Global Nuclear Fuel

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

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Agenda

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- Model 30B UF6 Cylinder
- Transport Regulations
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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.
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?
§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).
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
Option 1
Petition for Rule Change
10CFR71, 49CFR173.417
Standards alignment

Option 2
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 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.
SCALE6.1 Full 30B Model Construct

=csas6
infinite 30B close packed array: theoretical uf6 + 0.005 hf, var. enr, var. i/u
h2o
c_{v7}.endf
read composition
uf6 1 den=5 0.996 300 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"
cyliner 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"
cyliner 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 3
com="single 30b cylinder"
cyliner 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 4
com="single 30b cylinder"
cyliner 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 5
com="single 30b cylinder"
cyliner 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"
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
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"
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 – Heel Cylinder

Since the regulatory mass limit for heel cylinder is 11.3 kg; margin exists for both 5% (50 kg) and 8% (25 kg)
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 long term 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).
References


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