THE DEMISE OF THE NUCLEAR POWER INDUSTRY AND THE PROSPECT OF ITS REVIVAL

by D.S.G. Pollock

http://www.le.ac.uk/users/dsgp1/index.html

An account is given of the history of nuclear power generation, its technologies and the prospects of its revival.

It is proposed that a revival of nuclear power generation is the only way in which we can meet the existing and projected demands for energy, if we are not to continue to burn fossil fuels in a way that will lead to disastrous climate change.

The revival of the nuclear industry will depend, in the long run, on the exploitation of technologies that, for historic reasons, have been sidelined. It will also depend on our overcoming the phobias that have been stimulated by nuclear weaponry and which have been exacerbated by nuclear accidents that could have been avoided.

The opening of the Calder Hall nuclear power station on October 17th 1956

The dial showing the nuclear generated electricity being fed into the National Grid

The Atom

The generic atomic nucleus is denoted by

$$ {}^{A}_{Z}K $$

A : the atomic mass = protons + neutrons,

Z : the atomic number = number of protons,

K : the symbol for a chemical element found in the periodic table.

An example is the uranium-235 isotope, denoted by

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

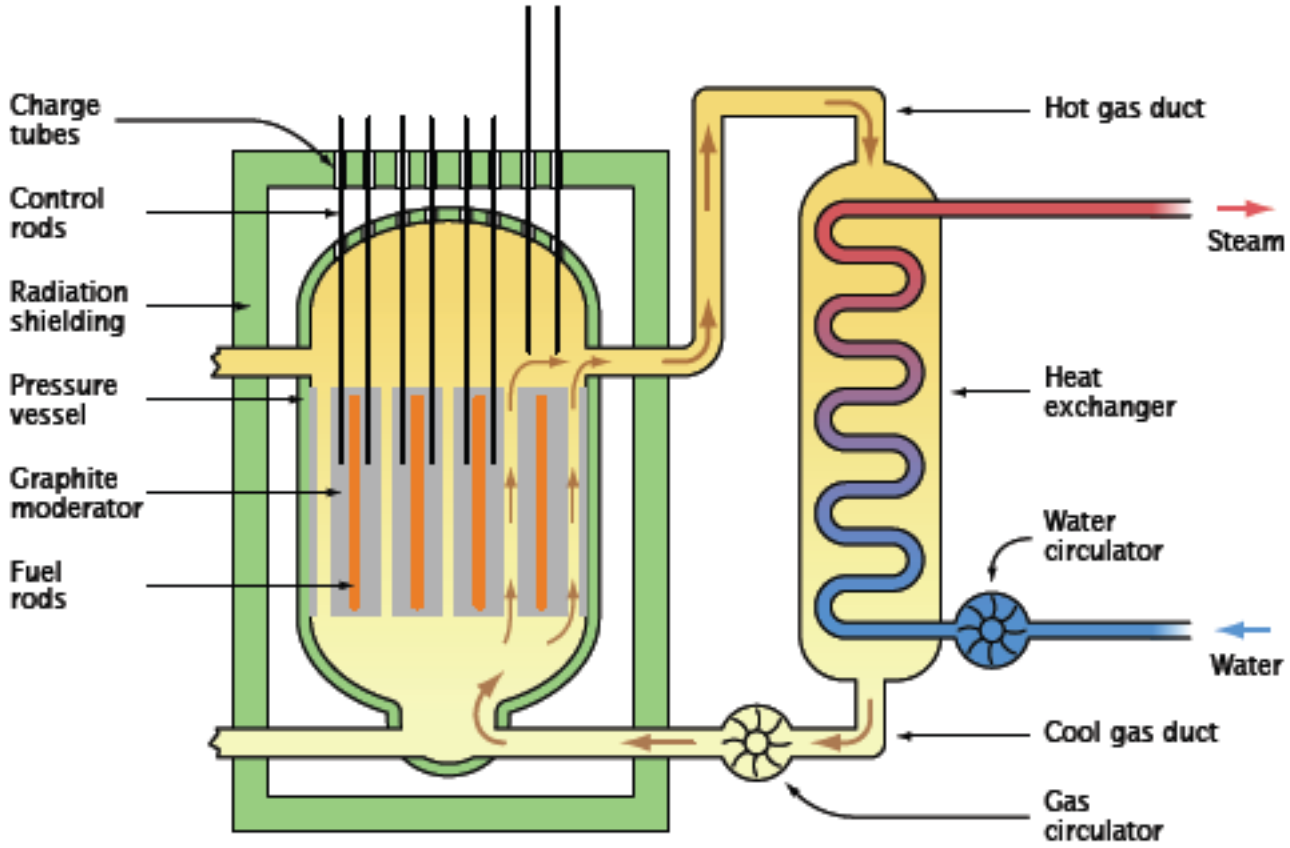
Uranium Fission

Nuclear energy is released when the fission of a heavy nucleus, such as U-235, is induced by the absorption of a neutron.

The fission products, in this case, are typically cesium-140, rubium-93, three neutrons and $200MeV$ (200 million electron volts) of energy:

$$ {}^{1}_{0}n + {}^{235}_{92}U \longrightarrow {}^{140}_{55}Cs + {}^{93}_{37}Rb + 3{}^{1}_{0}n + 200MeV. $$

For comparison, one can note that the combustion of an atom of carbon to produce carbon dioxide generates $10eV$ (10 electron volts) of energy.



A schematic diagram of the Magnox gas-cooled reactor

An arial photograph purporting to be of Calder Hall

The Production of Plutonium

In the process of burning uranium in a conventional reactor, some of the non-fissile U-238, which forms the preponderant mass of the original fuel, will be converted into the fissile Pu-239 plutonium isotope.

The conversion of U-238 to Pu-239, via the intermediate neptunium Np-239 isotope, can be represented as follows:

$$^{238}_{92}U + ^{1}_{0}n \longrightarrow ^{239}_{92}U \xrightarrow{\beta-} ^{239}_{93}Np \xrightarrow{\beta-} ^{239}_{94}Pu.$$

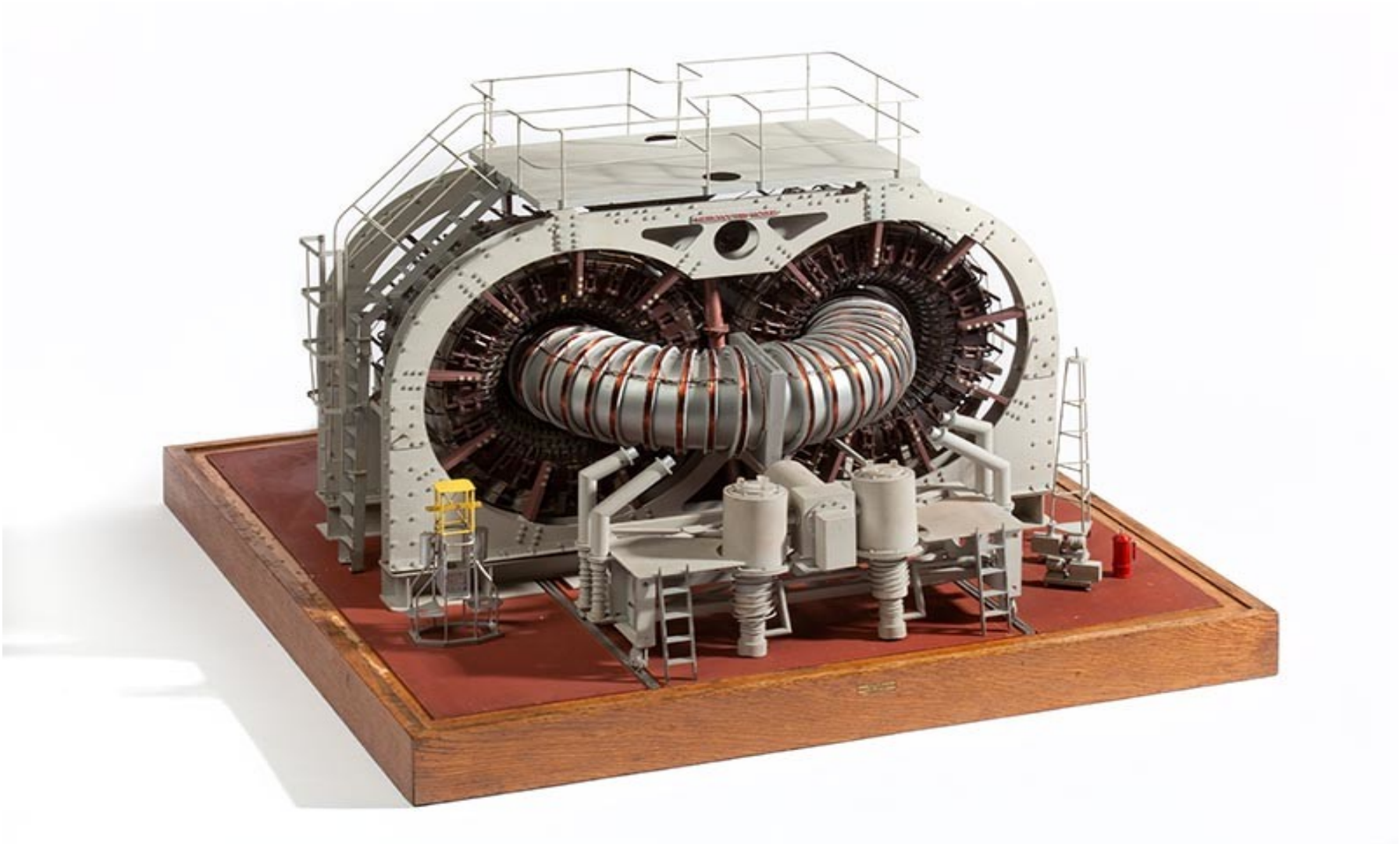
The chimneys at Windscale associated with the plutonium piles

Nuclear Fusion

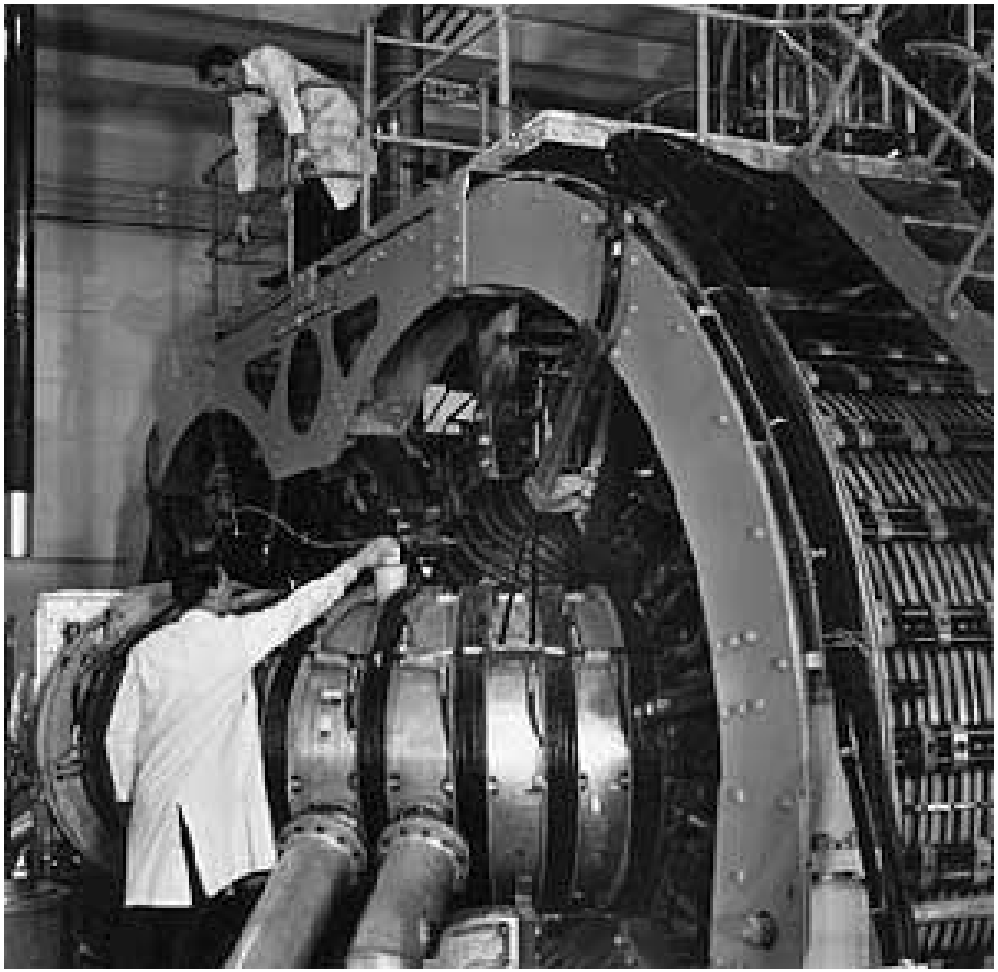
Nuclear energy is released by the fusion of two light nuclei, as when two heavy hydrogen nuclei (deuterium) combine to produce a helium-3 atom and a free neutron and 3.2 MeV of energy:

$$ {}^{2}_{1}H + {}^{2}_{1}H \longrightarrow {}^{3}_{2}He + {}^{1}_{0}n + 3.2MeV. $$

Fusion powers the sun. On earth, it occurs in H-bomb explosions. Controlled fusion has been attempted for almost 50 years without significant success. An early attempt occurred in the U.K. with the ZETA machine.

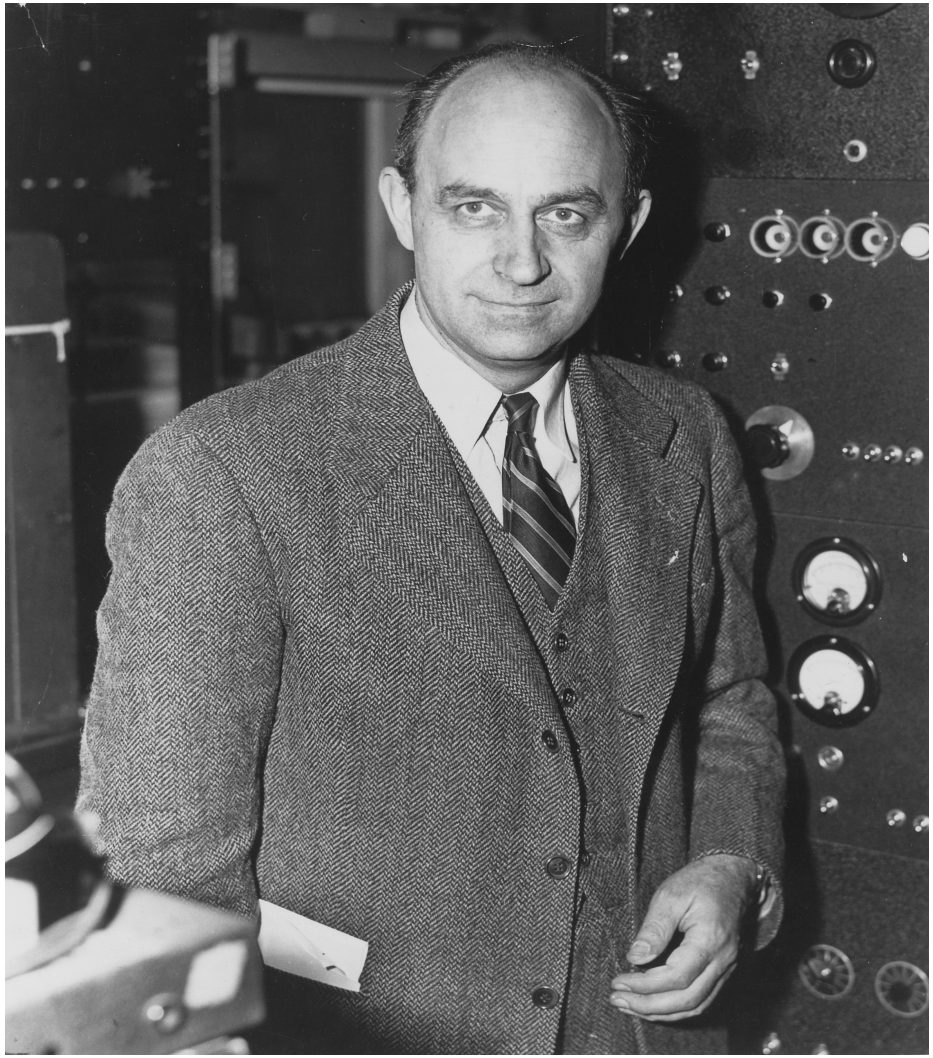


A model of ZETA: Zero Energy Thermonuclear Assembly



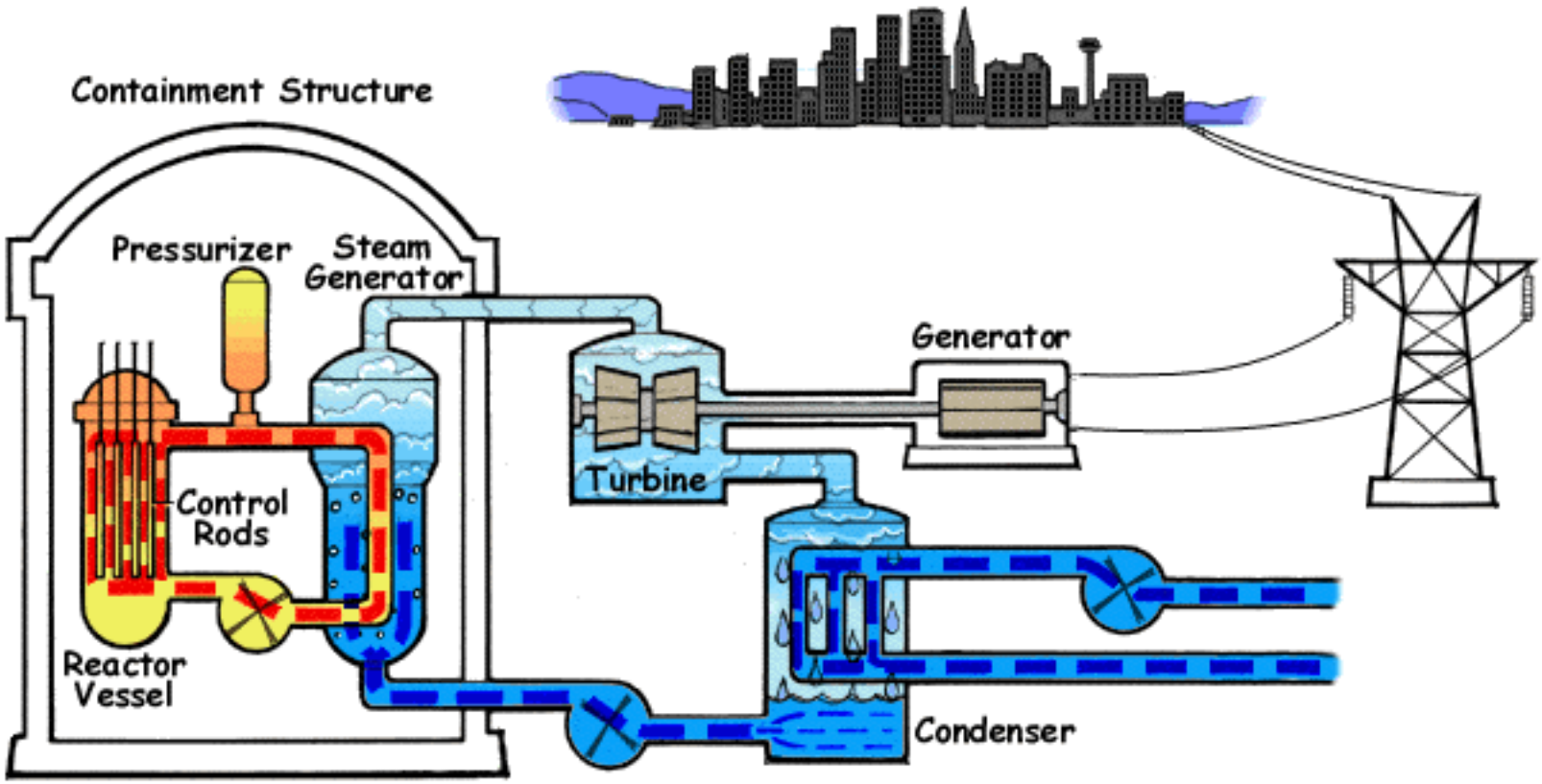
ZETA in reality

JET: Joint Europeans Torus



Enrico Fermi (left) and Hyman Rickover

The Nautilus nuclear submarine, launched in 1954



A schematic diagram of the pressurised light-water reactor

Eugene Wigner (left) and Alvin Weinburg

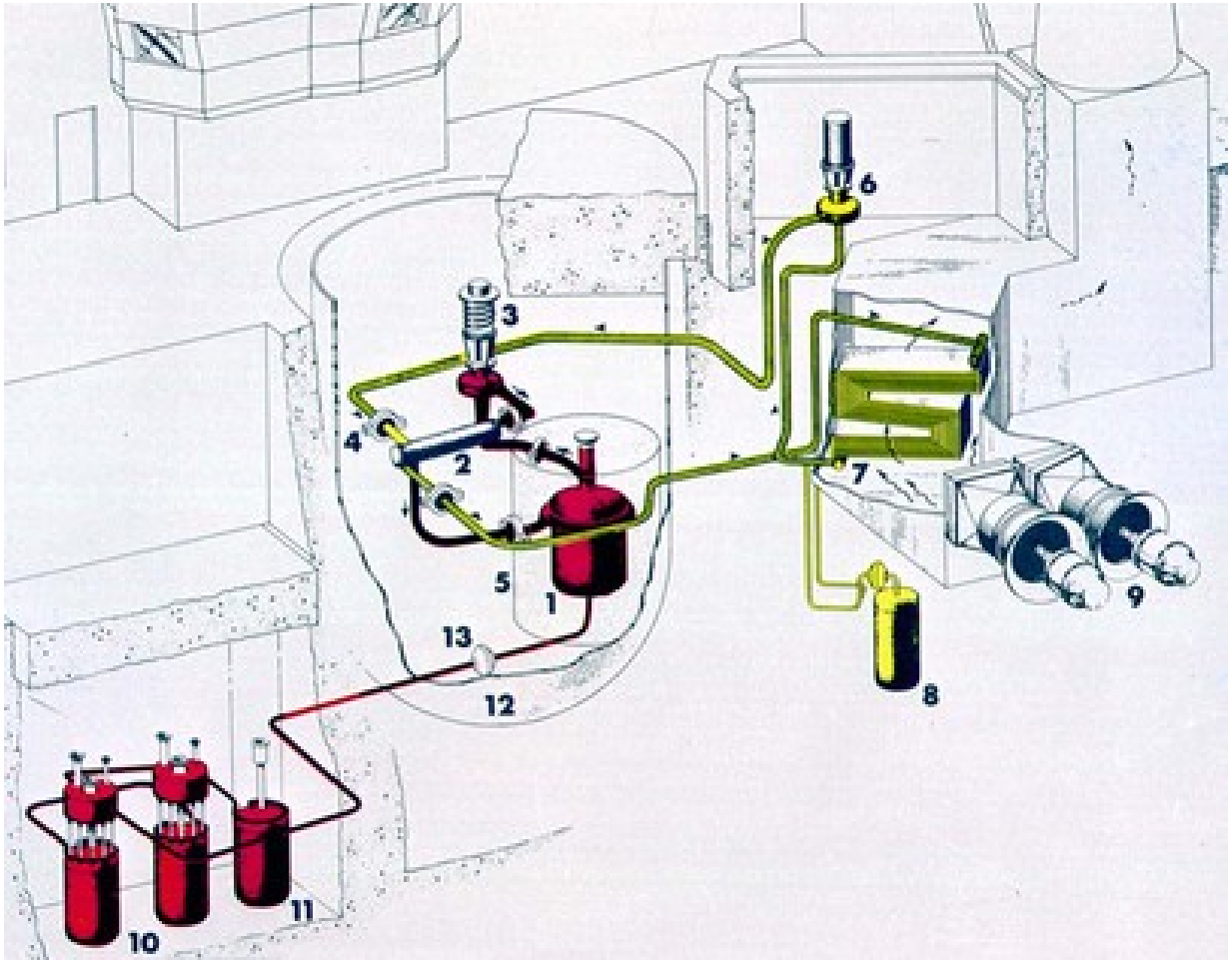
The Thorium Fuel Cycle

In common with Uranium 238, Thorum is described as a fertile material from which fissile material can be bred.

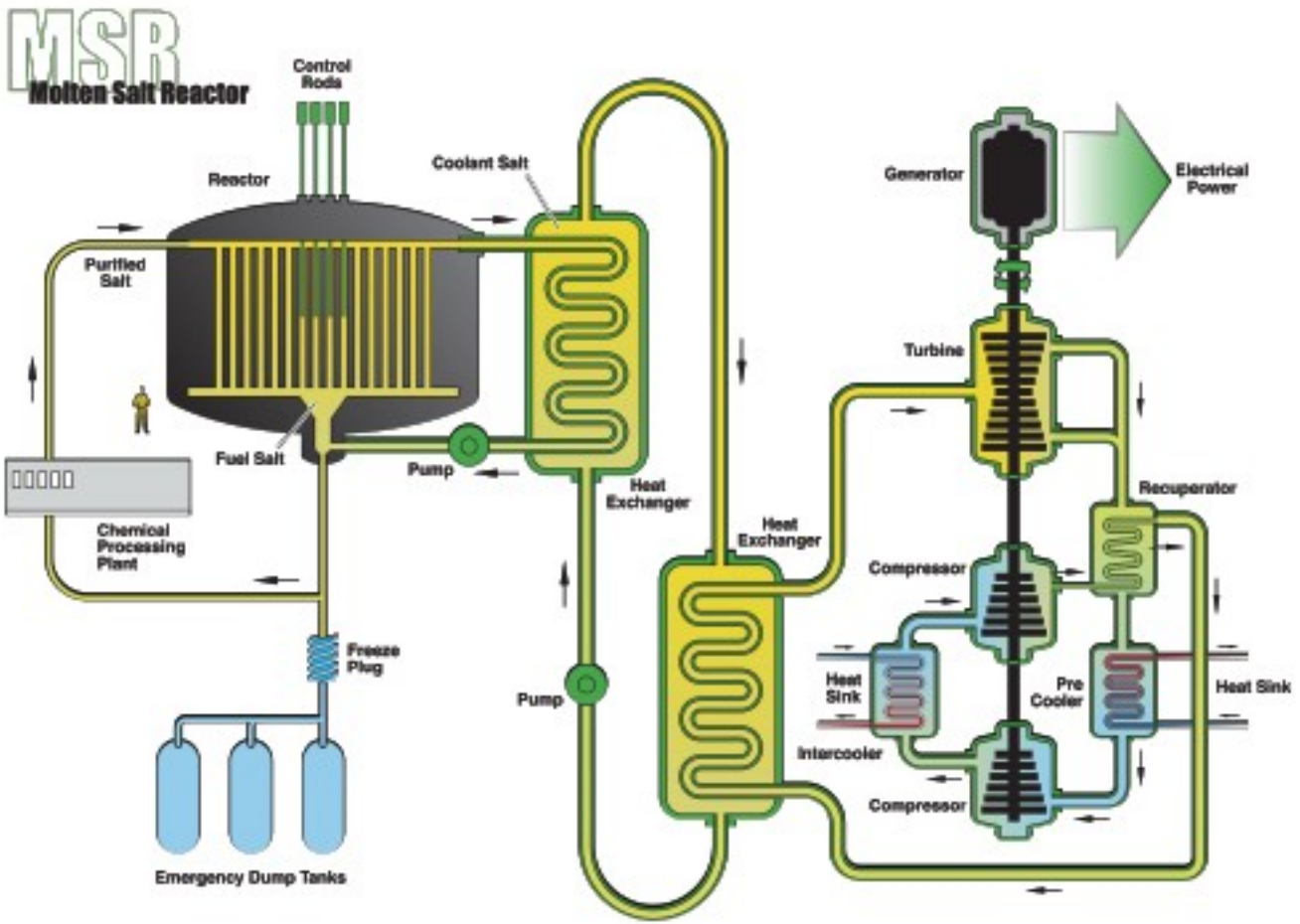
In the thorium cycle, the fissile U-233 isotope is formed when thorium absorbs a nutron and is converted into an isotope that tansmutes into protactinium and thence into the uranium fuel:

$$ {}^{1}_{0}n + {}^{232}_{90}Th \longrightarrow {}^{233}_{90}Th \xrightarrow{\beta-} {}^{233}_{91}Pa \xrightarrow{\beta-} {}^{233}_{92}U. $$

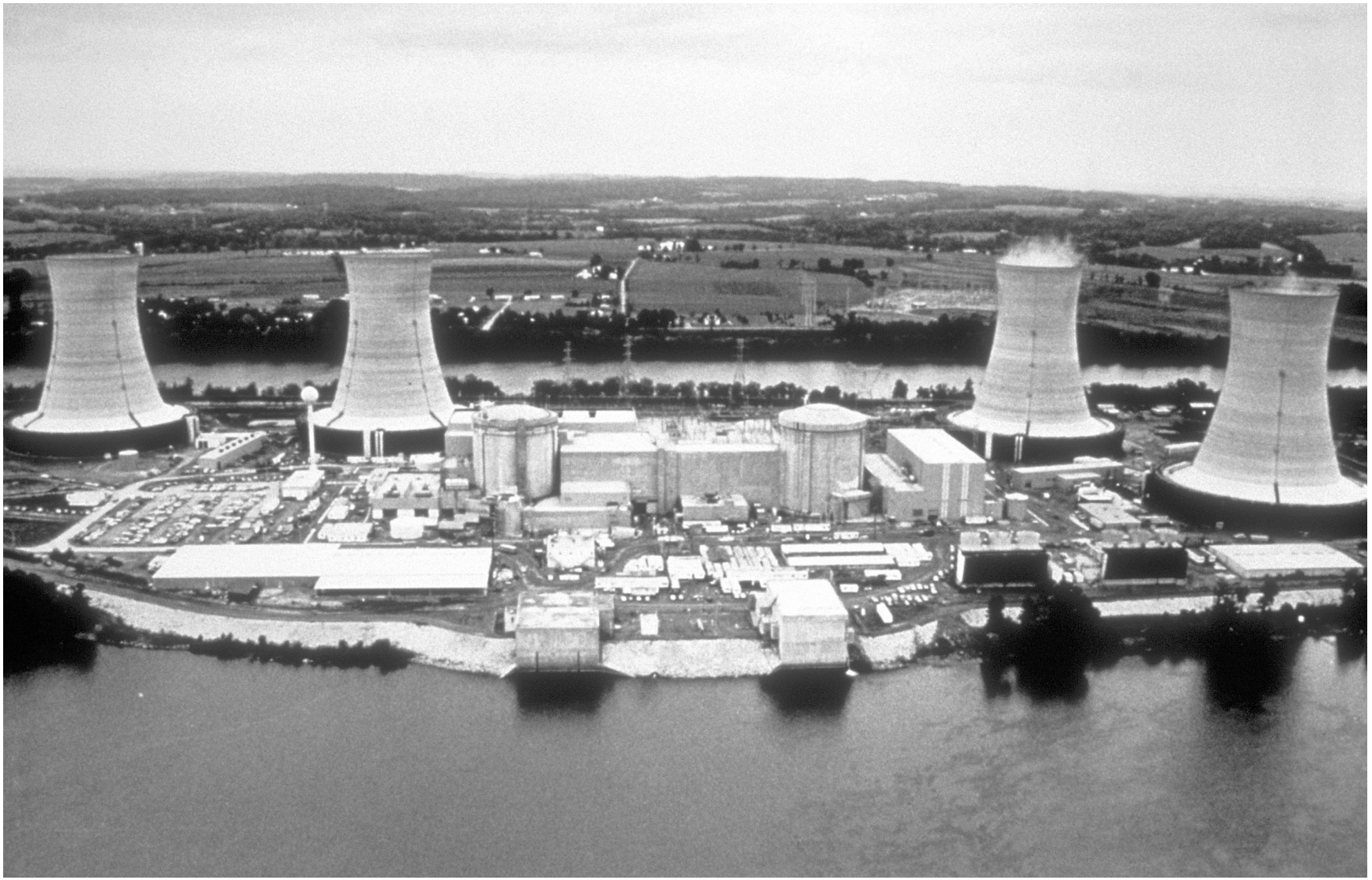
The intensity of the nuclear flux that is required in order to convert Thorium-232 to the fissile Uranium-233 is less than that which is required for the conversion of Uranium-238 to Plutonium.



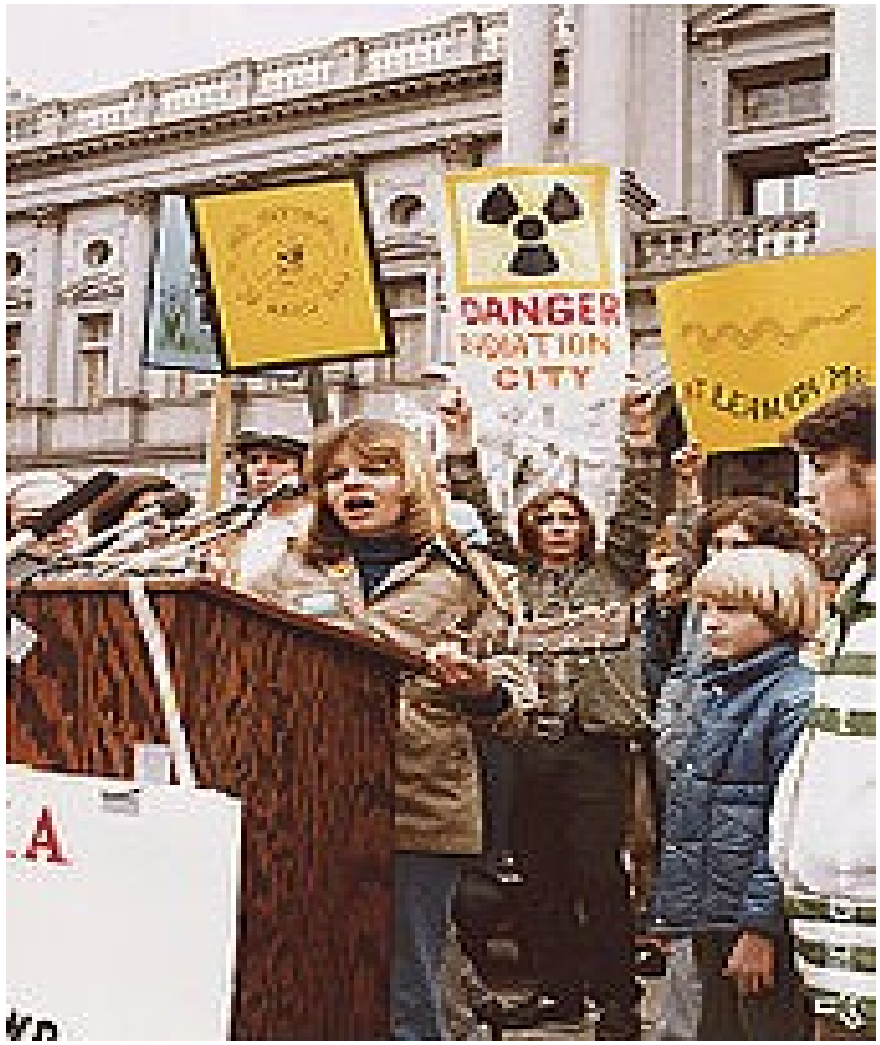
The Molten Salt Reactor at Oak Ridge National Laboratory



A schematic diagram of the molten salt reactor



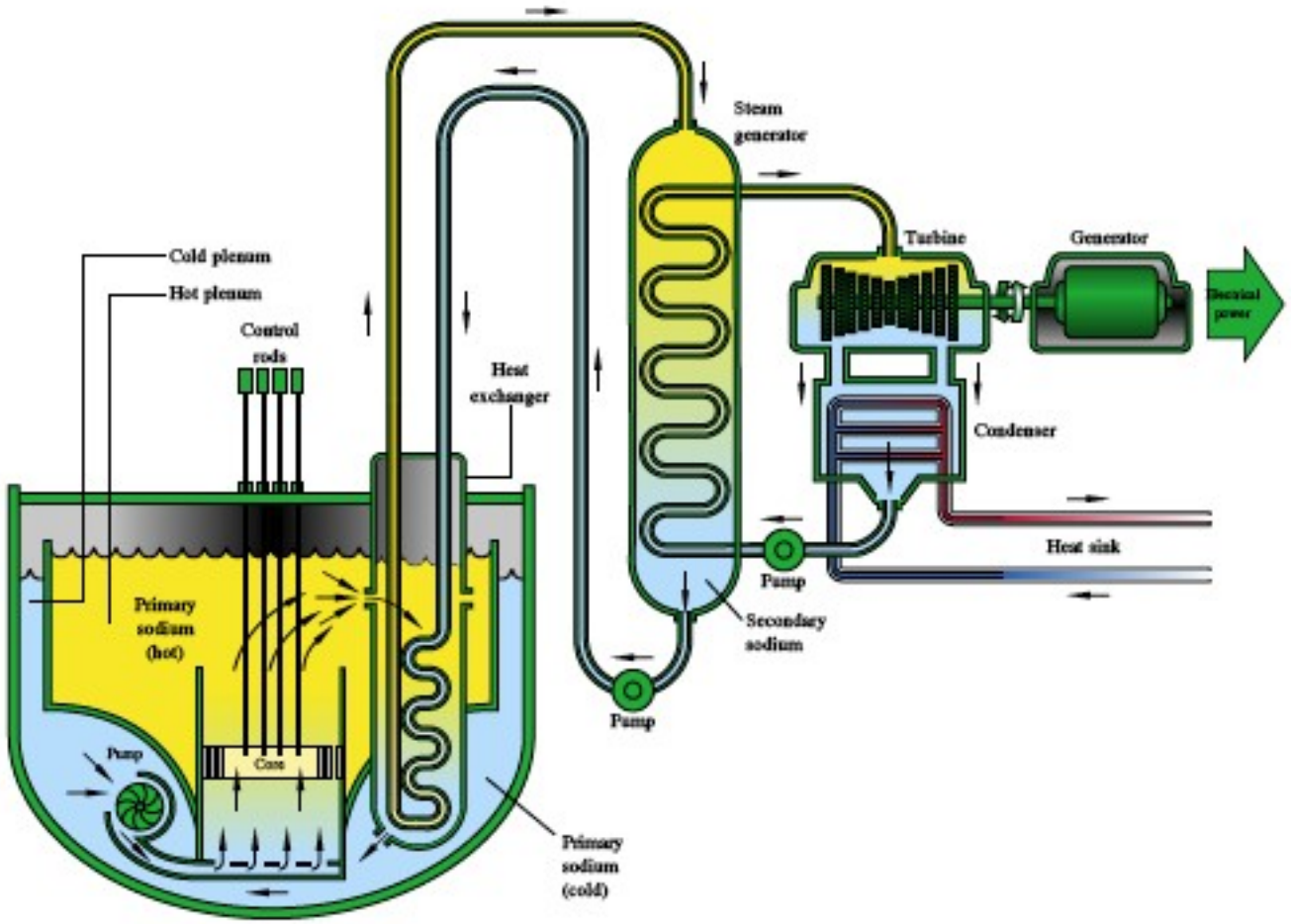
Three Mile Island, the scene of a nuclear accident in 1979



The anti-nuclear protests occasioned by the accident at Three Mile Island

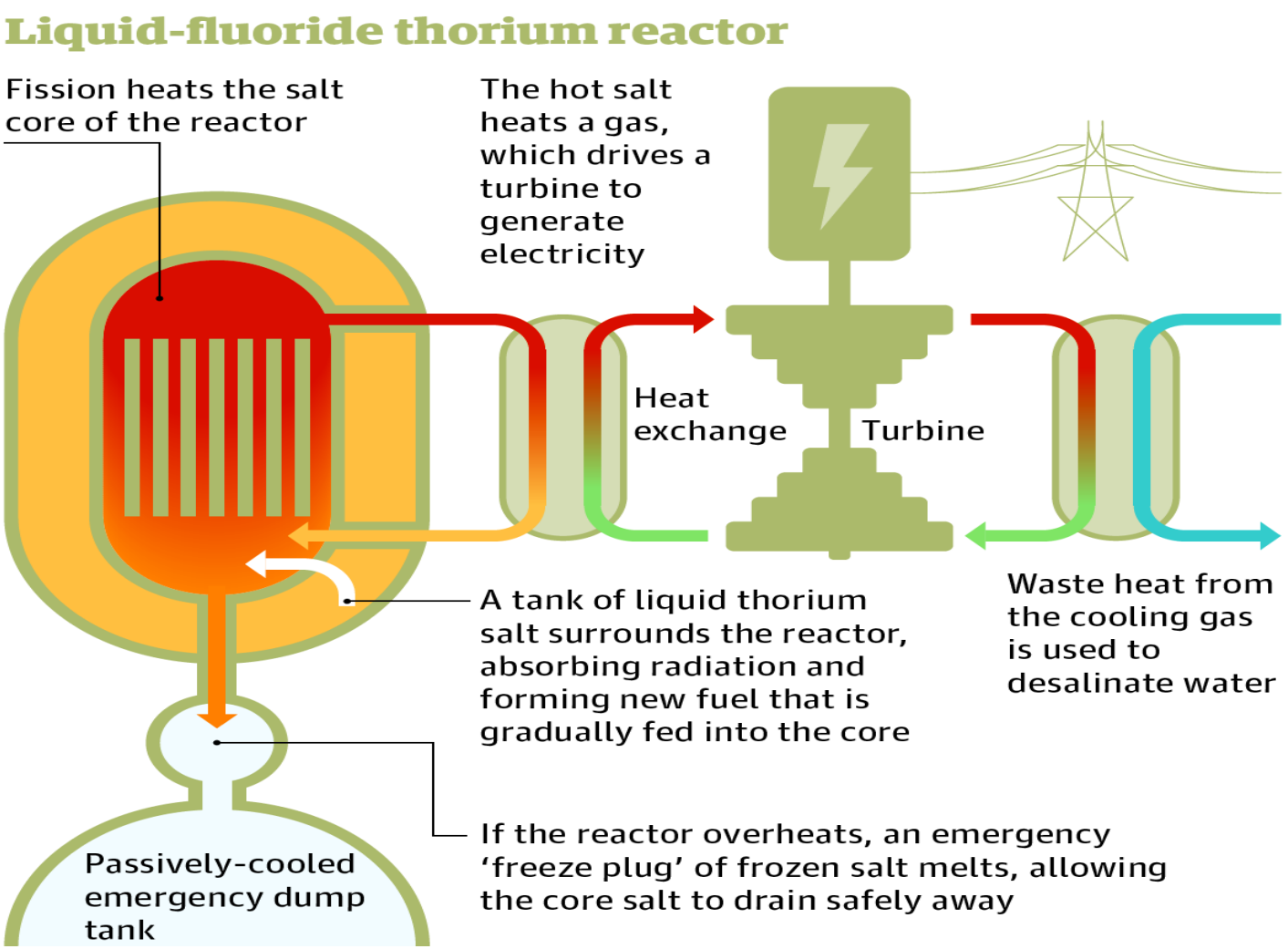
The consequences of the nuclear explosion at Chernobyl in1986

The consequences of the nuclear explosion at Fuckushima in 2011



A schematic diagram of the liquid sodium fast breeder reactor

An anti-nuclear protest in France concerning the Superphenix reactor, using the language of the protests against nuclear weapons tests



A schematic diagram of a blanket and core LFTR reactor