THE ELEPHANT AND YUCCA MOUNTAIN

by James C. Kennedy
and John Kutsch

Dealing with the 77,000 tons of accumulated spent fuel from the U.S. civilian nuclear solid fuel energy program is an enormous and unresolved issue. But like most of the world's problems, the stockpiling of spent nuclear fuel from solid fuel Light Water Reactors (LWR) is the result of a policy choice based on the goals and objectives of a different time – the cold war years. A better alternative was developed and exists, but it was intentionally sidelined and defunded.

As a consequence, spent fuel costs continue to mount and LWR fleet decommissioning timelines may be pushed forward as a result of Natural Gas pricing. If decommissioning timelines compress, DOE set-aside resources for spent fuel may prove insufficient. It may also be true regarding the decommissioning obligations for many of the private sector utility companies. The cultivation of this nuclear technology has not led to abundance. How did we get in this mess?

Safety, proliferation and waste issues were generally understood as our nation embarked on its current pathway. Unfortunately, the cold war was the ultimate driver behind all high level policy decisions. Solid fuel LWRs and Fast Breeder Reactors (FBRs) were the favored dual-use technology for the production of civilian power and potential weapons material (Plutonium). In fact, much of U.S. electoral politics, National Lab funding and one's career in physics or National Security issues were largely related to the 'warhead count'.

A better, safer alternative for civilian power was in development but it had no nuclear weapons potential and little funding. At the request of President Kennedy, the Atomic Energy Commission, under Glenn Seaborg, was asked to recommend the best options for the future of civilian nuclear energy. The 1962 Seaborg Commission Report recommended this alternative, but with the demise of the U.S.' 35th President this recommendation was lost or ignored.

Later, Alvin Weinberg, the patent holder to the LWR, again recommended this safer alternative and was fired from his job as Director of Oak Ridge National Labs. To quote Chet Holifield, the Chairman of the Atomic Energy Commission who terminated Weinberg: "…if you are concerned about the safety of reactors, then I think it might be time for you to leave nuclear energy." The Sacking of the director sent a clear message. It was 1973[ii].

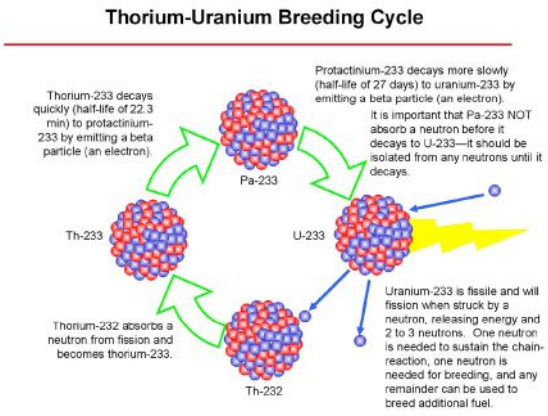
A SAFER ALTERNATIVE?

The method of which we are discussing is an operational reactor based on a Liquid Fuel Cycle and Molten Salts. There were four operational Molten Salt Reactors (MSR) built at Oak Ridge. The most recent, the Molten Salt Reactor Experiment (MSRE) fueled with U-233 operated for nearly 20,000 hours, from 1965 to 1969. However, the MSRE demonstrated the sustainability of a Thorium 232/Uranium 233 neutron economy (see Figure 1, next page), the preferred configuration promoted by Alvin Weinberg, Eugene Wigner and Edward Teller, called the "Pure Cycle".

Using the Pure Cycle, neutrons from small amounts of Uranium 233 (U-233) are used to convert a much larger amount of cheap, abundant and proliferation resistant Thorium 232 into more U-233. The natural decay chain of U-233 results in the highest possible fuel utility and lowest possible transuranic waste. The Pure Cycle allows for almost 100 percent fuel utilization, resulting in almost no transuranic waste and 1/1000th the geologic storage requirements of the solid fuel cycle.

Of course you could use almost any fissile isotope to initiate the reaction including spent fuel from LWR stockpiles, U-235 or the weapons grade HEU currently scheduled for blend-down[iii]. The ultimate choice, or mixture, of Uranium/Plutonium isotopes will result in a variation of residual actinides, transuranics and geologic storage requirements. But even in the worst case scenarios the resulting transuranics and geologic storage requirements are a fraction of any solid fuel/LWR configuration.

The liquid fuel cycle permits the online purging of Xenon, Krypton and other neutron absorbers[iv] and the fluorination and processing of other actinides[v], allowing for the continuous burn-down of transuranics.



LEFT:
Figure 1: U233 Fuel Cycle

Consider the following advantages of Th-MSR and the liquid fuel cycle:

- 99 percent fuel utility, with less than 1 percent actinide waste;
- Only a small fraction of the waste is transuranic;
- On-line extraction of valuable fission products;
- Relatively short geologic storage requirements (500 to 1,000 years vs. 300,000 years);
- No chance of overheating – no chance of meltdowns;
- No Zirconium clad fuel bundles, no water for cooling (or massive cooling towers) – no chance of gas phase expansion or hydrogen explosion;
- No chance of gas phase expansion or hydrogen explosion – no chance of widespread radioactive release;
- No chance of gas phase or explosive events – no need for massive containment structures;
- Walk away safe for all conceivable system failures based on physics and gravity. Fuel salts automatically drain into storage tanks where continued fission is impossible (see Figure 2, next page);
- No massive containment systems or cooling towers – construction is modular and 'design permitted' units are manufactured on an assembly line (think: distributed power);
- Th-MSR is a load follower that quickly responds to wide fluctuations in demand;
- Th-MSR.AB reactors could be located at existing LWR sites utilizing and burning-down spent fuel that could be stored onsite, while supplementing or replacing electric energy generation;
- Thorium does not require enrichment and is a common waste product from rare earth mining – U.S. Geologic Survey resource estimates indicate 10,000 years of resource availability assuming a 100 percent conversion to Th-MSR from coal and existing LWR nuclear;
- Annual Thorium availability as a byproduct of existing mining operations already equals 'fuel ton' requirements for a global roll-out of commercial Th-MSR reactors – no mining necessary (an end to the stockpiling of Depleted Uranium – another DOE off balance sheet liability);
- Independent studies put the cost of Th-MSR systems at $2 million per MW; and
- All-in financing, construction, personnel, fuel, security, site permitting, etc., put energy cost at less than $.02 Kw (competitive against Natural Gas even below $2 per million BTU).

WHY IT MATTERS IN NUCLEAR DECOMMISSIONING

Why should any of this concern us within the context of nuclear decommissioning? Because none of the advantages outlined are achievable with conventional LWRs or any solid fuel cycle. Maintaining and continuing to deploy traditional solid fuel system will only increase volume and the aggregate cost of spent fuel as it relates to decommissioning.

Matters only get worse if utility companies move to natural gas as an alternative to the costly maintenance, upgrades and operation of their existing nuclear reactors.

Post-Fukushima decommissioning studies in Japan have shown that the cost of decommissioning and dealing with the accumulated spent fuel could be much greater than anticipated. Based on some of the estimates coming out of Japan, the same could be true for the U.S. With the termination of the Yucca Mountain project, the U.S spent fuel issue could end up costing hundreds of billions of dollars. Even under the best case scenario green-lighting Yucca Mountain will cost at least $96 billionvi. The DOE has collected less than $40 billion to deal with the spent fuel liability. Who eats the balance…?

THE LIQUID FUEL SALT CYCLE

Let's consider an alternative path. Spent fuel retains well over 95 percent of its energy potential. Rather than just sequestering all of that potential energy and continuing on the existing LWR solid fuel paradigm we should consider the recommendations of the Seaborg Commission, Weinberg, Wigner, Teller and many others: the liquid fuel salt cycle.

Why not embark on the development of Thorium Molten Salt Reactors (Th-MSR)? Most of this new fleet of Th-MSR reactors could be deployed as replacements for coal-fired power stations, cutting U.S. greenhouse emissions by 40 percent.

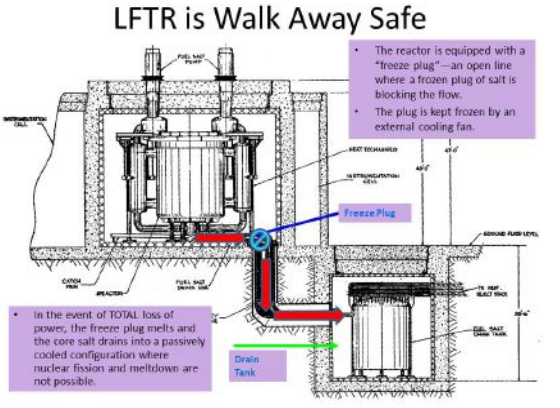
Some of these Th-MSRs could also be operated as Actinide Burners (Th-MSR.AB) at existing LWR facilities – the indefinite home of all spent fuel from the civilian energy program. As such, the dangerous transuranic and actinide waste from the nation's stockpile of spent fuel could be reduced by as much as +90 percent. The remaining fraction, with a dramatically reduced geologic storage requirement, could continue to be stored onsite (reflecting the status quo) or shipped to a centralized geologic storage facility.

Th-MSR development and deployment would also halt the current DOE goal of deploying a new fleet of LWRs. Rolling out a new fleet of LWRs with no plan for dealing with the past or future accumulation of spent fuel is imprudent, to say the least.

SCIENCE VS. INSANITY

The Th-MSR and MSR.AB could be commercially developed and deployed for less than what it may cost to move, process, vitrify and store the 77,000 tons of spent fuel. A fleet of Th-

BELOW: Figure 2: Diagram of the Molten Salt Reactor Experiment (MSRE)



ABOVE:
To watch a video discussing the link between Thorium and Rare Earths, visit: http://www.youtube.com/watch?v=tyqYP6f66Mw

MSR.ABs could then utilize nearly all of the energy potential trapped inside the spent fuel, offering a solution to the spent fuel problem.

There is considerable private sector interest in developing Th-MSR, but private investment requires a regulatory pathway. That is not likely while the DOE and Nuclear Regulatory Commission (NRC) continue to maintain their singular and myopic preference for limited variations of Uranium based solid fuels.

DOE inclinations are conveyed whenever they or the NRC/National Lab echo chamber reiterate the same tired litany of non-factual and dismissive statements when asked about Thorium or the liquid fuel cycle. The playlist typically starts with disinformation, overstating early obstacles in Th-MSR development that were fully overcome and conclude by pretending to 'weigh the cost' of switching technologies, while continuing to ignore the mounting cost of continuing down the current solid fuel LWR path. It is a well-rehearsed and unified front[vii] that is designed to protect and promote solid fuels to the exclusion of all other options. This needs to change.

Exploring alternatives is a pre-condition of science. Repeating the same mistake over and over again… is the definition of insanity. It is time to lift up the discarded mantle of science and complete the tasks that were left to us.

About the Authors:

James C. Kennedy *works on Rare Earth and Thorium Energy issues. He is currently working with bipartisan House & Senate Leadership and the White House on a Rare Earth and Thorium bill. Kennedy contributed to the recent Senator Murkowski S. 1113 Rare Earth Bill. and contributed to the previous S. 4032 Rare Earth bill introduced by Senator Christopher Bond and Senator Evan Bayh in the 111th Congress.*

Kennedy has authored papers on Rare Earths and consulted on the topic with the DOD, DOE, members of Congress, the financial industry and other rare earth companies. He is currently working on federal legislation regarding the strategic re-development of the U.S. rare earth industry and energy. Kennedy has presented on Rare Earths and/or Energy at the following conferences: Oak Ridge National Laboratories; Google's Thorium Energy Conference; Missouri Science & Technology University in Rolla; The Materials Science and Technology organization; The Minerals Metals & Materials Society; Small Modular Nuclear Reactor Conference; Society of Mining, Metallurgy and Exploration; and Thorium Energy Alliance.

John Kutsch *is the executive director of the Thorium Energy Alliance. He provides his clients with world class innovation and engineering, and is an expert in CAD and Project Life Cycle Management. Other areas of expertise include Fabrication, Materials Selection, Prototype Production, Casting, Forming, Rapid prototyping and computer visualization of a CAD model's stress analysis, Quality Function Deployment and performance modeling to ensure client receives the design they envisioned. Kutsch manages and integrates his own skills with the best team members he has discovered over the years.*

The Thorium Energy Alliance, a 501c3, advocates for the development of a Thorium Energy Economy. Additional documentation, technical reports, resources, educational materials & thorium community links can be found at: http://thoriumenergyalliance.com/ThoriumSite/resources.html

[1] Fracking has resulted in natural gas prices below $3 per million BTU. At these price levels natural gas looks like a lower cost option than the operation and maintenance cost required for an aging fleet of LWRs. At least two energy companies are considering postponing scheduled maintenance for their nuclear reactors, shuttering their reactors and switching to natural gas for replacement generation.

[1] The final push for the technology was attempted by Oak Ridge Th-MSR advocates, but that funding was redirected towards Fast Breeder Reactors.

[1] The Savanna River MOX facility blend-down project is now expected to exceed $10 billion. The project was initiated with a humble cost estimate of just $800 million. This single use facility is being built to blend down just 34 tons of HEU from dismantled nuclear weapons (that translates to more than $130,000 per pound).

[1] The liquid fuel cycle allows for the purging and capture of neutron absorbing gases that can be stored until safe or reintroduced into the fuel cycle after trans mutational decay.

[1] The liquid fuel cycle allows for fluorination and the removal of useful actinides and other fission byproducts and the removal and reintroduction of trans uranic and actinides for maximum fuel utility and waste minimization

[1] Consider DoE's track record on initial project estimates and final cost. Like the Savanna River example above, final cost tend to be off by a number of factors.

[1] Careers inside and out of the DoE, NRC and National Labs and the direction and funding of the National Labs are highly correlated to conformity with DoE preferences. I was enlightened by a very high level director at a National Lab "that anyone working inside or outside of the DoE or National Labs that is even suspected of supporting non-DoE projects, initiatives or preferences will have their careers ruined" and that "the DoE is the most vindictive agency in the Federal Government."

Supporting and referenced documents can be found at: http://threeconsulting.com/resources.html under the "Reports" heading.