Nuclear Energy

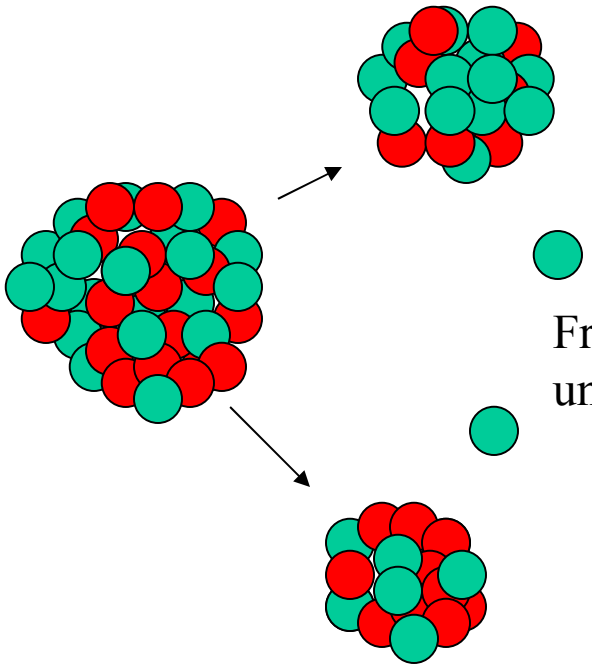
Robert Oppenheimer and Gen. Leslie Groves examine the Trinity test site after the successful detonation of the first nuclear warhead in New Mexico.

- History
  - Discovery
  - Role in WWII
  - Nuclear Power Generation
  - Nuclear proliferation in the Cold War
- Fission
  - Physics
  - Power
- Fusion
  - Physics
  - Power (future)
- Waste
- Fear

The History of Events leading up to the Nuclear Age

1896 - Henri Becquerel discovers radiation.
1901 - Max Planck invents quanta to solve the problem of blackbody radiation
1905 - Albert Einstein publishes his special theory of relativity with the famous equation $E = mc^2$
1911 - Ernest Rutherford's atom modal debuts
1915 - Niels Bohr's atom modal debuts
1927 - Erwin Schrödinger and Werner Heisenberg independently discover the fundamental equations of Quantum Mechanics
1930 - P. A. M. Dirac publishes "The Principles of Quantum Mechanics" showing the equivalence of the 2 forms
193? - Otto Hahn and Lise Meitner discover nuclear fission of Uranium
1939 - Albert Einstein writes President Roosevelt that the Nazis are working on an atom bomb and that the US ought to follow suit
1941 - Manhattan Project begins
1945 - The US drops 2 atom bombs on Japan

Nuclear Fission



Freed neutrons react with other unstable Nuclei.

When a large nucleus is bombarded with a neutron, it acts like an unstable drop of water and fissions into daughter nucleons, usually including one or more free neutrons. These neutrons in turn react with other nuclei, causing a chain reaction if enough fissionable heavy nuclei are present. This is the mechanism of the first atomic bombs. However, if a neutron absorber is used, a stable sustainable reaction can result. This is how modern nuclear power plant operate.

Modern Nuclear Reactors

Most modern reactors have a similar design with fuel rods powering the reaction and control rods mediating the reactions by absorbing neutrons.

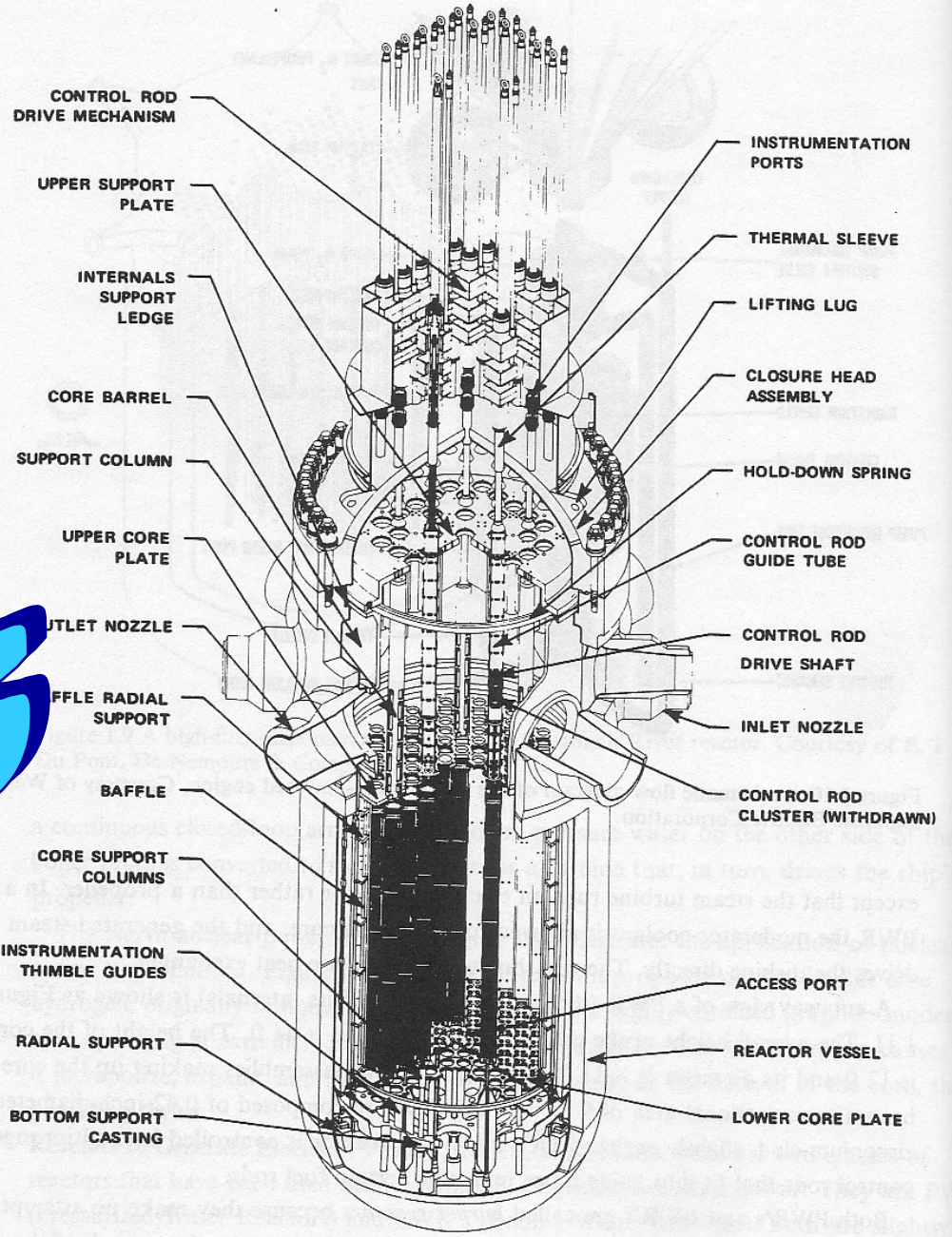


Figure 1.11 Cutaway of a typical pressurized-water reactor. Courtesy of Westinghouse Electric Corporation.

Nuclear Fusion

Stellar Hydrogen Burning: $^{1}H + {}^{1}H \rightarrow {}^{2}H + e^{+} + \nu_e$

$^{2}H + {}^{1}H \rightarrow {}^{3}He + \gamma$

31% → $^{3}He + {}^{4}He \rightarrow {}^{7}Be + \gamma$

69% → $^{3}He + {}^{3}He \rightarrow {}^{4}He + 2\ {}^{1}H$ (PP I)

99.7% → $^{7}Be + e^{-} \rightarrow {}^{7}Li + \nu_e$

$^{7}Li + {}^{1}H \rightarrow 2\,{}^{4}He$ (PP II)

.03% → $^{7}Be + {}^{1}H \rightarrow {}^{8}Be + \gamma$

$^{8}Be \rightarrow {}^{8}Be + e^{+} + \nu_e$

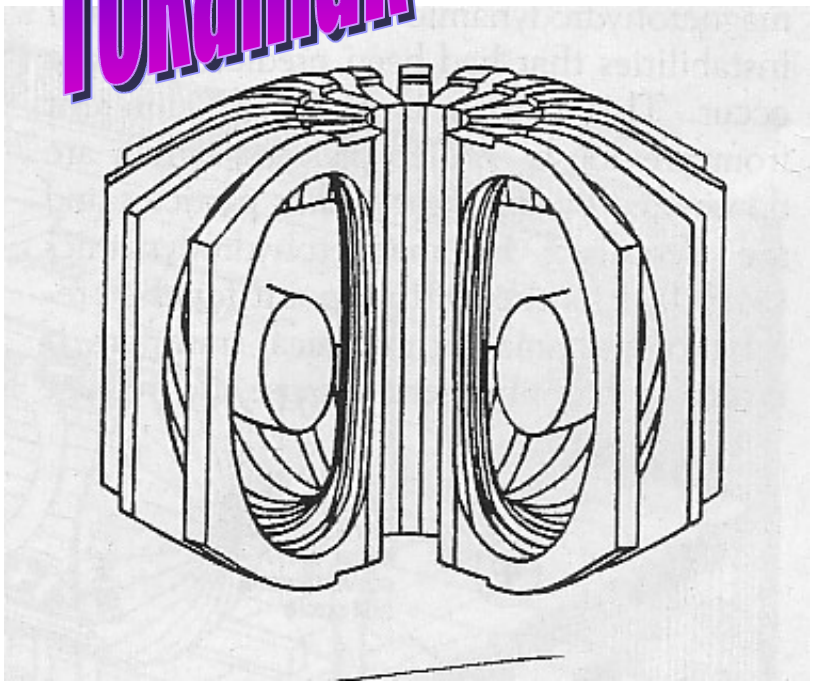
$^{8}Be \rightarrow 2\,{}^{4}He$ (PP III)

- This is the way stars burn hydrogen. On earth we are currently attempting to duplicate it, however, not without some difficulty because of the intense gravitational and magnetic fields present on the sun. Note that He and some γ–radiation are the only byproducts.

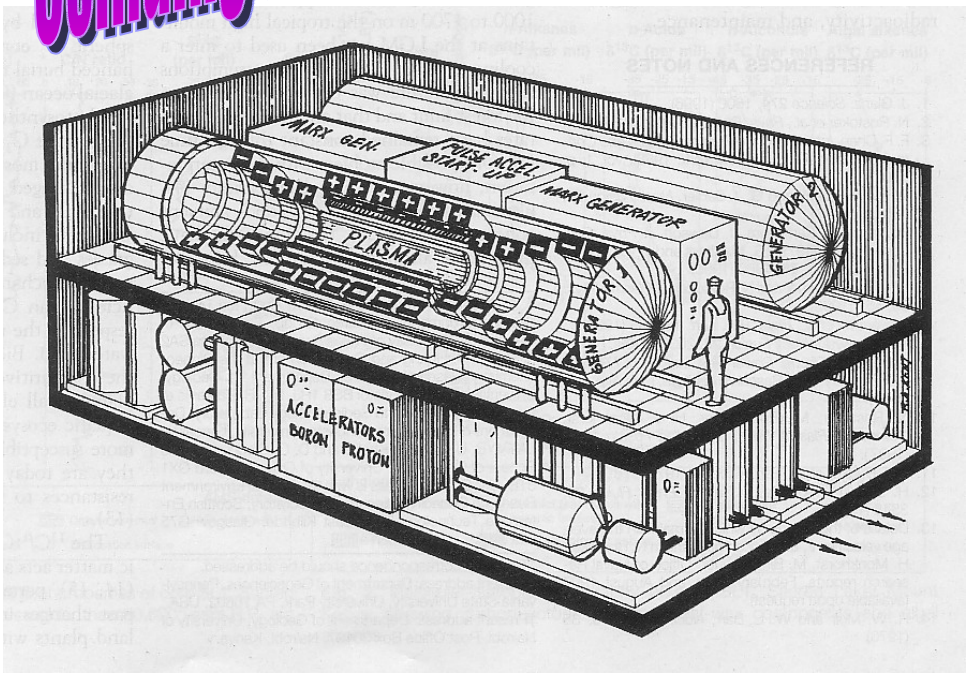
Fusion Reactors

(none have reached break-even yet)

Tokamak



Colliding Beam



Laser

No real good picture for this one, but basically the idea is to take the Hydrogen and put it under intense pressure and heat using lasers.

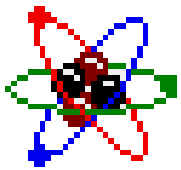
Nuclear Waste

Fission

- Fission facilities produce the waste and are forced to store it onsite
- Most states have laws prohibiting transfer of nuclear waste
- Disarmament also presents wastes in warhead disposal
- Yucca Mountain proposed as national disposal site
  - Geologically stable
  - Remote location
  - Nevada, with a small population, has difficulty fighting it

Fusion

- Fusion, however, produces Helium as it's ash
- Poorly funded in US because of fear and misinformation
- US pulled out of multinational ITER consortium in 1997 effectively killing it
- Promising, but experimental reactors have yet to reach break-even



Fear

- Influence of Cold war on baby-boomers
- Populous still uneducated on the subject
- Chernobyl and Three Mile Island
  - Very different incidents
  - Chernobyl was a complete meltdown
  - At Three Mile Island some containment water leaked
- No new plants in the US in 20 years a result

References

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