BISHOP HEBER
HIGH SCHOOL

Nuclear Reactors: Safety aspects

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Problem Sheet

Continuing work on the fission calculations sheet

Lesson Objectives

1. To know some of the safety features of a nuclear reactor
2. To know what can happen if things go wrong!
3. To know how radioactive waste is processed and stored

Textbook pp. 193-194

REMINDER: Office hours are week 1 Tuesdays 3.45–5.0 p.m. in Rm. 19.
Next office hours: Tuesday 21 May 2013

Specification Requirement

Safety aspects
Fuel used, shielding, emergency shutdown.
Production, handling and storage of radioactive waste materials.

[AQA GCE AS and A Level Specification Physics A, 2009/10 onwards]

Fuel used

- Often pellets of uranium (IV) oxide, enriched to about 3% U-235,[1] in ceramic form.
- Pellets are placed in a narrow hollow tube, made of zirconium or magnesium(narrow to allow the neutron to escape to be moderated).
- After a few years, the fuel rod does not contain enough U-235 any more.
- This depleted uranium will no longer support a chain reaction.
- Spent fuel rods are also rather radioactive (much more so than new fuel rods)!

[1] from 0.6% naturally

Spent fuel

Spent fuel rods contain highly radioactive substances from fission products, so they are removed remotely to be dealt with:

1. They are still generating heat from radioactive decay, so they are stored for a time in *cooling ponds* for up to a year. Their activity is reduced considerably by the time the fuel is removed from the pond.
2. The fuel is remotely removed from its cladding, and is dissolved in nitric acid and an organic solvent. It is allowed to settle in a separating tank.
3. The following are removed:
   - Uranium, to be reprocessed for re-use.
   - Plutonium, to be used in other reactors, and weapons
   - Fission products—the main component of high-level active nuclear waste—which have to be stored indefinitely.

Shielding

- There is a great deal of radiation produced in the reactor, so it is essential that personnel are protected by shielding.
- α and β radiation both have limited range and are easily stopped, but the γ rays and neutrons are very penetrating.
- To stop these, thick concrete shields (5 m) are placed around the reactor.
- The core also has an inner casing of steel, as a pressure vessel, designed mostly to stop the escape of any radioactive gases.

Emergency shut-down

- The fission process can be stopped very quickly by inserting the controls rods fully into the reactor.[2]
- This reduces the energy produced, but it cannot stop the heat produced by the decay of the fission products.
- The cooling system needs to continue to operate to take this energy out. If this fails, the heat produced will melt this core (melt-down).
- In the event of coolant loss, there are huge supplies of water available to keeping flooding the core.

Whatever goes wrong, it is not possible for a nuclear reactor to explode like a nuclear weapon.

[2] They are suspended electromagnetically, so that in the event of power failure they simply drop.

Production, handling and disposal of active wastes

Radioactive waste is placed into one of three categories, depending on the amount of radiation that is produced.

- Low level waste
  Only slightly radiactive, e.g. protective clothing, instruments in contact with radiation, cooling water.
- Intermediate level waste
  Including materials exposed to intense radiation, e.g. fuel cans, reactor components.
- High level waste
  Mainly fission fragments from reprocessed fuel.

Storage of radioactive waste

- Low level waste
  Stored inside steel containers in large vaults. Cooling water is treated to remove radioactive substances and then released into the sea.
- Intermediate level waste
  Covered in concrete and placed in steel drums, which are placed underground.
- High level waste
  Converted into a type of glass vitrification and stored in a carefully selected geological repository, possibly for thousands of years.