Gas-cooled Reactor with capacity 90 MW

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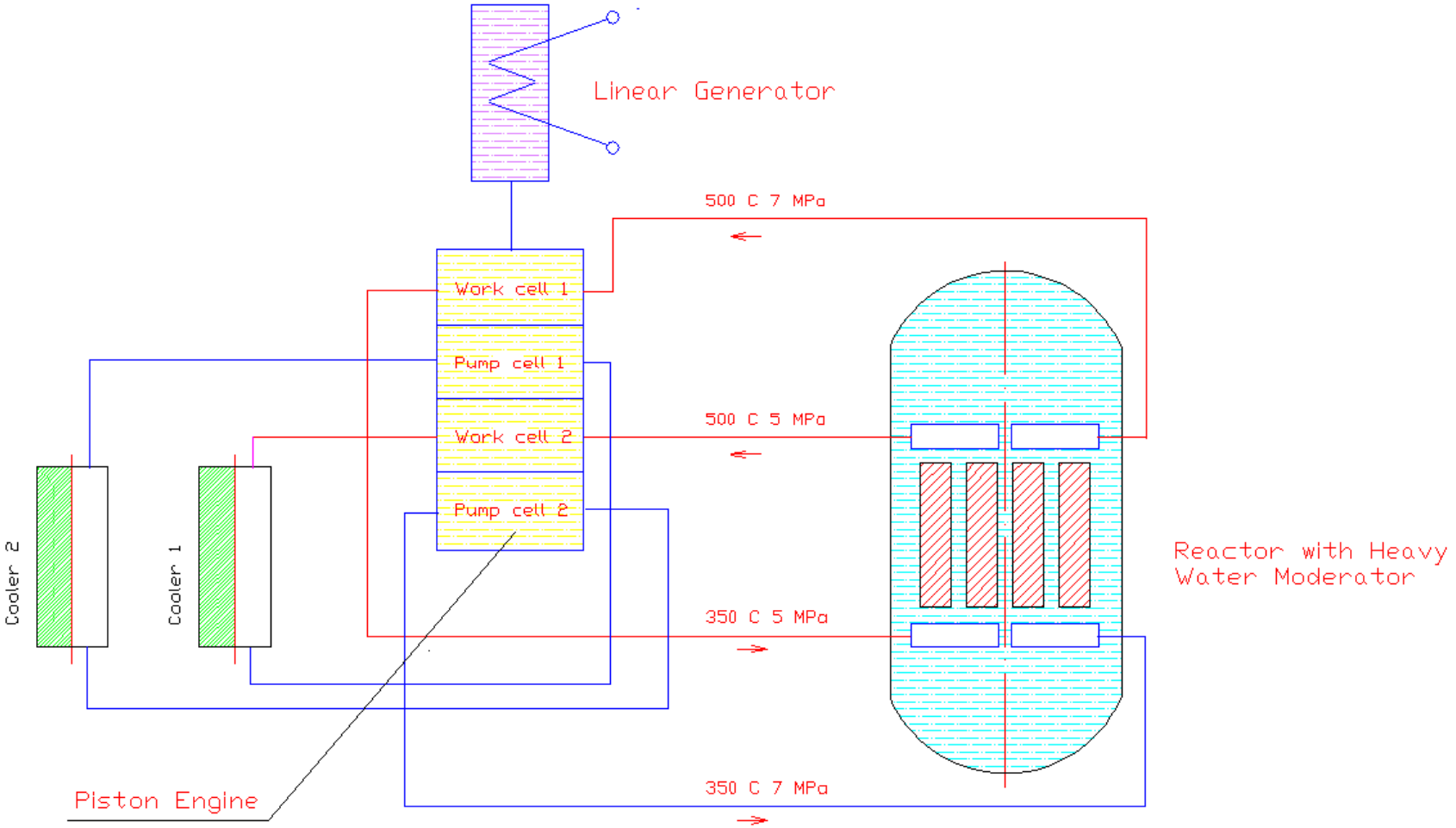
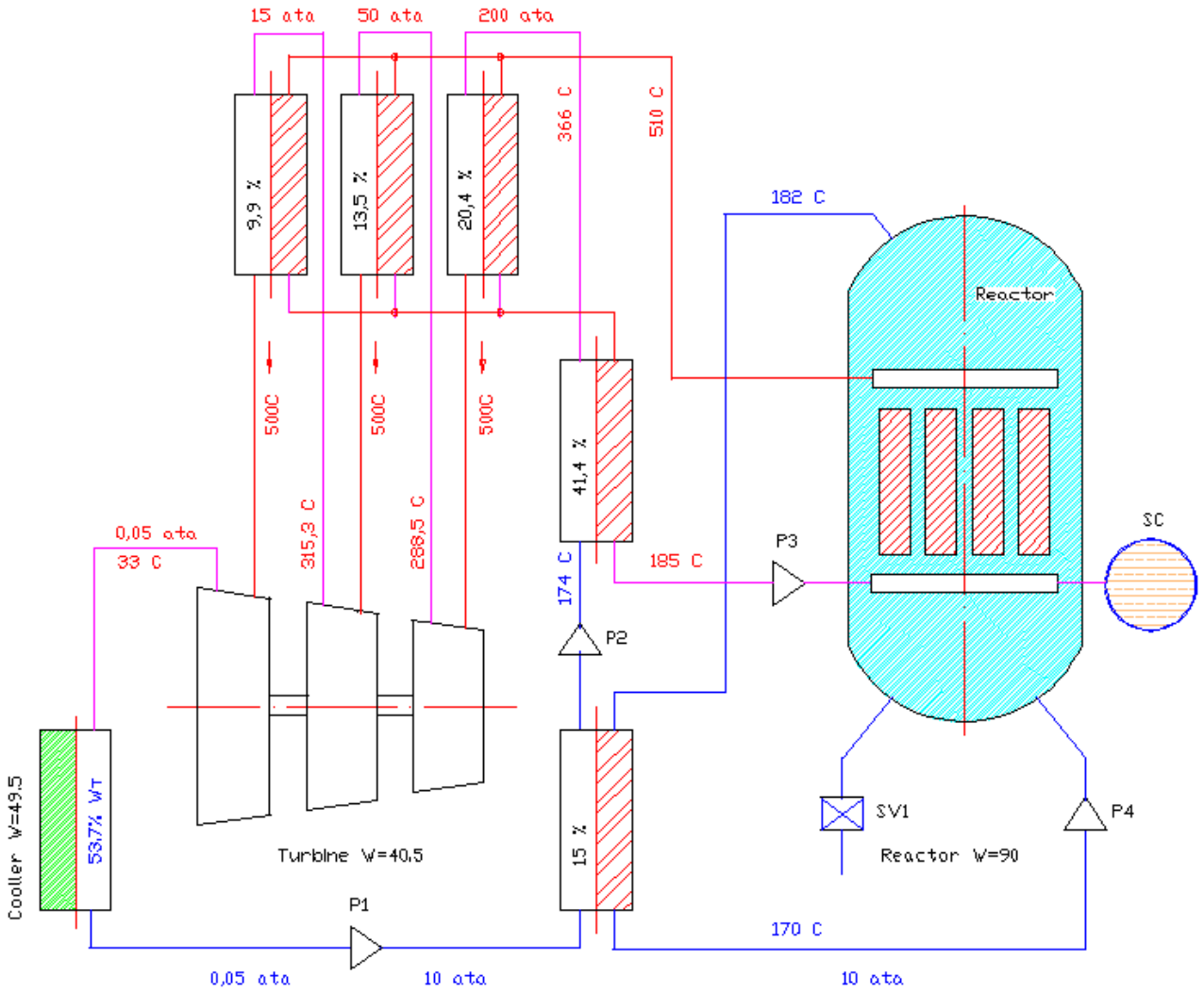
LCPP with gas-cooled reactor and piston engine in Brayton cycle



Descriptions of gas-cooled reactors

	EL-4	Lucens	KKN	KC-150
Country	France	Switzerland	Germany	Czechoslovakia
Startup	1967	1966 (critic)	1970	1972
W thermal, MW	250	30	316	610
Coolant	CO_2	CO_2	CO_2	CO_2
Fuel	UO_2	Metal	UO_2	Metal
Diameter of Fuel element, mm	11	17	15	7.2
T coolant input, ^oC	260	223	252	112
T coolant output, ^oC	500	378	550	427
P coolant, MPa	6.0	6.2	6.0	6.5
P steam, MPa	6.83	2.2	12.2	3.15
T max steam, ^oC	450	367	530	410
Efficiency, %	28	25.3	31.8	19.8

Power Plant with gas cooled reactor and Rankine cycle

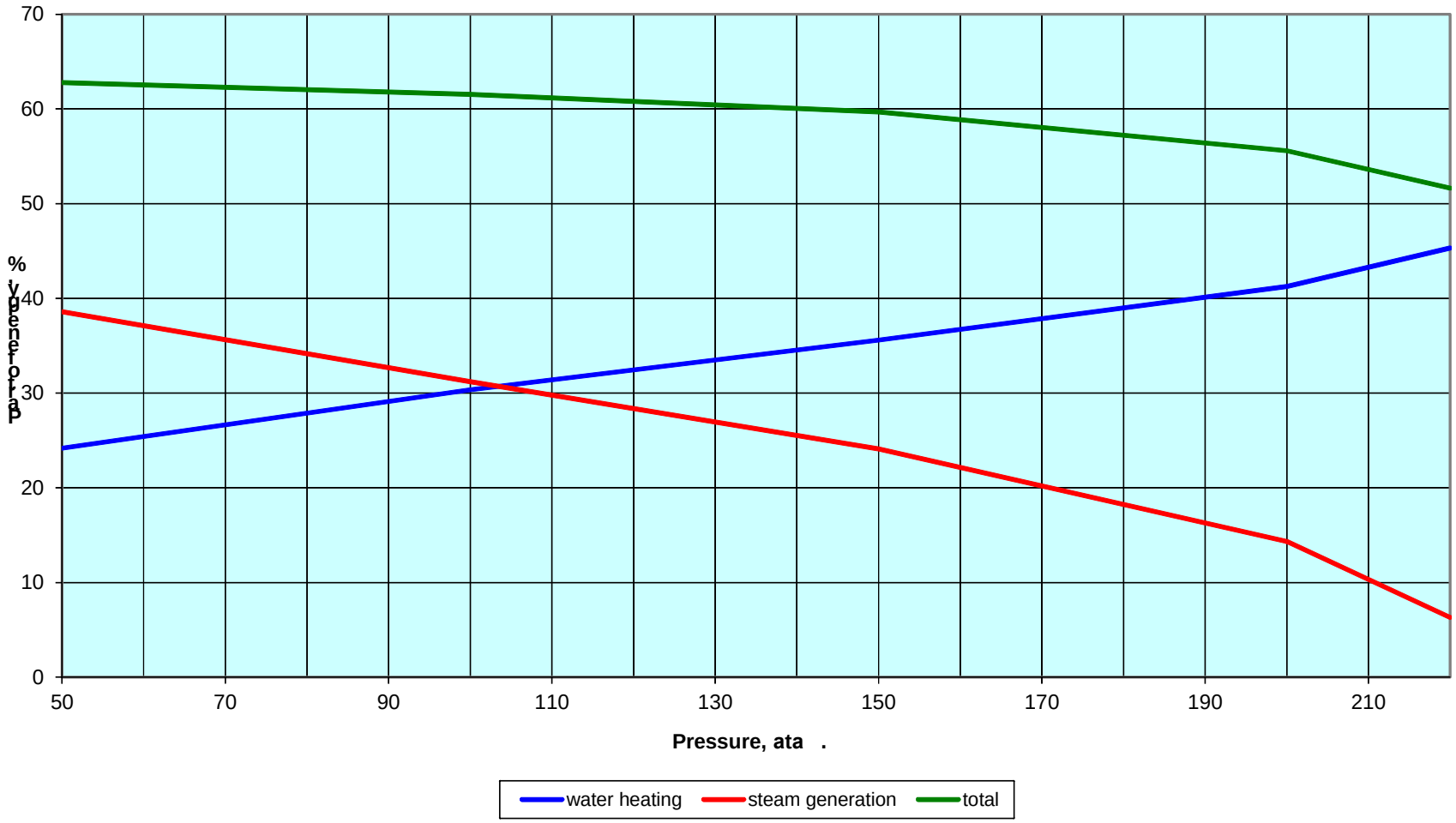


Power transmission in Rankine cycle

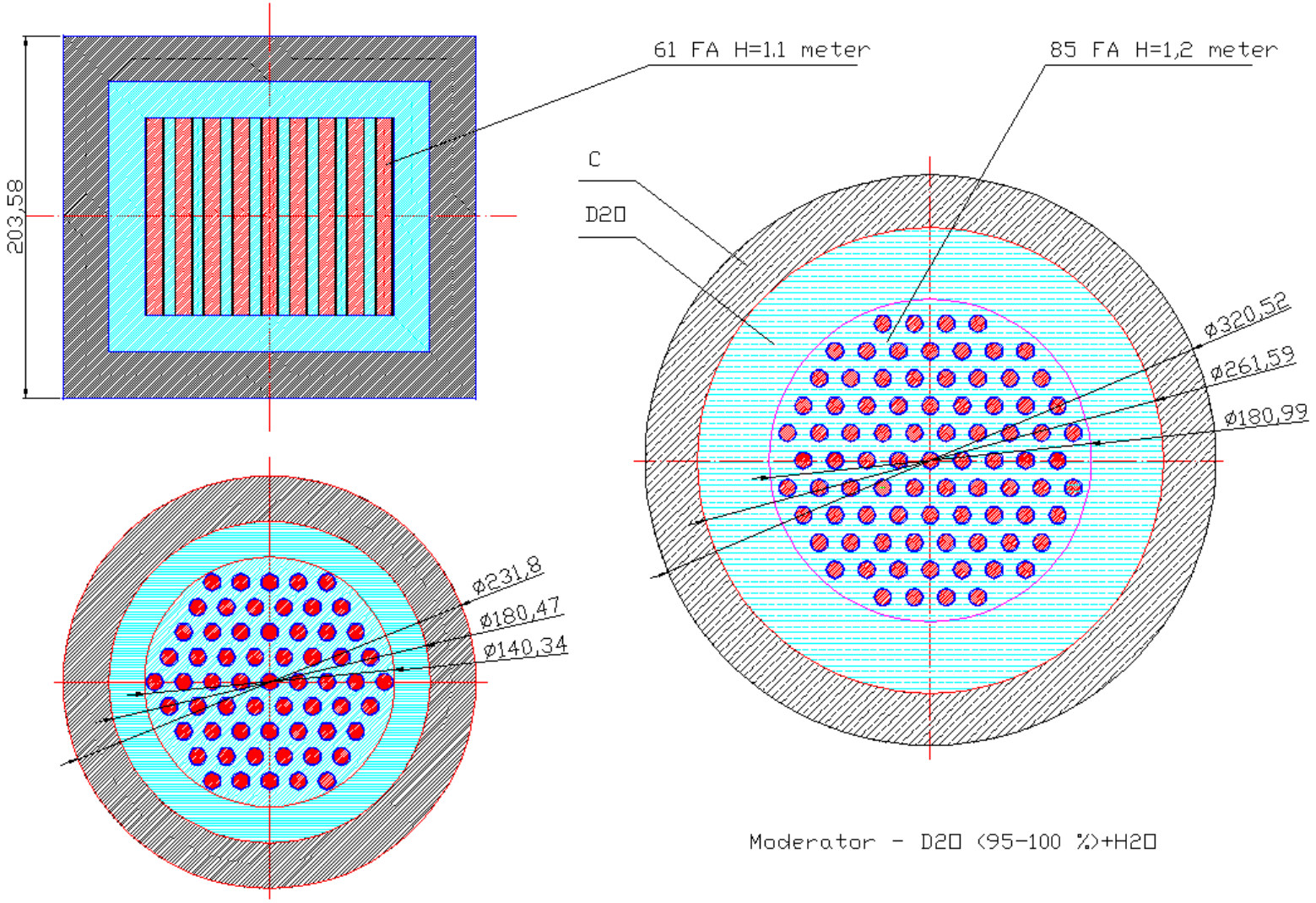
- - Water heating from 31 °C to 174 °C - 15.00 %;
- - Water heating from 174 °C to 365.8 °C - 15,00 %;
- - Vaporization (365.8 °C) - 26.39 %;
- - 1 steam overheating (365.8 – 500 °C) - 20.40 %;
- - 2 steam overheating (300.0 – 500 °C) - 13.50 %;
- - 3 steam overheating (278.3 – 500 °C) - 9.91 %.
- The energy allocating in moderator to warm water up to 174 °C.

- Thermal power, MW - 90
- Electric power, MW - 36 – 40.5

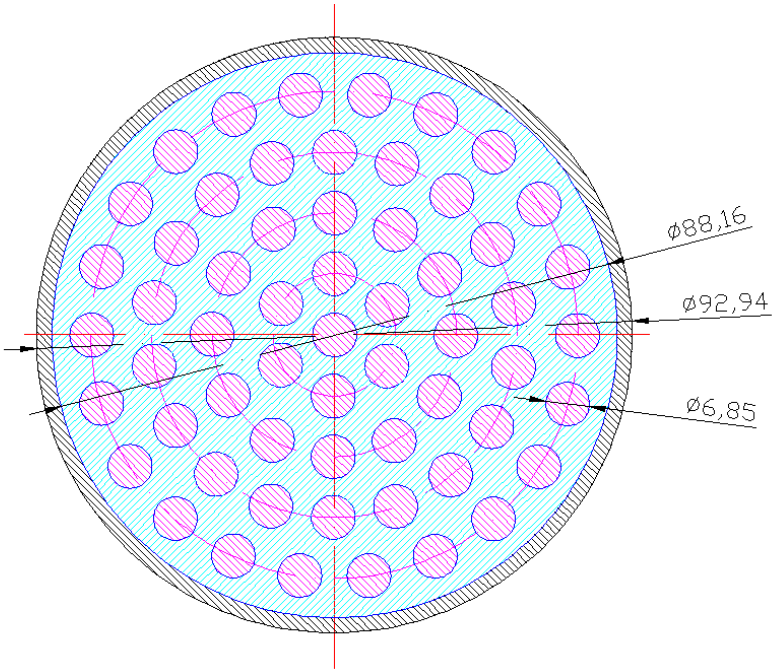
Heating water and vaporization dependences in Rankine cycle from maximum steam pressure



Reactor Core. Alternatives.

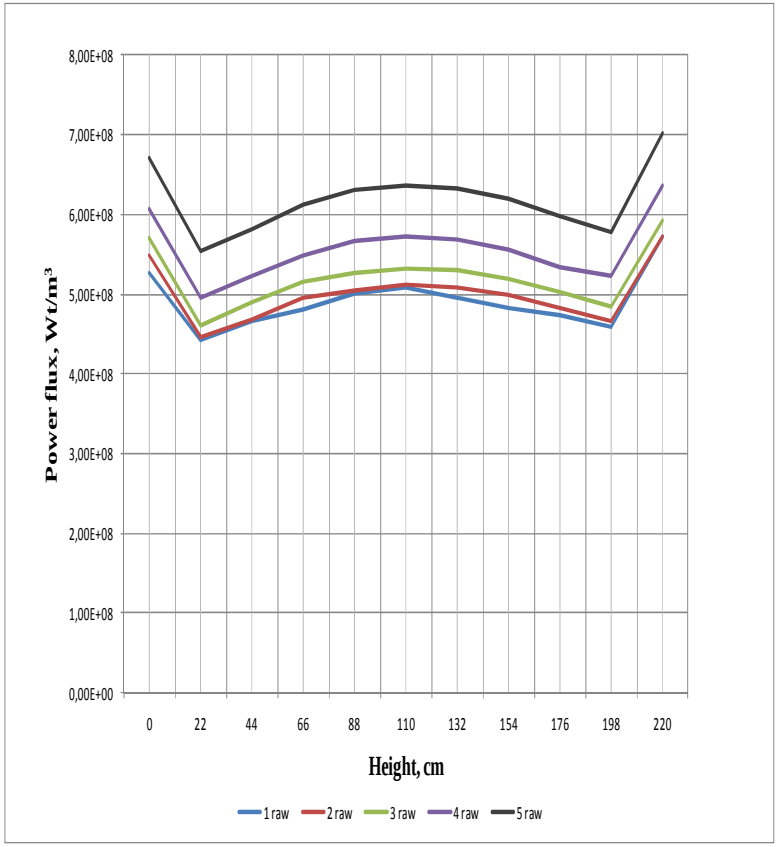


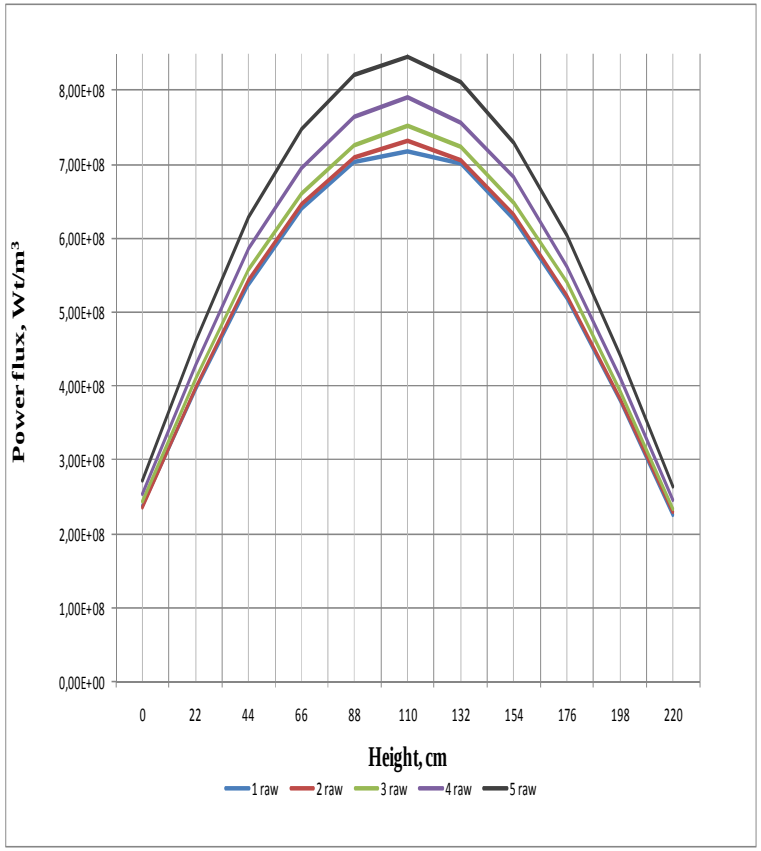
Fuel assembly of gas-cooled reactor



Quantity FA in reactor – 61 - 85.
Fuel element length – 110 - 120 cm.
Quantity FE at different radius: 1, 6, 12, 18, 22.
Quantity FE in FA – 59.
External diameter of FE – 9,3 mm.
FA Power – 1,05 – 1.45 MW.
Heat release in moderator – 0,08 MW.

Power flux height distribution by raw of fuel elements in reactor variants with heavy and light water moderator





Triangle lattice spacing of FA – 16 cm (D_2O) or 12 cm (H_2O).

Comparison of descriptions of Gas-cooled reactor and VVER-1000

Descriptions \ reactor	Gas-cooled	VVER-1000
Thermal power, MW	2136	3100
Electric power, MW	1000	1000
Dissipate power, MW	1136	2100
Pressure of coolant, MPa	6,0	16,0
Pressure of steam, MPa	20	6,4
Temperature of steam, °C	500	280
Efficiency, %	43	31
Fuel enrichment, %	2,5	4,0
Fuel burnup, MW*day/kg	41,0	39,8
Fuel costs for output of energy	1.0	1,95

Mass comparison of unit of Power plant with VVER-1000 and gas-cooled reactor

	VVER-1000	Gas-cooled reactor with water moderator				
		Water heating	vaporization	1 st heating	2 nd heating	3 th heating
W, MWt	4*800	341	941	463.7	306.9	225.0
P, MPa	16.0	1.0	16.0		6.0	
M, kg	4*204 000	45 000	240 000	120 000	50 000	40 000
Mass sum	816 600	495 000				
Mass of turbine, relative unity	1,0	0,85				

Campain specifications with U-Th fuel

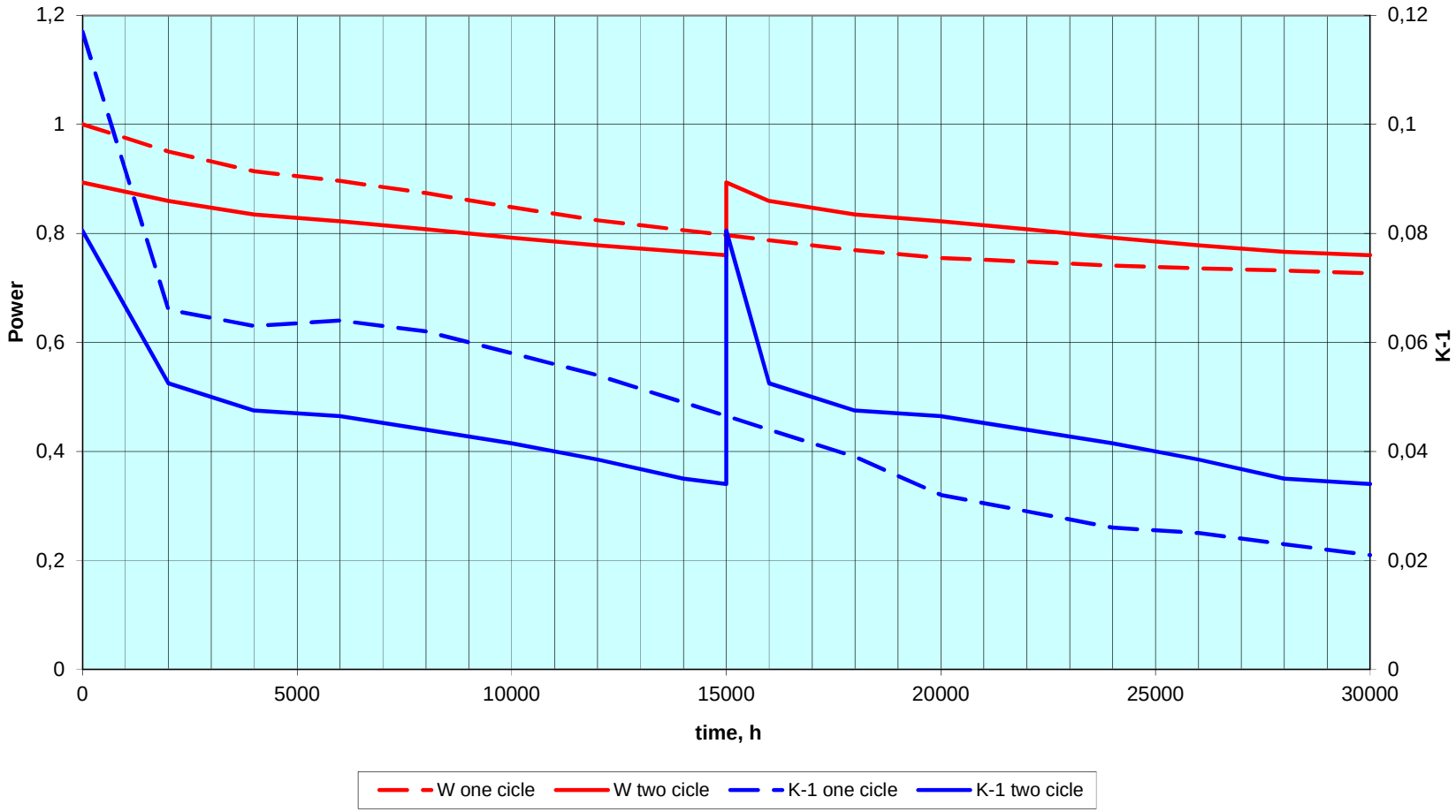
Thermal power	– 90 MW.
Fuel mass	– 2312 kg.
Th portion in fuel	~25-40 %.
Fuel cycle	– closed.
Fission material content in fuel	– 1,5 – 2,5 %.
U-235 content in fission material at the beginning of campain	– 38,7 %.
U-233 content in fission material at the beginning of campain	– 38,3 %.
Pu-239 content in fission material at the beginning of campain	– 16,9 %.
Pu-241 content in fission material at the beginning of campain	– 6,1 %.
Fuel burnup in campain	– 48,7 MW*day/kg.

Delivery of fuel materials is in natural uranium and thorium.

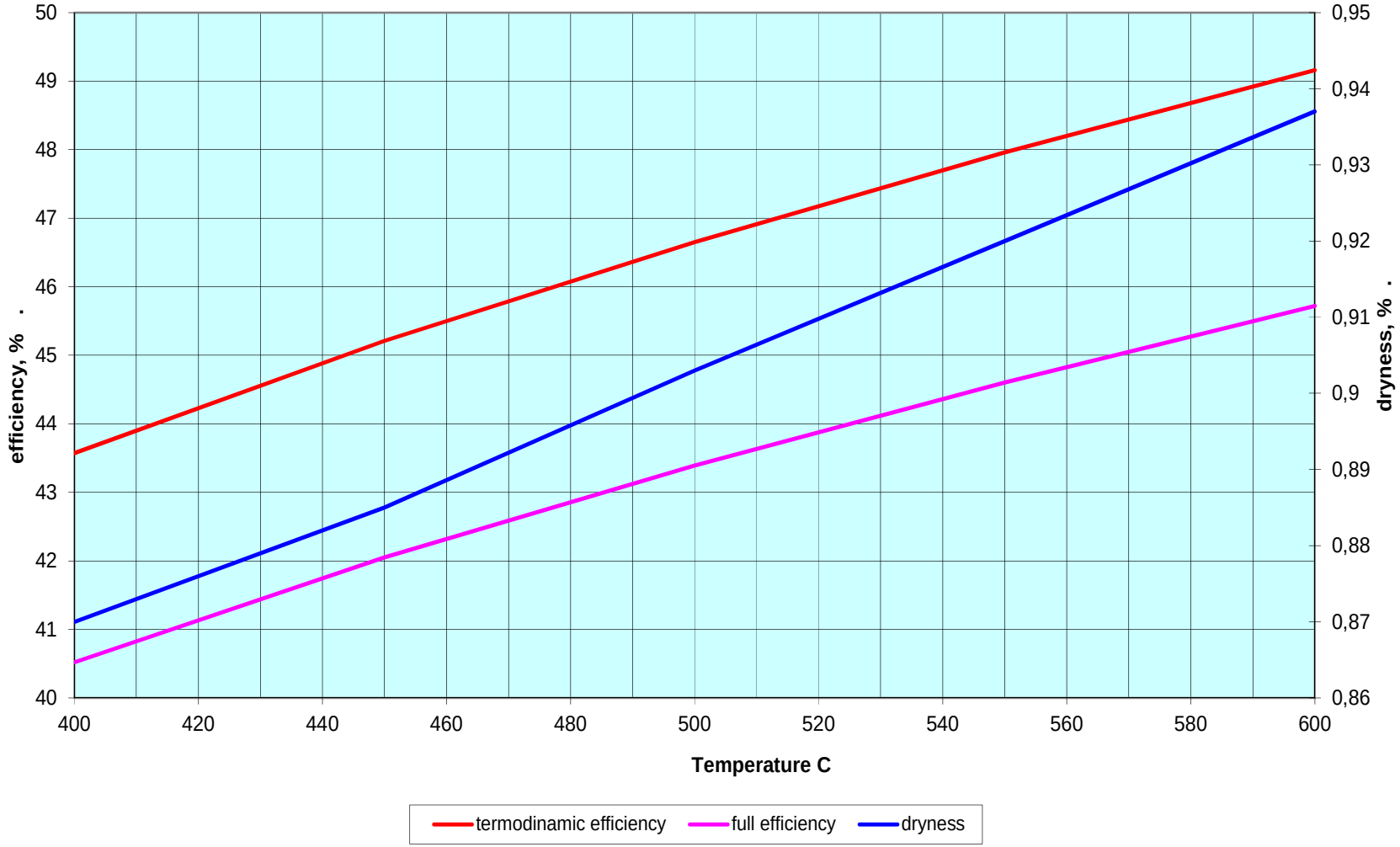
Annual planing of natural uranium	– 510 kg.
Annual planing of natural thorium	– 14 kg.

Comment: Annual planing of natural uranium for VVER-1000 *relative to thermal power in 10 time less, relative to electric power in 14 time less.*

Dependence of Power and Reactivity for 1 and 2 fuel recharging in Campain



Potential of Technology: Efficiency and vapor quality with steam temperature increase



Technical Decision Using in this Work

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2. **V.M.Kotov**. The piston machine. – The author's certificate of the USSR # 1267013, published. 07. 01.1986, Transaction # 40. - 3 p.
3. **V.M.Kotov, L.N.Tikhomirov**. The piston engine with closed work cycle. - Preliminary patent of RK, #14124, published. 01.07.2004, Transaction. # 3. - 2 p.
4. **V.M.Kotov.** Mode of operation of termal engine and piston engine for its realization. – Patent of Russian Federation # 2284420. Published 27 09 2006, # 27.
5. **V.M.Kotov.** The piston machine (variants) Preliminary patent of RK # 13699, 09. 09.2003, Transaction # 11. - 4 p.
6. **V.M.Kotov.** Mode of reproduction fission materials in closed cicle of nuclear reactor. – Innovative patent of Republic of Kazakhstan # 19336, 15.04.2008.
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8. V.M. Kotov. Gas cooled reactor with water coolant and way of its control. Innovation patent of Republic of Kazakhstan №. 23234 from 20 September 2010. (in Russian).
9. V.M. Kotov Uranium-thorium fuel rod. Innovation patent of Republic of Kazakhstan №. 23235 from 20 September 2010. (in Russian).
10. V.M. Kotov, R.A. Irkimbekov. Power reactor campaign characteristics calculation. // NNC herald. **3,** 118-122 (2011) Kurchatov, (in Russian).
11. V.M. Kotov. Gas-cooled reactor with Rankine steam engine. - Innovative patent of Republic of Kazakhstan # 26118, 20 06 2012.

Conclusion

Achievement high marketability of concerned gas-cooled reactor and Rankine cycle cause by next premises:

1. Possibility of heating gas coolant up to 500 ^{o}C in Fuel Assembly with good used fuel rod, increase steam pressure relative to coolant pressure;
2. Using energy of neutron moderation and heat flow over from fuel assembly;
3. Possibility of removal heat shield in fuel assembly;
4. Using multistep steam overheating which reduce steam humidity on turbine outlet;
5. Reducing heat exchanger mass from behind increase efficiency and reduce reactor thermal power;
6. Reducing expenditure on coolant pumping;
7. Using mixture of heavy and light water in moderator which reduce heavy water mass and its cost;
8. Reducing needs in fuel from behind high efficiency and good fuel reproduction;
9. Reducing fission materials content in fuel at the beginning of campain and, so, cost of fuel enrichment;