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Repository and Deep Borehole Disposition of Plutonium

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Control and disposition of excess weapons plutonium is a growing issue as both the United States and Russia retire a large number of nuclear weapons. A variety of options are under consideration to ultimately dispose of this material. Permanent disposition includes two broad categories: direct Pu disposal where the material is considered waste and disposed of, and Pu utilization, where the potential energy content of the material is exploited via fissioning.

Virtually all plutonium disposition options have in common the generation of one or more final waste streams which will require disposal as transuranic (TRU) or high-level radioactive waste (HLW). These waste streams must be assessed for disposal suitability and potential impacts on disposal systems. Disposal system options include the existing repository programs for TRU and HLW, or a custom Pu disposal facility.

Disposal requirements depend on the nature of the waste, with initial differentiation between HLW and all other types. High-level wastes are designated for emplacement in a geologic repository, which has specific regulations regarding waste form suitability and performance requirements. Mixed oxide reactor fuel (MOX), Pu based fuels, Pu mixed with defense HLW and accelerator based conversion wastes qualify as HLW. Plutonium metal, Pu oxide or immobilized forms without added radionuclides could be disposed of in a TRU repository or a custom facility developed for plutonium.

For disposal in a HLW repository a number of waste form characteristics can impact the waste management system:

- Radionuclide inventory
- Chemical and mechanical attributes
- Criticality control
- Thermal output
- Release rates (aqueous/gaseous)
- Diversion resistance

Disposal of these wastes could impact the waste management system in several ways:

- Repository design and operation
- Repository performance prediction and licensing
- Transportation and interim storage
- Safeguards and security
- Public perception
- Cost and schedule

For HLW disposal concepts, plutonium becomes a waste form which requires evaluation for suitability and performance. An example is the option of loading plutonium oxide into borosilicate glass for repository disposal. While the borosilicate glass is an expected waste form, Pu loaded glass would have different thermal output, a potential criticality concern, greater diversion potential and differing radionuclide release properties. The suitability of such a waste form for geologic disposal is being assessed, and design, operational and performance impacts on a repository evaluated. Recent analyses include criticality potential, long term thermal output, long term radionuclide release, neutron generation and effects of alpha decay.

Plutonium utilization concepts may result in either spent reactor fuel or waste streams from chemical metallurgical reprocessing, either of which would require evaluation for disposal suitability and performance. Examples include metallic waste from pyrometallurgical processing of IFR fuel or very high burnup ceramic fuel from a once through MHR. This type of waste is outside of the current design basis for the first geologic repository and is being evaluated for design, operational and performance impacts. Impacts of mixed oxide (MOX) fuel on repository performance, waste package design and criticality control are in progress.

The primary alternative to a high-level radioactive waste repository for the ultimate disposal of plutonium is development of a custom geologic facility designed just for plutonium. A variety of geologic facility types have been considered, but the concept currently being assessed is the deep borehole.

The deep borehole disposal concept centers around a host rock which has a long history of geologic stability, has little free water, what free water may be present is ancient and has no recent history of communication with accessible or usable ground water. The safety argument is the expectation that there will not be significant pathways for migration of plutonium to the accessible environment. Such host sites are expected to be found at considerable depths in many areas of the world. The "deep" in deep borehole means deep enough to meet the isolation requirements, and probably varies with location. Suitable geology may be found at depths from 2 to10 kilometers. A series of seals would be placed between the emplacement zone and accessible or usable ground water zones. The remainder of the hole would be stemmed and sealed. Within the emplacement zone, plutonium bearing packages could be cemented in grout or surrounded with a suitable packing material to reduce free void volumes and retard migration. Very large lithostatic loads in the filled hole will tend to prevent large void volumes. Similar loads in the host rock compress existing fractures and result in low bulk permeability and little water flow. Water which has been trapped in the host rock for geologic times is usually very high in ionic strength. The natural vertical density gradient in such deep stagnant brines is potentially a benefit in overcoming any induced thermal buoyancy due to decay heat from the plutonium. The number of holes and borehole diameter required varies with differing operational concepts and the capacity required. Several conceptual designs have been developed and are being evaluated.

Perhaps the greatest unknown for the deep borehole option, or any custom final plutonium disposal method, is the uncertain regulatory status. Current radioactive waste management regulations evolved without separated plutonium being considered a waste. Applicable regulations for siting, constructing, operating and closing a custom Pu disposal facility do not exist, and would have to be considered in parallel with any serious development project.

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