THE MIXED ECONOMIES OF VOLUME REDUCTION

J.W. Voss, Golder Associates, Inc.
B.D. Guilbeault, Pacific Gas & Electric

INTRODUCTION

During the past few years, the nuclear industry's perspective of the best approach to the treatment of all types of radioactive waste has been shifted from minimum treatment prior to disposal to volume reduction. This shift has occurred for a number of reasons, the strongest of which as been a diminishing and uncertain disposal capacity. The approaches followed to achieve volume reduction range from simple, in-house programs to minimize the volume of waste generated to complex systems to reduce the treated volumes of wastes.

Technologies designed to reduce the volumes of wastes for disposal fall in one of two general categories: (1) compaction or (2) combustion. Compaction systems are relatively simple, providing the hardware necessary to compress untreated wastes and to package the wastes into a disposal container. Combustion systems oxidize combustible waste materials, generating ash and airbore products of combustion, both of which must subsequently be treated and disposed of. New compaction systems have been introduced to the industry at an agressive pace, each offering improved performance in one manner or another. Combustion systems have also been introduced to the industry at a reasonably brisk pace. Additionally, combustion systems have, in the past decade, been the subject of considerable Federal analysis and development

Comparison of available volume reduction systems must be performed with care to ensure that total systems are compared against all performance requirements and all significant additional performance attributes. It is too easy to focus only upon partial systems or individual performance attributes, missing or discounting information which is critical to defensible decision making. This paper will focus upon defining total systems, performance requirements and attributes, and relevant performance data on individual volume reduction systems. It is emphasized that decisions on selection of volume reduction technologies or approaches must be made by individual facility managers, giving full consideration to the individual circumstances present at a particular facility. There is no singular best answer or approach except that it must be logical and defensible.

DEFINING THE SYSTEM

Throughout this paper, the term "system" shall be used to mean the entire low-level waste management system, from the point of generation through waste disposal, as shown in Fig. 1. As indicated, the entire waste system includes many components which are outside of the main facility, the most significant of which are the transportation, off-site storage facility (if any) and the disposal facility. Additionally, the waste management systems has interfaces with the main facility, from which it receives generated wastes, and supplies, and returns recycled resources such as steam, or decontaminated water. The waste management facility and the main facility have common interfaces with the environment, to which both may release effluents.

Focusing now on the waste treatment portion of the system, this subsystem may be visualized as shown in Fig. 2. Three categories of radwastes are generated by all facilities: (1) off-gas; (2) solids; and (3) liquids. Accordingly, there must be a treatment system for each. Additionally, in treating each category of waste, secondary wastes of each form are also generated, and must be treated. Thus, in comparing systems and technologies for solid radwaste, the system which must be considered is as shown in Fig. 3.

One additional definition of the system must be made, concerning time. The performance of the system must consider the total life cycle of operation. It is insufficient to only consider the normal operating performance of alternate systems, ignoring maintenance and planned refitting impacts. For example, most incinerators require extensive refitting at set intervals. Such refitting may result in significant costs, waste generation, environmental effluents, and occupational exposures. This element of performance must be considered in comparing systems.

ELEMENTS OF PERFORMANCE

Radwaste systems have many attributes of performance. It is insufficient to only consider, for example, the net volumes of treated radwastes. Attributes of system performance include the following:

1. Cost
   - 1.1 Capital by year
   - 1.2 Operating by year
   - 1.3 Planned refit or maintenance by year
   - 1.4 Decommissioning by year
2. Occupational Radiation Exposure
   - 2.1 Operating
   - 2.2 Planned refit or maintenance
   - 2.3 Decommissioning
3. Non-Radiologic Occupational Hazard
   - 3.1 Construction
   - 3.2 Operations
   - 3.3 Maintenance
   - 3.4 Decommissioning
4. Radiologic Effluents
   - 4.1 Liquid
   - 4.2 Gaseous
5. Non-Radiologic Effluents
   - 5.1 Liquid
   - 5.2 Gaseous
6. Predicted Reliability
7. Predicted Capacity
8. Flexibility
9. Licensability
10. Complexity
11. Waste Form
12. Waste Volume

While all of the performance elements are attributes of the total waste system, it is also necessary to define the center of responsibility for each attribute. For example, capital and decommissioning costs of the transporting wastes are not directly borne by the generator, although such costs are reflected in the operating costs. Similarly, occupational exposures at the disposal facility are not the responsibility of the generator.

PERFORMANCE REQUIREMENTS

Waste treatment systems have performance requirements which define the minimum acceptable performance. In general, the performance requirements of the waste system are:

1. Radioactive waste management services should not in any way disrupt or adversely impact the main functions of the facility.
2. Radioactive waste management must be performed in a manner which adequately protects the health and safety of workers and the public, as well as the quality of the environment, as defined by applicable Federal, state and local laws.
3. Radioactive waste management should be performed at a minimum cost.

Often, these performance requirements are more precisely performance thresholds, coupled with a minimization or maximization objective. For example, occupational exposure has a whole body annual threshold of 5 rem for each worker. However, the ALARA principal of exposure is also applicable, where both are defined in 10CFR20. These relationships are generalized in Fig. 4.

One performance requirement of particular importance is the waste form. The waste form is subject to the rules of NRC. For wastes which can be disposed of in shallow land burial, 10CFR61 is the applicable rule defining, among other things, waste form. However, when a waste must be disposed of in a repository, 10CFR60 becomes the applicable rule. It is significant that, while 10CFR60 does not prohibit combustible waste forms, early indications from DOE are that combustible waste forms will not be accepted for disposal in a Federal repository. The existing precident for this position is the WIPP acceptance criteria. Unfortunately, "combustible" has not been precisely defined, leaving open the questions of a bitumen waste form for repository disposal. The key consideration, however, in this topic is that disposal requirements on the waste form could preclude any waste treatment technology which does not render the treated waste as non-combustible.

When examined on a system basis, it is significant that minimization of the treated waste volume is not necessarily a direct system performance requirement. Achieving the other performance objectives and meeting performance requirements is the key consideration, and to the extent that minimizing the volume of treated wastes leads to the other objectives, then it is significant. Volumes of treated wastes do become significant in another sense, however, in that (1) a facility has a maximum disposal volume allocation, or (2) a facility management has the perception that at some point in the future, no disposal capacity will be available to him, suggesting that minimization of storage volume might be a key objective.

VR SYSTEM EVALUATIONS

On a system basis, it seems intuitively obvious that minimization of the treated waste volumes will minimize costs. Volume reduction technologies, however, cannot be blindly accepted without evaluating system performance potential, considering all areas of performance. If volume reduction (VR) works as intended, the result is that the radioactivity in a facility's wastes is concentrated, occupying a smaller volume that the waste originally occupied. The simplest example of VR is compaction of dry trash. As a result of concentrating the waste form, however, it's radiation level may also increase, though not generally in direct proportion to the factor of concentration. This increased radiation level may require modifications of the operating facility for additional shielding to reduce radiation exposure of the plant workers. In the extreme case, remote hot cells may be required because of the increase in radiation levels.

Some volume reduction systems are mechanically complex and sophisticated. A typical system requires many mechanical, electrical and service system interfaces. This sophistication is complicated by shielding requirements, and may be accompanied by lower operational reliability and more critical maintenance requirements. Additionally, there may be complex interfaces between volume reduction systems which require not only the mass transfer interfaces but surge storage capacity. The surge capacity adds a further facet of complexity to the operation and control of the entire waste disposal system.

One unique risk of some VR systems is that when a total system accounting of treated waste volumes is performed, there may not be a net reduction of waste volume, but rather an increase in volume with only a redistribution of radioactivity. An example of such a system might include an incinerator. Most vendors predict at least a fifty-to-one reduction in waste volumes through incineration, based on a comparison of feed-to-ash volumes. However, the requirements of 10CFR61.56 will likely require immobilization of the ash, which will at least double the volume of ash. Considering the incinerator off-gas, certainly particulate filtering will be required. While prefiltering may be accomplished with cyclone or equivalent component, ultimately a HEPA bank will be required, and conceivably a charcoal bed, depending on the feed contaminants. Additionally due to PolyVinal Chloride (PVC), neoprene or other chlorinated materials among the feed streams, a wet scrubber will be required to remove chlorine to meet the Environmental Protection Agency (EPA) emission requirements. Wet scrubbers of this function are typically sodium based and result in very large quantities of marginally contaminated sodium chloried solution. For example, the incineration of one pound of PVC may result in between 3 and 4 liters of 2M scrub solution, or "blow down". This "blow down" may be reconcentrated to 6M or three times without taking special precautions to prevent precipitation of salts. Subsequent volume reduction steps will dictate the final volume of the immobilized blow-down. It is not difficult to postulate waste feeds which, because of chlorine content, result in very nearly as much final solidified waste volume as the *initial feed. Still* two more elements of the volume reduction system must be examined in order to comprehensively account for all wastes. The first is the initial trash fraction which may be sorted as being non-combustible. The volume of this material is a function of the plant operations. The final element in the volume accounting is the wastes which result from routine maintenance, and upkeep of the equipment. The system described in this example will require periodic rebricking or relining of the combustion chamber of the incinerator. This will occur several times over the plant lifetime, on the order of once each decade, if design objectives are met. Accompanying such a procedure is a thorough decontamination of the entire volume reduction system. Thus, as simplisti- as it may seem, a volume reduction "system" must be carefully analyzed to ensure that on a true systems-accounting basis, a net volume reduction will actually occur, and not a redistribution of radioactivity into various waste streams of equal or larger volume than that of the initial waste.

In the previous example, an indication of an additional liability of volume reduction systems was indirectly noted. This is that many systems, in order to meet maximum economy, must employ a number of major components. In the previous example, incineration of the combustible fractions is the major volume reduction objective. In order to accomplish this, however, a waste sorting station is required to remove the non-combustible fraction. A shredding unit is also a likely necessity as a pre-feed preparation. A pneumatic or gravity ash transfer and storage system is required. An off-gas scrubbing and cleaning system is needed, probably including an operational and standby HEPA filter bank. There are totally new components needed to replace an existing system such as a self contained compactor. The most-offered solution to the concentration of the dilute sodium chloride solutions produced by the off-gas systems is to process them in the evaporator along with other plant liquid waste streams. This solution tends to cause the size of the evaporator to increase to maintain the required processing rates. The eventual effects of processing these solutions which contain chloride has not yet been closely examined. However, the operational experience with many liquid radioactive waste evaporators when processing solutions containing very low concentrations of chlorides is that the equipment lifetime was severely reduced. If the probable result of processing this material in the existing plant evaporator is the reduction of equipment life or the over design of the incineration system to provide a means of disposal of the liquids generated by the off-gas system, then a processing train consisting of a surge tank, wiped film evaporator or the like will be necessary to ensure that the waste processing operations do not interfere with routine plant operations.

The final potential liability of volume reduction is concerned with the results of concentration of radionuclides in the final waste form for disposal. The obvious result of the volume reduction is higher radiation levels. These higher levels will result in higher unit transportation and disposal. The increased cost for transportation and disposal, if the analysis of the post volume-reduction system volumes is done properly will be offset by reduced volumes for disposal. One facet of the higher radiation levels in wastes is the probable reclassification of the wastes from Class A waste to Class C waste by the provisions of 10CFR61.55. Of more significance is the concentration of transuranic nuclides in the reactor wastes to levels which approach or exceed the 100 nCi/gm cutoff of Class C waste. Depending upon the specific interpretation of NRC's rule, a plant may find that it has suspect or verified TRU wastes for which no current means of commercial disposal is available. A decision must then be made whether or not to attemp to dilute the TRU's to acceptable levels and thereby accepting the additional transportation and disposal cost and possible legal or waste form constraints, or long-term storage of the waste until a disposal mechanism is available. The long-term storage has a further constraint from the current NRC restriction of five year storage at the reactor site. This previous potential liability must be seriously addressed as several studies done over the past few years have shown that several reactors have had TRU contamination in excess of 100 nCi/gm, particularily in the materials originating from the cleanup of the primary coolant.

Combining of these elements into the analysis of economics of volume reduction is mandatory. Volume reduction systems are capital intensive, as complicated by the necessity of multiple components to support the overall radwaste management needs of the plant. These systems may be expensive to operate and maintain depending upon the quality and design objectives of the system. With the introduction of new systems, and new combinations of integrated working systems, overall reliability of these systems may suffer, at least initially. Additional capital may be required to construct radiation barriers such as shield walls. Unit shipping and disposal costs will additionally increase, with the hope that these are offset by decreased volumes. However, it is possible in some systems and probably in poorly engineered systems, that overall waste volumes may not decrease, but rather achieve only a redistribution of the radionuclides and a net increase in final disposal volume. In the extreme, the increased concentration of radionuclides could potentially result in small quantities of TRU wastes.

Volume reduction systems have, of course, assets to offset the potential and real liabilities. Through proper design and application, waste generation can be dramatically reduced, potentially lowering overall waste management costs. Additionally, uniform, acceptable waste forms can be produced from virtually all waste streams. This becomes a significant factor if the wastes must be disposed of in a repository. If a waste generator is faced with the need to store all of his wastes, due to the lack of access to an operating burial ground, the overall volume of the waste to be temporarily stored could be significantly decreased by volume reduction, thereby resulting in both an economic benefit as well as a physical solution to the storage problem.

SUMMARY

In summary, the nuclear waste management industry should continue to focus on the total system. It is too easy to accept a new technology as a panacea simply because it appears to cure one sympton or another. Waste treatment systems should be evaluated on a total system basis, with particular attention to the areas of performance or interface restrictions.

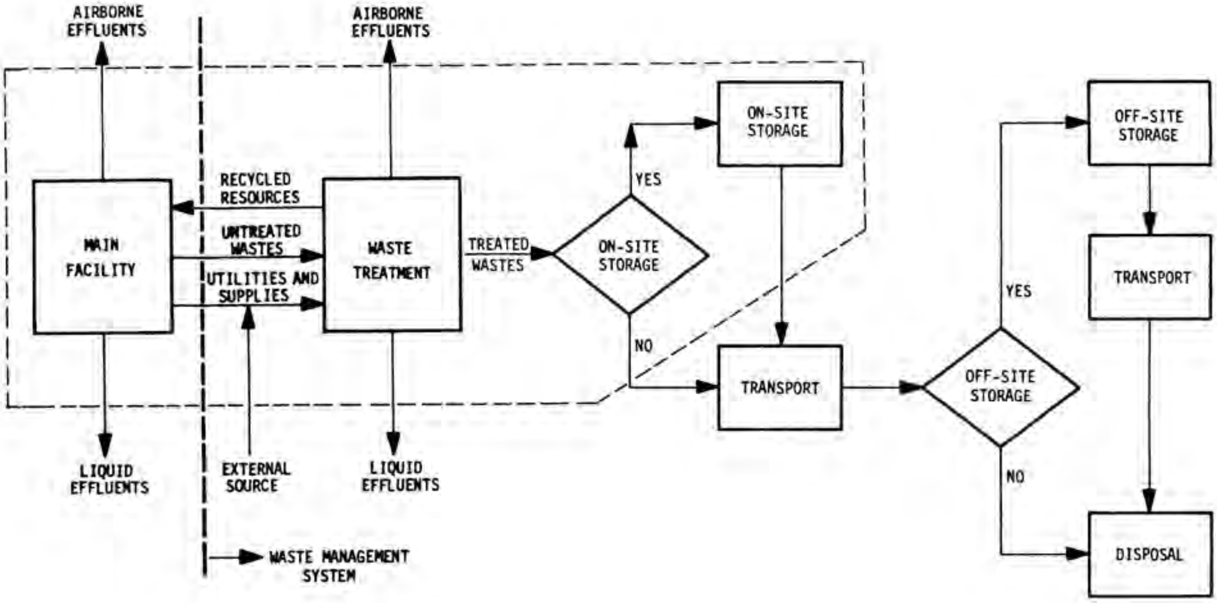
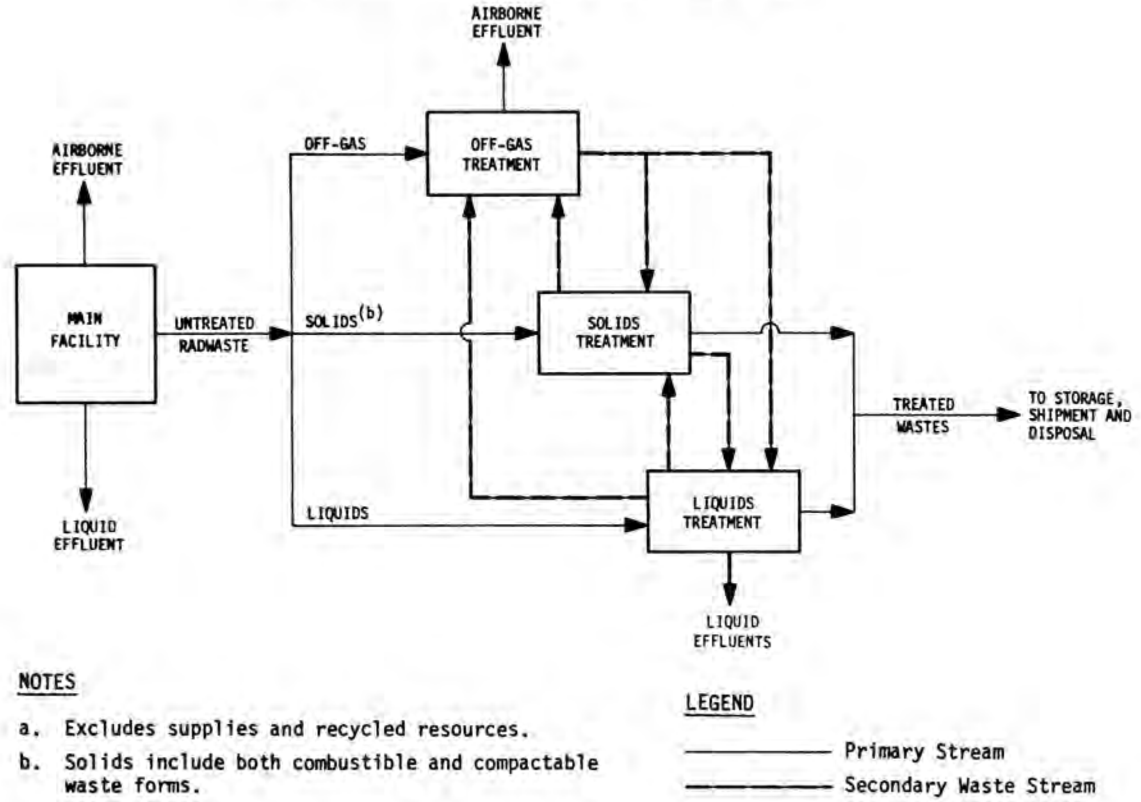


Fig. 1 Low-Level Radioactive Waste Management

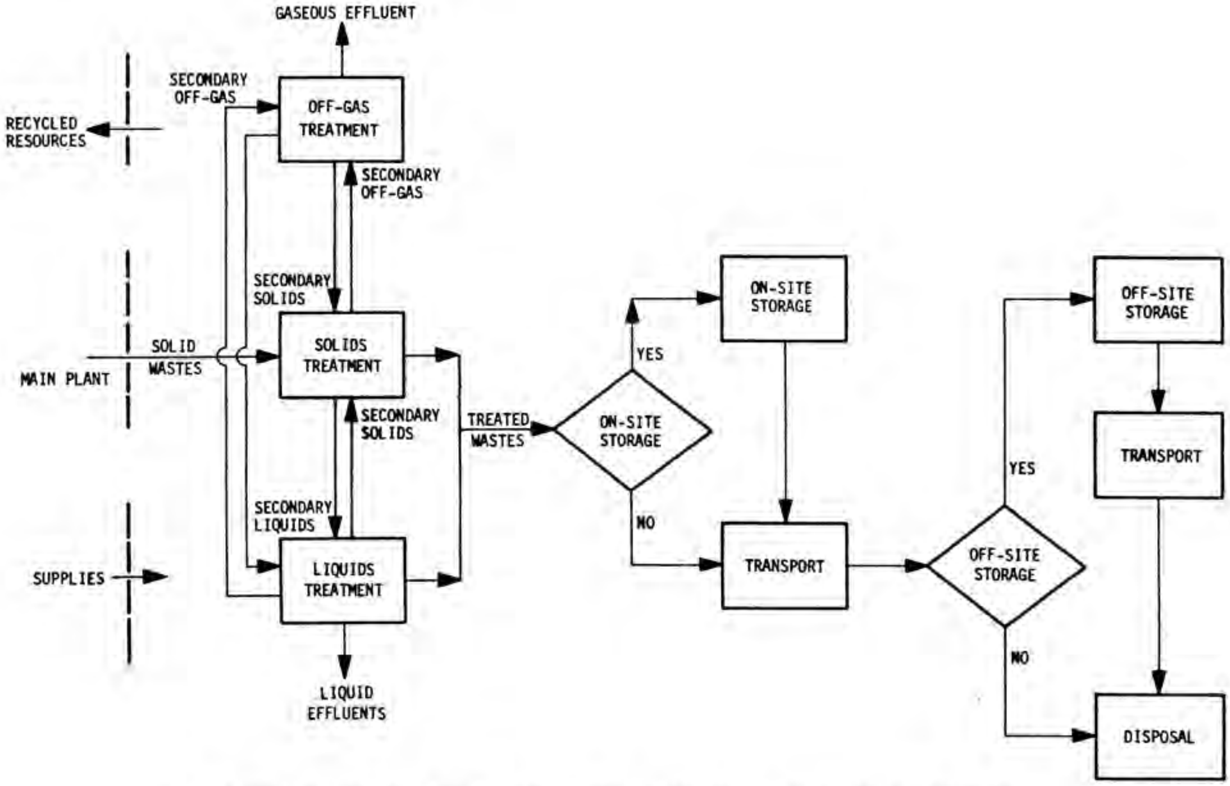


NOTES

a. Excludes supplies and recycled resources.

b. Solids include both combustible and compactable waste forms.

Fig. 2 Waste Treatment Subsystem(3)



a. Secondary wastes from primary solids treatment as well as from primary liquids and off-gas treatment. Effluents from all treatment.

Fig. 3 Solid Radwaste System [a]

Fig. 4 Centers of Accountability (a) Performance Requirements and Objects

	SUBSYSTEM				
PERFORMANCE ATTRIBUTE	WASTE TREATMENT	ON-SITE STORAGE	SHIPMENT	OFF-SITE STORAGE	WASTE DISPOSAL
1.1 CAPITAL COST 1.2 OPERATING COST 1.3 REFIT/MAINTENANCE 1.4 DECOMMISSIONING	MINIMIZE	MINIMIZE	MINIMIZE	MINIMIZE	MINIMIZE
2.1 OP. RAD. EXP. 2.2 REF./MAIN. RAD. EXP. 2.3 DECOM. RAD. EXP.	10CFR20 PLUS ALARA				
3.1 CONST. OCC. HAZ. 3.2 OPS.OCC. HAZ. 3.3 REF./MAIN. OCC. HAZ. 3.4 DECOM. OCC. HAZ.	OSHA	OSHA	OSHA	OSHA	OSHA
4.1 LIQUID RAD. EFF. 4.2 GAS RAD. EFF.	10CFR20 and 40CFR191				
5.1 LIQUID NRAD. EFF. 5.2 GAS NRAD. EFF.	RULES OF EPA				
6. RELIABILITY	– MAXIMIZE				
7. CAPACITY	– MAXIMIZE				
8. FLEXIBILITY	– MAXIMIZE				
9. LICENSE					
10. COMPLEX	– MINIMIZE				
11. WASTE FORM	10CFR60 10CFR61				
12. WASTE VOLUME	– MINIMIZE(a)				

(a) As relevant to achieving all other requirements and objectives and relative to disposal quotas.