NO LFP CALCULATION IS REQUIRED IF K99=0
      IF(K99.EQ.0)RETURN
      DO 95 I=1,IFP
      J=IFP0+I
      DO 94 KJ=1,NLFP
      IF(IDDK(J).NE.IDLFP(KJ))GO TO 94
      ADLFP=ADLFP+ADDK(J)
      GO TO 95
 94   CONTINUE
 95   CONTINUE
      ADCRIT(K99)=ADLFP
      RETURN
      END
C
C
C
C--------------------------------------------------------------------
     SUBROUTINE WRTICE
      COMMON /CONST/ BCONV,BURN,COOL,MIXF,IDMOD,SMACT0
      COMMON /INDEX/ NBURN,NCRIT,NLITL,ILE,IACT,IFP,ITOT,NCYC
      COMMON /UNTNOS/ N72,NOUT,N71,NORS,NICE
      COMMON /IDENT/ IDLITL(40),IDCRIT(200),IDDK(2000)
      COMMON /ADENS/ ADLITL(40),LTYP(40),ADCRIT(200),ADDK(2000)
      COMMON /TITLE/ ITTL(20)
     DIMENSION I2(200),I5(200),I11(201),IDACT(7)
     CHARACTER*4 DUM,T,ICE,END
      DATA IDACT/92234,92235,92236,92238,94239,94240,94241/
C
     T = '  T '
     ICE = '#ICE'
```

```
      END = 'END '
      MIX=1
C
      WRITE(NICE,110)ICE
      WRITE(NICE,110)ITTL
 110  FORMAT(20A4)
C
      DUM = '1$$ '
      WRITE(NICE,110)DUM
      II = 0
      I4 = 10
      KOPT = 4
      WRITE(NICE,120)MIX,NCRIT,II,II,II,I4,KOPT
 120  FORMAT(6I12)
      WRITE(NICE,110)T
C
      DO 10 I=1,NCRIT
  10  I2(I)=1
C
      DUM = '2$$ '
      WRITE(NICE,110)DUM
      WRITE(NICE,120)(I2(I),I=1,NCRIT)
C
      IF(IDMOD.EQ.0)GO TO 35
      DO 30 J=1,7
      DO 30 I=1,NCRIT
      IF(IDCRIT(I).NE.IDACT(J))GO TO 30
      IDCRIT(I)=IDCRIT(I)+100000*IDMOD
  30  CONTINUE
  35  CONTINUE
C
      DUM = '3$$ '
      WRITE(NICE,110)DUM
      WRITE(NICE,120)(IDCRIT(I),I=1,NCRIT)
C
      DUM = '4** '
      WRITE(NICE,110)DUM
      WRITE(NICE,130)(ADCRIT(I),I=1,NCRIT)
 130  FORMAT(1P,6E12.4)
C
      I5(1)=4
      DUM = '5$$ '
      WRITE(NICE,110)DUM
      WRITE(NICE,120)(I5(I),I=1,MIX)
      WRITE(NICE,110)T
C
      DUM= '7$$ '
      WRITE(NICE,110)DUM
      WRITE(NICE,140)
      WRITE(NICE,110)T
 140  FORMAT('  A8 2 E')
C
      I11(1)=1
      I11(2)=MIXF
      DUM = '11$$'
      WRITE(NICE,110)DUM
      WRITE(NICE,120)(I11(I),I=1,MIX+1)
      WRITE(NICE,110)T
      WRITE(NICE,110)END
C
      RETURN
      END
C-----------------------------------------------------------------------
      SUBROUTINE WRTKENO
       COMMON /CONST/ BCONV,BURN,COOL,MIXF,IDMOD,SMACT0
       COMMON /INDEX/ NBURN,NCRIT,NLITL,ILE,IACT,IFP,ITOT,NCYC
       COMMON /UNTNOS/ N72,NOUT,N71,NORS,NICE
       COMMON /IDENT/ IDLITL(40),IDCRIT(200),IDDK(2000)
```

```
      COMMON /ADENS/ ADLITL(40),LTYP(40),ADCRIT(200),ADDK(2000)
      COMMON /TITLE/ ITTL(20)
     CHARACTER*2 INAME(105),ICS(200)
      DIMENSION MASS(200),IDACT(7)
      DATA IDACT/92234,92235,92236,92238,94239,94240,94241/
     DATA INAME/' H','HE','LI','BE',' B',' C',' N',' O',' F','NE','NA',
    & 'MG','AL','SI',' P',' S',
    &'CL','AR',' K','CA','SC','TI',' V','CR','MN','FE','CO',
    &'NI','CU','ZN','GA','GE','AS','SE','BR','KR','RB',
    &'SR',' Y','ZR','NB','MO','TC','RU','RH','PD','AG','CD',
    &'IN','SN','SB','TE',' I','XE','CS','BA','LA','CE',
    &'PR','ND','PM','SM','EU','GD','TB','DY','HO','ER',
    &'TM','YB','LU','HF','TA',' W','RE','OS','IR','PT',
    &'AU','HG','TL','PB','BI','PO','AT','RN','FR','RA',
    &'AC','TH','PA',' U','NP','PU','AM','CM','BK','CF',
    &'ES','FM','MD','NO','LR','RF','HA'/
      DO 15 K=1,NCRIT
      IF(IDCRIT(K).EQ.99999)GO TO 15
      IZ=IDCRIT(K)/1000
      MASS(K)=IDCRIT(K)-IZ*1000
      IDFF=IZ/100
      IF(IDFF.GT.0)IZ=IZ-IDFF*100
      ICS(K)=INAME(IZ)
 15   CONTINUE
      DO 20 I=1,4
 20   WRITE(NOUT,101)
      WRITE(NOUT,202)
      WRITE(NOUT,101)
      DO 30 J=1,NCRIT
      IF(IDCRIT(J).EQ.99999)GO TO 30
      IF(ICS(J).EQ.' O')THEN
      WRITE(NOUT,206)ICS(J),MIXF,ADCRIT(J)
      GO TO 30
      END IF
      IF(MASS(J).LT.10)WRITE(NOUT,203)ICS(J),MASS(J),MIXF,ADCRIT(J)
      IF(MASS(J).GE.10.AND.MASS(J).LT.100)WRITE(NOUT,204)ICS(J),
    &MASS(J),MIXF,ADCRIT(J)
      IF(MASS(J).GE.100)WRITE(NOUT,205)ICS(J),MASS(J),MIXF,ADCRIT(J)
  30  CONTINUE
C
     IF(IDMOD.EQ.0)GO TO 5
     DO 3 J=1,7
     DO 3 I=1,NCRIT
     IF(IDCRIT(I).NE.IDACT(J))GO TO 3
     IDCRIT(I)=IDCRIT(I)+100000*IDMOD
  3  CONTINUE
  5  CONTINUE
C
      DO 10 I=1,4
 10   WRITE(NOUT,101)
      WRITE(NOUT,102)
      WRITE(NOUT,101)
      WRITE(NOUT,104)MIXF
      WRITE(NOUT,103)(IDCRIT(J),ADCRIT(J),J=1,NCRIT)
      RETURN
 101  FORMAT(A4)
 102  FORMAT(' FOR USE WHEN MIXING IN KENO')
 103  FORMAT(I9,2X,1P,E10.4)
 104  FORMAT(' MIX=',I4)
 202  FORMAT(' FOR USE IN CSAS')
 203  FORMAT(2X,A2,'-',I1,4X,I3,2X,'0',2X,1P,E10.4,'  END')
 204  FORMAT(2X,A2,'-',I2,3X,I3,2X,'0',2X,1P,E10.4,'  END')
 205  FORMAT(2X,A2,'-',I3,2X,I3,2X,'0',2X,1P,E10.4,'  END')
 206  FORMAT(2X,A2,6X,I3,2X,'0',2X,1P,E10.4,'  END')
      END
C----------------------------------------------------------------------
```

SNIKR3 FORTRAN Listing

```
C
      PROGRAM SNIKR3
       COMMON /CONST/ BCONV,BURN,COOL,MIXF,IDMOD,SMACT0
       COMMON /INDEX/ NBURN,NCRIT,NLITL,ILE,IACT,IFP,ITOT,NCYC
       COMMON /UNTNOS/ N72,NOUT,N71,NORS,NICE
       COMMON /IDENT/ IDLITL(40),IDCRIT(210),IDDK(2000)
       COMMON /ADENS/ ADLITL(40),LTYP(40),ADCRIT(200),ADDK(2000)
       COMMON /TITLE/ ITTL(20)
       DIMENSION TYM(20)
C  READ SNIKR1 INPUT AGAIN
      CALL RDINPT1
C  READ INPUT TO SNIKR NEEDED TO SET UP ICE RUN
      NCOOL=0
      CALL RDINPT3(NCOOL)
C  RETRIEVE NUMBER DENSITIES AT COOLTIME FOR NUCLIDES TO BE USED IN
C  CRITICALITY ANALYSES
      NNCT=0
      NNCL=1
      IF(NCOOL.LT.0)THEN
      NCOOL=0
      NNCL=11
      END IF
 1000 CONTINUE
      NNCT=NNCT+1
      NPOS=NCOOL+NNCT
      CALL RDF71(NPOS,TYM)
      REWIND N71
      CALL LITEL(1)
      CALL CLECT(0)
C  SET UP ICE RUN TO CREATE MIXTURE CROSS SECTIONS FOR KENO CALCS
C  FIRST REMOVE ANY NUCLIDES WITH NUMBER DENSITIES LESS THAN 1E-24
      WRITE(NOUT,107)NPOS
      WRITE(NOUT,108)TYM(NPOS)
      WRITE(NICE,107)NPOS
      WRITE(NICE,108)TYM(NPOS)
      CALL WRTICE
C  USE MIXED CROSS SECTIONS WRITTEN ON UNIT NICE IN KENO CALC
C  **********CHECK FILE NOUT FOR MESSAGES
C
C  WRITE NUMBER DENSITIES FOR MIXING IN KENO TO ...NOUT3
  107 FORMAT('ISOTOPIC RESULTS FOR COOL STEP ',I2)
  108 FORMAT('ORIGENS COOLING TIME (YR) =',F6.2)
      CALL WRTKENO
      IF(NNCT.LT.NNCL)GO TO 1000
      STOP
      END
C
C  READ INPUT DATA FOR PHASE ONE CALCULATIONS, READING SAS2H OUTPUT
C  AND SETTING UP ORIGEN-S DECAY ONLY CASE
C
C-------------------------------------------------------------------
      SUBROUTINE RDINPT1
       COMMON /CONST/ BCONV,BURN,COOL,MIXF,IDMOD,SMACT0
       COMMON /INDEX/ NBURN,NCRIT,NLITL,ILE,IACT,IFP,ITOT,NCYC
       COMMON /UNTNOS/ N72,NOUT,N71,NORS,NICE
       COMMON /IDENT/ IDLITL(40),IDCRIT(210),IDDK(2000)
       COMMON /ADENS/ ADLITL(40),LTYP(40),ADCRIT(200),ADDK(2000)
       COMMON /TITLE/ ITTL(20)
      CHARACTER*6 ICHK
      N5=5
      READ(N5,110)ICHK
C  READ AND CHECK IF APPROPRIATE PHASE INPUT - SNIKR1
      IF(ICHK.NE.'SNIKR1')STOP 5101
C  READ TITLE CARD
      READ(N5,120)ITTL
```

```
C  READ LABEL AND CHECK TO BE SURE BURN DATA IS NEXT
      READ(N5,110)ICHK
      IF(ICHK.NE.'READ B')STOP 5102
C  READ N72, UNIT NUMBER FOR SAS2H FILE 72 OUTPUT TO BE READ FROM
      READ(N5,130)N72
C  READ NOUT, UNIT NUMBER FOR OUTPUT TO BE WRITTEN TO
      READ(N5,140)NOUT
C  READ BURNUP IN MWD/MTU THAT NUMBER DENSITIES ARE TO BE RETRIEVED FROM N72
      READ(N5,150)BURN
C  READ METAL (MTU/ASSEMBLY), BCONV IS CONVERSION FACTOR FOR BURNUPS
C  READ FROM N72
C     READ(N5,160)BCONV
C   **** MODIFIED SNIKR, NOW READ FROM SAS2H OUTPUT
C
C  READ NCYC, NUMBER OF BURN CYCLES USED TO PRODUCE SAS2H OUTPUT ON N72
      READ(N5,170)NCYC
C  READ AND CHECK THAT THIS IS END OF BURNUP DATA
      READ(N5,110)ICHK
      IF(ICHK.NE.'END BU')STOP 5103
C  READ AND CHECK THAT DECAY DATA BEGINS WITH NEXT CARD
      READ(N5,110)ICHK
      IF(ICHK.NE.'READ D')STOP 5104
C  READ NORS, UNIT NUMBER FOR ORIGEN-S INPUT TO BE WRITTEN
      READ(N5,140)NORS
C  READ N71, UNIT NUMBER FOR ORIGEN-S INPUT TO BE WRITTEN FOR PHASE 3
      READ(N5,130)N71
C  READ COOLING TIME IN YEARS TO BE USED TO SET UP ORIGEN-S DECAY CASE
      READ(N5,180)COOL
C  READ THE NUMBER OF LIGHT ELEMENTS TO BE SPECIFIED IN THE DECAY CASE
      READ(N5,190)NLITL
C  READ AND CHECK THAT THIS IS THE END OF DECAY DATA
      READ(N5,110)ICHK
      IF(ICHK.NE.'END DE')STOP 5105
C  IF NLITL IS GREATER THAN ZERO READ IN ID'S OF LIGHT ELEMENTS
      IF(NLITL.EQ.0)GO TO 1000
      READ(N5,195)(IDLITL(I),ADLITL(I),LTYP(I),I=1,NLITL)
 1000 CONTINUE
C
C  WRITE INPUT TO NOUT
C
C     WRITE(NOUT,120)ITTL
C     WRITE(NOUT,130)N72
C     WRITE(NOUT,140)NOUT
C     WRITE(NOUT,150)BURN
C     WRITE(NOUT,160)BCONV
C     WRITE(NOUT,170)NCYC
C     WRITE(NOUT,140)NORS
C     WRITE(NOUT,180)COOL
C     WRITE(NOUT,190)NLITL
      RETURN
  110 FORMAT(A6)
  120 FORMAT(20A4)
  130 FORMAT(4X,I2)
  140 FORMAT(5X,I2)
  150 FORMAT(5X,F8.1)
  160 FORMAT(6X,F6.4)
  170 FORMAT(5X,I2)
  180 FORMAT(8X,F6.2)
  190 FORMAT(8X,I2)
  195 FORMAT(1X,I5,1P,E10.4,0P,2X,I1)
      END
C
C
C---------------------------------------------------------------------
      SUBROUTINE RDINPT3(NCOOL)
       COMMON /CONST/ BCONV,BURN,COOL,MIXF,IDMOD,SMACT0
       COMMON /INDEX/ NBURN,NCRIT,NLITL,ILE,IACT,IFP,ITOT,NCYC
       COMMON /UNTNOS/ N72,NOUT,N71,NORS,NICE
```

```
        COMMON /IDENT/ IDLITL(40),IDCRIT(210),IDDK(2000)
        COMMON /ADENS/ ADLITL(40),LTYP(40),ADCRIT(200),ADDK(2000)
        COMMON /TITLE/ ITTL(20)
       CHARACTER*6 ICHK
       DIMENSION IDAT1(25),IDAT2(37),IDAT3(49),IDAT4(193)
       DATA IDAT1/92234,92235,92236,92238,94238,94239,94240,94241,
      &94242,95241,8016,42095,43099,45103,55133,55135,60143,60145,
      &62147,62149,62150,62151,62152,63153,64155/
       DATA IDAT2/92234,92235,92236,92238,93237,94238,94239,94240,94241,
      &94242,95241,95243,96244,8016,40093,42095,43099,44101,45103,46105,
      &46108,47109,55133,55135,59141,60143,60145,61147,62147,62149,
      &62150,62151,62152,63153,63154,63155,64155/
       DATA IDAT3/92234,92235,92236,92238,93237,94238,94239,94240,94241,
      &94242,95241,95243,96244,8016,36083,40093,42095,43099,
      &44101,44103,45103,45105,46105,46108,47109,53135,54131,54135,
      &55133,55134,55135,59141,60143,60145,60147,60148,61147,61148,
      &61149,62147,62149,62150,62151,62152,63153,63154,63155,64155,
      &99999/
       DATA IDAT4/ 32072,32073,32074,32076,33075,34076,34077,34078,34080,
      &34082,35079,35081,36080,36082,36083,36084,36085,36086,37085,37086,
      &37087,38086,38087,38088,38089,38090,39089,39090,39091,40090,40091,
      &40092,40093,40094,40095,40096,41093,41094,41095, 8016,42095,42096,
      &42097,42098,42099,42100,43099,44099,44100,44101,44102,44104,44105,
      &44106,46104,46105,46106,46107,46108,46110,47107,47109,47111,48108,
      &48110,48111,48112,48113,48114,      48116,49113,49115,50115,50116,
      &50117,50118,50119,50120,50122,50123,50124,50125,50126,51121,51123,
      &51124,51125,51126,52122,52123,52124,52125,52126,      52128,
      &52130,52132,53127,53129,53130,53131,54128,54129,54130,54131,54132,
      &54133,54134,54136,55133,55134,55135,55136,55137,56134,56135,56136,
      &56137,56138,56140,57139,57140,58140,58141,58142,58143,58144,59141,
      &59142,59143,60142,60143,60144,60145,60146,60150,61151,62147,62148,
      &62150,62151,62152,62153,62154,63151,63152,63156,63157,64154,64156,
      &64157,64158,64160,65159,65160,66160,66161,66162,66163,66164,67165,
      &68166,68167,44103,45103,45105,53135,54135,60147,60148,61147,61148,
      &62149,61149,63153,63154,63155,      64155,90232,91233,92233,92234,
      &92235,92236,92238,93237,94238,94239,94240,94241,94242,95241,
      &95243,96244/
       N5=5
       READ(N5,110)ICHK
C  READ AND CHECK IF APPROPRIATE PHASE INPUT - SNIKR3
       IF(ICHK.NE.'SNIKR3')STOP 5301
C  READ TITLE CARD
       READ(N5,120)ITTL
C  READ LABEL AND CHECK TO BE SURE MXFUEL DATA IS NEXT
       READ(N5,110)ICHK
       IF(ICHK.NE.'READ M')STOP 5302
C  READ N72, UNIT NUMBER FOR ORIGEN-S FILE 71 OUTPUT TO BE READ FROM
       READ(N5,130)N71
C  READ NICE, UNIT NUMBER FOR ICE INPUT TO BE WRITTEN TO
       READ(N5,140)NICE
C  READ NOUT, UNIT NUMBER FOR OUTPUT TO BE WRITTEN TO
       READ(N5,140)NOUT
C  READ NCOOL, NUMBER OF COOLING STEP FOR WHICH DENSITIES ARE TO BE READ
       IF(NCOOL.GT.0)READ(N5,110)
       IF(NCOOL.EQ.0)READ(N5,145)NCOOL
C  READ FLAG NFIS TO DETERMINE WHICH FUEL NUCLIDES WILL BE USED IN
C  KENO CALCULATIONS:
C             =0  USE TTC713 INTERSECTION WITH SID BIERMAN'S NUCS
C             =-1 USE TTC713
C             =-2 USE TTC713 U SID U VEPCO U CASMO
C             =-3 USE ALL 27BURNUPLIB NUCLIDES
C             =N  READ IN USER'S CHOICE OF NUCLIDES
       READ(N5,150)NFIS
       IF(NFIS.EQ.0)THEN
       NCRIT=25
       DO 10 I=1,NCRIT
   10  IDCRIT(I)=IDAT1(I)
       GO TO 500
```

```
      END IF
      IF(NFIS.EQ.-1)THEN
      NCRIT=37
      DO 20 I=1,NCRIT
  20  IDCRIT(I)=IDAT2(I)
      GO TO 500
      END IF
      IF(NFIS.EQ.-2)THEN
      NCRIT=49
      DO 21 I=1,NCRIT
  21  IDCRIT(I)=IDAT3(I)
      GO TO 500
      END IF
      IF(NFIS.EQ.-3)THEN
      NCRIT=193
      DO 31 I=1,NCRIT
  31  IDCRIT(I)=IDAT4(I)
      GO TO 500
      END IF
      IF(NFIS.GT.0)NCRIT=NFIS
 500  CONTINUE
C  READ MIXTURE NUMBER TO BE USED FOR FUEL OF THIS BURN IN KENO CALCULATIONS
      READ(N5,160)MIXF
C  READ INTEGER MODIFIER FOR FUEL NUCLIDE ID'S FOR USE IN ICE RUN
      READ(N5,145)IDMOD
C  READ AND CHECK THAT THIS IS END OF FUEL MIX DATA
      READ(N5,110)ICHK
      IF(ICHK.NE.'END MX')STOP 5303
C  IF FISPROD IS GREATER THAN ZERO READ IN ID'S OF ELEMENTS IN FUEL FOR
C  CRITICALITY CALCULATIONS
      IF(NFIS.LE.0)GO TO 1000
      READ(N5,170)(IDCRIT(I),I=1,NCRIT)
 1000 CONTINUE
C
C  WRITE INPUT TO NOUT
C
      WRITE(NOUT,120)ITTL
      WRITE(NOUT,130)N71
      WRITE(NOUT,140)NICE
      WRITE(NOUT,140)NOUT
      WRITE(NOUT,145)NCOOL
      WRITE(NOUT,150)NFIS
      WRITE(NOUT,160)MIXF
      WRITE(NOUT,145)IDMOD
      WRITE(NOUT,170)(IDCRIT(I),I=1,NCRIT)
  110 FORMAT(A6)
  120 FORMAT(20A4)
  130 FORMAT(4X,I2)
  140 FORMAT(5X,I2)
  145 FORMAT(6X,I2)
  150 FORMAT(8X,I3)
  160 FORMAT(5X,I4)
  170 FORMAT(10(1X,I5))
      RETURN
      END
C---------------------------------------------------------------------
       SUBROUTINE RDF71(NPOS,TYM)
C
C  THIS ROUTINE READS ATOM DENSITIES FROM THE BINARY OUTPUT
C  FILE ON UNIT 'N71' WRITTEN FROM ORIGEN-S FOR THE DECAY TIME
C  CORRESPONDING TO THE POSITION, NPOS(EQUAL TO NCOOL+1, WHERE
C  NCOOL IS RETURNED FROM SUBROUTINE TYMSTP), AND AT THE
C  REQUESTED BURNUP, BURN.
C
       COMMON /CONST/ BCONV,BURN,COOL,MIXF,IDMOD,SMACT0
       COMMON /INDEX/ NBURN,NCRIT,NLITL,ILE,IACT,IFP,ITOT,NCYC
       COMMON /UNTNOS/ N72,NOUT,N71,NORS,NICE
       COMMON /IDENT/ IDLITL(40),IDCRIT(210),IDDK(2000)
```

```
      COMMON /ADENS/ ADLITL(40),LTYP(40),ADCRIT(200),ADDK(2000)
      COMMON /TITLE/ ITTL(20)
      DIMENSION TYM(20)
C
C  IDDK AND ADDK ARE ARRAYS CONTAINING THE ID'S AND NUMBER DENSITIES FOR
C  ALL NUCLIDES USED IN THE ORIGEN-S DECAY
C  CASE.  IN THIS ROUTINE THEY ARE USED TO RETRIEVE DATA FROM UNIT N71
C  BEFORE IT IS CONDENSED INTO THE ADCRIT ARRAY WHICH WILL CONTAIN NUMBER
C  DENSITIES CORRESPONDING TO THE ID'S GIVEN IN IDCRIT.  IDCRIT CONTAINS
C  IDS FOR THE NUCLIDES TO BE USED IN THE CRITICALITY ANALYSIS.  THE
C  DENSITIES STORED IN ADCRIT ARE BURNUP DEPENDENT.
C
C  FILES NEEDED IN THIS SUBROUTINE SHOULD BE OPENED BY THE MAIN PROGRAM
C
  10  READ(N71,END=100)ITOT,ILE,IACT,IFP,ND1,ND2,NSTEP,
     &N1,N2,N3,N4,N5,N6,N7,N8,N9,N10,N11,N12,N13,N14,N15,
     &N16,N17,N18,N19,N20,N21,N22,N23,R1,R2,R3,R4,TYM(NPOS)
      WRITE(NOUT,102)ITOT,ILE,IACT,IFP,NSTEP,TYM(NPOS)
      IF(NSTEP.EQ.NPOS) THEN
        READ(N71,END=100) (IDDK(I),I=1,ITOT),(ADDK(I),I=1,ITOT)
        DO 15 I=1,ITOT
  15    IDDK(I)=IDDK(I)/10
        IA1=ILE+1
        IA2=ILE+IACT
        WRITE(NOUT,103)(IDDK(I),ADDK(I),I=IA1,IA2)
        GO TO 20
      ENDIF
      READ(N71,END=100)IDUMY
      GO TO 10
 100  WRITE(NOUT,101)N71
 101  FORMAT('0'/'****ERROR READING UNIT ',I2)
      STOP 7101
  20  CONTINUE
  102 FORMAT(5(1X,I4),F6.2)
  103 FORMAT(4(I8,2X,1P,E10.4))
      RETURN
      END
C---------------------------------------------------------------------
      SUBROUTINE LITEL(IFLAG)
C
C  THIS SUBROUTINE CHECKS TO SEE IF ANY
C  LIGHT ELEMENTS ARE REQUESTED BY THE
C  USER, IF OXYGEN IS NOT EXPLICITLY
C  REQUESTED IT IS ADDED.
C
      COMMON /CONST/ BCONV,BURN,COOL,MIXF,IDMOD,SMACT0
      COMMON /INDEX/ NBURN,NCRIT,NLITL,ILE,IACT,IFP,ITOT,NCYC
      COMMON /UNTNOS/ N72,NOUT,N71,NORS,NICE
      COMMON /IDENT/ IDLITL(40),IDCRIT(210),IDDK(2000)
      COMMON /ADENS/ ADLITL(40),LTYP(40),ADCRIT(200),ADDK(2000)
      COMMON /TITLE/ ITTL(20)
C
      IF(NLITL.NE.0)GO TO 10
      NLITL=1
      IDLITL(1)=8016
      LTYP(1)=1
      GO TO 30
   10 CONTINUE
      DO 20 I=1,NLITL
      IF(IDLITL(I).EQ.8016)GO TO 35
   20 CONTINUE
      NLITL=NLITL+1
      IDLITL(NLITL)=8016
      LTYP(NLITL)=1
   30 CONTINUE
      IF(IFLAG.EQ.1)GO TO 45
      ADLITL(NLITL)=2.0*SMACT0
      WRITE(NOUT,110)ADLITL(NLITL)
```

```
  110  FORMAT('ADLITL(NLITL)=',1PE10.4)
   35  CONTINUE
       DO 40 I=1,NLITL
       DO 40 J=1,ILE
       IDLT=IDLITL(I)*10
       IF(IDLT.NE.IDDK(J))GO TO 40
       WRITE(NOUT,150)IDDK(J),ADDK(J)
       IF(LTYP(I).EQ.1)ADDK(J)=ADLITL(I)
       IF(LTYP(I).EQ.2.AND.ADDK(J).EQ.0.)ADDK(J)=ADLITL(I)
       IF(LTYP(I).EQ.3.AND.ADDK(J).NE.0.)ADDK(J)=ADDK(J)+ADLITL(I)
       WRITE(NOUT,140)IDLT,ADLITL(I)
       WRITE(NOUT,150)IDDK(J),ADDK(J)
   40  CONTINUE
   45  CONTINUE
       DO 50 I=1,NLITL
   50  IF(IDLITL(I).EQ.8016)WRITE(NOUT,120)ADLITL(I)
       DO 60 J=1,ITOT
   60  IF(IDDK(J).EQ.80160)WRITE(NOUT,130)J,IDDK(J),ADDK(J)
       RETURN
  120  FORMAT('ADLITL FOR 8016= ',1PE10.4)
  130  FORMAT(I2,I10,' ADDK FOR 8016=',1PE10.4)
  140  FORMAT('LITEL ARRAY',2X,I6,2X,1PE10.4)
  150  FORMAT('DECAY ARRAY',2X,I6,2X,1PE10.4)
       END
C---------------------------------------------------------------------
       SUBROUTINE CLECT(IFLAG)
       COMMON /CONST/ BCONV,BURN,COOL,MIXF,IDMOD,SMACT0
       COMMON /INDEX/ NBURN,NCRIT,NLITL,ILE,IACT,IFP,ITOT,NCYC
       COMMON /UNTNOS/ N72,NOUT,N71,NORS,NICE
       COMMON /IDENT/ IDLITL(40),IDCRIT(210),IDDK(2000)
       COMMON /ADENS/ ADLITL(40),LTYP(40),ADCRIT(200),ADDK(2000)
       COMMON /TITLE/ ITTL(20)
       DIMENSION IDLFP(165)
      DATA IDLFP/ 32072,32073,32074,32076,33075,34076,34077,34078,34080,
     &34082,35079,35081,36080,36082,36083,36084,36085,36086,37085,37086,
     &37087,38086,38087,38088,38089,38090,39089,39090,39091,40090,40091,
     &40092,40093,40094,40095,40096,41093,41094,41095,42094,42095,42096,
     &42097,42098,42099,42100,43099,44099,44100,44101,44102,44104,44105,
     &44106,46104,46105,46106,46107,46108,46110,47107,47109,47111,48108,
     &48110,48111,48112,48113,48114,48601,48116,49113,49115,50115,50116,
     &50117,50118,50119,50120,50122,50123,50124,50125,50126,51121,51123,
     &51124,51125,51126,52122,52123,52124,52125,52126,52601,52128,52611,
     &52130,52132,53127,53129,53130,53131,54128,54129,54130,54131,54132,
     &54133,54134,54136,55133,55134,55135,55136,55137,56134,56135,56136,
     &56137,56138,56140,57139,57140,58140,58141,58142,58143,58144,59141,
     &59142,59143,60142,60143,60144,60145,60146,60150,61151,62147,62148,
     &62150,62151,62152,62153,62154,63151,63152,63156,63157,64154,64156,
     &64157,64158,64160,65159,65160,66160,66161,66162,66163,66164,67165,
     &68166,68167/
      NLFP=165
C
C  EXTRACT NUCLIDES NEEDED FOR CRITICALITY CALCULATIONS FOR THIS
C  BURNUP AND COOLING TIME.  TAKE REQUESTED LIGHT ELEMENTS FROM
C  THE LIGHT ELEMENT LIBRARY (1ST ILE ENTRIES IN IDDK/ADDK),
C  ACTINIDES FROM THE ACTINIDE DATA (NEXT IACT ENTRIES IN IDDK/ADDK),
C  AND FISSION PRODUCTS FROM THE FINAL IFP ENTRIES IN IDDK/ADDK)
C
C  NLITL WILL BE AT LEAST 1, TO ACCOUNT FOR OXYGEN.  THE ONLY
C  SITUATION THAT WILL ALLOW IT TO BE LARGER THAN 1 IS IF THE
C  USER HAS CHOSEN TO INPUT A SET OF ISOTOPICS DIFFERENT FROM
C  THE BURNUP CREDIT NUCLIDES (IE., TTC-0713 OR BIERMAN'S) AND
C  HAS CHOSEN TO ENTER MORE LIGHT ELEMENTS THAN JUST OXYGEN
C
C  IF IFLAG=1 CHANGE ALL IDDK BY FACTOR OF 10 (FROM 72 NOT 71)
       IF(IFLAG.EQ.0)GO TO 20
       DO 10 I=1,ITOT
   10  IDDK(I)=IDDK(I)/10
   20  CONTINUE
```

```
      DO 40 I=1,NLITL
      DO 30 J=1,ILE
      IF(IDDK(J).NE.IDLITL(I)) GO TO 30
      ADLITL(I)=ADDK(J)
      GO TO 40
   30 CONTINUE
      WRITE(NOUT,102)IDLITL(I),N71
  102 FORMAT('0'/'****ERROR, NO MATCH FOR LIGHT ELEMENT ',I8,
     &' WAS FOUND ON UNIT ',I2)
      STOP 7102
   40 CONTINUE
      NLP1=ILE+1
      DO 70 I=1,NCRIT
       IF(IDCRIT(I).EQ.99999)GO TO 70
      ADCRIT(I)=0.0
      DO 60 J=NLP1,ITOT
      IF(IDDK(J).NE.IDCRIT(I)) GO TO 60
      ADCRIT(I)=ADDK(J)
      GO TO 70
   60 CONTINUE
      DO 65 K=1,NLITL
      IF(IDCRIT(I).EQ.IDLITL(K))GO TO 70
   65 CONTINUE
      WRITE(NOUT,103)IDCRIT(I),N71
  103 FORMAT('0'/'****ERROR, NO MATCH FOR NUCLIDE ',I8,
     &' WAS FOUND ON UNIT ',I2)
      STOP 7103
   70 CONTINUE
C  ADD CONTRIBUTION FROM LIGHT ELEMENT AND ACTINIDE/FISSION PRODUCT LIBR
      DO 80 I=1,NLITL
      DO 80 J=1,NCRIT
      IF(IDCRIT(J).NE.IDLITL(I))GO TO 80
      ADCRIT(J)=ADCRIT(J)+ADLITL(I)
   80 CONTINUE
C   COMPUTE NUMBER DENSITY FOR LUMPED-FISSION PRODUCT IF REQUESTED
C   ONLY AVAILABLE FOR NFIS=-2  (FOR MIKEY'S USE ONLY)***
      ADLFP=0.0
      IFP0=ILE+IACT
C  DO WE NEED TO CALCULATE A LUMPED FISSION PRODUCT
C  CHECK TO SEE IF IDCRIT=99999, IF SO CALCULATE LFP
C  ALSO (IF ICKFP=1) CHECK TO SEE IF ANY NUCLIDE IN IDCRIT IS ALSO
C  IN IDLFP, IF SO SET IDLFP TO ZERO
C
C  ICKFP=0 WILL CALCULATE THE VIRGINIA POWER LUMPED FISSION PRODUCT
C  EXPLICITLY
      ICKFP=0
C
C ICKFP=1 CALCULATES VP LFP MINUS FP IN IDCRIT ARRAY ###DON'T USE NOW
C     ICKFP=1
      K99=0
      DO 92 KL=1,NCRIT
      IF(IDCRIT(KL).EQ.99999)K99=KL
      IF(ICKFP.EQ.0)GO TO 92
      DO 90 J=1,NLFP
      IF(IDLFP(J).NE.IDCRIT(KL))GO TO 90
      WRITE(NOUT,110)IDLFP(J)
      IDLFP(J)=0
      GO TO 92
   90 CONTINUE
   92 CONTINUE
  110 FORMAT(I10,' NUCLIDE WAS IN IDLFP AND IDCRIT')
C   NO LFP CALCULATION IS REQUIRED IF K99=0
      IF(K99.EQ.0)RETURN
      DO 95 I=1,IFP
      J=IFP0+I
      DO 94 KJ=1,NLFP
      IF(IDDK(J).NE.IDLFP(KJ))GO TO 94
      ADLFP=ADLFP+ADDK(J)
```

```
       GO TO 95
   94  CONTINUE
   95  CONTINUE
       ADCRIT(K99)=ADLFP
       RETURN
       END
C
C
C
C---------------------------------------------------------------------
      SUBROUTINE WRTICE
       COMMON /CONST/ BCONV,BURN,COOL,MIXF,IDMOD,SMACT0
       COMMON /INDEX/ NBURN,NCRIT,NLITL,ILE,IACT,IFP,ITOT,NCYC
       COMMON /UNTNOS/ N72,NOUT,N71,NORS,NICE
       COMMON /IDENT/ IDLITL(40),IDCRIT(210),IDDK(2000)
       COMMON /ADENS/ ADLITL(40),LTYP(40),ADCRIT(200),ADDK(2000)
       COMMON /TITLE/ ITTL(20)
      DIMENSION I2(200),I5(200),I11(201),IDACT(7)
      CHARACTER*4 DUM,T,ICE,END
       DATA IDACT/92234,92235,92236,92238,94239,94240,94241/
C
      T = '  T '
      ICE = '#ICE'
      END = 'END '
      MIX=1
C
      WRITE(NICE,110)ICE
      WRITE(NICE,110)ITTL
  110 FORMAT(20A4)
C
      DUM = '1$$ '
      WRITE(NICE,110)DUM
      II = 0
      I4 = 10
      KOPT = 4
      WRITE(NICE,120)MIX,NCRIT,II,II,II,I4,KOPT
  120 FORMAT(6I12)
      WRITE(NICE,110)T
C
      DO 10 I=1,NCRIT
   10 I2(I)=1
C
      DUM = '2$$ '
      WRITE(NICE,110)DUM
      WRITE(NICE,120)(I2(I),I=1,NCRIT)
C
      IF(IDMOD.EQ.0)GO TO 35
      DO 30 J=1,7
      DO 30 I=1,NCRIT
      IF(IDCRIT(I).NE.IDACT(J))GO TO 30
      IDCRIT(I)=IDCRIT(I)+100000*IDMOD
   30 CONTINUE
   35 CONTINUE
C
      DUM = '3$$ '
      WRITE(NICE,110)DUM
      WRITE(NICE,120)(IDCRIT(I),I=1,NCRIT)
C
      DUM = '4** '
      WRITE(NICE,110)DUM
      WRITE(NICE,130)(ADCRIT(I),I=1,NCRIT)
  130 FORMAT(1P,6E12.4)
C
      I5(1)=4
      DUM = '5$$ '
      WRITE(NICE,110)DUM
      WRITE(NICE,120)(I5(I),I=1,MIX)
      WRITE(NICE,110)T
```

```
C
      DUM= '7$$ '
      WRITE(NICE,110)DUM
      WRITE(NICE,140)
      WRITE(NICE,110)T
 140  FORMAT('  A8 2 E')
C
      I11(1)=1
      I11(2)=MIXF
      DUM = '11$$'
      WRITE(NICE,110)DUM
      WRITE(NICE,120)(I11(I),I=1,MIX+1)
      WRITE(NICE,110)T
      WRITE(NICE,110)END
C
      RETURN
      END
C-----------------------------------------------------------------------
      SUBROUTINE WRTKENO
       COMMON /CONST/ BCONV,BURN,COOL,MIXF,IDMOD,SMACT0
       COMMON /INDEX/ NBURN,NCRIT,NLITL,ILE,IACT,IFP,ITOT,NCYC
       COMMON /UNTNOS/ N72,NOUT,N71,NORS,NICE
       COMMON /IDENT/ IDLITL(40),IDCRIT(210),IDDK(2000)
       COMMON /ADENS/ ADLITL(40),LTYP(40),ADCRIT(200),ADDK(2000)
       COMMON /TITLE/ ITTL(20)
      CHARACTER*2 INAME(105),ICS(200)
       DIMENSION MASS(200),IDACT(7)
       DATA IDACT/92234,92235,92236,92238,94239,94240,94241/
      DATA INAME/' H','HE','LI','BE',' B',' C',' N',' O',' F','NE','NA',
     & 'MG','AL','SI',' P',' S',
     &'CL','AR',' K','CA','SC','TI',' V','CR','MN','FE','CO',
     &'NI','CU','ZN','GA','GE','AS','SE','BR','KR','RB',
     &'SR',' Y','ZR','NB','MO','TC','RU','RH','PD','AG','CD',
     &'IN','SN','SB','TE',' I','XE','CS','BA','LA','CE',
     &'PR','ND','PM','SM','EU','GD','TB','DY','HO','ER',
     &'TM','YB','LU','HF','TA',' W','RE','OS','IR','PT',
     &'AU','HG','TL','PB','BI','PO','AT','RN','FR','RA',
     &'AC','TH','PA',' U','NP','PU','AM','CM','BK','CF',
     &'ES','FM','MD','NO','LR','RF','HA'/
       DO 15 K=1,NCRIT
       IF(IDCRIT(K).EQ.99999)GO TO 15
       IZ=IDCRIT(K)/1000
       MASS(K)=IDCRIT(K)-IZ*1000
       IDFF=IZ/100
       IF(IDFF.GT.0)IZ=IZ-IDFF*100
       ICS(K)=INAME(IZ)
  15   CONTINUE
       DO 20 I=1,4
  20   WRITE(NOUT,101)
       WRITE(NOUT,202)
       WRITE(NOUT,101)
       DO 30 J=1,NCRIT
       IF(IDCRIT(J).EQ.99999)GO TO 30
       IF(ICS(J).EQ.' O')THEN
       WRITE(NOUT,206)ICS(J),MIXF,ADCRIT(J)
       GO TO 30
       END IF
       IF(MASS(J).LT.10)WRITE(NOUT,203)ICS(J),MASS(J),MIXF,ADCRIT(J)
       IF(MASS(J).GE.10.AND.MASS(J).LT.100)WRITE(NOUT,204)ICS(J),
     &MASS(J),MIXF,ADCRIT(J)
       IF(MASS(J).GE.100)WRITE(NOUT,205)ICS(J),MASS(J),MIXF,ADCRIT(J)
   30  CONTINUE
C
      IF(IDMOD.EQ.0)GO TO 5
      DO 3 J=1,7
      DO 3 I=1,NCRIT
      IF(IDCRIT(I).NE.IDACT(J))GO TO 3
      IDCRIT(I)=IDCRIT(I)+100000*IDMOD
```

```
    3  CONTINUE
    5  CONTINUE
C
       DO 10 I=1,4
  10   WRITE(NOUT,101)
       WRITE(NOUT,102)
       WRITE(NOUT,101)
       WRITE(NOUT,104)MIXF
       WRITE(NOUT,103)(IDCRIT(J),ADCRIT(J),J=1,NCRIT)
       RETURN
  101  FORMAT(A4)
  102  FORMAT(' FOR USE WHEN MIXING IN KENO')
  103  FORMAT(I9,2X,1P,E10.4)
  104  FORMAT(' MIX=',I4)
  202  FORMAT(' FOR USE IN CSAS')
  203  FORMAT(2X,A2,'-',I1,4X,I3,2X,'0',2X,1P,E10.4,'  END')
  204  FORMAT(2X,A2,'-',I2,3X,I3,2X,'0',2X,1P,E10.4,'  END')
  205  FORMAT(2X,A2,'-',I3,2X,I3,2X,'0',2X,1P,E10.4,'  END')
  206  FORMAT(2X,A2,6X,I3,2X,'0',2X,1P,E10.4,'  END')
       END
```

Sample SNIKR Output

```
S1C2 QC LOC #12  (BATCH S1/2) 15831 MWD/MTU
    71
    75
    73
     2
    -2
     1
     4
 92234 92235 92236 92238 93237 94238 94239 94240 94241 94242
 95241 95243 96244  8016 36083 40093 42095 43099 44101 44103
 45103 45105 46105 46108 47109 53135 54131 54135 55133 55134
 55135 59141 60143 60145 60147 60148 61147 61148 61149 62147
 62149 62150 62151 62152 63153 63154 63155 64155 99999
 1609  687  101  821    1  0.00
 1609  687  101  821    2  0.08
 1609  687  101  821    3  0.27
    2004  6.8461E-08   81207  4.2968E-23   81208  1.0178E-20   81209  5.6336E-27
   82206  6.4606E-22   82207  1.9362E-18   82208  2.1419E-15   82209  2.3139E-23
   82210  7.5877E-20   82211  3.2610E-22   82212  5.8908E-18   82214  7.3830E-24
   83209  1.4592E-19   83210  4.6716E-23   83211  1.9241E-23   83212  5.5872E-19
   83213  5.4119E-24   83214  5.4822E-24   84210  6.9113E-22   84211  2.1752E-28
   84212  2.9363E-29   84213  8.1193E-33   84214  7.5422E-31   84215  2.6799E-28
   84216  2.3069E-23   84218  8.4040E-25   85217  6.3820E-29   86219  5.9620E-25
   86220  8.5508E-21   86222  1.5171E-21   87221  5.6905E-25   87223  3.0765E-24
   88223  1.4873E-19   88224  4.8632E-17   88225  2.3622E-21   88226  2.3188E-16
   88228  8.3685E-23   89225  1.7071E-21   89227  1.1711E-16   89228  1.0179E-26
   90227  2.5195E-19   90228  9.2478E-15   90229  4.1707E-16   90230  2.1549E-11
   90231  1.1684E-15   90232  2.2511E-12   90233  0.0000E+00   90234  3.2258E-13
   91231  5.6670E-12   91232  1.4848E-37   91233  1.4128E-13   91234  1.0875E-17
   91234  5.9787E-18   92232  1.2475E-12   92233  3.2192E-11   92234  3.9336E-06
   92235  2.8245E-04   92236  5.5514E-05   92237  4.5014E-12   92238  2.1843E-02
   92239  0.0000E+00   92240  1.8466E-31   93236  3.2695E-11   93237  4.1219E-06
   93238  1.2582E-15   93239  2.0145E-13   93240  1.6152E-33   93240  1.5606E-35
   94236  4.1572E-15   94238  6.7548E-07   94239  1.0118E-04   94240  2.6256E-05
   94241  1.3658E-05   94242  2.2806E-06   94243  1.0072E-23   94244  9.4942E-21
   94245  0.0000E+00   95241  4.8607E-07   95242  6.8737E-09   95242  8.2247E-14
   95243  2.3058E-07   95244  0.0000E+00   95245  2.6307E-25   96242  3.6198E-08
   96243  9.0157E-10   96244  2.5573E-08   96245  5.6316E-10   96246  3.5682E-11
   96247  2.7790E-13   96248  1.0708E-14   96249  2.3386E-28   96250  2.7742E-23
   97249  6.6004E-17   97250  2.0689E-31   98249  2.4795E-17   98250  9.5689E-18
   98251  3.9299E-18   98252  1.1656E-18   98253  3.0084E-23   98254  2.7037E-25
   99253  1.8708E-22
ADLITL FOR 8016= 0.0000E+00
ISOTOPIC RESULTS FOR COOL STEP  3
ORIGENS COOLING TIME (YR) =  0.27


 FOR USE IN CSAS

   U-234    1  0  3.9336E-06  END
   U-235    1  0  2.8245E-04  END
   U-236    1  0  5.5514E-05  END
   U-238    1  0  2.1843E-02  END
  NP-237    1  0  4.1219E-06  END
  PU-238    1  0  6.7548E-07  END
  PU-239    1  0  1.0118E-04  END
  PU-240    1  0  2.6256E-05  END
  PU-241    1  0  1.3658E-05  END
  PU-242    1  0  2.2806E-06  END
  AM-241    1  0  4.8607E-07  END
  AM-243    1  0  2.3058E-07  END
  CM-244    1  0  2.5573E-08  END
   O        1  0  4.5425E-02  END
  KR-83     1  0  1.5402E-06  END
```

```
 ZR-93      1  0  2.1149E-05  END
 MO-95      1  0  2.0312E-05  END
 TC-99      1  0  2.2028E-05  END
 RU-101     1  0  1.9971E-05  END
 RU-103     1  0  2.6063E-07  END
 RH-103     1  0  1.3102E-05  END
 RH-105     1  0  2.8445E-28  END
 PD-105     1  0  8.3881E-06  END
 PD-108     1  0  2.5766E-06  END
 AG-109     1  0  1.7831E-06  END
  I-135     1  0  0.0000E+00  END
 XE-131     1  0  1.0146E-05  END
 XE-135     1  0  0.0000E+00  END
 CS-133     1  0  2.4025E-05  END
 CS-134     1  0  1.1673E-06  END
 CS-135     1  0  8.3186E-06  END
 PR-141     1  0  2.0945E-05  END
 ND-143     1  0  1.7631E-05  END
 ND-145     1  0  1.3196E-05  END
 ND-147     1  0  3.8702E-10  END
 ND-148     1  0  6.4108E-06  END
 PM-147     1  0  4.4808E-06  END
 PM-148     1  0  4.2081E-11  END
 PM-149     1  0  1.0986E-21  END
 SM-147     1  0  1.5822E-06  END
 SM-149     1  0  9.9207E-08  END
 SM-150     1  0  5.1276E-06  END
 SM-151     1  0  3.5356E-07  END
 SM-152     1  0  2.4213E-06  END
 EU-153     1  0  1.5000E-06  END
 EU-154     1  0  3.4167E-07  END
 EU-155     1  0  1.4913E-07  END
 GD-155     1  0  7.0200E-09  END
```

```
FOR USE WHEN MIXING IN KENO

MIX=   1
  492234  3.9336E-06
  492235  2.8245E-04
  492236  5.5514E-05
  492238  2.1843E-02
   93237  4.1219E-06
   94238  6.7548E-07
  494239  1.0118E-04
  494240  2.6256E-05
  494241  1.3658E-05
   94242  2.2806E-06
   95241  4.8607E-07
   95243  2.3058E-07
   96244  2.5573E-08
    8016  4.5425E-02
   36083  1.5402E-06
   40093  2.1149E-05
   42095  2.0312E-05
   43099  2.2028E-05
   44101  1.9971E-05
   44103  2.6063E-07
   45103  1.3102E-05
   45105  2.8445E-28
   46105  8.3881E-06
   46108  2.5766E-06
   47109  1.7831E-06
   53135  0.0000E+00
   54131  1.0146E-05
   54135  0.0000E+00
```

55133	2.4025E-05
55134	1.1673E-06
55135	8.3186E-06
59141	2.0945E-05
60143	1.7631E-05
60145	1.3196E-05
60147	3.8702E-10
60148	6.4108E-06
61147	4.4808E-06
61148	4.2081E-11
61149	1.0986E-21
62147	1.5822E-06
62149	9.9207E-08
62150	5.1276E-06
62151	3.5356E-07
62152	2.4213E-06
63153	1.5000E-06
63154	3.4167E-07
63155	1.4913E-07
64155	7.0200E-09
99999	7.3267E-04

APPENDIX D

KENO V.a BOC MODEL SETUP INPUT EXAMPLES

This appendix gives examples of the input for the different calculational steps for setting up the Surry Unit 1 Cycle 2 KENO V.a model for BOC (HZP).

Table D.1. SNIKR/ORIGEN-S input for fuel assembly isotopics

```
//ST5ASY1  JOB (35899),'S M BOWMAN 6011',TIME=1,
// NOTIFY=ST5,MSGCLASS=T
//*MAIN CLASS=SHORT
//PROCLIB DD DISP=SHR,DSN=TZA.PROCLIB.CNTL
//A EXEC FORTVCLG,REGION=2048K
//FORT.SYSPRINT DD DUMMY
//FORT.SYSIN DD DSN=ST5.SNIKR1.FORT,DISP=SHR
//*
//*######################################
//* #####NEED JCL FOR UNITS N72,NOUT,NORS,NOUT3,NICE
//*######################################
//GO.FT05F001 DD *
SNIKR1
S1C2 QC LOC #1   (BATCH S1A2) 15316 MWD/MTU
READ BURNUP
N72=72
NOUT=70
BURN=15316.0
NCYC= 4
END BURNUP
READ DECAY
NORS=74
N71=71
COOLTME=0.271
LIGHTEL=0
END DECAY
//GO.FT70F001 DD UNIT=SYSDA,SPACE=(TRK,(4,2),RLSE),
//      DSN=&&NOUT1,
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(NEW,PASS)
//GO.FT72F001 DD UNIT=,SPACE=,LABEL=(,,,IN),
//     DISP=SHR,DSN=OWH.SUR1B.WES15F72,
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=6400)
//GO.FT73F001 DD UNIT=DISK,SPACE=(TRK,(4,2),RLSE),
//      DSN=X.ST535899.S1C2BA1.NOUT3,
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(NEW,CATLG)
//GO.FT74F001 DD UNIT=SYSDA,SPACE=(TRK,(4,2),RLSE),
//      DSN=&&NORS,
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(NEW,PASS)
//GO.FT75F001 DD UNIT=SYSDA,SPACE=(TRK,(4,2),RLSE),
//      DSN=&&NICE,
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(NEW,PASS)
/*
//*C###########################
//*C###EXECUTE ORS AT THIS POINT
//*C###########################
//B EXEC SCALE41,REGION=1640K
//GO.FT05F001 DD SPACE=(480,(500,20))
//GO.FT13F001 DD SYSOUT=*,DCB=(RECFM=FA,BLKSIZE=133,BUFL=150)
//GO.FT40F001 DD DUMMY
//GO.FT71F001 DD UNIT=DISK,SPACE=(TRK,(5,10)),DISP=(NEW,CATLG),
//    DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6136,BUFL=6136),
//    DSN=X.ST535899.S1C2BA1.FT71
//GO.SYSIN DD DISP=(OLD,PASS),DSN=&&NORS
/*
//C EXEC FORTVCLG,REGION=2048K
//FORT.SYSPRINT DD DUMMY
//FORT.SYSIN DD DSN=ST5.SNIKR3.FORT,DISP=SHR
//*
//*######################################
//* #####NEED JCL FOR UNITS N71,NOUT,NICE
//*######################################
//GO.FT05F001 DD *
SNIKR1
S1C2 QC LOC #1   (BATCH S1A2) 15316 MWD/MTU
```

Table D.1. (continued)

```
READ BURNUP
N72=72
NOUT=70
BURN=15316.0
NCYC= 4
END BURNUP
READ DECAY
NORS=74
N71=71
COOLTME=20
LIGHTEL=0
END DECAY
SNIKR3
S1C2 QC LOC #1   (BATCH2) 15316 MWD/MTU
READ MXFUEL
N71=71
NICE=75
NOUT=73
NCOOL= 2
FISPROD= -2
MIXF=   1
IDMOD= 2
END MXFUEL
//GO.FT71F001 DD UNIT=,SPACE=,LABEL=(,,,IN),
//    DISP=SHR,DSN=X.ST535899.S1C2BA1.FT71,
//     DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6136,BUFL=6136)
//GO.FT73F001 DD UNIT=DISK,SPACE=(TRK,(4,2),RLSE),
//     DSN=X.ST535899.S1C2BA1.NOUT3,
//     DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=SHR
//GO.FT75F001 DD UNIT=SYSDA,SPACE=(TRK,(4,2),RLSE),
//     DSN=&&NICE,
//     DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(OLD,DELETE)
```

Table D.2. SNIKR/ORIGEN-S input for cross-section set average isotopics

---

```
//ST5SNKX1 JOB (35899),'S M BOWMAN 6011',TIME=1,
// NOTIFY=ST5,MSGCLASS=T
//*MAIN CLASS=SHORT
//PROCLIB DD DISP=SHR,DSN=TZA.PROCLIB.CNTL
//A EXEC FORTVCLG,REGION=2048K
//FORT.SYSPRINT DD DUMMY
//FORT.SYSIN DD DSN=ST5.SNIKR1.FORT,DISP=SHR
//*
//*#######################################
//* #####NEED JCL FOR UNITS N72,NOUT,NORS,NOUT3,NICE
//*#######################################
//GO.FT05F001 DD *
SNIKR1
S1C2 (BATCH S1A2) CROSS SECTION SET #1  12044 MWD/MTU
READ BURNUP
N72=72
NOUT=70
BURN=12044.0
NCYC= 4
END BURNUP
READ DECAY
NORS=74
N71=71
COOLTME=0.271
LIGHTEL=0
END DECAY
//GO.FT70F001 DD UNIT=SYSDA,SPACE=(TRK,(4,2),RLSE),
//      DSN=&&NOUT1,
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(NEW,PASS)
//GO.FT72F001 DD UNIT=,SPACE=,LABEL=(,,,IN),
//     DISP=SHR,DSN=OWH.SUR1B.WES15F72,
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=6400)
//GO.FT73F001 DD UNIT=DISK,SPACE=(TRK,(4,2),RLSE),
//      DSN=X.ST535899.S1C2B1X1.NOUT3,
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(NEW,CATLG)
//GO.FT74F001 DD UNIT=SYSDA,SPACE=(TRK,(4,2),RLSE),
//      DSN=&&NORS,
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(NEW,PASS)
//GO.FT75F001 DD UNIT=SYSDA,SPACE=(TRK,(4,2),RLSE),
//      DSN=&&NICE,
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(NEW,PASS)
/*
//*C############################
//*C###EXECUTE ORS AT THIS POINT
//*C############################
//B EXEC SCALE41,REGION=1640K
//GO.FT05F001 DD SPACE=(480,(500,20))
//GO.FT13F001 DD SYSOUT=*,DCB=(RECFM=FA,BLKSIZE=133,BUFL=150)
//GO.FT40F001 DD DUMMY
//GO.FT71F001 DD UNIT=DISK,SPACE=(TRK,(5,10)),DISP=(NEW,CATLG),
//    DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6136,BUFL=6136),
//    DSN=X.ST535899.S1C2B1X1.FT71
//GO.SYSIN DD DISP=(OLD,PASS),DSN=&&NORS
/*
//C EXEC FORTVCLG,REGION=2048K
//FORT.SYSPRINT DD DUMMY
//FORT.SYSIN DD DSN=ST5.SNIKR3.FORT,DISP=SHR
//*
//*#######################################
//* #####NEED JCL FOR UNITS N71,NOUT,NICE
//*#######################################
//GO.FT05F001 DD *
SNIKR1
```

Table D.2. (continued)

```
S1C2 (BATCH S1A2) CROSS SECTION SET #1  12044 MWD/MTU
READ BURNUP
N72=72
NOUT=70
BURN=12044.0
NCYC= 4
END BURNUP
READ DECAY
NORS=74
N71=71
COOLTME=20
LIGHTEL=0
END DECAY
SNIKR3
S1C2 (BATCH S1A2) CROSS SECTION SET #1  12044 MWD/MTU
READ MXFUEL
N71=71
NICE=75
NOUT=73
NCOOL= 2
FISPROD= -2
MIXF=   1
IDMOD= 0
END MXFUEL
//GO.FT71F001 DD UNIT=,SPACE=,LABEL=(,,,IN),
//    DISP=SHR,DSN=X.ST535899.S1C2B1X1.FT71,
//     DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6136,BUFL=6136)
//GO.FT73F001 DD UNIT=DISK,SPACE=(TRK,(4,2),RLSE),
//     DSN=X.ST535899.S1C2B1X1.NOUT3,
//     DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=SHR
//GO.FT75F001 DD UNIT=SYSDA,SPACE=(TRK,(4,2),RLSE),
//     DSN=&&NICE,
//     DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(OLD,DELETE)
```

Table D.3. CSASN input for cross-section sets with important actinides only

```
//ST5XS3 JOB (35899),'S BOWMAN 6011',MSGCLASS=T,TIME=10,
//   NOTIFY=ST5
//*MAIN CLASS=STANDBY
//PROCLIB DD DSN=TZA.PROCLIB.CNTL,DISP=SHR
//  EXEC SCALE41,GOSIZE=2048K
//GO.FT04F001 DD DSN=X.ST535899.S1C2B1X3.XSEC,UNIT=DISK,DISP=(,CATLG)
//GO.SYSIN DD *
=CSASN
SURRY 1 CYCLE 2 BOC BATCH 2 XS SET 3
27BURNUP  LATTICECELL
 U-234    1  0  4.0418E-06  559  END
 U-235    1  0  3.0494E-04  559  END
 U-236    1  0  5.1930E-05  559  END
 U-238    1  0  2.1872E-02  559  END
PU-239    1  0  9.7136E-05  559  END
PU-240    1  0  2.3203E-05  559  END
PU-241    1  0  1.1649E-05  559  END
 O        1  0  4.5425E-02  559  END
ZIRCALLOY 2  1              559  END
H2O       3  DEN=.7540  1   559  END
BORON     3  DEN=.7540 1030.E-6 559 END
END COMP
SQUAREPITCH   1.43002 0.92939 1 3 1.07188 2 0.94844 0  END
END
```

Table D.4. CSASN input for cross-section set 4

```
//ST5XS4 JOB (35899),'S BOWMAN 6011',MSGCLASS=T,TIME=10,
//    NOTIFY=ST5
//PROCLIB DD DSN=TZA.PROCLIB.CNTL,DISP=SHR
//  EXEC SCALE41,GOSIZE=2048K
//GO.FT04F001 DD DSN=X.ST535899.S1C2B2X4.XSEC,UNIT=DISK,DISP=(,CATLG)
//GO.SYSIN DD *
=CSASN
SURRY 1 CYCLE 2 BOC BATCH 2 XS SET 4  (INCLUDES FP'S & STRUCT. MATLS)
27BURNUP  LATTICECELL
 U-234     10 0  3.9228E-06  559  END
 U-235     10 0  2.8025E-04  559  END
 U-236     10 0  5.5860E-05  559  END
 U-238     10 0  2.1840E-02  559  END
NP-237     10 0  4.1783E-06  559  END
PU-238     10 0  6.9222E-07  559  END
PU-239     10 0  1.0155E-04  559  END
PU-240     10 0  2.6561E-05  559  END
PU-241     10 0  1.3859E-05  559  END
PU-242     10 0  2.3422E-06  559  END
AM-241     10 0  4.9596E-07  559  END
AM-243     10 0  2.3959E-07  559  END
CM-244     10 0  2.6937E-08  559  END
 O         10 0  4.5425E-02  559  END
KR-83      10 0  1.5517E-06  559  END
ZR-93      10 0  2.1339E-05  559  END
MO-95      10 0  2.0518E-05  559  END
TC-99      10 0  2.2234E-05  559  END
RU-101     10 0  2.0173E-05  559  END
RU-103     10 0  2.6116E-07  559  END
RH-103     10 0  1.3227E-05  559  END
RH-105     10 0  2.8557E-28  559  END
PD-105     10 0  8.5012E-06  559  END
PD-108     10 0  2.6191E-06  559  END
AG-109     10 0  1.8102E-06  559  END
XE-131     10 0  1.0233E-05  559  END
CS-133     10 0  2.4249E-05  559  END
CS-134     10 0  1.1885E-06  559  END
CS-135     10 0  8.4019E-06  559  END
PR-141     10 0  2.1150E-05  559  END
ND-143     10 0  1.7765E-05  559  END
ND-145     10 0  1.3314E-05  559  END
ND-147     10 0  3.8690E-10  559  END
ND-148     10 0  6.4748E-06  559  END
PM-147     10 0  4.4999E-06  559  END
PM-148     10 0  4.2285E-11  559  END
PM-149     10 0  1.1010E-21  559  END
SM-147     10 0  1.6032E-06  559  END
SM-149     10 0  9.9348E-08  559  END
SM-150     10 0  5.1860E-06  559  END
SM-151     10 0  3.5499E-07  559  END
SM-152     10 0  2.4453E-06  559  END
EU-153     10 0  1.5217E-06  559  END
EU-154     10 0  3.4900E-07  559  END
EU-155     10 0  1.5148E-07  559  END
GD-155     10 0  7.1305E-09  559  END
ZIRCALLOY 1 1.     559 END
SS304     2 1.     559 END
H2O       3  DEN=.7540  1      559  END
BORON     3  DEN=.7540 1030.E-6 559  END
SS304     4  0.5    559 END
H2O       4  DEN=.7540 0.5      559  END
BORON     4  DEN=.7540 515.E-6   559  END
SS304     5 1.     559 END
H2O       6  DEN=.7540 1.0    559 END
BORON     6  DEN=.7540 1030.E-6 559 END
```

Table D.4 (continued)

```
SS304      7 1.     559 END
H2O        8  DEN=.7540 1.0       559 END
BORON      8  DEN=.7540 1030.E-6 559 END
SS304      9 1.     559 END
END
SQUAREPITCH   1.43002 0.92939 10 3 1.07188 1 0.94844 0  END
END
```

Table D.5. WAX input for cross-section library generation

```
//ST5WAX   JOB (35899),'S.M.BOWMAN 6011',MSGCLASS=T,
//  NOTIFY=ST5,TIME=5
//*MAIN CLASS=SHORT
//PROCLIB DD DSN=TZA.PROCLIB.CNTL,DISP=SHR
//  EXEC SCALE41,GOSIZE=2048K
//GO.FT04F001 DD DSN=X.ST535899.S1C2BOC.XSECLIB,UNIT=DISK,DISP=(,CATLG)
//GO.FT33F001 DD DSN=X.ST535899.S1C2B1X1.XSEC,DISP=SHR
//GO.FT34F001 DD DSN=X.ST535899.S1C2B1X2.XSEC,DISP=SHR
//GO.FT35F001 DD DSN=X.ST535899.S1C2B1X3.XSEC,DISP=SHR
//GO.FT36F001 DD DSN=X.ST535899.S1C2B2X4.XSEC,DISP=SHR
//GO.FT37F001 DD DSN=X.ST535899.S1C2B4A.XSEC5,DISP=SHR
//GO.FT38F001 DD DSN=X.ST535899.S1C2B4BB.XSEC6,DISP=SHR
//GO.FT39F001 DD DSN=X.ST535899.S1C2B4BF.XSEC7,DISP=SHR
//GO.FT40F001 DD DSN=X.ST535899.S1C2B4CN.XSEC8,DISP=SHR
//GO.FT41F001 DD DSN=X.ST535899.S1C2B4CF.XSEC9,DISP=SHR
//GO.SYSIN DD *
=WAX
'WRITE FINAL LIBRARY TO UNIT 4 / BIGGEST INPUT LIB IS ON UNIT 36
0$$ 4 36
'INPUT XSEC'S FROM 9 LIBS
1$$ 9    T
'INPUT XSEC'S FOR FUEL XSEC SET 1
2$$ 33 7 T
3$$  92234  92235  92236  92238  94239  94240  94241
4$$ 192234 192235 192236 192238 194239 194240 194241 T
'INPUT XSEC'S FOR FUEL XSEC SET 2
2$$ 34 7 T
3$$  92234  92235  92236  92238  94239  94240  94241
4$$ 292234 292235 292236 292238 294239 294240 294241 T
'INPUT XSEC'S FOR FUEL XSEC SET 3
2$$ 35 7 T
3$$  92234  92235  92236  92238  94239  94240  94241
4$$ 392234 392235 392236 392238 394239 394240 394241 T
'INPUT XSEC'S FOR FUEL XSEC SET 4 + FP'S + STRUCT. MAT'LS
2$$ 36 0 T
'INPUT XSEC'S FOR FUEL XSEC SET 5
2$$ 37 4 T
3$$  92234  92235  92236  92238
4$$ 592234 592235 592236 592238 T
'INPUT XSEC'S FOR FUEL XSEC SET 6 + BP'S
2$$ 38 7 T
3$$  92234  92235  92236  92238
    408016  405010  405011
4$$ 692234 692235 692236 692238
    618016  615010  615011  T
'INPUT XSEC'S FOR FUEL XSEC SET 7 + BP'S
2$$ 39 7 T
3$$  92234  92235  92236  92238
    408016  405010  405011
4$$ 792234 792235 792236 792238
    718016  715010  715011  T
'INPUT XSEC'S FOR FUEL XSEC SET 8
2$$ 40 4 T
3$$  92234  92235  92236  92238
4$$ 892234 892235 892236 892238 T
'INPUT XSEC'S FOR FUEL XSEC SET 9 + BP'S
2$$ 41 9 T
3$$  92234  92235  92236  92238
    408016   11023   13027  405010  405011
4$$ 992234 992235 992236 992238
    918016   11023   13027  915010  915011  T
END
```

Table D.6. XSDRNPM input for eighth-core assembly location 1

```
//ST5XSDA1 JOB (35899),'SM BOWMAN 6011',TIME=1,MSGCLASS=T,
//  NOTIFY=ST5
//*MAIN CLASS=SHORT
//PROCLIB DD DSN=TZA.PROCLIB.CNTL,DISP=SHR
//  EXEC SCALE41
//GO.FT04F001 DD DSN=X.ST535899.S1C2HZP.XSECLIB,DISP=SHR,UNIT=
//GO.SYSIN DD *
=XSDRN
S1C2 EC LOC #1 BATCH1A2 15316 MWD/MTU TO COMPARE TO CSAS1X
1$$ 2 4 28 1 3 3 51 8 3 1 20 25 E
2$$ -2 -1 0 A7 -1 E  5** A4 0. 0.  E T
13$$ 46R1 2 4R3
14$$
292234 292235 292236 292238 93237 94238
294239 294240 294241 94242 95241 95243
 96244 8016 36083 40093 42095 43099
 44101 44103 45103 45105 46105 46108
 47109       54131       55133 55134
 55135 59141 60143 60145 60147 60148
 61147 61148 61149 62147 62149 62150
 62151 62152 63153 63154 63155 64155
40302 1001 308016 5010 5011
15**
2.5995E-06 1.7239E-04 4.5095E-05 2.2116E-02 3.9458E-06 7.5414E-07
9.9162E-05 3.0659E-05 1.5536E-05 3.3306E-06 5.8892E-07 3.7273E-07
4.6932E-08 4.5716E-02 1.3831E-06 1.9667E-05 1.9298E-05 2.1214E-05
1.9551E-05 2.4752E-07 1.3318E-05 2.8730E-28 9.3576E-06 3.1631E-06
2.1643E-06 9.8371E-06 2.3157E-05 1.2171E-06 7.3294E-06 2.0068E-05
1.6027E-05 1.2431E-05 3.3671E-10 6.2102E-06 4.0752E-06 3.6833E-11
9.9070E-22 1.5723E-06 8.5723E-08 4.9195E-06 3.0263E-07 2.4727E-06
1.5927E-06 3.9107E-07 1.6014E-07 7.3936E-09
4.25156E-02 5.04213E-02 2.52107E-02 8.54876E-06  3.47054E-05  T
33## F1 T
35**
 0 2.57205E-02 6.03261E-02 1.13413E-01 2.32347E-01 3.51282E-01
 4.04369E-01 4.38974E-01 4.64695E-01 4.65931E-01 4.69457E-01
 4.72983E-01 4.74220E-01 4.82232E-01 5.05080E-01 5.27927E-01
 5.35940E-01 5.45498E-01 5.56918E-01 5.71102E-01 5.89833E-01
 6.17477E-01 6.71371E-01 7.25264E-01 7.52908E-01 7.71639E-01
 7.85823E-01 7.97243E-01 8.06802E-01
36$$ 8R1 4R2 4R3 12R4
39$$ 1 0 2 3 40$$ F3 T
END
```

Table D.7. CSAS1X input for eighth-core assembly location 1

```
//ST5CXA1  JOB (35899),'S BOWMAN 6011',MSGCLASS=T,TIME=10,
//   NOTIFY=ST5
//*MAIN CLASS=FIVE
//PROCLIB DD DSN=TZA.PROCLIB.CNTL,DISP=SHR
//  EXEC SCALE41,GOSIZE=2048K
//GO.SYSIN DD *
=CSAS1X
S1C2 QC LOC #1   (BATCH2) 15316 MWD/MTU
27BURNUP  LATTICECELL
   U-234    1  0  2.5995E-06  559  END
   U-235    1  0  1.7239E-04  559  END
   U-236    1  0  4.5095E-05  559  END
   U-238    1  0  2.2116E-02  559  END
  NP-237    1  0  3.9458E-06  559  END
  PU-238    1  0  7.5414E-07  559  END
  PU-239    1  0  9.9162E-05  559  END
  PU-240    1  0  3.0659E-05  559  END
  PU-241    1  0  1.5536E-05  559  END
  PU-242    1  0  3.3306E-06  559  END
  AM-241    1  0  5.8892E-07  559  END
  AM-243    1  0  3.7273E-07  559  END
  CM-244    1  0  4.6932E-08  559  END
   O        1  0  4.5716E-02  559  END
  KR-83     1  0  1.3831E-06  559  END
  ZR-93     1  0  1.9667E-05  559  END
  MO-95     1  0  1.9298E-05  559  END
  TC-99     1  0  2.1214E-05  559  END
  RU-101    1  0  1.9551E-05  559  END
  RU-103    1  0  2.4752E-07  559  END
  RH-103    1  0  1.3318E-05  559  END
  RH-105    1  0  2.8730E-28  559  END
  PD-105    1  0  9.3576E-06  559  END
  PD-108    1  0  3.1631E-06  559  END
  AG-109    1  0  2.1643E-06  559  END
   I-135    1  0  0.0000E+00  559  END
  XE-131    1  0  9.8371E-06  559  END
  XE-135    1  0  0.0000E+00  559  END
  CS-133    1  0  2.3157E-05  559  END
  CS-134    1  0  1.2171E-06  559  END
  CS-135    1  0  7.3294E-06  559  END
  PR-141    1  0  2.0068E-05  559  END
  ND-143    1  0  1.6027E-05  559  END
  ND-145    1  0  1.2431E-05  559  END
  ND-147    1  0  3.3671E-10  559  END
  ND-148    1  0  6.2102E-06  559  END
  PM-147    1  0  4.0752E-06  559  END
  PM-148    1  0  3.6833E-11  559  END
  PM-149    1  0  9.9070E-22  559  END
  SM-147    1  0  1.5723E-06  559  END
  SM-149    1  0  8.5723E-08  559  END
  SM-150    1  0  4.9195E-06  559  END
  SM-151    1  0  3.0263E-07  559  END
  SM-152    1  0  2.4727E-06  559  END
  EU-153    1  0  1.5927E-06  559  END
  EU-154    1  0  3.9107E-07  559  END
  EU-155    1  0  1.6014E-07  559  END
  GD-155    1  0  7.3936E-09  559  END
ZIRCALLOY 2  1              559  END
H2O       3  DEN=.7540  1   559  END
BORON     3  DEN=.7540 1030.E-6 559 END
END COMP
SQUAREPITCH   1.43002 0.92939 1 3 1.07188 2 0.94844 0  END
END
```

Table D.8. KENO V.a input file for BOC, HZP

```
//ST5S1C2B JOB (35899),'S.M.BOWMAN 6011',MSGCLASS=T,
//  NOTIFY=ST5,TIME=80
//*MAIN CLASS=STANDBY
//PROCLIB DD DSN=TZA.PROCLIB.CNTL,DISP=SHR
//KENO EXEC SCALE41,REGION.GO=3500K
//GO.FT04F001 DD DISP=SHR,LABEL=(,,,IN),
//   DSN=X.ST535899.S1C2BOC.XSECLIB,UNIT=
//GO.FT05F001 DD VOL=SER=,UNIT=SYSDA,DISP=(NEW,PASS),
// SPACE=(4800,(0040,20)),DCB=BLKSIZE=4800
//GO.FT08F001 DD UNIT=SYSDA,SPACE=(CYL,(20,5)),
// DCB=(DSORG=DA,RECFM=F)
//GO.FT09F001 DD UNIT=SYSDA,SPACE=(CYL,(20,5)),
// DCB=(DSORG=DA,RECFM=F)
//GO.FT34F001 DD DSN=X.ST535899.S1C2BOC.KENOVRST,
//  DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6136,BUFL=6136),
//  UNIT=DISK,SPACE=(TRK,(05,05)),DISP=(,CATLG)
//GO.SYSIN DD *
#KENOV
SURRY 1 CYCLE 2 BOC (1/8 CORE SYM) HZP, ARO NO XE
'
' *** * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
' *** *                                                             *
' *** *           FULL CORE KENO5A REACTOR CONFIGURATION            *
' *** *           FOR SURRY UNIT-1 BOC-2   HZP, ARO NO XE           *
' *** *                       1 PLANE  MODEL                        *
' *** *                                                             *
' *** *                            BY                               *
' *** *                       STEVE BOWMAN                          *
' *** *               OAK RIDGE NATIONAL LABORATORY                 *
' *** *                                                             *
' *** *                         AUG. 1992                           *
' *** * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
'
READ PARM
RUN=YES PLT=YES NUB=YES FDN=YES TME=80.0 GEN=403 NPG=1000
WRS=34 RES=100
LIB=4 NB8=2400  NL8=880 END PARM

READ MIXT
MIX=101
'ASSY 1
'S1C2 EC LOC #1   (BATCH 1A2) 15316 MWD/MTU
   292234  2.5995E-06
   292235  1.7239E-04
   292236  4.5095E-05
   292238  2.2116E-02
    93237  3.9458E-06
    94238  7.5414E-07
   294239  9.9162E-05
   294240  3.0659E-05
   294241  1.5536E-05
    94242  3.3306E-06
    95241  5.8892E-07
    95243  3.7273E-07
    96244  4.6932E-08
     8016  4.5716E-02
    36083  1.3831E-06
    40093  1.9667E-05
    42095  1.9298E-05
    43099  2.1214E-05
    44101  1.9551E-05
    44103  2.4752E-07
    45103  1.3318E-05
    45105  2.8730E-28
    46105  9.3576E-06
    46108  3.1631E-06
```

Table D.8. (continued)

```
    47109  2.1643E-06
    54131  9.8371E-06
    55133  2.3157E-05
    55134  1.2171E-06
    55135  7.3294E-06
    59141  2.0068E-05
    60143  1.6027E-05
    60145  1.2431E-05
    60147  3.3671E-10
    60148  6.2102E-06
    61147  4.0752E-06
    61148  3.6833E-11
    61149  9.9070E-22
    62147  1.5723E-06
    62149  8.5723E-08
    62150  4.9195E-06
    62151  3.0263E-07
    62152  2.4727E-06
    63153  1.5927E-06
    63154  3.9107E-07
    63155  1.6014E-07
    64155  7.3936E-09
MIX=102
'ASSY 2
'S1C2 EC LOC #2 BATCH 4B  0 MWD/MTU
792234     5.17375E-06
792235     6.11176E-04
792236     2.79807E-06
792238     2.25095E-02
  8016     4.62574E-02
MIX=103
'ASSY 3
'S1C2 EC LOC #3   (BATCH 1A2) 12535 MWD/MTU
   192234  2.7473E-06
   192235  2.0387E-04
   192236  4.0293E-05
   192238  2.2175E-02
    93237  3.0435E-06
    94238  4.7006E-07
   194239  9.2646E-05
   194240  2.4680E-05
   194241  1.1805E-05
    94242  2.0065E-06
    95241  4.0047E-07
    95243  1.7924E-07
    96244  1.7015E-08
     8016  4.5716E-02
    36083  1.1972E-06
    40093  1.6497E-05
    42095  1.5813E-05
    43099  1.7617E-05
    44101  1.5998E-05
    44103  2.3814E-07
    45103  1.0987E-05
    45105  2.6751E-28
    46105  7.1754E-06
    46108  2.3045E-06
    47109  1.6230E-06
    54131  8.2735E-06
    55133  1.9254E-05
    55134  8.5156E-07
    55135  5.9704E-06
    59141  1.6549E-05
```

Table D.8. (continued)

```
     60143  1.3818E-05
     60145  1.0417E-05
     60147  3.3887E-10
     60148  5.0956E-06
     61147  3.7376E-06
     61148  3.3271E-11
     61149  9.5133E-22
     62147  1.2080E-06
     62149  8.2718E-08
     62150  3.9405E-06
     62151  2.7658E-07
     62152  2.0353E-06
     63153  1.1990E-06
     63154  2.5830E-07
     63155  1.1797E-07
     64155  5.4325E-09
MIX=104
'ASSY 4
'S1C2 EC LOC #4 BATCH 4B  0 MWD/MTU
792234      5.17375E-06
792235      6.11176E-04
792236      2.79807E-06
792238      2.25095E-02
  8016      4.62574E-02
MIX=105
'ASSY 5
'S1C2 EC LOC #5   (BATCH 2) 15224 MWD/MTU
     92234  3.9749E-06
     92235  2.9091E-04
     92236  5.4175E-05
     92238  2.1854E-02
     93237  3.9091E-06
     94238  6.1418E-07
     94239  9.9710E-05
     94240  2.5090E-05
     94241  1.2889E-05
     94242  2.0547E-06
     95241  4.4905E-07
     95243  1.9853E-07
     96244  2.0841E-08
      8016  4.5425E-02
     36083  1.4958E-06
     40093  2.0425E-05
     42095  1.9528E-05
     43099  2.1243E-05
     44101  1.9207E-05
     44103  2.5861E-07
     45103  1.2620E-05
     45105  2.8013E-28
     46105  7.9631E-06
     46108  2.4178E-06
     47109  1.6818E-06
     54131  9.8084E-06
     55133  2.3174E-05
     55134  1.0876E-06
     55135  8.0025E-06
     59141  2.0168E-05
```

Table D.8. (continued)

```
    60143  1.7112E-05
    60145  1.2745E-05
    60147  3.8752E-10
    60148  6.1682E-06
    61147  4.4050E-06
    61148  4.1269E-11
    61149  1.0895E-21
    62147  1.5027E-06
    62149  9.8649E-08
    62150  4.9068E-06
    62151  3.4806E-07
    62152  2.3296E-06
    63153  1.4185E-06
    63154  3.1455E-07
    63155  1.4045E-07
    64155  6.6116E-09
MIX=106
'ASSY 6
'S1C2 EC LOC #6 BATCH 4B 0 MWD/MTU
692234     5.17375E-06
692235     6.11176E-04
692236     2.79807E-06
692238     2.25095E-02
  8016     4.62574E-02
MIX=107
'ASSY 7
'S1C2 EC LOC #7   (BATCH 1A2) 14764 MWD/MTU
   292234  2.6284E-06
   292235  1.7825E-04
   292236  4.4219E-05
   292238  2.2128E-02
    93237  3.7642E-06
    94238  6.9173E-07
   294239  9.8054E-05
   294240  2.9502E-05
   294241  1.4809E-05
    94242  3.0430E-06
    95241  5.5024E-07
    95243  3.2693E-07
    96244  3.9133E-08
     8016  4.5716E-02
    36083  1.3480E-06
    40093  1.9049E-05
    42095  1.8616E-05
    43099  2.0509E-05
    44101  1.8847E-05
    44103  2.4580E-07
    45103  1.2864E-05
    45105  2.8363E-28
    46105  8.9131E-06
    46108  2.9854E-06
    47109  2.0546E-06
    54131  9.5353E-06
    55133  2.2393E-05
    55134  1.1409E-06
    55135  7.0594E-06
    59141  1.9373E-05
    60143  1.5609E-05
    60145  1.2039E-05
    60147  3.3709E-10
    60148  5.9893E-06
    61147  4.0170E-06
    61148  3.6212E-11
    61149  9.8345E-22
```

Table D.8. (continued)

```
     62147  1.4995E-06
    62149  8.5195E-08
    62150  4.7245E-06
    62151  2.9761E-07
    62152  2.3875E-06
    63153  1.5126E-06
    63154  3.6278E-07
    63155  1.5116E-07
    64155  6.9758E-09
MIX=108
'ASSY 8
'S1C2 EC LOC #8  (BATCH 4C) 0 MWD/MTU
892234     6.57077E-06
892235     7.78116E-04
892236     3.49016E-06
892238     2.22935E-02
  8016     4.61634E-02
MIX=109
'ASSY 9
'S1C2 EC LOC #9   (BATCH 2) 16280 MWD/MTU
    92234  3.9031E-06
    92235  2.7632E-04
    92236  5.6478E-05
    92238  2.1834E-02
    93237  4.2805E-06
    94238  7.2308E-07
    94239  1.0220E-04
    94240  2.7111E-05
    94241  1.4223E-05
    94242  2.4556E-06
    95241  5.1397E-07
    95243  2.5645E-07
    96244  2.9534E-08
     8016  4.5425E-02
    36083  1.5724E-06
    40093  2.1681E-05
    42095  2.0888E-05
    43099  2.2606E-05
    44101  2.0537E-05
    44103  2.6210E-07
    45103  1.3455E-05
    45105  2.8759E-28
    46105  8.7064E-06
    46108  2.6965E-06
    47109  1.8590E-06
    54131  1.0392E-05
    55133  2.4650E-05
    55134  1.2274E-06
    55135  8.5521E-06
    59141  2.1518E-05
    60143  1.8007E-05
    60145  1.3527E-05
    60147  3.8667E-10
    60148  6.5902E-06
    61147  4.5337E-06
    61148  4.2648E-11
    61149  1.1053E-21
    62147  1.6411E-06
    62149  9.9595E-08
    62150  5.2914E-06
    62151  3.5758E-07
    62152  2.4886E-06
    63153  1.5612E-06
```

Table D.8. (continued)

```
    63154  3.6243E-07
    63155  1.5577E-07
    64155  7.3326E-09
MIX=110
'ASSY 10
'S1C2 EC LOC #10  BATCH4A   0 MWD/MTU
592234     3.51641E-06
592235     4.34171E-04
592236     2.09192E-06
592238     2.26136E-02
  8016     4.61067E-02
MIX=111
'ASSY 11
'S1C2 EC LOC #11  (BATCH 2) 14128 MWD/MTU
   392234  4.0502E-06
   392235  3.0672E-04
   392236  5.1644E-05
   392238  2.1874E-02
    93237  3.5312E-06
    94238  5.1218E-07
   394239  9.6796E-05
   394240  2.2967E-05
   394241  1.1495E-05
    94242  1.6783E-06
    95241  3.8453E-07
    95243  1.4860E-07
    96244  1.3963E-08
     8016  4.5425E-02
    36083  1.4131E-06
    40093  1.9103E-05
    42095  1.8099E-05
    43099  1.9813E-05
    44101  1.7824E-05
    44103  2.5479E-07
    45103  1.1740E-05
    45105  2.7205E-28
    46105  7.2114E-06
    46108  2.1410E-06
    47109  1.5026E-06
    54131  9.1884E-06
    55133  2.1623E-05
    55134  9.4935E-07
    55135  7.4304E-06
    59141  1.8761E-05
    60143  1.6148E-05
    60145  1.1921E-05
    60147  3.8847E-10
    60148  5.7296E-06
    61147  4.2552E-06
    61148  3.9671E-11
    61149  1.0722E-21
    62147  1.3600E-06
    62149  9.7536E-08
    62150  4.5102E-06
    62151  3.3793E-07
    62152  2.1621E-06
    63153  1.2741E-06
    63154  2.6836E-07
    63155  1.2564E-07
    64155  5.9143E-09
MIX=112
'ASSY 12
'S1C2 EC LOC #12  (BATCH 2) 15831 MWD/MTU
```

Table D.8. (continued)

```
    92234  3.9336E-06
    92235  2.8245E-04
    92236  5.5514E-05
    92238  2.1843E-02
    93237  4.1219E-06
    94238  6.7548E-07
    94239  1.0118E-04
    94240  2.6256E-05
    94241  1.3658E-05
    94242  2.2806E-06
    95241  4.8607E-07
    95243  2.3058E-07
    96244  2.5573E-08
     8016  4.5425E-02
    36083  1.5402E-06
    40093  2.1149E-05
    42095  2.0312E-05
    43099  2.2028E-05
    44101  1.9971E-05
    44103  2.6063E-07
    45103  1.3102E-05
    45105  2.8445E-28
    46105  8.3881E-06
    46108  2.5766E-06
    47109  1.7831E-06
    54131  1.0146E-05
    55133  2.4025E-05
    55134  1.1673E-06
    55135  8.3186E-06
    59141  2.0945E-05
    60143  1.7631E-05
    60145  1.3196E-05
    60147  3.8702E-10
    60148  6.4108E-06
    61147  4.4808E-06
    61148  4.2081E-11
    61149  1.0986E-21
    62147  1.5822E-06
    62149  9.9207E-08
    62150  5.1276E-06
    62151  3.5356E-07
    62152  2.4213E-06
    63153  1.5000E-06
    63154  3.4167E-07
    63155  1.4913E-07
    64155  7.0200E-09
MIX=113
'ASSY 13
'S1C2 EC LOC #13  (BATCH 2) 14371 MWD/MTU
   392234  4.0334E-06
   392235  3.0315E-04
   392236  5.2218E-05
   392238  2.1870E-02
    93237  3.6143E-06
    94238  5.3385E-07
   394239  9.7474E-05
   394240  2.3440E-05
   394241  1.1804E-05
    94242  1.7583E-06
    95241  3.9856E-07
    95243  1.5882E-07
    96244  1.5315E-08
     8016  4.5425E-02
    36083  1.4317E-06
    40093  1.9398E-05
```

Table D.8. (continued)

```
    42095  1.8416E-05
    43099  2.0132E-05
    44101  1.8131E-05
    44103  2.5567E-07
    45103  1.1937E-05
    45105  2.7387E-28
    46105  7.3763E-06
    46108  2.2013E-06
    47109  1.5419E-06
    54131  9.3271E-06
    55133  2.1969E-05
    55134  9.7940E-07
    55135  7.5574E-06
    59141  1.9074E-05
    60143  1.6365E-05
    60145  1.2105E-05
    60147  3.8824E-10
    60148  5.8269E-06
    61147  4.2899E-06
    61148  4.0040E-11
    61149  1.0761E-21
    62147  1.3916E-06
    62149  9.7795E-08
    62150  4.5979E-06
    62151  3.4020E-07
    62152  2.1994E-06
    63153  1.3058E-06
    63154  2.7829E-07
    63155  1.2884E-07
    64155  6.0647E-09
MIX=114
'ASSY 14
'S1C2 EC LOC #14  BATCH4C   0 MWD/MTU
992234     6.57077E-06
992235     7.78116E-04
992236     3.49016E-06
992238     2.22935E-02
  8016     4.61634E-02
MIX=115
'ASSY 15
'S1C2 EC LOC #15  BATCH4C   0 MWD/MTU
892234     6.57077E-06
892235     7.78116E-04
892236     3.49016E-06
892238     2.22935E-02
  8016     4.61634E-02
MIX=116
'ASSY 16
'S1C2 EC LOC #16  (BATCH 1A2) 11553 MWD/MTU
   192234  2.8009E-06
   192235  2.1625E-04
   192236  3.8351E-05
   192238  2.2195E-02
    93237  2.7349E-06
    94238  3.8744E-07
   194239  8.9689E-05
   194240  2.2495E-05
   194241  1.0467E-05
    94242  1.6157E-06
    95241  3.3893E-07
    95243  1.3129E-07
    96244  1.1204E-08
     8016  4.5716E-02
    36083  1.1259E-06
    40093  1.5345E-05
```

Table D.8. (continued)

```
    42095  1.4552E-05
    43099  1.6319E-05
    44101  1.4741E-05
    44103  2.3424E-07
    45103  1.0138E-05
    45105  2.5965E-28
    46105  6.4418E-06
    46108  2.0247E-06
    47109  1.4403E-06
    54131  7.6958E-06
    55133  1.7843E-05
    55134  7.3445E-07
    55135  5.4917E-06
    59141  1.5292E-05
    60143  1.2974E-05
    60145  9.6841E-06
    60147  3.3978E-10
    60148  4.7009E-06
    61147  3.5888E-06
    61148  3.1730E-11
    61149  9.3562E-22
    62147  1.0821E-06
    62149  8.1430E-08
    62150  3.5980E-06
    62151  2.6685E-07
    62152  1.8760E-06
    63153  1.0670E-06
    63154  2.1747E-07
    63155  1.0484E-07
    64155  4.8230E-09
MIX=117
'ASSY 17
'S1C2 EC LOC #17  BATCH4A  0 MWD/MTU
592234     3.51641E-06
592235     4.34171E-04
592236     2.09192E-06
592238     2.26136E-02
  8016     4.61067E-02
MIX=118
'ASSY 18
'S1C2 EC LOC #18  (BATCH 2) 15787 MWD/MTU
    92234  3.9366E-06
    92235  2.8306E-04
    92236  5.5419E-05
    92238  2.1844E-02
    93237  4.1064E-06
    94238  6.7092E-07
    94239  1.0107E-04
    94240  2.6172E-05
    94241  1.3603E-05
    94242  2.2638E-06
    95241  4.8337E-07
    95243  2.2815E-07
    96244  2.5205E-08
     8016  4.5425E-02
    36083  1.5370E-06
    40093  2.1096E-05
    42095  2.0255E-05
    43099  2.1971E-05
    44101  1.9916E-05
    44103  2.6049E-07
    45103  1.3067E-05
    45105  2.8414E-28
    46105  8.3572E-06
    46108  2.5650E-06
```

Table D.8. (continued)

```
    47109  1.7758E-06
    54131  1.0121E-05
    55133  2.3964E-05
    55134  1.1614E-06
    55135  8.2957E-06
    59141  2.0889E-05
    60143  1.7593E-05
    60145  1.3163E-05
    60147  3.8706E-10
    60148  6.3932E-06
    61147  4.4754E-06
    61148  4.2023E-11
    61149  1.0980E-21
    62147  1.5765E-06
    62149  9.9168E-08
    62150  5.1116E-06
    62151  3.5315E-07
    62152  2.4146E-06
    63153  1.4941E-06
    63154  3.3967E-07
    63155  1.4849E-07
    64155  6.9900E-09
MIX=119
'ASSY 19
'S1C2 EC LOC #19  (BATCH 1A2) 14187 MWD/MTU
   292234  2.6587E-06
   292235  1.8457E-04
   292236  4.3264E-05
   292238  2.2140E-02
    93237  3.5754E-06
    94238  6.2972E-07
   294239  9.6806E-05
   294240  2.8276E-05
   294241  1.4040E-05
    94242  2.7553E-06
    95241  5.1038E-07
    95243  2.8314E-07
    96244  3.2042E-08
     8016  4.5716E-02
    36083  1.3104E-06
    40093  1.8397E-05
    42095  1.7899E-05
    43099  1.9768E-05
    44101  1.8110E-05
    44103  2.4396E-07
    45103  1.2386E-05
    45105  2.7967E-28
    46105  8.4543E-06
    46108  2.8033E-06
    47109  1.9409E-06
    54131  9.2152E-06
    55133  2.1589E-05
    55134  1.0630E-06
    55135  6.7772E-06
    59141  1.8646E-05
    60143  1.5161E-05
    60145  1.1624E-05
    60147  3.3752E-10
    60148  5.7582E-06
    61147  3.9518E-06
    61148  3.5519E-11
    61149  9.7559E-22
    62147  1.4236E-06
    62149  8.4610E-08
    62150  4.5210E-06
```

Table D.8. (continued)

```
    62151  2.9228E-07
    62152  2.2976E-06
    63153  1.4298E-06
    63154  3.3422E-07
    63155  1.4211E-07
    64155  6.5547E-09
MIX=120
'ASSY 20
'S1C2 EC LOC #20  BATCH4C   0 MWD/MTU
892234     6.57077E-06
892235     7.78116E-04
892236     3.49016E-06
892238     2.22935E-02
  8016     4.61634E-02
MIX=121
'ASSY 21
'S1C2 EC LOC #21  (BATCH 2) 16587 MWD/MTU
    92234  3.8824E-06
    92235  2.7220E-04
    92236  5.7124E-05
    92238  2.1829E-02
    93237  4.3897E-06
    94238  7.5674E-07
    94239  1.0288E-04
    94240  2.7692E-05
    94241  1.4607E-05
    94242  2.5793E-06
    95241  5.3327E-07
    95243  2.7522E-07
    96244  3.2483E-08
     8016  4.5425E-02
    36083  1.5941E-06
    40093  2.2042E-05
    42095  2.1280E-05
    43099  2.2999E-05
    44101  2.0923E-05
    44103  2.6309E-07
    45103  1.3694E-05
    45105  2.8971E-28
    46105  8.9258E-06
    46108  2.7796E-06
    47109  1.9113E-06
    54131  1.0560E-05
    55133  2.5076E-05
    55134  1.2693E-06
    55135  8.7114E-06
    59141  2.1909E-05
    60143  1.8261E-05
    60145  1.3752E-05
    60147  3.8642E-10
    60148  6.7128E-06
    61147  4.5684E-06
    61148  4.3023E-11
    61149  1.1097E-21
    62147  1.6815E-06
    62149  9.9849E-08
    62150  5.4037E-06
    62151  3.6032E-07
    62152  2.5343E-06
    63153  1.6032E-06
    63154  3.7696E-07
    63155  1.6043E-07
    64155  7.5518E-09
MIX=122
'ASSY 22
```

Table D.8. (continued)

```
'S1C2 EC LOC #22  (BATCH 2) 16298 MWD/MTU
    92234  3.9019E-06
    92235  2.7608E-04
    92236  5.6516E-05
    92238  2.1834E-02
    93237  4.2869E-06
    94238  7.2502E-07
    94239  1.0224E-04
    94240  2.7145E-05
    94241  1.4245E-05
    94242  2.4628E-06
    95241  5.1509E-07
    95243  2.5752E-07
    96244  2.9702E-08
     8016  4.5425E-02
    36083  1.5737E-06
    40093  2.1702E-05
    42095  2.0911E-05
    43099  2.2629E-05
    44101  2.0560E-05
    44103  2.6216E-07
    45103  1.3469E-05
    45105  2.8771E-28
    46105  8.7192E-06
    46108  2.7014E-06
    47109  1.8620E-06
    54131  1.0401E-05
    55133  2.4675E-05
    55134  1.2299E-06
    55135  8.5614E-06
    59141  2.1541E-05
    60143  1.8022E-05
    60145  1.3540E-05
    60147  3.8665E-10
    60148  6.5974E-06
    61147  4.5358E-06
    61148  4.2671E-11
    61149  1.1055E-21
    62147  1.6435E-06
    62149  9.9611E-08
    62150  5.2980E-06
    62151  3.5774E-07
    62152  2.4912E-06
    63153  1.5636E-06
    63154  3.6327E-07
    63155  1.5604E-07
    64155  7.3454E-09
MIX=123
'ASSY 23
'S1C2 EC LOC #23  BATCH4C   0 MWD/MTU
992234     6.57077E-06
992235     7.78116E-04
992236     3.49016E-06
992238     2.22935E-02
  8016     4.61634E-02
MIX=124
'ASSY 24
'S1C2 EC LOC #24  BATCH4C   0 MWD/MTU
892234     6.57077E-06
892235     7.78116E-04
892236     3.49016E-06
892238     2.22935E-02
  8016     4.61634E-02
MIX=125
'ASSY 25
```

Table D.8. (continued)

```
'S1C2 EC LOC #25  BATCH4A  0 MWD/MTU
592234     3.51641E-06
592235     4.34171E-04
592236     2.09192E-06
592238     2.26136E-02
  8016     4.61067E-02
MIX=126
'ASSY 26
'S1C2 EC LOC #26  BATCH4C   0 MWD/MTU
892234     6.57077E-06
892235     7.78116E-04
892236     3.49016E-06
892238     2.22935E-02
  8016     4.61634E-02
MIX=1
 40302  4.25156E-02
MIX=2
 24304  1.74286E-02
 25055  1.73633E-03
 26304  5.93579E-02
 28304  7.72073E-03
MIX=3
  1001  5.04213E-02
308016  2.52107E-02
  5010  8.54876E-06
  5011  3.47054E-05
MIX=4
 424304  8.71428E-03
 425055  8.68166E-04
 426304  2.96789E-02
 428304  3.86037E-03
 401001  2.52107E-02
 408016  1.26053E-02
 405010  4.27438E-06
 405011  1.73527E-05
MIX=5
 524304  1.74286E-02
 525055  1.73633E-03
 526304  5.93579E-02
 528304  7.72073E-03
MIX=6
601001  5.04213E-02
608016  2.52107E-02
605010  8.54876E-06
605011  3.47054E-05
MIX=7
 724304  1.74286E-02
 725055  1.73633E-03
 726304  5.93579E-02
 728304  7.72073E-03
MIX=8
801001  5.04213E-02
808016  2.52107E-02
805010  8.54876E-06
805011  3.47054E-05
MIX=9
 924304  1.74286E-02
 925055  1.73633E-03
 926304  5.93579E-02
 928304  7.72073E-03
MIX=11
'S1C2  BP FOR EC LOC #2  BATCH4B
   718016   4.49700E-02
   715010   9.59500E-04
   715011   3.86300E-03
```

Table D.8. (continued)

```
    11023   1.65000E-03
    13027   5.80000E-04
MIX=12
'S1C2  BP FOR EC LOC #4  BATCH4B
   718016   4.49700E-02
   715010   9.59500E-04
   715011   3.86300E-03
    11023   1.65000E-03
    13027   5.80000E-04
MIX=13
'S1C2 DEPLETED BP FOR EC LOC #6  BATCH4B
   618016   4.49700E-02
   615010   2.38000E-05
   615011   3.86300E-03
    11023   1.65000E-03
    13027   5.80000E-04
MIX=14
'S1C2  BP FOR EC LOC #14  BATCH4C
   918016   4.49700E-02
   915010   9.59500E-04
   915011   3.86300E-03
    11023   1.65000E-03
    13027   5.80000E-04
MIX=15
'S1C2  BP FOR EC LOC #23  BATCH4C
   918016   4.49700E-02
   915010   9.59500E-04
   915011   3.86300E-03
    11023   1.65000E-03
    13027   5.80000E-04
END MIXT

READ GEOM

'--- FUEL PINS
UNIT 101
CYLINDER 0101 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 102
CYLINDER 0102 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 103
CYLINDER 0103 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 104
CYLINDER 0104 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 105
CYLINDER 0105 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 106
CYLINDER 0106 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
```

Table D.8. (continued)

```
UNIT 107
CYLINDER 0107 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 108
CYLINDER 0108 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 109
CYLINDER 0109 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 110
CYLINDER 0110 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 111
CYLINDER 0111 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 112
CYLINDER 0112 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 113
CYLINDER 0113 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 114
CYLINDER 0114 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 115
CYLINDER 0115 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 116
CYLINDER 0116 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 117
CYLINDER 0117 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 118
CYLINDER 0118 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 119
CYLINDER 0119 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
```

Table D.8. (continued)

```
UNIT 120
CYLINDER 0120 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 121
CYLINDER 0121 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 122
CYLINDER 0122 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 123
CYLINDER 0123 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 124
CYLINDER 0124 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 125
CYLINDER 0125 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 126
CYLINDER 0126 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0

'--- GUIDE TUBE
UNIT 161
CYLINDER   3  1 0.613918 365.76 0.0
CYLINDER   1  1 0.690118 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0

'--- BP RODS
UNIT 162
CYLINDER   0 1 0.283845 365.76 0.0
CYLINDER   2 1 0.300355 365.76 0.0
CYLINDER   0 1 0.308610 365.76 0.0
CYLINDER  11 1 0.502920 365.76 0.0
CYLINDER   0 1 0.508635 365.76 0.0
CYLINDER   2 1 0.555625 365.76 0.0
CYLINDER   3  1 0.613918 365.76 0.0
CYLINDER   1  1 0.690118 365.76 0.0
CUBOID     3  1 2P0.71501 2P0.71501 365.76 0.0
UNIT 163
CYLINDER   0 1 0.283845 365.76 0.0
CYLINDER   2 1 0.300355 365.76 0.0
CYLINDER   0 1 0.308610 365.76 0.0
CYLINDER  12 1 0.502920 365.76 0.0
CYLINDER   0 1 0.508635 365.76 0.0
CYLINDER   2 1 0.555625 365.76 0.0
CYLINDER   3  1 0.613918 365.76 0.0
CYLINDER   1  1 0.690118 365.76 0.0
CUBOID     3  1 2P0.71501 2P0.71501 365.76 0.0
UNIT 164
CYLINDER   0 1 0.283845 365.76 0.0
```

Table D.8. (continued)

```
CYLINDER   2 1 0.300355 365.76 0.0
CYLINDER   0 1 0.308610 365.76 0.0
CYLINDER  13 1 0.502920 365.76 0.0
CYLINDER   0 1 0.508635 365.76 0.0
CYLINDER   2 1 0.555625 365.76 0.0
CYLINDER   3  1 0.613918 365.76 0.0
CYLINDER   1  1 0.690118 365.76 0.0
CUBOID     3  1 2P0.71501 2P0.71501 365.76 0.0
UNIT 165
CYLINDER   0 1 0.283845 365.76 0.0
CYLINDER   2 1 0.300355 365.76 0.0
CYLINDER   0 1 0.308610 365.76 0.0
CYLINDER  14 1 0.502920 365.76 0.0
CYLINDER   0 1 0.508635 365.76 0.0
CYLINDER   2 1 0.555625 365.76 0.0
CYLINDER   3  1 0.613918 365.76 0.0
CYLINDER   1  1 0.690118 365.76 0.0
CUBOID     3  1 2P0.71501 2P0.71501 365.76 0.0
UNIT 166
CYLINDER   0 1 0.283845 365.76 0.0
CYLINDER   2 1 0.300355 365.76 0.0
CYLINDER   0 1 0.308610 365.76 0.0
CYLINDER  15 1 0.502920 365.76 0.0
CYLINDER   0 1 0.508635 365.76 0.0
CYLINDER   2 1 0.555625 365.76 0.0
CYLINDER   3  1 0.613918 365.76 0.0
CYLINDER   1  1 0.690118 365.76 0.0
CUBOID     3  1 2P0.71501 2P0.71501 365.76 0.0

'--- FUEL ASSY'S
UNIT 1
ARRAY     0101 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 2
ARRAY     0102 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 3
ARRAY     0103 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 4
ARRAY     0104 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 5
ARRAY     0105 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 6
ARRAY     0106 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 7
ARRAY     0107 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 8
ARRAY     0108 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 9
ARRAY     0109 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 10
ARRAY     0110 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 11
ARRAY     0111 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 12
ARRAY     0112 2R-10.72515 0.0
```

Table D.8. (continued)

```
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 13
ARRAY     0113 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 14
ARRAY     0114 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 15
ARRAY     0115 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 16
ARRAY     0116 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 17
ARRAY     0117 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 18
ARRAY     0118 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 19
ARRAY     0119 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 20
ARRAY     0120 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 21
ARRAY     0121 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 22
ARRAY     0122 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 23
ARRAY     0123 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 24
ARRAY     0124 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 25
ARRAY     0125 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 26
ARRAY     0126 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1

'--- BAFFLE REGION
UNIT 41
COM=! CORNER SQUARE !
 CUBOID   2 1    1.905     0.0       1.905     0.0  365.76 0.0
UNIT 42
COM=! HORIZONTAL STRIP (1 ASS'Y WIDE) !
 CUBOID   2 1   21.50364   0.0       1.905     0.0  365.76 0.0
UNIT 43
COM=! VERTICAL STRIP (1 ASS'Y HIGH) !
 CUBOID   2 1    1.905     0.0      21.50364   0.0  365.76 0.0
UNIT 44
COM=! HORIZONTAL STRIP (2 ASS'YS WIDE) !
CUBOID   2 1     43.00728  0.0      1.905      0.0  365.76 0.0
UNIT 45
COM=! HORIZONTAL STRIP (1 ASS'Y WIDE) BOTTOM OF Y AXIS !
 CUBOID   2 1    21.50364  0.0      0.0       -1.905 365.76 0.0
```

Table D.8. (continued)

```
UNIT 46
COM=! HORIZONTAL STRIP (2 ASS'YS WIDE) BOTTOM OF Y AXIS !
CUBOID   2 1     43.00728  0.0       0.0        -1.905 365.76 0.0

'---ROWS OF ASSY'S W/ BAFFLE REGIONS ON EACH END
UNIT 51
COM=! ROW 1 !
ARRAY  1  -34.16046  -12.65682 0.0
UNIT 52
COM=! ROW 2 !
ARRAY  2  -77.16774  -10.75182 0.0
UNIT 53
COM=! ROW 3 !
ARRAY  3  -98.67138  -10.75182 0.0
UNIT 54
COM=! ROW 4 !
ARRAY  4 -120.17502  -10.75182 0.0
UNIT 55
COM=! ROWS 5 & 6 !
ARRAY  5 -141.67866  -21.50364 0.0
UNIT 57
COM=! ROWS 7 - 9 !
ARRAY  7 -163.18230  -32.25546 0.0
UNIT 60
COM=! ROWS 10 & 11 !
ARRAY 10 -141.67866  -21.50364 0.0
UNIT 62
COM=! ROW 12 !
ARRAY 12 -120.17502  -10.75182 0.0
UNIT 63
COM=! ROW 13 !
ARRAY 13  -98.67138  -10.75182 0.0
UNIT 64
COM=! ROW 14 !
ARRAY 14  -77.16774  -10.75182 0.0
UNIT 65
COM=! ROW 15 !
ARRAY 15  -34.16046  -10.75182 0.0

GLOBAL UNIT 70
CYLINDER 3 1 170.02125 365.76 0.0
HOLE  57   0.0      0.0       0.0
HOLE  55   0.0    -53.75910  0.0
HOLE  60   0.0     53.75910  0.0
HOLE  54   0.0    -86.01456  0.0
HOLE  62   0.0     86.01456  0.0
HOLE  53   0.0   -107.51820  0.0
HOLE  63   0.0    107.51820  0.0
HOLE  52   0.0   -129.02184  0.0
HOLE  64   0.0    129.02184  0.0
HOLE  51   0.0   -150.52548  0.0
HOLE  65   0.0    150.52548  0.0
HOLE  44  -77.16774  139.77366  0
HOLE  46  -77.16774 -139.77466  0
HOLE  44   34.16046  139.77366  0
HOLE  46   34.16046 -139.77466  0
HOLE  42  -98.67138  118.27002  0
HOLE  45  -98.67138 -118.27002  0
HOLE  42   77.16774  118.27002  0
HOLE  45   77.16774 -118.27002  0
HOLE  42 -120.17502   96.76638  0
HOLE  45 -120.17502  -96.76738  0
HOLE  42   98.67138   96.76638  0
HOLE  45   98.67138  -96.76738  0
```

Table D.8. (continued)

```
HOLE  42 -141.67866   75.26274  0
HOLE  45 -141.67866  -75.26274  0
HOLE  42  120.17502   75.26274  0
HOLE  45  120.17502  -75.26274  0
HOLE  42 -163.18230   32.25546  0
HOLE  45 -163.18230  -32.25546  0
HOLE  42  141.67866   32.25546  0
HOLE  45  141.67866  -32.25546  0
CYLINDER 4 1 170.02125 390.76 -25.0
REFLECTOR  5 1  5.08    0.0 0.0 1
REFLECTOR  6 1  6.0325  0.0 0.0 1
REFLECTOR  7 1  6.82625 0.0 0.0 1
REFLECTOR  8 1 11.43    0.0 0.0 1
REFLECTOR  9 1 19.89582 0.0 0.0 1
CUBOID  0 1 2P220.0 2P220.0 390.76 -25.0
END GEOM

READ ARRAY

'--- FUEL ASSY'S
ARA=101   NUX=15 NUY=15 NUZ=1     FILL  F101
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=102   NUX=15 NUY=15 NUZ=1
COM=/   ASSY 2 -- 8 FRESH BP   /
FILL F102
  A33 161     A36 162     A40 162      A43 161
  A53 161     A65 161     A71 161      A78 162
  A88 162    A109 161    A113 161     A117 161   A138 162
 A148 162    A155 161    A161 161     A173 161
 A183 161    A186 162    A190 162     A193 161     END FILL
ARA=103   NUX=15 NUY=15 NUZ=1     FILL  F103
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=104   NUX=15 NUY=15 NUZ=1
COM=/   ASSY 4 -- 8 FRESH BP   /
FILL F104
  A33 161     A36 163     A40 163      A43 161
  A53 161     A65 161     A71 161      A78 163
  A88 163    A109 161    A113 161     A117 161   A138 163
 A148 163    A155 161    A161 161     A173 161
 A183 161    A186 163    A190 163     A193 161     END FILL
ARA=105   NUX=15 NUY=15 NUZ=1     FILL  F105
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=106   NUX=15 NUY=15 NUZ=1
COM=/   ASSY 6 -- 12 DEPLETED BP   /
FILL F106
  A33 164     A36 164     A40 164      A43 164
  A53 161     A65 161     A71 161      A78 164
  A88 164    A109 161    A113 161     A117 161   A138 164

 A148 164    A155 161    A161 161     A173 161
 A183 164    A186 164    A190 164     A193 164     END FILL
ARA=107   NUX=15 NUY=15 NUZ=1     FILL  F107
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
```

Table D.8. (continued)

```
 A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=108   NUX=15 NUY=15 NUZ=1     FILL  F108
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=109   NUX=15 NUY=15 NUZ=1     FILL  F109
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=110   NUX=15 NUY=15 NUZ=1     FILL  F110
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=111   NUX=15 NUY=15 NUZ=1     FILL  F111
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=112   NUX=15 NUY=15 NUZ=1     FILL  F112
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=113   NUX=15 NUY=15 NUZ=1     FILL  F113
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=114   NUX=15 NUY=15 NUZ=1
COM=/   ASSY 14 -- 20 FRESH BP   /
FILL F114
  A33 165     A36 165     A40 165      A43 165
  A53 165     A65 165     A71 165      A78 165
  A88 165    A109 165    A113 161     A117 165   A138 165
 A148 165    A155 165    A161 165     A173 165
 A183 165    A186 165    A190 165     A193 165     END FILL
ARA=115   NUX=15 NUY=15 NUZ=1     FILL  F115
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=116   NUX=15 NUY=15 NUZ=1     FILL  F116
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=117   NUX=15 NUY=15 NUZ=1     FILL  F117
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
```

Table D.8. (continued)

```
ARA=118   NUX=15 NUY=15 NUZ=1     FILL  F118
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=119   NUX=15 NUY=15 NUZ=1     FILL  F119
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=120   NUX=15 NUY=15 NUZ=1     FILL  F120
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=121   NUX=15 NUY=15 NUZ=1     FILL  F121
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=122   NUX=15 NUY=15 NUZ=1     FILL  F122
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=123   NUX=15 NUY=15 NUZ=1
COM=/   ASSY 23 -- 12 FRESH BP   /
FILL F123
  A33 166     A36 166     A40 166      A43 166
  A53 161     A65 161     A71 161      A78 166
  A88 166    A109 161    A113 161     A117 161   A138 166
 A148 166    A155 161    A161 161     A173 161
 A183 166    A186 166    A190 166     A193 166     END FILL
ARA=124   NUX=15 NUY=15 NUZ=1     FILL  F124
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=125   NUX=15 NUY=15 NUZ=1     FILL  F125
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=126   NUX=15 NUY=15 NUZ=1     FILL  F126
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL


'--- ROWS OF FUEL ASSY'S
ARA=1   NUX=5  NUY=2  NUZ=1    FILL
                          41  42  42 1B2
                          43  15   8 1B2
 END FILL
ARA=2   NUX=9   NUY=1  NUZ=1    FILL
                  43  24  20  14   7 1B4
 END FILL
```

Table D.8. (continued)

```
ARA=3   NUX=11  NUY=1  NUZ=1    FILL
              43  26  23  19  13   6 1B5
 END FILL
ARA=4   NUX=13  NUY=1  NUZ=1    FILL
          43  26  25  22  18  12   5 1B6
 END FILL
ARA=5   NUX=15  NUY=2  NUZ=1    FILL
      43  24  23  22  21  17  11   4 1B7
      43  20  19  18  17  16  10   3 1B7
 END FILL
ARA=7   NUX=17  NUY=3  NUZ=1    FILL
  43  15  14  13  12  11  10   9   2 1B8
  43   8   7   6   5   4   3   2   1 1B25
 END FILL
ARA=10  NUX=15  NUY=2  NUZ=1    FILL
      43  20  19  18  17  16  10   3 1B7
      43  24  23  22  21  17  11   4 1B7
 END FILL
ARA=12  NUX=13  NUY=1  NUZ=1    FILL
          43  26  25  22  18  12   5 1B6
 END FILL
ARA=13  NUX=11  NUY=1  NUZ=1    FILL
              43  26  23  19  13   6 1B5
 END FILL
ARA=14  NUX=9   NUY=1  NUZ=1    FILL
                  43  24  20  14   7 1B4
 END FILL
ARA=15  NUX=5  NUY=2  NUZ=1    FILL
                          43  15   8 1B2
                          41  42  42 1B2               END FILL
END ARRAY
READ PLOT
TTL=! SURRY UNIT 1 CYCLE 2 FULL CORE BY GEOM UNIT !
PIC=UNIT
XUL=-200  YUL=200  XLR=200  YLR=-200  UAX=1 VDN=-1  NAX=130  END
TTL=!  ASSEMBLY LOC 2 !
PIC=MAT  NCH=! 12 45555567890ABCDEFGHIJKLMNOPQRSTUVWXYZ!
XUL=-11  YUL=32.5  XLR=11  YLR=10.5  UAX=1 VDN=-1  NAX=130  END
TTL=! SURRY UNIT 1 CYCLE 2 FULL CORE BY COMPOSITION!
PIC=MAT  NCH=! 1/ 4/ / /55555ABCDEFGHIJKLMNOPQRSTUVWXYZ!
XUL=-200  YUL=200  XLR=200  YLR=-200  UAX=1 VDN=-1  NAX=260 NDN=148  END
END PLOT
END DATA
END
```

APPENDIX E

KENO V.a EOC MODEL SETUP INPUT EXAMPLES

This appendix gives examples of the input for the different calculational steps for setting up the Surry Unit 1 Cycle 2 KENO V.a models for EOC (HFP).

Table E.1. SNIKR/ORIGEN-S input for fuel assembly isotopics

```
//ST5ASY10 JOB (35899),'S M BOWMAN 6011',TIME=1,
// NOTIFY=ST5,MSGCLASS=T
//*MAIN CLASS=SHORT
//PROCLIB DD DISP=SHR,DSN=TZA.PROCLIB.CNTL
//A EXEC FORTVCLG,REGION=2048K
//FORT.SYSPRINT DD DUMMY
//FORT.SYSIN DD DSN=ST5.SNIKR1.FORT,DISP=SHR
//*
//*######################################
//* #####NEED JCL FOR UNITS N72,NOUT,NORS,NOUT3,NICE
//*######################################
//GO.FT05F001 DD *
SNIKR1
S1C2 QC LOC #10  (BATCH 4A) 8070 MWD/MTU
READ BURNUP
N72=72
NOUT=70
BURN=8070.0
NCYC= 3
END BURNUP
READ DECAY
NORS=74
N71=71
COOLTME=0.0
LIGHTEL=0
END DECAY
SNIKR3
S1C2 QC LOC #10  (BATCH 4A) 8070 MWD/MTU
READ MXFUEL
N71=71
NICE=75
NOUT=73
NCOOL= 0
FISPROD= -2
MIXF=   1
IDMOD= 5
END MXFUEL
//GO.FT70F001 DD UNIT=SYSDA,SPACE=(TRK,(4,2),RLSE),
//      DSN=&&NOUT1,
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(NEW,PASS)
//GO.FT72F001 DD UNIT=,SPACE=,LABEL=(,,,IN),
//     DISP=SHR,DSN=OWH.SUR3E.WES15F72,
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=6400)
//GO.FT73F001 DD UNIT=DISK,SPACE=(TRK,(4,2),RLSE),
//      DSN=X.ST535899.S1C2EA10.NOUT3,
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(NEW,CATLG)
//GO.FT75F001 DD UNIT=SYSDA,SPACE=(TRK,(4,2),RLSE),
//      DSN=&&NICE,
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(NEW,PASS)
```

Table E.2. SNIKR/ORIGEN-S input for BP isotopics

```
//ST5BP2   JOB (35899),'S M BOWMAN 6011',TIME=1,
// NOTIFY=ST5,MSGCLASS=T
//*MAIN CLASS=SHORT
//PROCLIB DD DISP=SHR,DSN=TZA.PROCLIB.CNTL
//A EXEC FORTVCLG,REGION=2048K
//FORT.SYSPRINT DD DUMMY
//FORT.SYSIN DD DSN=ST5.SNIKR1.FORT,DISP=SHR
//*
//*########################################
//* #####NEED JCL FOR UNITS N72,NOUT,NORS,NOUT3,NICE
//*########################################
//GO.FT05F001 DD *
SNIKR1
S1C2 BP FOR QC LOC #2 @ EOC  8639 MWD/MTU
READ BURNUP
N72=72
NOUT=70
BURN=8639.0
NCYC= 3
END BURNUP
READ DECAY
NORS=74
N71=71
COOLTME=0.0
LIGHTEL= 5
END DECAY
  8016  0.04497   1
 11023  0.0       3
 13027  0.0       3
  5010  0.0       3
  5011  0.0       3
SNIKR3
S1C2 BP FOR QC LOC #2 @ EOC  8639 MWD/MTU
READ MXFUEL
N71=71
NICE=75
NOUT=73
NCOOL= 0
FISPROD=  5
MIXF=   1
IDMOD= 7
END MXFUEL
  8016 11023 13027  5010  5011
//GO.FT70F001 DD UNIT=SYSDA,SPACE=(TRK,(4,2),RLSE),
//      DSN=&&NOUT1,
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(NEW,PASS)
//GO.FT72F001 DD UNIT=,SPACE=,LABEL=(,,,IN),
//     DISP=SHR,DSN=OWH.SUR5E.WES15F72,
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=6400)
//GO.FT73F001 DD UNIT=DISK,SPACE=(TRK,(4,2),RLSE),
//      DSN=X.ST535899.S1C2BP2.NOUT3,
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(NEW,CATLG)
//GO.FT75F001 DD UNIT=SYSDA,SPACE=(TRK,(4,2),RLSE),
//      DSN=&&NICE,
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(NEW,PASS)
```

Table E.3. CSASN input for cross-section sets with important actinides only

```
//ST5XS3 JOB (35899),'S BOWMAN 6011',MSGCLASS=T,TIME=10,
//   NOTIFY=ST5
//*MAIN CLASS=FIVE
//PROCLIB DD DSN=TZA.PROCLIB.CNTL,DISP=SHR
//  EXEC SCALE41,GOSIZE=2048K
//GO.FT04F001 DD DSN=X.ST535899.S1C2E2X3.XSEC,UNIT=DISK,DISP=(,CATLG)
//GO.SYSIN DD *
=CSASN
S1C2 (BATCH 2) CROSS SECTION SET #3     21653 MWD/MTU
27BURNUP  LATTICECELL
   U-234    1  0  3.5464E-06  910  END
   U-235    1  0  2.1085E-04  910  END
   U-236    1  0  6.6360E-05  910  END
   U-238    1  0  2.1733E-02  910  END
  PU-239    1  0  1.0902E-04  910  END
  PU-240    1  0  3.6776E-05  910  END
  PU-241    1  0  2.0775E-05  910  END
   O        1  0  4.5425E-02  910  END
ZIRCALLOY 2  1              595  END
H2O       3  DEN=.7331  1   569  END
BORON     3  DEN=.7331  123.E-6 569 END
END COMP
SQUAREPITCH   1.43002 0.92939 1 3 1.07188 2 0.94844 0  END
END
```

Table E.4. CSASN input for cross-section set 4

```
//ST5XS4 JOB (35899),'S BOWMAN 6011',MSGCLASS=T,TIME=10,
//   NOTIFY=ST5
//PROCLIB DD DSN=TZA.PROCLIB.CNTL,DISP=SHR
//  EXEC SCALE41,GOSIZE=2048K
//GO.FT04F001 DD DSN=X.ST535899.S1C2E2X4.XSEC,UNIT=DISK,DISP=(,CATLG)
//GO.SYSIN DD *
=CSASN
S1C2 (BATCH 2) CROSS SECTION SET #4 22998 MWD/MTU (W/FP'S & STRUC.MATLS)
27BURNUP  LATTICECELL
   U-234   10  0  3.4601E-06  910  END
   U-235   10  0  1.9663E-04  910  END
   U-236   10  0  6.8382E-05  910  END
   U-238   10  0  2.1707E-02  910  END
  NP-237   10  0  6.5222E-06  910  END
  PU-238   10  0  1.5576E-06  910  END
  PU-239   10  0  1.1051E-04  910  END
  PU-240   10  0  3.9023E-05  910  END
  PU-241   10  0  2.2241E-05  910  END
  PU-242   10  0  5.8604E-06  910  END
  AM-241   10  0  5.1411E-07  910  END
  AM-243   10  0  8.9496E-07  910  END
  CM-244   10  0  1.5744E-07  910  END
   O       10  0  4.5425E-02  910  END
  KR-83    10  0  1.9918E-06  910  END
  ZR-93    10  0  2.9274E-05  910  END
  MO-95    10  0  2.4791E-05  910  END
  TC-99    10  0  3.0724E-05  910  END
  RU-101   10  0  2.8951E-05  910  END
  RU-103   10  0  2.5193E-06  910  END
  RH-103   10  0  1.6243E-05  910  END
  RH-105   10  0  6.3926E-08  910  END
  PD-105   10  0  1.3603E-05  910  END
  PD-108   10  0  4.7117E-06  910  END
  AG-109   10  0  3.0480E-06  910  END
   I-135   10  0  2.2261E-08  910  END
  XE-131   10  0  1.3451E-05  910  END
  XE-135   10  0  6.9796E-09  910  END
  CS-133   10  0  3.3202E-05  910  END
  CS-134   10  0  2.5788E-06  910  END
  CS-135   10  0  1.0881E-05  910  END
  PR-141   10  0  2.7914E-05  910  END
  ND-143   10  0  2.2063E-05  910  END
  ND-145   10  0  1.8232E-05  910  END
  ND-147   10  0  3.0222E-07  910  END
  ND-148   10  0  9.2701E-06  910  END
  PM-147   10  0  5.4119E-06  910  END
  PM-148   10  0  3.3859E-08  910  END
  PM-149   10  0  5.2678E-08  910  END
  SM-147   10  0  1.9007E-06  910  END
  SM-149   10  0  7.6254E-08  910  END
  SM-150   10  0  7.8581E-06  910  END
  SM-151   10  0  4.0761E-07  910  END
  SM-152   10  0  3.4443E-06  910  END
  EU-153   10  0  2.4896E-06  910  END
  EU-154   10  0  7.5842E-07  910  END
  EU-155   10  0  2.9263E-07  910  END
  GD-155   10  0  1.5128E-09  910  END
ZIRCALLOY 1 1.     595 END
SS304     2 1.     569 END
H2O       3  DEN=.7331  1      569  END
BORON     3  DEN=.7331 123.E-6 569   END
SS304     4  0.5     569 END
H2O       4  DEN=.7331 0.5      569  END
BORON     4  DEN=.7331 61.5E-6   569  END
```

Table E.4. (continued)

```
SS304      5 1.      566 END
H2O        6  DEN=.7436 1.0    564 END
BORON      6  DEN=.7436 123.E-6 564 END
SS304      7 1.      561 END
H2O        8  DEN=.7540 1.0      559 END
BORON      8  DEN=.7540 123.E-6 559 END
SS304      9 1.      559 END
END COMP
SQUAREPITCH   1.43002 0.92939 10 3 1.07188 1 0.94844 0  END
END
```

Table E.5. WAX input for cross-section library generation

```
//ST5WAX   JOB (35899),'S.M.BOWMAN 6011',MSGCLASS=T,
//  NOTIFY=ST5,TIME=5
//*MAIN CLASS=SHORT
//PROCLIB DD DSN=TZA.PROCLIB.CNTL,DISP=SHR
//  EXEC SCALE41,GOSIZE=2048K
//GO.FT04F001 DD DSN=X.ST535899.S1C2EOC.XSECLIB,UNIT=DISK,DISP=(,CATLG)
//GO.FT33F001 DD DSN=X.ST535899.S1C2E1X1.XSEC,DISP=SHR
//GO.FT34F001 DD DSN=X.ST535899.S1C2E1X2.XSEC,DISP=SHR
//GO.FT35F001 DD DSN=X.ST535899.S1C2E2X3.XSEC,DISP=SHR
//GO.FT36F001 DD DSN=X.ST535899.S1C2E2X4.XSEC,DISP=SHR
//GO.FT37F001 DD DSN=X.ST535899.S1C2E4A.XSEC,DISP=SHR
//GO.FT38F001 DD DSN=X.ST535899.S1C2E4BB.XSEC,DISP=SHR
//GO.FT39F001 DD DSN=X.ST535899.S1C2E4BF.XSEC,DISP=SHR
//GO.FT40F001 DD DSN=X.ST535899.S1C2E4C1.XSEC,DISP=SHR
//GO.FT41F001 DD DSN=X.ST535899.S1C2E4C2.XSEC,DISP=SHR
//GO.FT42F001 DD DSN=X.ST535899.S1C2E4CF.XSEC,DISP=SHR
//GO.SYSIN DD *
=WAX
'WRITE FINAL LIBRARY TO UNIT 4 / BIGGEST INPUT LIB IS ON UNIT 36
0$$ 4 36
'INPUT XSEC'S FROM 10 LIBS
1$$ 10   T
'INPUT XSEC'S FOR FUEL XSEC SET 1
2$$ 33 7 T
3$$  92234  92235  92236  92238  94239  94240  94241
4$$ 192234 192235 192236 192238 194239 194240 194241 T
'INPUT XSEC'S FOR FUEL XSEC SET 2
2$$ 34 7 T
3$$  92234  92235  92236  92238  94239  94240  94241
4$$ 292234 292235 292236 292238 294239 294240 294241 T
'INPUT XSEC'S FOR FUEL XSEC SET 3
2$$ 35 7 T
3$$  92234  92235  92236  92238  94239  94240  94241
4$$ 392234 392235 392236 392238 394239 394240 394241 T
'INPUT XSEC'S FOR FUEL XSEC SET 4 + FP'S + STRUCT. MAT'LS
2$$ 36 0 T
'INPUT XSEC'S FOR FUEL XSEC SET 5
2$$ 37 7 T
3$$  92234  92235  92236  92238  94239  94240  94241
4$$ 592234 592235 592236 592238 594239 594240 594241 T
'INPUT XSEC'S FOR FUEL XSEC SET 6 + BP'S
2$$ 38 10 T
3$$  92234  92235  92236  92238  94239  94240  94241
    408016  405010  405011
4$$ 692234 692235 692236 692238 694239 694240 694241
    618016  615010  615011  T
'INPUT XSEC'S FOR FUEL XSEC SET 7 + BP'S
2$$ 39 10 T
3$$  92234  92235  92236  92238  94239  94240  94241
    408016  405010  405011
4$$ 792234 792235 792236 792238 794239 794240 794241
    718016  715010  715011  T
'INPUT XSEC'S FOR FUEL XSEC SET 8
2$$ 40 7 T
3$$  92234  92235  92236  92238  94239  94240  94241
4$$ 892234 892235 892236 892238 894239 894240 894241  T
'INPUT XSEC'S FOR FUEL XSEC SET 9
2$$ 41 7 T
3$$  92234  92235  92236  92238  94239  94240  94241
4$$ 992234 992235 992236 992238 994239 994240 994241  T
'INPUT XSEC'S FOR FUEL XSEC SET 10 + BP'S
2$$ 42 12 T
3$$  92234  92235  92236  92238  94239  94240  94241
    408016   11023   13027  405010  405011
4$$ 1092234 1092235 1092236 1092238 1094239 1094240 1094241
    1018016   11023   13027  1015010  1015011  T
END
```

Table E.6. XSDRNPM input for eighth-core assembly location 9

```
//ST5XSDA9 JOB (35899),'SM BOWMAN 6011',TIME=1,MSGCLASS=T,
//  NOTIFY=ST5
//*MAIN CLASS=SHORT
//PROCLIB DD DSN=TZA.PROCLIB.CNTL,DISP=SHR
//  EXEC SCALE41
//GO.FT04F001 DD DSN=X.ST535899.S1C2EOC.XSECLIB,DISP=SHR,UNIT=
//GO.SYSIN DD *
=XSDRN
S1C2 EC LOC #9 BATCH 2 24144 MWD/MTU TO COMPARE TO CSAS1X
1$$ 2 4 26 1 3 3 53 8 3 1 20 25 E
2$$ -2 -1 0 A7 -1 E  5** A4 0. 0.  E T
13$$ 48R1 2 4R3
14$$
 92234  92235  92236  92238 93237 94238
 94239  94240  94241  94242 95241 95243
 96244 8016 36083 40093 42095 43099
 44101 44103 45103 45105 46105 46108
 47109 53135 54131 54135 55133 55134
 55135 59141 60143 60145 60147 60148
 61147 61148 61149 62147 62149 62150
 62151 62152 63153 63154 63155 64155
40302 1001 308016 5010 5011
15**
3.3875E-06 1.8515E-04 6.9972E-05 2.1685E-02 6.9477E-06 1.7429E-06
1.1167E-04 4.0876E-05 2.3436E-05 6.5687E-06 5.4508E-07 1.0570E-06
1.9789E-07 4.5425E-02 2.0528E-06 3.0517E-05 2.6081E-05 3.2099E-05
3.0381E-05 2.5178E-06 1.7059E-05 6.3582E-08 1.4513E-05 5.0956E-06
3.2616E-06 2.1636E-08 1.3988E-05 6.8619E-09 3.4689E-05 2.8235E-06
1.1326E-05 2.9372E-05 2.2821E-05 1.8995E-05 2.9336E-07 9.7265E-06
5.5290E-06 3.4212E-08 5.1977E-08 1.9818E-06 7.7881E-08 8.2841E-06
4.1740E-07 3.6012E-06 2.6595E-06 8.3548E-07 3.1898E-07 1.6861E-09
4.25156E-02 4.90237E-02 2.45119E-02 9.92574E-07  4.02956E-06  T
33## F1 T
35**
 0 2.57205E-02 6.03261E-02 1.13413E-01 2.32347E-01 3.51282E-01
 4.04369E-01 4.38974E-01 4.64695E-01 4.65931E-01 4.69457E-01
 4.72983E-01 4.74220E-01 4.82232E-01 5.05080E-01 5.27927E-01
 5.35940E-01 5.47612E-01 5.62189E-01 5.81613E-01 6.10811E-01
 6.71371E-01 7.31930E-01 7.61128E-01 7.80552E-01 7.95129E-01
 8.06802E-01
36$$ 8R1 4R2 4R3 10R4
39$$ 1 0 2 3 40$$ F3 T
END
```

Table E.7. CSAS1X input for eighth-core assembly location 9

```
//ST5CXA9  JOB (35899),'S BOWMAN 6011',MSGCLASS=T,TIME=10,
//   NOTIFY=ST5
//*MAIN CLASS=FIVE
//PROCLIB DD DSN=TZA.PROCLIB.CNTL,DISP=SHR
//  EXEC SCALE41,GOSIZE=2048K
//GO.SYSIN DD *
=CSAS1X
S1C2 QC LOC #9   (BATCH 2) 24144 MWD/MTU
27BURNUP  LATTICECELL
   U-234    1  0  3.3875E-06  910  END
   U-235    1  0  1.8515E-04  910  END
   U-236    1  0  6.9972E-05  910  END
   U-238    1  0  2.1685E-02  910  END
  NP-237    1  0  6.9477E-06  910  END
  PU-238    1  0  1.7429E-06  910  END
  PU-239    1  0  1.1167E-04  910  END
  PU-240    1  0  4.0876E-05  910  END
  PU-241    1  0  2.3436E-05  910  END
  PU-242    1  0  6.5687E-06  910  END
  AM-241    1  0  5.4508E-07  910  END
  AM-243    1  0  1.0570E-06  910  END
  CM-244    1  0  1.9789E-07  910  END
   O        1  0  4.5425E-02  910  END
  KR-83     1  0  2.0528E-06  910  END
  ZR-93     1  0  3.0517E-05  910  END
  MO-95     1  0  2.6081E-05  910  END
  TC-99     1  0  3.2099E-05  910  END
  RU-101    1  0  3.0381E-05  910  END
  RU-103    1  0  2.5178E-06  910  END
  RH-103    1  0  1.7059E-05  910  END
  RH-105    1  0  6.3582E-08  910  END
  PD-105    1  0  1.4513E-05  910  END
  PD-108    1  0  5.0956E-06  910  END
  AG-109    1  0  3.2616E-06  910  END
   I-135    1  0  2.1636E-08  910  END
  XE-131    1  0  1.3988E-05  910  END
  XE-135    1  0  6.8619E-09  910  END
  CS-133    1  0  3.4689E-05  910  END
  CS-134    1  0  2.8235E-06  910  END
  CS-135    1  0  1.1326E-05  910  END
  PR-141    1  0  2.9372E-05  910  END
  ND-143    1  0  2.2821E-05  910  END
  ND-145    1  0  1.8995E-05  910  END
  ND-147    1  0  2.9336E-07  910  END
  ND-148    1  0  9.7265E-06  910  END
  PM-147    1  0  5.5290E-06  910  END
  PM-148    1  0  3.4212E-08  910  END
  PM-149    1  0  5.1977E-08  910  END
  SM-147    1  0  1.9818E-06  910  END
  SM-149    1  0  7.7881E-08  910  END
  SM-150    1  0  8.2841E-06  910  END
  SM-151    1  0  4.1740E-07  910  END
  SM-152    1  0  3.6012E-06  910  END
  EU-153    1  0  2.6595E-06  910  END
  EU-154    1  0  8.3548E-07  910  END
  EU-155    1  0  3.1898E-07  910  END
  GD-155    1  0  1.6861E-09  910  END
ZIRCALLOY 2 1.     595 END
H2O       3  DEN=.7331  1      569  END
BORON     3  DEN=.7331 123.E-6 569   END
END COMP
SQUAREPITCH   1.43002 0.92939 1 3 1.07188 2 0.94844 0  END
END
```

Table E.8. KENO V.a input file for EOC, HFP

```
//USMS1C2E JOB (35899),'S.M.BOWMAN 6011',MSGCLASS=T,
//  NOTIFY=USM,TIME=80
//*MAIN CLASS=WHENEVER
//PROCLIB DD DSN=TZA.PROCLIB.CNTL,DISP=SHR
//KENO EXEC SCALE41,REGION.GO=3500K
//GO.FT04F001 DD DISP=SHR,LABEL=(,,,IN),
//   DSN=X.ST535899.S1C2EOC.XSECLIB,UNIT=
//GO.FT05F001 DD VOL=SER=,UNIT=SYSDA,DISP=(NEW,PASS),
// SPACE=(4800,(0040,20)),DCB=BLKSIZE=4800
//GO.FT08F001 DD UNIT=SYSDA,SPACE=(CYL,(20,5)),
// DCB=(DSORG=DA,RECFM=F)
//GO.FT09F001 DD UNIT=SYSDA,SPACE=(CYL,(20,5)),
// DCB=(DSORG=DA,RECFM=F)
//GO.FT34F001 DD DSN=X.USM35899.S1C2EOC.KENOVRST,
//  DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6136,BUFL=6136),
//  UNIT=DISK,SPACE=(TRK,(05,05)),DISP=(,CATLG)
//GO.SYSIN DD *
#KENOV
SURRY 1 CYCLE 2 EOC (1/8 CORE SYM) HFP, ARO EQ XE
'
' *** * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
' *** *                                                               *
' *** *           FULL CORE KENO5A REACTOR CONFIGURATION              *
' *** *           FOR SURRY UNIT-1 EOC-2   HFP, ARO EQ XE             *
' *** *                       1 PLANE  MODEL                          *
' *** *                                                               *
' *** *                             BY                                *
' *** *                        STEVE BOWMAN                           *
' *** *                 OAK RIDGE NATIONAL LABORATORY                 *
' *** *                                                               *
' *** *                          AUG. 1992                            *
' *** * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
'
READ PARM
RUN=YES PLT=YES NUB=YES FDN=YES TME=80.0 GEN=403 NPG=1000
WRS=34 RES=100
LIB=4 NB8=2400  NL8=880 END PARM

READ MIXT
MIX=101
'ASSY 1
'S1C2 QC LOC #1   (BATCH S1A2) 22094 MWD/MTU
   292234  2.2606E-06
   292235  1.1314E-04
   292236  5.3321E-05
   292238  2.1971E-02
    93237  6.0105E-06
    94238  1.6381E-06
   294239  1.0598E-04
   294240  4.3303E-05
   294241  2.3537E-05
    94242  7.7555E-06
    95241  5.9727E-07
    95243  1.2858E-06
    96244  2.5592E-07
     8016  4.5716E-02
    36083  1.7478E-06
    40093  2.6869E-05
    42095  2.3580E-05
    43099  2.9344E-05
    44101  2.8144E-05
    44103  2.3902E-06
    45103  1.6397E-05
    45105  6.3365E-08
    46105  1.4951E-05
```

Table E.8. (continued)

```
    46108  5.5846E-06
    47109  3.5434E-06
    53135  1.9677E-08
    54131  1.2902E-05
    54135  5.7419E-09
    55133  3.1703E-05
    55134  2.6031E-06
    55135  9.6832E-06
    59141  2.6654E-05
    60143  1.9679E-05
    60145  1.6988E-05
    60147  2.6435E-07
    60148  8.9165E-06
    61147  4.8434E-06
    61148  3.0326E-08
    61149  4.7154E-08
    62147  1.9134E-06
    62149  6.4451E-08
    62150  7.3876E-06
    62151  3.5283E-07
    62152  3.4528E-06
    63153  2.5811E-06
    63154  8.2751E-07
    63155  3.0933E-07
    64155  1.4853E-09
MIX=102
'ASSY 2
'S1C2 QC LOC #2   (BATCH 4B) 8639 MWD/MTU
   792234  4.4946E-06
   792235  4.1576E-04
   792236  3.7517E-05
   792238  2.2357E-02
    93237  1.8365E-06
    94238  1.6134E-07
   794239  8.0102E-05
   794240  1.2827E-05
   794241  5.3932E-06
    94242  4.2545E-07
    95241  3.7966E-08
    95243  2.3605E-08
    96244  1.4790E-09
     8016  4.6258E-02
    36083  9.5746E-07
    40093  1.2296E-05
    42095  5.2978E-06
    43099  1.2482E-05
    44101  1.1077E-05
    44103  2.3660E-06
    45103  5.3362E-06
    45105  5.0730E-08
    46105  3.7712E-06
    46108  1.0107E-06
    47109  7.2872E-07
    53135  2.5598E-08
    54131  5.6017E-06
    54135  8.2940E-09
    55133  1.3312E-05
    55134  4.4251E-07
    55135  3.1148E-06
    59141  9.2788E-06
    60143  9.8831E-06
    60145  7.6873E-06
    60147  3.5426E-07
    60148  3.6038E-06
    61147  3.3392E-06
```

Table E.8. (continued)

```
    61148  2.0847E-08
    61149  4.9184E-08
    62147  2.4084E-07
    62149  6.9475E-08
    62150  3.0753E-06
    62151  3.0388E-07
    62152  1.3085E-06
    63153  6.3822E-07
    63154  1.0065E-07
    63155  7.5293E-08
    64155  3.6042E-10
MIX=103
'ASSY 3
'S1C2 QC LOC #3   (BATCH S1A2) 19597 MWD/MTU
   192234  2.3812E-06
   192235  1.3240E-04
   192236  5.0802E-05
   192238  2.2026E-02
    93237  5.2094E-06
    94238  1.2608E-06
   194239  1.0368E-04
   194240  3.8973E-05
   194241  2.0890E-05
    94242  5.9544E-06
    95241  5.3928E-07
    95243  8.7079E-07
    96244  1.4902E-07
     8016  4.5716E-02
    36083  1.6261E-06
    40093  2.4280E-05
    42095  2.1216E-05
    43099  2.6359E-05
    44101  2.4983E-05
    44103  2.1318E-06
    45103  1.4791E-05
    45105  5.6257E-08
    46105  1.2804E-05
    46108  4.6416E-06
    47109  3.0255E-06
    53135  1.7980E-08
    54131  1.1753E-05
    54135  5.6483E-09
    55133  2.8512E-05
    55134  2.0854E-06
    55135  8.8314E-06
    59141  2.3770E-05
    60143  1.8248E-05
    60145  1.5357E-05
    60147  2.4209E-07
    60148  7.9187E-06
    61147  4.5998E-06
    61148  2.6635E-08
    61149  4.1812E-08
    62147  1.7426E-06
    62149  6.2871E-08
    62150  6.4516E-06
    62151  3.3222E-07
    62152  3.1030E-06
    63153  2.2038E-06
    63154  6.5621E-07
    63155  2.5139E-07
    64155  1.3054E-09
MIX=104
'ASSY 4
```

Table E.8. (continued)

```
'S1C2 QC LOC #4   (BATCH 4B) 8373 MWD/MTU
   792234  4.5144E-06
   792235  4.2076E-04
   792236  3.6657E-05
   792238  2.2361E-02
    93237  1.7598E-06
    94238  1.4976E-07
   794239  7.8594E-05
   794240  1.2304E-05
   794241  5.0927E-06
    94242  3.8563E-07
    95241  3.4623E-08
    95243  2.0351E-08
    96244  1.2004E-09
     8016  4.6258E-02
    36083  9.3192E-07
    40093  1.1941E-05
    42095  5.0063E-06
    43099  1.2104E-05
    44101  1.0734E-05
    44103  2.3414E-06
    45103  5.1205E-06
    45105  5.0154E-08
    46105  3.6224E-06
    46108  9.6170E-07
    47109  6.9425E-07
    53135  2.5605E-08
    54131  5.4287E-06
    54135  8.2976E-09
    55133  1.2900E-05
    55134  4.1622E-07
    55135  3.0176E-06
    59141  8.9260E-06
    60143  9.5825E-06
    60145  7.4652E-06
    60147  3.5455E-07
    60148  3.4936E-06
    61147  3.2552E-06
    61148  2.0286E-08
    61149  4.8819E-08
    62147  2.2717E-07
    62149  6.8975E-08
    62150  2.9643E-06
    62151  2.9966E-07
    62152  1.2636E-06
    63153  6.1067E-07
    63154  9.4074E-08
    63155  7.2607E-08
    64155  3.4711E-10
MIX=105
'ASSY 5
'S1C2 QC LOC #5   (BATCH 2) 22670 MWD/MTU
    92234  3.4811E-06
    92235  2.0002E-04
    92236  6.7905E-05
    92238  2.1714E-02
    93237  6.4015E-06
    94238  1.5066E-06
    94239  1.1016E-04
    94240  3.8482E-05
    94241  2.1889E-05
    94242  5.6639E-06
    95241  5.0550E-07
    95243  8.5159E-07
```

Table E.8. (continued)

```
    96244  1.4709E-07
     8016  4.5425E-02
    36083  1.9738E-06
    40093  2.8915E-05
    42095  2.4437E-05
    43099  3.0329E-05
    44101  2.8542E-05
    44103  2.5096E-06
    45103  1.6016E-05
    45105  6.3736E-08
    46105  1.3346E-05
    46108  4.6038E-06
    47109  2.9873E-06
    53135  2.2326E-08
    54131  1.3296E-05
    54135  7.0016E-09
    55133  3.2775E-05
    55134  2.5103E-06
    55135  1.0757E-05
    59141  2.7506E-05
    60143  2.1845E-05
    60145  1.8012E-05
    60147  3.0320E-07
    60148  9.1394E-06
    61147  5.3770E-06
    61148  3.3634E-08
    61149  5.2612E-08
    62147  1.8777E-06
    62149  7.5800E-08
    62150  7.7345E-06
    62151  4.0481E-07
    62152  3.3990E-06
    63153  2.4413E-06
    63154  7.3686E-07
    63155  2.8528E-07
    64155  1.4710E-09
MIX=106
'ASSY 6
'S1C2 QC LOC #6   (BATCH 4B) 8428 MWD/MTU
   692234  4.5225E-06
   692235  4.1763E-04
   692236  3.6898E-05
   692238  2.2364E-02
    93237  1.7039E-06
    94238  1.4274E-07
   694239  7.6720E-05
   694240  1.2177E-05
   694241  4.9335E-06
    94242  3.7962E-07
    95241  3.3775E-08
    95243  1.9744E-08
    96244  1.1602E-09
     8016  4.6258E-02
    36083  9.4204E-07
    40093  1.2079E-05
    42095  5.1356E-06
    43099  1.2221E-05
    44101  1.0819E-05
    44103  2.3172E-06
    45103  5.1614E-06
    45105  4.9322E-08
    46105  3.6055E-06
    46108  9.4992E-07
    47109  6.8633E-07
```

Table E.8. (continued)

```
    53135  2.5388E-08
    54131  5.4794E-06
    54135  8.1094E-09
    55133  1.3028E-05
    55134  4.1499E-07
    55135  2.9921E-06
    59141  9.0520E-06
    60143  9.6856E-06
    60145  7.5418E-06
    60147  3.5183E-07
    60148  3.5213E-06
    61147  3.2928E-06
    61148  2.0195E-08
    61149  4.8276E-08
    62147  2.3394E-07
    62149  6.7153E-08
    62150  2.9980E-06
    62151  2.9409E-07
    62152  1.2773E-06
    63153  6.1119E-07
    63154  9.3853E-08
    63155  7.1456E-08
    64155  3.3622E-10
MIX=107
'ASSY 7
'S1C2 QC LOC #7   (BATCH S1A2) 20407 MWD/MTU
   192234  2.3415E-06
   192235  1.2585E-04
   192236  5.1680E-05
   192238  2.2008E-02
    93237  5.4682E-06
    94238  1.3779E-06
   194239  1.0448E-04
   194240  4.0421E-05
   194241  2.1780E-05
    94242  6.5200E-06
    95241  5.5830E-07
    95243  9.9513E-07
    96244  1.7918E-07
     8016  4.5716E-02
    36083  1.6671E-06
    40093  2.5128E-05
    42095  2.1956E-05
    43099  2.7334E-05
    44101  2.6009E-05
    44103  2.2410E-06
    45103  1.5297E-05
    45105  5.9315E-08
    46105  1.3491E-05
    46108  4.9417E-06
    47109  3.1930E-06
    53135  1.8791E-08
    54131  1.2130E-05
    54135  5.7008E-09
    55133  2.9553E-05
    55134  2.2486E-06
    55135  9.1026E-06
    59141  2.4687E-05
    60143  1.8719E-05
    60145  1.5892E-05
    60147  2.5281E-07
    60148  8.2426E-06
    61147  4.6814E-06
    61148  2.8120E-08
```

Table E.8. (continued)

```
    61149  4.4160E-08
    62147  1.7996E-06
    62149  6.3456E-08
    62150  6.7542E-06
    62151  3.3882E-07
    62152  3.2180E-06
    63153  2.3254E-06
    63154  7.1035E-07
    63155  2.6964E-07
    64155  1.3440E-09
MIX=108
'ASSY 8
'S1C2 QC LOC #8   (BATCH 4C) 6398 MWD/MTU
   992234  6.0296E-06
   992235  6.1621E-04
   992236  3.2638E-05
   992238  2.2199E-02
    93237  1.1181E-06
    94238  6.1200E-08
   994239  5.8932E-05
   994240  6.4441E-06
   994241  2.0270E-06
    94242  8.0340E-08
    95241  1.3309E-08
    95243  1.1859E-09
    96244  0.0000E+00
     8016  4.6164E-02
    36083  7.6150E-07
    40093  9.4898E-06
    42095  4.2931E-06
    43099  9.2959E-06
    44101  8.1638E-06
    44103  1.5107E-06
    45103  3.8990E-06
    45105  2.8787E-08
    46105  2.3548E-06
    46108  4.8747E-07
    47109  3.4828E-07
    53135  1.8259E-08
    54131  4.2194E-06
    54135  8.6854E-09
    55133  1.0006E-05
    55134  2.1029E-07
    55135  3.4167E-06
    59141  7.0745E-06
    60143  7.7740E-06
    60145  5.8934E-06
    60147  2.5648E-07
    60148  2.6683E-06
    61147  2.6819E-06
    61148  1.1168E-08
    61149  3.0902E-08
    62147  2.0540E-07
    62149  7.6616E-08
    62150  1.8602E-06
    62151  2.9094E-07
    62152  8.7150E-07
    63153  3.8610E-07
    63154  4.2005E-08
    63155  5.0104E-08
    64155  3.9974E-10
MIX=109
'ASSY 9
'S1C2 QC LOC #9   (BATCH 2) 24144 MWD/MTU
    92234  3.3875E-06
```

Table E.8. (continued)

```
     92235   1.8515E-04
     92236   6.9972E-05
     92238   2.1685E-02
     93237   6.9477E-06
     94238   1.7429E-06
     94239   1.1167E-04
     94240   4.0876E-05
     94241   2.3436E-05
     94242   6.5687E-06
     95241   5.4508E-07
     95243   1.0570E-06
     96244   1.9789E-07
      8016   4.5425E-02
     36083   2.0528E-06
     40093   3.0517E-05
     42095   2.6081E-05
     43099   3.2099E-05
     44101   3.0381E-05
     44103   2.5178E-06
     45103   1.7059E-05
     45105   6.3582E-08
     46105   1.4513E-05
     46108   5.0956E-06
     47109   3.2616E-06
     53135   2.1636E-08
     54131   1.3988E-05
     54135   6.8619E-09
     55133   3.4689E-05
     55134   2.8235E-06
     55135   1.1326E-05
     59141   2.9372E-05
     60143   2.2821E-05
     60145   1.8995E-05
     60147   2.9336E-07
     60148   9.7265E-06
     61147   5.5290E-06
     61148   3.4212E-08
     61149   5.1977E-08
     62147   1.9818E-06
     62149   7.7881E-08
     62150   8.2841E-06
     62151   4.1740E-07
     62152   3.6012E-06
     63153   2.6595E-06
     63154   8.3548E-07
     63155   3.1898E-07
     64155   1.6861E-09
MIX=110
'ASSY 10
'S1C2 QC LOC #10  (BATCH 4A) 8070 MWD/MTU
    592234   3.0239E-06
    592235   2.6715E-04
    592236   3.0412E-05
    592238   2.2459E-02
     93237   1.5903E-06
     94238   1.4777E-07
    594239   7.4163E-05
    594240   1.4624E-05
    594241   5.8037E-06
     94242   5.7891E-07
     95241   4.1562E-08
     95243   3.0280E-08
     96244   1.7935E-09
      8016   4.6108E-02
```

Table E.8. (continued)

```
     36083   8.4804E-07
     40093   1.1102E-05
     42095   5.0047E-06
     43099   1.1501E-05
     44101   1.0291E-05
     44103   2.2392E-06
     45103   5.1629E-06
     45105   5.0740E-08
     46105   3.8216E-06
     46108   1.1369E-06
     47109   8.3067E-07
     53135   2.2898E-08
     54131   5.2297E-06
     54135   6.0544E-09
     55133   1.2278E-05
     55134   4.1588E-07
     55135   2.3139E-06
     59141   8.5904E-06
     60143   8.8232E-06
     60145   6.9908E-06
     60147   3.1451E-07
     60148   3.3203E-06
     61147   3.0492E-06
     61148   1.9125E-08
     61149   4.4446E-08
     62147   2.2897E-07
     62149   4.9551E-08
     62150   3.0479E-06
     62151   2.3323E-07
     62152   1.3065E-06
     63153   6.2481E-07
     63154   1.0348E-07
     63155   6.9350E-08
     64155   2.5783E-10
MIX=111
'ASSY 11
'S1C2 QC LOC #11  (BATCH 2) 21879 MWD/MTU
    392234  3.5319E-06
    392235  2.0840E-04
    392236  6.6712E-05
    392238  2.1729E-02
     93237  6.1124E-06
     94238  1.3874E-06
    394239  1.0928E-04
    394240  3.7159E-05
    394241  2.1026E-05
     94242  5.2015E-06
     95241  4.8511E-07
     95243  7.5245E-07
     96244  1.2421E-07
      8016  4.5425E-02
     36083  1.9294E-06
     40093  2.8045E-05
     42095  2.3609E-05
     43099  2.9372E-05
     44101  2.7553E-05
     44103  2.4666E-06
     45103  1.5484E-05
     45105  6.2716E-08
      6105  1.2732E-05
     46108  4.3474E-06
     47109  2.8415E-06
     53135  2.2257E-08
     54131  1.2920E-05
```

Table E.8. (continued)

```
     54135  7.0315E-09
     55133  3.1743E-05
     55134  2.3479E-06
     55135  1.0464E-05
     59141  2.6539E-05
     60143  2.1316E-05
     60145  1.7476E-05
     60147  3.0250E-07
     60148  8.8240E-06
     61147  5.2906E-06
     61148  3.2856E-08
     61149  5.1934E-08
     62147  1.8226E-06
     62149  7.4749E-08
     62150  7.4336E-06
     62151  3.9807E-07
     62152  3.2891E-06
     63153  2.3255E-06
     63154  6.8583E-07
     63155  2.6791E-07
     64155  1.3856E-09
MIX=112
'ASSY 12
'S1C2 QC LOC #12  (BATCH 2) 22793 MWD/MTU
     92234  3.4732E-06
     92235  1.9874E-04
     92236  6.8085E-05
     92238  2.1711E-02
     93237  6.4467E-06
     94238  1.5256E-06
     94239  1.1029E-04
     94240  3.8686E-05
     94241  2.2021E-05
     94242  5.7373E-06
     95241  5.0872E-07
     95243  8.6769E-07
     96244  1.5091E-07
      8016  4.5425E-02
     36083  1.9806E-06
     40093  2.9050E-05
     42095  2.4569E-05
     43099  3.0477E-05
     44101  2.8695E-05
     44103  2.5138E-06
     45103  1.6101E-05
     45105  6.3823E-08
     46105  1.3442E-05
     46108  4.6442E-06
     47109  3.0100E-06
     53135  2.2308E-08
     54131  1.3354E-05
     54135  6.9940E-09
     55133  3.2935E-05
     55134  2.5359E-06
     55135  1.0803E-05
     59141  2.7659E-05
     60143  2.1927E-05
     60145  1.8094E-05
     60147  3.0292E-07
     60148  9.1884E-06
     61147  5.3902E-06
     61148  3.3725E-08
     61149  5.2652E-08
     62147  1.8863E-06
     62149  7.5969E-08
```

Table E.8. (continued)

```
    62150  7.7809E-06
    62151  4.0586E-07
    62152  3.4160E-06
    63153  2.4594E-06
    63154  7.4492E-07
    63155  2.8803E-07
    64155  1.4862E-09
MIX=113
'ASSY 13
'S1C2 QC LOC #13  (BATCH 2) 21427 MWD/MTU
   392234  3.5611E-06
   392235  2.1332E-04
   392236  6.6004E-05
   392238  2.1738E-02
    93237  5.9487E-06
    94238  1.3218E-06
   394239  1.0875E-04
   394240  3.6391E-05
   394241  2.0523E-05
    94242  4.9449E-06
    95241  4.7364E-07
    95243  6.9922E-07
    96244  1.1240E-07
     8016  4.5425E-02
    36083  1.9034E-06
    40093  2.7545E-05
    42095  2.3152E-05
    43099  2.8823E-05
    44101  2.6987E-05
    44103  2.4299E-06
    45103  1.5188E-05
    45105  6.1779E-08
    46105  1.2385E-05
    46108  4.2032E-06
    47109  2.7588E-06
    53135  2.2075E-08
    54131  1.2705E-05
    54135  7.0340E-09
    55133  3.1151E-05
    55134  2.2570E-06
    55135  1.0300E-05
    59141  2.5997E-05
    60143  2.1012E-05
    60145  1.7167E-05
    60147  3.0016E-07
    60148  8.6437E-06
    61147  5.2399E-06
    61148  3.2263E-08
    61149  5.1219E-08
    62147  1.7910E-06
    62149  7.4186E-08
    62150  7.2598E-06
    62151  3.9423E-07
    62152  3.2259E-06
    63153  2.2598E-06
    63154  6.5730E-07
    63155  2.5822E-07
    64155  1.3463E-09
MIX=114
'ASSY 14
'S1C2 QC LOC #14  (BATCH 4C) 6487 MWD/MTU
  1092234  5.9717E-06
  1092235  6.1813E-04
  1092236  3.3318E-05
  1092238  2.2186E-02
```

Table E.8. (continued)

```
     93237  1.3067E-06
     94238  7.8765E-08
   1094239  6.7521E-05
   1094240  7.1809E-06
   1094241  2.5684E-06
     94242  1.0245E-07
     95241  1.5312E-08
     95243  2.3148E-09
     96244  0.0000E+00
      8016  4.6164E-02
     36083  7.6015E-07
     40093  9.4814E-06
     42095  3.8262E-06
     43099  9.3228E-06
     44101  8.2520E-06
     44103  1.7426E-06
     45103  3.8259E-06
     45105  3.4810E-08
     46105  2.4865E-06
     46108  5.4447E-07
     47109  3.8888E-07
     53135  2.0965E-08
     54131  4.2113E-06
     54135  9.7820E-09
     55133  1.0013E-05
     55134  2.3956E-07
     55135  3.3583E-06
     59141  6.8743E-06
     60143  7.6995E-06
     60145  5.9055E-06
     60147  2.9315E-07
     60148  2.6996E-06
     61147  2.6545E-06
     61148  1.3416E-08
     61149  3.6635E-08
     62147  1.7682E-07
     62149  8.6470E-08
     62150  1.9258E-06
     62151  3.1399E-07
     62152  8.6999E-07
     63153  4.0652E-07
     63154  4.7572E-08
     63155  5.5139E-08
     64155  4.1977E-10
MIX=115
'ASSY 15
'S1C2 QC LOC #15  (BATCH 4C) 5100 MWD/MTU
    892234  6.1380E-06
    892235  6.4624E-04
    892236  2.7294E-05
    892238  2.2219E-02
     93237  8.1613E-07
     94238  3.5066E-08
    894239  4.9491E-05
    894240  4.5478E-06
    894241  1.2083E-06
     94242  3.1990E-08
     95241  5.6860E-09
     95243  0.0000E+00
     96244  0.0000E+00
      8016  4.6164E-02
     36083  6.1766E-07
     40093  7.6264E-06
     42095  2.8086E-06
     43099  7.4090E-06
```

Table E.8. (continued)

```
    44101  6.5032E-06
    44103  1.4226E-06
    45103  2.8725E-06
    45105  2.6800E-08
    46105  1.7841E-06
    46108  3.4200E-07
    47109  2.4200E-07
    53135  1.8290E-08
    54131  3.3381E-06
    54135  8.6856E-09
    55133  7.9294E-06
    55134  1.3320E-07
    55135  2.7199E-06
    59141  5.3017E-06
    60143  6.1273E-06
    60145  4.7373E-06
    60147  2.5766E-07
    60148  2.1296E-06
    61147  2.1864E-06
    61148  8.9528E-09
    61149  2.9782E-08
    62147  1.3153E-07
    62149  7.3759E-08
    62150  1.4357E-06
    62151  2.6234E-07
    62152  6.6470E-07
    63153  2.8639E-07
    63154  2.5797E-08
    63155  4.0315E-08
    64155  3.1348E-10
MIX=116
'ASSY 16
'S1C2 QC LOC #16  (BATCH S1A2) 18501 MWD/MTU
   192234  2.4355E-06
   192235  1.4176E-04
   192236  4.9517E-05
   192238  2.2050E-02
    93237  4.8606E-06
    94238  1.1107E-06
   194239  1.0249E-04
   194240  3.6946E-05
   194241  1.9636E-05
    94242  5.2208E-06
    95241  5.1194E-07
    95243  7.1808E-07
    96244  1.1436E-07
     8016  4.5716E-02
    36083  1.5680E-06
    40093  2.3118E-05
    42095  2.0232E-05
    43099  2.5030E-05
    44101  2.3592E-05
    44103  1.9580E-06
    45103  1.4118E-05
    45105  5.1322E-08
    46105  1.1887E-05
    46108  4.2450E-06
    47109  2.8002E-06
    53135  1.6606E-08
    54131  1.1232E-05
    54135  5.5533E-09
    55133  2.7094E-05
    55134  1.8729E-06
    55135  8.4639E-06
    59141  2.2549E-05
```

Table E.8. (continued)

```
    60143   1.7592E-05
    60145   1.4623E-05
    60147   2.2386E-07
    60148   7.4803E-06
    61147   4.4857E-06
    61148   2.4328E-08
    61149   3.7987E-08
    62147   1.6607E-06
    62149   6.1994E-08
    62150   6.0448E-06
    62151   3.2333E-07
    62152   2.9450E-06
    63153   2.0404E-06
    63154   5.8543E-07
    63155   2.2765E-07
    64155   1.2742E-09
MIX=117
'ASSY 17
'S1C2 QC LOC #17  (BATCH 4A) 7599 MWD/MTU
   592234   3.0475E-06
   592235   2.7373E-04
   592236   2.9327E-05
   592238   2.2467E-02
    93237   1.4828E-06
    94238   1.3062E-07
   594239   7.1971E-05
   594240   1.3692E-05
   594241   5.3070E-06
    94242   4.9445E-07
    95241   3.5941E-08
    95243   2.3132E-08
    96244   1.1199E-09
     8016   4.6108E-02
    36083   8.1227E-07
    40093   1.0586E-05
    42095   4.5705E-06
    43099   1.0933E-05
    44101   9.7700E-06
    44103   2.1985E-06
    45103   4.8232E-06
    45105   4.9743E-08
    46105   3.5719E-06
    46108   1.0477E-06
    47109   7.6798E-07
    53135   2.2911E-08
    54131   4.9665E-06
    54135   6.0449E-09
    55133   1.1659E-05
    55134   3.7560E-07
    55135   2.1928E-06
    59141   8.0635E-06
    60143   8.3974E-06
    60145   6.6640E-06
    60147   3.1505E-07
    60148   3.1546E-06
    61147   2.9255E-06
    61148   1.8271E-08
    61149   4.3880E-08
    62147   2.0829E-07
    62149   4.8813E-08
    62150   2.8569E-06
    62151   2.2730E-07
    62152   1.2342E-06
    63153   5.8052E-07
    63154   9.2507E-08
```

Table E.8. (continued)

```
    63155  6.5136E-08
    64155  2.4103E-10
MIX=118
'ASSY 18
'S1C2 QC LOC #18  (BATCH 2) 22535 MWD/MTU
    92234  3.4897E-06
    92235  2.0143E-04
    92236  6.7705E-05
    92238  2.1716E-02
    93237  6.3519E-06
    94238  1.4858E-06
    94239  1.1001E-04
    94240  3.8258E-05
    94241  2.1744E-05
    94242  5.5838E-06
    95241  5.0198E-07
    95243  8.3413E-07
    96244  1.4298E-07
     8016  4.5425E-02
    36083  1.9663E-06
    40093  2.8768E-05
    42095  2.4293E-05
    43099  3.0166E-05
    44101  2.8373E-05
    44103  2.5042E-06
    45103  1.5924E-05
    45105  6.3618E-08
    46105  1.3240E-05
    46108  4.5597E-06
    47109  2.9623E-06
    53135  2.2337E-08
    54131  1.3232E-05
    54135  7.0090E-09
    55133  3.2599E-05
    55134  2.4823E-06
    55135  1.0706E-05
    59141  2.7339E-05
    60143  2.1755E-05
    60145  1.7921E-05
    60147  3.0339E-07
    60148  9.0856E-06
    61147  5.3625E-06
    61148  3.3525E-08
    61149  5.2549E-08
    62147  1.8683E-06
    62149  7.5615E-08
    62150  7.6835E-06
    62151  4.0366E-07
    62152  3.3803E-06
    63153  2.4214E-06
    63154  7.2805E-07
    63155  2.8228E-07
    64155  1.4549E-09
MIX=119
ASSY 19
'S1C2 QC LOC #19  (BATCH S1A2) 19939 MWD/MTU
   192234  2.3612E-06
   192235  1.2907E-04
   192236  5.1251E-05
   192238  2.2017E-02
    93237  5.3393E-06
    94238  1.3190E-06
```

Table E.8. (continued)

```
   194239  1.0409E-04
   194240  3.9706E-05
   194241  2.1341E-05
    94242  6.2362E-06
    95241  5.4892E-07
    95243  9.3204E-07
    96244  1.6367E-07
     8016  4.5716E-02
    36083  1.6469E-06
    40093  2.4707E-05
    42095  2.1586E-05
    43099  2.6850E-05
    44101  2.5499E-05
    44103  2.1892E-06
    45103  1.5044E-05
    45105  5.7870E-08
    46105  1.3148E-05
    46108  4.7917E-06
    47109  3.1096E-06
    53135  1.8414E-08
    54131  1.1943E-05
    54135  5.6770E-09
    55133  2.9036E-05
    55134  2.1668E-06
    55135  8.9674E-06
    59141  2.4229E-05
    60143  1.8486E-05
    60145  1.5627E-05
    60147  2.4783E-07
    60148  8.0815E-06
    61147  4.6411E-06
    61148  2.7410E-08
    61149  4.3054E-08
    62147  1.7715E-06
    62149  6.3173E-08
    62150  6.6035E-06
    62151  3.3553E-07
    62152  3.1610E-06
    63153  2.2648E-06
    63154  6.8323E-07
    63155  2.6049E-07
    64155  1.3228E-09
MIX=120
'ASSY 20
'S1C2 QC LOC #20  (BATCH 4C) 7334 MWD/MTU
   992234  5.9519E-06
   992235  5.9526E-04
   992236  3.6344E-05
   992238  2.2185E-02
    93237  1.3524E-06
    94238  8.6070E-08
   994239  6.5175E-05
   994240  7.8718E-06
   994241  2.7127E-06
    94242  1.3588E-07
    95241  2.1630E-08
    95243  4.3612E-09
    96244  1.1118E-10
     8016  4.6164E-02
    36083  8.6220E-07
    40093  1.0815E-05
    42095  5.4220E-06
    43099  1.0644E-05
    44101  9.3611E-06
    44103  1.5658E-06
```

Table E.8. (continued)

```
    45105  3.0151E-08
    46105  2.7880E-06
    46108  6.0440E-07
    47109  4.3264E-07
    53135  1.8239E-08
    54131  4.8447E-06
    54135  8.6785E-09
    55133  1.1488E-05
    55134  2.7547E-07
    55135  3.9181E-06
    59141  8.3522E-06
    60143  8.9287E-06
    60145  6.7154E-06
    60147  2.5569E-07
    60148  3.0560E-06
    61147  3.0136E-06
    61148  1.2676E-08
    61149  3.1674E-08
    62147  2.6561E-07
    62149  7.8488E-08
    62150  2.1727E-06
    62151  3.0934E-07
    62152  1.0208E-06
    63153  4.6405E-07
    63154  5.6558E-08
    63155  5.7580E-08
    64155  4.6441E-10
MIX=121
'ASSY 21
'S1C2 QC LOC #21  (BATCH 2) 23534 MWD/MTU
    92234  3.4260E-06
    92235  1.9119E-04
    92236  6.9141E-05
    92238  2.1697E-02
    93237  6.7206E-06
    94238  1.6429E-06
    94239  1.1106E-04
    94240  3.9897E-05
    94241  2.2806E-05
    94242  6.1876E-06
    95241  5.2841E-07
    95243  9.6871E-07
    96244  1.7550E-07
     8016  4.5425E-02
    36083  2.0207E-06
    40093  2.9857E-05
    42095  2.5385E-05
    43099  3.1369E-05
    44101  2.9620E-05
    44103  2.5252E-06
    45103  1.6620E-05
    45105  6.3951E-08
    46105  1.4026E-05
    46108  4.8899E-06
    47109  3.1477E-06
    53135  2.2042E-08
    54131  1.3703E-05
    54135  6.9321E-09
    55133  3.3898E-05
    55134  2.6923E-06
    55135  1.1087E-05
    59141  2.8590E-05
    60143  2.2419E-05
    60145  1.8590E-05
    60147  2.9908E-07
```

Table E.8. (continued)

```
    60148  9.4836E-06
    61147  5.4677E-06
    61148  3.4104E-08
    61149  5.2522E-08
    62147  1.9384E-06
    62149  7.7011E-08
    62150  8.0584E-06
    62151  4.1219E-07
    62152  3.5179E-06
    63153  2.5688E-06
    63154  7.9414E-07
    63155  3.0483E-07
    64155  1.5887E-09
MIX=122
'ASSY 22
'S1C2 QC LOC #22  (BATCH 2) 22989 MWD/MTU
    92234  3.4607E-06
    92235  1.9672E-04
    92236  6.8369E-05
    92238  2.1707E-02
    93237  6.5189E-06
    94238  1.5561E-06
    94239  1.1050E-04
    94240  3.9009E-05
    94241  2.2231E-05
    94242  5.8550E-06
    95241  5.1387E-07
    95243  8.9375E-07
    96244  1.5715E-07
     8016  4.5425E-02
    36083  1.9913E-06
    40093  2.9264E-05
    42095  2.4781E-05
    43099  3.0713E-05
    44101  2.8940E-05
    44103  2.5191E-06
    45103  1.6236E-05
    45105  6.3922E-08
    46105  1.3596E-05
    46108  4.7087E-06
    47109  3.0463E-06
    53135  2.2264E-08
    54131  1.3446E-05
    54135  6.9803E-09
    55133  3.3190E-05
    55134  2.5770E-06
    55135  1.0877E-05
    59141  2.7903E-05
    60143  2.2057E-05
    60145  1.8226E-05
    60147  3.0226E-07
    60148  9.2665E-06
    61147  5.4110E-06
    61148  3.3853E-08
    61149  5.2678E-08
    62147  1.9000E-06
    62149  7.6241E-08
    62150  7.8547E-06
    62151  4.0753E-07
    62152  3.4430E-06
    63153  2.4882E-06
    63154  7.5783E-07
    63155  2.9243E-07
    64155  1.5116E-09
MIX=123
```

Table E.8. (continued)

```
'ASSY 23
'S1C2 QC LOC #23  (BATCH 4C) 7429 MWD/MTU
  1092234  5.8889E-06
  1092235  5.9779E-04
  1092236  3.7021E-05
  1092238  2.2170E-02
    93237  1.5703E-06
    94238  1.0927E-07
  1094239  7.4402E-05
  1094240  8.7104E-06
  1094241  3.3846E-06
    94242  1.6744E-07
    95241  2.4271E-08
    95243  6.5368E-09
    96244  2.2577E-10
     8016  4.6164E-02
    36083  8.5984E-07
    40093  1.0794E-05
    42095  4.8744E-06
    43099  1.0668E-05
    44101  9.4550E-06
    44103  1.8153E-06
    45103  4.5723E-06
    45105  3.6410E-08
    46105  2.9421E-06
    46108  6.7263E-07
    47109  4.8083E-07
    53135  2.0945E-08
    54131  4.8351E-06
    54135  9.7791E-09
    55133  1.1494E-05
    55134  3.1190E-07
    55135  3.8499E-06
    59141  8.1400E-06
    60143  8.8554E-06
    60145  6.7222E-06
    60147  2.9231E-07
    60148  3.0893E-06
    61147  2.9849E-06
    61148  1.5161E-08
    61149  3.7605E-08
    62147  2.2866E-07
    62149  8.8805E-08
    62150  2.2523E-06
    62151  3.3545E-07
    62152  1.0182E-06
    63153  4.8833E-07
    63154  6.3635E-08
    63155  6.3594E-08
    64155  4.9030E-10
MIX=124
'ASSY 24
'S1C2 QC LOC #24  (BATCH 4C) 5508 MWD/MTU
   892234  6.1038E-06
   892235  6.3667E-04
   892236  2.8999E-05
   892238  2.2213E-02
    93237  9.0815E-07
    94238  4.2234E-08
   894239  5.2557E-05
   894240  5.1334E-06
   894241  1.4491E-06
    94242  4.3597E-08
    95241  7.5921E-09
    95243  0.0000E+00
```

Table E.8. (continued)

```
    96244  0.0000E+00
     8016  4.6164E-02
    36083  6.6340E-07
    40093  8.2152E-06
    42095  3.2651E-06
    43099  8.0043E-06
    44101  7.0252E-06
    44103  1.4518E-06
    45103  3.1944E-06
    45105  2.7436E-08
    46105  1.9597E-06
    46108  3.8564E-07
    47109  2.7407E-07
    53135  1.8280E-08
    54131  3.6169E-06
    54135  8.6867E-09
    55133  8.5845E-06
    55134  1.5577E-07
    55135  2.9391E-06
    59141  5.8591E-06
    60143  6.6506E-06
    60145  5.1027E-06
    60147  2.5728E-07
    60148  2.2991E-06
    61147  2.3466E-06
    61148  9.6646E-09
    61149  3.0140E-08
    62147  1.5354E-07
    62149  7.4690E-08
    62150  1.5681E-06
    62151  2.7172E-07
    62152  7.2967E-07
    63153  3.1668E-07
    63154  3.0395E-08
    63155  4.3319E-08
    64155  3.4017E-10
MIX=125
'ASSY 25
'S1C2 QC LOC #25  (BATCH 4A) 6883 MWD/MTU
   592234  3.0897E-06
   592235  2.8583E-04
   592236  2.7325E-05
   592238  2.2481E-02
    93237  1.2966E-06
    94238  1.0300E-07
   594239  6.7796E-05
   594240  1.2040E-05
   594241  4.4525E-06
    94242  3.6231E-07
    95241  2.7010E-08
    95243  1.2768E-08
    96244  1.9671E-10
     8016  4.6108E-02
    36083  7.4707E-07
    40093  9.6588E-06
    42095  3.8258E-06
    43099  9.9171E-06
    44101  8.8435E-06
    44103  2.1192E-06
    45103  4.2235E-06
    45105  4.7893E-08
    46105  3.1392E-06
    46108  8.9593E-07
    47109  6.6022E-07
    53135  2.2936E-08
```

Table E.8. (continued)

```
    54131  4.4932E-06
    54135  6.0246E-09
    55133  1.0550E-05
    55134  3.0867E-07
    55135  1.9781E-06
    59141  7.1275E-06
    60143  7.6229E-06
    60145  6.0770E-06
    60147  3.1605E-07
    60148  2.8595E-06
    61147  2.6950E-06
    61148  1.6695E-08
    61149  4.2843E-08
    62147  1.7335E-07
    62149  4.7436E-08
    62150  2.5212E-06
    62151  2.1651E-07
    62152  1.1054E-06
    63153  5.0464E-07
    63154  7.4599E-08
    63155  5.7980E-08
    64155  2.1256E-10
MIX=126
'ASSY 26
'S1C2 QC LOC #26  (BATCH 4C) 6072 MWD/MTU
   892234  6.0568E-06
   892235  6.2364E-04
   892236  3.1318E-05
   892238  2.2204E-02
    93237  1.0397E-06
    94238  5.3724E-08
   894239  5.6647E-05
   894240  5.9587E-06
   894241  1.8069E-06
    94242  6.5064E-08
    95241  1.0967E-08
    95243  4.5395E-10
    96244  0.0000E+00
     8016  4.6164E-02
    36083  7.2583E-07
    40093  9.0245E-06
    42095  3.9114E-06
    43099  8.8239E-06
    44101  7.7468E-06
    44103  1.4899E-06
    45103  3.6406E-06
    45105  2.8299E-08
    46105  2.2082E-06
    46108  4.4911E-07
    47109  3.2042E-07
    53135  1.8267E-08
    54131  3.9996E-06
    54135  8.6864E-09
    55133  9.4864E-06
    55134  1.8948E-07
    55135  3.2419E-06
    59141  6.6293E-06
    60143  7.3654E-06
    60145  5.6048E-06
    60147  2.5677E-07
    60148  2.5332E-06
    61147  2.5613E-06
    61148  1.0625E-08
    61149  3.0626E-08
    62147  1.8579E-07
```

Table E.8. (continued)

```
    62149  7.5927E-08
    62150  1.7527E-06
    62151  2.8409E-07
    62152  8.1953E-07
    63153  3.6014E-07
    63154  3.7501E-08
    63155  4.7582E-08
    64155  3.7771E-10
MIX=1
 40302  4.25156E-02
MIX=2
 24304  1.74286E-02
 25055  1.73633E-03
 26304  5.93579E-02
 28304  7.72073E-03
MIX=3
  1001  4.90237E-02
308016  2.45119E-02
  5010  9.92574E-07
  5011  4.02956E-06
MIX=4
 424304  8.71428E-03
 425055  8.68166E-04
 426304  2.96789E-02
 428304  3.86037E-03
 401001  2.45119E-02
 408016  1.22559E-02
 405010  4.96287E-07
 405011  2.01478E-06
MIX=5
 524304  1.74286E-02
 525055  1.73633E-03
 526304  5.93579E-02
 528304  7.72073E-03
MIX=6
601001  4.97259E-02
608016  2.48629E-02
605010  1.00679E-06
605011  4.08727E-06
MIX=7
 724304  1.74286E-02
 725055  1.73633E-03
 726304  5.93579E-02
 728304  7.72073E-03
MIX=8
801001  5.04213E-02
808016  2.52107E-02
805010  1.02087E-06
805011  4.14444E-06
MIX=9
 924304  1.74286E-02
 925055  1.73633E-03
 926304  5.93579E-02
 928304  7.72073E-03
MIX=11
'S1C2  BP FOR EC LOC #2  BATCH4B
   718016  4.4970E-02
   715010  1.2337E-04
   715011  3.8630E-03
    11023  1.6495E-03
    13027  5.7991E-04
MIX=12
'S1C2  BP FOR EC LOC #4  BATCH4B
   718016   4.49700E-02
   715010  1.3432E-04
```

Table E.8. (continued)

```
   715011  3.8630E-03
    11023  1.6495E-03
    13027  5.7992E-04
MIX=13
'S1C2 DEPLETED BP FOR EC LOC #6  BATCH4B
   618016   4.49700E-02
   615010  1.7243E-06
   615011  3.8630E-03
    11023  1.6494E-03
    13027  5.7989E-04
MIX=14
'S1C2  BP FOR EC LOC #14  BATCH4C
  1018016   4.49700E-02
  1015010  3.6537E-04
  1015011  3.8630E-03
    11023  1.6498E-03
    13027  5.7996E-04
MIX=15
'S1C2  BP FOR EC LOC #23  BATCH4C
  1018016   4.49700E-02
  1015010  3.0873E-04
  1015011  3.8630E-03
    11023  1.6497E-03
    13027  5.7995E-04
END MIXT

READ GEOM


'--- FUEL PINS
UNIT 101
CYLINDER 0101 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 102
CYLINDER 0102 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 103
CYLINDER 0103 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 104
CYLINDER 0104 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 105
CYLINDER 0105 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 106
CYLINDER 0106 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 107
CYLINDER 0107 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 108
```

Table E.8. (continued)

```
CYLINDER 0108 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 109
CYLINDER 0109 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 110
CYLINDER 0110 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 111
CYLINDER 0111 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 112
CYLINDER 0112 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 113
CYLINDER 0113 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 114
CYLINDER 0114 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 115
CYLINDER 0115 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 116
CYLINDER 0116 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 117
CYLINDER 0117 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 118
CYLINDER 0118 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 119
CYLINDER 0119 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 120
CYLINDER 0120 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 121
```

Table E.8. (continued)

```
CYLINDER 0121 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 122
CYLINDER 0122 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 123
CYLINDER 0123 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 124
CYLINDER 0124 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 125
CYLINDER 0125 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
UNIT 126
CYLINDER 0126 1 .464693 365.76 0.0
CYLINDER   0 1 .474218 365.76 0.0
CYLINDER   1 1 .535940 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0

'--- GUIDE TUBE
UNIT 161
CYLINDER   3  1 0.613918 365.76 0.0
CYLINDER   1  1 0.690118 365.76 0.0
CUBOID     3  1 2P.71501 2P.71501 365.76 0.0
'--- BP RODS
UNIT 162
CYLINDER   0 1 0.283845 365.76 0.0
CYLINDER   2 1 0.300355 365.76 0.0
CYLINDER   0 1 0.308610 365.76 0.0
CYLINDER  11 1 0.502920 365.76 0.0
CYLINDER   0 1 0.508635 365.76 0.0
CYLINDER   2 1 0.555625 365.76 0.0
CYLINDER   3  1 0.613918 365.76 0.0
CYLINDER   1  1 0.690118 365.76 0.0
CUBOID     3  1 2P0.71501 2P0.71501 365.76 0.0
UNIT 163
CYLINDER   0 1 0.283845 365.76 0.0
CYLINDER   2 1 0.300355 365.76 0.0
CYLINDER   0 1 0.308610 365.76 0.0
CYLINDER  12 1 0.502920 365.76 0.0
CYLINDER   0 1 0.508635 365.76 0.0
CYLINDER   2 1 0.555625 365.76 0.0
CYLINDER   3  1 0.613918 365.76 0.0
CYLINDER   1  1 0.690118 365.76 0.0
CUBOID     3  1 2P0.71501 2P0.71501 365.76 0.0
UNIT 164
CYLINDER   0 1 0.283845 365.76 0.0
CYLINDER   2 1 0.300355 365.76 0.0
CYLINDER   0 1 0.308610 365.76 0.0
CYLINDER  13 1 0.502920 365.76 0.0
CYLINDER   0 1 0.508635 365.76 0.0
CYLINDER   2 1 0.555625 365.76 0.0
CYLINDER   3  1 0.613918 365.76 0.0
CYLINDER   1  1 0.690118 365.76 0.0
```

Table E.8. (continued)

```
CUBOID      3  1 2P0.71501 2P0.71501 365.76 0.0
UNIT 165
CYLINDER   0 1 0.283845 365.76 0.0
CYLINDER   2 1 0.300355 365.76 0.0
CYLINDER   0 1 0.308610 365.76 0.0
CYLINDER  14 1 0.502920 365.76 0.0
CYLINDER   0 1 0.508635 365.76 0.0
CYLINDER   2 1 0.555625 365.76 0.0
CYLINDER   3  1 0.613918 365.76 0.0
CYLINDER   1  1 0.690118 365.76 0.0
CUBOID     3  1 2P0.71501 2P0.71501 365.76 0.0
UNIT 166
CYLINDER   0 1 0.283845 365.76 0.0
CYLINDER   2 1 0.300355 365.76 0.0
CYLINDER   0 1 0.308610 365.76 0.0
CYLINDER  15 1 0.502920 365.76 0.0
CYLINDER   0 1 0.508635 365.76 0.0
CYLINDER   2 1 0.555625 365.76 0.0
CYLINDER   3  1 0.613918 365.76 0.0
CYLINDER   1  1 0.690118 365.76 0.0
CUBOID     3  1 2P0.71501 2P0.71501 365.76 0.0

'--- FUEL ASSY'S
UNIT 1
ARRAY     0101 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 2
ARRAY     0102 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 3
ARRAY     0103 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 4
ARRAY     0104 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 5
ARRAY     0105 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 6
ARRAY     0106 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 7
ARRAY     0107 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 8
ARRAY     0108 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 9
ARRAY     0109 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 10
ARRAY     0110 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 11
ARRAY     0111 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 12
ARRAY     0112 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 13
ARRAY     0113 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 14
ARRAY     0114 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
```

Table E.8. (continued)

```
UNIT 15
ARRAY     0115 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 16
ARRAY     0116 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 17
ARRAY     0117 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 18
ARRAY     0118 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 19
ARRAY     0119 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 20
ARRAY     0120 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 21
ARRAY     0121 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 22
ARRAY     0122 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 23
ARRAY     0123 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 24
ARRAY     0124 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 25
ARRAY     0125 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1
UNIT 26
ARRAY     0126 2R-10.72515 0.0
REFLECTOR   3  1 4R0.02667 2R0.0 1

'--- BAFFLE REGION
UNIT 41
COM=! CORNER SQUARE !
 CUBOID   2 1    1.905     0.0       1.905     0.0  365.76 0.0
UNIT 42
COM=! HORIZONTAL STRIP (1 ASS'Y WIDE) !
 CUBOID   2 1   21.50364   0.0       1.905     0.0  365.76 0.0
UNIT 43
COM=! VERTICAL STRIP (1 ASS'Y HIGH) !
 CUBOID   2 1    1.905     0.0      21.50364   0.0  365.76 0.0
UNIT 44
COM=! HORIZONTAL STRIP (2 ASS'YS WIDE) !
CUBOID   2 1     43.00728  0.0      1.905      0.0  365.76 0.0
UNIT 45
COM=! HORIZONTAL STRIP (1 ASS'Y WIDE) BOTTOM OF Y AXIS !
 CUBOID   2 1    21.50364  0.0      0.0       -1.905 365.76 0.0
UNIT 46
COM=! HORIZONTAL STRIP (2 ASS'YS WIDE) BOTTOM OF Y AXIS !
CUBOID   2 1     43.00728  0.0      0.0       -1.905 365.76 0.0

'---ROWS OF ASSY'S W/ BAFFLE REGIONS ON EACH END
UNIT 51
COM=! ROW 1 !
ARRAY  1  -34.16046  -12.65682 0.0
UNIT 52
COM=! ROW 2 !
ARRAY  2  -77.16774  -10.75182 0.0
UNIT 53
```

Table E.8. (continued)

```
COM=! ROW 3 !
ARRAY  3  -98.67138  -10.75182 0.0
UNIT 54
COM=! ROW 4 !
ARRAY  4 -120.17502  -10.75182 0.0
UNIT 55
COM=! ROWS 5 & 6 !
ARRAY  5 -141.67866  -21.50364 0.0
UNIT 57
COM=! ROWS 7 - 9 !
ARRAY  7 -163.18230  -32.25546 0.0
UNIT 60
COM=! ROWS 10 & 11 !
ARRAY 10 -141.67866  -21.50364 0.0
UNIT 62
COM=! ROW 12 !
ARRAY 12 -120.17502  -10.75182 0.0
UNIT 63
COM=! ROW 13 !
ARRAY 13  -98.67138  -10.75182 0.0
UNIT 64
COM=! ROW 14 !
ARRAY 14  -77.16774  -10.75182 0.0
UNIT 65
COM=! ROW 15 !
ARRAY 15  -34.16046  -10.75182 0.0

GLOBAL UNIT 70
CYLINDER 3 1 170.02125 365.76 0.0
HOLE  57   0.0      0.0       0.0
HOLE  55   0.0    -53.75910  0.0
HOLE  60   0.0     53.75910  0.0
HOLE  54   0.0    -86.01456  0.0
HOLE  62   0.0     86.01456  0.0
HOLE  53   0.0  -107.51820  0.0
HOLE  63   0.0   107.51820  0.0
HOLE  52   0.0  -129.02184  0.0
HOLE  64   0.0   129.02184  0.0
HOLE  51   0.0  -150.52548  0.0
HOLE  65   0.0   150.52548  0.0
HOLE  44  -77.16774  139.77366  0
HOLE  46  -77.16774 -139.77466  0
HOLE  44   34.16046  139.77366  0
HOLE  46   34.16046 -139.77466  0
HOLE  42  -98.67138  118.27002  0
HOLE  45  -98.67138 -118.27002  0
HOLE  42   77.16774  118.27002  0
HOLE  45   77.16774 -118.27002  0
HOLE  42 -120.17502   96.76638  0
HOLE  45 -120.17502  -96.76738  0
HOLE  42   98.67138   96.76638  0
HOLE  45   98.67138  -96.76738  0
HOLE  42 -141.67866   75.26274  0
HOLE  45 -141.67866  -75.26274  0
HOLE  42  120.17502   75.26274  0
HOLE  45  120.17502  -75.26274  0
HOLE  42 -163.18230   32.25546  0
HOLE  45 -163.18230  -32.25546  0
HOLE  42  141.67866   32.25546  0
HOLE  45  141.67866  -32.25546  0
CYLINDER 4 1 170.02125 390.76 -25.0
REFLECTOR  5 1  5.08     0.0 0.0 1
REFLECTOR  6 1  6.0325   0.0 0.0 1
REFLECTOR  7 1  6.82625 0.0 0.0 1
REFLECTOR  8 1 11.43     0.0 0.0 1
```

Table E.8. (continued)

```
REFLECTOR  9 1 19.89582 0.0 0.0 1
CUBOID  0 1 2P220.0 2P220.0 390.76 -25.0
END GEOM

READ ARRAY

'--- FUEL ASSY'S
ARA=101   NUX=15 NUY=15 NUZ=1     FILL  F101
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=102   NUX=15 NUY=15 NUZ=1
COM=/   ASSY 2 -- 8 FRESH BP   /
FILL F102
  A33 161     A36 162     A40 162      A43 161
  A53 161     A65 161     A71 161      A78 162
  A88 162    A109 161    A113 161     A117 161   A138 162
 A148 162    A155 161    A161 161     A173 161
 A183 161    A186 162    A190 162     A193 161     END FILL
ARA=103   NUX=15 NUY=15 NUZ=1     FILL  F103
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=104   NUX=15 NUY=15 NUZ=1
COM=/   ASSY 4 -- 8 FRESH BP   /
FILL F104
  A33 161     A36 163     A40 163      A43 161
  A53 161     A65 161     A71 161      A78 163
  A88 163    A109 161    A113 161     A117 161   A138 163
 A148 163    A155 161    A161 161     A173 161
 A183 161    A186 163    A190 163     A193 161     END FILL
ARA=105   NUX=15 NUY=15 NUZ=1     FILL  F105
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=106   NUX=15 NUY=15 NUZ=1
COM=/   ASSY 6 -- 12 DEPLETED BP   /
FILL F106
  A33 164     A36 164     A40 164      A43 164
  A53 161     A65 161     A71 161      A78 164
  A88 164    A109 161    A113 161     A117 161   A138 164
 A148 164    A155 161    A161 161     A173 161
 A183 164    A186 164    A190 164     A193 164     END FILL
ARA=107   NUX=15 NUY=15 NUZ=1     FILL  F107
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=108   NUX=15 NUY=15 NUZ=1     FILL  F108
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=109   NUX=15 NUY=15 NUZ=1     FILL  F109
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
```

Table E.8. (continued)

```
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=110   NUX=15 NUY=15 NUZ=1     FILL  F110
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=111   NUX=15 NUY=15 NUZ=1     FILL  F111
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=112   NUX=15 NUY=15 NUZ=1     FILL  F112
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=113   NUX=15 NUY=15 NUZ=1     FILL  F113
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=114   NUX=15 NUY=15 NUZ=1
COM=/   ASSY 14 -- 20 FRESH BP   /
FILL F114
  A33 165     A36 165     A40 165      A43 165
  A53 165     A65 165     A71 165      A78 165
  A88 165    A109 165    A113 161     A117 165   A138 165
 A148 165    A155 165    A161 165     A173 165
 A183 165    A186 165    A190 165     A193 165     END FILL
ARA=115   NUX=15 NUY=15 NUZ=1     FILL  F115
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=116   NUX=15 NUY=15 NUZ=1     FILL  F116
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=117   NUX=15 NUY=15 NUZ=1     FILL  F117
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=118   NUX=15 NUY=15 NUZ=1     FILL  F118
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=119   NUX=15 NUY=15 NUZ=1     FILL  F119
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=120   NUX=15 NUY=15 NUZ=1     FILL  F120
```

Table E.8. (continued)

```
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=121   NUX=15 NUY=15 NUZ=1      FILL  F121
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=122   NUX=15 NUY=15 NUZ=1      FILL  F122
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=123   NUX=15 NUY=15 NUZ=1
COM=/   ASSY 23 -- 12 FRESH BP   /
FILL F123
  A33 166     A36 166     A40 166      A43 166
  A53 161     A65 161     A71 161      A78 166
  A88 166    A109 161    A113 161     A117 161   A138 166
 A148 166    A155 161    A161 161     A173 161
 A183 166    A186 166    A190 166     A193 166     END FILL
ARA=124   NUX=15 NUY=15 NUZ=1      FILL  F124
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=125   NUX=15 NUY=15 NUZ=1      FILL  F125
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL
ARA=126   NUX=15 NUY=15 NUZ=1      FILL  F126
  A33 161     A36 161     A40 161      A43 161
  A53 161     A65 161     A71 161      A78 161
  A88 161    A109 161    A113 161     A117 161   A138 161
 A148 161    A155 161    A161 161     A173 161
 A183 161    A186 161    A190 161     A193 161     END FILL

'--- ROWS OF FUEL ASSY'S
ARA=1   NUX=5  NUY=2  NUZ=1     FILL
                          41  42  42 1B2
                          43  15   8 1B2
 END FILL
ARA=2   NUX=9   NUY=1  NUZ=1     FILL
                  43  24  20  14   7 1B4
 END FILL
ARA=3   NUX=11  NUY=1  NUZ=1     FILL
              43  26  23  19  13   6 1B5
 END FILL
ARA=4   NUX=13  NUY=1  NUZ=1     FILL
          43  26  25  22  18  12   5 1B6
 END FILL
ARA=5   NUX=15  NUY=2  NUZ=1     FILL
      43  24  23  22  21  17  11   4 1B7
   43  20  19  18  17  16  10   3 1B7
END FILL
ARA=7   NUX=17  NUY=3  NUZ=1     FILL
43  15  14  13  12  11  10   9   2 1B8
43   8   7   6   5   4   3   2   1 1B25
```

Table E.8. (continued)

```
 END FILL
ARA=10  NUX=15  NUY=2  NUZ=1    FILL
      43  20  19  18  17  16  10   3 1B7
      43  24  23  22  21  17  11   4 1B7
 END FILL
ARA=12  NUX=13  NUY=1  NUZ=1    FILL
          43  26  25  22  18  12   5 1B6
 END FILL
ARA=13  NUX=11  NUY=1  NUZ=1    FILL
              43  26  23  19  13   6 1B5
 END FILL
ARA=14  NUX=9   NUY=1  NUZ=1    FILL
                  43  24  20  14   7 1B4
 END FILL
ARA=15  NUX=5  NUY=2  NUZ=1    FILL
                          43  15   8 1B2
                          41  42  42 1B2               END FILL
END ARRAY
READ PLOT
TTL=! SURRY UNIT 1 CYCLE 2 FULL CORE BY GEOM UNIT !
PIC=UNIT
XUL=-200  YUL=200  XLR=200  YLR=-200  UAX=1 VDN=-1  NAX=130  END
TTL=!  ASSEMBLY LOC 2 !
PIC=MAT  NCH=! 12 45555567890ABCDEFGHIJKLMNOPQRSTUVWXYZ!
XUL=-11  YUL=32.5  XLR=11  YLR=10.5  UAX=1 VDN=-1  NAX=130  END
TTL=! SURRY UNIT 1 CYCLE 2 FULL CORE BY COMPOSITION!
PIC=MAT  NCH=! 1/ 4/ / /55555ABCDEFGHIJKLMNOPQRSTUVWXYZ!
XUL=-200  YUL=200  XLR=200  YLR=-200  UAX=1 VDN=-1  NAX=260 NDN=148  END
END PLOT
END DATA
END
```

INTERNAL DISTRIBUTION

1. C. W. Alexander
2-3. S. M. Bowman
4. B. L. Broadhead
5. J. A. Bucholz
6. R. D. Dabbs
7-8. M. D. DeHart
9. M. B. Emmett
10. N. M. Greene
11. O. W. Hermann
12. M. Kuliasha
13. L. C. Leal
14. S. B. Ludwig
15. S. K. Martin
16. G. E. Michaels
17. B. D. Murphy
18-22. L. F. Norris
23. J. V. Pace
24-28. C. V. Parks
29. L. M. Petrie
30. R. T. Primm
31. J.-P. Renier
32. J. W. Roddy
33. R. W. Roussin
34. J. C. Ryman
35. C. H. Shappert
36. R. M. Westfall
37. B. A. Worley
38. R. Q. Wright
39-40. Laboratory Records Dept.
41. Laboratory Records, ORNL-RC
    Document Reference Section
42. ORNL Y-12 Research Library
43. Central Research Library
44. ORNL Patent Section

EXTERNAL DISTRIBUTION

45. R. Anderson, General Nuclear Systems, Inc., 220 Stoneridge Dr., Columbia, SC 29210
46. M. G. Bailey, Office of Nuclear Material Safety & Safeguards, U.S. Nuclear Regulatory Commission, MS TWFN 8F5, Washington, DC 20555
47. L. Barrett, Office of Civilian Radioactive Waste Management, RW-232 20545, U.S. Department of Energy, Washington, DC 20545
48. P. Baylor, Office of Civilian Radioactive Waste Management, RW-36, U.S. Department of Energy, Washington, DC 20545
49. C. J. Benson, Bettis Atomic Power Laboratory, P.O. Box 79, West Mifflin, PA 15122
50. J. Bickel, U.S. Department of Energy, Albuquerque Operations Office, P.O. Box 5400, Albuquerque, NM 87115
51. L. Blalock, U.S. Department of Energy, M-261 Quince Orchard, Washington, DC 20585-0002
52. J. Boshoven, GA Technologies, Inc., P.O. Box 85608, 10955 John J. Hopkins Dr., San Diego, CA 92121
53. M. C. Brady, Sandia National Laboratories, 101 Convention Center Drive, Suite 880, Las Vegas, NV 89109
54. P. Bunton, U.S. Department of Energy, RW-1, Washington, DC 20545
55. R. J. Cacciapouti, Yankee Atomic Electric Co., 1617 Worcester Rd., Framington, MA 01701
56. R. Carlson, Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, CA 94550
57. C. R. Chappell, U.S. Nuclear Regulatory Commission, Office of Nuclear Materials Safety and Safeguards, TWFN 8F5, Washington, DC 20555
58. J. S. Choi, Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, CA 94550
59. J. Clark, 2650 Park Tower Drive, Suite 800, Vienna, VA 22180
60. J. Conde, Consejo de Seguridad Nuclear, Justo Dorado, 11, 28040 Madrid, Spain

61. D. R. Conners, Bettis Atomic Power Laboratory, P.O. Box 79, West Mifflin, PA 15122
62. M. Conroy, U.S. Department of Energy, M-261 Quince Orchard, Washington, DC 20585-0002
63. P. J. Cooper, Sandia National Laboratories, P.O. Box 5800, Albuquerque, NM 87185-0716
64. W. Davidson, Los Alamos National Laboratory, Group A4, MSF-611, Los Alamos, NM 87845
65-67. F. J. Davis, Sandia National Laboratories, P.O. Box 5800, Div. 6302, MS 1333, Albuquerque, NM 87185-0716
68. D. Dawson, Transnuclear, Inc., 2 Skyline Dr., Hawthorne, NY 10532-2120
69. T. W. Doering, TESS, B&W Fuel Co., MS 423, Suite 527, P.O. Box 98608, 101 Convention Center Drive, Las Vegas, NV 89109
70. R. Doman, Nuclear Packaging, Inc., 1010 S. 336th St., Suite 220, Federal Way, WA 98003
71. E. Easton, U.S. Nuclear Regulatory Commission, Office of Nuclear Materials Safety and Safeguards, Washington, DC 20555
72. R. C. Ewing, Sandia National Laboratories, P.O. Box 5800, Div. 6643, MS 0716, Albuquerque, NM 87185-0716
73. C. Garcia, U.S. Department of Energy, Albuquerque Operations Office, P.O. Box 5400, Albuquerque, NM 87115
74. S. Hanauer, U.S. Department of Energy, RW-22, Washington, DC 20545
75. C. Haughney, U.S. Nuclear Regulatory Commission, Office of Nuclear Materials Safety and Safeguards, TWFN 8F5, Washington, DC 20555
76. L. Hassler, Babcock & Wilcox, P.O. Box 10935, Lynchburg, VA 24506-0935
77. E. Johnson, E. R. Johnson Associates, Inc., 9302 Lee Hwy, Suite 200, Fairfax, VA 22031
78. R. Kelleher, International Atomic Energy Agency, Division of Publications, Wagramerstrasse 5, P.O. Box 100, Vienna, Austria A-1400
79. R. Kidman, Los Alamos National Laboratory, Group A4, MSF-611, Los Alamos, NM 87845
80. C. Kouts, Office of Civilian Radioactive Waste Management, RW-36, U.S. Department of Energy, Washington, DC 20545
81. S. Kraft, Nuclear Energy Institute, 1776 I Street, Suite 400, Washington, DC 20086
82. P. Krishna, TRW Environmental Safety Systems, 600 Maryland Ave. S.W., Suite 695, Washington, DC 20024
83. A. Kubo, 2650 Park Tower Drive, Suite 800, Vienna, VA 22180
84. W. H. Lake, Office of Civilian Radioactive Waste Management, U.S. Department of Energy, RW-46, Washington, DC 20585
85-87. R. Lambert, Electric Power Research Institute, 3412 Hillview Ave., Palo Alto, CA 94304
88-90. D. Lancaster, 2650 Park Tower Drive, Suite 800, Vienna, VA 22180
91. D. Langstaff, U.S. Department of Energy, Richland Operations Office, P.O. Box 550, Richland, WA 99352
92. D. Lillian, U.S. Department of Energy, M-261 Quince Orchard, Washington, DC 20585-0002
93. C. Marotta, 1504 Columbia Ave., Rockville, MD 20850
94. M. Mason, Transnuclear, Two Skyline Drive, Hawthorne, NY 10532-2120
95. J. Massey, Sierra Nuclear Corporation, 5619 Scotts Valley Drive, Number 240, Scotts Valley, CA 95066
96. W. Mings, U.S. Department of Energy, Idaho Operations Office, 550 2nd St., Idaho Falls, ID 83401
97. A. Mobashevan, Roy F. Weston, Inc., 955 L'Enfant Plaza, SW, 8th Floor, Washington, DC 20024
98. R. Morgan, 2650 Park Tower Drive, Suite 800, Vienna, VA 22180
99. P. K. Nair, Manager, Engineered Barrier System, Center for Nuclear Waste Regulatory Analyses, Southwest Research Institute, 6220 Culebra Road, San Antonio, TX 78238-5166

100. D. Napolitano, Nuclear Assurance Corp., 5720 Peachtree Parkway, Norcross, GA 30092
101. C. W. Nilsen, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, MS TWFN-9F29, Washington, DC 20555
102. D. J. Nolan, 2650 Park Tower Drive, Suite 800, Vienna, VA 22180
103-104. Office of Scientific and Technical Information, U.S. Department of Energy, P.O. Box 62, Oak Ridge, TN 37831
105. Office of the Assistant Manager for Energy Research and Development, Department of Energy Oak Ridge Operations (DOE-ORO), P.O. Box 2008, Oak Ridge, TN 37831
106. C. E. Olson, Sandia National Laboratories, P.O. Box 5800, Div. 6631, MS 0715, Albuquerque, NM 87185-0716
107. N. Osgood, U.S. Nuclear Regulatory Commission, Office of Nuclear Materials Safety and Safeguards, TWFN 8F5, Washington, DC 20555
108. O. Ozer, Electric Power Research Institute, 3412 Hillview Ave., Palo Alto, CA 94304
109. P. Pacquin, General Nuclear Systems, Inc., 220 Stoneridge Dr., Columbia, SC 29210
110. T. Parish, Department of Nuclear Engineering, Texas A & M University, College Station, TX 77843-3313
111-113. M. Rahimi, 2650 Park Tower Drive, Suite 800, Vienna, VA 22180
114. B. Rasmussen, Duke Power Co., P.O. Box 33189, Charlotte, NC 28242
115. T. L. Sanders, Sandia National Laboratories, P.O. Box 5800, Div. 6609, MS 0720, Albuquerque, NM 87185-0716
116. K. D. Seager, Sandia National Laboratories, P.O. Box 5800, Div. 6643, MS 0716, Albuquerque, NM 87185-0716
117. M. Smith, U.S. Department of Energy, Yucca Mountain Project Office, 101 Convention Center Dr., Las Vegas, NV 89190
118. M. Smith, Virginia Power Co., P.O. Box 2666, Richmond, VA 23261
119. K. B. Sorenson, Sandia National Laboratories, P.O. Box 5800, Div. 6643, MS 0716, Albuquerque, NM 87185-0716
120. F. C. Sturz, Office of Nuclear Material Safety & Safeguards, U.S. Nuclear Regulatory Commission, MS TWFN 8F5, Washington, DC 20555
121. J. Sun, Florida Power & Light Co., P.O. Box 029100, Miami, FL 33102
122. T. Suto, Power Reactor and Nuclear Fuel Development Corp., 1-9-13, Akasaka, Minato-Ku,, Tokyo, Japan
123. R. J. Talbert, Battelle Pacific Northwest Laboratory, P.O. Box 999, Richland, WA 99352
124. T. Taylor, INEL, P.O. Box 4000, MS 3428, Idaho Falls, ID 83403
125. B. Thomas, VECTRA Technologies, Inc., 6203 San Ignacio Ave., Suite 100, San Jose, CA 95119
126. D. A. Thomas, B&W Fuel Co., 101 Convention Center Drive, Suite 527, MS 423, Las Vegas, NV 89109
127. J. R. Thornton, TRW Enviornmental Safety Systems, 2650 Park Tower Dr., Suite 800, Vienna, VA 22180
128. G. Walden, Duke Power Co., P.O. Box 33189, Charlotte, NC 28242
129. M. E. Wangler, U.S. Department of Energy, EH-33.2, Washington, DC 20585-0002
130. R. Weller, U.S. Nuclear Regulatory Commission, TWFN 7J9, Washington, DC 20555
131. A. Wells, 2846 Peachtree Walk, Duluth, GA 30136
132. W. Weyer, Wissenschaftlich-Technische Ingenieurberatung GMBH, Mozartstrasse 13, 5177 Titz-Rodingen, Federal Republic of Germany
133. B. H. White, Office of Nuclear Material Safety & Safeguards, U.S. Nuclear Regulatory Commission, MS TWFN 8F5, Washington, DC 20555
134. J. Williams, Office of Civilian Radioactive Waste Management, U.S. Department of Energy, RW-46, Washington, DC 20545

135. M. L. Williams, LSU Nuclear Science Center, Baton Rouge, LA 70803
136. C. J. Withee, Office of Nuclear Material Safety & Safeguards, U.S. Nuclear Regulatory Commission, MS TWFN 8F5, Washington, DC 20555
137. R. Yang, Electric Power Research Institute, 3412 Hillview Ave., Palo Alto, CA 94304