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Thorium - Uranium Fuel Cycle in Safe Reactors, the Time is Now*

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Synopsis

The thorium-uranium fuel cycle has several advantages that make it attractive. Some of these beneficial properties are of particular interest now as they help alleviate current concerns. The Th-U cycle has neutronic advantages when utilized in thermal or epithermal reactors. Some of these reactors enjoy extraordinary safety qualities. The combination of these traits suggest that now is an appropriate time to deploy and begin exploiting the Th-U fuel cycle.

Proliferation, Diversion, Terrorist Groups

The Th-U fuel cycle has an inherent security advantage. The U-233 has, for all practical purposes, some quantity of U-232 mixed in with the U-233. The U-232 decays, in various steps, to Tl-208 which, in turn, decays emitting a 2.6 MeV gamma. This hard gamma emission requires substantial shielding and remote operations to handle and to manipulate the U-233. Furthermore, it makes clandestine operation all but impossible. Particularly for deviant groups it is not practical to hide, transport or smuggle the U-233 to any location of action without being readily detectable and locatable. For legitimate operations with U-233, in the past, the uranium was chemically separated prior to handling, thus allowing for a few weeks of relative ease of operation with limited exposure. However, the U-232 signature could not be eliminated, and it takes elaborate facilities to separate the uranium in some liquid or gaseous form.

Weapons Grade Fissile

Uranium-233 is generally not acceptable as a weapons grade fissile material because of its limited shelf life. After a short time the U-233 becomes hazardous, or even lethal to handle without massive shielding and remote handling. Furthermore, the ease of detectability of the fissile material makes it undesirable. The ease of detectability also severely curtails the usefulness of the material for terrorist or deviant groups. The trade in this material, open or clandestine, is restricted by the ease of detection.

No Enrichment

The Th-U-233 fuel has no enrichment step. This reduces the number of handling steps, transportation and manipulation. Thus safety is greatly enhanced, there is less opportunity for diverting material, for sabotage or accidents. This reduced handling and manipulation is also a potential for improved economy.

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DISCLAIMER

As a side benefit; large scale uranium enrichment technology can be phased out and eventually eliminated. The non availability of the technology will make it more difficult for countries, or any group, to acquire weapons grade material whether it is a weapons country or not. Eventually natural uranium reactors can be phased out too which in turn makes it difficult and requires elaborate steps to produce quality weapons grade fissile material.

Disposing of HEU and PU

The Th-U-233 fuel allows for disposal of plutonium and high enriched uranium. The Pu and HEU can be blended with the U-233 for burning. By retaining, or "replacing," the Pu and HEU in the reactor, it can be burned completely. Any fissile make-up that is necessary can be derived from conversion of thorium. Particularly the HEU, but also the Pu, is suitable to start up the Th-U cycle as there are only limited amounts of U-233 available. Such a disposition of the HEU and Pu can circumvent much of the manipulation and head-end blending or other treatment of the weapons grade material that may be necessary for disposing of it by other means. If HEU is not blended down, with U-238, prior to its use in reactors, the generation of new plutonium is avoided. For the longer outlook, LWR spent fuel with the plutonium in it could be disposed of in a similar way by burning its fissile content with the U-233.

Breeding or Sustaining Reactors

The Th-U fuel cycle allows for sustaining, or gradually expanding, the nuclear energy economy. The Th-U fuel is amenable to low breeding in a thermal or an epithermal neutron flux. The fuel cycle can be adjusted to either sustain a reactor operation indefinitely or produce a small excess of fuel. As need and acceptability allow a slight fissile surplus production can allow for an expansion of the system and thus for the disposal of spent fuel from other reactors.

Safety of Th-U-233 Fueled Reactors

The Th-U fuel cycle is particularly suitable for two kinds of reactors namely the HTGRs and MSRs. Both of these type reactors have from their inception emphasized advantages of operating in the Th-U cycle. Both of these reactor types also enjoy extraordinary safety features. The HTGRs and the MSRs have inherent and passive safety features to the extent that they exclude most, if not all, severe accidents. Many of these safety features are associated with a large negative temperature reactivity coefficient and a large thermal capacity.

Actinides

The Th-U fuel cycle creates only minute, and negligible, quantities of waste actinides and plutonium. The ability of the cycle to self sustain, or even expand, allows for the use of some neutrons to transmute long-lived isotopes and long-lived waste actinides, from other sources, such as spent fuel. This has the potential to simplify the disposal of spent fuel.

Waste

The waste from the Th-U fuel cycle is essentially free of long-lived actinides. A modified cycle can also transmute long-lived isotopes in the waste. For a fluid fuel reactor, with processing, the waste can be essentially free of fissile materials. This greatly relives many of the difficulties associated with the disposal of spent fuel and nuclear waste. Under ideal circumstances, with adequate separation of the waste by elements, the high level waste can be all but eliminated.

By widely deploying the Th-U cycle reactors and circulating spent fuel through these reactors, the waste issue can be greatly simplified for existing reactors and for the already accumulated spent fuel.

Transition

The available amounts of U-233 are limited. HEU is best suited to initiate the Th-U cycle. The HEU can be viewed, in an overall scheme, as being "converted" into U-233. The same "conversion" can be accomplished with plutonium, in a somewhat longer process because the "conversion" of the Pu into U is also associated with a chemical element conversion. The utilization and deployment of the plutonium "conversion" require research and development of the processing steps.