Atlantic Richfield Hanford Company
 Richland, Washington 99352

MASTER

**ENGINEERING STUDY
 ALTERNATIVE EVAPORATIVE FACILITIES
 FOR THE B TANK FARM COMPLEX**

by

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I. INTRODUCTION

Since startup, the ITS #2 bottoms system has not performed as satisfactorily as originally anticipated. Poor performance is attributed to (1) the ITS #2 electric immersion heater sheath temperatures becoming limited (300°-400° F) at high solution salt concentrations (~50%) due to scale formation and, (2) an increase in recycle boiling point which becomes limiting at the 250° F maximum allowable 112-BY tank temperature limit.

These temperature limits result in a large accumulation of liquid recycle and as feed becomes more concentrated in the future, ITS #2 boiloff rate will substantially decrease. Partial nitric acid (HNO_3) neutralization of the recycle to partially reduce the concentration of one of the major compounds (sodium hydroxide- NaOH) causing the boiling point rise will reduce recycle inventory (by approximately 12%) but does not appreciably increase boiloff as only an additional two percent of the original water present in the recycle can be evaporated (reference 1). The ITS #2 evaporator can be operated longer by HNO_3 neutralization but primarily because dilution water is being added from the 57 wt.% HNO_3 and is being formed during the neutralization reaction.

Since HNO_3 neutralization does not, on an overall basis, improve ITS #2 boiloff capacity nor will it result in a complete solidification of recycle, other means must be used to solidify the remaining recycle. Phosphoric acid (H_3PO_4) partial neutralization will solidify the recycle, but this is not economically attractive because of the much larger salt cake storage capacity required to store the resultant salts, reference 2. Transferring the recycle to the 242-S evaporator in West Area to obtain recycle inventory reduction and solidification is more practical. However,

this results in not utilizing a large amount of available solids storage capacity (approximately 6 million gallons) in the B Tank Farm Complex, reference 3.

Therefore, a study was made to determine a more efficient operating evaporator than the ITS #2 unit and/or provide a solid product whereby the available solids storage capacity in the B Tank Farm Complex can be utilized. The following alternative evaporating schemes were investigated for incorporation into the B tank farm bottoms system.

- . Spray Drying
- . Forced Circulation Vacuum Crystallization-Evaporation
- . Scraped Tube Evaporation (Vacuum and Atmospheric)
- . Forced Circulation Atmospheric Evaporation
- . Natural Circulation, Atmospheric Calandria Evaporation

This report contains the results of this study. All capital estimates were generated by ARHCO and are approximate and should be used for comparison only. They include both fabrication and installation costs and are based on 1974 dollars.

II. SUMMARY

The results of this study indicate that spray drying using the 102-BY bottoms tank as a containment vessel is the most attractive process for eliminating ITS #2 operational problems and at the same time utilizing all the solids storage tanks available in the B tank farm complex. It produces the best quality product (potentially a 1 to 5% moisture content) of all the processes studied. The solids product would be conveyed pneumatically to other tanks in the B tank farm complex for storage. It can be installed more quickly and at a low capital cost, 0.5-0.7 million dollars.

Several problem areas exist in spray drying that need further study. Entrainment could be high and bulk density

may be relatively low. Tank temperature limits could be exceeded but we do not at this time feel that this will be a problem as drying is almost instantaneous. Development and pilot plant work are required to determine the best approach to eliminate these problems.

Scraped tube vacuum evaporation is an attractive alternate to spray drying. It also produces a dry (3-5% moisture) product which is substantially denser and entrainment should be considerably lower. On an overall basis, it is inferior to spray drying because it requires more capital (\$2 to \$3 million) and, all equipment including both the evaporator and offgas facilities, must be relocated from tank to tank. It consists of a single 36-inch diameter, 18-foot long single tube with inner scraper blades, all inserted in a 42-inch riser.

Forced circulation or scraped tube atmospheric evaporation are also attractive alternatives to ITS #2 evaporation but only if increased operating efficiency is desired. A moist product (30-40% moisture) similar to that produced in our present bottoms systems will result from either type evaporator. As in all atmospheric type evaporators, these evaporators are limited by the 250° F maximum boiling point specification. A large recycle inventory will still develop and available bottoms solids storage space in the B farm complex cannot be utilized. Basically the forced circulation evaporator consists of a tube and shell heat exchanger inserted into a 42-inch tank riser in tank 112-BY and is fed by a high volume pump (1000 gpm). It can be installed at a low capital cost (\$500,000). The scraped tube evaporator would also be installed in a 42-inch riser in tank 112-BY and would be of similar design as required for the scraped vacuum evaporators except that no vacuum facilities are required and would be centrally located. It can be installed for a slightly higher cost than the forced circulation atmospheric evaporator (\$600,000).

Forced circulation vacuum evaporation such as 242-S or Parkinson type evaporation and natural circulation atmospheric evaporation (similar to 242-T) are not as attractive as spray drying, vacuum scraped tube evaporation, or forced circulation atmospheric evaporation. High capital costs or poor process operation make these alternatives less attractive.

III. BACKGROUND INFORMATION

The ITS #2 unit was installed in the 200 East Area to provide an evaporation facility for the bottoms tank system. It consists of a 4,000 KW electric immersion heater (10 gpm boiloff capacity) with an associated vapor handling system. It was provided with a shroud to improve circulation and was installed in a pit riser over tank 112-BY.

The concentrated product from 112-BY is circulated through a series of 500,000 and 750,000 gallon tanks where solids are generated as the solution cools. Cooling is provided by water evaporation as ambient air is drawn over the liquid surface by an exhaust ventilation unit and by conduction heat losses to the surrounding soil. A typical ITS bottoms system contains six tanks, circulates an average of 50 gpm of salt solution and produces a temperature of about 130° F in the last tank.

Fresh feed is blended with recycle material from the bottoms cooling loop in tank 109-BY prior to feeding to the evaporator. The cool feed is pumped to the evaporator, heated to boiling and 20 to 25 percent of its original volume is boiled off.

IV. DEFINITION OF PROBLEM

The ITS #2 poor performance record is attributed to poor evaporator circulation which results in scale formation and high sheath temperatures and, to the presence of sodium hydroxide (NaOH) and sodium aluminate (NaAlO_2) which cause an increase in boiling point and results in a continual increasing recycle inventory. It is anticipated that when the Purex Plant shuts down in early fiscal year 1973, the major source of dilute feed stock, the ITS #2 problems will become more severe.

A. Heater Sheath Temperatures

The ITS #2 heater performs satisfactorily on dilute feed (5% salts concentration-mixture of Purex coating and organic wash wastes) but as the salts become more

concentrated due to boiling, localized saturation occurs and scale formation results because of inadequate circulation. The scale insulates the sheath, and results in high sheath temperatures; thus, reducing boiloff or shutting down of the unit if the maximum allowable sheath temperature is reached.

B. Boiling Point Rise

The blended feeds to the ITS #2 unit contains appreciable concentrations of NaOH (3.2M) and NaAlO₂ (1.5M). However, their concentrations are not high enough to precipitate upon cooling. They build up in the recycle and cause the boiling point to rise, approaching 250° F maximum 112-BY tank temperature limit before their solubility limits are reached. Since evaporation must take place below 250° F, the recycle inventory is continually increasing and after all fresh feed is processed, a large inventory of liquid recycle will have accumulated.

Partial neutralization of the NaOH by HNO₃ will lower the boiling point, resulting in an increase in salt precipitation (12%) and a reduction in recycle inventory but an insignificant increase in boiloff (2%). After HNO₃ neutralization and recycle equilibrium is reached (based on tank temperature limits), the boiling point will again increase to 250° F, due to primarily unprecipitated NaAlO₂ which becomes concentrated in the recycle, reference 2. The recycle inventory still remains high even though it has been reduced primarily because of the additional salts which precipitated upon cooling the HNO₃ neutralized recycle.

This remaining partially neutralized recycle must be either transferred to the 242-S evaporator for further evaporation and solids deposition or neutralized further with phosphoric acid to obtain a solid salt cake. Since both of these processing schemes inherently have a high cost and because of poor ITS #2 operation, other alternative evaporation processes were investigated for incorporation.

V. ALTERNATIVE EVAPORATIVE SYSTEMS

Three basic processing concepts were investigated in this study:

- (1) Spray Drying
- (2) Vacuum Evaporation
 - Forced Circulation
 - Scraped Tube
- (3) Atmospheric Evaporation
 - Forced Circulation
 - Scraped Tube
 - Natural Circulation

These alternative systems were evaluated on the basis that all units would have a boiloff capacity of 10 gpm and if additional solids generation could be promoted, the B farm complex tanks would be used as the solids receivers.

A. Spray Drying

The results of our cursory evaluation show that spray drying is considerably superior for evaporating and solidifying our wastes than the normal boiling evaporation methods. It produces a drier product and eliminates the scale formation which occurs on boiling heat transfer surfaces. Evaporation occurs in the vapor space and does not come in contact with a surface during the drying step.

Conversations with a leading spray drier manufacturer representative (Bowen Engineering Inc.), and with Julian Smith (consultant from Cornell University) led us to believe that our waste solutions can be solidified by spray drying. They generally felt a low moisture product could be produced which could be easily stored and retrieved.

1. Spray Drying Principles

Basically, spray drying is achieved by passing hot air (500° to 1300° F), which supplies the heat

required for evaporation, either co-currently or counter-currently through a stream of atomized liquid feed. Drying is almost instantaneous, occurring within 3 to 20 seconds and yielding a low moisture product (1 to 5%), usually on a one pass basis. The temperature of the hot air decreases to its vapor-liquid equilibrium saturation temperature (180° to 200° F) and is then exhausted from the containment vessel at this temperature. The particle temperature is never greater than this equilibrium temperature. Cesium and ruthenium vaporization will not occur with our feed solutions as their volatilization temperatures are never approached in this process contrary to what occurs in the calcination processes.

Atomization of the feed is usually accomplished by high pressure nozzles or centrifugal discs. Solid particles can be produced ranging in size from 50 to 600 microns. Drop size is controlled by feed pressure or disc peripheral velocity. Particle size can be controlled to a greater degree with a disc, producing particles with a relatively constant diameter.

Average bulk density is relatively low for a spray dried product. Bulk density can be increased by lower particle diameter but entrainment increases. Bulk density must be balanced against entrainment for each particular situation.

2. Problem Processing Areas

Although we feel that spray drying is feasible for processing our wastes, several problem areas need further investigation to insure its applicability to our situation:

- a. The hygroscopic nature of the produce resulting from NaOH in the feed is not known as to how it will eventually affect the dryness of the product. If this is a problem, the solutions can be neutralized to eliminate the NaOH, reference 1.

- b. If spray drying is performed utilizing a bottoms tank as a containment vessel, inefficient gas-spray contacting could occur, thus causing high offgas temperatures and possibly exceeding the allowable tank temperature limit (200° F). However, we do not feel this will occur as drying is almost instantaneous.
- c. Spray drying will result in offgas entrainment problems. Utilizing a bottoms tank as a gravity settler will remove virtually all particles greater than five microns. By controlling the size of particles to greater than 100 microns, entrainment loadings can be minimized. However, larger size particles result in a lower average bulk density requiring more space for storage. Average bulk density must be balanced against entrainment loadings.

3. Alternative Bottoms Tank Spray Drying Concepts

Three concepts were evaluated that are applicable to our system in East Area:

- Case A Spray drying in a bottoms tank
 utilizing the tank as a contain-
 ment vessel.
- Case B Spray drying in a pipe inserted
 in a tank riser.
- Case C Spray drying in a containment
 vessel located in a tank pump pit.

All cases were based on feeding hot preconcentrated solution from 112-BX through existing transfer lines to a centrifugal disc atomizer located in tank 102-BX. A centrifugal atomizer was chosen because of better particle size control. Hot air would be supplied by the existing ITS #1 compressor and heater and would be passed co-current to feed flow. Offgases would be reconditioned by the

ITS #1 offgas equipment or by using an electrostatic precipitator followed by an existing filter and fan exhaust unit currently being used to vent existing bottoms tanks.

The solids will be conveyed by a pneumatic system utilizing the existing buried transfer lines. An air jet will suck solids from the 102-BY tank into a solids receiver located in a pit above the 102-BY tank. The solids will be combined with compressed air and transported to other bottoms tanks.

a. Case A - Spray Drying In Tank

Spray drying utilizing a bottoms tank as the drying containment vessel is the most attractive case as it requires the least capital (\$0.5-0.7 million) and the least construction time. However, the efficiency of contacting the gas with the gas droplets could be lower than the other two cases.

The equipment required is shown in the attached Figure 1, Case A. A centrifugal disc atomizer is installed in the center riser of a B farm complex bottoms tank and extended to below the tank dome. A hot air insulated duct along with a liquid feed pipe is extended down the riser and terminated immediately above the disc. The disc would be driven by an electric motor.

b. Case B - Spray Drying In A Riser

Spray drying in a pipe located in a riser would insure good gas-spray contacting but could result in particles adhering to the pipe walls and plugging the system. Although the capital required for this case is the same as Case A, it is not as attractive because of the pluggage problem.

Figure 1, Case B shows the equipment required. It requires almost the same equipment as Case A except that a 36-inch pipe is inserted in a 42-inch riser and extended below the tank dome. The atomizer disc is located in this pipe. A slinger disc is also required at the discharge of the pipe to distribute solids in the tank.

c. Case C - Spray Drying in Pump Pit

Spray drying in a containment vessel located in a tank center pump pit would provide good spray liquid contact and prevent buildup of solids on the walls. However, it requires a higher capital investment (\$0.6-0.8 million).

Figure 1, Case C shows the equipment required. A containment vessel would be located in a pump pit and both the solids and hot air would be discharged to the tank down the center 42-inch riser. A slinger disc is required to distribute the solids in the tank.

B. Vacuum Forced Circulation Evaporation

1. 242-S

Installation of a vacuum forced circulation evaporator-crystallizer would provide improved evaporation facilities in the B tank farm complex and also the bottoms tanks could be utilized for solids storage. However, it is not as attractive as spray drying because lower quality product is obtained (25 to 30% moisture content), requires more capital (\$3 to \$4 million) and a longer time to install.

Figure 2 shows the equipment required for vacuum forced circulation evaporation. This concept is based on the 242-S evaporator scheme as is presently being installed in West Area. Slurries would be transported via the existing transfer lines at high velocity. A slip stream would be discharged to the bottoms tank and the remaining slurry would be recycled back to the evaporator's bottoms product pump.

2. Parkson Evaporator

Parkson type evaporators operate on basically the same principles as the 242-S evaporator except the feed is evaporated at sonic velocities (500-1000 fps) in a plate type evaporator. Obviously, the only advantage of a Parkson evaporator over a 242-S evaporator is that scaling tendency of the heat transfer surface will be lower due to the much higher velocities and heat transfer coefficients will be higher, thus requiring lower heat transfer area. However, it has a disadvantage in that high erosion of the heat transfer area could occur resulting in higher maintenance and increased probability of leakage of radioactive contaminants into the steam condensate.

Tests have been made by the Parkson Company on our synthetic ITS feeds and the results show that the unit can handle our feeds. However, we feel that this type unit has no advantage over a 242-S type evaporator as a unit which could fit in a pump has a low boiloff rate (0.5-2.0 gpm) and a unit of 10 gpm boiloff capacity would require a centralized location because of the size of the equipment required. It would require approximately the same capital as for the 242-S type evaporator (\$3-4 million).

C. Scraped Tube Evaporation

a. Vacuum Operation

Scraped tube evaporators are used for boiling high scale forming solutions. Rotary blades constantly scrap scale from a tube, thus maintaining a high constant overall heat transfer coefficient (200 to 350 Btu/hr.-ft.²-F). This results in units having significantly smaller heat transfer areas for evaporating high scale forming solutions relative to other type evaporative units. It produces a low moisture product (5-10%) when operated under vacuum on a one pass basis.

Figure 3 illustrates a scraped tube evaporator scheme which would be applicable to our bottoms system. Because of the low heat transfer area required, a unit with a 10 gpm boiloff capacity, could be placed in a 42-inch riser. This entire unit would be re-located to a downstream tank after each tank is filled with solids. A centrally located unit is not feasible as the product could not be transported readily to each bottoms tank.

Basically, the scheme consists of inserting in a bottoms tank 42-inch riser, a 36-inch I.D. tube by 18 feet long with four metal scraper blades mounted on a single shaft and driven by an electric motor. Vacuum is created by a two-stage jet evacuator system. Solid product is discharged through the bottom of the evaporator. A valve or barometric leg on the evaporator bottom is used to maintain vacuum. Offgases exit from a disengaging vessel on top of the evaporator and are routed to the two stage ejector system, a de-entrainer, HEPA filters and fan all mounted on skids for moving from tank to tank.

Scraped tube evaporation is an attractive alternate to spray drying as it produces a drier and denser product but it requires a high capital (\$3 to \$4 million) outlay. It is superior to the other processes studied and to the ITS #2 heater as it yields a drier solid product and is not limited by the boiling point rise of the solution when operated under vacuum.

2. Atmospheric Operation

Installation of a scraped tube evaporator operating at atmospheric pressure would be advantageous only if improved evaporator performance is desired. This type operation would be limited by the boiling point rise and thus would not significantly increase solids precipitation or reduce inventory recycle. Solids product from this type evaporator would have a high total moisture content (30-40%) and would be similar to those solids presently being formed in the bottoms tanks.

The evaporator itself would be similar in design to that required for vacuum operation except that no vacuum facilities are required. It would be a centrally located unit mounted in a 42-inch riser over the 112-BY tank. Existing ITS #2 offgas facilities would be used to recondition the vapor. Such a unit could be installed for approximately \$600,000.

Savannah River is evaluating scraped evaporation operating under atmospheric pressure to solidify their wastes (reference 4). They are combining the evaporator with an encapsulation facility which will result in storing waste solids in steel containers.

D. Forced Circulation Atmospheric Evaporation

Installation of a forced circulation atmospheric evaporator would provide better operation than can be obtained with the ITS #2 immersion heater and it would slightly decrease recycle inventory by increasing boiloff and salts precipitation upon cooling. However, a large recycle inventory would still remain as it is not capable of overcoming the boiling point rise because of the tank temperature limit and all of the available B tank farm complex solids storage capacity could not be utilized.

Liquid feed velocity through this type evaporator is high (10 fps) which minimizes tube side scale formation, thus maintaining constant heat transfer from the heating medium.

Figure 4 shows the equipment and flow scheme for a forced circulation evaporator. A tube and shell heat exchanger with steam on the shell side would be installed in a 42-inch riser over tank 112-BY. A 1,000 gpm pump would be installed in tank 109-BY to provide feed to the evaporator. Capital required for this system is approximately \$0.5 million.

Although considerable operating advantages can be obtained with this system over the ITS #2 heater, it is inferior to spray drying since the large recycle inventory cannot be solidified with the present bottoms tank cooling system.

E. Natural Circulation Atmospheric Calandria Evaporation

The 242-T evaporator is a natural circulation atmospheric calandria evaporator. As past operating data shows, it is highly susceptible to process side fouling although not as much as the ITS #2 electric immersion heater and it is also limited by the boiling rise as the NaOH and NaAlO_2 become more concentrated in the recycle.

We do not feel that this type evaporator will significantly improve operating efficiency in the 200 East Area as it still will not reduce recycle inventory and is still susceptible to significant process side fouling.

Figure 5 shows the equipment required for installing a calandria evaporator in the 242-B Building. Equipment facilities required are the same as installed in the 242-T evaporator. Approximately two million dollars is required to install such a system.

VI. REFERENCES

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3. ARH-2400 (unclassified), April 1972, D.E. Larson, "Atlantic Richfield Hanford Company High-Level Liquid Radioactive Waste Management Program"
4. USAEC Report DP-1135, June 1968, C.B. Goodlett, "Concentration of Radioactive Wastes" E.I. duPont de Nemours and Co., Savannah River Laboratory, Aiken, South Carolina

CAPITAL COST -
CASE A - 0.5
CASE B - 0.5
CASE C - 0.6

IT'S #1 EXIST.
HEPA FILTERS
AND STACK

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FIGURE 2
VACUUM EVAPORATOR-CRYSTALLIZER

BASIS: 10 GPM WATER EVAPORATION RATE
14 GPM SOLIDS FORMED WITH
25-35% TOTAL MOISTURE
CONTENT
CAPITAL - 3-4.0 MILLION

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FIGURE 4
ATMOSPHERIC FORCED CIRCULATION
EVAPORATION IN TANK

BASIS: 10 GPM WATER EVAPORATION RATE
CAPITAL COST - \$0.5 MILLION

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FIGURE 5
242-B EVAPORATOR
ATMOSPHERIC EVAPORATION
SAME AS 242-T OPERATION

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