DAW VOLUME REDUCTION AND SOLIDIFICATION BY THE SCREW COMPACTOR

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ABSTRACT

High amounts of dry active waste (DAW) are generated at nuclear power stations. Treatment requires many man-hours and expensive equipment, which, as a result, economically burdens their waste management. To solve these problems, a new technology called the Screw Compactor was developed by JGC Corporation. The Screw Compactor, which consists of one axial screw housed in a shell, melts DAW by compression and friction heat; thermo-plastics such as polyethylene which is contained in DAW, are utilized as a binder, mixed with other materials, then extruded from the Screw Compactor. Results obtained from an actual size mobile type demonstration prove that the Screw Compactor can volume-reduce a wide range of DAW and ion-exchange resins, both economically and efficiently, to yield products that meet 10 CFR Part 61.

BACKGROUND

Nuclear power plants generate large amounts of dry active waste called DAW. Treatment of this DAW requires many man-hours and expensive equipment, resulting in an economical burden for waste management.

JGC and Owl Co. in Japan perceived these problems and developed a new technology called the Screw Compactor.

During various basic tests using simulated DAW, such important functions as operability, reliability, maintainability, product properties and volume reductivity were confirmed by a full size demonstration Screw Compactor.

Composition of DAW

Wastes generated at nuclear power plants are composed of liquid waste or concentrates, spent ion-exchange resins, filters and compactible and non-compactible wastes. Data cited from an EPRI report indicating the average portion of each waste at PWR power stations are shown in Fig. 1.

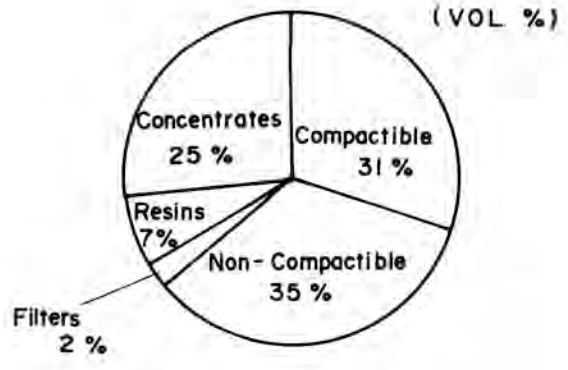

Fig. 1. PWR Waste Composition.

Though compactible waste, which comprises 31% of total waste, is the major objective of the Screw Compactor, it can also treat some non-compactible waste and ion-exchange resins.

Fig. 2, cited from EPRI data, shows the average composition of DAW generated at PWR power stations. These data reveal that 23% of the total DAW consists of PVC and other plastic materials. Since DAW contains relatively large amounts of plastics which act as a binder, this DAW would be the best feed stock for the Screw Compactor.

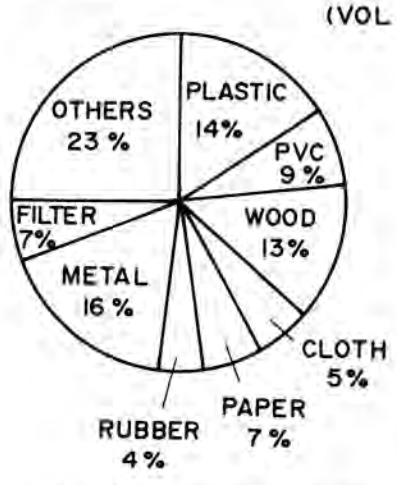

Fig. 2. Composition of DAW at PWRs.

Treatment and Volume Reduction Options

Various treatment and volume reduction options are presently available for DAW. Features of each option are briefly discussed below.

The first option would be an Incinerator. Several have been operating for years with satisfactory technical results, especially due to their high volume reduction factors. However, incinerators have several inevitable drawbacks: non-combustible wastes must be treated by other methods; they

generate contaminated off-gas; and they require troublesome ash handling systems. In ion-exchange resin combustion, a scrubbing system must additionally be provided, since off-gas includes not only radionuclides but also sulfate and sulfuric compounds which may cause environmental problems. A scrubbing system, however, usually generates a large amount of secondary waste.

A Shredder/Compactor could be next recommended for DAW containing non-combustibles (favorable cost performances are reported). However, springback problems must first be overcome to attain a sufficient volume reduction factor, especially when waste contains a considerable amount of plastic materials such as PVC and polyethylene.

While a Super Compactor can achieve a high volume reduction factor and also solve the springback problems, its installation cost is expensive.

The Screw Compactor, then as the best option, would be recommended for wastes that contain large amounts of plastics and ion-exchange resins, and reasonable amounts small pieces of metal or non-combustible waste, such as used cable wires and used filters.

THE SCREW COMPACTOR

Concept of the Screw Compactor

The Screw Compactor, as illustrated in Fig. 3, consists of one axial screw housed in a shell structure incorporating a DAW shredder, mixer, hopper and cutter.

Shredded DAW is received in the hopper, then fed into the Screw Compactor. Waste containing thermoplastic materials such as polyethylene are melted by compressive and friction heat while being extruded by the Screw Compactor, then are mixed with other wastes to form volume-reduced solidified waste. The cutter shears the extrusions into pellets which are then filled into containers for disposal. Most compactible and non-compactible DAW can be volume-reduced and compacted by the Screw Compactor.

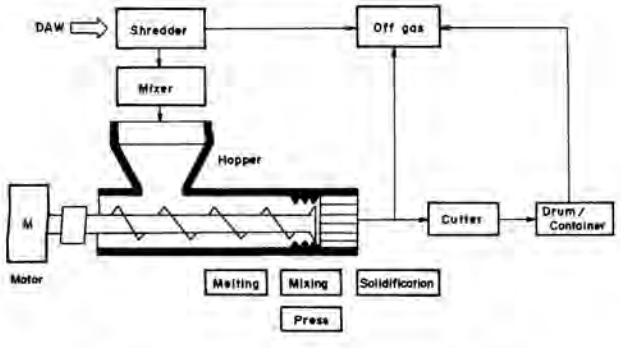

Fig. 3. Concept of the Screw Compactor.

Construction of the Screw Compactor

Construction of the screw, shell and nozzle is shown in Fig. 4.

The screw pitch and diameter are the key design points which provide compressive force and friction heat to melt thermoplastics. As the pitch and diameter of the screw decreases in proportion to its proximity to the molding nozzle, the wastes compress and squeeze into the nozzle. As they do so, they are further chopped by a blade on the screw tip. Friction and compression generate heat in the wastes, and the thermoplastics contained in them melt, fusing the wastes. As the wastes are continuously fed from the mixer, fused and mixed waste ejected from the nozzle which is fixed at the end of the Screw Compactor.

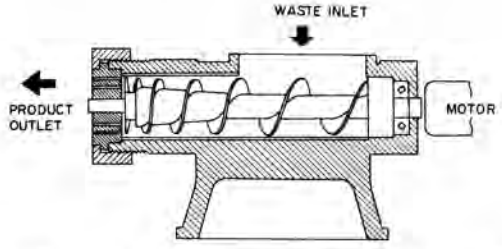

Fig. 4. Construction of the Screw Compactor.

TEST RESULTS

Features of the Screw Compactor Products

The molten plastics, which are the key of this technology, offer the following excellent product properties:

Molten plastic waste is an effective binder for solidifying wastes to form:

1. a non-springback and highly volume-reduced waste form
2. a dense waste form incorporating accompanied waste such as ion-exchange resins and non-combustible wastes firmly fixed within form
3. a water-resistant waste form due to its water repellent surface
4. a waste form having a fair compressive strength due to multi-effects of the waste matrix and waste filler
5. a relatively uniform waste shape resulting from the kneading effect of the screw
6. a liquid-free waste form resulting from the squeezing and heating effect

Volume Reduction Factor (VRF)

Table I shows two typical test run results. For pellet products, an overall VRF of 6 to 7 was attained. The design of the Screw Compactor additionally permits higher packaging efficiency through easy attachment of a piston-like machine onto the end of the Screw Compactor which allows formation of the pellets into pillar-shaped products: this increases the VRF to 8 to 12.

TABLE I

Volume Reduction Factor of DAW

Waste Composition (wt%)	Run 1	Run 2
Cloth	37	29
Plastics (PE, PVC)	42	26
Rubber	1	1
Wood	2	6
Insulation	5	8
Concrete, Sand	6	11
Metal	7	19
VRF Pellet products	7	6
VRF Pillar-shaped products	12	8

Treatment of Ion-Exchange Resins

One of the features of the Screw Compactor is its applicability for combining spent ion-exchange resins with DAW. Tests were conducted by using cation and anion-exchange resins and mixture of the two with DAW at a mixing ratio of 50/50 wt%.

Results were as follows:

1. The product became dense when the resins were solidified with PVC.
2. The resins were fixed in molten PVC and polyethylene while bead resins were neither fused nor crushed.
3. A volume reduction factor of 2.5 was observed.

The typical test result of ion-exchange resin treatment is shown in Table II.

TABLE II

Volume Reduction Factor of Ion-Exchange Resin-DAW Mixture

Waste Composition (wt%)	
Cloth	3
Plastics (PE, PVC)	33
Rubber	4
Others	10
Ion-Exchange Resin (*1)	50
VRF	2.5

(*1) Water content 42 wt%

Product Properties

Specific Gravity: Although the specific gravity of products changes with waste composition, an average 0.99 kg/cm^2 was obtained.

Compressive Strength: The compressive strengths of almost all sample products were higher than 50 kg/cm^2, with an average of 70 kg/cm^2.

Leachability: Measurement of the products' leachability shows that the leaching rate after 90 days is in the order to 10^{-4} - 10^{-5}, with a leach index of 12.

Immersion: After 90 days immersion, products maintained high compressive strength with rare volume change.

Free Liquid: No free water was contained in the products.

Product properties as summarized in Table III.

TABLE III

Product Properties

Item	Properties
Specific gravity (g/cm^3)	0.99
Compressive strength (kg/cm^2)	70
Leaching rate (90 days)	10^{-4} - 10^{-5}
Leach index (90 days)	12
Free liquid	None
Homogeneity	Good
Biodegradation	Good
Thermal cycle	Good

MOBILE TYPE SCREW COMPACTOR

Outline

The 300 kg/hr capacity Screw Compactor can handle all wastes, except large metals, that are generated by four nuclear power plants and can be housed on a trailer.

A typical mobile Screw Compactor consists of the following components as illustrated in Fig. 5:

1. Shredding system
2. Mixing system
3. Screw Compactor
4. Drum filling system
5. Off-gas system

Operation and Maintenance

The Screw Compactor is so designed that the system can treat a wide range of waste and be easily operated and maintained.

1. Roughly sorted wastes, with a plastics composition of 10 wt% or higher, are acceptable.
2. Operation temperature is so low, at the range of 150°C, that no hazardous gas is generated.
3. At daily startup, waste which is left in the nozzle section of the Screw Compactor after the previous day's operation is softened by electrical heating. However, during normal operation, the Screw Compactor generates sufficient compression and friction heat to fuse plastics. No external heating is required.
4. The Screw Compactor requires only electricity to operate the whole system.
5. During maintenance, to reduce radiation exposure, non-radioactive wastes are fed to the Screw Compactor and contaminants are

replaced. A nozzle at the end of the Screw Compactor can be easily disassembled.

6. Only one operator is needed to input the waste bags and replace the filled containers.

CONCLUSION

The Screw Compactor volume reduces a wide range of DAW and ion-exchange resins, and yields superior products that meet 10 CFR Part 61.

Full scale demonstration plant tests have confirmed the Screw Compactor's excellent operability and maintainability. In addition, the Screw Compactor's economical advantages exceed other options.

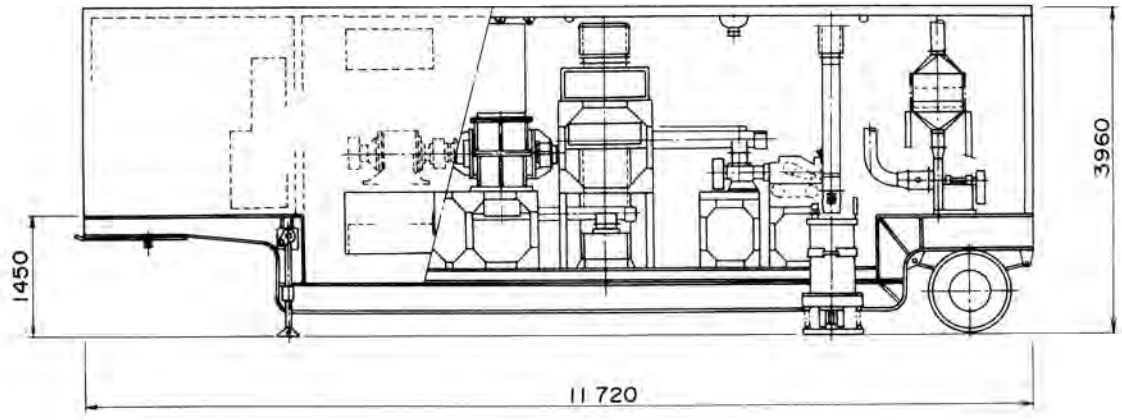

Fig. 5. Mobile Type Screw Compactor.