NUCLEAR POWER

OF THE FUTURE

GROUP PROJECT

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NUCLEAR POWER IN THE FUTURE

Fossil fuels have been a dominant energy source for thousands of years, and we still have a substantial amount left on Earth. But as the population increases, the environment is strained and technology develops, the search for alternative energy is crucial.

The nuclear power generation started over 50 years ago, initiated by the discovery of nuclear fission in 1938. It has been a sometimes controversial source of power, due to insufficient information to the public and a constant issue of safety. Today, almost 17 per cent of the worlds electricity demand is supplied by nuclear power; in France an impressing 77 per cent of the electricity comes from nuclear reactors.

But couldn't these numbers be higher? What are the limiting factors today and what can be improved?

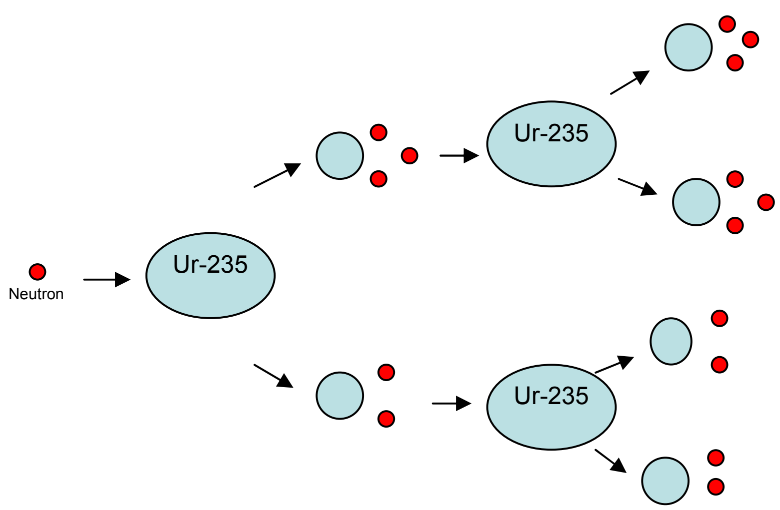
The conventional production of nuclear energy is based on the energy released by fission – a splitting of uranium atoms. In addition to energy (ΔE) and the fission products (B + D), the process releases neutrons (νn).

General equation of low-energy fission by neutrons:

$$A + n \rightarrow B + D + \nu n + \Delta E$$

The neutron produced in the first reaction, will then be able to react with another nuclide and cause another fission:

Fig.1 Neutron induced chain reaction



If the numbers of neutrons are just sufficient to keep the reaction in balance, the result is a 'critical reactor' – and a self-sustained chain reaction is achieved.
U-235 and Pu-239 nuclides capture a neutron and thereby we get a fission, producing 200 MeV of heat pr neutron. The heat is used to make steam, which drives electricity-producing turbines.

The expression 'critical reactor' means that they operate with fissile material (U-235, Pu-239) above a critical mass. Above this mass there will be a surplus of neutrons from the fission which will sustain the chain-reaction. The control mechanism ensures that the numbers of neutrons per generation is only one, by using neutron-absorbing rods in the reactor. If the control mechanism is damaged, the increase in neutrons will lead to an escalation of the nuclear reaction and the reactor will eventually explode, if the heat from the reaction is not removed.

Below the critical mass, the neutrons must come from the outside in order for the reaction to continue. This is the case in Accelerator Driven Systems (ADS). The fissile material does not generate enough neutrons itself, so a particle accelerator creates an intense neutron beam to supply the reaction. Cut off this supply of neutrons - deliberately or accidentally - and the reactor reverts to its natural, somnolent state. An explosive chain reaction is not just unlikely: It is prevented by the laws of physics.

There are two major problems with nuclear power production; safety and waste. With this new system, both aspects are taken care of: Reduction of hazards related to handling and management of radioactive wastes through nuclear transmutation AND improvement of operational safety of nuclear power facilities. The latter is due to the reduced need of fissile material and the first one is due mainly to transmutation of radioactive waste. Transmutation is converting the hazardous long-lived isotopes to non-radioactive or short-lived nuclides. Instead of storing U-235 for millions of years, the neutron-induced fission gives to lighter isotopes with relatively short half-lives.

ADS does not rely on fissile material that produce enough neutrons for a chain reaction. Therefore, other fuels than enriched Uranium and Plutonium can be used. This is advantageous as only one per cent of the energy of the mined Uranium is extracted in traditional reactors.
ADS, or Accelerator-Driven Transmutation of Wastes (ATW), can be used to transmute the waste products from traditional reactors in addition to handling its own waste. It must be partitioned, since it contains all possible nuclides. The calculation of masses, the fission products and energy of the particle beam from the accelerator is an important issue. Not all particles can be used; must nuclei are not fissile and the particle must be able to penetrate nuclei and interact with the nucleons. The most effective nuclear process that can be used for transmutation is neutron absorption. But using the accelerator is a costly affair, since we need a high amount of power to generate it. 10-20 per cent of the electricity derived from the reactor is used to operate the accelerator, but still plenty of energy to be used for commercial purposes.

ATW, a future cost-effective transmutation of nuclear waste, is a step in the right direction. It will need years of development, until technology can deliver an accelerator with the desired stability, efficiency, reliability, and operability.

ADS is also a very good alternative to the traditional nuclear power production. It can be used with the plants we have today and shows an increased level of safety. But there will always be the chance of something going catastrophically wrong. The job is to make it as small as possible.

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