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MCNP Model of Los Alamos Neutron Pod

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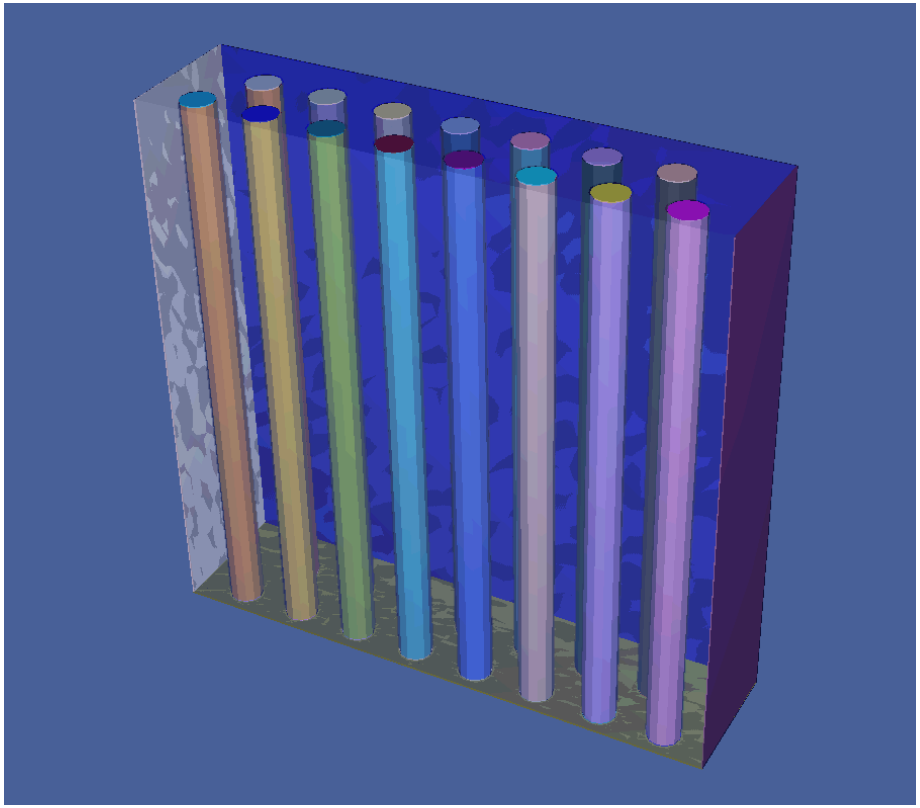
Background

- The Neutron Pod (NPOD) is a neutron multiplicity counter developed by Los Alamos National Laboratory (LANL)
- The NPOD employs helium-3 proportional counters embedded in a high-density polyethylene moderator with an exterior cadmium wrapper
- The NPOD is similar to other neutron multiplicity counters (e.g., coincidence well counters employed by the IAEA), but it is designed to be portable
- The NPOD has been recently used in two series of subcritical benchmark measurements of plutonium reflected by nickel and polyethylene

Overall NPOD Design

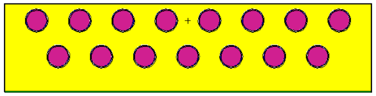
- The NPOD uses 15 helium-3 proportional counters arranged in two rows
  - Front row: 8 counters
  - Back row: 7 counters
  - Counter diameter / length: 1” × 16.6”
  - Gas mixture: He-3 / CO_2
  - He-3 partial pressure: 10 atm nominal
- The He-3 counters are embedded in a polyethylene moderator
  - Dimensions: 16.6” high × 16 30/32” wide × 4” deep
  - Density: 0.962 g/cm^3 nominal
- The moderator is wrapped on all six sides by a cadmium metal absorber
  - Thickness: 0.031” nominal
  - Density: 8.65 g/cm^3



Proportional Counter Arrangement

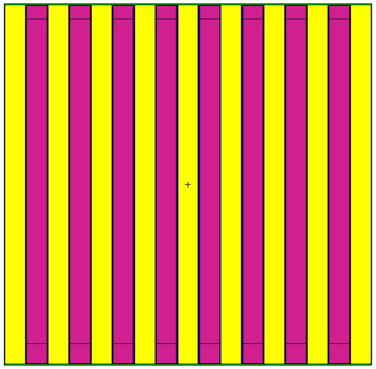
- Front row: 8 counters
  - #1 - #8 number from left to right
  - Centerline 0.75" from front of poly
- Back row: 7 counters
  - #9 - #15 number from right to left
  - Centerline 2.4" from front of poly
- Horizontal pitch: 2"

Front

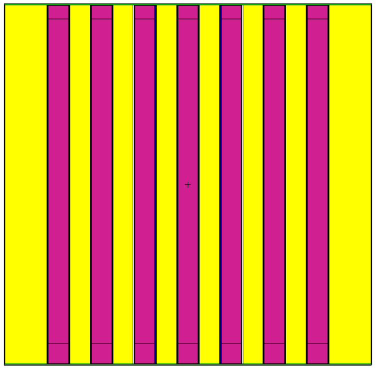


Back

Front Row

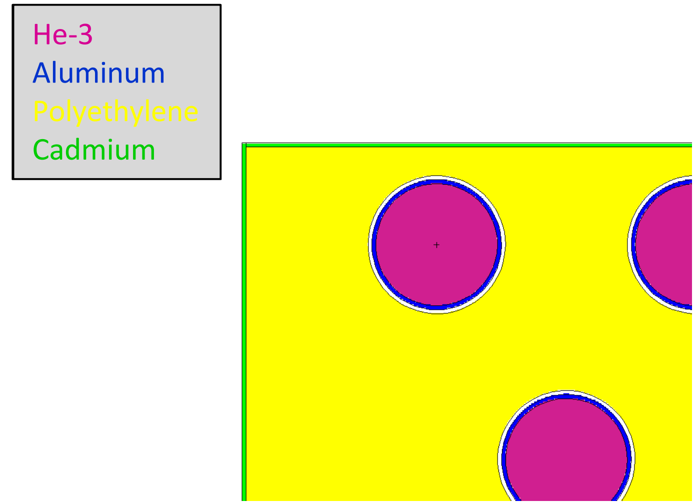


Back Row



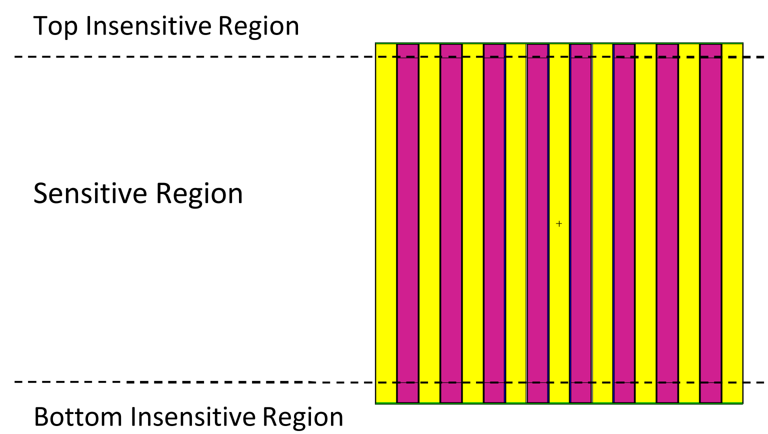
Proportional Counter Details

- Fill gas: 94 atom% He-3 / 6 atom% CO_2
- He-3 partial pressure: 10 atm nominal
- Inside diameter: 0.938”
- Sensitive length: 15”
- Bottom insensitive region: 0.919” long
- Top insensitive region: 0.619”



- Counter wall: aluminum, 2.7 g/cm^3
- Wall thickness: 0.031” (radial, top, and bottom)

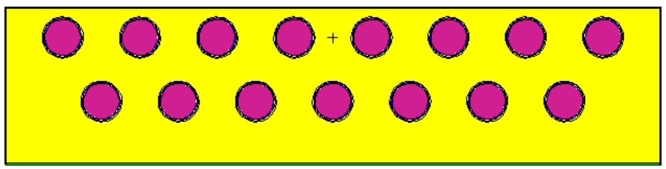
- Radial gap between counter wall and polyethylene: 0.03”



Moderator Details

- The moderator is constructed from a single block of high density polyethylene (C_2H_4)
  - Dimensions: 16.6” high × 16 30/32” wide x 4” deep
  - Density: 0.962 g/cm^3 nominal
- The moderator has two rows of through-holes for the proportional counters
  - Hole diameter: 1.06”
  - Horizontal pitch: 2”
  - Front row horizontal centerline is set 0.75” from front of moderator
  - Back row horizontal centerline is set 2.4” from front of moderator

Front



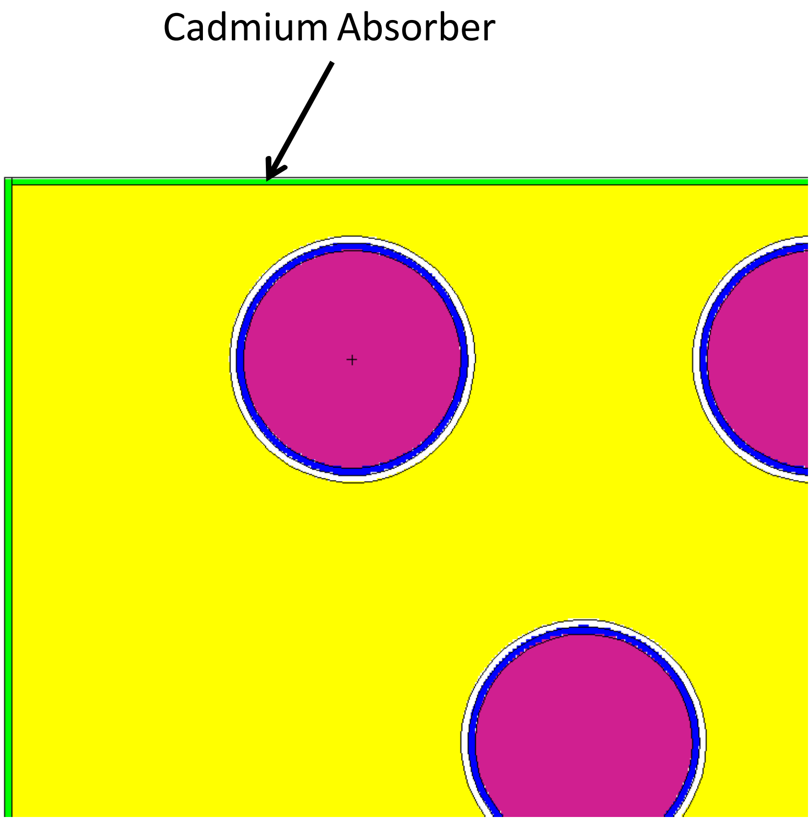
Back

Cadmium Absorber Details

- The moderator is wrapped on all six sides by a thin sheet of cadmium – the cadmium serves to minimize sensitivity to neutrons scattered by the environment

- Absorber material: cadmium metal
- Density: 8.65 g/cm^3 nominal
- Thickness: 0.031” nominal

- The top absorber has 15 small holes to permit connection to the proportional counter electrodes, but those holes have a negligible effect on neutron transport



Example MCNP Input Decks

- Two example MCNP input decks are attached
  - Both decks were used to estimate NPOD neutron detection efficiency vs. energy
  - First deck “pteff.i” calculates efficiency for a point source 50 cm from the front of the cadmium absorber
  - Second deck “pleff.i” calculates efficiency for a monodirectional planar source “aimed” at the front face of NPOD

SNL1

pteff.i

SNL2

pleff.i

Excerpt from example MCNP input deck

```
c ------------------------------------------------------------------------------
c problem boundary
c ------------------------------------------------------------------------------
c
9000 0 -9000 (-4101:+4102:-4201:+4202:-4301:+4302) imp:n=1
9999 0 +9000 imp:n=0

c ------------------------------------------------------------------------------
c he-3
c ------------------------------------------------------------------------------
c
1101 100  c/z 1.905 -17.78 1.19126 $ tube 1 (far left in front row)
1102 100  c/z 1.905 -12.70 1.19126 $ tube 2
1103 100  c/z 1.905  -7.62 1.19126 $ tube 3
1104 100  c/z 1.905  -2.54 1.19126 $ tube 4
1105 100  c/z 1.905   2.54 1.19126 $ tube 5
1106 100  c/z 1.905   7.62 1.19126 $ tube 6
1107 100  c/z 1.905  12.7  1.19126 $ tube 7
1108 100  c/z 1.905  17.78 1.19126 $ tube 8
c ------------------------------------------------------------------------------
1109 100  c/z 6.096  15.24 1.19126 $ tube 9 (far right in back row)
1110 100  c/z 6.096  10.16 1.19126 $ tube 10
1111 100  c/z 6.096   5.08 1.19126 $ tube 11
1112 100  c/z 6.096   0    1.19126 $ tube 12
1113 100  c/z 6.096  -5.08 1.19126 $ tube 13
1114 100  c/z 6.096 -10.16 1.19126 $ tube 14
1115 100  c/z 6.096 -15.24 1.19126 $ tube 15
c ------------------------------------------------------------------------------
2301 100  pz    2.413   $ bottom of sensitive region
2302 100  pz   40.513   $ top of sensitive region
2311 100  pz    0.07874 $ bottom of lower insensitive region
2312 100  pz   42.08526 $ top of upper insensitive region
c
c ------------------------------------------------------------------------------
c tube wall
c ------------------------------------------------------------------------------
c
1201 100  c/z 1.905 -17.78 1.27 $ tube 1
1202 100  c/z 1.905 -12.70 1.27 $ tube 2
1203 100  c/z 1.905  -7.62 1.27 $ tube 3
1204 100  c/z 1.905  -2.54 1.27 $ tube 4
1205 100  c/z 1.905   2.54 1.27 $ tube 5
1206 100  c/z 1.905   7.62 1.27 $ tube 6
1207 100  c/z 1.905  12.7  1.27 $ tube 7
1208 100  c/z 1.905  17.78 1.27 $ tube 8
c ------------------------------------------------------------------------------
```

Slide 8

SNL1 See file attachments
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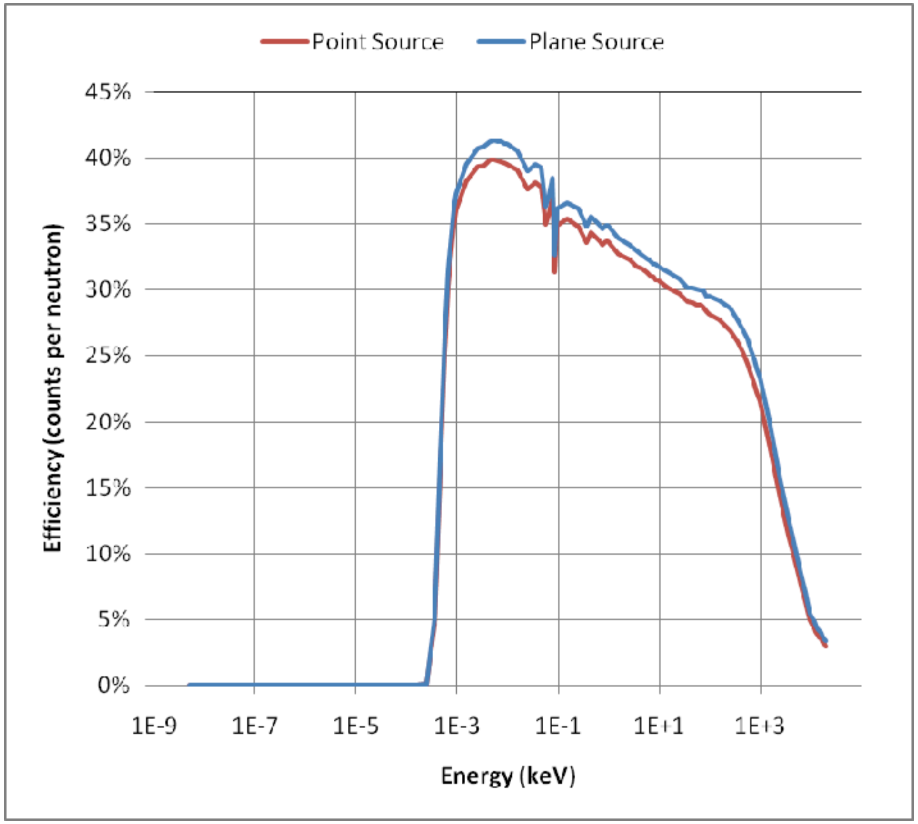
SNL2 See file attachments
Sandia National Laboratories, 4/27/2009

Neutron Detection Efficiency Calculations

- The two preceding example input decks were used to calculate the NPOD's neutron detection efficiency vs. energy
  - Point source: isotropic source 50 cm from the front cadmium face aligned with the horizontal and vertical center of the NPOD
  - Plane source: monodirectional (directed at the NPOD front face)
  - Both sources had uniformly distributed energy spectra
  - Efficiency was calculated as the He-3 (n, p) reaction rate divided by the inward-directed current on front face
  - The (n, p) reaction rate tally was segmented over the source energy distribution
  - The efficiency is the probability of counting a neutron of a given energy incident on the front face of the NPOD



Summary

- MCNP models of the LANL neutron pod (NPOD) multiplicity counter were constructed
  - The models include the He-3 proportional counters, polyethylene moderator, and cadmium absorber
  - The models exclude the NPOD control box (located on the top of the NPOD) – it is assumed to have a negligible effect on neutron transport
- The MCNP models were used to estimate the NPOD's neutron detection efficiency vs. energy
- The MCNP models will also be used to evaluate recent subcritical benchmark measurements of plutonium reflected polyethylene