FUSRAP Experience Transporting LLW and 11e(2) Waste Materials by Rail, Intermodal Container, and Truck

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INTRODUCTION

During the 1940's, 1950's, and 1960's, many sites in the United States were used by the Manhattan Engineer District (MED) and the Atomic Energy Commission (AEC) for processing and storing uranium and thorium ores and metals. Some of the sites were owned by the Federal Government; others were owned by universities or other institutions; and still others, such as chemical plants, were privately owned. The Formerly Utilized Sites Remedial Action Program (FUSRAP) is one of several U.S. Department of Energy (DOE) programs created to address radioactive contamination in excess of guidelines at a number of these sites. FUSRAP currently includes 46 sites in 14 states.

Generally, the sites contain low-level radioactive waste (LLW) and 11e(2) material (by-product material produced from the extraction of uranium or thorium from ores as defined by the Atomic Energy Act of 1954 as amended). FUSRAP will eventually need to address approximately 1.5 million m^3 (2 million yd^3) of contaminated material primarily composed of soil and rubble.

This paper describes FUSRAP experience in packaging and transporting waste material for disposal and treatment and the lessons learned from these experiences.

OVERVIEW OF FUSRAP SITES

FUSRAP sites vary widely in their locations, waste types, and operational status. Site locations range from operational chemical plants to private homes in residential neighborhoods. The transport modes available at a site are often the key factor in choosing the packaging for the waste.

Packaging is generally selected after the mode of transport has been determined. Typically, loose conveyance of material is preferred because this method saves the cost of renting or purchasing packaging. For rail, the preferred packaging method is open top gondola, which provides high capacity and ease of loading. When rail access is not available at or near a FUSRAP site, intermodal transport is often used. The primary packaging for intermodal transport is "roll on/roll off" boxes, 15- to 33-m^3 (20- to 25-yd^3) boxes with metal lids. The most expensive choice for transport is exclusive highway. Packaging for highway modes includes low-specific-activity (LSA) boxes, drums, intermodals commonly referred to as sea/land containers, bulk bags, and 15-m^3 dumps. Examples of transportation and packaging methods used on FUSRAP are provided in Table 1.

Table 1. Examples of FUSRAP Transportation and Packaging

Site	Waste Type	DOT Class	Packaging	Mode
Colonie	Soil, debris, solidified liquids	3,6,7,9	LSA box, drum, bag, sea/land, other	Truck
Adrian	Debris, solidified sludge	Non-regulated	LSA box	Truck
Maywood	Soil	9	Gondola	Rail
Aliquippa	Soil	Non-regulated	Intermodal, LSA box	Rail, truck
St. Louis	Soil, asbestos	9, Non-regulated	Gondola, intermodal	Rail
Elza Gate	Soil, debris	7, 9	Dump	Truck

PACKAGING EXPERIENCE

Miscellaneous Packaging Types

A wide variety of packaging and transport modes has been used for FUSRAP materials. In addition to the more traditional drums and LSA boxes for small-quantity transport, materials have been packaged in supercompacted innerpacks, disposable bags, sea/land containers, and waste tanks. These more innovative approaches have provided cost reductions for waste packaging materials, waste transportation, and disposal.

Supercompaction and incineration coupled with supercompaction have been used on FUSRAP primarily for volume reduction and the associated disposal cost savings. These measures have also resulted in significant packaging cost savings. For example, building debris consisting of roofing materials (rubber matting, tarpaper, and styrofoam insulation) was supercompacted. This resulted in a volume reduction ratio of over 4:1 and reduced the volume of material to be packaged and disposed of. When supercompaction is combined with incineration, a volume reduction ratio of up to 400:1 can be realized.

However, there are potential disadvantages to this type of volume reduction. For example, a disposal facility used by FUSRAP has a maximum debris size restriction of $2.5 \times 2.5 \times 0.25$ m. The final size of the supercompacted material depends on the properties of the material and the volume of material loaded into the compactor. The more material that can be compacted at one time, the lower the cost for the compaction operation. Several trials were needed to determine the quantity of material that could be supercompacted to produce a finished product (referred to as a puck) less than 0.25 m thick. Care should be taken to ensure that the finished product will meet the size requirements of the disposal facility because it is difficult to reduce the size of a supercompacted puck.

Disposable 0.76-m^3 (1-yd^3) bags also proved to be a cost-effective means of packaging. A building at one FUSRAP site contained a pile with 760 m^3 (1,000 yd^3) of soil that had to be moved as decontamination of the building progressed. Bagging the soil facilitated movement of the material while maintaining maximum flexibility for selection of a final transport mode; bags can be easily transported by rail gondola, intermodal container, or truck. The use of bags resulted in a cost savings of approximately $130,000 compared to LSA boxes.

Sea/land containers, which have also been used by FUSRAP, offer several advantages that can be evaluated for each material to determine their suitability. Advantages include

- ease of loading;
- size that allows large, bulky items to be loaded without requiring size reduction; and
- low cost — a sea/land container can typically be rented for less than $20/day and purchased for less than $2,000.

The primary disadvantage is that the large size of the container makes it difficult to move and handle; on smaller sites this can be a challenging problem.

An unconventional packaging method with limited application but large potential for cost savings is the use of waste material as packaging. One FUSRAP site had several portable plastic tanks that were slated for incineration. Rather than cut up these tanks and put them into other packaging, the tanks themselves were used as packaging for other waste destined for incineration.

Rail Shipments (Gondolas)

FUSRAP has shipped over 400 gondolas totaling approximately 37,000 metric tons and 25,000 m^3 (32,700 yd^3) of material. An additional 30,000 m^3 (39,240 yd^3) is planned for shipment during fiscal year 1996.

A disposal facility used by FUSRAP has a rail car rollover capability that allows for quick and efficient dumping of gondola shipments. However, care must be taken to ensure that the gondolas used meet the rollover machine size requirements to avoid additional costs for rail car unloading. The gondola cars used by FUSRAP are generally 16 m (17.4 yd) long and have a net capacity of approximately 88,000 kg (193,600 lb).

Gondola shipments are made in uncovered cars using a heavy-duty liner as the waste package. Before the liner is installed, each gondola car is prepared by padding sharp edges. Drain holes in the bottom of the railcar are left open to allow drainage of rain water that accumulates during transport. Final preparation work for the gondola includes the inspection of brakes and springs and the removal of any previous hazardous material placards or labels.

Made of a 0.5-mm reinforced polyethylene material, the liner weighs approximately 68 kg (150 lb) and must be moved with a front-end loader or forklift. Two people can install a liner in approximately 20 minutes. When installed, the liner extends over the sides of the car to 15 cm above the ground. This protects the sides of the car from contamination during the loading process. During loading, the material is weighed with a calibrated scale on a front-end loader bucket. This scale is checked twice daily using concrete cylinders of known weight. Elastic shock cords are used to close and secure the liner and make it a strong, tight waste package. The elastic cords allow the material to shift during transport without ripping or tearing the liner. Closing and sealing the liner takes two people approximately 25 to 30 minutes.

Each gondola contains approximately 58 m^3 (76 yd^3) of material. The loading process typically takes 25-30 minutes per car. If necessary, a front-end loader is used to position cars during the loading process. Shipments made by rail are tracked using computer software provided by the rail company; the software provides a direct connection to the rail company's electronic tracking network.

There are some inherent disadvantages in using gondolas. One of the most frequent disadvantages experienced by FUSRAP is railcar unavailability. There is an industry-wide shortage of these cars. Some railroad companies must go to other rail companies to fill customer requirements, and a 30-day lead time for delivery to a site is often requested by the rail company.

Inaccessibility is another potential disadvantage. Many of the smaller and some larger FUSRAP sites are not accessible by rail service. If the volume of material shipped from a site is not large enough to recoup the capital expenditures for track upgrade or new track installation, the use of gondolas for bulk shipment may not be cost-effective. At one FUSRAP site, a cost study was performed to determine the volume at which it would be cheaper to upgrade the rail system and ship by gondola instead of shipping by intermodal container; it was determined that break-even would occur at 4,500 m^3 (5,886 yd^3).

Flexibility is another potential issue with using gondola railcars. FUSRAP sites with below-grade excavations may have frequent schedule-related changes because of weather, unexpected below-ground conditions, and other factors that can affect the shipping schedule. In many instances, the railroad companies have not been able to rapidly respond to schedule changes. If production is ahead of schedule, additional cars may not be available until the delivery time planned in the original schedule. Delays in the shipping schedule may mean that gondolas are staged for longer than planned.

For shipping campaigns of 200 gondolas or less, it is difficult to arrange predictable gondola transit times. As a result, re-use of gondolas during a single shipping campaign may not be possible. This increases transportation costs.

Intermodal Containers

FUSRAP has shipped over 5,700 m^3 (7,456 yd^3) of soil and debris in intermodal containers. Each intermodal container has a capacity of 15-19 m^3 (20-25 yd^3). However, typically only 10.5 m^3 (13.7 yd^3), weighing approximately 17,200 kg (37,926 lb), can be loaded because of the density of the material.

FUSRAP has used two different types of intermodal containers. One design has a solid metal lid, and the other design has a split lid, one side sliding over the other. Both styles are equipped with a tailgate for easy unloading. Most of the FUSRAP shipments made in intermodal containers are non-regulated radioactively contaminated soil and debris, which do not meet the Department of Transportation (DOT) definition of a hazardous material. Like the gondola railcars, intermodal containers are inspected before use to ensure compliance with structural integrity requirements. Each intermodal container is prepared, and a 0.3-mm plastic liner is installed. The container is normally loaded with a front-end loader.

At FUSRAP sites without access to a rail siding, intermodal containers offer an attractive transportation rate compared to over-the-road rates. Intermodal containers also provide the advantage of door-to-door service. The containers are brought to the site by either flatbed truck or roll-on-roll-off chassis. The containers are then loaded and picked up by roll-on-roll-off tractor/trailer rigs and transported to a railhead for transport by rail to the disposal facility. The containers can also be used for temporary storage of material prior to shipment. A 23,000-kg (50,715-lb) capacity forklift has been used to move intermodal containers on some sites. The forklift is large enough to unload the container on delivery and load the container onto a truck trailer when it is ready for shipment.

Additional advantages of intermodal containers are security and protection. The container provides protection against the weather and unintentional release of materials, and the container lids and tailgates are lockable. This protects the integrity of the shipment during transport.

A few intermodal shipments were received at a disposal facility with free-standing liquid, which is not in compliance with the disposal facility's operating licenses. Problems with water in FUSRAP intermodal shipments were determined to have been caused by

- loading frozen soil, which released water during transport;

- loading overly moist soils; and
- using some intermodal containers of the split lid design, which if not properly sealed allowed rainwater intrusion during transport.

To address the potential problem areas with free-standing liquids in intermodal shipments, a four-phase moisture control plan has been implemented.

1. Based on waste liquid limit tests and evaluations, an allowable loading moisture content range is established. The waste moisture content is compared to the allowable loading moisture content range, and potential problems can be identified before excavation and loading. Mitigation efforts can be planned accordingly.
2. Waste moisture conditions are evaluated onsite to determine the effectiveness of the moisture control efforts.
3. When the waste is loaded, final moisture content measurements are made to verify that the waste moisture content is within the allowable range.
4. Before acceptance on the site, intermodal containers are inspected to verify that they are structurally sound (no holes or leaks). Before loading, an additional inspection verifies that no water or other liquid has been introduced to the container and that the container has not been damaged during movement from a staging area to the loading area.

PACKAGING AND TRANSPORTATION COSTS

FUSRAP sites vary in size from small sites, containing waste volumes ranging from less than 50 m^3 to several thousand cubic meters, to very large sites with several hundred thousand cubic meters. The small sites are typically cleaned up in a few weeks, while the large sites undergo remedial action over a period of years. In addition, some FUSRAP sites contain a wide variety of waste types, which are transported to several treatment/disposal facilities.

Access to transportation varies among FUSRAP sites. Sites located near large industrial facilities such as the St. Louis site and Maywood, New Jersey, site often have onsite or nearby rail spurs. Most smaller FUSRAP sites do not have direct rail access and are limited to truck transport or must incur additional costs to gain access to rail service.

DOE regulations and guidelines provide that shipments must be packaged and routed using the mode and carrier that can provide the required services at the lowest overall delivered costs to the government. Characteristics of the various packaging and transportation modes available for a site need to be compared for accessibility, capacity, and cost. Speed of delivery and claim history are often criteria for selecting a transportation mode for DOE shipments. However, for FUSRAP shipments, transit time and smoothness of transport are not significant factors and are not part of the selection process.

For typical FUSRAP sites with waste volumes greater than 50 m^3 (65 yd^3), four methods of waste material packaging and transportation are typically considered:

- Bulk transport by rail gondola
  - — Load onsite (if possible)
  - — Load offsite
- Bulk transport by intermodal container
  - — Load onsite
- Bulk transport by truck
  - — Load onsite
- Packaged transport by flatbed truck
  - — Load onsite

The method of material packaging (bulk versus package) needs to be considered to allow all potentially attractive alternatives to be evaluated. Bulk transport by rail gondola is the low-cost alternative when onsite rail access is available. When there is no direct rail access onsite, transporting the material to an offsite rail loading location may be a low-cost option.

In addition to transportation costs, disposal cost must be evaluated if it varies with the mode of delivery. The low-cost packaging and transportation alternatives for a site may be determined in part by disposal pricing. At a disposal facility used by FUSRAP, delivery in bags by truck costs 14 percent less than delivery by intermodal because of the additional handling and labor required upon delivery. For large-volume shipping campaigns, this can be a major factor in determining the packaging and transportation mode.

Finally, the costs of site preparation and operations should be included in the packaging and transport mode selection process. Site preparation can involve constructing staging areas, load-out facilities, and haul roads and other activities that can have a significant impact on cost and schedule. The cost of constructing an offsite loading facility needs to be weighed against the corresponding increased cost of transporting directly from onsite. Operations costs for both onsite and offsite facilities include the costs of personnel and equipment required for load-out.

The following cost comparison factors apply to all four packaging and transport modes evaluated for FUSRAP sites:

- onsite labor,
- onsite equipment,
- packaging cost,
- transportation cost, and
- disposal cost.

For offsite loading operations, additional factors need to be considered:

- offsite preparation,
- offsite access agreements,

- offsite labor,
- offsite equipment,
- local transportation to offsite facility,
- decontamination operations, and
- offsite demobilization.

Packaging operations involve the following additional factors:
- packaging equipment, if applicable;
- labor for packaging operation;
- equipment for package movement (forklift, crane, etc.);
- cost of packages; and
- disposal cost for packages, if applicable.

The site schedule may play a major role in determining the packaging and transportation mode. For a small site with a short schedule, little time may be available for setting up the infrastructure and access agreements needed for an offsite loading operation. Also, the greater flexibility of truck transport may be a deciding factor for short-schedule cleanups. On short notice, the availability of trucks and intermodal containers is typically much greater than that of rail gondolas.

Transportation costs vary significantly with the various modes available to FUSRAP sites. For example, the unit rate costs for bulk transport from a FUSRAP site on the east coast to a western state disposal facility are:

Rail gondola	\$0.05 /m^3-km
Intermodal container	\$0.08 /m^3-km
Truck	\$0.13/ m^3-km

These straight transportation costs may need to be adjusted for factors such as demurrage, container rental and storage, detention time, deadhead delivery charges, switching charges, and container liners and padding.

The ability of the carriers to supply the requested number of containers on a specified delivery schedule must also be considered during transport mode selection. For a typical FUSRAP shipment with a material density of 1,615 kg/m^3 (100 lb/ft^3), the weight capacity of a single truck is 12.5 m^3 (16.4 yd^3); for an intermodal container 10.5 m^3 (13.7 yd^3) of material; and for a rail gondola 53 m^3 (69.3 yd^3) of the same material. Transportation for small shipping campaigns is more likely to be by trucks or intermodal containers because they are more readily available. For large shipping campaigns, the number of containers needed makes it more likely that rail gondolas will be used. For example in a 1,520-m^3 (1,988-yd^3) campaign, 29 gondolas, 122 dump trucks, or 145 intermodals would be required. More containers in a shipping campaign generally means that a greater support effort is required to schedule and coordinate delivery to the site and load the containers. The efficiency of handling fewer containers onsite also typically leads to a shorter schedule.