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Technology - Savannah River Processes

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Printed for
The United States Atomic Energy Commission
Contract AT(07-2)-1

DECLASSIFIED [redacted]

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ABSTRACT

Performance data were obtained for the TNX replacement evaporator when operated within the limits imposed by a new control system. This system was designed to avoid conditions which might lead to a repetition of an earlier explosion due to inclusion of organic material in the uranyl nitrate-nitric acid system, which was heated to elevated temperature. The true heat transfer coefficient was found to be 280 BTU/hr-ft^2- $^\circ$F for all concentrations of solutions to be evaporated in the plant, and will allow operation at design capacities.

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OPERATION OF TNX EVAPORATOR

INTRODUCTION

On January 12, 1953 the original evaporator of the TNX Semiworks was destroyed by an explosion(1). The replacement evaporator was provided with instrumentation and equipment safeguards to prevent another explosion, and the evaporator was installed behind a barricade.

Laboratory work showed that limiting the temperature to 266°F (130°C) was one way to assure safer operation. Consequently, controls to limit the temperature were incorporated in the design of the plant evaporators as well as in the replacement evaporator at the semiworks. The steam pressure on the coils was limited to 25 psig by a back-pressure controller, and the solution temperature was limited to 239°F (115°C) by a temperature controller designed to shut off the steam supply and to sound an alarm when the set temperature was exceeded.

Since the restriction on steam pressure might reduce the capacity of the evaporators, and since most of the previous data were obtained at steam pressures in excess of 25 psig, the present work was undertaken to determine the heat transfer coefficient of the new evaporator at the semiworks.

SUMMARY

The new instrumentation of the replacement evaporation at TNX was satisfactory and the temperature limits did not prevent attainment of reasonable capacities. Heat transfer coefficients of 280 ± 20 BTU/ft^2-hr-°F were consistently obtained with uranium solutions, nitric acid, and water. The coefficient appeared to decrease as the concentration of salts or nitric acid in the bottoms increased, but the decrease was not permanent and did not exceed 10% in any run.

Detailed examination of the evaporator data from one months operation, and spot checks at monthly intervals for 5 months, did not reveal any evidence of fouling.

Capacity calculations indicate that the plant evaporators will operate at a processing rate of three batches (2.4 metric tons) of uranium per day within the steam pressure limit of 25 psig.

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DISCUSSION

The TNX evaporator is approximately one-fourth of plant scale and was used intermittently for TNX requirements which were broad enough so that all the evaporation services in the plant were simulated. In addition, the TNX evaporator was used to distil water and to concentrate miscellaneous wastes. When the first evaporator exploded, it was being used to reduce the acidity of uranyl nitrate solution by volatilizing nitric acid at high temperature[1].

DESCRIPTION OF EQUIPMENT

The body of the second evaporator was identical to the one that was destroyed[1]. Heating coils (1", Schedule 40, 304 ELC stainless steel pipe) provided 140 ft^2 of heat transfer area. The column and condenser were the same units that had been used previously. The bottom three plates of the column (du Pont Drawing W145176) were distorted by the explosion, and these were straightened and the column was reinstalled. The evaporator was installed outside the building and behind a concrete barrier, but the piping arrangements were substantially unchanged except for additional horizontal runs of pipe. Details are shown in Figure 1 and du Pont Drawings W158629 and W145175.

The steam flow was regulated by a flow controller (orifice meter), and the steam pressure was limited to a maximum of 25 psig by a back-pressure controller. This pressure corresponds to a temperature of 266°F or 130°C. In addition, the solution temperature was limited to 239°F (115°C) by a thermocouple-potentiometer instrument arranged to shut off the steam and sound an audible alarm. Additional instrumentation as shown in Figure 1 was required to improve the operability of the evaporator. Pressure in the evaporator body could be relieved through a water seal pot consisting of an 8-inch diameter pipe immersed to a depth of 24 inches in water contained in a 55-gallon drum.

TEMPERATURE MEASUREMENT

The themocouple which measured the temperature of the boiling liquid was installed with the reference junction at atmospheric saturated steam temperature by locating the reference junction in the vapor space of the top of the column.

INITIAL EVAPORATOR STUDIES -HEAT LOSSES

The evaporator was first operated to produce 5600 gallons of process (distilled) water, but a shutdown was required to repair a leaky steam coil. Type 347 stainless welding rod was used. The evaporator was operated again to make process water, and to concentrate a synthetic nitric acid waste.

The heat transfer coefficients and heat losses tabulated in Table I were obtained from data collected during the first week of operation. Both steam condensate rate and boil up rate were determined by the time required to collect given weights of each. Since pure water and steam were used, precise determinations of the boiling temperature and steam temperature were possible. Steam was supplied to the evaporator control valve as saturated steam at approximately 140 psig and was throttled to the steam coil pressure. Steam flow rates were varied from 500 to 2000 lbs/hr. This variation in flow rates resulted in temperature differences from 16°F to 53°F between the boiling liquid and condensing steam.

The heat transfer coefficient was 268 BTU/ft^2-hr-°F for the conditions of this experiment, and was independent of evaporation rate.

Heat losses were determined from the condensate and product heat and material balances. The steam quality was assumed to be 100% and all experimental variances were accumulated in the heat loss calculation. On this basis, the heat losses from the column and condenser ammounted to 160,000 BTU/hr with a variation between 89,000 and 225,000 BTU/hr.

ROUTINE EVAPORATOR PERFORMANCE

Uranyl nitrate, nitric acid, and water feeds were evaporated during the months of June, July,and August, 1953, as necessary to recover materials for semiworks operations. Because of these changes in feed, it was impossible to determine whether or not continuous use of a single type of feed over a period of time would result in a permanent decrease in the transfer coefficient. However, as many as three successive heels of the same material were prepared without any permanent decrease in the transfer coefficient.

Successful operation of the evaporator and associated instrumentation showed that adherence to the TNX Evaporator Operational Standard* was possible without seriously limiting capacity. The 239°F (115°C) limitation on the temperature of the boiling solution was never exceeded, and laboratory experiments with simulated low activity waste heels showed that this temperature was approached only at the end of the evaporation cycle.

The heat transfer coefficient dropped 10% in a single run as the salt concentration increased. This decrease was not permanent, however, since start-up conditions of the following run restored the original high value. Continued

* Appendix

operation with only one type of process solution might result in fouling of the heat transfer surfaces but this was not observed at the semiworks and could not be evaluated extensively. Results obtained during the months of July and August are shown in Tables II, III and IV. These data indicate that the coefficients were random numbers and show no specific fouling effects.

CALCULATIONS

Heat Losses and Heat Transfer Coefficients With Water Feed

The heat losses were determined by the following method:

Let W_s = Weight of Steam lbs/hr

W_p = Weight of Product lbs/hr

h_{fg_o} = Latent heat of boiling at atmospheric pressure BTU/lb

h_{g_1} = Heat content of saturated steam at supply pressure

h_{f_1} = Heat content of water at temperature of supply steam

h_{f_2} = Heat content of condensate leaving steam coils

x = Steam quality

Q_1 = Heat losses

Then the heat supplied with steam is

$$(W_s)\ (x)\ (h_{g_1}-h_{f_2}) + (W_s)\ (1-x)\ (h_{f_1}-h_{f_2}),$$

the heat removed by product is

$$(W_p)\ (h_{fg_o}),$$

and the heat balance is

$$(W_s)\ (x)\ (h_{g_1}-h_{f_2}) + (W_s)\ (1-x)\ (h_{f_1}-h_{f_2}) = Q_1 + (W_p)\ (h_{fg_o}).$$

By combining terms,

$$(W_s)\ (x)\ (h_{g_1}-h_{f_1}) + (W_s)\ (h_{f_1}-h_{f_2}) = Q_1 + (W_p)\ (h_{fg_o}).$$

The heat losses can be determined by plotting

$$(W_p)\ (h_{fg_o}) - (W_s)\ (h_{f_1}-h_{f_2}) \text{ vs } (W_s)\ (h_{g_1}-h_{f_1}).$$

The slope is x and the heat losses will be the value of

$$Q_1 = (W_s)\ (h_{f_1} - h_{f_2}) - (W_p)\ (h_{fg_o}) \text{ when } (W_s)\ (h_{g_1} - h_{f_1}) = 0.$$

This plot is shown on Figure 2 with notations of heat losses and quality. Heat losses were also calculated individually since the steam quality appeared to be close to 100%. Heat losses calculated by this method contain all the individual experimental variances. Another method of presenting these variances is to include the average of the heat losses as an output item in the overall heat balance. A summary of such heat balances is tabulated in Table I, and shows that the maximum deviation was 9.8% of heat input unaccounted for.

A sample calculation for a steam flow rate of 1564 lbs/hr is shown below:

Supply Steam pressure	150 psi ga
Steam Chest pressure	25.6 psi ga
Temperature of Steam at Steam Chest Pressure	250.9°F
Boiling Point of Water at Barometric Pressure	211.7°F
Driving Force across Steam Coils	39.2°F

Overhead Product = 1382 lbs/hr

Heat Loss Q_1 = 160,000 BTU/hr

Heat Output from Evaporator (Q) = 1382 (970) + 160,000 = 1.50×10^6 BTU/hr

Heat Transfer Area (A) = 140 ft^2

$$U_o = \frac{Q}{A\Delta T} = \frac{1.50 \times 10^6}{(140)(39.2)} = 273 \text{ BTU/hr-ft}^2\text{-°F}$$

Heat Supplied by Steam (1564) (1196-219)=1.52×10^6BTU/hr

Error in heat balance $\frac{0.02}{1.52} \times 100$ = 1.3% of heat input

Heat Transfer Coefficient With Nitric Acid and Uranyl Nitrate Feeds

The foregoing principles were used also in treating the data from nitric acid and nitrate feeds, but an additional problem was to determine accurately the boiling points of the salt solutions. As discussed under Equipment, thermocouples were installed to record the boiling point elevation due to both salts and hydrostatic head. This temperature difference was added to the boiling point of water at standard pressure to obtain the actual boiling temperature.

During normal evaporator operation, the heat supplied by the steam, Q, is equal to the sum of the heat removed by the overhead and the losses or:

$$Q = W_p \, h_{fg_o} + Q_l$$

where W_p is equal to the reflux plus the take off liquid (essentially pure water). Q_l amounted to an average of 160,000 BTU/hr and this figure was used for all results found in Tables II, III, and IV.

Sample Calculation: (See Table III)
Solution: HNO_3
Date : 7/29/53
Time : 1500

Boiling Point Elevation	=	15.8°F
Boiling Point of Water at Barometric Pressure	=	211.8°F
Boiling Point of Solution	=	227.6°F
Temperature of Steam at Steam Chest Pressure	=	266.8°F
Driving Force Across Steam Coils	=	39.2°F

Reflux Rate = .38 gpm

Take-Off Rate = 2.38 gpm

Heat Loss = 160,000 BTU/hr

Heat Supplied by Steam (Q) = (2.38 + .38) gpm (8.33 lbs/gal) $\left(\frac{60 \text{ min}}{\text{hr}}\right)$ (970.3 BTU/lb) + 160,000 BTU/hr = 1.50×10^6 BTU/hr

Heat Transfer Area (A) = 140 ft^2

$$U_o = \frac{Q}{A \Delta T} = \frac{1.50 \times 10^6}{140 (39.2)} = 273 \text{ BTU/hr-ft}^2\text{-°F}$$

Evaporation of Concentrate from Low Activity Waste

Figure 3 is a distillation curve of a salt solution which approximates the expected low activity waste heels. The composition of the vapor overhead must be 7.2% HNO_3 to be in equilibrium with the feed. This overhead vapor has a temperature of 230°F (110°C). This vapor composition was attained with 3% overhead product and a boiler temperature of 115°C.

No plant difficulties should be encountered with formation of salt crystals in the cooled heel. Salt crystals were not observed on cooling a 26% inorganic salt solution to 41°F, while the plant concentrations should be only about 20% inorganic salt.

Capacity of Plant Evaporators

Capacity estimates and service requirements for the four process evaporators are summarized in Tables V and VI. They reveal that the low activity waste and the 1EU evaporator will have very little excess capacity. However, since the 1EU evaporator will be in an outside location, a second unit can easily be added.

Capacity of the low activity waste evaporator is limited by the maximum allowable vapor velocity, which, if exceeded, would cause radioactive materials to be entrained and would result in a reduction of the decontamination factor. If plant experience proves unsatisfactory, the capacity of the low activity evaporators can be readily expanded in the four spare spaces provided.

Some evaporators that have been purchased have a 25% smaller heat transfer area, but these are to be used for locations where neutral or alkaline wastes are being evaporated or where there is no possibility of TBP contamination. These locations include the head end evaporator, the high activity waste evaporator (2 required), and the laboratory waste evaporator. Steam temperatures in these evaporators can be adjusted to the optimum for maximum heat flux unless the resulting vapor velocity is limited by entrainment of radioactivity.

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2. Du Pont Engineering Drawings: W145175
W145176
W145309
W158629

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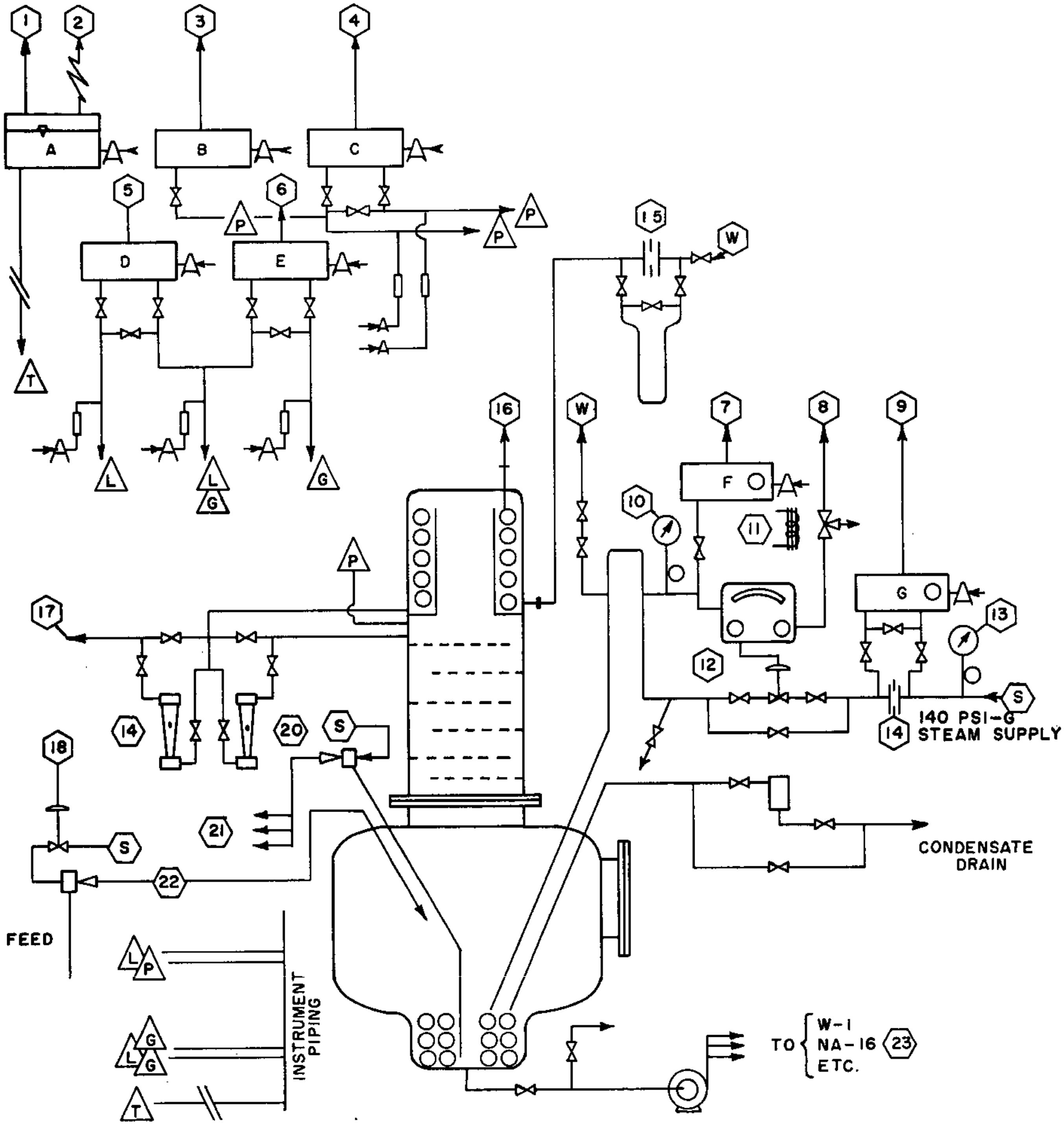

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FLOW DIAGRAM FOR REPLACEMENT TNX EVAPORATOR

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LEGEND FOR FIGURE 1

A O Recorded on I-21	Brown Electronik- Pneumatic Transmitter also operates an electrical control signal set to turn off 110 V to solenoid air valve, 11 , when boiling liquid temperature exceeds 115°C. Transmitter range 0-150°C.
B O Recorded on I-11 Green Pen	Differential Pressure- Pneumatic Transmitter to transmit gage pressure in evaporator boiler. Transmitter range 0-200 inches water.
C O Recorded on I-11 Purple Pen	Differential Pressure- Pneumatic Transmitter to transmit column pressure drop. Transmitter range 0-12 inches water.
D O Recorded on I-23	Differential Pressure- Pneumatic Transmitter to transmit hydrostatic head in evaporator (Liquid Level). Transmitter range 0-120 inches of water.
E O Recorded on I-11 Red Pen	Differential Pressure- Pneumatic Transmitter to transmit evaporator liquid specific gravity. Transmitts specific gravity 0.9 to 1.9 units.
F O Recorded on I-22	Pressure- Pneumatic Transmitter to transmit steam chest pressure. Transmitter range 0 to 30 psi.
G O Recorded on I-24	Differential Pressure- Pneumatic Transmitter to transmit steam flow orifice differential. Transmitter range 0-100 inches of water which is equivalent to 2500 lbs/hr of 140 psig steam.
T T	I.C. Thermocouple leads from Potentiometer A O to boiling liquid.
L L G G	Liquid level and specific gravity leads to evaporator. Specific gravity has fixed differential of 9.4 inches.
P P	Evaporator pressure and column pressure drop leads to evaporator.
S	High Pressure steam supply 140 psig.

W Cooling water supply.

1 Transmitter air to I-21. Temperature indicator recorder.

2 Electrical leads to air switch and alarm. Acting as temperature limiter by shutting off air supply to the steam control valve.

3 Transmitted air to I-11 Evaporator pressure indicator-recorder.

4 Transmitted air to I-11 Column pressure drop indicator and recorder.

5 Transmitted air to I-23. Liquid level indicator, recorder, controller. Controls steam supply to evaporator feed jet at point 18.

6 Transmitted air to I-11. Specific gravity indicator recorder.

7 Transmitted air to I-22. Steam chest pressure indicator, recorder.

8 Controller air pressure from I-24. Steam flow control.

9 Transmitted air to I-24. Steam flow measurement indicator, recorder, controller.

10 Bourdon tube steam pressure gage 0-30 psig.

11 Electrical air switch for temperature limiter.

12 Back pressure pneumatic controller set to control at maximum steam pressure of 25 psig.

13 Bourdon tube steam pressure gage 0-140 psig.

14 Orifice plate steam flow meter 1.419 inches diameter.

15 Orifice plate and mercury manometer for condenser. 1.455 inches diameter 48 inch mercury manometer.

(16) Condenser water to drain.

(17) Overhead product to W-2 or drain.

(18) Controlled air supply to steam supply of J-9 jet. Used to control liquid level in evaporator.

(19) Product rotameter.

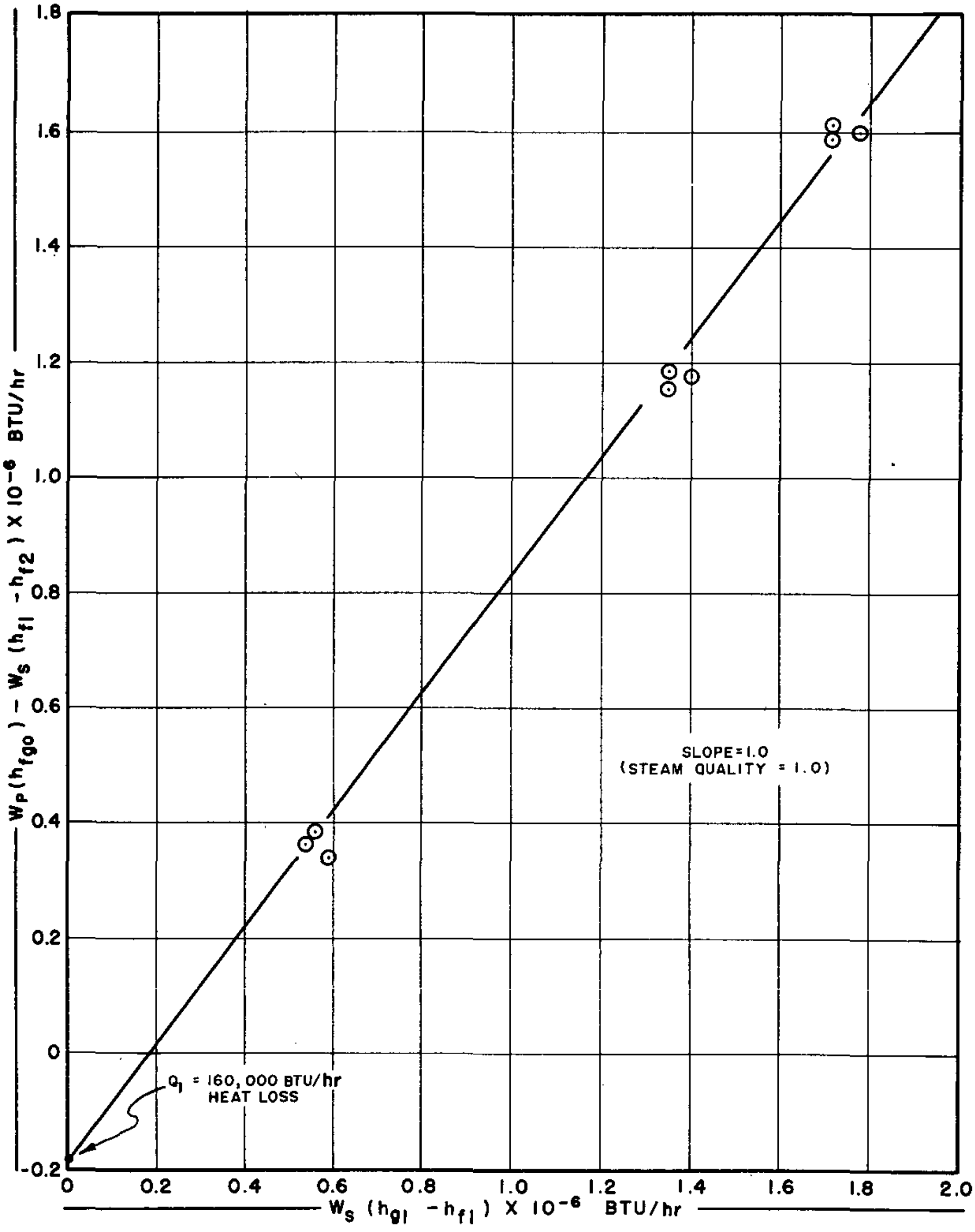
(20) Reflux rotameter.

(21) Concentrated heel discharge from evaporator by J-4 jet.

(22) Liquid feed to evaporator.

(23) Concentrated heel discharge from evaporator by P-4 pump.

Figure 2



HEAT BALANCE PLOT

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Figure 3

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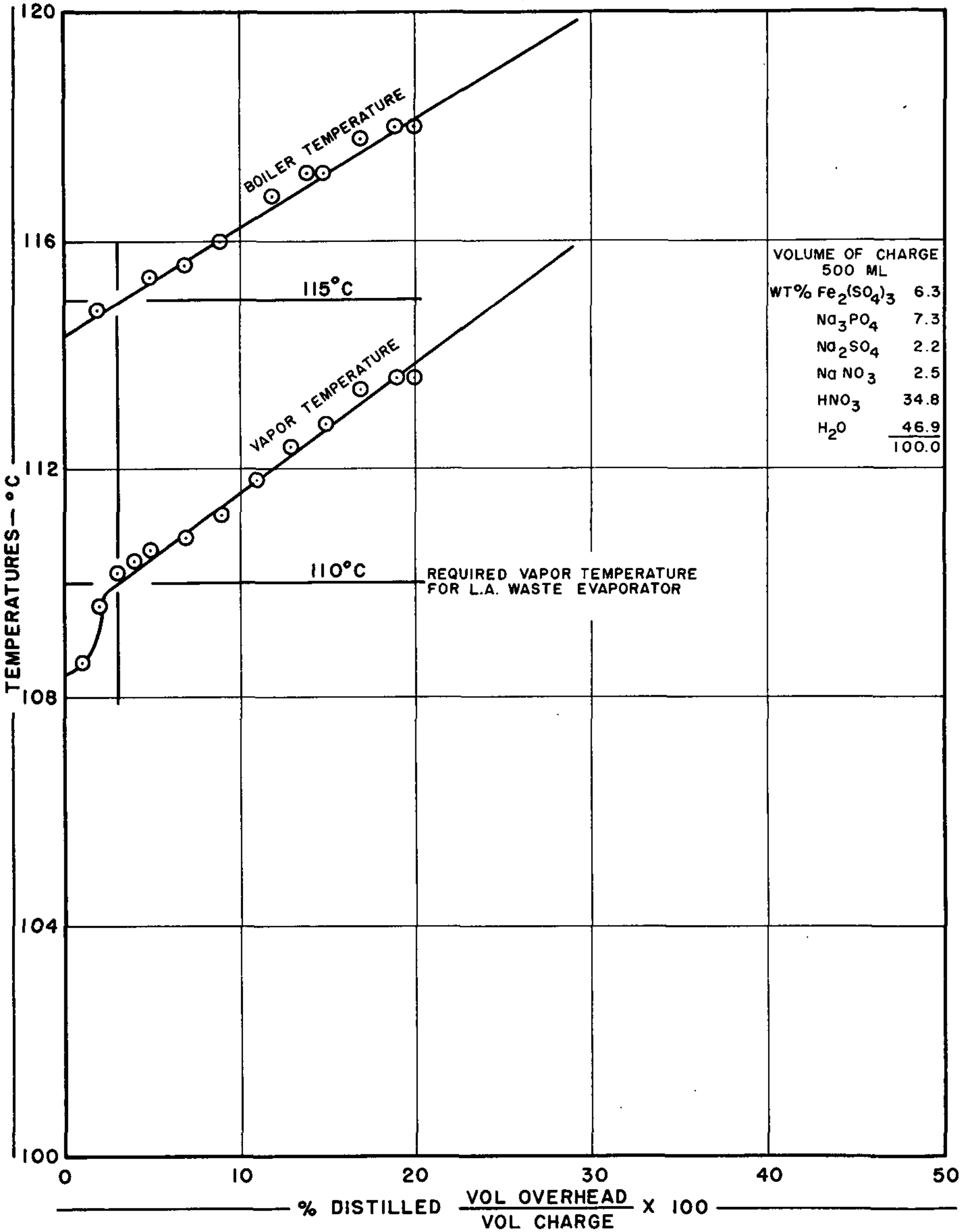

DISTILLATION CURVES FOR CONCENTRATE FROM LOW ACTIVITY WASTE FOR 7.2 % HNO_3 IN VAPOR AT 110°C

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TABLE I

EVAPORATOR PERFORMANCE TEST

ON WATER

U_o ave. = 268 BTU/ft^2-hr-°F
Area = 140 ft^2

Item	Units	Nominal Steam Flow Rate, lbs/hr								
		537			1525			1985		
Condensate Collected	(lbs/hr)	676	628	650	1564	1572	1616	2007	2002	1969
Overhead Product Collected	(lbs/hr)	463	489	495	1382	1403	1403	1858	1852	1858
Δt_b Temperature drop across steam coils	(°F)	16.8	17.6	17.6	39.2	39.2	39.7	52.5	51.2	53.2
Total Heat Released by Steam	(10^6 BTU/hr)	0.675	0.626	0.648	1.52	1.58	1.58	1.93	1.93	1.89
Calculated Heat Losses	(10^6 BTU/hr)	0.225	0.162	0.167	0.184	0.172	0.213	0.127	0.127	0.089
Total Heat Removed by Product & Losses (Losses taken as 0.16 MM BTU/hr)	(10^6 BTU/hr)	0.609	0.635	0.655	1.50	1.52	1.52	1.96	1.96	1.96
Loss or Gain in Heat Balance	%	-9.8	+1.4	+1.1	-1.3	-3.4	-3.4	-1.8	+0.9	+3.9
Overall Heat Transfer Coefficient	(BTU/hr-ft^2-°F)	259	258	267	273	277	274	268	273	263

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TABLE II

EVAPORATION OF RAW WATER

U_o ave. = 287 BTU/hr-ft^2-°F

Area = 140 ft^2

Heat Loss = 160,000 BTU/hr

Date	7/14/53	7/14/53	7/14/53	7/14/53	7/14/53	7/15/53	7/31/53	7/31/53	8/3/53
Time	0100	0400	1200	1800	2300	0200	1400	2000	0900
Boiling Point Elevation, °F	2.16	2.25	2.00	2.16	2.25	2.08	2.08	1.91	2.16
H_2O Boiling Point, °F	211.8	211.8	211.8	211.8	211.8	211.8	211.8	211.8	211.8
Solution Boiling Point, °F	213.96	214.05	213.8	213.96	214.05	213.88	213.88	213.71	213.86
Steam Chest Pressure, psia	30.4	30.4	34.4	34.6	34.6	34.6	32.6	32.6	33.2
Steam Chest Temperature, °F	251.09	251.09	258.26	258.60	258.60	258.60	255.12	255.12	256.19
Temp. Driving Force (ΔT), °F	37.13	37.04	44.46	44.64	44.55	44.72	41.19	41.46	42.23
Reflux Rate, gpm	.55	.57	.60	.5	.57	.32	.52	.50	.52
Take-Off Rate, gpm	2.15	2.17	2.7	2.8	2.75	2.88	2.70	2.70	2.80
U_o, BTU/hr-ft^2-°F	283	285	283	282	283	273	297	295	301

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TABLE III

EVAPORATION OF NITRIC ACID SOLUTIONS

U_o ave. = 282 BTU/hr-ft^2 -°F

Area = 140 ft^2

Heat Loss = 160,000 BTU/hr

Date	7/29/53	7/15/53	7/15/53	7/23/53	7/23/53	7/23/53	7/28/53
Time	1500	0930	1500	1100	1700	2000	2200
Boiling Point Elevation, °F	15.8	7.32	15.30	10.12	5.08	10.05	8.5
H_2O Boiling Point, °F	211.8	211.8	211.8	211.8	211.8	211.8	211.8
Solution Boiling Point, °F	227.6	219.12	227.10	221.92	216.88	221.85	220.3
Steam Chest Pressure, psia	39.8	37.4	40.0	38.6	35.8	37.8	37.0
Steam Chest Temperature, °F	266.84	263.21	267.25	265.10	260.62	263.84	262.57
Temp. Driving Force (ΔT), °F	39.24	44.09	40.15	43.18	43.74	41.99	42.27
Reflux Rate, gpm	.38	.55	.25	.57	.38	.5	.58
Take-Off Rate, gpm	2.38	2.65	2.70	2.4	2.95	2.7	2.65
U_o, BTU/hr-ft^2-°F	272	277	283	265	293	291	292

TABLE IV

EVAPORATION OF URANYL NITRATE SOLUTIONS

U_o ave. = 272 BTU/hr-ft^2-°F

Area = 140 ft^2

Heat Loss = 160,000 BTU/hr

Date	7/8/53	7/9/53	7/10/53	7/13/53	7/16/53	7/17/53	7/20/53
Time	1800	1800	0200	0400	1600	0700	0800
Boiling Point Elevation, °F	3.48	3.57	10.6	7.06	12.00	9.50	4.33
H_2O Boiling Point, °F	211.8	211.8	211.8	211.8	211.8	211.8	211.8
Solution Boiling Point, °F	215.28	215.37	222.4	218.86	223.80	221.3	216.13
Steam Chest Pressure, psia	35.4	35	39.6	37.8	39.2	38.6	37.0
Steam Chest Temperature, °F	359.94	259.28	266.64	263.84	266.03	265.10	262.57
Temp. Driving Force (ΔT), °F	44.66	43.91	44.24	44.98	42.23	43.80	46.44
Reflux Rate, gpm	.8	.55	.5	.38	.5	.625	.57
Take-Off Rate, gpm	2.45	2.8	2.4	2.87	2.6	2.30	2.98
U_o, BTU/hr-ft^2-°F	277	289	253	275	281	257	289

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TABLE IV (Continued)

EVAPORATION OF URANYL NITRATE SOLUTIONS

U_o ave. 272 BTU/hr-ft^2-°F

Area = 140 ft^2

Heat Loss = 160,000 BTU/hr

Date	7/20/53	7/24/53	7/24/53	7/27/53	7/28/53	7/30/53	7/30/53	8/4/53
Time	1600	0700	2100	2300	0600	0700	2300	1100
Boiling Point Elevation, °F	13.70	11.65	15.30	8.5	11.48	7.65	6.48	15.2
H_2O Boiling Point, °F	211.8	211.8	211.8	211.8	211.8	211.8	211.8	211.8
Solution Boiling Point, °F	225.50	223.45	227.10	220.3	223.28	219.45	218.28	227
Steam Chest Pressure, psia	39.4	37.6	40.2	38.2	39.4	37.4	36.6	39.4
Steam Chest Temperature, °F	266.33	263.52	267.55	264.47	266.33	263.21	261.92	266.33
Temp. Driving Force (ΔT), °F	40.83	40.07	40.74	44.17	43.05	43.76	43.64	38.93
Reflux Rate, gpm	.75	.45	.25	.42	.38	.65	.55	.28
Take-Off Rate, gpm	2.1	2.2	2.3	2.75	2.55	2.55	2.75	2.65
U_o, BTU/hr-ft^2-°F	270	258	245	274	263	279	288	287

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TABLE V

EVAPORATOR CAPACITIES FOR PLANT SERVICE

Evaporator Location	H.A.Waste	L.A.Waste	1CU	1EU
Evaporators specified	2	2	2	1
Type of operation	Series	Parallel	Parallel	Single
Area of Coils ft^2/evaporator	422	563	563	563
Mechanism Controlling Rate	Vapor Velocity	Vapor Velocity	Vapor Velocity	Heat Transfer
% of Design Capacity	159	79 to 102	110	93

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TABLE VI

EVAPORATOR SERVICE IN 221-F

E. P. No.	Description	Coil Area ft^2/evaporator	Number of Evaporators Installed	Spare Modules
311.1 311.31	1st Cycle Uranium Concentration (1CU)	563	2	None
311.2	2nd Cycle Uranium Concentration (1EU)	422	1	Outside Location
311.22	Head End	422	1	None
311.12 311.27	High Activity Waste (Series Operation)	422	2	2
311.8 311.25	Low Activity Waste	563	2	4
311.30	Lab Waste Concentrator	422	1	None
311.11	Re Run	422	1	None
311.18-1 311.18-2	General Purpose	Forced Feed Separate heat exchanger	2	Outside Location

APPENDIX

STANDARDS FOR EVAPORATOR OPERATION - TNX

Evaporator

Applicability

These regulations specify the limits within which the TNX (Building 678-G) evaporator must be operated.

Basis

The operating limits are based on laboratory investigations of the hazards involved in evaporating uranyl nitrate, HNO_3, H_2O systems containing tributyl phosphate. These investigations have been reported and tentatively define the ranges of concentration, temperature, and heating rate that may be safety employed in evaporating such systems.

Regulations for Evaporator Operation

1. The following instruments must be in working order:

   a. Liquid temperature recorder,
   b. Column differential pressure recorder,
   c. Steam coil pressure limiter, recorder,
   d. Evaporator high temperature alarm,
   e. Liquid level recorder,
   f. Specific gravity recorder,
   g. Steam flow recorder.

2. No materials containing any separate-phase organic material may be charged to the evaporator.

3. The steam flow rate must not exceed 2200 pounds per hour.

4. The steam pressure must not exceed 25 psig.

5. The liquid temperature must never exceed 115°C.

6. The column pressure drop must not exceed 10 in.

7. The specific gravity of the evaporator contents must never attain a value greater than 1.8.

8. No personnel shall be allowed in exposed positions while the evaporator is in operation.

9. Condenser cooling water must flow with a minimum rate of 8000 gallons per hour.

[redacted]

Feeding the Evaporator

Applicability

These regulations specify the sequence of operations that must be followed in feeding the evaporator.

Basis

The regulations are based on a study of evaporation operation and tankage involved. They are designed to keep separate-phase organic material from entering the evaporator.

Regulations

1. The evaporator must be fed only from evaporator feed tanks.

2. No transfer piping connections may exist between any evaporator feed tank and any tank used to store organic material.

3. All separate-phase organic material must be removed from evaporator charges before they are transferred to evaporator feed tanks.

4. Before a transfer to evaporator feed tanks is made, the charge must be visually examined for both heavy and light organic phase by a shift engineer, and results of the examination must be entered in the log book.

5. After the charge is received in evaporator feed tanks, a sample shall be submitted for analysis of total phosphate. It is not necessary to wait for the analytical results before proceeding with the evaporation.

6. The shift engineer must visually examine the contents of E-8 or A-9 for both heavy and light organic phase, and enter the results of his examination in the log book before charging the evaporator.

[redacted]