SAFETY ANALYSIS REPORT

FOR THE

HI-STAR 100 CASK SYSTEM

HOLTEC REPORT HI-951251, REVISION 5

NRC DOCKET NO. 71-9261

Volume 1 of 2

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Volume 2 of 2

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6.3-5	4		Fig. 6.A.5	4
6.3-6	4		Fig. 6.A.6	4
Fig. 6.3.1	4		6.B-1	4
Fig. 6.3.2	4		6.B-2	4
Fig. 6.3.3	4		6.C-1	4
Fig. 6.3.4	4		6.C-2	4
Fig. 6.3.5	4		6.C-3	4
Fig. 6.3.6	4		6.C-4	4
Fig. 6.3.7	4		6.C-5	4
6.4-1	4		6.C-6	4
6.4-2	4		6.C-7	4
6.4-3	4		6.C-8	4
6.4-4	4		6.C-9	4
6.4-5	4		6.C-10	4
6.4-6	4		6.C-11	4
Fig. 6.4.1	4		6.C-12	4
Fig. 6.4.2	4		6.C-13	4
Fig. 6.4.3	4		6.C-14	4
Fig. 6.4.4	4		6.C-15	4
Fig. 6.4.5	4		6.C-16	4
Fig. 6.4.6	4		6.C-17	4
Fig. 6.4.7	4		6.C-18	4
Fig. 6.4.8	4		6.C-19	4
6.5-1	4		6.C-20	4
6.6-1	4		6.C-21	4
6.6-2	4		6.C-22	4
6.A-1	4		6.C-23	4
6.A-2	4		6.C-24	4
6.A-3	4		6.C-25	4
6.A-4	4		6.C-26	4
6.A-5	4		6.C-27	4
6.A-6	4		6.C-28	4
6.A-7	4		6.C-29	4
6.A-8	4		6.C-30	4
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6.C-38	4		Fig. 7.1.5	4
6.C-39	4		Fig. 7.1.6	4
6.C-40	4		Fig. 7.1.7	4
6.C-41	4		Fig. 7.1.8	4
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7.1-9	4		Fig. 7.1.23	4
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7.1-18	4		7.2-1	4
7.1-19	4		7.2-2	4
7.1-20	4		7.2-3	4
7.1-21	4		7.2-4	4
7.1-22	4		7.2-5	4
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7.1-24	4		7.2-7	4
7.1-25	4		7.2-8	4
7.1-26	4		7.2-9	4
7.1-27	4		7.2-10	4
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7.1-30	4		Fig. 7.2.3	4
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8.1-9	4			
8.1-10	4			
8.1-11	4			
8.1-12	4			
8.1-13	4			
8.1-14	4			
8.1-15	4			
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8.2-4	4			
Fig. 8.2.1	4			
8.A-1	4			
8.A-2	4			
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8.A-5	4			
8.A-6	4			
8.A-7	4			
8.B-1	4			

2.2 WEIGHTS AND CENTERS OF GRAVITY

Table 2.2.1 provides the weights of the individual HI-STAR 100 components as well as the total system weights. The weight of the impact limiter is also provided.

The location of the calculated centers of gravity (CGs) are presented in Table 2.2.2. All centers of gravity are located on the cask centerline since the non-axisymmetry effects of the cask system plus contents are negligible.

Table 2.2.3 provides the lift weight for the HI-STAR 100 System when the heaviest fully loaded MPC is lifted from the fuel pool. The effect of buoyancy is neglected, and the weight of rigging is set at a conservative value.

Table 2.2.1
HI-STAR 100 WEIGHT DATA†

Item	Weight (lb)
➤ Overpack††	153,080
• Overpack closure plate	7,984
➤ MPC-24	
• Without SNF	38,511
• Fully loaded with SNF	78,831
➤ Overpack with loaded MPC-24	231,910
➤ MPC-32	
• Without SNF	35,097
• Fully loaded with SNF	88,857
➤ Overpack with fully loaded MPC-32	241,937
➤ MPC-68	
• Without SNF	38,532
• Fully loaded with SNF	86,132
➤ Overpack with fully loaded MPC-68	239,211
➤ Overpack with minimum weight MPC without SNF	188,177
➤ Bottom impact limiter	16,332
➤ Top impact limiter	16,977
➤ Total weight of transport package†††	
• With MPC-24	265,219
• With MPC-32	275,246
• With MPC-68	272,520

† All calculated weights are rounded up to the nearest whole number.

†† Including overpack closure plate.

††† Excluding the weights of the transport frame and personnel barrier.

Table 2.2.2

CENTERS OF GRAVITY OF HI-STAR 100 CONFIGURATIONS

Component	Height of CG Above Datum, inches
Overpack empty	98.4
MPC-24 empty	109.5
MPC-32 empty	111.2
MPC-68 empty	110.5
MPC-24 with fuel in overpack	101.0
MPC-32 with fuel in overpack	101.0
MPC-68 with fuel in overpack	101.1

The datum used for calculations involving the overpack is the bottom of the overpack bottom plate. The datum used for calculations involving the MPC only is the bottom of MPC baseplate (Figure 2.2.1).

Table 2.2.3

LIFT WEIGHT ABOVE POOL

Item	Weight (lb)
Total weight of overpack	153,080
Total weight of MPC-32 + fuel	88,857†
Overpack closure plate	-7,984
Water in MPC and overpack	16,657
Lift yoke	3,200
Inflatable annulus seal	50
TOTAL	253,859††

† Includes MPC closure ring.

†† Trunnion rating and crane limits may require temporary water removal from the HI-STAR 100 System during removal from the pool. (See Chapter 7).

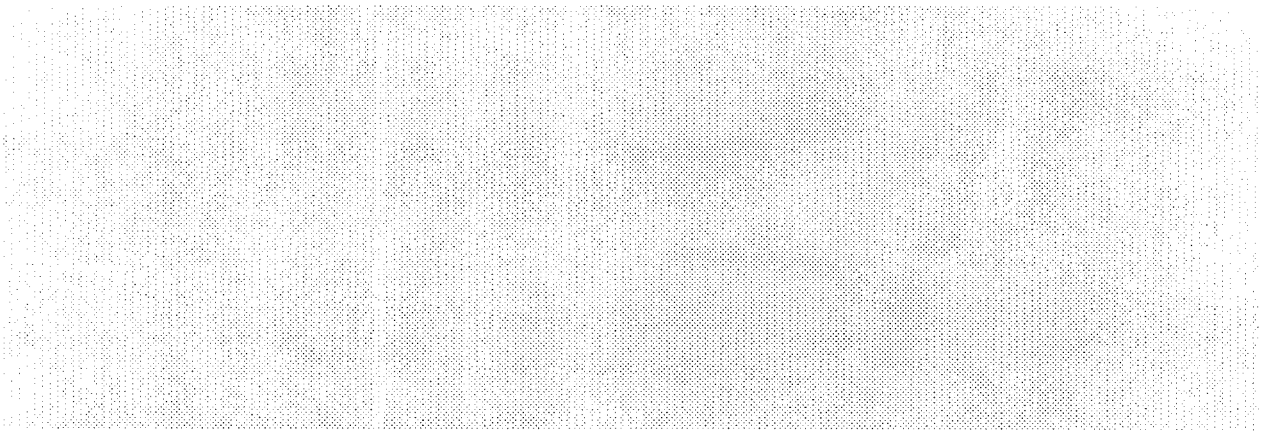
APPENDIX 2.Q: FABRICATION STRESSES

2.Q.1

The results from this evaluation are included as added stresses in the overpack finite element analysis and the results of the overpack stress analysis includes the fabrication stresses in the final safety margins.

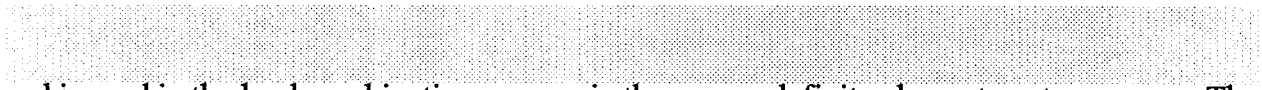
2.Q.2

2.Q.3



For the purposes of load combination with other mandated load cases, the maximum circumferential stress at the middle surface

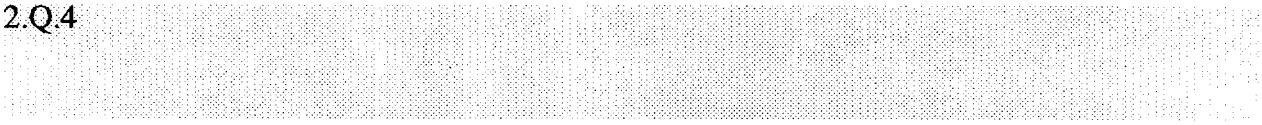
is designated as the fabrication membrane stress level



and is used in the load combination process in the overpack finite element post-processor. The fabrication stresses generated here are also included in the appropriate Code Case N-284 evaluations since a compressive stress state is developed.

The notations "inner, outer, and middle" used in the tables refer to inner surface, outer surface, and mid-plane stress locations

2.Q.4



These stresses are required to be added to the stress components obtained from the finite element analysis of other load cases, and the safety margins on stress intensity reported include the fabrication stress effect.

Where appropriate, the fabrication stresses reported herein need to be included in the Code Case N-284 evaluations of the overpack confinement shell.

Table 2.Q.1

FABRICATION STRESS S_m (psi) IN THE OVERPACK CONFINEMENT

SHELL
(COF = 0.0)

Location (degrees)	**Confinement Shell**					
-90	Inner	-16266				
	Outer	-4569				
	Middle	-10418				
-80	Inner	-14256				
	Outer	-6756				
	Middle	-10506				
0	Inner	-8716				
	Outer	-11185				
	Middle	-9951				
90	Inner	-11399				
	Outer	-7416				
	Middle	-9408				

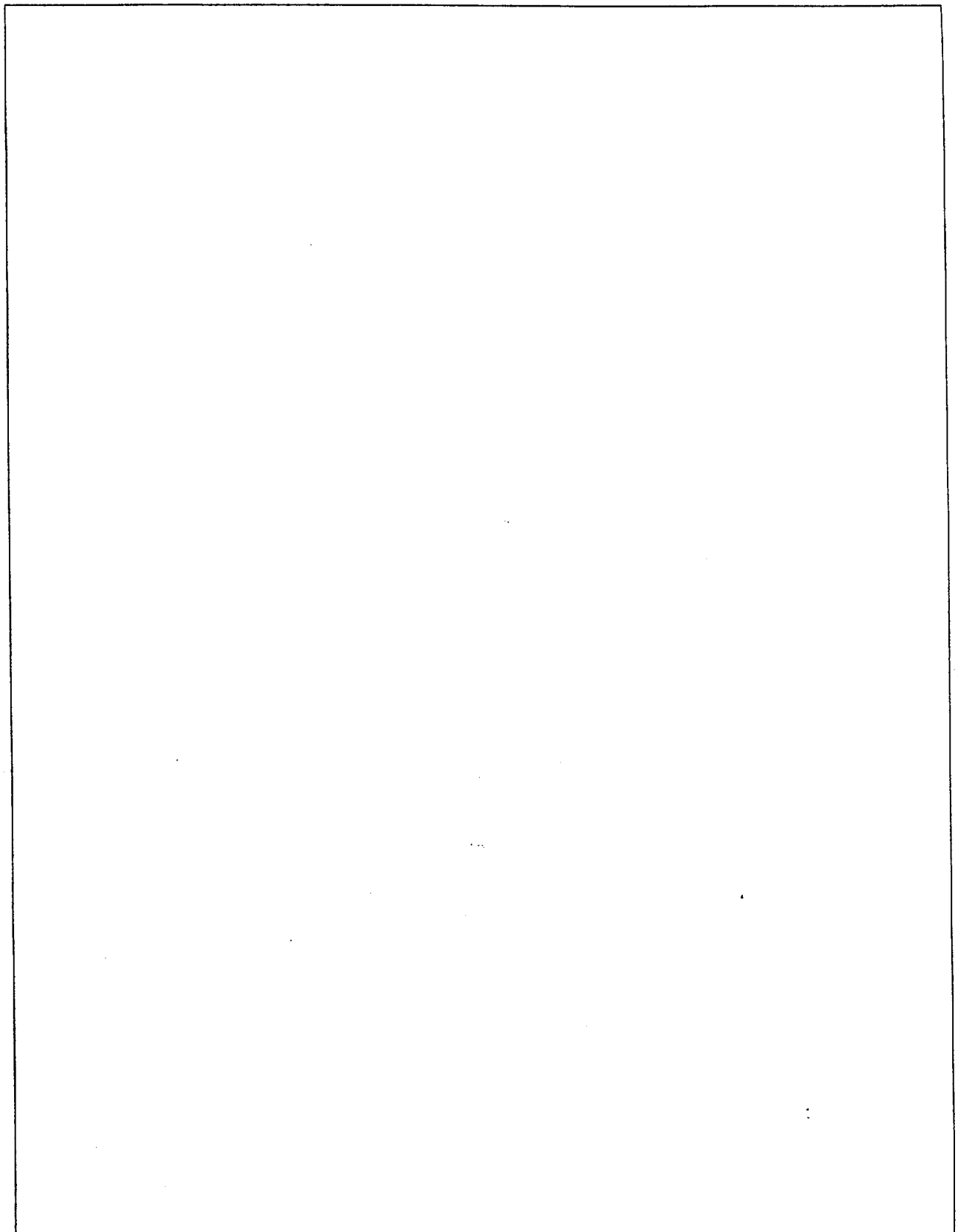


FIGURE 2.Q.1;

Table 5.1.9

DOSE RATES AT ONE METER FOR ACCIDENT CONDITIONS
MPC-68 DESIGN BASIS FUEL AT WORST CASE BURNUP AND COOLING TIME
40,000 MWD/MTU AND 10-YEAR COOLING

Dose Point Location	Fuel Gammas† (mrem/hr)	^{60}Co Gammas (mrem/hr)	Neutrons (mrem/hr)	Totals (mrem/hr)
1	6.23	24.62	83.20	114.05
2	30.31	0.53	231.64	262.47
3	2.43	15.61	53.38	71.42
4	1.41	13.55	40.00	54.95
5	0.04	0.10	9.47	9.62
6	7.97	411.86	82.09	501.92
10CFR71.51 Limit				1000.00

† Gammas generated by neutron capture are included with fuel gammas.

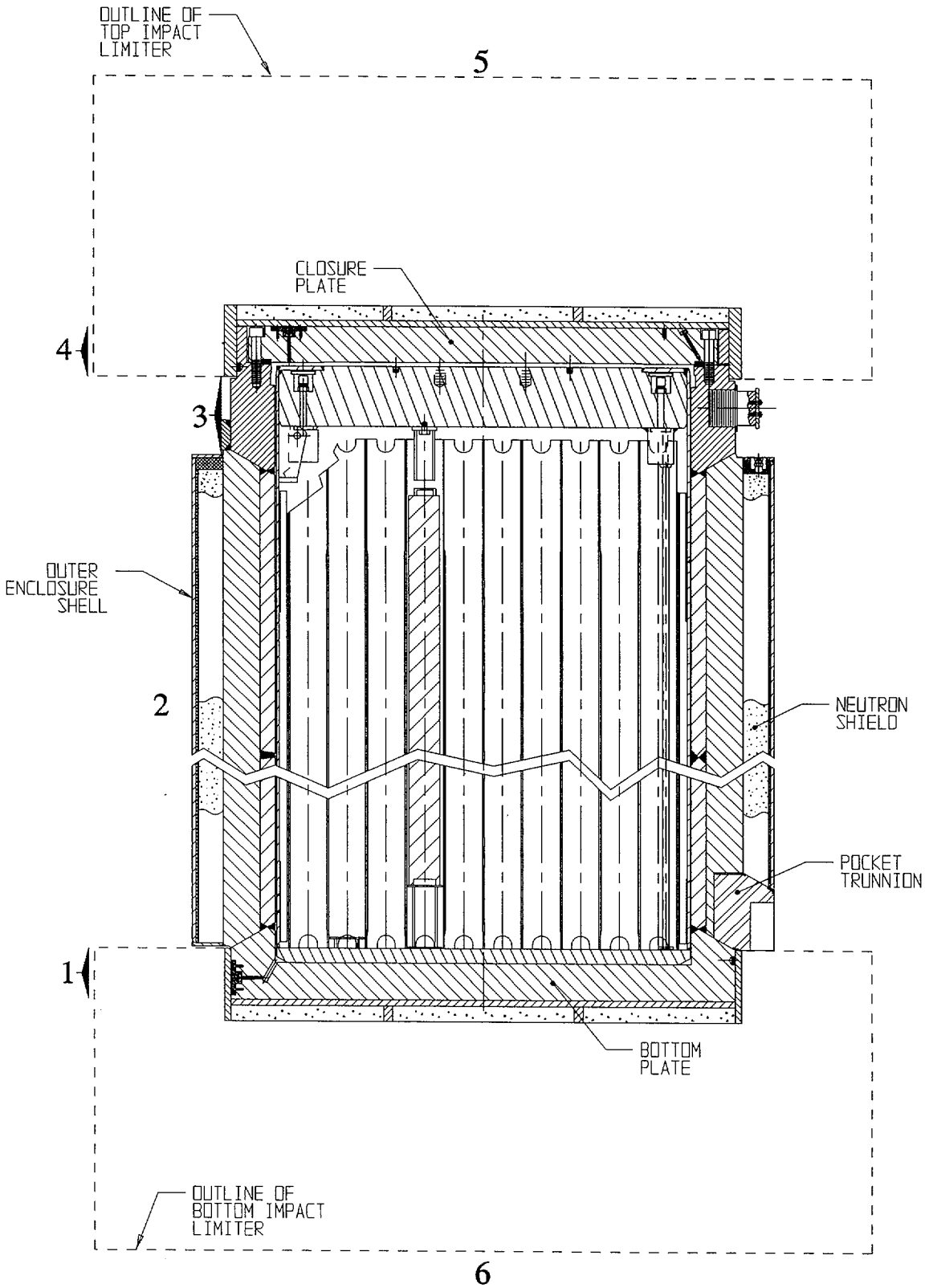


FIGURE 5.1.1; CROSS SECTION ELEVATION VIEW OF THE HI-STAR 100 SYSTEM WITH DOSE POINT LOCATIONS DURING NORMAL CONDITIONS

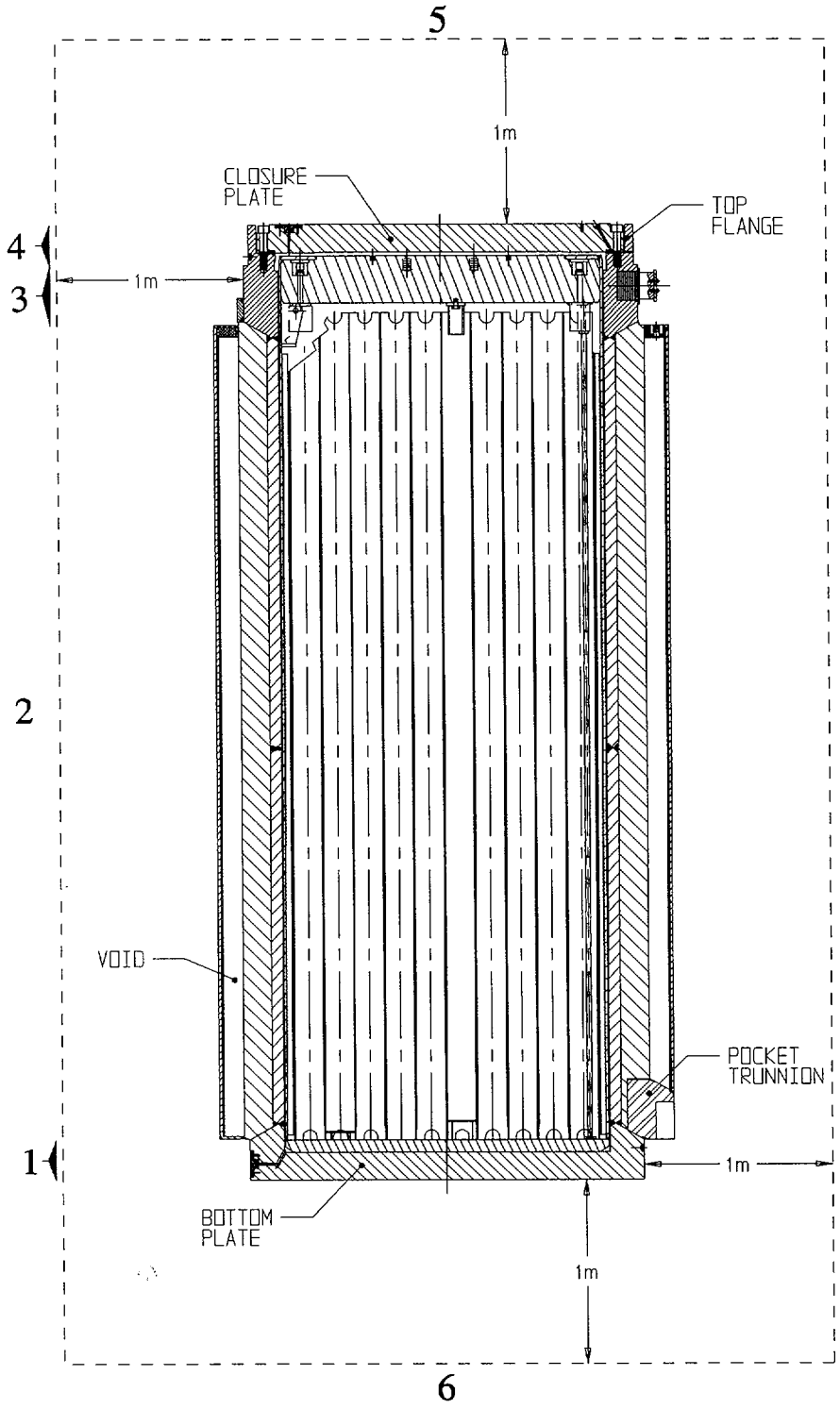


FIGURE 5.1.2; CROSS SECTION ELEVATION VIEW OF THE HI-STAR 100 SYSTEM WITH DOSE POINT LOCATIONS DURING ACCIDENT CONDITIONS

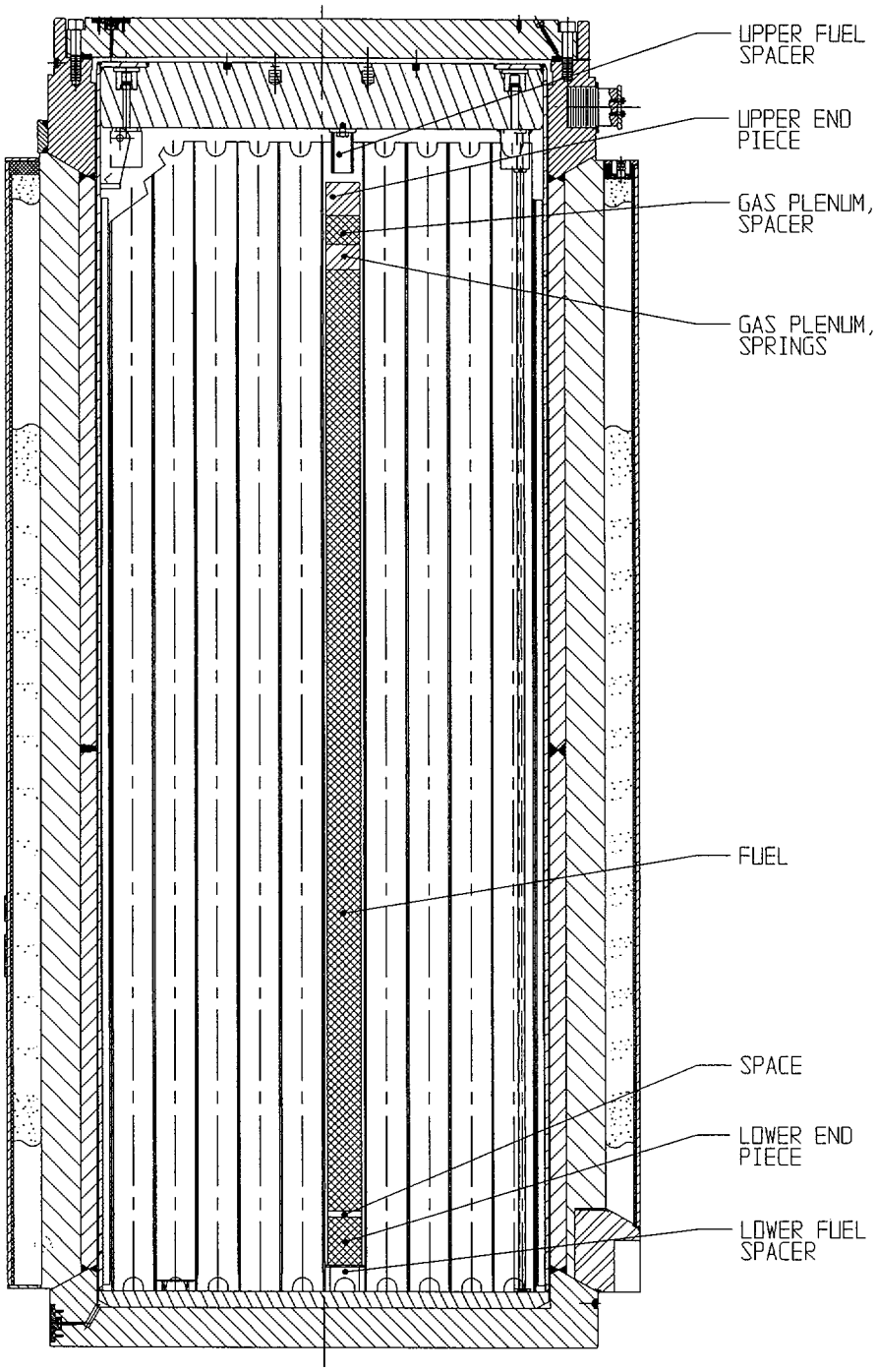


FIGURE 5.3.7; AXIAL LOCATION OF PWR DESIGN BASIS FUEL IN THE HI-STAR 100 SYSTEM

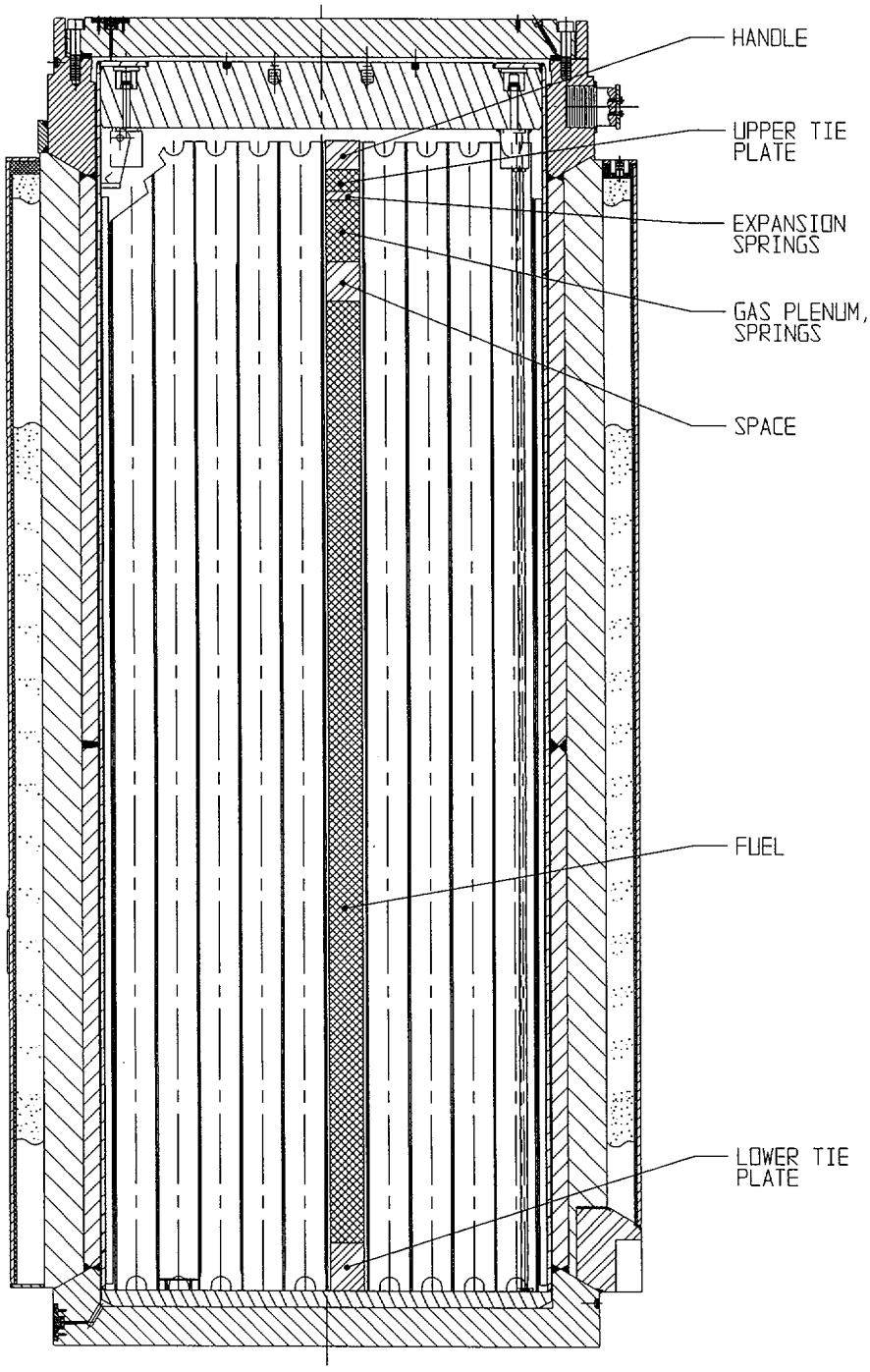


FIGURE 5.3.8; AXIAL LOCATION OF BWR DESIGN BASIS FUEL IN THE HI-STAR 100 SYSTEM

```
836   pz    1187.425    $ 2 meter + 12 feet
837   pz    1200.00
c
c         steel spine and holtite cells
c
1000      px    0.0
1001      px  -0.635
1002      px   0.635
1011   1  px  -0.635
1012   1  px   0.635
1021   2  px  -0.635
1022   2  px   0.635
1031   3  px  -0.635
1032   3  px   0.635
1041   4  px  -0.635
1042   4  px   0.635
1051   5  px  -0.635
1052   5  px   0.635
1061   6  px  -0.635
1062   6  px   0.635
1071   7  px  -0.635
1072   7  px   0.635
1081   8  px  -0.635
1082   8  px   0.635
1091   9  px  -0.635
1092   9  px   0.635
c
1101   px   15.71625  $ pocket trunion
1102   px   8.09625   $ pocket trunion opening
1103   px  -8.09625   $ pocket trunion opening 6 3/8 inches thick
1104   px  -15.71625  $ pocket trunion - 9 3/8 inches thick
c
2000      py   0.0
2001      py  -0.635
2002      py   0.635
2011   1  py  -0.635
2012   1  py   0.635
2021   2  py  -0.635
2022   2  py   0.635
2031   3  py  -0.635
2032   3  py   0.635
2041   4  py  -0.635
2042   4  py   0.635
2051   5  py  -0.635
2052   5  py   0.635
2061   6  py  -0.635
2062   6  py   0.635
2071   7  py  -0.635
2072   7  py   0.635
2081   8  py  -0.635
2082   8  py   0.635
2091   9  py  -0.635
2092   9  py   0.635
c
2101   py   15.71625  $ pocket trunion
2102   py   8.09625   $ pocket trunion opening
2103   py  -8.09625   $ pocket trunion opening 6 3/8 inches thick
2104   py  -15.71625  $ pocket trunion - 9 3/8 inches thick
c
c     OVERPACK surfaces /\ /\ /\ /\ /\
c
c     BLANK LINE

c     BLANK LINE
c
```

```
*tr1    0 0 0  9 279 90  99  9 90 90 90 0
*tr2    0 0 0 18 288 90 108 18 90 90 90 0
*tr3    0 0 0 27 297 90 117 27 90 90 90 0
*tr4    0 0 0 36 306 90 126 36 90 90 90 0
*tr5    0 0 0 45 315 90 135 45 90 90 90 0
*tr6    0 0 0 54 324 90 144 54 90 90 90 0
*tr7    0 0 0 63 333 90 153 63 90 90 90 0
*tr8    0 0 0 72 342 90 162 72 90 90 90 0
*tr9    0 0 0 81 351 90 171 81 90 90 90 0
c
c         PHOTON MATERIALS
c
c     fuel 3.4 w/o U235  10.412 gm/cc
c     m1            92235.01p   -0.029971
c                   92238.01p   -0.851529
c                   8016.01p    -0.1185
c     c     homogenized fuel  density 3.979996 gm/cc
c     m2            92235.01p   -0.024483
c                   92238.01p   -0.695601
c                    8016.01p   -0.096801
c                   40000.01p   -0.183115
c     c     zirconium 6.55 gm/cc
c     m3            40000.01p   1.          $ Zr Clad
c     c     stainless steel 7.92 gm/cc
c     m5            24000.01p   -0.19
c                   25055.01p   -0.02
c                   26000.01p   -0.695
c                   28000.01p   -0.095
c     c     boral  2.644 gm/cc
c     m6            5010.01p    -0.044226
c                   5011.01p    -0.201474
c                   13027.01p   -0.6861
c                   6000.01p    -0.0682
c     c     holtite 1.61 gm/cc
c     m7            6000.01p  -0.2766039
c                  13027.01p  -0.21285
c                   1001.01p  -0.0592
c                   8016.01p  -0.42372
c                   7014.01p  -0.0198
c                   5010.01p  -0.0014087
c                   5011.01p  -0.0064174
c     c     carbon steel 7.82 gm/cc
c     m8      6000.01p -0.005 26000.01p -0.995
c     c     air density 1.17e-3 gm/cc
c     m9      7014.01p 0.78 8016.01p 0.22
c     c
c     c         NEUTRON MATERIALS
c
c     fuel 3.4 w/o U235  10.412 gm/cc
m1          92235.50c   -0.029971
            92238.50c   -0.851529
            8016.50c    -0.1185
c     homogenized fuel  density 3.979996 gm/cc
m2          92235.50c   -0.024483
            92238.50c   -0.695601
             8016.50c   -0.096801
            40000.35c   -0.183115
c     helium  1e-4 gm/cc
m3     2004.50c 1.0
c     stainless steel 7.92 gm/cc
m5          24000.50c   -0.19
            25055.50c   -0.02
            26000.55c   -0.695
            28000.50c   -0.095
c     boral  2.644 gm/cc
```

```
m6           5010.50c    -0.044226
             5011.56c    -0.201474
             13027.50c   -0.6861
             6000.50c    -0.0682
c     holtite 1.61 gm/cc
m7           6000.50c  -0.2766039
            13027.50c  -0.21285
             1001.50c  -0.0592
             8016.50c  -0.42372
             7014.50c  -0.0198
             5010.50c  -0.0014087
             5011.56c  -0.0064174
mt7    lwtr.01t
c     carbon steel 7.82 gm/cc
m8      6000.50c -0.005 26000.55c -0.995
c     air density 1.17e-3 gm/cc
m9      7014.50c 0.78 8016.50c 0.22
c
phys:n   20 0.0
phys:p   100 0
c     imp:n   1 228r 0
c     imp:p   1 228r 0
nps     500000
prdmp    j   -30   1   2
c     print   10 110 160 161 20 170
print
mode n p
c
sdef  par=1  erg=d1 axs=0 0 1 x=d4 y=fx d5 z=d3
c
c    energy dist for gammas in the fuel
c
c    si1  h  0.7 1.0 1.5 2.0 2.5 3.0
c    sp1     0  0.31 0.31 0.15 0.15 0.08
c
c    energy dist for neutrons in the fuel
c
si1  h  0.1 0.4 0.9 1.4 1.85 3.0 6.43 20.0
sp1     0   0.03787 0.1935 0.1773 0.1310 0.2320 0.2098 0.01853
c
c    energy dist for Co60 gammas
c
c    si1  d 1.3325 1.1732
c    sp1    0.5    0.5
c
c    axial dist for neut and phot in fuel
c
si3  h 40.3479 55.5879 70.8279 101.3079 162.2679 223.2279
       284.1879 345.1479 375.6279 390.8679 406.1079
sp3    0 0.009167 0.031667 0.086250 0.194583 0.199167
       0.193750 0.178750 0.072083 0.025833 0.009167
sb3    0 1 1 1 1 1 1 1 1 1 1
c
c    axial dist for Co60 - a zero prob is in the fuel
c
c    si3  h 21.59 40.3479 421.3479 445.4271 448.8561 457.3397 468.63
c    sp3    0     0.547   0.0      0.125    0.045    0.227    0.056
c
si4  s               15 16
           13 14 15 16 17 18
        12 13 14 15 16 17 18 19
        12 13 14 15 16 17 18 19
     11 12 13 14 15 16 17 18 19 20
     11 12 13 14 15 16 17 18 19 20
        12 13 14 15 16 17 18 19
```

```
            12 13 14 15 16 17 18 19
               13 14 15 16 17 18
                     15 16
sp4   1 67r
c
ds5   s                 30 30
               29 29 29 29 29 29
            28 28 28 28 28 28 28 28
            27 27 27 27 27 27 27 27
         26 26 26 26 26 26 26 26 26 26
         25 25 25 25 25 25 25 25 25 25
            24 24 24 24 24 24 24 24
            23 23 23 23 23 23 23 23
               22 22 22 22 22 22
                     21 21
c
si11  -80.6831 -67.6783
si12  -64.1985 -51.1937
si13  -47.7139 -34.7091
si14  -31.2293 -18.2245
si15  -14.7447 -1.7399
si16   1.7399   14.7447
si17   18.2245  31.2293
si18   34.7091  47.7139
si19   51.1937  64.1985
si20   67.6783  80.6831
c
si21  -80.6831 -67.6783
si22  -64.1985 -51.1937
si23  -47.7139 -34.7091
si24  -31.2293 -18.2245
si25  -14.7447 -1.7399
si26   1.7399   14.7447
si27   18.2245  31.2293
si28   34.7091  47.7139
si29   51.1937  64.1985
si30   67.6783  80.6831
sp11  0 1
sp12  0 1
sp13  0 1
sp14  0 1
sp15  0 1
sp16  0 1
sp17  0 1
sp18  0 1
sp19  0 1
sp20  0 1
sp21  0 1
sp22  0 1
sp23  0 1
sp24  0 1
sp25  0 1
sp26  0 1
sp27  0 1
sp28  0 1
sp29  0 1
sp30  0 1
c
#         imp:n    imp:p
   301       1        1
   302       1        1
   303       1        1
   304       1        1
   305       2        1
   306       2        1
```

2021	1	1
2022	1	1
2023	1	1
2024	1	1
2025	1	1
2026	1	1
3000	128	1
3001	128	1
3002	256	1
3003	256	1
3004	512	1
3010	1	1
3011	1	1
3012	1	1
3013	1	1
3014	1	1
3020	8	1
3021	8	1
3022	8	1
3023	16	1
3024	16	1
3025	32	1
3026	32	1
3027	64	1
3028	64	1
3029	64	1
3030	1	1
3031	1	1
3032	1	1
3033	1	1
3034	1	1
3035	1	1
3036	1	1
3037	1	1
3038	1	1
3039	1	1
3042	4	1
3047	1	1
9000	512	1
9001	512	1
9002	512	1
9003	512	1
9004	512	1
9010	1	1
9011	1	1
9012	1	1
9013	1	1
9014	1	1
9100	32	1
9101	32	1
9102	32	1
9103	32	1
9104	32	1
9110	1	1
9111	1	1
9112	1	1
9113	1	1
9114	1	1
9200	1	1
9201	1	1
9202	1	1
9203	1	1
9204	1	1
9205	1	1
9206	1	1

```
  9207      1         1
  9208      1         1
  9209      1         1
  9210      1         1
  9211      1         1
  9212      1         1
  9213      1         1
  9214      1         1
  9215      1         1
  9216      1         1
  9217      1         1
  9218      1         1
  9219      1         1
  9220      1         1
  9221      1         1
  9222      1         1
  9223      1         1
  9224      1         1
  9999      0         0
c
c       neutron dose factors
c
c    2.5e-8   1.0e-7   1.0e-6   1.0e-5   1.0e-4   1.0e-3   1.0e-2      0.1
c       0.5      1.0      2.5      5.0      7.0      10.0     14.0      20.0
c    3.67e-6  3.67e-6  4.46e-6  4.54e-6  4.18e-6  3.76e-6  3.56e-6 2.17e-5
c       9.26e-5  1.32e-4  1.25e-4  1.56e-4  1.47e-4  1.47e-4  2.08e-4 2.27e-4
c
c       photon dose factors
c
c    0.01  0.03  0.05  0.07  0.1  0.15  0.2  0.25  0.3  0.35  0.4  0.45
c         0.5  0.55  0.6  0.65  0.7  0.8  1.0  1.4  1.8  2.2  2.6  2.8  3.25
c         3.75  4.25  4.75  5.0  5.25  5.75  6.25  6.75  7.5  9.0  11.0
c         13.0  15.0
c   3.96e-06  5.82e-07  2.90e-07  2.58e-07  2.83e-07  3.79e-07  5.01e-07
c       6.31e-07  7.59e-07  8.78e-07  9.85e-07  1.08e-06  1.17e-06  1.27e-06
c       1.36e-06  1.44e-06  1.52e-06  1.68e-06  1.98e-06  2.51e-06  2.99e-06
c       3.42e-06  3.82e-06  4.01e-06  4.41e-06  4.83e-06  5.23e-06  5.60e-06
c       5.80e-06  6.01e-06  6.37e-06  6.74e-06  7.11e-06  7.66e-06  8.77e-06
c       1.03e-05  1.18e-05  1.33e-05
c
f2:n   600 810 811 812 813
fs2    -740 -741 -742 -743 -744 -745 -746 -747 -748 -749 -750 -751 -752 t
fc2    1ft all
ft2    scx 1
de2   2.5e-8   1.0e-7   1.0e-6   1.0e-5   1.0e-4   1.0e-3   1.0e-2      0.1
      0.5      1.0      2.5      5.0      7.0      10.0      14.0      20.0
df2   3.67e-6  3.67e-6  4.46e-6  4.54e-6  4.18e-6  3.76e-6  3.56e-6 2.17e-5
      9.26e-5  1.32e-4  1.25e-4  1.56e-4  1.47e-4  1.47e-4  2.08e-4 2.27e-4
fq2   u s
tf2   3j 2
c
f12:n  695 830 831 832 833
fs12   -740 -741 -742 -743 -744 -745 -746 -747 -748 -749 -750 -751 -752 t
fc12    1ft all
ft12    scx 1
de12   2.5e-8   1.0e-7   1.0e-6   1.0e-5   1.0e-4   1.0e-3   1.0e-2      0.1
      0.5      1.0      2.5      5.0      7.0      10.0      14.0      20.0
df12   3.67e-6  3.67e-6  4.46e-6  4.54e-6  4.18e-6  3.76e-6  3.56e-6 2.17e-5
      9.26e-5  1.32e-4  1.25e-4  1.56e-4  1.47e-4  1.47e-4  2.08e-4 2.27e-4
fq12   u s
tf12   3j 2
c
c      PHOTON TALLIES
c
f102:p   600 810 811 812 813
```

```
fs102     -740 -741 -742 -743 -744 -745 -746 -747 -748 -749 -750 -751 -752 t
fc102     1ft all
ft102     scx 1
de102     0.01  0.03  0.05  0.07  0.1  0.15  0.2  0.25  0.3  0.35  0.4  0.45
          0.5  0.55  0.6  0.65  0.7  0.8  1.0  1.4  1.8  2.2  2.6  2.8  3.25
          3.75  4.25  4.75  5.0  5.25  5.75  6.25  6.75  7.5  9.0  11.0
          13.0  15.0
df102     3.96e-06  5.82e-07  2.90e-07  2.58e-07  2.83e-07  3.79e-07  5.01e-07
          6.31e-07  7.59e-07  8.78e-07  9.85e-07  1.08e-06  1.17e-06  1.27e-06
          1.36e-06  1.44e-06  1.52e-06  1.68e-06  1.98e-06  2.51e-06  2.99e-06
          3.42e-06  3.82e-06  4.01e-06  4.41e-06  4.83e-06  5.23e-06  5.60e-06
          5.80e-06  6.01e-06  6.37e-06  6.74e-06  7.11e-06  7.66e-06  8.77e-06
          1.03e-05  1.18e-05  1.33e-05
fq102     u s
tf102     3j 2
c
f112:p    695 830 831 832 833
fs112     -740 -741 -742 -743 -744 -745 -746 -747 -748 -749 -750 -751 -752 t
fc112     1ft all
ft112     scx 1
de112     0.01  0.03  0.05  0.07  0.1  0.15  0.2  0.25  0.3  0.35  0.4  0.45
          0.5  0.55  0.6  0.65  0.7  0.8  1.0  1.4  1.8  2.2  2.6  2.8  3.25
          3.75  4.25  4.75  5.0  5.25  5.75  6.25  6.75  7.5  9.0  11.0
          13.0  15.0
df112     3.96e-06  5.82e-07  2.90e-07  2.58e-07  2.83e-07  3.79e-07  5.01e-07
          6.31e-07  7.59e-07  8.78e-07  9.85e-07  1.08e-06  1.17e-06  1.27e-06
          1.36e-06  1.44e-06  1.52e-06  1.68e-06  1.98e-06  2.51e-06  2.99e-06
          3.42e-06  3.82e-06  4.01e-06  4.41e-06  4.83e-06  5.23e-06  5.60e-06
          5.80e-06  6.01e-06  6.37e-06  6.74e-06  7.11e-06  7.66e-06  8.77e-06
          1.03e-05  1.18e-05  1.33e-05
fq112     u s
tf112     3j 2
```