SFRs by Russia

This presentation is mainly based on: Handbook of Generation IV Nuclear Reactors, 2023. 2 nd edition, Editor: I.L. Pioro, Elsevier – Woodhead Publishing (WP), Kidlington, UK, 1079 pages (hard copy) and 197 pages (Appendices 3 – 9 on website: https://www.elsevier.com/books-and-journals/bookcompanion/9780128205884): https://shop.elsevier.com/books/handbook-of-generation-iv-nuclear-reactors/pioro/978-0-12-820588-4; https://www.sciencedirect.com/book/9780128205884/handbook-of-generation-iv-nuclear-reactors#book-info and https://www.gen4.org/gif/jcms/c_208948/see-link-for-further-information.

History and geography of Russian fast reactors

http://www.okbm.nnov.ru/upload/iblock/340/hkrhdgf35afpjuduvd7n2v0848fr0rye.pdf

Key-design parameters of USSR / Russian SFRs – BN reactors

http://www.okbm.nnov.ru/upload/iblock/340/hkrhdgf35afpjuduvd7n2v0848fr0rye.pdf; accessed Feb. 19, 2022

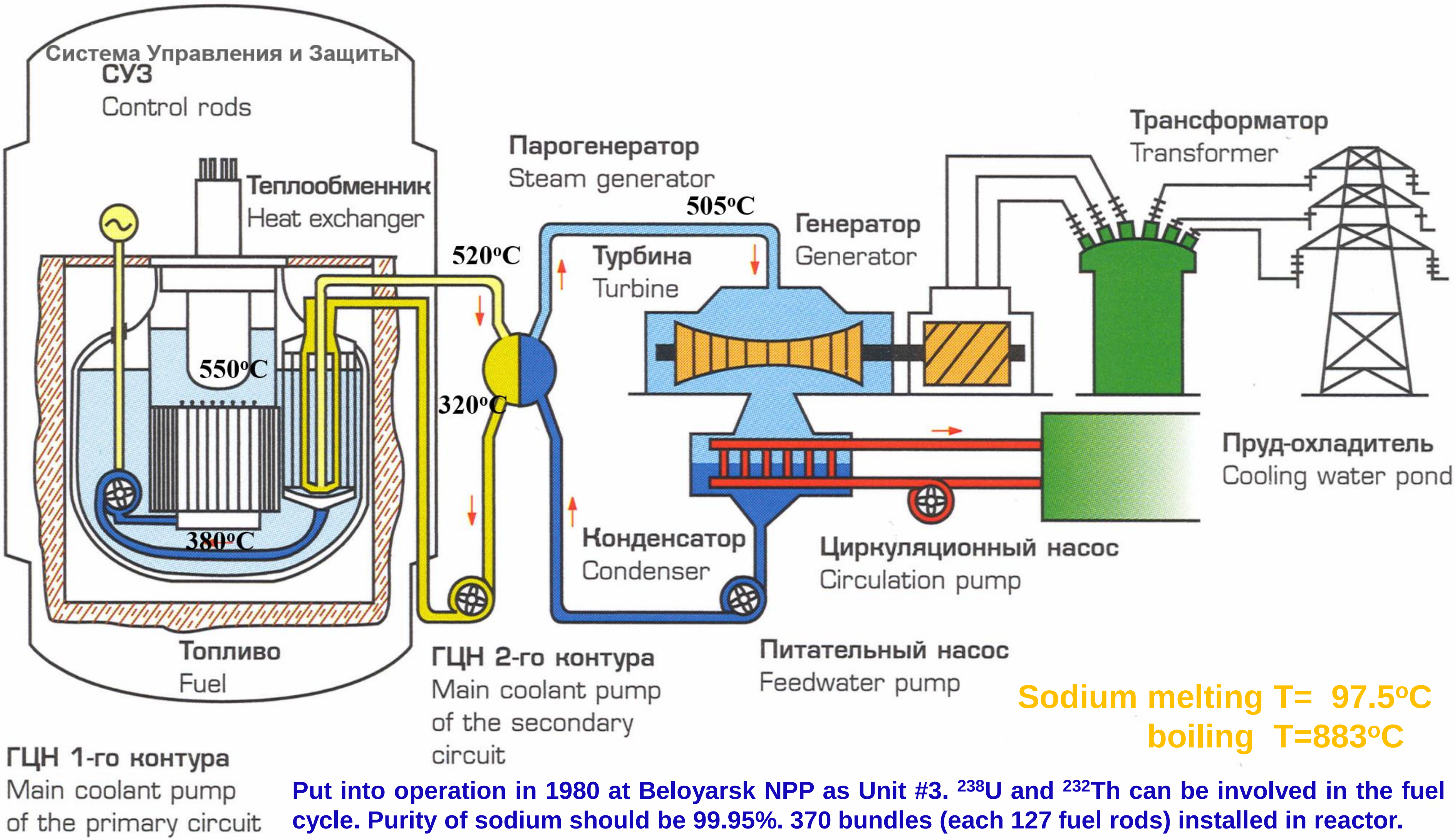
No.	Parameter	BN-350	**BN-600***	**BN-800***	BN-1200**
1	**Generation of reactor**	II	**III**	**III$^+$**	IV
2	**Thermal power, MW_{th}**	750	**1470**	**2100**	2800
3	**Electrical power, MW_{el}**	150	**600**	**880**	1220
4	**Thermal efficiency of NPP: gross / net**	20 / -	**40.8 / 40.0**	**41.9 / 38.8**	43.6 / 40.5
5	**Basic components:** **No of turbines × type** **No of generators × type**	-	 **3×K-200-130** **3×ТГВ-200-М**	 **1×K-800-130** **1×ТЗВ-800-2**	 1×K-1200-160 1×ТЗВ-1200-2
6	**Vessel: Diameter, m** **Height, m**	-	**12.86** **12.60**	**12.96** **14.82**	16.9 20.72
	Layout	Loop	**Integral**	**Integral**	Integral
7	**No of heat-transfer loops**	-	**3**	**3**	4
8	**Temperature of reactor coolant: sodium, primary loop – T_{in}/T_{out}, °C**	280/440	**377/550**	**354/547**	410/550
9	**Temperature of intermediate coolant: sodium, secondary loop – T_{in}/T_{out}, °C**	270/420	**328/518**	**309/505**	355/527
10	**Temperature of power-cycle working fluid: water/steam – T_{in}/T_{out}, °C**	160/410	**240/505**	**210/490**	275/510
11	**Pressure at steam-generator outlet, MPa**	4.9	**14**	**14**	17
12	**Scheme of steam reheat with**		**Sodium**	**Steam**	Steam
13	**Basic unchangeable components service term, years**		**30**	**40**	60
14	**Fuel**	UO_2	**UO_2**	**MOX*** **	MOX / UN+20%PuN
15	**Fuel enrichment, % (zones: internal/intermediate/external)**	17-26	**17/20/27**	**17/20/24**	20
16	**Breeding ratio**	0.93 Pu factor	**0.85** **Pu factor**	**1.0**	1.2-1.4
17	**Basic unchangeable components service term, years**	-	**30 (41)**	**40**	60

*** BN-600 and BN-800 are currently in operation at Beloyarsk NPP; BN-600 commercial start – 1981 and BN-800 - 2016. Prototype of these SFRs was BOR-60 as a demonstration model with 45-75% enriched MOX fuel.**

**** BN-1200 – design of Generation-IV Russian SFR (to be built after 2030).**

***** MOX fuel appeared as a result of an agreement signed between Russia & US in 2000 on the disposal of military plutonium (TVEL/ROSATOM)**

Simplified scheme of Liquid-Metal Fast-Breeder Reactor (LMFBR) – Russian BN-600 (BN – Fast Sodium) Sodium-cooled Fast Reactor (SFR) (courtesy of ROSENERGOATOM).



Sodium melting T= 97.5°C
boiling T=883°C

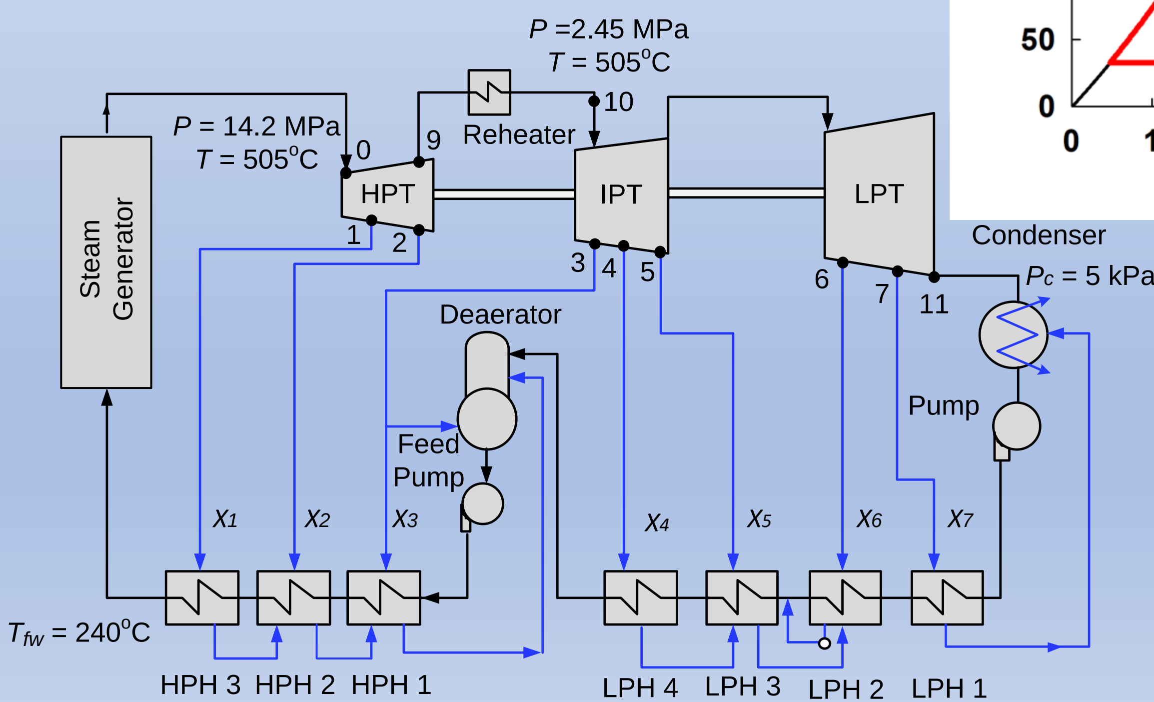
Put into operation in 1980 at Beloyarsk NPP as Unit #3. ^{238}U and ^{232}Th can be involved in the fuel cycle. Purity of sodium should be 99.95%. 370 bundles (each 127 fuel rods) installed in reactor.

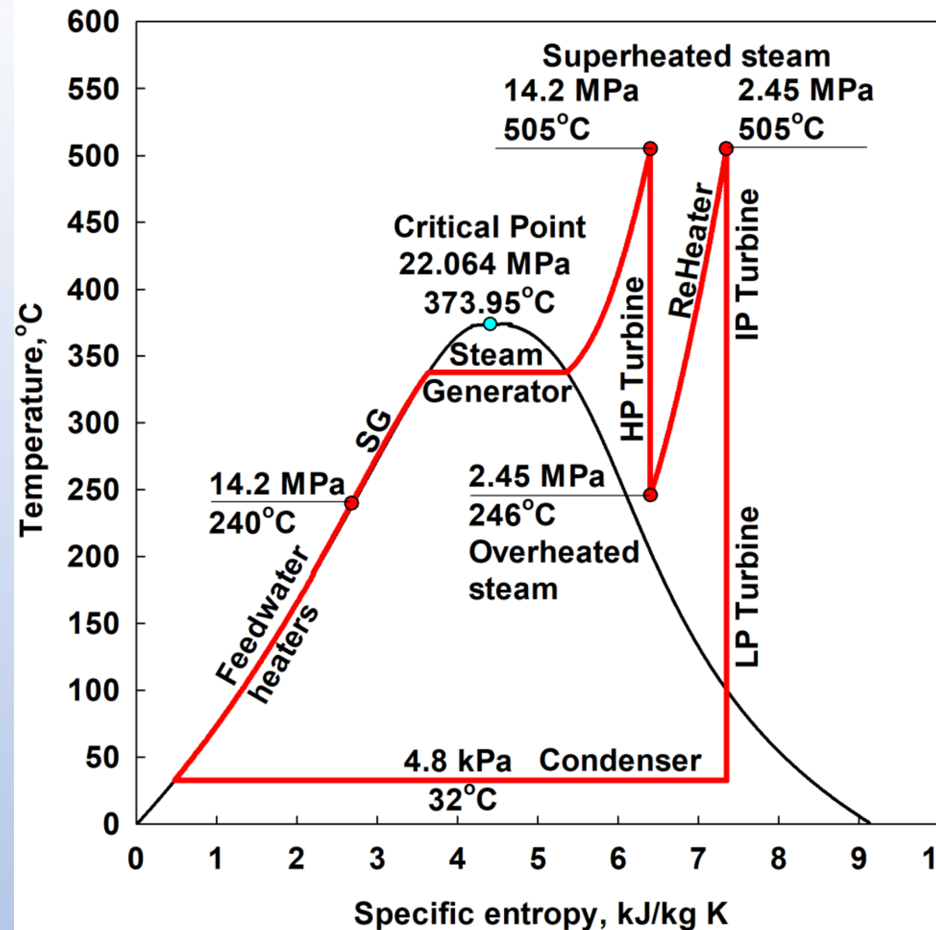
Sodium
Can cause serious or permanent injury.
Can be ignited under almost all ambient temperature conditions (autoignition temperature in air of liquid Na: 120 – 470°C).
Readily undergoes violent chemical changes at elevated temperatures and pressures.
Reacts violently or explosively with water with hydrogen generation.

Thermodynamic layout of 600-MW$_{el}$ BN-600 SFR NPP

Grigor'ev, V.A. and Zorin, V.M., Editors, 1988. Thermal and Nuclear Power Plants. Handbook, (In Russian), 2nd edition, Energoatomizdat Publishing House, Moscow, Russia, 625 pages.

Margulova, T.Ch., 1995. Nuclear Power Plants, (in Russian), Izdat Publishing House, Moscow, Russia, 289 pages.

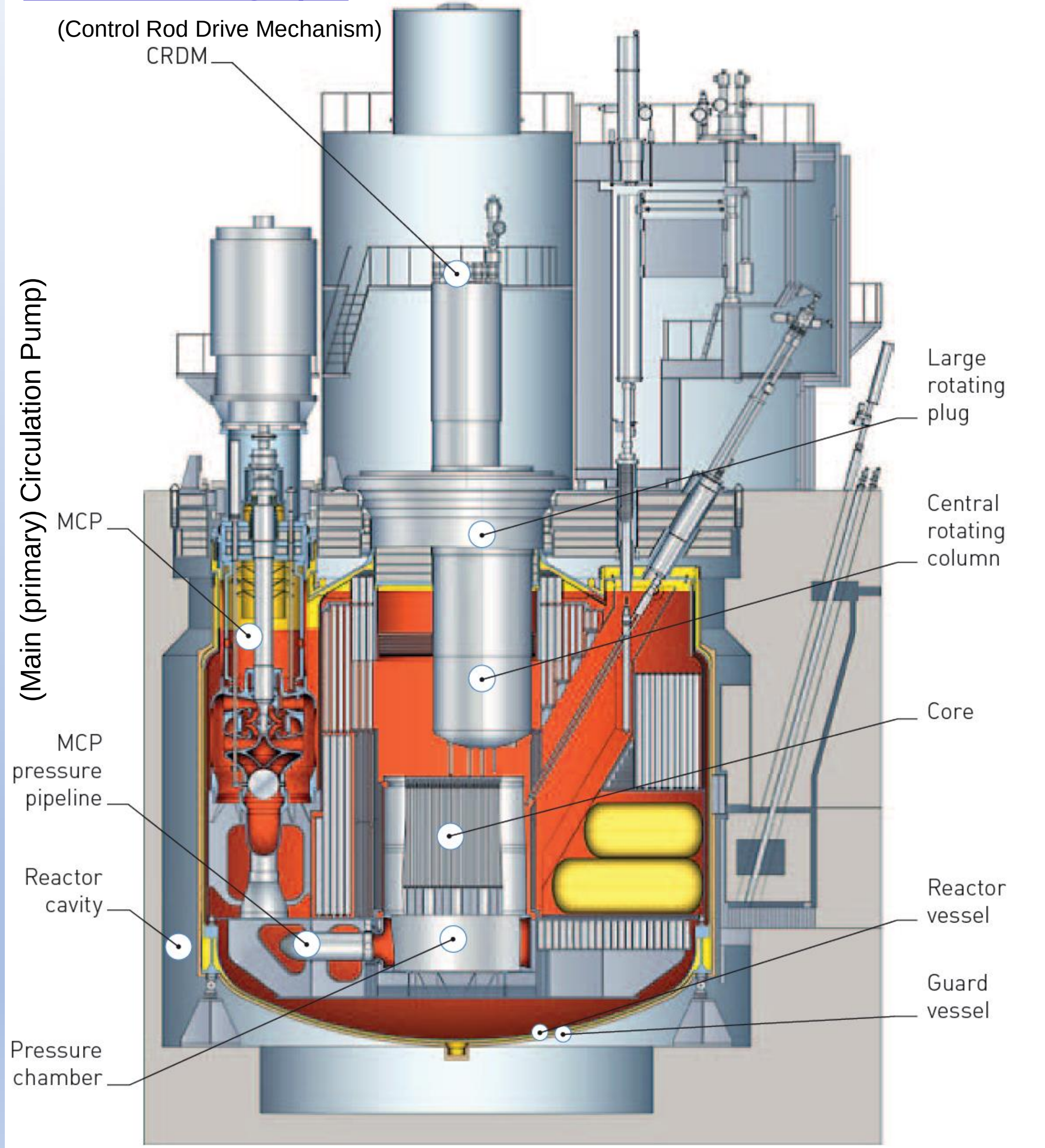




Simplified *T–s* diagram of subcritical-pressure superheated-steam Rankine cycle with reheat option (secondary steam is reheated with liquid sodium from intermediate loop in preheater) of SFR (BN-600) NPP (winter operation).

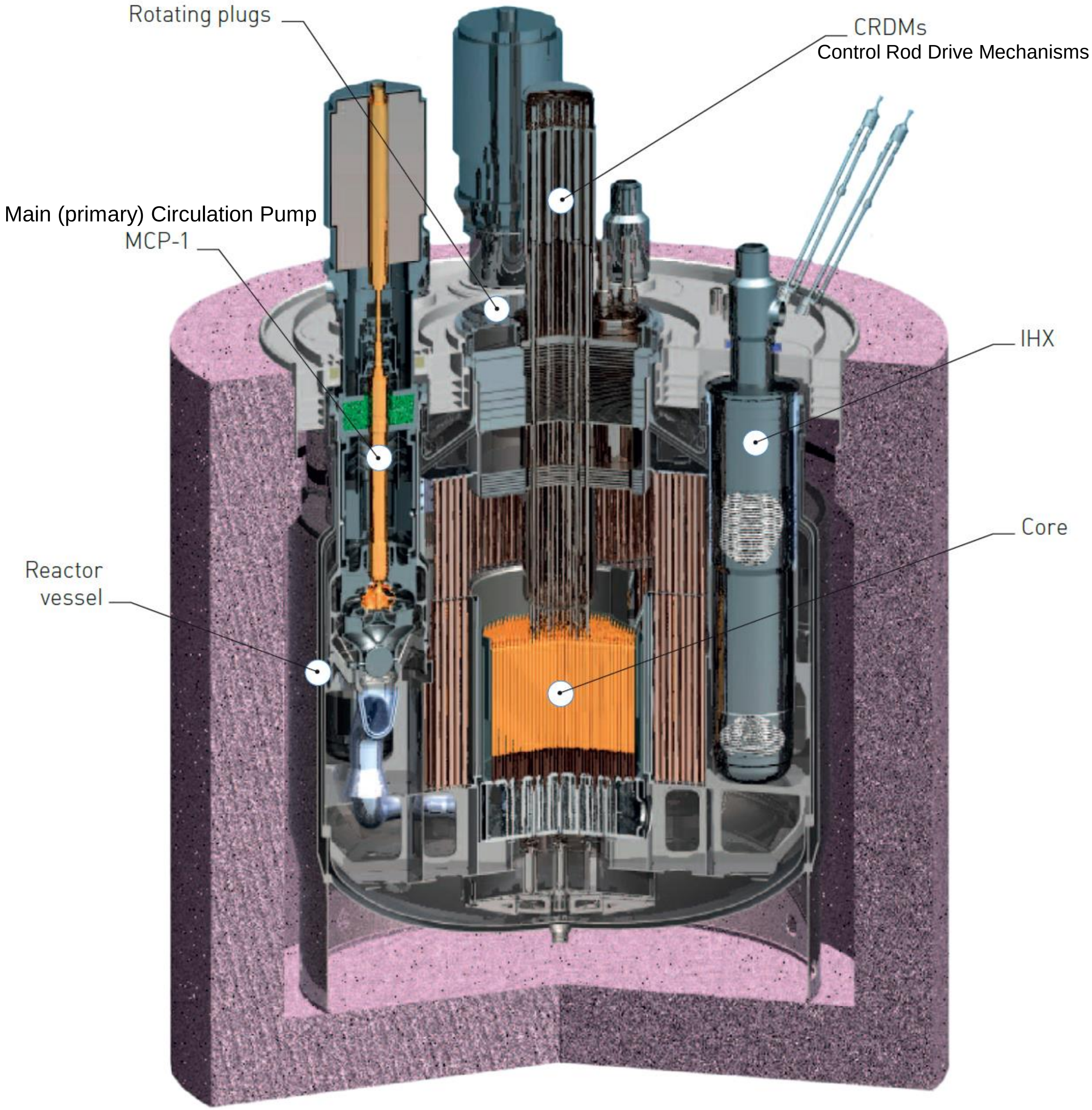
JSC "Afrikantov OKBM" is the Chief Designer of BN-600.

http://www.okbm.nnov.ru/upload/iblock/340/hkrhdgf35afpjuduvd7n2v0848fr0rye.pdf; accessed Feb. 19, 2022



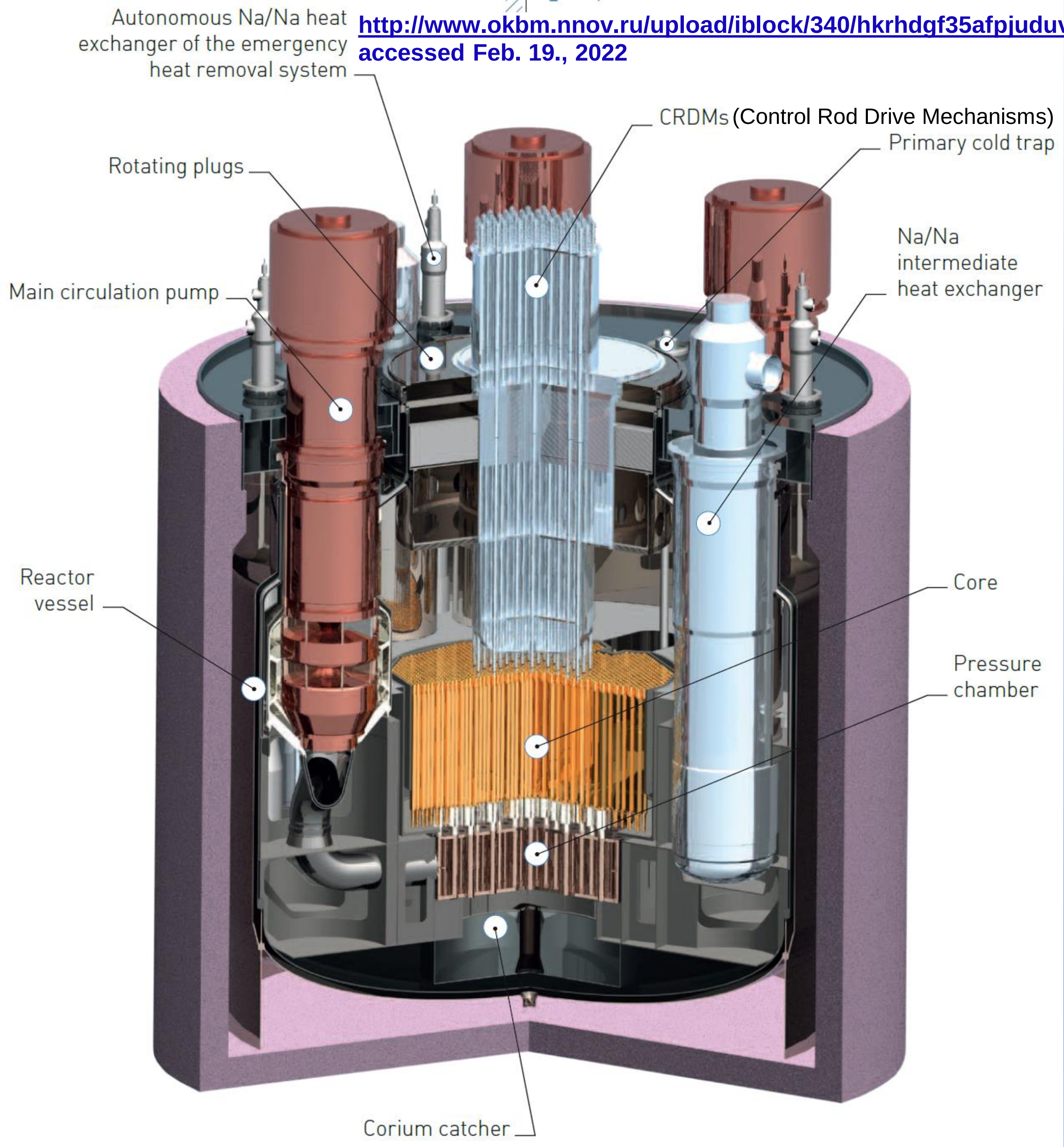
BN-600 main primary equipment

Sodium-cooled Fast Reactor (SFR) - BN-800, 820 MW_{el}, Beloyarsk NPP, year 2017 (Courtesy of ROSATOM):
https://www.flickr.com/photos/rosatom/35647612034/in/album-72157671632599611/



BN-800 main primary equipment

Turbine-generator hall of BN-800 reactor, 820 MW_{el}, Beloyarsk NPP, year 2015 (Courtesy of ROSATOM): https://www.flickr.com/photos/rosatom/28920213252/in/album-72157671632599611/



http://www.okbm.nnov.ru/upload/iblock/340/hkrhdgf35afpjuduvd7n2v0848fr0rye.pdf; accessed Feb. 19., 2022

(Control Rod Drive Mechanisms)

BN-1200 main primary equipment

EVOLUTION OF TECHNICAL SOLUTIONS FOR SAFETY ENHANCEMENT OF FAST REACTOR DESIGNS

http://www.okbm.nnov.ru/upload/iblock/340/hkrhdgf35afpjuduvd7n2v0848fr0rye.pdf; accessed Feb. 19., 2022

	BN-600	BN-800	BN-1200
	Gen.-III	Gen.-III+	Gen.-IV
1. Solutions for sodium circuits:			
– sodium-sodium intermediate circuit	+	+	+
– jacketing of vessels with radioactive sodium	+	+	+
– jacketing of pipelines with radioactive sodium	+	+	Pipelines with radioactive sodium have been excluded
– jacketing of secondary pipelines	-/+ (partially)	-/+ (partially)	+
2. Emergency protection:			
– active	+	+	+
– passive based on hydraulically suspended rods	-	+	+
– passive based on the temperature principle	-	-	+
3. Emergency heat removal system:			
– within the tertiary circuit	+		
– air heat exchangers are connected to the secondary circuit	-	+	
– air heat exchangers are connected to the primary circuit	-	-	+
4. Core melt retaining system	-	+	+
5. Emergency discharge isolation system	-	-	+

Solutions adopted for the design of reactor plants, use of passive safety systems and inherent safety properties of the sodium coolant make it possible to ensure the safety level that excludes necessity of population evacuation in case of any technically possible accidents.