DEVELOPMENT OF A FACILITY FOR FABRICATING NUCLEAR WASTE CANISTERS FROM RADIOACTIVELY CONTAMINATED STEEL[a]

J. A. Logan, M. M. Larsen
Idaho National Engineering Laboratory
EG&G Idaho, Inc.
Idaho Falls, Idaho 83415

ABSTRACT

This paper describes design of a facility and processes capable of using radioactively contaminated waste steel as the principal raw material for fabricating stainless steel canisters to be used for disposal of nuclear high-level waste. By such action, expenditure (i.e., permanent loss to society) of thousands of tons of uncontaminated chromium and nickel to fabricate such canisters can be avoided. Moreover, the cost and risks involved in disposing of large accumulations of radioactively contaminated steel as low-level radioactive waste (LLRW), that would otherwise be necessary, can also be avoided.

The canister fabrication processes (involving centrifugal casting) described herein have been tested and proven for this application. The performance characteristics of stainless steel canisters so fabricated have been tested and agreed to by the organizations that have been involved in this development work (Battelle Memorial Institute, DuPont, EG&G and the Savannah River Laboratory) as equivalent to the performance characteristics of canisters fabricated of uncontaminated wrought stainless steel.

It is estimated that the production cost for fabricating canisters by the methods described will not differ greatly from the production cost using uncontaminated wrought steel, and the other costs avoided by not having to dispose of the contaminated steel as LLRW could cause this method to produce the lowest ultimate overall costs.

INTRODUCTION

Currently, the large quantities of radioactively contaminated metal that have accumulated at various nuclear facilities throughout the United States are classified as low-level radioactive waste (LLRW), due to be disposed of at considerable expense. Contamination on the surfaces of this metal is subject to possible migration if mobilized (e.g. by water) during residence at the disposal sites. The cost of LLRW disposal by shallow land burial now is in the range of \$30 to \$50 per cubic foot, and this cost is likely to rise as more secure disposal methods are adopted to better ensure the long term isolation of contaminants in the waste.

Efforts have been made at various times to find ways to clean surface-contaminated metal and return it to unrestricted use to avoid the expense and the risks associated with its disposal as radioactive waste. However, the expense of cleaning the metal, the uncertainty as to whether metal that has been taken through decontamination processing will dependably prove adequately clean, and the lack of a well accepted de-minimus cleanliness level permitting unrestricted re-use, have prevented adoption of large-scale practices for recycling radioactively contaminated metal.

The problems associated with accumulations of radioactively contaminated metal are likely to become more severe as many nuclear power plants reach their end-of-life in the next several decades and undergo dismantling, thereby adding greatly to the total amount of such metal.

In 1982, the above considerations - and an inquiry from the Savannah River Plant - caused personnel in EG&G Idaho's Waste Treatment Development group, under the direction of the U.S. Department of Energy, to commence exploring the feasibility of recycling surface-contaminated metal into a re-use application not sensitive to the continued presence of limited amounts of radioactive contamination: specifically, using the metal as raw material for fabricating nuclear waste canisters.

The total amount of contaminated steel available throughout the U.S. was assessed by EG&G Idaho personnel and found ample to supply the raw material for fabricating thousands of the stainless steel canisters (see Fig. 1.) that will be needed for encapsulation of high level waste - in the manner now being implemented at the Defense Waste Processing Facility at Savannah River, and in cleanup operations at the West Valley Nuclear Fuel Reprocessing Site. This assessment work is reported in a separate Waste Management '86 paper, entitled "Test Programs Conducted in Support of HLW Canister Fabrication Using Radioactively Contaminated Steel."

The basic canister fabrication approach decided upon by the EG&G Idaho Waste Treatment Development group involves using relatively lightly contaminated metal as raw material (and partly decontaminating the more contaminated portion of that); melting the metal in an induction furnace; adjusting the alloy composition in an argon-oxygen decarburizer; centrifugally casting the metal to form a hollow cylinder about two feet in diameter and ten feet long; machining this to produce the cylindrical main portion of the canister; and welding end pieces to this cylinder to form the complete canister.

a Work supported by the Department of Energy under DOE Contract No. DE-AC07-76ID01570.

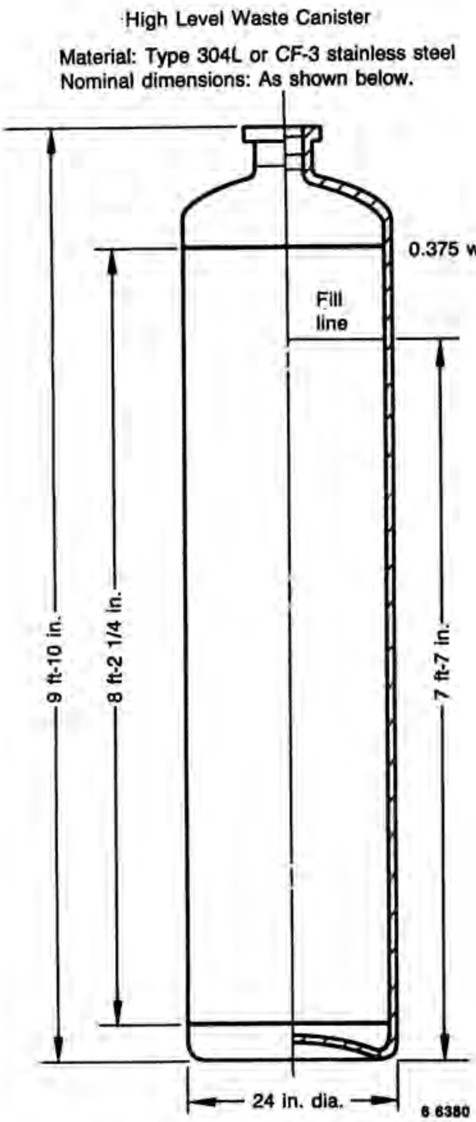

Fig. 1. High-Level Waste Canister.

To assess the adequacy of canisters produced by these methods, various test programs were conducted - at the Idaho National Engineering Laboratory, at Battelle-Columbus and Battelle-PNL, at the DuPont Laboratory in Wilmington, and at the Savannah River Laboratory. These included "spiking" metal melts with known contaminants to assess their effects on the process and the products; centrifugally casting contaminated metal; fabricating several full size canisters and cylindrical main sections; and testing and examining them in various ways, to ascertain the adequacy of such canisters for receiving molten borosilicate glass containing high-level waste and their adequacy for retaining the solidified waste material for extended time periods. At the end of these tests, all organizations involved (including Battelle, DuPont, EG&G and the Savannah River Laboratory) agreed on the adequacy of canisters so produced. These tests are also reported separately, in the above-mentioned paper.

CANISTER FABRICATION FACILITY DEVELOPMENT

Having determined that ample contaminated steel is available, and having confirmed satisfactory methods for producing canisters from this contaminated metal, design work at the Idaho National Engineering Laboratory (INEL) proceeded toward establishing a facility in which the capability could be developed to fabricate such canisters at a rate of several hundred per year.

A review of possible locations for such a facility resulted in the conclusion that the best location would be at the Waste Experimental Reduction Facility (WERF) at the INEL. The WERF already has some of the characteristics appropriate for developing canister fabrication capabilities. In fact, WERF accomplished the previously-mentioned tests involving melting metal spiked with known amounts of contaminants. The WERF has an operating staff which already has the capability of sizing (cutting), decontaminating, and melting metal containing radioactive contamination comparable to that identified for canister fabrication. Moreover, the equipment and systems now in WERF could be modified to provide some of the services (e.g., electric power and offgas control) required for developing canister fabrication capabilities.

The existence of the operating staff at WERF (about 15 people) means that much of the manpower required for the initial rather widely-spaced operations needed for testing equipment and developing procedures for canister fabrication could be made available at minimal cost. The WERF staff already has many of the operating qualifications needed for conducting the work.

Two basic approaches were pursued for creating a facility capable of producing the stainless steel canisters. The first approach was to pursue establishing an essentially stand-alone facility, to be located next to the WERF facility, and intended to be ultimately capable of producing canisters at a rate of 500 per year. The second approach was to pursue building a minimal WERF extension about two-thirds the size of the stand-alone facility, in which one of each unit of equipment essential for canister fabrication would be installed, and to use that to fully develop all portions of the process - after which the extension could be expanded as desired.

For the first approach, the facility would from the beginning contain all the equipment considered needed for eventually fabricating 500 canisters per year, including:

- o one or two coreless induction furnaces
- o one 4 ton Argon-Oxygen Decarburizer (AOD - a unit patented by Union Carbide Corp., used for molten metal refining and alloy adjustment)
- o two dual-mold centrifugal casting machines
- o one vertical heat treating furnace and quench tank
- o one or two lathes and a boring machine
- o two automatic welding machines
- o radiographic and liquid penetrant testing equipment.

Figure 2 shows the prospective location for the facility in relation to the WERF; and Fig. 3 depicts the internal layout of the canister fabrication facility. Principal operations would be as follows:

- o Metal sizing activities would be conducted at a rate of about 300 tons per year using

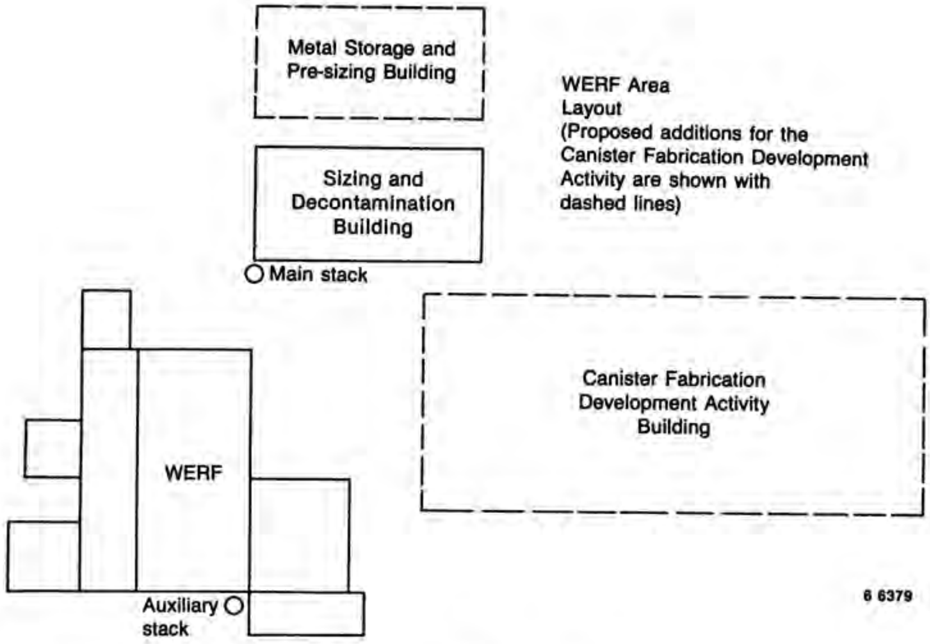

Fig. 2. WERF Area Layout.

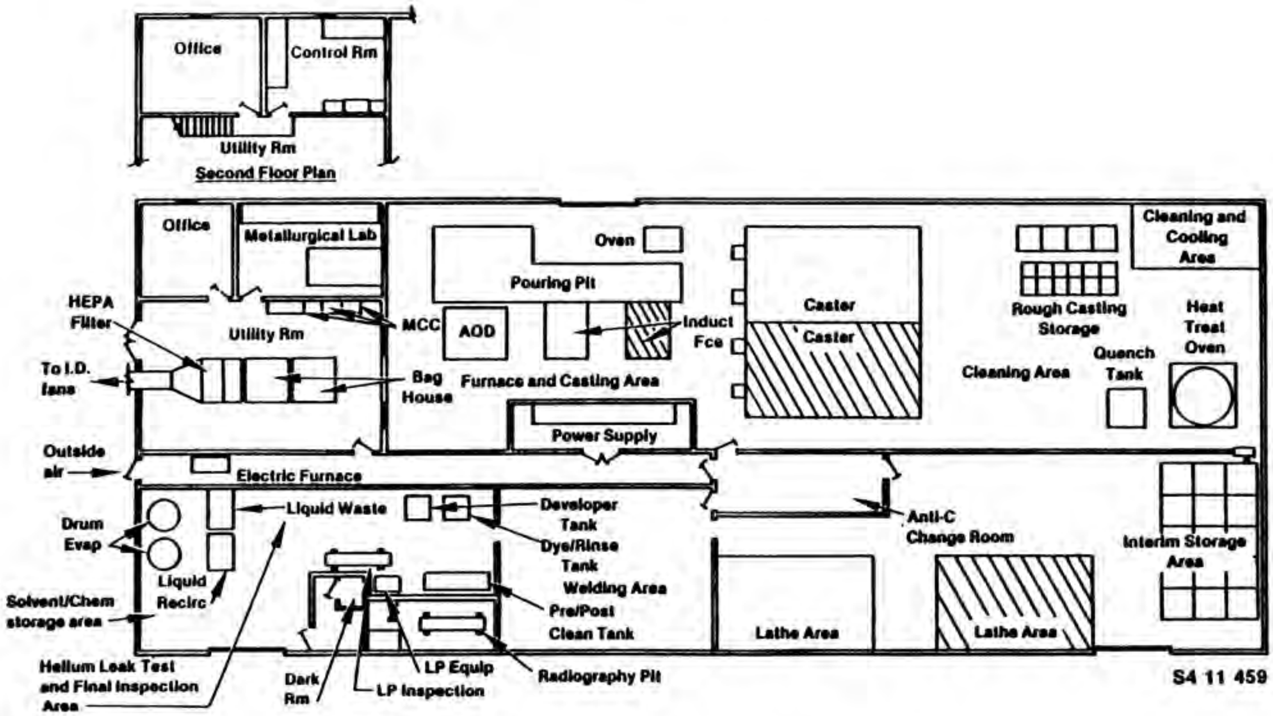

Fig. 3. Conceptual Layout of Canister Fabrication Facility.

plasma arc torches in the WERF sizing room. This room would be enlarged as necessary to accommodate these activities along with and partially in lieu of similar work now underway at a rate not much different.

o Metal decontamination would be conducted at a rate less than the metal sizing rate, since much of the available metal will not need partial decontamination to produce canisters having a radiation intensity less than 0.5 mrem per hour at near contact - the preferred upper limit. This work would be accomplished using the electropolishing equipment that is presently in the existing WERF Decontamination Shop, which would be enlarged if necessary to accomplish the amount of decontamination work found to be needed.

o Metal melting activities in an 8000 lb coreless induction furnace. These would be similar to the metal melting activities conducted in WERF's existing 2000 lb coreless induction furnace.

- o The molten metal would be transferred directly to a 4 ton Argon-Oxygen Decarburizer and in it the carbon in the melt would be reduced to desired levels by oxidation and off-gasing of the resultant carbon dioxide,

  the alloy composition would be adjusted as necessary by the addition of alloying metals, and then the metal would be poured into a ladle for transport to the casting equipment.

- o Metal casting would be accomplished in two dual-mold centrifugal casting machines to produce as many as four cylindrical castings at a time, which then would be heat treated (solution annealed) and cleaned for machining.

- o Machining and boring would be performed on two separate machines for that purpose, and the canister top and bottom pieces (both fabricated of uncontaminated metal by a subcontractor) would then be attached using two automatic welding machines.

- o Non-destructive testing would occur at appropriate points in the production process. This testing would include real-time radiography and liquid penetrant testing.

The conceptual design of this facility was completed and reported in September 1983[1]. The preliminary design for the facility was completed in July 1985[2]. Much of the facility is a scale-up of technology already in use at WERF. The main areas involving potential problems, that are new to WERF, or at least not well-developed, are:

- o Production-scale metal decontamination. Electropolishing may not prove to be the best and most cost-effective method. Convenient partial metal decontamination will be an important element in overall facility contamination control.

- o Operation of the Argon-Oxygen Decarburizer (new to WERF) and control of the AOD's offgas. This offgas reaches high transient flows and temperatures, and it is desirable to provide heat removal and filtration equipment that can handle these without incurring excessive capital equipment costs or system maintenance costs.

- o Successful centrifugal casting and heat treating of the rather large thin-wall cylinders involved would also be new to WERF. The process has considerable accident potential, and it appears that some work is needed to improve its overall efficiency as well as its safety.

- o Efficient production-rate machining of the large castings to produce the cylindrical main portion of each canister. The specified dimensional tolerances require excellent metal cutting performance, considering the flexibility of these cylinders, and this needs to be consistently and efficiently achieved.

In summary, no problems are apparent that seem insurmountable. It is estimated that final design and construction of the facility would cost about $20 million (1985 dollars) and could be accomplished in about three years.

Thereafter, after full capabilities have been developed in all the necessary processing activities, it is estimated that the direct production cost per canister (at a production rate of 500 canisters per year) would be about $5000. This is not much different than the cost of procuring canisters made from uncontaminated metal; and it offers the advantages of conserving uncontaminated strategic materials such as chromium and nickel, and of reducing the volume of low-level waste metal that must be placed in disposal facility - by about 30 cu. ft. of disposal facility space for each canister made using recycled metal. At current and near-future projected waste disposal facility charges, this saving in disposal facility space has a value which would offset much of the canister production cost.

The second concept pursued for establishing facility capability to produce canisters involves extending the WERF, using a building about two-thirds the size of the full-production facility. The extension would be just large enough to house one of each unit of equipment necessary for canister fabrication, and would tap into the WERF for such services as electric power and offgas control. Constructing and equipping such an extension would cost an estimated $14 million. In this extension (see Reference 3), all the steps involved in canister fabrication could be undertaken and improved to the point where production practicality and cost per canister would be known quite accurately. Moreover, with a limited extension such as this, 100 to 200 canisters per year could probably be produced, using a limited number of personnel in addition to the WERF personnel staff. Subsequently, this extension could be enlarged to support whatever total production rate of canisters might be desired.

Regardless of whether the first or second approach is taken, the result would be an effective commencement of recycling the contaminated metals generated by the nuclear industry, in an application that should be mutually acceptable to all interested parties - including those who (because of their concern about possible environmental impacts) have opposed previous efforts to recycle radioactively contaminated metal. If the nuclear industry is to continue and to grow, recycling of the metal which it uses is highly desirable - instead of continuing to bury the many thousands of tons of metal resources contained in each generation of nuclear plants.

After this first contaminated metal recycling activity becomes well established, others (such as fabrication of components for future nuclear plants) can come along as recycling technology improves and as additional satisfactory applications are identified.

Even if the net dollar cost of the first contaminated metal recycling activity is initially found to be somewhat higher than the sum of the costs that would otherwise be incurred, it is still desirable now to establish a recycling method that is at least technically satisfactory, so that an operating recycling facility will exist where improvements and further applications of metal recycling technology can be fostered. By so doing, many of the problems now perceived with large and ever-increasing volumes of LLRW in need of permanent disposal (which include large quantities of our metal resources), would subside.

Note: At present, further action on this program has been suspended because of nonavailability of funding.

REFERENCES

1. J. A. Logan, M. M. Larsen and R. Y. Maughan, Conceptual Design for the Canister Fabrication Development Activity, EG&G Idaho WM-F1-83-020, June 1983.

2. EG&G Idaho ltr D. L. Uhl to J. B. Whitsett (DOE-ID) subj. Transmittal of the Canister Fabrication Development Activity Title I Design Specifications and Drawings, Uhl-451-85.

3. EG&G Idaho ltr D. L. Uhl to J. B. Whitsett (DOE-ID) subj. Alternative Prospective Programs for Canister Fabrication Development Activity, to Adjust to Limited Funding Availability, Uhl-659-84 dated 12/31/84.