



Australian Government

*synroc*ANSTO
Low-risk nuclear waste form design

Low-Risk Alternative Waste Forms to Lock Up Nuclear Waste

Meeting the Challenge of the DOE Legacy Clean Up

White Paper

Australian Nuclear Science &
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Low-Risk Alternative Waste Forms to Lock Up Nuclear Waste

Executive Summary

The highest cost component of the US Department of Energy's (DOE) clean up challenge centers on high-level waste (HLW). Consequently the greatest opportunities for cost and schedule savings lie in optimizing the approach to HLW clean up.

*synroc*ANSTO's low-risk, tailored, alternative waste forms offer significant overall cost and processing schedule savings in cleaning up legacy waste sites via:

- **Higher waste loadings** (fewer disposal canisters);
- **Enhanced chemical durability** (lower environmental risk);
- **Greater processing flexibility;**
- **Lower off-gas emissions.**

The use of alternative waste forms for problematic wastes also lowers the overall risk of the DOE's accelerated clean-up challenge by providing high performance HLW treatment alternatives.

The waste form is the key component of the immobilization process.

To achieve maximum cost savings and optimum performance, the selection of the waste form should be driven by the characteristics of the nuclear waste to be immobilized, rather than by adopting a single baseline approach. At the same time, it is the waste form that determines how well the waste is locked up (chemical durability), and the number of disposal canisters required (waste loading and repository storage efficiency).

The use of tailored, high-performance, alternative waste forms that include ceramics and glass-ceramics, coupled with alternative mature process technologies such as hot-isostatic pressing, sintering and cold-crucible induction melting, offers significant performance improvements and efficiency savings to the cleanup program for wastes difficult to incorporate in glass.

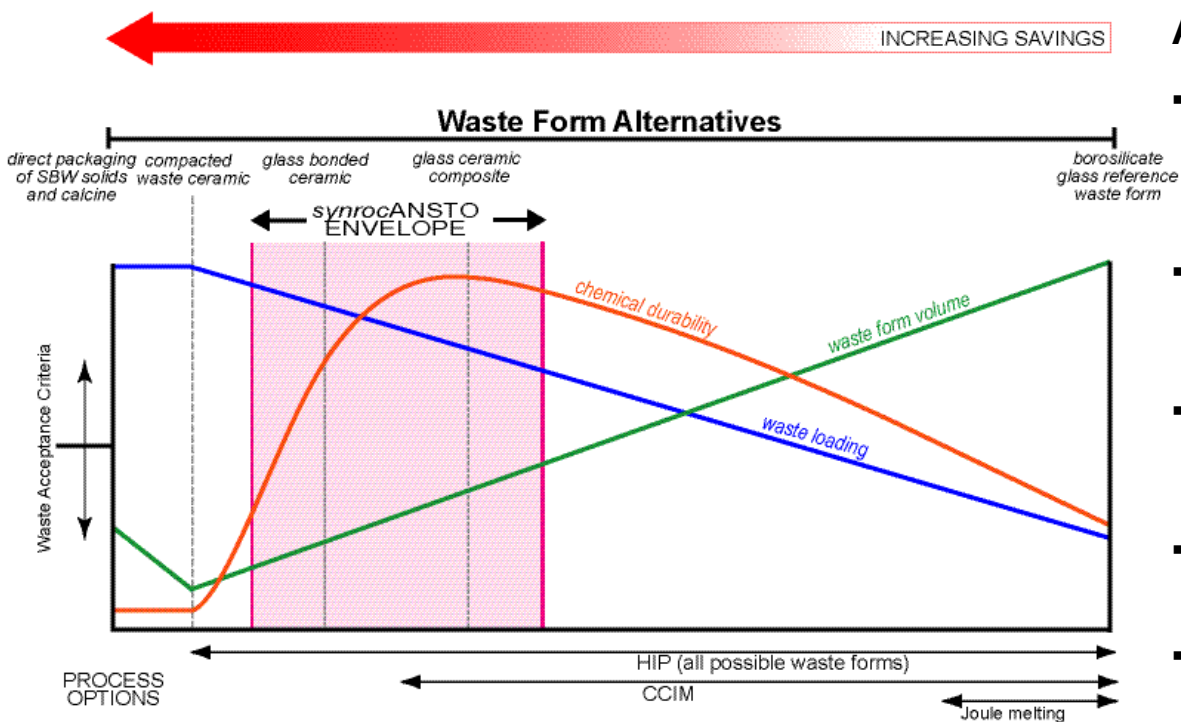
INEEL SBW and HLW Calcines

The following diagram illustrates the benefits of *synroc*ANSTO's alternative waste forms approach when applied to INEEL SBW and HLW calcines.

The current baseline approach is shown on the right-hand side of the diagram. Due to the significant quantity of waste components that are problematic to incorporate in glass, the baseline borosilicate glass technology has a relatively low waste loading, high waste form volume and minimum acceptable chemical durability - and therefore the maximum cost over the lifetime of the immobilization campaign.

If relatively high value is given to only two factors – cost savings and waste form durability – then the optimum alternative corresponds to the *synroc*ANSTO envelope of glass-ceramics.

Waste Form Options for SBW and Calcines



Potential Advantages

- 50% (over \$2B) cost savings over baseline processes
- 7-year reduction in cleanup schedules
- 6700 fewer canisters –50% volume reduction
- retrofit current processing facilities
- virtual elimination of off-gas

By tailoring the selection and design of the waste form and process technology to suit the unique characteristics of these waste streams, waste loadings of 50-70% are possible.

The significant increase in waste loading achievable with glass-ceramics means that 6,700 fewer disposal canisters (50% reduction) are required to complete the cleanup compared to the nearly 14,000 disposal canisters required by borosilicate glass. INEEL and ANSTO have determined that the use of *synrocANSTO* glass-ceramic waste forms for SBW and HLW calcines offers 50% cost savings (over \$2 billion) and a 7 year reduction in processing schedules over the baseline borosilicate glass[#].

The glass-ceramic waste form immobilization technology is also exceedingly flexible in regard to process and chemistry. Two formulations have been shown to incorporate the entire compositional range of the HLW calcine bin sets with a third formulation developed for the SBW. The breadth of the processing window minimizes risk from compositional uncertainty of the waste feed stream, while still maintaining significantly higher waste loadings and chemical durability than that of borosilicate glass.

Actinides

synrocANSTO's alternative waste forms are equally beneficial for actinide-rich waste streams. These benefits were highlighted by the competitive selection of a pyrochlore-rich ceramic over lanthanide borosilicate glass by the DOE for the immobilization of excess weapons plutonium in the late '90s. The pyrochlore-rich ceramic, and associated process, was designed specifically to take into account

[#] Joint INEEL-ANSTO White Paper "Reduced Cost / Low Risk Waste Forms for INEEL Liquid Tank Waste and INEEL HLW Calcine", June 2004.

the unique immobilization challenges posed by impure fissile plutonium. Specific advantages of the pyrochlore-rich ceramic over lanthanide borosilicate glass included:

- much greater proliferation resistance (10-1000 times more chemically durable);
- immobilizes 50% more plutonium;
- 8 times lower neutron dose;
- inbuilt criticality safety over the lifecycle.

*synroc*ANSTO's alternative waste forms can be readily designed to accommodate other actinide-rich waste streams, including compositionally diverse and heterogeneous waste streams that are often considered intractable because of their complex chemistry and incompatibility with borosilicate glass.

Technetium, Cesium, Strontium and Iodine

*synroc*ANSTO's waste forms also benefit the management of niche waste streams containing technetium, cesium, strontium and iodine through developing a range of waste form solutions that manage the unique risks posed by these waste streams.

The integration of waste form and process design enables the elimination of volatility concerns during consolidation, via the use of hot-isostatic pressing technology (HIP). The waste forms use extremely durable *synroc* phases that have demonstrated their ability to incorporate these radionuclides and survive over geological timeframes. The resulting matrix achieves maximum waste loadings whilst minimizing associated environmental risks related to off-gas emissions and final repository disposal.

*synroc*ANSTO's high-performance waste forms are designed particularly for problematic HLW streams difficult to incorporate in glass. They offer lower risk, lower cost options to the diverse HLW DOE legacy cleanup challenge, via flexible and proven process technologies.

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