(c) High Flux Australian Reactor (HIFAR)

HIFAR is located in Lucas Heights near Sydney, Australia and was operated by the Australian Nuclear Science and technology Organisation (ANSTO). It had a thermal power output of 10 MW and was in operation from 1958 - 2007, primarily for materials research and radionuclide production for medicine, agriculture, research and industry.

Based on the DIDO reactor at Harwell in the UK, HIFAR was cooled and moderated by heavy water, and the fuel was enriched uranium metal. There was also a graphite neutron reflector surrounding the core.

HIFAR first went critical at 11:15 pm local time on January 26, 1958, and was first run at full power of 10MW (thermal) in 1960. The initial fuel load was highly enriched uranium, but over the years the enrichment level of new fuel was steadily reduced, in line with international trends designed to reduce the danger of diversion of research reactor fuel for weapons programs. HIFAR completed conversion to low enriched uranium fuel (LEU) in 2006. Of the six DIDO class reactors built including DIDO itself, HIFAR was the last still in operation.

Starting in 2006, OPAL, a 20MW replacement reactor, was commissioned on an adjacent site. OPAL will be served by the same complex of research, isotope production and remote handling laboratories. The two reactors were run in parallel for six months while OPAL was being tested. HIFAR was then permanently shut down and OPAL took over HIFAR's role of Australia's only operating nuclear reactor. Decommissioning of HIFAR is expected to take around ten years from shutdown

HIFAR was permanently shut down on 30th January 2007. When the decision was made to prepare the reactor for safe enclosure it was chosen as a model to demonstrate the transition from operation to decommissioning. This could not be demonstrated at PRR-1 because it had already been cleaned out in connection with the various repairs after the occurrence of a leak in the pool.

The decommissioning process for HIFAR will be carried out in the following four stages:

- Stage one, which is the transition phase, entails the removal of fuel and draining of heavy water from the facility. The spent fuel will eventually be shipped the USA and no waste will return to Australia. The heavy water will be sold for re-treatment.

- Stage two, which is the safe enclosure, will take place over approximately the next 10 years and involves maintaining the reactor whilst the decay of radioactive materials takes place within the reactor.

- Stage three, which will involve dismantling the reactor and removing radioactive waste to a national radioactive waste repository, is to occur around 2016.

- The fourth and final stage will be returning the site for unrestricted use.

The reactor can be characterised in the following way:

1. Design

HIFAR is housed in a circular steel building 21 metres in diameter and 21 metres high, which is sealed. Access for people and equipment is through personnel and vehicle airlocks. The reactor is at the centre of the building within heavy shielding approximately 6 metres high and 7 metres across.

Twenty-five fuel assemblies were suspended vertically in a 2 metre diameter aluminium tank of heavy water. The fuel assemblies, each about 10 cm diameter, are spaced 15 cm apart and the uranium fuel in each assembly is 61 cm long. Thus the uranium core of the reactor fitted within an area 92 cm diameter and 61 cm high (about the same size as a domestic washing machine) located at the centre of the aluminium tank.

The quantity of uranium in one fuel element was 283 grams; the whole core therefore contained just over 7 kilograms of uranium. This was enriched to about 60% U-235.

Each fuel element consisted of several concentric metal tubes through which heavy water was pumped at high speed for cooling. The 2 mm thickness of each tube was an enclosed 'sandwich', in which the 'meat' contained the uranium fuel. The aluminium cladding, the 'bread', protected the uranium from corrosion and prevents escape of radioactive fission products.

The aluminium tank, containing 6 tonnes of heavy water, was enclosed in a steel tank packed with graphite, which conserved neutrons by reflecting them back into the reactor. The steel tank was encased in a 10 cm thick lead shield and then in a 1.5 m thick biological shield of especially dense concrete. This absorbed neutrons and other harmful radiation, thus protecting the operators from radiation exposure.

Some 58 sealed tubes, both vertical and horizontal, penetrated the reactor, enabling scientists to place materials close to the core to study the effects on them of radiation and to produce radioisotopes.

2. Moderation, cooling and control

The heavy water which was basic to HIFAR's design had the important function of slowing down the neutrons which were liberated by fission in the reactor core.

Heavy water, which has deuterium atoms instead of ordinary hydrogen, is generally indistinguishable from ordinary water, but it is about 10% denser. It is not radioactive and occurs naturally in all water to the extent of about one part in 6,500. Its relative rarity means that pure heavy water is very expensive to produce. It sells for about $500 per litre.

The heavy water circulated through heat exchangers, which transferred the heat to ordinary water. It was then dissipated in cooling towers. HIFAR operated at atmospheric pressure and a maximum temperature of about 51° C - well below boiling point.

Control of reactors is achieved by inserting materials, such as boron or cadmium, which absorb neutrons. In HIFAR there were six cadmium arms 1.45 metres long, shaped like railway signal arms, and which could be moved in an arc between the rows of fuel elements. Their position determined the reactor power. Since the number of neutrons can build up very quickly, the safety system has been designed to avert this by rapid insertion of the control arms.

3. Safety

HIFAR worked on a 28-day cycle - 24 days working, with four days shut down to change fuel elements and to maintain and check essential safety mechanisms. The control room was staffed 24 hours a day all year round, regardless of whether the reactor is operating.

In the event of any condition exceeding safe operating limits, the reactor protection system would automatically shut it down. This is done by the release of the cadmium control arms which drop between the fuel elements to absorb all of the free neutrons.

A number of cooling systems with back-up safety mechanisms installed in the reactor would operate if there were any likelihood of its fuel overheating.

The whole reactor was housed in a steel containment building in which the air is maintained at slightly less than atmospheric pressure. In the unlikely event of any release of radioactive material from the reactor, the building automatically seals to prevent any contamination of the environment.

Used Fuel

HIFAR's fuel was fabricated in the USA and the UK. In line with recommendations from several government inquiries, the used fuel has been sent overseas for either disposal or reprocessing, depending on the country of origin of the fuel. In 1963 and 1996, ANSTO shipped a total of 264 used fuel elements to the UK. In 1998, 240 were sent to the USA. A total of 1288 used fuel elements were sent to France for reprocessing in four shipments between 1999 and 2004. In 2006 a second shipment of 330 used fuel elements was sent to the USA. This left some 130 HIFAR used fuel elements destined for the USA.

HIFAR used fuel elements are stored on site and were accumulating at the rate of 38 per year. A sum of $88 million (1997 dollars) has been allocated for reprocessing UK-origin used fuel in Europe and shipping US-origin used fuel to the USA.

UK reprocessing was under a 1967 fuel purchase agreement, and the separated uranium was used in the UK for offsetting against ANSTO fuel purchases. The wastes from the reprocessing of the used fuel sent in the 1996 shipment will be held there for up to 25 years and then returned to Australia. It is classified as intermediate-level waste.