VITRIFICATION

Advances in Remote Handling and Robotics

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ABSTRACT

India has mastered the technology of vitrification of High Level Liquid Waste (HLLW) both by using metallic and ceramic melters for the management of HLLW generated from reprocessing of research as well as power reactor fuels. Interim storage and surveillance facility for Vitrified Waste Product (VWP) packages is operational and valuable experience has been gained in safe handling of these packages through the public domain during transportation as well as at the storage end. Remote handling plays an important role in the vitrification and in storage facility. Various remote handling tools and systems have been deployed in the vitrification facilities as per process requirements. Mechanical and electrical Master Slave Manipulators (MSM), Power Manipulators (PM), in-cell cranes, pneumatically and electrically driven trolleys and transfer systems, impact wrenches and various types of grapplers operated mechanically, electrically or pneumatically, are the major remote handling tools and systems utilized in the present facilities. Based on feedback of operational experience, new generation of remote handling equipment e.g. robots, advanced manipulators, sensors have been developed incorporating modern remote technologies. This has resulted in greater reliability, cost saving, minimum man-rem expenditure and downtime of systems in the vitrification facility. This paper discusses the past experience of remote handling in vitrification facility and advances made in remote handling including remote viewing for adoption in existing and upcoming facilities for better reliability, productivity and safety.

KEYWORDS: Vitrification, Remote handling, Remote viewing, MSM, In-cell crane, Remote welding.

IN INDIA, vitrification of High-level Liquid Waste (HLLW) generated in reprocessing plant is carried out in glass matrix in waste immobilization facilities located at Tromaby, Tarapur and Kalpakkam[1]. Work on the next facility, which will be an integrated reprocessing and waste management facility, is in progress at Tarapur. WIP Trombay employs Induction Heated Metallic Melter for HLW vitrification, while facilities in Tarapur and Kalpakkam utilize Joule heated Ceramic Melters. The major operation in vitrification of HLW consists of pouring of VWP inside a canister, capping, decontamination and over packing, which needs to be carried out remotely. Further handling of the over pack in a shielded cask for transportation, emplacing the same into interim storage/disposal facilities, liquid sampling and handling of filters etc. requires remote handling systems. These systems are also critical for dismantling of aged Melters. With development of advanced waste treatment processes & recovery of Cs-137 for production of Cs glass pencils demands precision remote handling for safe operation[2]. NRG has made necessary advancement and developed the requisite remote handling tools to meet remote handling and operation requirements of hot cell which are elaborated in subsequent sections.

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Remote Handling in Vitrification Facility, Trombay

The remote handling systems are the backbone of a waste management facility. The HL vitrification bay of WIP is equipped with three induction melters for production of vitrified glass products. The system is supported by various remote handling gadgets such as canister positioning system, transfer trolleys, self-actuated mechanical grapplers, advanced SERVO manipulators, three piece manipulators, in-cell crane, in-cell viewing system etc[3]. A 2 Te capacity in-cell crane (Fig.1) and trolleys are being utilised for material handling and movement of canisters and over-packs during vitrification operations. Self-actuated mechanical grapplers ensures failsafe gripping and handling of empty and glass filled canisters throughout its movement from inter cell trolleys to canister positioning system and then to the welding station for remote lid welding and over-packing as shown in Fig.2.

With technological advancement and waste separation techniques, WMD has been generating valuable products such as Cs-137 source pencils, Sr-90 and Ru-106 eye plaques which are milestones in the indigenous resource developments for medical treatment. These achievements are the results of robust remote handling facilities deployed. The Cs-137 source pencil production setup has been installed at area 19 of HL bay. The system consist of a scaled down induction re-melting furnace, pencil indexing arrangement with trolley and three piece manipulators for handling of pencils during operation shown in Fig.3. The challenge is to carry out pouring of predefined glass mass in small pencils of 23mm diameter precisely, sealing of the thin section pencils with quality welds that passes stringent quality checks set by

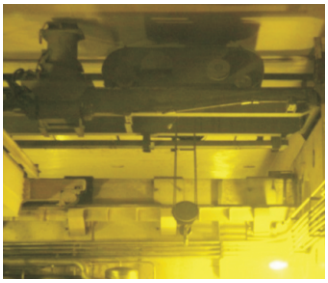

Fig.1: In-cell (2 T) crane in hot cell.

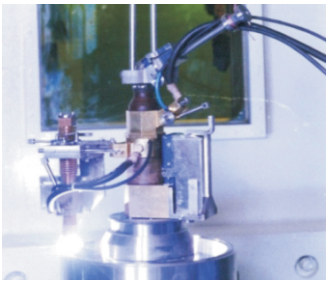

Fig.2: Remote welding of canister.

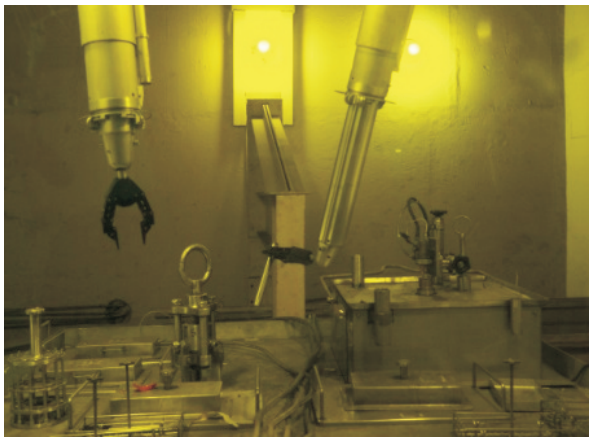

Fig.3: Cs-137 source pencils handling by TPM.

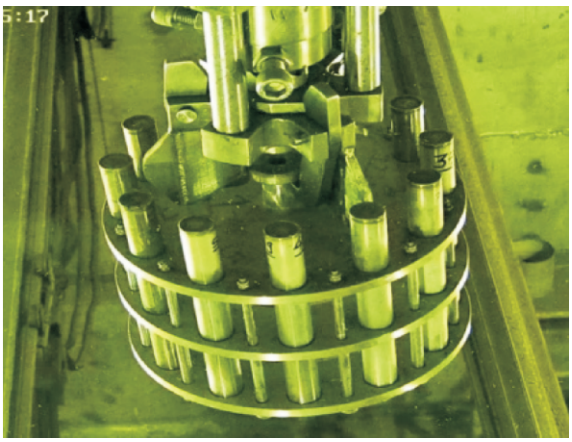

Fig.4: Cs-137 source pencils in cage.

regulatory agencies and handling of small but highly concentrated radioactive source. Since installation, more than 230 pencils have been produced and shipped to BRIT for deployment in blood irradiators depicted in Fig.4. The successful use of three piece manipulators with excellent operator skills has made it possible to achieve this target safely.

The advanced SERVO manipulator shown in Fig.5 is another value addition to remote handling operations playing a crucial role during maintenance activities[4]. The slave arm replicating the human hand movements with six degrees of freedom and 15 kg handling capacity, has approach to almost every corner of the melter cell (area-18) due to its mounting on a telescopic, movable carriage. The induction furnaces can be refurbished easily with the help of the SERVO Manipulator and In-cell crane, replacing its process pot/susceptor. Thus, plant operations can resume with minimum man-rem expenditure and downtime. Three piece manipulators as shown in Fig.6 installed in vitrfication bay (area-19 & area-21) have been a critical remote handling gadget in Cs source pencil fabrication. The precise handling with safety and reliability can be ensured with these manipulators over a sizeable approach area, for pencil handling into the indexing table for glass pouring, weighing, and transferring to cages for further processing. At the welding station, lid capping, welding and decontamination; and leak testing are crucial activities where operator skills and manipulator's finite movements comes into the picture. Key features are through the wall tube type, six degree of freedom, motion transmission from master to slave through many joints by a set of wire rope, metal tapes or other linkages & a payload of 22 kg. Articulated manipulator is another type used for radioactive sampling.

The in-cell viewing system is an equally important aspect of remote handling system. Six radiation shielding windows have been installed at different locations in HL bay area. The oil filled shielding windows provide equivalent radiation shielding of concrete wall with limited view of hot cell. The passive system has minimum maintenance requirement with a prolonged life of 30-40 years.

In addition, 10 CCTV cameras have been installed at various locations of different cells, depending on operational requirements, remote handling and remote maintenance of systems. The standard CCTV cameras have limited life span in highly radioactive areas. In order to enhance the camera life various fixtures and systems have been developed and deployed in hot cell.

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With the experience gained in remote handling and with the availability of better electronics, improvements in remote handling equipments have been carried out. This enhances safe handling of highly radioactive materials. A new facility is being retrofitted at WIP Trombay named as Rad Waste Management Facility (RWMF) incorporating advanced system for increased reliability and higher productivity, resulting in reduced risk of radiation exposure to operators. Equipment design is modular in construction for easy remote maintenance using robotic devices, employing advanced materials with high radiation resistance for increased life.

Important design changes incorporated in RWMF are the process pot with mechanical plug (Fig.7), process pot coupling system, canister positioning system, closed pouring system, Cs glass pouring system (Fig.8). These changes potentially

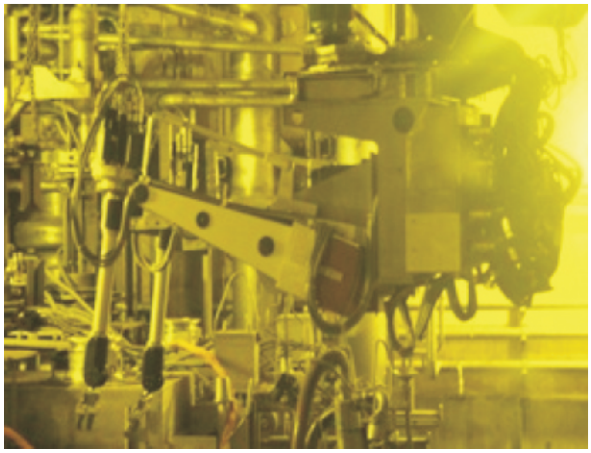

Fig.5: ASM slave arm.

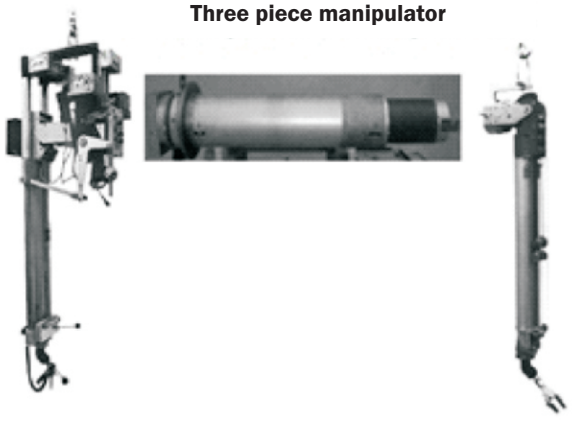

Fig.6: TPM for remote handling.

Fig.7: Process pot Assembly.

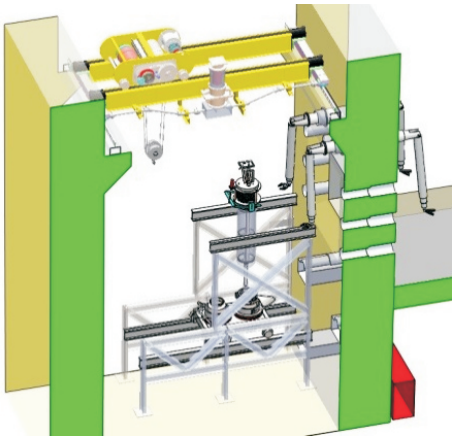

Fig.8: Vitrification system.

Fig.9: Mobile Robo for remote DC of hotcell.

reduce the maintenance of system and enhance the life of system. The major designs changes will be validated by setting up testing facility and simulate the modified system under real conditions.

Wireless decontamination mobile robot (Fig.9) has been developed in coordination with Electronics & Instrumentation Systems Division (EISD) for hot cell decontamination. The mobile robot comprises various features compatible with hot cell operations such as scrubbing action and remote replacement of scrubber, water and acid spray with remote refill, remote charging etc. The mobile robot can be brought out of the hot cell for completion of major maintenance. This mobile robot has three degrees of freedom, which allows coverage of nearly the entire hot-cell area. Individual wheels are provided with motor and power steering is programmed. Remote replaceable camera is mounted on the unit for remote viewing of the area.

Automatic miniature welding machine is another development for the precision welding of glass pencils. Vitrified Cs glass pencils made of a 23mm diameter inner tube and a 25.4 mm outer tube are seal welded on lids. Autogenous Pulse Tungsten Inert Gas (TIG) Welding shown in Fig.10 is used for seal welding of pencils having wall thickness of 0.4 mm at lid portion which has to be remotely carried out inside the hot cells. Precision operations in this miniature welding such as the positioning of the lid, placing weld head above the pencil lip, maintaining the gap and alignment between electrode tip and weld pool are carried out manually with the help of manipulators. This sometimes results in unsatisfactory welding. In order to overcome this, a fully automated version of the advanced welding machine has been developed. The key features of this welding machine is that it has three degrees of freedom, 2 translation motion on electrode and one rotational motion on collet. Further, it has provision of a Graphic User Interface (GUI) based system which can be operated remotely with precision of 5 micron in movements. Modular design helps in remote replacement of electrode and other components.

A remotely replaceable Internet Protocol (IP) based wireless camera system depicts in Fig.11 is recent development for existing in-cell crane mounted camera. The development would result in negligible man-rem expenditure as well as system downtime with its remote replace ability and auto latching connector design features.

Various advances in remote viewing have also been carried out to facilitate better vision while handling highly

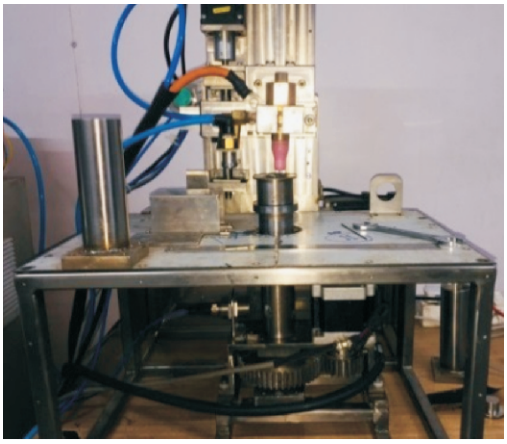

Fig.10: Automated Cs Pencil Welding.

radioactive materials inside hot cells. Development of a telescope mounted camera as shown in Fig.12 on a rotary swing arm has been designed and installed on partition wall of area-18 for viewing glass pouring and to aid remote handling operation during operation and maintenance activities. The swing arm can move the camera behind the shielding when not in use, thus reducing exposure time and prolonging camera life considerably.

Most of the cameras have been installed through wall Embedment Plug (EP). A pneumatic cylinder based retractable camera mounting has been designed and installed to optimise camera exposure. The advanced version of retractable mounting system can enhance camera life further by providing

Fig.11: Remotely replaceable wireless camera system.

Fig.12: Telescope -mounted camera.

Fig.13: EP Hot-cell Retractable camera.

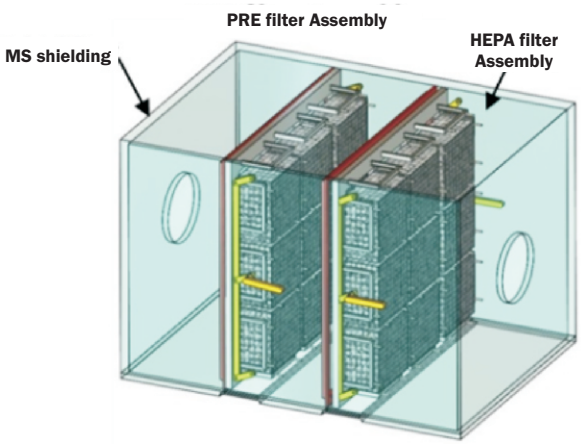

Fig.14: Series arrangement of Pre and HEPA filters.

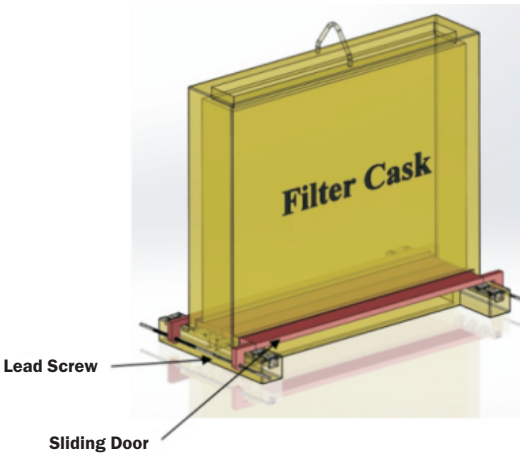

Fig.15: Filter cask for remote replacement of filter bank.

additional shielding on hot side with mechanical movements through lead screw mechanism as depicted in Fig.13. The newer technologies such as power line Ethernet transmission have been successfully implemented for replacement of existing camera systems in hard to reach hot cell areas, where additional cable laying is not possible.

Manual replacement of ventilation exhaust filters results in large man-rem expenditure and plant down time. Remote replacement of these filters in a cubicle concept has been adopted in an upcoming facility. Hot cell exhaust is routed through filtration cubicle to plant suction plenum before being discharge to stack. Filters along with frame will brought in the cask with the help of a crane for further disposal. Figs.14 and 15 shows the cubicle and cask for these systems.

A compact remote cutting machine, shown in Fig.16, has been developed to recover precious metals from disused sources. Low speed source cutting machine was developed for varying sizes of sources of 6mm dia. to 30 mm dia. in a glove box. Cutting speed was optimised to 50-70 rpm with varying dead weight controlled feed arrangement depending on source size. For Ru-106 eye plaque production, programmable pneumatically assisted resistance brazing machine with digital microcontroller (Fig.17) was developed in WIP, Trombay of BARC.

Conclusions

The continuous up-gradation of remote handling systems with plant specific requirements and evolving technological developments has made it possible to achieve goals of developing indigenous products for societal benefits besides safe management of radioactive waste. With advancement in remote engineering technology, waste management plants of BARC have achieved several milestones while generating several valuable products such as Cs-137 source pencils, Ru-106 eye plaques, Y-90 based treatment etc. Till now, more than 230 nos. of Cs-137 source pencils and more than 15 nos. of Ru-106 eye plaques have been produced for medical applications. These achievements have been made only because of safe, reliable and advanced remote handling systems.

Fig.16: Remote cutting machine for disused sources.

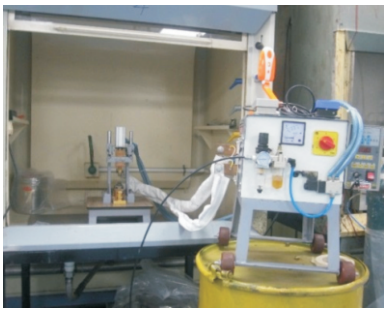

Fig.17: Remote resistance brazing machine.

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