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MASTER

ENGINEERING STUDY,
DISPOSITION OF TERMINAL LIQUORS FOR INTERIM STORAGE

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February, 1975

PREPARED FOR THE U.S. ENERGY RESEARCH AND DEVELOPMENT
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Waste Management Process Engineering and Design
Development Engineering Department
Research and Engineering Division

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ENGINEERING STUDY
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FOR INTERIM STORAGE

INTRODUCTION

Hanford high-level radioactive liquid wastes are being partially converted to a solid form by evaporation. The product from the evaporation processes is a slurry from which a salt cake is accumulated in existing underground storage tanks via settling. The supernatant mother liquor is recycled back to the evaporator process. After successive passes through the evaporator, the recycle stream reaches a terminal stage (where further evaporation does not produce an acceptable salt cake). This liquor, hereafter called terminal liquor, is rich in caustic, aluminum, and ^{137}Cs . Evaporation processes thus result in the production of salt cake and terminal liquors.

There are several potential processes which are being developed for the disposition of these terminal liquors. The eight alternatives that best meet the needs of terminal liquor disposition on a timely basis are aimed at rendering the liquors to a confined, immobile form for an interim storage time on the order of tens of years. Long-term storage, not considered here, is on the order of a hundred to possibly thousands of years.

Eight Optional Processes to Achieve Interim
Storage of Terminal Liquors

1. Nitric acid - evaporation
2. Nitric acid - clay
3. Aluminum removal
4. Liquid in double-shell tanks
5. 242-S mush
6. Wiped film mush
7. Clay in single-shell tanks
8. Clay in drums

The purpose of this document is to present an engineering study of these eight alternatives. The study will serve to provide a basis for process development priorities, timing, capital budget submissions, product form acceptability, and costs.

SUMMARY

Development of processing technology to achieve interim storage of terminal liquor products will reduce the required number of double-shell storage tanks and the probability of liquid waste leak occurrence from single-shell tanks. Double-shell tank storage of terminal liquor is one of the most costly interim storage alternatives, but is considered to be proven technology and provides a basis for comparing other alternatives. Interim storage of acceptable salt cake products in single-shell tanks provides the greatest cost savings, as capital expenditure for double-shell tank construction is reduced.

The eight alternative processes (illustrated in Figure 1) were chosen as being technologically feasible within the time frame* dictated by budgeting procedures and terminal liquor availability. Solidified waste products acceptable for single-shell tank storage were assumed to be placed in available single-shell tanks (Options 2, 3, 7, and partial neutralization). Double-shell tanks were used only for the more mobile terminal liquors or semi-solid mush products (Options 1, 4, 5, and 6). Placement of an amount of waste products acceptable for single-shell tanks in double-shell tanks automatically increases the required double-shell tank volume by that amount.

The mush, the chemical neutralization, and the clay in-tank processes offer potential savings of tens of millions of dollars over double-shell tank storage of terminal liquors. In order to achieve this cost savings the process development and demonstration must be completed prior to the beginning of double-shell tank construction (December, 1976) expected to be funded from a fiscal year 1977 line item. Budgeting for these additional double-shell tanks must proceed since the processing options discussed here are not yet available and may not prove to be available at the required time.

The results of this study are useful primarily as a comparative tool and indicate the following topics for additional study. Process technology development to achieve interim storage of terminal liquor products receives the greatest emphasis as a means of reducing capital expenditures. Interim storage product criteria, waste inventory, and conversion to final form are areas which require definition to allow a full comparison of the alternatives for disposition of terminal liquors. The pseudotechnical nature of product acceptability criteria is important to the evaluation of the partial neutralization and alumina removal alternatives. More accurate estimates of terminal liquor quantity and composition are required to give a sound

*NOTE: Alternative 3 requires time for the budget cycle.

technical basis for choosing the appropriate processing alternative. The preliminary estimates used for this study are based on the best information available at the time of writing; and are subject to change as more is learned about the waste inventory. Retrieval and reprocessing operations may affect the comparisons presented by this study.

BACKGROUND DISCUSSION

The Hanford Waste Solidification Program has been treating aqueous radioactive solutions in the 200 Areas by evaporation and crystallization processes for about ten years. The salt crystal and associated interstitial liquors are deposited and stored in existing tanks (500,000 to 1,000,000 gallon) underground reinforced concrete, carbon steel lined tanks. The salts fractionally crystallized by this process result in depositing primarily sodium nitrate, carbonate, and phosphate salts. The NaOH , NaAlO_2 , and ^{238}Pu (the major source of radiolytic heat generation in salt cake) remain mostly in solution. The remaining liquors are approaching a composition such that by further evaporation and crystallization alone, an unacceptable salt cake is formed, e.g., the salt cake is deliquescent, high heat generating, and nondrainable.

Acceptable salt cakes consist of sodium nitrate, carbonate, and phosphate fractionally crystallized from solution, stored in the single-shell carbon steel tanks, and drainable liquors removed from the salt cake. Unacceptable salt cakes require storage in a system of high integrity to prevent the escape of radionuclides to the environment. The double-shell tank (two carbon steel liners) provides high integrity storage for product forms that are unacceptable in single-shell tanks. Double-shell tank storage costs are high, around five dollars per gallon in FY 1976 dollars, and time is required for budgeting and construction to be completed.

Six double-shell tanks are in the budget for FY 1976 and the remainder needed to store terminal liquor are planned for the FY 1977 budget. Essentially all terminal liquors and waste evaporator-crystallizer operations would then be in double-shell tanks by early calendar year 1979.

The incentive to process terminal liquors before 1979 is largely to reduce the number of new double-shell tanks that must be built. Thus, process options that would not reduce the volume of terminal liquors before 1979 are of less interest at this time. Storage of terminal liquors in double-shell tanks is considered safe at least through 1990 and probably longer. Storage time in excess of 20 to 30 years may require building spare tanks in the 1990s to replace any that develop leaks.

If sufficient additional double-shell tank storage does not become available, the likelihood of radionuclide release to the environment will be significantly increased. This will result primarily from being forced to store terminal liquor or other unacceptable product forms in single-shell tanks. Lack of double-shell tanks would increase the attractiveness of clay-in-tank treatment, partial neutralization, and aluminum removal processes to reduce the volume of liquids stored in single-shell tanks. Possibly poor product characteristics resulting from these processes would likely be overshadowed by an effort to prevent radionuclide releases.

The goal of the process options study discussed herein is to reduce the number of new tanks that must be constructed. Process options for conversion of terminal liquors to suitably form for long-term storage or final disposal are not within the scope of this study. Any processes employed after 1975 to convert terminal liquors to another form should be aimed at being suitable for long-term (hundreds of years) permanent storage or disposal.

TERMINAL LIQUOR

Current evaporation processes result in a terminal liquor which will require special treatment in order to render the waste to an acceptable immobile form for an interim storage time. A current estimate for the volume of terminal liquor is about 10 million gallons. This estimate is somewhat variable and is dependent on a number of undefined and unknown parameters. However, for the purpose of this study, a basis of 10 million gallons of terminal liquor has been selected. Table I presents the estimated composition of the terminal liquor. The terminal liquor will have varying small concentrations of carbonate, sulfate, phosphate; small amounts of short-lived fission products; and little, if any, ^{90}Sr or plutonium.

TABLE I
TERMINAL LIQUOR COMPOSITION

<u>Compound</u>	<u>Concentration</u>
NaOH	5.5 M
NaNO ₃	2.7 M*
NaNO ₂	2.0 M*
NaAlO ₂	1.4 M*
H ₂ O	50 wt %
^{137}Cs	2 to 4 Ci/gal

*These estimates may be in error by as much as a factor of two.

INTERIM STORAGE PHILOSOPHY

Hanford high-level liquid wastes are being converted from a mobile liquid form to an immobile retrievable form. This reduces the chance of inadvertent loss of the radioactive waste to the environs during the interim storage period. The interim period is considered to be on the order of tens of years. This interim period allows development to proceed on determining

an acceptable long-term solution to the waste problem. Consequently, waste stored for an interim time should be not only immobile and stable for that time period, but must also be retrievable and amenable to some undefined future reprocessing, if such is required.

"Retrievability" and "reprocessing" are presently subjective criterion. Salt cake in an underground single-shell tank is considered retrievable and reprocessable. Any other waste form must be assessed as to the qualities of its retrievability and reprocessability. The assessment of these qualities is subjective pending better definition.

BASIC ASSUMPTIONS

Several basic assumptions have gone into the selection and evaluation of the disposition options for terminal liquors presented in this study. The volume and composition of the terminal liquors, presented earlier, are two of these assumptions. Options that were selected afford a complete disposition of all the terminal liquors. For example, nitric acid addition to the terminal liquors, in itself, will not completely immobilize all the terminal liquors. Consequently, a second treatment such as double-shell tank storage of the terminal liquid or a salt mush product stored in double-shell tanks is needed to complete the option. Technological development requirements are assumed to be successfully complete according to program plans. Process development which is not currently active has not been considered in this study. For this study, product forms are assessed as follows:

Acceptable Product Forms

- . Nitrate-type salt cake in a single-shell tank
- . Liquid stored in a double-shell tank
- . Caustic-salt cake mush in a double-shell tank
- . Clay product in any container (tank/drum)

Unacceptable Product Forms

- . Liquid in a single-shell tank
- . Caustic-salt cake mush in a single-shell tank

OPTIONAL SOLUTIONS AVAILABLE

Eight different options were selected for the disposition of terminal liquors for interim storage. Some options are actually combinations of two different options (i.e., nitric neutralization-evaporation of residual liquids to a mush). A considerable number of these combinations can be made. The eight which have been selected were chosen on the basis of the confidence placed in the successful and timely technology development. Processes or options not selected for study can be categorized as:

- . Long-term storage mode;
- . Unacceptable product characteristic;
- . Technological development required which is not now being pursued.

AVAILABLE OPTIONS STUDIED

Eight options have been identified and considered in this study. These options are schematically shown in Figure 1. The options selected are as follows:

1. Nitric Acid - Evaporation
Nitric acid neutralization producing an acceptable salt cake¹ and a residual liquor requiring final evaporation to a caustic salt mush for double-shell tank storage.
2. Nitric Acid - Clay
Nitric acid neutralization producing acceptable salt cake and a residual liquor suitable for clay solidification in a single-shell tank.
3. Aluminum Removal
Nitric acid or silica addition producing acceptable single-shell storage products and a negligible volume of residual liquors.
4. Liquid in Double-Shell Tanks
Terminal liquor storage in double-shell tanks.
5. 242-S Mush
Continued evaporation of terminal liquors in 242-S (or 242-A) producing semi-solid "mush" for double-shell tank storage.
6. Wiped-Film Mush
Continued evaporation of terminal liquors in a wiped-film evaporator producing a more concentrated "mush" for double-shell tank storage.

7. Clay in Tanks
Monolithic clay product stored in single-shell tanks.
8. Clay in Drums
Clay product contained in sealed drums stored in an engineered vault.

OPTIONS NOT STUDIED

A number of options are not included in this study. The following is a list of some of those options with a brief description and the reason why the option was not selected for study.

1. Long-Term Storage Products: Glass, Calcine, Cement, Asphalt
These processes result in a product which may well be suited for long-term storage, but the required process development and funding time is too long for interim storage of terminal liquor.
2. Spray Drying
A spray dried product may be a viable product form for interim storage. However, since this technology is not being actively pursued at this time, this option has been omitted.
3. Mush in a Single-Shell Tank
Continued evaporation of terminal liquors in the existing vacuum evaporator-crystallizer would result in a caustic salt cake mush. This is considered an unacceptable waste form for single-shell tank storage. A liquid phase is present in the mush product due to storage temperatures resulting from radiolytic heat generation. The mush product also has deliquescent properties at ambient conditions.
4. Liquid in Single-Shell Tank
Current waste containment philosophy precludes the interim storage of liquid in existing single-shell tanks because of limited capabilities for leak detection and secondary containment of leaks.
5. Diatomaceous Earth Sorbed Waste
Liquors sorbed by diatomaceous earth is established technology. The liquid waste is held by capillary forces in the interstices of the diatom particles. This mechanism for liquid retention may or may not be acceptable.
6. Phosphoric Acid Solidification
The phosphoric acid solidification process, originally the planned terminal liquor treatment, has proven to be technically unworkable. An engineering thermo-analysis, coupled with laboratory studies, has shown that this treatment results in a product which is partially fluid. The process results in an unacceptable waste form.²

7. Waste Decontamination

Some on-going laboratory studies have indicated that the terminal liquors might be amenable to decontamination. This process is considered to be a long-term solution to the terminal liquor problem, and has not been included in this study.

OPTIONAL PROCESSES DISCUSSION

Nitric acid partial neutralization is a terminal liquor processing option currently being developed for use in 1976. The addition of nitric acid to the caustic waste neutralizes a portion of the caustic to produce evaporable water and sodium nitrate salt. The net effect is to allow reconcentration of the caustic to the feed value, simultaneously producing sodium nitrate salt cake and a reduced volume of terminal liquor. Water boil-off proportional to the acid added for neutralization will return the caustic to a terminal liquor concentration.

Current estimates of the allowable extent of neutralization vary with the type of feed liquor, especially the aluminum concentration in the liquor. Over-neutralization may produce aluminum solids whose interim storage technology is not yet defined. Figure 2 illustrates the current concept of nitric acid partial neutralization of terminal liquor to produce sodium nitrate solids suitable for single-shell storage and a reduced volume of terminal liquor. Technology development is continuing for the partial neutralization process to more accurately define the flowsheet parameters. The disposition of the terminal liquor resulting from neutralization gives rise to the following three types of optional processes.

1. NITRIC ACID - EVAPORATION

The flowsheet for this process illustrates volume reduction by extensive evaporation of the nitric acid neutralization mother liquor to produce a high caustic-aluminum semi-solid material suitable for interim storage in a double-shell tank. This type of evaporation has been studied on a pilot scale with a liquor of a composition different than that predicted to result from partial neutralization. A volume reduction up to 60 percent of the feed liquor volume is likely to be attainable by processing the partial neutralization mother liquor in 242-S facilities. A wiped-film evaporator may be capable of reducing the same feed to 50 percent of the original volume.

Extensive evaporation in the 242-S Facility is illustrated by Figure 3. The volume reduction is not expected to be as large for the partial neutralization mother liquor as compared to the original terminal liquor. The reason for this is the higher salt concentration in the partially neutralized mother liquor. Double-shell tank storage is expected to be required for this product because of the required evaporator operating conditions, high caustic and aluminate concentrations which result in a deliquescent product, and the expected high cesium concentration or heat generation rate of the product.

Similar considerations apply to Figure 4 for the wiped-film evaporator. An advantage of this flowsheet is the larger volume reduction that may be obtained with this evaporator. Additional advantages of the wiped-film evaporator include excellent solids handling capability and higher operating temperatures, though timing may prove to be unfavorable. The 242-S evaporation would utilize existing facilities, avoiding additional capital expenditures, and present fewer timing problems. Solids handling difficulties may require modifications to the slurry lines or multi-pass evaporations.

2. NITRIC ACID - CLAY STORAGE

This process would utilize the clay process to solidify the mother liquor resulting from nitric acid partial neutralization. The clay product storage mode chosen for this flowsheet involves placement in a single-shell tank. Amenability of the partial neutralization mother liquor to the clay process has not been demonstrated. The clay process requires high caustic levels for reaction to cancrinite, but absorption alone may be acceptable. Refer to the following sections "Clay in Tanks" and "Clay in Drums" and Figures 9 through 11 for additional discussion of the clay process.

3. ALUMINUM REMOVAL - EVAPORATION

The objective shown by this flowsheet (Figure 5) is production of a negligible amount of remaining mother liquor. This is to be accomplished by producing an aluminum solid that is acceptable for interim storage in single-shell tanks. Neutralization of caustic in conjunction with production of acceptable aluminum, nitrate, and nitrite solids by evaporation may conceivably reduce the residual liquor volume to essentially zero. The technology for this option is not available though development efforts are proceeding. Acceptability of aluminum-silicate solids in a single-shell tank for interim storage must be established before development efforts in this direction may be applied to terminal liquor treatment. A flowsheet using Bayer process principles to precipitate aluminum trihydroxide (gibbsite) from terminal liquors is also being developed. This process does not require silica addition, but has not been demonstrated to work in the chemical system of terminal liquors.

These options are being considered because of the advantages they may offer if the technology and product acceptability can be demonstrated on a timely basis. The advantages include utilization of existing major facilities, low cost for new facilities, favorable timing, possibility of producing an acceptable single-shell tank product, and the possibility of a process that goes to completion. Disadvantages include the need for extensive technology development and questionable acceptability of small particle-size solids for interim storage.

4. LIQUID STORAGE IN DOUBLE-SHELL TANKS

Terminal liquors may be safely stored for the interim time period in double-shell tanks. This disposition option for terminal liquors is considered to be established technology, readily retrievable and reprocessible, and is being proposed for budget planning. This storage method would also permit a timely development of alternative methods of either interim or long-term storage.

Figure 6 illustrates the double-shell tank liquid storage mode. The liquid is held in a static condition and is subjected to extensive surveillance. The required facilities, i.e., double-shell tanks, are in the budgeting process and cost three to five dollars per gallon. Double-shell tankage is being requested in FY 1976 and 1977 budgets and all tanks should be operable by mid FY 1980.

Terminal liquids stored in double-shell tanks for an interim time offer advantages in retrievability and reprocessability since they are stored as a liquid which is readily pumpable and no additives have been used. The mobility of the waste itself is high, but the new double-barrier containment tanks preclude the loss of liquid waste to the environs. The disadvantages of double-shelled storage are: high cost, high surveillance effort, and the need to either replace double-shell tanks after their 20-year lifetime or move to another storage option.

5. 242-S MUSH

Extensive evaporation of terminal liquors in the 242-S or -A facility, as shown by Figure 7, will provide further volume reduction and produce a semi-solid product dependent upon storage temperature. The products of this process are expected to require interim storage in double-shell tanks. Hygroscopicity, heat generation rate, and chemical stability considerations make these products unlikely candidates for interim storage in single-shell tanks. A current estimate of the volume reduction possible by extensive evaporation in 242-S or -A is 50 percent.⁵ Further pilot plant study of the process is required to provide a more definitive estimate. The process advantages include the availability of existing evaporator facilities, low cost, and rapid solidification contingent upon double-shell tank availability. Questions concerning heat content, corrosion rates of the carbon steel tank liner, and the applicability of 242-S evaporators to much production must be determined.

6. WIPED-FILM MUSH

Extensive evaporation of terminal liquors with a wiped-film evaporator will provide a volume reduction of stored wastes, as shown by Figure 8.⁴ These products are expected to be similar to those described in the section

on "242-S Mush" and will require double-shell tank storage for similar reasons. A smaller volume of waste requiring double-shell tank storage is expected because of the higher operating temperature obtainable in a wiped-film evaporator as opposed to the 242-S or -A facility.

The mechanically scraped walls of the evaporator aid heat transfer, provide turbulent mixing, prevent fouling of the heat transfer surface, and allow high solids concentrations in the process liquor. These factors indicate fewer operating problems due to unusually viscous or high solids content wastes generated by extensive evaporation. The small size of the wiped-film evaporator may allow placement of the unit in a riser of the bottoms receiver tank and reduce the problems associated with handling the concentrated waste products. Nitric acid neutralization with wiped-film evaporation may be useful to prevent excessive caustic concentration in the waste product. Excess caustic may cause corrosion problems during interim storage.

A disadvantage is the timing required for technology development and budgeting requirements. The wiped-film evaporator is being developed for waste solidification at the Savannah River Laboratory. Savannah River Laboratory technology may be applicable to terminal liquor solidification at Hanford. Capital funding will be required so that the wiped-film evaporator will be available for use when needed. This option would require extensive use of SRL technology and designs.

7. CLAY IN TANKS

The terminal liquors could be treated with a kaolin or bentonite clay and stored as a monolith in a single-shell tank. Technology for this option is in the development stage⁵ and the option could be available in 1975 or 1976. Two processing flowsheets are available with this terminal liquid treatment option: in-tank mixed and mechanical-mixed. Figures 9 and 10 illustrate the flowsheets for in-tank-mixed and mechanical-mixed, respectively.

In-Tank-Mixed

The in-tank-mixed flowsheet for the monolith clay in a single-shell tank would be accomplished by utilizing the existing cement spreading or diatomite spreading equipment. The dry clay is simply spread or thrown into the tank, the terminal liquid would be sorbed up, and the mixture reacted under proper temperature control to form a monolithic, rich clay product. The product form is generally a sodium aluminosilicate mixed with unreacted clay, sorbed liquid, and occluded salts. The bulk product can be readily made into a soft mud-like material or varied in hardness and dryness to a brittle, hard, dry product depending on the clay choice, mixing ratios, and reaction temperature.

Mechanical-Mixed

The mechanical-mixed flowsheet would be accomplished using a mixer in a pit over the tank. The clay and terminal liquor would be mixed at properly controlled temperatures, and the mixture discharged directly into the receiving tank. The product formed would be essentially the same as the product form of the in-tank-mixed flowsheet with perhaps a small increase in clay use efficiency and, therefore, less volume increase. This flowsheet would require the construction of mixing pits and terminal liquid piping. The flowsheet also affords the possible use of the vapor space volume of the waste tank as storage space, minimizing the number of required storage tanks.

At the time of this study, the resultant products from these two flowsheets appear to be nearly identical. The waste form is immobile and stable. The product retrievability is being studied at this time, and is thus classified as unknown. The ability to reprocess this waste form may be difficult since the clay-waste product is only partially soluble.

The advantages of an in-tank clay process are that cost for storage tanks is minimal; the technology development is approaching the prototype stage; and the dry product matrix is immobile and stable. The disadvantages are that reprocessing or retrieving this waste form may be difficult, and the volume increase of the product is about 40 percent.

8. CLAY IN DRUMS

Terminal liquors can be treated with a clay, packed in a drum, and stored for an interim time in a concrete vault. Figure 11 is a possible flowsheet for such a process. This plant flowsheet mixes the clay and terminal liquors and casts the mixture into a drum. The drum is subjected to a curing or reacting chamber (i.e., an oven) and stored en masse in an underground concrete storage vault. This terminal liquor option can readily be modified to accommodate items such as clay binder additions, pelleting the product, and storage in various containers.

The product form would be essentially the same quality as the previously discussed clay processes. The product is immobile and stable, and is readily retrievable due to the drum-in-vault storage system. Future processing of the product would be difficult. This method might be considered a long-term storage option rather than an interim option. It is considered to be expensive in that there are required capital expenditures for a clay-waste processing plant and for vault storage.

COMPARISON OF THE ALTERNATIVE PROCESSES

This section compares the selected alternatives based on storage requirements, product form or character, process timing, and process costs.

Table II presents the storage volume requirements for the selected options based on the previous option discussions. Storage volume requirements range from a combination of zero in single-shell tanks and 10 million gallons in double-shell tanks (Option 4) to no new double-shell tanks and 14 million gallons of single-shell tank storage (Options 2, 3, and 7).

Table III presents an assessment of the product form with respect to the various characteristics desired for a terminal liquor product in interim storage. As discussed previously, parts of this assessment are subjective and are necessarily a value judgment. Stability, immobility, and surveillance requirements are more favorable for Options 2, 3, and 7 although retrievability and reprocessability become less favorable or unknown for these options. Double-shell tank storage (Options 1, 4, 5, and 6) offers favorable retrieval and reprocessing characteristics. These options require double-shell tank storage because of the unfavorable mobility and stability of the waste product form.

Table IV presents the estimated timing of each of the options. Timing is, of course, dependent on funding requirements and process development success. For this timing assessment, an assumption was made that all process development work will (1) be completed on time as planned, and (2) will result in a technically viable process. Figure 12 details planned time schedules for development of various options. This figure points out the need for timely development and demonstration prior to construction of double-shell tanks funded in the FY 1977 budget.

Table V presents an assessment of the process costs. Two totalizing columns have been included: one including the estimated storage charges for all double-shell and single-shell tanks; the other including only FY 1977 tankage costs. This was done primarily because capital funds for hooking up single-shell tanks (U, A, AX farms and 242-A Evaporator-Crystallizer) have been appropriated. A significant volume of double-shell tank storage is being funded (SY Tank Farm plus six additional double-shell tanks). The plant costs are gross estimates based on conceptual ideas and, as such, are subject to revision. Chemical costs are based on current chemical market prices.

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TABLE II

COMPARISON OF THE OPTIONS FOR INTERIM STORAGE
OF TERMINAL LIQUOR
BASIS SUMMARY

Option	Product Form(s)	<u>Millions of Gallons Stored</u>	
		<u>Single Shell Tanks</u>	<u>Double Shell Tanks</u>
1. Nitric Acid Neutralization 242-S Mush	Salt Cake in Single-Shell Tanks Mush (242-S) in Double-Shell Tanks	2 0	0 4
2. Nitric Acid Neutralization and Clay	Salt Cake in Single-Shell Tanks Clay in Tank (Single-Shell Tanks)	2 9	0 0
3. Aluminum Removal	Salt Cake in Single-Shell Tanks Mixed Salt Cake in Single-Shell Tanks	2 6	0 0
4. Double-Shell Storage	Liquid in Double-Shell Tanks	0	10
5. 242-S Mush	Mush in Double-Shell Tanks	0	5
6. Wiped-Film Mush	Mush in Double-Shell Tanks	0	4
7. Clay in Tank	Clay in Single-Shell Tanks	14	0
8. Clay in Drums	Clay in Drums in a Vault	13 (Vault Storage)	

TABLE III

COMPARISON OF THE OPTIONS FOR INTERIM STORAGE OF TERMINAL LIQUOR
SYSTEMATIZED MANAGEMENT PROJECTION

<u>Option</u>	<u>Immobility</u>	<u>Retrievability</u>	<u>Stability</u>	<u>Amenability For Further Processing</u>	<u>Surveillance Requirements</u>
1. NITRIC ACID NEUTRALIZATION					
Salt Cake in Single-Shell Tank	Accepted	Accepted	Accepted	Good	Medium
Mush (242-S) Double-Shell Tank	Mush in Double Containment	Excellent	Deliquescence	Good	Medium-High
2. NITRIC ACID NEUTRALIZATION AND CLAY					
Salt Cake in Single-Shell Tank	Accepted	Accepted	Accepted	Good	Medium
Clay in Single-Shell Tank	High	Unknown	Good	Difficult	Low
3. ALUMINUM REMOVAL					
Salt Cake in Single-Shell Tank	Accepted	Accepted	Accepted	Good	Medium
Mixed Salt Cake in Single-Shell Tank	Unestablished	Probably Acceptable	Probably Acceptable	Unknown	Medium
4. DOUBLE-SHELL STORAGE	Mobile Liquid Double Containment	Immediately Pumpable	Liquid	Best	High
5. 242-S MUSH	Mush in Double Containment	Excellent	Tends Toward Deliquescence	Good	Medium-High
6. WIPED-FILM MUSH	Mush in Double Containment	Excellent	Tends Toward Deliquescence	Good	Medium-High
7. CLAY IN SINGLE-SHELL TANK	High	Unknown	Good	Difficult	Low
8. CLAY IN DRUMS	High	Inherent	Good	Difficult	Low

TABLE IV

COMPARISON OF THE OPTIONS FOR INTERIM STORAGE OF TERMINAL LIQUOR
TIMING AND TECHNOLOGY REQUIREMENTS

<u>Option</u>	Required Technology Development (Projected FY Date)	Projected Date For Operable Facility		
		<u>Budget Year</u>	<u>Operating Date</u>	<u>Completion</u>
1. NITRIC ACID NEUTRALIZATION 242-S MUSH				
Salt Cake (SST)	Process Test (1975)	---	1976	1978
Mush - 242-S (DST)	Process Test (1976)	---	1975	1979
2. NITRIC ACID NEUTRALIZATION AND CLAY				
Salt Cake (SST)	Process Test (1975)	---	1976	1978
Clay In-Tank Mixed (SST)	Process Test (1976)	1978	1977	1979
3. ALUMINUM REMOVAL				
Salt Cake (SST)	Process Test (1975)	---	1976	1978
Salt (SST)	Process Test (1976)	---	1977	1979
4. DOUBLE-SHELL STORAGE (DST)	None	1976-1977	1978-1980	1980
5. 242-S MUSH (DST)	Process Test (1976)	---	1976	1979
6. WIPED-FILM MUSH (DST)	1 Year	1978	1980	1982
7. CLAY IN TANK (SST)				
Equipment Mixed	Process Test (1977)	1978	1980	1982
Mixed In-Tank	Process Test (1976)	---	1977	1979
8. CLAY IN DRUMS (VAULT)	1 Year	1978	1980	1983

(DST) = Double-Shell Tank

(SST) = Single-Shell Tank

TABLE V

COMPARISON OF THE OPTIONS FOR INTERIM STORAGE OF TERMINAL LIQUOR
COST ESTIMATES
(FISCAL YEAR 1975 DOLLARS)

Option	Storage* Costs		Plant Cost (\$ in Millions)	Chemical** Material Cost (\$ in Millions)	Total Cost (\$ in Millions)	Total Additional Cost (\$ in Millions)
	Cell no	Cost (\$ in Millions)				
1. NITRIC ACID NEUTRALIZATION Salt Cake in SST Mush (242-S) in DST	2 3.0	1 18	0.5 0	0.6 0	1) 1)	1
2. NITRIC ACID NEUTRALIZATION AND CLAY Salt Cake in SST Clay Mixed in SST	2 8.4	1 0.4	0.5 0	0.6 1.6	4	3
3. ALUMINUM REMOVAL Salt Cake in SST Mixed Salt Cake in SST	2 5.3	1 2.6	0.2 0.5	(Silicon Dioxide) 0.4 (Nitric Acid) 1.6	6	3
4. DOUBLE-SHELL STORAGE (DST)	10	50	0	0	50	30***
5. 242-S MUSH (DST)	5	25	0	0	25	0
6. WIPED-FILM MUSH (DST)	4	20	2	0	22	2
7. CLAY IN DRUMS (VAULT)	18.2	25	30	(Clay) 2.5 (Drums) 4.0	62	62
8. CLAY IN TANK Equipment Mixed (DST) Mixed in Tank (SST)	14 14	7 0.7	0 0	2.5 2.5	10 3	10 3

* Vault - Personal communication - MC Dr. ...
DST \$2.5 per gallon (Salt Cake)
\$2.5 per gallon (Clay)
DST \$2.5 per gallon

** Clay at \$200,000 per million gallons
50 percent acid 3¢ per gallon
Silicon dioxide at \$50 per ton
*** Assuming six additional tanks will be
required to store all terminal liquors.

(DST) = Double-Shell Tank
(SST) = Single-Shell Tank

FIG. 1. EIGHT OPTIONAL PROCESSES TO ACHIEVE INTERIM STORAGE

FIG. 2 FLOWSHEET FOR PARTIAL NEUTRALIZATION OF
TERMINAL LIQUOR IN THE 242-S EVAPORATOR CRYSTALLIZER

FIG. 3 FLOWSHEET FOR EXTENSIVE EVAPORATION OF PARTIAL NEUTRALIZATION MOTHER LIQUOR IN THE 242-S FACILITY

FIG. 4 FLOWSHEET FOR EXTENSIVE EVAPORATION OF PARTIAL NEUTRALIZATION MOTHER LIQUOR IN A WIPED FILM EVAPORATOR

FIG. 5

FLWSHEET FOR ALUMINUM REMOVAL TREATMENT OF PARTIAL NEUTRALIZATION MOTHER LIQUOR

FIG. 6 TERMINAL LIQUIDS STORED IN MILLION GALLON DOUBLE SHELL TANKS

FIG. 7 FLOWSHEET FOR EXTENSIVE EVAPORATION OF TERMINAL LIQUOR IN THE 242-S FACILITY

FIG. 8 FLOWSHEET FOR EXTENSIVE EVAPORATION OF TERMINAL LIQUOR IN A WIPED FILM EVAPORATOR

FIG. 9 MONOLITHIC AQUEOUS SILICATE - MIXED IN SINGLE SHELL TANKS

FIG.10 MONOLITHIC AQUIOUS SILICATE - EQUIPMENT MIXED IN SINGLE SHELL TANKS

FIG.II AQUEOUS SILICATE IN DRUMS

Calendar Year	1975	1976	1977	1978	1979	
Fiscal Year		1976	1977	1978	1979	1980

Double-Shell
Tanks

SY CONSTRUCTION

SZ, AW CONSTRUCTION

SW FUND.

SW CONSTRUCTION

Nitric Acid
Partial
Neutraliza-
tion

PT

CONSTRUCTION

242-S Mush
Demo

PILOT TESTS

P. DEMO

Aluminum
Removal

LAB AND
PILOT TESTS

PROTO TEST

Wiped Film

PILOT
TESTS

PROTO
DESIGN
CONSTR

PROTO
TEST

(PT = Process Test)

Clay Mixed
In-Tank

PT
PROPOSAL

PROTO
DEMO

Clay in
Drums

PROCESS DEV

FUNDING

CONSTRUCTION

Funding

Deadline

FIGURE 12

MUNICIPAL LIQUOR TREATMENT PROCESS DEVELOPMENT SCHEDULE

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