PRODUCTION OF CESIUM PENCILS

Challenges to Innovations

Jyoti Diwan, Aniruddha Dharashiokar, S. Wadhwa, Amar Kumar, Neelima S. Tomar and C. P. Kaushik

ABSTRACT

High Level Radioactive Liquid Waste (HLLW) contains many useful radio isotopes having several industrial as well as medical applications. Separation and recovery of useful isotopes from radioactive waste and their deployment for societal application make the waste a material of resource. Radioisotope of Cesium, ^{137}Cs, is one of the gamma emitting radionuclides which has immense potential for use as a sealed gamma source in radiation technology applications such as irradiation of blood and foodstuffs, sterilization of medical supplies and radiation processing of sewage sludge [2]. ^{137}Cs, one of the major constituent of the nuclear waste, is a suitable substitute for ^{60}Co as a radioactive source because of its longer life. Several challenges are faced during the extraction of ^{137}Cs from HLLW, immobilization of ^{137}Cs in glass matrix, production of Cesium glass pencils, their remote welding and quality assurance before transportation in shielded cask to BRIT for deployment in hospitals as blood irradiator .Challenges faced during each step and the innovative techniques adopted are discussed in the present article.

KEYWORDS: HLLW, Partitioning, ^{137}Cs, Immobilization, Remote viewing, Cs glass pencil.

INDIA has adopted a closed fuel cycle by reprocessing the spent fuel for energy security as envisaged by Dr. Homi J. Bhabha, the founder of Indian Nuclear Power Programme[1]. High level liquid waste originates from the spent fuel reprocessing plants. Over 90% of the radioactivity of this waste is contributed by fission generated Cesium and Strontium radioisotopes, making HLLW a source for Cs recovery. India has taken a conscious decision of deploying Cesium in a vitrified form as an irradiation source. India is the only country to have the technology of partitioning of High Level Liquid Waste (HLLW) and manufacturing ^{137}Cs in vitrified form. Waste Management Division of Nuclear Recycle Group has achieved a milestone in the production of radioactive Cesium glass pencil to be used towards societal benefits in the healthcare sector for blood irradiators. The preparation of ^{137}Cs based radiation sources involves processes like recovery of the radioelement from nuclear waste, immobilization of the recovered Cs in vitreous matrix, pouring of Cs glass in stainless steel pencils, remote encapsulation, leak testing and transportation (Fig.1).

Partitioning of High Level Liquid Waste

With the advent of new technologies based on partitioning of waste, long lived radioactive waste constituents are separated prior to immobilization in a glass matrix. HLLW contains many useful fission products such as ^{137}Cs, ^{90}Sr and ^{106}Ru. Separation and recovery of these fission products not only reduces the waste burden to the environment but also gives value addition to drive social impact[1]. Challenge lies in the recovery of cesium from radioactive waste stream which has the presence of other radioactive fission products, long lived minor actinides and inactive constituents added during reprocessing. To address the same, development of novel extractant and separation equipment to recover ^{137}Cs in pure form was done indigenously.

The plant scale facility at Waste Immobilization Plant, Trombay for recovery of Cesium from HLLW has been accomplished using solvent extraction process (Fig.2) after testing the efficacy of process on laboratory scale.

Immobilization of ^{137}Cs Solution in Vitrified Form

During vitrification, cesium nitrate is added to the melter as the feed solution along with other glass forming additives at a controlled rate. The vitrification is carried out in Induction

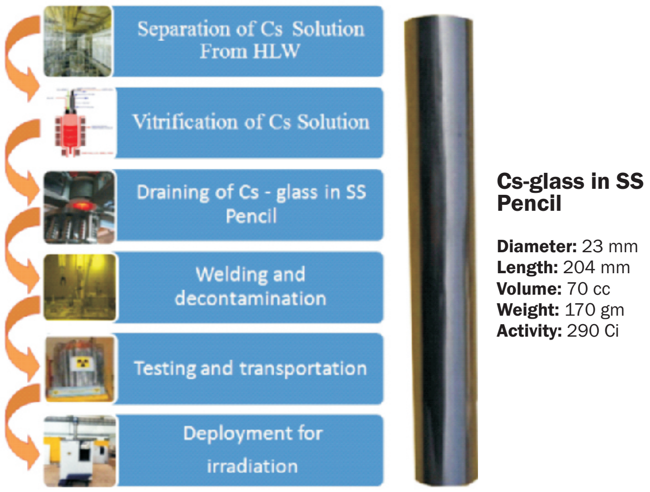
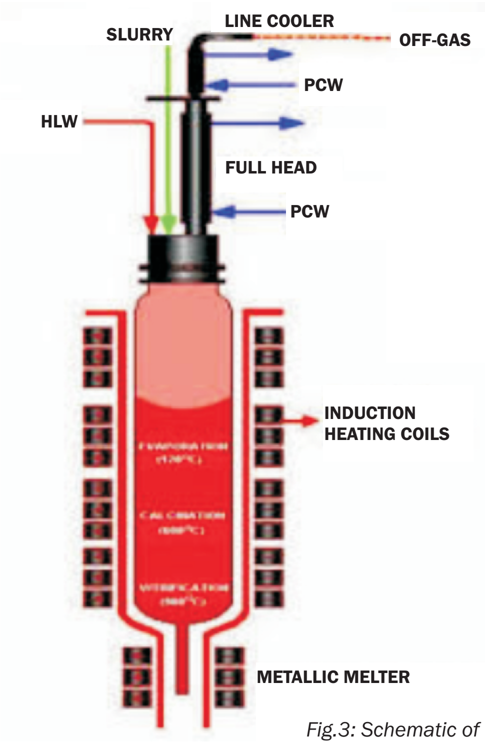


Fig.1: Overview of Cs pencil Making Process.

Fig.2: Partitioning of HLLW for selective extraction of ^{137}Cs in Hot cell.

The authors are from Waste Management Division, Bhabha Atomic Research Centre, Mumbai & Homi Bhabha National Institute, Mumbai.



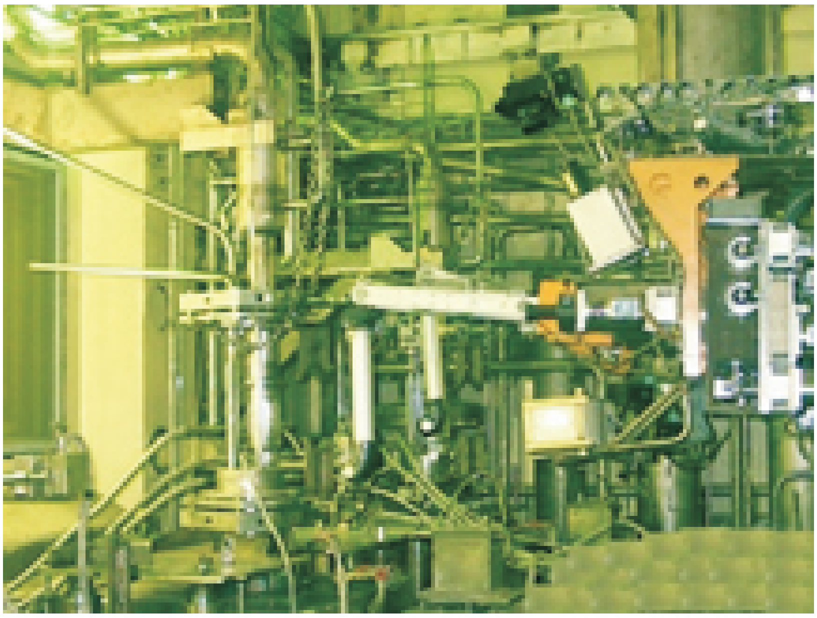


Fig.3: Schematic of Induction Heated Metallic Melter (left) and IHMM in operation (right).

Heated Metallic Melter (IHMM) as per the standard operating procedure with existing system based on predetermined temperature profile. For making Cesium pencils, a batch of 8 kg Cesium glass must be melted in the IHMM (Fig.3), completely drained in a small process pot, called the dispenser for its further remelting using custom designed IHMM and poured into small stainless steel pencils.

It was very challenging to prepare cesium glass in smaller batch size in the IHMM which was optimized for handling large volumes. This was negotiated with the modification in the operating practices based on expertise gained over decades in vitrification technology. Due to the volatile nature of cesium at high temperature, carryover of cesium in off-gas stream was an additional challenge. This was addressed by multiple scrubbing, modified operating procedures and elaborates off gas cleaning system. As opening of the dispenser process pot is lesser as compared to the canister ,special arrangement has been made to ensure safe draining of molten glass completely in the pot. A partially closed pouring system has been designed, installed and operated during Cs glass pouring to minimize carryover of volatile cesium towards the ventilation exhaust filter bank.

Production of Cesium Glass Pencils at Industrial Scale

Retrofitting of remelting furnace along with associated trolley arrangement (Fig.4) in an existing hot-cell was one of the major challenges. The same was very much important for remelting of cesium glass, pouring in a dispenser, and draining of a precise amount of cesium glass into SS pencils (Fig.5). As a result of dedicated team efforts, successful installation and commissioning of the system was carried out.

The available power supply for remelting and draining of glass was inadequate and the same was modified with enhanced capacity power supply to overcome the power transfer issue. Weighing system of the remelting furnace plays an important role as the molten Cesium glass has to be poured in small stainless steel pencils of 23 mm diameter and 204 mm length in a precise manner. Challenge with respect to precise weighing of the pencil glass pouring was resolved with industrial grade weighing system mounted on remotely replaceable cage. After pouring, pencil lid is placed remotely prior to remote welding and encapsulating (Fig.6).

Remote viewing system plays an important role in checking the weld quality and thus ,ensuring the quality of sealed source of Cs glass pencil. Improved viewing system with IP cameras was installed in welding cell which resulted in zero rejection of pencils. The produced pencils are subjected to various stringent quality assurance checks on par with international standards. The mechanisms involved in pencil welding system, leak detection test, surface decontamination system etc. have been in house developed at Waste Management Division.

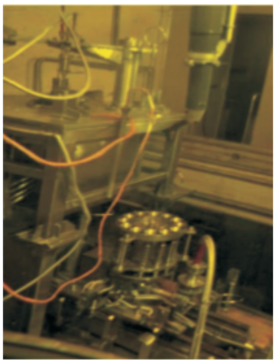


Fig.4: Remelting furnace.

Fig.5: Pouring of Cs glass.

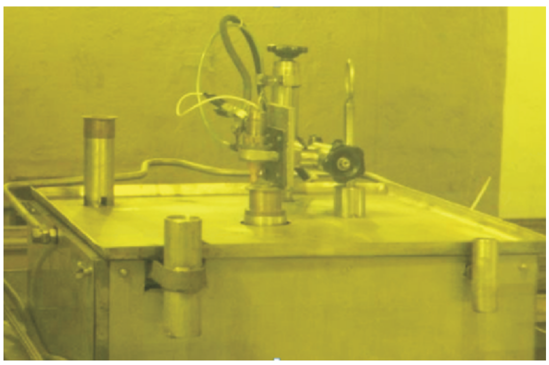
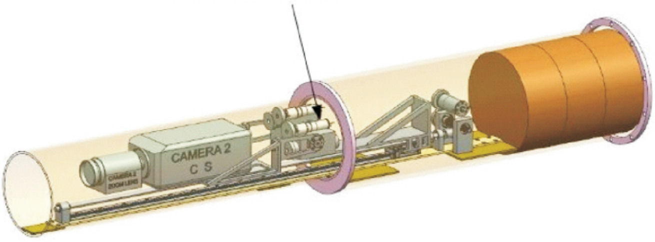


Fig.6: Welding of Cs glass pencil.



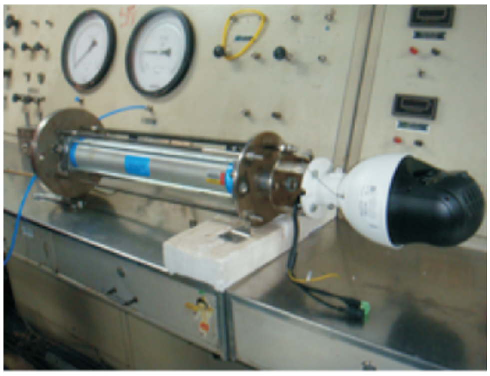


Fig.8: (a) Retractable Camera System for EP, (b) Retractable System with IP camera.

Fig.9: Radiation resistant camera.

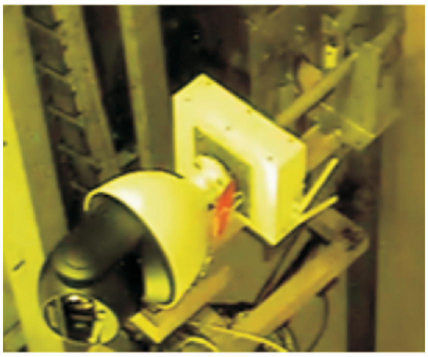


Fig.10: Wireless camera on cell crane.

Fig.11: Periscope based camera.

Fig.12: Telescope based camera.

As all the operations inside the hot-cell are done remotely, reliable remote viewing system is a must for safe and successful remote handling operations. Due to increase in radiation field inside the hot-cell during Cs pencil production, frequency of replacement of cameras of remote viewing system increased significantly. Various innovative developments have been carried out for increasing the usable life of the cameras. These include retractable design for EP cameras (Fig.8), Radiation Resistant (RR) camera system (Fig.9), wireless camera for in cell crane (Fig.10), periscope based camera on in cell crane and telescopic camera (Fig.12) for viewing pouring and material handling in the vitrification cell. Replacing CCD cameras with IP has shown encouraging results with respect to usable life enhancement in radiation field.

The Cs pencils are transported to BRIT in a lead shielded cask, from where these are subsequently transferred to blood irradiators for shipment to various hospitals. Ten such pencils containing radioactive cesium are used in each blood irradiator. The irradiation of blood is very much essential to prevent Transfusion Associated-Graft Versus Host Disease (TA-GVHD) particularly for immune-deficient patients.

Conclusions

With various innovative developments, the challenges in production of Cesium glass pencils at industrial scale were overcome. This resulted in production of 230 Nos. of Cs pencils of specific activity in the range of 1.4-4.5 Ci/gram which were handed over to BRIT. In the Indian context, as mentioned, HLLW is a wealth, since many isotopes present in this waste have societal application. With the present philosophy of recovery and reuse, we stand in the position to recover and supply ^{137}Cs to serve humanity at large. Various qualities of Cesium such as longer half-life, lower shielding requirement and amenability to be used in non-dispersive glass form make it a more suitable irradiation source. India is a forerunner in this technology for selectively partitioning of Cesium from HLLW, immobilizing in vitreous matrix and thereby deploying in blood irradiator.

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