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CONDITIONING PROCESSES FOR INCINERATOR ASHES

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SUMMARY

Three conditioning processes for alpha-bearing solid waste incineration ashes were investigated and compared according to technical and economic criteria: isostatic pressing, cold-crucible direct-induction melting and cement-resin matrix embedding.

1 INTRODUCTION

Applied research in the area of conditioning solid alpha-bearing waste incineration ashes has been conducted in recent years by the *Commissariat à l'Energie Atomique* under the auspices of the General Directorate for Science, Research and Development of the Commission of the European Communities. The objectives of this program have been to enhance the quality of the finished product for long-term storage, and to ensure maximum volume reduction.

Incinerable wastes taken into account for this study consisted of the following standard composition: 50% polyvinyl chloride (glove box sleeves), 5% polyethylene (bags), 35% rubber (equal amounts of latex and neoprene), 10% cellulose (equal amounts of cotton and cleansing tissues). This mix corresponds to projected wastes from a future mixed oxide fuel fabrication plant with an annual production of 100 metric tons. The conditioning unit will be required to process 1700 kg (i.e. 5.7 m^3) of ashes produced by the incineration facility each year.

Three ash containment processes were investigated and compared: isostatic pressing, melting and cement-resin matrix embedding. An engineering study was also carried out by a specialized department to determine the operating flow diagram and chronology, the resulting plant layout and process control principles under nuclearized operating conditions. The investment costs and annual operating costs were assessed.

2 ISOSTATIC PRESSING

Technical Overview

Compaction by high-temperature isostatic pressing involves applying multidirectional pressure on a vacuum-sealed container filled with waste ashes. The feasibility of this process was demonstrated with cylindrical stainless steel canisters of increasing diameters: 36 mm to define the pressing parameters, 140 mm to assess the physicochemical properties of the compacted ashes, and 300 mm to demonstrate industrial feasibility. Each cylinder was first packed successively using a 100 MPa unidirectional press to an ash density of about 1.6 to 1.8 $g \cdot cm^{-3}$. The canister was then fitted with a lid and vacuum-sealed before proceeding with the actual isostatic compaction process under a pressure of 150 MPa at 800°C, with a 2-hour residence time for the 36 and 140 mm dia canisters, and 4 hours for the 300 mm dia canisters.

Examination of a cross section through the canisters showed that the ashes were uniformly compacted. The physicochemical properties of the resulting material were investigated. The compression strength and leaching resistance were highly satisfactory (see comparative table in § 5 below).

A modified formula with a glass frit additive was investigated and found to be very effective in increasing the density of the resulting product, but the greater complexity of the process and severely deformed canisters outweighed this advantage.

Process Schematic

The two-part schematic (Figures 1 and 1a) indicates the major process equipment requirements and the chronology of operations up to the constitution of the waste package. The process was designed for 180 mm diameter canisters to allow the pressed products to be placed inside the larger R7 canisters used for vitrified fission product solutions. Each R7 canister can accommodate two layers of three pressed ash containers. Fifteen working days (i.e. 3 weeks) would be required on a 2-shift basis to process 1700 kg of ashes annually, producing 86 compressed canisters occupying 15 R7 waste canisters.

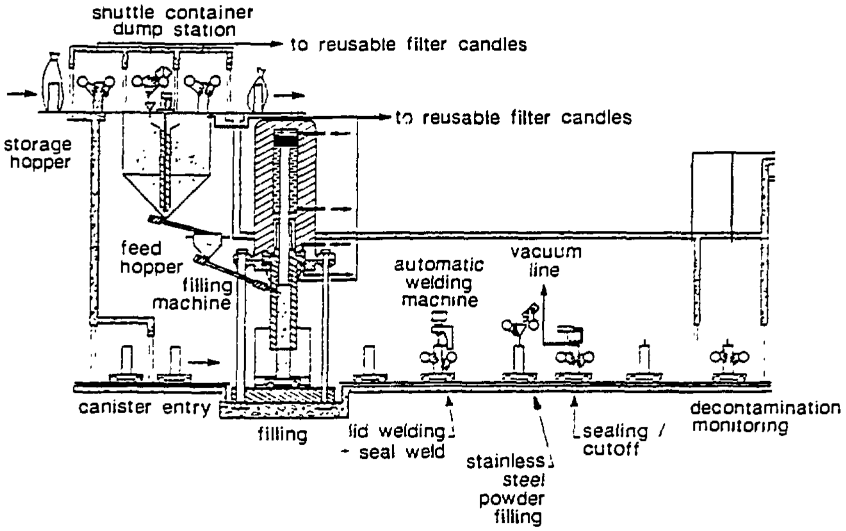

Figure 1 - ISOSTATIC PRESSING SCHEMATIC DIAGRAM

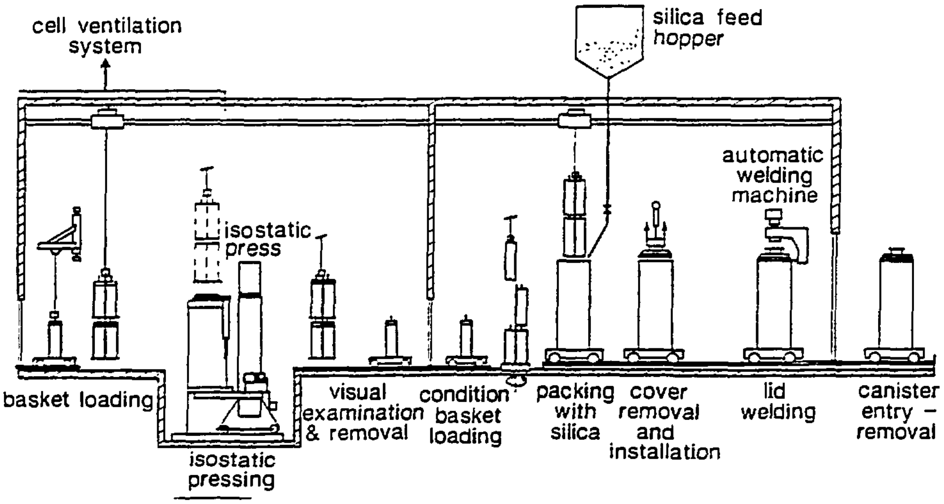

Figure 1a - ISOSTATIC PRESSING SCHEMATIC DIAGRAM

Proposed Layout

The isostatic pressing process layout based on the preceding flowsheet is shown in Figure 2.

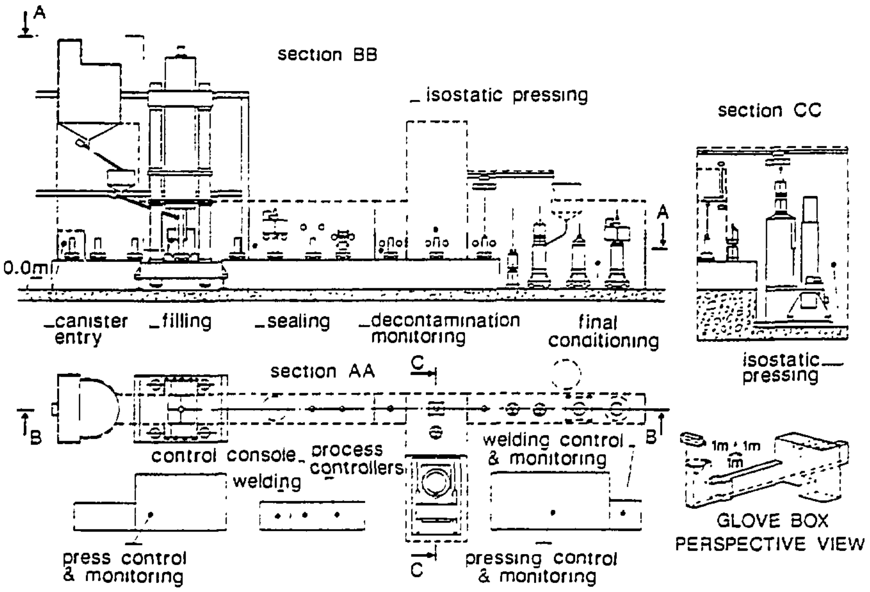

Figure 2 - ISOSTATIC PRESSING PROCESS LAYOUT

3 COLD-CRUCIBLE DIRECT INDUCTION MELTING

The ashes can be melted without additives at 1300 or 1400°C, but greater process flexibility is achieved by adding a primary glass.

Technical Overview

The objective is to form a new glass material from the primary glass and the waste ashes. The two technical aspects of the problems are the primary glass composition and the technological process.

Glass Composition

Two series of laboratory tests using ashes with silica (network former) and fluxing agent additives demonstrated that ash vitrification was feasible, and that a primary glass additive is preferable to allow easier melting and conditioning of ashes with different compositions, ensuring at least minimal network formation while allowing the process to be implemented at lower temperatures. Further testing will be required to specify the glass formula best suited to the induction heating process, requiring a glass resistivity between 1 and 10 Ω·cm at the process temperature.

Technological Process

The direct induction melting facility comprises the following specific equipment items:

- the current generator (approx 10 000 V at 100–200 kHz);
- the furnace, comprising a cold crucible, an inductor and a casting system.

The copper crucible is an assembly of independent water-cooled quadrants and is transparent to the electromagnetic field. The resulting induced currents dissipate their energy by Joule effect in the glass and ash melt batch.

Process feasibility was demonstrated by the SDHA at Marcoule using existing equipment with a glass composition routinely used to vitrify fission product solutions. The operation includes three major steps:

- First, the primary glass is melted to form the process heel, a routine step in glass melting.
- The ash and primary glass mixture is then added to the heel (the ashes melt readily and are perfectly incorporated into the glass)
- The molten mass is cast when a suitable level is reached in the crucible.

Throughput rates of 15 or even 20 kg·h^{-1} were obtained in cold crucibles 35 and 55 cm in diameter by melting airborne ashes from a domestic garbage incinerator together with 25–50% previously formed glass.

Process Schematic

Figure 3 shows the chronological order of the operations and indicates the required process equipment. A conditioning unit of this type would be operated two weeks a year in three 8-hour shifts 5 days a week to process 1700 kg of ashes. It would produce a total of six R7 glass canisters each year.

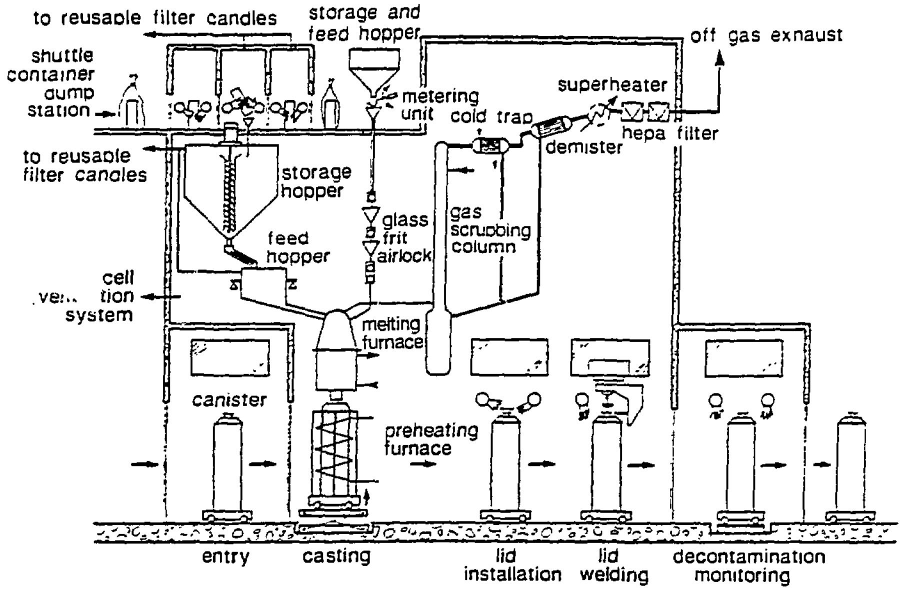

Figure 3 – DIRECT-INDUCTION MELTING SCHEMATIC DIAGRAM

Proposed Layout

The direct induction ash conditioning process schematic implies the layout shown in Figure 4.

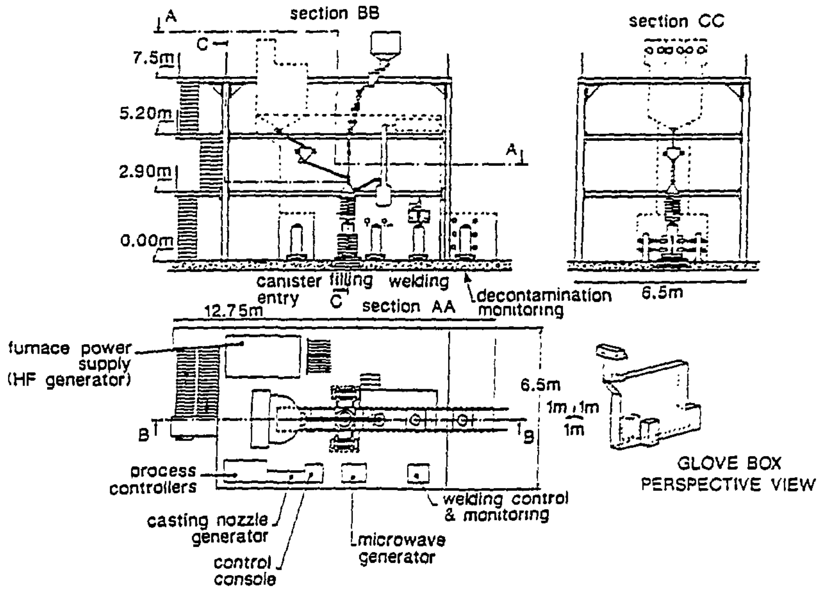

Figure 4 – DIRECT-INDUCTION MELTING PROCESS LAYOUT

4 CEMENT-RESIN MATRIX EMBEDDING

Technical Overview

This process ensures uniform embedding of ashes in a cement and thermosetting resin matrix. Weighed quantities of ashes, cement, water, resin and hardener are mixed together, and the resulting material is poured into 100- or 200-liter waste drums.

The results of compression strength and leaching resistance measurements on the embedded material are indicated in the comparative table in § 5 below.

Process Schematic

The process chronology is indicated in the diagram (Figure 5) together with the equipment requirements. Seven working days by two shifts would be necessary to condition 1700 kg of ashes in fourteen 200-liter drums.

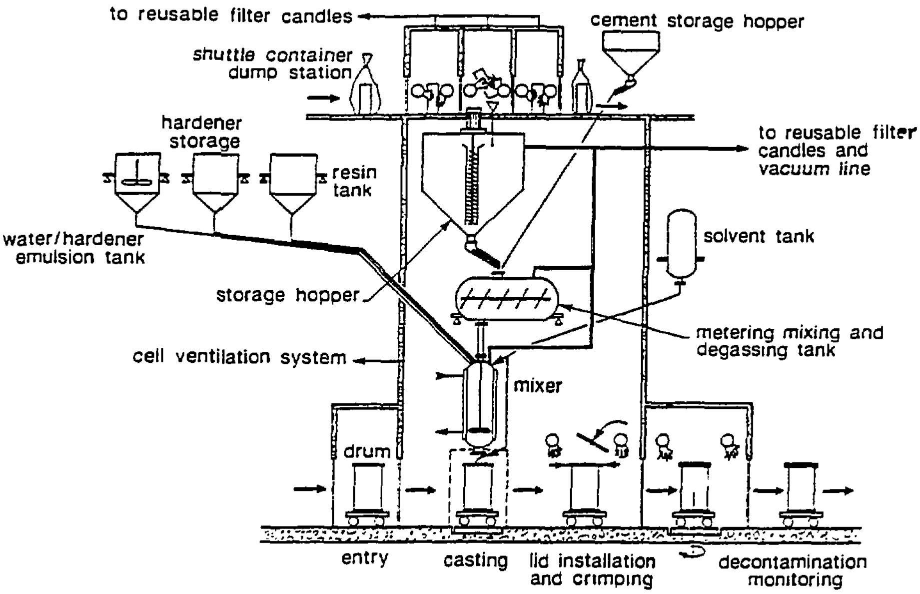

Figure 5 – CEMENT-RESIN EMBEDDING SCHEMATIC DIAGRAM

Proposed Layout

The proposed resin-cement matrix embedding facility is shown in Figure 6.

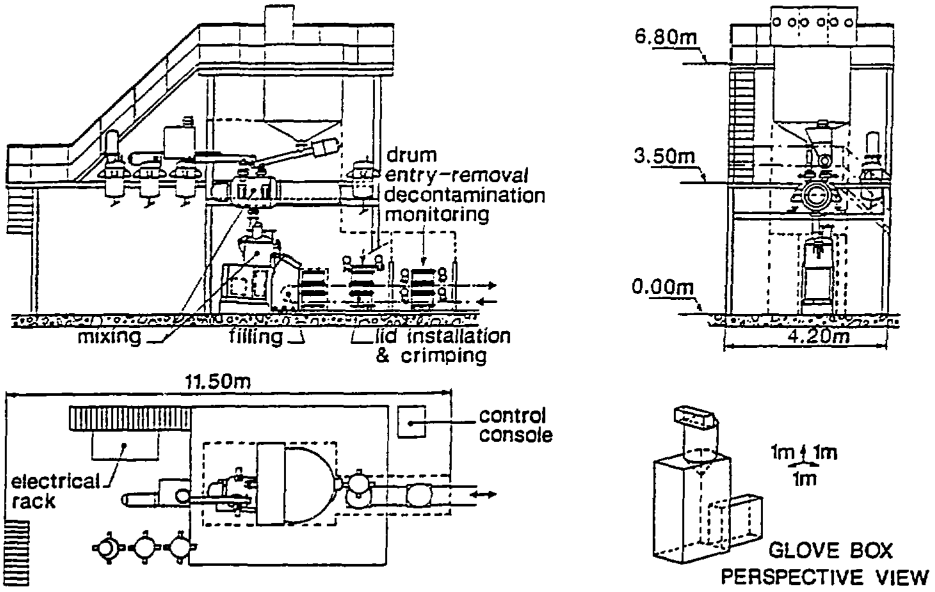

Figure 6 – CEMENT-RESIN EMBEDDING PROCESS LAYOUT

5 TECHNICAL AND ECONOMIC COMPARISON OF THE THREE PROCESSES

Technical Assessment

Two major parameters are compared in the following table:

- the final product quality, indicated by compression strength and leaching resistance measurements;
- the volume reduction factor, (the ratio of the final product volume to the initial ash volume).

Technical Parameters		Direct Induction Melting	Isostatic Pressing	Resin-Cement Matrix Embedding
Mechanical Properties	Compression Strength	100 MPa	100–200 MPa	65 MPa
Dynamic Leaching Resistance	Mass loss ($g \cdot cm^{-2} d^{-1}$) after 14 days	2.16×10^{-4}	7.40×10^{-4}	12.72×10^{-4}
Final Product Volume*		1.1 m^3	2.8 m^3	3.1 m^3

* corresponding to the annual ash volume of 1700 kg (i.e. 5.7 m^3) of ashes

Table 1 - TECHNICAL ASSESSMENT

Except for the higher compression strength of the isostatically pressed material, the most favorable results were obtained for cold-crucible direct induction melting; this product gave better results for all three criteria than resin-cement embedding.

The comparative volume reduction is illustrated in Figure 7.

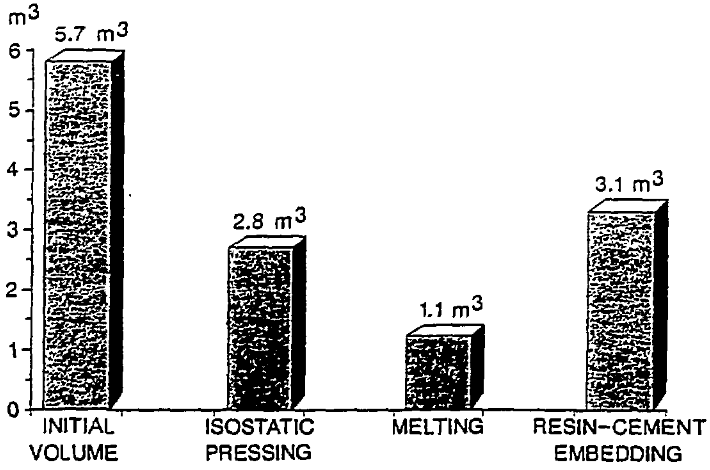

Figure 7 – COMPARISON BETWEEN INITIAL* AND CONDITIONED ASH VOLUMES (*ANNUAL INCINERATION FACILITY PRODUCTION VOLUME)

Economic Assessment

In addition to the final waste volume, the three processes were compared according to the following criteria:

- layout volume (i.e. α containment volume): Figure 8 shows that the isostatic pressing facility would require the largest floorspace and volume, while the other two processes have similar layout requirements.
- investment cost: Figure 9 clearly indicates the cost-ineffectiveness of isostatic pressing (due to the prohibitive cost of the unidirectional and isostatic presses); the investment costs for melting would be about 1.5 times higher than for embedding.
- annual costs (including depreciation): Figure 10 again shows the cost handicap of the isostatic pressing process; annual operating costs for the melting process would again be about 1.5 times higher than for embedding.

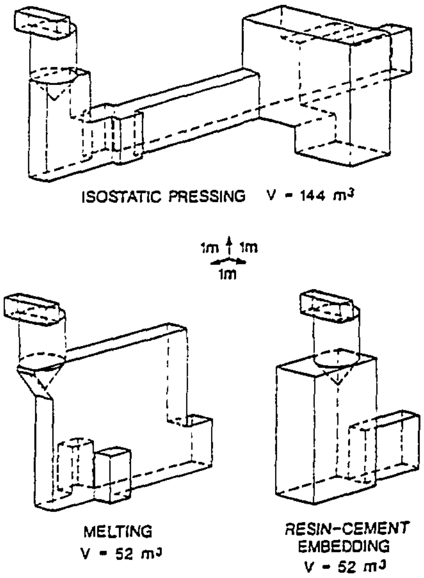

Figure 8 – COMPARATIVE LAYOUT VOLUMES (α CONTAINMENT)

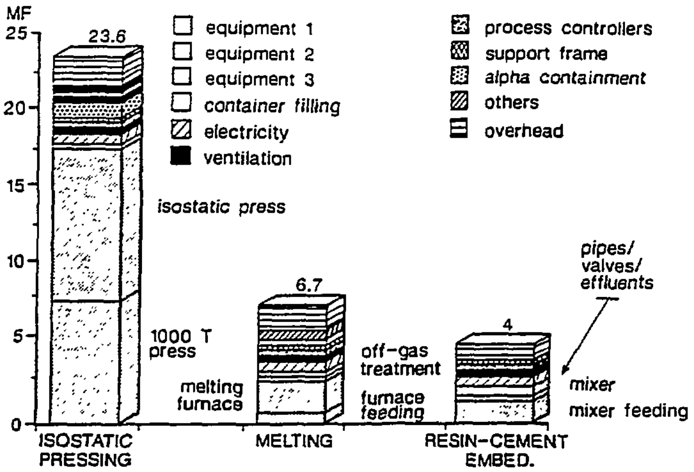

Figure 9 – COMPARATIVE CAPITAL COST

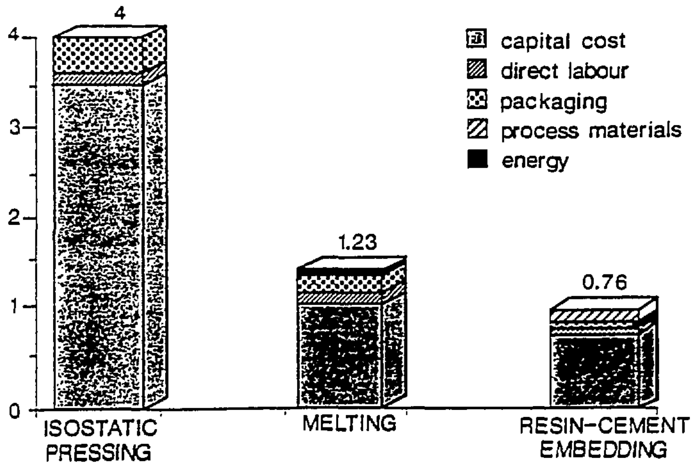

Figure 10 - COMPARATIVE TOTAL ANNUAL COST (MILLIONS OF FRANCS)

PROCESS	COST	FEASIBILITY	FINAL VOLUME	PRODUCT QUALITY	TOTAL
HIP	1	1	2	2	6
Melting	2	2	3	3	10
Embedding	3	3	1	1	8

1: poor
2: satisfactory
3: very good

Table 2 - OVERALL COMPARISON

6 CONCLUSIONS

Despite the good quality of the finished product, the isostatic pressing process for ash conditioning is heavily penalized by a containment volume 3 times larger and investment and operating costs 3 to 4 times higher than for the other two processes.

Compared with the resin-cement matrix embedding process, cold-crucible direct induction melting requires a similar layout volume and incurs investment and operating costs about 1.5 times higher. Conversely, the final product quality is significantly better with induction melting, and the final volume reduction is nearly 3 times greater (this parameter is very significant in the case of a geological repository, and thus from an overall cost-effectiveness standpoint).

In the final analysis (Table 2), on the basis of the four major criteria considered (cost, feasibility, final product volume and quality) induction melting is the most favorable process.