# Current Status of SMRs Development AND DEPLOYMENT

I.L. PIORO1, R.B. DUFFEY2, R.S. EL-EMAM1, and L. JACOBS1

1 Ontario Tech University

Oshawa, Ontario, Canada

E-mail: Igor.Pioro@ontariotechu.ca; Rami.Elemam@ontariotechu.ca; and Les.Jacobs@ontariotechu.ca

2 Idaho, USA

E-mail: Duffeyrb@gmail.com

**Abstract**

Nuclear power is the concentrated and reliable source of almost infinite energy, which is independent of weather conditions; has high-capacity factors, making units suitable for continuous base-load operation, essentially, negligible operating emissions of carbon dioxide, relatively small amount of wastes is generated compared to alternate fossil-fuel thermal power plants; also, a relatively small amount of fuel is required compared to that of fossil-fuel thermal power plants. As a result, nuclear power is considered as the most viable source for electricity generation within next 50 – 100 years. Currently, 446 nuclear-power reactors of 7 types are connected to electrical grids around the world. SMRs are today’s a very “hot” topic in nuclear engineering worldwide. In general, there are about 108 concepts / designs of SMRs. However, only 4 SMRs of two different types are currently in operation. Therefore, it is important to summarize SMRs design specifics for efficient and safe implementation in the nuclear-power industry.

## INTRODUCTION

Nuclear power is the concentrated and reliable source of almost infinite energy, which is independent of weather conditions; has high-capacity factors, making units suitable for continuous base-load operation, essentially, negligible operating emissions of carbon dioxide (if the whole cycle is considered), relatively small amount of wastes is generated compared to alternate fossil-fuel thermal power plants; also, a relatively small amount of fuel is required compared to that of fossil-fuel thermal power plants; and Nuclear Power Plants (NPPs) can supply relatively cheap electricity for re-charging of electrical vehicles during night hours as they usually operate on a full load (capacity) 24/7. As a result, nuclear power is considered as the most viable source for electricity generation within next 50 – 100 years.

Currently, 446 nuclear-power reactors are connected to electrical grids around the world, which belongs to 7 types: 1) Pressurized Water Reactors (PWRs) (313 including 2 Small Modular Reactors (SMRs)); 2) Boiling Water Reactors (BWRs) (60); 3) Pressurized Heavy-Water Reactors (PHWRs) (49); 4) Light-water Graphite-moderated Reactors (LGRs) (11, only in Russia); 5) Advanced Gas-cooled Reactors (AGRs) (8, CO2-cooled, only in UK); 6) Liquid-Metal Fast-Breeder Reactors (LMFBRs) – Sodium-cooled Fast Reactors (SFRs) (3, 2 in Russia and 1 in China (actually, a Generation-IV concept)); and 7) Gas-Cooled Reactors (GCRs) (2 (both of them are SMRs), Helium-cooled, only in China (actually, a Very-High-Temperature-Reactor (VHTR) concept of the Generation IV (Gen-IV)) (basic parameters of all current reactors and corresponding Rankine cycles are listed in Tables 1 and 2).

Currently, the share of electricity generation at NPPs in the world is ~9.2%, which is, unfortunately, less compared to that in 2010 – 14.4%, i.e., just before the Fukushima Daiichi NPP severe accident (the record % of generation was in 1995 – 17.5%) (<https://www.worldenergydata.org/world-electricity-generation/>)!

## current statistics on smrs

SMRs[[1]](#footnote-1) (installed capacities ≤300 MWel) are today’s a very “hot” topic in nuclear engineering worldwide. In general, there are about 108 concepts / designs of SMRs (based on information in [1‑4]), which can be classified as: 1) Water-cooled SMRs (land based) ‒ 33; 2) Water-cooled SMRs (marine based) ‒ 7; 3) High-Temperature Gas-cooled SMRs (He-cooled) ‒ 21; 4) Fast-neutron-spectrum SMRs (SFRs; Lead-cooled Fast Reactors (LFRs), and Lead-Bismuth-Eutectic (LBE)-cooled Fast Reactors (can be also designated as LFRs) ‒ 26; 5) Molten-Salt SMRs ‒ 17; and 6) Other SMRs ‒ 4. From all these 108 SMRs only two KLT-40S reactors (PWRs, Generation-III) (OKBM Afrikantov, Russia) have been constructed, installed on a barge, and put into operation in December of 2019 in the port of Pevek, Chukotka and two High Temperature Reactors Pebble-bed Module (HTRs-PM) SMRs (VHTR concept, He-cooled) were constructed and put into operation in March of 2022 in China.

In general, as of today, a number of small nuclear-power reactors with installed capacities (10 – 300 MWel) operate around the world (in total 22: China – 1 SFR 20 MWel; India (all PHWRs) – 1 – 90 MWel (51-year old); 2 – 150 MWel; 1 – 187 MWel; and 14 ‑ ~200 MWel; and Russia – 3 – 11 MWel (47‑49-year old). Moreover, some of them operate successfully for about 50 years! However, they cannot be named as SMRs. Also, France, Russia, UK, USA and other countries have great experience in successful development, manufacturing, and operation of submarines’, icebreakers’, aircraft carriers’, and other ships’ propulsion reactors. Therefore, many modern designs / concepts of SMRs are based on these achievements. Also, it should be mentioned that a large number of SMR designs and concepts is based on the Generation-IV nuclear-power-reactors concepts and 3 SMR concepts are based on heat pipes.

To the best of our knowledge the following summary can be presented:

SMR concepts / designs by countries:

1. S. Africa – 4 High Temperature Gas-cooled Reactors (HTGRs);
2. Argentina – 1 PWR;
3. Canada – 6 (1 SuperCritical Water-cooled Reactor (SCWR) + 1 PHWR; 1 HTGR; 2 Molten Salt Reactors (MSRs); and 1 Other);
4. China – 13 (7 PWRs land-base; 1 PWR marine-based; 2 HTGRs; 1 Fast Reactor; and 2 MSRs);
5. Czech Republic – 2 (1 HWR; and 1 MSR);
6. Denmark – 3 MSRs;
7. France – 5 (2 PWRs; 2 HTGRs; and 1 SFR);
8. India – 2 PHWRs;
9. Indonesia – 1 HTGR;
10. Italy ‑ 2 LFRs;
11. Japan ‑ 12 (4 PWRs land-base; 2 HTGRs; 4 Fast Reactors; 1 MSR; and 1 other type reactor);
12. Luxemburg – 2 (2 LFRs);
13. S. Korea – 5 (1 PWR and 4 Fast Reactors);
14. Russia – 15 (5 PWRs land-base; 5 PWRs marine-based; 3 HTGRs; and 2 Fast Reactors);
15. Sweden – 1 LFR;
16. UK – 4 (PWR; HTGR; and 2 MSRs); and
17. USA – 27 (5 PWRs land-base; 5 HTGRs; 9 Fast Reactors; 6 MSRs; and 2 other type reactors).

SMRs under construction:

1. Argentina – 1 PWR – CAREM[[2]](#footnote-2) (Central Argentina de Elementos Modulares);
2. Canada – Several BWRs – BWRX-300 (General Electric (USA) – Hitachi Nuclear Energy (Japan));
3. China – 1 PWR ‑ ACP100;
4. Russia – Several PWRs – RITM-200M (Generation-III+) and 1 LFR – BREST-OD-300 (Fast Reactor with Inherent safety Lead Coolant ‑ Experimental Demonstration) (Generation-IV concept).

SMRs designed and ready for construction:

1. USA – PWR by the NuScale Power, LLC; and PWR – SMR-160 by the Holtec International.

Additional information on a status of 21 SMRs readiness for deployment can be found in [4]. Also, the latest and official information on SMRs deployment are listed on the websites of the national nuclear-supervisory / safety agencies, commissions, etc, i.e., the U.S. Nuclear Regulatory Commission (NRC) (USA): <https://www.nrc.gov/reactors/new-reactors/smr/licensing-activities.html>; the Canadian Nuclear Safety Commission (CNSC) (Canada): <https://www.cnsc-ccsn.gc.ca/eng/reactors/power-plants/pre-licensing-vendor-design-review/#R3>; etc.

TABLE 1a. BASIC PARAMETERS OF ALL CURRENT REACTORS’ TYPES (BASED ON DATA [3]).

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **No** | **Reactor type** | **Fuel bundle****orientation** | **Sheath (cladding)****material2** | **Neutron****spectrum** | **Reactor** | **Reactor coolant** | **Refueling** | **Fuel5** | **Fuel****enrichment, %** | **HTC6****kW/m2K** |
| **Coolant** | **Moderator** | ***P*, MPa** | ***T*, °C** |
| **1** | PWR | RPV | Vert. | Zr | Th. | H2O | 15‑16.2 | 295→330 | Batch | UO2 | 3‑5 | ~30 |
| SMR KLT-40S | RPV | Vert. | Zr | Th. | H2O | 12.7 | 280→316 | Batch | UO2 | 18.6 | ‑ |
| **2** | BWR | RPV | Vert. | Zr | Th. | H2O | 7.2 | 287.7 | Batch | UO2 | ~2 | ~60 |
| **3** | PHWR (CANDU®) | PCh | Hor. | Zr | Th. | D2O | D2O3 | 11→10 | 260→310 | On-line | UO2 | 0.7 | ~50 |
| **4** | AGR | RPV1 | Vert. | SS | Th. | CO2 | C | ~4 | 290→650 | Batch4 | UO2 | 2.5‑3.5 | ~2‑5 |
| **5** | GCR7 (HTR PM) | RPV | ‑8 | ‑8 | Th. | He | C | 7.0 | 250→750 | ‑ | UO2 | 8.5 | ‑ |
| **6** | LGR (RBMK) | PCh | Vert. | Zr | Th. | H2O | C | 6.9 | 284.9 | On-line | UO2 | 2‑2.4 | ~60 |
| **7** | LMFBR (SFR: BN-800) | V | Vert. | SS | Fast | Na | ‑ | ~0.1 | 354→547 | Batch | MOX | 17/20/24 | 55‑85 |

1 Concrete RPV. 2 Zr – Zirconium alloys; SS – Stainless Steel. 3 CANDU®-reactor moderator has *P*=~0.1 MPa at the top of calandria vessel and *T*=~70°C. 4 AGRs were designed to be refueled on-line. However, it was found that during refueling at full power fuel assemblies can vibrate, due to that the on-line refueling was suspended from 1988 till the mid-1990s. Nowadays, only refueling at a part load or in shut-down state is now undertaken in AGRs. 5 Commonly used fuel. 6 Heat Transfer Coefficients (HTCs) are approximate values, shown just for reference purposes. 7 Design parameters. 8 Spherical fuel with diameter of 6 cm.

TABLE 1b. BASIC PARAMETERS OF ALL CURRENT REACTORS’ TYPES POWER CYCLES (BASED ON DATA FROM [3]).

| **No** | **Reactor type** | **Cycle1** | **No of loops** | **Rankine-cycle parameters** | **Thermal efficiencies (gross), %** |
| --- | --- | --- | --- | --- | --- |
| **Primary steam** | **Secondary-steam reheat** |
| ***P*in, MPa** | ***T*in, °C** | **Steam** | ***P*in, MPa** | ***T*in, °C** | **Steam** |
| **1** | PWR | Indirect | 2 | 7.72 | 292.5 | Saturated | 2 | 265 | Overheated | Up to 38 |
| SMR KLT-40S | Indirect | 2 | 3.72 | 290 | Overheated | N/A | Up to 26 |
| **2** | BWR | Direct | 1 | 7.2 | 287.7 | Saturated | 1.7 | 258 | Overheated | Up to 34 |
| **3** | PHWR (CANDU®) | Indirect | 2 | 4.7 | 260.1 | Saturated | ~1.2 | 240 | Overheated | Up to 34 |
| **4** | AGR | Indirect | 2 | 17 | 560 | Superheated | 4 | 560 | Superheated | Up to 42 |
| **5** | GCR3 (HTR PM) | Indirect | 2 | 14.1 | 566 | Superheated | 3.54 | 5604 | Superheated | 40 |
| **6** | LGR (RBMK) | Direct | 1 | 6.9 | 284.9 | Saturated | ~0.3 | ~263 | Overheated | Up to 33 |
| **7** | LMFBR (SFR: BN-800) | Indirect | 32 | 14.2 | 505 | Superheated | 2.5 | 505 | Superheated | Up to 40 |

1 All current reactors connected to Rankine steam cycle (light-water working fluid). 2 BN-800 has 3 loops: 1) liquid sodium circulating inside reactor; 2) intermediate loop with liquid sodium; and 3) water-steam in Rankine cycle. 3 Design parameters. 4 Estimated parameters.

TABLE 2. TYPICAL RANGES OF THERMAL EFFICIENCIES (GROSS) OF MODERN NPPs (BASED ON DATA IN [3]).

| **No** | **Power Plant** | **Gr. Th. Eff.** |
| --- | --- | --- |
| **1** | AGR NPP (Reactor Coolant (RC) ‑ carbon-dioxide: *P*=4 MPa, *T*=290‒650°C); (Rankine-cycle steam: *P*in=17 MPa (*T*sat=352.3°C) & *T*in=560°C (*T*cr=374°C); and *P*reheat≈4 MPa (*T*sat=250.4°C), *T*reheat=560°C). | Up to 43% |
| **2** | GCR HTR‑PM NPP (RC ‑ helium: *P*=7 MPa, *T*=250‒750°C; and Rankine-cycle steam: *P*in=14.2 MPa (*T*sat=337.8°C), *T*in=556°C (*T*cr=374°C); and *P*reheat≈3.5 MPa (*T*sat=242.6°C), *T*reheat=560°C). | Up to 42% |
| **3** | SFR BN-600 & BN-800 NPP (RC: P=0.1 MPa, *T*=377‑550°C, and Rankine-cycle steam: *P*in=14.2 MPa (*T*sat=337.8°C), *T*in=505°C (*T*cr=374°C); and *P*reheat≈2.5 MPa (*T*sat=224°C), *T*reheat=505°C). | Up to 40% |
| **4** | PWR NPP (RC: *P*=15.5 MPa (*T*sat=344.8°C), *T*out=327°C; steam: *P*in=7.8 MPa, *T*in=*T*sat=293.3°C; and *P*reheat≈2 MPa (*T*sat=212.4°C), *T*reheat≈265°C). | Up to 36‑38% |
| **5** | BWR or Advanced BWR NPP (RC: *P*=7.2 MPa, *T*out=*T*sat=287.7°C; steam: *P*=7.2 MPa, *T*in=*T*sat=287.7°C and *P*reheat≈1.7 MPa (*T*sat=204.3°C), *T*reheat≈258°C. | Up to 34% |
| **12** | PHWR NPP (CANDU®-6, current fleet) (RC: *P*in=11 MPa / *P*out=9.9 MPa (*T*sat=310.3°C) & *T*=260‒310°C; steam: *P*in=4.7 MPa, *T*in=*T*sat=260.1°C; and *P*reheat≈1.2 MPa (*T*sat=188°C), *T*reheat≈240°C). | Up to 32% |
| **13** | PWR SMR NPP (RITM-200M, Russia) (not yet in operation as SMR NPP) (RC: *P*=15.7 MPa (*T*sat=345.8°C), *T*=277‒313°C; steam: *P*in=3.82 MPa, *T*in=295°C (*T*sat=247.6°C). | Up to 31% |
| **14** | PWR SMR NPP (KLT-40S, Russia) (RC: *P*=12.7 MPa (*T*sat=329°C), *T*=280‒316°C; steam: *P*in=3.72 MPa, *T*in=290°C (*T*sat=246.1°C). | Up to 26% |

## DESIGN SPECIFICS OF OPERATING AND DESIGNED SMRS

One of the most important parameters of any nuclear / thermal power plant including NPPs with SMRs is the thermal efficiency (see Table 2). Analysis of the data in Table 2 shows that operating NPP with the two SMRs HTRs-PM, cooled with high temperature helium, has reasonably high thermal efficiency of 42% gross just 1% lower than that of AGRs NPPs (43%), which is the highest thermal efficiency of any current NPP nowadays. However, if alternative ‑ combined power cycles are used, it can be even significantly higher thermal efficiency (for details, see in [3]). On the opposite, the floating NPP with the two PWRs ‑ KLT-40S reactors has one of the lowest thermal efficiencies in the nuclear-power industry – only 26%. This is due to the smaller size and corresponding to that installed capacities of these SMRs and the absence of the secondary-steam reheat (see Tables 1 and 2, Fig. 1, and in [3]). However, another design specifics is the overheated primary steam at the turbine inlet, which is not used in any other NPPs with PWRs.

This deficiency of the NPP with KLT-40s reactors was “fixed’ in the RITM-200M design in which steam generators were installed inside the pressure vessel in the ring arrangement and due to that the thermal efficiency has been increased up to 31% (see Tables 1 and 2 and in [3])! However, it is still the lowest thermal efficiency for medium and large PWRs NPPs.

TABLE 3. MAIN DESIGN PARAMETERS OF SMRs – PWRs: KLT-40S; RITM-200M; NuScale; SMR-160; and BWRX-300 (BASED ON DATA IN [1‑3]).

| **Parameters** | **KLT–40S** | **RITM-200M** | **ACP100** | **NuScale** | **SMR-160** | **BWRX-300** |
| --- | --- | --- | --- | --- | --- | --- |
| Reactor type | PWR |  | Integral PWR | PWR | BWR |
| Generation of SMRs | III | III+ | ‑ | ‑ | ‑ | ‑ |
| Reactor coolant / moderator | Light water / Light water |
| Thermal power, MWth | 150 | 175 | 385 | 200 | 525 | 870 |
| Electric power, gross / net, MWel | 38.5 / 35 | 55 / 50 | 125 | 60 | 160 | 270‑290 |
| Thermal efficiency, % | ~26 | ~31 | 32 | 30 | 30.4 | 31‑33 |
| Expected capacity factor, % | 60 ‒ 70 | 65 | ‑ | ‑ | ‑ | ‑ |
| Max output thermal power, MW | 84.9 | ‑ | ‑ | ‑ | ‑ | ‑ |
| Production of desalinated water, m3/day | 40,000 ‒ 100,000\* | ‑ |  | ‑ | ‑ | ‑ |
| Operating range of power, % | 10 ‒ 100 | ‑ |  | ‑ | ‑ | ‑ |
| Primary circuit pressure (*T*sat, °C), MPa | 12.7 (329°C) | 15.7 (346°C) | 15 | 13.8 (336°C) | 15.5 (345°C) | 7.2 (288°C) |
| Primary circuit *T*in/*T*out,°C | 280 / 316 | 277 / 313 | 286.5 / 319.5 | 265 / 321 | 229 / 321 | 270 / 288 |
| Reactor coolant mass-flow rate, t/h | 680 | 3250 |  | ‑ |  |  |
| Primary circuit circulation mode | Forced | **Natural circulation** |
| Power cycle | Indirect Rankine cycle | Direct Rankine cycle |
| *P*steam at steam-generator outlet, MPa | 3.72 | 3.82 | 4.6 | 4.3 | 3.4 | 7.2 |
| *T*sat at *P*steam, °C | 246.1 | 247.4 | 258.8 | 254.7 | 240.9 | 287.7 |
| Overheated *T*steam at SG outlet,°C | 290 | 295 |  | ‑ | ‑ | N/A |
| Steam mass-flow rate, t/h | 240 | 261 (280) |  | ‑ | ‑ | ‑ |
| *T* feedwater in ‒ out, °C | 70 ‒ 130 (170) | ‑ |  | ‑ | ‑ | ‑ |
| RPV height / diameter, m | 4.8 / 2.0 | 9.2 / 3.5 | 10 / 3.35 | 17.8 /3 | 15 / 3 | 26 / 4 |
| Mass of reactor pressure vessel, ton | 46.5 | ‑ | 300 | 800 | 295 | 485 |
| Fuel type / Assembly array | UO2 pellets in silumin matrix | UO2 pellet / hexagonal | UO2 / 17 × 17 | UO2 pellet / 17 × 17 | UO2 pellet / square | UO2 / 10 × 10 |
| Fuel assembly active length, m | 1.2 | 2.0 |  | ‑ | ‑ | ‑ |
| Number of fuel assemblies | 121 | 241 | 57 | 37 | 57 | 240 |
| Core service life, h | 21,000 | 75,000 |  | ‑ |  | ‑ |
| Refueling interval, years | ~3\*\* | Up to 10 | 2 | 2 | 2 | 1‑2 |
| Fuel enrichment, % | **18.6** | **Up to 20** | <4.95 | <4.95 | 4.95 | 3.40 (avg) /. 4.95 (max) |
| Fuel burnup, GWd/t | 45.4 | ‑ | ‑ | >30 | 45 | 49.5 |
| Plant footprint. m2 | ‑ | ‑ | 200,000 | 140,000 | 20,500 | 8,400 |

\* In case of Floating Nuclear Power-DeSalination Complex (FNPDSC);

\*\* The Floating Nuclear Thermal Power Plant (FNThPP) will save up to 200,000 metric tons of coal and 100,000 tons of fuel oil per year. Every 12 years, the FNThPP will be towed back to the manufacturing plant and overhauled there.

TABLE 4. MAIN DESIGN PARAMETERS OF SMR HTR-PM (VHTR GEN-IV CONCEPT) (MAIN DESIGN SPECIFICS COMPARED TO THOSE OF AGRS ARE SHOWN IN BOLD) (BASED ON DATA IN [2]).

| **Parameter** | **Value** |
| --- | --- |
| Reactor type / No. of reactors | **Modular pebble-bed** high-temperature gas-cooled reactor / 2 |
| Reactor Coolant / Moderator | **Helium** / Graphite |
| Installed capacity | 2 × 250 MWth / 210 MWel; **Two reactors connected to one Rankine cycle** |
| Thermal efficiency | 42% (gross) |
| Primary circulation | Forced with **downward flow of He in reactor core** |
| Pressure of reactor coolant | **7 MPa** |
| Temperature of reactor coolant | ***T*out** / *T*in = **750°C** / 250°C |
| RPV height / diameter (inner) | 25 m / 5.7 m |
| Active core diameter/height | 3 m / 11 m |
| Average core power density  | 3.22 MW/m3 |
| RPV weight | 800 ton |
| Steam pressure / temperature  | **14.1 MPa** / **570** |
| Main steam flow rate at turbine inlet | 673 t/h |
| Fuel type | **TRISO (UO2); Spherical elements (6-cm OD) with coated particle fuel** |
| No. of fuel assemblies in core | **420,000** |
| Fuel enrichment | **8.5%** |
| Core discharge burnup | 90 GWd/ton |
| Fuel loading per fuel element | **7 g** |
| Fuel cycle / Refuelling | LEU, open cycle, spent fuel intermediate storage at plant / On-line |
| Reactivity control mechanism | Control rod insertion |
| Safety systems | **Combined active and passive** |
| Special features | **Inherent safety, no need for offsite emergency measures** |
| Design life / Seismic design (SSE) | 40 years / 0.2 g |

|  |  |
| --- | --- |
| A diagram of a temperature  Description automatically generated | *FIG. 1. Comparison of T – s diagrams of NPPs with PWR ‑ Evolutionary Power Reactor (EPR) (the largest reactor by installed capacity 1660 MWel net and the most efficient NPP with PWRs, BWRs and PHWRs); PWR – VVER (Russian PWR); and SMRs – RITM-200M and KLT-40S.* |

TABLE 5. MAIN DESIGN PARAMETERS OF SMR BREST-OD-300 (LFR GEN-IV CONCEPT) (MAIN DESIGN SPECIFICS COMPARED TO THOSE OF SFRS ARE SHOWN IN BOLD) (BASED ON DATA IN [1; 3]).

| **Technical Parameters** | **Value** |
| --- | --- |
| Reactor Type | LMFBR ‑ **Lead-cooled** Fast Reactor (LFR) |
| Reactor Connection to Steam Generator (SG) | **Double-Loop** |
| Thermal / Electrical Capacity | 700 MWth / 300 MWel |
| Gross Thermal Efficiency | **43.5%** |
| Circulation Type / Max Lead Velocity | Forced circulation / 1.9 m/s |
| Operating Pressure (Primary) | Low pressure |
| Core Inlet / Outlet Coolant Temperature | 420°C / 535°C |
| Water-Steam *T* at SG Inlet / Outlet & Outlet *P* | 340°C / 505°C / **17 MPa\*** |
| Max Fuel-Cladding Temperature | 650°C |
| Fuel Assembly | **Mixed uranium plutonium nitride ‑ (U + Pu) N** |
| Core Charge (U + Pu + MA)N | 19 t |
| Charge (Pu + MA) / 239Pu + 241Pu))N | 2.5 / 1.8 t t |
| Fuel Rod ODs / Fuel Rods Pitch | 9.7 – 10.5 mm / 13.0 mm |
| No. of Fuel Assemblies in Core / Enrichment | 169 / 14.5% |
| Fuel Lifetime | 5 years |
| Core breeding ratio / Core Discharge Burnup | 1.05 / 61.45 GWd/ton |
| Refuelling Cycle | 900‑1500 days |
| Reactivity Control Mechanism | Shim and automatic control rods (*Δρ* ≈ 12.5 *β*eff) |
| Safety Systems / Design Life / Plant Footprint | Passive / 30 years / 80 m × 80 m |
| RPV Height / Diameter / Weight | 17.5 m / 2.65 m / 27,000 ton |
| Fuel Cycle Requirement | **Closed fuel cycle. Used nitride of depleted U with Pu** |
| Distinguishing Features | **Inherent safety due to natural properties of lead, fuel, core, and cooling design** |
| Current Status | Under construction at Seversk (Siberia, Russia) |

\* **Possible supercritical-pressure Rankine cycle at 24 MPa.**

All other specifics of the operating and designed SMRs / NPPs are shown in **bold** in Tables 3 ‑ 5, which includes a higher level of fuels enrichment, i.e., 8.5% in HTRs-PM and up to 18.6% and 20% in KLT-40S and RITM-200M, respectively; natural circulation in several PWRs and BWR(s); helium reactor coolant and TRISO fuel in HTRs-PM; and lead reactor coolant and mixed uranium-plutonium nitride fuel in BREST-OD-300.

## REFERENCES

1. ADVANCES IN SMALL MODULAR REACTOR TECHNOLOGY DEVELOPMENTS. A Supplement to: ARIS, IAEA, 424 pages, (2022): <https://aris.iaea.org/Publications/SMR_booklet_2022.pdf>.
2. HANDBOOK OF SMALL MODULAR NUCLEAR REACTORS, Editors: Ingersoll, D.T., and Carelli, M.D., 2nd edition, Elsevier – Woodhead Publishing (WP), Duxford, UK, 609 pages, (2021).
3. HANDBOOK OF GENERATION IV NUCLEAR REACTORS, 2nd ed., Editor: I.L. Pioro, Elsevier – Woodhead Publishing (WP), Kidlington, UK, (2023, )1079 pages (hard copy) and 197 pages (Appendices 3 – 9 on website):<https://www.gen-4.org/gif/jcms/c_208948/see-link-for-further-information>.
4. THE NEA SMALL MODULAR REACTOR DASHBOARD, Nuclear Energy Agency (NEA), OECD, NEA No. 7650, 78 pages, (2023): https://www.oecd-nea.org/jcms/pl\_78743/the-nea-small-modular-reactor-dashboard?details=true.
1. Sometimes, the acronym SMRs means Small- and Medium-size Reactors. However, it is more appropriate to use the acronym S&MRs instead of SMRs for these types of reactors! [↑](#footnote-ref-1)
2. Due to financial problems the construction has been stalled. [↑](#footnote-ref-2)