

Cleaning up the Nuclear Waste at Hanford

The disposal of waste from the nuclear industry is a major problem. One of the worst affected sites is Hanford in Washington where thousands of people have been employed and billions of dollars have been spent just in preparation for a clean-up effort which is still many years away. But it is far from certain that the best possible option is being pursued.

by Adrian Ashfield, Ashfield Associates

Plутonium for the military was produced at the Hanford site until 1987. As a result 54 million gallons, comprising 60% of the country's most radioactive waste is stored there in 177 underground tanks, built between the 1940s and 1960s with a 20-year life expectancy.

The US Department of Energy (DOE) was charged with developing a plan to clean up the site in the 1980s. They employed as many as 18,000 people [1] at Hanford with an annual budget of \$1.5 billion – thousands more people than were employed when the site was in operation. Despite this huge expenditure, the waste still sits there except for the 1+ million gallons that have leaked from 67 of the 149 older single walled tanks.

A recent EPA audit stated. "Delays in the 30-year, \$50 billion effort to clean up hazardous wastes at Hanford are increasing the risks." [2] The DOE has indeed produced many plans and also developed procedures that allow them to report progress. These procedures

result in very slow actual progress and will result in a staggering estimated \$130 billion cost for completion.

Early efforts to solve the problem

It was recognized many years ago that the most effective way to immobilize the radioactive elements in the waste would be to trap them in glass. The challenge is to find a way of converting the waste to glass and storing that glass.

In 1974, Larry Penberthy demonstrated a molybdenum electrode furnace to Battelle-PNL. The demo was successful, and Battelle ordered a set of drawings for a 1 ton/day furnace. The furnace was built, but was dismantled a year later without testing. Battelle later stated that the process was already in wide commercial use and there was not enough research to be done. Instead, Battelle designed its own furnace using nickel alloy electrodes. This limited the furnace to producing a low-melting point, soft borosilicate glass. [3]

In a later demonstration, Penberthy

Electromelt designed and built a 6 ton/day vitrification furnace for the DOE in nine months for \$900,000 in 1981. In a proving run in June and July of 1981, the furnace produced excellent glass, but, despite having commissioned it, the DOE refused to inspect it. Instead the DOE hired a local company to cut it up and take the remains to the local scrap yard. [4] Just why is not clear but probably because DOE, lacking in-house expertise, relied on the opinion of a large contractor with a competing process. We understand that the Duratek furnace later suffered a similar fate although ironically this is now the DOE's preferred design.

Recent events

Two years ago the DOE awarded a \$3 million contract to British Nuclear Fuels Ltd. (BNFL) to develop a fixed price to vitrify 10% of the waste. They planned to start operation in 2007 with 10% of the waste vitrified by 2018. Eighteen months later the estimated cost had risen from \$6.9 billion to \$15.2 billion and the DOE cancelled

the contract in May 2000.

In August 2000 the DOE issued a new RFP (Solicitation No. DE-RP27-00RV14136) for companies to bid on continuing this same plan. In drafting the RFP, it has been made clear that no other alternatives will be considered. The main difference is that the contract is one of cost + incentive, instead of the contractor having to finance the operation until glass was delivered to the DOE.

The successful bidder is expected to use a scaled up version of the tiny all-electric furnace design with nickel alloy electrodes. The intention is to begin operation in 2007 and complete vitrification of 10% of the waste by 2018.

High cost option

A major contributor to the high cost of the DOE's preferred option is the department's insistence that the nuclear waste is separated by ion exchange into high and low levels. The vitrified high level waste is then to be deposited in the proposed Yucca Mountain site. The

low-level waste would also be vitrified but buried on site.

The extra processing involved dramatically increases the cost and our estimates place the total cost of the clean up at around \$130 billion with completion in 2070. There is also the technical disadvantage that the soft borosilicate glass composition is two orders of magnitude poorer in leaching resistance than alumino-silicate glass.

Reducing costs

The DOE plan is not the only viable solution. The most urgent problem is to prevent radioactive material leaking from the old tanks. DOE's plan is to pump liquid from the old tanks to newer ones. This double handling of very hazardous wastes increases both cost and risk, and with the present plan the liquid waste will not be stabilized by vitrification for decades. The liquid should be vitrified first.

Also, the ion-exchange separation step is unnecessary because the half-life of cesium and strontium is so short (32 years). In six half-lives (192

years), the activity will have decayed down to that of Class C low-level waste all by itself.

BNFL planned to use furnaces scaled up from 2.5 tons/day to 10 tons/day. The cost of the glassmaking step could be cut to less than half that projected by BNFL if industrial type furnaces rated at 50 tons/day were used. Yet more could be saved by avoiding the need to build repositories. The vitrified waste could be granulated and poured back into the emptied tanks.

The National Research Council recently published a report stating that 109 nuclear weapon development sites (including Hanford) will never be free enough of radioactive debris to allow unrestricted public use. Chairman Thomas Leschine elaborated to the LA Times that complete cleanup would be impossible at some sites and too expensive at others. "You lose the political will ... to continue pouring money into the problem." [5] Particularly if so much of it is wasted. If humans must be kept off the site anyway, what is the justification for transporting the vitri-

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fied waste off site to another very expensive storage facility?

Alternative proposal

Larry Penberthy has been involved in developing solutions to the Hanford clean-up since the process began. His current proposal, put forward through Penberthy Vitrification Inc (PVI) is both faster and less costly than the approach currently being adopted by the DOE.

The proposal centers on dealing with the liquid waste first. The 5 million gallons of liquid from the storage tanks would be solidified to a manageable form by absorption in diatomaceous earth (which provides most of the glass formers required). This solid material would then be fed into a Penberthy all-electric furnace to form a stable alumino-silicate glass which would be quenched in water to a granular form and fed back into the existing underground tanks - No liquids, no leaks.

Not counting time and cost to obtain permits, a 50 ton/day unit could be in operation in 2002 and all liquids vitrified in three years for an estimated \$356 million. That is completed before operations would even start with the current DOE plan. For comparison, furnaces around the world melt 40,000 tons of glass per day using Penberthy processes.

In this way, the vitrification process could be tested by starting with the liquids. They are 10% of the total. Once the liquids are vitrified the possibility of leaks is eliminated. Then Congress can decide whether it wants to vitrify the solids at an additional cost of \$8 billion, completed by 2012 using

eight similar Penberthy units, or, for \$129 billion with the DOE plan.

Process technology

In essence, the objective is to vitrify only the liquid portion of the tank contents, on the basis that only liquids can leak [6]. Solids do not leak from a buried tank, and so there would be little gain from vitrifying them. They will decay where they are, 100ft. underground, and radiation risk to workers trying to excavate it would be avoided.

The method proposed is to use heated auger equipment into which the liquids are mixed with diatomaceous earth (DE) and powdered coke. On heating, the following changes take place:

A. Water is evaporated, to go through filters before being condensed.

B. Organics are evaporated and go through an electrically heated chamber for oxidation before going through filters and release.

C. On further heating, the coke reacts with the sodium nitrate to form sodium oxide and gaseous nitrogen and carbon monoxide. The sodium, cesium and strontium oxides react with the silica of the DE but the DE remains a stable granular solid. The gases pass through another hot chamber and filters before release.

The glass furnace is rated 50 tons of glass per day, which consumes the liquids at the rate of 7000 gallons/day. The total quantity of liquid is 5,000,000 gallons, which at this rate will be used up in 700 days. The resulting glass would be granulated and fed back into one of the now empty tanks, where the radioactivity will decay to Class C Low Level in 190 years.

The part of the cesium and strontium that remains in the sludge will also decay, but it is surrounded by longer half-life elements which require permanent storage in the tanks. When cool enough, the tanks may be filled with local dirt and capped with a concrete dome.

Heated auger system

A pair of 10in diameter augers in a double 12in diameter casing has a feed hopper at the entry end. The length is estimated to be 100ft. The casing is surrounded by a tunnel made of insulating firebrick. A series of electric elements heat the tube from below.

The diatomaceous earth (DE) is fed into the hopper. As it moves along through the tube, the tank liquid is metered in to provide the required silica/soda final ratio desired in the glass. This ratio is 72 parts by weight SiO_2 to 15 parts Na_2O . DE is porous, and soaks up the liquid as soon as it is fed in.

The water in the mix is vaporized to steam which exits through spaced top ports in the tube. This steam will have in it a small amount of cesium and strontium as dust, and will be filtered and handled accordingly. After the water has evaporated, heating is continued to drive off organics. The vapors pass through an electrically heated chamber supplied with a balanced amount of air for oxidation. The temperature is 1600°F (970°C), low enough to avoid NOx formation. Again, these gases will have trace Cs and Sr, and will be filtered well before release.

After the organics are driven off, powdered carbon is

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metered into the dry mix in the tube, in a controlled ratio to react with the sodium nitrate/nitrite to convert it to Na_2O . The Na_2O actively combines with the silica of the DE, but does not melt because the temperature is kept below 1600°F (970°C). The DE mix remains granular.

Melter

The melter (vitrification furnace) is a well-known Cornelius/Penberthy furnace. Two such furnaces melting amber glass for bottles were operating in 1952 at Northwestern Glass, Seattle, and were converted from carbon electrodes to Penberthy molybdenum electrodes in 1952 and 1953. Each produced 30 tons of glass per day. They operated cold top for years.

The basic Cornelius furnace design was a refractory-lined metal box, inside dimension 10ft x 18ft x 60in deep. There was a traveling batch car which received a load of batch from a storage hopper at one end of the furnace and traveled slowly along the length of the furnace to deposit a layer of batch on the previous layer which had been melting out from below. Each new layer was about 1in thick. The total thickness of the batch blanket was 10in.

The granules from the auger pre-treatment system are mixed at the furnace with limestone and alumina to make this composition by weight:

SiO_2 , 72%; Na_2O , 15%; CaO , 10%; $\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$, 3%

This glass has been a standard glass for containers and plate glass for centuries. Its leaching resistance far exceeds that of the soft borosilicate glass proposed by BNFL.

The glass furnace will be located in a pit, 30ft x 50ft x 20ft deep. An x-y crane runs on rails along the 50ft side walls, under a roof having moderate shielding.

Around the rim of the pit will be eight Penberthy Hi-D lead glass windows in concrete control booths. The walls of the pit will be faced with water-cooled plates to absorb the radiant heat from the furnace. The power supply for the furnace will be 1500kW 400Hz, single phase, from motor-generator sets for highest reliability.

For this project, PVI would be teamed with a major glass furnace builder and a large engineering and construction firm.

References

1. *W.S.J. March 28, 1995*
2. *The Seattle Times July 10, 2000*
3. *Penberthy Paper #033 Mod 1*
4. *Report #1 Foundation for Affordable Nuclear Waste Disposal.*
5. *LA Times August 8, 2000*
6. *Penberthy paper #033 Mod 1*

Footnote

Adrian Ashfield (ashfield@concentric.net) is collaborating with Larry Penberthy on this project. He previously headed engineering for Canning Town Glass in the U.K., Domglas in Canada, Anchor Hocking and Wheaton Industries in the U.S., before starting Ashfield Associates in 1981.

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