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TECHNICAL DIVISION

ENGINEERING DEVELOPMENT SECTION

PILOT MODEL EVAPORATOR
FOR
CONCENTRATION OF RADIO-ACTIVE CHEMICAL WASTES

S. E. BEALL

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PILOT MODEL EVAPORATOR FOR CONCENTRATION OF RADIO-ACTIVE CHEMICAL WASTES

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0.0 ABSTRACT

A scale model of the evaporator designed for concentration and decontamination of radiochemical wastes was installed and operated for two weeks. Satisfactory operation of the designed system is predicted by the experimental work which indicates:

1. An overall heat transfer coefficient of 150 to 250 BTU/Hr-Ft^2-^{o}F.
2. No scaling in acid solutions.
3. Evaporation rates greater than the required 12.8 lbs/hr-ft^2 heating surface.
4. Decontamination factors greater than 10^3 and perhaps as high as 10^5 (exclusive of Iodine).

1.0 INTRODUCTION

Recently there has been great emphasis on reducing the quantities of radioactive wastes discharged from Oak Ridge National Laboratory and other Atomic Energy Commission Sites. Several possible methods of minimizing both gaseous and liquid waste activities are under study at present. This report describes one means of handling liquid radiochemical wastes to effect a reduction of at least 20 to 1 in the volume of stored waste with an accompanying decontamination of greater than 10^3 in the activity of the discharged waste.

At the present time the activity of all liquid chemical wastes which may be discharged from this laboratory into the Clinch River is limited to 5 curies per day. It is highly desirable that this quantity immediately be reduced to a much smaller figure, say 5 millicuries per day.

In the past it has been possible to operate the waste disposal system so that discharged activity was held below the 5 curie limit. This has been accomplished by routing all highly active waste streams to a 170,000 gal. concrete tank (Tk. W-5), neutralizing here and permitting this tank to overflow to a second 170,000 gallon tank (Tk. W-6). The overflow from the second storage tank is discharged to a 1,400,000 gallon open pond and indirectly to the River. Low intensity wastes amounting to an estimated 0.1 curie maximum by-pass the concrete tank and go directly to the open pond. (Unless these very dilute activities are handled differently than at present, they may be the limiting factor on decontamination with any system which processes material in the concrete tanks only.) Such a handling procedure results in a decay time of perhaps 10 weeks in the concrete tanks and 40 weeks in the open pond, which has been sufficient for the activities handled in the past.

The previous history of activities discharged by the 706-D and Hot Pilot Plant operations have little significance at present because both plants are working material of several times higher activity levels than previously. Building 706-D is now using 3-day old Hanford metal which produces roughly 10^3 curies of 8-day iodine waste per run. These runs are made at least 4 times per year. The Redox Hot Pilot Plant is processing 100-day old Hanford metal and can produce long half-live chemical wastes of $\sim$200 curies per day at maximum capacity. All other sources of waste activity are relatively unimportant at the present time.

The decay time allowable in the waste disposal system is still sufficient for the 706-D Building iodine - 10 weeks in tanks W-5 and W-6 would take it through 9 half-lives from 10^3 curies to $\sim$2 curies. However, the wastes from the Redox Hot Pilot Plant have a very long half-live average and cannot

be significantly reduced by passage through the storage system. Relief for the already over-taxed liquid waste disposal system must be provided immediately.

The possibility of installing an evaporation system to reduce the volume of material stored and thus provide much longer decay times has been investigated actively for several months. In August, 1948, a decision was made to design facilities for the evaporation of 300 gallons of water per hour from the active waste effluent of the laboratory. Although the design was considered adequate by ordinary industrial evaporation standards and was to be constructed almost entirely of surplus equipment, reports from other sites indicated the possibility of a severe scaling problem in an evaporator of this type used for waste solutions. As a result, a pilot model of the large evaporator has been installed and operated to obtain first-hand data on heat-transfer and scaling, decontamination and evaporation rates. The time allotted for this assignment was five weeks.

2.0 EQUIPMENT AND DESIGN

Figure 1 shows the general equipment layout of the pilot evaporator system. In view of the fact that the apparatus was designed, installed and operating within two weeks, it is not surprising that many desirable refinements were omitted.

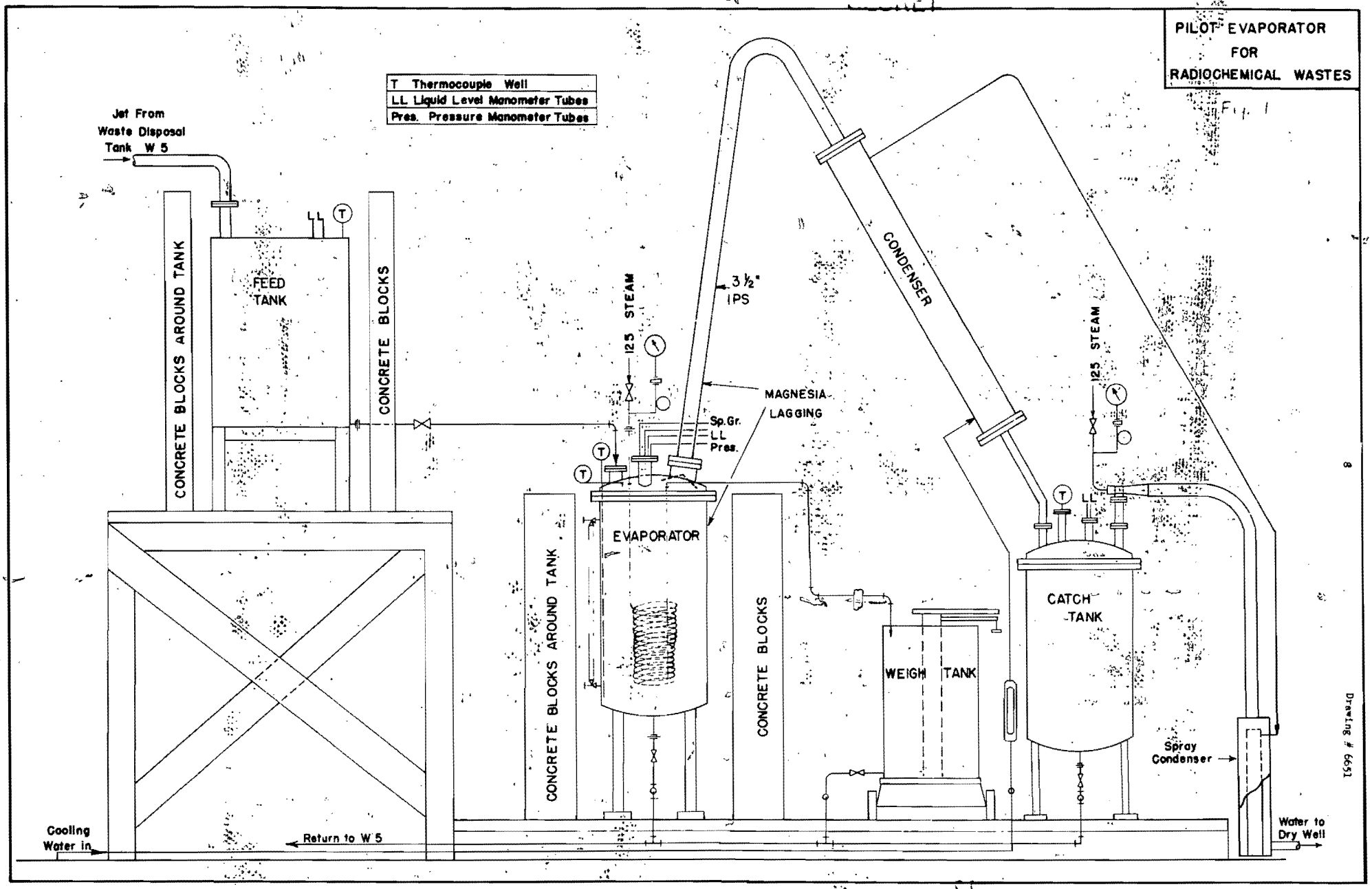
The design of the pilot installation followed that of the full-scale arrangement as closely as possible and varied only where necessary to utilize existing equipment pieces. Stainless steel was used for all surfaces in contact with process solutions. Concrete blocks were used for shielding. Pertinent comparative design data are:

Comparative Data for Pilot Model
and Full-Scale Evaporators

	Pilot	Full-Scale	Ratio
Evaporator Tank:			
Height	4 ft.	10 ft.	1:2.5
Diameter	2 ft.	7 ft.	1:3.5
Volume	~100 gal.	2350 gal.	1:24
Liquid Surface Area	3.1 ft^2	38.2 ft^2	1:12
Heat Trans. Surface	16 ft^2 (coil)	196 ft^2 (tubes)	1:16
Heating Surface/ft^2 Liquid Surface	5.1	5.1	1:1
Height Heating Surface	26 in.	52 in.	1:2
Height Vapor Space	~20	~60 in.	1:3
Condenser:			
Heat Transfer Area	50 ft^2 (1 condenser)	400 ft^2 (8 condensers)	1:8
Cooling Water Req'd ($T = 50^\circ$ F)	15 gpm	~120 gpm (8 condensers)	
Dia. Vapor Line	$3\frac{1}{2}$ in.	12 in.	
Velocity in Vapor Line (Atmos. Press.)	28 ft/sec at 250 #/hr.	24 ft/sec at 2500 #/hr.	

To briefly describe the flow of materials in Figure 1, waste solution was jetted from tank W-5 to the feed tank located on a 6 foot high platform. It flowed by gravity to the evaporator where a steam coil vaporized the water which then passed through the condenser, was condensed and drained into the catch tank. Concentrated waste from the evaporator was returned to tank W-5. Steam condensate was collected in the weigh tank.

Additional detail on all equipment pieces is given in Appendix 6.1.



Drawing # 6651

3.0 OPERATION

The series of experimental runs was planned for measurements of:

1. Overall heat transfer coefficients to boiling water.
2. Overall heat transfer coefficients to boiling active waste solution.
3. Scaling rate with waste solution.
4. Evaporation rates at various steam pressures to 110 psig.
5. Decontamination factors at various evaporation rates.
6. Necessity for entrainment separator.
7. Necessity for vacuum operation.
8. Shielding requirements.

Generally, the equipment was operated with continuous feed until the 500 lb. evaporator heel represented a 20 to 1 concentration of the feed solution. The first run to determine heat transfer coefficients with water in the system was followed by five runs with active wastes. Runs 1, 2 and 3 were made at 20 psig steam pressure, Run 4 at pressures increasing in 15 lb. steps to 90 psig, and Run 5 under 17 inches mercury vacuum at 10 psig steam. Operating details of all runs are discussed in Appendix 6.2.

4.0 RESULTS

4.1 Heat Transfer Coefficients

Coefficients were calculated for all runs on the basis of steam consumption as determined by steam condensate weight data. Temperature differences were taken as the difference between saturated steam and 212° F.

4.1 Heat Transfer Coefficients (Con't.)

Although work by J. O. Davis[2] of this laboratory indicates perhaps a 3° F increase in boiling point as concentration increases to 20:1, this rise was not within the accuracy of the temperature recorder used on the Pilot Plant. Results were checked frequently with calculations based on feed and evaporation rates. A summary is presented in Table 1 and plotted in Figure 2.

All the data except those at 75 and 90 psig in Run No. 4 and perhaps Run No. 5 under vacuum are thought to be reliable. (Time was not available for repeating these runs). At the higher steam pressures in Run No. 4 it was necessary to operate with the heating surface partially submerged to prevent excessive entrainment. Therefore it was necessary to estimate the heat transfer area from the liquid level indicator which was often difficult to read. However, these estimates should be within 20%, the results probably being too high.

It is seen that the measured coefficients vary from 150 to $\sim$250 BTU/Hr-Ft^2-$^{\circ}$F. Although these values are somewhat lower than those calculated from reported data, they are reasonable. The data taken during the active waste runs are in fair agreement with the data on water.

[redacted]

TABLE 1

Heat Transfer Coefficients for Pilot Plant Evaporator

Run No.	Duration	Evaporator Heel	Steam Pressure	Evaporator Pressure	Final Concentration Ratio	
Water Run	2 hours	water	20 psig	atm.		157 BTU/Hr-Ft^2-^{o}F
	2		30 "	"		175 " " " "
	2		40 "	"		192 " " " "
	2		50 "	"		188 " " " "
	2		60 "	"		215 " " " "
	2		110 "	"		235 " " " "
#1	48 hours	pH = 9.2 contained sludge	20 "	"	10:1	150 " " " "
#2	85 hours	pH = 4.2 clear supernate	20 "	"	20:1	156 " " " "
#3	86 hours	pH = 4.1 clear supernate	20 "	"	20:1	170 " " " "
#4	8	pH = 2.0	30 "	"	15:1	160 " " " "
	9	pH = 2.5	45 "	"	~ 20:1	184 " " " "
	8	pH = 2.8	60 "	"	~25:1	222 " " " "
	8	pH = 3.8	75 "	"	~30:1	278 ?" " " "
	6	pH = 4.0	90 "	"	~35:1	271 ?" " " "
#5	15	pH = 7.2 clear supernate	10 "	17 in Hg Vac.	5:1	141 " " " "

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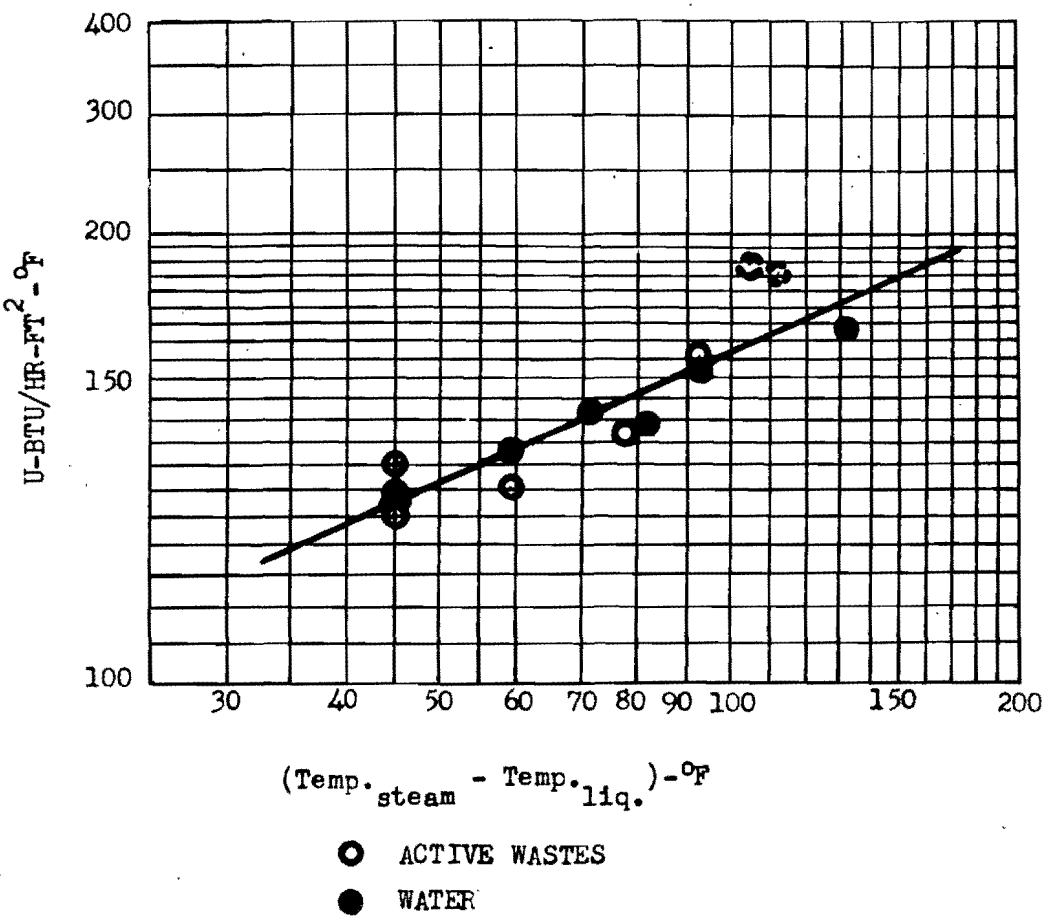
Drawing # 6652

Figure 2

OVERALL HEAT TRANSFER COEFFICIENT
VS ΔT



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4.2 Scale Formation

There is no evidence that scale formation will be a problem if the waste solution feed is acid. It was assumed that all the feed solution taken from waste tank W-5 would be basic (the tank is concrete) as was the feed in Run No. 1, and that Runs No. 2 and 3 would be made under basic conditions which would aggravate scale formation. However, Runs No. 2 and 3 were completed before it was learned that the pH had dropped below 7.0. Although there was no indication of scale formation in Run No. 1 (the coefficient remained at 150), one might suspect that the higher coefficients of Runs 2 ($U_{ave.} = 156$) and 3 ($U_{ave.} = 170$) resulted from gradual removal of scale formed early in Run No. 1. The fact that hour-to-hour coefficients in both Runs No. 2 and 3 remained constant is proof that such was not the case. However, scaling may have been noticeable had several consecutive runs been made with basic solution.

Ionic analyses on both acid and basic waste solutions are reported in Table II. These concentrations of ions increase by the volume-reduction factor ($\sim$20) toward the end of a run. In Run No. 4 which was started with a 15:1 concentration, the final solids concentration was 350 to 400 gms/liter - a volume reduction of $\sim$35 to 1 over the feed liquid.

TABLE II

Ionic Analyses of Feed Solutions
for Pilot Plant Evaporator

Analysis	Concentration - gms/liter	
	Acid Samples	Basic Samples*
U	0.88	0.026
Na	2.1	9.5
Ca	0.037	0.01
Mg	0.005	0.01
Al	0.07	0.4
Fe	0.003	0.001
Cl	0.26	0.35
F	0.005	0.005
CO_3	0.50	2.75
SO_4	0.50	0.9
PO_4	0.003	0.002
NO_3	7.9	17.7

* Represents average results of weekly composites taken over period 7-26-48 to 8-26-48.

4.3 Evaporation Rate

The full-scale system must evaporate water at the rate of 12.8 pounds per square foot of heating surface for its intended output of 2500 pounds per hour. Figure 3 is a plot of evaporation rates at various steam pressures for the small equipment. From these data one can judge that the large plant should be able to operate at capacity with 35 to 40 pound steam pressure, assuming no scaling and proper entrainment separation. The problem of entrainment is, of course, interrelated with rate of evaporation and may be the factor which limits the rate because of its effect on decontamination. (See decontamination).

4.4 Decontamination

As discussed in the introduction, a reduction in the activity of the present effluent from the concrete storage tanks to at least one-thousandth its present level is the goal of the large evaporator installation. The pilot model has proved definitely that this goal is attainable.

The five runs of this investigation were made under rather severe conditions, from a decontamination standpoint. Building 706-D had just completed a run with a 3-day old Hanford material which produced approximately a thousand curies of iodine waste activity. This in addition to $\sim$ 200 curies/day of long-lived activity from the Redox Hot Pilot Plant increased the intensity of the waste liquid stored in W-5 to 10^6 - 10^7 dis/ml/min during the time the experimental evaporator runs were made. This count is approximately a factor of 10 below the expected activity of the diluted waste which will be fed directly from the Redox Building to the large evaporator. Radiochemical analysis of the feed material gave the results in Table III. As may be seen, the various activities in the feed

Drawing # 6653

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Figure 3

EVAPORATION RATE
VS
STEAM PRESSURE

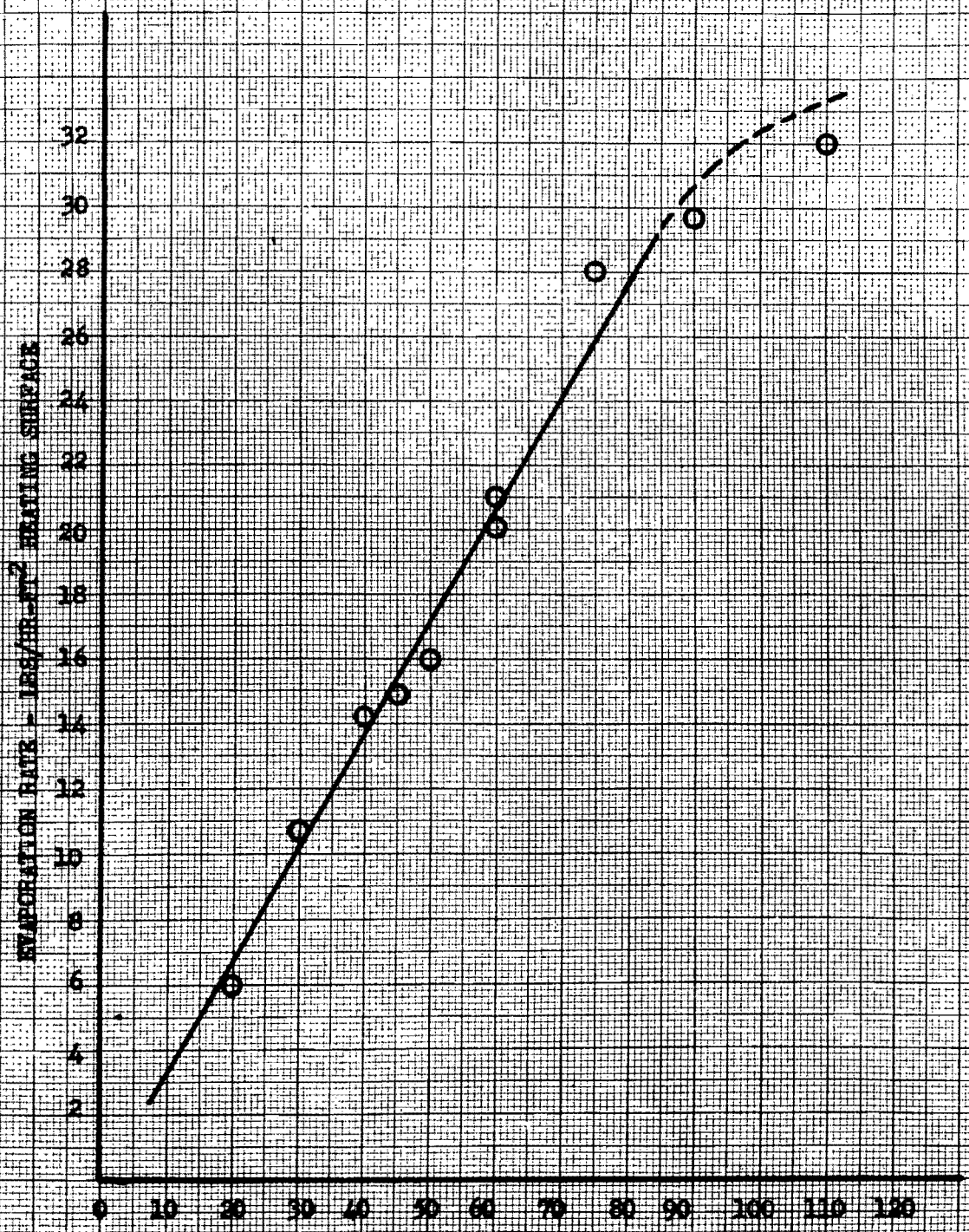

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TABLE III

Radiochemical Analyses of Feed Solutions for Pilot Plant Evaporator

Run No.	pH	Total Solids gms/L	Disintegrations per ml per minute								
			Gross β	Gross γ	Ru β	Zr β	Ce β	Sr β	Cs β	TRE* (-Ce) β	I^{131} β
1 (Supernate)	9.20	17.2	1.07×10^6	0.03×10^5	0.38×10^5	0.01×10^5	0.32×10^5	0.87×10^5	4.2×10^5	0.48×10^5	3.07×10^5
1 (Sludge)	----	all	7.0×10^7	-------	0.9×10^5	0.6×10^5	19.0×10^5	3.1×10^5	0.9×10^5	21.0×10^5	neg.
2 (Supernate)	4.20	20.0	4.99×10^6	0.13×10^5	0.61×10^5	0.42×10^5	17.3×10^5	0.37×10^5	0.56×10^5	0.78×10^5	18.6×10^5
3 (Supernate)	4.10	17.6	9.66×10^6	6.0×10^5	1.10×10^5	0.23×10^5	34.0×10^5	15.0×10^5	6.94×10^5	13.7×10^5	1.95×10^5
4 (Supernate)	7.70	10.3	3.50×10^6	4.0×10^5	1.30×10^5	0.13×10^5	2.67×10^5	16.4×10^5	9.20×10^5	2.93×10^5	1.77×10^5
5 (Supernate)	7.20	10.5	3.96×10^6	9.0×10^5	0.11×10^5	0.91×10^5	2.37×10^5	12.6×10^5	1.05×10^5	3.41×10^5	0.58×10^5

* Total rare earths less cerium.

4.4 Decontamination (Con't.)

stream vary considerably in amount from time to time as wastes are added to tank W-5. The pH's above 7 indicate that sodium carbonate was added to neutralize and to precipitate approximately half the dissolved solids. Some activity (roughly 10%) is carried down with the precipitate. Thus the precipitate is highly concentrated activity (see Table III) and should not be allowed to enter the evaporator, not only because of its greater intensity but also because it increases foaming and entrainment. An even more practical reason is that the material is already solid, the eventual state to which all liquid wastes are to be processed.

Figure 4 is a plot of typical data on the activity of the evaporator heel and decontamination as a run progresses. The decontamination factor (ratio activity in evaporator to activity in product stream) is seen to increase as the evaporator activity increases, resulting in a product of constant activity ($\sim 10^4$ d/ml/min). This level of activity is low enough to be sent directly into the settling basin. In fact, if one assumes a product of 10^4 d/ml/min. and a discharge rate of 300 gals/hr., the total activity in 24 hours would be $\sim$ 0.13 curies per day. If the evaporator is fed directly from waste sources as is planned, the feed should count roughly ten times higher on the average and result in a product count proportionately higher. The total activity discharged would then be $\sim$ 1.3 curies, assuming that the decontamination factor is no better than reported here.

However, there is good evidence that the evaporator can be operated to give higher decontamination factors. Examine the comparison of feed and condensate activities in Table IV. Note that the principal activity in the condensate stream is iodine^{131} (except in Run No. 5, basic solution), greatly out of proportion to its concentration in the feed stream. This great increase

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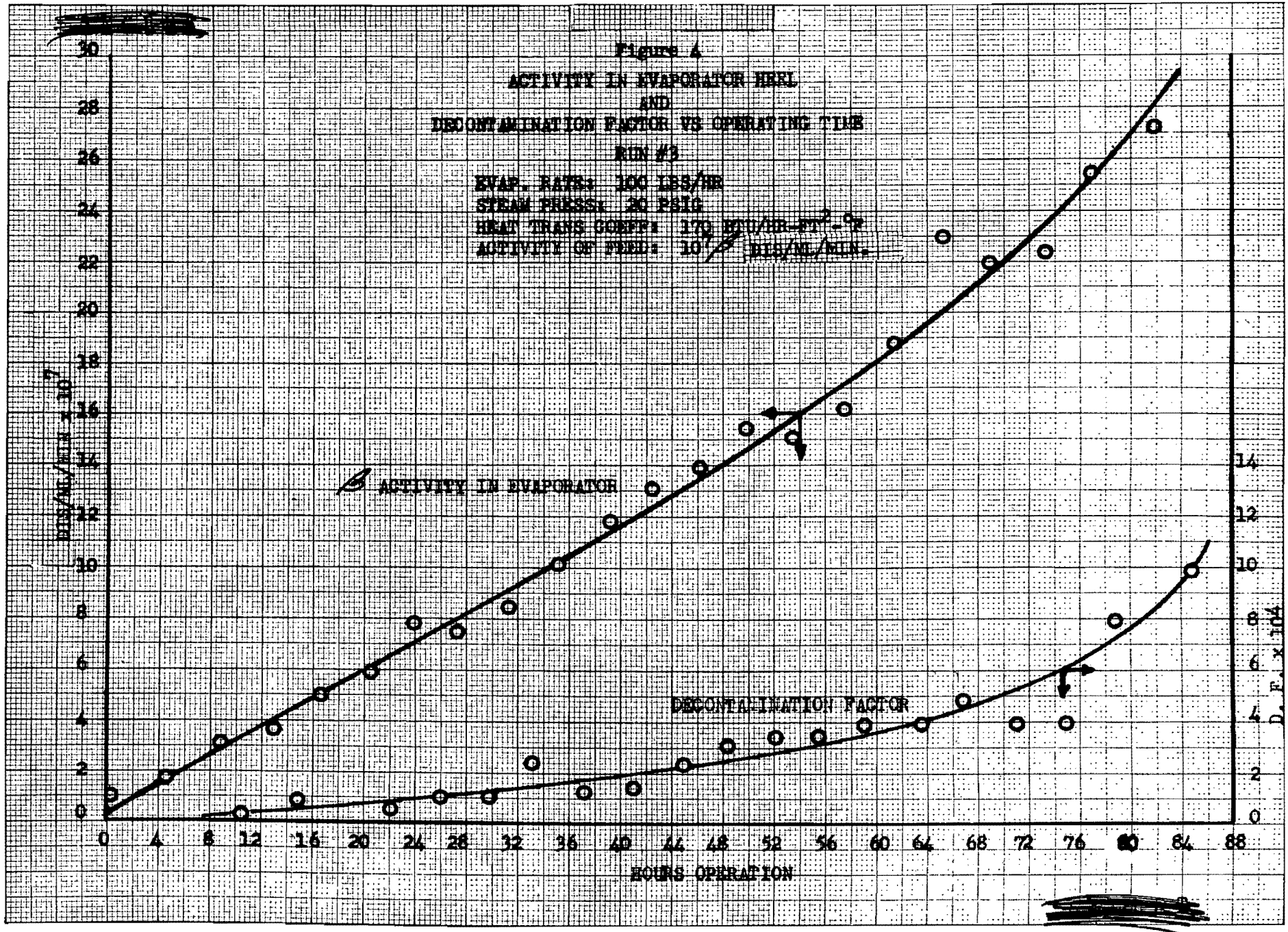

Drawing # 6654

TABLE IV

Comparison of Activities in Feed Solution and in Product Condensate

	FEED							CONDENSATE			
Run No.	pH	I	Sr	Ce	Cs	TRE	Ru	I	Sr	Cs	Ru
1	9.20	30%	8%	3%	40%	5%	4%	---	- not	analyzed	-
2	4.20	35%	8%	35%	12%	16%	1%	90%	---	---	neg.
3	4.10	2%	16%	35%	7%	14%	1%	90%	---	---	neg.
4 30 psig	7.70	5%	45%	8%	26%	8%	3%	70%	30%	neg.	neg.
45 psig	(Acid heel of Run No. 3 not drained)	"	"	"	"	"	"	10%	1%	10%	neg.
60 psig		"	"	"	"	"	"	30%	10%	7%	neg.
75 psig		"	"	"	"	"	"	40%	6%	10%	neg.
90 psig		"	"	"	"	"	"	65%	5%	10%	5%
5 (vacuum)	7.20	1%	31%	6%	27%	9%	1%	10%	20%	65%	6%

[redacted]

4.4 Decontamination (Con't.)

indicates the volatilization of iodine from the acid solution. The short half-life (8 days) of the iodine makes it relatively unimportant because if it were discharged directly to the settling pond, it would decay through $\sim$35 periods to reduce its original value by a factor of $\sim 10^{10}$. Volatilization might be prevented by the addition of a complexing agent. It is known[3] that the presence of microgram quantities of mercury reduces iodine liberation from some waste solutions by formation of an HgI_4 complex. However, the possibility of producing some gaseous iodine may make it desirable to continue storing wastes from barium runs in tank W-5 for 8 to 10 weeks before evaporation. Removal of iodine should increase the decontamination factor by 5 to 10.

Except for the volatilized iodine, the contamination of the condensate stream is by entrainment. The pilot evaporator was operated without an entrainment separator but the design of the full scale facility includes this piece of equipment. In the discussion of Run No. 4 (See Appendix 6.2, Operations) it is noted also that insufficient vapor space was available to prevent serious entrainment at high steam pressures. The large evaporator has a 3-times greater height of vapor space which, in conjunction with a separator, should permit operation without entrainment at a much higher temperature differences. The increase in decontamination efficiency will, of course, be directly proportional to the effectiveness (an unknown, at present) of the entrainment separator. In the event that an entrainment separator is unsatisfactory, the contaminated condensate might be passed through a resin bed. Resins have been found efficient in the removal of the rare earths, strontium and cesium ions and appear promising as a

[redacted]

4.4 Decontamination (Con't.)

solution if the problem arises. Decontamination factors of ~ 200 can be expected with resin treatment of those wastes.[4] A laboratory investigation is now underway to determine efficiency and capacities for the case at hand.

4.5 Vacuum Operation

Vacuum operation was not investigated sufficiently to justify conclusive statements. However, there is no doubt that evaporation at atmospheric pressure is more desirable both economically and from an operational standpoint. Since the runs at atmospheric pressure provide sufficient evidence of satisfactory operation, provision for vacuum operation is not thought necessary.

4.6 Shielding Requirements

With approximately 50 gallons of concentrated waste solution counting 10^8 β dis/ml/min and 10^6 γ dis/ml/min, the activity intensity at the surface of the evaporator was 1 r/hr. Two six-inch thicknesses of concrete reduced this activity to 15 mr/hr. At the same time the feed tank, with 60 gallons of waste solution counting 10^7 β dis/ml/min and 10^6 γ dis/ml/min, read 700 mr at the surface and 20 mr through 6 inches of concrete. These thicknesses of shielding were adequate for pilot plant operations.

S. E. Beall

S. E. Beall

1/28/49

Date

[redacted]

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APPENDIX

6.10 EQUIPMENT (See Sketch 1)

6.11 Feed Tank

Height: 48 inches
Diameter: 32 inches
Volume: ~150 gal.
Material: Type 347 Stainless Steel

The tank was mounted on a 6 foot high platform to allow gravity flow of feed to the evaporator. A type CL-1A steam jet from waste tank W-5 supplied waste solution at 4 to 8 hour intervals as needed. The top of this tank was sealed except for a 2-inch vent line and an overflow back to W-5. Liquid level and specific gravity dip pipes, and a thermocouple well were quarter-inch 1PS pipe. A half-inch air sparger was provided for agitation.

6.12 Evaporator Tank

Height: 48 inches
Diameter: 24 inches
Volume: ~100 gal.
Material: Type 347 Stainless Steel

Steam Coil

Pipe Size: 1/2 inch, 1PS
Diameter: 18 inches
Height: 26 inches
Surface Area: 16 ft^2
Material: Type 347 Stainless Steel

The steam coil was located one inch above the tank bottom, concentric with the wall and welded through the bolted cover. Vapor space above the top of the coil was approximately 20 inches. A 7-inch diameter shallow cone baffle plate was welded in the 6-inch flanged opening to which the 3½-inch vapor line was attached. Although the vapor line appears inordinately

6.12 Evaporator Tank (Con't.)

high, the height was necessary for installation of the condenser at a 60° angle as in the full-scale plant.

Other attachments to the tank cover included a half-inch feed line, 1/4-inch IPS dip pipes for liquid level, specific gravity and thermocouple wells, and a vacuum-pressure equalizer line. A 3/4-inch drain line and a 1/8-inch sample line were attached at the tank bottom. The tank and the vapor line were lagged with a 2-inch thickness of magnesia and weather-proofed.

6.13 Condenser

Type: Shell and tube
Length: 6 ft.
No. tubes: 44
Dia. tubes: 3/4 inch
Surface Area: 50 ft^2
Shell material: Black iron
Tube material: Stainless Steel

Thermocouple wells were provided at inlets and exits of the shell (water temperatures) and tubes (vapor and condensate temperatures). A sample line at the condensate end was provided for frequent sampling and inspection of the condensed liquid.

6.14 Condensate Receiver

Height: 48 inches
Diameter: 24 inches
Volume: ~100 gal.
Material: Type 347 Stainless Steel

A CL-1A steam jet mounted on top of the catch tank served to evacuate the system and maintain a 20-inch Hg. vacuum in the evaporator when desired. The steam discharged from the jet was condensed in a spray condenser fed with cooling water from the condenser.

6.14 Condensate Receiver (Con't.)

A liquid level, dip pipe, vacuum equalizer, and thermocouple well of 1/4-inch pipe were mounted through the top of the tank, with a 1/2-inch air sparger for agitation. Drainage and sampling lines were attached at the bottom of the tank.

6.15 Steam Condensate Weigh Tank

A 55 gallon stainless steel drum mounted on a 1000-pound capacity Fairbanks platform scale served as a collector for steam condensate. A length of tygon tubing connected the drain outlet to the waste drain line.

6.16 Shielding

Concrete blocks, 6 in. x 6 in. x 12 in., were used for shielding. Two six-inch layers were stacked around the evaporator tank and a single six-inch layer around the feed tank.

6.17 Instrumentation

An instrument board, not shown in Figure 1, contained three 36-inch manometers for indication of the weights of liquid in the feed, evaporator and catch tanks. Two 18-inch manometers showed the specific gravities of the feed and evaporator tank liquids. An 8-point Micromax instrument recorded temperatures in all tanks as well as condenser water and vapor temperatures.

APPENDIX

6.20 OPERATIONS

6.21 Water Runs

Initial operating experience was obtained during 24 hours operation with water in the system. Data were collected for heat transfer coefficients at steam pressures up to 110 psig. Minor difficulties such as leaking flanges and valves were corrected during this period.

The system then was charged with an inactive waste solution containing ionic concentrations as indicated by analysis of the active waste liquid. After 6 hours operation at maximum evaporation rate without evidence of scaling or other difficulties, the equipment was drained and readied for active runs.

6.22 Run No. 1

The first run with active waste solution was made at 20 psig steam pressure with the system at atmospheric pressure. Difficulties appeared immediately after running the first charge to the evaporator. Steam to the heating coil had been on 4 or 5 minutes when the evaporator liquid level manometer began moving very erratically. It appeared that the manometer line was blocked by a slug of condensed vapor, so the line was disconnected for draining. Shortly afterward, the evaporator pressure surged upward for an instant and forced hot waste solution out the manometer line, spraying several onlookers. At the same time a quantity of liquid from the evaporator was carried up through the condenser and into the catch tank, thoroughly contaminating both. The system was shut down immediately.

6.22 Run No. 1 (Con't.)

Several factors contributed to this mishap: The evaporator should have been only partially filled and brought to boiling before increasing the liquid level to the operating level. Heat should have been applied gradually. A large amount of suspended solids in the feed liquid resulted in excessive foaming and bumping.

A second attempt to put the system in operation was more successful. Evaporation at a rate of 100 lbs. per hour was continued for 24 hours with the intention of decontaminating the condenser and catch tank. During this period operators were trained to make continuous 3-shift operation possible. Feed material from W-5 contained a large amount suspended matter throughout Run No. 1, making it difficult to maintain steady-state conditions.

After completion of Run No. 1, all additions of waste to W-5 were stopped and the tank allowed to settle. In the meantime the equipment was rinsed thoroughly to remove any remaining solids.

6.23 Runs Nos. 2 and 3

Runs Nos. 2 and 3 were both made with clear supernate at 20 psig steam (other conditions equal) for a measure of reproducibility. Some trouble was experienced with maintaining a constant evaporator level in Run No. 2. At levels above 28 inches, entrainment was severe enough to carry color into the catch tank. In Run No. 3, operator functions were sufficiently routine that excellent results were obtained.

Each of these runs required approximately 90 hours of continuous evaporation to concentrate 10,000 lbs. of waste to 500 lbs., the rate of water removal averaging 105 lbs/hr.

6.24 Run No. 4

This run was started without removing the evaporator heel remaining after completion of Run No. 3. Coil steam pressures of 30, 45, 60, 75 and 90 psig were held 8 hours each. One difficulty encountered was that of preventing serious entrainment carryover. As the higher steam pressures increased both the violence of boiling and the vapor velocity, the liquid level of the evaporator had to be reduced to prevent foaming over. Approximate operating levels for no visible entrainment were:

20 #'s - 26-28 inches
30 " - 25 inches
45 " - 20 inches
60 " - 17 inches
75 " - 15 inches
90 " - 12 inches

Successful operation at pressures above 45 psi requires experience for which time was not available. At least a duplicate of this run would have been necessary for good data.

After six hours operation at 30 psig steam pressure an attempt to partially drain the evaporator showed the evaporator drain line to be frozen. The solids content of the evaporator heel was ~300 gms per liter at this time. The application of steam to the drain line was successful in thawing the line. This incident suggests steam tracing for lines 1 inch or smaller and at least lagging for larger lines.

At the end of this run background activity had increased to several hundred mr at some points and was considered hazardous to operating personnel who had already received several overexposures.

A deadline of December 20th, had been set for completion of this work so that construction could be started on waste unloading facilities for the

6.24 Run No. 4 (Con't.)

Atomic Energy Commission. Run No. 4 was completed on December 18th, leaving 48 hours for decontamination of equipment and completion of a vacuum run.

It was decided to decontaminate and operate under vacuum conditions in the remaining time.

6.25 Run No. 5

After decontamination 18 hours were available for vacuum operation. The run was made at 10 psig steam pressure, 17 inches mercury vacuum with a ΔT equivalent to $\sim$35 psig steam at atmospheric pressure in the evaporator. Although the system required more attention and rates were somewhat more erratic than in previous runs no difficulties appeared which could not have been eliminated with more operating experience.

APPENDIX

6.30 Improvement of Equipment and Procedures

From the operational experience accumulated during this investigation several suggestions for improvement of equipment and control may be noted:

6.31 Decontamination after severe entrainment.

Once the condenser and catch tank becomes contaminated, several hours normal operation are necessary to eliminate the contamination from the product stream. During this time condensate should not be discharged, but returned to the system for reevaporation. Much more rapid decontamination is possible with live steam. This suggests a steam line discharging just below the top of the evaporator tank. With condenser cooling water off, all equipment beyond the evaporator could be effectively decontaminated in much less time.

6.32 Start-up Precautions

Start ups should be made with a low liquid level in the evaporator, the level being increased gradually after boiling has begun. Cautious starts are good insurance against contamination which might linger in the condenser and catch tank.

6.33 Evaporator liquid-level and specific gravity indicators

In the pilot evaporator dip tubes for liquid level and specific gravity manometers were located in the main body of the tank. A side arm outside the tank or a protected well inside would have been much more satisfactory.

The Well-type 36 inch manometers used in this installation were unsatisfactory. Taylor or Ring Balance Recorders should be used in the final installation.

6.34 Protection of Drain and Sample Lines

The freezing (or plugging with precipitate) of the evaporator drain and sample lines suggests that every precaution be taken to prevent such an occurrence where larger quantities of activity are involved. Lines exposed to low temperatures should be steam traced and rinsed after each use. Lines smaller than one inch should not be used for gravity flow.

6.35 Sludge Elimination

The elimination of all sludge from evaporator feed is highly desirable for many reasons including better decontamination, smoother operation, lower activities handled, and fewer plugged lines. Special care should be taken to see that the intakes of all jets to the feed tanks are located in the clear-supernate zone of the supply tanks and that the supply tanks are not agitated unnecessarily when feed is to be withdrawn.

6.36 Condensate Monitoring

The monitoring of the product stream from the condensers to give a continuous record of decontamination would be highly desirable. Such a device could be used to shut down the system automatically, if an operator were not in attendance. Several types of ion chambers and Geiger tube monitors have been used satisfactorily for measuring activities of flowing steams and it is not unlikely that one of these designs[5,6] could be adopted.

6.37 Decontamination of Equipment

After draining all tanks, rinsing and evaporating 1000 lbs of water in the system, Cutie Pie readings at contact showed 300 mr/hr in the feed tank and 400 mr/hr on the evaporator. The feed tank was then filled with a 10% nitric acid solution and steam sparged for one hour. The nitric acid

6.37 Decontamination of Equipment (Con't.)

was fed into the evaporator and boiled for 8 hours. This treatment was repeated and followed by 2 hot water rinses, after which the feed tank read 5 mr/hr., the evaporator 60 mr/hr., the condenser 20 mr/hr., and the catch tank 2-3 mr/hr. The entire installation was then dismantled and sent to the burial grounds.

APPENDIX

6.40 Estimation of Waste Activities

6.41 Daily Waste from Redox Hot Pilot Plant

Basis: Dissolver Solution Activity

(a) Volumn of Dissolver Solution processed per week at maximum rate = ~75 gals.

(b) Activity of Dissolver Solution - 10^{10} dis/ml/min.

Assume that entire quantity of activity reaches waste tank W-5 - at 10 gallons per day, curies discharged per day:

$$\frac{10 \text{ gals/day} \times 4 \times 10^{3} \text{ ml/gal} \times 10^{10} \text{ dis/ml/min}}{3.7 \times 10^{10} \text{ dis/sec/curie} \times 60 \text{ sec/min}} = \sim 200 \text{ curies/day}$$

6.42 Wastes from D-Building to Tank W-5 for one Ba^{140} Run -

Basis: 2500 curies Ba^{140} in metal dissolved

Fiss. Yield of Ba^{140} = ~6%

Fiss. Yield of I^{131} = ~ 3%

Amount I^{131} = ~1300 curies

Assume an average processing time of 8 days so that half this amount is sent to waste Tank W-5.

Amount I^{131} to W-5 = ~ 650 curies.

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