

CHALLENGES IN RETROFITTING OF CERAMIC MELTER IN PLACE OF LIQUID FED METALLIC MELTER

R. K. Gupta, U. Dani, K. N. S. Fair, K. Banerjee
Nuclear Recycle Group
Bhabha Atomic Research Centre
Trombay, Mumbai-400085, India

ABSTRACT

A modified pot glass process using induction heated liquid-fed metallic melter is adopted in India for vitrification of high-level radioactive wastes. Although all the operational vitrification plants are using this technology presently, it is recognized that induction of ceramic melters in place of metallic melters would be advantageous. The liquid fed metallic melter has limitations with respect to processing throughput and also calls for frequent remote replacement of the process pot. This replacement puts a heavy demand on the operations and is also not cost effective. Adoption of liquid fed ceramic melters in place of metallic melters calls for their retrofitting in the vitrification cell initially designed for metallic melter. This retrofitting is being carried out in one of the operating vitrification plants.

Considerations had to be given right from design to decommissioning of the ceramic melter, which had to be made compact without sacrificing the enhanced throughput. This involved critical analysis and design of the main electrodes with respect to their geometry and configuration. The options of slurry and frit feeding both had to be carefully designed keeping in view of the limited cell height. Side pouring of the molten glass from the melter could not be considered because of the constricted cell geometry and thus redundancy had to be provided by incorporating an additional bottom drain as stand by. In view of the compactness cylindrical geometry of the melter as against rectangular geometry was also considered.

The compactness of the melter was also dictated from decommissioning considerations. In view of the space constraints in the existing cell, it is necessary to lift the entire melter unit through the cell top and decommission it in a shielded environment, elsewhere. This called for limiting the entire weight of the melter including refractories within 10 tonnes and this was dictated by the availability of the material handling system in the existing cell.

Existing waste management facilities are co-located with the reprocessing facilities at various reactor sites in India and as such do not call for vitrification plants with very high processing capacities. On successful operation of this ceramic melter, replacement of existing metallic melters with ceramic melters will be carried out in a phased manner.

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INTRODUCTION

The Indian Nuclear Programme envisages reprocessing of spent fuel to recover uranium and plutonium and recycling the same to the fuel cycle. High-level liquid radioactive waste generated during reprocessing at different sites is vitrified in suitable borosilicate glass matrices with minor

variation to account for site-specific changes in the waste composition. The induction heated liquid-fed metallic melter based on modified pot-glass process was adopted in India in mid seventies. Despite the success achieved in Waste Immobilization Plants in Tarapur and subsequently at Trombay, the shortcomings of the pot glass process like low throughput, limitation on glass melting temperature and dependency on operator skill were some issues, which needed to be addressed. Besides complex remote handling requirements, necessitated by frequent connection/disconnection of process lines and melter replacement brought out the need for adoption of an alternate technology. One of the most viable technologies for vitrification is the utilization of Joule-Heated Ceramic Melter (JHCM).

In this context and also keeping in tune with the international trends, development of Joule-Heated Ceramic Melter (JHCM) was initiated in India some time back. However, by the time the technology development was completed and made mature enough for plant scale adoption, the civil construction for the next vitrification plant at Tarapur was already over. The design layout and dimensions of the hot cells for this plant were suitable for installation of a metallic melter with its off-gas clean up system and associated remote handling gadgets. Retrofitting of JHCM in these cells was a challenge in itself. It involved not only housing the JHCM and other associated systems but also had to address regular Operation and maintenance of the plant. Besides, a well-planned strategy for final decontamination, decommissioning and dismantling of JHCM had to be evolved.

FACILITY DESCRIPTION

Cell Layout

This plant has a civil structure, which comprises of three blocks, namely a storage block, a process block and a service block. The process block has four concrete shielded cells. Of these, two hot cells namely cell-2 and cell-3 are earmarked for processing high-level acidic radioactive waste. These cells have internal dimensions of 7 meter long x 4 meter wide x 15.25 meter high with 1 meter thick concrete walls all around for shielding. Cell-2 has three compartments. The upper compartment of cell-2 is meant for housing the main melter unit and canister-sealing unit. The height of this compartment is only 7 meters. The middle compartment is utilized for product removal and the bottom compartment houses the waste storage tanks. All operations requiring viewing and manipulation are to be carried out in the upper and middle compartments of cell-2.

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The cell roof has an opening of 5 meter x 2.5 meter shielded by removable roof covers through which large sized equipment can be taken out of the cell using a 30-tonne electrical overhead crane operating above the cells. This EOT crane also serves handling of the shipping cask for vitrified product from another location. A side view of the upper portion of the melter cell (cell-2) housing JHCM is shown in Fig. 1.

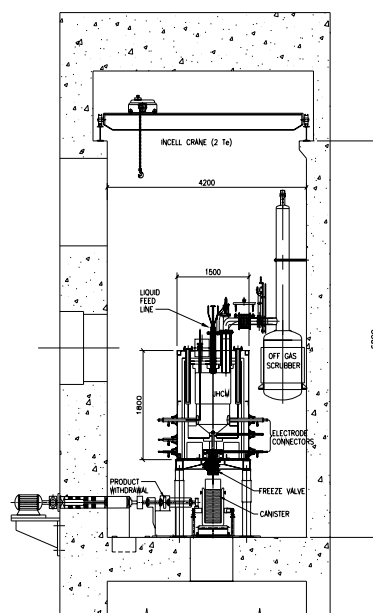


Fig. 1 Side view of the melter cell housing JHCM

The cell-3 has two compartments. The upper portion of cell-3 is essentially meant for housing waste concentration and off-gas treatment equipment. These consist primarily of thermo-siphon evaporators; fractionators; condensers; storage tanks; scrubbers etc. The cell-3 is a blind cell and as such there is no provision for any viewing or manipulation. However shielding recesses have been installed for housing pumps, control valves etc. The bottom compartment houses a waste storage tank for receiving high-level liquid waste.

Joule-Heated Ceramic Melter

The JHCM is designed for an average liquid feed throughput of 25 LPH. The external dimensions of JHCM are 1.5 x 1.5 meters and an overall height of 1.8 meters. The main melter refractory is high corrosion-resistant glass-contact Alumina-Zirconia-Silica refractory. This is backed up with layers of insulating refractory. There is Plenum-heating section, which supplies the initial heat to raise the temperature of the cavity glass to conduction zone after which the glass is further heated by passing an alternating current between electrodes in contact with molten glass. Plenum heating employs 15 silicon carbide heating elements of 2 KW power each. The melter has main electrodes of inconel 690 with a total power of 60 KW. The melter cavity has a hold up volume of 125 liters of molten glass. This capacity is sufficient to provide a mean residence time of around 25 hours at the normal glass production rate of 1.5 Kg/hour. Although the option for slurry feeding of glass forming additives to the melter has been provided, the solid glass frit is planned to be fed routinely to reduce the evaporation load and thereby enhancing the throughput of the melter. About 100 kgs of vitrified waste product is drained in stainless canister by energizing freeze valve heated by an independent furnace. The whole process is continuous except during a short period required for canister change over. A cut-away section of the melter depicting the main components and constructional features is shown in Fig. 2. below.

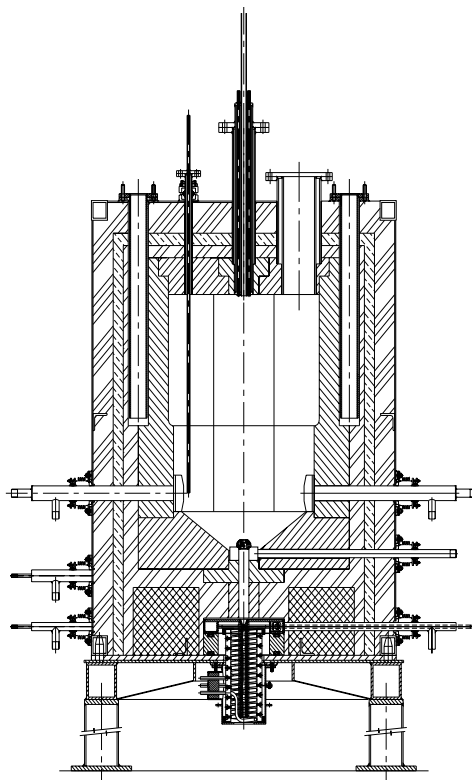


Fig. 2 Cut-away sectional view of the JHCM showing refractory and other components

The entire melting furnace is encased in a stainless steel box on suitable structural support. The melter is provided with dedicated instrumentation monitoring temperature, level, flow and power. The off-gas from the melter is composed primarily of steam, air, and oxides of nitrogen, aerosols, and volatile species. Aerosol entrainment is generally less than 0.2% of weight percent of the waste fed to the melter. The off-gases are collected in the area above the melting surface, which is maintained at a negative pressure. From there the gases are removed by the off-gas treatment system through a scrubber mounted near the melter. The scrubber removes most of the entrained particulates and nearly all the steam. The design of the scrubber is such that it takes care of the periodic off-gas flow surges, which occur in the melt pool at times. The remaining off gases are passed through conventional off-gas cleaning equipment to meet the emission standards. The melter top showing feed lines, off-gas jumper, melter scrubber and other process lines housed in the melter cell are shown in Fig. 3 below.



Fig. 3 Top View Of JHCM & Associated Equipment housed in the Melter Cell

RETROFITTING OF CERAMIC MELTER

General

Ceramic melters have an advantage of high throughputs resulting in the economy of operation and ease of process control. Vitrification facilities in India, however, are located in close vicinity to the reprocessing plants serving as dedicated units. This approach has an inherent advantage since it helps in obviating the need for long-distance transportation of high-level liquid waste and also results in designing and operating vitrification facilities with moderate throughputs.

Factors Associated with Retrofitting

The metallic melter initially proposed was designed for an average throughput of 25 LPH and the same had to be replaced by a JHCM of comparable throughput. Even for a comparable throughput, the physical size of the ceramic melter is 2-3 times bigger. However, the design of the melter was dictated by space constraints and the essentiality of having to use the existing remote handling features. The main task, therefore, was to design a ceramic melter in a way to effectively utilize the existing remote handling equipment and associated plant utilities and services.

Equipment Layout and Piping

The change over from metallic melter to ceramic melter involved the reorientation of the in-cell canister-handling scheme requiring necessary modifications in the layout. In addition, there was a constraint in the form of having to utilize existing openings and other embedments in the cell walls. An additional limitation was suitably locating melter cell equipment like off-gas scrubber, condenser, condensate collection feed tanks and associated piping inside the melter cell in a way that the remote operations envisaged could be carried out smoothly. The original philosophy of the removal of the melter as a whole using the roof opening and 30-Tonne overhead crane had to be

retained in the case of the ceramic melter as well. This dictated the overall dimensions and weight of the melter. The space constraints in the melter cell involved difficulties in routing of pipelines. Keeping in view the free space required for the reach of the remote handling gadgets during operation, layout for remote handling was carried out very carefully with a lot of innovations.

Decommissioning Aspects

The melter has been sized in such a way that at the end of its designated life, the entire unit, after decontamination, can be taken out of the cell for decommissioning in another area through the roof hatch using the 30-tonne EOT crane. The in-situ decommissioning has been eliminated. A similar melter can be introduced from the same roof hatch and plant operations can be continued. The discarded unit is taken up for decommissioning at another location within the facility. In the absence of an alternative process cell with identical facilities for vitrification, in-situ decommissioning was not planned in the melter cell. This would also help in reducing process downtime. The cramped space in the melter cell was another reason for not planning in-situ decommissioning.

Design Features of the Melter

Without sacrificing the throughput, the size of the melter had to be optimized. The consideration was given to the design and mounting of the electrode system. The circulation of the molten glass pool had to be enhanced so as to obtain a higher feed rate and therefore a higher throughput. A three-electrode system was conceived where the two sidewall electrodes are expected to supply energy to the top layer of the glass, close to the cold cap. The current generated between the side and the bottom electrode could be controlled to supply required energy near the bottom of the melter. The heat generated near the bottom will enhance convective mixing of the glass thereby preventing formation of a viscous cold glass layer onto the bottom of the melter. The advantage of this design is a thorough glass pool circulation resulting in enhanced feed rates for the given geometry and size of the melter. To counter any unforeseen problem in the product withdrawal the freeze valve pipe section has been fitted with two separate induction heated segments. The two-zone induction heated section is planned so that string formation at the end of product withdrawal is avoided.

Remote handling aspects

Remote handling in the vitrification plant of SSSF, Tarapur is confined to Cell-2. An in-cell crane of 2 Tonne capacity and three pairs of heavy duty extended reach manipulators serve as the handling tools in the top compartment of cell-2. For viewing into the cell, three radiation-shielding windows are provided in addition to local CCTV systems. Major remote handling operations in this cell are the following:

- Positioning of canister below the melter in order to receive molten glass selectively at the desired pouring location.
- Handling of open/filled canister without capping.
- Handling of over pack, which is the secondary containment with two sealed canisters in one over pack.
- Handling of canister/over pack lids and the remote welding head.

- Handling of removable off gas jumper and operation of its remote operated flange connectors.
- Operations for changing thermocouple connectors on the top of ceramic melter.
- Remote replacement of line cooler in off gas line.
- Clean up of frit feed line and off gas nozzle on the top of the melter.
- Product removal in the middle compartment of cell-2.

Most of these operations had already been considered while designing the remote handling systems for the metallic melter. The decision to retrofit the ceramic melter had to address remote handling in an overall perspective with additional operational features associated with the JHCM. Ideally this would call for an introduction of a power manipulator on the top of the melter but the same was not provided for in the existing melter cell nor could this be introduced during retrofitting. Hence the design had to be modified to complete all the remote manipulations and handling with only one cell crane and Master-Slave Manipulators - (MSM). In view of the limited head room available; the laying of the feed lines needed careful planning to ensure unhindered canister movement during operation. Various slopes especially those for frit feeding had to be carefully routed to ensure feeding without any choking. In general the layout in the melter cell housing the ceramic melter, associated process equipment, canister handling system and piping was optimized with respect to the limitations of available space and amenability to the access by remote handling tools. Since only the existing civil embedments had to be utilized, innovation in routing of pipelines with respect to providing necessary slopes and bunching along the walls had to be well planned. A typical view showing the associated equipment piping complexities with feed line slopes and bunching of lines is shown in Fig. 4.



Fig. 4 A typical view of pipe routing and equipment layout on the top of JHCM

CONCLUSIONS

It has been possible to retrofit the JHCM in the vitrification cell initially designed and designated for housing a metallic melter. Working within the constraints with respect to the layout and design of the cell, it was very difficult to accommodate equipment and piping and yet incorporate provision for carrying out remote operations/replacements of components additionally envisaged by JHCM. For a designated throughput, the melter size and weight had to be restricted by design improvisation and considerations for dismantling/decommissioning. The plant is in the advanced stages of construction and is expected to be commissioned by March 2004.