LLNL-SM-461182

Nuclear Criticality Safety Division

TRAINING MODULE

CSG-TM-016

COG SOFTWARE

Lawrence Livermore National Laboratory
Livermore, California

Nuclear Criticality Safety Division

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CSG-TM-016

COG SOFTWARE

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Approval History

Revision	Preparer	Reviewer	Approver	Date	Remarks
0	S.T. Huang	D.P. Heinrichs	S.T. Huang	April 30, 1999	Initial version
1	D.P. Heinrichs	A.W. Krass	D.P. Heinrichs	July 9, 2010	Sample problems

Course Plan

Objective

The student will demonstrate a basic level of competency as a COG code user by completing the hands-on criticality safety calculations provided in this training module.

Method of instruction

The instructor will provide each student with a Notebook (with contents specified below) and mentor the student as necessary for the student to successfully complete and execute the sample exercise problems (or equivalent problems).

Requirements

(1) The student must have access to a computer with a text editor and a postscript viewer (or ps2pdf converter with an Adobe Acrobat Reader). The computer must also have C shell (csh) or TC shell (tcsh) installed with Perl. PC/Windows computers additionally require Cygwin to emulate a LINUX-like environment.

(2) Prior to scheduling this course, the student must have and obtained the COG installation package from RSICC (or the OECD NEA Databank). Upon request, LLNL may provide user assistance to install the COG code package and Cygwin as required.

(3) The course duration is approximately 28 hours (3.5 days).

References

(1) http://cog.llnl.gov
(2) http://icsbep.inel.gov/handbook.shtml

Notebook contents

(1) CSG-TM-016, COG Software
(2) Mentor Sheet, Training Modules CSG-TM-009, CSG-TM-010, CSG-TM-016, MCNP, SCALE/KENO, and COG Computer Codes
(3) Evaluation of Training Form
(4) COG10 software installation README file
(5) CSAM06-102, Installation and Verification of the COG 10 Code on Unclassified Workstation, Surya
(6) UCRL-TM-202590, COG – A Multiparticle Monte Carlo Transport Code – User's Manual, Fifth Edition, September 1, 2002
(7) UCRL-CONF-224715, COG – Publicly Available Now to Criticality Safety Practitioners
(8) LLNL-PROC-422485, COG – Special Features of Interest to Criticality Safety Practitioners

Course Content

1 Installation and verification

1.1 Hardware review
1.2 Operating system review
1.3 The COG website – http://cog.llnl.gov
1.4 Obtaining the code from RSICC or the OECD NEA Databank
1.5 Installation – COG10 software installation README file
1.6 Running the verification test problems
1.7 Installation and verification documentation for SQA – CSAM06-102

2 Getting started

2.1 The COG manual – UCRL-TM-202590
2.2 Problem #1 – Jezebel – PU-MET-FAST-001 ——— Sample Problem

2.2.1 Review of COG input deck ——— Manual, p. 443
2.2.2 Review of COG data-blocks and keywords ——— Manual, p. 16
2.2.3 Review of COG comment characters ——— Manual, p. 17

2.3 Running COG

2.3.1 Running interactively in the foreground ——— Manual, p. 10
2.3.2 Running in the background ——— Manual, p. 10
2.3.3 Batch processing on LLNL machines
2.3.4 Killing jobs ——— Manual, p. 10

2.4 Reviewing the sample problem output ——— Manual, p. 445

2.4.1 Review starting random numbers
2.4.2 Review K calculation results
2.4.3 Review fraction of fissions, absorptions, escapes
2.4.4 Review mean times
2.4.5 Review optical paths
2.4.6 Review summary tables
2.4.7 Review restart, timing and misc. memory information

2.5 Additional useful features

2.5.1 Add a volume calculation — Manual, p. 123
2.5.2 Assign colors and make a color picture — Manual, p. 112,148
2.5.3 Increase the volume calculation resolution — Manual, p. 123
2.5.4 Discuss boundary conditions and defaults — Manual, p. 99

3 <u>Student exercises</u>

3.1 Problem #2 – HEU-MET-FAST-001 — Fissile metal
3.2 Problem #3 – HEU-MET-FAST-058 — Non-fissile material
3.3 Problem #4 – U233-SOL-INTER-001 — Fissile solution
3.4 Problem #5 – LEU-COMP-THERM-033 — Fissile compound
3.5 Instructor completion of Mentor Sheet Qualification Criteria 1:
Modeling fissile and non-fissile materials

4 <u>Introduction to UNITS</u>

4.1 Review of the DEFINE UNIT specifications — Manual, p. 103
4.2 Review of the USE UNIT specifications — Manual, p. 105
4.3 Review of the FILL specification and default — Manual, p. 97
4.4 Problem #6 – HCT002-20 — Complex Unit
4.5 Instructor completion of Mentor Sheet Qualification Criteria 2:
Modeling single unit geometry

5 <u>Finite and infinite and array geometries</u>

5.1 Review BOUNDARY conditions — Manual, p. 99
5.2 Problem #7 – HEU-COMP-THERM-001-7 — Finite Array
5.3 Problem #7a — Interstitial moderator
5.4 Problem #7b — Interstitial material
5.5 Problem #8 – PU-COMP-INTER-001 — Infinite Medium
5.6 Problem #9 – HEU-COMP-INTER-005 — Infinite Array
5.7 Instructor completion of Mentor Sheet Qualification Critieria 3:
Modeling finite and infinite array geometries

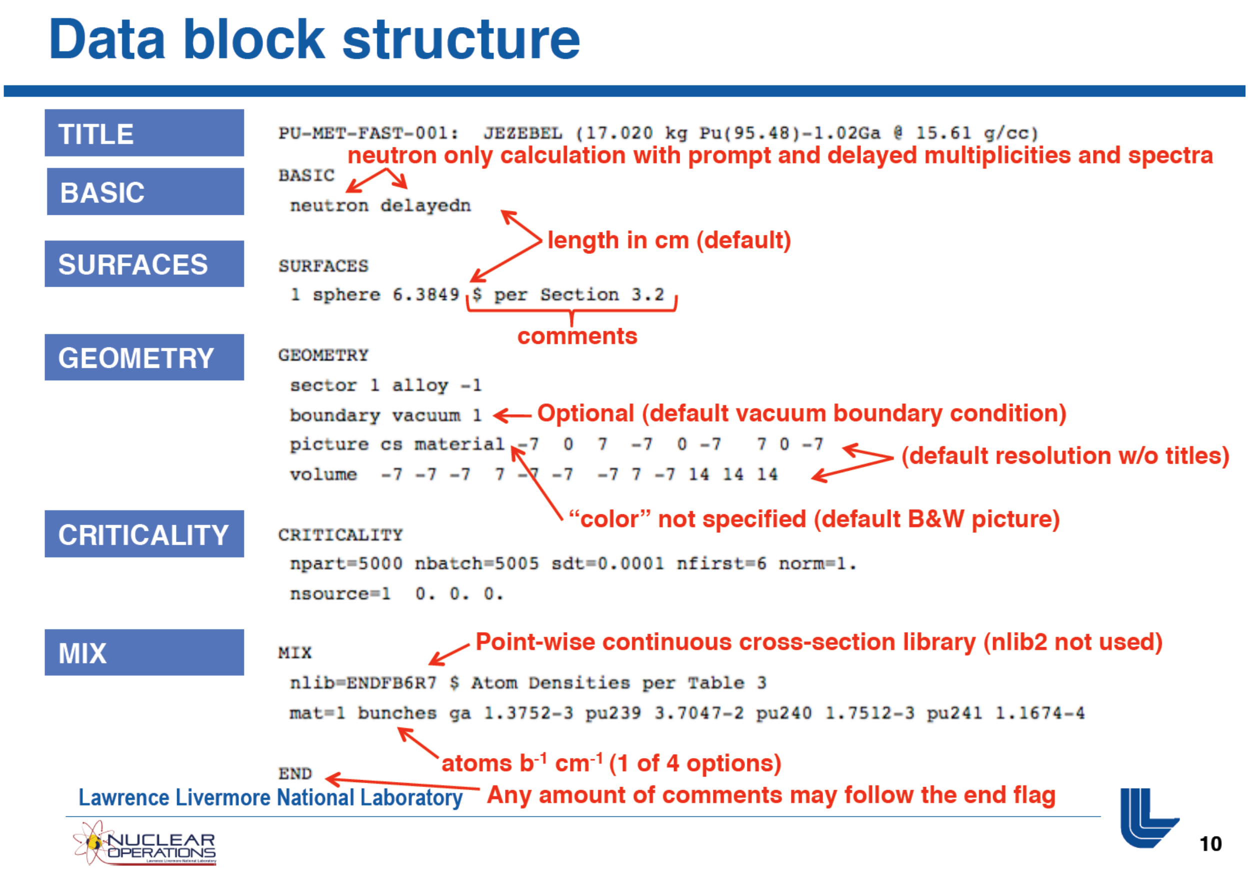
6 <u>Concluding material</u>

6.1 Student feedback and completion of "Evaluation of Training" forms
6.2 Needs for advanced COG training?
6.3 Awarding of course completion certificates

Problem #1

PU-MET-FAST-001-1

Bare Sphere of Plutonium-239 Metal (^{239}Pu Jezebel)



Problem #2

HEU-MET-FAST-001-1

Bare, Highly Enriched Uranium Sphere (Godiva)

3.1 Model: Solid unreflected sphere (Godiva) of uranium metal.

3.2 Dimensions: The radius of the bare sphere is 8.7407 cm.

3.3 Materials: The density of the uranium sphere is 18.74 g/cm^3.

The wt. % of ^{234}U is 1.02 (or 4.9184 x 10^{-4} atoms/b-cm).

The wt. % of ^{235}U is 93.72 (or 4.4994 x 10^{-2} atoms/b-cm).

The remainder is ^{238}U (or 2.4984 x 10^{-3} atoms/b-cm).

3.4 Benchmark k-eff: 1.000 ± 0.003.

4.0 Student's COG results:

Problem #3

HEU-MET-FAST-058-1

Highly Enriched Uranium Metal Spheres with Beryllium Reflectors

3.1 Model: Simple one-dimensional spherical-geometry model.

3.2 Dimensions:

Table 18. Benchmark-Model Outer Radial Dimensions.

No.	Be	Ni	Air	HEU	Beryllium
1	0.4983 cm	0.5207 cm	0.5555 cm	5.1805 cm	25.4497 cm

3.3 Materials:

Table 19. Atom Densities.

Material	Isotope or Element	Composition (wt.%)	Mass (grams)	Atom Density (atoms/barn-cm)
Be (internal) (1.7751 g/cm^3)	Be	100.00	0.92	1.1862×10^{-1}
Ni (8.90 g/cm^3)	Ni	100.00	0.65	9.1290×10^{-2}
Air (1.2046×10^{-3} g/cm^3)	N	74.521	--	3.8595×10^{-5}
	O	22.906	--	1.0386×10^{-5}
	Ar	2.542	--	4.6160×10^{-7}
	C	0.027	--	1.6307×10^{-8}
	Rare Gases	0.004	--	--
HEU (Core No. 1) (18.5075 g/cm^3)	^{234}U	1.00	107.65	4.7621×10^{-4}
	^{235}U	93.17	10,029.79	4.4179×10^{-2}
	^{238}U	5.83	627.60	2.7295×10^{-3}
	HEU	100.00	10,765.04	--
Be (outer) (1.84 g/cm^3)	Be	100.00	--	1.2295×10^{-1}

3.4 Benchmark k-eff: 1.0000 ± 0.0026.

4.0 Student's COG results:

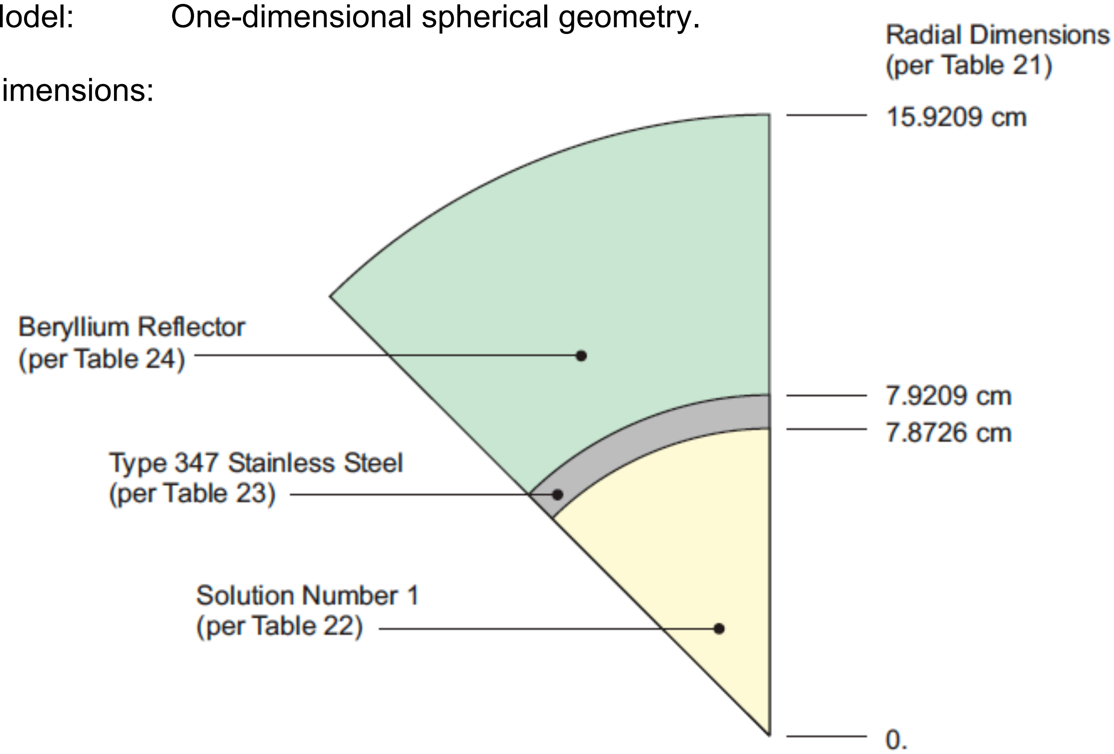
Problem #4

U233-SOL-INTER-001-1

Uranyl-Fluoride (233U) Solutions in Spherical Stainless Steel Vessels
with Reflectors of Be, CH_2 and Be-CH_2 Composites – Part I

3.1 Model: One-dimensional spherical geometry.

3.2 Dimensions:



3.3 Materials:

^{233}U Solution No. 1

Solution →	No. 1
Isotope or Nuclide	Atom
^{232}U	4.5608×10^{-8}
^{233}U	2.2379×10^{-3}
^{234}U	2.4316×10^{-5}
^{235}U	8.9598×10^{-7}
^{238}U	7.1284×10^{-6}
H	5.5183×10^{-2}
O	3.2043×10^{-2}
F	4.7182×10^{-3}

SS Type 347 at 8.0 g/cc

Nuclide	Composition (wt.%)	Atom Density (atoms/barn-cm)
Fe	71	6.1248×10^{-2}
Cr	18	1.6678×10^{-2}
Ni	11	9.0264×10^{-3}

Beryllium at 1.82 g/cc

Material	Nuclide	Atom Density (atoms/barn-cm)
Beryllium	Be	1.2161×10^{-1}

3.4 Benchmark k-eff: 1.0000 ± 0.0083.

4.0 Student's COG results:

Problem #5

LEU-COMP-THERM-033-24

Reflected and Unreflected Assemblies of 2 and 3%-Enriched Uranium Fluoride in Paraffin

3.1 Model: Simple three-dimensional cuboid model.

3.2 Dimensions: 76.65 x 76.65 x 78.08 cm^3

3.3 Materials:

Table 10. Atom Densities (atoms/barn-cm) for UF_4-Paraffin Fuel Mixtures.

Isotopes → Mixture↓	^{235}U	^{238}U	^{234}U	H	C	F
$U(2)F_4$-1	1.5799E-04	7.6424E-03	1.5867E-06	3.0908E-02	1.4860E-02	3.1208E-02

11

3.4 Benchmark k-eff: 1.0000 ± 0.0040.

4.0 Student's COG results:

Problem #6

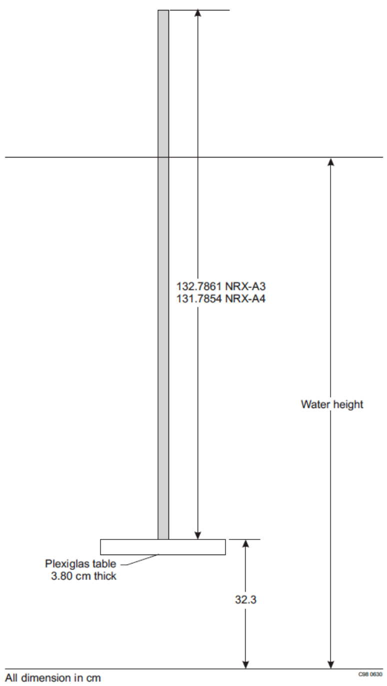
HEU-COMP-THERM-002-20

Graphite and Water Moderated NRX-A3 and NRX-A4 Assemblies

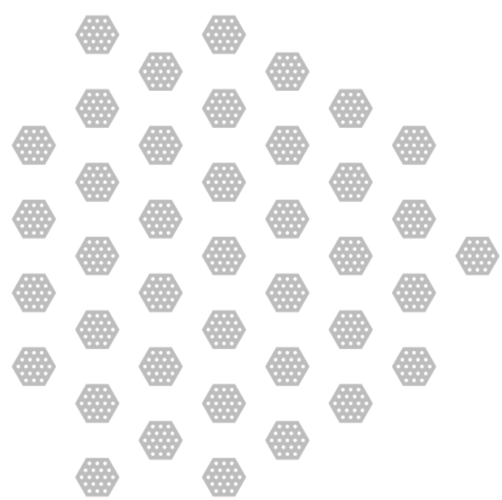
3.1 Model: Plane array of 40 NRX-A4 elements in water.

3.2 Dimensions: Critical water height of 162.9 cm.
Plexiglas table is 58 x 58 x 3.80 cm^3.
Lattice pitch of the NRX-A4 elements is 3.73634-cm.
Effectively infinite water lateral reflection.
Each NRX-A4 element measures 1.91516-cm "across-the-flats" and has 19 (0.25146-cm diameter) holes
on a 0.41048-cm pitch.

Axial view



Plane view



3.3 Materials:

Nuclide	Atoms/barn-cm NRX-A4
^{235}U	1.0716×10^{-3}
^{238}U	7.7806×10^{-5}
C	9.3228×10^{-2}

Material	Nuclide	Atoms/barn-cm
Water (20°C, air-free, 0.9982 g/cm^3)	H	6.6735×10^{-2}
	O	3.3368×10^{-2}
Plexiglas (ρ=1.18 g/cm^3)	H	5.6782×10^{-2}
	C	3.5489×10^{-2}
	O	1.4196×10^{-2}

3.4 Benchmark k-eff: 1.0020 ± 0.0043.

4.0 Student's COG results:

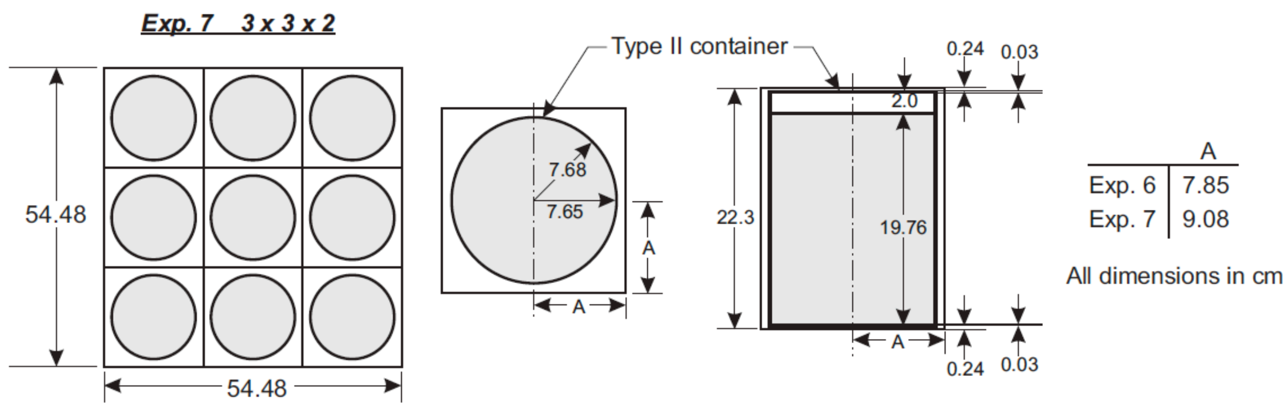
Problem #7

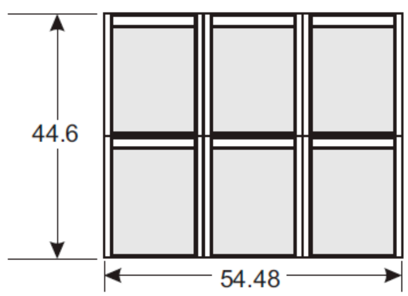
HEU-COMP-MIX-001-7

Arrays of Cans of Highly Enriched Uranium Dioxide Reflected by Polyethylene

3.1 Model: 6”-polyethylene reflected 3x3x2 array of Type II cans

3.2 Dimensions: 2.80 cm horizontal gaps between units
0.24 cm gap between CH_2 reflector and tops and bottoms of cans
0.48 cm gap between stacked cans





All arrays surrounded by 15.24 cm polyethylene in 3 dimensions (not shown).

UO_2 at 5.505(0.998949) g/cm^3
0.87799 gU/gUO2
0.9911 g^{234}U/gU
93.1528 g^{235}U/gU
0.3367 g^{236}U/gU
5.5194 g^{238}U/gU

3.3 Materials:

CH_2 at 0.92 g/cm^3

Material	atoms/cm-barn
Polyethylene	
H	7.8996 x 10^{-2}
C	3.9498 x 10^{-2}

Fe-1C at 8.45 g/cm^3

Material	atoms/barn-cm
Carbon Steel Can[a]	
Fe	9.0207 x 10^{-2}
C	4.2367 x 10^{-5}
UO_2 Contents	
U^{234}	1.2313 x 10^{-4}
U^{235}	1.1524 x 10^{-2}
U^{236}	4.1476 x 10^{-5}
U^{238}	6.7418 x 10^{-4}
O	2.5255 x 10^{-2}

(a) Based on density of 8.45 g/cm^3.

3.4 Benchmark k-eff: 0.9997 ± 0.0038.

4.0 Student’s COG results:

Problem #7-a

Exercise: Add interstitial water outside and in-between Type II cans (flooding).

Student's COG results:

Problem #7-b

Exercise: Add interstitial alumina (Al_2O_3) outside and in-between Type II cans.

Student's COG results:

Student's remarks on the pros and cons of using "SECTOR" versus "FILL" to model the interstitial materials:

Problem #8

PU-COMP-INTER-001-1

K-infinity Experiments in Intermediate Neutron Spectra for ^{239}Pu

3.1 Model: A single-material infinite (homogeneous) medium.

3.2 Dimensions: Model as a "box" with reflecting boundary conditions.

3.3 Materials:

Homogeneous Plutonium/Boron/Graphite Null-Reactivity Sample	H	1.077×10^{-4}
	$^{10}B^{(a)}$	1.0151×10^{-4}
	^{11}B	4.0859×10^{-4}
	C	7.090×10^{-2}
	O	2.707×10^{-3}
	Ca	8.280×10^{-4}
	^{239}Pu	2.735×10^{-4}
	^{240}Pu	1.549×10^{-5}
	^{241}Pu	1.072×10^{-6}
	^{242}Pu	5.800×10^{-8}

3.4 Benchmark k-inf: 1.0000 ± 0.0110.

4.0 Student's COG results:

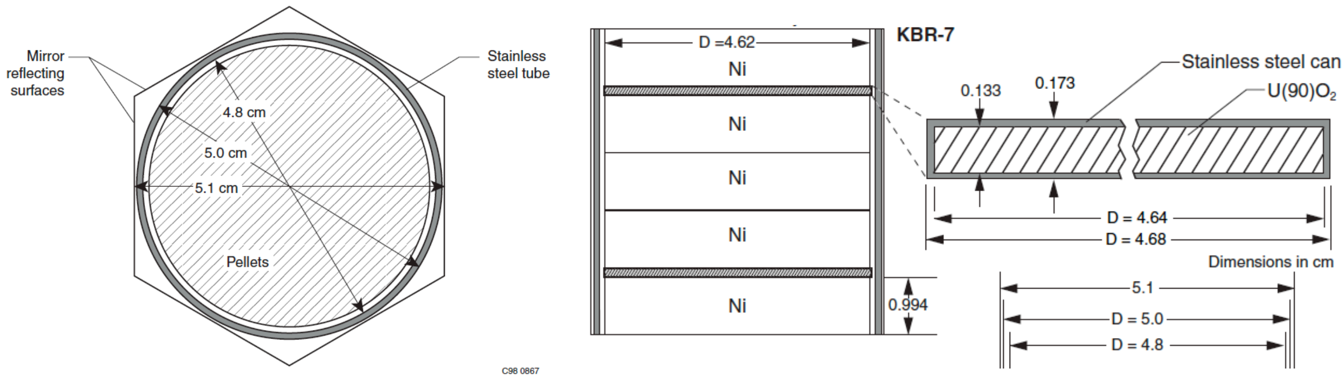
Problem #9

HEU-COMP-INTER-005 (KBR-7)

K-infinity Experiments in Intermediate Neutron Spectra for Various Structural Materials

3.1 Model: Infinite lattice of hexagonal-pitched cells.

3.2 Dimensions: 5.1-cm pitch



Plane view Axial view

3.3 Materials:

Pellet or Tube	Density (g/cm^3)	Nuclide	Atomic Density
Stainless Steel Tube	8.13314	Fe	6.1216E-02
		Cr	1.6579E-02
		Ni	8.5122E-03
		Mn	1.0698E-03
		Ti	6.1377E-04
		Si	8.7196E-04
		C	4.0778E-04
Uranium Dioxide Pellet	6.6698	^{235}U	1.3536E-02
		^{238}U	1.4663E-03
		O	3.0377E-02
Can of the Uranium Dioxide Pellet	7.9502	Fe	5.9839E-02
		Cr	1.6206E-02
		Ni	8.3207E-03
		Mn	1.0458E-03
		Ti	5.9996E-04
		Si	8.5234E-04
		C	3.9861E-04
Nickel Pellet	8.8698	Ni	9.0921E-02
		Co	9.0636E-05

3.4 Benchmark k-eff: 1.032 ± 0.004.

4.0 Student's COG results:

Lawrence Livermore National Laboratory
Nuclear Operations Directorate
Nuclear Criticality Safety Division

Evaluation of Training

CSG-TM-016	COG Software
Course Number	*Course Title*
David P. Heinrichs	
Instructor	*Completion Date*

Please circle the number that best expresses your opinion:

	NOT AT ALL ⟷ ABSOLUTELY
Overall, the course met my expectations.	1 2 3 4 5 6 7 8 9 10
The information provided was understandable.	1 2 3 4 5 6 7 8 9 10
The instruction was interesting.	1 2 3 4 5 6 7 8 9 10
This information will be useful in my job.	1 2 3 4 5 6 7 8 9 10

Comments – Do you have any comments about the material, instruction or practicality of this course?

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How can we improve this course?

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Should we contact you? – Would you like us to contact you regarding comments or questions? If so, please print your name and contact information:

Name: ______________________________

Phone: ______________ **Email:** ______________________

Thank You!