CURRENT STATUS AND FUTURE POTENTIAL FOR ADVANCED VOLUME REDUCTION TECHNOLOGIES

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ABSTRACT

With escalating costs for disposal of low-level radioactive waste (LLW) from nuclear power plants, and the possibility of unavailability of disposal space, some nuclear power utilities responded by commiting to implementing advanced volume reduction (VR) systems. This paper presents recent experience to implement advanced volume reduction technologies; their performance and typical operating and capital costs. This experience in the light of current economic conditions may enable us to predict the direction that future advanced VR technology commitments is taking.

INTRODUCTION

Several years ago the NRC promoted volume reduction (VR) for low-level radioactive waste from nuclear plants. Commitments were made by utilities to implement advanced VR technologies to become more independent from commercial burial facility restrictions, and also possibly reduce LLW disposal costs at the same time. Immediate responses to the need for VR may have caused some utilities to acquire maximum VR at any cost (almost). That urgency may have now lessened because the 1986 deadline for establishment of regional compacts will not be met by any compact region which does not have an operational LLW disposal facility. Also, projected cost savings with VR may be less than anticipated because of burial facility schedules which now include radiation level and curie surcharges. In light of the changed conditions, some nuclear power utilities are reconsidering their VR commitments and plans in order to implement less capital intensive VR alternatives.

A recently completed survey[1] sponsored by the Electric Power Research Institute (EPRI) provides information on the status of VR commitments by nuclear power utilities in the United States. Another recently completed study[2] also sponsored by EPRI to characterize advanced VR technologies provides performance and cost information which can be used to better understand current VR commitments and new VR alternatives to meet evolving conditions. These EPRI projects will be used in the following development to indicate future trends for volume reduction technologies.

CURRENT VR COMMITMENTS

Table 1 lists the status of VR commitments by nuclear power plants in mid-1983. A total of 55 VR commitments are indicated which include a total of 21 improved compactors, 6 fluid bed technology systems (dryer/incinerators or dryers), 20 evaporator crystallizers, and 6 evaporator extruder systems. These systems are either installed as retrofit systems or into new facilities. Additionally, commitments are noted for two mobile VR systems: one (1) a wiped-film evaporator system, and one (1) a mobile controlled air incinerator.

Of the 55 VR commitments, 17 are for the SE and NW compact regions which each currently have an operating commercial LLW disposal facility. Nuclear power plants in compact regions with current disposal facilities have committed to VR alternatives to approximately the same degree as nuclear plants in compact regions which do not have an operating LLW disposal facility. Thus, there seems to have been as much concern for VR in compact regions with waste disposal facilities as those without. The mix of VR commitments for PWRs (35 systems) and BWRs (20 systems) is also approximately in proportion to the ratio of the number of PWR plants to BWR plants.

Table 2 indicates VR commitments according to plant operating status. In the survey, with approximately twice as many operating plants included as plants under construction, it appears plants under construction are more likely to commit to advanced VR technologies than currently operating plants.

TYPICAL PERFORMANCE AND COSTS OF VR ALTERNATIVES

A major component of LLW disposal costs relates to packaging, transportation and burial. These costs are related to the disposal volume of the radwaste. Table 3 presents volume reduction factors (VRF) for advanced VR technologies being implemented in the United States. This factor is a measure of VR system performance for various combinations of waste stream and solidification agent. Application of these VRFs to typical nuclear power plant wastes in ONWI-20[3], leads to annual waste generation for disposal as noted in Table 4. This table can be used to indicate the overall effectiveness of various advanced VR technologies by comparison with the no VR case.

The complete evaluation of VR technology economics includes capital costs for equipment and facilities, and operating costs for maintenance and labor as well as disposal costs. An estimate of typical capital costs, and maintenance and operating labor costs are presented in Table 5 for VR technologies now being implemented.

Estimated savings over a 30 year life for the VR technologies now being implemented are indicated in Table 6 from the recently completed EPRI study[4] on VR strategies. Calculated savings are presented for BWRs with deep bed and filter/demineralizer condensate polishing systems (CPS), and PWRs with and without CPS. These savings are calculated values for a specific set of conditions and are representative strictly only for those conditions, but may be used for indicating relative trends. Calculations for comparison of VR alternatives for a nuclear plant should be performed using the EPRI study methodology[4] and site specific data.

For the typical conditions considered, improved compactors are cost effective. Supercompactors can result in a life cycle savings of about 20 million dollars, however, this savings is based on maximum compaction in volume efficient packaging for transportation and disposal which has not yet been demonstrated.

Fluid bed technology (dryer and incinerator) results in a 25 million dollar savings over the life cycle for a BWR with a deep bed CPS, and negative savings for the other reactor/CPS combinations. Relatively large savings are estimated for the evaporator extruder system for typical BWRs. It can be seen in Table 1 that the evaporator extruder system has been selected by four BWR nuclear plants, possibly because of the indicated favorable economics. The evaporator crystallizer, mobile wiped-film evaporator and mobile incinerator all appear to be cost effective for the conditions considered, especially for BWRs with deep bed CPS and the large quantity of waste that characterizes that case.

FACTORS AFFECTING ADVANCED VR COMMITMENTS

It is evident that LLW disposal in compact regions without an existing disposal facility will not be able to complete a new disposal facility by the 1986 date specified in the Low-Level Radioactive Waste Management Policy Act of 1982. There is the general feeling that since new disposal facilities will not be available in the near future that some accommodation will be necessary to continue to accept LLW at existing waste disposal facilities, either commercial or governmental. The urgency to implement advanced VR technologies has accordingly been lessened. Volume reduction has become less cost beneficial as radiation level and curie surcharges have been instituted at commercial disposal facilities. These two factors have caused some nuclear plants to reconsider implementing VR alternatives. The high capital cost to implement large VR facilities is a deterrent because of the scarcity of available capital and the uncertainty of future economic conditions. This is especially true when volume minimization practices have been successful to reduce waste generation.

Conservative criteria established for VR systems and facilities resulted in VR facility designs with heavy emphasis on concrete shielding and correspondingly large facility costs. When waste stream characteristics permit, relaxed criteria for VR systems could significantly reduce facility costs by minimizing space requirements and reducing shield wall thicknesses.

Another factor that affects VR implementation is the availability of contractor services. Mobile systems provided by contractors can effectively provide LLW management functions as may be required without the need for a large capital expenditure for permanent or retrofit VR facilities.

FUTURE TRENDS IN VR ALTERNATIVES

Volume Minimization

Costs associated with the implementation of any VR technology are reduced when waste quantities are reduced. This simple approach of Volume Minimization is being widely pursued. Operating procedures are used to reduce the quantity of material which becomes radioactively contaminated and other procedures are being utilized to segregate non-radioactive material to eliminate its disposal as radioactive material. Getting non-operating equipment such as evaporators to function again is another example of Volume Minimization.

Significant Volume Minimization has been demonstrated[5] by several BWR plants with deep bed ion exchange CPS by throwing away spent resin instead of regenerating the resin. The increased volume of resin used is minimal but the reduction in regeneration solutions is significant. Also, spent resin from relatively clean CPS service may be reused for radwaste cleanup systems.

Mobile Systems

Mobile systems already have achieved significant acceptance in nuclear plants to provide radwaste management functions without the need to install permanent or major retrofit VR systems and facilities. While a mobile system provided as a service can be cost beneficial, in some cases even large service charges can be tolerated to avoid large capital investments that may be required for more extensive permanent or retrofit VR facilities. Mobile systems are now quite common for dewatering of ion exchange resins, and sludges; and for filtration and demineralization of liquid waste streams. A mobile controlled air incineration was purchased in 1983 and a mobile thin-film evaporator system has also been committed for a nuclear plant.

Operation of the mobile incinerator may be the first demonstration of a modern radwaste incinerator because delays in licensing the Byron nuclear plant has deferred startup of the fluid bed incinerator/dryer to 1985 or beyond. Mobile systems are clearly a promising VR option for the future.

Super Compactors and Shredder/Compactors

Supercompactors are being considered by nuclear plants but have not yet bee committed for any nuclear plants. Packaging to efficiently contain the compacted dry active waste for disposal must be demonstrated in order to fully utilize the volume reduction potential of this technology.

A shredder/compactor will be implemented shortly in a nuclear power plant to demonstrate this technology. While improved compaction of dry active waste is reported it is expected that the full benefit of the shredder/compactor will be realized in actual practice when normally non-compactible materials (wood, conduit, hose, etc.) are shredded and incorporated into the disposal container along with compactible trash.

Other VR Technologies

The near future seems to be a period when extensive VR systems and facilities may be deferred in favor of low cost VR options. In one case already purchased VR systems have been cancelled as not being necessary because the Southeast compact will be available to serve nuclear plants in that region. Retrofit VR systems will continue to be attractive, as will be mobile systems, because large capital investments for an expensive building is not necessary.

An interesting VR technology with significant volume reduction for ion exchange resins is the wet-oxidation process developed in Japan. While disposal costs are minimized by the effective volume reduction, it appears that the cost of catalyst and peroxide used in the process may offset the disposal cost savings.

New volume reduction technologies may have a difficult time in being accepted since VR system acquisitions by nuclear plants may be few in number in the near future.

Table 1

SUMMARY OF ADVANCED VR COMMITMENTS

	SE & NW COMPACTS		OTHER COMPACTS	
	PWR	BWR	PWR	BWR
Improved Compactors	6	0	6	9
Fluid Bed Dryer/Incin.	2	0	3	0
Fluid Bed Dryer	1	0	0	0
Evaporator Crystallizer	5	2	9	4
Evaporator Extruder	0	0	2	4
Mobile Wiped-Film Evap.	1	0	0	0
Mobile Incin.	0	0	0	1
Totals	15	2	20	18

Table 2

VR COMMITMENTS ACCORDING TO PLANT OPERATING STATUS

	OPERATING PLANTS		PLANTS UNDER CONSTRUCTION	
	PWR	BWR	PWR	BWR
Improved Compactors	8	5	4	4
Fluid Bed Dryer/Incin.	1	0	4	0
Fluid Bed Dryer	0	0	1	0
Evaporator Crystallizer	5	2	9	4
Evaporator Extruder	0	1	2	3
Mobile Wiped-Film Evap.	1	0	0	0
Mobile Incin.	0	1	0	0
Totals	15	9	20	11

Table 3

EFFECTIVE VOLUME REDUCTION FACTORS*

Waste Stream	Compactors Improved	Compactors Super	Incin/Dryer Cement	Incin/Dryer Dow	Incin/Dryer Bitumen	Evap/Cryst Cement	Evap/Cryst Dow	Evaporator Extruder Bitumen	Mobile Evaporator Bitumen
Trash	1.5	2.3	27	30	27	-	-	-	-
Conc. Liq. (PWR)	-	-	-	10.4	-	3.5	3.9	6.6	5.4
Conc. Liq. (BWR)	-	-	-	4.5	-	2.1	1.7	3.8	2.4
IX Resin	-	-	-	4.0	-	-	-	2.0	1.4
Sludge	-	-	-	4.0	-	-	-	2.0	-

$$\text{*Effective Volume Reduction Factor} = \frac{\text{Waste Volume Before Volume Reduction}}{\text{Volume Packaged Waste for Disposal}}$$

Table 4

SUMMARY OF WASTE GENERATION WITH ADVANCED VOLUME REDUCTION PROCESSES (drums/year)

	BWR		PWR	
	Deep Bed	Filter/Demin	No CPS	With CPS
No VR	6789	3569	2639	2764
Improved Compactor	6443	3223	2301	2426
Supercompactor	5914	2694	1734	1859
F/B Dryer/Incin	3175	2442	842	776
Evap. Crystallizer	4991	3485	1923	1880
Evap. Extruder	2784	2092	1744	1735
Mobile Wiped-Film	4191	3447	1792	1796
Mobile Incinerator	5783	2563	1658	1783

TABLE 5

CAPITAL AND OPERATING COSTS FOR ADVANCED VOLUME REDUCTION TECHNOLOGIES

(Dec 1982 $\$ \times 10^{-6}$)

	Capital Cost	Annual Maintenance	Annual Operating Labor
No VR	-	0.10	0.10
Improved Compactor	0.17	0.11	0.10
Supercompactor	3.8	0.16	0.10
F/B Dryer/Incin.	24	0.32	0.18
Evap. Crystallizer	7.1	0.15	0.13
Evap. Extruder	8.6	0.20	0.18
Mobil Wiped-Film	4.3	0.14	0.18
Mobil Incinerator	2.6	0.16	0.18

Table 6

VR TECHNOLOGY SAVINGS (30 YEAR LIFE)

	BWR		PWR	
	Deep Bed	Filter/ Demin	No CPS	With CPS
No VR	5	5	5	5
Supercompactor	20	20	20	20
F/B Dryer/Incin	25	(5)	(5)	(1)
Evap. Crystallizer	10	0	5	8
Evap. Extruder	80	45	1	5
Mobile Wiped-Film	45	5	8	10
Mobile Incinerator	15	15	15	15

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