EVALUATION OF ON-SITE COMPACTION AND ON-SITE FABRICATION OF MODULAR CONCRETE CANISTERS FOR THE STATE OF TEXAS

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ABSTRACT

The Texas Low-Level Radioactive Waste Disposal Authority has evaluated two choices which influence the design of its LLW disposal facility. These choices are on-site compaction of LLW (beyond compaction at the generators' facilities) and on-site fabrication or purchase from off-site source of modular concrete canisters for LLW disposal. The viability of on-site compaction is influenced by the amount of waste to be compacted, secondary effects on the costs of waste disposal, and differences in worker exposures. Two methods of on-site compaction were examined; (1) use of a permanently installed on-site compactor and (2) use of mobile compaction service on a periodic basis.

In examining the second question, four conceptual canister designs were considered and structural and material requirements of each design were determined. The costs of the necessary components of the fabrication facility were estimated. The incremental operating costs to fabricate the canisters on-site were also estimated, with account being taken of associated labor and material costs.

The assessment of the fabricate/purchase option depends on the incremental cost of disposal which is influenced by the percent of revenues to an off-site supplier generated through the sale of canisters to the Authority. Other considerations are the need to maintain quality of materials and workmanship and the availability of excess labor capacity at the disposal facility.

BACKGROUND

The Texas Low-Level Radioactive Waste Disposal Authority (the Authority) is designing a low-level radioactive waste (LLW) disposal facility to dispose all LLW generated in the State of Texas. Conceptual designs(1) were prepared and evaluated. The Authority has determined that all Class A waste in containers with contact dose rates less than 1000mrem/hr will be disposed in modular concrete canisters.

Two questions remained unresolved in the conceptual design process:

- Should the Authority provide for onsite compaction of waste received at the facility?
- Should the modular concrete canisters be fabricated on-site or purchased from off-site sources?

These matters were addressed by the Authority and the results are presented in the following sections.

ONSITE COMPACTION

Compactable Waste

Three waste streams were determined to have the characteristics necessary to qualify them for compaction: compactable trash from pressurized water reactor power plants (P-COTRASH), compactable trash from institutional sources (I-COTRASH), and low-activity trash from industrial sources (N-LOTRASH). All such waste was assumed to be delivered to the facility in 55-gallon drums. The annual volume of such waste received at the disposal facility is projected to total about 44,000 ft^3/yr.

The volume reduction achieved as a result of on-site compaction depends on waste stream characteristics and range from 1.4 for P-COTRASH to about 2.7 for the other two candidate waste streams. The overall volume reduction factor was estimated to be about 1.6, based on the assumption of modest compaction at all generators facilities. The compactible waste volume actually disposed (after compaction) was projected to be about 27,000 ft^3/yr.

Compaction Costs

Since each modular concrete canister has an effective capacity of about 103 ft^3, a total of about 160 canisters per year would be saved (not required) as a result of compaction. At a unit price ranging between $1,000 and $1,500 each (assuming circular canisters), the potential savings in canister costs were estimated to range from about $160,000 and $242,000 per year.

No differences in operating labor costs were considered. It was assumed that the disposal facility is staffed with a minimum work force, but that there is excess labor capacity that can be utilized at the compaction facility or wherever else labor might be required. It was estimated that the excavation savings would total about $10,000 per year.

The installed capital cost of compaction depends of the type of equipment used. If an installed fixed compaction system were opted, the capital cost would be about $1,600,000. However, it is possible to install a mobile trailer mounted compactor and house it in a modest enclosure for a cost of about $1,200,000. In neither case were the costs of effluent control equipment considered. In the economics evaluations of on-site compaction, this latter value was assumed.

The costs of compaction services include mobilization and per unit processed charges. The mobilization charge depends on the distance the equipment must be transported to complete the needed compaction campaign. For this effort, the mobilization charge was estimated to range from $10,000 to $14,000. The per unit (per drum) charge was estimated to be about $27, without an overpack container. It was assumed that waste campaigns would be undertaken four times each year. Thus, the annual cost of using a compaction service was estimated to be about $217,000 per year, assuming the greater mobilization cost.

Assessment of Onsite Compaction

The net present value of on-site compaction with installed equipment was calculated using the Internal Rate of Return (IRR) method and assuming economic conditions available to the Authority. The results of these evaluations are presented in Fig. 1 for a range of assumed modular concrete canister costs. Given a cost of capital (IRR), the minimum economical unit canister cost which justifies compaction can be determined.

Capital is available to the Authority from the State Treasury at a cost of about 7.5 percent per year. Therefore, the minimum economical unit canister cost (circular canisters) which justifies compaction is found from Fig. 1 to lie between $650 and $700 each.

If a compaction service were utilized, the economic analyses are more straight forward since the only question is the relative operating costs of compacting or not compacting. The cost savings of compaction, when a compaction service is utilized, also depends on the unit cost of the concrete canisters. The cost of the compaction service was estimated to be about $217,000 per year, while the cost savings can be estimated from the number of canisters saved (not used because of compaction) and their unit cost. When the savings are greater than the cost, the service is justified.

It was determined that the unit cost of circular canisters must be greater than about $1,350 to economically justify the use of a compaction service.

There are other than economic factors to be considered in the decision of whether to compact. A key consideration could be radiological impacts. The radiological impacts of waste compaction were not quantitatively evaluated and are difficult to resolve qualitatively. However, we judge that if economics are marginal, as they appear to be, considerations incident to maintaining radiation exposures as low as reasonably achievable (ALARA) will outweigh economic considerations.

MODULAR CONCRETE CANISTERS

As noted above, the cost of concrete canisters is an important consideration. In the conceptual design performed earlier for the Authority, is was simply assumed that the canisters would be fabricated on-site. As the Authority preceded to preliminary design activities, the question of fabricating on-site or purchasing from off-site sources was engaged. The resulting evaluations are presented in the following sections.

Canister Designs

Through a simple geometric proof, it was shown that only four canister configurations would allow the canisters to be placed in the disposal units on a regular pattern with no voids between adjacent sides: triangular, square, hexagonal, and circular. Canister designs, consisting of structural element thicknesses and steel reinforcing requirements, were prepared for each of these canister configurations. These designs are based on structural analyses of expected loading conditions and expected material properties.

The designs of the canisters are summarized in Table I. Wall thicknesses, for example, range from 4 inches for the circular canister to 8.5 inches for the triangular canister, while inner wall reinforcing requirements range from 0.083 to 0.52 in ^{2}ft. Based on these designs, the empty and filled canister weights were estimated. The filled canister weights range from 40,000 to 84,000 lb.

Other effects of canister configuration were assessed: the incremental annual disposal unit excavation volume, incremental annual disposal unit backfill volume, and the overall placement efficiency. These are also summarized in Table I.

The annual canister requirements were calculated to be 560, 610, 730, and 730 triangular, square, hexagonal, and circular canisters, respectively.

Capital Cost of Fabrication Facility

The costs of a canister fabrication facility were estimated, based, in part, on information obtained from a large-diameter concrete pipe fabricator. These costs assume that the canisters are fabricated with a casting process using "no-slump" concrete which is followed by a steam curing process. The process and materials are assumed to satisfy requirements of ASTM C-76 and ACI 349.

The estimates of capital costs include equipment necessary to form reinforcement, cast the canisters, steam cure canisters, and handle canisters. With a contingency

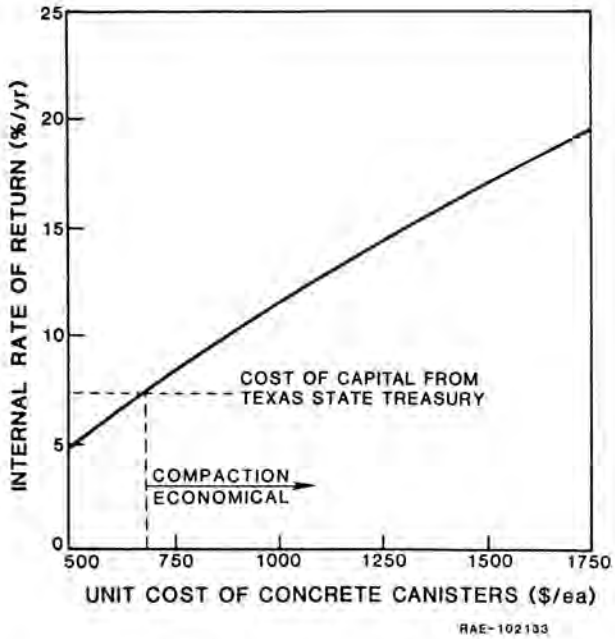

Fig. 1. Internal Rate of Return for Installed Compaction as a Function of Concrete Canister Unit Cost.

TABLE I

Characteristics of Canister Designs

Characteristics	Candidate Canister			
	Triangle	Square	Hexagon	Circle
Minimum wall thickness (in)	8.5	6.5	5.0	4.0
Inner wall reinforcement requirement (in^2/ft)	0.52	0.27	0.16	0.083
Base reinforcement requirement (in^2/ft)	0.23	0.19	0.22	0.21
Empty canister weight (lb)	40,000	24,000	17,000	13,000
Filled canister weight (lb)	84,000	59,000	47,000	40,000
Annual excavation volume (yd^3/yr)	23,000	15,000	15,000	15,000
Annual backfill volume (yd^3/yr)	9,500	4,600	5,000	6,400
Operate placement efficiency efficiency (%)	41	49	47	51

allowance of 20 percent, the total capital costs were estimated to be about $1,825,000, $1,650,000, $1,560,000, and $1,520,000 for the triangular, square, hexagonal, and circular canisters, respectively.

Three sets of economic conditions were considered. For on-site fabrication (public ownership case) it was assumed that the cost of capital was 7.5 percent per year (a rate available to the Authority) and that all capital costs would be recovered over 20 years as required by Texas legislation. Under these conditions, the initial capital would be amortized with annual allowances ranging from $149,000 to $179,000 per year.

Two extreme cases were assumed for purchase from off-site sources (private ownership cases). The conservative private case assumes that the initial capital investment will be recovered over a 5 year period at a cost of capital of 16.9 percent per year. It was further assumed that there are no other sources of revenues beyond sale of canisters to the Authority. In the optimistic private case, it was assumed that initial capital investments would be recovered over a twenty-year period, at a cost of capital of 16.9 percent per year, with only 25 percent of the supplier's revenues arising from sale of canisters to the Authority.

Based on the economic conditions stated above, the initial capital investment would be recovered with annual amortization allowances ranging from $473,000 to $568,000 for the conservative private case and from $67,000 to $81,000 per year for the optimistic private case.

Operating Costs for Canister Fabrication

Labor costs were based on the small workforce required to fabricate the canisters, assuming full-time occupation with this activity. A total of 8.5 full-time equivalent workers were estimated to be necessary, with an assumed direct labor rate of $15.00 per hour. The labor overhead was taken to be 30 percent of the direct labor cost. The direct labor and labor overhead costs were estimated to total about $340,000 per year.

Material costs were estimated on the basis of the designs described earlier. Concrete and steel costs were estimated from material takeoffs prepared from the designs and the total volume of waste estimated to be disposed in canisters. The material costs were calculated to range from $144,000 to $470,000 per year, depending on canister design.

Allowing for general overhead costs of 5 percent of labor and material costs, the total canister fabrication costs were estimated to range from $511,000 to $801,000 per year.

Incremental disposal costs were estimated and considered the relative amounts of grout used in each canister type, excavation volumes, and backfill volumes. These ranged from $112,000 to $264,000 per year. Thus the total operating costs were estimated to range from $683,000 to $1,065,000.

Assessment of On-Site Fabrication Versus Purchase from Offsite Sources

The economic analyses are summarized in Table II for the four canister configurations considered. Referring to the incremental costs per cubic foot of waste disposed in canisters ($/ft^3), it is apparent that there is little economic incentive to consider the triangular canister further. The other three canister configurations appear to be economically similar, with the circular canister holding a slight advantage. In order to conclude the assessment, the Authority selected only circular canister for further evaluations.

As suggested above, the choice of fabricating canisters on-site or purchasing them from off-site sources is influenced by the economic conditions available to the off-site source. Particularly, it depends on what fraction of the supplier's total revenues are generated by sales of canisters to the Authority. This dependence is depicted in Fig. 2. As the fraction of total revenues approaches zero, the incremental cost of waste disposal in canisters approaches the range of $4 to $5 per cubic foot of waste disposed. As the fraction of total revenues approaches 100 percent, the incremental canister disposal cost approaches the range of $15 to $16 per cubic foot of waste disposed.

We judged that it would be unlikely that less than 20 percent or more than 50 percent of total revenues would be generated from sales of canisters to the Authority. In this range, the incremental cost of disposal in circular canisters ranges from about $7 to about $11 per cubic foot of waste disposed, including the estimated transportation costs.

The incremental cost of canister disposal, assuming on-site canister fabrication is about $10 per cubic foot of waste disposed. Thus, this question appears to be difficult to resolve on economic grounds alone.

Other factors not addressed quantitatively include the ability to maintain adequate control over materials and workmanship used in fabrication and the availability of excess labor capacity at the disposal facility. These factors tend to suggest that on-site canister fabrication may be preferable to purchase from off-site sources.

CONCLUSIONS

Based on conditions expected at the Texas low-level radioactive waste disposal facility, the economics of on-site waste compaction and on-site canister fabrication were evaluated. In both cases, the economics are not decisive and the decision will probably be made on the basis of other factors, such as the need to maintain occupational radiation exposures as low as reasonably achievable (ALARA), the need to assure adequate quality of material and

TABLE II

Results of Economics Evaluations of Modular Concrete Canisters

	Candidate Canister			
	Triangle	Square	Hexagon	Circle
Fabricate On-Site (Public Case)				
Canister unit cost ($/ea)	2210	1590	1260	1140
Incremental disposal cost ($/ft^3)	14.90	11.50	11.00	10.00
Purchase Off-Site (Conservative Private Case)				
Canister unit cost ($/ea)	2900	2170	1720	1590
Incremental disposal cost ($/ft^3)	19.50	15.70	15.00	13.80
Purchase Off-Site (Optimistic Private Case)				
Canister unit cost ($/ea)	2040	1440	1150	1030
Incremental disposal cost ($/ft^3)	13.70	10.40	10.00	9.00

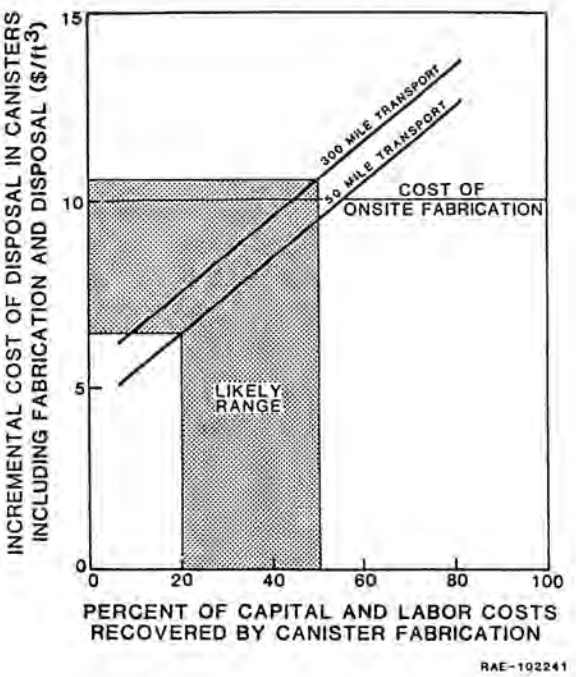

Fig. 2. Incremental Cost of Disposal in Canisters as a Function of the Fracture of Revenues from Canister Sales to the Authority.

workmanship, and the availability of excess labor capacity at the disposal facility.

REFERENCES

1. "Low-Level Radioactive Waste Disposal Facilities: Conceptual Designs and Assessments; Summary Report," Rogers and Associates Engineering Corporation for Texas Low-Level Radioactive Waste Disposal Authority, Five Volumes (February 1987).