Spent Fuel Transport Container C-30

Part II. Using of the old type transport cask C-30 for an improved fuel VVER-440

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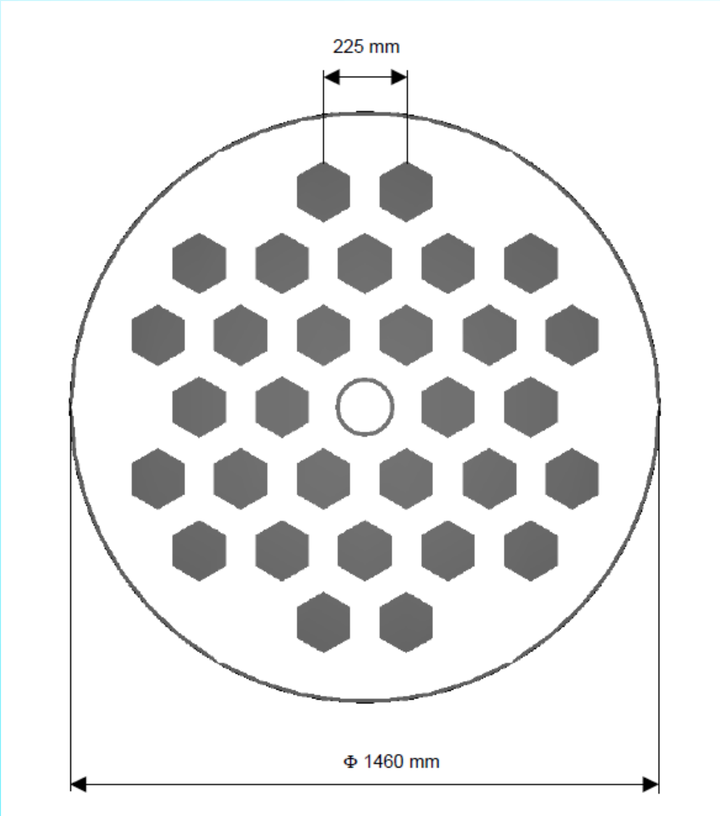
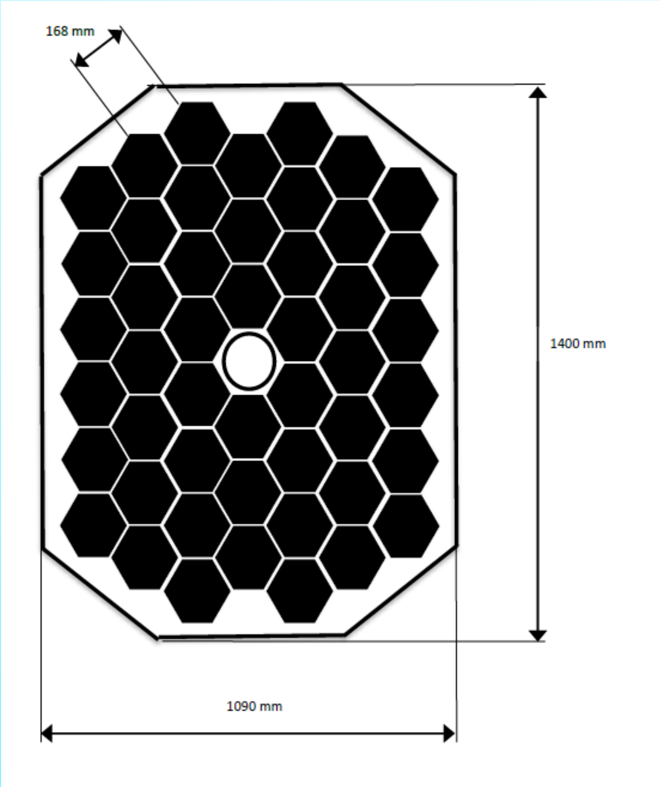
Introduction

The transport cask C-30 with basket T-12 was developed in former East Germany for VVER-440 fuel with enrichment 3.6 %. Later was in Slovakia developed the new compact basket KZ-48 for VVER-440 fuel with enrichment 4.4 % and maximal burnup 55 MWd/kgU. The present licence is for VVER-440 fuel with enrichment 4.4 % and maximal burnup 60 MWd/kgU. The future licence need to be for VVER-440 fuel with average enrichment 4.87 % and maximal burnup 70 MWd/kgU.

the basket T-12



the basket KZ-48



fuel

- **3.6 %** = original fuel of 1st generation, original basket **T-12**. All fuel pins have the same enrichment 3.6 % of U235.
- **4.25 %** = fuel 2nd generation with burnable absorber, fuel pins have radial profiled enrichment (maximal enrichment is 4.4 % U235) and 6 pins contain burnable absorber Gd_2O_3. This fuel is in present transported in transport cask C-30 in the basket **KZ-48**. The present license for transport cask C-30 with basket KZ-48 is for fuel with maximal enrichment 4.4 % and maximal burnup 60 MWd/kgU.
- **4.87 %** = present fuel 2nd generation with burnable absorber, fuel pins have radial profiled enrichment (maximal enrichment is 4.95 % U235) and 6 pins contain burnable absorber Gd_2O_3. This fuel is in present in core and in 5 - 6 years will be transported in cask C-30 in the basket **KZ-48**. Estimated burnup should be 70 MWd/kgU. The safety report for this fuel will be prepared in 4 years.

used codes and libraries

The SCALE 6.1.2 system was used for criticality and inventory analyses. The criticality calculations were with the KENO VI module (Monte Carlo method) and library v7-238 (continuous energy) carried out. The inventory calculations were with the ORIGEN module and libraries vver440(3.6), vver440(4.25) and vver440(4.87) carried out.

Criticality calculation

- for safety analyses

$$k_{eff} = k_{eff}^{calc} + 2\sigma_{MC} + 2_{\sigma exper} + \Delta k^{unc}$$

- in this article

$$k_{eff} = k_{eff}^{calc,conserv} + 2\sigma_{MC} + 2_{\sigma exper}$$

limits:

routine condition $k_{eff} < 0.95$

accidental condition $k_{eff} < 0.98$

Tab. 1 Multiplication coefficient kef, 1 cask C-30

enrichment and basket	condition	
	routine	accident
	$k_{ef} < 0.95$	$k_{ef} < 0.98$
3.6% in T-12	0.85727	1.22095
4.4% in KZ-48	0.87908	0.95381
4.87% in KZ-48	0.89909	0.97504

Inventory analyses

3.6 %

- **Burnup 42 MWd/kg, cooling time 2.8 y = average burnup in basket T-12 (basic value for relative comparison)**
- **burnup 46 MWd/kg, cooling time 2.8 y = maximal burnup in basket T-12**

4.25 %

- **Burnup 50 MWd/kg, cooling time 3.6 y = average burnup in basket KZ-48 (first license)**
- **Burnup 55 MWd/kg, cooling time 3.6 y = maximal burnup in basket KZ-48 (first license)**
- **Burnup 60 MWd/kg, cooling time 3.9 y = maximal burnup in basket KZ-48 (present license for higher burnup)**

4.87 %

- **Burnup 60 MWd/kg, cooling time 4 y = maximal burnup in basket KZ-48 in peripheral zone**
- **Burnup 70 MWd/kg, cooling time 5 y = maximal burnup in basket KZ-48 in central zone**

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Tab. 2. Activity

			activity		
enrich.	burnup	cooling time	1 assembly	1cask	1 assembly
[%]	[MWd/kgU]	[y]	[Bq]	[Bq]	relative
3.6	42	2.8	4.703E+15	1.411E+17	1.000
	46	2.8	5.112E+15		1.087
4.4	50	3.6	4.593E+15	2.205E+17	0.977
	55	3.6	4.995E+15		1.062
	60	3.9	5.118E+15		1.088
4.87	60	4	4.890E+15		1.040
	70	5	4.971E+15		1.057

Tab.3 Decay heat

			decay heat		
enrich.	burnup	cooling time	1 assembly	1cask	1 assembly
[%]	[MWd/kgU]	[y]	[W]	[kW]	relative
3.6	42	2.8	457.2	13.72	1.000
	46	2.8	514.7		1.126
4.4	50	3.6	440.6	21.15	0.964
	55	3.6	502.3		1.099
	60	3.9	532.8		1.165
4.87	60	4	487.2		1.066
	70	5	529.1		1.157
		limit	800	24	

Tab.4 Photon source

			photons		
enrich.	burnup	cooling time	1 assembly	1cask	1 assembly
[%]	[MWd/kgU]	[y]	[s^{-1}]	[s^{-1}]	relative
3.6	42	2.8	2.731E+15	8.194E+16	1.000
	46	2.8	3.043E+15		1.114
4.4	50	3.6	2.515E+15	1.207E+17	0.921
	55	3.6	2.814E+15		1.030
	60	3.9	2.881E+15		1.055
4.87	60	4	2.611E+15		0.956
	70	5	2.555E+15		0.936

Tab.5 Neutron source

			neutrons		
enrich.	burnup	cooling time	1 assembly	1cask	1 assembly
[%]	[MWd/kgU]	[y]	[s^{-1}]	[s^{-1}]	relative
3.6	42	2.8	8.749E+07	2.625E+09	1.000
	46	2.8	1.264E+08		1.445
4.4	50	3.6	1.350E+08	6.480E+09	1.543
	55	3.6	1.956E+08		2.236
	60	3.9	2.693E+08		3.079
4.87	60	4	2.268E+08		2.592
	70	5	3.852E+08		4.403

Shielding analyses

The limits are:

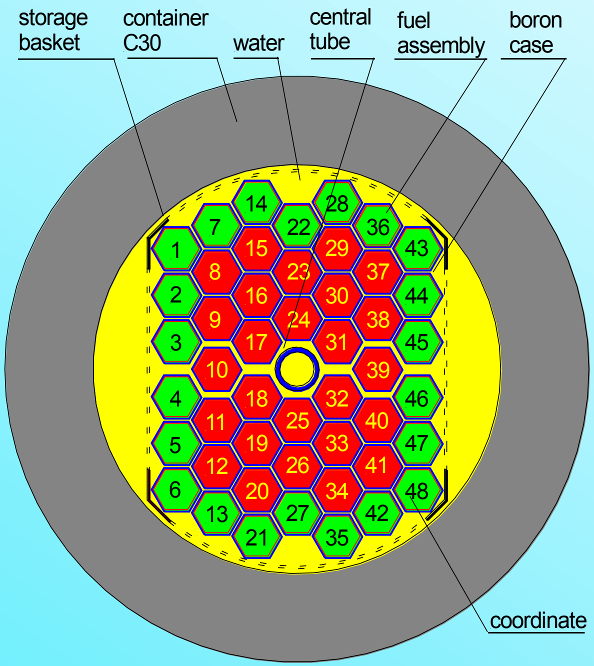
- **2 mSv/h for surface**
- **0.1 mSv/h in distance 2 m from surface.**

Fuel 3.6 %

The original case (30 assemblies 3.6 % in the basket T-12, average burnup in cask 42 MWd/kgU, maximal burnup of assembly 46 MWd/kgU) meets limits without problems

zone configuration (fuel 3.84%/4.25%)

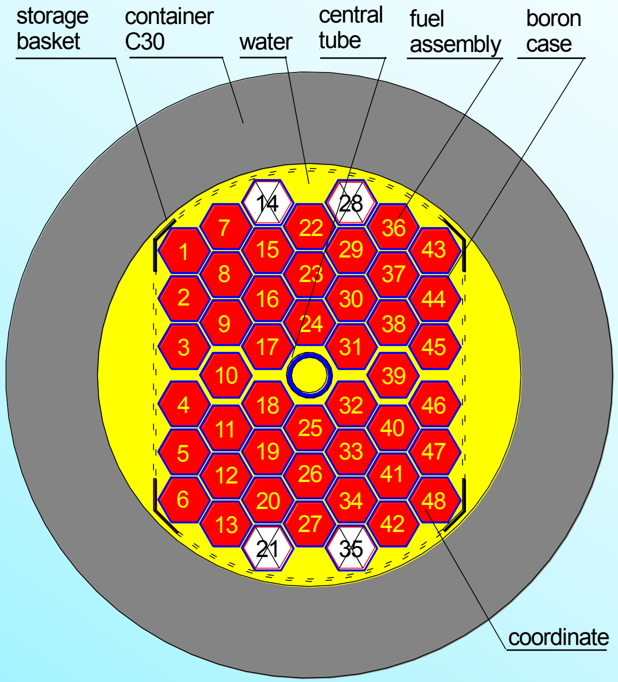
variant No.2



peripheral zone
3.84%
55MWd/kgU
(22 FA)

central zone
3.84%
60MWd/kgU
(26 FA)

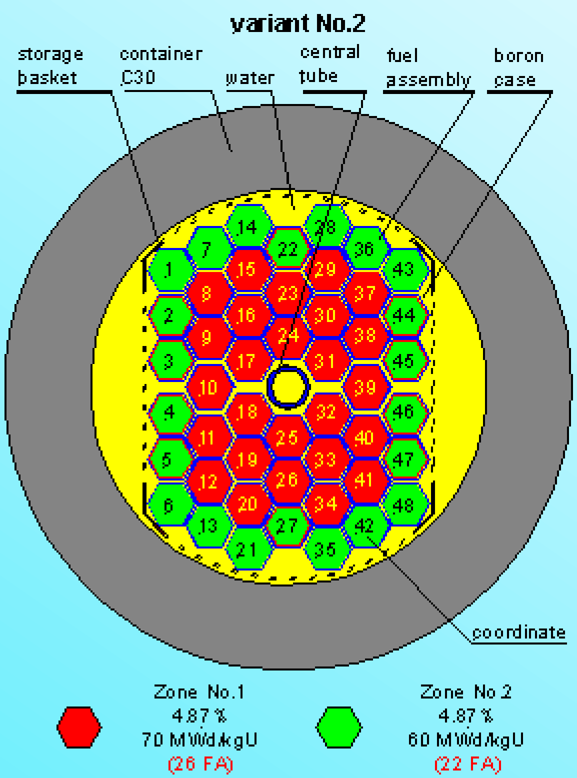
variant No.3

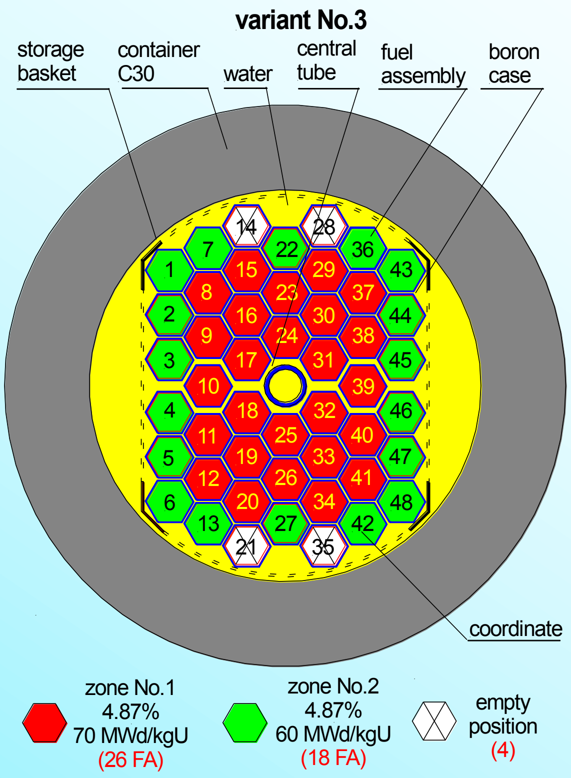


3.84%
60MWd/kgU
(44 FA)

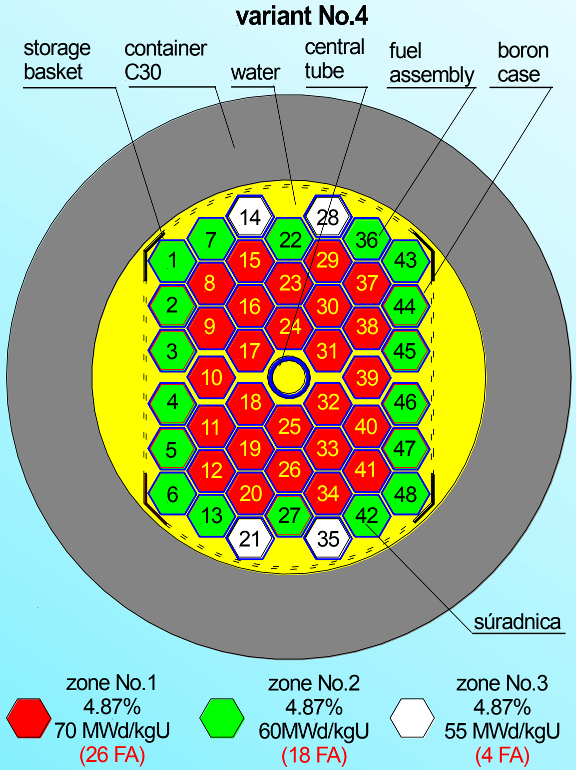
empty
position(4)

Two zone configuration (fuel 4.87%)





Three zone configuration (fuel 4.87%)



Conclusion

By using a new improved fuel in old type of transport cask is necessary to check safety limits and use some new actions (and/or):

- criticality: if is necessary is possible to use burnup credit
- decay heat:
  - prolong cooling time
  - decrease number of assemblies in cask
- dose:
  - prolong cooling time
  - decrease number of assemblies in cask
  - areas according burnup
  - additional shielding

Conclusion (cont.)

The very old design transport cask C-30 is possible to use for improved fuel with higher enrichment and higher burnup. To keep safety limits is necessary to prolong cooling time and/or have some restriction. The other way is to develop a totally new transport cask.