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**Evaporation Studies on  
Oak Ridge National Laboratory  
Liquid Low-Level Waste**

V. L. Fowler  
J. J. Perona

OAK RIDGE NATIONAL LABORATORY

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FOR THE UNITED STATES  
DEPARTMENT OF ENERGY



Chemical Technology Division

**EVAPORATION STUDIES ON OAK RIDGE NATIONAL LABORATORY  
LIQUID LOW-LEVEL WASTE**

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J. J. Perona

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Date Published: March 1993

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It is subject to revision or correction and therefore does not represent a  
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# EVAPORATION STUDIES ON OAK RIDGE NATIONAL LABORATORY LIQUID LOW-LEVEL WASTE

V. L. Fowler  
J. J. Perona

## ABSTRACT

Evaporation studies were performed with Melton Valley storage tank liquid low-level radioactive waste concentrate and with surrogates (nonradioactive) to determine the feasibility of a proposed out-of-tank-evaporation project. Bench-scale tests indicated that volume reductions ranging from 30 to 55% could be attained. Vendor-site tests were conducted (with surrogate waste forms) using a bench-scale single-stage, low-pressure (subatmospheric), low-temperature (120 to 173°F) evaporator similar to units in operation at several nuclear facilities. Vendor tests were successful; a 30% volume reduction was attained with no crystallization of solids and no foaming, as would be expected from a high pH solution. No fouling of the heat exchanger surfaces occurred during these tests. It is projected that 52,000 to 120,000 gal of water could be evaporated from the supernate stored in the Melton and Bethel Valley liquid low-level radioactive waste (LLLW) storage tanks with this type of evaporator.

## 1. INTRODUCTION

The evolving underground injection control regulations (Chap. 1200-4-6) of the rules of the Water Quality Board for the state of Tennessee (first issued May 22, 1985) have led to the discontinuation of the hydrofracture process, which was used at the Oak Ridge National Laboratory (ORNL) to dispose of concentrated LLLW from the mid-1960s until late 1984. Since late 1984, LLLW concentrate generated at ORNL has been stored in the eight 50,000-gal Melton Valley storage tanks (MVSTs), identified as W-24 through W-31, and in four 50,000-gal Bethel Valley evaporator service tanks, identified as C-1, C-2, W-21, and W-23. The operational safety requirement for these 12 tanks dictates that they be filled to no more than 95% of their capacity (and maintain at least 50,000 gal free volume), or 520,000 gal.<sup>1</sup> An operational flexibility limit (OFL) of 470,000 gal for the subject tanks has been established by Waste Management personnel. The LLLW data base indicates that as of

January 1992, the 12 tanks contained a total inventory of 460,500 gal (sludge and supernate), which approaches the OFL. To avoid shutdown of the ORNL LLLW system before 1997, when new storage tanks will come on line, interim waste treatment options must be implemented. Interim treatment options include source reduction, supernate evaporation (in-tank and out-of-tank), and solidification in concrete.<sup>2</sup> Since late 1988, ~ 100,000 gal has been solidified and an additional 50,000-gal solidification program is planned for FY 1993. Assuming a 50% volume increase during solidification, a final waste volume totaling ~ 225,000 gal of Class L-IV waste will have been produced. Currently, there is no U.S. Department of Energy-approved disposal method for this class of waste.

Operation of the in-tank-evaporation process (sparging six MVSTs with dehumidified air) will evaporate an estimated 11,000 gal in 1992 and 1993<sup>2,3</sup>, and the planned solidification campaign (50,000 gal) in FY 1993 will reduce the current inventory; however, according to current LLLW generation projections, including source reductions, the inventory will reach the OFL of 470,000 gal in November 1994. To avoid reaching the OFL, an out-of-tank evaporation (OTE) process has been chosen as the waste treatment option to prevent the need for additional solidification campaigns. The OTE process will not result in production of any solid waste.

In support of the OTE process, evaporation studies have been performed using surrogate waste forms and actual MVST supernate. This report describes those activities.

## 2. PRELIMINARY VOLUME REDUCTION STUDIES

Bench-scale preliminary volume reduction studies were performed to determine the maximum volume reduction ratios that could be achieved before crystallization of the dissolved salts occurred, using a simulated and actual MVST supernate. The major component of the MVST supernate is sodium, approximately 4 mol/L. Other cations such

as Ca, Mg, K, Al, and Fe are present in concentrations up to about 0.25 *M*. Nitrates are present in quantities of about 4 mol/L. The pH ranges from about 9 to >13. The supernate contains various beta and gamma-emitting radionuclides, primarily <sup>90</sup>Sr and <sup>137</sup>Cs. The transuranic content of the liquid is generally less than 100 nCi/mL. The actual composition of the stored LLLW has been well documented in other reports<sup>4,5</sup> and will not be repeated in this report.

## 2.1 VOLUME REDUCTION BY BOILING AT ATMOSPHERIC PRESSURE

### 2.1.1 Scouting Studies

A 1.2-L aliquot of simulated supernate, formulation based upon the MVST W-29 composition as detailed in the Peretz report<sup>4</sup>, was evaporated in a boiling flask equipped with a heating mantle. The vapor was routed to a total condenser. Evaporation continued until crystals formed in the concentrate. At this point, the concentrate was cooled to ambient temperature (73° F). Small aliquots of the distillate were then added back to the concentrate, with agitation, until the precipitated solids were dissolved. A volume reduction of 38% was determined (E. D. Collins, MMES, personal communication to V. L. Fowler, January 4 and 28, 1988). The test was then repeated using a 1.2-L aliquot from an archive sample of W-29 supernate (acquired in November 1985). The test procedure followed was the same as described previously, and it was determined that a volume reduction of 38% was achieved (E. D. Collins, MMES, personal communication to V. L. Fowler, January 4 and 28, 1988). Analytical results of samples from the MVST W-29 test are presented in Table 1.

**Table 1. Melton Valley storage tank W-29 supernate volume reduction: component distribution**

Component	Feed	Concentrate	Distillate
Gross alpha, Bq/mL	6.50E+0	9.60E+0	9.08E+0
Gross beta, Bq/mL	2.59E+5	3.98E+5	3.11E+2
Gross gamma, c/m/mL	2.73E+6	4.46E+6	1.10E+4
pH	13.0	13.3	9.4
OH <sup>-</sup> , <i>M</i>	0.40	0.69	0.0006
sp gr, g/cc	1.2486	1.4137	0.9978
Total solids, mg/mL	79.8	135.0	N.R. <sup>a</sup>

<sup>a</sup>N.R. = assay not requested.

The decontamination factors (DF) for gross beta and gamma, respectively, are 833 and 250, but they are meaningless in that no liquid/vapor separator or demister was present in the system. The DF as calculated from the analytical data shown in Table 1 are

$$DF = \text{feed concentration/distillate concentration}$$

The tests described indicated that MVST supernate volume reduction by elevated-temperature evaporation was indeed a viable alternative to solidification. Therefore, bench-scale tests were continued.

### 2.1.2 Additional Studies

Because the surrogate scouting study described in Sect. 2.1.1 was based on supernate compositions as presented in the Peretz report<sup>4</sup>, and using an MVST supernate sample acquired in 1985, additional studies were performed with surrogate supernates formulated from the analytical data (samples collected from the MVSTs from September 19 to December 5, 1989) presented in the Sears report<sup>5</sup>. Discussions with evaporator vendors indicated that high pH could contribute to extreme foaming and that silica in concentrations of greater than 100 mg/L could create extreme fouling of the heat exchanger surfaces. Therefore, MVST W-

24 and W-28 supernates were selected because these two tanks represent the extremes in pH (13.1 and 9.1, respectively) and silica content (245 mg/L and <1.0 mg/L, respectively). The surrogate compositions used in these studies is presented in Table 2.

**Table 2. Melton Valley storage tank surrogate supernate composition**

Component	W-24		W-28	
	(g/L)	(mol/L)	(g/L)	(mol/L)
NaNO <sub>3</sub>	369.80	4.35	354.50	4.17
KNO <sub>3</sub>	28.30	0.28	66.70	0.66
Na <sub>2</sub> CO <sub>3</sub>	15.90	0.15	1.06	0.01
NaCl	4.27	0.07	4.09	0.07
NaOH	0.66	0.02	0.05	<0.01
Ca(NO <sub>3</sub> ) <sub>2</sub> ·4H <sub>2</sub> O	0.05	<0.01	47.23	0.20
MgCl <sub>2</sub> ·6H <sub>2</sub> O	0.01	<0.01	13.37	0.07
Na <sub>2</sub> SiO <sub>3</sub> ·9H <sub>2</sub> O	2.48	0.01	0.00	0.00

The test equipment and procedures for this series of tests were identical to those used in the tests described in Sect. 2.1.1. Four evaporations were conducted, two each using W-24 and W-28 surrogates. The results are presented in Table 3.

Table 3. Melton Valley storage tank surrogate solution distillation data summary

	W-24		W-28	
	1	2	3	4
	<b>pH</b>			
Feed	13.2	13.2	9.1	9.1
Concentrate	13.4	13.4	6.7	5.2
Distillate	7.3	7.6	7.4	7.4
	<b>Density, g/cc</b>			
Feed	1.246	1.244	1.275	1.264
Concentrate	1.363	1.349	1.417	1.389
Distillate	1.002	1.003	1.002	1.002
Percentage of volume reduction	32.1	32.2	33.7	33.5

These data, with respect to densities and pH, are consistent with the data presented in Table 1. The volume reduction was less than the 38% achieved with the actual MVST W-29 supernate, although the volume reduction achieved continued to merit consideration of evaporation by distillation.

## 2.2 VOLUME REDUCTION BY AIR SPARGING AT AMBIENT TEMPERATURE AND PRESSURE

Evaporation studies were conducted by sparging dry air through a 3.8 *M* sodium nitrate solution and actual MVST supernate samples. The sodium nitrate solution was reduced by 50 volume percent, at which time crystals began to form. The pH of the solution dropped from 11.5 to 6.8 during the evaporation process because of carbonate formation due to

absorption of carbon dioxide from the sparge air (E. D. Collins, MMES, personal communication to V. L. Fowler, January 28, 1988).

Bench-scale sparging tests were also conducted on supernate samples from six of the MVSTs (samples not available from W-29 and W-30). The volume of water evaporated from the MVSTs before solids began to precipitate ranged from 38 to 55% (J. F. Walker, MMES, internal communication to T. J. Abraham, June 1988).

These results indicate that significantly higher volume reductions may be possible than are projected from the experiments on W-24 and W-28 surrogates reported in Sect. 2.1.2. The introduction of carbon dioxide by air sparging tends to lower the solution pH, increasing the solubilities of the dissolved salts. Because the MVSTs are currently being sparged with dry air (the in-tank evaporation process), it is important to investigate the significance of this phenomenon for projected volume reductions.

### **2.3 VOLUME REDUCTION BY BOILING AT SUBATMOSPHERIC PRESSURES AND LOW TEMPERATURES**

Based on a study by Bechtel National, Inc. (completed in 1991 under contract to ORNL), a single-stage, motor-driven, vapor compression evaporator was suggested for the OTE process; a proven off-the-shelf evaporator design should be used. Bechtel recommended that scaling and fouling tests be performed before detailed equipment specifications are completed. LICON, Inc., meets these criteria in that its vapor compression evaporators are presently in use at Three Mile Island, unit 2, where over 1 million gal of LLLW has already been successfully processed, and at the Rocky Flats Plant where an estimated 8 million gal of LLLW (solar pond water) will be reduced to less than 10,000 gal. To determine the feasibility of using this type of evaporator (subatmospheric, low temperature) for volume reduction of the ORNL LLLW, Professional Analyses, Inc., contracted with LICON to perform scaling/fouling studies using an MVST surrogate waste

form. The fouling/scaling studies were conducted at the LICON facilities using a laboratory-scale evaporator unit similar in design to existing nuclear units.

The two surrogate waste forms used in these studies were based on the component concentrations contained in MVST W-24 and W-28, which exhibit the extremes in pH (13.1 and 9.1, respectively) and silica content (245 mg/L and <1.0 mg/L, respectively). The formulation for these surrogates was presented in Sect. 2.1.2, Table 2. Nine tests were conducted (five with W-24 and four with W-28) using a single-stage low pressure (subatmospheric) evaporator containing 2.1 ft<sup>2</sup> of heat exchanger surface rated at a nominal 3.0 gph evaporative rate. The evaporator pressures and temperatures tested ranged from 122°F and 25 in. Hg (vacuum) to 173°F and 19.5 in. Hg. Under these operating conditions, the evaporation rates obtained ranged from 0.3 to 2.6 gph. Concentration factors of 1.43 (30% volume reduction) were achieved for both surrogates without precipitation of solids when the concentrate was cooled to ambient temperature. No fouling of the heat exchanger tubes occurred and no foaming problems were encountered in any of the tests. Analyses of distillate samples for total dissolved solids were conducted. Solids content ranged from 2.4 to 4.2 mg/L, resulting in an average decontamination factor of  $1.9 \times 10^5$  (DF = concentrate concentration/distillate concentration).

Assuming that a DF of  $1.9 \times 10^5$  is achievable for the radionuclides contained in the MVSTs, only <sup>137</sup>Cs would exceed the Process Waste Treatment Plant waste acceptance criteria of 400 Bq/L in the distillate produced from evaporation of supernate from all eight MVSTs. The <sup>137</sup>Cs content would be highest in the distillate produced from W-26, ~ 3,700 Bq/L.

Surface radiation dose rates for a 5,000 gal capacity tank truck transporting OTE distillate to the Process Waste Treatment Plant have been calculated at 12 mR/h, well below

the LLLW system waste acceptance criteria of 200 mR/h surface radiation limit established for tanker and dumpster trucks.

Based upon the performance of the surrogate testing, LICON recommends that a single-effect, hot water or steam-heated evaporator be used for the OTE process. Before the LICON tests, a vapor recompression evaporator was identified as a promising technology because it is being used successfully at Three Mile Island for concentrating boric acid accident water. The testing revealed that the relatively high boiling point elevation (18°F) for MVST supernates would largely negate the anticipated energy savings from vapor recompression. The hot water or steam-heated evaporator is mechanically simpler, replacing the vapor compressor with a condenser.

The LICON tests demonstrated that the evaporation could be carried out in the boiling point range of 155–175°F with a maximum boiling point elevation of 20°F and achieve good evaporation rates with no heat exchanger fouling. The LICON test report is included as the appendix to this report.

### **3. PROJECTED LIQUID LOW-LEVEL WASTE VOLUME REDUCTIONS BY THE OUT-OF-TANK EVAPORATION PROCESS**

During the initial evaluation of the OTE process, it was projected that ~ 120,000 gal of water could be evaporated from the concentrated LLLW at ORNL. The projection was based on an assumption that the eight MVSTs and four of the Bethel Valley service tanks would contain the operational safety requirement limit of 520,000 gal [351,600 gal of supernate and 168,400 gal of sludge<sup>5</sup> (D. J. Peterson, MMES, personal communication to V. L. Fowler, Sept. 8, 1992)] at OTE startup. Early feasibility studies indicated the LLLW supernate volume could be reduced by an average of 35%, resulting in a volume reduction of 123,060 gal. Recent tests with surrogates indicate that a 30% volume reduction is more

realistic. Evaporation to a volume reduction of 25% (contingency factor of 5%) would result in an increased storage capacity of 87,900 gal.

Recent evaluations (S. M. Robinson, MMES, personal communication to V. L. Fowler, Sept. 7, 1992), based on information from the LLLW data base as of January 1992, indicate that only 211,000 gal of supernate will be available for evaporation at OTE startup. This estimate assumes that (1) 50,000 gal of supernate will be solidified in FY 1993, (2) 11,000 gal will be evaporated by in-tank evaporation in FY 1992 and FY 1993, and (3) no more than 43,000 gal (generator estimates) of LLLW will be generated during FY 1992 and FY 1993. Assuming a maximum 25% volume reduction, then 52,750 gal of water could be evaporated.

Those volume reduction projections include the assumptions that the sludge volume estimates are correct and that transfers of supernate from supply tanks to the OTE feed tanks (W-29 and W-30) will be complete; that is, tank liquid levels can be pumped down to the supernate/sludge interface.

### 3.1 OPERATIONAL TIME REQUIREMENTS

One proposed operating schedule for the OTE is 24 h/day, 5 days/week. Assuming an evaporative rate of 30 gal/h, and no down time for maintenance, the time required to evaporate 52,750 gal (minimum projection) is 16 weeks. Thirty-four weeks would be required to evaporate the projected maximum of 123,060 gal. Additional time is required for refilling the OTE feed tanks (W-29 and W-30). One operating scenario would require ten transfers, and settling time for bulk solids must be allowed after each transfer. Each transfer would require approximately 8 h. The settling time required, based on data obtained from earlier sedimentation tests<sup>6</sup>, is estimated at about 1 to 2 h for a 12-ft-diameter MVST. To be conservative, 1 week should be allowed for refilling of the OTE feed tanks and settling of solids before each restart. The total time required for transfers, settling, and evaporation is

then estimated at 26 to 43 weeks for the projected minimum/maximum volume reductions. With each transfer, supernates will become mixed and lose their individual identity. This change in feed composition will need to be evaluated with respect to the volume of water that can be evaporated from each feed batch. This could be determined during the week-long settling period allowed after each feed tank refill. The operating schedule realistically should follow a 24 h/day, 7 day/week evaporation schedule to fit the Waste Management Operations shift schedule. Actual operating procedures will be developed before OTE startup.

#### 4. SUMMARY AND RECOMMENDATIONS

Feasibility studies performed to date indicate that the LLLW supernate contained in the Melton Valley and Bethel Valley storage facilities can be concentrated to near saturation by evaporation of excess water. The volume of water evaporated in tests using surrogate and actual MVST supernate ranged from 30 to 55% before precipitation of solids occurred. (The range was due to variations in waste composition and pH.) In previous tests, higher volume reductions were attained by sparging with dry air (38 to 55%) than by boiling (30 to 38%). Those results indicate that increased carbonates, due to carbon dioxide absorption from the dry sparge air, decrease the pH and thus increase the solubility of the dissolved salts. Additional studies are suggested to refine this operating parameter.

All tests to date indicate that the supernate contained in the ORNL LLLW storage tanks can be further concentrated by factors ranging from 1.4 to 2.0 without creating additional solids. The recommended evaporator for removal of excess water from the supernate is a single-stage unit operating at about 20 in. Hg (vacuum) and at about 170°F. This temperature reduces the possibility of excessive foaming and minimizes scaling/fouling of the heat exchanger surfaces.

## 5. REFERENCES

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2. S. M. Robinson et al., Status of the ORNL Liquid Low-Level Waste Management Upgrades, ORNL/TM-12299, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., 1993.
3. J. F. Walker, Jr. et al., In-Tank Evaporation Demonstration Tests. ORNL/TM-12036, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., October 1992.
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5. M. B. Sears et al., Sampling and Analysis of Radioactive Liquid Wastes and Sludges in the Melton Valley and Evaporator Facility Storage Tanks at ORNL, ORNL/TM-11652, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., September 1990.
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**Appendix. FINAL REPORT SURROGATE SOLUTION TEST  
OAK RIDGE NATIONAL LABORATORY  
LICON, INC.**



The logo for LICON INC. features the word "LICON" in a large, bold, sans-serif font. To the right of "LICON", the letters "INC" are stacked vertically in a smaller font. The entire logo is set against a dark, horizontal background that tapers off to the left.

DATE: September 23, 1992

TO: Vic Fowler  
Oak Ridge National Lab

FROM: Rod Williamson *RCW/keh*

SUBJECT: Authorization to Duplicate Surrogate Solution Test Final Report

---

Dear Vic:

Please consider this authorization to duplicate our Surrogate Solution Test Final Report for use as an appendix to the volume reduction report you are working on.

REF: RCW92038.keh



**FINAL REPORT SURROGATE SOLUTION TEST  
OAK RIDGE NATIONAL LABORATORY**

**Test for PAI Corporation  
116 Milan Way, Oak Ridge, TN 37830**

**Under Contract DE-AC05-88OR21794  
Task PAI-002-88  
Subcontract No. PAI 9201**

**Submitted by: LICON, Incorporated  
200 E. Government St, Suite 130  
Pensacola, FL 32801  
Job No. 2107-T**

**Date: September 9, 1992**

**Report By: Kenith Grant, Application Engineer  
Testing By: Johnny Campbell/Kenith Grant  
Coordinated By: Rodney Williamson, V.P. Sales**

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## I. INTRODUCTION

On July 16, 1992, PAI Corporation approved execution of testing under Subcontract No. PAI-9201. This authorized LICON, Inc. to begin pilot-testing surrogate samples for evaporation feasibility.

Oak Ridge National Laboratories presently has eight 50,000 gallon storage tanks containing radioactive waste water. Each tank is comprised of approximately 50% solids and 50% supernate. It is the intent of ORNL to facilitate additional storage for radioactive waste water without construction of new storage tanks.

Preliminary evaporation tests were performed by PAI Corporation within a laboratory environment at atmospheric conditions. These results suggested that a possible 30% volume reduction could be achieved through evaporation. Since these initial tests were performed at atmospheric conditions, the possibility for further concentration and or less scale formation at sub-atmospheric conditions were in order.

LICON, Inc. has been requested to analyze volume reduction of the supernate by approximately 30%. A 30% reduction of supernate would provide an additional 7,500 gallons of storage per tank providing an overall increased capacity of 60,000 gallons.

Feasibility testing was performed on two surrogate samples provided by PAI Corporation. The two test samples provided were modeled after the composition in tanks W-24 and W-28 (Appendix D). Hence, these surrogate samples were given the corresponding designations. From these surrogate samples a series of tests were performed to determine solution characteristics when subjected to sub-atmospheric evaporation. The physical results of these tests were recorded for analysis and samples of feed, distillate and concentrate returned with Vic Fowler (PAI) and Joe Perona (ORNL) for analysis. The results of the physical analysis are reported here to best predict the necessary design criteria required to accomplish a 30% supernate volume reduction with an accompanying decontamination factor of at least  $10^5$ .

## II. EQUIPMENT DESCRIPTION (Refer to Flow Diagram)

After envisioning the need for waste water volume reduction and recycling, LICON was formed in November 1975. LICON evaporators were designed after nearly 30 patents in seawater distillation. The primary goals were to adapt what was learned in shipboard seawater distillation to a compact, corrosion and scale resistant unit capable of both high purity and high concentration. In 1979 energy efficiency was added to the design criteria.

Although vertical tube arrangements were tried, the idea was abandoned in order to move away from the vertical calandria which required field assembly and made tube removal and cleaning difficult at best. A compact horizontal tube arrangement was the result (101) with twin uptakes into a vertical separator (103). The twin uptakes greatly increase the release area from the surface of the boiling liquor. Vapor lift into the vertical separator allows lighter liquids to be carried up to the separator where some flashing occurs allowing more vapor to flash off and further separating vapor from dissolved ions. This all takes place prior to the vapor going through one to three mist eliminators (104, 105). This coupled with optional reversal of vapor flow and vapor washing allows LICON horizontal tube evaporators to obtain excellent decontamination factors, which LICON measures as the difference in the TDS of the distillate versus the TDS (Total Dissolved Solids) of the boiling liquor which is LICON's concentrate.

After passing through the separator distilled water vapor enters a horizontal condenser (102) where cooling water circulating on the inside of a patented bayonet tube arrangement (112) condenses the distilled water vapor on the outside of the tube. This condensed vapor is removed as distilled water along with non-condensable gases by a hydraulically driven venturi jet eductor (406). This discharges into an atmospheric distillate tank (401) where non-condensable vapors are vented and the distilled water accumulates. As the level in the tank rises a float switch (404) opens a solenoid valve (LCV 404) and a portion of the distilled water is pumped out at approximately 40 psig. The distilled water is continually monitored by a conductivity meter (CIC 407) and is cooled by a distillate cooler (403).

The feed is vacuum dragged into the horizontal evaporator from the concentrate tank (601). Liquid at the bottom of the separator and a portion from the evaporator are continually pumped (602) back to the concentrate tank for recycling. This allows for high recirculation velocities which helps to keep the heat exchanger (110) flushed of solids. The high recirculation rates, low temperature of operation and the use of chemical feed treatments, when necessary allows LICON evaporators to achieve a much higher degree of concentration with less problems and servicing than comparable vertical tube equipment. Heating for this

lab unit is accomplished by three electric heaters (203). Hot water is circulated by the hot water circulation pump (202). The patented compact bayonet tube design allows for high heat transfer rates which helps in the overall compact design of the system.

### III. TEST CRITERIA

During the course of contract negotiations, an initial set of test parameters were proposed by Mr. Rodney Williamson to PAI Corporation (ORNL) on April 28, 1992. These parameters presented by Mr. Williamson underwent a series of changes up to the testing period, July 14, 1992. The following is a record of evolution:

#### A. Initial Parameters

The following items are the original parameters proposed by Mr. Williamson for surrogate solution testing:

Test Parameter - April 28, 1992

1. Foaming
2. Vapor Velocity
3. Scaling
4. Concentration Ratio
5. Temperature & Pressure
6. Circulation Rate
7. pH

\* Test criteria is listed in Appendix B; correspondence date April 28, 1992.

#### B. Intermediate Parameters

Prior to the arrival of Mr. Fowler and Mr. Perona, July 13, 1992, a meeting was held at LICON, Inc. concerning the test parameters from April 28, 1992. In attendance of this meeting were the following:

Robert McElroy  
John Campbell  
Ken Grant

Design Engineer  
Testing Engineer  
Applications Engineer

The results of the meeting are as follows:

Test Parameters - July 13, 1992

1.	Foaming	Test Variable/Observed
2.	Vapor Velocity	Test Variable/Observed
3.	Scaling	Test Variable/Observed
4.	Concentration Ratio	Test Variable/Observed
5.	Temperature & Pressure	Test Constant
6.	Circulation Rate	Test Constant
7.	pH	Test Variable/Observed

\* Test Criteria is listed in Appendix B; correspondence date July 13, 1992.

**C. Actual Parameters**

With the arrival of Mr. Fowler and Mr. Perona, testing commenced on July 14, 1992. The following is a listing of the actual data parameters used in the testing of surrogate samples W-24 and W-28:

Test Parameters - July 14, 1992

1.	Foaming	Test Variable/Observed
2.	Vapor Velocity	Test Variable/Observed
3.	Scaling	Test Variable/Observed
4.	Concentration Ratio	Test Variable/Observed
5.	Evaporator Feed Temp.	Test Constant
6.	Circulation Rate	Test Constant
7.	pH	Test Constant
8.	Pressure (Vapor) & Temp.	Test Variable

\* Test data located in Appendix A.

As listed, the test parameters underwent several changes up to the actual test themselves. Nine tests were performed; Five on surrogate W-24, and four on surrogate W-28. A steady state test of six hours was added to the high silica water of W-24 (Test #6). It was determined that the pH of both samples was to be held constant. Also the circulation rate as well as evaporative feed temperature were to be held constant. These three input parameters numbers five, six and seven would allow for proper emphasis on surrogate characteristics three, four and eight under sub-atmospheric evaporation. For a given set of test constants, data was to be collected which would determine concentration ratio, vapor velocity, and scaling. Observations concerning foaming and/or foam characteristics were also

within the test criteria. The evaporator tube bundle was weighed before and after every test to detect minute scale formation. In addition to the listed parameters, distillate conductivity was continually monitored. Varying the temperature and therefore the pressure would indicate if this had any effect upon the distillate conductivity or scaling. This additional data was used to facilitate sub-atmospheric evaporation feasibility. Since different technicians may vary operation of the equipment slightly, three other tests were added and run by Kenith Grant to check the consistency of the previous tests. These tests, one on W-28 test #9 at 153°F, and two on W-24 tests #7 at 157°F and #8 at 133°F, confirmed the results of the previous tests by weighing both the concentrate and the distillate produced.

#### **IV. TEST PROCEDURE**

##### **A. LICON Standard Test Procedure (Refer to Appendix C)**

##### **B. PAI Corporation (ORNL) Test Procedure**

During the period from July 14, 1992 to July 20, 1992 a series of five tests were conducted. Two tests were performed on surrogate W-24 while three tests were performed on surrogate W-28. Before each test, the C-3 was flushed clean with city water. The titanium tube bundle in the evaporator was dried then weighed. When testing was complete, the bundle was removed again for weighing to determine possible scale formation. Distillate and concentrate pH was monitored during testing. Apart from these procedures, test data collection was identical to that during a standard test. To verify vapor velocity calculations and other recorded data, three additional tests were run during the week of August 31. During these tests the tube bundle was not weighed.

### III. TEST RESULTS

#### A. Analysis Criteria

Testing of surrogate samples W-24 and W-28 were conducted under standard LICON conditions. Interpreting the results of the testing gave way to two categories:

##### 1. Observed Data

Data under this category is collected and interpreted directly. One example of observed data is foaming. During operation, the test operator views the evaporator chamber and separator through sight windows. Foaming characteristics are recorded. Detrimental foam carryover can be viewed through the separator window and incidental foaming can be viewed and judged in the evaporator sight window. The testing of surrogates W-24 and W-28 involved three observed data parameters.

##### a. Foaming

The presence of foam is almost always associated with higher pH's and lower concentrations, however high pH's do not always mean that foaming will be a detrimental problem. Foaming is simply observed in the areas cited above, as well as in the concentrate tank.

##### b. Scaling

The evaporator tube bundle is removed, dried, and weighed before and after each test to determine scale deposition, except for tests 7, 8 and 9 as noted.

##### c. Concentration Ratio

A predetermined sample is processed through the C-3 until precipitation of solids begin to occur. When saturation is achieved, testing is complete. The ratio of remaining concentrate to initial concentrate volume is referred to as the concentration ratio. Concentration ratio during tests 7, 8 and 9 was not the primary objective, so tests were terminated prior to the precipitation of solids.

## 2. Calculated Data

Calculated data is what the name implies, and is determined through raw data collection. When the operator records raw data during a test, this data is analyzed and processed using applicable formulas to determine a physical result. This result is referred to as calculated data. Surrogates W-24 and W-28 were tested for boiling point elevation and vapor velocities.

### a. Boiling Point Elevation (BPE)

Boiling point elevation is the difference between the vapor temperature and the solution temperature. Generally as dissolved ions increase the boiling point of the liquid increases, as is the case with salt water. This boiling point rise takes additional energy and is a critical factor in designing evaporators.

### b. Vapor Velocity

Velocity at which the vapor produced during distillation travels is determined by specific volume at saturation temperature, production rate of distillate, and cross sectional area of travel (Figure 1). High vapor velocities can have a detrimental effect on decontamination factors and to low a vapor velocity can bring contamination over by simple Brownian Motion.

\*Note: Refer to Appendix E for sample calculations.

## B. **Surrogate W-28 (Non-Silica) (See Test Charts 1, 2 and 9, and 5)**

A series of three tests, numbers 1, 2 and 5, were performed on the W-28 surrogate. Each test started with five gallons and was operated at a different pressure and therefore vapor temperature. In addition, test 9 was run to further verify results. From the results submitted it becomes easily apparent that the low temperature tests do not offer any improvement in decon or scale formation, so the data generated is dealt with in only a rudimentary manner.

### 1. Observed Data (Foaming, Vapor Velocity, Scaling, Concentration and Conductivity)

During testing of the W-28 surrogate, no foaming was observed at any time. This was somewhat to be expected with a surrogate

solution with no surfactants present. Due to the relatively high salt concentration in the Melton Valley Storage Tanks, foaming is not expected to be a problem there either, with or without the presence of surfactants. At no time did the vapor velocity appear to be bringing contaminated liquor over into the distillate. Weight measurements of the evaporator tube bundle to a thousandth of a pound or a tenth of a gram before and after each test revealed no scale formation. A maximum concentration ratio of 2.0 : 1 was achieved during test number 5 allowing for an approximate 40-50% volume reduction of the W-28 surrogate.

## 2. Calculated Data (Production, BPE, and Vapor Velocity)

The test chart lists the values for production, boiling point elevation, vapor velocity, and the recorded conductivity in microsemms. As expected, the data collected reveals increasing BPE with increasing concentration. The data reveals that salting out takes place between 18 and 20°F BPE regardless of the operating temperatures. However, tests run in 1979 with more accurate instrumentation by the University of West Virginia on chromic acid and cyanide solutions revealed that decreasing temperatures do decrease BPE slightly. These tests revealed that there are no significant differences.

There was also no apparent correlation between vapor velocities and distillate quality. Although exceeding design velocities of the mesh would most certainly decrease distillate quality, it should be noticed that starting and sometimes ending distillate quality will be somewhat higher. The starting quality is due to absorbed CO<sub>2</sub> in the distillate and the ending quality can be affected by high levels at equipment shutdown and the force of the breaking vacuum pulling some contaminants over.

Test number 5 shows an unusually high distillate production rate in relation to the similar operating temperatures of tests 3 and 7. LICON has no explanation of this except perhaps as an error in data collection. We would have repeated the test, but saw no point in it since operating in the 130 - 138° vapor temperature range showed no benefits.

**TEST # 1 - W-28**

JULY 14, 1992

TIME	VAPOR TEMP. (°F)	PROD. RATE ( <sup>lb</sup> /HR)	BPE (°F) ΔT: T-6 & T-7	VAPOR VEL. ( <sup>Ft</sup> /s)	CONDUCTIVITY MICRO - <sup>1</sup> / <sub>cm</sub>
1400	118	N/A	4	N/A	2.3
1500	116	N/A	7	N/A	1.4
1600	117	N/A	8	N/A	1.3

**TESTS # 2 & # 9 - W-28**

JULY 15 &amp; SEPT. 1, 1992

TIME	VAPOR TEMP. (°F)	PROD. RATE ( <sup>lb</sup> /HR)	BPE (°F) ΔT: T-6 & T-7	VAPOR VEL. ( <sup>Ft</sup> /s)	CONDUCTIVITY MICRO - <sup>1</sup> / <sub>cm</sub>
#2					
1405	157	8.34	11	N/A	2.9
1425	154	12.51	15	6.71	2.5
#9					
1430	153	10.15	9	5.56	2.2

**TEST # 5- W-28**

JULY 20, 1992

TIME	VAPOR TEMP. (°F)	PROD. RATE ( <sup>lb</sup> /HR)	BPE (°F) $\Delta T$ : T-6 & T-7	VAPOR VEL. ( <sup>F</sup> /s)	CONDUCTIVITY MICRO - <sup>s</sup> /cm
1430	138	16.68	9	13.0	1.2

### C. Surrogate W-24 (with Silica) (See test charts 3 and 7 & 4 and 8)

Three tests were performed on the W-24 surrogate. Two tests, numbers 3 and 4, emphasized boiling point elevation vapor velocity characteristics and decontamination between the concentrate and the distillate while the third test (Test # 6)\* concentrated on steady-state operation and scale formation within a range of concentration ratios. Tests numbers 7 and 8 were run by a different operator to further verify the results. Each test was started with five gallons of feed. The following are the results of the tests:

#### 1. Observed Data

As in the case of the W-28 surrogate solution, the W-24 revealed no foaming tendencies. Weight measurements of the tube bundle before and after each test revealed no scaling tendencies. A maximum concentration ratio of 2.0 to 1 was achieved allowing for an approximate 40-50% reduction of the W-24 surrogate. These concentration ratios will later be confirmed by water analysis. During the number six test additional salt build-up was noticed on the heat exchanger, however this was not attached as scale.

#### 2. Calculated Data

As discovered in the testing of W-28, the W-24 boiling point elevation increased as saturation was approached. Other data showed no significant difference between W-28 tests.

#### 3. Steady State Operation

The primary purpose behind Test # 6 was to determine the characteristics of W-24 under steady state operation. It was requested that further inquiry into the possible formation of scale be pursued. The presence of silica within the W-24 surrogate had no significant affect upon the titanium tube bundle after eleven hours of steady state operation. Careful observation of the W-24 surrogate contents in comparison to the W-24 supernate contents provided by PAI Corporation, revealed the presence of several metal elements within the actual W-24 supernate samples. The presence of these metal elements suggest that the actual contents of the tank might

\* Raw data for Test # 6 is listed in Appendix F.

give rise to scaling problems. Further studies into this area revealed that as long as the pH of the W-24 supernate was maintained between 11 -11.5, there should be no scale formation\*.

The results of Test # 6 were based on a 20 - 45% volume reduction. The W-24 surrogate was concentrated to 20% which equates to one gallon of distillate removal from a 5 gallon test sample. Once the 20% concentration was achieved, the distillate dump (TC5) was directed back into the concentrate tank (601). This plumbing modification allowed Test # 6 to simulate steady-state operation at a minimum concentration of 20% increasing to a maximum concentration of approximately 40% right before the distillate is transferred. Operating at these concentration levels allowed for a scaling study at steady state conditions. Also, the boiling point elevation could be analyzed at steady-state conditions for anticipated levels of concentration.

**TESTS # 3 & # 7 - W-24**

JULY 16 &amp; AUGUST 31, 1992

TIME	VAPOR TEMP. (°F)	PROD. RATE ( <sup>b</sup> /HR)	BPE (°F) ΔT: T-6 & T-7	VAPOR VEL. ( <sup>f</sup> /s)	CONDUCTIVITY MICRO - <sup>μ</sup> /cm
<b>#3</b>					
1000	141	N/A	8	N/A	2.1
1030	138	8.34	11	6.5	0.8
1100	135	8.34	14	7.0	0.6
1118	132	N/A	18	N/A	1.1
<b>#7</b>					
1325	134	3.15	6	2.7	2.6

**TESTS # 4 & # 8 - W-24**

JULY 16 &amp; SEPT. 1, 1992

TIME	VAPOR TEMP. (°F)	PROD. RATE ( <sup>b</sup> /HR)	BPE (°F) ΔT: T-6 & T-7	VAPOR VEL. ( <sup>f</sup> /s)	CONDUCTIVITY MICRO - <sup>μ</sup> /cm
<b>#4</b>					
1440	161	N/A	10	N/A	---
1455	160	16.68	12	7.8	1.2
1520	155	13.01	18	6.8	1.4
<b>#8</b>					
0900	159	13.29	11	6.35	1.4

## TEST # 6 - W-24

AUGUST 20, 1992

TIME	VAPOR TEMP. (°F)	PROD. RATE ( <sup>lb</sup> /HR)	BPE (°F) ΔT:T-6 & T-7	VAPOR VEL. ( <sup>Ft</sup> /s)	CONDUCTIVITY MICRO - <sup>°</sup> /cm
1400	138	Recycled Dist.	9	N/A	8
1500	137	Recycled Dist.	11	N/A	10
1600	139	Recycled Dist.	12	N/A	7
1700	133	Recycled Dist.	9	N/A	10
0919	146	Recycled Dist.	6	N/A	9
1017	146	Recycled Dist.	8	N/A	8
1107	148	Recycled Dist.	6	N/A	8
1210	146	Recycled Dist.	7	N/A	7
1338	147	Recycled Dist.	5	N/A	6
1430	147	Recycled Dist.	6	N/A	5.8
1525	148	Recycled Dist.	6	N/A	5.9

## V. CONCLUSION

The data and observations collected from nine tests involving two surrogate solutions allows for confident replies concerning treatment by evaporation. Data from these tests support the premise that volume reduction by approximately 30% is attainable through sub-atmospheric evaporation. The results also show that steady-state operation at concentration levels ranging from 20% to 40% can be achieved and maintained with minimal scale formation, as applied to the surrogate test solution. Computer analysis contained in Appendix F indicates that scaling of the W-24 tank could be controlled with simple pH adjustment. The gradual increase in BPE as the concentration increases suggests that a simple temperature differential controller maybe the easiest way to control the concentrate extraction. As soon as crystals form the BPE drops. Therefore monitoring the vapor temperature and the concentration recycle temperature differential will allow a set point to be established to start a concentrate extraction pump. Test data reveals that between 18-20° BPE precipitation occurs. Although the decontamination factors were good and acceptable further improvements are always welcomed and these will be addressed in the recommendations.

The percent volume reduction is figured as the amount of distillate produced divided by the starting feed volume which was always five gallons. The decon factors, as calculated by PAI, are shown in Appendix A dated 8/19/92 by Vic Fowler. Since actual DF will be dependent upon chemical analysis, this data was not duplicated in the body of the report.

Vapor velocities indicate that there are no significant distillate conductivity improvements with lower vapor velocities in the operating temperature ranges that were studied. Standard LICON design for separator and mesh velocities will be maintained in the design for this evaporator. PAI Corporation and Oak Ridge National Laboratories should be confident in further pursuits into implementing vacuum evaporation for volume reduction of radioactive wastewater.

During test number 6, the exchanger was first rubbed by hand to remove any non-attached salt, then weighed. The difference in weight was 2.355 lbs at the start and 2.358 lbs. at the finish. This difference is not significant and can be explained by non-attached salt. It does tell us, however that in the design of the operational unit, it would be helpful to have a distilled water spray flush on top of the tube bundle at shut down to wash salt build up off the bundle. This could also be controlled by concentrate removal prior to saturation.

\* Note: Refer to Appendix F for test data and observations.

## VII. RECOMMENDATIONS

As a result of numerous meetings and telephone conversations, several issues have been addressed with regard to the final design of this evaporator. It is LICON's recommendation that a single-effect, hot water or steam heated evaporator be used. Based upon the performance of the surrogate testing, the only modifications that we would recommend are vapor washing, spray flushing of the evaporator, deflector plates on the vapor uptakes and reversal of flow of the vapor prior to condensation. All but flushing the evaporator have to do with achieving better decontamination. The unit should be designed to operate in the range of 155-175°F vapor temperature with a maximum of 20°F boiling point elevation.

Final decisions need to be made by ORNL with regard to evaporative capacity and the support services, such as hot water heating or steam and cooling towers or radiators. Also, the amount of and area of shielding need to be defined. LICON would recommend that just the evaporator and concentrate portion be lead shielded. Total automation of the system will allow remote operation, and with the use of dual concentrate pumps and possibly eductors, maintenance will be further minimized. With proper research and engineering, volume reduction of the radioactive supernate will be successful.

## **APPENDICES**

**APPENDIX A**

**TEST RESULTS: SURROGATE W-24 & W-28  
JULY 23, 1992**

July 23, 1992

Mr. Vic Fowler  
 Mr. Joe Perona  
 Oak Ridge National Lab.  
 Bldg. 3017  
 P. O. Box 2008  
 Oak Ridge, TN 37831-6342

REF: Pilot Testing on Surrogate Solutions  
 for PAI Corporation  
 Subcontract No. PAI-9201

Gentlemen:

We at LICON want to thank you for confidence in our company and your assistance during the pilot testing at our Pensacola facility. As you witnessed, the test results were exceptional and point toward a successful installation.

The following are observations and procedures obtained through the feasibility study.

1. Mixing

There was some pH changes noticed after mixing each drum's contents prior to testing. I do not believe the changes would affect the evaporator's performance, but is listed here as incidental information.

Drum W-29<sup>nd</sup> Before mixing 11.7 pH  
 After mixing 11.6 pH

Drum W-28 Before mixing 8.3 pH  
 After mixing 8.8 pH

2. Foaming Results

Test #1	No foam
Test #2	No foam
Test #3	No foam
Test #4	No foam
Test #5	No foam

Page 2  
July 23, 1992

3. Concentration Ratios

According to the reduction ratios at the point of salting out, the only variable is the operating temperatures. We were able to obtain higher reduction numbers at higher temperatures because the solubility increased as well.

4. Vapor Velocities

The separation performance did not vary significantly as the velocities changed in sink with the vapor temperatures.

5. Variation of pH

The results were so terrific on the 2 pH variations provided, it was deemed by all to be satisfactory and further variance unnecessary.

6. Scaling Tendencies

With the samples provided, there was no scaling observed or measured after any of the tests. After each test, the bundle would be removed and water rinsed to dissolve any salt crystals. The cleaning did not involve the scrubbing of the tube surfaces at any time. The assembly was air dried before weighing.

**LICON**

**LICON INCORPORATED  
LOG SHEET  
PILOT EVAPORATION/CONCENTRATION TEST**

CLIENT: Oak Ridge National Lab JOB# 2107-T

Test # 1

DATE: <u>July 14, 1992</u>						
TIME:	<u>11:00</u>	<u>12:00</u>	<u>2:00</u>	<u>3:00</u>	<u>4:00</u>	
<b>TEMPERATURES: °F</b>						
T-1 CONDENSER IN	<u>91</u>	<u>90</u>	<u>86</u>	<u>89</u>	<u>88</u>	
T-2 CONDENSER OUT	<u>96</u>	<u>92</u>	<u>87</u>	<u>99</u>	<u>98</u>	
T-3 EVAPORATOR OUT	<u>128</u>	<u>118</u>	<u>129</u>	<u>132</u>	<u>133</u>	
T-4 EVAPORATOR IN	<u>128</u>	<u>118</u>	<u>129</u>	<u>133</u>	<u>133</u>	
T-5 DISTILLATE	<u>104</u>	<u>107</u>	<u>110</u>	<u>109</u>	<u>114</u>	
T-6 VAPOR	<u>116</u>	<u>112</u>	<u>118</u>	<u>116</u>	<u>117</u>	<u>8° BPE</u>
T-7 CONC. RECYCLE	<u>122</u>	<u>116</u>	<u>125</u>	<u>124</u>	<u>125</u>	
T-8 EVAPORATOR FEED	<u>119</u>	<u>115</u>	<u>123</u>	<u>122</u>	<u>123</u>	
<b>FLOWS:</b>						
605 FEED (GPH)	<u>50</u>	<u>60</u>	<u>60</u>	<u>60</u>	<u>60</u>	
COOLING WATER (GPH)	<u>30</u>	<u>30</u>	<u>90</u>	<u>60</u>	<u>60</u>	
<b>PRESSURES:</b>						
P1 DISTILLATE PUMP	PSI	<u>35</u>	<u>35</u>	<u>35</u>	<u>35</u>	<u>35</u>
P2 COOLING PUMP	"	<u>39</u>	<u>39</u>	<u>21</u>	<u>45</u>	<u>45</u>
P3 HEATING PUMP	"	<u>11</u>	<u>11</u>	<u>11</u>	<u>10</u>	<u>10</u>
C1 VACUUM	in./Hg.	<u>26</u>	<u>26</u>	<u>25</u>	<u>25</u>	<u>25</u>
C2 CONC. PUMP	PSI	<u>0-5</u>	<u>0-5</u>	<u>0-5</u>	<u>0-5</u>	<u>0-5</u>
TOTAL AMPS		<u>N.A.</u>	<u>-</u>			
VOLTAGE		<u>220</u>	<u>-</u>			
HOUR METER READING		<u>N.A.</u>	<u>-</u>			
VOLUME CHECK	Gallons	<u>-</u>	<u>-</u>			
407 CONDUCTIVITY	Micro S/cm	<u>16.5</u>		<u>2.3</u>	<u>1.4</u>	<u>1.3</u>
SAMPLE		<u>1</u>		<u>2</u>	<u>3</u>	<u>4</u>
DISTILLATE pH		<u>N.A.</u>		<u>8.3</u>	<u>8.0</u>	<u>8.0</u>
CONCENTRATE pH		<u>8.2</u>		<u>7.8</u>	<u>7.7</u>	<u>7.5</u>
<b>NOTES:</b>						
<u>W-28 Surrogate</u> <u>5 gallons Initial volume</u>						
<u>Feed Sample pH 8.8</u> <u>No foaming</u>						
<u>Temperature increased at 12:00</u> <u>No Scaling</u>						
<u>Initial Evaporator Heat Exchanger Weight 1070 grams</u>						
<u>Heat Exchanger Weight after pilot test 1070 grams</u>						
OPERATOR <u>John D. Campbell</u> PROJECT MANAGER <u>John D. Campbell</u>						

**LICON**

**LICON INCORPORATED**  
**LOG SHEET**  
**PILOT EVAPORATION/CONCENTRATION TEST**

Test #1

CLIENT: Oak Ridge National Lab JOB# 2107-T

DATE: July 15, 1992	9:30	9:45				
TIME:						
<b>TEMPERATURES:</b>						
T-1 CONDENSER IN	91	91				
T-2 CONDENSER OUT	91	99				
T-3 EVAPORATOR OUT	130	142				
T-4 EVAPORATOR IN	130	143				
T-5 DISTILLATE						
T-6 VAPOR	122	120				
T-7 CONC. RECYCLE	136	135				
T-8 EVAPORATOR FEED	129					
<b>FLOWS:</b>						
605 FEED (GPH)	60	60				
COOLING WATER (GPH)	60	60				
<b>PRESSURES:</b>						
P1 DISTILLATE PUMP	35	35				
P2 COOLING PUMP	45	45				
P3 HEATING PUMP	10	10				
C1 VACUUM	25	25				
C2 CONC. PUMP	0-5	0-5				
TOTAL AMPS						
VOLTAGE						
HOUR METER READING						
VOLUME CHECK Gallons	1.75					
407 CONDUCTIVITY Micro S/cm	11.0	1.5				
SAMPLE	5, 6*	7*, 8				
DISTILLATE pH						
CONCENTRATE pH						

## NOTES:

\* Denotes concentrate sample Test restarted at 9:15

Salt formation at 9:45

OPERATOR John D. Campbell PROJECT MANAGER John D. Campbell

**LICON**

LICON INCORPORATED  
LOG SHEET  
PILOT EVAPORATION/CONCENTRATION TEST

CLIENT: Oak Ridge National Lab JOB# 2107-T

Test #2

DATE:	July 15, 1992					
TIME:	1:35	2:05	2:20	2:25	2:48	
TEMPERATURES: °F						
T-1 CONDENSER IN	87	88		87		
T-2 CONDENSER OUT	121	124		122		
T-3 EVAPORATOR OUT	178	180		180		
T-4 EVAPORATOR IN	183	183		182		
T-5 DISTILLATE	136	147		144		
T-6 VAPOR	153	157		154	] 15° BPE	
T-7 CONC. RECYCLE	162	168		169		
T-8 EVAPORATOR FEED	150	163		165		
FLOWS:						
605 FEED (GPH)	50	50		50		
COOLING WATER (GPH)	50	50		50		
PRESSURES:						
P1 DISTILLATE PUMP	35	35		35		
P2 COOLING PUMP	49	49		49		
P3 HEATING PUMP	7-8	10		7-8		
C1 VACUUM	20.5	20.5		20.5		
C2 CONC. PUMP	5-10	5-10		5-10		
TOTAL AMPS						
VOLTAGE						
HOUR METER READING						
VOLUME CHECK Tank level	.75	1.25	1.63	1.75	2.25	
407 CONDUCTIVITY micro S/cm	3.2	2.9		2.5	3.1	
SAMPLE	1	2	3*	*4, 5	*6, 7	
DISTILLATE pH	7.7	7.4				
CONCENTRATE pH	7.5	7.5				
NOTES:						
* Denotes concentrate sample						
2:48 Salting out in evaporator, Test Terminated <span style="border: 1px solid black; border-radius: 50%; padding: 2px;">20° BPE</span> <span style="float: right;">W-28</span>						
Evaporator heat exchanger "after test" weight = 1070 grams						
No Scaling						
OPERATOR	John D. Campbell			PROJECT MANAGER	John D. Campbell	

**LICON**

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**LOG SHEET**  
**PILOT EVAPORATION/CONCENTRATION TEST**

Test # 3 CLIENT: Oak Ridge National Lab JOB# 2107-T

DATE: July 16 1992						
TIME:	9:30	10:00	10:30	11:00	11:18	11:26
TEMPERATURES: °F						
T-1 CONDENSER IN	88	87	87	87	88	
T-2 CONDENSER OUT	116	111	110	108	107	
T-3 EVAPORATOR OUT	162	158	159	158	159	
T-4 EVAPORATOR IN	166	160	161	160	160	
T-5 DISTILLATE	128	132	130	128	125	
T-6 VAPOR	143	141	138	135	132	131
T-7 CONC. RECYCLE	150	149	149	149	150	149
T-8 EVAPORATOR FEED	135	146	146	146	147	
FLOWS:						
605 FEED (GPH)	60	60	60	60	60	
COOLING WATER (GPH)	60	60	60	60	60	
PRESSURES:						
P1 DISTILLATE PUMP PSI	35	35	35	35.5	35	
P2 COOLING PUMP "	50	46	46	46.5	46.5	
P3 HEATING PUMP "	11	12	12	11.5	13	
C1 VACUUM in./Hg	22.5	22.5	23.0	23.0	23.5	
C2 CONC. PUMP PSI	5-10	7-12	7-12	7-12	7-12	
TOTAL AMPS	230					
VOLTAGE	220					
HOUR METER READING	N.A.					
VOLUME CHECK	-	.5	1.0	1.5	1.75	1.8
407 CONDUCTIVITY micro S/cm	7.8	2.1	0.8	0.6	1.1	7.4
SAMPLE	1	2	3	4, 5	6, 7	8, 9
DISTILLATE pH	8.5	7.9	7.3			
CONCENTRATE pH	11.0					

## NOTES:

Salting out at 11:26

BPE = 18°F

W-24

No Scaling

Heat Exchanger weight after test 1070 grams

OPERATOR John D. CampbellPROJECT MANAGER John D. Campbell

**LICON**

**LICON INCORPORATED**  
**LOG SHEET**  
**PILOT EVAPORATION/CONCENTRATION TEST**

CLIENT: Oak Ridge National Lab JOB# 2107-T

Test #4

DATE: <u>July 16, 1992</u>						
TIME:	<u>2:25</u>	<u>2:40</u>	<u>2:55</u>	<u>3:05</u>	<u>3:20</u>	
TEMPERATURES: °F						
T-1 CONDENSER IN	<u>89</u>	<u>89</u>	<u>88</u>		<u>89</u>	
T-2 CONDENSER OUT	<u>124</u>	<u>125</u>	<u>124</u>		<u>123</u>	
T-3 EVAPORATOR OUT	<u>186</u>	<u>185</u>	<u>184</u>		<u>186</u>	
T-4 EVAPORATOR IN	<u>192</u>	<u>189</u>	<u>190</u>		<u>189</u>	
T-5 DISTILLATE	<u>144</u>	<u>151</u>	<u>150</u>		<u>147</u>	
T-6 VAPOR	<u>160</u>	<u>161</u>	<u>160</u>	<u>158</u>	<u>155</u>	
T-7 CONC. RECYCLE	<u>168</u>	<u>171</u>	<u>172</u>	<u>173</u>	<u>173</u>	
T-8 EVAPORATOR FEED	<u>155</u>	<u>166</u>	<u>167</u>		<u>169</u>	
FLOWS:						
605 FEED (GPH)	<u>60</u>	<u>60</u>	<u>60</u>	<u>60</u>	<u>60</u>	
COOLING WATER (GPH)	<u>60</u>	<u>60</u>	<u>60</u>	<u>60</u>	<u>60</u>	
PRESSURES:						
P1 DISTILLATE PUMP	PSI	<u>35</u>	<u>35</u>	<u>35.5</u>		<u>35</u>
P2 COOLING PUMP	"	<u>47</u>	<u>47</u>	<u>48</u>		<u>48</u>
P3 HEATING PUMP	"	<u>8</u>	<u>8</u>	<u>10</u>		<u>10</u>
C1 VACUUM	In/Hg.	<u>19.5</u>	<u>19.0</u>	<u>19.0</u>		<u>20.0</u>
C2 CONC. PUMP	PSI	<u>2-8</u>	<u>2-8</u>	<u>2-10</u>		<u>2-10</u>
TOTAL AMPS		<u>N.A.</u>				
VOLTAGE		<u>220</u>				
HOUR METER READING						
VOLUME CHECK		<u>0.5</u>	<u>1</u>	<u>1.5</u>	<u>1.75</u>	<u>2.4</u>
407 CONDUCTIVITY	micro S/cm	<u>3.8</u>		<u>1.2</u>	<u>1.3</u>	<u>1.4</u>
SAMPLE		<u>1</u>		<u>2,3</u>	<u>4,5</u>	<u>6,7</u>
DISTILLATE pH						
CONCENTRATE pH						
NOTES:						
<u>Salting out at 3:20                      B.P.E = 18°F      W-24</u>						
<u>No Scaling</u>						
<u>Heat Exchanger weight after test      1070 grams</u>						
OPERATOR <u>John D. Campbell</u> PROJECT MANAGER <u>John D. Campbell</u>						

VLF 8-19-92

OTE: Preliminary Evaluation From LICON Tests:

W-24 Surrogate: Feed TDS=405,665 mg/L, pH=12.8, Si=210 mg/L

W-28 Surrogate: Feed TDS=391,836 mg/L, pH= 9.1, Si=&lt;0.2 mg/L

Test No.	Vol. Red. (%)	Evap. Press. ("Hg)	Conc. Temp. (°F)	Vapor Temp. (°F)	Recycle Rate (GPH)	Evaporation Rate (GPH)	DF** (Conc./Dist.)
#1, W-28	-30	25.0	136.0	122.0	60.0	0.32	1.4x10 <sup>5</sup>
#2, W-28	-30	20.5	169.0	154.0	50.0	1.85	2.2x10 <sup>5</sup>
#3, W-24	-30	23.5	150.0	132.0	60.0	0.95	2.3x10 <sup>5</sup>
#4, W-24	-30	19.5	173.0	155.0	60.0	2.62	1.9x10 <sup>5</sup>

Comments:

- No Foaming Problems during any Test.
- No Scaling/Fouling of HX surfaces occurred (2.08 ft<sup>2</sup> HX Surface)

• Volume Reduction, %=(Dist./Feed)100

\*\* Decontamination Factor (DF)=Conc./Dist., based on TDS

VLF 8-19-92

Sample Solids Content and Densities

Test No.	FEED		Concentrate*		Distillate*	
	TDS (mg/L)	Density (g/mL)	TDS (mg/L)	Density (g/mL)	TDS (mg/L)	Density (g/mL)
#1, W-28	391,386	1.266	579,521	1.454	4.23	1.005
#2, W-28	391,386	1.266	579,521	1.444	2.66	1.002
#3, W-24	405,665	1.236	559,765	1.414	2.41	1.004
#4, W-24	405,665	1.236	559,765	1.391	2.91	1.004

\* Analytical data from samples attained at a Volume Reduction of ~30%.



**LICON**

**LICON INCORPORATED  
LOG SHEET  
PILOT EVAPORATION/CONCENTRATION TEST**

TEST #6  
8/20/92

8/20/92

CLIENT: OAK RIDGE NAT. LABS JOB# 2107-T

DATE: <u>AUG. 20, 92</u>	<u>1400</u>	<u>1500</u>	<u>1600</u>	<u>1700</u>	
TIME: <u>STARTUP 1230</u>					

SHUT DOWN 1700 HRS

## TEMPERATURES:

T-1 CONDENSER IN	<u>119</u>	<u>121</u>	<u>122</u>	<u>120</u>
T-2 CONDENSER OUT	<u>124</u>	<u>124</u>	<u>126</u>	<u>122</u>
T-3 EVAPORATOR OUT	<u>163</u>	<u>162</u>	<u>162</u>	<u>166</u>
T-4 EVAPORATOR IN	<u>166</u>	<u>167</u>	<u>166</u>	<u>168</u>
T-5 DISTILLATE	<u>128</u>	<u>128</u>	<u>130</u>	<u>128</u>
T-6 VAPOR	<u>138</u>	<u>137</u>	<u>139</u>	<u>133</u>
T-7 CONC. RECYCLE	<u>147</u>	<u>148</u>	<u>147</u>	<u>142</u>
T-8 EVAPORATOR FEED	<u>143</u>	<u>142</u>	<u>140</u>	<u>138</u>

## FLOWS:

605 FEED (GPH) <u>2-DM</u>	<u>0.75</u>	<u>0.25</u>	<u>0.50</u>	<u>0.50</u>
COOLING WATER (GPH) <u>G.F.M.</u>	<u>7.5</u>	<u>7.0</u>	<u>7.0</u>	<u>7.0</u>

## PRESSURES:

P1 DISTILLATE PUMP	<u>35</u>	<u>35</u>	<u>35</u>	<u>35</u>
P2 COOLING PUMP	<u>26</u>	<u>20</u>	<u>20</u>	<u>20</u>
P3 HEATING PUMP	<u>10</u>	<u>9</u>	<u>9</u>	<u>9</u>
C1 VACUUM	<u>23"</u>	<u>23"</u>	<u>23"</u>	<u>23"</u>
C2 CONC. PUMP	<u>5</u>	<u>2</u>	<u>3</u>	<u>3</u>

## TOTAL AMPS

## VOLTAGE

## HOUR METER READING

## VOLUME CHECK

407 CONDUCTIVITY <u>115 G.M.</u>	<u>8</u>	<u>10</u>	<u>7</u>	<u>10</u>
SAMPLE				
DISTILLATE pH	<u>7.8</u>	<u>7.6</u>	<u>7.9</u>	<u>7.9</u>
CONCENTRATE pH	<u>11.3</u>	<u>11.2</u>	<u>11.1</u>	<u>11.2</u>

\* W-24 SURROGATE

## NOTES:

\* TUBE BUNDLE WAS PULLED AND WEIGHED BEFORE TEST

TUBE BUNDLE WEIGHT = 2.355 lbs

\* 5 GALLON SAMPLE W-24

\* ACHIEVED 2.25 GALLONS OF DISTILLATE = 45% REDUCTION IN VOLUME

\* RETURNED 1.27 GALLONS OF DISTILLATE TO CONCENTRATE TANK AND RECYCLED DISTILLATE BACK TO CONCENTRATE.

OPERATOR

Ken Hunt

PROJECT MANAGER





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LOG SHEET  
PILOT EVAPORATION/CONCENTRATION TEST**

CLIENT: OAK RIDGE NAT. LABS JOB# 2107-T

TEST# 7

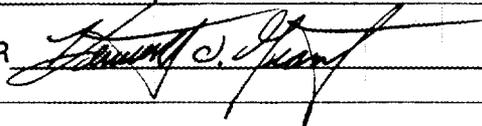
DATE:	<u>AUGUST 31, 92</u>				
TIME:	<u>STARTUP 1055</u>	<u>1125</u>	<u>1225</u>	<u>1325</u>	<u>1435</u>
	<u>SHUT DOWN 1451</u>				
<b>TEMPERATURES:</b>					
T-1 CONDENSER IN	<u>123</u>	<u>124</u>	<u>125</u>	<u>125</u>	
T-2 CONDENSER OUT	<u>125</u>	<u>126</u>	<u>127</u>	<u>127</u>	
T-3 EVAPORATOR OUT	<u>150</u>	<u>152</u>	<u>151</u>	<u>151</u>	
T-4 EVAPORATOR IN	<u>152</u>	<u>154</u>	<u>153</u>	<u>153</u>	
T-5 DISTILLATE	<u>128</u>	<u>129</u>	<u>130</u>	<u>130</u>	
T-6 VAPOR	<u>133</u>	<u>133</u>	<u>134</u>	<u>134</u>	
T-7 CONC. RECYCLE	<u>138</u>	<u>140</u>	<u>140</u>	<u>141</u>	
T-8 EVAPORATOR FEED	<u>134</u>	<u>137</u>	<u>137</u>	<u>138</u>	
<b>FLOWS:</b>					
605 FEED (GPH)	<u>30</u>	<u>24</u>	<u>24</u>	<u>24</u>	
COOLING WATER (GPH)	<u>180</u>	<u>180</u>	<u>150</u>	<u>120</u>	
<b>PRESSURES:</b>					
P1 DISTILLATE PUMP	<u>35</u>	<u>35</u>	<u>35</u>	<u>35</u>	
P2 COOLING PUMP	<u>18</u>	<u>13</u>	<u>14</u>	<u>14</u>	
P3 HEATING PUMP	<u>14</u>	<u>14</u>	<u>14</u>	<u>14</u>	
C1 VACUUM	<u>24</u>	<u>23</u>	<u>23</u>	<u>23</u>	
C2 CONC. PUMP	<u>2</u>	<u>2</u>	<u>2</u>	<u>2</u>	
TOTAL AMPS					
VOLTAGE					
HOUR METER READING					
VOLUME CHECK					
407 CONDUCTIVITY $\mu\text{S}/\text{cm}$		<u>3.2</u>	<u>2.6</u>	<u>1.4</u>	
SAMPLE					
DISTILLATE pH	<u>---</u>	<u>8.1</u>	<u>8.0</u>	<u>9.0</u>	
CONCENTRATE pH	<u>---</u>	<u>11.8</u>	<u>11.4</u>	<u>11.6</u>	

\* W-24 SURROGATE

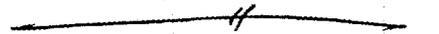
## NOTES:

SAMPLE WEIGHT - 46.898 lbsCONCENTRATE WT.  $\approx$  33.334 lbs - LOSSES DUE TO TRANSFERDISTILLATE PRODUCED - 10.982 lbs - BETWEEN 1125 - 1451AVERAGE PRODUCTION - 0.38 GPHVOLUME REDUCTION = 23.4%VOLUME REDUCTION =  $\frac{\text{DIST. PROD.}}{\text{SAMPLE WT.}}$ 

OPERATOR



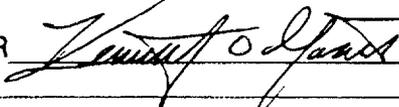
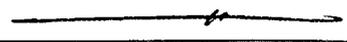
PROJECT MANAGER



**LICON INCORPORATED**  
**LOG SHEET**  
**PILOT EVAPORATION/CONCENTRATION TEST**

CLIENT: OAK RIDGE NAT. LABS JOB# 2107-T

TEST #8

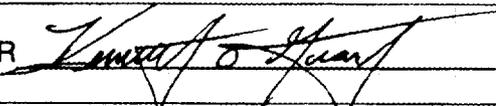
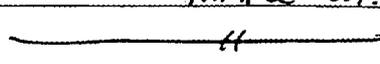
DATE: <u>SEPTEMBER 1, 92</u>					
TIME: <u>0745 STARTUP</u>	<u>0830</u>	<u>0900</u>	<u>0930</u>		
<u>0935 SHUTDOWN</u>					
<b>TEMPERATURES:</b>					
T-1 CONDENSER IN	<u>146</u>	<u>148</u>	<u>146</u>		
T-2 CONDENSER OUT	<u>148</u>	<u>149</u>	<u>147</u>		
T-3 EVAPORATOR OUT	<u>170</u>	<u>183</u>	<u>186</u>		
T-4 EVAPORATOR IN	<u>186</u>	<u>188</u>	<u>190</u>		
T-5 DISTILLATE	<u>148</u>	<u>152</u>	<u>150</u>		
T-6 VAPOR	<u>158</u>	<u>159</u>	<u>156</u>		
T-7 CONC. RECYCLE	<u>166</u>	<u>170</u>	<u>169</u>		
T-8 EVAPORATOR FEED	<u>151</u>	<u>165</u>	<u>166</u>		
<b>FLOWS:</b>					
605 FEED (GPH)	<u>27</u>	<u>27</u>	<u>27</u>		
COOLING WATER (GPH)	<u>240</u>	<u>240</u>	<u>240</u>		
<b>PRESSURES:</b>					
P1 DISTILLATE PUMP	<u>35</u>	<u>35</u>	<u>35</u>		
P2 COOLING PUMP	<u>47</u>	<u>46</u>	<u>45</u>		
P3 HEATING PUMP	<u>12</u>	<u>12</u>	<u>12</u>		
C1 VACUUM	<u>2</u>	<u>2</u>	<u>2</u>		
C2 CONC. PUMP	<u>19</u>	<u>19</u>	<u>19</u>		
TOTAL AMPS					
VOLTAGE					
HOUR METER READING					
VOLUME CHECK					
407 CONDUCTIVITY <u>µS/cm</u>	<u>3.4</u>	<u>1.4</u>	<u>1.2</u>		
SAMPLE					
DISTILLATE pH	<u>8.4</u>	<u>8.7</u>	<u>8.4</u>		
CONCENTRATE pH	<u>11.4</u>	<u>11.4</u>	<u>11.7</u>		
* W-24 SURROGATE					
<b>NOTES:</b>					
<u>SAMPLE WEIGHT - 44.062 lbs</u>					
<u>CONCENTRATE WT. ≈ 23.728 lbs - LOSSES DUE TO TRANSFER</u>					
<u>DISTILLATE PRODUCED - 19.936 lbs. - BETWEEN 0800 - 0930</u>					
<u>AVERAGE PRODUCTION - 1.6 GPH</u>					
<u>VOLUME REDUCTION - 45.2%</u>					
<u>VOL. RED = DIST. PROD.</u>					
<u>SAMPLE WT.</u>					
OPERATOR	<u></u>		PROJECT MANAGER	<u></u>	

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**PILOT EVAPORATION/CONCENTRATION TEST**

CLIENT: OAK RIDGE NAT. LABS JOB# 2107-T

TEST #9

DATE:	SEPTEMBER 1, 1992						
TIME:	1320 STARTUP	1350	1430	1520			
	1535 SHUTDOWN						
<b>TEMPERATURES:</b>							
T-1 CONDENSER IN	143	146	145				
T-2 CONDENSER OUT	144	147	146				
T-3 EVAPORATOR OUT	174	173	174				
T-4 EVAPORATOR IN	177	175	176				
T-5 DISTILLATE	145	149	148				
T-6 VAPOR	152	153	153				
T-7 CONC. RECYCLE	161	164	164				
T-8 EVAPORATOR FEED	154	161	161				
<b>FLOWS:</b>							
605 FEED (GPH)	30	30	30				
COOLING WATER (GPH)	300	180	60				
<b>PRESSURES:</b>							
P1 DISTILLATE PUMP	35	35	35				
P2 COOLING PUMP	49	21	19				
P3 HEATING PUMP	13	13	13				
C1 VACUUM	20.5	20.5	20.5				
C2 CONC. PUMP	2	2	2				
TOTAL AMPS							
VOLTAGE							
HOUR METER READING							
VOLUME CHECK							
407 CONDUCTIVITY $\mu\text{S}/\text{cm}$	2.8	2.2	2.4				
SAMPLE							
DISTILLATE pH	8.7	8.8	8.2				
CONCENTRATE pH	8.5	8.4	8.4				
* W-28 SURROGATE							
<b>NOTES:</b>							
SAMPLE WEIGHT - 43.492 lbs							
CONCENTRATE WT $\approx$ 22.141 lbs - LOSSES DUE TO TRANSFER							
DISTILLATE PRODUCED - 20.291 lbs BETWEEN 1335 - 1535							
AVERAGE PRODUCTION - 1.22 GPH							
VOLUME REDUCTION - 46.7% VOLUME RED = $\frac{\text{DIST. PRODUCED}}{\text{SAMPLE WT.}}$							
OPERATOR				PROJECT MANAGER			

**APPENDIX B**

**LETTERS OF CORRESPONDENCE**

April 28, 1992

Mr. Vic Fowler  
Oak Ridge National Laboratory  
Bldg. 3017  
P. O. Box 2008  
Oak Ridge, TN 37831-6342

REF: Proposal 920429-080000-ORNL  
Proposal for a Pilot Test

Dear Mr. Fowler:

We want to thank you and Joe Perona for visiting the LICON facility on April 16. We enjoyed having you and always welcome the opportunity to show off our equipment to people who can appreciate it.

In response to your request to run extended surrogate test solutions at LICON's facility to study scaling tendencies, we propose the following test schedule and variables. Accurate weight measurement of the tube bundle will be made at the start and end of each test. As we discussed during our meeting, LICON will record all operating data temperatures and pressures and monitor the following six control factors.

1. Foaming

Is antifoam required? If so, how much? What type? We will test 3 different antifoams if needed.

2. Circulation Rate (Recirc to evaporator)

We will vary the feed rate to the evaporator from 5 GPH, 10 GPH, 30 GPH and 60 GPH and record the effects on scale, carry over and concentration ratios.

3. Temperatures & Pressures

Temperatures and pressures (vacuum) will be changed from a maximum of 26" Hg up to 17" Hg in approx. 3" Hg increments.

4. Concentration ratio

Varying degrees of concentration ratios will be plotted at 85, 90, 95 and maximum achievable percent volume reduction. These can be compared with chemical analytical data for which we will send you samples to analyze. We have Hach test kit capability only, but we can analyze for 1-3 chemicals.

5. pH

pH will be adjusted from 6.5, 7.5, 10 and 13 and compared with scaling, foaming and DF results.

6. Vapor Velocities

Vapor velocities through the mesh and in the vapor uptakes will be calculated for each condition.

A total of four tests will be conducted and run for 15 hours (each), under each set of operating parameters; for example test 1 will be at feed 5 GPH (2 GPH over evaporation rate) 26" Hg, 85% concentration, pH 13. Test 2 will be at feed 10 GPH, 24" Hg, 90% concentration, pH 10. Similarly for tests 3 and 4. Note, these parameters may be changed and noted as such if field observations and test results warrant it. Following each test, the tube bundle will be weighed and the equipment cleaned. The results will be turned in to an engineer for evaluation and inclusion into a final report. Rates for LICON technicians and engineers are printed at \$550 per day for technicians and \$650 per day for engineers (copy enclosed). Rental use for the equipment is \$200 per day.

The price does not include the purchase of chemicals. When the exact surrogate solution is decided upon, LICON can purchase the chemicals or ORNL may purchase the chemicals and forward them to LICON. All final concentrate will be shipped back to ORNL for disposal. All solutions will be mixed using distillate water as evaporated from city water using a LICON evaporator. After review of this data similar tests may be warranted to further expand upon the data being collected.

If you have any questions, please feel free to call either Bob McElroy or myself.

Regards,



Rodney C. Williamson  
Vice President, Sales

cc: J. Campbell-Service Manager  
B. McElroy-Plant Manager

REF: Rodney\0300.tel

**LICON**

To: Vic Fowler  
Oak Ridge National Laboratory

cc: Robert McElroy  
Rodney Williamson  
John Campbell

From: Ken Grant *KG*

Date: July 13, 1992

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During a meeting between Bob McElroy, Johnny Campbell, and myself, the following strategy for testing surrogate samples W-24 and W-28 were tentatively agreed upon:

- I. Each surrogate solution will undergo 5 separate tests.
- II. Each Test will occur at a specified saturation temperature along with it's corresponding saturation pressure.
- III. During the course of each testing period, data will be collected for foaming characteristics, concentration ratios, and vapor velocities.
- IV. Foaming will be controlled by the addition of anti-foam or pH adjustment. All data concerning these adjustments will be recorded.
- V. Concentration ratios will be observed and recorded for each of the separate tests.
- VI. Scaling tendencies and amounts for each test are to be recorded.

Based on the levels of Sodium Nitrate within the surrogate solution, we initially estimate our reduction capability to be 2:1.

## **APPENDIX C**

**LICON, Inc.  
STANDARD SAMPLE TEST PROCEDURE**

## PILOT TESTING STANDARD PROCEDURE

1. Written or faxed copy of Purchase Order covering all costs including pilot test, shipping etc.
2. Chemical analysis or customer provided description of the sample composition.
3. Knowledge of personal and equipment hazards associated with each waste water sample.
4. Customer Requirements of the Test Results:
  - a. Quick turn-around especially on biologically active samples.
  - b. Lab analysis on request and prior notice.
  - c. Return of all concentrate volume and distillate samples collected during pilot test to the customer.
  - d. Written report and data sheet sent to the customer ASAP.
5. Test Procedure:
  - a. Start machine on clean water to establish proper operation.
  - b. Obtain representative feed sample for LICON records by mixing and shaking sample containers.
  - c. Drain clean water from concentrate tank and fill with test sample.
  - d. Record pH and conductivity of representative sample.
  - e. Perform "shake" test to determine foaming characteristics. Add appropriate defoamer amount and repeat shake test. Record all findings including type of antifoam most effective.
  - f. Start processing of sample in pilot unit.
  - g. No discharge of any liquid including distillate product until determined non-hazardous.
  - h. Observe and record phase changes during "heat-up" phase, especially foaming and distillate quality trends.
  - i. Record data and collect distillate samples every 30 minutes detailing any changes and volume reduction.
  - j. Process as far as volume will allow for maximum reduction ratio.
  - k. Collect all concentrate from tank bottom and all piping into sample containers.

- l. Inspect for heat exchanger scaling, if present pull out hbx for full examination. Record amount, hardness, texture and color, retain large sample.
- m. Notation of any and all damage to test equipment resulting from a test solution.
- n. Complete flushing and cleaning of the pilot test unit and other equipment used in test period.

6. LICON Requirements:

- a. Retainment of 250 ml of feed, final concentrate and final distillate samples for LICON's records.
- b. Original data sheet and copy of report.
- c. Copies of the above sent to appropriate sales staff.
- d. Proper packaging of test samples for shipment.
- e. Prompt invoicing of pilot test, shipping costs, etc.

**APPENDIX D**

**SUPERNATE COMPOSITIONS**

Supernate Compositions; Based Upon W-24 and W-28 Data as per Sears report representing worst case for pH and Si content. WLF, 6-9-92

=====  
 File name: OTE-SUR2.WKQ

Component	W-24		W-28	
	Supernate (g/L)	moles/L	Supernate (g/L)	moles/L
NaNO3	369.80	4.35	354.50	4.17
KNO3	28.30	0.29	66.70	0.66
Na2CO3	15.90	0.15	1.06	0.01
NaCl	4.27	0.07	4.09	0.07
NaOH	0.66	0.02	0.05	0.00
Ca(NO3)2*4H2O	0.05	0.00	47.23	0.20
MgCl2*6H2O	0.01	0.00	13.37	0.07
Na2SiO3*9H2O	2.48	0.01	0.00	0.00
pH	13.10		9.10	

=====

Volume Reduction Calculations (3) (For use in Component Saturation Values)  
 \*\*\*\*Based on solubility of NaHO3 as 88 g/100 g of H2O\*\*\*\*

Basis is one (1) liter of SOLUTION.

Assumptions: Use limiting agent (Na or Nitrate conc.) to determine % red.  
 Subtract only K (grams) in determining H2O  
 (i.e. negligible other metals and anions)  
 (Do include excess Na or NO3)

		Tank W-24	Tank W-25	Tank W-26	Tank W-27	Tank W-28	Tank W-31	Tank W-29	Tank W-30
Input --	Density (g/ml)	1.2348	1.2018	1.2177	1.2118	1.2852	1.2075	1.2261	1.2218
	K (mg)	11000	17000	51000	8500	26000	9500	10000	9300
	Na (mg)	100000	78000	68000	90000	96000	94000	110000	100000
	Nitrate (M)	4.1900	4.1900	3.2900	4.5200	5.9700	4.5200	4.5200	4.3500
Output --	Nitrate (mole)	4.1900	4.1900	3.2900	4.5200	5.9700	4.5200	4.5200	4.3500
	Na (mole)	4.3478	3.3913	2.9565	3.9130	4.1739	4.0870	4.7826	4.3478
Limiting Agent---									
	Nitrate (mole)	4.1900	0.0000	0.0000	0.0000	0.0000	0.0000	4.5200	0.0000
	Na (mole)	0.0000	3.3913	2.9565	3.9130	4.1739	4.0870	0.0000	4.3478
	NaHO3 (g)	356.1500	288.2609	251.3043	332.6087	354.7826	347.3913	384.2000	369.5652
Excess Agent---									
	Na or HO3 (g)	3.6300	49.5191	20.6757	37.6313	111.3574	26.8487	6.0400	0.1348
Total Others---									
	RCRA metals (g)	0.0212	0.0183	0.0290	0.0200	0.0208	0.0167	0.0175	0.0227
	Process metals (g)	0.3160	0.3156	1.1880	2.6306	9.4770	0.0351	0.0579	0.1109
	Anions (g)	13.1089	13.0380	14.0306	13.0380	15.4840	13.3925	13.3216	13.1089
	H2O (g)	850.5740	833.6482	879.4725	817.3714	768.0782	810.3157	812.4630	829.5575
	Min. H2O (g)	404.7159	327.5692	285.5731	377.9644	403.1621	394.7628	436.5909	419.9605
	Mass Reduction (g)	445.8581	506.0790	593.8993	439.4069	364.9161	415.5529	375.8721	409.5970
	Max. % Reduction at Saturation	36.11%	42.11%	48.77%	36.26%	28.39%	34.41%	30.66%	33.52%
Volume Reduction Factor		1.80	2.02	2.46	1.78	1.57	1.71	1.60	1.69
Volume in tanks	(gal)	34200	24000	30100	29200	43600	39600		
	(liters)	129400	90900	113900	110500	165100	149900		
Volume of supernate after reduction	(gal)	21851	13894	15420	18612	31220	25972		
	(liter)	82677	52622	58348	70432	118222	98313		

MAX TANK SIZE : 50,000 GALLONS

Component Saturation Values based on information provided  
in Table 1. (To the right of this Table in the Spreadsheet)

VIC

		W-24	W-25	W-26	W-27	W-28	W-29	W-30	W-31
% Vol. Reduction		36.11%	42.11%	48.77%	36.26%	28.39%	30.66%	33.52%	34.41%
TDS	mg/mL	5.90E+02	6.01E+02	7.20E+02	5.62E+02	6.77E+02	5.41E+02	5.61E+02	5.35E+02
TS	mg/mL	5.99E+02	5.77E+02	7.14E+02	5.57E+02	6.68E+02	5.47E+02	5.84E+02	5.32E+02
Density	g/ml	1.9326	2.0760	2.3770	1.9012	1.7948	1.7681	1.8380	1.8411
IC	mg/L	2.99E+03	2.73E+01	5.04E+03	7.37E+00	9.78E+00	6.78E+02	9.01E+02	2.88E+01
TC	mg/L	3.76E+03	8.26E+02	7.53E+03	5.71E+02	8.11E+02	1.37E+03	1.15E+03	7.07E+02
TOC	mg/L	7.65E+02	7.98E+02	2.50E+03	5.63E+02	8.02E+02	6.95E+02	2.51E+02	6.79E+02
Ag	mg/L	1.08E+00	1.19E+00	2.34E+00	1.08E+00	9.64E-01	9.95E-01	1.04E+00	1.05E+00
As	mg/L	5.79E+00	6.39E+00	7.22E+00	5.80E+00	5.17E+00	5.34E+00	5.57E+00	5.64E+00
Ba	mg/L	4.54E-01	5.53E+00	3.90E-01	6.43E+00	8.10E+00	1.44E+00	1.22E+00	5.34E+00
Cd	mg/L	3.44E-01	2.07E-01	8.78E+00	1.88E-01	7.12E-01	1.73E-01	1.81E-01	1.83E-01
Cr	mg/L	4.85E+00	3.28E+00	3.51E+00	4.39E+00	5.31E-01	3.46E+00	4.36E+00	9.15E+00
Hg	mg/L	7.20E-02	9.33E-02	1.56E-01	7.53E-02	1.96E-01	1.30E-01	1.50E-01	2.29E-01
Ni	mg/L	5.95E-01	7.77E-01	1.60E+01	5.96E-01	1.96E+00	5.48E-01	5.72E-01	5.79E-01
Pb	mg/L	1.05E+01	3.63E+00	6.25E+00	3.29E+00	2.93E+00	3.17E+00	4.06E+00	3.20E+00
Se	mg/L	7.36E+00	8.12E+00	9.17E+00	7.37E+00	6.56E+00	6.78E+00	7.07E+00	7.17E+00
Ti	mg/L	2.19E+00	2.42E+00	2.73E+00	2.30E+00	1.96E+00	2.02E+00	2.11E+00	2.13E+00
Al	mg/L	7.20E+01	7.26E+00	9.37E+00	6.59E+00	7.26E+00	2.60E+01	5.11E+01	6.40E+00
B	mg/L	1.49E+00	1.04E+00	7.61E+00	1.05E+00	4.89E-01	6.35E-01	6.62E-01	3.05E-01
Ca	mg/L	1.13E+01	4.84E+02	3.90E+01	4.08E+03	1.09E+04	6.35E+00	1.52E+01	1.20E+02
Co	mg/L	8.92E-01	9.85E-01	1.11E+00	8.94E-01	7.96E-01	0.00E+00	0.00E+00	8.69E-01
Fe	mg/L	4.07E+00	4.49E+00	5.08E+00	4.08E+00	3.63E+00	3.75E+00	3.91E+00	3.96E+00
K	mg/L	1.72E+04	2.94E+04	9.96E+04	1.33E+04	3.63E+04	1.44E+04	1.40E+04	1.45E+04
Mg	mg/L	2.03E+00	2.25E+00	6.83E+00	2.04E+00	2.23E+03	1.87E+00	1.96E+00	1.98E+00
Na	mg/L	1.57E+05	1.35E+05	1.33E+05	1.41E+05	1.34E+05	1.59E+05	1.50E+05	1.43E+05
Si	mg/L	3.83E+02	1.73E+00	2.32E+01	1.57E+00	1.40E+00	1.44E+00	1.50E+00	1.31E+01
Sr	mg/L	1.16E+00	3.97E+01	1.44E+00	2.82E+01	9.08E+01	2.88E+00	2.71E+00	1.83E+01
Th	mg/L	3.44E+00	3.80E+00	1.95E+01	3.45E+00	3.07E+00	1.44E+00	1.50E+00	3.35E+00
U	mg/L	1.47E+01	1.73E-01	2.21E+03	1.57E-01	1.40E-01	6.35E+00	8.57E+00	3.81E-01
Chloride	M	1.14E-01	1.23E-01	1.93E-01	1.11E-01	1.96E-01	1.17E-01	1.19E-01	1.11E-01
Fluoride	M	4.07E-02	4.49E-02	5.08E-02	4.08E-02	3.63E-02	3.75E-02	3.91E-02	3.96E-02
Nitrate	M	6.56E+00	7.24E+00	6.42E+00	7.09E+00	8.34E+00	6.52E+00	6.54E+00	6.89E+00
Phosphate	M	8.30E-02	9.16E-02	1.03E-01	8.32E-02	7.40E-02	7.64E-02	7.97E-02	8.08E-02
Sulfate	M	8.14E-02	8.98E-02	1.02E-01	8.16E-02	7.26E-02	7.50E-02	7.82E-02	7.93E-02
pH		13.7	13.0	12.3	12.2	12.1	14.0	13.3	12.2
OH	M	4.54E-01	1.04E-01	1.95E-02	1.57E-02	1.40E-02	9.95E-01	1.96E-01	1.52E-02
CO3	M	2.35E-01	1.73E-02	3.90E-01	1.57E-02	1.40E-02	6.63E-02	7.97E-02	1.52E-02
HCO3	M	1.57E-02	1.73E-02	3.90E-02	1.57E-02	1.40E-02	1.44E-02	1.50E-02	1.52E-02
Alpha	Cl/gal	8.01E-07	3.53E-07	2.06E-04	2.89E-06	6.29E-06	1.48E-06	1.54E-06	1.56E-07
Beta	Cl/gal	3.68E-02	6.93E-02	4.39E-01	5.30E-02	1.40E-01	3.04E-02	2.95E-02	5.58E-02
C-14	Cl/gal	1.26E-04	5.81E-05	2.46E-05	2.91E-05	2.39E-05	1.34E-05	1.35E-05	1.75E-05
Ce-144	Cl/gal	1.18E-04	2.30E-04	4.59E-04	1.20E-04	2.57E-04	1.97E-04	1.90E-04	1.22E-04
Co-60	Cl/gal	5.27E-05	3.32E-04	2.44E-03	4.96E-05	1.25E-03	9.19E-05	7.53E-05	5.04E-05
Cs-134	Cl/gal	2.15E-04	6.66E-04	2.62E-03	2.58E-04	1.51E-03	3.74E-04	3.10E-04	7.81E-04
Cs-137	Cl/gal	3.54E-02	5.78E-02	4.13E-01	3.47E-02	8.09E-02	3.25E-02	2.89E-02	3.57E-02
Eu-152	Cl/gal	5.12E-05	2.83E-05	4.19E-05	1.77E-05	2.39E-04	3.10E-05	3.08E-05	1.45E-05
Eu-154	Cl/gal	9.61E-06	2.12E-05	4.79E-05	1.06E-05	1.05E-04	2.11E-05	1.85E-05	1.05E-05
Eu-155	Cl/gal	6.40E-05	1.22E-04	2.40E-04	6.42E-05	1.33E-04	1.06E-04	1.02E-04	6.55E-05
H-3	Cl/gal	4.93E-05	6.10E-05	1.23E-04	3.35E-05	1.70E-05	2.97E-05	3.11E-05	2.43E-05
Nb-95	Cl/gal	4.48E-05	1.11E-05	2.80E-05	4.81E-06	1.71E-05	9.29E-05	8.46E-06	5.15E-06
Ru-106	Cl/gal	1.76E-04	3.36E-04	5.59E-04	1.77E-04	4.31E-04	3.00E-04	2.92E-04	1.72E-04
Sr-90	Cl/gal	1.46E-04	3.45E-03	9.79E-05	8.94E-03	2.50E-02	1.04E-03	1.03E-03	1.15E-02
Zr-95	Cl/gal	8.01E-05	2.12E-05	5.39E-05	8.35E-06	3.14E-05	1.49E-05	1.52E-05	8.89E-06

**APPENDIX E**  
**SAMPLE CALCULATIONS**

**PRODUCTION RATE**

T1 (Condenser In) = 87°F  
 T2 (Condenser Out) = 121°F  
 Cooling Water (GPH) = 50

$$P = M * C * (\text{Delta-T})$$

$$(\text{lb}/\text{HR}) (\text{BTU}/\text{lb } ^\circ\text{F}) (^\circ\text{F})$$

$$M = \text{Cooling Water (GPH)}$$

$$C = 1 \text{ BTU}/\text{lb } ^\circ\text{F}$$

$$\text{Delta-T} = (T-2 - T-1) ^\circ\text{F}$$

Test # 1 / W-28 / July 14, 1992 / 12:00

T-1 = 90°F  
 T-2 = 92°F  
 M = 60 GPH

$$P = (60 \text{ GAL}/\text{H}) (8.34 \text{ lb}/\text{GAL}) (1 \text{ BTU}/\text{lb } ^\circ\text{F}) (2 ^\circ\text{F})$$

$$P = 1000.8 \text{ BTU}/\text{HR}$$

It requires 1,000 BTU's to produce 1 lb. of steam.

$$P = 1 \text{ lb}/\text{HR}$$

**VAPOR VELOCITY**

Test # 2 / W-28 / July 15, 1992 / 14:25

$$\text{PRODUCTION} = 12.51 \text{ lb/HR}$$

T6 (Vapor) = 154 °F

$$v_g = 88.52 \text{ Ft}^3/\text{Lb} \quad (\text{Specific Volume})$$

$$Q = V * A$$

$$V = Q/A$$

Q = Volumetric Flow Data

V = Velocity

A = Cross-Sectional Area

3" SCH 80 CPVC

OD = 3.5"

Thickness = 0.3"

ID = 2.9"

$$A = (3.14) (\text{DIA}^2)/4$$

$$A = 0.0459 \text{ Ft}^2$$

$$V = (12.51 \text{ Lb/Hr}) (88.52 \text{ Ft}^3/\text{Lb})/0.046 \text{ Ft}^2$$

$$V = 24,147 \text{ Ft/Hr}$$

$$V = 6.71 \text{ Ft/Sec}$$

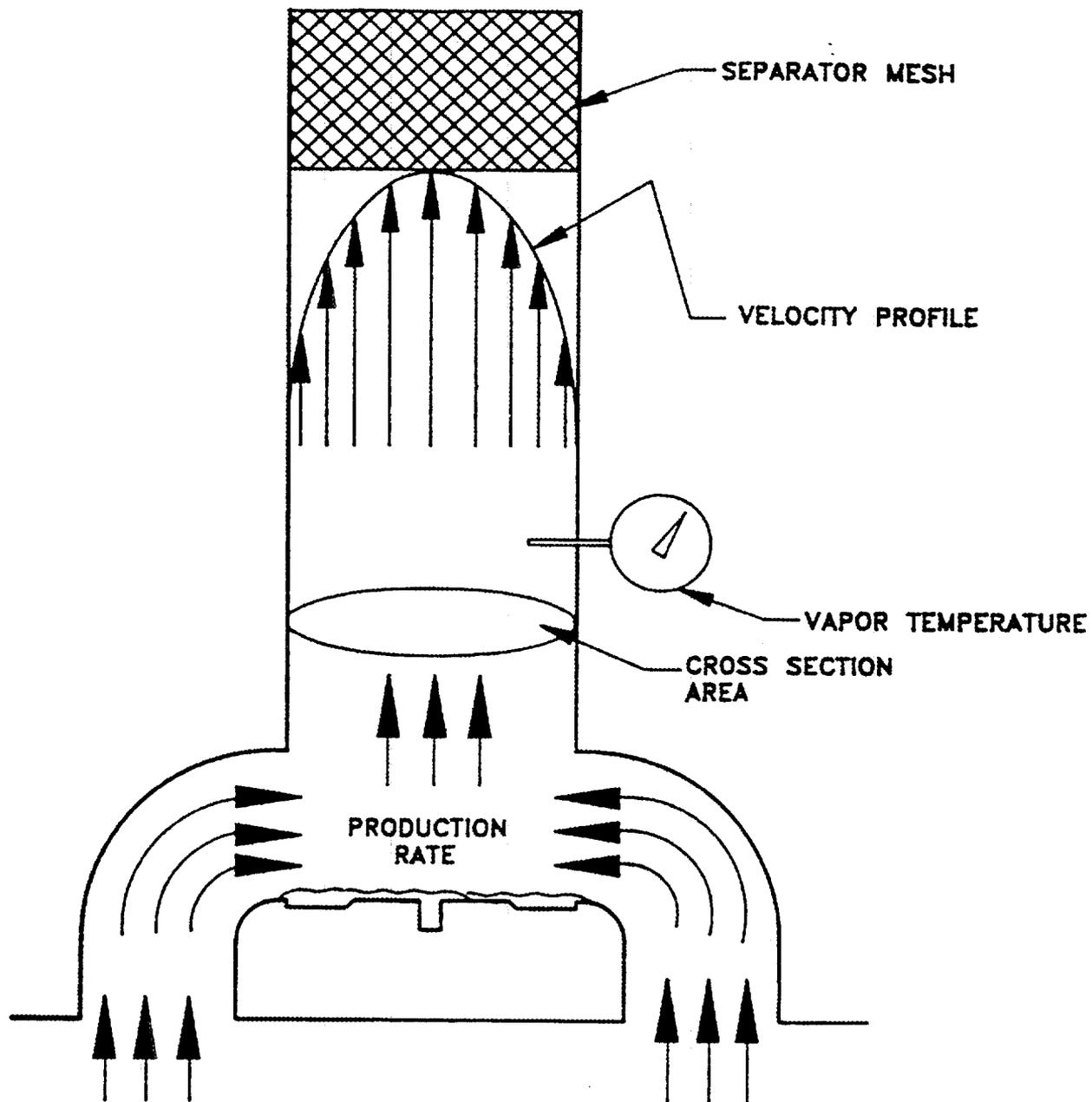


FIG. 1 VAPOR VELOCITY

**BOILING POINT ELEVATION**

Test # 1 / W-28 / July 14, 1992 / 12:00

$$\text{BPE} = (T7 - T6) \text{ } ^\circ\text{F}$$

BPE = Boiling Point Elevation

T7 = Concentrate Recycle

T6 = Vapor

$$\text{BPE} = 116^\circ\text{F} - 112^\circ\text{F}$$

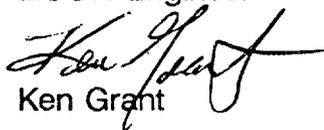
$$\text{BPE} = 4^\circ\text{F}$$

**APPENDIX F**  
**SCALE DEPOSITION**

AUGUST 27, 1992

The following report was supplied by LEPO Custom Manufacturing, Midland, Texas. From the information provided by PAI Corporation regarding the chemistry of tank W-24 (Appendix D - Volume Reduction Calculations) LEPO analyzed the possible formation of scale due to high silica presence. In order to accomplish the analysis, LEPO simulated the W-24 solution and applied sub-atmospheric evaporation conditions. The results of these conditions are documented on the following pages. It is to be understood that the results of this report are based on simulated parameters which were designed to best represent what actually exists at ORNL.

LICON Engineer

A handwritten signature in black ink, appearing to read "Ken Grant", written in a cursive style.

Ken Grant

Ryznar attempted to quantify the relationship between calcium carbonate saturation state and scale formation.

Ryznar stability index can be summarized as follows:

- RSI < 6        scale tendency increases as the index decreases;
- RSI > 7        calcium carbonate formation will probably not lead to a protective corrosion inhibitor film;
- RSI > 8        mild steel corrosion becomes an increasing problem.

Like the Langelier Saturation Index, the Ryznar Index is applicable to lower TDS waters.

#### SUMMARY OF ANALYSIS AND RECOMMENDATIONS

THE ORNL PROJECT WATER SAMPLE W-24, REDUCED FLUID, SHOWS ONLY TWO MOLECULES THAT CAN CAUSE PROBLEMS, BRUCITE AND HYDROXYAPATITE.

BRUCITE, A PRECURSOR TO MAGNESIUM SILICATE MAY BE CONTROLLED BY ADJUSTING THE PH TO 11.2,  $\pm 0.0$   $\pm 0.3$  WITH HYDROCHLORIC ACID (HCL). THIS ACTION MOVES THE BRUCITE INTO THE PERMANENT SOLUBLE RANGE WITH TEMPERATURE RANGING FROM 70 DEG F TO 180 DEG F.

HYDROXYAPATITE, BECOMES DOMINANT AT PH'S OVER 12.4. IF THE PH IS ADJUSTED FOR BRUCITE, THIS ACTION WILL ALSO CONTROL THE FORMATION OF HYDROXYAPATITE SCALING TENDENCIES.

AT THIS STAGE OF THE STUDY I SEE NO NEED FOR A SCALE INHIBITOR OR SCALE REMOVER.

PLEASE CALL IF HAVE ANY QUESTIONS.

RESPECTFULLY YOURS,

AL KULIK

---

Downhole SAT(tm)  
SURFACE WATER CHEMISTRY INPUT

---

LICON ORNL

SAMPLE W-24  
REDUCED FLUID

Report Date: 08-25-92      Sampled: 08-25-92  
Sample ID#: 0                      at 1219

---

## CATIONS

Calcium(as Ca)	11.30
Magnesium(as Mg)	2.03
Barium(as Ba)	0.50
Strontium(as Sr)	1.16
Sodium(as Na)	157028
Potassium(as K)	17200
Lithium(as Li)	0.00
Iron(as Fe)	4.07
Ammonia(as NH3)	0.00
Aluminum(as Al)	72.00
Boron(as B)	1.50

## ANIONS

Chloride(as Cl)	4042
Sulfate(as SO4)	6.50
Bicarbonate(as HCO3)	957.00
Carbonate(as CO3)	14100
Silica(as Si)	383.00
Phosphate(as PO4)	7.90
H2S (as H2S)	0.00
Fluoride(as F)	0.77
Nitrate(as NO3)	406.70

## PARAMETERS

pH	13.70
Temperature(Deg F)	180.00
Calculated T.D.S.	482609

Pressure(Atm.)	0.31
P-CO2(Atm)	0.00465
Density(g/ml)	1.20

---

LEPO: CUSTOM MFG. INC.  
MIDLAND, TEXAS

DownHole SAT(tm)  
SURFACE WATER DEPOSITION POTENTIAL INDICATORS

LICON ORNL

SAMPLE W-24  
REDUCED FLUID

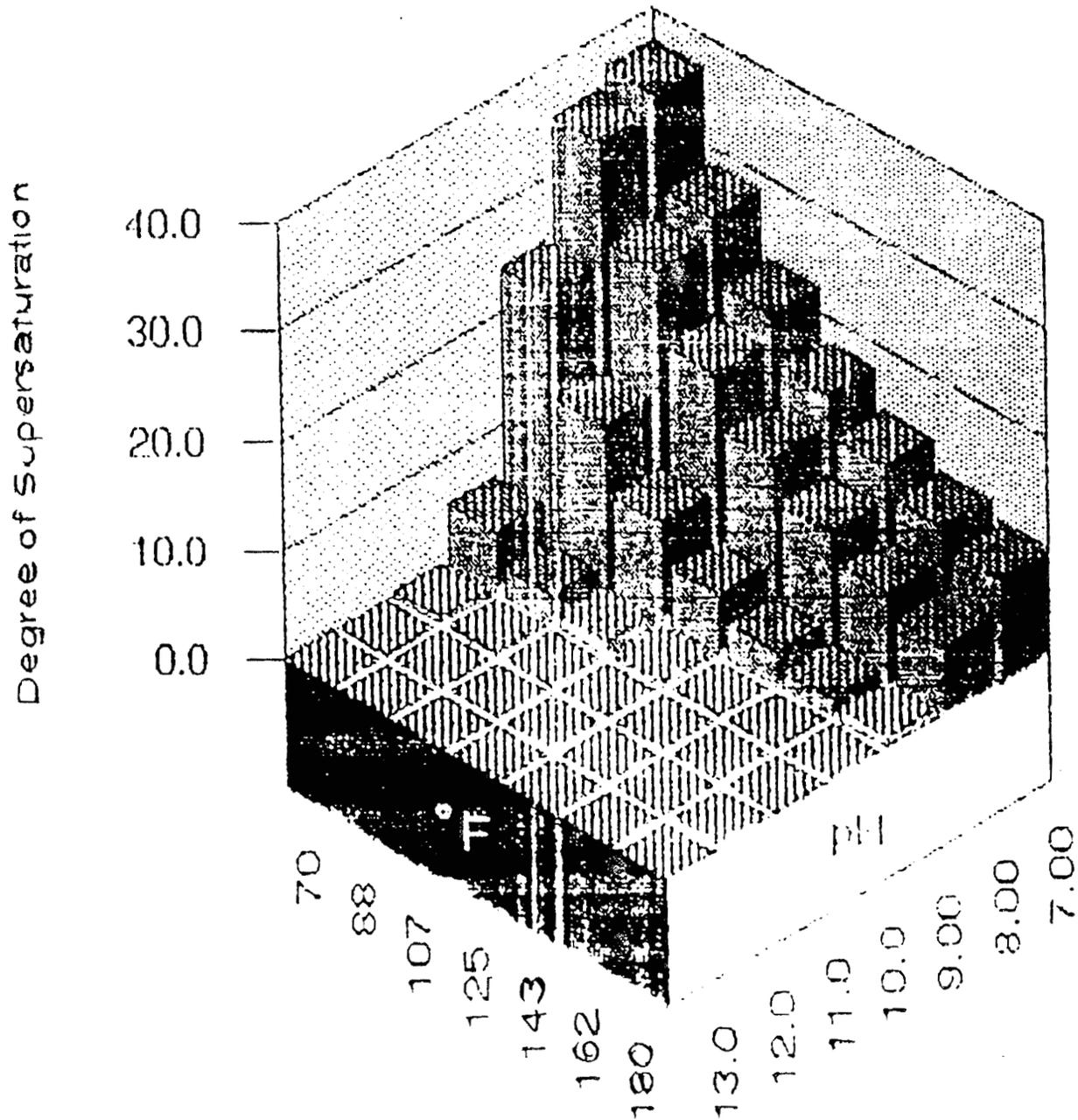
Report Date: 08-25-92      Sampled: 08-25-92  
Sample ID#: 0                      at 1219

## SATURATION LEVEL

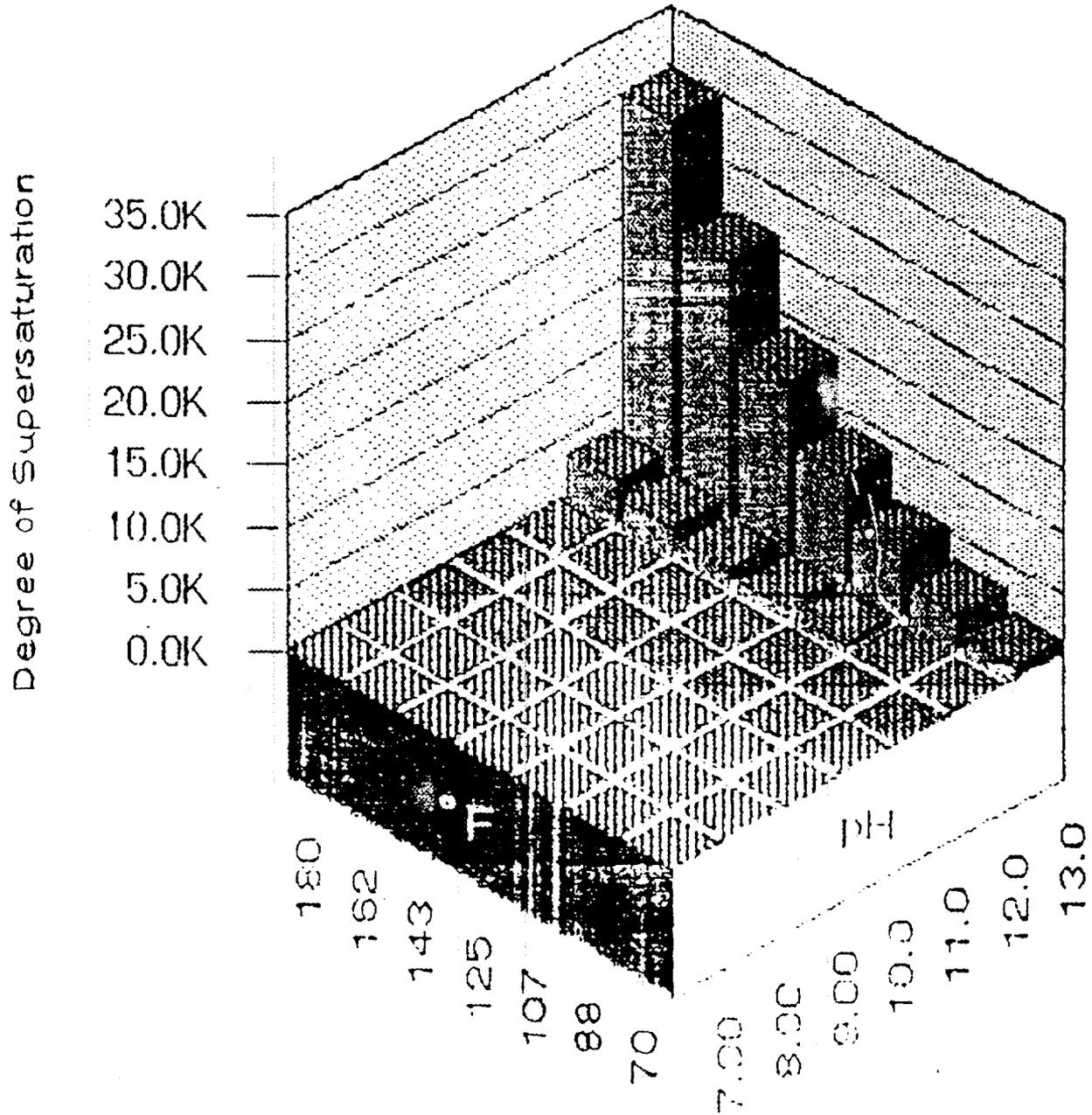
## COMMON INDICES

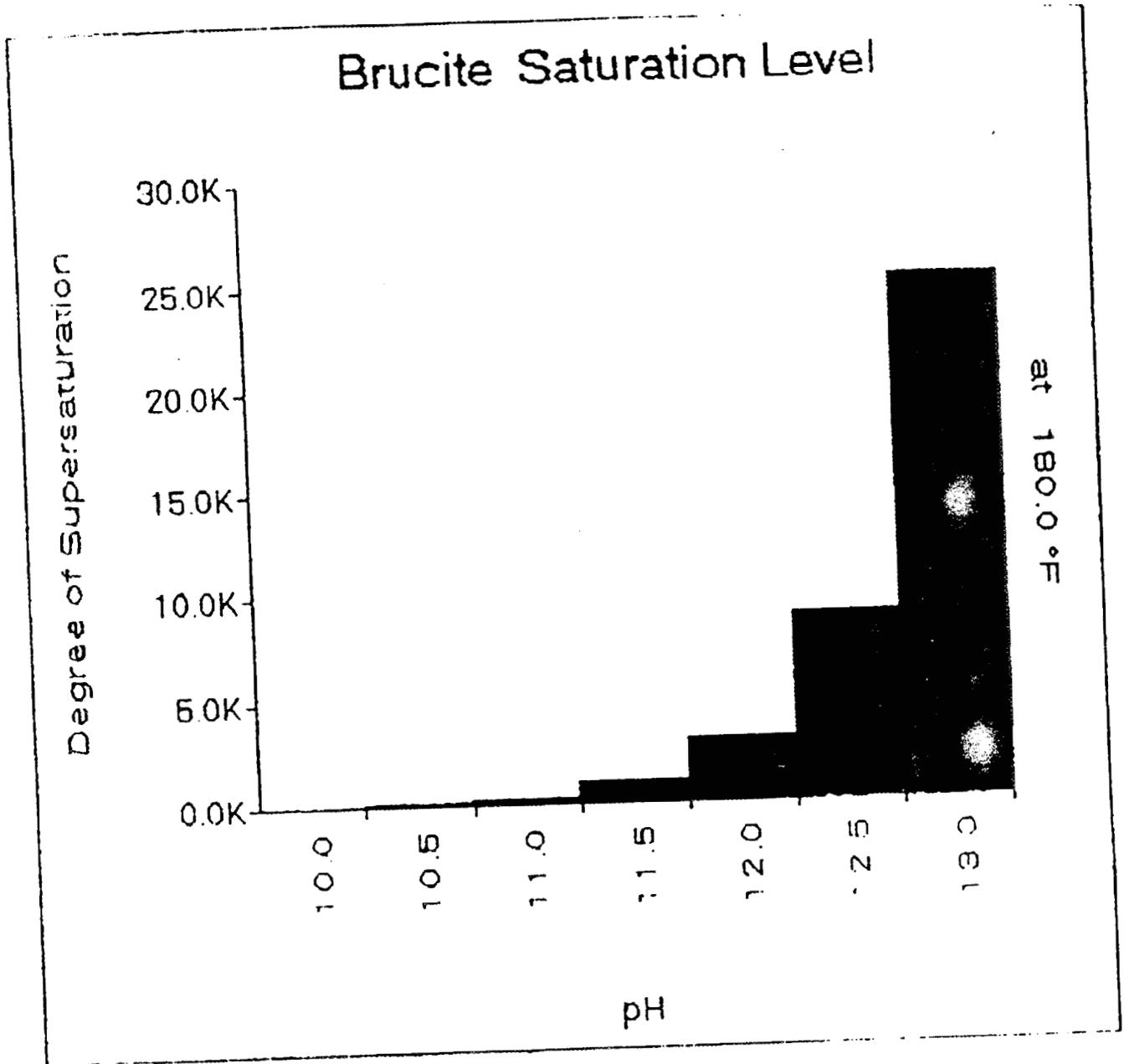
Calcite	CaCO3	0.00	Langelier	-14.0
Aragonite	CaCO3	0.00	Ryznar	14.0
Witherite	BaCO3	0.00	Puckorius	14.0
Siderite	FeCO3	0.00	Stiff-Davis	-14.0
Magnesite	MgCO3	0.00	Odde-Tomson	-14.0
Anhydrite	CaSO4	< 0.001	Larson-Skold	99.0
Gypsum	CaSO4*2H2O	< 0.001		
Barite	BaSO4	< 0.001		
Celestite	SrSO4	< 0.001		
Tricalcium phosphate	Ca3(PO4)2	< 0.001	BOUND IONS	TOTAL
Hydroxyapatite	Ca5(PO4)3(OH)	31.00		FRI
Strengite	FePO4*2H2O	< 0.001	Calcium	9.42 < 0.00
Bruceite	Mg(OH)2	78558	Barium	0.42 0.0
Amorphous Iron	Fe(OH)3	< 0.001	Carbonate	0.00 0.0
Amorphous silica	SiO2	< 0.001	Phosphate	6.58 6.0
Fluorite	CaF2	< 0.001	Sulfate	5.42 0.0

# Amorphous Silica Saturation Level



# Brucite Saturation Level

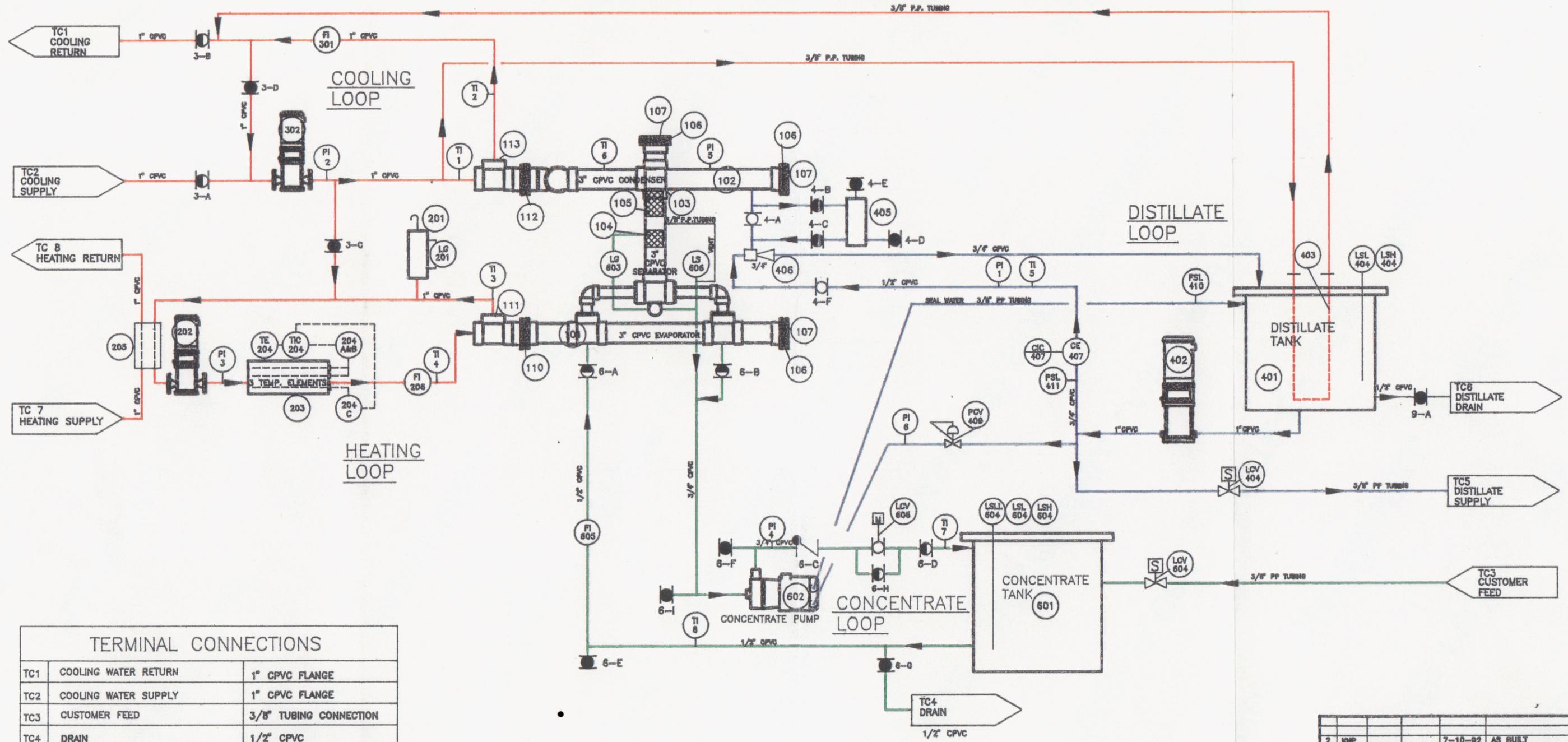




**APPENDIX G**  
**FLOW DIAGRAM**



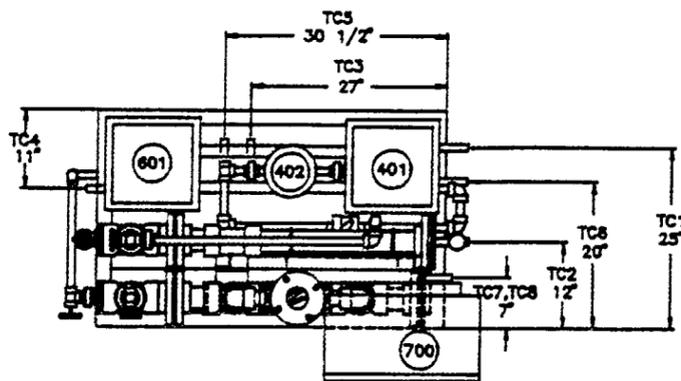
NORMAL TEMPERATURES AND PRESSURES					
TI 1	CONDENSER IN	130 - 135°F	TI 8	EVAPORATOR FEED	145 - 155°F
TI 2	CONDENSER OUT	135 - 140°F	PI 1	DISTILLATE PUMP	35-40 psig
TI 3	EVAPORATOR OUT	180 - 185°F	PI 2	COOLING PUMP	5-10 psig
TI 4	EVAPORATOR IN	185 - 190°F	PI 3	HEATING PUMP	5-10 psig
TI 5	DISTILLATE	140 - 145°F	PI 4	CONCENTRATE PUMP	5 psig
TI 6	VAPOR	150 - 155°F	PI 8	VACUUM	28-29" Hg
TI 7	CONCENTRATE RECYCLE	150 - 160°F	PI 6	SEAL WATER	



TERMINAL CONNECTIONS		
TC1	COOLING WATER RETURN	1" CPVC FLANGE
TC2	COOLING WATER SUPPLY	1" CPVC FLANGE
TC3	CUSTOMER FEED	3/8" TUBING CONNECTION
TC4	DRAIN	1/2" CPVC
TC5	DISTILLATE SUPPLY	3/8" TUBING CONNECTION
TC6	DISTILLATE DRAIN	1/2" CPVC
TC7	HEATING SUPPLY	1" CPVC FLANGE
TC8	HEATING RETURN	1" CPVC FLANGE

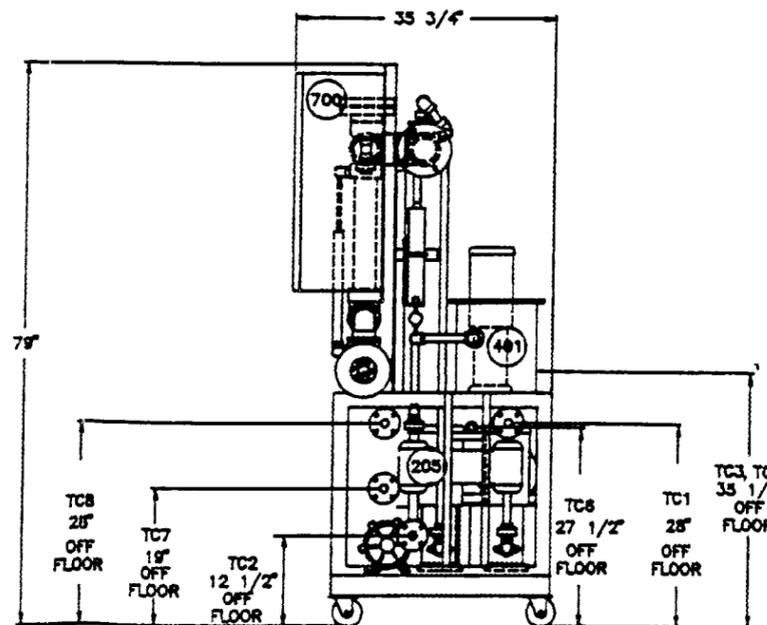
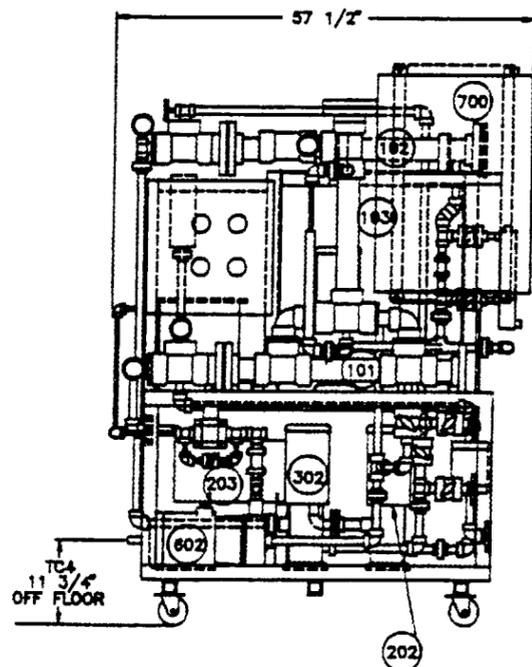
RED - HEATING  
 ORANGE - COOLING  
 BLUE - DISTILLATE  
 GREEN - CONCENTRATE  
 BLACK - DRAIN

2	KMP	7-10-82	AS BUILT		
1	KMP	5-20-82	ADD SEAL WATER LINE		
0	KMP	5-12-82	PRELIMINARY		
REV.	DRAWN	CHECKED	APPROVED	DATE	REMARKS
		LICON, INC. TEST UNIT FOR: UNIV. OF TEXAS, EL PASO			
PIPING & INSTRUMENTATION MODEL C-3 DISTILLER/CONCENTRATOR					
SCALE	NTS	CODE ID.	9	DRAWING NO.	2405-01
			SHEET	1 OF 1	REV. 2



TERMINAL CONNECTIONS		
TC1	COOLING RETURN	1" CPVC
TC2	COOLING SUPPLY	1" CPVC
TC3	CUSTOMER'S FEED	3/8" P.P. TUBING
TC4	DRAIN	1/2" CPVC
TC5	DISTILLATE SUPPLY	5/8" P.P. TUBING
TC6	DISTILLATE DRAIN	1/2" CPVC
TC7	HEATING SUPPLY	1" CPVC
TC8	HEATING RETURN	1" CPVC

MAJOR EQUIPMENT LIST	
101	EVAPORATOR 3" CPVC 2" UPTAKES
102	CONDENSER 3" CPVC
103	SEPARATOR 3" CPVC
202	HEAT PUMP
203	INLINE HEATER
205	HEAT EXCHANGER
302	COOLING PUMP
401	DISTILLATE TANK
402	DISTILLATE PUMP
601	CONCENTRATE TANK
602	CONCENTRATE PUMP
700	ELECTRICAL PANEL



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REV	DATE	BY	CHKD	APPROVED
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		UNIVERSITY OF TEXAS EL PASO, TEXAS		
GENERAL ARRANGEMENT MODEL C-3				

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