CRWMS/M&O

Design Analysis Cover Sheet

Complete only applicable items.

1.

QA: L

2. DESIGN ANALYSIS TITLE SAS2H Analysis of Radiochemical Assay Samples from H.B. Robinson PWR Reactor			
3. DOCUMENT IDENTIFIER (Including Rev. No.) B00000000-01717-0200-00140 REV 00			4. TOTAL PAGES 29
5. TOTAL ATTACHMENTS 2	6. ATTACHMENT NUMBERS - NO. OF PAGES IN EACH I-6 pp.; II-22 pp.		
	Printed Name	Signature	Date
7. Originator	Marcus Nichol	D. Thomas FOR MARCUS NICHOL	09/02/97
8. Checker	David Henderson	David P. Henderson	9-2-97
9. Lead Design Engineer	Dan Thomas	D. Thomas	09/02/97
10. Department Manager	Hugh Benton	Hugh A. Benton	9/2/97

11. REMARKS

CRWMS/M&O

Design Analysis Revision Record

Complete only applicable items.

1.

2. DESIGN ANALYSIS TITLE

SAS2H Analysis of Radiochemical Assay Samples from H.B. Robinson Reactor

3. DOCUMENT IDENTIFIER (Including Rev. No.)

B00000000-01717-0200-00140 REV 00

4. Revision No.	5. Description of Revision
00	Initial Issuance

Table of Contents:

Item Page

1. Purpose 4

2. Quality Assurance 4

3. Method 4

4. Design Inputs 5
   - 4.1 Design Parameters 5
   - 4.2 Criteria 13
   - 4.3 Assumptions 14
   - 4.4 Codes and Standards 14

5. References 15

6. Use of Computer Software 16

7. Design Analysis 17
   - 7.1 SCALE Input Data Blocks 1, 2, and 3 17
   - 7.2 SCALE Input Data Block 4 17
   - 7.3 SCALE Input Data Blocks 5 Through 7 18
   - 7.4 SCALE Input Data Block 8 19
   - 7.5 SCALE Input Data Blocks 9 Through 16 23
   - 7.6 Comparison of Calculated and Measured Concentrations 24
   - 7.7 Results 25

8. Conclusions 28

9. Attachments 29

1. Purpose

The purpose of this design analysis is to determine the accuracy of the SAS2H module of SCALE 4.3 in predicting isotopic concentrations of spent fuel assemblies. The objective is to develop a methodology for modeling assemblies similar to those evaluated within this analysis and to establish the consistency of SAS2H predictions. The results of this analysis may then be applied to future depletion calculations using SAS2H in which no measurements are available.

2. Quality Assurance

The Quality Assurance (QA) program applies to this analysis. The work reported in this document is part of the Waste Package Design analysis that will eventually support the License Application Design phase. This activity, when appropriately confirmed, can impact the proper functioning of the Mined Geologic Disposal System (MGDS) waste package; the waste package has been identified as an MGDS Q-List item important to safety and waste isolation (pp. 4, 15, Reference 5.1). The waste package is on the Q-List by direct inclusion by the Department of Energy (DOE), without conducting a QAP-2-3 evaluation. The Waste Package Development Department (WPDD) responsible manager has evaluated this activity in accordance with QAP-2-0, *Conduct of Activities*. The *Perform Criticality, Thermal, Structural, and Shielding Analyses* (Reference 5.2) evaluation has determined the preparation and review of this design analysis is subject to *Quality Assurance Requirements and Description* (Reference 5.3) requirements. As specified in NLP-3-18, this activity is subject to QA controls.

The analysis described in this document supports development of the disposal criticality analysis methodology. No designs were analyzed in this document. This document will not directly support any construction, fabrication, or procurement activity and therefore is not required to be procedurally controlled as TBV (to be verified). The calculation design inputs or information used in this document come from data accepted by the Nuclear Regulatory Commission and by the scientific and engineering community as established fact. The specific references are listed in Section 5 and identified in Section 7. The information is therefore not treated as unqualified data.

3. Method

The analytical model employed for this analysis was the SAS2H module of the SCALE sequence. Based upon fuel design, power history, and operating data for specific assemblies in the H.B. Robinson pressurized water reactor (PWR), a computational model was developed for use with the SAS2H module of SCALE. The SAS2H module is used to perform a fuel depletion analysis to predict the isotopic concentrations in localized areas of assembly pins (pellet samples) subsequent to irradiation and cooling time. The isotopic concentrations predicted by the SAS2H module are then compared with measured concentrations of the same localized areas (axial locations) of the assembly pins to determine the accuracy of the developed model. The measured isotopic

concentrations used for comparisons in the analysis are obtained from a separate report (Reference 5.6).

4. Design Inputs

The sources for the design parameters are References 5.4 through 5.9. References 5.4 and 5.5 provides information on molar masses and half-lives; the assembly design, power history and operating parameters are obtained from References 5.6 and 5.7; the cladding composition from Reference 5.8; and a list of trace elements in the fuel is derived from Reference 5.9.

4.1 Design Parameters

The half-life of ^{99}Tc and molar masses of selected elements are obtained from Reference 5.4, while the molar mass of ^{99}Tc is obtained from Reference 5.5. The half-life and molar masses are provided below within three significant figures. Precision beyond three significant figures is not necessary since the calculated isotopic concentrations from SCALE are only to three significant figures. Also, the weight per mole of enriched uranium is approximated by the weight per mole of natural uranium since the weight percent of enrichment is small.

Mole of natural uranium = 238 g,
Half-Life of $^{99}Tc = 2.13 \times 10^5$ years,
6.02×10^{23} atoms per mole. (Reference 5.4)
Mole of ^{99}Tc = 98.9 g. (Reference 5.5)

General spent fuel characteristics for each pellet sample are presented in Table 4-1 and include the initial ^{235}U enrichment, final burnup and the cooling time (Table 2, Reference 5.6). The initial enrichment of all samples is 2.561 wt% ^{235}U and the burnup ranges from 16.02 to 31.66 GWd/MTU. The cooling time for the samples at axial locations of 11 cm and 26 cm is 3,936 days, while the cooling time for the samples at axial locations of 199 cm and 226 cm is 3,631 days.

Assembly design parameters are presented in Table 4-2 (Table 8, Reference 5.6). The samples come from a Westinghouse 15 x 15 assembly with one instrument tube and 20 guide tube positions. A cross section of a Westinghouse 15 x 15 assembly is presented in Figure 4-1 (Figure 8, Reference 5.6). During operation the instrument tube was empty and there were 12 burnable poison rods during the first cycle of irradiation. Burnable poison rod composition and dimensions are included in Tables 4-2 through 4-4 (Tables 11 and 12, Reference 5.6). The borosilicate glass density was given as 2.23 g/cm^3.

The operating parameters in Table 4-5 include the cumulative burnups, average specific powers, fuel temperatures, average cycle boron concentrations and the position of the burnable poison rods (Tables 8 and 9, Reference 5.6; Table 3.8, Reference 5.7). The assembly was irradiated for two cycles; however, data reported in Reference 5.6 contains two intervals for each cycle to allow for

downtime at the cycle midpoints. Reference 5.6 approximated a linear decreasing specific power based on reactor data, which was normalized to the final total burnup to produce the interval burnups and corresponding average specific powers in Table 4-5. Fuel temperatures could not be obtained for the H. B. Robinson samples, therefore, it is assumed that the fuel temperatures are the same as those for Turkey Point, also a Westinghouse 15 x 15, Reference 5.7.

Moderator conditions for each sample are given in Table 4-6 and include the moderator temperature and density (Table 10, Reference 5.6). The moderator temperatures obtained were based upon a sinusoidal function of axial height, with inlet and outlet moderator temperatures 546.5°F and 600.6°F, respectively. The moderator density given in Reference 5.6 was determined from the moderator temperature and the nominal pressure of 2250 psia.

The composition of the cladding, Zircaloy-4, is presented in Table 4-7, and has a density of 6.56 g/cm^3 (Reference 5.8). A list of trace elements in the fuel used in updating cross sections during the depletion analysis is presented in Table 4-8 and developed with consideration of elements used in (Table 1, Reference 5.9). A generic set of light element weights for PWRs that is typically used in depletion analyses is included in Table 4-9 (Table 17, Reference 5.6). Variations in light element masses per unit fuel in different PWRs are small when compared to this generic set (p. 2-2, Reference 5.9). This data is provided in units of kg/MTUO_2 or kg/MTU depending on the units required in the analysis.

The measured isotopic concentrations are presented in Tables 4-10 and 4-11 (Tables 28 and 29, Reference 5.6). The measurements were performed at the Materials Characterization Center at Pacific Northwest Laboratory for fuel pellets at four different axial positions in Rod N-9 of Assembly B05. Eight actinides and one fission product were measured and are presented with units of g of isotope per g of UO_2 for the actinides (Table 4-10) and Curies per g UO_2 for the fission product (Table 4-11).

Table 4-1. Spent Fuel Characteristic Parameters for H. B. Robinson PWR

Test Assembly B05, Rod N-9		
Enrichment: 2.561 wt % ^{235}U		
Axial Location from Bottom of Assembly, cm	**Burnup, GWd/MTU**	**Cooling Time, days**
11	16.02	3936
26	23.81	3936
199	28.47	3631
226	31.66	3631

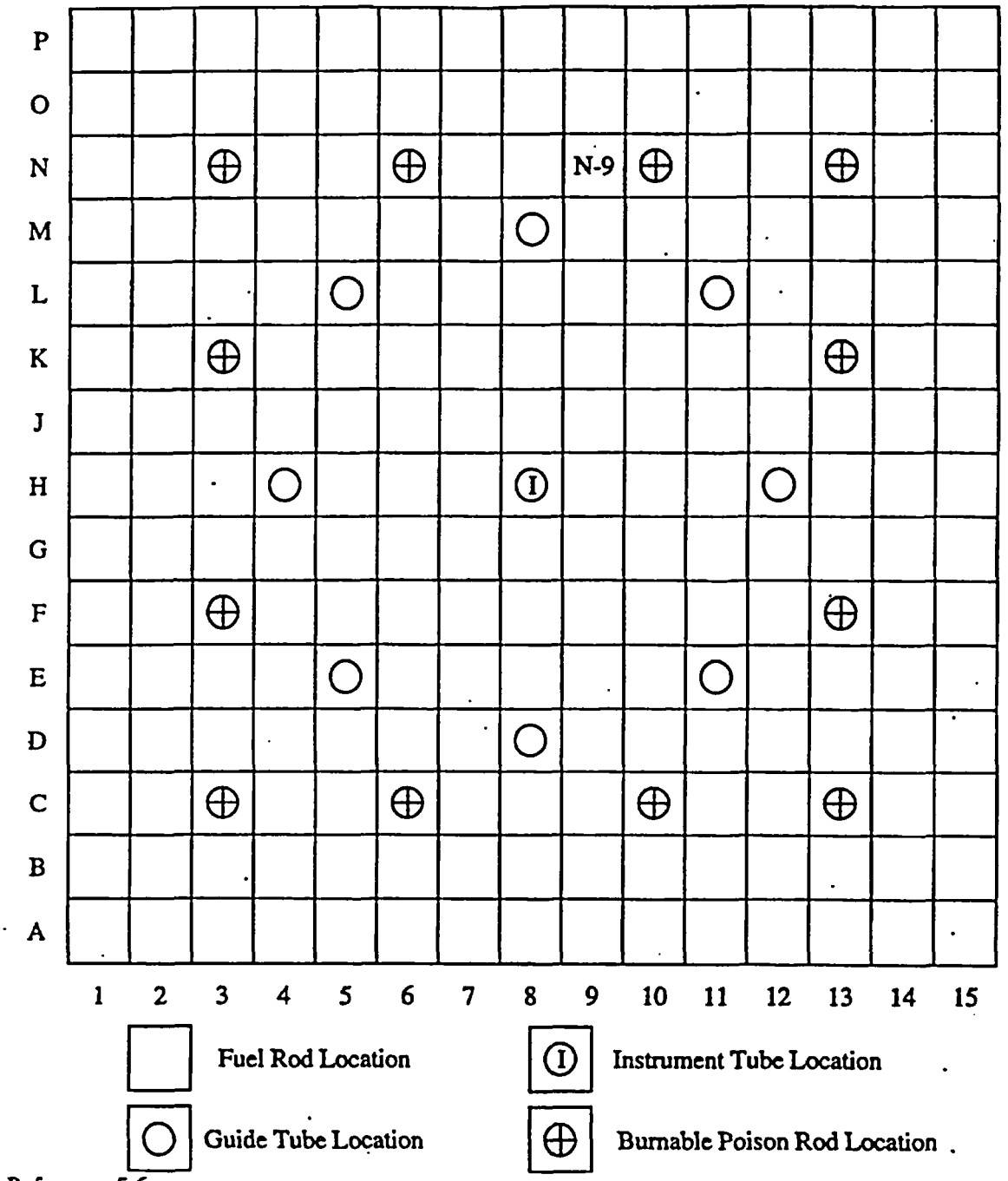
Reference 5.6

Table 4-2. Assembly Design Parameters H. B. Robinson PWR

Parameter	Data
Assembly general data:	
Designer	Westinghouse
Lattice	15 x 15
Number of Fuel Rods	204
Number of Guide Tubes	20
Number of Guide Tubes with Burnable Poison Rod (Cycle 1)	12
Number of Instrument Tubes	1
Assembly Pitch, cm	21.50
Assembly Fuel, kg U	443.7
Fuel Rod Data:	
Type of Fuel Pellet	UO_2
Enrichment,	
wt % ^{235}U	2.561
wt % ^{234}U	0.023
wt % ^{236}U	0.013
Pellet Stack Density, g/cm^3	9.944
Rod Pitch, cm	1.4300
Rod Outside Diameter (OD), cm	1.0719
Rod Inside Diameter (ID), cm	0.9484
Pellet Diameter, cm	0.9294
Active Fuel Length, cm	365.76
Clad Material	Zircaloy-4
Guide Tube Data:	
Inner Radius, cm	0.6502
Outer Radius, cm	0.6934
Tube Material	Zircaloy-4
Burnable Poison Rod Data:	
Air OD, cm	0.5677
SS304 OD, cm	0.6007
Air OD, cm	0.6172
Borosilicate Glass OD, cm	1.0058
Air OD, cm	1.0173
SS304 OD, cm	1.1151

Reference 5.6

Figure 4-1. Cross Section of H. B. Robinson Assembly



Reference 5.6

Table 4-3. Borosilicate Glass Composition

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

Reference 5.6

Table 4-4. Borosilicate Glass Atom Densities

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	N/A
^{10}B	N/A	9.595×10^{-4}
^{11}B	N/A	3.863×10^{-3}
Total	0.99402	N/A

Reference 5.6

Table 4-3. Borosilicate Glass Composition

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

Reference 5.6

Table 4-4. Borosilicate Glass Atom Densities

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	N/A
^{10}B	N/A	9.595×10^{-4}
^{11}B	N/A	3.863×10^{-3}
Total	0.99402	N/A

Reference 5.6

Table 4-5. Operating Data H. B. Robinson PWR

	Sample Identifier	Axial Location, cm	Cycle 1 First Interval	Cycle 1 Second Interval	Cycle 2 First Interval	Cycle 2 Second Interval
Uptime, days	all	all	243.5	243.5	156.0	156.0
Downtime, days	all	all	40.0	64.0	39.0	See Table 4-1
Cumulative Burnup, GWd/MTU	N-9B-S	11	5.08	9.99	13.04	16.02
	N-9B-N	26	7.85	15.18	19.60	23.81
	N-9C-J	199	9.62	18.41	23.61	28.47
	N-9C-D	226	10.88	20.68	26.39	31.66
Specific Power, MW/MTU	N-9B-S	11	20.86	20.15	19.57	18.11
	N-9B-N	26	32.23	30.10	28.35	26.99
	N-9C-J	199	39.50	36.11	33.33	31.16
	N-9C-D	226	44.68	40.25	36.61	33.78
Fuel Temperature, K	all	all	922	922	922	922
Cladding Temperature, K	all	all	595	595	595	595
Average Soluble Boron, ppm	all	all	652.5	247.5	652.5	247.5
Burnable poison fixture, in/out	all	all	in	in	out	out

References 5.6 and 5.7

Table 4-6. Moderator Conditions H. B. Robinson PWR

Pellet Sample Identifier	Axial Location (cm)	Total Burnup (GWd/MTU)	Moderator Temperature		Density of Moderator (g/cm^3)
			°F	K	
N-9B-S	11	16.02	546.6	559	0.7544
N-9B-N	26	23.81	547.2	559	0.7538
N-9C-J	199	28.47	577.3	576	0.7208
N-9C-D	226	31.66	583.3	579	0.7135

Reference 5.6

Table 4-7. Composition of Zircaloy-4

Material	Weight Percent
O	0.12
Cr	0.10
Fe	0.20
Sn	1.40
Zr	98.18
Density = 6.56 g/cm^3	

Reference 5.8

Table 4-8. Nuclides Updated in SAS2H

^{83}Kr	^{85}Kr	^{89}Y	^{90}Sr	^{95}Mo	^{93}Zr
^{94}Zr	^{94}Nb	^{95}Zr	^{99}Tc	^{101}Ru	^{103}Rh
^{105}Rh	^{106}Ru	^{105}Pd	^{108}Pd	^{109}Ag	^{124}Sb
^{131}Xe	^{132}Xe	^{134}Cs	^{135}Xe	^{135}Cs	^{136}Xe
^{136}Ba	^{137}Cs	^{139}La	^{141}Pr	^{143}Pr	^{143}Nd
^{144}Ce	^{145}Nd	^{147}Nd	^{147}Pm	^{147}Sm	^{148}Pm
^{149}Sm	^{150}Sm	^{151}Sm	^{152}Sm	^{153}Eu	^{154}Eu
^{155}Gd	^{155}Eu				

Reference 5.9

Table 4-9. Light Element Mass per Unit of Fuel in a Typical PWR

Element	kg/MTUO$_2$
O	119.0
Cr	5.2
Mn	0.29
Fe	11.0
Co	0.066
Ni	8.7
Zr	195.0
Nb	0.63
Sn	3.2

Reference 5.6

Table 4-10. Measured Isotopic Concentrations (g/g UO_2)

Axial Location, cm	11	26	199	226
Sample Identification	N-9B-S	N-9B-N	N-9C-J	N-9C-D
Burnup, GWd/MTU	16.02	23.81	28.47	31.66
^{235}U	1.07E-2	7.21E-3	6.18E-3	4.86E-3
^{236}U	2.19E-3	2.74E-3	2.82E-3	3.00E-3
^{238}U	8.47E-1	8.47E-1	8.34E-1	8.42E-1
^{238}Pu	2.83E-5	6.95E-5	1.14E-4	1.30E-4
^{239}Pu	3.64E-3	4.02E-3	4.39E-3	4.20E-3
^{240}Pu	1.09E-3	1.67E-3	1.97E-3	2.12E-3
^{241}Pu	3.04E-4	5.04E-4	6.81E-4	6.92E-4
^{237}Np	1.55E-4	2.60E-4	3.04E-4	3.33E-4

Reference 5.6

Table 4-11. Measured Isotopic Concentrations (Ci/g UO_2)

Axial Location, cm	11	26	199	226
Sample Identification	N-9B-S	N-9B-N	N-9C-J	N-9C-D
Burnup, GWd/MTU	16.02	23.81	28.47	31.66
^{99}Tc	5.44E-6	8.09E-6	8.95E-6	1.01E-5

Reference 5.6

4.2 Criteria

The design of the waste package will depend on waste package configuration criticality analyses performed using an acceptable disposal criticality analysis methodology. Criteria that relate to the development and design of repository and engineered barrier components are derived from the applicable requirements and planning documents. The Engineered Barrier Design Requirements Document (EBDRD, Reference 5.12) provides requirements for engineered barrier segment design. The Repository Design Requirements Document (RDRD, Reference 5.13) provides requirements for repository design. The Controlled Design Assumptions Document (Reference 5.14) provides guidance for requirements listed in the EBDRD and RDRD which have unqualified or unconfirmed data associated with the requirement.

This analysis supports the disposal criticality analysis methodology by providing input, in the form of fuel depletion results, to benchmark calculations which address the prediction of both spent fuel isotopic compositions and their associated reactivity. These benchmark calculations will contribute to the determination of bias values in the method of critical multiplication factor calculation that is implemented by the analytic tools to be used in the disposal criticality methodology. The requirements for utilizing the bias in the method of calculation of the critical multiplication factor for disposal configurations containing spent nuclear fuel are located in Section 3.2.2.5 of the RDRD and Section 3.2.2.6 of the EBDRD. This analysis does not satisfy these requirements, but the results from this analysis will be used as input to subsequent analyses which will satisfy these requirements.

4.3 Assumptions

4.3.1 The fuel temperatures are assumed to be the same as for the Turkey Point Unit 3 temperatures from Table 3.8, Reference 5.7. This basis for this assumption is that the relationship between power and temperature in Turkey Point and H. B. Robinson are similar. The reason is that both reactors utilize the Westinghouse 15 x 15 assembly design and the samples for H. B. Robinson were irradiated at approximately the same specific power as those from Turkey Point Unit 3. This assumption is used in Section 7.2.

4.4 Codes and Standards

There are no applicable codes or standards for this design analysis.

5. References

5.1 *Yucca Mountain Site Characterization Project Q-List*, YMP/90-55Q REV 4, Yucca Mountain Site Characterization Project.

5.2 *QAP-2-0 Activity Evaluations: ID #WP-20, Perform Criticality, Thermal, Structural, and Shielding Analyses*, Civilian Radioactive Waste Management System (CRWMS) Management and Operating Contractor (M&O), August 3, 1997.

5.3 *Quality Assurance Requirements and Description*, DOE/RW-0333P REV 7, U.S. Department of Energy (DOE) Office of Civilian Radioactive Waste Management (OCRWM).

5.4 *Nuclides and Isotopes*, General Electric Company, 14ed., 1989.

5.5 G. Audi and A. H. Wapstra, *Atomic Mass Adjustments: 'The 1995 Update to the Atomic Mass Evaluation'*, Nuclear Physics A595 Vol. 4, p. 409-480.

5.6 *Validation of the Scale System for PWR Spent Fuel Isotopic Composition Analyses*, ORNL/TM-12667, Oak Ridge National Laboratory, March 1995.

5.7 *Fuel Inventory and Afterheat Power Studies of Uranium-Fueled Pressurized-Water-Reactor Fuel Assemblies Using the SAS2 and ORIGEN-S Modules of SCALE with an ENDF/B-V Updated Cross Section Library*, NUREG/CR-2397, ORNL/CSD-90.

5.8 *Material Compositions and Number Densities for Neutronics Calculations*, Document Identifier (DI) Number: BBA000000-01717-0200-00002 REV 00, CRWMS M&O.

5.9 *SCALE-4 Analysis of Pressurized Water Reactor Critical Configurations: Volume 2-Sequoyah Unit 2 Cycle 3*, ORNL/TM-12294/V2, March 1995.

5.10 *SCALE 4.3, A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation for Workstations and Personal Computers*, NUREG/CR-0200 REV 5, ORNL/NUREG/CSD-2/R5, Volumes 1-3, Oak Ridge National Laboratory.

5.11 *Software Qualification Report for the SCALE Modular Code System*, DI Number: 30011-2002 REV 01, CRWMS M&O.

5.12 *Engineered Barrier Design Requirements Document*, YMP/CM-0024, REV 00, ICN 01, DOE OCRWM.

5.13 *Repository Design Requirements Document*, YMP/CM-0023, REV 00, ICN 01, DOE OCRWM.

5.14 *Controlled Design Assumptions Document*, DI#: B00000000-01717-4600-00032 REV 04, ICN 01, CRWMS M&O.

6. Use of Computer Software

A. Reference 5.10 describes the SAS2H module of SCALE 4.3 that is used with the 44GROUPNDF5 cross section library to calculate the isotopic concentrations for the specified burnup and cooling time. The computer code's spatially independent point depletion model is appropriate for comparison with pellet sample measurements, and is used within the range of validation, as described in Reference 5.11, in accordance with the QAP-SI series procedures. SCALE is obtained from the Software Configuration Management in accordance with appropriate procedures. SCALE's CSCI number is 30011 V4.3 and is installed on the WPDD HP 9000, 700 Workstation with CRWMS M&O tag number 110433.

B. *Lotus 1-2-3* Release 5 for Windows 95 is an Acquired Software spreadsheet program as defined in QAP-SI-0. User defined formulas and/or algorithms, inputs and results, are documented in the appropriate sections.

7. Design Analysis

The SAS2H module of SCALE 4.3 is used to perform one-dimensional (1-D) neutron transport and point depletion analyses on the H. B. Robinson assemblies using the preferred 44GROUPNDF5 cross-section library. To properly model the neutron flux spectrum and the nuclide composition changes, it is necessary to define the compositions, temperatures, and geometry of the fuel assembly. This is accomplished with the use of data blocks in which similar parameters are grouped together.

7.1 SCALE Input Data Blocks 1, 2, and 3

Data blocks 1 through 3 define the SCALE module to be used, the title of the input file, the cross section library to be used, and the lattice type to be modeled. The module used is SAS2H and the cross sectional library is 44GROUPNDF5, abbreviated as 44GROUP. The 44GROUP cross section library is recommended by Oak Ridge National Laboratory. Since SAS2H is only to be used for isotopic depletion/generation, the 'parm=skipshipdata' option is used so that a shipping cask shielding analysis is not performed. The title is arbitrary and should contain information that is sample specific, while the lattice type is "latticecell" to reflect the array characteristic of the assembly.

7.2 SCALE Input Data Block 4

Data block 4 defines the material compositions present in the assembly. A unique mixture number is assigned to each composition, and follows the form of mixture 1 for fuel, mixture 2 for cladding and mixture 3 for moderator.

The fuel mixture is specified as UO_2 with a density and isotopic weight percentages from Table 4-2 and a fuel temperature from Table 4-5. Isotopes which are selected as needing their cross sections updated during the depletion analysis are included in the fuel mixture. A standard list of trace fuel elements is given in Table 4-8 and defined in the fuel mixture to have a concentration of 10^{-20} atoms/barn·cm.

The cladding material of Zircaloy-4 is not contained within the Standard Composition Library in SCALE 4.3 and must be defined as an arbitrary material. The cladding is defined with a density and isotopic weight percentages from Table 4-7 and temperature given in Table 4-5.

The moderator temperature, density and boron concentration are given in Tables 4-5 and 4-6, and is composed of H_2O and boron. The boron is defined as an arbitrary material with the moderator density and temperature, a volume fraction equal to the average boron concentration of the first interval of the first cycle, and a standard boron composition from the Standard Composition Library designated as 5000.

Three additional mixtures must be specified. These are the stainless steel 304 cladding of the burnable poison rod, the borosilicate glass of the burnable poison rod and the air in between the borosilicate glass and cladding. The air between the borosilicate glass and the cladding is given the mixture number of 4, and is defined as nitrogen with an atom density of 5×10^{-5} atoms/barn-cm, and a temperature equal to the moderator temperature. The stainless steel 304 is given the mixture number of 5 with a temperature also equal to the moderator temperature. Finally, the borosilicate glass composition is given a mixture number of 6 with atom densities from Table 4-4 and again a temperature equal to the moderator temperature.

It is noted that subsequent to performing the SAS2H calculation on sample N-9C-D it was discovered that there was an error in the temperature for mixture number 5. The error consisted of a -3 K difference between the temperature specified in the SAS2H input file and the temperature specified in Table 4-6. It is determined that such error will not effect the calculation of the isotopic concentrations.

7.3 SCALE Input Data Blocks 5 Through 7

The unit fuel rod cell geometry is defined in data block 5. The 'squarepitch' designation for the type of lattice is appropriate since the fuel assembly consists of a square array of fuel rods. Fuel rod, cladding and pitch dimensions are given in Table 4-2 with the mixture number for each composition defined in Section 7.2. The gap mixture is defined as 0.

Data block 6 allows the user to specify such parameters as the spatial mesh, angular quadrature and the convergence criteria. It is determined that the default values are sufficient and such options are not used in this design model.

In data block 7 the user defines general assembly data and determines the level of detail in which the assembly is to be modeled. The number of fuel rods per assembly is given in Table 4-2 and the length is calculated so that an assembly contains 1 $MTUO_2$, using the following equation:

$$Length = \frac{1}{\frac{\pi}{4}(POD)^2(PDen)(NFR)} \cdot \frac{10^6 gUO_2}{1MTUO_2} \qquad \text{Equation 7-1}$$

Where:

Length = Length Required for an Assembly to Contain 1 $MTUO_2$ (cm)
POD = Fuel Pellet Diameter (cm)
PDen = Fuel Pellet Density (gUO_2/cm^3)
NFR = Number of Fuel Rods

Since, measured isotopic concentrations are presented in either grams or Ci per gram UO_2 of isotope per gram UO_2 and SCALE presents concentrations in grams of isotope per assembly, it is possible to alter the length so that the assembly contains 1 $MTUO_2$. This is possible since the 1-D transport

calculation is axially independent, consequently the length of the assembly does not impact the neutron flux spectrum nor the nuclide cross sections. The resulting length for the Robinson assembly is 726.63 cm.

The assembly was irradiated for two cycles that are both broken into two equivalent irradiation time intervals each. It is determined that approximately 80 days per cross section library is sufficient to accurately model the change in nuclide cross sections with increasing burnup, without overburdening the SAS2H code. Therefore, the number of libraries per cycle are specified as three. To obtain the concentrations of all interested nuclides, a print level of 5 is chosen, while an input level of 2 is defined so that a Path B model may be utilized. The number of light elements is nine and is determined from Table 4-9, while the number of zones is eleven which is determined by the Path B model described in Section 7.4.

SAS2H calculates a linear boron concentration let down over each cycle when the number of libraries per cycle are specified as greater than one. The methodology calculates an initial boron concentration equal to 1.9 times the average boron concentration and a final boron concentration calculated as 0.1 times the average boron concentration. These two end points are used to determine a linear fit for the boron concentration let down, which is used to calculate the boron concentrations for each library in the cycle. However, a problem arises when the cycle specified is not a full cycle but rather an interval of a cycle. (It is sometimes necessary to specify an interval as a cycle in SAS2H so that either a period of downtime during the actual cycle or a power change during the actual cycle may be modeled.) In this case SAS2H would let down the boron concentration to 0.1 times the average boron concentration for the first interval and jump up to 1.9 times the average boron concentration for the beginning of the second cycle. In reality, the jump does not exist and, therefore, the modeling of the boron concentration let down is inexact. A solution to this problem would be to split all cycles into approximately 80 day intervals and change the number of libraries per cycle to one. However, experience with the SAS2H code indicates that the error due to an inexact boron concentration let down function, such as described here, is usually less than 0.5%. Therefore, allowing the SAS2H code to perform a boron concentration over an interval of a cycle is an acceptable approximation to the actual boron concentration let down.

7.4 SCALE Input Data Block 8

The Path B model for Robinson changes from cycle 1 to cycle 2, since the burnable poison rod is withdrawn in cycle 2. For cycle 1 the burnable poison rod is centralized with a surrounding guide tube which is further surrounded by the homogenized fuel and moderator mixture and finally the moderator between assemblies. The equation below is used to determine the number of fuel unit cells that surround the burnable poison rod by conserving the fuel to moderator volume ratio. All of the following equations used to calculate the Path B model dimensions are derived. The results of the fuel-unit-cell calculations are presented in Table 7-1, and the resulting Path B model dimensions are presented in Table 7-2.

$$x = \frac{(\frac{F}{M})(CUCMV)}{(FV)-(\frac{F}{M})(MV)} \qquad \text{Equation 7-2}$$

$$\frac{F}{M} = \frac{(NFR)(\frac{\pi}{4})(POD)^2}{(NFR)[RP^2-(\frac{\pi}{4})(COD)^2]+(NGTE)[RP^2-(\frac{\pi}{4})(GTOD)^2+(\frac{\pi}{4})(GTID)^2]+(NGTR)[RP^2-(\frac{\pi}{4})(GTOD)^2+(\frac{\pi}{4})(GTID)^2-(\frac{\pi}{4})(BPROD)^2]+[RP^2-(\frac{\pi}{4})(ITOD)^2+(\frac{\pi}{4})(ITID)^2]} \qquad \text{Equation 7-3}$$

$$CUCMV = RP^2-(\frac{\pi}{4})(GTOD)^2+(\frac{\pi}{4})(GTID)^2-(\frac{\pi}{4})(BPROD)^2 \qquad \text{Equation 7-4}$$

$$FV = (\frac{\pi}{4})(POD)^2 \qquad \text{Equation 7-5}$$

$$MV = RP^2-(\frac{\pi}{4})(COD)^2 \qquad \text{Equation 7-6}$$

Where:

x = Number of Unit Fuel Cells per Central Poison Rod or Guide Tube (Cycle 2)
F/M = Fuel to Moderator Volume Ratio
NFR = Number of Fuel Rods
POD = Fuel Pellet Outer Diameter
RP = Rod Pitch
COD = Cladding Outer Diameter
NGTE = Number of Empty (Non-Rodded) Guide Tubes
GTOD = Guide Tube Outer Diameter
GTID = Guide Tube Inner Diameter
NGTR = Number of Rodded Guide Tubes
BPROD = Outside Diameter of Burnable Poison Rod
CUCMV = Central Unit Cell Moderator Volume
FV = Fuel Volume of Fuel One Unit Cell
MV = Moderator Volume of One Fuel Unit Cell

Once the number of fuel cells per burnable poison rod is determined the geometry of the Path B model is calculated. Since the burnable poison rod unit cell is centralized, the dimensions of the burnable poison rod and surrounding guide tube are the same as those presented in Table 4-2.

The radius for the moderator surrounding the guide tube, but still within the guide tube cell, is calculated with the following equation:

$$R_9=\sqrt{(\frac{1}{\pi})RP^2} \qquad \text{Equation 7-7}$$

Where:

R_9 = Radius of Moderator Surrounding Guide Tube

The area of an annular region is calculated by the difference between the outer circular area and the inner circular area. Equation 7-8 is the basis for the Equations 7-9 and 7-10 which determine the radii of the homogenized fuel zone and the outer moderator zone.

$$ARA=\pi(ORAR^2-IRAR^2) \qquad \text{Equation 7-8}$$

Where:

ARA = Annular Region Area
ORAR = Outer Radius of Annular Region
IRAR = Inner Radius of Annular Region

The area of the homogenized fuel zone surrounding the guide tube unit cell is equal to the number of fuel unit cells surrounding the guide tube multiplied by the area of a fuel unit cell. Consequently, the radius of the homogenized fuel zone is computed with the following equation:

$$R_{10}=\sqrt{(\frac{x}{\pi})RP^2+R_9^2} \qquad \text{Equation 7-9}$$

Where:

R_{10} = Radius of Homogenized Fuel and Moderator Zone

The mixture number of the homogenized fuel and moderator mixture must be specified as 500. The code then determines the composition of the region based upon the dimensions and mixtures specified in the fuel unit cell data block 5.

The moderator between assemblies is determined by calculating the total moderator volume and multiplying by the fraction of unit cells in the larger unit cell of the Path B model. The total moderator volume between assemblies is determined by the assembly pitch and the fuel cell pitch multiplied by the number of unit cells. The radius of the moderator between assemblies is calculated from the following equation:

$$R_{11}=\sqrt{\frac{(x+1)}{\pi*NCell}[AP^2-(NCell)(RP^2)]+R_{10}^2}$$ Equation 7-10

Where:

R_{11} = Radius of Moderator Between Assemblies
NCell = Number of Cells in Assembly
AP = Assembly Pitch

During cycle 2 the burnable poison rods are not present. For the Path B model of cycle 2, the guide tube is centralized with the homogenized fuel and moderator surrounding, followed by the between assembly moderator. Due to the nature of the SAS2H input file, eleven zones must be declared. Therefore, the dimensions of the burnable poison rod are used as the first six zones with a composition of moderator. The dimensions and compositions of zones 7, 8 and 9 are the same as those for the cycle 1 Path B model. These zones represent the guide tube and the moderator surrounding the guide tube inside the guide tube unit cell. Zones 10 and 11 have the same composition as in cycle 1; however, since the non-rodded guide tube is centralized and contains more moderator than if it were rodded, the number of fuel unit cells surrounding the guide tube is greater.

The number of fuel unit cells needed for each centralized guide tube unit cell is calculated by Equation 7-2 with an exception to Equations 7-3 and 7-4. Since there are no rodded guide tubes, Equations 7-3 and 7-4 are modified to reflect such conditions and are shown below:

$$\frac{F}{M}=\frac{(NFR)(\frac{\pi}{4})(POD)^2}{(NFR)[RP^2-(\frac{\pi}{4})(COD)^2]+(NGTE)[RP^2-(\frac{\pi}{4})(GTOD)^2+(\frac{\pi}{4})(GTID)^2]+[RP^2-(\frac{\pi}{4})(ITOD)^2+(\frac{\pi}{4})(ITID)^2]}$$ Equation 7-11

$$CUCMV=RP^2-(\frac{\pi}{4})(GTOD)^2+(\frac{\pi}{4})(GTID)^2$$ Equation 7-12

Equations 7-5 through 7-10 are used without modification to determine the dimensions of the of the Path B zones.

Table 7-1. Calculation of Fuel Unit Cell per Guide Tube Unit Cell

	F/M	CUCMV, cm^2	FV, cm^2	MV, cm^2	x
Cycle 1	0.5313	0.8859	0.6784	1.1425	6.5975
Cycle 2	0.5085	1.8626	0.6784	1.1425	9.7143

Table 7-2. Path B Model Dimensions

	Cycle 1		Cycle 2	
	Radius, cm	Composition	Radius, cm	Composition
R_1	0.2839	Air	0.2839	Moderator
R_2	0.3004	SS304	0.3004	Moderator
R_3	0.3086	Air	0.3086	Moderator
R_4	0.5029	Borosilicate Glass	0.5029	Moderator
R_5	0.5087	Air	0.5087	Moderator
R_6	0.5576	SS304	0.5576	Moderator
R_7	0.6502	Moderator	0.6502	Moderator
R_8	0.6934	Zircaloy-4	0.6934	Zircaloy-4
R_9	0.8068	Moderator	0.8068	Moderator
R_{10}	2.2238	Fuel/Moderator	2.6408	Fuel/Moderator
R_{11}	2.2290	Moderator	2.6470	Moderator

7.5 SCALE Input Data Blocks 9 Through 16

Data block 9 is used to describe the power history of the reactor. The specific power, fuel irradiation period, the length of downtime, the fraction of boron and moderator density, and the temperature during the cycle may all be defined. The specific power is in units of $MW/MTUO_2$ and must be converted from the average specific powers given in Table 4-5 with the relation of 238 g U is equal to 270 g UO_2. The irradiation period and length of downtime are both defined in days with values presented in Table 4-5. The moderator density is constant over both cycles and the boron fraction is determined by dividing the cycle interval average boron concentration found in Table 4-5 by the boron concentration specified in data block 4, Section 7.2. The boron fraction is specified with the command 'bfrac='. Values for the specific power and boron fraction are presented in Table 7-3. Please note that the specific power for sample N-9B-S during the second interval of the second cycle

is incorrect. The correct value is obtained by subtracting the burnup from the first interval of the second cycle from the final burnup, and dividing by the number of days irradiated in the second interval of the second cycle. The resulting specific power is 19.10 MW/MTU.

Table 7-3. Specific Power and Boron Fractions

	Cycle 1 Interval 1	Cycle 1 Interval 2	Cycle 2 Interval 1	Cycle 2 Interval 2
Boron Fraction	1	0.3793	1	0.3793
Specific Power, MW/MTUO_2				
Sample N-9B-S	18.39	17.76	17.25	16.84
Sample N-9B-N	28.41	26.53	24.99	23.79
Sample N-9C-J	34.82	31.83	29.38	27.47
Sample N-9C-D	39.38	35.48	32.27	29.78

Light elements and their effective weight, in kg per assembly, are entered in data block 10. Table 4-9 provides a generic set of light elements and their weights, in kg per MTUO_2. Since the fuel length is altered so that there is 1 MTUO_2 per assembly the use of light elements with weights of kg per MTUO_2 is appropriate.

Data blocks 11 through 15 describe the parameters used in radial shielding analysis of a shipping cask and are not necessary in performing the depletion analysis. Data block 16 denotes the end of the SCALE input.

7.6 Comparison of Calculated and Measured Concentrations

Comparisons of corresponding calculated and measured concentrations are performed on a percent difference basis. The difference between the measured and the calculated value is divided by the measured value to determine the accuracy of the SAS2H calculation. A positive percent difference represents an over-prediction by the code, while a negative percent difference represents an under-prediction by the code.

Measured concentrations presented in Table 4-10 have units of g of isotope per g of UO_2, while calculated concentrations presented in Table 7-4 have units of g of isotope per Metric Ton of UO_2. Therefore, the measured concentrations must be multiplied by 10^6 gUO_2/MTUO_2 to obtain similar units.

Measured concentrations presented in Table 4-11 have units of Curies per g UO_2. The activity of a particular isotope per gram UO_2 is converted to grams of that isotope per gram UO_2 using the half-life and molar mass presented in Section 4.1 and the following equation:

$$\left(\frac{Yg}{gUO_2}\right)=\left(\frac{XCi}{gUO_2}\right)\left(\frac{3.7x10^{10}Bq}{Ci}\right)\left(\frac{1}{\lambda}\right)\left(\frac{3.16x10^{7}s}{1yr}\right)\left(\frac{1mole}{6.02x10^{23}atoms}\right)\left(\frac{Mass}{1mole}\right) \qquad \text{Equation 7-13}$$

Where:

Y = Measured Value Used in Comparison (g isotope/g UO_2)
X = Measured Value from SAS2H (Ci isotope/g UO_2)

$$\lambda=\frac{\ln(2)}{T_{1/2}} \quad (yr^{-1})$$

$T_{1/2}$ = Half-life of Isotope (yr)
Mass = Molar Mass of Isotope

Percent differences for the actinides and fission products are presented in Table 7-5.

In an attempt to determine the impact of the assumption of a fuel temperature of 922 K, a sensitivity analysis is performed. Two assemblies representing low and high burnups, N-9B-S and N-9C-D, are used to observe the changes in isotopic concentrations with a 100 K decrease in fuel temperature. The results are reported in Tables 7-6 and 7-7.

7.7 Results

SAS2H predicted isotopic concentrations are presented in Table 7-4. The calculated concentrations are obtained through the methodology described in Sections 7.1 through 7.5, and with the input parameters defined in Section 4.1. Calculated concentrations are compared with measured concentrations as described in Section 7.6 to determine the accuracy of the SAS2H module. Results of the comparison, in the form of percent differences, are presented in Table 7-5. Also the results of the sensitivity analysis are reported in Tables 7-6 and 7-7.

Table 7-4. Calculated concentrations (g/MTUO_2)

Sample Identification	N-9B-S	N-9B-N	N-9C-J	N-9C-D
Burnup, GWd/MTU	16.02	23.81	28.47	31.66
^{99}Tc	3.61E2	5.19E2	6.07E2	6.65E2
^{235}U	1.11E4	7.64E3	6.21E3	5.32E3
^{236}U	2.13E3	2.66E3	2.88E3	2.99E3
^{238}U	8.47E5	8.42E5	8.38E5	8.35E5
^{237}Np	1.49E2	2.47E2	3.12E2	3.54E2
^{238}Pu	2.76E1	6.62E1	1.00E2	1.25E2
^{239}Pu	4.02E3	4.40E3	4.61E3	4.68E3
^{240}Pu	1.16E3	1.73E3	2.03E3	2.21E3
^{241}Pu	3.14E2	5.12E2	6.54E2	7.18E2

Table 7-5. Percent Difference Between Measured and Calculated [(C/M-1)*100]

Sample Identification	N-9B-S	N-9B-N	N-9C-J	N-9C-D
^{99}Tc	12.40	8.66	14.88	11.52
^{235}U	3.74	5.96	0.49	9.47
^{236}U	-2.74	-2.92	2.13	-0.33
^{238}U	0.00	-0.59	0.48	-0.83
^{237}Np	-3.87	-5.00	2.63	6.31
^{238}Pu	-2.47	-4.75	-12.28	-3.85
^{239}Pu	10.44	9.45	5.01	11.43
^{240}Pu	6.42	3.59	3.05	4.25
^{241}Pu	3.29	1.59	-3.96	3.76

Table 7-6. Sensitivity Analysis for Sample N-9B-S

	Calculated Concentration, g/MTUO$_2$		% Change in Calculated Concentrations
	Modeled Conditions	Fuel Temperature Decrease of 100 K	
^{99}Tc	3.61E2	3.61E2	0.00
^{235}U	1.11E4	1.11E4	0.00
^{236}U	2.13E3	2.14E3	0.47
^{238}U	8.47E5	8.47E5	0.00
^{237}Np	1.49E2	1.49E2	0.00
^{238}Pu	2.76E1	2.76E1	0.00
^{239}Pu	4.02E3	3.98E3	-1.00
^{240}Pu	1.16E3	1.16E3	0.00
^{241}Pu	3.14E2	3.11E2	-0.96

Table 7-7. Sensitivity Analysis for Sample N-9C-D

	Calculated Concentration, g/MTUO$_2$		% Change in Calculated Concentrations
	Modeled Conditions	Fuel Temperature Decrease of 100 K	
^{99}Tc	6.65E2	6.65E2	0.00
^{235}U	5.32E3	5.27E3	-0.94
^{236}U	2.99E3	3.00E3	0.33
^{238}U	8.35E5	8.35E5	0.00
^{237}Np	3.54E2	3.52E2	-0.56
^{238}Pu	1.25E2	1.25E2	0.00
^{239}Pu	4.68E3	4.62E3	-1.28
^{240}Pu	2.21E3	2.21E3	0.00
^{241}Pu	7.18E2	7.10E2	-1.11

8. Conclusions

The accuracy in which the SAS2H module is able to predict isotopic concentrations is indicated by the percent differences presented in Table 7-5. Inspection of such results reveals that the code has a tendency to over-predict ^{99}Tc, ^{235}U, ^{239}Pu, and ^{240}Pu, while it tends to under-predict ^{238}Pu. Percent differences from this analysis are compared with results from Reference 5.6, in which similar calculations were performed with a previous version of SCALE and the 27burnuplib cross section library. The concentrations calculated in Reference 5.6 for the most part agree with the concentrations calculated in this analysis; however, significant differences are seen for the plutonium isotopes. Since there is a significant difference in the Path B model from Reference 5.6 and the model contained within, it cannot be determined what is responsible for the differences between calculated concentrations.

Results from the sensitivity analysis of the isotopic concentrations with fuel temperature reveal that most calculated isotopic concentrations decreased by around 1.28% or less with a 100 K decrease in fuel temperature. However, ^{236}U is seen to increase slightly for a 100 K decrease in fuel temperature. For the sample at relatively low burnup, N-9B-S, the isotopes of ^{239}Pu and ^{241}Pu decreased by 1.00% and 0.96%, respectively; ^{236}U increased by 0.47% and the remaining isotopes are unchanged. For the sample at relatively high burnup, N-9C-D, the isotopes of ^{235}U, ^{237}Np, ^{239}Pu and ^{241}Pu all decreased by 1.28% or less, while ^{236}U increased by 0.33%. Since the actual fuel temperature is not expected to deviate more than 200 K from the temperature assumed, it is concluded that the assumption of a fuel temperature of 922 K does not significantly effect the calculated isotopic concentrations.

The SAS2H code normally predicts isotopic concentrations as a radial assembly average; however, measurements are performed on individual pellet samples. Therefore, local pellet conditions are modeled as closely as possible in this analysis so that a more realistic pellet composition can be determined. However, approximations made to obtain local pellet conditions will influence the calculated isotopic concentrations.

In general, the SAS2H module of SCALE is adequate in predicting isotopic concentrations for samples from H. B. Robinson, using the methodology presented. While over-prediction or under-prediction is significant for a few isotopes, the majority of calculated concentrations are very close to the measured concentrations. Although the assumptions for the fuel temperature do effect the resulting isotopic concentrations, the effect is not significant enough to account for all variation between the measured and calculated concentrations. More detailed operating data are expected to improve the accuracy of the calculated concentrations in relation to the corresponding measurements. It is recommended that future analyses use more detailed data if possible.

9. Attachments

Attachment I includes six pages and contains the input files used in the modeling of the H. B. Robinson samples. A description of the parameters contained within the input files is found in Sections 7.1 through 7.5.

Included in Attachment II is an extraction from each of the output files, containing the following information:

- echo of the SAS2H input deck,
- time/date stamp for when the SAS2H depletion calculation was performed,
- the output extraction of information pertinent to the Radiochemical Assay evaluations from the final ORIGEN calculation of the SAS2H depletion calculation.

rob9g16.input

```
=sas2h    parm=skipshipdata
H.B. Robinson N-9B-S 16.02 GWd/MTU, 11 cm, July 97
'
'
'
'   mixtures of fuel-pin-unitcell
'
44group     latticecell
'
'
'
uo2  1 den=9.944 1  922
      92234 0.023 92235 2.561 92236 0.013 92238 97.403  end
kr-83  1 0 1-20 922  end
kr-85  1 0 1-20 922  end
y-89   1 0 1-20 922  end
sr-90  1 0 1-20 922  end
zr-93  1 0 1-20 922  end
zr-94  1 0 1-20 922  end
zr-95  1 0 1-20 922  end
nb-94  1 0 1-20 922  end
mo-95  1 0 1-20 922  end
tc-99  1 0 1-20 922  end
ru-101 1 0 1-20 922  end
ru-106 1 0 1-20 922  end
rh-103 1 0 1-20 922  end
rh-105 1 0 1-20 922  end
pd-105 1 0 1-20 922  end
pd-108 1 0 1-20 922  end
ag-109 1 0 1-20 922  end
sb-124 1 0 1-20 922  end
xe-131 1 0 1-20 922  end
xe-132 1 0 1-20 922  end
xe-135 1 0 1-20 922  end
xe-136 1 0 1-20 922  end
cs-134 1 0 1-20 922  end
cs-135 1 0 1-20 922  end
cs-137 1 0 1-20 922  end
ba-136 1 0 1-20 922  end
la-139 1 0 1-20 922  end
pr-141 1 0 1-20 922  end
pr-143 1 0 1-20 922  end
ce-144 1 0 1-20 922  end
nd-143 1 0 1-20 922  end
nd-145 1 0 1-20 922  end
nd-147 1 0 1-20 922  end
pm-147 1 0 1-20 922  end
pm-148 1 0 1-20 922  end
sm-147 1 0 1-20 922  end
sm-149 1 0 1-20 922  end
sm-150 1 0 1-20 922  end
sm-151 1 0 1-20 922  end
sm-152 1 0 1-20 922  end
eu-153 1 0 1-20 922  end
eu-154 1 0 1-20 922  end
eu-155 1 0 1-20 922  end
gd-155 1 0 1-20 922  end
'
arbm-zirc4 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
        40000 98.18 2 1.0 595   end
'
h2o 3 den=0.7544 1 559  end
arbm-bormod 0.7544 1 1 0 0 5000 100 3 652.5e-6 559  end
'
n    4 0 5-5 559  end
'
ss304 5 1 559  end
'
o    6 0 0.04497 559  end
na   6 0 0.00165 559  end
al   6 0 0.00058 559  end
si   6 0 0.01799 559  end
k    6 0 0.00011 559  end
b-10  6 0 9.595-4 559  end
b-11  6 0 3.863-3 559  end
'
'    653 ppm boron (wt) in moderator
'------------------------
end comp
'
'------------------------
'fuel-pin-cell geometry:
'
squarepitch  1.43 0.9294 1 3 1.0719 2 0.9484 0  end
'
'------------------------
'
'
'    assembly and cycle parameters
'
npin/assm=204 fuelngth=726.63 ncycles=4 nlib/cyc=3
printlevel=5 lightel=9 inplevel=2 numztotal=11
mxrepeats=0  end
'
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
'
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
'
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
'
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
'
power=18.39 burn=243.5  down=40  end
power=17.76 burn=243.5  down=64  bfrac=0.3793  end
power=17.25 burn=156.0  down=39  bfrac=1.0  end
power=16.84 burn=156.0  down=3936  bfrac=0.3793  end
 o 119 cr 5.2 mn 0.29
 fe 11 co 0.066 ni 8.7
 zr 195 nb 0.63 sn 3.2
'
'  the above light elements converted to kg per mtuo2
'------------------------
'
end
```

rob9g23.input

```
=sas2h    parm=skipshipdata
H.B. Robinson N-9B-N 23.81 GWd/MTU, 26 cm, July 97
'
'
'
'  mixtures of fuel-pin-unitcell
'
44group    latticecell
'
'
'
uo2  1 den=9.944 1  922
      92234 0.023 92235 2.561 92236 0.013 92238 97.403  end
kr-83  1 0 1-20 922  end
kr-85  1 0 1-20 922  end
y-89  1 0 1-20 922  end
sr-90  1 0 1-20 922  end
zr-93  1 0 1-20 922  end
zr-94  1 0 1-20 922  end
zr-95  1 0 1-20 922  end
nb-94  1 0 1-20 922  end
mo-95  1 0 1-20 922  end
tc-99  1 0 1-20 922  end
ru-101 1 0 1-20 922  end
ru-106 1 0 1-20 922  end
rh-103 1 0 1-20 922  end
rh-105 1 0 1-20 922  end
pd-105 1 0 1-20 922  end
pd-108 1 0 1-20 922  end
ag-109 1 0 1-20 922  end
sb-124 1 0 1-20 922  end
xe-131 1 0 1-20 922  end
xe-132 1 0 1-20 922  end
xe-135 1 0 1-20 922  end
xe-136 1 0 1-20 922  end
cs-134 1 0 1-20 922  end
cs-135 1 0 1-20 922  end
cs-137 1 0 1-20 922  end
ba-136 1 0 1-20 922  end
la-139 1 0 1-20 922  end
pr-141 1 0 1-20 922  end
pr-143 1 0 1-20 922  end
ce-144 1 0 1-20 922  end
nd-143 1 0 1-20 922  end
nd-145 1 0 1-20 922  end
nd-147 1 0 1-20 922  end
pm-147 1 0 1-20 922  end
pm-148 1 0 1-20 922  end
sm-147 1 0 1-20 922  end
sm-149 1 0 1-20 922  end
sm-150 1 0 1-20 922  end
sm-151 1 0 1-20 922  end
sm-152 1 0 1-20 922  end
eu-153 1 0 1-20 922  end
eu-154 1 0 1-20 922  end
eu-155 1 0 1-20 922  end
gd-155 1 0 1-20 922  end
'
arbm-zirc4 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
       40000 98.18 2 1.0 595   end
'
h2o 3 den=0.7538 1 559  end
arbm-bormod 0.7538 1 1 0 0 5000 100 3 652.5e-6 559  end
'
n    4 0 5-5 559  end
'
ss304 5 1 559  end
'
o    6 0 0.04497 559  end
na   6 0 0.00165 559  end
al   6 0 0.00058 559  end
si   6 0 0.01799 559  end
k    6 0 0.00011 559  end
b-10  6 0 9.595-4 559  end
b-11  6 0 3.863-3 559  end
'
'    653 ppm boron (wt) in moderator
'-------------------------
end comp
'
'-------------------------
'fuel-pin-cell geometry:
'
squarepitch  1.43 0.9294 1 3 1.0719 2 0.9484 0  end
'
'-------------------------
'
'
'    assembly and cycle parameters
'
npin/assm=204 fuelngth=726.63 ncycles=4 nlib/cyc=3
printlevel=5 lightel=9 inplevel=2 numztotal=11
mxrepeats=0  end
'
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
'
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
'
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
'
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
'
power=28.41 burn=243.5  down=40  end
power=26.53 burn=243.5  down=64  bfrac=0.3793  end
power=24.99 burn=156.0  down=39  bfrac=1.0  end
power=23.79 burn=156.0  down=3936  bfrac=0.3793  end
 o 119 cr 5.2 mn 0.29
 fe 11 co 0.066 ni 8.7
 zr 195 nb 0.63 sn 3.2
'
'  the above light elements converted to kg per mtuo2
'-------------------------
'
end
```

rob9g28.input

```
=sas2h    parm=skipshipdata
H.B. Robinson N-9C-J 28.47 GWd/MTU, 199 cm, July 97
'
'
'
'   mixtures of fuel-pin-unitcell
'
44group    latticecell
'
'
'
uo2  1 den=9.944 1  922
      92234 0.023 92235 2.561 92236 0.013 92238 97.403  end
kr-83  1 0 1-20 922  end
kr-85  1 0 1-20 922  end
y-89   1 0 1-20 922  end
sr-90  1 0 1-20 922  end
zr-93  1 0 1-20 922  end
zr-94  1 0 1-20 922  end
zr-95  1 0 1-20 922  end
nb-94  1 0 1-20 922  end
mo-95  1 0 1-20 922  end
tc-99  1 0 1-20 922  end
ru-101 1 0 1-20 922  end
ru-106 1 0 1-20 922  end
rh-103 1 0 1-20 922  end
rh-105 1 0 1-20 922  end
pd-105 1 0 1-20 922  end
pd-108 1 0 1-20 922  end
ag-109 1 0 1-20 922  end
sb-124 1 0 1-20 922  end
xe-131 1 0 1-20 922  end
xe-132 1 0 1-20 922  end
xe-135 1 0 1-20 922  end
xe-136 1 0 1-20 922  end
cs-134 1 0 1-20 922  end
cs-135 1 0 1-20 922  end
cs-137 1 0 1-20 922  end
ba-136 1 0 1-20 922  end
la-139 1 0 1-20 922  end
pr-141 1 0 1-20 922  end
pr-143 1 0 1-20 922  end
ce-144 1 0 1-20 922  end
nd-143 1 0 1-20 922  end
nd-145 1 0 1-20 922  end
nd-147 1 0 1-20 922  end
pm-147 1 0 1-20 922  end
pm-148 1 0 1-20 922  end
sm-147 1 0 1-20 922  end
sm-149 1 0 1-20 922  end
sm-150 1 0 1-20 922  end
sm-151 1 0 1-20 922  end
sm-152 1 0 1-20 922  end
eu-153 1 0 1-20 922  end
eu-154 1 0 1-20 922  end
eu-155 1 0 1-20 922  end
gd-155 1 0 1-20 922  end
'
arbm-zirc4 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
       40000 98.18 2 1.0 595   end
'
h2o 3 den=0.7208 1 576  end
arbm-bormod 0.7208 1 1 0 0 5000 100 3 652.5e-6 576  end
'
n    4 0 5-5 576  end
'
ss304 5 1 576  end
'
o    6 0 0.04497 576  end
na   6 0 0.00165 576  end
al   6 0 0.00058 576  end
si   6 0 0.01799 576  end
k    6 0 0.00011 576  end
b-10  6 0 9.595-4 576  end
b-11  6 0 3.863-3 576  end
'
'    653 ppm boron (wt) in moderator
'-----------------------
end comp
'
'-----------------------
'fuel-pin-cell geometry:
'
squarepitch  1.43 0.9294 1 3 1.0719 2 0.9484 0  end
'
'-----------------------
'
'
'    assembly and cycle parameters
'
npin/assm=204 fuelngth=726.63 ncycles=4 nlib/cyc=3
printlevel=5 lightel=9 inplevel=2 numztotal=11
mxrepeats=0  end
'
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
'
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
'
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
'
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
'
power=34.82 burn=243.5  down=40  end
power=31.83 burn=243.5  down=64  bfrac=0.3793   end
power=29.38 burn=156.0  down=39  bfrac=1.0   end
power=27.47 burn=156.0  down=3631  bfrac=0.3793   end
 o 119 cr 5.2 mn 0.29
 fe 11 co 0.066 ni 8.7
 zr 195 nb 0.63 sn 3.2
'
'  the above light elements converted to kg per mtuo2
'-----------------------
'
end
```

rob9g32.input

```
=sas2h    parm=skipshipdata
H.B. Robinson N-9C-D 31.66 GWd/MTU, 226 cm July 97
'
'
'
'  mixtures of fuel-pin-unitcell
'
44group    latticecell
'
'
'
uo2  1 den=9.944 1  922
      92234 0.023 92235 2.561 92236 0.013 92238 97.403  end
kr-83  1 0 1-20 922  end
kr-85  1 0 1-20 922  end
y-89   1 0 1-20 922  end
sr-90  1 0 1-20 922  end
zr-93  1 0 1-20 922  end
zr-94  1 0 1-20 922  end
zr-95  1 0 1-20 922  end
nb-94  1 0 1-20 922  end
mo-95  1 0 1-20 922  end
tc-99  1 0 1-20 922  end
ru-101 1 0 1-20 922  end
ru-106 1 0 1-20 922  end
rh-103 1 0 1-20 922  end
rh-105 1 0 1-20 922  end
pd-105 1 0 1-20 922  end
pd-108 1 0 1-20 922  end
ag-109 1 0 1-20 922  end
sb-124 1 0 1-20 922  end
xe-131 1 0 1-20 922  end
xe-132 1 0 1-20 922  end
xe-135 1 0 1-20 922  end
xe-136 1 0 1-20 922  end
cs-134 1 0 1-20 922  end
cs-135 1 0 1-20 922  end
cs-137 1 0 1-20 922  end
ba-136 1 0 1-20 922  end
la-139 1 0 1-20 922  end
pr-141 1 0 1-20 922  end
pr-143 1 0 1-20 922  end
ce-144 1 0 1-20 922  end
nd-143 1 0 1-20 922  end
nd-145 1 0 1-20 922  end
nd-147 1 0 1-20 922  end
pm-147 1 0 1-20 922  end
pm-148 1 0 1-20 922  end
sm-147 1 0 1-20 922  end
sm-149 1 0 1-20 922  end
sm-150 1 0 1-20 922  end
sm-151 1 0 1-20 922  end
sm-152 1 0 1-20 922  end
eu-153 1 0 1-20 922  end
eu-154 1 0 1-20 922  end
eu-155 1 0 1-20 922  end
gd-155 1 0 1-20 922  end
'
arbm-zirc4 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
      40000 98.18 2 1.0 595   end
'
h2o 3 den=0.7135 1 579  end
arbm-bormod 0.7135 1 1 0 0 5000 100 3 652.5e-6 579  end
'
n    4 0 5-5 579  end
'
ss304 5 1 576  end
'
o    6 0 0.04497 579  end
na   6 0 0.00165 579  end
al   6 0 0.00058 579  end
si   6 0 0.01799 579  end
k    6 0 0.00011 579  end
b-10  6 0 9.595-4 579  end
b-11  6 0 3.863-3 579  end
'
'    653 ppm boron (wt) in moderator
'-----------------------
end comp
'
'-----------------------
'fuel-pin-cell geometry:
'
squarepitch  1.43 0.9294 1 3 1.0719 2 0.9484 0  end
'
'-----------------------
'
'
'
'    assembly and cycle parameters
'
npin/assm=204 fuelngth=726.63 ncycles=4 nlib/cyc=3
printlevel=5 lightel=9 inplevel=2 numztotal=11
mxrepeats=0  end
'
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
'
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
'
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
'
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
'
power=39.38 burn=243.5  down=40  end
power=35.48 burn=243.5  down=64  bfrac=0.3793  end
power=32.27 burn=156.0  down=39  bfrac=1.0  end
power=29.78 burn=156.0  down=3631  bfrac=0.3793  end
 o 119 cr 5.2 mn 0.29
 fe 11 co 0.066 ni 8.7
 zr 195 nb 0.63 sn 3.2
'
'  the above light elements converted to kg per mtuo2
'-----------------------
'
end
```

rob9g16less100.input

```
=sas2h    parm=skipshipdata
H.B. Robinson N-9B-S 16.02 GWd/MTU, 11 cm, July 97
'
'
'
'  mixtures of fuel-pin-unitcell
'
44group    latticecell
'
'
'
uo2  1 den=9.944 1  822
      92234 0.023 92235 2.561 92236 0.013 92238 97.403  end
kr-83  1 0 1-20 822  end
kr-85  1 0 1-20 822  end
y-89  1 0 1-20 822  end
sr-90  1 0 1-20 822  end
zr-93  1 0 1-20 822  end
zr-94  1 0 1-20 822  end
zr-95  1 0 1-20 822  end
nb-94  1 0 1-20 822  end
mo-95  1 0 1-20 822  end
tc-99  1 0 1-20 822  end
ru-101 1 0 1-20 822  end
ru-106 1 0 1-20 822  end
rh-103 1 0 1-20 822  end
rh-105 1 0 1-20 822  end
pd-105 1 0 1-20 822  end
pd-108 1 0 1-20 822  end
ag-109 1 0 1-20 822  end
sb-124 1 0 1-20 822  end
xe-131 1 0 1-20 822  end
xe-132 1 0 1-20 822  end
xe-135 1 0 1-20 822  end
xe-136 1 0 1-20 822  end
cs-134 1 0 1-20 822  end
cs-135 1 0 1-20 822  end
cs-137 1 0 1-20 822  end
ba-136 1 0 1-20 822  end
la-139 1 0 1-20 822  end
pr-141 1 0 1-20 822  end
pr-143 1 0 1-20 822  end
ce-144 1 0 1-20 822  end
nd-143 1 0 1-20 822  end
nd-145 1 0 1-20 822  end
nd-147 1 0 1-20 822  end
pm-147 1 0 1-20 822  end
pm-148 1 0 1-20 822  end
sm-147 1 0 1-20 822  end
sm-149 1 0 1-20 822  end
sm-150 1 0 1-20 822  end
sm-151 1 0 1-20 822  end
sm-152 1 0 1-20 822  end
eu-153 1 0 1-20 822  end
eu-154 1 0 1-20 822  end
eu-155 1 0 1-20 822  end
gd-155 1 0 1-20 822  end
'
arbm-zirc4 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
      40000 98.18 2 1.0 595  end
'
h2o 3 den=0.7544 1 559  end
arbm-bormod 0.7544 1 1 0 0 5000 100 3 652.5e-6 559  end
'
n   4 0 5-5 559  end
'
ss304 5 1 559  end
'
o   6 0 0.04497 559  end
na  6 0 0.00165 559  end
al  6 0 0.00058 559  end
si  6 0 0.01799 559  end
k   6 0 0.00011 559  end
b-10  6 0 9.595-4 559  end
b-11  6 0 3.863-3 559  end
'
'   653 ppm boron (wt) in moderator
'-------------------------
end comp
'
'-------------------------
'fuel-pin-cell geometry:
'
squarepitch  1.43 0.9294 1 3 1.0719 2 0.9484 0  end
'
'-------------------------
'
'
'    assembly and cycle parameters
'
npin/assm=204 fuelngth=726.63 ncycles=4 nlib/cyc=3
printlevel=5 lightel=9 inplevel=2 numztotal=11
mxrepeats=0  end
'
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
'
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
'
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
'
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
'
power=18.39 burn=243.5  down=40  end
power=17.76 burn=243.5  down=64  bfrac=0.3793  end
power=17.25 burn=156.0  down=39  bfrac=1.0  end
power=16.84 burn=156.0  down=3936  bfrac=0.3793  end
 o 119 cr 5.2 mn 0.29
 fe 11 co 0.066 ni 8.7
 zr 195 nb 0.63 sn 3.2
'
'  the above light elements converted to kg per mtuo2
'-------------------------
'
end
```

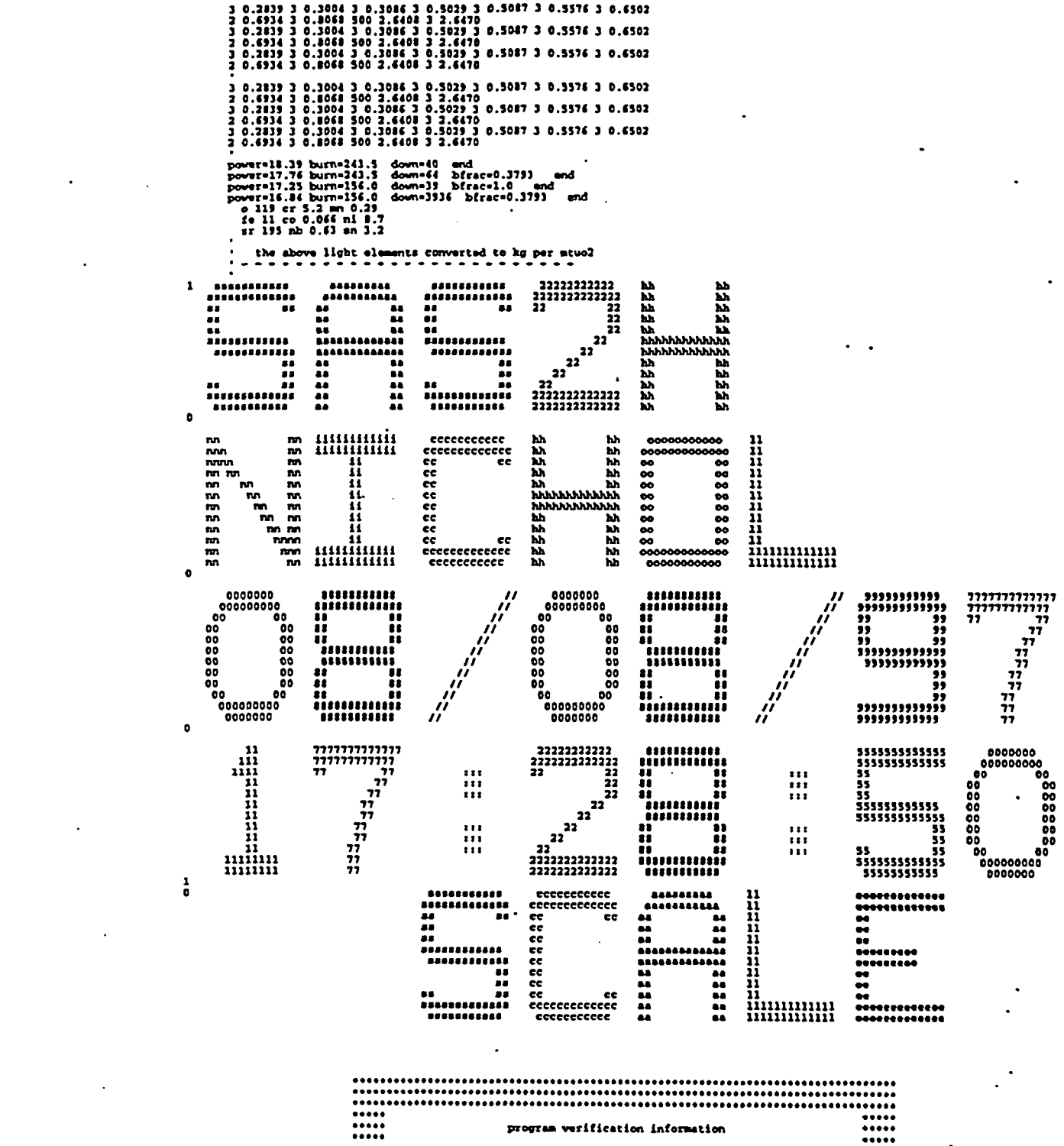
rob9g32less100.input

```
=sas2h   parm=skipshipdata
H.B. Robinson N-9C-D 31.66 GWd/MTU, 226 cm July 97
'
'
'
'   mixtures of fuel-pin-unitcell
'
44group     latticecell
'
'
'
uo2  1 den=9.944 1  822
      92234 0.023 92235 2.561 92236 0.013 92238 97.403  end
kr-83  1 0 1-20 822  end
kr-85  1 0 1-20 822  end
y-89   1 0 1-20 822  end
sr-90  1 0 1-20 822  end
zr-93  1 0 1-20 822  end
zr-94  1 0 1-20 822  end
zr-95  1 0 1-20 822  end
nb-94  1 0 1-20 822  end
mo-95  1 0 1-20 822  end
tc-99  1 0 1-20 822  end
ru-101 1 0 1-20 822  end
ru-106 1 0 1-20 822  end
rh-103 1 0 1-20 822  end
rh-105 1 0 1-20 822  end
pd-105 1 0 1-20 822  end
pd-108 1 0 1-20 822  end
ag-109 1 0 1-20 822  end
sb-124 1 0 1-20 822  end
xe-131 1 0 1-20 822  end
xe-132 1 0 1-20 822  end
xe-135 1 0 1-20 822  end
xe-136 1 0 1-20 822  end
cs-134 1 0 1-20 822  end
cs-135 1 0 1-20 822  end
cs-137 1 0 1-20 822  end
ba-136 1 0 1-20 822  end
la-139 1 0 1-20 822  end
pr-141 1 0 1-20 822  end
pr-143 1 0 1-20 822  end
ce-144 1 0 1-20 822  end
nd-143 1 0 1-20 822  end
nd-145 1 0 1-20 822  end
nd-147 1 0 1-20 822  end
pm-147 1 0 1-20 822  end
pm-148 1 0 1-20 822  end
sm-147 1 0 1-20 822  end
sm-149 1 0 1-20 822  end
sm-150 1 0 1-20 822  end
sm-151 1 0 1-20 822  end
sm-152 1 0 1-20 822  end
eu-153 1 0 1-20 822  end
eu-154 1 0 1-20 822  end
eu-155 1 0 1-20 822  end
gd-155 1 0 1-20 822  end
'
arbm-zirc4 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
       40000 98.18 2 1.0 595   end
'
h2o 3 den=0.7135 1 579  end
arbm-bormod 0.7135 1 1 0 0 5000 100 3 652.5e-6 579  end
'
n    4 0 5-5 579  end
'
ss304 5 1 576  end
'
o    6 0 0.04497 579  end
na   6 0 0.00165 579  end
al   6 0 0.00058 579  end
si   6 0 0.01799 579  end
k    6 0 0.00011 579  end
b-10  6 0 9.595-4 579  end
b-11  6 0 3.863-3 579  end
'
'    653 ppm boron (wt) in moderator
'------------------------
end comp
'
'------------------------
'fuel-pin-cell geometry:
'
squarepitch  1.43 0.9294 1 3 1.0719 2 0.9484 0  end
'
'------------------------
'
'
'    assembly and cycle parameters
'
npin/assm=204 fuelngth=726.63 ncycles=4 nlib/cyc=3
printlevel=5 lightel=9 inplevel=2 numztotal=11
mxrepeats=0  end
'
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
'
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
'
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
'
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
'
power=39.38 burn=243.5  down=40  end
power=35.48 burn=243.5  down=64  bfrac=0.3793  end
power=32.27 burn=156.0  down=39  bfrac=1.0  end
power=29.78 burn=156.0  down=3631  bfrac=0.3793  end
 o 119 cr 5.2 mn 0.29
 fe 11 co 0.066 ni 8.7
 zr 195 nb 0.63 sn 3.2
'
'  the above light elements converted to kg per mtuo2
'------------------------
'
end
```

rob9g16.sum

```
0*************************************************************************
 *                                                                       *
 *                    SCALE4.3  Bulletin  Board                          *
 *                    --------  --------  -----                          *
 *                                                                       *
 *                      Welcome to SCALE-4.3.                            *
 *                                                                       *
 *                                                                       *
 *************************************************************************
1          primary module access and input record ( scale driver - 95/03/29 - 09:06:37 )
-   module sas2h    will be called
     N.B. Robinson N-9B-S 16.02 GWd/MTU, 11 cm,  July 97
     '
     '
     '
     '    mixtures of fuel-pin-unitcell
     '
     44group      latticecell
     '
     '
     '
     uo2  1 den=9.944 1  922
              92234 0.023 92235 2.561 92236 0.013 92238 97.403  end
     kr-83  1 0 1-20 922  end
     kr-85  1 0 1-20 922  end
     y-89   1 0 1-20 922  end
     sr-90  1 0 1-20 922  end
     sr-93  1 0 1-20 922  end
     zr-94  1 0 1-20 922  end
     zr-95  1 0 1-20 922  end
     nb-94  1 0 1-20 922  end
     mo-95  1 0 1-20 922  end
     tc-99  1 0 1-20 922  end
     ru-101 1 0 1-20 922  end
     ru-106 1 0 1-20 922  end
     rh-103 1 0 1-20 922  end
     rh-105 1 0 1-20 922  end
     pd-105 1 0 1-20 922  end
     pd-108 1 0 1-20 922  end
     ag-109 1 0 1-20 922  end
     sb-124 1 0 1-20 922  end
     xe-131 1 0 1-20 922  end
     xe-132 1 0 1-20 922  end
     xe-135 1 0 1-20 922  end
     xe-136 1 0 1-20 922  end
     cs-134 1 0 1-20 922  end
     cs-135 1 0 1-20 922  end
     cs-137 1 0 1-20 922  end
     ba-136 1 0 1-20 922  end
     la-139 1 0 1-20 922  end
     pr-141 1 0 1-20 922  end
     pr-143 1 0 1-20 922  end
     ce-144 1 0 1-20 922  end
     nd-143 1 0 1-20 922  end
     nd-145 1 0 1-20 922  end
     nd-147 1 0 1-20 922  end
     pm-147 1 0 1-20 922  end
     pm-148 1 0 1-20 922  end
     sm-147 1 0 1-20 922  end
     sm-149 1 0 1-20 922  end
     sm-150 1 0 1-20 922  end
     sm-151 1 0 1-20 922  end
     sm-152 1 0 1-20 922  end
     eu-153 1 0 1-20 922  end
     eu-154 1 0 1-20 922  end
     eu-155 1 0 1-20 922  end
     gd-155 1 0 1-20 922  end
     '
     arbm-zirc4 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
              40000 98.18 2 1.0 595   end
     '
     h2o 3 den=0.7544 1 559  end
     arbm-bormod 0.7544 1 1 0 0 5000 100 3 652.5e-6 559  end
     '
     n      4 0 5-5 559  end
     '
     ss304 5 1 559  end
     '
     o      6 0 0.04497 559  end
     na     6 0 0.00165 559  end
     al     6 0 0.00058 559  end
     si     6 0 0.01799 559  end
     k      6 0 0.00011 559  end
     b-10   6 0 9.595-4 559  end
     b-11   6 0 3.863-3 559  end
     '
     '       653 ppm boron (wt) in moderator
     ' - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
     end comp
     '
     ' - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
     'fuel-pin-cell geometry:
     '
     squarepitch  1.43 0.9294 1 3 1.0719 2 0.9484 0  end
     '
     ' - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
     '
     '
     '       assembly and cycle parameters
     '
     npin/assm=204 fuelngth=726.63 ncycles=4 nlib/cyc=3
     printlevel=5 lightel=9 inplevel=2 numztotal=11
     mxrepeats=0  end
     '
     4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
     2 0.6934 3 0.8068 500 2.2238 3 2.2290
     4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
     2 0.6934 3 0.8068 500 2.2238 3 2.2290
     4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
```

```
2 0.6934 3 0.8068 500 2.2238 3 2.2290
*
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
*
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
*
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
*
power=18.39 burn=241.5  down=40  end
power=17.76 burn=243.5  down=64  bfrac=0.3793   end
power=17.25 burn=156.0  down=39  bfrac=1.0   end
power=16.84 burn=156.0  down=3936  bfrac=0.3793   end
  o 119 cr 5.2 mn 0.29
  fe 11 co 0.066 ni 8.7
  sr 195 nb 0.63 sn 3.2
*
*   the above light elements converted to kg per mtuo2
*  - - - - - - - - - - - - - - - - - - - - - - - -
*
```



```
*****                    code system:    scale  version:    4.3                 *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
*****                 program:  sas2                                             *****
*****                                                                            *****
*****            creation date:  03/07/97                                        *****
*****                                                                            *****
*****                 library:  /opt/neut/$scale4.3/bin                          *****
*****                                                                            *****
*****                                                                            *****
*****       this is not a   scale  configuration controlled code                 *****
*****                                                                            *****
*****                 jobname:  nichol                                           *****
*****                                                                            *****
*****       date of execution:  08/08/97                                         *****
*****                                                                            *****
*****       time of execution:  17:28:50                                         *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
```

```
1
0
0
0
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
              initial  1E-18 d
     o 16    1.19E+05  1.19E+05
   total     3.45E+05  3.45E+05
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
              initial  1E-18 d
     u234    2.03E+02  2.03E+02
     u235    2.26E+04  2.26E+04
     u236    1.15E+02  1.15E+02
     u238    8.58E+05  8.58E+05
   total     8.81E+05  8.81E+05
0                                        basis =
0                     initial        20.3 d        40.6 d        60.9 d        81.2 d        81.2 d
0                     initial        20.3 d        40.6 d        60.9 d        81.2 d        81.2 d
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
              initial  656.0 d  1312.0 d  1968.0 d  2624.0 d  3280.0 d  3936.0 d
     o 16    1.19E+05  1.19E+05  1.19E+05  1.19E+05  1.19E+05  1.19E+05  1.19E+05
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
              initial  656.0 d  1312.0 d  1968.0 d  2624.0 d  3280.0 d  3936.0 d
    mo 95    6.94E+00  8.14E+00  8.15E+00  8.15E+00  8.15E+00  8.15E+00  8.15E+00
    tc 99    6.63E-06  6.72E-06  6.72E-06  6.72E-06  6.72E-06  6.72E-06  6.72E-06
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
              initial  656.0 d  1312.0 d  1968.0 d  2624.0 d  3280.0 d  3936.0 d
   total     3.45E+05  3.45E+05  3.45E+05  3.45E+05  3.45E+05  3.45E+05  3.45E+05
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
              initial  656.0 d  1312.0 d  1968.0 d  2624.0 d  3280.0 d  3936.0 d
     u233    1.01E-03  1.12E-03  1.21E-03  1.29E-03  1.38E-03  1.47E-03  1.56E-03
     u234    1.53E+02  1.53E+02  1.53E+02  1.54E+02  1.54E+02  1.55E+02  1.55E+02
     u235    1.11E+04  1.11E+04  1.11E+04  1.11E+04  1.11E+04  1.11E+04  1.11E+04
     u236    2.13E+03  2.13E+03  2.13E+03  2.13E+03  2.13E+03  2.13E+03  2.13E+03
     u238    8.47E+05  8.47E+05  8.47E+05  8.47E+05  8.47E+05  8.47E+05  8.47E+05
    np237    1.44E+02  1.47E+02  1.47E+02  1.48E+02  1.48E+02  1.49E+02  1.49E+02
    pu236    1.04E-04  6.81E-05  4.43E-05  2.89E-05  1.88E-05  1.22E-05  7.96E-06
    pu238    2.70E+01  2.95E+01  2.92E+01  2.88E+01  2.84E+01  2.80E+01  2.76E+01
    pu239    2.70E+01  2.95E+01  2.92E+01  2.88E+01  2.84E+01  2.80E+01  2.76E+01
    pu239    3.99E+03  4.03E+03  4.03E+03  4.03E+03  4.03E+03  4.03E+03  4.02E+03
    pu240    1.16E+03  1.16E+03  1.16E+03  1.16E+03  1.16E+03  1.16E+03  1.16E+03
    pu241    5.29E+02  4.85E+02  4.45E+02  4.08E+02  3.74E+02  3.43E+02  3.14E+02
    pu242    1.07E+02  1.07E+02  1.07E+02  1.07E+02  1.07E+02  1.07E+02  1.07E+02
    am241    1.93E+01  6.32E+01  1.03E+02  1.40E+02  1.73E+02  2.04E+02  2.32E+02
   am242m    3.29E-01  3.26E-01  3.24E-01  3.21E-01  3.18E-01  3.15E-01  3.12E-01
    am243    1.08E+01  1.08E+01  1.08E+01  1.08E+01  1.08E+01  1.08E+01  1.08E+01
   total     8.67E+05  8.67E+05  8.67E+05  8.67E+05  8.67E+05  8.67E+05  8.67E+05
0                                        element concentrations, grams
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
              initial  656.0 d  1312.0 d  1968.0 d  2624.0 d  3280.0 d  3936.0 d
    mo 95    2.90E+02  3.42E+02  3.42E+02  3.42E+02  3.42E+02  3.42E+02  3.42E+02
    tc 99    3.59E+02  3.61E+02  3.61E+02  3.61E+02  3.61E+02  3.61E+02  3.61E+02
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
              initial  656.0 d  1312.0 d  1968.0 d  2624.0 d  3280.0 d  3936.0 d
    ru101    3.31E+02  3.31E+02  3.31E+02  3.31E+02  3.31E+02  3.31E+02  3.31E+02
    rh103    2.11E+02  2.32E+02  2.32E+02  2.32E+02  2.32E+02  2.32E+02  2.32E+02
    ag109    3.40E+01  3.40E+01  3.40E+01  3.40E+01  3.40E+01  3.40E+01  3.40E+01
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
              initial  656.0 d  1312.0 d  1968.0 d  2624.0 d  3280.0 d  3936.0 d
    nd143    4.00E+02  4.11E+02  4.11E+02  4.11E+02  4.11E+02  4.11E+02  4.11E+02
    nd145    3.11E+02  3.11E+02  3.11E+02  3.11E+02  3.11E+02  3.11E+02  3.11E+02
    sm147    4.05E+01  8.12E+01  1.07E+02  1.22E+02  1.32E+02  1.38E+02  1.42E+02
    sm149    1.52E+00  2.08E+00  2.08E+00  2.08E+00  2.08E+00  2.08E+00  2.08E+00
    sm150    1.16E+02  1.16E+02  1.16E+02  1.16E+02  1.16E+02  1.16E+02  1.16E+02
    sm151    8.37E+00  8.37E+00  8.26E+00  8.15E+00  8.03E+00  7.92E+00  7.81E+00
    eu151    1.77E-02  1.34E-01  2.49E-01  3.63E-01  4.75E-01  5.85E-01  6.94E-01
    sm152    6.24E+01  6.24E+01  6.24E+01  6.24E+01  6.24E+01  6.24E+01  6.24E+01
    eu153    3.91E+01  3.94E+01  3.94E+01  3.94E+01  3.94E+01  3.94E+01  3.94E+01
    gd155    1.81E-02  4.24E-01  7.35E-01  9.74E-01  1.16E+00  1.30E+00  1.40E+00
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
              initial  656.0 d  1312.0 d  1968.0 d  2624.0 d  3280.0 d  3936.0 d
   total     1.45E+04  1.45E+04  1.45E+04  1.45E+04  1.45E+04  1.45E+04  1.45E+04
```

rob9g23.sum

```
0*************************************************************************
 *                                                                       *
 *                    SCALE4.3  Bulletin  Board                          *
 *                    --------  --------  -----                          *
 *                                                                       *
 *                      Welcome to SCALE-4.3.                            *
 *                                                                       *
 *                                                                       *
 *************************************************************************
1        primary module access and input record ( scale driver - 95/03/29 - 09:06:37 )
-   module sas2h    will be called
     N.B. Robinson N-9B-W 23.81 GWd/MTU, 26 cm, July 97
     '
     '
     '
     '    mixtures of fuel-pin-unitcell
     '
     44group      latticecell
     '
     '
     '
     uo2  1 den=9.944 1  922
             92234 0.023 92235 2.561 92236 0.013 92238 97.403  end
     kr-83  1 0 1-20 922  end
     kr-85  1 0 1-20 922  end
     y-89   1 0 1-20 922  end
     sr-90  1 0 1-20 922  end
     sr-93  1 0 1-20 922  end
     sr-94  1 0 1-20 922  end
     sr-95  1 0 1-20 922  end
     nb-94  1 0 1-20 922  end
     mo-95  1 0 1-20 922  end
     tc-99  1 0 1-20 922  end
     ru-101 1 0 1-20 922  end
     ru-106 1 0 1-20 922  end
     rh-103 1 0 1-20 922  end
     rh-105 1 0 1-20 922  end
     pd-105 1 0 1-20 922  end
     pd-108 1 0 1-20 922  end
     ag-109 1 0 1-20 922  end
     sb-124 1 0 1-20 922  end
     xe-131 1 0 1-20 922  end
     xe-132 1 0 1-20 922  end
     xe-135 1 0 1-20 922  end
     xe-136 1 0 1-20 922  end
     cs-134 1 0 1-20 922  end
     cs-135 1 0 1-20 922  end
     cs-137 1 0 1-20 922  end
     ba-136 1 0 1-20 922  end
     la-139 1 0 1-20 922  end
     pr-141 1 0 1-20 922  end
     pr-143 1 0 1-20 922  end
     ce-144 1 0 1-20 922  end
     nd-143 1 0 1-20 922  end
     nd-145 1 0 1-20 922  end
     nd-147 1 0 1-20 922  end
     pm-147 1 0 1-20 922  end
     pm-148 1 0 1-20 922  end
     sm-147 1 0 1-20 922  end
     sm-149 1 0 1-20 922  end
     sm-150 1 0 1-20 922  end
     sm-151 1 0 1-20 922  end
     sm-152 1 0 1-20 922  end
     eu-153 1 0 1-20 922  end
     eu-154 1 0 1-20 922  end
     eu-155 1 0 1-20 922  end
     gd-155 1 0 1-20 922  end
     '
     arbm-zirc4 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
                40000 98.18 2 1.0 595   end
     '
     h2o 3 den=0.7538 1 559  end
     arbm-bormod 0.7538 1 1 0 0 5000 100 3 652.5e-6 559  end
     '
     n     4 0 5-5 559  end
     '
     ss304 5 1 559  end
     '
     o     6 0 0.04497 559  end
     na    6 0 0.00165 559  end
     al    6 0 0.00058 559  end
     si    6 0 0.01799 559  end
     k     6 0 0.00011 559  end
     b-10  6 0 9.595-4 559  end
     b-11  6 0 3.863-3 559  end
     '
     '      653 ppm boron (wt) in moderator
     ' - - - - - - - - - - - - - - - - - - - - - - - - - - -
     end comp
     '
     ' - - - - - - - - - - - - - - - - - - - - - - - - - - -
     'fuel-pin-cell geometry:
     '
     squarepitch  1.43 0.9294 1 3 1.0719 2 0.9484 0  end
     '
     ' - - - - - - - - - - - - - - - - - - - - - - - - - - -
     '
     '
     '       assembly and cycle parameters
     '
     npin/assm=204 fuelngth=726.63 ncycles=4 mlib/cyc=3
     printlevel=5 lightel=9 inplevel=2 numxtotal=11
     mxrepeats=0  end
     '
     4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
     2 0.6934 3 0.8068 500 2.2238 3 2.2290
     4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
     2 0.6934 3 0.8068 500 2.2238 3 2.2290
     4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
```

```
2 0.6934 3 0.8068 500 2.2238 3 2.2290
.
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
.
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
.
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
.
power=28.41 burn=243.5  down=40  end
power=26.53 burn=243.5  down=64  bfrac=0.3793   end
power=24.99 burn=156.0  down=39  bfrac=1.0   end
power=23.79 burn=156.0  down=3936  bfrac=0.3793   end
  o 119 cr 5.2 mn 0.29
  fe 11 co 0.066 ni 8.7
  zr 195 nb 0.63 sn 3.2
.
.   the above light elements converted to kg per mtuo2
. - - - - - - - - - - - - - - - - - - - - - - - -
.
```

```
*****                    code system:    scale  version:    4.3                 *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
*****                 program:  sas2                                             *****
*****                                                                            *****
*****            creation date:  03/07/97                                        *****
*****                                                                            *****
*****                 library:  /opt/neut/Scale4.3/bin                           *****
*****                                                                            *****
*****                                                                            *****
*****       this is not a   scale  configuration controlled code                 *****
*****                                                                            *****
*****                 jobname:  nichol                                           *****
*****                                                                            *****
*****      date of execution:  08/08/97                                          *****
*****                                                                            *****
*****      time of execution:  17:57:47                                          *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
```

```
1
0
0
0
0                                          nuclide concentrations, grams
                                           basis =single reactor assembly
                initial  1E-18 d
      o 16    1.19E+05  1.19E+05
   total      3.45E+05  3.45E+05
0                                          nuclide concentrations, grams
                                           basis =single reactor assembly
                initial  1E-18 d
      u234    2.03E+02  2.03E+02
      u235    2.26E+04  2.26E+04
      u236    1.15E+02  1.15E+02
      u238    8.58E+05  8.58E+05
   total      8.81E+05  8.81E+05
0                                          basis =
0                   initial        20.3 d        40.6 d        60.9 d        81.2 d        81.2 d
0                   initial        20.3 d        40.6 d        60.9 d        81.2 d        81.2 d
                                           basis = single reactor assembly
                charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
      o 16    7.42E+03  7.42E+03  7.42E+03  7.42E+03  7.42E+03  7.42E+03
                                           basis = single reactor assembly
                charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
                                           basis = single reactor assembly
                charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
                                           basis = single reactor assembly
                charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
      mo 95     .00E+00  4.97E-05  3.44E-04  1.01E-03  2.09E-03  2.09E-03
      tc 99     .00E+00  3.87E-12  4.07E-11  1.51E-10  3.71E-10  3.71E-10
                                           basis = single reactor assembly
                charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
                                           basis = single reactor assembly
                charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
   totals     1.02E+04  1.02E+04  1.02E+04  1.02E+04  1.02E+04  1.02E+04
                                           basis = single reactor assembly
                charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
      u233     .00E+00  3.31E-07  6.49E-07  9.66E-07  1.22E-06  1.22E-06
      u234    8.66E-01  8.55E-01  8.44E-01  8.34E-01  8.23E-01  8.23E-01
      u235    9.60E-01  9.33E-01  9.06E-01  8.80E-01  8.56E-01  8.56E-01
      u236    4.85E-01  1.00E+00  1.51E+00  1.99E+00  2.45E+00  2.45E+00
      u238    3.61E+03  3.60E+03  3.60E+03  3.60E+03  3.60E+03  3.60E+03
     np237     .00E+00  7.67E-03  2.19E-02  3.89E-02  5.78E-02  5.78E-02
     pu236     .00E+00  2.41E-10  1.51E-09  4.13E-09  8.26E-09  8.26E-09
     pu238     .00E+00  4.03E-05  2.94E-04  8.47E-04  1.73E-03  1.73E-03
     pu238     .00E+00  4.03E-05  2.94E-04  8.47E-04  1.73E-03  1.73E-03
     pu239     .00E+00  1.51E+00  3.19E+00  4.71E+00  6.08E+00  6.08E+00
     pu240     .00E+00  2.49E-02  1.03E-01  2.21E-01  3.69E-01  3.69E-01
     pu241     .00E+00  1.04E-03  8.79E-03  2.85E-02  6.32E-02  6.32E-02
     pu242     .00E+00  5.76E-06  1.01E-04  5.01E-04  1.50E-03  1.50E-03
                                           basis = single reactor assembly
                charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
     am241     .00E+00  6.60E-07  1.13E-05  5.63E-05  1.69E-04  1.69E-04
     am242m    .00E+00  1.22E-09  4.07E-08  2.88E-07  1.10E-06  1.10E-06
     am243     .00E+00  2.23E-08  8.06E-07  6.07E-06  2.45E-05  2.45E-05
   totals     3.70E+03  3.70E+03  3.70E+03  3.70E+03  3.69E+03  3.69E+03
                decay data, including gamma and total energy, are from endf/b-vi
0                   1697    total number of nuclides in library
0                                          nuclide concentrations, grams
                                           basis =single reactor assembly
                initial  656.0 d  1312.0 d  1968.0 d  2624.0 d  3280.0 d  3936.0 d
      o 16    1.19E+05  1.19E+05  1.19E+05  1.19E+05  1.19E+05  1.19E+05  1.19E+05
0                                          nuclide concentrations, grams
                                           basis =single reactor assembly
                initial  656.0 d  1312.0 d  1968.0 d  2624.0 d  3280.0 d  3936.0 d
      mo 95   1.04E+01  1.23E+01  1.23E+01  1.23E+01  1.23E+01  1.23E+01  1.23E+01
      tc 99   2.27E-05  2.31E-05  2.31E-05  2.31E-05  2.31E-05  2.31E-05  2.31E-05
0                                          nuclide concentrations, grams
                                           basis =single reactor assembly
                initial  656.0 d  1312.0 d  1968.0 d  2624.0 d  3280.0 d  3936.0 d
   total      3.45E+05  3.45E+05  3.45E+05  3.45E+05  3.45E+05  3.45E+05  3.45E+05
0                                          nuclide concentrations, grams
                                           basis =single reactor assembly
                initial  656.0 d  1312.0 d  1968.0 d  2624.0 d  3280.0 d  3936.0 d
      u233    1.19E-03  1.34E-03  1.49E-03  1.63E-03  1.78E-03  1.93E-03  2.08E-03
      u234    1.32E+02  1.33E+02  1.34E+02  1.35E+02  1.36E+02  1.37E+02  1.38E+02
      u235    7.64E+03  7.64E+03  7.64E+03  7.64E+03  7.64E+03  7.64E+03  7.64E+03
      u236    2.66E+03  2.66E+03  2.66E+03  2.66E+03  2.66E+03  2.66E+03  2.66E+03
      u238    8.42E+05  8.42E+05  8.42E+05  8.42E+05  8.42E+05  8.42E+05  8.42E+05
     np237    2.39E+02  2.44E+02  2.44E+02  2.45E+02  2.46E+02  2.46E+02  2.47E+02
     pu236    2.71E-04  1.77E-04  1.15E-04  7.51E-05  4.89E-05  3.18E-05  2.07E-05
     pu238    6.45E+01  7.07E+01  7.01E+01  6.91E+01  6.81E+01  6.72E+01  6.62E+01
     pu238    6.45E+01  7.07E+01  7.01E+01  6.91E+01  6.81E+01  6.72E+01  6.62E+01
     pu239    4.34E+03  4.40E+03  4.40E+03  4.40E+03  4.40E+03  4.40E+03  4.40E+03
     pu240    1.73E+03  1.73E+03  1.73E+03  1.73E+03  1.73E+03  1.73E+03  1.73E+03
     pu241    8.62E+02  7.90E+02  7.25E+02  6.65E+02  6.09E+02  5.59E+02  5.12E+02
```

pu242	2.82E+02	2.82E+02	2.82E+02	2.82E+02	2.82E+02	2.82E+02	2.82E+02
am241	3.00E+01	1.01E+02	1.67E+02	2.26E+02	2.81E+02	3.31E+02	3.76E+02
am242m	5.51E-01	5.46E-01	5.41E-01	5.36E-01	5.32E-01	5.27E-01	5.22E-01
am243	4.33E+01	4.33E+01	4.33E+01	4.33E+01	4.33E+01	4.33E+01	4.33E+01
total	8.60E+05	8.60E+05	8.60E+05	8.60E+05	8.60E+05	8.60E+05	8.60E+05

0
0 element concentrations, grams
muclide concentrations, grams
basis =single reactor assembly

	initial	656.0 d	1312.0 d	1968.0 d	2624.0 d	3280.0 d	3936.0 d
mo 95	4.88E+02	4.88E+02	4.88E+02	4.88E+02	4.88E+02	4.88E+02	4.88E+02
tc 99	5.17E+02	5.19E+02	5.19E+02	5.19E+02	5.19E+02	5.19E+02	5.19E+02

0
nuclide concentrations, grams
basis =single reactor assembly

	initial	656.0 d	1312.0 d	1968.0 d	2624.0 d	3280.0 d	3936.0 d
ru101	4.91E+02	4.91E+02	4.91E+02	4.91E+02	4.91E+02	4.91E+02	4.91E+02
rh103	3.04E+02	3.35E+02	3.35E+02	3.35E+02	3.35E+02	3.35E+02	3.35E+02
ag109	5.91E+01	5.93E+01	5.93E+01	5.93E+01	5.93E+01	5.93E+01	5.93E+01

0
nuclide concentrations, grams
basis =single reactor assembly

	initial	656.0 d	1312.0 d	1968.0 d	2624.0 d	3280.0 d	3936.0 d
nd143	5.31E+02	5.46E+02	5.46E+02	5.46E+02	5.46E+02	5.46E+02	5.46E+02
nd145	4.38E+02	4.39E+02	4.39E+02	4.39E+02	4.39E+02	4.39E+02	4.39E+02
sm147	5.17E+01	1.03E+02	1.36E+02	1.56E+02	1.68E+02	1.76E+02	1.81E+02
sm149	1.61E+00	2.50E+00	2.50E+00	2.50E+00	2.50E+00	2.50E+00	2.50E+00
sm150	1.84E+02	1.84E+02	1.84E+02	1.84E+02	1.84E+02	1.84E+02	1.84E+02
sm151	9.69E+00	9.73E+00	9.60E+00	9.46E+00	9.33E+00	9.21E+00	9.08E+00
eu151	1.30E-02	1.48E-01	2.82E-01	4.14E-01	5.44E-01	6.72E-01	7.99E-01
sm152	9.09E+01	9.09E+01	9.09E+01	9.09E+01	9.09E+01	9.09E+01	9.09E+01
eu153	6.91E+01	6.97E+01	6.97E+01	6.97E+01	6.97E+01	6.97E+01	6.97E+01

0
nuclide concentrations, grams
basis =single reactor assembly

	initial	656.0 d	1312.0 d	1968.0 d	2624.0 d	3280.0 d	3936.0 d
gd155	2.35E-02	7.64E-01	1.33E+00	1.77E+00	2.10E+00	2.36E+00	2.55E+00
total	2.14E+04	2.14E+04	2.14E+04	2.14E+04	2.14E+04	2.14E+04	2.14E+04

rob9g28.sum

```
0*****************************************************************************
 *                                                                           *
 *                    SCALE4.3  Bulletin  Board                              *
 *                    --------  --------  -----                              *
 *                                                                           *
 *                      Welcome to SCALE-4.3.                                *
 *                                                                           *
 *                                                                           *
 *****************************************************************************
1          primary module access and input record ( scale driver - 95/03/29 - 09:06:37 )
-   module sas2h    will be called
     N.B. Robinson N-9C-J 28.47 GWd/MTU, 199 cm, July 97
     *
     *
     *
     *    mixtures of fuel-pin-unitcell
     *
     44group      latticecell
     *
     *
     *
     uo2  1 den=9.944 1  922
              92234 0.023 92235 2.561 92236 0.013 92238 97.403  end
     kr-83  1 0 1-20 922  end
     kr-85  1 0 1-20 922  end
     y-89   1 0 1-20 922  end
     sr-90  1 0 1-20 922  end
     zr-93  1 0 1-20 922  end
     zr-94  1 0 1-20 922  end
     zr-95  1 0 1-20 922  end
     nb-94  1 0 1-20 922  end
     mo-95  1 0 1-20 922  end
     tc-99  1 0 1-20 922  end
     ru-101 1 0 1-20 922  end
     ru-106 1 0 1-20 922  end
     rh-103 1 0 1-20 922  end
     rh-105 1 0 1-20 922  end
     pd-105 1 0 1-20 922  end
     pd-108 1 0 1-20 922  end
     ag-109 1 0 1-20 922  end
     sb-124 1 0 1-20 922  end
     xe-131 1 0 1-20 922  end
     xe-132 1 0 1-20 922  end
     xe-135 1 0 1-20 922  end
     xe-136 1 0 1-20 922  end
     cs-134 1 0 1-20 922  end
     cs-135 1 0 1-20 922  end
     cs-137 1 0 1-20 922  end
     ba-136 1 0 1-20 922  end
     la-139 1 0 1-20 922  end
     pr-141 1 0 1-20 922  end
     pr-143 1 0 1-20 922  end
     ce-144 1 0 1-20 922  end
     nd-143 1 0 1-20 922  end
     nd-145 1 0 1-20 922  end
     nd-147 1 0 1-20 922  end
     pm-147 1 0 1-20 922  end
     pm-148 1 0 1-20 922  end
     sm-147 1 0 1-20 922  end
     sm-149 1 0 1-20 922  end
     sm-150 1 0 1-20 922  end
     sm-151 1 0 1-20 922  end
     sm-152 1 0 1-20 922  end
     eu-153 1 0 1-20 922  end
     eu-154 1 0 1-20 922  end
     eu-155 1 0 1-20 922  end
     gd-155 1 0 1-20 922  end
     *
     arbm-zirc4 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
                40000 98.18 2 1.0 595   end
     *
     h2o 3 den=0.7208 1 576  end
     arbm-bormod 0.7208 1 1 0 0 5000 100 3 652.5e-6 576  end
     *
     n     4 0 5-5 576  end
     *
     ss304 5 1 576  end
     *
     o     6 0 0.04497 576  end
     na    6 0 0.00165 576  end
     al    6 0 0.00058 576  end
     si    6 0 0.01799 576  end
     k     6 0 0.00011 576  end
     b-10  6 0 9.595-4 576  end
     b-11  6 0 3.863-3 576  end
     *
     *      653 ppm boron (wt) in moderator
     * - - - - - - - - - - - - - - - - - - - - - - - - - -
     end comp
     *
     * - - - - - - - - - - - - - - - - - - - - - - - - - -
     *fuel-pin-cell geometry:
     *
     squarepitch  1.43 0.9294 1 3 1.0719 2 0.9484 0  end
     *
     * - - - - - - - - - - - - - - - - - - - - - - - - - -
     *
     *
     *       assembly and cycle parameters
     *
     npin/assm=204 fuelngth=726.63 ncycles=4 nlib/cyc=3
     printlevel=5 lightel=9 inplevel=2 numstotal=11
     mxrepeats=0  end
     *
     4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
     2 0.6934 3 0.8068 500 2.2238 3 2.2290
     4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
     2 0.6934 3 0.8068 500 2.2238 3 2.2290
     4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
```

```
2 0.6934 3 0.8068 500 2.2238 3 2.2290
.
4 0.2839 3 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 3 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 3 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
.
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
.
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
.
power=34.82 burn=243.5  down=40  end
power=31.83 burn=243.5  down=64  bfrac=0.3793   end
power=29.38 burn=156.0  down=39  bfrac=1.0   end
power=27.47 burn=156.0  down=3631  bfrac=0.3793   end
  o 119 cr 5.2 mn 0.29
  fe 11 co 0.066 ni 8.7
  zr 195 nb 0.63 sn 3.2
.
.   the above light elements converted to kg per mtuo2
. - - - - - - - - - - - - - - - - - - - - - - - -
.
```

```
1  ###########      #########      ############     22222222222    hh         hh
   #############    ############   #############    2222222222222  hh         hh
   ##         ##    ##         ##  ##         ##   22         22  hh         hh
   ##             ##         ##  ##             ##             22  hh         hh
   ##             ##         ##  ##             ##             22  hh         hh
   #############  ##############  #############                22  hhhhhhhhhhhhhh
    ############  ##############   ############               22   hhhhhhhhhhhhhh
                ##  ##         ##             ##           22      hh         hh
                ##  ##         ##             ##         22        hh         hh
   ##         ##  ##         ##  ##         ##   22               hh         hh
   #############  ##         ##  #############    2222222222222    hh         hh
    ###########   ##         ##   ############    2222222222222    hh         hh
0

   nn         nn  iiiiiiiiiiiii    eeeeeeeeeee    hh         hh    oooooooooo    ll
   nnn        nn  iiiiiiiiiiiii    eeeeeeeeeeee   hh         hh    oooooooooooo  ll
   nnnn       nn      ii           ee         ee  hh         hh    oo        oo  ll
   nn nn      nn      ii           ee             hh         hh    oo        oo  ll
   nn  nn     nn      ii           ee             hh         hh    oo        oo  ll
   nn   nn    nn      ii           ee             hhhhhhhhhhhhhh   oo        oo  ll
   nn    nn   nn      ii           ee             hhhhhhhhhhhhhh   oo        oo  ll
   nn     nn  nn      ii           ee             hh         hh    oo        oo  ll
   nn      nn nn      ii           ee             hh         hh    oo        oo  ll
   nn       nnnn      ii           ee         ee  hh         hh    oo        oo  ll
   nn        nnn  iiiiiiiiiiiii    eeeeeeeeeeee   hh         hh    oooooooooooo  llllllllllll
   nn         nn  iiiiiiiiiiiii    eeeeeeeeeee    hh         hh    oooooooooooo  llllllllllll
0

     0000000      ###########              //     0000000      ###########              //    99999999999   7777777777777
    000000000    #############            //     000000000    #############            //   9999999999999  7777777777777
   00       00   ##         ##          //      00       00   ##         ##          //    99         99  77         77
  00         00  ##         ##         //       00         00 ##         ##         //     99         99          77
  00         00  ##         ##        //        00         00 ##         ##        //      99         99         77
  00         00   ###########        //          00         00  ###########        //       99         99        77
  00         00   ###########       //           00         00  ###########       //        9999999999999       77
  00         00  ##         ##     //            00         00 ##         ##     //          3999999999999     77
  00         00  ##         ##    //             00         00 ##         ##    //                     99    77
   00       00   ##         ##   //              00         00  ##         ##   //                     99   77
    000000000    #############  //                000000000    #############  //                     99  77
     0000000      ###########  //                  0000000      ###########  //                     99  77
0

       11         ###########                        11         ###########                    5555555555555   66666666666
      111        #############                      111        #############                  5555555555555   66666666666
     1111        ##         ##        :::         1111        ##         ##        :::        55              66
       11        ##         ##        :::           11        ##         ##        :::        55              66
       11        ##         ##        :::           11        ##         ##        :::        55              66
       11         ###########                       11         ###########                    5555555555555   66666666666
       11         ###########                       11         ###########                    5555555555555   66666666666
       11        ##         ##        :::           11        ##         ##        :::                   55  66        66
       11        ##         ##        :::           11        ##         ##        :::                   55  66        66
       11        ##         ##        :::           11        ##         ##        :::        55         55  66        66
   11111111      #############                   11111111      #############                  5555555555555   66666666666
   11111111       ###########                    11111111       ###########                    5555555555555    666666666
1
0                                  ###########     eeeeeeeeeee     #########    11             oooooooooooo
                                  #############   eeeeeeeeeeee    ###########  11             oooooooooooo
                                  ##         ##   ee         ee  ##         ##  11             oo
                                  ##             ee             ##         ##  11             oo
                                  ##             ee             ##         ##  11             oo
                                  #############  ee             #############  11             oooooooo
                                   ############  ee              ############  11             oooooooo
                                             ##  ee             ##         ##  11             oo
                                             ##  ee             ##         ##  11             oo
                                  ##         ##  ee         ee  ##         ##  11             oo
                                  #############  eeeeeeeeeeee    ############  11111111111111 oooooooooooo
                                   ###########    eeeeeeeeeee    ###########  11111111111111 oooooooooooo
```

```
**********************************************************************
**********************************************************************
**********************************************************************
*****                                                            *****
*****              program verification information               *****
*****                                                            *****
```

```
*****                    code system:    scale  version:    4.3                 *****
*****
*****************************************************************************
*****************************************************************************
*****                                                                       *****
*****                                                                       *****
*****                 program:  sas2                                        *****
*****
*****            creation date:  03/07/97                                   *****
*****
*****                 library:  /opt/neut/Scale4.3/bin                      *****
*****
*****
*****      this is not a   scale  configuration controlled code             *****
*****
*****                 jobname:  michol                                      *****
*****
*****      date of execution:  08/08/97                                     *****
*****
*****      time of execution:  18:18:56                                     *****
*****
*****                                                                       *****
*****************************************************************************
*****************************************************************************
*****************************************************************************
1
0
0
0
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  1E-18 d
     o 16  1.19E+05  1.19E+05
   total   3.45E+05  3.45E+05
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  1E-18 d
     u234  2.03E+02  2.03E+02
     u235  2.26E+04  2.26E+04
     u236  1.15E+02  1.15E+02
     u238  8.58E+05  8.58E+05
   total   8.81E+05  8.81E+05
0                                        basis =
0                 initial        20.3 d        40.6 d        60.9 d        81.2 d        81.2 d
0                 initial        20.3 d        40.6 d        60.9 d        81.2 d        81.2 d
                                         basis = single reactor assembly
            charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
     o 16  7.42E+03  7.42E+03  7.42E+03  7.42E+03  7.42E+03  7.42E+03
                                         basis = single reactor assembly
            charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
                                         basis = single reactor assembly
            charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
                                         basis = single reactor assembly
            charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
     mo 95   .00E+00  6.26E-05  4.33E-04  1.27E-03  2.63E-03  2.63E-03
     tc 99   .00E+00  7.79E-12  8.24E-11  3.04E-10  7.48E-10  7.48E-10
                                         basis = single reactor assembly
            charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
                                         basis = single reactor assembly
            charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
   totals  1.02E+04  1.02E+04  1.02E+04  1.02E+04  1.02E+04  1.02E+04
                                         basis = single reactor assembly
            charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
     u233   .00E+00  4.11E-07  8.04E-07  1.16E-06  1.50E-06  1.50E-06
     u234  8.66E-01  8.53E-01  8.39E-01  8.26E-01  8.13E-01  8.13E-01
     u235  9.60E+01  9.27E+01  8.95E+01  8.64E+01  8.35E+01  8.35E+01
     u236  4.85E-01  1.11E+00  1.73E+00  2.31E+00  2.85E+00  2.85E+00
     u238  3.61E+03  3.60E+03  3.60E+03  3.60E+03  3.60E+03  3.60E+03
   np237   .00E+00  9.74E-03  2.83E-02  5.07E-02  7.59E-02  7.59E-02
   pu236   .00E+00  3.81E-10  2.42E-09  6.67E-09  1.34E-08  1.34E-08
   pu238   .00E+00  6.28E-05  4.45E-04  1.35E-03  2.78E-03  2.78E-03
   pu238   .00E+00  6.28E-05  4.45E-04  1.35E-03  2.78E-03  2.78E-03
   pu239   .00E+00  1.86E+00  3.91E+00  5.71E+00  7.29E+00  7.29E+00
   pu240   .00E+00  3.77E-02  1.53E-01  3.24E-01  5.30E-01  5.30E-01
   pu241   .00E+00  1.94E-03  1.62E-02  5.16E-02  1.12E-01  1.12E-01
   pu242   .00E+00  1.32E-05  2.29E-04  1.12E-03  3.29E-03  3.29E-03
                                         basis = single reactor assembly
            charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
   am241   .00E+00  1.24E-06  2.10E-05  1.02E-04  3.01E-04  3.01E-04
   am242m  .00E+00  2.80E-09  9.10E-08  6.26E-07  2.32E-06  2.32E-06
   am243   .00E+00  6.42E-08  2.31E-06  1.71E-05  6.76E-05  6.77E-05
   totals  3.70E+03  3.70E+03  3.70E+03  3.69E+03  3.69E+03  3.69E+03
                 decay data; including gamma and total energy, are from endf/b-vi
0                 1697    total number of nuclides in library
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  605.2 d  1210.3 d  1815.5 d  2420.7 d  3025.8 d  3631.0 d
     o 16  1.19E+05  1.19E+05  1.19E+05  1.19E+05  1.19E+05  1.19E+05  1.19E+05
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  605.2 d  1210.3 d  1815.5 d  2420.7 d  3025.8 d  3631.0 d
     mo 95  1.30E+01  1.53E+01  1.53E+01  1.53E+01  1.53E+01  1.53E+01  1.53E+01
     tc 99  4.42E-05  4.48E-05  4.48E-05  4.48E-05  4.48E-05  4.48E-05  4.48E-05
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  605.2 d  1210.3 d  1815.5 d  2420.7 d  3025.8 d  3631.0 d
   total   3.45E+05  3.45E+05  3.45E+05  3.45E+05  3.45E+05  3.45E+05  3.45E+05
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  605.2 d  1210.3 d  1815.5 d  2420.7 d  3025.8 d  3631.0 d
     u233  1.26E-03  1.43E-03  1.61E-03  1.78E-03  1.95E-03  2.13E-03  2.30E-03
     u234  1.21E+02  1.22E+02  1.23E+02  1.25E+02  1.26E+02  1.27E+02  1.29E+02
     u235  6.21E+03  6.21E+03  6.21E+03  6.21E+03  6.21E+03  6.21E+03  6.21E+03
     u236  2.87E+03  2.87E+03  2.87E+03  2.87E+03  2.87E+03  2.88E+03  2.88E+03
     u238  8.38E+05  8.38E+05  8.38E+05  8.38E+05  8.38E+05  8.38E+05  8.38E+05
   np237  3.02E+02  3.09E+02  3.09E+02  3.10E+02  3.10E+02  3.11E+02  3.12E+02
   pu236  4.36E-04  2.95E-04  1.98E-04  1.33E-04  8.98E-05  6.04E-05  4.07E-05
   pu238  9.73E+01  1.06E+02  1.06E+02  1.04E+02  1.03E+02  1.02E+02  1.00E+02
   pu238  9.73E+01  1.06E+02  1.06E+02  1.04E+02  1.03E+02  1.02E+02  1.00E+02
   pu239  4.54E+03  4.61E+03  4.61E+03  4.61E+03  4.61E+03  4.61E+03  4.61E+03
   pu240  2.03E+03  2.03E+03  2.03E+03  2.03E+03  2.03E+03  2.03E+03  2.03E+03
   pu241  1.06E+03  9.76E+02  9.01E+02  8.31E+02  7.67E+02  7.08E+02  6.54E+02
```

pu242	4.23E+02	4.23E+02	4.23E+02	4.23E+02	4.23E+02	4.23E+02	4.23E+02
am241	3.54E+01	1.17E+02	1.91E+02	2.60E+02	3.23E+02	3.81E+02	4.35E+02
am242m	6.82E-01	6.76E-01	6.71E-01	6.65E-01	6.60E-01	6.55E-01	6.49E-01
am243	7.93E+01	7.94E+01	7.94E+01	7.94E+01	7.94E+01	7.94E+01	7.94E+01
total	8.56E+05	8.56E+05	8.56E+05	8.56E+05	8.56E+05	8.56E+05	8.56E+05

0 element concentrations, grams
0 nuclide concentrations, grams
basis =single reactor assembly

	initial	605.2 d	1210.3 d	1815.5 d	2420.7 d	3025.8 d	3631.0 d
mo 95	4.90E+02	5.69E+02	5.69E+02	5.69E+02	5.69E+02	5.69E+02	5.69E+02
tc 99	6.04E+02	6.07E+02	6.07E+02	6.07E+02	6.07E+02	6.07E+02	6.07E+02

0 nuclide concentrations, grams
basis =single reactor assembly

	initial	605.2 d	1210.3 d	1815.5 d	2420.7 d	3025.8 d	3631.0 d
ru101	5.85E+02	5.85E+02	5.85E+02	5.85E+02	5.85E+02	5.85E+02	5.85E+02
rh103	3.55E+02	3.92E+02	3.92E+02	3.92E+02	3.92E+02	3.92E+02	3.92E+02
ag109	7.55E+01	7.56E+01	7.56E+01	7.56E+01	7.56E+01	7.56E+01	7.56E+01

0 nuclide concentrations, grams
basis =single reactor assembly

	initial	605.2 d	1210.3 d	1815.5 d	2420.7 d	3025.8 d	3631.0 d
nd143	5.96E+02	6.14E+02	6.14E+02	6.14E+02	6.14E+02	6.14E+02	6.14E+02
nd145	5.07E+02	5.07E+02	5.07E+02	5.07E+02	5.07E+02	5.07E+02	5.07E+02
sm147	5.58E+01	1.08E+02	1.42E+02	1.66E+02	1.78E+02	1.87E+02	1.93E+02
sm149	1.72E+00	2.82E+00	2.82E+00	2.82E+00	2.82E+00	2.82E+00	2.82E+00
sm150	2.26E+02	2.26E+02	2.26E+02	2.26E+02	2.26E+02	2.26E+02	2.26E+02
sm151	1.10E+01	1.11E+01	1.10E+01	1.08E+01	1.07E+01	1.06E+01	1.04E+01
eu151	1.24E-02	1.55E-01	2.96E-01	4.35E-01	5.72E-01	7.08E-01	8.42E-01
sm152	1.06E+02	1.06E+02	1.06E+02	1.06E+02	1.06E+02	1.06E+02	1.06E+02
eu153	8.90E+01	8.97E+01	8.97E+01	8.97E+01	8.97E+01	8.97E+01	8.97E+01

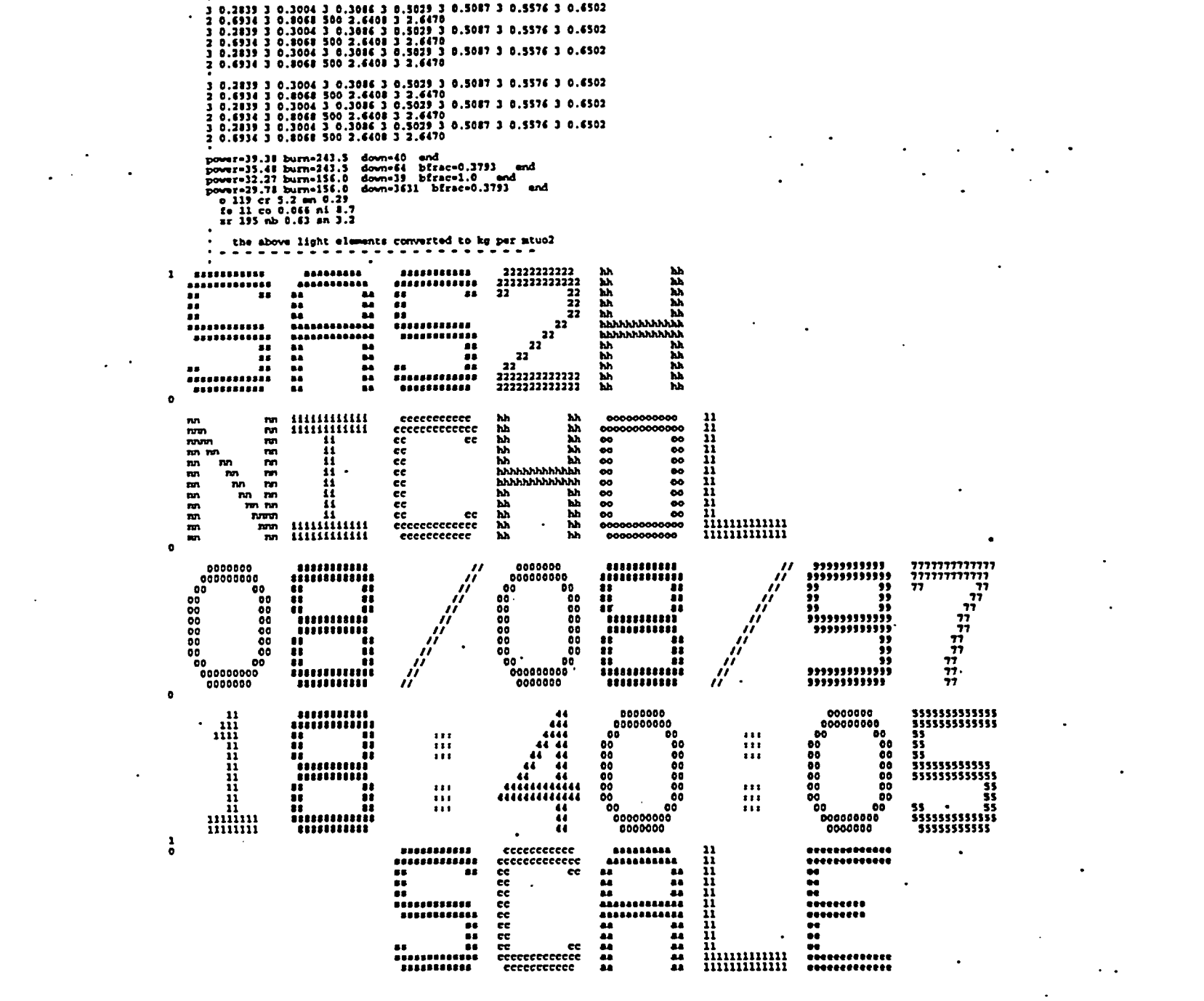
0 nuclide concentrations, grams
basis =single reactor assembly

	initial	605.2 d	1210.3 d	1815.5 d	2420.7 d	3025.8 d	3631.0 d
gd155	2.88E-02	9.41E-01	1.63E+00	2.21E+00	2.65E+00	2.99E+00	3.26E+00
total	2.56E+04	2.56E+04	2.56E+04	2.56E+04	2.56E+04	2.56E+04	2.56E+04

rob9g32.sum

```
0*************************************************************************
 *                                                                       *
 *                    SCALE4.3  Bulletin  Board                          *
 *                    --------  --------  -----                          *
 *                                                                       *
 *                      Welcome to SCALE-4.3.                            *
 *                                                                       *
 *                                                                       *
 *************************************************************************
1          primary module access and input record ( scale driver - 95/03/29 - 09:06:37 )
-   module sas2h    will be called
     N.B. Robinson N-9C-D 31.66 GWd/MTU, 226 cm July 97
     *
     *
     *
     *    mixtures of fuel-pin-unitcell
     *
     44group       latticecell
     *
     *
     *
     uo2  1 den=9.944 1  922
              92234 0.023 92235 2.561 92236 0.013 92238 97.403  end
     kr-83  1 0 1-20 922  end
     kr-85  1 0 1-20 922  end
     y-89   1 0 1-20 922  end
     sr-90  1 0 1-20 922  end
     zr-93  1 0 1-20 922  end
     zr-94  1 0 1-20 922  end
     zr-95  1 0 1-20 922  end
     nb-94  1 0 1-20 922  end
     mo-95  1 0 1-20 922  end
     tc-99  1 0 1-20 922  end
     ru-101 1 0 1-20 922  end
     ru-106 1 0 1-20 922  end
     rh-103 1 0 1-20 922  end
     rh-105 1 0 1-20 922  end
     pd-105 1 0 1-20 922  end
     pd-108 1 0 1-20 922  end
     ag-109 1 0 1-20 922  end
     sb-124 1 0 1-20 922  end
     xe-131 1 0 1-20 922  end
     xe-132 1 0 1-20 922  end
     xe-135 1 0 1-20 922  end
     xe-136 1 0 1-20 922  end
     cs-134 1 0 1-20 922  end
     cs-135 1 0 1-20 922  end
     cs-137 1 0 1-20 922  end
     ba-136 1 0 1-20 922  end
     la-139 1 0 1-20 922  end
     pr-141 1 0 1-20 922  end
     pr-143 1 0 1-20 922  end
     ce-144 1 0 1-20 922  end
     nd-143 1 0 1-20 922  end
     nd-145 1 0 1-20 922  end
     nd-147 1 0 1-20 922  end
     pm-147 1 0 1-20 922  end
     pm-148 1 0 1-20 922  end
     sm-147 1 0 1-20 922  end
     sm-149 1 0 1-20 922  end
     sm-150 1 0 1-20 922  end
     sm-151 1 0 1-20 922  end
     sm-152 1 0 1-20 922  end
     eu-153 1 0 1-20 922  end
     eu-154 1 0 1-20 922  end
     eu-155 1 0 1-20 922  end
     gd-155 1 0 1-20 922  end
     *
     arbm-zirc4 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
                40000 98.18 2 1.0 595   end
     *
     h2o 3 den=0.7135 1 579  end
     arbm-bormod 0.7135 1 1 0 0 5000 100 3 652.5e-6 579  end
     *
     n     4 0 5-5 579  end
     *
     ss304 5 1 576  end
     *
     o     6 0 0.04497 579  end
     na    6 0 0.00165 579  end
     al    6 0 0.00058 579  end
     si    6 0 0.01799 579  end
     k     6 0 0.00011 579  end
     b-10  6 0 9.595-4 579  end
     b-11  6 0 3.863-3 579  end
     *
     *      653 ppm boron (wt) in moderator
     * - - - - - - - - - - - - - - - - - - - - - - - - - - -
     end comp
     *
     * - - - - - - - - - - - - - - - - - - - - - - - - - - -
     *fuel-pin-cell geometry:
     *
     squarepitch  1.43 0.9294 1 3 1.0719 2 0.9484 0  end
     *
     * - - - - - - - - - - - - - - - - - - - - - - - - - - -
     *
     *
     *       assembly and cycle parameters
     *
     npin/assm=204 fuelngth=726.43 ncycles=4 nlib/cyc=3
     printlevel=5 lightel=9 inplevel=2 numztotal=11
     mxrepeats=0  end
     *
     4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
     2 0.6934 3 0.8068 500 2.2238 3 2.2290
     4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
     2 0.6934 3 0.8068 500 2.2238 3 2.2290
     4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
```

```
2 0.6934 3 0.8068 500 2.2238 3 2.2290
.
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
.
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
.
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
.
power=39.38 burn=243.5  down=40  end
power=35.48 burn=243.5  down=64  bfrac=0.3793   end
power=32.27 burn=156.0  down=39  bfrac=1.0   end
power=29.78 burn=156.0  down=3631  bfrac=0.3793   end
  o 119 cr 5.2 sm 0.29
  fe 11 co 0.066 ni 8.7
  zr 195 nb 0.63 sn 3.2
.
.   the above light elements converted to kg per mtuo2
. - - - - - - - - - - - - - - - - - - - - - - - -
.
```



program verification information

```
*****                    code system:    scale  version:    4.3                 *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
*****                 program:  sas2                                             *****
*****              creation date:  03/07/97                                      *****
*****                 library:  /opt/neut/Scale4.3/bin                           *****
*****                                                                            *****
*****                                                                            *****
*****        this is not a   scale  configuration controlled code                *****
*****                                                                            *****
*****                 jobname:  nichol                                           *****
*****                                                                            *****
*****        date of execution:  08/08/97                                        *****
*****                                                                            *****
*****        time of execution:  18:40:05                                        *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
1
0'
0'
0'
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  1E-18 d
     o 16   1.19E+05  1.19E+05
   total    3.45E+05  3.45E+05
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  1E-18 d
     u234   2.03E+02  2.03E+02
     u235   2.26E+04  2.26E+04
     u236   1.15E+02  1.15E+02
     u238   8.58E+05  8.58E+05
   total    8.81E+05  8.81E+05
0                                        basis =
0                 initial        20.3 d        40.6 d        60.9 d        81.2 d        81.2 d
0                 initial        20.3 d        40.6 d        60.9 d        81.2 d        81.2 d
                                         basis = single reactor assembly
            charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
     o 16   7.42E+03  7.42E+03  7.42E+03  7.42E+03  7.42E+03  7.42E+03
                                         basis = single reactor assembly
            charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
                                         basis = single reactor assembly
            charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
                                         basis = single reactor assembly
            charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
     mo 95   .00E+00  7.09E-05  6.92E-04  1.44E-03  2.98E-03  2.99E-03
     tc 99   .00E+00  1.14E-11  1.21E-10  4.47E-10  1.10E-09  1.10E-09
                                         basis = single reactor assembly
            charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
                                         basis = single reactor assembly
            charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
   totals   1.02E+04  1.02E+04  1.02E+04  1.02E+04  1.02E+04  1.02E+04
                                         basis = single reactor assembly
            charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
     u233   .00E+00  4.64E-07  9.05E-07  1.31E-06  1.67E-06  1.67E-06
     u234   8.66E-01  8.51E-01  8.36E-01  8.21E-01  8.06E-01  8.06E-01
     u235   9.60E+01  9.23E+01  8.87E+01  8.53E+01  8.21E+01  8.21E+01
     u236   4.85E-01  1.19E+00  1.88E+00  2.52E+00  3.12E+00  3.12E+00
     u238   3.61E+03  3.60E+03  3.60E+03  3.60E+03  3.59E+03  3.59E+03
    np237   .00E+00  1.11E-02  3.26E-02  5.90E-02  8.88E-02  8.88E-02
    pu236   .00E+00  4.92E-10  3.16E-09  8.76E-09  1.77E-08  1.77E-08
    pu238   .00E+00  8.08E-05  6.03E-04  1.76E-03  3.63E-03  3.63E-03
    pu238   .00E+00  8.08E-05  6.03E-04  1.76E-03  3.63E-03  3.63E-03
    pu239   .00E+00  2.10E+00  4.37E+00  6.34E+00  8.05E+00  8.05E+00
    pu240   .00E+00  4.75E-02  1.92E-01  4.00E-01  6.48E-01  6.48E-01
    pu241   .00E+00  2.74E-03  2.28E-02  7.15E-02  1.54E-01  1.54E-01
    pu242   .00E+00  2.10E-05  3.63E-04  1.75E-03  5.10E-03  5.10E-03
                                         basis = single reactor assembly
            charge    20.3 d    40.6 d    60.9 d    81.2 d    81.2 d
    am241   .00E+00  1.75E-06  2.94E-05  1.42E-04  4.14E-04  4.14E-04
    am242m  .00E+00  4.42E-09  1.42E-07  9.59E-07  3.49E-06  3.49E-06
    am243   .00E+00  1.16E-07  4.16E-06  3.05E-05  1.20E-04  1.20E-04
   totals   3.70E+03  3.70E+03  3.70E+03  3.69E+03  3.69E+03  3.69E+03
            decay data, including gamma and total energy, are from endf/b-vi
0                 1697    total number of nuclides in library
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  605.2 d  1210.3 d  1815.5 d  2420.7 d  3025.8 d  3631.0 d
     o 16   1.19E+05  1.19E+05  1.19E+05  1.19E+05  1.19E+05  1.19E+05  1.19E+05
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  605.2 d  1210.3 d  1815.5 d  2420.7 d  3025.8 d  3631.0 d
     mo 95   1.46E+01  1.72E+01  1.72E+01  1.72E+01  1.72E+01  1.72E+01  1.72E+01
     tc 99   6.35E-05  6.44E-05  6.44E-05  6.44E-05  6.44E-05  6.44E-05  6.44E-05
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  605.2 d  1210.3 d  1815.5 d  2420.7 d  3025.8 d  3631.0 d
   total    3.45E+05  3.45E+05  3.45E+05  3.45E+05  3.45E+05  3.45E+05  3.45E+05
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  605.2 d  1210.3 d  1815.5 d  2420.7 d  3025.8 d  3631.0 d
     u233   1.27E-03  1.67E-03  1.67E-03  1.86E-03  2.06E-03  2.26E-03  2.45E-03
     u234   1.13E+02  1.15E+02  1.17E+02  1.18E+02  1.20E+02  1.22E+02  1.23E+02
     u235   5.32E+03  5.32E+03  5.32E+03  5.32E+03  5.32E+03  5.32E+03  5.32E+03
     u236   2.99E+03  2.99E+03  2.99E+03  2.99E+03  2.99E+03  2.99E+03  2.99E+03
     u238   8.35E+05  8.35E+05  8.35E+05  8.35E+05  8.35E+05  8.35E+05  8.35E+05
    np237   3.42E+02  3.49E+02  3.50E+02  3.51E+02  3.51E+02  3.52E+02  3.54E+02
    pu236   5.66E-04  3.82E-04  2.57E-04  1.73E-04  1.17E-04  7.84E-05  5.28E-05
    pu238   1.22E+02  1.32E+02  1.31E+02  1.30E+02  1.28E+02  1.27E+02  1.25E+02
    pu238   1.22E+02  1.32E+02  1.31E+02  1.30E+02  1.28E+02  1.27E+02  1.25E+02
    pu239   4.61E+03  4.68E+03  4.68E+03  4.68E+03  4.68E+03  4.68E+03  4.68E+03
    pu240   2.20E+03  2.20E+03  2.21E+03  2.21E+03  2.21E+03  2.21E+03  2.21E+03
    pu241   1.16E+03  1.07E+03  9.89E+02  9.13E+02  8.43E+02  7.78E+02  7.18E+02
```

pu242	5.27E+02	5.27E+02	5.27E+02	5.27E+02	5.27E+02	5.27E+02	5.27E+02
am241	3.78E+01	1.27E+02	2.09E+02	2.84E+02	3.54E+02	4.18E+02	4.76E+02
am242m	7.39E-01	7.33E-01	7.27E-01	7.21E-01	7.15E-01	7.09E-01	7.03E-01
am243	1.10E+02	1.10E+02	1.10E+02	1.10E+02	1.10E+02	1.10E+02	1.10E+02
total	8.53E+05	8.53E+05	8.53E+05	8.53E+05	8.53E+05	8.53E+05	8.53E+05

0 element concentrations, grams
0 nuclide concentrations, grams
basis =single reactor assembly

	initial	605.2 d	1210.3 d	1815.5 d	2420.7 d	3025.8 d	3631.0 d
mo 95	5.38E+02	6.22E+02	6.22E+02	6.22E+02	6.22E+02	6.22E+02	6.22E+02
tc 99	6.62E+02	6.65E+02	6.65E+02	6.65E+02	6.65E+02	6.65E+02	6.65E+02

0 nuclide concentrations, grams
basis =single reactor assembly

	initial	605.2 d	1210.3 d	1815.5 d	2420.7 d	3025.8 d	3631.0 d
ru101	6.49E+02	6.49E+02	6.49E+02	6.49E+02	6.49E+02	6.49E+02	6.49E+02
rh103	3.87E+02	4.28E+02	4.28E+02	4.28E+02	4.28E+02	4.28E+02	4.28E+02
ag109	8.65E+01	8.67E+01	8.67E+01	8.67E+01	8.67E+01	8.67E+01	8.67E+01

0 nuclide concentrations, grams
basis =single reactor assembly

	initial	605.2 d	1210.3 d	1815.5 d	2420.7 d	3025.8 d	3631.0 d
nd143	6.34E+02	6.53E+02	6.53E+02	6.53E+02	6.53E+02	6.53E+02	6.53E+02
nd145	5.52E+02	5.52E+02	5.52E+02	5.52E+02	5.52E+02	5.52E+02	5.52E+02
sm147	5.81E+01	1.23E+02	1.48E+02	1.71E+02	1.86E+02	1.95E+02	2.01E+02
sm149	1.76E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00
sm150	2.56E+02	2.56E+02	2.56E+02	2.56E+02	2.56E+02	2.56E+02	2.56E+02
sm151	1.17E+01	1.18E+01	1.17E+01	1.15E+01	1.14E+01	1.12E+01	1.11E+01
eu151	1.18E-02	1.64E-01	3.14E-01	4.61E-01	6.08E-01	7.52E-01	8.94E-01
sm152	1.16E+02	1.16E+02	1.16E+02	1.16E+02	1.16E+02	1.16E+02	1.16E+02
eu153	1.03E+02	1.04E+02	1.04E+02	1.04E+02	1.04E+02	1.04E+02	1.04E+02

0 nuclide concentrations, grams
basis =single reactor assembly

	initial	605.2 d	1210.3 d	1815.5 d	2420.7 d	3025.8 d	3631.0 d
gd155	3.19E-02	1.10E+00	1.94E+00	2.60E+00	3.11E+00	3.52E+00	3.83E+00
total	2.84E+04	2.84E+04	2.84E+04	2.84E+04	2.84E+04	2.84E+04	2.84E+04

rob9g16less100.sum

```
*************************************************************************
*                                                                       *
*                    SCALE4.3  Bulletin  Board                          *
*                    --------  --------  -----                          *
*                                                                       *
*                      Welcome to SCALE-4.3.                            *
*                                                                       *
*                                                                       *
*                                                                       *
*************************************************************************
1          primary module access and input record ( scale driver - 95/03/29 - 09:06:37 )
-   module sas2h    will be called
     M.B. Robinson W-9B-S 16.02 GWd/MTU, 11 cm,  July 97
     *
     *
     *
     *    mixtures of fuel-pin-unitcell
     *
     44group      latticecell
     *
     *
     *
     uo2  1 den=9.944 1  822
              92234 0.023 92235 2.561 92236 0.013 92238 97.403  end
     kr-83  1 0 1-20 822  end
     kr-85  1 0 1-20 822  end
     y-89   1 0 1-20 822  end
     zr-90  1 0 1-20 822  end
     zr-93  1 0 1-20 822  end
     zr-94  1 0 1-20 822  end
     zr-95  1 0 1-20 822  end
     nb-94  1 0 1-20 822  end
     mo-95  1 0 1-20 822  end
     tc-99  1 0 1-20 822  end
     ru-101 1 0 1-20 822  end
     ru-106 1 0 1-20 822  end
     rh-103 1 0 1-20 822  end
     rh-105 1 0 1-20 822  end
     pd-105 1 0 1-20 822  end
     pd-108 1 0 1-20 822  end
     ag-109 1 0 1-20 822  end
     sb-124 1 0 1-20 822  end
     xe-131 1 0 1-20 822  end
     xe-132 1 0 1-20 822  end
     xe-135 1 0 1-20 822  end
     xe-136 1 0 1-20 822  end
     cs-134 1 0 1-20 822  end
     cs-135 1 0 1-20 822  end
     cs-137 1 0 1-20 822  end
     ba-136 1 0 1-20 822  end
     la-139 1 0 1-20 822  end
     pr-141 1 0 1-20 822  end
     pr-143 1 0 1-20 822  end
     ce-144 1 0 1-20 822  end
     nd-143 1 0 1-20 822  end
     nd-145 1 0 1-20 822  end
     nd-147 1 0 1-20 822  end
     pm-147 1 0 1-20 822  end
     pm-148 1 0 1-20 822  end
     sm-147 1 0 1-20 822  end
     sm-149 1 0 1-20 822  end
     sm-150 1 0 1-20 822  end
     sm-151 1 0 1-20 822  end
     sm-152 1 0 1-20 822  end
     eu-153 1 0 1-20 822  end
     eu-154 1 0 1-20 822  end
     eu-155 1 0 1-20 822  end
     gd-155 1 0 1-20 822  end
     *
     arbm-zirc4 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
                40000 98.18 2 1.0 595   end
     *
     h2o 3 den=0.7544 1 559  end
     arbm-bormod 0.7544 1 1 0 0 5000 100 3 652.5e-6 559  end
     *
     n     4 0 5-5 559  end
     *
     ss304 5 1 559  end
     *
     o     6 0 0.04497 559  end
     na    6 0 0.00165 559  end
     al    6 0 0.00058 559  end
     si    6 0 0.01799 559  end
     k     6 0 0.00011 559  end
     b-10  6 0 9.595-4 559  end
     b-11  6 0 3.863-3 559  end
     *
     *      553 ppm boron (wt) in moderator
     * - - - - - - - - - - - - - - - - - - - - - - - - -
     end comp
     *
     * - - - - - - - - - - - - - - - - - - - - - - - - -
     *fuel-pin-cell geometry:
     *
     squarepitch  1.43 0.9294 1 3 1.0719 2 0.9484 0  end
     *
     * - - - - - - - - - - - - - - - - - - - - - - - - -
     *
     *
     *       assembly and cycle parameters
     *
     npin/assm=204 fuelngth=726.63 ncycles=4 nlib/cyc=3
     printlevel=5 lightel=9 inplevel=2 numrtotal=11
     mxrepeats=0  end
     *
     4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
     2 0.6934 3 0.8068 500 2.2238 3 2.2290
     4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
     2 0.6934 3 0.8068 500 2.2238 3 2.2290
     4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
```

```
2 0.6934 3 0.8068 500 2.2238 3 2.2290
*
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
*
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
*
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
*
power=18.39 burn=243.5  down=40  end
power=17.76 burn=243.5  down=64  bfrac=0.3793   end
power=17.25 burn=156.0  down=39  bfrac=1.0   end
power=16.84 burn=156.0  down=3936  bfrac=0.3793   end
  o 119 cr 5.2 sn 0.29
  fe 11 co 0.066 ni 8.7
  sr 195 nb 0.63 sn 3.2
*
*   the above light elements converted to kg per mtuo2
* - - - - - - - - - - - - - - - - - - - - - - - - - -
*
```

```
1  ############     #########     ############    22222222222   hh         hh
  ##############   ############   ##############  2222222222222  hh         hh
  ##          ##   ##        ##   ##          ##  22        22   hh         hh
  ##               ##        ##   ##                       22   hh         hh
  ##               ##        ##   ##                       22   hh         hh
  ############     ##############   ##############          22   hhhhhhhhhhhhhh
   ############    ##############    ############         22    hhhhhhhhhhhhhh
             ##    ##        ##               ##       22       hh         hh
             ##    ##        ##               ##    22          hh         hh
  ##         ##    ##        ##   ##          ##  22            hh         hh
  ##############   ##        ##   ##############  2222222222222  hh         hh
   ############    ##        ##    ############   2222222222222  hh         hh
0

  nn          nn  iiiiiiiiiiii    eeeeeeeeeee    hh         hh   oooooooooooo   ll
  nnn         nn  iiiiiiiiiiii   eeeeeeeeeeeee   hh         hh  ooooooooooooo  ll
  nnnn        nn      ii         ee         ee   hh         hh  oo         oo  ll
  nn nn       nn      ii         ee              hh         hh  oo         oo  ll
  nn  nn      nn      ii         ee              hh         hh  oo         oo  ll
  nn   nn     nn      ii         ee              hhhhhhhhhhhhhh  oo         oo  ll
  nn    nn    nn      ii         ee              hhhhhhhhhhhhhh  oo         oo  ll
  nn     nn   nn      ii         ee              hh         hh  oo         oo  ll
  nn      nn  nn      ii         ee              hh         hh  oo         oo  ll
  nn       nn nn      ii         ee              hh         hh  oo         oo  ll
  nn        nnnn      ii         ee         ee   hh         hh  oo         oo  ll
  nn         nnn  iiiiiiiiiiii   eeeeeeeeeeeee   hh         hh  ooooooooooooo  llllllllllll
  nn          nn  iiiiiiiiiiii    eeeeeeeeeee    hh         hh   oooooooooooo  llllllllllll
0

     0000000      ##########                //     0000000      ##########                //   99999999999   7777777777777
   000000000     ############              //    000000000     ############              //  9999999999999  777777777777
  00       00    ##        ##             //   00       00    ##        ##             //   99         99  77         77
 00         00   ##        ##            //   00         00   ##        ##            //    99         99           77
 00         00   ##        ##           //    00         00   ##        ##           //     99         99          77
 00         00    ##########           //     00         00    ##########           //      99999999999         77
 00         00    ##########          //      00         00    ##########          //       99999999999        77
 00         00   ##        ##        //       00         00   ##        ##        //                 99        77
 00         00   ##        ##       //        00         00   ##        ##       //                  99       77
  00       00    ##        ##      //          00       00    ##        ##      //                   99      77
   000000000     ############     //            000000000     ############     //  9999999999999    99      77
    0000000       ##########     //              0000000       ##########     //   999999999999     99      77
0

      11         99999999999                     0000000          11                          11          11
     111        9999999999999                   000000000        111                         111         111
    1111        99        99        :::        00       00     1111            :::          1111        1111
      11        99        99        :::        00         00     11            :::            11          11
      11        99        99        :::        00         00     11            :::            11          11
      11        9999999999999                  00         00     11                           11          11
      11         999999999999                  00         00     11                           11          11
      11                  99        :::        00         00     11            :::            11          11
      11                  99        :::        00         00     11            :::            11          11
      11                  99        :::         00       00      11            :::            11          11
   11111111     9999999999999                    000000000      11111111                    11111111    11111111
   11111111     999999999999                      0000000       11111111                    11111111    11111111
1
0                                  ###########    eeeeeeeeeee    ##########    11          eeeeeeeeeeee
                                  #############  eeeeeeeeeeeee  ###########    11          eeeeeeeeeeee
                                  ##         ##  ee         ee  ##        ##    11          ee
                                  ##             ee         ee  ##        ##    11          ee
                                  ##             ee         ee  ##        ##    11          ee
                                  #############  ee             ##############  11          eeeeeeeeee
                                   #############  ee             ##############  11          eeeeeeeeee
                                             ##  ee         ee  ##        ##    11          ee
                                             ##  ee         ee  ##        ##    11          ee
                                  ##         ##  ee         ee  ##        ##    11          ee
                                  #############  eeeeeeeeeeeee  ##        ##    1111111111111  eeeeeeeeeeeee
                                   ###########    eeeeeeeeeee   ##        ##    1111111111111  eeeeeeeeeeeee
```

program verification information

```
*****                 code system:    scale  version:    4.3                 *****
*****                                                                          *****
*****                                                                          *****
*****                                                                          *****
*****                                                                          *****
*****                                                                          *****
*****                 program:  sas2                                           *****
*****                                                                          *****
*****            creation date:  03/07/97                                      *****
*****                                                                          *****
*****                 library:  /opt/neut/Scale4.3/bin                         *****
*****                                                                          *****
*****                                                                          *****
*****        this is not a   scale  configuration controlled code              *****
*****                                                                          *****
*****                 jobname:  nichol                                         *****
*****                                                                          *****
*****       date of execution:  08/08/97                                       *****
*****                                                                          *****
*****       time of execution:  19:01:11                                       *****
*****                                                                          *****
*****                                                                          *****
*****                                                                          *****
*****                                                                          *****
*****                                                                          *****
*****                                                                          *****
1
0
0
0
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  1E-18 d
     o 16  1.19E+05  1.19E+05
   total   3.45E+05  3.45E+05
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  1E-18 d
     u234  2.03E+02  2.03E+02
     u235  2.26E+04  2.26E+04
     u236  1.15E+02  1.15E+02
     u238  8.58E+05  8.58E+05
   total   8.81E+05  8.81E+05
0                                       basis =
0                 initial        20.3 d        40.6 d        60.9 d        81.2 d        81.2 d
0                 initial        20.3 d        40.6 d        60.9 d        81.2 d        81.2 d
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  656.0 d  1312.0 d  1968.0 d  2624.0 d  3280.0 d  3936.0 d
     o 16  1.19E+05  1.19E+05  1.19E+05  1.19E+05  1.19E+05  1.19E+05  1.19E+05
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  656.0 d  1312.0 d  1968.0 d  2624.0 d  3280.0 d  3936.0 d
    mo 95  6.93E+00  8.14E+00  8.14E+00  8.14E+00  8.14E+00  8.14E+00  8.14E+00
    tc 99  6.62E-06  6.71E-06  6.71E-06  6.71E-06  6.71E-06  6.71E-06  6.71E-06
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  656.0 d  1312.0 d  1968.0 d  2624.0 d  3280.0 d  3936.0 d
   total   3.45E+05  3.45E+05  3.45E+05  3.45E+05  3.45E+05  3.45E+05  3.45E+05
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  656.0 d  1312.0 d  1968.0 d  2624.0 d  3280.0 d  3936.0 d
    u233  1.02E-03  1.11E-03  1.20E-03  1.29E-03  1.38E-03  1.47E-03  1.56E-03
    u234  1.53E+02  1.53E+02  1.53E+02  1.54E+02  1.54E+02  1.55E+02  1.55E+02
    u235  1.11E+04  1.11E+04  1.11E+04  1.11E+04  1.11E+04  1.11E+04  1.11E+04
    u236  2.14E+03  2.14E+03  2.14E+03  2.14E+03  2.14E+03  2.14E+03  2.14E+03
    u238  8.47E+05  8.47E+05  8.47E+05  8.47E+05  8.47E+05  8.47E+05  8.47E+05
   np237  1.44E+02  1.47E+02  1.47E+02  1.47E+02  1.48E+02  1.48E+02  1.49E+02
   pu236  1.04E-04  6.78E-05  4.42E-05  2.87E-05  1.87E-05  1.22E-05  7.93E-06
   pu238  2.70E+01  2.95E+01  2.92E+01  2.88E+01  2.84E+01  2.80E+01  2.76E+01
   pu238  2.70E+01  2.95E+01  2.92E+01  2.88E+01  2.84E+01  2.80E+01  2.76E+01
   pu239  3.94E+03  3.98E+03  3.98E+03  3.98E+03  3.98E+03  3.98E+03  3.98E+03
   pu240  1.16E+03  1.16E+03  1.16E+03  1.16E+03  1.16E+03  1.16E+03  1.16E+03
   pu241  5.24E+02  4.80E+02  4.40E+02  4.04E+02  3.70E+02  3.39E+02  3.11E+02
   pu242  1.06E+02  1.06E+02  1.06E+02  1.06E+02  1.06E+02  1.06E+02  1.06E+02
   am241  1.91E+01  6.25E+01  1.02E+02  1.38E+02  1.72E+02  2.02E+02  2.29E+02
  am242m  3.25E-01  3.22E-01  3.20E-01  3.17E-01  3.14E-01  3.11E-01  3.08E-01
   am243  1.07E+01  1.07E+01  1.07E+01  1.07E+01  1.07E+01  1.07E+01  1.07E+01
   total  8.67E+05  8.67E+05  8.67E+05  8.67E+05  8.67E+05  8.67E+05  8.67E+05
0                                        element concentrations, grams
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  656.0 d  1312.0 d  1968.0 d  2624.0 d  3280.0 d  3936.0 d
    mo 95  2.91E+02  3.42E+02  3.42E+02  3.42E+02  3.42E+02  3.42E+02  3.42E+02
    tc 99  3.59E+02  3.61E+02  3.61E+02  3.61E+02  3.61E+02  3.61E+02  3.61E+02
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  656.0 d  1312.0 d  1968.0 d  2624.0 d  3280.0 d  3936.0 d
   ru101  3.31E+02  3.31E+02  3.31E+02  3.31E+02  3.31E+02  3.31E+02  3.31E+02
   rh103  2.31E+02  2.31E+02  2.31E+02  2.31E+02  2.31E+02  2.31E+02  2.31E+02
   ag109  3.38E+01  3.39E+01  3.39E+01  3.39E+01  3.39E+01  3.39E+01  3.39E+01
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  656.0 d  1312.0 d  1968.0 d  2624.0 d  3280.0 d  3936.0 d
   nd143  4.00E+02  4.11E+02  4.11E+02  4.11E+02  4.11E+02  4.11E+02  4.11E+02
   nd145  3.11E+02  3.11E+02  3.11E+02  3.11E+02  3.11E+02  3.11E+02  3.11E+02
   sm147  4.04E+01  8.12E+01  1.07E+02  1.22E+02  1.32E+02  1.38E+02  1.42E+02
   sm149  1.51E+00  2.07E+00  2.07E+00  2.07E+00  2.07E+00  2.07E+00  2.07E+00
   sm150  1.16E+02  1.16E+02  1.16E+02  1.16E+02  1.16E+02  1.16E+02  1.16E+02
   sm151  8.32E+00  8.32E+00  8.21E+00  8.09E+00  7.98E+00  7.87E+00  7.77E+00
   eu151  1.75E-02  1.33E-01  2.48E-01  3.60E-01  4.72E-01  5.81E-01  6.90E-01
   sm152  6.24E+01  6.24E+01  6.24E+01  6.24E+01  6.24E+01  6.24E+01  6.24E+01
   eu153  3.91E+01  3.93E+01  3.93E+01  3.93E+01  3.93E+01  3.93E+01  3.93E+01
   gd155  1.79E-02  4.23E-01  7.34E-01  9.73E-01  1.16E+00  1.30E+00  1.40E+00
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
            initial  656.0 d  1312.0 d  1968.0 d  2624.0 d  3280.0 d  3936.0 d
   total  1.45E+04  1.45E+04  1.45E+04  1.45E+04  1.45E+04  1.45E+04  1.45E+04
```

rob9g32less100.sum

```
0*********************************************************************
 *                                                                   *
 *                    SCALE4.3  Bulletin  Board                      *
 *                    --------  --------  -----                      *
 *                                                                   *
 *                      Welcome to SCALE-4.3.                        *
 *                                                                   *
 *                                                                   *
 *********************************************************************
1          primary module access and input record ( scale driver - 95/03/29 - 09:06:37 )
-   module sas2h    will be called
     M.B. Robinson W-9C-D 31.66 GWd/MTU, 226 cm July 97
     *
     *
     *
     *    mixtures of fuel-pin-unitcell
     *
     44group      latticecell
     *
     *
     *
     uo2  1 den=9.944 1  822
              92234 0.023 92235 2.561 92236 0.013 92238 97.403  end
     kr-83   1 0 1-20 822  end
     kr-85   1 0 1-20 822  end
     y-89    1 0 1-20 822  end
     zr-90   1 0 1-20 822  end
     zr-93   1 0 1-20 822  end
     zr-94   1 0 1-20 822  end
     zr-95   1 0 1-20 822  end
     nb-94   1 0 1-20 822  end
     mo-95   1 0 1-20 822  end
     tc-99   1 0 1-20 822  end
     ru-101  1 0 1-20 822  end
     ru-106  1 0 1-20 822  end
     rh-103  1 0 1-20 822  end
     rh-105  1 0 1-20 822  end
     pd-105  1 0 1-20 822  end
     pd-108  1 0 1-20 822  end
     ag-109  1 0 1-20 822  end
     sb-124  1 0 1-20 822  end
     xe-131  1 0 1-20 822  end
     xe-132  1 0 1-20 822  end
     xe-135  1 0 1-20 822  end
     xe-136  1 0 1-20 822  end
     cs-134  1 0 1-20 822  end
     cs-135  1 0 1-20 822  end
     cs-137  1 0 1-20 822  end
     ba-136  1 0 1-20 822  end
     la-139  1 0 1-20 822  end
     pr-141  1 0 1-20 822  end
     pr-143  1 0 1-20 822  end
     ce-144  1 0 1-20 822  end
     nd-143  1 0 1-20 822  end
     nd-145  1 0 1-20 822  end
     nd-147  1 0 1-20 822  end
     pm-147  1 0 1-20 822  end
     pm-148  1 0 1-20 822  end
     sm-147  1 0 1-20 822  end
     sm-149  1 0 1-20 822  end
     sm-150  1 0 1-20 822  end
     sm-151  1 0 1-20 822  end
     sm-152  1 0 1-20 822  end
     eu-153  1 0 1-20 822  end
     eu-154  1 0 1-20 822  end
     eu-155  1 0 1-20 822  end
     gd-155  1 0 1-20 822  end
     *
     arbm-zirc4 6.56 5 0 0 0 8016 0.12 24000 0.10 26000 0.20 50000 1.40
               40000 98.18 2 1.0 595   end
     *
     h2o 3 den=0.7135 1 579  end
     arbm-borwod 0.7135 1 1 0 0 5000 100 3 652.5e-6 579  end
     *
     n      4 0 5-5 579  end
     *
     ss304 5 1 576  end
     *
     o      6 0 0.04497 579  end
     na     6 0 0.00165 579  end
     al     6 0 0.00058 579  end
     si     6 0 0.01799 579  end
     k      6 0 0.00011 579  end
     b-10   6 0 9.595-4 579  end
     b-11   6 0 3.863-3 579  end
     *
     *      653 ppm boron (wt) in moderator
     * - - - - - - - - - - - - - - - - - - - - - - - - -
     end comp
     *
     * - - - - - - - - - - - - - - - - - - - - - - - - -
     *fuel-pin-cell geometry:
     *
     squarepitch  1.43 0.9294 1 3 1.0719 2 0.9484 0  end
     *
     * - - - - - - - - - - - - - - - - - - - - - - - - -
     *
     *
     *       assembly and cycle parameters
     *
     npin/assm=204 fuelngth=726.63 ncycles=4 nlib/cyc=3
     printlevel=5 lightel=9 inplevel=2 numztotal=11
     exrepeats=0  end
     *
     4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
     2 0.6934 3 0.8068 500 2.2238 3 2.2290
     4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
     2 0.6934 3 0.8068 500 2.2238 3 2.2290
     4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
```

```
2 0.6934 3 0.8068 500 2.2238 3 2.2290
*
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
4 0.2839 5 0.3004 4 0.3086 6 0.5029 4 0.5087 5 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.2238 3 2.2290
*
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
*
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
3 0.2839 3 0.3004 3 0.3086 3 0.5029 3 0.5087 3 0.5576 3 0.6502
2 0.6934 3 0.8068 500 2.6408 3 2.6470
*
power=39.38 burn=243.5  down=40  end
power=35.48 burn=243.5  down=64  bfrac=0.3793   end
power=32.27 burn=156.0  down=39  bfrac=1.0   end
power=29.78 burn=156.0  down=3631  bfrac=0.3793   end
  o 119 cr 5.2 mn 0.29
  fe 11 co 0.066 ni 8.7
  zr 195 nb 0.63 sn 3.2
*
*   the above light elements converted to kg per mtuo2
* - - - - - - - - - - - - - - - - - - - - - - - -
*
```

```
1  ############     ##########     ############    22222222222    hh         hh
  ##############   ############   ##############  2222222222222  hh         hh
  ##          ##   ##        ##   ##          ##  22        22   hh         hh
  ##              ##        ##   ##              22        22   hh         hh
  ##              ##        ##   ##              22        22   hh         hh
  ############    ##############   ##############          22   hhhhhhhhhhhhhh
   ############   ##############    ############         22    hhhhhhhhhhhhhh
             ##   ##        ##              ##       22        hh         hh
             ##   ##        ##              ##    22           hh         hh
  ##         ##   ##        ##   ##         ##  22             hh         hh
  ##############   ##        ##   ##############  2222222222222  hh         hh
   ############    ##        ##    ############   2222222222222  hh         hh
0
```

```
nn          nn  iiiiiiiiiiii    cccccccccccc    hh         hh    oooooooooooo    11
nnn         nn  iiiiiiiiiiii    cccccccccccc    hh         hh    oooooooooooo    11
nnnn        nn      ii          cc        cc    hh         hh    oo        oo    11
nn nn       nn      ii          cc              hh         hh    oo        oo    11
nn  nn      nn      ii          cc              hh         hh    oo        oo    11
nn   nn     nn      ii          cc              hhhhhhhhhhhhhh    oo        oo    11
nn    nn    nn      ii          cc              hhhhhhhhhhhhhh    oo        oo    11
nn     nn   nn      ii          cc              hh         hh    oo        oo    11
nn      nn  nn      ii          cc              hh         hh    oo        oo    11
nn       nnnn       ii          cc        cc    hh         hh    oo        oo    11
nn        nnn  iiiiiiiiiiii    cccccccccccc    hh         hh    oooooooooooo    1111111111111
nn         nn  iiiiiiiiiiii     cccccccccc     hh         hh     oooooooooo     1111111111111
0
```

```
    0000000       ##########              //    0000000       ##########              //   99999999999   7777777777777
   000000000     ############            //    000000000     ############            //  9999999999999  7777777777777
  00       00    ##        ##          //    00       00    ##        ##          //   99         99  77         77
 00         00   ##        ##         //    00         00   ##        ##         //    99         99          77
 00         00    ##########         //     00         00    ##########         //     99         99         77
 00         00    ##########        //      00         00    ##########        //      9999999999999        77
 00         00   ##        ##      //       00         00   ##        ##      //        999999999999        77
  00       00    ##        ##     //         00       00    ##        ##     //                 99        77
   000000000     ############   //            000000000     ############   //                 99        77
    0000000       ##########   //              0000000       ##########   //                 99       77
0
```

```
      11        99999999999                   22222222222   22222222222                      11        ##########
     111       9999999999999                 2222222222222 2222222222222                    111       ############
    1111       99        99        :::       22        22  22        22        :::         1111       ##        ##
      11       99        99        :::                 22            22        :::           11       ##        ##
      11       99        99        :::                 22            22        :::           11       ##        ##
      11       9999999999999                       22            22                          11        ##########
      11        999999999999                     22            22                           11        ##########
      11                  99        :::         22            22        :::                 11       ##        ##
      11                  99        :::       22            22          :::                 11       ##        ##
      11                  99        :::     22            22            :::                 11       ##        ##
   11111111     9999999999999                 2222222222222 2222222222222                 11111111    ############
   11111111     999999999999                  2222222222222 2222222222222                 11111111     ##########
1
0
```

```
                          ##########    cccccccccc     #########    11          ##############
                         ############  cccccccccccc   ###########   11          ##############
                         ##        ##  cc        cc   ##       ##   11          ##          ##
                         ##            cc             ##       ##   11          ##          ##
                         ##            cc             ##       ##   11          ##          ##
                         ############  cc             ############## 11          ##########
                          ############ cc             ############## 11          ##########
                                   .## cc             ##       ##   11          ##          ##
                                   ##  cc             ##       ##   11          ##          ##
                         ##        ##  cc        cc   ##       ##   11          ##          ##
                         ############  cccccccccccc   ############## 1111111111111 ##############
                          ##########    cccccccccc     ##########   1111111111111 ##############
```

```
*****************************************************************************
*****************************************************************************
*****************************************************************************
*****                                                                   *****
*****                 program verification information                   *****
*****                                                                   *****
```

```
*****                    code system:    scale  version:    4.3                 *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
*****                 program:  sas2                                             *****
*****                                                                            *****
*****           creation date:  03/07/97                                         *****
*****                                                                            *****
*****                 library:  /opt/neut/Scale4.3/bin                           *****
*****                                                                            *****
*****                                                                            *****
*****       this is not a   scale  configuration controlled code                 *****
*****                                                                            *****
*****                 jobname:  nichol                                           *****
*****                                                                            *****
*****       date of execution:  08/08/97                                         *****
*****                                                                            *****
*****       time of execution:  19:22:18                                         *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
*****                                                                            *****
```

```
1
0
0
0
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
              initial  1E-18 d
     o 16    1.19E+05  1.19E+05
   total     3.45E+05  3.45E+05
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
              initial  1E-18 d
     u234    2.03E+02  2.03E+02
     u235    2.26E+04  2.26E+04
     u236    1.15E+02  1.15E+02
     u238    8.58E+05  8.58E+05
   total     8.81E+05  8.81E+05
0                                        basis =
0                 initial        20.3 d        40.6 d        60.9 d        81.2 d        81.2 d
0                 initial        20.3 d        40.6 d        60.9 d        81.2 d        81.2 d
                                         basis = single reactor assembly
              charge    20.3 d   40.6 d    60.9 d    81.2 d    81.2 d
     o 16    7.42E+03  7.42E+03  7.42E+03  7.42E+03  7.42E+03  7.42E+03
                                         basis = single reactor assembly
              charge    20.3 d   40.6 d    60.9 d    81.2 d    81.2 d
                                         basis = single reactor assembly
              charge    20.3 d   40.6 d    60.9 d    81.2 d    81.2 d
                                         basis = single reactor assembly
              charge    20:3 d   40.6 d    60.9 d    81.2 d    81.2 d
    mo 95     .00E+00  7.09E-05  4.91E-04  1.44E-03  2.98E-03  2.98E-03
    tc 99     .00E+00  1.13E-11  1.21E-10  4.46E-10  1.09E-09  1.09E-09
                                         basis = single reactor assembly
              charge    20.3 d   40.6 d    60.9 d    81.2 d    81.2 d
                                         basis = single reactor assembly
              charge    20.3 d   40.6 d    60.9 d    81.2 d    81.2 d
   totals    1.02E+04  1.02E+04  1.02E+04  1.02E+04  1.02E+04  1.02E+04
                                         basis = single reactor assembly
              charge    20.3 d   40.6 d    60.9 d    81.2 d    81.2 d
     u233     .00E+00  4.63E-07  9.03E-07  1.30E-06  1.67E-06  1.67E-06
     u234    8.66E-01  8.51E-01  8.36E-01  8.21E-01  8.06E-01  8.06E-01
     u235    9.60E+01  9.23E+01  8.87E+01  8.53E+01  8.21E+01  8.21E+01
     u236    4.85E-01  1.19E+00  1.88E+00  2.52E+00  3.13E+00  3.13E+00
     u238    3.61E+03  3.60E+03  3.60E+03  3.60E+03  3.59E+03  3.59E+03
    np237     .00E+00  1.11E-02  3.26E-02  5.89E-02  8.87E-02  8.87E-02
    pu236     .00E+00  4.90E-10  3.15E-09  8.73E-09  1.76E-08  1.76E-08
    pu238     .00E+00  8.07E-05  6.02E-04  1.76E-03  3.63E-03  3.63E-03
    pu238     .00E+00  8.07E-05  6.02E-04  1.76E-03  3.63E-03  3.63E-03
    pu239     .00E+00  2.08E-00  4.33E+00  6.29E+00  7.98E+00  7.98E+00
    pu240     .00E+00  4.71E-02  1.90E-01  3.97E-01  6.44E-01  6.44E-01
    pu241     .00E+00  2.72E-03  2.26E-02  7.10E-02  1.53E-01  1.53E-01
    pu242     .00E+00  2.08E-05  3.61E-04  1.74E-03  5.07E-03  5.07E-03
                                         basis = single reactor assembly
              charge    20.3 d   40.6 d    60.9 d    81.2 d    81.2 d
    am241     .00E+00  1.74E-06  2.92E-05  1.41E-04  4.10E-04  4.10E-04
    am242m    .00E+00  4.38E-09  1.41E-07  9.51E-07  3.47E-06  3.47E-06
    am243     .00E+00  1.15E-07  4.13E-06  3.03E-05  1.19E-04  1.19E-04
   totals    3.70E+03  3.70E+03  3.70E+03  3.69E+03  3.69E+03  3.69E+03
                decay data, including gamma and total energy, are from endf/b-vi
0                 1697    total number of nuclides in library
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
              initial  605.2 d  1210.3 d  1815.5 d  2420.7 d  3025.8 d  3631.0 d
     o 16    1.19E+05  1.19E+05  1.19E+05  1.19E+05  1.19E+05  1.19E+05  1.19E+05
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
              initial  605.2 d  1210.3 d  1815.5 d  2420.7 d  3025.8 d  3631.0 d
    mo 95    1.46E+01  1.72E+01  1.72E+01  1.72E+01  1.72E+01  1.72E+01  1.72E+01
    tc 99    6.36E-05  6.45E-05  6.45E-05  6.45E-05  6.45E-05  6.45E-05  6.45E-05
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
              initial  605.2 d  1210.3 d  1815.5 d  2420.7 d  3025.8 d  3631.0 d
   total     3.45E+05  3.45E+05  3.45E+05  3.45E+05  3.45E+05  3.45E+05  3.45E+05
0                                        nuclide concentrations, grams
                                         basis =single reactor assembly
              initial  605.2 d  1210.3 d  1815.5 d  2420.7 d  3025.8 d  3631.0 d
     u233    1.26E-03  1.46E-03  1.65E-03  1.85E-03  2.05E-03  2.24E-03  2.44E-03
     u234    1.13E+02  1.15E+02  1.16E+02  1.18E+02  1.20E+02  1.21E+02  1.23E+02
     u235    5.27E+03  5.27E+03  5.27E+03  5.27E+03  5.27E+03  5.27E+03  5.27E+03
     u236    2.99E+03  2.99E+03  2.99E+03  2.99E+03  3.00E+03  3.00E+03  3.00E+03
     u238    8.35E+05  8.35E+05  8.35E+05  8.35E+05  8.35E+05  8.35E+05  8.35E+05
    np237    3.41E+02  3.48E+02  3.49E+02  3.49E+02  3.50E+02  3.51E+02  3.52E+02
    pu236    5.63E-04  3.81E-04  2.56E-04  1.72E-04  1.16E-04  7.81E-05  5.25E-05
    pu238    1.21E+02  1.32E+02  1.31E+02  1.30E+02  1.28E+02  1.26E+02  1.25E+02
    pu238    1.21E+02  1.32E+02  1.31E+02  1.30E+02  1.28E+02  1.26E+02  1.25E+02
    pu239    4.54E+03  4.62E+03  4.62E+03  4.62E+03  4.62E+03  4.62E+03  4.62E+03
    pu240    2.20E+03  2.20E+03  2.20E+03  2.20E+03  2.20E+03  2.20E+03  2.21E+03
    pu241    1.15E+03  1.06E+03  9.78E+02  9.03E+02  8.33E+02  7.69E+02  7.10E+02
```

pu242	5.27E+02	5.27E+02	5.27E+02	5.27E+02	5.27E+02	5.27E+02	5.27E+02
am241	3.72E+01	1.25E+02	2.06E+02	2.81E+02	3.49E+02	4.13E+02	4.71E+02
am242m	7.25E-01	7.19E-01	7.13E-01	7.07E-01	7.01E-01	6.96E-01	6.90E-01
am243	1.09E+02	1.09E+02	1.09E+02	1.09E+02	1.09E+02	1.09E+02	1.09E+02
total	8.53E+05	8.53E+05	8.53E+05	8.53E+05	8.53E+05	8.53E+05	8.53E+05

0 element concentrations, grams
0 nuclide concentrations, grams
basis =single reactor assembly

	initial	605.2 d	1210.3 d	1815.5 d	2420.7 d	3025.8 d	3631.0 d
mo 95	5.39E+02	6.23E+02	6.23E+02	6.23E+02	6.23E+02	6.23E+02	6.23E+02
tc 99	6.62E+02	6.65E+02	6.65E+02	6.65E+02	6.65E+02	6.65E+02	6.65E+02

0 nuclide concentrations, grams
basis =single reactor assembly

	initial	605.2 d	1210.3 d	1815.5 d	2420.7 d	3025.8 d	3631.0 d
ru101	6.49E+02	6.49E+02	6.49E+02	6.49E+02	6.49E+02	6.49E+02	6.49E+02
rh103	3.86E+02	4.27E+02	4.27E+02	4.27E+02	4.27E+02	4.27E+02	4.27E+02
ag109	8.62E+01	8.63E+01	8.63E+01	8.63E+01	8.63E+01	8.63E+01	8.63E+01

0 nuclide concentrations, grams
basis =single reactor assembly

	initial	605.2 d	1210.3 d	1815.5 d	2420.7 d	3025.8 d	3631.0 d
nd143	6.32E+02	6.51E+02	6.51E+02	6.51E+02	6.51E+02	6.51E+02	6.51E+02
nd145	5.52E+02	5.52E+02	5.52E+02	5.52E+02	5.52E+02	5.52E+02	5.52E+02
sm147	5.81E+01	1.13E+02	1.48E+02	1.71E+02	1.85E+02	1.95E+02	2.01E+02
sm149	1.74E+00	2.98E+00	2.98E+00	2.98E+00	2.98E+00	2.98E+00	2.98E+00
sm150	2.56E+02	2.56E+02	2.56E+02	2.56E+02	2.56E+02	2.56E+02	2.56E+02
sm151	1.16E+01	1.17E+01	1.16E+01	1.14E+01	1.13E+01	1.11E+01	1.10E+01
eu151	1.15E-02	1.62E-01	3.10E-01	4.57E-01	6.01E-01	7.44E-01	8.85E-01
sm152	1.16E+02	1.16E+02	1.16E+02	1.16E+02	1.16E+02	1.16E+02	1.16E+02
eu153	1.03E+02	1.03E+02	1.03E+02	1.03E+02	1.03E+02	1.03E+02	1.03E+02

0 nuclide concentrations, grams
basis =single reactor assembly

	initial	605.2 d	1210.3 d	1815.5 d	2420.7 d	3025.8 d	3631.0 d
gd155	3.14E-02	1.10E+00	1.94E+00	2.60E+00	3.11E+00	3.52E+00	3.83E+00
total	2.84E+04	2.84E+04	2.84E+04	2.84E+04	2.84E+04	2.84E+04	2.84E+04