CAN LIGHT WATER REACTORS BE PROLIFERATION RESISTANT?

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During the last decade several questions were raised concerning the proliferation issues of Light Water Reactors (LWRs) in comparison with other types of power reactors, particularly Gas Cooled Reactors (GCRs) and Heavy Water Reactors (HWRs). These questions were strongly highlighted when the Agreed Framework between the United States and the DPRK was signed in October 1994 and following the formation of KEDO organization to provide two LWRs to DPRK in replacement of all its GCRs in its nuclear program[1, 2]. One might summarize the main questions into three groups, mainly:

1. Can LWRs produce weapon-grade Plutonium (Pu)?
2. Why the LWR type is considered as a better option with regard to non-proliferation compared to other power reactors - particularly GCR and HWR types?
3. How LWRs could be more resistant to proliferation?

To try to answer these questions, two tables[3] are presented containing different numerical parameters for Pu production capability of the three main reactor types (LWRs, GCRs and HWRs) of a 400 MWe power reactor unit. Table (1) lists these parameters during normal operation, while table (2) lists the same parameters during abnormal operation to produce weapon grade Pu.

Back now to answer the previous questions:

1. CAN LWRS PRODUCE WEAPON-GRADE PU?

As clearly seen from table 2, weapon-grade Pu could be produced in LWR fuel, as in the fuel of most other power reactor types, by limiting fuel irradiation to two or three months only. However, such production, though possible, is exceptional. In a recent study[4] 5% of LWRs under IAEA safeguards have spent fuel inventory containing limited amount of high-grade Pu. As listed in table (1) the equilibrium irradiation (burnup) of discharged fuel is in the order of 33,000 MWD/T. However and due to lower enrichment of initial inventory almost half of that burnup is produced. In normal situations the discharged initial inventory has a Pu grade which is less than weapon grade and is unlikely to be used for weapon production.

2. WHY THE LWR TYPE IS CONSIDERED AS A BETTER OPTION FOR NON-PROLIFERATION?

Referring to table (1), one can conclude that LWRs make less Pu per MWe compared to GCR (though HWRs make the lowest Pu per MWe). For the same power, LWRs produce the lowest Pu per year compared to both GCRs and HWRs. The Pu grade of discharged fuel of LWRs is much less than that of GCRs (though equal to HWRs). Therefore, in normal commercial operation, LWRs could be considered as a better non-proliferation option compared to GCRs. In addition, the change of mode of operation to produce weapon-grade Pu or more Pu quantity would be easier to detect for LWRs than for GCRs. This is mainly due to the fact that GCRs can be re-fuelled on-load (i.e. while the reactor is in operation), wheres LWRs should be shut down first and reactor vessel should be opened, which are easier indicators to be monitored.

3. HOW LWRS COULD BE MORE RESISTANT TO PROLIFERATION?

Currently there are close to 200 LWRs under the IAEA safeguards regime. Standard safeguards measures are implemented at these reactors to assure no diversion of declared nuclear material and peaceful use of these reactors for power production.

Increasing the confidence level in such assurance might be needed on the basis of particular agreements. The measures to increase the confidence level could be summarized in the following headings:

i. Non-proliferation commitment (e.g. ratification of comprehensive safeguards agreements and Additional Protocol, successful completion of verification of initial inventory, positive safeguards conclusion for the declared nuclear material and absence of undeclared nuclear material and activities, ..etc).

ii. Application of different safeguards measures (e.g. use of unannounced inspections, complementary access, remote and environmental monitoring systems, advanced NDA for spent fuel, verification of irradiated non-fuel items …etc.).

iii. Additional specific agreements (e.g. limitation of out of core inventory, delivery of enriched fuel, restriction of spent fuel reprocessing, ..etc.)

iv. LWR design specifications[5] (e.g. related to fuel assemblies, restriction of pin removals, core, spent fuel pond, control rooms…etc.).

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2. Special report "KEDO/NPEC executive directors exchange of letters", Northeast Asia peace and security network, Jan. 16, 2001.
3. Y. Abushady "A Computational Scheme for Plutonium Production in Different Reactor Systems", Nuclear Safeguards Symposium, INMM, Vienna, October 14, 1985.
4. J. Carlson et al, "Non-Proliferation and Safeguards Issues", IAEA symposium, Vienna, October 1997.
5. "Design Measures to Facilitate Implementation of Safeguards at Future Water Cooled Nuclear Power Plants", IAEA, technical report series No. 392, Vienna, 1998.

Table (1)

Normal Plutonium Production of a 400 MWe power reactor unit of different types

Reactor Type	LWR (PWR)	GCR	HWR
Specific Power (MWth/Tu)	37	2.4	20
Fuel residence time (years)	3	3	2
Discharge fuel irradiation (MWD/T)	33,000	3,000	8,500
Pu (Kg) per ton U	9	2	4
Pu (Kg) per MWe	0.1	0.26	0.08
Annual Pu production (Kg)	92	260	168
% Pu grade (Pu fissile / Pu total)	70	83	69

Table (2)

Abnormal Plutonium Production of a 400 MWe power reactor unit to produce weapon grade Plutonium

Reactor Type	LWR (PWR)	GCR	HWR
Fuel residence time (days)	80	380	50
Discharge fuel irradiation (MWD/T)	3,000	800	1,000
Pu (Kg) per ton U	1.6	0.72	0.84
Annual Pu production (Kg)	180	200	400