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7. Abstract

This study determines whether the existing 242-A Evaporator should continue to be used to concentrate the Hanford Site radioactive liquid tank wastes or be replaced by an alternative waste concentration process. Using the same philosophy, the study also determines what the waste concentration mechanism should be for the future TWRS program. Excess water from liquid DST waste should be removed to reduce the volume of waste feed for pretreatment, immobilization, and to free up storage capacity in existing tanks to support interim stabilization of SSTs, terminal cleanout of excess facilities, and other site remediation activities.

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TANK WASTE CONCENTRATION MECHANISM STUDY

September 1994

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Richland, Washington

MASTER

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LIST OF TERMS

ACV	Administrative control values
ALARA	As low as reasonably achievable
CERCLA	*Comprehensive Environmental Response, Compensation and Liability Act of 1980*
DCG	Derived Concentration Guides
DF	Decontamination factor
DOE	U.S. Department of Energy
DST	Double-shell tank
LLW	Low-level waste
RCRA	*Resource Conservation and Recovery Act of 1976*
RO	Reverse osmosis
SRS	Savannah River Site
SST	Single-shell tank
TWRS	Tank Waste Remediation System
VRF	Volume reduction factor
WHC	Westinghouse Hanford Company

TANK WASTE CONCENTRATION MECHANISM STUDY

1.0 INTRODUCTION

A process must be selected to concentrate and reduce the volume of the Hanford Site radioactive liquid wastes. Waste volume reduction facilitates the management of liquid wastes requiring interim storage in the underground tank system. The selected waste concentration process will be operated for a minimum of 10 years until the concentration mechanism(s) supporting the Tank Waste Remediation System (TWRS) Treatment Complex begins operation in the year 2005 (Swanson et al. 1994). The evaporator functions and requirements support study, currently under preparation, will address the time period after the year 2005.

1.1 BACKGROUND AND SCOPE

Liquid radioactive and chemical wastes have been generated from nuclear material production and research activities at the Hanford Site in Washington State since 1944. The wastes were transferred to a system of underground, reinforced-concrete, steel-lined tanks for interim storage. The tank system consisted of 177 tanks which were arranged in 18 tank farms; 149 tanks were single-shell tanks (SSTs) and 28 tanks were double-shell tanks (DSTs). Since November 1980, the SSTs were removed from active service and all newly generated radioactive wastes were sent to the DSTs.

The upgraded 242-A forced circulation evaporator is currently being used to reduce the volume of radioactive liquid wastes requiring storage in the DSTs. The DSTs hold a total volume of 91,000 m^3 of waste that contain approximately 100,000 Mg of chemicals and 92 MCi of long-lived radionuclides. The wastes stored in the SSTs were evaporated as part of the SST stabilization operations. Some of the SSTs still contain interstitial liquid. The retrieval operation due to start in the year 2003 will require large volumes of water. This operation is incorporating water recycle as a way to manage the large volumes of water. Should concentration support be necessary for this operation, it will be performed at the prospective pretreatment facility.

1.2 PURPOSE AND NEED

This study determines whether the existing 242-A Evaporator should continue to be used to concentrate the Hanford Site radioactive liquid tank wastes or be replaced by an alternative waste concentration process. Using the same philosophy, the study also determines what the waste concentration mechanism should be for the future TWRS program. Excess water from liquid DST waste should be removed to reduce the volume of waste feed for pretreatment, immobilization, and to free up storage capacity in existing tanks to support interim stabilization of SSTs, terminal cleanout of excess facilities, and other site remediation activities (Flyckt 1990).

2.0 EXECUTIVE SUMMARY

This report evaluates the feasibility of continuing the use of the 242-A Evaporator to concentrate radioactive liquid wastes at the Hanford Site. The wastes presently within the tank system and any new radioactive liquid wastes generated from Hanford Site remediation actions are being accumulated in the underground DSTs. Six concentration alternatives were identified to process and to reduce the volume of the tank wastes. These included: no action (managing the tank system without concentrating the waste), evaporation, selective precipitation, reverse osmosis, ion exchange, and crystallization. Performance measures have been developed to assess and discriminate among the alternatives.

It was concluded from a qualitative evaluation of the alternatives that the waste concentration function was best accomplished by continuing the use of the 242-A Evaporator. The upgraded 242-A Evaporator was judged to have the processing capacity and operating life capable of satisfying system requirements. During its operating life, additional upgrades may be required to the 242-A Evaporator. This option offered considerable savings in capital costs (building and equipment/process costs) over the alternatives that involved the construction of a new facility.

In conclusion, the evaporation method for Hanford Site waste is well demonstrated and provides the necessary decontamination factor (DF) required. Other concentration mechanisms are not well developed for Hanford Site waste and would impact schedule availability for the entire program. Also, most other concentration mechanisms require a second form of concentration to achieve what evaporation can do by itself. For these reasons, evaporation would satisfy system requirements.

3.0 TECHNICAL FINDINGS AND CONCLUSIONS

Six alternative waste concentration processes have been identified and evaluated. Evaporation was found to be capable of producing a highly decontaminated condensate product and a concentrated waste stream at a reasonable cost. Operating risks were minimized since the process could adapt to changes in feed composition with little effect on the resulting effluent water quality.

This alternative could either be implemented with the continued use of the upgraded 242-A Evaporator or with the construction of a new evaporator. Although no formal decision has been developed, cost and technical considerations resulted in the selection of continuing the use of the upgraded 242-A Evaporator until the waste concentration mechanism supporting the TWRS separations/low-level waste (LLW) facility is operational.

4.0 SYSTEM FUNCTIONS AND REQUIREMENTS

The following functions and requirements are taken from the *Tank Waste Remediation System Functions and Requirements* (Decision 4.2.1.5, March 1994) report (Grygiel 1993) and the *242-A Evaporator/Crystallizer Safety Analysis Report* (Lavender 1993). The *Tank Waste Remediation System Functions and Requirements* (Grygiel 1993) contains more requirements for the entire system. The main requirements from the function titled "Concentrate Waste" were used as the base requirements. Requirements assigned to the functions are: performance requirements, which are imposed on the function by the TWRS Program itself; and constraints, which are requirements placed on the function by sources external to the TWRS Program (e.g., Congress, Washington State Department of Ecology, U.S. Department of Energy [DOE] Orders).

4.1 SYSTEM FUNCTIONS

The function of the concentrate waste mechanism is to remove excess water from liquid DST waste to reduce volume of waste requiring storage in the existing underground tanks. The water will be removed from tank wastes with sufficient purity to be treated as liquid effluent for eventual discharge to the environment. The concentrated tank waste as a product of this process will remain pumpable without dilution when returned to the DSTs for storage.

4.2 PERFORMANCE REQUIREMENTS

1. Ammonia (NH_3) in the feed could potentially result in releases in excess of the *Comprehensive Environmental Response, Compensation and Liability Act of 1980* (CERCLA) and the Washington State Administrative Code (WAC) *Dangerous Waste Regulations* (WAC 173-303) limits. The CERCLA reportable quantities are 454-kg (1,000-lb) ammonium hydroxide and 45-kg (100-lb) ammonia gas per 24-hour period. The WAC 173-303 limit is 1-wt% ammonium hydroxide (NH_4OH). The maximum ammonia concentration in the feed is 2,644 x (R-1)/R (where R = feed rate divided by the product rate) (Lavender 1993)

2. Manage the airborne, liquid, and solid effluent concentrations in compliance with Environmental Compliance establishing the Derived Concentration Guides (DCG) found in the *Environmental Compliance Manual*, WHC-CM-7-5; *Radioactive Waste Management*, DOE Order 5820.2A; and *Dangerous Waste Regulations*, WAC 173-303. Liquid effluent decontamination requirements for the concentration mechanism are presented in Table 1.

Table 1. Liquid Effluent Decontamination Requirements.

Isotope	Feed Stream (uCi/mL)	Process Condensate (uCi/mL)	Process DF[1] Requirement
^{239}Pu	1.1 E-03	8.0 E-10	1.4 E+06
^{90}Sr	7.6 E+00	4.6 E-06	1.7 E+06
^{137}Cs	3.5 E+02	5.4 E-07	6.6 E+08
^{238}U	9.3 E-06	2.6 E-08	3.6 E+02
^{99}Tc	8.5 E-02	2.4 E-04	3.5 E+02
^{129}I	2.7 E-04	2.0 E+04	1.4 E+00

Data based on 242-A Evaporator Process Flowsheet (Lavender 1993).

[1]DF = Decontamination Factor, defined as:

$$DF = \frac{\text{specific activity of feed}}{\text{specific activity of process condensate}}$$

3. Maintain contamination of the waste effluent streams at an as low as reasonably achievable (ALARA) level in accordance with DOE orders (see reference section).

   The compliance assessment (Gelman 1991) provides a comparative evaluation of the Westinghouse Hanford Company policies and procedures to DOE Order 5400.5. No major deficiencies were noted in the compliance assessment.

   The ALARA philosophy regarding the Evaporator design and operation has ensured Westinghouse Hanford management that all public dose exposure pathways from routine operation of the Evaporator does not cause, in one year, an effective dose equivalent >100 mrem. This includes the 10 mrem annual airborne emissions criteria. Calculations in Sections 8.4 and 8.6 of the FSAR support the guidelines of DOE Order 5400.5. This assessment also provides a summary of the Westinghouse Hanford ALARA process and the implementation of ALARA and ALARA practices into everyday operations. The ALARA program is described in Section 8.1 of the FSAR.

4. Low-activity liquid effluent wastes are monitored, sampled, and disposed of in compliance with the stream release standards established within WHC-CM-7-5, WHC-CM-5-16, and DOE Order 5400.5. Airborne effluents are sufficiently filtered and monitored before release to ensure compliance (Lavender 1993, Crummel 1993). Release limits and alarm setpoints are based on administrative control values (ACV) for radionuclides discharged to the soil column on the Hanford Site. The ACVs are determined based on the half-life of the radionuclide, retention in the soil, and travel time to the site

boundary to prevent a groundwater concentration of radionuclides equal to or exceeding 0.04 DCG at the site boundary.

4.3 CONSTRAINTS

1. For the purpose of economy and enhancing the safety of high-level waste storage, processing programs shall be developed and implemented at the generating site to reduce the quantity of waste being sent to storage, and techniques (e.g., evaporation) shall be introduced to further reduce the waste volume in storage (DOE 5820.2A, Chapter I, 3.b.[7][a]).

2. Waste generation and waste management systems that significantly change the chemical and physical forms of the waste shall be technically assessed to assure compatibility and retrievability (DOE 5820.2A, Chapter I, 3.b.[7][e]) (Carothers 1991).

3. Waste acceptance criteria shall be established for each LLW treatment, storage, and disposal facility, and submitted to the cognizant field organization (DOE 5820.2A, Chapter III, 3.e[2] (Crummel 1993).

4. Chemical, physical, or biological treatment of hazardous waste must comply with [Section] 265.17(b). Hazardous wastes or treatment reagents must not be placed in the treatment process or equipment it they could cause the treatment process or equipment to rupture, leak, corrode, or otherwise fail before the end of its intended life. Where hazardous waste is continuously fed into a treatment process or equipment, the process or equipment must be equipped with a means to stop this inflow (e.g., a waste feed cut-off system or by-pass system to a standby containment device) (40 CFR 265.401).

5. The chemistry of liquid high-level waste shall be adjusted to control corrosion within design limits for the storage system (DOE 5820.2A, Chapter I, 3.b[7][c]).

6. Treatment reagents shall not be placed in a tank system without proven effective mitigative action if they could cause the tank, its ancillary equipment, or the containment system to rupture, leak, or otherwise fail (DOE 5820.2A, Chapter I, 3.b[7][d]).

5.0 DESCRIPTION OF ALTERNATIVES

The following waste concentration alternatives were considered in the study.

- No action (manage tank system without concentration of tank waste)
- Evaporation
- Selective precipitation
- Ion exchange
- Reverse osmosis
- Crystallization.

The *Handbook of Separation Techniques for Chemical Engineers* (Schweitzer 1979) and the *Chemical Engineering Handbook* (Perry and Chilton 1973) were reviewed to determine potential processes for the removal of waster from tank wastes. A brief discussion of each concentration mechanism is provided in the following sections. A section identifying the advantages and disadvantages are provided for each alternative. Tank space was only considered a disadvantage for the no action case since all other cases would have some form of concentration mechanism and the impact would be approximately the same.

The performances of the waste treatment processes are measured by two parameters namely, DF and volume reduction factor (VRF). These are defined as follows:

$$DF = \frac{\text{specific activity of feed}}{\text{specific activity of process condensate}}$$

$$VRF = \frac{\text{volume of feed}}{\text{volume of concentrated waste}}$$

Basic features of the alternatives are summarized in Table 2.

5.1 NO ACTION

Radioactive liquid wastes at the Hanford Site will be stored without reduction in volume. Generators of new radioactive liquid waste will be required to either cease the generation of waste or conduct waste volume reduction locally. New DSTs may be needed to store wastes and support treatment and disposal actions. This alternative does not achieve an integrated waste volume reduction program for the site and fails to meet the system function requirements. For these reasons, it is not considered a viable option.

Table 2. Main Features of Waste Concentration Processes.

	242-A Evaporator	Conventional Evaporation	Selective Precipitation	Ion Exchange	Reverse Osmosis
Liquid Radwaste Characteristics	Low detergent content required (foaming problem)	Low detergent content required (foaming problem)	Not sensitive to highly salt laden solutions, possible negative effects when oils, detergents and complexing agents are present	Suitable for ionic active species, low suspended and dissolved salt content	Suitable for wastes with high salt and suspended species content.
Decontamination Factor (DF)	10^4-10^5	10^4-10^5	10-100	10-10^4	10-100
Volume Reduction Factor (VRF)	2 (wet slurry)	Depends on the salt content in the solution	10-100 (wet sludge) 200-10^4 (dried solid)	500-10^4	10-100
Conventional Combination with other processes	Combined crystallization function followed by ion exchange polishing	Condensate can be subsequently treated by ion exchange and/or crystallization	Possible with evaporation	Possible with evaporation	Possible with evaporation

Based on information from BARC-1534 (Panicker 1990), Radioactive Liquid Effluent Management.

Advantages:

1. Capital and maintenance costs associated with operating new waste concentration facilities can be avoided.

Disadvantages:

1. Without waste concentration, the available tank storage capacity will be filled in approximately five years (Koreski 1994).

2. Construction of additional DSTs to accommodate the generation of new wastes may be required.

3. To achieve waste volume reduction locally would involve significant cost due to the duplication of effort at all facilities requiring waste volume reduction.

5.2 EVAPORATION

Evaporation is capable of producing a concentrated waste stream and a highly purified water stream without the generation of secondary waste. Achievable decontamination factors are high (DFs = 10^4-10^5) and remain relatively constant even when the chemical characteristics of the waste stream change. This process involves the heating of liquid radioactive waste to remove water and other volatile compounds; the bulk of non-volatile components such as salts and radionuclides remain in solution. It does, however, have a high energy consumption which results in a moderately high operating cost. Evaporation may be employed with the use of the existing forced circulation 242-A evaporator or with the construction of a new evaporator such as a bent tube evaporator.

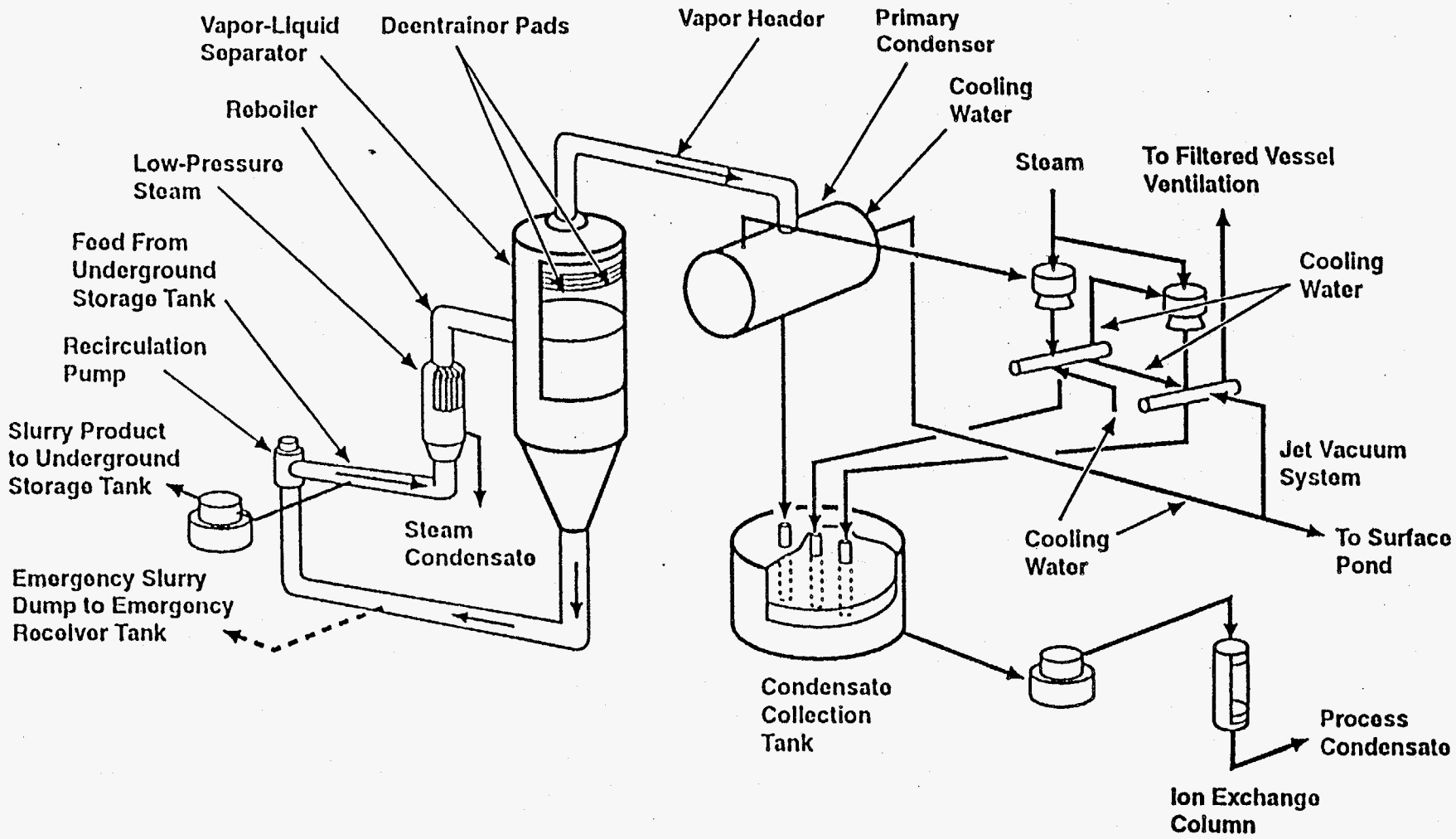
5.2.1 242-A Evaporator/Crystallizer

The 242-A Evaporator/Crystallizer was constructed in 1976 to be the primary waste concentrator for the Hanford Site underground DST wastes. A simplified schematic of the process is shown in Figure 1. The evaporator uses a conventional, forced-circulation, vacuum evaporation/ crystallization system. Wastes are fed continuously into the evaporator and separated into a more concentrated slurry stream and a processed condensate stream. Ion exchange is used to remove any residual cesium and strontium radionuclides from the condensate stream. The evaporator was restarted April 15, 1994, after having undergone extensive upgrades (project B-534). This project resulted in a planned life extension of approximately 10 years (Flyckt 1990).

Advantages:

1. The continuous recirculation maintains a thorough mixing of the concentrated liquid and ensures good heat transfer.

Figure 1. 242-A Evaporator/Crystallizer Simplified Schematic.



2. Because of the high velocity of the liquid through the heat exchanger, this evaporator can be used in solutions that are prone to salting, scaling, and fouling.

3. Existing procedures and equipment may be used since the facility is already in use.

4. There is good heat transfer coefficient.

Disadvantages:

1. Because of the high capacity requirements of the recirculation pump, power demand is high.

2. Maintenance requirements are relatively high because the system is mechanically complicated.

3. Salt deposits may result in the plugging of tube inlets.

4. There is a high energy cost of driving steam and vacuum operations.

5. There is a risk of concentrating volatile ammonia in offgas system.

5.2.2 Bent Tube Evaporator

A bent tube evaporator (bundle-in-column or horizontal-tube thermosiphon reboiler) consists of a horizontal tube bundle inserted inside a simple cylindrical vessel. The tube bundle is filled with saturated steam and heats the liquid waste flowing in the vessel. As the water is boiled off, the remaining liquid waste becomes concentrated with contaminants and is transferred out of the vessel through a bottom opening (Perry and Chilton 1973).

As the evaporator operates, a layer of scale begins to form on the tubes. This scale continues to build up until it is no longer economical to operate the evaporator. The evaporator is then shut down, drained of the concentrated liquid, and refilled with clean water at ambient temperature. The steam tube is rapidly repressurized with saturated steam. Descaling is achieved by dissolving in new liquid and by thermal shock (Pesgrove 1992).

Advantages:

1. Since the process takes place in a single vessel, the evaporator requires a smaller footprint than the forced-circulation evaporator.

2. The design provides a large surface area for vapor-liquid disengagement which reduces the "carry-over" of contaminants. (Better DF).

3. It has low construction and maintenance cost since the process does not use any rotating machinery.

Disadvantages:

1. Depending upon the nature of the liquid being processed, the frequency of the descale/desalt process may substantially increase.

2. Tubes are subject to stresses and breakage due to descale process.

3. It has lower heat transfer coefficients.

4. Take-off is more difficult to control.

5. Batch size is limited.

5.3 SELECTIVE PRECIPITATION

Selective precipitation removes hazardous components and radionuclides by the addition of co-precipitants (or scavengers) to promote the rapid precipitation of contaminants. The solids containing the contaminants are filtered from the waste stream and stored as concentrated waste in the tank system. Precipitation processes are typically unable of providing DFs greater than 100 for a particular radionuclide or group of radionuclides. Since separation is not complete, this process is normally used in conjunction with other separation methods (e.g., evaporation). Figure 2 depicts a sample selective precipitation system that could be used to perform the waste concentration function.

The two main types of precipitants used in the nuclear industry are ferric hydroxide and hexacyanoferrates. Ferric hydroxide ($Fe(OH)_3$) is particularly useful for actinide removal and hexacyanoferrates are useful for fission product removal. Methods for removing transuranics, strontium, and technetium radionuclides from alkaline Hanford Site waste solutions are not well developed; however, initial scouting tests are underway.

Advantages:

1. Capital and maintenance costs are lower for the selective precipitation step since the process is mechanically simple.

2. It removes only the targeted contaminants. Potassium, calcium, and other non-radioactive ions are not pulled out of solution.

Disadvantages:

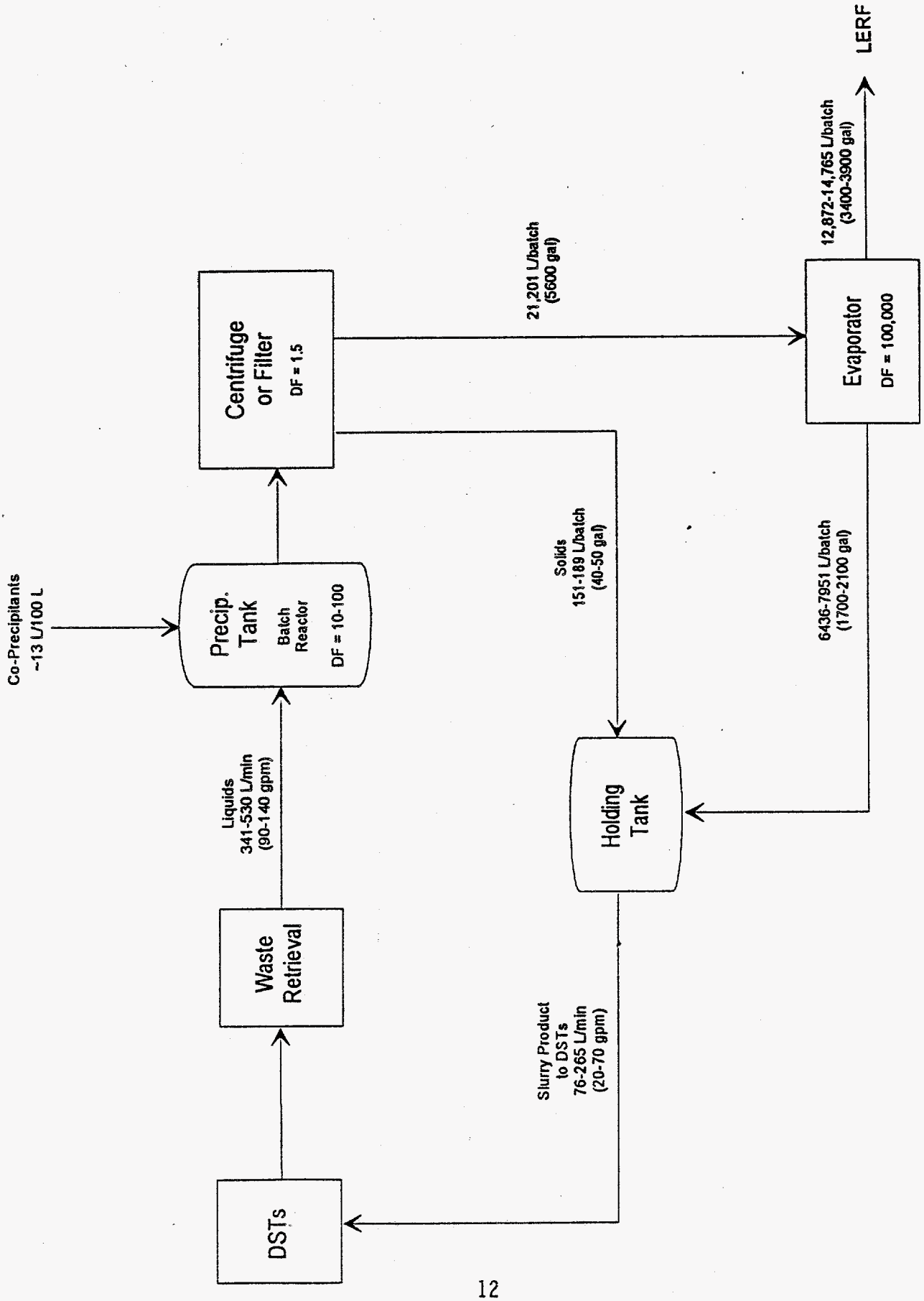
1. Large amounts of chemicals are involved.

2. Separations are not complete and supporting treatment processes are often needed.

3. Precipitation processes are typically batch reactions.

4. DFs are unacceptable.

Figure 2. Selective Precipitation Process Description



5.4 ION EXCHANGE

This process requires the installation of a series of columns packed with ion exchange media suitable for selectively removing contaminants from a liquid waste stream. The contaminants in the waste stream are exchanged for ionic species bonded to the ion exchange media. When the ion exchange media become loaded, they are either regenerated with strong acids/bases or treated as solid radioactive waste and disposed. Figure 3 shows a sample ion exchange system.

The regeneration process prepares the ion exchange media for reuse by removing the adsorbed radionuclides and contaminants with a series of acidic or caustic washes. The resulting solution generally requires further concentration, usually by evaporation. However, if the spent media are disposed of after a single use, a large amount of secondary waste is generated. The cost of storing the increased volume of waste must be balanced against the cost to regenerate the ion exchange media.

Advantages:

1. Rapid initial removal rates of certain contaminant ions (e.g. ^{137}Cs and ^{90}Sr) from liquid radioactive waste. DFs = 10 - 10^4.

Disadvantages:

1. Colloids and/or complexed nuclides can lead to inconsistent DFs and to bed blockage.

2. It requires frequent resin changeouts. Spent resins must be treated, stored, and disposed of as solid radioactive waste.

3. It may not remove all hazardous/radioactive constituents.

4. Operating costs are extremely high.

5. There is organic fouling of resin.

5.5 REVERSE OSMOSIS

Reverse osmosis (RO) separates dissolved ions and particulates from low-activity liquid waste by using a semi-permeable membrane. The waste stream is forced through multiple stages of filter and osmosis membrane units by an applied pressure greater than the normal osmotic pressure. This process generates a liquid phase depleted in radionuclides and hazardous components and a concentrated waste stream. The contaminant solids are accumulated at the membrane and washed off by a cleaning solution regularly. The achievable water purity, however, is not as high as that for other concentration methods. The typical application for RO is desalination of seawater or treatment of brackish water. It also has been applied to high concentration of suspended solids with the use of agitation to prevent cake formation (Perry and Chilton 1973). When the liquid phase is rich in radionuclides RO is combined with evaporation methods since the volume of the feed streams is typically large (Perry and Chilton 1973). Figure 4 shows a sample RO process.

Figure 3. Ion Exchange Process Description.

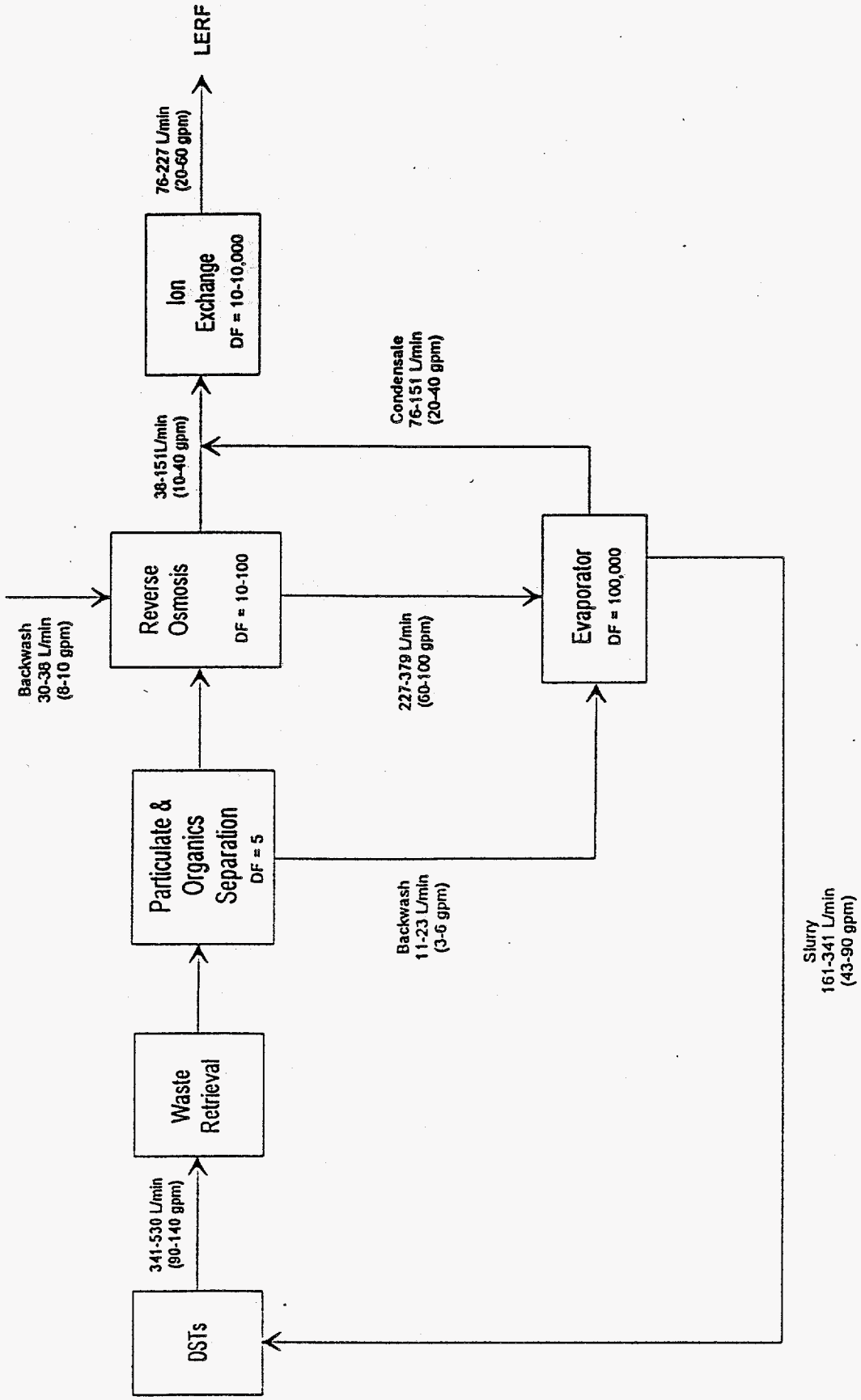
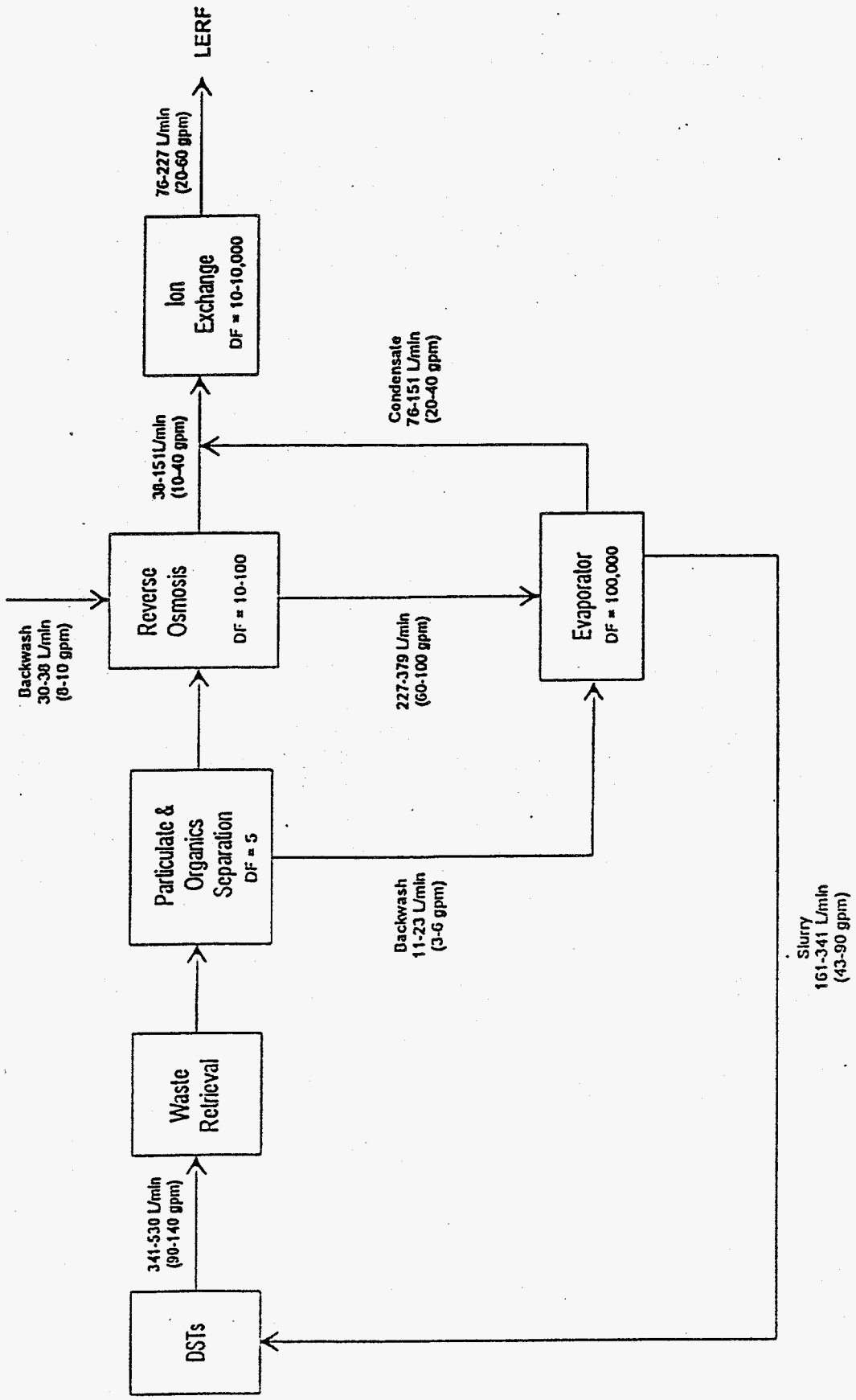


Figure 4. Reverse Osmosis Process Description.



Advantages:

1. Energy consumption is low.

Disadvantages:

1. It has a high maintenance process; membranes require frequent replacement.

2. Spent membranes require disposal as radioactive solid waste.

3. Membranes need to be backwashed 3 to 4 times a day, which results in a large daily down time.

4. There is low achievable throughput.

5. Processed stream quality is relatively poor. DFs = 10 - 100 only after multiple stages.

6. A second form of concentration mechanism may be needed to achieve process flowrate requirements.

5.6 CRYSTALLIZATION

5.6.1 Fractional Crystallization

Fractional crystallization is used to purify aqueous streams by the controlled growth of contaminant solids from a supersaturated solution, usually provided by an evaporator. Purification occurs by the rejection of solutes at the liquid/solid interface which are incompatible with the growing crystal because of atomic size, charge, or molecular state. The resulting solids are removed, leaving behind a decontaminated supernatant liquor.

Advantages:

1. There is no generation of secondary waste.

Disadvantages:

1. Process requires an evaporator to pre-concentrate the waste stream for crystallization.

2. The processes are generally slow.

3. Separations are incomplete.

4. It can produce a waste product that is too concentrated to store safely (i.e., tank 241-SY-101).

5. Mechanical handling of solid separation becomes expensive and frequent.

Since fractional crystallization is already a part of the concentration process used at the 242-A Evaporator/Crystallizer facility, it will not be considered as an independent alternative.

5.6.2 Freeze Crystallization

Freeze crystallization involves the removal of water from a waste stream by the formation of water crystals. A refrigerant is bubbled up through the liquid waste to directly freeze out the water while the contaminants preferentially remain in the waste solution. The ice crystals, which float to the surface, are separated from the waste and rinsed to remove any residual contaminants adhering to the crystal surfaces. Laboratory data based on actual tank waste for freeze crystallization processes, however, are limited. Hence, flowsheets have yet to be developed and the process is not ready for implementation. For this reason, freeze crystallization is not further pursued as a viable option.

Advantages:

1. Energy consumption is less than that for evaporation.

2. There is no generation of secondary waste.

Disadvantages:

1. A process flowsheet has not been developed.

2. It is difficult to separate out ice crystals from liquid radioactive wastes (mechanical complexity).

3. It involves complicated machinery that will require maintenance.

4. Equipment capacities are necessarily large and make the process impractical.

5. It can produce a waste product that is too concentrated to store safely (i.e., tank 241-SY-101).

6.0 COMPARISON OF ALTERNATIVES

The alternatives selected for further consideration are: evaporation, selective precipitation, ion exchange, and reverse osmosis. The alternatives were evaluated qualitatively with respect to those performance measures and values determined to be important for the safe and cost effective storage of Hanford Site tank waste. The relative performance risks of the alternatives were rated with the qualitative factors of low, medium, and high. The results of the evaluation are summarized in Table 3.

6.1 HEALTH AND SAFETY RISK

The selection of a preferred concentration mechanism is affected by the health and safety issues associated with each alternative. The potential for an accident and the risk of chemical and/or radiological exposure are assessed. The health and safety of the worker and the environment must be maintained and protected during the operating life of the concentration process.

6.1.1 Preliminary Discussion

The alternatives can all be designed to provide adequate protection against accidental radiological and toxicological exposure to the workers and the environment. Operating and maintenance activities involving direct contact with hazardous materials will be performed remotely with the exception of the routine sampling of dilute LLW. As a result, the concentration mechanisms are all rated low risk.

- Evaporation - Low
- Selective Precipitation - Low
- Ion Exchange - Low
- Reverse Osmosis - Low.

6.2 WASTE MINIMIZATION IMPACT

The generation of secondary waste from processing, transportation, and disposal must be minimized. The volume reduction factor (VRF) will be used to denote the ratio between the volume of material currently in the DST inventory and the final volume of processed concentrate waste. A rough evaluation of the resulting waste volume requiring storage is used to determine impact.

6.2.1 Preliminary Discussion

Evaporation has a low impact because it does not introduce any secondary waste aside from the occasional replacement of offgas filters. VRFs are limited only by the salt content of the waste stream.

- Evaporation - Low

Table 3. Performance Measure Risks for Waste Concentration Processes.

Performance Measure Risk	Evaporation (242-A Evaporator)	Evaporation (New Facility)	Selective Precipitation	Ion Exchange	Reverse Osmosis
1. Health and Safety Risk	Low	Low	Low	Low	Low
2. Waste Minimization Impact	Low	Low	Medium	High	High
3. Stakeholder Interest Risk	Low	Low	Low	Low	Low
4. Technical and Operability Risks	Low	Low	Medium	High	High
5. Implementation Time and Schedule Impact	Low	High	High	High	High
6. Life-Cycle Cost	Low	High	Medium	Medium	High
Overall risk rating	Low	Medium	Medium	High	High
Order of recommendation	1	2	3	4	5

Health and Safety Risk and Stakeholder Interest Risk do not serve as discriminators and were not used in the overall rating of the alternatives.

Selective precipitation is rated with a medium impact. The addition of chemicals to the waste stream to promote the precipitation of contaminants adds to the total volume of waste. This process provides VRFs of 10-100. However, since precipitation is limited by solubility laws, the waste stream must undergo further treatment to extract chemical and radioactive contaminants not removed by precipitation.

- Selective Precipitation - Medium

Ion exchange will generate a large amount of secondary waste if the exhausted resins are disposed after a single use and is rated high impact. On the other hand, if bed regeneration is practiced, the regenerant solutions usually require further waste concentration by evaporation.

- Ion Exchange - High

Reverse osmosis is rated high impact. The osmosis membranes require frequent replacement which require disposal as solid waste. VRFs of 10-100 are typically observed when the addition of secondary waste is not considered. The overall VRFs also depend on the inactive salt load, operating pressure, and the radiological stability of the membranes.

- Reverse Osmosis - High

6.3 STAKEHOLDER INTEREST RISK

The impact on stakeholders (workers, unions, local communities, Indian Nations, state and federal regulatory authorities) is evaluated for each alternative. Values previously identified by the stakeholders are explained in detail in the final report of *Hanford Future Site Uses Working Group* (1992) and the final report of *Hanford Tank Waste Task Force* (1993). It was concluded that each alternative could be designed to uphold stakeholder values. Therefore, this performance measure does not serve as a discriminator between concentration processes.

- Evaporation - Low
- Selective Precipitation - Low
- Ion Exchange - Low
- Reverse Osmosis - Low.

6.4 TECHNICAL AND OPERABILITY RISKS

Each alternative must be able to meet system operating needs and requirements. A well-developed process has a higher probability for success than a process still undergoing research and development. The technical and operability risk of using unproven processes must also be considered.

6.4.1 Preliminary Discussion

Evaporation has a low risk since it is currently being used at the 242-A Evaporator to concentrate radioactive liquid waste. Procedures and

specifications have already been established for the effective and safe operation of the facility. The 242-A Evaporator has the processing capacity and useful operating life capable of meeting the system requirements. Providing a comparison between the crystallizer and bent tube evaporator indicates that the performance is almost equal in maintenance downtime, overall efficiency, and ALARA concerns (Pesgrove 1992). The efficiency rating is 28.7 percent for crystallizer and 24.6 percent for the bent tube evaporator. The efficiency rating is based on operations at Hanford and Savannah River Site (SRS). It should be noted that the Hanford throughput is almost double that of SRS. Assuming the performance is based on volume throughput, this would indicate that the SRS type evaporator (bent tube) would fail twice as fast bringing its overall efficiency rating down and ALARA man rem expended per year to the same value as the crystallizer.

- Evaporation - Low

Selective precipitation has a medium risk since it is only effective at removing certain groups of radionuclides. Methods for removing transuranics, strontium, and technetium radionuclides from the complex tank waste solutions have not been developed and require further investigation. For this reason, selective precipitation will be used in conjunction with an evaporator to ensure adequate effluent decontamination.

- Selective Precipitation - Medium

Ion exchange is mechanically easier to operate and has fewer mechanical problems than evaporation. However, ion exchange does suffer from several operating problems which results in a high risk. The presence of colloids and/or complexed nuclides can lead to inconsistent process efficiencies and to bed blockage. High salt content in the feed stream also has a severe impact on the operating life of the resins. Furthermore, this system may not be able to adequately decontaminate the waste at all times since the exchange capacity of the resins decrease with use.

- Ion Exchange - High

The reverse osmosis system requires mechanically complicated, remotely-operated machinery to perform membrane replacement. The replacement and maintenance of the membranes also results in a large down time for the facility. A typical application for RO is seawater or brackish water. Separation of high concentrations of suspended solids is a possible application when agitation is used to prevent cake formation on the membrane (Perry and Chilton 1973). Operation of this concentration method involves other mechanical equipment requiring frequent maintenance and a second form of concentration to achieve the product result required for discharge. The complexity of the process results in a high technical and operability risk.

- Reverse Osmosis - High.

6.5 IMPLEMENTATION TIME AND SCHEDULE IMPACT

The selected concentration mechanism should be a simple, well-developed process that can be easily implemented within scheduling constraints. The use

of the 242-A Evaporator has a low impact because existing procedures and specifications may continue to be used. On the other hand, the construction of a new evaporator to replace the 242-A Evaporator would have a high impact on the schedule. An extensive amount of time is needed for facility design, development, and implementation.

- Evaporation (242-A Evaporator) - Low
- Evaporation (New Facility) - High

The selection of an alternative process such as selective precipitation, reverse osmosis, and ion exchange would also require the construction of a new facility and the procurement of system equipment. These processes are rated high risk.

- Selective Precipitation - High
- Ion Exchange - High
- Reverse Osmosis - High.

6.6 LIFE-CYCLE COST

The life-cycle cost for each alternative should be roughly estimated. This cost includes: capital, operating, and maintenance costs.

6.6.1 Preliminary Discussion

Evaporation using the 242-A Evaporator has a low life-cycle cost because the existing facility can be used. The original total construction cost to build the 242-A Evaporator in 1974-1976 was $6.8 million. If the 242-A Evaporator is to be upgraded, the capital cost in 1992 dollars is estimated at $15.6 million. This cost only includes the construction cost to build 242-A Evaporator. The replacement evaporator would require additional upgrades to be brought into compliance with existing regulations. The capital cost would escalate to provide additional equipment upgrades.

The capital cost to construct a new evaporator is estimated at $15-19 million in 1992 dollars with a total start-up cost of $156 million (Elliot 1992). The total cost includes construction, external connections to other facilities, waste emission control improvements, instrumentation upgrade, design improvements, *Resource Conservation and Recovery Act of 1976* (RCRA) compliance requirements, and engineering and design costs.

The operating costs associated with evaporation techniques are higher than those of the other alternatives. However, savings in capital costs from using the existing 242-A Evaporator facility will more than offset these small differences in operating costs.

- Evaporation (242-A Evaporator) - Low
- Evaporation (New Facility) - High

Selective precipitation represents a high cost because new equipment, including a supporting evaporator, must be designed, procured, built, and implemented. The exact application to Hanford Site waste must be developed.

And this method of concentration must be enhanced with an evaporation capacity in order to achieve the DF required for discharge. For these reasons the cost is expected to be higher than that of a new evaporation facility.

- Selective Precipitation - High

Ion exchange represents a high cost due to the required construction of a new facility. It is true that the ion exchange system requires less maintenance than the other alternatives because of the use of simpler equipment. However, operating costs would increase overall to provide resin changeouts, regeneration of resins, and treating the regenerant solution for discharge. Operability risk is much higher than other concentration methods.

- Ion Exchange - High

Reverse osmosis has a high cost resulting from the costs of constructing a new facility. This method of concentration must be enhanced with an evaporation capacity in order to achieve the DF required for discharge. For these reasons the cost is expected to be higher than that of a new evaporation facility. Operating costs, however, are extremely high because of the rapid exhaustion of the osmosis membranes.

- Reverse Osmosis - High

6.7 ASSUMPTIONS AND UNCERTAINTIES

During the preparation of this study, a number of assumptions were made. The impact of these uncertainties are considered and evaluated.

1. Capital cost savings by continuing the use of the 242-A Evaporator are assumed to compensate for the higher operating cost for evaporation. Only very large deviations from the current operating costs would affect the conclusions made in this study.

2. Project B-534 upgrades on the 242-A Evaporator has resulted in an assumed planned life extension of 10 years. The upgrades included installation of a spare condenser, pumps, vessel vent system and upgraded instrumentation. If the useful operating life of the evaporator does not meet project requirements, further upgrades may be needed in the future.

6.8 SUMMARY COMPARISON AND CONCLUSIONS

Evaporation, selective precipitation, reverse osmosis, and ion exchange have been considered for further evaluation. Performance measures and values were developed to differentiate between waste concentration processes.

Evaporation by the continued operation of the 242-A Evaporator was found to be as good as or better than the other alternatives on all performance measures and values. The liquid waste would be concentrated and processed for storage with very little generation of secondary waste. The use of an existing facility also provided significant cost advantages since it avoided

the large capital cost associated with the construction of a new facility. The 242-A Evaporator met all technical and system requirements for the planned operating life. The option of constructing a new evaporator facility was not selected because of the prohibitive life-cycle cost and scheduling risk.

The other alternatives had significant operating limitations. Selective precipitation and ion exchange depended heavily on equilibrium processes. Observable process efficiencies were sensitive to changes in feed composition or operating conditions. The inherent nature of these mechanisms did not allow for complete decontamination. Evaporation was required in conjunction to these treatments to effectively remove activity and to reduce the volume to facilitate consequent confinement in isolation.

Reverse osmosis was found to be useful as a precursor to evaporation to reduce the processing load and the resulting operating cost. Decontamination factors associated with reverse osmosis were not very high, but it effectively removed solid particulates from the waste stream. The process also consumed less energy than evaporation since it was operated at ambient temperature, however the cost to maintain and replace the membranes greatly increased the overall operating cost. The high life-cycle cost removed this alternative from further consideration.

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