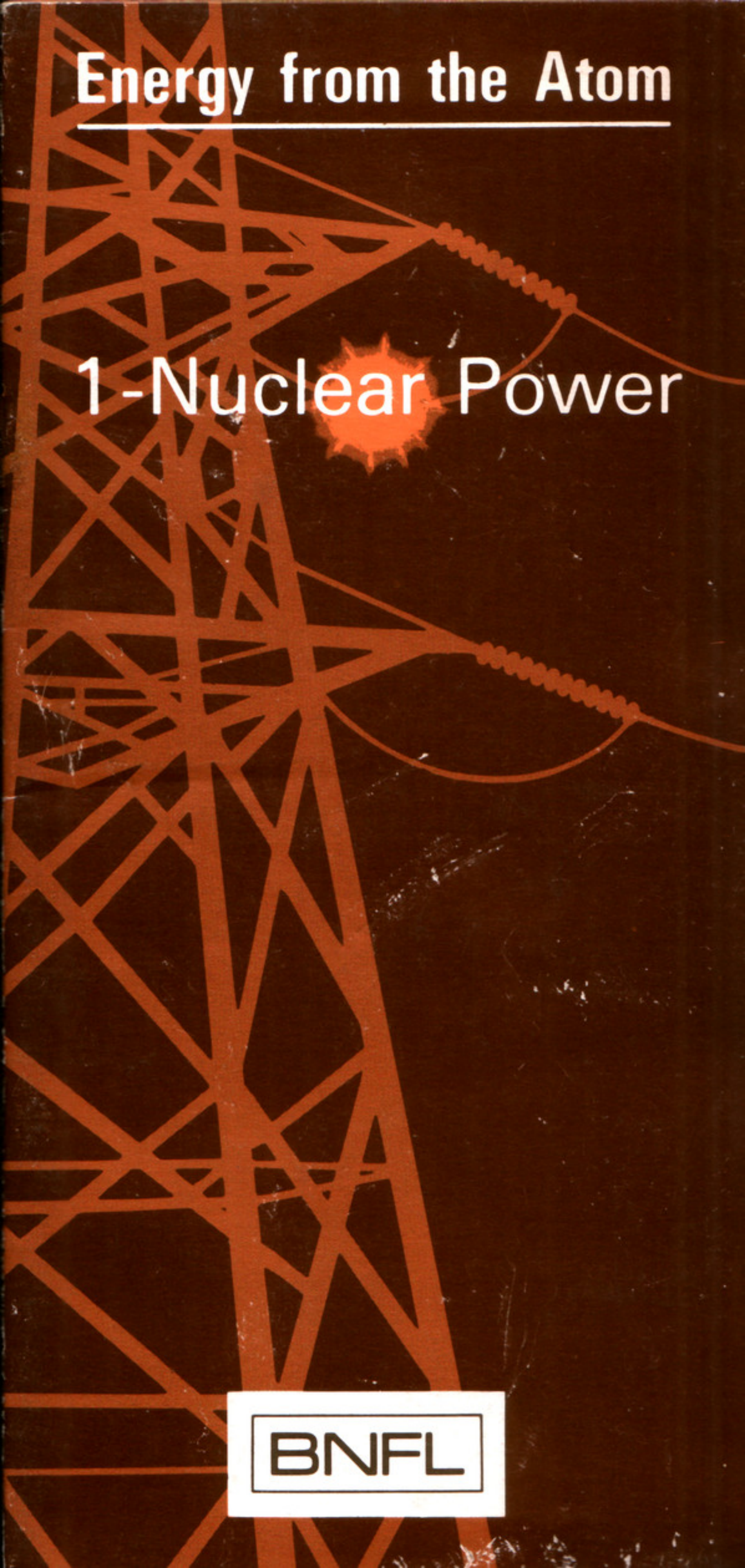
Energy from the Atom

1-Nuclear Power



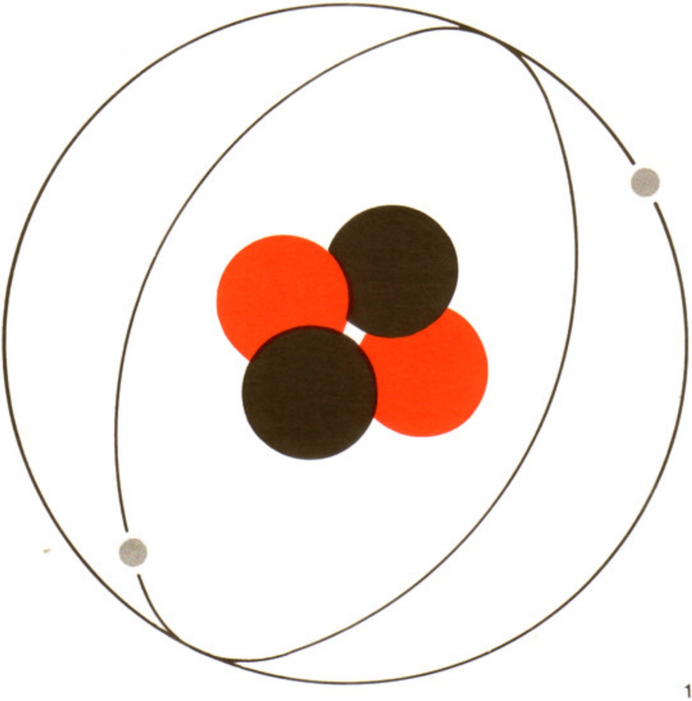
BNFL

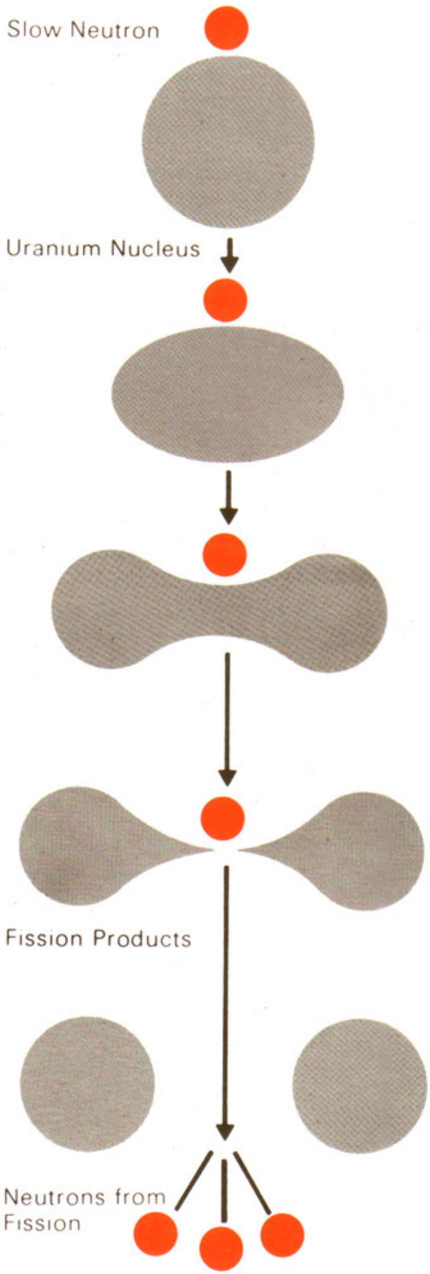
People and all things around us are made of atoms, each about a hundredth of a millionth of an inch across. They consist of a nucleus with electrons circulating around it, rather like planets revolving about the sun.

The nucleus itself is not a solid unit. It is made up of two different kinds of particles called protons and neutrons.

Some atoms, including certain atoms of uranium, break into fragments when a single neutron is added to the central nucleus. When this happens the uranium atom splits into two smaller atoms and energy is released in the form of heat.

An atom of helium has two protons and two neutrons in its nucleus, around which orbit two electrons.





Nuclear Fission

Two or three neutrons are also given off which can split further nuclei to continue the process. The continuing splitting process is called a chain reaction and is the basis of nuclear power.

Uranium fuel in a nuclear reactor gets hot as the atoms split in the uranium. A coolant fluid, gas or liquid, flows over the hot fuel transferring the heat from the core of the reactor to boilers where water is converted to steam and used to drive turbo-generators to produce electricity.

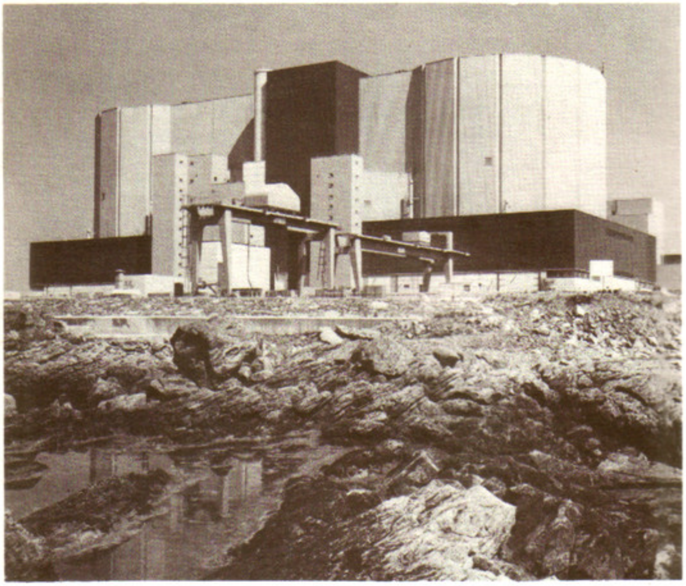
The only significant difference between a nuclear power station and a coal or oil-fired station is that the heat which produces steam for the generating equipment comes from nuclear fuel in a reactor and not from coal or oil burned in a furnace.

Uranium fuel in a reactor is surrounded by what is known as a moderator. This slows down the flying neutrons to ensure that the splitting process is carried out efficiently. The moderator can be graphite, heavy or ordinary water.

In the majority of the nuclear power stations operating in Britain, both the fuel and the moderator are enclosed in a reactor vessel which is connected to a number of water boilers. Heat from the reactor is transferred by a coolant gas, carbon dioxide, to the boilers where steam is produced to drive the turbines.

Britain was the first country to prove that economic nuclear power was possible. In 1956, Calder Hall at Windscale Works, Cumbria, became the

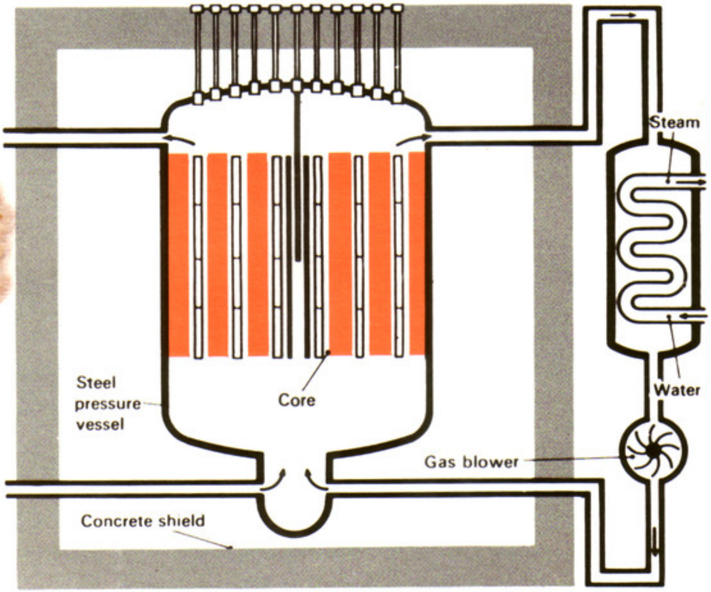
Wylfa nuclear power station on Anglesey has two 590 MW (e) Magnox reactors.



first large-scale nuclear power station to operate in the world. It has been producing electricity steadily and safely ever since, as also has its sister station at Chapelcross at Annan in southern Scotland, which began operating in 1958. Both stations generate about 200 megawatts of electricity using four reactors. Between them the two stations have generated about 75 thousand million units of electricity.

Based on the successful development of Calder Hall and Chapelcross, Britain pressed ahead with the world's first programme of commercial-size nuclear power stations. These are known as "Magnox" stations because the uranium metal rods are contained in a magnesium alloy (magnox) container or can. The first commercial station came into operation at Berkeley in Gloucestershire in 1962. There are now nine of these stations in operation, each with two reactors. They have been

Magnox Reactors

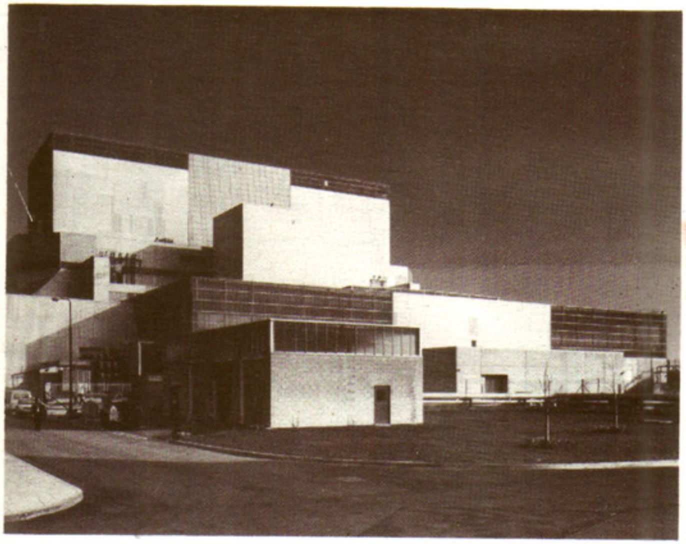


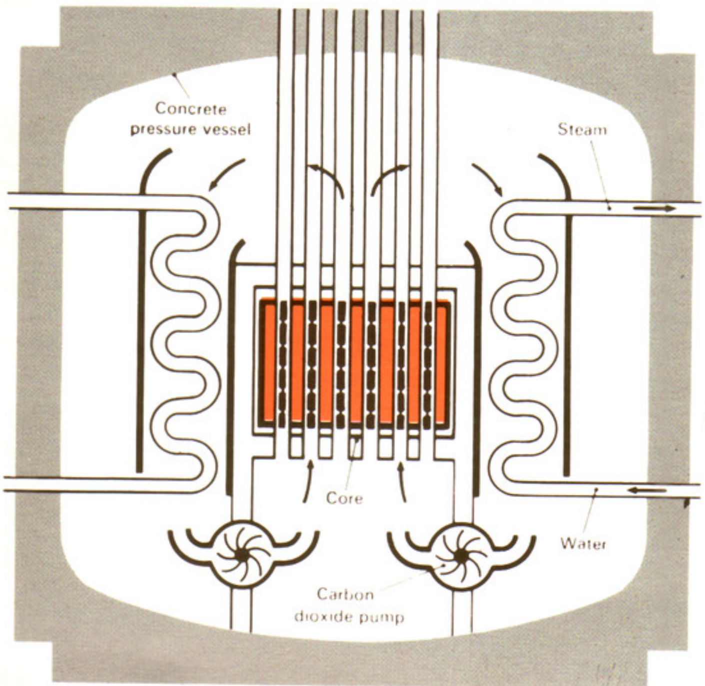
safe, reliable, economic and have become known as the "nuclear workhorses" of our electricity generating system. In a typical year they produce about 10% of the electricity generated in this country.

Some idea of the energy available through atomic power can be gauged from the fact that one 3½ ft fuel element used in the Wylfa, Anglesey nuclear power station is equivalent to 150 tonnes of coal. Each of the two Wylfa reactors contain approximately 49,000 fuel elements and one fuel element can produce power continuously for the five years of its life in the reactor.

The average cost of generating electricity in a nuclear power station is now about 40% cheaper than the cost of generating the same electricity in an oil-fired station and about 10% less than the cost of generating it in a coal-fired station.

Hinkley Point B Advanced Gas-cooled Reactor power station in Somerset.





Nuclear power stations also have a first-class safety record. Operating experience of Magnox stations is now equivalent to over 450 reactor years. During that time no harm has been caused by radiation to any of the workers at the stations or members of the general public.

Advanced Gas-cooled Reactors

During the 1960s a further development of the Magnox system led to the introduction of the Advanced Gas-cooled Reactor, called the AGR, which operates at higher temperatures and efficiencies. The United Kingdom's second nuclear power programme is based on this system and there are seven stations in various stages of commissioning or construction.

The basic concept of the AGR is the same as for the Magnox designs. A graphite moderator is used and carbon dioxide gas is the coolant. The fuel differs, however, consisting of enriched uranium oxide pellets encased in stainless steel tubes arranged in clusters.

Nuclear fuel is enriched by increasing the fissionable, or fissile, content of the fuel, *i.e.* the part which maintains the atom "splitting" process. Uranium consists mainly of two isotopes, uranium 238 and uranium 235, of which U235 is the more important since this is the "fissile" isotope on which the chain reaction depends. By increasing the U235 content in fuel it becomes more effective and economic; reactors are able to operate at higher temperatures, and increased power, and can be built in smaller, more compact, sizes.

The seven AGR power stations are located at Hinkley Point, Hunterston, Dungeness, Hartlepool, Torness and two at Heysham. Early in 1976 electricity was first generated by heat from one of the Hinkley Point reactors, followed shortly by one of the reactors at Hunterston.

Fast Reactors

A fast reactor is unique in that it can produce more fuel than it consumes. A blanket of uranium fits around the reactor core in a position where it absorbs neutrons from the fuel. Plutonium is formed in this blanket which can be used, after extraction, to manufacture more fuel for the reactor. Thus, as fuel is burned up in the core, more fuel is being manufactured in the blanket.

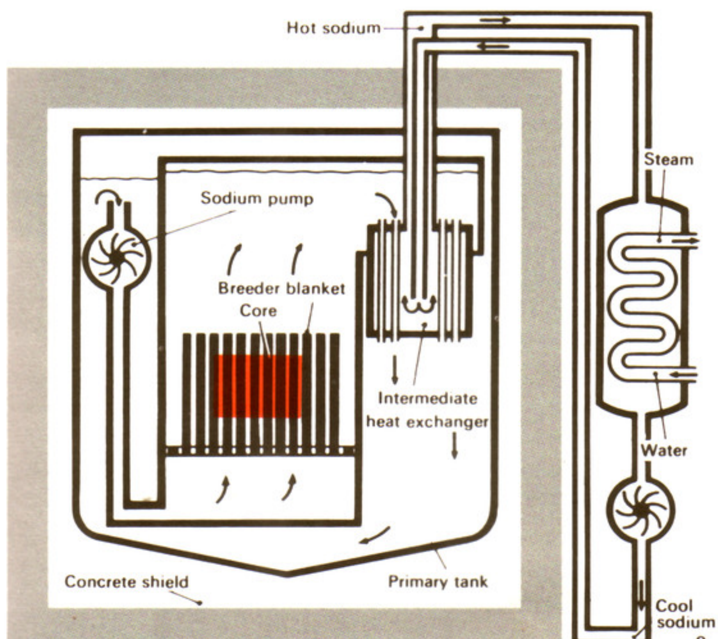
No moderator is used in a fast reactor and neutrons move around at high speed. Because there is no moderator the reactor core is small compared to

The 250 MW (e) Prototype Fast Reactor at Dounreay in Scotland.

other reactor systems, and the fuel is highly enriched in fissile atoms, either with more uranium 235 or plutonium 239, or a mixture of the two.

Vast quantities of heat are produced which need to be removed from the reactor core very quickly. Liquid sodium is used to do this and is continually pumped through the core to transfer heat to the steam generators.

A 14 MW(e) experimental fast reactor operated at Dounreay in Scotland for 15 years. This permitted the testing and proving of a variety of types of fuel and also established the operating characteristics of sodium-cooled fast reactor systems. Heat from the reactor enabled electricity to be supplied to the North of Scotland Hydro Electricity Board on a regular and reliable basis.



A much larger fast breeder reactor power station, known as the Prototype Fast Reactor, is operational at Dounreay and is capable of producing 250 megawatts of electricity. It paves the way for larger reactor stations of the same type, producing 1,000 megawatts of electricity and upwards, which might be built later this century.

Fast reactors are in theory able to burn all the uranium that is fed to them, and in practice can produce more than 60 times as much energy from a given weight of uranium as current reactor designs. Furthermore they are capable of converting to useable nuclear fuel the 99 per cent of uranium 238 that the present nuclear power stations are unable to use. The 20,000 tonnes of uranium 238 already in stock in this country would, if used to its fullest extent in fast reactors, be equivalent to more than 40,000 million tonnes of coal.

Experience in this country supports the view that the fast-breeder reactor will be a safe, reliable and economic source of power for the production of electricity. The fact that such a system also produces sufficient fuel for its own needs makes it an incomparable system to fulfil the world's long-term energy needs.

Nuclear facts

Nuclear power uses as fuel 'uranium' for which there is little other use.

Up to 14% of Britain's electricity is currently produced by nuclear power.

Calder Hall, the world's first nuclear power station, began operating in 1956. It is still producing electricity for the National Grid.

An expanded nuclear power programme has been announced by the Government. By the year 2000 we expect nuclear power to supply up to 30% of our electricity needs, releasing dwindling supplies of oil, natural gas and coal for more efficient use in the chemical, plastics and other industries, including transport.

One kilogram of enriched uranium AGR fuel is equivalent to about 80 tonnes of coal.

The costs of producing electricity in England and Wales in 1980/81 per kilowatt hour were:- Magnox nuclear stations 1.65p, AGR nuclear stations 1.45p, coal stations 1.85p, oil stations 2.62p (CEGB Annual Report and Accounts 1980/81).

The conversion of recycled uranium to plutonium and its utilisation in fast reactors will give us at least a sixty-fold increase in energy. Britain's present stocks of used uranium, if utilised to their fullest extent in fast reactors, would be equivalent to more than 40 thousand million tonnes of coal.

We are exposed to 'background' radiation all the time. Any additional radiation exposure that the general public gets from nuclear power is less than 0.2% of the total background radiation level.

All the highly radioactive residues produced to date from Britain's nuclear power stations would, if collected together, occupy about the volume of a pair of three bedroomed, semi-detached, family houses.

The highly radioactive residues arising from spent nuclear fuel recycling will be converted into a form of glass. In this form, all such wastes from our nuclear power programme up to the year 2,000 can be stored in properly engineered and shielded structures occupying an area no larger than a football pitch.

There has been more research into nuclear power as an energy source and into quantifying its risks than for any other form of fuel.

Stringent safety and security precautions exist to protect employees and the public from any possible hazard from nuclear power. The nuclear industry has an excellent safety record.

Comparative studies of public and occupational health effects of various sources of power leave no doubt that electricity generation from uranium offers far less of a public health hazard than from coal or oil.

The statistical hazard of a member of the public dying as a result of a nuclear power station accident is less than that of being struck by lightning.

Spent nuclear fuel is transported in massive, thick-walled, steel containers. They are built to withstand extreme accidents and must meet stringent design test requirements. In 20 years of use these flasks have travelled more than 3 million miles without harm to the public.

BNFL

Published as a contribution to the wider understanding of nuclear power by

Information Services
British Nuclear Fuels Limited
Risley
Warrington WA3 6AS

Further information on atomic energy and its applications can be obtained from:

Information Services Branch
UK Atomic Energy Authority
11 Charles II Street
LONDON SW1Y 4QP

Information Services
Central Electricity Generating Board
Sudbury House
15 Newgate Street
LONDON EC1A 7AU

Amersham International Ltd.
White Lion Road
Amersham, Bucks HP7 9LL

Revised and reprinted October 1981

299/50M/1181

ISBN No. 85327