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Title: Comparision of Incidental Reflection From Containerized Maintenance/Housekeeping Solutions and One Inch of Water

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Subject: Comparision of Incidental Reflection From Containerized Maintenance / Housekeeping Solutions and One Inch of Water

1 Summary

This document addresses the incidental reflector reactivity worth of containerized maintenance/housekeeping fluids for use in PF-4 at Los Alamos National Laboratory (LANL). The intent of the document is to analyze containerized maintenance/housekeeping fluids which will be analyzed as water that may be present under normal conditions of an operation. The reactivity worth is compared to the reactivity worth due to 1-inch of close-fitting 4π water reflection and 1-inch of close-fitting radial water reflection. Both have been used to bound incidental reflection by 2-liter bottles in criticality safety evaluations. The conclusion is that, when the maintenance/housekeeping fluids are containerized the reactivity increase from a configuration which is bounding of normal conditions (up to eight bottles modeled with 2-liters of solution at varying diameter) is bound by 1-inch of close fitting 4π water relection.

Derivative Classification Review			
☒ UNCLASSIFIED ☐ Export Controlled Information ☐ Official Use Only ☐ Unclassified Controlled Nuclear Information		☐ CONFIDENTIAL ☐ SECRET ☐ Restricted Data ☐ Formerly Restricted Data ☐ National Security Information Guidance Used:	
DC/RO Name/Z Number: 135267 Ernie Elliott	Organization: NCS	Signature:	Date: 3/14/16

2 Material Compositions

The compositions modeled in MCNP6 are presented in Table 1 below.

Table 1 - Material Information

Material	Composition Weight Fraction (Atom Fraction)	Full Theoretical Density (g/cc)	Cross Sections
Water	Hydrogen (0.667) Oxygen (0.333)	1.0	1001.80c 8016.80c lwtr.20t
High Density Polyethylene (HDPE)	Hydrogen (0.667) Carbon (0.333)	0.97	1001.80c 6000.80c poly.20t
Plutonium	^{239}Pu (1.0)	19.84	94239.80c

3 Methodology

Simple MCNP6 models were constructed to compare the reflection characteristics of representative bottles of maintenance/housekeeping fluids. The bottles are represented by 2-liter cylindrical volumes of water. Note, that at smaller diameters, modeling 2-liter of solution resulted in unrealistically tall cylinders. These cylinders are representative of smaller volumes of solution. The reactivity worth of the bottles was compared to the reactivity worth of 1-inch of radial water reflection as well as 1-inch of 4π water reflection. The bottle material was conservatively modeled as HDPE. The fissile material considered in the model is a 4.5 kg Pu(0) cylinder. When the Pu cylinder was modeled collocated with 2-liter bottles all items were aligned veritically along the z= 0 plane. Material information from **Table 1** was used in the models. The MCNP calculations reported in this document were performed on the "Moonlight" High Performance Cluster (HPC) using MCNP6 with ENDF/B-VII.1 continuous energy cross-section sets. MCNP6 Version 1.0 and the ENDF/B-VII.1 cross section data on the Moonlight HPC were approved-for-use by NCS-MEMO-15-011 [**Ref. 1**] and validated in NCS-TECH-15-005 [**Ref. 2**] satisfying the requirements defined in ANSI/ANS-8.24. Determination of a USL is not considered in this document as it's purpose is to compare the reactivity effects of 1-inch water reflection and the presence of 2-liter bottles.

Table 2 below shows the color scheme used in the model figures.

Table 2 – Model Illustration Color Legend

Material	Color
Plutonium	
Water	
HDPE	

4 Results

To begin with, 1-inch of radial water reflection was modeled around the 4500 g Pu metal ingot. The H/D of the Pu metal ingot was varied from 0.7 to 2.0. This configuration can be found in **Figure 1**.

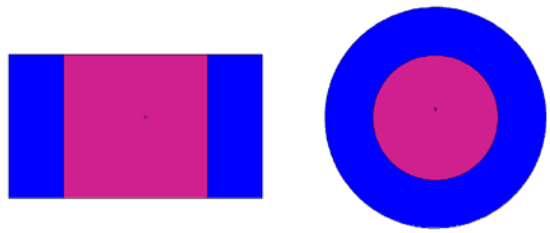

Figure 1 – 1 inch Radial Water Reflection Side View (left) & Top View (right)

The results of these computations can be found in **Figure 3**.

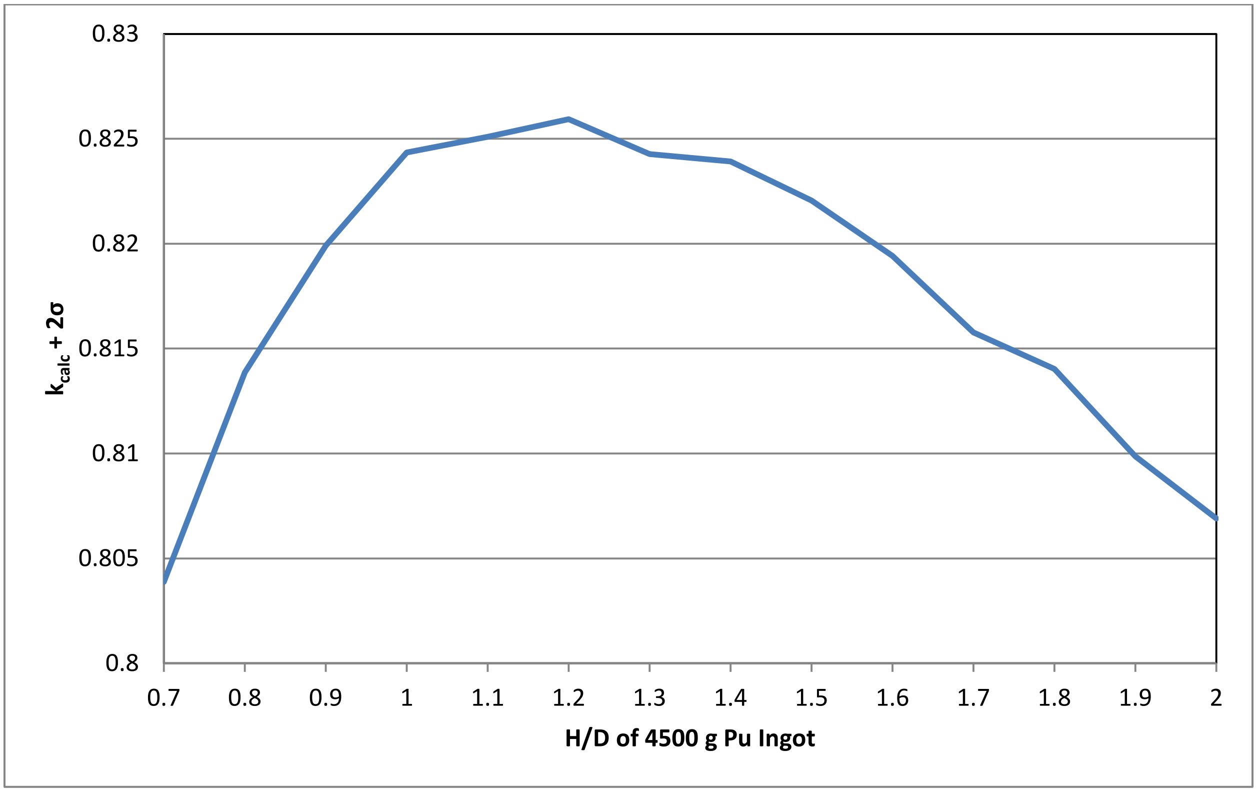

Figure 2 – 1 inch Radial Water Reflection while Varying H/D of Pu Ingot

The maximum k_{eff} for this configuration occurs at an H/D of 1.2 was equal to **0.826**.

Next, one inch of 4π water reflection was modeled around the 4500 g Pu metal ingot. The H/D of the Pu metal ingot was varied from 0.7 to 2.0. This configuration can be found in **Figure 3**.

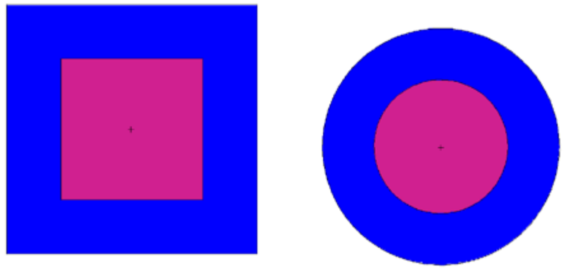

Figure 3 – 1 inch 4π Water Reflection
Side View (left) & Top View (right)

The results of these computations can be found in **Figure 4**.

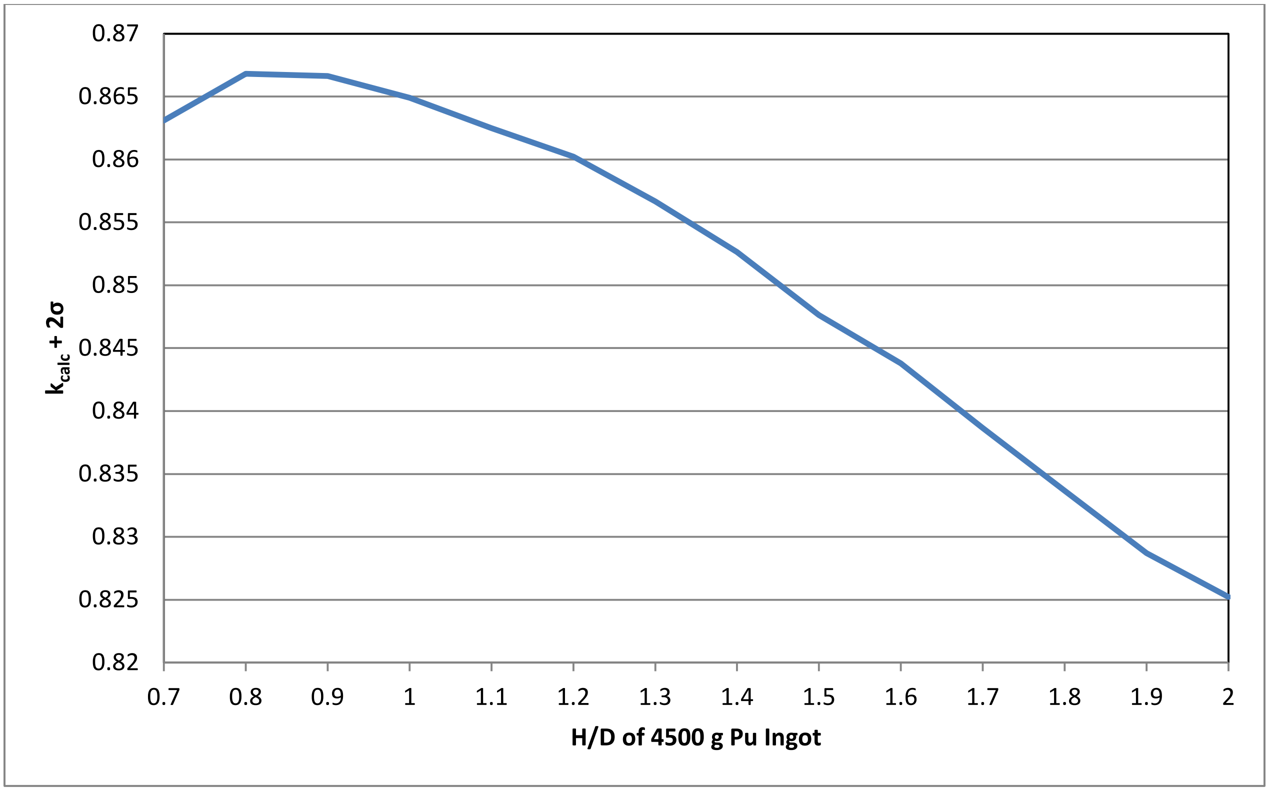

Figure 4 – 1 inch 4π Water Reflection while Varying H/D of Pu Ingot

The maximum k_{eff} for this configuration occurs at an H/D of 0.8 was equal to **0.867**.

Next, to model the presence of maintenance/housekeeping fluids, three through eight, 2-liter cylinders of water were placed in direct contact, surrounding the 4500 g Pu metal ingot. The H/D of the Pu metal ingot was specified to be equal to 1. The radii of the water cylinders were specified to allow each of the bottles to be in direct contact with the Pu metal ingot, as well as in direct contact with each other. The height was then calculated from these radii and a total volume of 2 liters. The configurations for three, five and eight bottles can be found in **Figure 5**, **Figure 6**, and **Figure 7** respectively.

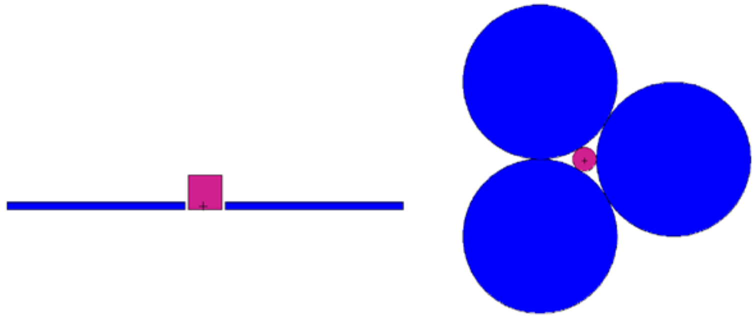

Figure 5 – Three 2-liter Bottles, Close Fitting
Side View (left) & Top View (right)

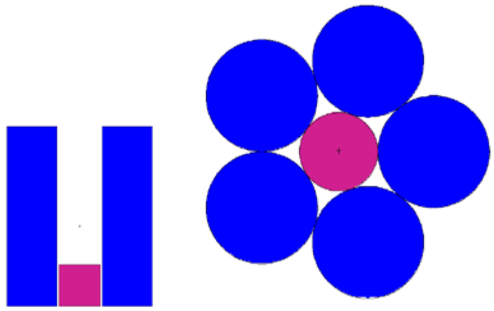

Figure 6 – Five 2-liter Bottles, Close Fitting
Side View (left) & Top View (right)

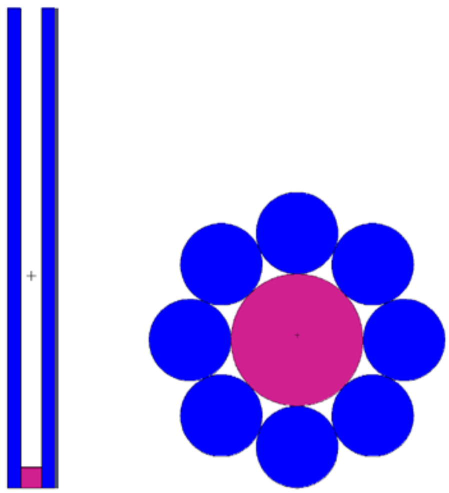

Figure 7 – Eight 2-liter Bottles, Close Fitting
Side View (left) & Top View (right)

The height of the bottles in this study exceed what can be expected in normal operations but the number of bottles surrounding the ingot is being optimized and conservatively represents smaller volumes of solution with these smaller diameters. The results of these computations were compared against the results for 1-inch of radial and 4π water reflection and can be found in **Figure 8**.

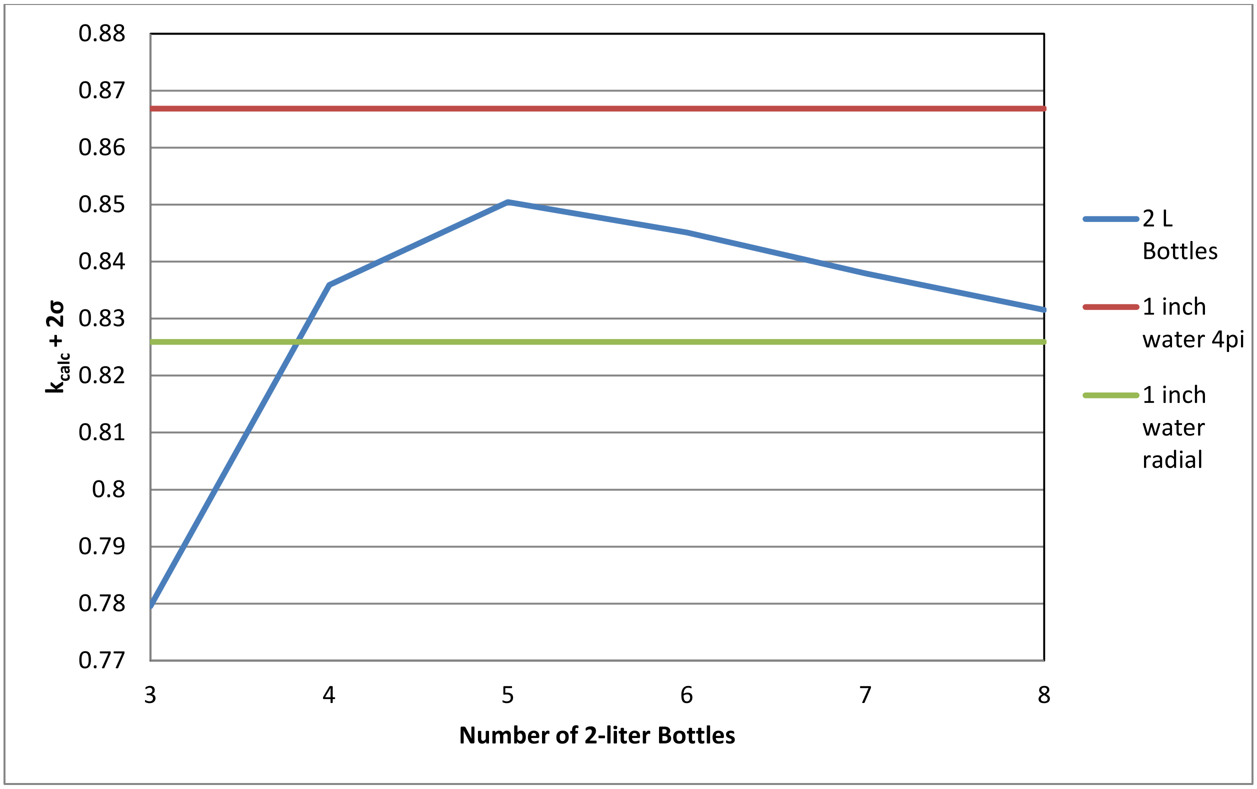

Figure 8 – Comparison between 2 L Bottles and 1-inch Water Reflection

The greatest k_{eff} occurs when there are five 2-liter bottles surrounding the 4500 g Pu metal ingot and is equal to **0.851**. Looking at the reactivity results in **Figure 8**, it can be seen that there are competing effects of thicker reflection (larger diameter bottles) versus more closely fitting reflection (smaller diameter bottles). As mentioned, the maximum reactivity occurred at five bottles of fluid. At this point, increasing the number of bottles around the ingot, which requires reducing bottle diameter, results in a continued decrease in reactivity. Because of this trend, more than eight bottles will not be investigated. The results presented in **Figure 8** have a higher reactivity than 1-inch of radial water reflection but are bound by 1-inch of 4π water reflection.

Next the effect of changing the radius of the water cylinders is investigated. Some of the previous models resulted in heights of the water cylinders that are not present in the facility, so reducing the heights in these models was prudent. Conversly, some of the models resulted in cylinder heights that were smaller than could be expected (three bottles) so a look at an increase in height was also needed.

The H/D of the three bottle configuration was initially equal to 0.03. To capture the reactivity effects due to changes in H/D of the bottles, the H/D was varied from 0.03 to 2.5. As the H/D of the bottles increases the bottles will no longer be in contact with each other. The results of these computations can be found in **Figure 9**.

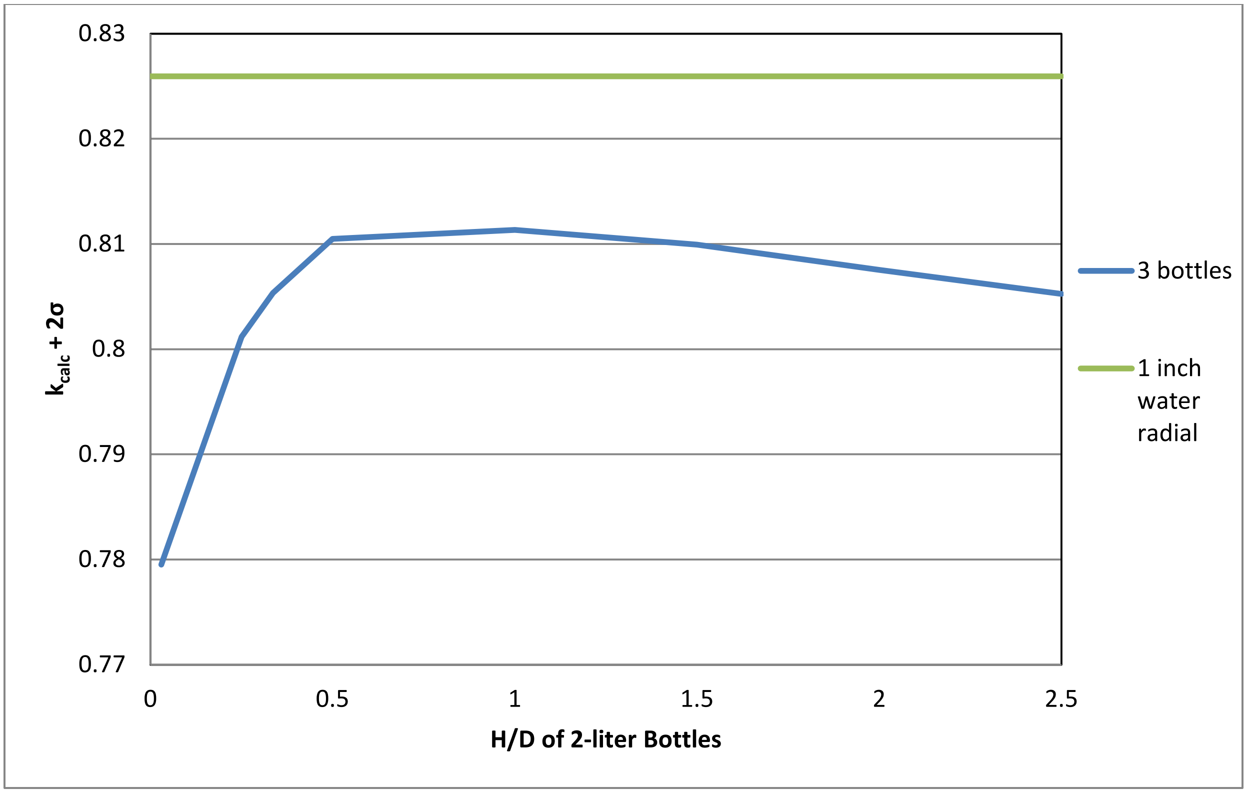

Figure 9 – Variation in H/D of Three 2-liter Bottles

The greatest k_{eff} occurs at an H/D of 1 and was equal to **0.812**. All values were less than the maximum k_{eff} for 1-inch of radial water reflection.

The H/D of the four bottle configuration was initially equal to 0.627. To capture the reactivity effects due to changes in H/D of the bottles, the H/D was varied from 0.2 to 2.0. As the H/D of the bottles decreases below 0.627, the bottles will no longer be in direct contact with the Pu metal ingot. As the H/D of the bottles increases past 0.627, the bottles will no longer be in contact with each other. The results of these computations can be found in **Figure 10**.

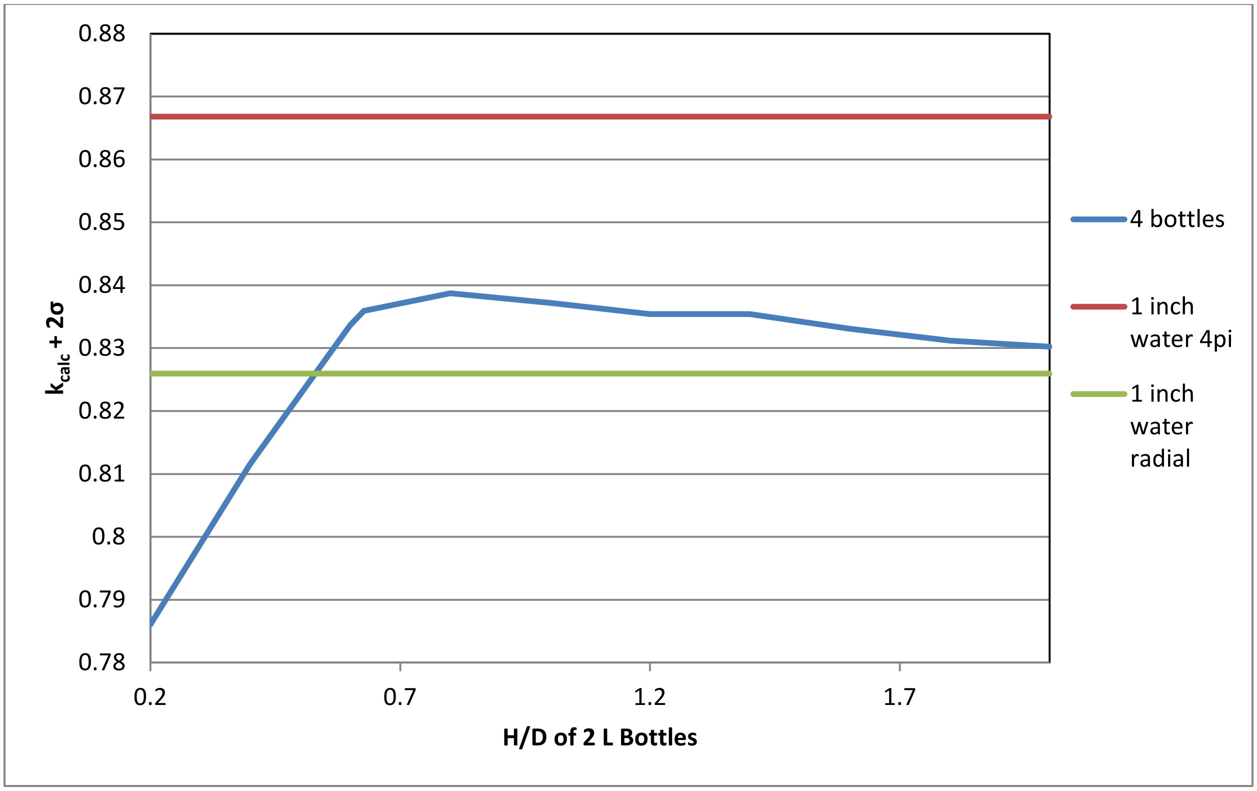

Figure 10 – Variation in H/D of Four 2-liter Bottles

The greatest k_{eff} occurs at an H/D of 0.8 and was equal to **0.839**.

The H/D of the five bottle configuration was initially equal to 3.041. To capture the reactivity effects due to changes in H/D of the bottles, the H/D was varied from 0.2 to 5.0. As the H/D of the bottles decreases below 3.041, the bottles will no longer be in direct contact with the Pu metal ingot. As the H/D of the bottles increases past 3.041, the bottles will no longer be in contact with each other. The results of these computations can be found in **Figure 11**.

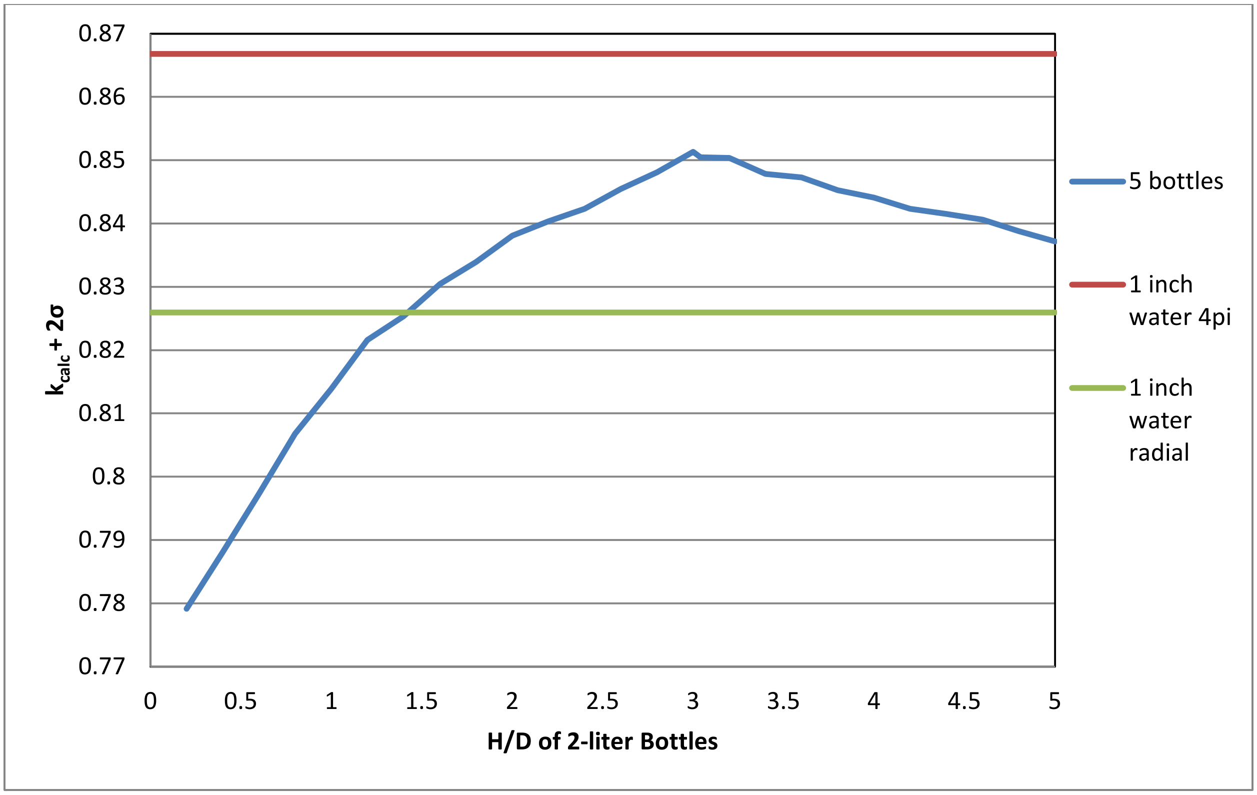

Figure 11 – Variation in H/D of Five 2-liter Bottles

The maximum k_{eff} occurs at an H/D of 3.0 and was equal to **0.852**. This value is statistically equivalent to the base case with an H/D of 3.041. All of the values for this configuration were less than the maximum k_{eff} calculated for the 1-inch of 4π water reflection. Some values were less than the maximum k_{eff} for 1-inch of radial water reflection.

The H/D of the six bottle configuration was initially equal to 8.82. To capture the reactivity effects due to changes in H/D of the bottles, the H/D was varied from 1.0 to 8.82. The H/D was not increased beyond this point because a height greater than this is unrealistic. As the H/D decreases below 8.82, the bottles will no longer be in direct contact with the Pu metal ingot. The results of these computations can be found in **Figure 13**.

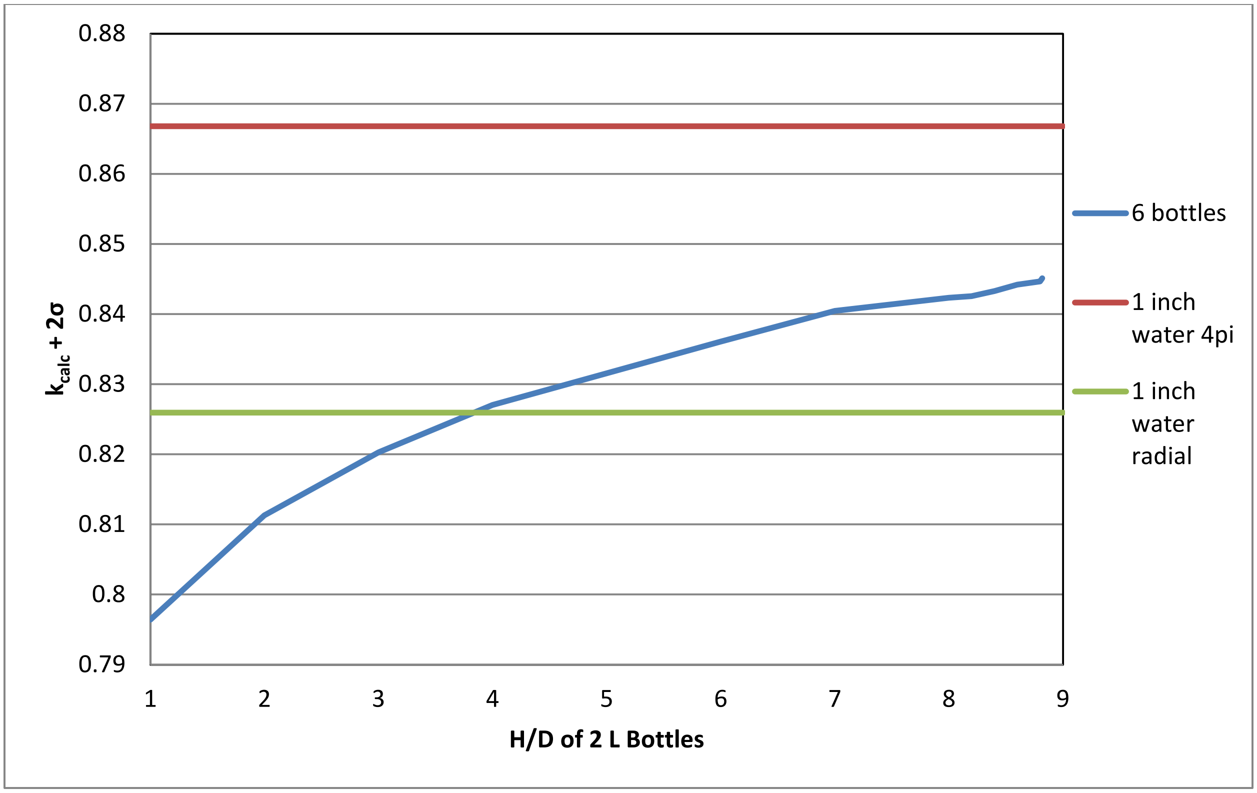

Figure 12 – Variation in H/D of Six 2-liter Bottles

The maximum k_{eff} occurs at the original H/D of 8.82 and was equal to **0.845**. All of the values for this configuration were less than the maximum k_{eff} calculated for the 1-inch of 4π water reflection. Some values were less than the maximum k_{eff} for 1-inch of radial water reflection.

Because six bottles could form an alternative symmetric configuration, the possibility for the arrangement of the bottles in alternating positions or layers was looked at. In this this configuration three of the six bottles were held in stationary contact with the ingot as the H/D of the bottles was varied. This resulted in the distance of the other three bottles from the ingot to increase. The H/D of the bottles in this configuration was varied from 0.2 to 8.82. See **Figure 13**.

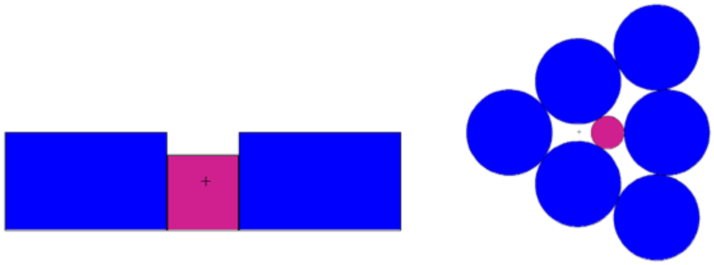

Figure 13 – Six 2-liter Bottles, Alternating Positions
Side View (left) & Top View (right)

The results of these computations can be found in **Figure 14**.

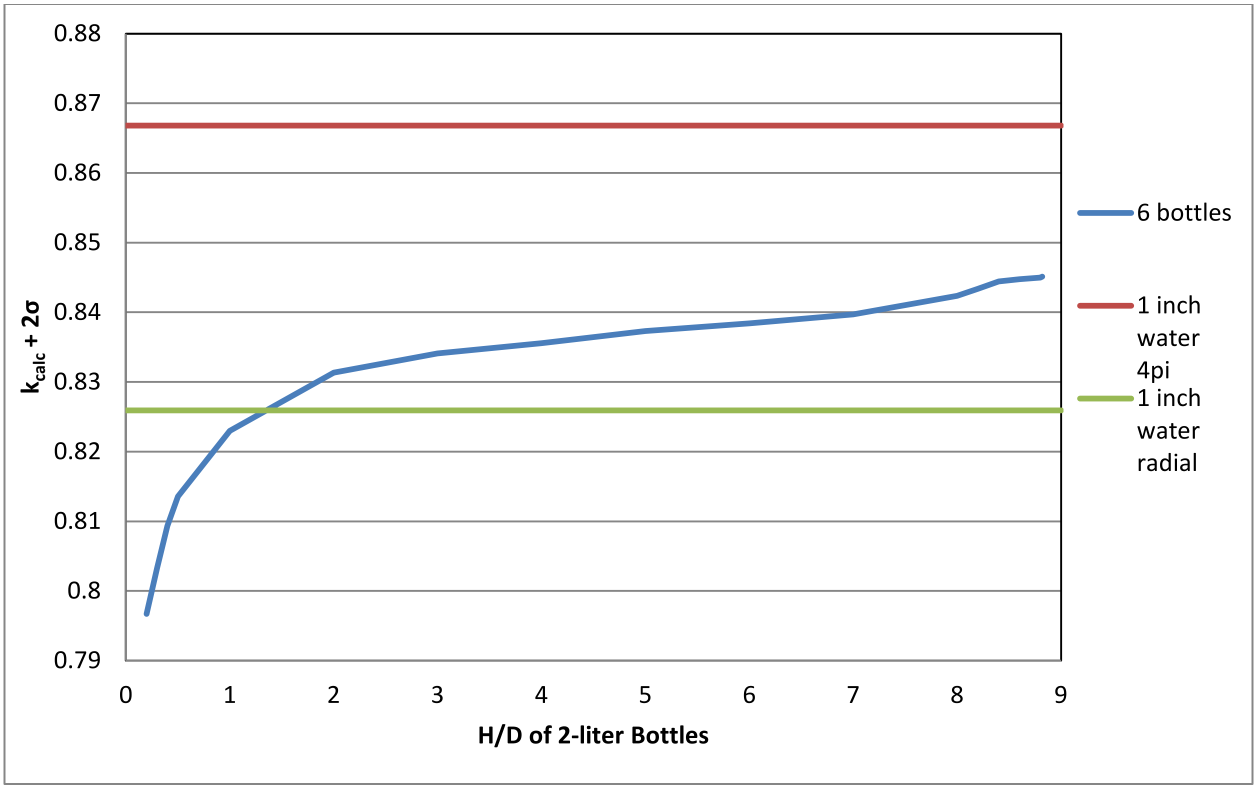

Figure 14 – Variation in H/D of Six 2-liter Bottles in Alternating Positions

The maximum k_{eff} still occurs at the original H/D of 8.82 and was equal to **0.846**. All of the values for this configuration were less than the maximum k_{eff} calculated for the 1-inch of 4π water reflection. Some values were less than the maximum k_{eff} for 1-inch of radial water reflection.

The H/D of the seven bottle configuration was initially equal to 19.59. To capture the reactivity effects due to changes in H/D of the bottles, the H/D was varied from 1.0 to 19.59. The H/D was not increased beyond this point because a height greater than this is unrealistic. As the H/D decreases below 19.59, the bottles will no longer be in direct contact with the Pu metal ingot. The results of these computations can be found in **Figure 15**.

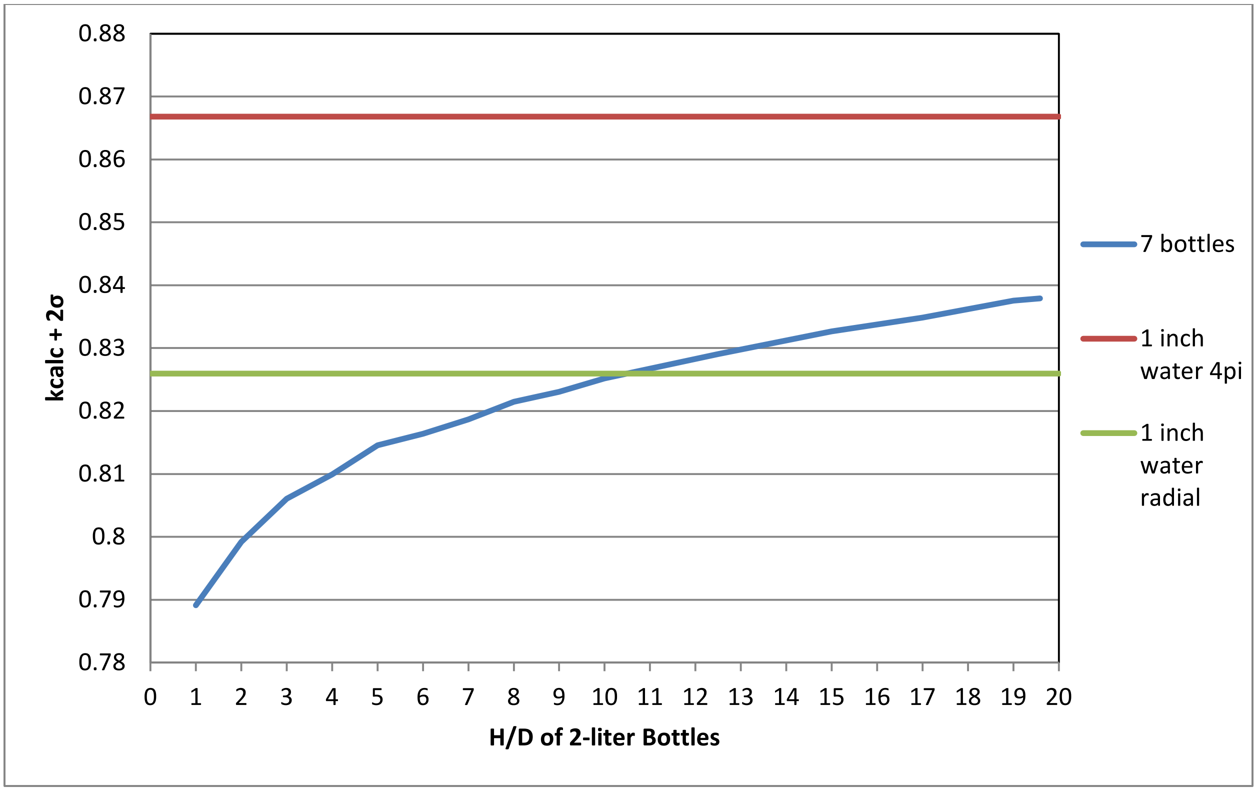

Figure 15 – Variation in H/D of Seven 2-liter Bottles

The maximum k_{eff} still occurs at the original H/D of 19.59 and was equal to **0.838**. All of the values for this configuration were less than the maximum k_{eff} calculated for the 1-inch of 4π water reflection. Some values were less than the maximum k_{eff} for 1-inch of radial water reflection.

Because seven bottles will not form an alternative symmetric configuration and results from the reduction in H/D was bounded by the results from the H/D reduction six bottle configuration (**Figure 13**), the possibility for the arrangement of the bottles in alternating positions or layers was not looked at.

The H/D of the eight bottle configuration was initially equal to 37.01. To capture the reactivity effects due to changes in H/D of the bottles, the H/D was varied from 1.0 to 37.01. The H/D was not increased beyond this point because this is unrealistic. As the H/D decreases below 37.01, the bottles will no longer be in direct contact with the Pu metal ingot. The results of these computations can be found in **Figure 16**.

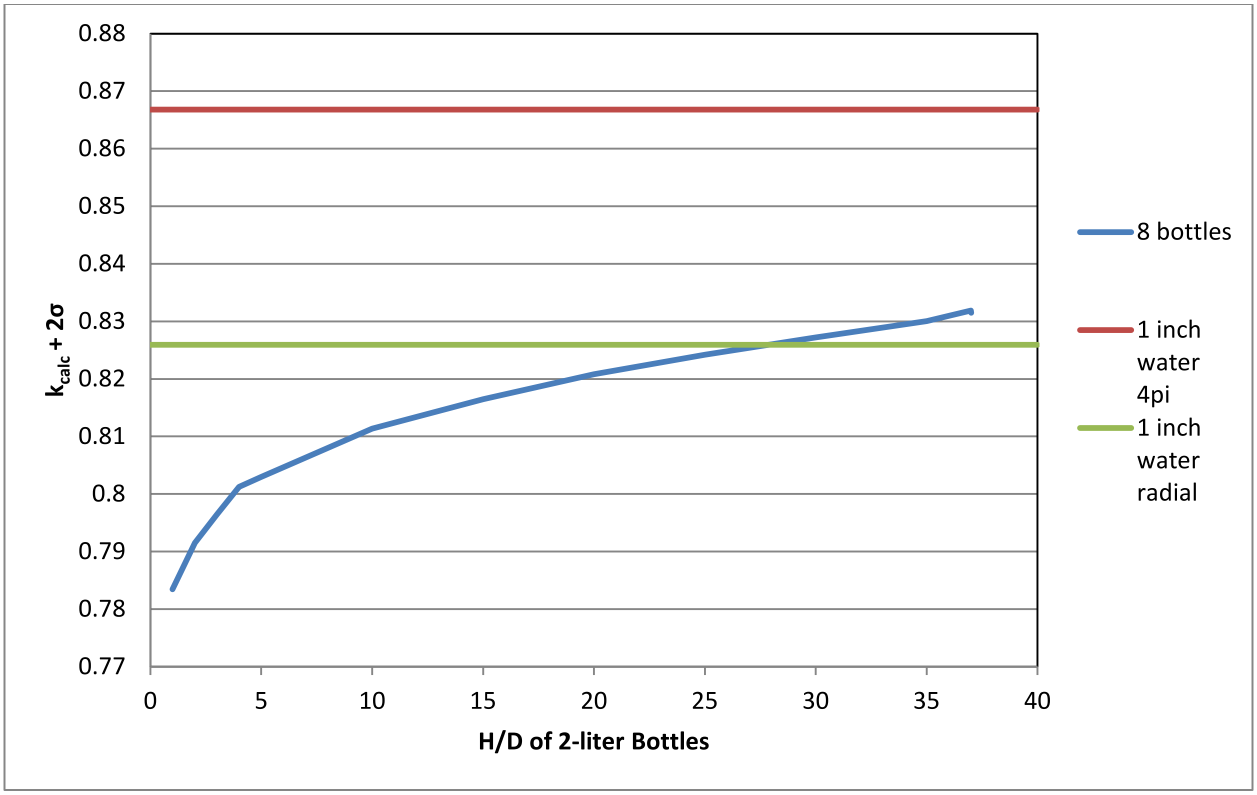

Figure 16 – Variation in H/D of Eight 2-liter Bottles

The maximum k_{eff} still occurs at an H/D of 37 and was equal to **0.832**. All of the values for this configuration were less than the maximum k_{eff} calculated for the 1-inch of 4π water reflection. Some values were less than the maximum k_{eff} for 1-inch of radial water reflection.

Because eight bottles could form an alternative symmetric configuration, the possibility for the arrangement of the bottles in alternating positions or layers was looked at. In this this configuration four of the eight bottles were held in stationary contact with the ingot as the H/D of the bottles was varied. This resulted in an increase in distance of the other four bottles from the ingot. The H/D of the bottles in this configuration was varied from 0.627 to 37.01. See **Figure 17**.

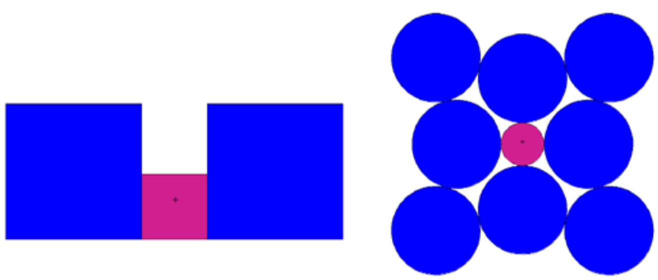

Figure 17 – Eight 2-liter Bottles, Alternating Positions
Side View (left) & Top View (right)

The results of these computations can be found in **Figure 18**.

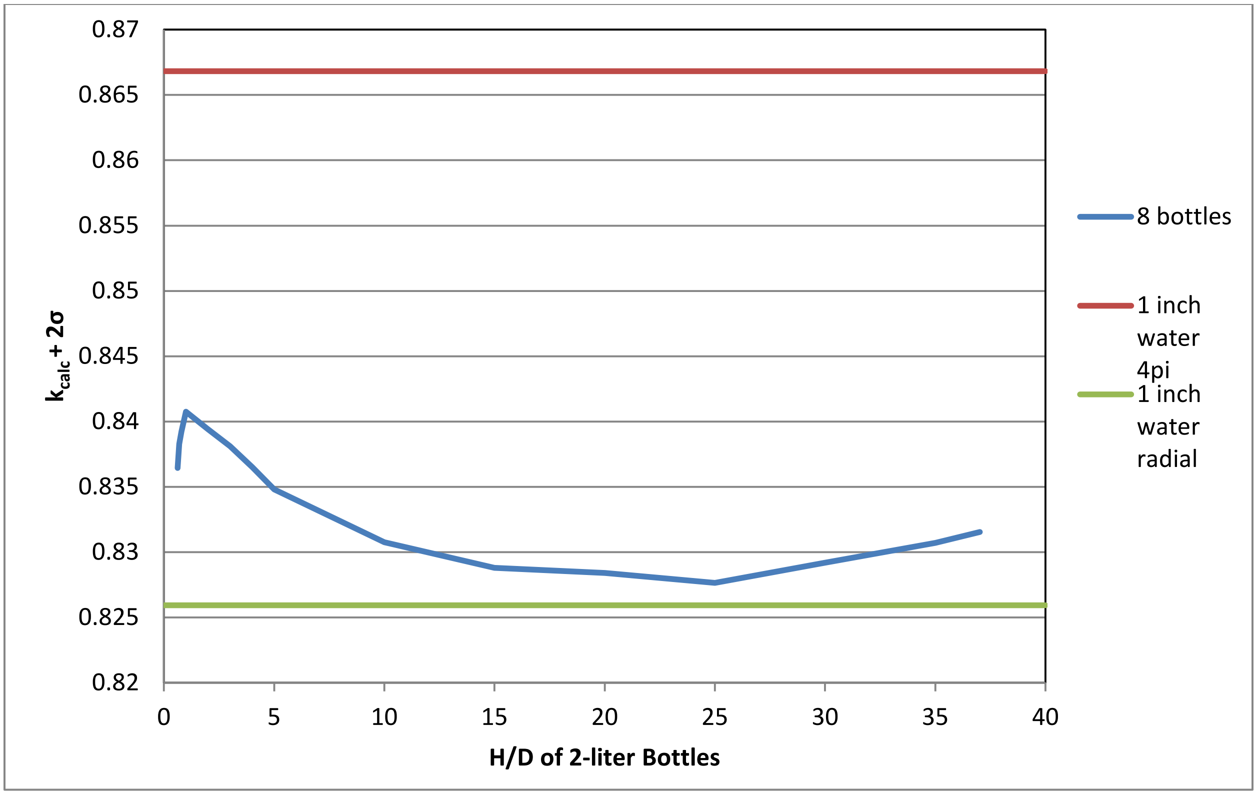

Figure 18 – Variation in H/D of Eight 2-liter Bottles in Alternating Positions

The maximum k_{eff} still occurs at the original H/D of 1.0 and was equal to **0.841**. All of the values for this configuration were less than the maximum k_{eff} calculated for the 1-inch of 4π water reflection. All values were greater than the maximum k_{eff} for 1-inch of radial water reflection.

Next the effect of varying the H/D of the 4500 g Pu metal ingot was investigated. Since the configuration with five 2-liter bottles resulted in the greatest k_{eff}, the H/D of metal ingot was varied within this configuration. The H/D of Pu metal ingot was varied from 1.0 to 2.0. Because the H/D of the bottles are dependent on the H/D of the metal ingot, direct contact of the bottles with the metal ingot was modeled.

The results of these computations can be found in **Figure 19**.

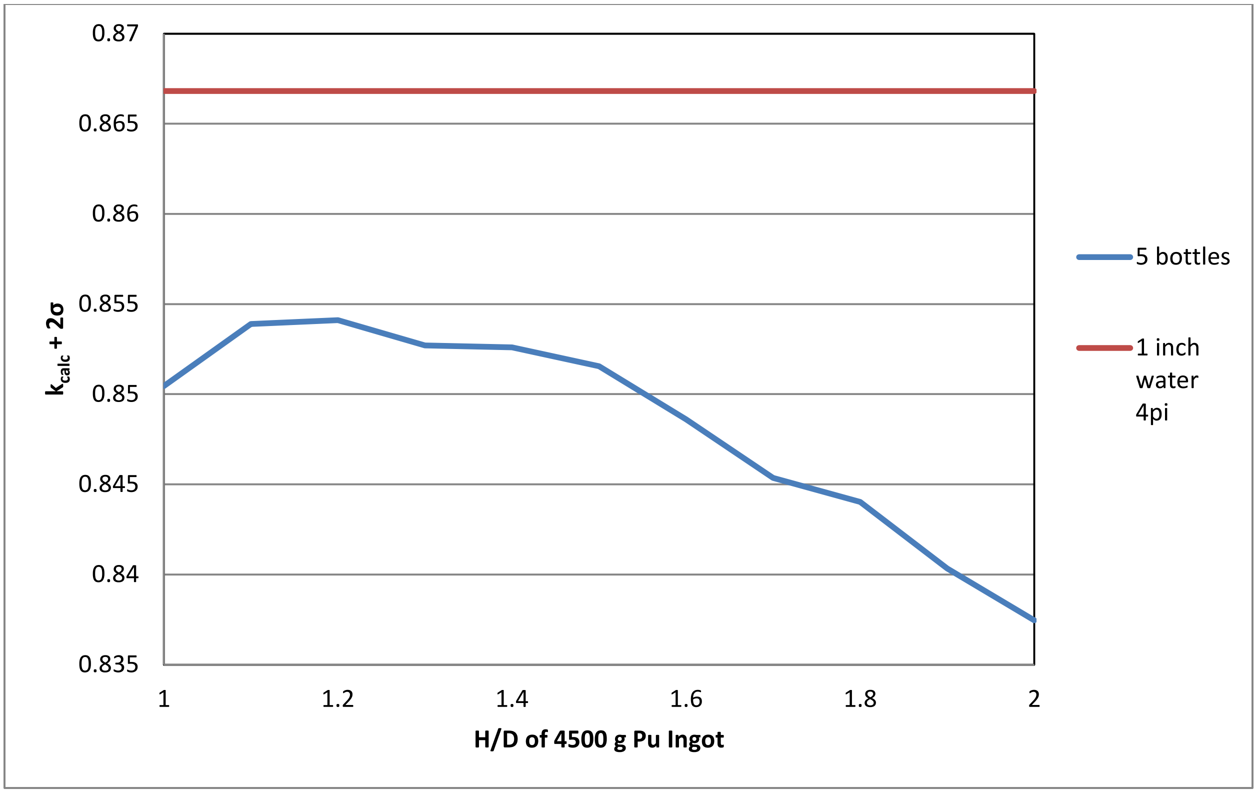

Figure 19 – Variation in H/D of 4500 g Pu Metal Ingot in Five 2-liter Bottle Configuration

The greatest k_{eff} occurs at an H/D of 1.2 and was equal to **0.855**. All of the values for this configuration were less than the maximum k_{eff} calculated for the 1-inch of 4π water reflection and greater than the maximum k_{eff} for 1-inch of radial water reflection.

Finally, the reactivity effect due to the presence of the bottle material, polyethylene, was investigated. The most reactive configuration of five 2-liter bottles surrounding a 4500 g Pu metal ingot was altered. As with the last configuration, the H/D of Pu metal ingot was varied from 1.0 to 2.0. Because the H/D of the bottles are dependent on the H/D of the metal ingot, direct contact of the bottles with the metal ingot was modeled. The polyethylene was specified to be HDPE. The thickness of the polyethylene was varied from 0.05 cm to 0.5 cm. The polyethylene was modeled as close fitting and fully surrounded the bottles. An upper thickness of 0.5 cm is judged to capture the upper average thickness of a polyethylene bottle. Any variation in thicknesses on top or bottom of the bottle is bounded by modeling a uniform thickness surrounding the water. **Figure 20** depicts this configuration.

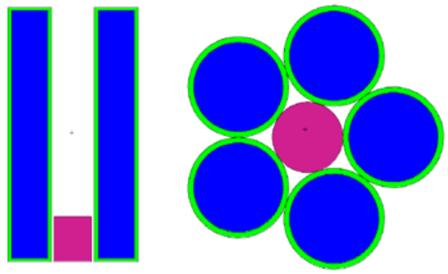

Figure 20 – Five 2-liter Bottles, Surrounded by HDPE, Close Fitting Side View (left) & Top View (right)

The results of these computations can be found in **Figure 21**.

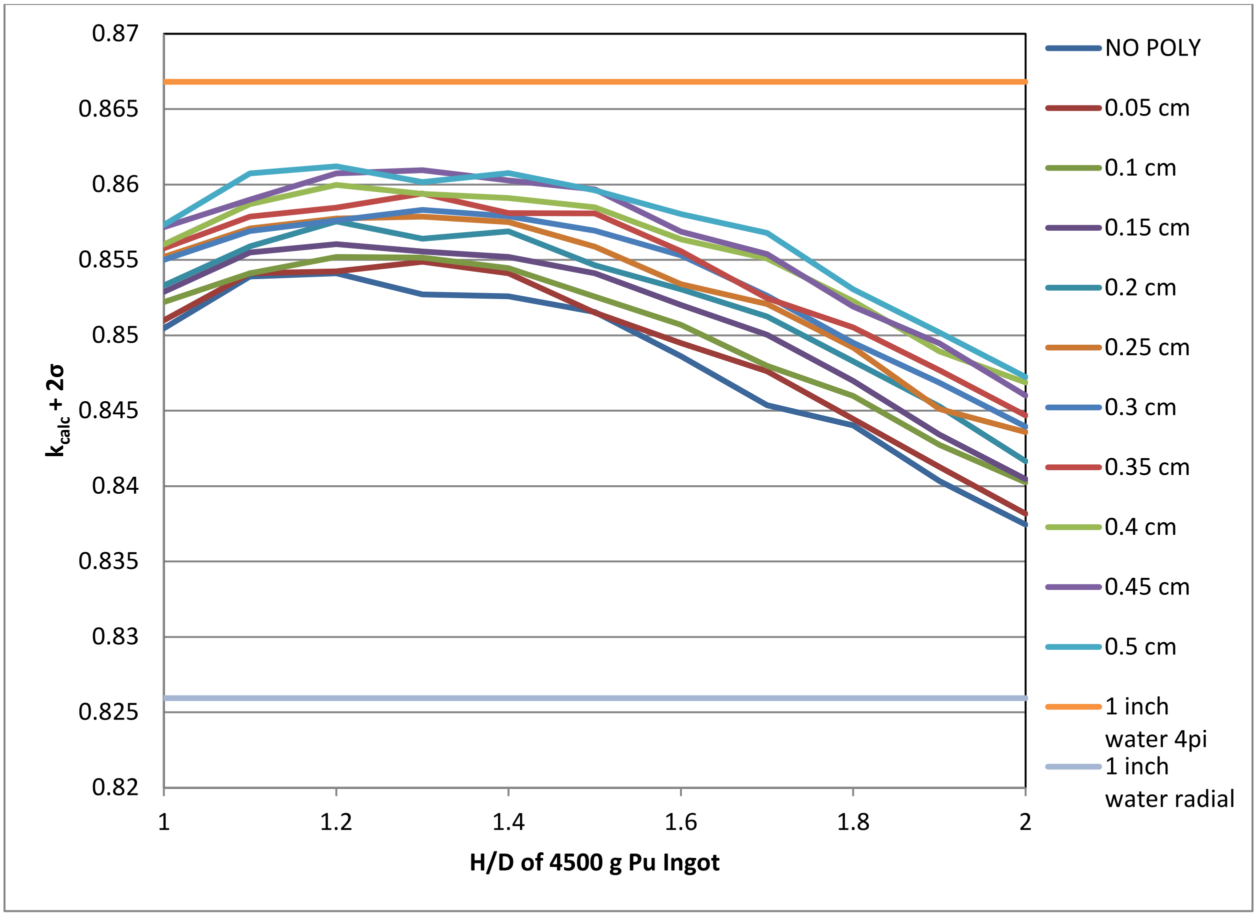

Figure 21 – Variation in H/D of 4500 g Pu Metal Ingot in Five 2-liter Bottles Surrounded by HDPE Configuration

The greatest k_{eff} occurs at an ingot H/D of 1.2, a HDPE thickness of 0.5 cm, and was equal to **0.862**. All of the values for this configuration were less than the maximum k_{eff} calculated for the 1-inch of 4π water reflection and greater than the maximum k_{eff} for 1-inch of radial water reflection.

5 Conclusion

Based on the analysis performed, the reactivity increase from the reflection due to maintenance/housekeeping fluid under normal conditions (represented with up to eight bottles of solution) is bound by 1-inch of close fitting 4π water reflection. The reactivity increase is not bound by 1-inch of close fitting radial reflection.

This analysis only looked at a reactivity comparison of maintenance/housekeeping fluids (represented by various 2-liter bottle configurations) and 1-inch of water reflection. The 1-inch of water reflection is typically used in analyses to account for incidental reflection from several sources beyond just maintenance/housekeeping fluids. These other sources of incidental reflection are not addressed in this document. Before applying these results analysts should consider other sources of incidental reflection in the operation being evaluated.

6 References

1 **NCS-MEMO-15-011**, *Approval for Use of MCNP6 Version 1 on the Moonlight HPC.*
2 **NCS-TECH-15-005**, *Validation of MCNP6 Version 1.0 with the ENDF/B-VII.1 Cross Section Library for Plutonium Metals, Oxides, and Solutions on the High Performance Computing Platform Moonlight.*