International
Nuclear
Fuel
Cycle
Evaluation

XA 9907100

# INFCE

INFCE/DEP./WG.8/37

The Light Water Natural Uranium Reactor

# THE LIGHT WATER NATURAL URANIUM REACTOR

DRAFT

# The Light Water Natural Uranium Reactor

by A. Radkowsky

A practical light water natural uranium reactor would be of great importance both from an economic and nonproliferation standpoint. It would be much cheaper than reactors of the CANDU type which require a large investment of heavy water and a costly plant design to minimize leaks. Since there would be no need for enriched material, there would be no excuse for smaller nations to build isotope separation facilities or to extract plutonium for recycling back into the reactor. Operation would be on the basis of the throwaway cycle. This would constitute a distinct gain towards the goal of nonproliferation of materials that could be used for nuclear weapons.

It is already well known 1/ that in straightforward uranium metal light water lattice experiments, as conducted by the Oak Ridge National Laboratory at the end of World War II, approximate criticality canbe obtained. With a special design of lattice optimization it is feasible to gain some per cent of reactivity sufficient to overcome equilibrium xenon and samarium and provide a small margin of reactivity for about 7500 MWD per ton of burnup, about the same as is obtained in the heavy water CANDU reactors. Loss of reactivity with burnup is relatively small because of the good conversion ratio in a natural uranium lattice.

With uranium oxide fuel the reactivity level would perhaps be too low to obtain a reasonable burnup. There has been concern about using uranium metal in a reactor on account of the well known phase change. This has apparently been overcome by fabricating the metallic rods by powder metallurgy. The other problem is the metal water reaction. However, this can only occur if there is a cladding defect. Even with oxide fuel a cladding defect can result in having to shut the reactor down. Thus it is necessary in any case to exercise extreme care and to have 'zero defect' cladding.

/..

In the CANDU reactor there is the attractive feature of on-line refueling. This is accomplished by having each cluster of fuel rods in a special small zirconium pressure vessel. The absorption of the zirconium walls causes appreciable loss in reactivity. Actually the pressure tube construction would be necessary in any case in order to avoid the necessity of pumping the huge volume of heavy moderator as coolant.

In a light water natural uranium reactor the reactivity margin may not be sufficient for the on-line refueling feature. Furthermore the volume of light water, serving as both coolant and moderator, is far too small to necessitate such an arrangement. However, the core will probably be too large for a conventional pressure vessel. Therefore, although pressurized water operation is contemplated, a larger vessel, similar to that of a Boiling Water Reactor, BWR, will be utilized. The pressure will have to be relatively low and efficiency will be reduced. However, this is also true of CANDU. In order to use the pressure tube construction, pressure is also reduced for pressurized water operation, and thermal efficiency is only 28%, as compared with conventional PWRs. The gains from using natural uranium fuel are still great enough to compensate for this loss of efficiency.

Another advantage of this type of reactor is that it could be converted to the thorium cycle by a self-induced procedure which would bring the thorium up to the reactivity of natural uranium. Then this thorium could be used to induce reactivity in fresh thorium, and the process could be continued indefinitely, conserving uranium supplies. There would be no need to go to the costly process of extracting the uranium-233 to form it into fuel elements. Thus proliferation possibilities would be avoided, as well as the cost of setting up a new multi-billion dollar industry.

/...

In addition to designing a special core to work on light water and natural uranium, we have studied another interesting possibility. A new type of light water seed blanket core would be designed with the seed having 20% enrichment and the blanket a special combination of elements of natural uranium and thorium, relatively close packed, but sufficient spacing for heat transfer purposes. The blanket would deliver approximately half the total energy for about 10,000 MWD/T, so this type of core would be just as economical or better in uranium ore consumption as present cores. However, the blanket could then be shipped to a developing nations and with increase in metal to water ratio could have enough reactivity to produce another 35,000 MWD/T. The individual fuel rods would not have to be separated, merely increased water would have to be provided between clusters,and the coolant flow properly orificed. With this type of assembly a conventional pressure vessel and oxide fuel could be used. It is well known that oxide fuel can withstand irradiation of 50,000 MWD/T or more. This scheme would provide more energy for the uranium mined and would avoid distributing 20% U-235 fuel which, while safe, can be converted into weapons material with relatively little separative work.

A seed blanket core arrangement with a seed driving a subcritical blanket is quite analogous to 'far out' proposals for fusion fission hybrids or accelerator driven lattices.

In the hybrid the fusion reactor acts as a neutron source. In the accelerator concept the highly energetic nucleons produce a source of neutrons by spallation. In each case these sources drive a subcritical lattice. In a seed blanket core the same thing is accomplished,but far more simply, since it avoids an interface problem of great technical difficulty. Moreover, the constraint of criticality and the close coupling of seed and blanket result in the blanket reactivity arriving at a 'secular' equilibrium value for a long period. Any decrease in blanket reactivity results in the seed assuming a great share of the total core power and pouring

/....

more neutrons into the blanket. This tends to cause more fissile fuel production in the blanket and restore it to the previous reactivity level. Just the opposite happens if the blanket reactivity rose. The constant reactivity in the blanket also means a constant power sharing between the seed and blanket.

Control of either of the types of cores proposed would be by conventional means, control rods, soluble poison, and possibly a small amount of burnable poison.

Reference

1. Weinberg and Wigner Theory of Nuclear Chain Reaction.