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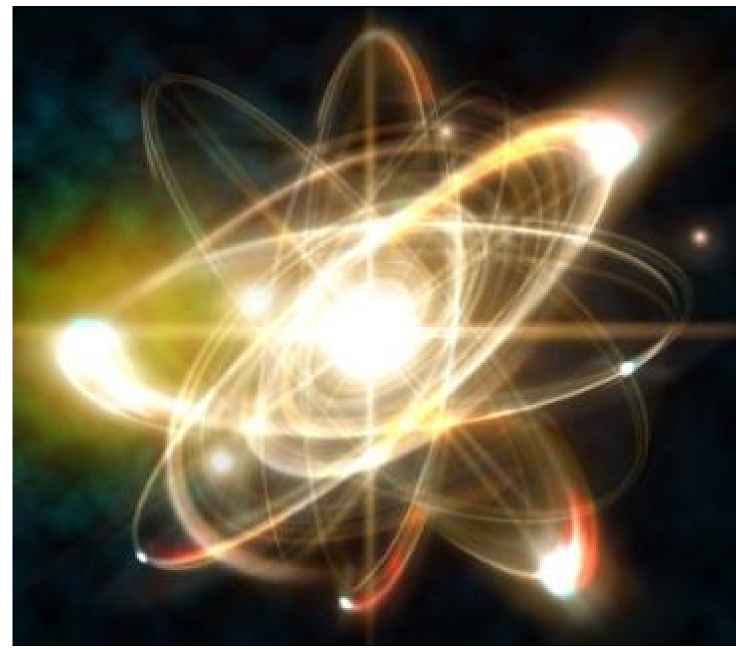
Model 30B UF6 Cylinder Transport in Support of LEU+: Technical and Regulatory Challenges



NCSD Technical Session Panel:
New Developments in Shipping Packages Related to Criticality Safety

Lon Paulson
June 10, 2020

2020 ANS Virtual Annual Meeting

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Agenda

- Introduction
- Model 30B UF6 Cylinder
- Transport Regulations
- Calculations and Results
- Conclusions
- References

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Introduction to LEU+

Low-enriched Uranium plus or "LEU+" – uranium material enrichments up to ~10% U235 used to support accident tolerant fuel (ATF) designs for existing LWR fleet ➔ FOCUS OF THIS DISCUSSION

High Assay Low-enriched Uranium or "HALEU" – uranium material enrichments up to 20% U235 used to support advanced reactor designs (TRISO, SMR, micro-reactors) ➔ NOT THE FOCUS OF THIS DISCUSSION

SNM-1097 license amendment was submitted to the USNRC in OCT2019; and now undergoing active NRC review. The license amendment requests GNF-A ability to process material enrichments up to 8% enrichment (our current SNM-1097 license restricts GNF-A to not more than 5% enrichment).

GNF-A is now rebaselining the entire nuclear fuel conversion, fuel fabrication, and balance of plant systems from a nuclear criticality safety and ISA perspective to permit 8% material enrichment processing.

Feedstock delivery of UF6 enriched to ~ 8% is assumed; but NEI/industry discussions have pointed out existing regulatory framework is problematic.

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Model 30B UF6 Cylinder - I

6.7 UF_6 Cylinder Model 30B

Nominal Diameter	30 in. (76 cm)
Nominal Length	81 in. (206 cm)
Wall Thickness	1/2 in. (1.25 cm)
Nominal Tare Weight	1,400 lb (635 kg)
Maximum Net Weight	5,020 lb (2,277 kg)
Nominal Gross Weight	6,420 lb (2,912 kg)
Minimum Volume	26 ft^3 (736 liters)
Basic Material of Construction	Steel (ASTM A-516)
Service Pressure	200 psig (1380 kPa gage)
Hydrostatic Test Pressure	400 psig (2760 kPa gage)
Isotopic Content Limit	5.0% ^{235}U (max. with moderation control)

Valve Used - Type 51 - 1-inch valve.

GNF-A has over 50 years of OE/LL involving fissile transport including Model 30B UF6 cylinders enriched up to 5 wt% U235.

Can the container be demonstrated safe for transport of UF6 enriched up to 8 wt% U235?

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Model 30B UF6 Cylinder - II

Authorized Heel Contents

Research and Special Programs Admin., DOT **§ 173.417**

TABLE 3—ALLOWABLE CONTENT OF URANIUM HEXAFLUORIDE (UF_6) "HEELS" IN A SPECIFICATION 7A CYLINDER

Maximum cylinder diameter		Cylinder volume		Maximum uranium-235 enrichment (weight percent)	Maximum "Heel" weight per cylinder			
					UF6		Uranium-235	
Cm	Inches	Liters	Cubic feet		kg	lb	kg	lb
12.7	5	8.8	0.311	100.0	0.045	0.1	0.031	0.07
20.3	8	39.0	1.359	12.5	0.227	0.5	0.019	0.04
30.5	12	68.0	2.410	5.0	0.454	1.0	0.015	0.03
76.0	30	725.0	25.64	5.0	11.3	25.0	0.383	0.84
122.0	48	3,084.0	[1]108.9	4.5	22.7	50.0	0.690	1.52
122.0	48	4,041.0	[2]142.7	4.5	22.7	50.0	0.690	1.52

[1] 10 ton.
[2] 14 ton.

§173.420 Uranium hexafluoride (fissile, fissile excepted and non-fissile).

(4) Uranium hexafluoride must be in solid form.
(5) The volume of solid uranium hexafluoride, except solid depleted uranium hexafluoride, at 20 °C (68 °F) may not exceed 61% of the certified volumetric capacity of the packaging. The volume of solid depleted uranium hexafluoride at 20 °C (68 °F) may not exceed 62% of the certified volumetric capacity of the packaging.
(6) The pressure in the package at 20 °C (68 °F) must be less than 101.3 kPa (14.7 psia).

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Model 30B UF6 Cylinder - III

Transport of loaded 30B UF6 cylinders in UX-30 [DN-30] "overpack" in secured on flatrack

Transport of bare "heel" cylinders

30B Transport Regulations

Option1

Petition for Rule Change

10CFR71, 49CFR173.417

Standards alignment

Option2

Seek NRC exemption via UX-30 SAR amendment

Pursue domestic transport

Fissile material contents must assure compliance with ASTM C787 and C996. which require a minimum 99.5% purity. The maximum H/U atomic ratio of 0.088 allowed according to 49 CFR 173.417, Table 6, corresponds to 0.5% impurity, with all the impurity being assumed hydrogenous (hydrogen fluoride or HF).

For the UX-30 overpack criticality control relies upon specification of maximum H/U ratio, or equivalently, minimum UF6 purity.

30B Transport Regulations

Ultimately a domestic rule change is needed to both 10CFR71 and 49CFR173.

- 10 CFR 71.55(g)(4) - The uranium is enriched to not more than 5 weight percent uranium-235.
- 49 CFR 173.417(a)(2) – “Heel” requirements: less than 5 weight percent in a 30-inch cylinder
- ANSI N14.1 – 30B/C: 5 weight percent

The current regulatory enrichment limit of 5.0 wt% U235 for hydrogenous moderation exclusion on the Model 30B UF6 cylinder is arbitrary.

Hydrogenous (e.g., water) exclusion equally applies to 8.0 wt. % U235 enriched UF6 contents.

The “leak tight” packaging feature of the Model 30B UF6 cylinder within overpack is not changed nor impacted from an incremental change to the uranium hexafluoride enrichment.

The probability of and an accident is not increased, nor are the consequences.

A generic UX-30 **SAR amendment to support exemption for transport of UF6 enriched to LEU+ level (8 wt% U235) is more likely to succeed in the near term.**

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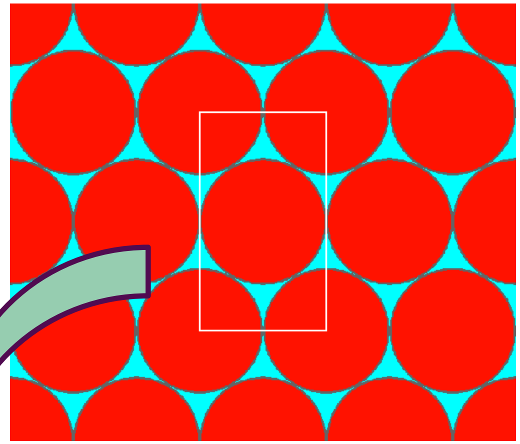
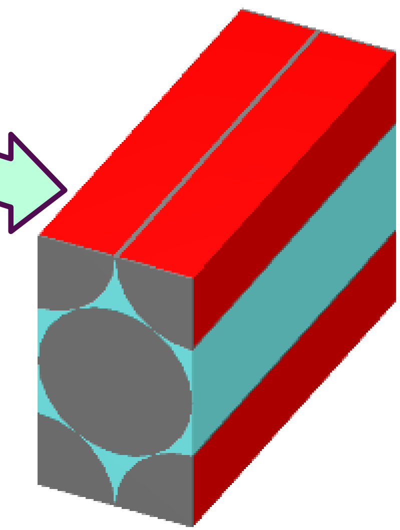
SCALE6.1 Full 30B Model Construct

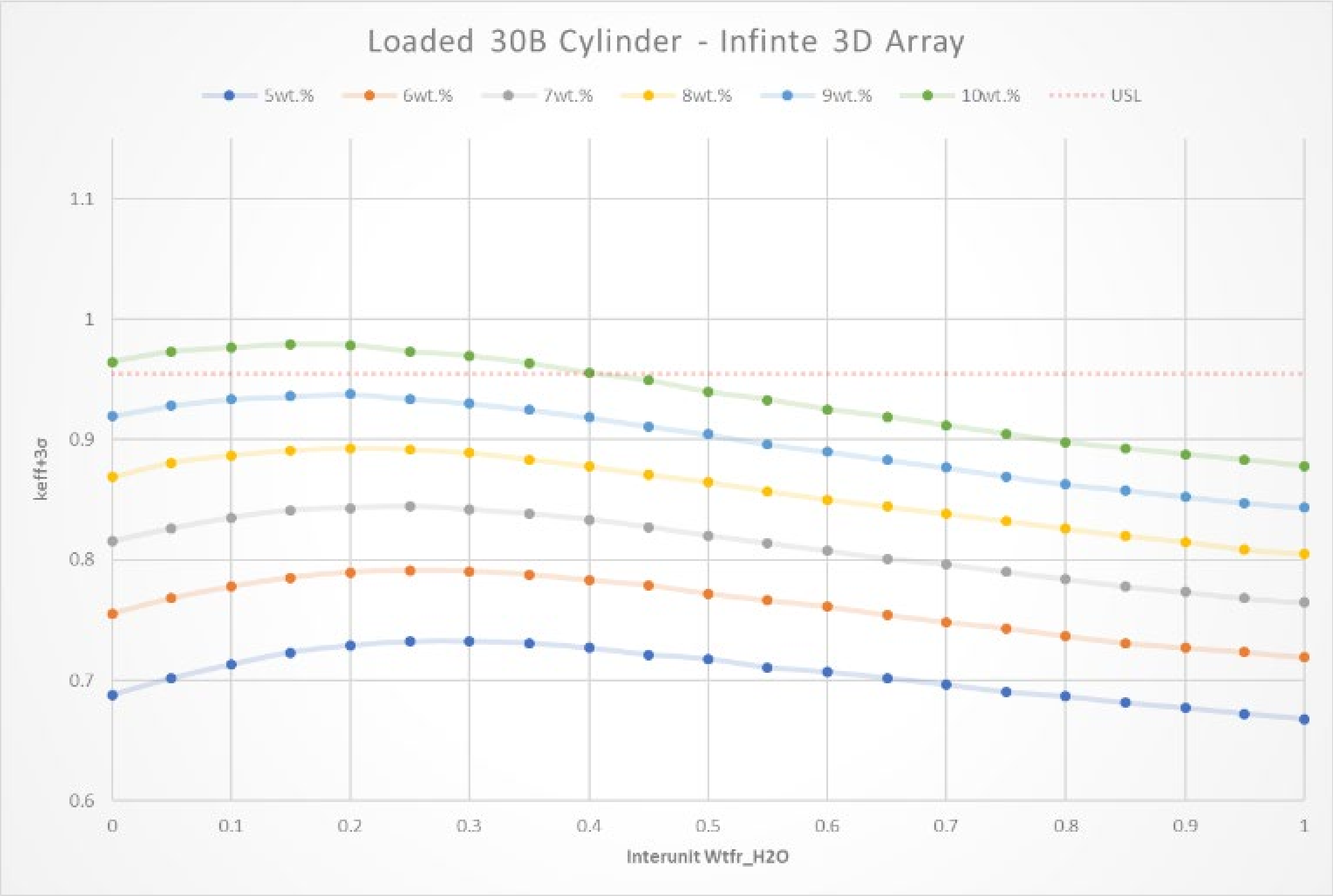
```
=csas6
infinite 30B close packed array: theoretical uf6 + 0.005 hf, var. enr, var. i/u
h2o
ce_v7_endf
read composition
 uf6        1 den=5 0.995 300
                          92235 5
                          92238 95   end
 hf         1 den=5 0.005 300   end
 carbonsteel 2 1 300   end
 h2o         3 den=0.30 1 300   end
end composition
read parameter
 gen=250
 npg=5000
 nsk=50
 htm=yes
end parameter
read geometry
unit 1
com="single 30b cylinder"
 ycylinder 1    38.1   102.87  -102.87
 ycylinder 2   39.37   104.14  -104.14
 media 1 1 1
 media 2 1 2 -1
 boundary 2
unit 2
com="single 30b cylinder"
 ycylinder 1    38.1   102.87  -102.87
 ycylinder 2   39.37   104.14  -104.14  chord +x=0  c
 media 1 1 1
 media 2 1 2 -1
 boundary 2
unit 3
com="single 30b cylinder"
 ycylinder 1    38.1   102.87  -102.87
 ycylinder 2   39.37   104.14  -104.14  chord -z=0  cl
 media 1 1 1
 media 2 1 2 -1
 boundary 2
```





```
unit 4
 com="single 30b cylinder"
 ycylinder 1     38.1   102.87  -102.87
 ycylinder 2    39.37   104.14  -104.14  chord -x=0  chord +z=0
 media 1 1 1
 media 2 1 2 -1
 boundary 2
unit 5
com="single 30b cylinder"
 ycylinder 1     38.1   102.87  -102.87
 ycylinder 2    39.37   104.14  -104.14  chord -x=0  chord -z=0
 media 1 1 1
 media 2 1 2 -1
 boundary 2
global unit 6
com="30b cylinder infinite array"
 cuboid 1    39.37   -39.37   104.14  -104.14   68.191  -68.191
 hole 1
 hole 2   origin  x=-39.37 y=0 z=-68.191
 hole 3   origin  x=-39.37 y=0 z=68.191
 hole 4   origin  x=39.37 y=0 z=-68.191
 hole 5   origin  x=39.37 y=0 z=68.191
 media 3 1 1
 boundary 1
 end geometry
 read bnds
  body=1
    all=mirror
  end bnds
  end data
  end
```

Results – Full Cylinder



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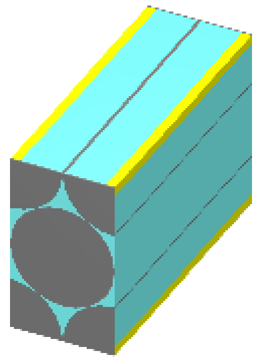
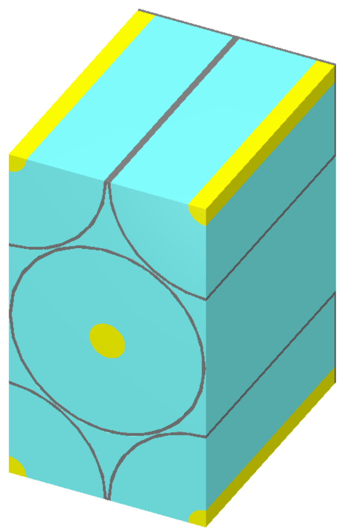
SCALE6.1 30B Heel Model Construct

```
csas6
30b heel cylinder,infinite array,huf,10
ce_v7_endf
read composition
 uo2f2       1 den=1.6587 0.45 300
                           92235 8
                           92238 92   end
 h2o         1 den=1.6587 0.55 300   end
 carbonsteel 2 1 293   end
 h2o         3 den=0.0005 1 293   end
end composition
read parameter
 gen=250
 npg=5000
 nsk=50
 htm=no
end parameter
read geometry
unit 1
com="fuel region"
 ycylinder 1   7.1545   102.87  -102.87
 ycylinder 2     38.1   102.87  -102.87
 ycylinder 3    39.37   104.14  -104.14
 media 1 1 1
 media 3 1 2 -1
 media 2 1 3 -2
 boundary 3
unit 2
com="fuel region"
 ycylinder 1   7.1545   102.87  -102.87
 ycylinder 2     38.1   102.87  -102.87
 ycylinder 3    39.37   104.14  -104.14  chord +
 media 1 1 1
 media 3 1 2 -1
 media 2 1 3 -2
 boundary 3
unit 3
com="fuel region"
 ycylinder 1   7.1545   102.87  -102.87
 ycylinder 2     38.1   102.87  -102.87
 ycylinder 3    39.37   104.14  -104.14  chord -z=0  chord +x=0
 media 1 1 1
 media 3 1 2 -1
 media 2 1 3 -2
 boundary 3
unit 4
com="fuel region"
 ycylinder 1   7.1545   102.87  -102.87
 ycylinder 2     38.1   102.87  -102.87
 ycylinder 3    39.37   104.14  -104.14  chord -x=0  chord +z=0
 media 1 1 1
 media 3 1 2 -1
 media 2 1 3 -2
 boundary 3
unit 5
com="fuel region"
 ycylinder 1   7.1545   102.87  -102.87
 ycylinder 2     38.1   102.87  -102.87
 ycylinder 3    39.37   104.14  -104.14  chord -x=0  chord -z=0
 media 1 1 1
 media 3 1 2 -1
 media 2 1 3 -2
 boundary 3
global unit 6
com="30b heel cylinder infinite array"
 cuboid 1   39.37   -39.37   104.14  -104.14   68.191  -68.191
 hole 1
 hole 2   origin  x=-39.37 y=0 z=-68.191
 hole 3   origin  x=-39.37 y=0 z=68.191
 hole 4   origin  x=39.37 y=0 z=-68.191
 hole 5   origin  x=39.37 y=0 z=68.191
 media 3 1 1
 boundary 1
end geometry
read bnds
  body=1
    all=mirror
  end bnds
end data
end
```





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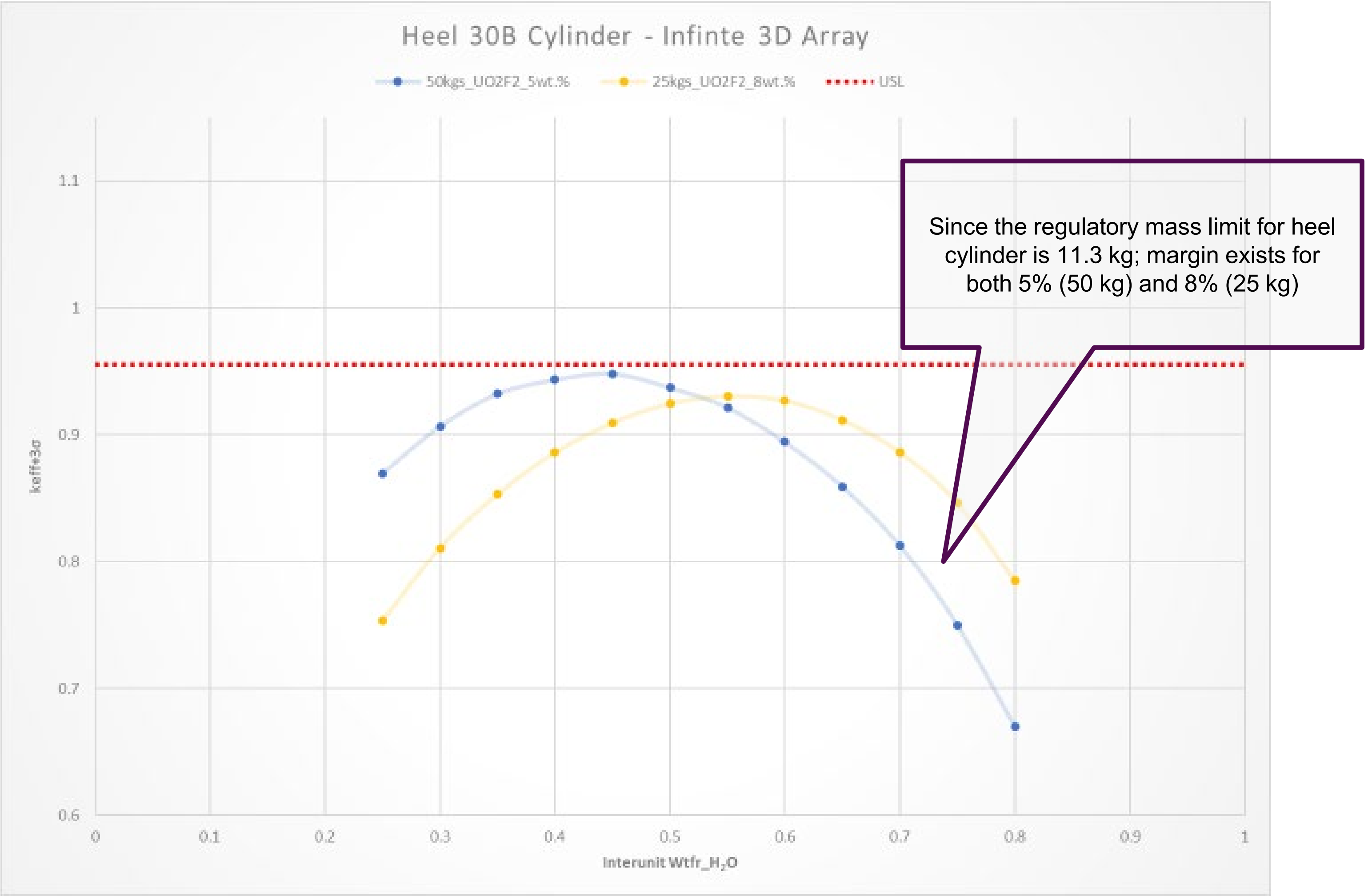
Results – Heel Cylinder



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Conclusions

- Material UF6 feedstock enriched up to 8 wt.% U235 can be safely transported in Model 30B UF6 cylinder contained in UX-30 overpacks to GNF-A for re-conversion/ATF fuel fabrication purposes.

- The existing Model 30B UF6 cylinder is a USDOT specification cylinder with a proven track record of containment. The Model 30B specification UF6 cylinder contained in the CHT designed UX-30 overpack is a Type B, Fissile nuclear package licensed by the USNRC

- The criticality safety evaluation for the CHT designed UX-30 relies on the ORNL/TM-I 1947, Criticality Safety Review of 2 1/2- ,10-, and 14-Ton UF6 Cylinders and assumptions about the purity of UF6 specified by ASTM C787 and C996.

- A *generic* UX-30 SAR amendment appears feasible to meet near term industry needs in support of accident tolerant fuel (ATF) fuel designs. This work demonstrates the CSI is zero for loaded or heel 30B UF6 cylinders. The current certificate assignment of CSI = 5.0 per 49 CFR 173.417, Table 6, for loaded cylinders has no basis.

- A longterm NEI initiative to relax the current regulatory 5% enrichment constraint will require petition for rule change (USNRC, USDOT, +IAEA) with commensurate updates to national consensus standards (ASTM, ANSI N14.1).

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References

1. Model No. UX-30, USNRC Certificate of Compliance for Radioactive Materials Package, Package Identification Number USA/9196/B(U)F-96, Rev. 30, November 2018.

2. ORNL/TM-I 1947, Criticality Safety Review of 2 1/2-. 10-. and 14-Ton UF6 Cylinders. B.L. Broadhead, Martin Marietta Energy Systems, Oak Ridge National Laboratory, October 1991.

3. ASTM C787, “Standard Specifications for Uranium Hexafluoride for Enrichment,” 2015.

4. ASTM C996, “Standard Specifications for Uranium Hexafluoride Enriched to Less Than 5% U-235,” 2015.

5. Safety Analysis Report for the Model UX-30 Package, Rev. 4, June 2018, Columbiana High Tech, 1802 Fairfax Road, Greensboro, NC.

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Q & A