Model Transfer Cask for Automated Handling of Canisters in Storage Vaults

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ABSTRACT

India has adopted a "Closed Fuel Cycle" philosophy, where spent nuclear fuel is regarded as a material of resource. The nuclear waste management practices adopted in India are at par with international practices in accordance with the guidelines of the International Atomic Energy Agency (IAEA). The waste management practices require interim storage of Cat–III & Cat–IV high beta-gamma (alpha and non-alpha) waste canisters inside engineered storage vaults. These canisters are ultimately disposed either in deep geological repository or shielded concrete trenches depending upon their radioactivity. There is a need for development of an Automated Transfer Cask System (ATCS), which can remotely and safely transfer canisters into the interim storage vaults. The major challenge in the development of a transfer cask is remote alignment of cask with the vault-port and the subsequent remote handling of vault-lid and transfer of canister into the storage vault without breaching the shielded integrity during transfer. Thus, a scaled down model has been designed, manufactured and demonstrated successfully for automated handling of lid and transfer of canisters. The developed transfer cask comprises of motorised drives, grapplers, load cells and is equipped with PLC based control system for safe transfer of canisters. This paper describes the design philosophy, constructional features, remote handling features, safety interlocks and performance feedback gained during demonstration of the system.

Keywords: Canister, Transfer Cask, Radioactive, Storage vault, Grappler, Repository

Introduction

Automated Transfer Cask System (ATCS) is a special type of lead shielded cask, which is planned to be used in conjunction with an EOT crane to enable automated transfer of canisters at desired storage locations of interim storage vaults. Fig. 1 shows the fully developed Automated Transfer Cask System (ATCS).

In the existing Solid Waste Storage and Surveillance Facility (SSSF), Tarapur, transfer of Vitrified Waste Product (VWP) canisters is being carried out sequentially with human intervention in batch mode [1].

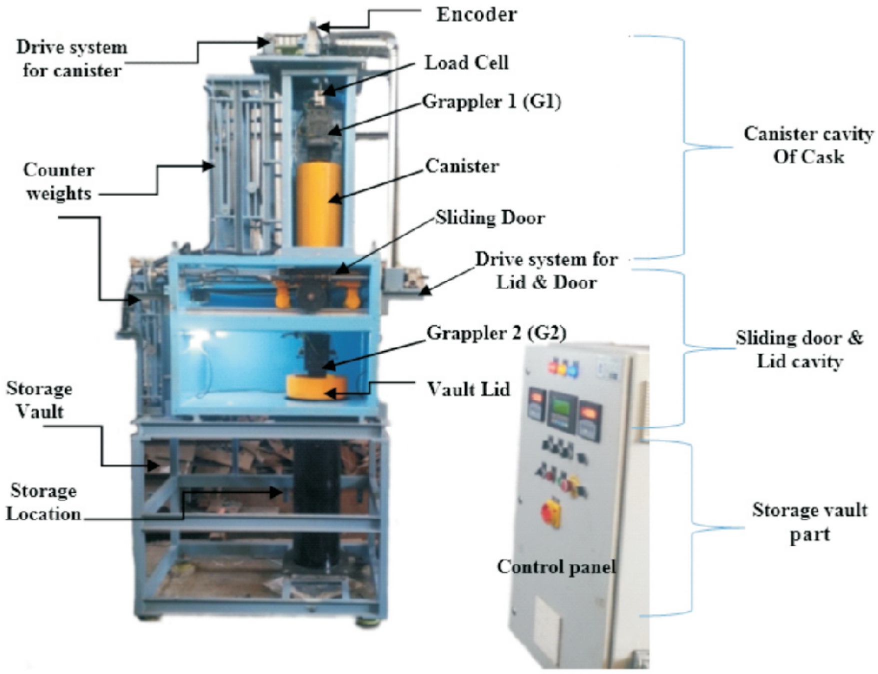


Fig. 1: The Automated Transfer Cask System (ATCS)

Fig. 2: Solid Storage and Surveillance Facility at Tarapur

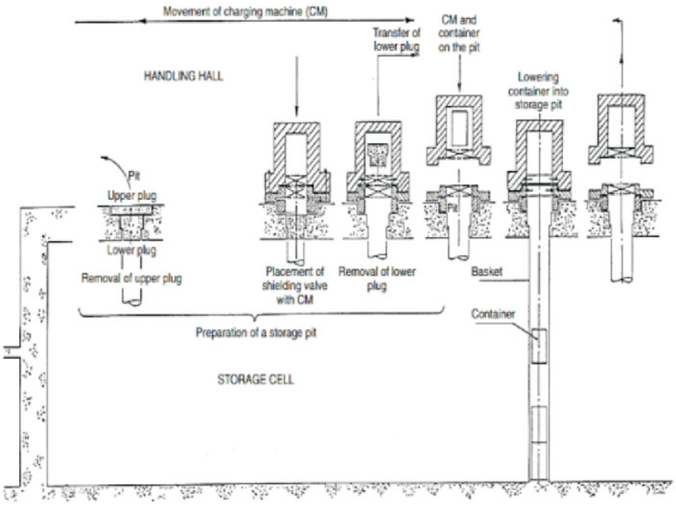


Fig. 3: Operational sequence for transfer of canister in storage vault at Belgium

Fig. 2 shows photograph of SSSF, Tarapur. At SSSF, for transfer of VWP canisters in storage vault, a shielded loading platform is placed over the vault-port and loading platform door is opened. Now, the crane hook is engaged with the vault-lid and the lid is lifted to a height within complementary shield such that loading platform door is closed without radiation streaming. Thereafter the transfer cask is kept on the loading platform where both the loading platform-door and cask-doors are opened one after the other. The canister is then transferred inside the storage vault using lifting links attached to a crane hook. The cask and loading platform doors are closed and transfer cask is taken away. Lastly, the storage location is closed by first bringing the lid held by crane within complementary shield of loading platform door. Then the loading platform door is opened and finally, the lid is placed inside the vault cavity. Similarly, unloading operations are carried out by reversing the operation sequence. The present practice has its limitations such as the process is carried out in batch mode; the process requires administrative control during handling of the vault lid& canister and the facility requires crane with higher height of lift.

In Belgium, transfer of VWP canisters is carried out using two separate transfer casks, one meant for the lid and other for canister [2]. Fig. 3 shows operational sequence for transfer of canister in storage vault. This system involves multiple number of handling equipment and series of steps for transfer of canister into storage vault.

Considering the rate at which the nuclear industry is growing, automation of crane & transfer cask of interim storage facilities was felt necessary. Hence, it becomes imperative to develop a transfer cask system, which automates the transfer process, reduces the number of sequential steps and limits the man-rem expenditure. In this regard, a novel scaled down model of ATCS has been designed, developed and demonstrated for automated handling of storage vault-lid (housed within the cask shield cavity) & transfer of canister from cask to vault and vice versa.

System Description

The developed system is a scale down model of ATCS. The system is divided into three zones; first zone has a canister cavity containing grappler G1 for handling of canister along with its motorized drive system. The second middle zone has a sliding shielded door and lid cavity containing grappler G2 for handling of vault-lid and motorized drive mechanism for up & down movement of grappler as well as for movement of sliding door. The third zone depicts the dummy storage vault for simulating the vault lid storage as well as canister storage.

The system is provided with end limit switches, encoders and load cells for its automated operation using PLC. The system is designed for operation in Auto & manual mode using interlocks and in admin mode during maintenance. Operational sequence of loading cycle is described below.

- Placement of ATCS on storage location i.e. vault port.
- Lowering the lid grappler G2 and engage with vault-lid.
- Lifting the lid using G2 up to the Top Dead Centre (TDC).
- Opening the sliding door along with vault- lid in the door & lid cavity.
- Lowering the canister into storage vault till its bottom most position and disengage the canister grappler G1.
- Retracting G1 back to the home position.
- Closing the sliding door along with vault- lid attached to G2.
- Lowering the G2 and placement of vault-lid into the vault.
- Taking the G2 to home position and lift the ATCS for next consignment.

Similar operations shall be carried out for unloading cycle by reversing the operation 'e'. It can be observed from above sequences that in the whole process, the lid is confined within the ATCS shielding cavity itself thereby maintaining the integrity of the storage vault at all times and the confined space is relentlessly maintained which eliminates the chances of radiation streaming.

Main System Components & Special Features

Following are the main components of ATCS: (i) Grappler (ii) Vault lid (iii) Load Cell (iv) Sliding Door (v) Drive system and (vi) Control Panel.

(i) Grappler: Fig. 4 shows Normally closed type (fail/safe) Electromagnetic grappler developed for handling of vault lid and canister. Electromagnets are actucated only when grappler fingers are needed to be opened for handling of canister/lid. In case of failure of electrical supply, the grappler retains grip position by spring force. In addition, manual override provision is provided in the grappler to disengage the jaws from outside the cask using remote tool.

(ii) Vault lid : Vault lid is a part of storage vault and provides radiation shielding to vault port. The thimble of vault lid is made compatible for remote handling with grappler jaws.

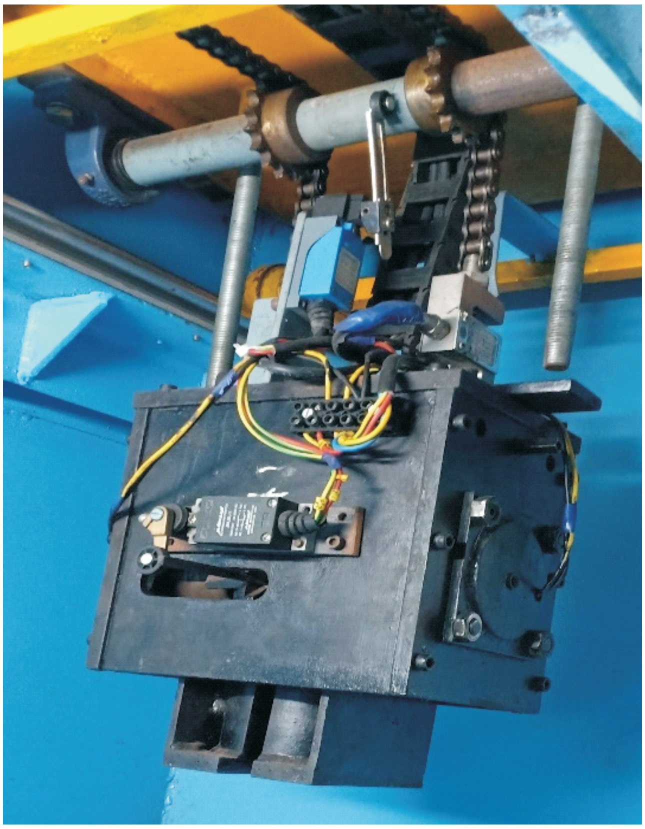
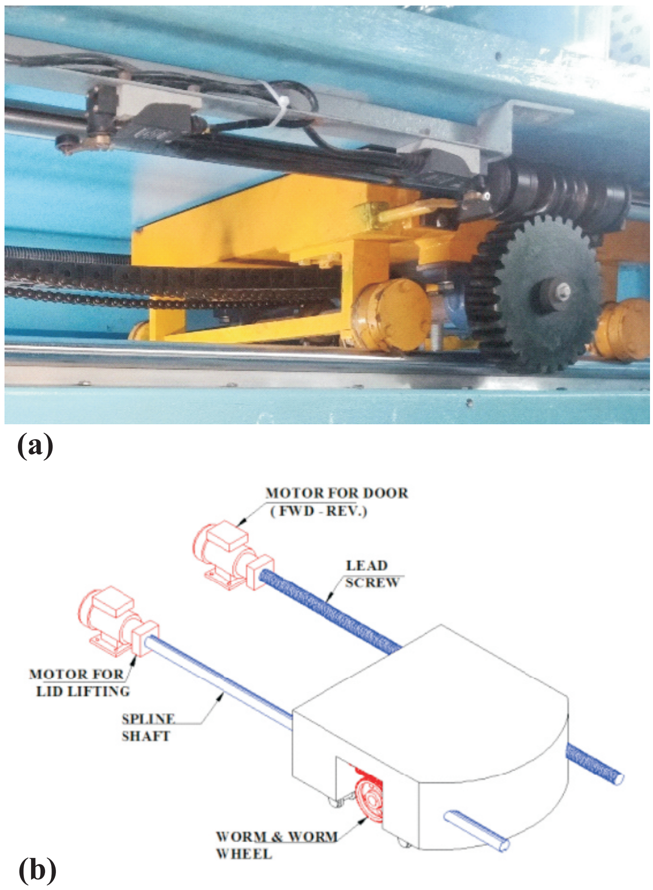


Fig. 4: Electro-magnetic Grappler



(a)

(b)

Fig. 5: Sliding Door (a) & its associated mechanism (b)

(iii) Load Cell : In additon to limit switches, load cell is required to detect presence, absence or stuck-up of canister or lid during transfer. The system has been provided with two load cells placed between grappler and lifting chain.

(iv) Sliding Door : The sliding door provides shielding and also facilitates handling of lid. A special type of drive mechanism as shown in Fig.5 was needed for integrated movement of door as well as handling of vault lid. In order to achieve this, sliding door has been provided with two drives, i.e. lead screw drive for movement of door and secondly, spline shaft fitted with worm drive for handling of vault lid. The handling of vault lid is achieved by rotation of splined shaft which rotates worm wheel even when the sliding door is stationary and as worm wheel is attached to lifting chain sprocket for vertical movement of the grappler G2. The spline shaft also facilitates movement of vault lid within the cask cavity when sliding door opens and closes during the transfer operation without any entanglement of electrical cables.

(v) Drive System : The drive system comprises of three sets of induction motors and gear boxes corresponding to the three different motions required. First motion involves the chain and sprocket drive to lift and lower the canister via grappler G1, second motion also involves chain and sprocket drive coupled with worm wheel drive to lift and lower the lid via grappler G2 and the third motion consists of lead screw drive for movement of sliding door for its opening and closing. All the three drives have been provided with manual override features to operate the drives independently during emergency.

(vi) Control Panel : The control panel is PLC based and equipped with an HMI to visualize and operate the system in auto, manual or admin mode. Fig.6 shows the photograph of control panel. Any alarms, indications or faults are noticeable in the HMI. Emergency button is provided to terminate all the operation instantaneously. The control panel has Toggle type switches, Push Buttons, Selector Switches for manual operation of the system. The panel also has digital display for load cell readings. The PLC logic has two different programs for storage (Disposal) and retracting (retrieving) cycles which operator has to select before commencement of auto or manual mode operations. Automated and safety interlock operation of system is achieved by sensing the feedback of lever type limit switches, encoder, tooth type inductive proximity sensors and load cells.

Fig. 6: Control panel

Fig. 7: Lever type limit switch

Fig. 8: Load Cell

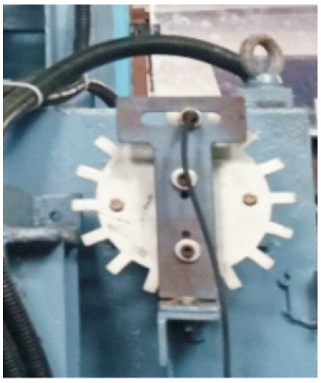


Fig. 9: Tooth type proximity sensor

Fig. 10: Encoder

Fig. 7, 8, 9 & 10 depict various sensors used in the system. Cable take-up and management of lifting chain during its up&down movements were resolved using drag chain and counter weight arrangements respectively.

System Safety Interlocks

Following safety interlocks are incorporated for Auto & Manual mode operations.

a) The Reverse / Forward motion of Cask Shielded Sliding door is enabled only if Canister Grappler G1 is at it stop most position and Vault Lid lifting Grappler G2 is loaded & is at its top most position.

b) During Canister Disposal cycle, Canister DOWN motion is enabled only if load cell measures the weight of canister and shielding door is in fully opened position.

c) During Canister retrieval cycle, Grappler G1 DOWN motion is enabled only if load cell measures No weight and shielding door is in fully opened position.

d) Vault Lid lifting Grappler G2 up/down motion enable only if sliding door is fully closed.

e) Both Grapplers open (un-grip) only when respective load cells measure No Load.

f) Lid Grappler (G2) interlocks for jaws opening (un-grip) and closing (grip) are different for lid lifting and lid unloading operation.

- Lid loading/lifting operation: Lid Grappler (G2) Jaws open 50 mm prior to lid lifting thimble position measured by encoder and closes at lid lifting position and lid lifted till it reaches its top most position.
- Lid unloading/loweringoperation: Lid Grappler (G2) Jaws open only when lid reaches its bottom most storage location sensed by limit switch& load cell and closes immediately after 50mm up motion of grappler measured by encoder.

g) Canister Grappler (G1) interlocks for Jaws opening and closing are different for canister disposal and retrieval cycle.

- Disposal cycle: Canister Grappler (G1) Jaws open only when canister reaches its bottom most storage location sensed by limit switch& load cell and closes immediately after 100mm up motion of grappler measured by encoder.
- Retrieval cycle: Canister Grappler (G1) Jaws open 100 mm prior to canister lifting position measured by encoder and closes at canister lifting position and canister lifted till it reaches its top most position.

h) Load cell interlocks for Canister and Vault lid vertical up/down movement are different for loading & unload cycle:

Experience Gained During Performance Trials

Due to developmental nature of the system, the system has been tested repeatedly to generate base line data and ensuring safety during the operation. Following are major improvisation incorporated in the system design.

a. Underweight/Overweight alarm: During lowering operation, in an event of the canister or lid getting stuck in its path, the load cell shall detect the underweight and PLC will raise Underweight alarm and terminates the operation. Furthermore, during lifting operation, if canister/lid stuck-up in its path, load cell will detect the overweight and PLC will raise overweight alarm and terminates the operation.

b. Incorporation of Load cells: Safety interlocks are different for loading and unloading cycles. Hence, in addition to limit switches & encoders, load cells were introduced in both canister&lid grapplers to identify presence of canister/lid. Hence, load cell plays vital role in automation & safety of this system.

c. Grappler Electromagnetic Coil Over-heating: To avoid overheating of electro-magnetic coil of grappler, the time of actuation is kept as low as possible and this has been achieved using encoders feedback

Future Scope

The developed ATCS demonstrates retrieval and disposal for single canister. However, interim storage vault houses minimum 3 canisters stacked one above the other. Future scope in design of ATCS shall involve modification of PLC program for transfer of 3 canisters. In the auto cycle, PLC shall first execute dummy cycle to ascertain the presence and actual position of canisters inside vault.

Instead of lifting/lowering of ATCS using crane during alignment with port, ATCS will remain 100 mm above surface floor of vault and local shielding shall be moved up &down for maintaining radiation integrity. This shall simplify the crane design.

Conclusion

The model Automated Transfer Cask System has been tested and demonstrated successfully. The system not only serves in reducing the man-rem expenditure of the material handling personnel but also simplifies the remote emplacement of canister in the storage vault with adequate safety and reliability. The experience gained in the demonstration trials of ATCS will pave the way for execution of plant scale "Automated Transfer Cask System" meant for active plant operations.

Acknowledgments

The authors are thankful to Shri Vismai Singh, SO/D, NRB and Shri B. S. Jatav, TO/D, NRB for their contribution in design & inspection of Instrumentation & electrical system respectively. Authors are also thankful to Shri R. Srinath, SO/D, NRB for his support in preparation of this report.

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