5.4 SHIELDING EVALUATION

The MCNP-4A code was used for all of the shielding analyses [5.1.1]. MCNP is a continuous energy, three-dimensional, coupled neutron-photon-electron Monte Carlo transport code. Continuous energy cross section data are represented with sufficient energy points to permit linear-linear interpolation between points. The individual cross section libraries used for each nuclide are those recommended by the MCNP manual. All of these data are based on ENDF/B-V data. MCNP has been extensively benchmarked against experimental data by the large user community. References [5.4.2], [5.4.3], and [5.4.4] are three examples of the benchmarking that has been performed.

The energy distribution of the source term, as described earlier, is used explicitly in the MCNP model. A different MCNP calculation is performed for each of the three source terms (neutron, decay gamma, and ^{60}Co). The axial distribution of the fuel source term is described in Table 2.1.11 and Figures 2.1.3 and 2.1.4. The PWR and BWR axial burnup distributions were obtained from References [5.4.5] and [5.4.6], respectively. These axial distributions were obtained from operating plants and are representative of PWR and BWR fuel with burnups greater than 30,000 MWD/MTU. The ^{60}Co source in the hardware was assumed to be uniformly distributed over the appropriate regions.

It has been shown that the neutron source strength varies as the burnup level raised by the power of 4.2. Since this relationship is non-linear and since the burnup in the axial center of a fuel assembly is greater than the average burnup, the neutron source strength in the axial center of the assembly is greater than the relative burnup times the average neutron source strength. In order to account for this effect, the neutron source strength in each of the 10 axial nodes listed in Table 2.1.11 was determined by multiplying the average source strength by the relative burnup level raised to the power of 4.2. The peak relative burnups listed in Table 2.1.11 for the PWR and BWR fuels are 1.105 and 1.195 respectively. Using the power of 4.2 relationship results in a 37.6% ($1.105^{4.2}/1.105$) and 76.8% ($1.195^{4.2}/1.195$) increase in the neutron source strength in the peak nodes for the PWR and BWR fuel respectively. The total neutron source strength increases by 15.6% for the PWR fuel assemblies and 36.9% for the BWR fuel assemblies.

MCNP was used to calculate doses at the various desired locations. MCNP calculates neutron or photon flux and these values can be converted into dose by the use of dose response functions. This is done internally in MCNP and the dose response functions are listed in the input file in Appendix 5.C. The response functions used in these calculations are listed in Table 5.4.1 and were taken from ANSI/ANS 6.1.1, 1977 [5.4.1].

The HI-STORM shielding analysis was performed for conservative burnup and cooling time combinations which bound the uniform and regionalized loading specifications for zircaloy clad fuel specified in Appendix B to the CoC. Therefore, the HI-STORM shielding analysis presented in this chapter is conservatively bounding for the MPC-24, MPC-32, and MPC-68.

Tables 5.1.1 through 5.1.3 provide the maximum dose rates adjacent to the HI-STORM overpack during normal conditions for each of the MPCs. Tables 5.1.4 through 5.1.6 provide the maximum dose rates at one meter from the overpack. A detailed discussion of the normal, off-normal, and accident condition dose rates is provided in Sections 5.1.1 and 5.1.2.

Tables 5.1.7 and 5.1.8 provide dose rates for the 100-ton and 125-ton HI-TRAC transfer casks, respectively, with the MPC-24 loaded with design basis fuel in the normal condition, in which the MPC is dry and the HI-TRAC water jacket is filled with water. Table 5.4.2 shows the corresponding dose rates adjacent to and one meter away from the 100-ton HI-TRAC for the fully flooded MPC condition with an empty water-jacket (condition in which the HI-TRAC is removed from the spent fuel pool). Table 5.4.3 shows the dose rates adjacent to and one meter away from the 100-ton HI-TRAC for the fully flooded MPC condition with the water jacket filled with water (condition in which welding operations are performed). Dose locations 4 and 5, which are on the top and bottom of the HI-TRAC were not calculated at the one-meter distance for these configurations. For the conditions involving a fully flooded MPC, the internal water level was 10 inches below the MPC lid. These dose rates represent the various conditions of the HI-TRAC during operations. Comparing these results to Table 5.1.7 indicates that the dose rates in the upper and lower portions of the HI-TRAC are reduced by about 50% with the water in the MPC. The dose at the center of the HI-TRAC is reduced by approximately 50% when there is also water in the water jacket and is essentially unchanged when there is no water in the water jacket as compared to the normal condition results shown in Table 5.1.7.

The burnup and cooling time combination of 42,500 MWD/MTU and 5 years was selected for the 100-ton MPC-24 HI-TRAC analysis because this combination of burnup and cooling time results in the highest dose rates, and therefore, bounds all other requested combinations in the 100-ton HI-TRAC. For comparison, dose rates corresponding to a burnup of 52,500 MWD/MTU and 10 year cooling time for the MPC-24 are provided in Table 5.4.4. The dose rate at 1 meter from the pool lid was not calculated because a concrete floor was placed 6 inches below the pool lid to account for potential ground scattering. These results clearly indicate that as the burnup and cooling time increase, the reduction in the gamma dose rate due to the increased cooling time results in a net decrease in the total dose rate. This result is due to the fact that the dose rates surrounding the 100-ton HI-TRAC transfer cask are gamma dominated.

In contrast, the dose rates surrounding the HI-TRAC 125 and 125D transfer casks have significantly higher neutron component. Therefore, the dose rates at 57,500 MWD/MTU burnup and 12 year cooling are slightly higher than the dose rates at 42,500 MWD/MTU burnup and 5 year cooling. The dose rates for the 125-ton HI-TRACs with the MPC-24 at 57,500 MWD/MTU and 12 year cooling are listed in Table 5.1.8 of Section 5.1. For comparison, dose rates corresponding to a burnup of 42,500 MWD/MTU and 5 year cooling time for the MPC-24 are provided in Table 5.4.5.

Tables 5.4.9 and 5.4.10 provide dose rates adjacent to and one meter away from the 100-ton HI-TRAC with the MPC-68 at burnup and cooling time combinations of 40,000 MWD/MTU and

5 years and 50,000 MWD/MTU and 10 years, respectively. The dose rate at 1 meter from the pool lid was not calculated because a concrete floor was placed 6 inches below the pool lid to account for potential ground scattering. These results demonstrate that the dose rates on contact at the top and bottom of the 100-ton HI-TRAC are somewhat higher in the MPC-68 case than in the MPC-24 case. However, the MPC-24 produces higher dose rates than the MPC-68 at the center of the HI-TRAC, on-contact, and at locations 1 to 2 feet away from the HI-TRAC. Therefore, the MPC-24 is still used for the exposure calculations in Chapter 10 of the FSAR.

Tables 5.4.11 and 5.4.12 provide dose rates adjacent to and one meter away from the 100-ton HI-TRAC with the MPC-32 at burnup and cooling time combinations of 32,500 MWD/MTU and 5 years and 45,000 MWD/MTU and 10 years, respectively. The dose rate at 1 meter from the pool lid was not calculated because a concrete floor was placed 6 inches below the pool lid to account for potential ground scattering. These results demonstrate that the dose rates on contact at the top and bottom of the 100-ton HI-TRAC are somewhat higher in the MPC-32 case than in the MPC-24 case. However, the MPC-24 produces comparable or higher dose rates than the MPC-32 at the center of the HI-TRAC, on-contact, and at locations 1 to 2 feet away from the HI-TRAC. Therefore, the MPC-24 is still used for the exposure calculations in Chapter 10 of the FSAR.

As mentioned in Section 5.0, all MPCs offer a regionalized loading pattern as described in Appendix B to the CoC. This loading pattern authorizes fuel of higher decay heat than uniform loading (i.e. higher burnups and shorter cooling times) to be stored in the center region, region 1, of the MPC. The outer region, region 2, of the MPC in regionalized loading is authorized to store fuel of lower decay heat than uniform loading (i.e. lower burnups and longer cooling times). From a shielding perspective, the older fuel on the outside provides shielding for the inner fuel in the radial direction. Regionalized patterns were specifically analyzed in each MPC in the 100-ton HI-TRAC. Based on analysis using the same burnup and cooling times in region 1 and 2 the following percentages were calculated for dose location 2 on the 100-ton HI-TRAC.

- Approximately 21%, 27%, and 8% of the neutron dose at the edge of the water jacket comes from region 1 fuel assemblies in the MPC-32, MPC-68, and MPC-24 respectively. Region 1 contains 12 (38% of total), 32 (47% of total), and 4 (17% of total) assemblies in the MPC-32, MPC-68, and MPC-24 respectively.
- Approximately 1%, 2%, and 0.2% of the photon dose at the edge of the water jacket comes from region 1 fuel assemblies in the MPC-32, MPC-68, and MPC-24 respectively.

These results clearly indicate that the outer fuel assemblies shield almost all of the gamma source from the inner assemblies in the radial direction and a significant percentage of the neutron source. The conclusion from this analysis is that the total dose rate on the external radial surfaces of the cask can be greatly reduced by placing longer cooled and lower burnup fuels on the outside of the basket. In the axial direction, regionalized loading results in higher dose rates in the center portion of the cask since the region 2 assemblies are not shielding the region 1 assemblies for axial dose locations.

All burnup and cooling time combinations for regionalized loading were analyzed and compared to the dose rates from uniform loading patterns. It was concluded that, in general, the radial dose rates from regionalized loading are bounded by the radial dose rates from uniform loading patterns. Therefore, dose rates for specific regionalized loading patterns are not presented in this chapter. In the axial direction, the reverse may be true since the inner fuel assemblies in a regionalized loading pattern have a higher burnup than the assemblies in the uniform loading patterns. However, as depicted in the graphical data in Section 5.1.1, the dose rate along the pool or transfer lids decrease substantially moving radially outward from the center of the lid. Therefore, this increase in the dose rate in the center of the lids due to regionalized loading does not significantly impact the occupational exposure. Section 5.4.9 provides additional discussion on regionalized loading dose rates compared to uniform loading dose rates.

Unless otherwise stated all tables containing dose rates for design basis fuel refer to design basis intact zircaloy clad fuel.

Since MCNP is a statistical code, there is an uncertainty associated with the calculated values. In MCNP the uncertainty is expressed as the relative error which is defined as the standard deviation of the mean divided by the mean. Therefore, the standard deviation is represented as a percentage of the mean. The relative error for the total dose rates presented in this chapter were typically less than 5% and the relative error for the individual dose components was typically less than 10%.

5.4.1 Streaming Through Radial Steel Fins and Pocket Trunnions and Azimuthal Variations

The HI-STORM 100 overpack and the HI-TRAC utilize radial steel fins for structural support and cooling. The attenuation of neutrons through steel is substantially less than the attenuation of neutrons through concrete and water. Therefore, it is possible to have neutron streaming through the fins that could result in a localized dose peak. The reverse is true for photons, which would result in a localized reduction in the photon dose. In addition to the fins, the pocket trunnions in the HI-TRAC 100 and 125 are essentially blocks of steel that are approximately 12 inches wide and 12 inches high. The effect of the pocket trunnion on neutron streaming and photon transmission will be more substantial than the effect of a single fin.

Analysis of the pocket trunnions in the HI-TRAC 100 and 125 and the steel fins in the HI-TRAC 100, 125, and 125D indicate that neutron streaming is noticeable at the surface of the transfer cask. The neutron dose rate on the surface of the pocket trunnion is approximately 5 times higher than the circumferential average dose rate at that location. The gamma dose rate is approximately 10 times lower than the circumferential average dose rate at that location. The streaming at the rib location is the largest in the HI-TRAC 125D because the ribs are thicker than in the HI-TRAC 100 or 125. The neutron dose rate on the surface of the rib in the 125D is approximately 3 times higher than the circumferential average dose rate at that location. The gamma dose rate on the surface of the rib in the 125D is approximately 3 times lower than the circumferential average dose rate at that location. At one meter from the cask surface there is little difference between the dose rates calculated over the fins and the pocket trunnions compared to the other areas of the water jackets.

These conclusions indicate that localized neutron streaming is noticeable on the surface of the transfer casks. However, at one meter from the surface the streaming has dissipated. Since most HI-TRAC operations will involve personnel moving around the transfer cask at some distance from the cask only surface average dose rates are reported in this chapter.

Below each lifting trunnion, there is a localized area where the water jacket has been reduced in height by 4.125 inches to accommodate the lift yoke (see Figures 5.3.12 and 5.3.13). This area experiences a significantly higher than average dose rate on contact of the HI-TRAC. The peak dose in this location is 1.5 Rem/hr for the MPC-32, 1.4 Rem/hr for the MPC-68 and 1.3 Rem/hr for the MPC-24 in the 100-ton HI-TRAC and 649 mrem/hr for the MPC-24 in the HI-TRAC 125D. At a distance of 1 to 2 feet from the edge of the HI-TRAC the localized effect is greatly reduced. This dose rate is acceptable because during lifting operations the lift yoke will be in place, which, due to the additional lift yoke steel (~3 inches), will greatly reduce the dose rate. However, more importantly, people will be prohibited from being in the vicinity of the lifting trunnions during lifting operations as a standard rigging practice. In addition the lift yoke is remote in its attachment and detachment, further minimizing personnel exposure. Immediately following the detachment of the lift yoke, in preparation for closure operations, temporary shielding may be placed in this area. Any temporary shielding (e.g., lead bricks, water tanks, lead blankets, steel plates, etc.) is sufficient to attenuate the localized hot spot. The operating procedure in Chapter 8 discusses the placement of temporary shielding in this area. For the 100-ton HI-TRAC, the optional temporary shield ring will replace the water that was lost from the axial reduction in the water jacket thereby eliminating the localized hot spot. When the HI-TRAC is in the horizontal position, during transport operations, it will (at a minimum) be positioned a few feet off the ground by the transport vehicle and therefore this location below the lifting trunnions will be positioned above people which will minimize the effect on personnel exposure. In addition, good operating practice will dictate that personnel remain at least a few feet away from the transport vehicle. During vertical transport of a loaded HI-TRAC, the localized hot spot will be even further from the operating personnel. Based on these considerations, the conclusion is that this localized hot spot does not significantly impact the personnel exposure.

5.4.2 Damaged Fuel Post-Accident Shielding Evaluation

5.4.2.1 Dresden 1 and Humboldt Bay Damaged Fuel

As discussed in Section 5.2.5.2, the analysis presented below, even though it is for damaged fuel, demonstrates the acceptability of storing intact Humboldt Bay 6x6 and intact Dresden 1 6x6 fuel assemblies.

For the damaged fuel and fuel debris accident condition, it is conservatively assumed that the damaged fuel cladding ruptures and all the fuel pellets fall and collect at the bottom of the damaged fuel container. The inner dimension of the damaged fuel container, specified in the Design Drawings of Chapter 1, and the design basis damaged fuel and fuel debris assembly dimensions in Table 5.2.2 are used to calculate the axial height of the rubble in the damaged fuel container assuming 50% compaction. Neglecting the fuel pellet to cladding inner diameter gap, the volume of cladding and fuel pellets available for deposit is calculated assuming the fuel rods are solid. Using the volume in conjunction with the damaged fuel container, the axial height of rubble is calculated to be 80 inches.

Dividing the total fuel gamma source for a 6x6 fuel assembly in Table 5.2.7 by the 80 inch rubble height provides a gamma source per inch of 3.41E+12 photon/s. Dividing the total neutron source for a 6x6 fuel assembly in Table 5.2.18 by 80 inches provides a neutron source per inch of 2.75E+05 neutron/s. These values are both bounded by the BWR design basis fuel gamma source per inch and neutron source per inch values of 1.08E+13 photon/s and 9.17E+05 neutron/s, respectively. These BWR design basis values were calculated by dividing the total source strengths for 40,000 MWD/MTU and 5 year cooling in Tables 5.2.6 and 5.2.17 by the active fuel length of 144 inches. Therefore, damaged Dresden 1 and Humboldt Bay fuel assemblies are bounded by the design basis intact BWR fuel assembly for accident conditions. No explicit analysis of the damaged fuel dose rates from Dresden 1 or Humboldt Bay fuel assemblies are provided as they are bounded by the intact fuel analysis.

5.4.2.2 Generic PWR and BWR Damaged Fuel

The Holtec Generic PWR and BWR DFCs are designed to accommodate any PWR or BWR fuel assembly that can physically fit inside the DFC. Damaged fuel assemblies under normal conditions, for the most part, resemble intact fuel assemblies from a shielding perspective. Under accident conditions, it can not be guaranteed that the damaged fuel assembly will remain intact. As a result, the damaged fuel assembly may begin to resemble fuel debris in its possible configuration after an accident.

Since damaged fuel is identical to intact fuel from a shielding perspective no specific analysis is required for damaged fuel under normal conditions. However, a generic shielding evaluation was performed to demonstrate that fuel debris under normal or accident conditions, or damaged fuel in a post-accident configuration, will not result in a significant increase in the dose rates around the 100-ton HI-TRAC. Only the 100-ton HI-TRAC was analyzed because it can be concluded that if the dose rate change is not significant for the 100-ton HI-TRAC then the change will not be significant for the 125-ton HI-TRACs or the HI-STORM overpacks.

Fuel debris or a damaged fuel assembly which has collapsed can have an average fuel density which is higher than the fuel density for an intact fuel assembly. If the damaged fuel assembly were to fully or partially collapse, the fuel density in one portion of the assembly would increase and the density in the other portion of the assembly would decrease. This scenario was analyzed with MCNP-4A in a conservative bounding fashion to determine the potential change in dose rate as a result of fuel debris or a damaged fuel assembly collapse. The analysis consisted of modeling the fuel assemblies in the damaged fuel locations in the MPC-24 (4 peripheral locations in the MPC-24E or MPC-24EF) and the MPC-68 (16 peripheral locations) with a fuel density that was twice the normal fuel density and correspondingly increasing the source rate for these locations by a factor of two. A flat axial power distribution was used which is approximately representative of the source distribution if the top half of an assembly collapsed into the bottom half of the assembly. Increasing the fuel density over the entire fuel length, rather than in the top half or bottom half of the fuel assembly, is conservative and provides the dose rate change in both the top and bottom portion of the cask.

Tables 5.4.13 and 5.4.14 provide the results for the MPC-24 and MPC-68, respectively. Only the radial dose rates are provided since the axial dose rates will not be significantly affected because the damaged fuel assemblies are located on the periphery of the baskets. A comparison of these results to the results in Tables 5.1.7 and 5.4.9 indicate that the dose rates in the top and bottom portion of the 100-ton HI-TRAC increase by less than 20% while the dose rate in the center of the HI-TRAC actually decreases a little bit. The increase in the bottom and top is due to the assumed flat power distribution. The dose rates shown in Tables 5.4.13 and 5.4.14 were averaged over the circumference of the cask. Since almost all of the peripheral cells in the MPC-68 are filled with DFCs, an azimuthal variation would not be expected for the MPC-68. However, since there are only 4 DFCs in the MPC-24E, an azimuthal variation in dose due to the damaged fuel/fuel debris might be expected. Therefore, the dose rates were evaluated in four smaller regions, one outside each DFC, that encompass about 44% of the circumference. There was no significant change in the dose rate as a result of the localized dose calculation. These results indicate that the potential effect on the dose rate is not very significant for the storage of damaged fuel and/or fuel debris. This conclusion is further reinforced by the fact that the majority of the significantly damaged fuel assemblies in the spent fuel inventories are older assemblies from the earlier days of nuclear plant operations. Therefore, these assemblies will have a considerably lower burnup and longer cooling times than the assemblies analyzed in this chapter.

5.4.3 Site Boundary Evaluation

NUREG-1536 [5.2.1] states that detailed calculations need not be presented since SAR Chapter 12 assigns ultimate compliance responsibilities to the site licensee. Therefore, this subsection describes, by example, the general methodology for performing site boundary dose calculations. The site-specific fuel characteristics, burnup, cooling time, and the site characteristics would be factored into the evaluation performed by the licensee.

As an example of the methodology, the dose from a single HI-STORM overpack loaded with an MPC-24 and various arrays of loaded HI-STORMs at distances equal to and greater than 100 meters were evaluated with MCNP. In the model, the casks were placed on an infinite slab of dirt to account for earth-shine effects. The atmosphere was represented by dry air at a uniform density corresponding to 20 degrees C. The height of air modeled was 700 meters. This is more than sufficient to properly account for skyshine effects. The models included either 500 or 1050 meters of air around the cask. Based on the behavior of the dose rate as a function of distance, 50 meters of air, beyond the detector locations, is sufficient to account for back-scattering. Therefore, the HI-STORM MCNP off-site dose models account for back scattering by including more than 50 meters of air beyond the detector locations for all cited dose rates. Since gamma back-scattering has an effect on the off-site dose, it is recommended that the site-specific evaluation under 10CFR72.212 include at least 50 to 100 meters of air, beyond the detector locations, in the calculational models.

The MCNP calculations of the off-site dose used a two-stage process. In the first stage a binary surface source file (MCNP terminology) containing particle track information was written for particles crossing the outer radial and top surfaces of the HI-STORM overpack. In the second stage of the calculation, this surface source file was used with the particle tracks originating on the outer edge of the overpack and the dose rate was calculated at the desired location (hundreds of meters away from the overpack). The results from this two-stage process are statistically the same as the results from a single calculation. However, the advantage of the two-stage process is that each stage can be optimized independently.

The annual dose, assuming 100% occupancy (8760 hours), at 200 meters from one cask is presented in Table 5.4.6 for the design basis burnup and cooling time analyzed. This table indicates that the dose due to neutrons is 7 % of the total dose. This is an important observation because it implies that simplistic analytical methods such as point kernel techniques may not properly account for the neutron transmissions and could lead to low estimates of the site boundary dose.

The annual dose, assuming 8760 hour occupancy, at distance from an array of casks was calculated in three steps.

1. The annual dose from the radiation leaving the side of the HI-STORM 100 overpack was calculated at the distance desired. Dose value = A.

2. The annual dose from the radiation leaving the top of the HI-STORM 100 overpack was calculated at the distance desired. Dose value = B.

3. The annual dose from the radiation leaving the side of a HI-STORM 100 overpack, when it is behind another cask, was calculated at the distance desired. The casks have an assumed 15-foot pitch. Dose value = C.

The doses calculated in the steps above are listed in Table 5.4.7 for the bounding burnup and cooling time of 52,500 MWD/MTU and 5-year cooling. Using these values, the annual dose (at the center of the long side) from an arbitrary 2 by Z array of HI-STORM 100 overpacks can easily be calculated. The following formula describes the method.

Z = number of casks along long side

Dose = ZA + 2ZB + ZC

As an example, the dose from a 2x3 array at 300 meters is presented.

1. The annual dose from the side of a single cask: Dose A = 5.20
2. The annual dose from the top of a single cask: Dose B = 6.57e-2
3. The annual dose from the side of a cask positioned behind another cask: Dose C = 1.04

Using the formula shown above (Z=3), the total dose at 300 meters from a 2x3 array of HI-STORM overpacks is 19.11 mrem/year, assuming a 8760 hour occupancy.

An important point to notice here is that the dose from the side of the back row of casks is 16 % of the total dose. This is a significant contribution and one that would probably not be accounted for properly by simpler methods of analysis.

The results for various typical arrays of HI-STORM overpacks can be found in Section 5.1. While the off-site dose analyses were performed for typical arrays of casks containing design basis fuel, compliance with the requirements of 10CFR72.104(a) can only be demonstrated on a site-specific basis. Therefore, a site-specific evaluation of dose at the controlled area boundary must be performed for each ISFSI in accordance with 10CFR72.212. The site-specific evaluation will consider the site-specific characteristics (such as exposure duration and the number of casks deployed), dose from other portions of the facility and the specifics of the fuel being stored (burnup and cooling time).

5.4.4 Stainless Steel Clad Fuel Evaluation

Table 5.4.8 presents the dose rates at the center of the HI-STORM 100 overpack, adjacent and at one meter distance, from the stainless steel clad fuel. These dose rates, when compared to Tables 5.1.1 through 5.1.6, are similar to the dose rates from the design basis zircaloy clad fuel, indicating that these fuel assemblies are acceptable for storage.

As described in Section 5.2.3, it would be incorrect to compare the total source strength from the stainless steel clad fuel assemblies to the source strength from the design basis zircaloy clad fuel assemblies since these assemblies do not have the same active fuel length and since there is a significant gamma source from Cobalt-60 activation in the stainless steel. Therefore it is necessary to calculate the dose rates from the stainless steel clad fuel and compare them to the dose rates from the zircaloy clad fuel. In calculating the dose rates, the source term for the stainless steel fuel was calculated with an artificial active fuel length of 144 inches to permit a simple comparison of dose rates from stainless steel clad fuel and zircaloy clad fuel at the center of the HI-STORM 100 overpack. Since the true active fuel length is shorter than 144 inches and since the end fitting masses of the stainless steel clad fuel are assumed to be identical to the end fitting masses of the zircaloy clad fuel, the dose rates at the other locations on the overpack are bounded by the dose rates from the design basis zircaloy clad fuel, and therefore, no additional dose rates are presented.

5.4.5 Mixed Oxide Fuel Evaluation

The source terms calculated for the Dresden 1 GE 6x6 MOX fuel assemblies can be compared to the source terms for the BWR design basis zircaloy clad fuel assembly (GE 7x7) which demonstrates that the MOX fuel source terms are bounded by the design basis source terms and no additional shielding analysis is needed.

Since the active fuel length of the MOX fuel assemblies is shorter than the active fuel length of the design basis fuel, the source terms must be compared on a per inch basis. Dividing the total fuel gamma source for the MOX fuel in Table 5.2.22 by the 110 inch active fuel height provides a gamma source per inch of 2.36e+12 photons/s. Dividing the total neutron source for the MOX fuel assemblies in Table 5.2.23 by 110 inches provides a neutron source strength per inch of 3.06e+5 neutrons/s. These values are both bounded by the BWR design basis fuel gamma source per inch and neutron source per inch values of 1.08e+13 photons/s and 9.17e+5 neutrons/s. These BWR design basis values were calculated by dividing the total source strengths for 40,000 MWD/MTU and 5 year cooling in Tables 5.2.6 and 5.2.17 by the active fuel length of 144 inches. This comparison shows that the MOX fuel source terms are bound by the design basis source terms. Therefore, no explicit analysis of dose rates is provided for MOX fuel.

Since the MOX fuel assemblies are Dresden Unit 1 6x6 assemblies, they can also be considered as damaged fuel. Using the same methodology as described in Section 5.4.2.1, the source term for the MOX fuel is calculated on a per inch basis assuming a post accident rubble height of 80 inches. The resulting gamma and neutron source strengths are 3.25e+12 photons/s and 4.21e+5 neutrons/s. These values are also bounded by the design basis fuel gamma source per inch and neutron source per inch. Therefore, no explicit analysis of dose rates is provided for MOX fuel in a post accident configuration.

5.4.6 Non-Fuel Hardware

As discussed in Section 5.2.4, non-fuel hardware in the form of BPRAs, TPDs, CRAs, and APSRs are permitted for storage, integral with a PWR fuel assembly, in the HI-STORM 100 System. Since each device occupies the same location within an assembly, only one device will be present in a given assembly. BPRAs and TPDs are authorized for unrestricted storage in an MPC while the CRAs and APSRs are restricted to the center four locations in the MPC-24, MPC-24E, MPC-24EF and MPC-32. The calculation of the source term and a description of the bounding fuel devices was provided in Section 5.2.4. The dose rate due to BPRAs and TPDs being stored in a fuel assembly was explicitly calculated. Table 5.4.15 provides the dose rates at various locations on the surface and one meter from the 100-ton HI-TRAC due to the BPRAs and TPDs for the MPC-24 and MPC-32. These results were added to the totals in the other table to provide the total dose rate with BPRAs. Table 5.4.15 indicates that the dose rates from BPRAs bound the dose rates from TPDs.

As discussed in Section 5.2.4, two different configurations were analyzed for CRAs and three different configurations were analyzed for APSRs. The dose rate due to CRAs and APSRs being stored in the inner four fuel locations was explicitly calculated for dose locations around the 100-ton HI-TRAC. Tables 5.4.16 and 5.4.17 provide the results for the different configurations of CRAs and APSRs, respectively, in the MPC-24 and MPC-32. These results indicate the dose rate on the radial surfaces of the overpack due to the storage of these devices is minimal and the dose rate out the top of the overpack is essentially 0. The latter is due to the fact that CRAs and APSRs do not achieve significant activation in the upper portion of the devices due to the manner in which they are utilized during normal reactor operations. In contrast, the dose rate out the bottom of the overpack is substantial due to these devices. However, as noted in Tables 5.4.16 and 5.4.17, the dose rate at the edge of the transfer lid is almost negligible due to APSRs and CRAs. Therefore, even though the dose rates calculated (using a very conservative source term evaluation) are daunting, they do not pose a risk from an operations perspective because they are localized in nature. Section 5.1.1 provides additional discussion on the acceptability of the relatively high localized doses on the bottom of the HI-TRACs.

5.4.7 Dresden Unit 1 Antimony-Beryllium Neutron Sources

Dresden Unit 1 has antimony-beryllium neutron sources which are placed in the water rod location of their fuel assemblies. These sources are steel rods which contain a cylindrical antimony-beryllium source which is 77.25 inches in length. The steel rod is approximately 95 inches in length. Information obtained from Dresden Unit 1 characterizes these sources in the following manner: "About one-quarter pound of beryllium will be employed as a special neutron source material. The beryllium produces neutrons upon gamma irradiation. The gamma rays for the source at initial start-up will be provided by neutron-activated antimony (about 865 curies). The source strength is approximately 1E+8 neutrons/second."

As stated above, beryllium produces neutrons through gamma irradiation and in this particular case antimony is used as the gamma source. The threshold gamma energy for producing neutrons from beryllium is 1.666 MeV. The outgoing neutron energy increases as the incident gamma energy increases. Sb-124, which decays by Beta decay with a half life of 60.2 days, produces a gamma of energy 1.69 MeV which is just energetic enough to produce a neutron from beryllium. Approximately 54% of the Beta decays for Sb-124 produce gammas with energies greater than or equal to 1.69 MeV. Therefore, the neutron production rate in the neutron source can be specified as 5.8E-6 neutrons per gamma (1E+8/865/3.7e+10/0.54) with energy greater than 1.666 MeV or 1.16E+5 neutrons/curie (1E+8/865) of Sb-124.

With the short half life of 60.2 days all of the initial Sb-124 is decayed and any Sb-124 that was produced while the neutron source was in the reactor is also decayed since these neutron sources are assumed to have the same minimum cooling time as the Dresden 1 fuel assemblies (array classes 6x6A, 6x6B, 6x6C, and 8x8A) of 18 years. Therefore, there are only two possible gamma sources which can produce neutrons from this antimony-beryllium source. The first is the gammas from the decay of fission products in the fuel assemblies in the MPC. The second gamma source is from Sb-124 which is being produced in the MPC from neutron activation from neutrons from the decay of fission products.

MCNP calculations were performed to determine the gamma source as a result of decay gammas from fuel assemblies and Sb-124 activation. The calculations explicitly modeled the 6x6 fuel assembly described in Table 5.2.2. A single fuel rod was removed and replaced by a guide tube. In order to determine the amount of Sb-124 that is being activated from neutrons in the MPC it was necessary to estimate the amount of antimony in the neutron source. The O.D. of the source was assumed to be the I.D. of the steel rod encasing the source (0.345 in.). The length of the source is 77.25 inches. The beryllium is assumed to be annular in shape encompassing the antimony. Using the assumed O.D. of the beryllium and the mass and length, the I.D. of the beryllium was calculated to be 0.24 inches. The antimony is assumed to be a solid cylinder with an O.D. equal to the I.D. of the beryllium. These assumptions are conservative since the antimony and beryllium are probably encased in another material which would reduce the mass of antimony. A larger mass of antimony is conservative since the calculated activity of Sb-124 is directly proportional to the initial mass of antimony.

The number of gammas from fuel assemblies with energies greater than 1.666 MeV entering the 77.25 inch long neutron source was calculated to be 1.04E+8 gammas/sec which would produce a neutron source of 603.2 neutrons/sec (1.04E+8 * 5.8E-6). The steady state amount of Sb-124 activated in the antimony was calculated to be 39.9 curies. This activity level would produce a neutron source of 4.63E+6 neutrons/sec (39.9 * 1.16E+5) or 6.0E+4 neutrons/sec/inch (4.63E+6/77.25). These calculations conservatively neglect the reduction in antimony and beryllium which would have occurred while the neutron sources were in the core and being irradiated at full reactor power.

Since this is a localized source (77.25 inches in length) it is appropriate to compare the neutron source per inch from the design basis Dresden Unit 1 fuel assembly, 6x6, containing an Sb-Be neutron source to the design basis fuel neutron source per inch. This comparison, presented in Table 5.4.18, demonstrates that a Dresden Unit 1 fuel assembly containing an Sb-Be neutron source is bounded by the design basis fuel.

As stated above, the Sb-Be source is encased in a steel rod. Therefore, the gamma source from the activation of the steel was considered assuming a burnup of 120,000 MWD/MTU which is the maximum burnup assuming the Sb-Be source was in the reactor for the entire 18 year life of Dresden Unit 1. The cooling time assumed was 18 years which is the minimum cooling time for Dresden Unit 1 fuel. The source from the steel was bounded by the design basis fuel assembly. In conclusion, storage of a Dresden Unit 1 Sb-Be neutron source in a Dresden Unit 1 fuel assembly is acceptable and bounded by the current analysis.

5.4.8 Thoria Rod Canister

Based on a comparison of the gamma spectra from Tables 5.2.37 and 5.2.7 for the thoria rod canister and design basis 6x6 fuel assembly, respectively, it is difficult to determine if the thoria rods will be bounded by the 6x6 fuel assemblies. However, it is obvious that the neutron spectra from the 6x6, Table 5.2.18, bounds the thoria rod neutron spectra, Table 5.2.38, with a significant margin. In order to demonstrate that the gamma spectrum from the single thoria rod canister is bounded by the gamma spectrum from the design basis 6x6 fuel assembly, the gamma dose rate on the outer radial surface of the 100-ton HI-TRAC and the HI-STORM overpack was estimated conservatively assuming an MPC full of thoria rod canisters. This gamma dose rate was compared to an estimate of the dose rate from an MPC full of design basis 6x6 fuel assemblies. The gamma dose rate from the 6x6 fuel was higher for the 100-ton HI-TRAC and only 15% lower for the HI-STORM overpack than the dose rate from an MPC full of thoria rod canisters. This in conjunction with the significant margin in neutron spectrum and the fact that there is only one thoria rod canister clearly demonstrates that the thoria rod canister is acceptable for storage in the MPC-68 or the MPC-68F.

5.4.9 Regionalized Loading Dose Rate Evaluation

Dose rates were calculated for regionalized loading patterns for the MPC-24, MPC-32, and MPC-68 using MCNP-4A. All burnup and cooling time combinations in Appendix B to the CoC were analyzed for both uniform and regionalized loading. The dose rates for all dose locations reported in this chapter were compared for the uniform loading patterns and the regionalized loading patterns.

It was determined that for the MPC-32, all radial surface and 1 meter dose rates for regionalized loading were bounded by the uniform loading dose rates reported in this chapter. The maximum calculated surface dose rates in the axial locations for regionalized loading were less than 15% higher than the uniform dose rates reported in this chapter for the surface of the overpack. At one-meter from the overpack, dose location 4 (in the center) was the only dose location which produced a slightly higher (5%) dose rate for regionalized loading compared to uniform loading.

For the MPC-24 it was determined that the maximum calculated dose rates in the axial direction for regionalized loading were less than 21% higher than the maximum calculated dose rates for uniform loading reported in this chapter. At one meter distance, the uniform loading dose rates reported in this chapter bound the regionalized loading dose rates. In the radial direction, the uniform loading dose rates reported in this chapter bound the regionalized loading dose rates for both surface and one-meter locations.

For the MPC-68 it was determined that all radial surface and 1 meter dose rates for regionalized loading were bounded by the uniform loading dose rates reported in this chapter. The maximum calculated surface dose rates in the axial locations for regionalized loading were less than 21% higher than the uniform dose rates reported in this chapter for the surface of the overpack. At one-meter from the overpack, dose locations 4 (in the center) and 5 (transfer lid center) were the only dose locations which produced a slightly higher (5% and 1.5% respectively) dose rate for regionalized loading compared to uniform loading.

Based on these results it can be stated that regionalized loading patterns will reduce the dose rate in the radial direction by shielding the hotter fuel on the inside of the cask with colder fuel on the outside of the cask. However, in the axial direction the localized dose rates in the center of the cask may increase as a result of the regionalized loading pattern. This is a localized effect, which has dissipated at the edge of the cask, and therefore will not result in a significant increase to the occupational exposure rates. In addition, it should be mentioned that the localized increase on the bottom center of the overpack is an area where workers will normally not be present and the increase in the top center of the overpack is an area where workers minimize their stay.

Table 5.4.1

FLUX-TO-DOSE CONVERSION FACTORS
(FROM [5.4.1])

Gamma Energy (MeV)	**(rem/hr)/ (photon/cm^2-s)**
0.01	3.96E-06
0.03	5.82E-07
0.05	2.90E-07
0.07	2.58E-07
0.1	2.83E-07
0.15	3.79E-07
0.2	5.01E-07
0.25	6.31E-07
0.3	7.59E-07
0.35	8.78E-07
0.4	9.85E-07
0.45	1.08E-06
0.5	1.17E-06
0.55	1.27E-06
0.6	1.36E-06
0.65	1.44E-06
0.7	1.52E-06
0.8	1.68E-06
1.0	1.98E-06
1.4	2.51E-06
1.8	2.99E-06
2.2	3.42E-06

Table 5.4.1 (continued)

FLUX-TO-DOSE CONVERSION FACTORS
(FROM [5.4.1])

Gamma Energy (MeV)	(rem/hr)/ (photon/cm^2-s)
2.6	3.82E-06
2.8	4.01E-06
3.25	4.41E-06
3.75	4.83E-06
4.25	5.23E-06
4.75	5.60E-06
5.0	5.80E-06
5.25	6.01E-06
5.75	6.37E-06
6.25	6.74E-06
6.75	7.11E-06
7.5	7.66E-06
9.0	8.77E-06
11.0	1.03E-05
13.0	1.18E-05
15.0	1.33E-05

Table 5.4.1 (continued)

FLUX-TO-DOSE CONVERSION FACTORS
(FROM [5.4.1])

Neutron Energy (MeV)	Quality Factor	(rem/hr)†/(n/cm^2-s)
2.5E-8	2.0	3.67E-6
1.0E-7	2.0	3.67E-6
1.0E-6	2.0	4.46E-6
1.0E-5	2.0	4.54E-6
1.0E-4	2.0	4.18E-6
1.0E-3	2.0	3.76E-6
1.0E-2	2.5	3.56E-6
0.1	7.5	2.17E-5
0.5	11.0	9.26E-5
1.0	11.0	1.32E-4
2.5	9.0	1.25E-4
5.0	8.0	1.56E-4
7.0	7.0	1.47E-4
10.0	6.5	1.47E-4
14.0	7.5	2.08E-4
20.0	8.0	2.27E-4

† Includes the Quality Factor.

Table 5.4.2

DOSE RATES FOR THE 100-TON HI-TRAC FOR THE FULLY FLOODED MPC CONDITION WITH AN EMPTY NEUTRON SHIELD
MPC-24 DESIGN BASIS ZIRCALOY CLAD FUEL AT
42,500 MWD/MTU AND 5-YEAR COOLING

Dose Point† Location	Fuel Gammas†† (mrem/hr)	^{60}Co Gammas (mrem/hr)	Neutrons (mrem/hr)	Totals (mrem/hr)	Totals with BPRAs (mrem/hr)
ADJACENT TO THE 100-TON HI-TRAC					
1	11.98	208.28	17.67	237.93	240.36
2	832.91	0.49	307.58	1140.98	1329.90
3	2.87	316.93	4.29	324.09	446.27
4	11.60	240.82	0.71	253.13	348.08
5 (pool lid)	33.90	1355.73	2.42	1392.06†††	1401.52
ONE METER FROM THE 100-TON HI-TRAC					
1	109.69	47.02	43.72	200.43	224.97
2	366.56	6.37	100.08	473.00	556.78
3	43.99	77.09	18.08	139.17	180.31

Note: MPC internal water level is 10 inches below the MPC lid.

† Refer to Figures 5.1.2 and 5.1.4.

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

††† Cited dose rates correspond to the cask center. Figures 5.1.6, 5.1.7, and 5.1.11 illustrate the substantial reduction in dose rates moving radially outward from the axial center of the HI-TRAC.

Table 5.4.3

DOSE RATES FOR THE 100-TON HI-TRAC FOR THE FULLY FLOODED MPC CONDITION WITH A FULL NEUTRON SHIELD
MPC-24 DESIGN BASIS ZIRCALOY CLAD FUEL AT 42,500 MWD/MTU AND 5-YEAR COOLING

Dose Point† Location	Fuel Gammas†† (mrem/hr)	^{60}Co Gammas (mrem/hr)	Neutrons (mrem/hr)	Totals (mrem/hr)	Totals with BPRAs (mrem/hr)
ADJACENT TO THE 100-TON HI-TRAC					
1	9.94	208.39	2.30	220.63	222.58
2	484.93	0.33	20.09	505.35	612.64
3	1.72	316.17	0.40	318.29	439.86
4	11.58	240.81	0.73	253.13	348.07
5 (pool lid)	33.79	1355.87	2.05	1391.71†††	1401.15
ONE METER FROM THE 100-TON HI-TRAC					
1	62.48	32.38	2.68	97.55	111.28
2	211.20	2.57	7.56	221.34	268.28
3	24.97	53.19	0.91	79.07	105.88

Note: MPC internal water level is 10 inches below the MPC lid.

† Refer to Figures 5.1.2 and 5.1.4.

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

††† Cited dose rates correspond to the cask center. Figures 5.1.6, 5.1.7, and 5.1.11 illustrate the substantial reduction in dose rates moving radially outward from the axial center of the HI-TRAC.

Table 5.4.4

DOSE RATES FROM THE 100-TON HI-TRAC FOR NORMAL CONDITIONS
MPC-24 DESIGN BASIS ZIRCALOY CLAD FUEL AT
52,500 MWD/MTU AND 10-YEAR COOLING

Dose Point Location	Fuel Gammas (mrem/hr)	(n,γ) Gammas (mrem/hr)	^{60}Co Gammas (mrem/hr)	Neutrons (mrem/hr)	Totals (mrem/hr)	Totals with BPRAs (mrem/hr)
ADJACENT TO THE 100-TON HI-TRAC						
1	15.02	19.24	364.33	272.44	671.03	678.96
2	429.66	78.51	0.43	146.51	655.11	884.67
3	3.94	3.77	200.88	227.95	436.55	574.46
3 (temp)	1.80	6.71	93.11	3.66	105.29	168.56
4	9.98	1.49	161.68	280.60	453.74	569.34
4 (outer)	2.72	0.95	40.25	189.42	233.33	262.42
5 (pool lid)	74.81	27.47	1835.64	1829.84	3767.75	3827.89
5 (transfer)	192.71	1.51	2735.38	1047.89	3977.49	4067.40
5(t-outer)	44.12	0.51	264.76	413.98	723.38	743.32
ONE METER FROM THE 100-TON HI-TRAC						
1	56.59	10.34	54.16	44.29	165.38	195.54
2	189.01	23.94	4.28	54.19	271.42	373.07
3	23.56	5.76	44.99	21.26	95.57	141.47
3 (temp)	23.42	6.19	38.32	8.04	75.96	117.34
4	3.39	0.26	49.91	69.91	123.47	159.28
5 (transfer)	79.07	0.28	1117.41	292.41	1489.17	1525.50
5(t-outer)	9.82	0.89	100.72	83.95	195.39	199.01

Notes:

- Refer to Figures 5.1.2 and 5.1.4 for dose locations.
- Dose location 3(temp) represents dose location 3 with temporary shielding installed.
- Dose location 4(outer) is the radial segment at dose location 4 which is 18-30 inches from the center of the overpack.
- Dose location 5(t-outer) is the radial segment at dose location 5 (transfer lid) which is 30-42 and 54-66 inches from the center of the lid for the adjacent and one meter locations, respectively. The inner radius of the HI-TRAC is 34.375 in. and the outer radius of the water jacket is 44.375 in.
- Dose rate based on no water within the MPC. For the majority of the duration that the HI-TRAC pool lid is installed, the MPC cavity will be flooded with water. The water within the MPC greatly reduces the dose rate.

Table 5.4.5

DOSE RATES FROM THE 125-TON HI-TRAC FOR NORMAL CONDITIONS
MPC-24 DESIGN BASIS ZIRCALOY CLAD FUEL AT
42,500 MWD/MTU AND 5-YEAR COOLING

Dose Point Location	Fuel Gammas (mrem/hr)	(n,γ) Gammas (mrem/hr)	^{60}Co Gammas (mrem/hr)	Neutrons (mrem/hr)	Totals (mrem/hr)	Totals with BPRAs (mrem/hr)
ADJACENT TO THE 125-TON HI-TRAC						
1	3.96	12.95	74.95	87.10	178.97	179.63
2	70.38	38.36	0.01	60.33	169.07	183.80
3	0.88	1.37	46.37	138.96	187.59	205.89
4	24.90	1.76	253.74	160.84	441.23	548.40
4 (outer)	3.01	1.26	31.51	3.37	39.15	52.33
5 (pool)	35.11	0.65	390.89	556.82	983.46	990.62
5 (transfer)	38.67	1.00	447.94	92.22	579.83	584.92
ONE METER FROM THE 125-TON HI-TRAC						
1	9.32	5.17	9.61	14.33	38.43	40.32
2	31.44	12.43	0.39	20.57	64.83	71.40
3	3.55	2.92	9.37	12.79	28.62	33.19
4	6.93	0.42	61.09	16.56	85.01	110.69
5 (transfer)	15.19	0.19	216.56	15.97	247.92	250.64

Notes:

- Refer to Figures 5.1.2 and 5.1.4 for dose locations.
- Dose location 4(outer) is the radial segment at dose location 4 which is 18-24 inches from the center of the overpack.
- Dose rate based on no water within the MPC. For the majority of the duration that the HI-TRAC pool lid is installed, the MPC cavity will be flooded with water. The water within the MPC greatly reduces the dose rate.

Table 5.4.6

ANNUAL DOSE AT 200 METERS FROM A SINGLE HI-STORM OVERPACK WITH AN MPC-24 WITH DESIGN BASIS ZIRCALOY CLAD FUEL†

Dose Component	**52,500 MWD/MTU 5-Year Cooling (mrem/yr)**
Fuel gammas††	16.52
^{60}Co Gammas	2.17
Neutrons	1.50
Total	20.19

† 8760 hour annual occupancy is assumed.

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

Table 5.4.7

DOSE VALUES USED IN CALCULATING ANNUAL DOSE FROM VARIOUS ISFSI CONFIGURATIONS
52,500 MWD/MTU AND 5-YEAR COOLING ZIRCALOY CLAD FUEL†

Distance	A Side of Overpack (mrem/yr)	B Top of Overpack (mrem/yr)	C Side of Shielded Overpack (mrem/yr)
100 meters	129.0	1.59	25.80
150 meters	45.6	0.61	9.12
200 meters	19.9	0.27	3.98
250 meters	9.72	0.13	1.94
300 meters	5.20	6.57e-2	1.04
350 meters	3.05	3.35e-2	0.61
400 meters	1.75	1.77e-2	0.35

† 8760 hour annual occupancy is assumed.

Table 5.4.8

DOSE RATES AT THE CENTERLINE OF THE OVERPACK FOR
DESIGN BASIS STAINLESS STEEL CLAD FUEL
WITHOUT BPRAs

Dose Point[†] Location	Fuel Gammas[††] (mrem/hr)	^{60}Co Gammas (mrem/hr)	Neutrons (mrem/hr)	Totals (mrem/hr)
MPC-24 (40,000 MWD/MTU AND 8-YEAR COOLING)				
2 (Adjacent)	36.97	0.02	1.11	38.10
2 (One Meter)	18.76	0.17	0.50	19.43
MPC-32 (40,000 MWD/MTU AND 9-YEAR COOLING)				
2 (Adjacent)	37.58	0.00	1.49	39.08
2 (One Meter)	18.74	0.25	0.58	19.57
MPC-68 (22,500 MWD/MTU AND 10-YEAR COOLING)				
2 (Adjacent)	17.79	0.01	0.10	17.90
2 (One Meter)	8.98	0.13	0.04	9.15

† Refer to Figure 5.1.1.

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

Table 5.4.9

DOSE RATES FROM THE 100-TON HI-TRAC FOR NORMAL CONDITIONS
MPC-68 DESIGN BASIS ZIRCALOY CLAD FUEL AT
40,000 MWD/MTU AND 5-YEAR COOLING

Dose Point Location	Fuel Gammas (mrem/hr)	(n,γ) Gammas (mrem/hr)	^{60}Co Gammas (mrem/hr)	Neutrons (mrem/hr)	Totals (mrem/hr)
ADJACENT TO THE 100-TON HI-TRAC					
1	38.21	13.11	884.16	175.11	1110.58
2	893.89	64.66	0.56	117.12	1076.23
3	2.14	1.36	535.10	74.19	612.80
3 (temp)	1.32	2.19	254.09	1.37	258.97
4	4.91	0.58	210.60	96.74	312.82
4 (outer)	1.39	0.39	55.78	57.95	115.51
5 (pool lid)	114.16	16.05	3959.24	1049.66	5139.11
5(transfer lid)	183.52	0.75	5965.40	661.25	6810.92
5 (t-outer)	64.15	0.31	525.96	246.99	837.41
ONE METER FROM THE 100-TON HI-TRAC					
1	121.31	7.95	82.57	30.94	242.78
2	383.23	18.30	6.09	40.37	447.99
3	29.82	3.14	121.08	8.57	162.61
3 (temp)	29.78	3.28	98.08	4.11	135.26
4	1.98	0.11	70.28	20.16	92.53
5(transfer lid)	90.70	0.32	2646.66	177.18	2914.86
5 (t-outer)	11.23	0.57	223.53	50.10	285.42

Notes:

- Refer to Figures 5.1.2 and 5.1.4 for dose locations.
- Dose location 3(temp) represents dose location 3 with temporary shielding installed.
- Dose location 4(outer) is the radial segment at dose location 4 which is 18-30 inches from the center of the overpack.
- Dose location 5(t-outer) is the radial segment at dose location 5 (transfer lid) which is 30-42 and 54-66 inches from the center of the lid for the adjacent and one meter locations, respectively. The inner radius of the HI-TRAC is 34.375 in. and the outer radius of the water jacket is 44.375 in.
- Dose rate based on no water within the MPC. For the majority of the duration that the HI-TRAC pool lid is installed, the MPC cavity will be flooded with water. The water within the MPC greatly reduces the dose rate.

Table 5.4.10

DOSE RATES FROM THE 100-TON HI-TRAC FOR NORMAL CONDITIONS
MPC-68 DESIGN BASIS ZIRCALOY CLAD FUEL AT
50,000 MWD/MTU AND 10-YEAR COOLING

Dose Point Location	Fuel Gammas (mrem/hr)	(n,γ) Gammas (mrem/hr)	^{60}Co Gammas (mrem/hr)	Neutrons (mrem/hr)	Totals (mrem/hr)
ADJACENT TO THE 100-TON HI-TRAC					
1	15.11	19.37	501.33	258.76	794.57
2	367.98	95.55	0.32	173.08	636.93
3	0.75	2.02	303.41	109.64	415.81
3 (temp)	0.48	3.24	144.07	2.03	149.82
4	1.68	0.85	119.41	142.95	264.89
4 (outer)	0.49	0.57	31.63	85.63	118.32
5 (pool lid)	44.84	23.72	2244.93	1551.16	3864.65
5(transfer lid)	83.23	1.11	3382.44	977.18	4443.96
5 (t-outer)	26.72	0.47	298.23	364.99	690.41
ONE METER FROM THE 100-TON HI-TRAC					
1	50.03	11.75	46.82	45.73	154.33
2	157.59	27.05	3.45	59.65	247.74
3	12.25	4.64	68.65	12.66	98.21
3 (temp)	12.23	4.85	55.61	6.08	78.78
4	0.76	0.16	39.85	29.80	70.57
5(transfer lid)	38.01	0.47	1500.68	261.84	1801.00
5 (t-outer)	4.71	0.84	126.74	74.03	206.32

Notes:

- Refer to Figures 5.1.2 and 5.1.4 for dose locations.
- Dose location 3(temp) represents dose location 3 with temporary shielding installed.
- Dose location 4(outer) is the radial segment at dose location 4 which is 18-30 inches from the center of the overpack.
- Dose location 5(t-outer) is the radial segment at dose location 5 (transfer lid) which is 30-42 and 54-66 inches from the center of the lid for the adjacent and one meter locations, respectively. The inner radius of the HI-TRAC is 34.375 in. and the outer radius of the water jacket is 44.375 in.
- Dose rate based on no water within the MPC. For the majority of the duration that the HI-TRAC pool lid is installed, the MPC cavity will be flooded with water. The water within the MPC greatly reduces the dose rate.

Table 5.4.11

DOSE RATES FROM THE 100-TON HI-TRAC FOR NORMAL CONDITIONS
MPC-32 DESIGN BASIS ZIRCALOY CLAD FUEL
32,500 MWD/MTU AND 5-YEAR COOLING

Dose Point Location	Fuel Gammas (mrem/hr)	(n,γ) Gammas (mrem/hr)	^{60}Co Gammas (mrem/hr)	Neutrons (mrem/hr)	Totals (mrem/hr)	Totals with BPRAs (mrem/hr)
ADJACENT TO THE 100-TON HI-TRAC						
1	34.19	6.26	713.29	91.01	844.75	854.30
2	908.57	27.74	1.02	52.05	989.38	1260.07
3	11.14	1.22	450.32	71.69	534.37	743.66
4	28.45	0.80	337.51	89.81	456.58	622.75
4 (outer)	7.59	0.32	84.67	61.11	153.68	195.46
5 (pool)	217.00	8.76	3935.75	592.50	4754.00	4830.44
5 (transfer)	403.36	0.34	5939.74	332.20	6675.64	6767.42
5(t-outer)	73.70	0.18	500.60	132.39	706.87	725.52
ONE METER FROM THE 100-TON HI-TRAC						
1	119.57	3.67	106.31	15.04	244.59	279.86
2	399.54	8.71	8.10	18.99	435.35	555.53
3	51.57	2.07	92.54	7.15	153.34	215.38
4	8.54	0.12	100.64	22.18	131.48	180.84
5 (transfer)	166.15	0.11	2361.13	92.74	2620.13	2660.63
5(t-outer)	17.09	0.35	209.36	27.00	253.81	257.96

Notes:

- Refer to Figures 5.1.2 and 5.1.4 for dose locations.
- Dose location 4(outer) is the radial segment at dose location 4 which is 18-30 inches from the center of the overpack.
- Dose location 5(t-outer) is the radial segment at dose location 5 (transfer lid) which is 30-42 and 54-66 inches from the center of the lid for the adjacent and one meter locations, respectively. The inner radius of the HI-TRAC is 34.375 in. and the outer radius of the water jacket is 44.375 in.
- Dose rate based on no water within the MPC. For the majority of the duration that the HI-TRAC pool lid is installed, the MPC cavity will be flooded with water. The water within the MPC greatly reduces the dose rate.

Table 5.4.12

DOSE RATES FROM THE 100-TON HI-TRAC FOR NORMAL CONDITIONS
MPC-32 DESIGN BASIS ZIRCALOY CLAD FUEL
45,000 MWD/MTU AND 10-YEAR COOLING

Dose Point Location	Fuel Gammas (mrem/hr)	(n,γ) Gammas (mrem/hr)	^{60}Co Gammas (mrem/hr)	Neutrons (mrem/hr)	Totals (mrem/hr)	Totals with BPRAs (mrem/hr)
ADJACENT TO THE 100-TON HI-TRAC						
1	14.91	13.25	442.90	192.77	663.83	673.38
2	422.32	58.76	0.64	110.24	591.95	862.64
3	4.50	2.59	279.61	151.86	438.55	647.84
4	12.19	1.70	209.57	190.21	413.67	579.84
4 (outer)	3.10	0.67	52.57	129.44	185.79	227.56
5 (pool)	102.06	18.55	2443.80	1254.97	3819.38	3895.82
5 (transfer)	190.81	0.72	3688.12	703.71	4583.37	4675.15
5(t-outer)	34.38	0.39	310.83	280.41	626.01	644.67
ONE METER FROM THE 100-TON HI-TRAC						
1	54.75	7.78	66.01	31.84	160.38	195.65
2	185.04	18.46	5.03	40.22	248.74	368.92
3	23.55	4.38	57.46	15.15	100.54	162.59
4	3.39	0.24	62.49	46.97	113.10	162.46
5 (transfer)	77.12	0.23	1466.08	196.43	1739.86	1780.36
5(t-outer)	7.85	0.74	130.00	57.20	195.78	199.93

Notes:

- Refer to Figures 5.1.2 and 5.1.4 for dose locations.
- Dose location 4(outer) is the radial segment at dose location 4 which is 18-30 inches from the center of the overpack.
- Dose location 5(t-outer) is the radial segment at dose location 5 (transfer lid) which is 30-42 and 54-66 inches from the center of the lid for the adjacent and one meter locations, respectively. The inner radius of the HI-TRAC is 34.375 in. and the outer radius of the water jacket is 44.375 in.
- Dose rate based on no water within the MPC. For the majority of the duration that the HI-TRAC pool lid is installed, the MPC cavity will be flooded with water. The water within the MPC greatly reduces the dose rate.

Table 5.4.13

DOSE RATES FROM THE 100-TON HI-TRAC FOR ACCIDENT CONDITIONS
WITH FOUR DAMAGED FUEL CONTAINERS
MPC-24 DESIGN BASIS ZIRCALOY CLAD FUEL
42,500 MWD/MTU AND 5-YEAR COOLING
WITHOUT BPRAs

Dose Point† Location	Fuel Gammas (mrem/hr)	(n,γ) Gammas (mrem/hr)	^{60}Co Gammas (mrem/hr)	Neutrons (mrem/hr)	Totals (mrem/hr)
ADJACENT TO THE 100-TON HI-TRAC					
1	48.07	15.17	627.06	230.25	920.55
2	996.02	54.95	0.75	100.04	1151.76
3	13.63	3.41	345.75	221.02	583.80
ONE METER FROM THE 100-TON HI-TRAC					
1	140.31	7.79	93.21	34.99	276.30
2	442.10	17.01	7.37	37.68	504.15
3	63.42	4.45	77.43	20.56	165.86

† Refer to Figures 5.1.2 and 5.1.4.

Table 5.4.14

DOSE RATES FROM THE 100-TON HI-TRAC FOR ACCIDENT CONDITIONS
WITH SIXTEEN DAMAGED FUEL CONTAINERS
MPC-68 DESIGN BASIS ZIRCALOY CLAD FUEL
40,000 MWD/MTU AND 5-YEAR COOLING

Dose Point† Location	Fuel Gammas (mrem/hr)	(n,γ) Gammas (mrem/hr)	^{60}Co Gammas (mrem/hr)	Neutrons (mrem/hr)	Totals (mrem/hr)
ADJACENT TO THE 100-TON HI-TRAC					
1	90.03	18.80	884.16	324.33	1317.31
2	845.02	65.12	0.56	110.16	1020.86
3	2.60	2.76	535.10	164.10	704.57
ONE METER FROM THE 100-TON HI-TRAC					
1	141.32	9.84	82.57	46.71	280.44
2	369.64	19.91	6.09	44.10	439.74
3	40.76	4.37	121.08	17.02	183.23

† Refer to Figures 5.1.2 and 5.1 4.

Table 5.4.15

DOSE RATES DUE TO BPRAs AND TPDs FROM THE 100-TON HI-TRAC FOR NORMAL CONDITIONS

Dose Point Location	MPC-24 BPRAs (mrem/hr)	MPC-24 TPDs (mrem/hr)	MPC-32 BPRAs (mrem/hr)	MPC-32 TPDs (mrem/hr)
ADJACENT TO THE 100-TON HI-TRAC				
1	7.93	0.00	9.55	0.01
2	229.56	0.03	270.69	0.04
3	137.91	125.75	209.28	188.04
3 (temp)	63.27	56.21	86.91	76.97
4	115.60	106.71	166.17	156.15
4 (outer)	29.09	27.12	41.78	39.32
5 (pool lid)	60.14	0.00	76.44	0.00
5(transfer lid)	89.91	0.00	91.78	0.00
5(t-outer)	19.94	0.00	18.65	0.00
ONE METER FROM THE 100-TON HI-TRAC				
1	30.16	0.18	35.26	0.23
2	101.65	1.20	120.18	1.62
3	45.90	38.93	62.05	54.93
3 (temp)	41.38	35.01	54.88	48.77
4	35.81	33.37	49.36	47.19
5(transfer lid)	36.33	0.00	40.50	0.00
5(t-outer)	3.62	0.00	4.15	0.00

Notes:

- Refer to Figures 5.1.2 and 5.1.4 for dose locations.
- Dose location 3(temp) represents dose location 3 with temporary shielding installed.
- Dose location 4(outer) is the radial segment at dose location 4 which is 18-30 inches from the center of the overpack.
- Dose location 5(t-outer) is the radial segment at dose location 5 (transfer lid) which is 30-42 and 54-66 inches from the center of the lid for the adjacent and one meter locations, respectively. The inner radius of the HI-TRAC is 34.375 in. and the outer radius of the water jacket is 44.375 in.
- Dose rate based on no water within the MPC. For the majority of the duration that the HI-TRAC pool lid is installed, the MPC cavity will be flooded with water. The water within the MPC greatly reduces the dose rate.

Table 5.4.16

DOSE RATES DUE TO CRAs FROM THE 100-TON HI-TRAC
FOR NORMAL CONDITIONS

	MPC-24		MPC-32	
Dose Point Location	**Config. 1 (mrem/hr)**	**Config. 2 (mrem/hr)**	**Config. 1 (mrem/hr)**	**Config. 2 (mrem/hr)**
ADJACENT TO THE 100-TON HI-TRAC				
1	5.39	1.02	3.28	0.68
2	0.09	0.00	0.01	0.00
3	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00
5 (pool lid)	919.59	170.85	1141.10	213.24
5(transfer lid)	1519.98	287.72	2012.93	380.57
5(t-outer)	1.54	0.25	1.01	0.19
ONE METER FROM THE 100-TON HI-TRAC				
1	1.20	0.20	0.69	0.14
2	0.26	0.03	0.05	0.01
3	0.01	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00
5(transfer lid)	223.62	41.60	257.95	49.19
5(t-outer)	8.26	1.54	8.87	1.70

Notes:

- Refer to Figures 5.1.2 and 5.1.4 for dose locations.
- Dose location 5(t-outer) is the radial segment at dose location 5 (transfer lid) which is 30-42 and 54-66 inches from the center of the lid for the adjacent and one meter locations, respectively. The inner radius of the HI-TRAC is 34.375 in. and the outer radius of the water jacket is 44.375 in.
- Dose rate based on no water within the MPC. For the majority of the duration that the HI-TRAC pool lid is installed, the MPC cavity will be flooded with water. The water within the MPC greatly reduces the dose rate.

Table 5.4.17

DOSE RATES DUE TO APSRs FROM THE 100-TON HI-TRAC FOR NORMAL CONDITIONS

	MPC-24			MPC-32		
Dose Point Location	**Config. 1 (mrem/hr)**	**Config. 2 (mrem/hr)**	**Config. 3 (mrem/hr)**	**Config. 1 (mrem/hr)**	**Config. 2 (mrem/hr)**	**Config. 3 (mrem/hr)**
ADJACENT TO THE 100-TON HI-TRAC						
1	12.42	2.35	12.25	7.57	1.56	7.51
2	0.21	0.01	9.12	0.03	0.00	0.19
3	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00
5 (pool lid)	1996.57	371.98	1941.51	2414.84	453.88	2687.17
5(transfer)	3021.08	572.85	2994.54	3980.02	750.17	3860.83
5(t-outer)	3.41	0.54	3.57	2.23	0.42	1.94
ONE METER FROM THE 100-TON HI-TRAC						
1	2.73	0.46	3.49	1.57	0.32	1.58
2	0.61	0.07	3.31	0.12	0.02	0.18
3	0.02	0.00	0.04	0.01	0.00	0.01
4	0.00	0.00	0.00	0.00	0.00	0.00
5(transfer)	458.06	84.81	444.44	521.02	99.10	510.78
5(t-outer)	17.11	3.19	17.36	18.34	3.48	18.20

Notes:

- Refer to Figures 5.1.2 and 5.1.4 for dose locations.
- Dose location 5(t-outer) is the radial segment at dose location 5 (transfer lid) which is 30-42 and 54-66 inches from the center of the lid for the adjacent and one meter locations, respectively. The inner radius of the HI-TRAC is 34.375 in. and the outer radius of the water jacket is 44.375 in.
- Dose rate based on no water within the MPC. For the majority of the duration that the HI-TRAC pool lid is installed, the MPC cavity will be flooded with water. The water within the MPC greatly reduces the dose rate.

Table 5.4.18

COMPARISON OF NEUTRON SOURCE PER INCH PER SECOND FOR DESIGN BASIS 7X7 FUEL AND DESIGN BASIS DRESDEN UNIT 1 FUEL

Assembly	**Active fuel length (inch)**	**Neutrons per sec per inch**	**Neutrons per sec per inch with Sb-Be source**	**Reference for neutrons per sec per inch**
7x7 design basis	144	9.17E+5	N/A	Table 5.2.17 - 40 GWD/MTU and 5 year cooling
6x6 design basis	110	2.0E+5	2.6E+5	Table 5.2.18
6x6 design basis MOX	110	3.06E+5	3.66E+5	Table 5.2.23

5.5 REGULATORY COMPLIANCE

Chapters 1 and 2 and this chapter of this FSAR describe in detail the shielding structures, systems, and components (SSCs) important to safety.

This chapter has evaluated these shielding SSCs important to safety and has assessed the impact on health and safety resulting from operation of an independent spent fuel storage installation (ISFSI) utilizing the HI-STORM 100 System.

It has been shown that the design of the shielding system of the HI-STORM 100 System is in compliance with 10CFR72 and that the applicable design and acceptance criteria including 10CFR20 have been satisfied. Thus, this shielding evaluation provides reasonable assurance that the HI-STORM 100 System will allow safe storage of spent fuel.

5.6 REFERENCES

[5.1.1] J.F. Briesmeister, Ed., "MCNP - A General Monte Carlo N-Particle Transport Code, Version 4A." Los Alamos National Laboratory, LA-12625-M (1993).

[5.1.2] O.W. Hermann, C.V. Parks, "SAS2H: A Coupled One-Dimensional Depletion and Shielding Analysis Module," NUREG/CR-0200, Revision 5, (ORNL/NUREG/CSD-2/V2/R5), Oak Ridge National Laboratory, September 1995.

[5.1.3] O.W. Hermann, R.M. Westfall, "ORIGEN-S: SCALE System Module to Calculate Fuel Depletion, Actinide Transmutation, Fission Product Buildup and Decay, and Associated Radiation Source Terms," NUREG/CR-0200, Revision 5, (ORNL/NUREG/CSD-2/V2/R5), Oak Ridge National Laboratory, September 1995.

[5.2.1] NUREG-1536, SRP for Dry Cask Storage Systems, USNRC, Washington, DC, January 1997.

[5.2.2] A.G. Croff, M.A. Bjerke, G.W. Morrison, L.M. Petrie, "Revised Uranium-Plutonium Cycle PWR and BWR Models for the ORIGEN Computer Code," ORNL/TM-6051, Oak Ridge National Laboratory, September 1978.

[5.2.3] A. Luksic, "Spent Fuel Assembly Hardware: Characterization and 10CFR 61 Classification for Waste Disposal," PNL-6906-vol. 1, Pacific Northwest Laboratory, June 1989.

[5.2.4] J.W. Roddy et al., "Physical and Decay Characteristics of Commercial LWR Spent Fuel," ORNL/TM-9591/V1&R1, Oak Ridge National Laboratory, January 1996.

[5.2.5] "Characteristics of Spent Fuel, High Level Waste, and Other Radioactive Wastes Which May Require Long-Term Isolation," DOE/RW-0184, U.S. Department of Energy, December 1987.

[5.2.6] "Spent Nuclear Fuel Discharges from U.S. Reactors 1994," SR/CNEAF/96-01, Energy Information Administration, U.S. Department of Energy, February 1996.

[5.2.7] "Characteristics Database System LWR Assemblies Database," DOE/RW-0184-R1, U.S. Department of Energy, July 1992.

[5.2.8] O. W. Hermann, et al., "Validation of the Scale System for PWR Spent Fuel Isotopic Composition Analyses," ORNL/TM-12667, Oak Ridge National Laboratory, March 1995.

[5.2.9] M. D. DeHart and O. W. Hermann, "An Extension of the Validation of SCALE (SAS2H) Isotopic Predictions for PWR Spent Fuel," ORNL/TM-13317, Oak Ridge National Laboratory, September 1996.

[5.2.10] O. W. Hermann and M. D. DeHart, "Validation of SCALE (SAS2H) Isotopic Predictions for BWR Spent Fuel," ORNL/TM-13315, Oak Ridge National Laboratory, September 1998.

[5.2.11] "Summary Report of SNF Isotopic Comparisons for the Disposal Criticality Analysis Methodology," B00000000-01717-5705-00077 REV 00, CRWMS M&O, September 1997.

[5.2.12] "Isotopic and Criticality Validation of PWR Actinide-Only Burnup Credit," DOE/RW-0497, U.S. Department of Energy, May 1997.

[5.2.13] B. D. Murphy, "Prediction of the Isotopic Composition of UO_2 Fuel from a BWR: Analysis of the DU1 Sample from the Dodewaard Reactor," ORNL/TM-13687, Oak Ridge National Laboratory, October 1998.

[5.2.14] O. W. Hermann, et al., "Technical Support for a Proposed Decay Heat Guide Using SAS2H/ORIGEN-S Data," NUREG/CR-5625, ORNL-6698, Oak Ridge National Laboratory, September 1994.

[5.4.1] "American National Standard Neutron and Gamma-Ray Flux-to-Dose Rate Factors", ANSI/ANS-6.1.1-1977.

[5.4.2] D. J. Whalen, et al., "MCNP: Photon Benchmark Problems," LA-12196, Los Alamos National Laboratory, September 1991.

[5.4.3] D. J. Whalen, et al., "MCNP: Neutron Benchmark Problems," LA-12212, Los Alamos National Laboratory, November 1991.

[5.4.4] J. C. Wagner, et al., "MCNP: Criticality Safety Benchmark Problems," LA-12415, Los Alamos National Laboratory, October 1992.

[5.4.5] S. E. Turner, "Uncertainty Analysis - Axial Burnup Distribution Effects," presented in "Proceedings of a Workshop on the Use of Burnup Credit in Spent Fuel Transport Casks," SAND-89-0018, Sandia National Laboratory, Oct. 1989.

[5.4.6] Commonwealth Edison Company, Letter No. NFS-BND-95-083, Chicago, Illinois.

APPENDIX 5.A

SAMPLE INPUT FILE FOR SAS2H

(Total number of pages in this appendix : 3)

```
=SAS2H    PARM='halt05,skipshipdata'
bw 15x15 PWR assembly
' fuel temp 923
44groupndf5    LATTICECELL
UO2 1 0.95 923 92234 0.03204 92235 3.6 92236 0.01656
    92238 96.3514 END
'
' Zirc 4 composition
ARBM-ZIRC4 6.55 4 1 0 0 50000 1.7 26000 0.24 24000 0.13 40000 97.93
           2 1.0 595 END
'
' water with 652.5 ppm boron
H2O       3 DEN=0.7135 1  579 END
ARBM-BORMOD  0.7135 1 1 0 0 5000 100 3 652.5E-6  579  END
'
co-59   3 0 1-20 579 end
kr-83   1 0 1-20 923 end
kr-84   1 0 1-20 923 end
kr-85   1 0 1-20 923 end
kr-86   1 0 1-20 923 end
sr-90   1 0 1-20 923 end
y-89    1 0 1-20 923 end
zr-94   1 0 1-20 923 end
zr-95   1 0 1-20 923 end
mo-94   1 0 1-20 923 end
mo-95   1 0 1-20 923 end
nb-94   1 0 1-20 923 end
nb-95   1 0 1-20 923 end
tc-99   1 0 1-20 923 end
ru-106   1 0 1-20 923 end
rh-103   1 0 1-20 923 end
rh-105   1 0 1-20 923 end
sb-124   1 0 1-20 923 end
sn-126   1 0 1-20 923 end
xe-131   1 0 1-20 923 end
xe-132   1 0 1-20 923 end
xe-134   1 0 1-20 923 end
'
xe-135   1 0 1-09 923 end
'
xe-136   1 0 1-20 923 end
cs-133   1 0 1-20 923 end
cs-134   1 0 1-20 923 end
cs-135   1 0 1-20 923 end
cs-137   1 0 1-20 923 end
ba-136   1 0 1-20 923 end
la-139   1 0 1-20 923 end
ce-144   1 0 1-20 923 end
pr-143   1 0 1-20 923 end
nd-143   1 0 1-20 923 end
nd-144   1 0 1-20 923 end
nd-145   1 0 1-20 923 end
nd-146   1 0 1-20 923 end
nd-147   1 0 1-20 923 end
nd-148   1 0 1-20 923 end
nd-150   1 0 1-20 923 end
pm-147   1 0 1-20 923 end
pm-148   1 0 1-20 923 end
pm-149   1 0 1-20 923 end
```

```
sm-147  1 0 1-20 923 end
sm-148  1 0 1-20 923 end
sm-149  1 0 1-20 923 end
sm-150  1 0 1-20 923 end
sm-151  1 0 1-20 923 end
sm-152  1 0 1-20 923 end
eu-151  1 0 1-20 923 end
eu-153  1 0 1-20 923 end
eu-154  1 0 1-20 923 end
eu-155  1 0 1-20 923 end
gd-154  1 0 1-20 923 end
gd-155  1 0 1-20 923 end
gd-157  1 0 1-20 923 end
gd-158  1 0 1-20 923 end
gd-160  1 0 1-20 923 end
'
END COMP
'
' - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
'
'  FUEL-PIN-CELL GEOMETRY:
'
SQUAREPITCH  1.44272 0.950468 1 3 1.08712 2 0.97028 0 END
'
' - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
'
'  MTU in this model is 0.495485 based on fuel dimensions provided
'
'  1 power cycle will be used and a library will be generated every
'  2500 MWD/MTU  power level is 40 MW/MTU
'  therefore 62.5 days per 2500 MWD/MTU
'  Below
'  BURN=62.5*NLIB/CYC
'  POWER=MTU*40
'
'  Number of libraries is 20 which is 50,000 MWD/MTU burnup (20*2500)
'
'  ASSEMBLY AND CYCLE PARAMETERS:
'
NPIN/ASSM=208 FUELNGTH=365.76 NCYCLES=1 NLIB/CYC=20
PRINTLEVEL=1
LIGHTEL=5  INPLEVEL=1   NUMHOLES=17
NUMINStr= 0  ORTUBE= 0.6731  SRTUBE=0.63246   END
POWER=19.81938  BURN=1250.0  END
'
 O  66.54421
 FE  0.24240868
 ZR 98.78151  CR  0.1311304   SN  1.714782
'
END
=SAS2H    PARM='restarts,halt10,skipshipdata'
bw 15x15 PWR assembly
END
=SAS2H    PARM='restarts,halt15,skipshipdata'
bw 15x15 PWR assembly
END
=SAS2H    PARM='restarts,halt20,skipshipdata'
bw 15x15 PWR assembly
END
```

APPENDIX 5.B

SAMPLE INPUT FILE FOR ORIGEN-S

(Total number of pages in this appendix : 7)

```
#ORIGENS
0$$  A4 33 A8 26 A11 71  E
1$$  1 T
bw 15x15 FUEL -- FT33F001 -
'
' SUBCASE  1 LIBRARY POSITION  1
'
'   lib     pos      grms   photon group
3$$ 33  A3  1  0  A16 2   E T
35$$ 0 T
56$$  5  5  A6 3  A10  0  A13 9  A15 3 A19 1 E
57** 0.0 A3 1.E-5 0.05556 E T
 FUEL 3.6
BW 15x15 0.495485 MTU
58** 19.81938  19.81938 19.81938 19.81938  19.81938
60**  1.0000   3.0000  15.0000  30.0000  62.5
66$$ A1 2 A5 2 A9 2  E
73$$  922350  922340  922360  922380  80000  500000
      260000  240000  400000
74** 17837.45 158.7533 82.05225 477406.4 66544.21 1714.782
     242.0868 131.1304 98781.51
75$$  2  2  2  2  4  4  4  4  4  T
'
' SUBCASE  2 LIBRARY POSITION  2
'
3$$ 33  A3   2  0  A16 2  A33 0  E T
35$$ 0 T
56$$  3  3  A6 3  A10   5  A15 3 A19 1 E
57** 0.0 A3 1.E-5  0.05556 E T
 fuel
BW 15X15
58** 19.81938 19.81938 19.81938
60** 18.5 37.0 62.5
66$$ A1 2 A5 2 A9 2  E T
'
' SUBCASE  3 LIBRARY POSITION  3
'
3$$ 33  A3   3  0  A16 2  A33 0  E T
35$$ 0 T
56$$  3  3  A6 3  A10   3  A15 3 A19 1 E
57** 0.0 A3 1.E-5  0.05556 E T
 fuel
BW 15X15
58** 19.81938 19.81938 19.81938
60** 18.5 37.0 62.5
66$$ A1 2 A5 2 A9 2  E T
'
' SUBCASE  4 LIBRARY POSITION  4
'
3$$ 33  A3   4  0  A16 2  A33 0  E T
35$$ 0 T
56$$  3  3  A6 3  A10   3  A15 3 A19 1 E
57** 0.0 A3 1.E-5  0.05556 E T
 fuel
BW 15X15
58** 19.81938 19.81938 19.81938
60** 18.5 37.0 62.5
66$$ A1 2 A5 2 A9 2  E T
'
```

```
' SUBCASE  5 LIBRARY POSITION  5
'
3$$ 33  A3   5  0  A16 2  A33 0  E T
35$$ 0 T
56$$  3  3  A6 3  A10   3  A15 3 A19 1 E
57** 0.0 A3 1.E-5  0.05556 E T
 fuel
BW 15X15
58** 19.81938 19.81938 19.81938
60** 18.5 37.0 62.5
66$$ A1 2 A5 2 A9 2  E T
'
' SUBCASE  6 LIBRARY POSITION  6
'
3$$ 33  A3   6  0  A16 2  A33 0  E T
35$$ 0 T
56$$  3  3  A6 3  A10   3  A15 3 A19 1 E
57** 0.0 A3 1.E-5  0.05556 E T
 fuel
BW 15X15
58** 19.81938 19.81938 19.81938
60** 18.5 37.0 62.5
66$$ A1 2 A5 2 A9 2  E T
'
' SUBCASE  7 LIBRARY POSITION  7
'
3$$ 33  A3   7  0  A16 2  A33 0  E T
35$$ 0 T
56$$  3  3  A6 3  A10   3  A15 3 A19 1 E
57** 0.0 A3 1.E-5  0.05556 E T
 fuel
BW 15X15
58** 19.81938 19.81938 19.81938
60** 18.5 37.0 62.5
66$$ A1 2 A5 2 A9 2  E T
'
' SUBCASE  8 LIBRARY POSITION  8
'
3$$ 33  A3   8  0  A16 2  A33 0  E T
35$$ 0 T
56$$  3  3  A6 3  A10   3  A15 3 A19 1 E
57** 0.0 A3 1.E-5  0.05556 E T
 fuel
BW 15X15
58** 19.81938 19.81938 19.81938
60** 18.5 37.0 62.5
66$$ A1 2 A5 2 A9 2  E T
'
' SUBCASE  9 LIBRARY POSITION  9
'
3$$ 33  A3   9  0  A16 2  A33 0  E T
35$$ 0 T
56$$  3  3  A6 3  A10   3  A15 3 A19 1 E
57** 0.0 A3 1.E-5  0.05556 E T
 fuel
BW 15X15
58** 19.81938 19.81938 19.81938
60** 18.5 37.0 62.5
66$$ A1 2 A5 2 A9 2  E T
```

```
'
' SUBCASE 10 LIBRARY POSITION 10
'
3$$ 33  A3  10  0  A16 2  A33 0  E T
35$$ 0 T
56$$  3  3  A6 3  A10   3  A15 3 A19 1 E
57** 0.0 A3 1.E-5  0.05556 E T
 fuel
BW 15X15
58** 19.81938 19.81938 19.81938
60** 18.5 37.0 62.5
66$$ A1 2 A5 2 A9 2  E T
'
' SUBCASE 11 LIBRARY POSITION 11
'
3$$ 33  A3  11  0  A16 2  A33 0  E T
35$$ 0 T
56$$  3  3  A6 3  A10   3  A15 3 A19 1 E
57** 0.0 A3 1.E-5  0.05556 E T
 fuel
BW 15X15
58** 19.81938 19.81938 19.81938
60** 18.5 37.0 62.5
66$$ A1 2 A5 2 A9 2  E T
'
' SUBCASE 12 LIBRARY POSITION 12
'
3$$ 33  A3  12  0  A16 2  A33 0  E T
35$$ 0 T
56$$  3  3  A6 3  A10   3  A15 3 A19 1 E
57** 0.0 A3 1.E-5  0.05556 E T
 fuel
BW 15X15
58** 19.81938 19.81938 19.81938
60** 18.5 37.0 62.5
66$$ A1 2 A5 2 A9 2  E T
'
' SUBCASE 13 LIBRARY POSITION 13
'
3$$ 33  A3  13  0  A16 2  A33 0  E T
35$$ 0 T
56$$  3  3  A6 3  A10   3  A15 3 A19 1 E
57** 0.0 A3 1.E-5  0.05556 E T
 fuel
BW 15X15
58** 19.81938 19.81938 19.81938
60** 18.5 37.0 62.5
66$$ A1 2 A5 2 A9 2  E T
'
' SUBCASE 14 LIBRARY POSITION 14
'
3$$ 33  A3  14  0  A16 2  A33 0  E T
35$$ 0 T
56$$  3  3  A6 3  A10   3  A15 3 A19 1 E
57** 0.0 A3 1.E-5  0.05556 E T
 fuel
BW 15X15
58** 19.81938 19.81938 19.81938
60** 18.5 37.0 62.5
```

```
66$$ A1 2 A5 2 A9 2  E T
'
' SUBCASE 15 LIBRARY POSITION 15
'
3$$ 33  A3  15  0  A16 2  A33 0  E T
35$$ 0 T
56$$  3  3  A6 3  A10   3  A15 3 A19 1 E
57** 0.0 A3 1.E-5  0.05556 E T
 fuel
BW 15X15
58** 19.81938 19.81938 19.81938
60** 18.5 37.0 62.5
66$$ A1 2 A5 2 A9 2  E T
'
' SUBCASE 16 LIBRARY POSITION 16
'
3$$ 33  A3  16  0  A16 2  A33 0  E T
35$$ 0 T
56$$  3  3  A6 3  A10   3  A15 3 A19 1 E
57** 0.0 A3 1.E-5  0.05556 E T
 fuel
BW 15X15
58** 19.81938 19.81938 19.81938
60** 18.5 37.0 62.5
66$$ A1 2 A5 2 A9 2  E T
'
' SUBCASE 17 LIBRARY POSITION 17
'
3$$ 33  A3  17  0  A16 2  A33 0  E T
35$$ 0 T
56$$  3  3  A6 3  A10   3  A15 3 A19 1 E
57** 0.0 A3 1.E-5  0.05556 E T
 fuel
BW 15X15
58** 19.81938 19.81938 19.81938
60** 18.5 37.0 62.5
66$$ A1 2 A5 2 A9 2  E T
'
' SUBCASE 18 LIBRARY POSITION 18
'
3$$ 33  A3  18  A4 7 0  A16 2  A33 18  E T
35$$ 0 T
56$$  3  3  A6 1  A10  3  A15 3 A19 1 E
57** 0.0 A3 1.E-5  0.05556 E T
 fuel
BW 15X15
58** 19.81938 19.81938 19.81938
60** 18.5 37.0 62.5
66$$ A1 2 A5 2 A9 2  E T
'
' SUBCASE - decay
'
54$$ A8 1 E
56$$ 0 9 A6 1 A10 3 A14 3 A15 1 A19 1 E
57** 0.0 0 1.E-5  E T
 fuel enrichment above
60** 0.5 0.75 1.0 4.0 8.0 12.0 24.0 48.0 96.0
61** F0.1
65$$
```

```
'GRAM-ATOMS   GRAMS    CURIES     WATTS-ALL  WATTS-GAMMA
     3Z      0  1  0    0 0 0      1 0 0        3Z          6Z
     3Z      0  1  0    0 0 0      1 0 0        3Z          6Z
     3Z      0  1  0    0 0 0      1 0 0        3Z          6Z   T
'
' SUBCASE - decay
'
54$$ A8 1 E
56$$ 0 9 A6 1 A10 9 A14 4 A15 1 A19 1 E
57** 4.0 0 1.E-5  E T
 fuel enrichment above
60** 10.0 20.0 30.0 60.0 90.0 120.0 180.0 240.0 365.0
61** F0.1
65$$
'GRAM-ATOMS   GRAMS    CURIES     WATTS-ALL  WATTS-GAMMA
     3Z      0  1  0    0 0 0      1 0 0        3Z          6Z
     3Z      0  1  0    0 0 0      1 0 0        3Z          6Z
     3Z      0  1  0    0 0 0      1 0 0        3Z          6Z   T
'
' SUBCASE - decay
'
54$$ A8 0 E
56$$ 0 9 A6 1 A10 9 A14 5 A15 1 A19 1 E
57** 1.0 0 1.E-5  E T
 fuel enrichment above
60** 1.5 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0
61** F1.0e-5
65$$
'GRAM-ATOMS   GRAMS    CURIES     WATTS-ALL  WATTS-GAMMA
     3Z      0  1  0    1 0 0      1 0 0        3Z          6Z
     3Z      0  1  0    1 0 0      1 0 0        3Z          6Z
     3Z      0  1  0    1 0 0      1 0 0        3Z          6Z
81$$ 2 0 26 1 E
82$$ 0 2 2 2 2 2 2 2 2
83**  1.1E+7  8.0E+6 6.0E+6 4.0E+6 3.0E+6 2.5E+6 2.0E+6 1.5E+6
      1.0E+6  7.0E+5 4.5E+5 3.0E+5 1.5E+5 1.0E+5 7.0E+4 4.5E+4
      3.0E+4  2.0E+4 1.0E+4
84**  20.0E+6 6.43E+6 3.0E+6 1.85E+6 1.40E+6 9.00E+5 4.00E+5 1.0E+5 T
'
'
'
'
'
'
'
'
' SUBCASE - decay
'
54$$ A8 0 E
56$$ 0 10 A6 1 A10 9 A14 5 A15 1 A19 1 E
57** 10.0 0 1.E-5  E T
 fuel enrichment above
60** 11.0 12.0 13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0
61** F1.0e-5
65$$
'GRAM-ATOMS   GRAMS    CURIES     WATTS-ALL  WATTS-GAMMA
     3Z      0  1  0    1 0 0      1 0 0        3Z          6Z
     3Z      0  1  0    1 0 0      1 0 0        3Z          6Z
     3Z      0  1  0    1 0 0      1 0 0        3Z          6Z
```

```
81$$ 2 0 26 1 E
82$$ 2 2 2 2 2 2 2 2 2 2
83**  1.1E+7  8.0E+6 6.0E+6 4.0E+6 3.0E+6 2.5E+6 2.0E+6 1.5E+6
      1.0E+6  7.0E+5 4.5E+5 3.0E+5 1.5E+5 1.0E+5 7.0E+4 4.5E+4
      3.0E+4  2.0E+4 1.0E+4
84**  20.0E+6 6.43E+6 3.0E+6 1.85E+6 1.40E+6 9.00E+5 4.00E+5 1.0E+5 T
'
'
'
'
'
'
'
'
'
'
' END
'
56$$ F0 T
END
```

APPENDIX 5.C

SAMPLE INPUT FILE FOR MCNP

(Total number of pages in this appendix : 61)

```
message:   outp=hs24c11o  srctp=hs24c11s  runtpe=hs24c11r
           mctal=hs24c11m  wssa=hs24c11w  rssa=pt001w

hs24c11
c
c     origin is 6 inches below mpc
c
c     only cells that contain material are split axially
c     importance splitting is not done in cells with 0 material
c
c     axial segmentation is at the following boundaries
c     615, 620, 420, 430, 445, 455, 675, 651, 652 ,653
c     654, 655, 656, 657, 680
c
c     universe 1
c
301    0              (-40:41:-42:43)   -400 u=1
302    0    37 -38      -12         400 -410 u=1
303    0    37 -38   15             400 -410 u=1
304    0    35 -36              -20 400 -410 u=1
305    0    35 -36          23      400 -410 u=1
306    0    37 -38      -12         435 -460 u=1
307    0    37 -38   15             435 -460 u=1
308    0    35 -36              -20 435 -460 u=1
309    0    35 -36          23      435 -460 u=1
310    0    37 -38      -10         410 -435 u=1
311    0    37 -38   17             410 -435 u=1
312    0    35 -36              -18 410 -435 u=1
313    0    35 -36          25      410 -435 u=1
314    5 -7.92       10 -11 26 -27 410 -420 u=-1 $ left
315    6 -2.644      11 -12 26 -27 410 -420 u=-1 $ left
316    6 -2.644      15 -16 26 -27 410 -420 u=-1 $ right
317    5 -7.92       16 -17 26 -27 410 -420 u=-1 $ right
318    5 -7.92       28 -29 18 -19 410 -420 u=-1 $ bot
319    6 -2.644      28 -29 19 -20 410 -420 u=-1 $ bot
320    6 -2.644      28 -29 23 -24 410 -420 u=-1 $ top
321    5 -7.92       28 -29 24 -25 410 -420 u=-1 $ top
322    5 -7.92       10 -11 26 -27 420 -430 u=-1 $ left
323    6 -2.644      11 -12 26 -27 420 -430 u=-1 $ left
324    6 -2.644      15 -16 26 -27 420 -430 u=-1 $ right
325    5 -7.92       16 -17 26 -27 420 -430 u=-1 $ right
326    5 -7.92       28 -29 18 -19 420 -430 u=-1 $ bot
327    6 -2.644      28 -29 19 -20 420 -430 u=-1 $ bot
328    6 -2.644      28 -29 23 -24 420 -430 u=-1 $ top
329    5 -7.92       28 -29 24 -25 420 -430 u=-1 $ top
330    5 -7.92       10 -11 26 -27 430 -435 u=-1 $ left
331    6 -2.644      11 -12 26 -27 430 -435 u=-1 $ left
332    6 -2.644      15 -16 26 -27 430 -435 u=-1 $ right
333    5 -7.92       16 -17 26 -27 430 -435 u=-1 $ right
334    5 -7.92       28 -29 18 -19 430 -435 u=-1 $ bot
335    6 -2.644      28 -29 19 -20 430 -435 u=-1 $ bot
336    6 -2.644      28 -29 23 -24 430 -435 u=-1 $ top
337    5 -7.92       28 -29 24 -25 430 -435 u=-1 $ top
338    0             10 -12 27 -38 410 -435 u=-1 $ left
339    0             10 -12 37 -26 410 -435 u=-1 $ left
340    0             15 -17 27 -38 410 -435 u=-1 $ right
341    0             15 -17 37 -26 410 -435 u=-1 $ right
342    0             35 -28 18 -20 410 -435 u=-1 $ bot
343    0             29 -36 18 -20 410 -435 u=-1 $ bot
344    0             35 -28 23 -25 410 -435 u=-1 $ top
345    0             29 -36 23 -25 410 -435 u=-1 $ top
346    5 -7.92       12 -15 20 -23 (-13:-21:22:14) 400 -420 u=-1
347    5 -7.92       12 -15 20 -23 (-13:-21:22:14) 420 -430 u=-1
348    5 -7.92       12 -15 20 -23 (-13:-21:22:14) 430 -445 u=-1
349    5 -7.92       12 -15 20 -23 (-13:-21:22:14) 445 -460 u=-1
```

```
350     0              13 -14 21 -22 (-40:41:-42:43) 400 -455 u=-1
351     9 -1.17e-3                           460        u=1
c       fuel element
352     0              40 -41 42 -43         -415 u=1
353     5 -1.0783      40 -41 42 -43 415 -420 u=-1 $ lower nozzle
354     0              40 -41 42 -43 420 -425 u=-1 $ space
355     2 -3.8699      40 -41 42 -43 425 -430 u=-1 $ active fuel
356     5 -0.1591      40 -41 42 -43 430 -440 u=-1 $ space
357     5 -0.1591      40 -41 42 -43 440 -445 u=-1 $ plenum spacer
358     5 -1.5410      40 -41 42 -43 445 -455 u=-1 $ top nozzle
359     0              13 -14 21 -22 455 -460 u=-1
c
360     5 -7.92        38 -23 -12  400 -420 u=1
361     5 -7.92        20 -37 -12  400 -420 u=1
362     5 -7.92        12 -35  23  400 -420 u=1
363     5 -7.92        12 -35 -20  400 -420 u=1
364     5 -7.92        36 -15  23  400 -420 u=1
365     5 -7.92        36 -15 -20  400 -420 u=1
366     5 -7.92        38 -23  15  400 -420 u=1
367     5 -7.92        20 -37  15  400 -420 u=1
368     5 -7.92        38 -23 -12  420 -430 u=1
369     5 -7.92        20 -37 -12  420 -430 u=1
370     5 -7.92        12 -35  23  420 -430 u=1
371     5 -7.92        12 -35 -20  420 -430 u=1
372     5 -7.92        36 -15  23  420 -430 u=1
373     5 -7.92        36 -15 -20  420 -430 u=1
374     5 -7.92        38 -23  15  420 -430 u=1
375     5 -7.92        20 -37  15  420 -430 u=1
376     5 -7.92        38 -23 -12  430 -445 u=1
377     5 -7.92        20 -37 -12  430 -445 u=1
378     5 -7.92        12 -35  23  430 -445 u=1
379     5 -7.92        12 -35 -20  430 -445 u=1
380     5 -7.92        36 -15  23  430 -445 u=1
381     5 -7.92        36 -15 -20  430 -445 u=1
382     5 -7.92        38 -23  15  430 -445 u=1
383     5 -7.92        20 -37  15  430 -445 u=1
384     5 -7.92        38 -23 -12  445 -460 u=1
385     5 -7.92        20 -37 -12  445 -460 u=1
386     5 -7.92        12 -35  23  445 -460 u=1
387     5 -7.92        12 -35 -20  445 -460 u=1
388     5 -7.92        36 -15  23  445 -460 u=1
389     5 -7.92        36 -15 -20  445 -460 u=1
390     5 -7.92        38 -23  15  445 -460 u=1
391     5 -7.92        20 -37  15  445 -460 u=1
392     0              23 -12      400 -460 u=1
393     0              23  15      400 -460 u=1
394     0              15 -20      400 -460 u=1
395     0             -12 -20      400 -460 u=1
c
c     universe 2
c
401     0              (-40:41:-42:43)   -400 u=2
402     0    37 -38       -12            400 -410 u=2
403     0    37 -38    15                400 -410 u=2
404     0    35 -36                  -20 400 -410 u=2
405     0    35 -36             23       400 -410 u=2
406     0    37 -38       -12            435 -460 u=2
407     0    37 -38    15                435 -460 u=2
408     0    35 -36                  -20 435 -460 u=2
409     0    35 -36             23       435 -460 u=2
410     0    37 -38       -10            410 -435 u=2
411     0    37 -38    17                410 -435 u=2
412     0    35 -36                  -18 410 -435 u=2
413     0    35 -36             25       410 -435 u=2
414     5 -7.92        10 -11 26 -27 410 -420 u=-2 $ left
```

```
415     6 -2.644     11 -12 26 -27 410 -420 u=-2 $ left
416     6 -2.644     15 -16 30 -31 410 -420 u=-2 $ right
417     5 -7.92      16 -17 30 -31 410 -420 u=-2 $ right
418     5 -7.92      28 -29 18 -19 410 -420 u=-2 $ bot
419     6 -2.644     28 -29 19 -20 410 -420 u=-2 $ bot
420     6 -2.644     32 -33 23 -24 410 -420 u=-2 $ top
421     5 -7.92      32 -33 24 -25 410 -420 u=-2 $ top
422     5 -7.92      10 -11 26 -27 420 -430 u=-2 $ left
423     6 -2.644     11 -12 26 -27 420 -430 u=-2 $ left
424     6 -2.644     15 -16 30 -31 420 -430 u=-2 $ right
425     5 -7.92      16 -17 30 -31 420 -430 u=-2 $ right
426     5 -7.92      28 -29 18 -19 420 -430 u=-2 $ bot
427     6 -2.644     28 -29 19 -20 420 -430 u=-2 $ bot
428     6 -2.644     32 -33 23 -24 420 -430 u=-2 $ top
429     5 -7.92      32 -33 24 -25 420 -430 u=-2 $ top
430     5 -7.92      10 -11 26 -27 430 -435 u=-2 $ left
431     6 -2.644     11 -12 26 -27 430 -435 u=-2 $ left
432     6 -2.644     15 -16 30 -31 430 -435 u=-2 $ right
433     5 -7.92      16 -17 30 -31 430 -435 u=-2 $ right
434     5 -7.92      28 -29 18 -19 430 -435 u=-2 $ bot
435     6 -2.644     28 -29 19 -20 430 -435 u=-2 $ bot
436     6 -2.644     32 -33 23 -24 430 -435 u=-2 $ top
437     5 -7.92      32 -33 24 -25 430 -435 u=-2 $ top
438     0            10 -12 27 -38 410 -435 u=-2 $ left
439     0            10 -12 37 -26 410 -435 u=-2 $ left
440     0            15 -17 31 -38 410 -435 u=-2 $ right
441     0            15 -17 37 -30 410 -435 u=-2 $ right
442     0            35 -28 18 -20 410 -435 u=-2 $ bot
443     0            29 -36 18 -20 410 -435 u=-2 $ bot
444     0            35 -32 23 -25 410 -435 u=-2 $ top
445     0            33 -36 23 -25 410 -435 u=-2 $ top
446     5 -7.92      12 -15 20 -23 (-13:-21:22:14) 400 -420 u=-2
447     5 -7.92      12 -15 20 -23 (-13:-21:22:14) 420 -430 u=-2
448     5 -7.92      12 -15 20 -23 (-13:-21:22:14) 430 -445 u=-2
449     5 -7.92      12 -15 20 -23 (-13:-21:22:14) 445 -460 u=-2
450     0            13 -14 21 -22 (-40:41:-42:43) 400 -455 u=-2
451     9 -1.17e-3                                 460     u=2
c       fuel element
452     0            40 -41 42 -43     -415 u=2
453     5 -1.0783    40 -41 42 -43 415 -420 u=-2 $ lower nozzle
454     0            40 -41 42 -43 420 -425 u=-2 $ space
455     2 -3.8699    40 -41 42 -43 425 -430 u=-2 $ active fuel
456     5 -0.1591    40 -41 42 -43 430 -440 u=-2 $ space
457     5 -0.1591    40 -41 42 -43 440 -445 u=-2 $ plenum spacer
458     5 -1.5410    40 -41 42 -43 445 -455 u=-2 $ top nozzle
459     0            13 -14 21 -22 455 -460 u=-2
c
460     5 -7.92      38 -23 -12  400 -420 u=2
461     5 -7.92      20 -37 -12  400 -420 u=2
462     0            12 -35  23  400 -420 u=2
463     5 -7.92      12 -35 -20  400 -420 u=2
464     0            36 -15  23  400 -420 u=2
465     5 -7.92      36 -15 -20  400 -420 u=2
466     0            38 -23  15  400 -420 u=2
467     0            20 -37  15  400 -420 u=2
468     5 -7.92      38 -23 -12  420 -430 u=2
469     5 -7.92      20 -37 -12  420 -430 u=2
470     0            12 -35  23  420 -430 u=2
471     5 -7.92      12 -35 -20  420 -430 u=2
472     0            36 -15  23  420 -430 u=2
473     5 -7.92      36 -15 -20  420 -430 u=2
474     0            38 -23  15  420 -430 u=2
475     0            20 -37  15  420 -430 u=2
476     5 -7.92      38 -23 -12  430 -445 u=2
477     5 -7.92      20 -37 -12  430 -445 u=2
```

```
478     0              12 -35  23  430 -445 u=2
479     5 -7.92        12 -35 -20  430 -445 u=2
480     0              36 -15  23  430 -445 u=2
481     5 -7.92        36 -15 -20  430 -445 u=2
482     0              38 -23  15  430 -445 u=2
483     0              20 -37  15  430 -445 u=2
484     5 -7.92        38 -23 -12  445 -460 u=2
485     5 -7.92        20 -37 -12  445 -460 u=2
486     0              12 -35  23  445 -460 u=2
487     5 -7.92        12 -35 -20  445 -460 u=2
488     0              36 -15  23  445 -460 u=2
489     5 -7.92        36 -15 -20  445 -460 u=2
490     0              38 -23  15  445 -460 u=2
491     0              20 -37  15  445 -460 u=2
492     0              23 -12      400 -460 u=2
493     0              23  15      400 -460 u=2
494     0              15 -20      400 -460 u=2
495     0             -12 -20      400 -460 u=2
c
c      universe 3
c
501     0              (-40:41:-42:43)    -400 u=3
502     0    37 -38       -12         400 -410 u=3
503     0    37 -38    15             400 -410 u=3
504     0    35 -36              -20  400 -410 u=3
505     0    35 -36           23      400 -410 u=3
506     0    37 -38       -12         435 -460 u=3
507     0    37 -38    15             435 -460 u=3
508     0    35 -36              -20  435 -460 u=3
509     0    35 -36           23      435 -460 u=3
510     0    37 -38       -10         410 -435 u=3
511     0    37 -38    17             410 -435 u=3
512     0    35 -36              -18  410 -435 u=3
513     0    35 -36           25      410 -435 u=3
514     5 -7.92        10 -11 30 -31 410 -420 u=-3 $ left
515     6 -2.644       11 -12 30 -31 410 -420 u=-3 $ left
516     6 -2.644       15 -16 26 -27 410 -420 u=-3 $ right
517     5 -7.92        16 -17 26 -27 410 -420 u=-3 $ right
518     5 -7.92        28 -29 18 -19 410 -420 u=-3 $ bot
519     6 -2.644       28 -29 19 -20 410 -420 u=-3 $ bot
520     6 -2.644       32 -33 23 -24 410 -420 u=-3 $ top
521     5 -7.92        32 -33 24 -25 410 -420 u=-3 $ top
522     5 -7.92        10 -11 30 -31 420 -430 u=-3 $ left
523     6 -2.644       11 -12 30 -31 420 -430 u=-3 $ left
524     6 -2.644       15 -16 26 -27 420 -430 u=-3 $ right
525     5 -7.92        16 -17 26 -27 420 -430 u=-3 $ right
526     5 -7.92        28 -29 18 -19 420 -430 u=-3 $ bot
527     6 -2.644       28 -29 19 -20 420 -430 u=-3 $ bot
528     6 -2.644       32 -33 23 -24 420 -430 u=-3 $ top
529     5 -7.92        32 -33 24 -25 420 -430 u=-3 $ top
530     5 -7.92        10 -11 30 -31 430 -435 u=-3 $ left
531     6 -2.644       11 -12 30 -31 430 -435 u=-3 $ left
532     6 -2.644       15 -16 26 -27 430 -435 u=-3 $ right
533     5 -7.92        16 -17 26 -27 430 -435 u=-3 $ right
534     5 -7.92        28 -29 18 -19 430 -435 u=-3 $ bot
535     6 -2.644       28 -29 19 -20 430 -435 u=-3 $ bot
536     6 -2.644       32 -33 23 -24 430 -435 u=-3 $ top
537     5 -7.92        32 -33 24 -25 430 -435 u=-3 $ top
538     0              10 -12 31 -38 410 -435 u=-3 $ left
539     0              10 -12 37 -30 410 -435 u=-3 $ left
540     0              15 -17 27 -38 410 -435 u=-3 $ right
541     0              15 -17 37 -26 410 -435 u=-3 $ right
542     0              35 -28 18 -20 410 -435 u=-3 $ bot
543     0              29 -36 18 -20 410 -435 u=-3 $ bot
544     0              35 -32 23 -25 410 -435 u=-3 $ top
```

```
545    0              33 -36 23 -25 410 -435 u=-3 $ top
546    5 -7.92        12 -15 20 -23 (-13:-21:22:14) 400 -420 u=-3
547    5 -7.92        12 -15 20 -23 (-13:-21:22:14) 420 -430 u=-3
548    5 -7.92        12 -15 20 -23 (-13:-21:22:14) 430 -445 u=-3
549    5 -7.92        12 -15 20 -23 (-13:-21:22:14) 445 -460 u=-3
550    0              13 -14 21 -22 (-40:41:-42:43) 400 -455 u=-3
551    9 -1.17e-3                               460      u=3
c      fuel element
552    0              40 -41 42 -43     -415 u=3
553    5 -1.0783      40 -41 42 -43 415 -420 u=-3 $ lower nozzle
554    0              40 -41 42 -43 420 -425 u=-3 $ space
555    2 -3.8699      40 -41 42 -43 425 -430 u=-3 $ active fuel
556    5 -0.1591      40 -41 42 -43 430 -440 u=-3 $ space
557    5 -0.1591      40 -41 42 -43 440 -445 u=-3 $ plenum spacer
558    5 -1.5410      40 -41 42 -43 445 -455 u=-3 $ top nozzle
559    0              13 -14 21 -22 455 -460 u=-3
c
560    0              38 -23 -12  400 -420 u=3
561    0              20 -37 -12  400 -420 u=3
562    0              12 -35  23  400 -420 u=3
563    5 -7.92        12 -35 -20  400 -420 u=3
564    0              36 -15  23  400 -420 u=3
565    5 -7.92        36 -15 -20  400 -420 u=3
566    5 -7.92        38 -23  15  400 -420 u=3
567    5 -7.92        20 -37  15  400 -420 u=3
568    5 -7.92        38 -23 -12  420 -430 u=3
569    5 -7.92        20 -37 -12  420 -430 u=3
570    0              12 -35  23  420 -430 u=3
571    0              12 -35 -20  420 -430 u=3
572    5 -7.92        36 -15  23  420 -430 u=3
573    0              36 -15 -20  420 -430 u=3
574    5 -7.92        38 -23  15  420 -430 u=3
575    5 -7.92        20 -37  15  420 -430 u=3
576    5 -7.92        38 -23 -12  430 -445 u=3
577    5 -7.92        20 -37 -12  430 -445 u=3
578    0              12 -35  23  430 -445 u=3
579    0              12 -35 -20  430 -445 u=3
580    5 -7.92        36 -15  23  430 -445 u=3
581    0              36 -15 -20  430 -445 u=3
582    5 -7.92        38 -23  15  430 -445 u=3
583    5 -7.92        20 -37  15  430 -445 u=3
584    5 -7.92        38 -23 -12  445 -460 u=3
585    5 -7.92        20 -37 -12  445 -460 u=3
586    0              12 -35  23  445 -460 u=3
587    0              12 -35 -20  445 -460 u=3
588    5 -7.92        36 -15  23  445 -460 u=3
589    0              36 -15 -20  445 -460 u=3
590    5 -7.92        38 -23  15  445 -460 u=3
591    5 -7.92        20 -37  15  445 -460 u=3
592    0              23 -12      400 -460 u=3
593    0              23  15      400 -460 u=3
594    0              15 -20      400 -460 u=3
595    0             -12 -20      400 -460 u=3
c
c    universe 4
c
601    0             (-40:41:-42:43)   -400 u=4
602    0    37 -38      -12          400 -410 u=4
603    0    37 -38  15               400 -410 u=4
604    0    35 -36               -20 400 -410 u=4
605    0    35 -36          23       400 -410 u=4
606    0    37 -38      -12          435 -460 u=4
607    0    37 -38  15               435 -460 u=4
608    0    35 -36               -20 435 -460 u=4
609    0    35 -36          23       435 -460 u=4
```

```
610     0   37 -38     -10         410 -435 u=4
611     0   37 -38  17             410 -435 u=4
612     0   35 -36             -18 410 -435 u=4
613     0   35 -36          25     410 -435 u=4
614     5 -7.92     10 -11 30 -31 410 -420 u=-4 $ left
615     6 -2.644    11 -12 30 -31 410 -420 u=-4 $ left
616     6 -2.644    15 -16 26 -27 410 -420 u=-4 $ right
617     5 -7.92     16 -17 26 -27 410 -420 u=-4 $ right
618     5 -7.92     32 -33 18 -19 410 -420 u=-4 $ bot
619     6 -2.644    32 -33 19 -20 410 -420 u=-4 $ bot
620     6 -2.644    28 -29 23 -24 410 -420 u=-4 $ top
621     5 -7.92     28 -29 24 -25 410 -420 u=-4 $ top
622     5 -7.92     10 -11 30 -31 420 -430 u=-4 $ left
623     6 -2.644    11 -12 30 -31 420 -430 u=-4 $ left
624     6 -2.644    15 -16 26 -27 420 -430 u=-4 $ right
625     5 -7.92     16 -17 26 -27 420 -430 u=-4 $ right
626     5 -7.92     32 -33 18 -19 420 -430 u=-4 $ bot
627     6 -2.644    32 -33 19 -20 420 -430 u=-4 $ bot
628     6 -2.644    28 -29 23 -24 420 -430 u=-4 $ top
629     5 -7.92     28 -29 24 -25 420 -430 u=-4 $ top
630     5 -7.92     10 -11 30 -31 430 -435 u=-4 $ left
631     6 -2.644    11 -12 30 -31 430 -435 u=-4 $ left
632     6 -2.644    15 -16 26 -27 430 -435 u=-4 $ right
633     5 -7.92     16 -17 26 -27 430 -435 u=-4 $ right
634     5 -7.92     32 -33 18 -19 430 -435 u=-4 $ bot
635     6 -2.644    32 -33 19 -20 430 -435 u=-4 $ bot
636     6 -2.644    28 -29 23 -24 430 -435 u=-4 $ top
637     5 -7.92     28 -29 24 -25 430 -435 u=-4 $ top
638     0           10 -12 31 -38 410 -435 u=-4 $ left
639     0           10 -12 37 -30 410 -435 u=-4 $ left
640     0           15 -17 27 -38 410 -435 u=-4 $ right
641     0           15 -17 37 -26 410 -435 u=-4 $ right
642     0           35 -32 18 -20 410 -435 u=-4 $ bot
643     0           33 -36 18 -20 410 -435 u=-4 $ bot
644     0           35 -28 23 -25 410 -435 u=-4 $ top
645     0           29 -36 23 -25 410 -435 u=-4 $ top
646     5 -7.92     12 -15 20 -23 (-13:-21:22:14) 400 -420 u=-4
647     5 -7.92     12 -15 20 -23 (-13:-21:22:14) 420 -430 u=-4
648     5 -7.92     12 -15 20 -23 (-13:-21:22:14) 430 -445 u=-4
649     5 -7.92     12 -15 20 -23 (-13:-21:22:14) 445 -460 u=-4
650     0           13 -14 21 -22 (-40:41:-42:43) 400 -455 u=-4
651     9 -1.17e-3                                 460      u=4
c       fuel element
652     0           40 -41 42 -43     -415 u=4
653     5 -1.0783   40 -41 42 -43 415 -420 u=-4 $ lower nozzle
654     0           40 -41 42 -43 420 -425 u=-4 $ space
655     2 -3.8699   40 -41 42 -43 425 -430 u=-4 $ active fuel
656     5 -0.1591   40 -41 42 -43 430 -440 u=-4 $ space
657     5 -0.1591   40 -41 42 -43 440 -445 u=-4 $ plenum spacer
658     5 -1.5410   40 -41 42 -43 445 -455 u=-4 $ top nozzle
659     0           13 -14 21 -22 455 -460 u=-4
c
660     0           38 -23 -12  400 -420 u=4
661     0           20 -37 -12  400 -420 u=4
662     5 -7.92     12 -35  23  400 -420 u=4
663     0           12 -35 -20  400 -420 u=4
664     5 -7.92     36 -15  23  400 -420 u=4
665     0           36 -15 -20  400 -420 u=4
666     5 -7.92     38 -23  15  400 -420 u=4
667     5 -7.92     20 -37  15  400 -420 u=4
668     0           38 -23 -12  420 -430 u=4
669     0           20 -37 -12  420 -430 u=4
670     5 -7.92     12 -35  23  420 -430 u=4
671     0           12 -35 -20  420 -430 u=4
672     5 -7.92     36 -15  23  420 -430 u=4
```

```
673     0            36 -15 -20   420 -430 u=4
674     5 -7.92      38 -23  15   420 -430 u=4
675     5 -7.92      20 -37  15   420 -430 u=4
676     0            38 -23 -12   430 -445 u=4
677     0            20 -37 -12   430 -445 u=4
678     5 -7.92      12 -35  23   430 -445 u=4
679     0            12 -35 -20   430 -445 u=4
680     5 -7.92      36 -15  23   430 -445 u=4
681     0            36 -15 -20   430 -445 u=4
682     5 -7.92      38 -23  15   430 -445 u=4
683     5 -7.92      20 -37  15   430 -445 u=4
684     0            38 -23 -12   445 -460 u=4
685     0            20 -37 -12   445 -460 u=4
686     5 -7.92      12 -35  23   445 -460 u=4
687     0            12 -35 -20   445 -460 u=4
688     5 -7.92      36 -15  23   445 -460 u=4
689     0            36 -15 -20   445 -460 u=4
690     5 -7.92      38 -23  15   445 -460 u=4
691     5 -7.92      20 -37  15   445 -460 u=4
692     0            23 -12       400 -460 u=4
693     0            23  15       400 -460 u=4
694     0            15 -20       400 -460 u=4
695     0           -12 -20       400 -460 u=4
c
c     universe 5
c
701     0            (-40:41:-42:43)    -400 u=5
702     0     37 -38     -12          400 -410 u=5
703     0     37 -38  15              400 -410 u=5
704     0     35 -36              -20 400 -410 u=5
705     0     35 -36          23      400 -410 u=5
706     0     37 -38     -12          435 -460 u=5
707     0     37 -38  15              435 -460 u=5
708     0     35 -36              -20 435 -460 u=5
709     0     35 -36          23      435 -460 u=5
710     0     37 -38     -10          410 -435 u=5
711     0     37 -38  17              410 -435 u=5
712     0     35 -36              -18 410 -435 u=5
713     0     35 -36          25      410 -435 u=5
714     5 -7.92      10 -11 26 -27 410 -420 u=-5 $ left
715     6 -2.644     11 -12 26 -27 410 -420 u=-5 $ left
716     6 -2.644     15 -16 30 -31 410 -420 u=-5 $ right
717     5 -7.92      16 -17 30 -31 410 -420 u=-5 $ right
718     5 -7.92      32 -33 18 -19 410 -420 u=-5 $ bot
719     6 -2.644     32 -33 19 -20 410 -420 u=-5 $ bot
720     6 -2.644     28 -29 23 -24 410 -420 u=-5 $ top
721     5 -7.92      28 -29 24 -25 410 -420 u=-5 $ top
722     5 -7.92      10 -11 26 -27 420 -430 u=-5 $ left
723     6 -2.644     11 -12 26 -27 420 -430 u=-5 $ left
724     6 -2.644     15 -16 30 -31 420 -430 u=-5 $ right
725     5 -7.92      16 -17 30 -31 420 -430 u=-5 $ right
726     5 -7.92      32 -33 18 -19 420 -430 u=-5 $ bot
727     6 -2.644     32 -33 19 -20 420 -430 u=-5 $ bot
728     6 -2.644     28 -29 23 -24 420 -430 u=-5 $ top
729     5 -7.92      28 -29 24 -25 420 -430 u=-5 $ top
730     5 -7.92      10 -11 26 -27 430 -435 u=-5 $ left
731     6 -2.644     11 -12 26 -27 430 -435 u=-5 $ left
732     6 -2.644     15 -16 30 -31 430 -435 u=-5 $ right
733     5 -7.92      16 -17 30 -31 430 -435 u=-5 $ right
734     5 -7.92      32 -33 18 -19 430 -435 u=-5 $ bot
735     6 -2.644     32 -33 19 -20 430 -435 u=-5 $ bot
736     6 -2.644     28 -29 23 -24 430 -435 u=-5 $ top
737     5 -7.92      28 -29 24 -25 430 -435 u=-5 $ top
738     0            10 -12 27 -38 410 -435 u=-5 $ left
739     0            10 -12 37 -26 410 -435 u=-5 $ left
```

```
740    0            15 -17 31 -38 410 -435 u=-5 $ right
741    0            15 -17 37 -30 410 -435 u=-5 $ right
742    0            35 -32 18 -20 410 -435 u=-5 $ bot
743    0            33 -36 18 -20 410 -435 u=-5 $ bot
744    0            35 -28 23 -25 410 -435 u=-5 $ top
745    0            29 -36 23 -25 410 -435 u=-5 $ top
746    5 -7.92      12 -15 20 -23 (-13:-21:22:14) 400 -420 u=-5
747    5 -7.92      12 -15 20 -23 (-13:-21:22:14) 420 -430 u=-5
748    5 -7.92      12 -15 20 -23 (-13:-21:22:14) 430 -445 u=-5
749    5 -7.92      12 -15 20 -23 (-13:-21:22:14) 445 -460 u=-5
750    0            13 -14 21 -22 (-40:41:-42:43) 400 -455 u=-5
751    9 -1.17e-3                                460      u=5
c      fuel element
752    0            40 -41 42 -43     -415 u=5
753    5 -1.0783    40 -41 42 -43 415 -420 u=-5 $ lower nozzle
754    0            40 -41 42 -43 420 -425 u=-5 $ space
755    2 -3.8699    40 -41 42 -43 425 -430 u=-5 $ active fuel
756    5 -0.1591    40 -41 42 -43 430 -440 u=-5 $ space
757    5 -0.1591    40 -41 42 -43 440 -445 u=-5 $ plenum spacer
758    5 -1.5410    40 -41 42 -43 445 -455 u=-5 $ top nozzle
759    0            13 -14 21 -22 455 -460 u=-5
c
760    5 -7.92      38 -23 -12  400 -420 u=5
761    5 -7.92      20 -37 -12  400 -420 u=5
762    5 -7.92      12 -35  23  400 -420 u=5
763    0            12 -35 -20  400 -420 u=5
764    5 -7.92      36 -15  23  400 -420 u=5
765    0            36 -15 -20  400 -420 u=5
766    0            38 -23  15  400 -420 u=5
767    0            20 -37  15  400 -420 u=5
768    5 -7.92      38 -23 -12  420 -430 u=5
769    5 -7.92      20 -37 -12  420 -430 u=5
770    5 -7.92      12 -35  23  420 -430 u=5
771    0            12 -35 -20  420 -430 u=5
772    5 -7.92      36 -15  23  420 -430 u=5
773    0            36 -15 -20  420 -430 u=5
774    0            38 -23  15  420 -430 u=5
775    0            20 -37  15  420 -430 u=5
776    5 -7.92      38 -23 -12  430 -445 u=5
777    5 -7.92      20 -37 -12  430 -445 u=5
778    5 -7.92      12 -35  23  430 -445 u=5
779    0            12 -35 -20  430 -445 u=5
780    5 -7.92      36 -15  23  430 -445 u=5
781    0            36 -15 -20  430 -445 u=5
782    0            38 -23  15  430 -445 u=5
783    0            20 -37  15  430 -445 u=5
784    5 -7.92      38 -23 -12  445 -460 u=5
785    5 -7.92      20 -37 -12  445 -460 u=5
786    5 -7.92      12 -35  23  445 -460 u=5
787    0            12 -35 -20  445 -460 u=5
788    5 -7.92      36 -15  23  445 -460 u=5
789    0            36 -15 -20  445 -460 u=5
790    0            38 -23  15  445 -460 u=5
791    0            20 -37  15  445 -460 u=5
792    0            23 -12      400 -460 u=5
793    0            23  15      400 -460 u=5
794    0            15 -20      400 -460 u=5
795    0           -12 -20      400 -460 u=5
c
c       egg crate
c
c      storage locations
c
c      201    0  -301      -112 101      620 -675
202    0  -301 112 -113 101      620 -675
```

```
203   0  -301 113 -114 101      620 -675
c     204   0  -301 114      101      620 -675
c
205   0  -301      -111 102      620 -675
206   0  -301 111 -112 102 -101 620 -675
101   0  -301 112 -113 102 -101 620 -675
      fill=3 (-13.68679 68.43395 0.0)
102   0  -301 113 -114 102 -101 620 -675
      fill=2 ( 13.68679 68.43395 0.0)
207   0  -301 114 -115 102 -101 620 -675
208   0  -301 115       102      620 -675
c
c     209   0  -301      -110 103      620 -675
210   0  -301 110 -111 103 -102 620 -675
103   0       111 -112 103 -102 620 -675
      fill=3 (-41.06037 41.06037 0.0)
104   0       112 -113 103 -102 620 -675
      fill=1 (-13.68679 41.06037 0.0)
105   0       113 -114 103 -102 620 -675
      fill=1 ( 13.68679 41.06037 0.0)
106   0       114 -115 103 -102 620 -675
      fill=2 ( 41.06037 41.06037 0.0)
211   0  -301 115 -116 103 -102 620 -675
c     212   0  -301 116      103      620 -675
c
213   0  -301      -110 104 -103 620 -675
107   0  -301 110 -111 104 -103 620 -675
      fill=3 (-68.43395 13.68679 0.0)
108   0       111 -112 104 -103 620 -675
      fill=1 (-41.06037 13.68679 0.0)
109   0       112 -113 104 -103 620 -675
      fill=1 (-13.68679 13.68679 0.0)
110   0       113 -114 104 -103 620 -675
      fill=1 ( 13.68679 13.68679 0.0)
111   0       114 -115 104 -103 620 -675
      fill=1 ( 41.06037 13.68679 0.0)
112   0  -301 115 -116 104 -103 620 -675
      fill=2 ( 68.43395 13.68679 0.0)
214   0  -301 116       104 -103 620 -675
c
215   0  -301      -110 105 -104 620 -675
113   0  -301 110 -111 105 -104 620 -675
      fill=4 (-68.43395 -13.68679 0.0)
114   0       111 -112 105 -104 620 -675
      fill=1 (-41.06037 -13.68679 0.0)
115   0       112 -113 105 -104 620 -675
      fill=1 (-13.68679 -13.68679 0.0)
116   0       113 -114 105 -104 620 -675
      fill=1 ( 13.68679 -13.68679 0.0)
117   0       114 -115 105 -104 620 -675
      fill=1 ( 41.06037 -13.68679 0.0)
118   0  -301 115 -116 105 -104 620 -675
      fill=5 ( 68.43395 -13.68679 0.0)
216   0  -301 116       105 -104 620 -675
c
c     217   0  -301      -110      -105 620 -675
218   0  -301 110 -111 106 -105 620 -675
119   0       111 -112 106 -105 620 -675
      fill=4 (-41.06037 -41.06037 0.0)
120   0       112 -113 106 -105 620 -675
      fill=1 (-13.68679 -41.06037 0.0)
121   0       113 -114 106 -105 620 -675
      fill=1 ( 13.68679 -41.06037 0.0)
122   0       114 -115 106 -105 620 -675
      fill=5 ( 41.06037 -41.06037 0.0)
```

```
219     0  -301 115 -116 106 -105 620 -675
c       220   0  -301 116           -105 620 -675
c
221     0  -301      -111      -106 620 -675
222     0  -301 111 -112 107 -106 620 -675
123     0  -301 112 -113 107 -106 620 -675
        fill=4 (-13.68679 -68.43395 0.0)
124     0  -301 113 -114 107 -106 620 -675
        fill=5 ( 13.68679 -68.43395 0.0)
223     0  -301 114 -115 107 -106 620 -675
224     0  -301 115           -106 620 -675
c
c       225   0  -301      -112      -107 620 -675
226     0  -301 112 -113      -107 620 -675
227     0  -301 113 -114      -107 620 -675
c       228   0  -301 114           -107 620 -675
c
1001     5 -7.92 301 -302 610 -615  $ MPC shell
1003     5 -7.92 301 -302 615 -616  $ MPC shell
1005     5 -7.92 301 -302 616 -620  $ MPC shell
1007     5 -7.92 301 -302 620 -420  $ MPC shell
1009     5 -7.92 301 -302 420 -430  $ MPC shell
1011     5 -7.92 301 -302 430 -445  $ MPC shell
1013     5 -7.92 301 -302 445 -460  $ MPC shell
1014     5 -7.92 301 -302 460 -675  $ MPC shell
1015     5 -7.92 301 -302 675 -651  $ MPC shell
1017     5 -7.92 301 -302 651 -652  $ MPC shell
1019     5 -7.92 301 -302 652 -653  $ MPC shell
1021     5 -7.92 301 -302 653 -654  $ MPC shell
1023     5 -7.92 301 -302 654 -655  $ MPC shell
1025     5 -7.92 301 -302 655 -656  $ MPC shell
1027     5 -7.92 301 -302 656 -657  $ MPC shell
1028     5 -7.92 301 -302 657 -658  $ MPC shell
1029     5 -7.92 301 -302 658 -659  $ MPC shell
1031     5 -7.92 301 -302 659 -680  $ MPC shell
c
1051     5 -7.92      -301 610 -615  $ MPC baseplate
1052     5 -7.92      -301 615 -616  $ MPC baseplate
1053     5 -7.92      -301 616 -620  $ MPC baseplate
1060     5 -7.92      -301 675 -651  $ MPC lid
1061     5 -7.92      -301 651 -652  $ MPC lid
1062     5 -7.92      -301 652 -653  $ MPC lid
1063     5 -7.92      -301 653 -654  $ MPC lid
1064     5 -7.92      -301 654 -655  $ MPC lid
1065     5 -7.92      -301 655 -656  $ MPC lid
1066     5 -7.92      -301 656 -657  $ MPC lid
1067     5 -7.92      -301 657 -658  $ MPC lid
1068     5 -7.92      -301 658 -659  $ MPC lid
1069     5 -7.92      -301 659 -680  $ MPC lid
c
c        overpack universes
c
c       pedastal
c
2001    8 -7.82    -302 801 -610
2002    8 -7.82    -302 802 -801
2003    8 -7.82    -302 803 -802
2004    8 -7.82    -302 804 -803
2005    8 -7.82    -302 805 -804
c
2006    7 -2.35      -306 806 -805
2007    7 -2.35      -306 807 -806
2008    7 -2.35      -306 808 -807
2009    7 -2.35      -306 809 -808
2010    7 -2.35      -306 810 -809
```

```
2011   7 -2.35       -306 811 -810
2012   7 -2.35       -306 812 -811
2013   7 -2.35       -306 813 -812
2014   7 -2.35       -306 814 -813
c
2016   8 -7.82  306 -302 806 -805
2017   8 -7.82  306 -302 807 -806
2028   8 -7.82  306 -302 808 -807
2019   8 -7.82  306 -302 809 -808
2020   8 -7.82  306 -302 810 -809
2021   8 -7.82  306 -302 811 -810
2022   8 -7.82  306 -302 812 -811
2023   8 -7.82  306 -302 813 -812
2024   8 -7.82  306 -302 814 -813
c      overpack baseplate
2031   8 -7.82      -302 815 -814
2032   8 -7.82      -302 816 -815
2033   7 -2.35      -302 817 -816
c      gap between overpack and lid
3001   9 -1.17e-3 -302 680 -901
c
c     lid
c
3002   8 -7.82    -307 901 -902
3003   8 -7.82    -307 902 -903
c
3004   7 -2.35    -305 903 -904
3005   7 -2.35    -305 904 -905
3006   7 -2.35    -305 905 -906
3007   7 -2.35    -305 906 -907
3008   7 -2.35    -305 907 -908
3009   7 -2.35    -305 908 -909
c
3010   8 -7.82  305 -307 903 -904
3011   8 -7.82  305 -307 904 -905
3012   8 -7.82  305 -307 905 -906
3013   8 -7.82  305 -307 906 -907
3014   8 -7.82  305 -307 907 -908
3015   8 -7.82  305 -307 908 -909
c
3021   8 -7.82    -307 909 -910
3022   8 -7.82    -307 910 -911
3023   8 -7.82    -307 911 -912
3024   8 -7.82    -307 912 -913
c
3030   0          -303 913 -914
3031   0          -303 914 -915
3032   0          -303 915 -916
3033   0          -303 916 -917
3034   0          -303 917 -918
c
3035   8 -7.82 303 -304 913 -914
3036   8 -7.82 303 -304 914 -915
3037   8 -7.82 303 -304 915 -916
3038   8 -7.82 303 -304 916 -917
3039   0       303 -304 917 -918
c
3040   7 -2.35 304 -307 913 -914
3041   7 -2.35 304 -307 914 -915
3042   7 -2.35 304 -307 915 -916
3043   7 -2.35 304 -307 916 -917
3044   0       304 -307 917 -918
c
c
c      steel,concrete and air in gap between mpc and overpack
```

```
c
4000    7 -2.35     302 -700 817 -816
4001    8 -7.82     302 -700 816 -815
4002    8 -7.82     302 -700 815 -814
4003    9 -1.17e-3 302 -700 814 -813
4004    9 -1.17e-3 302 -700 813 -812
4005    9 -1.17e-3 302 -700 812 -811
4006    9 -1.17e-3 302 -700 811 -810
4007    9 -1.17e-3 302 -700 810 -809
4008    9 -1.17e-3 302 -700 809 -808
4009    9 -1.17e-3 302 -700 808 -807
4010    9 -1.17e-3 302 -700 807 -806
4011    9 -1.17e-3 302 -700 806 -805
4012    9 -1.17e-3 302 -700 805 -804
4013    9 -1.17e-3 302 -700 804 -803
4014    9 -1.17e-3 302 -700 803 -802
4015    9 -1.17e-3 302 -700 802 -801
4016    9 -1.17e-3 302 -700 801 -610
4017    9 -1.17e-3 302 -700 610 -615
4018    9 -1.17e-3 302 -700 615 -620
4019    9 -1.17e-3 302 -700 620 -420
4020    9 -1.17e-3 302 -700 420 -430
4021    9 -1.17e-3 302 -700 430 -445
4022    9 -1.17e-3 302 -700 445 -460
4023    9 -1.17e-3 302 -700 460 -675
4024    9 -1.17e-3 302 -700 675 -651
4025    9 -1.17e-3 302 -700 651 -652
4026    9 -1.17e-3 302 -700 652 -653
4027    9 -1.17e-3 302 -700 653 -654
4028    9 -1.17e-3 302 -700 654 -655
4029    9 -1.17e-3 302 -700 655 -656
4030    9 -1.17e-3 302 -700 656 -657
4031    9 -1.17e-3 302 -700 657 -658
4032    9 -1.17e-3 302 -700 658 -659
4033    9 -1.17e-3 302 -700 659 -680
4034    9 -1.17e-3 302 -700 680 -901
4035    9 -1.17e-3 307 -700 901 -902
4036    9 -1.17e-3 307 -700 902 -903
4037    9 -1.17e-3 307 -700 903 -904
4038    9 -1.17e-3 307 -700 904 -905
4039    9 -1.17e-3 307 -700 905 -906
4040    9 -1.17e-3 307 -700 906 -907
4041    9 -1.17e-3 307 -700 907 -908
4042    9 -1.17e-3 307 -700 908 -909
4043    8 -7.82     307 -700 909 -910
4044    8 -7.82     307 -700 910 -911
4045    8 -7.82     307 -700 911 -912
4046    8 -7.82     307 -700 912 -913
4047    7 -2.35     307 -700 913 -914
4048    7 -2.35     307 -700 914 -915
4049    7 -2.35     307 -700 915 -916
4050    7 -2.35     307 -700 916 -917
4051    0     307 -700 917 -918
c
c       importance splitting regions in overpack
c
5000    7 -2.35    700 -701 817 -816
5001    0     700 -701 816 -815  fill=10
5002    0     700 -701 815 -814  fill=10
5003    0     700 -701 814 -813  fill=11
5004    0     700 -701 813 -812  fill=11
5005    0     700 -701 812 -811  fill=11
5006    0     700 -701 811 -810  fill=11
5007    0     700 -701 810 -809  fill=11
5008    0     700 -701 809 -808  fill=11
```

```
5009    0     700 -701 808 -807  fill=11
5010    8 -7.82    700 -701 807 -806
5011    8 -7.82    700 -701 806 -805
5012    8 -7.82    700 -701 805 -804
5013    8 -7.82    700 -701 804 -803
5014    8 -7.82    700 -701 803 -802
5015    8 -7.82    700 -701 802 -801
5016    8 -7.82    700 -701 801 -610
5017    8 -7.82    700 -701 610 -615
5018    8 -7.82    700 -701 615 -620
5019    8 -7.82    700 -701 620 -420
5020    8 -7.82    700 -701 420 -430
5021    8 -7.82    700 -701 430 -445
5022    8 -7.82    700 -701 445 -460
5023    8 -7.82    700 -701 460 -675
5024    8 -7.82    700 -701 675 -651
5025    8 -7.82    700 -701 651 -652
5026    8 -7.82    700 -701 652 -653
5027    8 -7.82    700 -701 653 -654
5028    8 -7.82    700 -701 654 -655
5029    8 -7.82    700 -701 655 -656
5030    8 -7.82    700 -701 656 -657
5031    8 -7.82    700 -701 657 -658
5032    8 -7.82    700 -701 658 -659
5033    8 -7.82    700 -701 659 -680
5034    8 -7.82    700 -701 680 -901
5035    8 -7.82    700 -701 901 -902
5036    8 -7.82    700 -701 902 -903
5037    8 -7.82    700 -701 903 -904
5038    0     700 -701 904 -905  fill=13
5039    0     700 -701 905 -906  fill=13
5040    0     700 -701 906 -907  fill=13
5041    0     700 -701 907 -908  fill=13
5042    0     700 -701 908 -909  fill=13
5043    8 -7.82    700 -701 909 -910
5044    8 -7.82    700 -701 910 -911
5045    8 -7.82    700 -701 911 -912
5046    8 -7.82    700 -701 912 -913
5047    7 -2.35    700 -701 913 -914
5048    7 -2.35    700 -701 914 -915
5049    7 -2.35    700 -701 915 -916
5050    7 -2.35    700 -701 916 -917
5051    0     700 -701 917 -918
c
5100    7 -2.35   701 -702 817 -816
5101    0     701 -702 816 -815  fill=10
5102    0     701 -702 815 -814  fill=10
5103    0     701 -702 814 -813  fill=11
5104    0     701 -702 813 -812  fill=11
5105    0     701 -702 812 -811  fill=11
5106    0     701 -702 811 -810  fill=11
5107    0     701 -702 810 -809  fill=11
5108    0     701 -702 809 -808  fill=11
5109    0     701 -702 808 -807  fill=11
5110    8 -7.82    701 -311 807 -806
5111    8 -7.82    701 -311 806 -805
5112    8 -7.82    701 -311 805 -804
5113    8 -7.82    701 -311 804 -803
5114    8 -7.82    701 -311 803 -802
5115    8 -7.82    701 -311 802 -801
5116    8 -7.82    701 -311 801 -610
5117    8 -7.82    701 -311 610 -615
5118    8 -7.82    701 -311 615 -620
5119    8 -7.82    701 -311 620 -420
5120    8 -7.82    701 -311 420 -430
```

```
5121    8 -7.82     701 -311 430 -445
5122    8 -7.82     701 -311 445 -460
5123    8 -7.82     701 -311 460 -675
5124    8 -7.82     701 -311 675 -651
5125    8 -7.82     701 -311 651 -652
5126    8 -7.82     701 -311 652 -653
5127    8 -7.82     701 -311 653 -654
5128    8 -7.82     701 -311 654 -655
5129    8 -7.82     701 -311 655 -656
5130    8 -7.82     701 -311 656 -657
5131    8 -7.82     701 -311 657 -658
5132    8 -7.82     701 -311 658 -659
5133    8 -7.82     701 -311 659 -680
5134    8 -7.82     701 -311 680 -901
5135    8 -7.82     701 -311 901 -902
5136    8 -7.82     701 -311 902 -903
5137    8 -7.82     701 -311 903 -904
5138    0     701 -702 904 -905  fill=13
5139    0     701 -702 905 -906  fill=13
5140    0     701 -702 906 -907  fill=13
5141    0     701 -702 907 -908  fill=13
5142    0     701 -702 908 -909  fill=13
5143    8 -7.82     701 -702 909 -910
5144    8 -7.82     701 -702 910 -911
5145    8 -7.82     701 -702 911 -912
5146    8 -7.82     701 -702 912 -913
5147    7 -2.35     701 -702 913 -914
5148    7 -2.35     701 -702 914 -915
5149    7 -2.35     701 -702 915 -916
5150    7 -2.35     701 -702 916 -917
5151    0     701 -702 917 -918
c
5200    7 -2.35    702 -703 817 -816
5201    0     702 -703 816 -815  fill=10
5202    0     702 -703 815 -814  fill=10
5203    0     702 -703 814 -813  fill=11
5204    0     702 -703 813 -812  fill=11
5205    0     702 -703 812 -811  fill=11
5206    0     702 -703 811 -810  fill=11
5207    0     702 -703 810 -809  fill=11
5208    0     702 -703 809 -808  fill=11
5209    0     702 -703 808 -807  fill=11
5210    0     311 -703 807 -806  fill=112
5211    0     311 -703 806 -805  fill=112
5212    0     311 -703 805 -804  fill=112
5213    0     311 -703 804 -803  fill=112
5214    0     311 -703 803 -802  fill=112
5215    0     311 -703 802 -801  fill=112
5216    0     311 -703 801 -610  fill=112
5217    0     311 -703 610 -615  fill=112
5218    0     311 -703 615 -620  fill=112
5219    0     311 -703 620 -420  fill=112
5220    0     311 -703 420 -430  fill=112
5221    0     311 -703 430 -445  fill=112
5222    0     311 -703 445 -460  fill=112
5223    0     311 -703 460 -675  fill=112
5224    0     311 -703 675 -651  fill=112
5225    0     311 -703 651 -652  fill=112
5226    0     311 -703 652 -653  fill=112
5227    0     311 -703 653 -654  fill=112
5228    0     311 -703 654 -655  fill=112
5229    0     311 -703 655 -656  fill=112
5230    0     311 -703 656 -657  fill=112
5231    0     311 -703 657 -658  fill=112
5232    0     311 -703 658 -659  fill=112
```

```
5233    0     311 -703 659 -680  fill=112
5234    0     311 -703 680 -901  fill=112
5235    0     311 -703 901 -902  fill=112
5236    0     311 -703 902 -903  fill=112
5237    0     311 -703 903 -904  fill=112
5238    0     702 -703 904 -905  fill=13
5239    0     702 -703 905 -906  fill=13
5240    0     702 -703 906 -907  fill=13
5241    0     702 -703 907 -908  fill=13
5242    0     702 -703 908 -909  fill=13
5243    8 -7.82     702 -703 909 -910
5244    8 -7.82     702 -703 910 -911
5245    8 -7.82     702 -703 911 -912
5246    8 -7.82     702 -703 912 -913
5247    7 -2.35     702 -703 913 -914
5248    7 -2.35     702 -703 914 -915
5249    7 -2.35     702 -703 915 -916
5250    7 -2.35     702 -703 916 -917
5251    0     702 -703 917 -918
c
5300    7 -2.35    703 -705 817 -816
5301    0     703 -705 816 -815  fill=10
5302    0     703 -705 815 -814  fill=10
5303    0     703 -705 814 -813  fill=11
5304    0     703 -705 813 -812  fill=11
5305    0     703 -705 812 -811  fill=11
5306    0     703 -705 811 -810  fill=11
5307    0     703 -705 810 -809  fill=11
5308    0     703 -705 809 -808  fill=11
5309    0     703 -705 808 -807  fill=11
5310    0     703 -705 807 -806  fill=112
5311    0     703 -705 806 -805  fill=112
5312    0     703 -705 805 -804  fill=112
5313    0     703 -705 804 -803  fill=112
5314    0     703 -705 803 -802  fill=112
5315    0     703 -705 802 -801  fill=112
5316    0     703 -705 801 -610  fill=112
5317    0     703 -705 610 -615  fill=112
5318    0     703 -705 615 -620  fill=112
5319    0     703 -705 620 -420  fill=112
5320    0     703 -705 420 -430  fill=112
5321    0     703 -705 430 -445  fill=112
5322    0     703 -705 445 -460  fill=112
5323    0     703 -705 460 -675  fill=112
5324    0     703 -705 675 -651  fill=112
5325    0     703 -705 651 -652  fill=112
5326    0     703 -705 652 -653  fill=112
5327    0     703 -705 653 -654  fill=112
5328    0     703 -705 654 -655  fill=112
5329    0     703 -705 655 -656  fill=112
5330    0     703 -705 656 -657  fill=112
5331    0     703 -705 657 -658  fill=112
5332    0     703 -705 658 -659  fill=112
5333    0     703 -705 659 -680  fill=112
5334    0     703 -705 680 -901  fill=112
5335    0     703 -705 901 -902  fill=112
5336    0     703 -705 902 -903  fill=112
5337    0     703 -705 903 -904  fill=112
5338    0     703 -705 904 -905  fill=13
5339    0     703 -705 905 -906  fill=13
5340    0     703 -705 906 -907  fill=13
5341    0     703 -705 907 -908  fill=13
5342    0     703 -705 908 -909  fill=13
5343    8 -7.82     703 -705 909 -910
5344    8 -7.82     703 -705 910 -911
```

```
5345    8 -7.82     703 -705 911 -912
5346    8 -7.82     703 -705 912 -913
5347    0     703 -705 913 -914  fill=14
5348    0     703 -705 914 -915  fill=14
5349    0     703 -705 915 -916  fill=14
5350    0     703 -705 916 -917  fill=14
5351    0     703 -705 917 -918
c
c       5401    0     704 -705 816 -815  fill=10
c       5402    0     704 -705 815 -814  fill=10
c       5403    0     704 -705 814 -813  fill=11
c       5404    0     704 -705 813 -812  fill=11
c       5405    0     704 -705 812 -811  fill=11
c       5406    0     704 -705 811 -810  fill=11
c       5407    0     704 -705 810 -809  fill=11
c       5408    0     704 -705 809 -808  fill=11
c       5409    0     704 -705 808 -807  fill=11
c       5410    0     704 -705 807 -806  fill=112
c       5411    0     704 -705 806 -805  fill=112
c       5412    0     704 -705 805 -804  fill=112
c       5413    0     704 -705 804 -803  fill=112
c       5414    0     704 -705 803 -802  fill=112
c       5415    0     704 -705 802 -801  fill=112
c       5416    0     704 -705 801 -610  fill=112
c       5417    0     704 -705 610 -615  fill=112
c       5418    0     704 -705 615 -620  fill=112
c       5419    0     704 -705 620 -420  fill=112
c       5420    0     704 -705 420 -430  fill=112
c       5421    0     704 -705 430 -445  fill=112
c       5422    0     704 -705 445 -460  fill=112
c       5423    0     704 -705 460 -675  fill=112
c       5424    0     704 -705 675 -651  fill=112
c       5425    0     704 -705 651 -652  fill=112
c       5426    0     704 -705 652 -653  fill=112
c       5427    0     704 -705 653 -654  fill=112
c       5428    0     704 -705 654 -655  fill=112
c       5429    0     704 -705 655 -656  fill=112
c       5430    0     704 -705 656 -657  fill=112
c       5431    0     704 -705 657 -658  fill=112
c       5432    0     704 -705 658 -659  fill=112
c       5433    0     704 -705 659 -680  fill=112
c       5434    0     704 -705 680 -901  fill=112
c       5435    0     704 -705 901 -902  fill=112
c       5436    0     704 -705 902 -903  fill=112
c       5437    0     704 -705 903 -904  fill=112
c       5438    0     704 -705 904 -905  fill=13
c       5439    0     704 -705 905 -906  fill=13
c       5440    0     704 -705 906 -907  fill=13
c       5441    0     704 -705 907 -908  fill=13
c       5442    0     704 -705 908 -909  fill=13
c       5443    8 -7.82     704 -705 909 -910
c       5444    8 -7.82     704 -705 910 -911
c       5445    8 -7.82     704 -705 911 -912
c       5446    8 -7.82     704 -705 912 -913
c       5447    0     704 -705 913 -914  fill=14
c       5448    0     704 -705 914 -915  fill=14
c       5449    0     704 -705 915 -916  fill=14
c       5450    0     704 -705 916 -917  fill=14
c       5451    0     704 -705 917 -918
c
5500    7 -2.35    705 -707 817 -816
5501    0     705 -707 816 -815  fill=10
5502    0     705 -707 815 -814  fill=10
5503    0     705 -707 814 -813  fill=11
5504    0     705 -707 813 -812  fill=11
```

```
5505     0      705 -707 812 -811  fill=11
5506     0      705 -707 811 -810  fill=11
5507     0      705 -707 810 -809  fill=11
5508     0      705 -707 809 -808  fill=11
5509     0      705 -707 808 -807  fill=11
5510     0      705 -707 807 -806  fill=112
5511     0      705 -707 806 -805  fill=112
5512     0      705 -707 805 -804  fill=112
5513     0      705 -707 804 -803  fill=112
5514     0      705 -707 803 -802  fill=112
5515     0      705 -707 802 -801  fill=112
5516     0      705 -707 801 -610  fill=112
5517     0      705 -707 610 -615  fill=112
5518     0      705 -707 615 -620  fill=112
5519     0      705 -707 620 -420  fill=112
5520     0      705 -707 420 -430  fill=112
5521     0      705 -707 430 -445  fill=112
5522     0      705 -707 445 -460  fill=112
5523     0      705 -707 460 -675  fill=112
5524     0      705 -707 675 -651  fill=112
5525     0      705 -707 651 -652  fill=112
5526     0      705 -707 652 -653  fill=112
5527     0      705 -707 653 -654  fill=112
5528     0      705 -707 654 -655  fill=112
5529     0      705 -707 655 -656  fill=112
5530     0      705 -707 656 -657  fill=112
5531     0      705 -707 657 -658  fill=112
5532     0      705 -707 658 -659  fill=112
5533     0      705 -707 659 -680  fill=112
5534     0      705 -707 680 -901  fill=112
5535     0      705 -707 901 -902  fill=112
5536     0      705 -707 902 -903  fill=112
5537     0      705 -707 903 -904  fill=112
5538     0      705 -707 904 -905  fill=13
5539     0      705 -707 905 -906  fill=13
5540     0      705 -707 906 -907  fill=13
5541     0      705 -707 907 -908  fill=13
5542     0      705 -707 908 -909  fill=13
5543     8 -7.82     705 -707 909 -910
5544     8 -7.82     705 -707 910 -911
5545     8 -7.82     705 -707 911 -912
5546     8 -7.82     705 -707 912 -913
5547     0      705 -716 913 -914
5548     0      705 -716 914 -915
5549     0      705 -716 915 -916
5550     0      705 -716 916 -917
5551     0      705 -716 917 -918
c
c       5601    0     706 -707 816 -815  fill=10
c       5602    0     706 -707 815 -814  fill=10
c       5603    0     706 -707 814 -813  fill=11
c       5604    0     706 -707 813 -812  fill=11
c       5605    0     706 -707 812 -811  fill=11
c       5606    0     706 -707 811 -810  fill=11
c       5607    0     706 -707 810 -809  fill=11
c       5608    0     706 -707 809 -808  fill=11
c       5609    0     706 -707 808 -807  fill=11
c       5610    0     706 -707 807 -806  fill=112
c       5611    0     706 -707 806 -805  fill=112
c       5612    0     706 -707 805 -804  fill=112
c       5613    0     706 -707 804 -803  fill=112
c       5614    0     706 -707 803 -802  fill=112
c       5615    0     706 -707 802 -801  fill=112
c       5616    0     706 -707 801 -610  fill=112
c       5617    0     706 -707 610 -615  fill=112
```

```
c       5618   0     706 -707 615 -620  fill=112
c       5619   0     706 -707 620 -420  fill=112
c       5620   0     706 -707 420 -430  fill=112
c       5621   0     706 -707 430 -445  fill=112
c       5622   0     706 -707 445 -460  fill=112
c       5623   0     706 -707 460 -675  fill=112
c       5624   0     706 -707 675 -651  fill=112
c       5625   0     706 -707 651 -652  fill=112
c       5626   0     706 -707 652 -653  fill=112
c       5627   0     706 -707 653 -654  fill=112
c       5628   0     706 -707 654 -655  fill=112
c       5629   0     706 -707 655 -656  fill=112
c       5630   0     706 -707 656 -657  fill=112
c       5631   0     706 -707 657 -658  fill=112
c       5632   0     706 -707 658 -659  fill=112
c       5633   0     706 -707 659 -680  fill=112
c       5634   0     706 -707 680 -901  fill=112
c       5635   0     706 -707 901 -902  fill=112
c       5636   0     706 -707 902 -903  fill=112
c       5637   0     706 -707 903 -904  fill=112
c       5638   0     706 -707 904 -905  fill=13
c       5639   0     706 -707 905 -906  fill=13
c       5640   0     706 -707 906 -907  fill=13
c       5641   0     706 -707 907 -908  fill=13
c       5642   0     706 -707 908 -909  fill=13
c       5643   8 -7.82     706 -707 909 -910
c       5644   8 -7.82     706 -707 910 -911
c       5645   8 -7.82     706 -707 911 -912
c       5646   8 -7.82     706 -707 912 -913
c       5647   0     706 -707 913 -914
c       5648   0     706 -707 914 -915
c       5649   0     706 -707 915 -916
c       5650   0     706 -707 916 -917
c       5651   0     706 -707 917 -918
c
5700    7 -2.35   707 -709 817 -816
5701    0     707 -709 816 -815  fill=10
5702    0     707 -709 815 -814  fill=10
5703    0     707 -709 814 -813  fill=11
5704    0     707 -709 813 -812  fill=11
5705    0     707 -709 812 -811  fill=11
5706    0     707 -709 811 -810  fill=11
5707    0     707 -709 810 -809  fill=11
5708    0     707 -709 809 -808  fill=11
5709    0     707 -709 808 -807  fill=11
5710    0     707 -709 807 -806  fill=112
5711    0     707 -709 806 -805  fill=112
5712    0     707 -709 805 -804  fill=112
5713    0     707 -709 804 -803  fill=112
5714    0     707 -709 803 -802  fill=112
5715    0     707 -709 802 -801  fill=112
5716    0     707 -709 801 -610  fill=112
5717    0     707 -709 610 -615  fill=112
5718    0     707 -709 615 -620  fill=112
5719    0     707 -709 620 -420  fill=112
5720    0     707 -709 420 -430  fill=112
5721    0     707 -709 430 -445  fill=112
5722    0     707 -709 445 -460  fill=112
5723    0     707 -709 460 -675  fill=112
5724    0     707 -709 675 -651  fill=112
5725    0     707 -709 651 -652  fill=112
5726    0     707 -709 652 -653  fill=112
5727    0     707 -709 653 -654  fill=112
5728    0     707 -709 654 -655  fill=112
5729    0     707 -709 655 -656  fill=112
```

```
5730   0     707 -709 656 -657  fill=112
5731   0     707 -709 657 -658  fill=112
5732   0     707 -709 658 -659  fill=112
5733   0     707 -709 659 -680  fill=112
5734   0     707 -709 680 -901  fill=112
5735   0     707 -709 901 -902  fill=112
5736   0     707 -709 902 -903  fill=112
5737   0     707 -709 903 -904  fill=112
5738   0     707 -709 904 -905  fill=13
5739   0     707 -709 905 -906  fill=13
5740   0     707 -709 906 -907  fill=13
5741   0     707 -709 907 -908  fill=13
5742   0     707 -709 908 -909  fill=13
5743   8 -7.82     707 -709 909 -910
5744   8 -7.82     707 -709 910 -911
5745   8 -7.82     707 -709 911 -912
5746   8 -7.82     707 -709 912 -913
c      5747   0     707 -709 913 -914
c      5748   0     707 -709 914 -915
c      5749   0     707 -709 915 -916
c      5750   0     707 -709 916 -917
c      5751   0     707 -709 917 -918
c
c      5801   0     708 -709 816 -815  fill=10
c      5802   0     708 -709 815 -814  fill=10
c      5803   0     708 -709 814 -813  fill=11
c      5804   0     708 -709 813 -812  fill=11
c      5805   0     708 -709 812 -811  fill=11
c      5806   0     708 -709 811 -810  fill=11
c      5807   0     708 -709 810 -809  fill=11
c      5808   0     708 -709 809 -808  fill=11
c      5809   0     708 -709 808 -807  fill=11
c      5810   0     708 -709 807 -806  fill=112
c      5811   0     708 -709 806 -805  fill=112
c      5812   0     708 -709 805 -804  fill=112
c      5813   0     708 -709 804 -803  fill=112
c      5814   0     708 -709 803 -802  fill=112
c      5815   0     708 -709 802 -801  fill=112
c      5816   0     708 -709 801 -610  fill=112
c      5817   0     708 -709 610 -615  fill=112
c      5818   0     708 -709 615 -620  fill=112
c      5819   0     708 -709 620 -420  fill=112
c      5820   0     708 -709 420 -430  fill=112
c      5821   0     708 -709 430 -445  fill=112
c      5822   0     708 -709 445 -460  fill=112
c      5823   0     708 -709 460 -675  fill=112
c      5824   0     708 -709 675 -651  fill=112
c      5825   0     708 -709 651 -652  fill=112
c      5826   0     708 -709 652 -653  fill=112
c      5827   0     708 -709 653 -654  fill=112
c      5828   0     708 -709 654 -655  fill=112
c      5829   0     708 -709 655 -656  fill=112
c      5830   0     708 -709 656 -657  fill=112
c      5831   0     708 -709 657 -658  fill=112
c      5832   0     708 -709 658 -659  fill=112
c      5833   0     708 -709 659 -680  fill=112
c      5834   0     708 -709 680 -901  fill=112
c      5835   0     708 -709 901 -902  fill=112
c      5836   0     708 -709 902 -903  fill=112
c      5837   0     708 -709 903 -904  fill=112
c      5838   0     708 -709 904 -905  fill=13
c      5839   0     708 -709 905 -906  fill=13
c      5840   0     708 -709 906 -907  fill=13
c      5841   0     708 -709 907 -908  fill=13
c      5842   0     708 -709 908 -909  fill=13
```

```
c       5843    8 -7.82     708 -709 909 -910
c       5844    8 -7.82     708 -709 910 -911
c       5845    8 -7.82     708 -709 911 -912
c       5846    8 -7.82     708 -709 912 -913
c       5847    0      708 -709 913 -914
c       5848    0      708 -709 914 -915
c       5849    0      708 -709 915 -916
c       5850    0      708 -709 916 -917
c       5851    0      708 -709 917 -918
c
5900    7 -2.35    709 -711 817 -816
5901    0     709 -711 816 -815  fill=10
5902    0     709 -711 815 -814  fill=10
5903    0     709 -711 814 -813  fill=11
5904    0     709 -711 813 -812  fill=11
5905    0     709 -711 812 -811  fill=11
5906    0     709 -711 811 -810  fill=11
5907    0     709 -711 810 -809  fill=11
5908    0     709 -711 809 -808  fill=11
5909    0     709 -711 808 -807  fill=11
5910    0     709 -711 807 -806  fill=112
5911    0     709 -711 806 -805  fill=112
5912    0     709 -711 805 -804  fill=112
5913    0     709 -711 804 -803  fill=112
5914    0     709 -711 803 -802  fill=112
5915    0     709 -711 802 -801  fill=112
5916    0     709 -711 801 -610  fill=112
5917    0     709 -711 610 -615  fill=112
5918    0     709 -711 615 -620  fill=112
5919    0     709 -711 620 -420  fill=112
5920    0     709 -711 420 -430  fill=112
5921    0     709 -711 430 -445  fill=112
5922    0     709 -711 445 -460  fill=112
5923    0     709 -711 460 -675  fill=112
5924    0     709 -711 675 -651  fill=112
5925    0     709 -711 651 -652  fill=112
5926    0     709 -711 652 -653  fill=112
5927    0     709 -711 653 -654  fill=112
5928    0     709 -711 654 -655  fill=112
5929    0     709 -711 655 -656  fill=112
5930    0     709 -711 656 -657  fill=112
5931    0     709 -711 657 -658  fill=112
5932    0     709 -711 658 -659  fill=112
5933    0     709 -711 659 -680  fill=112
5934    0     709 -711 680 -901  fill=112
5935    0     709 -711 901 -902  fill=112
5936    0     709 -711 902 -903  fill=112
5937    0     709 -711 903 -904  fill=112
5938    0     709 -711 904 -905  fill=13
5939    0     709 -711 905 -906  fill=13
5940    0     709 -711 906 -907  fill=13
5941    0     709 -711 907 -908  fill=13
5942    0     709 -711 908 -909  fill=13
5943    8 -7.82     709 -711 909 -910
5944    8 -7.82     709 -711 910 -911
5945    8 -7.82     709 -711 911 -912
5946    8 -7.82     709 -711 912 -913
c       5947    0      709 -711 913 -914
c       5948    0      709 -711 914 -915
c       5949    0      709 -711 915 -916
c       5950    0      709 -711 916 -917
c       5951    0      709 -711 917 -918
c
c       6001    0      710 -711 816 -815  fill=10
c       6002    0      710 -711 815 -814  fill=10
```

```
c       6003   0     710 -711 814 -813   fill=11
c       6004   0     710 -711 813 -812   fill=11
c       6005   0     710 -711 812 -811   fill=11
c       6006   0     710 -711 811 -810   fill=11
c       6007   0     710 -711 810 -809   fill=11
c       6008   0     710 -711 809 -808   fill=11
c       6009   0     710 -711 808 -807   fill=11
c       6010   0     710 -711 807 -806   fill=112
c       6011   0     710 -711 806 -805   fill=112
c       6012   0     710 -711 805 -804   fill=112
c       6013   0     710 -711 804 -803   fill=112
c       6014   0     710 -711 803 -802   fill=112
c       6015   0     710 -711 802 -801   fill=112
c       6016   0     710 -711 801 -610   fill=112
c       6017   0     710 -711 610 -615   fill=112
c       6018   0     710 -711 615 -620   fill=112
c       6019   0     710 -711 620 -420   fill=112
c       6020   0     710 -711 420 -430   fill=112
c       6021   0     710 -711 430 -445   fill=112
c       6022   0     710 -711 445 -460   fill=112
c       6023   0     710 -711 460 -675   fill=112
c       6024   0     710 -711 675 -651   fill=112
c       6025   0     710 -711 651 -652   fill=112
c       6026   0     710 -711 652 -653   fill=112
c       6027   0     710 -711 653 -654   fill=112
c       6028   0     710 -711 654 -655   fill=112
c       6029   0     710 -711 655 -656   fill=112
c       6030   0     710 -711 656 -657   fill=112
c       6031   0     710 -711 657 -658   fill=112
c       6032   0     710 -711 658 -659   fill=112
c       6033   0     710 -711 659 -680   fill=112
c       6034   0     710 -711 680 -901   fill=112
c       6035   0     710 -711 901 -902   fill=112
c       6036   0     710 -711 902 -903   fill=112
c       6037   0     710 -711 903 -904   fill=112
c       6038   0     710 -711 904 -905   fill=13
c       6039   0     710 -711 905 -906   fill=13
c       6040   0     710 -711 906 -907   fill=13
c       6041   0     710 -711 907 -908   fill=13
c       6042   0     710 -711 908 -909   fill=13
c       6043   8 -7.82     710 -711 909 -910
c       6044   8 -7.82     710 -711 910 -911
c       6045   8 -7.82     710 -711 911 -912
c       6046   8 -7.82     710 -711 912 -913
c       6047   0     710 -711 913 -914
c       6048   0     710 -711 914 -915
c       6049   0     710 -711 915 -916
c       6050   0     710 -711 916 -917
c       6051   0     710 -711 917 -918
c
6100   7 -2.35   711 -713 817 -816
6101   0     711 -713 816 -815  fill=10
6102   0     711 -713 815 -814  fill=10
6103   0     711 -713 814 -813  fill=11
6104   0     711 -713 813 -812  fill=11
6105   0     711 -713 812 -811  fill=11
6106   0     711 -713 811 -810  fill=11
6107   0     711 -713 810 -809  fill=11
6108   0     711 -713 809 -808  fill=11
6109   0     711 -713 808 -807  fill=11
6110   0     711 -713 807 -806  fill=112
6111   0     711 -713 806 -805  fill=112
6112   0     711 -713 805 -804  fill=112
6113   0     711 -713 804 -803  fill=112
6114   0     711 -713 803 -802  fill=112
```

```
6115   0    711 -713 802 -801  fill=112
6116   0    711 -713 801 -610  fill=112
6117   0    711 -713 610 -615  fill=112
6118   0    711 -713 615 -620  fill=112
6119   0    711 -713 620 -420  fill=112
6120   0    711 -713 420 -430  fill=112
6121   0    711 -713 430 -445  fill=112
6122   0    711 -713 445 -460  fill=112
6123   0    711 -713 460 -675  fill=112
6124   0    711 -713 675 -651  fill=112
6125   0    711 -713 651 -652  fill=112
6126   0    711 -713 652 -653  fill=112
6127   0    711 -713 653 -654  fill=112
6128   0    711 -713 654 -655  fill=112
6129   0    711 -713 655 -656  fill=112
6130   0    711 -713 656 -657  fill=112
6131   0    711 -713 657 -658  fill=112
6132   0    711 -713 658 -659  fill=112
6133   0    711 -713 659 -680  fill=112
6134   0    711 -713 680 -901  fill=112
6135   0    711 -713 901 -902  fill=112
6136   0    711 -713 902 -903  fill=112
6137   0    711 -713 903 -904  fill=112
6138   0    711 -713 904 -905  fill=13
6139   0    711 -713 905 -906  fill=13
6140   0    711 -713 906 -907  fill=13
6141   0    711 -713 907 -908  fill=13
6142   0    711 -713 908 -909  fill=13
6143   8 -7.82    711 -713 909 -910
6144   8 -7.82    711 -713 910 -911
6145   8 -7.82    711 -713 911 -912
6146   8 -7.82    711 -713 912 -913
c      6147   0    711 -713 913 -914
c      6148   0    711 -713 914 -915
c      6149   0    711 -713 915 -916
c      6150   0    711 -713 916 -917
c      6151   0    711 -713 917 -918
c
c      6201   0    712 -713 816 -815  fill=10
c      6202   0    712 -713 815 -814  fill=10
c      6203   0    712 -713 814 -813  fill=11
c      6204   0    712 -713 813 -812  fill=11
c      6205   0    712 -713 812 -811  fill=11
c      6206   0    712 -713 811 -810  fill=11
c      6207   0    712 -713 810 -809  fill=11
c      6208   0    712 -713 809 -808  fill=11
c      6209   0    712 -713 808 -807  fill=11
c      6210   0    712 -713 807 -806  fill=112
c      6211   0    712 -713 806 -805  fill=112
c      6212   0    712 -713 805 -804  fill=112
c      6213   0    712 -713 804 -803  fill=112
c      6214   0    712 -713 803 -802  fill=112
c      6215   0    712 -713 802 -801  fill=112
c      6216   0    712 -713 801 -610  fill=112
c      6217   0    712 -713 610 -615  fill=112
c      6218   0    712 -713 615 -620  fill=112
c      6219   0    712 -713 620 -420  fill=112
c      6220   0    712 -713 420 -430  fill=112
c      6221   0    712 -713 430 -445  fill=112
c      6222   0    712 -713 445 -460  fill=112
c      6223   0    712 -713 460 -675  fill=112
c      6224   0    712 -713 675 -651  fill=112
c      6225   0    712 -713 651 -652  fill=112
c      6226   0    712 -713 652 -653  fill=112
c      6227   0    712 -713 653 -654  fill=112
```

```
c       6228    0     712 -713 654 -655   fill=112
c       6229    0     712 -713 655 -656   fill=112
c       6230    0     712 -713 656 -657   fill=112
c       6231    0     712 -713 657 -658   fill=112
c       6232    0     712 -713 658 -659   fill=112
c       6233    0     712 -713 659 -680   fill=112
c       6234    0     712 -713 680 -901   fill=112
c       6235    0     712 -713 901 -902   fill=112
c       6236    0     712 -713 902 -903   fill=112
c       6237    0     712 -713 903 -904   fill=112
c       6238    0     712 -713 904 -905   fill=13
c       6239    0     712 -713 905 -906   fill=13
c       6240    0     712 -713 906 -907   fill=13
c       6241    0     712 -713 907 -908   fill=13
c       6242    0     712 -713 908 -909   fill=13
c       6243    8 -7.82     712 -713 909 -910
c       6244    8 -7.82     712 -713 910 -911
c       6245    8 -7.82     712 -713 911 -912
c       6246    8 -7.82     712 -713 912 -913
c       6247    0     712 -713 913 -914
c       6248    0     712 -713 914 -915
c       6249    0     712 -713 915 -916
c       6250    0     712 -713 916 -917
c       6251    0     712 -713 917 -918
c
6300    7 -2.35   713 -714 817 -816
6301    0     713 -714 816 -815   fill=10
6302    0     713 -714 815 -814   fill=10
6303    0     713 -714 814 -813   fill=11
6304    0     713 -714 813 -812   fill=11
6305    0     713 -714 812 -811   fill=11
6306    0     713 -714 811 -810   fill=11
6307    0     713 -714 810 -809   fill=11
6308    0     713 -714 809 -808   fill=11
6309    0     713 -714 808 -807   fill=11
6310    0     713 -714 807 -806   fill=112
6311    0     713 -714 806 -805   fill=112
6312    0     713 -714 805 -804   fill=112
6313    0     713 -714 804 -803   fill=112
6314    0     713 -714 803 -802   fill=112
6315    0     713 -714 802 -801   fill=112
6316    0     713 -714 801 -610   fill=112
6317    0     713 -714 610 -615   fill=112
6318    0     713 -714 615 -620   fill=112
6319    0     713 -714 620 -420   fill=112
6320    0     713 -714 420 -430   fill=112
6321    0     713 -714 430 -445   fill=112
6322    0     713 -714 445 -460   fill=112
6323    0     713 -714 460 -675   fill=112
6324    0     713 -714 675 -651   fill=112
6325    0     713 -714 651 -652   fill=112
6326    0     713 -714 652 -653   fill=112
6327    0     713 -714 653 -654   fill=112
6328    0     713 -714 654 -655   fill=112
6329    0     713 -714 655 -656   fill=112
6330    0     713 -714 656 -657   fill=112
6331    0     713 -714 657 -658   fill=112
6332    0     713 -714 658 -659   fill=112
6333    0     713 -714 659 -680   fill=112
6334    0     713 -714 680 -901   fill=112
6335    0     713 -714 901 -902   fill=112
6336    0     713 -714 902 -903   fill=112
6337    0     713 -714 903 -904   fill=112
6338    0     713 -714 904 -905   fill=13
6339    0     713 -714 905 -906   fill=13
```

```
6340   0     713 -714 906 -907  fill=13
6341   0     713 -714 907 -908  fill=13
6342   0     713 -714 908 -909  fill=13
6343   8 -7.82    713 -714 909 -910
6344   8 -7.82    713 -714 910 -911
6345   8 -7.82    713 -714 911 -912
6346   8 -7.82    713 -714 912 -913
c      6347   0    713 -714 913 -914
c      6348   0    713 -714 914 -915
c      6349   0    713 -714 915 -916
c      6350   0    713 -714 916 -917
c      6351   0    713 -714 917 -918
c
6400   7 -2.35   714 -715 817 -816
6401   0     714 -715 816 -815  fill=10
6402   0     714 -715 815 -814  fill=10
6403   0     714 -715 814 -813  fill=11
6404   0     714 -715 813 -812  fill=11
6405   0     714 -715 812 -811  fill=11
6406   0     714 -715 811 -810  fill=11
6407   0     714 -715 810 -809  fill=11
6408   0     714 -715 809 -808  fill=11
6409   0     714 -715 808 -807  fill=11
6410   0     714 -715 807 -806  fill=112
6411   0     714 -715 806 -805  fill=112
6412   0     714 -715 805 -804  fill=112
6413   0     714 -715 804 -803  fill=112
6414   0     714 -715 803 -802  fill=112
6415   0     714 -715 802 -801  fill=112
6416   0     714 -715 801 -610  fill=112
6417   0     714 -715 610 -615  fill=112
6418   0     714 -715 615 -620  fill=112
6419   0     714 -715 620 -420  fill=112
6420   0     714 -715 420 -430  fill=112
6421   0     714 -715 430 -445  fill=112
6422   0     714 -715 445 -460  fill=112
6423   0     714 -715 460 -675  fill=112
6424   0     714 -715 675 -651  fill=112
6425   0     714 -715 651 -652  fill=112
6426   0     714 -715 652 -653  fill=112
6427   0     714 -715 653 -654  fill=112
6428   0     714 -715 654 -655  fill=112
6429   0     714 -715 655 -656  fill=112
6430   0     714 -715 656 -657  fill=112
6431   0     714 -715 657 -658  fill=112
6432   0     714 -715 658 -659  fill=112
6433   0     714 -715 659 -680  fill=112
6434   0     714 -715 680 -901  fill=112
6435   0     714 -715 901 -902  fill=112
6436   0     714 -715 902 -903  fill=112
6437   0     714 -715 903 -904  fill=112
6438   0     714 -715 904 -905  fill=13
6439   0     714 -715 905 -906  fill=13
6440   0     714 -715 906 -907  fill=13
6441   0     714 -715 907 -908  fill=13
6442   0     714 -715 908 -909  fill=13
6443   0     714 -715 909 -910  fill=15
6444   0     714 -715 910 -911  fill=15
6445   0     714 -715 911 -912  fill=15
6446   0     714 -715 912 -913  fill=15
c      6447   0    714 -715 913 -914
c      6448   0    714 -715 914 -915
c      6449   0    714 -715 915 -916
c      6450   0    714 -715 916 -917
c      6451   0    714 -715 917 -918
```

```
c
6500    7 -2.35    715 -716 817 -816
6501    0     715 -716 816 -815  fill=10
6502    0     715 -716 815 -814  fill=10
6503    0     715 -716 814 -813  fill=11
6504    0     715 -716 813 -812  fill=11
6505    0     715 -716 812 -811  fill=11
6506    0     715 -716 811 -810  fill=11
6507    0     715 -716 810 -809  fill=11
6508    0     715 -716 809 -808  fill=11
6509    0     715 -716 808 -807  fill=11
6510    0     715 -716 807 -806  fill=12
6511    0     715 -716 806 -805  fill=12
6512    0     715 -716 805 -804  fill=12
6513    0     715 -716 804 -803  fill=12
6514    0     715 -716 803 -802  fill=12
6515    0     715 -716 802 -801  fill=12
6516    0     715 -716 801 -610  fill=12
6517    0     715 -716 610 -615  fill=12
6518    0     715 -716 615 -620  fill=12
6519    0     715 -716 620 -420  fill=12
6520    0     715 -716 420 -430  fill=12
6521    0     715 -716 430 -445  fill=12
6522    0     715 -716 445 -460  fill=12
6523    0     715 -716 460 -675  fill=12
6524    0     715 -716 675 -651  fill=12
6525    0     715 -716 651 -652  fill=12
6526    0     715 -716 652 -653  fill=12
6527    0     715 -716 653 -654  fill=12
6528    0     715 -716 654 -655  fill=12
6529    0     715 -716 655 -656  fill=12
6530    0     715 -716 656 -657  fill=12
6531    0     715 -716 657 -658  fill=12
6532    0     715 -716 658 -659  fill=12
6533    0     715 -716 659 -680  fill=12
6534    0     715 -716 680 -901  fill=12
6535    0     715 -716 901 -902  fill=12
6536    0     715 -716 902 -903  fill=12
6537    0     715 -716 903 -904  fill=12
6538    0     715 -716 904 -905  fill=13
6539    0     715 -716 905 -906  fill=13
6540    0     715 -716 906 -907  fill=13
6541    0     715 -716 907 -908  fill=13
6542    0     715 -716 908 -909  fill=13
6543    0     715 -716 909 -910
6544    0     715 -716 910 -911
6545    0     715 -716 911 -912
6546    0     715 -716 912 -913
c       6547    0     715 -716 913 -914
c       6548    0     715 -716 914 -915
c       6549    0     715 -716 915 -916
c       6550    0     715 -716 916 -917
c       6551    0     715 -716 917 -918
c
6601    0     716 -717 816 -815
6602    0     716 -717 815 -814
6603    0     716 -717 814 -813
6604    0     716 -717 813 -812
6605    0     716 -717 812 -811
6606    0     716 -717 811 -810
6607    0     716 -717 810 -809
6608    0     716 -717 809 -808
6609    0     716 -717 808 -807
6610    0     716 -717 807 -806
6611    0     716 -717 806 -805
```

```
6612  0   716 -717 805 -804
6613  0   716 -717 804 -803
6614  0   716 -717 803 -802
6615  0   716 -717 802 -801
6616  0   716 -717 801 -610
6617  0   716 -717 610 -615
6618  0   716 -717 615 -620
6619  0   716 -717 620 -420
6620  0   716 -717 420 -430
6621  0   716 -717 430 -445
6622  0   716 -717 445 -460
6623  0   716 -717 460 -675
6624  0   716 -717 675 -651
6625  0   716 -717 651 -652
6626  0   716 -717 652 -653
6627  0   716 -717 653 -654
6628  0   716 -717 654 -655
6629  0   716 -717 655 -656
6630  0   716 -717 656 -657
6631  0   716 -717 657 -658
6632  0   716 -717 658 -659
6633  0   716 -717 659 -680
6634  0   716 -717 680 -901
6635  0   716 -717 901 -902
6636  0   716 -717 902 -903
6637  0   716 -717 903 -904
6638  0   716 -717 904 -905
6639  0   716 -717 905 -906
6640  0   716 -717 906 -907
6641  0   716 -717 907 -908
6642  0   716 -717 908 -909
6643  0   716 -717 909 -910
6644  0   716 -717 910 -911
6645  0   716 -717 911 -912
6646  0   716 -717 912 -913
6647  0   716 -717 913 -914
6648  0   716 -717 914 -915
6649  0   716 -717 915 -916
6650  0   716 -717 916 -917
6651  0   716 -717 917 -918
c
c      overpack universes
c      overpack baseplate
10001  8 -7.82     371 -372 373 -374  u=10
10002  8 -7.82     374 -362           u=10
10003  8 -7.82     374  363           u=10
10004  9 -1.17e-3 374 362 -363        u=10
10005  8 -7.82     -371  367 -374     u=10
10006  8 -7.82     -371  373 -366     u=10
10007  9 -1.17e-3 -371  366 -367      u=10
10008  8 -7.82     -373 -362          u=10
10009  8 -7.82     -373 363           u=10
10010  9 -1.17e-3 -373 362 -363       u=10
10011  8 -7.82      372 373 -366      u=10
10012  8 -7.82      372 367 -374      u=10
10013  9 -1.17e-3  372 366 -367       u=10
c
c      walls and top of bottom duct
10101  8 -7.82      361 -362 -932      u=11
10102  8 -7.82      363 -364 -932      u=11
10103  8 -7.82      362 -363  931 -932 u=11
c
10104  8 -7.82      365 -366 -932      u=11
10105  8 -7.82      367 -368 -932      u=11
10106  8 -7.82      366 -367  931 -932 u=11
```

```
c      inner and outer shell between bottom ducts
10107  8 -7.82      368 364 -932 315   u=11
10108  8 -7.82      368 -361 -932 315  u=11
10109  8 -7.82     -365 364 -932 315   u=11
10110  8 -7.82     -365 -361 -932 315  u=11
c
10111  8 -7.82      368 364 -932 -310  u=11
10112  8 -7.82      368 -361 -932 -310 u=11
10113  8 -7.82     -365 364 -932 -310  u=11
10114  8 -7.82     -365 -361 -932 -310 u=11
c      concrete and radial plates between bottom ducts
10121  8 -7.82      310 -315 391 -392  -932 u=11
10122  8 -7.82      310 -315 393 -394  -932 u=11
c
10131  7 -2.35      310 -315 394 -365  -932 u=11
10132  7 -2.35      310 -315 368 -391  -932 u=11
10133  7 -2.35      310 -315 392  364  -932 u=11
10134  7 -2.35      310 -315 -361 394  -932 u=11
10135  7 -2.35      310 -315 368 -393  -932 u=11
10136  7 -2.35      310 -315 392 -365  -932 u=11
10137  7 -2.35      310 -315 -391 -361 -932 u=11
10138  7 -2.35      310 -315 364 -393  -932 u=11
c      air and grid spacers in bottom ducts
10141  9 -1.17e-3  362 -363 -931 263 -264 u=11
10142  9 -1.17e-3  366 -367 -931 261 -262 u=11
c
10143  9 -1.17e-3  362 -201 -931 (-263:264) u=11
10144  9 -1.17e-3  206 -363 -931 (-263:264) u=11
10145  9 -1.17e-3  201 -202 -221 (-263:264) u=11
10146  5 -7.92      202 -203 -221 (-273:274) u=11
11146  9 -1.17e-3  202 -203 -221 273 -274 (-263:264) u=11
10147  9 -1.17e-3  203 -204 -221 (-263:264) u=11
10148  5 -7.92      204 -205 -221 (-273:274) u=11
11148  9 -1.17e-3  204 -205 -221 273 -274 (-263:264) u=11
10149  9 -1.17e-3  205 -206 -221 (-263:264) u=11
10150  5 -7.92      201 -202 221 -222 (-263:264) u=11
10151  5 -7.92      202 -203 221 -222 (-263:264) u=11
10152  5 -7.92      203 -204 221 -222 (-263:264) u=11
10153  5 -7.92      204 -205 221 -222 (-263:264) u=11
10154  5 -7.92      205 -206 221 -222 (-263:264) u=11
10155  9 -1.17e-3  201 -202 222 -223 (-263:264) u=11
10156  5 -7.92      202 -203 222 -223 (-263:264) u=11
10157  9 -1.17e-3  203 -204 222 -223 (-263:264) u=11
10158  5 -7.92      204 -205 222 -223 (-263:264) u=11
10159  9 -1.17e-3  205 -206 222 -223 (-263:264) u=11
10160  5 -7.92      201 -202 223 -224 (-263:264) u=11
10161  5 -7.92      202 -203 223 -224 (-263:264) u=11
10162  5 -7.92      203 -204 223 -224 (-263:264) u=11
10163  5 -7.92      204 -205 223 -224 (-263:264) u=11
10164  5 -7.92      205 -206 223 -224 (-263:264) u=11
10165  9 -1.17e-3  201 -202 224 -225 (-263:264) u=11
10166  5 -7.92      202 -203 224 -225 (-263:264) u=11
10167  9 -1.17e-3  203 -204 224 -225 (-263:264) u=11
10168  5 -7.92      204 -205 224 -225 (-263:264) u=11
10169  9 -1.17e-3  205 -206 224 -225 (-263:264) u=11
10170  9 -1.17e-3  201 -206 225 -931 (-263:264) u=11
c
10243  9 -1.17e-3  366 -211 -931 (-261:262) u=11
10244  9 -1.17e-3  216 -367 -931 (-261:262) u=11
10245  9 -1.17e-3  211 -212 -221 (-261:262) u=11
10246  5 -7.92      212 -213 -221 (-261:262) u=11
10247  9 -1.17e-3  213 -214 -221 (-261:262) u=11
10248  5 -7.92      214 -215 -221 (-261:262) u=11
10249  9 -1.17e-3  215 -216 -221 (-261:262) u=11
10250  5 -7.92      211 -212 221 -222 (-261:262) u=11
```

```
10251  5 -7.92      212 -213 221 -222 (-261:262) u=11
10252  5 -7.92      213 -214 221 -222 (-261:262) u=11
10253  5 -7.92      214 -215 221 -222 (-261:262) u=11
10254  5 -7.92      215 -216 221 -222 (-261:262) u=11
10255  9 -1.17e-3   211 -212 222 -223 (-261:262) u=11
10256  5 -7.92      212 -213 222 -223 (-261:262) u=11
10257  9 -1.17e-3   213 -214 222 -223 (-261:262) u=11
10258  5 -7.92      214 -215 222 -223 (-261:262) u=11
10259  9 -1.17e-3   215 -216 222 -223 (-261:262) u=11
10260  5 -7.92      211 -212 223 -224 (-261:262) u=11
10261  5 -7.92      212 -213 223 -224 (-261:262) u=11
10262  5 -7.92      213 -214 223 -224 (-261:262) u=11
10263  5 -7.92      214 -215 223 -224 (-261:262) u=11
10264  5 -7.92      215 -216 223 -224 (-261:262) u=11
10265  9 -1.17e-3   211 -212 224 -225 (-261:262) u=11
10266  5 -7.92      212 -213 224 -225 (-261:262) u=11
10267  9 -1.17e-3   213 -214 224 -225 (-261:262) u=11
10268  5 -7.92      214 -215 224 -225 (-261:262) u=11
10269  9 -1.17e-3   215 -216 224 -225 (-261:262) u=11
10270  9 -1.17e-3   211 -216 225 -931 (-261:262) u=11
c
c      inner, outer shells and concrete between top and bot ducts
c
10301  8 -7.82     932       -311 u=11
10302  8 -7.82     932        315 u=11
10303  8 -7.82  932       311 -315 391 -392  u=11
10304  8 -7.82  932       311 -315 393 -394  u=11
10305  7 -2.35  932       311 -315 394 -391  u=11
10306  7 -2.35  932       311 -315 392  394  u=11
10307  7 -2.35  932       311 -315 392 -393  u=11
10308  7 -2.35  932      311 -315 -391 -393  u=11
c
11302  8 -7.82              315 u=12
11303  8 -7.82            -315 391 -392  u=12
11304  8 -7.82            -315 393 -394  u=12
11305  7 -2.35            -315 394 -391  u=12
11306  7 -2.35            -315 392  394  u=12
11307  7 -2.35            -315 392 -393  u=12
11308  7 -2.35           -315 -391 -393  u=12
c
13303  8 -7.82            391 -392  u=112
13304  8 -7.82            393 -394  u=112
13305  7 -2.35            394 -391  u=112
13306  7 -2.35            392  394  u=112
13307  7 -2.35            392 -393  u=112
13308  7 -2.35           -391 -393  u=112
c
12301  8 -7.82         -933 -311 u=13
12302  8 -7.82         -933  315 u=13
12303  8 -7.82      -933  311 -315 391 -392  u=13
12304  8 -7.82      -933  311 -315 393 -394  u=13
12305  7 -2.35      -933  311 -315 394 -391  u=13
12306  7 -2.35      -933  311 -315 392  394  u=13
12307  7 -2.35      -933  311 -315 392 -393  u=13
12308  7 -2.35      -933 311 -315 -391 -393  u=13
c      top duct bottom plates
10309  8 -7.82  933 -934 351 -354  u=13
10310  8 -7.82  933 -934 355 -358  u=13
c      top duct walls
10311  8 -7.82  934      351 -352  u=13
10312  8 -7.82  934      353 -354  u=13
10313  8 -7.82  934      355 -356  u=13
10314  8 -7.82  934      357 -358  u=13
c      inner and outer shell between top ducts
10407  8 -7.82      358 354  933 315   u=13
```

```
10408  8 -7.82      358 -351  933 315  u=13
10409  8 -7.82     -355 354  933 315   u=13
10410  8 -7.82     -355 -351  933 315  u=13
c
10411  8 -7.82      358 354  933 -310  u=13
10412  8 -7.82      358 -351  933 -310 u=13
10413  8 -7.82     -355 354  933 -310  u=13
10414  8 -7.82     -355 -351  933 -310 u=13
c      concrete and radial plates next to top ducts
10421  8 -7.82      310 -315 391 -392  933 -935 u=13
10422  8 -7.82      310 -315 393 -394  933 -935 u=13
c
10431  7 -2.35      310 -315 394 -355  933 -935 u=13
10432  7 -2.35      310 -315 358 -391  933 -935 u=13
10433  7 -2.35      310 -315 392  354  933 -935 u=13
10434  7 -2.35      310 -315 -351 394  933 -935 u=13
10435  7 -2.35      310 -315 358 -393  933 -935 u=13
10436  7 -2.35      310 -315 392 -355  933 -935 u=13
10437  7 -2.35      310 -315 -391 -351 933 -935 u=13
10438  7 -2.35      310 -315 354 -393  933 -935 u=13
c
c      air and grid spacers in top ducts
10441  9 -1.17e-3  352 -353  934 263 -264 u=13
10442  9 -1.17e-3  356 -357  934 261 -262 u=13
c
10443  9 -1.17e-3  352 -231  934 (-263:264) u=13
10444  9 -1.17e-3  236 -353  934 (-263:264) u=13
c
10445  9 -1.17e-3  231 -232 934 -251 (-263:264) u=13
10446  5 -7.92     232 -233 934 -251 (-263:264) u=13
10447  9 -1.17e-3  233 -234 934 -251 (-263:264) u=13
10448  5 -7.92     234 -235 934 -251 (-263:264) u=13
10449  9 -1.17e-3  235 -236 934 -251 (-263:264) u=13
10450  5 -7.92     231 -232 251 -252 (-263:264) u=13
10451  5 -7.92     232 -233 251 -252 (-263:264) u=13
10452  5 -7.92     233 -234 251 -252 (-263:264) u=13
10453  5 -7.92     234 -235 251 -252 (-263:264) u=13
10454  5 -7.92     235 -236 251 -252 (-263:264) u=13
10455  9 -1.17e-3  231 -232 252 -253 (-263:264) u=13
10456  5 -7.92     232 -233 252 -253 (-263:264) u=13
10457  9 -1.17e-3  233 -234 252 -253 (-263:264) u=13
10458  5 -7.92     234 -235 252 -253 (-263:264) u=13
10459  9 -1.17e-3  235 -236 252 -253 (-263:264) u=13
10470  9 -1.17e-3  231 -236 253      (-263:264) u=13
c
10543  9 -1.17e-3  356 -241  934 (-261:262) u=13
10544  9 -1.17e-3  246 -357  934 (-261:262) u=13
c
10545  9 -1.17e-3  241 -242 934 -251 (-261:262) u=13
10546  5 -7.92     242 -243 934 -251 (-261:262) u=13
10547  9 -1.17e-3  243 -244 934 -251 (-261:262) u=13
10548  5 -7.92     244 -245 934 -251 (-261:262) u=13
10549  9 -1.17e-3  245 -246 934 -251 (-261:262) u=13
10550  5 -7.92     241 -242 251 -252 (-261:262) u=13
10551  5 -7.92     242 -243 251 -252 (-261:262) u=13
10552  5 -7.92     243 -244 251 -252 (-261:262) u=13
10553  5 -7.92     244 -245 251 -252 (-261:262) u=13
10554  5 -7.92     245 -246 251 -252 (-261:262) u=13
10555  9 -1.17e-3  241 -242 252 -253 (-261:262) u=13
10556  5 -7.92     242 -243 252 -253 (-261:262) u=13
10557  9 -1.17e-3  243 -244 252 -253 (-261:262) u=13
10558  5 -7.92     244 -245 252 -253 (-261:262) u=13
10559  9 -1.17e-3  245 -246 252 -253 (-261:262) u=13
10570  9 -1.17e-3  241 -246 253      (-261:262) u=13
c      top plate
```

```
10641  8 -7.82     358 354  935 310 -315   u=13
10642  8 -7.82     358 -351  935 310 -315  u=13
10643  8 -7.82    -355 354  935 310 -315   u=13
10644  8 -7.82    -355 -351  935 310 -315  u=13
c
10701  8 -7.82    -314 u=15
10702  0           314 u=15
c
10711  7 -2.35     -312       u=14
10712  8 -7.82      312 -313 u=14
10713  0            313       u=14
c
99999   0 -817:918:717:(716 -816)
c
c      BLANK LINE

c      BLANK LINE
c
c      MPC surfaces\/ \/ \/ \/ \/
c
10     px        -12.169775
11     px        -12.017375
12     px        -11.826875
13     px        -11.1125
14     px         11.1125
15     px         11.826875
16     px         12.017375
17     px         12.169775
18     py        -12.169775
19     py        -12.017375
20     py        -11.826875
21     py        -11.1125
22     py         11.1125
23     py         11.826875
24     py         12.017375
25     py         12.169775
c
26     py  -9.525
27     py   9.525
28     px  -9.525
29     px   9.525
30     py  -6.35
31     py   6.35
32     px  -6.35
33     px   6.35
c
35     px  -11.46969
36     px   11.46969
37     py  -11.46969
38     py   11.46969
c
40     px  -10.8204
41     px   10.8204
42     py  -10.8204
43     py   10.8204
c
101    py  82.12074
102    py  54.74716
103    py  27.37358
104    py  0.0
105    py -27.37358
106    py -54.74716
107    py -82.12074
c
116    px  82.12074
```

```
115   px  54.74716
114   px  27.37358
113   px  0.0
112   px -27.37358
111   px -54.74716
110   px -82.12074
c
301   cz   85.56625
302   cz   86.83625
c
c     620   pz    21.59     $ MPC baseplate        - 2.5 inches
400   pz   23.876   $ start of egg crate
410   pz   28.8925  $ start of boral
415   pz   32.004   $ begin fuel element
420   pz   50.7365  $ end of lower nozzle
425   pz   53.2765  $ end of space/ start of active fuel
430   pz   419.0365 $ end of active fuel
435   pz   425.1325 $ boral ends
440   pz   428.72025 $ space above fuel
445   pz   439.83275 $ plenum spacer ends
455   pz   452.6915  $ top of top nozzle
460   pz   467.614   $ top of basket
c
610   pz    15.24     $ overpack baseplate
615   pz    17.78
616   pz    20.32
620   pz    21.59     $ MPC baseplate       - 2.5 inches
675   pz    474.98    $ bottom of MPC in lid - 178.5 inches from 620
651   pz    476.25    $ 0.25 inch first segment
652   pz    478.79
653   pz    481.33
654   pz    483.87
655   pz    486.41
656   pz    488.95
657   pz    491.49
658   pz    494.03
659   pz    496.57
680   pz    499.11    $ top of MPC outer lid
c
c     MPC surfaces/\ /\ /\ /\ /\
c
c     overpack surfaces
c
303   cz    80.01     $ ID of item 27
304   cz    81.28     $ OD of item 27
305   cz    85.09     $ ID of item 7
306   cz    86.20125  $ ID of item 5
307   cz    87.63     $ OD of item 7
c
310   cz    96.52     $ outer rad of item 3 overpack inner shell
311   cz    98.425    $ outer rad of item 28
312   cz    107.95   $ ID of item 26
313   cz    109.22   $ OD of item 26
314   cz    160.02   $ OD of item 10
315   cz    166.37   $ ID of item 2
c     top duct planes
351   px    -33.02  $ start of item 12
352   px    -31.75  $ end of item 12
353   px     31.75  $ start of item 12
354   px     33.02  $ end of item 12
c
355   py    -33.02  $ start of item 12
356   py    -31.75  $ end of item 12
357   py     31.75  $ start of item 12
358   py     33.02  $ end of item 12
```

```
c      bottom duct planes
361    px     -20.955  $ start of item 13
362    px     -19.05   $ end of item 13
363    px      19.05   $ start of item 13
364    px      20.955  $ end of item 13
c
365    py     -20.955  $ start of item 13
366    py     -19.05   $ end of item 13
367    py      19.05   $ start of item 13
368    py      20.955  $ end of item 13
c      cutouts in item 1
371    px     -123.19
372    px      123.19
373    py     -123.19
374    py      123.19
c        item 14
391    1 py    -0.9525    $ steel plate in concrete at 45/225 degrees
392    1 py     0.9525    $ steel plate in concrete at 45/225 degrees
393    1 px    -0.9525    $ steel plate in concrete at 135/315 degrees
394    1 px     0.9525    $ steel plate in concrete at 135/315 degrees
c
c      bottom shielding cross plates
c
201    px   -18.57375
202    px   -6.35
203    px   -5.715
204    px    5.715
205    px    6.35
206    px    18.57375
c
211    py   -18.57375
212    py   -6.35
213    py   -5.715
214    py    5.715
215    py    6.35
216    py    18.57375
c
221    pz   -32.8168
222    pz   -32.1818
223    pz   -24.3586
224    pz   -23.7236
225    pz   -15.9004
c
c      top shielding cross plates
c
231    px   -31.27375
232    px   -10.795
233    px   -10.16
234    px    10.16
235    px    10.795
236    px    31.27375
c
241    py   -31.27375
242    py   -10.795
243    py   -10.16
244    py    10.16
245    py    10.795
246    py    31.27375
c
251    pz    523.24
252    pz    523.875
253    pz    530.86
c      end of cross plates in openings
261    px   -107.315
262    px    107.315
```

```
263   py   -107.315
264   py    107.315
c     end of part of bottom cross plates
271   px   -124.46
272   px    124.46
273   py   -124.46
274   py    124.46
c
c     radial planes in overpack
700   cz     93.345  $ ID of overpack
701   cz     95.885
702   cz     98.5  $ slightly diff from  311
703   cz     103.505
704   cz     108.585
705   cz     113.665
706   cz     118.745
707   cz     123.825
708   cz     128.905
709   cz     133.985
710   cz     139.065
711   cz     144.145
712   cz     149.225
713   cz     154.305
714   cz     159.385
715   cz     164.465
716   cz     168.275
717   cz     169.275
c
c     planes in pedestal
c
801   pz     12.7
802   pz     10.16
803   pz     7.62
804   pz     5.08
805   pz     2.54  $ bottom of item 24
806   pz    -2.54
807   pz    -7.62
808   pz    -12.7
809   pz    -17.78
810   pz    -22.86
811   pz    -27.94
812   pz    -33.02
813   pz    -38.1
814   pz    -40.64 $ start of item 1
815   pz    -43.18 $
816   pz    -45.72 $ ground
817   pz    -76.20
c
c     planes in lid
c
901   pz     501.65 $ start of item 6
902   pz     502.285 $ 0.25 inch segement from start
903   pz     504.825 $ end of item 6
904   pz     509.905
905   pz     513.715
906   pz     516.3 $ end of item 8 plus a little
907   pz     521.335
908   pz     526.415
909   pz     531.495 $ end of concrete start of item 10
910   pz     534.035
911   pz     536.575
912   pz     539.115
913   pz     541.655 $ end of item 10
914   pz     546.735
915   pz     551.815
```

```
916   pz    556.895
917   pz    561.975
918   pz    562.975
c
c     planes in overpack
c
931   pz   -15.24   $ bottom of item 11
932   pz   -10.16   $ top of item 11
933   pz    513.08  $ bottom of item 8 and top of item 28
934   pz    516.255 $ top of item 8
935   pz    529.59  $ start of item 9
c
c     for tallying
c
501   pz   -45.72
502   pz   -30.48
503   pz   -15.24
504   pz   0.00
505   pz   15.24
506   pz   30.48
507   pz   45.72
508   pz   60.96
509   pz   76.20
510   pz   91.44
511   pz   106.68
512   pz   121.92
513   pz   137.16
514   pz   152.40
515   pz   167.64
516   pz   182.88
517   pz   198.12
518   pz   213.36
519   pz   228.60
520   pz   243.84
521   pz   259.08
522   pz   274.32
523   pz   289.56
524   pz   304.80
525   pz   320.04
526   pz   335.28
527   pz   350.52
528   pz   365.76
529   pz   381.00
530   pz   396.24
531   pz   411.48
532   pz   426.72
533   pz   441.96
534   pz   457.20
535   pz   472.44
536   pz   487.68
537   pz   502.92
538   pz   518.16
539   pz   533.40
c
550   cz   15.24
551   cz   30.48
552   cz   45.72
553   cz   60.96
554   cz   76.20
555   cz   91.44
556   cz   106.68
557   cz   121.92
558   cz   137.16
559   cz   152.40
560   cz   167.64
```

```
c
c     BLANK LINE

c     BLANK LINE
c
*tr1    0 0 0 45   315   90  135   45   90  90 90 0
c
c         PHOTON MATERIALS
c
c     fuel 3.4 w/o U235  10.412 gm/cc
m1            92235.01p   -0.029971
              92238.01p   -0.851529
              8016.01p    -0.1185
c     homogenized fuel  density 3.8699 gm/cc
m2            92235.01p   -0.027652
              92238.01p   -0.719715
               8016.01p   -0.100469
              40000.01p   -0.149015
              50000.01p   -0.002587
              26000.01p   -0.000365
              24000.01p   -0.000198
c     zirconium 6.55 gm/cc
m3            40000.01p   1.          $ Zr Clad
c     stainless steel 7.92 gm/cc
m5            24000.01p   -0.19
              25055.01p   -0.02
              26000.01p   -0.695
              28000.01p   -0.095
c     boral  2.644 gm/cc
m6            5010.01p    -0.044226
              5011.01p    -0.201474
              13027.01p   -0.6861
              6000.01p    -0.0682
c              Concrete (NBS Ordinary) @ 2.35 g/cc (Ref: LA-12827-M)
m7            14000.01p  -0.315
              13027.01p  -0.048
              8016.01p   -0.500
              1001.01p   -0.006
              11023.01p  -0.017
              20000.01p  -0.083
              26000.01p  -0.012
              19000.01p  -0.019
c     carbon steel 7.82 gm/cc
m8      6000.01p -0.005 26000.01p -0.995
c     air density 1.17e-3 gm/cc
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
c     m1            92235.50c   -0.029971
c                   92238.50c   -0.851529
c                   8016.50c    -0.1185
c     c     homogenized fuel  density 3.8699 gm/cc
c     m2            92235.50c   -0.027652
c                   92238.50c   -0.719715
c                    8016.50c   -0.100469
c                   40000.35c   -0.149015
c                   50000.35c   -0.002587
c                   26000.55c   -0.000365
c                   24000.50c   -0.000198
c     c     helium  1e-4 gm/cc
c     m3     2004.50c 1.0
c     c     stainless steel 7.92 gm/cc
c     m5            24000.50c   -0.19
```

```
c                    25055.50c   -0.02
c                    26000.55c   -0.695
c                    28000.50c   -0.095
c      c     boral   2.644 gm/cc
c      m6            5010.50c     -0.044226
c                    5011.56c     -0.201474
c                    13027.50c   -0.6861
c                    6000.50c    -0.0682
c      c              Concrete (NBS Ordinary) @ 2.35 g/cc (Ref: LA-12827-M)
c      m7            14000.50c  -0.315
c                    13027.50c  -0.048
c                    8016.50c   -0.500
c                    1001.50c   -0.006
c                    11023.50c  -0.017
c                    20000.50c  -0.083
c                    26000.55c  -0.012
c                    19000.50c  -0.019
c      mt7          lwtr.01t
c      c     carbon steel 7.82 gm/cc
c      m8       6000.50c -0.005 26000.55c -0.995
c      c     air density 1.17e-3 gm/cc
c      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     13500000
prdmp    j   -60   1   2
c     print   10 110 160 161 20 170
print
mode p
ssw   716 917
c
sdef  par=2  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  0.43 0.27 0.22 0.04 0.04
c
c    energy dist for neutrons in the fuel
c
c    si1  h  0.1 0.4 0.9 1.4 1.85 3.0 6.43 20.0
c    sp1     0   0.03787 0.1935 0.1773 0.1310 0.2320 0.2098 0.01853
c
c    energy dist for Co60 gammas
c
si1  l 1.3325 1.1732
sp1    0.5    0.5
c
c    axial dist for phot in fuel
c
c    si3  h 53.2765 68.5165 83.7565 114.2365 175.1965 236.1565
c           297.1165 358.0765 388.5565 403.7965 419.0365
c    sp3  0 0.022854 0.035321 0.08975 0.184167 0.183 0.179833
c           0.175017 0.080033 0.030575 0.019458
c    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
si3  h 32.004 50.7365 419.0365 428.72025 439.83275 452.6915
sp3    0       0.44     0.0        0.05      0.05       0.46
sb3    0       0.50     0.0        0.05      0.10       0.35
c
```

```
si4   s          13 14
              12 13 14 15
           11 12 13 14 15 16
           11 12 13 14 15 16
              12 13 14 15
                 13 14
sp4   1 23r
c
ds5   s                26 26
                    25 25 25 25
                 24 24 24 24 24 24
                 23 23 23 23 23 23
                    22 22 22 22
                       21 21
c
si11   -79.25435 -57.61355
si12   -51.88077 -30.23997
si13   -24.50719 -2.86639
si14     2.86639   24.50719
si15    30.23997   51.88077
si16    57.61355   79.25435
c
si21   -79.25435 -57.61355
si22   -51.88077 -30.23997
si23   -24.50719 -2.86639
si24     2.86639   24.50719
si25    30.23997   51.88077
si26    57.61355   79.25435
c
sp11   0 1
sp12   0 1
sp13   0 1
sp14   0 1
sp15   0 1
sp16   0 1
sp21   0 1
sp22   0 1
sp23   0 1
sp24   0 1
sp25   0 1
sp26   0 1
c
#    imp:p
314      2
315      2
316      2
317      2
318      2
319      2
320      2
321      2
346      2
353      2
360      2
361      2
362      2
363      2
364      2
365      2
366      2
367      2
414      2
415      2
416      2
417      2
```

418	2
419	2
420	2
421	2
446	2
453	2
460	2
461	2
462	2
463	2
464	2
465	2
466	2
467	2
514	2
515	2
516	2
517	2
518	2
519	2
520	2
521	2
546	2
553	2
560	2
561	2
562	2
563	2
564	2
565	2
566	2
567	2
614	2
615	2
616	2
617	2
618	2
619	2
620	2
621	2
646	2
653	2
660	2
661	2
662	2
663	2
664	2
665	2
666	2
667	2
714	2
715	2
716	2
717	2
718	2
719	2
720	2
721	2
746	2
753	2
760	2
761	2
762	2
763	2
764	2

765	2
766	2
767	2
322	1
323	1
324	1
325	1
326	1
327	1
328	1
329	1
347	1
355	1
368	1
369	1
370	1
371	1
372	1
373	1
374	1
375	1
422	1
423	1
424	1
425	1
426	1
427	1
428	1
429	1
447	1
455	1
468	1
469	1
470	1
471	1
472	1
473	1
474	1
475	1
522	1
523	1
524	1
525	1
526	1
527	1
528	1
529	1
547	1
555	1
568	1
569	1
570	1
571	1
572	1
573	1
574	1
575	1
622	1
623	1
624	1
625	1
626	1
627	1
628	1
629	1

647	1
655	1
668	1
669	1
670	1
671	1
672	1
673	1
674	1
675	1
722	1
723	1
724	1
725	1
726	1
727	1
728	1
729	1
747	1
755	1
768	1
769	1
770	1
771	1
772	1
773	1
774	1
775	1
330	2
331	2
332	2
333	2
334	2
335	2
336	2
337	2
348	2
356	2
357	2
376	2
377	2
378	2
379	2
380	2
381	2
382	2
383	2
430	2
431	2
432	2
433	2
434	2
435	2
436	2
437	2
448	2
456	2
457	2
476	2
477	2
478	2
479	2
480	2
481	2
482	2

483	2
530	2
531	2
532	2
533	2
534	2
535	2
536	2
537	2
548	2
556	2
557	2
576	2
577	2
578	2
579	2
580	2
581	2
582	2
583	2
630	2
631	2
632	2
633	2
634	2
635	2
636	2
637	2
648	2
656	2
657	2
676	2
677	2
678	2
679	2
680	2
681	2
682	2
683	2
730	2
731	2
732	2
733	2
734	2
735	2
736	2
737	2
748	2
756	2
757	2
776	2
777	2
778	2
779	2
780	2
781	2
782	2
783	2
349	4
358	4
384	4
385	4
386	4
387	4
388	4

389	4
390	4
391	4
449	4
458	4
484	4
485	4
486	4
487	4
488	4
489	4
490	4
491	4
549	4
558	4
584	4
585	4
586	4
587	4
588	4
589	4
590	4
591	4
649	4
658	4
684	4
685	4
686	4
687	4
688	4
689	4
690	4
691	4
749	4
758	4
784	4
785	4
786	4
787	4
788	4
789	4
790	4
791	4
351	8
451	8
551	8
651	8
751	8
1051	16
1052	8
1053	4
1060	24
1061	24
1062	72
1063	72
1064	216
1065	216
1066	648
1067	648
1068	1944
1069	1944
1001	16
1003	8
1005	8
1007	4

```
1009        2
1011        4
1013        8
1014        16
1015        48
1017        24
1019        72
1021        72
1023        216
1025        216
1027        648
1028        648
1029        1944
1031        1944
c
2001        32
2002        64
2003        128
2004        256
2005        512
2006        1024
2007        1024
2008        2048
2009        2048
2010        4096
2011        4096
2012        8192
2013        8192
2014        16384
c
2016        1024
2017        1024
2028        2048
2019        2048
2020        4096
2021        4096
2022        8192
2023        8192
2024        16384
c
2031        16384
2032        16384
2033        16384
c
3001        3888
3002        3888
3003        3888
c
3004        7776
3005        7776
3006        7776
3007        7776
3008        15552
3009        15552
c
3010        7776
3011        7776
3012        7776
3013        7776
3014        15552
3015        15552
c
3021        46656
3022        46656
3023        139968
```

```
3024     139968
c
3030     1
3031     1
3032     1
3033     1
3034     1
c
3035     279936
3036     279936
3037     559872
3038     559872
3039     1
c
3040     279936
3041     279936
3042     559872
3043     559872
3044     1
c
4000     32768
4001     32768
4002     32768
4003     32768
4004     16384
4005     16384
4006     8192
4007     8192
4008     4096
4009     4096
4010     2048
4011     2048
4012     1024
4013     512
4014     256
4015     128
4016     64
4017     32
4018     16
4019     8
4020     4
4021     8
4022     16
4023     32
4024     96
4025     48
4026     144
4027     144
4028     432
4029     432
4030     1296
4031     1296
4032     3888
4033     3888
4034     7776
4035     7776
4036     7776
4037     15552
4038     15552
4039     15552
4040     15552
4041     31104
4042     31104
4043     93312
4044     93312
```

```
4045    279936
4046    279936
4047    559872
4048    559872
4049    1119744
4050    1119744
4051    1
c
5000    32768
5001    32768
5002    32768
5003    32768
5004    16384
5005    16384
5006    8192
5007    8192
5008    4096
5009    4096
5010    2048
5011    2048
5012    1024
5013    512
5014    256
5015    128
5016    64
5017    32
5018    16
5019    8
5020    4
5021    8
5022    16
5023    32
5024    96
5025    48
5026    144
5027    144
5028    432
5029    432
5030    1296
5031    1296
5032    3888
5033    3888
5034    7776
5035    7776
5036    7776
5037    15552
5038    15552
5039    15552
5040    15552
5041    31104
5042    31104
5043    93312
5044    93312
5045    279936
5046    279936
5047    559872
5048    559872
5049    1119744
5050    1119744
5051    1
c
5100    65536
5101    65536
5102    65536
5103    65536
```

```
5104     32768
5105     32768
5106     16384
5107     16384
5108     8192
5109     8192
5110     4096
5111     4096
5112     2048
5113     1024
5114     512
5115     256
5116     128
5117     64
5118     32
5119     16
5120     8
5121     16
5122     32
5123     64
5124     192
5125     96
5126     288
5127     288
5128     864
5129     864
5130     2592
5131     2592
5132     7776
5133     7776
5134     15552
5135     15552
5136     15552
5137     31104
5138     31104
5139     31104
5140     31104
5141     62208
5142     62208
5143     186624
5144     186624
5145     559872
5146     559872
5147     1119744
5148     1119744
5149     2239488
5150     2239488
5151     1
c
5200     131072
5201     131072
5202     131072
5203     131072
5204     65536
5205     65536
5206     32768
5207     32768
5208     16384
5209     16384
5210     8192
5211     8192
5212     4096
5213     2048
5214     1024
5215     512
```

```
5216      256
5217      128
5218      64
5219      32
5220      16
5221      32
5222      64
5223      128
5224      384
5225      192
5226      576
5227      576
5228      1728
5229      1728
5230      5184
5231      5184
5232      15552
5233      15552
5234      31104
5235      31104
5236      31104
5237      62208
5238      62208
5239      62208
5240      62208
5241      124416
5242      124416
5243      373248
5244      373248
5245      1119744
5246      1119744
5247      2239488
5248      2239488
5249      4478976
5250      4478976
5251      1
c
5300      262144
5301      262144
5302      262144
5303      262144
5304      131072
5305      131072
5306      65536
5307      65536
5308      32768
5309      32768
5310      16384
5311      16384
5312      8192
5313      4096
5314      2048
5315      1024
5316      512
5317      256
5318      128
5319      64
5320      32
5321      64
5322      128
5323      256
5324      768
5325      384
5326      1152
5327      1152
```

```
5328      3456
5329      3456
5330      10368
5331      10368
5332      31104
5333      31104
5334      62208
5335      62208
5336      62208
5337      124416
5338      124416
5339      124416
5340      124416
5341      248832
5342      248832
5343      746496
5344      746496
5345      2239488
5346      2239488
5347      4478976
5348      4478976
5349      8957952
5350      8957952
5351      1
c
5500      524288
5501      524288
5502      524288
5503      524288
5504      262144
5505      262144
5506      131072
5507      131072
5508      65536
5509      65536
5510      32768
5511      32768
5512      16384
5513      8192
5514      4096
5515      2048
5516      1024
5517      512
5518      256
5519      128
5520      64
5521      128
5522      256
5523      512
5524      1536
5525      768
5526      2304
5527      2304
5528      6912
5529      6912
5530      20736
5531      20736
5532      62208
5533      62208
5534      124416
5535      124416
5536      124416
5537      248832
5538      248832
5539      248832
```

```
5540      248832
5541      497664
5542      497664
5543      1492992
5544      1492992
5545      4478976
5546      4478976
5547      1
5548      1
5549      1
5550      1
5551      1
c
5700      1048576
5701      1048576
5702      1048576
5703      1048576
5704      524288
5705      524288
5706      262144
5707      262144
5708      131072
5709      131072
5710      65536
5711      65536
5712      32768
5713      16384
5714      8192
5715      4096
5716      2048
5717      1024
5718      512
5719      256
5720      128
5721      256
5722      512
5723      1024
5724      3072
5725      1536
5726      4608
5727      4608
5728      13824
5729      13824
5730      41472
5731      41472
5732      124416
5733      124416
5734      248832
5735      248832
5736      248832
5737      497664
5738      497664
5739      497664
5740      497664
5741      995328
5742      995328
5743      2985984
5744      2985984
5745      8957952
5746      8957952
c
5900      2097152
5901      2097152
5902      2097152
5903      2097152
```

5904	1048576
5905	1048576
5906	524288
5907	524288
5908	262144
5909	262144
5910	131072
5911	131072
5912	65536
5913	32768
5914	16384
5915	8192
5916	4096
5917	2048
5918	1024
5919	512
5920	256
5921	512
5922	1024
5923	2048
5924	6144
5925	3072
5926	9216
5927	9216
5928	27648
5929	27648
5930	82944
5931	82944
5932	248832
5933	248832
5934	497664
5935	497664
5936	497664
5937	995328
5938	995328
5939	995328
5940	995328
5941	1990656
5942	1990656
5943	5971968
5944	5971968
5945	17915904
5946	17915904
c	
6100	4194304
6101	4194304
6102	4194304
6103	4194304
6104	2097152
6105	2097152
6106	1048576
6107	1048576
6108	524288
6109	524288
6110	262144
6111	262144
6112	131072
6113	65536
6114	32768
6115	16384
6116	8192
6117	4096
6118	2048
6119	1024
6120	512

```
6121      1024
6122      2048
6123      4096
6124      12288
6125      6144
6126      18432
6127      18432
6128      55296
6129      55296
6130      165888
6131      165888
6132      497664
6133      497664
6134      995328
6135      995328
6136      995328
6137      1990656
6138      1990656
6139      1990656
6140      1990656
6141      3981312
6142      3981312
6143      11943936
6144      11943936
6145      35831808
6146      35831808
c
6300      8388608
6301      8388608
6302      8388608
6303      8388608
6304      4194304
6305      4194304
6306      2097152
6307      2097152
6308      1048576
6309      1048576
6310      524288
6311      524288
6312      262144
6313      131072
6314      65536
6315      32768
6316      16384
6317      8192
6318      4096
6319      2048
6320      1024
6321      2048
6322      4096
6323      8192
6324      24576
6325      12288
6326      36864
6327      36864
6328      110592
6329      110592
6330      331776
6331      331776
6332      995328
6333      995328
6334      1990656
6335      1990656
6336      1990656
6337      3981312
```

```
6338    3981312
6339    3981312
6340    3981312
6341    7962624
6342    7962624
6343    23887872
6344    23887872
6345    71663616
6346    71663616
c
6400    8388608
6401    8388608
6402    8388608
6403    8388608
6404    4194304
6405    4194304
6406    2097152
6407    2097152
6408    1048576
6409    1048576
6410    524288
6411    524288
6412    262144
6413    131072
6414    65536
6415    32768
6416    16384
6417    8192
6418    4096
6419    2048
6420    1024
6421    2048
6422    4096
6423    8192
6424    24576
6425    12288
6426    36864
6427    36864
6428    110592
6429    110592
6430    331776
6431    331776
6432    995328
6433    995328
6434    1990656
6435    1990656
6436    1990656
6437    3981312
6438    3981312
6439    3981312
6440    3981312
6441    7962624
6442    7962624
6443    23887872
6444    23887872
6445    71663616
6446    71663616
c
6500    16777216
6501    16777216
6502    16777216
6503    16777216
6504    8388608
6505    8388608
6506    4194304
```

```
6507      4194304
6508      2097152
6509      2097152
6510      1048576
6511      1048576
6512      524288
6513      262144
6514      131072
6515      65536
6516      32768
6517      16384
6518      8192
6519      4096
6520      2048
6521      4096
6522      8192
6523      16384
6524      49152
6525      24576
6526      73728
6527      73728
6528      221184
6529      221184
6530      663552
6531      663552
6532      1990656
6533      1990656
6534      3981312
6535      3981312
6536      3981312
6537      7962624
6538      7962624
6539      7962624
6540      7962624
6541      15925248
6542      15925248
6543      47775744
6544      47775744
6545      143327232
6546      143327232
c
6601      1
6602      1
6603      1
6604      1
6605      1
6606      1
6607      1
6608      1
6609      1
6610      1
6611      1
6612      1
6613      1
6614      1
6615      1
6616      1
6617      1
6618      1
6619      1
6620      1
6621      1
6622      1
6623      1
6624      1
```

```
 6625     1
 6626     1
 6627     1
 6628     1
 6629     1
 6630     1
 6631     1
 6632     1
 6633     1
 6634     1
 6635     1
 6636     1
 6637     1
 6638     1
 6639     1
 6640     1
 6641     1
 6642     1
 6643     1
 6644     1
 6645     1
 6646     1
 6647     1
 6648     1
 6649     1
 6650     1
 6651     1
c
c
301     1
302     1
303     1
304     1
305     1
306     1
307     1
308     1
309     1
310     1
311     1
312     1
313     1
338     1
339     1
340     1
341     1
342     1
343     1
344     1
345     1
350     1
352     1
354     1
359     1
392     1
393     1
394     1
395     1
401     1
402     1
403     1
404     1
405     1
406     1
407     1
```

408	1
409	1
410	1
411	1
412	1
413	1
438	1
439	1
440	1
441	1
442	1
443	1
444	1
445	1
450	1
452	1
454	1
459	1
492	1
493	1
494	1
495	1
501	1
502	1
503	1
504	1
505	1
506	1
507	1
508	1
509	1
510	1
511	1
512	1
513	1
538	1
539	1
540	1
541	1
542	1
543	1
544	1
545	1
550	1
552	1
554	1
559	1
592	1
593	1
594	1
595	1
601	1
602	1
603	1
604	1
605	1
606	1
607	1
608	1
609	1
610	1
611	1
612	1
613	1
638	1

639	1
640	1
641	1
642	1
643	1
644	1
645	1
650	1
652	1
654	1
659	1
692	1
693	1
694	1
695	1
701	1
702	1
703	1
704	1
705	1
706	1
707	1
708	1
709	1
710	1
711	1
712	1
713	1
738	1
739	1
740	1
741	1
742	1
743	1
744	1
745	1
750	1
752	1
754	1
759	1
792	1
793	1
794	1
795	1
202	1
203	1
205	1
206	1
101	1
102	1
207	1
208	1
210	1
103	1
104	1
105	1
106	1
211	1
213	1
107	1
108	1
109	1
110	1
111	1
112	1

```
214     1
215     1
113     1
114     1
115     1
116     1
117     1
118     1
216     1
218     1
119     1
120     1
121     1
122     1
219     1
221     1
222     1
123     1
124     1
223     1
224     1
226     1
227     1
10001  1
10002  1
10003  1
10004  1
10005  1
10006  1
10007  1
10008  1
10009  1
10010  1
10011  1
10012  1
10013  1
10101  1
10102  1
10103  1
10104  1
10105  1
10106  1
10107  1
10108  1
10109  1
10110  1
10111  1
10112  1
10113  1
10114  1
10121  1
10122  1
10131  1
10132  1
10133  1
10134  1
10135  1
10136  1
10137  1
10138  1
10141  1
10142  1
10143  1
10144  1
10145  1
```

10146	1
11146	1
10147	1
10148	1
11148	1
10149	1
10150	1
10151	1
10152	1
10153	1
10154	1
10155	1
10156	1
10157	1
10158	1
10159	1
10160	1
10161	1
10162	1
10163	1
10164	1
10165	1
10166	1
10167	1
10168	1
10169	1
10170	1
10243	1
10244	1
10245	1
10246	1
10247	1
10248	1
10249	1
10250	1
10251	1
10252	1
10253	1
10254	1
10255	1
10256	1
10257	1
10258	1
10259	1
10260	1
10261	1
10262	1
10263	1
10264	1
10265	1
10266	1
10267	1
10268	1
10269	1
10270	1
10301	1
10302	1
10303	1
10304	1
10305	1
10306	1
10307	1
10308	1
11302	1
11303	1

11304	1
11305	1
11306	1
11307	1
11308	1
13303	1
13304	1
13305	1
13306	1
13307	1
13308	1
12301	1
12302	1
12303	1
12304	1
12305	1
12306	1
12307	1
12308	1
10309	1
10310	1
10311	1
10312	1
10313	1
10314	1
10407	1
10408	1
10409	1
10410	1
10411	1
10412	1
10413	1
10414	1
10421	1
10422	1
10431	1
10432	1
10433	1
10434	1
10435	1
10436	1
10437	1
10438	1
10441	1
10442	1
10443	1
10444	1
10445	1
10446	1
10447	1
10448	1
10449	1
10450	1
10451	1
10452	1
10453	1
10454	1
10455	1
10456	1
10457	1
10458	1
10459	1
10470	1
10543	1
10544	1

```
10545  1
10546  1
10547  1
10548  1
10549  1
10550  1
10551  1
10552  1
10553  1
10554  1
10555  1
10556  1
10557  1
10558  1
10559  1
10570  1
10641  1
10642  1
10643  1
10644  1
10701  1
10702  1
10711  1
10712  1
10713  1
99999    0
c
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
c
c     PHOTON TALLIES
c
f102:p  716 917
ft102    scx 3
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
c
```

APPENDIX 5.D

DOSE RATE COMPARISON FOR DIFFERENT COBALT IMPURITY LEVELS

(Total number of pages in this appendix : 6)

The dose rate adjacent to and one meter from the 100-ton HI-TRAC and the HI-STORM overpack are presented on Tables 5.D.1 through 5.D.4 for the MPC-24 with different burnup and cooling times and different assumed Cobalt-59 impurity levels for inconel. The HI-TRAC results were calculated for an earlier design which utilized 30 steel fins 0.375 inches thick compared to 10 steel fins 1.25 inches thick. The change in rib design only affects the magnitude of the dose rates presented for the radial surface but does not affect the conclusions discussed below. The following burnup and cooling time combinations are presented.

<u>100-ton HI-TRAC</u>

- 35,000 MWD/MTU and 5 year cooling
  1000 ppm (1.0 gm/kg) Cobalt-59 impurity in inconel
- 45,000 MWD/MTU and 9 year cooling
  4700 ppm (4.7 gm/kg) Cobalt-59 impurity in inconel

<u>HI-STORM</u>

- 45,000 MWD/MTU and 5 year cooling
  1000 ppm (1.0 gm/kg) Cobalt-59 impurity in inconel
- 45,000 MWD/MTU and 9 year cooling
  4700 ppm (4.7 gm/kg) Cobalt-59 impurity in inconel

On Tables 5.D.1 through 5.D.4, the contribution to the dose rate from activation in incore grid spacers is explicitly shown.

These results demonstrate that the dose rates at the longer cooling time are essentially equivalent to (within 11%) or bounded by the dose rates at the shorter cooling times even though a very conservative Cobalt-59 impurity level of 4700 ppm was assumed for the longer cooling times.

Table 5.2.1 shows the masses of inconel and steel that are used in the modeling of the PWR fuel assembly. When 4700 ppm was used for the impurity level in the inconel, an effective Cobalt-59 impurity level was used for the regions containing both steel and inconel. The following table summarizes the impurity levels that were used.

Region	Regional Co-59 impurity when 1000 ppm in inconel assumed	Regional Co-59 impurity when 4700 ppm in inconel assumed
Lower end fitting	1000 ppm	1340 ppm
Incore grid spacers	1000 ppm	4700 ppm
Gas plenum springs	1000 ppm	3417 ppm
Gas plenum spacer	1000 ppm	3417 ppm
Upper end fitting	1000 ppm	1000 ppm

Table 5.D.1

DOSE RATES ADJACENT TO 100-TON HI-TRAC FOR NORMAL CONDITIONS
MPC-24 DESIGN BASIS ZIRCALOY CLAD FUEL

Dose Point † Location	Incore Grid Spacer ^{60}Co Gammas (mrem/hr)	Fuel Gammas (mrem/hr)	(n,γ) Gammas (mrem/hr)	^{60}Co Gammas (mrem/hr)	Neutrons (mrem/hr)	Totals (mrem/hr)
4700 ppm Co-59 in inconel						
45,000 MWD/MTU AND 9-YEAR COOLING						
1	12.20	11.89	12.65	507.16	171.98	715.87
2	345.15	332.90	52.81	0.75	88.26	819.87
3	4.72	5.19	1.98	369.24	214.70	595.83
4	7.13	8.11	0.97	197.76	180.55	394.52
5 (pool lid)	48.63	54.68	17.52	2557.68	1194.17	3872.68
5(transfer lid)	137.52	155.17	0.97	3811.45	674.42	4779.53
1000 ppm Co-59 in inconel						
35,000 MWD/MTU AND 5-YEAR COOLING						
1	3.73	27.05	6.51	543.06	88.57	668.92
2	105.37	696.56	27.19	0.80	45.46	875.38
3	1.44	11.44	1.02	473.51	110.57	597.98
4	2.18	17.87	0.50	241.22	92.97	354.74
5 (pool lid)	28.09	186.49	8.27	2751.19	554.51	3528.55
5(transfer lid)	41.98	293.57	0.50	4081.28	347.33	4764.66

† Refer to Figure 5.1.4.

Table 5.D.2

DOSE RATES AT 1 METER FROM 100-TON HI-TRAC FOR NORMAL CONDITIONS
MPC-24 DESIGN BASIS ZIRCALOY CLAD FUEL

Dose Point † Location	Incore Grid Spacer ^{60}Co Gammas (mrem/hr)	Fuel Gammas (mrem/hr)	(n,γ) Gammas (mrem/hr)	^{60}Co Gammas (mrem/hr)	Neutrons (mrem/hr)	Totals (mrem/hr)
4700 ppm Co-59 in inconel						
45,000 MWD/MTU AND 9-YEAR COOLING						
1	44.32	43.03	7.14	73.99	27.98	196.46
2	148.49	143.94	16.40	6.18	32.38	347.39
3	18.76	18.25	3.88	72.75	13.83	127.47
4	2.19	2.80	0.17	61.70	44.87	111.73
5(transfer lid)	55.57	64.25	0.18	1556.99	188.18	1865.16
1000 ppm Co-59 in inconel						
35,000 MWD/MTU AND 5-YEAR COOLING						
1	13.53	91.20	3.68	79.16	14.41	201.97
2	45.33	302.99	8.44	6.13	16.68	379.57
3	5.73	38.74	2.00	71.95	7.12	125.54
4	0.67	6.21	0.09	74.47	23.11	104.55
5(transfer lid)	16.96	128.14	0.09	1667.22	96.91	1909.32

† Refer to Figure 5.1.4.

Table 5.D.3

DOSE RATES ADJACENT TO HI-STORM OVERPACK FOR NORMAL CONDITIONS
MPC-24 DESIGN BASIS ZIRCALOY CLAD FUEL

Dose Point † Location	Incore Grid Spacer ^{60}Co Gammas (mrem/hr)	Fuel Gammas†† (mrem/hr)	^{60}Co Gammas (mrem/hr)	Neutrons (mrem/hr)	Totals (mrem/hr)
4700 ppm Co-59 in inconel					
45,000 MWD/MTU AND 9-YEAR COOLING					
1	0.54	2.95	3.86	2.37	9.72
2	7.73	10.40	0.03	1.48	19.63
3	0.36	1.97	2.59	1.18	6.11
4	0.10	0.53	0.33	3.10	4.06
1000 ppm Co-59 in inconel					
45,000 MWD/MTU AND 5-YEAR COOLING					
1	0.20	5.68	4.87	2.76	13.51
2	2.73	28.93	0.03	1.88	33.58
3	3.87	0.13	3.21	1.38	8.59
4	0.04	0.91	0.36	3.60	4.91

† Refer to Figures 5.1.1.

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

Table 5.D.4

DOSE RATES ONE METER FROM HI-STORM OVERPACK FOR NORMAL CONDITIONS
MPC-24 DESIGN BASIS ZIRCALOY CLAD FUEL

Dose Point † Location	Incore Grid Spacer ^{60}Co Gammas (mrem/hr)	Fuel Gammas†† (mrem/hr)	^{60}Co Gammas (mrem/hr)	Neutrons (mrem/hr)	Totals (mrem/hr)
4700 ppm Co-59 in inconel					
45,000 MWD/MTU AND 9-YEAR COOLING					
1	0.77	2.01	2.30	0.46	5.54
2	3.90	5.14	0.39	0.64	10.08
3	0.44	1.09	1.72	0.18	3.42
4	0.05	0.23	0.14	0.94	1.37
1000 ppm Co-59 in inconel					
45,000 MWD/MTU AND 5-YEAR COOLING					
1	0.28	4.49	2.90	0.54	8.21
2	1.41	14.98	0.25	0.78	17.42
3	0.16	2.57	2.09	0.21	5.03
4	0.02	0.42	0.16	1.10	1.70

† Refer to Figures 5.1.1.

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

APPENDIX 5.E

Dose Rates for a HI-STORM 100 Overpack With and Without an Inner Shield Shell

(Total number of pages in this appendix : 4)

In June 2001, the inner shield shell of the HI-STORM 100 overpack was removed. As a compensating change, the density of the concrete in the body of the overpack was increased to 155 lb/cuft as discussed in Section 5.3. This appendix presents a comparison of the dose rates calculated for a HI-STORM 100 overpack with and without an inner shield shell. The MPC-24 was used in this analysis. Table 5.E.1 presents the results for the overpack containing the inner shield shell and Table 5.E.2 presents the results for the overpack without the inner shield shell and the higher density concrete in the body of the overpack.

The results indicate that the change in shielding configuration does not significantly impact the dose rates. The dose rates for the surface of the ducts show a slight increase (7%) when the inner shield shell is removed while the midplane surface shows an even smaller increase (2%). The dose rates for the top of the overpack are reduced when the inner shield shell is removed and the concrete density is increased. All one meter locations are essentially identical.

Therefore, based on the results presented in this appendix, the analysis in the main body of the chapter uses the HI-STORM 100 overpack with the inner shield present.

Table 5.E.1

DOSE RATES FOR THE HI-STORM 100 OVERPACK FOR NORMAL CONDITIONS
MPC-24 DESIGN BASIS ZIRCALOY CLAD FUEL AT BOUNDING
BURNUP AND COOLING TIME
45,000 MWD/MTU AND 5-YEAR COOLING
INNER SHIELD SHELL IS PRESENT

Dose Point† Location	**Fuel Gammas†† (mrem/hr)**	**^{60}Co Gammas (mrem/hr)**	**Neutrons (mrem/hr)**	**Totals (mrem/hr)**
Surface				
1	5.88	4.87	2.76	13.51
2	31.67	0.03	1.88	33.58
3	4.00	3.21	1.38	8.59
4	0.95	0.36	3.60	4.91
One Meter				
1	4.77	2.90	0.54	8.21
2	16.39	0.25	0.78	17.42
3	2.73	2.09	0.21	5.03
4	0.44	0.16	1.10	1.70

† Refer to Figure 5.1.1.

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

Table 5.E.2

DOSE RATES FOR THE HI-STORM 100 OVERPACK FOR NORMAL CONDITIONS
MPC-24 DESIGN BASIS ZIRCALOY CLAD FUEL AT BOUNDING
BURNUP AND COOLING TIME
45,000 MWD/MTU AND 5-YEAR COOLING
INNER SHIELD SHELL IS REMOVED

Dose Point† Location	Fuel Gammas†† (mrem/hr)	^{60}Co Gammas (mrem/hr)	Neutrons (mrem/hr)	Totals (mrem/hr)
Surface				
1	6.48	5.67	2.28	14.43
2	32.37	0.05	1.62	34.04
3	4.23	3.67	1.24	9.14
4	0.88	0.33	3.36	4.56
One Meter				
1	4.70	3.33	0.36	8.39
2	16.70	0.30	0.69	17.69
3	2.80	1.94	0.25	4.99
4	0.40	0.18	0.94	1.51

† Refer to Figure 5.1.1.

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