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ENGINEERING DATA TRANSMITTAL

Page 1 of 1

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1	1	Design Authority				1	1	Peer Review J. V. Nelson	<i>JV Nelson</i> 7/21/99
	1	Design Agent							
1	1	Cog Engineer - S. F. Kessler	<i>S. F. Kessler</i>	7/21/99					
1	1	Cog Manager - R. G. Morgan	<i>R. G. Morgan</i>	7/21/99, R3-26					
		QA							
1	1	Safety - L. J. Garvin	<i>L. J. Garvin</i>	7/22/99					

18. <i>S. F. Kessler</i> S. F. Kessler Signature of EDT Originator Date 7/21/99	19. <i>R. G. Morgan</i> R. G. Morgan Authorized Representative for Receiving Organization Date 7/21/99	20. <i>R. G. Morgan</i> R. G. Morgan Design Authority/ Cognizant Manager Date 7/21/99	21. DOE APPROVAL (if required) Ctrl. No. ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments
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Complete Misloading of a Mark IV MCO with Mark 1A Fuel

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Abstract: The purpose of this analysis is to determine the worst case scenario for a total misload of a Mark IV MCO with Mark 1A fuel and scrap. This study is not intended to classify any of the components of the baskets

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COMPLETE MISLOADING OF A MARK IV MCO WITH MARK 1A FUEL

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J. V. Nelson, FDNW Criticality and Shielding

COMPLETE MIS-LOADING OF A MARK IV MCO WITH MARK 1A FUEL

1.0 Purpose

The purpose of this analysis is to determine the worst case scenario for a total misload of a Mark IV Multi-Canister Overpack (MCO) with Mark 1A fuel and scrap. This study is not intended to classify any of the components of the baskets.

2.0 Input Data

- The model of the MCO was the same as described in HNF-SD-SNF-CSER-005, *Criticality Safety Evaluation Report for the MCO*, Revision 4.
- Each fuel basket contained 54 Mark 1A fuel assemblies, 20.9 inches in length.
- Each basket contained the central pipe, which is required to lift the basket and to allow insertion of the long process tube for drying at the Cold Vacuum Drying (CVD) Facility.
- The optimization parameters for the scrap were derived in HNF-SD-SNF-CSER-010, *Criticality Safety Evaluation Report for the K Basin Fuel Retrieval Subproject*, Revision 0.

3.0 Assumptions

- The MCO was flooded in the transportation cask.
- The scrap in the scrap baskets was modeled as being optimized for the maximum k_{eff} .
- The scrap was assumed to fill the entire scrap basket volume in the MCO, including the small volume above the top scrap basket below the filter guard plate.
- The scrap baskets did not include copper dividers.
- Scrap was excluded from the inner central pipe region of the scrap basket.
- Mark 1A scrap was enriched to 1.25 wt% U^{235} , no credit for burn-up was taken.
- The fuel baskets were modeled as being filled.

4.0 Methods of Calculation

MCNP4B was used for all calculations. For completeness, the calculations were performed by modeling two misloaded scrap baskets with three misloaded fuel baskets, a misloaded scrap basket in either the top and bottom tier of the MCO with four misloaded fuel baskets, and five misloaded fuel baskets. Because of the limited volume in the MCO, a full scrap basket load of 980 kg will not fit in the scrap basket at optimal conditions. Therefore, the scrap was modeled at optimum conditions, filling the scrap basket volume, for the maximum k_{eff} . This mass is slightly less than the maximum loading for a Mark IV scrap basket. Partially loaded fuel baskets were not considered. The calculated k_{eff} was corrected for bias and uncertainties using the method described in HNF-SD-SNF-CSER-005, Revision 4.

5.0 Findings and Conclusions

Table 1 lists the results.

Table 1: Results

Description	Case	k_{calc}	σ_c	k_{eff}
Two misloaded scrap baskets and three misloaded fuel baskets	mk4r.1k	0.97561	0.00077	0.98666
Mark 1A scrap basket in the bottom tier with four misloaded fuel baskets	mk4r.1g	0.97560	0.00075	0.98664
Mark 1A scrap basket in the top tier with four misloaded fuel baskets	mk4r.1h	0.97149	0.00086	0.98256
Five misloaded fuel baskets	mk4r.1n	0.86237	0.00082	0.87343

$$k_{eff} = k_{calc} + 0.0004 + ([0.01]^2 + [1.645]^2 \sigma_c^2 + 0.002083^2)^{1/2}$$

The results show that a misloaded MCO containing scrap baskets, when flooded, will exceed a k_{eff} of 0.95 but will still be subcritical. A completely misloaded MCO containing only fuel baskets will not exceed the 0.95 limit. ANSI/ANS STD 8.1, DOE Order 5480.24, and the HNF-PRO's require application of the double contingency principle to ensure a criticality accident is not possible due to a single change in process conditions. The complete misloading of an MCO would require multiple violations of administrative controls. An inventory listing the contents of each storage canister exists for both basins. This inventory is used to develop the fuel retrieval sequence to minimize handling Mark 1A and Mark IV simultaneously. Because the fuels are stored in different types of canisters, operators can visually distinguish what type of fuel they are handling. This represents two controls over the loading of baskets that would have to be violated repeatedly to completely misload an MCO.

6.0 MCNP Input Files

imk4r.1k

Basic model for MCO loaded with 2 scrap baskets and 3 fuel baskets.

- c All fuel baskets loaded with 20.9 in mk1a assemblies. Both scrap baskets
- c Contain mk1a scrap.
- c Scrap baskets contain the central pipe.
- c Revised 1.25" basket base plates for all baskets.
- c Fuel basket containing intact fuel assemblies

```

2 0 -17 18 -19 20 -21 22 u=8 lat=2
   fill=-5:5 -5:5 0:0
2 2 2 2 2 2 2 2 2 2 2 2 $ 1
2 2 2 2 2 2 3 3 3 2 2 2 $ 2
2 2 2 2 3 3 3 3 3 3 2 2 $ 3
2 2 2 3 3 3 3 3 3 3 2 2 $ 4
2 2 3 3 3 3 3 3 3 3 2 2 $ 5
2 2 3 3 3 3 2 3 3 3 2 2 $ 6 level 1
2 3 3 3 3 3 3 3 3 2 2 2 $ 7
2 3 3 3 3 3 3 3 2 2 2 2 $ 8
2 3 3 3 3 3 3 2 2 2 2 2 $ 9
2 2 3 3 3 2 2 2 2 2 2 2 $ 10
2 2 2 2 2 2 2 2 2 2 2 2 $ 11
c 1 2 3 4 5 6 7 8 9 10 11
c Mark 4 scrap optimized lattice
5 0 -11 12 -13 14 -15 16 fill=4 u=1 lat=2 $ scrap hex
6 5 -18.8200 -5 u=4 $ scrap pin
7 10 -6.49000 5 -6 u=4 $ scrap clad
8 236 -1.00000 6 u=4 $ scrap cell
c Scrap basket
9 0 -125 122 128 fill=1 u=9 $ scrap in basket
10 20 -8.03 -128 127 122 u=9 $ central pipe
11 236 -1.00 -127 -122 u=9 $ pipe interior
13 20 -8.03 -122 127 -125 u=9 $ basket base
14 20 -8.03 125 -126 u=9 $ basket side
15 236 -1.00 126 u=9 $ outside basket
16 236 -1.00 -127 122 u=9 $ inside central pipe
c fictitious water cell for fuel basket lattice
24 236 -1.00 -144 u=2 $ fictitious cl
c fuel basket
25 20 -8.03 -128 127 122 -123 u=7 $ tube wall
26 236 -1.00 -127 -123 u=7 $ central tube
27 20 -8.03 -122 127 -130 u=7 $ bottom plate
28 20 -8.03 -128 127 123 u=7 $ tube wall
29 236 -1.00 -127 123 u=7 $ central tube
31 236 -1.00 -129 128 123 u=7 $ above fuel
32 20 -8.03000 129 122 -130 u=7 $ fuel basket side
33 0 -129 122 128 -123 fill=8 u=7 $ fuel in basket
34 236 -1.00 130 u=7 $ outside fuel basket
c fuel and scrap basket stack
51 0 -149 fill=19 u=11 $ mk1a scrap basket
52 0 146 -149 #51 trel=2 fill=7 u=11 $ fuel basket
53 0 146 -149 #52 trel=3 fill=7 u=11 $ fuel basket
54 0 146 -149 #53 trel=4 fill=7 u=11 $ fuel basket
55 0 146 -149 #54 trel=5 fill=19 u=11 $ mk1a scrap basket
59 0 152 #55 fill=20 u=11 $ mk1a scrap above top basket
c MCO and baskets
60 0 (-160 146 -150) fill=11 u=12 $ interior
61 20 -8.03 160 -161 146 u=12 $ MCO shell
62 236 -1.00 161 -162 146 u=12 $ cask annulus

```

```

63 20 -8.03 162 146          u=12 $ cask
64 20 -8.03 -146            u=12 $ cask bottom
65 20 -8.03 -160 165        u=12 $ mco top
66 20 -8.03 -160 150 -151   u=12 $ filter guard
67 236 -1.00 -160 151 -165   u=12 $ top gap
68 0 164 -163 -166          fill=12 $ mco cask
c Mk1a intact fuel structure
115 236 -1.00 50            u=3 $ between fuels
116 10 -6.49 -50 49         u=3 $ Zr-2 clad
117 4 -18.82 -49 48         u=3 $ 1.250% U-235
118 10 -6.49 -48 47         u=3 $ Zr-2 clad
119 236 -1.00 -47 46        u=3 $ H2O
120 10 -6.49 -46 45         u=3 $ Zr-2 clad
121 5 -18.82 -45 44         u=3 $ 0.947% U-235
122 10 -6.49 -44 43         u=3 $ Zr-2 clad
123 236 -1.00 -43          u=3 $ H2O
c Mark 1a scrap optimized lattice
125 0 -181 182 -183 184 -185 186 fill=14 u=20 lat=2 $ scrap hex
126 4 -18.8200 -175         u=14 $ scrap pin
127 10 -6.49000 175 -176    u=14 $ scrap clad
128 236 -1.00000 176        u=14 $ scrap cell
c mk1a Scrap basket
129 0 -195 122 198          fill=20 u=19 $ scrap in basket
130 236 -1.00 -197 -122     u=19 $ pipe interior
131 20 -8.03 -122 197 -195  u=19 $ basket base
132 0 195 -196             fill=20 u=19 $ basket side
133 0 196                 fill=20 u=19 $ outside basket
134 20 -8.03 -198 197 122   u=19 $ central pipe
135 236 -1.00 -197 122     u=19 $ inside central pipe
145 2 0.06520 -164 141 -144 $ basin floor
146 236 -1.000 -144 -143 166 $ water above MCO
147 236 -1.000 -166 163 164 -144 $ surrounding water
149 0 -141 :144 :143        $ outside world

5  cz  0.8000000
6  cz  0.8572000
11 p  0.8660254 -0.5000000 0.0000000 1.3992000
12 p  0.8660254 -0.5000000 0.0000000 -1.3992000
13 p  0.8660254 0.5000000 0.0000000 1.3992000
14 p  0.8660254 0.5000000 0.0000000 -1.3992000
15 py 1.3992000
16 py -1.3992000
17 p  0.86602540 -0.5 0.0 3.4925
18 p  0.86602540 -0.5 0.0 -3.4925
19 p  0.86602540 0.5 0.0 3.4925
20 p  0.86602540 0.5 0.0 -3.4925
21 py 3.4925
22 py -3.4925
43 cz 0.5588 $ H2O
44 cz 0.6223 $ Zr-2 clad
45 cz 1.4808 $ fuel
46 cz 1.5824 $ Zr-2 clad
47 cz 2.2441 $ H2O
48 cz 2.3076 $ Zr-2 clad
49 cz 2.9896 $ fuel
50 cz 3.0531 $ Zr-2 clad
122 pz 0.0000000
123 pz 53.086000
c scrap basket side
125 cz 28.79725000
126 cz 29.08751997
c process tube pipe

```

```

127  cz  2.2225000
128  cz  3.4925000
c fuel basket side
129  cz  28.41625
130  cz  28.73375
141  pz  -113.67300
143  pz  900.00000
144  cz  500.00000
146  pz  -3.1750000
149  pz  67.68338
150  pz  353.83470
151  pz  357.64470
152  pz  351.11690
c MCO
160  cz  29.2100
161  cz  30.4800
162  cz  32.0004
163  cz  51.0540
164  pz  -8.2804
165  pz  375.000
166  pz  398.1196
175  cz  0.6500000
176  cz  0.7107000
181  p   0.8660254  -0.5000000  0.0000000  1.2013000
182  p   0.8660254  -0.5000000  0.0000000  -1.2013000
183  p   0.8660254  0.5000000  0.0000000  1.2013000
184  p   0.8660254  0.5000000  0.0000000  -1.2013000
185  py  1.2013000
186  py  -1.2013000
c mkla scrap basket side
195  cz  28.77001997
196  cz  29.08751997
c process tube pipe
197  cz  2.2225000
198  cz  3.4925000

tr2  0.00 0.00 70.858380
tr3  0.00 0.00 141.71676
tr4  0.00 0.00 212.57514
tr5  0.00 0.00 283.43352
mode n
m4    92235.50 -0.01250 92238.50 -0.98750  $ outer fuel
m5    92235.50 -0.00947 92238.50 -0.99053  $ inner fuel
m236  1001.50c 0.666700 8016.50c 0.333300
m10   40000.50c -1.000000
m20   26000.55c 67.970001 24000.50c 20.000000 28000.50c 10.000000
      25055.50c 2.000000 6000.50c 0.030000
m2    1001.50 0.064200 8016.50 0.591600 14000.50 0.240500
      20000.50 0.073800 26000.55 0.029900
imp:n  1.00000 59r 0.00000 $ 5, 139
mt236 lwtr.01t
mt2    lwtr.01t
print  40 60 80 100 110 126
prdm p j 300
kcode  2000 1. 20 300
ksrc   9.7 0. 20. -9.7 0.0 85.0 9.7 -9.7 150.0
      -9.7 -9.7 250.0 0.0 -9.7 320.0

```

imk4r.1g

Basic model for MCO loaded with 1 scrap basket and 4 fuel baskets.

c All fuel baskets loaded with 20.9 in mkla assemblies. Bottom scrap basket

c contains mk1a scrap.
c Scrap baskets contain the central pipe.
c Revised 1.25" basket base plates for all baskets.
c fuel basket containing intact fuel assemblies
2 0 -17 18 -19 20 -21 22 u=8 lat=2
fill=-5:5 -5:5 0:0
2 2 2 2 2 2 2 2 2 2 2 2 \$ 1
2 2 2 2 2 2 3 3 3 2 2 2 \$ 2
2 2 2 2 3 3 3 3 3 3 2 2 \$ 3
2 2 2 3 3 3 3 3 3 3 2 2 \$ 4
2 2 3 3 3 3 3 3 3 3 2 2 \$ 5
2 2 3 3 3 2 3 3 3 2 2 2 \$ 6 level 1
2 3 3 3 3 3 3 3 3 2 2 2 \$ 7
2 3 3 3 3 3 3 3 2 2 2 2 \$ 8
2 3 3 3 3 3 3 2 2 2 2 2 \$ 9
2 2 3 3 3 2 2 2 2 2 2 2 \$ 10
2 2 2 2 2 2 2 2 2 2 2 2 \$ 11
c 1 2 3 4 5 6 7 8 9 10 11
c Mark 4 scrap optimized lattice
5 0 -11 12 -13 14 -15 16 fill=4 u=1 lat=2 \$ scrap hex
6 5 -18.8200 -5 u=4 \$ scrap pin
7 10 -6.49000 5 -6 u=4 \$ scrap clad
8 236 -1.00000 6 u=4 \$ scrap cell
c Scrap basket
9 0 -125 122 128 fill=1 u=9 \$ scrap in basket
10 20 -8.03 -128 127 122 u=9 \$ central pipe
11 236 -1.00 -127 -122 u=9 \$ pipe interior
13 20 -8.03 -122 127 -125 u=9 \$ basket base
14 20 -8.03 125 -126 u=9 \$ basket side
15 236 -1.00 126 u=9 \$ outside basket
16 236 -1.00 -127 122 u=9 \$ inside central pipe
c fictitious water cell for fuel basket lattice
24 236 -1.00 -144 u=2 \$ fictitious cl
c fuel basket
25 20 -8.03 -128 127 122 -123 u=7 \$ tube wall
26 236 -1.00 -127 -123 u=7 \$ central tube
27 20 -8.03 -122 127 -130 u=7 \$ bottom plate
28 20 -8.03 -128 127 123 u=7 \$ tube wall
29 236 -1.00 -127 123 u=7 \$ central tube
31 236 -1.00 -129 128 123 u=7 \$ above fuel
32 20 -8.03000 129 122 -130 u=7 \$ fuel basket side
33 0 -129 122 128 -123 fill=8 u=7 \$ fuel in basket
34 236 -1.00 130 u=7 \$ outside fuel basket
c fuel and scrap basket stack
51 0 -149 fill=19 u=11 \$ mk1a scrap basket
52 0 146 -149 #51 trcl=2 fill=7 u=11 \$ fuel basket
53 0 146 -149 #52 trcl=3 fill=7 u=11 \$ fuel basket
54 0 146 -149 #53 trcl=4 fill=7 u=11 \$ fuel basket
55 0 146 -149 #54 trcl=5 fill=7 u=11 \$ fuel basket
59 236 -1.000 152 #55 u=11 \$ above top basket
c MCO and baskets
60 0 (-160 146 -150) fill=11 u=12 \$ interior
61 20 -8.03 160 -161 146 u=12 \$ MCO shell
62 236 -1.00 161 -162 146 u=12 \$ cask annulus
63 20 -8.03 162 146 u=12 \$ cask
64 20 -8.03 -146 u=12 \$ cask bottom
65 20 -8.03 -160 165 u=12 \$ mco top
66 20 -8.03 -160 150 -151 u=12 \$ filter guard
67 236 -1.00 -160 151 -165 u=12 \$ top gap
68 0 164 -163 -166 fill=12 \$ mco cask
c Mk1a intact fuel structure
115 236 -1.00 50 u=3 \$ between fuels

```

116 10 -6.49 -50 49 u=3 $ Zr-2 clad
117 4 -18.82 -49 48 u=3 $ 1.250% U-235
118 10 -6.49 -48 47 u=3 $ Zr-2 clad
119 236 -1.00 -47 46 u=3 $ H2O
120 10 -6.49 -46 45 u=3 $ Zr-2 clad
121 5 -18.82 -45 44 u=3 $ 0.947% U-235
122 10 -6.49 -44 43 u=3 $ Zr-2 clad
123 236 -1.00 -43 u=3 $ H2O
c Mark 1a scrap optimized lattice
125 0 -181 182 -183 184 -185 186 fill=14 u=20 lat=2 $ scrap hex
126 4 -18.8200 -175 u=14 $ scrap pin
127 10 -6.49000 175 -176 u=14 $ scrap clad
128 236 -1.00000 176 u=14 $ scrap cell
c mk1a Scrap basket
129 0 -195 122 198 fill=20 u=19 $ scrap in basket
130 236 -1.00 -197 -122 u=19 $ pipe interior
131 20 -8.03 -122 197 -195 u=19 $ basket base
132 0 195 -196 fill=20 u=19 $ basket side
133 0 196 fill=20 u=19 $ outside basket
134 20 -8.03 -198 197 122 u=19 $ central pipe
135 236 -1.00 -197 122 u=19 $ inside central pipe
145 2 0.06520 -164 141 -144 $ basin floor
146 236 -1.000 -144 -143 166 $ water above MCO
147 236 -1.000 -166 163 164 -144 $ surrounding water
149 0 -141 :144 :143 $ outside world

5 cz 0.8000000
6 cz 0.8572000
11 p 0.8660254 -0.5000000 0.0000000 1.3992000
12 p 0.8660254 -0.5000000 0.0000000 -1.3992000
13 p 0.8660254 0.5000000 0.0000000 1.3992000
14 p 0.8660254 0.5000000 0.0000000 -1.3992000
15 py 1.3992000
16 py -1.3992000
17 p 0.86602540 -0.5 0.0 3.4925
18 p 0.86602540 -0.5 0.0 -3.4925
19 p 0.86602540 0.5 0.0 3.4925
20 p 0.86602540 0.5 0.0 -3.4925
21 py 3.4925
22 py -3.4925
43 cz 0.5588 $ H2O
44 cz 0.6223 $ Zr-2 clad
45 cz 1.4808 $ fuel
46 cz 1.5824 $ Zr-2 clad
47 cz 2.2441 $ H2O
48 cz 2.3076 $ Zr-2 clad
49 cz 2.9896 $ fuel
50 cz 3.0531 $ Zr-2 clad
122 pz 0.0000000
123 pz 53.086000
c scrap basket side
125 cz 28.79725000
126 cz 29.08751997
c process tube pipe
127 cz 2.2225000
128 cz 3.4925000
c fuel basket side
129 cz 28.41625
130 cz 28.73375
141 pz -113.67300
143 pz 900.00000
144 cz 500.00000

```

```

146 pz -3.1750000
149 pz 67.68338
150 pz 353.83470
151 pz 357.64470
152 pz 351.11690
c MCO
160 cz 29.2100
161 cz 30.4800
162 cz 32.0004
163 cz 51.0540
164 pz -8.2804
165 pz 375.000
166 pz 398.1196
175 cz 0.6500000
176 cz 0.7107000
181 p 0.8660254 -0.5000000 0.0000000 1.2013000
182 p 0.8660254 -0.5000000 0.0000000 -1.2013000
183 p 0.8660254 0.5000000 0.0000000 1.2013000
184 p 0.8660254 0.5000000 0.0000000 -1.2013000
185 py 1.2013000
186 py -1.2013000
c mk1a scrap basket side
195 cz 28.77001997
196 cz 29.08751997
c process tube pipe
197 cz 2.2225000
198 cz 3.4925000

tr2 0.00 0.00 70.858380
tr3 0.00 0.00 141.71676
tr4 0.00 0.00 212.57514
tr5 0.00 0.00 283.43352
mode n
m4 92235.50 -0.01250 92238.50 -0.98750 $ outer fuel
m5 92235.50 -0.00947 92238.50 -0.99053 $ inner fuel
m236 1001.50c 0.666700 8016.50c 0.333300
m10 40000.50c -1.000000
m20 26000.55c 67.970001 24000.50c 20.000000 28000.50c 10.000000
25055.50c 2.000000 6000.50c 0.030000
m2 1001.50 0.064200 8016.50 0.591600 14000.50 0.240500
20000.50 0.073800 26000.55 0.029900
imp:n 1.00000 59r 0.00000 $ 5, 139
mt236 lwtr.01t
mt2 lwtr.01t
print 40 60 80 100 110 126
prtmp j 300
kcode 2000 1. 20 300
ksrc 9.7 0. 20. -9.7 0.0 85.0 9.7 -9.7 150.0
-9.7 -9.7 250.0 0.0 -9.7 320.0

```

imk4r.1h

Basic model for MCO loaded with 1 scrap basket and 4 fuel baskets.

c All fuel baskets loaded with 20.9 in mk1a assemblies. Top scrap basket

c contains mk1a scrap.

c Scrap baskets contain the central pipe.

c Revised 1.25" basket base plates for all baskets.

c fuel basket containing intact fuel assemblies

```

2 0 -17 18 -19 20 -21 22 u=8 lat=2
fill=-5:5 -5:5 0:0
2 2 2 2 2 2 2 2 2 2 2 $ 1
2 2 2 2 2 2 3 3 3 2 2 $ 2

```

```

2 2 2 2 3 3 3 3 3 3 2 $ 3
2 2 2 3 3 3 3 3 3 3 2 $ 4
2 2 3 3 3 3 3 3 3 3 2 $ 5
2 2 3 3 3 2 3 3 3 2 2 $ 6 level 1
2 3 3 3 3 3 3 3 3 2 2 $ 7
2 3 3 3 3 3 3 3 2 2 2 $ 8
2 3 3 3 3 3 3 2 2 2 2 $ 9
2 2 3 3 3 2 2 2 2 2 2 $ 10
2 2 2 2 2 2 2 2 2 2 2 $ 11
c 1 2 3 4 5 6 7 8 9 10 11
c Mark 4 scrap optimized lattice
5 0 -11 12 -13 14 -15 16 fill=4 u=1 lat=2 $ scrap hex
6 5 -18.8200 -5 u=4 $ scrap pin
7 10 -6.49000 5 -6 u=4 $ scrap clad
8 236 -1.00000 6 u=4 $ scrap cell
c Scrap basket
9 0 -125 122 128 fill=1 u=9 $ scrap in basket
10 20 -8.03 -128 127 122 u=9 $ central pipe
11 236 -1.00 -127 -122 u=9 $ pipe interior
13 20 -8.03 -122 127 -125 u=9 $ basket base
14 20 -8.03 125 -126 u=9 $ basket side
15 236 -1.00 126 u=9 $ outside basket
16 236 -1.00 -127 122 u=9 $ inside central pipe
c fictitious water cell for fuel basket lattice
24 236 -1.00 -144 u=2 $ fictitious cl
c fuel basket
25 20 -8.03 -128 127 122 -123 u=7 $ tube wall
26 236 -1.00 -127 -123 u=7 $ central tube
27 20 -8.03 -122 127 -130 u=7 $ bottom plate
28 20 -8.03 -128 127 123 u=7 $ tube wall
29 236 -1.00 -127 123 u=7 $ central tube
31 236 -1.00 -129 128 123 u=7 $ above fuel
32 20 -8.03000 129 122 -130 u=7 $ fuel basket side
33 0 -129 122 128 -123 fill=8 u=7 $ fuel in basket
34 236 -1.00 130 u=7 $ outside fuel basket
c fuel and scrap basket stack
51 0 -149 fill=7 u=11 $ fuel basket
52 0 146 -149 #51 trcl=2 fill=7 u=11 $ fuel basket
53 0 146 -149 #52 trcl=3 fill=7 u=11 $ fuel basket
54 0 146 -149 #53 trcl=4 fill=7 u=11 $ fuel basket
55 0 146 -149 #54 trcl=5 fill=19 u=11 $ mk1a scrap basket
59 0 152 #55 fill=20 u=11 $ mk1a scrap above top basket
c MCO and baskets
60 0 (-160 146 -150) fill=11 u=12 $ interior
61 20 -8.03 160 -161 146 u=12 $ MCO shell
62 236 -1.00 161 -162 146 u=12 $ cask annulus
63 20 -8.03 162 146 u=12 $ cask
64 20 -8.03 -146 u=12 $ cask bottom
65 20 -8.03 -160 165 u=12 $ mco top
66 20 -8.03 -160 150 -151 u=12 $ filter guard
67 236 -1.00 -160 151 -165 u=12 $ top gap
68 0 164 -163 -166 fill=12 $ mco cask
c Mk1a intact fuel structure
115 236 -1.00 50 u=3 $ between fuels
116 10 -6.49 -50 49 u=3 $ Zr-2 clad
117 4 -18.82 -49 48 u=3 $ 1.250% U-235
118 10 -6.49 -48 47 u=3 $ Zr-2 clad
119 236 -1.00 -47 46 u=3 $ H2O
120 10 -6.49 -46 45 u=3 $ Zr-2 clad
121 5 -18.82 -45 44 u=3 $ 0.947% U-235
122 10 -6.49 -44 43 u=3 $ Zr-2 clad
123 236 -1.00 -43 u=3 $ H2O

```

c Mark 1a scrap optimized lattice

125 0 -181 182 -183 184 -185 186 fill=14 u=20 lat=2 \$ scrap hex
 126 4 -18.8200 -175 u=14 \$ scrap pin
 127 10 -6.49000 175 -176 u=14 \$ scrap clad
 128 236 -1.00000 176 u=14 \$ scrap cell

c mk1a Scrap basket

129 0 -195 122 198 fill=20 u=19 \$ scrap in basket
 130 236 -1.00 -197 -122 u=19 \$ pipe interior
 131 20 -8.03 -122 197 -195 u=19 \$ basket base
 132 0 195 -196 fill=20 u=19 \$ basket side
 133 0 196 fill=20 u=19 \$ outside basket
 134 20 -8.03 -198 197 122 u=19 \$ central pipe
 135 236 -1.00 -197 122 u=19 \$ inside central pipe
 145 2 0.06520 -164 141 -144 \$ basin floor
 146 236 -1.000 -144 -143 166 \$ water above MCO
 147 236 -1.000 -166 163 164 -144 \$ surrounding water
 149 0 -141 :144 :143 \$ outside world

5 cz 0.8000000
 6 cz 0.8572000
 11 p 0.8660254 -0.5000000 0.0000000 1.3992000
 12 p 0.8660254 -0.5000000 0.0000000 -1.3992000
 13 p 0.8660254 0.5000000 0.0000000 1.3992000
 14 p 0.8660254 0.5000000 0.0000000 -1.3992000
 15 py 1.3992000
 16 py -1.3992000
 17 p 0.86602540 -0.5 0.0 3.4925
 18 p 0.86602540 -0.5 0.0 -3.4925
 19 p 0.86602540 0.5 0.0 3.4925
 20 p 0.86602540 0.5 0.0 -3.4925
 21 py 3.4925
 22 py -3.4925
 43 cz 0.5588 \$ H2O
 44 cz 0.6223 \$ Zr-2 clad
 45 cz 1.4808 \$ fuel
 46 cz 1.5824 \$ Zr-2 clad
 47 cz 2.2441 \$ H2O
 48 cz 2.3076 \$ Zr-2 clad
 49 cz 2.9896 \$ fuel
 50 cz 3.0531 \$ Zr-2 clad

122 pz 0.0000000
 123 pz 53.086000

c scrap basket side

125 cz 28.79725000
 126 cz 29.08751997

c process tube pipe

127 cz 2.2225000
 128 cz 3.4925000

c fuel basket side

129 cz 28.41625
 130 cz 28.73375
 141 pz -113.67300
 143 pz 900.00000
 144 cz 500.00000
 146 pz -3.1750000
 149 pz 67.68338
 150 pz 353.83470
 151 pz 357.64470
 152 pz 351.11690

c MCO

160 cz 29.2100
 161 cz 30.4800

```

162  cz  32.0004
163  cz  51.0540
164  pz  -8.2804
165  pz  375.000
166  pz  398.1196
175  cz  0.6500000
176  cz  0.7107000
181  p   0.8660254 -0.5000000 0.0000000 1.2013000
182  p   0.8660254 -0.5000000 0.0000000 -1.2013000
183  p   0.8660254 0.5000000 0.0000000 1.2013000
184  p   0.8660254 0.5000000 0.0000000 -1.2013000
185  py  1.2013000
186  py -1.2013000
c mk1a scrap basket side
195  cz  28.77001997
196  cz  29.08751997
c process tube pipe
197  cz  2.2225000
198  cz  3.4925000

tr2  0.00 0.00 70.858380
tr3  0.00 0.00 141.71676
tr4  0.00 0.00 212.57514
tr5  0.00 0.00 283.43352
mode n
m4   92235.50 -0.01250 92238.50 -0.98750      $ outer fuel
m5   92235.50 -0.00947 92238.50 -0.99053      $ inner fuel
m236 1001.50c 0.666700 8016.50c 0.333300
m10  40000.50c -1.000000
m20  26000.55c 67.970001 24000.50c 20.000000 28000.50c 10.000000
      25055.50c 2.000000 6000.50c 0.030000
m2   1001.50 0.064200 8016.50 0.591600 14000.50 0.240500
      20000.50 0.073800 26000.55 0.029900
imp:n 1.00000 59r      0.00000 $ 5, 139
mt236 lwtr.01t
mt2   lwtr.01t
print 40 60 80 100 110 126
prtmp j 300
kcode 2000 1. 20 300
ksrc 9.7 0. 20. -9.7 0.0 85.0 9.7 -9.7 150.0
      -9.7 -9.7 250.0 0.0 -9.7 320.0

```

imk4r.1n

Basic model for MCO loaded with 5 fuel baskets.

c All fuel baskets loaded with 20.9 in mk1a assemblies.

c Revised 1.25" basket base plates for all baskets.

c fuel basket containing intact fuel assemblies

```

2  0 -17 18 -19 20 -21 22  u=8 lat=2
    fill=-5:5 -5:5 0:0
      2 2 2 2 2 2 2 2 2 2 2 2 $ 1
      2 2 2 2 2 2 2 3 3 3 2 2 $ 2
      2 2 2 2 3 3 3 3 3 3 2 $ 3
      2 2 2 3 3 3 3 3 3 3 2 $ 4
      2 2 3 3 3 3 3 3 3 3 2 $ 5
      2 2 3 3 3 2 3 3 3 2 2 $ 6 level 1
      2 3 3 3 3 3 3 3 3 2 2 $ 7
      2 3 3 3 3 3 3 3 2 2 2 $ 8
      2 3 3 3 3 3 3 2 2 2 2 $ 9
      2 2 3 3 3 2 2 2 2 2 2 $ 10
      2 2 2 2 2 2 2 2 2 2 2 $ 11
c   1 2 3 4 5 6 7 8 9 10 11

```

```

c Mark 4 scrap optimized lattice
5 0 -11 12 -13 14 -15 16 fill=4 u=1 lat=2 $ scrap hex
6 5 -18.8200 -5 u=4 $ scrap pin
7 10 -6.49000 5 -6 u=4 $ scrap clad
8 236 -1.00000 6 u=4 $ scrap cell

c Scrap basket
9 0 -125 122 fill=1 u=9 $ scrap in basket
11 236 -1.00 -127 -122 u=9 $ pipe interior
13 20 -8.03 -122 127 -125 u=9 $ basket base
14 20 -8.03 125 -126 u=9 $ basket side
15 236 -1.00 126 u=9 $ outside basket

c fictitious water cell for fuel basket lattice
24 236 -1.00 -144 u=2 $ fictitious cl

c fuel basket
25 20 -8.03 -128 127 122 -123 u=7 $ tube wall
26 236 -1.00 -127 -123 u=7 $ central tube
27 20 -8.03 -122 127 -130 u=7 $ bottom plate
28 20 -8.03 -128 127 123 u=7 $ tube wall
29 236 -1.00 -127 123 u=7 $ central tube
31 236 -1.00 -129 128 123 u=7 $ above fuel
32 20 -8.03000 129 122 -130 u=7 $ fuel basket side
33 0 -129 122 128 -123 fill=8 u=7 $ fuel in basket
34 236 -1.00 130 u=7 $ outside fuel basket

c fuel and scrap basket stack
51 0 -149 fill=7 u=11 $ fuel basket
52 0 146 -149 #51 trcl=2 fill=7 u=11 $ fuel basket
53 0 146 -149 #52 trcl=3 fill=7 u=11 $ fuel basket
54 0 146 -149 #53 trcl=4 fill=7 u=11 $ fuel basket
55 0 146 -149 #54 trcl=5 fill=7 u=11 $ fuel basket
59 236 -1.000 152 #55 u=11 $ above top basket

c MCO and baskets
60 0 (-160 146 -150) fill=11 u=12 $ interior
61 20 -8.03 160 -161 146 u=12 $ MCO shell
62 236 -1.00 161 -162 146 u=12 $ cask annulus
63 20 -8.03 162 146 u=12 $ cask
64 20 -8.03 -146 u=12 $ cask bottom
65 20 -8.03 -160 165 u=12 $ mco top
66 20 -8.03 -160 150 -151 u=12 $ filter guard
67 236 -1.00 -160 151 -165 u=12 $ top gap
68 0 164 -163 -166 fill=12 $ mco cask

c Mk1a intact fuel structure
115 236 -1.00 50 u=3 $ between fuels
116 10 -6.49 -50 49 u=3 $ Zr-2 clad
117 4 -18.82 -49 48 u=3 $ 1.250% U-235
118 10 -6.49 -48 47 u=3 $ Zr-2 clad
119 236 -1.00 -47 46 u=3 $ H2O
120 10 -6.49 -46 45 u=3 $ Zr-2 clad
121 5 -18.82 -45 44 u=3 $ 0.947% U-235
122 10 -6.49 -44 43 u=3 $ Zr-2 clad
123 236 -1.00 -43 u=3 $ H2O

c Mark 1a scrap optimized lattice
125 0 -181 182 -183 184 -185 186 fill=14 u=20 lat=2 $ scrap hex
126 4 -18.8200 -175 u=14 $ scrap pin
127 10 -6.49000 175 -176 u=14 $ scrap clad
128 236 -1.00000 176 u=14 $ scrap cell

c mk1a Scrap basket
129 0 -195 122 fill=20 u=19 $ scrap in basket
130 236 -1.00 -197 -122 u=19 $ pipe interior
131 20 -8.03 -122 197 -195 u=19 $ basket base
132 0 195 -196 fill=20 u=19 $ basket side
133 0 196 fill=20 u=19 $ outside basket
135 2 0.06520 -164 141 -144 $ basin floor

```

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136	236	-1.000	-144	-143	166		\$ water above MCO
137	236	-1.000	-166	163	164	-144	\$ surrounding water
139	0	-141	144	143			\$ outside world
5	cz	0.8000000					
6	cz	0.8572000					
11	p	0.8660254	-0.5000000	0.0000000	1.3992000		
12	p	0.8660254	-0.5000000	0.0000000	-1.3992000		
13	p	0.8660254	0.5000000	0.0000000	1.3992000		
14	p	0.8660254	0.5000000	0.0000000	-1.3992000		
15	py	1.3992000					
16	py	-1.3992000					
17	p	0.86602540	-0.5	0.0	3.4925		
18	p	0.86602540	-0.5	0.0	-3.4925		
19	p	0.86602540	0.5	0.0	3.4925		
20	p	0.86602540	0.5	0.0	-3.4925		
21	py			3.4925			
22	py			-3.4925			
43	cz	0.5588	\$ H2O				
44	cz	0.6223	\$ Zr-2 clad				
45	cz	1.4808	\$ fuel				
46	cz	1.5824	\$ Zr-2 clad				
47	cz	2.2441	\$ H2O				
48	cz	2.3076	\$ Zr-2 clad				
49	cz	2.9896	\$ fuel				
50	cz	3.0531	\$ Zr-2 clad				
122	pz	0.0000000					
123	pz	53.086000					
c scrap basket side							
125	cz	28.79725000					
126	cz	29.08751997					
c process tube pipe							
127	cz	2.2225000					
128	cz	3.4925000					
c fuel basket side							
129	cz	28.41625					
130	cz	28.73375					
141	pz	-113.67300					
143	pz	900.00000					
144	cz	500.00000					
146	pz	-3.1750000					
149	pz	67.68338					
150	pz	353.83470					
151	pz	357.64470					
152	pz	351.11690					
c MCO							
160	cz	29.2100					
161	cz	30.4800					
162	cz	32.0004					
163	cz	51.0540					
164	pz	-8.2804					
165	pz	375.000					
166	pz	398.1196					
175	cz	0.6500000					
176	cz	0.7107000					
181	p	0.8660254	-0.5000000	0.0000000	1.2013000		
182	p	0.8660254	-0.5000000	0.0000000	-1.2013000		
183	p	0.8660254	0.5000000	0.0000000	1.2013000		
184	p	0.8660254	0.5000000	0.0000000	-1.2013000		
185	py	1.2013000					
186	py	-1.2013000					
c mk1a scrap basket side							


```

195    cz    28.77001997
196    cz    29.08751997
c process tube pipe
197    cz    2.2225000
198    cz    3.4925000

tr2  0.00 0.00 70.858380
tr3  0.00 0.00 141.71676
tr4  0.00 0.00 212.57514
tr5  0.00 0.00 283.43352
mode n
m4    92235.50 -0.01250 92238.50 -0.98750    $ outer fuel
m5    92235.50 -0.00947 92238.50 -0.99053    $ inner fuel
m236 1001.50c 0.666700 8016.50c 0.333300
m10   40000.50c -1.000000
m20   26000.55c 67.970001 24000.50c 20.000000 28000.50c 10.000000
      25055.50c 2.000000 6000.50c 0.030000
m2    1001.50 0.064200 8016.50 0.591600 14000.50 0.240500
      20000.50 0.073800 26000.55 0.029900
imp:n  1.00000 55r    0.00000 $ 5, 139
mt236 lwtr.01t
mt2    lwtr.01t
print 40 60 80 100 110 126
prdmp j 300
kcode 2000 1. 20 300
ksrc  9.7 0. 20. -9.7 0.0 85.0 9.7 -9.7 150.0
      -9.7 -9.7 250.0 0.0 -9.7 320.0

```

SNF-4848 REV 0

FLUOR DANIEL NORTHWEST

TECHNICAL PEER REVIEWS

CHECKLIST FOR TECHNICAL PEER REVIEW

Document Reviewed:

Title: Complete Misloading of a Mark IV MCO with Mark IA Fuel (SNF-4848, Rev 0)

Author: S. F. Kessler

Date: 7/19/99

Scope of Review: Full document

Yes No* NA

☐	☐	☒	**Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
☒	☐	☐	Problem completely defined.
☐	☐	☒	Accident scenarios developed in a clear and logical manner.
☒	☐	☐	Necessary assumptions explicitly stated and supported.
☒	☐	☐	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☐	☐	☒	Mathematical derivations checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside of range of established validity justified.
☒	☐	☐	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
☒	☐	☐	Software input correct and consistent with document reviewed.
☒	☐	☐	Software output consistent with input and with results reported in document reviewed.
☒	☐	☐	Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
☒	☐	☐	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.
☒	☐	☐	Format consistent with applicable guides or other standards.
☐	☐	☒	**Review calculations, comments, and/or notes are attached.
☒	☐	☐	Traceability
☒	☐	☐	Document approved (for example, the reviewer affirms the technical accuracy of the document).

J. V. Nelson

Reviewer (printed name and signature)

7/19/99

Date

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