A Borated-Alumimum Cask Design for Used Fuel Cooling

Part 1 - Modeling, simulation, and design approaches

A Center for Advanced Energy Studies Collaboration
University of Idaho-Idaho Falls
Boise State University
with
Sakae Casting USA, LLC

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Center for Advanced Energy Studies
@TheDoctorRAB

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Allow me to introduce the team

Prof. Bob Borrelli, University of Idaho-Idaho Falls (CAES) - ME!

Prof. Richard N. Christensen, University of Idaho-Idaho Falls (CAES)
Nuclear Engineering Program Director

Prof. Brian Jaques - Boise State Univeristy
Samuel Pedersen - Boise State University - Graduate Student

Mr. Takashi Suzuki - CEO - Sakae Casting

Mr. Mark Delligatti, President - Table Rock, LLC
30 years experience in licensing casks at NRC

What's the story behind this project?

(Briefly)

Not your typical research project

Sakae wants to apply aluminum casting and plate designs to the nuclear market

Dr. Marc Skinner (Executive Officer IF) approached Sakae through REDI and our State Senator Kelly Anthon

Marc introduced the Sakae team to Prof. Christensen at a reception in Blackfoot that I apparently wasn't invited to in 2017

Rich drew up a concept on a napkin, as he does, for a used fuel cooling cask that could apply their casting technology

A few weeks later, I saw a bunch of Japanese people walking around CAES, so I stuck my nose in, as I do, and got involved

Then we roped in Brian

What is unique about Sakae?

Casting technology is a vacuum process using sand molds

Method of casting the aluminum and the cooling tubes allows for more efficient heat transfer

Process costs less overall

The Idaho Global Entrepreneurial Mission awards funds for products to go to market

We submitted an application in May 2017 - 2 years to design, fabricate, test prototype (It's not like a typical proposal)

We didn't get it but worked on the feedback over the summer to submit in September

We were invited to the big city in Boise to present the proposal to the Council

After fielding their questions, they settled on a year of funding to model, design, and work on a market plan

Hooray!


株式会社 栄鋳造所
SAKAE CASTING TEL:042-651-9790

Why though?

We make the arugment that there are some used fuel pools filling up

More on this in Part 2 - I wanted to make this presentation technical and not be repetitive in the next presentation

Assemblies need several years cooling before transfer to standard dry casks (Understand that some are transferred sooner - not necessarily internationally)

Design a cask that could serve as an intermediate option between pool and dry storage

Intended for onsite storage - not a dual purpose cask - storage only

We have several challenges

Thermal cooling - determining heat transfer coeffients in the cooling tubes and cask materials - Rich

Materials optimization - Boron chemical form, solid solution with aluminum, homogeneity - Brian

Shielding - How thick will the cask be? How much boron do we need? - ME!

Licensing - What are the right regulations? What is needed for licensing? - ME!

Market penetration - Who wants it? - Sakae

What are some design constraints for this cask?

Occupational safety (dose)

Effective heat removal

Mechanical strength

Cost

Realistically, the cask probably will only be effective for certain fuel types

Test different enrichments, cooling age

I used ORIGEN for burnup and depletion

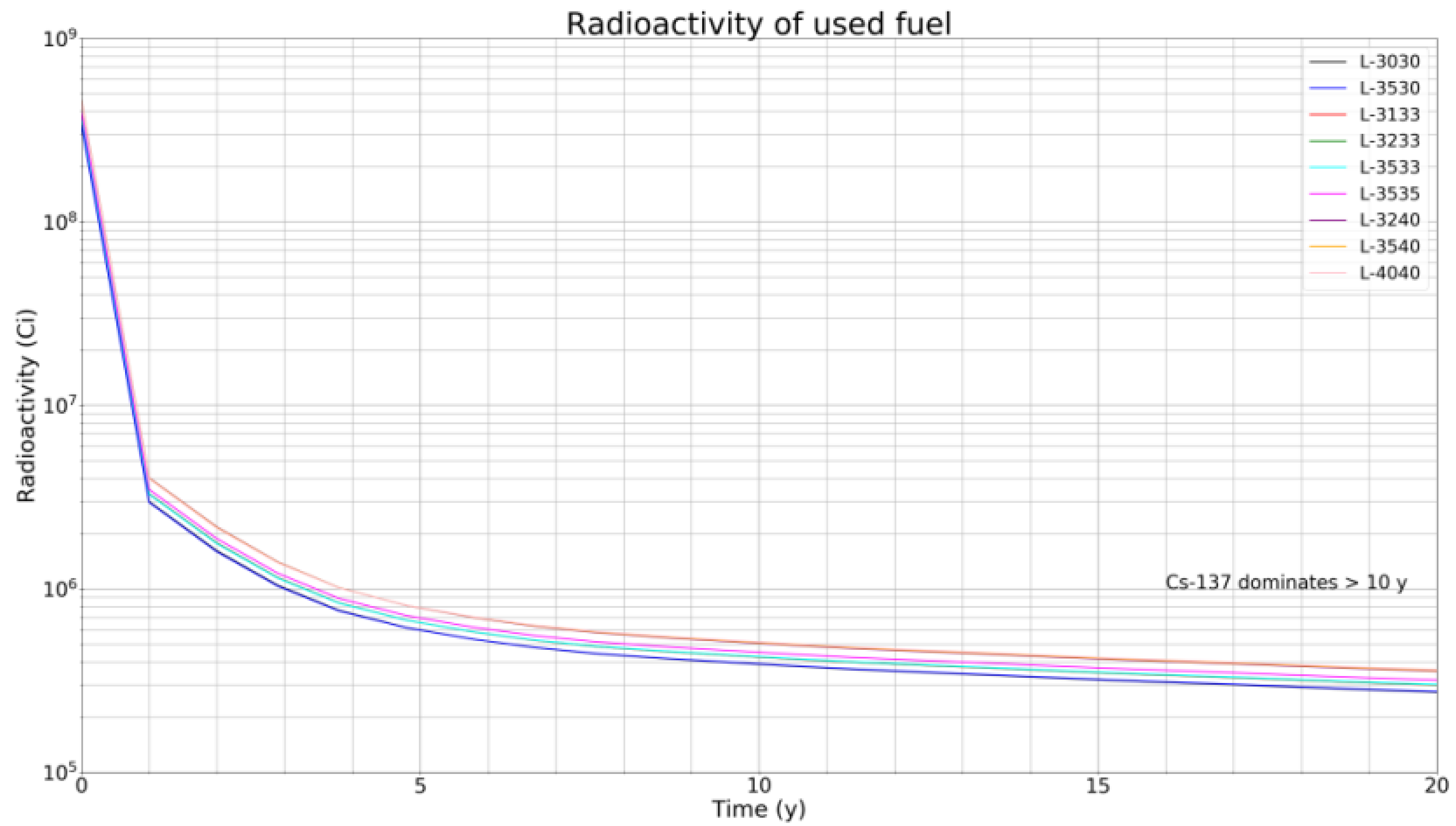
Thanks to Steve Skutnik for some slides

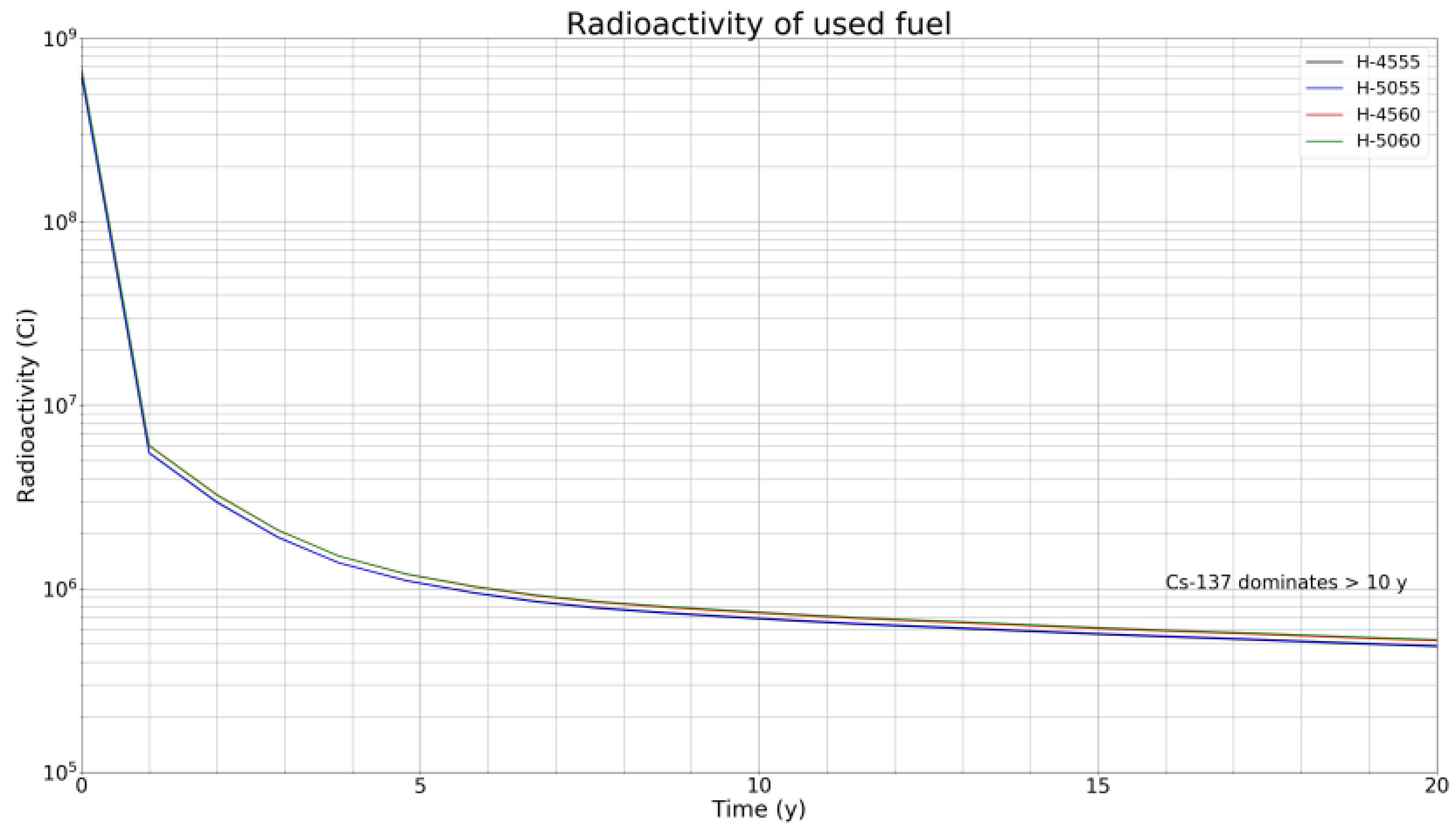
Divided the cases in to low burnup, typical burnup, high burnup

(Read - N-XXYY - X.X% and YY GWD/MTU)

L-3030,L-3530,L-3033,L-3133,L-3233,L-3533,L-3240,L-3540,L-4040
T-4045,T-4545,T-5045,T-4050,T-4250,T-42550,T-4550,T-5050
H-4555,H-5055,H-4560,**H-5060**

Westinghouse 17x17 PWR
515 day cycle length and pool cooling (decay) from discharge out to 20 years


Radioactivity of used fuel
Radioactivity (Ci)
Time (y)
L-3030
L-3530
L-3133
L-3233
L-3533
L-3535
L-3240
L-3540
L-4040
Cs-137 dominates > 10 y


Radioactivity of used fuel
H-4555
H-5055
H-4560
H-5060
Cs-137 dominates > 10 y
Radioactivity (Ci)
Time (y)
10^9
10^8
10^7
10^6
10^5
0
5
10
15
20

Cask design with MCNP

(oh no)

What's the plan?

I decided that the cask probably would only be useful for older fuel

I wanted to start with a neutron shielding model

Cm-244 shown in ORIGEN simulations to be dominant emitter across the board

Start with initial Sakae cask design

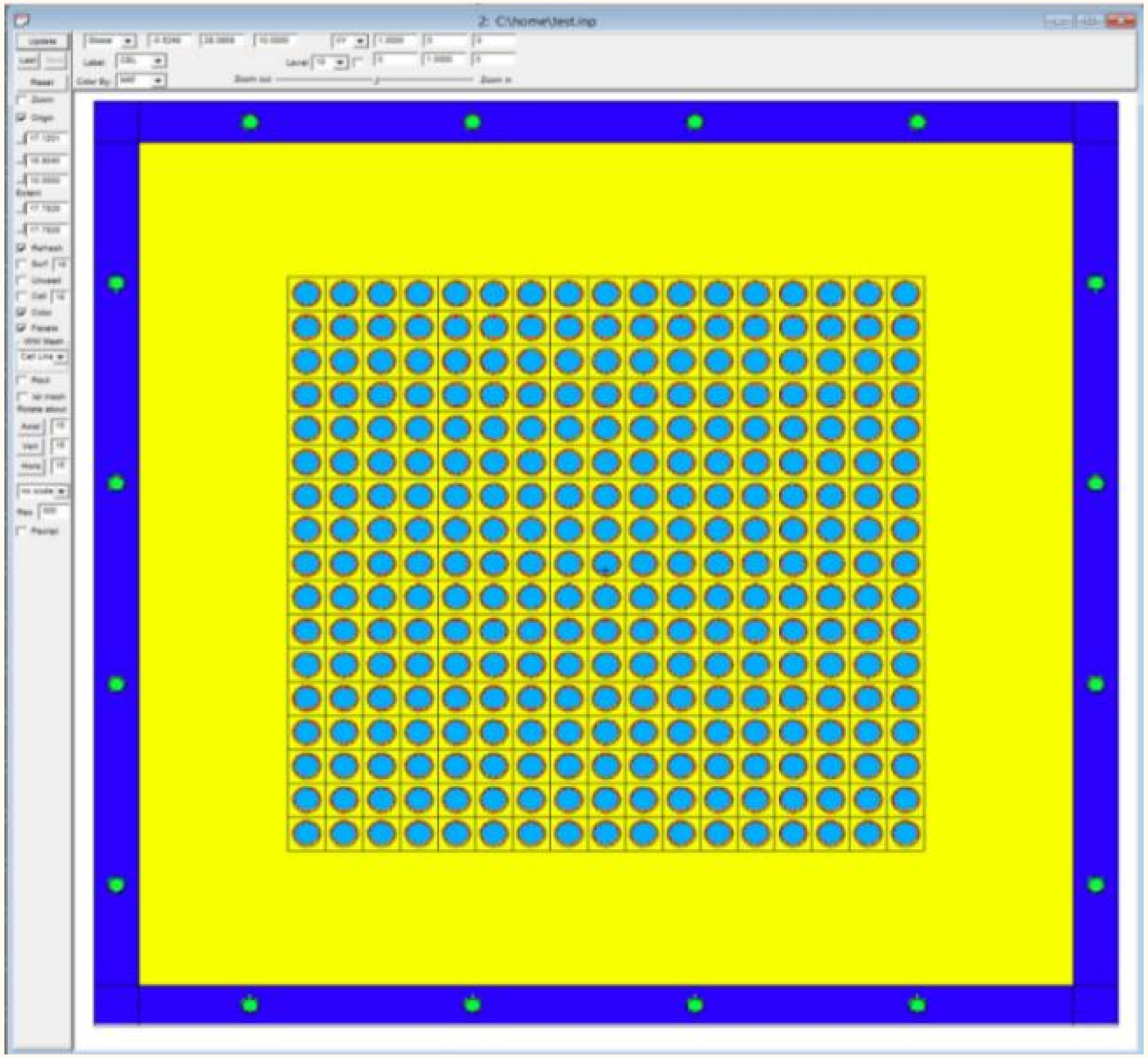
Simulate neutron emission for dose

Vary weight percent in the plates

Vary thickness

VISED views

Got started with help from Seth Dustin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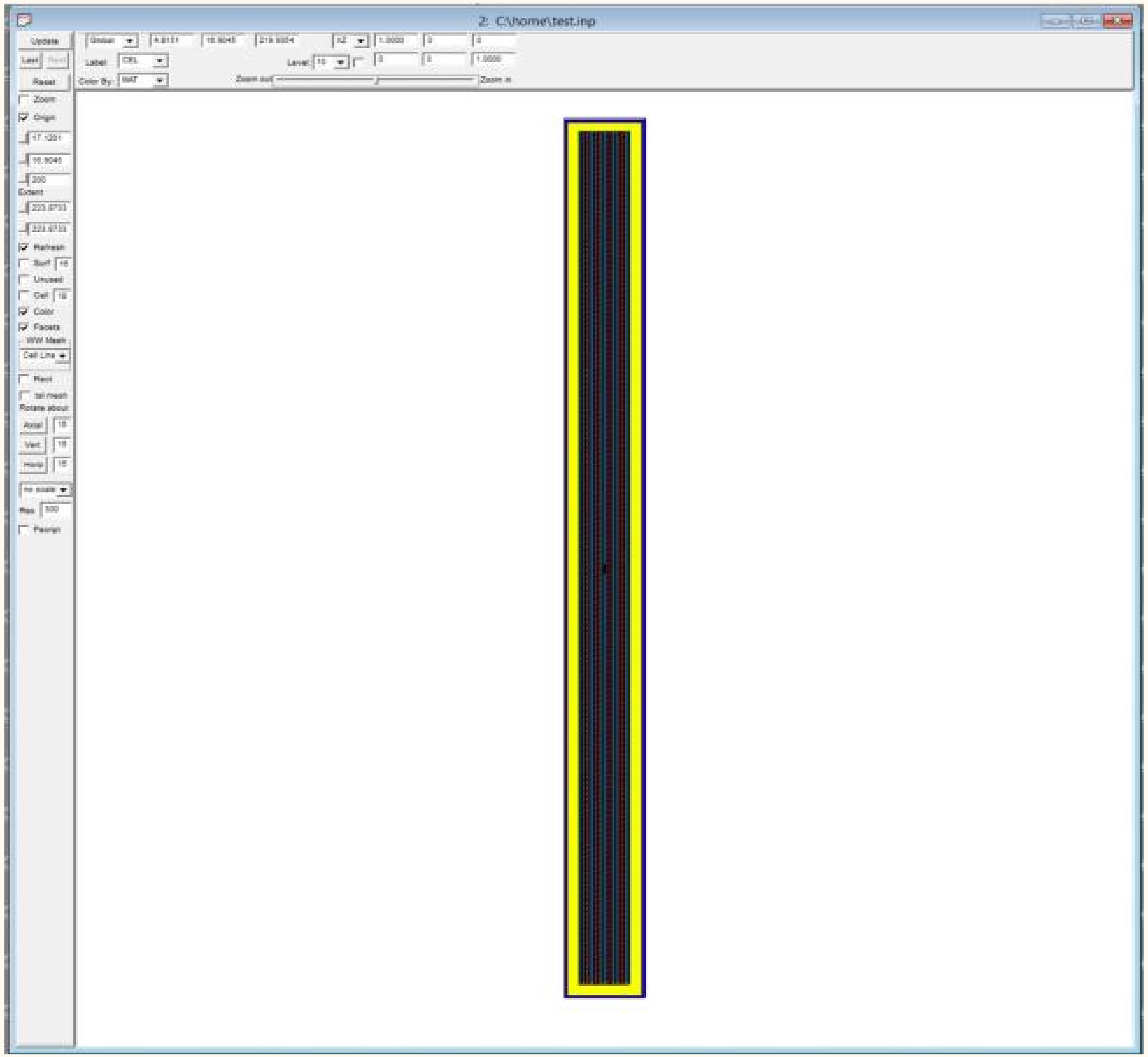
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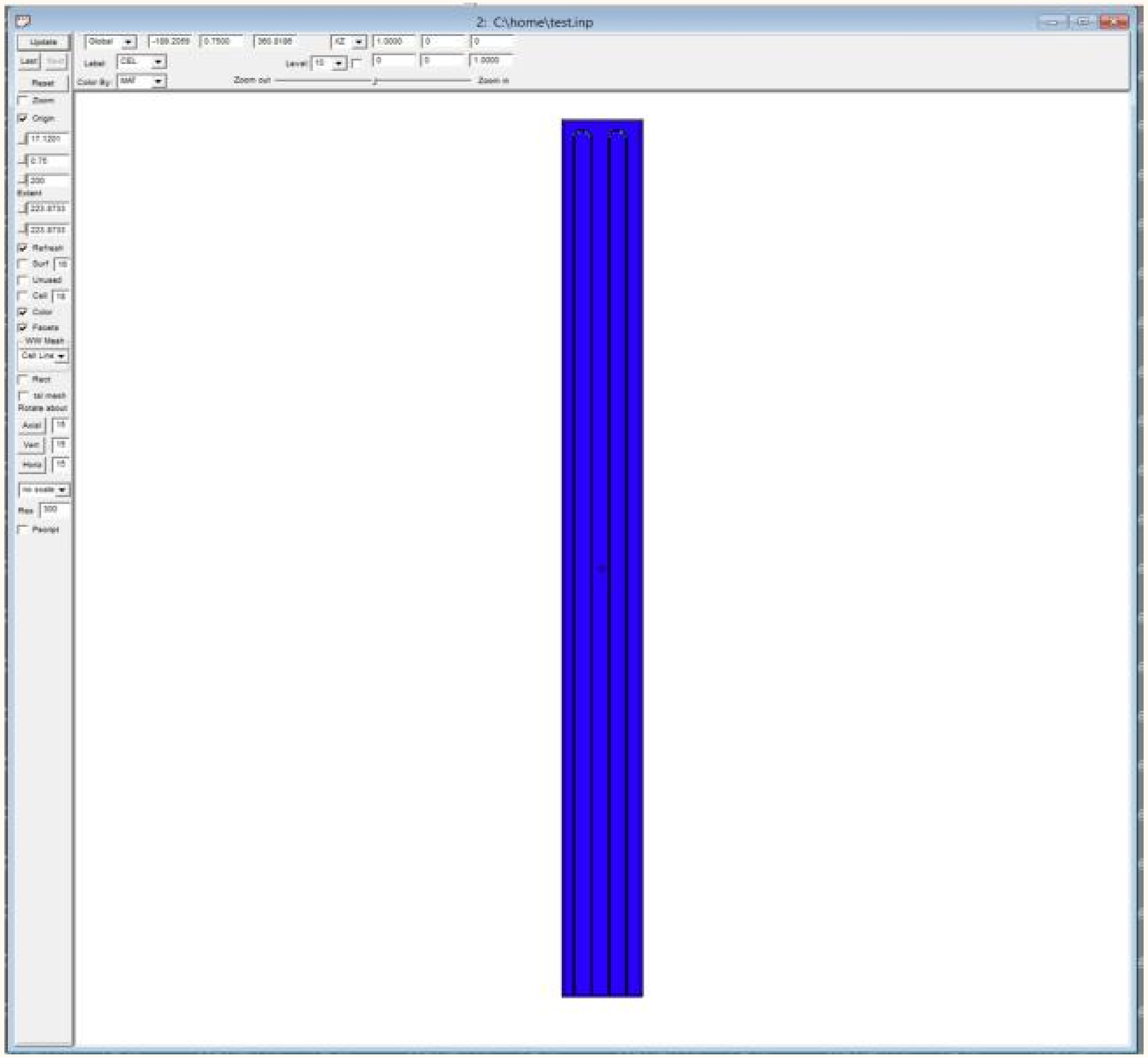
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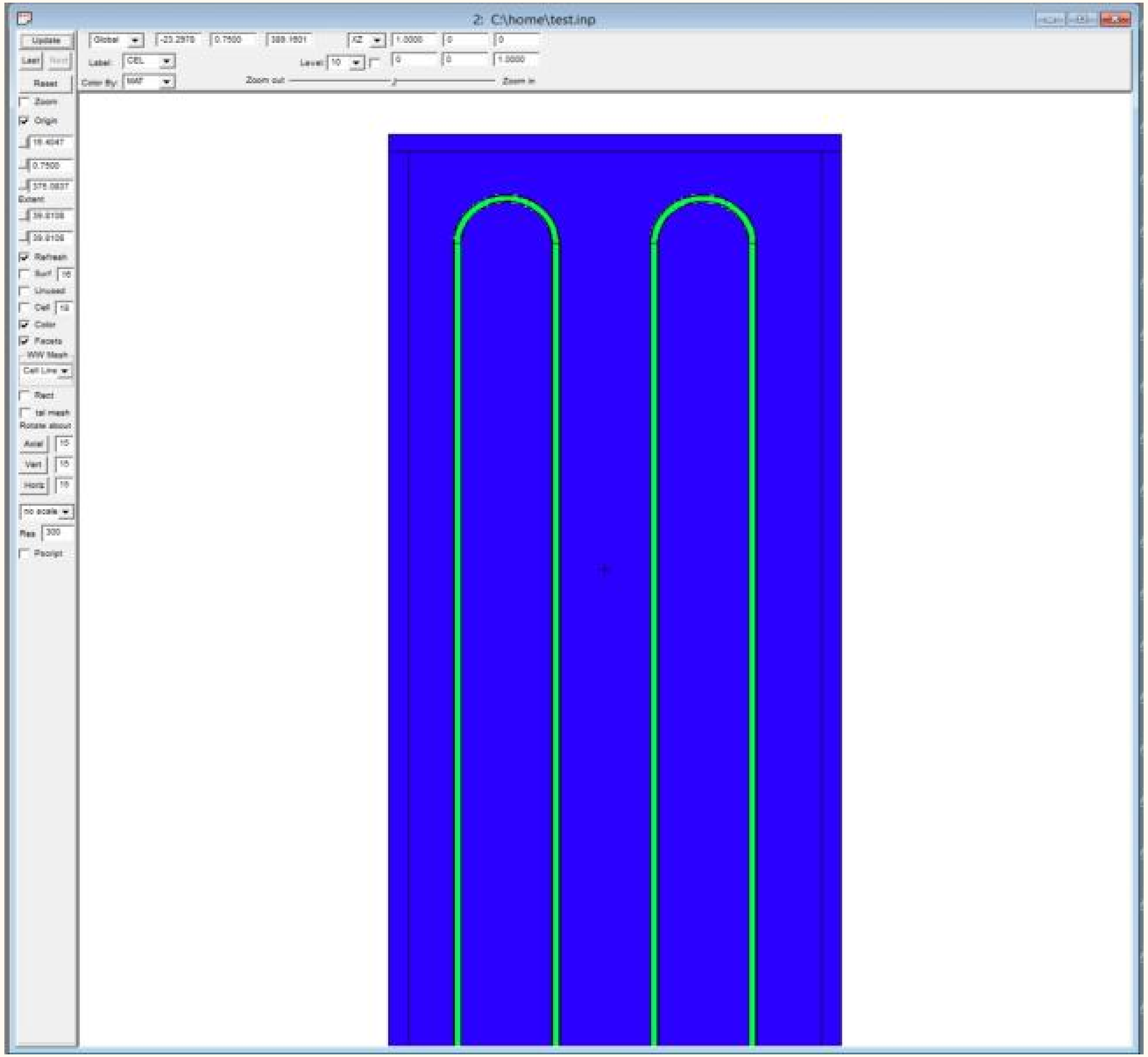
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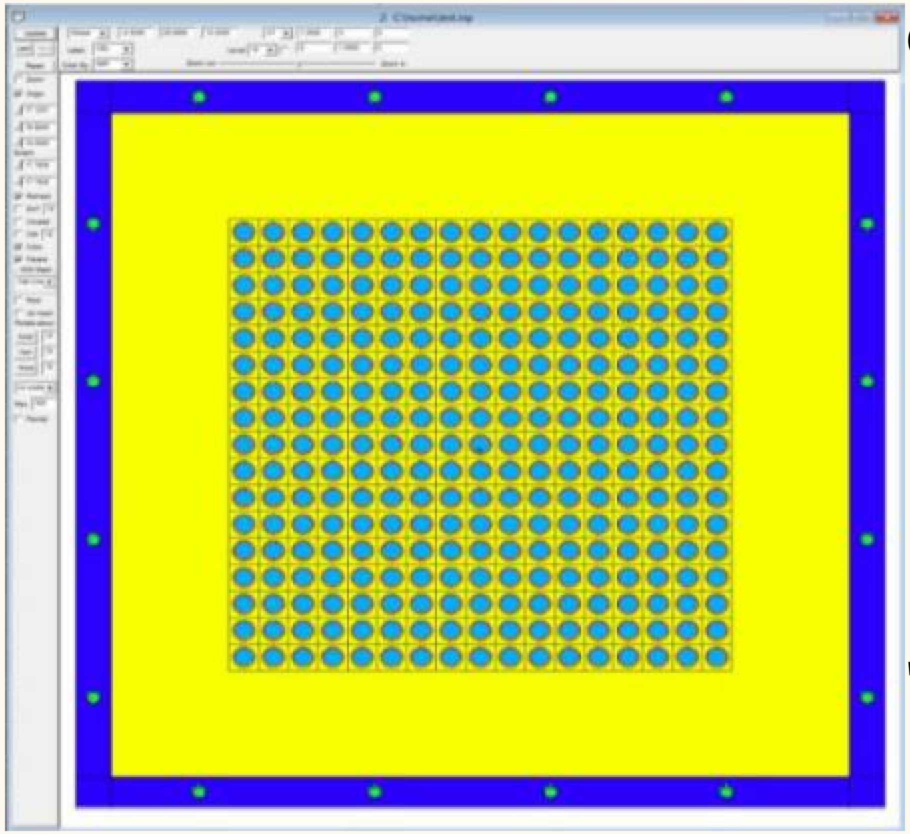
MCNP modeling notes for your interest



Cask has backfill
Filled with different materials

Lattice card 17x17 unit cells - pitch 12.54 mm

Material card taken from ORIGEN output

Pipes equally positioned on plates
More can be added

"Welds" are separate cells
Material can be changed independently

MCNP output notes for your interest

Standard defaults for dose card

SDEF card - 5 source points per rod (POS)

ERG = Spontaneous Cm fission energy distribution

F2 tally for outward normal on each plate

NPS 1E6 passed all tests for error and VOV

Few where cap and plug had slope 2.9

Few where FOM trend during last half of problem

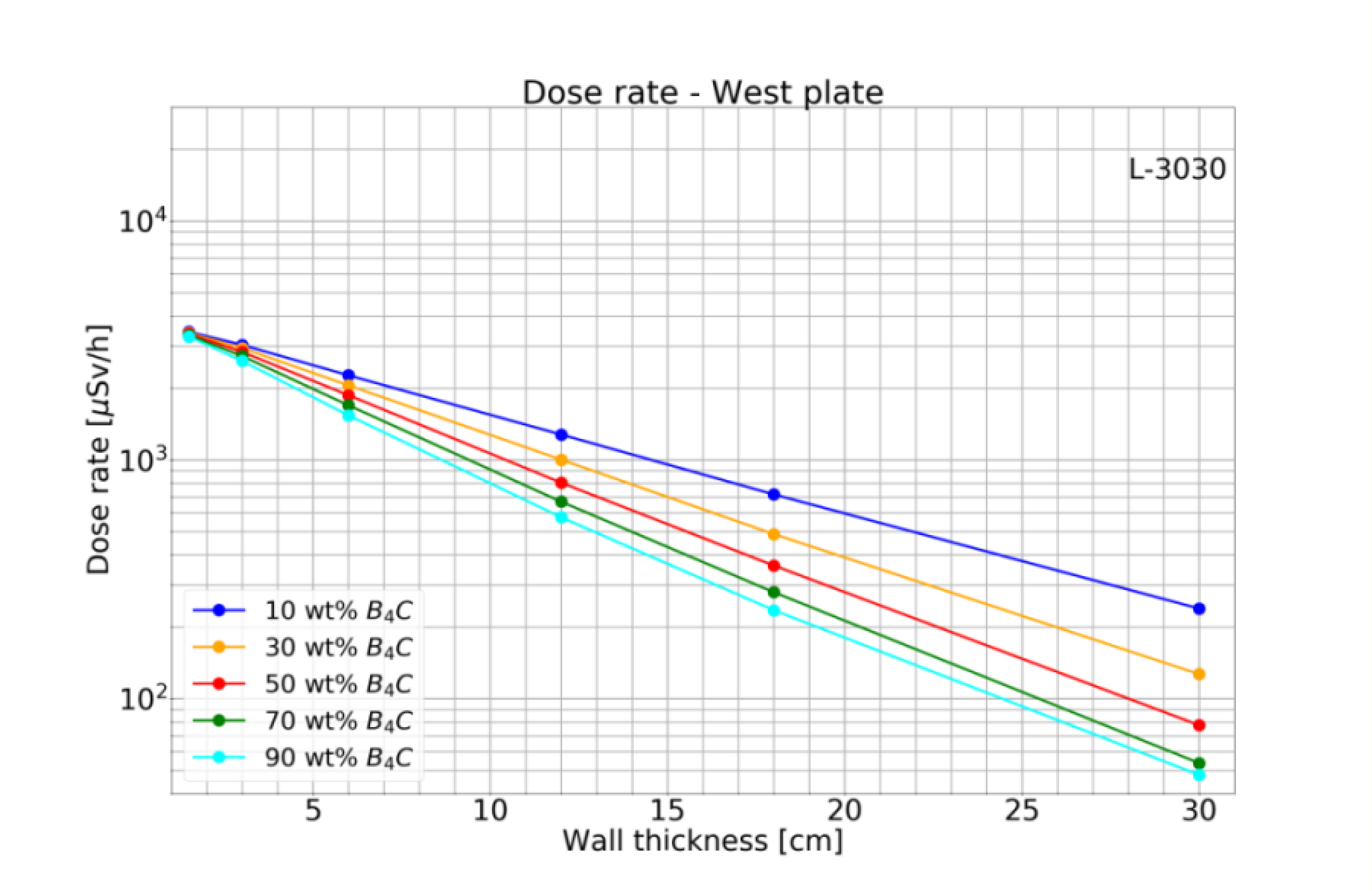
Equal(ish) dose rates off plates - showing results for west plate

Results so far

Low burnup 3030 results

International Commission on Radiological Protection limit for neutrons

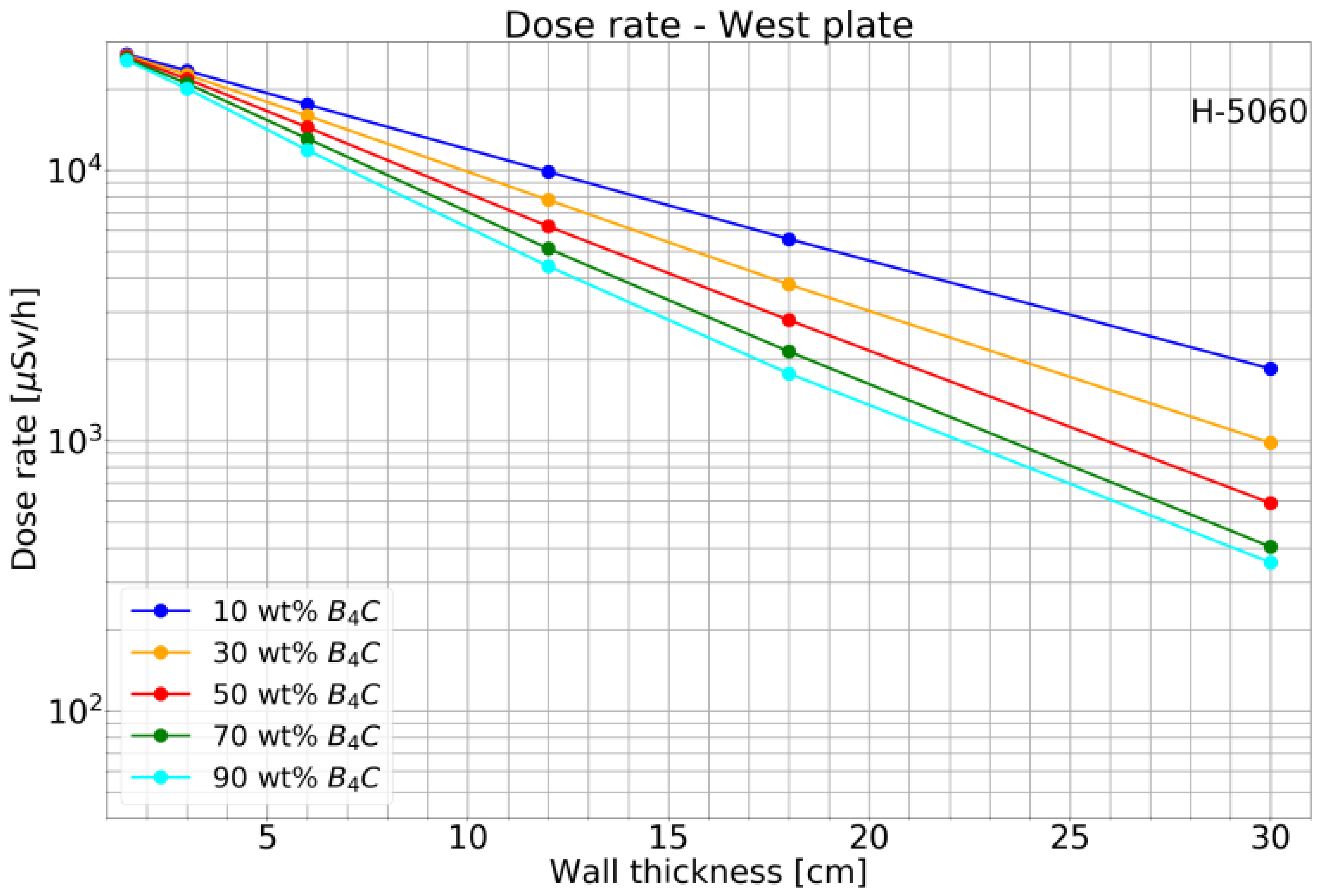
L-3030	10wt%	30wt%	50wt%	70wt%	90wt%
1.5 cm	3.4E3	3.4E3	3.4E3	3.3E3	3.3E3
3 cm	3.0E3	2.9E3	2.8E3	2.7E3	2.6E3
6 cm	2.3E3	2.0E3	1.9E3	1.6E3	1.5E3
12 cm	1.3E3	1.0E3	8.0E2	6.7E2	5.7E2
18 cm	7.2E2	4.9E2	3.6E2	2.8E2	2.3E2
30 cm	2.4E2	1.3E2	7.7E1	5.2E1	4.8E1


Dose rate - West plate
L-3030
Dose rate [μSv/h]
Wall thickness [cm]
10 wt% B4C
30 wt% B4C
50 wt% B4C
70 wt% B4C
90 wt% B4C

High burnup 5060 results

International Commission on Radiological Protection limit   for neutrons

H-5060	10wt%	30wt%	50wt%	70wt%	90wt%
1.5 cm	2.7E4	2.7E4	2.6E4	2.6E4	2.5E4
3 cm	2.3E4	2.3E4	2.2E4	2.0E4	2.0E4
6 cm	1.8E4	1.6E4	1.4E4	1.3E4	1.2E4
12 cm	9.9E3	7.8E3	6.2E3	5.1E3	4.2E3
18 cm	5.5E3	3.8E3	2.8E3	2.1E3	1.8E3
30 cm	1.8E3	9.8E2	5.9E2	4.0E2	3.5E2



Dose rate - West plate
H-5060
Dose rate [μSv/h]
10^4
10^3
10^2
5
10
15
20
25
30
Wall thickness [cm]
10 wt% B_4C
30 wt% B_4C
50 wt% B_4C
70 wt% B_4C
90 wt% B_4C

What's next?

What design and modeling enhancements can be made?

Stick with modeling L-3030 and H-5060

Design review with the team to bound realistic boron loading and plate thickness

Add Cs-137 source

Vary backfill material

Put the cask in something else

Determine significance of neutron activation of aluminum
Beta emission at 2.7 MeV and gamma emission at 1.8 MeV

Find students I can actually pay to help me