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Suggestion of Efficient High Dose Spent Filter Handling and Compaction Equipment

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Spent filters with a high radiation dose rate of 2 mSv·hr^{-1} or more are not easily managed. So far, the Korean policy for spent filter disposal is to store them temporarily at nuclear power plants until the waste filters can be easily managed. Nuclear power plant decommissioning in Korea is starting with Kori unit 1. Volume reduction of waste generated during decommissioning can reduce the cost and optimize the space usage at disposal site. Therefore, efficient volume reduction is a very important factor during the decommissioning process. A conceptual method, based on the experiences of developing 200 and 800 ton compactors at Orion EnC, has been developed considering worker exposure with the followings a crusher (upgrade of compaction efficiency), an automatic dose measuring system with a NaI(Tl) detector, a shield box, an inner drum to prepare for easy handling of drums and packaging, a 30 ton compactor, and an automatic robot system. This system achieves a volume reduction ratio of up to 85.7%; hence, the system can reduce the disposal cost and waste volume. It can be applied to other types of wastes that are not easily managed due to high dose rates and remote control operation necessity.

Keywords: High dose, Spent filter, Handling system, Compaction equipment

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1. Introduction

At present nuclear power plants in Korea have many high dose spent filters which can't be handled easily due to the high dose (> 2 mSv·hr^{-1}). So far high dose spent filters were temporarily stored at site for decaying the radioactive nuclides which is the KHNP's policy. By this reason the spent filters are stored at the designated area at site with shielded wall against high exposure. For the handling and compaction in consideration of future spent filter disposal, an efficient system to handle and compact the spent filters is needed. During the handling and compaction work, automatic handling system is needed for reducing the exposure and protecting the workers safely against radiation exposure [1]. So far, the high dose spent filter handling system has not developed, but it is needed to empty the filters at storage area near soon before the decommissioning of a nuclear power plant. For safety handling and efficient reduction of spent filters, etc. ORION EnC proposes and develops a conceptual system which can treat high dose spent filters efficiently and can safely protect workers against radiation exposure by automatically loading the system and compacting the spent filters. Based on our calculations, the volume reduction rate of this system is estimated to be about 5 or more.

The high level spent filter reduction system proposed in this paper has more effective reduction and treatment capabilities, and it will also be very usefully used for the treatment of radioactive high level spent filters generated during the decommissioning process of nuclear power plants.

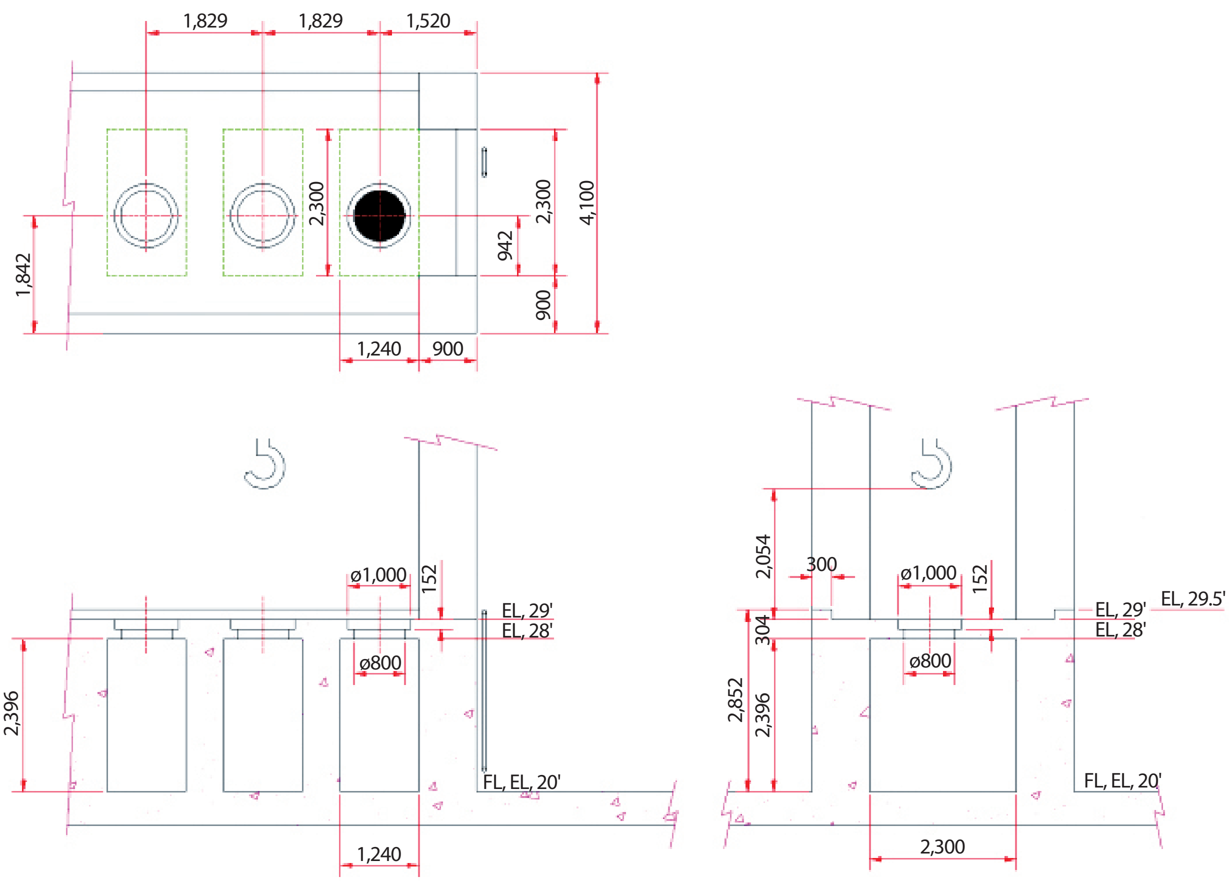


Fig. 1. Layout of Kori 1 Spent Fuel Storage Area.

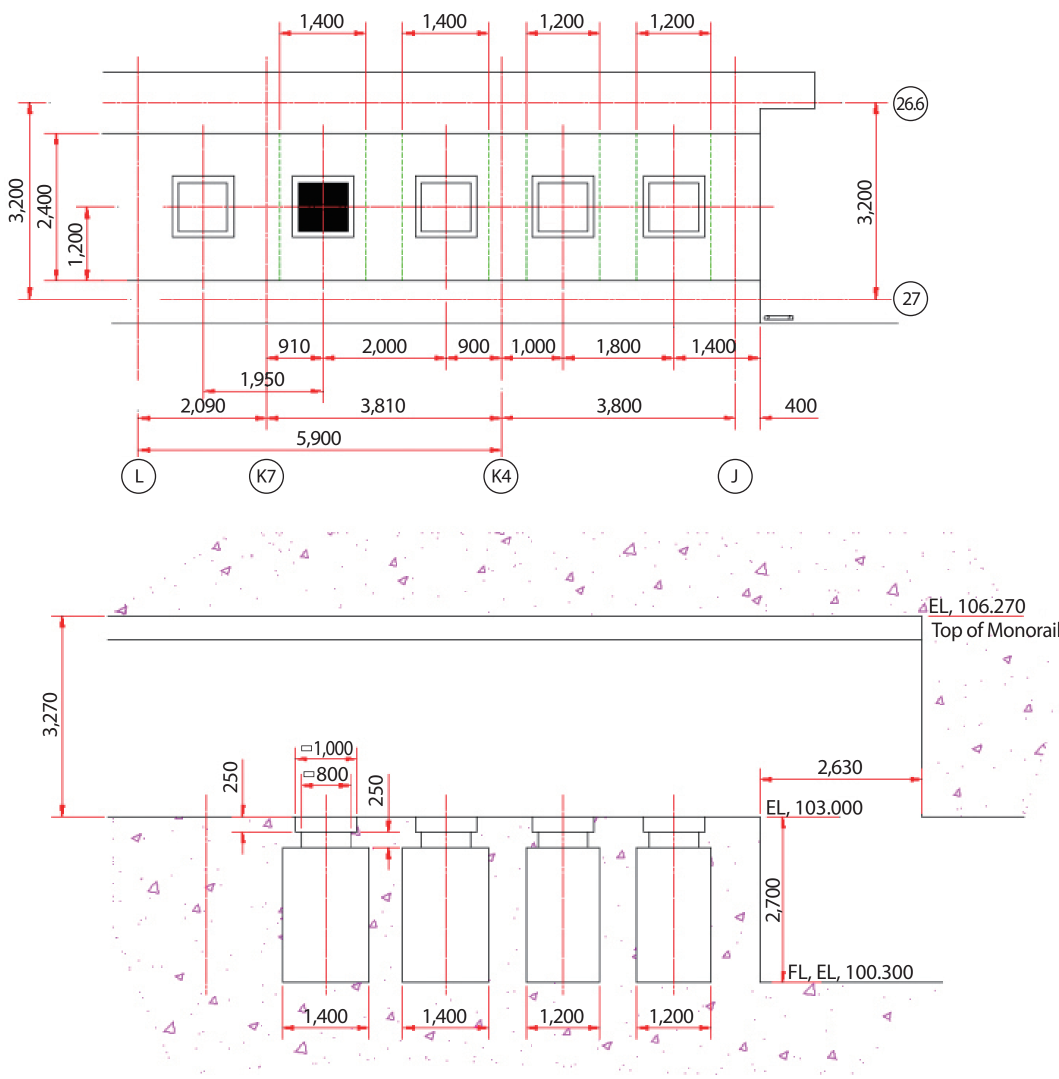


Fig. 2. Layout of Kori 2 Spent Fuel Storage Area.

2. Suggestion of Automatic Handling and Compacting Equipment

2.1 Background

High dose filters in nuclear power plants have been temporarily stored at designated storage area which is well shielded shown in Figs. 1 and 2 to reduce the radioactivity because the radiation exposure dose rate is too high (more than 2 mSv·hr^{-1}) [2]. High dose spent filters generated in Liquid Radwaste System (LRS), etc. are SFP (Spent Fuel Pool) skimmer filters, RCP (Reactor Coolant Pump) seal injection filters, Reactor coolant filters, CVCS (Chemical Volume Control System) injection filters, FDT (Floor Drain Tank) filters, W/E (Waste Evaporation) filters, WHT (Waste Holdup Tank) filters, etc. The typical LRS filters and SFP skimmer filters whose outer frames are made of S/S are shown in Fig. 3. The filters are cylindrical type and the

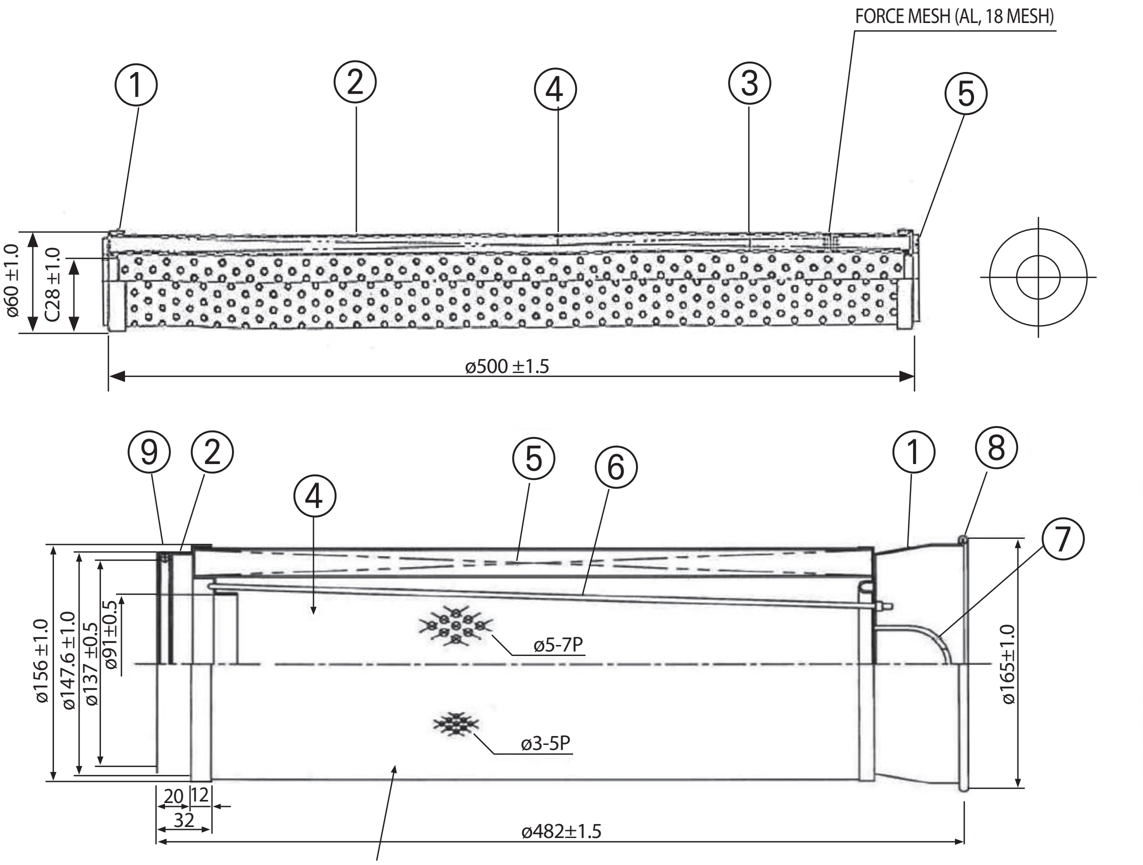


Fig. 3. Sketch of high dose filters (LRS filter (up) & Spent Fuel Pool skimmer filter (down) (Explanation of each number omitted).

lengths are 70 cm as below.

To reduce the volume of filters the radiation and radioactivity measurements are essential because the WAC (Waste Acceptance Criteria) of container for disposal of spent filters requires the surface dose rate of outer surface of container shall be below 10 mSv·hr^{-1} and the nuclide and radioactivity conditions shall be judged if they are satisfied.

To make the disposal of high dose spent filters the compaction of filters is needed to make sure of the maximum possible reduction ratio from the economic point of view. And the automatic handling equipment for high dose spent filter equipment is needed to make sure of reducing workers' exposure from radiation and protecting workers against radiation hazards [3].

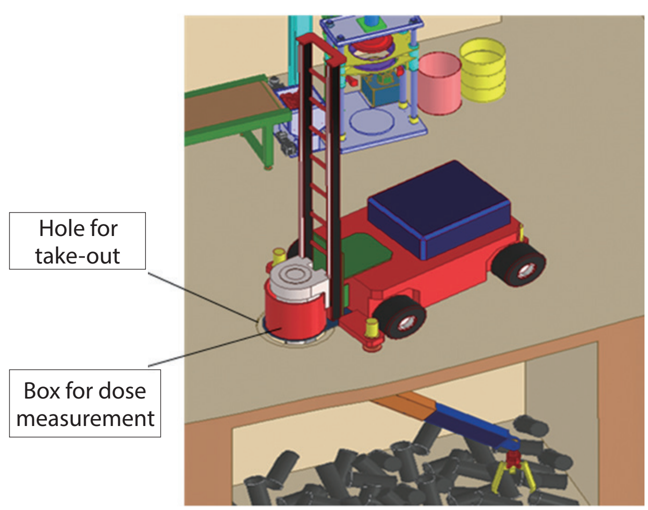


Fig. 4. Robot system for measuring dose rate and take-out filters.

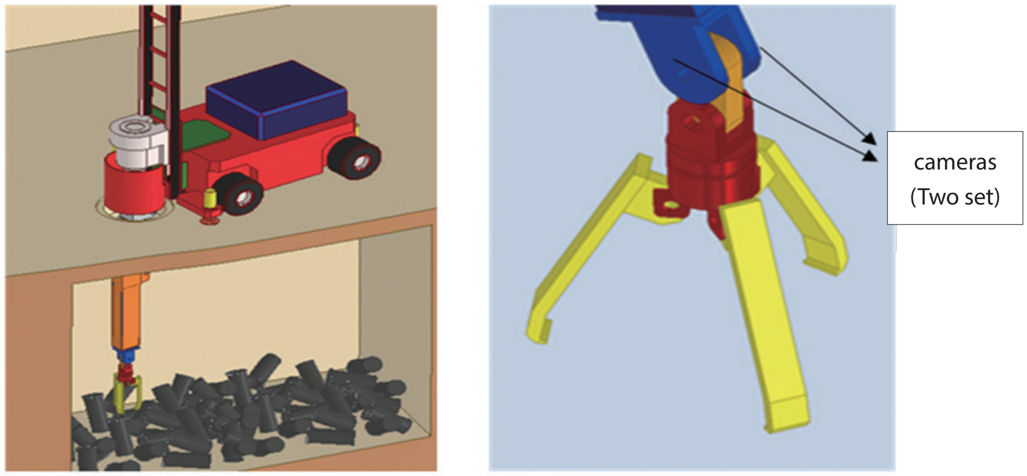


Fig. 5. Take-out handling of target filter.

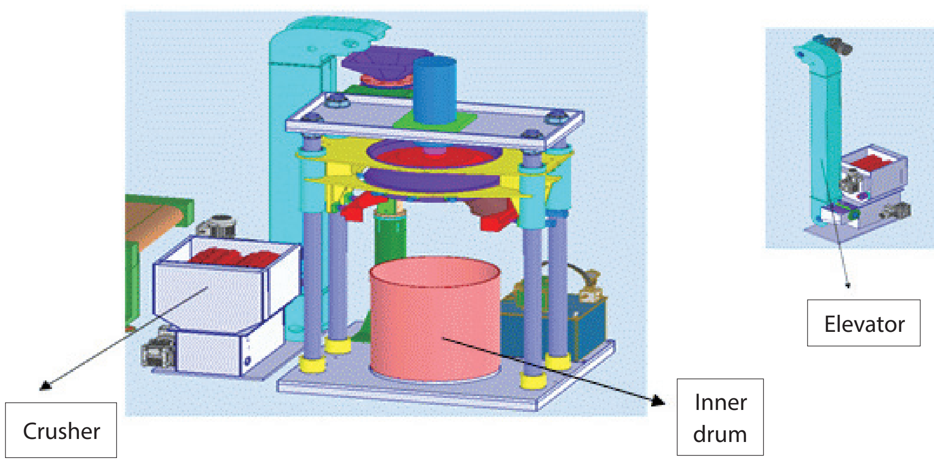


Fig. 6. Filter compaction system.

2.2 Conceptual Approach for Adoption of High Dose Spent Filter Handling and Compaction Equipment

2.2.1 Classification of Spent Filters by Dose Rate Identification

The classification of spent filters by dose rate is important because when packing the containers the outer surface dose rate (below 10 mSv·hr^{-1}) should be considered.

Spent filters having too high dose rate may not store in container adequately because the volume of container is limited due to too much high dose rate in consideration that the void fraction shall exceed 85% in container according to WAC [4]. But as shown in Figs. 1 and 2 the storage area is higher radiation exposure area and the access of workers are not easy. In consideration of this difficulty the automatic dose measurement and filter take-out robot system is recommended (Fig. 4).

The target filters are taken out by robot system up to operation area and the radiation dose rate of filter is measured inside the box. The box contains radiation measurement sensor (NaI 3” × 3” detector) to check the radiation dose

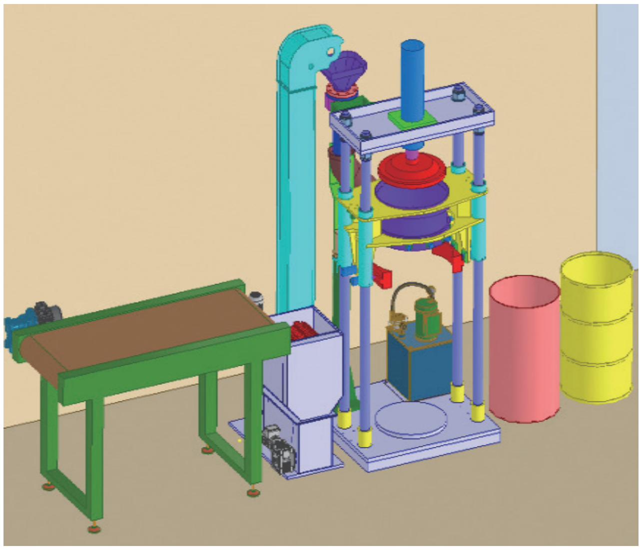


Fig. 7. Configuration of filter compaction system.

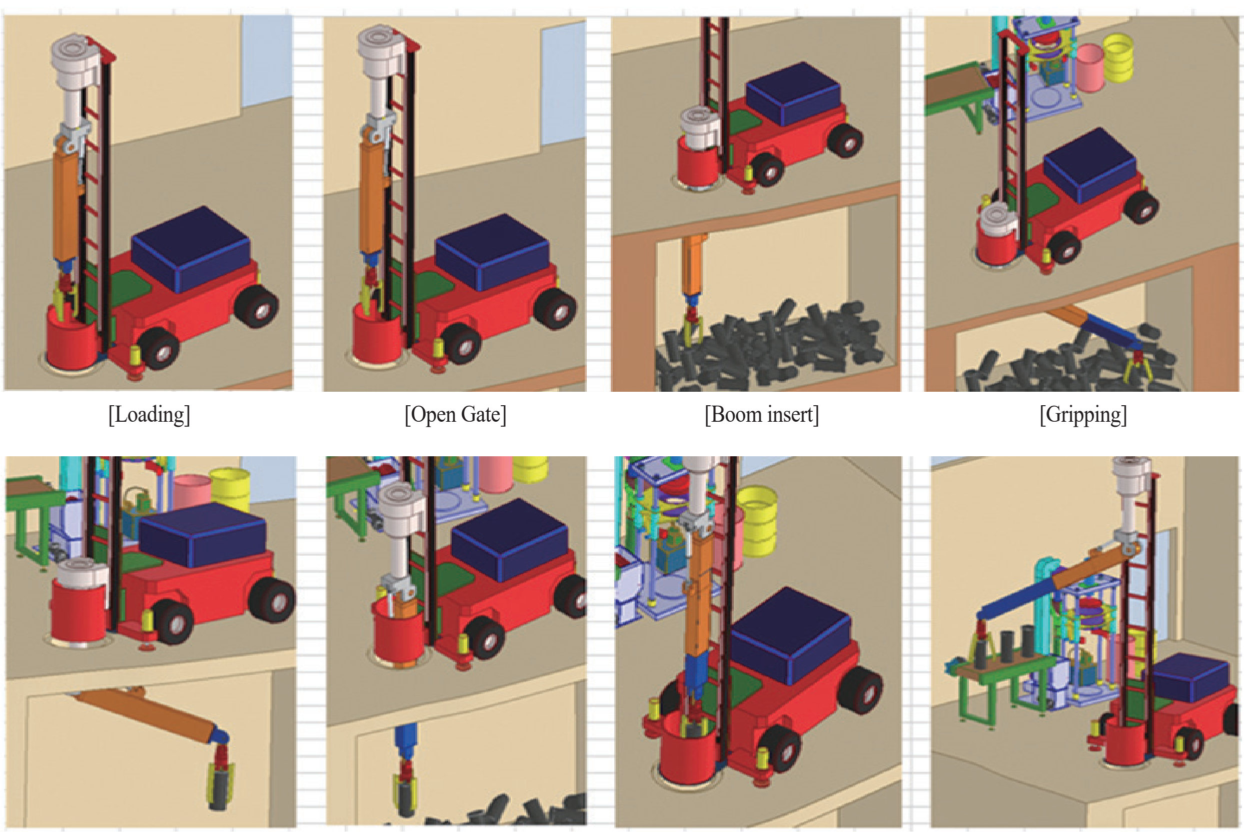
and the effect of background of storage area and operation area is excluded because the box is shielded. After checking the dose, the too much high dose filters are returned to the storage area for further decade and the adequate filters are handled for the compaction as the next step.

2.2.2 Filter Take-out Application

The location of filter in storage area is identified through the CCTV as shown in Fig. 5. the take-out robot consists of 3 arms for safe capturing of the filter. Two cameras can be rotated according to the worker's indication which is sent by main remote-control panel.

2.2.3 Filter Compaction

To maximize the reduction ratio the crusher is ready to



[Loading] [Open Gate] [Boom insert] [Gripping]

[Take-out] [Boom withdraw] [Radiation measurement] [Transport to Conveyor]

Fig. 8. Procedure of Robot handling and application system.

Table 1. Specifications of compaction equipment

Part		Specifications
Power		AC 380–480 V. 3 Phase. 60 Hz. 50 A
Main Motor		AC 380–480 V. 3 Phase. 60 Hz. 10 HP, 4 pole
Main control	Type	P.L.C & HMI control type
	P.L.C	XGB Series
	Touch Screen	XP 40 Series
	Panel meter	GP 4AD
	Pressure Control	Proportional control valve & Relief Valve
Actuation Method		Hydraulic and Conveyor actuation
Main Cylinder	Specification	Φ 280, 700 stroke, double (total work length: 1,000 mm)
	Use Pressure	250 $kgf \cdot cm^{-2}$
	Pressure power	30 tons
	Speed	1.7 $m \cdot min^{-1}$
Hydraulic tank capacity		120 L
Cooling method		Radiator
Hydraulic Control method		Solenoid & manifold
Hydraulic Actuation oil		GS No. 46
Conveyor	Control type	Invert control
	Power	AC 380–480V. 3 Phase. 60 Hz. 50 A
	Motor & Reducer	0.75 kw, 3 Phase, 120:1 ratio
	Speed	10 $m \cdot min^{-1}$
Elevator	Type	Bucket Lift type
	Power	AC 380–480V. 3 Phase. 60 Hz. 50 A
	Control type	Invert control
	Motor & Reducer	0.75 kw, 3 Phase. 200:1 ratio
	Speed	6 $m \cdot min^{-1}$
Crusher	Power	AC 380–480V. 3 Phase. 60 Hz. 50 A
	Type	Rotation Lake Type
	Motor & Reducer	Motor: 5.5. kW, Reducer Ratio: 120:1

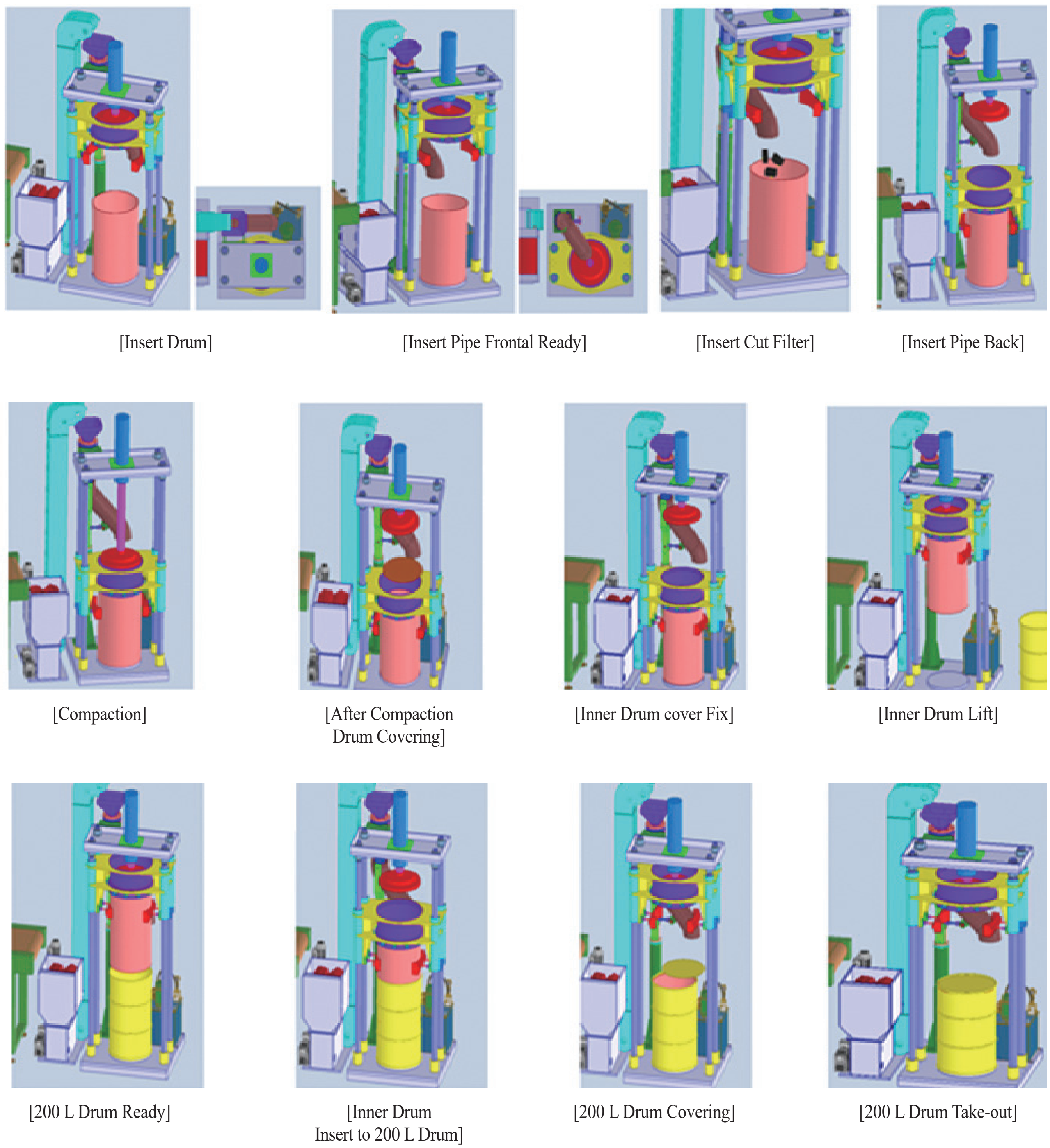


Fig. 9. Procedure of Robot handling and application system.

crush the filter to the dimension of below 100×100×100 mm³ and as the next step the compaction equipment is applied (Fig. 6).

The compaction equipment can provide the sole filter packing capability by setting inner drum for store spent filter and the inner drum is made of austenite series plate and the thickness is about 1–2 mm in consideration of filter loading weight.

2.2.4 Conceptual Layout of Filter Compaction Equipment

As shown in Fig. 7, the compaction equipment consists of conveyor which convey the filter, crusher, spent fuel filter transport elevator, elevator motor for moving of elevator, inner drum, main control panel, main cylinder, oil tank to supply hydraulic pressure, etc.

2.3 Characteristics of High Dose Spent Filter Handling and Compaction Equipment

2.3.1 Handling System

The robot system has the functions to grip, take-out, withdraw and transport the filter (to conveyor) as well as measuring the radiation dose inside the shielded box. The handling and robot application works are proceeded shown in Fig. 8.

2.3.2 Compaction System

The compaction system is operated by hydraulic pressure and the compaction power is 30 tons. The loading speed is 1.7 m·min^{-1} and the filter are compacted about up to 85.7%. The main specifications of compaction equipment are shown in Table 1.

The procedure composes sequentially as insert drum, insert pipe loading to drum, insert cut filter, insert pipe withdrawal to the backside, compaction work, drum covering after compaction, inner drum cover fixing, inner drum lift, 200 L drum loading, and 200 L drum take-out, etc. as shown in Fig. 9.

2.4 Key Technologies

2.4.1 Summary

The equipment can solve the problems in classifying dose rate of filters by shielded box and measurement device preparation, exposing of high dose radiation by remote control robot system application, producing low reduction ratio efficiency by adopting crusher and 30 tons compaction equipment at the same time.

In addition to above merits, the radioactivity measurement in drum can be possible based on reduction ratio calculation and the scaling factor can be gotten through DTC method using MCNP code [5]. But this explanation is not handled in this paper in detail.

2.4.2 Handling System

The unwanted spent filters which are not necessary for urgent disposal (more decay time needed) can be returned to storage area by using robot system after checking the outer surface dose rate.

The measurement system can provide outer surface dose rate of drum per activity towards each gamma emitting nuclides such as ^{60}Co, ^{137}Cs, etc. by calculating the compaction ratio using MCNP code.

In case of using shielded DAW (dry active waste) drum or spent filter drum used at nuclear power plant instead of 200 L drum for cut spent filters, the measurement of outer surface dose rate of drum per activity can also be possible [6].

The targeted outer surface dose rate is fixed (for example, 2 mSv·hr^{-1}) the possible storage radioactivity in drum can be calculated by using MCNP code by reflecting compaction ratio.

The system can utilize DTC (Dose to Curie) method for scaling factor application [7-8].

2.4.3 Compaction System

The compaction (reduction) ratio can be calculated towards filter frame (S/S) & flange and filter mesh. Filter

Table 2. Calculations of each reduction ratio of filter mesh and filter frame (flange)

Calculation data	
Filter mesh (paper is same)	Filter frame (flange is same)
ⓐ Average vacancy ratio (V') V'= [V1]_1 + [V2]_2 = 21.5% where, [V1]_1 is 8.5% which is self-vacancy ratio of filter mesh after compaction and [V2]_2 is 13% which is vacancy ration except filter mesh after compaction (self vacancy ratio is vacancy ratio which filter frame has by himself and vacancy ratio except filter mesh is the vacancy ratio of vacant space. ⓑ Inner Drum volume = ID Φ 450 × H 680 mm= 105 L (≅100 L) ⓒ Weight of filter mesh before compaction (100 L basis without air weight) = 100 L × filter frame specific gravity (0.7–1; here 0.85 is applied) × 0.372 (volume fraction) = 31.6 kg ⓓ Filter mesh weight after compaction = (Total volume (100%)−V'(21.5%) × specific gravity (0.85) = 62.7 kg ⓔ Compaction ratio = 31.6 ÷ 62.7 ≅ 50% (50% is less)	ⓐ Vacancy ratio (V') in no load V'= [V1]_1 + [V2]_2 = 57.5% where, [V1]_1 is 0% which is filter frame vacancy ratio and [V2]_2 is 57.5% which is vacancy ration except filter frame. ⓑ Inner Drum volume = ID Φ 450 × H 680 mm= 105 L (≅100 L) ⓒ Weight of filter frame before compaction (100 L basis without air weight) = 100 L × filter frame specific gravity (6.9 is applied) × 0.13 (volume fraction) = 89.7 kg ⓓ Filter frame vacancy ratio in case of 30 tons compaction = [V3]_1 + [V4]_2 = 21% (where [V3]_1 is frame vacancy ratio after compaction (0%) and [V4]_2 is vacancy ratio except frame after compaction (9.1%) ⓔ Filter mesh weight after compaction = (Total volume (100%)−V'(9.1%) × specific gravity (6.9) = 627.2 kg ⓕ Compaction ratio = 89.7 ÷ 627.2 ≅ 14.3% (85.7% is less)

mesh is expected to have the reduction ratio like paper based on ORION EnC's compaction experiences in case of 30 tons compaction. Filter frame is made of S/S and it has some vacant space the average specific gravity can be calculated as 6.9. Thus, the reduction ratios of filter mesh and frame (flange also) are calculated as about 50% and 85.7% respectively. The calculations of each reduction ratio of filter mesh and filter frame (flange) are shown in Table 2.

The accurate reduction ratio can be identified after dismantling the filter but if the ratio of filter frame is expected as minimum 70%, the expected compaction ratio is 80% as calculated as below.

$$(85.7\% \times 70\%) \div (85.7\% \times 70\% + 50\% \times 30\%) = 80\%$$

Thus, the reduction ratio is more than 5. So this equipment can reduce the high dose spent filter as having more than 5 reduction ratio. This means the equipment can contribute the efficient volume reduction of high dose spent filter.

3. Conclusions

The automatic handling and compaction equipment for high dose spent filter are developed as conceptual basis which can show high reduction capability. ORION EnC introduces the shielded measurement system for classifying dose of spent filters and prepares the crusher equipment before compaction, etc. for upgrading the compaction efficiency. The robot system and compaction equipment will be helpful for decommissioning of nuclear power plant as good method for high dose spent filter disposal. Because the compaction equipment is well developed at ORION

EnC and the basis of robot system for decommissioning is also under development by governmental support. So the high dose spent filter automatic handling and compaction equipment can be adopted in Korean decontamination industry when the pilot scale system will be ready and successfully operated in future.

Acknowledgements

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