

Perspectives on Generation IV Reactors

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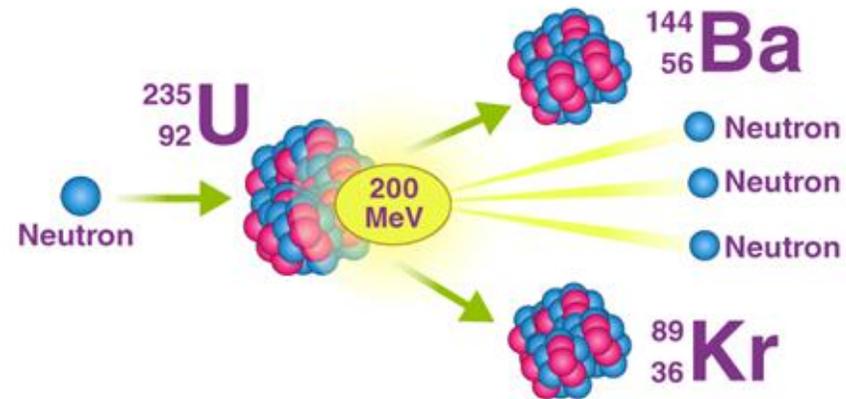
Nuclear History – Radioactivity Discovered

- In 1896, Henri Becquerel discovered that when uranium salts were wrapped in black paper in a dark location they caused blackening of photographic plates. He concluded that the uranium salts were emitting some type of invisible radiation.
- In 1898, Marie and Pierre Curie discovered two additional elements that emitted radiation. These were polonium and radium
- In 1902, Ernest Rutherford and Frederick Soddy determined that the emanation of radioactivity evolved over time in an exponential fashion. From measuring the heat generated by the radioactive decay they calculated the enormous energy available in the nucleus
- In 1913, H. G. Wells wrote, “The World Set Free” He anticipated the development of atomic energy in 1933 and of atomic weapons in 1956

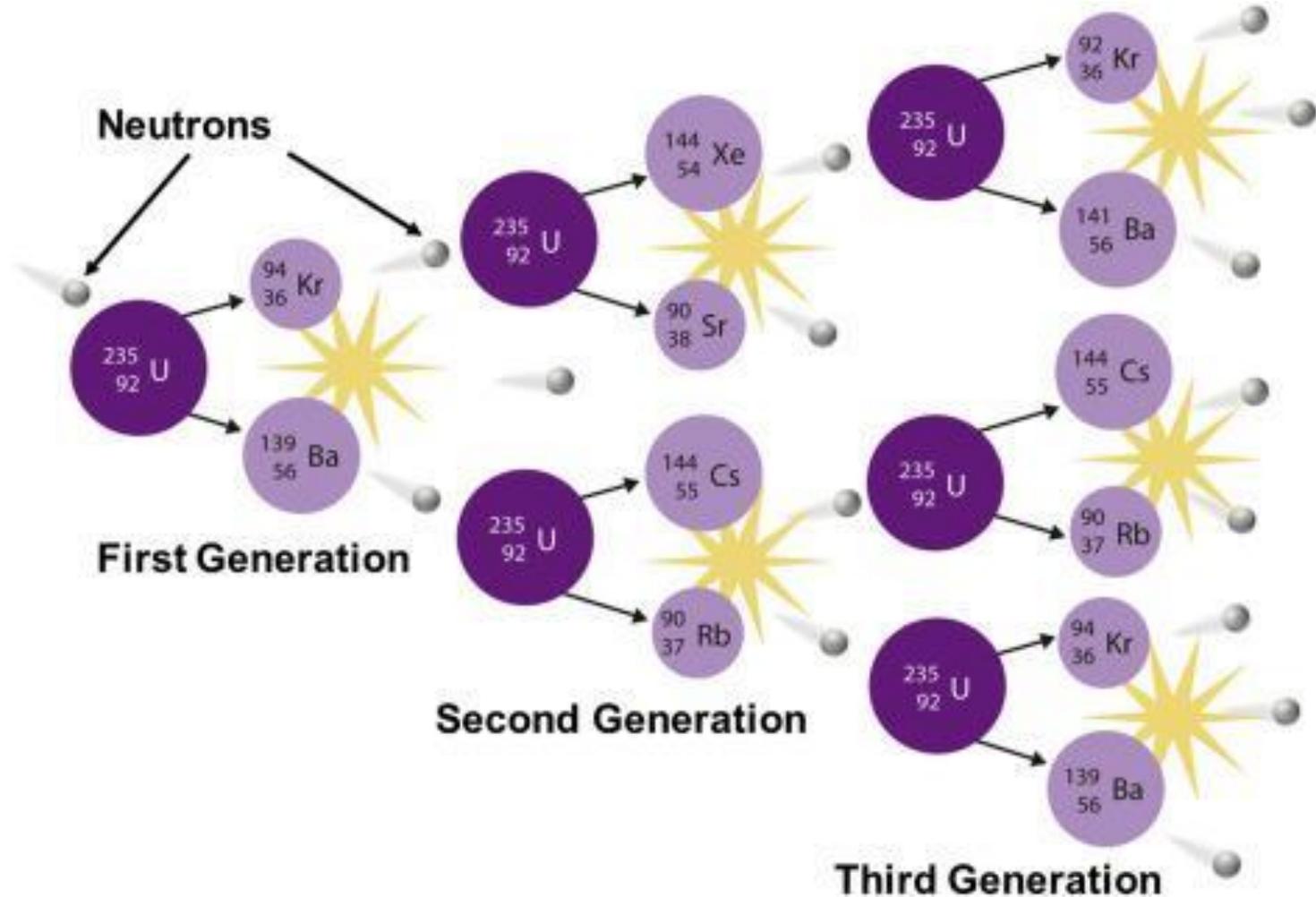
Fission Reaction

NUCLEAR FISSION

BYJU'S
The Learning App



Fission Reaction



First Reactor – Fermi- December 2, 1942



Nautilus Launch 15 January 1955



CIVILIAN NUCLEAR POWER -1

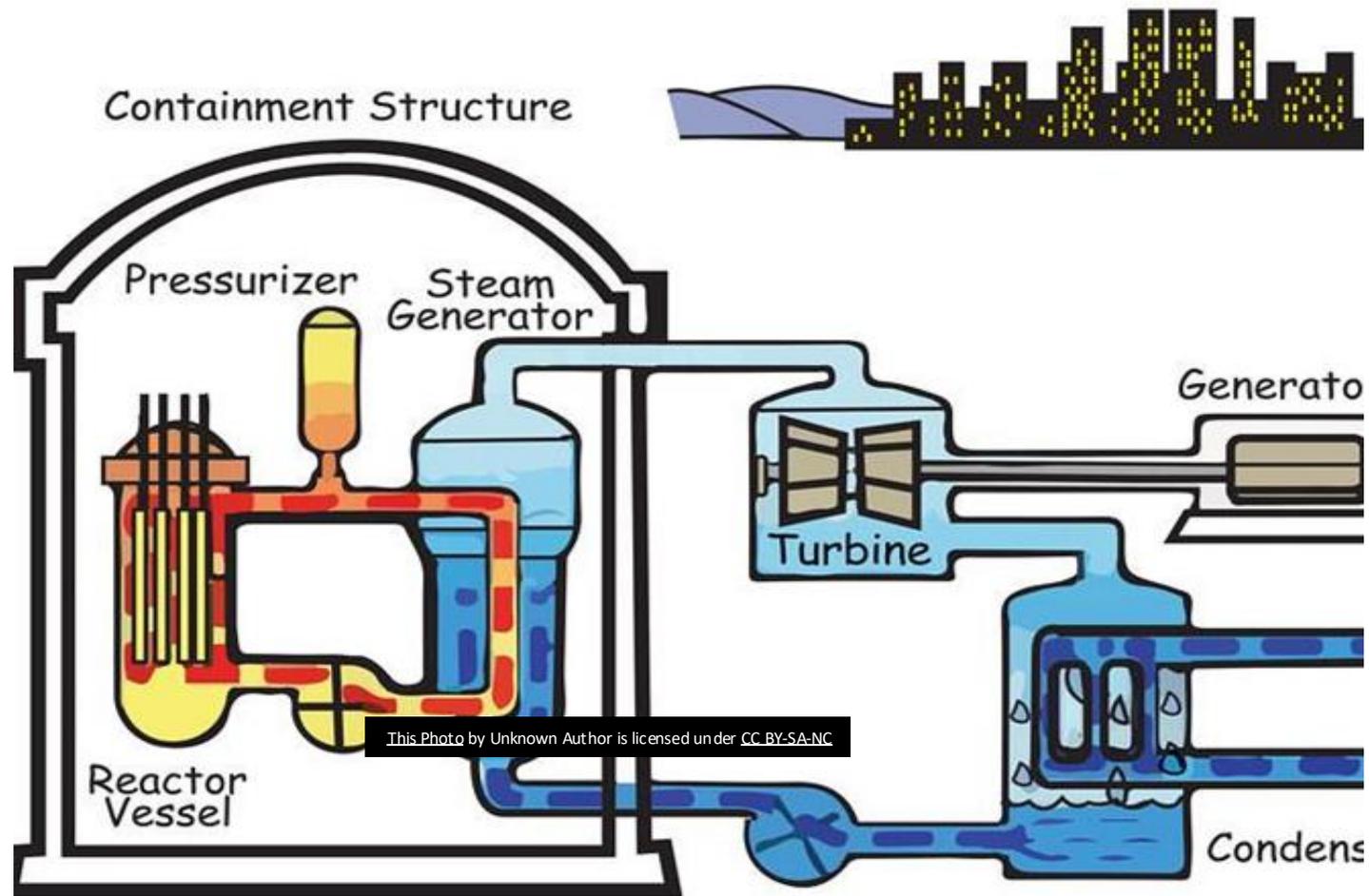
The World's First Nuclear Power Station was the OBNINSK NUCLEAR POWER PLANT in the Soviet Union which started on June 27, 1954. It generated only 5 Megawatts electric.

The second was a gas cooled reactor at CALDER HALL in the UK which opened in October 1956. It consisted of 4 60 Megawatt electric units.

CIVILIAN NUCLEAR POWER – 2

In the United States, the decision was made to develop nuclear energy in the private sector. Since all nuclear work had been done in secret in government laboratories, Admiral Rickover needed to kickstart activities in the private sector. He transferred a 60 Megawatt electric reactor that had been built for an aircraft carrier, but not installed, to use at a power plant in Shippingport, Pennsylvania which reached criticality on December 18, 1957. This reactor used 93% enriched uranium.

The Pressurized-Water Reactor



Pressurized water reactor

Reactor Construction History

- Most nuclear reactors were constructed in the 1960s, 1970s, and 1980s.
- Most of the U.S. nuclear generating capacity came online between 1970 and 1990.
- Currently there are about 440 operating nuclear reactors in the world and about 70 being built.

The Three Major Accidents

Three Mile Island - March 28, 1979

Came close to having a hydrogen explosion

Chernobyl - April 26, 1986

Steam explosion and hydrogen explosion

Fukushima - March 11, 2011

Multiple hydrogen explosions

Following Reactor Construction Hiatus 1986 - 2000

- Generation IV International Forum Established - January 2000
International Collaboration to develop safe, economical reactors.

Nine Countries – United States, Argentina, Brazil, Canada, France, Japan, the Republic of Korea, the Republic of South Africa, and the United Kingdom

Joining this group subsequently were five additional members – Switzerland, Euratom, China, Russia and Australia

Now based in Nuclear Energy Agency of the Organization of Economic Cooperation and Development (OECD) in Paris with more than 30 members.

Generation IV International Forum - History

- In first two years 100 experts evaluated 130 design concepts against four overarching goals:
 1. Sustainability
 2. Economics
 3. Safety
 4. Proliferation Resistance
- Six designs were identified with four being actively pursued.
- Some initiatives pursued jointly and some independently.
- GIF maintained a Technology Roadmap taking into account both government programs and private developers.
- Sodium cooled fast reactor gained most attention with activity in the U.S., Russia, France and Japan.
- GIF has shaped agenda, shared knowledge, aligned standards, and maintained international focus on decarbonization.

Generation IV Nuclear Reactors International Initiative - Guidelines - 2001

- A fail-safe technology
- No need for pressure containment to keep water from boiling
- Easily manageable waste—no deaths from waste in past or anticipated
- Bomb grade plutonium and toxic waste used as low-cost fuel
- Modular construction in factories reduces cost of fabrication
- No danger of steam explosions
- No danger of hydrogen gas explosions
- Problems of weapons proliferation avoided

Four Most Active Designs of Gen IV Forum

- Sodium Cooled **Fast Reactor** – History of Integral Fast Reactor at Argonne National Laboratory – operational 1986 – closed 1994.
- Gas Cooled Reactor – History of Calder Hall – 1956-2003
- Lead Cooled **Fast Reactor**
- Molten Salt Cooled Reactor – History at Oak Ridge – 1950-1976

Fast Reactors: Sodium Cooled and Lead Cooled Reactors do not use a moderator. They require more highly enriched uranium-235, typically around 20%. The fast neutrons can also cause fission in uranium-238 as well as be absorbed by uranium-238 to create plutonium-239 which is also fissionable. With significant production of plutonium-239 the reactor can produce more fuel than it uses and is thus designated as a Breeder Reactor.

Current Status

More than 50 companies world-wide developing new nuclear reactor designs

*Bill Gates Company TerraPower is building Natrium, a liquid sodium cooled reactor in Wyoming. Has potential to replace dozens of coal fired power plants, keeping electricity producing and distributing infrastructure in place.

*Kairos Power is building a Fluoride Salt cooled reactor in Oak Ridge, Tennessee

*China and Russia are pursuing lead-bismuth cooled reactors

*China built the first helium cooled reactor in 2023

Recent Developments – February 2026

- China began construction of the Xuwei nuclear energy complex to provide power for petrochemical manufacturing that incorporates a helium cooled Generation IV reactor. With these power plants that can operate at 1000 degree Celsius, 11% of the world's greenhouse gases can be eliminated. Solar and wind are unable to achieve this temperature.
- Such reactors have the potential of producing economical hydrogen that can be used at even higher temperatures to process steel and concrete which today each account for about 8% of the world's greenhouse gases.

New Initiatives

- In October of 2025, the US Department of Energy entered into a program to provide up to \$80 billion to Westinghouse for construction of 8 1000 Megawatt electric pressurized water reactors.
- China built 37 reactors during the past decade while the US built 2! With a 6.3 year construction time - compared with 9.4 year average
- Currently 32 reactors are under construction in China.
- France has a program in which French engineers regain nuclear savvy through immersion in Chinese construction programs. One wonders if Westinghouse should be engaging in a similar initiative.

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