Criticality Safety Code Validation with LWBR's SB Core

Valerie L. Putman

January 2003

***Idaho National Engineering and Environmental Laboratory
Bechtel BWXT Idaho, LLC***

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Abstract

The first set of critical experiments from the Shippingport Light Water Breeder Reactor Program included eight, simple geometry critical cores built with $^{233}\text{UO}_2\text{-ZrO}_2$, $^{235}\text{UO}_2\text{-ZrO}_2$, ThO_2 , and $\text{ThO}_2\text{-}^{233}\text{UO}_2$ nuclear materials. These cores are evaluated, described, and modeled to provide benchmarks and validation information for INEEL criticality safety calculation methodology. In addition to consistency with INEEL methodology, benchmark development and nuclear data are consistent with International Criticality Safety Benchmark Evaluation Project methodology.

Section 1 of this report introduces the experiments and the reason they are useful for validating some INEEL criticality safety calculations. Section 2 provides detailed experiment descriptions based on currently available experiment reports. Section 3 identifies criticality safety validation requirement sources and summarizes requirements that most affect this report. Section 4 identifies relevant hand calculation and computer code calculation methodologies used in the experiment evaluation, benchmark development, and validation calculations. Section 5 provides a detailed experiment evaluation. This section identifies resolutions for currently unavailable and discrepant information. Section 5 also reports calculated experiment uncertainty effects. Section 6 describes the developed benchmarks. Section 6 includes calculated sensitivities to various benchmark features and parameters. Section 7 summarizes validation results. Appendices describe various assumptions and their bases, list experimenter calculations results for items that were independently calculated for this validation work, report other information gathered and developed by SCIENTEC personnel while evaluating these same experiments, and list benchmark sample input and miscellaneous supplementary data.

Key Words: critical assembly, uranium oxide, thorium oxide, UO_2 , ThO_2 , ^{235}U , ^{233}U , ^{232}Th , ZrO_2 , HEU, Shippingport Light Water Breeder Reactor, LWBR, water moderation, water reflection, heterogeneous, thermal, MCNP4b2, SCALE4.3, ENDF/B-IV, ENDF/B-V.

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Acronyms, Abbreviations, and Symbols

DOES NOT INCLUDE ROMAN NUMERALS, STANDARD CHEMICAL SYMBOLS (for example, “H” for “hydrogen”), OR STANDARD UNIT ABBREVIATIONS FOR DIMENSIONS AND PHYSICAL PROPERTIES (for example, “cm” for “centimeter” or “eV” for “electron volt”)

#	number identifier (for example, an alphanumeric serial number)
Δ	difference (for example, $\Delta k = k - k_{\text{ref}}$)
Δk_{stdU}	k_{eff} difference due to standard uncertainty (specifically, the effects of a standard uncertainty on k_{eff})
σ	standard deviation microscopic cross section
ρ_{0i}	theoretical mass density of nuclide i (g/cm^3)
σ_a	microscopic neutron absorption cross section
ρ_i	mass density of nuclide i (g/cm^3)
σ_s	microscopic neutron scatter cross section
<	less than
$\leq$	less than or equal to; does not exceed
>	greater than
$\geq$	greater than or equal to; not less than
$\times$	by, as in 2×4 or width $\times$ height
Σ	summation macroscopic cross section
Σ_a	macroscopic neutron absorption cross section
Σ_s	macroscopic neutron scatter cross section
§	section, part, or paragraph
a%	atom percent
a/b-cm	atoms per barn-centimeter
avg	average fission group
AISI	American Iron and Steel Institute
amu	atomic mass unit
ANS	American Nuclear Society: La Grange Park, Illinois
ANSI	American National Standards Institute
approx	approximate, approximation
ASME	American Society of Mechanical Engineers: New York, New York
ASTM	American Society for Testing Materials: West Conshohocken, Pennsylvania
BBWI	Bechtel BWXT Idaho, LLC: Idaho Falls, Idaho. INEEL primary contractor at the time this report was issued.
B_z^2	axial (along the vertical axis) buckling
CL	centerline, usually a line across which a configuration is symmetrical
CRC	Chemical Rubber Company, Inc.

CSAS	criticality safety analysis sequence, a SCALE module descriptor. A CSAS module runs specific codes, with names such as BONAMI, NITAWL, and KENO, in a specific sequence
D	diameter
DOE	United States Department of Energy: Washington D. C.
ENDF/B	Evaluated Nuclear Data File/Version B (a U.S. nuclear data resource)
equiv	equivalent
EXT	external, as in an external report number
FEM	fissile equivalent mass (see Equation A-6, p.A-5)
H: <i>i</i>	ratio of hydrogen to nuclide <i>i</i> (a nuclide-density ratio unless otherwise indicated)
HEU	high enriched uranium, technically > 20 wt% ²³⁵ U. Redefined as > 60 wt% here for consistency with ICSBEP.
ibid	ibidem (in the same book and chapter as cited immediately before)
ICSBEP	members, project, and/or publication of the International Criticality Safety Benchmark Evaluation Project, under auspices of Nuclear Energy Agency (NEA) of the Organization for Economic Co-Operation and Development (OECD). ¹
ID	inner diameter identifier (for example, an alphanumeric serial number)
INEEL	Idaho National Engineering and Environmental Laboratory, formerly Idaho National Engineering Laboratory (INEL), formerly National Reactor Testing Station (NRTS): Idaho Falls and Scoville, Idaho. For this report <i>INEEL</i> includes only areas and projects administered by the current prime contractor.
INT	internal, as in an internal report number
IR	inner radius
k	k_{eff} for this report
k_{eff}	effective neutron multiplication factor
k_{inf}	infinite neutron multiplication factor
k_{ref}	base case k_{eff} for a specific set of comparisons
ℓ	liter
LANL	Los Alamos National Laboratory: Los Alamos, New Mexico
LMITCO	Lockheed Martin Idaho Technologies Company: Idaho Falls, Idaho (former INEEL prime-contractor)
LWBR	Light Water Breeder Reactor
MCNP™	Monte Carlo Neutral-, or N-, Particle Transport Code System. Registered trademark of the Regents of the University of California. ²
N_A	Avogadro's number
NA	not applicable
$N \times 10^M$	$N \times 10^M$ where <i>N</i> and <i>M</i> are numerals
N_i	atom density of nuclide <i>i</i> (atoms/b-cm)
NS	not specified
nuclide	atom, element or molecule
OD	outer diameter
OR	outer radius
ORNL	Oak Ridge National Laboratory: Oak Ridge, Tennessee

p	page
pp	pages
ppm	parts per million
PRD	program requirements document, a type of INEEL document type
R	radius
ref	reference
rev	revision
S (or s)	spacing or pitch (surface to surface unless otherwise specified)
SAE	Society of Automotive Engineers
SB	seed and blanket (not to be confused with later, much better known LWBR seed-and-blanket core designs) also sometimes called <i>small blanket</i>
SCALE TM	Standardized Computer Analyses for Licensing Evaluation. Registered trademark of ORNL. ³
SNF	spent nuclear fuel
spec	specification
SST	stainless steel type
typ	typical
U(xx)	uranium; xx is ²³⁵ U enrichment (BOL wt% unless otherwise specified)
VF	void fraction
vol	volume
vol%	volume percent
W	width
WAPD	Westinghouse Atomic Power Division: Pittsburgh, Pennsylvania
w_i	mass percent of component i
W_i	nuclear mass of component i (g/g-mole or amu)
wt%	weight percent or, more accurately, mass percent
WVF	water volume fraction
X	when used in a dimensionless ratio (for example, H:X), the sum of fissionable nuclide (unless otherwise indicated, uranium, plutonium, and thorium) masses or atoms.

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1 Introduction

The LWBR Program was chartered to develop a commercially viable breeder reactor using contemporary (1960s and 1970s) light-water reactor technology. Building on innovative concepts and experiment results, LWBR design centered on a fuel blend of ^{233}U and ^{232}Th oxides and on a variable-geometry nuclear-control concept. The program included several sets of critical experiments, an operational research reactor, associated ^{233}U production, and associated fuel-manufacturing facilities.

The reactor and associated facilities are decommissioned, but LWBR nuclear material still exists. This material is in interim storage at the INEEL until it can be used elsewhere or shipped to a permanent repository. Much of this material is intact or nearly intact fuel assemblies from the reactor and experiments. However, inventories include fuel rods, disassembled or never assembled fuel components, manufacturing scrap, and pieces left over from destructive fuel examinations.

This report describes and evaluates the first set of LWBR critical experiments, building and modeling benchmarks using standard INEEL criticality safety calculation techniques. Results help validate criticality safety calculations that support INEEL's LWBR fuel storage and handling activities. Results also help validate INEEL criticality safety calculations that model or envelop other nuclear materials that include ^{232}Th , ^{233}U , and/or ^{235}U .

2 Experiment Description^{4,5}

2.1 Overview

The first set of LWBR critical experiments included eight water-flooded critical assemblies, designated *SB cores* for their seed-and-blanket configurations. These cores were designed to provide nuclear parameter information for LWBR blankets. Seed fuel was made of either a $^{235}\text{UO}_2\text{-ZrO}_2$ or $^{233}\text{UO}_2\text{-ZrO}_2$ matrix, but neither matrix was used in the final LWBR fuel design. Blanket fuel was made of either a $^{232}\text{ThO}_2$ or $^{233}\text{UO}_2\text{-}^{232}\text{ThO}_2$ matrix, and both matrices were used in the final LWBR fuel design.

The eight assemblies included five rectangular (SB-1, SB-2, SB-2½, SB-3, and SB-4) and three hexagonal (SB-5, SB-6, SB-7) cores. Experimenters respectively designated these cores wet and dry (or wet and dry blanket assemblies) due to their relative solid-to-water volume ratios in the blanket region. However, the blanket region was water flooded in all cases. A geometric (rectangular/hexagonal), rather than water (wet/dry), designation is used here to avoid confusion and possible misunderstanding.

2.2 Configurations

Figure 1 and Figure 2 illustrate the experiment environment. Each core rested on a support structure under a lead shield plug in a reactor tank, inside a containment vessel. The cylindrical stainless steel reactor tank had a ¼ in. thick wall and a 6 ft inner diameter. The tank was externally shielded with ½ in. thick lead. During operations this tank was filled with water. The reactor tank was located off-center in a cylindrical 17 ft diameter containment and moderator-storage vessel.

Figure 3 shows general dimensions and locations of major items inside the SB reactor tank. Experiments were conducted on a ¾ in. thick stainless steel base plate. The plate rested on spacers on a 1 in. thick stainless steel tabletop over a core support structure. Core structures were radially centered in the tank with miscellaneous supporting structures for fuel rod spacing, control blade mechanisms, and a lead shield-plug. This shield plug rested on a 1 in. thick, 5 ft diameter, aluminum plate about 7 in. above

Figure 1. A Rectangular SB Core, Reactor Tank, and Containment Vessel

Figure 2. General Plant Arrangement

active fuel. Plug thickness varied from 6 in. near its center to 2 in. at its edge. Figure 3 also shows a 2½ in. thick, half density zircaloy structure immediately above the core. This half density structure most probably represents a homogenized model of rod plugs, end caps, and spacing grids described later. In addition, boxes that represent the core in many figures are drawing simplifications. Experiment structures do *not* include a core box.

4

copied from WAPD graphic EP R1172

Figure 4. Rectangular SB Core Support Structures and Reactor Tank

copied from WAPD graphic EP R1174

Figure 5. Hexagonal SB Core Support Structures and Reactor Tank

hexagonal lattices had triangular pitched rod arrays in which blanket and seed rods had approximately the same pitch. Seed sizes were adjusted to obtain clean, slightly supercritical cores to support the planned measurement programs. Table 1 summarizes lattice and core loading information. Figure 6 through Figure 13 show individual core fuel rod arrays. Figure 8 and Figure 13 include arrows to identify rectangular and hexagonal core orientation for comparison with benchmarks described later.

Table 1. SB Core Lattices^a

core ID	SB-1	SB-2	SB-2½	SB-3	SB-4	SB-5	SB-6	SB-7
<i>Overall Assembly</i>								
lattice	square	square	square	square	square	triangular	triangular	triangular
geometry	rectangular	rectangular	rectangular	rectangular	rectangular	hexagonal	hexagonal	hexagonal
# of rods	1588	1480	288	1288	1402	1261	1261	1261
<i>seed</i>								
fissile^b	²³⁵ U	²³³ U	²³³ U	²³³ U	²³⁵ U	²³⁵ U	²³³ U	²³³ U
pitch (in.)	0.362	0.362	0.362	0.362	0.362	0.5701	0.5701	0.5701
H:U^c	37	38	38	38	37	107	110	110
W:U^d	26	27	27	27	26	76	78	78
# of rods	576	340	288	224	376	217	148	115
<i>blanket</i>								
composition^e	ThO ₂	ThO ₂	NA	UO ₂ -ThO ₂	UO ₂ -ThO ₂	ThO ₂	ThO ₂	UO ₂ -ThO ₂
type^f	wet	wet	NA	wet	wet	dry	dry	dry
pitch (in.)	0.7239	0.7239	NA	0.7239	0.7239	0.5714	0.5714	0.5704g
H:Th^h	4.4	4.4	NA	4.4	4.4	0.46	0.46	0.45
W:Thⁱ	1.97	1.97	NA	1.97	1.97	0.21	0.21	0.21
# of rods	1012	1140	0	1064	1026	1044	1113	1146

a. Milani & Weiss, WAPD-TM-614, Table 3 and Figures 20 through 27.⁴

b. Seed is nominally UO₂(26 wt%)-ZrO₂, but the primary fissile isotope, ²³³U or ²³⁵U, varies.

c. Hydrogen a% to uranium a% ratio.

d. Water volume to uranium volume ratio.

e. Composition is either ThO₂ or nominally UO₂(1 wt%)-ThO₂. In the latter case the primary fissile isotope is ²³³U.

f. All cores were water flooded. *Wet* and *dry* refer to relative H:X ratios in the blanket.

g. Experiment reports list a 0.5704 in. pitch, which is probably a typographical error. A 0.5714 in. pitch (average) is probably correct because the same rod grids were used for all hexagonal cores. The only grid modifications between cores were in the number and location of inserts to place seed rods in locations that would otherwise have blanket rods. Inserts did not change the center-to-center rod pitch.

h. Hydrogen a% to thorium a% ratio.

i. Water volume to thorium volume ratio.

seed: 26 wt% $^{235}\text{UO}_2\text{-ZrO}_2$

pitch = 0.362 in.

H:U = 37 a%

I- $B_Z^2 = 39.2 \times 10^{-4}$

II- $B_Z^2 = 37.0 \times 10^{-4}$

III- $B_Z^2 = 35.5 \times 10^{-4}$

blanket: ThO_2

pitch = 0.7239 in.

H:Th = 4.4 a%

IV- $B_Z^2 = 35.0 \times 10^{-4}$

V- $B_Z^2 = 31.0 \times 10^{-4}$

VI- $B_Z^2 = 28.0 \times 10^{-4}$

water reflector: VII- $B_Z^2 = 27.0 \times 10^{-4}$

from WAPD
graphic EP
R1180

Figure 6. Core SB-1 Fuel Rod Array

seed: 26 wt% $^{233}\text{UO}_2\text{-ZrO}_2$

pitch = 0.362 in.

H:U = 38 a%

I- $B_Z^2 = 38.7 \times 10^{-4}$

II- $B_Z^2 = 37.3 \times 10^{-4}$

blanket: ThO_2

pitch = 0.7239 in.

H:Th = 4.4 a%

III- $B_Z^2 = 35.0 \times 10^{-4}$

IV- $B_Z^2 = 31.0 \times 10^{-4}$

V- $B_Z^2 = 29.0 \times 10^{-4}$

water reflector, VI- $B_Z^2 = 28.0 \times 10^{-4}$

from WAPD
graphic EP
R1181

Figure 7. Core SB-2 Fuel Rod Array

from WAPD
graphic EP
R1182

Figure 8. Core SB-2 $\frac{1}{2}$ Fuel Rod Array

Figure 9. Core SB-3 Fuel Rod Array

Figure 10. Core SB-4 Fuel Rod Array

Figure 11. Core SB-5 Fuel Rod Array

Figure 12. Core SB-6 Fuel Rod Array

Figure 13. Core SB-7 Fuel Rod Array

- j. Although experiment report indicates a 0.5704 in. blanket rod pitch, experimenter Chuck Emert indicated the same rod grid was used for all hexagonal cores. The only modification was number and location of inserts to place seed rods in locations otherwise used for blanket rods. Therefore, the SB-7 blanket rod pitch was probably 0.5714 in., matching Cores SB-5 and SB-6 (Figure 11 and Figure 12).

These experiments used four fuel rod matrices: $^{235}\text{UO}_2\text{-ZrO}_2$ seed, $^{233}\text{UO}_2\text{-ZrO}_2$ seed, $^{232}\text{ThO}_2$ blanket, and $^{233}\text{UO}_2\text{-}^{232}\text{ThO}_2$ blanket. Subject rods had the same external and fuel-matrix length, but seed rods were slightly less than half the diameter of blanket rods. Rods with similar diameters were visually very similar. Each rod of interest consists of a fuel-pellet stack between zircaloy-2 plugs, all within a seamless zircaloy-2 tube, with welded zircaloy-2 end caps. Fuel pellets within a stack were flat-ended cylinders of identical composition and diameter, and varying lengths. (Pellets were cut as necessary to achieve desired stack height.) Table 2 and Figure 14 summarize dimensional information.

Blanket test rods were also available, but experimenters apparently did not install such rods in any core for its clean critical measurement. These rods and associated structures therefore did not affect subject experiments and are not described here. Similarly, detector foils and wires are not described because they were not installed until after subject clean critical measurements.

Upper and lower $\frac{1}{4}$ in. thick stainless steel spacer plates maintained core configuration and lattice spacing. Each spacer-plate penetration accommodated one blanket rod or one insert and one or four seed rods. Spacer-plate penetration diameters are not specified but must have been only slightly larger than the blanket rod outer diameter.

- Figure 15 illustrates spacer plate, insert, and rod arrangement for rectangular cores. Each spacer-plate penetration accommodated either one blanket rod or an insert and four seed rods. Grid and insert specifications should have maintained a 1:2 ratio between seed and blanket rod pitches.^k In addition, an intermediate support “plate” at the core midplane helped minimize fuel rod bowing in rectangular cores. It was made of $0.02 \times 0.100 \times 11$ in. rectangular zirconium wire welded into an 11×11 in. grid.
- Figure 17 illustrates spacer plate and rod arrangement for hexagonal cores. A plastic insert reduced the rod-spacer-plate penetration diameter, to accommodate one seed rod in a blanket rod position. Apparently grid and insert specifications should have maintained a 1:1 ratio between seed and blanket rod pitches.^k Figure 17 also shows that hexagonal cores included six rod-spacer bars above the core. These bars are not described further in the experiment report.

Four parallel borated stainless steel control blades^l within the seed array controlled approaches to critical. Figure 15, Figure 16, Figure 18, and Figure 19 are the only currently available experiment report figures that show these blades. The upper rod-grid structure guided blade movement. Blades were withdrawn uniformly, as a bank, and were almost fully withdrawn during operations. Experimenters reported that control blades caused no perturbations in clean-critical experiment measurements. Readily available reports do not identify more precise information about blade composition, dimensions, locations, or withdrawal heights. Interviews (Appendix C) indicate:

- Each control blade was $0.070 \times 24 \times \sim 3$ in. (thick $\times$ length $\times$ width) and was inserted about 1 in. into the fuel region.
- Blades were radially located in the same place in all eight cores.
- Blades were nearly equidistant from each other and were not located between the outer two rows of the smallest core.

Blade positions can be reconstructed from these descriptions and from experimenter calculated buckling information listed in Figure 6 through Figure 13.

k. Charles J. Emert, Bettis Atomic Power Laboratory, telephone conversations with and messages for Valerie L. Putman, LMITCO, April 2000.

l. Called *control rods* in experiment reports, they are called *control blades* here to better describe their geometry.

Table 2. SB Fuel Rod Average Dimensions^m

	Seed		Blanket	
	²³³ UO ₂ -ZrO ₂	²³⁵ UO ₂ -ZrO ₂	ThO ₂	²³³ UO ₂ -ThO ₂
number made	396	625	1386	1331
overall length (in.)	20.83	20.83	20.83	20.83
end cap length, except test rods (in.)	0.88	0.88	0.88	0.88
zircaloy-2 plug length (in.)	2	2	2	2
active fuel length (in.) ⁿ	15	15	15	15
fuel pellet diameter (in.) ^o	0.2113	0.2108	0.4885	0.4903
clad inner diameter (in.) ^p	0.2195	0.2195	0.4988	0.4984
clad outer diameter (in.) ^p	0.2545	0.2545	0.5698	0.5694

Figure 14. SB Fuel Rods^q

- m. Milani & Weiss, WAPD-TM-614 §II.C, Table 2, Figure 6, Appendices D & E.⁴ Frankhouser, et. al., WAPD-TM-588 §IV, Figure 1, Tables 6 & 11.⁵
- n. Fuel length specification: 15.00 ± 0.06 in.
- o. Seed pellet specification: 0.210 ± 0.003 in. diameter; 0.250 in. length.
Blanket pellet specification: 0.489 ± 0.005 in. diameter; 0.6 in. length.
Seed and blanket pellet specification: 0.004 in. max. from perpendicular; 0.003 in. max. from flat end-face.
- p. Seed rod clad specification: 0.216 + 0.006, -0.000 in. inner diameter; 0.0160 + 0.0032, -0.0000 in. thick.
Blanket rod clad specification: 0.496 + 0.005, -0.000 in. inner diameter; 0.033 + 0.005, -0.000 in. thick.
- q. Milani & Weiss, WAPD-TM-614 Figure 6 & Appendix E.⁴ Frankhouser, et. al., WAPD-TM-588 Figure 1.⁵

Figure 15. Rectangular Core Rod Spacer Plate

Figure 16. Schematic Top View of SB-Cores^r

r. Core SB-6's orientation here is mirror image of, or rotated 120° from, the orientation implied in Figure 12. This difference will not affect benchmarking because SB cores are symmetric.

Figure 17. Hexagonal Core Rods and Spacer Plates

Figure 16, Figure 18, and Figure 19 also show traverse locations, where detector foils, flux wires, and blanket test rods (with sample packages) were located for various measurements. However, clean cores apparently did not include any of these measurement items.

Experiment report figures show various items that its text does not describe well:

- There was at least one neutron (startup) source located near each core's center. Startup sources and their associated hardware are typically much less significant than control elements (for example, SB control blades) and are typically negligible in k_{eff} calculations.

Figure 18. Schematic Top View of Rectangular SB Cores Showing Traverse Locations

- Various structural items and instruments were located outside the active fuel region. Those that are not described further in this report were at least several inches from the fuel region.

2.3 Materials

These LWBR fuel matrices were unique for LWBR and other reactor programs. Table 3 and Table 4 respectively list pellet uranium isotopic compositions and mass densities for subject matrices

Figure 19. Schematic Top View of SB Hexagonal Cores Showing Traverse Locations^s

($^{233}\text{UO}_2\text{-ZrO}_2$ seed, $^{235}\text{UO}_2\text{-ZrO}_2$ seed, ThO_2 blanket, and $^{233}\text{UO}_2\text{-ThO}_2$ blanket). Table 5 lists analyses results for uranyl nitrate from which ^{233}U seed and blanket pellets were made. Table 6 lists ^{233}U fuel matrix impurities, determined by chemical analysis. Experimenters reported that total impurities for all fuel matrices were less than the equivalent of 80 ppm boron. Gadolinium, the only significant impurity, was present in thorium feed at 5 to 10 ppm. Elemental gadolinium has a 7.9004 g/cm^3 theoretical density. However, Gd_2O_3 , with a 7.407 g/cm^3 theoretical density, is a more common form of this contaminant.⁶

Fuel cladding, end plugs, and end caps were made of Zircaloy-2. Table 7 lists Zircaloy-2 chemical compositions based on various sources and values used here.

s. Core SB-6's orientation here is mirror image of, or rotated 120° from, orientation implied in Figure 12. This difference will not affect benchmarking because SB cores are symmetric.

Table 3. SB Fuel Pellet Uranium Analysis^t

	²³³ UO ₂ -ThO ₂ blanket	²³³ UO ₂ -ZrO ₂ seed	²³³ UO ₂ feed powder ^u	²³⁵ UO ₂ -ZrO ₂ seed	UF ₆ feed for ²³⁵ UO ₂ -ZrO ₂
nominal wt% in material					
UO ₂	1 ^v	26.8 ^v			NA
U	1	26		26	
average wt% in material					
U	0.939 ^w	24.47 ^w		24.70 ± 0.07	
²³³ U or ²³⁵ U	0.913	23.81		22.90 ± 0.07	
isotopic wt% in uranium					
²³² U	< 0.05	< 0.05			
(²³² U a%)	(38 ppm)	(38 ppm)	(39 ± 4 ppm)		
²³³ U	97.19	97.29	97.20 ± 0.04		
²³⁴ U	1.55	1.56	1.56 ± 0.02		0.892
²³⁵ U	< 0.05	< 0.05	0.06 ± 0.01	92.73 ^x	93.14
²³⁶ U	< 0.05	< 0.05	0.014 ± 0.005		0.263
²³⁸ U	1.23	1.14	1.16 ± 0.02		5.706

Table 4. SB Fuel Pellet Mass Density^y

	percent of theoretical density			theoretical density (g/cm ³)
	average	minimum	maximum	
²³³ UO ₂ -ZrO ₂	93.42	88.47	95.82	6.94
²³⁵ UO ₂ -ZrO ₂	95.11	92.81	98.60	6.95
²³³ UO ₂ -ThO ₂	94.07	90.53	96.81	10.04
ThO ₂	94.6	93.0	95.5	10.03

t. Milani & Weiss, WAPD-TM-614, Appendices B & C.⁴ Frankhouser, et. al., WAPD-TM-588, Tables 3 & 10.⁵

u. Sources do not indicate which fuel matrix used this ²³³UO₂ feed. The feed's ²³³U isotopic is discrepant with the ²³³UO₂-ZrO₂ seed, and the feed's ²³⁸U isotopic is discrepant with ²³³UO₂-ThO₂ blanket.

v. Apparently experimenters calculated UO₂ wt%s based on uranium or ²³³U measurements. They did not directly measure UO₂ wt%s in finished pellets.

w. "Corrected to $U - 233 - \frac{(233)}{(238)}$,"

x. Difference between UO₂ and UF₆ enrichments due to line contamination with natural uranium.

y. Milani & Weiss, WAPD-TM-614, Appendix D.⁴ Frankhouser, et. al., WAPD-TM-588, Tables 7 & 8.⁵

Table 5. ^{233}U Uranyl Nitrate Analysis

	from Table 3 of Frankhouser, et. al., WAPD-TM-588 ⁵		from Appendix A of Milani & Weiss, WAPD-TM-614 ⁴	
	batch 1	batch 2	batch 1 (used for blanket)	batch 2 (used for seed)
total volume (ℓ)	54.115	48.406	54.115	48.406
solution analysis				
U total (mg/ml UNH)	131.94	128.18	131.94	128.18
^{233}U (mg/ml UNH)	128.43	124.76	128.43	124.76
Th (mg/ml UNH) ^z	0.86	1.13	0.86	1.13
(or wt% ^{233}U)	0.67	0.89	0.67	0.89
HNO_3 (molar)	0.0375	0.0365	0.0375	0.0365
weight				
U total (g)	7140	6205	7140	6205
^{233}U (g)	6950	6039	6950	6039
uranium isotopic				
^{232}U	0.05 a%	0.05 a%	0.05 a%	0.05 a%
^{233}U ^{aa}	38. ppm	38. ppm	38. ppm	38. ppm
^{233}U	97.24 wt%	97.22 wt%	97.34 a%	97.33 a%
^{234}U	1.53 wt%	1.56 wt%	1.53 a%	1.55 a%
^{235}U	0.05 wt%	0.05 wt%	<0.05 a%	<0.05 a%
^{236}U	0.05 wt%	0.05 wt%	<0.05 a%	<0.05 a%
^{238}U	1.12 wt%	1.12 wt%	1.10 a%	1.10 a%
thorium isotopic^{bb}				
^{228}Th a%	0.02	0.03	< 0.02	< 0.03
^{229}Th a%	0.02	0.03	< 0.02	< 0.03
^{230}Th a%	0.02	0.03	< 0.02	< 0.03
^{231}Th a%	0.02	0.03	< 0.02	< 0.03
^{232}Th a%	100	100	100	100
^{233}Th a%	masked by ^{233}U	masked by ^{233}U	masked by ^{233}U	masked by ^{233}U
^{234}Th a%	masked by ^{232}Th	masked by ^{232}Th	masked by ^{232}Th	masked by ^{232}Th

z. In one place manufacturer's report also indicates 1.43 wt% thorium in $^{233}\text{UO}_2$ powder (Frankhouser, et. al., WAPD-TM-588, Table 3).⁵ However, all other readily available data indicates that, *if* thorium was present in pellet UO_2 , it was a minor impurity.

aa. A ^{232}U value based on ^{233}U , irradiation history to produce ^{233}U , and activity spectrum with respect to time.

bb. Experiment report indicates no difference is intended in values between these two batches. 0.02 and 0.03 a% are detection limits for the two analyses. ^{233}U material, as uranyl nitrate, was purified before making UO_2 powder for fuel pellets. Purification included adding natural thorium nitrate to uranyl nitrate solutions, before solvent extraction. One reason for this addition is that thorium was removed during solvent extraction, thereby removing much of the initial ^{228}Th that was present as a decay daughter of ^{232}U . Seed fuel matrices most probably contained no more than negligible, trace quantities of thorium after this solvent extraction process. There is some indication (Table 6 footnote) that, *if* present, thorium was less than 0.1 ppm of the UO_2 powder.

Table 6. Chemical Analysis Results for Impurities (ppm)^{cc}

element	²³³ UO ₂ feed powder	ThO ₂ feed powder	²³³ UO ₂ -ThO ₂ pellet
Ag	-		
Al	37	< 50	40
As	0.04	-	0.04
Au	-		
B	6	1	0.1
Ba	3	-	3
Be	-	-	1
Bi	-		
C	not checked	186	-
Ca	32	< 50	54
Cd	-	< 0.5	-
Ce	-	-	29
Cl	4	10	0.8
Co	122	< 5	7
Cr	141	< 30	57
Cs	-		
Cu	-	< 20	0.06
Dy	-	2.2	6
Er	-	-	2
Eu	-		
F	0.1	< 10	0.07
Fe	1090	95	183
Ga	0.2	-	0.6
Gd	-	2.9, 2.9	5
Ge	-	-	0.2
Hf	-	< 35	-
Hg	37	-	0.3
Ho	-	-	1
In	-		
Ir	-		
K	15	< 25	0.3
La	-	-	12
Li	-	-	0.007
Lu	-		
Mg	20	< 50	64

cc. "Elements for which no number is reported do not exceed 0.1 ppm, if present, except for C and O which were not checked." (Frankhouser, et. al., WAPD-TM-588 Tables 2 & 4)⁵

Table 6. Chemical Analysis Results for Impurities (ppm) (continued)^{cc}

element	²³³ UO ₂ feed powder	ThO ₂ feed powder	²³³ UO ₂ -ThO ₂ pellet
Mn	-	< 5	0.05
Mo	9	< 25	2
N	43	< 50	11
Na	4	< 50	0.1
Nb	0.6	-	0.8
Nd	-	detected only	12
Ni	262	75	278
Os	-		
P	6	-	1
Pb	0.1	< 5	0.5
Pd	-		
Pr	-	-	3
Pt	-		
Pu	15	-	0.2
Rb	0.1		
Re	-		
Rh	-		
Ru	-		
S	7	-	2
Sb	-		
Sc	-	-	0.3
Se		-	0.08
Si	428	45	188
Sm	-	-	4
Sn	-	< 5	1
Sr	0.05	-	0.3
Ta	-		
Tb	-	< 5	1
Tc	-		
Ti	23	<5	97
Tl	-		
Tm	-		
U		< 1	
V	0.7	-	0.5
W	33	-	11
Y	-	detected only	49
Yb	-		
Zn	0.04		
Zr	27	-	21

Table 7. Zircaloy-2 Composition and Density

	Tipton 1960 ⁷	Lynch 1975 ⁸ (typ.)	Perry & Chilton 1973 ⁹	ASM 1990, Vol. 2 ¹⁰ , (nom.); Thomas 1996 ¹¹	ICSBEP, MIX-COMP-THERM-002 ¹	ICSBEP, MIX-COMP-THERM-004 ¹	SCALE4.3 §M.8 ³	used here (nom.)
density								
(g/cm ³)	6.57			6.56	6.57	6.523	6.56	6.56
(ft/in ³)			0.237					0.237
wt%								
Cr	0.05-0.15			0.1	0.05-0.15	0.098	0.1	0.10
Fe	0.07-0.20	0.15	0.12	0.1	0.07-0.2	0.141	0.125	0.13
Hf		0.02	0.02					0.00
N	0.010 max ^{dd}						0.05	0.00
Ni	0.03-0.08	0.05	0.05	0.05	0.03-0.06	0.06		0.05
O				0.12 typ				0.00
Sn	1.20-1.70	1.46	1.46	1.4	1.2-1.7	1.48	1.5	1.50
Zr	balance	balance	balance	98.23	balance	98.221	98.2225	98.23
other	many ^{ee}	0.25 other	0.25 other					0.00

Water functioned as coolant, moderator, and reflector. Typical critical experiment water is demineralized with few contaminants. A 0.9982 g/cm³ water density is used here for 20°C (about 68°F), based on SCALE4.3 data (Reference 3, §M.8) and data presented in Table 8.

Table 8. Water Mass Densities (g/cm³)

°C	Perry & Chilton 1973 ⁹	Lide 1996 ¹²	Green 1997 ¹³	°C	Perry & Chilton 1973 ⁹	Lide 1996 ¹²	Green 1997 ¹³
0	0.99987	0.99984	0.999839	60	0.98324	0.98320	0.983200
10	0.99973	0.99970	0.999699	70	0.97781	0.97778	0.977771
20	0.99823	0.99821	0.998204	80	0.97183	0.97182	0.971799
30	0.99568	0.99565	0.995647	90	0.96534	0.96535	0.965321
40	0.99225	0.99222	0.992215	100	0.95838	0.95840	0.958365
50	0.98807	0.98803	0.988037	200	0.8628		

dd. 0.008 average.

ee. Many isotopes, expressed in ppm. Cumulative total is less than 0.01 wt%.

Control blades were made of borated stainless steel. An internal Bettis memo indicates they were made of Type 304 stainless steel with 0.787 wt% ^{10}B and negligible ^{11}B (see §C.2). Contemporary methods for making borated steel typically produced a material in which boron either replaced iron or most significantly affected iron wt%.^{7,11} Table 9 lists Type 304 stainless steel chemical compositions and densities based on various sources. Table 10 lists borated and unborated Type 304 stainless steel descriptions used in this validation.

Other materials and material components do not significantly affect this report because of material quantity, placement, or distribution in subject cores. Identified items, some of which are described further in Appendix D, include:

- Activated nuclides and fission products that would affect k_{eff} are only an issue to the extent that they remain after producing ^{233}U . Most such nuclides decayed away by the time experiments were conducted, or were removed during fuel manufacturing. Few additional nuclides were generated during subject experiments because they were conducted at negligible power levels and because a critical state was maintained only as long as necessary to obtain specified measurements.
- Heating effects during the experiments are negligible here. Subject experiments were conducted at negligible power levels, too low to significantly change solid-material densities or effectively heat water beyond startup temperatures.
- Fuel rods were back filled with a gaseous Ar-He(10 vol%) mixture (Frankhouser, et. al., WAPD-TM-588, Table 6).⁵ This gas has a negligible Σ_a and Σ_s under subject conditions.
- Rectangular cores had an intermediate support “plate” made from welded zirconium wire. Elemental zirconium has a 6.49 g/cm³ theoretical density.⁶ However, this wire occupies negligible volume in the core.
- Plastic was used for rod spacer plate inserts for hexagonal cores, and possibly for a few other items. Typical plastics, such as polyethylene, are made of hydrocarbons and have densities near 1.0 g/cm³.⁶ Plastics can usually be approximated as water.
- Although various detector materials were used for some measurements, these materials were apparently not installed in subject clean critical cores.
- Apparently most experiment structural materials were made from stainless steel. Instrument housings were also probably made from stainless steel. Steel materials were most probably an austenitic steel (one or more of Types 304, 308, 316, or 347 stainless steel), based on typical materials in contemporary Bettis experiment programs.^{ff} Austenitic steels are roughly 69 wt% Fe, 19 wt% Cr, 10 wt% Ni, and 2 wt% other nuclides, with about a 7.9 g/cm³ bulk density. Magnesium is the only minor constituent having a significant thermal σ_a . Magnesium typically has a 2 wt% *maximum* in stainless steels, but actual values depend on raw ore source(s) and on steel recycling during manufacture.^{7,18,11}
- Some experiment structural materials and, possibly, instrument housings were made from aluminum alloys. Aluminum alloys range from 88 to 99.99 wt% aluminum with densities of about 2.69 to 2.70 g/cm³ (ASTM B 209-96; ASM 1990 Vol 2).^{14,10} Alloys typically used in critical experiments have more than 95 wt% aluminum and no other components with significant thermal Σ_a s and/or Σ_s s.
- Lead served as radiation shields. Typical lead has at least 99.9 wt% Pb and negligible quantities of Ag, Cu, As, Sb, Sn, Zn, Fe, & Bi.¹⁵ Lead has a 1.35 g/cm³ theoretical density.⁶

ff. Type 304L stainless steel is not likely here because Bettis personnel usually identified 304L due to its relatively high carbon content compared to other austenitic steels.

Table 9. SS 304 Composition and Density

	Miner & Seastone 1955, ¹⁶ Tipton 1960 ¹¹ (from AISI criteria)	Lyman 1961 ¹⁷ (nom.)	Lynch 1975 ⁸ (typ.)	ASM 1978 ¹⁸ (typ.)	SAE J405 JAN89 ¹⁹	ASM 1990, ¹⁰ Vol 1	Thomas 1996, ¹¹ (from ASTM A 240/A 240M- 94b, 1995)	SCALE 4.3 §M.8
density								
(g/cm ³)		7.9				8.0	7.9	7.92
(lb/in ³)		0.29	0.29	0.29		0.29		
wt%								
Fe	balance	balance	balance	balance	balance	balance	balance [68.745]	69.5
C	0.08 max	0.08 max	0.08	0.08	0.08 max	0.08 max	0.08 max [0.08]	
Cr	18.00-20.00	19	18-20	18-20	18.00-20.00	18.0-20.0	18-20 [19.000]	19.0
Mn	2.00 max	2 max	2	2.0	2.00 max	2.00 max	2.00 max	2.0
Ni	8.00-11.00	10	8-12	8-10.5	8.00-10.50	8.0-10.5	8-10.5 [9.250]	9.5
N							0.10 max	
P	0.040 max		0.045	0.045	0.045 max	0.045 max	0.045 max	
Si	1.00 max	1 max	1	1.0	1.00 max	1.00 max	0.75 max	
S	0.030 max		0.030	0.030	0.030 max	0.03 max	0.03 max	

Table 10. Unborated and Borated SS304 Characteristics Used Here

	unborated	borated
density		
(g/cm ³)	7.92	7.92
wt%		
Fe	70.175	69.423
C	0.04	0.04
Cr	19.00	19.00
Mn	1.00	1.00
Ni	9.25	9.25
P	0.02	0.02
Si	0.50	0.50
S	0.015	0.015
¹⁰ B	0.00	0.787

- Filtered air circulated through the containment vessel at about 1000 ft³/min. It was maintained at a small negative pressure with respect to vessel surroundings. At sea level, unpolluted dry air is roughly 78% N₂, 21% O₂, 1% Ar, 0.03% CO₂. It has a 0.0011 or 0.0012 g/cm³ density.¹² With little irradiation, air has a negligible Σ_a and Σ_s .

2.4 Other Information

Experiments evaluated here were conducted at 20°C (about 68°F). Two additional experiments were performed at 480°F, but they are not included here because readily available information is insufficient to model them.

Experimenters did not report additional raw or measured data. However, they reported normalized and calculated results based on material descriptions and on other measurements. For example, they reported calculated atom densities (Table B-1), k_{eff} s (Table B-2), and axial buckling values (Figure 6 through Figure 13). They also provided plots of dose rates, fission ratios, neutron capture ratios, and thermal activation shape.

Experimenters also reported:

- “All cores were approximately clean critical, with an excess reactivity of only a few tenths of one percent.” (Milani & Weiss, WAPD-TM-614, p. 5):⁴
- “In general, experimental points [data measured for activation and fission traverses] have an uncertainty of $\pm 3\%$. For those measurements in which the data points have calculated foil effect corrections applied, the total uncertainty is $\pm 5\%$.” (Milani & Weiss, WAPD-TM-614, p. 14):⁴

Experimenters determined regional axial buckling values (Figure 6 through Figure 13) from β -activity measurements using irradiated flux wires. These wires were 15×0.03 in. (height × diameter) stacks of 0.5in. long U(6)-Zr wires that were taped to selected fuel rods through each core. Experimenters fitted measured values to a cosine curve using a least square fit. However, “in core SB-2½ [Figure 8], axial buckling was determined from the critical control-blade bank height using

$$B_z^2 = \left(\frac{\pi}{H_C + 2\delta} \right)^2 \quad \text{Equation 1}$$

where H_C is the bank height and δ is the extrapolation distance, approximately 8 cm.” (Milani & Weiss, WAPD-TM-614, p. 11):⁴

It was not practical to retrieve desired logbooks and other archived documents for this validation. However, various INEEL and Scientec personnel obtained additional LWBR fuel and program information. Millan Straka and Abe Weitzberg of Scientec shared information included in Appendix C as part of an exchange with this author. In addition, LWBR experimenter Emert confirmed that reported dimensions represent calculated averages unless specifically indicated otherwise.^{gg}

3 Validation Requirements

No unique requirements apply to this validation. Criticality-safety-specific validation requirements are established in ANSI/ANS-8.1-1983 (R 1988), which is currently endorsed by the U. S. Department of Energy and U. S. Nuclear Regulatory Commission.²⁰ These requirements are supplemented and, in a few

gg. Charles J. Emert, Bettis Atomic Power Laboratory, telephone conversations with and messages for Valerie L. Putman, LMITCO, April 2000.

cases, interpreted by the Department of Energy at headquarters or locally and by INEEL. The requirements, as interpreted, are specified in the *INEEL Criticality Safety Manual*.²¹

Criticality safety criteria require software code verification, method validation, well-documented analysis, and independent review before a criticality safety evaluation's results are used. Validation must address bias, methodology uncertainty, and experiment uncertainty effects.

Validations are typically performed and documented as part of a criticality safety evaluation. However, validations may be documented separately, as in this case. For convenience this report uses a format blending DOE requirements for documenting criticality safety evaluations and ICSBEP practices for documenting benchmark experiments.

4 Validation Methodology

This validation focuses on developing suitable benchmark descriptions of subject experiments and on the capabilities of INEEL standard k_{eff} calculation methods. Validation calculations typically model benchmarks developed from simple geometry experiments having a measured k_{eff} at or near 1.00, such as these SB cores. Modeling and evaluation details depend on experiment, codes of interest, and, sometimes, a real-world system to which a validation is applied.

Benchmarks are developed here using standard bases and assumptions (Appendix A), considering experimenter-intended configurations. Nominal measured data values are used directly assuming a then-typical three decimal place accuracy. However, more decimal places are used for values converted from engineering to metric units to preserve continuity with the originally measured unit. Other model specifics (component locations, atom densities, averages, and interpolated data) are independently calculated by hand to ensure consistency with current methodology and standard assumptions.

Final results, sensitivity effects, and uncertainty effects are expressed as k_{eff} s or Δk_{eff} s. All k_{eff} s are calculated with computer codes on INEEL Criticality Safety's networked system of Hewlett Packard workstations, with the 10.20 UNIX operating system.

- MCNP4b2's *kcode* option, mostly with its associated, recommended, continuous-energy cross-section libraries.² These libraries are primarily based on ENDF/B-V data. For comparison, final benchmark calculations were also performed with continuous-energy libraries based on ENDF/B-VI data where available. Subject code and libraries are installed, maintained, and verified by qualified INEEL criticality safety personnel in accordance with an approved quality assurance plan.²² MCNP4b2 and the code-developer-recommended libraries were used throughout model development, sensitivity studies, and uncertainty studies.
- SCALE 4.3's CSAS25 module with associated ENDF/B-IV-based 27-group cross-section libraries, and with associated ENDF/B-V-based 44- and 238-group cross-section libraries.³ CSAS25 processes cross section data with BONAMI and NITAWL-II, and calculates k_{eff} with KENO.Va. This code package, module, and its libraries are installed, maintained, and verified by qualified INEEL criticality safety personnel in accordance with an approved quality assurance plan.²³

Uncertainty and sensitivity effects are evaluated by determining a Δk between calculated k_{eff} s for a mirrored-core benchmark model and for a model that incorporates a bounding change in a relevant parameter. These models minimize calculation time and provide comparison points for other symmetrical core calculations. Mirrored-core models of rectangular cores explicitly represent the quadrant shown in Figure 6 through Figure 10. They define the indicated centerlines as mirror-reflecting boundaries to incorporate the entire core. Mirror-core models of hexagonal cores represent the core half in the -y direction, and define the x-z plane axis as a mirror-reflecting boundary. Addressed in §6, any effects unique to this modeling technique cancel out in Δk results. Effects of other consistently used

simplifications similarly cancel out. Appendix D lists nuclide densities that incorporate composition changes for these calculations.

For comparison purposes all k_{eff} calculation results are presented as listed in code output. Such listing does not indicate calculation precision or accuracy. Calculated k_{eff} s typically have three or four significant figures (typically no more than three decimal places). This is true whether or not one reduces a Monte Carlo code's statistical uncertainty by increasing the calculation's number of neutrons per generation, the number of generations, or both.

Finally, dimensional values input to MCNP and SCALE typically include non-significant digits. For example, a diameter reported as 0.211 in. is input as a radius of 0.26797 cm, although the value has only three significant digits. Additional digits do not imply increased precision. Instead, they are included to preserve traceability between code input and values listed in experiment reports and fuel specifications.

5 Experiment Evaluation

5.1 Currently Missing Information

Experiment reports include details commensurate with experiment purposes and modeling techniques. Experimenters designed SB cores to investigate blanket fuel nuclear parameters with contemporary one- and two-dimensional codes. They were most interested in effects at or near blanket axial centers. Detailed descriptions for other items and characteristics are not now readily available. Benchmarking is possible without additional information, but further information might help refine uncertainty and sensitivity estimates. For example:

- Available reports do not describe component manufacturing tolerances, measurement uncertainties, or measured value ranges with a few exceptions (fuel pellet feed materials, fuel pellet dimensions, and cladding diameters). For material compositions and small or thin dimensions, typical, contemporary tolerances range from $\pm 12.5\%$ for off-the-shelf industrial items, to $\pm 10\%$ for nuclear-grade items, to $\pm 5\%$ for special nuclear items. In well-funded cases such as the LWBR program, a tolerance might be significantly less for essential nuclear items.
- Experimenters did not identify temperature measurement uncertainties, temperature gradients, or water circulation. However, typical water-flooded critical experiments at or near room temperature do not show significant gradients or circulation.
- Experimenters did not identify reactor tank and containment vessel heights. From other dimensions, the reactor tank was much more than 5 ft high. The 17 ft diameter containment vessel was probably the 14 ft 11 $\frac{5}{8}$ in. high vessel used in later LWBR experiments (WAPD-TM-1101, pp. 2, 21).²⁴
- Various undescribed or partially described materials, structures, and instruments were located outside the active fuel region (Figure 2 through Figure 5). Undescribed items apparently occupied a relatively small volume at various well-spaced locations. Partial descriptions for other items are sufficient to approximate relevant structures (§6.1 and Appendix D).

Relevant surviving documents (fuel manufacturing specifications, structural component specifications, drawings, logbooks, data recording sheets, calculation work-sheets, full and/or detailed reports, etc.) were sent to naval program archival storage. Little information is available to facilitate document retrieval.

Criticality safety validation models typically resolve issues such as missing and/or discrepant information in a manner that will not increase calculated base case k_{eff} s (Appendix A). This strategy, combined with uncertainty analysis, is adequate in handling subtle differences between reported information and as-built, as-run experiments for criticality safety purposes.

5.2 Discrepancies

Some reported data seem discrepant for various reasons. Some data include typographical or transcription errors, incorporate normalizations to facilitate a specific use, and/or represent nominal or averaged values. Other data represent conservative, maxima, or minima values.

Reported data are therefore compared to each other within the experiment report and, where practical, to data from other LWBR reports. Experimenter calculated values are also compared to independently calculated values. Apparent discrepancies are identified and resolved in text or footnotes where the relevant items are described (typically in §2). They are identified and resolved only to the extent necessary to provide consistent benchmark descriptions for criticality safety validation.

5.3 Uncertainties

Experiment description uncertainties that should be considered include manufacturing tolerances, composition uncertainties, measurement uncertainties, and data-reconstruction uncertainties. Individual contributors are evaluated separately using methods described in §A.5, based on bounding values described later in this section. Table 11 summarizes a cumulative uncertainty and its individual contributors. Fuel matrix impurities are the major contributor to the 0.0111 Δk total. However, this total is also somewhat larger than the actual experiment uncertainty because some effects are counted more than once. This occurs because, contrary to assumption, most of these parameters are not completely independent of every other parameter.

Table 11. Experiment k_{eff} Uncertainties, Individual Factors

contributing factor	$\Delta k_{\text{stdU},i}$	applicable k_{eff} calculation cases and $\Delta k_{\text{stdU},i}$ equation
rod pitch	0.0016	Table D-1 cases SB2Rp+ & SB25Rp-, Equation A-11
cladding thickness	0.0020	Table D-2 cases SB2cl++ & SB2cl--, Equation A-11
fuel matrix OD and stack height	0.0040	Table D-3 cases SB2dim+ & SB2dim-, Equation A-11
fuel matrix bulk density	0.0039	Table D-4 cases SB2Den+ & SB2Den-, Equation A-11
fuel matrix ^{233}U in uranium	0.0008	Table D-8 cases SB4Uu+ & SB4Uu-, Equation A-12
fuel matrix UO_2 wt%	0.0008	Table D-8 cases SB4Uo+ & SB4Uo-, Equation A-11
fuel matrix impurities	0.0085	Table D-4 case SB2GD+, Table D-8 case SB4GD-, Equation A-11
control blade composition	0.0005	Table D-12 cases SB6cb+b & SB6cb-b, Equation A-11
control blade dimensions, locations, Ht	0.0011	Table D-12 cases SB2high & SB6low, Equation A-12
water temperature uncertainties	0.0010	Table D-9 cases SB25warm & SB25cool, Equation A-12
reactor critical measurement	0.0030	assumption explained later in this section
<hr/>		
Δk_{stdU}	0.0111	Equation A-13

Table 11 also indicates the cases and equation used to quantify an individual uncertainty. Tables in Appendix D summarize calculation cases, results, and compositions used to identify important uncertainty factors and estimate their individual effects. Most calculations model cores SB-2 and SB-4 because they are the simplest geometry cores with the most material that, together, include all fuel matrices.

Table D-1 lists calculation results modeling a bounding ± 0.00254 cm (± 0.001 in.) rod pitch uncertainty. This assumed uncertainty is based on average rod spacing values reported in Figure 6 through Figure 13,

the intended 1:2 ratio for rectangular core seed and blanket pitches, the intended 1:1 ratio for hexagonal core seed and blanket pitches, and tolerances identified in later LWBR reactor specifications.

Table D-2 lists calculation results modeling maximum and minimum cladding thicknesses (Table 2 footnotes). Calculations in which clad thickness varied with constant rod pitch produced unreasonably large Δk_{eff} s. However, these models also, coincidentally, vary water displacement between fuel rods. Table D-1 results indicate SB k_{eff} s are very sensitive to this water. Models that include rod pitch adjustments showed similar effects because thickness uncertainties differ for seed and blanket rods, but rod pitches could not be varied independently with this modeling method. Enveloping cases were therefore remodeled by varying clad density with constant rod pitch and clad volume. This strategy maintains water separation and appropriately varies the total number of nuclei in cladding, but does not maintain cladding nuclei separation. Resultant Δk_{eff} s are more reasonable but still much larger than typical. Results most probably confirm that this density strategy is a first order, or slightly better, approximation of the subject effect. Experience indicates these effects mask uncertainty effects associated with Zircaloy-2 composition and impurities.

Table D-3 through Table D-8 list calculation results modeling individual fuel matrix uncertainties, primarily represented as variations in fissile nuclide parameters. Fissile nuclide quantities and distribution in a fuel rod are a function of:

- Fuel pellet dimensions (Table 3 footnotes).
- Fuel length, 15.00 ± 0.006 in. (Table 3 footnotes).
- Fuel pellet densities (Table 4).
- Isotopic concentrations in uranium. A bounding ± 0.05 wt% uncertainty is assumed for primary fissile isotopes (^{233}U or ^{235}U), based on uncertainties reported for $^{233}\text{UO}_2$ powder (Table 3) and on typical contemporary critical experiment fuel specifications.
- Uranium concentrations in fuel pellets. A bounding ± 0.5 % uranium, or UO_2 , concentration uncertainty is assumed, based on uncertainties reported for ^{235}U seed pellets (Table 3) and on typical contemporary critical experiment fuel specifications.
- Significant fuel matrix impurities, primarily gadolinium in the thorium of blanket fuel. When modeling impurities as ^{10}B , a bounding 0 to 80 ppm $^{10}\text{B}:\text{Th}$ mass ratio is assumed based on §2.3.

Effects from one or more of the listed fuel matrix uncertainties incorporate or, based on experience, are assumed to mask other fuel matrix uncertainty effects. For example:

- Pellet diameter uncertainties incorporate radial gap thickness uncertainties.
- Fuel density and length uncertainty effects mask effects of gaps between stacked fuel pellets. Such gaps are typically very, very small and do not significantly affect fuel densities over the active fuel region.
- Pellet density and UO_2 concentration uncertainty effects incorporate ThO_2 and ZrO_2 concentration uncertainty effects. Modeled ThO_2 and ZrO_2 concentrations are changed to produce desired variations in these other characteristics.
- ^{233}U - and ^{235}U -concentration uncertainty effects incorporate ^{238}U -concentration uncertainty effects. Modeled ^{238}U concentrations are changed to produce desired fissile isotope concentration variations.
- Fissile uranium concentration uncertainty effects mask concentration uncertainty effects of other uranium isotopes. For each fuel matrix, ^{232}U , ^{234}U , and ^{236}U have similar σ_s s and relatively negligible concentrations (two to four orders of magnitude less). The same is true for ^{235}U concentrations in the ^{233}U seed and blanket matrices.

Other fuel rod uncertainties (for example, axial length tolerances of zircaloy plugs) are neglected here. Experience indicates such uncertainties have negligible effect on calculated k_{eff} s because they do not directly affect the core's active fuel region, and because they do not significantly affect core reflector materials or thicknesses.

Table D-12 lists calculation results modeling control blade uncertainties. Rectangular core SB-2 and hexagonal core SB-6 are used because control blades are inserted furthest in these cores. Control blade height measurements were as accurate and precise as practical with contemporary measurements, but direct measurements are not reported. A relatively large, bounding ± 0.75 cm uncertainty is assumed here to envelop data reconstruction uncertainties.^{hh} A ± 0.008 wt% ($\pm 1\%$) ^{10}B uncertainty is assumed for control blade composition based on experimenter interviews and typical specifications for similar items in other similarly funded nuclear research programs. Results indicate control blade presence is much more important than precise information about blade dimensions, positions, and compositions.

Table D-9 lists calculation results assuming a bounding $\pm 2.5^\circ\text{C}$ water temperature uncertainty. This value is assumed because (a) temperatures were measured rather than estimated, (b) containment vessel air flow would have insulated the reactor tank from room temperature fluctuations and (c) experiment figures do not show any heat sources or sinks other than the core itself. Core SB-2½ is used here because, as the smallest core, it should be most sensitive to changes in water density, which would result from changes in temperature. The effects on other cores were not calculated because rod pitch variations (Table D-1) involve similar effects.

A measured 1.002 ± 0.003 k_{eff} is assumed for all cores except Core SB-2½, which is assumed to have a measured 1.000 ± 0.003 k_{eff} . These values are assumed for several reasons. Experimenters indicated clean, critical experiments had an excess reactivity of a few tenths of a percent. Interviews (Appendix C) indicated all experiments were slightly supercritical, except Core SB-2½, which apparently was critical within measurement capabilities. Using an analytical model with a reported $\pm 0.4\%$ uncertainty, experimenters calculated approximate 1.01 k_{eff} s (Table B-2). A 1.0015 k_{eff} would result in an approximate \$0.25 excess reactivity, which is typical for measuring critical experiment characteristics. Very slightly supercritical conditions would also be needed at clean critical conditions to ensure the cores would be critical when neutron absorbing test materials were added for later measurements. Finally, experimenters would have minimized measured core reactivity uncertainties, but a larger uncertainty should be assumed here because measured values were not reported.

5.4 Experiment k_{eff}

Table 12 lists experiment k_{eff} s based on an imprecise description of measured k_{eff} s, an assumed measurement uncertainty, and experiment description uncertainty effects. Experiment description effects are included here because they are not attributable to modeling or k_{eff} calculation methods.

6 Benchmarks

6.1 Overview

Developed using formulas, bases, and assumptions summarized in Appendix A, benchmarks are *simplified* representations of these experiments. Benchmarks model the fuel region in detail and include the control blades, but neglect other structures.

hh. This bounding 0.75 cm (about ± 0.6 in. or $\pm 6\%$) uncertainty is slightly more than the variation in blade heights calculated by different personnel using experimenter calculated axial buckling values and various estimation methods.

Table 12. Experiment k_{eff} s and Cumulative Uncertainties

core	$k_{\text{eff}} \pm 1\sigma$	core	$k_{\text{eff}} \pm 1\sigma$
SB-1	1.002 ± 0.019	SB-5	1.002 ± 0.019
SB-2	1.002 ± 0.019	SB-6	1.002 ± 0.019
SB-2½	1.000 ± 0.019	SB-7	1.002 ± 0.019
SB-3	1.002 ± 0.019		
SB-4	1.002 ± 0.019		

6.2 Configurations

Figure 20 through Figure 28 illustrate benchmark models. Each benchmark consists of a water flooded fuel rod array with four borated Type 304 stainless steel control blades and with a 30.48 cm thick water reflector. Table 13 indicates control blade coordinates for all eight cores. Table 14 and Table 15 respectively indicate coordinates for positioning fuel rods in rectangular and hexagonal cores. For convenience, benchmark positions are measured relative to the active core center.

With one exception fuel rod arrays consist of an inner array of identical seed rods (either $^{233}\text{UO}_2\text{-ZrO}_2$ or $^{235}\text{UO}_2\text{-ZrO}_2$) and an outer array of identical blanket rods (either $^{233}\text{UO}_2\text{-}^{232}\text{ThO}_2$ or $^{232}\text{ThO}_2$) in either a rectangular or hexagonal lattice. The exception, core SB-2½, consists of a rectangular array of identical $^{233}\text{UO}_2\text{-ZrO}_2$ seed rods. Rod pitches are based on experimenter calculated averages listed in Figure 6 through Figure 13, but incorporate the intended seed-to-blanket rod pitch ratios by rounding calculated averages, expressed in inches, to three digits.ⁱⁱ Therefore:

- Rectangular lattice cores (Cores SB-1, SB-2, SB-2½, SB-3, and SB-4) have square pitched rods with seed rod arrays at half the pitch of blanket rod arrays (respectively, 0.91948 cm [0.362 in.] and 1.83896 cm [0.724 in.]).
- Hexagonal lattice cores (Cores SB-5, SB-6, and SB-7) have the same triangular pitch in both seed and blanket rod arrays (1.45034 cm [0.571 in.]).

Figure 29 illustrates benchmark fuel rods. Each Zircaloy-2 clad fuel rod has an active fuel length centered between two Zircaloy-2 end plugs. As with rod pitches, rod dimensions are based on fuel rod manufacturing specifications, incorporating experimenter calculated rod averages, expressed in inches, rounded to three digits. This strategy results in benchmark $^{233}\text{UO}_2\text{-ZrO}_2$ and $^{235}\text{UO}_2\text{-ZrO}_2$ seed rods that have the same dimensions, as experiment designers intended. However, $^{232}\text{ThO}_2$ and $^{233}\text{UO}_2\text{-}^{232}\text{ThO}_2$ blanket rods have very slightly different dimensions. This difference should be negligible, but it was maintained as a more accurate representation of the actual experiments. In all cases, resultant benchmark rod dimensions are well within manufacturing tolerances. Therefore, for the benchmarks:

- $^{233}\text{UO}_2\text{-ZrO}_2$ and $^{235}\text{UO}_2\text{-ZrO}_2$ seed rods have a 0.53594 cm (0.211 in) fuel pellet diameter, 0.55880 cm (0.220 in.) cladding inner diameter, 0.64770 cm (0.255 in) cladding outer diameter, 38.1000 cm (15.0 in.) fuel length, and 52.9082 cm (20.83 in.) overall length.
- $^{232}\text{ThO}_2$ blanket rods have a 1.24206 cm (0.489 in) fuel pellet diameter, 1.26746 cm (0.499 in.) cladding inner diameter, 1.4478 cm (0.570 in) cladding outer diameter, 38.1000 cm (15.0 in.) fuel length, and 52.9082 cm (20.83 in.) overall length.

ii. Experiment reports did not identify rod pitch tolerances, but this strategy is assumed to produce core rod pitches that are well within those tolerances.

Figure 20. Benchmark Configuration Overview

	Seed Rod	Blanket Rod	Control Blade
symbol	●	○	—
fuel matrix	$^{235}\text{UO}_2\text{-ZrO}_2$	ThO_2	not applicable
square pitch (cm)	0.91948	1.83896	not applicable
array size (outer edge)	24×24	34×34	1×4

Figure 21. Benchmark Core SB-1 Loading, 18 cm elevation

	Seed Rod	Blanket Rod	Control Blade
symbol	●	○	—
fuel matrix	$^{233}\text{UO}_2\text{-ZrO}_2$	ThO_2	not applicable
square pitch (cm)	0.91948	1.83896	not applicable
array size (outer edge)	$(18 \times 18) + 16$	35×35	1×4

Figure 22. Benchmark Core SB-2 Loading, 18 cm elevation

	Seed Rod	Control Blade
symbol
fuel matrix	$^{233}\text{UO}_2\text{-ZrO}_2$	not applicable
square pitch (cm)	0.91948	not applicable
array size (outer edge)	18×16	1×4

Figure 23. Benchmark Core SB-2½ Loading, 18 cm elevation

	Seed Rod	Blanket Rod	Control Blade
symbol	●	○	—
fuel matrix	$^{233}\text{UO}_2\text{-ZrO}_2$	$^{233}\text{UO}_2\text{-ThO}_2$	not applicable
square pitch (cm)	0.91948	1.83896	not applicable
array size (outer edge)	$(12 \times 18) + 8$	32×35	1×4

Figure 24. Benchmark Core SB-3 Loading, 18 cm elevation

	Seed Rod	Blanket Rod	Control Blade
symbol	●	○	—
fuel matrix	$^{235}\text{UO}_2\text{-ZrO}_2$	$^{233}\text{UO}_2\text{-ThO}_2$	not applicable
square pitch (cm)	0.91948	1.83896	not applicable
array size (outer edge)	$(20 \times 18) + 16$	32×35	1×4

Figure 25. Benchmark Core SB-4 Loading, 18 cm elevation

	Seed Rod	Blanket Rod	Control Blade
symbol	●	○	▬
fuel matrix	$^{235}\text{UO}_2\text{-ZrO}_2$	ThO_2	not applicable
triangular pitch (cm)	1.45034	1.45034	not applicable
# rings to outer edge ^{jj}	9	21	not applicable

Figure 26. Benchmark Core SB-5 Loading, 18 cm elevation

jj. Number of fuel rod rings from core center to indicated rod array's outer edge, counting center rod as a ring.

	Seed Rod	Blanket Rod	Control Blade
symbol	●	○	—
fuel matrix	$^{233}\text{UO}_2\text{-ZrO}_2$	ThO_2	not applicable
triangular pitch (cm)	1.45034	1.45034	not applicable
# rings to outer edge ^{kk}	7½	21	not applicable

Figure 27. Benchmark Core SB-6 Loading, 18 cm elevation

kk. Number of fuel rod rings from core center to indicated rod array's outer edge, counting center rod as a ring.

	Seed Rod	Blanket Rod	Control Blade
symbol	●	○	—
fuel matrix	$^{233}\text{UO}_2\text{-ZrO}_2$	$^{233}\text{UO}_2\text{-ThO}_2$	not applicable
triangular pitch (cm)	1.45034	1.45034	not applicable
# rings to outer edge ^{II}	$6\frac{2}{3}$	21	not applicable

Figure 28. Benchmark Core SB-7 Loading, 18 cm elevation

II. Number of fuel rod rings from core center to indicated rod array's outer edge, counting center rod as a ring.

Table 13. Control Blade Coordinates (cm)

core ID	blade ID	x (blade center)	y (blade center)	z (blade lower edge)
all cores	a	0	5.517	see below
all cores	b	0	1.839	see below
all cores	c	0	-1.839	see below
all cores	d	0	-5.517	see below
SB-1	all blades	0	see above	16.44
SB-2	all blades	0	see above	15.91
SB-2½	all blades	0	see above	16.05
SB-3	all blades	0	see above	16.71
SB-4	all blades	0	see above	17.46
SB-5	all blades	0	see above	15.87
SB-6	all blades	0	see above	14.07
SB-7	all blades	0	see above	17.09

Table 14. Rectangular-Core Fuel-Rod X and Y Coordinates (cm)^{mm}

seed-rod center	blanket-rod center (even number of rods in row or column)	blanket-rod center (odd number of rods in row or column)
0.45974	0.91948	0.00000
1.37922	2.75844	1.83896
2.29870	4.59740	3.67792
3.21818	6.43636	5.51688
4.13766	8.27532	7.35584
5.05714	10.11428	9.19480
5.97662	11.95324	11.03376
6.89610	13.79220	12.87272
7.81558	15.63116	14.71168
8.73506	17.47012	16.55064
9.65454	19.30908	18.38960
10.57402	21.14804	20.22856
	22.98700	22.06752
	24.82596	23.90648
	26.66492	25.74544
	28.50388	27.58440
	30.34284	29.42336
		31.26232

mm. The x-coordinate value for a rod is the same as its y-coordinate value.

Table 15. Hexagonal-Core Fuel-Rod X and Y Coordinate (cm)

Fuel-Rod Row Centerline ± y coordinate	Fuel-Rod Center ± x coordinate (row at y = 0.0 cm)	Fuel-Rod Center ± x coordinate (row at y = 1.25603 cm)
0.00000	0.00000	0.72517
1.25603	1.45034	2.17551
2.51206	2.90068	3.62585
3.76809	4.35102	5.07619
5.02413	5.80136	6.52653
6.28016	7.25170	7.97687
7.53619	8.70204	9.42721
8.79222	10.15238	10.87755
10.04825	11.60272	12.32789
11.30428	13.05306	13.77823
12.56031	14.50340	15.22857
13.81634	15.95374	16.67891
15.07238	17.40408	18.12925
16.32841	18.85442	19.57959
17.58444	20.30476	21.02993
18.84047	21.75510	22.48027
20.09650	23.20544	23.93061
21.35253	24.65578	25.38095
22.60856	26.10612	26.83129
23.86459	27.55646	28.28163
25.12063	29.00680

Figure 29. Benchmark Fuel Rod

- $^{233}\text{UO}_2\text{-}^{232}\text{ThO}_2$ blanket rods have a 1.24460 cm (0.490 in.) fuel pellet diameter, 1.26492 cm (0.498 in.) cladding inner diameter, 1.44526 cm (0.569 in.) cladding outer diameter, 38.1000 cm (15.0 in.) fuel length, and 52.9082 cm (20.83 in.) overall length.

Identified as *a*, *b*, *c*, and *d* for convenience, each control blade is 7.62 cm (3 in.) wide and 0.1778 cm (0.070 in.) thick. Partially inserted into the seed rod array, modeled blade length depends on withdrawal height because blades extend only to the top of each benchmark's water reflector. Control blade locations and heights (Table 13) were reconstructed using information from interviews, core sketches, and experimenter-calculated axial buckling values.

To be equidistant and centered, with no blades between the outer two rows of the smallest core (SB-2½), blades were radially located as shown on Figure 23. Assuming blades are centered between fuel rod rows, these radial locations relative to core center are (Table 13):

$$y_{blade\ a\ center} = -y_{blade\ d\ center} = 6 \times 0.362\ in. = 2.172\ in. = 5.51688\ cm \quad \text{Equation 2}$$

$$y_{blade\ b\ center} = -y_{blade\ c\ center} = 2 \times 0.362\ in. = 0.724\ in = 1.83896\ cm \quad \text{Equation 3}$$

Control blade heights are calculated from axial buckling information (Equation 1 and Figure 6 through Figure 13). Manipulating Equation 1 yields:

$$H_{critical, bank, SB-2\frac{1}{2}} = \frac{\pi}{\sqrt{B_z^2}} - 2\delta \quad \text{Equation 4}$$

Equation 4's result is relative to the bottom of the fuel region. It must therefore be translated relative to core centerline by subtracting 19.05 cm (see Table 13 for results).

Control blade heights for the other seven cores were first estimated using a similar equation, assuming a uniform extrapolation length for each zone ($\delta = 8\ cm$), and averaging B_z^2 values across zones in each experiment's seed region. Relative to core centerline (19.05 cm above the bottom of the fuel region):

$$H_{critical, bank, 1stEst} = \frac{\pi}{\sqrt{B_{z, aveSeed}^2}} - 16\ cm - 19.05\ cm \quad \text{Equation 5}$$

Further calculation refinements were also tried. This first estimate (Equation 5) was ultimately used (see Table 13) because it produced the highest blade positions, reducing but not eliminating blade effects. In addition, blade heights from refined calculations were very near first estimate results as long as the reported cosine-shaped flux profile was considered in each refinement.

6.3 Materials

Table 16 through Table 19 list benchmark material descriptions. Lists include input bulk densities, input uranium isotopic wt%s, atom densities, and *resultant* nuclide wt%s to better document compositions and to facilitate comparison with other systems.ⁿⁿ Appendix A lists general formulas and nuclide atomic masses used to calculate these atom densities.

The $^{233}\text{UO}_2\text{-ZrO}_2$ seed composition is based on average pellet density (Table 4), listed uranium isotopics, and, initially, 24.47 wt% uranium in pellets (Table 3). ^{232}U , ^{235}U , and ^{236}U isotopic wt%s are averages that make up the difference between 100% and the sum of major isotopes. The wt%s listed for these minor uranium isotopes are below maximum values specified in fuel manufacturing specifications. Resultant nuclide wt%s yield a total uranium wt% of 23.57 wt%, which is less than the value input to these calculations. However, the method yields a UO_2 wt% consistent with Table 3. Each listed nuclide density is well within 5% of experimenter-calculated value (Table B-1), except for ^{232}U for which an experiment report error is suspected. Differences between Table 16 and Table B-1 are attributed to including uranium isotopes experimenters neglected and to the suspected ^{232}U error.

The $^{235}\text{UO}_2\text{-ZrO}_2$ seed composition is based on average pellet density, listed uranium isotopics, and 24.7 wt% uranium in pellets (Table 3). Uranium isotopic wt%s were adjusted using UF_6 feed's U_i : ^{235}U ratios to account for reported contamination effects (Table 3). Calculated from atom densities, nuclide wt%s do not sum to 100 wt% because of round-off effects. As expected, listed atom densities are well within 1% of experimenter-calculated densities (Table B-1).

nn Resultant nuclide wt% are calculated from listed benchmark atom densities and bulk densities.

Table 16. Fuel Matrices at 20°C

nuclide	²³³ UO ₂ -ZrO ₂ Seed Matrix (6.4833g/cm ³)			²³⁵ UO ₂ -ZrO ₂ Seed Matrix (6.6101g/cm ³)		
	(wt% in U)	(resultant wt%)	(atom/b-cm)	(wt% in U)	(resultant wt%)	(atom/b-cm)
²³² U ^{oo}	0.0033	8.0e-4	1.3217e-7	0	0	0
²³³ U	97.29	22.93	3.8411e-3	0	0	0
²³⁴ U	1.56	0.37	6.1327e-5	0.888	0.22	3.7309e-5
²³⁵ U	0.0033	8.0e-4	1.3048e-7	92.73	22.90	3.8791e-3
²³⁶ U	0.0033	8.0e-4	1.2993e-7	0.262	0.06	1.0907e-5
²³⁸ U	1.14	0.7	4.4061e-5	6.120	1.51	2.5278e-4
¹⁶ O	NA	22.24	5.4281e-2	NA	22.04	5.4840e-2
Zr	NA	54.19	2.3194e-2	NA	53.26	2.3240e-2
sums:	100.0	100.00	8.1421e-2	100.0	99.99	8.2260e-2
nuclide	²³³ UO ₂ - ²³² ThO ₂ Blanket Matrix (9.4446 g/cm ³)			²³² ThO ₂ Blanket Matrix (9.4884 g/cm ³)		
	(wt% in U)	(resultant wt%)	(atom/b-cm)	(wt% in U)	(resultant wt%)	(atom/b-cm)
²³² U ^{oo}	0.01	9.39e-5	2.3017e-8	NA	NA	NA
²³³ U	97.19	0.913	2.2274e-4	NA	NA	NA
²³⁴ U	1.55	0.0146	3.5370e-6	NA	NA	NA
²³⁵ U	0.01	9.4e-5	2.2722e-8	NA	NA	NA
²³⁶ U	0.01	9.4e-5	2.2626e-8	NA	NA	NA
²³⁸ U	1.23	0.0115	2.7595e-6	NA	NA	NA
²³² Th	NA	86.94	2.1311e-2	NA	87.88	2.1641e-2
¹⁶ O	NA	12.120	4.3080e-2	NA	12.12	4.3282e-2
Gd	NA	4.4e-4	1.5796e-7 ^{pp}	NA	4.4e-4	1.5967e-7 ^{qq}
sums:	100.00	100.00	6.4621e-2	NA	100.0	6.4923e-2

The ThO₂ blanket composition is based on its molecular formula and average pellet density (Table 4). Gd₂O₃ at a 5 ppm $w_{Gd}:w_{Th}$ concentration is included, but does not significantly affect nuclide wt%, bulk density, or summed densities. Listed N_{Th} and N_O densities are well within 2% of experimenter-calculated densities (Table B-1), after correcting for a transcription error (²³²U vs. ²³²Th). The difference in Gd densities is due to calculation methods differences (w_i ratio vs. N_i ratio, 5ppm vs. about 5.5ppm).

The UO₂-ThO₂ blanket composition is based on average pellet density (Table 4), listed uranium isotopics, and 0.939 wt% uranium in the pellets (Table 3). ²³²U, ²³⁵U, and ²³⁶U isotopic wt% are averages that make up the difference between 100% and the sum of major isotopes (²³³U, ²³⁴U, and ²³⁸U). The wt% listed for these minor uranium isotopes are well below maximum values specified in fuel manufacturing

oo. Neglected for calculations with SCALE4.3's GROUP44NDF5 and GROUP238NDF5 libraries.

pp. Equivalent to 5.22e-6 volume fraction compared to natural gadolinium at 7.9 g/cm³ theoretical density (for use with SCALE4.3's GROUP44NDF5 and GROUP238NDF5 libraries).

qq. Equivalent to 5.28-e6 volume fraction compared to natural gadolinium at 7.9 g/cm³ theoretical density (for use with SCALE4.3's GROUP44NDF5 and GROUP238NDF5 libraries).

specifications. Gd_2O_3 at a 5 ppm $w_{\text{Gd}}:w_{\text{Th}}$ concentration is included, but does not significantly affect nuclide wt%, bulk density, or summed densities. All but two listed atom densities are well within 1% of experimenter-calculated densities (Table B-1), after correcting for a transcription error (^{232}U vs. ^{232}Th). Exceptions are ^{238}U and Gd atom densities. Reasons for a 10% difference between ^{238}U values are unknown because total uranium atom densities are within 0.1%. The difference in Gd densities is due to calculation methods (w_i ratio vs. N_i ratio, and 5 ppm vs. about 5.5 ppm). For comparison, this matrix has atom ratios of 96 Th: ^{233}U and 93 Th:U, and wt% ratios of 96 Th: ^{233}U and 92 Th:U.

Table 17 lists water moderator and reflector composition, based on the molecular formula and indicated bulk density.

Table 17. Water Atom Densities at 20°C (0.9982 g/cm³)

nuclide	N (atoms/b-cm)
H	0.066735
O	0.033368
sum:	0.10010

Table 18 lists Zircaloy-2 composition, based on indicated wt%s and bulk density.

Table 18. Zircaloy-2 Composition (6.56 g/cm³)

nuclide	wt% (Table 7)	N (atoms/b-cm)
Zr	98.22	4.2537e-2
Cr	0.10	7.5977e-5
Fe	0.13	8.8422e-5
Ni	0.05	3.3656e-5
Sn	1.50	4.9918e-4rr
sums:	100.0	4.3234e-2

Table 19 lists control blade composition, based on indicated wt%s and bulk density. The benchmark material is essentially Type 304 stainless steel in which ^{10}B replaces some iron.

6.4 Sensitivities

These benchmarks simplify experiment descriptions by neglecting components that do not significantly affect system k_{eff} . Experience and engineering judgment typically guide this simplification process. However, calculations were completed to quantify system sensitivity, support engineering judgment, and provide additional information.

rr Equivalent to 0.0135 volume fraction compared to natural tin at 7.31 g/cm³ theoretical density (for use with SCALE4.3's GROUP44NDF5 and GROUP238NDF5 libraries).

Table 19. Control Blade Composition (7.92 g/cm³)

nuclide	wt% (Table 10)	N (atoms/b-cm)
Fe	69.423	5.9289e-2
C	0.04	1.5884e-4
Cr	19.00	1.7428e-2
Mn	1.00	8.6816e-4
Ni	9.25	7.5171e-3
P	0.02	3.0797e-5
S	0.015	2.2308e-5
Si	0.50	8.4910e-4
¹⁰ B	0.787	3.7488e-3
sums:	100.0	8.9912e-2

Table D-14 summarizes calculation results modeling various items neglected in benchmarks. Most of these items are outside the active fuel region. The SB-3 and SB-7 cores were modeled because they are the largest rectangular and hexagonal cores having the most material of interest (²³³U and ²³³UO₂-²³²ThO₂). Table D-15 and Table D-16 describe dimensions and compositions for items that are not included in benchmark models. Models that represent most items (cases SB3xdet, SB7xdet) produce the same k_{eff} s statistically as mirrored-core benchmark models, which represent only the fuel rod array, control blades, and a tight-fitting 1 foot thick water reflector (cases SB3a, SB7a). However, various items have competing effects. Models that represent some items and not others might or might not produce statistically similar results, depending on which items are represented. In addition, models with control blades (cases SB3a and SB7a) produce significantly lower k_{eff} s than models without blades (cases SB3udet and SB7udet). Results therefore support neglecting all items that are not inside the fuel rod array, with exception of control blades and a thick water reflector. Further, benchmarks do not require the addition of a modeling bias or uncertainty to the previously calculated experiment uncertainty. Experiment k_{eff} s and cumulative uncertainties listed in Table 12 may therefore be applied directly to these benchmark models.

Supporting calculations were not performed to demonstrate system sensitivity to the following simplifications. These are very standard simplifications with negligible effect, based on experience and good engineering judgment.

- Inert gas, Ar-He(10 vol%), between fuel pellets and cladding is modeled as void.
- The neutron (startup) source and its associated hardware are modeled as water.
- In rectangular cores the intermediate support “plate” of zirconium wire is modeled as water.

For further information, Table D-17 lists MCNP4b2 calculation results comparing mirrored-core representations with full-core representations. These modeling techniques *should* produce the same k_{eff} s statistically because cores are fully symmetric. Most results are within 2σ of each other and therefore satisfy this expectation. However, in two cases the k_{eff} difference is greater. Reasons for these differences are not yet identified but the differences are not significant for typical criticality safety validation uses.

Benchmark sensitivities to parameters that are not affected by modeling simplification(s) are not specifically calculated here. The magnitude of such sensitivities is indicated through calculations to

quantify the effects of individual experiment uncertainties (part 5.3 and associated Appendix D data). For example, a 0.001 in. change in rod pitch can cause a 0.004 change in k_{eff} (Table 11) and a 0.6 in. (or 6%) change in control blade height can cause a 0.002 change in k_{eff} (Table D-12).

6.5 Calculation Results

Table 20 and Table 21 respectively list MCNP4b2 and SCALE4.3/CSAS25/*hole* validation calculation results using input listed in Appendix E. Appendix A describes methods and formulae used to identify and quantify calculation methodology trends, uncertainties, and biases. Although the following differences are apparent, they are not statistically significant:

Table 20. Benchmark MCNP4b2 Calculated k_{eff} s

core	experiment $k_{\text{eff}} \pm 1\sigma$	calculated $k_{\text{eff}} \pm 1\sigma$	
		primarily ENDF/B-V ^{ss}	primarily ENDF/B-VI ^{ss}
SB-1	1.002 $\pm$ 0.011	0.99761 $\pm$ 0.00057	1.00233 $\pm$ 0.00059
SB-2	1.002 $\pm$ 0.011	0.99693 $\pm$ 0.00063	0.99444 $\pm$ 0.00092
SB-2½	1.000 $\pm$ 0.011	0.99793 $\pm$ 0.00060	0.99505 $\pm$ 0.00061
SB-3	1.002 $\pm$ 0.011	0.99610 $\pm$ 0.00052	0.99413 $\pm$ 0.00053
SB-4	1.002 $\pm$ 0.011	0.99692 $\pm$ 0.00049	0.99941 $\pm$ 0.00049
SB-5	1.002 $\pm$ 0.011	0.99774 $\pm$ 0.00053	0.99686 $\pm$ 0.00056
SB-6	1.002 $\pm$ 0.011	0.98999 $\pm$ 0.00059	0.98937 $\pm$ 0.00062
SB-7	1.002 $\pm$ 0.011	0.99475 $\pm$ 0.00055	0.99341 $\pm$ 0.00055
<i>ave., all cores</i>		0.99600 $\pm$ 0.00264	0.99563 $\pm$ 0.00394
<i>ave., ²³³U cores (not SB-1, -5)</i>		0.99544 $\pm$ 0.00287	0.99430 $\pm$ 0.00322
<i>ave., ²³³U seeds (not SB-1, -4, -5)</i>		0.99514 $\pm$ 0.00311	0.99328 $\pm$ 0.00226
<i>ave., ²³⁵U seeds (SB-1, -4, -5)</i>		0.99742 $\pm$ 0.00441	0.99953 $\pm$ 0.00274
<i>ave., ThO₂ (SB-1, -2, -5, -6)</i>		0.99557 $\pm$ 0.00374	0.99757 $\pm$ 0.00538
<i>ave., ²³³UO₂-ThO₂ (SB-3, -4, -7)</i>		0.99592 $\pm$ 0.00110	0.99565 $\pm$ 0.00328
<i>ave., rectangular cores</i>		0.99710 $\pm$ 0.00709	0.99707 $\pm$ 0.00363
<i>ave., hexagonal cores</i>		0.99416 $\pm$ 0.00391	0.99321 $\pm$ 0.00375

- Calculated k_{eff} s for hexagonal cores appear to be slightly lower than for rectangular cores.
- Hexagonal benchmark SB-6, with a ²³³UO₂-ZrO₂ seed and a ThO₂ and blanket, produces the lowest k_{eff} s.
- All except one MCNP4b2 calculated k_{eff} is less than its respective experiment k_{eff} .

ss. See Table A-1. MCNP-recommended libraries were used. In all cases cross sections for chromium, gadolinium iron, tin, and ²³²U are, therefore, respectively based on ENDF/V-B, ENDF/III-B, ENDF/V-B, ENDF/III-B, and ENDF/VI-B data.

Table 21. Benchmark SCALE4.3/CSAS25/hole Calculated k_{eff} s

core	experiment $k_{\text{eff}} \pm 1\sigma$	calculated $k_{\text{eff}} \pm 1\sigma$			
		ENDF/B-IV		ENDF/B-V	
		27GROUPNDF4	218GROUPNDF4	44GROUPNDF5	238GROUPNDF5
SB-1 ^{tt}	1.002 $\pm$ 0.019	1.00525 $\pm$ 0.00080	1.00462 $\pm$ 0.00077	1.00756 $\pm$ 0.00082	1.00436 $\pm$ 0.00148
SB-2 ^{tt}	1.002 $\pm$ 0.019	1.00997 $\pm$ 0.00089	1.00954 $\pm$ 0.00087	0.99990 $\pm$ 0.00090	0.99316 $\pm$ 0.00085
SB-2½	1.000 $\pm$ 0.019	1.01437 $\pm$ 0.00083	1.01477 $\pm$ 0.00087	1.00048 $\pm$ 0.00092	0.99318 $\pm$ 0.00091
SB-3	1.002 $\pm$ 0.019	1.00539 $\pm$ 0.00066	1.00403 $\pm$ 0.00068	0.99691 $\pm$ 0.00068	0.99091 $\pm$ 0.00067
SB-4	1.002 $\pm$ 0.019	1.00447 $\pm$ 0.00065	1.00227 $\pm$ 0.00064	1.00412 $\pm$ 0.00059	1.00076 $\pm$ 0.00062
SB-5 ^{tt}	1.002 $\pm$ 0.019	0.99854 $\pm$ 0.00077	0.99827 $\pm$ 0.00077	1.00388 $\pm$ 0.00081	1.00169 $\pm$ 0.00077
SB-6 ^{tt}	1.002 $\pm$ 0.019	0.99705 $\pm$ 0.00090	0.99745 $\pm$ 0.00085	0.99204 $\pm$ 0.00085	0.98900 $\pm$ 0.00083
SB-7	1.002 $\pm$ 0.019	1.00168 $\pm$ 0.00076	1.00118 $\pm$ 0.00074	0.99987 $\pm$ 0.00079	0.99419 $\pm$ 0.00072
<i>ave., all cores</i>		1.00459 $\pm$ 0.00570	1.00402 $\pm$ 0.00579	1.00045 $\pm$ 0.00482	0.99676 $\pm$ 0.00683
<i>ave., ²³³U cores (not SB-1, -5)</i>		1.00549 $\pm$ 0.00609	1.00487 $\pm$ 0.00626	0.99869 $\pm$ 0.00404	0.99467 $\pm$ 0.00661
<i>ave., ²³³U seeds (not SB-1, -4, -5)</i>		1.00569 $\pm$ 0.00679	1.00539 $\pm$ 0.00685	0.99761 $\pm$ 0.00340	0.99209 $\pm$ 0.00210
<i>ave., ²³⁵U seeds (SB-1, -4, -5)</i>		1.00275 $\pm$ 0.00367	1.00172 $\pm$ 0.00321	1.00519 $\pm$ 0.00206	1.00227 $\pm$ 0.00187
<i>ave., ThO₂ (SB-1, -2, -5, -6)</i>		1.00270 $\pm$ 0.00602	1.00247 $\pm$ 0.00570	1.00845 $\pm$ 0.00665	0.99705 $\pm$ 0.00719
<i>ave., ²³³UO₂-ThO₂ (SB-3, -4, -7)</i>		1.00385 $\pm$ 0.00193	1.00249 $\pm$ 0.00144	1.00030 $\pm$ 0.00362	0.99529 $\pm$ 0.00502
<i>ave., rectangular cores</i>		1.00789 $\pm$ 0.00422	1.00705 $\pm$ 0.00509	1.00179 $\pm$ 0.00412	0.99647 $\pm$ 0.00577
<i>ave., hexagonal cores</i>		0.99909 $\pm$ 0.00236	0.99897 $\pm$ 0.00196	0.99860 $\pm$ 0.00602	0.99496 $\pm$ 0.00638

- MCNP4b2 results are generally less than SCALE4.3/CSAS25 results. (See Figure 30).
- SCALE4.3 238-group cross section libraries generally produce lower calculated k_{eff} s than its collapsed 44-group libraries. (See Figure 30).

Every calculated k_{eff} is well within its respective experiment's 0.011 Δk_{stdU} uncertainty, showing good correlation between these calculation methods and measured k_{eff} s. Therefore, for INEEL purposes, MCNP4b2 and SCALE4.3/CSAS25 calculations do not typically require a non-conservative calculation bias when applied to systems closely resembling these benchmarks. However, criticality safety personnel must address the atypically large 0.011 Δk_{stdU} experiment uncertainty before establishing limits based on calculations validated with these experiments.

Various information is listed to assist readers in determining if these benchmarks and this validation apply to their specific evaluation needs.

- Table 22 lists calculated Th:U_i atom ratios based on the number and type of fuel rods in each core.
- Table 23 lists calculated H:X atom ratios based on fuel-rod-cell models, assuming cell contents are homogenized throughout cell volume. In the case of rectangular cores, a fuel rod cell has a square-cross-section, with a side width equal to the rod pitch and a length equal to the fuel rod length. In the

tt. Corrected code input and k_{eff} results provided by Mark N. Neeley, BBWI, June 2002.

Table 22. Benchmark Th:U_i Atom Ratios

ratio	SB-1	SB-2	SB-2½	SB-3	SB-4	SB-5	SB-6	SB-7
blanket Th: ²³³ U	NA	NA	0	96	96	NA	NA	96
blanket Th:U	NA	NA	0	93	93	NA	NA	93
ave. core Th: ²³³ U	NA	120	0	57	96	NA	280	72
ave. core Th: ²³⁵ U	64	NA	0	NA	73	170	NA	NA
ave. core Th:U	59	120	0	56	39	160	270	70

Table 23. Benchmark Rod Cell H:X Atom Ratios

ratio	SB-1	SB-2	SB-2½	SB-3	SB-4	SB-5	SB-6	SB-7
<i>averaged over seed</i>								
H: ²³³ U	NA	40	40	40	NA	NA	110	110
H: ²³⁵ U	39	NA	NA	NA	39	110	NA	NA
H:U	37	39	39	39	37	110	110	110
H:FEM	39	28	28	28	39	110	82	82
<i>averaged over blanket</i>								
H: ²³³ U	NA	NA	NA	430	430	NA	NA	45
H:U	NA	NA	NA	420	420	NA	NA	44
H: ²³² Th	4.4	4.4	NA	4.5	4.5	0.45	0.45	0.47
H:(²³³ U+Th)	4.4	4.4	NA	4.5	4.5	0.45	0.45	0.46
H:(U+Th)	4.4	4.4	NA	4.5	4.5	0.45	0.45	0.46
H:FEM, no Th ^{uu}	NA	NA	NA	310	310	NA	NA	32
H:FEM ^{vv}	63	63	NA	53	53	6.4	6.4	5.5
<i>averaged over core</i>								
H: ²³³ U	NA	450	40	260	430	NA	110	36
H: ²³⁵ U	240	NA	NA	NA	330	72	NA	NA
H:U	220	440	39	250	180	67	110	35
H: ²³² Th	3.7	3.7	NA	4.5	4.5	0.41	0.40	0.49
H:(²³³ U+ ²³⁵ U+Th)	3.6	3.6	40	4.4	4.4	0.41	0.39	0.49
H(U+Th)	3.6	3.6	39	4.4	4.4	0.41	0.39	0.49
H:FEM, no Th ^{uu}	240	320	28	180	160	72	78	26
H:FEM ^{vv}	43	45	NA	48	46	5.4	5.3	5.5

uu. Equation A-6, but set thorium component to zero.

vv. Equation A-6.

Figure 30. Benchmark Calculated k_{eff} s

case of hexagonal cores, a fuel rod cell has a hexagonal cross-section with a diameter equal to the rod pitch and a length equal to the fuel rod length. Each water flooded cell contains one fuel rod.

- Table D-18 lists calculated neutron spectra output from SCALE4.3 calculations using the 44-group library and *hole* geometry option. The SB benchmarks are thermal energy systems.

7 Benchmark and Validation Conclusions

Described SB experiments, and their simplified benchmark descriptions have a $1.002 \pm 0.011 k_{\text{eff}}$, except core SB-2½, which has a $1.000 \pm 0.011 k_{\text{eff}}$.

MCNP4b2 and SCALE4.3/CSAS25 calculations do not typically require a non-conservative calculation bias when applied to systems closely resembling these benchmarks. This validation also did not find any statistically significant trends in these calculation methodologies. Although MCNP generally produced slightly lower k_{eff} s than SCALE, differences between these codes and subject cross-section libraries are masked by benchmark uncertainties.

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Appendix A

Bases and General Assumptions

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A.1 Introduction

Benchmark development and evaluation primarily use standard criticality safety assumptions, bases, and formulas. However, benchmark models differ from criticality-safety-evaluation models because the goal is to produce an accurate, reasonably simplified model, rather than to produce a guaranteed conservative model. In addition, benchmarks are used to ensure that calculated k_{eff} s for a similar real world system will not be less than the system's actual k_{eff} . Most bases and assumptions are readily evident, described in the text, or both. Most formulas are readily identifiable from context or results. However, these standard assumptions, bases, and formulas are listed in this appendix for reader convenience.

A.2 Assumptions

Applicable standard assumptions, based on good engineering judgment and experience, include:

- Discrepancies are resolved, and simplifications are usually made, in a manner that will not increase calculated base case k_{eff} s and, preferably, will not decrease Δk_{eff} s. Where effects are significant, this strategy increases final negative (non-conservative) methodology biases.^a
- With possible exception of special testing materials, fission and activation products are negligible because critical experiments and startup tests are typically run for relatively short irradiation times at very low power levels.
- Data from direct measurements are less likely to incorporate errors than manipulated data (for example, normalized data).
- Handbook and national standard descriptions contemporary with item manufacture are more reliable than later descriptions for off-the-shelf materials. Using preferred descriptions avoids unlikely, but possible, differences due to technological changes after manufacture.
- Nominal, typical, or average dimension and composition values adequately describe as-built items. If only a range is specified, the range's arithmetic mean is typically used. If only a maximum value is specified, one half the maximum value is used unless there is reason to suspect the average value is different (for example, a maximum is specified for an undesirable but difficult-to-remove component).
- The extent to which an item or material effects system k_{eff} , and consequently the extent to which it must be modeled accurately, depends on its location with respect to active fissile material and its averaged macroscopic cross sections at neutron energies of interest. Nearby items have more effect than distant items. Similarly, materials with large Σ_a s and/or large Σ_s s have more effect than materials with small Σ_a s and/or large Σ_s s.
- Material impurities, contaminants, and constituents of less than 1 wt% are negligible, with possible exception of nuclides that have relatively large Σ_a s.
- If a non-negligible nuclide is not included in a cross-section library, a nuclide with similar cross sections, in the neutron energy range of concern, is usually an adequate substitute.
- Most gases (for example, air, argon, and helium) are negligible and modeled as void. In experiments such gases are typically in a clean but otherwise natural form. In this form they are very weak neutron absorbers and very inefficient neutron scatterers.
- One foot (about 30 cm) thick water is essentially an infinite neutron reflector, and provides neutronic isolation.

a This strategy also decreases final positive (conservative) biases, reducing any credit one might take for methods that consistently calculate k_{eff} s higher than measured k_{eff} s. However, INEEL criticality safety evaluation techniques currently do not take credit for conservative biases identified in methodology validations.

- Systems are at standard room temperature, 20°C, and standard atmospheric pressure, 1 atm, unless explicitly stated otherwise.

A.3 Atom Density Formulas

Atom density calculations are based on the following:

- Table A-1 lists relevant nuclide masses consistent with INEEL and ICSBEP methodology.
- The nuclide density of component i in material m is usually calculated as:

$$N_i = \frac{\rho_i N_A}{W_i 10^{24} \text{ b/cm}^2} \quad \text{Equation A-1}$$

where:

N_i (particles/b-cm) is expressed with *no more than* five figures.

N_A = Avogadro's number, 6.0221×10^{23} particles/g-mole, consistent with INEEL and ICSBEP methodology.^{25,12,1}

ρ_i = nuclide i 's mass concentration (g/cm³).

W_i = nuclide i 's atomic mass (g/g-mole), to *no more than* five figures.

- If nuclide concentration is given as a wt% w_i of material m , the nuclide density formula is:

$$N_i = \rho_m \times \frac{w_i}{100} \times \frac{N_A}{W_i} \times \frac{1}{10^{24} \text{ b/cm}^2} \quad \text{Equation A-2}$$

Unless stated otherwise, w_i s are *not* normalized to sum to 100%.

- Alternatively, nuclide densities might be calculated using a molecular formula. Using water (H₂O) as an example, the atom density formula becomes

$$\frac{N_H}{2} = N_O = \frac{\rho_{\text{water}} N_A}{(2W_H + W_O) 10^{24} \text{ b/cm}^2} \quad \text{Equation A-3}$$

- The relationship between concentrations expressed in wt% w_i and atom% a_i is

$$a_i = w_i \times \frac{W_m}{W_i} \quad \text{Equation A-4}$$

where:

$$W_m = \sum_i w_i W_i \quad \text{Equation A-5}$$

Unless stated otherwise, a_i s are *not* normalized to sum to 100%.

If data are not sufficient to calculate all atom densities with one formula, densities are calculated with the best combination of formulas for the data available. For example, it might be necessary to use molecular formulas to calculate atom densities for each molecule of a compound, and wt% to sum these atom densities correctly for the overall compound.

Table A-1. Atomic Masses and Identifiers Used Here

element	nuclide	(amu) ²⁵	MCNP4b ²² ID used for ENDF/V-B	ENDF/VI-B	SCALE4.3 ID ³ used for ENDF/IV-B	ENDF/V-B
aluminum (Al)	²⁷ Al	26.9815	13027.50c	not used	not used	not used
boron (B)	¹⁰ B	10.0129	5010.50c	5010.60c	B-10	B-10
carbon (C)	natural	12.0111	6000.50c	6000.60c	C	C
chromium (Cr)	natural	51.996	24000.50c	24000.50c	CR	CR
gadolinium (Gd)	natural	157.25	64000.35c	64000.35c	GD	GDb
hydrogen (H)	¹ H	1.0079	1001.50c	1001.60c	H	H
iron (Fe)	natural	55.847	26000.55c	26000.55c	FE	FE
lead (Pb)	natural	207.2	82000.50c	not used	not used	not used
manganese (Mn)	⁵⁵ Mn	54.9380	25055.50c	25055.60c	MN	MN
nickel (Ni)	natural	58.69	28000.50c	28000.50c	NI	NI
oxygen (O)	¹⁶ O	15.9994	8016.50c	8016.60c	O	O
phosphorus (P)	³¹ P	30.9738	15031.50c	15031.60c	P	P
silicon (Si)	natural	28.0855	14000.50c	14000.60c	SI	SI
sulfur (S)	³² S	32.07	16032.50c	16032.60c	S	S
thorium (Th)	²³² Th	232.0381	90232.50c	90232.60c	TH-232	TH-232
tin (Sn)	natural	118.710	50000.35c	50000.35c	SN	SN ^b
uranium (U)	²³² U	232.0371	92232.60c	92232.60c	not included ^c	U-232
	²³³ U	233.0396	92233.50c	92233.60c	U-233	U-233
	²³⁴ U	234.0041	92234.50c	92234.60c	U-234	U-234
	²³⁵ U	235.0439	92235.50c	92235.60c	U-235	U-235
	²³⁶ U	236.0456	92236.50c	92236.60c	U-236	U-236
	²³⁸ U	238.0508	92238.50c	92238.60c	U-238	U-238
zirconium (Zr)	natural	91.224	40000.50c	40000.60c	ZR	ZR

Fissile nuclides are individually included in this report's calculation models, but it is sometimes easier to understand results if fissile masses are expressed in *FEM* terms. The usual *FEM* equation is based on minimum critical solution masses and breeding in irradiated thorium.²⁶ It is **valid only for single unit, thermal systems**, but can provide a starting point for more complex thermal systems:

$$FEM = (1.4 \times {}^{233}\text{U}) + (1.0 \times {}^{235}\text{U}) + (1.6 \times {}^{239}\text{Pu}) + (0.07 \times {}^{232}\text{Th}) \quad \text{Equation A-6}$$

b Either a volume fraction of natural element, or isotopic N_i values, must be entered when using SCALE4.3's 44GROUPNDF5 and 238GROUPNDF5 libraries. For relevant cases, determined a volume fraction.

c SCALE4.3 27GROUPNDF4 libraries do not include ²³²U. For relevant cases, evenly divided ²³²U atom density between ²³⁵U and ²³⁶U.

A.4 Mean and Standard Deviation Formulas

In most cases values to be averaged are, or are assumed to be, normally distributed. An average value for n values of q , as used here and programmed into most calculators, is:

$$q_{ave} = \frac{\sum_{i=1}^n q_i}{n} \quad \text{Equation A-7}$$

Statistical variation in q_i s (specifically, q_i deviation from q_{ave}), as used here and programmed into most calculators, is:

$$\sigma_{q,ave} = \sqrt{\frac{\sum_{i=1}^n (q_{ave} - q_i)^2}{n}} \quad \text{Equation A-8}$$

These averaging formulas do not incorporate statistical variations in q_i values (for example, MCNP or SCALE's output σ_i associated with an output $k_{eff,i}$). Such variations are neglected here because they are typically third-order effects and do not significantly affect average k_{eff} s, biases, and uncertainties.

A.5 Experiment Uncertainty Analysis

Experiment uncertainty is a summation of individual effects, including relevant experiment measurement uncertainties and experiment description uncertainties. Experiment uncertainty analysis therefore requires identifying each contributor q_i , estimating an uncertainty associated with that contributor, and determining the effect on k_{eff} for that uncertainty. Individual contributors are identified based on experience, and selected to be as independent as practical based on experiment descriptions.

However, for these experiments, standard uncertainty data are not readily available for individual contributors. Instead, relevant uncertainty values are expressed in terms of bounding Δq_i values such as manufacturer tolerances and reasonable assumptions about the range of measured values. Lacking further information about actual q_i values within its Δq_i bounds, experiment uncertainty analysis therefore includes defining a *Type B standard uncertainty* for each contributor.

Consistent with ICSBEP methodology a *Type B standard uncertainty* is defined as, “a best estimate of the standard deviation of the measurand, based on whatever relevant information is available about the probability distribution of the value of the measurand.”^d

- For a contributor value expressed as $q_i \pm \Delta q_i$, the standard uncertainty, $\Delta q_{std,i}$, is defined as:^d

$$\Delta q_{std,i} = \frac{\Delta q_i}{\sqrt{3}} \quad \text{Equation A-9}$$

- For a contributor value expressed as $q_i (+\Delta q_{i,+}, -\Delta q_{i,-})$ the standard uncertainty, $\Delta q_{std,i}$, is defined as:^d

$$\Delta q_{std,i} = \frac{\Delta q_{i,+} + \Delta q_{i,-}}{2\sqrt{3}} \quad \text{Equation A-10}$$

d. *Guide to the Expression of Uncertainties for the Evaluation of Critical Experiments* in Reference 1

Considering the size of bounding Δq_i and noting that the change in a calculated k_{eff} is generally linear for a sufficiently small change in the calculation model, $\Delta k_{\text{stdU},i}$ (the effect on k_{eff} due to $\Delta q_{\text{std},i}$) can be calculated based on the k_{eff} s calculated based on the nominal, maximum, and minimum values of q_i .

- If k_{eff} for $q_{i,\text{nom}}$ ($k_{\text{ref},i}$) falls between k_{eff} s for $q_{i,\text{max}}$ and $q_{i,\text{min}}$, the effect of the standard uncertainty is:

$$\Delta k_{\text{stdU},i} = \frac{|\Delta k_{q_{i,\text{max}}}| + |\Delta k_{q_{i,\text{min}}}|}{2\sqrt{3}} \quad \text{Equation A-11}$$

- Otherwise, the effect is:

$$\Delta k_{\text{stdU},i} = \frac{\left\| \Delta k_{q_{i,\text{max}}}, \Delta k_{q_{i,\text{min}}} \right\|_{\text{max}}}{\sqrt{3}} \quad \text{Equation A-12}$$

where:

$$\Delta k_{q_{i,\text{max}}} = k_{\text{ref},i} - k_{q_{i,\text{max}}}$$

$$\Delta k_{q_{i,\text{min}}} = k_{\text{ref},i} - k_{q_{i,\text{min}}}$$

$k_{\text{ref},i}$ is the calculated k_{eff} with nominal value q_i .

$k_{q_{i,\text{max}}}$ is the calculated k_{eff} with the maximum value of q_i .

$k_{q_{i,\text{min}}}$ is the calculated k_{eff} with the minimum value of q_i .

$\Delta k_{\text{stdU},i}$ is the effect on k_{eff} due to $\Delta q_{\text{std},i}$.

To ensure that this strategy remains valid, the maximum of $\Delta k_{q_{i,\text{max}}}$ and $\Delta k_{q_{i,\text{min}}}$ should be relatively small. Therefore, calculations that produce a bounding Δk of 0.005 or larger are investigated further. Sometimes a different model is developed to estimate the contributor's effect because the original model did not vary the contributor independently. However, if the model independently varies the desired contributor, calculations are repeated with minor variations to ensure that results are not unduly influenced by a specific calculation factor. Such minor variations involve starting neutron source descriptions, starting random numbers, using $\frac{1}{2}\Delta q_i$ and $2\Delta q_i$, and, if a cross section library might be suspect, atom density values for the relevant nuclide. The relatively large bounding Δk is retained or revised as appropriate based on repeat calculations, or is used as a basis for not including a particular experiment in the benchmarks.

However, k_{eff} s are calculated here with MCNP, which introduces its own calculational standard deviation, σ . Therefore, bounding $\Delta k_{q_{i,\text{max}}}$ and $\Delta k_{q_{i,\text{min}}}$ that are less than $\sigma\sqrt{2}$ can be considered negligible if σ is sufficiently small.

Since, by assumption and to the extent practical, there is no correlation in uncertainties, the cumulative uncertainty here is:

$$\Delta k_{\text{stdU}} = \sqrt{\sum_{i=1}^n \Delta k_{\text{stdU},i}^2} \quad \text{Equation A-13}$$

However, individual uncertainty contributors are not fully independent, contrary to assumption. This summation formula therefore counts parts of individual contributors more than once. This double count is acceptable because it is minimized to the extent practical and because it is conservative for most INEEL criticality safety applications.

A.6 Benchmark Bias Formulas

At its simplest, INEEL criticality safety methodology bias is a minimum quantity necessary to ensure that, for a reasonably similar real-world system, the calculated k_{eff} is not less than the actual k_{eff} , especially for k_{eff} s that are near to or greater than 0.95:

$$k_{\text{eff},\text{actual}} \leq (k_{\text{eff}} + 2\sigma + \text{bias})_{\text{calculated}} \quad \text{Equation A-14}$$

where

$k_{\text{eff},\text{actual}}$ incorporates any non-conservative measurement uncertainty effects, assuming that k_{eff} were measured.

σ is the uncertainty associated with the calculation(s). In the case of Monte Carlo codes such as MCNP, the code outputs this value along with its calculated k_{eff} .

The emphasis on k_{eff} values near to or greater than 0.95 arises because INEEL criticality safety limits are typically set to maintain a minimum safety margin of $0.05\Delta k$ (specifically, system k_{eff} does not exceed 0.95 for normal and single accident conditions).²¹

Methodology bias incorporates significant deviations of calculated k_{eff} s from experiment k_{eff} s. Biases can be constants, but are typically functions of one or more parameters. However, at INEEL biases do not typically incorporate experiment uncertainty effects. If calculations are validated using experiments with non-negligible uncertainties, such as these SB cores, INEEL criticality safety personnel must explicitly and separately address the uncertainty effect before establishing criticality safety limits.

INEEL criticality safety methodology does not include credit for conservative deviations from actual k_{eff} s. Therefore, if all calculated benchmark k_{eff} s exceed their respective experiment $k_{\text{eff}} - \Delta k_{\text{uncertainty}}$ values, and experiment uncertainties ($\Delta k_{\text{uncertainty}}$ s) are reasonably small, calculation bias is set to zero.

If some calculated benchmark k_{eff} s are less than their respective experiment $k_{\text{eff}} - \Delta k_{\text{uncertainty}}$ values, and experiment uncertainties ($\Delta k_{\text{uncertainty}}$ s) are reasonably small, calculation bias is usually set to:

$$\text{bias} = k_{\text{eff},\text{experiment,ave}} - k_{\text{eff,ave}} - t_p \quad \text{Equation A-15}$$

where t_p represents the cumulative effect of any parameter-specific trends. Its value is typically either zero or a function of relevant parameters. This bias does not incorporate $\sigma_{k_{\text{eff,ave}}}$ because this uncertainty should be on the order of an individual calculated k_{eff} 's uncertainty and, therefore, adequately addressed by Equation A-14.

Alternate bias formulas can be more appropriate if experiment uncertainties ($\Delta k_{\text{uncertainty}}$ s) and/or calculation methodology uncertainties ($\sigma_{k_{\text{eff,ave}}}$) are not reasonably small. As determined in §5.3 and listed in Table 12, SB experiments uncertainties are about $0.019\Delta k$, but *might* not be unreasonable. Equation A-15 is judged adequate here because experiment uncertainties and calculation biases of this magnitude will not adversely affect LWBR storage limits at INEEL.

To determine if calculation results indicate trends, plots are generated of calculated k_{eff} s (ordinate) with respect to each relevant benchmark parameter, p_i (abscissa). In subject calculations, parameters include seed and blanket materials, fuel rod numbers, square and hexagonal core designs, control blade height, H:X ratios, Th:^xU ratios, and SCALE4.3-calculated average neutron energies. Plots also include appropriate comparison(s) with $k_{\text{eff,benchmark}}$, $k_{\text{eff,benchmark,ave}}$, or both. Figure A-1 is an example of such a plot for subject calculations. In SB core cases, such plots appeared to show some very small trends but none were judged statistically significant.

Figure A-1. Example of Data Plot to Help Identify Trends

Unless it is obvious there is no pattern in individual k_{eff} s, a best-fit data curve is generated using a least-squares fit, first-order polynomial, or second-order polynomial. If a resultant $k_{eff,calculated}$ curve deviates from the appropriate comparison line by no more than that line's uncertainty, then the deviation is judged not significant. Otherwise, further analysis is warranted. This further analysis is not described here because all apparent trends and deviations for subject calculation results were well within the experiment uncertainty.

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Appendix B

Experimenter Calculated Data

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Table B-1. Experimenter Calculated Nuclide Densities^a

nuclide	N (10 ²⁴ atoms/cm ³)			
	²³³ UO ₂ -ZrO ₂	seed ²³⁵ UO ₂ -ZrO ₂	blanket ThO ₂	UO ₂ -ThO ₂
²³³ U	0.0039899	none	none	0.00022289
²³⁴ U	0.000063967	0.0000375851	none	0.000003549
²³⁵ U	none	0.00387879	none	none
²³⁶ U	none	0.0000108258	none	none
²³⁸ U	0.000046986	0.000251232	none	0.0000028447
²³² U	0.000036321 ^b	none	0.021594 ^c	0.021296 ^c
O	0.053856	0.054868	0.043990	0.043333
Zr	0.022792	0.0232558	none	none
Gdd	none	none	0.00000011265	0.00000011214

Table B-2. Experimenter Calculated k_{eff}s

core design	core	analytical model e	$\frac{\lambda \text{ Flame}}{\lambda \text{ PDQ}}$	analytical model with material buckling	$\frac{\lambda \text{ P3MG-1}}{\lambda \text{ WANDA}}$
rectangular	SB-1	1.011	1.000	0.999	1.008
	SB-2	1.010	0.995	0.994	1.008
	SB-2½	1.010	NC	0.997	NC
	SB-3	1.011	0.999	0.998	1.009
	SB-4	1.015	NC	1.003	1.005
hexagonal	SB-5	1.008	NC	1.004	1.014
	SB-6	1.019	NC	1.011	1.019
	SB-7	1.018	NC	1.009	1.022

a Milani & Weiss, WAPD-TM-614, Appendix E.⁴

b The ²³²U value is inconsistent with the 38 ppm (²³³U) value indicated elsewhere in the experiment report. If 38 ppm is correct, the ²³²U value here should be 0.000000151616. This listed value might represent ²³²Th, which is consistent with one description (Table 5), but inconsistent with two other descriptions, elsewhere in the experiment report.

c This ²³²U value is not plausible for blanket matrices, and the source table did not list ²³²Th atom density values. This ²³²U identification most probably results from a transcription error confusing ²³²U and ²³²Th.

d Listed Gd nuclide densities are slightly more than the quoted 5 ppm of associated N_{U-232}. In these cases, "U-232" is most probably a transcription error for "Th-232".

e Experimenters reported a $\pm 0.4\%$ uncertainty for this method.

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Appendix C

Scientec-Provided Control Blade Information

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C.1 Introduction

Milan Straka and Abe Weitzberg of Scientec and Valerie Putman of INEEL assisted each other in obtaining information about, and modeling, subject experiments during 1999 and 2000. Information included reports, information sources, best MCNP input as of May 1999 (without control blade data) and January 2000 (with control blade data), control blade descriptions based on interviews of several Bettis personnel during 1999, and an excerpt from Scientec's proprietary report. Scientec-provided information is included here to preserve it and facilitate comparisons. Transmitted information is quoted directly, but formats are changed to conform better with this validation report's format. Reference numbers are likewise changed to avoid confusion between numbering in this validation report and Scientec's report.

C.2 Preliminary Information^a

"...Basically, we are just hoping to resolve the reasons why your cores are a little supercritical. The experimenters say that the cores themselves were run a few tenths supercritical to get some power out to irradiate foils, and it looks like the blades were inserted about 1 inch into the active fuel. That should take care of much of the excess reactivity."

C.3 Excerpts from Scientec Report^b

Specific Benchmark Experiments Related to Elk River Fuel

Two sets of critical experiments with specific applicability to the thorium-uranium Elk River fuel were examined for use as benchmarks. They are the Light Water Breeder Reactor Small Uranium-233 Fueled Seed and Blanket (SB) Critical Experiments at Bettis Atomic Power Laboratory (Reference 4) and the Thorium Uranium Physics Experiments (TUPE) at Babcock and Wilcox (Reference 27).

Seed Blanket Experiments

The five clean critical experiments identified in Table 3 were selected from WAPD-TM-614 (Reference 4).

Table 3. Seed Blanket Critical Experiments

<u>NUMBER</u>	<u>IDENTIFIER</u>	<u>DESCRIPTION</u>	<u>REFERENCE</u>
17	SB1(S1)	LWBR HEUO ₂ Seed, thorium oxide blanket	WAPD-TM-614 ⁴
18	SB2	LWBR U ²³³ O ₂ Seed, thorium oxide blanket	WAPD-TM-614
19	SB25(SB2H)	LWBR U ²³³ O ₂ Seed, no blanket	WAPD-TM-614
20	SB3	LWBR U ²³³ O ₂ Seed, U ²³³ O ₂ -thorium oxide blanket	WAPD-TM-614
21	SB4	LWBR HEUO ₂ Seed, U ²³³ O ₂ -thorium oxide blanket	WAPD-TM-614

Note: Parenthetical identifiers were also used as file names on executed MCNP runs.

These cases contained arrays of steel clad fuel pins containing thorium and uranium-233 and uranium-235 oxides, and also had enriched boron steel control elements slightly inserted into the top of the cores. The inclusion of the control rod effects allowed the verification of MCNP for the poisoned plates of the

a Abe Weitzberg, Scientec, e-mail to Valerie L. Putman, LMITCO, June 28, 1999.

b Millan Straka and Abe Weitzberg, Scientec, e-mail to Valerie L. Putman, BBWI, January 10, 2000.

transport basket. MCNP input decks without modeling of control rods were obtained from a criticality engineer who was analyzing these cores for inclusion in a future update of IHECSBE. These decks were verified against the information in Reference 4 and used to calculate uncontrolled reactivities as shown in Table 4 under NO CONTROL. Because these results were unacceptably high and the models did not include known effects, additional modeling of the control rods was performed.

Table 4. Summary of Benchmark Calculations for Seed Blanket Cores

<u>IDENTIFIER</u>	DEFINED EXPERIMENTAL	CALCULATED K-EFFECTIVE		
	<u>K-EFFECTIVE</u>	<u>NO CONTROL</u>	<u>UNIFORM CONTROL</u>	<u>EXPT CONTROL</u>
			Case Suffix DI	Case Suffix DG
SB1(S1)	1.001±0.001	1.00943±0.00121	1.00082±0.00117	1.00095±0.00121
SB2	1.001±0.001	1.00932±0.00128	1.00206±0.00138	1.00255±0.00136
SB25(SB2H)	1.000±0.001	1.00579±0.00124	0.99996±0.00131	No Change
SB3	1.001±0.001	1.00430±0.00105	1.00119±0.00108	0.99706±0.00109
SB4	1.001±0.001	1.00615±0.00108	1.00096±0.00098	1.00204±0.00104

Information about the size and composition of the control elements was obtained from Charles J. Emert of Westinghouse Bettis Atomic Laboratory. He stated that based on internal memo WAPD-SC-502 Supplement 1, the control elements were 304 stainless steel with 0.787 weight percent boron-10 and no boron-11. The elements were 0.070 inches thick, 24 inches long, and approximately 3 inches wide.

No information was readily available about control rod positions at criticality. Reference 4 describes the critical configuration of the clean, uncontrolled cores, meaning that all of the control elements were raised to their highest position, level with the top of the active fuel. These cores were stated to be a few tenths of a percent supercritical, and there was little or no perturbation of the flux distribution or reactivity from the poison material. However, included in the report was a discussion of the calculation of the axial buckling for bare seed core SB2.5 in which the control element critical bank height was a factor. Also, Figures 20 through 24 of Reference 4, showed measured axial buckling values for different traverses through the cores. The critical bank heights were evaluated for all five cores using equation

$$B_z^2 = \pi^2 / (H_c + 2 \delta)^2$$

Where B_z^2 is the measured axial buckling, H_c is the critical control rod bank height, and δ is the extrapolation distance obtained by fitting axial flux traverses. δ is stated to be about 8 cm for core SB2.5, and there is only one stated buckling of $37.8 \cdot 10^{-4} \text{ cm}^{-2}$. Therefore a unique bank height of 35.098 cm is obtained, equivalent to a rod insertion of 38.1-35.098 or 3.002 cm. For the other cores several axial bucklings are given, corresponding to different traverses through the core. Accordingly two options were evaluated. One was to assume an average buckling for all cores together with the assumption that the extrapolation distance for core SB2.5 was applicable to all of the cores. The second was to use only the axial bucklings from the centermost regions of the seed, where the control rods would be most important, together with the same extrapolation distance. The results for the calculations with the first option are shown in Table 4 under UNIFORM CONTROL, and the second option under EXPT CONTROL.

It was confirmed by one of the original experimenters that during the critical experiments, a variety of foils were irradiated to provide flux distribution measurements for different neutron spectra and specific nuclear reactions. These experiments were conducted with the cores slightly supercritical and on a slowly rising period to reach somewhat higher power levels, so that there would be more flux available to

facilitate the foil irradiation. Thus the measured bucklings from the foil irradiations were probably for slightly supercritical cores. Because the above equation was stated to be applicable to core SB2.5 at critical, the experimental value for k-effective is taken to be 1.000 for that core. For the other cores, it is assumed that their k-effectives are slightly supercritical with some small uncertainty, or 1.001 ± 0.001 .

From the results presented in Table 4 it can be seen that the inclusion of the control elements is statistically significant in all cases, but the difference between the two controlled options is relatively small. Accordingly, this set of experiments is acceptable for benchmarking and the second more detailed analysis will be used in the statistical analysis.

Thorium Uranium Physics Experiments (TUPE)

Table 5. Thorium Uranium Physics Experiments

<u>NUMBER</u>	<u>IDENTIFIER</u>	<u>DESCRIPTION</u>	<u>REFERENCE</u>
22	TU15A	Uniform lattice thoria-urania, 15/1, W/F 1.38	BAW-1191 ²⁷
23	TU15B(TU15B1)	Uniform lattice thoria-urania, 15/1, W/F 1.64	BAW-1191
24	TU15D	Uniform lattice thoria-urania, 15/1, W/F 2.95	BAW-1191
25	TU25D	Uniform lattice thoria-urania, 25/1, W/F 3.64	BAW-1191

Note: Parenthetical identifiers were also used as file names on executed MCNP runs.

These cases (Reference 27) contained arrays of aluminum clad fuel pins containing thoria and highly enriched uranium-235 oxides, with varying water to fuel area ratios. The experiments were brought to just critical by adjusting the critical water heights. The initial calculations were made with only the uranium and thorium oxides in the fuel. A second series of calculations was run adding 3.1 parts per million by weight of natural gadolinium (relative to thorium). The gadolinium was by far the fuel impurity with the most impact on reactivity. The results are shown in Table 6.

Table 6. Summary of Benchmark Calculations for TUPE Cores

<u>IDENTIFIER</u>	<u>DEFINED EXPERIMENTAL</u>	<u>CALCULATED K-EFFECTIVE</u>	
	<u>K-EFFECTIVE</u>	<u>Only Th and U</u>	<u>Gd added</u>
TU15A	1.000	1.00641 ± 0.00096	1.00566 ± 0.00102
TU15B(TU15B1)	1.000	1.00022 ± 0.00097	0.99788 ± 0.00096
TU15D	1.000	1.01005 ± 0.00095	1.00962 ± 0.00099
TU25D	1.000	1.01769 ± 0.00077	1.01478 ± 0.00085

From the results in Table 6 it can be seen that the differences between the calculated and experimental reactivities for the TU15A and TU15B cores could be considered to be from the same population as previously observed for the generic and Seed-Blanket benchmarks. However the differences for the TU15D and TU25D are substantially greater, in the range of three to five standard deviations as calculated from the results in Table 7. By accepted practice these cases must be considered to be outliers, and because the large deviations are not understood, these cases should not be included in the benchmarking analysis. The cases that included gadolinium showed slight improvement, but they confirmed that the discrepancies were not likely the result of errors in composition.

The calculation of the TUPE cores did confirm that for these fuels similar to Elk River, MCNP tended to overpredict calculated reactivities, which is in the conservative direction intended for use of the code and libraries.

C.4 Control Blade Positions

Table C-1 lists control blade heights as reconstructed by Scientec and INEEL personnel. Scientec calculations used the EXPT CONTROL method described in §C.3. INEEL calculations are described in §6.2 in the body of this validation report. Core SB-2½ blade heights are surprisingly discrepant, although Scientec and INEEL personnel used the same calculation method. Reasons for this discrepancy are not yet identified. The same data, including fuel height (38.10 cm), were used, and the same total withdrawal height (35.098 cm) and insertion depth (3.002 cm) were calculated. Apparently the difference occurs in translating this blade height relative to the model's axial centerline (specifically, $(\frac{1}{2} \times 38.10) - 3.002$ for INEEL's case). However, model centerlines should be the same because Scientec apparently did not modify the INEEL-supplied input in that respect.

Table C-1. Reconstructed Control Blade Height Comparison

core	blade bottom relative to fuel centerline (cm)	
	Scientec (§C.5.0 through C.5.5)	INEEL (Table 13)
SB-1	15.84644	16.44
SB-2	15.45035	15.91
SB-2½	16.517	16.05
SB-3	16.38935	16.71
SB-4	17.02139	17.46

C.5 Scientec-modified MCNP4b Input

To conserve space, blank comment lines are deleted and a double column format is used. Single lines of input might therefore appear as multiple lines here.

C.5.1 SB1DG

```

LWBR SB-1 simplification e
c Control blades inserted 3.203563 cm. past fuel
c rectangular array
c U235, 576 UO2-ZrO2 seed rods (24x24 array)
c 1120 ThO2 blanket rods (34x34 - 6x6 array)
c change blanket rod pitch to exactly twice seed rod pitch
c use 3 decimal places of fuel & pitch measurements
c neglect structural material including table
c neglect anything >1ft above, below, or radially from rods
c Cells
c surface order: pz1 ... cz1 ... (axial, then radial)
c seed rod, infinitely long
11 5 -6.56 1 -21 u=1 imp:n=1
12 2 8.2418-2 2 -1 -21 u=1 imp:n=1
13 5 -6.56 -2 -21 u=1 imp:n=1
14 0 21 -22 u=1 imp:n=1
15 5 -6.56 22 -23 u=1 imp:n=1
16 6 -0.9982 23 u=1 imp:n=1
c seed rod array
31 0 -31 32 -33 34 lat=1 fill=1 u=3 imp:n=1
32 0 -99 trcl=1 fill=3 u=4 imp:n=1
c water rod
41 6 -0.9982 -99 u=5 imp:n=1
c blanket rod, infinitely long
51 5 -6.56 1 -41 u=9 imp:n=1
52 3 6.4923-2 2 -1 -41 u=9 imp:n=1

```

```

53 5 -6.56 -2 -41 u=9 imp:n=1
54 0 41 -42 u=9 imp:n=1
55 5 -6.56 42 -43 u=9 imp:n=1
56 6 -0.9982 43 u=9 imp:n=1
c 1/4 core + water on all sides
61 0 -51 52 -53 54 lat=1 u=8 imp:n=1
fill=-1:18 -18:1 0:0
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 4 4 4 4 4 4 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 4 4 4 4 4 4 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 4 4 4 4 4 4 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 4 4 4 4 4 4 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 4 4 4 4 4 4 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
75 0 -5 6 -66 69 fill=8 u=6 imp:n=1
76 6 -0.9982 9:-10:66:-69 u=6 imp:n=1
77 0 -99 trcl=2 fill=6 u=7 imp:n=1

```

```

78      6   -0.9982      10 -6 -66 69      u=6  imp:n=1
79      6   -0.9982      5 -9 -66 69      u=6  imp:n=1
c put core in experiment tank 1 ft larger radius than core
91      7   .09013387  111 -112 -103 104 -7 92      imp:n=1
92      7   .09013387  121 -122 -103 104 -7 92      imp:n=1
98      0      -91 92 -93 -7 8 # (111 -112 -103 104)
      # (121 -122 -103 104) fill=7      imp:n=1
99      0      91:-92:93:7:-8      imp:n=0

c Surfaces
c elevations, pz, 0.00 = middle of fuel region
1      pz      19.05      $ top of fuel region
2      pz      -19.05      $ bottom of fuel region
5      pz      26.416      $ top of rod
6      pz      -26.416      $ bottom of rod
7      pz      56.896      $ 1 ft above rod
8      pz      -56.896      $ 1 ft below rod
c solid spacer plates -
c just put here to test sensitivity, fill with water to
ignore
9      pz      27.686      $ top 1/2" spacer plate
10     pz      -27.686      $ bottom 1/2" spacer plate
c 235U seed radial surfaces
21     cz      0.268      $ 0.211in. OD Seed fuel pellet/zirc
plug
22     cz      0.279      $ 0.220in. ID Seed clad
23     cz      0.324      $ 0.255in. OD Seed clad
c seed rod window surfaces, pitch = 0.362in. = 0.91948cm
31     px      0.45974
32     px      -0.45974
33     py      0.45974
34     py      -0.45974
c ThO2 Blanket radial surfaces
41     cz      0.622      $ 0.490in. OD blanket pellet/zirc plug
42     cz      0.635      $ 0.500in. ID blanket clad
43     cz      0.724      $ 0.570in. OD blanket clad
c blanket rod window (square cell) surfaces
c actual pitch reported as 0.7239in. = 1.83871cm
c change to 2*seed pitch = 0.724in. = 1.83896cm
c this is also window for 2x2 array of seed rods
51     px      0.91948
52     px      -0.91948
53     py      0.91948
54     py      -0.91948
c 1/4 core window (square cell) surfaces
66     px      32.0825      $ 17.5*pitch
69     py      -32.0825      $ 17.5*pitch
c radial tank and model boundaries
91     cz      91.44      $ 6ft diameter experiment tank
91     cz      62.56      $ tank w radius 1 ft greater than core
*92    px      0.00      $ reflected surface
*93    py      0.00      $ reflected surface
99     cz      259.08      $ 17ft containment tank (neglected)
c Control rod (assume 1/16" thick, extends in 5 seed
rows,
c penetration of rods based on surface
c      104 -- 19.05 = top of fuel,
c assume between seed rows 2&3 and 6&7)
103    px      3.81
104    pz      15.84644
111    py      -1.9289
112    py      -1.7511
121    py      -5.6089
122    py      -5.4311

c Materials, Avogadro's number = 6.0221+23 particles/g-
mole
m2     $ 235U02-ZrO2 Seed, 6.6101g/cc, Ntot = 8.2418-2
      8016.50c 5.4945-2 $ Oxygen
      40000.56c 2.3310-2 $ Zr
      92234.50c 3.7474-5 $ U-234      0.892wt% in U
      92235.50c 3.9891-3 $ U-235      92.73wt% in U
      92236.50c 1.0957-5 $ U-236      0.263wt% in U
      92238.50c 2.3568-4 $ U-238      5.706wt% in U
m3     $ ThO2 blanket, 6.6101g/cc, Ntot = 6.4923-2
      8016.50c 4.3282-2
      90232.50c 2.1641-2
m5     $ zircaloy-2 cladding, 6.56 g/cc, Ntot=4.3234-2
      40000.56c 4.2537-2 $ Zirconium      98.23 wt%
      28000.50c 3.3656-5 $ Nickel      0.05 wt%
      24000.50c 7.5977-5 $ Chromium      0.10 wt%
      26000.55c 8.8422-5 $ Iron      0.13 wt%
      50000.35c 4.9918-4 $ Tin      1.5 wt%
m6     $ water, 0.9982 g/cc, Ntot=1.0011-2
      1001.50c 6.6742-2
      8016.50c 3.3371-2
mt6    lwtr.01t
c      m7 is SS plate with 0.787% B (absorber plate)
m7     5010.50c 3.749e-3
      24000.50c 1.7638e-2      29000.50c 1.9145e-4
      26000.55c 5.5634e-2      25055.50c 1.4394e-3
      42000.50c 1.5119e-4      28000.50c 8.0684e-3
c translate coordinates to center core array
*tr1   -0.45974      0.45974      0.0      0 90 90      90
0 90    90 90 0      1
*tr2   -0.91948      -0.91948      0.0      0 90 90      90
0 90    90 90 0      1
mode n

```

	pramp	100	50	0	1	
kcode			1500		1.0	100
ksrc						500
	0.5	-0.5	0			
	0.5	-0.5	20			
	0.5	-0.5	-20			
	0.5	-2.2	0			
	0.5	-5	0			
	0.5	-7	0			
	0.5	-10.6	0			
	0.5	-10.6	20			
	0.5	-10.6	-20			
	2.2	-0.5	0			
	2.2	-2.2	0			
	2.2	-5	0			
	2.2	-7	0			
	2.2	-10.6	0			
	5	-0.5	0			
	5	-2.2	0			
	5	-5	0			
	5	-7	0			
	5	-10.6	0			
	7	-0.5	0			
	7	-2.2	0			
	7	-5	0			
	7	-7	0			
	7	-10.6	0			
	10.6	-0.5	0			
	10.6	-0.5	20			
	10.6	-0.5	-20			
	10.6	-2.2	0			
	10.6	-5	0			
	10.6	-7	0			
	10.6	-10.6	0			
	10.6	-10.6	20			
	10.6	-10.6	-20			

C.5.2 SB2DG

```
LWBR SB-2 simplification e with Thorium
c Control blades inserted 3.59965 cm past fuel
c rectangular array
c U233, 340 UO2-ZrO2 seed rods (18x18 +16 array)
c 1142 ThO2 blanket rods (35x35 - 9x9 - 2 array)
c add Thorium to seed based on WAPD-TM-614 App A
c blanket rod pitch = exactly twice seed rod pitch
c so put 2x2 seed rod array in appropriate positions
c           of blanket rod array
c use 3 decimal places of fuel & pitch measurements
c neglect structural material including table
c neglect anything >1ft above, below, or radially from
rods
c Cells
c surface order: pz1 ... cz1 ... (axial, then radial)
c seed rod, infinitely long
11   5    -6.56        1      -21                u=1 imp:n=1
12   1     8.1995-2    2     -1 -21              u=1 imp:n=1
13   5    -6.56        2     -21              u=1 imp:n=1
14   0                    21   -22             u=1 imp:n=1
15   5    -6.56        22   -23             u=1 imp:n=1
16   6    -0.9982       23                   u=1 imp:n=1
c seed rod array
31   0                  -31 32 -33 34 lat=1 fill=1 u=3 imp:n=1
32   0                  -99          trcl=1 fill=3 u=4 imp:n=1
c water rod
41   6    -0.9982               -99                u=5 imp:n=1
c blanket rod, infinitely long
51   5    -6.56        1      -41                u=9 imp:n=1
52   3     6.4923-2    2     -1 -41              u=9 imp:n=1
53   5    -6.56        2     -41              u=9 imp:n=1
54   0                    41   -42             u=9 imp:n=1
55   5    -6.56        42   -43             u=9 imp:n=1
56   6    -0.9982       43                   u=9 imp:n=1
61   0                  -51 52 -53 54 lat=1      u=8 imp:n=1
                        fill=-1:20 -18:1 0:0
                          5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
                          5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
                          5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
                          5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
                          5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
                          5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
                          5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
                          5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
                          5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
                          5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
                          5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
                          5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
                          5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
                          5 5 4 4 4 4 4 4 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
                          5 5 4 4 4 4 4 4 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
                          5 5 4 4 4 4 4 4 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
                          5 5 4 4 4 4 4 4 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
                          5 5 4 4 4 4 4 4 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
                          5 5 4 4 4 4 4 4 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
                          5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
75   0                      -5 6 -66 69         fill=8 u=6 imp:n=1
76   6    -0.9982       9:-10:66:-69          u=6 imp:n=1
```

Appendix C Scientec-Provided Control Blade Information

```

77 0 -99 trcl=2 fill=6 u=7 imp:n=1
78 6 -0.9982 10 -6 -66 69 u=6 imp:n=1
79 6 -0.9982 5 -9 -66 69 u=6 imp:n=1
c put core in experiment tank 1 ft larger radius than core
91 7 .09013387 111 -112 -103 104 -7 92 imp:n=1
92 7 .09013387 121 -122 -103 104 -7 92 imp:n=1
98 0 -91 92 -93 -7 8 #(111 -112 -103 104)
#(121 -122 -103 104) fill=7 imp:n=1
99 0 91:-92:93:7:-8 imp:n=0

c Surfaces
c elevations, pz, 0.00 = middle of fuel region
1 pz 19.05 $ top of fuel region
2 pz -19.05 $ bottom of fuel region
c 3 pz 21.59 $ top of top Zr plug
c 4 pz -21.59 $ bottom of bottom Zr plug
5 pz 26.416 $ top of rod
6 pz -26.416 $ bottom of rod
7 pz 56.896 $ 1 ft above rod
8 pz -56.896 $ 1 ft below rod
c solid spacer plates
c just put here to test sensitvty, fill with water to
ignore
9 pz 27.686 $ top 1/2" spacer plate
10 pz -27.686 $ bottom 1/2" spacer plate
c 233U seed radial surfaces
21 cz 0.268 $ 0.211in. OD Seed fuel pellet/zirc
plug
22 cz 0.279 $ 0.220in. ID Seed clad
23 cz 0.324 $ 0.255in. OD Seed clad
c seed rod window surfaces, pitch = 0.362in. = 0.91948cm
31 px 0.45974
32 px -0.45974
33 py 0.45974
34 py -0.45974
c ThO2 Blanket radial surfaces
41 cz 0.622 $ 0.490in. OD blanket pellet/zirc plug
42 cz 0.635 $ 0.500in. ID blanket clad
43 cz 0.724 $ 0.570in. OD blanket clad
c blanket rod window surfaces, pitch = 0.724in. =
1.83896cm
51 px 0.91948
52 px -0.91948
53 py 0.91948
54 py -0.91948
c 1/4 core window surfaces
66 px 34.020799 $ 18.5*pitch = 18.5*1.83896 - tad
69 py -32.181799 $ 17.5*pitch = 17.5*1.83896 - tad
c radial tank and model boundaries
c 91 cz 91.44 $ 6ft diameter experiment tank
91 cz 64.50 $ tank w radius 1 ft greater than core
*92 px 0.00 $ reflected surface
*93 py 0.00 $ reflected surface
99 cz 259.08 $ 17ft containment tank (neglected)
c Control rod (assume 1/16" thick, extends in 5 seed
rows,
c penetration of rods based on surface
c 104 -- 19.05 = top of fuel)
103 px 3.81
104 pz 15.45035
111 py -1.9289
112 py -1.7511
121 py -5.6089
122 py -5.4311

c
c Materials, Avogadro's number = 6.0221+23 particles/g-
mole
m1 $ 233UO2-ZrO2 Seed, 6.4833g/cc, Ntot = 8.1995-2
8016.50c 5.4663-2 $ Oxygen
40000.56c 2.3194-2 $ Zr
92233.50c 3.9891-3 $ U-233 97.19wt% in U
92234.50c 6.3273-5 $ U-234 1.55wt% in U
92238.50c 4.9365-5 $ U-238 1.23wt% in U
90232.50c 3.6287-5 $ Th-232
m3 $ ThO2 blanket, 6.6101g/cc, Ntot = 6.4923-2
8016.50c 4.3282-2
90232.50c 2.1641-2
m5 $ zircaloy-2 cladding, 6.56 g/cc, Ntot=4.3234-2
40000.56c 4.2537-2 $ Zirconium 98.23 wt%
28000.50c 3.3656-5 $ Nickel 0.05 wt%
24000.50c 7.5977-5 $ Chromium 0.10 wt%
26000.55c 8.8422-5 $ Iron 0.13 wt%
50000.35c 4.9918-4 $ Tin 1.5 wt%
m6 $ water, 0.9982 g/cc, Ntot=1.0011-2
1001.50c 6.6742-2
8016.50c 3.3371-2
mt6 lwtr.01t
c m7 is SS plate with 0.787% B (absorber plate)
m7 5010.50c 3.749e-3
24000.50c 1.7638e-2 29000.50c 1.9145e-4
26000.55c 5.5634e-2 25055.50c 1.4394e-3
42000.50c 1.5119e-4 28000.50c 8.0684e-3
c translate coordinates to center core array
*tr1 -0.45974 -0.45974 0.0 0 90 90 90
0 90 90 0 1
*tr2 -1.83896 0.0 0.0 0 90 90 90
0 90 90 0 1

```

```

mode n
prdmp 100 50 0 1
kcode 1500 1.0 100 500
ksrc 0.5 -0.5 0
0.5 -0.5 20
0.5 -0.5 -20
0.5 -2.2 0
0.5 -5 0
0.5 -7 0
0.5 -9.75 0
0.5 -9.75 20
0.5 -9.75 -20
7.75 -7.75 0
7.75 -7.75 20
7.75 -7.75 -20
2.2 -0.5 0
2.2 -2.2 0
2.2 -5 0
2.2 -7 0
5 -0.5 0
5 -2.2 0
5 -5 0
5 -7 0
7 -0.5 0
7 -2.2 0
7 -5 0
7 -7 0
7.75 -7.75 0
7.75 -7.75 20
7.75 -7.75 -20
9.75 -0.5 0
9.75 -0.5 20
9.75 -0.5 -20

```

C.5.3 SB25DI

```

LWBR SB-2.5 simplification e with Thorium
c Control blades inserted 2.583 cm past fuel
c rectangular array
c U233, 340 UO2-ZrO2 seed rods (18x16)
c no blanket
c add Thorium to seed based on WAPD-TM-614 App A
c use 3 decimal places of fuel & pitch measurements
c neglect structural material including table
c neglect anything >1ft above, below, or radially from
rods
c Cells
c surface order: pz1 ... cz1 ... (axial, then radial)
c seed rod, infinitely long
11 5 -6.56 1 -21 u=1 imp:n=1
12 1 8.1995-2 2 -1 -21 u=1 imp:n=1
13 5 -6.56 -2 -21 u=1 imp:n=1
14 0 21 -22 u=1 imp:n=1
15 5 -6.56 22 -23 u=1 imp:n=1
16 6 -0.9982 23 u=1 imp:n=1
c seed rod array
31 0 -31 32 -33 34 lat=1 fill=1 u=3 imp:n=1
32 0 -99 trcl=1 fill=3 u=4 imp:n=1
75 0 -5 6 -66 69 fill=4 u=6 imp:n=1
76 6 -0.9982 9:-10:66:-69 u=6 imp:n=1
78 6 -0.9982 10 -6 -66 69 u=6 imp:n=1
79 6 -0.9982 5 -9 -66 69 u=6 imp:n=1
c put core in experiment tank 1 ft larger radius than core
91 7 .09013387 111 -112 -103 104 -7 92 imp:n=1
92 7 .09013387 121 -122 -103 104 -7 92 imp:n=1
98 0 -91 92 -93 -7 8 #(111 -112 -103 104)
#(121 -122 -103 104) fill=6 imp:n=1
99 0 91:-92:93:7:-8 imp:n=0

c Surfaces
c elevations, pz, 0.00 = middle of fuel region
1 pz 19.05 $ top of fuel region
2 pz -19.05 $ bottom of fuel region
c 3 pz 21.59 $ top of top Zr plug
c 4 pz -21.59 $ bottom of bottom Zr plug
5 pz 26.416 $ top of rod
6 pz -26.416 $ bottom of rod
7 pz 56.896 $ 1 ft above rod
8 pz -56.896 $ 1 ft below rod
c solid spacer plates
c just put here to test sensitvty, fill with water to
ignore
9 pz 27.686 $ top 1/2" spacer plate
10 pz -27.686 $ bottom 1/2" spacer plate
c 233U seed radial surfaces
21 cz 0.268 $ 0.211in. OD Seed fuel pellet/zirc
plug
22 cz 0.279 $ 0.220in. ID Seed clad
23 cz 0.324 $ 0.255in. OD Seed clad
c seed rod window surfaces, pitch = 0.362in. = 0.91948cm
31 px 0.45974
32 px -0.45974
33 py 0.45974
34 py -0.45974
c 1/4 core window surfaces
66 px 8.2753199 $ 9*pitch = 9*0.91948 - tad

```


[illegible]

C.5.4 SB3DG

```

LWBR SB-3 simplification e with Thorium
c Control blades inserted 2.660652 cm past fuel
c rectangular array
c U233, 224 UO2-ZrO2 seed rods (12x18 +8 array)
c 232 233UO2-ThO2 blanket rods (16x18 - 6x9 - 2 array)
c add Thorium to seed based on WAPD-TM-614 App A
c change blanket rod pitch to exactly twice seed rod pitch
c use 3 decimal places of fuel & pitch measurements
c neglect structural material including table
c neglect anything >1ft above, below, or radially from
rods
c Cells
c surface order: pz1 ... cz1 ... (axial, then radial)
c seed rod, infinitely long
11 5 -6.56 1 -21 u=1 imp:n=1
12 1 8.1995-2 2 -1 -21 u=1 imp:n=1
13 5 -6.56 -2 -21 u=1 imp:n=1
14 0 21 -22 u=1 imp:n=1
15 5 -6.56 22 -23 u=1 imp:n=1
16 6 -0.9982 23 u=1 imp:n=1
c

```

```

c seed rod array
31 0 -31 32 -33 34 lat=1 fill=1 u=3 imp:n=1
32 0 -99 trcl=1 fill=3 u=4 imp:n=1
c water rod
41 6 -0.9982 -99 u=5 imp:n=1
c blanket rod, infinitely long
51 5 -6.56 1 -41 u=9 imp:n=1
52 4 6.4664-2 2 -1 -41 u=9 imp:n=1
53 5 -6.56 -2 -41 u=9 imp:n=1
54 0 -41 -42 u=9 imp:n=1
55 5 -6.56 42 -43 u=9 imp:n=1
56 6 -0.9982 43 u=9 imp:n=1
c build 1/4 core and surround with water
61 0 -51 52 -53 54 lat=1 u=8 imp:n=1
fill=-1:18 -18:1 0:0
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 4 4 4 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 4 4 4 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 4 4 4 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 4 4 4 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 4 4 4 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
75 0 -5 6 -66 69 fill=8 u=6 imp:n=1
76 6 -0.9982 9:-10:66:-69 u=6 imp:n=1
77 0 -99 trcl=2 fill=6 u=7 imp:n=1
78 6 -0.9982 10 -6 -66 69 u=6 imp:n=1
79 6 -0.9982 5 -9 -66 69 u=6 imp:n=1
c put core in experiment tank 1 ft larger radius than core
91 7 .09013387 111 -112 -103 104 -7 92 imp:n=1
92 7 .09013387 121 -122 -103 104 -7 92 imp:n=1
98 0 -91 92 -93 -7 8 # (111 -112 -103 104)
# (121 -122 -103 104) fill=7 imp:n=1
99 0 91:-92:93:7:-8 imp:n=0
c Surfaces
c elevations, pz, 0.00 = middle of fuel region
1 pz 19.05 $ top of fuel region
2 pz -19.05 $ bottom of fuel region
5 pz 26.416 $ top of rod
6 pz -26.416 $ bottom of rod
7 pz 56.896 $ 1 ft above rod
8 pz -56.896 $ 1 ft below rod
c solid spacer plates
c just put here to test sensitivity, fill with water to
ignore
9 pz 27.686 $ top 1/2" spacer plate
10 pz -27.686 $ bottom 1/2" spacer plate
c 233U seed radial surfaces
21 cz 0.268 $ 0.211in. OD Seed fuel pellet/zirc
plug
22 cz 0.279 $ 0.220in. ID Seed clad
23 cz 0.324 $ 0.255in. OD Seed clad
c seed rod window surfaces, pitch = 0.362in. = 0.91948cm
31 px 0.45974
32 px -0.45974
33 py 0.45974
34 py -0.45974
c 233UO2-ThO2 Blanket radial surfaces
41 cz 0.622 $ 0.490in. OD blanket pellet/zirc plug
42 cz 0.635 $ 0.500in. ID blanket clad
43 cz 0.724 $ 0.570in. OD blanket clad
c blanket rod window surfaces
c actual pitch reported as 0.7239in. = 1.83871cm
c change to 2*seed pitch = 0.724in. = 1.83896cm
c this is also window for 2x2 array of seed rods
51 px 0.91948
52 px -0.91948
53 py 0.91948
54 py -0.91948
c 1/4 core window surfaces
66 px 30.342799 $ 16.5*pitch = 16.5*1.83896 - tad
69 py -32.181799 $ 17.5*pitch = 17.5*1.83896 - tad
c radial tank and model boundaries
91 cz 60.82 $ tank w radius 1 ft greater than core
*92 px 0.00 $ reflected surface
*93 py 0.00 $ reflected surface
99 cz 259.08 $ 17ft containment tank (neglected)
c Control rod (assume 1/16" thick, extends in 5 seed
rows,
c penetration of rods based on surface
c 104 -- 19.05 = top of fuel,
c assume between seed rows 2&3 and 6&7)
103 px 3.81
104 pz 16.38935
111 py -1.9289

```

28.5	-20	0
28.5	-31.5	0

c Materials, Avogadro's number = 6.0221+23 particles/g-mole									
m1	\$ 233UO2-ZrO2	Seed, 6.4833g/cc,	Ntot = 8.1995-2						
	8016.50c	5.4663-2	\$ Oxygen						
	40000.56c	2.3194-2	\$ Zr						
	92233.50c	3.9891-3	\$ U-233	97.19wt%	in U				
	92234.50c	6.3273-5	\$ U-234	1.55wt%	in U				
	92238.50c	4.9365-5	\$ U-238	1.23wt%	in U				
	90232.50c	3.6287-5	\$ Th-232						
m4	\$ 233UO2-ThO2	blanket-, 9.4446g/cc,	Ntot = 6.4664-2						
	8016.50c	4.3109-2	\$ Oxygen						
	90232.50c	2.1326-2	\$ Th-232						
	92233.50c	2.2283-4	\$ U-233	97.29wt%	in U				
	92234.50c	3.5598-6	\$ U-234	1.56wt%	in U				
	92238.50c	2.5576-6	\$ U-238	1.14wt%	in U				
	64000.35c	1.1214-7	\$ Gadolinium	contaminant					
m5	\$ zircaloy-2	cladding, 6.56 g/cc,	Ntot=4.3234-2						
	40000.56c	4.2537-2	\$ Zirconium	98.23 wt%					
	28000.50c	3.3656-5	\$ Nickel	0.05 wt%					
	24000.50c	7.5977-5	\$ Chromium	0.10 wt%					
	26000.55c	8.8422-5	\$ Iron	0.13 wt%					
	50000.35c	4.9918-4	\$ Tin	1.5 wt%					
m6	\$ water, 0.9982 g/cc,	Ntot=1.0011-2							
	1001.50c	6.6742-2							
	8016.50c	3.3371-2							
mt6	lwtr.01t								
c	m7 is SS plate with 0.787% B (absorber plate)								
m7	5010.50c	3.749e-3							
	24000.50c	1.7638e-2	29000.50c	1.9145e-4					
	26000.55c	5.5634e-2	25055.50c	1.4394e-3					
	42000.50c	1.5119e-4	28000.50c	8.0684e-3					
c	translate coordinates to	center core array							
*tr1	-0.45974	-0.45974	0.0	0	90	90			
0 90	90 90	0 1							
*tr2	-0.91948	0.0	0.0	0	90	90			
0 90	90 90	0 1							
mode n									
prdmp	100 50 0 1								
kcode	1500	1.0	100	500					
ksrc	0.5	-0.5	0						
	0.5	-0.5	20						
	0.5	-0.5	-20						
	0.5	-2.2	0						
	0.5	-5	0						
	0.5	-7.75	0						
	2.2	-0.5	0						
	2.2	-2.2	0						
	2.2	-5	0						
	2.2	-7.75	0						
	5	-0.5	0						
	5	-2.2	0						
	5	-5	0						
	5	-7.75	0						
	5	-7.75	20						
	5	-7.75	-20						
	0.75	-9.5	0						
	0.75	-14.5	0						
	0.75	-20	0						
	0.75	-31.5	0						
	3	-9.5	0						
	3	-14.5	0						
	6.5	-9.5	0						
	6.5	-14.5	0						
	6.5	-20	0						
	6.5	-31.5	0						
	10	-0.25	0						
	10	-4	0						
	10	-9.5	0						
	10	-14.5	0						
	14	-0.25	0						
	14	-4	0						
	14	-9.5	0						
	14	-14.5	0						
	14	-20	0						
	14	-31.5	0						
	17.5	-0.25	0						
	17.5	-4	0						
	17.5	-9.5	0						
	17.5	-14.5	0						
	21	-0.25	0						
	21	-4	0						
	21	-9.5	0						
	21	-14.5	0						
	21	-20	0						
	21	-31.5	0						
	25	-0.25	0						
	25	-4	0						
	25	-9.5	0						
	25	-14.5	0						
	28.5	-0.25	0						
	28.5	-4	0						
	28.5	-9.5	0						
	28.5	-14.5	0						

C.5.5 SB4DG

```

WBR SB-4 simplification e
c Control blades inserted 2.028609 cm past fuel
c rectangular array
c U235, 376 UO2-ZrO2 seed rods (20x18 +16 array)
c 227 233UO2-ThO2 blanket rods (16x16 - 5x5 - 4 array)
c change blanket rod pitch to exactly twice seed rod pitch
c use 3 decimal places of fuel & pitch measurements
c neglect structural material including table
c neglect anything >1ft above, below, or radially from
rods
c Cells
c surface order: pz1 ... cz1 ... (axial, then radial)
c seed rod, infinitely long
11 5 -6.56 1 -21 u=1 imp:n=1
12 2 8.2418-2 2 -1 -21 u=1 imp:n=1
13 5 -6.56 -2 -21 u=1 imp:n=1
14 0 21 -21 u=1 imp:n=1
15 5 -6.56 22 -23 u=1 imp:n=1
16 6 -0.9982 23 u=1 imp:n=1
c seed rod array
31 0 -31 32 -33 34 lat=1 fill=1 u=3 imp:n=1
32 0 -99 trcl=1 fill=3 u=4 imp:n=1
c water rod
41 6 -0.9982 -99 u=5 imp:n=1
c blanket rod, infinitely long
51 5 -6.56 1 -41 u=9 imp:n=1
52 4 6.4664-2 2 -1 -41 u=9 imp:n=1
53 5 -6.56 -2 -41 u=9 imp:n=1
54 0 41 -42 u=9 imp:n=1
55 5 -6.56 42 -43 u=9 imp:n=1
56 6 -0.9982 43 u=9 imp:n=1
c build 1/4 core and surround with water
61 0 -51 52 -53 54 lat=1 u=8 imp:n=1
fill=-1:18 -18:1 0:0
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 5
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 5
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 5
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 5
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 5
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 5
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 5
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 5
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 5
5 5 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 5
5 5 4 4 4 4 4 4 9 9 9 9 9 9 9 9 9 9 9 9 5
5 5 4 4 4 4 4 4 9 9 9 9 9 9 9 9 9 9 9 9 5
5 5 4 4 4 4 4 4 9 9 9 9 9 9 9 9 9 9 9 9 5
5 5 4 4 4 4 4 4 9 9 9 9 9 9 9 9 9 9 9 9 5
5 5 4 4 4 4 4 4 9 9 9 9 9 9 9 9 9 9 9 9 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
75 0 -5 6 -66 69 fill=8 u=6 imp:n=1
76 6 -0.9982 9:-10:66:-69 u=6 imp:n=1
77 0 -99 trcl=2 fill=6 u=7 imp:n=1
78 6 -0.9982 10 -6 -66 69 u=6 imp:n=1
79 6 -0.9982 5 -9 -66 69 u=6 imp:n=1
c put core in experiment tank 1 ft larger radius than core
91 7 .09013387 111 -112 -103 104 -7 92 imp:n=1
92 7 .09013387 121 -122 -103 104 -7 92 imp:n=1
98 0 -91 92 -93 -7 8 # (111 -112 -103 104)
#(121 -122 -103 104) fill=7 imp:n=1
99 0 91:-92:93:7:-8 imp:n=0

c Surfaces
c elevations, pz, 0.00 = middle of fuel region
1 pz 19.05 $ top of fuel region
2 pz -19.05 $ bottom of fuel region
c 3 pz 21.59 $ top of top Zr plug
c 4 pz -21.59 $ bottom of bottom Zr plug
5 pz 26.416 $ top of rod
6 pz -26.416 $ bottom of rod
7 pz 56.896 $ 1 ft above rod
8 pz -56.896 $ 1 ft below rod
c solid spacer plates
c just put here to test sensitivity, fill with water to
ignore
9 pz 27.686 $ top 1/2" spacer plate
10 pz -27.686 $ bottom 1/2" spacer plate
c 233U seed radial surfaces
21 cz 0.268 $ 0.211in. OD Seed fuel pellet/zirc
plug
22 cz 0.279 $ 0.220in. ID Seed clad
23 cz 0.324 $ 0.255in. OD Seed clad
c seed rod window surfaces, pitch = 0.362in. = 0.91948cm
31 px 0.45974
32 px -0.45974
33 py 0.45974
34 pv -0.45974

```

Criticality Safety Code Validation with LWBR's SB Cores

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c 233UO2-ThO2 Blanket radial surfaces
41 cz 0.622 $ 0.490in. OD blanket pellet/zirc plug
42 cz 0.635 $ 0.500in. ID blanket clad
43 cz 0.724 $ 0.570in. OD blanket clad
c blanket rod window surfaces
c actual pitch reported as 0.7239in. = 1.83871cm
c change to 2*seed pitch = 0.724in. = 1.83896cm
c this is also window for 2x2 array of seed rods
51 px 0.91948
52 px -0.91948
53 py 0.91948
54 py -0.91948
c 1/4 core window surfaces
66 px 30.342799 $ 16.5*pitch = 16.5*1.83896 - tad
69 py -32.181799 $ 17.5*pitch = 17.5*1.83896 - tad
c radial tank and model boundaries
c 91 cz 91.44 $ 6ft diameter experiment tank
91 cz 60.82 $ tank w radius 1 ft greater than core
*92 px 0.00 $ reflected surface
*93 py 0.00 $ reflected surface
99 cz 259.08 $ 17ft containment tank (neglected)
c Control rod (assume 1/16" thick, extends in 5 seed
rows,
c penetration of rods based on surface
c 104 -- 19.05 = top of fuel,
c assume between seed rows 2&3 and 6&7)
103 px 3.81
104 pz 17.02139
111 py -1.9289
112 py -1.7511
121 py -5.6089
122 py -5.4311

c
c Materials, Avogadro's number = 6.0221+23 particles/g-
mole
m2 $ 235UO2-ZrO2 Seed, 6.6101g/cc, Ntot = 8.2418-2
8016.50c 5.4945-2 $ Oxygen
40000.56c 2.3310-2 $ Zr
92234.50c 3.7474-5 $ U-234 0.892wt% in U
92235.50c 3.9891-3 $ U-235 92.73wt% in U
92236.50c 1.0957-5 $ U-236 0.263wt% in U
92238.50c 2.3568-4 $ U-238 5.706wt% in U
m4 $ 233UO2-ThO2 blanket, 9.4446g/cc, Ntot = 6.4664-2
8016.50c 4.3109-2 $ Oxygen
90232.50c 2.1326-2 $ Th-232
92233.50c 2.2283-4 $ U-233 97.29wt% in U
92234.50c 3.5598-6 $ U-234 1.56wt% in U
92238.50c 2.5576-6 $ U-238 1.14wt% in U
64000.35c 1.1214-7 $ Gadolinium contaminant
m5 $ zircaloy-2 cladding, 6.56 g/cc, Ntot=4.3234-2
40000.56c 4.2537-2 $ Zirconium 98.23 wt%
28000.50c 3.3656-5 $ Nickel 0.05 wt%
24000.50c 7.5977-5 $ Chromium 0.10 wt%
26000.55c 8.8422-5 $ Iron 0.13 wt%
50000.35c 4.9918-4 $ Tin 1.5 wt%
m6 $ water, 0.9982 g/cc, Ntot=1.0011-2
1001.50c 6.6742-2
8016.50c 3.3371-2
mt6 lwtr.01t
c m7 is SS plate with 0.787% B (absorber plate)
m7 5010.50c 3.749e-3
24000.50c 1.7638e-2 29000.50c 1.9145e-4
26000.55c 5.5634e-2 25055.50c 1.4394e-3
42000.50c 1.5119e-4 28000.50c 8.0684e-3

c translate coordinates to center core array
*tr1 -0.45974 -0.45974 0.0 0 90 90 90
0 90 90 90 0 1
*tr2 -0.91948 0.0 0.0 0 90 90 90
0 90 90 90 0 1
mode n
prtmp 100 50 0 1
kcode 1500 1.0 100 500
ksrc 0.5 -0.5 0
0.5 -0.5 20
0.5 -0.5 -20
0.5 -2.2 0
0.5 -5 0
0.5 -7.75 0
2.2 -0.5 0
2.2 -2.2 0
2.2 -5 0
2.2 -7.75 0
5 -0.5 0
5 -2.2 0
5 -5 0
5 -7.75 0
5 -7.75 20
5 -7.75 -20
0.75 -9.5 0
0.75 -14.5 0
0.75 -20 0
0.75 -31.5 0
3 -9.5 0
3 -14.5 0
6.5 -9.5 0
6.5 -14.5 0
6.5 -20 0
6.5 -31.5 0
10 -0.25 0
10 -4 0
10 -9.5 0
10 -14.5 0
14 -0.25 0
14 -4 0
14 -9.5 0
14 -14.5 0
17.5 -0.25 0
17.5 -4 0
17.5 -9.5 0
17.5 -14.5 0
21 -0.25 0
21 -4 0
21 -9.5 0
21 -14.5 0
21 -20 0
21 -31.5 0
25 -0.25 0
25 -4 0
25 -9.5 0
25 -14.5 0
28.5 -0.25 0
28.5 -4 0
28.5 -9.5 0
28.5 -14.5 0
28.5 -20 0
28.5 -31.5 0

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Appendix D

Supporting and Supplementary Data

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Table D-1. Rod Pitch Uncertainty Effects

case ID	case description	$k_{\text{eff}} \pm 1\sigma$	Δk_{eff}	$\Delta k_{\text{eff}}/\sqrt{3}$
SB2a	core SB-2 with nominal rod pitch	0.99669 ± 0.00089	NA (k_{ref})	NA (k_{ref})
SB2Rp+	case SB2a with maximum rod pitch	1.00041 ± 0.00086	0.00372	0.00215
SB2Rp-	case SB2a with minimum rod pitch	0.99473 ± 0.00087	-0.00196	-0.00113
SB25a	core SB-2½ with nominal rod pitch	0.99912 ± 0.00091	NA (k_{ref})	NA (k_{ref})
SB25Rp+	case SB25a with maximum seed rod pitch	0.99958 ± 0.00086	0.00046	0.00027
SB25Rp-	case SB25a with minimum seed rod pitch	0.99558 ± 0.00088	-0.00354	-0.00204
SB4a	core SB-4 with nominal rod pitch	0.99964 ± 0.00066	NA (k_{ref})	NA (k_{ref})
SB4Rp+	case SB4a with maximum rod pitch	1.00002 ± 0.00072	0.00038	0.00022
SB4Rp-	case SB4a with minimum rod pitch	0.99782 ± 0.00068	-0.00182	-0.00105
SB5a	core SB-5 with nominal pitch	0.99581 ± 0.00079	NA (k_{ref})	NA (k_{ref})
SB5Rp+	case SB5a with maximum rod pitch	0.99609 ± 0.00080	0.00028	0.00016
SB5Rp-	case SB5a with minimum rod pitch	0.99631 ± 0.00083	0.00050	0.00029
SB7a	core SB-7 with nominal pitch	0.99353 ± 0.00078	NA (k_{ref})	NA (k_{ref})
SB7Rp+	case SB7a with maximum rod pitch	0.99284 ± 0.00076	-0.00069	-0.00040
SB7Rp-	case SB7a with minimum rod pitch	0.99127 ± 0.00077	-0.00226	-0.00130

Table D-2. Cladding Thickness Uncertainty Effects

case ID	case description	$k_{\text{eff}} \pm 1\sigma$	Δk_{eff}	$\Delta k_{\text{eff}}/\sqrt{3}$
SB2a	nominal clad thickness, core SB-2	0.99669 ± 0.00089	NA (k_{ref})	NA (k_{ref})
SB2cl++	case SB2a, but increase cladding density	0.99914 ± 0.00087	0.00245	0.00141
SB2cl--	case SB2a, but decrease cladding density	0.99212 ± 0.00084	-0.00457	-0.00264
SB2Zr+	case SB2a, but maximum clad thickness	0.99527 ± 0.00092	-0.00142	-0.00082
SB2Zr-	case SB2a, but minimum clad thickness	0.98449 ± 0.00091	-0.01220	-0.00704
SB2zr+	case SB2a, but maximum seed clad thickness	0.98303 ± 0.00096	-0.01366	-0.00789
SB2zr-	case SB2a, but minimum seed clad thickness	0.98783 ± 0.00085	-0.00886	-0.00512
SB2ZR+	case SB2a, but max blanket clad thickness	0.99871 ± 0.00090	0.00202	0.00117
SB2ZR-	case SB2a, but min blanket clad thickness	0.98341 ± 0.00088	-0.01328	0.00767
SB4a	nominal clad thickness, core SB-4	0.99964 ± 0.00066	NA (k_{ref})	NA (k_{ref})
SB4cl++	case SB4a, but increase cladding density	1.00103 ± 0.00067	0.00139	0.00080
SB4cl--	case SB4a, but decrease cladding density	0.99774 ± 0.00068	-0.00190	-0.00110
SB4Zr+	case SB4a, but maximum clad thickness	0.98826 ± 0.00068	-0.01138	-0.00657
SB4Zr-	case SB4a, but minimum clad thickness	0.99147 ± 0.00070	-0.00817	-0.00472
SB4zr+	case SB4a, but maximum seed clad thickness	0.98866 ± 0.00065	-0.01098	-0.00634
SB4zr-	case SB4a, but minimum seed clad thickness	0.99140 ± 0.00071	-0.00824	-0.00476
SB4ZR+	case SB4a, but max blanket clad thickness	0.99809 ± 0.00066	0.00155	0.00089
SB4ZR-	case SB4a, but min blanket clad thickness	0.99730 ± 0.00068	0.00234	0.00135

Table D-3. Fuel Dimension Uncertainty Effects

case ID	case description	$k_{\text{eff}} \pm 1\sigma$	Δk_{eff}	$\Delta k_{\text{eff}}/\sqrt{3}$
SB2a	nominal fuel dimensions, core SB-2	0.99669 ± 0.00089	NA (k_{ref})	NA (k_{ref})
SB2dim+	case SB2a, but maximum fuel dimensions	1.00461 ± 0.00089	0.00792	0.00457
SB2dim-	case SB2a, but minimum fuel dimensions	0.99066 ± 0.00088	-0.00603	-0.00348
SB2od+	case SB2a, but maximum seed pellet OD	1.00169 ± 0.00092	0.00500	0.00289
SB2od-	case SB2a, but minimum seed pellet OD	0.99179 ± 0.00088	-0.00490	-0.00283
SB2OD+	case SB2a, but maximum blanket pellet OD	0.99705 ± 0.00090	0.00036	0.00021
SB2OD-	case SB2a, but minimum blanket pellet OD	0.99638 ± 0.00088	-0.00031	-0.00018
SB2L+	case SB2a, but max fuel length (15.06 in.)	0.99799 ± 0.00087	0.00130	0.00075
SB2L-	case SB2a, but min fuel length (14.94 in.)	0.99461 ± 0.00089	-0.00208	-0.00120
SB4a	nominal fuel pellet dimensions, core SB-4	0.99964 ± 0.00066	NA (k_{ref})	NA (k_{ref})
SB4dim+	case SB4a, but maximum fuel dimensions	1.00095 ± 0.00066	0.00131	0.00076
SB4dim-	case SB4a, but minimum fuel dimensions	0.99446 ± 0.00066	-0.00518	-0.00299
SB4od+	case SB4a, but maximum seed pellet OD	1.00277 ± 0.00072	0.00313	0.00181
SB4od-	case SB4a, but minimum seed pellet OD	0.99423 ± 0.00069	-0.00541	-0.00312
SB4OD+	case SB4a, but maximum blanket pellet OD	0.99964 ± 0.00067	0.00	0.00
SB4OD-	case SB4a, but minimum blanket pellet OD	0.99519 ± 0.00068	-0.00445	-0.00257
SB4L+	case SB4a, but max fuel length (15.06 in.)	1.00067 ± 0.00060	0.00103	0.00059
SB4L-	case SB4a, but min fuel length (14.94 in.)	0.99891 ± 0.00070	-0.00073	-0.00042

Table D-4. Core SB-2 Fuel Composition Uncertainty Effects

case ID	case description	$k_{\text{eff}} \pm 1\sigma$	Δk_{eff}	$\Delta k_{\text{eff}}/\sqrt{3}$
SB2a	nominal fuel composition, core SB-2	0.99669 ± 0.00089	NA (k_{ref})	NA (k_{ref})
SB2Den+	case SB2a, but maximum fuel pellet density	1.00112 ± 0.00091	0.00443	0.00256
SB2Den-	case SB2a, but minimum fuel pellet density	0.98752 ± 0.00087	-0.00917	-0.00529
SB2den+	case SB2a, but maximum seed pellet density	1.00188 ± 0.00085	0.00519	0.00300
SB2den-	case SB2a, but minimum seed pellet density	0.98818 ± 0.00087	-0.00851	-0.00491
SB2u+	case SB2a, but maximum ^{233}U in seed U	0.99615 ± 0.00094	-0.00054	-0.00031
SB2u-	case SB2a, but minimum ^{233}U in seed U	0.99606 ± 0.00094	-0.00063	-0.00036
SB2uo+	case SB2a, but maximum UO_2 in seed pellet	0.99584 ± 0.00086	-0.00085	-0.00049
SB2uo-	case SB2a, but minimum UO_2 in seed pellet	0.99693 ± 0.00089	0.00024	0.00014
SB2DEN+	case SB2a, but maximum blanket pellet density	0.99797 ± 0.00092	0.00128	0.00074
SB2DEN-	case SB2a, but minimum blanket pellet density	0.99490 ± 0.00094	-0.00179	-0.00103
SB2GD+	case SB2a with no Gd and with 80 ppm ^{10}B	0.97027 ± 0.00092	-0.02642	-0.01525
SB2GD-	case SB2a with no Gd and no ^{10}B	0.99772 ± 0.00089	0.00103	0.00059

Table D-5. $^{233}\text{UO}_2\text{-ZrO}_2$ Seed Matrix Nuclide Values for Table D-4

nuclide	N_i (atom/b-cm)					$U_{\max}$ in pellet	$U_{\min}$ in pellet
	nominal (Table 16)	$\rho_{\max}$ 6.6499 g/cm ³	$\rho_{\min}$ 6.1398 g/cm ³	$^{233}\text{U}_{\max}$ in U 97.24 wt%	$^{233}\text{U}_{\min}$ in U 97.14 wt%	26.93 wt% UO_2	26.67 wt% UO_2
^{232}U	3.9652e-7	4.0670e-7	3.7551e-7	3.9652e-7	3.9652e-7	3.9850e-7	3.9454e-7
^{233}U	3.8372e-3	3.9358e-3	3.6339e-3	3.8392e-3	3.8352e-3	3.8564e-3	3.8180e-3
^{234}U	6.0934e-5	6.2500e-5	5.7705e-5	6.0934e-5	6.0934e-5	6.1239e-5	6.0629e-5
^{235}U	3.9145e-7	4.0150e-7	3.7070e-7	3.9145e-7	3.9145e-7	3.9340e-7	3.8949e-7
^{236}U	3.8986e-7	3.9988e-7	3.6920e-7	3.8986e-7	3.8986e-7	3.9181e-7	3.8791e-7
^{238}U	4.7540e-5	4.8761e-5	4.5021e-5	4.5607e-5	4.9472e-5	4.7777e-5	4.7302e-5
O	5.4281e-2	5.5675e-2	5.1405e-2	5.4281e-2	5.4281e-2	5.4235e-2	5.4326e-2
Zr	2.3194e-2	2.3789e-2	2.1965e-2	2.3194e-2	2.3194e-2	2.3151e-2	2.3236e-2
sums	8.1421e-2	8.3513e-2	7.7107e-2	8.1421e-2	8.1421e-2	8.1353e-2	8.1489e-2

Table D-6. $^{232}\text{ThO}_2$ Blanket Matrix Nuclide Values for Table D-4

nuclide	N_i (atom/b-cm)				
	nominal (Table 16)	$\rho_{\max}$ 9.5787 g/cm ³	$\rho_{\min}$ 9.3279 g/cm ³	no Gd	no Gd, 80 ppm ^{10}B
^{232}Th	2.1641e-2	2.1847e-2	2.1275e-2	2.1641e-2	2.1641e-2
O	4.3282e-2	4.3694e-2	4.2550e-2	4.3282e-2	4.3282e-2
Gd	1.5967e-7	1.6119e-7	1.5697e-7	0	0
^{10}B	0	0	0	0	4.5653e-5
sums:	6.4923e-2	6.5541e-2	6.3825e-2	6.4923e-2	6.4968e-2

Table D-7. $^{235}\text{UO}_2\text{-ZrO}_2$ Seed Matrix Nuclide Values for Table D-8

nuclide	N_i (atom/b-cm)					$U_{\max}$ in pellet	$U_{\min}$ in pellet
	nominal (Table 16)	$\rho_{\max}$ 6.8527 g/cm ³	$\rho_{\min}$ 6.4503 g/cm ³	$^{235}\text{U}_{\max}$ in U 92.78 wt%	$^{235}\text{U}_{\min}$ in U 92.68 wt%	24.82 wt% U	24.58 wt% U
^{234}U	3.7309e-5	3.8678e-5	3.6407e-5	3.7309e-5	3.7309e-5	3.7495e-5	3.7122e-5
^{235}U	3.8791e-3	4.0214e-3	3.7853e-3	3.8812e-3	3.8770e-3	3.8985e-3	3.8597e-3
^{236}U	1.0909e-5	1.1309e-5	1.0645e-5	1.0909e-5	1.0909e-5	1.0964e-5	1.0854e-5
^{238}U	2.5278e-4	2.6206e-4	2.4667e-4	2.5072e-4	2.5485e-4	2.5404e-4	2.5152e-4
O	5.4840e-2	5.6853e-2	5.3514e-2	5.4840e-2	5.4840e-2	5.4791e-2	5.4889e-2
Zr	2.3240e-2	2.4093e-2	2.2678e-2	2.3240e-2	2.3240e-2	2.3195e-2	2.3285e-2
sums	8.2260e-2	8.5279e-2	8.0271e-2	8.2260e-2	8.2260e-2	8.2187e-2	8.2334e-2

Table D-8. Core SB-4 Fuel Composition Uncertainty Effects

case ID	case description	$k_{\text{eff}} \pm 1\sigma$	Δk_{eff}	$\Delta k_{\text{eff}}/\sqrt{3}$
SB4a	nominal fuel composition, core SB-4	0.99964 ± 0.00066	NA (k_{ref})	NA (k_{ref})
SB4Den+	case SB4a, but maximum fuel pellet density	1.00345 ± 0.00065	0.00381	0.00220
SB4Den-	case SB4a, but minimum fuel pellet density	0.99474 ± 0.00067	-0.00490	-0.00283
SB4Uu+	case SB4a, but maximum ^{233}U and ^{235}U in U	1.00055 ± 0.00067	0.00091	0.00053
SB4Uu-	case SB4a, but minimum ^{233}U and ^{235}U in U	1.00098 ± 0.00068	0.00134	0.00077
SB4Uo+	case SB4a, but maximum UO_2	0.99994 ± 0.00069	0.00030	0.00017
SB4Uo-	case SB4a, but minimum UO_2	0.99723 ± 0.00072	-0.00241	-0.00139
SB4den+	case SB4a, but maximum seed pellet density	1.00235 ± 0.00068	0.00271	0.00156
SB4den-	case SB4a, but minimum seed pellet density	0.99741 ± 0.00073	-0.00223	-0.00129
SB4u+	case SB4a, but maximum ^{235}U in seed U	1.00050 ± 0.00071	0.00086	0.00050
SB4u-	case SB4a, but minimum ^{235}U in seed U	0.99755 ± 0.00071	-0.00209	-0.00121
SB4uo+	case SB4a, but maximum UO_2 in seed pellet	0.99908 ± 0.00068	-0.00056	-0.00032
SB4uo-	case SB4a, but minimum UO_2 in seed pellet	1.00088 ± 0.00071	0.00124	0.00072
SB4DEN+	case SB4a, but maximum blanket pellet density	1.00272 ± 0.00067	0.00308	0.00178
SB4DEN-	case SB4a, but minimum blanket pellet density	0.99452 ± 0.00071	-0.00512	-0.00296
SB4U+	case SB4a, but maximum ^{233}U in blanket U	0.99908 ± 0.00068	-0.00056	-0.00032
SB4U-	case SB4a, but minimum ^{233}U in blanket U	0.99869 ± 0.00070	-0.00095	-0.00055
SB4UO+	case SB4a, but maximum UO_2 in blanket pellet	0.99893 ± 0.00068	-0.00071	-0.00041
SB4UO-	case SB4a, but minimum UO_2 in blanket pellet	0.99930 ± 0.00067	-0.00034	-0.00020
SB4GD+	case SB4a with no Gd and with 80 ppm ^{10}B	0.99977 ± 0.00064	0.00013	0.00008
SB4GD-	case SB4a with no Gd and no ^{10}B	1.00270 ± 0.00064	0.00306	0.00177

Table D-9. Water Temperature Uncertainty Effects

case ID	case description	$k_{\text{eff}} \pm 1\sigma$	Δk_{eff}	$\Delta k_{\text{eff}}/\sqrt{3}$
SB25warm	22.5°C water temperature, core SB-2½	0.99739 ± 0.00086	-0.00173	-0.00100
SB25a	20.0°C water temperature, core SB-2½	0.99912 ± 0.00091	NA (k_{ref})	NA (k_{ref})
SB25cool	17.5°C water temperature, core SB-2½	0.99885 ± 0.00088	-0.00027	-0.00016

Table D-10. Water Nuclide Densities for Table D-9

nuclide	N (atoms/b-cm)		
	22.5°C (0.9976 g/cm ³) case SB25warm	20.0°C (0.9982 g/cm ³) (Table 17)	17.5°C (0.9986 g/cm ³) case SB25cool
H	0.066694	0.066735	0.066760
O	0.033347	0.033368	0.033380
<i>sums:</i>	0.10004	0.10010	0.10014

Table D-11. ²³³UO₂-²³²ThO₂ Blanket Matrix Nuclide Values for Table D-8

nuclide	N _i (atom/b-cm)				
	nominal (Table 16)	$\rho_{\max}$ 9.7197 g/cm ³	$\rho_{\min}$ 9.0892 g/cm ³	²³³ U _{max} in U 97.34 wt%	²³³ U _{min} in U 97.24 wt%
²³² U	7.6722e-9	7.8957e-9	7.3835e-9	7.6722e-9	7.6722e-9
²³³ U	2.2297e-4	2.2946e-4	2.1457e-4	2.2308e-4	2.2285e-4
²³⁴ U	3.5598e-6	3.6635e-6	3.4259e-6	3.5598e-6	3.5598e-6
²³⁵ U	7.5741e-9	7.7947e-9	7.2890e-9	7.5741e-9	7.5741e-9
²³⁶ U	7.5434e-9	7.7631e-9	7.2595e-9	7.5434e-9	7.5434e-9
²³⁸ U	2.5576e-6	2.6321e-6	2.4614e-6	2.4454e-6	2.6698e-6
²³² Th	2.1311e-2	2.1939e-2	2.0509e-2	2.1311e-2	2.1311e-2
O	4.3081e-2	4.4335e-2	4.1459e-2	4.3081e-2	4.3081e-2
Gd	1.5796e-7	1.6181e-7	1.5132e-7	1.5796e-7	1.5796e-7
<i>sums:</i>	6.4621e-2	6.6503e-2	6.2189e-2	6.4621e-2	6.4621e-2

nuclide	N _i (atom/b-cm)			
	U _{max} in pellet 0.944 wt% U	U _{min} in pellet 0.934 wt% U	no Gd	no Gd, 80 ppm ¹⁰ B
²³² U	7.7106e-9	7.6338e-9	7.6722e-9	7.6722e-9
²³³ U	2.2408e-4	2.2185e-4	2.2297e-4	2.2297e-4
²³⁴ U	3.5776e-6	3.5420e-6	3.5598e-6	3.5598e-6
²³⁵ U	7.6119e-9	7.5362e-9	7.5741e-9	7.5741e-9
²³⁶ U	7.5811e-9	7.5056e-9	7.5434e-9	7.5434e-9
²³⁸ U	2.5704e-6	2.5448e-6	2.5576e-6	2.5576e-6
²³² Th	2.1310e-2	2.1312e-2	2.1311e-2	2.1311e-2
O	4.3081e-2	4.3081e-2	4.3081e-2	4.3080e-2
Gd	1.5795e-7	1.5797e-7	0	0
¹⁰ B	0	0	0	4.5442e-5
<i>sums:</i>	6.4621e-2	6.4621e-2	6.4621e-2	6.4666e-2

Table D-12. Control Blade Uncertainty Effects

case ID	case description	$k_{\text{eff}} \pm 1\sigma$	Δk_{eff}	$\Delta k_{\text{eff}}/\sqrt{3}$
SB2a	reconstructed control blades, core SB-2	0.99669 ± 0.00089	NA (k_{ref})	NA (k_{ref})
SB2udet	case SB2a, but no control blades	1.00291 ± 0.00086	0.00622	0.00359
SB2high	case SB2a, but 16.66 cm blade bank height	0.99547 ± 0.00083	-0.00122	-0.00070
SB2low	case SB2a, but 15.16 cm blade bank height	0.99479 ± 0.00086	-0.00190	-0.00110
SB2cb+b	case SB2a, but 0.795 wt% ^{10}B in control blades	0.99599 ± 0.00087	-0.00070	-0.00040
SB2cb-b	case SB2a, but 0.779 wt% ^{10}B in control blades	0.99685 ± 0.00092	0.00016	0.00009
SB6a	reconstructed control blades, core SB-6	0.98920 ± 0.00086	NA (k_{ref})	NA (k_{ref})
SB6udet	case SB6a, but no control blades	1.00292 ± 0.00088	0.01372	0.00792
SB6high	case SB6a, but 14.82 cm blade bank height	0.99140 ± 0.00086	0.00220	0.00127
SB6low	case SB6a, but 13.32 cm blade bank height	0.98787 ± 0.00083	-0.00133	-0.00077
SB6cb+b	case SB6a, but 0.795 wt% ^{10}B in control blades	0.98842 ± 0.00086	-0.00078	-0.00045
SB6cb-b	case SB6a, but 0.779 wt% ^{10}B in control blades	0.99000 ± 0.00085	0.00080	0.00046

Table D-13. Borated SS304 Nuclide Values for Table D-12

nuclide	N (atoms/b-cm)		
	0.795 wt% ^{10}B	0.787 wt% ^{10}B (Table 19)	0.779 wt% ^{10}B
Fe	5.9283e-2	5.9289e-2	5.9296e-2
C	1.5884e-4	1.5884e-4	1.5884e-4
Cr	1.7428e-2	1.7428e-2	1.7428e-2
Mn	8.6816e-4	8.6816e-4	8.6816e-4
Ni	7.5171e-3	7.5171e-3	7.5171e-3
P	3.0797e-5	3.0797e-5	3.0797e-5
S	2.2308e-5	2.2308e-5	2.2308e-5
Si	8.4910e-4	8.4910e-4	8.4910e-4
^{10}B	3.7869e-3	3.7488e-3	3.7107e-3
<i>sums:</i>	8.9944e-2	8.9912e-2	8.9882e-2

Table D-14. Benchmark Sensitivity to Item Presence

case ID	case description	$k_{\text{eff}} \pm 1\sigma$	Δk_{eff}	$\Delta \text{magnitude}$
SB3xdet	<i>all reflection</i> : SB3w8det with lead shields, tank walls shield plug support plate & pillars, tabletop, & under-core support	0.99521 ± 0.00075	0.00040	within 1σ
SB3wdet	case SB3xdet, but neglect items more than 1 ft from fuel matrix	0.99447 ± 0.00069	-0.00034	within 1σ
SB3w1det	case SB3w3det with tabletop and under-core support	0.99599 ± 0.00077	0.00118	within 2σ
SB3w2det	case SB3w3det with shield plug and its support plate	0.99499 ± 0.00070	0.00018	within 1σ
SB3w3det	<i>radial reflection only</i> : case SB3w8det with shield plug support pillars, tank wall, and wall shield	0.99284 ± 0.00073	-0.00233	significant
SB3w4det	case SB3w6det with tank wall and wall shield	0.99502 ± 0.00072	0.00021	within 1σ
SB3w5det	case SB3w6det with shield plug support pillars	0.99521 ± 0.00075	0.00040	within 1σ
SB3w6det	<i>axial reflection only</i> : case SB3w8det with shield plug, shield plug support plate, tabletop, & under-core support	0.99502 ± 0.00072	0.00021	within 1σ
SB3w8det	case SB3vdet with water extended to tank wall	0.99304 ± 0.00069	-0.00177	significant
SB3vdet	case SB3a with rod spacer plates	0.99453 ± 0.00071	-0.00028	within 1σ
SB3udet	case SB3a without control blades	1.00033 ± 0.00076	0.00552	significant
SB3a	mirrored-core benchmark model of core SB-3	0.99481 ± 0.00072	NA (k_{ref})	NA (k_{ref})
SB7xdet	<i>all reflection</i> : SB7w8det with lead shields, tank walls, shield plug support plate & pillars, tabletop, & under-core support	0.99474 ± 0.00079	0.00121	within 2σ
SB7wdet	case SB7xdet, but neglect items more than 1 ft from fuel matrix	0.99569 ± 0.00078	0.00216	significant
SB7w1det	case SB7w3det with tabletop and under-core support	0.99466 ± 0.00078	0.00113	within 2σ
SB7w2det	case SB7w3det with shield plug and its support plate	0.99443 ± 0.00081	0.00090	within 2σ
SB7w3det	<i>radial reflection only</i> : case SB7w8det with shield plug support pillars, tank wall, and wall shield	0.99507 ± 0.00075	0.00154	within 3σ
SB7w4det	case SB7w6det with tank wall and wall shield	0.99431 ± 0.00080	0.00078	within 1σ
SB7w5det	case SB7w6det with shield plug support pillars	0.99474 ± 0.00079	0.00121	within 2σ
SB7w6det	<i>axial reflection only</i> : case SB7w8det with shield plug, shield plug support plate, tabletop, & under-core support	0.99431 ± 0.00080	0.00078	within 1σ
SB7w8det	case SB7vdet with water extended to tank wall	0.99507 ± 0.00075	0.00154	within 3σ
SB7vdet	case SB7a with rod spacer plates	0.99489 ± 0.00077	0.00136	within 2σ
SB7udet	case SB7a without control blades	1.00107 ± 0.00081	0.00754	significant
SB7a	mirrored-core benchmark model of core SB-7	0.99353 ± 0.00078	NA (k_{ref})	NA (k_{ref})

Table D-15. Unborated Stainless Steel for Table D-14^a

	full-density SS304	half-density SS304
model dimensions	<i>reactor tank wall:</i> cylinder with 91.440 cm IR, 92.075 cm OR & ≥ 99.06 cm high wall (6 ft ID, $\frac{1}{4}$ in thick, ≥ 39 in. high), concentric with core, bottom at elevation -56.896 cm ^b <i>shield-plug support pillar(s):</i> 0.381 cm OR (3in. OD), reactor-tank-high cylinder(s) centered at x, y coordinates 40, -40 cm &, for core SB-7, at -40, -40 cm <i>base plate + tabletop:</i> disk with 4.445 cm height, 76.2 cm OR ($1\frac{3}{4}$ in. height, 5 ft. OD) & top at elevation -26.4541	<i>rod spacer plates:</i> ^c 0.635 cm ($\frac{1}{4}$ in.) thick plates tightly surrounding fuel rod, top of top plate at elevation 26.4541 cm, bottom of bottom plate at elevation -26.4541 cm. <i>support structures under tabletop:</i> single 25.9969 cm thick, 76.2 cm OR (10.235 in. thick, 60 in. OD) disk, , bottom at elevation -56.896 cm <i>In both cases, perforations are modeled by reducing plate mass density</i>
mass density (g/cm³)	see Table 10	4.4591
chemical composition	see Table 10	$\frac{1}{2}$ wt% in Table 10 + $\frac{1}{2}$ wt% of water
metal vol%	100	50
water vol%	0	50
N (atoms/b-cm)		
Fe	5.9932e-2	2.9966e-2
C	1.5884e-4	7.9418e-5
Cr	1.7428e-2	8.7142e-3
Mn	8.6816e-4	4.3408e-4
Ni	7.5171e-3	3.7586e-3
P	3.0797e-5	1.5399e-5
S	2.2308e-5	1.1154e-5
Si	8.4910e-4	4.2455e-4
H	0.	3.3368e-2
O	0.	1.6684e-2
sums:	8.6806e-2	4.3403e-2

- a. Rod spacer plates and most structural materials were made from one or more unspecified stainless steel types, most probably an austenitic steel. Austenitic steels are roughly 69 wt% Fe, 19 wt% Cr, 1 0wt% Ni, and 2 wt% other nuclides. The only minor constituent having a possibly significant Σ_a is Mg. It typically has a 2 wt% *maximum*, but actual values depend on recycling extent during manufacture and raw ore source(s). Densities are about 7.9 or 8.0 g/cm³.^{7,18,11} A composition survey of stainless steel Types 304, 308, 316, and 347 indicates Type 304 values used here represent an average for contemporary austenitic steels.
- b. Model height varied to include entire control blade height.
- c. Rod-spacer-plate inserts were used to position seed rods in locations otherwise designed for blanket rods. This design allowed experimenters to vary seed array sizes to achieve desired clean critical conditions. However, insert material is not fully identified. In these calculations plastic inserts (for hexagonal cores and, possibly, for rectangular cores) are approximated as part of water in a homogenized SS 304-water mixture. Steel inserts (possibly for rectangular cores) are approximated as part of SS 304 in a homogenized SS 304-water mixture.

Table D-16. Aluminum and Lead for Table D-14

	aluminum	lead
model dimensions	<i>shield plug support plate</i> : disk with 2.54 cm (1 in.) height, 76.2 cm OR (5 ft OD) & bottom at elevation 36.83 cm	<i>shield plug</i> : three stacked, 5.08 cm (2 in.) high disks. Bottom disk has 76.2 cm OR (5 ft OD) & bottom at elevation 39.37 cm. Middle disk has 45.72 cm OR (3 ft OD) & bottom at elevation 44.45 cm. Top disk has 17.78 cm OR (14 in OD) & bottom at elevation 49.53 cm. <i>tank wall shield</i> : cylinder with 92.075 cm IR, 93.345 cm OR (½ in. thick wall), reactor tank height, & bottom at elevation -56.896 cm
mass density	Al: 2.6989g/cm ³ (theoretical, used here) alloys: approximately 2.69g/cm ³ . ^{7,18,11}	Pb: 1.35 g/cm ³ (theoretical) ⁶
chemical composition	Used 100% Al. Aluminum alloys range from 88 to 99.99 wt% Al. ^{14,10} Most typical critical experiment alloys have > 95 wt% Al & no other components with significant thermal Σ_a s &/or Σ_s s.	Used 100% Pb. Typical lead has ≥ 99.9 wt% Pb & negligible quantities of Ag, Cu, As, Sb, Sn, Zn, Fe, & Bi. ¹⁵
N (atoms/b-cm)		
Al	0.060238	
Pb		0.0039237

Table D-17. Sensitivity to MCNP Reflected Surface Modeling

core	$k_{\text{eff}} \pm 1\sigma$		Δk_{eff}
	full core (k_0)	mirrored core	
SB-1	0.99761 $\pm$ 0.00057	0.99878 $\pm$ 0.00057	-0.00117
SB-2	0.99693 $\pm$ 0.00063	0.99760 $\pm$ 0.00062	-0.00067
SB-2½	0.99793 $\pm$ 0.00060	0.99801 $\pm$ 0.00065	0.00008
SB-3	0.99610 $\pm$ 0.00052	0.99541 $\pm$ 0.00050	0.00069
SB-4	0.99692 $\pm$ 0.00049	0.99894 $\pm$ 0.00046	0.00202
SB-5	0.99774 $\pm$ 0.00053	0.99677 $\pm$ 0.00055	0.00097
SB-6	0.98999 $\pm$ 0.00059	0.98960 $\pm$ 0.00061	0.00002
SB-7	0.99475 $\pm$ 0.00055	0.99460 $\pm$ 0.00057	0.00016

**Table D-18. Average Neutron Spectra Information
(SCALE4.3/CSAS25/44GROUPNDF5/hole)**

core(s)	fuel type(s)	$k_{\text{eff}} \pm 1\sigma$	ave. fission group	average fission group's energy range (eV)	average lethargy energy causing fission	system's energy ^d
<i>infinite array of one fuel rod type, with pitch identical to indicated core(s)</i>						
SB-2, -2½, -3	²³³ UO ₂ -ZrO ₂	1.90019 ± 0.00091	27.90	≤4.00e-1, >3.75e-1	1.337	thermal
SB-1, -4	²³⁵ UO ₂ -ZrO ₂	1.63774 ± 0.00081	30.87	≤3.25e-1, >2.75e-1	5.257e-1	thermal
SB-1, -2	ThO ₂	0.01773 ± 0.00005	5.09	≤3.00e6, >2.479e6	3.117e6	fast
SB-3, -4	²³³ UO ₂ -ThO ₂	0.73838 ± 0.00046	34.11	≤2.00e-1, >1.50e-1	1.657e-1	thermal
SB-6, -7	²³³ UO ₂ -ZrO ₂	1.83123 ± 0.00072	33.16	≤2.25e-1, >2.00e-1	2.067e-1	thermal
SB-5	²³⁵ UO ₂ -ZrO ₂	1.62853 ± 0.00066	35.07	≤1.50e-1, >1.00e-1	1.165e-1	thermal
SB-5, -6	ThO ₂	0.03855 ± 0.00008	5.34	≤3.00e6, >2.479e6	2.933e6	fast
SB-7	²³³ UO ₂ -ThO ₂	0.55436 ± 0.00040	23.94	≤3.00e0, >1.77e0	8.879	intermediate
<i>actual experiment/benchmark array</i>						
SB-1	²³⁵ UO ₂ -ZrO ₂ /ThO ₂	1.00756 ± 0.00082	30.85	≤3.25e-1, >2.75e-1	5.701e-1	thermal
SB-2	²³³ UO ₂ -ZrO ₂ /ThO ₂	0.99990 ± 0.00090	28.12	≤3.75e-1, >3.50e-1	1.385	thermal
SB-2½	²³³ UO ₂ -ZrO ₂	1.00048 ± 0.00092	29.97	≤3.50e-1, >3.25e-1	7.133e-1	thermal
SB-3	²³³ UO ₂ -ZrO ₂ / ²³³ UO ₂ -ThO ₂	0.99691 ± 0.00068	31.25	≤2.75e-1, >2.50e-1	4.445e-1	thermal
SB-4	²³⁵ UO ₂ -ZrO ₂ / ²³³ UO ₂ -ThO ₂	1.00412 ± 0.00059	32.38	≤2.50e-1, >2.25e-1	3.121e-1	thermal
SB-5	²³⁵ UO ₂ -ZrO ₂ /ThO ₂	1.00388 ± 0.00081	34.41	≤2.00e-1, >1.50e-1	1.589e-1	thermal
SB-6	²³³ UO ₂ -ZrO ₂ /ThO ₂	0.99204 ± 0.00085	32.11	≤2.50e-1, >2.25e-1	3.330e-1	thermal
SB-7	²³³ UO ₂ -ZrO ₂ / ²³³ UO ₂ -ThO ₂	0.99987 ± 0.00079	30.646	≤3.25e-1, >2.75e-1	5.704e-1	thermal

Table D-19. Effect of Benchmark ²³³UO₂-ThO₂ Blanket Rod Diameters

core	$k_{\text{eff}} \pm 1\sigma$ (primarily ENDF/B-V)			$k_{\text{eff}} \pm 1\sigma$ (primarily ENDF/B-IV)		
	0.569in. OD	0.570in. OD	Δk_{eff}	0.569in. OD	0.570in. OD	Δk_{eff}
SB-3	0.99610 ± 0.00052	0.99592 ± 0.00049	-0.00018	0.99413 ± 0.00053	0.99363 ± 0.00052	0.00050
SB-4	0.99692 ± 0.00049	0.99861 ± 0.00048	-0.00169	0.99941 ± 0.00049	0.99864 ± 0.00049	0.00077
SB-7	0.99475 ± 0.00055	0.99309 ± 0.00056	-0.00175	0.99341 ± 0.00055	0.99187 ± 0.00055	0.00154

d ICSBEP definitions are used here, but spectra calculation methods differ. "Fast, intermediate, and thermal systems are defined as systems in which over 50% of the fissions occur at energies over 100 keV, from 0.625 eV to 100 keV, and less than 0.625 eV, respectively. Systems for which over 50% of the fissions do not occur in any one of these three energy ranges are classified as 'mixed' spectra systems."¹

Appendix E

Benchmark Model Inputs

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```

96 6 1.0010-1 -6 u=14 imp:n=1 $ water below core
c put it all together
97 0 -91 12 -15 fill=13 imp:n=1 $
98 0 -91 16 -12 fill=14 imp:n=1 $
101 0 91:15:-16 imp:n=0 $ outside

c Surfaces
c fixed elevations, pz, 0.00 = middle of fuel region
1 pz 19.05 $ fuel top (1/2 15in fuel length)
2 pz -19.05 $ fuel bottom
5 pz 26.4541 $ rod top (1/2 20.83in rod length)
6 pz -26.4541 $ rod bottom
12 pz 16.44 $ control blade bank lower edge
15 pz 49.53 $ 1 ft above fuel
16 pz -49.53 $ 1 ft below fuel
c 235U seed radial surfaces
21 cz 0.26797 $ 0.211in. OD Seed fuel pellet/zirc plug
22 cz 0.27940 $ 0.220in. ID Seed clad
23 cz 0.32385 $ 0.255in. OD Seed clad
c seed rod window (square cell) surfaces, pitch = 0.362in. = 0.91948cm
31 px 0.45974
32 px -0.45974
33 py 0.45974
34 py -0.45974
c ThO2 Blanket radial surfaces, nominal
41 cz 0.62103 $ 0.489in. OD blanket pellet/zirc plug
42 cz 0.63373 $ 0.499in. ID blanket clad
43 cz 0.72390 $ 0.570in. OD blanket clad
c blanket rod window (square cell) surfaces
c use desired 2*seed pitch = 0.724in. = 1.83896cm
c this is also window for 2x2 array of seed rods
51 px 0.91948
52 px -0.91948
53 py 0.91948
54 py -0.91948
c core window (square cell) surfaces
66 px 32.0825 $ 17.5*pitch
67 px -32.0825 $ 17.5*pitch
68 py 32.0825 $ 17.5*pitch
69 py -32.0825 $ 17.5*pitch
c core R=45.37cm for below
c control blades
73 px 3.81 $ bank right edge (1/2 3in. width)
74 px -3.81 $ bank left edge (1/2 3in. width)
75 py 5.42798 $ blade a inner edge (-12seedpitch + .5[.07in])
76 py 5.60578 $ blade a outer edge (-12seedpitch - .5[.07in])
77 py 1.75006 $ blade b inner edge (-4seedpitch + .5[.07in])
78 py 1.92786 $ blade b outer edge (-4seedpitch - .5[.07in])
79 py -1.75006 $ blade c inner edge (-4seedpitch + .5[.07in])
80 py -1.92786 $ blade c outer edge (-4seedpitch - .5[.07in])
81 py -5.42798 $ blade d inner edge (-12seedpitch + .5[.07in])
82 py -5.60578 $ blade d outer edge (-12seedpitch - .5[.07in])
c radial tank and model boundaries
91 cz 75.86 $ core + 1ft
99 cz 259.08 $ 17ft diameter containment tank (neglected)

c Materials, Avogadro's number = 6.0221+23 particles/g-mole
m2 $ 235UO2-ZrO2 Seed, 6.6101g/cc, Ntot = 8.2260-2
8016.50c 5.4840-2 $ Oxygen 22.04wt% in matrix
40000.50c 2.3240-2 $ Zr 53.26wt% in matrix
92234.50c 3.7309-5 $ U-234 0.888wt% in U, 0.22wt% in matrix
92235.50c 3.8791-3 $ U-235 92.73wt% in U, 22.90wt% in matrix
92236.50c 1.0907-5 $ U-236 0.262wt% in U, 0.06wt% in matrix
92238.50c 2.5278-4 $ U-238 6.120wt% in U, 1.51wt% in matrix
m3 $ ThO2 blanket, 9.4884g/cc, Ntot = 6.4923-2
8016.50c 4.3282-2 $ Oxygen 12.12wt% in matrix
90232.50c 2.1641-2 $ Th-232 87.88wt% in matrix
64000.35c 1.5967-7 $ Gd contaminant, 5ppm gGd/gTh
m5 $ zircaloy-2 cladding plugs etc, 6.56 g/cc, Ntot=4.3234-2
40000.50c 4.2537-2 $ Zr 98.23 wt%
24000.50c 7.5977-5 $ Cr 0.10 wt%
26000.55c 8.8422-5 $ Fe 0.13 wt%
28000.50c 3.3656-5 $ Ni 0.05 wt%
50000.35c 4.9918-4 $ Tin 1.50 wt%
m6 $ water, 0.9982 g/cc, Ntot=1.0010-1
1001.50c 6.6735-2
8016.50c 3.3368-2
mt6 lwtr.01t
m10 $ borated SS304 control blades, 7.92g/cc, Ntot=8.9912-2
26000.55c 5.9289-2 $ Fe 69.423 wt%
5010.50c 3.7488-3 $ B-10 0.787 wt%
6000.50c 1.5884-4 $ C 0.04 wt%
24000.50c 1.7428-2 $ Cr 19.00 wt%
25055.50c 8.6816-4 $ Mn 1.00 wt%
28000.50c 7.5171-3 $ Ni 9.25 wt%
15031.50c 3.0797-5 $ P 0.02 wt%
16032.50c 2.2308-5 $ S 0.015 wt%
14000.50c 8.4910-4 $ Si 0.50 wt%
c translate coordinates to center core array
*tr1 -0.45974 0.45974 0.0 0 90 90 90 0 90 90 0 0 1
*tr2 -0.91948 -0.91948 0.0 0 90 90 90 0 90 90 0 0 1
mode n
kcode 3000 1.0 100 1000
print
ksrc 0.5 -0.5 0 0.5 -10.6 0

```

0.5	-0.5	19	0.5	-10.6	19
0.5	-0.5	-19	0.5	-10.6	-19
0.5	-2.2	0	0.5	-30	0
0.5	-5	0	0.5	-30	19
0.5	-7	0	0.5	-30	-19
2.2	-0.5	0			
2.2	-2.2	0			
2.2	-5	0			
2.2	-7	0			
2.2	-10.6	0			
5	-0.5	0	7	-0.5	0
5	-2.2	0	7	-2.2	0
5	-5	0	7	-5	0
5	-7	0	7	-7	0
5	-10.6	0	7	-10.6	0
10.6	-0.5	0	10.6	-10.6	0
10.6	-0.5	19	10.6	-10.6	19
10.6	-0.5	-19	10.6	-10.6	-19
10.6	-2.2	0			
10.6	-5	0			
10.6	-7	0			
30	-30	0	30	-0.5	0
30	-30	19	30	-0.5	19
30	-30	-19	30	-0.5	-19
-0.5	-0.5	0	-0.5	-10.6	0
-0.5	-0.5	19	-0.5	-10.6	19
-0.5	-0.5	-19	-0.5	-10.6	-19
-0.5	-2.2	0	-0.5	-30	0
-0.5	-5	0	-0.5	-30	19
-0.5	-7	0	-0.5	-30	-19
-2.2	-0.5	0			
-2.2	-2.2	0			
-2.2	-5	0			
-2.2	-7	0			
-2.2	-10.6	0			
-5	-0.5	0	-7	-0.5	0
-5	-2.2	0	-7	-2.2	0
-5	-5	0	-7	-5	0
-5	-7	0	-7	-7	0
-5	-10.6	0	-7	-10.6	0
-10.6	-0.5	0	-10.6	-10.6	0
-10.6	-0.5	19	-10.6	-10.6	19
-10.6	-0.5	-19	-10.6	-10.6	-19
-10.6	-2.2	0			
-10.6	-5	0			
-10.6	-7	0			
-30	-30	0	-30	-0.5	0
-30	-30	19	-30	-0.5	19
-30	-30	-19	-30	-0.5	-19
0.5	0.5	0	0.5	10.6	0
0.5	0.5	19	0.5	10.6	19
0.5	0.5	-19	0.5	10.6	-19
0.5	2.2	0	0.5	30	0
0.5	5	0	0.5	30	19
0.5	7	0	0.5	30	-19
2.2	0.5	0			
2.2	2.2	0			
2.2	5	0			
2.2	7	0			
2.2	10.6	0			
5	0.5	0	7	0.5	0
5	2.2	0	7	2.2	0
5	5	0	7	5	0
5	7	0	7	7	0
5	10.6	0	7	10.6	0
10.6	0.5	0	10.6	10.6	0
10.6	0.5	19	10.6	10.6	19
10.6	0.5	-19	10.6	10.6	-19
10.6	2.2	0			
10.6	5	0			
10.6	7	0			
30	30	0	30	0.5	0
30	30	19	30	0.5	19
30	30	-19	30	0.5	-19
-0.5	0.5	0	-0.5	10.6	0
-0.5	0.5	19	-0.5	10.6	19
-0.5	0.5	-19	-0.5	10.6	-19
-0.5	2.2	0	-0.5	30	0
-0.5	5	0	-0.5	30	19
-0.5	7	0	-0.5	30	-19
-2.2	0.5	0			
-2.2	2.2	0			
-2.2	5	0			
-2.2	7	0			
-2.2	10.6	0			
-5	0.5	0	-7	0.5	0
-5	2.2	0	-7	2.2	0
-5	5	0	-7	5	0
-5	7	0	-7	7	0
-5	10.6	0	-7	10.6	0
-10.6	0.5	0	-10.6	10.6	0
-10.6	0.5	19	-10.6	10.6	19
-10.6	0.5	-19	-10.6	10.6	-19
-10.6	2.2	0			
-10.6	5	0			

[illegible]

```

2 pz -19.05 $ fuel bottom
5 pz 26.4541 $ rod top (1/2 20.83in rod length)
6 pz -26.4541 $ rod bottom
12 pz 15.91 $ control blade bank lower edge
15 pz 49.53 $ 1 ft above fuel
16 pz -49.53 $ 1 ft below fuel
c 233U seed radial surfaces
21 cz 0.26797 $ 0.211in. OD Seed fuel pellet/zirc plug
22 cz 0.27940 $ 0.220in. ID Seed clad
23 cz 0.32385 $ 0.255in. OD Seed clad
c seed rod window (square cell) surfaces, pitch = 0.362in. = 0.91948cm
31 px 0.45974
32 px -0.45974
33 py 0.45974
34 py -0.45974
c ThO2 Blanket radial surfaces, nominal
41 cz 0.62103 $ 0.489in. OD blanket pellet/zirc plug
42 cz 0.63373 $ 0.499in. ID blanket clad
43 cz 0.72390 $ 0.570in. OD blanket clad
c blanket rod window (square cell) surfaces, pitch = 0.724in. = 1.83896cm
51 px 0.91948
52 px -0.91948
53 py 0.91948
54 py -0.91948
c core window (square cell) surfaces
66 px 34.020799 $ 18.5*pitch = 18.5*1.83896 - tad
67 px -34.020799 $ 18.5*pitch = 18.5*1.83896 - tad
68 py 32.181799 $ 17.5*pitch = 17.5*1.83896 - tad
69 py -32.181799 $ 17.5*pitch = 17.5*1.83896 - tad
c core R=48.12cm for below
c control blades
73 px 3.81 $ bank right edge (1/2 3in. width)
74 px -3.81 $ bank left edge (1/2 3in. width)
75 py 5.42798 $ blade a inner edge (-12seedpitch + .5[.07in])
76 py 5.60578 $ blade a outer edge (-12seedpitch - .5[.07in])
77 py 1.75006 $ blade b inner edge (-4seedpitch + .5[.07in])
78 py 1.92786 $ blade b outer edge (-4seedpitch - .5[.07in])
79 py -1.75006 $ blade c inner edge (-4seedpitch + .5[.07in])
80 py -1.92786 $ blade c outer edge (-4seedpitch - .5[.07in])
81 py -5.42798 $ blade d inner edge (-12seedpitch + .5[.07in])
82 py -5.60578 $ blade d outer edge (-12seedpitch - .5[.07in])
c radial tank and model boundaries
91 cz 78.60 $ core + 1ft
99 cz 259.08 $ 17ft diameter containment tank (neglected)

c Materials Data, Avogadro's number = 6.0221+23 particles/g-mole
m1 $ 233UO2-ZrO2 Seed, 6.4833g/cc, Ntot = 8.1421-2
8016.50c 5.4281-2 $ Oxygen 22.24wt% in seed
40000.50c 2.3194-2 $ Zr 54.19wt% in seed
92232.60c 1.3217-7 $ U-232 0.0033wt% in U, 8e-4wt% in seed
92233.50c 3.8411-3 $ U-233 97.29wt% in U, 22.93wt% in seed
92234.50c 6.1327-5 $ U-234 1.56wt% in U, 0.37wt% in seed
92235.50c 1.3048-7 $ U-235 0.0033wt% in U, 8e-4wt% in seed
92236.50c 1.2993-7 $ U-236 0.0033wt% in U, 8e-4wt% in seed
92238.50c 4.4061-5 $ U-238 1.14wt% in U, 0.27wt% in seed
m3 $ ThO2 blanket, 9.4884g/cc, Ntot = 6.4923-2
8016.50c 4.3282-2 $ Oxygen 12.12wt% in matrix
90232.50c 2.1641-2 $ Th232 87.88wt% in matrix
64000.35c 1.5967-7 $ Gd contaminant, 5ppm gGd/gTh
m5 $ zircaloy-2 cladding plugs etc, 6.56 g/cc, Ntot=4.3234-2
40000.50c 4.2537-2 $ Zr 98.23 wt%
24000.50c 7.5977-5 $ Cr 0.10 wt%
26000.55c 8.8422-5 $ Fe 0.13 wt%
28000.50c 3.3656-5 $ Ni 0.05 wt%
50000.35c 4.9918-4 $ Sn 1.50 wt%
m6 $ water, 0.9982 g/cc, Ntot=1.0010-1
1001.50c 6.6735-2
8016.50c 3.3368-2
mt6 lwtr.01t
m10 $ borated SS304 control blades, 7.92g/cc, Ntot=8.9912-2
26000.55c 5.9289-2 $ Fe 69.423 wt%
5010.50c 3.7488-3 $ B-10 0.787 wt%
6000.50c 1.5884-4 $ C 0.04 wt%
24000.50c 1.7428-2 $ Cr 19.00 wt%
25055.50c 8.6816-4 $ Mn 1.00 wt%
28000.50c 7.5171-3 $ Ni 9.25 wt%
15031.50c 3.0797-5 $ P 0.02 wt%
16032.50c 2.2308-5 $ S 0.015 wt%
14000.50c 8.4910-4 $ Si 0.50 wt%
c translate coordinates to center core array
*tr1 -0.45974 -0.45974 0.0 0 90 90 90 0 90 90 0 0 1
mode n
kcode 3000 1.0 100 1000
print
ksrc 0.5 0.5 0 -0.5 -0.5 0
0.5 0.5 19 -0.5 -0.5 19
0.5 0.5 -19 -0.5 -0.5 -19
0.5 2.2 0 -0.5 -2.2 0
0.5 5 0 -0.5 -5 0
0.5 7 0 -0.5 -7 0
0.5 31.5 0 -0.5 -31.5 0
0.5 31.5 19 -0.5 -31.5 19
0.5 31.5 -19 -0.5 -31.5 -19
2.2 0.5 0 -2.2 0.5 0 -2.2 -0.5 0 2.2 -0.5 0
2.2 2.2 0 -2.2 2.2 0 -2.2 -2.2 0 2.2 -2.2 0

```

2.2	5	0	-2.2	5	0	-2.2	-5	0	2.2	-5	0
2.2	7	0	-2.2	7	0	-2.2	-7	0	2.2	-7	0
5	0.5	0	-5	0.5	0	-5	-0.5	0	5	-0.5	0
5	2.2	0	-5	2.2	0	-5	-2.2	0	5	-2.2	0
5	5	0	-5	5	0	-5	-5	0	5	-5	0
5	7	0	-5	7	0	-5	-7	0	5	-7	0
7	0.5	0	-7	0.5	0	-7	-0.5	0	7	-0.5	0
7	2.2	0	-7	2.2	0	-7	-2.2	0	7	-2.2	0
7	5	0	-7	5	0	-7	-5	0	7	-5	0
7	7	0	-7	7	0	-7	-7	0	7	-7	0
31.5	0.5	0	-31.5	0.5	0	-31.5	-0.5	0	31.5	-0.5	0
31.5	0.5	19	-31.5	0.5	19	-31.5	-0.5	19	31.5	-0.5	19
31.5	0.5	-19	-31.5	0.5	-19	-31.5	-0.5	-19	31.5	-0.5	-19
31.5	31.5	0	-31.5	31.5	0	-31.5	-31.5	0	31.5	-31.5	0
31.5	31.5	19	-31.5	31.5	19	-31.5	-31.5	19	31.5	-31.5	19
31.5	31.5	-19	-31.5	31.5	-19	-31.5	-31.5	-19	31.5	-31.5	-19

E.1.3 Core SB-2½

```

full LWBR SB-2.5 fuel rods, control blades, + 1ft water
c Cold critical
c rectangular array
c U233, 340 UO2-ZrO2 seed rods (18x16)
c no blanket
c Cells
c surface order: pz1 ... cz1 ... (axial, then radial)
c seed rod, infinitely long
11 5 4.3234-2 1 -21 u=1 imp:n=1 $ top zircaloy plug
12 1 8.1421-2 2 -1 -21 u=1 imp:n=1 $ 233UO2-ZrO2 seed
13 5 4.3234-2 -2 -21 u=1 imp:n=1 $ bottom zircaloy plug
14 0 21 -22 u=1 imp:n=1 $ void around meat
15 5 4.3234-2 22 -23 u=1 imp:n=1 $ zircaloy clad
16 6 1.0010-1 23 u=1 imp:n=1 $ surrounding water
31 0 -31 32 -33 34 lat=1 fill=1 u=3 imp:n=1 $ seed rod array
32 0 -99 trcl=1 fill=3 u=4 imp:n=1 $ center seed rod array
75 0 -66 67 -68 69 fill=4 u=6 imp:n=1 $ cut array in +-x, +-y
76 6 1.0010-1 66:-67:68:-69 u=6 imp:n=1 $ water around core
c rod array with control blade bank
78 10 8.9912-2 -73 74 -76 75 u=13 imp:n=1 $ control blade a
79 10 8.9912-2 -73 74 -78 77 u=13 imp:n=1 $ control blade b
80 10 8.9912-2 -73 74 -79 80 u=13 imp:n=1 $ control blade c
81 10 8.9912-2 -73 74 -81 82 u=13 imp:n=1 $ control blade d
82 0 -5 #78 #79 #80 #81 fill=6 u=13 imp:n=1 $ core
83 6 1.0010-1 5 #78 #79 #80 #81 u=13 imp:n=1 $ water above core
c rod without control blade bank
93 0 +6 fill=6 u=14 imp:n=1 $ core
96 6 1.0010-1 -6 u=14 imp:n=1 $ water below core
c put it all together
97 0 -91 12 -15 fill=13 imp:n=1 $
98 0 -91 16 -12 fill=14 imp:n=1 $
101 0 91:15:-16 imp:n=0 $ outside

c Surfaces
c fixed elevations, pz, 0.00 = middle of fuel region
1 pz 19.05 $ fuel top (1/2 15in fuel length)
2 pz -19.05 $ fuel bottom
5 pz 26.4541 $ rod top (1/2 20.83in rod length)
6 pz -26.4541 $ rod bottom
12 pz 16.05 $ control blade bank lower edge
15 pz 49.53 $ 1 ft above fuel
16 pz -49.53 $ 1 ft below fuel
c 233U seed radial surfaces
21 cz 0.26797 $ 0.211in. OD Seed fuel pellet/zirc plug
22 cz 0.27940 $ 0.220in. ID Seed clad
23 cz 0.32385 $ 0.255in. OD Seed clad
c seed rod window (square cell) surfaces, pitch = 0.362in. = 0.91948cm
31 px 0.45974
32 px -0.45974
33 py 0.45974
34 py -0.45974
c core window (square cell) surfaces
66 px 8.2753199 $ 9*pitch = 9*0.91948 - tad
67 px -8.2753199 $ 9*pitch = 9*0.91948 - tad
68 py 7.3558399 $ 8*pitch = 8*0.91948 - tad
69 py -7.3558399 $ 8*pitch = 8*0.91948 - tad
c core R=11.71cm for below
c control blades
73 px 3.81 $ bank right edge (1/2 3in. width)
74 px -3.81 $ bank left edge (1/2 3in. width)
75 py 5.42798 $ blade a inner edge (-12seedpitch + .5[.07in])
76 py 5.60578 $ blade a outer edge (-12seedpitch - .5[.07in])
77 py 1.75006 $ blade b inner edge (-4seedpitch + .5[.07in])
78 py 1.92786 $ blade b outer edge (-4seedpitch - .5[.07in])
79 py -1.75006 $ blade c inner edge (-4seedpitch + .5[.07in])
80 py -1.92786 $ blade c outer edge (-4seedpitch - .5[.07in])
81 py -5.42798 $ blade d inner edge (-12seedpitch + .5[.07in])
82 py -5.60578 $ blade d outer edge (-12seedpitch - .5[.07in])
c radial tank and model boundaries
91 cz 42.18 $ core + 1ft
99 cz 259.08 $ 17ft diameter containment tank (neglected)

c Materials Data, Avogadro's number = 6.0221+23 particles/g-mole
m1 $ 233UO2-ZrO2 Seed, 6.4833g/cc, Ntot = 8.1421-2

```



```

      8016.50c 5.4281-2 $ Oxygen 22.24wt% in seed
      40000.50c 2.3194-2 $ Zr 54.19wt% in seed
      92232.60c 1.3217-7 $ U-232 0.0033wt% in U, 8e-4wt% in seed
      92233.50c 3.8411-3 $ U-233 97.29wt% in U, 22.93wt% in seed
      92234.50c 6.1327-5 $ U-234 1.56wt% in U, 0.37wt% in seed
      92235.50c 1.3048-7 $ U-235 0.0033wt% in U, 8e-4wt% in seed
      92236.50c 1.2993-7 $ U-236 0.0033wt% in U, 8e-4wt% in seed
      92238.50c 4.4061-5 $ U-238 1.14wt% in U, 0.27wt% in seed
m5 $ zircaloy-2 cladding plugs etc, 6.56 g/cc, Ntot=4.3234-2
      40000.50c 4.2537-2 $ Zr 98.23 wt%
      24000.50c 7.5977-5 $ Cr 0.10 wt%
      26000.55c 8.8422-5 $ Fe 0.13 wt%
      28000.50c 3.3656-5 $ Ni 0.05 wt%
      50000.35c 4.9918-4 $ Tin 1.50 wt%
m6 $ water, 0.9982 g/cc, Ntot=1.0010-1
      1001.50c 6.6735-2
      8016.50c 3.3368-2
mt6 lwtr.01t
m10 $ borated SS304 control blades, 7.92g/cc, Ntot=8.9912-2
      26000.55c 5.9289-2 $ Fe 69.423 wt%
      5010.50c 3.7488-3 $ B-10 0.787 wt%
      6000.50c 1.5884-4 $ C 0.04 wt%
      24000.50c 1.7428-2 $ Cr 19.00 wt%
      25055.50c 8.6816-4 $ Mn 1.00 wt%
      28000.50c 7.5171-3 $ Ni 9.25 wt%
      15031.50c 3.0797-5 $ P 0.02 wt%
      16032.50c 2.2308-5 $ S 0.015 wt%
      14000.50c 8.4910-4 $ Si 0.50 wt%
c translate coordinates to center core array
*tr1 -0.45974 0.45974 0.0 0 90 90 90 0 90 90 0 0 1
mode n
kcode 3000 1.0 100 1000
print
ksrc
      0.5 -0.5 0 0.5 -7.75 0
      0.5 -0.5 19 0.5 -7.75 19
      0.5 -0.5 -19 0.5 -7.75 -19
      0.5 -2.2 0 0.5 -5 0
      2.2 -0.5 0 5 -0.5 0
      2.2 -2.2 0 5 -5 0
      7.75 -0.5 0 7.75 -7.75 0
      7.75 -0.5 19 7.75 -7.75 19
      7.75 -0.5 -19 7.75 -7.75 -19
      9.75 -0.5 0
      9.75 -0.5 19
      9.75 -0.5 -19
      -0.5 -0.5 0 -0.5 -7.75 0
      -0.5 -0.5 19 -0.5 -7.75 19
      -0.5 -0.5 -19 -0.5 -7.75 -19
      -0.5 -2.2 0 -0.5 -5 0
      -2.2 -0.5 0 -5 -0.5 0
      -2.2 -2.2 0 -5 -5 0
      -7.75 -0.5 0 -7.75 -7.75 0
      -7.75 -0.5 19 -7.75 -7.75 19
      -7.75 -0.5 -19 -7.75 -7.75 -19
      -9.75 -0.5 0
      -9.75 -0.5 19
      -9.75 -0.5 -19
      0.5 2.2 0 0.5 5 0
      2.2 0.5 0 5 0.5 0
      2.2 2.2 0 5 5 0
      7.75 0.5 0 7.75 7.75 0
      7.75 0.5 19 7.75 7.75 19
      7.75 0.5 -19 7.75 7.75 -19
      -0.5 2.2 0 -0.5 5 0
      -2.2 0.5 0 -5 0.5 0
      -2.2 2.2 0 -5 5 0
      -7.75 0.5 0 -7.75 7.75 0
      -7.75 0.5 19 -7.75 7.75 19
      -7.75 0.5 -19 -7.75 7.75 -19

```

E.1.4 Core SB-3

```

full LWBR SB-3 fuel rods, control blades, and 1ft water reflector
c Cold critical
c rectangular array
c U233, 224 UO2-ZrO2 seed rods (12x18 +8 array)
c 232 233UO2-ThO2 blanket rods (16x18 - 6x9 - 2 array)
c Cells
c surface order: pz1 ... cz1 ... (axial, then radial)
c seed rod, infinitely long
11 5 4.3234-2 1 -21 u=1 imp:n=1 $ top zircaloy plug
12 1 8.1421-2 2 -1 -21 u=1 imp:n=1 $ 233UO2-ZrO2 seed
13 5 4.3234-2 -2 -21 u=1 imp:n=1 $ bottom zircaloy plug
14 0 21 -22 u=1 imp:n=1 $ void around meat
15 5 4.3234-2 22 -23 u=1 imp:n=1 $ zircaloy clad
16 6 1.0010-1 23 u=1 imp:n=1 $ surrounding water
31 0 -31 32 -33 34 lat=1 fill=1 u=3 imp:n=1 $ seed rod array
32 0 -99 trcl=1 fill=3 u=4 imp:n=1 $ center seed rod array
41 6 1.0010-1 -99 u=5 imp:n=1 $ water rod
c blanket rod, infinitely long
51 5 4.3234-2 1 -41 u=9 imp:n=1 $ top zircaloy plug
52 4 6.4621-2 2 -1 -41 u=9 imp:n=1 $ 233UO2-ThO2 blanket
53 5 4.3234-2 -2 -41 u=9 imp:n=1 $ bottom zircaloy plug

```

E-10

```

73 px      3.81      $ bank right edge (1/2 3in. width)
74 px     -3.81      $ bank left edge (1/2 3in. width)
75 py      5.42798  $ blade a inner edge (-12seedpitch + .5[.07in])
76 py      5.60578  $ blade a outer edge (-12seedpitch - .5[.07in])
77 py      1.75006  $ blade b inner edge (-4seedpitch + .5[.07in])
78 py      1.92786  $ blade b outer edge (-4seedpitch - .5[.07in])
79 py     -1.75006  $ blade c inner edge (-4seedpitch + .5[.07in])
80 py     -1.92786  $ blade c outer edge (-4seedpitch - .5[.07in])
81 py     -5.42798  $ blade d inner edge (-12seedpitch + .5[.07in])
82 py     -5.60578  $ blade d outer edge (-12seedpitch - .5[.07in])
c model boundaries
91 cz      72.      $ core boundary +1ft
99 cz     259.08    $ 17ft diameter containment tank (neglected)

c Materials Data, Avogadro's number = 6.0221+23 particles/g-mole
m1 $ 233U02-ZrO2 Seed, 6.4833g/cc, Ntot = 8.1421-2
    8016.50c  5.4281-2  $ Oxygen      22.24wt% in seed
    40000.50c 2.3194-2  $ Zr         54.19wt% in seed
    92232.60c 1.3217-7  $ U-232     0.0033wt% in U, 8e-4wt% in seed
    92233.50c 3.8411-3  $ U-233    97.29wt% in U, 22.93wt% in seed
    92234.50c 6.1327-5  $ U-234     1.56wt% in U, 0.37wt% in seed
    92235.50c 1.3048-7  $ U-235     0.0033wt% in U, 8e-4wt% in seed
    92236.50c 1.2993-7  $ U-236     0.0033wt% in U, 8e-4wt% in seed
    92238.50c 4.4061-5  $ U-238     1.14wt% in U, 0.27wt% in seed
m4 $ 233U02-ThO2 blanket, 9.4446g/cc, Ntot = 6.4621-2
    8016.50c  4.3081-2  $ Oxygen      12.120wt% in blanket
    90232.50c 2.1311-2  $ Th232      86.940wt% in blanket
    92232.60c 2.3017-8  $ U232        0.01wt% in U, 9e-5wt% in blanket
    92233.50c 2.2274-4  $ U233      97.19wt% in U, 0.9130wt% in blanket
    92234.50c 3.5370-6  $ U234       1.55wt% in U, 0.0146wt% in blanket
    92235.50c 2.2722-8  $ U235       0.01wt% in U, 9e-5wt% in blanket
    92236.50c 2.2626-8  $ U236       0.01wt% in U, 9e-5wt% in blanket
    92238.50c 2.7595-6  $ U238       1.23wt% in U, 0.0115wt% in blanket
    64000.35c 1.5796-7  $ Gd          contaminant, 5ppm gGd/gTh      4e-4wt% in blanket
m5 $ zircaloy-2 cladding plugs etc, 6.56 g/cc, Ntot=4.3234-2
    40000.50c 4.2537-2  $ Zr         98.23 wt%
    24000.50c 7.5977-5  $ Cr          0.10 wt%
    26000.55c 8.8422-5  $ Fe          0.13 wt%
    28000.50c 3.3656-5  $ Ni          0.05 wt%
    50000.35c 4.9918-4  $ Sn          1.50 wt%
m6 $ water, 0.9982 g/cc, Ntot=1.0010-1
    1001.50c  6.6735-2
    8016.50c  3.3368-2
mt6 lwtr.01t
m10 $ borated SS304 control blades, 7.92g/cc, Ntot=8.9912-2
    26000.55c 5.9289-2  $ Fe         69.423 wt%
    5010.50c  3.7488-3  $ B-10       0.787 wt%
    6000.50c  1.5884-4  $ C           0.04 wt%
    24000.50c 1.7428-2  $ Cr         19.00 wt%
    25055.50c 8.6816-4  $ Mn          1.00 wt%
    28000.50c 7.5171-3  $ Ni          9.25 wt%
    15031.50c 3.0797-5  $ P           0.02 wt%
    16032.50c 2.2308-5  $ S           0.015 wt%
    14000.50c 8.4910-4  $ Si          0.50 wt%
c translate coordinates to center core array
*tr1 -0.45974 -0.45974 0.0 0 90 90 90 0 90 90 90 0 0 1
*tr2 -0.91948 0.0 0.0 0 0 90 90 90 0 90 90 90 0 0 1
mode n
kcode 3000 1.0 100 1000
print
ksrc 0.5 -0.5 0 0.75 -9.5 0
      0.5 -0.5 19 0.75 -14.5 0
      0.5 -0.5 -19 0.75 -20 0
      0.5 -2.2 0 0.75 -31.5 0
      0.5 -5 0
      0.5 -7.75 0
      2.2 -0.5 0 2.2 -5 0
      2.2 -2.2 0 2.2 -7.75 0
      3 -9.5 0 3 -14.5 0
      5 -0.5 0 5 -7.75 0
      5 -2.2 0 5 -7.75 19
      5 -5 0 5 -7.75 -19
      6.5 -9.5 0 6.5 -20 0
      6.5 -14.5 0 6.5 -31.5 0
      10 -0.25 0 10 -9.5 0
      10 -4 0 10 -14.5 0
      14 -0.25 0 14 -14.5 0
      14 -4 0 14 -20 0
      14 -9.5 0 14 -31.5 0
      17.5 -0.25 0 17.5 -9.5 0
      17.5 -4 0 17.5 -14.5 0
      21 -0.25 0 21 -14.5 0
      21 -4 0 21 -20 0
      21 -9.5 0 21 -31.5 0
      25 -0.25 0 25 -9.5 0
      25 -4 0 25 -14.5 0
      28.5 -0.25 0 28.5 -14.5 0
      28.5 -4 0 28.5 -20 0
      28.5 -9.5 0 28.5 -31.5 0
      2.2 0.5 0 2.2 5 0
      2.2 2.2 0 2.2 7.75 0
      3 9.5 0 3 14.5 0
      5 0.5 0 5 7.75 0
      5 2.2 0 5 7.75 19
      5 5 0 5 7.75 -19

```

6.5	9.5	0	6.5	20	0
6.5	14.5	0	6.5	31.5	0
10	0.25	0	10	9.5	0
10	4	0	10	14.5	0
14	0.25	0	14	14.5	0
14	4	0	14	20	0
14	9.5	0	14	31.5	0
17.5	0.25	0	17.5	9.5	0
17.5	4	0	17.5	14.5	0
21	0.25	0	21	14.5	0
21	4	0	21	20	0
21	9.5	0	21	31.5	0
25	0.25	0	25	9.5	0
25	4	0	25	14.5	0
28.5	0.25	0	28.5	14.5	0
28.5	4	0	28.5	20	0
28.5	9.5	0	28.5	31.5	0
-0.5	0.5	0	-0.75	9.5	0
-0.5	0.5	19	-0.75	14.5	0
-0.5	0.5	-19	-0.75	20	0
-0.5	2.2	0	-0.75	31.5	0
-0.5	5	0			
-0.5	7.75	0			
-2.2	0.5	0	-2.2	5	0
-2.2	2.2	0	-2.2	7.75	0
-3	9.5	0	-3	14.5	0
-5	0.5	0	-5	7.75	0
-5	2.2	0	-5	7.75	19
-5	5	0	-5	7.75	-19
-6.5	9.5	0	-6.5	20	0
-6.5	14.5	0	-6.5	31.5	0
-10	0.25	0	-10	9.5	0
-10	4	0	-10	14.5	0
-14	0.25	0	-14	14.5	0
-14	4	0	-14	20	0
-14	9.5	0	-14	31.5	0
-17.5	0.25	0	-17.5	9.5	0
-17.5	4	0	-17.5	14.5	0
-21	0.25	0	-21	14.5	0
-21	4	0	-21	20	0
-21	9.5	0	-21	31.5	0
-25	0.25	0	-25	9.5	0
-25	4	0	-25	14.5	0
-28.5	0.25	0	-28.5	14.5	0
-28.5	4	0	-28.5	20	0
-28.5	9.5	0	-28.5	31.5	0
-2.2	-0.5	0	-2.2	-5	0
-2.2	-2.2	0	-2.2	-7.75	0
-3	-9.5	0	-3	-14.5	0
-5	-0.5	0	-5	-7.75	0
-5	-2.2	0	-5	-7.75	19
-5	-5	0	-5	-7.75	-19
-6.5	-9.5	0	-6.5	-20	0
-6.5	-14.5	0	-6.5	-31.5	0
-10	-0.25	0	-10	-9.5	0
-10	-4	0	-10	-14.5	0
-14	-0.25	0	-14	-14.5	0
-14	-4	0	-14	-20	0
-14	-9.5	0	-14	-31.5	0
-17.5	-0.25	0	-17.5	-9.5	0
-17.5	-4	0	-17.5	-14.5	0
-21	-0.25	0	-21	-14.5	0
-21	-4	0	-21	-20	0
-21	-9.5	0	-21	-31.5	0
-25	-0.25	0	-25	-9.5	0
-25	-4	0	-25	-14.5	0
-28.5	-0.25	0	-28.5	-14.5	0
-28.5	-4	0	-28.5	-20	0
-28.5	-9.5	0	-28.5	-31.5	0

E.1.5 Core SB-4

```

full LWBR SB-3 fuel rods, control blades, and 1ft water reflector
c Cold critical
c rectangular array
c U233, 224 UO2-ZrO2 seed rods (12x18 +8 array)
c 232 233UO2-ThO2 blanket rods (16x18 - 6x9 - 2 array)
c Cells
c surface order: pz1 ... cz1 ... (axial, then radial)
c seed rod, infinitely long
11 5 4.3234-2 1 -21 u=1 imp:n=1 $ top zircaloy plug
12 1 8.1421-2 2 -1 -21 u=1 imp:n=1 $ 233UO2-ZrO2 seed
13 5 4.3234-2 -2 -21 u=1 imp:n=1 $ bottom zircaloy plug
14 0 21 -22 u=1 imp:n=1 $ void around meat
15 5 4.3234-2 22 -23 u=1 imp:n=1 $ zircaloy clad
16 6 1.0010-1 23 u=1 imp:n=1 $ surrounding water
31 0 -31 32 -33 34 lat=1 fill=1 u=3 imp:n=1 $ seed rod array
32 0 -99 trcl=1 fill=3 u=4 imp:n=1 $ center seed rod array
41 6 1.0010-1 -99 u=5 imp:n=1 $ water rod
c blanket rod, infinitely long
51 5 4.3234-2 1 -41 u=9 imp:n=1 $ top zircaloy plug
52 4 6.4621-2 2 -1 -41 u=9 imp:n=1 $ 233UO2-ThO2 blanket
53 5 4.3234-2 -2 -41 u=9 imp:n=1 $ bottom zircaloy plug

```


Appendix E Benchmark Model Inputs

```

73 px      3.81      $ bank right edge (1/2 3in. width)
74 px     -3.81      $ bank left edge (1/2 3in. width)
75 py     5.42798    $ blade a inner edge (-12seedpitch + .5[.07in])
76 py     5.60578    $ blade a outer edge (-12seedpitch - .5[.07in])
77 py     1.75006    $ blade b inner edge (-4seedpitch + .5[.07in])
78 py     1.92786    $ blade b outer edge (-4seedpitch - .5[.07in])
79 py     -1.75006    $ blade c inner edge (-4seedpitch + .5[.07in])
80 py     -1.92786    $ blade c outer edge (-4seedpitch - .5[.07in])
81 py     -5.42798    $ blade d inner edge (-12seedpitch + .5[.07in])
82 py     -5.60578    $ blade d outer edge (-12seedpitch - .5[.07in])
c model boundaries
91 cz      72.      $ core boundary +1ft
99 cz    259.08      $ 17ft diameter containment tank (neglected)

c Materials Data, Avogadro's number = 6.0221+23 particles/g-mole
m1 $ 233UO2-ZrO2 Seed, 6.4833g/cc, Ntot = 8.1421-2
    8016.50c  5.4281-2  $ Oxygen      22.24wt% in seed
    40000.50c 2.3194-2  $ Zr        54.19wt% in seed
    92232.60c 1.3217-7  $ U-232    0.0033wt% in U, 8e-4wt% in seed
    92233.50c 3.8411-3  $ U-233   97.29wt% in U, 22.93wt% in seed
    92234.50c 6.1327-5  $ U-234    1.56wt% in U, 0.37wt% in seed
    92235.50c 1.3048-7  $ U-235    0.0033wt% in U, 8e-4wt% in seed
    92236.50c 1.2993-7  $ U-236    0.0033wt% in U, 8e-4wt% in seed
    92238.50c 4.4061-5  $ U-238    1.14wt% in U, 0.27wt% in seed
m4 $ 233UO2-ThO2 blanket, 9.4446g/cc, Ntot = 6.4621-2
    8016.50c  4.3081-2  $ Oxygen      12.120wt% in blanket
    90232.50c 2.1311-2  $ Th232     86.940wt% in blanket
    92232.60c 2.3017-8  $ U232      0.01wt% in U, 9e-5wt% in blanket
    92233.50c 2.2274-4  $ U233     97.19wt% in U, 0.9130wt% in blanket
    92234.50c 3.5370-6  $ U234      1.55wt% in U, 0.0146wt% in blanket
    92235.50c 2.2722-8  $ U235      0.01wt% in U, 9e-5wt% in blanket
    92236.50c 2.2626-8  $ U236      0.01wt% in U, 9e-5wt% in blanket
    92238.50c 2.7595-6  $ U238      1.23wt% in U, 0.0115wt% in blanket
    64000.35c 1.5796-7  $ Gd        contaminant, 5ppm gGd/gTh      4e-4wt% in blanket
m5 $ zircaloy-2 cladding plugs etc, 6.56 g/cc, Ntot=4.3234-2
    40000.50c 4.2537-2  $ Zr        98.23 wt%
    24000.50c 7.5977-5  $ Cr         0.10 wt%
    26000.55c 8.8422-5  $ Fe         0.13 wt%
    28000.50c 3.3656-5  $ Ni         0.05 wt%
    50000.35c 4.9918-4  $ Sn         1.50 wt%
m6 $ water, 0.9982 g/cc, Ntot=1.0010-1
    1001.50c  6.6735-2
    8016.50c  3.3368-2
mt6 lwtr.01t
m10 $ borated SS304 control blades, 7.92g/cc, Ntot=8.9912-2
    26000.55c 5.9289-2  $ Fe        69.423 wt%
    5010.50c  3.7488-3  $ B-10      0.787 wt%
    6000.50c  1.5884-4  $ C         0.04 wt%
    24000.50c 1.7428-2  $ Cr        19.00 wt%
    25055.50c 8.6816-4  $ Mn        1.00 wt%
    28000.50c 7.5171-3  $ Ni        9.25 wt%
    15031.50c 3.0797-5  $ P         0.02 wt%
    16032.50c 2.2308-5  $ S         0.015 wt%
    14000.50c 8.4910-4  $ Si        0.50 wt%
c translate coordinates to center core array
*tr1 -0.45974 -0.45974 0.0 0 90 90 90 0 90 90 90 0 0 1
*tr2 -0.91948 0.0 0.0 0 0 90 90 90 0 90 90 90 0 0 1
mode n
kcode 3000 1.0 100 1000
print
ksrc 0.5 -0.5 0 0.75 -9.5 0
      0.5 -0.5 19 0.75 -14.5 0
      0.5 -0.5 -19 0.75 -20 0
      0.5 -2.2 0 0.75 -31.5 0
      0.5 -5 0
      0.5 -7.75 0
      2.2 -0.5 0 2.2 -5 0
      2.2 -2.2 0 2.2 -7.75 0
      3 -9.5 0 3 -14.5 0
      5 -0.5 0 5 -7.75 0
      5 -2.2 0 5 -7.75 19
      5 -5 0 5 -7.75 -19
      6.5 -9.5 0 6.5 -20 0
      6.5 -14.5 0 6.5 -31.5 0
      10 -0.25 0 10 -9.5 0
      10 -4 0 10 -14.5 0
      14 -0.25 0 14 -14.5 0
      14 -4 0 14 -20 0
      14 -9.5 0 14 -31.5 0
      17.5 -0.25 0 17.5 -9.5 0
      17.5 -4 0 17.5 -14.5 0
      21 -0.25 0 21 -14.5 0
      21 -4 0 21 -20 0
      21 -9.5 0 21 -31.5 0
      25 -0.25 0 25 -9.5 0
      25 -4 0 25 -14.5 0
      28.5 -0.25 0 28.5 -14.5 0
      28.5 -4 0 28.5 -20 0
      28.5 -9.5 0 28.5 -31.5 0
      2.2 0.5 0 2.2 5 0
      2.2 2.2 0 2.2 7.75 0
      3 9.5 0 3 14.5 0
      5 0.5 0 5 7.75 0
      5 2.2 0 5 7.75 19
      5 5 0 5 7.75 -19

```

6.5	9.5	0	6.5	20	0
6.5	14.5	0	6.5	31.5	0
10	0.25	0	10	9.5	0
10	4	0	10	14.5	0
14	0.25	0	14	14.5	0
14	4	0	14	20	0
14	9.5	0	14	31.5	0
17.5	0.25	0	17.5	9.5	0
17.5	4	0	17.5	14.5	0
21	0.25	0	21	14.5	0
21	4	0	21	20	0
21	9.5	0	21	31.5	0
25	0.25	0	25	9.5	0
25	4	0	25	14.5	0
28.5	0.25	0	28.5	14.5	0
28.5	4	0	28.5	20	0
28.5	9.5	0	28.5	31.5	0
-0.5	0.5	0	-0.75	9.5	0
-0.5	0.5	19	-0.75	14.5	0
-0.5	0.5	-19	-0.75	20	0
-0.5	2.2	0	-0.75	31.5	0
-0.5	5	0			
-0.5	7.75	0			
-2.2	0.5	0	-2.2	5	0
-2.2	2.2	0	-2.2	7.75	0
-3	9.5	0	-3	14.5	0
-5	0.5	0	-5	7.75	0
-5	2.2	0	-5	7.75	19
-5	5	0	-5	7.75	-19
-6.5	9.5	0	-6.5	20	0
-6.5	14.5	0	-6.5	31.5	0
-10	0.25	0	-10	9.5	0
-10	4	0	-10	14.5	0
-14	0.25	0	-14	14.5	0
-14	4	0	-14	20	0
-14	9.5	0	-14	31.5	0
-17.5	0.25	0	-17.5	9.5	0
-17.5	4	0	-17.5	14.5	0
-21	0.25	0	-21	14.5	0
-21	4	0	-21	20	0
-21	9.5	0	-21	31.5	0
-25	0.25	0	-25	9.5	0
-25	4	0	-25	14.5	0
-28.5	0.25	0	-28.5	14.5	0
-28.5	4	0	-28.5	20	0
-28.5	9.5	0	-28.5	31.5	0
-2.2	-0.5	0	-2.2	-5	0
-2.2	-2.2	0	-2.2	-7.75	0
-3	-9.5	0	-3	-14.5	0
-5	-0.5	0	-5	-7.75	0
-5	-2.2	0	-5	-7.75	19
-5	-5	0	-5	-7.75	-19
-6.5	-9.5	0	-6.5	-20	0
-6.5	-14.5	0	-6.5	-31.5	0
-10	-0.25	0	-10	-9.5	0
-10	-4	0	-10	-14.5	0
-14	-0.25	0	-14	-14.5	0
-14	-4	0	-14	-20	0
-14	-9.5	0	-14	-31.5	0
-17.5	-0.25	0	-17.5	-9.5	0
-17.5	-4	0	-17.5	-14.5	0
-21	-0.25	0	-21	-14.5	0
-21	-4	0	-21	-20	0
-21	-9.5	0	-21	-31.5	0
-25	-0.25	0	-25	-9.5	0
-25	-4	0	-25	-14.5	0
-28.5	-0.25	0	-28.5	-14.5	0
-28.5	-4	0	-28.5	-20	0
-28.5	-9.5	0	-28.5	-31.5	0

E.1.6 Core SB-5

```

full LWBR SB-5 fuel rods, control blades, +lft water
c Cold critical
c hexagonal array
c U235, 217 UO2-ZrO2 seed rods
c ThO2 blanket rods
c Cells
c surface order: pz1 ... cz1 ... (axial, then radial)
c seed rod, infinitely long
11 5 4.3234-2 1 -21 u=1 imp:n=1 $ top zircaloy plug + cap
12 2 8.2260-2 2 -1 -21 u=1 imp:n=1 $ 235UO2-ZrO2 seed
13 5 4.3234-2 -2 -21 u=1 imp:n=1 $ bottom zircaloy plug + cap
14 0 21 -22 u=1 imp:n=1 $ void around meat
15 5 4.3234-2 22 -23 u=1 imp:n=1 $ zircaloy clad
16 6 1.0010-1 23 u=1 imp:n=1 $ surrounding water
19 6 1.0010-1 -99 u=2 imp:n=1 $ water rod
c blanket rod, infinitely long
51 5 4.3234-2 1 -41 u=9 imp:n=1 $ top zircaloy plug
52 3 6.4923-2 2 -1 -41 u=9 imp:n=1 $ ThO2 blanket
53 5 4.3234-2 -2 -41 u=9 imp:n=1 $ bottom zircaloy plug
54 0 41 -42 u=9 imp:n=1 $ void around meat
55 5 4.3234-2 42 -43 u=9 imp:n=1 $ zircaloy clad

```

```

56      6      1.0010-1      43      u=9 imp:n=1 $ surrounding water
c   ore array
61    0      -52 55 -51 54 -56 53 lat=2 u=8 imp:n=1
           fill=-24:24 -24:24 0:0
                2 27R 2 16R 2 3R
                  2 26R 2 17R 2 3R
                    2 25R 2 18R 2 3R
                      2 24R 2 19R 2 3R
                        2 23R 9 20R 2 3R
                          2 22R 9 21R 2 3R
                            2 21R 9 22R 2 3R
                              2 20R 9 23R 2 3R
                                2 19R 9 24R 2 3R
                                  2 18R 9 25R 2 3R
                                    2 17R 9 26R 2 3R
                                      2 16R 9 27R 2 3R
                                        2 15R 9 28R 2 3R
                                          2 14R 9 29R 2 3R
                                            2 13R 9 30R 2 3R
                                              2 12R 9 31R 2 3R
                                                2 11R 9 11R 1 1 1 1 1 1 1 1 9 11R 2 3R
                                                  2 10R 9 11R 1 1 1 1 1 1 1 1 1 1 9 11R 2 3R
                                                    2 9R 9 11R 1 1 1 1 1 1 1 1 1 1 1 9 11R 2 3R
                                                      2 8R 9 11R 1 1 1 1 1 1 1 1 1 1 1 1 9 11R 2 3R
                                                        2 7R 9 11R 1 1 1 1 1 1 1 1 1 1 1 1 1 9 11R 2 3R
                                                          2 6R 9 11R 1 1 1 1 1 1 1 1 1 1 1 1 1 1 9 11R 2 3R
                                                            2 5R 9 11R 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 9 11R 2 3R
                                                              2 4R 9 11R 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 9 11R 2 3R
                                                                2 3R 9 11R 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 9 11R 2 3R
                                                                  2 3R 9 11R 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 9 11R 2 4R
                                                                    2 3R 9 11R 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 9 11R 2 5R
                                                                      2 3R 9 11R 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 9 11R 2 6R
                                                                        2 3R 9 11R 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 9 11R 2 7R
                                                                          2 3R 9 11R 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 9 11R 2 8R
                                                                            2 3R 9 11R 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 9 11R 2 9R
                                                                              2 3R 9 11R 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 9 11R 2 10R
                                                                                2 3R 9 11R 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 9 11R 2 11R
                                                                                  2 3R 9 31R 2 12R
                                                                                    2 3R 9 30R 2 13R
                                                                                      2 3R 9 29R 2 14R
                                                                                        2 3R 9 28R 2 15R
                                                                                          2 3R 9 27R 2 16R
                                                                                            2 3R 9 26R 2 17R
                                                                                              2 3R 9 25R 2 18R
                                                                                                2 3R 9 24R 2 19R
                                                                                                  2 3R 9 23R 2 20R
                                                                                                      2 3R 9 22R 2 21R
                                                                                                          2 3R 9 21R 2 22R
                                                                                                              2 3R 9 20R 2 23R
                                                                                                                  2 3R 2 19R 2 24R
                                                                                                                      2 3R 2 18R 2 25R
                                                                                                                          2 3R 2 17R 2 26R
                                                                                                                              2 3R 2 16R 2 27R
75    0          -69          fill=8 u=6 imp:n=1 $ cut array
76    6      1.0010-1      69          u=6 imp:n=1 $ water around core
c rod array with control blade bank
78 10 8.9912-2 -73 74 -76 75 u=13 imp:n=1 $ control blade a
79 10 8.9912-2 -73 74 -78 77 u=13 imp:n=1 $ control blade b
80 10 8.9912-2 -73 74 -79 80 u=13 imp:n=1 $ control blade c
81 10 8.9912-2 -73 74 -81 82 u=13 imp:n=1 $ control blade d
82 0 -5 #78 #79 #80 #81 fill=6 u=13 imp:n=1 $ core
83 6 1.0010-1 5 #78 #79 #80 #81 u=13 imp:n=1 $ water above core
c rod array without control blade bank
93 0 +6 fill=6 u=14 imp:n=1 $ core
96 6 1.0010-1 -6 u=14 imp:n=1 $ water below core
c put it all together
97 0 -91 12 -15 fill=13 imp:n=1 $
98 0 -91 16 -12 fill=14 imp:n=1 $
101 0 91:15:-16 imp:n=0 $ outside

c Surfaces
c fixed elevations, pz, 0.00 = middle of fuel region
1 pz 19.05 $ fuel top (1/2 15in fuel length)
2 pz -19.05 $ fuel bottom
5 pz 26.4541 $ rod top (1/2 20.83in rod length)
6 pz -26.4541 $ rod bottom
12 pz 15.87 $ control blade bank lower edge
15 pz 49.53 $ 1 ft above fuel
16 pz -49.53 $ 1 ft below fuel
c 235U seed radial surfaces
21 cz 0.26797 $ 0.211in. OD Seed fuel pellet/zirc plug
22 cz 0.27940 $ 0.220in. ID Seed clad
23 cz 0.32385 $ 0.255in. OD Seed clad
c ThO2 Blanket radial surfaces
41 cz 0.62103 $ 0.489in. OD blanket pellet/zirc plug
42 cz 0.63373 $ 0.499in. ID blanket clad
43 cz 0.72390 $ 0.570in. OD blanket clad
c blanket rod window (hex cell) surfaces, pitch = 0.571in. = 1.45034cm
51 p 1 1.73205 0 1.45034
52 px 0.72517
53 p -1 1.73205 0 -1.45034
54 p 1 1.73205 0 -1.45034
55 px -0.72517
56 p -1 1.73205 0 1.45034
c core window surfaces

```



```

69 cz 29.8 $ 20.5*pitch=29.7320 but round up
c control blades
73 px 3.81 $ bank right edge (1/2 3in. width)
74 px -3.81 $ bank left edge (1/2 3in. width)
75 py 5.42798 $ blade a inner edge (from core SB-2.5)
76 py 5.60578 $ blade a outer edge (from core SB-2.5)
77 py 1.75006 $ blade b inner edge (from core SB-2.5)
78 py 1.92786 $ blade b outer edge (from core SB-2.5)
79 py -1.75006 $ blade c inner edge (from core SB-2.5)
80 py -1.92786 $ blade c outer edge (from core SB-2.5)
81 py -5.42798 $ blade d inner edge (from core SB-2.5)
82 py -5.60578 $ blade d outer edge (from core SB-2.5)
c model boundaries
91 cz 60.28 $ core + 1ft
99 cz 259.08 $ 17ft diameter containment tank (neglected)

c Materials Data, Avogadro's number = 6.0221+23 particles/g-mole
m2 $ 235UO2-ZrO2 Seed, 6.6101g/cc, Ntot = 8.2260-2
    8016.50c 5.4840-2 $ Oxygen 22.04wt% in matrix
    40000.50c 2.3240-2 $ Zr 53.26wt% in matrix
    92234.50c 3.7309-5 $ U-234 0.888wt% in U, 0.22wt% in matrix
    92235.50c 3.8791-3 $ U-235 92.73wt% in U, 22.90wt% in matrix
    92236.50c 1.0907-5 $ U-236 0.262wt% in U, 0.06wt% in matrix
    92238.50c 2.5278-4 $ U-238 6.120wt% in U, 1.51wt% in matrix
m3 $ ThO2 blanket, 9.4884g/cc, Ntot = 6.4923-2
    8016.50c 4.3282-2 $ Oxygen 12.12wt% in matrix
    90232.50c 2.1641-2 $ Th-232 87.88wt% in matrix
    64000.35c 1.5967-7 $ Gd contaminant, 5ppm gGd/gTh
m5 $ zircaloy-2 cladding plugs etc, 6.56 g/cc, Ntot=4.3234-2
    40000.50c 4.2537-2 $ Zr 98.23 wt%
    24000.50c 7.5977-5 $ Cr 0.10 wt%
    26000.55c 8.8422-5 $ Fe 0.13 wt%
    28000.50c 3.3656-5 $ Ni 0.05 wt%
    50000.35c 4.9918-4 $ Tin 1.50 wt%
m6 $ water, 0.9982 g/cc, Ntot=1.0010-1
    1001.50c 6.6735-2
    8016.50c 3.3368-2
mt6 lwtr.01t
m10 $ borated SS304 control blades, 7.92g/cc, Ntot=8.9912-2
    26000.55c 5.9289-2 $ Fe 69.423 wt%
    5010.50c 3.7488-3 $ B-10 0.787 wt%
    6000.50c 1.5884-4 $ C 0.04 wt%
    24000.50c 1.7428-2 $ Cr 19.00 wt%
    25055.50c 8.6816-4 $ Mn 1.00 wt%
    28000.50c 7.5171-3 $ Ni 9.25 wt%
    15031.50c 3.0797-5 $ P 0.02 wt%
    16032.50c 2.2308-5 $ S 0.015 wt%
    14000.50c 8.4910-4 $ Si 0.50 wt%

mode n
kcode 3000 1.0 100 1000
print
ksarc
    0 -0.1 0 0 -5 0
    0 -0.1 19 0 -5 19
    0 -0.1 -19 0 -5 -19
    0 -7.5 0 0 -15 0
    0 -7.5 19 0 -15 19
    0 -7.5 -19 0 -15 -19
    0 -25 0
    0 -25 19
    0 -25 -19
    3 -2.5 0 -3 -2.5 0
    5 -6.2 0 -5 -6.2 0
    5 -6.2 19 -5 -6.2 19
    5 -6.2 -19 -5 -6.2 -19
    7.1 -1 0 -7.1 -1 0
    7.1 -1 19 -7.1 -1 19
    7.1 -1 -19 -7.1 -1 -19
    7.1 -7.5 0 -7.1 -7.5 0
    14.5 -15 0 -14.5 -15 0
    14.5 -25 0 -14.5 -25 0
    14.5 -25 19 -14.5 -25 19
    14.5 -25 -19 -14.5 -25 -19
    16 -1 0 -16 -1 0
    29 -1 0 -29 -1 0
    29 -1 19 -29 -1 19
    29 -1 -19 -29 -1 -19
    0 5 0
    0 5 19
    0 5 -19
    0 15 0 0 25 0
    0 15 19 0 25 19
    0 15 -19 0 25 -19
    3 2.5 0 -3 2.5 0
    5 6.2 0 -5 6.2 0
    5 6.2 19 -5 6.2 19
    5 6.2 -19 -5 6.2 -19
    7.1 7.5 0 -7.1 7.5 0
    14.5 15 0 -14.5 15 0
    14.5 25 0 -14.5 25 0
    14.5 25 19 -14.5 25 19
    14.5 25 -19 -14.5 25 -19

```

E.1.7 Core SB-6

```

full LWBR SB-5 fuel rods, control blades, +1ft water
c Cold critical
c hexagonal array
c U235, 217 UO2-ZrO2 seed rods
c ThO2 blanket rods
c Cells
c surface order: pz1 ... cz1 ... (axial, then radial)
c seed rod, infinitely long
11 5 4.3234-2 1 -21 u=1 imp:n=1 $ top zircaloy plug + cap
12 2 8.2260-2 2 -1 -21 u=1 imp:n=1 $ 235UO2-ZrO2 seed
13 5 4.3234-2 -2 -21 u=1 imp:n=1 $ bottom zircaloy plug + cap
14 0 21 -22 u=1 imp:n=1 $ void around meat
15 5 4.3234-2 22 -23 u=1 imp:n=1 $ zircaloy clad
16 6 1.0010-1 23 u=1 imp:n=1 $ surrounding water
19 6 1.0010-1 -99 u=2 imp:n=1 $ water rod
c blanket rod, infinitely long
51 5 4.3234-2 1 -41 u=9 imp:n=1 $ top zircaloy plug
52 3 6.4923-2 2 -1 -41 u=9 imp:n=1 $ ThO2 blanket
53 5 4.3234-2 -2 -41 u=9 imp:n=1 $ bottom zircaloy plug
54 0 41 -42 u=9 imp:n=1 $ void around meat
55 5 4.3234-2 42 -43 u=9 imp:n=1 $ zircaloy clad
56 6 1.0010-1 43 u=9 imp:n=1 $ surrounding water
c ore array
61 0 -52 55 -51 54 -56 53 lat=2 u=8 imp:n=1
fill=-24:24 -24:24 0:0
2 27R 2 16R 2 3R
2 26R 2 17R 2 3R
2 25R 2 18R 2 3R
2 24R 2 19R 2 3R
2 23R 9 20R 2 3R
2 22R 9 21R 2 3R
2 21R 9 22R 2 3R
2 20R 9 23R 2 3R
2 19R 9 24R 2 3R
2 18R 9 25R 2 3R
2 17R 9 26R 2 3R
2 16R 9 27R 2 3R
2 15R 9 28R 2 3R
2 14R 9 29R 2 3R
2 13R 9 30R 2 3R
2 12R 9 31R 2 3R
2 11R 9 11R 1 1 1 1 1 1 1 1 9 11R 2 3R
2 10R 9 11R 1 1 1 1 1 1 1 1 9 11R 2 3R
2 9R 9 11R 1 1 1 1 1 1 1 1 9 11R 2 3R
2 8R 9 11R 1 1 1 1 1 1 1 1 9 11R 2 3R
2 7R 9 11R 1 1 1 1 1 1 1 1 9 11R 2 3R
2 6R 9 11R 1 1 1 1 1 1 1 1 9 11R 2 3R
2 5R 9 11R 1 1 1 1 1 1 1 1 9 11R 2 3R
2 4R 9 11R 1 1 1 1 1 1 1 1 9 11R 2 3R
2 3R 9 11R 1 1 1 1 1 1 1 1 9 11R 2 3R
2 3R 9 11R 1 1 1 1 1 1 1 1 9 11R 2 4R
2 3R 9 11R 1 1 1 1 1 1 1 1 9 11R 2 5R
2 3R 9 11R 1 1 1 1 1 1 1 1 9 11R 2 6R
2 3R 9 11R 1 1 1 1 1 1 1 1 9 11R 2 7R
2 3R 9 11R 1 1 1 1 1 1 1 1 9 11R 2 8R
2 3R 9 11R 1 1 1 1 1 1 1 1 9 11R 2 9R
2 3R 9 11R 1 1 1 1 1 1 1 1 9 11R 2 10R
2 3R 9 11R 1 1 1 1 1 1 1 1 9 11R 2 11R
2 3R 9 31R 2 12R
2 3R 9 30R 2 13R
2 3R 9 29R 2 14R
2 3R 9 28R 2 15R
2 3R 9 27R 2 16R
2 3R 9 26R 2 17R
2 3R 9 25R 2 18R
2 3R 9 24R 2 19R
2 3R 9 23R 2 20R
2 3R 9 22R 2 21R
2 3R 9 21R 2 22R
2 3R 9 20R 2 23R
2 3R 2 19R 2 24R
2 3R 2 18R 2 25R
2 3R 2 17R 2 26R
2 3R 2 16R 2 27R
75 0 -69 fill=8 u=6 imp:n=1 $ cut array
76 6 1.0010-1 69 u=6 imp:n=1 $ water around core
c rod array with control blade bank
78 10 8.9912-2 -73 74 -76 75 u=13 imp:n=1 $ control blade a
79 10 8.9912-2 -73 74 -78 77 u=13 imp:n=1 $ control blade b
80 10 8.9912-2 -73 74 -79 80 u=13 imp:n=1 $ control blade c
81 10 8.9912-2 -73 74 -81 82 u=13 imp:n=1 $ control blade d
82 0 -5 #78 #79 #80 #81 fill=6 u=13 imp:n=1 $ core
83 6 1.0010-1 5 #78 #79 #80 #81 u=13 imp:n=1 $ water above core
c rod array without control blade bank
93 0 +6 fill=6 u=14 imp:n=1 $ core
96 6 1.0010-1 -6 u=14 imp:n=1 $ water below core
c put it all together
97 0 -91 12 -15 fill=13 imp:n=1 $
98 0 -91 16 -12 fill=14 imp:n=1 $
101 0 91:15:-16 imp:n=0 $ outside
c Surfaces

```

```

c fixed elevations, pz, 0.00 = middle of fuel region
1 pz 19.05 $ fuel top (1/2 15in fuel length)
2 pz -19.05 $ fuel bottom
5 pz 26.4541 $ rod top (1/2 20.83in rod length)
6 pz -26.4541 $ rod bottom
12 pz 15.87 $ control blade bank lower edge
15 pz 49.53 $ 1 ft above fuel
16 pz -49.53 $ 1 ft below fuel
c 235U seed radial surfaces
21 cz 0.26797 $ 0.211in. OD Seed fuel pellet/zirc plug
22 cz 0.27940 $ 0.220in. ID Seed clad
23 cz 0.32385 $ 0.255in. OD Seed clad
c ThO2 Blanket radial surfaces
41 cz 0.62103 $ 0.489in. OD blanket pellet/zirc plug
42 cz 0.63373 $ 0.499in. ID blanket clad
43 cz 0.72390 $ 0.570in. OD blanket clad
c blanket rod window (hex cell) surfaces, pitch = 0.571in. = 1.45034cm
51 p 1 1.73205 0 1.45034
52 px 0.72517
53 p -1 1.73205 0 -1.45034
54 p 1 1.73205 0 -1.45034
55 px -0.72517
56 p -1 1.73205 0 1.45034
c core window surfaces
69 cz 29.8 $ 20.5*pitch=29.7320 but round up
c control blades
73 px 3.81 $ bank right edge (1/2 3in. width)
74 px -3.81 $ bank left edge (1/2 3in. width)
75 py 5.42798 $ blade a inner edge (from core SB-2.5)
76 py 5.60578 $ blade a outer edge (from core SB-2.5)
77 py 1.75006 $ blade b inner edge (from core SB-2.5)
78 py 1.92786 $ blade b outer edge (from core SB-2.5)
79 py -1.75006 $ blade c inner edge (from core SB-2.5)
80 py -1.92786 $ blade c outer edge (from core SB-2.5)
81 py -5.42798 $ blade d inner edge (from core SB-2.5)
82 py -5.60578 $ blade d outer edge (from core SB-2.5)
c model boundaries
91 cz 60.28 $ core + 1ft
99 cz 259.08 $ 17ft diameter containment tank (neglected)

c Materials Data, Avogadro's number = 6.0221+23 particles/g-mole
m2 $ 235UO2-ZrO2 Seed, 6.6101g/cc, Ntot = 8.2260-2
8016.50c 5.4840-2 $ Oxygen 22.04wt% in matrix
40000.50c 2.3240-2 $ Zr 53.26wt% in matrix
92234.50c 3.7309-5 $ U-234 0.888wt% in U, 0.22wt% in matrix
92235.50c 3.8791-3 $ U-235 92.73wt% in U, 22.90wt% in matrix
92236.50c 1.0907-5 $ U-236 0.262wt% in U, 0.06wt% in matrix
92238.50c 2.5278-4 $ U-238 6.120wt% in U, 1.51wt% in matrix
m3 $ ThO2 blanket, 9.4884g/cc, Ntot = 6.4923-2
8016.50c 4.3282-2 $ Oxygen 12.12wt% in matrix
90232.50c 2.1641-2 $ Th-232 87.88wt% in matrix
64000.35c 1.5967-7 $ Gd contaminant, 5ppm gGd/gTh
m5 $ zircaloy-2 cladding plugs etc, 6.56 g/cc, Ntot=4.3234-2
40000.50c 4.2537-2 $ Zr 98.23 wt%
24000.50c 7.5977-5 $ Cr 0.10 wt%
26000.55c 8.8422-5 $ Fe 0.13 wt%
28000.50c 3.3656-5 $ Ni 0.05 wt%
50000.35c 4.9918-4 $ Tin 1.50 wt%
m6 $ water, 0.9982 g/cc, Ntot=1.0010-1
1001.50c 6.6735-2
8016.50c 3.3368-2
mt6 lwtr.01t
m10 $ borated SS304 control blades, 7.92g/cc, Ntot=8.9912-2
26000.55c 5.9289-2 $ Fe 69.423 wt%
5010.50c 3.7488-3 $ B-10 0.787 wt%
6000.50c 1.5884-4 $ C 0.04 wt%
24000.50c 1.7428-2 $ Cr 19.00 wt%
25055.50c 8.6816-4 $ Mn 1.00 wt%
28000.50c 7.5171-3 $ Ni 9.25 wt%
15031.50c 3.0797-5 $ P 0.02 wt%
16032.50c 2.2308-5 $ S 0.015 wt%
14000.50c 8.4910-4 $ Si 0.50 wt%

mode n
kcode 3000 1.0 100 1000
print
ksrc 0 -0.1 0 0 -5 0
0 -0.1 19 0 -5 19
0 -0.1 -19 0 -5 -19
0 -7.5 0 0 -15 0
0 -7.5 19 0 -15 19
0 -7.5 -19 0 -15 -19
0 -25 0
0 -25 19
0 -25 -19
3 -2.5 0 -3 -2.5 0
5 -6.2 0 -5 -6.2 0
5 -6.2 19 -5 -6.2 19
5 -6.2 -19 -5 -6.2 -19
7.1 -1.1 0 -7.1 -1.1 0
7.1 -1.1 19 -7.1 -1.1 19
7.1 -1.1 -19 -7.1 -1.1 -19
7.1 -7.5 0 -7.1 -7.5 0
14.5 -15 0 -14.5 -15 0
14.5 -25 0 -14.5 -25 0
14.5 -25 19 -14.5 -25 19

```

```

14.5 -25 -19 -14.5 -25 -19
16 -.1 0 -16 -.1 0
29 -.1 0 -29 -.1 0
29 -.1 19 -29 -.1 19
29 -.1 -19 -29 -.1 -19
0 5 0
0 5 19
0 5 -19
0 15 0 0 25 0
0 15 19 0 25 19
0 15 -19 0 25 -19
3 2.5 0 -3 2.5 0
5 6.2 0 -5 6.2 0
5 6.2 19 -5 6.2 19
5 6.2 -19 -5 6.2 -19
7.1 7.5 0 -7.1 7.5 0
14.5 15 0 -14.5 15 0
14.5 25 0 -14.5 25 0
14.5 25 19 -14.5 25 19
14.5 25 -19 -14.5 25 -19

```

E.1.8 Core SB-7

full LWBR SB-7 fuel rods, control blades, & 1ft water reflector

```

c Cold critical
c hexagonal array
c U233, 121 UO2-ZrO2 seed rods
c 233UO2-ThO2 blanket rods
c Cells
c surface order: pz1 ... cz1 ... (axial, then radial)
c seed rod, infinitely long
11 5 4.3234-2 1 -21 u=1 imp:n=1 $ top zircaloy plug
12 1 8.1421-2 2 -1 -21 u=1 imp:n=1 $ 233UO2-ZrO2 seed
13 5 4.3234-2 -2 -21 u=1 imp:n=1 $ bottom zircaloy plug
14 0 21 -22 u=1 imp:n=1 $ void around meat
15 5 4.3234-2 22 -23 u=1 imp:n=1 $ zircaloy clad
16 6 1.0010-1 23 u=1 imp:n=1 $ surrounding water
19 6 1.0010-1 -99 u=2 imp:n=1 $ water rod
c blanket rod, infinitely long
51 5 4.3234-2 1 -41 u=9 imp:n=1 $ top zircaloy plug
52 4 6.4621-2 2 -1 -41 u=9 imp:n=1 $ 233UO2-ThO2 blanket
53 5 4.3234-2 -2 -41 u=9 imp:n=1 $ bottom zircaloy plug
54 0 41 -42 u=9 imp:n=1 $ void around meat
55 5 4.3234-2 42 -43 u=9 imp:n=1 $ zircaloy clad
56 6 1.0010-1 43 u=9 imp:n=1 $ surrounding water
c full core array
61 0 -52 55 -51 54 -56 53 lat=2 u=8 imp:n=1
fill=-24:24 -24:24 0:0
2 27R 2 16R 2 3R
2 26R 2 17R 2 3R
2 25R 2 18R 2 3R
2 24R 2 19R 2 3R
2 23R 9 20R 2 3R
2 22R 9 21R 2 3R
2 21R 9 22R 2 3R
2 20R 9 23R 2 3R
2 19R 9 24R 2 3R
2 18R 9 25R 2 3R
2 17R 9 26R 2 3R
2 16R 9 27R 2 3R
2 15R 9 28R 2 3R
2 14R 9 29R 2 3R
2 13R 9 30R 2 3R
2 12R 9 31R 2 3R
2 11R 9 11R 9 9 9 9 9 9 9 9 9 9 11R 2 3R
2 10R 9 11R 9 9 9 9 9 9 9 9 9 9 11R 2 3R
2 9R 9 11R 9 9 9 1 1 9 1 1 9 9 9 11R 2 3R
2 8R 9 11R 9 9 1 1 1 1 1 1 1 9 9 11R 2 3R
2 7R 9 11R 9 9 1 1 1 1 1 1 1 1 9 9 11R 2 3R
2 6R 9 11R 9 9 9 1 1 1 1 1 1 1 1 9 9 11R 2 3R
2 5R 9 11R 9 9 1 1 1 1 1 1 1 1 1 9 9 11R 2 3R
2 4R 9 11R 9 9 1 1 1 1 1 1 1 1 1 1 9 9 11R 2 3R
2 3R 9 11R 9 9 9 1 1 1 1 1 1 1 1 1 9 9 9 11R 2 3R
2 3R 9 11R 9 9 1 1 1 1 1 1 1 1 1 1 9 9 9 11R 2 4R
2 3R 9 11R 9 9 1 1 1 1 1 1 1 1 1 1 9 9 9 11R 2 5R
2 3R 9 11R 9 9 9 1 1 1 1 1 1 1 1 9 9 9 11R 2 6R
2 3R 9 11R 9 9 1 1 1 1 1 1 1 1 1 9 9 9 11R 2 7R
2 3R 9 11R 9 9 1 1 1 1 1 1 1 1 1 9 9 9 11R 2 8R
2 3R 9 11R 9 9 9 1 1 9 1 1 9 9 9 9 11R 2 9R
2 3R 9 11R 9 9 9 9 9 9 9 9 9 9 9 11R 2 10R
2 3R 9 11R 9 9 9 9 9 9 9 9 9 9 9 11R 2 11R
2 3R 9 31R 2 12R
2 3R 9 30R 2 13R
2 3R 9 29R 2 14R
2 3R 9 28R 2 15R
2 3R 9 27R 2 16R
2 3R 9 26R 2 17R
2 3R 9 25R 2 18R
2 3R 9 24R 2 19R
2 3R 9 23R 2 20R
2 3R 9 22R 2 21R
2 3R 9 21R 2 22R
2 3R 9 20R 2 23R

```

```

2 3R 2 19R 2 24R
2 3R 2 18R 2 25R
2 3R 2 17R 2 26R
2 3R 2 16R 2 27R
75 0 -69 fill=8 u=6 imp:n=1 $ cut array
76 6 1.0010-1 69 u=6 imp:n=1 $ water around core
c rod array with control blade bank
78 10 8.9912-2 -73 74 -76 75 u=13 imp:n=1 $ control blade a
79 10 8.9912-2 -73 74 -78 77 u=13 imp:n=1 $ control blade b
80 10 8.9912-2 -73 74 -79 80 u=13 imp:n=1 $ control blade c
81 10 8.9912-2 -73 74 -81 82 u=13 imp:n=1 $ control blade d
82 0 -5 #78 #79 #80 #81 fill=6 u=13 imp:n=1 $ core
83 6 1.0010-1 5 #78 #79 #80 #81 u=13 imp:n=1 $ water above core
c rod array without control blade bank
93 0 +6 fill=6 u=14 imp:n=1 $ core
96 6 1.0010-1 -6 u=14 imp:n=1 $ water below core
c put it all together
97 0 -91 12 -15 fill=13 imp:n=1 $
98 0 -91 16 -12 fill=14 imp:n=1 $
101 0 91:15:-16 imp:n=0 $ outside

c Surfaces
c fixed elevations, pz, 0.00 = middle of fuel region
1 pz 19.05 $ fuel top (1/2 15in fuel length)
2 pz -19.05 $ fuel bottom
5 pz 26.4541 $ rod top (1/2 20.83in rod length)
6 pz -26.4541 $ rod bottom
12 pz 17.09 $ control blade bank lower edge
15 pz 49.53 $ 1 ft above fuel
16 pz -49.53 $ 1 ft below fuel
c 233U seed radial surfaces
21 cz 0.26797 $ 0.211in. OD Seed fuel pellet/zirc plug
22 cz 0.27940 $ 0.220in. ID Seed clad
23 cz 0.32385 $ 0.255in. OD Seed clad
c 233UO2-ThO2 Blanket radial surfaces
41 cz 0.62230 $ 0.490in. OD blanket pellet/zirc plug
42 cz 0.63246 $ 0.498in. ID blanket clad
43 cz 0.72263 $ 0.569in. OD blanket clad
c blanket rod window (hex cell) surfaces, pitch = 0.571in. = 1.45034cm
51 p 1 1.73205 0 1.45034
52 px 0.72517
53 p -1 1.73205 0 -1.45034
54 p 1 1.73205 0 -1.45034
55 px -0.72517
56 p -1 1.73205 0 1.45034
c core window surfaces
69 cz 29.8 $ 20.5*pitch=29.7320 but round up
c control blades
73 px 3.81 $ bank right edge (1/2 3in. width)
74 px -3.81 $ bank left edge (1/2 3in. width)
75 py 5.42798 $ blade a inner edge (from core SB-2.5)
76 py 5.60578 $ blade a outer edge (from core SB-2.5)
77 py 1.75006 $ blade b inner edge (from core SB-2.5)
78 py 1.92786 $ blade b outer edge (from core SB-2.5)
79 py -1.75006 $ blade c inner edge (from core SB-2.5)
80 py -1.92786 $ blade c outer edge (from core SB-2.5)
81 py -5.42798 $ blade d inner edge (from core SB-2.5)
82 py -5.60578 $ blade d outer edge (from core SB-2.5)
c radial tank and model boundaries
91 cz 60.28 $ core window + 1ft
99 cz 259.08 $ 17ft diameter containment tank (neglected)

c Materials Data, Avogadro's number = 6.0221+23 particles/g-mole
m1 $ 233UO2-ZrO2 Seed, 6.4833g/cc, Ntot = 8.1421-2
8016.50c 5.4281-2 $ Oxygen 22.24wt% in seed
40000.50c 2.3194-2 $ Zr 54.19wt% in seed
92232.60c 1.3217-7 $ U-232 0.0033wt% in U, 8e-4wt% in seed
92233.50c 3.8411-3 $ U-233 97.29wt% in U, 22.93wt% in seed
92234.50c 6.1327-5 $ U-234 1.56wt% in U, 0.37wt% in seed
92235.50c 1.3048-7 $ U-235 0.0033wt% in U, 8e-4wt% in seed
92236.50c 1.2993-7 $ U-236 0.0033wt% in U, 8e-4wt% in seed
92238.50c 4.4061-5 $ U-238 1.14wt% in U, 0.27wt% in seed
m4 $ 233UO2-ThO2 blanket, 9.4446g/cc, Ntot = 6.4621-2
8016.50c 4.3081-2 $ Oxygen 12.120wt% in blanket
90232.50c 2.1311-2 $ Th232 86.940wt% in blanket
92232.60c 2.3017-8 $ U232 0.01wt% in U, 9e-5wt% in blanket
92233.50c 2.2274-4 $ U233 97.19wt% in U, 0.9130wt% in blanket
92234.50c 3.5370-6 $ U234 1.55wt% in U, 0.0146wt% in blanket
92235.50c 2.2722-8 $ U235 0.01wt% in U, 9e-5wt% in blanket
92236.50c 2.2626-8 $ U236 0.01wt% in U, 9e-5wt% in blanket
92238.50c 2.7595-6 $ U238 1.23wt% in U, 0.0115wt% in blanket
64000.35c 1.5796-7 $ Gd contaminant, 5ppm gGd/gTh 4e-4wt% in blanket
m5 $ zircaloy-2 cladding plugs etc., 6.56 g/cc, Ntot=4.3234-2
40000.50c 4.2537-2 $ Zr 98.23 wt%
24000.50c 7.5977-5 $ Cr 0.10 wt%
26000.55c 8.8422-5 $ Fe 0.13 wt%
28000.50c 3.3656-5 $ Ni 0.05 wt%
50000.35c 4.9918-4 $ Sn 1.5 wt%
m6 $ water, 0.9982 g/cc, Ntot=1.0010-1
1001.50c 6.6735-2
8016.50c 3.3368-2
mt6 lwtr.01t
m10 $ borated SS304 control blades, 7.92g/cc, Ntot=8.9912-2
26000.55c 5.9289-2 $ Fe 69.423 wt%
5010.50c 3.7488-3 $ B-10 0.787 wt%

```

6000.50c	1.5884-4	\$ C	0.04	wt%
24000.50c	1.7428-2	\$ Cr	19.00	wt%
25055.50c	8.6816-4	\$ Mn	1.00	wt%
28000.50c	7.5171-3	\$ Ni	9.25	wt%
15031.50c	3.0797-5	\$ P	0.02	wt%
16032.50c	2.2308-5	\$ S	0.015	wt%
14000.50c	8.4910-4	\$ Si	0.50	wt%

mode n	3000	1.0	100	1000	
kcode					
print					
ksrc	0	-0.1	0	0	-5 0
	0	-0.1	19	0	-5 19
	0	-0.1	-19	0	-5 -19
	0	-7.5	0	0	-15 0
	0	-7.5	19	0	-15 19
	0	-7.5	-19	0	-15 -19
	0	-25	0		
	0	-25	19		
	0	-25	-19		
	3	-2.5	0	-3	-2.5 0
	5	-6.2	0	-5	-6.2 0
	5	-6.2	19	-5	-6.2 19
	5	-6.2	-19	-5	-6.2 -19
	7.1	-1	0	-7.1	-1 0
	7.1	-1	19	-7.1	-1 19
	7.1	-1	-19	-7.1	-1 -19
	7.1	-7.5	0	-7.1	-7.5 0
	14.5	-15	0	-14.5	-15 0
	14.5	-25	0	-14.5	-25 0
	14.5	-25	19	-14.5	-25 19
	14.5	-25	-19	-14.5	-25 -19
	16	-1	0	-16	-1 0
	29	-1	0	-29	-1 0
	29	-1	19	-29	-1 19
	29	-1	-19	-29	-1 -19
	0	5	0		
	0	5	19		
	0	5	-19		
	0	15	0	0	25 0
	0	15	19	0	25 19
	0	15	-19	0	25 -19
	3	2.5	0	-3	2.5 0
	5	6.2	0	-5	6.2 0
	5	6.2	19	-5	6.2 19
	5	6.2	-19	-5	6.2 -19
	7.1	7.5	0	-7.1	7.5 0
	14.5	15	0	-14.5	15 0
	14.5	25	0	-14.5	25 0
	14.5	25	19	-14.5	25 19
	14.5	25	-19	-14.5	25 -19

E.2 SCALE4.3

To facilitate comparison between rectangular and hexagonal cores, KENO Va's *hole* option is used in all cases. To conserve space with these very long inputs, a double column format is used and input lines to plot data are deleted. In a few cases, single input lines appear on multiple lines here.

Use information from Table 16 through Table 19 footnotes, and from Table A-1 to use a different cross section library from the library indicated by the listing heading.

E.2.1 Core SB-1, 44 Group ENDF/B-V

```
=CSAS25      PARM=SIZE=200000
full LWBR SB-1 fuel rods, control blades, and 1ft water
reflector
44GROUPNDF5 LATTICECELL
' mix 1 = 235UO2-ZrO2 Seed
O          1 0 5.4840-2      END
ZR         1 0 2.3240-2      END
U-234      1 0 3.7309-5      END
U-235      1 0 3.8791-3      END
U-236      1 0 1.0907-5      END
U-238      1 0 2.5278-4      END
' mix 2 = ThO2 blanket
O-16       2 0 4.3282-2      END
TH-232     2 0 2.1641-2      END
GD         2 5.28-6          END
' mix 3 = zirc-2 cladding etc, 6.56 g/cc, Ntot=4.3234-2
ZR         3 0 4.2537-2      END
CR         3 0 7.5977-5      END
FE         3 0 8.8422-5      END
NI         3 0 3.3656-5      END
SN         3 0.0135          END
' mix 4 = water, 0.9982 g/cc, Ntot=1.0010-1
H          4 0 6.6735-2      END
O          4 0 3.3368-2      END

' mix 5 = borated SS304 control blades, 7.92g/cc,
Ntot=8.9912-2
FE         5 0 5.9289-2      END
B-10       5 0 3.7488-3      END
C          5 0 1.5884-4      END
CR         5 0 1.7428-2      END
MN         5 0 8.6816-4      END
NI         5 0 7.5171-3      END
P          5 0 3.0797-5      END
S          5 0 2.2308-5      END
SI         5 0 8.4910-4      END
END COMP
SQUAREPITCH 0.91948 0.53594 1 4 0.64770 3 0.55880 0
END
MORE DATA RES=2 CYLINDER 0.62103
DAN(2)=0.197645 END
KENOV.A
READ PARAM
GEN=500 NPG=3000 NSK=50 TME=3000
FLX=YES FDN=YES FMP=YES NUB=YES RUN=YES
END PARAM
READ GEOM
UNIT 1
COM=*Seed rod in water*
```

CYLINDER	1	1	0.26797	2P19.05		HOLE	1	1.37922	5.97662	0.
CYLINDER	0	1	0.27940	2P19.05		HOLE	1	2.29870	5.97662	0.
CYLINDER	3	1	0.32385	2P26.4541		HOLE	1	3.21818	5.97662	0.
UNIT 3										
COM=*blanket rod in water*										
CYLINDER	2	1	0.62103	2P19.05		HOLE	1	4.13766	5.97662	0.
CYLINDER	0	1	0.63373	2P19.05		HOLE	1	5.05714	5.97662	0.
CYLINDER	3	1	0.72390	2P26.4541		HOLE	1	5.97662	5.97662	0.
UNIT 4										
COM=*control blade in water*										
CUBOID	5	1	2P3.81	2P0.0889	49.53	HOLE	1	6.89610	5.97662	0.
16.44						HOLE	1	8.73506	5.97662	0.
CUBOID	4	1	2P3.81	2P0.0889	2P49.53	HOLE	1	9.65454	5.97662	0.
UNIT 5										
COM=*rod array with blades, use holes to handle all*										
CYLINDER	4	1	45.52	2P49.5301		HOLE	1	10.57402	5.97662	0.
COM=*control blades & why rod array is by holes*										
HOLE	4	0.		5.51688	0.	HOLE	1	4.13766	6.89610	0.
HOLE	4	0.		1.83896	0.	HOLE	1	5.05714	6.89610	0.
HOLE	4	0.		-1.83896	0.	HOLE	1	5.97662	6.89610	0.
HOLE	4	0.		-5.51688	0.	HOLE	1	6.89610	6.89610	0.
COM=*+x,+y quadrant from center out*										
HOLE	1		0.45974	0.45974	0.	HOLE	1	7.81558	6.89610	0.
HOLE	1		1.37922	0.45974	0.	HOLE	1	8.73506	6.89610	0.
HOLE	1		2.29870	0.45974	0.	HOLE	1	9.65454	6.89610	0.
HOLE	1		3.21818	0.45974	0.	HOLE	1	10.57402	6.89610	0.
HOLE	1		4.13766	0.45974	0.	HOLE	1	0.45974	7.81558	0.
HOLE	1		5.05714	0.45974	0.	HOLE	1	1.37922	7.81558	0.
HOLE	1		5.97662	0.45974	0.	HOLE	1	2.29870	7.81558	0.
HOLE	1		6.89610	0.45974	0.	HOLE	1	3.21818	7.81558	0.
HOLE	1		7.81558	0.45974	0.	HOLE	1	4.13766	7.81558	0.
HOLE	1		8.73506	0.45974	0.	HOLE	1	5.05714	7.81558	0.
HOLE	1		9.65454	0.45974	0.	HOLE	1	5.97662	7.81558	0.
HOLE	1		10.57402	0.45974	0.	HOLE	1	6.89610	7.81558	0.
HOLE	1		0.45974	1.37922	0.	HOLE	1	7.81558	7.81558	0.
HOLE	1		1.37922	1.37922	0.	HOLE	1	8.73506	7.81558	0.
HOLE	1		2.29870	1.37922	0.	HOLE	1	9.65454	7.81558	0.
HOLE	1		3.21818	1.37922	0.	HOLE	1	10.57402	7.81558	0.
HOLE	1		4.13766	1.37922	0.	HOLE	1	0.45974	8.73506	0.
HOLE	1		5.05714	1.37922	0.	HOLE	1	1.37922	8.73506	0.
HOLE	1		5.97662	1.37922	0.	HOLE	1	2.29870	8.73506	0.
HOLE	1		6.89610	1.37922	0.	HOLE	1	3.21818	8.73506	0.
HOLE	1		7.81558	1.37922	0.	HOLE	1	4.13766	8.73506	0.
HOLE	1		8.73506	1.37922	0.	HOLE	1	5.05714	8.73506	0.
HOLE	1		9.65454	1.37922	0.	HOLE	1	5.97662	8.73506	0.
HOLE	1		10.57402	1.37922	0.	HOLE	1	6.89610	8.73506	0.
HOLE	1		0.45974	2.29870	0.	HOLE	1	7.81558	8.73506	0.
HOLE	1		1.37922	2.29870	0.	HOLE	1	8.73506	8.73506	0.
HOLE	1		2.29870	2.29870	0.	HOLE	1	9.65454	8.73506	0.
HOLE	1		3.21818	2.29870	0.	HOLE	1	10.57402	8.73506	0.
HOLE	1		4.13766	2.29870	0.	HOLE	1	0.45974	9.65454	0.
HOLE	1		5.05714	2.29870	0.	HOLE	1	1.37922	9.65454	0.
HOLE	1		5.97662	2.29870	0.	HOLE	1	2.29870	9.65454	0.
HOLE	1		6.89610	2.29870	0.	HOLE	1	3.21818	9.65454	0.
HOLE	1		7.81558	2.29870	0.	HOLE	1	4.13766	9.65454	0.
HOLE	1		8.73506	2.29870	0.	HOLE	1	5.05714	9.65454	0.
HOLE	1		9.65454	2.29870	0.	HOLE	1	5.97662	9.65454	0.
HOLE	1		10.57402	2.29870	0.	HOLE	1	6.89610	9.65454	0.
HOLE	1		0.45974	3.21818	0.	HOLE	1	7.81558	9.65454	0.
HOLE	1		1.37922	3.21818	0.	HOLE	1	8.73506	9.65454	0.
HOLE	1		2.29870	3.21818	0.	HOLE	1	9.65454	9.65454	0.
HOLE	1		3.21818	3.21818	0.	HOLE	1	10.57402	9.65454	0.
HOLE	1		4.13766	3.21818	0.	HOLE	1	0.45974	10.57402	0.
HOLE	1		5.05714	3.21818	0.	HOLE	1	1.37922	10.57402	0.
HOLE	1		5.97662	3.21818	0.	HOLE	1	2.29870	10.57402	0.
HOLE	1		6.89610	3.21818	0.	HOLE	1	3.21818	10.57402	0.
HOLE	1		7.81558	3.21818	0.	HOLE	1	4.13766	10.57402	0.
HOLE	1		8.73506	3.21818	0.	HOLE	1	5.05714	10.57402	0.
HOLE	1		9.65454	3.21818	0.	HOLE	1	5.97662	10.57402	0.
HOLE	1		10.57402	3.21818	0.	HOLE	1	6.89610	10.57402	0.
HOLE	1		0.45974	4.13766	0.	HOLE	1	7.81558	10.57402	0.
HOLE	1		1.37922	4.13766	0.	HOLE	1	8.73506	10.57402	0.
HOLE	1		2.29870	4.13766	0.	HOLE	3	9.65454	10.57402	0.
HOLE	1		3.21818	4.13766	0.	HOLE	3	10.57402	10.57402	0.
HOLE	1		4.13766	4.13766	0.	HOLE	3	11.95324	0.91948	0.
HOLE	1		5.05714	4.13766	0.	HOLE	3	13.79220	0.91948	0.
HOLE	1		5.97662	4.13766	0.	HOLE	3	15.63116	0.91948	0.
HOLE	1		6.89610	4.13766	0.	HOLE	3	17.47012	0.91948	0.
HOLE	1		7.81558	4.13766	0.	HOLE	3	19.30908	0.91948	0.
HOLE	1		8.73506	4.13766	0.	HOLE	3	21.14804	0.91948	0.
HOLE	1		9.65454	4.13766	0.	HOLE	3	22.98700	0.91948	0.
HOLE	1		10.57402	4.13766	0.	HOLE	3	24.82596	0.91948	0.
HOLE	1		0.45974	5.05714	0.	HOLE	3	26.66492	0.91948	0.
HOLE	1		1.37922	5.05714	0.	HOLE	3	28.50388	0.91948	0.
HOLE	1		2.29870	5.05714	0.	HOLE	3	30.34284	0.91948	0.
HOLE	1		3.21818	5.05714	0.	HOLE	3	11.95324	2.75844	0.
HOLE	1		4.13766	5.05714	0.	HOLE	3	13.79220	2.75844	0.
HOLE	1		5.05714	5.05714	0.	HOLE	3	15.63116	2.75844	0.
HOLE	1		5.97662	5.05714	0.	HOLE	3	17.47012	2.75844	0.
HOLE	1		6.89610	5.05714	0.	HOLE	3	19.30908	2.75844	0.
HOLE	1		7.81558	5.05714	0.	HOLE	3	21.14804	2.75844	0.
HOLE	1		8.73506	5.05714	0.	HOLE	3	22.98700	2.75844	0.
HOLE	1		9.65454	5.05714	0.	HOLE	3	24.82596	2.75844	0.
HOLE	1		10.57402	5.05714	0.	HOLE	3	26.66492	2.75844	0.
HOLE	1		0.45974	5.97662	0.	HOLE	3	28.50388	2.75844	0.
HOLE	1					HOLE	3	30.34284	2.75844	0.
						HOLE	3	11.95324	4.59740	0.
						HOLE	3	13.79220	4.59740	0.

Appendix E Benchmark Model Inputs

HOLE	3	15.63116	4.59740	0.	HOLE	3	4.59740	17.47012	0.
HOLE	3	17.47012	4.59740	0.	HOLE	3	6.43636	17.47012	0.
HOLE	3	19.30908	4.59740	0.	HOLE	3	8.27532	17.47012	0.
HOLE	3	21.14804	4.59740	0.	HOLE	3	10.11428	17.47012	0.
HOLE	3	22.98700	4.59740	0.	HOLE	3	11.95324	17.47012	0.
HOLE	3	24.82596	4.59740	0.	HOLE	3	13.79220	17.47012	0.
HOLE	3	26.66492	4.59740	0.	HOLE	3	15.63116	17.47012	0.
HOLE	3	28.50388	4.59740	0.	HOLE	3	17.47012	17.47012	0.
HOLE	3	30.34284	4.59740	0.	HOLE	3	19.30908	17.47012	0.
HOLE	3	11.95324	6.43636	0.	HOLE	3	21.14804	17.47012	0.
HOLE	3	13.79220	6.43636	0.	HOLE	3	22.98700	17.47012	0.
HOLE	3	15.63116	6.43636	0.	HOLE	3	24.82596	17.47012	0.
HOLE	3	17.47012	6.43636	0.	HOLE	3	26.66492	17.47012	0.
HOLE	3	19.30908	6.43636	0.	HOLE	3	28.50388	17.47012	0.
HOLE	3	21.14804	6.43636	0.	HOLE	3	30.34284	17.47012	0.
HOLE	3	22.98700	6.43636	0.	HOLE	3	0.91948	19.30908	0.
HOLE	3	24.82596	6.43636	0.	HOLE	3	2.75844	19.30908	0.
HOLE	3	26.66492	6.43636	0.	HOLE	3	4.59740	19.30908	0.
HOLE	3	28.50388	6.43636	0.	HOLE	3	6.43636	19.30908	0.
HOLE	3	30.34284	6.43636	0.	HOLE	3	8.27532	19.30908	0.
HOLE	3	11.95324	8.27532	0.	HOLE	3	10.11428	19.30908	0.
HOLE	3	13.79220	8.27532	0.	HOLE	3	11.95324	19.30908	0.
HOLE	3	15.63116	8.27532	0.	HOLE	3	13.79220	19.30908	0.
HOLE	3	17.47012	8.27532	0.	HOLE	3	15.63116	19.30908	0.
HOLE	3	19.30908	8.27532	0.	HOLE	3	17.47012	19.30908	0.
HOLE	3	21.14804	8.27532	0.	HOLE	3	19.30908	19.30908	0.
HOLE	3	22.98700	8.27532	0.	HOLE	3	21.14804	19.30908	0.
HOLE	3	24.82596	8.27532	0.	HOLE	3	22.98700	19.30908	0.
HOLE	3	26.66492	8.27532	0.	HOLE	3	24.82596	19.30908	0.
HOLE	3	28.50388	8.27532	0.	HOLE	3	26.66492	19.30908	0.
HOLE	3	30.34284	8.27532	0.	HOLE	3	28.50388	19.30908	0.
HOLE	3	11.95324	10.11428	0.	HOLE	3	30.34284	19.30908	0.
HOLE	3	13.79220	10.11428	0.	HOLE	3	0.91948	21.14804	0.
HOLE	3	15.63116	10.11428	0.	HOLE	3	2.75844	21.14804	0.
HOLE	3	17.47012	10.11428	0.	HOLE	3	4.59740	21.14804	0.
HOLE	3	19.30908	10.11428	0.	HOLE	3	6.43636	21.14804	0.
HOLE	3	21.14804	10.11428	0.	HOLE	3	8.27532	21.14804	0.
HOLE	3	22.98700	10.11428	0.	HOLE	3	10.11428	21.14804	0.
HOLE	3	24.82596	10.11428	0.	HOLE	3	11.95324	21.14804	0.
HOLE	3	26.66492	10.11428	0.	HOLE	3	13.79220	21.14804	0.
HOLE	3	28.50388	10.11428	0.	HOLE	3	15.63116	21.14804	0.
HOLE	3	30.34284	10.11428	0.	HOLE	3	17.47012	21.14804	0.
HOLE	3	0.91948	11.95324	0.	HOLE	3	19.30908	21.14804	0.
HOLE	3	2.75844	11.95324	0.	HOLE	3	21.14804	21.14804	0.
HOLE	3	4.59740	11.95324	0.	HOLE	3	22.98700	21.14804	0.
HOLE	3	6.43636	11.95324	0.	HOLE	3	24.82596	21.14804	0.
HOLE	3	8.27532	11.95324	0.	HOLE	3	26.66492	21.14804	0.
HOLE	3	10.11428	11.95324	0.	HOLE	3	28.50388	21.14804	0.
HOLE	3	11.95324	11.95324	0.	HOLE	3	30.34284	21.14804	0.
HOLE	3	13.79220	11.95324	0.	HOLE	3	0.91948	22.98700	0.
HOLE	3	15.63116	11.95324	0.	HOLE	3	2.75844	22.98700	0.
HOLE	3	17.47012	11.95324	0.	HOLE	3	4.59740	22.98700	0.
HOLE	3	19.30908	11.95324	0.	HOLE	3	6.43636	22.98700	0.
HOLE	3	21.14804	11.95324	0.	HOLE	3	8.27532	22.98700	0.
HOLE	3	22.98700	11.95324	0.	HOLE	3	10.11428	22.98700	0.
HOLE	3	24.82596	11.95324	0.	HOLE	3	11.95324	22.98700	0.
HOLE	3	26.66492	11.95324	0.	HOLE	3	13.79220	22.98700	0.
HOLE	3	28.50388	11.95324	0.	HOLE	3	15.63116	22.98700	0.
HOLE	3	30.34284	11.95324	0.	HOLE	3	17.47012	22.98700	0.
HOLE	3	0.91948	13.79220	0.	HOLE	3	19.30908	22.98700	0.
HOLE	3	2.75844	13.79220	0.	HOLE	3	21.14804	22.98700	0.
HOLE	3	4.59740	13.79220	0.	HOLE	3	22.98700	22.98700	0.
HOLE	3	6.43636	13.79220	0.	HOLE	3	24.82596	22.98700	0.
HOLE	3	8.27532	13.79220	0.	HOLE	3	26.66492	22.98700	0.
HOLE	3	10.11428	13.79220	0.	HOLE	3	28.50388	22.98700	0.
HOLE	3	11.95324	13.79220	0.	HOLE	3	30.34284	22.98700	0.
HOLE	3	13.79220	13.79220	0.	HOLE	3	0.91948	24.82596	0.
HOLE	3	15.63116	13.79220	0.	HOLE	3	2.75844	24.82596	0.
HOLE	3	17.47012	13.79220	0.	HOLE	3	4.59740	24.82596	0.
HOLE	3	19.30908	13.79220	0.	HOLE	3	6.43636	24.82596	0.
HOLE	3	21.14804	13.79220	0.	HOLE	3	8.27532	24.82596	0.
HOLE	3	22.98700	13.79220	0.	HOLE	3	10.11428	24.82596	0.
HOLE	3	24.82596	13.79220	0.	HOLE	3	11.95324	24.82596	0.
HOLE	3	26.66492	13.79220	0.	HOLE	3	13.79220	24.82596	0.
HOLE	3	28.50388	13.79220	0.	HOLE	3	15.63116	24.82596	0.
HOLE	3	30.34284	13.79220	0.	HOLE	3	17.47012	24.82596	0.
HOLE	3	0.91948	15.63116	0.	HOLE	3	19.30908	24.82596	0.
HOLE	3	2.75844	15.63116	0.	HOLE	3	21.14804	24.82596	0.
HOLE	3	4.59740	15.63116	0.	HOLE	3	22.98700	24.82596	0.
HOLE	3	6.43636	15.63116	0.	HOLE	3	24.82596	24.82596	0.
HOLE	3	8.27532	15.63116	0.	HOLE	3	26.66492	24.82596	0.
HOLE	3	10.11428	15.63116	0.	HOLE	3	28.50388	24.82596	0.
HOLE	3	11.95324	15.63116	0.	HOLE	3	30.34284	24.82596	0.
HOLE	3	13.79220	15.63116	0.	HOLE	3	0.91948	26.66492	0.
HOLE	3	15.63116	15.63116	0.	HOLE	3	2.75844	26.66492	0.
HOLE	3	17.47012	15.63116	0.	HOLE	3	4.59740	26.66492	0.
HOLE	3	19.30908	15.63116	0.	HOLE	3	6.43636	26.66492	0.
HOLE	3	21.14804	15.63116	0.	HOLE	3	8.27532	26.66492	0.
HOLE	3	22.98700	15.63116	0.	HOLE	3	10.11428	26.66492	0.
HOLE	3	24.82596	15.63116	0.	HOLE	3	11.95324	26.66492	0.
HOLE	3	26.66492	15.63116	0.	HOLE	3	13.79220	26.66492	0.
HOLE	3	28.50388	15.63116	0.	HOLE	3	15.63116	26.66492	0.
HOLE	3	30.34284	15.63116	0.	HOLE	3	17.47012	26.66492	0.
HOLE	3	0.91948	17.47012	0.	HOLE	3	19.30908	26.66492	0.
HOLE	3	2.75844	17.47012	0.	HOLE	3	21.14804	26.66492	0.

Criticality Safety Code Validation with LWBR's SB Cores

HOLE	3	22.98700	26.66492	0.	HOLE	1	-6.89610	4.13766	0.
HOLE	3	24.82596	26.66492	0.	HOLE	1	-7.81558	4.13766	0.
HOLE	3	26.66492	26.66492	0.	HOLE	1	-8.73506	4.13766	0.
HOLE	3	28.50388	26.66492	0.	HOLE	1	-9.65454	4.13766	0.
HOLE	3	30.34284	26.66492	0.	HOLE	1	-10.57402	4.13766	0.
HOLE	3	0.91948	28.50388	0.	HOLE	1	-0.45974	5.05714	0.
HOLE	3	2.75844	28.50388	0.	HOLE	1	-1.37922	5.05714	0.
HOLE	3	4.59740	28.50388	0.	HOLE	1	-2.29870	5.05714	0.
HOLE	3	6.43636	28.50388	0.	HOLE	1	-3.21818	5.05714	0.
HOLE	3	8.27532	28.50388	0.	HOLE	1	-4.13766	5.05714	0.
HOLE	3	10.11428	28.50388	0.	HOLE	1	-5.05714	5.05714	0.
HOLE	3	11.95324	28.50388	0.	HOLE	1	-5.97662	5.05714	0.
HOLE	3	13.79220	28.50388	0.	HOLE	1	-6.89610	5.05714	0.
HOLE	3	15.63116	28.50388	0.	HOLE	1	-7.81558	5.05714	0.
HOLE	3	17.47012	28.50388	0.	HOLE	1	-8.73506	5.05714	0.
HOLE	3	19.30908	28.50388	0.	HOLE	1	-9.65454	5.05714	0.
HOLE	3	21.14804	28.50388	0.	HOLE	1	-10.57402	5.05714	0.
HOLE	3	22.98700	28.50388	0.	HOLE	1	-0.45974	5.97662	0.
HOLE	3	24.82596	28.50388	0.	HOLE	1	-1.37922	5.97662	0.
HOLE	3	26.66492	28.50388	0.	HOLE	1	-2.29870	5.97662	0.
HOLE	3	28.50388	28.50388	0.	HOLE	1	-3.21818	5.97662	0.
HOLE	3	30.34284	28.50388	0.	HOLE	1	-4.13766	5.97662	0.
HOLE	3	0.91948	30.34284	0.	HOLE	1	-5.05714	5.97662	0.
HOLE	3	2.75844	30.34284	0.	HOLE	1	-5.97662	5.97662	0.
HOLE	3	4.59740	30.34284	0.	HOLE	1	-6.89610	5.97662	0.
HOLE	3	6.43636	30.34284	0.	HOLE	1	-7.81558	5.97662	0.
HOLE	3	8.27532	30.34284	0.	HOLE	1	-8.73506	5.97662	0.
HOLE	3	10.11428	30.34284	0.	HOLE	1	-9.65454	5.97662	0.
HOLE	3	11.95324	30.34284	0.	HOLE	1	-10.57402	5.97662	0.
HOLE	3	13.79220	30.34284	0.	HOLE	1	-0.45974	6.89610	0.
HOLE	3	15.63116	30.34284	0.	HOLE	1	-1.37922	6.89610	0.
HOLE	3	17.47012	30.34284	0.	HOLE	1	-2.29870	6.89610	0.
HOLE	3	19.30908	30.34284	0.	HOLE	1	-3.21818	6.89610	0.
HOLE	3	21.14804	30.34284	0.	HOLE	1	-4.13766	6.89610	0.
HOLE	3	22.98700	30.34284	0.	HOLE	1	-5.05714	6.89610	0.
HOLE	3	24.82596	30.34284	0.	HOLE	1	-5.97662	6.89610	0.
HOLE	3	26.66492	30.34284	0.	HOLE	1	-6.89610	6.89610	0.
HOLE	3	28.50388	30.34284	0.	HOLE	1	-7.81558	6.89610	0.
HOLE	3	30.34284	30.34284	0.	HOLE	1	-8.73506	6.89610	0.
COM=-x,+y quadrant from center out*									
HOLE	1	-0.45974	0.45974	0.	HOLE	1	-9.65454	6.89610	0.
HOLE	1	-1.37922	0.45974	0.	HOLE	1	-10.57402	6.89610	0.
HOLE	1	-2.29870	0.45974	0.	HOLE	1	-0.45974	7.81558	0.
HOLE	1	-3.21818	0.45974	0.	HOLE	1	-1.37922	7.81558	0.
HOLE	1	-4.13766	0.45974	0.	HOLE	1	-2.29870	7.81558	0.
HOLE	1	-5.05714	0.45974	0.	HOLE	1	-3.21818	7.81558	0.
HOLE	1	-5.97662	0.45974	0.	HOLE	1	-4.13766	7.81558	0.
HOLE	1	-6.89610	0.45974	0.	HOLE	1	-5.05714	7.81558	0.
HOLE	1	-7.81558	0.45974	0.	HOLE	1	-5.97662	7.81558	0.
HOLE	1	-8.73506	0.45974	0.	HOLE	1	-6.89610	7.81558	0.
HOLE	1	-9.65454	0.45974	0.	HOLE	1	-7.81558	7.81558	0.
HOLE	1	-10.57402	0.45974	0.	HOLE	1	-8.73506	7.81558	0.
HOLE	1	-0.45974	1.37922	0.	HOLE	1	-8.73506	7.81558	0.
HOLE	1	-1.37922	1.37922	0.	HOLE	1	-9.65454	7.81558	0.
HOLE	1	-2.29870	1.37922	0.	HOLE	1	-10.57402	7.81558	0.
HOLE	1	-3.21818	1.37922	0.	HOLE	1	-0.45974	8.73506	0.
HOLE	1	-4.13766	1.37922	0.	HOLE	1	-1.37922	8.73506	0.
HOLE	1	-5.05714	1.37922	0.	HOLE	1	-2.29870	8.73506	0.
HOLE	1	-5.97662	1.37922	0.	HOLE	1	-3.21818	8.73506	0.
HOLE	1	-6.89610	1.37922	0.	HOLE	1	-4.13766	8.73506	0.
HOLE	1	-7.81558	1.37922	0.	HOLE	1	-5.05714	8.73506	0.
HOLE	1	-8.73506	1.37922	0.	HOLE	1	-5.97662	8.73506	0.
HOLE	1	-9.65454	1.37922	0.	HOLE	1	-6.89610	8.73506	0.
HOLE	1	-10.57402	1.37922	0.	HOLE	1	-7.81558	8.73506	0.
HOLE	1	-0.45974	2.29870	0.	HOLE	1	-8.73506	8.73506	0.
HOLE	1	-1.37922	2.29870	0.	HOLE	1	-9.65454	8.73506	0.
HOLE	1	-2.29870	2.29870	0.	HOLE	1	-10.57402	8.73506	0.
HOLE	1	-3.21818	2.29870	0.	HOLE	1	-0.45974	9.65454	0.
HOLE	1	-4.13766	2.29870	0.	HOLE	1	-1.37922	9.65454	0.
HOLE	1	-5.05714	2.29870	0.	HOLE	1	-2.29870	9.65454	0.
HOLE	1	-5.97662	2.29870	0.	HOLE	1	-3.21818	9.65454	0.
HOLE	1	-6.89610	2.29870	0.	HOLE	1	-4.13766	9.65454	0.
HOLE	1	-7.81558	2.29870	0.	HOLE	1	-5.05714	9.65454	0.
HOLE	1	-8.73506	2.29870	0.	HOLE	1	-5.97662	9.65454	0.
HOLE	1	-9.65454	2.29870	0.	HOLE	1	-6.89610	9.65454	0.
HOLE	1	-10.57402	2.29870	0.	HOLE	1	-7.81558	9.65454	0.
HOLE	1	-0.45974	3.21818	0.	HOLE	1	-8.73506	9.65454	0.
HOLE	1	-1.37922	3.21818	0.	HOLE	1	-9.65454	9.65454	0.
HOLE	1	-2.29870	3.21818	0.	HOLE	1	-10.57402	9.65454	0.
HOLE	1	-3.21818	3.21818	0.	HOLE	1	-0.45974	10.57402	0.
HOLE	1	-4.13766	3.21818	0.	HOLE	1	-1.37922	10.57402	0.
HOLE	1	-5.05714	3.21818	0.	HOLE	1	-2.29870	10.57402	0.
HOLE	1	-5.97662	3.21818	0.	HOLE	1	-3.21818	10.57402	0.
HOLE	1	-6.89610	3.21818	0.	HOLE	1	-4.13766	10.57402	0.
HOLE	1	-7.81558	3.21818	0.	HOLE	1	-5.05714	10.57402	0.
HOLE	1	-8.73506	3.21818	0.	HOLE	1	-5.97662	10.57402	0.
HOLE	1	-9.65454	3.21818	0.	HOLE	1	-6.89610	10.57402	0.
HOLE	1	-10.57402	3.21818	0.	HOLE	1	-7.81558	10.57402	0.
HOLE	1	-0.45974	4.13766	0.	HOLE	1	-8.73506	10.57402	0.
HOLE	1	-1.37922	4.13766	0.	HOLE	1	-9.65454	10.57402	0.
HOLE	1	-2.29870	4.13766	0.	HOLE	1	-10.57402	10.57402	0.
HOLE	1	-3.21818	4.13766	0.	HOLE	3	-11.95324	0.91948	0.
HOLE	1	-4.13766	4.13766	0.	HOLE	3	-13.79220	0.91948	0.
HOLE	1	-5.05714	4.13766	0.	HOLE	3	-15.63116	0.91948	0.
HOLE	1	-5.97662	4.13766	0.	HOLE	3	-17.47012	0.91948	0.
HOLE	1	-6.89610	4.13766	0.	HOLE	3	-19.30908	0.91948	0.
HOLE	1	-7.81558	4.13766	0.	HOLE	3	-21.14804	0.91948	0.
HOLE	1	-8.73506	4.13766	0.					

Appendix E Benchmark Model Inputs

HOLE	3	-22.98700	0.91948	0.	HOLE	3	-2.75844	15.63116	0.
HOLE	3	-24.82596	0.91948	0.	HOLE	3	-4.59740	15.63116	0.
HOLE	3	-26.66492	0.91948	0.	HOLE	3	-6.43636	15.63116	0.
HOLE	3	-28.50388	0.91948	0.	HOLE	3	-8.27532	15.63116	0.
HOLE	3	-30.34284	0.91948	0.	HOLE	3	-10.11428	15.63116	0.
HOLE	3	-11.95324	2.75844	0.	HOLE	3	-11.95324	15.63116	0.
HOLE	3	-13.79220	2.75844	0.	HOLE	3	-13.79220	15.63116	0.
HOLE	3	-15.63116	2.75844	0.	HOLE	3	-15.63116	15.63116	0.
HOLE	3	-17.47012	2.75844	0.	HOLE	3	-17.47012	15.63116	0.
HOLE	3	-19.30908	2.75844	0.	HOLE	3	-19.30908	15.63116	0.
HOLE	3	-21.14804	2.75844	0.	HOLE	3	-21.14804	15.63116	0.
HOLE	3	-22.98700	2.75844	0.	HOLE	3	-22.98700	15.63116	0.
HOLE	3	-24.82596	2.75844	0.	HOLE	3	-24.82596	15.63116	0.
HOLE	3	-26.66492	2.75844	0.	HOLE	3	-26.66492	15.63116	0.
HOLE	3	-28.50388	2.75844	0.	HOLE	3	-28.50388	15.63116	0.
HOLE	3	-30.34284	2.75844	0.	HOLE	3	-30.34284	15.63116	0.
HOLE	3	-11.95324	4.59740	0.	HOLE	3	-0.91948	17.47012	0.
HOLE	3	-13.79220	4.59740	0.	HOLE	3	-2.75844	17.47012	0.
HOLE	3	-15.63116	4.59740	0.	HOLE	3	-4.59740	17.47012	0.
HOLE	3	-17.47012	4.59740	0.	HOLE	3	-6.43636	17.47012	0.
HOLE	3	-19.30908	4.59740	0.	HOLE	3	-8.27532	17.47012	0.
HOLE	3	-21.14804	4.59740	0.	HOLE	3	-10.11428	17.47012	0.
HOLE	3	-22.98700	4.59740	0.	HOLE	3	-11.95324	17.47012	0.
HOLE	3	-24.82596	4.59740	0.	HOLE	3	-13.79220	17.47012	0.
HOLE	3	-26.66492	4.59740	0.	HOLE	3	-15.63116	17.47012	0.
HOLE	3	-28.50388	4.59740	0.	HOLE	3	-17.47012	17.47012	0.
HOLE	3	-30.34284	4.59740	0.	HOLE	3	-19.30908	17.47012	0.
HOLE	3	-11.95324	6.43636	0.	HOLE	3	-21.14804	17.47012	0.
HOLE	3	-13.79220	6.43636	0.	HOLE	3	-22.98700	17.47012	0.
HOLE	3	-15.63116	6.43636	0.	HOLE	3	-24.82596	17.47012	0.
HOLE	3	-17.47012	6.43636	0.	HOLE	3	-26.66492	17.47012	0.
HOLE	3	-19.30908	6.43636	0.	HOLE	3	-28.50388	17.47012	0.
HOLE	3	-21.14804	6.43636	0.	HOLE	3	-30.34284	17.47012	0.
HOLE	3	-22.98700	6.43636	0.	HOLE	3	-0.91948	19.30908	0.
HOLE	3	-24.82596	6.43636	0.	HOLE	3	-2.75844	19.30908	0.
HOLE	3	-26.66492	6.43636	0.	HOLE	3	-4.59740	19.30908	0.
HOLE	3	-28.50388	6.43636	0.	HOLE	3	-6.43636	19.30908	0.
HOLE	3	-30.34284	6.43636	0.	HOLE	3	-8.27532	19.30908	0.
HOLE	3	-11.95324	8.27532	0.	HOLE	3	-10.11428	19.30908	0.
HOLE	3	-13.79220	8.27532	0.	HOLE	3	-11.95324	19.30908	0.
HOLE	3	-15.63116	8.27532	0.	HOLE	3	-13.79220	19.30908	0.
HOLE	3	-17.47012	8.27532	0.	HOLE	3	-15.63116	19.30908	0.
HOLE	3	-19.30908	8.27532	0.	HOLE	3	-17.47012	19.30908	0.
HOLE	3	-21.14804	8.27532	0.	HOLE	3	-19.30908	19.30908	0.
HOLE	3	-22.98700	8.27532	0.	HOLE	3	-21.14804	19.30908	0.
HOLE	3	-24.82596	8.27532	0.	HOLE	3	-22.98700	19.30908	0.
HOLE	3	-26.66492	8.27532	0.	HOLE	3	-24.82596	19.30908	0.
HOLE	3	-28.50388	8.27532	0.	HOLE	3	-26.66492	19.30908	0.
HOLE	3	-30.34284	8.27532	0.	HOLE	3	-28.50388	19.30908	0.
HOLE	3	-11.95324	10.11428	0.	HOLE	3	-30.34284	19.30908	0.
HOLE	3	-13.79220	10.11428	0.	HOLE	3	-0.91948	21.14804	0.
HOLE	3	-15.63116	10.11428	0.	HOLE	3	-2.75844	21.14804	0.
HOLE	3	-17.47012	10.11428	0.	HOLE	3	-4.59740	21.14804	0.
HOLE	3	-19.30908	10.11428	0.	HOLE	3	-6.43636	21.14804	0.
HOLE	3	-21.14804	10.11428	0.	HOLE	3	-8.27532	21.14804	0.
HOLE	3	-22.98700	10.11428	0.	HOLE	3	-10.11428	21.14804	0.
HOLE	3	-24.82596	10.11428	0.	HOLE	3	-11.95324	21.14804	0.
HOLE	3	-26.66492	10.11428	0.	HOLE	3	-13.79220	21.14804	0.
HOLE	3	-28.50388	10.11428	0.	HOLE	3	-15.63116	21.14804	0.
HOLE	3	-30.34284	10.11428	0.	HOLE	3	-17.47012	21.14804	0.
HOLE	3	-0.91948	11.95324	0.	HOLE	3	-19.30908	21.14804	0.
HOLE	3	-2.75844	11.95324	0.	HOLE	3	-21.14804	21.14804	0.
HOLE	3	-4.59740	11.95324	0.	HOLE	3	-22.98700	21.14804	0.
HOLE	3	-6.43636	11.95324	0.	HOLE	3	-24.82596	21.14804	0.
HOLE	3	-8.27532	11.95324	0.	HOLE	3	-26.66492	21.14804	0.
HOLE	3	-10.11428	11.95324	0.	HOLE	3	-28.50388	21.14804	0.
HOLE	3	-11.95324	11.95324	0.	HOLE	3	-30.34284	21.14804	0.
HOLE	3	-13.79220	11.95324	0.	HOLE	3	-0.91948	22.98700	0.
HOLE	3	-15.63116	11.95324	0.	HOLE	3	-2.75844	22.98700	0.
HOLE	3	-17.47012	11.95324	0.	HOLE	3	-4.59740	22.98700	0.
HOLE	3	-19.30908	11.95324	0.	HOLE	3	-6.43636	22.98700	0.
HOLE	3	-21.14804	11.95324	0.	HOLE	3	-8.27532	22.98700	0.
HOLE	3	-22.98700	11.95324	0.	HOLE	3	-10.11428	22.98700	0.
HOLE	3	-24.82596	11.95324	0.	HOLE	3	-11.95324	22.98700	0.
HOLE	3	-26.66492	11.95324	0.	HOLE	3	-13.79220	22.98700	0.
HOLE	3	-28.50388	11.95324	0.	HOLE	3	-15.63116	22.98700	0.
HOLE	3	-30.34284	11.95324	0.	HOLE	3	-17.47012	22.98700	0.
HOLE	3	-0.91948	13.79220	0.	HOLE	3	-19.30908	22.98700	0.
HOLE	3	-2.75844	13.79220	0.	HOLE	3	-21.14804	22.98700	0.
HOLE	3	-4.59740	13.79220	0.	HOLE	3	-22.98700	22.98700	0.
HOLE	3	-6.43636	13.79220	0.	HOLE	3	-24.82596	22.98700	0.
HOLE	3	-8.27532	13.79220	0.	HOLE	3	-26.66492	22.98700	0.
HOLE	3	-10.11428	13.79220	0.	HOLE	3	-28.50388	22.98700	0.
HOLE	3	-11.95324	13.79220	0.	HOLE	3	-30.34284	22.98700	0.
HOLE	3	-13.79220	13.79220	0.	HOLE	3	-0.91948	24.82596	0.
HOLE	3	-15.63116	13.79220	0.	HOLE	3	-2.75844	24.82596	0.
HOLE	3	-17.47012	13.79220	0.	HOLE	3	-4.59740	24.82596	0.
HOLE	3	-19.30908	13.79220	0.	HOLE	3	-6.43636	24.82596	0.
HOLE	3	-21.14804	13.79220	0.	HOLE	3	-8.27532	24.82596	0.
HOLE	3	-22.98700	13.79220	0.	HOLE	3	-10.11428	24.82596	0.
HOLE	3	-24.82596	13.79220	0.	HOLE	3	-11.95324	24.82596	0.
HOLE	3	-26.66492	13.79220	0.	HOLE	3	-13.79220	24.82596	0.
HOLE	3	-28.50388	13.79220	0.	HOLE	3	-15.63116	24.82596	0.
HOLE	3	-30.34284	13.79220	0.	HOLE	3	-17.47012	24.82596	0.
HOLE	3	-0.91948	15.63116	0.	HOLE	3	-19.30908	24.82596	0.

HOLE	3	-21.14804	24.82596	0.	HOLE	1	-1.37922	-3.21818	0.
HOLE	3	-22.98700	24.82596	0.	HOLE	1	-2.29870	-3.21818	0.
HOLE	3	-24.82596	24.82596	0.	HOLE	1	-3.21818	-3.21818	0.
HOLE	3	-26.66492	24.82596	0.	HOLE	1	-4.13766	-3.21818	0.
HOLE	3	-28.50388	24.82596	0.	HOLE	1	-5.05714	-3.21818	0.
HOLE	3	-30.34284	24.82596	0.	HOLE	1	-5.97662	-3.21818	0.
HOLE	3	-0.91948	26.66492	0.	HOLE	1	-6.89610	-3.21818	0.
HOLE	3	-2.75844	26.66492	0.	HOLE	1	-7.81558	-3.21818	0.
HOLE	3	-4.59740	26.66492	0.	HOLE	1	-8.73506	-3.21818	0.
HOLE	3	-6.43636	26.66492	0.	HOLE	1	-9.65454	-3.21818	0.
HOLE	3	-8.27532	26.66492	0.	HOLE	1	-10.57402	-3.21818	0.
HOLE	3	-10.11428	26.66492	0.	HOLE	1	-0.45974	-4.13766	0.
HOLE	3	-11.95324	26.66492	0.	HOLE	1	-1.37922	-4.13766	0.
HOLE	3	-13.79220	26.66492	0.	HOLE	1	-2.29870	-4.13766	0.
HOLE	3	-15.63116	26.66492	0.	HOLE	1	-3.21818	-4.13766	0.
HOLE	3	-17.47012	26.66492	0.	HOLE	1	-4.13766	-4.13766	0.
HOLE	3	-19.30908	26.66492	0.	HOLE	1	-5.05714	-4.13766	0.
HOLE	3	-21.14804	26.66492	0.	HOLE	1	-5.97662	-4.13766	0.
HOLE	3	-22.98700	26.66492	0.	HOLE	1	-6.89610	-4.13766	0.
HOLE	3	-24.82596	26.66492	0.	HOLE	1	-7.81558	-4.13766	0.
HOLE	3	-26.66492	26.66492	0.	HOLE	1	-8.73506	-4.13766	0.
HOLE	3	-28.50388	26.66492	0.	HOLE	1	-9.65454	-4.13766	0.
HOLE	3	-30.34284	26.66492	0.	HOLE	1	-10.57402	-4.13766	0.
HOLE	3	-0.91948	28.50388	0.	HOLE	1	-0.45974	-5.05714	0.
HOLE	3	-2.75844	28.50388	0.	HOLE	1	-1.37922	-5.05714	0.
HOLE	3	-4.59740	28.50388	0.	HOLE	1	-2.29870	-5.05714	0.
HOLE	3	-6.43636	28.50388	0.	HOLE	1	-3.21818	-5.05714	0.
HOLE	3	-8.27532	28.50388	0.	HOLE	1	-4.13766	-5.05714	0.
HOLE	3	-10.11428	28.50388	0.	HOLE	1	-5.05714	-5.05714	0.
HOLE	3	-11.95324	28.50388	0.	HOLE	1	-5.97662	-5.05714	0.
HOLE	3	-13.79220	28.50388	0.	HOLE	1	-6.89610	-5.05714	0.
HOLE	3	-15.63116	28.50388	0.	HOLE	1	-7.81558	-5.05714	0.
HOLE	3	-17.47012	28.50388	0.	HOLE	1	-8.73506	-5.05714	0.
HOLE	3	-19.30908	28.50388	0.	HOLE	1	-9.65454	-5.05714	0.
HOLE	3	-21.14804	28.50388	0.	HOLE	1	-10.57402	-5.05714	0.
HOLE	3	-22.98700	28.50388	0.	HOLE	1	-0.45974	-5.97662	0.
HOLE	3	-24.82596	28.50388	0.	HOLE	1	-1.37922	-5.97662	0.
HOLE	3	-26.66492	28.50388	0.	HOLE	1	-2.29870	-5.97662	0.
HOLE	3	-28.50388	28.50388	0.	HOLE	1	-3.21818	-5.97662	0.
HOLE	3	-30.34284	28.50388	0.	HOLE	1	-4.13766	-5.97662	0.
HOLE	3	-0.91948	30.34284	0.	HOLE	1	-5.05714	-5.97662	0.
HOLE	3	-2.75844	30.34284	0.	HOLE	1	-5.97662	-5.97662	0.
HOLE	3	-4.59740	30.34284	0.	HOLE	1	-6.89610	-5.97662	0.
HOLE	3	-6.43636	30.34284	0.	HOLE	1	-7.81558	-5.97662	0.
HOLE	3	-8.27532	30.34284	0.	HOLE	1	-8.73506	-5.97662	0.
HOLE	3	-10.11428	30.34284	0.	HOLE	1	-9.65454	-5.97662	0.
HOLE	3	-11.95324	30.34284	0.	HOLE	1	-10.57402	-5.97662	0.
HOLE	3	-13.79220	30.34284	0.	HOLE	1	-0.45974	-6.89610	0.
HOLE	3	-15.63116	30.34284	0.	HOLE	1	-1.37922	-6.89610	0.
HOLE	3	-17.47012	30.34284	0.	HOLE	1	-2.29870	-6.89610	0.
HOLE	3	-19.30908	30.34284	0.	HOLE	1	-3.21818	-6.89610	0.
HOLE	3	-21.14804	30.34284	0.	HOLE	1	-4.13766	-6.89610	0.
HOLE	3	-22.98700	30.34284	0.	HOLE	1	-5.05714	-6.89610	0.
HOLE	3	-24.82596	30.34284	0.	HOLE	1	-5.97662	-6.89610	0.
HOLE	3	-26.66492	30.34284	0.	HOLE	1	-6.89610	-6.89610	0.
HOLE	3	-28.50388	30.34284	0.	HOLE	1	-7.81558	-6.89610	0.
HOLE	3	-30.34284	30.34284	0.	HOLE	1	-8.73506	-6.89610	0.
COM=-x, -y quadrant from center out*					HOLE	1	-9.65454	-6.89610	0.
HOLE	1	-0.45974	-0.45974	0.	HOLE	1	-10.57402	-6.89610	0.
HOLE	1	-1.37922	-0.45974	0.	HOLE	1	-0.45974	-7.81558	0.
HOLE	1	-2.29870	-0.45974	0.	HOLE	1	-1.37922	-7.81558	0.
HOLE	1	-3.21818	-0.45974	0.	HOLE	1	-2.29870	-7.81558	0.
HOLE	1	-4.13766	-0.45974	0.	HOLE	1	-3.21818	-7.81558	0.
HOLE	1	-5.05714	-0.45974	0.	HOLE	1	-4.13766	-7.81558	0.
HOLE	1	-5.97662	-0.45974	0.	HOLE	1	-5.05714	-7.81558	0.
HOLE	1	-6.89610	-0.45974	0.	HOLE	1	-5.97662	-7.81558	0.
HOLE	1	-7.81558	-0.45974	0.	HOLE	1	-6.89610	-7.81558	0.
HOLE	1	-8.73506	-0.45974	0.	HOLE	1	-7.81558	-7.81558	0.
HOLE	1	-9.65454	-0.45974	0.	HOLE	1	-8.73506	-7.81558	0.
HOLE	1	-10.57402	-0.45974	0.	HOLE	1	-9.65454	-7.81558	0.
HOLE	1	-0.45974	-1.37922	0.	HOLE	1	-10.57402	-7.81558	0.
HOLE	1	-1.37922	-1.37922	0.	HOLE	1	-0.45974	-8.73506	0.
HOLE	1	-2.29870	-1.37922	0.	HOLE	1	-1.37922	-8.73506	0.
HOLE	1	-3.21818	-1.37922	0.	HOLE	1	-2.29870	-8.73506	0.
HOLE	1	-4.13766	-1.37922	0.	HOLE	1	-3.21818	-8.73506	0.
HOLE	1	-5.05714	-1.37922	0.	HOLE	1	-4.13766	-8.73506	0.
HOLE	1	-5.97662	-1.37922	0.	HOLE	1	-5.05714	-8.73506	0.
HOLE	1	-6.89610	-1.37922	0.	HOLE	1	-5.97662	-8.73506	0.
HOLE	1	-7.81558	-1.37922	0.	HOLE	1	-6.89610	-8.73506	0.
HOLE	1	-8.73506	-1.37922	0.	HOLE	1	-7.81558	-8.73506	0.
HOLE	1	-9.65454	-1.37922	0.	HOLE	1	-8.73506	-8.73506	0.
HOLE	1	-10.57402	-1.37922	0.	HOLE	1	-9.65454	-8.73506	0.
HOLE	1	-0.45974	-2.29870	0.	HOLE	1	-10.57402	-8.73506	0.
HOLE	1	-1.37922	-2.29870	0.	HOLE	1	-0.45974	-9.65454	0.
HOLE	1	-2.29870	-2.29870	0.	HOLE	1	-1.37922	-9.65454	0.
HOLE	1	-3.21818	-2.29870	0.	HOLE	1	-2.29870	-9.65454	0.
HOLE	1	-4.13766	-2.29870	0.	HOLE	1	-3.21818	-9.65454	0.
HOLE	1	-5.05714	-2.29870	0.	HOLE	1	-4.13766	-9.65454	0.
HOLE	1	-5.97662	-2.29870	0.	HOLE	1	-5.05714	-9.65454	0.
HOLE	1	-6.89610	-2.29870	0.	HOLE	1	-5.97662	-9.65454	0.
HOLE	1	-7.81558	-2.29870	0.	HOLE	1	-6.89610	-9.65454	0.
HOLE	1	-8.73506	-2.29870	0.	HOLE	1	-7.81558	-9.65454	0.
HOLE	1	-9.65454	-2.29870	0.	HOLE	1	-8.73506	-9.65454	0.
HOLE	1	-10.57402	-2.29870	0.	HOLE	1	-9.65454	-9.65454	0.
HOLE	1	-0.45974	-3.21818	0.	HOLE	1	-10.57402	-9.65454	0.

Appendix E Benchmark Model Inputs

HOLE	1	-0.45974	-10.57402	0.	HOLE	3	-0.91948	-13.79220	0.
HOLE	1	-1.37922	-10.57402	0.	HOLE	3	-2.75844	-13.79220	0.
HOLE	1	-2.29870	-10.57402	0.	HOLE	3	-4.59740	-13.79220	0.
HOLE	1	-3.21818	-10.57402	0.	HOLE	3	-6.43636	-13.79220	0.
HOLE	1	-4.13766	-10.57402	0.	HOLE	3	-8.27532	-13.79220	0.
HOLE	1	-5.05714	-10.57402	0.	HOLE	3	-10.11428	-13.79220	0.
HOLE	1	-5.97662	-10.57402	0.	HOLE	3	-11.95324	-13.79220	0.
HOLE	1	-6.89610	-10.57402	0.	HOLE	3	-13.79220	-13.79220	0.
HOLE	1	-7.81558	-10.57402	0.	HOLE	3	-15.63116	-13.79220	0.
HOLE	1	-8.73506	-10.57402	0.	HOLE	3	-17.47012	-13.79220	0.
HOLE	1	-9.65454	-10.57402	0.	HOLE	3	-19.30908	-13.79220	0.
HOLE	1	-10.57402	-10.57402	0.	HOLE	3	-21.14804	-13.79220	0.
HOLE	3	-11.95324	-0.91948	0.	HOLE	3	-22.98700	-13.79220	0.
HOLE	3	-13.79220	-0.91948	0.	HOLE	3	-24.82596	-13.79220	0.
HOLE	3	-15.63116	-0.91948	0.	HOLE	3	-26.66492	-13.79220	0.
HOLE	3	-17.47012	-0.91948	0.	HOLE	3	-28.50388	-13.79220	0.
HOLE	3	-19.30908	-0.91948	0.	HOLE	3	-30.34284	-13.79220	0.
HOLE	3	-21.14804	-0.91948	0.	HOLE	3	-0.91948	-15.63116	0.
HOLE	3	-22.98700	-0.91948	0.	HOLE	3	-2.75844	-15.63116	0.
HOLE	3	-24.82596	-0.91948	0.	HOLE	3	-4.59740	-15.63116	0.
HOLE	3	-26.66492	-0.91948	0.	HOLE	3	-6.43636	-15.63116	0.
HOLE	3	-28.50388	-0.91948	0.	HOLE	3	-8.27532	-15.63116	0.
HOLE	3	-30.34284	-0.91948	0.	HOLE	3	-10.11428	-15.63116	0.
HOLE	3	-11.95324	-2.75844	0.	HOLE	3	-11.95324	-15.63116	0.
HOLE	3	-13.79220	-2.75844	0.	HOLE	3	-13.79220	-15.63116	0.
HOLE	3	-15.63116	-2.75844	0.	HOLE	3	-15.63116	-15.63116	0.
HOLE	3	-17.47012	-2.75844	0.	HOLE	3	-17.47012	-15.63116	0.
HOLE	3	-19.30908	-2.75844	0.	HOLE	3	-19.30908	-15.63116	0.
HOLE	3	-21.14804	-2.75844	0.	HOLE	3	-21.14804	-15.63116	0.
HOLE	3	-22.98700	-2.75844	0.	HOLE	3	-22.98700	-15.63116	0.
HOLE	3	-24.82596	-2.75844	0.	HOLE	3	-24.82596	-15.63116	0.
HOLE	3	-26.66492	-2.75844	0.	HOLE	3	-26.66492	-15.63116	0.
HOLE	3	-28.50388	-2.75844	0.	HOLE	3	-28.50388	-15.63116	0.
HOLE	3	-30.34284	-2.75844	0.	HOLE	3	-30.34284	-15.63116	0.
HOLE	3	-11.95324	-4.59740	0.	HOLE	3	-0.91948	-17.47012	0.
HOLE	3	-13.79220	-4.59740	0.	HOLE	3	-2.75844	-17.47012	0.
HOLE	3	-15.63116	-4.59740	0.	HOLE	3	-4.59740	-17.47012	0.
HOLE	3	-17.47012	-4.59740	0.	HOLE	3	-6.43636	-17.47012	0.
HOLE	3	-19.30908	-4.59740	0.	HOLE	3	-8.27532	-17.47012	0.
HOLE	3	-21.14804	-4.59740	0.	HOLE	3	-10.11428	-17.47012	0.
HOLE	3	-22.98700	-4.59740	0.	HOLE	3	-11.95324	-17.47012	0.
HOLE	3	-24.82596	-4.59740	0.	HOLE	3	-13.79220	-17.47012	0.
HOLE	3	-26.66492	-4.59740	0.	HOLE	3	-15.63116	-17.47012	0.
HOLE	3	-28.50388	-4.59740	0.	HOLE	3	-17.47012	-17.47012	0.
HOLE	3	-30.34284	-4.59740	0.	HOLE	3	-19.30908	-17.47012	0.
HOLE	3	-11.95324	-6.43636	0.	HOLE	3	-21.14804	-17.47012	0.
HOLE	3	-13.79220	-6.43636	0.	HOLE	3	-22.98700	-17.47012	0.
HOLE	3	-15.63116	-6.43636	0.	HOLE	3	-24.82596	-17.47012	0.
HOLE	3	-17.47012	-6.43636	0.	HOLE	3	-26.66492	-17.47012	0.
HOLE	3	-19.30908	-6.43636	0.	HOLE	3	-28.50388	-17.47012	0.
HOLE	3	-21.14804	-6.43636	0.	HOLE	3	-30.34284	-17.47012	0.
HOLE	3	-22.98700	-6.43636	0.	HOLE	3	-0.91948	-19.30908	0.
HOLE	3	-24.82596	-6.43636	0.	HOLE	3	-2.75844	-19.30908	0.
HOLE	3	-26.66492	-6.43636	0.	HOLE	3	-4.59740	-19.30908	0.
HOLE	3	-28.50388	-6.43636	0.	HOLE	3	-6.43636	-19.30908	0.
HOLE	3	-30.34284	-6.43636	0.	HOLE	3	-8.27532	-19.30908	0.
HOLE	3	-11.95324	-8.27532	0.	HOLE	3	-10.11428	-19.30908	0.
HOLE	3	-13.79220	-8.27532	0.	HOLE	3	-11.95324	-19.30908	0.
HOLE	3	-15.63116	-8.27532	0.	HOLE	3	-13.79220	-19.30908	0.
HOLE	3	-17.47012	-8.27532	0.	HOLE	3	-15.63116	-19.30908	0.
HOLE	3	-19.30908	-8.27532	0.	HOLE	3	-17.47012	-19.30908	0.
HOLE	3	-21.14804	-8.27532	0.	HOLE	3	-19.30908	-19.30908	0.
HOLE	3	-22.98700	-8.27532	0.	HOLE	3	-21.14804	-19.30908	0.
HOLE	3	-24.82596	-8.27532	0.	HOLE	3	-22.98700	-19.30908	0.
HOLE	3	-26.66492	-8.27532	0.	HOLE	3	-24.82596	-19.30908	0.
HOLE	3	-28.50388	-8.27532	0.	HOLE	3	-26.66492	-19.30908	0.
HOLE	3	-30.34284	-8.27532	0.	HOLE	3	-28.50388	-19.30908	0.
HOLE	3	-11.95324	-10.11428	0.	HOLE	3	-30.34284	-19.30908	0.
HOLE	3	-13.79220	-10.11428	0.	HOLE	3	-0.91948	-21.14804	0.
HOLE	3	-15.63116	-10.11428	0.	HOLE	3	-2.75844	-21.14804	0.
HOLE	3	-17.47012	-10.11428	0.	HOLE	3	-4.59740	-21.14804	0.
HOLE	3	-19.30908	-10.11428	0.	HOLE	3	-6.43636	-21.14804	0.
HOLE	3	-21.14804	-10.11428	0.	HOLE	3	-8.27532	-21.14804	0.
HOLE	3	-22.98700	-10.11428	0.	HOLE	3	-10.11428	-21.14804	0.
HOLE	3	-24.82596	-10.11428	0.	HOLE	3	-11.95324	-21.14804	0.
HOLE	3	-26.66492	-10.11428	0.	HOLE	3	-13.79220	-21.14804	0.
HOLE	3	-28.50388	-10.11428	0.	HOLE	3	-15.63116	-21.14804	0.
HOLE	3	-30.34284	-10.11428	0.	HOLE	3	-17.47012	-21.14804	0.
HOLE	3	-0.91948	-11.95324	0.	HOLE	3	-19.30908	-21.14804	0.
HOLE	3	-2.75844	-11.95324	0.	HOLE	3	-21.14804	-21.14804	0.
HOLE	3	-4.59740	-11.95324	0.	HOLE	3	-22.98700	-21.14804	0.
HOLE	3	-6.43636	-11.95324	0.	HOLE	3	-24.82596	-21.14804	0.
HOLE	3	-8.27532	-11.95324	0.	HOLE	3	-26.66492	-21.14804	0.
HOLE	3	-10.11428	-11.95324	0.	HOLE	3	-28.50388	-21.14804	0.
HOLE	3	-11.95324	-11.95324	0.	HOLE	3	-30.34284	-21.14804	0.
HOLE	3	-13.79220	-11.95324	0.	HOLE	3	-0.91948	-22.98700	0.
HOLE	3	-15.63116	-11.95324	0.	HOLE	3	-2.75844	-22.98700	0.
HOLE	3	-17.47012	-11.95324	0.	HOLE	3	-4.59740	-22.98700	0.
HOLE	3	-19.30908	-11.95324	0.	HOLE	3	-6.43636	-22.98700	0.
HOLE	3	-21.14804	-11.95324	0.	HOLE	3	-8.27532	-22.98700	0.
HOLE	3	-22.98700	-11.95324	0.	HOLE	3	-10.11428	-22.98700	0.
HOLE	3	-24.82596	-11.95324	0.	HOLE	3	-11.95324	-22.98700	0.
HOLE	3	-26.66492	-11.95324	0.	HOLE	3	-13.79220	-22.98700	0.
HOLE	3	-28.50388	-11.95324	0.	HOLE	3	-15.63116	-22.98700	0.
HOLE	3	-30.34284	-11.95324	0.	HOLE	3	-17.47012	-22.98700	0.

HOLE	3	-19.30908	-22.98700	0.	HOLE	1	6.89610	-1.37922	0.
HOLE	3	-21.14804	-22.98700	0.	HOLE	1	7.81558	-1.37922	0.
HOLE	3	-22.98700	-22.98700	0.	HOLE	1	8.73506	-1.37922	0.
HOLE	3	-24.82596	-22.98700	0.	HOLE	1	9.65454	-1.37922	0.
HOLE	3	-26.66492	-22.98700	0.	HOLE	1	10.57402	-1.37922	0.
HOLE	3	-28.50388	-22.98700	0.	HOLE	1	0.45974	-2.29870	0.
HOLE	3	-30.34284	-22.98700	0.	HOLE	1	1.37922	-2.29870	0.
HOLE	3	-0.91948	-24.82596	0.	HOLE	1	2.29870	-2.29870	0.
HOLE	3	-2.75844	-24.82596	0.	HOLE	1	3.21818	-2.29870	0.
HOLE	3	-4.59740	-24.82596	0.	HOLE	1	4.13766	-2.29870	0.
HOLE	3	-6.43636	-24.82596	0.	HOLE	1	5.05714	-2.29870	0.
HOLE	3	-8.27532	-24.82596	0.	HOLE	1	5.97662	-2.29870	0.
HOLE	3	-10.11428	-24.82596	0.	HOLE	1	6.89610	-2.29870	0.
HOLE	3	-11.95324	-24.82596	0.	HOLE	1	7.81558	-2.29870	0.
HOLE	3	-13.79220	-24.82596	0.	HOLE	1	8.73506	-2.29870	0.
HOLE	3	-15.63116	-24.82596	0.	HOLE	1	9.65454	-2.29870	0.
HOLE	3	-17.47012	-24.82596	0.	HOLE	1	10.57402	-2.29870	0.
HOLE	3	-19.30908	-24.82596	0.	HOLE	1	0.45974	-3.21818	0.
HOLE	3	-21.14804	-24.82596	0.	HOLE	1	1.37922	-3.21818	0.
HOLE	3	-22.98700	-24.82596	0.	HOLE	1	2.29870	-3.21818	0.
HOLE	3	-24.82596	-24.82596	0.	HOLE	1	3.21818	-3.21818	0.
HOLE	3	-26.66492	-24.82596	0.	HOLE	1	4.13766	-3.21818	0.
HOLE	3	-28.50388	-24.82596	0.	HOLE	1	5.05714	-3.21818	0.
HOLE	3	-30.34284	-24.82596	0.	HOLE	1	5.97662	-3.21818	0.
HOLE	3	-0.91948	-26.66492	0.	HOLE	1	6.89610	-3.21818	0.
HOLE	3	-2.75844	-26.66492	0.	HOLE	1	7.81558	-3.21818	0.
HOLE	3	-4.59740	-26.66492	0.	HOLE	1	8.73506	-3.21818	0.
HOLE	3	-6.43636	-26.66492	0.	HOLE	1	9.65454	-3.21818	0.
HOLE	3	-8.27532	-26.66492	0.	HOLE	1	10.57402	-3.21818	0.
HOLE	3	-10.11428	-26.66492	0.	HOLE	1	0.45974	-4.13766	0.
HOLE	3	-11.95324	-26.66492	0.	HOLE	1	1.37922	-4.13766	0.
HOLE	3	-13.79220	-26.66492	0.	HOLE	1	2.29870	-4.13766	0.
HOLE	3	-15.63116	-26.66492	0.	HOLE	1	3.21818	-4.13766	0.
HOLE	3	-17.47012	-26.66492	0.	HOLE	1	4.13766	-4.13766	0.
HOLE	3	-19.30908	-26.66492	0.	HOLE	1	5.05714	-4.13766	0.
HOLE	3	-21.14804	-26.66492	0.	HOLE	1	5.97662	-4.13766	0.
HOLE	3	-22.98700	-26.66492	0.	HOLE	1	6.89610	-4.13766	0.
HOLE	3	-24.82596	-26.66492	0.	HOLE	1	7.81558	-4.13766	0.
HOLE	3	-26.66492	-26.66492	0.	HOLE	1	8.73506	-4.13766	0.
HOLE	3	-28.50388	-26.66492	0.	HOLE	1	9.65454	-4.13766	0.
HOLE	3	-30.34284	-26.66492	0.	HOLE	1	10.57402	-4.13766	0.
HOLE	3	-0.91948	-28.50388	0.	HOLE	1	0.45974	-5.05714	0.
HOLE	3	-2.75844	-28.50388	0.	HOLE	1	1.37922	-5.05714	0.
HOLE	3	-4.59740	-28.50388	0.	HOLE	1	2.29870	-5.05714	0.
HOLE	3	-6.43636	-28.50388	0.	HOLE	1	3.21818	-5.05714	0.
HOLE	3	-8.27532	-28.50388	0.	HOLE	1	4.13766	-5.05714	0.
HOLE	3	-10.11428	-28.50388	0.	HOLE	1	5.05714	-5.05714	0.
HOLE	3	-11.95324	-28.50388	0.	HOLE	1	5.97662	-5.05714	0.
HOLE	3	-13.79220	-28.50388	0.	HOLE	1	6.89610	-5.05714	0.
HOLE	3	-15.63116	-28.50388	0.	HOLE	1	7.81558	-5.05714	0.
HOLE	3	-17.47012	-28.50388	0.	HOLE	1	8.73506	-5.05714	0.
HOLE	3	-19.30908	-28.50388	0.	HOLE	1	9.65454	-5.05714	0.
HOLE	3	-21.14804	-28.50388	0.	HOLE	1	10.57402	-5.05714	0.
HOLE	3	-22.98700	-28.50388	0.	HOLE	1	0.45974	-5.97662	0.
HOLE	3	-24.82596	-28.50388	0.	HOLE	1	1.37922	-5.97662	0.
HOLE	3	-26.66492	-28.50388	0.	HOLE	1	2.29870	-5.97662	0.
HOLE	3	-28.50388	-28.50388	0.	HOLE	1	3.21818	-5.97662	0.
HOLE	3	-30.34284	-28.50388	0.	HOLE	1	4.13766	-5.97662	0.
HOLE	3	-0.91948	-30.34284	0.	HOLE	1	5.05714	-5.97662	0.
HOLE	3	-2.75844	-30.34284	0.	HOLE	1	5.97662	-5.97662	0.
HOLE	3	-4.59740	-30.34284	0.	HOLE	1	6.89610	-5.97662	0.
HOLE	3	-6.43636	-30.34284	0.	HOLE	1	7.81558	-5.97662	0.
HOLE	3	-8.27532	-30.34284	0.	HOLE	1	8.73506	-5.97662	0.
HOLE	3	-10.11428	-30.34284	0.	HOLE	1	9.65454	-5.97662	0.
HOLE	3	-11.95324	-30.34284	0.	HOLE	1	10.57402	-5.97662	0.
HOLE	3	-13.79220	-30.34284	0.	HOLE	1	0.45974	-6.89610	0.
HOLE	3	-15.63116	-30.34284	0.	HOLE	1	1.37922	-6.89610	0.
HOLE	3	-17.47012	-30.34284	0.	HOLE	1	2.29870	-6.89610	0.
HOLE	3	-19.30908	-30.34284	0.	HOLE	1	3.21818	-6.89610	0.
HOLE	3	-21.14804	-30.34284	0.	HOLE	1	4.13766	-6.89610	0.
HOLE	3	-22.98700	-30.34284	0.	HOLE	1	5.05714	-6.89610	0.
HOLE	3	-24.82596	-30.34284	0.	HOLE	1	5.97662	-6.89610	0.
HOLE	3	-26.66492	-30.34284	0.	HOLE	1	6.89610	-6.89610	0.
HOLE	3	-28.50388	-30.34284	0.	HOLE	1	7.81558	-6.89610	0.
HOLE	3	-30.34284	-30.34284	0.	HOLE	1	8.73506	-6.89610	0.
COM=*+x,-y quadrant from center out*					HOLE	1	9.65454	-6.89610	0.
HOLE	1	0.45974	-0.45974	0.	HOLE	1	10.57402	-6.89610	0.
HOLE	1	1.37922	-0.45974	0.	HOLE	1	0.45974	-7.81558	0.
HOLE	1	2.29870	-0.45974	0.	HOLE	1	1.37922	-7.81558	0.
HOLE	1	3.21818	-0.45974	0.	HOLE	1	2.29870	-7.81558	0.
HOLE	1	4.13766	-0.45974	0.	HOLE	1	3.21818	-7.81558	0.
HOLE	1	5.05714	-0.45974	0.	HOLE	1	4.13766	-7.81558	0.
HOLE	1	5.97662	-0.45974	0.	HOLE	1	5.05714	-7.81558	0.
HOLE	1	6.89610	-0.45974	0.	HOLE	1	5.97662	-7.81558	0.
HOLE	1	7.81558	-0.45974	0.	HOLE	1	6.89610	-7.81558	0.
HOLE	1	8.73506	-0.45974	0.	HOLE	1	7.81558	-7.81558	0.
HOLE	1	9.65454	-0.45974	0.	HOLE	1	8.73506	-7.81558	0.
HOLE	1	10.57402	-0.45974	0.	HOLE	1	9.65454	-7.81558	0.
HOLE	1	0.45974	-1.37922	0.	HOLE	1	10.57402	-7.81558	0.
HOLE	1	1.37922	-1.37922	0.	HOLE	1	0.45974	-8.73506	0.
HOLE	1	2.29870	-1.37922	0.	HOLE	1	1.37922	-8.73506	0.
HOLE	1	3.21818	-1.37922	0.	HOLE	1	2.29870	-8.73506	0.
HOLE	1	4.13766	-1.37922	0.	HOLE	1	3.21818	-8.73506	0.
HOLE	1	5.05714	-1.37922	0.	HOLE	1	4.13766	-8.73506	0.
HOLE	1	5.97662	-1.37922	0.	HOLE	1	5.05714	-8.73506	0.

Appendix E Benchmark Model Inputs

HOLE	1	5.97662	-8.73506	0.	HOLE	3	30.34284	-10.11428	0.
HOLE	1	6.89610	-8.73506	0.	HOLE	3	0.91948	-11.95324	0.
HOLE	1	7.81558	-8.73506	0.	HOLE	3	2.75844	-11.95324	0.
HOLE	1	8.73506	-8.73506	0.	HOLE	3	4.59740	-11.95324	0.
HOLE	1	9.65454	-8.73506	0.	HOLE	3	6.43636	-11.95324	0.
HOLE	1	10.57402	-8.73506	0.	HOLE	3	8.27532	-11.95324	0.
HOLE	1	0.45974	-9.65454	0.	HOLE	3	10.11428	-11.95324	0.
HOLE	1	1.37922	-9.65454	0.	HOLE	3	11.95324	-11.95324	0.
HOLE	1	2.29870	-9.65454	0.	HOLE	3	13.79220	-11.95324	0.
HOLE	1	3.21818	-9.65454	0.	HOLE	3	15.63116	-11.95324	0.
HOLE	1	4.13766	-9.65454	0.	HOLE	3	17.47012	-11.95324	0.
HOLE	1	5.05714	-9.65454	0.	HOLE	3	19.30908	-11.95324	0.
HOLE	1	5.97662	-9.65454	0.	HOLE	3	21.14804	-11.95324	0.
HOLE	1	6.89610	-9.65454	0.	HOLE	3	22.98700	-11.95324	0.
HOLE	1	7.81558	-9.65454	0.	HOLE	3	24.82596	-11.95324	0.
HOLE	1	8.73506	-9.65454	0.	HOLE	3	26.66492	-11.95324	0.
HOLE	1	9.65454	-9.65454	0.	HOLE	3	28.50388	-11.95324	0.
HOLE	1	10.57402	-9.65454	0.	HOLE	3	30.34284	-11.95324	0.
HOLE	1	0.45974	-10.57402	0.	HOLE	3	0.91948	-13.79220	0.
HOLE	1	1.37922	-10.57402	0.	HOLE	3	2.75844	-13.79220	0.
HOLE	1	2.29870	-10.57402	0.	HOLE	3	4.59740	-13.79220	0.
HOLE	1	3.21818	-10.57402	0.	HOLE	3	6.43636	-13.79220	0.
HOLE	1	4.13766	-10.57402	0.	HOLE	3	8.27532	-13.79220	0.
HOLE	1	5.05714	-10.57402	0.	HOLE	3	10.11428	-13.79220	0.
HOLE	1	5.97662	-10.57402	0.	HOLE	3	11.95324	-13.79220	0.
HOLE	1	6.89610	-10.57402	0.	HOLE	3	13.79220	-13.79220	0.
HOLE	1	7.81558	-10.57402	0.	HOLE	3	15.63116	-13.79220	0.
HOLE	1	8.73506	-10.57402	0.	HOLE	3	17.47012	-13.79220	0.
HOLE	1	9.65454	-10.57402	0.	HOLE	3	19.30908	-13.79220	0.
HOLE	1	10.57402	-10.57402	0.	HOLE	3	21.14804	-13.79220	0.
HOLE	3	11.95324	-0.91948	0.	HOLE	3	22.98700	-13.79220	0.
HOLE	3	13.79220	-0.91948	0.	HOLE	3	24.82596	-13.79220	0.
HOLE	3	15.63116	-0.91948	0.	HOLE	3	26.66492	-13.79220	0.
HOLE	3	17.47012	-0.91948	0.	HOLE	3	28.50388	-13.79220	0.
HOLE	3	19.30908	-0.91948	0.	HOLE	3	30.34284	-13.79220	0.
HOLE	3	21.14804	-0.91948	0.	HOLE	3	0.91948	-15.63116	0.
HOLE	3	22.98700	-0.91948	0.	HOLE	3	2.75844	-15.63116	0.
HOLE	3	24.82596	-0.91948	0.	HOLE	3	4.59740	-15.63116	0.
HOLE	3	26.66492	-0.91948	0.	HOLE	3	6.43636	-15.63116	0.
HOLE	3	28.50388	-0.91948	0.	HOLE	3	8.27532	-15.63116	0.
HOLE	3	30.34284	-0.91948	0.	HOLE	3	10.11428	-15.63116	0.
HOLE	3	11.95324	-2.75844	0.	HOLE	3	11.95324	-15.63116	0.
HOLE	3	13.79220	-2.75844	0.	HOLE	3	13.79220	-15.63116	0.
HOLE	3	15.63116	-2.75844	0.	HOLE	3	15.63116	-15.63116	0.
HOLE	3	17.47012	-2.75844	0.	HOLE	3	17.47012	-15.63116	0.
HOLE	3	19.30908	-2.75844	0.	HOLE	3	19.30908	-15.63116	0.
HOLE	3	21.14804	-2.75844	0.	HOLE	3	21.14804	-15.63116	0.
HOLE	3	22.98700	-2.75844	0.	HOLE	3	22.98700	-15.63116	0.
HOLE	3	24.82596	-2.75844	0.	HOLE	3	24.82596	-15.63116	0.
HOLE	3	26.66492	-2.75844	0.	HOLE	3	26.66492	-15.63116	0.
HOLE	3	28.50388	-2.75844	0.	HOLE	3	28.50388	-15.63116	0.
HOLE	3	30.34284	-2.75844	0.	HOLE	3	30.34284	-15.63116	0.
HOLE	3	11.95324	-4.59740	0.	HOLE	3	0.91948	-17.47012	0.
HOLE	3	13.79220	-4.59740	0.	HOLE	3	2.75844	-17.47012	0.
HOLE	3	15.63116	-4.59740	0.	HOLE	3	4.59740	-17.47012	0.
HOLE	3	17.47012	-4.59740	0.	HOLE	3	6.43636	-17.47012	0.
HOLE	3	19.30908	-4.59740	0.	HOLE	3	8.27532	-17.47012	0.
HOLE	3	21.14804	-4.59740	0.	HOLE	3	10.11428	-17.47012	0.
HOLE	3	22.98700	-4.59740	0.	HOLE	3	11.95324	-17.47012	0.
HOLE	3	24.82596	-4.59740	0.	HOLE	3	13.79220	-17.47012	0.
HOLE	3	26.66492	-4.59740	0.	HOLE	3	15.63116	-17.47012	0.
HOLE	3	28.50388	-4.59740	0.	HOLE	3	17.47012	-17.47012	0.
HOLE	3	30.34284	-4.59740	0.	HOLE	3	19.30908	-17.47012	0.
HOLE	3	11.95324	-6.43636	0.	HOLE	3	21.14804	-17.47012	0.
HOLE	3	13.79220	-6.43636	0.	HOLE	3	22.98700	-17.47012	0.
HOLE	3	15.63116	-6.43636	0.	HOLE	3	24.82596	-17.47012	0.
HOLE	3	17.47012	-6.43636	0.	HOLE	3	26.66492	-17.47012	0.
HOLE	3	19.30908	-6.43636	0.	HOLE	3	28.50388	-17.47012	0.
HOLE	3	21.14804	-6.43636	0.	HOLE	3	30.34284	-17.47012	0.
HOLE	3	22.98700	-6.43636	0.	HOLE	3	0.91948	-19.30908	0.
HOLE	3	24.82596	-6.43636	0.	HOLE	3	2.75844	-19.30908	0.
HOLE	3	26.66492	-6.43636	0.	HOLE	3	4.59740	-19.30908	0.
HOLE	3	28.50388	-6.43636	0.	HOLE	3	6.43636	-19.30908	0.
HOLE	3	30.34284	-6.43636	0.	HOLE	3	8.27532	-19.30908	0.
HOLE	3	11.95324	-8.27532	0.	HOLE	3	10.11428	-19.30908	0.
HOLE	3	13.79220	-8.27532	0.	HOLE	3	11.95324	-19.30908	0.
HOLE	3	15.63116	-8.27532	0.	HOLE	3	13.79220	-19.30908	0.
HOLE	3	17.47012	-8.27532	0.	HOLE	3	15.63116	-19.30908	0.
HOLE	3	19.30908	-8.27532	0.	HOLE	3	17.47012	-19.30908	0.
HOLE	3	21.14804	-8.27532	0.	HOLE	3	19.30908	-19.30908	0.
HOLE	3	22.98700	-8.27532	0.	HOLE	3	21.14804	-19.30908	0.
HOLE	3	24.82596	-8.27532	0.	HOLE	3	22.98700	-19.30908	0.
HOLE	3	26.66492	-8.27532	0.	HOLE	3	24.82596	-19.30908	0.
HOLE	3	28.50388	-8.27532	0.	HOLE	3	26.66492	-19.30908	0.
HOLE	3	30.34284	-8.27532	0.	HOLE	3	28.50388	-19.30908	0.
HOLE	3	11.95324	-10.11428	0.	HOLE	3	30.34284	-19.30908	0.
HOLE	3	13.79220	-10.11428	0.	HOLE	3	0.91948	-21.14804	0.
HOLE	3	15.63116	-10.11428	0.	HOLE	3	2.75844	-21.14804	0.
HOLE	3	17.47012	-10.11428	0.	HOLE	3	4.59740	-21.14804	0.
HOLE	3	19.30908	-10.11428	0.	HOLE	3	6.43636	-21.14804	0.
HOLE	3	21.14804	-10.11428	0.	HOLE	3	8.27532	-21.14804	0.
HOLE	3	22.98700	-10.11428	0.	HOLE	3	10.11428	-21.14804	0.
HOLE	3	24.82596	-10.11428	0.	HOLE	3	11.95324	-21.14804	0.
HOLE	3	26.66492	-10.11428	0.	HOLE	3	13.79220	-21.14804	0.
HOLE	3	28.50388	-10.11428	0.	HOLE	3	15.63116	-21.14804	0.

HOLE	3	17.47012	-21.14804	0.	HOLE	3	26.66492	-26.66492	0.
HOLE	3	19.30908	-21.14804	0.	HOLE	3	28.50388	-26.66492	0.
HOLE	3	21.14804	-21.14804	0.	HOLE	3	30.34284	-26.66492	0.
HOLE	3	22.98700	-21.14804	0.	HOLE	3	0.91948	-28.50388	0.
HOLE	3	24.82596	-21.14804	0.	HOLE	3	2.75844	-28.50388	0.
HOLE	3	26.66492	-21.14804	0.	HOLE	3	4.59740	-28.50388	0.
HOLE	3	28.50388	-21.14804	0.	HOLE	3	6.43636	-28.50388	0.
HOLE	3	30.34284	-21.14804	0.	HOLE	3	8.27532	-28.50388	0.
HOLE	3	0.91948	-22.98700	0.	HOLE	3	10.11428	-28.50388	0.
HOLE	3	2.75844	-22.98700	0.	HOLE	3	11.95324	-28.50388	0.
HOLE	3	4.59740	-22.98700	0.	HOLE	3	13.79220	-28.50388	0.
HOLE	3	6.43636	-22.98700	0.	HOLE	3	15.63116	-28.50388	0.
HOLE	3	8.27532	-22.98700	0.	HOLE	3	17.47012	-28.50388	0.
HOLE	3	10.11428	-22.98700	0.	HOLE	3	19.30908	-28.50388	0.
HOLE	3	11.95324	-22.98700	0.	HOLE	3	21.14804	-28.50388	0.
HOLE	3	13.79220	-22.98700	0.	HOLE	3	22.98700	-28.50388	0.
HOLE	3	15.63116	-22.98700	0.	HOLE	3	24.82596	-28.50388	0.
HOLE	3	17.47012	-22.98700	0.	HOLE	3	26.66492	-28.50388	0.
HOLE	3	19.30908	-22.98700	0.	HOLE	3	28.50388	-28.50388	0.
HOLE	3	21.14804	-22.98700	0.	HOLE	3	30.34284	-28.50388	0.
HOLE	3	22.98700	-22.98700	0.	HOLE	3	0.91948	-30.34284	0.
HOLE	3	24.82596	-22.98700	0.	HOLE	3	2.75844	-30.34284	0.
HOLE	3	26.66492	-22.98700	0.	HOLE	3	4.59740	-30.34284	0.
HOLE	3	28.50388	-22.98700	0.	HOLE	3	6.43636	-30.34284	0.
HOLE	3	30.34284	-22.98700	0.	HOLE	3	8.27532	-30.34284	0.
HOLE	3	0.91948	-24.82596	0.	HOLE	3	10.11428	-30.34284	0.
HOLE	3	2.75844	-24.82596	0.	HOLE	3	11.95324	-30.34284	0.
HOLE	3	4.59740	-24.82596	0.	HOLE	3	13.79220	-30.34284	0.
HOLE	3	6.43636	-24.82596	0.	HOLE	3	15.63116	-30.34284	0.
HOLE	3	8.27532	-24.82596	0.	HOLE	3	17.47012	-30.34284	0.
HOLE	3	10.11428	-24.82596	0.	HOLE	3	19.30908	-30.34284	0.
HOLE	3	11.95324	-24.82596	0.	HOLE	3	21.14804	-30.34284	0.
HOLE	3	13.79220	-24.82596	0.	HOLE	3	22.98700	-30.34284	0.
HOLE	3	15.63116	-24.82596	0.	HOLE	3	24.82596	-30.34284	0.
HOLE	3	17.47012	-24.82596	0.	HOLE	3	26.66492	-30.34284	0.
HOLE	3	19.30908	-24.82596	0.	HOLE	3	28.50388	-30.34284	0.
HOLE	3	21.14804	-24.82596	0.	HOLE	3	30.34284	-30.34284	0.
HOLE	3	22.98700	-24.82596	0.	CUBOID	4	1	4P45.52	2P49.5301
HOLE	3	24.82596	-24.82596	0.	GLOBAL				
HOLE	3	26.66492	-24.82596	0.	UNIT 6				
HOLE	3	28.50388	-24.82596	0.	ARRAY	1	2R-45.52	-49.5301	
HOLE	3	30.34284	-24.82596	0.	REFLECTOR	4	2	4*3.1	2*0
HOLE	3	0.91948	-26.66492	0.					10
HOLE	3	2.75844	-26.66492	0.	END GEOM				
HOLE	3	4.59740	-26.66492	0.	READ ARRAY				
HOLE	3	6.43636	-26.66492	0.	NUX=1 NUY=1 NUZ=1 FILL F5 END FILL				
HOLE	3	8.27532	-26.66492	0.	END ARRAY				
HOLE	3	10.11428	-26.66492	0.	READ BIAS				
HOLE	3	11.95324	-26.66492	0.	ID=500 2 11				
HOLE	3	13.79220	-26.66492	0.	END BIAS				
HOLE	3	15.63116	-26.66492	0.	READ START				
HOLE	3	17.47012	-26.66492	0.	NST=1 XSM=-31 YSM=-31 ZSM=-19.05				
HOLE	3	19.30908	-26.66492	0.	XSP=31 YSP=31 ZSP=19.05				
HOLE	3	21.14804	-26.66492	0.	END START				
HOLE	3	22.98700	-26.66492	0.	END DATA				
HOLE	3	24.82596	-26.66492	0.	END				

E.2.2 Core SB-2, 238 Group ENDF/B-V

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=CSAS25 PARM=SIZE=200000
full LWBR SB-2 fuel rods, control blades, and 1ft water
reflector
238GROUPPNDP5 LATTICECELL
' mix 1 = 233UO2-ZrO2 Seed
O 1 0 5.4281-2 END
ZR 1 0 2.3194-2 END
U-232 1 0 1.3217-7 END
U-233 1 0 3.8411-3 END
U-234 1 0 6.1327-5 END
U-235 1 0 1.3048-7 END
U-236 1 0 1.2993-7 END
U-238 1 0 4.4061-5 END
' mix 2 = ThO2 blanket
O-16 2 0 4.3282-2 END
TH-232 2 0 2.1641-2 END
GD 2 5.28-6 END
' mix 3 = zirc-2 cladding etc, 6.56 g/cc, Ntot=4.3234-2
ZR 3 0 4.2537-2 END
CR 3 0 7.5977-5 END
FE 3 0 8.8422-5 END
NI 3 0 3.3656-5 END
SN 3 0.0135 END
' mix 4 = water, 0.9982 g/cc, Ntot=1.0010-1
H 4 0 6.6735-2 END
O 4 0 3.3368-2 END
' mix 5 = borated SS304 control blades, 7.92g/cc,
Ntot=8.9912-2
FE 5 0 5.9289-2 END
B-10 5 0 3.7488-3 END
C 5 0 1.5884-4 END
CR 5 0 1.7428-2 END
MN 5 0 8.6816-4 END
NI 5 0 7.5171-3 END
P 5 0 3.0797-5 END

S 5 0 2.2308-5 END
SI 5 0 8.4910-4 END
END COMP
SQUAREPITCH 0.91948 0.53594 1 4 0.64770 3 0.55880 0
END
MORE DATA RES=2 CYLINDER 0.62103
DAN(2)=0.197645 END
KENOV.A
READ PARAM
GEN=500 NPG=3000 NSK=50 TME=3000
FLX=YES FDN=YES FMP=YES NUB=YES RUN=YES
END PARAM
READ GEOM
UNIT 1
COM=*Seed rod in water*
CYLINDER 1 1 0.26797 2P19.05
CYLINDER 0 1 0.27940 2P19.05
CYLINDER 3 1 0.32385 2P26.4541
UNIT 3
COM=*blanket rod in water*
CYLINDER 2 1 0.62103 2P19.05
CYLINDER 0 1 0.63373 2P19.05
CYLINDER 3 1 0.72390 2P26.4541
UNIT 4
COM=*control blade in water*
CUBOID 5 1 2P3.81 2P0.0889 49.53
15.91
CUBOID 4 1 2P3.81 2P0.0889 2P49.53
UNIT 5
COM=*rod array with blades, use holes to handle all*
CYLINDER 4 1 48.12 2P49.5301
COM=*control blades*
HOLE 4 0. 5.51688 0.
HOLE 4 0. 1.83896 0.
HOLE 4 0. -1.83896 0.

```

Appendix E Benchmark Model Inputs

HOLE	4	0.	-5.51688	0.	HOLE	3	27.58440	0.	0.
COM=+x,+y	quadrant	from center	out*		HOLE	3	29.42336	0.	0.
HOLE	1	0.45974	0.45974	0.	HOLE	3	31.26232	0.	0.
HOLE	1	1.37922	0.45974	0.	HOLE	3	9.19480	1.83896	0.
HOLE	1	2.29870	0.45974	0.	HOLE	3	11.03376	1.83896	0.
HOLE	1	3.21818	0.45974	0.	HOLE	3	12.87272	1.83896	0.
HOLE	1	4.13766	0.45974	0.	HOLE	3	14.71168	1.83896	0.
HOLE	1	5.05714	0.45974	0.	HOLE	3	16.55064	1.83896	0.
HOLE	1	5.97662	0.45974	0.	HOLE	3	18.38960	1.83896	0.
HOLE	1	6.89610	0.45974	0.	HOLE	3	20.22856	1.83896	0.
HOLE	1	7.81558	0.45974	0.	HOLE	3	22.06752	1.83896	0.
HOLE	1	8.73506	0.45974	0.	HOLE	3	23.90648	1.83896	0.
HOLE	1	9.65454	0.45974	0.	HOLE	3	25.74544	1.83896	0.
HOLE	1	0.45974	1.37922	0.	HOLE	3	27.58440	1.83896	0.
HOLE	1	1.37922	1.37922	0.	HOLE	3	29.42336	1.83896	0.
HOLE	1	2.29870	1.37922	0.	HOLE	3	31.26232	1.83896	0.
HOLE	1	3.21818	1.37922	0.	HOLE	3	9.19480	3.67792	0.
HOLE	1	4.13766	1.37922	0.	HOLE	3	11.03376	3.67792	0.
HOLE	1	5.05714	1.37922	0.	HOLE	3	12.87272	3.67792	0.
HOLE	1	5.97662	1.37922	0.	HOLE	3	14.71168	3.67792	0.
HOLE	1	6.89610	1.37922	0.	HOLE	3	16.55064	3.67792	0.
HOLE	1	7.81558	1.37922	0.	HOLE	3	18.38960	3.67792	0.
HOLE	1	0.45974	2.29870	0.	HOLE	3	20.22856	3.67792	0.
HOLE	1	1.37922	2.29870	0.	HOLE	3	22.06752	3.67792	0.
HOLE	1	2.29870	2.29870	0.	HOLE	3	23.90648	3.67792	0.
HOLE	1	3.21818	2.29870	0.	HOLE	3	25.74544	3.67792	0.
HOLE	1	4.13766	2.29870	0.	HOLE	3	27.58440	3.67792	0.
HOLE	1	5.05714	2.29870	0.	HOLE	3	29.42336	3.67792	0.
HOLE	1	5.97662	2.29870	0.	HOLE	3	31.26232	3.67792	0.
HOLE	1	6.89610	2.29870	0.	HOLE	3	9.19480	5.51688	0.
HOLE	1	7.81558	2.29870	0.	HOLE	3	11.03376	5.51688	0.
HOLE	1	0.45974	3.21818	0.	HOLE	3	12.87272	5.51688	0.
HOLE	1	1.37922	3.21818	0.	HOLE	3	14.71168	5.51688	0.
HOLE	1	2.29870	3.21818	0.	HOLE	3	16.55064	5.51688	0.
HOLE	1	3.21818	3.21818	0.	HOLE	3	18.38960	5.51688	0.
HOLE	1	4.13766	3.21818	0.	HOLE	3	20.22856	5.51688	0.
HOLE	1	5.05714	3.21818	0.	HOLE	3	22.06752	5.51688	0.
HOLE	1	5.97662	3.21818	0.	HOLE	3	23.90648	5.51688	0.
HOLE	1	6.89610	3.21818	0.	HOLE	3	25.74544	5.51688	0.
HOLE	1	7.81558	3.21818	0.	HOLE	3	27.58440	5.51688	0.
HOLE	1	0.45974	4.13766	0.	HOLE	3	29.42336	5.51688	0.
HOLE	1	1.37922	4.13766	0.	HOLE	3	31.26232	5.51688	0.
HOLE	1	2.29870	4.13766	0.	HOLE	3	9.19480	7.35584	0.
HOLE	1	3.21818	4.13766	0.	HOLE	3	11.03376	7.35584	0.
HOLE	1	4.13766	4.13766	0.	HOLE	3	12.87272	7.35584	0.
HOLE	1	5.05714	4.13766	0.	HOLE	3	14.71168	7.35584	0.
HOLE	1	5.97662	4.13766	0.	HOLE	3	16.55064	7.35584	0.
HOLE	1	6.89610	4.13766	0.	HOLE	3	18.38960	7.35584	0.
HOLE	1	7.81558	4.13766	0.	HOLE	3	20.22856	7.35584	0.
HOLE	1	0.45974	5.05714	0.	HOLE	3	22.06752	7.35584	0.
HOLE	1	1.37922	5.05714	0.	HOLE	3	23.90648	7.35584	0.
HOLE	1	2.29870	5.05714	0.	HOLE	3	25.74544	7.35584	0.
HOLE	1	3.21818	5.05714	0.	HOLE	3	27.58440	7.35584	0.
HOLE	1	4.13766	5.05714	0.	HOLE	3	29.42336	7.35584	0.
HOLE	1	5.05714	5.05714	0.	HOLE	3	31.26232	7.35584	0.
HOLE	1	5.97662	5.05714	0.	HOLE	3	1.83896	9.19480	0.
HOLE	1	6.89610	5.05714	0.	HOLE	3	3.67792	9.19480	0.
HOLE	1	7.81558	5.05714	0.	HOLE	3	5.51688	9.19480	0.
HOLE	1	0.45974	5.97662	0.	HOLE	3	7.35584	9.19480	0.
HOLE	1	1.37922	5.97662	0.	HOLE	3	9.19480	9.19480	0.
HOLE	1	2.29870	5.97662	0.	HOLE	3	11.03376	9.19480	0.
HOLE	1	3.21818	5.97662	0.	HOLE	3	12.87272	9.19480	0.
HOLE	1	4.13766	5.97662	0.	HOLE	3	14.71168	9.19480	0.
HOLE	1	5.05714	5.97662	0.	HOLE	3	16.55064	9.19480	0.
HOLE	1	5.97662	5.97662	0.	HOLE	3	18.38960	9.19480	0.
HOLE	1	6.89610	5.97662	0.	HOLE	3	20.22856	9.19480	0.
HOLE	1	0.45974	6.89610	0.	HOLE	3	22.06752	9.19480	0.
HOLE	1	1.37922	6.89610	0.	HOLE	3	23.90648	9.19480	0.
HOLE	1	2.29870	6.89610	0.	HOLE	3	25.74544	9.19480	0.
HOLE	1	3.21818	6.89610	0.	HOLE	3	27.58440	9.19480	0.
HOLE	1	4.13766	6.89610	0.	HOLE	3	29.42336	9.19480	0.
HOLE	1	5.05714	6.89610	0.	HOLE	3	31.26232	9.19480	0.
HOLE	1	5.97662	6.89610	0.	HOLE	3	0.	11.03376	0.
HOLE	1	6.89610	6.89610	0.	HOLE	3	1.83896	11.03376	0.
HOLE	1	7.81558	6.89610	0.	HOLE	3	3.67792	11.03376	0.
HOLE	1	0.45974	7.81558	0.	HOLE	3	5.51688	11.03376	0.
HOLE	1	1.37922	7.81558	0.	HOLE	3	7.35584	11.03376	0.
HOLE	1	2.29870	7.81558	0.	HOLE	3	9.19480	11.03376	0.
HOLE	1	3.21818	7.81558	0.	HOLE	3	11.03376	11.03376	0.
HOLE	1	4.13766	7.81558	0.	HOLE	3	12.87272	11.03376	0.
HOLE	1	5.05714	7.81558	0.	HOLE	3	14.71168	11.03376	0.
HOLE	1	5.97662	7.81558	0.	HOLE	3	16.55064	11.03376	0.
HOLE	1	6.89610	7.81558	0.	HOLE	3	18.38960	11.03376	0.
HOLE	1	7.81558	7.81558	0.	HOLE	3	20.22856	11.03376	0.
HOLE	1	0.45974	8.73506	0.	HOLE	3	22.06752	11.03376	0.
HOLE	1	0.45974	9.65454	0.	HOLE	3	23.90648	11.03376	0.
HOLE	3	11.03376	0.	0.	HOLE	3	25.74544	11.03376	0.
HOLE	3	12.87272	0.	0.	HOLE	3	27.58440	11.03376	0.
HOLE	3	14.71168	0.	0.	HOLE	3	29.42336	11.03376	0.
HOLE	3	16.55064	0.	0.	HOLE	3	31.26232	11.03376	0.
HOLE	3	18.38960	0.	0.	HOLE	3	0.	12.87272	0.
HOLE	3	20.22856	0.	0.	HOLE	3	1.83896	12.87272	0.
HOLE	3	22.06752	0.	0.	HOLE	3	3.67792	12.87272	0.
HOLE	3	23.90648	0.	0.	HOLE	3	5.51688	12.87272	0.
HOLE	3	25.74544	0.	0.	HOLE	3	7.35584	12.87272	0.

HOLE	3	9.19480	12.87272	0.	HOLE	3	18.38960	22.06752	0.
HOLE	3	11.03376	12.87272	0.	HOLE	3	20.22856	22.06752	0.
HOLE	3	12.87272	12.87272	0.	HOLE	3	22.06752	22.06752	0.
HOLE	3	14.71168	12.87272	0.	HOLE	3	23.90648	22.06752	0.
HOLE	3	16.55064	12.87272	0.	HOLE	3	25.74544	22.06752	0.
HOLE	3	18.38960	12.87272	0.	HOLE	3	27.58440	22.06752	0.
HOLE	3	20.22856	12.87272	0.	HOLE	3	29.42336	22.06752	0.
HOLE	3	22.06752	12.87272	0.	HOLE	3	31.26232	22.06752	0.
HOLE	3	23.90648	12.87272	0.	HOLE	3	0.	23.90648	0.
HOLE	3	25.74544	12.87272	0.	HOLE	3	1.83896	23.90648	0.
HOLE	3	27.58440	12.87272	0.	HOLE	3	3.67792	23.90648	0.
HOLE	3	29.42336	12.87272	0.	HOLE	3	5.51688	23.90648	0.
HOLE	3	31.26232	12.87272	0.	HOLE	3	7.35584	23.90648	0.
HOLE	3	0.	14.71168	0.	HOLE	3	9.19480	23.90648	0.
HOLE	3	1.83896	14.71168	0.	HOLE	3	11.03376	23.90648	0.
HOLE	3	3.67792	14.71168	0.	HOLE	3	12.87272	23.90648	0.
HOLE	3	5.51688	14.71168	0.	HOLE	3	14.71168	23.90648	0.
HOLE	3	7.35584	14.71168	0.	HOLE	3	16.55064	23.90648	0.
HOLE	3	9.19480	14.71168	0.	HOLE	3	18.38960	23.90648	0.
HOLE	3	11.03376	14.71168	0.	HOLE	3	20.22856	23.90648	0.
HOLE	3	12.87272	14.71168	0.	HOLE	3	22.06752	23.90648	0.
HOLE	3	14.71168	14.71168	0.	HOLE	3	23.90648	23.90648	0.
HOLE	3	16.55064	14.71168	0.	HOLE	3	25.74544	23.90648	0.
HOLE	3	18.38960	14.71168	0.	HOLE	3	27.58440	23.90648	0.
HOLE	3	20.22856	14.71168	0.	HOLE	3	29.42336	23.90648	0.
HOLE	3	22.06752	14.71168	0.	HOLE	3	31.26232	23.90648	0.
HOLE	3	23.90648	14.71168	0.	HOLE	3	0.	25.74544	0.
HOLE	3	25.74544	14.71168	0.	HOLE	3	1.83896	25.74544	0.
HOLE	3	27.58440	14.71168	0.	HOLE	3	3.67792	25.74544	0.
HOLE	3	29.42336	14.71168	0.	HOLE	3	5.51688	25.74544	0.
HOLE	3	31.26232	14.71168	0.	HOLE	3	7.35584	25.74544	0.
HOLE	3	0.	16.55064	0.	HOLE	3	9.19480	25.74544	0.
HOLE	3	1.83896	16.55064	0.	HOLE	3	11.03376	25.74544	0.
HOLE	3	3.67792	16.55064	0.	HOLE	3	12.87272	25.74544	0.
HOLE	3	5.51688	16.55064	0.	HOLE	3	14.71168	25.74544	0.
HOLE	3	7.35584	16.55064	0.	HOLE	3	16.55064	25.74544	0.
HOLE	3	9.19480	16.55064	0.	HOLE	3	18.38960	25.74544	0.
HOLE	3	11.03376	16.55064	0.	HOLE	3	20.22856	25.74544	0.
HOLE	3	12.87272	16.55064	0.	HOLE	3	22.06752	25.74544	0.
HOLE	3	14.71168	16.55064	0.	HOLE	3	23.90648	25.74544	0.
HOLE	3	16.55064	16.55064	0.	HOLE	3	25.74544	25.74544	0.
HOLE	3	18.38960	16.55064	0.	HOLE	3	27.58440	25.74544	0.
HOLE	3	20.22856	16.55064	0.	HOLE	3	29.42336	25.74544	0.
HOLE	3	22.06752	16.55064	0.	HOLE	3	31.26232	25.74544	0.
HOLE	3	23.90648	16.55064	0.	HOLE	3	0.	27.58440	0.
HOLE	3	25.74544	16.55064	0.	HOLE	3	1.83896	27.58440	0.
HOLE	3	27.58440	16.55064	0.	HOLE	3	3.67792	27.58440	0.
HOLE	3	29.42336	16.55064	0.	HOLE	3	5.51688	27.58440	0.
HOLE	3	31.26232	16.55064	0.	HOLE	3	7.35584	27.58440	0.
HOLE	3	0.	18.38960	0.	HOLE	3	9.19480	27.58440	0.
HOLE	3	1.83896	18.38960	0.	HOLE	3	11.03376	27.58440	0.
HOLE	3	3.67792	18.38960	0.	HOLE	3	12.87272	27.58440	0.
HOLE	3	5.51688	18.38960	0.	HOLE	3	14.71168	27.58440	0.
HOLE	3	7.35584	18.38960	0.	HOLE	3	16.55064	27.58440	0.
HOLE	3	9.19480	18.38960	0.	HOLE	3	18.38960	27.58440	0.
HOLE	3	11.03376	18.38960	0.	HOLE	3	20.22856	27.58440	0.
HOLE	3	12.87272	18.38960	0.	HOLE	3	22.06752	27.58440	0.
HOLE	3	14.71168	18.38960	0.	HOLE	3	23.90648	27.58440	0.
HOLE	3	16.55064	18.38960	0.	HOLE	3	25.74544	27.58440	0.
HOLE	3	18.38960	18.38960	0.	HOLE	3	27.58440	27.58440	0.
HOLE	3	20.22856	18.38960	0.	HOLE	3	29.42336	27.58440	0.
HOLE	3	22.06752	18.38960	0.	HOLE	3	31.26232	27.58440	0.
HOLE	3	23.90648	18.38960	0.	HOLE	3	0.	29.42336	0.
HOLE	3	25.74544	18.38960	0.	HOLE	3	1.83896	29.42336	0.
HOLE	3	27.58440	18.38960	0.	HOLE	3	3.67792	29.42336	0.
HOLE	3	29.42336	18.38960	0.	HOLE	3	5.51688	29.42336	0.
HOLE	3	31.26232	18.38960	0.	HOLE	3	7.35584	29.42336	0.
HOLE	3	0.	20.22856	0.	HOLE	3	9.19480	29.42336	0.
HOLE	3	1.83896	20.22856	0.	HOLE	3	11.03376	29.42336	0.
HOLE	3	3.67792	20.22856	0.	HOLE	3	12.87272	29.42336	0.
HOLE	3	5.51688	20.22856	0.	HOLE	3	14.71168	29.42336	0.
HOLE	3	7.35584	20.22856	0.	HOLE	3	16.55064	29.42336	0.
HOLE	3	9.19480	20.22856	0.	HOLE	3	18.38960	29.42336	0.
HOLE	3	11.03376	20.22856	0.	HOLE	3	20.22856	29.42336	0.
HOLE	3	12.87272	20.22856	0.	HOLE	3	22.06752	29.42336	0.
HOLE	3	14.71168	20.22856	0.	HOLE	3	23.90648	29.42336	0.
HOLE	3	16.55064	20.22856	0.	HOLE	3	25.74544	29.42336	0.
HOLE	3	18.38960	20.22856	0.	HOLE	3	27.58440	29.42336	0.
HOLE	3	20.22856	20.22856	0.	HOLE	3	29.42336	29.42336	0.
HOLE	3	22.06752	20.22856	0.	HOLE	3	31.26232	29.42336	0.
HOLE	3	23.90648	20.22856	0.	HOLE	3	0.	31.26232	0.
HOLE	3	25.74544	20.22856	0.	HOLE	3	1.83896	31.26232	0.
HOLE	3	27.58440	20.22856	0.	HOLE	3	3.67792	31.26232	0.
HOLE	3	29.42336	20.22856	0.	HOLE	3	5.51688	31.26232	0.
HOLE	3	31.26232	20.22856	0.	HOLE	3	7.35584	31.26232	0.
HOLE	3	0.	22.06752	0.	HOLE	3	9.19480	31.26232	0.
HOLE	3	1.83896	22.06752	0.	HOLE	3	11.03376	31.26232	0.
HOLE	3	3.67792	22.06752	0.	HOLE	3	12.87272	31.26232	0.
HOLE	3	5.51688	22.06752	0.	HOLE	3	14.71168	31.26232	0.
HOLE	3	7.35584	22.06752	0.	HOLE	3	16.55064	31.26232	0.
HOLE	3	9.19480	22.06752	0.	HOLE	3	18.38960	31.26232	0.
HOLE	3	11.03376	22.06752	0.	HOLE	3	20.22856	31.26232	0.
HOLE	3	12.87272	22.06752	0.	HOLE	3	22.06752	31.26232	0.
HOLE	3	14.71168	22.06752	0.	HOLE	3	23.90648	31.26232	0.
HOLE	3	16.55064	22.06752	0.	HOLE	3	25.74544	31.26232	0.

Appendix E Benchmark Model Inputs

HOLE	3	27.58440	31.26232	0.	HOLE	3	-23.90648	0.	0.
HOLE	3	29.42336	31.26232	0.	HOLE	3	-25.74544	0.	0.
HOLE	3	31.26232	31.26232	0.	HOLE	3	-27.58440	0.	0.
COM=-x,+y quadrant from center out*					HOLE	3	-29.42336	0.	0.
HOLE	1	-0.45974	0.45974	0.	HOLE	3	-31.26232	0.	0.
HOLE	1	-1.37922	0.45974	0.	HOLE	3	-9.19480	1.83896	0.
HOLE	1	-2.29870	0.45974	0.	HOLE	3	-11.03376	1.83896	0.
HOLE	1	-3.21818	0.45974	0.	HOLE	3	-12.87272	1.83896	0.
HOLE	1	-4.13766	0.45974	0.	HOLE	3	-14.71168	1.83896	0.
HOLE	1	-5.05714	0.45974	0.	HOLE	3	-16.55064	1.83896	0.
HOLE	1	-5.97662	0.45974	0.	HOLE	3	-18.38960	1.83896	0.
HOLE	1	-6.89610	0.45974	0.	HOLE	3	-20.22856	1.83896	0.
HOLE	1	-7.81558	0.45974	0.	HOLE	3	-22.06752	1.83896	0.
HOLE	1	-8.73506	0.45974	0.	HOLE	3	-23.90648	1.83896	0.
HOLE	1	-9.65454	0.45974	0.	HOLE	3	-25.74544	1.83896	0.
HOLE	1	-10.45974	1.37922	0.	HOLE	3	-27.58440	1.83896	0.
HOLE	1	-1.37922	1.37922	0.	HOLE	3	-29.42336	1.83896	0.
HOLE	1	-2.29870	1.37922	0.	HOLE	3	-31.26232	1.83896	0.
HOLE	1	-3.21818	1.37922	0.	HOLE	3	-9.19480	3.67792	0.
HOLE	1	-4.13766	1.37922	0.	HOLE	3	-11.03376	3.67792	0.
HOLE	1	-5.05714	1.37922	0.	HOLE	3	-12.87272	3.67792	0.
HOLE	1	-5.97662	1.37922	0.	HOLE	3	-14.71168	3.67792	0.
HOLE	1	-6.89610	1.37922	0.	HOLE	3	-16.55064	3.67792	0.
HOLE	1	-7.81558	1.37922	0.	HOLE	3	-18.38960	3.67792	0.
HOLE	1	-8.73506	2.29870	0.	HOLE	3	-20.22856	3.67792	0.
HOLE	1	-9.65454	2.29870	0.	HOLE	3	-22.06752	3.67792	0.
HOLE	1	-10.45974	2.29870	0.	HOLE	3	-23.90648	3.67792	0.
HOLE	1	-1.37922	2.29870	0.	HOLE	3	-25.74544	3.67792	0.
HOLE	1	-2.29870	2.29870	0.	HOLE	3	-27.58440	3.67792	0.
HOLE	1	-3.21818	2.29870	0.	HOLE	3	-29.42336	3.67792	0.
HOLE	1	-4.13766	2.29870	0.	HOLE	3	-31.26232	3.67792	0.
HOLE	1	-5.05714	2.29870	0.	HOLE	3	-9.19480	5.51688	0.
HOLE	1	-5.97662	2.29870	0.	HOLE	3	-11.03376	5.51688	0.
HOLE	1	-6.89610	2.29870	0.	HOLE	3	-12.87272	5.51688	0.
HOLE	1	-7.81558	2.29870	0.	HOLE	3	-14.71168	5.51688	0.
HOLE	1	-8.73506	3.21818	0.	HOLE	3	-16.55064	5.51688	0.
HOLE	1	-9.65454	3.21818	0.	HOLE	3	-18.38960	5.51688	0.
HOLE	1	-10.45974	3.21818	0.	HOLE	3	-20.22856	5.51688	0.
HOLE	1	-1.37922	3.21818	0.	HOLE	3	-22.06752	5.51688	0.
HOLE	1	-2.29870	3.21818	0.	HOLE	3	-23.90648	5.51688	0.
HOLE	1	-3.21818	3.21818	0.	HOLE	3	-25.74544	5.51688	0.
HOLE	1	-4.13766	3.21818	0.	HOLE	3	-27.58440	5.51688	0.
HOLE	1	-5.05714	3.21818	0.	HOLE	3	-29.42336	5.51688	0.
HOLE	1	-5.97662	3.21818	0.	HOLE	3	-31.26232	5.51688	0.
HOLE	1	-6.89610	3.21818	0.	HOLE	3	-9.19480	7.35584	0.
HOLE	1	-7.81558	3.21818	0.	HOLE	3	-11.03376	7.35584	0.
HOLE	1	-8.73506	4.13766	0.	HOLE	3	-12.87272	7.35584	0.
HOLE	1	-9.65454	4.13766	0.	HOLE	3	-14.71168	7.35584	0.
HOLE	1	-10.45974	4.13766	0.	HOLE	3	-16.55064	7.35584	0.
HOLE	1	-1.37922	4.13766	0.	HOLE	3	-18.38960	7.35584	0.
HOLE	1	-2.29870	4.13766	0.	HOLE	3	-20.22856	7.35584	0.
HOLE	1	-3.21818	4.13766	0.	HOLE	3	-22.06752	7.35584	0.
HOLE	1	-4.13766	4.13766	0.	HOLE	3	-23.90648	7.35584	0.
HOLE	1	-5.05714	4.13766	0.	HOLE	3	-25.74544	7.35584	0.
HOLE	1	-5.97662	4.13766	0.	HOLE	3	-27.58440	7.35584	0.
HOLE	1	-6.89610	4.13766	0.	HOLE	3	-29.42336	7.35584	0.
HOLE	1	-7.81558	4.13766	0.	HOLE	3	-31.26232	7.35584	0.
HOLE	1	-8.73506	5.05714	0.	HOLE	3	-9.19480	9.19480	0.
HOLE	1	-9.65454	5.05714	0.	HOLE	3	-11.03376	9.19480	0.
HOLE	1	-10.45974	5.05714	0.	HOLE	3	-12.87272	9.19480	0.
HOLE	1	-1.37922	5.05714	0.	HOLE	3	-14.71168	9.19480	0.
HOLE	1	-2.29870	5.05714	0.	HOLE	3	-16.55064	9.19480	0.
HOLE	1	-3.21818	5.05714	0.	HOLE	3	-18.38960	9.19480	0.
HOLE	1	-4.13766	5.05714	0.	HOLE	3	-20.22856	9.19480	0.
HOLE	1	-5.05714	5.05714	0.	HOLE	3	-22.06752	9.19480	0.
HOLE	1	-5.97662	5.05714	0.	HOLE	3	-23.90648	9.19480	0.
HOLE	1	-6.89610	5.05714	0.	HOLE	3	-25.74544	9.19480	0.
HOLE	1	-7.81558	5.05714	0.	HOLE	3	-27.58440	9.19480	0.
HOLE	1	-8.73506	5.97662	0.	HOLE	3	-29.42336	9.19480	0.
HOLE	1	-9.65454	5.97662	0.	HOLE	3	-31.26232	9.19480	0.
HOLE	1	-10.45974	5.97662	0.	HOLE	3	-9.19480	11.03376	0.
HOLE	1	-1.37922	5.97662	0.	HOLE	3	-11.03376	11.03376	0.
HOLE	1	-2.29870	5.97662	0.	HOLE	3	-12.87272	11.03376	0.
HOLE	1	-3.21818	5.97662	0.	HOLE	3	-14.71168	11.03376	0.
HOLE	1	-4.13766	5.97662	0.	HOLE	3	-16.55064	11.03376	0.
HOLE	1	-5.05714	5.97662	0.	HOLE	3	-18.38960	11.03376	0.
HOLE	1	-5.97662	5.97662	0.	HOLE	3	-20.22856	11.03376	0.
HOLE	1	-6.89610	5.97662	0.	HOLE	3	-22.06752	11.03376	0.
HOLE	1	-7.81558	5.97662	0.	HOLE	3	-23.90648	11.03376	0.
HOLE	1	-8.73506	6.89610	0.	HOLE	3	-25.74544	11.03376	0.
HOLE	1	-9.65454	6.89610	0.	HOLE	3	-27.58440	11.03376	0.
HOLE	1	-10.45974	6.89610	0.	HOLE	3	-29.42336	11.03376	0.
HOLE	1	-1.37922	6.89610	0.	HOLE	3	-31.26232	11.03376	0.
HOLE	1	-2.29870	6.89610	0.	HOLE	3	-9.19480	12.87272	0.
HOLE	1	-3.21818	6.89610	0.	HOLE	3	-11.03376	12.87272	0.
HOLE	1	-4.13766	6.89610	0.	HOLE	3	-12.87272	12.87272	0.
HOLE	1	-5.05714	6.89610	0.	HOLE	3	-14.71168	12.87272	0.
HOLE	1	-5.97662	6.89610	0.	HOLE	3	-16.55064	12.87272	0.
HOLE	1	-6.89610	6.89610	0.	HOLE	3	-18.38960	12.87272	0.
HOLE	1	-7.81558	6.89610	0.	HOLE	3	-20.22856	12.87272	0.
HOLE	1	-8.73506	7.81558	0.	HOLE	3	-22.06752	12.87272	0.
HOLE	1	-9.65454	7.81558	0.	HOLE	3	-23.90648	12.87272	0.
HOLE	1	-10.45974	7.81558	0.	HOLE	3	-25.74544	12.87272	0.
HOLE	1	-1.37922	7.81558	0.	HOLE	3	-27.58440	12.87272	0.
HOLE	1	-2.29870	7.81558	0.	HOLE	3	-29.42336	12.87272	0.
HOLE	1	-3.21818	7.81558	0.	HOLE	3	-31.26232	12.87272	0.
HOLE	1	-4.13766	7.81558	0.	HOLE	3	-9.19480	14.71168	0.
HOLE	1	-5.05714	7.81558	0.	HOLE	3	-11.03376	14.71168	0.
HOLE	1	-5.97662	7.81558	0.	HOLE	3	-12.87272	14.71168	0.
HOLE	1	-6.89610	7.81558	0.	HOLE	3	-14.71168	14.71168	0.
HOLE	1	-7.81558	7.81558	0.	HOLE	3	-16.55064	14.71168	0.
HOLE	1	-8.73506	8.73506	0.	HOLE	3	-18.38960	14.71168	0.
HOLE	1	-9.65454	8.73506	0.	HOLE	3	-20.22856	14.71168	0.
HOLE	1	-10.45974	8.73506	0.	HOLE	3	-22.06752	14.71168	0.
HOLE	1	-1.37922	8.73506	0.	HOLE	3	-23.90648	14.71168	0.
HOLE	1	-2.29870	8.73506	0.	HOLE	3	-25.74544	14.71168	0.
HOLE	1	-3.21818	8.73506	0.	HOLE	3	-27.58440	14.71168	0.
HOLE	1	-4.13766	8.73506	0.	HOLE	3	-29.42336	14.71168	0.
HOLE	1	-5.05714	8.73506	0.	HOLE	3	-31.26232	14.71168	0.
HOLE	1	-5.97662	8.73506	0.	HOLE	3	-9.19480	16.55064	0.
HOLE	1	-6.89610	8.73506	0.	HOLE	3	-11.03376	16.55064	0.
HOLE	1	-7.81558	8.73506	0.	HOLE	3	-12.87272	16.55064	0.
HOLE	1	-8.73506	9.65454	0.	HOLE	3	-14.71168	16.55064	0.
HOLE	1	-9.65454	9.65454	0.	HOLE	3	-16.55064	16.55064	0.
HOLE	1	-10.45974	9.65454	0.	HOLE	3	-18.38960	16.55064	0.
HOLE	1	-1.37922	9.65454	0.	HOLE	3	-20.22856	16.55064	0.
HOLE	1	-2.29870	9.65454	0.	HOLE	3	-22.06752	16.55064	0.
HOLE	1	-3.21818	9.65454	0.	HOLE	3	-23.90648	16.55064	0.
HOLE	1	-4.13766	9.65454	0.	HOLE	3	-25.74544	16.55064	0.
HOLE	1	-5.05714	9.65454	0.	HOLE	3	-27.58440	16.55064	0.
HOLE	1	-5.97662	9.65454	0.	HOLE	3	-29.42336	16.55064	0.
HOLE	1	-6.89610	9.65454	0.	HOLE	3	-31.26232	16.55064	0.
HOLE	1	-7.81558	9.65454	0.	HOLE	3	-9.19480	18.38960	0.
HOLE	1	-8.73506	9.65454	0.	HOLE	3	-11.03376	18.38960	0.
HOLE	1	-9.65454	9.65454	0.	HOLE	3	-12.87272	18.38960	0.
HOLE	1	-10.45974	9.65454	0.	HOLE	3	-14.71168	18.38960	0.
HOLE	1	-1.37922	9.65454	0.	HOLE	3	-16.55064	18.38960	0.
HOLE	1	-2.29870	9.65454	0.	HOLE	3	-18.38960	18.38960	0.
HOLE	1	-3.21818	9.65454	0.	HOLE	3	-20.22856	18.38960	0.
HOLE	1	-4.13766	9.65454	0.	HOLE	3	-22.06752	18.38960	0.
HOLE	1	-5.05714	9.65454	0.	HOLE	3	-23.90648	18.38960	0.
HOLE	1	-5.97662	9.65454	0.	HOLE	3	-25.74544	18.38960	0.
HOLE	1	-6.89610	9.65454	0.	HOLE	3	-27.58440	18.38960	0.
HOLE	1	-7.81558	9.65454	0.	HOLE	3	-29.42336	18.38960	0.
HOLE	1	-8.73506	9.65454	0.	HOLE	3	-31.26232	18.38960	0.
HOLE	1	-9.65454	9.65454	0.	HOLE	3	-9.19480	20.22856	0.
HOLE	1								

HOLE	3	-9.19480	12.87272	0.	HOLE	3	-27.58440	22.06752	0.
HOLE	3	-11.03376	12.87272	0.	HOLE	3	-29.42336	22.06752	0.
HOLE	3	-12.87272	12.87272	0.	HOLE	3	-31.26232	22.06752	0.
HOLE	3	-14.71168	12.87272	0.	HOLE	3	-1.83896	23.90648	0.
HOLE	3	-16.55064	12.87272	0.	HOLE	3	-3.67792	23.90648	0.
HOLE	3	-18.38960	12.87272	0.	HOLE	3	-5.51688	23.90648	0.
HOLE	3	-20.22856	12.87272	0.	HOLE	3	-7.35584	23.90648	0.
HOLE	3	-22.06752	12.87272	0.	HOLE	3	-9.19480	23.90648	0.
HOLE	3	-23.90648	12.87272	0.	HOLE	3	-11.03376	23.90648	0.
HOLE	3	-25.74544	12.87272	0.	HOLE	3	-12.87272	23.90648	0.
HOLE	3	-27.58440	12.87272	0.	HOLE	3	-14.71168	23.90648	0.
HOLE	3	-29.42336	12.87272	0.	HOLE	3	-16.55064	23.90648	0.
HOLE	3	-31.26232	12.87272	0.	HOLE	3	-18.38960	23.90648	0.
HOLE	3	-1.83896	14.71168	0.	HOLE	3	-20.22856	23.90648	0.
HOLE	3	-3.67792	14.71168	0.	HOLE	3	-22.06752	23.90648	0.
HOLE	3	-5.51688	14.71168	0.	HOLE	3	-23.90648	23.90648	0.
HOLE	3	-7.35584	14.71168	0.	HOLE	3	-25.74544	23.90648	0.
HOLE	3	-9.19480	14.71168	0.	HOLE	3	-27.58440	23.90648	0.
HOLE	3	-11.03376	14.71168	0.	HOLE	3	-29.42336	23.90648	0.
HOLE	3	-12.87272	14.71168	0.	HOLE	3	-31.26232	23.90648	0.
HOLE	3	-14.71168	14.71168	0.	HOLE	3	-1.83896	25.74544	0.
HOLE	3	-16.55064	14.71168	0.	HOLE	3	-3.67792	25.74544	0.
HOLE	3	-18.38960	14.71168	0.	HOLE	3	-5.51688	25.74544	0.
HOLE	3	-20.22856	14.71168	0.	HOLE	3	-7.35584	25.74544	0.
HOLE	3	-22.06752	14.71168	0.	HOLE	3	-9.19480	25.74544	0.
HOLE	3	-23.90648	14.71168	0.	HOLE	3	-11.03376	25.74544	0.
HOLE	3	-25.74544	14.71168	0.	HOLE	3	-12.87272	25.74544	0.
HOLE	3	-27.58440	14.71168	0.	HOLE	3	-14.71168	25.74544	0.
HOLE	3	-29.42336	14.71168	0.	HOLE	3	-16.55064	25.74544	0.
HOLE	3	-31.26232	14.71168	0.	HOLE	3	-18.38960	25.74544	0.
HOLE	3	-1.83896	16.55064	0.	HOLE	3	-20.22856	25.74544	0.
HOLE	3	-3.67792	16.55064	0.	HOLE	3	-22.06752	25.74544	0.
HOLE	3	-5.51688	16.55064	0.	HOLE	3	-23.90648	25.74544	0.
HOLE	3	-7.35584	16.55064	0.	HOLE	3	-25.74544	25.74544	0.
HOLE	3	-9.19480	16.55064	0.	HOLE	3	-27.58440	25.74544	0.
HOLE	3	-11.03376	16.55064	0.	HOLE	3	-29.42336	25.74544	0.
HOLE	3	-12.87272	16.55064	0.	HOLE	3	-31.26232	25.74544	0.
HOLE	3	-14.71168	16.55064	0.	HOLE	3	-1.83896	27.58440	0.
HOLE	3	-16.55064	16.55064	0.	HOLE	3	-3.67792	27.58440	0.
HOLE	3	-18.38960	16.55064	0.	HOLE	3	-5.51688	27.58440	0.
HOLE	3	-20.22856	16.55064	0.	HOLE	3	-7.35584	27.58440	0.
HOLE	3	-22.06752	16.55064	0.	HOLE	3	-9.19480	27.58440	0.
HOLE	3	-23.90648	16.55064	0.	HOLE	3	-11.03376	27.58440	0.
HOLE	3	-25.74544	16.55064	0.	HOLE	3	-12.87272	27.58440	0.
HOLE	3	-27.58440	16.55064	0.	HOLE	3	-14.71168	27.58440	0.
HOLE	3	-29.42336	16.55064	0.	HOLE	3	-16.55064	27.58440	0.
HOLE	3	-31.26232	16.55064	0.	HOLE	3	-18.38960	27.58440	0.
HOLE	3	-1.83896	18.38960	0.	HOLE	3	-20.22856	27.58440	0.
HOLE	3	-3.67792	18.38960	0.	HOLE	3	-22.06752	27.58440	0.
HOLE	3	-5.51688	18.38960	0.	HOLE	3	-23.90648	27.58440	0.
HOLE	3	-7.35584	18.38960	0.	HOLE	3	-25.74544	27.58440	0.
HOLE	3	-9.19480	18.38960	0.	HOLE	3	-27.58440	27.58440	0.
HOLE	3	-11.03376	18.38960	0.	HOLE	3	-29.42336	27.58440	0.
HOLE	3	-12.87272	18.38960	0.	HOLE	3	-31.26232	27.58440	0.
HOLE	3	-14.71168	18.38960	0.	HOLE	3	-1.83896	29.42336	0.
HOLE	3	-16.55064	18.38960	0.	HOLE	3	-3.67792	29.42336	0.
HOLE	3	-18.38960	18.38960	0.	HOLE	3	-5.51688	29.42336	0.
HOLE	3	-20.22856	18.38960	0.	HOLE	3	-7.35584	29.42336	0.
HOLE	3	-22.06752	18.38960	0.	HOLE	3	-9.19480	29.42336	0.
HOLE	3	-23.90648	18.38960	0.	HOLE	3	-11.03376	29.42336	0.
HOLE	3	-25.74544	18.38960	0.	HOLE	3	-12.87272	29.42336	0.
HOLE	3	-27.58440	18.38960	0.	HOLE	3	-14.71168	29.42336	0.
HOLE	3	-29.42336	18.38960	0.	HOLE	3	-16.55064	29.42336	0.
HOLE	3	-31.26232	18.38960	0.	HOLE	3	-18.38960	29.42336	0.
HOLE	3	-1.83896	20.22856	0.	HOLE	3	-20.22856	29.42336	0.
HOLE	3	-3.67792	20.22856	0.	HOLE	3	-22.06752	29.42336	0.
HOLE	3	-5.51688	20.22856	0.	HOLE	3	-23.90648	29.42336	0.
HOLE	3	-7.35584	20.22856	0.	HOLE	3	-25.74544	29.42336	0.
HOLE	3	-9.19480	20.22856	0.	HOLE	3	-27.58440	29.42336	0.
HOLE	3	-11.03376	20.22856	0.	HOLE	3	-29.42336	29.42336	0.
HOLE	3	-12.87272	20.22856	0.	HOLE	3	-31.26232	29.42336	0.
HOLE	3	-14.71168	20.22856	0.	HOLE	3	-1.83896	31.26232	0.
HOLE	3	-16.55064	20.22856	0.	HOLE	3	-3.67792	31.26232	0.
HOLE	3	-18.38960	20.22856	0.	HOLE	3	-5.51688	31.26232	0.
HOLE	3	-20.22856	20.22856	0.	HOLE	3	-7.35584	31.26232	0.
HOLE	3	-22.06752	20.22856	0.	HOLE	3	-9.19480	31.26232	0.
HOLE	3	-23.90648	20.22856	0.	HOLE	3	-11.03376	31.26232	0.
HOLE	3	-25.74544	20.22856	0.	HOLE	3	-12.87272	31.26232	0.
HOLE	3	-27.58440	20.22856	0.	HOLE	3	-14.71168	31.26232	0.
HOLE	3	-29.42336	20.22856	0.	HOLE	3	-16.55064	31.26232	0.
HOLE	3	-31.26232	20.22856	0.	HOLE	3	-18.38960	31.26232	0.
HOLE	3	-1.83896	22.06752	0.	HOLE	3	-20.22856	31.26232	0.
HOLE	3	-3.67792	22.06752	0.	HOLE	3	-22.06752	31.26232	0.
HOLE	3	-5.51688	22.06752	0.	HOLE	3	-23.90648	31.26232	0.
HOLE	3	-7.35584	22.06752	0.	HOLE	3	-25.74544	31.26232	0.
HOLE	3	-9.19480	22.06752	0.	HOLE	3	-27.58440	31.26232	0.
HOLE	3	-11.03376	22.06752	0.	HOLE	3	-29.42336	31.26232	0.
HOLE	3	-12.87272	22.06752	0.	HOLE	3	-31.26232	31.26232	0.
HOLE	3	-14.71168	22.06752	0.	COM=*-x,-y quadrant from center out*				
HOLE	3	-16.55064	22.06752	0.	HOLE	1	-0.45974	-0.45974	0.
HOLE	3	-18.38960	22.06752	0.	HOLE	1	-1.37922	-0.45974	0.
HOLE	3	-20.22856	22.06752	0.	HOLE	1	-2.29870	-0.45974	0.
HOLE	3	-22.06752	22.06752	0.	HOLE	1	-3.21818	-0.45974	0.
HOLE	3	-23.90648	22.06752	0.	HOLE	1	-4.13766	-0.45974	0.
HOLE	3	-25.74544	22.06752	0.	HOLE	1	-5.05714	-0.45974	0.

Appendix E Benchmark Model Inputs

HOLE	1	-5.97662	-0.45974	0.	HOLE	3	-16.55064	-3.67792	0.
HOLE	1	-6.89610	-0.45974	0.	HOLE	3	-18.38960	-3.67792	0.
HOLE	1	-7.81558	-0.45974	0.	HOLE	3	-20.22856	-3.67792	0.
HOLE	1	-8.73506	-0.45974	0.	HOLE	3	-22.06752	-3.67792	0.
HOLE	1	-9.65454	-0.45974	0.	HOLE	3	-23.90648	-3.67792	0.
HOLE	1	-0.45974	-1.37922	0.	HOLE	3	-25.74544	-3.67792	0.
HOLE	1	-1.37922	-1.37922	0.	HOLE	3	-27.58440	-3.67792	0.
HOLE	1	-2.29870	-1.37922	0.	HOLE	3	-29.42336	-3.67792	0.
HOLE	1	-3.21818	-1.37922	0.	HOLE	3	-31.26232	-3.67792	0.
HOLE	1	-4.13766	-1.37922	0.	HOLE	3	-9.19480	-5.51688	0.
HOLE	1	-5.05714	-1.37922	0.	HOLE	3	-11.03376	-5.51688	0.
HOLE	1	-5.97662	-1.37922	0.	HOLE	3	-12.87272	-5.51688	0.
HOLE	1	-6.89610	-1.37922	0.	HOLE	3	-14.71168	-5.51688	0.
HOLE	1	-7.81558	-1.37922	0.	HOLE	3	-16.55064	-5.51688	0.
HOLE	1	-0.45974	-2.29870	0.	HOLE	3	-18.38960	-5.51688	0.
HOLE	1	-1.37922	-2.29870	0.	HOLE	3	-20.22856	-5.51688	0.
HOLE	1	-2.29870	-2.29870	0.	HOLE	3	-22.06752	-5.51688	0.
HOLE	1	-3.21818	-2.29870	0.	HOLE	3	-23.90648	-5.51688	0.
HOLE	1	-4.13766	-2.29870	0.	HOLE	3	-25.74544	-5.51688	0.
HOLE	1	-5.05714	-2.29870	0.	HOLE	3	-27.58440	-5.51688	0.
HOLE	1	-5.97662	-2.29870	0.	HOLE	3	-29.42336	-5.51688	0.
HOLE	1	-6.89610	-2.29870	0.	HOLE	3	-31.26232	-5.51688	0.
HOLE	1	-7.81558	-2.29870	0.	HOLE	3	-9.19480	-7.35584	0.
HOLE	1	-0.45974	-3.21818	0.	HOLE	3	-11.03376	-7.35584	0.
HOLE	1	-1.37922	-3.21818	0.	HOLE	3	-12.87272	-7.35584	0.
HOLE	1	-2.29870	-3.21818	0.	HOLE	3	-14.71168	-7.35584	0.
HOLE	1	-3.21818	-3.21818	0.	HOLE	3	-16.55064	-7.35584	0.
HOLE	1	-4.13766	-3.21818	0.	HOLE	3	-18.38960	-7.35584	0.
HOLE	1	-5.05714	-3.21818	0.	HOLE	3	-20.22856	-7.35584	0.
HOLE	1	-5.97662	-3.21818	0.	HOLE	3	-22.06752	-7.35584	0.
HOLE	1	-6.89610	-3.21818	0.	HOLE	3	-23.90648	-7.35584	0.
HOLE	1	-7.81558	-3.21818	0.	HOLE	3	-25.74544	-7.35584	0.
HOLE	1	-0.45974	-4.13766	0.	HOLE	3	-27.58440	-7.35584	0.
HOLE	1	-1.37922	-4.13766	0.	HOLE	3	-29.42336	-7.35584	0.
HOLE	1	-2.29870	-4.13766	0.	HOLE	3	-31.26232	-7.35584	0.
HOLE	1	-3.21818	-4.13766	0.	HOLE	3	-1.83896	-9.19480	0.
HOLE	1	-4.13766	-4.13766	0.	HOLE	3	-3.67792	-9.19480	0.
HOLE	1	-5.05714	-4.13766	0.	HOLE	3	-5.51688	-9.19480	0.
HOLE	1	-5.97662	-4.13766	0.	HOLE	3	-7.35584	-9.19480	0.
HOLE	1	-6.89610	-4.13766	0.	HOLE	3	-9.19480	-9.19480	0.
HOLE	1	-7.81558	-4.13766	0.	HOLE	3	-11.03376	-9.19480	0.
HOLE	1	-0.45974	-5.05714	0.	HOLE	3	-12.87272	-9.19480	0.
HOLE	1	-1.37922	-5.05714	0.	HOLE	3	-14.71168	-9.19480	0.
HOLE	1	-2.29870	-5.05714	0.	HOLE	3	-16.55064	-9.19480	0.
HOLE	1	-3.21818	-5.05714	0.	HOLE	3	-18.38960	-9.19480	0.
HOLE	1	-4.13766	-5.05714	0.	HOLE	3	-20.22856	-9.19480	0.
HOLE	1	-5.05714	-5.05714	0.	HOLE	3	-22.06752	-9.19480	0.
HOLE	1	-5.97662	-5.05714	0.	HOLE	3	-23.90648	-9.19480	0.
HOLE	1	-6.89610	-5.05714	0.	HOLE	3	-25.74544	-9.19480	0.
HOLE	1	-7.81558	-5.05714	0.	HOLE	3	-27.58440	-9.19480	0.
HOLE	1	-0.45974	-5.97662	0.	HOLE	3	-29.42336	-9.19480	0.
HOLE	1	-1.37922	-5.97662	0.	HOLE	3	-31.26232	-9.19480	0.
HOLE	1	-2.29870	-5.97662	0.	HOLE	3	-1.83896	-11.03376	0.
HOLE	1	-3.21818	-5.97662	0.	HOLE	3	-3.67792	-11.03376	0.
HOLE	1	-4.13766	-5.97662	0.	HOLE	3	-5.51688	-11.03376	0.
HOLE	1	-5.05714	-5.97662	0.	HOLE	3	-7.35584	-11.03376	0.
HOLE	1	-5.97662	-5.97662	0.	HOLE	3	-9.19480	-11.03376	0.
HOLE	1	-6.89610	-5.97662	0.	HOLE	3	-11.03376	-11.03376	0.
HOLE	1	-0.45974	-6.89610	0.	HOLE	3	-12.87272	-11.03376	0.
HOLE	1	-1.37922	-6.89610	0.	HOLE	3	-14.71168	-11.03376	0.
HOLE	1	-2.29870	-6.89610	0.	HOLE	3	-16.55064	-11.03376	0.
HOLE	1	-3.21818	-6.89610	0.	HOLE	3	-18.38960	-11.03376	0.
HOLE	1	-4.13766	-6.89610	0.	HOLE	3	-20.22856	-11.03376	0.
HOLE	1	-5.05714	-6.89610	0.	HOLE	3	-22.06752	-11.03376	0.
HOLE	1	-5.97662	-6.89610	0.	HOLE	3	-23.90648	-11.03376	0.
HOLE	1	-6.89610	-6.89610	0.	HOLE	3	-25.74544	-11.03376	0.
HOLE	1	-7.81558	-6.89610	0.	HOLE	3	-27.58440	-11.03376	0.
HOLE	1	-0.45974	-7.81558	0.	HOLE	3	-29.42336	-11.03376	0.
HOLE	1	-1.37922	-7.81558	0.	HOLE	3	-31.26232	-11.03376	0.
HOLE	1	-2.29870	-7.81558	0.	HOLE	3	-1.83896	-12.87272	0.
HOLE	1	-3.21818	-7.81558	0.	HOLE	3	-3.67792	-12.87272	0.
HOLE	1	-4.13766	-7.81558	0.	HOLE	3	-5.51688	-12.87272	0.
HOLE	1	-5.05714	-7.81558	0.	HOLE	3	-7.35584	-12.87272	0.
HOLE	1	-5.97662	-7.81558	0.	HOLE	3	-9.19480	-12.87272	0.
HOLE	1	-6.89610	-7.81558	0.	HOLE	3	-11.03376	-12.87272	0.
HOLE	1	-7.81558	-7.81558	0.	HOLE	3	-12.87272	-12.87272	0.
HOLE	1	-0.45974	-8.73506	0.	HOLE	3	-14.71168	-12.87272	0.
HOLE	1	-0.45974	-9.65454	0.	HOLE	3	-16.55064	-12.87272	0.
HOLE	3	-9.19480	-1.83896	0.	HOLE	3	-18.38960	-12.87272	0.
HOLE	3	-11.03376	-1.83896	0.	HOLE	3	-20.22856	-12.87272	0.
HOLE	3	-12.87272	-1.83896	0.	HOLE	3	-22.06752	-12.87272	0.
HOLE	3	-14.71168	-1.83896	0.	HOLE	3	-23.90648	-12.87272	0.
HOLE	3	-16.55064	-1.83896	0.	HOLE	3	-25.74544	-12.87272	0.
HOLE	3	-18.38960	-1.83896	0.	HOLE	3	-27.58440	-12.87272	0.
HOLE	3	-20.22856	-1.83896	0.	HOLE	3	-29.42336	-12.87272	0.
HOLE	3	-22.06752	-1.83896	0.	HOLE	3	-31.26232	-12.87272	0.
HOLE	3	-23.90648	-1.83896	0.	HOLE	3	-1.83896	-14.71168	0.
HOLE	3	-25.74544	-1.83896	0.	HOLE	3	-3.67792	-14.71168	0.
HOLE	3	-27.58440	-1.83896	0.	HOLE	3	-5.51688	-14.71168	0.
HOLE	3	-29.42336	-1.83896	0.	HOLE	3	-7.35584	-14.71168	0.
HOLE	3	-31.26232	-1.83896	0.	HOLE	3	-9.19480	-14.71168	0.
HOLE	3	-9.19480	-3.67792	0.	HOLE	3	-11.03376	-14.71168	0.
HOLE	3	-11.03376	-3.67792	0.	HOLE	3	-12.87272	-14.71168	0.
HOLE	3	-12.87272	-3.67792	0.	HOLE	3	-14.71168	-14.71168	0.
HOLE	3	-14.71168	-3.67792	0.	HOLE	3	-16.55064	-14.71168	0.

HOLE	3	-18.38960	-14.71168	0.	HOLE	3	-5.51688	-25.74544	0.
HOLE	3	-20.22856	-14.71168	0.	HOLE	3	-7.35584	-25.74544	0.
HOLE	3	-22.06752	-14.71168	0.	HOLE	3	-9.19480	-25.74544	0.
HOLE	3	-23.90648	-14.71168	0.	HOLE	3	-11.03376	-25.74544	0.
HOLE	3	-25.74544	-14.71168	0.	HOLE	3	-12.87272	-25.74544	0.
HOLE	3	-27.58440	-14.71168	0.	HOLE	3	-14.71168	-25.74544	0.
HOLE	3	-29.42336	-14.71168	0.	HOLE	3	-16.55064	-25.74544	0.
HOLE	3	-31.26232	-14.71168	0.	HOLE	3	-18.38960	-25.74544	0.
HOLE	3	-1.83896	-16.55064	0.	HOLE	3	-20.22856	-25.74544	0.
HOLE	3	-3.67792	-16.55064	0.	HOLE	3	-22.06752	-25.74544	0.
HOLE	3	-5.51688	-16.55064	0.	HOLE	3	-23.90648	-25.74544	0.
HOLE	3	-7.35584	-16.55064	0.	HOLE	3	-25.74544	-25.74544	0.
HOLE	3	-9.19480	-16.55064	0.	HOLE	3	-27.58440	-25.74544	0.
HOLE	3	-11.03376	-16.55064	0.	HOLE	3	-29.42336	-25.74544	0.
HOLE	3	-12.87272	-16.55064	0.	HOLE	3	-31.26232	-25.74544	0.
HOLE	3	-14.71168	-16.55064	0.	HOLE	3	-1.83896	-27.58440	0.
HOLE	3	-16.55064	-16.55064	0.	HOLE	3	-3.67792	-27.58440	0.
HOLE	3	-18.38960	-16.55064	0.	HOLE	3	-5.51688	-27.58440	0.
HOLE	3	-20.22856	-16.55064	0.	HOLE	3	-7.35584	-27.58440	0.
HOLE	3	-22.06752	-16.55064	0.	HOLE	3	-9.19480	-27.58440	0.
HOLE	3	-23.90648	-16.55064	0.	HOLE	3	-11.03376	-27.58440	0.
HOLE	3	-25.74544	-16.55064	0.	HOLE	3	-12.87272	-27.58440	0.
HOLE	3	-27.58440	-16.55064	0.	HOLE	3	-14.71168	-27.58440	0.
HOLE	3	-29.42336	-16.55064	0.	HOLE	3	-16.55064	-27.58440	0.
HOLE	3	-31.26232	-16.55064	0.	HOLE	3	-18.38960	-27.58440	0.
HOLE	3	-1.83896	-18.38960	0.	HOLE	3	-20.22856	-27.58440	0.
HOLE	3	-3.67792	-18.38960	0.	HOLE	3	-22.06752	-27.58440	0.
HOLE	3	-5.51688	-18.38960	0.	HOLE	3	-23.90648	-27.58440	0.
HOLE	3	-7.35584	-18.38960	0.	HOLE	3	-25.74544	-27.58440	0.
HOLE	3	-9.19480	-18.38960	0.	HOLE	3	-27.58440	-27.58440	0.
HOLE	3	-11.03376	-18.38960	0.	HOLE	3	-29.42336	-27.58440	0.
HOLE	3	-12.87272	-18.38960	0.	HOLE	3	-31.26232	-27.58440	0.
HOLE	3	-14.71168	-18.38960	0.	HOLE	3	-1.83896	-29.42336	0.
HOLE	3	-16.55064	-18.38960	0.	HOLE	3	-3.67792	-29.42336	0.
HOLE	3	-18.38960	-18.38960	0.	HOLE	3	-5.51688	-29.42336	0.
HOLE	3	-20.22856	-18.38960	0.	HOLE	3	-7.35584	-29.42336	0.
HOLE	3	-22.06752	-18.38960	0.	HOLE	3	-9.19480	-29.42336	0.
HOLE	3	-23.90648	-18.38960	0.	HOLE	3	-11.03376	-29.42336	0.
HOLE	3	-25.74544	-18.38960	0.	HOLE	3	-12.87272	-29.42336	0.
HOLE	3	-27.58440	-18.38960	0.	HOLE	3	-14.71168	-29.42336	0.
HOLE	3	-29.42336	-18.38960	0.	HOLE	3	-16.55064	-29.42336	0.
HOLE	3	-31.26232	-18.38960	0.	HOLE	3	-18.38960	-29.42336	0.
HOLE	3	-1.83896	-20.22856	0.	HOLE	3	-20.22856	-29.42336	0.
HOLE	3	-3.67792	-20.22856	0.	HOLE	3	-22.06752	-29.42336	0.
HOLE	3	-5.51688	-20.22856	0.	HOLE	3	-23.90648	-29.42336	0.
HOLE	3	-7.35584	-20.22856	0.	HOLE	3	-25.74544	-29.42336	0.
HOLE	3	-9.19480	-20.22856	0.	HOLE	3	-27.58440	-29.42336	0.
HOLE	3	-11.03376	-20.22856	0.	HOLE	3	-29.42336	-29.42336	0.
HOLE	3	-12.87272	-20.22856	0.	HOLE	3	-31.26232	-29.42336	0.
HOLE	3	-14.71168	-20.22856	0.	HOLE	3	-1.83896	-31.26232	0.
HOLE	3	-16.55064	-20.22856	0.	HOLE	3	-3.67792	-31.26232	0.
HOLE	3	-18.38960	-20.22856	0.	HOLE	3	-5.51688	-31.26232	0.
HOLE	3	-20.22856	-20.22856	0.	HOLE	3	-7.35584	-31.26232	0.
HOLE	3	-22.06752	-20.22856	0.	HOLE	3	-9.19480	-31.26232	0.
HOLE	3	-23.90648	-20.22856	0.	HOLE	3	-11.03376	-31.26232	0.
HOLE	3	-25.74544	-20.22856	0.	HOLE	3	-12.87272	-31.26232	0.
HOLE	3	-27.58440	-20.22856	0.	HOLE	3	-14.71168	-31.26232	0.
HOLE	3	-29.42336	-20.22856	0.	HOLE	3	-16.55064	-31.26232	0.
HOLE	3	-31.26232	-20.22856	0.	HOLE	3	-18.38960	-31.26232	0.
HOLE	3	-1.83896	-22.06752	0.	HOLE	3	-20.22856	-31.26232	0.
HOLE	3	-3.67792	-22.06752	0.	HOLE	3	-22.06752	-31.26232	0.
HOLE	3	-5.51688	-22.06752	0.	HOLE	3	-23.90648	-31.26232	0.
HOLE	3	-7.35584	-22.06752	0.	HOLE	3	-25.74544	-31.26232	0.
HOLE	3	-9.19480	-22.06752	0.	HOLE	3	-27.58440	-31.26232	0.
HOLE	3	-11.03376	-22.06752	0.	HOLE	3	-29.42336	-31.26232	0.
HOLE	3	-12.87272	-22.06752	0.	HOLE	3	-31.26232	-31.26232	0.
HOLE	3	-14.71168	-22.06752	0.	COM=*x,-y quadrant from center out*				
HOLE	3	-16.55064	-22.06752	0.	HOLE	1	0.45974	-0.45974	0.
HOLE	3	-18.38960	-22.06752	0.	HOLE	1	1.37922	-0.45974	0.
HOLE	3	-20.22856	-22.06752	0.	HOLE	1	2.29870	-0.45974	0.
HOLE	3	-22.06752	-22.06752	0.	HOLE	1	3.21818	-0.45974	0.
HOLE	3	-23.90648	-22.06752	0.	HOLE	1	4.13766	-0.45974	0.
HOLE	3	-25.74544	-22.06752	0.	HOLE	1	5.05714	-0.45974	0.
HOLE	3	-27.58440	-22.06752	0.	HOLE	1	5.97662	-0.45974	0.
HOLE	3	-29.42336	-22.06752	0.	HOLE	1	6.89610	-0.45974	0.
HOLE	3	-31.26232	-22.06752	0.	HOLE	1	7.81558	-0.45974	0.
HOLE	3	-1.83896	-23.90648	0.	HOLE	1	8.73506	-0.45974	0.
HOLE	3	-3.67792	-23.90648	0.	HOLE	1	9.65454	-0.45974	0.
HOLE	3	-5.51688	-23.90648	0.	HOLE	1	0.45974	-1.37922	0.
HOLE	3	-7.35584	-23.90648	0.	HOLE	1	1.37922	-1.37922	0.
HOLE	3	-9.19480	-23.90648	0.	HOLE	1	2.29870	-1.37922	0.
HOLE	3	-11.03376	-23.90648	0.	HOLE	1	3.21818	-1.37922	0.
HOLE	3	-12.87272	-23.90648	0.	HOLE	1	4.13766	-1.37922	0.
HOLE	3	-14.71168	-23.90648	0.	HOLE	1	5.05714	-1.37922	0.
HOLE	3	-16.55064	-23.90648	0.	HOLE	1	5.97662	-1.37922	0.
HOLE	3	-18.38960	-23.90648	0.	HOLE	1	6.89610	-1.37922	0.
HOLE	3	-20.22856	-23.90648	0.	HOLE	1	7.81558	-1.37922	0.
HOLE	3	-22.06752	-23.90648	0.	HOLE	1	0.45974	-2.29870	0.
HOLE	3	-23.90648	-23.90648	0.	HOLE	1	1.37922	-2.29870	0.
HOLE	3	-25.74544	-23.90648	0.	HOLE	1	2.29870	-2.29870	0.
HOLE	3	-27.58440	-23.90648	0.	HOLE	1	3.21818	-2.29870	0.
HOLE	3	-29.42336	-23.90648	0.	HOLE	1	4.13766	-2.29870	0.
HOLE	3	-31.26232	-23.90648	0.	HOLE	1	5.05714	-2.29870	0.
HOLE	3	-1.83896	-25.74544	0.	HOLE	1	5.97662	-2.29870	0.
HOLE	3	-3.67792	-25.74544	0.	HOLE	1	6.89610	-2.29870	0.

Appendix E Benchmark Model Inputs

HOLE	1	7.81558	-2.29870	0.	HOLE	3	9.19480	-7.35584	0.
HOLE	1	0.45974	-3.21818	0.	HOLE	3	11.03376	-7.35584	0.
HOLE	1	1.37922	-3.21818	0.	HOLE	3	12.87272	-7.35584	0.
HOLE	1	2.29870	-3.21818	0.	HOLE	3	14.71168	-7.35584	0.
HOLE	1	3.21818	-3.21818	0.	HOLE	3	16.55064	-7.35584	0.
HOLE	1	4.13766	-3.21818	0.	HOLE	3	18.38960	-7.35584	0.
HOLE	1	5.05714	-3.21818	0.	HOLE	3	20.22856	-7.35584	0.
HOLE	1	5.97662	-3.21818	0.	HOLE	3	22.06752	-7.35584	0.
HOLE	1	6.89610	-3.21818	0.	HOLE	3	23.90648	-7.35584	0.
HOLE	1	7.81558	-3.21818	0.	HOLE	3	25.74544	-7.35584	0.
HOLE	1	0.45974	-4.13766	0.	HOLE	3	27.58440	-7.35584	0.
HOLE	1	1.37922	-4.13766	0.	HOLE	3	29.42336	-7.35584	0.
HOLE	1	2.29870	-4.13766	0.	HOLE	3	31.26232	-7.35584	0.
HOLE	1	3.21818	-4.13766	0.	HOLE	3	1.83896	-9.19480	0.
HOLE	1	4.13766	-4.13766	0.	HOLE	3	3.67792	-9.19480	0.
HOLE	1	5.05714	-4.13766	0.	HOLE	3	5.51688	-9.19480	0.
HOLE	1	5.97662	-4.13766	0.	HOLE	3	7.35584	-9.19480	0.
HOLE	1	6.89610	-4.13766	0.	HOLE	3	9.19480	-9.19480	0.
HOLE	1	7.81558	-4.13766	0.	HOLE	3	11.03376	-9.19480	0.
HOLE	1	0.45974	-5.05714	0.	HOLE	3	12.87272	-9.19480	0.
HOLE	1	1.37922	-5.05714	0.	HOLE	3	14.71168	-9.19480	0.
HOLE	1	2.29870	-5.05714	0.	HOLE	3	16.55064	-9.19480	0.
HOLE	1	3.21818	-5.05714	0.	HOLE	3	18.38960	-9.19480	0.
HOLE	1	4.13766	-5.05714	0.	HOLE	3	20.22856	-9.19480	0.
HOLE	1	5.05714	-5.05714	0.	HOLE	3	22.06752	-9.19480	0.
HOLE	1	5.97662	-5.05714	0.	HOLE	3	23.90648	-9.19480	0.
HOLE	1	6.89610	-5.05714	0.	HOLE	3	25.74544	-9.19480	0.
HOLE	1	7.81558	-5.05714	0.	HOLE	3	27.58440	-9.19480	0.
HOLE	1	0.45974	-5.97662	0.	HOLE	3	29.42336	-9.19480	0.
HOLE	1	1.37922	-5.97662	0.	HOLE	3	31.26232	-9.19480	0.
HOLE	1	2.29870	-5.97662	0.	HOLE	3	0.	-11.03376	0.
HOLE	1	3.21818	-5.97662	0.	HOLE	3	1.83896	-11.03376	0.
HOLE	1	4.13766	-5.97662	0.	HOLE	3	3.67792	-11.03376	0.
HOLE	1	5.05714	-5.97662	0.	HOLE	3	5.51688	-11.03376	0.
HOLE	1	5.97662	-5.97662	0.	HOLE	3	7.35584	-11.03376	0.
HOLE	1	6.89610	-5.97662	0.	HOLE	3	9.19480	-11.03376	0.
HOLE	1	0.45974	-6.89610	0.	HOLE	3	11.03376	-11.03376	0.
HOLE	1	1.37922	-6.89610	0.	HOLE	3	12.87272	-11.03376	0.
HOLE	1	2.29870	-6.89610	0.	HOLE	3	14.71168	-11.03376	0.
HOLE	1	3.21818	-6.89610	0.	HOLE	3	16.55064	-11.03376	0.
HOLE	1	4.13766	-6.89610	0.	HOLE	3	18.38960	-11.03376	0.
HOLE	1	5.05714	-6.89610	0.	HOLE	3	20.22856	-11.03376	0.
HOLE	1	5.97662	-6.89610	0.	HOLE	3	22.06752	-11.03376	0.
HOLE	1	6.89610	-6.89610	0.	HOLE	3	23.90648	-11.03376	0.
HOLE	1	7.81558	-6.89610	0.	HOLE	3	25.74544	-11.03376	0.
HOLE	1	0.45974	-7.81558	0.	HOLE	3	27.58440	-11.03376	0.
HOLE	1	1.37922	-7.81558	0.	HOLE	3	29.42336	-11.03376	0.
HOLE	1	2.29870	-7.81558	0.	HOLE	3	31.26232	-11.03376	0.
HOLE	1	3.21818	-7.81558	0.	HOLE	3	0.	-12.87272	0.
HOLE	1	4.13766	-7.81558	0.	HOLE	3	1.83896	-12.87272	0.
HOLE	1	5.05714	-7.81558	0.	HOLE	3	3.67792	-12.87272	0.
HOLE	1	5.97662	-7.81558	0.	HOLE	3	5.51688	-12.87272	0.
HOLE	1	6.89610	-7.81558	0.	HOLE	3	7.35584	-12.87272	0.
HOLE	1	7.81558	-7.81558	0.	HOLE	3	9.19480	-12.87272	0.
HOLE	1	0.45974	-8.73506	0.	HOLE	3	11.03376	-12.87272	0.
HOLE	1	0.45974	-9.65454	0.	HOLE	3	12.87272	-12.87272	0.
HOLE	3	9.19480	-1.83896	0.	HOLE	3	14.71168	-12.87272	0.
HOLE	3	11.03376	-1.83896	0.	HOLE	3	16.55064	-12.87272	0.
HOLE	3	12.87272	-1.83896	0.	HOLE	3	18.38960	-12.87272	0.
HOLE	3	14.71168	-1.83896	0.	HOLE	3	20.22856	-12.87272	0.
HOLE	3	16.55064	-1.83896	0.	HOLE	3	22.06752	-12.87272	0.
HOLE	3	18.38960	-1.83896	0.	HOLE	3	23.90648	-12.87272	0.
HOLE	3	20.22856	-1.83896	0.	HOLE	3	25.74544	-12.87272	0.
HOLE	3	22.06752	-1.83896	0.	HOLE	3	27.58440	-12.87272	0.
HOLE	3	23.90648	-1.83896	0.	HOLE	3	29.42336	-12.87272	0.
HOLE	3	25.74544	-1.83896	0.	HOLE	3	31.26232	-12.87272	0.
HOLE	3	27.58440	-1.83896	0.	HOLE	3	0.	-14.71168	0.
HOLE	3	29.42336	-1.83896	0.	HOLE	3	1.83896	-14.71168	0.
HOLE	3	31.26232	-1.83896	0.	HOLE	3	3.67792	-14.71168	0.
HOLE	3	9.19480	-3.67792	0.	HOLE	3	5.51688	-14.71168	0.
HOLE	3	11.03376	-3.67792	0.	HOLE	3	7.35584	-14.71168	0.
HOLE	3	12.87272	-3.67792	0.	HOLE	3	9.19480	-14.71168	0.
HOLE	3	14.71168	-3.67792	0.	HOLE	3	11.03376	-14.71168	0.
HOLE	3	16.55064	-3.67792	0.	HOLE	3	12.87272	-14.71168	0.
HOLE	3	18.38960	-3.67792	0.	HOLE	3	14.71168	-14.71168	0.
HOLE	3	20.22856	-3.67792	0.	HOLE	3	16.55064	-14.71168	0.
HOLE	3	22.06752	-3.67792	0.	HOLE	3	18.38960	-14.71168	0.
HOLE	3	23.90648	-3.67792	0.	HOLE	3	20.22856	-14.71168	0.
HOLE	3	25.74544	-3.67792	0.	HOLE	3	22.06752	-14.71168	0.
HOLE	3	27.58440	-3.67792	0.	HOLE	3	23.90648	-14.71168	0.
HOLE	3	29.42336	-3.67792	0.	HOLE	3	25.74544	-14.71168	0.
HOLE	3	31.26232	-3.67792	0.	HOLE	3	27.58440	-14.71168	0.
HOLE	3	9.19480	-5.51688	0.	HOLE	3	29.42336	-14.71168	0.
HOLE	3	11.03376	-5.51688	0.	HOLE	3	31.26232	-14.71168	0.
HOLE	3	12.87272	-5.51688	0.	HOLE	3	0.	-16.55064	0.
HOLE	3	14.71168	-5.51688	0.	HOLE	3	1.83896	-16.55064	0.
HOLE	3	16.55064	-5.51688	0.	HOLE	3	3.67792	-16.55064	0.
HOLE	3	18.38960	-5.51688	0.	HOLE	3	5.51688	-16.55064	0.
HOLE	3	20.22856	-5.51688	0.	HOLE	3	7.35584	-16.55064	0.
HOLE	3	22.06752	-5.51688	0.	HOLE	3	9.19480	-16.55064	0.
HOLE	3	23.90648	-5.51688	0.	HOLE	3	11.03376	-16.55064	0.
HOLE	3	25.74544	-5.51688	0.	HOLE	3	12.87272	-16.55064	0.
HOLE	3	27.58440	-5.51688	0.	HOLE	3	14.71168	-16.55064	0.
HOLE	3	29.42336	-5.51688	0.	HOLE	3	16.55064	-16.55064	0.
HOLE	3	31.26232	-5.51688	0.	HOLE	3	18.38960	-16.55064	0.

HOLE	3	20.22856	-16.55064	0.	HOLE	3	11.03376	-25.74544	0.
HOLE	3	22.06752	-16.55064	0.	HOLE	3	12.87272	-25.74544	0.
HOLE	3	23.90648	-16.55064	0.	HOLE	3	14.71168	-25.74544	0.
HOLE	3	25.74544	-16.55064	0.	HOLE	3	16.55064	-25.74544	0.
HOLE	3	27.58440	-16.55064	0.	HOLE	3	18.38960	-25.74544	0.
HOLE	3	29.42336	-16.55064	0.	HOLE	3	20.22856	-25.74544	0.
HOLE	3	31.26232	-16.55064	0.	HOLE	3	22.06752	-25.74544	0.
HOLE	3	0.	-18.38960	0.	HOLE	3	23.90648	-25.74544	0.
HOLE	3	1.83896	-18.38960	0.	HOLE	3	25.74544	-25.74544	0.
HOLE	3	3.67792	-18.38960	0.	HOLE	3	27.58440	-25.74544	0.
HOLE	3	5.51688	-18.38960	0.	HOLE	3	29.42336	-25.74544	0.
HOLE	3	7.35584	-18.38960	0.	HOLE	3	31.26232	-25.74544	0.
HOLE	3	9.19480	-18.38960	0.	HOLE	3	0.	-27.58440	0.
HOLE	3	11.03376	-18.38960	0.	HOLE	3	1.83896	-27.58440	0.
HOLE	3	12.87272	-18.38960	0.	HOLE	3	3.67792	-27.58440	0.
HOLE	3	14.71168	-18.38960	0.	HOLE	3	5.51688	-27.58440	0.
HOLE	3	16.55064	-18.38960	0.	HOLE	3	7.35584	-27.58440	0.
HOLE	3	18.38960	-18.38960	0.	HOLE	3	9.19480	-27.58440	0.
HOLE	3	20.22856	-18.38960	0.	HOLE	3	11.03376	-27.58440	0.
HOLE	3	22.06752	-18.38960	0.	HOLE	3	12.87272	-27.58440	0.
HOLE	3	23.90648	-18.38960	0.	HOLE	3	14.71168	-27.58440	0.
HOLE	3	25.74544	-18.38960	0.	HOLE	3	16.55064	-27.58440	0.
HOLE	3	27.58440	-18.38960	0.	HOLE	3	18.38960	-27.58440	0.
HOLE	3	29.42336	-18.38960	0.	HOLE	3	20.22856	-27.58440	0.
HOLE	3	31.26232	-18.38960	0.	HOLE	3	22.06752	-27.58440	0.
HOLE	3	0.	-20.22856	0.	HOLE	3	23.90648	-27.58440	0.
HOLE	3	1.83896	-20.22856	0.	HOLE	3	25.74544	-27.58440	0.
HOLE	3	3.67792	-20.22856	0.	HOLE	3	27.58440	-27.58440	0.
HOLE	3	5.51688	-20.22856	0.	HOLE	3	29.42336	-27.58440	0.
HOLE	3	7.35584	-20.22856	0.	HOLE	3	31.26232	-27.58440	0.
HOLE	3	9.19480	-20.22856	0.	HOLE	3	0.	-29.42336	0.
HOLE	3	11.03376	-20.22856	0.	HOLE	3	1.83896	-29.42336	0.
HOLE	3	12.87272	-20.22856	0.	HOLE	3	3.67792	-29.42336	0.
HOLE	3	14.71168	-20.22856	0.	HOLE	3	5.51688	-29.42336	0.
HOLE	3	16.55064	-20.22856	0.	HOLE	3	7.35584	-29.42336	0.
HOLE	3	18.38960	-20.22856	0.	HOLE	3	9.19480	-29.42336	0.
HOLE	3	20.22856	-20.22856	0.	HOLE	3	11.03376	-29.42336	0.
HOLE	3	22.06752	-20.22856	0.	HOLE	3	12.87272	-29.42336	0.
HOLE	3	23.90648	-20.22856	0.	HOLE	3	14.71168	-29.42336	0.
HOLE	3	25.74544	-20.22856	0.	HOLE	3	16.55064	-29.42336	0.
HOLE	3	27.58440	-20.22856	0.	HOLE	3	18.38960	-29.42336	0.
HOLE	3	29.42336	-20.22856	0.	HOLE	3	20.22856	-29.42336	0.
HOLE	3	31.26232	-20.22856	0.	HOLE	3	22.06752	-29.42336	0.
HOLE	3	0.	-22.06752	0.	HOLE	3	23.90648	-29.42336	0.
HOLE	3	1.83896	-22.06752	0.	HOLE	3	25.74544	-29.42336	0.
HOLE	3	3.67792	-22.06752	0.	HOLE	3	27.58440	-29.42336	0.
HOLE	3	5.51688	-22.06752	0.	HOLE	3	29.42336	-29.42336	0.
HOLE	3	7.35584	-22.06752	0.	HOLE	3	31.26232	-29.42336	0.
HOLE	3	9.19480	-22.06752	0.	HOLE	3	0.	-31.26232	0.
HOLE	3	11.03376	-22.06752	0.	HOLE	3	1.83896	-31.26232	0.
HOLE	3	12.87272	-22.06752	0.	HOLE	3	3.67792	-31.26232	0.
HOLE	3	14.71168	-22.06752	0.	HOLE	3	5.51688	-31.26232	0.
HOLE	3	16.55064	-22.06752	0.	HOLE	3	7.35584	-31.26232	0.
HOLE	3	18.38960	-22.06752	0.	HOLE	3	9.19480	-31.26232	0.
HOLE	3	20.22856	-22.06752	0.	HOLE	3	11.03376	-31.26232	0.
HOLE	3	22.06752	-22.06752	0.	HOLE	3	12.87272	-31.26232	0.
HOLE	3	23.90648	-22.06752	0.	HOLE	3	14.71168	-31.26232	0.
HOLE	3	25.74544	-22.06752	0.	HOLE	3	16.55064	-31.26232	0.
HOLE	3	27.58440	-22.06752	0.	HOLE	3	18.38960	-31.26232	0.
HOLE	3	29.42336	-22.06752	0.	HOLE	3	20.22856	-31.26232	0.
HOLE	3	31.26232	-22.06752	0.	HOLE	3	22.06752	-31.26232	0.
HOLE	3	0.	-23.90648	0.	HOLE	3	23.90648	-31.26232	0.
HOLE	3	1.83896	-23.90648	0.	HOLE	3	25.74544	-31.26232	0.
HOLE	3	3.67792	-23.90648	0.	HOLE	3	27.58440	-31.26232	0.
HOLE	3	5.51688	-23.90648	0.	HOLE	3	29.42336	-31.26232	0.
HOLE	3	7.35584	-23.90648	0.	HOLE	3	31.26232	-31.26232	0.
HOLE	3	9.19480	-23.90648	0.	CUBOID	4	1	4P48.12	2P49.5301
HOLE	3	11.03376	-23.90648	0.	GLOBAL				
HOLE	3	12.87272	-23.90648	0.	UNIT 6				
HOLE	3	14.71168	-23.90648	0.	ARRAY	1	2R-48.12	-49.5301	
HOLE	3	16.55064	-23.90648	0.	REFLECTOR	4	2	4*3.1	2*0
HOLE	3	18.38960	-23.90648	0.	END GEOM				10
HOLE	3	20.22856	-23.90648	0.	READ ARRAY				
HOLE	3	22.06752	-23.90648	0.	NUX=1	NUY=1	NUZ=1	FILL	F5
HOLE	3	23.90648	-23.90648	0.	END ARRAY				
HOLE	3	25.74544	-23.90648	0.	READ BIAS				
HOLE	3	27.58440	-23.90648	0.	ID=500	2	11		
HOLE	3	29.42336	-23.90648	0.	END BIAS				
HOLE	3	31.26232	-23.90648	0.	READ START				
HOLE	3	0.	-25.74544	0.	NST=1	XSM=-32	YSM=-32	ZSM=-19.05	
HOLE	3	1.83896	-25.74544	0.	XSP=32	YSP=32	ZSP=19.05		
HOLE	3	3.67792	-25.74544	0.	END START				
HOLE	3	5.51688	-25.74544	0.	END DATA				
HOLE	3	7.35584	-25.74544	0.	END				
HOLE	3	9.19480	-25.74544	0.					

HOLE	1	-1.37922	5.05714	0.	HOLE	1	-5.05714	-6.89610	0.
HOLE	1	-2.29870	5.05714	0.	HOLE	1	-5.97662	-6.89610	0.
HOLE	1	-3.21818	5.05714	0.	HOLE	1	-6.89610	-6.89610	0.
HOLE	1	-4.13766	5.05714	0.	HOLE	1	-7.81558	-6.89610	0.
HOLE	1	-5.05714	5.05714	0.	COM=*x,-y quadrant from center out*				
HOLE	1	-5.97662	5.05714	0.	HOLE	1	0.45974	-0.45974	0.
HOLE	1	-6.89610	5.05714	0.	HOLE	1	1.37922	-0.45974	0.
HOLE	1	-7.81558	5.05714	0.	HOLE	1	2.29870	-0.45974	0.
HOLE	1	-0.45974	5.97662	0.	HOLE	1	3.21818	-0.45974	0.
HOLE	1	-1.37922	5.97662	0.	HOLE	1	4.13766	-0.45974	0.
HOLE	1	-2.29870	5.97662	0.	HOLE	1	5.05714	-0.45974	0.
HOLE	1	-3.21818	5.97662	0.	HOLE	1	5.97662	-0.45974	0.
HOLE	1	-4.13766	5.97662	0.	HOLE	1	6.89610	-0.45974	0.
HOLE	1	-5.05714	5.97662	0.	HOLE	1	7.81558	-0.45974	0.
HOLE	1	-5.97662	5.97662	0.	HOLE	1	0.45974	-1.37922	0.
HOLE	1	-6.89610	5.97662	0.	HOLE	1	1.37922	-1.37922	0.
HOLE	1	-7.81558	5.97662	0.	HOLE	1	2.29870	-1.37922	0.
HOLE	1	-0.45974	6.89610	0.	HOLE	1	3.21818	-1.37922	0.
HOLE	1	-1.37922	6.89610	0.	HOLE	1	4.13766	-1.37922	0.
HOLE	1	-2.29870	6.89610	0.	HOLE	1	5.05714	-1.37922	0.
HOLE	1	-3.21818	6.89610	0.	HOLE	1	5.97662	-1.37922	0.
HOLE	1	-4.13766	6.89610	0.	HOLE	1	6.89610	-1.37922	0.
HOLE	1	-5.05714	6.89610	0.	HOLE	1	7.81558	-1.37922	0.
HOLE	1	-5.97662	6.89610	0.	HOLE	1	0.45974	-2.29870	0.
HOLE	1	-6.89610	6.89610	0.	HOLE	1	1.37922	-2.29870	0.
HOLE	1	-7.81558	6.89610	0.	HOLE	1	2.29870	-2.29870	0.
COM=-x,-y quadrant from center out*					HOLE	1	3.21818	-2.29870	0.
HOLE	1	-0.45974	-0.45974	0.	HOLE	1	4.13766	-2.29870	0.
HOLE	1	-1.37922	-0.45974	0.	HOLE	1	5.05714	-2.29870	0.
HOLE	1	-2.29870	-0.45974	0.	HOLE	1	5.97662	-2.29870	0.
HOLE	1	-3.21818	-0.45974	0.	HOLE	1	6.89610	-2.29870	0.
HOLE	1	-4.13766	-0.45974	0.	HOLE	1	7.81558	-2.29870	0.
HOLE	1	-5.05714	-0.45974	0.	HOLE	1	0.45974	-3.21818	0.
HOLE	1	-5.97662	-0.45974	0.	HOLE	1	1.37922	-3.21818	0.
HOLE	1	-6.89610	-0.45974	0.	HOLE	1	2.29870	-3.21818	0.
HOLE	1	-7.81558	-0.45974	0.	HOLE	1	3.21818	-3.21818	0.
HOLE	1	-0.45974	-1.37922	0.	HOLE	1	4.13766	-3.21818	0.
HOLE	1	-1.37922	-1.37922	0.	HOLE	1	5.05714	-3.21818	0.
HOLE	1	-2.29870	-1.37922	0.	HOLE	1	5.97662	-3.21818	0.
HOLE	1	-3.21818	-1.37922	0.	HOLE	1	6.89610	-3.21818	0.
HOLE	1	-4.13766	-1.37922	0.	HOLE	1	7.81558	-3.21818	0.
HOLE	1	-5.05714	-1.37922	0.	HOLE	1	0.45974	-4.13766	0.
HOLE	1	-5.97662	-1.37922	0.	HOLE	1	1.37922	-4.13766	0.
HOLE	1	-6.89610	-1.37922	0.	HOLE	1	2.29870	-4.13766	0.
HOLE	1	-7.81558	-1.37922	0.	HOLE	1	3.21818	-4.13766	0.
HOLE	1	-0.45974	-2.29870	0.	HOLE	1	4.13766	-4.13766	0.
HOLE	1	-1.37922	-2.29870	0.	HOLE	1	5.05714	-4.13766	0.
HOLE	1	-2.29870	-2.29870	0.	HOLE	1	5.97662	-4.13766	0.
HOLE	1	-3.21818	-2.29870	0.	HOLE	1	6.89610	-4.13766	0.
HOLE	1	-4.13766	-2.29870	0.	HOLE	1	7.81558	-4.13766	0.
HOLE	1	-5.05714	-2.29870	0.	HOLE	1	0.45974	-5.05714	0.
HOLE	1	-5.97662	-2.29870	0.	HOLE	1	1.37922	-5.05714	0.
HOLE	1	-6.89610	-2.29870	0.	HOLE	1	2.29870	-5.05714	0.
HOLE	1	-7.81558	-2.29870	0.	HOLE	1	3.21818	-5.05714	0.
HOLE	1	-0.45974	-3.21818	0.	HOLE	1	4.13766	-5.05714	0.
HOLE	1	-1.37922	-3.21818	0.	HOLE	1	5.05714	-5.05714	0.
HOLE	1	-2.29870	-3.21818	0.	HOLE	1	5.97662	-5.05714	0.
HOLE	1	-3.21818	-3.21818	0.	HOLE	1	6.89610	-5.05714	0.
HOLE	1	-4.13766	-3.21818	0.	HOLE	1	7.81558	-5.05714	0.
HOLE	1	-5.05714	-3.21818	0.	HOLE	1	0.45974	-5.97662	0.
HOLE	1	-5.97662	-3.21818	0.	HOLE	1	1.37922	-5.97662	0.
HOLE	1	-6.89610	-3.21818	0.	HOLE	1	2.29870	-5.97662	0.
HOLE	1	-7.81558	-3.21818	0.	HOLE	1	3.21818	-5.97662	0.
HOLE	1	-0.45974	-4.13766	0.	HOLE	1	4.13766	-5.97662	0.
HOLE	1	-1.37922	-4.13766	0.	HOLE	1	5.05714	-5.97662	0.
HOLE	1	-2.29870	-4.13766	0.	HOLE	1	5.97662	-5.97662	0.
HOLE	1	-3.21818	-4.13766	0.	HOLE	1	6.89610	-5.97662	0.
HOLE	1	-4.13766	-4.13766	0.	HOLE	1	7.81558	-5.97662	0.
HOLE	1	-5.05714	-4.13766	0.	HOLE	1	0.45974	-6.89610	0.
HOLE	1	-5.97662	-4.13766	0.	HOLE	1	1.37922	-6.89610	0.
HOLE	1	-6.89610	-4.13766	0.	HOLE	1	2.29870	-6.89610	0.
HOLE	1	-7.81558	-4.13766	0.	HOLE	1	3.21818	-6.89610	0.
HOLE	1	-0.45974	-5.05714	0.	HOLE	1	4.13766	-6.89610	0.
HOLE	1	-1.37922	-5.05714	0.	HOLE	1	5.05714	-6.89610	0.
HOLE	1	-2.29870	-5.05714	0.	HOLE	1	5.97662	-6.89610	0.
HOLE	1	-3.21818	-5.05714	0.	HOLE	1	6.89610	-6.89610	0.
HOLE	1	-4.13766	-5.05714	0.	HOLE	1	7.81558	-6.89610	0.
HOLE	1	-5.05714	-5.05714	0.	CUBOID	4	1	4P11.71	2P49.5301
HOLE	1	-5.97662	-5.05714	0.	GLOBAL				
HOLE	1	-6.89610	-5.05714	0.	UNIT 6				
HOLE	1	-7.81558	-5.05714	0.	ARRAY	1	2R-11.71	-49.5301	
HOLE	1	-0.45974	-5.97662	0.	REFLECTOR	4	2	4*3.1	2*0
HOLE	1	-1.37922	-5.97662	0.	END GEOM				10
HOLE	1	-2.29870	-5.97662	0.	READ ARRAY				
HOLE	1	-3.21818	-5.97662	0.	NUX=1 NUY=1 NUZ=1 FILL F5 END FILL				
HOLE	1	-4.13766	-5.97662	0.	END ARRAY				
HOLE	1	-5.05714	-5.97662	0.	READ BIAS				
HOLE	1	-5.97662	-5.97662	0.	ID=500 2 11				
HOLE	1	-6.89610	-5.97662	0.	END BIAS				
HOLE	1	-7.81558	-5.97662	0.	READ START				
HOLE	1	-0.45974	-6.89610	0.	NST=1 XSM=-10 YSM=-8 ZSM=-19.05				
HOLE	1	-1.37922	-6.89610	0.	XSP=10 YSP=8 ZSP=19.05				
HOLE	1	-2.29870	-6.89610	0.	END START				
HOLE	1	-3.21818	-6.89610	0.	END DATA				
HOLE	1	-4.13766	-6.89610	0.	END				

E.2.4 Core SB-3, 27 group ENDF/B-IV

```

=CSAS25      PARM=SIZE=200000
full LWBR SB-3 fuel rods, control blades, and 1ft water
reflector
27GROUPNDF4 LATTICECELL
' mix 1 = 233UO2-ZrO2 Seed
O      1 0 5.4281-2      END
ZR      1 0 2.3194-2      END
U-233   1 0 3.8411-3      END
U-234   1 0 6.1327-5      END
U-235   1 0 1.3048-7      END
U-236   1 0 1.2993-7      END
U-238   1 0 4.4061-5      END
' mix 2 = 233UO2-ThO2 blanket
O-16    2 0 4.3081-2      END
TH-232  2 0 2.1311-2      END
U-233   2 0 2.2274-4      END
U-234   2 0 3.5370-6      END
U-235   2 0 2.2722-8      END
U-236   2 0 2.2626-8      END
U-238   2 0 2.7595-6      END
GD      2 0 1.5967-7      END
' mix 3 = zirc-2 cladding etc, 6.56 g/cc, Ntot=4.3234-2
ZR      3 0 4.2537-2      END
CR      3 0 7.5977-5      END
FE      3 0 8.8422-5      END
NI      3 0 3.3656-5      END
SN      3 0 4.9918-4      END
' mix 4 = water, 0.9982 g/cc, Ntot=1.0010-1
H      4 0 6.6735-2      END
O      4 0 3.3368-2      END
' mix 5 = borated SS304 control blades, 7.92g/cc,
Ntot=8.9912-2
FE      5 0 5.9289-2      END
B-10    5 0 3.7488-3      END
C      5 0 1.5884-4      END
CR      5 0 1.7428-2      END
MN      5 0 8.6816-4      END
NI      5 0 7.5171-3      END
P      5 0 3.0797-5      END
S      5 0 2.2308-5      END
SI      5 0 8.4910-4      END
END COMP
SQUAREPITCH 0.91948 0.53594 1 4 0.64770 3 0.55880 0
END
MORE DATA RES=2 CYLINDER 0.62230
DAN(2)=0.196804 END
KENOV.A
READ PARAM
GEN=500 NPG=3000 NSK=50 TME=4000
FLX=YES FDN=YES FMP=YES NUB=YES RUN=YES
END PARAM
READ GEOM
UNIT 1
COM=*Seed rod in water*
CYLINDER 1 1 0.26797 2P19.05
CYLINDER 0 1 0.27940 2P19.05
CYLINDER 3 1 0.32385 2P26.4541
UNIT 3
COM=*blanket rod in water*
CYLINDER 2 1 0.62230 2P19.05
CYLINDER 0 1 0.63246 2P19.05
CYLINDER 3 1 0.72263 2P26.4541
UNIT 4
COM=*control blade in water*
CUBOID 5 1 2P3.81 2P0.0889 49.53
16.71
CUBOID 4 1 2P3.81 2P0.0889 2P49.53
UNIT 5
COM=*rod array with blades, use holes to handle all*
CYLINDER 4 1 45.37 2P49.5301
COM=*control blades & why rod array is by holes*
HOLE 4 0. 5.51688 0.
HOLE 4 0. 1.83896 0.
HOLE 4 0. -1.83896 0.
HOLE 4 0. -5.51688 0.
COM=*+x,+y quadrant from center out*
HOLE 1 0.45974 0.45974 0.
HOLE 1 1.37922 0.45974 0.
HOLE 1 2.29870 0.45974 0.
HOLE 1 3.21818 0.45974 0.
HOLE 1 4.13766 0.45974 0.
HOLE 1 5.05714 0.45974 0.
HOLE 1 5.97662 0.45974 0.
HOLE 1 6.89610 0.45974 0.
HOLE 1 0.45974 1.37922 0.
HOLE 1 1.37922 1.37922 0.
HOLE 1 2.29870 1.37922 0.
HOLE 1 3.21818 1.37922 0.
HOLE 1 4.13766 1.37922 0.
HOLE 1 5.05714 1.37922 0.
HOLE 1 0.45974 2.29870 0.
HOLE 1 1.37922 2.29870 0.
HOLE 1 2.29870 2.29870 0.
HOLE 1 3.21818 2.29870 0.
HOLE 1 4.13766 2.29870 0.
HOLE 1 5.05714 2.29870 0.
HOLE 1 0.45974 3.21818 0.
HOLE 1 1.37922 3.21818 0.
HOLE 1 2.29870 3.21818 0.
HOLE 1 3.21818 3.21818 0.
HOLE 1 4.13766 3.21818 0.
HOLE 1 5.05714 3.21818 0.
HOLE 1 0.45974 4.13766 0.
HOLE 1 1.37922 4.13766 0.
HOLE 1 2.29870 4.13766 0.
HOLE 1 3.21818 4.13766 0.
HOLE 1 4.13766 4.13766 0.
HOLE 1 5.05714 4.13766 0.
HOLE 1 0.45974 5.05714 0.
HOLE 1 1.37922 5.05714 0.
HOLE 1 2.29870 5.05714 0.
HOLE 1 3.21818 5.05714 0.
HOLE 1 4.13766 5.05714 0.
HOLE 1 5.05714 5.05714 0.
HOLE 1 0.45974 5.97662 0.
HOLE 1 1.37922 5.97662 0.
HOLE 1 2.29870 5.97662 0.
HOLE 1 3.21818 5.97662 0.
HOLE 1 4.13766 5.97662 0.
HOLE 1 5.05714 5.97662 0.
HOLE 1 0.45974 6.89610 0.
HOLE 1 1.37922 6.89610 0.
HOLE 1 2.29870 6.89610 0.
HOLE 1 3.21818 6.89610 0.
HOLE 1 4.13766 6.89610 0.
HOLE 1 5.05714 6.89610 0.
HOLE 1 0.45974 7.81558 0.
HOLE 1 1.37922 7.81558 0.
HOLE 1 2.29870 7.81558 0.
HOLE 1 3.21818 7.81558 0.
HOLE 1 4.13766 7.81558 0.
HOLE 1 5.05714 7.81558 0.
HOLE 3 6.43636 1.83896 0.
HOLE 3 8.27532 1.83896 0.
HOLE 3 10.11428 1.83896 0.
HOLE 3 11.95324 1.83896 0.
HOLE 3 13.79220 1.83896 0.
HOLE 3 15.63116 1.83896 0.
HOLE 3 17.47012 1.83896 0.
HOLE 3 19.30908 1.83896 0.
HOLE 3 21.14804 1.83896 0.
HOLE 3 22.98700 1.83896 0.
HOLE 3 24.82596 1.83896 0.
HOLE 3 26.66492 1.83896 0.
HOLE 3 28.50388 1.83896 0.
HOLE 3 6.43636 3.67792 0.
HOLE 3 8.27532 3.67792 0.
HOLE 3 10.11428 3.67792 0.
HOLE 3 11.95324 3.67792 0.
HOLE 3 13.79220 3.67792 0.
HOLE 3 15.63116 3.67792 0.
HOLE 3 17.47012 3.67792 0.
HOLE 3 19.30908 3.67792 0.
HOLE 3 21.14804 3.67792 0.
HOLE 3 22.98700 3.67792 0.
HOLE 3 24.82596 3.67792 0.
HOLE 3 26.66492 3.67792 0.
HOLE 3 28.50388 3.67792 0.
HOLE 3 6.43636 5.51688 0.
HOLE 3 8.27532 5.51688 0.
HOLE 3 10.11428 5.51688 0.
HOLE 3 11.95324 5.51688 0.
HOLE 3 13.79220 5.51688 0.
HOLE 3 15.63116 5.51688 0.
HOLE 3 17.47012 5.51688 0.
HOLE 3 19.30908 5.51688 0.
HOLE 3 21.14804 5.51688 0.
HOLE 3 22.98700 5.51688 0.
HOLE 3 24.82596 5.51688 0.
HOLE 3 26.66492 5.51688 0.
HOLE 3 28.50388 5.51688 0.
HOLE 3 6.43636 7.35584 0.
HOLE 3 8.27532 7.35584 0.
HOLE 3 10.11428 7.35584 0.
HOLE 3 11.95324 7.35584 0.
HOLE 3 13.79220 7.35584 0.
HOLE 3 15.63116 7.35584 0.
HOLE 3 17.47012 7.35584 0.
HOLE 3 19.30908 7.35584 0.
HOLE 3 21.14804 7.35584 0.
HOLE 3 22.98700 7.35584 0.
HOLE 3 24.82596 7.35584 0.

```

HOLE	3	26.66492	7.35584	0.	HOLE	3	24.82596	18.38960	0.
HOLE	3	28.50388	7.35584	0.	HOLE	3	26.66492	18.38960	0.
HOLE	3	0.91948	9.19480	0.	HOLE	3	28.50388	18.38960	0.
HOLE	3	2.75844	9.19480	0.	HOLE	3	0.91948	20.22856	0.
HOLE	3	4.59740	9.19480	0.	HOLE	3	2.75844	20.22856	0.
HOLE	3	6.43636	9.19480	0.	HOLE	3	4.59740	20.22856	0.
HOLE	3	8.27532	9.19480	0.	HOLE	3	6.43636	20.22856	0.
HOLE	3	10.11428	9.19480	0.	HOLE	3	8.27532	20.22856	0.
HOLE	3	11.95324	9.19480	0.	HOLE	3	10.11428	20.22856	0.
HOLE	3	13.79220	9.19480	0.	HOLE	3	11.95324	20.22856	0.
HOLE	3	15.63116	9.19480	0.	HOLE	3	13.79220	20.22856	0.
HOLE	3	17.47012	9.19480	0.	HOLE	3	15.63116	20.22856	0.
HOLE	3	19.30908	9.19480	0.	HOLE	3	17.47012	20.22856	0.
HOLE	3	21.14804	9.19480	0.	HOLE	3	19.30908	20.22856	0.
HOLE	3	22.98700	9.19480	0.	HOLE	3	21.14804	20.22856	0.
HOLE	3	24.82596	9.19480	0.	HOLE	3	22.98700	20.22856	0.
HOLE	3	26.66492	9.19480	0.	HOLE	3	24.82596	20.22856	0.
HOLE	3	28.50388	9.19480	0.	HOLE	3	26.66492	20.22856	0.
HOLE	3	0.91948	11.03376	0.	HOLE	3	28.50388	20.22856	0.
HOLE	3	2.75844	11.03376	0.	HOLE	3	0.91948	22.06752	0.
HOLE	3	4.59740	11.03376	0.	HOLE	3	2.75844	22.06752	0.
HOLE	3	6.43636	11.03376	0.	HOLE	3	4.59740	22.06752	0.
HOLE	3	8.27532	11.03376	0.	HOLE	3	6.43636	22.06752	0.
HOLE	3	10.11428	11.03376	0.	HOLE	3	8.27532	22.06752	0.
HOLE	3	11.95324	11.03376	0.	HOLE	3	10.11428	22.06752	0.
HOLE	3	13.79220	11.03376	0.	HOLE	3	11.95324	22.06752	0.
HOLE	3	15.63116	11.03376	0.	HOLE	3	13.79220	22.06752	0.
HOLE	3	17.47012	11.03376	0.	HOLE	3	15.63116	22.06752	0.
HOLE	3	19.30908	11.03376	0.	HOLE	3	17.47012	22.06752	0.
HOLE	3	21.14804	11.03376	0.	HOLE	3	19.30908	22.06752	0.
HOLE	3	22.98700	11.03376	0.	HOLE	3	21.14804	22.06752	0.
HOLE	3	24.82596	11.03376	0.	HOLE	3	22.98700	22.06752	0.
HOLE	3	26.66492	11.03376	0.	HOLE	3	24.82596	22.06752	0.
HOLE	3	28.50388	11.03376	0.	HOLE	3	26.66492	22.06752	0.
HOLE	3	0.91948	12.87272	0.	HOLE	3	28.50388	22.06752	0.
HOLE	3	2.75844	12.87272	0.	HOLE	3	0.91948	23.90648	0.
HOLE	3	4.59740	12.87272	0.	HOLE	3	2.75844	23.90648	0.
HOLE	3	6.43636	12.87272	0.	HOLE	3	4.59740	23.90648	0.
HOLE	3	8.27532	12.87272	0.	HOLE	3	6.43636	23.90648	0.
HOLE	3	10.11428	12.87272	0.	HOLE	3	8.27532	23.90648	0.
HOLE	3	11.95324	12.87272	0.	HOLE	3	10.11428	23.90648	0.
HOLE	3	13.79220	12.87272	0.	HOLE	3	11.95324	23.90648	0.
HOLE	3	15.63116	12.87272	0.	HOLE	3	13.79220	23.90648	0.
HOLE	3	17.47012	12.87272	0.	HOLE	3	15.63116	23.90648	0.
HOLE	3	19.30908	12.87272	0.	HOLE	3	17.47012	23.90648	0.
HOLE	3	21.14804	12.87272	0.	HOLE	3	19.30908	23.90648	0.
HOLE	3	22.98700	12.87272	0.	HOLE	3	21.14804	23.90648	0.
HOLE	3	24.82596	12.87272	0.	HOLE	3	22.98700	23.90648	0.
HOLE	3	26.66492	12.87272	0.	HOLE	3	24.82596	23.90648	0.
HOLE	3	28.50388	12.87272	0.	HOLE	3	26.66492	23.90648	0.
HOLE	3	0.91948	14.71168	0.	HOLE	3	28.50388	23.90648	0.
HOLE	3	2.75844	14.71168	0.	HOLE	3	0.91948	25.74544	0.
HOLE	3	4.59740	14.71168	0.	HOLE	3	2.75844	25.74544	0.
HOLE	3	6.43636	14.71168	0.	HOLE	3	4.59740	25.74544	0.
HOLE	3	8.27532	14.71168	0.	HOLE	3	6.43636	25.74544	0.
HOLE	3	10.11428	14.71168	0.	HOLE	3	8.27532	25.74544	0.
HOLE	3	11.95324	14.71168	0.	HOLE	3	10.11428	25.74544	0.
HOLE	3	13.79220	14.71168	0.	HOLE	3	11.95324	25.74544	0.
HOLE	3	15.63116	14.71168	0.	HOLE	3	13.79220	25.74544	0.
HOLE	3	17.47012	14.71168	0.	HOLE	3	15.63116	25.74544	0.
HOLE	3	19.30908	14.71168	0.	HOLE	3	17.47012	25.74544	0.
HOLE	3	21.14804	14.71168	0.	HOLE	3	19.30908	25.74544	0.
HOLE	3	22.98700	14.71168	0.	HOLE	3	21.14804	25.74544	0.
HOLE	3	24.82596	14.71168	0.	HOLE	3	22.98700	25.74544	0.
HOLE	3	26.66492	14.71168	0.	HOLE	3	24.82596	25.74544	0.
HOLE	3	28.50388	14.71168	0.	HOLE	3	26.66492	25.74544	0.
HOLE	3	0.91948	16.55064	0.	HOLE	3	28.50388	25.74544	0.
HOLE	3	2.75844	16.55064	0.	HOLE	3	0.91948	27.58440	0.
HOLE	3	4.59740	16.55064	0.	HOLE	3	2.75844	27.58440	0.
HOLE	3	6.43636	16.55064	0.	HOLE	3	4.59740	27.58440	0.
HOLE	3	8.27532	16.55064	0.	HOLE	3	6.43636	27.58440	0.
HOLE	3	10.11428	16.55064	0.	HOLE	3	8.27532	27.58440	0.
HOLE	3	11.95324	16.55064	0.	HOLE	3	10.11428	27.58440	0.
HOLE	3	13.79220	16.55064	0.	HOLE	3	11.95324	27.58440	0.
HOLE	3	15.63116	16.55064	0.	HOLE	3	13.79220	27.58440	0.
HOLE	3	17.47012	16.55064	0.	HOLE	3	15.63116	27.58440	0.
HOLE	3	19.30908	16.55064	0.	HOLE	3	17.47012	27.58440	0.
HOLE	3	21.14804	16.55064	0.	HOLE	3	19.30908	27.58440	0.
HOLE	3	22.98700	16.55064	0.	HOLE	3	21.14804	27.58440	0.
HOLE	3	24.82596	16.55064	0.	HOLE	3	22.98700	27.58440	0.
HOLE	3	26.66492	16.55064	0.	HOLE	3	24.82596	27.58440	0.
HOLE	3	28.50388	16.55064	0.	HOLE	3	26.66492	27.58440	0.
HOLE	3	0.91948	18.38960	0.	HOLE	3	28.50388	27.58440	0.
HOLE	3	2.75844	18.38960	0.	HOLE	3	0.91948	29.42336	0.
HOLE	3	4.59740	18.38960	0.	HOLE	3	2.75844	29.42336	0.
HOLE	3	6.43636	18.38960	0.	HOLE	3	4.59740	29.42336	0.
HOLE	3	8.27532	18.38960	0.	HOLE	3	6.43636	29.42336	0.
HOLE	3	10.11428	18.38960	0.	HOLE	3	8.27532	29.42336	0.
HOLE	3	11.95324	18.38960	0.	HOLE	3	10.11428	29.42336	0.
HOLE	3	13.79220	18.38960	0.	HOLE	3	11.95324	29.42336	0.
HOLE	3	15.63116	18.38960	0.	HOLE	3	13.79220	29.42336	0.
HOLE	3	17.47012	18.38960	0.	HOLE	3	15.63116	29.42336	0.
HOLE	3	19.30908	18.38960	0.	HOLE	3	17.47012	29.42336	0.
HOLE	3	21.14804	18.38960	0.	HOLE	3	19.30908	29.42336	0.
HOLE	3	22.98700	18.38960	0.	HOLE	3	21.14804	29.42336	0.

Appendix E Benchmark Model Inputs

HOLE	3	22.98700	29.42336	0.	HOLE	3	-15.63116	3.67792	0.
HOLE	3	24.82596	29.42336	0.	HOLE	3	-17.47012	3.67792	0.
HOLE	3	26.66492	29.42336	0.	HOLE	3	-19.30908	3.67792	0.
HOLE	3	28.50388	29.42336	0.	HOLE	3	-21.14804	3.67792	0.
HOLE	3	0.91948	31.26232	0.	HOLE	3	-22.98700	3.67792	0.
HOLE	3	2.75844	31.26232	0.	HOLE	3	-24.82596	3.67792	0.
HOLE	3	4.59740	31.26232	0.	HOLE	3	-26.66492	3.67792	0.
HOLE	3	6.43636	31.26232	0.	HOLE	3	-28.50388	3.67792	0.
HOLE	3	8.27532	31.26232	0.	HOLE	3	-6.43636	5.51688	0.
HOLE	3	10.11428	31.26232	0.	HOLE	3	-8.27532	5.51688	0.
HOLE	3	11.95324	31.26232	0.	HOLE	3	-10.11428	5.51688	0.
HOLE	3	13.79220	31.26232	0.	HOLE	3	-11.95324	5.51688	0.
HOLE	3	15.63116	31.26232	0.	HOLE	3	-13.79220	5.51688	0.
HOLE	3	17.47012	31.26232	0.	HOLE	3	-15.63116	5.51688	0.
HOLE	3	19.30908	31.26232	0.	HOLE	3	-17.47012	5.51688	0.
HOLE	3	21.14804	31.26232	0.	HOLE	3	-19.30908	5.51688	0.
HOLE	3	22.98700	31.26232	0.	HOLE	3	-21.14804	5.51688	0.
HOLE	3	24.82596	31.26232	0.	HOLE	3	-22.98700	5.51688	0.
HOLE	3	26.66492	31.26232	0.	HOLE	3	-24.82596	5.51688	0.
HOLE	3	28.50388	31.26232	0.	HOLE	3	-26.66492	5.51688	0.
COM=-x,y quadrant from center out*									
HOLE	1	-0.45974	0.45974	0.	HOLE	3	-28.50388	5.51688	0.
HOLE	1	-1.37922	0.45974	0.	HOLE	3	-6.43636	7.35584	0.
HOLE	1	-2.29870	0.45974	0.	HOLE	3	-8.27532	7.35584	0.
HOLE	1	-3.21818	0.45974	0.	HOLE	3	-10.11428	7.35584	0.
HOLE	1	-4.13766	0.45974	0.	HOLE	3	-11.95324	7.35584	0.
HOLE	1	-5.05714	0.45974	0.	HOLE	3	-13.79220	7.35584	0.
HOLE	1	-5.97662	0.45974	0.	HOLE	3	-15.63116	7.35584	0.
HOLE	1	-6.89610	0.45974	0.	HOLE	3	-17.47012	7.35584	0.
HOLE	1	-0.45974	1.37922	0.	HOLE	3	-19.30908	7.35584	0.
HOLE	1	-1.37922	1.37922	0.	HOLE	3	-21.14804	7.35584	0.
HOLE	1	-2.29870	1.37922	0.	HOLE	3	-22.98700	7.35584	0.
HOLE	1	-3.21818	1.37922	0.	HOLE	3	-24.82596	7.35584	0.
HOLE	1	-4.13766	1.37922	0.	HOLE	3	-26.66492	7.35584	0.
HOLE	1	-5.05714	1.37922	0.	HOLE	3	-28.50388	7.35584	0.
HOLE	1	-0.45974	2.29870	0.	HOLE	3	-0.91948	9.19480	0.
HOLE	1	-1.37922	2.29870	0.	HOLE	3	-2.75844	9.19480	0.
HOLE	1	-2.29870	2.29870	0.	HOLE	3	-4.59740	9.19480	0.
HOLE	1	-3.21818	2.29870	0.	HOLE	3	-6.43636	9.19480	0.
HOLE	1	-4.13766	2.29870	0.	HOLE	3	-8.27532	9.19480	0.
HOLE	1	-5.05714	2.29870	0.	HOLE	3	-10.11428	9.19480	0.
HOLE	1	-0.45974	3.21818	0.	HOLE	3	-11.95324	9.19480	0.
HOLE	1	-1.37922	3.21818	0.	HOLE	3	-13.79220	9.19480	0.
HOLE	1	-2.29870	3.21818	0.	HOLE	3	-15.63116	9.19480	0.
HOLE	1	-3.21818	3.21818	0.	HOLE	3	-17.47012	9.19480	0.
HOLE	1	-4.13766	3.21818	0.	HOLE	3	-19.30908	9.19480	0.
HOLE	1	-5.05714	3.21818	0.	HOLE	3	-21.14804	9.19480	0.
HOLE	1	-0.45974	4.13766	0.	HOLE	3	-22.98700	9.19480	0.
HOLE	1	-1.37922	4.13766	0.	HOLE	3	-24.82596	9.19480	0.
HOLE	1	-2.29870	4.13766	0.	HOLE	3	-26.66492	9.19480	0.
HOLE	1	-3.21818	4.13766	0.	HOLE	3	-28.50388	9.19480	0.
HOLE	1	-4.13766	4.13766	0.	HOLE	3	-0.91948	11.03376	0.
HOLE	1	-5.05714	4.13766	0.	HOLE	3	-2.75844	11.03376	0.
HOLE	1	-0.45974	5.05714	0.	HOLE	3	-4.59740	11.03376	0.
HOLE	1	-1.37922	5.05714	0.	HOLE	3	-6.43636	11.03376	0.
HOLE	1	-2.29870	5.05714	0.	HOLE	3	-8.27532	11.03376	0.
HOLE	1	-3.21818	5.05714	0.	HOLE	3	-10.11428	11.03376	0.
HOLE	1	-4.13766	5.05714	0.	HOLE	3	-11.95324	11.03376	0.
HOLE	1	-5.05714	5.05714	0.	HOLE	3	-13.79220	11.03376	0.
HOLE	1	-0.45974	5.97662	0.	HOLE	3	-15.63116	11.03376	0.
HOLE	1	-1.37922	5.97662	0.	HOLE	3	-17.47012	11.03376	0.
HOLE	1	-2.29870	5.97662	0.	HOLE	3	-19.30908	11.03376	0.
HOLE	1	-3.21818	5.97662	0.	HOLE	3	-21.14804	11.03376	0.
HOLE	1	-4.13766	5.97662	0.	HOLE	3	-22.98700	11.03376	0.
HOLE	1	-5.05714	5.97662	0.	HOLE	3	-24.82596	11.03376	0.
HOLE	1	-0.45974	6.89610	0.	HOLE	3	-26.66492	11.03376	0.
HOLE	1	-1.37922	6.89610	0.	HOLE	3	-28.50388	11.03376	0.
HOLE	1	-2.29870	6.89610	0.	HOLE	3	-0.91948	12.87272	0.
HOLE	1	-3.21818	6.89610	0.	HOLE	3	-2.75844	12.87272	0.
HOLE	1	-4.13766	6.89610	0.	HOLE	3	-4.59740	12.87272	0.
HOLE	1	-5.05714	6.89610	0.	HOLE	3	-6.43636	12.87272	0.
HOLE	1	-0.45974	7.81558	0.	HOLE	3	-8.27532	12.87272	0.
HOLE	1	-1.37922	7.81558	0.	HOLE	3	-10.11428	12.87272	0.
HOLE	1	-2.29870	7.81558	0.	HOLE	3	-11.95324	12.87272	0.
HOLE	1	-3.21818	7.81558	0.	HOLE	3	-13.79220	12.87272	0.
HOLE	1	-4.13766	7.81558	0.	HOLE	3	-15.63116	12.87272	0.
HOLE	1	-5.05714	7.81558	0.	HOLE	3	-17.47012	12.87272	0.
HOLE	3	-6.43636	1.83896	0.	HOLE	3	-19.30908	12.87272	0.
HOLE	3	-8.27532	1.83896	0.	HOLE	3	-21.14804	12.87272	0.
HOLE	3	-10.11428	1.83896	0.	HOLE	3	-22.98700	12.87272	0.
HOLE	3	-11.95324	1.83896	0.	HOLE	3	-24.82596	12.87272	0.
HOLE	3	-13.79220	1.83896	0.	HOLE	3	-26.66492	12.87272	0.
HOLE	3	-15.63116	1.83896	0.	HOLE	3	-28.50388	12.87272	0.
HOLE	3	-17.47012	1.83896	0.	HOLE	3	-0.91948	14.71168	0.
HOLE	3	-19.30908	1.83896	0.	HOLE	3	-2.75844	14.71168	0.
HOLE	3	-21.14804	1.83896	0.	HOLE	3	-4.59740	14.71168	0.
HOLE	3	-22.98700	1.83896	0.	HOLE	3	-6.43636	14.71168	0.
HOLE	3	-24.82596	1.83896	0.	HOLE	3	-8.27532	14.71168	0.
HOLE	3	-26.66492	1.83896	0.	HOLE	3	-10.11428	14.71168	0.
HOLE	3	-28.50388	1.83896	0.	HOLE	3	-11.95324	14.71168	0.
HOLE	3	-6.43636	3.67792	0.	HOLE	3	-13.79220	14.71168	0.
HOLE	3	-8.27532	3.67792	0.	HOLE	3	-15.63116	14.71168	0.
HOLE	3	-10.11428	3.67792	0.	HOLE	3	-17.47012	14.71168	0.
HOLE	3	-11.95324	3.67792	0.	HOLE	3	-19.30908	14.71168	0.
HOLE	3	-13.79220	3.67792	0.	HOLE	3	-21.14804	14.71168	0.
HOLE	3				HOLE	3	-22.98700	14.71168	0.

HOLE	3	-24.82596	14.71168	0.	HOLE	3	-22.98700	25.74544	0.
HOLE	3	-26.66492	14.71168	0.	HOLE	3	-24.82596	25.74544	0.
HOLE	3	-28.50388	14.71168	0.	HOLE	3	-26.66492	25.74544	0.
HOLE	3	-0.91948	16.55064	0.	HOLE	3	-28.50388	25.74544	0.
HOLE	3	-2.75844	16.55064	0.	HOLE	3	-0.91948	27.58440	0.
HOLE	3	-4.59740	16.55064	0.	HOLE	3	-2.75844	27.58440	0.
HOLE	3	-6.43636	16.55064	0.	HOLE	3	-4.59740	27.58440	0.
HOLE	3	-8.27532	16.55064	0.	HOLE	3	-6.43636	27.58440	0.
HOLE	3	-10.11428	16.55064	0.	HOLE	3	-8.27532	27.58440	0.
HOLE	3	-11.95324	16.55064	0.	HOLE	3	-10.11428	27.58440	0.
HOLE	3	-13.79220	16.55064	0.	HOLE	3	-11.95324	27.58440	0.
HOLE	3	-15.63116	16.55064	0.	HOLE	3	-13.79220	27.58440	0.
HOLE	3	-17.47012	16.55064	0.	HOLE	3	-15.63116	27.58440	0.
HOLE	3	-19.30908	16.55064	0.	HOLE	3	-17.47012	27.58440	0.
HOLE	3	-21.14804	16.55064	0.	HOLE	3	-19.30908	27.58440	0.
HOLE	3	-22.98700	16.55064	0.	HOLE	3	-21.14804	27.58440	0.
HOLE	3	-24.82596	16.55064	0.	HOLE	3	-22.98700	27.58440	0.
HOLE	3	-26.66492	16.55064	0.	HOLE	3	-24.82596	27.58440	0.
HOLE	3	-28.50388	16.55064	0.	HOLE	3	-26.66492	27.58440	0.
HOLE	3	-0.91948	18.38960	0.	HOLE	3	-28.50388	27.58440	0.
HOLE	3	-2.75844	18.38960	0.	HOLE	3	-0.91948	29.42336	0.
HOLE	3	-4.59740	18.38960	0.	HOLE	3	-2.75844	29.42336	0.
HOLE	3	-6.43636	18.38960	0.	HOLE	3	-4.59740	29.42336	0.
HOLE	3	-8.27532	18.38960	0.	HOLE	3	-6.43636	29.42336	0.
HOLE	3	-10.11428	18.38960	0.	HOLE	3	-8.27532	29.42336	0.
HOLE	3	-11.95324	18.38960	0.	HOLE	3	-10.11428	29.42336	0.
HOLE	3	-13.79220	18.38960	0.	HOLE	3	-11.95324	29.42336	0.
HOLE	3	-15.63116	18.38960	0.	HOLE	3	-13.79220	29.42336	0.
HOLE	3	-17.47012	18.38960	0.	HOLE	3	-15.63116	29.42336	0.
HOLE	3	-19.30908	18.38960	0.	HOLE	3	-17.47012	29.42336	0.
HOLE	3	-21.14804	18.38960	0.	HOLE	3	-19.30908	29.42336	0.
HOLE	3	-22.98700	18.38960	0.	HOLE	3	-21.14804	29.42336	0.
HOLE	3	-24.82596	18.38960	0.	HOLE	3	-22.98700	29.42336	0.
HOLE	3	-26.66492	18.38960	0.	HOLE	3	-24.82596	29.42336	0.
HOLE	3	-28.50388	18.38960	0.	HOLE	3	-26.66492	29.42336	0.
HOLE	3	-0.91948	20.22856	0.	HOLE	3	-28.50388	29.42336	0.
HOLE	3	-2.75844	20.22856	0.	HOLE	3	-0.91948	31.26232	0.
HOLE	3	-4.59740	20.22856	0.	HOLE	3	-2.75844	31.26232	0.
HOLE	3	-6.43636	20.22856	0.	HOLE	3	-4.59740	31.26232	0.
HOLE	3	-8.27532	20.22856	0.	HOLE	3	-6.43636	31.26232	0.
HOLE	3	-10.11428	20.22856	0.	HOLE	3	-8.27532	31.26232	0.
HOLE	3	-11.95324	20.22856	0.	HOLE	3	-10.11428	31.26232	0.
HOLE	3	-13.79220	20.22856	0.	HOLE	3	-11.95324	31.26232	0.
HOLE	3	-15.63116	20.22856	0.	HOLE	3	-13.79220	31.26232	0.
HOLE	3	-17.47012	20.22856	0.	HOLE	3	-15.63116	31.26232	0.
HOLE	3	-19.30908	20.22856	0.	HOLE	3	-17.47012	31.26232	0.
HOLE	3	-21.14804	20.22856	0.	HOLE	3	-19.30908	31.26232	0.
HOLE	3	-22.98700	20.22856	0.	HOLE	3	-21.14804	31.26232	0.
HOLE	3	-24.82596	20.22856	0.	HOLE	3	-22.98700	31.26232	0.
HOLE	3	-26.66492	20.22856	0.	HOLE	3	-24.82596	31.26232	0.
HOLE	3	-28.50388	20.22856	0.	HOLE	3	-26.66492	31.26232	0.
HOLE	3	-0.91948	22.06752	0.	HOLE	3	-28.50388	31.26232	0.
HOLE	3	-2.75844	22.06752	0.	COM=-x,-y quadrant from center out*				
HOLE	3	-4.59740	22.06752	0.	HOLE	1	-0.45974	-0.45974	0.
HOLE	3	-6.43636	22.06752	0.	HOLE	1	-1.37922	-0.45974	0.
HOLE	3	-8.27532	22.06752	0.	HOLE	1	-2.29870	-0.45974	0.
HOLE	3	-10.11428	22.06752	0.	HOLE	1	-3.21818	-0.45974	0.
HOLE	3	-11.95324	22.06752	0.	HOLE	1	-4.13766	-0.45974	0.
HOLE	3	-13.79220	22.06752	0.	HOLE	1	-5.05714	-0.45974	0.
HOLE	3	-15.63116	22.06752	0.	HOLE	1	-5.97662	-0.45974	0.
HOLE	3	-17.47012	22.06752	0.	HOLE	1	-6.89610	-0.45974	0.
HOLE	3	-19.30908	22.06752	0.	HOLE	1	-0.45974	-1.37922	0.
HOLE	3	-21.14804	22.06752	0.	HOLE	1	-1.37922	-1.37922	0.
HOLE	3	-22.98700	22.06752	0.	HOLE	1	-2.29870	-1.37922	0.
HOLE	3	-24.82596	22.06752	0.	HOLE	1	-3.21818	-1.37922	0.
HOLE	3	-26.66492	22.06752	0.	HOLE	1	-4.13766	-1.37922	0.
HOLE	3	-28.50388	22.06752	0.	HOLE	1	-5.05714	-1.37922	0.
HOLE	3	-0.91948	23.90648	0.	HOLE	1	-0.45974	-2.29870	0.
HOLE	3	-2.75844	23.90648	0.	HOLE	1	-1.37922	-2.29870	0.
HOLE	3	-4.59740	23.90648	0.	HOLE	1	-2.29870	-2.29870	0.
HOLE	3	-6.43636	23.90648	0.	HOLE	1	-3.21818	-2.29870	0.
HOLE	3	-8.27532	23.90648	0.	HOLE	1	-4.13766	-2.29870	0.
HOLE	3	-10.11428	23.90648	0.	HOLE	1	-5.05714	-2.29870	0.
HOLE	3	-11.95324	23.90648	0.	HOLE	1	-0.45974	-3.21818	0.
HOLE	3	-13.79220	23.90648	0.	HOLE	1	-1.37922	-3.21818	0.
HOLE	3	-15.63116	23.90648	0.	HOLE	1	-2.29870	-3.21818	0.
HOLE	3	-17.47012	23.90648	0.	HOLE	1	-3.21818	-3.21818	0.
HOLE	3	-19.30908	23.90648	0.	HOLE	1	-4.13766	-3.21818	0.
HOLE	3	-21.14804	23.90648	0.	HOLE	1	-5.05714	-3.21818	0.
HOLE	3	-22.98700	23.90648	0.	HOLE	1	-0.45974	-4.13766	0.
HOLE	3	-24.82596	23.90648	0.	HOLE	1	-1.37922	-4.13766	0.
HOLE	3	-26.66492	23.90648	0.	HOLE	1	-2.29870	-4.13766	0.
HOLE	3	-28.50388	23.90648	0.	HOLE	1	-3.21818	-4.13766	0.
HOLE	3	-0.91948	25.74544	0.	HOLE	1	-4.13766	-4.13766	0.
HOLE	3	-2.75844	25.74544	0.	HOLE	1	-5.05714	-4.13766	0.
HOLE	3	-4.59740	25.74544	0.	HOLE	1	-0.45974	-5.05714	0.
HOLE	3	-6.43636	25.74544	0.	HOLE	1	-1.37922	-5.05714	0.
HOLE	3	-8.27532	25.74544	0.	HOLE	1	-2.29870	-5.05714	0.
HOLE	3	-10.11428	25.74544	0.	HOLE	1	-3.21818	-5.05714	0.
HOLE	3	-11.95324	25.74544	0.	HOLE	1	-4.13766	-5.05714	0.
HOLE	3	-13.79220	25.74544	0.	HOLE	1	-5.05714	-5.05714	0.
HOLE	3	-15.63116	25.74544	0.	HOLE	1	-0.45974	-5.97662	0.
HOLE	3	-17.47012	25.74544	0.	HOLE	1	-1.37922	-5.97662	0.
HOLE	3	-19.30908	25.74544	0.	HOLE	1	-2.29870	-5.97662	0.
HOLE	3	-21.14804	25.74544	0.	HOLE	1	-3.21818	-5.97662	0.

Appendix E Benchmark Model Inputs

HOLE	1	-4.13766	-5.97662	0.	HOLE	3	-2.75844	-11.03376	0.
HOLE	1	-5.05714	-5.97662	0.	HOLE	3	-4.59740	-11.03376	0.
HOLE	1	-0.45974	-6.89610	0.	HOLE	3	-6.43636	-11.03376	0.
HOLE	1	-1.37922	-6.89610	0.	HOLE	3	-8.27532	-11.03376	0.
HOLE	1	-2.29870	-6.89610	0.	HOLE	3	-10.11428	-11.03376	0.
HOLE	1	-3.21818	-6.89610	0.	HOLE	3	-11.95324	-11.03376	0.
HOLE	1	-4.13766	-6.89610	0.	HOLE	3	-13.79220	-11.03376	0.
HOLE	1	-5.05714	-6.89610	0.	HOLE	3	-15.63116	-11.03376	0.
HOLE	1	-0.45974	-7.81558	0.	HOLE	3	-17.47012	-11.03376	0.
HOLE	1	-1.37922	-7.81558	0.	HOLE	3	-19.30908	-11.03376	0.
HOLE	1	-2.29870	-7.81558	0.	HOLE	3	-21.14804	-11.03376	0.
HOLE	1	-3.21818	-7.81558	0.	HOLE	3	-22.98700	-11.03376	0.
HOLE	1	-4.13766	-7.81558	0.	HOLE	3	-24.82596	-11.03376	0.
HOLE	1	-5.05714	-7.81558	0.	HOLE	3	-26.66492	-11.03376	0.
HOLE	3	-8.27532	0.	0.	HOLE	3	-28.50388	-11.03376	0.
HOLE	3	-10.11428	0.	0.	HOLE	3	-0.91948	-12.87272	0.
HOLE	3	-11.95324	0.	0.	HOLE	3	-2.75844	-12.87272	0.
HOLE	3	-13.79220	0.	0.	HOLE	3	-4.59740	-12.87272	0.
HOLE	3	-15.63116	0.	0.	HOLE	3	-6.43636	-12.87272	0.
HOLE	3	-17.47012	0.	0.	HOLE	3	-8.27532	-12.87272	0.
HOLE	3	-19.30908	0.	0.	HOLE	3	-10.11428	-12.87272	0.
HOLE	3	-21.14804	0.	0.	HOLE	3	-11.95324	-12.87272	0.
HOLE	3	-22.98700	0.	0.	HOLE	3	-13.79220	-12.87272	0.
HOLE	3	-24.82596	0.	0.	HOLE	3	-15.63116	-12.87272	0.
HOLE	3	-26.66492	0.	0.	HOLE	3	-17.47012	-12.87272	0.
HOLE	3	-28.50388	0.	0.	HOLE	3	-19.30908	-12.87272	0.
HOLE	3	-6.43636	-1.83896	0.	HOLE	3	-21.14804	-12.87272	0.
HOLE	3	-8.27532	-1.83896	0.	HOLE	3	-22.98700	-12.87272	0.
HOLE	3	-10.11428	-1.83896	0.	HOLE	3	-24.82596	-12.87272	0.
HOLE	3	-11.95324	-1.83896	0.	HOLE	3	-26.66492	-12.87272	0.
HOLE	3	-13.79220	-1.83896	0.	HOLE	3	-28.50388	-12.87272	0.
HOLE	3	-15.63116	-1.83896	0.	HOLE	3	-0.91948	-14.71168	0.
HOLE	3	-17.47012	-1.83896	0.	HOLE	3	-2.75844	-14.71168	0.
HOLE	3	-19.30908	-1.83896	0.	HOLE	3	-4.59740	-14.71168	0.
HOLE	3	-21.14804	-1.83896	0.	HOLE	3	-6.43636	-14.71168	0.
HOLE	3	-22.98700	-1.83896	0.	HOLE	3	-8.27532	-14.71168	0.
HOLE	3	-24.82596	-1.83896	0.	HOLE	3	-10.11428	-14.71168	0.
HOLE	3	-26.66492	-1.83896	0.	HOLE	3	-11.95324	-14.71168	0.
HOLE	3	-28.50388	-1.83896	0.	HOLE	3	-13.79220	-14.71168	0.
HOLE	3	-6.43636	-3.67792	0.	HOLE	3	-15.63116	-14.71168	0.
HOLE	3	-8.27532	-3.67792	0.	HOLE	3	-17.47012	-14.71168	0.
HOLE	3	-10.11428	-3.67792	0.	HOLE	3	-19.30908	-14.71168	0.
HOLE	3	-11.95324	-3.67792	0.	HOLE	3	-21.14804	-14.71168	0.
HOLE	3	-13.79220	-3.67792	0.	HOLE	3	-22.98700	-14.71168	0.
HOLE	3	-15.63116	-3.67792	0.	HOLE	3	-24.82596	-14.71168	0.
HOLE	3	-17.47012	-3.67792	0.	HOLE	3	-26.66492	-14.71168	0.
HOLE	3	-19.30908	-3.67792	0.	HOLE	3	-28.50388	-14.71168	0.
HOLE	3	-21.14804	-3.67792	0.	HOLE	3	-0.91948	-16.55064	0.
HOLE	3	-22.98700	-3.67792	0.	HOLE	3	-2.75844	-16.55064	0.
HOLE	3	-24.82596	-3.67792	0.	HOLE	3	-4.59740	-16.55064	0.
HOLE	3	-26.66492	-3.67792	0.	HOLE	3	-6.43636	-16.55064	0.
HOLE	3	-28.50388	-3.67792	0.	HOLE	3	-8.27532	-16.55064	0.
HOLE	3	-6.43636	-5.51688	0.	HOLE	3	-10.11428	-16.55064	0.
HOLE	3	-8.27532	-5.51688	0.	HOLE	3	-11.95324	-16.55064	0.
HOLE	3	-10.11428	-5.51688	0.	HOLE	3	-13.79220	-16.55064	0.
HOLE	3	-11.95324	-5.51688	0.	HOLE	3	-15.63116	-16.55064	0.
HOLE	3	-13.79220	-5.51688	0.	HOLE	3	-17.47012	-16.55064	0.
HOLE	3	-15.63116	-5.51688	0.	HOLE	3	-19.30908	-16.55064	0.
HOLE	3	-17.47012	-5.51688	0.	HOLE	3	-21.14804	-16.55064	0.
HOLE	3	-19.30908	-5.51688	0.	HOLE	3	-22.98700	-16.55064	0.
HOLE	3	-21.14804	-5.51688	0.	HOLE	3	-24.82596	-16.55064	0.
HOLE	3	-22.98700	-5.51688	0.	HOLE	3	-26.66492	-16.55064	0.
HOLE	3	-24.82596	-5.51688	0.	HOLE	3	-28.50388	-16.55064	0.
HOLE	3	-26.66492	-5.51688	0.	HOLE	3	-0.91948	-18.38960	0.
HOLE	3	-28.50388	-5.51688	0.	HOLE	3	-2.75844	-18.38960	0.
HOLE	3	-6.43636	-7.35584	0.	HOLE	3	-4.59740	-18.38960	0.
HOLE	3	-8.27532	-7.35584	0.	HOLE	3	-6.43636	-18.38960	0.
HOLE	3	-10.11428	-7.35584	0.	HOLE	3	-8.27532	-18.38960	0.
HOLE	3	-11.95324	-7.35584	0.	HOLE	3	-10.11428	-18.38960	0.
HOLE	3	-13.79220	-7.35584	0.	HOLE	3	-11.95324	-18.38960	0.
HOLE	3	-15.63116	-7.35584	0.	HOLE	3	-13.79220	-18.38960	0.
HOLE	3	-17.47012	-7.35584	0.	HOLE	3	-15.63116	-18.38960	0.
HOLE	3	-19.30908	-7.35584	0.	HOLE	3	-17.47012	-18.38960	0.
HOLE	3	-21.14804	-7.35584	0.	HOLE	3	-19.30908	-18.38960	0.
HOLE	3	-22.98700	-7.35584	0.	HOLE	3	-21.14804	-18.38960	0.
HOLE	3	-24.82596	-7.35584	0.	HOLE	3	-22.98700	-18.38960	0.
HOLE	3	-26.66492	-7.35584	0.	HOLE	3	-24.82596	-18.38960	0.
HOLE	3	-28.50388	-7.35584	0.	HOLE	3	-26.66492	-18.38960	0.
HOLE	3	-0.91948	-9.19480	0.	HOLE	3	-28.50388	-18.38960	0.
HOLE	3	-2.75844	-9.19480	0.	HOLE	3	-0.91948	-20.22856	0.
HOLE	3	-4.59740	-9.19480	0.	HOLE	3	-2.75844	-20.22856	0.
HOLE	3	-6.43636	-9.19480	0.	HOLE	3	-4.59740	-20.22856	0.
HOLE	3	-8.27532	-9.19480	0.	HOLE	3	-6.43636	-20.22856	0.
HOLE	3	-10.11428	-9.19480	0.	HOLE	3	-8.27532	-20.22856	0.
HOLE	3	-11.95324	-9.19480	0.	HOLE	3	-10.11428	-20.22856	0.
HOLE	3	-13.79220	-9.19480	0.	HOLE	3	-11.95324	-20.22856	0.
HOLE	3	-15.63116	-9.19480	0.	HOLE	3	-13.79220	-20.22856	0.
HOLE	3	-17.47012	-9.19480	0.	HOLE	3	-15.63116	-20.22856	0.
HOLE	3	-19.30908	-9.19480	0.	HOLE	3	-17.47012	-20.22856	0.
HOLE	3	-21.14804	-9.19480	0.	HOLE	3	-19.30908	-20.22856	0.
HOLE	3	-22.98700	-9.19480	0.	HOLE	3	-21.14804	-20.22856	0.
HOLE	3	-24.82596	-9.19480	0.	HOLE	3	-22.98700	-20.22856	0.
HOLE	3	-26.66492	-9.19480	0.	HOLE	3	-24.82596	-20.22856	0.
HOLE	3	-28.50388	-9.19480	0.	HOLE	3	-26.66492	-20.22856	0.
HOLE	3	-0.91948	-11.03376	0.	HOLE	3	-28.50388	-20.22856	0.

Criticality Safety Code Validation with LWBR's SB Cores

HOLE	3	-0.91948	-22.06752	0.	HOLE	3	-28.50388	-31.26232	0.
HOLE	3	-2.75844	-22.06752	0.	COM=+x,-y quadrant from center out*				
HOLE	3	-4.59740	-22.06752	0.	HOLE	1	0.45974	-0.45974	0.
HOLE	3	-6.43636	-22.06752	0.	HOLE	1	1.37922	-0.45974	0.
HOLE	3	-8.27532	-22.06752	0.	HOLE	1	2.29870	-0.45974	0.
HOLE	3	-10.11428	-22.06752	0.	HOLE	1	3.21818	-0.45974	0.
HOLE	3	-11.95324	-22.06752	0.	HOLE	1	4.13766	-0.45974	0.
HOLE	3	-13.79220	-22.06752	0.	HOLE	1	5.05714	-0.45974	0.
HOLE	3	-15.63116	-22.06752	0.	HOLE	1	5.97662	-0.45974	0.
HOLE	3	-17.47012	-22.06752	0.	HOLE	1	6.89610	-0.45974	0.
HOLE	3	-19.30908	-22.06752	0.	HOLE	1	0.45974	-1.37922	0.
HOLE	3	-21.14804	-22.06752	0.	HOLE	1	1.37922	-1.37922	0.
HOLE	3	-22.98700	-22.06752	0.	HOLE	1	2.29870	-1.37922	0.
HOLE	3	-24.82596	-22.06752	0.	HOLE	1	3.21818	-1.37922	0.
HOLE	3	-26.66492	-22.06752	0.	HOLE	1	4.13766	-1.37922	0.
HOLE	3	-28.50388	-22.06752	0.	HOLE	1	5.05714	-1.37922	0.
HOLE	3	-0.91948	-23.90648	0.	HOLE	1	0.45974	-2.29870	0.
HOLE	3	-2.75844	-23.90648	0.	HOLE	1	1.37922	-2.29870	0.
HOLE	3	-4.59740	-23.90648	0.	HOLE	1	2.29870	-2.29870	0.
HOLE	3	-6.43636	-23.90648	0.	HOLE	1	3.21818	-2.29870	0.
HOLE	3	-8.27532	-23.90648	0.	HOLE	1	4.13766	-2.29870	0.
HOLE	3	-10.11428	-23.90648	0.	HOLE	1	5.05714	-2.29870	0.
HOLE	3	-11.95324	-23.90648	0.	HOLE	1	0.45974	-3.21818	0.
HOLE	3	-13.79220	-23.90648	0.	HOLE	1	1.37922	-3.21818	0.
HOLE	3	-15.63116	-23.90648	0.	HOLE	1	2.29870	-3.21818	0.
HOLE	3	-17.47012	-23.90648	0.	HOLE	1	3.21818	-3.21818	0.
HOLE	3	-19.30908	-23.90648	0.	HOLE	1	4.13766	-3.21818	0.
HOLE	3	-21.14804	-23.90648	0.	HOLE	1	5.05714	-3.21818	0.
HOLE	3	-22.98700	-23.90648	0.	HOLE	1	0.45974	-4.13766	0.
HOLE	3	-24.82596	-23.90648	0.	HOLE	1	1.37922	-4.13766	0.
HOLE	3	-26.66492	-23.90648	0.	HOLE	1	2.29870	-4.13766	0.
HOLE	3	-28.50388	-23.90648	0.	HOLE	1	3.21818	-4.13766	0.
HOLE	3	-0.91948	-25.74544	0.	HOLE	1	4.13766	-4.13766	0.
HOLE	3	-2.75844	-25.74544	0.	HOLE	1	5.05714	-4.13766	0.
HOLE	3	-4.59740	-25.74544	0.	HOLE	1	0.45974	-5.05714	0.
HOLE	3	-6.43636	-25.74544	0.	HOLE	1	1.37922	-5.05714	0.
HOLE	3	-8.27532	-25.74544	0.	HOLE	1	2.29870	-5.05714	0.
HOLE	3	-10.11428	-25.74544	0.	HOLE	1	3.21818	-5.05714	0.
HOLE	3	-11.95324	-25.74544	0.	HOLE	1	4.13766	-5.05714	0.
HOLE	3	-13.79220	-25.74544	0.	HOLE	1	5.05714	-5.05714	0.
HOLE	3	-15.63116	-25.74544	0.	HOLE	1	0.45974	-5.97662	0.
HOLE	3	-17.47012	-25.74544	0.	HOLE	1	1.37922	-5.97662	0.
HOLE	3	-19.30908	-25.74544	0.	HOLE	1	2.29870	-5.97662	0.
HOLE	3	-21.14804	-25.74544	0.	HOLE	1	3.21818	-5.97662	0.
HOLE	3	-22.98700	-25.74544	0.	HOLE	1	4.13766	-5.97662	0.
HOLE	3	-24.82596	-25.74544	0.	HOLE	1	5.05714	-5.97662	0.
HOLE	3	-26.66492	-25.74544	0.	HOLE	1	0.45974	-6.89610	0.
HOLE	3	-28.50388	-25.74544	0.	HOLE	1	1.37922	-6.89610	0.
HOLE	3	-0.91948	-27.58440	0.	HOLE	1	2.29870	-6.89610	0.
HOLE	3	-2.75844	-27.58440	0.	HOLE	1	3.21818	-6.89610	0.
HOLE	3	-4.59740	-27.58440	0.	HOLE	1	4.13766	-6.89610	0.
HOLE	3	-6.43636	-27.58440	0.	HOLE	1	5.05714	-6.89610	0.
HOLE	3	-8.27532	-27.58440	0.	HOLE	1	0.45974	-7.81558	0.
HOLE	3	-10.11428	-27.58440	0.	HOLE	1	1.37922	-7.81558	0.
HOLE	3	-11.95324	-27.58440	0.	HOLE	1	2.29870	-7.81558	0.
HOLE	3	-13.79220	-27.58440	0.	HOLE	1	3.21818	-7.81558	0.
HOLE	3	-15.63116	-27.58440	0.	HOLE	1	4.13766	-7.81558	0.
HOLE	3	-17.47012	-27.58440	0.	HOLE	1	5.05714	-7.81558	0.
HOLE	3	-19.30908	-27.58440	0.	HOLE	3	8.27532	0.	0.
HOLE	3	-21.14804	-27.58440	0.	HOLE	3	10.11428	0.	0.
HOLE	3	-22.98700	-27.58440	0.	HOLE	3	11.95324	0.	0.
HOLE	3	-24.82596	-27.58440	0.	HOLE	3	13.79220	0.	0.
HOLE	3	-26.66492	-27.58440	0.	HOLE	3	15.63116	0.	0.
HOLE	3	-28.50388	-27.58440	0.	HOLE	3	17.47012	0.	0.
HOLE	3	-0.91948	-29.42336	0.	HOLE	3	19.30908	0.	0.
HOLE	3	-2.75844	-29.42336	0.	HOLE	3	21.14804	0.	0.
HOLE	3	-4.59740	-29.42336	0.	HOLE	3	22.98700	0.	0.
HOLE	3	-6.43636	-29.42336	0.	HOLE	3	24.82596	0.	0.
HOLE	3	-8.27532	-29.42336	0.	HOLE	3	26.66492	0.	0.
HOLE	3	-10.11428	-29.42336	0.	HOLE	3	28.50388	0.	0.
HOLE	3	-11.95324	-29.42336	0.	HOLE	3	6.43636	-1.83896	0.
HOLE	3	-13.79220	-29.42336	0.	HOLE	3	8.27532	-1.83896	0.
HOLE	3	-15.63116	-29.42336	0.	HOLE	3	10.11428	-1.83896	0.
HOLE	3	-17.47012	-29.42336	0.	HOLE	3	11.95324	-1.83896	0.
HOLE	3	-19.30908	-29.42336	0.	HOLE	3	13.79220	-1.83896	0.
HOLE	3	-21.14804	-29.42336	0.	HOLE	3	15.63116	-1.83896	0.
HOLE	3	-22.98700	-29.42336	0.	HOLE	3	17.47012	-1.83896	0.
HOLE	3	-24.82596	-29.42336	0.	HOLE	3	19.30908	-1.83896	0.
HOLE	3	-26.66492	-29.42336	0.	HOLE	3	21.14804	-1.83896	0.
HOLE	3	-28.50388	-29.42336	0.	HOLE	3	22.98700	-1.83896	0.
HOLE	3	-0.91948	-31.26232	0.	HOLE	3	24.82596	-1.83896	0.
HOLE	3	-2.75844	-31.26232	0.	HOLE	3	26.66492	-1.83896	0.
HOLE	3	-4.59740	-31.26232	0.	HOLE	3	28.50388	-1.83896	0.
HOLE	3	-6.43636	-31.26232	0.	HOLE	3	6.43636	-3.67792	0.
HOLE	3	-8.27532	-31.26232	0.	HOLE	3	8.27532	-3.67792	0.
HOLE	3	-10.11428	-31.26232	0.	HOLE	3	10.11428	-3.67792	0.
HOLE	3	-11.95324	-31.26232	0.	HOLE	3	11.95324	-3.67792	0.
HOLE	3	-13.79220	-31.26232	0.	HOLE	3	13.79220	-3.67792	0.
HOLE	3	-15.63116	-31.26232	0.	HOLE	3	15.63116	-3.67792	0.
HOLE	3	-17.47012	-31.26232	0.	HOLE	3	17.47012	-3.67792	0.
HOLE	3	-19.30908	-31.26232	0.	HOLE	3	19.30908	-3.67792	0.
HOLE	3	-21.14804	-31.26232	0.	HOLE	3	21.14804	-3.67792	0.
HOLE	3	-22.98700	-31.26232	0.	HOLE	3	22.98700	-3.67792	0.
HOLE	3	-24.82596	-31.26232	0.	HOLE	3	24.82596	-3.67792	0.
HOLE	3	-26.66492	-31.26232	0.	HOLE	3	26.66492	-3.67792	0.

Appendix E Benchmark Model Inputs

HOLE	3	28.50388	-3.67792	0.	HOLE	3	8.27532	-16.55064	0.
HOLE	3	6.43636	-5.51688	0.	HOLE	3	10.11428	-16.55064	0.
HOLE	3	8.27532	-5.51688	0.	HOLE	3	11.95324	-16.55064	0.
HOLE	3	10.11428	-5.51688	0.	HOLE	3	13.79220	-16.55064	0.
HOLE	3	11.95324	-5.51688	0.	HOLE	3	15.63116	-16.55064	0.
HOLE	3	13.79220	-5.51688	0.	HOLE	3	17.47012	-16.55064	0.
HOLE	3	15.63116	-5.51688	0.	HOLE	3	19.30908	-16.55064	0.
HOLE	3	17.47012	-5.51688	0.	HOLE	3	21.14804	-16.55064	0.
HOLE	3	19.30908	-5.51688	0.	HOLE	3	22.98700	-16.55064	0.
HOLE	3	21.14804	-5.51688	0.	HOLE	3	24.82596	-16.55064	0.
HOLE	3	22.98700	-5.51688	0.	HOLE	3	26.66492	-16.55064	0.
HOLE	3	24.82596	-5.51688	0.	HOLE	3	28.50388	-16.55064	0.
HOLE	3	26.66492	-5.51688	0.	HOLE	3	0.91948	-18.38960	0.
HOLE	3	28.50388	-5.51688	0.	HOLE	3	2.75844	-18.38960	0.
HOLE	3	6.43636	-7.35584	0.	HOLE	3	4.59740	-18.38960	0.
HOLE	3	8.27532	-7.35584	0.	HOLE	3	6.43636	-18.38960	0.
HOLE	3	10.11428	-7.35584	0.	HOLE	3	8.27532	-18.38960	0.
HOLE	3	11.95324	-7.35584	0.	HOLE	3	10.11428	-18.38960	0.
HOLE	3	13.79220	-7.35584	0.	HOLE	3	11.95324	-18.38960	0.
HOLE	3	15.63116	-7.35584	0.	HOLE	3	13.79220	-18.38960	0.
HOLE	3	17.47012	-7.35584	0.	HOLE	3	15.63116	-18.38960	0.
HOLE	3	19.30908	-7.35584	0.	HOLE	3	17.47012	-18.38960	0.
HOLE	3	21.14804	-7.35584	0.	HOLE	3	19.30908	-18.38960	0.
HOLE	3	22.98700	-7.35584	0.	HOLE	3	21.14804	-18.38960	0.
HOLE	3	24.82596	-7.35584	0.	HOLE	3	22.98700	-18.38960	0.
HOLE	3	26.66492	-7.35584	0.	HOLE	3	24.82596	-18.38960	0.
HOLE	3	28.50388	-7.35584	0.	HOLE	3	26.66492	-18.38960	0.
HOLE	3	0.91948	-9.19480	0.	HOLE	3	28.50388	-18.38960	0.
HOLE	3	2.75844	-9.19480	0.	HOLE	3	0.91948	-20.22856	0.
HOLE	3	4.59740	-9.19480	0.	HOLE	3	2.75844	-20.22856	0.
HOLE	3	6.43636	-9.19480	0.	HOLE	3	4.59740	-20.22856	0.
HOLE	3	8.27532	-9.19480	0.	HOLE	3	6.43636	-20.22856	0.
HOLE	3	10.11428	-9.19480	0.	HOLE	3	8.27532	-20.22856	0.
HOLE	3	11.95324	-9.19480	0.	HOLE	3	10.11428	-20.22856	0.
HOLE	3	13.79220	-9.19480	0.	HOLE	3	11.95324	-20.22856	0.
HOLE	3	15.63116	-9.19480	0.	HOLE	3	13.79220	-20.22856	0.
HOLE	3	17.47012	-9.19480	0.	HOLE	3	15.63116	-20.22856	0.
HOLE	3	19.30908	-9.19480	0.	HOLE	3	17.47012	-20.22856	0.
HOLE	3	21.14804	-9.19480	0.	HOLE	3	19.30908	-20.22856	0.
HOLE	3	22.98700	-9.19480	0.	HOLE	3	21.14804	-20.22856	0.
HOLE	3	24.82596	-9.19480	0.	HOLE	3	22.98700	-20.22856	0.
HOLE	3	26.66492	-9.19480	0.	HOLE	3	24.82596	-20.22856	0.
HOLE	3	28.50388	-9.19480	0.	HOLE	3	26.66492	-20.22856	0.
HOLE	3	0.91948	-11.03376	0.	HOLE	3	28.50388	-20.22856	0.
HOLE	3	2.75844	-11.03376	0.	HOLE	3	0.91948	-22.06752	0.
HOLE	3	4.59740	-11.03376	0.	HOLE	3	2.75844	-22.06752	0.
HOLE	3	6.43636	-11.03376	0.	HOLE	3	4.59740	-22.06752	0.
HOLE	3	8.27532	-11.03376	0.	HOLE	3	6.43636	-22.06752	0.
HOLE	3	10.11428	-11.03376	0.	HOLE	3	8.27532	-22.06752	0.
HOLE	3	11.95324	-11.03376	0.	HOLE	3	10.11428	-22.06752	0.
HOLE	3	13.79220	-11.03376	0.	HOLE	3	11.95324	-22.06752	0.
HOLE	3	15.63116	-11.03376	0.	HOLE	3	13.79220	-22.06752	0.
HOLE	3	17.47012	-11.03376	0.	HOLE	3	15.63116	-22.06752	0.
HOLE	3	19.30908	-11.03376	0.	HOLE	3	17.47012	-22.06752	0.
HOLE	3	21.14804	-11.03376	0.	HOLE	3	19.30908	-22.06752	0.
HOLE	3	22.98700	-11.03376	0.	HOLE	3	21.14804	-22.06752	0.
HOLE	3	24.82596	-11.03376	0.	HOLE	3	22.98700	-22.06752	0.
HOLE	3	26.66492	-11.03376	0.	HOLE	3	24.82596	-22.06752	0.
HOLE	3	28.50388	-11.03376	0.	HOLE	3	26.66492	-22.06752	0.
HOLE	3	0.91948	-12.87272	0.	HOLE	3	28.50388	-22.06752	0.
HOLE	3	2.75844	-12.87272	0.	HOLE	3	0.91948	-23.90648	0.
HOLE	3	4.59740	-12.87272	0.	HOLE	3	2.75844	-23.90648	0.
HOLE	3	6.43636	-12.87272	0.	HOLE	3	4.59740	-23.90648	0.
HOLE	3	8.27532	-12.87272	0.	HOLE	3	6.43636	-23.90648	0.
HOLE	3	10.11428	-12.87272	0.	HOLE	3	8.27532	-23.90648	0.
HOLE	3	11.95324	-12.87272	0.	HOLE	3	10.11428	-23.90648	0.
HOLE	3	13.79220	-12.87272	0.	HOLE	3	11.95324	-23.90648	0.
HOLE	3	15.63116	-12.87272	0.	HOLE	3	13.79220	-23.90648	0.
HOLE	3	17.47012	-12.87272	0.	HOLE	3	15.63116	-23.90648	0.
HOLE	3	19.30908	-12.87272	0.	HOLE	3	17.47012	-23.90648	0.
HOLE	3	21.14804	-12.87272	0.	HOLE	3	19.30908	-23.90648	0.
HOLE	3	22.98700	-12.87272	0.	HOLE	3	21.14804	-23.90648	0.
HOLE	3	24.82596	-12.87272	0.	HOLE	3	22.98700	-23.90648	0.
HOLE	3	26.66492	-12.87272	0.	HOLE	3	24.82596	-23.90648	0.
HOLE	3	28.50388	-12.87272	0.	HOLE	3	26.66492	-23.90648	0.
HOLE	3	0.91948	-14.71168	0.	HOLE	3	28.50388	-23.90648	0.
HOLE	3	2.75844	-14.71168	0.	HOLE	3	0.91948	-25.74544	0.
HOLE	3	4.59740	-14.71168	0.	HOLE	3	2.75844	-25.74544	0.
HOLE	3	6.43636	-14.71168	0.	HOLE	3	4.59740	-25.74544	0.
HOLE	3	8.27532	-14.71168	0.	HOLE	3	6.43636	-25.74544	0.
HOLE	3	10.11428	-14.71168	0.	HOLE	3	8.27532	-25.74544	0.
HOLE	3	11.95324	-14.71168	0.	HOLE	3	10.11428	-25.74544	0.
HOLE	3	13.79220	-14.71168	0.	HOLE	3	11.95324	-25.74544	0.
HOLE	3	15.63116	-14.71168	0.	HOLE	3	13.79220	-25.74544	0.
HOLE	3	17.47012	-14.71168	0.	HOLE	3	15.63116	-25.74544	0.
HOLE	3	19.30908	-14.71168	0.	HOLE	3	17.47012	-25.74544	0.
HOLE	3	21.14804	-14.71168	0.	HOLE	3	19.30908	-25.74544	0.
HOLE	3	22.98700	-14.71168	0.	HOLE	3	21.14804	-25.74544	0.
HOLE	3	24.82596	-14.71168	0.	HOLE	3	22.98700	-25.74544	0.
HOLE	3	26.66492	-14.71168	0.	HOLE	3	24.82596	-25.74544	0.
HOLE	3	28.50388	-14.71168	0.	HOLE	3	26.66492	-25.74544	0.
HOLE	3	0.91948	-16.55064	0.	HOLE	3	28.50388	-25.74544	0.
HOLE	3	2.75844	-16.55064	0.	HOLE	3	0.91948	-27.58440	0.
HOLE	3	4.59740	-16.55064	0.	HOLE	3	2.75844	-27.58440	0.
HOLE	3	6.43636	-16.55064	0.	HOLE	3	4.59740	-27.58440	0.

HOLE	3	6.43636	-27.58440	0.	HOLE	3	6.43636	-31.26232	0.
HOLE	3	8.27532	-27.58440	0.	HOLE	3	8.27532	-31.26232	0.
HOLE	3	10.11428	-27.58440	0.	HOLE	3	10.11428	-31.26232	0.
HOLE	3	11.95324	-27.58440	0.	HOLE	3	11.95324	-31.26232	0.
HOLE	3	13.79220	-27.58440	0.	HOLE	3	13.79220	-31.26232	0.
HOLE	3	15.63116	-27.58440	0.	HOLE	3	15.63116	-31.26232	0.
HOLE	3	17.47012	-27.58440	0.	HOLE	3	17.47012	-31.26232	0.
HOLE	3	19.30908	-27.58440	0.	HOLE	3	19.30908	-31.26232	0.
HOLE	3	21.14804	-27.58440	0.	HOLE	3	21.14804	-31.26232	0.
HOLE	3	22.98700	-27.58440	0.	HOLE	3	22.98700	-31.26232	0.
HOLE	3	24.82596	-27.58440	0.	HOLE	3	24.82596	-31.26232	0.
HOLE	3	26.66492	-27.58440	0.	HOLE	3	26.66492	-31.26232	0.
HOLE	3	28.50388	-27.58440	0.	HOLE	3	28.50388	-31.26232	0.
HOLE	3	0.91948	-29.42336	0.	CUBOID	4	1	4P45.37	2P49.5301
HOLE	3	2.75844	-29.42336	0.	GLOBAL				
HOLE	3	4.59740	-29.42336	0.	UNIT 6				
HOLE	3	6.43636	-29.42336	0.	ARRAY	1	2R-45.37	-49.5301	
HOLE	3	8.27532	-29.42336	0.	REFLECTOR	4	2	4*3.1	2*0
HOLE	3	10.11428	-29.42336	0.	END GEOM				10
HOLE	3	11.95324	-29.42336	0.	READ ARRAY				
HOLE	3	13.79220	-29.42336	0.	NUX=1	NUY=1	NUZ=1	FILL	F5
HOLE	3	15.63116	-29.42336	0.	END ARRAY				
HOLE	3	17.47012	-29.42336	0.	READ BIAS				
HOLE	3	19.30908	-29.42336	0.	ID=500	2	11		
HOLE	3	21.14804	-29.42336	0.	END BIAS				
HOLE	3	22.98700	-29.42336	0.	READ START				
HOLE	3	24.82596	-29.42336	0.	NST=1	XSM=-30	YSM=-32	ZSM=-19.05	
HOLE	3	26.66492	-29.42336	0.	XSP=30	YSP=32	ZSP=19.05		
HOLE	3	28.50388	-29.42336	0.	END START				
HOLE	3	0.91948	-31.26232	0.	END DATA				
HOLE	3	2.75844	-31.26232	0.	END				
HOLE	3	4.59740	-31.26232	0.					

E.2.5 Core SB-4, 218 group ENDF/B-IV library

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=CSAS25    PARM=SIZE=200000
full LWBR SB-3 fuel rods, control blades, and 1ft water
reflector
27GROUPNDF4 LATTICECELL
' mix 1 = 233UO2-ZrO2 Seed
O          1 0 5.4281-2    END
ZR          1 0 2.3194-2    END
U-233      1 0 3.8411-3    END
U-234      1 0 6.1327-5    END
U-235      1 0 1.3048-7    END
U-236      1 0 1.2993-7    END
U-238      1 0 4.4061-5    END
' mix 2 = 233UO2-ThO2 blanket
O-16       2 0 4.3081-2    END
TH-232     2 0 2.1311-2    END
U-233      2 0 2.2274-4    END
U-234      2 0 3.5370-6    END
U-235      2 0 2.2722-8    END
U-236      2 0 2.2626-8    END
U-238      2 0 2.7595-6    END
GD          2 0 1.5967-7    END
' mix 3 = zirc-2 cladding etc, 6.56 g/cc, Ntot=4.3234-2
ZR          3 0 4.2537-2    END
CR          3 0 7.5977-5    END
FE          3 0 8.8422-5    END
NI          3 0 3.3656-5    END
SN          3 0 4.9918-4    END
' mix 4 = water, 0.9982 g/cc, Ntot=1.0010-1
H           4 0 6.6735-2    END
O           4 0 3.3368-2    END
' mix 5 = borated SS304 control blades, 7.92g/cc,
Ntot=8.9912-2
FE          5 0 5.9289-2    END
B-10       5 0 3.7488-3    END
C           5 0 1.5884-4    END
CR          5 0 1.7428-2    END
MN          5 0 8.8616-4    END
NI          5 0 7.5171-3    END
P           5 0 3.0797-5    END
S           5 0 2.2308-5    END
SI          5 0 8.4910-4    END
END COMP
SQUAREPITCH 0.91948 0.53594 1 4 0.64770 3 0.55880 0
END
MORE DATA   RES=2    CYLINDER    0.62230
DAN(2)=0.196804  END
KENOV.A
READ PARAM
GEN=500  NPG=3000  NSK=50  TME=4000
FLX=YES  FDN=YES  FMP=YES  NUB=YES  RUN=YES
END PARAM
READ GEOM
UNIT 1
COM=*Seed rod in water*
CYLINDER 1 1 0.26797 2P19.05
CYLINDER 0 1 0.27940 2P19.05
CYLINDER 3 1 0.32385 2P26.4541
UNIT 3
COM=*blanket rod in water*
CYLINDER 2 1 0.62230 2P19.05
CYLINDER 0 1 0.63246 2P19.05
CYLINDER 3 1 0.72263 2P26.4541
UNIT 4
COM=*control blade in water*
CUBOID 5 1 2P3.81 2P0.0889 49.53
16.71
CUBOID 4 1 2P3.81 2P0.0889 2P49.53
UNIT 5
COM=*rod array with blades, use holes to handle all*
CYLINDER 4 1 45.37 2P49.5301
COM=*control blades & why rod array is by holes*
HOLE 4 0. 5.51688 0.
HOLE 4 0. 1.83896 0.
HOLE 4 0. -1.83896 0.
HOLE 4 0. -5.51688 0.
COM=*+x,+y quadrant from center out*
HOLE 1 0.45974 0.45974 0.
HOLE 1 1.37922 0.45974 0.
HOLE 1 2.29870 0.45974 0.
HOLE 1 3.21818 0.45974 0.
HOLE 1 4.13766 0.45974 0.
HOLE 1 5.05714 0.45974 0.
HOLE 1 5.97662 0.45974 0.
HOLE 1 6.89610 0.45974 0.
HOLE 1 0.45974 1.37922 0.
HOLE 1 1.37922 1.37922 0.
HOLE 1 2.29870 1.37922 0.
HOLE 1 3.21818 1.37922 0.
HOLE 1 4.13766 1.37922 0.
HOLE 1 5.05714 1.37922 0.
HOLE 1 0.45974 2.29870 0.
HOLE 1 1.37922 2.29870 0.
HOLE 1 2.29870 2.29870 0.
HOLE 1 3.21818 2.29870 0.
HOLE 1 4.13766 2.29870 0.
HOLE 1 5.05714 2.29870 0.
HOLE 1 0.45974 3.21818 0.
HOLE 1 1.37922 3.21818 0.
HOLE 1 2.29870 3.21818 0.
HOLE 1 3.21818 3.21818 0.
HOLE 1 4.13766 3.21818 0.
HOLE 1 5.05714 3.21818 0.
HOLE 1 0.45974 4.13766 0.
HOLE 1 1.37922 4.13766 0.
HOLE 1 2.29870 4.13766 0.
HOLE 1 3.21818 4.13766 0.
HOLE 1 4.13766 4.13766 0.
HOLE 1 5.05714 4.13766 0.
HOLE 1 0.45974 5.05714 0.
HOLE 1 1.37922 5.05714 0.
HOLE 1 2.29870 5.05714 0.
HOLE 1 3.21818 5.05714 0.
HOLE 1 4.13766 5.05714 0.
HOLE 1 5.05714 5.05714 0.
HOLE 1 0.45974 5.97662 0.
HOLE 1 1.37922 5.97662 0.
HOLE 1 2.29870 5.97662 0.
HOLE 1 3.21818 5.97662 0.

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Appendix E Benchmark Model Inputs

HOLE	1	4.13766	5.97662	0.	HOLE	3	24.82596	11.03376	0.
HOLE	1	5.05714	5.97662	0.	HOLE	3	26.66492	11.03376	0.
HOLE	1	0.45974	6.89610	0.	HOLE	3	28.50388	11.03376	0.
HOLE	1	1.37922	6.89610	0.	HOLE	3	0.91948	12.87272	0.
HOLE	1	2.29870	6.89610	0.	HOLE	3	2.75844	12.87272	0.
HOLE	1	3.21818	6.89610	0.	HOLE	3	4.59740	12.87272	0.
HOLE	1	4.13766	6.89610	0.	HOLE	3	6.43636	12.87272	0.
HOLE	1	5.05714	6.89610	0.	HOLE	3	8.27532	12.87272	0.
HOLE	1	0.45974	7.81558	0.	HOLE	3	10.11428	12.87272	0.
HOLE	1	1.37922	7.81558	0.	HOLE	3	11.95324	12.87272	0.
HOLE	1	2.29870	7.81558	0.	HOLE	3	13.79220	12.87272	0.
HOLE	1	3.21818	7.81558	0.	HOLE	3	15.63116	12.87272	0.
HOLE	1	4.13766	7.81558	0.	HOLE	3	17.47012	12.87272	0.
HOLE	1	5.05714	7.81558	0.	HOLE	3	19.30908	12.87272	0.
HOLE	3	6.43636	1.83896	0.	HOLE	3	21.14804	12.87272	0.
HOLE	3	8.27532	1.83896	0.	HOLE	3	22.98700	12.87272	0.
HOLE	3	10.11428	1.83896	0.	HOLE	3	24.82596	12.87272	0.
HOLE	3	11.95324	1.83896	0.	HOLE	3	26.66492	12.87272	0.
HOLE	3	13.79220	1.83896	0.	HOLE	3	28.50388	12.87272	0.
HOLE	3	15.63116	1.83896	0.	HOLE	3	0.91948	14.71168	0.
HOLE	3	17.47012	1.83896	0.	HOLE	3	2.75844	14.71168	0.
HOLE	3	19.30908	1.83896	0.	HOLE	3	4.59740	14.71168	0.
HOLE	3	21.14804	1.83896	0.	HOLE	3	6.43636	14.71168	0.
HOLE	3	22.98700	1.83896	0.	HOLE	3	8.27532	14.71168	0.
HOLE	3	24.82596	1.83896	0.	HOLE	3	10.11428	14.71168	0.
HOLE	3	26.66492	1.83896	0.	HOLE	3	11.95324	14.71168	0.
HOLE	3	28.50388	1.83896	0.	HOLE	3	13.79220	14.71168	0.
HOLE	3	6.43636	3.67792	0.	HOLE	3	15.63116	14.71168	0.
HOLE	3	8.27532	3.67792	0.	HOLE	3	17.47012	14.71168	0.
HOLE	3	10.11428	3.67792	0.	HOLE	3	19.30908	14.71168	0.
HOLE	3	11.95324	3.67792	0.	HOLE	3	21.14804	14.71168	0.
HOLE	3	13.79220	3.67792	0.	HOLE	3	22.98700	14.71168	0.
HOLE	3	15.63116	3.67792	0.	HOLE	3	24.82596	14.71168	0.
HOLE	3	17.47012	3.67792	0.	HOLE	3	26.66492	14.71168	0.
HOLE	3	19.30908	3.67792	0.	HOLE	3	28.50388	14.71168	0.
HOLE	3	21.14804	3.67792	0.	HOLE	3	0.91948	16.55064	0.
HOLE	3	22.98700	3.67792	0.	HOLE	3	2.75844	16.55064	0.
HOLE	3	24.82596	3.67792	0.	HOLE	3	4.59740	16.55064	0.
HOLE	3	26.66492	3.67792	0.	HOLE	3	6.43636	16.55064	0.
HOLE	3	28.50388	3.67792	0.	HOLE	3	8.27532	16.55064	0.
HOLE	3	6.43636	5.51688	0.	HOLE	3	10.11428	16.55064	0.
HOLE	3	8.27532	5.51688	0.	HOLE	3	11.95324	16.55064	0.
HOLE	3	10.11428	5.51688	0.	HOLE	3	13.79220	16.55064	0.
HOLE	3	11.95324	5.51688	0.	HOLE	3	15.63116	16.55064	0.
HOLE	3	13.79220	5.51688	0.	HOLE	3	17.47012	16.55064	0.
HOLE	3	15.63116	5.51688	0.	HOLE	3	19.30908	16.55064	0.
HOLE	3	17.47012	5.51688	0.	HOLE	3	21.14804	16.55064	0.
HOLE	3	19.30908	5.51688	0.	HOLE	3	22.98700	16.55064	0.
HOLE	3	21.14804	5.51688	0.	HOLE	3	24.82596	16.55064	0.
HOLE	3	22.98700	5.51688	0.	HOLE	3	26.66492	16.55064	0.
HOLE	3	24.82596	5.51688	0.	HOLE	3	28.50388	16.55064	0.
HOLE	3	26.66492	5.51688	0.	HOLE	3	0.91948	18.38960	0.
HOLE	3	28.50388	5.51688	0.	HOLE	3	2.75844	18.38960	0.
HOLE	3	6.43636	7.35584	0.	HOLE	3	4.59740	18.38960	0.
HOLE	3	8.27532	7.35584	0.	HOLE	3	6.43636	18.38960	0.
HOLE	3	10.11428	7.35584	0.	HOLE	3	8.27532	18.38960	0.
HOLE	3	11.95324	7.35584	0.	HOLE	3	10.11428	18.38960	0.
HOLE	3	13.79220	7.35584	0.	HOLE	3	11.95324	18.38960	0.
HOLE	3	15.63116	7.35584	0.	HOLE	3	13.79220	18.38960	0.
HOLE	3	17.47012	7.35584	0.	HOLE	3	15.63116	18.38960	0.
HOLE	3	19.30908	7.35584	0.	HOLE	3	17.47012	18.38960	0.
HOLE	3	21.14804	7.35584	0.	HOLE	3	19.30908	18.38960	0.
HOLE	3	22.98700	7.35584	0.	HOLE	3	21.14804	18.38960	0.
HOLE	3	24.82596	7.35584	0.	HOLE	3	22.98700	18.38960	0.
HOLE	3	26.66492	7.35584	0.	HOLE	3	24.82596	18.38960	0.
HOLE	3	28.50388	7.35584	0.	HOLE	3	26.66492	18.38960	0.
HOLE	3	0.91948	9.19480	0.	HOLE	3	28.50388	18.38960	0.
HOLE	3	2.75844	9.19480	0.	HOLE	3	0.91948	20.22856	0.
HOLE	3	4.59740	9.19480	0.	HOLE	3	2.75844	20.22856	0.
HOLE	3	6.43636	9.19480	0.	HOLE	3	4.59740	20.22856	0.
HOLE	3	8.27532	9.19480	0.	HOLE	3	6.43636	20.22856	0.
HOLE	3	10.11428	9.19480	0.	HOLE	3	8.27532	20.22856	0.
HOLE	3	11.95324	9.19480	0.	HOLE	3	10.11428	20.22856	0.
HOLE	3	13.79220	9.19480	0.	HOLE	3	11.95324	20.22856	0.
HOLE	3	15.63116	9.19480	0.	HOLE	3	13.79220	20.22856	0.
HOLE	3	17.47012	9.19480	0.	HOLE	3	15.63116	20.22856	0.
HOLE	3	19.30908	9.19480	0.	HOLE	3	17.47012	20.22856	0.
HOLE	3	21.14804	9.19480	0.	HOLE	3	19.30908	20.22856	0.
HOLE	3	22.98700	9.19480	0.	HOLE	3	21.14804	20.22856	0.
HOLE	3	24.82596	9.19480	0.	HOLE	3	22.98700	20.22856	0.
HOLE	3	26.66492	9.19480	0.	HOLE	3	24.82596	20.22856	0.
HOLE	3	28.50388	9.19480	0.	HOLE	3	26.66492	20.22856	0.
HOLE	3	0.91948	11.03376	0.	HOLE	3	28.50388	20.22856	0.
HOLE	3	2.75844	11.03376	0.	HOLE	3	0.91948	22.06752	0.
HOLE	3	4.59740	11.03376	0.	HOLE	3	2.75844	22.06752	0.
HOLE	3	6.43636	11.03376	0.	HOLE	3	4.59740	22.06752	0.
HOLE	3	8.27532	11.03376	0.	HOLE	3	6.43636	22.06752	0.
HOLE	3	10.11428	11.03376	0.	HOLE	3	8.27532	22.06752	0.
HOLE	3	11.95324	11.03376	0.	HOLE	3	10.11428	22.06752	0.
HOLE	3	13.79220	11.03376	0.	HOLE	3	11.95324	22.06752	0.
HOLE	3	15.63116	11.03376	0.	HOLE	3	13.79220	22.06752	0.
HOLE	3	17.47012	11.03376	0.	HOLE	3	15.63116	22.06752	0.
HOLE	3	19.30908	11.03376	0.	HOLE	3	17.47012	22.06752	0.
HOLE	3	21.14804	11.03376	0.	HOLE	3	19.30908	22.06752	0.
HOLE	3	22.98700	11.03376	0.	HOLE	3	21.14804	22.06752	0.

Criticality Safety Code Validation with LWBR's SB Cores

HOLE	3	22.98700	22.06752	0.	HOLE	1	-2.29870	1.37922	0.
HOLE	3	24.82596	22.06752	0.	HOLE	1	-3.21818	1.37922	0.
HOLE	3	26.66492	22.06752	0.	HOLE	1	-4.13766	1.37922	0.
HOLE	3	28.50388	22.06752	0.	HOLE	1	-5.05714	1.37922	0.
HOLE	3	0.91948	23.90648	0.	HOLE	1	-0.45974	2.29870	0.
HOLE	3	2.75844	23.90648	0.	HOLE	1	-1.37922	2.29870	0.
HOLE	3	4.59740	23.90648	0.	HOLE	1	-2.29870	2.29870	0.
HOLE	3	6.43636	23.90648	0.	HOLE	1	-3.21818	2.29870	0.
HOLE	3	8.27532	23.90648	0.	HOLE	1	-4.13766	2.29870	0.
HOLE	3	10.11428	23.90648	0.	HOLE	1	-5.05714	2.29870	0.
HOLE	3	11.95324	23.90648	0.	HOLE	1	-0.45974	3.21818	0.
HOLE	3	13.79220	23.90648	0.	HOLE	1	-1.37922	3.21818	0.
HOLE	3	15.63116	23.90648	0.	HOLE	1	-2.29870	3.21818	0.
HOLE	3	17.47012	23.90648	0.	HOLE	1	-3.21818	3.21818	0.
HOLE	3	19.30908	23.90648	0.	HOLE	1	-4.13766	3.21818	0.
HOLE	3	21.14804	23.90648	0.	HOLE	1	-5.05714	3.21818	0.
HOLE	3	22.98700	23.90648	0.	HOLE	1	-0.45974	4.13766	0.
HOLE	3	24.82596	23.90648	0.	HOLE	1	-1.37922	4.13766	0.
HOLE	3	26.66492	23.90648	0.	HOLE	1	-2.29870	4.13766	0.
HOLE	3	28.50388	23.90648	0.	HOLE	1	-3.21818	4.13766	0.
HOLE	3	0.91948	25.74544	0.	HOLE	1	-4.13766	4.13766	0.
HOLE	3	2.75844	25.74544	0.	HOLE	1	-5.05714	4.13766	0.
HOLE	3	4.59740	25.74544	0.	HOLE	1	-0.45974	5.05714	0.
HOLE	3	6.43636	25.74544	0.	HOLE	1	-1.37922	5.05714	0.
HOLE	3	8.27532	25.74544	0.	HOLE	1	-2.29870	5.05714	0.
HOLE	3	10.11428	25.74544	0.	HOLE	1	-3.21818	5.05714	0.
HOLE	3	11.95324	25.74544	0.	HOLE	1	-4.13766	5.05714	0.
HOLE	3	13.79220	25.74544	0.	HOLE	1	-5.05714	5.05714	0.
HOLE	3	15.63116	25.74544	0.	HOLE	1	-0.45974	5.97662	0.
HOLE	3	17.47012	25.74544	0.	HOLE	1	-1.37922	5.97662	0.
HOLE	3	19.30908	25.74544	0.	HOLE	1	-2.29870	5.97662	0.
HOLE	3	21.14804	25.74544	0.	HOLE	1	-3.21818	5.97662	0.
HOLE	3	22.98700	25.74544	0.	HOLE	1	-4.13766	5.97662	0.
HOLE	3	24.82596	25.74544	0.	HOLE	1	-5.05714	5.97662	0.
HOLE	3	26.66492	25.74544	0.	HOLE	1	-0.45974	6.89610	0.
HOLE	3	28.50388	25.74544	0.	HOLE	1	-1.37922	6.89610	0.
HOLE	3	0.91948	27.58440	0.	HOLE	1	-2.29870	6.89610	0.
HOLE	3	2.75844	27.58440	0.	HOLE	1	-3.21818	6.89610	0.
HOLE	3	4.59740	27.58440	0.	HOLE	1	-4.13766	6.89610	0.
HOLE	3	6.43636	27.58440	0.	HOLE	1	-5.05714	6.89610	0.
HOLE	3	8.27532	27.58440	0.	HOLE	1	-0.45974	7.81558	0.
HOLE	3	10.11428	27.58440	0.	HOLE	1	-1.37922	7.81558	0.
HOLE	3	11.95324	27.58440	0.	HOLE	1	-2.29870	7.81558	0.
HOLE	3	13.79220	27.58440	0.	HOLE	1	-3.21818	7.81558	0.
HOLE	3	15.63116	27.58440	0.	HOLE	1	-4.13766	7.81558	0.
HOLE	3	17.47012	27.58440	0.	HOLE	1	-5.05714	7.81558	0.
HOLE	3	19.30908	27.58440	0.	HOLE	3	-6.43636	1.83896	0.
HOLE	3	21.14804	27.58440	0.	HOLE	3	-8.27532	1.83896	0.
HOLE	3	22.98700	27.58440	0.	HOLE	3	-10.11428	1.83896	0.
HOLE	3	24.82596	27.58440	0.	HOLE	3	-11.95324	1.83896	0.
HOLE	3	26.66492	27.58440	0.	HOLE	3	-13.79220	1.83896	0.
HOLE	3	28.50388	27.58440	0.	HOLE	3	-15.63116	1.83896	0.
HOLE	3	0.91948	29.42336	0.	HOLE	3	-17.47012	1.83896	0.
HOLE	3	2.75844	29.42336	0.	HOLE	3	-19.30908	1.83896	0.
HOLE	3	4.59740	29.42336	0.	HOLE	3	-21.14804	1.83896	0.
HOLE	3	6.43636	29.42336	0.	HOLE	3	-22.98700	1.83896	0.
HOLE	3	8.27532	29.42336	0.	HOLE	3	-24.82596	1.83896	0.
HOLE	3	10.11428	29.42336	0.	HOLE	3	-26.66492	1.83896	0.
HOLE	3	11.95324	29.42336	0.	HOLE	3	-28.50388	1.83896	0.
HOLE	3	13.79220	29.42336	0.	HOLE	3	-6.43636	3.67792	0.
HOLE	3	15.63116	29.42336	0.	HOLE	3	-8.27532	3.67792	0.
HOLE	3	17.47012	29.42336	0.	HOLE	3	-10.11428	3.67792	0.
HOLE	3	19.30908	29.42336	0.	HOLE	3	-11.95324	3.67792	0.
HOLE	3	21.14804	29.42336	0.	HOLE	3	-13.79220	3.67792	0.
HOLE	3	22.98700	29.42336	0.	HOLE	3	-15.63116	3.67792	0.
HOLE	3	24.82596	29.42336	0.	HOLE	3	-17.47012	3.67792	0.
HOLE	3	26.66492	29.42336	0.	HOLE	3	-19.30908	3.67792	0.
HOLE	3	28.50388	29.42336	0.	HOLE	3	-21.14804	3.67792	0.
HOLE	3	0.91948	31.26232	0.	HOLE	3	-22.98700	3.67792	0.
HOLE	3	2.75844	31.26232	0.	HOLE	3	-24.82596	3.67792	0.
HOLE	3	4.59740	31.26232	0.	HOLE	3	-26.66492	3.67792	0.
HOLE	3	6.43636	31.26232	0.	HOLE	3	-28.50388	3.67792	0.
HOLE	3	8.27532	31.26232	0.	HOLE	3	-6.43636	5.51688	0.
HOLE	3	10.11428	31.26232	0.	HOLE	3	-8.27532	5.51688	0.
HOLE	3	11.95324	31.26232	0.	HOLE	3	-10.11428	5.51688	0.
HOLE	3	13.79220	31.26232	0.	HOLE	3	-11.95324	5.51688	0.
HOLE	3	15.63116	31.26232	0.	HOLE	3	-13.79220	5.51688	0.
HOLE	3	17.47012	31.26232	0.	HOLE	3	-15.63116	5.51688	0.
HOLE	3	19.30908	31.26232	0.	HOLE	3	-17.47012	5.51688	0.
HOLE	3	21.14804	31.26232	0.	HOLE	3	-19.30908	5.51688	0.
HOLE	3	22.98700	31.26232	0.	HOLE	3	-21.14804	5.51688	0.
HOLE	3	24.82596	31.26232	0.	HOLE	3	-22.98700	5.51688	0.
HOLE	3	26.66492	31.26232	0.	HOLE	3	-24.82596	5.51688	0.
HOLE	3	28.50388	31.26232	0.	HOLE	3	-26.66492	5.51688	0.
COM=-x,+y	quadrant	from center	out*		HOLE	3	-28.50388	5.51688	0.
HOLE	1	-0.45974	0.45974	0.	HOLE	3	-6.43636	7.35584	0.
HOLE	1	-1.37922	0.45974	0.	HOLE	3	-8.27532	7.35584	0.
HOLE	1	-2.29870	0.45974	0.	HOLE	3	-10.11428	7.35584	0.
HOLE	1	-3.21818	0.45974	0.	HOLE	3	-11.95324	7.35584	0.
HOLE	1	-4.13766	0.45974	0.	HOLE	3	-13.79220	7.35584	0.
HOLE	1	-5.05714	0.45974	0.	HOLE	3	-15.63116	7.35584	0.
HOLE	1	-5.97662	0.45974	0.	HOLE	3	-17.47012	7.35584	0.
HOLE	1	-6.89610	0.45974	0.	HOLE	3	-19.30908	7.35584	0.
HOLE	1	-0.45974	1.37922	0.	HOLE	3	-21.14804	7.35584	0.
HOLE	1	-1.37922	1.37922	0.	HOLE	3	-22.98700	7.35584	0.

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HOLE	3	-21.14804	29.42336	0.	HOLE	3	-15.63116	-1.83896	0.
HOLE	3	-22.98700	29.42336	0.	HOLE	3	-17.47012	-1.83896	0.
HOLE	3	-24.82596	29.42336	0.	HOLE	3	-19.30908	-1.83896	0.
HOLE	3	-26.66492	29.42336	0.	HOLE	3	-21.14804	-1.83896	0.
HOLE	3	-28.50388	29.42336	0.	HOLE	3	-22.98700	-1.83896	0.
HOLE	3	-0.91948	31.26232	0.	HOLE	3	-24.82596	-1.83896	0.
HOLE	3	-2.75844	31.26232	0.	HOLE	3	-26.66492	-1.83896	0.
HOLE	3	-4.59740	31.26232	0.	HOLE	3	-28.50388	-1.83896	0.
HOLE	3	-6.43636	31.26232	0.	HOLE	3	-6.43636	-3.67792	0.
HOLE	3	-8.27532	31.26232	0.	HOLE	3	-8.27532	-3.67792	0.
HOLE	3	-10.11428	31.26232	0.	HOLE	3	-10.11428	-3.67792	0.
HOLE	3	-11.95324	31.26232	0.	HOLE	3	-11.95324	-3.67792	0.
HOLE	3	-13.79220	31.26232	0.	HOLE	3	-13.79220	-3.67792	0.
HOLE	3	-15.63116	31.26232	0.	HOLE	3	-15.63116	-3.67792	0.
HOLE	3	-17.47012	31.26232	0.	HOLE	3	-17.47012	-3.67792	0.
HOLE	3	-19.30908	31.26232	0.	HOLE	3	-19.30908	-3.67792	0.
HOLE	3	-21.14804	31.26232	0.	HOLE	3	-21.14804	-3.67792	0.
HOLE	3	-22.98700	31.26232	0.	HOLE	3	-22.98700	-3.67792	0.
HOLE	3	-24.82596	31.26232	0.	HOLE	3	-24.82596	-3.67792	0.
HOLE	3	-26.66492	31.26232	0.	HOLE	3	-26.66492	-3.67792	0.
HOLE	3	-28.50388	31.26232	0.	HOLE	3	-28.50388	-3.67792	0.
COM=-x,-y quadrant from center out*					HOLE	3	-6.43636	-5.51688	0.
HOLE	1	-0.45974	-0.45974	0.	HOLE	3	-8.27532	-5.51688	0.
HOLE	1	-1.37922	-0.45974	0.	HOLE	3	-10.11428	-5.51688	0.
HOLE	1	-2.29870	-0.45974	0.	HOLE	3	-11.95324	-5.51688	0.
HOLE	1	-3.21818	-0.45974	0.	HOLE	3	-13.79220	-5.51688	0.
HOLE	1	-4.13766	-0.45974	0.	HOLE	3	-15.63116	-5.51688	0.
HOLE	1	-5.05714	-0.45974	0.	HOLE	3	-17.47012	-5.51688	0.
HOLE	1	-5.97662	-0.45974	0.	HOLE	3	-19.30908	-5.51688	0.
HOLE	1	-6.89610	-0.45974	0.	HOLE	3	-21.14804	-5.51688	0.
HOLE	1	-0.45974	-1.37922	0.	HOLE	3	-22.98700	-5.51688	0.
HOLE	1	-1.37922	-1.37922	0.	HOLE	3	-24.82596	-5.51688	0.
HOLE	1	-2.29870	-1.37922	0.	HOLE	3	-26.66492	-5.51688	0.
HOLE	1	-3.21818	-1.37922	0.	HOLE	3	-28.50388	-5.51688	0.
HOLE	1	-4.13766	-1.37922	0.	HOLE	3	-6.43636	-7.35584	0.
HOLE	1	-5.05714	-1.37922	0.	HOLE	3	-8.27532	-7.35584	0.
HOLE	1	-0.45974	-2.29870	0.	HOLE	3	-10.11428	-7.35584	0.
HOLE	1	-1.37922	-2.29870	0.	HOLE	3	-11.95324	-7.35584	0.
HOLE	1	-2.29870	-2.29870	0.	HOLE	3	-13.79220	-7.35584	0.
HOLE	1	-3.21818	-2.29870	0.	HOLE	3	-15.63116	-7.35584	0.
HOLE	1	-4.13766	-2.29870	0.	HOLE	3	-17.47012	-7.35584	0.
HOLE	1	-5.05714	-2.29870	0.	HOLE	3	-19.30908	-7.35584	0.
HOLE	1	-0.45974	-3.21818	0.	HOLE	3	-21.14804	-7.35584	0.
HOLE	1	-1.37922	-3.21818	0.	HOLE	3	-22.98700	-7.35584	0.
HOLE	1	-2.29870	-3.21818	0.	HOLE	3	-24.82596	-7.35584	0.
HOLE	1	-3.21818	-3.21818	0.	HOLE	3	-26.66492	-7.35584	0.
HOLE	1	-4.13766	-3.21818	0.	HOLE	3	-28.50388	-7.35584	0.
HOLE	1	-5.05714	-3.21818	0.	HOLE	3	-0.91948	-9.19480	0.
HOLE	1	-0.45974	-4.13766	0.	HOLE	3	-2.75844	-9.19480	0.
HOLE	1	-1.37922	-4.13766	0.	HOLE	3	-4.59740	-9.19480	0.
HOLE	1	-2.29870	-4.13766	0.	HOLE	3	-6.43636	-9.19480	0.
HOLE	1	-3.21818	-4.13766	0.	HOLE	3	-8.27532	-9.19480	0.
HOLE	1	-4.13766	-4.13766	0.	HOLE	3	-10.11428	-9.19480	0.
HOLE	1	-5.05714	-4.13766	0.	HOLE	3	-11.95324	-9.19480	0.
HOLE	1	-0.45974	-5.05714	0.	HOLE	3	-13.79220	-9.19480	0.
HOLE	1	-1.37922	-5.05714	0.	HOLE	3	-15.63116	-9.19480	0.
HOLE	1	-2.29870	-5.05714	0.	HOLE	3	-17.47012	-9.19480	0.
HOLE	1	-3.21818	-5.05714	0.	HOLE	3	-19.30908	-9.19480	0.
HOLE	1	-4.13766	-5.05714	0.	HOLE	3	-21.14804	-9.19480	0.
HOLE	1	-5.05714	-5.05714	0.	HOLE	3	-22.98700	-9.19480	0.
HOLE	1	-0.45974	-5.97662	0.	HOLE	3	-24.82596	-9.19480	0.
HOLE	1	-1.37922	-5.97662	0.	HOLE	3	-26.66492	-9.19480	0.
HOLE	1	-2.29870	-5.97662	0.	HOLE	3	-28.50388	-9.19480	0.
HOLE	1	-3.21818	-5.97662	0.	HOLE	3	-0.91948	-11.03376	0.
HOLE	1	-4.13766	-5.97662	0.	HOLE	3	-2.75844	-11.03376	0.
HOLE	1	-5.05714	-5.97662	0.	HOLE	3	-4.59740	-11.03376	0.
HOLE	1	-0.45974	-6.89610	0.	HOLE	3	-6.43636	-11.03376	0.
HOLE	1	-1.37922	-6.89610	0.	HOLE	3	-8.27532	-11.03376	0.
HOLE	1	-2.29870	-6.89610	0.	HOLE	3	-10.11428	-11.03376	0.
HOLE	1	-3.21818	-6.89610	0.	HOLE	3	-11.95324	-11.03376	0.
HOLE	1	-4.13766	-6.89610	0.	HOLE	3	-13.79220	-11.03376	0.
HOLE	1	-5.05714	-6.89610	0.	HOLE	3	-15.63116	-11.03376	0.
HOLE	1	-0.45974	-7.81558	0.	HOLE	3	-17.47012	-11.03376	0.
HOLE	1	-1.37922	-7.81558	0.	HOLE	3	-19.30908	-11.03376	0.
HOLE	1	-2.29870	-7.81558	0.	HOLE	3	-21.14804	-11.03376	0.
HOLE	1	-3.21818	-7.81558	0.	HOLE	3	-22.98700	-11.03376	0.
HOLE	1	-4.13766	-7.81558	0.	HOLE	3	-24.82596	-11.03376	0.
HOLE	1	-5.05714	-7.81558	0.	HOLE	3	-26.66492	-11.03376	0.
HOLE	3	-8.27532	0.	0.	HOLE	3	-28.50388	-11.03376	0.
HOLE	3	-10.11428	0.	0.	HOLE	3	-0.91948	-12.87272	0.
HOLE	3	-11.95324	0.	0.	HOLE	3	-2.75844	-12.87272	0.
HOLE	3	-13.79220	0.	0.	HOLE	3	-4.59740	-12.87272	0.
HOLE	3	-15.63116	0.	0.	HOLE	3	-6.43636	-12.87272	0.
HOLE	3	-17.47012	0.	0.	HOLE	3	-8.27532	-12.87272	0.
HOLE	3	-19.30908	0.	0.	HOLE	3	-10.11428	-12.87272	0.
HOLE	3	-21.14804	0.	0.	HOLE	3	-11.95324	-12.87272	0.
HOLE	3	-22.98700	0.	0.	HOLE	3	-13.79220	-12.87272	0.
HOLE	3	-24.82596	0.	0.	HOLE	3	-15.63116	-12.87272	0.
HOLE	3	-26.66492	0.	0.	HOLE	3	-17.47012	-12.87272	0.
HOLE	3	-28.50388	0.	0.	HOLE	3	-19.30908	-12.87272	0.
HOLE	3	-6.43636	-1.83896	0.	HOLE	3	-21.14804	-12.87272	0.
HOLE	3	-8.27532	-1.83896	0.	HOLE	3	-22.98700	-12.87272	0.
HOLE	3	-10.11428	-1.83896	0.	HOLE	3	-24.82596	-12.87272	0.
HOLE	3	-11.95324	-1.83896	0.	HOLE	3	-26.66492	-12.87272	0.
HOLE	3	-13.79220	-1.83896	0.	HOLE	3	-28.50388	-12.87272	0.

Appendix E Benchmark Model Inputs

HOLE	3	-0.91948	-14.71168	0.	HOLE	3	-28.50388	-23.90648	0.
HOLE	3	-2.75844	-14.71168	0.	HOLE	3	-0.91948	-25.74544	0.
HOLE	3	-4.59740	-14.71168	0.	HOLE	3	-2.75844	-25.74544	0.
HOLE	3	-6.43636	-14.71168	0.	HOLE	3	-4.59740	-25.74544	0.
HOLE	3	-8.27532	-14.71168	0.	HOLE	3	-6.43636	-25.74544	0.
HOLE	3	-10.11428	-14.71168	0.	HOLE	3	-8.27532	-25.74544	0.
HOLE	3	-11.95324	-14.71168	0.	HOLE	3	-10.11428	-25.74544	0.
HOLE	3	-13.79220	-14.71168	0.	HOLE	3	-11.95324	-25.74544	0.
HOLE	3	-15.63116	-14.71168	0.	HOLE	3	-13.79220	-25.74544	0.
HOLE	3	-17.47012	-14.71168	0.	HOLE	3	-15.63116	-25.74544	0.
HOLE	3	-19.30908	-14.71168	0.	HOLE	3	-17.47012	-25.74544	0.
HOLE	3	-21.14804	-14.71168	0.	HOLE	3	-19.30908	-25.74544	0.
HOLE	3	-22.98700	-14.71168	0.	HOLE	3	-21.14804	-25.74544	0.
HOLE	3	-24.82596	-14.71168	0.	HOLE	3	-22.98700	-25.74544	0.
HOLE	3	-26.66492	-14.71168	0.	HOLE	3	-24.82596	-25.74544	0.
HOLE	3	-28.50388	-14.71168	0.	HOLE	3	-26.66492	-25.74544	0.
HOLE	3	-0.91948	-16.55064	0.	HOLE	3	-28.50388	-25.74544	0.
HOLE	3	-2.75844	-16.55064	0.	HOLE	3	-0.91948	-27.58440	0.
HOLE	3	-4.59740	-16.55064	0.	HOLE	3	-2.75844	-27.58440	0.
HOLE	3	-6.43636	-16.55064	0.	HOLE	3	-4.59740	-27.58440	0.
HOLE	3	-8.27532	-16.55064	0.	HOLE	3	-6.43636	-27.58440	0.
HOLE	3	-10.11428	-16.55064	0.	HOLE	3	-8.27532	-27.58440	0.
HOLE	3	-11.95324	-16.55064	0.	HOLE	3	-10.11428	-27.58440	0.
HOLE	3	-13.79220	-16.55064	0.	HOLE	3	-11.95324	-27.58440	0.
HOLE	3	-15.63116	-16.55064	0.	HOLE	3	-13.79220	-27.58440	0.
HOLE	3	-17.47012	-16.55064	0.	HOLE	3	-15.63116	-27.58440	0.
HOLE	3	-19.30908	-16.55064	0.	HOLE	3	-17.47012	-27.58440	0.
HOLE	3	-21.14804	-16.55064	0.	HOLE	3	-19.30908	-27.58440	0.
HOLE	3	-22.98700	-16.55064	0.	HOLE	3	-21.14804	-27.58440	0.
HOLE	3	-24.82596	-16.55064	0.	HOLE	3	-22.98700	-27.58440	0.
HOLE	3	-26.66492	-16.55064	0.	HOLE	3	-24.82596	-27.58440	0.
HOLE	3	-28.50388	-16.55064	0.	HOLE	3	-26.66492	-27.58440	0.
HOLE	3	-0.91948	-18.38960	0.	HOLE	3	-28.50388	-27.58440	0.
HOLE	3	-2.75844	-18.38960	0.	HOLE	3	-0.91948	-29.42336	0.
HOLE	3	-4.59740	-18.38960	0.	HOLE	3	-2.75844	-29.42336	0.
HOLE	3	-6.43636	-18.38960	0.	HOLE	3	-4.59740	-29.42336	0.
HOLE	3	-8.27532	-18.38960	0.	HOLE	3	-6.43636	-29.42336	0.
HOLE	3	-10.11428	-18.38960	0.	HOLE	3	-8.27532	-29.42336	0.
HOLE	3	-11.95324	-18.38960	0.	HOLE	3	-10.11428	-29.42336	0.
HOLE	3	-13.79220	-18.38960	0.	HOLE	3	-11.95324	-29.42336	0.
HOLE	3	-15.63116	-18.38960	0.	HOLE	3	-13.79220	-29.42336	0.
HOLE	3	-17.47012	-18.38960	0.	HOLE	3	-15.63116	-29.42336	0.
HOLE	3	-19.30908	-18.38960	0.	HOLE	3	-17.47012	-29.42336	0.
HOLE	3	-21.14804	-18.38960	0.	HOLE	3	-19.30908	-29.42336	0.
HOLE	3	-22.98700	-18.38960	0.	HOLE	3	-21.14804	-29.42336	0.
HOLE	3	-24.82596	-18.38960	0.	HOLE	3	-22.98700	-29.42336	0.
HOLE	3	-26.66492	-18.38960	0.	HOLE	3	-24.82596	-29.42336	0.
HOLE	3	-28.50388	-18.38960	0.	HOLE	3	-26.66492	-29.42336	0.
HOLE	3	-0.91948	-20.22856	0.	HOLE	3	-28.50388	-29.42336	0.
HOLE	3	-2.75844	-20.22856	0.	HOLE	3	-0.91948	-31.26232	0.
HOLE	3	-4.59740	-20.22856	0.	HOLE	3	-2.75844	-31.26232	0.
HOLE	3	-6.43636	-20.22856	0.	HOLE	3	-4.59740	-31.26232	0.
HOLE	3	-8.27532	-20.22856	0.	HOLE	3	-6.43636	-31.26232	0.
HOLE	3	-10.11428	-20.22856	0.	HOLE	3	-8.27532	-31.26232	0.
HOLE	3	-11.95324	-20.22856	0.	HOLE	3	-10.11428	-31.26232	0.
HOLE	3	-13.79220	-20.22856	0.	HOLE	3	-11.95324	-31.26232	0.
HOLE	3	-15.63116	-20.22856	0.	HOLE	3	-13.79220	-31.26232	0.
HOLE	3	-17.47012	-20.22856	0.	HOLE	3	-15.63116	-31.26232	0.
HOLE	3	-19.30908	-20.22856	0.	HOLE	3	-17.47012	-31.26232	0.
HOLE	3	-21.14804	-20.22856	0.	HOLE	3	-19.30908	-31.26232	0.
HOLE	3	-22.98700	-20.22856	0.	HOLE	3	-21.14804	-31.26232	0.
HOLE	3	-24.82596	-20.22856	0.	HOLE	3	-22.98700	-31.26232	0.
HOLE	3	-26.66492	-20.22856	0.	HOLE	3	-24.82596	-31.26232	0.
HOLE	3	-28.50388	-20.22856	0.	HOLE	3	-26.66492	-31.26232	0.
HOLE	3	-0.91948	-22.06752	0.	HOLE	3	-28.50388	-31.26232	0.
HOLE	3	-2.75844	-22.06752	0.	COM=*+x,-y quadrant from center out*				
HOLE	3	-4.59740	-22.06752	0.	HOLE	1	0.45974	-0.45974	0.
HOLE	3	-6.43636	-22.06752	0.	HOLE	1	1.37922	-0.45974	0.
HOLE	3	-8.27532	-22.06752	0.	HOLE	1	2.29870	-0.45974	0.
HOLE	3	-10.11428	-22.06752	0.	HOLE	1	3.21818	-0.45974	0.
HOLE	3	-11.95324	-22.06752	0.	HOLE	1	4.13766	-0.45974	0.
HOLE	3	-13.79220	-22.06752	0.	HOLE	1	5.05714	-0.45974	0.
HOLE	3	-15.63116	-22.06752	0.	HOLE	1	5.97662	-0.45974	0.
HOLE	3	-17.47012	-22.06752	0.	HOLE	1	6.89610	-0.45974	0.
HOLE	3	-19.30908	-22.06752	0.	HOLE	1	0.45974	-1.37922	0.
HOLE	3	-21.14804	-22.06752	0.	HOLE	1	1.37922	-1.37922	0.
HOLE	3	-22.98700	-22.06752	0.	HOLE	1	2.29870	-1.37922	0.
HOLE	3	-24.82596	-22.06752	0.	HOLE	1	3.21818	-1.37922	0.
HOLE	3	-26.66492	-22.06752	0.	HOLE	1	4.13766	-1.37922	0.
HOLE	3	-28.50388	-22.06752	0.	HOLE	1	5.05714	-1.37922	0.
HOLE	3	-0.91948	-23.90648	0.	HOLE	1	0.45974	-2.29870	0.
HOLE	3	-2.75844	-23.90648	0.	HOLE	1	1.37922	-2.29870	0.
HOLE	3	-4.59740	-23.90648	0.	HOLE	1	2.29870	-2.29870	0.
HOLE	3	-6.43636	-23.90648	0.	HOLE	1	3.21818	-2.29870	0.
HOLE	3	-8.27532	-23.90648	0.	HOLE	1	4.13766	-2.29870	0.
HOLE	3	-10.11428	-23.90648	0.	HOLE	1	5.05714	-2.29870	0.
HOLE	3	-11.95324	-23.90648	0.	HOLE	1	0.45974	-3.21818	0.
HOLE	3	-13.79220	-23.90648	0.	HOLE	1	1.37922	-3.21818	0.
HOLE	3	-15.63116	-23.90648	0.	HOLE	1	2.29870	-3.21818	0.
HOLE	3	-17.47012	-23.90648	0.	HOLE	1	3.21818	-3.21818	0.
HOLE	3	-19.30908	-23.90648	0.	HOLE	1	4.13766	-3.21818	0.
HOLE	3	-21.14804	-23.90648	0.	HOLE	1	5.05714	-3.21818	0.
HOLE	3	-22.98700	-23.90648	0.	HOLE	1	0.45974	-4.13766	0.
HOLE	3	-24.82596	-23.90648	0.	HOLE	1	1.37922	-4.13766	0.
HOLE	3	-26.66492	-23.90648	0.	HOLE	1	2.29870	-4.13766	0.

HOLE	1	3.21818	-4.13766	0.	HOLE	3	8.27532	-9.19480	0.
HOLE	1	4.13766	-4.13766	0.	HOLE	3	10.11428	-9.19480	0.
HOLE	1	5.05714	-4.13766	0.	HOLE	3	11.95324	-9.19480	0.
HOLE	1	0.45974	-5.05714	0.	HOLE	3	13.79220	-9.19480	0.
HOLE	1	1.37922	-5.05714	0.	HOLE	3	15.63116	-9.19480	0.
HOLE	1	2.29870	-5.05714	0.	HOLE	3	17.47012	-9.19480	0.
HOLE	1	3.21818	-5.05714	0.	HOLE	3	19.30908	-9.19480	0.
HOLE	1	4.13766	-5.05714	0.	HOLE	3	21.14804	-9.19480	0.
HOLE	1	5.05714	-5.05714	0.	HOLE	3	22.98700	-9.19480	0.
HOLE	1	0.45974	-5.97662	0.	HOLE	3	24.82596	-9.19480	0.
HOLE	1	1.37922	-5.97662	0.	HOLE	3	26.66492	-9.19480	0.
HOLE	1	2.29870	-5.97662	0.	HOLE	3	28.50388	-9.19480	0.
HOLE	1	3.21818	-5.97662	0.	HOLE	3	0.91948	-11.03376	0.
HOLE	1	4.13766	-5.97662	0.	HOLE	3	2.75844	-11.03376	0.
HOLE	1	5.05714	-5.97662	0.	HOLE	3	4.59740	-11.03376	0.
HOLE	1	0.45974	-6.89610	0.	HOLE	3	6.43636	-11.03376	0.
HOLE	1	1.37922	-6.89610	0.	HOLE	3	8.27532	-11.03376	0.
HOLE	1	2.29870	-6.89610	0.	HOLE	3	10.11428	-11.03376	0.
HOLE	1	3.21818	-6.89610	0.	HOLE	3	11.95324	-11.03376	0.
HOLE	1	4.13766	-6.89610	0.	HOLE	3	13.79220	-11.03376	0.
HOLE	1	5.05714	-6.89610	0.	HOLE	3	15.63116	-11.03376	0.
HOLE	1	0.45974	-7.81558	0.	HOLE	3	17.47012	-11.03376	0.
HOLE	1	1.37922	-7.81558	0.	HOLE	3	19.30908	-11.03376	0.
HOLE	1	2.29870	-7.81558	0.	HOLE	3	21.14804	-11.03376	0.
HOLE	1	3.21818	-7.81558	0.	HOLE	3	22.98700	-11.03376	0.
HOLE	1	4.13766	-7.81558	0.	HOLE	3	24.82596	-11.03376	0.
HOLE	1	5.05714	-7.81558	0.	HOLE	3	26.66492	-11.03376	0.
HOLE	3	8.27532	0.	0.	HOLE	3	28.50388	-11.03376	0.
HOLE	3	10.11428	0.	0.	HOLE	3	0.91948	-12.87272	0.
HOLE	3	11.95324	0.	0.	HOLE	3	2.75844	-12.87272	0.
HOLE	3	13.79220	0.	0.	HOLE	3	4.59740	-12.87272	0.
HOLE	3	15.63116	0.	0.	HOLE	3	6.43636	-12.87272	0.
HOLE	3	17.47012	0.	0.	HOLE	3	8.27532	-12.87272	0.
HOLE	3	19.30908	0.	0.	HOLE	3	10.11428	-12.87272	0.
HOLE	3	21.14804	0.	0.	HOLE	3	11.95324	-12.87272	0.
HOLE	3	22.98700	0.	0.	HOLE	3	13.79220	-12.87272	0.
HOLE	3	24.82596	0.	0.	HOLE	3	15.63116	-12.87272	0.
HOLE	3	26.66492	0.	0.	HOLE	3	17.47012	-12.87272	0.
HOLE	3	28.50388	0.	0.	HOLE	3	19.30908	-12.87272	0.
HOLE	3	6.43636	-1.83896	0.	HOLE	3	21.14804	-12.87272	0.
HOLE	3	8.27532	-1.83896	0.	HOLE	3	22.98700	-12.87272	0.
HOLE	3	10.11428	-1.83896	0.	HOLE	3	24.82596	-12.87272	0.
HOLE	3	11.95324	-1.83896	0.	HOLE	3	26.66492	-12.87272	0.
HOLE	3	13.79220	-1.83896	0.	HOLE	3	28.50388	-12.87272	0.
HOLE	3	15.63116	-1.83896	0.	HOLE	3	0.91948	-14.71168	0.
HOLE	3	17.47012	-1.83896	0.	HOLE	3	2.75844	-14.71168	0.
HOLE	3	19.30908	-1.83896	0.	HOLE	3	4.59740	-14.71168	0.
HOLE	3	21.14804	-1.83896	0.	HOLE	3	6.43636	-14.71168	0.
HOLE	3	22.98700	-1.83896	0.	HOLE	3	8.27532	-14.71168	0.
HOLE	3	24.82596	-1.83896	0.	HOLE	3	10.11428	-14.71168	0.
HOLE	3	26.66492	-1.83896	0.	HOLE	3	11.95324	-14.71168	0.
HOLE	3	28.50388	-1.83896	0.	HOLE	3	13.79220	-14.71168	0.
HOLE	3	6.43636	-3.67792	0.	HOLE	3	15.63116	-14.71168	0.
HOLE	3	8.27532	-3.67792	0.	HOLE	3	17.47012	-14.71168	0.
HOLE	3	10.11428	-3.67792	0.	HOLE	3	19.30908	-14.71168	0.
HOLE	3	11.95324	-3.67792	0.	HOLE	3	21.14804	-14.71168	0.
HOLE	3	13.79220	-3.67792	0.	HOLE	3	22.98700	-14.71168	0.
HOLE	3	15.63116	-3.67792	0.	HOLE	3	24.82596	-14.71168	0.
HOLE	3	17.47012	-3.67792	0.	HOLE	3	26.66492	-14.71168	0.
HOLE	3	19.30908	-3.67792	0.	HOLE	3	28.50388	-14.71168	0.
HOLE	3	21.14804	-3.67792	0.	HOLE	3	0.91948	-16.55064	0.
HOLE	3	22.98700	-3.67792	0.	HOLE	3	2.75844	-16.55064	0.
HOLE	3	24.82596	-3.67792	0.	HOLE	3	4.59740	-16.55064	0.
HOLE	3	26.66492	-3.67792	0.	HOLE	3	6.43636	-16.55064	0.
HOLE	3	28.50388	-3.67792	0.	HOLE	3	8.27532	-16.55064	0.
HOLE	3	6.43636	-5.51688	0.	HOLE	3	10.11428	-16.55064	0.
HOLE	3	8.27532	-5.51688	0.	HOLE	3	11.95324	-16.55064	0.
HOLE	3	10.11428	-5.51688	0.	HOLE	3	13.79220	-16.55064	0.
HOLE	3	11.95324	-5.51688	0.	HOLE	3	15.63116	-16.55064	0.
HOLE	3	13.79220	-5.51688	0.	HOLE	3	17.47012	-16.55064	0.
HOLE	3	15.63116	-5.51688	0.	HOLE	3	19.30908	-16.55064	0.
HOLE	3	17.47012	-5.51688	0.	HOLE	3	21.14804	-16.55064	0.
HOLE	3	19.30908	-5.51688	0.	HOLE	3	22.98700	-16.55064	0.
HOLE	3	21.14804	-5.51688	0.	HOLE	3	24.82596	-16.55064	0.
HOLE	3	22.98700	-5.51688	0.	HOLE	3	26.66492	-16.55064	0.
HOLE	3	24.82596	-5.51688	0.	HOLE	3	28.50388	-16.55064	0.
HOLE	3	26.66492	-5.51688	0.	HOLE	3	0.91948	-18.38960	0.
HOLE	3	28.50388	-5.51688	0.	HOLE	3	2.75844	-18.38960	0.
HOLE	3	6.43636	-7.35584	0.	HOLE	3	4.59740	-18.38960	0.
HOLE	3	8.27532	-7.35584	0.	HOLE	3	6.43636	-18.38960	0.
HOLE	3	10.11428	-7.35584	0.	HOLE	3	8.27532	-18.38960	0.
HOLE	3	11.95324	-7.35584	0.	HOLE	3	10.11428	-18.38960	0.
HOLE	3	13.79220	-7.35584	0.	HOLE	3	11.95324	-18.38960	0.
HOLE	3	15.63116	-7.35584	0.	HOLE	3	13.79220	-18.38960	0.
HOLE	3	17.47012	-7.35584	0.	HOLE	3	15.63116	-18.38960	0.
HOLE	3	19.30908	-7.35584	0.	HOLE	3	17.47012	-18.38960	0.
HOLE	3	21.14804	-7.35584	0.	HOLE	3	19.30908	-18.38960	0.
HOLE	3	22.98700	-7.35584	0.	HOLE	3	21.14804	-18.38960	0.
HOLE	3	24.82596	-7.35584	0.	HOLE	3	22.98700	-18.38960	0.
HOLE	3	26.66492	-7.35584	0.	HOLE	3	24.82596	-18.38960	0.
HOLE	3	28.50388	-7.35584	0.	HOLE	3	26.66492	-18.38960	0.
HOLE	3	0.91948	-9.19480	0.	HOLE	3	28.50388	-18.38960	0.
HOLE	3	2.75844	-9.19480	0.	HOLE	3	0.91948	-20.22856	0.
HOLE	3	4.59740	-9.19480	0.	HOLE	3	2.75844	-20.22856	0.
HOLE	3	6.43636	-9.19480	0.	HOLE	3	4.59740	-20.22856	0.

HOLE	3	6.43636	-20.22856	0.	HOLE	3	6.43636	-27.58440	0.
HOLE	3	8.27532	-20.22856	0.	HOLE	3	8.27532	-27.58440	0.
HOLE	3	10.11428	-20.22856	0.	HOLE	3	10.11428	-27.58440	0.
HOLE	3	11.95324	-20.22856	0.	HOLE	3	11.95324	-27.58440	0.
HOLE	3	13.79220	-20.22856	0.	HOLE	3	13.79220	-27.58440	0.
HOLE	3	15.63116	-20.22856	0.	HOLE	3	15.63116	-27.58440	0.
HOLE	3	17.47012	-20.22856	0.	HOLE	3	17.47012	-27.58440	0.
HOLE	3	19.30908	-20.22856	0.	HOLE	3	19.30908	-27.58440	0.
HOLE	3	21.14804	-20.22856	0.	HOLE	3	21.14804	-27.58440	0.
HOLE	3	22.98700	-20.22856	0.	HOLE	3	22.98700	-27.58440	0.
HOLE	3	24.82596	-20.22856	0.	HOLE	3	24.82596	-27.58440	0.
HOLE	3	26.66492	-20.22856	0.	HOLE	3	26.66492	-27.58440	0.
HOLE	3	28.50388	-20.22856	0.	HOLE	3	28.50388	-27.58440	0.
HOLE	3	0.91948	-22.06752	0.	HOLE	3	0.91948	-29.42336	0.
HOLE	3	2.75844	-22.06752	0.	HOLE	3	2.75844	-29.42336	0.
HOLE	3	4.59740	-22.06752	0.	HOLE	3	4.59740	-29.42336	0.
HOLE	3	6.43636	-22.06752	0.	HOLE	3	6.43636	-29.42336	0.
HOLE	3	8.27532	-22.06752	0.	HOLE	3	8.27532	-29.42336	0.
HOLE	3	10.11428	-22.06752	0.	HOLE	3	10.11428	-29.42336	0.
HOLE	3	11.95324	-22.06752	0.	HOLE	3	11.95324	-29.42336	0.
HOLE	3	13.79220	-22.06752	0.	HOLE	3	13.79220	-29.42336	0.
HOLE	3	15.63116	-22.06752	0.	HOLE	3	15.63116	-29.42336	0.
HOLE	3	17.47012	-22.06752	0.	HOLE	3	17.47012	-29.42336	0.
HOLE	3	19.30908	-22.06752	0.	HOLE	3	19.30908	-29.42336	0.
HOLE	3	21.14804	-22.06752	0.	HOLE	3	21.14804	-29.42336	0.
HOLE	3	22.98700	-22.06752	0.	HOLE	3	22.98700	-29.42336	0.
HOLE	3	24.82596	-22.06752	0.	HOLE	3	24.82596	-29.42336	0.
HOLE	3	26.66492	-22.06752	0.	HOLE	3	26.66492	-29.42336	0.
HOLE	3	28.50388	-22.06752	0.	HOLE	3	28.50388	-29.42336	0.
HOLE	3	0.91948	-23.90648	0.	HOLE	3	0.91948	-31.26232	0.
HOLE	3	2.75844	-23.90648	0.	HOLE	3	2.75844	-31.26232	0.
HOLE	3	4.59740	-23.90648	0.	HOLE	3	4.59740	-31.26232	0.
HOLE	3	6.43636	-23.90648	0.	HOLE	3	6.43636	-31.26232	0.
HOLE	3	8.27532	-23.90648	0.	HOLE	3	8.27532	-31.26232	0.
HOLE	3	10.11428	-23.90648	0.	HOLE	3	10.11428	-31.26232	0.
HOLE	3	11.95324	-23.90648	0.	HOLE	3	11.95324	-31.26232	0.
HOLE	3	13.79220	-23.90648	0.	HOLE	3	13.79220	-31.26232	0.
HOLE	3	15.63116	-23.90648	0.	HOLE	3	15.63116	-31.26232	0.
HOLE	3	17.47012	-23.90648	0.	HOLE	3	17.47012	-31.26232	0.
HOLE	3	19.30908	-23.90648	0.	HOLE	3	19.30908	-31.26232	0.
HOLE	3	21.14804	-23.90648	0.	HOLE	3	21.14804	-31.26232	0.
HOLE	3	22.98700	-23.90648	0.	HOLE	3	22.98700	-31.26232	0.
HOLE	3	24.82596	-23.90648	0.	HOLE	3	24.82596	-31.26232	0.
HOLE	3	26.66492	-23.90648	0.	HOLE	3	26.66492	-31.26232	0.
HOLE	3	28.50388	-23.90648	0.	HOLE	3	28.50388	-31.26232	0.
HOLE	3	0.91948	-25.74544	0.	CUBOID	4	1	4P45.37	2P49.5301
HOLE	3	2.75844	-25.74544	0.	GLOBAL				
HOLE	3	4.59740	-25.74544	0.	UNIT 6				
HOLE	3	6.43636	-25.74544	0.	ARRAY	1	2R-45.37	-49.5301	
HOLE	3	8.27532	-25.74544	0.	REFLECTOR	4	2	4*3.1	2*0
HOLE	3	10.11428	-25.74544	0.	END GEOM				10
HOLE	3	11.95324	-25.74544	0.	READ ARRAY				
HOLE	3	13.79220	-25.74544	0.	NUX=1	NUY=1	NUZ=1	FILL	F5
HOLE	3	15.63116	-25.74544	0.	END ARRAY				
HOLE	3	17.47012	-25.74544	0.	READ BIAS				
HOLE	3	19.30908	-25.74544	0.	ID=500	2	11		
HOLE	3	21.14804	-25.74544	0.	END BIAS				
HOLE	3	22.98700	-25.74544	0.	READ START				
HOLE	3	24.82596	-25.74544	0.	NST=1	XSM=-30	YSM=-32	ZSM=-19.05	
HOLE	3	26.66492	-25.74544	0.	XSP=30	YSP=32	ZSP=19.05		
HOLE	3	28.50388	-25.74544	0.	END START				
HOLE	3	0.91948	-27.58440	0.	END DATA				
HOLE	3	2.75844	-27.58440	0.	END				
HOLE	3	4.59740	-27.58440	0.					

E.2.6 Core SB-5, 238 Group ENDF/B-V

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=CSAS25    PARM=SIZE=200000
full LWBR SB-5 fuel rods, control blades, and 1ft water
reflector
238GROUPNDF5 LATTICECELL
' mix 1 = 235UO2-ZrO2 Seed
O          1 0 5.4840-2    END
ZR         1 0 2.3240-2    END
U-234      1 0 3.7309-5    END
U-235      1 0 3.8791-3    END
U-236      1 0 1.0907-5    END
U-238      1 0 2.5278-4    END
' mix 2 = ThO2 blanket
O-16       2 0 4.3282-2    END
TH-232     2 0 2.1641-2    END
GD         2 5.28-6        END
' mix 3 = zirc-2 cladding etc, 6.56 g/cc, Ntot=4.3234-2
ZR         3 0 4.2537-2    END
CR         3 0 7.5977-5    END
FE         3 0 8.8422-5    END
NI         3 0 3.3656-5    END
SN         3 0.0135        END
' mix 4 = water, 0.9982 g/cc, Ntot=1.0010-1
H          4 0 6.6735-2    END
O          4 0 3.3368-2    END
' mix 5 = borated SS304 control blades, 7.92g/cc,
Ntot=8.9912-2
FE         5 0 5.9289-2    END
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B-10      5 0 3.7488-3    END
C          5 0 1.5884-4    END
CR         5 0 1.7428-2    END
MN         5 0 8.6816-4    END
NI         5 0 7.5171-3    END
P          5 0 3.0797-5    END
S          5 0 2.2308-5    END
SI         5 0 8.4910-4    END
END COMP
TRIANGPITCH 0.91948 0.53594 1 4 0.64770 3 0.55880 0
END
MORE DATA RES=2 CYLINDER 0.62103
DAN(2)=0.702856 END
KENOV.A
READ PARAM
GEN=500 NPG=3000 NSK=50 TME=4000
FLX=YES FDN=YES FMP=YES NUB=YES RUN=YES
END PARAM
READ GEOM
UNIT 1
COM=*Seed rod in water*
CYLINDER 1 1 0.26797 2P19.05
CYLINDER 0 1 0.27940 2P19.05
CYLINDER 3 1 0.32385 2P26.4541
UNIT 3
COM=*blanket rod in water*
CYLINDER 2 1 0.62103 2P19.05
```


CYLINDER	0	1	0.63373	2P19.05		HOLE	3	-2.17551	21.35253	0.
CYLINDER	3	1	0.72390	2P26.4541		HOLE	3	-0.72517	21.35253	0.
UNIT 4						HOLE	3	0.72517	21.35253	0.
COM=*control blade in water*						HOLE	3	2.17551	21.35253	0.
CUBOID	5	1	2P3.81	2P0.0889	49.53	HOLE	3	3.62585	21.35253	0.
15.87						HOLE	3	5.07619	21.35253	0.
CUBOID	4	1	2P3.81	2P0.0889	2P49.53	HOLE	3	6.52653	21.35253	0.
UNIT 5						HOLE	3	7.97687	21.35253	0.
COM=*rod array with blades*						HOLE	3	9.42721	21.35253	0.
CYLINDER	4	1	29.8	2P49.5301		HOLE	3	10.87755	21.35253	0.
COM=*control blades*						HOLE	3	12.32789	21.35253	0.
HOLE	4	0.	5.51688	0.		HOLE	3	13.77823	21.35253	0.
HOLE	4	0.	1.83896	0.		HOLE	3	15.22857	21.35253	0.
HOLE	4	0.	-1.83896	0.		HOLE	3	16.67891	21.35253	0.
HOLE	4	0.	-5.51688	0.		COM=*+16 row*				
COM=*+20 row*						HOLE	3	-17.40408	20.09650	0.
HOLE	3	-14.50340	25.12063	0.		HOLE	3	-15.95374	20.09650	0.
HOLE	3	-13.05306	25.12063	0.		HOLE	3	-14.50340	20.09650	0.
HOLE	3	-11.60272	25.12063	0.		HOLE	3	-13.05306	20.09650	0.
HOLE	3	-10.15238	25.12063	0.		HOLE	3	-11.60272	20.09650	0.
HOLE	3	-8.70204	25.12063	0.		HOLE	3	-10.15238	20.09650	0.
HOLE	3	-7.25170	25.12063	0.		HOLE	3	-8.70204	20.09650	0.
HOLE	3	-5.80136	25.12063	0.		HOLE	3	-7.25170	20.09650	0.
HOLE	3	-4.35102	25.12063	0.		HOLE	3	-5.80136	20.09650	0.
HOLE	3	-2.90068	25.12063	0.		HOLE	3	-4.35102	20.09650	0.
HOLE	3	-1.45034	25.12063	0.		HOLE	3	-2.90068	20.09650	0.
HOLE	3	0.	25.12063	0.		HOLE	3	-1.45034	20.09650	0.
HOLE	3	1.45034	25.12063	0.		HOLE	3	0.	20.09650	0.
HOLE	3	2.90068	25.12063	0.		HOLE	3	1.45034	20.09650	0.
HOLE	3	4.35102	25.12063	0.		HOLE	3	2.90068	20.09650	0.
HOLE	3	5.80136	25.12063	0.		HOLE	3	4.35102	20.09650	0.
HOLE	3	7.25170	25.12063	0.		HOLE	3	5.80136	20.09650	0.
HOLE	3	8.70204	25.12063	0.		HOLE	3	7.25170	20.09650	0.
HOLE	3	10.15238	25.12063	0.		HOLE	3	8.70204	20.09650	0.
HOLE	3	11.60272	25.12063	0.		HOLE	3	10.15238	20.09650	0.
HOLE	3	13.05306	25.12063	0.		HOLE	3	11.60272	20.09650	0.
HOLE	3	14.50340	25.12063	0.		HOLE	3	13.05306	20.09650	0.
COM=*+19 row*						HOLE	3	14.50340	20.09650	0.
HOLE	3	-15.22857	23.86459	0.		HOLE	3	15.95374	20.09650	0.
HOLE	3	-13.77823	23.86459	0.		HOLE	3	17.40408	20.09650	0.
HOLE	3	-12.32789	23.86459	0.		COM=*+15 row*				
HOLE	3	-10.87755	23.86459	0.		HOLE	3	-18.12925	18.84047	0.
HOLE	3	-9.42721	23.86459	0.		HOLE	3	-16.67891	18.84047	0.
HOLE	3	-7.97687	23.86459	0.		HOLE	3	-15.22857	18.84047	0.
HOLE	3	-6.52653	23.86459	0.		HOLE	3	-13.77823	18.84047	0.
HOLE	3	-5.07619	23.86459	0.		HOLE	3	-12.32789	18.84047	0.
HOLE	3	-3.62585	23.86459	0.		HOLE	3	-10.87755	18.84047	0.
HOLE	3	-2.17551	23.86459	0.		HOLE	3	-9.42721	18.84047	0.
HOLE	3	-0.72517	23.86459	0.		HOLE	3	-7.97687	18.84047	0.
HOLE	3	0.72517	23.86459	0.		HOLE	3	-6.52653	18.84047	0.
HOLE	3	2.17551	23.86459	0.		HOLE	3	-5.07619	18.84047	0.
HOLE	3	3.62585	23.86459	0.		HOLE	3	-3.62585	18.84047	0.
HOLE	3	5.07619	23.86459	0.		HOLE	3	-2.17551	18.84047	0.
HOLE	3	6.52653	23.86459	0.		HOLE	3	-0.72517	18.84047	0.
HOLE	3	7.97687	23.86459	0.		HOLE	3	0.72517	18.84047	0.
HOLE	3	9.42721	23.86459	0.		HOLE	3	2.17551	18.84047	0.
HOLE	3	10.87755	23.86459	0.		HOLE	3	3.62585	18.84047	0.
HOLE	3	12.32789	23.86459	0.		HOLE	3	5.07619	18.84047	0.
HOLE	3	13.77823	23.86459	0.		HOLE	3	6.52653	18.84047	0.
HOLE	3	15.22857	23.86459	0.		HOLE	3	7.97687	18.84047	0.
COM=*+18 row*						HOLE	3	9.42721	18.84047	0.
HOLE	3	-15.95374	22.60856	0.		HOLE	3	10.87755	18.84047	0.
HOLE	3	-14.50340	22.60856	0.		HOLE	3	12.32789	18.84047	0.
HOLE	3	-13.05306	22.60856	0.		HOLE	3	13.77823	18.84047	0.
HOLE	3	-11.60272	22.60856	0.		HOLE	3	15.22857	18.84047	0.
HOLE	3	-10.15238	22.60856	0.		HOLE	3	16.67891	18.84047	0.
HOLE	3	-8.70204	22.60856	0.		HOLE	3	18.12925	18.84047	0.
HOLE	3	-7.25170	22.60856	0.		COM=*+14 row*				
HOLE	3	-5.80136	22.60856	0.		HOLE	3	-18.85442	17.58444	0.
HOLE	3	-4.35102	22.60856	0.		HOLE	3	-17.40408	17.58444	0.
HOLE	3	-2.90068	22.60856	0.		HOLE	3	-15.95374	17.58444	0.
HOLE	3	-1.45034	22.60856	0.		HOLE	3	-14.50340	17.58444	0.
HOLE	3	0.	22.60856	0.		HOLE	3	-13.05306	17.58444	0.
HOLE	3	1.45034	22.60856	0.		HOLE	3	-11.60272	17.58444	0.
HOLE	3	2.90068	22.60856	0.		HOLE	3	-10.15238	17.58444	0.
HOLE	3	4.35102	22.60856	0.		HOLE	3	-8.70204	17.58444	0.
HOLE	3	5.80136	22.60856	0.		HOLE	3	-7.25170	17.58444	0.
HOLE	3	7.25170	22.60856	0.		HOLE	3	-5.80136	17.58444	0.
HOLE	3	8.70204	22.60856	0.		HOLE	3	-4.35102	17.58444	0.
HOLE	3	10.15238	22.60856	0.		HOLE	3	-2.90068	17.58444	0.
HOLE	3	11.60272	22.60856	0.		HOLE	3	-1.45034	17.58444	0.
HOLE	3	13.05306	22.60856	0.		HOLE	3	0.	17.58444	0.
HOLE	3	14.50340	22.60856	0.		HOLE	3	1.45034	17.58444	0.
HOLE	3	15.95374	22.60856	0.		HOLE	3	2.90068	17.58444	0.
COM=*+17 row*						HOLE	3	4.35102	17.58444	0.
HOLE	3	-16.67891	21.35253	0.		HOLE	3	5.80136	17.58444	0.
HOLE	3	-15.22857	21.35253	0.		HOLE	3	7.25170	17.58444	0.
HOLE	3	-13.77823	21.35253	0.		HOLE	3	8.70204	17.58444	0.
HOLE	3	-12.32789	21.35253	0.		HOLE	3	10.15238	17.58444	0.
HOLE	3	-10.87755	21.35253	0.		HOLE	3	11.60272	17.58444	0.
HOLE	3	-9.42721	21.35253	0.		HOLE	3	13.05306	17.58444	0.
HOLE	3	-7.97687	21.35253	0.		HOLE	3	14.50340	17.58444	0.
HOLE	3	-6.52653	21.35253	0.		HOLE	3	15.95374	17.58444	0.
HOLE	3	-5.07619	21.35253	0.		HOLE	3	17.40408	17.58444	0.
HOLE	3	-3.62585	21.35253	0.		HOLE	3	18.85442	17.58444	0.

COM=+13 row*				HOLE	3	-15.95374	12.56031	0.
HOLE	3	-19.57959	16.32841	0.	HOLE	3	-14.50340	12.56031
HOLE	3	-18.12925	16.32841	0.	HOLE	3	-13.05306	12.56031
HOLE	3	-16.67891	16.32841	0.	HOLE	3	-11.60272	12.56031
HOLE	3	-15.22857	16.32841	0.	HOLE	3	-10.15238	12.56031
HOLE	3	-13.77823	16.32841	0.	HOLE	3	-8.70204	12.56031
HOLE	3	-12.32789	16.32841	0.	HOLE	3	-7.25170	12.56031
HOLE	3	-10.87755	16.32841	0.	HOLE	3	-5.80136	12.56031
HOLE	3	-9.42721	16.32841	0.	HOLE	3	-4.35102	12.56031
HOLE	3	-7.97687	16.32841	0.	HOLE	3	-2.90068	12.56031
HOLE	3	-6.52653	16.32841	0.	HOLE	3	-1.45034	12.56031
HOLE	3	-5.07619	16.32841	0.	HOLE	3	0.	12.56031
HOLE	3	-3.62585	16.32841	0.	HOLE	3	1.45034	12.56031
HOLE	3	-2.17551	16.32841	0.	HOLE	3	2.90068	12.56031
HOLE	3	-0.72517	16.32841	0.	HOLE	3	4.35102	12.56031
HOLE	3	0.72517	16.32841	0.	HOLE	3	5.80136	12.56031
HOLE	3	2.17551	16.32841	0.	HOLE	3	7.25170	12.56031
HOLE	3	3.62585	16.32841	0.	HOLE	3	8.70204	12.56031
HOLE	3	5.07619	16.32841	0.	HOLE	3	10.15238	12.56031
HOLE	3	6.52653	16.32841	0.	HOLE	3	11.60272	12.56031
HOLE	3	7.97687	16.32841	0.	HOLE	3	13.05306	12.56031
HOLE	3	9.42721	16.32841	0.	HOLE	3	14.50340	12.56031
HOLE	3	10.87755	16.32841	0.	HOLE	3	15.95374	12.56031
HOLE	3	12.32789	16.32841	0.	HOLE	3	17.40408	12.56031
HOLE	3	13.77823	16.32841	0.	HOLE	3	18.85442	12.56031
HOLE	3	15.22857	16.32841	0.	HOLE	3	20.30476	12.56031
HOLE	3	16.67891	16.32841	0.	HOLE	3	21.75510	12.56031
HOLE	3	18.12925	16.32841	0.	COM=+9 row*			
HOLE	3	19.57959	16.32841	0.	HOLE	3	-22.48027	11.30428
COM=+12 row*				HOLE	3	-21.02993	11.30428	0.
HOLE	3	-20.30476	15.07238	0.	HOLE	3	-19.57959	11.30428
HOLE	3	-18.85442	15.07238	0.	HOLE	3	-18.12925	11.30428
HOLE	3	-17.40408	15.07238	0.	HOLE	3	-16.67891	11.30428
HOLE	3	-15.95374	15.07238	0.	HOLE	3	-15.22857	11.30428
HOLE	3	-14.50340	15.07238	0.	HOLE	3	-13.77823	11.30428
HOLE	3	-13.05306	15.07238	0.	HOLE	3	-12.32789	11.30428
HOLE	3	-11.60272	15.07238	0.	HOLE	3	-10.87755	11.30428
HOLE	3	-10.15238	15.07238	0.	HOLE	3	-9.42721	11.30428
HOLE	3	-8.70204	15.07238	0.	HOLE	3	-7.97687	11.30428
HOLE	3	-7.25170	15.07238	0.	HOLE	3	-6.52653	11.30428
HOLE	3	-5.80136	15.07238	0.	HOLE	3	-5.07619	11.30428
HOLE	3	-4.35102	15.07238	0.	HOLE	3	-3.62585	11.30428
HOLE	3	-2.90068	15.07238	0.	HOLE	3	-2.17551	11.30428
HOLE	3	-1.45034	15.07238	0.	HOLE	3	-0.72517	11.30428
HOLE	3	0.	15.07238	0.	HOLE	3	0.72517	11.30428
HOLE	3	1.45034	15.07238	0.	HOLE	3	2.17551	11.30428
HOLE	3	2.90068	15.07238	0.	HOLE	3	3.62585	11.30428
HOLE	3	4.35102	15.07238	0.	HOLE	3	5.07619	11.30428
HOLE	3	5.80136	15.07238	0.	HOLE	3	6.52653	11.30428
HOLE	3	7.25170	15.07238	0.	HOLE	3	7.97687	11.30428
HOLE	3	8.70204	15.07238	0.	HOLE	3	9.42721	11.30428
HOLE	3	10.15238	15.07238	0.	HOLE	3	10.87755	11.30428
HOLE	3	11.60272	15.07238	0.	HOLE	3	12.32789	11.30428
HOLE	3	13.05306	15.07238	0.	HOLE	3	13.77823	11.30428
HOLE	3	14.50340	15.07238	0.	HOLE	3	15.22857	11.30428
HOLE	3	15.95374	15.07238	0.	HOLE	3	16.67891	11.30428
HOLE	3	17.40408	15.07238	0.	HOLE	3	18.12925	11.30428
HOLE	3	18.85442	15.07238	0.	HOLE	3	19.57959	11.30428
HOLE	3	20.30476	15.07238	0.	HOLE	3	21.02993	11.30428
COM=+11 row*				HOLE	3	22.48027	11.30428	0.
HOLE	3	-21.02993	13.81634	0.	COM=+8 row*			
HOLE	3	-19.57959	13.81634	0.	HOLE	3	-23.20544	10.04825
HOLE	3	-18.12925	13.81634	0.	HOLE	3	-21.75510	10.04825
HOLE	3	-16.67891	13.81634	0.	HOLE	3	-20.30476	10.04825
HOLE	3	-15.22857	13.81634	0.	HOLE	3	-18.85442	10.04825
HOLE	3	-13.77823	13.81634	0.	HOLE	3	-17.40408	10.04825
HOLE	3	-12.32789	13.81634	0.	HOLE	3	-15.95374	10.04825
HOLE	3	-10.87755	13.81634	0.	HOLE	3	-14.50340	10.04825
HOLE	3	-9.42721	13.81634	0.	HOLE	3	-13.05306	10.04825
HOLE	3	-7.97687	13.81634	0.	HOLE	3	-11.60272	10.04825
HOLE	3	-6.52653	13.81634	0.	HOLE	3	-10.15238	10.04825
HOLE	3	-5.07619	13.81634	0.	HOLE	3	-8.70204	10.04825
HOLE	3	-3.62585	13.81634	0.	HOLE	3	-7.25170	10.04825
HOLE	3	-2.17551	13.81634	0.	HOLE	1	-5.80136	10.04825
HOLE	3	-0.72517	13.81634	0.	HOLE	1	-4.35102	10.04825
HOLE	3	0.72517	13.81634	0.	HOLE	1	-2.90068	10.04825
HOLE	3	2.17551	13.81634	0.	HOLE	1	-1.45034	10.04825
HOLE	3	3.62585	13.81634	0.	HOLE	1	0.	10.04825
HOLE	3	5.07619	13.81634	0.	HOLE	1	1.45034	10.04825
HOLE	3	6.52653	13.81634	0.	HOLE	1	2.90068	10.04825
HOLE	3	7.97687	13.81634	0.	HOLE	1	4.35102	10.04825
HOLE	3	9.42721	13.81634	0.	HOLE	1	5.80136	10.04825
HOLE	3	10.87755	13.81634	0.	HOLE	3	7.25170	10.04825
HOLE	3	12.32789	13.81634	0.	HOLE	3	8.70204	10.04825
HOLE	3	13.77823	13.81634	0.	HOLE	3	10.15238	10.04825
HOLE	3	15.22857	13.81634	0.	HOLE	3	11.60272	10.04825
HOLE	3	16.67891	13.81634	0.	HOLE	3	13.05306	10.04825
HOLE	3	18.12925	13.81634	0.	HOLE	3	14.50340	10.04825
HOLE	3	19.57959	13.81634	0.	HOLE	3	15.95374	10.04825
HOLE	3	21.02993	13.81634	0.	HOLE	3	17.40408	10.04825
COM=+10 row*				HOLE	3	18.85442	10.04825	0.
HOLE	3	-21.75510	12.56031	0.	HOLE	3	20.30476	10.04825
HOLE	3	-20.30476	12.56031	0.	HOLE	3	21.75510	10.04825
HOLE	3	-18.85442	12.56031	0.	HOLE	3	23.20544	10.04825
HOLE	3	-17.40408	12.56031	0.	COM=+7 row*			

HOLE	3	-23.93061	8.79222	0.	HOLE	3	9.42721	6.28016	0.
HOLE	3	-22.48027	8.79222	0.	HOLE	3	10.87755	6.28016	0.
HOLE	3	-21.02993	8.79222	0.	HOLE	3	12.32789	6.28016	0.
HOLE	3	-19.57959	8.79222	0.	HOLE	3	13.77823	6.28016	0.
HOLE	3	-18.12925	8.79222	0.	HOLE	3	15.22857	6.28016	0.
HOLE	3	-16.67891	8.79222	0.	HOLE	3	16.67891	6.28016	0.
HOLE	3	-15.22857	8.79222	0.	HOLE	3	18.12925	6.28016	0.
HOLE	3	-13.77823	8.79222	0.	HOLE	3	19.57959	6.28016	0.
HOLE	3	-12.32789	8.79222	0.	HOLE	3	21.02993	6.28016	0.
HOLE	3	-10.87755	8.79222	0.	HOLE	3	22.48027	6.28016	0.
HOLE	3	-9.42721	8.79222	0.	HOLE	3	23.93061	6.28016	0.
HOLE	3	-7.97687	8.79222	0.	HOLE	3	25.38095	6.28016	0.
HOLE	1	-6.52653	8.79222	0.	COM=+4 row*				
HOLE	1	-5.07619	8.79222	0.	HOLE	3	-26.10612	5.02413	0.
HOLE	1	-3.62585	8.79222	0.	HOLE	3	-24.65578	5.02413	0.
HOLE	1	-2.17551	8.79222	0.	HOLE	3	-23.20544	5.02413	0.
HOLE	1	-0.72517	8.79222	0.	HOLE	3	-21.75510	5.02413	0.
HOLE	1	0.72517	8.79222	0.	HOLE	3	-20.30476	5.02413	0.
HOLE	1	2.17551	8.79222	0.	HOLE	3	-18.85442	5.02413	0.
HOLE	1	3.62585	8.79222	0.	HOLE	3	-17.40408	5.02413	0.
HOLE	1	5.07619	8.79222	0.	HOLE	3	-15.95374	5.02413	0.
HOLE	1	6.52653	8.79222	0.	HOLE	3	-14.50340	5.02413	0.
HOLE	3	7.97687	8.79222	0.	HOLE	3	-13.05306	5.02413	0.
HOLE	3	9.42721	8.79222	0.	HOLE	3	-11.60272	5.02413	0.
HOLE	3	10.87755	8.79222	0.	HOLE	3	-10.15238	5.02413	0.
HOLE	3	12.32789	8.79222	0.	HOLE	1	-8.70204	5.02413	0.
HOLE	3	13.77823	8.79222	0.	HOLE	1	-7.25170	5.02413	0.
HOLE	3	15.22857	8.79222	0.	HOLE	1	-5.80136	5.02413	0.
HOLE	3	16.67891	8.79222	0.	HOLE	1	-4.35102	5.02413	0.
HOLE	3	18.12925	8.79222	0.	HOLE	1	-2.90068	5.02413	0.
HOLE	3	19.57959	8.79222	0.	HOLE	1	-1.45034	5.02413	0.
HOLE	3	21.02993	8.79222	0.	HOLE	1	0.	5.02413	0.
HOLE	3	22.48027	8.79222	0.	HOLE	1	1.45034	5.02413	0.
HOLE	3	23.93061	8.79222	0.	HOLE	1	2.90068	5.02413	0.
COM=+6 row*					HOLE	1	4.35102	5.02413	0.
HOLE	3	-24.65578	7.53619	0.	HOLE	1	5.80136	5.02413	0.
HOLE	3	-23.20544	7.53619	0.	HOLE	1	7.25170	5.02413	0.
HOLE	3	-21.75510	7.53619	0.	HOLE	1	8.70204	5.02413	0.
HOLE	3	-20.30476	7.53619	0.	HOLE	3	10.15238	5.02413	0.
HOLE	3	-18.85442	7.53619	0.	HOLE	3	11.60272	5.02413	0.
HOLE	3	-17.40408	7.53619	0.	HOLE	3	13.05306	5.02413	0.
HOLE	3	-15.95374	7.53619	0.	HOLE	3	14.50340	5.02413	0.
HOLE	3	-14.50340	7.53619	0.	HOLE	3	15.95374	5.02413	0.
HOLE	3	-13.05306	7.53619	0.	HOLE	3	17.40408	5.02413	0.
HOLE	3	-11.60272	7.53619	0.	HOLE	3	18.85442	5.02413	0.
HOLE	3	-10.15238	7.53619	0.	HOLE	3	20.30476	5.02413	0.
HOLE	3	-8.70204	7.53619	0.	HOLE	3	21.75510	5.02413	0.
HOLE	1	-7.25170	7.53619	0.	HOLE	3	23.20544	5.02413	0.
HOLE	1	-5.80136	7.53619	0.	HOLE	3	24.65578	5.02413	0.
HOLE	1	-4.35102	7.53619	0.	HOLE	3	26.10612	5.02413	0.
HOLE	1	-2.90068	7.53619	0.	COM=+3 row*				
HOLE	1	-1.45034	7.53619	0.	HOLE	3	-26.83129	3.76809	0.
HOLE	1	0.	7.53619	0.	HOLE	3	-25.38095	3.76809	0.
HOLE	1	1.45034	7.53619	0.	HOLE	3	-23.93061	3.76809	0.
HOLE	1	2.90068	7.53619	0.	HOLE	3	-22.48027	3.76809	0.
HOLE	1	4.35102	7.53619	0.	HOLE	3	-21.02993	3.76809	0.
HOLE	1	5.80136	7.53619	0.	HOLE	3	-19.57959	3.76809	0.
HOLE	1	7.25170	7.53619	0.	HOLE	3	-18.12925	3.76809	0.
HOLE	3	8.70204	7.53619	0.	HOLE	3	-16.67891	3.76809	0.
HOLE	3	10.15238	7.53619	0.	HOLE	3	-15.22857	3.76809	0.
HOLE	3	11.60272	7.53619	0.	HOLE	3	-13.77823	3.76809	0.
HOLE	3	13.05306	7.53619	0.	HOLE	3	-12.32789	3.76809	0.
HOLE	3	14.50340	7.53619	0.	HOLE	3	-10.87755	3.76809	0.
HOLE	3	15.95374	7.53619	0.	HOLE	1	-9.42721	3.76809	0.
HOLE	3	17.40408	7.53619	0.	HOLE	1	-7.97687	3.76809	0.
HOLE	3	18.85442	7.53619	0.	HOLE	1	-6.52653	3.76809	0.
HOLE	3	20.30476	7.53619	0.	HOLE	1	-5.07619	3.76809	0.
HOLE	3	21.75510	7.53619	0.	HOLE	1	-3.62585	3.76809	0.
HOLE	3	23.20544	7.53619	0.	HOLE	1	-2.17551	3.76809	0.
HOLE	3	24.65578	7.53619	0.	HOLE	1	-0.72517	3.76809	0.
COM=+5 row*					HOLE	1	0.72517	3.76809	0.
HOLE	3	-25.38095	6.28016	0.	HOLE	1	2.17551	3.76809	0.
HOLE	3	-23.93061	6.28016	0.	HOLE	1	3.62585	3.76809	0.
HOLE	3	-22.48027	6.28016	0.	HOLE	1	5.07619	3.76809	0.
HOLE	3	-21.02993	6.28016	0.	HOLE	1	6.52653	3.76809	0.
HOLE	3	-19.57959	6.28016	0.	HOLE	1	7.97687	3.76809	0.
HOLE	3	-18.12925	6.28016	0.	HOLE	1	9.42721	3.76809	0.
HOLE	3	-16.67891	6.28016	0.	HOLE	3	10.87755	3.76809	0.
HOLE	3	-15.22857	6.28016	0.	HOLE	3	12.32789	3.76809	0.
HOLE	3	-13.77823	6.28016	0.	HOLE	3	13.77823	3.76809	0.
HOLE	3	-12.32789	6.28016	0.	HOLE	3	15.22857	3.76809	0.
HOLE	3	-10.87755	6.28016	0.	HOLE	3	16.67891	3.76809	0.
HOLE	3	-9.42721	6.28016	0.	HOLE	3	18.12925	3.76809	0.
HOLE	1	-7.97687	6.28016	0.	HOLE	3	19.57959	3.76809	0.
HOLE	1	-6.52653	6.28016	0.	HOLE	3	21.02993	3.76809	0.
HOLE	1	-5.07619	6.28016	0.	HOLE	3	22.48027	3.76809	0.
HOLE	1	-3.62585	6.28016	0.	HOLE	3	23.93061	3.76809	0.
HOLE	1	-2.17551	6.28016	0.	HOLE	3	25.38095	3.76809	0.
HOLE	1	-0.72517	6.28016	0.	HOLE	3	26.83129	3.76809	0.
HOLE	1	0.72517	6.28016	0.	COM=+2 row*				
HOLE	1	2.17551	6.28016	0.	HOLE	3	-27.55646	2.51206	0.
HOLE	1	3.62585	6.28016	0.	HOLE	3	-26.10612	2.51206	0.
HOLE	1	5.07619	6.28016	0.	HOLE	3	-24.65578	2.51206	0.
HOLE	1	6.52653	6.28016	0.	HOLE	3	-23.20544	2.51206	0.
HOLE	1	7.97687	6.28016	0.	HOLE	3	-21.75510	2.51206	0.

Appendix E Benchmark Model Inputs

HOLE	3	-20.30476	2.51206	0.	HOLE	1	-1.45034	0.	0.
HOLE	3	-18.85442	2.51206	0.	HOLE	1	0.	0.	0.
HOLE	3	-17.40408	2.51206	0.	HOLE	1	1.45034	0.	0.
HOLE	3	-15.95374	2.51206	0.	HOLE	1	2.90068	0.	0.
HOLE	3	-14.50340	2.51206	0.	HOLE	1	4.35102	0.	0.
HOLE	3	-13.05306	2.51206	0.	HOLE	1	5.80136	0.	0.
HOLE	3	-11.60272	2.51206	0.	HOLE	1	7.25170	0.	0.
HOLE	1	-10.15238	2.51206	0.	HOLE	1	8.70204	0.	0.
HOLE	1	-8.70204	2.51206	0.	HOLE	1	10.15238	0.	0.
HOLE	1	-7.25170	2.51206	0.	HOLE	1	11.60272	0.	0.
HOLE	1	-5.80136	2.51206	0.	HOLE	3	13.05306	0.	0.
HOLE	1	-4.35102	2.51206	0.	HOLE	3	14.50340	0.	0.
HOLE	1	-2.90068	2.51206	0.	HOLE	3	15.95374	0.	0.
HOLE	1	-1.45034	2.51206	0.	HOLE	3	17.40408	0.	0.
HOLE	1	0.	2.51206	0.	HOLE	3	18.85442	0.	0.
HOLE	1	1.45034	2.51206	0.	HOLE	3	20.30476	0.	0.
HOLE	1	2.90068	2.51206	0.	HOLE	3	21.75510	0.	0.
HOLE	1	4.35102	2.51206	0.	HOLE	3	23.20544	0.	0.
HOLE	1	5.80136	2.51206	0.	HOLE	3	24.65578	0.	0.
HOLE	1	7.25170	2.51206	0.	HOLE	3	26.10612	0.	0.
HOLE	1	8.70204	2.51206	0.	HOLE	3	27.55646	0.	0.
HOLE	1	10.15238	2.51206	0.	HOLE	3	29.00680	0.	0.
HOLE	3	11.60272	2.51206	0.	COM=-1 row*				
HOLE	3	13.05306	2.51206	0.	HOLE	3	-28.28163	-1.25603	0.
HOLE	3	14.50340	2.51206	0.	HOLE	3	-26.83129	-1.25603	0.
HOLE	3	15.95374	2.51206	0.	HOLE	3	-25.38095	-1.25603	0.
HOLE	3	17.40408	2.51206	0.	HOLE	3	-23.93061	-1.25603	0.
HOLE	3	18.85442	2.51206	0.	HOLE	3	-22.48027	-1.25603	0.
HOLE	3	20.30476	2.51206	0.	HOLE	3	-21.02993	-1.25603	0.
HOLE	3	21.75510	2.51206	0.	HOLE	3	-19.57959	-1.25603	0.
HOLE	3	23.20544	2.51206	0.	HOLE	3	-18.12925	-1.25603	0.
HOLE	3	24.65578	2.51206	0.	HOLE	3	-16.67891	-1.25603	0.
HOLE	3	26.10612	2.51206	0.	HOLE	3	-15.22857	-1.25603	0.
HOLE	3	27.55646	2.51206	0.	HOLE	3	-13.77823	-1.25603	0.
COM=+1 row*					HOLE	3	-12.32789	-1.25603	0.
HOLE	3	-28.28163	1.25603	0.	HOLE	1	-10.87755	-1.25603	0.
HOLE	3	-26.83129	1.25603	0.	HOLE	1	-9.42721	-1.25603	0.
HOLE	3	-25.38095	1.25603	0.	HOLE	1	-7.97687	-1.25603	0.
HOLE	3	-23.93061	1.25603	0.	HOLE	1	-6.52653	-1.25603	0.
HOLE	3	-22.48027	1.25603	0.	HOLE	1	-5.07619	-1.25603	0.
HOLE	3	-21.02993	1.25603	0.	HOLE	1	-3.62585	-1.25603	0.
HOLE	3	-19.57959	1.25603	0.	HOLE	1	-2.17551	-1.25603	0.
HOLE	3	-18.12925	1.25603	0.	HOLE	1	-0.72517	-1.25603	0.
HOLE	3	-16.67891	1.25603	0.	HOLE	1	0.72517	-1.25603	0.
HOLE	3	-15.22857	1.25603	0.	HOLE	1	2.17551	-1.25603	0.
HOLE	3	-13.77823	1.25603	0.	HOLE	1	3.62585	-1.25603	0.
HOLE	3	-12.32789	1.25603	0.	HOLE	1	5.07619	-1.25603	0.
HOLE	1	-10.87755	1.25603	0.	HOLE	1	6.52653	-1.25603	0.
HOLE	1	-9.42721	1.25603	0.	HOLE	1	7.97687	-1.25603	0.
HOLE	1	-7.97687	1.25603	0.	HOLE	1	9.42721	-1.25603	0.
HOLE	1	-6.52653	1.25603	0.	HOLE	1	10.87755	-1.25603	0.
HOLE	1	-5.07619	1.25603	0.	HOLE	3	12.32789	-1.25603	0.
HOLE	1	-3.62585	1.25603	0.	HOLE	3	13.77823	-1.25603	0.
HOLE	1	-2.17551	1.25603	0.	HOLE	3	15.22857	-1.25603	0.
HOLE	1	-0.72517	1.25603	0.	HOLE	3	16.67891	-1.25603	0.
HOLE	1	0.72517	1.25603	0.	HOLE	3	18.12925	-1.25603	0.
HOLE	1	2.17551	1.25603	0.	HOLE	3	19.57959	-1.25603	0.
HOLE	1	3.62585	1.25603	0.	HOLE	3	21.02993	-1.25603	0.
HOLE	1	5.07619	1.25603	0.	HOLE	3	22.48027	-1.25603	0.
HOLE	1	6.52653	1.25603	0.	HOLE	3	23.93061	-1.25603	0.
HOLE	1	7.97687	1.25603	0.	HOLE	3	25.38095	-1.25603	0.
HOLE	1	9.42721	1.25603	0.	HOLE	3	26.83129	-1.25603	0.
HOLE	1	10.87755	1.25603	0.	HOLE	3	28.28163	-1.25603	0.
HOLE	3	12.32789	1.25603	0.	COM=-2 row*				
HOLE	3	13.77823	1.25603	0.	HOLE	3	-27.55646	-2.51206	0.
HOLE	3	15.22857	1.25603	0.	HOLE	3	-26.10612	-2.51206	0.
HOLE	3	16.67891	1.25603	0.	HOLE	3	-24.65578	-2.51206	0.
HOLE	3	18.12925	1.25603	0.	HOLE	3	-23.20544	-2.51206	0.
HOLE	3	19.57959	1.25603	0.	HOLE	3	-21.75510	-2.51206	0.
HOLE	3	21.02993	1.25603	0.	HOLE	3	-20.30476	-2.51206	0.
HOLE	3	22.48027	1.25603	0.	HOLE	3	-18.85442	-2.51206	0.
HOLE	3	23.93061	1.25603	0.	HOLE	3	-17.40408	-2.51206	0.
HOLE	3	25.38095	1.25603	0.	HOLE	3	-15.95374	-2.51206	0.
HOLE	3	26.83129	1.25603	0.	HOLE	3	-14.50340	-2.51206	0.
HOLE	3	28.28163	1.25603	0.	HOLE	3	-13.05306	-2.51206	0.
COM=center (0) row*					HOLE	3	-11.60272	-2.51206	0.
HOLE	3	-29.00680	0.	0.	HOLE	1	-10.15238	-2.51206	0.
HOLE	3	-27.55646	0.	0.	HOLE	1	-8.70204	-2.51206	0.
HOLE	3	-26.10612	0.	0.	HOLE	1	-7.25170	-2.51206	0.
HOLE	3	-24.65578	0.	0.	HOLE	1	-5.80136	-2.51206	0.
HOLE	3	-23.20544	0.	0.	HOLE	1	-4.35102	-2.51206	0.
HOLE	3	-21.75510	0.	0.	HOLE	1	-2.90068	-2.51206	0.
HOLE	3	-20.30476	0.	0.	HOLE	1	-1.45034	-2.51206	0.
HOLE	3	-18.85442	0.	0.	HOLE	1	0.	-2.51206	0.
HOLE	3	-17.40408	0.	0.	HOLE	1	1.45034	-2.51206	0.
HOLE	3	-15.95374	0.	0.	HOLE	1	2.90068	-2.51206	0.
HOLE	3	-14.50340	0.	0.	HOLE	1	4.35102	-2.51206	0.
HOLE	3	-13.05306	0.	0.	HOLE	1	5.80136	-2.51206	0.
HOLE	1	-11.60272	0.	0.	HOLE	1	7.25170	-2.51206	0.
HOLE	1	-10.15238	0.	0.	HOLE	1	8.70204	-2.51206	0.
HOLE	1	-8.70204	0.	0.	HOLE	1	10.15238	-2.51206	0.
HOLE	1	-7.25170	0.	0.	HOLE	3	11.60272	-2.51206	0.
HOLE	1	-5.80136	0.	0.	HOLE	3	13.05306	-2.51206	0.
HOLE	1	-4.35102	0.	0.	HOLE	3	14.50340	-2.51206	0.
HOLE	1	-2.90068	0.	0.	HOLE	3	15.95374	-2.51206	0.

HOLE	3	17.40408	-2.51206	0.	HOLE	3	-12.32789	-6.28016	0.
HOLE	3	18.85442	-2.51206	0.	HOLE	3	-10.87755	-6.28016	0.
HOLE	3	20.30476	-2.51206	0.	HOLE	3	-9.42721	-6.28016	0.
HOLE	3	21.75510	-2.51206	0.	HOLE	1	-7.97687	-6.28016	0.
HOLE	3	23.20544	-2.51206	0.	HOLE	1	-6.52653	-6.28016	0.
HOLE	3	24.65578	-2.51206	0.	HOLE	1	-5.07619	-6.28016	0.
HOLE	3	26.10612	-2.51206	0.	HOLE	1	-3.62585	-6.28016	0.
HOLE	3	27.55646	-2.51206	0.	HOLE	1	-2.17551	-6.28016	0.
COM=-3 row*					HOLE	1	-0.72517	-6.28016	0.
HOLE	3	-26.83129	-3.76809	0.	HOLE	1	0.72517	-6.28016	0.
HOLE	3	-25.38095	-3.76809	0.	HOLE	1	2.17551	-6.28016	0.
HOLE	3	-23.93061	-3.76809	0.	HOLE	1	3.62585	-6.28016	0.
HOLE	3	-22.48027	-3.76809	0.	HOLE	1	5.07619	-6.28016	0.
HOLE	3	-21.02993	-3.76809	0.	HOLE	1	6.52653	-6.28016	0.
HOLE	3	-19.57959	-3.76809	0.	HOLE	1	7.97687	-6.28016	0.
HOLE	3	-18.12925	-3.76809	0.	HOLE	3	9.42721	-6.28016	0.
HOLE	3	-16.67891	-3.76809	0.	HOLE	3	10.87755	-6.28016	0.
HOLE	3	-15.22857	-3.76809	0.	HOLE	3	12.32789	-6.28016	0.
HOLE	3	-13.77823	-3.76809	0.	HOLE	3	13.77823	-6.28016	0.
HOLE	3	-12.32789	-3.76809	0.	HOLE	3	15.22857	-6.28016	0.
HOLE	3	-10.87755	-3.76809	0.	HOLE	3	16.67891	-6.28016	0.
HOLE	1	-9.42721	-3.76809	0.	HOLE	3	18.12925	-6.28016	0.
HOLE	1	-7.97687	-3.76809	0.	HOLE	3	19.57959	-6.28016	0.
HOLE	1	-6.52653	-3.76809	0.	HOLE	3	21.02993	-6.28016	0.
HOLE	1	-5.07619	-3.76809	0.	HOLE	3	22.48027	-6.28016	0.
HOLE	1	-3.62585	-3.76809	0.	HOLE	3	23.93061	-6.28016	0.
HOLE	1	-2.17551	-3.76809	0.	HOLE	3	25.38095	-6.28016	0.
HOLE	1	-0.72517	-3.76809	0.	COM=-6 row*				
HOLE	1	0.72517	-3.76809	0.	HOLE	3	-24.65578	-7.53619	0.
HOLE	1	2.17551	-3.76809	0.	HOLE	3	-23.20544	-7.53619	0.
HOLE	1	3.62585	-3.76809	0.	HOLE	3	-21.75510	-7.53619	0.
HOLE	1	5.07619	-3.76809	0.	HOLE	3	-20.30476	-7.53619	0.
HOLE	1	6.52653	-3.76809	0.	HOLE	3	-18.85442	-7.53619	0.
HOLE	1	7.97687	-3.76809	0.	HOLE	3	-17.40408	-7.53619	0.
HOLE	1	9.42721	-3.76809	0.	HOLE	3	-15.95374	-7.53619	0.
HOLE	3	10.87755	-3.76809	0.	HOLE	3	-14.50340	-7.53619	0.
HOLE	3	12.32789	-3.76809	0.	HOLE	3	-13.05306	-7.53619	0.
HOLE	3	13.77823	-3.76809	0.	HOLE	3	-11.60272	-7.53619	0.
HOLE	3	15.22857	-3.76809	0.	HOLE	3	-10.15238	-7.53619	0.
HOLE	3	16.67891	-3.76809	0.	HOLE	3	-8.70204	-7.53619	0.
HOLE	3	18.12925	-3.76809	0.	HOLE	1	-7.25170	-7.53619	0.
HOLE	3	19.57959	-3.76809	0.	HOLE	1	-5.80136	-7.53619	0.
HOLE	3	21.02993	-3.76809	0.	HOLE	1	-4.35102	-7.53619	0.
HOLE	3	22.48027	-3.76809	0.	HOLE	1	-2.90068	-7.53619	0.
HOLE	3	23.93061	-3.76809	0.	HOLE	1	-1.45034	-7.53619	0.
HOLE	3	25.38095	-3.76809	0.	HOLE	1	0.	-7.53619	0.
HOLE	3	26.83129	-3.76809	0.	HOLE	1	1.45034	-7.53619	0.
COM=-4 row*					HOLE	1	2.90068	-7.53619	0.
HOLE	3	-26.10612	-5.02413	0.	HOLE	1	4.35102	-7.53619	0.
HOLE	3	-24.65578	-5.02413	0.	HOLE	1	5.80136	-7.53619	0.
HOLE	3	-23.20544	-5.02413	0.	HOLE	1	7.25170	-7.53619	0.
HOLE	3	-21.75510	-5.02413	0.	HOLE	3	8.70204	-7.53619	0.
HOLE	3	-20.30476	-5.02413	0.	HOLE	3	10.15238	-7.53619	0.
HOLE	3	-18.85442	-5.02413	0.	HOLE	3	11.60272	-7.53619	0.
HOLE	3	-17.40408	-5.02413	0.	HOLE	3	13.05306	-7.53619	0.
HOLE	3	-15.95374	-5.02413	0.	HOLE	3	14.50340	-7.53619	0.
HOLE	3	-14.50340	-5.02413	0.	HOLE	3	15.95374	-7.53619	0.
HOLE	3	-13.05306	-5.02413	0.	HOLE	3	17.40408	-7.53619	0.
HOLE	3	-11.60272	-5.02413	0.	HOLE	3	18.85442	-7.53619	0.
HOLE	3	-10.15238	-5.02413	0.	HOLE	3	20.30476	-7.53619	0.
HOLE	1	-8.70204	-5.02413	0.	HOLE	3	21.75510	-7.53619	0.
HOLE	1	-7.25170	-5.02413	0.	HOLE	3	23.20544	-7.53619	0.
HOLE	1	-5.80136	-5.02413	0.	HOLE	3	24.65578	-7.53619	0.
HOLE	1	-4.35102	-5.02413	0.	COM=-7 row*				
HOLE	1	-2.90068	-5.02413	0.	HOLE	3	-23.93061	-8.79222	0.
HOLE	1	-1.45034	-5.02413	0.	HOLE	3	-22.48027	-8.79222	0.
HOLE	1	0.	-5.02413	0.	HOLE	3	-21.02993	-8.79222	0.
HOLE	1	1.45034	-5.02413	0.	HOLE	3	-19.57959	-8.79222	0.
HOLE	1	2.90068	-5.02413	0.	HOLE	3	-18.12925	-8.79222	0.
HOLE	1	4.35102	-5.02413	0.	HOLE	3	-16.67891	-8.79222	0.
HOLE	1	5.80136	-5.02413	0.	HOLE	3	-15.22857	-8.79222	0.
HOLE	1	7.25170	-5.02413	0.	HOLE	3	-13.77823	-8.79222	0.
HOLE	1	8.70204	-5.02413	0.	HOLE	3	-12.32789	-8.79222	0.
HOLE	3	10.15238	-5.02413	0.	HOLE	3	-10.87755	-8.79222	0.
HOLE	3	11.60272	-5.02413	0.	HOLE	3	-9.42721	-8.79222	0.
HOLE	3	13.05306	-5.02413	0.	HOLE	3	-7.97687	-8.79222	0.
HOLE	3	14.50340	-5.02413	0.	HOLE	1	-6.52653	-8.79222	0.
HOLE	3	15.95374	-5.02413	0.	HOLE	1	-5.07619	-8.79222	0.
HOLE	3	17.40408	-5.02413	0.	HOLE	1	-3.62585	-8.79222	0.
HOLE	3	18.85442	-5.02413	0.	HOLE	1	-2.17551	-8.79222	0.
HOLE	3	20.30476	-5.02413	0.	HOLE	1	-0.72517	-8.79222	0.
HOLE	3	21.75510	-5.02413	0.	HOLE	1	0.72517	-8.79222	0.
HOLE	3	23.20544	-5.02413	0.	HOLE	1	2.17551	-8.79222	0.
HOLE	3	24.65578	-5.02413	0.	HOLE	1	3.62585	-8.79222	0.
HOLE	3	26.10612	-5.02413	0.	HOLE	1	5.07619	-8.79222	0.
COM=-5 row*					HOLE	1	6.52653	-8.79222	0.
HOLE	3	-25.38095	-6.28016	0.	HOLE	3	7.97687	-8.79222	0.
HOLE	3	-23.93061	-6.28016	0.	HOLE	3	9.42721	-8.79222	0.
HOLE	3	-22.48027	-6.28016	0.	HOLE	3	10.87755	-8.79222	0.
HOLE	3	-21.02993	-6.28016	0.	HOLE	3	12.32789	-8.79222	0.
HOLE	3	-19.57959	-6.28016	0.	HOLE	3	13.77823	-8.79222	0.
HOLE	3	-18.12925	-6.28016	0.	HOLE	3	15.22857	-8.79222	0.
HOLE	3	-16.67891	-6.28016	0.	HOLE	3	16.67891	-8.79222	0.
HOLE	3	-15.22857	-6.28016	0.	HOLE	3	18.12925	-8.79222	0.
HOLE	3	-13.77823	-6.28016	0.	HOLE	3	19.57959	-8.79222	0.

Appendix E Benchmark Model Inputs

HOLE	3	21.02993	-8.79222	0.	HOLE	3	13.05306	-12.56031	0.
HOLE	3	22.48027	-8.79222	0.	HOLE	3	14.50340	-12.56031	0.
HOLE	3	23.93061	-8.79222	0.	HOLE	3	15.95374	-12.56031	0.
COM=-8 row*					HOLE	3	17.40408	-12.56031	0.
HOLE	3	-23.20544	-10.04825	0.	HOLE	3	18.85442	-12.56031	0.
HOLE	3	-21.75510	-10.04825	0.	HOLE	3	20.30476	-12.56031	0.
HOLE	3	-20.30476	-10.04825	0.	HOLE	3	21.75510	-12.56031	0.
HOLE	3	-18.85442	-10.04825	0.	COM=-11 row*				
HOLE	3	-17.40408	-10.04825	0.	HOLE	3	-21.02993	-13.81634	0.
HOLE	3	-15.95374	-10.04825	0.	HOLE	3	-19.57959	-13.81634	0.
HOLE	3	-14.50340	-10.04825	0.	HOLE	3	-18.12925	-13.81634	0.
HOLE	3	-13.05306	-10.04825	0.	HOLE	3	-16.67891	-13.81634	0.
HOLE	3	-11.60272	-10.04825	0.	HOLE	3	-15.22857	-13.81634	0.
HOLE	3	-10.15238	-10.04825	0.	HOLE	3	-13.77823	-13.81634	0.
HOLE	3	-8.70204	-10.04825	0.	HOLE	3	-12.32789	-13.81634	0.
HOLE	3	-7.25170	-10.04825	0.	HOLE	3	-10.87755	-13.81634	0.
HOLE	1	-5.80136	-10.04825	0.	HOLE	3	-9.42721	-13.81634	0.
HOLE	1	-4.35102	-10.04825	0.	HOLE	3	-7.97687	-13.81634	0.
HOLE	1	-2.90068	-10.04825	0.	HOLE	3	-6.52653	-13.81634	0.
HOLE	1	-1.45034	-10.04825	0.	HOLE	3	-5.07619	-13.81634	0.
HOLE	1	0.	-10.04825	0.	HOLE	3	-3.62585	-13.81634	0.
HOLE	1	1.45034	-10.04825	0.	HOLE	3	-2.17551	-13.81634	0.
HOLE	1	2.90068	-10.04825	0.	HOLE	3	-0.72517	-13.81634	0.
HOLE	1	4.35102	-10.04825	0.	HOLE	3	0.72517	-13.81634	0.
HOLE	1	5.80136	-10.04825	0.	HOLE	3	2.17551	-13.81634	0.
HOLE	3	7.25170	-10.04825	0.	HOLE	3	3.62585	-13.81634	0.
HOLE	3	8.70204	-10.04825	0.	HOLE	3	5.07619	-13.81634	0.
HOLE	3	10.15238	-10.04825	0.	HOLE	3	6.52653	-13.81634	0.
HOLE	3	11.60272	-10.04825	0.	HOLE	3	7.97687	-13.81634	0.
HOLE	3	13.05306	-10.04825	0.	HOLE	3	9.42721	-13.81634	0.
HOLE	3	14.50340	-10.04825	0.	HOLE	3	10.87755	-13.81634	0.
HOLE	3	15.95374	-10.04825	0.	HOLE	3	12.32789	-13.81634	0.
HOLE	3	17.40408	-10.04825	0.	HOLE	3	13.77823	-13.81634	0.
HOLE	3	18.85442	-10.04825	0.	HOLE	3	15.22857	-13.81634	0.
HOLE	3	20.30476	-10.04825	0.	HOLE	3	16.67891	-13.81634	0.
HOLE	3	21.75510	-10.04825	0.	HOLE	3	18.12925	-13.81634	0.
HOLE	3	23.20544	-10.04825	0.	HOLE	3	19.57959	-13.81634	0.
COM=-9 row*					HOLE	3	21.02993	-13.81634	0.
HOLE	3	-22.48027	-11.30428	0.	COM=-12 row*				
HOLE	3	-21.02993	-11.30428	0.	HOLE	3	-20.30476	-15.07238	0.
HOLE	3	-19.57959	-11.30428	0.	HOLE	3	-18.85442	-15.07238	0.
HOLE	3	-18.12925	-11.30428	0.	HOLE	3	-17.40408	-15.07238	0.
HOLE	3	-16.67891	-11.30428	0.	HOLE	3	-15.95374	-15.07238	0.
HOLE	3	-15.22857	-11.30428	0.	HOLE	3	-14.50340	-15.07238	0.
HOLE	3	-13.77823	-11.30428	0.	HOLE	3	-13.05306	-15.07238	0.
HOLE	3	-12.32789	-11.30428	0.	HOLE	3	-11.60272	-15.07238	0.
HOLE	3	-10.87755	-11.30428	0.	HOLE	3	-10.15238	-15.07238	0.
HOLE	3	-9.42721	-11.30428	0.	HOLE	3	-8.70204	-15.07238	0.
HOLE	3	-7.97687	-11.30428	0.	HOLE	3	-7.25170	-15.07238	0.
HOLE	3	-6.52653	-11.30428	0.	HOLE	3	-5.80136	-15.07238	0.
HOLE	3	-5.07619	-11.30428	0.	HOLE	3	-4.35102	-15.07238	0.
HOLE	3	-3.62585	-11.30428	0.	HOLE	3	-2.90068	-15.07238	0.
HOLE	3	-2.17551	-11.30428	0.	HOLE	3	-1.45034	-15.07238	0.
HOLE	3	-0.72517	-11.30428	0.	HOLE	3	0.	-15.07238	0.
HOLE	3	0.72517	-11.30428	0.	HOLE	3	1.45034	-15.07238	0.
HOLE	3	2.17551	-11.30428	0.	HOLE	3	2.90068	-15.07238	0.
HOLE	3	3.62585	-11.30428	0.	HOLE	3	4.35102	-15.07238	0.
HOLE	3	5.07619	-11.30428	0.	HOLE	3	5.80136	-15.07238	0.
HOLE	3	6.52653	-11.30428	0.	HOLE	3	7.25170	-15.07238	0.
HOLE	3	7.97687	-11.30428	0.	HOLE	3	8.70204	-15.07238	0.
HOLE	3	9.42721	-11.30428	0.	HOLE	3	10.15238	-15.07238	0.
HOLE	3	10.87755	-11.30428	0.	HOLE	3	11.60272	-15.07238	0.
HOLE	3	12.32789	-11.30428	0.	HOLE	3	13.05306	-15.07238	0.
HOLE	3	13.77823	-11.30428	0.	HOLE	3	14.50340	-15.07238	0.
HOLE	3	15.22857	-11.30428	0.	HOLE	3	15.95374	-15.07238	0.
HOLE	3	16.67891	-11.30428	0.	HOLE	3	17.40408	-15.07238	0.
HOLE	3	18.12925	-11.30428	0.	HOLE	3	18.85442	-15.07238	0.
HOLE	3	19.57959	-11.30428	0.	HOLE	3	20.30476	-15.07238	0.
HOLE	3	21.02993	-11.30428	0.	COM=-13 row*				
HOLE	3	22.48027	-11.30428	0.	HOLE	3	-19.57959	-16.32841	0.
COM=-10 row*					HOLE	3	-18.12925	-16.32841	0.
HOLE	3	-21.75510	-12.56031	0.	HOLE	3	-16.67891	-16.32841	0.
HOLE	3	-20.30476	-12.56031	0.	HOLE	3	-15.22857	-16.32841	0.
HOLE	3	-18.85442	-12.56031	0.	HOLE	3	-13.77823	-16.32841	0.
HOLE	3	-17.40408	-12.56031	0.	HOLE	3	-12.32789	-16.32841	0.
HOLE	3	-15.95374	-12.56031	0.	HOLE	3	-10.87755	-16.32841	0.
HOLE	3	-14.50340	-12.56031	0.	HOLE	3	-9.42721	-16.32841	0.
HOLE	3	-13.05306	-12.56031	0.	HOLE	3	-7.97687	-16.32841	0.
HOLE	3	-11.60272	-12.56031	0.	HOLE	3	-6.52653	-16.32841	0.
HOLE	3	-10.15238	-12.56031	0.	HOLE	3	-5.07619	-16.32841	0.
HOLE	3	-8.70204	-12.56031	0.	HOLE	3	-3.62585	-16.32841	0.
HOLE	3	-7.25170	-12.56031	0.	HOLE	3	-2.17551	-16.32841	0.
HOLE	3	-5.80136	-12.56031	0.	HOLE	3	-0.72517	-16.32841	0.
HOLE	3	-4.35102	-12.56031	0.	HOLE	3	0.72517	-16.32841	0.
HOLE	3	-2.90068	-12.56031	0.	HOLE	3	2.17551	-16.32841	0.
HOLE	3	-1.45034	-12.56031	0.	HOLE	3	3.62585	-16.32841	0.
HOLE	3	0.	-12.56031	0.	HOLE	3	5.07619	-16.32841	0.
HOLE	3	1.45034	-12.56031	0.	HOLE	3	6.52653	-16.32841	0.
HOLE	3	2.90068	-12.56031	0.	HOLE	3	7.97687	-16.32841	0.
HOLE	3	4.35102	-12.56031	0.	HOLE	3	9.42721	-16.32841	0.
HOLE	3	5.80136	-12.56031	0.	HOLE	3	10.87755	-16.32841	0.
HOLE	3	7.25170	-12.56031	0.	HOLE	3	12.32789	-16.32841	0.
HOLE	3	8.70204	-12.56031	0.	HOLE	3	13.77823	-16.32841	0.
HOLE	3	10.15238	-12.56031	0.	HOLE	3	15.22857	-16.32841	0.
HOLE	3	11.60272	-12.56031	0.	HOLE	3	16.67891	-16.32841	0.

HOLE	3	18.12925	-16.32841	0.	HOLE	3	-0.72517	-21.35253	0.
HOLE	3	19.57959	-16.32841	0.	HOLE	3	0.72517	-21.35253	0.
COM=-14 row*					HOLE	3	2.17551	-21.35253	0.
HOLE	3	-18.85442	-17.58444	0.	HOLE	3	3.62585	-21.35253	0.
HOLE	3	-17.40408	-17.58444	0.	HOLE	3	5.07619	-21.35253	0.
HOLE	3	-15.95374	-17.58444	0.	HOLE	3	6.52653	-21.35253	0.
HOLE	3	-14.50340	-17.58444	0.	HOLE	3	7.97687	-21.35253	0.
HOLE	3	-13.05306	-17.58444	0.	HOLE	3	9.42721	-21.35253	0.
HOLE	3	-11.60272	-17.58444	0.	HOLE	3	10.87755	-21.35253	0.
HOLE	3	-10.15238	-17.58444	0.	HOLE	3	12.32789	-21.35253	0.
HOLE	3	-8.70204	-17.58444	0.	HOLE	3	13.77823	-21.35253	0.
HOLE	3	-7.25170	-17.58444	0.	HOLE	3	15.22857	-21.35253	0.
HOLE	3	-5.80136	-17.58444	0.	HOLE	3	16.67891	-21.35253	0.
HOLE	3	-4.35102	-17.58444	0.	COM=-18 row*				
HOLE	3	-2.90068	-17.58444	0.	HOLE	3	-15.95374	-22.60856	0.
HOLE	3	-1.45034	-17.58444	0.	HOLE	3	-14.50340	-22.60856	0.
HOLE	3	0.	-17.58444	0.	HOLE	3	-13.05306	-22.60856	0.
HOLE	3	1.45034	-17.58444	0.	HOLE	3	-11.60272	-22.60856	0.
HOLE	3	2.90068	-17.58444	0.	HOLE	3	-10.15238	-22.60856	0.
HOLE	3	4.35102	-17.58444	0.	HOLE	3	-8.70204	-22.60856	0.
HOLE	3	5.80136	-17.58444	0.	HOLE	3	-7.25170	-22.60856	0.
HOLE	3	7.25170	-17.58444	0.	HOLE	3	-5.80136	-22.60856	0.
HOLE	3	8.70204	-17.58444	0.	HOLE	3	-4.35102	-22.60856	0.
HOLE	3	10.15238	-17.58444	0.	HOLE	3	-2.90068	-22.60856	0.
HOLE	3	11.60272	-17.58444	0.	HOLE	3	-1.45034	-22.60856	0.
HOLE	3	13.05306	-17.58444	0.	HOLE	3	0.	-22.60856	0.
HOLE	3	14.50340	-17.58444	0.	HOLE	3	1.45034	-22.60856	0.
HOLE	3	15.95374	-17.58444	0.	HOLE	3	2.90068	-22.60856	0.
HOLE	3	17.40408	-17.58444	0.	HOLE	3	4.35102	-22.60856	0.
HOLE	3	18.85442	-17.58444	0.	HOLE	3	5.80136	-22.60856	0.
COM=-15 row*					HOLE	3	7.25170	-22.60856	0.
HOLE	3	-18.12925	-18.84047	0.	HOLE	3	8.70204	-22.60856	0.
HOLE	3	-16.67891	-18.84047	0.	HOLE	3	10.15238	-22.60856	0.
HOLE	3	-15.22857	-18.84047	0.	HOLE	3	11.60272	-22.60856	0.
HOLE	3	-13.77823	-18.84047	0.	HOLE	3	13.05306	-22.60856	0.
HOLE	3	-12.32789	-18.84047	0.	HOLE	3	14.50340	-22.60856	0.
HOLE	3	-10.87755	-18.84047	0.	HOLE	3	15.95374	-22.60856	0.
HOLE	3	-9.42721	-18.84047	0.	COM=-19 row*				
HOLE	3	-7.97687	-18.84047	0.	HOLE	3	-15.22857	-23.86459	0.
HOLE	3	-6.52653	-18.84047	0.	HOLE	3	-13.77823	-23.86459	0.
HOLE	3	-5.07619	-18.84047	0.	HOLE	3	-12.32789	-23.86459	0.
HOLE	3	-3.62585	-18.84047	0.	HOLE	3	-10.87755	-23.86459	0.
HOLE	3	-2.17551	-18.84047	0.	HOLE	3	-9.42721	-23.86459	0.
HOLE	3	-0.72517	-18.84047	0.	HOLE	3	-7.97687	-23.86459	0.
HOLE	3	0.72517	-18.84047	0.	HOLE	3	-6.52653	-23.86459	0.
HOLE	3	2.17551	-18.84047	0.	HOLE	3	-5.07619	-23.86459	0.
HOLE	3	3.62585	-18.84047	0.	HOLE	3	-3.62585	-23.86459	0.
HOLE	3	5.07619	-18.84047	0.	HOLE	3	-2.17551	-23.86459	0.
HOLE	3	6.52653	-18.84047	0.	HOLE	3	-0.72517	-23.86459	0.
HOLE	3	7.97687	-18.84047	0.	HOLE	3	0.72517	-23.86459	0.
HOLE	3	9.42721	-18.84047	0.	HOLE	3	2.17551	-23.86459	0.
HOLE	3	10.87755	-18.84047	0.	HOLE	3	3.62585	-23.86459	0.
HOLE	3	12.32789	-18.84047	0.	HOLE	3	5.07619	-23.86459	0.
HOLE	3	13.77823	-18.84047	0.	HOLE	3	6.52653	-23.86459	0.
HOLE	3	15.22857	-18.84047	0.	HOLE	3	7.97687	-23.86459	0.
HOLE	3	16.67891	-18.84047	0.	HOLE	3	9.42721	-23.86459	0.
HOLE	3	18.12925	-18.84047	0.	HOLE	3	10.87755	-23.86459	0.
COM=-16 row*					HOLE	3	12.32789	-23.86459	0.
HOLE	3	-17.40408	-20.09650	0.	HOLE	3	13.77823	-23.86459	0.
HOLE	3	-15.95374	-20.09650	0.	HOLE	3	15.22857	-23.86459	0.
HOLE	3	-14.50340	-20.09650	0.	COM=-20 row*				
HOLE	3	-13.05306	-20.09650	0.	HOLE	3	-14.50340	-25.12063	0.
HOLE	3	-11.60272	-20.09650	0.	HOLE	3	-13.05306	-25.12063	0.
HOLE	3	-10.15238	-20.09650	0.	HOLE	3	-11.60272	-25.12063	0.
HOLE	3	-8.70204	-20.09650	0.	HOLE	3	-10.15238	-25.12063	0.
HOLE	3	-7.25170	-20.09650	0.	HOLE	3	-8.70204	-25.12063	0.
HOLE	3	-5.80136	-20.09650	0.	HOLE	3	-7.25170	-25.12063	0.
HOLE	3	-4.35102	-20.09650	0.	HOLE	3	-5.80136	-25.12063	0.
HOLE	3	-2.90068	-20.09650	0.	HOLE	3	-4.35102	-25.12063	0.
HOLE	3	-1.45034	-20.09650	0.	HOLE	3	-2.90068	-25.12063	0.
HOLE	3	0.	-20.09650	0.	HOLE	3	-1.45034	-25.12063	0.
HOLE	3	1.45034	-20.09650	0.	HOLE	3	0.	-25.12063	0.
HOLE	3	2.90068	-20.09650	0.	HOLE	3	1.45034	-25.12063	0.
HOLE	3	4.35102	-20.09650	0.	HOLE	3	2.90068	-25.12063	0.
HOLE	3	5.80136	-20.09650	0.	HOLE	3	4.35102	-25.12063	0.
HOLE	3	7.25170	-20.09650	0.	HOLE	3	5.80136	-25.12063	0.
HOLE	3	8.70204	-20.09650	0.	HOLE	3	7.25170	-25.12063	0.
HOLE	3	10.15238	-20.09650	0.	HOLE	3	8.70204	-25.12063	0.
HOLE	3	11.60272	-20.09650	0.	HOLE	3	10.15238	-25.12063	0.
HOLE	3	13.05306	-20.09650	0.	HOLE	3	11.60272	-25.12063	0.
HOLE	3	14.50340	-20.09650	0.	HOLE	3	13.05306	-25.12063	0.
HOLE	3	15.95374	-20.09650	0.	HOLE	3	14.50340	-25.12063	0.
HOLE	3	17.40408	-20.09650	0.	CUBOID	4	1	4P29.8	2P49.5301
COM=-17 row*					GLOBAL				
HOLE	3	-16.67891	-21.35253	0.	UNIT 6				
HOLE	3	-15.22857	-21.35253	0.	ARRAY	1	2R-29.8	-49.5301	
HOLE	3	-13.77823	-21.35253	0.	REFLECTOR	4	2	4*3.1	2*0
HOLE	3	-12.32789	-21.35253	0.	END GEOM				10
HOLE	3	-10.87755	-21.35253	0.	READ ARRAY				
HOLE	3	-9.42721	-21.35253	0.	NUX=1	NUY=1	NUZ=1	FILL	F5
HOLE	3	-7.97687	-21.35253	0.	END ARRAY			END	FILL
HOLE	3	-6.52653	-21.35253	0.	READ BIAS				
HOLE	3	-5.07619	-21.35253	0.	ID=500	2	11		
HOLE	3	-3.62585	-21.35253	0.	END BIAS				
HOLE	3	-2.17551	-21.35253	0.	READ START				

NST=1 XSM=-30 YSM=-26 ZSM=-19.05
 XSP=30 YSP=26 ZSP=19.05
 END START

END DATA
 END

E.2.7 Core SB-6, 27 Group ENDF/B-IV

```
=CSAS25 PARM=SIZE=200000
full LWBR SB-6 fuel rods, control blades, and 1ft water
reflector
27GROUPNDF4 LATTICECELL
' mix 1 = 233UO2-ZrO2 Seed
O 1 0 5.4281-2 END
ZR 1 0 2.3194-2 END
U-233 1 0 3.8411-3 END
U-234 1 0 6.1327-5 END
U-235 1 0 1.3048-7 END
U-236 1 0 1.2993-7 END
U-238 1 0 4.4061-5 END
' mix 2 = ThO2 blanket
O-16 2 0 4.3282-2 END
TH-232 2 0 2.1641-2 END
GD 2 0 1.5967-7 END
' mix 3 = zirc-2 cladding etc, 6.56 g/cc, Ntot=4.3234-2
ZR 3 0 4.2537-2 END
CR 3 0 7.5977-5 END
FE 3 0 8.8422-5 END
NI 3 0 3.3656-5 END
SN 3 0 4.9918-4 END
' mix 4 = water, 0.9982 g/cc, Ntot=1.0010-1
H 4 0 6.6735-2 END
O 4 0 3.3368-2 END
' mix 5 = borated SS304 control blades, 7.92g/cc,
Ntot=8.9912-2
FE 5 0 5.9289-2 END
B-10 5 0 3.7488-3 END
C 5 0 1.5884-4 END
CR 5 0 1.7428-2 END
MN 5 0 8.6816-4 END
NI 5 0 7.5171-3 END
P 5 0 3.0797-5 END
S 5 0 2.2308-5 END
SI 5 0 8.4910-4 END
END COMP
TRIANGPITCH 0.91948 0.53594 1 4 0.64770 3 0.55880 0
END
MORE DATA RES=2 CYLINDER 0.62103
DAN(2)=0.702856 END
KENOV.A
READ PARAM
GEN=500 NPG=3000 NSK=50 TME=4000
FLX=YES FDN=YES FMP=YES NUB=YES RUN=YES
END PARAM
READ GEOM
UNIT 1
COM=*Seed rod in water*
CYLINDER 1 1 0.26797 2P19.05
CYLINDER 0 1 0.27940 2P19.05
CYLINDER 3 1 0.32385 2P26.4541
UNIT 3
COM=*blanket rod in water*
CYLINDER 2 1 0.62103 2P19.05
CYLINDER 0 1 0.63373 2P19.05
CYLINDER 3 1 0.72390 2P26.4541
UNIT 4
COM=*control blade in water*
CUBOID 5 1 2P3.81 2P0.0889 49.53
14.07
CUBOID 4 1 2P3.81 2P0.0889 2P49.53
UNIT 5
COM=*rod array with blades*
CYLINDER 4 1 29.8 2P49.5301
COM=*control blades*
HOLE 4 0. 5.51688 0.
HOLE 4 0. 1.83896 0.
HOLE 4 0. -1.83896 0.
HOLE 4 0. -5.51688 0.
COM=*+20 row*
HOLE 3 -14.50340 25.12063 0.
HOLE 3 -13.05306 25.12063 0.
HOLE 3 -11.60272 25.12063 0.
HOLE 3 -10.15238 25.12063 0.
HOLE 3 -8.70204 25.12063 0.
HOLE 3 -7.25170 25.12063 0.
HOLE 3 -5.80136 25.12063 0.
HOLE 3 -4.35102 25.12063 0.
HOLE 3 -2.90068 25.12063 0.
HOLE 3 -1.45034 25.12063 0.
HOLE 3 0. 25.12063 0.
HOLE 3 1.45034 25.12063 0.
HOLE 3 2.90068 25.12063 0.
HOLE 3 4.35102 25.12063 0.
HOLE 3 5.80136 25.12063 0.
HOLE 3 7.25170 25.12063 0.
HOLE 3 8.70204 25.12063 0.
HOLE 3 10.15238 25.12063 0.
HOLE 3 11.60272 25.12063 0.
HOLE 3 13.05306 25.12063 0.
HOLE 3 14.50340 25.12063 0.
COM=*+19 row*
HOLE 3 -15.22857 23.86459 0.
HOLE 3 -13.77823 23.86459 0.
HOLE 3 -12.32789 23.86459 0.
HOLE 3 -10.87755 23.86459 0.
HOLE 3 -9.42721 23.86459 0.
HOLE 3 -7.97687 23.86459 0.
HOLE 3 -6.52653 23.86459 0.
HOLE 3 -5.07619 23.86459 0.
HOLE 3 -3.62585 23.86459 0.
HOLE 3 -2.17551 23.86459 0.
HOLE 3 -0.72517 23.86459 0.
HOLE 3 0.72517 23.86459 0.
HOLE 3 2.17551 23.86459 0.
HOLE 3 3.62585 23.86459 0.
HOLE 3 5.07619 23.86459 0.
HOLE 3 6.52653 23.86459 0.
HOLE 3 7.97687 23.86459 0.
HOLE 3 9.42721 23.86459 0.
HOLE 3 10.87755 23.86459 0.
HOLE 3 12.32789 23.86459 0.
HOLE 3 13.77823 23.86459 0.
HOLE 3 15.22857 23.86459 0.
COM=*+18 row*
HOLE 3 -15.95374 22.60856 0.
HOLE 3 -14.50340 22.60856 0.
HOLE 3 -13.05306 22.60856 0.
HOLE 3 -11.60272 22.60856 0.
HOLE 3 -10.15238 22.60856 0.
HOLE 3 -8.70204 22.60856 0.
HOLE 3 -7.25170 22.60856 0.
HOLE 3 -5.80136 22.60856 0.
HOLE 3 -4.35102 22.60856 0.
HOLE 3 -2.90068 22.60856 0.
HOLE 3 -1.45034 22.60856 0.
HOLE 3 0. 22.60856 0.
HOLE 3 1.45034 22.60856 0.
HOLE 3 2.90068 22.60856 0.
HOLE 3 4.35102 22.60856 0.
HOLE 3 5.80136 22.60856 0.
HOLE 3 7.25170 22.60856 0.
HOLE 3 8.70204 22.60856 0.
HOLE 3 10.15238 22.60856 0.
HOLE 3 11.60272 22.60856 0.
HOLE 3 13.05306 22.60856 0.
HOLE 3 14.50340 22.60856 0.
HOLE 3 15.95374 22.60856 0.
COM=*+17 row*
HOLE 3 -16.67891 21.35253 0.
HOLE 3 -15.22857 21.35253 0.
HOLE 3 -13.77823 21.35253 0.
HOLE 3 -12.32789 21.35253 0.
HOLE 3 -10.87755 21.35253 0.
HOLE 3 -9.42721 21.35253 0.
HOLE 3 -7.97687 21.35253 0.
HOLE 3 -6.52653 21.35253 0.
HOLE 3 -5.07619 21.35253 0.
HOLE 3 -3.62585 21.35253 0.
HOLE 3 -2.17551 21.35253 0.
HOLE 3 -0.72517 21.35253 0.
HOLE 3 0.72517 21.35253 0.
HOLE 3 2.17551 21.35253 0.
HOLE 3 3.62585 21.35253 0.
HOLE 3 5.07619 21.35253 0.
HOLE 3 6.52653 21.35253 0.
HOLE 3 7.97687 21.35253 0.
HOLE 3 9.42721 21.35253 0.
HOLE 3 10.87755 21.35253 0.
HOLE 3 12.32789 21.35253 0.
HOLE 3 13.77823 21.35253 0.
HOLE 3 15.22857 21.35253 0.
HOLE 3 16.67891 21.35253 0.
COM=*+16 row*
HOLE 3 -17.40408 20.09650 0.
HOLE 3 -15.95374 20.09650 0.
HOLE 3 -14.50340 20.09650 0.
HOLE 3 -13.05306 20.09650 0.
HOLE 3 -11.60272 20.09650 0.
HOLE 3 -10.15238 20.09650 0.
HOLE 3 -8.70204 20.09650 0.
HOLE 3 -7.25170 20.09650 0.
HOLE 3 -5.80136 20.09650 0.
HOLE 3 -4.35102 20.09650 0.
HOLE 3 -2.90068 20.09650 0.
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HOLE	3	-1.45034	20.09650	0.	HOLE	3	16.67891	16.32841	0.
HOLE	3	0.	20.09650	0.	HOLE	3	18.12925	16.32841	0.
HOLE	3	1.45034	20.09650	0.	HOLE	3	19.57959	16.32841	0.
HOLE	3	2.90068	20.09650	0.	COM=+12 row*				
HOLE	3	4.35102	20.09650	0.	HOLE	3	-20.30476	15.07238	0.
HOLE	3	5.80136	20.09650	0.	HOLE	3	-18.85442	15.07238	0.
HOLE	3	7.25170	20.09650	0.	HOLE	3	-17.40408	15.07238	0.
HOLE	3	8.70204	20.09650	0.	HOLE	3	-15.95374	15.07238	0.
HOLE	3	10.15238	20.09650	0.	HOLE	3	-14.50340	15.07238	0.
HOLE	3	11.60272	20.09650	0.	HOLE	3	-13.05306	15.07238	0.
HOLE	3	13.05306	20.09650	0.	HOLE	3	-11.60272	15.07238	0.
HOLE	3	14.50340	20.09650	0.	HOLE	3	-10.15238	15.07238	0.
HOLE	3	15.95374	20.09650	0.	HOLE	3	-8.70204	15.07238	0.
HOLE	3	17.40408	20.09650	0.	HOLE	3	-7.25170	15.07238	0.
COM=+15 row*					HOLE	3	-5.80136	15.07238	0.
HOLE	3	-18.12925	18.84047	0.	HOLE	3	-4.35102	15.07238	0.
HOLE	3	-16.67891	18.84047	0.	HOLE	3	-2.90068	15.07238	0.
HOLE	3	-15.22857	18.84047	0.	HOLE	3	-1.45034	15.07238	0.
HOLE	3	-13.77823	18.84047	0.	HOLE	3	0.	15.07238	0.
HOLE	3	-12.32789	18.84047	0.	HOLE	3	1.45034	15.07238	0.
HOLE	3	-10.87755	18.84047	0.	HOLE	3	2.90068	15.07238	0.
HOLE	3	-9.42721	18.84047	0.	HOLE	3	4.35102	15.07238	0.
HOLE	3	-7.97687	18.84047	0.	HOLE	3	5.80136	15.07238	0.
HOLE	3	-6.52653	18.84047	0.	HOLE	3	7.25170	15.07238	0.
HOLE	3	-5.07619	18.84047	0.	HOLE	3	8.70204	15.07238	0.
HOLE	3	-3.62585	18.84047	0.	HOLE	3	10.15238	15.07238	0.
HOLE	3	-2.17551	18.84047	0.	HOLE	3	11.60272	15.07238	0.
HOLE	3	-0.72517	18.84047	0.	HOLE	3	13.05306	15.07238	0.
HOLE	3	0.72517	18.84047	0.	HOLE	3	14.50340	15.07238	0.
HOLE	3	2.17551	18.84047	0.	HOLE	3	15.95374	15.07238	0.
HOLE	3	3.62585	18.84047	0.	HOLE	3	17.40408	15.07238	0.
HOLE	3	5.07619	18.84047	0.	HOLE	3	18.85442	15.07238	0.
HOLE	3	6.52653	18.84047	0.	HOLE	3	20.30476	15.07238	0.
HOLE	3	7.97687	18.84047	0.	COM=+11 row*				
HOLE	3	9.42721	18.84047	0.	HOLE	3	-21.02993	13.81634	0.
HOLE	3	10.87755	18.84047	0.	HOLE	3	-19.57959	13.81634	0.
HOLE	3	12.32789	18.84047	0.	HOLE	3	-18.12925	13.81634	0.
HOLE	3	13.77823	18.84047	0.	HOLE	3	-16.67891	13.81634	0.
HOLE	3	15.22857	18.84047	0.	HOLE	3	-15.22857	13.81634	0.
HOLE	3	16.67891	18.84047	0.	HOLE	3	-13.77823	13.81634	0.
HOLE	3	18.12925	18.84047	0.	HOLE	3	-12.32789	13.81634	0.
COM=+14 row*					HOLE	3	-10.87755	13.81634	0.
HOLE	3	-18.85442	17.58444	0.	HOLE	3	-9.42721	13.81634	0.
HOLE	3	-17.40408	17.58444	0.	HOLE	3	-7.97687	13.81634	0.
HOLE	3	-15.95374	17.58444	0.	HOLE	3	-6.52653	13.81634	0.
HOLE	3	-14.50340	17.58444	0.	HOLE	3	-5.07619	13.81634	0.
HOLE	3	-13.05306	17.58444	0.	HOLE	3	-3.62585	13.81634	0.
HOLE	3	-11.60272	17.58444	0.	HOLE	3	-2.17551	13.81634	0.
HOLE	3	-10.15238	17.58444	0.	HOLE	3	-0.72517	13.81634	0.
HOLE	3	-8.70204	17.58444	0.	HOLE	3	0.72517	13.81634	0.
HOLE	3	-7.25170	17.58444	0.	HOLE	3	2.17551	13.81634	0.
HOLE	3	-5.80136	17.58444	0.	HOLE	3	3.62585	13.81634	0.
HOLE	3	-4.35102	17.58444	0.	HOLE	3	5.07619	13.81634	0.
HOLE	3	-2.90068	17.58444	0.	HOLE	3	6.52653	13.81634	0.
HOLE	3	-1.45034	17.58444	0.	HOLE	3	7.97687	13.81634	0.
HOLE	3	0.	17.58444	0.	HOLE	3	9.42721	13.81634	0.
HOLE	3	1.45034	17.58444	0.	HOLE	3	10.87755	13.81634	0.
HOLE	3	2.90068	17.58444	0.	HOLE	3	12.32789	13.81634	0.
HOLE	3	4.35102	17.58444	0.	HOLE	3	13.77823	13.81634	0.
HOLE	3	5.80136	17.58444	0.	HOLE	3	15.22857	13.81634	0.
HOLE	3	7.25170	17.58444	0.	HOLE	3	16.67891	13.81634	0.
HOLE	3	8.70204	17.58444	0.	HOLE	3	18.12925	13.81634	0.
HOLE	3	10.15238	17.58444	0.	HOLE	3	19.57959	13.81634	0.
HOLE	3	11.60272	17.58444	0.	HOLE	3	21.02993	13.81634	0.
HOLE	3	13.05306	17.58444	0.	COM=+10 row*				
HOLE	3	14.50340	17.58444	0.	HOLE	3	-21.75510	12.56031	0.
HOLE	3	15.95374	17.58444	0.	HOLE	3	-20.30476	12.56031	0.
HOLE	3	17.40408	17.58444	0.	HOLE	3	-18.85442	12.56031	0.
HOLE	3	18.85442	17.58444	0.	HOLE	3	-17.40408	12.56031	0.
COM=+13 row*					HOLE	3	-15.95374	12.56031	0.
HOLE	3	-19.57959	16.32841	0.	HOLE	3	-14.50340	12.56031	0.
HOLE	3	-18.12925	16.32841	0.	HOLE	3	-13.05306	12.56031	0.
HOLE	3	-16.67891	16.32841	0.	HOLE	3	-11.60272	12.56031	0.
HOLE	3	-15.22857	16.32841	0.	HOLE	3	-10.15238	12.56031	0.
HOLE	3	-13.77823	16.32841	0.	HOLE	3	-8.70204	12.56031	0.
HOLE	3	-12.32789	16.32841	0.	HOLE	3	-7.25170	12.56031	0.
HOLE	3	-10.87755	16.32841	0.	HOLE	3	-5.80136	12.56031	0.
HOLE	3	-9.42721	16.32841	0.	HOLE	3	-4.35102	12.56031	0.
HOLE	3	-7.97687	16.32841	0.	HOLE	3	-2.90068	12.56031	0.
HOLE	3	-6.52653	16.32841	0.	HOLE	3	-1.45034	12.56031	0.
HOLE	3	-5.07619	16.32841	0.	HOLE	3	0.	12.56031	0.
HOLE	3	-3.62585	16.32841	0.	HOLE	3	1.45034	12.56031	0.
HOLE	3	-2.17551	16.32841	0.	HOLE	3	2.90068	12.56031	0.
HOLE	3	-0.72517	16.32841	0.	HOLE	3	4.35102	12.56031	0.
HOLE	3	0.72517	16.32841	0.	HOLE	3	5.80136	12.56031	0.
HOLE	3	2.17551	16.32841	0.	HOLE	3	7.25170	12.56031	0.
HOLE	3	3.62585	16.32841	0.	HOLE	3	8.70204	12.56031	0.
HOLE	3	5.07619	16.32841	0.	HOLE	3	10.15238	12.56031	0.
HOLE	3	6.52653	16.32841	0.	HOLE	3	11.60272	12.56031	0.
HOLE	3	7.97687	16.32841	0.	HOLE	3	13.05306	12.56031	0.
HOLE	3	9.42721	16.32841	0.	HOLE	3	14.50340	12.56031	0.
HOLE	3	10.87755	16.32841	0.	HOLE	3	15.95374	12.56031	0.
HOLE	3	12.32789	16.32841	0.	HOLE	3	17.40408	12.56031	0.
HOLE	3	13.77823	16.32841	0.	HOLE	3	18.85442	12.56031	0.
HOLE	3	15.22857	16.32841	0.	HOLE	3	20.30476	12.56031	0.

Appendix E Benchmark Model Inputs

HOLE	3	21.75510	12.56031	0.	HOLE	3	13.77823	8.79222	0.
COM=+9 row*					HOLE	3	15.22857	8.79222	0.
HOLE	3	-22.48027	11.30428	0.	HOLE	3	16.67891	8.79222	0.
HOLE	3	-21.02993	11.30428	0.	HOLE	3	18.12925	8.79222	0.
HOLE	3	-19.57959	11.30428	0.	HOLE	3	19.57959	8.79222	0.
HOLE	3	-18.12925	11.30428	0.	HOLE	3	21.02993	8.79222	0.
HOLE	3	-16.67891	11.30428	0.	HOLE	3	22.48027	8.79222	0.
HOLE	3	-15.22857	11.30428	0.	HOLE	3	23.93061	8.79222	0.
HOLE	3	-13.77823	11.30428	0.	COM=+6 row*				
HOLE	3	-12.32789	11.30428	0.	HOLE	3	-24.65578	7.53619	0.
HOLE	3	-10.87755	11.30428	0.	HOLE	3	-23.20544	7.53619	0.
HOLE	3	-9.42721	11.30428	0.	HOLE	3	-21.75510	7.53619	0.
HOLE	3	-7.97687	11.30428	0.	HOLE	3	-20.30476	7.53619	0.
HOLE	3	-6.52653	11.30428	0.	HOLE	3	-18.85442	7.53619	0.
HOLE	3	-5.07619	11.30428	0.	HOLE	3	-17.40408	7.53619	0.
HOLE	3	-3.62585	11.30428	0.	HOLE	3	-15.95374	7.53619	0.
HOLE	3	-2.17551	11.30428	0.	HOLE	3	-14.50340	7.53619	0.
HOLE	3	-0.72517	11.30428	0.	HOLE	3	-13.05306	7.53619	0.
HOLE	3	0.72517	11.30428	0.	HOLE	3	-11.60272	7.53619	0.
HOLE	3	2.17551	11.30428	0.	HOLE	3	-10.15238	7.53619	0.
HOLE	3	3.62585	11.30428	0.	HOLE	3	-8.70204	7.53619	0.
HOLE	3	5.07619	11.30428	0.	HOLE	3	-7.25170	7.53619	0.
HOLE	3	6.52653	11.30428	0.	HOLE	3	-5.80136	7.53619	0.
HOLE	3	7.97687	11.30428	0.	HOLE	1	-4.35102	7.53619	0.
HOLE	3	9.42721	11.30428	0.	HOLE	1	-2.90068	7.53619	0.
HOLE	3	10.87755	11.30428	0.	HOLE	1	-1.45034	7.53619	0.
HOLE	3	12.32789	11.30428	0.	HOLE	1	0.	7.53619	0.
HOLE	3	13.77823	11.30428	0.	HOLE	1	1.45034	7.53619	0.
HOLE	3	15.22857	11.30428	0.	HOLE	1	2.90068	7.53619	0.
HOLE	3	16.67891	11.30428	0.	HOLE	1	4.35102	7.53619	0.
HOLE	3	18.12925	11.30428	0.	HOLE	1	5.80136	7.53619	0.
HOLE	3	19.57959	11.30428	0.	HOLE	3	7.25170	7.53619	0.
HOLE	3	21.02993	11.30428	0.	HOLE	3	8.70204	7.53619	0.
HOLE	3	22.48027	11.30428	0.	HOLE	3	10.15238	7.53619	0.
COM=+8 row*					HOLE	3	11.60272	7.53619	0.
HOLE	3	-23.20544	10.04825	0.	HOLE	3	13.05306	7.53619	0.
HOLE	3	-21.75510	10.04825	0.	HOLE	3	14.50340	7.53619	0.
HOLE	3	-20.30476	10.04825	0.	HOLE	3	15.95374	7.53619	0.
HOLE	3	-18.85442	10.04825	0.	HOLE	3	17.40408	7.53619	0.
HOLE	3	-17.40408	10.04825	0.	HOLE	3	18.85442	7.53619	0.
HOLE	3	-15.95374	10.04825	0.	HOLE	3	20.30476	7.53619	0.
HOLE	3	-14.50340	10.04825	0.	HOLE	3	21.75510	7.53619	0.
HOLE	3	-13.05306	10.04825	0.	HOLE	3	23.20544	7.53619	0.
HOLE	3	-11.60272	10.04825	0.	HOLE	3	24.65578	7.53619	0.
HOLE	3	-10.15238	10.04825	0.	COM=+5 row*				
HOLE	3	-8.70204	10.04825	0.	HOLE	3	-25.38095	6.28016	0.
HOLE	3	-7.25170	10.04825	0.	HOLE	3	-23.93061	6.28016	0.
HOLE	3	-5.80136	10.04825	0.	HOLE	3	-22.48027	6.28016	0.
HOLE	3	-4.35102	10.04825	0.	HOLE	3	-21.02993	6.28016	0.
HOLE	3	-2.90068	10.04825	0.	HOLE	3	-19.57959	6.28016	0.
HOLE	3	-1.45034	10.04825	0.	HOLE	3	-18.12925	6.28016	0.
HOLE	3	0.	10.04825	0.	HOLE	3	-16.67891	6.28016	0.
HOLE	3	1.45034	10.04825	0.	HOLE	3	-15.22857	6.28016	0.
HOLE	3	2.90068	10.04825	0.	HOLE	3	-13.77823	6.28016	0.
HOLE	3	4.35102	10.04825	0.	HOLE	3	-12.32789	6.28016	0.
HOLE	3	5.80136	10.04825	0.	HOLE	3	-10.87755	6.28016	0.
HOLE	3	7.25170	10.04825	0.	HOLE	3	-9.42721	6.28016	0.
HOLE	3	8.70204	10.04825	0.	HOLE	3	-7.97687	6.28016	0.
HOLE	3	10.15238	10.04825	0.	HOLE	3	-6.52653	6.28016	0.
HOLE	3	11.60272	10.04825	0.	HOLE	1	-5.07619	6.28016	0.
HOLE	3	13.05306	10.04825	0.	HOLE	1	-3.62585	6.28016	0.
HOLE	3	14.50340	10.04825	0.	HOLE	1	-2.17551	6.28016	0.
HOLE	3	15.95374	10.04825	0.	HOLE	1	-0.72517	6.28016	0.
HOLE	3	17.40408	10.04825	0.	HOLE	1	0.72517	6.28016	0.
HOLE	3	18.85442	10.04825	0.	HOLE	1	2.17551	6.28016	0.
HOLE	3	20.30476	10.04825	0.	HOLE	1	3.62585	6.28016	0.
HOLE	3	21.75510	10.04825	0.	HOLE	1	5.07619	6.28016	0.
HOLE	3	23.20544	10.04825	0.	HOLE	1	6.52653	6.28016	0.
COM=+7 row*					HOLE	3	7.97687	6.28016	0.
HOLE	3	-23.93061	8.79222	0.	HOLE	3	9.42721	6.28016	0.
HOLE	3	-22.48027	8.79222	0.	HOLE	3	10.87755	6.28016	0.
HOLE	3	-21.02993	8.79222	0.	HOLE	3	12.32789	6.28016	0.
HOLE	3	-19.57959	8.79222	0.	HOLE	3	13.77823	6.28016	0.
HOLE	3	-18.12925	8.79222	0.	HOLE	3	15.22857	6.28016	0.
HOLE	3	-16.67891	8.79222	0.	HOLE	3	16.67891	6.28016	0.
HOLE	3	-15.22857	8.79222	0.	HOLE	3	18.12925	6.28016	0.
HOLE	3	-13.77823	8.79222	0.	HOLE	3	19.57959	6.28016	0.
HOLE	3	-12.32789	8.79222	0.	HOLE	3	21.02993	6.28016	0.
HOLE	3	-10.87755	8.79222	0.	HOLE	3	22.48027	6.28016	0.
HOLE	3	-9.42721	8.79222	0.	HOLE	3	23.93061	6.28016	0.
HOLE	3	-7.97687	8.79222	0.	HOLE	3	25.38095	6.28016	0.
HOLE	3	-6.52653	8.79222	0.	COM=+4 row*				
HOLE	3	-5.07619	8.79222	0.	HOLE	3	-26.10612	5.02413	0.
HOLE	3	-3.62585	8.79222	0.	HOLE	3	-24.65578	5.02413	0.
HOLE	3	-2.17551	8.79222	0.	HOLE	3	-23.20544	5.02413	0.
HOLE	3	-0.72517	8.79222	0.	HOLE	3	-21.75510	5.02413	0.
HOLE	1	0.72517	8.79222	0.	HOLE	3	-20.30476	5.02413	0.
HOLE	1	2.17551	8.79222	0.	HOLE	3	-18.85442	5.02413	0.
HOLE	1	3.62585	8.79222	0.	HOLE	3	-17.40408	5.02413	0.
HOLE	1	5.07619	8.79222	0.	HOLE	3	-15.95374	5.02413	0.
HOLE	3	6.52653	8.79222	0.	HOLE	3	-14.50340	5.02413	0.
HOLE	3	7.97687	8.79222	0.	HOLE	3	-13.05306	5.02413	0.
HOLE	3	9.42721	8.79222	0.	HOLE	3	-11.60272	5.02413	0.
HOLE	3	10.87755	8.79222	0.	HOLE	3	-10.15238	5.02413	0.
HOLE	3	12.32789	8.79222	0.	HOLE	3	-8.70204	5.02413	0.

HOLE	3	-7.25170	5.02413	0.	HOLE	3	17.40408	2.51206	0.
HOLE	1	-5.80136	5.02413	0.	HOLE	3	18.85442	2.51206	0.
HOLE	1	-4.35102	5.02413	0.	HOLE	3	20.30476	2.51206	0.
HOLE	1	-2.90068	5.02413	0.	HOLE	3	21.75510	2.51206	0.
HOLE	1	-1.45034	5.02413	0.	HOLE	3	23.20544	2.51206	0.
HOLE	1	0.	5.02413	0.	HOLE	3	24.65578	2.51206	0.
HOLE	1	1.45034	5.02413	0.	HOLE	3	26.10612	2.51206	0.
HOLE	1	2.90068	5.02413	0.	HOLE	3	27.55646	2.51206	0.
HOLE	1	4.35102	5.02413	0.	COM=+1 row*				
HOLE	1	5.80136	5.02413	0.	HOLE	3	-28.28163	1.25603	0.
HOLE	1	7.25170	5.02413	0.	HOLE	3	-26.83129	1.25603	0.
HOLE	3	8.70204	5.02413	0.	HOLE	3	-25.38095	1.25603	0.
HOLE	3	10.15238	5.02413	0.	HOLE	3	-23.93061	1.25603	0.
HOLE	3	11.60272	5.02413	0.	HOLE	3	-22.48027	1.25603	0.
HOLE	3	13.05306	5.02413	0.	HOLE	3	-21.02993	1.25603	0.
HOLE	3	14.50340	5.02413	0.	HOLE	3	-19.57959	1.25603	0.
HOLE	3	15.95374	5.02413	0.	HOLE	3	-18.12925	1.25603	0.
HOLE	3	17.40408	5.02413	0.	HOLE	3	-16.67891	1.25603	0.
HOLE	3	18.85442	5.02413	0.	HOLE	3	-15.22857	1.25603	0.
HOLE	3	20.30476	5.02413	0.	HOLE	3	-13.77823	1.25603	0.
HOLE	3	21.75510	5.02413	0.	HOLE	3	-12.32789	1.25603	0.
HOLE	3	23.20544	5.02413	0.	HOLE	3	-10.87755	1.25603	0.
HOLE	3	24.65578	5.02413	0.	HOLE	1	-9.42721	1.25603	0.
HOLE	3	26.10612	5.02413	0.	HOLE	1	-7.97687	1.25603	0.
COM=+3 row*					HOLE	1	-6.52653	1.25603	0.
HOLE	3	-26.83129	3.76809	0.	HOLE	1	-5.07619	1.25603	0.
HOLE	3	-25.38095	3.76809	0.	HOLE	1	-3.62585	1.25603	0.
HOLE	3	-23.93061	3.76809	0.	HOLE	1	-2.17551	1.25603	0.
HOLE	3	-22.48027	3.76809	0.	HOLE	1	-0.72517	1.25603	0.
HOLE	3	-21.02993	3.76809	0.	HOLE	1	0.72517	1.25603	0.
HOLE	3	-19.57959	3.76809	0.	HOLE	1	2.17551	1.25603	0.
HOLE	3	-18.12925	3.76809	0.	HOLE	1	3.62585	1.25603	0.
HOLE	3	-16.67891	3.76809	0.	HOLE	1	5.07619	1.25603	0.
HOLE	3	-15.22857	3.76809	0.	HOLE	1	6.52653	1.25603	0.
HOLE	3	-13.77823	3.76809	0.	HOLE	1	7.97687	1.25603	0.
HOLE	3	-12.32789	3.76809	0.	HOLE	3	9.42721	1.25603	0.
HOLE	3	-10.87755	3.76809	0.	HOLE	3	10.87755	1.25603	0.
HOLE	3	-9.42721	3.76809	0.	HOLE	3	12.32789	1.25603	0.
HOLE	1	-7.97687	3.76809	0.	HOLE	3	13.77823	1.25603	0.
HOLE	1	-6.52653	3.76809	0.	HOLE	3	15.22857	1.25603	0.
HOLE	1	-5.07619	3.76809	0.	HOLE	3	16.67891	1.25603	0.
HOLE	1	-3.62585	3.76809	0.	HOLE	3	18.12925	1.25603	0.
HOLE	1	-2.17551	3.76809	0.	HOLE	3	19.57959	1.25603	0.
HOLE	1	-0.72517	3.76809	0.	HOLE	3	21.02993	1.25603	0.
HOLE	1	0.72517	3.76809	0.	HOLE	3	22.48027	1.25603	0.
HOLE	1	2.17551	3.76809	0.	HOLE	3	23.93061	1.25603	0.
HOLE	1	3.62585	3.76809	0.	HOLE	3	25.38095	1.25603	0.
HOLE	1	5.07619	3.76809	0.	HOLE	3	26.83129	1.25603	0.
HOLE	1	6.52653	3.76809	0.	HOLE	3	28.28163	1.25603	0.
HOLE	3	7.97687	3.76809	0.	COM=*center (0) row*				
HOLE	3	9.42721	3.76809	0.	HOLE	3	-29.00680	0.	0.
HOLE	3	10.87755	3.76809	0.	HOLE	3	-27.55646	0.	0.
HOLE	3	12.32789	3.76809	0.	HOLE	3	-26.10612	0.	0.
HOLE	3	13.77823	3.76809	0.	HOLE	3	-24.65578	0.	0.
HOLE	3	15.22857	3.76809	0.	HOLE	3	-23.20544	0.	0.
HOLE	3	16.67891	3.76809	0.	HOLE	3	-21.75510	0.	0.
HOLE	3	18.12925	3.76809	0.	HOLE	3	-20.30476	0.	0.
HOLE	3	19.57959	3.76809	0.	HOLE	3	-18.85442	0.	0.
HOLE	3	21.02993	3.76809	0.	HOLE	3	-17.40408	0.	0.
HOLE	3	22.48027	3.76809	0.	HOLE	3	-15.95374	0.	0.
HOLE	3	23.93061	3.76809	0.	HOLE	3	-14.50340	0.	0.
HOLE	3	25.38095	3.76809	0.	HOLE	3	-13.05306	0.	0.
HOLE	3	26.83129	3.76809	0.	HOLE	3	-11.60272	0.	0.
COM=*+2 row*					HOLE	1	-10.15238	0.	0.
HOLE	3	-27.55646	2.51206	0.	HOLE	1	-8.70204	0.	0.
HOLE	3	-26.10612	2.51206	0.	HOLE	1	-7.25170	0.	0.
HOLE	3	-24.65578	2.51206	0.	HOLE	1	-5.80136	0.	0.
HOLE	3	-23.20544	2.51206	0.	HOLE	1	-4.35102	0.	0.
HOLE	3	-21.75510	2.51206	0.	HOLE	1	-2.90068	0.	0.
HOLE	3	-20.30476	2.51206	0.	HOLE	1	-1.45034	0.	0.
HOLE	3	-18.85442	2.51206	0.	HOLE	1	0.	0.	0.
HOLE	3	-17.40408	2.51206	0.	HOLE	1	1.45034	0.	0.
HOLE	3	-15.95374	2.51206	0.	HOLE	1	2.90068	0.	0.
HOLE	3	-14.50340	2.51206	0.	HOLE	1	4.35102	0.	0.
HOLE	3	-13.05306	2.51206	0.	HOLE	1	5.80136	0.	0.
HOLE	3	-11.60272	2.51206	0.	HOLE	1	7.25170	0.	0.
HOLE	3	-10.15238	2.51206	0.	HOLE	1	8.70204	0.	0.
HOLE	1	-8.70204	2.51206	0.	HOLE	3	10.15238	0.	0.
HOLE	1	-7.25170	2.51206	0.	HOLE	3	11.60272	0.	0.
HOLE	1	-5.80136	2.51206	0.	HOLE	3	13.05306	0.	0.
HOLE	1	-4.35102	2.51206	0.	HOLE	3	14.50340	0.	0.
HOLE	1	-2.90068	2.51206	0.	HOLE	3	15.95374	0.	0.
HOLE	1	-1.45034	2.51206	0.	HOLE	3	17.40408	0.	0.
HOLE	1	0.	2.51206	0.	HOLE	3	18.85442	0.	0.
HOLE	1	1.45034	2.51206	0.	HOLE	3	20.30476	0.	0.
HOLE	1	2.90068	2.51206	0.	HOLE	3	21.75510	0.	0.
HOLE	1	4.35102	2.51206	0.	HOLE	3	23.20544	0.	0.
HOLE	1	5.80136	2.51206	0.	HOLE	3	24.65578	0.	0.
HOLE	1	7.25170	2.51206	0.	HOLE	3	26.10612	0.	0.
HOLE	3	8.70204	2.51206	0.	HOLE	3	27.55646	0.	0.
HOLE	3	10.15238	2.51206	0.	HOLE	3	29.00680	0.	0.
HOLE	3	11.60272	2.51206	0.	COM=-1 row*				
HOLE	3	13.05306	2.51206	0.	HOLE	3	-28.28163	-1.25603	0.
HOLE	3	14.50340	2.51206	0.	HOLE	3	-26.83129	-1.25603	0.
HOLE	3	15.95374	2.51206	0.	HOLE	3	-25.38095	-1.25603	0.

HOLE	3	-23.93061	-1.25603	0.	HOLE	1	-2.17551	-3.76809	0.
HOLE	3	-22.48027	-1.25603	0.	HOLE	1	-0.72517	-3.76809	0.
HOLE	3	-21.02993	-1.25603	0.	HOLE	1	0.72517	-3.76809	0.
HOLE	3	-19.57959	-1.25603	0.	HOLE	1	2.17551	-3.76809	0.
HOLE	3	-18.12925	-1.25603	0.	HOLE	1	3.62585	-3.76809	0.
HOLE	3	-16.67891	-1.25603	0.	HOLE	1	5.07619	-3.76809	0.
HOLE	3	-15.22857	-1.25603	0.	HOLE	1	6.52653	-3.76809	0.
HOLE	3	-13.77823	-1.25603	0.	HOLE	3	7.97687	-3.76809	0.
HOLE	3	-12.32789	-1.25603	0.	HOLE	3	9.42721	-3.76809	0.
HOLE	3	-10.87755	-1.25603	0.	HOLE	3	10.87755	-3.76809	0.
HOLE	1	-9.42721	-1.25603	0.	HOLE	3	12.32789	-3.76809	0.
HOLE	1	-7.97687	-1.25603	0.	HOLE	3	13.77823	-3.76809	0.
HOLE	1	-6.52653	-1.25603	0.	HOLE	3	15.22857	-3.76809	0.
HOLE	1	-5.07619	-1.25603	0.	HOLE	3	16.67891	-3.76809	0.
HOLE	1	-3.62585	-1.25603	0.	HOLE	3	18.12925	-3.76809	0.
HOLE	1	-2.17551	-1.25603	0.	HOLE	3	19.57959	-3.76809	0.
HOLE	1	-0.72517	-1.25603	0.	HOLE	3	21.02993	-3.76809	0.
HOLE	1	0.72517	-1.25603	0.	HOLE	3	22.48027	-3.76809	0.
HOLE	1	2.17551	-1.25603	0.	HOLE	3	23.93061	-3.76809	0.
HOLE	1	3.62585	-1.25603	0.	HOLE	3	25.38095	-3.76809	0.
HOLE	1	5.07619	-1.25603	0.	HOLE	3	26.83129	-3.76809	0.
HOLE	1	6.52653	-1.25603	0.	COM=-4 row*				
HOLE	1	7.97687	-1.25603	0.	HOLE	3	-26.10612	-5.02413	0.
HOLE	3	9.42721	-1.25603	0.	HOLE	3	-24.65578	-5.02413	0.
HOLE	3	10.87755	-1.25603	0.	HOLE	3	-23.20544	-5.02413	0.
HOLE	3	12.32789	-1.25603	0.	HOLE	3	-21.75510	-5.02413	0.
HOLE	3	13.77823	-1.25603	0.	HOLE	3	-20.30476	-5.02413	0.
HOLE	3	15.22857	-1.25603	0.	HOLE	3	-18.85442	-5.02413	0.
HOLE	3	16.67891	-1.25603	0.	HOLE	3	-17.40408	-5.02413	0.
HOLE	3	18.12925	-1.25603	0.	HOLE	3	-15.95374	-5.02413	0.
HOLE	3	19.57959	-1.25603	0.	HOLE	3	-14.50340	-5.02413	0.
HOLE	3	21.02993	-1.25603	0.	HOLE	3	-13.05306	-5.02413	0.
HOLE	3	22.48027	-1.25603	0.	HOLE	3	-11.60272	-5.02413	0.
HOLE	3	23.93061	-1.25603	0.	HOLE	3	-10.15238	-5.02413	0.
HOLE	3	25.38095	-1.25603	0.	HOLE	3	-8.70204	-5.02413	0.
HOLE	3	26.83129	-1.25603	0.	HOLE	3	-7.25170	-5.02413	0.
HOLE	3	28.28163	-1.25603	0.	HOLE	1	-5.80136	-5.02413	0.
COM=-2 row*					HOLE	1	-4.35102	-5.02413	0.
HOLE	3	-27.55646	-2.51206	0.	HOLE	1	-2.90068	-5.02413	0.
HOLE	3	-26.10612	-2.51206	0.	HOLE	1	-1.45034	-5.02413	0.
HOLE	3	-24.65578	-2.51206	0.	HOLE	1	0.	-5.02413	0.
HOLE	3	-23.20544	-2.51206	0.	HOLE	1	1.45034	-5.02413	0.
HOLE	3	-21.75510	-2.51206	0.	HOLE	1	2.90068	-5.02413	0.
HOLE	3	-20.30476	-2.51206	0.	HOLE	1	4.35102	-5.02413	0.
HOLE	3	-18.85442	-2.51206	0.	HOLE	1	5.80136	-5.02413	0.
HOLE	3	-17.40408	-2.51206	0.	HOLE	1	7.25170	-5.02413	0.
HOLE	3	-15.95374	-2.51206	0.	HOLE	3	8.70204	-5.02413	0.
HOLE	3	-14.50340	-2.51206	0.	HOLE	3	10.15238	-5.02413	0.
HOLE	3	-13.05306	-2.51206	0.	HOLE	3	11.60272	-5.02413	0.
HOLE	3	-11.60272	-2.51206	0.	HOLE	3	13.05306	-5.02413	0.
HOLE	3	-10.15238	-2.51206	0.	HOLE	3	14.50340	-5.02413	0.
HOLE	1	-8.70204	-2.51206	0.	HOLE	3	15.95374	-5.02413	0.
HOLE	1	-7.25170	-2.51206	0.	HOLE	3	17.40408	-5.02413	0.
HOLE	1	-5.80136	-2.51206	0.	HOLE	3	18.85442	-5.02413	0.
HOLE	1	-4.35102	-2.51206	0.	HOLE	3	20.30476	-5.02413	0.
HOLE	1	-2.90068	-2.51206	0.	HOLE	3	21.75510	-5.02413	0.
HOLE	1	-1.45034	-2.51206	0.	HOLE	3	23.20544	-5.02413	0.
HOLE	1	0.	-2.51206	0.	HOLE	3	24.65578	-5.02413	0.
HOLE	1	1.45034	-2.51206	0.	HOLE	3	26.10612	-5.02413	0.
HOLE	1	2.90068	-2.51206	0.	COM=-5 row*				
HOLE	1	4.35102	-2.51206	0.	HOLE	3	-25.38095	-6.28016	0.
HOLE	1	5.80136	-2.51206	0.	HOLE	3	-23.93061	-6.28016	0.
HOLE	1	7.25170	-2.51206	0.	HOLE	3	-22.48027	-6.28016	0.
HOLE	3	8.70204	-2.51206	0.	HOLE	3	-21.02993	-6.28016	0.
HOLE	3	10.15238	-2.51206	0.	HOLE	3	-19.57959	-6.28016	0.
HOLE	3	11.60272	-2.51206	0.	HOLE	3	-18.12925	-6.28016	0.
HOLE	3	13.05306	-2.51206	0.	HOLE	3	-16.67891	-6.28016	0.
HOLE	3	14.50340	-2.51206	0.	HOLE	3	-15.22857	-6.28016	0.
HOLE	3	15.95374	-2.51206	0.	HOLE	3	-13.77823	-6.28016	0.
HOLE	3	17.40408	-2.51206	0.	HOLE	3	-12.32789	-6.28016	0.
HOLE	3	18.85442	-2.51206	0.	HOLE	3	-10.87755	-6.28016	0.
HOLE	3	20.30476	-2.51206	0.	HOLE	3	-9.42721	-6.28016	0.
HOLE	3	21.75510	-2.51206	0.	HOLE	3	-7.97687	-6.28016	0.
HOLE	3	23.20544	-2.51206	0.	HOLE	3	-6.52653	-6.28016	0.
HOLE	3	24.65578	-2.51206	0.	HOLE	1	-5.07619	-6.28016	0.
HOLE	3	26.10612	-2.51206	0.	HOLE	1	-3.62585	-6.28016	0.
HOLE	3	27.55646	-2.51206	0.	HOLE	1	-2.17551	-6.28016	0.
COM=-3 row*					HOLE	1	-0.72517	-6.28016	0.
HOLE	3	-26.83129	-3.76809	0.	HOLE	1	0.72517	-6.28016	0.
HOLE	3	-25.38095	-3.76809	0.	HOLE	1	2.17551	-6.28016	0.
HOLE	3	-23.93061	-3.76809	0.	HOLE	1	3.62585	-6.28016	0.
HOLE	3	-22.48027	-3.76809	0.	HOLE	1	5.07619	-6.28016	0.
HOLE	3	-21.02993	-3.76809	0.	HOLE	1	6.52653	-6.28016	0.
HOLE	3	-19.57959	-3.76809	0.	HOLE	3	7.97687	-6.28016	0.
HOLE	3	-18.12925	-3.76809	0.	HOLE	3	9.42721	-6.28016	0.
HOLE	3	-16.67891	-3.76809	0.	HOLE	3	10.87755	-6.28016	0.
HOLE	3	-15.22857	-3.76809	0.	HOLE	3	12.32789	-6.28016	0.
HOLE	3	-13.77823	-3.76809	0.	HOLE	3	13.77823	-6.28016	0.
HOLE	3	-12.32789	-3.76809	0.	HOLE	3	15.22857	-6.28016	0.
HOLE	3	-10.87755	-3.76809	0.	HOLE	3	16.67891	-6.28016	0.
HOLE	3	-9.42721	-3.76809	0.	HOLE	3	18.12925	-6.28016	0.
HOLE	1	-7.97687	-3.76809	0.	HOLE	3	19.57959	-6.28016	0.
HOLE	1	-6.52653	-3.76809	0.	HOLE	3	21.02993	-6.28016	0.
HOLE	1	-5.07619	-3.76809	0.	HOLE	3	22.48027	-6.28016	0.
HOLE	1	-3.62585	-3.76809	0.	HOLE	3	23.93061	-6.28016	0.

HOLE	3	25.38095	-6.28016	0.	HOLE	3	8.70204	-10.04825	0.
COM=-6 row*					HOLE	3	10.15238	-10.04825	0.
HOLE	3	-24.65578	-7.53619	0.	HOLE	3	11.60272	-10.04825	0.
HOLE	3	-23.20544	-7.53619	0.	HOLE	3	13.05306	-10.04825	0.
HOLE	3	-21.75510	-7.53619	0.	HOLE	3	14.50340	-10.04825	0.
HOLE	3	-20.30476	-7.53619	0.	HOLE	3	15.95374	-10.04825	0.
HOLE	3	-18.85442	-7.53619	0.	HOLE	3	17.40408	-10.04825	0.
HOLE	3	-17.40408	-7.53619	0.	HOLE	3	18.85442	-10.04825	0.
HOLE	3	-15.95374	-7.53619	0.	HOLE	3	20.30476	-10.04825	0.
HOLE	3	-14.50340	-7.53619	0.	HOLE	3	21.75510	-10.04825	0.
HOLE	3	-13.05306	-7.53619	0.	HOLE	3	23.20544	-10.04825	0.
HOLE	3	-11.60272	-7.53619	0.	COM=-9 row*				
HOLE	3	-10.15238	-7.53619	0.	HOLE	3	-22.48027	-11.30428	0.
HOLE	3	-8.70204	-7.53619	0.	HOLE	3	-21.02993	-11.30428	0.
HOLE	3	-7.25170	-7.53619	0.	HOLE	3	-19.57959	-11.30428	0.
HOLE	3	-5.80136	-7.53619	0.	HOLE	3	-18.12925	-11.30428	0.
HOLE	1	-4.35102	-7.53619	0.	HOLE	3	-16.67891	-11.30428	0.
HOLE	1	-2.90068	-7.53619	0.	HOLE	3	-15.22857	-11.30428	0.
HOLE	1	-1.45034	-7.53619	0.	HOLE	3	-13.77823	-11.30428	0.
HOLE	1	0.	-7.53619	0.	HOLE	3	-12.32789	-11.30428	0.
HOLE	1	1.45034	-7.53619	0.	HOLE	3	-10.87755	-11.30428	0.
HOLE	1	2.90068	-7.53619	0.	HOLE	3	-9.42721	-11.30428	0.
HOLE	1	4.35102	-7.53619	0.	HOLE	3	-7.97687	-11.30428	0.
HOLE	1	5.80136	-7.53619	0.	HOLE	3	-6.52653	-11.30428	0.
HOLE	3	7.25170	-7.53619	0.	HOLE	3	-5.07619	-11.30428	0.
HOLE	3	8.70204	-7.53619	0.	HOLE	3	-3.62585	-11.30428	0.
HOLE	3	10.15238	-7.53619	0.	HOLE	3	-2.17551	-11.30428	0.
HOLE	3	11.60272	-7.53619	0.	HOLE	3	-0.72517	-11.30428	0.
HOLE	3	13.05306	-7.53619	0.	HOLE	3	0.72517	-11.30428	0.
HOLE	3	14.50340	-7.53619	0.	HOLE	3	2.17551	-11.30428	0.
HOLE	3	15.95374	-7.53619	0.	HOLE	3	3.62585	-11.30428	0.
HOLE	3	17.40408	-7.53619	0.	HOLE	3	5.07619	-11.30428	0.
HOLE	3	18.85442	-7.53619	0.	HOLE	3	6.52653	-11.30428	0.
HOLE	3	20.30476	-7.53619	0.	HOLE	3	7.97687	-11.30428	0.
HOLE	3	21.75510	-7.53619	0.	HOLE	3	9.42721	-11.30428	0.
HOLE	3	23.20544	-7.53619	0.	HOLE	3	10.87755	-11.30428	0.
HOLE	3	24.65578	-7.53619	0.	HOLE	3	12.32789	-11.30428	0.
COM=-7 row*					HOLE	3	13.77823	-11.30428	0.
HOLE	3	-23.93061	-8.79222	0.	HOLE	3	15.22857	-11.30428	0.
HOLE	3	-22.48027	-8.79222	0.	HOLE	3	16.67891	-11.30428	0.
HOLE	3	-21.02993	-8.79222	0.	HOLE	3	18.12925	-11.30428	0.
HOLE	3	-19.57959	-8.79222	0.	HOLE	3	19.57959	-11.30428	0.
HOLE	3	-18.12925	-8.79222	0.	HOLE	3	21.02993	-11.30428	0.
HOLE	3	-16.67891	-8.79222	0.	HOLE	3	22.48027	-11.30428	0.
HOLE	3	-15.22857	-8.79222	0.	COM=-10 row*				
HOLE	3	-13.77823	-8.79222	0.	HOLE	3	-21.75510	-12.56031	0.
HOLE	3	-12.32789	-8.79222	0.	HOLE	3	-20.30476	-12.56031	0.
HOLE	3	-10.87755	-8.79222	0.	HOLE	3	-18.85442	-12.56031	0.
HOLE	3	-9.42721	-8.79222	0.	HOLE	3	-17.40408	-12.56031	0.
HOLE	3	-7.97687	-8.79222	0.	HOLE	3	-15.95374	-12.56031	0.
HOLE	3	-6.52653	-8.79222	0.	HOLE	3	-14.50340	-12.56031	0.
HOLE	3	-5.07619	-8.79222	0.	HOLE	3	-13.05306	-12.56031	0.
HOLE	3	-3.62585	-8.79222	0.	HOLE	3	-11.60272	-12.56031	0.
HOLE	3	-2.17551	-8.79222	0.	HOLE	3	-10.15238	-12.56031	0.
HOLE	3	-0.72517	-8.79222	0.	HOLE	3	-8.70204	-12.56031	0.
HOLE	1	0.72517	-8.79222	0.	HOLE	3	-7.25170	-12.56031	0.
HOLE	1	2.17551	-8.79222	0.	HOLE	3	-5.80136	-12.56031	0.
HOLE	1	3.62585	-8.79222	0.	HOLE	3	-4.35102	-12.56031	0.
HOLE	1	5.07619	-8.79222	0.	HOLE	3	-2.90068	-12.56031	0.
HOLE	3	6.52653	-8.79222	0.	HOLE	3	-1.45034	-12.56031	0.
HOLE	3	7.97687	-8.79222	0.	HOLE	3	0.	-12.56031	0.
HOLE	3	9.42721	-8.79222	0.	HOLE	3	1.45034	-12.56031	0.
HOLE	3	10.87755	-8.79222	0.	HOLE	3	2.90068	-12.56031	0.
HOLE	3	12.32789	-8.79222	0.	HOLE	3	4.35102	-12.56031	0.
HOLE	3	13.77823	-8.79222	0.	HOLE	3	5.80136	-12.56031	0.
HOLE	3	15.22857	-8.79222	0.	HOLE	3	7.25170	-12.56031	0.
HOLE	3	16.67891	-8.79222	0.	HOLE	3	8.70204	-12.56031	0.
HOLE	3	18.12925	-8.79222	0.	HOLE	3	10.15238	-12.56031	0.
HOLE	3	19.57959	-8.79222	0.	HOLE	3	11.60272	-12.56031	0.
HOLE	3	21.02993	-8.79222	0.	HOLE	3	13.05306	-12.56031	0.
HOLE	3	22.48027	-8.79222	0.	HOLE	3	14.50340	-12.56031	0.
HOLE	3	23.93061	-8.79222	0.	HOLE	3	15.95374	-12.56031	0.
COM=-8 row*					HOLE	3	17.40408	-12.56031	0.
HOLE	3	-23.20544	-10.04825	0.	HOLE	3	18.85442	-12.56031	0.
HOLE	3	-21.75510	-10.04825	0.	HOLE	3	20.30476	-12.56031	0.
HOLE	3	-20.30476	-10.04825	0.	HOLE	3	21.75510	-12.56031	0.
HOLE	3	-18.85442	-10.04825	0.	COM=-11 row*				
HOLE	3	-17.40408	-10.04825	0.	HOLE	3	-21.02993	-13.81634	0.
HOLE	3	-15.95374	-10.04825	0.	HOLE	3	-19.57959	-13.81634	0.
HOLE	3	-14.50340	-10.04825	0.	HOLE	3	-18.12925	-13.81634	0.
HOLE	3	-13.05306	-10.04825	0.	HOLE	3	-16.67891	-13.81634	0.
HOLE	3	-11.60272	-10.04825	0.	HOLE	3	-15.22857	-13.81634	0.
HOLE	3	-10.15238	-10.04825	0.	HOLE	3	-13.77823	-13.81634	0.
HOLE	3	-8.70204	-10.04825	0.	HOLE	3	-12.32789	-13.81634	0.
HOLE	3	-7.25170	-10.04825	0.	HOLE	3	-10.87755	-13.81634	0.
HOLE	3	-5.80136	-10.04825	0.	HOLE	3	-9.42721	-13.81634	0.
HOLE	3	-4.35102	-10.04825	0.	HOLE	3	-7.97687	-13.81634	0.
HOLE	3	-2.90068	-10.04825	0.	HOLE	3	-6.52653	-13.81634	0.
HOLE	3	-1.45034	-10.04825	0.	HOLE	3	-5.07619	-13.81634	0.
HOLE	3	0.	-10.04825	0.	HOLE	3	-3.62585	-13.81634	0.
HOLE	3	1.45034	-10.04825	0.	HOLE	3	-2.17551	-13.81634	0.
HOLE	3	2.90068	-10.04825	0.	HOLE	3	-0.72517	-13.81634	0.
HOLE	3	4.35102	-10.04825	0.	HOLE	3	0.72517	-13.81634	0.
HOLE	3	5.80136	-10.04825	0.	HOLE	3	2.17551	-13.81634	0.
HOLE	3	7.25170	-10.04825	0.	HOLE	3	3.62585	-13.81634	0.

Appendix E Benchmark Model Inputs

HOLE	3	5.07619	-13.81634	0.	HOLE	3	14.50340	-17.58444	0.
HOLE	3	6.52653	-13.81634	0.	HOLE	3	15.95374	-17.58444	0.
HOLE	3	7.97687	-13.81634	0.	HOLE	3	17.40408	-17.58444	0.
HOLE	3	9.42721	-13.81634	0.	HOLE	3	18.85442	-17.58444	0.
HOLE	3	10.87755	-13.81634	0.	COM=-15 row*				
HOLE	3	12.32789	-13.81634	0.	HOLE	3	-18.12925	-18.84047	0.
HOLE	3	13.77823	-13.81634	0.	HOLE	3	-16.67891	-18.84047	0.
HOLE	3	15.22857	-13.81634	0.	HOLE	3	-15.22857	-18.84047	0.
HOLE	3	16.67891	-13.81634	0.	HOLE	3	-13.77823	-18.84047	0.
HOLE	3	18.12925	-13.81634	0.	HOLE	3	-12.32789	-18.84047	0.
HOLE	3	19.57959	-13.81634	0.	HOLE	3	-10.87755	-18.84047	0.
HOLE	3	21.02993	-13.81634	0.	HOLE	3	-9.42721	-18.84047	0.
COM=-12 row*					HOLE	3	-7.97687	-18.84047	0.
HOLE	3	-20.30476	-15.07238	0.	HOLE	3	-6.52653	-18.84047	0.
HOLE	3	-18.85442	-15.07238	0.	HOLE	3	-5.07619	-18.84047	0.
HOLE	3	-17.40408	-15.07238	0.	HOLE	3	-3.62585	-18.84047	0.
HOLE	3	-15.95374	-15.07238	0.	HOLE	3	-2.17551	-18.84047	0.
HOLE	3	-14.50340	-15.07238	0.	HOLE	3	-0.72517	-18.84047	0.
HOLE	3	-13.05306	-15.07238	0.	HOLE	3	0.72517	-18.84047	0.
HOLE	3	-11.60272	-15.07238	0.	HOLE	3	2.17551	-18.84047	0.
HOLE	3	-10.15238	-15.07238	0.	HOLE	3	3.62585	-18.84047	0.
HOLE	3	-8.70204	-15.07238	0.	HOLE	3	5.07619	-18.84047	0.
HOLE	3	-7.25170	-15.07238	0.	HOLE	3	6.52653	-18.84047	0.
HOLE	3	-5.80136	-15.07238	0.	HOLE	3	7.97687	-18.84047	0.
HOLE	3	-4.35102	-15.07238	0.	HOLE	3	9.42721	-18.84047	0.
HOLE	3	-2.90068	-15.07238	0.	HOLE	3	10.87755	-18.84047	0.
HOLE	3	-1.45034	-15.07238	0.	HOLE	3	12.32789	-18.84047	0.
HOLE	3	0.	-15.07238	0.	HOLE	3	13.77823	-18.84047	0.
HOLE	3	1.45034	-15.07238	0.	HOLE	3	15.22857	-18.84047	0.
HOLE	3	2.90068	-15.07238	0.	HOLE	3	16.67891	-18.84047	0.
HOLE	3	4.35102	-15.07238	0.	HOLE	3	18.12925	-18.84047	0.
HOLE	3	5.80136	-15.07238	0.	COM=-16 row*				
HOLE	3	7.25170	-15.07238	0.	HOLE	3	-17.40408	-20.09650	0.
HOLE	3	8.70204	-15.07238	0.	HOLE	3	-15.95374	-20.09650	0.
HOLE	3	10.15238	-15.07238	0.	HOLE	3	-14.50340	-20.09650	0.
HOLE	3	11.60272	-15.07238	0.	HOLE	3	-13.05306	-20.09650	0.
HOLE	3	13.05306	-15.07238	0.	HOLE	3	-11.60272	-20.09650	0.
HOLE	3	14.50340	-15.07238	0.	HOLE	3	-10.15238	-20.09650	0.
HOLE	3	15.95374	-15.07238	0.	HOLE	3	-8.70204	-20.09650	0.
HOLE	3	17.40408	-15.07238	0.	HOLE	3	-7.25170	-20.09650	0.
HOLE	3	18.85442	-15.07238	0.	HOLE	3	-5.80136	-20.09650	0.
HOLE	3	20.30476	-15.07238	0.	HOLE	3	-4.35102	-20.09650	0.
COM=-13 row*					HOLE	3	-2.90068	-20.09650	0.
HOLE	3	-19.57959	-16.32841	0.	HOLE	3	-1.45034	-20.09650	0.
HOLE	3	-18.12925	-16.32841	0.	HOLE	3	0.	-20.09650	0.
HOLE	3	-16.67891	-16.32841	0.	HOLE	3	1.45034	-20.09650	0.
HOLE	3	-15.22857	-16.32841	0.	HOLE	3	2.90068	-20.09650	0.
HOLE	3	-13.77823	-16.32841	0.	HOLE	3	4.35102	-20.09650	0.
HOLE	3	-12.32789	-16.32841	0.	HOLE	3	5.80136	-20.09650	0.
HOLE	3	-10.87755	-16.32841	0.	HOLE	3	7.25170	-20.09650	0.
HOLE	3	-9.42721	-16.32841	0.	HOLE	3	8.70204	-20.09650	0.
HOLE	3	-7.97687	-16.32841	0.	HOLE	3	10.15238	-20.09650	0.
HOLE	3	-6.52653	-16.32841	0.	HOLE	3	11.60272	-20.09650	0.
HOLE	3	-5.07619	-16.32841	0.	HOLE	3	13.05306	-20.09650	0.
HOLE	3	-3.62585	-16.32841	0.	HOLE	3	14.50340	-20.09650	0.
HOLE	3	-2.17551	-16.32841	0.	HOLE	3	15.95374	-20.09650	0.
HOLE	3	-0.72517	-16.32841	0.	HOLE	3	17.40408	-20.09650	0.
HOLE	3	0.72517	-16.32841	0.	COM=-17 row*				
HOLE	3	2.17551	-16.32841	0.	HOLE	3	-16.67891	-21.35253	0.
HOLE	3	3.62585	-16.32841	0.	HOLE	3	-15.22857	-21.35253	0.
HOLE	3	5.07619	-16.32841	0.	HOLE	3	-13.77823	-21.35253	0.
HOLE	3	6.52653	-16.32841	0.	HOLE	3	-12.32789	-21.35253	0.
HOLE	3	7.97687	-16.32841	0.	HOLE	3	-10.87755	-21.35253	0.
HOLE	3	9.42721	-16.32841	0.	HOLE	3	-9.42721	-21.35253	0.
HOLE	3	10.87755	-16.32841	0.	HOLE	3	-7.97687	-21.35253	0.
HOLE	3	12.32789	-16.32841	0.	HOLE	3	-6.52653	-21.35253	0.
HOLE	3	13.77823	-16.32841	0.	HOLE	3	-5.07619	-21.35253	0.
HOLE	3	15.22857	-16.32841	0.	HOLE	3	-3.62585	-21.35253	0.
HOLE	3	16.67891	-16.32841	0.	HOLE	3	-2.17551	-21.35253	0.
HOLE	3	18.12925	-16.32841	0.	HOLE	3	-0.72517	-21.35253	0.
HOLE	3	19.57959	-16.32841	0.	HOLE	3	0.72517	-21.35253	0.
COM=-14 row*					HOLE	3	2.17551	-21.35253	0.
HOLE	3	-18.85442	-17.58444	0.	HOLE	3	3.62585	-21.35253	0.
HOLE	3	-17.40408	-17.58444	0.	HOLE	3	5.07619	-21.35253	0.
HOLE	3	-15.95374	-17.58444	0.	HOLE	3	6.52653	-21.35253	0.
HOLE	3	-14.50340	-17.58444	0.	HOLE	3	7.97687	-21.35253	0.
HOLE	3	-13.05306	-17.58444	0.	HOLE	3	9.42721	-21.35253	0.
HOLE	3	-11.60272	-17.58444	0.	HOLE	3	10.87755	-21.35253	0.
HOLE	3	-10.15238	-17.58444	0.	HOLE	3	12.32789	-21.35253	0.
HOLE	3	-8.70204	-17.58444	0.	HOLE	3	13.77823	-21.35253	0.
HOLE	3	-7.25170	-17.58444	0.	HOLE	3	15.22857	-21.35253	0.
HOLE	3	-5.80136	-17.58444	0.	HOLE	3	16.67891	-21.35253	0.
HOLE	3	-4.35102	-17.58444	0.	COM=-18 row*				
HOLE	3	-2.90068	-17.58444	0.	HOLE	3	-15.95374	-22.60856	0.
HOLE	3	-1.45034	-17.58444	0.	HOLE	3	-14.50340	-22.60856	0.
HOLE	3	0.	-17.58444	0.	HOLE	3	-13.05306	-22.60856	0.
HOLE	3	1.45034	-17.58444	0.	HOLE	3	-11.60272	-22.60856	0.
HOLE	3	2.90068	-17.58444	0.	HOLE	3	-10.15238	-22.60856	0.
HOLE	3	4.35102	-17.58444	0.	HOLE	3	-8.70204	-22.60856	0.
HOLE	3	5.80136	-17.58444	0.	HOLE	3	-7.25170	-22.60856	0.
HOLE	3	7.25170	-17.58444	0.	HOLE	3	-5.80136	-22.60856	0.
HOLE	3	8.70204	-17.58444	0.	HOLE	3	-4.35102	-22.60856	0.
HOLE	3	10.15238	-17.58444	0.	HOLE	3	-2.90068	-22.60856	0.
HOLE	3	11.60272	-17.58444	0.	HOLE	3	-1.45034	-22.60856	0.
HOLE	3	13.05306	-17.58444	0.	HOLE	3	0.	-22.60856	0.

HOLE	3	1.45034	-22.60856	0.	HOLE	3	-11.60272	-25.12063	0.
HOLE	3	2.90068	-22.60856	0.	HOLE	3	-10.15238	-25.12063	0.
HOLE	3	4.35102	-22.60856	0.	HOLE	3	-8.70204	-25.12063	0.
HOLE	3	5.80136	-22.60856	0.	HOLE	3	-7.25170	-25.12063	0.
HOLE	3	7.25170	-22.60856	0.	HOLE	3	-5.80136	-25.12063	0.
HOLE	3	8.70204	-22.60856	0.	HOLE	3	-4.35102	-25.12063	0.
HOLE	3	10.15238	-22.60856	0.	HOLE	3	-2.90068	-25.12063	0.
HOLE	3	11.60272	-22.60856	0.	HOLE	3	-1.45034	-25.12063	0.
HOLE	3	13.05306	-22.60856	0.	HOLE	3	0.	-25.12063	0.
HOLE	3	14.50340	-22.60856	0.	HOLE	3	1.45034	-25.12063	0.
HOLE	3	15.95374	-22.60856	0.	HOLE	3	2.90068	-25.12063	0.
COM=-19 row*					HOLE	3	4.35102	-25.12063	0.
HOLE	3	-15.22857	-23.86459	0.	HOLE	3	5.80136	-25.12063	0.
HOLE	3	-13.77823	-23.86459	0.	HOLE	3	7.25170	-25.12063	0.
HOLE	3	-12.32789	-23.86459	0.	HOLE	3	8.70204	-25.12063	0.
HOLE	3	-10.87755	-23.86459	0.	HOLE	3	10.15238	-25.12063	0.
HOLE	3	-9.42721	-23.86459	0.	HOLE	3	11.60272	-25.12063	0.
HOLE	3	-7.97687	-23.86459	0.	HOLE	3	13.05306	-25.12063	0.
HOLE	3	-6.52653	-23.86459	0.	HOLE	3	14.50340	-25.12063	0.
HOLE	3	-5.07619	-23.86459	0.	CUBOID	4 1 4P29.8	2P49.5301		
HOLE	3	-3.62585	-23.86459	0.	GLOBAL				
HOLE	3	-2.17551	-23.86459	0.	UNIT 6				
HOLE	3	-0.72517	-23.86459	0.	ARRAY	1 2R-29.8	-49.5301		
HOLE	3	0.72517	-23.86459	0.	REFLECTOR	4 2 4*3.1	2*0	10	
HOLE	3	2.17551	-23.86459	0.	END GEOM				
HOLE	3	3.62585	-23.86459	0.	READ ARRAY				
HOLE	3	5.07619	-23.86459	0.	NUX=1 NUY=1 NUZ=1 FILL F5 END FILL				
HOLE	3	6.52653	-23.86459	0.	END ARRAY				
HOLE	3	7.97687	-23.86459	0.	READ BIAS				
HOLE	3	9.42721	-23.86459	0.	ID=500 2 11				
HOLE	3	10.87755	-23.86459	0.	END BIAS				
HOLE	3	12.32789	-23.86459	0.	READ START				
HOLE	3	13.77823	-23.86459	0.	NST=1 XSM=-30 YSM=-26 ZSM=-19.05				
HOLE	3	15.22857	-23.86459	0.	XSP=30 YSP=26 ZSP=19.05				
COM=-20 row*					END START				
HOLE	3	-14.50340	-25.12063	0.	END DATA				
HOLE	3	-13.05306	-25.12063	0.	END				

E.2.8 Core SB-7, 218 Group ENDF/B-IV

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=CSAS25 PARM=SIZE=200000
full LWBR SB-7 fuel rods, control blades, and 1ft water
reflector
218GROUPNDF4 LATTICECELL
' mix 1 = 233UO2-ZrO2 Seed
O 1 0 5.4281-2 END
ZR 1 0 2.3194-2 END
U-233 1 0 3.8411-3 END
U-234 1 0 6.1327-5 END
U-235 1 0 1.3048-7 END
U-236 1 0 1.2993-7 END
U-238 1 0 4.4061-5 END
' mix 2 = 233UO2-ThO2 blanket
O-16 2 0 4.3081-2 END
TH-232 2 0 2.1311-2 END
U-233 2 0 2.2274-4 END
U-234 2 0 3.5598-6 END
U-235 2 0 2.2722-8 END
U-236 2 0 2.2626-8 END
U-238 2 0 2.7595-6 END
GD 2 0 1.5967-7 END
' mix 3 = zirc-2 cladding etc, 6.56 g/cc, Ntot=4.3234-2
ZR 3 0 4.2537-2 END
CR 3 0 7.5977-5 END
FE 3 0 8.8422-5 END
NI 3 0 3.3656-5 END
SN 3 0 4.9918-4 END
' mix 4 = water, 0.9982 g/cc, Ntot=1.0010-1
H 4 0 6.6735-2 END
O 4 0 3.3368-2 END
' mix 5 = borated SS304 control blades, 7.92g/cc,
Ntot=8.9912-2
FE 5 0 5.9289-2 END
B-10 5 0 3.7488-3 END
C 5 0 1.5884-4 END
CR 5 0 1.7428-2 END
MN 5 0 8.6816-4 END
NI 5 0 7.5171-3 END
P 5 0 3.0797-5 END
S 5 0 2.2308-5 END
SI 5 0 8.4910-4 END
END COMP
TRIANGPITCH 0.91948 0.53594 1 4 0.64770 3 0.55880 0
END
MORE DATA RES=2 CYLINDER 0.62230
DAN(2)=0.699627 END
KENOV.A
READ PARAM
GEN=500 NPG=3000 NSK=50 TME=4000
FLX=YES FDN=YES FMP=YES NUB=YES RUN=YES
END PARAM
READ GEOM
UNIT 1
COM=*Seed rod in water*
CYLINDER 1 1 0.26797 2P19.05
CYLINDER 0 1 0.27940 2P19.05
CYLINDER 3 1 0.32385 2P26.4541
UNIT 3
COM=*blanket rod in water*
CYLINDER 2 1 0.62230 2P19.05
CYLINDER 0 1 0.63246 2P19.05
CYLINDER 3 1 0.72263 2P26.4541
UNIT 4
COM=*control blade in water*
CUBOID 5 1 2P3.81 2P0.0889 49.53
17.09
CUBOID 4 1 2P3.81 2P0.0889 2P49.53
UNIT 5
COM=*rod array with blades*
CYLINDER 4 1 29.8 2P49.5301
COM=*control blades*
HOLE 4 0. 5.51688 0.
HOLE 4 0. 1.83896 0.
HOLE 4 0. -1.83896 0.
HOLE 4 0. -5.51688 0.
COM=*+20 row*
HOLE 3 -14.50340 25.12063 0.
HOLE 3 -13.05306 25.12063 0.
HOLE 3 -11.60272 25.12063 0.
HOLE 3 -10.15238 25.12063 0.
HOLE 3 -8.70204 25.12063 0.
HOLE 3 -7.25170 25.12063 0.
HOLE 3 -5.80136 25.12063 0.
HOLE 3 -4.35102 25.12063 0.
HOLE 3 -2.90068 25.12063 0.
HOLE 3 -1.45034 25.12063 0.
HOLE 3 0. 25.12063 0.
HOLE 3 1.45034 25.12063 0.
HOLE 3 2.90068 25.12063 0.
HOLE 3 4.35102 25.12063 0.
HOLE 3 5.80136 25.12063 0.
HOLE 3 7.25170 25.12063 0.
HOLE 3 8.70204 25.12063 0.
HOLE 3 10.15238 25.12063 0.
HOLE 3 11.60272 25.12063 0.
HOLE 3 13.05306 25.12063 0.
HOLE 3 14.50340 25.12063 0.
COM=*+19 row*
HOLE 3 -15.22857 23.86459 0.
HOLE 3 -13.77823 23.86459 0.
HOLE 3 -12.32789 23.86459 0.
HOLE 3 -10.87755 23.86459 0.
HOLE 3 -9.42721 23.86459 0.
HOLE 3 -7.97687 23.86459 0.
HOLE 3 -6.52653 23.86459 0.
HOLE 3 -5.07619 23.86459 0.
HOLE 3 -3.62585 23.86459 0.
HOLE 3 -2.17551 23.86459 0.

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Appendix E Benchmark Model Inputs

HOLE	3	-0.72517	23.86459	0.	HOLE	3	-7.97687	18.84047	0.
HOLE	3	0.72517	23.86459	0.	HOLE	3	-6.52653	18.84047	0.
HOLE	3	2.17551	23.86459	0.	HOLE	3	-5.07619	18.84047	0.
HOLE	3	3.62585	23.86459	0.	HOLE	3	-3.62585	18.84047	0.
HOLE	3	5.07619	23.86459	0.	HOLE	3	-2.17551	18.84047	0.
HOLE	3	6.52653	23.86459	0.	HOLE	3	-0.72517	18.84047	0.
HOLE	3	7.97687	23.86459	0.	HOLE	3	0.72517	18.84047	0.
HOLE	3	9.42721	23.86459	0.	HOLE	3	2.17551	18.84047	0.
HOLE	3	10.87755	23.86459	0.	HOLE	3	3.62585	18.84047	0.
HOLE	3	12.32789	23.86459	0.	HOLE	3	5.07619	18.84047	0.
HOLE	3	13.77823	23.86459	0.	HOLE	3	6.52653	18.84047	0.
HOLE	3	15.22857	23.86459	0.	HOLE	3	7.97687	18.84047	0.
COM=+18 row*					HOLE	3	9.42721	18.84047	0.
HOLE	3	-15.95374	22.60856	0.	HOLE	3	10.87755	18.84047	0.
HOLE	3	-14.50340	22.60856	0.	HOLE	3	12.32789	18.84047	0.
HOLE	3	-13.05306	22.60856	0.	HOLE	3	13.77823	18.84047	0.
HOLE	3	-11.60272	22.60856	0.	HOLE	3	15.22857	18.84047	0.
HOLE	3	-10.15238	22.60856	0.	HOLE	3	16.67891	18.84047	0.
HOLE	3	-8.70204	22.60856	0.	HOLE	3	18.12925	18.84047	0.
HOLE	3	-7.25170	22.60856	0.	COM=+14 row*				
HOLE	3	-5.80136	22.60856	0.	HOLE	3	-18.85442	17.58444	0.
HOLE	3	-4.35102	22.60856	0.	HOLE	3	-17.40408	17.58444	0.
HOLE	3	-2.90068	22.60856	0.	HOLE	3	-15.95374	17.58444	0.
HOLE	3	-1.45034	22.60856	0.	HOLE	3	-14.50340	17.58444	0.
HOLE	3	0.	22.60856	0.	HOLE	3	-13.05306	17.58444	0.
HOLE	3	1.45034	22.60856	0.	HOLE	3	-11.60272	17.58444	0.
HOLE	3	2.90068	22.60856	0.	HOLE	3	-10.15238	17.58444	0.
HOLE	3	4.35102	22.60856	0.	HOLE	3	-8.70204	17.58444	0.
HOLE	3	5.80136	22.60856	0.	HOLE	3	-7.25170	17.58444	0.
HOLE	3	7.25170	22.60856	0.	HOLE	3	-5.80136	17.58444	0.
HOLE	3	8.70204	22.60856	0.	HOLE	3	-4.35102	17.58444	0.
HOLE	3	10.15238	22.60856	0.	HOLE	3	-2.90068	17.58444	0.
HOLE	3	11.60272	22.60856	0.	HOLE	3	-1.45034	17.58444	0.
HOLE	3	13.05306	22.60856	0.	HOLE	3	0.	17.58444	0.
HOLE	3	14.50340	22.60856	0.	HOLE	3	1.45034	17.58444	0.
HOLE	3	15.95374	22.60856	0.	HOLE	3	2.90068	17.58444	0.
COM=+17 row*					HOLE	3	4.35102	17.58444	0.
HOLE	3	-16.67891	21.35253	0.	HOLE	3	5.80136	17.58444	0.
HOLE	3	-15.22857	21.35253	0.	HOLE	3	7.25170	17.58444	0.
HOLE	3	-13.77823	21.35253	0.	HOLE	3	8.70204	17.58444	0.
HOLE	3	-12.32789	21.35253	0.	HOLE	3	10.15238	17.58444	0.
HOLE	3	-10.87755	21.35253	0.	HOLE	3	11.60272	17.58444	0.
HOLE	3	-9.42721	21.35253	0.	HOLE	3	13.05306	17.58444	0.
HOLE	3	-7.97687	21.35253	0.	HOLE	3	14.50340	17.58444	0.
HOLE	3	-6.52653	21.35253	0.	HOLE	3	15.95374	17.58444	0.
HOLE	3	-5.07619	21.35253	0.	HOLE	3	17.40408	17.58444	0.
HOLE	3	-3.62585	21.35253	0.	HOLE	3	18.85442	17.58444	0.
HOLE	3	-2.17551	21.35253	0.	COM=+13 row*				
HOLE	3	-0.72517	21.35253	0.	HOLE	3	-19.57959	16.32841	0.
HOLE	3	0.72517	21.35253	0.	HOLE	3	-18.12925	16.32841	0.
HOLE	3	2.17551	21.35253	0.	HOLE	3	-16.67891	16.32841	0.
HOLE	3	3.62585	21.35253	0.	HOLE	3	-15.22857	16.32841	0.
HOLE	3	5.07619	21.35253	0.	HOLE	3	-13.77823	16.32841	0.
HOLE	3	6.52653	21.35253	0.	HOLE	3	-12.32789	16.32841	0.
HOLE	3	7.97687	21.35253	0.	HOLE	3	-10.87755	16.32841	0.
HOLE	3	9.42721	21.35253	0.	HOLE	3	-9.42721	16.32841	0.
HOLE	3	10.87755	21.35253	0.	HOLE	3	-7.97687	16.32841	0.
HOLE	3	12.32789	21.35253	0.	HOLE	3	-6.52653	16.32841	0.
HOLE	3	13.77823	21.35253	0.	HOLE	3	-5.07619	16.32841	0.
HOLE	3	15.22857	21.35253	0.	HOLE	3	-3.62585	16.32841	0.
HOLE	3	16.67891	21.35253	0.	HOLE	3	-2.17551	16.32841	0.
COM=+16 row*					HOLE	3	-0.72517	16.32841	0.
HOLE	3	-17.40408	20.09650	0.	HOLE	3	0.72517	16.32841	0.
HOLE	3	-15.95374	20.09650	0.	HOLE	3	2.17551	16.32841	0.
HOLE	3	-14.50340	20.09650	0.	HOLE	3	3.62585	16.32841	0.
HOLE	3	-13.05306	20.09650	0.	HOLE	3	5.07619	16.32841	0.
HOLE	3	-11.60272	20.09650	0.	HOLE	3	6.52653	16.32841	0.
HOLE	3	-10.15238	20.09650	0.	HOLE	3	7.97687	16.32841	0.
HOLE	3	-8.70204	20.09650	0.	HOLE	3	9.42721	16.32841	0.
HOLE	3	-7.25170	20.09650	0.	HOLE	3	10.87755	16.32841	0.
HOLE	3	-5.80136	20.09650	0.	HOLE	3	12.32789	16.32841	0.
HOLE	3	-4.35102	20.09650	0.	HOLE	3	13.77823	16.32841	0.
HOLE	3	-2.90068	20.09650	0.	HOLE	3	15.22857	16.32841	0.
HOLE	3	-1.45034	20.09650	0.	HOLE	3	16.67891	16.32841	0.
HOLE	3	0.	20.09650	0.	HOLE	3	18.12925	16.32841	0.
HOLE	3	1.45034	20.09650	0.	HOLE	3	19.57959	16.32841	0.
HOLE	3	2.90068	20.09650	0.	COM=+12 row*				
HOLE	3	4.35102	20.09650	0.	HOLE	3	-20.30476	15.07238	0.
HOLE	3	5.80136	20.09650	0.	HOLE	3	-18.85442	15.07238	0.
HOLE	3	7.25170	20.09650	0.	HOLE	3	-17.40408	15.07238	0.
HOLE	3	8.70204	20.09650	0.	HOLE	3	-15.95374	15.07238	0.
HOLE	3	10.15238	20.09650	0.	HOLE	3	-14.50340	15.07238	0.
HOLE	3	11.60272	20.09650	0.	HOLE	3	-13.05306	15.07238	0.
HOLE	3	13.05306	20.09650	0.	HOLE	3	-11.60272	15.07238	0.
HOLE	3	14.50340	20.09650	0.	HOLE	3	-10.15238	15.07238	0.
HOLE	3	15.95374	20.09650	0.	HOLE	3	-8.70204	15.07238	0.
HOLE	3	17.40408	20.09650	0.	HOLE	3	-7.25170	15.07238	0.
COM=+15 row*					HOLE	3	-5.80136	15.07238	0.
HOLE	3	-18.12925	18.84047	0.	HOLE	3	-4.35102	15.07238	0.
HOLE	3	-16.67891	18.84047	0.	HOLE	3	-2.90068	15.07238	0.
HOLE	3	-15.22857	18.84047	0.	HOLE	3	-1.45034	15.07238	0.
HOLE	3	-13.77823	18.84047	0.	HOLE	3	0.	15.07238	0.
HOLE	3	-12.32789	18.84047	0.	HOLE	3	1.45034	15.07238	0.
HOLE	3	-10.87755	18.84047	0.	HOLE	3	2.90068	15.07238	0.
HOLE	3	-9.42721	18.84047	0.	HOLE	3	4.35102	15.07238	0.

Criticality Safety Code Validation with LWBR's SB Cores

HOLE	3	5.80136	15.07238	0.	HOLE	3	6.52653	11.30428	0.
HOLE	3	7.25170	15.07238	0.	HOLE	3	7.97687	11.30428	0.
HOLE	3	8.70204	15.07238	0.	HOLE	3	9.42721	11.30428	0.
HOLE	3	10.15238	15.07238	0.	HOLE	3	10.87755	11.30428	0.
HOLE	3	11.60272	15.07238	0.	HOLE	3	12.32789	11.30428	0.
HOLE	3	13.05306	15.07238	0.	HOLE	3	13.77823	11.30428	0.
HOLE	3	14.50340	15.07238	0.	HOLE	3	15.22857	11.30428	0.
HOLE	3	15.95374	15.07238	0.	HOLE	3	16.67891	11.30428	0.
HOLE	3	17.40408	15.07238	0.	HOLE	3	18.12925	11.30428	0.
HOLE	3	18.85442	15.07238	0.	HOLE	3	19.57959	11.30428	0.
HOLE	3	20.30476	15.07238	0.	HOLE	3	21.02993	11.30428	0.
COM=+11 row*					HOLE	3	22.48027	11.30428	0.
HOLE	3	-21.02993	13.81634	0.	COM=+8 row*				
HOLE	3	-19.57959	13.81634	0.	HOLE	3	-23.20544	10.04825	0.
HOLE	3	-18.12925	13.81634	0.	HOLE	3	-21.75510	10.04825	0.
HOLE	3	-16.67891	13.81634	0.	HOLE	3	-20.30476	10.04825	0.
HOLE	3	-15.22857	13.81634	0.	HOLE	3	-18.85442	10.04825	0.
HOLE	3	-13.77823	13.81634	0.	HOLE	3	-17.40408	10.04825	0.
HOLE	3	-12.32789	13.81634	0.	HOLE	3	-15.95374	10.04825	0.
HOLE	3	-10.87755	13.81634	0.	HOLE	3	-14.50340	10.04825	0.
HOLE	3	-9.42721	13.81634	0.	HOLE	3	-13.05306	10.04825	0.
HOLE	3	-7.97687	13.81634	0.	HOLE	3	-11.60272	10.04825	0.
HOLE	3	-6.52653	13.81634	0.	HOLE	3	-10.15238	10.04825	0.
HOLE	3	-5.07619	13.81634	0.	HOLE	3	-8.70204	10.04825	0.
HOLE	3	-3.62585	13.81634	0.	HOLE	3	-7.25170	10.04825	0.
HOLE	3	-2.17551	13.81634	0.	HOLE	3	-5.80136	10.04825	0.
HOLE	3	-0.72517	13.81634	0.	HOLE	3	-4.35102	10.04825	0.
HOLE	3	0.72517	13.81634	0.	HOLE	3	-2.90068	10.04825	0.
HOLE	3	2.17551	13.81634	0.	HOLE	3	-1.45034	10.04825	0.
HOLE	3	3.62585	13.81634	0.	HOLE	3	0.	10.04825	0.
HOLE	3	5.07619	13.81634	0.	HOLE	3	1.45034	10.04825	0.
HOLE	3	6.52653	13.81634	0.	HOLE	3	2.90068	10.04825	0.
HOLE	3	7.97687	13.81634	0.	HOLE	3	4.35102	10.04825	0.
HOLE	3	9.42721	13.81634	0.	HOLE	3	5.80136	10.04825	0.
HOLE	3	10.87755	13.81634	0.	HOLE	3	7.25170	10.04825	0.
HOLE	3	12.32789	13.81634	0.	HOLE	3	8.70204	10.04825	0.
HOLE	3	13.77823	13.81634	0.	HOLE	3	10.15238	10.04825	0.
HOLE	3	15.22857	13.81634	0.	HOLE	3	11.60272	10.04825	0.
HOLE	3	16.67891	13.81634	0.	HOLE	3	13.05306	10.04825	0.
HOLE	3	18.12925	13.81634	0.	HOLE	3	14.50340	10.04825	0.
HOLE	3	19.57959	13.81634	0.	HOLE	3	15.95374	10.04825	0.
HOLE	3	21.02993	13.81634	0.	HOLE	3	17.40408	10.04825	0.
COM=+10 row*					HOLE	3	18.85442	10.04825	0.
HOLE	3	-21.75510	12.56031	0.	HOLE	3	20.30476	10.04825	0.
HOLE	3	-20.30476	12.56031	0.	HOLE	3	21.75510	10.04825	0.
HOLE	3	-18.85442	12.56031	0.	HOLE	3	23.20544	10.04825	0.
HOLE	3	-17.40408	12.56031	0.	COM=+7 row*				
HOLE	3	-15.95374	12.56031	0.	HOLE	3	-23.93061	8.79222	0.
HOLE	3	-14.50340	12.56031	0.	HOLE	3	-22.48027	8.79222	0.
HOLE	3	-13.05306	12.56031	0.	HOLE	3	-21.02993	8.79222	0.
HOLE	3	-11.60272	12.56031	0.	HOLE	3	-19.57959	8.79222	0.
HOLE	3	-10.15238	12.56031	0.	HOLE	3	-18.12925	8.79222	0.
HOLE	3	-8.70204	12.56031	0.	HOLE	3	-16.67891	8.79222	0.
HOLE	3	-7.25170	12.56031	0.	HOLE	3	-15.22857	8.79222	0.
HOLE	3	-5.80136	12.56031	0.	HOLE	3	-13.77823	8.79222	0.
HOLE	3	-4.35102	12.56031	0.	HOLE	3	-12.32789	8.79222	0.
HOLE	3	-2.90068	12.56031	0.	HOLE	3	-10.87755	8.79222	0.
HOLE	3	-1.45034	12.56031	0.	HOLE	3	-9.42721	8.79222	0.
HOLE	3	0.	12.56031	0.	HOLE	3	-7.97687	8.79222	0.
HOLE	3	1.45034	12.56031	0.	HOLE	3	-6.52653	8.79222	0.
HOLE	3	2.90068	12.56031	0.	HOLE	3	-5.07619	8.79222	0.
HOLE	3	4.35102	12.56031	0.	HOLE	3	-3.62585	8.79222	0.
HOLE	3	5.80136	12.56031	0.	HOLE	3	-2.17551	8.79222	0.
HOLE	3	7.25170	12.56031	0.	HOLE	3	-0.72517	8.79222	0.
HOLE	3	8.70204	12.56031	0.	HOLE	3	0.72517	8.79222	0.
HOLE	3	10.15238	12.56031	0.	HOLE	3	2.17551	8.79222	0.
HOLE	3	11.60272	12.56031	0.	HOLE	3	3.62585	8.79222	0.
HOLE	3	13.05306	12.56031	0.	HOLE	3	5.07619	8.79222	0.
HOLE	3	14.50340	12.56031	0.	HOLE	3	6.52653	8.79222	0.
HOLE	3	15.95374	12.56031	0.	HOLE	3	7.97687	8.79222	0.
HOLE	3	17.40408	12.56031	0.	HOLE	3	9.42721	8.79222	0.
HOLE	3	18.85442	12.56031	0.	HOLE	3	10.87755	8.79222	0.
HOLE	3	20.30476	12.56031	0.	HOLE	3	12.32789	8.79222	0.
HOLE	3	21.75510	12.56031	0.	HOLE	3	13.77823	8.79222	0.
COM=+9 row*					HOLE	3	15.22857	8.79222	0.
HOLE	3	-22.48027	11.30428	0.	HOLE	3	16.67891	8.79222	0.
HOLE	3	-21.02993	11.30428	0.	HOLE	3	18.12925	8.79222	0.
HOLE	3	-19.57959	11.30428	0.	HOLE	3	19.57959	8.79222	0.
HOLE	3	-18.12925	11.30428	0.	HOLE	3	21.02993	8.79222	0.
HOLE	3	-16.67891	11.30428	0.	HOLE	3	22.48027	8.79222	0.
HOLE	3	-15.22857	11.30428	0.	HOLE	3	23.93061	8.79222	0.
HOLE	3	-13.77823	11.30428	0.	COM=+6 row*				
HOLE	3	-12.32789	11.30428	0.	HOLE	3	-24.65578	7.53619	0.
HOLE	3	-10.87755	11.30428	0.	HOLE	3	-23.20544	7.53619	0.
HOLE	3	-9.42721	11.30428	0.	HOLE	3	-21.75510	7.53619	0.
HOLE	3	-7.97687	11.30428	0.	HOLE	3	-20.30476	7.53619	0.
HOLE	3	-6.52653	11.30428	0.	HOLE	3	-18.85442	7.53619	0.
HOLE	3	-5.07619	11.30428	0.	HOLE	3	-17.40408	7.53619	0.
HOLE	3	-3.62585	11.30428	0.	HOLE	3	-15.95374	7.53619	0.
HOLE	3	-2.17551	11.30428	0.	HOLE	3	-14.50340	7.53619	0.
HOLE	3	-0.72517	11.30428	0.	HOLE	3	-13.05306	7.53619	0.
HOLE	3	0.72517	11.30428	0.	HOLE	3	-11.60272	7.53619	0.
HOLE	3	2.17551	11.30428	0.	HOLE	3	-10.15238	7.53619	0.
HOLE	3	3.62585	11.30428	0.	HOLE	3	-8.70204	7.53619	0.
HOLE	3	5.07619	11.30428	0.	HOLE	3	-7.25170	7.53619	0.

Appendix E Benchmark Model Inputs

HOLE	3	-5.80136	7.53619	0.	HOLE	3	24.65578	5.02413	0.
HOLE	3	-4.35102	7.53619	0.	HOLE	3	26.10612	5.02413	0.
HOLE	1	-2.90068	7.53619	0.	COM=+3 row*				
HOLE	1	-1.45034	7.53619	0.	HOLE	3	-26.83129	3.76809	0.
HOLE	3	0.	7.53619	0.	HOLE	3	-25.38095	3.76809	0.
HOLE	1	1.45034	7.53619	0.	HOLE	3	-23.93061	3.76809	0.
HOLE	1	2.90068	7.53619	0.	HOLE	3	-22.48027	3.76809	0.
HOLE	3	4.35102	7.53619	0.	HOLE	3	-21.02993	3.76809	0.
HOLE	3	5.80136	7.53619	0.	HOLE	3	-19.57959	3.76809	0.
HOLE	3	7.25170	7.53619	0.	HOLE	3	-18.12925	3.76809	0.
HOLE	3	8.70204	7.53619	0.	HOLE	3	-16.67891	3.76809	0.
HOLE	3	10.15238	7.53619	0.	HOLE	3	-15.22857	3.76809	0.
HOLE	3	11.60272	7.53619	0.	HOLE	3	-13.77823	3.76809	0.
HOLE	3	13.05306	7.53619	0.	HOLE	3	-12.32789	3.76809	0.
HOLE	3	14.50340	7.53619	0.	HOLE	3	-10.87755	3.76809	0.
HOLE	3	15.95374	7.53619	0.	HOLE	3	-9.42721	3.76809	0.
HOLE	3	17.40408	7.53619	0.	HOLE	3	-7.97687	3.76809	0.
HOLE	3	18.85442	7.53619	0.	HOLE	3	-6.52653	3.76809	0.
HOLE	3	20.30476	7.53619	0.	HOLE	1	-5.07619	3.76809	0.
HOLE	3	21.75510	7.53619	0.	HOLE	1	-3.62585	3.76809	0.
HOLE	3	23.20544	7.53619	0.	HOLE	1	-2.17551	3.76809	0.
HOLE	3	24.65578	7.53619	0.	HOLE	1	-0.72517	3.76809	0.
COM=+5 row*					HOLE	1	0.72517	3.76809	0.
HOLE	3	-25.38095	6.28016	0.	HOLE	1	2.17551	3.76809	0.
HOLE	3	-23.93061	6.28016	0.	HOLE	1	3.62585	3.76809	0.
HOLE	3	-22.48027	6.28016	0.	HOLE	1	5.07619	3.76809	0.
HOLE	3	-21.02993	6.28016	0.	HOLE	3	6.52653	3.76809	0.
HOLE	3	-19.57959	6.28016	0.	HOLE	3	7.97687	3.76809	0.
HOLE	3	-18.12925	6.28016	0.	HOLE	3	9.42721	3.76809	0.
HOLE	3	-16.67891	6.28016	0.	HOLE	3	10.87755	3.76809	0.
HOLE	3	-15.22857	6.28016	0.	HOLE	3	12.32789	3.76809	0.
HOLE	3	-13.77823	6.28016	0.	HOLE	3	13.77823	3.76809	0.
HOLE	3	-12.32789	6.28016	0.	HOLE	3	15.22857	3.76809	0.
HOLE	3	-10.87755	6.28016	0.	HOLE	3	16.67891	3.76809	0.
HOLE	3	-9.42721	6.28016	0.	HOLE	3	18.12925	3.76809	0.
HOLE	3	-7.97687	6.28016	0.	HOLE	3	19.57959	3.76809	0.
HOLE	3	-6.52653	6.28016	0.	HOLE	3	21.02993	3.76809	0.
HOLE	1	-5.07619	6.28016	0.	HOLE	3	22.48027	3.76809	0.
HOLE	1	-3.62585	6.28016	0.	HOLE	3	23.93061	3.76809	0.
HOLE	1	-2.17551	6.28016	0.	HOLE	3	25.38095	3.76809	0.
HOLE	1	-0.72517	6.28016	0.	HOLE	3	26.83129	3.76809	0.
HOLE	1	0.72517	6.28016	0.	COM=+2 row*				
HOLE	1	2.17551	6.28016	0.	HOLE	3	-27.55646	2.51206	0.
HOLE	1	3.62585	6.28016	0.	HOLE	3	-26.10612	2.51206	0.
HOLE	1	5.07619	6.28016	0.	HOLE	3	-24.65578	2.51206	0.
HOLE	3	6.52653	6.28016	0.	HOLE	3	-23.20544	2.51206	0.
HOLE	3	7.97687	6.28016	0.	HOLE	3	-21.75510	2.51206	0.
HOLE	3	9.42721	6.28016	0.	HOLE	3	-20.30476	2.51206	0.
HOLE	3	10.87755	6.28016	0.	HOLE	3	-18.85442	2.51206	0.
HOLE	3	12.32789	6.28016	0.	HOLE	3	-17.40408	2.51206	0.
HOLE	3	13.77823	6.28016	0.	HOLE	3	-15.95374	2.51206	0.
HOLE	3	15.22857	6.28016	0.	HOLE	3	-14.50340	2.51206	0.
HOLE	3	16.67891	6.28016	0.	HOLE	3	-13.05306	2.51206	0.
HOLE	3	18.12925	6.28016	0.	HOLE	3	-11.60272	2.51206	0.
HOLE	3	19.57959	6.28016	0.	HOLE	3	-10.15238	2.51206	0.
HOLE	3	21.02993	6.28016	0.	HOLE	3	-8.70204	2.51206	0.
HOLE	3	22.48027	6.28016	0.	HOLE	1	-7.25170	2.51206	0.
HOLE	3	23.93061	6.28016	0.	HOLE	1	-5.80136	2.51206	0.
HOLE	3	25.38095	6.28016	0.	HOLE	1	-4.35102	2.51206	0.
COM=+4 row*					HOLE	1	-2.90068	2.51206	0.
HOLE	3	-26.10612	5.02413	0.	HOLE	1	-1.45034	2.51206	0.
HOLE	3	-24.65578	5.02413	0.	HOLE	1	0.	2.51206	0.
HOLE	3	-23.20544	5.02413	0.	HOLE	1	1.45034	2.51206	0.
HOLE	3	-21.75510	5.02413	0.	HOLE	1	2.90068	2.51206	0.
HOLE	3	-20.30476	5.02413	0.	HOLE	1	4.35102	2.51206	0.
HOLE	3	-18.85442	5.02413	0.	HOLE	1	5.80136	2.51206	0.
HOLE	3	-17.40408	5.02413	0.	HOLE	1	7.25170	2.51206	0.
HOLE	3	-15.95374	5.02413	0.	HOLE	3	8.70204	2.51206	0.
HOLE	3	-14.50340	5.02413	0.	HOLE	3	10.15238	2.51206	0.
HOLE	3	-13.05306	5.02413	0.	HOLE	3	11.60272	2.51206	0.
HOLE	3	-11.60272	5.02413	0.	HOLE	3	13.05306	2.51206	0.
HOLE	3	-10.15238	5.02413	0.	HOLE	3	14.50340	2.51206	0.
HOLE	3	-8.70204	5.02413	0.	HOLE	3	15.95374	2.51206	0.
HOLE	3	-7.25170	5.02413	0.	HOLE	3	17.40408	2.51206	0.
HOLE	1	-5.80136	5.02413	0.	HOLE	3	18.85442	2.51206	0.
HOLE	1	-4.35102	5.02413	0.	HOLE	3	20.30476	2.51206	0.
HOLE	1	-2.90068	5.02413	0.	HOLE	3	21.75510	2.51206	0.
HOLE	1	-1.45034	5.02413	0.	HOLE	3	23.20544	2.51206	0.
HOLE	1	0.	5.02413	0.	HOLE	3	24.65578	2.51206	0.
HOLE	1	1.45034	5.02413	0.	HOLE	3	26.10612	2.51206	0.
HOLE	1	2.90068	5.02413	0.	HOLE	3	27.55646	2.51206	0.
HOLE	1	4.35102	5.02413	0.	COM=+1 row*				
HOLE	1	5.80136	5.02413	0.	HOLE	3	-28.28163	1.25603	0.
HOLE	3	7.25170	5.02413	0.	HOLE	3	-26.83129	1.25603	0.
HOLE	3	8.70204	5.02413	0.	HOLE	3	-25.38095	1.25603	0.
HOLE	3	10.15238	5.02413	0.	HOLE	3	-23.93061	1.25603	0.
HOLE	3	11.60272	5.02413	0.	HOLE	3	-22.48027	1.25603	0.
HOLE	3	13.05306	5.02413	0.	HOLE	3	-21.02993	1.25603	0.
HOLE	3	14.50340	5.02413	0.	HOLE	3	-19.57959	1.25603	0.
HOLE	3	15.95374	5.02413	0.	HOLE	3	-18.12925	1.25603	0.
HOLE	3	17.40408	5.02413	0.	HOLE	3	-16.67891	1.25603	0.
HOLE	3	18.85442	5.02413	0.	HOLE	3	-15.22857	1.25603	0.
HOLE	3	20.30476	5.02413	0.	HOLE	3	-13.77823	1.25603	0.
HOLE	3	21.75510	5.02413	0.	HOLE	3	-12.32789	1.25603	0.
HOLE	3	23.20544	5.02413	0.	HOLE	3	-10.87755	1.25603	0.

HOLE	3	-9.42721	1.25603	0.	HOLE	1	7.97687	-1.25603	0.
HOLE	1	-7.97687	1.25603	0.	HOLE	3	9.42721	-1.25603	0.
HOLE	1	-6.52653	1.25603	0.	HOLE	3	10.87755	-1.25603	0.
HOLE	1	-5.07619	1.25603	0.	HOLE	3	12.32789	-1.25603	0.
HOLE	1	-3.62585	1.25603	0.	HOLE	3	13.77823	-1.25603	0.
HOLE	1	-2.17551	1.25603	0.	HOLE	3	15.22857	-1.25603	0.
HOLE	1	-0.72517	1.25603	0.	HOLE	3	16.67891	-1.25603	0.
HOLE	1	0.72517	1.25603	0.	HOLE	3	18.12925	-1.25603	0.
HOLE	1	2.17551	1.25603	0.	HOLE	3	19.57959	-1.25603	0.
HOLE	1	3.62585	1.25603	0.	HOLE	3	21.02993	-1.25603	0.
HOLE	1	5.07619	1.25603	0.	HOLE	3	22.48027	-1.25603	0.
HOLE	1	6.52653	1.25603	0.	HOLE	3	23.93061	-1.25603	0.
HOLE	1	7.97687	1.25603	0.	HOLE	3	25.38095	-1.25603	0.
HOLE	3	9.42721	1.25603	0.	HOLE	3	26.83129	-1.25603	0.
HOLE	3	10.87755	1.25603	0.	HOLE	3	28.28163	-1.25603	0.
HOLE	3	12.32789	1.25603	0.	COM=-2 row*				
HOLE	3	13.77823	1.25603	0.	HOLE	3	-27.55646	-2.51206	0.
HOLE	3	15.22857	1.25603	0.	HOLE	3	-26.10612	-2.51206	0.
HOLE	3	16.67891	1.25603	0.	HOLE	3	-24.65578	-2.51206	0.
HOLE	3	18.12925	1.25603	0.	HOLE	3	-23.20544	-2.51206	0.
HOLE	3	19.57959	1.25603	0.	HOLE	3	-21.75510	-2.51206	0.
HOLE	3	21.02993	1.25603	0.	HOLE	3	-20.30476	-2.51206	0.
HOLE	3	22.48027	1.25603	0.	HOLE	3	-18.85442	-2.51206	0.
HOLE	3	23.93061	1.25603	0.	HOLE	3	-17.40408	-2.51206	0.
HOLE	3	25.38095	1.25603	0.	HOLE	3	-15.95374	-2.51206	0.
HOLE	3	26.83129	1.25603	0.	HOLE	3	-14.50340	-2.51206	0.
HOLE	3	28.28163	1.25603	0.	HOLE	3	-13.05306	-2.51206	0.
COM=*center (0) row*					HOLE	3	-11.60272	-2.51206	0.
HOLE	3	-29.00680	0.	0.	HOLE	3	-10.15238	-2.51206	0.
HOLE	3	-27.55646	0.	0.	HOLE	3	-8.70204	-2.51206	0.
HOLE	3	-26.10612	0.	0.	HOLE	1	-7.25170	-2.51206	0.
HOLE	3	-24.65578	0.	0.	HOLE	1	-5.80136	-2.51206	0.
HOLE	3	-23.20544	0.	0.	HOLE	1	-4.35102	-2.51206	0.
HOLE	3	-21.75510	0.	0.	HOLE	1	-2.90068	-2.51206	0.
HOLE	3	-20.30476	0.	0.	HOLE	1	-1.45034	-2.51206	0.
HOLE	3	-18.85442	0.	0.	HOLE	1	0.	-2.51206	0.
HOLE	3	-17.40408	0.	0.	HOLE	1	1.45034	-2.51206	0.
HOLE	3	-15.95374	0.	0.	HOLE	1	2.90068	-2.51206	0.
HOLE	3	-14.50340	0.	0.	HOLE	1	4.35102	-2.51206	0.
HOLE	3	-13.05306	0.	0.	HOLE	1	5.80136	-2.51206	0.
HOLE	3	-11.60272	0.	0.	HOLE	1	7.25170	-2.51206	0.
HOLE	3	-10.15238	0.	0.	HOLE	3	8.70204	-2.51206	0.
HOLE	3	-8.70204	0.	0.	HOLE	3	10.15238	-2.51206	0.
HOLE	1	-7.25170	0.	0.	HOLE	3	11.60272	-2.51206	0.
HOLE	1	-5.80136	0.	0.	HOLE	3	13.05306	-2.51206	0.
HOLE	1	-4.35102	0.	0.	HOLE	3	14.50340	-2.51206	0.
HOLE	1	-2.90068	0.	0.	HOLE	3	15.95374	-2.51206	0.
HOLE	1	-1.45034	0.	0.	HOLE	3	17.40408	-2.51206	0.
HOLE	1	0.	0.	0.	HOLE	3	18.85442	-2.51206	0.
HOLE	1	1.45034	0.	0.	HOLE	3	20.30476	-2.51206	0.
HOLE	1	2.90068	0.	0.	HOLE	3	21.75510	-2.51206	0.
HOLE	1	4.35102	0.	0.	HOLE	3	23.20544	-2.51206	0.
HOLE	1	5.80136	0.	0.	HOLE	3	24.65578	-2.51206	0.
HOLE	1	7.25170	0.	0.	HOLE	3	26.10612	-2.51206	0.
HOLE	3	8.70204	0.	0.	HOLE	3	27.55646	-2.51206	0.
HOLE	3	10.15238	0.	0.	COM=-3 row*				
HOLE	3	11.60272	0.	0.	HOLE	3	-26.83129	-3.76809	0.
HOLE	3	13.05306	0.	0.	HOLE	3	-25.38095	-3.76809	0.
HOLE	3	14.50340	0.	0.	HOLE	3	-23.93061	-3.76809	0.
HOLE	3	15.95374	0.	0.	HOLE	3	-22.48027	-3.76809	0.
HOLE	3	17.40408	0.	0.	HOLE	3	-21.02993	-3.76809	0.
HOLE	3	18.85442	0.	0.	HOLE	3	-19.57959	-3.76809	0.
HOLE	3	20.30476	0.	0.	HOLE	3	-18.12925	-3.76809	0.
HOLE	3	21.75510	0.	0.	HOLE	3	-16.67891	-3.76809	0.
HOLE	3	23.20544	0.	0.	HOLE	3	-15.22857	-3.76809	0.
HOLE	3	24.65578	0.	0.	HOLE	3	-13.77823	-3.76809	0.
HOLE	3	26.10612	0.	0.	HOLE	3	-12.32789	-3.76809	0.
HOLE	3	27.55646	0.	0.	HOLE	3	-10.87755	-3.76809	0.
HOLE	3	29.00680	0.	0.	HOLE	3	-9.42721	-3.76809	0.
COM=-1 row*					HOLE	3	-7.97687	-3.76809	0.
HOLE	3	-28.28163	-1.25603	0.	HOLE	3	-6.52653	-3.76809	0.
HOLE	3	-26.83129	-1.25603	0.	HOLE	1	-5.07619	-3.76809	0.
HOLE	3	-25.38095	-1.25603	0.	HOLE	1	-3.62585	-3.76809	0.
HOLE	3	-23.93061	-1.25603	0.	HOLE	1	-2.17551	-3.76809	0.
HOLE	3	-22.48027	-1.25603	0.	HOLE	1	-0.72517	-3.76809	0.
HOLE	3	-21.02993	-1.25603	0.	HOLE	1	0.72517	-3.76809	0.
HOLE	3	-19.57959	-1.25603	0.	HOLE	1	2.17551	-3.76809	0.
HOLE	3	-18.12925	-1.25603	0.	HOLE	1	3.62585	-3.76809	0.
HOLE	3	-16.67891	-1.25603	0.	HOLE	1	5.07619	-3.76809	0.
HOLE	3	-15.22857	-1.25603	0.	HOLE	3	6.52653	-3.76809	0.
HOLE	3	-13.77823	-1.25603	0.	HOLE	3	7.97687	-3.76809	0.
HOLE	3	-12.32789	-1.25603	0.	HOLE	3	9.42721	-3.76809	0.
HOLE	3	-10.87755	-1.25603	0.	HOLE	3	10.87755	-3.76809	0.
HOLE	3	-9.42721	-1.25603	0.	HOLE	3	12.32789	-3.76809	0.
HOLE	1	-7.97687	-1.25603	0.	HOLE	3	13.77823	-3.76809	0.
HOLE	1	-6.52653	-1.25603	0.	HOLE	3	15.22857	-3.76809	0.
HOLE	1	-5.07619	-1.25603	0.	HOLE	3	16.67891	-3.76809	0.
HOLE	1	-3.62585	-1.25603	0.	HOLE	3	18.12925	-3.76809	0.
HOLE	1	-2.17551	-1.25603	0.	HOLE	3	19.57959	-3.76809	0.
HOLE	1	-0.72517	-1.25603	0.	HOLE	3	21.02993	-3.76809	0.
HOLE	1	0.72517	-1.25603	0.	HOLE	3	22.48027	-3.76809	0.
HOLE	1	2.17551	-1.25603	0.	HOLE	3	23.93061	-3.76809	0.
HOLE	1	3.62585	-1.25603	0.	HOLE	3	25.38095	-3.76809	0.
HOLE	1	5.07619	-1.25603	0.	HOLE	3	26.83129	-3.76809	0.
HOLE	1	6.52653	-1.25603	0.	COM=-4 row*				

HOLE	3	-26.10612	-5.02413	0.	HOLE	3	4.35102	-7.53619	0.
HOLE	3	-24.65578	-5.02413	0.	HOLE	3	5.80136	-7.53619	0.
HOLE	3	-23.20544	-5.02413	0.	HOLE	3	7.25170	-7.53619	0.
HOLE	3	-21.75510	-5.02413	0.	HOLE	3	8.70204	-7.53619	0.
HOLE	3	-20.30476	-5.02413	0.	HOLE	3	10.15238	-7.53619	0.
HOLE	3	-18.85442	-5.02413	0.	HOLE	3	11.60272	-7.53619	0.
HOLE	3	-17.40408	-5.02413	0.	HOLE	3	13.05306	-7.53619	0.
HOLE	3	-15.95374	-5.02413	0.	HOLE	3	14.50340	-7.53619	0.
HOLE	3	-14.50340	-5.02413	0.	HOLE	3	15.95374	-7.53619	0.
HOLE	3	-13.05306	-5.02413	0.	HOLE	3	17.40408	-7.53619	0.
HOLE	3	-11.60272	-5.02413	0.	HOLE	3	18.85442	-7.53619	0.
HOLE	3	-10.15238	-5.02413	0.	HOLE	3	20.30476	-7.53619	0.
HOLE	3	-8.70204	-5.02413	0.	HOLE	3	21.75510	-7.53619	0.
HOLE	3	-7.25170	-5.02413	0.	HOLE	3	23.20544	-7.53619	0.
HOLE	1	-5.80136	-5.02413	0.	HOLE	3	24.65578	-7.53619	0.
HOLE	1	-4.35102	-5.02413	0.	COM=*-7 row*				
HOLE	1	-2.90068	-5.02413	0.	HOLE	3	-23.93061	-8.79222	0.
HOLE	1	-1.45034	-5.02413	0.	HOLE	3	-22.48027	-8.79222	0.
HOLE	1	0.	-5.02413	0.	HOLE	3	-21.02993	-8.79222	0.
HOLE	1	1.45034	-5.02413	0.	HOLE	3	-19.57959	-8.79222	0.
HOLE	1	2.90068	-5.02413	0.	HOLE	3	-18.12925	-8.79222	0.
HOLE	1	4.35102	-5.02413	0.	HOLE	3	-16.67891	-8.79222	0.
HOLE	1	5.80136	-5.02413	0.	HOLE	3	-15.22857	-8.79222	0.
HOLE	3	7.25170	-5.02413	0.	HOLE	3	-13.77823	-8.79222	0.
HOLE	3	8.70204	-5.02413	0.	HOLE	3	-12.32789	-8.79222	0.
HOLE	3	10.15238	-5.02413	0.	HOLE	3	-10.87755	-8.79222	0.
HOLE	3	11.60272	-5.02413	0.	HOLE	3	-9.42721	-8.79222	0.
HOLE	3	13.05306	-5.02413	0.	HOLE	3	-7.97687	-8.79222	0.
HOLE	3	14.50340	-5.02413	0.	HOLE	3	-6.52653	-8.79222	0.
HOLE	3	15.95374	-5.02413	0.	HOLE	3	-5.07619	-8.79222	0.
HOLE	3	17.40408	-5.02413	0.	HOLE	3	-3.62585	-8.79222	0.
HOLE	3	18.85442	-5.02413	0.	HOLE	3	-2.17551	-8.79222	0.
HOLE	3	20.30476	-5.02413	0.	HOLE	3	-0.72517	-8.79222	0.
HOLE	3	21.75510	-5.02413	0.	HOLE	3	0.72517	-8.79222	0.
HOLE	3	23.20544	-5.02413	0.	HOLE	3	2.17551	-8.79222	0.
HOLE	3	24.65578	-5.02413	0.	HOLE	3	3.62585	-8.79222	0.
HOLE	3	26.10612	-5.02413	0.	HOLE	3	5.07619	-8.79222	0.
COM=*-5 row*					HOLE	3	6.52653	-8.79222	0.
HOLE	3	-25.38095	-6.28016	0.	HOLE	3	7.97687	-8.79222	0.
HOLE	3	-23.93061	-6.28016	0.	HOLE	3	9.42721	-8.79222	0.
HOLE	3	-22.48027	-6.28016	0.	HOLE	3	10.87755	-8.79222	0.
HOLE	3	-21.02993	-6.28016	0.	HOLE	3	12.32789	-8.79222	0.
HOLE	3	-19.57959	-6.28016	0.	HOLE	3	13.77823	-8.79222	0.
HOLE	3	-18.12925	-6.28016	0.	HOLE	3	15.22857	-8.79222	0.
HOLE	3	-16.67891	-6.28016	0.	HOLE	3	16.67891	-8.79222	0.
HOLE	3	-15.22857	-6.28016	0.	HOLE	3	18.12925	-8.79222	0.
HOLE	3	-13.77823	-6.28016	0.	HOLE	3	19.57959	-8.79222	0.
HOLE	3	-12.32789	-6.28016	0.	HOLE	3	21.02993	-8.79222	0.
HOLE	3	-10.87755	-6.28016	0.	HOLE	3	22.48027	-8.79222	0.
HOLE	3	-9.42721	-6.28016	0.	HOLE	3	23.93061	-8.79222	0.
HOLE	3	-7.97687	-6.28016	0.	COM=*-8 row*				
HOLE	3	-6.52653	-6.28016	0.	HOLE	3	-23.20544	-10.04825	0.
HOLE	1	-5.07619	-6.28016	0.	HOLE	3	-21.75510	-10.04825	0.
HOLE	1	-3.62585	-6.28016	0.	HOLE	3	-20.30476	-10.04825	0.
HOLE	1	-2.17551	-6.28016	0.	HOLE	3	-18.85442	-10.04825	0.
HOLE	1	-0.72517	-6.28016	0.	HOLE	3	-17.40408	-10.04825	0.
HOLE	1	0.72517	-6.28016	0.	HOLE	3	-15.95374	-10.04825	0.
HOLE	1	2.17551	-6.28016	0.	HOLE	3	-14.50340	-10.04825	0.
HOLE	1	3.62585	-6.28016	0.	HOLE	3	-13.05306	-10.04825	0.
HOLE	1	5.07619	-6.28016	0.	HOLE	3	-11.60272	-10.04825	0.
HOLE	3	6.52653	-6.28016	0.	HOLE	3	-10.15238	-10.04825	0.
HOLE	3	7.97687	-6.28016	0.	HOLE	3	-8.70204	-10.04825	0.
HOLE	3	9.42721	-6.28016	0.	HOLE	3	-7.25170	-10.04825	0.
HOLE	3	10.87755	-6.28016	0.	HOLE	3	-5.80136	-10.04825	0.
HOLE	3	12.32789	-6.28016	0.	HOLE	3	-4.35102	-10.04825	0.
HOLE	3	13.77823	-6.28016	0.	HOLE	3	-2.90068	-10.04825	0.
HOLE	3	15.22857	-6.28016	0.	HOLE	3	-1.45034	-10.04825	0.
HOLE	3	16.67891	-6.28016	0.	HOLE	3	0.	-10.04825	0.
HOLE	3	18.12925	-6.28016	0.	HOLE	3	1.45034	-10.04825	0.
HOLE	3	19.57959	-6.28016	0.	HOLE	3	2.90068	-10.04825	0.
HOLE	3	21.02993	-6.28016	0.	HOLE	3	4.35102	-10.04825	0.
HOLE	3	22.48027	-6.28016	0.	HOLE	3	5.80136	-10.04825	0.
HOLE	3	23.93061	-6.28016	0.	HOLE	3	7.25170	-10.04825	0.
HOLE	3	25.38095	-6.28016	0.	HOLE	3	8.70204	-10.04825	0.
COM=*-6 row*					HOLE	3	10.15238	-10.04825	0.
HOLE	3	-24.65578	-7.53619	0.	HOLE	3	11.60272	-10.04825	0.
HOLE	3	-23.20544	-7.53619	0.	HOLE	3	13.05306	-10.04825	0.
HOLE	3	-21.75510	-7.53619	0.	HOLE	3	14.50340	-10.04825	0.
HOLE	3	-20.30476	-7.53619	0.	HOLE	3	15.95374	-10.04825	0.
HOLE	3	-18.85442	-7.53619	0.	HOLE	3	17.40408	-10.04825	0.
HOLE	3	-17.40408	-7.53619	0.	HOLE	3	18.85442	-10.04825	0.
HOLE	3	-15.95374	-7.53619	0.	HOLE	3	20.30476	-10.04825	0.
HOLE	3	-14.50340	-7.53619	0.	HOLE	3	21.75510	-10.04825	0.
HOLE	3	-13.05306	-7.53619	0.	HOLE	3	23.20544	-10.04825	0.
HOLE	3	-11.60272	-7.53619	0.	COM=*-9 row*				
HOLE	3	-10.15238	-7.53619	0.	HOLE	3	-22.48027	-11.30428	0.
HOLE	3	-8.70204	-7.53619	0.	HOLE	3	-21.02993	-11.30428	0.
HOLE	3	-7.25170	-7.53619	0.	HOLE	3	-19.57959	-11.30428	0.
HOLE	3	-5.80136	-7.53619	0.	HOLE	3	-18.12925	-11.30428	0.
HOLE	3	-4.35102	-7.53619	0.	HOLE	3	-16.67891	-11.30428	0.
HOLE	1	-2.90068	-7.53619	0.	HOLE	3	-15.22857	-11.30428	0.
HOLE	1	-1.45034	-7.53619	0.	HOLE	3	-13.77823	-11.30428	0.
HOLE	3	0.	-7.53619	0.	HOLE	3	-12.32789	-11.30428	0.
HOLE	1	1.45034	-7.53619	0.	HOLE	3	-10.87755	-11.30428	0.
HOLE	1	2.90068	-7.53619	0.	HOLE	3	-9.42721	-11.30428	0.

HOLE	3	-7.97687	-11.30428	0.	HOLE	3	-7.25170	-15.07238	0.
HOLE	3	-6.52653	-11.30428	0.	HOLE	3	-5.80136	-15.07238	0.
HOLE	3	-5.07619	-11.30428	0.	HOLE	3	-4.35102	-15.07238	0.
HOLE	3	-3.62585	-11.30428	0.	HOLE	3	-2.90068	-15.07238	0.
HOLE	3	-2.17551	-11.30428	0.	HOLE	3	-1.45034	-15.07238	0.
HOLE	3	-0.72517	-11.30428	0.	HOLE	3	0.	-15.07238	0.
HOLE	3	0.72517	-11.30428	0.	HOLE	3	1.45034	-15.07238	0.
HOLE	3	2.17551	-11.30428	0.	HOLE	3	2.90068	-15.07238	0.
HOLE	3	3.62585	-11.30428	0.	HOLE	3	4.35102	-15.07238	0.
HOLE	3	5.07619	-11.30428	0.	HOLE	3	5.80136	-15.07238	0.
HOLE	3	6.52653	-11.30428	0.	HOLE	3	7.25170	-15.07238	0.
HOLE	3	7.97687	-11.30428	0.	HOLE	3	8.70204	-15.07238	0.
HOLE	3	9.42721	-11.30428	0.	HOLE	3	10.15238	-15.07238	0.
HOLE	3	10.87755	-11.30428	0.	HOLE	3	11.60272	-15.07238	0.
HOLE	3	12.32789	-11.30428	0.	HOLE	3	13.05306	-15.07238	0.
HOLE	3	13.77823	-11.30428	0.	HOLE	3	14.50340	-15.07238	0.
HOLE	3	15.22857	-11.30428	0.	HOLE	3	15.95374	-15.07238	0.
HOLE	3	16.67891	-11.30428	0.	HOLE	3	17.40408	-15.07238	0.
HOLE	3	18.12925	-11.30428	0.	HOLE	3	18.85442	-15.07238	0.
HOLE	3	19.57959	-11.30428	0.	HOLE	3	20.30476	-15.07238	0.
HOLE	3	21.02993	-11.30428	0.	COM=-13 row*				
HOLE	3	22.48027	-11.30428	0.	HOLE	3	-19.57959	-16.32841	0.
COM=-10 row*					HOLE	3	-18.12925	-16.32841	0.
HOLE	3	-21.75510	-12.56031	0.	HOLE	3	-16.67891	-16.32841	0.
HOLE	3	-20.30476	-12.56031	0.	HOLE	3	-15.22857	-16.32841	0.
HOLE	3	-18.85442	-12.56031	0.	HOLE	3	-13.77823	-16.32841	0.
HOLE	3	-17.40408	-12.56031	0.	HOLE	3	-12.32789	-16.32841	0.
HOLE	3	-15.95374	-12.56031	0.	HOLE	3	-10.87755	-16.32841	0.
HOLE	3	-14.50340	-12.56031	0.	HOLE	3	-9.42721	-16.32841	0.
HOLE	3	-13.05306	-12.56031	0.	HOLE	3	-7.97687	-16.32841	0.
HOLE	3	-11.60272	-12.56031	0.	HOLE	3	-6.52653	-16.32841	0.
HOLE	3	-10.15238	-12.56031	0.	HOLE	3	-5.07619	-16.32841	0.
HOLE	3	-8.70204	-12.56031	0.	HOLE	3	-3.62585	-16.32841	0.
HOLE	3	-7.25170	-12.56031	0.	HOLE	3	-2.17551	-16.32841	0.
HOLE	3	-5.80136	-12.56031	0.	HOLE	3	-0.72517	-16.32841	0.
HOLE	3	-4.35102	-12.56031	0.	HOLE	3	0.72517	-16.32841	0.
HOLE	3	-2.90068	-12.56031	0.	HOLE	3	2.17551	-16.32841	0.
HOLE	3	-1.45034	-12.56031	0.	HOLE	3	3.62585	-16.32841	0.
HOLE	3	0.	-12.56031	0.	HOLE	3	5.07619	-16.32841	0.
HOLE	3	1.45034	-12.56031	0.	HOLE	3	6.52653	-16.32841	0.
HOLE	3	2.90068	-12.56031	0.	HOLE	3	7.97687	-16.32841	0.
HOLE	3	4.35102	-12.56031	0.	HOLE	3	9.42721	-16.32841	0.
HOLE	3	5.80136	-12.56031	0.	HOLE	3	10.87755	-16.32841	0.
HOLE	3	7.25170	-12.56031	0.	HOLE	3	12.32789	-16.32841	0.
HOLE	3	8.70204	-12.56031	0.	HOLE	3	13.77823	-16.32841	0.
HOLE	3	10.15238	-12.56031	0.	HOLE	3	15.22857	-16.32841	0.
HOLE	3	11.60272	-12.56031	0.	HOLE	3	16.67891	-16.32841	0.
HOLE	3	13.05306	-12.56031	0.	HOLE	3	18.12925	-16.32841	0.
HOLE	3	14.50340	-12.56031	0.	HOLE	3	19.57959	-16.32841	0.
HOLE	3	15.95374	-12.56031	0.	COM=-14 row*				
HOLE	3	17.40408	-12.56031	0.	HOLE	3	-18.85442	-17.58444	0.
HOLE	3	18.85442	-12.56031	0.	HOLE	3	-17.40408	-17.58444	0.
HOLE	3	20.30476	-12.56031	0.	HOLE	3	-15.95374	-17.58444	0.
HOLE	3	21.75510	-12.56031	0.	HOLE	3	-14.50340	-17.58444	0.
COM=-11 row*					HOLE	3	-13.05306	-17.58444	0.
HOLE	3	-21.02993	-13.81634	0.	HOLE	3	-11.60272	-17.58444	0.
HOLE	3	-19.57959	-13.81634	0.	HOLE	3	-10.15238	-17.58444	0.
HOLE	3	-18.12925	-13.81634	0.	HOLE	3	-8.70204	-17.58444	0.
HOLE	3	-16.67891	-13.81634	0.	HOLE	3	-7.25170	-17.58444	0.
HOLE	3	-15.22857	-13.81634	0.	HOLE	3	-5.80136	-17.58444	0.
HOLE	3	-13.77823	-13.81634	0.	HOLE	3	-4.35102	-17.58444	0.
HOLE	3	-12.32789	-13.81634	0.	HOLE	3	-2.90068	-17.58444	0.
HOLE	3	-10.87755	-13.81634	0.	HOLE	3	-1.45034	-17.58444	0.
HOLE	3	-9.42721	-13.81634	0.	HOLE	3	0.	-17.58444	0.
HOLE	3	-7.97687	-13.81634	0.	HOLE	3	1.45034	-17.58444	0.
HOLE	3	-6.52653	-13.81634	0.	HOLE	3	2.90068	-17.58444	0.
HOLE	3	-5.07619	-13.81634	0.	HOLE	3	4.35102	-17.58444	0.
HOLE	3	-3.62585	-13.81634	0.	HOLE	3	5.80136	-17.58444	0.
HOLE	3	-2.17551	-13.81634	0.	HOLE	3	7.25170	-17.58444	0.
HOLE	3	-0.72517	-13.81634	0.	HOLE	3	8.70204	-17.58444	0.
HOLE	3	0.72517	-13.81634	0.	HOLE	3	10.15238	-17.58444	0.
HOLE	3	2.17551	-13.81634	0.	HOLE	3	11.60272	-17.58444	0.
HOLE	3	3.62585	-13.81634	0.	HOLE	3	13.05306	-17.58444	0.
HOLE	3	5.07619	-13.81634	0.	HOLE	3	14.50340	-17.58444	0.
HOLE	3	6.52653	-13.81634	0.	HOLE	3	15.95374	-17.58444	0.
HOLE	3	7.97687	-13.81634	0.	HOLE	3	17.40408	-17.58444	0.
HOLE	3	9.42721	-13.81634	0.	HOLE	3	18.85442	-17.58444	0.
HOLE	3	10.87755	-13.81634	0.	COM=-15 row*				
HOLE	3	12.32789	-13.81634	0.	HOLE	3	-18.12925	-18.84047	0.
HOLE	3	13.77823	-13.81634	0.	HOLE	3	-16.67891	-18.84047	0.
HOLE	3	15.22857	-13.81634	0.	HOLE	3	-15.22857	-18.84047	0.
HOLE	3	16.67891	-13.81634	0.	HOLE	3	-13.77823	-18.84047	0.
HOLE	3	18.12925	-13.81634	0.	HOLE	3	-12.32789	-18.84047	0.
HOLE	3	19.57959	-13.81634	0.	HOLE	3	-10.87755	-18.84047	0.
HOLE	3	21.02993	-13.81634	0.	HOLE	3	-9.42721	-18.84047	0.
COM=-12 row*					HOLE	3	-7.97687	-18.84047	0.
HOLE	3	-20.30476	-15.07238	0.	HOLE	3	-6.52653	-18.84047	0.
HOLE	3	-18.85442	-15.07238	0.	HOLE	3	-5.07619	-18.84047	0.
HOLE	3	-17.40408	-15.07238	0.	HOLE	3	-3.62585	-18.84047	0.
HOLE	3	-15.95374	-15.07238	0.	HOLE	3	-2.17551	-18.84047	0.
HOLE	3	-14.50340	-15.07238	0.	HOLE	3	-0.72517	-18.84047	0.
HOLE	3	-13.05306	-15.07238	0.	HOLE	3	0.72517	-18.84047	0.
HOLE	3	-11.60272	-15.07238	0.	HOLE	3	2.17551	-18.84047	0.
HOLE	3	-10.15238	-15.07238	0.	HOLE	3	3.62585	-18.84047	0.
HOLE	3	-8.70204	-15.07238	0.	HOLE	3	5.07619	-18.84047	0.

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HOLE      3      6.52653    -18.84047    0.
HOLE      3      7.97687    -18.84047    0.
HOLE      3      9.42721    -18.84047    0.
HOLE      3     10.87755    -18.84047    0.
HOLE      3     12.32789    -18.84047    0.
HOLE      3     13.77823    -18.84047    0.
HOLE      3     15.22857    -18.84047    0.
HOLE      3     16.67891    -18.84047    0.
HOLE      3     18.12925    -18.84047    0.
COM=-16 row*
HOLE      3     -17.40408    -20.09650    0.
HOLE      3     -15.95374    -20.09650    0.
HOLE      3     -14.50340    -20.09650    0.
HOLE      3     -13.05306    -20.09650    0.
HOLE      3     -11.60272    -20.09650    0.
HOLE      3     -10.15238    -20.09650    0.
HOLE      3      -8.70204    -20.09650    0.
HOLE      3      -7.25170    -20.09650    0.
HOLE      3      -5.80136    -20.09650    0.
HOLE      3      -4.35102    -20.09650    0.
HOLE      3      -2.90068    -20.09650    0.
HOLE      3      -1.45034    -20.09650    0.
HOLE      3         0.      -20.09650    0.
HOLE      3      1.45034    -20.09650    0.
HOLE      3      2.90068    -20.09650    0.
HOLE      3      4.35102    -20.09650    0.
HOLE      3      5.80136    -20.09650    0.
HOLE      3      7.25170    -20.09650    0.
HOLE      3      8.70204    -20.09650    0.
HOLE      3     10.15238    -20.09650    0.
HOLE      3     11.60272    -20.09650    0.
HOLE      3     13.05306    -20.09650    0.
HOLE      3     14.50340    -20.09650    0.
HOLE      3     15.95374    -20.09650    0.
HOLE      3     17.40408    -20.09650    0.
COM=-17 row*
HOLE      3     -16.67891    -21.35253    0.
HOLE      3     -15.22857    -21.35253    0.
HOLE      3     -13.77823    -21.35253    0.
HOLE      3     -12.32789    -21.35253    0.
HOLE      3     -10.87755    -21.35253    0.
HOLE      3      -9.42721    -21.35253    0.
HOLE      3      -7.97687    -21.35253    0.
HOLE      3      -6.52653    -21.35253    0.
HOLE      3      -5.07619    -21.35253    0.
HOLE      3      -3.62585    -21.35253    0.
HOLE      3      -2.17551    -21.35253    0.
HOLE      3      -0.72517    -21.35253    0.
HOLE      3       0.72517    -21.35253    0.
HOLE      3      2.17551    -21.35253    0.
HOLE      3      3.62585    -21.35253    0.
HOLE      3      5.07619    -21.35253    0.
HOLE      3      6.52653    -21.35253    0.
HOLE      3      7.97687    -21.35253    0.
HOLE      3      9.42721    -21.35253    0.
HOLE      3     10.87755    -21.35253    0.
HOLE      3     12.32789    -21.35253    0.
HOLE      3     13.77823    -21.35253    0.
HOLE      3     15.22857    -21.35253    0.
HOLE      3     16.67891    -21.35253    0.
COM=-18 row*
HOLE      3     -15.95374    -22.60856    0.
HOLE      3     -14.50340    -22.60856    0.
HOLE      3     -13.05306    -22.60856    0.
HOLE      3     -11.60272    -22.60856    0.
HOLE      3     -10.15238    -22.60856    0.
HOLE      3      -8.70204    -22.60856    0.
HOLE      3      -7.25170    -22.60856    0.
HOLE      3      -5.80136    -22.60856    0.
HOLE      3      -4.35102    -22.60856    0.
HOLE      3      -2.90068    -22.60856    0.
HOLE      3      -1.45034    -22.60856    0.
HOLE      3         0.      -22.60856    0.
HOLE      3      1.45034    -22.60856    0.
HOLE      3      2.90068    -22.60856    0.
HOLE      3      4.35102    -22.60856    0.
HOLE      3      5.80136    -22.60856    0.
HOLE      3      7.25170    -22.60856    0.
HOLE      3      8.70204    -22.60856    0.
HOLE      3     10.15238    -22.60856    0.
HOLE      3     11.60272    -22.60856    0.
HOLE      3     13.05306    -22.60856    0.
HOLE      3     14.50340    -22.60856    0.
HOLE      3     15.95374    -22.60856    0.
COM=-19 row*
HOLE      3     -15.22857    -23.86459    0.
HOLE      3     -13.77823    -23.86459    0.
HOLE      3     -12.32789    -23.86459    0.
HOLE      3     -10.87755    -23.86459    0.
HOLE      3      -9.42721    -23.86459    0.
HOLE      3      -7.97687    -23.86459    0.
HOLE      3      -6.52653    -23.86459    0.
HOLE      3      -5.07619    -23.86459    0.
HOLE      3      -3.62585    -23.86459    0.
HOLE      3      -2.17551    -23.86459    0.
HOLE      3      -0.72517    -23.86459    0.
HOLE      3       0.72517    -23.86459    0.
HOLE      3      2.17551    -23.86459    0.
HOLE      3      3.62585    -23.86459    0.
HOLE      3      5.07619    -23.86459    0.
HOLE      3      6.52653    -23.86459    0.
HOLE      3      7.97687    -23.86459    0.
HOLE      3      9.42721    -23.86459    0.
HOLE      3     10.87755    -23.86459    0.
HOLE      3     12.32789    -23.86459    0.
HOLE      3     13.77823    -23.86459    0.
HOLE      3     15.22857    -23.86459    0.
COM=-20 row*
HOLE      3     -14.50340    -25.12063    0.
HOLE      3     -13.05306    -25.12063    0.
HOLE      3     -11.60272    -25.12063    0.
HOLE      3     -10.15238    -25.12063    0.
HOLE      3      -8.70204    -25.12063    0.
HOLE      3      -7.25170    -25.12063    0.
HOLE      3      -5.80136    -25.12063    0.
HOLE      3      -4.35102    -25.12063    0.
HOLE      3      -2.90068    -25.12063    0.
HOLE      3      -1.45034    -25.12063    0.
HOLE      3         0.      -25.12063    0.
HOLE      3      1.45034    -25.12063    0.
HOLE      3      2.90068    -25.12063    0.
HOLE      3      4.35102    -25.12063    0.
HOLE      3      5.80136    -25.12063    0.
HOLE      3      7.25170    -25.12063    0.
HOLE      3      8.70204    -25.12063    0.
HOLE      3     10.15238    -25.12063    0.
HOLE      3     11.60272    -25.12063    0.
HOLE      3     13.05306    -25.12063    0.
HOLE      3     14.50340    -25.12063    0.
CUBOID    4      1  4P29.8      2P49.5301
GLOBAL
UNIT 6
ARRAY      1      2R-29.8      -49.5301
REFLECTOR  4      2  4*3.1      2*0      10
END GEOM
READ ARRAY
NUX=1  NUY=1  NUZ=1  FILL  F5  END FILL
END ARRAY
READ BIAS
ID=500  2  11
END BIAS
READ START
NST=1  XSM=-30  YSM=-26  ZSM=-19.05
XSP=30  YSP=26  ZSP=19.05
END START
END DATA
END
```