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CRWMS/M&O

Calculation Cover Sheet

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Page: 1 Of: 50

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Revision History

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REV 00		Initial Issue

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1. Purpose

The purpose of this calculation is to characterize the criticality safety aspects of N-Reactor fuel stored in a Department of Energy spent nuclear fuel (DOE-SNF) canister that contains four Multi-Canister Overpacks (MCO's). These calculations will be done to support the analysis that will be done to demonstrate concept viability related to pre-emplacement storage and use in the Monitored Geologic Repository (MGR) environment for the pre-closure time frame. The purpose of these calculations is to evaluate the criticality issues related to these intact fuels for the pre-closure time frame, including providing criticality evaluations which can be used to evaluate various storage configurations and input into the preliminary DOE-SNF canister design.

2. Method

The calculational method being employed in this calculation is MCNP4B2 computer code (Ref. 7.2) to calculate effective multiplication factors (k_{eff}) for various geometrical configurations of N-Reactor Spent Nuclear Fuel.

3. Assumptions

The following assumptions were used in the calculations.

3.1 Beginning of Life pre-irradiation uranium values were used based upon past criticality safety analysis (Ref. 7.5). This assumption is used throughout Section 5.

3.2 Scrap fuel was evaluated at a pre-irradiation enrichment of 1.25% throughout all Mark 1A SNF calculations in which scrap fuel is incorporated into the case. This is based upon the fact that no control exists upon the placement of either the Mark 1A inner assembly or outer assembly into the MCO scrap baskets. Use of the 1.25% enriched material is based upon this fact. Therefore all of the material in the Mark 1A scrap basket is evaluated as the higher enriched 1.25% material. This assumption is used throughout Section 5.

3.3 Past inspections by Hanford Fuel Operations indicate questionable structural integrity of the N-Reactor fuel. The fuel matrix comprising the elements was evaluated as heterogeneous spheres of fuel to account for possible structural questions. The mass of the fuel matrix was preserved and the spheres were spaced at the most reactive (optimum) pitch within the confines of the basket. This assumption was used throughout in all cases in Section 5, which the fuel was not evaluated as intact elements. The basis of this assumption is engineering judgment.

3.4 When the intact Mark 1A fuel matrix was evaluated as heterogeneous spheres, a weighted average of the inner and outer assembly pre-irradiation enrichment was used. This weighted average was calculated and evaluated as 1.15% enriched material. This assumption is used throughout Section 5. The basis of this assumption is engineering judgement.

3.5 A 30.48 cm thick water reflector of full density water (1.0 g/cm^3) was used in all cases that were evaluated with reflection. This is based upon a 30.48 cm (12 in.) thick water reflector being effectively equivalent to an infinite reflector. (Ref. 7.10 p. 106) This assumption is used throughout Section 5.

3.6 The MCO baskets used to store intact Mark IV elements have a 12-gauge stainless steel outer wall that extends 27.94 cm (11 in.) axially from the bottom of the basket. In all cases, in Section 5, incorporating intact Mark IV elements, this outer wall has been ignored for simplicity purposes. This is conservative based upon the fact that the presence of the outer wall will have a minor effect in reducing the interaction between adjacent MCO's and reduce the effect of the water reflection present around the basket. This assumption is used throughout Section 5.

3.7 The basket used to store intact fuel elements, for both Mark 1A and Mark IV, has an aluminum fuel spacer plate located in the bottom of the basket. In all of the cases, in Section 5, which included intact fuel elements, this basket was ignored. The presence of the spacer will have an insignificant negative effect on k_{eff}. This assumption is based upon engineering judgement. This assumption is used throughout Section 5.

3.8 The MCO has a shield plug assembly that is used as part of the closure mechanism. The shield plug was replaced with a void in the non-flooded cases, and water at varied density (0 to 100% theoretical) for the flooded cases. This assumption is used throughout Section 5 and is based upon engineering judgement.

3.9 The top lid of the MCO was simplified and evaluated as "squared off" in all cases in Section 5 in which the MCO was used. This assumption was based upon engineering judgment. This assumption is used throughout Section 5.

3.10 The scrap baskets contain six stainless steel plates that divide the basket into six compartments. These divider plates were ignored throughout all cases in Section 5, in order to simplify the case. This is a conservative assumption based upon the fact that the effect of the divider plates will be a reduction in the k_{eff} of the system. This assumption is used throughout Section 5.

3.11 The basket bottom plates have small drain holes present throughout the entire plate. These holes were ignored in all of the cases in Section 5, to simplify the case. Based upon engineering judgement, the presence of the holes will have an insignificant effect on k_{eff}. This assumption is used throughout Section 5.

3.12 The trapezoidal shaped structural posts, which support the outer stainless steel shroud of the baskets, have been ignored in all calculations. This assumption is based upon the fact that the exclusion is conservative, since it will have a positive effect on k_{eff}. This assumption is used throughout Section 5.

3.13 The inside cavity length of the MCO was evaluated as 406.7389 cm. The actual inside length appears to be 406.6286 cm (160.09 in.) (Ref. 7.8, Dwg. # H-2-828041). Due to the complicated design of the end cap and the design of the MCO cover, the inner length had to be derived from the dimensions on multiple drawings. The small difference between the actual length and the evaluated length will have an insignificant effect on the k_{eff}. This assumption is based upon engineering judgement and is used throughout Section 5.

3.14 A uranium density of 18.882 g/cm^3 was assumed. Calculations that preserved fuel matrix mass and volume yielded an average density of 18.512 g/cm^3 for the fuel matrix. This density was increased by 2%, to conservatively bounds any uncertainties related to the masses and volumes. This 2% increase is based upon engineering judgement stemming from review of the various data source documents (Ref. 7.5). This assumption is used throughout Section 5.

3.15 The entire length of the MCO was simplified and evaluated with a 60.96 cm outside diameter over its entire length in all cases in Section 5 in which the MCO was used. This assumption was based upon engineering judgment.

4. Use of Computer Software

4.1 Software Approved for Quality Assurance (QA) Work

4.1.1 MCNP4B and MCNP4B2

MCNP4B and MCNP4B2 computer code is used to calculate effective multiplication factors for the waste packages evaluated (Refs. 7.8 and 7.3).

- Program Name: MCNP
- Version/Revision Number: Version 4B
- Computer Software Configuration Item (CSCI) Number: 30033 V4BLV
- Computer Type: Hewlett Packard 9000 Workstations

The input files used are echoed in the output files. The output files are listed in attachments VI. The output files are stored on compact disc electronic media (Ref. 7.12).

a) The MCNP4B computer code (Ref. 7.2) is an appropriate tool to be utilized to determine the criticality potential, k_{eff}, of fresh and spent lattices of intact and degraded N-Reactor fuel assemblies.
b) This software has been validated over the range it was used.
c) It was previously obtained from the Civilian Radioactive Waste Management System (CRWMS) Management & Operating (M&O) Software Control Management (SCM) in accordance with appropriate procedures.

- Program Name: MCNP
- Version/Revision Number: Version 4B2
- Computer Software Configuration Item (CSCI) Number: 30033 V4B2LV
- Computer Type: Hewlett Packard 9000 Workstations

The input files used are echoed in the output files. The output files are listed in attachments VII. The output files are stored on compact disc electronic media (Ref. 7.12).

a) The MCNP4B2 computer code (Ref. 7.2) is an appropriate tool to be utilized to determine the criticality potential, k_{eff}, of fresh and spent lattices of intact and degraded N-Reactor fuel assemblies.
b) This software has been validated over the range it was used.
d) It was previously obtained from the Civilian Radioactive Waste Management System (CRWMS) Management & Operating (M&O) Software Control Management (SCM) in accordance with appropriate procedures.

4.2 Software Routines

4.2.1 Excel

- Title: Excel
- Version/Revision Number: Microsoft Excel 97

  The Excel spreadsheet program was used for simple numeric calculations as documented in Section 5 of this calculation file. The user-defined formulas, inputs, and results were documented in sufficient detail in the spreadsheets to allow an independent repetition of the various computations. The Excel files are stored on electronic media (Ref. 7.12) and as hardcopy in Attachment 5.

5. Calculation

5.1 Calculation Inputs

The number of digits for cited values does not necessarily indicate accuracy. It may reflect the value as reported in a reference or be an artifact of conversion.

5.1.1 Description of N-Reactor SNF

Criticality calculations of the intact form of N-Reactor Spent Nuclear Fuel (SNF) were performed using Beginning of Life (BOL) fuel loading quantities. This was shown to be conservative for these applications (Ref. 7.5, p. 4-1).

The details of the N-Reactor fuels were obtained from the N-Reactor data package provided by Hanford N-Reactor Operational Support personnel. The N-Reactor fuel considered consisted of two types, Mark 1A and Mark IV, which are very similar in design. Both of these fuels are metallic uranium fuels clad in Zircaloy-2. Each of the elements consists of a nested assembly configuration, in which an inner annular assembly is nested inside an outer annular assembly. Figure 5-1 shows an example of the Mark 1A and Mark IV type fuels.

5.1.1.1 N-Reactor Type Mark 1A SNF

The Mark 1A fuel consists of an inner assembly with a pre-irradiation enrichment of 0.947% and an outer assembly with a pre-irradiation enrichment of 1.25%. The length of the Mark 1A fuel ranges from 37.846 cm to 53.035 cm. The Mark 1A case used the 53.035 cm long elements. The pertinent dimensions and weights comprising the Mark1A elements are given in Table 5-1 (Ref. 7.5, p. 2-3). The Mark 1A fuel element inner and outer assemblies have Zircaloy-2 end caps having an axial length of 0.483 cm on each end.

The original configuration consists of forty-eight Mark 1A elements per basket (Figure 5-2). Six baskets containing Mark 1A SNF are then placed into a MCO. Previous criticality calculations (Ref. 7.5) allow two of the six baskets within the MCO to contain scrap or degraded Mark 1A fuel. These calculations indicate that these baskets need to be placed into the MCO as the bottom and top baskets. Four MCO's will then be placed into a 4-Multi-Canister Overpack Waste Package (4 MCO WP). The data inputs for the baskets, MCO's, and 4 MCO WP's will be described later in this report.

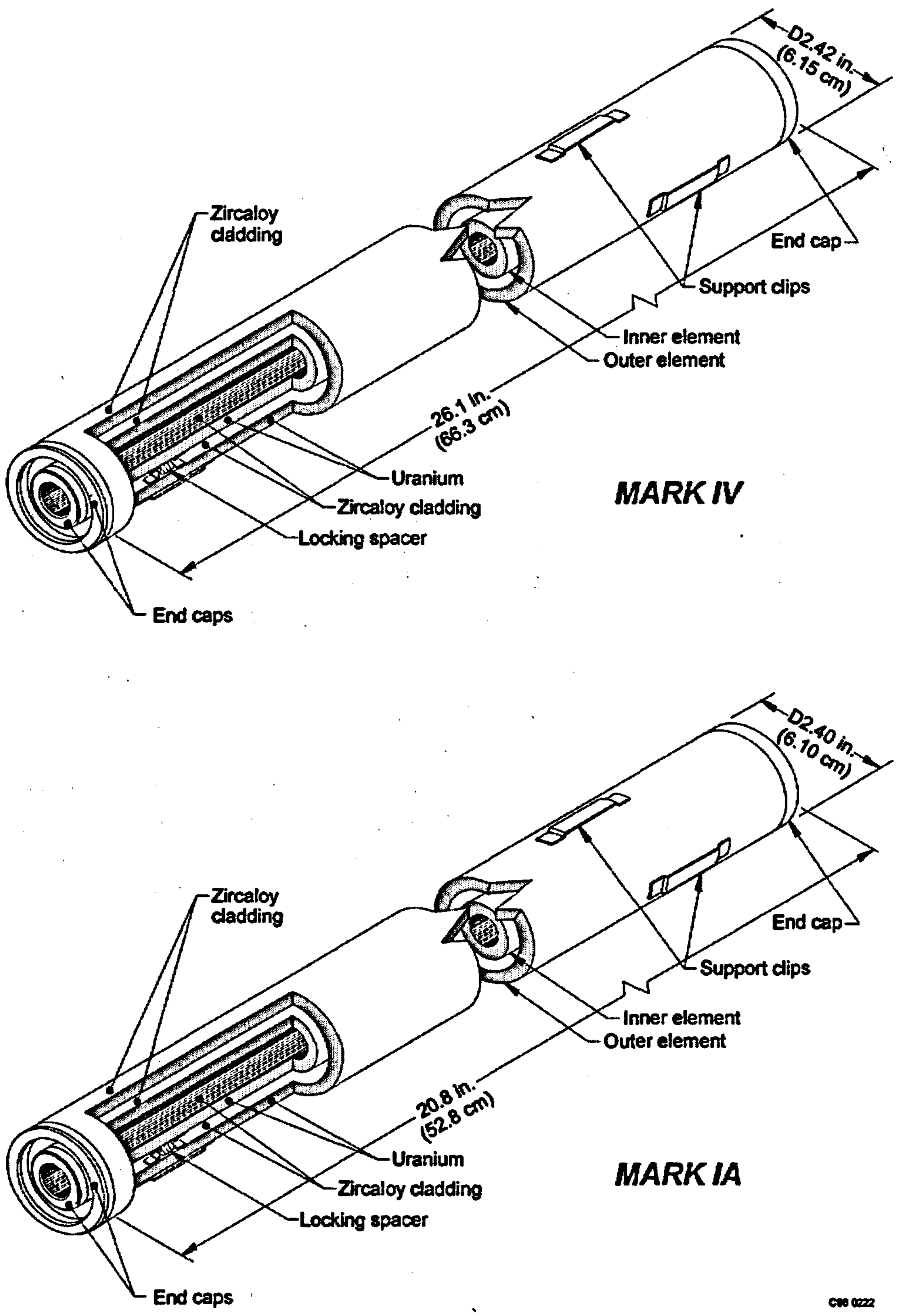
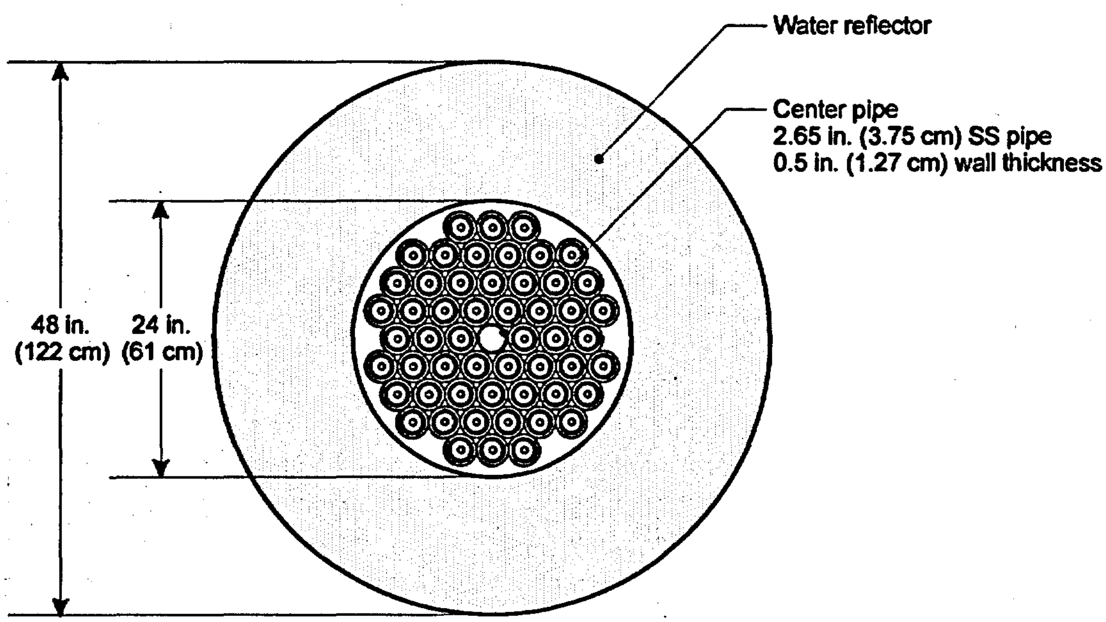


Figure 5-1. Schematic of N-Reactor Mark 1A and Mark IV Fuel Elements

Table 5-1. N-Reactor Fuel Assemblies Dimensions and Weights

	Mark IV	Mark 1A
Outer Tube Diameters:	cm	cm
Zirconium clad outer diameter	6.160	6.106
Uranium outer diameter	6.032	5.979
Uranium inner diameter	4.422	4.592
Zirconium clad inner diameter	4.321	4.481
Outer Tube Enrichment:	wt%	wt%
^{235}U	0.94700	1.2500
^{236}U	0.0392	0.0392
^{238}U	99.0138	98.7108
Inner Tube Diameters:	cm	cm
Zirconium clad outer diameter	3.249	3.165
Uranium outer diameter	3.096	2.962
Uranium inner diameter	1.321	1.245
Zirconium clad inner diameter	1.219	1.118
Inner Tube Enrichment:	wt%	wt%
^{235}U	0.94700	0.94700
^{236}U	0.03920	0.03920
^{238}U	99.0138	99.0138
Fuel Assembly Dimensions:	cm	cm
Maximum length	66.294	53.035
End cap thickness	0.483	0.483
Fuel Assembly Weight:	kg	kg
Maximum weight	23.4	16.6

Loading Arrangement for Mark IV Fuel in MCO Container



Loading Arrangement for Mark IA Fuel in MCO Container

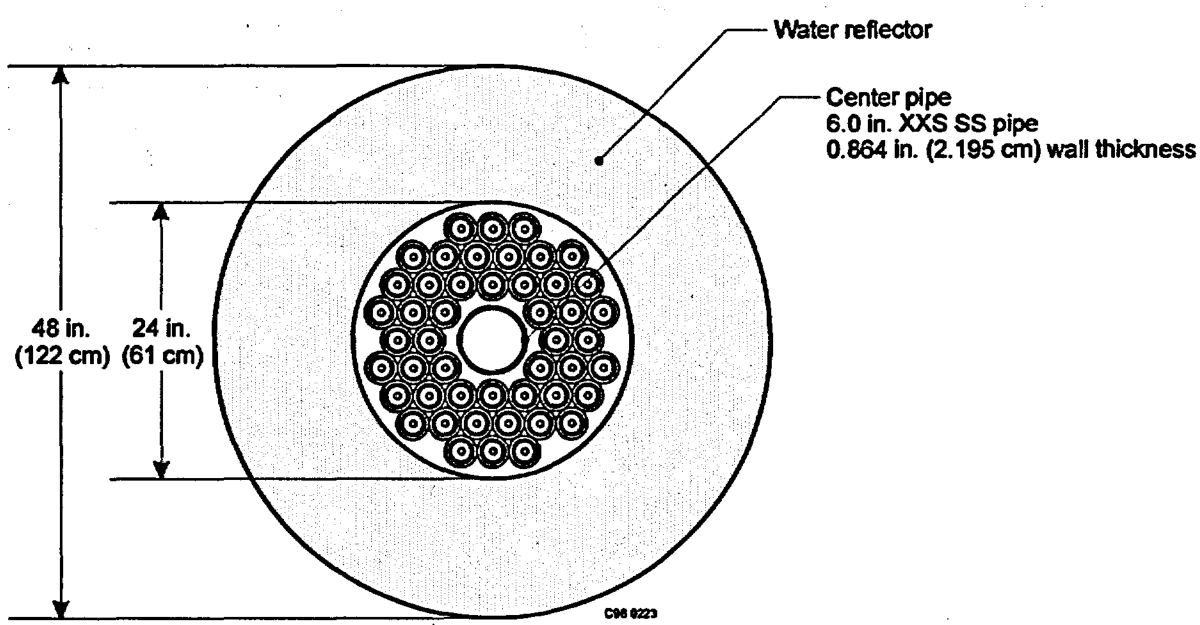


Figure 5-2. Example of Loading Arrangements in MCO's

5.1.1.2 N-Reactor Type Mark IV SNF

The Mark IV fuel consists of an inner assembly with a pre-irradiation enrichment of 0.947% and an outer assembly with a pre-irradiation enrichment of 0.947%. The length of the Mark IV fuel ranges from 44.196 cm to 66.294 cm. The Mark IV case used the 66.294 cm long elements. The pertinent dimensions and weights comprising the Mark IV elements are given in Table 5-1 (Ref. 7.5, p. 2-3). The Mark IV fuel element inner and outer assemblies have Zircaloy-2 end caps having an axial length of 0.483 cm on each end.

The original configuration consists of fifty-four Mark IV elements per basket (Figure 5-2). Five baskets containing Mark IV SNF are then placed into a MCO. Previous criticality safety calculations (Ref. 7.5) allow two of the five baskets within the MCO to contain scrap or degraded Mark IV fuel. These calculations indicate that the scrap baskets need to be placed into the MCO as the bottom and top baskets. Four MCO's will then be placed into a 4 MCO WP. The data inputs for the Mark IV baskets are described later in this report.

5.1.2 Description of N-Reactor SNF Storage Baskets

The Mark 1A and Mark IV N-Reactor SNF will be placed into storage baskets. Either six (Mark 1A) or five (Mark IV) baskets will be placed into an MCO. The baskets are designed such that when stacked, the lower end of the center pipe of the basket fits over the top end of the center pipe of the basket below. Thus, "nesting" the baskets together in a vertical stack.

5.1.2.1 N-Reactor Mark 1A SNF Storage Baskets

The basket is an annular type basket constructed of 304L stainless steel (Figure 5-3). The center pipe is comprised of nominal 6.0 in. XXS stainless steel material (actual dimension 6.625 in. or 16.8275 cm)), and the outer wall comprised of 18-gauge stainless steel sheet metal. The outer radius of the center pipe is 8.41357 cm with the inner radius of the outer shell equal to 28.70708 cm. The wall thickness of the center pipe is 2.19456 cm. The forty-eight elements are housed in the annular section. The inside height of the basket is 55.83428 cm, with an overall outer height of 58.88228 cm (Ref. 7.7, Sketches 5 and 6). The basket bottom plate is constructed from 3.048 cm thick stainless steel with drain holes drilled through. Each of the baskets contains an aluminum element spacer guide at the bottom of the basket. This spacer is approximately 5.0 cm thick and arranges the elements in the triangular pitch configuration as shown in Figure 5-2, (Ref. 7.8, Dwg. # H-2-828060).

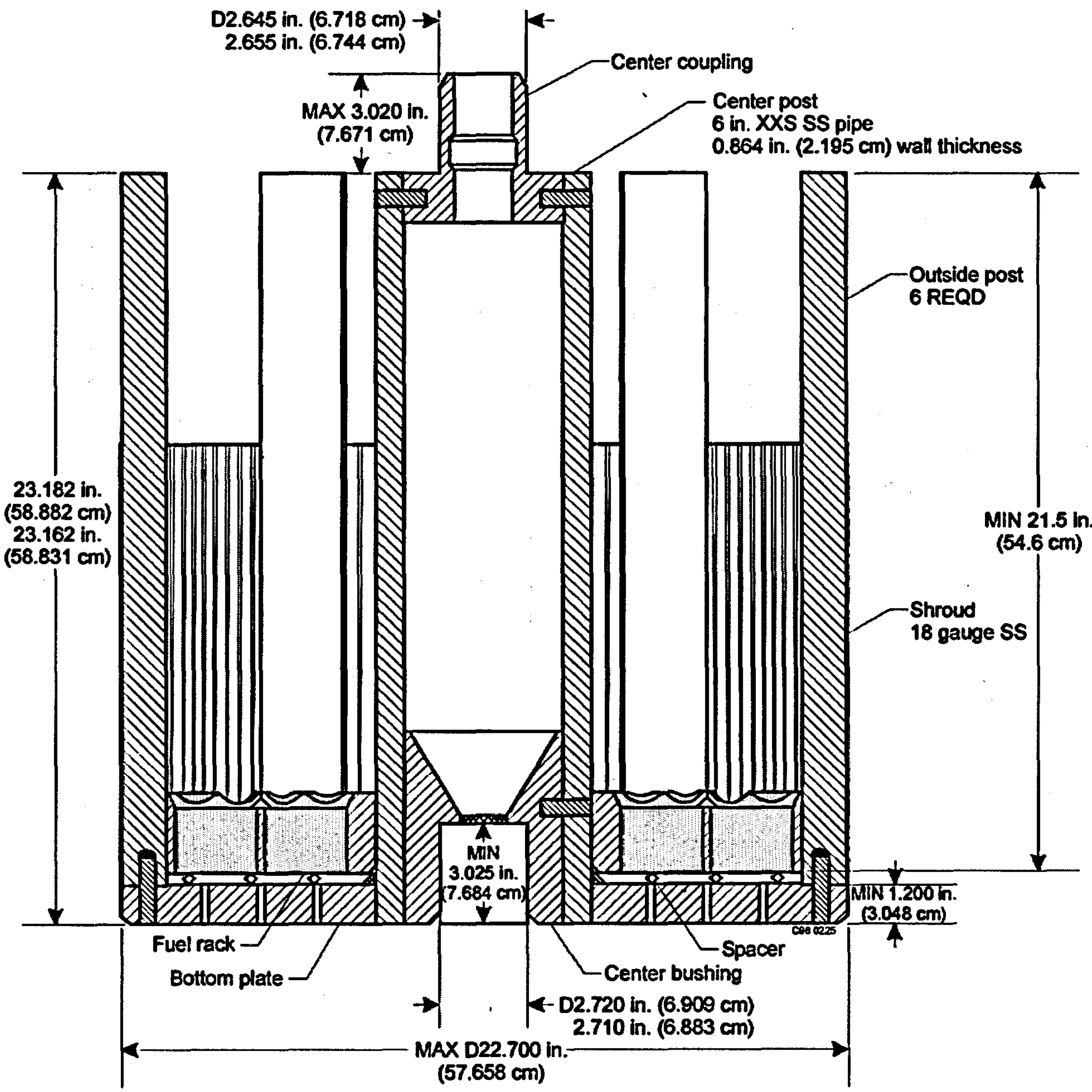


Figure 5-3. Mark 1A SNF Intact Element Storage Basket

In addition, the same basket used to store intact Mark 1A elements is also used to store Mark 1A scrap material. The scrap baskets do not have the aluminum spacer element guide located at the bottom (Figure 5-4). Scrap Mark 1A SNF consists of various sized pieces and sections comprised of Mark 1A elements that have structurally failed.

The scrap baskets are divided into six compartments separated by six stainless steel plates (Ref. 7.7, Sketch 6). These compartment dividers are conservatively ignored in this evaluation. In addition, the structural posts, which support the outer 18-gauge stainless steel shell, are also ignored in the case.

5.1.2.2 N-Reactor Mark IV SNF Storage Baskets

The Mark IV basket is also an annular type basket constructed of 304L stainless steel (Figure 5-5). The fifty-four elements are housed in the annular section. The center pipe is comprised of a 6.985 cm outside diameter stainless steel pipe, with a wall thickness of 1.27 cm (Ref. 7.8, Dwg. # H-2-828070). Unlike the Mark 1A fuel, in which the regular and scrap baskets are the same, the Mark IV regular baskets and scrap baskets have slight differences.

The basket used to house intact Mark IV fuel assemblies has an outer shell and six compartment dividers that extend approximately half the height of the bucket (Ref. 7.7, Sketch 8). The outside shell is constructed of 12-gauge 304L stainless steel as well as the basket dividers (Ref. 7.8, Dwg. # H-2-828070). The outer radius of the outer shell is 22.8290 cm (22.70 in. diameter). Each of the baskets, for intact assemblies, contains an aluminum element spacer guide at the bottom of the basket. This spacer is approximately 7.62 cm thick axially and arranges the Mark IV elements in the triangular pitch configuration at a typical center to center pitch of 6.985 cm (Ref. 7.8, Dwg. # H-2-828070), shown in Figure 5-2. The inside height of the basket is 67.818 cm, with an overall outer height of 70.66788 cm (Ref. 7.7, Sketch 8).

The Mark IV scrap basket is also an annular type basket constructed of 304L stainless steel (Figure 5-6). The Mark IV scrap material is housed in the annular section. The center pipe is comprised of a 6.985 cm outside diameter stainless steel pipe, with a wall thickness of 1.27 cm with an outer shell comprised of 12-gauge stainless steel sheet metal (Ref. 7.8, Dwg. # H-2-828070). The outer radius of the outer shell is equal to 28.8290 cm (22.70 in. diameter). The basket bottom plate is constructed from 0.635 cm thick stainless steel with drain holes drilled through (Ref. 7.7, Sketch 8). The scrap baskets do not contain the aluminum element spacer guide at the bottom of the basket.

The baskets are divided into six compartments separated by six stainless steel plates (Ref. 7.8, Dwg. # H-2-828075). These compartment dividers are conservatively ignored in this evaluation.

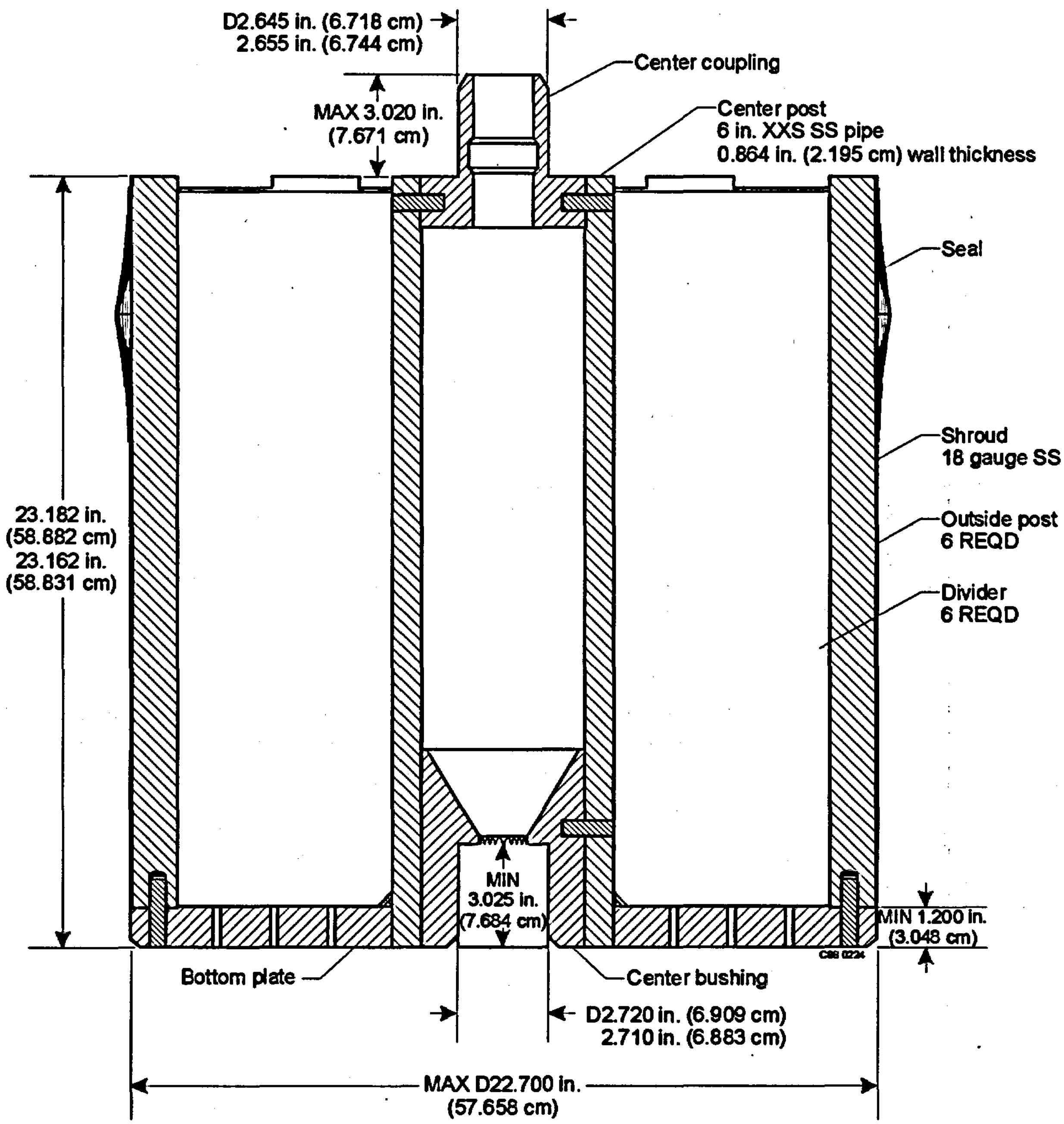


Figure 5-4. Mark 1A SNF Scrap Material Storage Basket

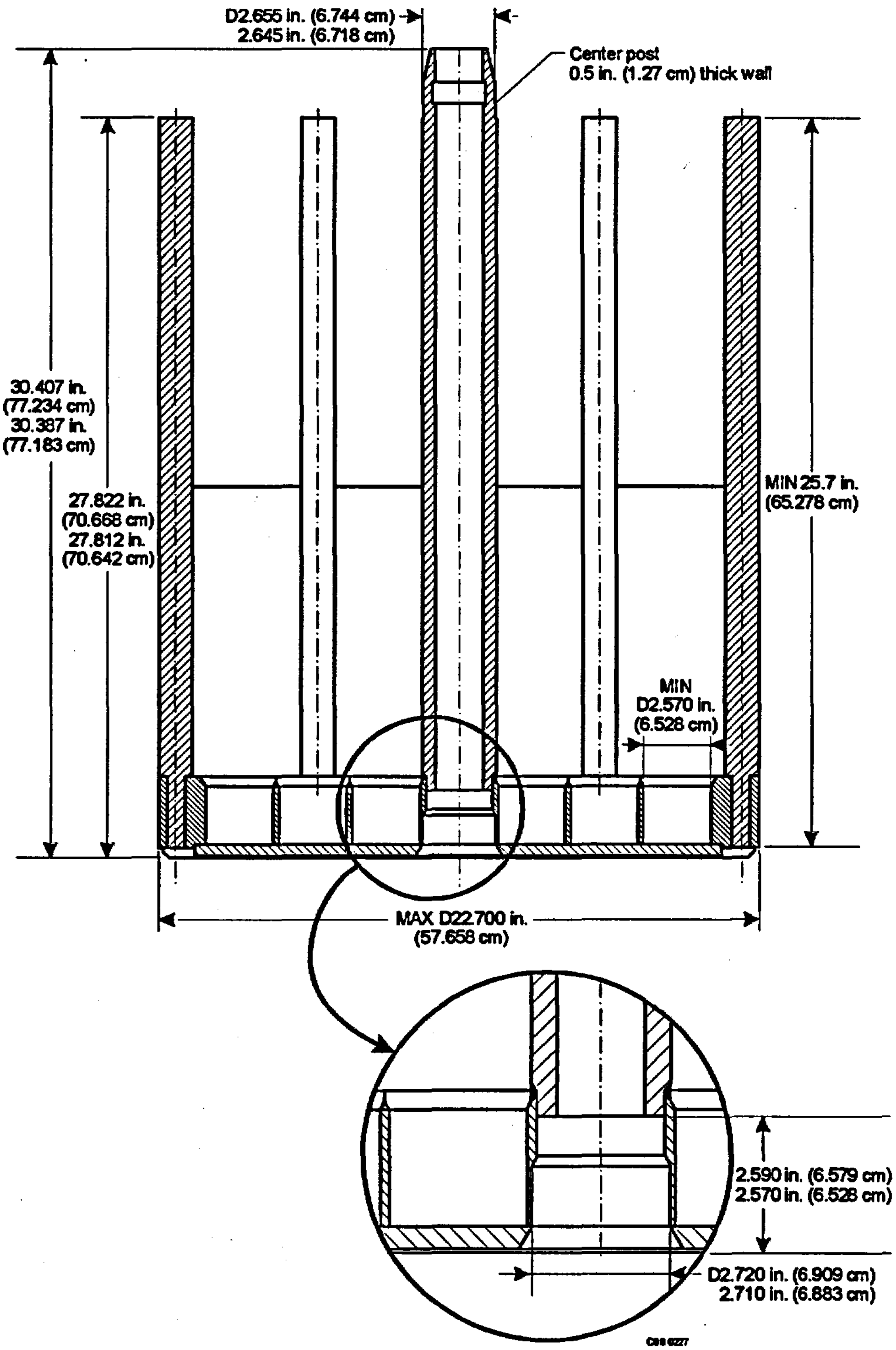


Figure 5-5. Mark IV SNF Intact Element Storage Basket

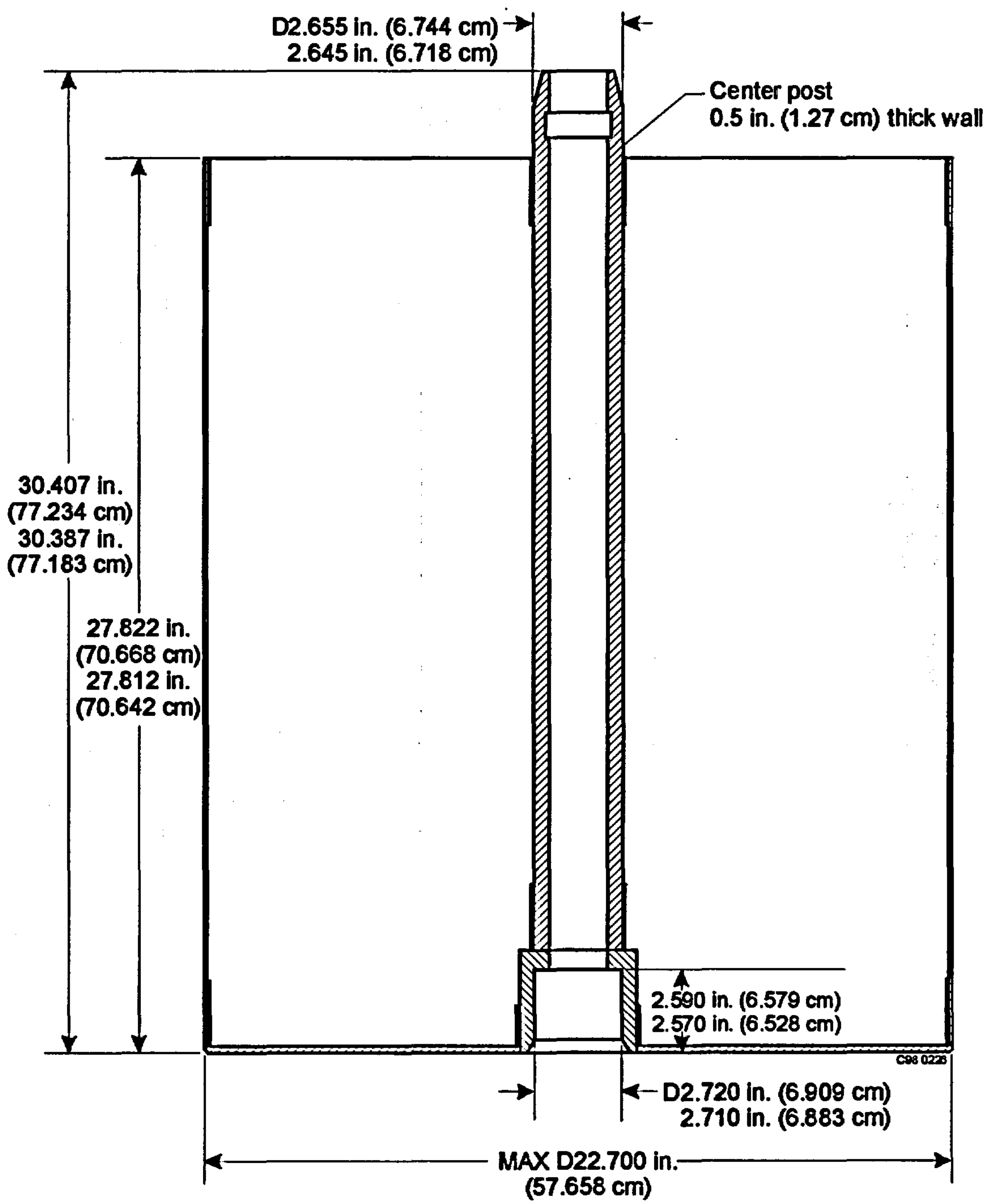


Figure 5-6. Mark IV SNF Scrap Material Storage Basket

5.1.3 Description of N-Reactor Multi-Canister Overpacks (MCO's)

The MCO's are constructed out of 304L stainless steel having an outside diameter 60.96 cm and a wall thickness of 2.54 cm (Figure 5-7). The top portion of the MCO has a slightly larger radius than the overall tube body in order to accommodate the top mechanical closure device. The MCO was evaluated with a 60.96 cm outside diameter over its entire length. The overall length of the MCO is 420.09 cm with an inner cavity height of 406.6286 cm (160.09 in.) (Ref. 7.8, Dwg. # H-2-828041).

The bottom plate has a thickness of 4.4704 cm with the top lid having a thickness of 8.9916 cm (Ref. 7.8, Dwg. # H-2-828041). The design of the top lid and the mechanical closure device is a very complex design and was simplified in these cases. The lid was squared off with the mechanical closure device being ignored.

In addition a central process tube constructed out of 304L stainless steel is present in the MCO's. This central process tube is located down the center of the MCO through the stacked baskets center pipes. The central process tube has an outer diameter of 3.3401 cm with a thickness of 0.90932cm (Ref. 7.8, Dwg. # H-2-828051).

5.1.4 Description of 4-Multi-Canister Overpack Waste Package (4 MCO WP's)

The final waste package will consist of four MCO's placed into a 4 MCO WP. The 4 MCO WP (Figure 5-8) has an inner diameter of 160.1 cm with an inner cavity height of 423.5 cm. The 4 MCO WP is constructed of an inner corrosion resistant shell and an outer corrosion allowance shell. The inner corrosion resistant shell is constructed of Hastelloy Alloy C-22 with 2.0 cm thick walls and 2.5 cm thick end shell lids. The outer corrosion allowance shell is constructed of A516 Grade 70 Carbon Steel with 10.0 cm thick walls and 11.0 cm end shell lids. The outer shell lids are recessed on both ends. The overall outer height of the 4 MCO WP is 498.5 cm.

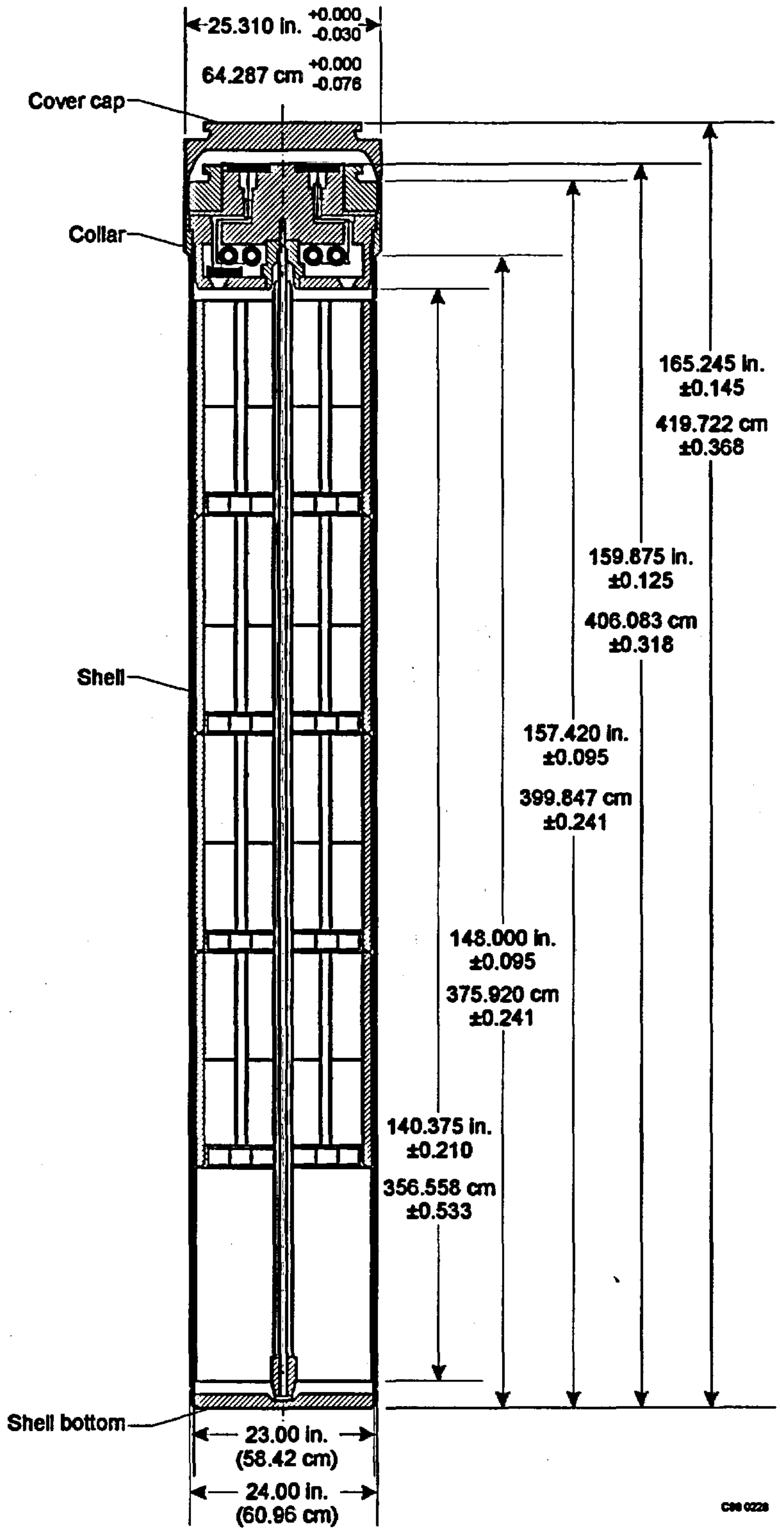


Figure 5-7. Multi-Canister Overpack - MCO

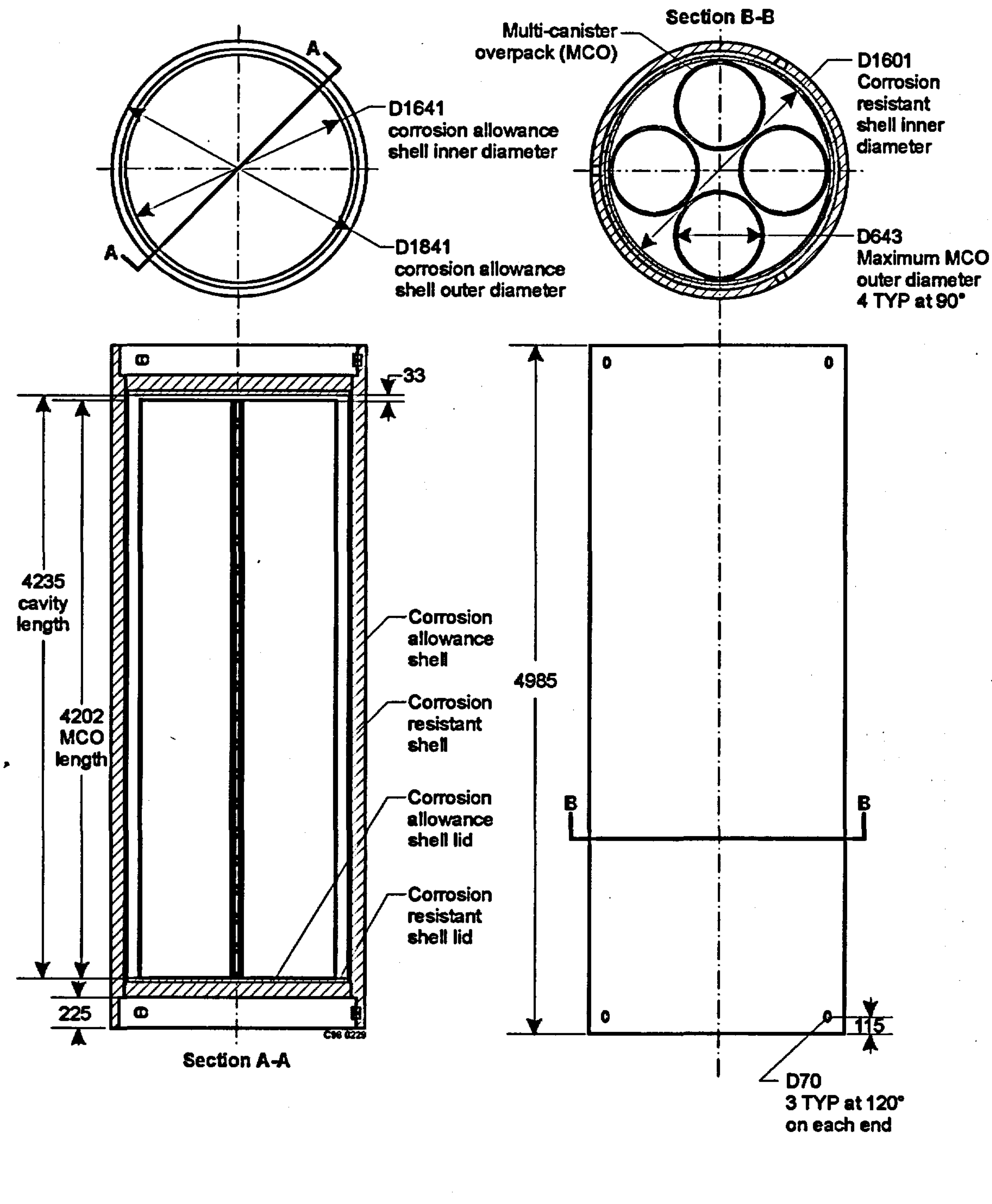


Figure 5-8. Four Multi-Canister Overpack Waste Package – (4 MCO WP)

5.2 Description of Cases Evaluated

5.2.1 Comparison Cases Between Type Mark 1A and Mark IV N-Reactor SNF

The first set of calculations included comparison cases between the type Mark 1A and Mark IV in order to determine if one of the fuels could be used as a bounding fuel to encompass both types. Various cases were used which incorporated intact, degraded, and a combination of intact and degraded material in the same MCO. The two types of fuels, Mark 1A and Mark IV, are not evaluated as being contained in the same MCO. Both single MCO and four MCO's in the 4 MCO WP cases are evaluated. In these cases the MCO(s) are evaluated containing intact fuel in all of the baskets, intact in the center baskets and degraded fuel in the top and bottom baskets, or degraded baskets in all of the baskets. All of these initial comparison cases are evaluated with the MCO(s) and 4 MCO WP flooded with full density water. The systems are also fully reflected with a 30.48 cm thick water reflector at full density.

5.2.1.1 Intact Mark 1A and Mark IV N-Reactor SNF

The first set of calculations included comparison cases between the type Mark 1A and Mark IV intact fuels. The fuels are evaluated as intact and stored as outlined in preceding sections. In each of the cases the maximum number of baskets were placed into the MCO.

5.2.1.2 Combination of Intact and Degraded Scrap Mark 1A and Mark IV N-Reactor SNF

This set of calculations included comparison cases between the type Mark 1A and Mark IV fuels which are evaluated as a combination of intact and degraded scrap material. In this set of cases the MCO(s) are loaded with a scrap basket on the top and bottom levels with the middle baskets containing intact fuel.

The Mark IV scrap baskets are evaluated containing 0.947% enriched material. The scrap mass was that equivalent to fifty-four Mark IV fuel elements. The Mark 1A baskets are evaluated containing 1.25% enriched material, equivalent to the material mass of 48 intact elements. This was done due to the fact that both degraded Mark 1A inner (0.947% enriched) and outer (1.25%) assemblies can be placed into the scrap baskets, without any control over the proportions between the two types of materials.

An evaluation (Attachment I) was completed to determine the most reactive size of spherical particle to use in the evaluation of the scrap material, along with the most reactive spacing between the spheres within the confines of the baskets. This study was completed using the type Mark 1A fuel. In addition, the sphere diameter was limited to the thickest radial fuel matrix dimension of a Mark 1A fuel element, 0.8585 cm.

In the cases evaluated, the maximum calculated k_{eff} was shown to occur with the spheres at this maximum diameter. This assumption was extrapolated to the Mark IV type fuel with the scrap evaluated at the thickest radial fuel matrix dimension of a Mark IV fuel element, 0.8875 cm (Figure 5-9).

5.2.1.3 Degraded Scrap Mark 1A and Mark IV N-Reactor SNF

Some question exists relating to the structural integrity of the N-Reactor fuels. The question is concerned about whether or not credit can be taken for the structural integrity of those fuels classified as intact. In order to address this situation a set of cases was developed in which all of the material contained in the baskets was evaluated as degraded.

The spherical case mentioned in the previous section was used to evaluate these cases. The Mark IV fuel was evaluated as 0.947% enriched material in each of the baskets housed in the MCO(s).

The Mark 1A scrap fuel case has a slight variation from the Mark IV scrap fuel case. The Mark 1A fuel scrap was evaluated as 1.25% enriched material and was placed into the top and bottom baskets. Once again the spherical configuration was used to evaluate this case. The middle baskets however, are evaluated containing 1.15% enriched fuel materials. This is a weighted-average of the Mark 1A inner and outer fuel tubes and is used to simulate the degraded inner and outer fuel tube scenario.

5.2.1.4 Evaluation of Comparison Cases Between Type Mark 1A and IV N-Reactor SNF

Comparison cases show that the Mark 1A and Mark IV fuel have very similar calculated k_{eff}'s for the normal case in which the fuel is evaluated as small spherical particles and no fuel is present in either the Mark 1A or IV basket center posts. Due to the smaller center post and the slightly higher mass loading, the intact Mark IV cases yielded a higher k_{eff} than the intact Mark 1A fuel. However, the limiting cases are those in which the fuel is evaluated as degraded and not as intact. An engineering judgment is used to determine that Mark 1A fuel is enveloping for the type of criticality calculations necessary to evaluate the N-Reactor fuel. In the normal cases the basket center post for the Mark 1A fuel is much larger than for the Mark IV fuel. If fuel is included in these central regions the calculated k_{eff} is greater for the Mark 1A fuel than for the Mark IV fuel, with the degraded spherical case. Therefore, the remaining cases only consider the Mark 1A type N-Reactor fuel. It is possible for small fragments to get into the center post area of the basket. Since this is a low enriched fuel, a homogeneous mixture of small particles and water is not conservative. For conservative purposes, the fuel in the center post region was evaluated as larger particles, even though they could not actually fit through the gap into the center region.

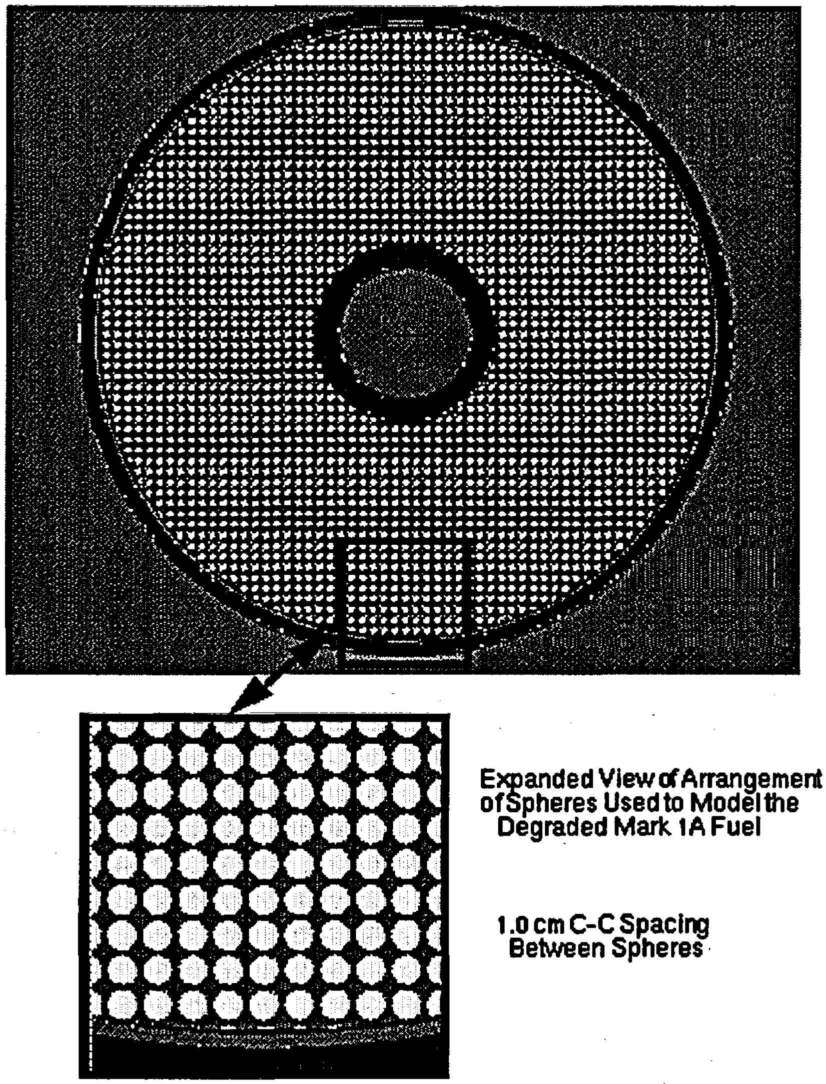


Figure 5-9. MCNP Plot – X-Y View of Heterogeneous Sphere Case Used

5.2.2 Cases Involving Various Degrees of Moderation

A set of cases was evaluated in which the density of the water in the MCO and the 4 MCO WP was varied to determine the most reactive configuration.

The density of the interstitial water present in an MCO containing Mark 1A fuel was varied form 10% to full density (1.0 g/cm^3). All of the voids within the MCO are evaluated at the various densities. The MCO itself was still fully reflected on the outside by a 30.48 cm thick layer of full density water (Figure 5-10).

Once the most reactive water density within the MCO was determined, a case was constructed that consisted of four optimally moderated MCO's in a 4 MCO WP which was filled with water which varied in density from 10% to 100%. The 4 MCO WP was fully reflected on the outside by a 30.48 cm thick layer of full density water (Figures 5-11 and 5-12).

5.2.3 Carbon Steel as Moderator Exclusion and/or Neutronic Poison

If the Mark 1A fuel is evaluated as optimally spaced small spherical particles to simulate degraded fuel, high k_{eff}'s result. If no credit can be taken for the structure of the fuel, then steps must be taken to ensure that the resulting k_{eff}'s are within the acceptance criteria. A possible solution is to include a material in each of the baskets that would act to exclude water and/or to neutronically poison the system, thus reducing k_{eff}. The material chosen was Grade 55 A 516 Carbon Steel.

A case was constructed which consisted of an MCO containing degraded Mark 1A fuel. The interstitial space between the small spheres was filled with a mixture of water and carbon steel at varied proportional densities (Figure 5-13), i.e., if the material contained 90% full density carbon steel, the remaining 10% void was filled with water.

A set of cases evaluated the effects of placing the carbon steel – water mixture, at various proportional densities as previously described, in the radial void spaces between intact elements within each basket (Figure 5-14). In these cases the central void and annular void regions of the elements were filled with full density water.

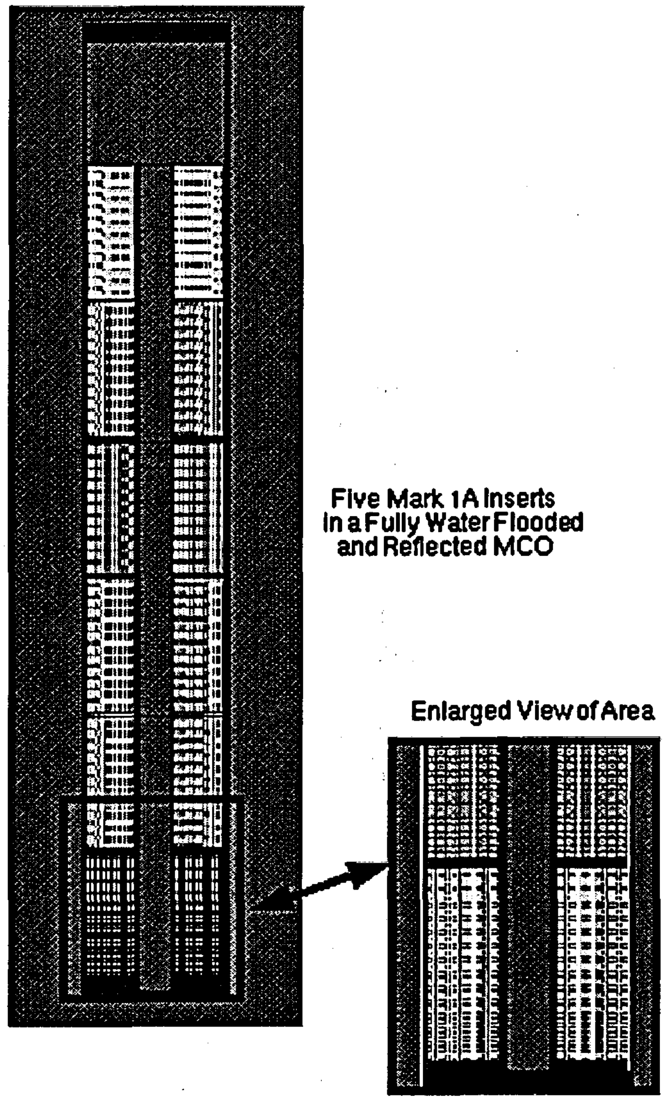


Figure 5-10. MCNP Plot – X-Z View of Single MCO

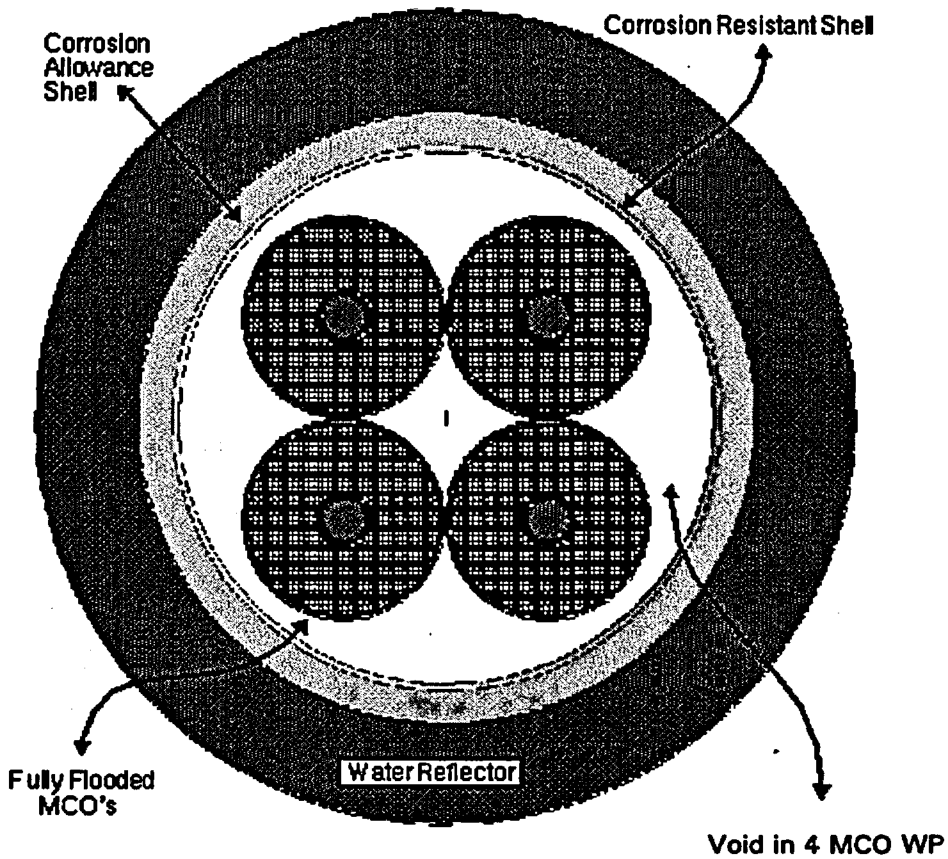


Figure 5-11. MCNP Plot – X-Y View of 4 MCO WP

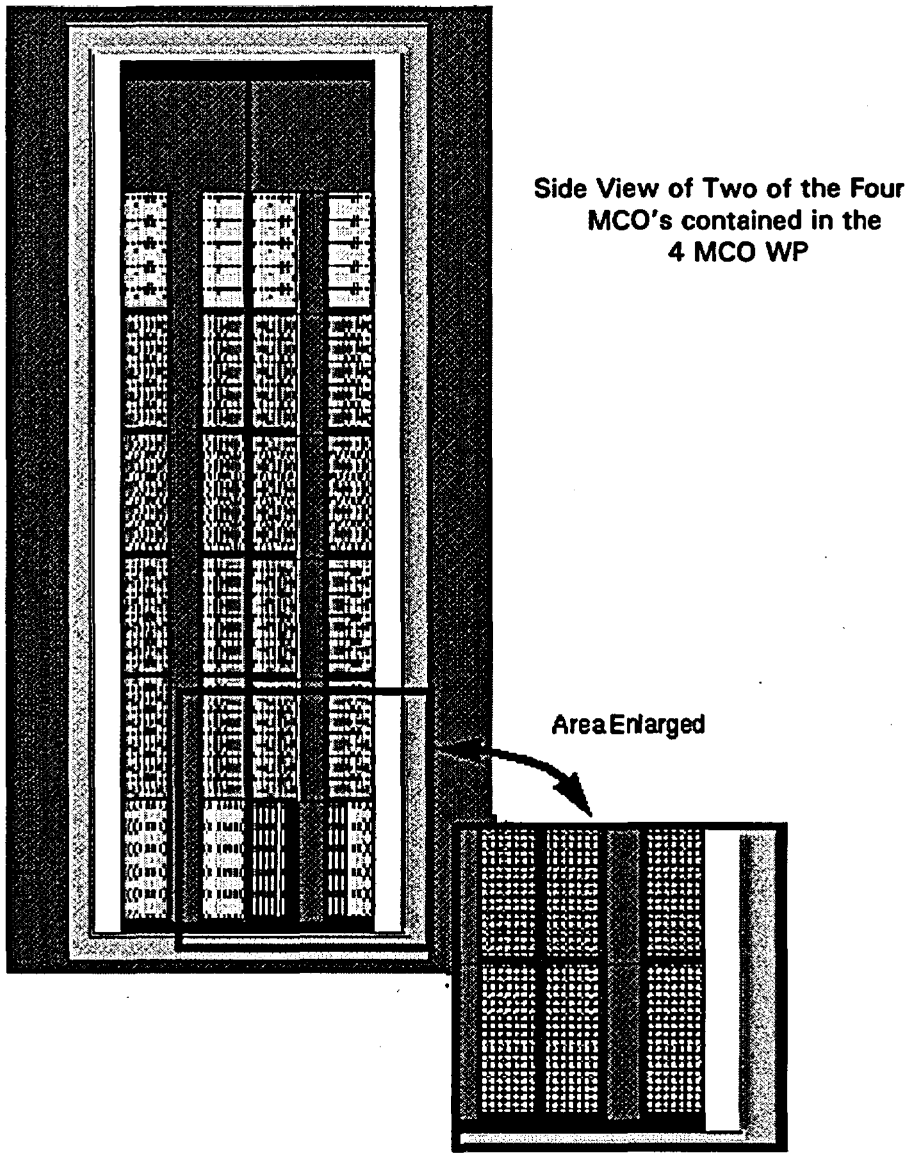


Figure 5-12. MCNP Plot – X-Z View of 4 MCO WP

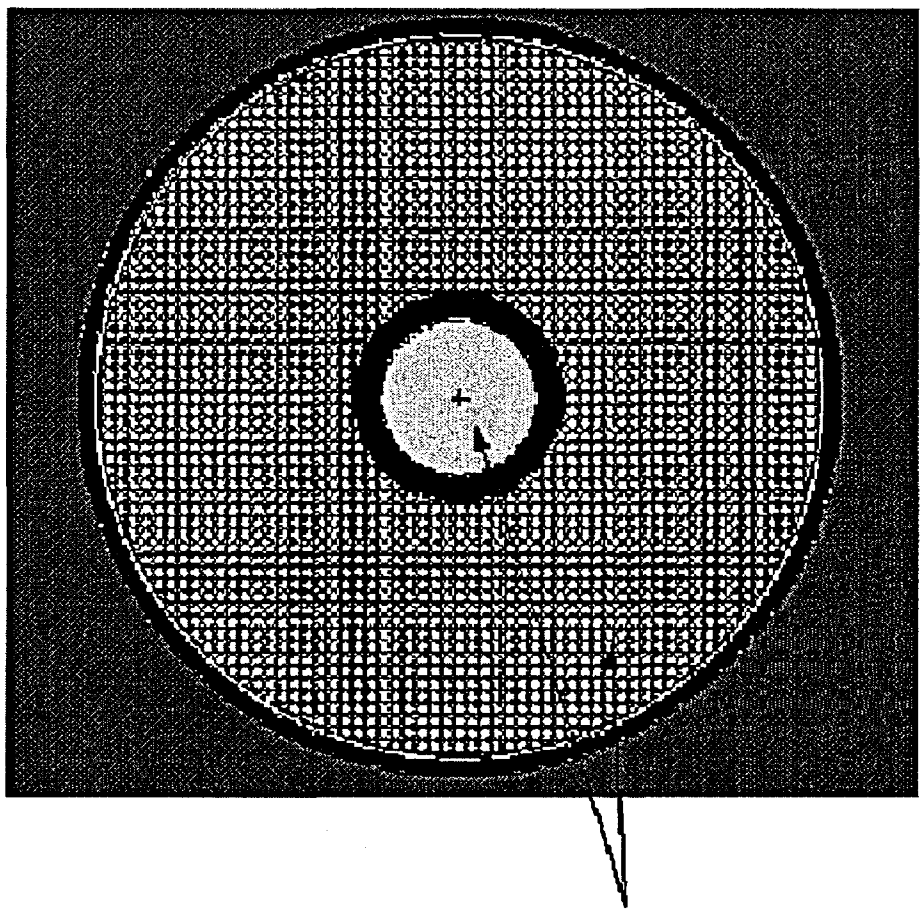


Figure 5-13. MCNP Plot – X-Y View of Interspersed Carbon Steel-Water Cases

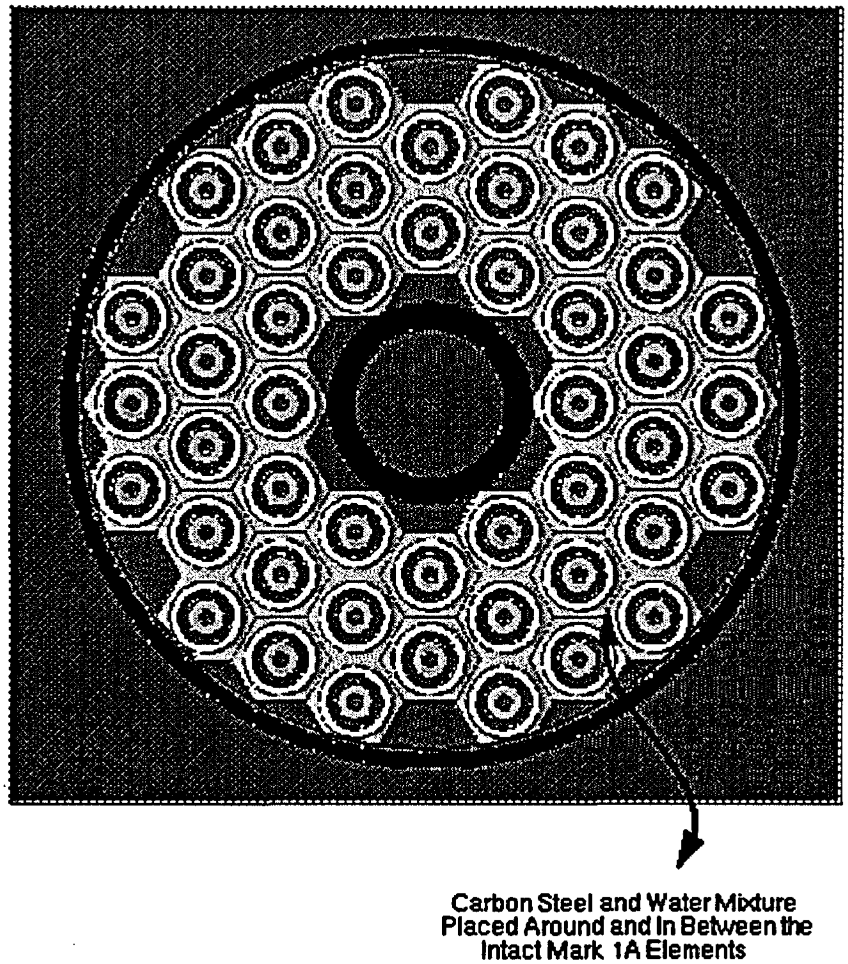


Figure 5-14. MCNP Plot – Intact Mark 1A Elements with Carbon Steel - Water Mixture in Radial Spaces

5.2.4 Basket Center Pipe Variations

In all of the following cases the MCO's were fully flooded and reflected with full density water. Also each of the MCO's were evaluated containing degraded Mark 1A fuel as previously discussed using the spherical case. In each of the following cases the central process tube was not included.

A case was constructed in which the basket center pipes are removed in order to evaluate the k_{eff} effects.

Another case was evaluated which considered the reactivity effects of shifting the center pipe 5.08 cm radially in one direction. This case was evaluated to provide comparison to a case included in the original criticality report. (Ref. 7.5, p. 5-5)

The final case in this section considered the reactivity effects of placing degraded fuel into the center pipe while each of the baskets was fully loaded with degraded fuel.

5.2.5 No Basket Center Pipe - Carbon Steel as Moderator Exclusion and/or Neutronic Poison

A set of cases was used to evaluate the decrease in k_{eff} due to the introduction of carbon steel, at various densities, into a basket which had the center pipe removed. The same ratio of carbon steel and water, as previously described, was used in this set of cases.

5.2.6 U-H_2O Mixture - Homogeneously Dispersed throughout the Basket - Mark 1A Fuel

In order to determine reactivity effects from particulate, a set of cases was developed. In these cases, the MCO was evaluated fully loaded with degraded Mark 1A fuel. The MCO was fully flooded and reflected with full density water. The water interspersed within the MCO was evaluated containing various gram quantities of the uranium fuel matrix. The gram quantities ranged from 0.001 g/L to 1 g/L. In these cases the basket center pipes were evaluated intact.

5.2.7 Zircaloy-2 Cladding Dispersed in Basket as Water Displacer - Mark 1A Fuel

Previous cases took no credit for the presence of Zircaloy-2 material comprising the cladding of the elements. The uranium metal fuel matrix of each of the elements is clad in Zircaloy-2. Although the structural integrity of the cladding is in question, it has been verified as being present. Zircaloy-2 has a low neutron absorption cross section. But when credit is taken for the volume of the Zircaloy-2, it will lower the available space (volume fraction) for water currently contained between the spaced heterogeneous spheres of fuel material.

The presence of the Zircaloy-2 material from the cladding was evaluated. In these cases, the amount of material representing cladding was dispersed through the water mixture within each of the baskets in the annular region only. Case variations were evaluated which considered the effects of placing Zircaloy-2 material in the center pipe along with the degraded fuel. In the limiting cases, no Zircaloy-2 was placed in the center pipe region along with the degraded fuel.

Cases were developed which considered fuel contained in the center pipe and fuel not contained in the center pipe. The 4 MCO WP was considered in this case. The individual MCO's were evaluated fully flooded with no water between them within the 4 MCO WP. Full density water reflection was placed around the outside of the 4 MCO WP.

5.2.8 Placement of Stainless Steel Cruciform between MCO's in the 4 MCO WP

The next set of cases developed was based on the case that was discussed in Section 5.2.6. In this set of cases however, each of the cases contained fuel in the center pipe. A set of cases was developed to determine the effect on the calculated k_{eff} if a stainless steel cruciform was placed into the 4 MCO WP in between the individual MCO's.

The top collars of the MCO's have an outer diameter of 64.2874 cm (25.31 in.) while the lower portion of the MCO has an outer diameter of 60.96 cm. The tolerances on loading four MCO's into a 4 MCO WP are quite tight but some room between the lower portion of the MCO's exists. Since this is where the fuel is housed the cruciform would not need to extend the full length of the 4 MCO WP.

Stainless steel plates, ranging in thickness from 1.0 to 4.0 cm, were evaluated. The type of material chosen for this case was 304L stainless steel. An example of the physical layout is shown in Figure 5-15.

5.2.9 Neutronically Poisoned Stainless Steel Cruciform between MCO's in the 4 MCO WP

Cases were evaluated that were similar to those discussed in Section 5.2.7. The case chosen as the base case is that which includes the 2.0 cm thick stainless steel cruciform. This was done since preliminary evaluations indicate that thickness greater than 2.0 cm would not allow enough room to place the individual MCO's into the waste package.

An evaluation was made to determine the magnitude of the effect on the calculated k_{eff} if a neutron absorbing material were integrated into the cruciform structure. The material of choice was gadolinium. Various gadolinium weight percents ranging from 0.01 to 2.0 wt% were considered.

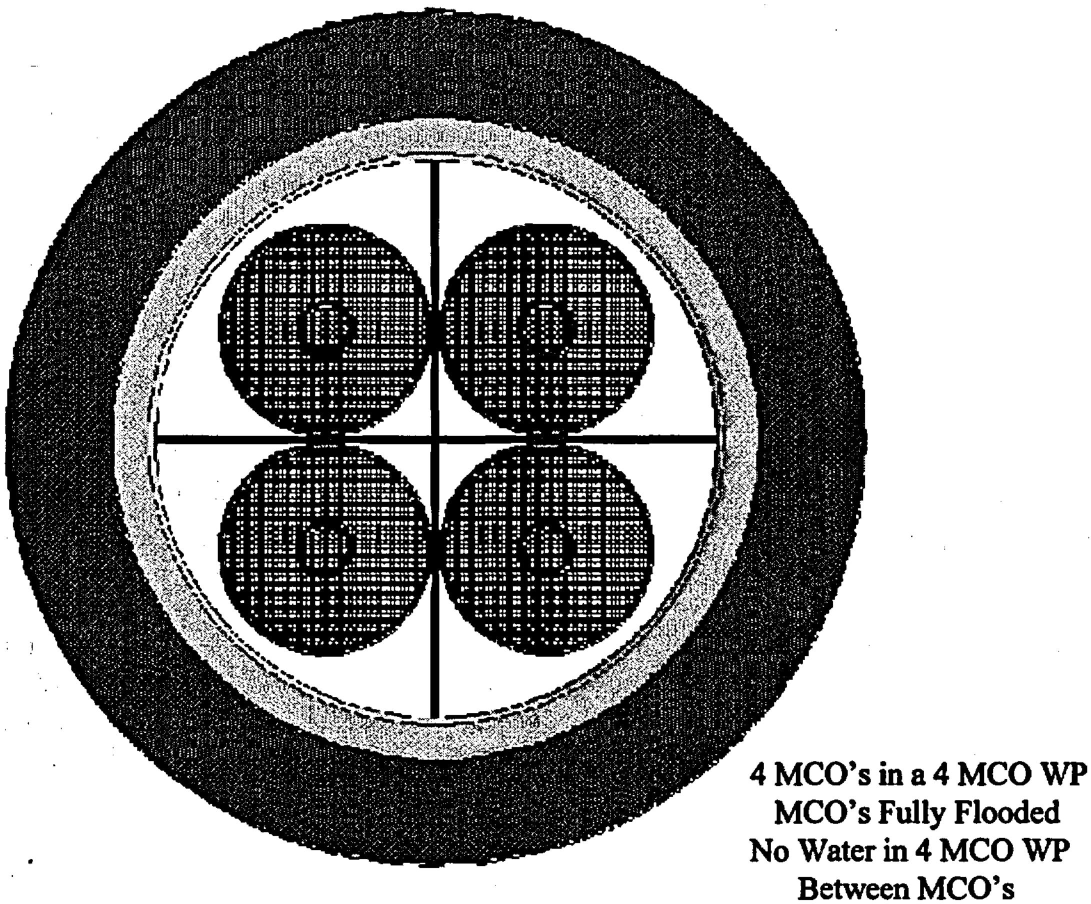


Figure 5-15. MCNP Plot – 4 MCO WP with Stainless Steel Cruciform Present

5.2.10 Incorporation of Stainless Steel Process Tube

The last case evaluated consisted of the incorporation of the central process tube. This tube is constructed of 304L stainless steel. It is an annular tube having an outer diameter of 1.315 in. (3.3401 cm) and a thickness of 0.358 in (0.90932 cm). This tube was ignored in all of the previous cases.

The process tube runs the entire length of the MCO down the center of each of the baskets. Various cases were considered to evaluate the effects of this center process tube. Cases for single MCO's, the 4 MCO WP with and without the stainless steel cruciform, and the 4 MCO WP with the Gd poisoned stainless steel cruciform present, were evaluated.

In this next set of cases, the fuel was placed between the central process tube and the center tube. No Zircaloy-2 material was interspersed between the heterogeneous spheres of fuel contained in this region. The fuel spheres contained in this region were evaluated at two radii. The first radius analyzed was the same radius used in the evaluation of the fuel spheres contained in the basket annular region, 0.42925 cm. An example of this configuration is shown in Figure 5-16.

The next case analyzed and evaluated fuel spheres having a radius of 0.25 cm to determine the effects of the smaller particles in the center tube. The change in the calculated k_{eff} due to the different sized particles occupying the basket center pipe was evaluated.

5.2.11 Evaluation of Neutronic Poisoned Center Rod in 4 MCO WP

An evaluation was made to determine if other materials were a better choice for the neutronic poisoning of the system. In these cases the loading in the scrap basket were reduced to 575 kg of uranium, which is the actual loading limitations on the Mark IA scrap baskets. Previous cases considered the most reactive configurations based upon a loading that was slightly higher. The previous cases considered the scrap as being comprised of the uranium from approximately 36 elements. This 575 kg mass limit is equivalent to approximately 34 elements.

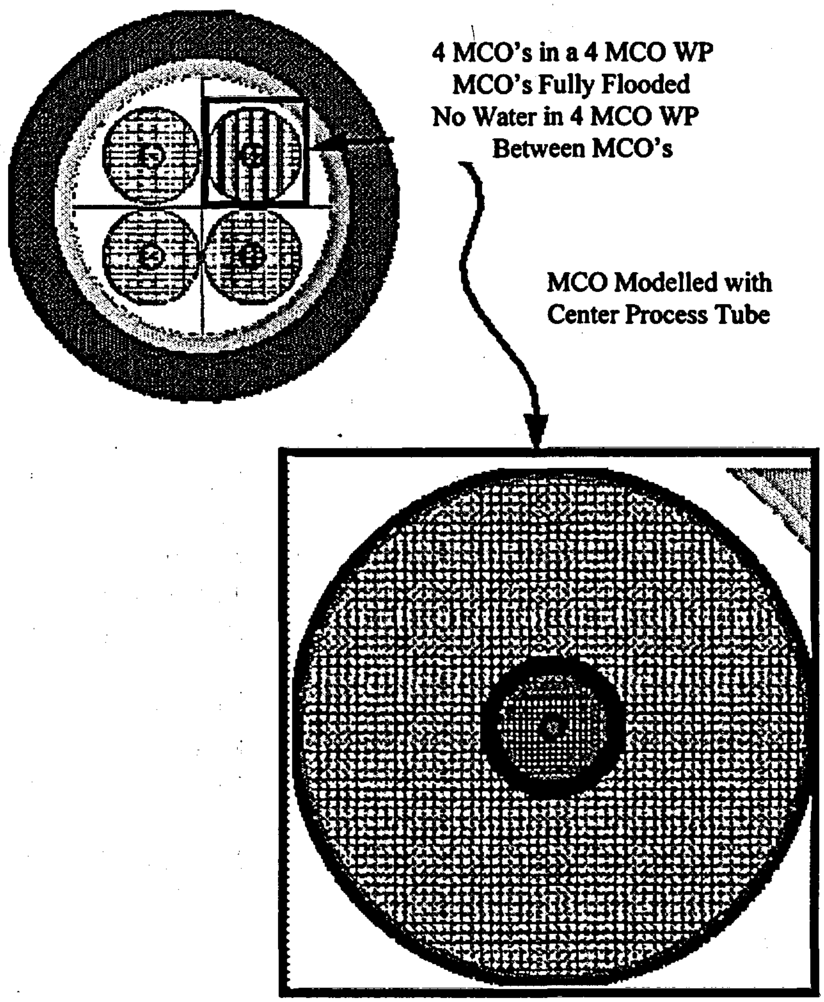


Figure 5-16. MCNP Plot – 4 MCO WP - Center Process Tube Included in MCO's

The first three cases considered incorporated a 14.4 cm rod located within the center of the 4 MCO WP within the array of the 4 MCO's. In the first case the center rod was included as graphite containing 2 wt% Gd. The remaining 4.0 cm 1.0 wt% Gd poisoned stainless steel cruciform was included in the case. No fuel was present in the center pipe region.

The second case is similar to the first case described in this section with the exception that the graphite center rod was enclosed with a 1.0 cm thick stainless steel shell.

Two variations on the previously outlined cases were also evaluated. The first incorporated a 14.4 cm boron carbide (B_4C) rod in the middle of the waste package instead of the previously described graphite rod. In this case the 4.0 cm thick 1.0 wt% Gd poisoned stainless steel cruciform was evaluated. The last case considered only the presence of the B_4C rod and didn't include the stainless steel cruciform.

An example of these configurations can be found in Figure 5-17.

5.2.12 Evaluation of Boron Carbide (B_4C) Rods Placed in the Fuel Baskets

Cases were evaluated to determine the effects of placing B_4C rods into the MCO in various configurations. The B_4C rods were evaluated at the same outer dimensions of the N-Reactor Mark 1A fuel elements. Three rods were placed into a basket at 120-degree intervals. In the first case, three rods were placed into each of the six fuel baskets. The next case considered only rods in the top and bottom scrap baskets. The last case considered B_4C rods in all six baskets with the fuel baskets evaluated with center pipes equivalent to the diameter of the Mark IV baskets.

Once again, the scrap baskets contained 575 kg of uranium. The spacing between the fuel spheres, in the scrap baskets, optimized at a slightly larger center to center pitch due to the configuration that included the B_4C poison rods.

The cruciform was not included in these cases.

An example of these configurations is shown in Figure 5-18.

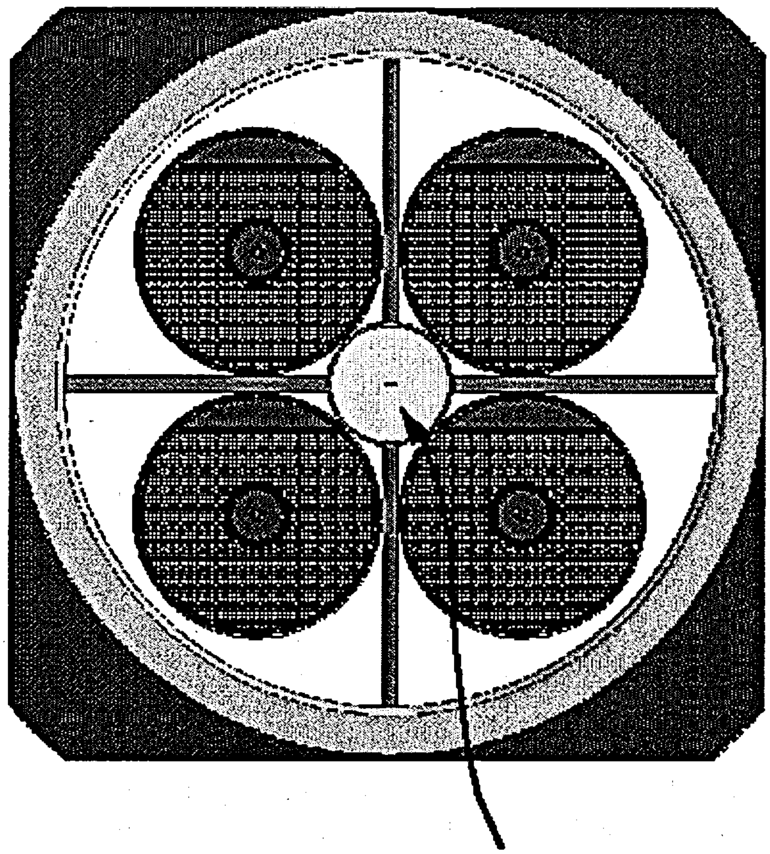


Figure 5-17. MCNP Plot – Neutronically Poisoned Rod Placed into Center of 4 MCO WP

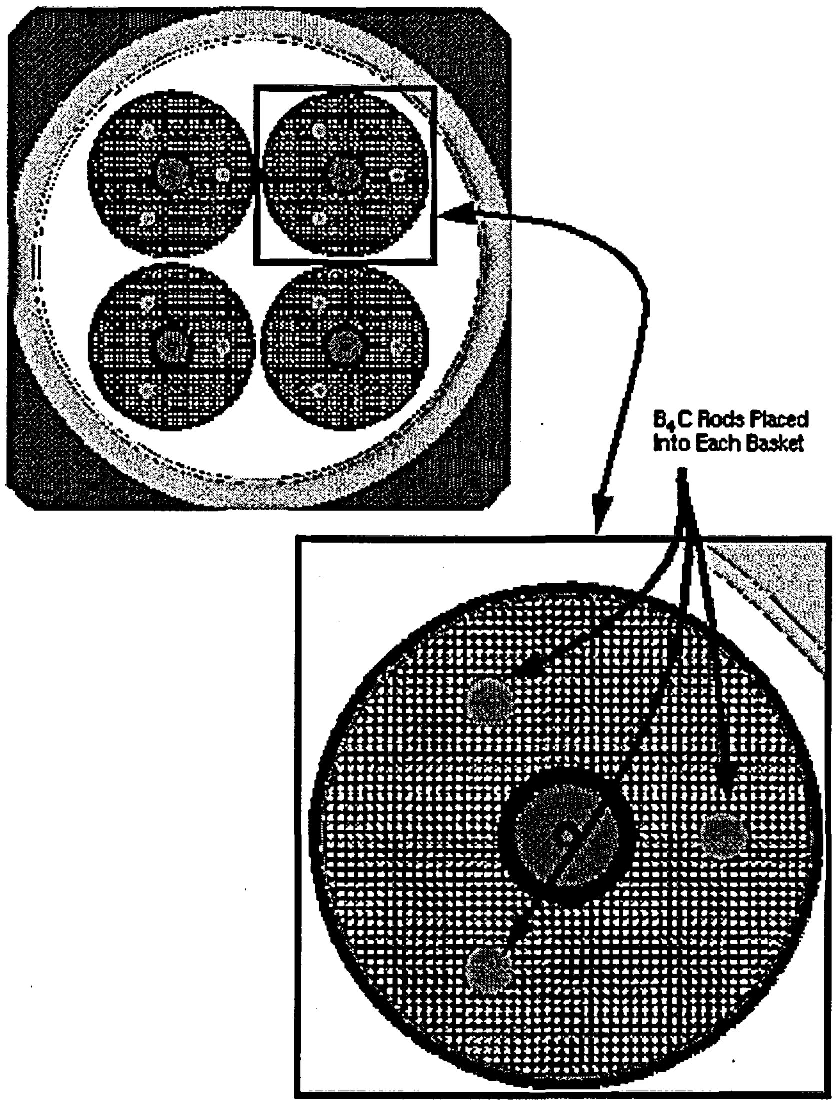


Figure 5-18. MCNP Plot – Neutronically Poisoned B_4C Rod Placed into MCO Baskets

6. Results

Existing data were used in the development of the results presented in this section. Therefore, the use of any data from this calculation for input into documents supporting procurement, fabrication, or construction is required to be identified and tracked as To Be Verified (TBV) in accordance with appropriate procedures.

6.1 Results from Comparison Cases of Type Mark 1A and Mark IV N-Reactor SNF

Cases were evaluated using both Mark 1A and Mark IV N-Reactor SNF as outlined in Section 5.2. Results from the various comparison cases are presented below.

6.1.1 Results from Intact Mark 1A and Mark IV N-Reactor SNF Cases

MCO's and 4 MCO WP's, containing intact Mark 1A or Mark IV N-Reactor SNF were evaluated. In these cases all of the MCO baskets were evaluated as described in Section 5.2.1.1. The results from the various intact cases are given in Table 6-1.

Table 6-1. Results from Intact Mark 1A and Mark IV N-Reactor SNF Cases

Input File	Type of Fuel	Configuration	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
mk1a_intact1	Mark 1A	Single MCO	0.7922 ± 0.0006	0.7934
mk4_intact1	Mark IV	Single MCO	0.8289 + 0.0005	0.8299
ldp_mk1a_intact1	Mark 1A	4 MCO's in 4 MCO WP	0.8151 ± 0.0006	0.8163
ldp_mk4_intact1	Mark IV	4 MCO's in 4 MCO WP	0.8411 ± 0.0004	0.8419

6.1.2 Results from Intact and Degraded Scrap Mark 1A and IV N-Reactor SNF Cases

MCO's and 4 MCO WP's, containing both intact and degraded Mark 1A or Mark IV N-Reactor SNF, were evaluated. These cases, as described in Section 5.2.1.2, were conservatively evaluated with the scrap material as optimally spaced spheres with the enrichments corresponding to the fuel type stored. The results from the various combinations of intact and degraded fuel cases are given in Table 6-2.

Table 6-2. Results from Intact and Degraded Scrap Mark 1A and Mark IV N-Reactor SNF

Input File	Type of Fuel	Configuration	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
mk1a_comb1a	Mark 1A	Single MCO	0.8783 ± 0.0005	0.8793
mk4_comb1	Mark IV	Single MCO	0.8407 ± 0.0005	0.8417
ldp_mk1a_comb1a	Mark 1A	4 MCO's in 4 MCO WP	0.9026 + 0.0005	0.9036
ldp_mk4_comb1	Mark IV	4 MCO's in 4 MCO WP	0.8562 + 0.0004	0.8570

6.1.3 Results from Degraded Fuel and Scrap Mark 1A and Mark IV N-Reactor SNF Cases

MCO's and 4 MCO WP's containing degraded fuel and scrap material from Mark 1A or Mark IV N-Reactor SNF were evaluated. These cases were evaluated as described in Section 5.2.1.3. The degraded fuel and the scrap material were both evaluated as optimally spaced spheres with the enrichments corresponding to the fuel stored. The results from the various combinations of the degraded and scrap fuel cases are given in Table 6-3.

Table 6-3. Results from Degraded and Scrap Mark 1A and Mark IV N-Reactor SNF

Input File	Type of Fuel	Configuration	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
mk1a_spheres1a	Mark 1A	Single MCO	0.8816 ± 0.0005	0.8826
mk4_spheres1	Mark IV	Single MCO	0.8989 ± 0.0005	0.8999
ldp_mk1a_spheres1a	Mark 1A	4 MCO's in 4 MCO WP	0.9054 ± 0.0005	0.9064
ldp_mk4_spheres1a	Mark IV	4 MCO's in 4 MCO WP	0.9118 + 0.0004	0.9126

6.2 Results of Various Degrees of Moderation within the MCO's and 4 MCO WP

MCO's containing Mark 1A fuel, degraded and scrap, were evaluated with various densities of water placed into the interstitial spaces between the heterogeneous fuel spheres within the MCO baskets. In these cases, the MCO's were reflected by full density water. The results of these cases are found in Table 6-4.

Table 6-4. Results from Cases Incorporating Water Moderator at Various Densities to Determine Optimum Moderation – Single MCO

Input File	% Density of Water within MCO	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
mk1a_h2o_10%a	10 %	0.3841 ± 0.0003	0.3847
mk1a_h2o_20%a	20 %	0.4788 ± 0.0004	0.4796
mk1a_h2o_30%a	30 %	0.5660 ± 0.0005	0.5670
mk1a_h2o_40%a	40 %	0.6404 ± 0.0005	0.6414
mk1a_h2o_50%a	50 %	0.7003 ± 0.0005	0.7013
mk1a_h2o_60%a	60 %	0.7514 ± 0.0005	0.7524
mk1a_h2o_70%a	70 %	0.7939 ± 0.0005	0.7949
mk1a_h2o_80%a	80 %	0.8286 ± 0.0005	0.8296
mk1a_h2o_90%a	90 %	0.8561 ± 0.0005	0.8571
mk1a_spheres1a	100 %	0.8816 ± 0.0005	0.8826

Once the optimum degree of moderation within the MCO was determined, four MCO's were placed into a 4 MCO WP. The water in between the MCO's, within the 4 MCO WP was evaluated at various densities (0 to 100% theoretical density). The results of these cases are given in Table 6-5.

Table 6-5. Results from Cases Incorporating Water Moderator at Various Densities to Determine Optimum Moderation – Four MCO's within a 4 MCO WP

Input File	% Density of Water within 4 MCO WP	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
ldp_mk1a_h2o_0%a	0%	0.9440 ± 0.0004	0.9448
ldp_mk1a_h2o_10%a	10 %	0.9325 ± 0.0004	0.9333
ldp_mk1a_h2o_20%a	20 %	0.9248 ± 0.0004	0.9256
ldp_mk1a_h2o_30%a	30 %	0.9200 ± 0.0004	0.9208
ldp_mk1a_h2o_40%a	40 %	0.9170 ± 0.0004	0.9178
ldp_mk1a_h2o_50%a	50 %	0.9143 ± 0.0004	0.9151
ldp_mk1a_h2o_60%a	60 %	0.9120 ± 0.0004	0.9128
ldp_mk1a_h2o_70%a	70 %	0.9099 ± 0.0004	0.9107
ldp_mk1a_h2o_80%a	80 %	0.9094 ± 0.0004	0.9102
ldp_mk1a_h2o_90%a	90 %	0.9067 ± 0.0004	0.9075
ldp_mk1a_spheres1a	100%	0.9054 ± 0.0005	0.9064

6.3 Results from Carbon Steel as Moderator Exclusion and/or Neutronic Poison

MCO's containing Mark 1A fuel, degraded and scrap, were evaluated with various densities of carbon steel placed into the interstitial spaces between fuel within the MCO baskets for either intact Mark 1A elements or the heterogeneous fuel sphere case of Mark 1A elements. In these cases the carbon steel was combined with water at various proportional densities to occupy the void spaces within the basket.

In the case of the intact elements, the carbon steel – water mixture only occupied the radial spaces between the intact fuel elements. The central void and annular regions within the element itself were filled with full density water. The results from these cases are found in Table 6-6.

Table 6-6. Results from Cases Incorporating Carbon Steel as Moderator Exclusion and/or Neutronic Poison within the Baskets as Carbon Steel–Water Mixture – Degraded Mark 1A Fuel Basket Center Pipes Intact

Input File	% Density of Carbon Steel	% Density of Water	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
mk1a_sphr_cs90%a	90 %	10 %	0.2456 ± 0.0002	0.2460
mk1a_sphr_cs80%a	80 %	20 %	0.3053 ± 0.0002	0.3057
mk1a_sphr_cs70%a	70 %	30 %	0.3647 ± 0.0003	0.3653
mk1a_sphr_cs60%a	60 %	40 %	0.4237 ± 0.0003	0.4243
mk1a_sphr_cs50%a	50 %	50 %	0.4842 ± 0.0004	0.4850
mk1a_sphr_cs40%a	40 %	60 %	0.5458 ± 0.0004	0.5466
mk1a_sphr_cs30%a	30 %	70 %	0.6146 ± 0.0004	0.6154
mk1a_sphr_cs20%a	20 %	80 %	0.6901 ± 0.0004	0.6909
mk1a_sphr_cs10%a	10 %	90 %	0.7783 ± 0.0005	0.7793

Intact elements were also evaluated containing various densities of carbon steel placed into the interstitial radial spaces between the intact fuel elements within the MCO baskets. In these cases the carbon steel was combined with water at various proportional densities to occupy the radial void spaces between the intact elements within the basket. The center and annular regions of the element itself were filled with full density water. The results from these cases are given in Table 6-7.

Table 6-7. Results from Cases Incorporating Carbon Steel as Moderator Exclusion and/or Neutronic Poison within the Radial Space Between Intact Mark 1A Elements within the Baskets – Carbon Steel Combined with Water at Various Densities – Basket Center Pipes Intact

Input File	% Density of Carbon Steel	% Density of Water	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
mk1a_intact_cs90%a	90 %	10 %	0.5129 ± 0.0005	0.5139
mk1a_intact_cs80%a	80 %	20 %	0.5349 ± 0.0005	0.5359
mk1a_intact_cs70%a	70 %	30 %	0.5597 ± 0.0005	0.5607
mk1a_intact_cs60%a	60 %	40 %	0.5839 ± 0.0005	0.5849
mk1a_intact_cs50%a	50 %	50 %	0.6114 ± 0.0005	0.6124
mk1a_intact_cs40%a	40 %	60 %	0.6408 ± 0.0006	0.6420
mk1a_intact_cs30%a	30 %	70 %	0.6722 ± 0.0006	0.6734
mk1a_intact_cs20%a	20 %	80 %	0.7070 ± 0.0007	0.7084
mk1a_intact_cs10%a	10 %	90 %	0.7468 ± 0.0007	0.7482

6.4 Results of Basket Center Pipe Variation Cases – Mark 1A N-Reactor SNF

6.4.1 Results from Carbon Steel within Baskets – No Center Pipe in Baskets – Mark 1A

MCO's containing Mark 1A fuel, degraded and scrap, were evaluated with various densities of carbon steel placed into the interstitial spaces between the heterogeneous fuel spheres within the MCO baskets. In these cases, the carbon steel was combined with water at various proportional densities to occupy the void spaces within the basket. The baskets were evaluated without the center pipes present. The cases were evaluated as described in Section 5.2.5, and the results can be found in Table 6-8.

Table 6-8. Results from Cases Incorporating Carbon Steel as Moderator Exclusion and/or Neutronic Poison within the Baskets Containing Degraded Fuel – Carbon Steel–Water Mixture at Various Densities – Mark 1A fuel – No Center Pipe in Basket

Input File	% Density of Carbon Steel	% Density of Water	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
mk1a_ncp_cs90%a	90 %	10 %	0.2861 ± 0.0002	0.2865
mk1a_ncp_cs80%a	80 %	20 %	0.3562 ± 0.0003	0.3568
mk1a_ncp_cs70%a	70 %	30 %	0.4222 ± 0.0003	0.4228
mk1a_ncp_cs60%a	60 %	40 %	0.4854 ± 0.0003	0.4860
mk1a_ncp_cs50%a	50 %	50 %	0.5496 ± 0.0003	0.5502
mk1a_ncp_cs40%a	40 %	60 %	0.6154 ± 0.0004	0.6162
mk1a_ncp_cs30%a	30 %	70 %	0.6886 ± 0.0004	0.6894
mk1a_ncp_cs20%a	20 %	80 %	0.7717 ± 0.0004	0.7725
mk1a_ncp_cs10%a	10 %	90 %	0.8656 ± 0.0005	0.8666
mk1a_ncp_h2oa	0 %	100 %	0.9802 ± 0.0005	0.9812

6.4.2 Other Basket Center Pipe Variation Cases – Degraded Mark 1A Fuel

MCO's containing Mark 1A fuel, degraded and scrap, were evaluated with the center pipes of the MCO baskets removed, offset, or filled with degraded fuel, as described in Section 5.2.4. The results from these cases can be found in Table 6-9.

Table 6-9. Results from Basket Center Pipe Variation Cases – Mark 1A Fuel

Input File	Center Pipe Present	Position of Center Pipe	Degraded Fuel in Center Pipe	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
mk1a_ncp_h2oa	No	Not Present	N/A	0.9802 ± 0.0005	0.9812
mk1a_deg_cp_filla	Yes	Centered	Yes	0.9200 ± 0.0005	0.9210
mk1a_deg_cp_offa	Yes	Offset 5.08 cm	No	0.8978 ± 0.0005	0.8988

6.4.3 Results from U-H_2O Mixture Dispersed in the Basket – Degraded Mark 1A Fuel

In order to determine reactivity effects from particulate, a set of cases was developed. In these cases the MCO was evaluated fully loaded with degraded Mark 1A fuel. The MCO was fully flooded and fully reflected with full density water. The water interspersed within the MCO was evaluated containing various gram quantities of the uranium fuel matrix. The results of these cases can be found in Table 6-10.

Table 6-10. Results from Uranium in Solution – Homogeneously Dispersed throughout the Basket - Degraded Mark 1A Fuel Case

Input File	Concentration of Uranium Fuel Matrix in Solution (g/L)	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
mk1a_deg_0.0001gcca	0.1	0.8766 + 0.0005	0.8776
mk1a_deg_0.0005gcca	0.5	0.8693 + 0.0005	0.8703
mk1a_deg_0.001gcca	1.0	0.8707 + 0.0005	0.8717
mk1a_deg_0.005gcca	5.0	0.8636+ 0.0005	0.8646
mk1a_deg_0.01gcca	10.0	0.8671 + 0.0005	0.8681

6.5 Results from Zircaloy-2 Cladding as Moderator Exclusion within the Baskets

Cases were evaluated as described in Section 5.2.7. These cases were developed which considered both fuel contained in the center pipe and fuel not contained in the center pipe. The 4 MCO WP was considered in this case. The individual MCO's were evaluated fully flooded with no water between them within the 4 MCO WP. Full density water reflection was placed around the outside of the 4 MCO WP. Two cases were evaluated. One with fuel in the center pipe, and another cases had no fuel in the center pipe. In each of these cases, the Zircaloy-2 material was only interspersed in the water in the annular region of the basket.

The results from these cases can be found in Table 6-11.

Table 6-11. Results from Cases Incorporating Zircaloy-2 from Element Cladding as Moderator Exclusion within the Baskets

Input File	Zircaloy 2 – Water – Fuel Mixture Present in Center Pipe	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
ldp_mk1a_zr_h2o0%c	No	0.9374 ± 0.0004	0.9382
ldp_mk1a_cpfill_zr_h2o0%b	Yes	0.9501 ± 0.0004	0.9509

6.6 Results from Non-Poisoned Cruciform between MCO's in 4 MCO WP

A set of cases was developed as described in Section 5.2.8 to determine k_{eff} if a stainless steel cruciform was placed into the 4 MCO WP in between the individual MCO's. Thickness' ranging from 1.0 to 4.0 cm were evaluated. In all of these cases, the fuel was present inside the center basket tube. The Zircaloy-2 material was interspersed only in the water between the fuel spheres in the annular region. The results from these cases are given in Table 6-12.

Table 6-12. Results from Cases Incorporating Non-Poisoned Stainless Steel Cruciform

Input File	Thickness of Stainless Steel Cruciform Between MCO's	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
ldp_mk1a_cpfill_zr_ss1.0a	1.0	0.9424 ± 0.0004	0.9432
ldp_mk1a_cpfill_zr_ss2.0a	2.0	0.9402 ± 0.0004	0.9412
ldp_mk1a_cpfill_zr_ss3.0a	3.0	0.9377 ± 0.0004	0.9385
ldp_mk1a_cpfill_zr_ss4.0a	4.0	0.9363 ± 0.0004	0.9371

6.7 Results from Gadolinium Poisoned Cruciform between MCO's in 4 MCO WP

A set of cases was developed as described in Section 5.2.9 to determine k_{eff} if a neutronically poisoned stainless steel cruciform was placed into the 4 MCO WP in between the individual MCO's. A thickness 2.0 cm was chosen as the base case to be evaluated. Various wt% of gadolinium was incorporated into the stainless steel cruciform. In all of these cases, the fuel was present inside the center basket tube. The Zircaloy-2 material was interspersed only in the water between the fuel spheres in the annular region.

The results from these cases are given in Table 6-13.

Table 6-13. Results from Cases Incorporating Poisoned Stainless Steel Cruciform

Input File	wt% of Gd Incorporated in Stainless Steel Cruciform Between MCO's	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
ldp_mk1a_cpfill_zr_ss2.0gd.01a	0.01	0.9484 ± 0.0004	0.9492
ldp_mk1a_cpfill_zr_ss2.0gd0.1a	0.1	0.9470 ± 0.0004	0.9478
ldp_mk1a_cpfill_zr_ss2.0gd1.0a	1.0	0.9446 ± 0.0003	0.9452

A last set of cases was evaluated in which only water, and no Zircaloy-2, was present between the fuel spheres located in the center pipe. The results from these cases are given in Table 6-14. This case consisted of 4 MCO's in the 4 MCO WP as previously outlined. The neutronically poisoned 2.0 cm thick stainless steel cruciform was included.

Table 6-14. Results from Zircaloy-2 between Fuel Particles in Annular Region Only

Input File	wt% of Gd Incorporated in Stainless Steel Cruciform Between MCO's	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
ldp_mk1a_cpfill_zr_ss2.0gd0.01	0.01	0.9408 ± 0.0003	0.9414
ldp_mk1a_cpfill_zr_ss2.0gd0.1	0.1	0.9392 ± 0.0004	0.9400
ldp_mk1a_cpfill_zr_ss2.0gd1.0	1.0	0.9367 ± 0.0004	0.9375

6.8 Results from Cases Incorporating 304L Stainless Steel Center Process Tube

The last set of cases considered consisted of those described in Section 5.2.10. In these cases, the change in k_{eff}, due to the presence of the stainless steel central process tube, was evaluated. The first subset of cases consisted of the region between the center process tube and the inside of the basket center pipe being filled with fuel spheres at a radius of 0.42925 cm. This was the maximum postulated radius particle size, and shown to be most reactive in the normal base configuration cases.

No Zircaloy-2 material was present in the water that was interspersed between the fuel spheres in this central region. Zircaloy material was evaluated in the water that was interspersed between the fuel spheres in the basket annular region. Once again four flooded MCO's were evaluated contained in a 4 MCO WP. No water existed between the MCO's within the 4 MCO WP. The neutronically poisoned 2.0 cm thick stainless steel plate was also present.

Table 6-15. Results from Inclusion of Center Process Tube – 0.42925 cm Radius Fuel

Input File	wt% of Gd Incorporated in Stainless Steel Cruciform Between MCO's	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
ldp_mk1a_cpfill_zr_ss2.0gd0.01b	0.01	0.9442 ± 0.0004	0.9450
ldp_mk1a_cpfill_zr_ss2.0gd0.1b	0.1	0.9438 ± 0.0004	0.9446
ldp_mk1a_cpfill_zr_ss2.0gd1.0b	1.0	0.9412 ± 0.0004	0.9420

This set of results outline the effect on k_{eff} due to replacing the larger fuel spheres (0.42925 cm radius), located in the central region, with the smaller 0.25 cm radius fuel spheres. Due to the presence of the center process tube an argument can be made that this is the largest sized particle that can migrate into the central region outside of the center process tube and inside of the basket enter pipe. The fourth case listed varies from the first three cases in that no zircalloy was evaluated in between the heterogeneous spheres in the scrap inserts. The results from this set of cases are given in Table 6-16.

Table 6-16. Results from Inclusion of Center Process Tube – 0.25 cm Radius Fuel

Input File	wt% of Gd Incorporated in Stainless Steel Cruciform Between MCO's	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
ldp_mk1a_cpfill_zr_ss2.0gd0.01c	0.01	0.9414 ± 0.0003	0.9420
ldp_mk1a_cpfill_zr_ss2.0gd0.1c	0.1	0.9406 ± 0.0004	0.9414
ldp_mk1a_cpfill_zr_ss2.0gd1.0c	1.0	0.9383 ± 0.0004	0.9391
ldp_mk1a_cpfill_zr_ss2.0gd1.0d	1.0	0.9492 ± 0.0004	0.9500

6.9 Results from Placement of Neutronically Poisoned Rod in Center of 4 MCO WP

These are the results from those cases as outlined in Section 5.2.11. As described in Section 5.2.11 an evaluation was made relating to the effect of placing a neutronically poisoned rod in the center of the 4 MCO WP. In these cases no fuel was placed in the center pipe of the baskets. Full water reflection exists outside of the 4 MCO WP with no water within the 4 MCO WP. The results are given in Table 6-17.

Table 6-17. Results from Inclusion of Neutronically Poisoned Center Rod

Input File	Cruciform Present	Material of Rod	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
inp42b	Yes	Graphite 2 wt% Gd	0.9076 ± 0.0004	0.9084
inp42d	Yes	Graphite 2 wt% Gd Enclosed In SS	0.9073 ± 0.0004	0.9081
inp42c	Yes	B_4C	0.8976 ± 0.0004	0.8984
b4cwp	No	B_4C	0.9112 ± 0.0004	0.9120

6.10 Results from Placement of B_4C Rods in Fuel Baskets

These are the results from those cases as outlined in Section 5.2.12. As described in Section 5.2.12 an evaluation was made relating to the effect of placing a neutronically poisoned rod in the fuel baskets of the MCO's. In these cases no fuel was placed in the center pipe of the baskets. Full water reflection exists outside of the 4 MCO WP with no water within the 4 MCO WP. The results are given in Table 6-18.

Table 6-18. Results from Inclusion of Neutronically Poisoned Center Rod

Input File	Location of B_4C Rods	Center Pipe of Fuel Basket	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
b4cmcoa	Top & Bottom	Mark1A	0.8583 ± 0.0004	0.8591
b4cmco	Every Basket	Mark 1A	0.9172 ± 0.0004	0.9180
bc4mcob	Every Basket	Mark IV	0.9171 ± 0.0004	0.9179

7. References

7.1 [Reserved]

7.2 Los Alamos National Laboratory (LANL) 1997. *MCNP- A General Monte Carlo Code for Neutron and Photon Transport Code, Version 4B – UC 705 and UC 700.* LA-12625-M, Version 4B. Los Alamos, New Mexico: LANL. ACC: MOL.19980624.0328.

7.3 Civilian Radioactive Waste Management System (CRWMS) Management and Operating (M&O) Contractor 1998. *Software Qualification Report for the MCNP Version 4B, A General Monte Carlo N-Particle Transport Code.* Computer Software Configuration Identifier (CSCI): 30033 V4BLV, Document Identifier Number: 30033-2003 REV 00. Las Vegas, Nevada: M&O. ACC: MOL.19980217.0561.

7.4 CRWMS M&O 1996. *Material Compositions and Number Densities For Neutronics Calculations.* BBA000000-01717-0200-00002 REV 00. Las Vegas, Nevada: M&O. ACC: MOL.19960624.0023.

7.5 Fluor Daniel Northwest 1997. *Criticality Safety Evaluation Report for Spent Nuclear Fuel Processing and Storage Facilities.* WHC-SD-SNF-CSER-005, Rev. 3. Hanford, Washington: Fluor Daniel Northwest. ACC: MOL.19980729.0238.

7.6 [Reserved]

7.7 Parsons Infrastructure and Technology Group, Inc. 1997. *Multi-Canister Overpack Drawings, HNF-SD-SNF-DR-003, Rev. 0, Appendices 1 and 19, Draft.* Hanford, Washington: Parsons Infrastructure and Technology Group, Inc. TIC: 239396.

7.8 CRWMS M&O 1998. *Software Qualification Report for the MCNP Version 4B2, A General Monte Carlo N-Particle Transport Code.* Computer Software Configuration Identifier (CSCI): 30033 V4B2LV, Document Identifier Number: 30033-2003 REV 00. Las Vegas, Nevada: M&O. ACC: MOL. 19980622.0637.

7.9 [Reserved]

7.10 LANL 1987. *Critical Dimensions of Systems Containing 235U, 239Pu, and 233U, 1986 Revision.* LA-10860-MS. Los Alamos, New Mexico: LANL. TIC: 209447.

7.11 General Electric (GE) Nuclear Energy 1996. *Nuclides and Isotopes*, Fifteenth Edition. San Jose, California: GE Nuclear Energy. TIC: 233705.

7.12 CRWMS M&O 1999. Electronic Media for: *N-Reactor Spent Nuclear Fuel Criticality Calculations: Intact Mode*. BBA000000-01717-210-00005 REV 00. Compact Disk. Las Vegas, Nevada: M&O. ACC: MOL.19990225.0001.

8. Attachments

The hardcopy attachments are listed in Table 8-1 below. Electronic attachments are provided on compact disc and are listed in Table V-1 for Excel Spreadsheet, Table VI-1 for Rev 00A MCNP cases and Table VII-1 for Rev 00B MCNP cases (Ref. 7.12).

Table 8-1. Attachments of Supporting Documentation for N-Reactor SNF Disposal Criticality Analysis

Attachment Number	Description	Pages
I	Summary Tables of Cases Used to Determine Optimum Particle size and Spacing	4
II	Summary Table of Cases Used to Determine Most Reactive Loading Per MCO Basket	1
III	Summary Table of Cases Used to Evaluate Various Neutronic Absorber Configurations	1
IV	Summary Table of Cases Used to Determine Optimum Pitch and Particle Sizes for Cases in which the Scrap Baskets were Limited to 575 kg of U	1
V	Summary Table and Excel Spreadsheets used in Engineering Calculations (Also Stored Electronically on CD)	19
VI	Summary Table of Rev 00A MCNP4B case inputs and outputs stored in electronic format	9
VII	Summary Table of Rev 00B MCNP4B2 case inputs and outputs stored in electronic format	9
VIII	Drawing/Sketch of the Physical Dimensions of the MCO Waste Package	1

Attachment I. Parametric Study to Determine Optimum Pitch for Heterogeneous N-Reactor Fuel Sphere Calculational Cases

A parametric study was completed to determine the most reactive (optimum) sized sphere and most reactive (optimum) spacing between spheres for the N-Reactor heterogeneous fuel sphere case. Due to the questionable structural integrity of the N-Reactor fuel a very conservative approach was taken in this evaluation.

This approach entailed dispersing heterogeneous pieces of fuel throughout the entire basket. The optimum spherical size was determined along with the optimum spacing between spheres. This parametric study considered an infinite by infinite by infinite array of fuel spheres. The maximum reactivity was determined.

The sizes of the particles (spheres) were limited to the thickest radial thickness of the actual fuel matrix, as constrained by the Zircaloy cladding. The results from the various particle sizes and spacing configurations are given below.

Table I-1. N-Reactor Spheres, Square Pitch Infinite Lattice
0.42925 cm Radius for Spheres

Output Filename	Distance Between Spheres Center to Center (C-C) (cm)	Distance Between Spheres Edge to Edge (E-E) (cm)	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
0.9cm.o	0.9	0.0415	1.0475 ± 0.0006	1.0487
1.0cm.o	1.0	0.1415	1.1193 ± 0.0006	1.1205
1.1cm.o	1.1	0.2415	1.1341 ± 0.0005	1.1351
1.2cm.o	1.2	0.3415	1.1213 ± 0.0004	1.1221
1.3cm.o	1.3	0.4415	1.0874 ± 0.0004	1.0882
1.4cm.o	1.4	0.5415	1.0393 ± 0.0004	1.0401
1.5cm.o	1.5	0.6415	0.9814 ± 0.0004	0.9822
1.6cm.o	1.6	0.7415	0.9197 ± 0.0004	0.9205

Table I-2. N-Reactor Spheres, Square Pitch Infinite Lattice
0.42 cm Radius for Spheres

Output Filename	Distance Between Spheres C-C (cm)	Distance Between Spheres E-E (cm)	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
0.85cm.o	0.85	0.01	1.0050 ± 0.0007	1.0064
0.9cm.o	0.9	0.06	1.0628 ± 0.0006	1.0640
1.0cm.o	1.0	0.16	1.1204 ± 0.0006	1.1216
1.1cm.o	1.1	0.26	1.1325 ± 0.0005	1.1335
1.2cm.o	1.2	0.36	1.1137 ± 0.0004	1.1145
1.3cm.o	1.3	0.46	1.0748+ 0.0004	1.0756
1.4cm.o	1.4	0.56	1.0222 + 0.0004	1.0230
1.5cm.o	1.5	0.66	0.9619 ± 0.0004	0.9627
1.6cm.o	1.6	0.76	0.8979 ± 0.0004	0.8987

Table I-3. N-Reactor Spheres, Square Pitch Infinite Lattice
0.41 cm Radius for Spheres

Output Filename	Distance Between Spheres C-C (cm)	Distance Between Spheres E-E (cm)	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
0.85cm.o	0.85	0.03	1.0305 ± 0.0006	1.0317
0.9cm.o	0.9	0.08	1.0789 ± 0.0006	1.0801
1.0cm.o	1.0	0.18	1.1265 ± 0.0005	1.1275
1.1cm.o	1.1	0.28	1.1303 ± 0.0005	1.1313
1.2cm.o	1.2	0.38	1.1032 ± 0.0005	1.1042
1.3cm.o	1.3	0.48	1.0589 + 0.0004	1.0597
1.4cm.o	1.4	0.58	1.0031 + 0.0004	1.0039
1.5cm.o	1.5	0.68	0.9409 ± 0.0004	0.9417
1.6cm.o	1.6	0.78	0.8738 ± 0.0004	0.8746

Table I-4. N-Reactor Spheres, Square Pitch Infinite Lattice
0.4 cm Radius for Spheres

Output Filename	Distance Between Spheres C-C (cm)	Distance Between Spheres E-E (cm)	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
0.8cm.o	0.8	0.0	0.9893 ± 0.0006	0.9905
0.9cm.o	0.9	0.1	1.0938 ± 0.0006	1.0950
1.0cm.o	1.0	0.2	1.1298 ± 0.0005	1.1308
1.1cm.o	1.1	0.3	1.1248 ± 0.0004	1.1256
1.2cm.o	1.2	0.4	1.0928 ± 0.0004	1.0936
1.3cm.o	1.3	0.5	1.0429 + 0.0004	1.0437
1.4cm.o	1.4	0.6	0.9829 + 0.0004	0.9837
1.5cm.o	1.5	0.7	0.9168 ± 0.0004	0.9176

Table I-5. N-Reactor Spheres, Square Pitch Infinite Lattice
0.38 cm Radius for Spheres

Output Filename	Distance Between Spheres C-C (cm)	Distance Between Spheres E-E (cm)	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
0.8cm.o	0.8	0.04	1.0414 ± 0.0006	1.0426
0.9cm.o	0.9	0.14	1.1146 ± 0.0005	1.1156
1.0cm.o	1.0	0.24	1.1299 ± 0.0005	1.1307
1.1cm.o	1.1	0.34	1.1071 ± 0.0004	1.1079
1.2cm.o	1.2	0.44	1.0625 ± 0.0004	1.0633
1.3cm.o	1.3	0.54	1.0029 + 0.0004	1.0037
1.4cm.o	1.4	0.64	0.9355 + 0.0004	0.9363
1.5cm.o	1.5	0.74	0.8659 ± 0.0004	0.8667

Table I-6. N-Reactor Spheres, Square Pitch Infinite Lattice
0.36 cm Radius for Spheres

Output Filename	Distance Between Spheres C-C (cm)	Distance Between Spheres E-E (cm)	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
0.8cm.o	0.8	0.08	1.0811 ± 0.0006	1.0823
0.9cm.o	0.9	0.18	1.1252 ± 0.0005	1.1262
1.0cm.o	1.0	0.28	1.1197 ± 0.0005	1.1207
1.1cm.o	1.1	0.38	1.0825 ± 0.0004	1.0833
1.2cm.o	1.2	0.48	1.0254 ± 0.0004	1.0262
1.3cm.o	1.3	0.58	0.9579 + 0.0004	0.9587
1.4cm.o	1.4	0.68	0.8837 ± 0.0004	0.8845

Table I-7. N-Reactor Spheres, Square Pitch Infinite Lattice
0.34 cm Radius for Spheres

Output Filename	Distance Between Spheres C-C (cm)	Distance Between Spheres E-E (cm)	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
0.7cm.o	0.7	0.02	1.0823 ± 0.0006	1.0835
0.8cm.o	0.8	0.12	1.1123 ± 0.0006	1.1235
0.9cm.o	0.9	0.22	1.1313 ± 0.0005	1.1323
1.0cm.o	1.0	0.32	1.1066 ± 0.0005	1.1076
1.1cm.o	1.1	0.42	1.0543 ± 0.0004	1.0551
1.2cm.o	1.2	0.52	0.9867 + 0.0004	0.9875
1.3cm.o	1.3	0.62	0.9104 ± 0.0004	0.9104

Attachment II. Parametric Study to Determine Optimum Loading for Heterogeneous N-Reactor Fuel Sphere Calculational Cases

Attachment I considered infinite arrays of fuel spheres to determine the most reactive (optimum) spacing versus size for the heterogeneous spheres of N-Reactor fuel. As shown in Attachment I the 0.42925 cm radius Mark IA fuel sphere was the most reactive. Another set of cases was evaluated in which the spacing between the spheres was varied, while constrained by the geometry of the fuel baskets and MCO. In these cases the 0.42925 cm radius fuel sphere was evaluated with the actual number of spheres present in the basket varying depending upon spacing, thus altering the fuel loading in each of the baskets. The results of these cases for the Mark 1A fuel are given in Table II-1.

Table II-1. Summary Table of Cases Used to Evaluate Most Reactive (Optimum) Spacing Between Particles

Output Filename	Spacing Between Spheres (cm)	Equivalent to # of Mark 1A Elements per Basket	$k_{eff} \pm 1\sigma$	$k_{eff} + 2\sigma$
0.9cm.o	0.9	65.5	0.8122 ± 0.0005	0.8132
1.0cm.o	1.0	45.0	0.8675 ± 0.0005	0.8685
1.05cm.o	1.05	41.2	0.8801 ± 0.0005	0.8811
1.1cm.o	1.1	36.0	0.8816 ± 0.0005	0.8826
1.15cm.o	1.15	31.3	0.8783 ± 0.0005	0.8793
1.2cm.o	1.2	27.5	0.8680 ± 0.0005	0.8690

As shown by these results, the highest k_{eff} was not achieved with the maximum fuel loading per basket (48 elements) but with a lower loading at a more optimized pitch. The most reactive pitch for these specific geometrical configurations compared well with those determine in the infinite array study completed in Attachment I. This arrangement was therefore used in the evaluation of the cases for this calculation.

Attachment III. Evaluation to Determine Effects of Various Neutronic Poisoning Configurations, N-Reactor Fuel Sphere Calculational Cases

An evaluation the effects of placing B_4C neutronic poison in various locations within the MCO was performed. The results from these cases are given in Table III-1.

Table III-1. Summary Table of Cases Used to Evaluate Various Neutronic Absorber Configurations.

Output Filename	Sphere Radius (cm)	Unit Cell Pitch (cm)	Absorber Form	Absorber Inner and Outer Radius (cm)	$k_{eff} \pm 2\sigma$
outaax	0.4	1.0782	3 B_4C rods in middle four baskets	0-3.053	0.9777 ± 0.0008
outaa	0.4	1.0782	3 B_4C rods in all baskets	0-3.053	0.9161 ± 0.0007
outubea	0.4	1.0782	cylindrical B_4C shell around center post in all baskets	3.6-6.39706	0.9294 ± 0.0007
outnewta	0.4	1.0782	cylindrical B_4C shell around center post in all baskets	3.6-6.6	0.9269 ± 0.0007

Attachment IV. Parametric Evaluation to Determine Optimum Pitch and Particle Size for the Cases Evaluated With Limited Mass of Uranium, N-Reactor Fuel Sphere Calculational Cases

An evaluation the effects of varying the particle size and pitch between particles in the MCO was performed. The results from these cases are given in Table IV-1.

Table IV-1. Summary Table of Cases Used to Evaluate Pitch and Particle Size

Output Filename	Particle Radius in Top & Bottom Baskets (cm)	Unit Cell Pitch in Top & Bottom Baskets (cm)	Sphere Radius in Middle Baskets (cm)	Unit Cell Pitch in Middle Baskets (cm)	$k_{eff} \pm 2\sigma$
outaa1	0.4	0.52581	0.4	0.48276	0.9307 ± 0.0007
outaa2	0.4	0.52581	0.4	0.525	0.9323 ± 0.0007
outaa4	0.4	0.52581	0.42	0.5069	0.9312 ± 0.0007
outaa5	0.4	0.52581	0.42	0.54	0.9326 ± 0.0008
outaa7	0.4	0.52581	0.42925	0.51807	0.9312 ± 0.0007
outaa8	0.4	0.52581	0.42925	0.55	0.9332 ± 0.0008
outba1	0.42	0.5521	0.4	0.48276	0.9309 ± 0.0007
outba2	0.42	0.5521	0.4	0.525	0.9323 ± 0.0008
outba4	0.42	0.5521	0.42	0.5069	0.9323 ± 0.0007
outba7	0.42	0.5521	0.42925	0.51807	0.9322 ± 0.0008
outba8	0.42	0.5521	0.42925	0.55	0.9330 ± 0.0008
outca1	0.42925	0.56426	0.4	0.48276	0.9314 ± 0.0008
outca2	0.42925	0.56426	0.4	0.525	0.9340 ± 0.0007
outca4	0.42925	0.56426	0.42	0.5069	0.9321 ± 0.0008
outca5	0.42925	0.56426	0.42	0.54	0.9339 ± 0.0007
outca7	0.42925	0.56426	0.42925	0.51807	0.9315 ± 0.0008
outca8	0.42925	0.56426	0.42925	0.55	0.9341 ± 0.0007

Attachment V

Table V-1. Excel Spreadsheets used in Engineering Calculations Stored in Electronic Format on Compact Disc (Ref. 7.12)

File Identifier	Description	File Size (Bytes)	Date Last Access	Sections Used
att5a.xls	Calculated Number Densities for N-Reactor Fuel Matrices	31,232	02/05/99 05:31p	All Sections in Section 5.0 were applicable
att5b.xls	Calculated Number Densities for H2O used in Interspersed Moderation Cases	16,896	02/05/99 02:171p	Section 5.2.2
att5c.xls	Calculated Number Densities for Placement of Carbon Steel within the MCO as a Moderator Exclusion Material	18,944	02/05/99 02:191p	Section 5.2.3
att5d.xls	Calculated Number Densities for the Dispersion of Uranium Solution at Various Concentrations throughout the MCO	23,040	02/05/99 02:20p	Section 5.2.6
att5e.xls	Calculated Number Densities and Volumes used in cases with no fuel in the center pipe and no central process tube evaluated, Zircaloy-2 evaluated as interspersed in the annular region	19,968	02/05/99 06:30p	Section 5.2.7
att5f.xls	Calculated Number Densities and Volumes used in cases with fuel in the center pipe and no central process tube evaluated, Zircaloy-2 evaluated as interspersed throughout MCO	18,944	02/05/99 04:35p	Section 5.2.7
att5g.xls	Calculated Number Densities and Volumes used in cases with fuel in the center pipe and central process tube evaluated, Zircaloy-2 evaluated as interspersed in the annular region only	19,456	02/05/99 04:38p	Sections 5.2.7- 5.2.12
att5h.xls	Calculated Number Densities and Volumes used in cases with fuel in the center pipe and central process tube evaluated, Zircaloy-2 evaluated as interspersed in the annular region only 0.25 cm radius particles	19,968	02/05/99 04:40p	Sections 5.2.7- 5.2.12

Attachment V-a. Calculation to Determine Fuel Matrix Volume Present in Mark 1A Fuel

Fuel Matrix - Inner Assembly

1. Radius Inner Edge of Inside Fuel Matrix (cm)	0.6225	
2. Radius Outer Edge of Inside Fuel Matrix (cm)	1.481	

Fuel Matrix - Outer Assembly

3. Radius Inner Edge of Outside Fuel Matrix (cm)	2.296	
4. Radius Outer Edge of Outside Fuel Matrix (cm)	2.9895	
Length of Fuel Region, L (cm)	52.0692	
Volume of Inner Fuel Assembly - Fuel Matrix Only (cm^3)		295.4021
Volume of Outer Fuel Assembly - Fuel Matrix Only (cm^3)		599.6023
Total Volume of Fuel Matrix - 1 Element (cm^3)		895.0045

All numbers from Ref. 7.5
Equation used to Calculate Volume
Volume (cm^3) = $(\pi \times (R_O)^2 \times L) - (\pi \times (R_I)^2 \times L)$

Number Densities For N-Reactor Fuel Matrices

N-Reactor Fuel - Mark 1A - Outer Assembly

Isotope	wt%	mass no. (M_A)	Number Density (N_x)
^{235}U	1.25	235.0439	6.08545E+20
^{238}U	98.7108	238.0508	4.7449E+22
^{236}U	0.0392	236.0456	1.9003E+19
	100		4.80765E+22

Formulas Used for Number Density Calculations

N_x = wt% x $\rho_{dens}(N_A/M_A)$ x 1 x 10^{-24} atoms/bn-cm

ρdens = 19.0 g/cm^3 (Reference 7.11)

N_A = 6.02252 x 10^{23} (Ref. 7.4, p. 30)

M_A (Ref. 7.4, p. 31)

N-Reactor Fuel - Mark 1A - Inner Assembly

Isotope	wt%	mass no. (M_A)	Number Density (N_x)
^{235}U	0.947	235.0439	4.61034E+20
^{238}U	99.0138	238.0508	4.75946E+22
^{236}U	0.0392	236.0456	1.9003E+19
	100		4.80747E+22

N-Reactor Fuel - Mark 1A - Weighted Average of Inner and Outer Assembly

Isotope	wt%	mass no. (M_A)	Number Density (N_x)
^{235}U	1.1518	235.0439	5.60738E+20
^{238}U	98.809	238.0508	4.74962E+22
^{236}U	0.0392	236.0456	1.9003E+19
	100		4.80759E+22

Calculation to Determine Amount of Zircaloy-2 Present in Mark 1A Fuel

Cladding - Inner Assembly

1. Radius Inner Edge of Inside Clad (cm)	0.559
2. Radius Outer Edge of Inside Clad (cm)	0.6225
3. Radius Inner Edge of Outside Clad (cm)	1.481
4. Radius Outer Edge of Outside Clad (cm)	1.5825

Cladding - Outer Assembly

5. Radius Inner Edge of Inside Clad (cm)	2.2405
6. Radius Outer Edge of Inside Clad (cm)	2.296
7. Radius Inner Edge of Outside Clad (cm)	2.9895
8. Radius Outer Edge of Outside Clad (cm)	3.053

Length of Fuel Region (cm)	52.0692
Length of End Pieces (cm)	0.483

Volume of Cladding Inner Assembly		Volume of Cladding Outer Assembly	
Inner Clad Volume (cm^3)	12.2726	Inner Clad Volume (cm^3)	41.1855
Outside Clad Volume (cm^3)	50.8645	Outside Clad Volume (cm^3)	62.7655
Total Vol of Clad - Inner Assembly (cm^3)	63.1371	Total Vol of Clad - Outer Assembly (cm^3)	103.9511

Volume of End Pieces	
Inner Assembly (cm^3)	6.6517
Outer Assembly (cm^3)	13.0525
Total Vol - End Pieces (cm^3)	19.7042

Total Volume of Zr Clad for a Single Element (cm^3)	186.7924

Attachment V-b. Calculated Number Densities for Reduced Density Interspersed Water Cases

% Density - H_2O	ρ_{H2O} (g/cm^3)	N^H (atoms/bn-cm)	N^O (atoms/bn-cm)	N^{TOT} (atoms/bn-cm)
100	1	6.6878E+22	3.3439E+22	1.00317E+23
90	0.9	6.01902E+22	3.00951E+22	9.02853E+22
80	0.8	5.35024E+22	2.67512E+22	8.02536E+22
70	0.7	4.68146E+22	2.34073E+22	7.02219E+22
60	0.6	4.01268E+22	2.00634E+22	6.01902E+22
50	0.5	3.3439E+22	1.67195E+22	5.01585E+22
40	0.4	2.67512E+22	1.33756E+22	4.01268E+22
30	0.3	2.00634E+22	1.00317E+22	3.00951E+22
20	0.2	1.33756E+22	6.6878E+21	2.00634E+22
15	0.15	1.00317E+22	5.01585E+21	1.50476E+22
10	0.1	6.6878E+21	3.3439E+21	1.00317E+22
5	0.05	3.3439E+21	1.67195E+21	5.01585E+21
1	0.01	6.6878E+20	3.3439E+20	1.00317E+21

Formula used to Calculate Number Densities

N^H @ Reduced Density = ρ_{H2O} x N^H @ 100% Density

N^O @ Reduced Density = ρ_{H2O} x N^O @ 100% Density

Number Densities for 100% Density H_2O (Ref. 7.4, p. I -19)

Attachment V-c. Number Density Calculations for Carbon Steel and Water Insert Filler Material

Calculated Number Densities for Interspersed Carbon Steel Cases

Theoretical Density Used (TD)

Grade 55 A 516 Carbon Steel (CS)	7.832 g/cm³ (Ref. 7.4, p. I-1)
Water (H_2O)	1.0 g/cm³ (Ref. 7.4, p. I-19)

Number Densities (atoms/bn-cm)

% TD CS	% TD H_2O	N^C	N^{Si}	N^P	N^S	N^{Mn}	N^{Fe}	N^H	N^O	N^{Total}
1.0000E+02	0.0000E+00	8.6395E-04	4.6184E-04	5.3300E-05	5.1635E-05	7.7272E-04	8.3223E-02	0.0000E+00	0.0000E+00	8.5426E-02
9.0000E+01	1.0000E+01	7.7756E-04	4.1566E-04	4.7970E-05	4.6472E-05	6.9545E-04	7.4901E-02	6.6878E-03	3.3439E-03	8.6916E-02
8.0000E+01	2.0000E+01	6.9116E-04	3.6947E-04	4.2640E-05	4.1308E-05	6.1818E-04	6.6578E-02	1.3376E-02	6.6878E-03	8.8405E-02
7.0000E+01	3.0000E+01	6.0477E-04	3.2329E-04	3.7310E-05	3.6145E-05	5.4090E-04	5.8256E-02	2.0063E-02	1.0032E-02	8.9894E-02
6.0000E+01	4.0000E+01	5.1837E-04	2.7710E-04	3.1980E-05	3.0981E-05	4.6363E-04	4.9934E-02	2.6751E-02	1.3376E-02	9.1383E-02
5.0000E+01	5.0000E+01	4.3198E-04	2.3092E-04	2.6650E-05	2.5818E-05	3.8636E-04	4.1612E-02	3.3439E-02	1.6720E-02	9.2872E-02
4.0000E+01	6.0000E+01	3.4558E-04	1.8474E-04	2.1320E-05	2.0654E-05	3.0909E-04	3.3289E-02	4.0127E-02	2.0063E-02	9.4361E-02
3.0000E+01	7.0000E+01	2.5919E-04	1.3855E-04	1.5990E-05	1.5491E-05	2.3182E-04	2.4967E-02	4.6815E-02	2.3407E-02	9.5850E-02
2.0000E+01	8.0000E+01	1.7279E-04	9.2368E-05	1.0660E-05	1.0327E-05	1.5454E-04	1.6645E-02	5.3502E-02	2.6751E-02	9.7339E-02
1.0000E+01	9.0000E+01	8.6395E-05	4.6184E-05	5.3300E-06	5.1635E-06	7.7272E-05	8.3223E-03	6.0190E-02	3.0095E-02	9.8828E-02
0.0000E+00	1.0000E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	6.6878E-02	3.3439E-02	1.0032E-01

Formulas used to calculate number densities

$N^i = N^i$ @ 100% TD x % TD CS or H_2O

Attachment V-d. Number Densities (atoms/bn-cm) For N-Reactor Fuel Dispersed In Solution Throughout Entire MCO

N-Reactor Fuel - Mark 1A - Weighted Average of Inner and Outer Assembly 1.15% Enriched

g/cm^3 fuel in sol	Isotope	wt%	mass no.	Number Densities	
0.01	235U	1.1518	235.0439	2.9513E+19	
	238U	98.809	238.0508	2.4998E+21	
	236U	0.0392	236.0456	1.0002E+18	
		100		2.5303E+21	$N^{U\ Total}$
Theo Dens of H_2O (g/cm^3)	H_2O				
1	H			6.6825E+22	
	O			3.3413E+22	
				1.0024E+23	$N^{H2O\ Total}$
				1.0277E+23	$N^{Total} = N^{U\ Total} + N^{H2O\ Total}$

N-Reactor Fuel - Mark 1A - Weighted Average of Inner and Outer Assembly 1.15% Enriched

g/cm^3 fuel in sol	Isotope	wt%	mass no.	Number Densities	
0.005	235U	1.1518	235.0439	1.47563E+19	
	238U	98.809	238.0508	1.2499E+21	
	236U	0.0392	236.0456	5.00079E+17	
		100		1.26516E+21	$N^{U\ Total}$

Theo Dens of H_2O (g/cm^3)	H_2O				
1	H			6.68427E+22	
	O			3.34214E+22	
				1.00264E+23	$N^{H2O\ Total}$
				1.01529E+23	$N^{Total} = N^{U\ Total} + N^{H2O\ Total}$

N-Reactor Fuel - Mark 1A - Weighted Average of Inner and Outer Assembly 1.15% Enriched

g/cm^3 fuel in sol	Isotope	wt%	mass no.	Number Densities	
0.001	235U	1.1518	235.0439	2.9513E+18	
	238U	98.809	238.0508	2.4998E+20	
	236U	0.0392	236.0456	1.0002E+17	
		100		2.5303E+20	$N^{U\ Total}$

Theo Dens of H_2O (g/cm^3)	H_2O		
1	H	6.6857E+22	
	O	3.3428E+22	
		1.0029E+23	$N^{H2O\ Total}$
		1.0054E+23	$N^{Total} = N^{U\ Total} + N^{H2O\ Total}$

N-Reactor Fuel - Mark 1A - Weighted Average of Inner and Outer Assembly 1.15% Enriched

g/cm³ fuel in sol	Isotope	wt%	mass no.	Number Densities	
0.0005	235U	1.1518	235.0439	1.4756E+18	
	238U	98.809	238.0508	1.2499E+20	
	236U	0.0392	236.0456	5.0008E+16	
		100		1.2652E+20	$N^{U\ Total}$
Theo Dens of H_2O (g/cm³)	H_2O				
1	H			6.6859E+22	
	O			3.3429E+22	
				1.0029E+23	$N^{H2O\ Total}$
				1.0041E+23	$N^{Total} = N^{U\ Total} + N^{H2O\ Total}$

N-Reactor Fuel - Mark 1A - Weighted Average of Inner and Outer Assembly 1.15% Enriched

g/cm³ fuel in sol	Isotope	wt%	mass no.	Number Densities	
0.0001	235U	1.1518	235.0439	2.9513E+17	
	238U	98.809	238.0508	2.4998E+19	
	236U	0.0392	236.0456	1.0002E+16	
		100		2.5303E+19	$N^{U\ Total}$

Theo Dens of H_2O (g/cm^3)	H_2O		
1	H	6.6860E+22	
	O	3.3430E+22	
		1.0029E+23	$N^{H2O\ Total}$
		1.0032E+23	$N^{Total} = N^{U\ Total} + N^{H2O\ Total}$

Formulas Used for Number Density Calculations

N^{Ui} = (g/cm^3 fuel in sol x wt % U_i x 6.02252) / M_A for U_i

N^{Oi} = (1000 - (g/cm^3 fuel in sol x 1000) / 18.882 g/cm^3))) x 6.022 x 10^{23} / 18.0152

N^{Hi} = 2 x N^{Oi}

All mass nos. (Ref. 7.11)

Attachment V-e. Volume Calculations of Mark 1A Fuel Inserts For H_2O-Zr Clad Cases - Center Pipe Not Filled, No Process Tube Modelled

Radius to Outside of Center Pipe (cm) (Ref. 7.7, Sketches 5 and 6)	8.41375	Theo. Dens. of Zircaloy-2 (g/cm^3)	6.56 (Ref. 7.4, p. I-16)
Radius to Inside Surface of Outer Insert Wall (cm) (Ref. 7.7, Sketches 5 and 6)	28.70708	Theo. Dens. of H_2O Used (g/cm^3)	1 (Ref. 7.4, p. I-19)
Inside height of Insert (cm) (Ref. 7.7, Sketches 5 and 6)	55.822		
Number of Fuel Elements	36	# of Elements in Center Pipe	0
Volume of Uranium Fuel Matrix from Single Element	895.0044	# of Elements in Annular Region	36
Volume of Zircaloy-2 Cladding from Single Element	169.1644		
Calculations for Fuel in Annular Region			
Volume of Fuel Elements Modelled - Fuel Matrix Only (cm^3)	32220.1584	Vol Frac of Zr	0.0609681
Volume of Zr Cladding from Mark 1A Fuel Elements Modelled (cm^3)	6089.9184		
Volume of Annular Region for Fuel in Insert (cm^3)	132107.131		
Volume of H_2O - Annular Insert Fuel Region (cm^3)	93797.05421		
Volume Available for H_2O and Zr - Annular Region (cm^3)	99886.97261		
Mass of Zircaloy-2 - Elements Modelled (g)	928.3412195		
Mass of Water in Annular Region (g)	93797.05421		
Density of H_2O in H_2O-Zr Mixture (g/cm^3)	0.939031905		
Density of Zr in H_2O-Zr Mixture (g/cm^3)	0.399950701		

Zircaloy-2 Number Densities (atoms/bn-cm)

Element	ρ_{theor} Zirc-2 (g/cm^3) 6.56	ρ_{act} Zirc-2 (g/cm^3) 0.399950701
O	2.9640E-04	1.8071E-05
Cr	7.5982E-05	4.6325E-06
Fe	7.0743E-05	4.3131E-06

H_2O Number Densities (atoms/bn-cm)

Element	ρ_{act} H_2O (g/cm^3) 0.939031905
O	3.1400E-02
H	6.2800E-02

Formulas Used

$N^i @ \rho_{act} = N^i @ \rho_{theor} \times \rho_{act}$

Zr	4.2544E-02	2.5938E-03	N^{Tot}	9.4201E-02
Ni	3.3647E-05	2.0514E-06		
Sn	4.6601E-04	2.8412E-05	$N^{O\,Tot}$	3.1418E-02
N^{Tot}	4.3487E-02	2.6513E-03	N^{Tot} Overall for H_2O-Zr mixture	9.6852E-02

Attachment V-f. Volume Calculations of Mark 1A Fuel Inserts For H_2O-Zr Clad Cases - Center Pipe Filled

Radius to Inside of Center Pipe (cm) (Ref. 7.7, Sketches 5 and 6)	6.21919
Radius to Outside of Center Pipe (cm) (Ref. 7.7, Sketches 5 and 6)	8.41375
Radius to Inside Surface of Outer Insert Wall (cm) (Ref. 7.7, Sketches 5 and 6)	28.70708
Inside height of Insert (cm) (Ref. 7.7, Sketches 5 and 6)	55.822
Volume of 48 Fuel Elements - Fuel Matrix Only (cm^3)	42960.211
Volume of Zr cladding from 48 Mark 1A Fuel Element (cm^3)	8966.0352
Volume of Void Region in Center Pipe (cm^3)	2162.243009
Volume of Annular Region for Fuel in Insert and Center Pipe (cm^3)	134269.374
Volume of H_2O - Annular Insert Fuel Region (cm^3)	82343.12782
Volume Available for H_2O and Zr - Annular Region (cm^3)	91309.16302
Density of H_2O in H_2O-Zr Mixture (g/cm^3)	0.901805745
Density of Zr in H_2O-Zr Mixture (g/cm^3)	0.64415431

Theor. Dens. of Zircaloy-2 (g/cm^3)	6.56	(Ref. 7.4, p. I-16)
Theo. Dens. of H_2O Used (g/cm^3)	1	(Ref. 7.4, p. I-19)

Formulas Used

$N^i @ \rho_{act} = N^i @ \rho_{theor} \times \rho_{act}$

Zircaloy-2 Number Densities (atoms/bn-cm)

Element	ρ_{theor} Zirc-2 (g/cm^3) 6.56	ρ_{act} Zirc-2 (g/cm^3) 0.6441
N^O	2.9640E-04	2.9105E-05
N^{Cr}	7.5982E-05	7.4610E-06
N^{Fe}	7.0743E-05	6.9466E-06
N^{Zr}	4.2544E-02	4.1776E-03
N^{Ni}	3.3647E-05	3.3039E-06
N^{Sn}	4.6601E-04	4.5760E-05

H_2O Number Densities (atoms/bn-cm)

Element	ρ_{act} H_2O (g/cm^3) 0.901
N^O	3.0155E-02
N^H	6.0310E-02
N^{Tot}	9.0466E-02
$N^{O\,Tot}$	3.0184E-02

N^{Tot}	4.3487E-02	4.2702E-03	N^{Tot} Overall for H_2O-Zr mixture	9.4736E-02

Attachment V-g. Volume Calculations of Mark 1A Fuel Inserts For H_2O-Zr Clad Cases - Center Pipe Filled Fuel Only, No Zr, Process Tube Modelled

Radius to Outside of Center Pipe (cm)	8.41375	Theo. Dens. of Zircaloy-2 (g/cm³)	6.56	(Ref. 7.4, p. I-16)
Radius to Inside Surface of Outer Insert Wall (cm)	28.70708	Theo. Dens. of H_2O Used (g/cm³)	1	(Ref. 7.4, p. I-19)
Inside height of Insert (cm)	55.822			
Number of Fuel Elements	38	# of Elements in Center Pipe	2	
Volume of Uranium fuel Matrix from single element	895.0044	# of Elements in Annular Region	36	
Volume of Zircaloy-2 Cladding from single element	169.1644			
Calculations for Fuel in Annular Region				
Volume of Fuel Elements Modelled - Fuel Matrix Only (cm³)	32220.1584	Formulas Used		
Volume of Zr cladding from Mark 1A Fuel Elements Modelled (cm³)	6428.2472			
Volume of Annular Region for Fuel in Insert (cm³)	132107.131	$N^i @ \rho_{act} = N^i @ \rho_{theor} \times \rho_{act}$		
Volume of H_2O - Annular Insert Fuel Region (cm³)	93458.72541			
Volume Available for H_2O and Zr - Annular Region (cm³)	99886.97261			
Mass of Zircaloy-2 - Elements Modelled (g)	979.9157317			
Mass of Water in Annular Region (g)	93458.72541			
Density of H_2O in H_2O-Zr Mixture (g/cm³)	0.935644789			
Density of Zr in H_2O-Zr Mixture (g/cm³)	0.422170184			

Zircaloy-2 Number Densities (atoms/bn-cm)

Element	ρ_{theor} Zirc-2 (g/cm³)	ρ_{act} Zirc-2 (g/cm³)
	6.56	0.422170184
N^O	2.9640E-04	1.9075E-05
N^{Cr}	7.5982E-05	4.8898E-06

H_2O Number Densities (atoms/bn-cm)

Element	ρ_{act} H_2O (g/cm³)
	0.935644789
N^O	3.1287E-02
N^H	6.2574E-02

N^{Fe}	7.0743E-05	4.5527E-06		
N^{Zr}	4.2544E-02	2.7379E-03	N^{Tot}	9.3861E-02
N^{Ni}	3.3647E-05	2.1654E-06		
N^{Sn}	4.6601E-04	2.9990E-05	$N^{O\ Tot}$	3.1306E-02
N^{Tot}	4.3487E-02	2.7986E-03	N^{Tot} Overall for H_2O-Zr mixture	9.6660E-02

Attachment V-h. Volume Calculations of Mark 1A Fuel Inserts For H_2O-Zr Clad Cases - Center Pipe Filled Fuel Only, No Zr, Process Tube Modelled, Fuel Spheres in Center Pipe Modelled at 0.25 cm Radius at a 0.2 cm E-E Spacing

Radius to Outside of Center Pipe (cm)	8.41375
Radius to Inside Surface of Outer Insert Wall (cm)	28.70708
Inside Height of Insert (cm)	55.822
Number of Fuel Elements	40
Volume of Uranium fuel Matrix from Single Element	895.0044
Volume of Zircaloy-2 Cladding from Single Element	169.1644
Calculations for Fuel In Annular Region	
Volume of Fuel Elements Modelled - Fuel Matrix Only (cm^3)	32220.1584
Volume of Zr Cladding from Mark 1A Fuel Elements Modelled (cm^3)	6766.576
Volume of Annular Region for Fuel in Insert (cm^3)	132107.131
Volume of H_2O - Annular Insert Fuel Region (cm^3)	93120.39661
Volume Available for H_2O and Zr - Annular Region (cm^3)	99886.97261
Mass of Zircaloy-2 - Elements Modelled (g)	1031.490244
Mass of Water In Annular Region (g)	93120.39661
Density of H_2O in H_2O-Zr Mixture (g/cm^3)	0.932257673
Density of Zr in H_2O-Zr Mixture (g/cm^3)	0.444389668

Theo. Dens. of Zircaloy-2 (g/cm^3)	6.56	(Ref. 7.4, p. I-16)
Theo. Dens. of H_2O Used (g/cm^3)	1	(Ref. 7.4, p. I-19)
# of Elements in Center Pipe	4	
# of Elements in Annular Region	36	
Vol Frac of Zirc-2 in Zirc-2 - Water Mix	0.067742327	

Formulas Used

$N^i @ \rho_{act} = N^i @ \rho_{theor} \times \rho_{act}$

Zircaloy-2 Number Densities (atoms/bn-cm)

Element	ρ_{theor} Zirc-2 (g/cm^3)	ρ_{act} Zirc-2 (g/cm^3)
	6.56	0.444389668
N^O	2.9640E-04	2.0079E-05

H_2O Number Densities (atoms/bn-cm)

Element	ρ_{act} H_2O (g/cm^3)
	0.932257673
N^O	3.1174E-02

N^{Cr}	7.5982E-05	5.1472E-06	N^{H}	6.2347E-02
N^{Fe}	7.0743E-05	4.7923E-06		
N^{Zr}	4.2544E-02	2.8820E-03	N^{Tot}	9.3521E-02
N^{Ni}	3.3647E-05	2.2793E-06		
N^{Sn}	4.6601E-04	3.1569E-05	$N^{O\ Tot}$	3.1194E-02
N^{Tot}	4.3487E-02	2.9459E-03	N^{Tot} Overall for H_2O-Zr mixture	9.6467E-02

Attachment VI
Table VI-1. Rev. 00A MCNP Inputs and Outputs used in Engineering Calculations Stored in Electronic Format on CD (Ref. 7.12)

File Size (bytes)	Date Last Access	File Name	Table Used
11,867	11-02-98 1:21p	ldp_mk1a_intact1	6-1
354,749	11-02-98 1:21p	ldp_mk1a_intact1.o	6-1
10,086	11-02-98 1:21p	ldp_mk4_intact1	6-1
365,249	11-02-98 1:21p	ldp_mk4_intact1.o	6-1
8,329	11-02-98 1:21p	mk1a_intact1	6-1
348,211	11-02-98 1:21p	mk1a_intact1.o	6-1
7,097	11-02-98 1:21p	mk4_intact1	6-1
346,702	11-02-98 1:21p	mk4_intact1.o	6-1
11,820	10-12-98 10:02a	ldp_mk1a_comb1a	6-2
369,698	10-12-98 10:02a	ldp_mk1a_comb1a.o	6-2
10,245	10-12-98 10:02a	ldp_mk4_comb1	6-2
368,800	10-12-98 10:02a	ldp_mk4_comb1.o	6-2
8,420	10-12-98 10:02a	mk1a_comb1a	6-2
352,439	10-12-98 10:02a	mk1a_comb1a.o	6-2
7,148	10-12-98 10:02a	mk4_comb1	6-2
348,850	10-12-98 10:02a	mk4_comb1.	6-2
11,849	11-02-98 1:45p	ldp_mk1a_spheres1a	6-3
365,455	11-02-98 1:45p	ldp_mk1a_spheres1a.o	6-3
10,300	11-02-98 1:45p	ldp_mk4_spheres1	6-3
364,805	11-02-98 1:45p	ldp_mk4_spheres1.o	6-3
8,435	11-02-98 1:45p	mk1a_spheres1a	6-3
350,483	11-02-98 1:45p	mk1a_spheres1a.o	6-3
8,715	10-12-98 10:02a	mk1a_spheres1b	6-3
348,033	10-12-98 10:02a	mk1a_spheres1b.o	6-3
7,183	11-02-98 1:45p	mk4_spheres1	6-3
345,798	11-02-98 1:45p	mk4_spheres1.o	6-3
8,600	10-12-98 10:03a	mk1a_h20_10%a	6-4
355,924	10-12-98 10:03a	mk1a_h20_10%a.o	6-4
8,600	10-12-98 10:03a	mk1a_h20_20%a	6-4
352,475	10-12-98 10:03a	mk1a_h20_20%a.o	6-4
8,600	10-12-98 10:03a	mk1a_h20_30%a	6-4
352,673	10-12-98 10:03a	mk1a_h20_30%a.o	6-4
8,601	10-12-98 10:03a	mk1a_h20_40%a	6-4
353,394	10-12-98 10:03a	mk1a_h20_40%a.o	6-4

File Size (bytes)	Date Last Access	File Name	Table Used
8,600	10-12-98 10:03a	mk1a_h20_50%a	6-4
353,308	10-12-98 10:03a	mk1a_h20_50%a.o	6-4
8,600	10-12-98 10:03a	mk1a_h20_60%a	6-4
352,672	10-12-98 10:03a	mk1a_h20_60%a.o	6-4
8,600	10-12-98 10:03a	mk1a_h20_70%a	6-4
352,672	10-12-98 10:03a	mk1a_h20_70%a.o	6-4
8,600	10-12-98 10:03a	mk1a_h20_80%a	6-4
350,566	10-12-98 10:03a	mk1a_h20_80%a.o	6-4
8,600	10-12-98 10:03a	mk1a_h20_90%a	6-4
350,530	10-12-98 10:03a	mk1a_h20_90%a.o	6-4
8,435	10-12-98 10:03a	mkla_spheres1	6-4
12,017	11-02-98 1:49p	ldp_mk1a_h2o_0%a	6-5
368,652	11-02-98 1:49p	ldp_mk1a_h2o_0%a.o	6-5
12,030	11-02-98 1:49p	ldp_mk1a_h2o_10%a	6-5
368,548	11-02-98 1:49p	ldp_mk1a_h2o_10%a.o	6-5
12,030	11-02-98 1:49p	ldp_mk1a_h2o_20%a	6-5
368,541	11-02-98 1:49p	ldp_mk1a_h2o_20%a.o	6-5
12,030	11-02-98 1:49p	ldp_mk1a_h2o_30%a	6-5
369,821	11-02-98 1:49p	ldp_mk1a_h2o_30%a.o	6-5
12,030	11-02-98 1:49p	ldp_mk1a_h2o_40%a	6-5
369,821	11-02-98 1:49p	ldp_mk1a_h2o_40%a.o	6-5
12,030	11-02-98 1:49p	ldp_mk1a_h2o_50%a	6-5
369,821	11-02-98 1:50p	ldp_mk1a_h2o_50%a.o	6-5
12,030	11-02-98 1:50p	ldp_mk1a_h2o_60%a	6-5
368,669	11-02-98 1:50p	ldp_mk1a_h2o_60%a.o	6-5
12,030	11-02-98 1:50p	ldp_mk1a_h2o_70%a	6-5
368,633	11-02-98 1:50p	ldp_mk1a_h2o_70%a.o	6-5
12,030	11-02-98 1:50p	ldp_mk1a_h2o_80%a	6-5
368,669	11-02-98 1:50p	ldp_mk1a_h2o_80%a.o	6-5
12,030	11-02-98 1:50p	ldp_mk1a_h2o_90%a	6-5
368,669	11-02-98 1:50p	ldp_mk1a_h2o_90%a.o	6-5
11,847	11-02-98 1:50p	ldp_mk1a_spheres1	6-5
8,864	11-02-98 1:50p	mk1a_sphr_cs10%a	6-6
351,007	11-02-98 1:50p	mk1a_sphr_cs10%a.o	6-6
8,866	11-02-98 1:50p	mk1a_sphr_cs20%a	6-6
352,195	11-02-98 1:50p	mk1a_sphr_cs20%a.o	6-6
8,864	11-02-98 1:50p	mk1a_sphr_cs30%a	6-6
352,003	11-02-98 1:50p	mk1a_sphr_cs30%a.o	6-6
8,866	11-02-98 1:50p	mk1a_sphr_cs40%a	6-6
352,297	11-02-98 1:50p	mk1a_sphr_cs40%a.o	6-6
8,864	11-02-98 1:50p	mk1a_sphr_cs50%a	6-6

File Size (bytes)	Date Last Access	File Name	Table Used
353,155	11-02-98 1:50p	mk1a_sphr_cs50%a.o	6-6
8,864	11-02-98 1:50p	mk1a_sphr_cs60%a	6-6
353,791	11-02-98 1:50p	mk1a_sphr_cs60%a.o	6-6
8,864	11-02-98 1:50p	mk1a_sphr_cs70%a	6-6
355,063	11-02-98 1:50p	mk1a_sphr_cs70%a.o	6-6
8,864	11-02-98 1:50p	mk1a_sphr_cs80%a	6-6
356,335	11-02-98 1:50p	mk1a_sphr_cs80%a.o	6-6
8,864	11-02-98 1:50p	mk1a_sphr_cs90%a	6-6
357,925	11-02-98 1:50p	mk1a_sphr_cs90%a.o	6-6
8,824	11-02-98 1:50p	mk1a_intact_cs10%a	6-7
348,504	11-02-98 1:50p	mk1a_intact_cs10%a.o	6-7
8,824	11-02-98 1:50p	mk1a_intact_cs20%a	6-7
348,504	11-02-98 1:51p	mk1a_intact_cs20%a.o	6-7
8,824	11-02-98 1:51p	mk1a_intact_cs30%a	6-7
372,305	11-02-98 1:51p	mk1a_intact_cs30%a.o	6-7
8,824	11-02-98 1:51p	mk1a_intact_cs40%a	6-7
347,220	11-02-98 1:51p	mk1a_intact_cs40%a.o	6-7
8,824	11-02-98 1:51p	mk1a_intact_cs50%a	6-7
348,408	11-02-98 1:51p	mk1a_intact_cs50%a.o	6-7
8,824	11-02-98 1:51p	mk1a_intact_cs60%a	6-7
346,164	11-02-98 1:51p	mk1a_intact_cs60%a.o	6-7
8,824	11-02-98 1:51p	mk1a_intact_cs70%a	6-7
348,504	11-02-98 1:51p	mk1a_intact_cs70%a.o	6-7
8,824	11-02-98 1:51p	mk1a_intact_cs80%a	6-7
348,504	11-02-98 1:51p	mk1a_intact_cs80%a.o	6-7
8,824	11-02-98 1:51p	mk1a_intact_cs90%a	6-7
339,389	11-02-98 1:51p	mk1a_intact_cs90%a.o	6-7
8,825	11-02-98 1:51p	mk1a_ncp_cs10%a	6-8
350,271	11-02-98 1:51p	mk1a_ncp_cs10%a.o	6-8
8,824	11-02-98 1:51p	mk1a_ncp_cs20%a	6-8
351,459	11-02-98 1:51p	mk1a_ncp_cs20%a.o	6-8
8,824	11-02-98 1:51p	mk1a_ncp_cs30%a	6-8
350,589	11-02-98 1:51p	mk1a_ncp_cs30%a.o	6-8
8,824	11-02-98 1:51p	mk1a_ncp_cs40%a	6-8
350,582	11-02-98 1:51p	mk1a_ncp_cs40%a.o	6-8
8,824	11-02-98 1:51p	mk1a_ncp_cs50%a	6-8
352,731	11-02-98 1:51p	mk1a_ncp_cs50%a.o	6-8
8,824	11-02-98 1:51p	mk1a_ncp_cs60%a	6-8
352,732	11-02-98 1:51p	mk1a_ncp_cs60%a.o	6-8
8,827	11-02-98 1:51p	mk1a_ncp_cs70%a	6-8
356,004	11-02-98 1:51p	mk1a_ncp_cs70%a.o	6-8

File Size (bytes)	Date Last Access	File Name	Table Used
8,824	11-02-98 1:51p	mk1a_ncp_cs80%a	6-8
357,492	11-02-98 1:51p	mk1a_ncp_cs80%a.o	6-8
8,824	11-02-98 1:51p	mk1a_ncp_cs90%a	6-8
359,655	11-02-98 1:51p	mk1a_ncp_cs90%a.o	6-8
8,394	11-02-98 1:51p	mk1a_ncp_h2oa	6-8
350,598	11-02-98 1:51p	mk1a_ncp_h2oa.o	6-8
8,493	11-02-98 1:52p	mk1a_deg_cp_filla	6-9
349,432	11-02-98 1:52p	mk1a_deg_cp_filla.o	6-9
8,584	11-02-98 1:52p	mk1a_deg_cp_offa	6-9
350,670	11-02-98 1:52p	mk1a_deg_cp_offa.o	6-9
8,770	11-02-98 1:52p	mk1a_deg_0.0001gcca	6-10
352,032	11-02-98 1:52p	mk1a_deg_0.0001gcca.o	6-10
8,770	11-02-98 1:52p	mk1a_deg_0.0005gcca	6-10
350,936	11-02-98 1:52p	mk1a_deg_0.0005gcca.o	6-10
8,769	11-02-98 1:52p	mk1a_deg_0.001gcca	6-10
352,130	11-02-98 1:52p	mk1a_deg_0.001gcca.o	6-10
8,769	11-02-98 1:52p	mk1a_deg_0.005gcca	6-10
350,324	11-02-98 1:52p	mk1a_deg_0.005gcca.o	6-10
8,767	11-02-98 1:52p	mk1a_deg_0.01gcca	6-10
350,194	11-02-98 1:52p	mk1a_deg_0.01gcca.o	6-10
12,438	11-02-98 1:52p	ldp_mk1a_cpfill_zr_h2o0%b	6-11
372,950	11-02-98 1:52p	ldp_mk1a_cpfill_zr_h2o0%b.o	6-11
12,509	11-02-98 1:53p	ldp_mk1a_zr_h2o0%c	6-11
371,812	11-02-98 1:53p	ldp_mk1a_zr_h2o0%c.o	6-11
12,626	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss1.0a	6-12
372,335	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss1.0a.o	6-12
12,626	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss2.0a	6-12
372,335	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss2.0a.o	6-12
12,626	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss3.0a	6-12
372,335	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss3.0a.o	6-12
12,626	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss4.0a	6-12
374,490	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss4.0a.o	6-12
14,435	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss2.0gd.01a	6-13
372,682	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss2.0gd.01a.o	6-13
14,432	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss2.0gd0.1a	6-13
378,095	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss2.0gd0.1a.o	6-13
14,435	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss2.0gd1.0a	6-13
379,615	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss2.0gd1.0a.o	6-13

File Size (bytes)	Date Last Access	File Name	Table Used
14,435	11-02-98 1:54p	ldp_mk1a_cpfill_zr_ss2.0gd.01a	6-14
372,682	11-02-98 1:54p	ldp_mk1a_cpfill_zr_ss2.0gd.01a.o	6-14
14,432	11-02-98 1:54p	ldp_mk1a_cpfill_zr_ss2.0gd0.1a	6-14
378,095	11-02-98 1:54p	ldp_mk1a_cpfill_zr_ss2.0gd0.1a.o	6-14
14,435	11-02-98 1:54p	ldp_mk1a_cpfill_zr_ss2.0gd1.0a	6-14
379,615	11-02-98 1:54p	ldp_mk1a_cpfill_zr_ss2.0gd1.0a.o	6-14
14,068	11-02-98 1:54p	ldp_mk1a_cpfill_zr_ss2.0_gd0.01b	6-15
373,161	11-02-98 1:54p	ldp_mk1a_cpfill_zr_ss2.0_gd0.01b.o	6-15
14,065	11-02-98 1:54p	ldp_mk1a_cpfill_zr_ss2.0_gd0.1b	6-15
373,175	11-02-98 1:54p	ldp_mk1a_cpfill_zr_ss2.0_gd0.1b.o	6-15
14,067	11-02-98 1:54p	ldp_mk1a_cpfill_zr_ss2.0_gd1.0b	6-15
373,175	11-02-98 1:54p	ldp_mk1a_cpfill_zr_ss2.0_gd1.0b.o	6-15
14,227	11-02-98 1:55p	ldp_mk1a_cpfill_zr_ss2.0_gd0.01c	6-16
373,842	11-02-98 1:55p	ldp_mk1a_cpfill_zr_ss2.0_gd0.01c.o	6-16
14,224	11-02-98 1:55p	ldp_mk1a_cpfill_zr_ss2.0_gd0.1c	6-16
372,688	11-02-98 1:55p	ldp_mk1a_cpfill_zr_ss2.0_gd0.1c.o	6-16
14,225	11-02-98 1:55p	ldp_mk1a_cpfill_zr_ss2.0_gd1.0c	6-16
377,022	11-02-98 1:55p	ldp_mk1a_cpfill_zr_ss2.0_gd1.0c.o	6-16
14,308	11-02-98 1:55p	ldp_mk1a_cpfill_zr_ss2.0_gd1.0d	6-16
373,298	11-02-98 1:55p	ldp_mk1a_cpfill_zr_ss2.0_gd1.0d.o	6-16
10,647	11-02-98 1:55p	b4cwp	6-17
362,900	11-02-98 1:55p	b4cwpo	6-17
11,093	11-02-98 1:55p	inp42b	6-17
364,472	11-02-98 1:55p	inp42bo	6-17
11,132	11-02-98 1:55p	inp42c	6-17
364,619	11-02-98 1:55p	inp42co	6-17
11,178	11-02-98 1:55p	inp42d	6-17
364,695	11-02-98 1:55p	inp42do	6-17
10,803	11-02-98 1:55p	b4cmco	6-18
11,043	11-02-98 1:55p	b4cmcoa	6-18
366,168	11-02-98 1:55p	b4cmcoao	6-18
11,042	11-02-98 1:55p	b4cmcob	6-18
367,164	11-02-98 1:55p	b4cmcobo	6-18
364,351	11-02-98 1:55p	b4cmcoo	6-18
1,392	11-02-98 11:48a	0.9cm	Appendix I-1
347,971	11-02-98 11:48a	0.9cm.o	Appendix I-1
1,392	11-02-98 11:48a	1.0cm	Appendix I-1

File Size (bytes)	Date Last Access	File Name	Table Used
347,971	11-02-98 11:48a	1.0cm.o	Appendix I-1
1,388	11-02-98 11:48a	1.1cm	Appendix I-1
347,872	11-02-98 11:48a	1.1cm.o	Appendix I-1
1,395	11-02-98 11:48a	1.2cm	Appendix I-1
346,783	11-02-98 11:48a	1.2cm.o	Appendix I-1
1,390	11-02-98 11:48a	1.3cm	Appendix I-1
347,872	11-02-98 11:48a	1.3cm.o	Appendix I-1
1,394	11-02-98 11:48a	1.4cm	Appendix I-1
348,094	11-02-98 11:48a	1.4cm.o	Appendix I-1
1,393	11-02-98 11:48a	1.5cm	Appendix I-1
348,289	11-02-98 11:48a	1.5cm.o	Appendix I-1
1,394	11-02-98 11:48a	1.6cm	Appendix I-1
348,607	11-02-98 11:48a	1.6cm.o	Appendix I-1
1,392	11-02-98 11:48a	1.7cm	Appendix I-1
348,607	11-02-98 11:48a	1.7cm.o	Appendix I-1
1,387	11-02-98 11:49a	0.85cm	Appendix I-2
347,011	11-02-98 11:49a	0.85cm.o	Appendix I-2
1,389	11-02-98 11:49a	0.9cm	Appendix I-2
347,875	11-02-98 11:49a	0.9cm.o	Appendix I-2
1,391	11-02-98 11:49a	1.0cm	Appendix I-2
347,011	11-02-98 11:49a	1.0cm.o	Appendix I-2
1,390	11-02-98 11:49a	1.1cm	Appendix I-2
346,912	11-02-98 11:49a	1.1cm.o	Appendix I-2
1,389	11-02-98 11:49a	1.2cm	Appendix I-2
347,776	11-02-98 11:49a	1.2cm.o	Appendix I-2
1,387	11-02-98 11:49a	1.3cm	Appendix I-2
347,971	11-02-98 11:49a	1.3cm.o	Appendix I-2
1,391	11-02-98 11:49a	1.4cm	Appendix I-2
348,190	11-02-98 11:49a	1.4cm.o	Appendix I-2
1,387	11-02-98 11:49a	1.5cm	Appendix I-2
347,137	11-02-98 11:49a	1.5cm.o	Appendix I-2
1,389	11-02-98 11:49a	1.6cm	Appendix I-2
348,607	11-02-98 11:49a	1.6cm.o	Appendix I-2
1,391	11-02-98 11:50a	0.85cm	Appendix I-3
347,966	11-02-98 11:50a	0.85cm.o	Appendix I-3
1,389	11-02-98 11:50a	0.9cm	Appendix I-3
348,608	11-02-98 11:50a	0.9cm.o	Appendix I-3
1,392	11-02-98 11:50a	1.0cm	Appendix I-3
347,420	11-02-98 11:50a	1.0cm.o	Appendix I-3
1,390	11-02-98 11:50a	1.1cm	Appendix I-3
348,512	11-02-98 11:50a	1.1cm.o	Appendix I-3

File Size (bytes)	Date Last Access	File Name	Table Used
1,387	11-02-98 11:50a	1.2cm	Appendix I-3
348,827	11-02-98 11:50a	1.2cm.o	Appendix I-3
1,389	11-02-98 11:50a	1.3cm	Appendix I-3
348,830	11-02-98 11:50a	1.3cm.o	Appendix I-3
1,387	11-02-98 11:50a	1.4cm	Appendix I-3
349,148	11-02-98 11:50a	1.4cm.o	Appendix I-3
1,389	11-02-98 11:50a	1.5cm	Appendix I-3
348,374	11-02-98 11:50a	1.5cm.o	Appendix I-3
1,389	11-02-98 11:50a	1.6cm	Appendix I-3
349,880	11-02-98 11:50a	1.6cm.o	Appendix I-3
1,391	11-02-98 11:50a	0.8cm	Appendix I-4
348,926	11-02-98 11:50a	0.8cm.o	Appendix I-4
1,388	11-02-98 11:50a	0.9cm	Appendix I-4
348,509	11-02-98 11:50a	0.9cm.o	Appendix I-4
1,390	11-02-98 11:50a	1.0cm	Appendix I-4
346,252	11-02-98 11:50a	1.0cm.o	Appendix I-4
1,390	11-02-98 11:50a	1.1cm	Appendix I-4
347,671	11-02-98 11:50a	1.1cm.o	Appendix I-4
1,391	11-02-98 11:50a	1.2cm	Appendix I-4
348,731	11-02-98 11:50a	1.2cm.o	Appendix I-4
1,383	11-02-98 11:50a	1.3cm	Appendix I-4
349,049	11-02-98 11:50a	1.3cm.o	Appendix I-4
1,390	11-02-98 11:50a	1.4cm	Appendix I-4
349,244	11-02-98 11:51a	1.4cm.o	Appendix I-4
1,389	11-02-98 11:51a	1.5cm	Appendix I-4
349,562	11-02-98 11:51a	1.5cm.o	Appendix I-4
1,391	11-02-98 11:51a	1.6cm	Appendix I-4
349,880	11-02-98 11:51a	1.6cm.o	Appendix I-4
1,390	11-02-98 11:51a	0.8cm	Appendix I-5
349,242	11-02-98 11:51a	0.8cm.o	Appendix I-5
1,388	11-02-98 11:51a	0.9cm	Appendix I-5
347,736	11-02-98 11:51a	0.9cm.o	Appendix I-5
1,384	11-02-98 11:51a	1.0cm	Appendix I-5
348,828	11-02-98 11:51a	1.0cm.o	Appendix I-5
1,387	11-02-98 11:51a	1.1cm	Appendix I-5
349,146	11-02-98 11:51a	1.1cm.o	Appendix I-5
1,380	11-02-98 11:51a	1.2cm	Appendix I-5
349,047	11-02-98 11:51a	1.2cm.o	Appendix I-5
1,385	11-02-98 11:51a	1.3cm	Appendix I-5
348,408	11-02-98 11:51a	1.3cm.o	Appendix I-5
1,390	11-02-98 11:51a	1.4cm	Appendix I-5

File Size (bytes)	Date Last Access	File Name	Table Used
349,878	11-02-98 11:51a	1.4cm.o	Appendix I-5
1,389	11-02-98 11:51a	1.5cm	Appendix I-5
350,100	11-02-98 11:51a	1.5cm.o	Appendix I-5
1,386	11-02-98 11:51a	1.6cm	Appendix I-5
350,514	11-02-98 11:51a	1.6cm.o	Appendix I-5
1,389	11-02-98 11:52a	0.8cm	Appendix I-6
346,584	11-02-98 11:52a	0.8cm.o	Appendix I-6
1,387	11-02-98 11:52a	0.9cm	Appendix I-6
348,924	11-02-98 11:52a	0.9cm.o	Appendix I-6
1,390	11-02-98 11:52a	1.0cm	Appendix I-6
348,924	11-02-98 11:52a	1.0cm.o	Appendix I-6
1,385	11-02-98 11:52a	1.1cm	Appendix I-6
347,958	11-02-98 11:52a	1.1cm.o	Appendix I-6
1,391	11-02-98 11:52a	1.2cm	Appendix I-6
349,461	11-02-98 11:52a	1.2cm.o	Appendix I-6
1,388	11-02-98 11:52a	1.3cm	Appendix I-6
348,726	11-02-98 11:52a	1.3cm.o	Appendix I-6
1,388	11-02-98 11:52a	1.4cm	Appendix I-6
350,196	11-02-98 11:52a	1.4cm.o	Appendix I-6
1,389	11-02-98 11:52a	1.5cm	Appendix I-6
345,675	12-08-98 9:10a	1.5cm.o	Appendix I-6
1,389	11-02-98 11:52a	1.6cm	Appendix I-6
350,832	11-02-98 11:52a	1.6cm.o	Appendix I-6
1,387	11-02-98 11:52a	0.7cm	Appendix I-7
347,937	11-02-98 11:52a	0.7cm.o	Appendix I-7
1,391	11-02-98 11:52a	0.8cm	Appendix I-7
347,739	11-02-98 11:52a	0.8cm.o	Appendix I-7
1,387	11-02-98 11:52a	0.9cm	Appendix I-7
348,609	11-02-98 11:53a	0.9cm.o	Appendix I-7
1,386	11-02-98 11:53a	1.0cm	Appendix I-7
348,828	11-02-98 11:53a	1.0cm.o	Appendix I-7
1,389	11-02-98 11:53a	1.1cm	Appendix I-7
347,994	11-02-98 11:53a	1.1cm.o	Appendix I-7
1,377	11-02-98 11:53a	1.2cm	Appendix I-7
349,563	11-02-98 11:53a	1.2cm.o	Appendix I-7
1,384	11-02-98 11:53a	1.3cm	Appendix I-7
349,563	11-02-98 11:53a	1.3cm.o	Appendix I-7
1,389	11-02-98 11:53a	1.4cm	Appendix I-7
348,729	11-02-98 11:53a	1.4cm.o	Appendix I-7
1,388	11-02-98 11:53a	1.5cm	Appendix I-7
350,199	11-02-98 11:53a	1.5cm.o	Appendix I-7

File Size (bytes)	Date Last Access	File Name	Table Used
1,392	11-02-98 11:53a	0.9cm	Appendix II-1
347,971	11-02-98 11:53a	0.9cm.o	Appendix II-1
1,395	11-02-98 11:53a	1.05cm	Appendix II-1
346,981	11-02-98 11:53a	1.05cm.o	Appendix II-1
1,392	11-02-98 11:53a	1.0cm	Appendix II-1
347,971	11-02-98 11:53a	1.0cm.o	Appendix II-1
1,396	11-02-98 11:53a	1.15cm	Appendix II-1
347,011	11-02-98 11:53a	1.15cm.o	Appendix II-1
1,388	11-02-98 11:53a	1.1cm	Appendix II-1
347,872	11-02-98 11:53a	1.1cm.o	Appendix II-1
1,395	11-02-98 11:53a	1.2cm	Appendix II-1
346,783	11-02-98 11:53a	1.2cm.o	Appendix II-1
365,334	11-02-98 11:54a	outaa	Appendix III-1
366,304	11-02-98 11:54a	outaax	Appendix III-1
366,637	11-02-98 11:54a	outnewta	Appendix III-1
364,481	11-02-98 11:54a	outubea	Appendix III-1
353,842	11-02-98 11:54a	outaa1	Appendix IV-1
354,994	11-02-98 11:55a	outaa2	Appendix IV-1
355,001	11-02-98 11:55a	outaa4	Appendix IV-1
353,849	11-02-98 11:55a	outaa5	Appendix IV-1
354,994	11-02-98 11:55a	outaa7	Appendix IV-1
354,041	11-02-98 11:55a	outaa8	Appendix IV-1
357,045	11-02-98 11:55a	outba1	Appendix IV-1
360,655	11-02-98 11:55a	outba2	Appendix IV-1
356,832	11-02-98 11:55a	outba4	Appendix IV-1
355,872	11-02-98 11:55a	outba7	Appendix IV-1
358,224	11-02-98 11:55a	outba8	Appendix IV-1
355,680	11-02-98 11:55a	outca1	Appendix IV-1
355,001	11-02-98 11:55a	outca2	Appendix IV-1
356,832	11-02-98 11:55a	outca4	Appendix IV-1
355,001	11-02-98 11:55a	outca5	Appendix IV-1
356,832	11-02-98 11:55a	outca7	Appendix IV-1
354,994	11-02-98 11:55a	outca8	Appendix IV-1

Attachment VII

Table VII-1. Rev. 00B MCNP Inputs and Outputs used in Engineering Calculations Stored in Electronic Format on CD (Ref. 7.12)

File Size (bytes)	Date Last Access	File Name	Table Used
11,867	11-02-98 1:21p	ldp_mk1a_intact1	6-1
354,749	11-02-98 1:21p	ldp_mk1a_intact1.o	6-1
10,086	11-02-98 1:21p	ldp_mk4_intact1	6-1
365,249	11-02-98 1:21p	ldp_mk4_intact1.o	6-1
8,329	11-02-98 1:21p	mk1a_intact1	6-1
348,211	11-02-98 1:21p	mk1a_intact1.o	6-1
7,097	11-02-98 1:21p	mk4_intact1	6-1
346,702	11-02-98 1:21p	mk4_intact1.o	6-1
11,820	10-12-98 10:02a	ldp_mk1a_comb1a	6-2
369,698	10-12-98 10:02a	ldp_mk1a_comb1a.o	6-2
10,245	10-12-98 10:02a	ldp_mk4_comb1	6-2
368,800	10-12-98 10:02a	ldp_mk4_comb1.o	6-2
8,420	10-12-98 10:02a	mk1a_comb1a	6-2
352,439	10-12-98 10:02a	mk1a_comb1a.o	6-2
7,148	10-12-98 10:02a	mk4_comb1	6-2
348,850	10-12-98 10:02a	mk4_comb1.	6-2
11,849	11-02-98 1:45p	ldp_mk1a_spheres1a	6-3
365,455	11-02-98 1:45p	ldp_mk1a_spheres1a.o	6-3
10,300	11-02-98 1:45p	ldp_mk4_spheres1	6-3
364,805	11-02-98 1:45p	ldp_mk4_spheres1.o	6-3
10,007	12-07-98 1:05p	ldp_mk4_spheres1a	6-3
359,447	12-07-98 1:05p	ldp_mk4_spheres1a.o	6-3
8,435	11-02-98 1:45p	mk1a_spheres1a	6-3
350,483	11-02-98 1:45p	mk1a_spheres1a.o	6-3
8,715	10-12-98 10:02a	mk1a_spheres1b	6-3
348,033	10-12-98 10:02a	mk1a_spheres1b.o	6-3
7,183	11-02-98 1:45p	mk4_spheres1	6-3
345,798	11-02-98 1:45p	mk4_spheres1.o	6-3
8,600	10-12-98 10:03a	mk1a_h20_10%a	6-4
355,924	10-12-98 10:03a	mk1a_h20_10%a.o	6-4
8,600	10-12-98 10:03a	mk1a_h20_20%a	6-4
352,475	10-12-98 10:03a	mk1a_h20_20%a.o	6-4
8,600	10-12-98 10:03a	mk1a_h20_30%a	6-4

File Size (bytes)	Date Last Access	File Name	Table Used
352,673	10-12-98 10:03a	mk1a_h20_30%a.o	6-4
8,601	10-12-98 10:03a	mk1a_h20_40%a	6-4
353,394	10-12-98 10:03a	mk1a_h20_40%a.o	6-4
8,600	10-12-98 10:03a	mk1a_h20_50%a	6-4
353,308	10-12-98 10:03a	mk1a_h20_50%a.o	6-4
8,600	10-12-98 10:03a	mk1a_h20_60%a	6-4
352,672	10-12-98 10:03a	mk1a_h20_60%a.o	6-4
8,600	10-12-98 10:03a	mk1a_h20_70%a	6-4
352,672	10-12-98 10:03a	mk1a_h20_70%a.o	6-4
8,600	10-12-98 10:03a	mk1a_h20_80%a	6-4
350,566	10-12-98 10:03a	mk1a_h20_80%a.o	6-4
8,600	10-12-98 10:03a	mk1a_h20_90%a	6-4
350,530	10-12-98 10:03a	mk1a_h20_90%a.o	6-4
8,435	10-12-98 10:03a	mkla_spheres1	6-4
12,017	11-02-98 1:49p	ldp_mk1a_h2o_0%a	6-5
368,652	11-02-98 1:49p	ldp_mk1a_h2o_0%a.o	6-5
12,030	11-02-98 1:49p	ldp_mk1a_h2o_10%a	6-5
368,548	11-02-98 1:49p	ldp_mk1a_h2o_10%a.o	6-5
12,030	11-02-98 1:49p	ldp_mk1a_h2o_20%a	6-5
368,541	11-02-98 1:49p	ldp_mk1a_h2o_20%a.o	6-5
12,030	11-02-98 1:49p	ldp_mk1a_h2o_30%a	6-5
369,821	11-02-98 1:49p	ldp_mk1a_h2o_30%a.o	6-5
12,030	11-02-98 1:49p	ldp_mk1a_h2o_40%a	6-5
369,821	11-02-98 1:49p	ldp_mk1a_h2o_40%a.o	6-5
12,030	11-02-98 1:49p	ldp_mk1a_h2o_50%a	6-5
369,821	11-02-98 1:50p	ldp_mk1a_h2o_50%a.o	6-5
12,030	11-02-98 1:50p	ldp_mk1a_h2o_60%a	6-5
368,669	11-02-98 1:50p	ldp_mk1a_h2o_60%a.o	6-5
12,030	11-02-98 1:50p	ldp_mk1a_h2o_70%a	6-5
368,633	11-02-98 1:50p	ldp_mk1a_h2o_70%a.o	6-5
12,030	11-02-98 1:50p	ldp_mk1a_h2o_80%a	6-5
368,669	11-02-98 1:50p	ldp_mk1a_h2o_80%a.o	6-5
12,030	11-02-98 1:50p	ldp_mk1a_h2o_90%a	6-5
368,669	11-02-98 1:50p	ldp_mk1a_h2o_90%a.o	6-5
11,847	11-02-98 1:50p	ldp_mk1a_spheres1	6-5
8,864	11-02-98 1:50p	mk1a_sphr_cs10%a	6-6
351,007	11-02-98 1:50p	mk1a_sphr_cs10%a.o	6-6
8,866	11-02-98 1:50p	mk1a_sphr_cs20%a	6-6
352,195	11-02-98 1:50p	mk1a_sphr_cs20%a.o	6-6
8,864	11-02-98 1:50p	mk1a_sphr_cs30%a	6-6
352,003	11-02-98 1:50p	mk1a_sphr_cs30%a.o	6-6

File Size (bytes)	Date Last Access	File Name	Table Used
8,866	11-02-98 1:50p	mk1a_sphr_cs40%a	6-6
352,297	11-02-98 1:50p	mk1a_sphr_cs40%a.o	6-6
8,864	11-02-98 1:50p	mk1a_sphr_cs50%a	6-6
353,155	11-02-98 1:50p	mk1a_sphr_cs50%a.o	6-6
8,864	11-02-98 1:50p	mk1a_sphr_cs60%a	6-6
353,791	11-02-98 1:50p	mk1a_sphr_cs60%a.o	6-6
8,864	11-02-98 1:50p	mk1a_sphr_cs70%a	6-6
355,063	11-02-98 1:50p	mk1a_sphr_cs70%a.o	6-6
8,864	11-02-98 1:50p	mk1a_sphr_cs80%a	6-6
356,335	11-02-98 1:50p	mk1a_sphr_cs80%a.o	6-6
8,864	11-02-98 1:50p	mk1a_sphr_cs90%a	6-6
357,925	11-02-98 1:50p	mk1a_sphr_cs90%a.o	6-6
8,824	11-02-98 1:50p	mk1a_intact_cs10%a	6-7
348,504	11-02-98 1:50p	mk1a_intact_cs10%a.o	6-7
8,824	11-02-98 1:50p	mk1a_intact_cs20%a	6-7
348,504	11-02-98 1:51p	mk1a_intact_cs20%a.o	6-7
8,824	11-02-98 1:51p	mk1a_intact_cs30%a	6-7
372,305	11-02-98 1:51p	mk1a_intact_cs30%a.o	6-7
8,824	11-02-98 1:51p	mk1a_intact_cs40%a	6-7
347,220	11-02-98 1:51p	mk1a_intact_cs40%a.o	6-7
8,824	11-02-98 1:51p	mk1a_intact_cs50%a	6-7
348,408	11-02-98 1:51p	mk1a_intact_cs50%a.o	6-7
8,824	11-02-98 1:51p	mk1a_intact_cs60%a	6-7
346,164	11-02-98 1:51p	mk1a_intact_cs60%a.o	6-7
8,824	11-02-98 1:51p	mk1a_intact_cs70%a	6-7
348,504	11-02-98 1:51p	mk1a_intact_cs70%a.o	6-7
8,824	11-02-98 1:51p	mk1a_intact_cs80%a	6-7
348,504	11-02-98 1:51p	mk1a_intact_cs80%a.o	6-7
8,824	11-02-98 1:51p	mk1a_intact_cs90%a	6-7
339,389	11-02-98 1:51p	mk1a_intact_cs90%a.o	6-7
8,825	11-02-98 1:51p	mk1a_ncp_cs10%a	6-8
350,271	11-02-98 1:51p	mk1a_ncp_cs10%a.o	6-8
8,824	11-02-98 1:51p	mk1a_ncp_cs20%a	6-8
351,459	11-02-98 1:51p	mk1a_ncp_cs20%a.o	6-8
8,824	11-02-98 1:51p	mk1a_ncp_cs30%a	6-8
350,589	11-02-98 1:51p	mk1a_ncp_cs30%a.o	6-8
8,824	11-02-98 1:51p	mk1a_ncp_cs40%a	6-8
350,582	11-02-98 1:51p	mk1a_ncp_cs40%a.o	6-8
8,824	11-02-98 1:51p	mk1a_ncp_cs50%a	6-8
352,731	11-02-98 1:51p	mk1a_ncp_cs50%a.o	6-8
8,824	11-02-98 1:51p	mk1a_ncp_cs60%a	6-8

File Size (bytes)	Date Last Access	File Name	Table Used
352,732	11-02-98 1:51p	mk1a_ncp_cs60%a.o	6-8
8,827	11-02-98 1:51p	mk1a_ncp_cs70%a	6-8
356,004	11-02-98 1:51p	mk1a_ncp_cs70%a.o	6-8
8,824	11-02-98 1:51p	mk1a_ncp_cs80%a	6-8
357,492	11-02-98 1:51p	mk1a_ncp_cs80%a.o	6-8
8,824	11-02-98 1:51p	mk1a_ncp_cs90%a	6-8
359,655	11-02-98 1:51p	mk1a_ncp_cs90%a.o	6-8
8,394	11-02-98 1:51p	mk1a_ncp_h2oa	6-8
350,598	11-02-98 1:51p	mk1a_ncp_h2oa.o	6-8
8,493	11-02-98 1:52p	mk1a_deg_cp_filla	6-9
349,432	11-02-98 1:52p	mk1a_deg_cp_filla.o	6-9
8,584	11-02-98 1:52p	mk1a_deg_cp_offa	6-9
350,670	11-02-98 1:52p	mk1a_deg_cp_offa.o	6-9
8,770	11-02-98 1:52p	mk1a_deg_0.0001gcca	6-10
352,032	11-02-98 1:52p	mk1a_deg_0.0001gcca.o	6-10
8,770	11-02-98 1:52p	mk1a_deg_0.0005gcca	6-10
350,936	11-02-98 1:52p	mk1a_deg_0.0005gcca.o	6-10
8,769	11-02-98 1:52p	mk1a_deg_0.001gcca	6-10
352,130	11-02-98 1:52p	mk1a_deg_0.001gcca.o	6-10
8,769	11-02-98 1:52p	mk1a_deg_0.005gcca	6-10
350,324	11-02-98 1:52p	mk1a_deg_0.005gcca.o	6-10
8,767	11-02-98 1:52p	mk1a_deg_0.01gcca	6-10
350,194	11-02-98 1:52p	mk1a_deg_0.01gcca.o	6-10
12,438	11-02-98 1:52p	ldp_mk1a_cpfill_zr_h2o0%b	6-11
372,950	11-02-98 1:52p	ldp_mk1a_cpfill_zr_h2o0%b.o	6-11
12,509	11-02-98 1:53p	ldp_mk1a_zr_h2o0%c	6-11
371,812	11-02-98 1:53p	ldp_mk1a_zr_h2o0%c.o	6-11
12,626	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss1.0a	6-12
372,335	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss1.0a.o	6-12
12,626	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss2.0a	6-12
372,335	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss2.0a.o	6-12
12,626	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss3.0a	6-12
372,335	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss3.0a.o	6-12
12,626	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss4.0a	6-12
374,490	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss4.0a.o	6-12
14,435	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss2.0gd.01a	6-13
372,682	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss2.0gd.01a.o	6-13
14,432	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss2.0gd0.1a	6-13

File Size (bytes)	Date Last Access	File Name	Table Used
378,095	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss2.0gd0.1a.o	6-13
14,435	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss2.0gd1.0a	6-13
379,615	11-02-98 1:53p	ldp_mk1a_cpfill_zr_ss2.0gd1.0a.o	6-13
13,238	12-29-98 1:19p	ldp_mk1a_cpfill_zr_ss2.0gd.01	6-14
370,193	12-29-98 1:19p	ldp_mk1a_cpfill_zr_ss2.0gd.01.o	6-14
13,213	12-29-98 1:19p	ldp_mk1a_cpfill_zr_ss2.0gd0.1	6-14
369,981	12-29-98 1:19p	ldp_mk1a_cpfill_zr_ss2.0gd0.1.o	6-14
13,213	12-29-98 1:20p	ldp_mk1a_cpfill_zr_ss2.0gd1.0	6-14
370,294	12-29-98 1:20p	ldp_mk1a_cpfill_zr_ss2.0gd1.0.o	6-14
14,068	11-02-98 1:54p	ldp_mk1a_cpfill_zr_ss2.0_gd0.01b	6-15
373,161	11-02-98 1:54p	ldp_mk1a_cpfill_zr_ss2.0_gd0.01b.o	6-15
14,065	11-02-98 1:54p	ldp_mk1a_cpfill_zr_ss2.0_gd0.1b	6-15
373,175	11-02-98 1:54p	ldp_mk1a_cpfill_zr_ss2.0_gd0.1b.o	6-15
14,067	11-02-98 1:54p	ldp_mk1a_cpfill_zr_ss2.0_gd1.0b	6-15
373,175	11-02-98 1:54p	ldp_mk1a_cpfill_zr_ss2.0_gd1.0b.o	6-15
14,227	11-02-98 1:55p	ldp_mk1a_cpfill_zr_ss2.0_gd0.01c	6-16
373,842	11-02-98 1:55p	ldp_mk1a_cpfill_zr_ss2.0_gd0.01c.o	6-16
14,224	11-02-98 1:55p	ldp_mk1a_cpfill_zr_ss2.0_gd0.1c	6-16
372,688	11-02-98 1:55p	ldp_mk1a_cpfill_zr_ss2.0_gd0.1c.o	6-16
14,225	11-02-98 1:55p	ldp_mk1a_cpfill_zr_ss2.0_gd1.0c	6-16
377,022	11-02-98 1:55p	ldp_mk1a_cpfill_zr_ss2.0_gd1.0c.o	6-16
14,308	11-02-98 1:55p	ldp_mk1a_cpfill_zr_ss2.0_gd1.0d	6-16
373,298	11-02-98 1:55p	ldp_mk1a_cpfill_zr_ss2.0_gd1.0d.o	6-16
10,647	11-02-98 1:55p	b4cwp	6-17
362,900	11-02-98 1:55p	b4cwpo	6-17
11,093	11-02-98 1:55p	inp42b	6-17
364,472	11-02-98 1:55p	inp42bo	6-17
11,132	11-02-98 1:55p	inp42c	6-17
364,619	11-02-98 1:55p	inp42co	6-17
11,178	11-02-98 1:55p	inp42d	6-17
364,695	11-02-98 1:55p	inp42do	6-17
10,803	11-02-98 1:55p	b4cmco	6-18
11,043	11-02-98 1:55p	b4cmcoa	6-18
366,168	11-02-98 1:55p	b4cmcoao	6-18
11,042	11-02-98 1:55p	b4cmcob	6-18
367,164	11-02-98 1:55p	b4cmcobo	6-18
364,351	11-02-98 1:55p	b4cmcoo	6-18

File Size (bytes)	Date Last Access	File Name	Table Used
1,392	11-02-98 11:48a	0.9cm	Appendix I-1
347,971	11-02-98 11:48a	0.9cm.o	Appendix I-1
1,392	11-02-98 11:48a	1.0cm	Appendix I-1
347,971	11-02-98 11:48a	1.0cm.o	Appendix I-1
1,388	11-02-98 11:48a	1.1cm	Appendix I-1
347,872	11-02-98 11:48a	1.1cm.o	Appendix I-1
1,395	11-02-98 11:48a	1.2cm	Appendix I-1
346,783	11-02-98 11:48a	1.2cm.o	Appendix I-1
1,390	11-02-98 11:48a	1.3cm	Appendix I-1
347,872	11-02-98 11:48a	1.3cm.o	Appendix I-1
1,394	11-02-98 11:48a	1.4cm	Appendix I-1
348,094	11-02-98 11:48a	1.4cm.o	Appendix I-1
1,393	11-02-98 11:48a	1.5cm	Appendix I-1
348,289	11-02-98 11:48a	1.5cm.o	Appendix I-1
1,394	11-02-98 11:48a	1.6cm	Appendix I-1
348,607	11-02-98 11:48a	1.6cm.o	Appendix I-1
1,392	11-02-98 11:48a	1.7cm	Appendix I-1
348,607	11-02-98 11:48a	1.7cm.o	Appendix I-1
1,387	11-02-98 11:49a	0.85cm	Appendix I-2
347,011	11-02-98 11:49a	0.85cm.o	Appendix I-2
1,389	11-02-98 11:49a	0.9cm	Appendix I-2
347,875	11-02-98 11:49a	0.9cm.o	Appendix I-2
1,391	11-02-98 11:49a	1.0cm	Appendix I-2
347,011	11-02-98 11:49a	1.0cm.o	Appendix I-2
1,390	11-02-98 11:49a	1.1cm	Appendix I-2
346,912	11-02-98 11:49a	1.1cm.o	Appendix I-2
1,389	11-02-98 11:49a	1.2cm	Appendix I-2
347,776	11-02-98 11:49a	1.2cm.o	Appendix I-2
1,387	11-02-98 11:49a	1.3cm	Appendix I-2
347,971	11-02-98 11:49a	1.3cm.o	Appendix I-2
1,391	11-02-98 11:49a	1.4cm	Appendix I-2
348,190	11-02-98 11:49a	1.4cm.o	Appendix I-2
1,387	11-02-98 11:49a	1.5cm	Appendix I-2
347,137	11-02-98 11:49a	1.5cm.o	Appendix I-2
1,389	11-02-98 11:49a	1.6cm	Appendix I-2
348,607	11-02-98 11:49a	1.6cm.o	Appendix I-2
1,391	11-02-98 11:50a	0.85cm	Appendix I-3
347,966	11-02-98 11:50a	0.85cm.o	Appendix I-3
1,389	11-02-98 11:50a	0.9cm	Appendix I-3
348,608	11-02-98 11:50a	0.9cm.o	Appendix I-3
1,392	11-02-98 11:50a	1.0cm	Appendix I-3

File Size (bytes)	Date Last Access	File Name	Table Used
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1,390	11-02-98 11:50a	1.1cm	Appendix I-3
348,512	11-02-98 11:50a	1.1cm.o	Appendix I-3
1,387	11-02-98 11:50a	1.2cm	Appendix I-3
348,827	11-02-98 11:50a	1.2cm.o	Appendix I-3
1,389	11-02-98 11:50a	1.3cm	Appendix I-3
348,830	11-02-98 11:50a	1.3cm.o	Appendix I-3
1,387	11-02-98 11:50a	1.4cm	Appendix I-3
349,148	11-02-98 11:50a	1.4cm.o	Appendix I-3
1,389	11-02-98 11:50a	1.5cm	Appendix I-3
348,374	11-02-98 11:50a	1.5cm.o	Appendix I-3
1,389	11-02-98 11:50a	1.6cm	Appendix I-3
349,880	11-02-98 11:50a	1.6cm.o	Appendix I-3
1,391	11-02-98 11:50a	0.8cm	Appendix I-4
348,926	11-02-98 11:50a	0.8cm.o	Appendix I-4
1,388	11-02-98 11:50a	0.9cm	Appendix I-4
348,509	11-02-98 11:50a	0.9cm.o	Appendix I-4
1,390	11-02-98 11:50a	1.0cm	Appendix I-4
346,252	11-02-98 11:50a	1.0cm.o	Appendix I-4
1,390	11-02-98 11:50a	1.1cm	Appendix I-4
347,671	11-02-98 11:50a	1.1cm.o	Appendix I-4
1,391	11-02-98 11:50a	1.2cm	Appendix I-4
348,731	11-02-98 11:50a	1.2cm.o	Appendix I-4
1,383	11-02-98 11:50a	1.3cm	Appendix I-4
349,049	11-02-98 11:50a	1.3cm.o	Appendix I-4
1,390	11-02-98 11:50a	1.4cm	Appendix I-4
349,244	11-02-98 11:51a	1.4cm.o	Appendix I-4
1,389	11-02-98 11:51a	1.5cm	Appendix I-4
349,562	11-02-98 11:51a	1.5cm.o	Appendix I-4
1,391	11-02-98 11:51a	1.6cm	Appendix I-4
349,880	11-02-98 11:51a	1.6cm.o	Appendix I-4
1,390	11-02-98 11:51a	0.8cm	Appendix I-5
349,242	11-02-98 11:51a	0.8cm.o	Appendix I-5
1,388	11-02-98 11:51a	0.9cm	Appendix I-5
347,736	11-02-98 11:51a	0.9cm.o	Appendix I-5
1,384	11-02-98 11:51a	1.0cm	Appendix I-5
348,828	11-02-98 11:51a	1.0cm.o	Appendix I-5
1,387	11-02-98 11:51a	1.1cm	Appendix I-5
349,146	11-02-98 11:51a	1.1cm.o	Appendix I-5
1,380	11-02-98 11:51a	1.2cm	Appendix I-5
349,047	11-02-98 11:51a	1.2cm.o	Appendix I-5

File Size (bytes)	Date Last Access	File Name	Table Used
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1,390	11-02-98 11:51a	1.4cm	Appendix I-5
349,878	11-02-98 11:51a	1.4cm.o	Appendix I-5
1,389	11-02-98 11:51a	1.5cm	Appendix I-5
350,100	11-02-98 11:51a	1.5cm.o	Appendix I-5
1,386	11-02-98 11:51a	1.6cm	Appendix I-5
350,514	11-02-98 11:51a	1.6cm.o	Appendix I-5
1,389	11-02-98 11:52a	0.8cm	Appendix I-6
346,584	11-02-98 11:52a	0.8cm.o	Appendix I-6
1,387	11-02-98 11:52a	0.9cm	Appendix I-6
348,924	11-02-98 11:52a	0.9cm.o	Appendix I-6
1,390	11-02-98 11:52a	1.0cm	Appendix I-6
348,924	11-02-98 11:52a	1.0cm.o	Appendix I-6
1,385	11-02-98 11:52a	1.1cm	Appendix I-6
347,958	11-02-98 11:52a	1.1cm.o	Appendix I-6
1,391	11-02-98 11:52a	1.2cm	Appendix I-6
349,461	11-02-98 11:52a	1.2cm.o	Appendix I-6
1,388	11-02-98 11:52a	1.3cm	Appendix I-6
348,726	11-02-98 11:52a	1.3cm.o	Appendix I-6
1,388	11-02-98 11:52a	1.4cm	Appendix I-6
350,196	11-02-98 11:52a	1.4cm.o	Appendix I-6
1,354	12-08-98 9:10a	1.5cm	Appendix I-6
345.675	12-08-98 9:10a	1.5cm.o	Appendix I-6
1,389	11-02-98 11:52a	1.6cm	Appendix I-6
350,832	11-02-98 11:52a	1.6cm.o	Appendix I-6
1,387	11-02-98 11:52a	0.7cm	Appendix I-7
347,937	11-02-98 11:52a	0.7cm.o	Appendix I-7
1,391	11-02-98 11:52a	0.8cm	Appendix I-7
347,739	11-02-98 11:52a	0.8cm.o	Appendix I-7
1,387	11-02-98 11:52a	0.9cm	Appendix I-7
348,609	11-02-98 11:53a	0.9cm.o	Appendix I-7
1,386	11-02-98 11:53a	1.0cm	Appendix I-7
348,828	11-02-98 11:53a	1.0cm.o	Appendix I-7
1,389	11-02-98 11:53a	1.1cm	Appendix I-7
347,994	11-02-98 11:53a	1.1cm.o	Appendix I-7
1,377	11-02-98 11:53a	1.2cm	Appendix I-7
349,563	11-02-98 11:53a	1.2cm.o	Appendix I-7
1,384	11-02-98 11:53a	1.3cm	Appendix I-7
349,563	11-02-98 11:53a	1.3cm.o	Appendix I-7
1,389	11-02-98 11:53a	1.4cm	Appendix I-7

File Size (bytes)	Date Last Access	File Name	Table Used
348,729	11-02-98 11:53a	1.4cm.o	Appendix I-7
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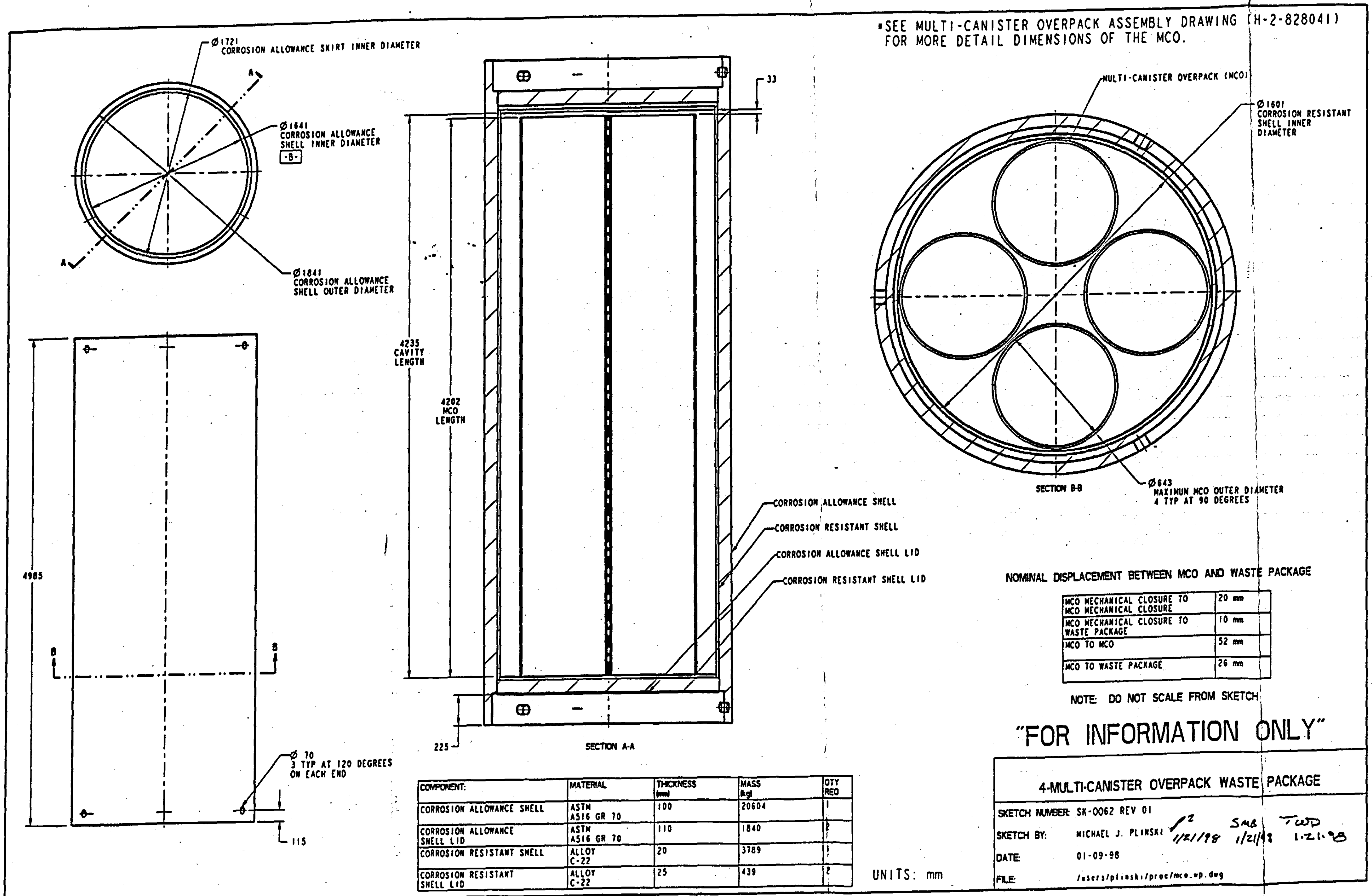
350,199	11-02-98 11:53a	1.5cm.o	Appendix I-7
1,392	11-02-98 11:53a	0.9cm	Appendix II-1
347,971	11-02-98 11:53a	0.9cm.o	Appendix II-1
1,395	11-02-98 11:53a	1.05cm	Appendix II-1
346,981	11-02-98 11:53a	1.05cm.o	Appendix II-1
1,392	11-02-98 11:53a	1.0cm	Appendix II-1
347,971	11-02-98 11:53a	1.0cm.o	Appendix II-1
1,396	11-02-98 11:53a	1.15cm	Appendix II-1
347,011	11-02-98 11:53a	1.15cm.o	Appendix II-1
1,388	11-02-98 11:53a	1.1cm	Appendix II-1
347,872	11-02-98 11:53a	1.1cm.o	Appendix II-1
1,395	11-02-98 11:53a	1.2cm	Appendix II-1
346,783	11-02-98 11:53a	1.2cm.o	Appendix II-1
365,334	11-02-98 11:54a	outaa	Appendix III-1
366,304	11-02-98 11:54a	outaax	Appendix III-1
366,637	11-02-98 11:54a	outnewta	Appendix III-1
364,481	11-02-98 11:54a	outubea	Appendix III-1
353,842	11-02-98 11:54a	outaa1	Appendix IV-1
354,994	11-02-98 11:55a	outaa2	Appendix IV-1
355,001	11-02-98 11:55a	outaa4	Appendix IV-1
353,849	11-02-98 11:55a	outaa5	Appendix IV-1
354,994	11-02-98 11:55a	outaa7	Appendix IV-1
354,041	11-02-98 11:55a	outaa8	Appendix IV-1
357,045	11-02-98 11:55a	outba1	Appendix IV-1
360,655	11-02-98 11:55a	outba2	Appendix IV-1
356,832	11-02-98 11:55a	outba4	Appendix IV-1
355,872	11-02-98 11:55a	outba7	Appendix IV-1
358,224	11-02-98 11:55a	outba8	Appendix IV-1
355,680	11-02-98 11:55a	outca1	Appendix IV-1
355,001	11-02-98 11:55a	outca2	Appendix IV-1
356,832	11-02-98 11:55a	outca4	Appendix IV-1
355,001	11-02-98 11:55a	outca5	Appendix IV-1
356,832	11-02-98 11:55a	outca7	Appendix IV-1
354,994	11-02-98 11:55a	outca8	Appendix IV-1



NOMINAL DISPLACEMENT BETWEEN MCO AND WASTE PACKAGE

MCO MECHANICAL CLOSURE TO MCO MECHANICAL CLOSURE	20 mm
MCO MECHANICAL CLOSURE TO WASTE PACKAGE	10 mm
MCO TO MCO	52 mm
MCO TO WASTE PACKAGE	26 mm

NOTE: DO NOT SCALE FROM SKETCH

COMPONENT	MATERIAL	THICKNESS (mm)	MASS (kg)	QTY REQ
CORROSION ALLOWANCE SHELL	ASTM A516 GR 70	100	20604	1
CORROSION ALLOWANCE SHELL LID	ASTM A516 GR 70	110	1840	2
CORROSION RESISTANT SHELL	ALLOY C-22	20	3789	1
CORROSION RESISTANT SHELL LID	ALLOY C-22	25	439	2

"FOR INFORMATION ONLY"

4-MULTI-CANISTER OVERPACK WASTE PACKAGE

SKETCH NUMBER: SK-0062 REV 01

SKETCH BY: MICHAEL J. PLINSKI 1/21/98 SMB 1/21/98 TWD 1-21-98

DATE: 01-09-98

FILE: /users/plinski/proe/mco_wp.dwg