CONF-781250--1

Lawrence Livermore Laboratory

THE ROCK MELT APPROACH TO NUCLEAR WASTE DISPOSAL IN GEOLOGICAL MEDIA

J.J. COHEN AND T. L. STEINBORN

JANUARY 1979

MASTER

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

This paper was prepared for submission to:
PROCEEDINGS OF SCIENCE UNDERLYING WASTE MANAGEMENT
December 1, 1978, BOSTON, MASSACHUSETTS

This is a preprint of a paper intended for publication in a journal or proceedings. Since changes may be made before publication, this preprint is made available with the understanding that it will not be cited or reproduced without the permission of the author.

THE ROCK-MELT APPROACH TO NUCLEAR WASTE DISPOSAL IN GEOLOGICAL
MEDIA

JERRY J. COHEN AND TERRY L. STEINBORN

LAWRENCE LIVERMORE LABORATORY

LIVERMORE, CALIFORNIA 94550

The effect of temperature rise due to decay heat has been a source of serious concern in conventionally proposed methods for disposal of nuclear waste in geologic media.^{1,2} Detrimental effects of increased temperatures can be manifested directly by degrading the waste form itself,³ or indirectly by alteration of surrounding geologic and hydrologic environment so as to enhance access of ground water to the waste.⁴

An unconventional method for geologic disposal of nuclear waste has been proposed which could utilize this decay heat for beneficial purposes.^{5,6} This is the rock-melt concept which calls for the direct addition of high level waste either in solution or slurry form into a deep mined cavity in silicate rock. Following the period of waste addition, the cavity is allowed to boil dry. Subsequently, the decay heat melts the waste and the surrounding rock. The molten rock dissolves the waste and the molten mixture grows, reaching its maximum radius in times typically estimated at tens to hundreds of years.⁵ When the rate of conductive heat loss from the system exceeds that of heat input from radioactive decay, the system begins to cool and solidify. Total resolidification could require several centuries. During that period, fission products will have essentially decayed away, leaving the actinide components. The ultimate result would be the encapsulation of this radioactive material in a relatively insoluble rock matrix deep underground. At 1000 years after initial emplacement, the relative toxicity of the resolidified rock mixture would be less than 1% that of natural pitchblende. This is due to the fact that the total heat output of the accumulated nuclear waste can melt large volumes of the surrounding rock. For example, assuming

operational conditions described in reference 5, the waste would constitute only about 1.0% of the final mixture and the resultant plutonium content would be 0.4 ppm.

Siting Consideration

Since the rock-melt concept does not require solidification of the waste, pre-disposal processing of the liquid high-level waste is unnecessary. If the waste repository and fuel reprocessing plant can be co-located, the need for waste transportation may also be eliminated. These steps have been identified as potentially the most hazardous in the sequence of waste management operations.⁷

Careful selection of the repository site can enhance the long-term isolation of the waste. It should be possible to locate a geologic site to effectively exclude water from the vicinity of the waste for the first several hundred years after emplacement. One possibly suitable medium might be a relatively unfractured and therefore dry granite body, where the waste could be emplaced several hundred meters deep within the rock unit. Another possibility would be a thick unit above the water table. For example, this condition can be found at the Nevada Test Site where the waste could be emplaced up to a thousand meters deep in dry alluvium or volcanic material. This vadose zone is characterized by little or no water motion and by a high porosity so that any water that might enter the vicinity of the waste would be driven off as steam, precluding potentially dangerous pressure build-up.

Stability of Final Waste Form

In addition to hydrology, careful site selection can also enhance the long-term (post-melting) stability of the waste. Previous studies summarized by Isaacson and Brownell⁸ (see Table 1) indicate the relative stability of various waste forms. Among these experimental waste forms are examples of waste incorporated in melted basalts. The resulting waste form appears to be somewhat more stable than either phosphate or borosilicate glass.

Under proper conditions waste stability might be even further enhanced if the burial is sufficiently deep, cooling will be slow enough to permit crystallization of the melt into very stable mineral phases. By selecting the host rock chemistry or by adding appropriate materials, (e.g., PO_4 , Zr, etc.) the diluted waste will be contained in mineral phases which are extremely resistant to leaching, such as monazite, zircon, thorite and many others. For example, natural zircons have survived several heating/cooling cycles over several billion years with little or no loss of actinides elements or their decay products. Methods proposed for incorporation of waste into stable mineralogic forms such as "synrock"⁹ could be utilized in a rock melt applications. This would take advantage of both approaches.

TABLE 1*
CHARACTERISTICS OF SOME HIGH-LEVEL RADIOACTIVE WASTES *

PROCESS	PRODUCT FORM	WATER LEACHABILITY g cm ⁻² day ⁻¹
Cesium Chloride	Salt	>10
Pot Calcination	Calcine	5 x 10 ⁻¹
Fluid Bed	Granules	5 x 10 ⁻¹
Spray Melt	Ceramic or Glass	1 x 10 ⁻⁴
Phosphate Glass	Phosphate Glass	1 x 10 ⁻⁴
Fingal & Others	Borosilicate Glass	5 x 10 ⁻⁶
Chalk River	Nepheline Syenite Glass	5 x 10 ⁻⁷
Czech or Hanford	Basalt Melt	10 ⁶ to 10 ⁷
Thermal	Aluminosilicate Melt	2 to 8 x 10 ⁻⁷
Hanford STOPPER	Crystalline Aluminosilicate	5 x 10 ⁻⁸
Pollucite	Crystalline Aluminosilicate	2.9 x 10 ⁻⁸
Zircon	Crystalline Silicate	< x 10 ⁻⁸

*Date from reference 8

REFERENCES

1. Subgroup Report on Alternative Technology Strategies for the Isolation of Nuclear Wastes Interagency Review Group on Nuclear Waste Management. Draft Report TID 28818 October 1978, Washington, D.C. Available from NTIS.
2. State of Geological Knowledge Regarding Potential Transport of High-Level Radioactive Waste from Deep Continental Repositories. Report of an Ad Hoc Panel of Earth Scientists EPA/520/4-78-004 USEPA April 1978.
3. Neville, C. W. Cook, An Appraisal of Hard Rock for Potential Underground Repositories of Radioactive Waste. LBL-7004, UC-70 TID 4500-R 66, LBL Univ. of CA, Berkeley, CA October 1977.
4. T. R. Anthony, H. E. Cline, Thermal Migration of Liquid Droplets in Salt 4th Symp on Salt, Northern Ohio Geologic Society. Vol. 1, p.313-321 Ed. A. H. Coogin, Cleveland, Ohio 1974.
5. J. J. Cohen, A. E. Lewis, R. L. Braun, In-Situ Incorporation of Nuclear Waste in Deep Molten Silicate Rock, Nuclear Technology 13:76 April 1972.
6. J. J. Cohen, R. L. Braun, L.L. Schwartz, and H.A. Tewes, Economic and Environmental Evaluation of Nuclear Waste Disposal by Underground In-Situ Melting, UCRL-51713, LLL, Livermore, CA November 1974.
7. "Determination of Performance Criteria for High-Level Solidified Nuclear Waste" NUREG-0279, U.S. Nuclear Regulatory Commission July 1977.
8. R.E. Isaacson, L.E. Brownell, Ultimate Storage of Radioactive Wastes in Terrestrial Environments, Proc. OECD-IAEA Symp on the Management of Radioactive Wastes from Fuel Reprocessing, Paris France, December 1972.
9. A.E. Ringwood, Safe Disposal of High Level Nuclear Reactor Wastes: A New Strategy, Australian National University Press, Brooks Australian, Norwalk, CT, July, 1978.

"Work performed under the auspices of the
U.S. Department of Energy by the Lawrence
Livermore Laboratory under contract number
W-7405-ENG-48."

NOTICE

"This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately-owned rights."

Reference to a company or product names does not imply approval or recommendation of the product by the University of California or the U.S. Department of Energy to the exclusion of others that may be suitable.