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India's third home-built 700 MWe nuclear reactor achieves criticality

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Context:

The nuclear power reactor that achieved criticality is the first of a new series of Pressurised Heavy Water Reactors (PHWRs) to be built at **Rajasthan Atomic Power Project in Rawatbhata (RAPP-7)**.

About

- **700 MWe units are the largest indigenous nuclear power reactors** built by the **Nuclear Power Corporation of India Limited (NPCIL)**, a public sector undertaking of the **Department of Atomic Energy**.
- These **reactors are pressurized heavy water reactors (PHWRs)**, which **use natural uranium as fuel and heavy water as coolant and moderator**.
- The reactor achieved criticality after meeting the specified conditions of the **Atomic Energy Regulatory Board (AERB)**, **India's nuclear safety regulator**.

Nuclear Criticality

- In nuclear reactor operation, criticality is the **self-sustaining state of a nuclear chain reaction**.
- When there is a **perfect balance between neutron production and loss rates**, the nuclear system is considered critical.
- During reactor startup, the **neutron population is gradually increased in a controlled manner**, ensuring **more neutrons are produced than lost**.
- When the desired power level is achieved, the nuclear reactor is placed into a **critical configuration**.
- **Subcritical** describes a nuclear system where **neutron loss exceeds neutron production**.
- **Supercritical** describes a nuclear system where **neutron production exceeds neutron loss**.

Key Highlights of India's Nuclear Power Sector:

Current Energy Landscape:

- India's **total installed power capacity presently stands at 428 GW**, expected to **double to 810 GW by 2030**.
- Nuclear power **contributes approx 3% to India's energy mix**.

Current Nuclear Power Scenario:

- India operates **24 reactors with a total capacity of 8,180 MWe**, contributing approximately **3% to the nation's energy mix**.
- **Eight additional units**, of which **RAPP-7 is one**, are under construction, **adding 6,800 MWe**.

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- This includes a **Prototype Fast Breeder Reactor (PFBR)** and **four Pressurized Water Reactors (PWRs)** based on **Russian technology**.
- The government has also sanctioned **ten indigenous Pressurized Heavy Water Reactors (PHWRs)** of **700 MW** each, aiming for significant capacity expansion by 2031.
- Plans for **10 more reactors are in the pre-project phase** to be progressively completed by 2031-32.

Pressurized Heavy-Water Reactor (PHWR)

- Uses **heavy water (deuterium oxide D₂O)** as its coolant and neutron moderator.
- The heavy water coolant is kept under pressure, allowing it to be heated to higher temperatures without boiling, much as in a pressurized water reactor.
- While heavy water is significantly **more expensive** than ordinary light water, it creates **greatly enhanced neutron economy**, allowing the reactor to **operate without fuel-enrichment facilities** (offsetting the additional expense of the heavy water) and enhancing the ability of the reactor to make use of alternate fuel cycles.

Advantages of PHWR

- PHWRs can use **natural uranium, reducing the need for fuel enrichment facilities**.
- Unlike other reactors, **PHWRs can be refueled without shutting down**.
- PHWRs have the **potential to use different types of fuel**, including **mixed oxide (MOX) fuel** and **thorium**, which is abundant in India.

Disadvantages

- **Heavy water is expensive** to produce and maintain due to its isotopic composition.
- The use of pressure tubes adds **complexity to the reactor's design** and increases maintenance needs.

PHWRs are predominantly used in **Canada (CANDU reactors)** and **India**.

Key Players and Regulatory Environment:

Key Players: The **Department of Atomic Energy (DAE)**, the **Nuclear Power Corporation of India (NPCIL)**, and the **National Thermal Power Corporation (NTPC)** are the key organizations that play a pivotal role in the nuclear energy sector in India.

All three are **under the control of the Union government**.

NPCIL is the **owner and operator of all nuclear power plants** (except the **PFBR variants**, owned by The **Indira Gandhi Centre for Atomic Research (IGCAR), DAE**) and the primary contact for all nuclear business in India.

NTPC is a major producer of electricity from coal and accounts for 70GW capacity and is seeking to adopt nuclear reactors as part of its strategy to phase out old coal plants.

Regulatory Oversight:

- The **Atomic Energy Regulatory Board (AERB)** oversees **nuclear safety and regulatory processes**, including site selection, construction, operation, and decommissioning.

AERB's responsibilities extend to nuclear applications in various sectors.

- **Nuclear Liability and Insurance:**

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- India ratified the Convention on **Supplementary Compensation for Nuclear Damage (CSC) in 2016**, establishing a global compensation regime for nuclear accidents.
- The **Civil Liability for Nuclear Damage Act (CLND), 2010**, sets liabilities for operators and mandates insurance to cover potential damages.
- The **Indian Nuclear Insurance Pool (INIP)**, backed by **General Insurance Corporation of India (GIC-Re)** and other insurers, provides USD 15 billion in coverage to protect suppliers against liability claims.