History of Nuclear Reactor Development

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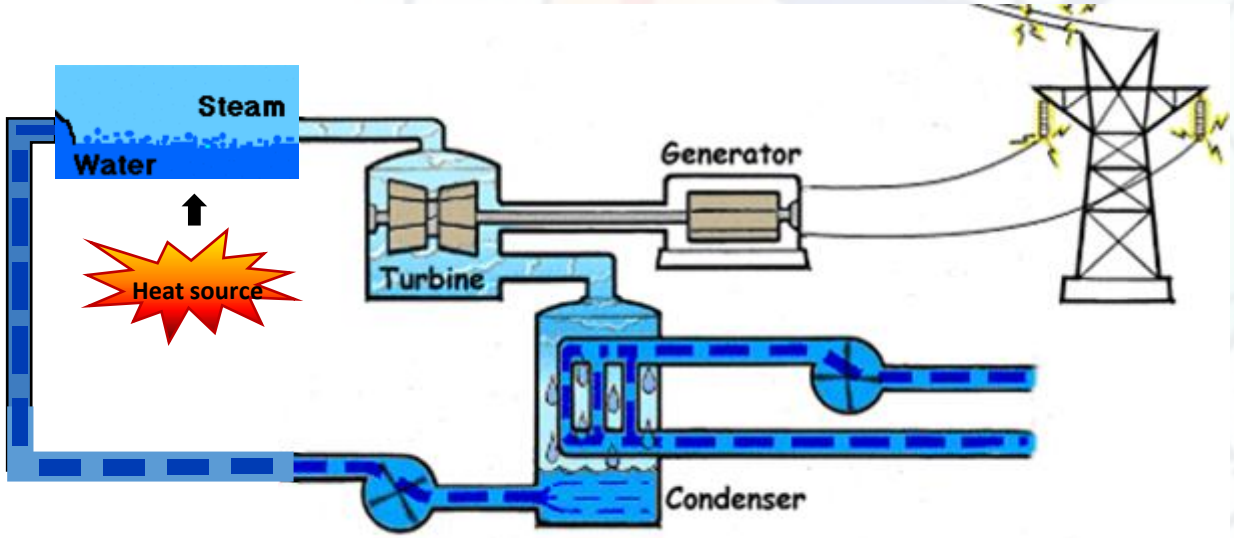
Nuclear Reactors

Nuclear Reactors are primarily used for the generation of the electric power

Sources of the electric power

- **Hydroelectric Power** -Large flooding area causing deforestation and loss of wildlife habitat, changes direction of river.
- **Wind Power** - Noise pollution, environmental impact
- **Solar power** - Low power generated from large area, depends on weather conditions
- **Thermal Power** - Non renewable fossil fuel , pollution, global warming



Schematic of Thermal Electric Power Station

- **Nuclear Power** – Heat is produced by Nuclear Reaction (not burning) in Uranium

Clean Energy !!!

Uranium ore is mined from the Earth

85% of Uranium is produced in 6 countries : Kazakhstan, Canada, Australia, Namibia Niger and Russia

Indian Uranium mines at Jaduguda And Tummalapalle

1000 kgs of Uranium ore produces 65 gms of usable Uranium

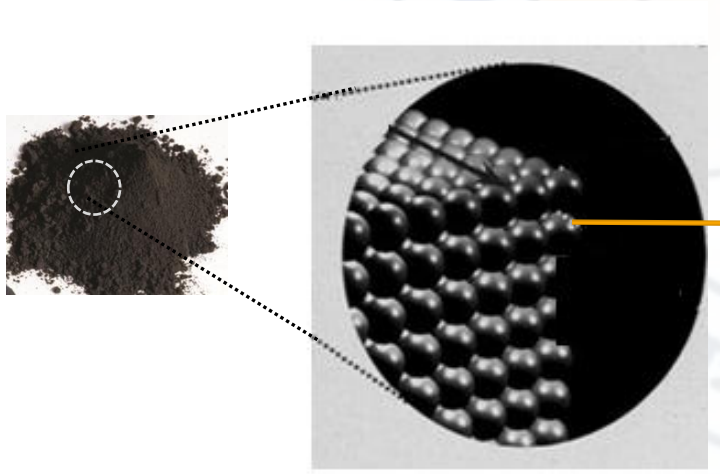
“Yellow cake” of Uranium

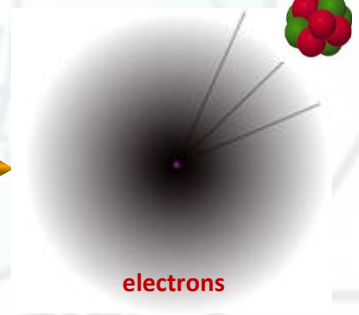
Uranium fuel pellets

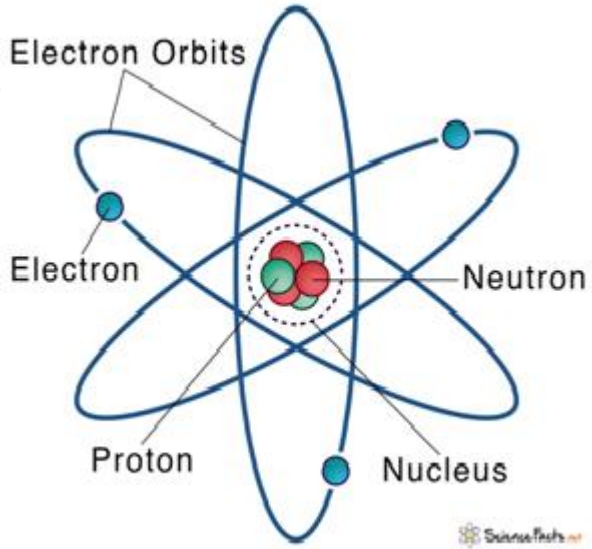
A Uranium fuel pellet, the size of a sugar cube, contains as much energy as 1000 kgs of coal !!!

Uranium fuel contains millions of Uranium atoms !!!

Objects around us are made up of tiny fundamental bits - Atoms !!!



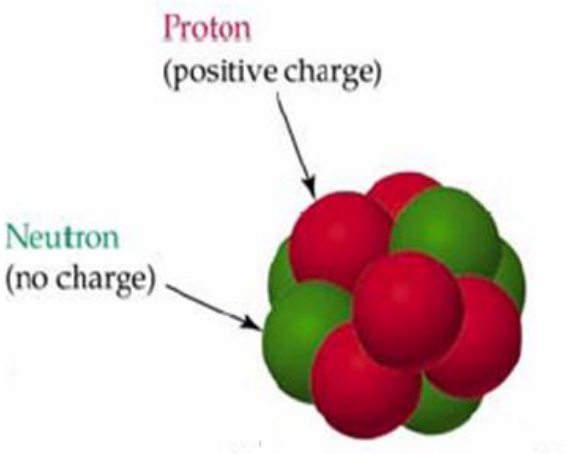




Number of protons and neutrons defines the type of Atom e.g.

Uranium atom is represented by

$$_{92}U^{235}$$



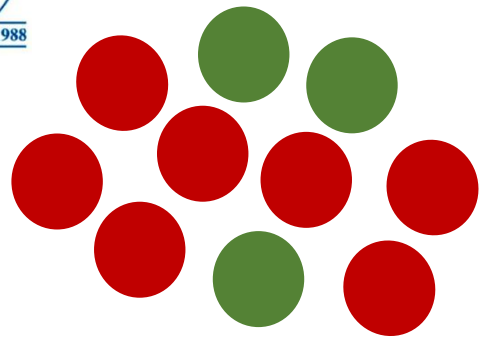
Protons repel each other !!!

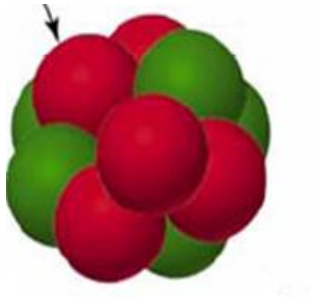
How neutrons are protons are held together in the nucleus??

Neutrons and protons are held together by strong attractive force !! – Nuclear Force

- **This nuclear force is stored in the nucleus in the form of ‘ Binding Energy’**

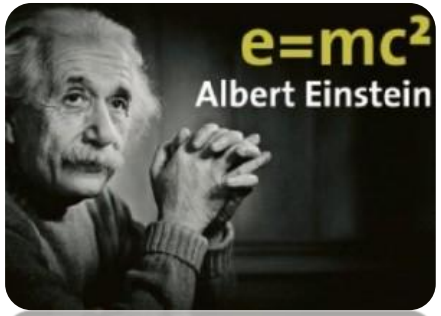
Binding Energy





+ Binding Energy

Mass of the nucleus is less than the sum of the masses of the neutrons and proton together ! There is a loss in mass !

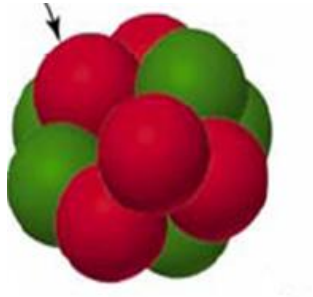


mass and energy are interconvertible; the mass can be converted into energy and vice-versa

Energy equals mass times the speed of light squared

loss in mass in the nucleus appears as the binding energy of the nucleus !!

Binding Energy



+ Binding Energy

Every nucleus has the Binding Energy associated with it

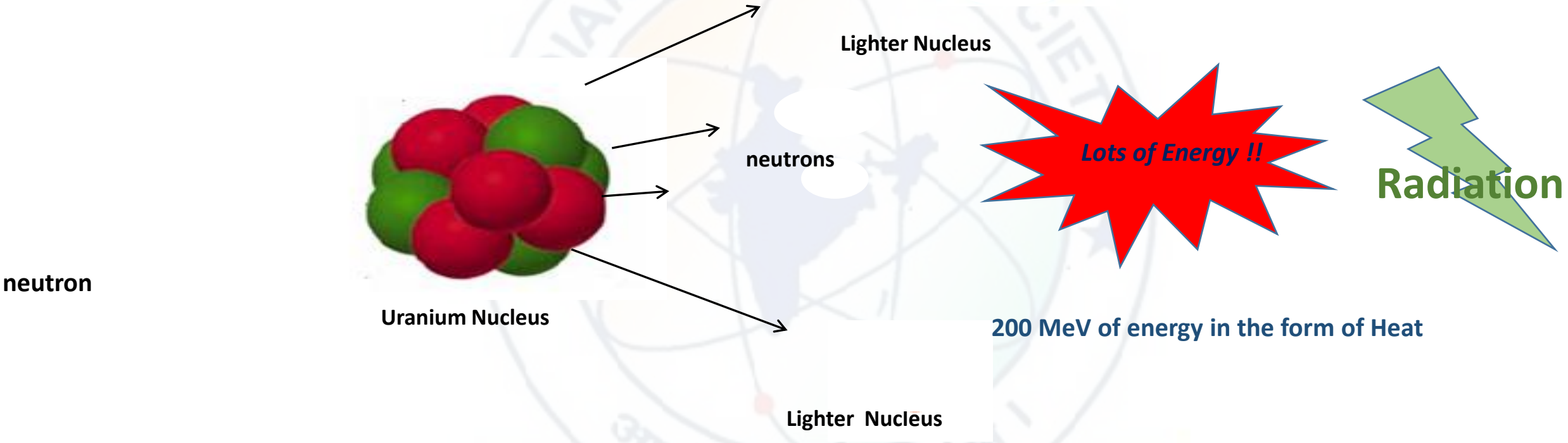
It means that if the binding energy of the nucleus is large, it requires more energy to break it. In other words, the nucleus is more stable

Nucleus of the Iron atom has the highest Binding Energy !!!

Iron is the most abundant element found in the Universe

Nuclear Fission !!!!

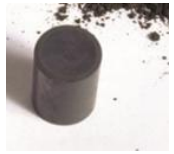
Mr. Otto Hahn and Mr. Strassman



Binding Energy of the lighter nuclei formed have more binding energy than the Binding Energy of Uranium Nucleus. This Difference in the Binding Energy is released in the form Heat

Energy released by burning of 1 gm of Carbon is 8,000 calories

Energy released by fission of 1 gm of Uranium is 20,00,00,00,000 calories



Neutron

Uranium

Neutron

Neutron

Uranium Nucleus

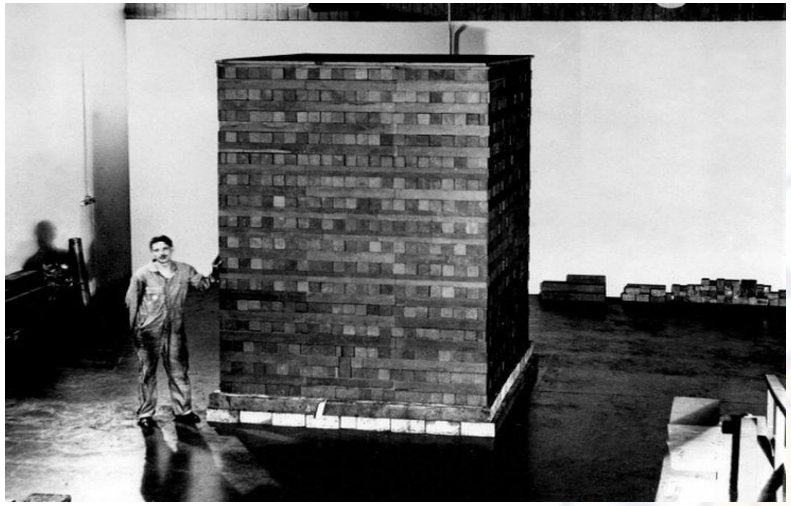
Neutron

Fission Chain Reaction !!!

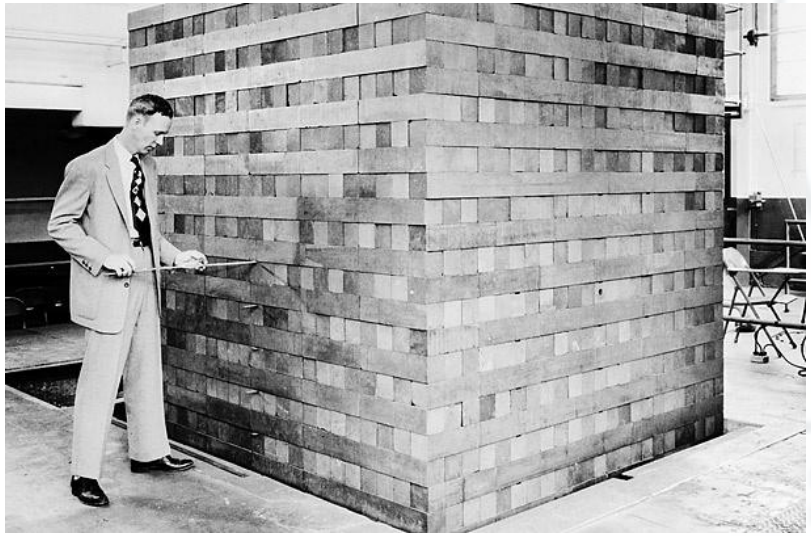
This phenomenon of fission chain reaction gave an idea the Scientists that if sufficient Uranium could be brought together under proper conditions – A fission chain reaction can be started

Top Secret Mission called 'The Manhattan Project' was started to split and utilize power of the Uranium Nucleus !!

In December 1942, Enrico Fermi with a small group of scientists gathered beneath the football stadium of Chicago University for an experiment to create a fission chain reaction



- Scientists built the pile structure by stacking layers of material called 'graphite' on top of a wooden frame.
- The graphite bars were fitted close to each other
- They called this structure as **CHICAGO PILE**



- Some Graphite bars were drilled with holes to fit lumps of Uranium to start the fission chain reaction
- Some were filled with 'safety rods or control rods' to control fission chain reaction
- On achieving the fission chain reaction, a secret message was delivered

"the Italian navigator has just landed in the New World"

Chicago Pile

World's First Nuclear Reactor !!!!

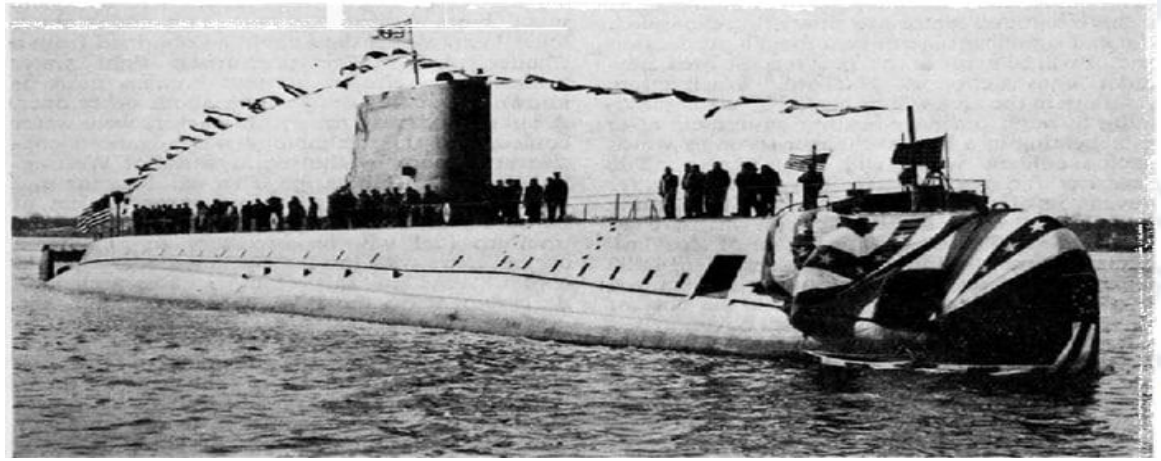
Man achieved the first fission Chain reaction and controlled it !

From 1945, the focus was to use nuclear energy for producing electricity and to propel ships / submarines

EBR 1 Nuclear Reactor

In 1951, the first production of usable nuclear electricity in the Idaho National Laboratory, USA was demonstrated in Experimental Breeder Reactor (EBR1)

The Nuclear Age was underway !!



USS Nautilus

By 1954, the Argonne National Laboratory , USA launched world's first nuclear powered submarine, USS NAUTILUS .

It sailed 50,000 miles with Uranium fuel carried on board and not refueling. It travelled underneath polar ice cap

Demonstrated that Nuclear Power was both safe and reliable !!

In December 1953, the US President Dwight David Eisenhower addressed the UN General Assembly in New York in his famous 'Atoms for Peace' speech to promote the peaceful uses of nuclear energy for the benefit of all mankind.

He proposed the formation of the
INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA)

IAEA

Under the watchful eye of the IAEA, several nuclear reactors were built in the ensuing decades, for producing electricity using the experience and technology developed during submarine development program

How does Nuclear Power Plant generate electricity ?

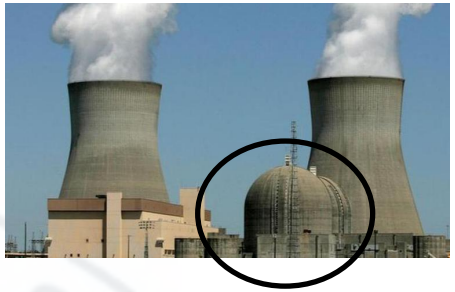
Reactor containment is the structure that contains the nuclear reactor and separates the nuclear reactor from the environment

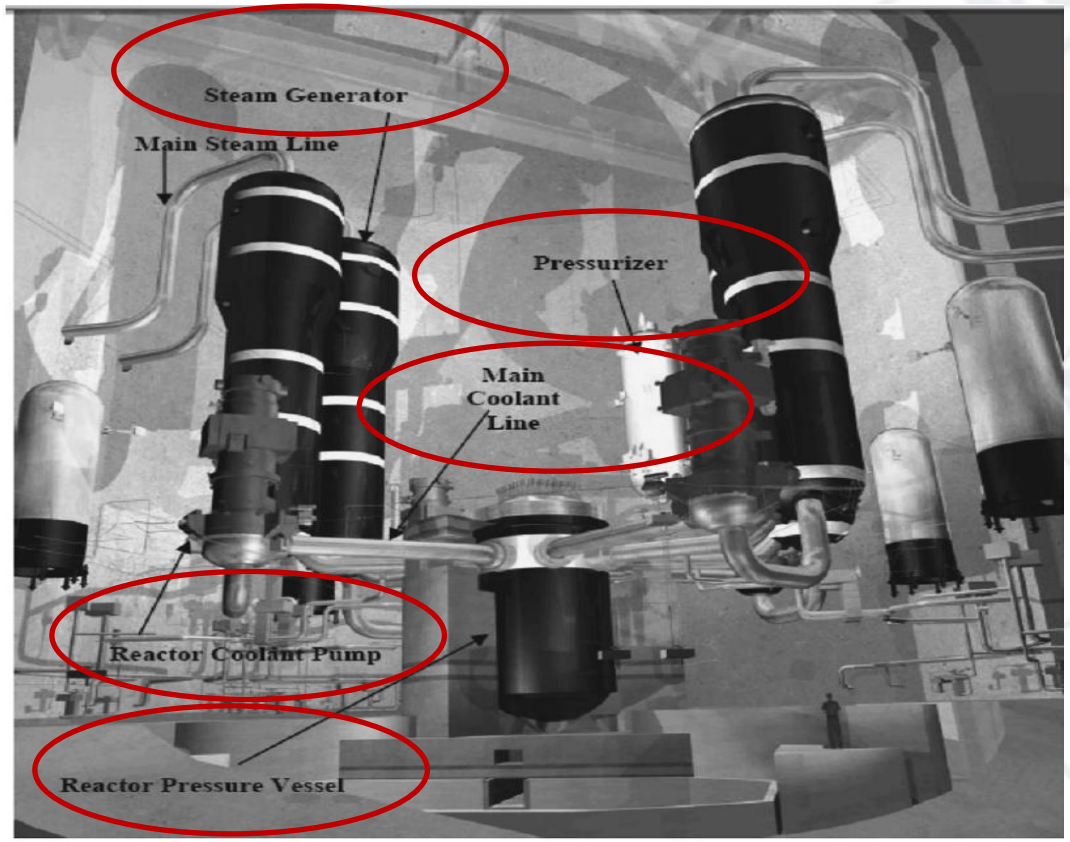
These are typically dome-shaped, made from steel and concrete

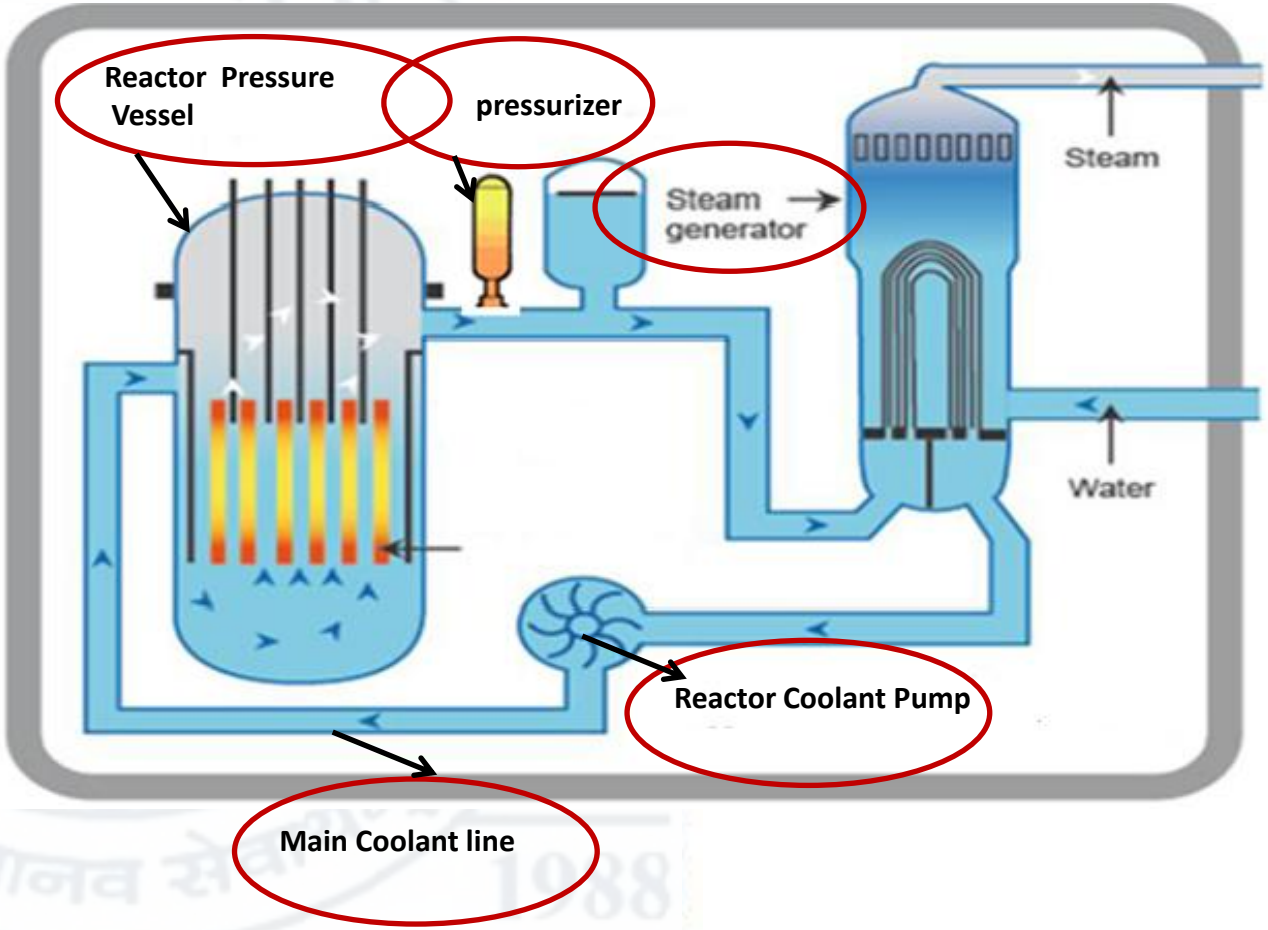
Cooling towers are used to remove excess heat generated in the nuclear reactor

Cooling towers just give out water vapor to the atmosphere and do not contribute to climate change !!

Reactor Containment







Research Reactors

Swimming Pool Type

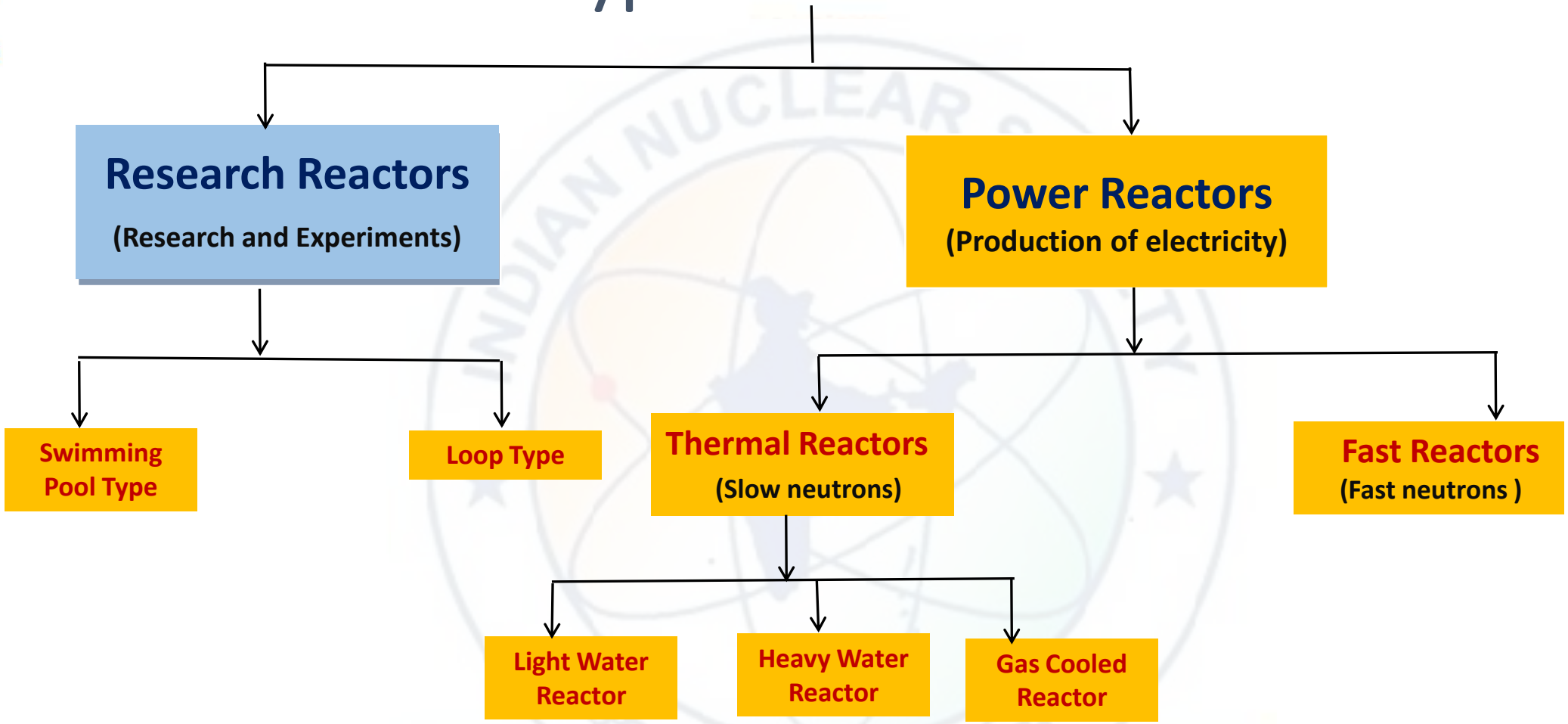
Fuel rods and control rods are immersed in a large pool of water

Cerenkov radiation gives water the soft blue glow!!

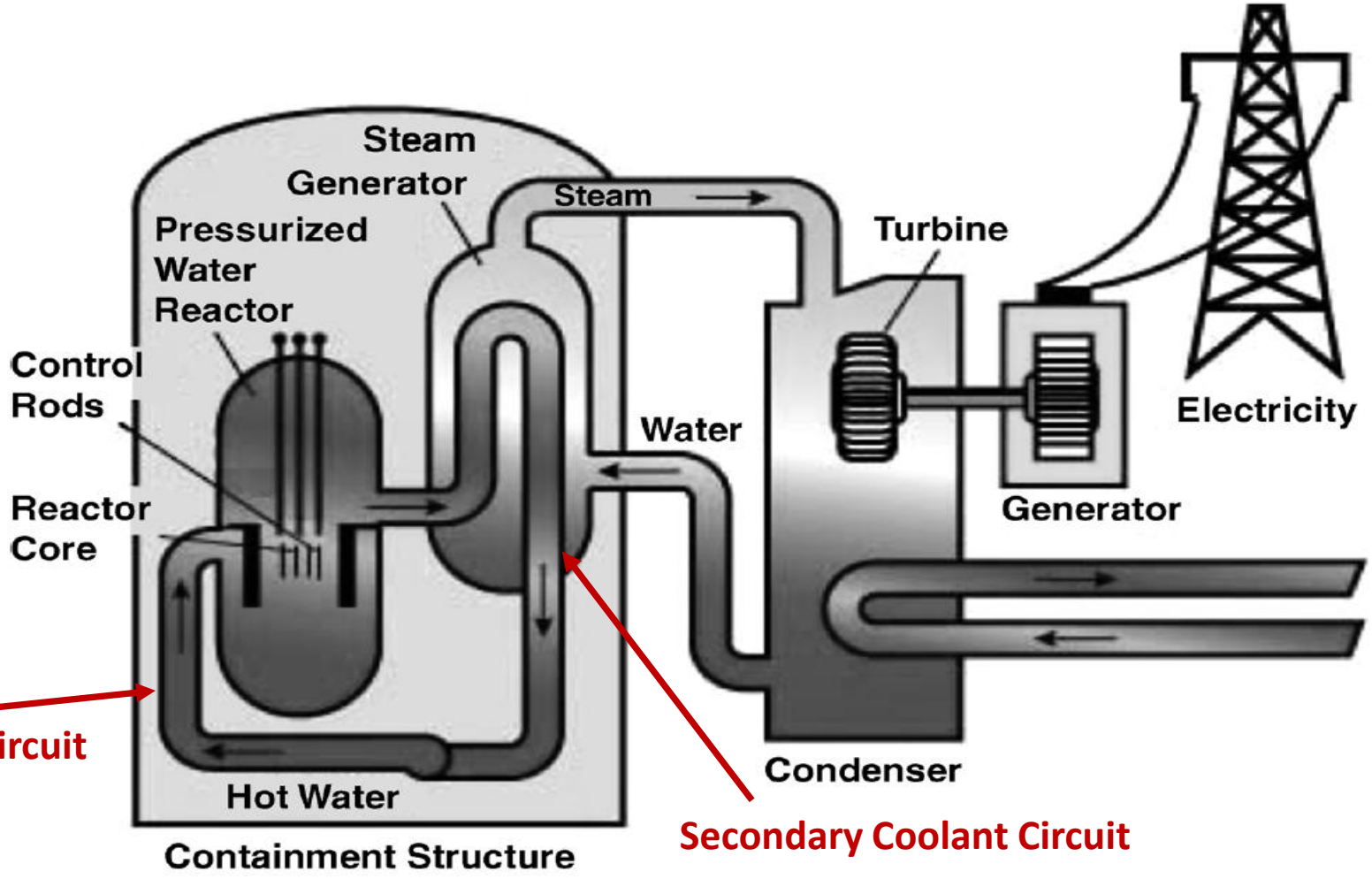
Tank Type

Fuel is contained in a pool but enclosed in a tank and the tank is cooled

Types of Reactors



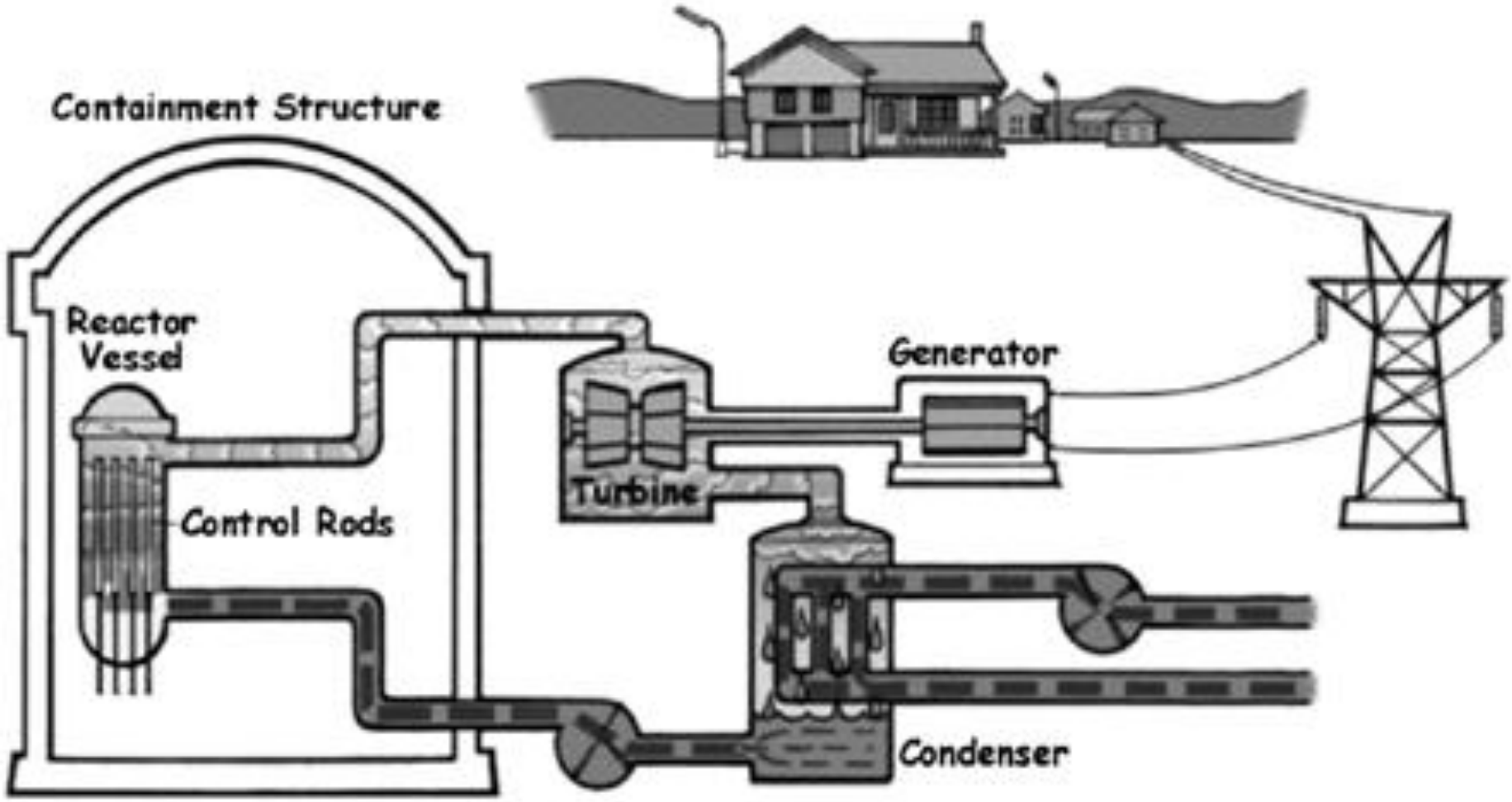
Pressurized Water Reactor (PWR)



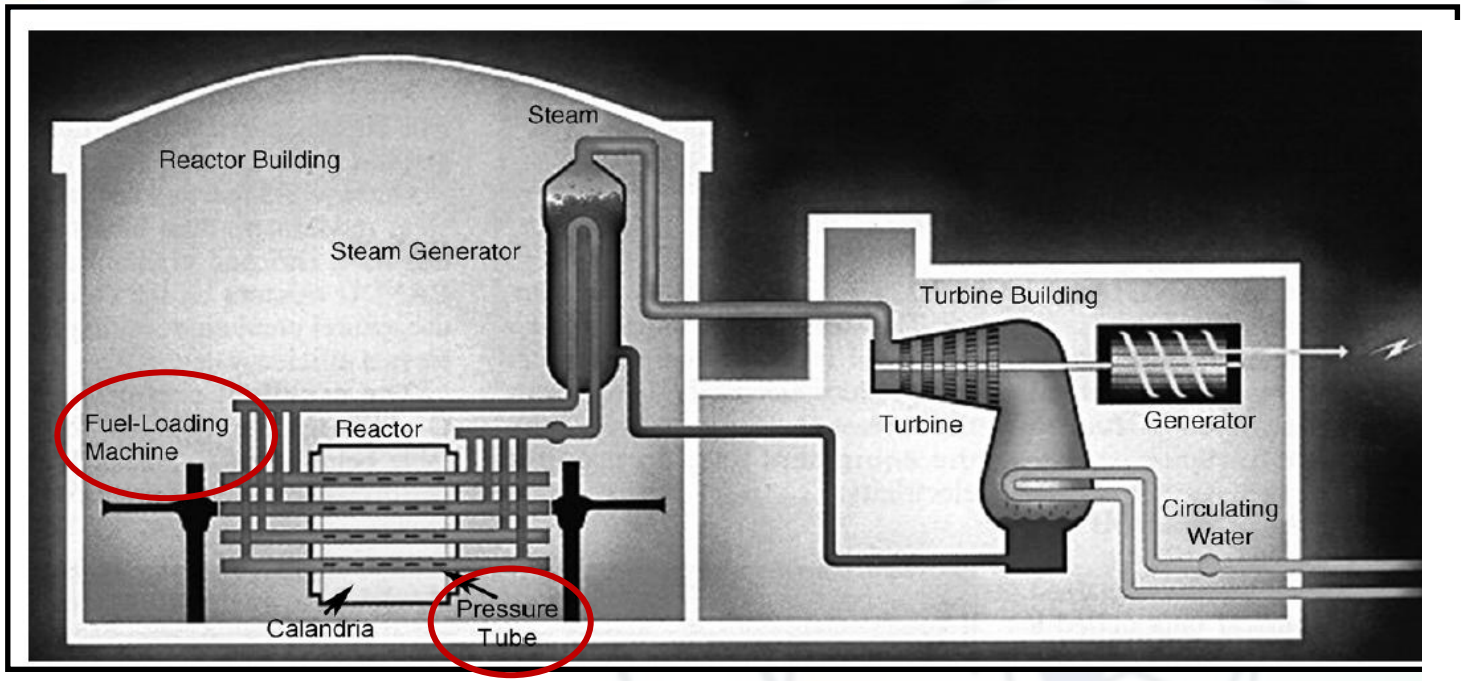
Fuel Rods

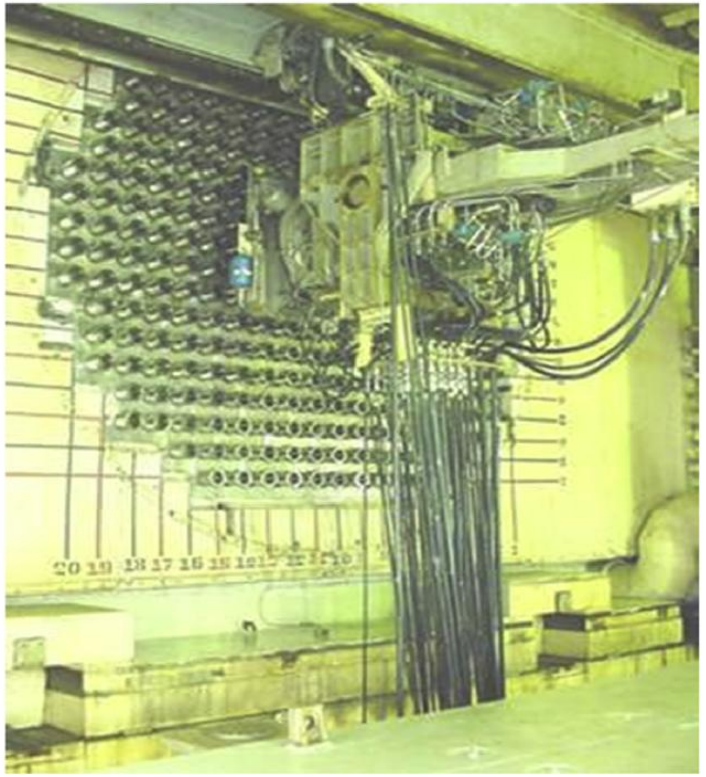
PWRs constitute the large majority of the World's Nuclear Power Plants

Boiling Water Reactor (BWR)

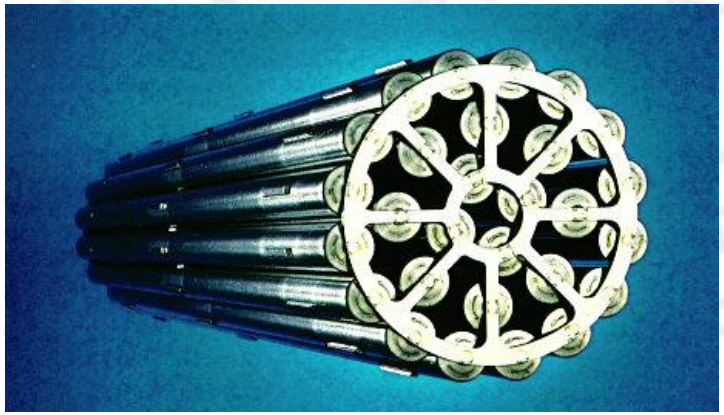


Pressurized Heavy Water Reactor





Fuel loading Machine loading Uranium Fuel Bundles



Uranium Fuel Bundles in the Pressure Tube

World Scenario

Reactor Type	Main Countries	Units	GWe
Pressurized Water Reactor (PWR)	US, FRANCE, JAPAN, RUSSIA, INDIA	268	249
Boiling Water Reactor (BWR)	US, JAPAN, SWEDEN	94	85
Pressurized Heavy Water Reactor (PHWR)	Canada, India, Argentina, South Korea	40	22
Gas Cooled Reactor (AGR, MAGNOX)	UK	23	12
Light Water Graphite Reactor (RBMK)	Russia	12	12
Fast Reactor	Japan, France, Russia, India	4	1
	Total	441	381

220 Research Reactors

India is the only developing nation to have indigenously established demonstrated and deployed nuclear reactors for electricity generation !

Indian Nuclear Programme

India entered into Nuclear age by establishing
The Tata Institute of Fundamental Research (TIFR)
on December 19, 1945, an initiative taken by
Dr. Homi *Jehangir* Bhabha

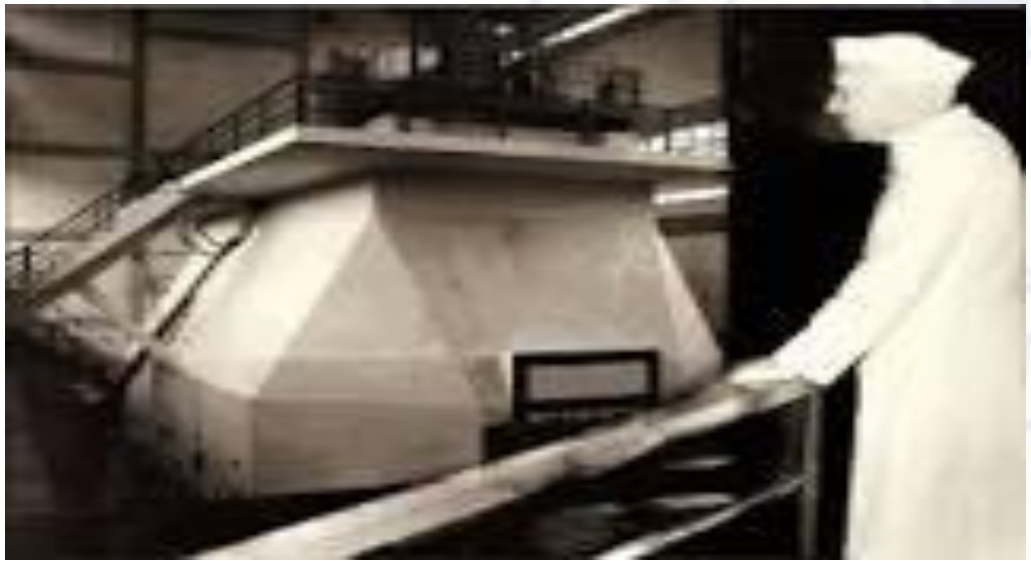
Dr. Homi Jehangir Bhabha - Father of Indian Nuclear Programn
(30 October 1909 – 24 January 1966)

On 10 of August 1948, **Atomic Energy Commission (AEC)** of India was established

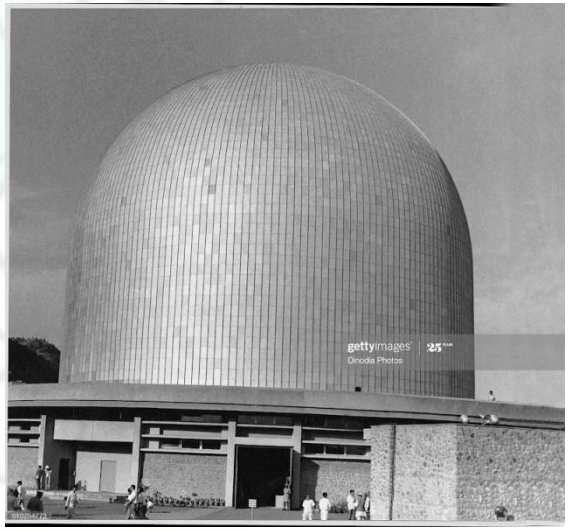
AEC was placed directly under the Prime Minister of INDIA
Dr. Bhabha was appointed as the Chairman of the AEC

The Department of Atomic Energy (DAE)
was established on August 4, 1954 with Head Quarters at
Old Yacht Club (OYC) Building, Bombay

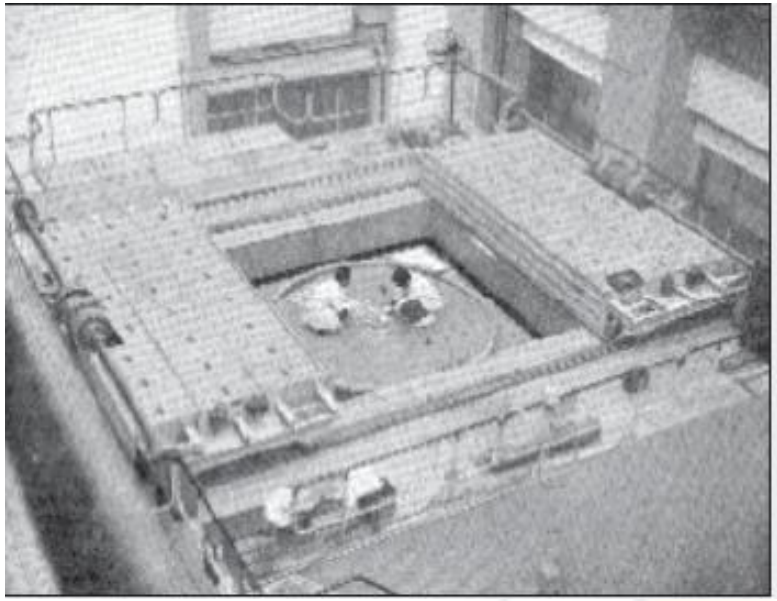
Bhabha Atomic Research Centre (BARC)



APSARA Reactor made critical in 1956 ***The first reactor in ASIA outside Soviet Union***



Canada India Reactor CIRUS
(Canada India Reactor Utility Services)
was brought to first criticality on July 10, 1960



ZERLINA achieve criticality on 14 January, 1961

This was the stepping stone to power reactors !!

India's first BWR nuclear power station at TARAPUR , Maharashtra was built in 1969

As the nuclear power program for the country was being formulated, it was planned to set up the required facilities for the Nuclear Power Plants within INDIA, to have self-reliance in complete nuclear technology.

- **Electronics Corporation of India limited (ECIL) was established in 1967 at Hyderabad**
  provides strong indigenous support in electronic systems and instruments related to Nuclear Power Plants

- **Uranium Corporation of India Limited (UCIL) was established in 1967 at Jaduguda (Bihar)**
  responsible for processing of Uranium from Uranium Mines

- **Nuclear Fuel Complex (NFC) was established in 1967 at Hyderabad**
  make the core components of the Nuclear Reactor, fuel rods, control rods etc

- **Nuclear Power Corporation of India Limited (NPCIL) was established in 1987 , headquarters at Mumbai**
  responsible for design, construction, commissioning and operation of nuclear power reactors

- **Atomic Energy Regulatory Board (AERB) was established in 1983 at Mumbai**
  Licensing and detail scrutiny of the safety of Nuclear Power Plants

Nuclear reactors in India : Power Reactors

22 nuclear power reactors are operational

BWR (Boiling Water Reactor)

Tarapur Atomic Power Station (TAPS) 2 UNITS

PHWR (Pressurised Heavy Water Reactor)

Rajasthan Atomic Power Station (RAPS) 6 UNITS

Madras Atomic Power Station (MAPS) 2 UNITS

Narora Atomic Power Station (NAPS) 2 UNITS

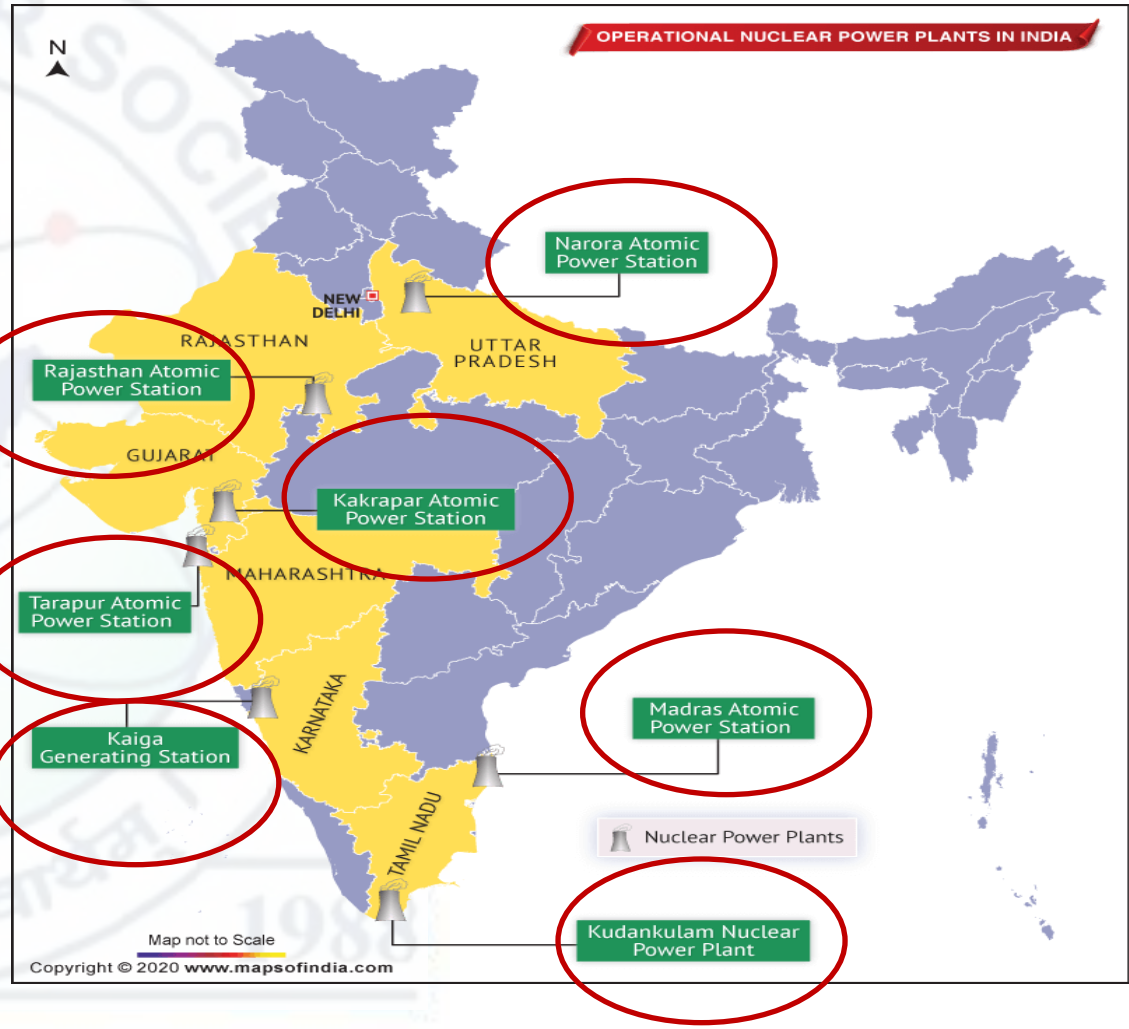
Kakrapara Atomic Power Station (KAPS) 2 UNITS

Tarapur Atomic Power Station (TAPS) 2 UNITS

Kaiga Atomic Power Station (KGS)) 4 UNITS

PWR (Pressurised Water Reactor)

VVER, Kudankulam 2 UNITS

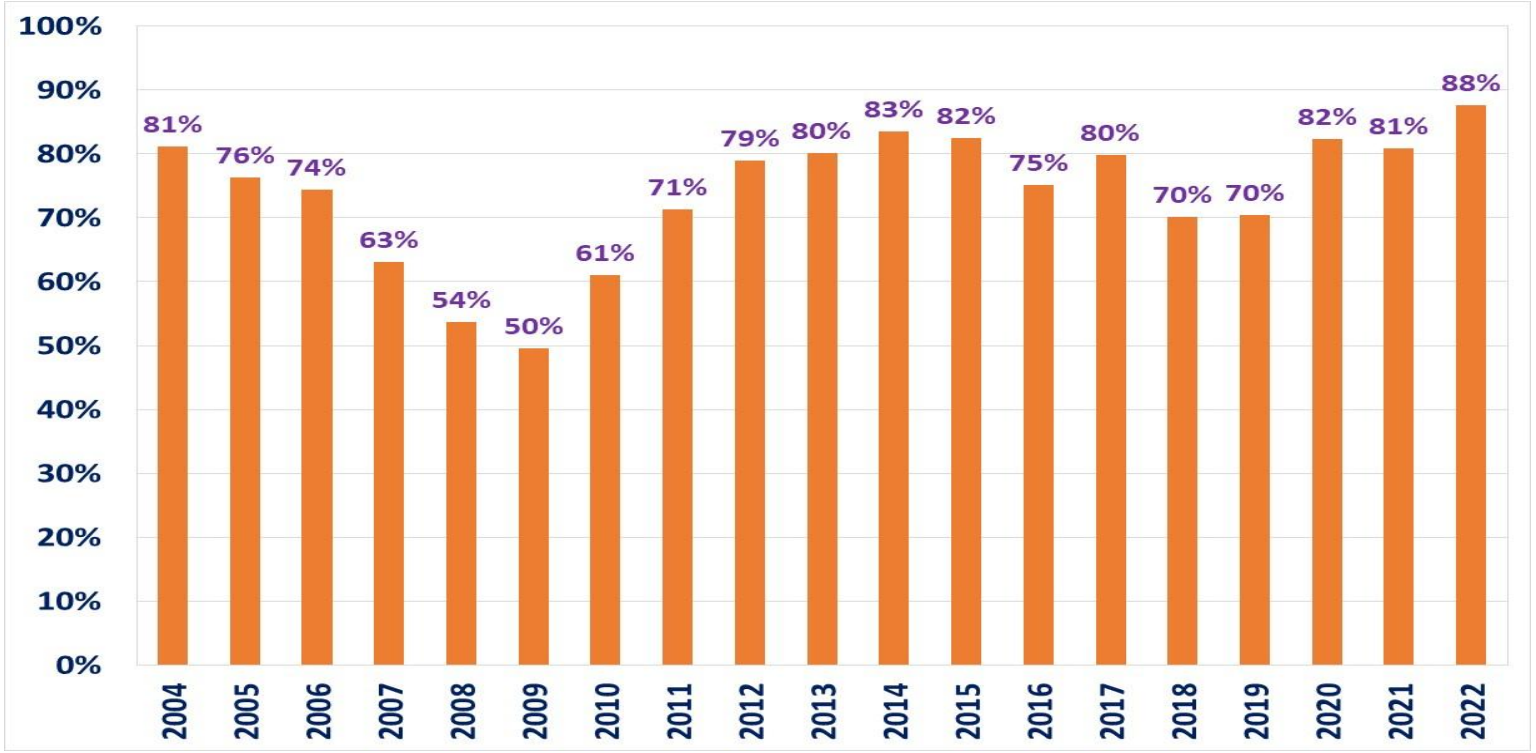


Total installed capacity – 6780 MWe

NARORA ATOMIC POWER STATION

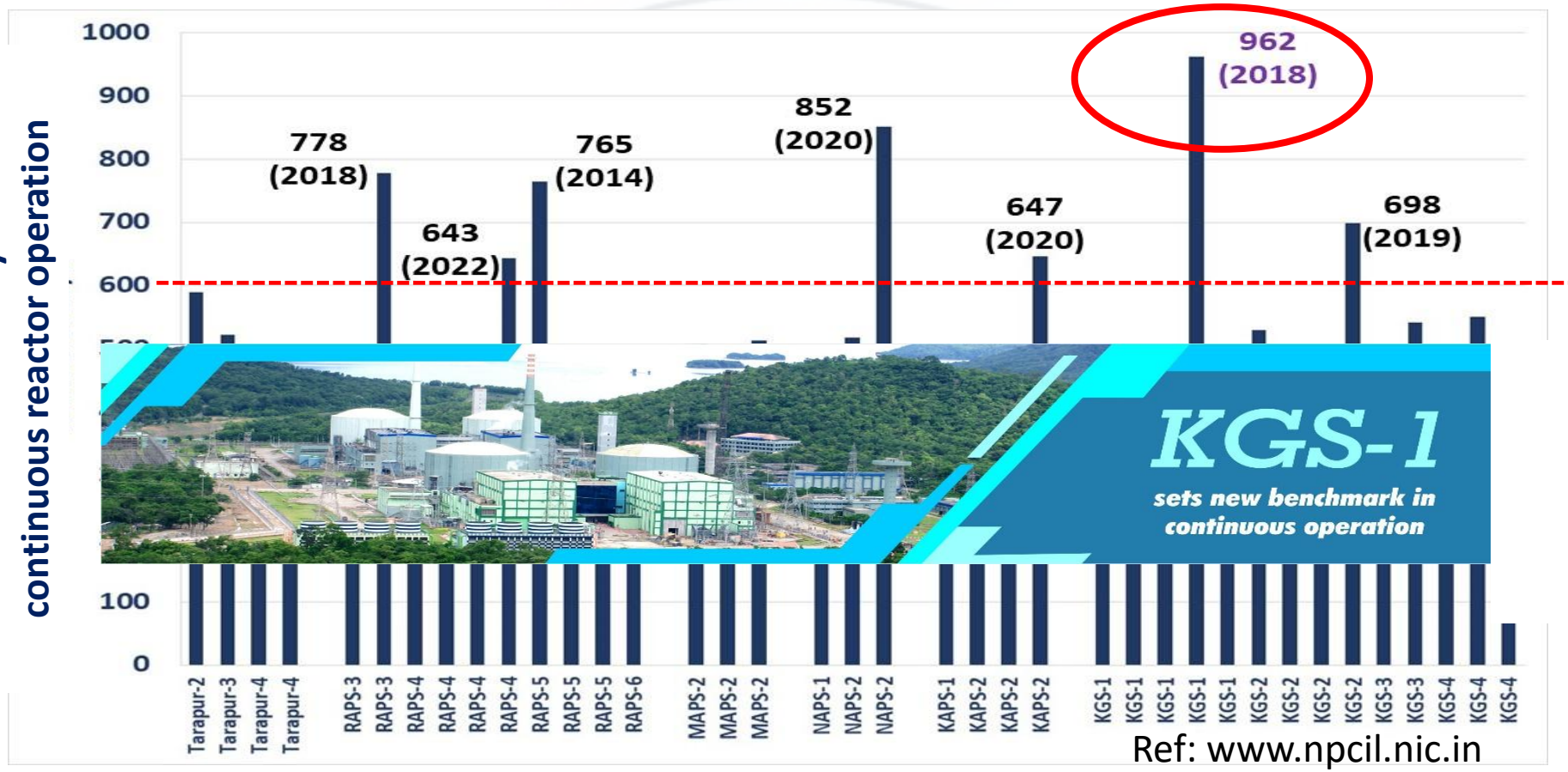
Landmark Achievements of INDIAN NUCLEAR POWER PLANTS

Completion of 52 years of operation of TAPS 1 & 2, oldest reactors in operation in the world



Capacity factor has improved significantly over last decade indicating consistent performance of Indian nuclear power plants

Landmark Achievements of INDIAN NUCLEAR POWER PLANTS



> 600 days (7 times)

962 days continuous operation

Ref: www.npcil.nic.in

Excellent performance with a world record at Kaiga site (Karnataka) for second longest continuous operation of a nuclear plant

Nuclear reactors in India : Research Reactors

- BARC houses Research Reactors in TROMBAY campus

- **Applications :**

Production of radioisotopes (atoms which emit radiation)

Radioisotopes are used in Agriculture, Food Technology Nuclear Medicine, Cancer diagnostics and treatment

Source of neutrons - Material testing and for scientific research

DHRUVA

Tank type Research Reactor

It produces 100 Mth Reactor Power

Heavy water is used as Moderator and Coolant

Cadmium is used as Control Rods

Applications

Sodium iodide and diagnostic capsules

Ingots of silicon ready for neutron transmutation doping used in Electronic industry including electric cars

KAMINI

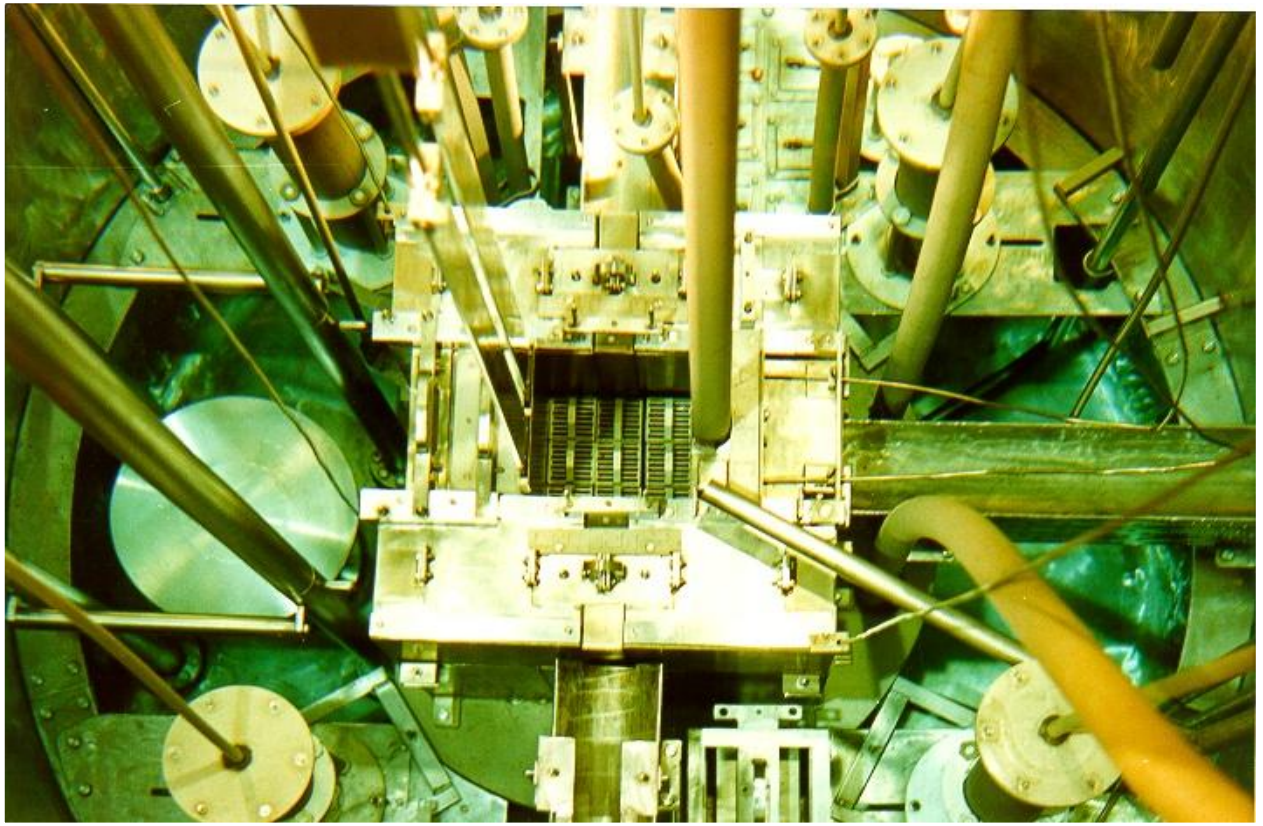
Tank Type Research Reactor

It produces 30 KWth Reactor Power

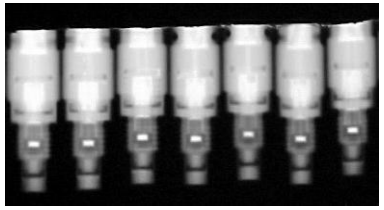
Only reactor in the world operating with **U-233** fuel which is produced from **Thorium**

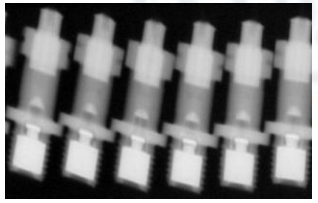
Light water is used as Moderator and Coolant

Cadmium is used as Control Rods



Applications





Neutron radiography of space components

Chandrayaan (Indian lunar probe) mission critical devices were successfully inspected at KAMINI

APSARA – U

Swimming Pool Type Research Reactor

It produces 2 MWth Reactor Power

Heavy water is used as Moderator

Light water is used as Coolant

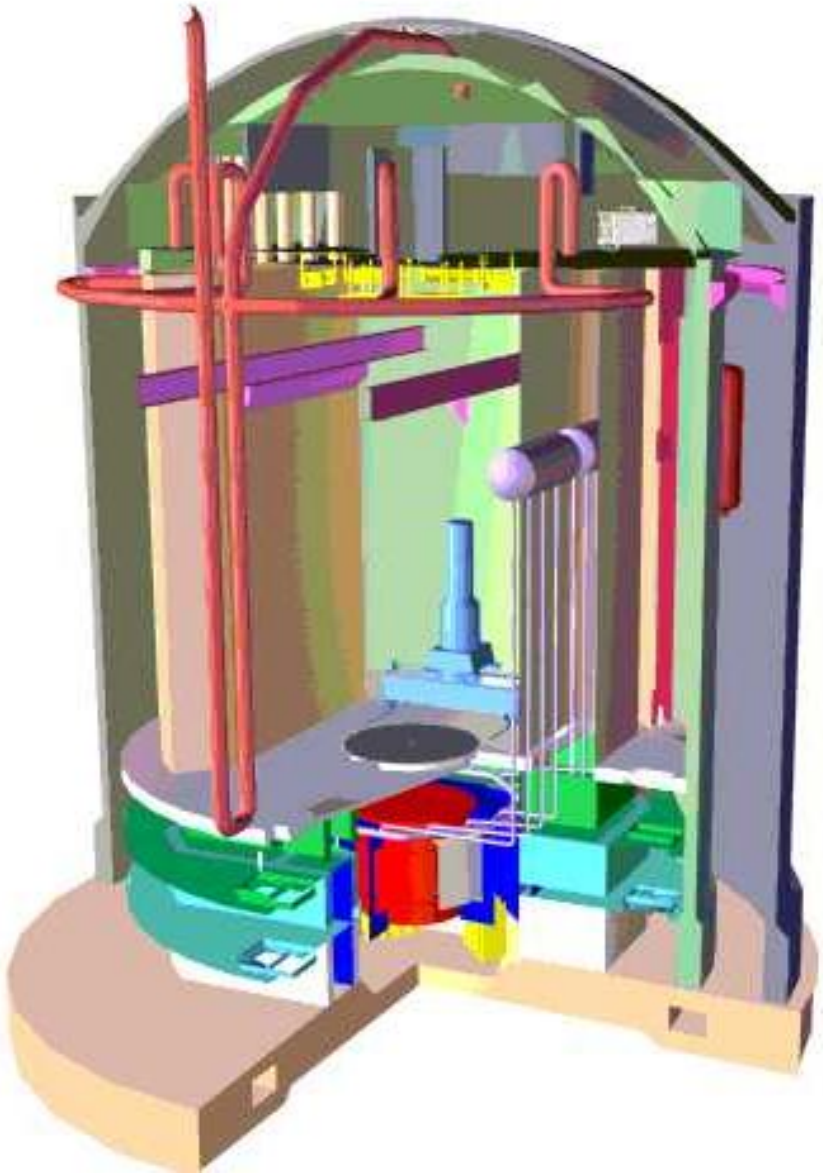
Hafnium is used as Control Rods

Achieved criticality in 2019 !!

The reactor will be used for research in Nuclear Physics, material science and radiation shielding

Advanced Reactors

Advanced Heavy Water Reactor (AHWR)



- The advanced heavy-water reactor (AHWR) is the latest Indian design for a next-generation nuclear reactor that burns thorium in its fuel core
- Thorium converts into nuclear fuel through nuclear reactions and its energy potential is three times that of uranium
- India has one of the largest reserves of thorium coastal beach placer sands in parts of Kerala, Tamil Nadu, Odisha, Andhra Pradesh, Maharashtra and Gujarat
- The utilization of thorium in power reactors presents an important long-term option for India

Prototype Fast Breeder Reactor

- Maximize the benefit of nuclear energy
- Provide a long term energy supply

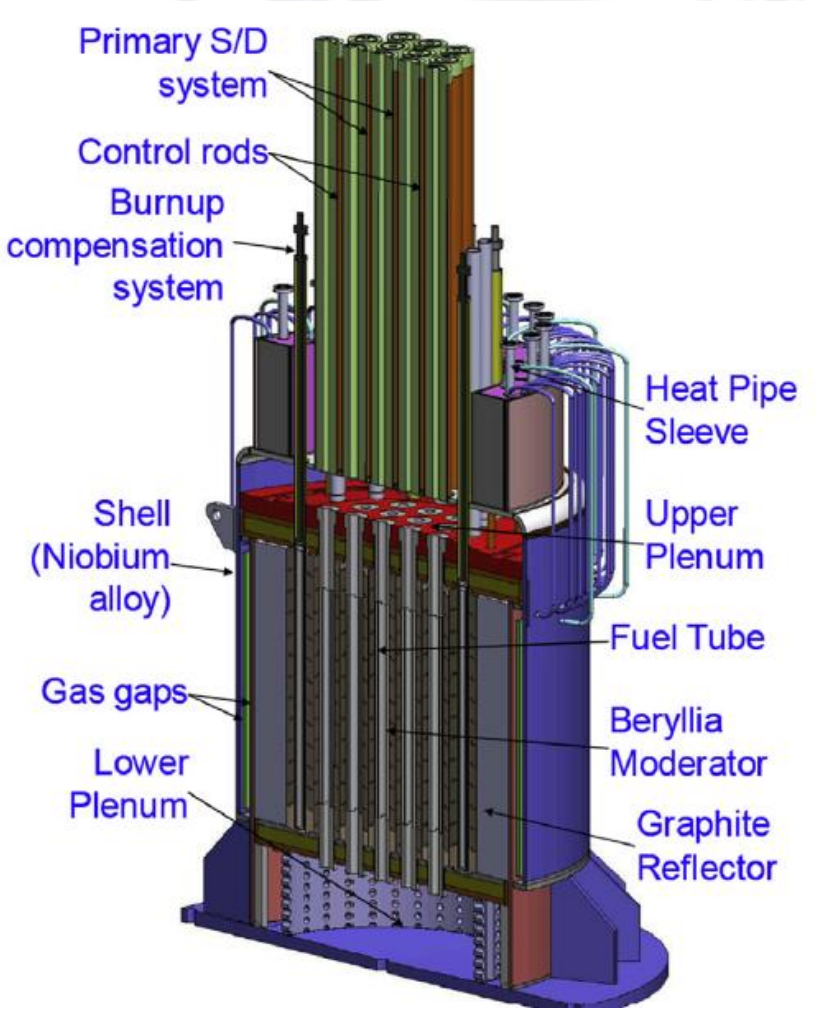
Prototype Fast Breeder Reactor

are designed which can produce **fuel along with the Electricity Generation**

BREEDER REACTOR!!!

Reactor for H_2 Production

Development of High Efficiency processes of Hydrogen Production by splitting water



CONCLUSION

Nuclear power generation has come a long way from the pioneering efforts of Enrico Fermi eight decades ago

From the most basic experimental reactors, we have reached great heights in meeting our power requirements through technologically advanced reactors

These reactors are not only highly power generation intensive but also economical and safe

The Indian nuclear power program has seen thousands and thousands of hours of safe and reliable operation

The high levels of design, conservatism and adherence to "Defense in Depth Criteria" ensure that

NUCLEAR POWER is the way for our FUTURE !!!

Thank you

indiannuclearsociety@gmail.com

आज़ादी का अमृत महोत्सव

TECHNOLOGIES FOR NEW INDIA@75