NRC-94-025

Westinghouse
Electric Corporation

Commercial Nuclear
Fuel Division

Drawer R
Columbia South Carolina 29250
(803) 776 2610

May 27, 1994

U. S. Nuclear Regulatory Commission
C. R. Chappell, Section Leader
Cask Certification Section 8F5, TWFN
Storage and Transport Systems Branch
Division of Industrial and Medical Nuclear Safety, IMNS
11555 Rockville Pike
Rockville, MD 20852

Subject: Docket 71-5450: Application for Approval of Packaging, RCC Shipping Containers.

Gentlemen:

The Westinghouse Electric Corporation hereby submits six (6) copies of an application for approval of packaging of fissile radioactive material (RCC Shipping Containers) -- package identification number USA/5450/AF.

If you have any questions concerning this submittal, please write to me at the above address; telephone (803) 776-2610, extension 3426; or fax (803) 695-3964.

C. F. Sanders

C. F. Sanders, Manager
Nuclear Material Management & Product Records

Delete LA

NT01
1/1

APPLICATION DETAILS

May 27, 1994

1. The shipments shall consist of 14x14 CE-1 type fuel assemblies.

2. The fuel stack will consist of 136.25 inches (nominal) of UO_2 enriched to 4.80% (maximum) ^{235}U, with the top 6.8 inches of the fuel made of annular pellets; the middle 122.65 inches of fuel made of solid pellets; and the bottom 6.8 inches of fuel made of annular pellets. Figure 1 shows the annular pellet; Figure 2 shows the fuel stack in the rod. The solid pellets are the same length and OD as the annular pellets.

3. All parameters for this fuel are listed in Table 1 of this application.

4. Clamping frames are positioned at each zircaloy grid, and the 14x14 CE-1 assembly has seven (7) zircaloy grids. Figure 4 illustrates the positions of the clamping frame arms along the assembly's length.

5. KENO calculations and benchmarking are discussed in following pages.

TABLE 1

FUEL ASSEMBLY PARAMETERS
CE-1 TYPE ASSEMBLY WITH ANNULAR END ZONES

Fuel Assembly Description	14 x 14
Fuel Assembly Type	CE-1
Nominal Pellet Diameter	0.3765
Annular Pellet Inner Diameter	0.183
Nominal Clad Thickness	0.0280
Clad Material	Zircaloy
Nominal Clad Outer Diameter	0.4400
Guide Thimble Diameter	1.1110
Guide Thimble Thickness	0.0380
Guide Thimble Material	Zircaloy
Instrumentation Tube Diameter	1.1110
Instrumentation Tube Thickness	0.0380
Instrumentation Tube Material	Zircaloy
Maximum Stack Length	137
Nominal Assembly Envelope	8.110
Kg's ^{235}U/Assembly	18.6
Nominal Lattice Pitch	0.5800
Assembly K_{∞}	0.9296

FIGURE 1

ENRICHED ANNULAR AXIAL BLANKET PELLET

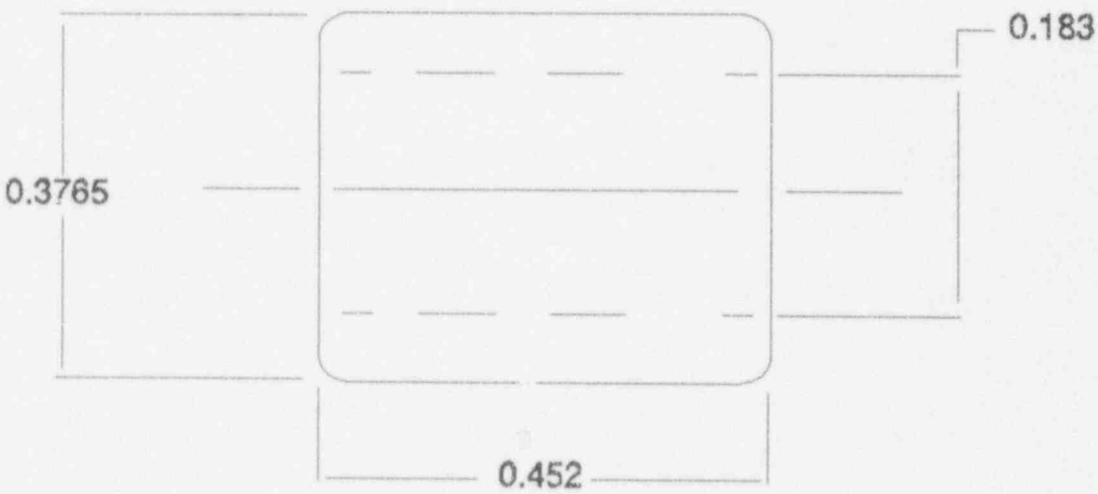


FIGURE 2

MAINE YANKEE 14X14 CE-1 FUEL STACK

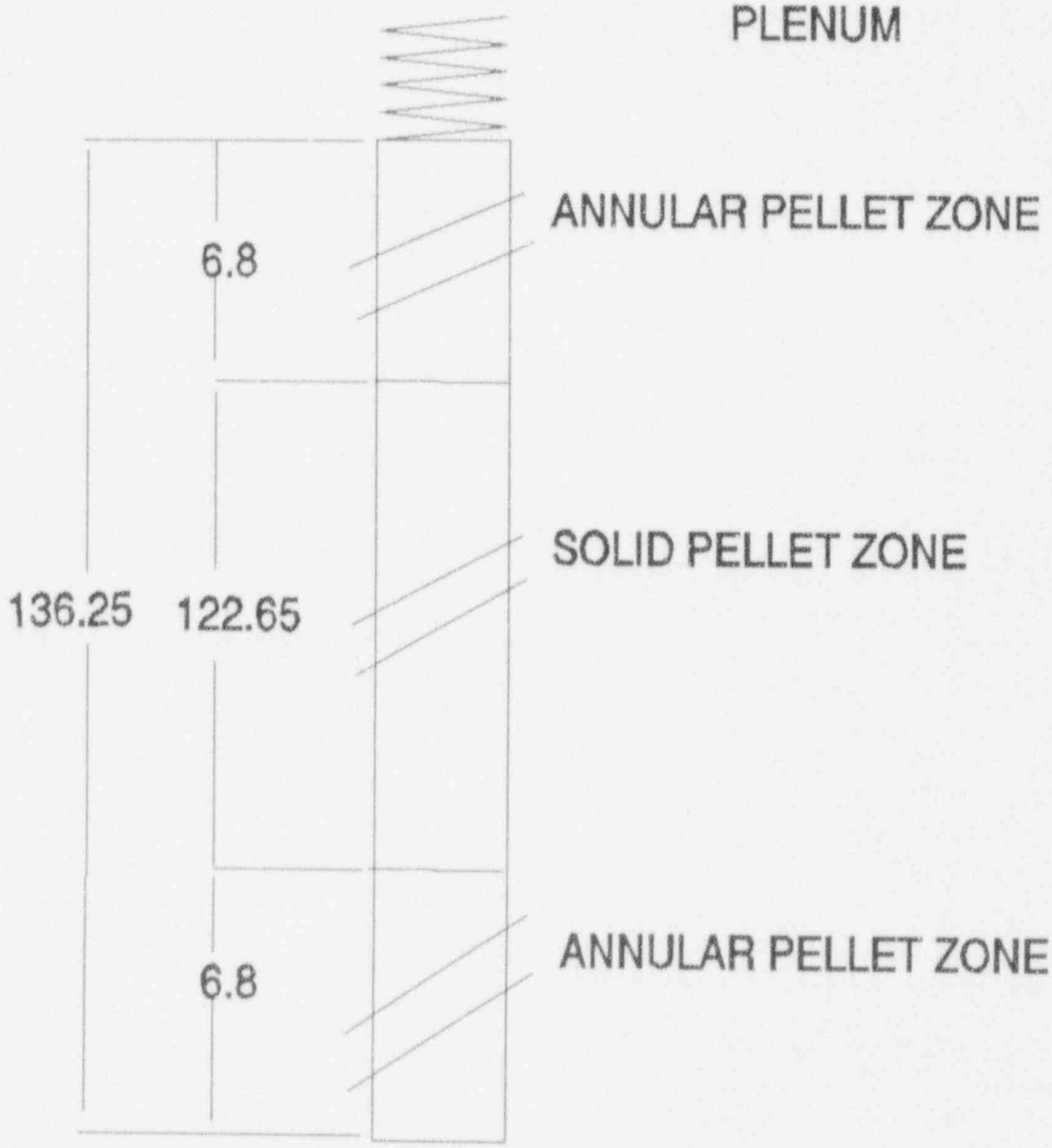
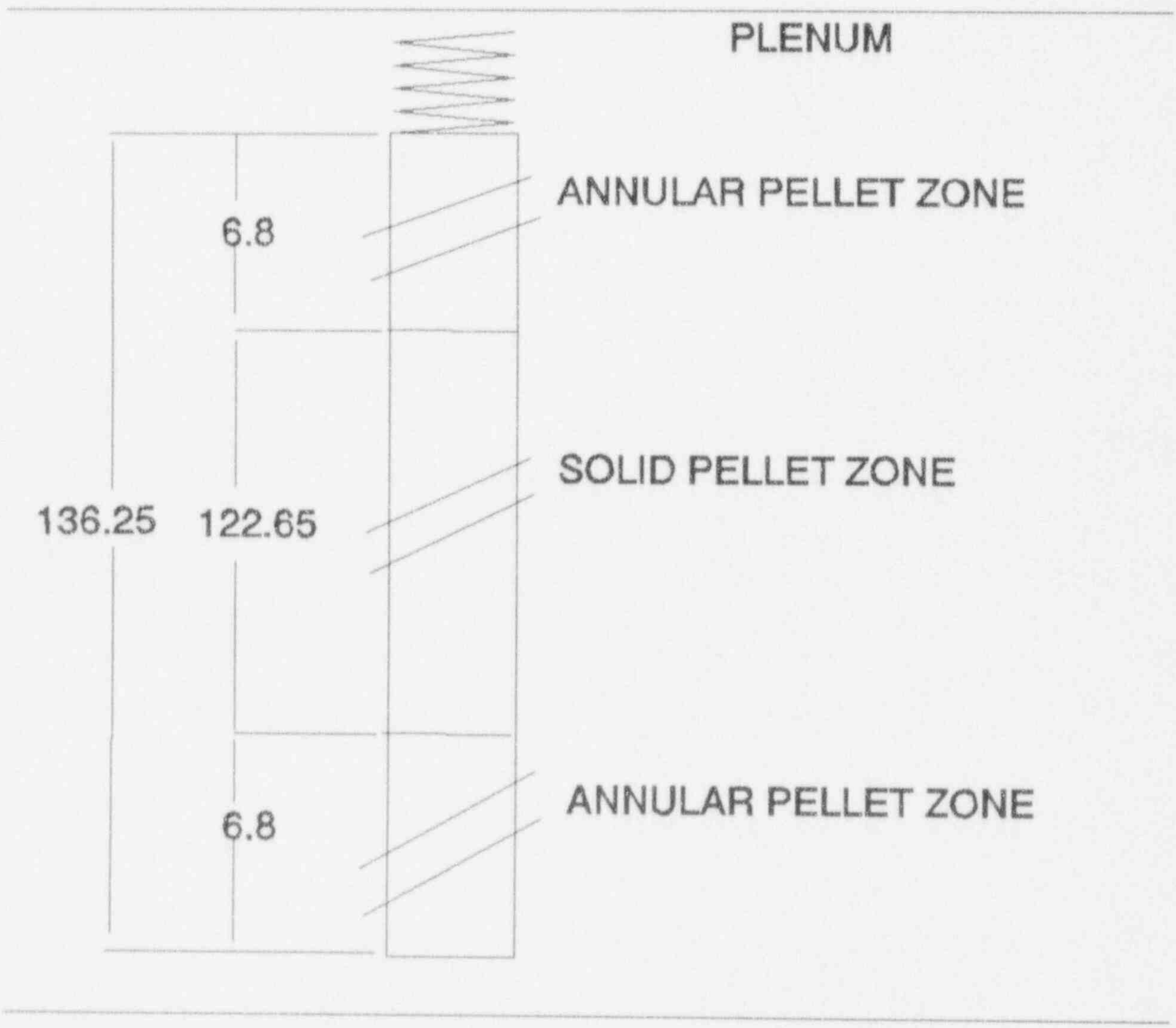


FIGURE 2

MAINE YANKEE 14X14 CE-1 FUEL STACK



FUEL PIN GAP FLOODING WITH ANNULAR FUEL BLANKETS

This section considers the effect of flooding inside a fuel pin with full density water and outside the pins with full and partial density water. Included in the analysis is 6.8 inches of annular fuel at the top and bottom of each assembly. All fuel is enriched to 4.8 w/o ^{235}U. The 14x14 CE-1 type fuel was considered. The KENO model of the shipping container used in the fuel pin gap flooding cases (with annular fuel measuring 6.8 inches at the top and bottom) is shown in Figure 3. For the fuel pin gap flooding evaluation, three-dimensional features were used to model the entire fuel stack length, including 6.8 inches of annular fuel at the top and bottom of the fuel stack length.

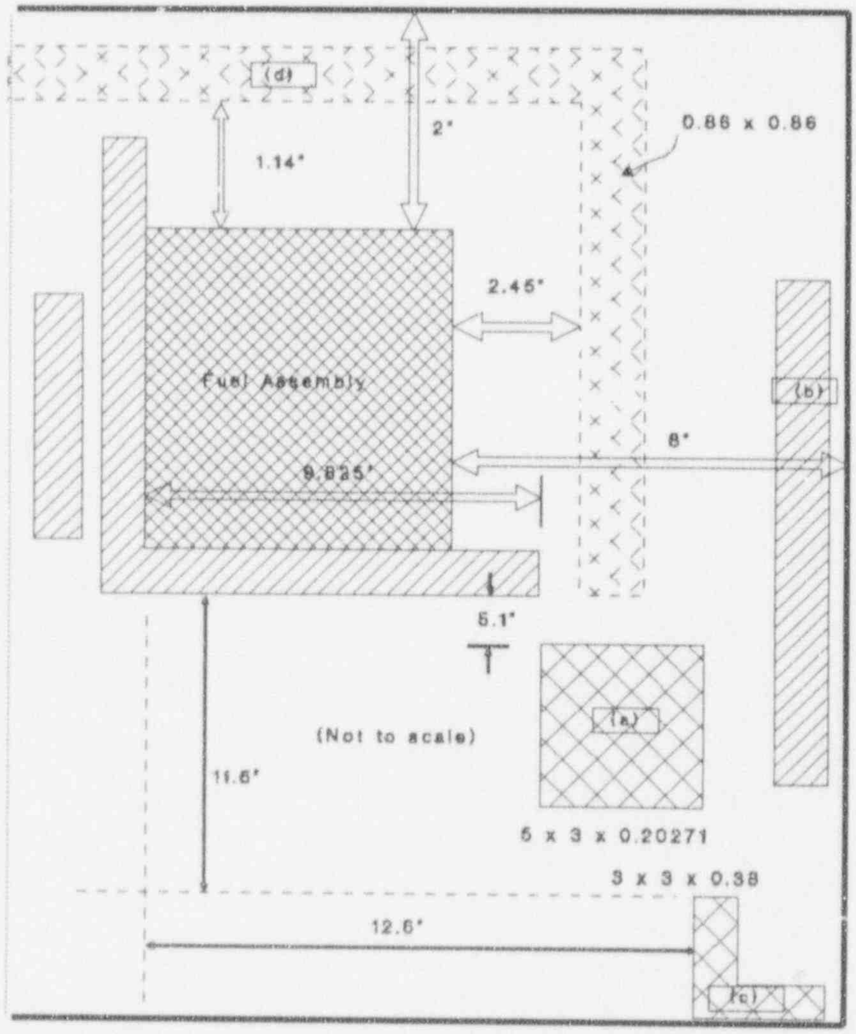
The fuel pin gap flooding model considered for 14x14 CE-1 type fuel assemblies is a 3D model which considers half the length of the shipping container with a reflective boundary condition at the mid-plane. Seven clamping arms are modeled symetrically about the shipping container mid-plane. This approximation will have little effect on the overall reactivity of the model since the clamping arms are very small (0.8 inches) relative to the arm center-to-center spacing (19 inches). Vertical gadolinia plates were included in the model. Additional steel components are also modeled here as in the optimum moderation cases. The clamping frame spacing is illustrated in Figure 4.

Results are shown in Table 2 for water flooding at full density in both the fuel pin gap and annular fuel blanket annulus. These results show that the K_{eff} limit is met for 14x14 CE-1 type fuel assemblies under conditions of full density water flooding in the fuel pin gap and annulus and and full density water outside the pins. The input deck for this 14x14 CE-1 type fuel assembly KENO model is listed in Table 5.

Results are shown in Figure 5 for water flooding at partial densities to determine the peak reactivity. The peak K_{eff} is listed in Table 2. The fuel pin gap and annulus remain flooded with full density water. Results show a K_{eff} much less than 0.95 for conditions of full water density flooding in the fuel pin gap and annulus and partial water density flooding outside the pins. The input deck for this KENO model is listed in Table 6.

FIGURE 3

KENO MODEL OF SQUARE LATTICE ASSEMBLY WITHIN CONTAINER



(a) UNISTRUT CHANNEL-SIDE STRONGBACK SKIN - 4X3X.25 CRADLE ANGLE
(b) 3x2x5/16 SEALING FLANGES - 1.65x7.19x.19 SHOCKMOUNT ANGLE
(c) 3x3x.38 SKID MOUNT FLANGE
(d) CLAMPFRAME

FIGURE 4

GRID (CLAMPING FRAME ARM) SPACING
14X14 MAINE YANKEE FUEL ASSEMBLY

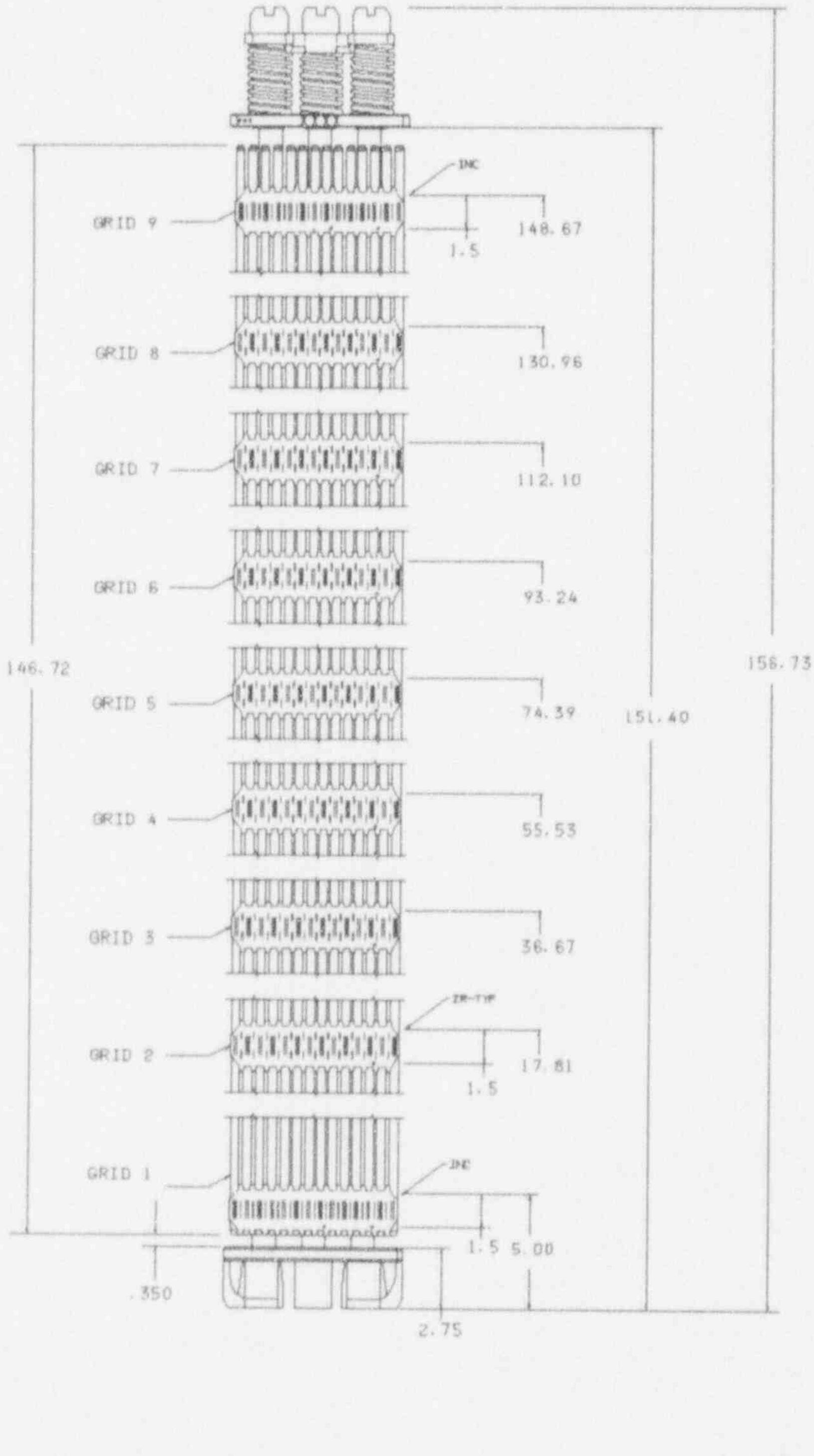


TABLE 2

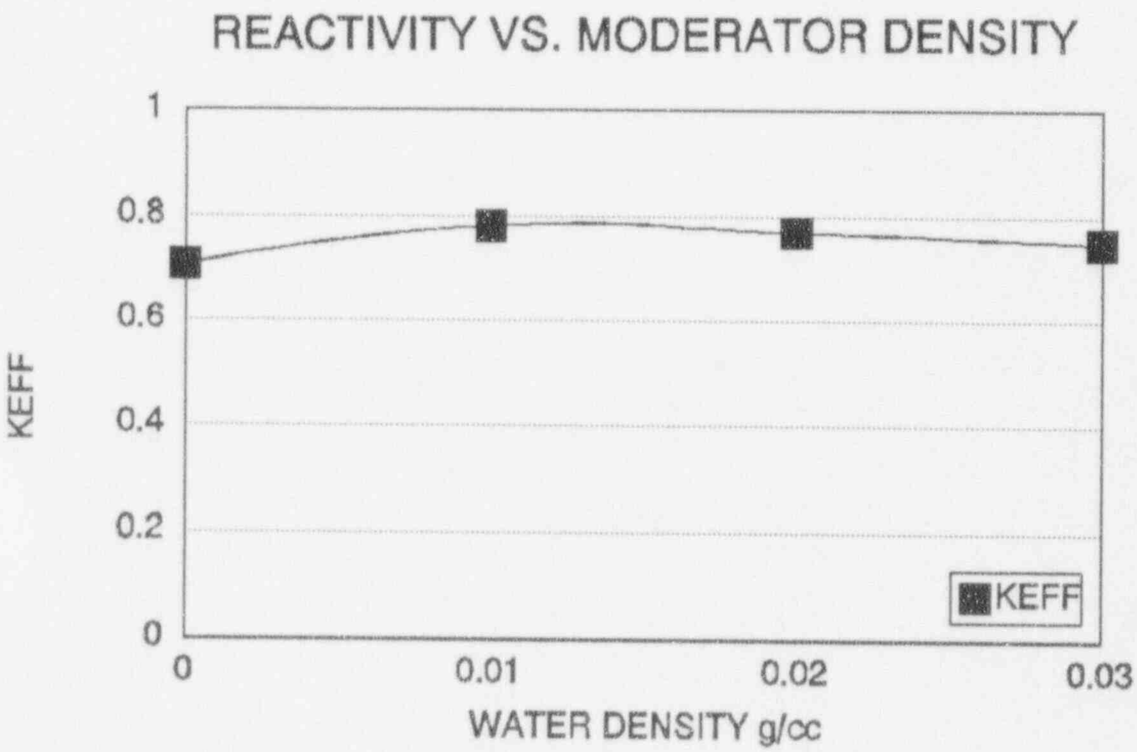
SUMMARY OF KENO CALCULATIONAL RESULTS

Assembly Type	Enrichment Wt.%	KENO $K_{eff} \pm 1\sigma$	95/95 with Bias
Fuel Pin Gap Flooding with Annular Fuel Blankets[1] -- Full Water Density Outside the Pins			
14x14 CE-1	4.8	0.9349 ± 0.00167	0.9466
Fuel Pin Gap Flooding with Annular Fuel Blankets[1] -- Partial Water Density Outside the Pins			
14x14 CE-1	4.8	0.7733 ± 0.00144	0.7843

[1] Annular fuel blankets consist of 6.8 inches of annular fuel and top and bottom of rods.

FIGURE 5

OPTIMUM MODERATION



BENCHMARK EXPERIMENTS AND APPLICABILITY

The criticality calculation method and cross-section values are verified by comparison with critical experiment data for fuel assemblies similar to those for which the shipping container is designed. This benchmarking data is sufficiently diverse to establish that the method bias and uncertainty will apply to shipping container conditions which include strong neutron absorbers and large water gaps.

A set of 32 critical experiments has been analyzed using the above method to demonstrate its applicability to criticality analysis and to establish the method bias and uncertainty. The benchmark experiments cover a wide range of geometries, materials and enrichments; ranging from relatively low enriched (2.35, 2.46, and 4.31 wt%), water moderated, oxide fuel arrays, separated by various materials (B_4C, aluminum, steel, water, etc) that simulate LWR fuel shipping and storage conditions; to dry, harder spectrum, uranium metal cylinder arrays at high enrichments (93.2 wt%), with various interspersed materials (Plexiglas and air). Comparison with these experiments demonstrates the wide range of applicability of the method.

DETAILS OF THE BENCHMARK CALCULATIONS

All experiments were modeled without complication. Material densities and geometries were taken directly from the references. No critical experiments were eliminated on the basis of anomalous results.

RESULTS OF THE BENCHMARK CALCULATIONS

Descriptions and results of the 32 critical experiments as executed on an HP-735 series workstation are provided in Table 3; benchmark calculation statistics are given in Table 4. These results are appropriate for all calculations performed after January 1, 1994.

The 32 low enriched, water-moderated experiments result in an average KENO Va K_{eff} of 0.9930. Comparison with the average measured experimental K_{eff} of 1.0007 results in a method bias of 0.0077. The standard deviation of the bias value is 0.0013 ΔK. The 95/95 one-sided tolerance limit factor for 32 values is 2.20. Thus, there is a 95 percent probability with a 95 percent confidence level that the uncertainty in reactivity, due to the method, is not greater than 0.0030 ΔK.

The results of even higher enrichment benchmark experiments show that the criticality method can correctly predict the reactivity of a hard spectrum environment, such as the optimum moderation scenario often considered in fresh rack and shipping cask designs. However, the results of such higher enrichment benchmarks are not incorporated into the criticality method bias because the enrichments are well beyond the range of typical applications. Basing the method bias solely on the 32 low enriched benchmarks results in a more appropriate and more conservative bias.

The final equation for all K_{eff} calculations is defined as follows:

$$Final\ K_{eff}=K_{nom}+B_{meth}+\sqrt{(Ks_{nom})^2+(Ks_{meth})^2}$$

where,

Final K_{eff} is the calculated K_{eff} with bias and all uncertainties included at the 95 percent confidence level;

K_{nom} is the average K_{eff} generated from Keno Va;

B_{meth} is the bias associated with the Keno methodology established from comparison with critical experiments;

Ks_{nom} is the 95/95 uncertainty on the KENO calculation result;

Ks_{meth} is the 95/95 uncertainty associated with the KENO method bias.

TABLE 3
BENCHMARK CRITICAL UO_2 ROD LATTICE EXPERIMENTS USING AN HP-735 WORKSTATION

Critical Number	Enrichment ^{235}U wt%	Reflector Material	Separating Material	Soluble Boron (ppm)	Measured K_{eff}	KENO Reactivity $K_{eff} \pm 1\sigma$
1	2.46	water	water	0	1.0002	0.9935 ± 0.0023
2	2.46	water	water	1037	1.0001	0.9936 ± 0.0019
3	2.46	water	water	764	1.0000	0.9946 ± 0.0019
4	2.46	water	B_4C pins	0	0.9999	0.9877 ± 0.0022
5	2.46	water	B_4C pins	0	1.0000	0.9884 ± 0.0022
6	2.46	water	B_4C pins	0	1.0097	1.0013 ± 0.0022
7	2.46	water	B_4C pins	0	0.9998	0.9957 ± 0.0023
8	2.46	water	B_4C pins	0	1.0083	0.9991 ± 0.0021
9	2.46	water	water	0	1.0030	0.9966 ± 0.0023
10	2.46	water	water	143	1.0001	0.9971 ± 0.0020
11	2.46	water	stainless steel	514	1.0000	0.9986 ± 0.0020
12	2.46	water	stainless steel	217	1.0000	0.9941 ± 0.0021
13	2.46	water	borated aluminum	15	1.0000	0.9923 ± 0.0022
14	2.46	water	borated aluminum	92	1.0001	0.9885 ± 0.0021
15	2.46	water	borated aluminum	395	0.9998	0.9842 ± 0.0021
16	2.46	water	borated aluminum	121	1.0001	0.9847 ± 0.0021
17	2.46	water	borated aluminum	487	1.0000	0.9852 ± 0.0020
18	2.46	water	borated aluminum	197	1.0002	0.9920 ± 0.0021
19	2.46	water	borated aluminum	634	1.0002	0.9892 ± 0.0020
20	2.46	water	borated aluminum	320	1.0003	0.9946 ± 0.0020
21	2.46	water	borated aluminum	72	0.9997	0.9877 ± 0.0022
22	2.35	water	borated aluminum	0	1.0000	0.9935 ± 0.0013
23	2.35	water	stainless steel	0	1.0000	0.9957 ± 0.0012
24	2.35	water	water	0	1.0000	0.9979 ± 0.0024
25	2.35	water	stainless steel	0	1.0000	0.9896 ± 0.0024
26	2.35	water	borated aluminum	0	1.0000	0.9884 ± 0.0023
27	2.35	water	B_4C	0	1.0000	0.9902 ± 0.0023
28	4.31	water	stainless steel	0	1.0000	0.9906 ± 0.0025
29	4.31	water	water	0	1.0000	0.9899 ± 0.0023
30	4.31	water	stainless steel	0	1.0000	1.0001 ± 0.0025
31	4.31	water	borated aluminum	0	1.0000	1.0007 ± 0.0025
32	4.31	water	borated aluminum	0	1.0000	1.0009 ± 0.0025

TABLE 4

BENCHMARK CALCULATION STATISTICS FOR AN HP-735 WORKSTATION

Number of Experiments	32
Average Measured K_{eff} (K_m)	1.0007
Average KENO Va K_{eff} (K_c)	0.9930
KENO Va Bias (K_m - K_c)	0.0077
Bias Standard Deviation (s)	0.0013
One Sided Tolerance Factor for 95/95 (k)	2.20
95/95 Bias Uncertainty (ks)	0.0030

REFERENCES

1. Ford III, W.E., et. al.; CSRL-V: PROCESSED ENDF/B-V 227-NEUTRON-GROUP AND POINTWISE CROSS-SECTION LIBRARIES FOR CRITICALITY SAFETY, REACTOR, AND SHIELDING STUDIES; NUREG/CR-2306; June 1982.

2. Greene, N.M., et. al.; AMPX: A MODULAR CODE SYSTEM FOR GENERATING COUPLED MULTIGROUP NEUTRON-GAMMA LIBRARIES FROM ENDF/B; ORNL-TM-3706; March 1976.

3. Petrie, L.M., Landers, N.F.; KENO Va - AN IMPROVED MONTE CARLO CRITICALITY PROGRAM WITH SUPERGROUPING; NUREG/CR-0200; December 1984.

4. N. M. Baldwin, "Critical Experiments Supporting Close Proximity Water Storage of Power Reactor Fuel," B&W-1484-7, July 1979.

5. S. R. Bierman and E. D. Clayton, "Criticality Separation Between Subcritical Clusters of 2.35 wt% 235U Enriched UO2 Rods in Water with Fixed Neutron Poisons," PNL-2438, Pacific Northwest Laboratory, October 1977.

6. S. R. Bierman and E. D. Clayton, "Criticality Experiments with Subcritical Clusters of 2.35 wt% and 4.31 wt% 235U Enriched UO2 Rods in Water at a Water-to-Fuel Volume Ratio of 1.6," PNL-3314, Pacific Northwest Laboratory, July 1980.

7. S. R. Bierman and E. D. Clayton, "Critical Separation Between Subcritical Clusters of 4.29 wt% 235U Enriched UO2 Rods in Water with Fixed Neutron Poisons," PNL-2615, Pacific Northwest Laboratory, August 1979.

8. J. T. Thomas, "Critical Three-Dimensional Arrays of U(93.2) Metal Cylinders," Nuclear Science and Engineering, Volume 52, pages 350-359, 1973.

TABLE 5

KENO INPUT FOR FULL WATER DENSITY CASE

```
Full Water Density Case

title-cask with 14x14 ce 4.80 w/o assembly, clamps

read parameters
  tme=60    run=yes   plt=yes
  gen=300   npg=310   nsk=005   lib=29
  xs1=yes   nub=yes
end parameters

read mixt  sct=2
mix= 1
' solid uo2 pellet 4.80 w/o (96.5% td, 0% dish)
         1192235     0.0011465
         1192238     0.022451
          118016     0.047195
mix= 2
' h2o at 1.00 g/cc in solid pellet gap
          231001     0.066854
          238016     0.033427
mix= 3
' solid zirc fuel rod cladding
         2140302     0.043326
mix= 4
' h2o at 1.00 g/cc in blanket fuel annulus
          151001     0.066854
          158016     0.033427
mix= 5
' annular uo2 pellet 4.80 w/o (96.5% td)
         2292235     0.0011465
         2292238     0.022451
          228016     0.047195
mix= 6
' h2o at 1.00 g/cc in annular pellet gap
          341001     0.066854
          348016     0.033427
mix= 7
```

```
' annular zirc fuel rod cladding
        3240302     0.043326
mix= 8
' h2o at 1.00 g/cc
          31001     0.066854
          38016     0.033427
mix= 9
'  carbon steel for strongback & shell
          36012     4.728898e-4
         315031     5.807008e-5
         316032     6.642906e-5
         325055     3.877064e-4
         326000     8.420119e-2
mix= 10
'  gadolinia oxide absorber (0.02 gm gd2o3/cm2 @ 0.01016 cm thickness)
          48016     9.810529e-3
         464152     1.308071e-5
         464154     1.373474e-4
         464155     9.679722e-4
         464156     1.347313e-3
         464157     1.026835e-3
         464158     1.622008e-3
         464160     1.425792e-3
mix= 11
'  carbon steel sheet for gd absorber
          56012     4.728898e-4
         515031     5.807008e-5
         516032     6.642906e-5
         525055     3.877064e-4
         526000     8.420119e-2
end mixt

read geometry
unit 1
com=" 14x14 ce fuel rod - enriched region"
cylinder   1  1    0.478155  155.7655  0.0
cylinder   2  1    0.48768   155.7655  0.0
cylinder   3  1    0.55880   155.7655  0.0
cuboid     8  1  4p0.73660   155.7655  0.0
unit 2
com=" 14x14 ce guide and instrument tube - enriched region"
cylinder   8  1    1.31445   155.7655  0.0
cylinder   3  1    1.41097   155.7655  0.0
```

```
cuboid     8  1  4p1.47320   155.7655  0.0
unit 3
com=" 14x14 cfa fuel rod - blanket region"
cylinder   4  1    0.23241    17.272  0.0
cylinder   5  1    0.478155   17.272  0.0
cylinder   6  1    0.48768    17.272  0.0
cylinder   7  1    0.55880    17.272  0.0
cuboid     8  1  4p0.73660    17.272  0.0
unit 4
com=" 14x14 ce  guide and instrument tube - blanket region"
cylinder   8  1    1.31445    17.272  0.0
cylinder   3  1    1.41097    17.272  0.0
cuboid     8  1  4p1.47320    17.272  0.0
unit 7      com='strong back, horizontal'
  cuboid    9 1 25.413 0.0  0.4572  0.0  204.01  0.0
unit 8      com='strong back, vertical'
  cuboid    9 1 0.4572 0.0  24.14   0.0  204.01  0.0
unit 9      com='verticle gad poison plat between assembly'
  cuboid   11 1 0.0889 0.0  18.415  0.0   204.01  0.0
  cuboid   10 1 .09906 -.01016 18.415 0.0 204.01  0.0
unit 10     com='rest of strongback and cradle'
  cuboid    8 1 7.1051 0.5149 12.1851 0.5149 204.01  0.0
  cuboid    9 1 7.62   0.0    12.70   0.0    204.01  0.0
unit 11     com='container flanges and bracket'
  cuboid    9 1 1.285  0.0    22.86   0.0    204.01  0.0
unit 12     com='skid angle'
  cuboid    8 1 7.62   0.9652 7.62    0.9652 204.01  0.0
  cuboid    9 1 7.62   0.0    7.62    0.0    204.01  0.0
unit 13     com='middle top clamping assembly'
  cuboid    9 1 26.21  0.0    2.1     0.0   1.05    0.0
unit 14     com='middle side clamping assembly'
  cuboid    9 1  2.1   0.0    25.69   0.0   1.05    0.0
unit 15     com='unistrut channel assembly'
  cuboid    8 1 1.799  0.0    3.556   0.7399 204.01  0.0
  cuboid    9 1 2.538  0.0    3.556   0.0    204.01  0.0
unit 16     com='top clamping assembly'
  cuboid    9 1 26.21  0.0    2.1     0.0   2.1     0.0
unit 17     com='side clamping assembly'
  cuboid    9 1  2.1   0.0    25.69   0.0   2.1     0.0

global
unit 21
com=" 14x14 ce assembly in cask "
```

```
array 1   0.0        0.0        0.0
cuboid      8  1    40.9448  -3.1    25.7048   -38.56    205.74   0.0

hole       7  -0.4572  -0.4572   0.0
hole       8  -0.4572   0        0.0
hole       9  -0.8979  -0.8128   0.0
hole      10  24.958   -18.237   0.0
hole      11  39.21    -12.7     0.0
hole      12  30.48    -37.9172  0.0
hole      13  0.01      23.60    0.0
hole      14  26.225     0.01    0.0
hole      16  0.01      23.60    48
hole      17  26.225     0.01    48
hole      16  0.01      23.6     96
hole      17  26.225     0.01    96
hole      16  0.01      23.6     144
hole      17  26.225     0.01    144
hole      15  -2.997    20.87    0.0
cuboid      9  1    41.17086    -3.1    25.93086   -38.786  205.74   0.0

unit 22
com=" 2x2 bundle of fuel rods - enriched region"
array 2 2r-1.47320 0.0

unit 23
com=" 2x2 bundle of fuel rods - blanket region"
array 3 2r-1.47320 0.0

end geom

read array
ara=1 nux=7 nuy=7 nuz=2 com=" 14x14 ce assembly "
loop
 22  1  7  1   1  7  1   1 1 1
  2  2  6  4   2  6  4   1 1 1
  2  4  4  1   4  4  1   1 1 1
 23  1  7  1   1  7  1   2 2 1
  4  2  6  4   2  6  4   2 2 1
  4  4  4  1   4  4  1   2 2 1
end loop

ara=2 nux=2 nuy=2 nuz=1 com="2x2 bundle of fuel rods - enriched region"
fill f1 end fill
```

```
ara=3 nux=2 nuy=2 nuz=1 com="2x2 bundle of fuel rods - blanket region"
fill f3 end fill

end array

read bounds
all=specular
end bounds

read plot
  ttl='box slice through cask'
  pic=box
  nch='0ugiugiabcdefhjklmnop.'
  xul= -4.0      yul= 26.0      zul= 48.2
  xlr= 45.0      ylr= -40.0     zlr= 48.2
  uax=1.0    vdn=-1.0   nax=130 end
  ttl='mat slice through cask'
  pic=mat
  nch='0u.z.u.z.sg.
  xul= -4.0      yul= 26.0      zul= 48.2
  xlr= 45.0      ylr= -40.0     zlr= 48.2
  uax=1.0    vdn=-1.0   nax=130 end
  ttl='mat slice through assembly'
  pic=mat
  nch='0u.z.u.z.sgs'
  xul= 0.0       yul= 21.0   zul= 48.2
  xlr= 21.0      ylr= 0.0    zlr= 48.2
  uax=1.0    vdn=-1.0   nax=130 end
  ttl='mat slice through annular pellet'
  pic=mat
  nch='0u.z.u.z.sgs'
  xui= 0.0       yul= 21.0   zul= 165.0
  xlr= 21.0      ylr= 0.0    zlr= 165.0
  uax=1.0    vdn=-1.0   nax=130 end end

end plot

end data
end
```

TABLE 6

KENO INPUT FOR PARTIAL WATER DENSITY CASE

Optimum Moderation Density Case

```
title-cask with 14x14 ce 4.80 w/o assembly, clamps

read parameters
 tme=60   run=yes   plt=yes
 gen=300  npg=310   nsk=005   lib=29
 xs1=yes  nub=yes
end parameters

read mixt  sct=2
mix= 1
' solid uo2 pellet 4.80 w/o (96.5% td, 0% dish)
        1192235    0.0011465
        1192238    0.022451
         118016    0.047195
mix= 2
' h2o at 1.00 g/cc in solid pellet gap
         231001    0.066854
         238016    0.033427
mix= 3
' solid zirc fuel rod cladding
       2140302    0.043326
mix= 4
' h2o at 1.00 g/cc in blanket fuel annulus
         151001    0.066854
         158016    0.033427
mix= 5
' annular uo2 pellet 4.80 w/o (96.5% td)
        2292235    0.0011465
        2292238    0.022451
         228016    0.047195
mix= 6
' h2o at 1.00 g/cc in annular pellet gap
         341001    0.066854
         348016    0.033427
mix= 7
' annular zirc fuel rod cladding
```

```
        3240302     0.043326
mix= 8
' h2o at 0.01 g/cc
         31001      0.00066854
         38016      0.00033427
mix= 9
'  carbon steel for strongback & shell
         36012      4.728898e-4
        315031      5.807008e-5
        316032      6.642906e-5
        325055      3.877064e-4
        326000      8.420119e-2
mix= 10
'  gadolinia oxide absorber (0.02 gm gd2o3/cm2 @ 0.01016 cm thickness)
         48016      9.810529e-3
        464152      1.308071e-5
        464154      1.373474e-4
        464155      9.679722e-4
        464156      1.347313e-3
        464157      1.026835e-3
        464158      1.622008e-3
        464160      1.425792e-3
mix= 11
'  carbon steel sheet for gd absorber
         56012      4.728898e-4
        515031      5.807008e-5
        516032      6.642906e-5
        525055      3.877064e-4
        526000      8.420119e-2
end mixt

read geometry
unit 1
com=" 14x14 ce fuel rod - enriched region"
cylinder   1  1    0.478155  155.7655  0.0
cylinder   2  1    0.48768   155.7655  0.0
cylinder   3  1    0.55880   155.7655  0.0
cuboid     8  1  4p0.73660   155.7655  0.0
unit 2
com=" 14x14 ce guide and instrument tube - enriched region"
cylinder   8  1    1.31445   155.7655  0.0
cylinder   3  1    1.41097   155.7655  0.0
cuboid     8  1  4p1.47320   155.7655  0.0
```

```
unit 3
com=" 14x14 ofa fuel rod - blanket region"
cylinder    4  1    0.23241     17.272  0.0
cylinder    5  1    0.478155    17.272  0.0
cylinder    6  1    0.48768     17.272  0.0
cylinder    7  1    0.55880     17.272  0.0
cuboid      8  1  4p0.73660     17.272  0.0
unit 4
com=" 14x14 ce  guide and instrument tube - blanket region"
cylinder    8  1    1.31445     17.272  0.0
cylinder    3  1    1.41097     17.272  0.0
cuboid      8  1  4p1.47320     17.272  0.0
unit 7       com='strong back, horizontal'
  cuboid     9 1 25.413 0.0  0.4572  0.0  204.01  0.0
unit 8       com='strong back, vertical'
  cuboid     9 1 0.4572 0.0  24.14   0.0  204.01  0.0
unit 9       com='verticle gad poison plat between assembly'
  cuboid    11 1 0.0889 0.0  18.415  0.0   204.01  0.0
  cuboid    10 1 .09906 -.01016 18.415 0.0 204.01  0.0
unit 10      com='rest of strongback and cradle'
  cuboid     8 1 7.1051 0.5149 12.1851 0.5149 204.01  0.0
  cuboid     9 1 7.62   0.0     12.70   0.0    204.01  0.0
unit 11      com='container flanges and bracket'
  cuboid     9 1 1.285  0.0     22.86   0.0    204.01  0.0
unit 12      com='skid angle'
  cuboid     8 1 7.62   0.9652 7.62    0.9652 204.01  0.0
  cuboid     9 1 7.62   0.0    7.62    0.0    204.01  0.0
unit 13      com='middle top clamping assembly'
  cuboid     9 1 26.21  0.0    2.1     0.0   1.05    0.0
unit 14      com='middle side clamping assembly'
  cuboid     9 1  2.1   0.0    25.69   0.0   1.05    0.0
unit 15      com='unistrut channel assembly'
  cuboid     8 1 1.799  0.0    3.556   0.7399 204.01  0.0
  cuboid     9 1 2.538  0.0    3.556   0.0    204.01  0.0
unit 16      com='top clamping assembly'
  cuboid     9 1 26.21  0.0    2.1     0.0   2.1     0.0
unit 17      com='side clamping assembly'
  cuboid     9 1  2.1   0.0    25.69   0.0   2.1     0.0

global
unit 21
com=" 14x14 ce assembly in cask "
array 1   0.0       0.0       0.0
```

```
cuboid     8  1   40.9448  -3.1    25.7048   -38.56    205.74   0.0

hole       7  -0.4572  -0.4572   0.0
hole       8  -0.4572   0         C.0
hole       9  -0.8979  -0.8128   0.0
hole      10  24.958   -18.237   0.0
hole      11  39.21    -12.7     0.0
hole      12  30.48    -37.9172  0.0
hole      13  0.01     23.60     0.0
hole      14  26.225    0.01     0.0
hole      16  0.01     23.60    48
hole      17  26.225    0.01    48
hole      16  0.01     23.6     96
hole      17  26.225    0.01    96
hole      16  0.01     23.6    144
hole      17  26.225    0.01   144
hole      15  -2.997   20.87     0.0
cuboid     9  1   41.17086   -3.1   25.93086   -38.786  205.74   0.0

unit 22
com=" 2x2 bundle of fuel rods - enriched region"
array 2 2r-1.47320 0.0

unit 23
com=" 2x2 bundle of fuel rods - blanket region"
array 3 2r-1.47320 0.0

end geom

read array
ara=1 nux=7 nuy=7 nuz=2 com=" 14x14 ce assembly "
loop
 22  1  7  1   1  7  1   1 1 1
  2  2  6  4   2  6  4   1 1 1
  2  4  4  1   4  4  1   1 1 1
 23  1  7  1   1  7  1   2 2 1
  4  2  6  4   2  6  4   2 2 1
  4  4  4  1   4  4  1   2 2 1
end loop

ara=2 nux=2 nuy=2 nuz=1 com="2x2 bundle of fuel rods - enriched region"
fill f1 end fill
```

```
ara=3 nux=2 nuy=2 nuz=1 com="2x2 bundle of fuel rods - blanket region"
fill f3 end fill

end array

read bounds
all=specular
end bounds

read plot
  ttl='box slice through cask'
  pic=box
  nch='0ugiugiabcdefhjklmnop.'
  xul= -4.0     yul= 26.0     zul= 48.2
  xlr= 45.0     ylr= -40.0    zlr= 48.2
  uax=1.0    vdn=-1.0   nax=130 end
  ttl='mat slice through cask'
  pic=mat
  nch='0u.z.u.z.sgs'
  xul= -4.0     yul= 26.0     zul= 48.2
  xlr= 45.0     ylr= -40.0    zlr= 48.2
  uax=1.0    vdn=-1.0   nax=130 end
  ttl='mat slice through assembly'
  pic=mat
  nch='0u.z.u.z.sgs'
  xul= 0.0      yul= 21.0   zul= 48.2
  xlr= 21.0     ylr= 0.0    zlr= 48.2
  uax=1.0    vdn=-1.0   nax=130 end
  ttl='mat slice through annular pellet'
  pic=mat
  nch='0u.z.u.z.sgs'
  xul= 0.0      yul= 21.0   zul= 165.0
  xlr= 21.0     ylr= 0.0    zlr= 165.0
  uax=1.0    vdn=-1.0   nax=130 end end

end plot

end data
end
```