CHARACTERIZATION OF INEL COMPACTIBLE LOW-LEVEL WASTES AND EVALUATION OF COMPACTOR OPTIONS[a]

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ABSTRACT

The volume reduction of solid low-level waste (LLW) generated at the Idaho National Engineering Laboratory (INEL) has been a high priority in recent years, due to the dwindling volume of available burial space. Volume reduction by incineration, plasma arc cutting, and melting have been reported previously and have had a dramatic effect on the volume of LLW disposed of at the INEL's Radioactive Waste Management Complex. The remaining LLW streams not eligible for these processes were characterized to determine the volume which may be reduced by compaction in a variety of compactor types. Various compactor options were investigated to determine the configuration best suited to the needs of the INEL. The study resulted in recommendations for pursuing an expanded LLW compaction program at the INEL.

INTRODUCTION

In recent years the Idaho National Engineering Laboratory (INEL) has developed a variety of processes to demonstrate volume-reduction techniques for solid low-level waste (LLW). These processes, which include incineration of dry combustibles and size reduction of metallics by plasma arc cutting and melting, were developed as pilot projects to study and demonstrate the technologies. The melting activity is currently inactive, but the other processes are in routine operation and make a significant contribution toward reducing the volume of LLW being disposed of at the INEL disposal facility.

A large percentage of the dry LLW being disposed of at the INEL's Radioactive Waste Management Complex (RWMC) is not eligible for volume reduction by either of these processes and is currently disposed of, loosely packed, in wooden boxes. The RWMC operates a bale compactor which has been used to compact a small fraction of the wastes not eligible for incineration, but the material compatible with the bale compactor is limited to paper, plastics, cloth, and other nonrigid materials. The compactor is nearing the end of its service life and requires replacement.

In considering a replacement for the bale compactor, it was decided to evaluate the feasibility of compacting a larger fraction of the LLW stream. The greater force capabilities of modern compactors have drastically altered the scope of what materials may be considered compactible. The development of super-compactors, with compaction pressures in the 6000 psi range at the ram face, relegates even the most rigid of materials to the "compactible" category.

A detailed characterization and evaluation of currently generated LLW at the INEL was performed to determine what portion might be considered compactible under several new sets of criteria. These new sets of criteria were based on the capabilities of several types of commercially available compactors, including drum compactors (to 50 tons force), box compactors (to 200 tons force), drum super-compactors (to 2200 tons force), and box super-compactors (to 5000 tons force).

Seven compactor options were evaluated in terms of cost, eligible compactible waste volume, and potential volume reductions. A decision analysis which considered initial capital costs, life cycle costs, compaction densities, and volume of disposal space saved was performed. The preferred option, based on this analysis, was to install a medium-force (200-ton) box compactor in the near term and then follow that with a 5000-ton box super-compactor. The box super-compactor would be used to further compact the boxes if operating experience and site needs justified the added cost to achieve the benefits of higher compaction densities and additional disposal space saved.

The new compactor will be located at the Waste Experimental Reduction Facility (WERF) at the INEL. The WERF also houses the LLW incinerator and the metal size-reducing facility. This location serves to centralize the processing, for volume reduction, of all INEL-generated LLW.

CHARACTERIZATION OF UNPROCESSED SOLID LLW

The INEL's unprocessed, solid LLW is currently disposed of in loosely packed wooden boxes. The

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contents of the boxes were characterized where possible by evaluation of detailed contents lists maintained by some site generators. Since most INEL generators currently characterize waste contents only by radiation level and estimated percentages of combustibles and metallics, much of the characterization required inspection of the waste container contents on site at the generation point.

From the characterization data thus obtained, it was determined that approximately 20% of the unprocessed INEL LLW should be considered noncompactible for the following reasons:

- High contact radiation levels (>200 mR/hr) - 13%
- Off-site-generated combustible waste, not currently segregated for incineration - 5%
- Large vessels - 1.5%
- Dirt - 1%

The remaining 80% was evaluated for compatibility with the various types of compactors considered in the study in terms of compaction container geometry and force capability. The results are presented in Fig. 1.

As can be seen from Fig. 1, the volume of unprocessed LLW which could be considered compactible for some types of compactors is a factor of 5 times the current compactible waste stream processed by the INEL's bale compactor. It should be noted also that the current compactible waste stream has been reduced by over 50% from previous years by the operation of the INEL's solid waste incinerator.

CHARACTERIZATION OF SWEPP-RECLASSIFIED LLW

The INEL has another potential source of compactible low-level waste in currently stored TRU waste, some of which will be reclassified to LLW after examination in the Stored Waste Examination Pilot Plant (SWEPP). Much of this waste was classified as TRU when the TRU limit was 10 nCi/g. The new TRU limit of 100 nCi/g will allow much of this waste to be reclassified and disposed of as LLW.

This waste is currently stored in drums and wooden boxes. The estimated volumes of drummed and boxed waste likely to be reclassified as LLW, and the corresponding volumes assumed to be compactible, are illustrated in Fig. 2. The estimates are based on content code and curie content data for the stored waste.

COMPACTOR EVALUATION

The volume reduction of dry active waste (DAW) by compaction is prevalent throughout the nuclear industry and has provided the impetus for much of the state-of-the-art advance in the compactor industry in recent years. There is a wide spectrum of compactors available with varying force capacities, features, loading modes, container types, and prices. However, they can generally be categorized as one of five types: bale compactors, drum compactors, box compactors, drum super-compactors, or box super-compactors. The basic characteristics of each are as follows:

- Bale compactors compact principally nonrigid material into rectangular cardboard boxes confined only by strapping. Force capabilities up to 50 tons are available. This is the type of unit currently at the RWMC. Compaction densities range up to 40 lb/ft^3.
- Drum compactors compact material into a drum. Some rigid materials are acceptable because the drum maintains the shape. Force capabilities are available up to 50 tons. A drum compactor may also compact the drum itself, if desired, but compaction densities are limited by low-force capability. Essentially, a drum compactor is comparable to a bale compactor, with better confinement of the waste but inferior disposal volume utilization.
- Box compactors compact material into a reinforced-metal box. Force capabilities are available up to 200 tons. Many rigid materials, including lighter metal components, are acceptable. Loaded drums may also be compacted. The primary advantage of a box compactor is that larger materials may be compacted and smaller items subsequently may be compacted into the void spaces. Compaction densities range up to 60 lb/ft^3.
- Drum super-compactors compact essentially all material that may be loaded into a drum by compacting the drum and contents at the same time. Force capabilities are available up to 2200 tons. The compacted drums are packaged in overpack drums (approximately 4 drums per overpack for disposal). This type of compactor was evaluated extensively by EG&G. Compaction densities were approximately 108 lb/ft^3 for the type of waste acceptable to a bale compactor, and up to 400 lb/ft^3 for waste mixes containing higher density material. A drum super-compactor removes and collects essentially all of the free liquids.
- Box super-compactors compact essentially all material (including loaded drums) that fits into the metal boxes used. The box and contents are compacted together. The box super-compactor may also compact drums alone with a change in dies. The compacted boxes are packaged in overpack boxes for disposal. Compaction densities are approximately the same as for drum super-compactors. The box super-compactor removes nearly all free liquids. The first unit of this type is in operation at a site near the Oak Ridge National Laboratory.

The industry was canvassed to determine the capabilities and costs of existing or in-fabrication compactors. The results (Table I) indicate a wide range of prices for any given type of compactor. Most of the variation is attributable to feature differences. Some manufacturers produce highly automated systems, while others offer only "bare bones" units. Most bale, drum, and box compactors have been in wide use for some time, while the super-compactors are just recently being marketed in the United States, though they have been in operation

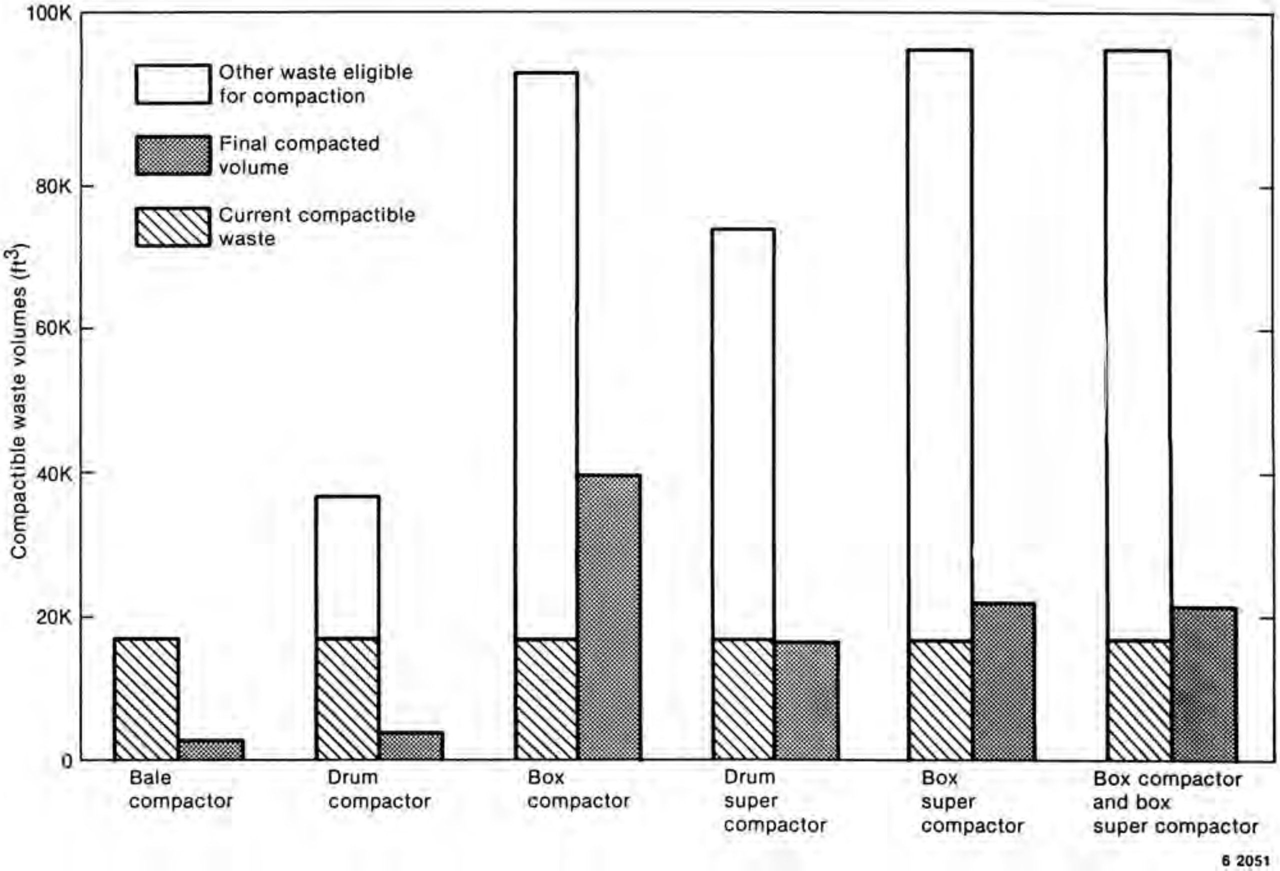

Fig. 1. Eligible annual compactible volumes.

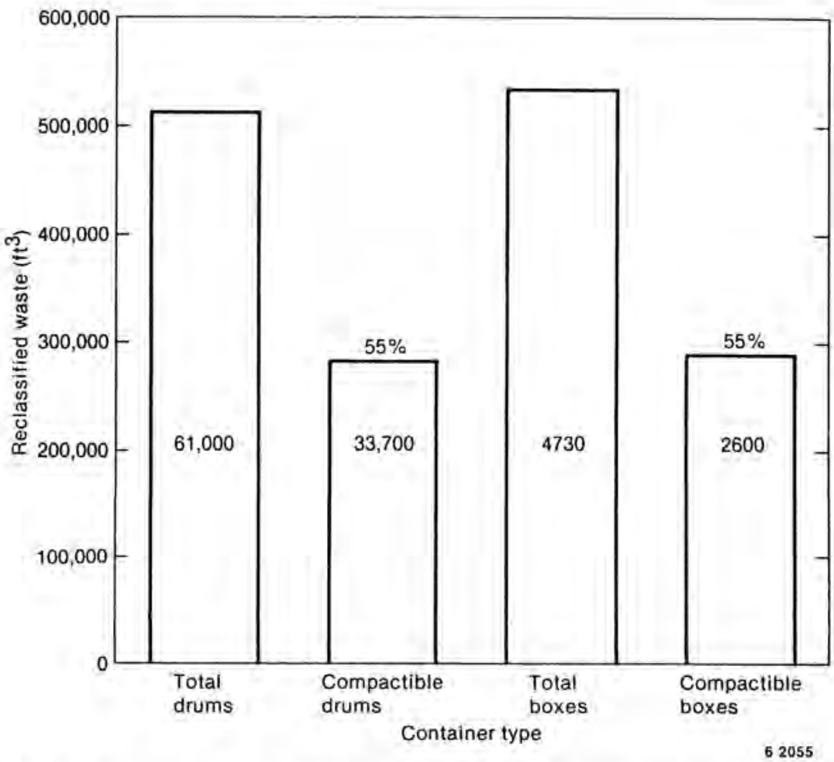

Fig. 2. Volume of SWEPP-reclassified waste considered to be compactible.

TABLE I

Compactor Vendor Survey

Compactor Type	Waste Forms Compacted[a]	Force Range (tons)	Stationary or Mobile	Units Sold	Price Range ($)
Bale Compactor	Bagged	3-50	S	Many	7K-70K
Drum Compactor	Bagged	3-50	S, M	Many	9K-70K
Box Compactor	Bagged	20-200	S	55	140K-300K
Drum Super-Compactor	Drum	1000-2200	S, M	9	750K-850K
Box Super-Compactor	Drum, box	5000	S	1	~1500K

a. Bale, drum, and box compactors compact the waste forms inside of containers. Drum and box super-compactors compact the container and the contents together, and then load them in overpack containers.

in Europe for several years. Although some units are marketed as mobile, all may be used in stationary installations. One option considered is contracting the services of a mobile drum super-compactor vendor to periodically compact drummed waste.

As was previously mentioned, drum super-compactors have been evaluated by EG&G, including compaction tests of several waste mixes. Additional evaluations would be required to gain the same level of familiarity with the other compactor types. However, the other compactor types are in wide general use, and discussions with both vendors and users have demonstrated that their characteristics are well defined.

Bale, drum, and box compactors are similar in that each involves compacting material into an open container. Compaction occurs in several cycles, with additional material added between each cycle until no more material can be added. In the case of the drum and box compactors, anti-springback devices may be added during any cycle to hold the compacted waste while the ram is retracted. The better designed units provide loading clearance above the container, filtration of the emissions, and container ejection mechanisms.

Bale and drum compactors are manufactured in basically the same force capacity ranges (10 to 50 tons). Since bale compactor compaction areas are 2 to 5 times larger, drum compactors yield better compaction efficiencies. Procurement costs for bale or drum compactors for a given force capacity are roughly the same. Cost per unit force decreases rapidly up to 50 tons (Fig. 3), while compaction density increases rapidly (Fig. 4). To fairly compare box compactor costs per unit force to drum compactor costs per unit force, we must normalize to a unit compaction area. Normalizing box compactors to a 55-gallon drum area (3.4 ft^2 for drums compared to 24 ft^2 for boxes) is reflected in Fig. 3. Box compactor costs per unit force are relatively constant, and compaction density increases only slightly with force capacity (see Fig. 4). A large incremental cost for both types of compactors is in HEPA filtration and encapsulation of the container.

The advantage of the box compactor over the bale or drum compactor is that larger-sized material can be placed in them, significantly increasing the amount of eligible compactible waste (see Fig. 1). Even with reduced compaction efficiency due to the presence of more solid material, the volume saved by box compaction over drum compaction is appreciable.

The super-compactors differ from other compactors in that they compact an already loaded container. Super-compactors also require overpack containers for disposal, since they invariably rupture the container during compaction. The drum and box compactors need overpacks only in the unlikely event of a container breach. In addition, super-compactors are able to compact metal and other solid objects. These characteristics make them good candidates to compact existing packaged waste, such as the SWEPP-reclassified waste. Obviously, the drum super-compactor can compact only the drummed waste, while the box super-compactor can process both drummed and boxed waste.

COMPACTOR OPTIONS

Various options were investigated to determine the compactor system best suited to the needs of the INEL. Seven options were selected for comparison in terms of cost, waste volumes which could be processed by each, potential volume reductions, and compacted waste form disposal characteristics. The seven options are:

- Option 1 50-ton bale compactor
- Option 2 50-ton drum compactor
- Option 3 200-ton box compactor
- Option 4 1000-ton drum super-compactor
- Option 5 5000-ton box super-compactor
- Option 6 A combination of Options 3 and 5
- Option 7 Contracting with a mobile drum super-compactor.

A cost analysis was performed to determine the total cost of each option, based on a 15-year operating life, in 1986 dollars. The baseline condition for the computation of cost data was no compactor at all (i.e., the RWMC bale compactor no longer operational and all eligible waste packaged in

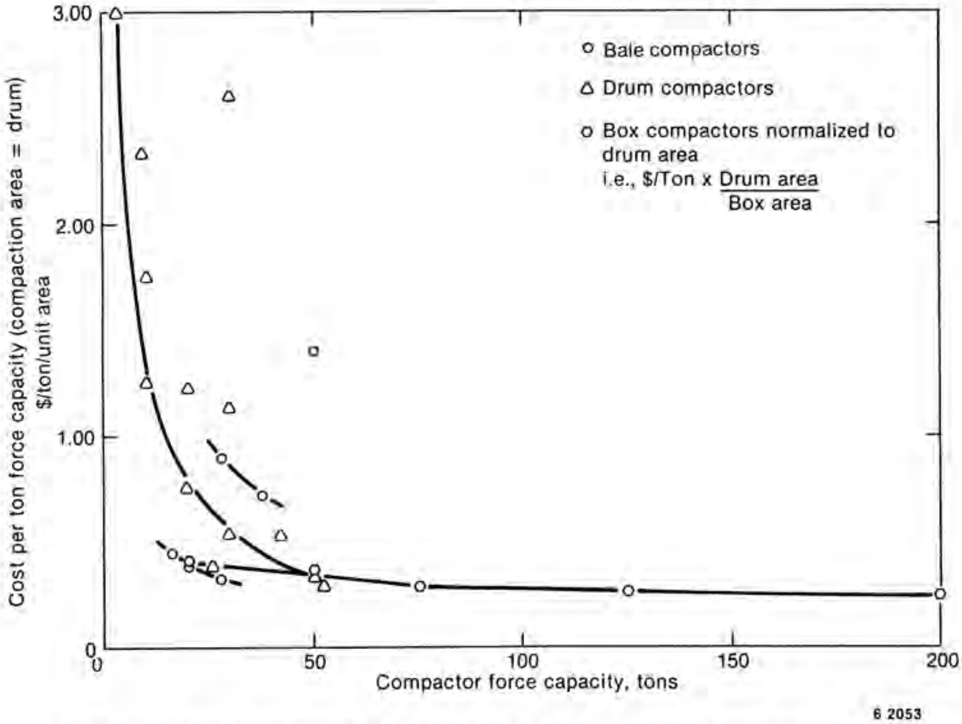

Fig. 3. Cost comparison vs. force capacity--low-force compactors.

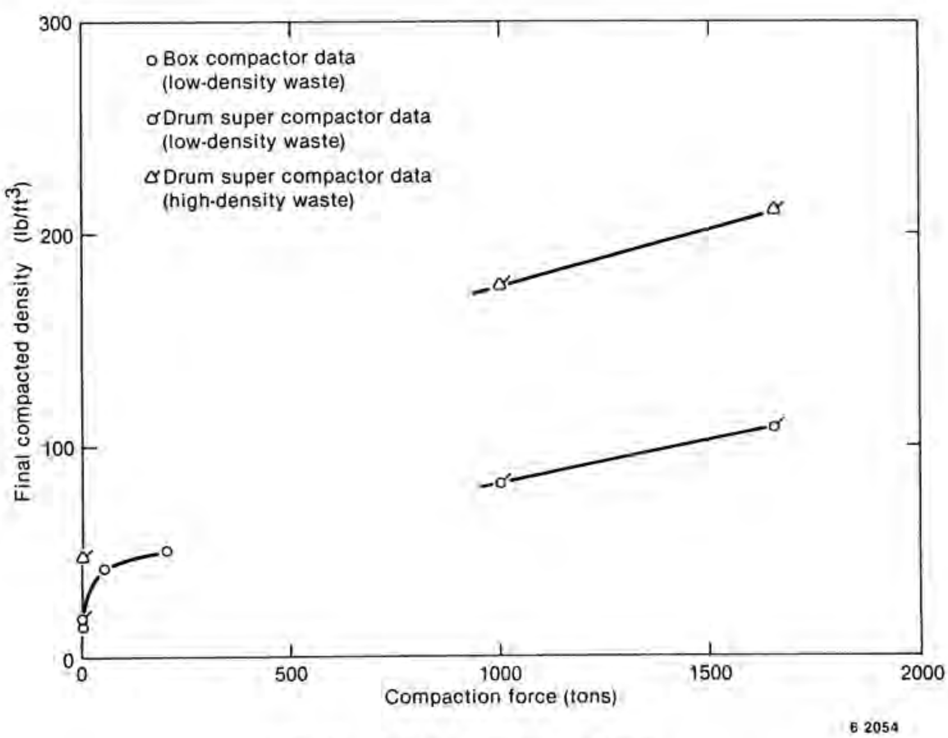

Fig. 4. Compaction density data.

wooden boxes for disposal at the RWMC). A cost savings is included in the analysis for the number of boxes that would have been required to contain the volume saved by compaction. A cost index parameter which attempts to identify the cost of saving a cubic foot of disposal space at the RWMC for each compactor option, was computed. This cost index can be compared to the cost of approximately $\$22/ft^3$ for disposing of this type of waste at the RWMC.

Table II summarizes the results of the compactor option comparisons.

TABLE II

Comparison of Compactor Option Characteristics

Characteristic	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
Initial (capital) cost ($)	119,000	119,000	379,000	979,000	1,657,000	397,000[a]	0
Cost index (INEL Waste)[b] ($)	-1.17	-1.59	2.40	9.12	7.89	6.13	15.03
Disposal space saved (INEL Waste, ft^3)[c] (Equivalent RWMC life)	217,000 (1.6 y)	347,000 (2.5 y)	780,000 (5.7 y)	858,000 (6.2 y)	1,095,000 (8.0 y)	1,095,000 (8.0 y)	858,000 (6.2 y)
Eligible INEL waste compactible (%)	12	20	67	54	69	69	54
Process SWEPP re-classified LLW	No	No	No	Drums	All	All	Drums
Transportation packaging	Repackaging required	DOT	DOT	DOT	DOT	DOT	DOT
Waste form disposal characteristics	Poor	Fair	Good	Fair	Good	Good	Fair
Compacted densities (for subsidence)	Fair	Fair	Fair	~Soil	~Soil	~Soil	~Soil
Waste stability and nuclide migration resistance	Poor	Fair	Fair	Good	Good	Good	Good

a. Purchase 200-ton box compactor initially, then a box super-compactor later.

b. Cost of saving a cubic foot of RWMC disposal space.

c. Based on the current INEL waste-generation rate of waste considered for compaction of 137,000 ft^3/y and 15-year operating life.

The values for disposal space volumes saved are based on compaction ratios as follows:

Drum and bale compactors	7:1 low-density waste only
Box compactors	7:1 low-density waste 2:1 mixed-density waste
Super-compactors	7:1 low-density waste 4:1 mixed-density waste

OPTION ANALYSIS

A decision analysis was performed (see Table III) for the seven options evaluated. The decision analysis considered capital cost, volume of waste that could be processed, volume of RWMC space saved, compaction density achieved, and total system costs over a 15-year compactor life. Compaction density achieved was included because of the impact it will have on future subsidence at the RWMC. Those compaction options that achieve densities near that of soil will essentially eliminate future subsidence. Compaction also reduces the need for grouting containers at the RWMC.

Each of the seven options was rated from 1 to 7 in each category in Table III. Weighting factors were not applied to differences in each option in a category, nor to any category over another. (All categories have been given equal consideration.) The total score for each option in Table III is based on the total of the scores of each option in each category.

Options 5 and 6 have the highest scores. Option 6, which combines Options 3 (which also had a high rating) and 5, reduces the total cost per cubic foot saved by pre-compacting the waste before super-compaction, which reduces the number of overpacks required. Since Option 6 had the highest score and includes Option 3, it was decided to initiate this option by purchasing and installing a 200-ton box compactor. The follow-up action is to plan for procurement and installation of a box super-compactor. In the event sufficient money is not available to complete procurement of a box super-compactor, the viable option 3 would have already been implemented.

The advantages of Option 6 are:

- The box compactor can compact over 67% of the eligible INEL-generated LLW
- The box compactor compacts material not acceptable to a bale or drum compactor
- The metal boxes to be used provide better container integrity than the wood boxes currently used
- The container shape provides more efficient disposal than bales or drums, and saves RWMC space
- Super-compaction provides package densities that are very close to the theoretical density of soil, essentially eliminating subsidence
- The need for grouting boxes at the RWMC is eliminated
- Over a 15-year period, the 200-ton compactor would save 5.7 years, and the box super-compactor would save 8.0 years, of disposal space, based on the current LLW-generation rate
- Super-compaction will significantly reduce nuclide migration by reducing the surface area
- Super-compaction provides significant volume reduction (up to 15:1 for some types of waste)
- The number of overpacks required is reduced by pre-compacting the waste, resulting in

TABLE III

Compactor Option Analysis

Option[a]	Capital Cost (Including Installation) ($K)		Annual Eligible Compactible Volume (ft^3)		Annual Volume Saved (ft^3)		Compaction Density (lb/ft^3)		Total Cost (15 years) ($K)		Cost Index ($\$/ft^3$)[b]	Total Score	Rating
1	119	5-1/2[c]	17,000	1[c]	14,500	1[c]	40	1-1/2[c]	-255	6[c]	-1.17	15	7
2	119	5-1/2	27,000	2	23,100	2	40	1-1/2	-552	7	-1.59	18	6
3	379	4	92,000	5	52,000	3	60	3	1,869	5	2.40	20	4
4	979	3	74,000	3-1/2	57,000	4-1/2	108	5-1/2	7,821	3	9.12	19-1/2	5
5	1,657	2	95,000	6-1/2	73,000	6-1/2	108	5-1/2	8,568	2	7.82	22-1/2	2
6	2,149	1	95,000	6-1/2	73,000	6-1/2	108	5-1/2	6,714	4	6.13	23-1/2	1
7	0	7	74,000	3-1/2	57,000	4-1/2	108	5-1/2	12,895	1	15.03	21-1/2	3

a. The options are: (1) 50-ton bale compactor; (2) 50-ton drum compactor; (3) 200-ton box compactor; (4) 1000-ton drum super-compactor; (5) 5000-ton box super-compactor; (6) a combination of options 3 and 5; (7) contracting with a mobile drum super-compactor.

b. The cost index ($\$/ft^3$ of RWMC space saved) is shown on the table but not rated since it is determined by dividing the total cost by total volume of space saved, and these factors have been included in the rating.

c. Numbers in these columns indicate the rating.

enough savings to pay for the 200-ton box compactor in 1.7 years of operation of the box super-compactor

- The box super-compactor can also be used (without pre-compaction) to process SWEPP-reclassified waste, if desired
- Super-compaction reduces the number of containers that will be handled at the RWMC, resulting in less manpower requirements, lower personnel radiation dose rates, and reduced maintenance on the handling equipment
- The reduced number of containers will result in fewer incidents, due to decreased handling
- Super-compaction will remove the free-standing liquids, which will result in fewer incidents of contamination spread from leaking containers.

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