VOLUME REDUCTION TECHNOLOGY

B. Karlsson, Chairman
W. Sturgeon, Co-Chairman

CHARACTERIZATION OF LOW-LEVEL RADWASTE
VOLUME REDUCTION SYSTEMS

L. RUTLAND, A.S.DAM
Burns and Roe, Inc.
633 Industrial Ave.
Paramus, N.J. 07652

M.D. NAUGHTON
Electric Power Research Institute
3412 Hillview Ave.
Palo Alto, Ca. 94303

ABSTRACT

The Electric Power Research Institute is sponsoring a study to develop a long range assessment of low-level radwaste (LLW) volume reduction (VR) options for nuclear power plants for scenarios accounting for evolving regulations, transportation requirements, and disposal facility conditions. Burns and Roe, Inc. is participating in this work with the characterization of advanced volume reduction systems in sufficient detail to permit utilities to evaluate representative processing alternatives. Equipment of the following general types were considered: compactor, incinerator, fluid bed dryer and incinerator, evaporator crystallizer, and evaporator extruder. Information was first developed to represent LLW generated for compactible trash and for liquid and slurry type radwaste streams from LWRs. Performance of the reference VR systems for the waste streams was estimated, and capital and operating costs were estimated for representative facilities that incorporate the reference advanced VR technologies.

PROJECT OVERVIEW

Advanced VR technologies have progressed to a degree where they are being increasingly accepted for use in nuclear power plants. The selection of a suitable VR system would be simpler if a utility only had to consider performance, and capital and operating costs. Dramatic changes in burial facility conditions and the regulatory climate, however, have made the implementation of advanced VR technologies more of a challenge. Of particular concern is the Low-Level Radioactive Waste Policy Act of 1980 which has prompted the formation of regional compacts for LLW disposal. When implemented in 1982,a few nuclear plants may find they no longer have to ship to a far away disposal facility, but many utilities may find they no longer have a disposal facility that will accept their LLW. In that case, on-site storage will become a necessity and volume reduction a decided benefit.

The Electric Power Research Institute is sponsoring a project to assess long term strategies for volume reduction and LLW disposal. The project objectives are to determine the long term applicability of VR technologies in the new regulatory environment, and to develop a data base for VR scoping studies by individual nuclear power utilities. Three organizations are cooperating in this project; they are:

Burns and Roe, Inc.(B&R)
Rogers and Associates Engineering Corp.(RAE)
The Analytical Sciences Corporation (TASC).

RAE is developing a disposal cost algorithm to characterize the newly developed regional burial facilities. TASC will assess regulatory impacts and VR strategies, and will provide overall technical direction. B&R in this study will characterize selected commercial VR technologies as to performance and associated costs. VR facility designs will be developed for each of the reference VR technologies. Associated on-site storage requirements and costs will also be determined. Where available, actual utility cost information will be related to costs estimated in this study.

In brief, the work by B&R proceeded with the following steps: development of a LLW source of the various waste streams from BWR and PWR reactors, selection of typical VR technology cases, consideration of packaging of VR processed wastes as solidified waste or packaging dry waste directly in high integrity containers, storage of packaged wastes on-site, and finally the specification of transportation shields and shipment data.

VR TECHNOLOGIES AND INSTALLATION CASES

VR Technologies

Volume reduction in this study is considered to be a reduction in waste volume beyond that typically achieved in nuclear power plants. For compactible trash (dry active waste) improved compaction, and incineration are considered for increased volume reduction. In this study volume reduction for liquid LLW is achieved by drying, crystallization, or evaporative extrusion. Slurry wastes are volume reduced by evaporative extrusion. Incineration of slurry type wastes is not considered in this study, but will be considered by B&R in a follow-on task. Five VR technologies were initially selected for consideration; they are:

- high pressure compactor
- incinerator
- fluid bed dryer and incinerator
- evaporator crystallizer
- evaporator extruder.

Also included in a subsequent task to this study will be consideration of ultra high pressure (forge) compactor, and mobile incineration. For each VR technology, equipment by a specific vendor was selected to represent that technology. This selection did not constitute an endorsement for any particular VR system or vendor, but is a convenient way to characterize the typical performance, facility requirements, and costs for a given VR technology.

VR Installation Cases

Burns and Roe developed typical facility designs as the basis for VR system performance and cost information. A facility design was developed for each individual VR technology considered and for several combinations of technologies. Ten separate cases are noted in Table I when retrofit and new facilities are considered.

TABLE I VOLUME REDUCTION SYSTEM INSTALLATION CASES

VR Technology	Retrofit System	New Structure
o Compactor	Case 1	-
o Incinerator	-	Case 2
o Fluid Bed Dryer/Incin.	-	Case 3
o Evap. Crystallizer	Case 4	-
o Evap. Extruder	Case 5	Case 6
o Fluid Bed Dryer/Incin. plus Evap. Crystallizer (3 + 4)	-	Case 7
o Fluid Bed Inc. plus Evap. Extruder (3 + 5)	-	Case 8
o Incin., Evap. Crystallizer, and Evaporator Extruder (2 + 4 + 5)	-	Case 9
o Mobile Incinerator	Case 10	-

It is noted in Table I that the VR technologies in each case are able to process only certain wastes from LWRs. For Cases 1 and 2, only dry active wastes (DAW) are processed. Case 3 and 7 are assumed not to process slurry wastes. Case 4 can only process liquid wastes, and Case 5 and 6 can process all wastes considered except for DAW. Only Cases 8 and 9 are assumed to be able to process essentially all DAW, liquid and slurry wastes from LWRs.

RADWASTE SOURCE CHARACTERIZATION

Radwaste Streams

Performance data for VR technologies were based on the typical radwaste from nuclear power plants. The radwaste streams considered are listed in Table II. Each waste stream is considered separately in the study to determine the effect of each VR technology on the individual waste streams. Non-compactible trash, while not amenable to VR, is included to permit an accounting of the interim storage requirements for that material.

TABLE II WASTE STREAMS

Process Wastes & Trash	Symbol
PWR Ion Exchange Resins	P-IXRESIN
PWR Concentrated Liquids	P-CONCLIQ
PWR Filter Sludges	P-FSLUDGE
PWR Compactible Trash	P-COTRASH
PWR Noncompactible Trash	P-NCTRASH
BWR Ion Exchange Resins	B-IXRESIN
BWR Concentrated Liquids	B-CONCLIQ
BWR Filter Sludges	B-SLUDGE
BWR Compactible Trash	B-COTRASH
BWR Noncompactible Trash	B-NCTRASH

Untreated Waste Volumes

Typical waste generation rates presented in Table III were used as the basis for this work. The values listed were taken directly (with a change of units) from ONWI-20, A Waste Inventory Report for Reactor and Fuel-Fabrication Facility Wastes, J. Phillips, et al, 1979. Condensate polishing has an effect on LLW generation in PWRs and BWRs. In BWRs waste volumes are presented separately for deep bed condensate polishing systems (CPS) and precoat (filter/demineralizer) CPS. PWRs are categorized by whether CPS is, or is not, included.

In Table III, routinely compacted trash is assume to have a specific gravity of 0.48 (30lb/ft^3), resin and sludges are in the dewatered condition, and PWR concentrated liquids are taken to be essentially 12% boric acid solutions and BWR concentrated liquids are 25% sodium sulfate solutions.

Volume Reduction and Volume Increase Factors

Volume reduction factors (VRF) and volume increase factors (VIF) are presented in Tables IV and V. VR technology performance for the applicable waste streams is characterized by the VRF, that is, the ratio of the untreated waste to that of the volume reduced and solidified (except for compacted waste) waste as packaged for disposition. VRF for trash is dependent on polyvinyl chloride content. A typical content of 5% was assumed. The resulting ash was assumed to contain the secondary wastes generated from the caustic scrubbing of the hydrochloric acid in the off-gases from PVC incineration. All the reference VR technologies were combined with a Dow binder solidification system, except for the cases which utilized the evaporator extruder. For evaporative extrusion, bitumen is the solidification agent.

Wastes that are not volume reduced will experience an increase in volume when they are routinely solidified for disposal. Typical volume increase factors (VIF) are presented for cement solidification.

TABLE III AVERAGE PLANT UNTREATED WASTE VOLUMES

Waste Volumes, (m^3/MW_e-yr)

	Boiling Water Reactors		Pressurized Water Reactors	
	deep bed CPS	precoat CPS	no CPS	with CPS
COTRASH	0.221	0.221	0.215	0.215
NCTRASH	0.105	0.105	0.122*	0.122*
IXRESIN	0.130	0.0065	0.0266	0.0091
CONCLIQ	0.360	0.0170	0.110	0.136
FSLUDGE	0.153	0.218	-	0.004
TOTAL	0.969	0.568	0.474	0.483

* Includes cartridge filters

TABLE IV EFFECTIVE VOLUME REDUCTION FACTORS

	Compactor	Incinerator		Fluid Bed Incin/Dryer	Evap/Cryst	Evaporator Extruder
Waste Stream		Dow	Bitumen	Dow	Dow	Bitumen
P-COTRASH	1.5	31	27	31	-	-
B-COTRASH	1.5	31	27	31	-	-
P-CONCLIQ	-	-	-	8.6	3.2	5.5
B-CONCLIQ	-	-	-	3.4	1.3	2.9
P-IXRESIN	-	-	-	-	-	2.0
B-IXRESIN	-	-	-	-	-	2.0
P-FSLUDGE	-	-	-	-	-	2.0
B-FLUDGE	-	-	-	-	-	2.0

TABLE V VOLUME INCREASE FACTORS *FOR NON-VR WASTES

	Cement
P-COTRASH	-
B-COTRASH	-
P-CONCLIQ	1.4
B-CONCLIQ	1.4
P-IXRESIN	1.4
B-IXRESIN	1.4
P-FSLUDGE	1.8
B-FSLUDGE	1.8

* Volume increase factor = $\frac{\text{volume solidified waste}}{\text{volume before solidification}}$

TABLE VI SUMMARY OF TREATED WASTE GENERATION
BOILING WATER REACTORS

Annual Waste Generation, drums (1000MW$_e$)

	Deep Bed CPS			Precoat CPS		
	Non-VR Waste	VR Waste	Total	Non-VR Waste	VR Waste	Total
No VR	6492	0	6492	3789	0	3789
Case 1	5378	743	6121	2675	743	3418
Case 2	5378	36	5414	2675	36	2711
Case 3 & 7	2838	570	3408	2555	61	2616
Case 4	3952	1008	4960	3669	48	3717
Case 5 & 6	1643	1341	2984	1643	597	2240
Case 8 & 9	529	1382	1911	529	638	1167

TABLE VII SUMMARY OF TREATED WASTE GENERATION
PRESSURIZED WATER REACTORS

Annual Waste Generation, drums (1000MW$_e$)

	No CPS			With CPS		
	Non-VR Waste	VR Waste	Total	Non-VR Waste	VR Waste	Total
No VR	2722	0	2722	2817	0	2817
Case 1	1636	724	2360	1731	724	2455
Case 2	1636	35	1671	1730	35	1765
Case 3 & 7	856	100	956	768	115	883
Case 4	1942	159	2101	771	1282	2053
Case 5 & 6	1754	169	1923	1754	159	1913
Case 8 & 9	668	209	877	668	199	867

TABLE VIII DATA FOR PACKAGES AND SHIPMENT OF WASTES

		Cost of Consumables,$		10CFR61 Class		Average Dose Rate,R/Hr		Shipping Cask		Weight Of Drum,KG		Drums per Trip		Total Weight Shipped,Tonne	
Waste Stream	VR Case	BWR	PWR	BWR	PWR	BWR	PWR	BWR	PWR	BWR	PWR	BWR	PWR	BWR	PWR
1. Dry Active Waste	1	35	35	A	A	0.11	0.10	VAN	VAN	166	166	118	118	20	20
	2	340	340	A	A	1.1	0.94	14D	21D	345	345	14	21	20	20
	3,7	340	340	A	A	1.1	0.94	14D	21D	345	345	14	21	20	20
	4	35	35	A	A	0.11	0.10	VAN	VAN	118	118	165	165	20	20
	5,6	35	35	A	A	0.11	0.10	VAN	VAN	118	118	165	165	20	20
	8,9	67	67	A	A	0.94	0.80	21D	21D	350	350	21	21	21	21
2. CONCLIQ	1	54	55	A	A	0.25	0.10	S.V	VAN	364	355	32	55	20	20
	2	54	55	A	A	0.25	0.10	S.V	VAN	364	355	32	55	20	20
	3,7	340	340	A	A	1.1	1.2	14D	14D	345	345	14	14	20	20
	4	340	340	A	A	0.55	0.44	21D	S.V	286	259	21	45	20	20
	5,6	66	71	A	A	0.79	0.5	21D	21D	341	323	21	21	21	20
	8,9	66	71	A	A	0.79	0.5	21D	21D	341	323	21	21	21	20
3. IXRESIN	1	53	53	B	A	4.3	0.03	14D	VAN	359	359	14	54	20	20
	2	53	53	B	A	4.3	0.03	14D	VAN	359	359	14	54	20	20
	3,7	53	53	B	A	4.3	0.03	14D	VAN	359	359	14	54	20	20
	4	53	53	B	A	4.3	0.03	14D	VAN	359	359	14	54	20	20
	5,6	64	64	B	A	10.0	0.08	14D	VAN	259	259	14	75	22	20
	8,9	64	64	B	A	10.0	0.08	14D	VAN	259	259	14	75	22	20
4. FSLUDGE	1	53	53	B	A	4.7	0.85	14D	21D	359	359	14	21	20	21
	2	53	53	B	A	4.7	0.85	14D	21D	359	359	14	21	20	21
	3,7	53	53	B	A	4.7	0.85	14D	21D	359	359	14	21	20	21
	4	53	53	B	A	4.7	0.85	14D	21D	359	359	14	21	20	21
	5,6	64	64	B	A	11.0	2.2	14D	14D	259	259	14	14	22	19
	8,9	64	64	B	A	11.0	2.2	14D	14D	259	259	14	14	22	19

PERFORMANCE OF VR TECHNOLOGIES

Waste Quantities with VR

Table VI summarizes the annual number of drums of Waste generated for each of the VR technology cases for BWR reactors with deep bed CPS, and also with precoat CPS. A "Non-VR" case is presented for comparison purposes. The columns for Non-VR waste correspond to the annual number of drums generated in a typical 1000 MWe reactor (with waste generation rates as presented in Table III) with the application of VIFs from Table V. The number of drums of waste that are generated with VR processing in each case are similarly developed using the VRFs in Table IV. For a deep bed CPS BWR of 1000 MWe it is seen in Table VI that 6492 drums of waste typically would be generated annually with no VR. In comparison, only 1911 drums would be generated with VR technology Cases 8, and 9. Corresponding quantities of treated wastes are presented in Table VII for PWR cases.

Data for Packages and Shipment of Wastes

Table VIII summarizes data estimated for wastes packaged for disposal for each of the waste streams and VR cases. Costs of consumables were based on per pound costs for cement, Dow binder, and asphalt of $0.04, $1.30, and $0.11, respectively. The classification of waste packages according to the new regulation, 10 CFR 61, is seen to be Class A for all waste streams and VR cases except for BWR ion exchange resins and filter sludges. These BWR wastes were determined typically to be Class B (because of Cs-137 activity).

Dose rates were calculated based on radionuclide concentrations presented in NUREG /CR-1759, Data Base for Radioactive Waste Management, USNRC, November, 1981. Short half-life radionuclide concentrations to augment the referenced data were developed by Rogers and Associates Engineers and were included in study.

Typical shipping casks are noted in Table VIII to match the shielding requirements of each type of packaged waste. The designation in the table of "VAN" indicates an unshielded van which is suitable for drums of waste up to 200 mr/hr. Such shipments are limited by space to 179 drums or fewer, and payloads of about 20 tonnes. The notation "S.V." is for a shielded van which can be used for drums of waste with average surface dose rates up to 500 mr/hr. Payloads for the shielded van are limited to 75 drums and a maximum weight not to exceed about 12 tonnes. The notations "21D" and "14D" are used to designate a 21 drum cask and 14 drum cask, respectively. The 21 drum cask can be used for drums with average dose rates up to 1 R/hr. The 14 drum cask can be used for drums with average dose rates up to 15 R/hr.

Typical weights of drums are presented for the various cases considered. These weights were used to determine the maximum number of drums that could be shipped in weight limited shipments (unshielded and shielded van shipments). Total shipping weights are also presented (not including the tractor or trailer) to enable the calculation of transportation costs.

VR TECHNOLOGY INSTALLATIONS

Burns and Roe developed general arrangements for each VR technology case considered in this study as the basis for the estimation of capital cost information. These installation designs are intended to embody sound practice, but are not represented as optimized arrangements. Sufficient detail was included to enable a reasonable estimate to be made of the facility costs for the structure, process equipment, and associated piping, electrical wiring, instrumentation and control, and HVAC equipment. Functional areas are included as required to house the process equipment, auxilliaries (electrical supply, compressed air , cooling water, process steam generator, and HVAC), and support areas.

Figure 1 depicts the general arrangement developed for one of the VR technology cases, Case 2 for the Controlled Air Incinerator Facility. This general arrangement is typical of the detail presented in the other general arrangements developed in this study.

Table IX is presented to indicate the floor areas that typify three of the VR Technology cases: Case 2 incinerator; Case 3, fluid bed dryer/incinerator; and Case 6, evaporator extruder. The evaporator extruder requires the least floor space of the three example cases, and the fluid bed technology case requires the largest floor space.

TABLE IX VR TECHNOLOGY SPACE REQUIREMENT

FLOOR AREA, ft^2

	Case 2 Incinerator	Case 3 Fluid Bed Tech.	Case 6 Evap. Extruder
Process Support Area	6,840	22,280	4,910
Auxilliaries Area	6,430	9,820	4,460
Total Area	13,270	32,100	9,370

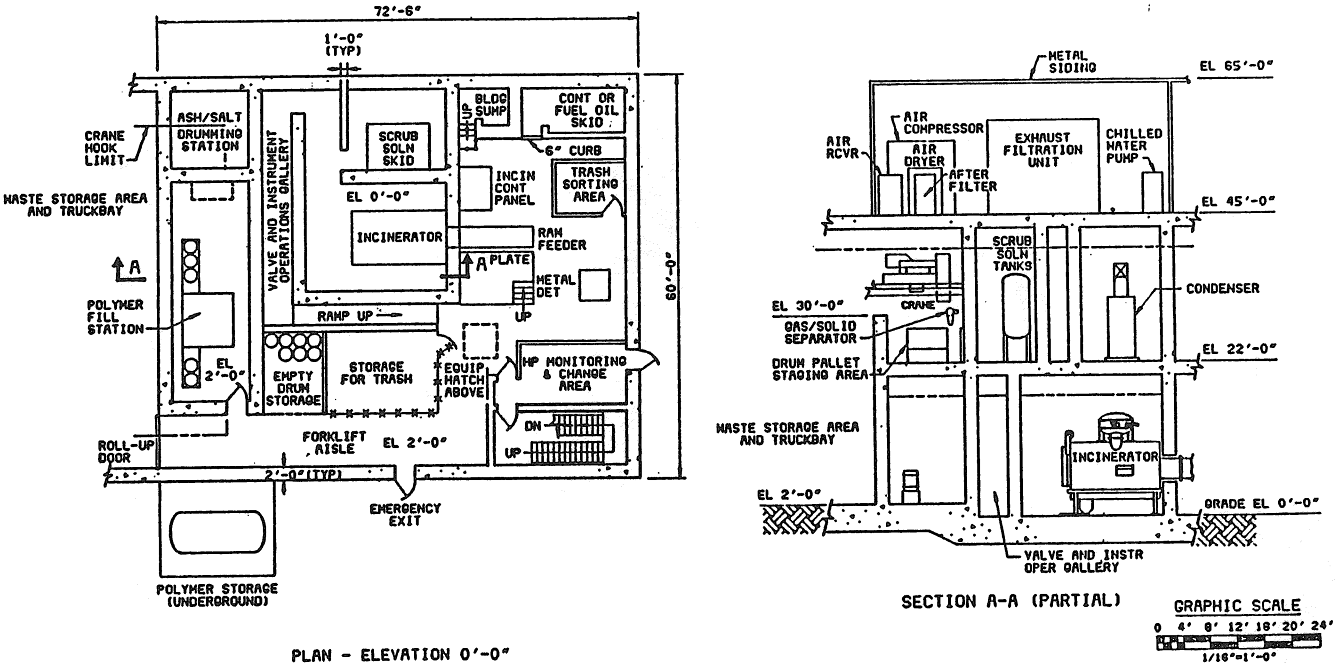
A preliminary estimate of capital costs for the three example facilities is presented in Table IX. As expected, it is seen that the facility costs are strongly influenced by the size of the facility. For the three cases included in the table it is seen that an evaporator extruder facility is the lowest in cost, with the fluid bed technology facility resulting in the highest costs. These costs are in first quarter 1983 dollars and include no interest or escalation costs.

TABLE X PRELIMINARY CAPITAL COST ESTIMATE

Cost, $\$x10^{-6}$

	Case 2 Incinerator	Case 3 Fluid Bed Tech.	Case 6 Evap. Extruder
Total Field Cost	11.9	21.0	7.5
Engineering, Design & Construction Mgmt.	1.8	3.2	1.1
Contingency	3.4	6.0	2.1
Total Capital Cost	17.1	30.2	10.7

Complete data for the VR Technology cases considered in this study will be presented in the Burns and Roe report for this work. The Burns and Roe report will be incorporated in the final project report to be published later this year. The various LLW disposal scenarios included in the final report should help nuclear power utilities to assess promising VR alternatives. A computer program will be developed and presented in the final report to enable each nuclear plant to tailor the model to their particular plant and regional factors.



PLAN - ELEVATION 0'-0"

SECTION A-A (PARTIAL)

Fig. 1. Controlled Air Incinerator Facility.