HOR HEU/LEU CORE CONVERSION: 8 YEARS OF EXPERIENCE

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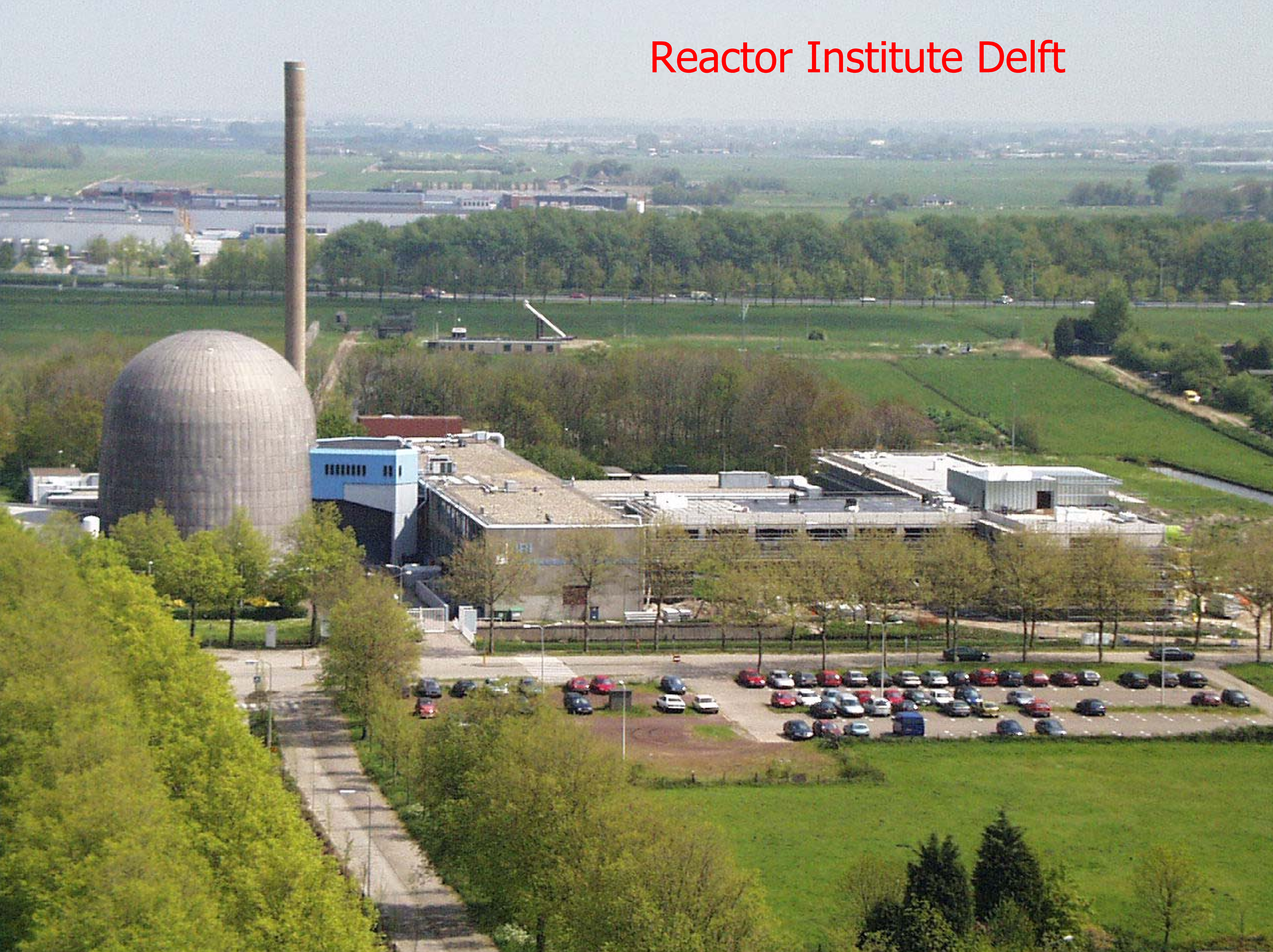
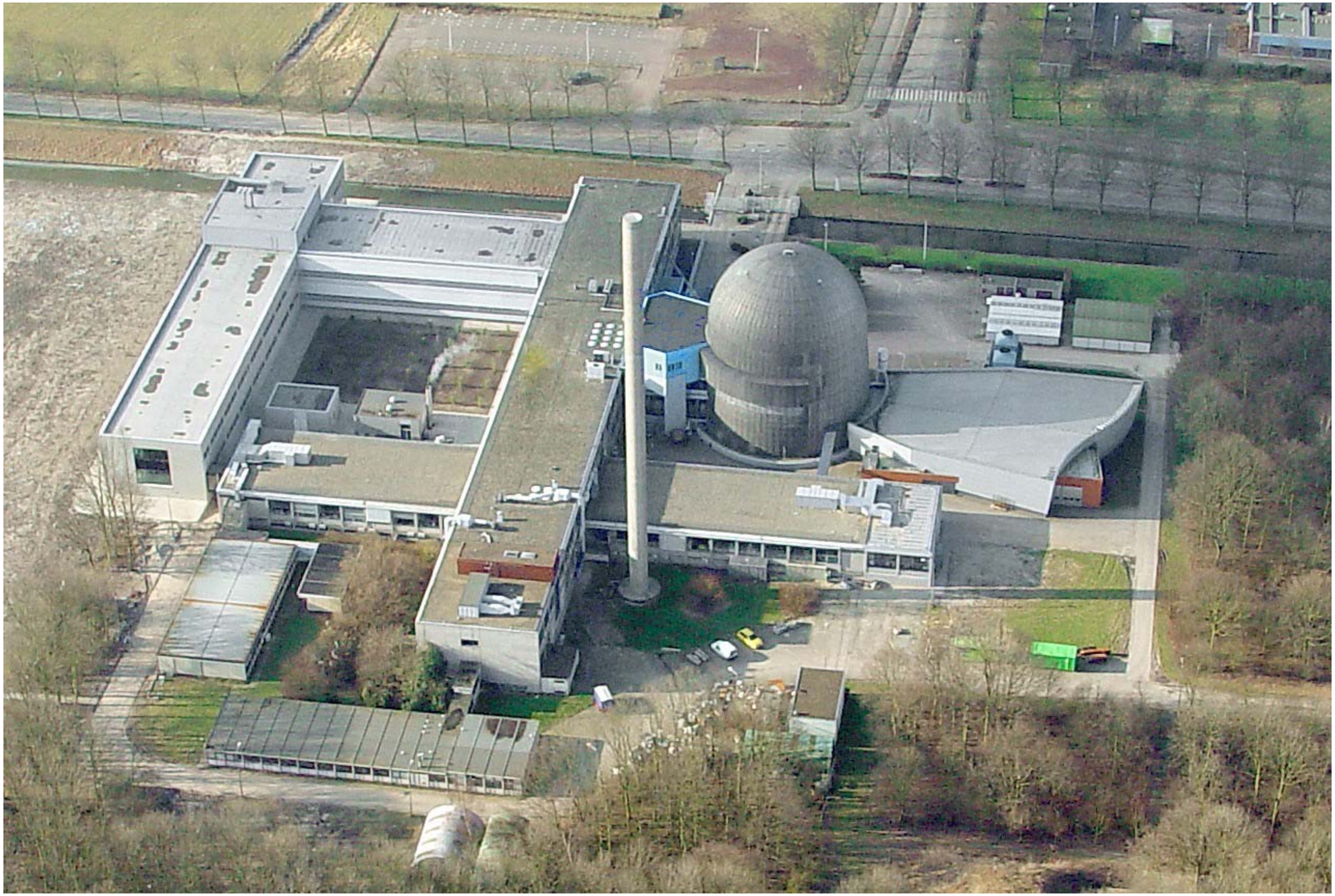


RID Site View



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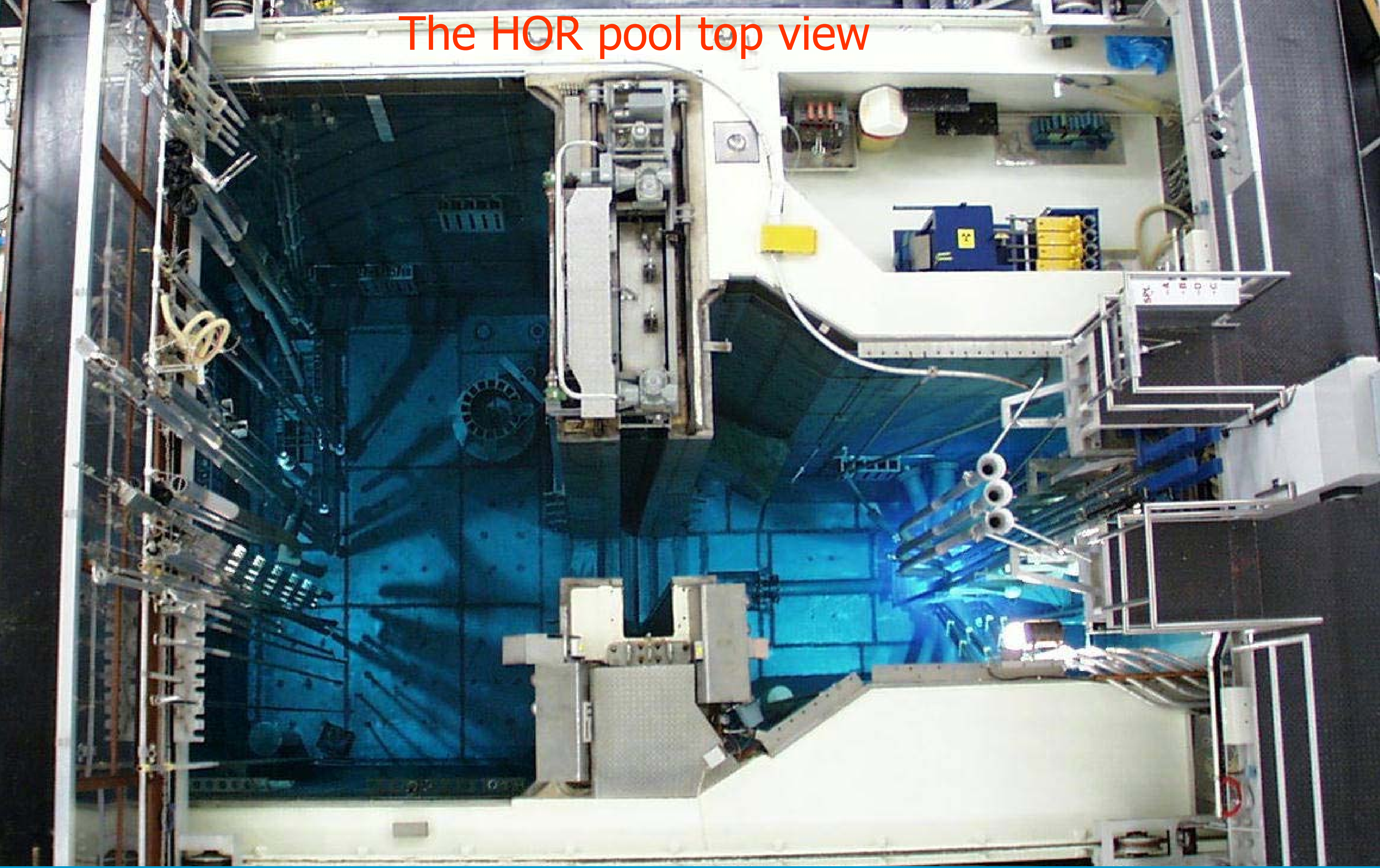
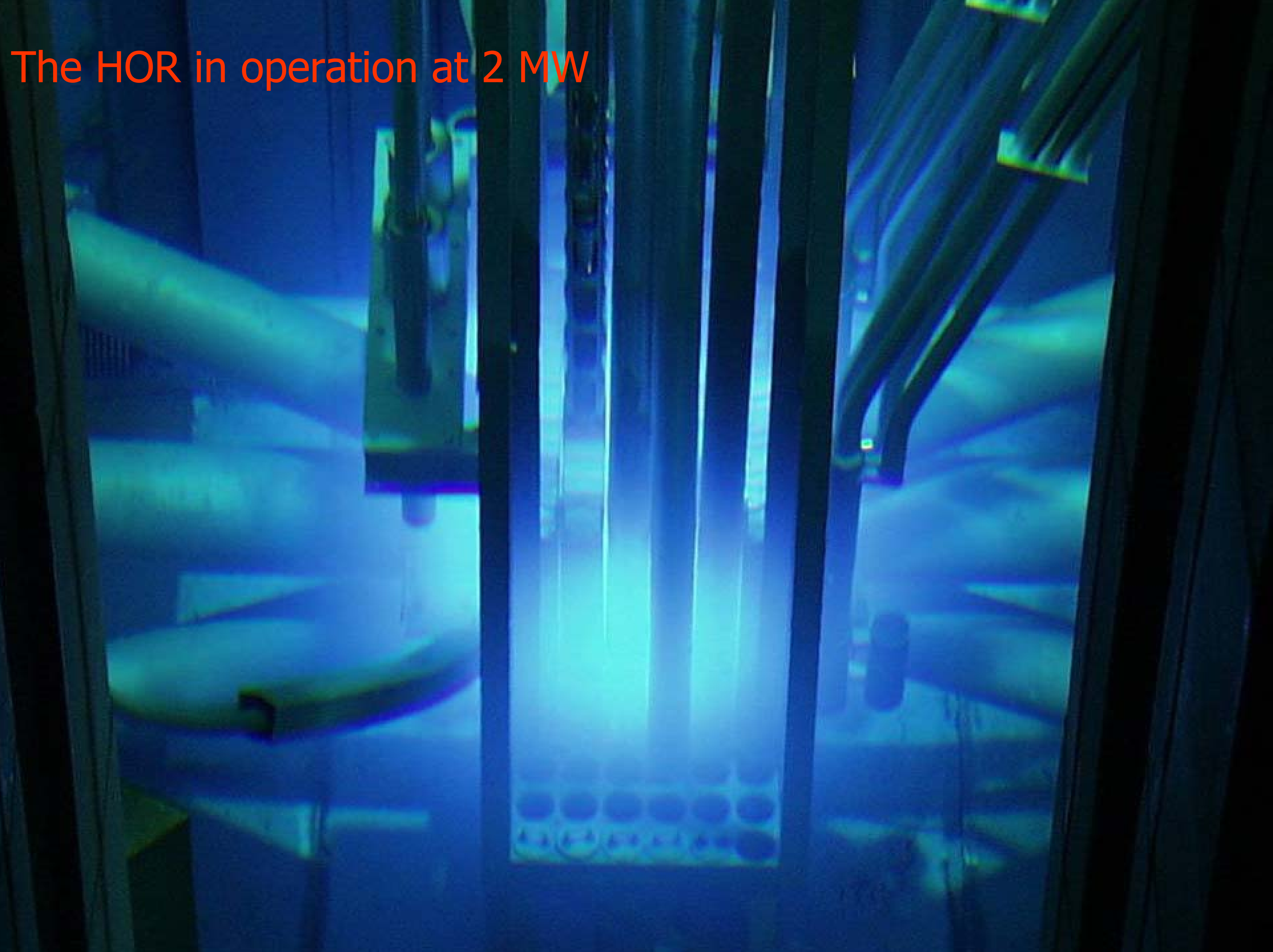
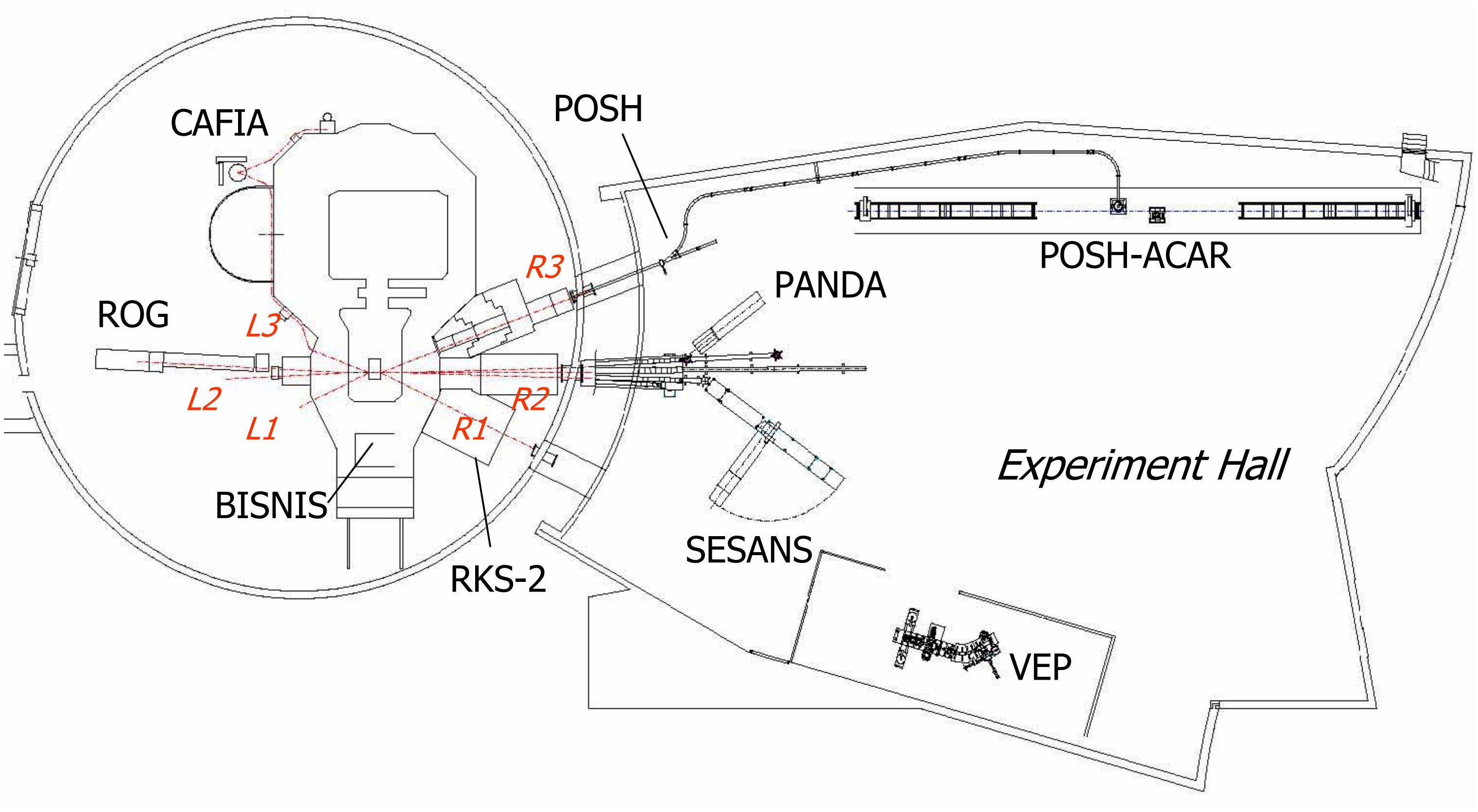
The HOR pool top view




The HOR in operation at 2 MW

HOR Facilities & Instruments Overview

Horizontal Lay-out of Reactor and adjacent Experiment Hall



HOR Beam Tube Arrangement

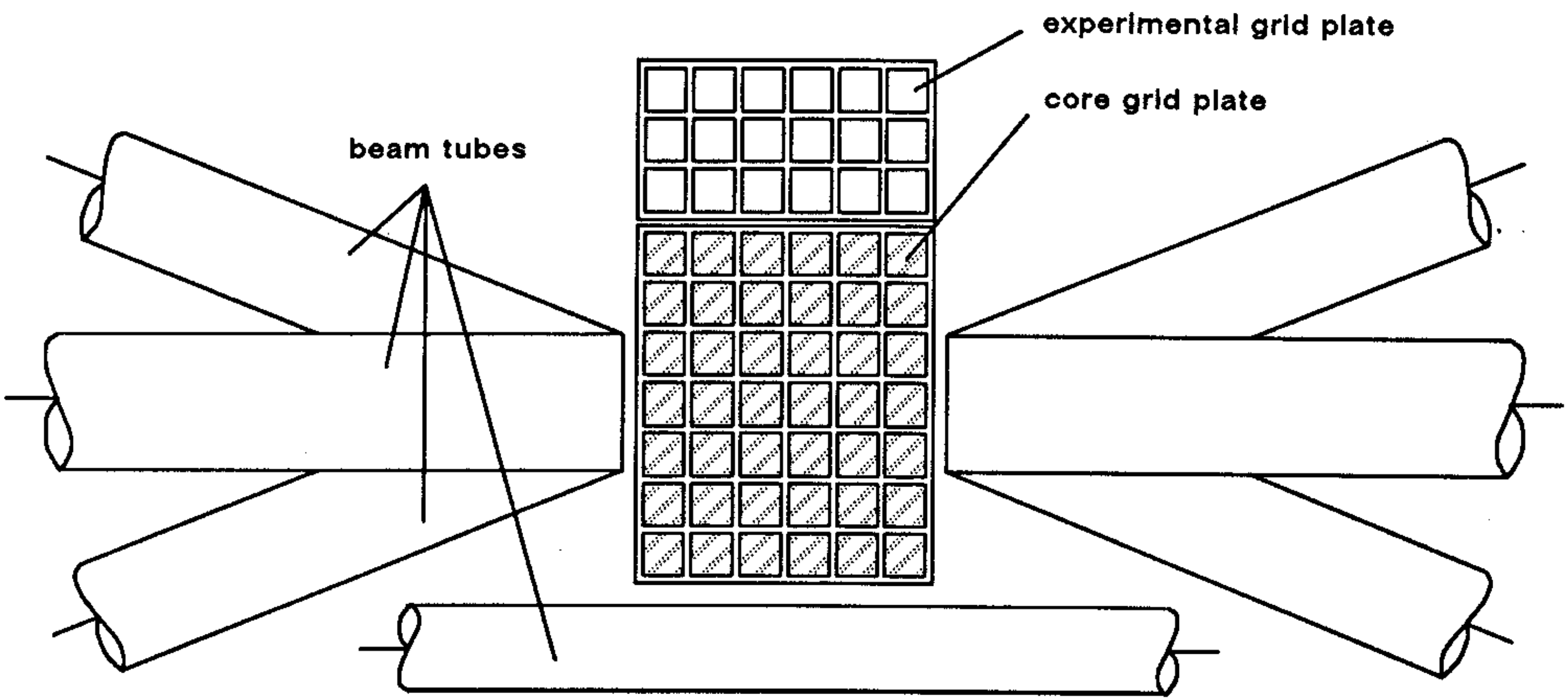


FIG. 1 ARRANGEMENT OF GRID PLATE AND BEAM TUBES

HOR General Data

- Pool type research reactor, 1st criticality 1963
- Max. licensed power 3 MW
- Steady operating power 2 MW
- MTR fuel type, 19 fuel plates
- HEU to LEU conversion started March 1998
- First full LEU core in Jan. 2005

HOR Fuel Assembly Properties

	HEU	LEU
Fuel meat material	UAl_x	U_3Si_2-Al
Uranium density [g/cm^3]	0,58	4.3
Uranium loading per FA [g]	204	1519
^{235}U loading per standard FA [g]	190	300
Enrichment [%]	93	19.75
Meat thickness [mm]	0.5	0.5
Cladding thickness [mm]	0.3	0.35
Fuel plate thickness [mm]	1.1	1.20
Moderator channel thickness [mm]	3.1	3.0
Number of plates in standard FA	19	19
Number of plates in control FA	10	10

HOR Core Conversion in 21 Steps

A1 R-19	B1 R-20		D1 R-17		F1 R-18
A2 D-72 48,3	B2 D-13 45,1	C2 D-73 39,4	D2 D-82 22,0	E2 D80 29,0	F2 D-12 44,5
A3 R-15	B3 D-74 39,4	C3 DC-12 35,1	D3 D-86 10,8	E3 DC-15 0,0	F3 D-77 34,1
A4 R-13	B4 D-81 23,7	C4 D-83 20,0	D4 D-87 8,5	E4 D-84 16,9	F4 D-76 33,0
A5 R-14	B5 D-37 44,1	C5 DC-13 24,4	D5 D-85 14,3	E5 DC-14 3,2	F5 D-75 35,3
A6 D-70 49,8	B6 D-38 44,3	C6 D-29 44,2	D6 D-79 30,0	E6 D-78 31,5	F6 D-34 44,6
A7 R-21	B7 R-22	C7 D-64 48,7	D7 D-31 44,8	E7 D-69 48,9	F7 R-23

Core 97-03

A2 P31	B1 R-19	C1 R-24	D1 R-29	E1 R-17	F1 R-18
A2 R-20	B2 Bigbebe	C2 E-03 25,5	D2 E-10 9,4	E2 E-02 26,3	F2 R-16
A3 R-15	B3 E-06 19,3	C3 DC-09 44,9	D3 D-74 49,2	E3 EC-01 0,0	F3 E-01 26,0
A4 R-13	B4 E-13 2,4	C4 D-75 44,6	D4 L R Smallbebe	E4 E-12 5,6	F4 E-09 11,4
A5 R-14	B5 E-07 16,6	C5 DC-14 40,3	D5 D-86 48,9	E5 DC-15 37,5	F5 E-08 12,6
A6 R-25	B6 R-28	C6 E-05 20,9	D6 E-11 8,0	E6 E-04 21,8	F6 R-26
A7 R-12	B7 R-22	C7 R-21	D7 R-27	E7 R-30	F7 R-23

Core 01-04

A1 P31	B1 R-19	C1 R-24	D1 R-29	E1 R-17	F1 R-18
A2 R-20	B2 Bigbebe	C2 E-08 35,0	D2 E-17 9,3	E2 E-14 20,4	F2 R-16
A3 R-15	B3 E-10 32,2	C3 EC-01 29,3	D3 E-02 48,4	E3 EC-04 8,1	F3 E-11 32,0
A4 R-13	B4 E-13 25,3	C4 E-04 41,4	D4 L R Smallbebe	E4 E-18 3,0	F4 E-19 0,0
A5 R-14	B5 E-09 33,6	C5 EC-02 25,9	D5 E-01 45,1	E5 EC-03 17,3	F5 E-12 27,3
A6 R-25	B6 R-28	C6 E-05 42,0	D6 E-16 14,0	E6 E-15 18,1	F6 R-26
A7 R-12	B7 R-22	C7 R-21	D7 R-27	E7 R-30	F7 R-23

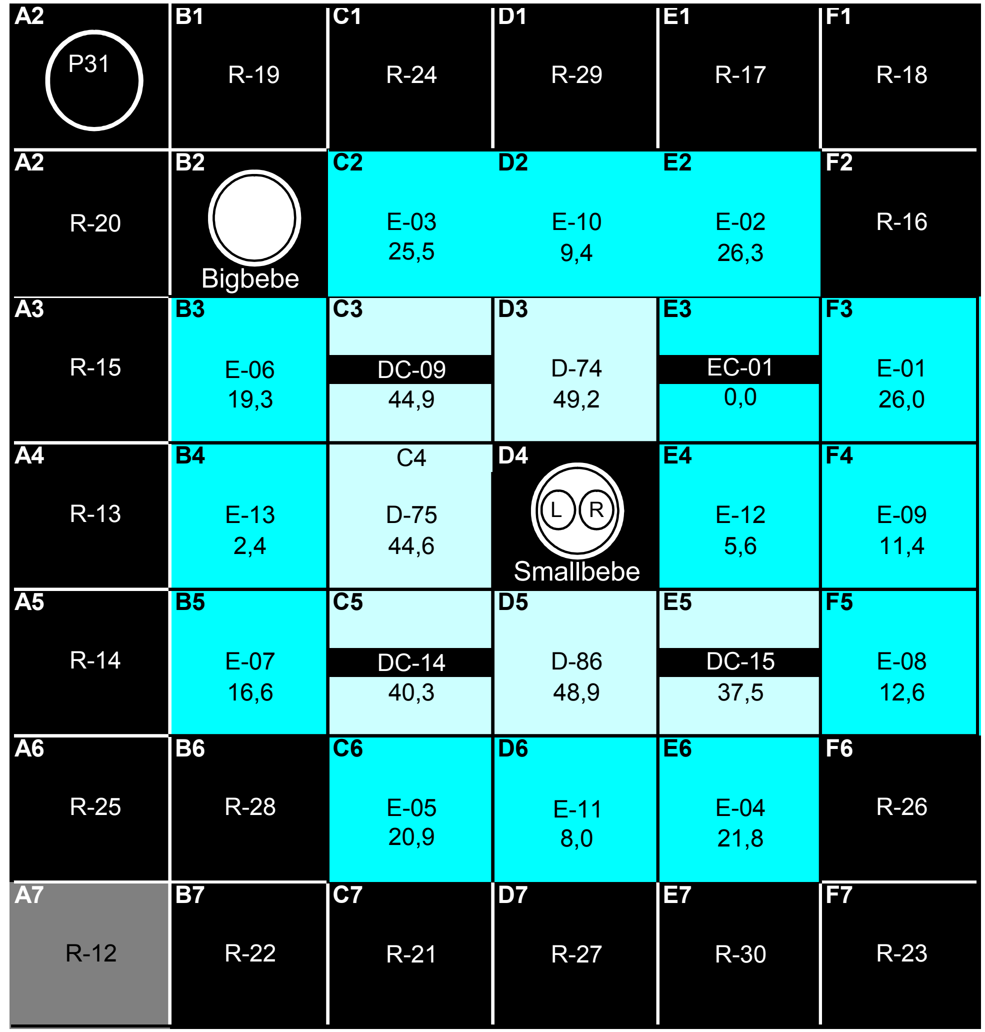
Core 05-01

HOR last full HEU core lay-out

A1 R-19	B1 R-20		D1 R-17		F1 R-18
A2 D-72 48,3	B2 D-13 45,1	C2 D-73 39,4	D2 D-82 22,0	E2 D80 29,0	F2 D-12 44,5
A3 R-15	B3 D-74 39,4	C3 DC-12 35,1	D3 D-86 10,8	E3 DC-15 0,0	F3 D-77 34,1
A4 R-13	B4 D-81 23,7	C4 D-83 20,0	D4 D-87 8,5	E4 D-84 16,9	F4 D-76 33,0
A5 R-14	B5 D-37 44,1	C5 DC-13 24,4	D5 D-85 14,3	E5 DC-14 3,2	F5 D-75 35,3
A6 D-70 49,8	B6 D-38 44,3	C6 D-29 44,2	D6 D-79 30,0	E6 D-78 31,5	F6 D-34 44,6
A7 R-21	B7 R-22	C7 D-64 48,7	D7 D-31 44,8	E7 D-69 48,9	F7 R-23

Core 97-03

HOR intermediate HEU/LEU core lay-out



Core 01-04

HOR 1st full LEU core lay-out

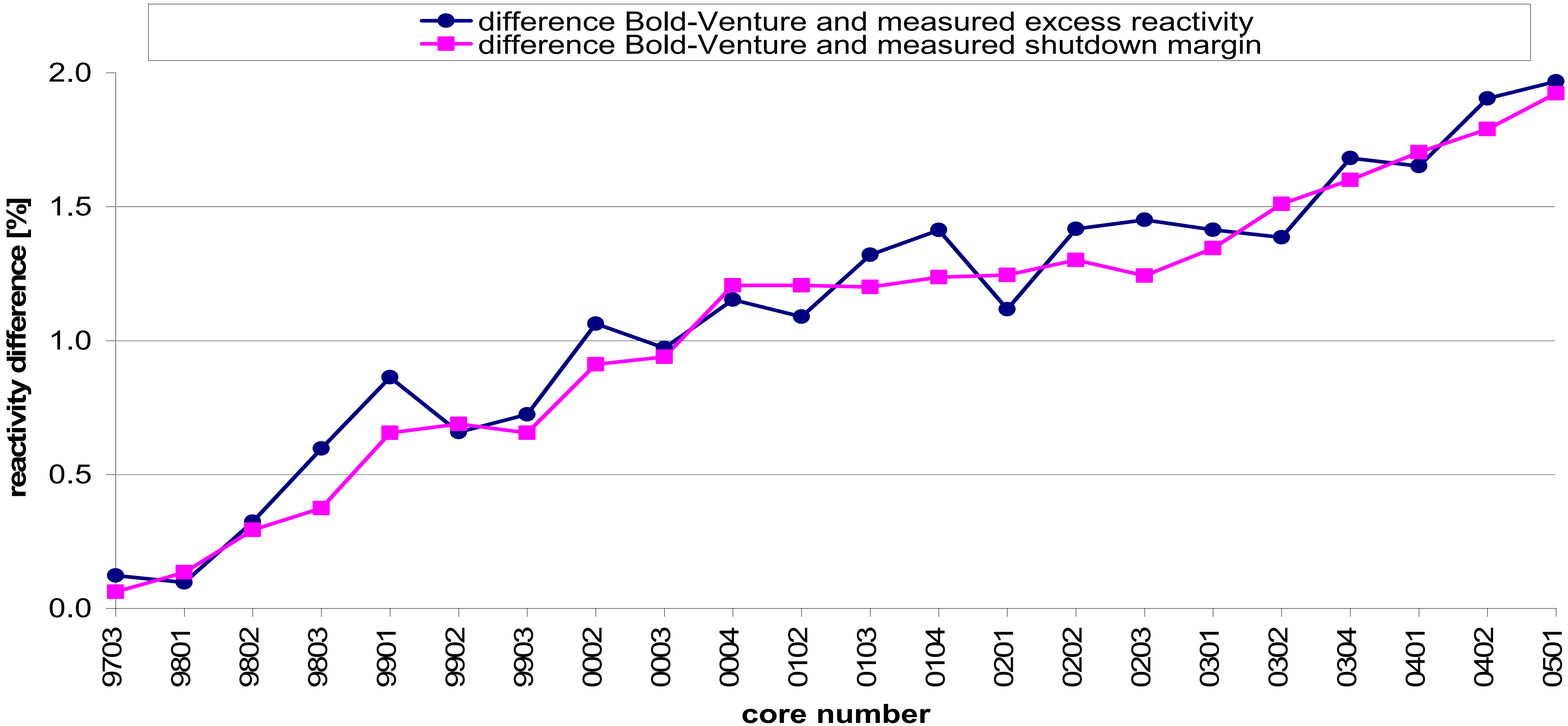
A1 P31	B1 R-19	C1 R-24	D1 R-29	E1 R-17	F1 R-18
A2 R-20	B2 Bigbebe	C2 E-08 35,0	D2 E-17 9,3	E2 E-14 20,4	F2 R-16
A3 R-15	B3 E-10 32,2	C3 EC-01 29,3	D3 E-02 48,4	E3 EC-04 8,1	F3 E-11 32,0
A4 R-13	B4 E-13 25,3	C4 E-04 41,4	D4 L R Smallbebe	E4 E-18 3,0	F4 E-19 0,0
A5 R-14	B5 E-09 33,6	C5 EC-02 25,9	D5 E-01 45,1	E5 EC-03 17,3	F5 E-12 27,3
A6 R-25	B6 R-28	C6 E-05 42,0	D6 E-16 14,0	E6 E-15 18,1	F6 R-26
A7 R-12	B7 R-22	C7 R-21	D7 R-27	E7 R-30	F7 R-23

Core 05-01

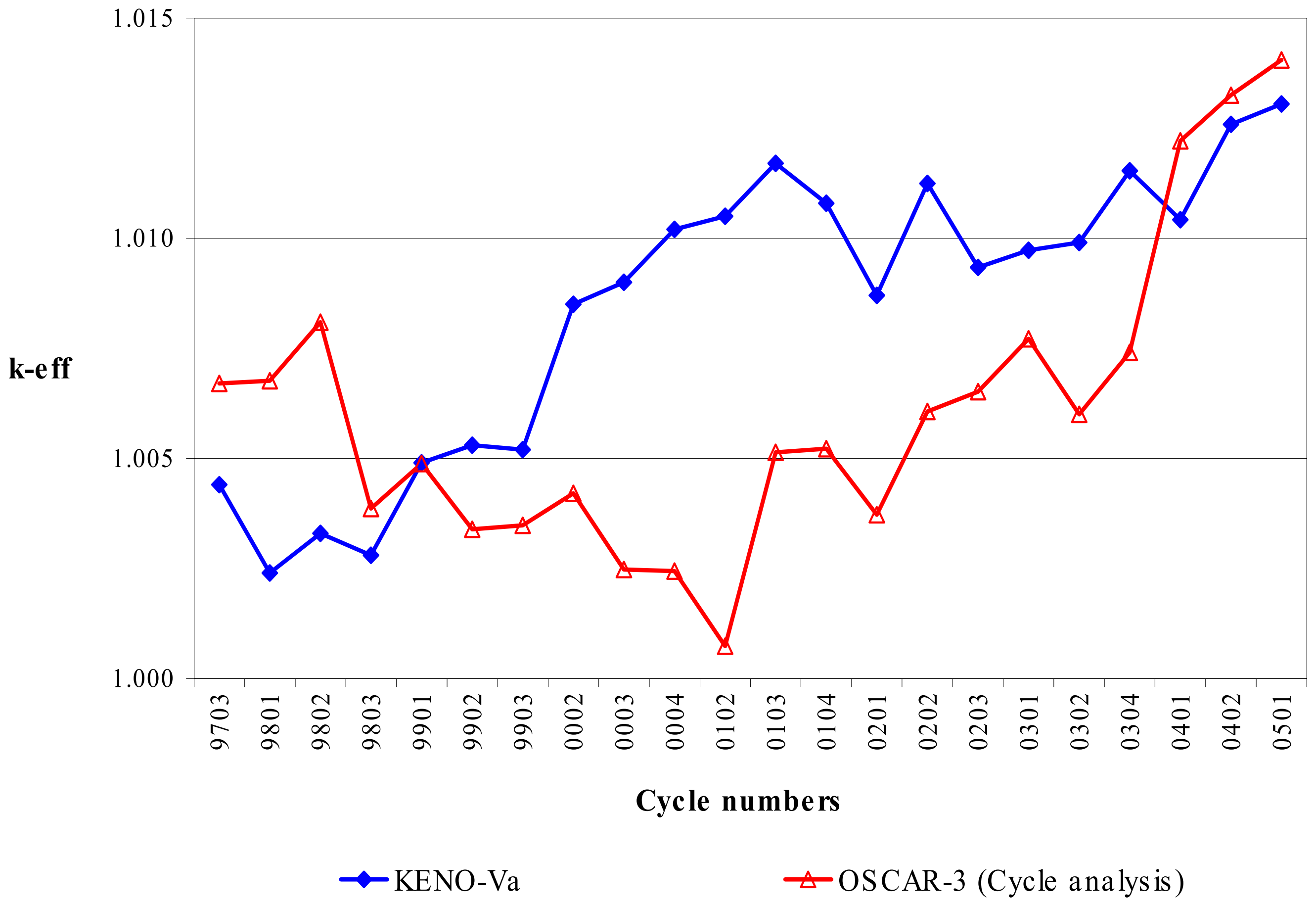
Nuclear DATA and Codes

- Cross sections based on JEF2.2 evaluated data file
- XMAS 172 fine-group energy structure
- SCALE-4.2 codes including Monte Carlo KENOVa (3D)
- Diffusion codes: Bold-Venture (2D) and OSCAR-3 (3D nodal)
- Using 5 and 6 broad-group energy structure
- Monte Carlo code MCNP used for facilities

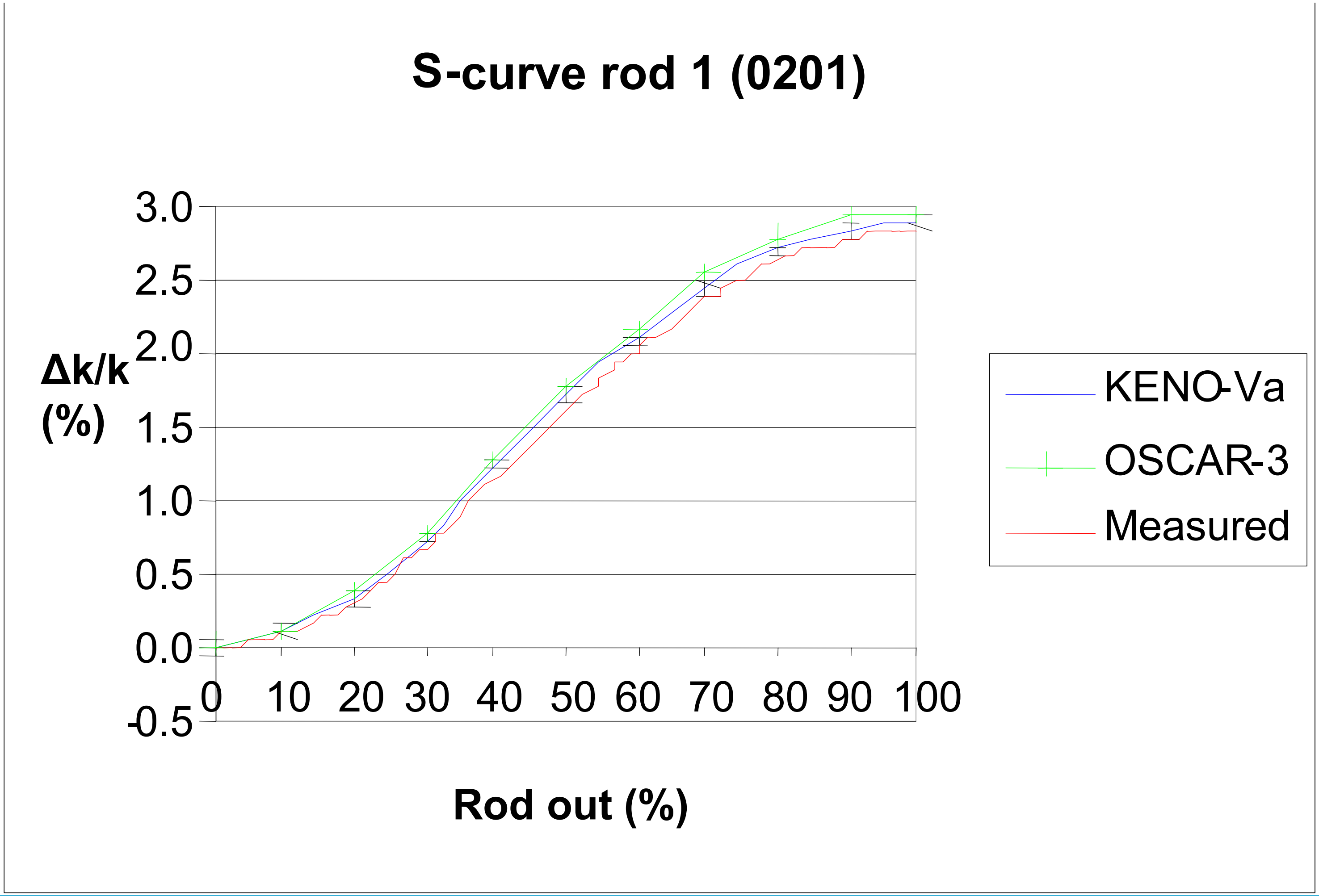
Difference in calculated and measured reactivity



Calculated keff at Beginning Of Cycle



Control rod S-curve Comparison



Performance and Utilization

- No significant flux penalties at beam ports
- In the periphery larger variations, partly due to configuration changes
- Highest thermal flux: 4.4x10E13 (in-core irrad.)
- Increased cycle length (about 1.5x), 2 reloads/yr
- Increased rod worth, better reactivity control
- Comparable fuel cycle cost

Conclusions

- Stepwise conversion was completed successfully (Start March 1998, full LEU core in Jan. 2005)
- No significant operational constraints
- Core compacting beneficial for performance/utilization
- Good overall predictions by core design calculations, but increased reactivity discrepancy with measurements
- 1^{st} LEU batch fuel failures, no root cause found