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INCINERATION ASH CONDITIONING PROCESSES

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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 corresponding to projected wastes from a future mixed oxide fuel fabrication plant with an annual throughput of 1700 kg (i.e. 5.7 m^3) of ashes produced by the incineration facility:

- 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).

The work focused mainly on compaction by high-temperature isostatic pressing, an is described here in some detail with the results obtained. An engineering study was also carried out to compare this technology with two other ash containment processes: direct-induction (cold crucible) melting and cement-resin matrix embedding.

ISOSTATIC PRESSING

Compaction by high-temperature isostatic pressing involves applying multidirectional pressure on a vacuum-sealed container filled with waste ashes.

Investigation Procedure

Small (36 mm dia) cylinders with actual waste ash samples were first used to determine basic process parameters: the type of container, the container filling method, the isostatic press operating parameters (temperature, pressure and time) and the effects of additives in the ash composition.

This step was followed by tests with 140 mm diameter cylinders containing actual waste ashes to determine the physicochemical properties of the resulting material, and by industrial feasibility tests on 300 mm dia cylinders containing incinerated domestic waste ashes.

Summary of Results

The objective was to obtain a solid product that adheres to the container walls without any apical void

Operating Parameters

A stainless steel container (as will certainly be required for radioactive ashes) with an inside diameter of 36 mm and a 3 mm wall thickness was selected for the tests. Each cylinder was first packed successively using a unidirectional press to an ash density of about 1.6 to 1.8 $g \cdot cm^{-3}$. The canister was then fitted with a cover and vacuum-sealed.

The optimum combination of process variables for the subsequent isostatic compaction process itself was a pressure of 150 MPa at a temperature of 800°C (1472°F) with a 2-hour residence time. The resulting specific gravity was relatively high (2.47) and the product adhered satisfactorily to the canister walls.

Tests were also conducted with glass frit additives, either to enhance the quality of the pressed material or to simplify the operating conditions while maintaining the same quality. The additive was found to be quite effective (s.g. 2.94 for a mixture containing 25% frit) but the canisters were highly deformed. The additives did not result in any simplification of the pressing procedure, and entails a number of drawbacks: powder mixtures (ashes and additives) are always difficult to prepare, and the resulting final volume would be greater than for the ashes alone. This option was therefore abandoned.

Physicochemical Properties

Containers 140 mm in diameter were produced to verify feasibility of the process in this size range and to determine the physicochemical properties of the compacted ashes.

At 800°C (1472°F) after 2 hours at 150 MPa the canisters were normally and regularly deformed. Examination of a cross section through the canisters showed that the ashes were uniformly compacted and adhered to the walls.

The compression resistance of the pressed ashes was excellent: 100 – 200 MPa.

The chemical quality was assessed from the ash leaching resistance under both static and dynamic (Soxhlet) conditions in boiling water, as routinely used to estimate the leach rates of glass specimens. The mean normalized mass losses observed after 14 days were 3.04×10^{-4} $g \cdot cm^{-2} d^{-1}$ under static conditions, and 7.41×10^{-4} $g \cdot cm^{-2} d^{-1}$ under dynamic conditions. These values are on the same order of magnitude as those measured for fission product containment glasses.

Industrial Feasibility

A 300 mm dia container was manufactured to confirm the industrial feasibility of the isostatic pressing process. After a 4-hour residence time at 800°C (1472°F) under a pressure of 150 MPa, the resulting calculated specific gravity was 2.4. The pressed ashes appeared uniformly compacted when observed on a cross section through the canister.

ISOSTATIC PRESSING, MELTING AND CEMENT-RESIN EMBEDDING PROCESS FEASIBILITY

For each of the three technologies, an engineering study defined the operating flowsheet listing the principal equipment items required and the operating sequence up to final conditioning.

The resulting plant layout and investment costs were also assessed, and will be discussed at the international workshop "Ashes 90" (Aix-en-Provence, France: June 12 – 15, 1990).

Isostatic Pressing

The process is shown in the schematic diagrams (Figures 1 and 1a).

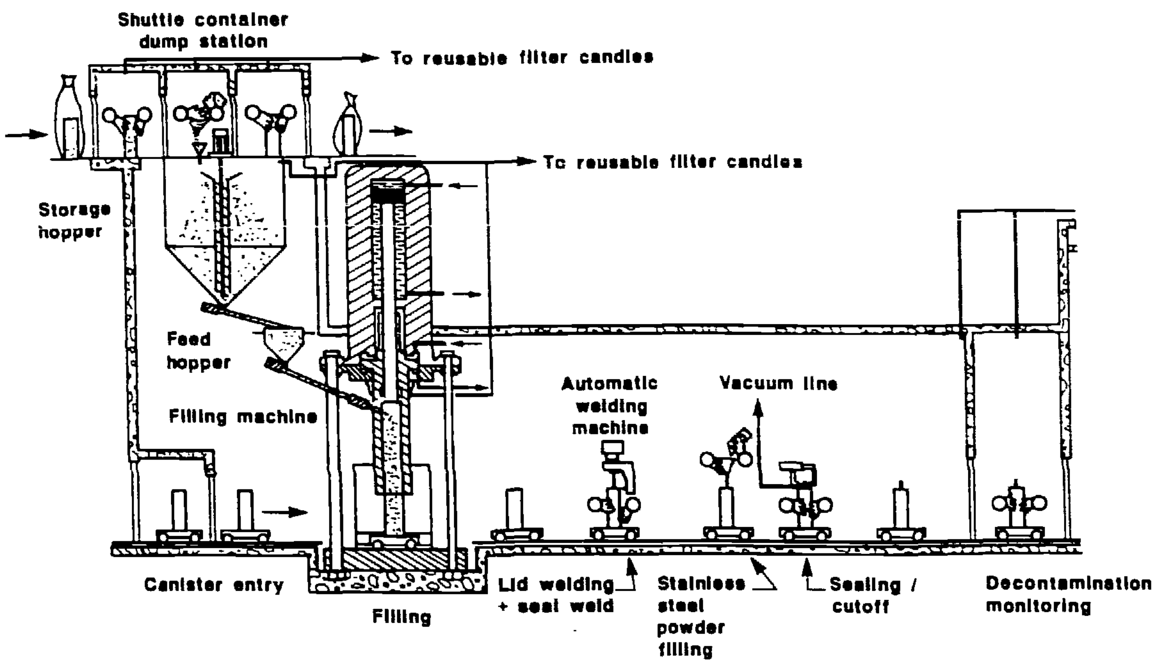

Figure 1 – α INCINERATION ASH CONDITIONING: ISOSTATIC PRESSING SCHEMATIC DIAGRAM

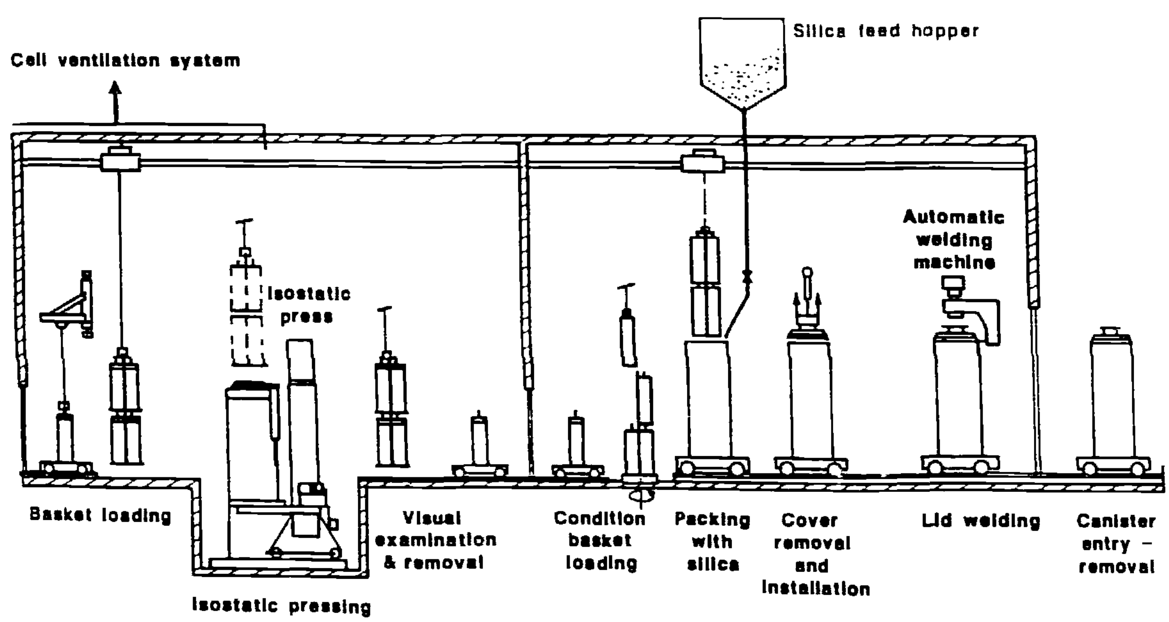

Figure 1a – α INCINERATION ASH CONDITIONING: ISOSTATIC PRESSING SCHEMATIC DIAGRAM

The five main process steps are:

- feeding ashes to the pressing line
- filling the canisters with ashes
- sealing the canisters
- isostatic pressing
- final conditioning.

Direct-Induction (Cold Crucible) Melting

The objective is to produce a new glass material in a metallic melting furnace from the primary glass and the waste ashes. Process feasibility was demonstrated with existing facilities used for vitrification of fission product solutions. The process is illustrated in Figure 2.

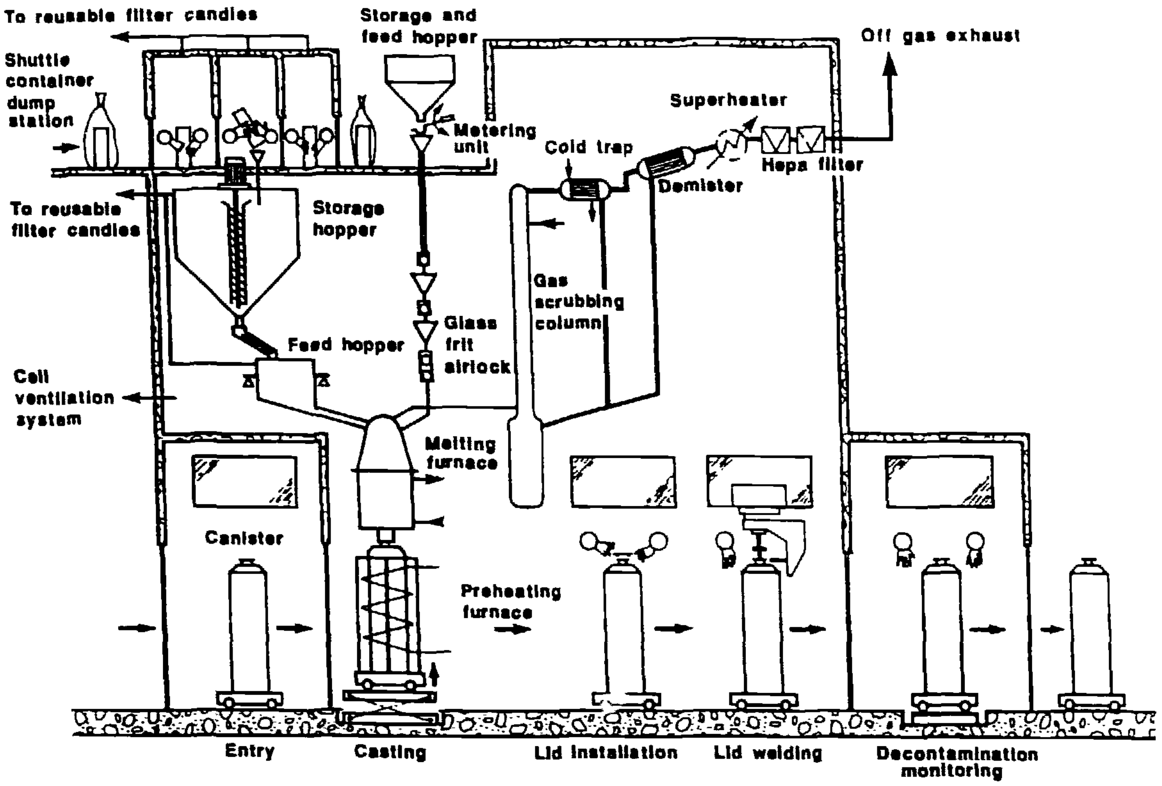

Figure 2 – α INCINERATION ASH CONDITIONING: MELTING SCHEMATIC DIAGRAM

The operating sequence includes the following major steps:

- feeding ashes and glass frit to the melting furnace
- melting and casting
- removal of the glass canister.

Cement-Resin Matrix Embedding

This process ensures uniform embedding of ashes in a cement and thermosetting resin matrix. The process is shown in Figure 3.

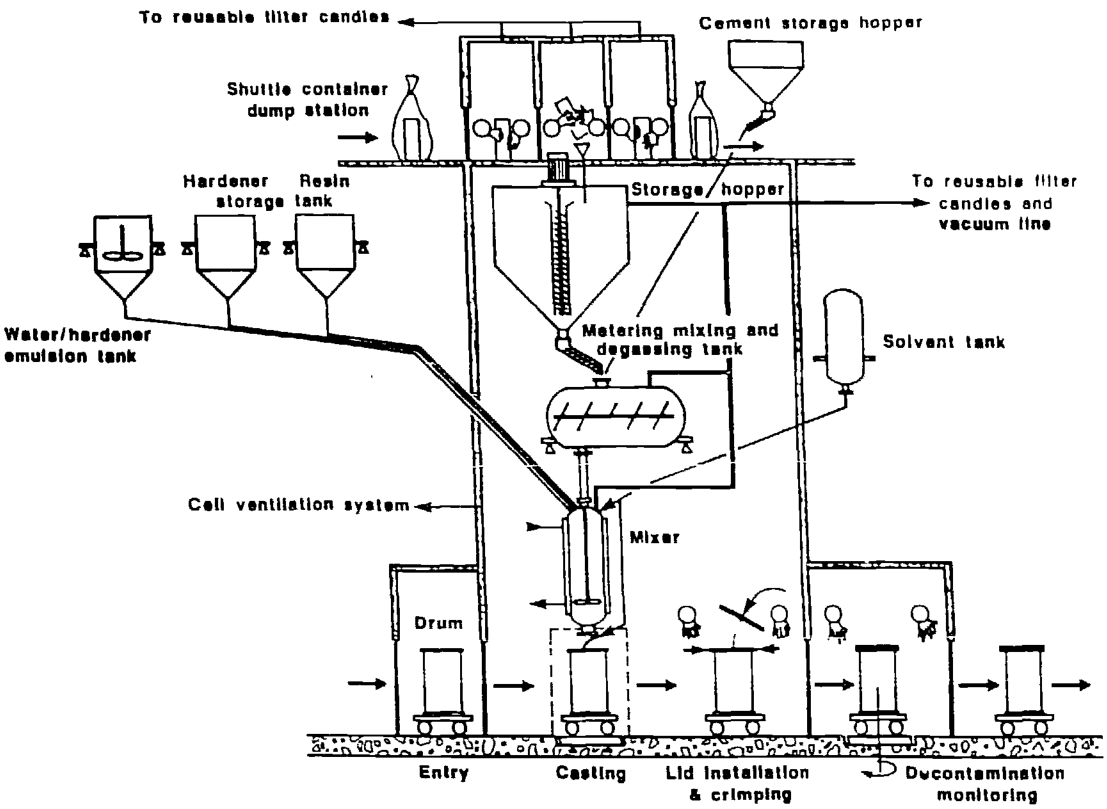

Figure 3 – α INCINERATION ASH CONDITIONING: CEMENT-RESIN EMBEDDING SCHEMATIC DIAGRAM

The embedding process includes the following steps:

- metering of feed streams by weight: ashes, cement, water, resin and hardener
- mixing of components
- casting of embedded material into drums.

TECHNICAL AND ECONOMIC COMPARISON

Comparative Waste Volume

The 1700 kg of ashes produced annually by the incineration facility represent a volume of 5.7 m^3. The corresponding final waste volumes produced by the conditioning processes are:

• isostatic pressing	2.8 m^3
• induction melting	1.1 m^3
• cement-resin embedding	3.1 m^3

The volume reduction is illustrated in Figure 4, which compares the final storage volumes to the initial ash volume.

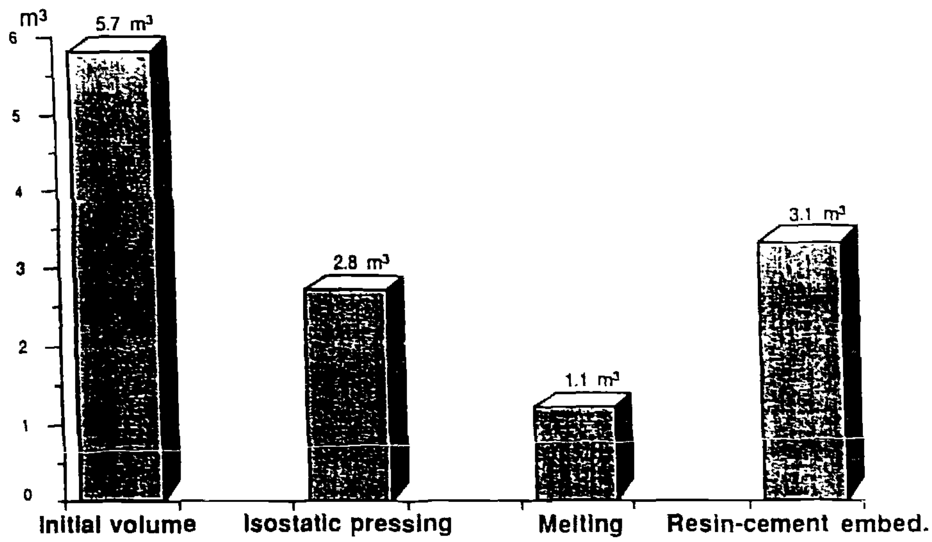

Figure 4 – COMPARISON BETWEEN INITIAL AND CONDITIONED ASH VOLUMES (ANNUAL PLANT OUTPUT)

Estimated Annual Cost

The annual cost was estimated for each process, including capital costs and proportional costs (personnel, packaging, process raw materials and energy). The three estimates are compared in Figure 5.

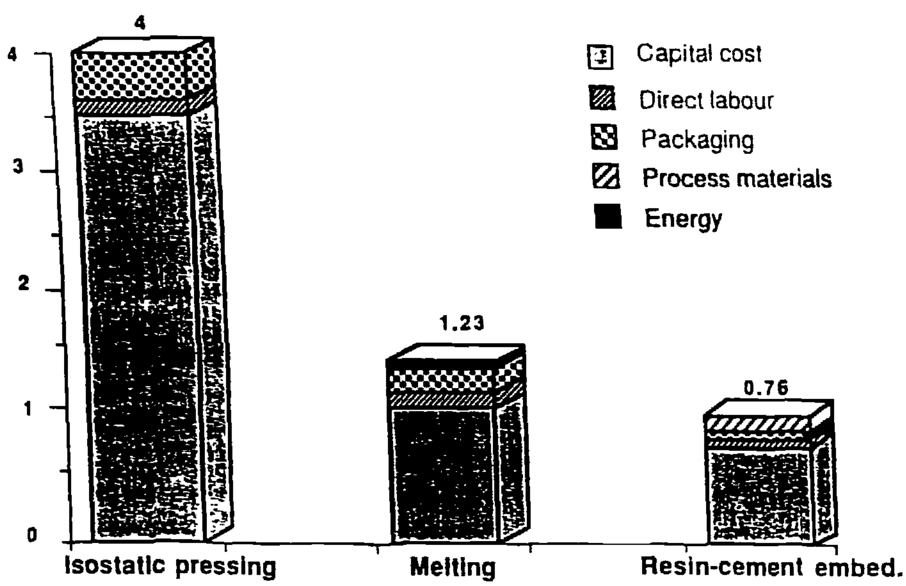

Figure 5 – COMPARATIVE TOTAL ANNUAL COSTS FOR THE THREE PROCESSES (MILLIONS OF FRANCS)

CONCLUSIONS

Despite the quality of the finished product, the isostatic pressing process for ash conditioning does not provide the highest volume reduction, but incurs by far the highest operating costs.

Induction melting is considerably less costly than isostatic pressing; the operating costs are about 1.5 times higher than for cement-resin embedding, but the volume reduction is nearly 3 times greater.

Cement-resin embedding involves the lowest operating costs, but results in the lowest volume reduction factor.