

UNCLASSIFIED

UNCLASSIFIED



OAK RIDGE NATIONAL LABORATORY  
Operated By  
CARBIDE AND CARBON CHEMICALS COMPANY

UCC

POST OFFICE BOX P  
OAK RIDGE, TENNESSEE

0

ORNL  
CENTRAL FILES NUMBER

CF-54-6-31

DATE: June 4, 1954

SUBJECT: Continuation of HRT Fuel Solution Evaporator Study

TO: W. R. Gall

FROM: C. L. Segaser

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission to the extent that such employee or contractor prepares, handles or distributes, or provides access to, any information pursuant to his employment or contract with the Commission.

- 1. A. S.
- 2. J. N.
- 3. S. E.
- 4. E. O.
- 5. R. B.
- 6. F. R.
- 7. A. H.
- 8. K. D.
- 9. H. C.
- 10. E. L.
- 11. F. L.
- 12. J. S.
- 13. M. C.
- 14. D. M. Eisenberg
- 15. W. K. Eister
- 16. D. E. Ferguson
- 17. W. R. Gall
- 18. H. E. Goeller
- 19. O. B. Graham
- 20. J. C. Gross
- 21. J. J. Harriston
- 22. W. G. Harms
- 23. P. H. Harnsreich
- 24. J. W. Hill

- 35. Thomas
- 36. Winkle
- 37. Walker
- 38. Weinberg
- 39. Winters
- 40. Schissel
- 41. Wood

- 42. RRP File
- 43. Laboratory Book
- 44. ORNL-20

Photostat Price \$ 1.80

Microfilm Price \$ 1.80

Available from the  
Office of Technical Services  
Department of Commerce  
Washington 25, D. C.

UNCLASSIFIED

UNCLASSIFIED

## DISCLAIMER

**This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.**

## **DISCLAIMER**

**Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.**

CLASSIFICATION CANCELLED

DATE APR 2 1957 *W*

For The Atomic Energy Commission

*H. F. Cancell*

Chief, Declassification Branch

CONFIDENTIAL

CONFIDENTIAL

CONFIDENTIAL

CONFIDENTIAL

CONFIDENTIAL COVER SHEET  
The manufacturing process is controlled  
by the Atomic Energy Commission  
for classification. The classification  
is placed in the record book, yet of  
the document classification, the record book  
RECYCLED PAPER

-1. In ORNL CF-54-5-2, two preliminary design studies of an evaporator for use with the HRT were presented. A third possible arrangement is shown by Figure 1 of this memorandum, in which the evaporation is presumed to occur in two inclined 4-inch - schedule 40 stainless steel steam-jacketed pipes supported below the inner dump tanks. In addition to the primary functions of supplying diluent steam for the recombiner gases and a means of fuel solution concentration, this arrangement should also tend to keep the fuel solution in the dump tanks agitated, and as the fuel solution becomes concentrated an "eversafe" storage volume of ~80 liters is automatically provided.

It was shown in ORNL CF-54-5-2, that for an evaporation rate of 1/2 gpm a calculated surface area of 8.5 ft<sup>2</sup> is required, based on the evaporation occurring from the surfaces of vertical steam-jacketed stainless steel pipes. The inner pipe of the arrangement shown by Figure 1 of CF-54-5-2 is a 4" - schedule 40 pipe, hence, this analysis for the surface area requirements is also applicable to the arrangement of Figure 1 herein. Actually, the proposal of an inclined pipe with the vaporizing fluid flowing at relatively high velocity thru the pipe should be more favorable to heat transfer than the arrangement shown in CF-54-5-2.

The general specifications for the evaporator schematically shown by Figure 1 herein are as follows:

Evaporation rate, gpm	0.500	1.00
*Pressure in evaporator, psia	14.7	14.7
*Evaporation temperature, °F	~ 212	~ 212
Heat balance:		
Rate, lb/hr	264	528
Heat transferred, Btu/hr	2.76 x 10 <sup>5</sup>	5.52 x 10 <sup>5</sup>

\* Elevation in boiling point was not considered and the properties were assumed those of H<sub>2</sub>O for this study. A factor of safety of 1.5 was applied to the final results.

## Heat transfer coefficients

Steam side coefficient, Btu/hr-ft <sup>2</sup> -°F	1500	1500
Wall coefficient, Btu/hr-ft <sup>2</sup> -°F	520	520
Boiling coefficient, Btu/hr-ft <sup>2</sup> -°F	2.3 $\Delta T_B^2$	2.3 $\Delta T_B^2$
Jacket steam pressure, psig	75	75
Jacket steam temperature, °F	320	320
Apparent temperature difference, °F	108	108
Calculated heat transfer area, ft <sup>2</sup>	8.5	17
Actual heat transfer area, ft <sup>2</sup>	12.5	25
Factor of safety	1.47	1.47
Apparent overall heat transfer coeff, Btu/hr-ft <sup>2</sup> -°F	204	204
Calculated overall heat transfer coeff., Btu/hr-ft <sup>2</sup> -°F	300	300
Heat flux, Btu/ft <sup>2</sup> -hr	22,000	22,000

Recirculation rate and outlet velocity from vaporizer pipe. In order to keep the solution in the inner dump tanks well mixed, it is desirable that the solution should be agitated during storage by recirculation at a relatively high rate. The following calculations indicate that for every pound of vapor released in the vaporizer pipe there will be recirculated 176 pounds of solution. If it is assumed that the dump tanks are fabricated from 14-inch schedule 40 stainless steel pipe and that following a dump the tanks will run approximately half full, the rate of recirculated solution will be 85 gpm per tank.

The velocity of vapor-solution mixture leaving the evaporator pipe and entering the dump tanks is shown to be 22.9 ft/sec. This mixture contains 176 times as much solution as it does vapor, hence an entrainment separator must be provided in the system to remove this moisture before the vapor-gas mixture enters the recombiner. Much of this moisture may be removed by settling out

in the dump tank vapor volume if the vapor-gas outlet is located at the opposite end of the tank from the evaporator outlet connection.

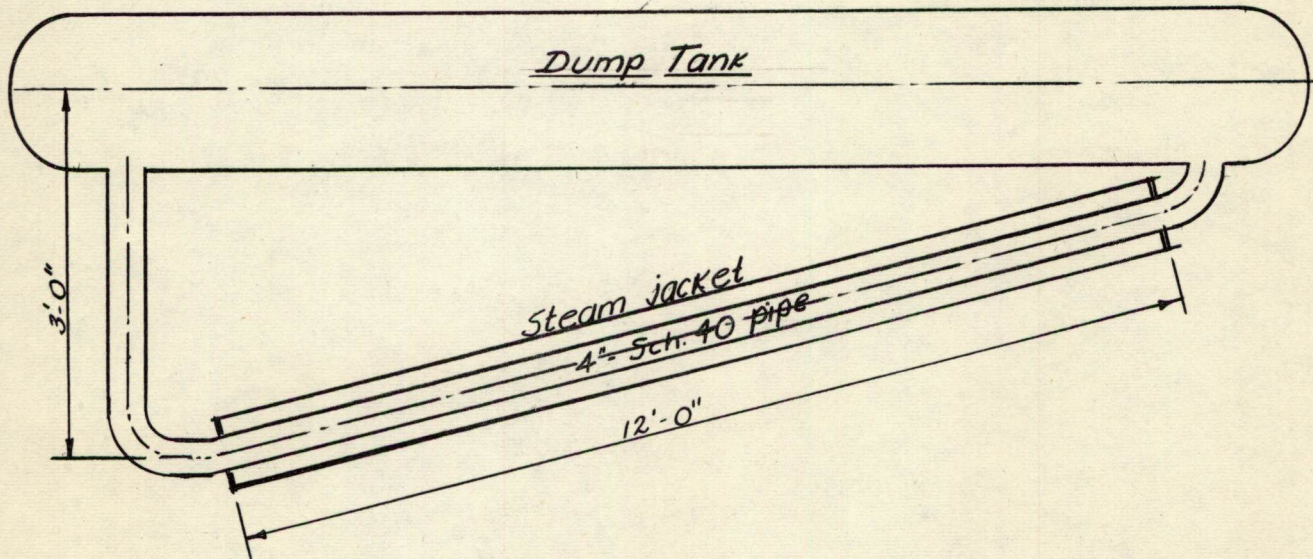


Figure 1  
Schematic Diagram of HRT Fuel Solution Evaporator

- A. Properties of Fuel Solution (16.3 g U/kg D<sub>2</sub>O)  
At 212°F

$$\text{Inlet} \begin{cases} \rho_1 = 68 \text{ lb/ft}^3 \\ \mu_1 = 0.823 \text{ lb/hr-ft} \end{cases}$$

The specific volume of vapor out of the vaporizing section may be estimated from steam tables, taking into account the density difference between H<sub>2</sub>O and D<sub>2</sub>O.

$$v_{\text{steam}} = \frac{26.8}{1.07} = 25 \text{ ft}^3/\text{lb}$$

$$\therefore \rho_{\text{steam}} = \frac{1}{25} = 0.04 \text{ lb/ft}^3$$

### B. Recirculation Ratios

Attained when the sum of the resistances in the vaporization circuit is equal to the hydrostatic driving force on the vaporizing fluid.

#### Principal resistances.

- (1) Pressure drop thru inlet piping.
- (2) Pressure drop thru vaporizer pipe.
- (3) Expansion loss due to vaporization.
- (4) Static pressure leg of vapor and solution in vaporizer pipe.
- (5) Pressure drop thru outlet piping.

#### Assumptions:

- (1) Expansion loss due to vaporization. Taken as two velocity heads based on the mean of the inlet and outlet densities.

$$\Delta p = \frac{G^2}{144 g \rho_{av}} \text{ psi}$$

- (2) Average density in vaporizing pipe. At the start of the vaporizing zone the density is that of liquid, whereas, at the outlet it is considerably less, even if the percentage converted to vapor is not very high. Likewise, with constant-flow area the velocity increases toward the outlet owing to the large volume of the exit fluid, although the mass velocity is constant. On the other hand, the viscosity effective upon the pressure drop probably does not vary much over the vaporizing zone, being that of the liquid throughout. The pressure drop can be computed using the mass velocity, the Reynolds number based on liquid properties at inlet conditions and the mean density between inlet and outlet.

703 005

$$\text{Approximate density} = \frac{v_1 + v_2}{2}$$

It is stated in Process Heat Transfer by Kern, that since the pressure drop is inversely proportional to the density, the approximate method is safe.

$$(3) \text{ Recirculation ratio } = \frac{\text{lbs/hr of solution leaving}}{\text{lbs/hr of vapor alone}}$$

Evaporation rate - 1 gpm total or 1/2 gpm per section.

$$1/2 \text{ gpm} = 4.4 \text{ lb/min at atm.}$$

$$\text{or } (4.4)(60) = 264 \text{ lb/hr of vapor at 14.7 psia.}$$

	Recirculation Ratio			
	1	10	100	176
Weight flow of vapor, lb/hr	264	264	264	264
Weight flow of recirculated soln., lb/hr	264	2640	26,400	46,500
Liquid volume out of vaporizer pipe, ft <sup>3</sup> /hr	3.89	38.9	389	683.0
Vapor volume out of vaporizer pipe ft <sup>3</sup> /hr	6600	6600	6600	6600
Total liquid and vapor volume out of vaporizer pipe, ft <sup>3</sup> /hr	6604	6639	6989	7283
Total liquid and vapor weight out of vaporizer pipe, lb/hr	528	2904	26,664	46,764
Specific volume of outlet mixture ft <sup>3</sup> /lb	12.5	2.29	0.262	0.156
Average specific volume of mixture in vaporizer pipe ft <sup>3</sup> /lb	6.26	1.15	0.138	0.0855
Average density of mixture in vaporizer pipe lb/ft <sup>3</sup>	0.160	0.870	7.25	11.70
Mass flow velocity in vaporizer pipe lb/hr-ft <sup>2</sup>	5970	32,800	302,000	529,000
Reynold's number based on inlet conditions DG/μ	2440	13,400	123,000	216,000

		Recirculation Ratio			
		1	10	100	176
(A) Pressure drop thru inlet section (Based on equivalent length of 6.25' of 4"-sch. 40 S.S. pipe)					
Liquid velocity in inlet pipe					
	{ ft/hr	87.8	482	4430	7780
	{ ft/sec	0.0244	0.134	1.230	2.16
Velocity head	ft	$9.25 \times 10^{-6}$	$2.78 \times 10^{-4}$	0.0236	0.0725
<u>Pressure drop</u> at inlet of approach pipe based on $0.5 \frac{V^2}{2g}$	{ ft	$4.62 \times 10^{-6}$	$1.39 \times 10^{-4}$	0.0118	0.0362
	{ psi	$2.18 \times 10^{-6}$	$6.56 \times 10^{-5}$	0.00557	0.0171
Reynold's number		2440	13,400	123,000	216,000
Friction factor		0.014	0.0085	0.0055	0.0050
<u>Pressure drop</u> thru approach pipe	{ ft	$9.68 \times 10^{-6}$	$1.77 \times 10^{-4}$	$9.63 \times 10^{-3}$	$2.70 \times 10^{-2}$
	{ psi	$4.57 \times 10^{-6}$	$8.35 \times 10^{-5}$	$4.54 \times 10^{-3}$	0.0127
(B) Pressure drop thru vaporizer pipe (Based on 12'-0" of 4" sch. 40 pipe)					
Mixture velocity thru vaporizer pipe	{ ft/hr	37,300	37,800	41,700	45,200
	{ ft/sec	10.4	10.46	11.60	12.55
Velocity head	ft	1.67	1.68	2.08	2.45
<u>Pressure drop</u>	{ ft	3.37	2.04	1.64	1.75
	{ psi	0.00375	0.0123	0.0825	0.142
(C) Expansion loss due to vaporization					
<u>Pressure drop</u>	{ ft	3.36	3.37	4.16	4.90
	{ psi	0.00374	0.0203	0.210	0.398

703 008

Recirculation Ratio

		1	10	100	176
(D) Static pressure leg of vapor and solution in vaporizer pipe based on 2.5 ft downcomer					
<u>Pressure drop</u>	$\left\{ \begin{array}{l} \text{ft} \\ \text{psi} \end{array} \right.$	0.00278	0.0151	0.126	0.204
(E) Pressure drop thru outlet section (Based on loss thru one 4"-sch. 40 El. and Expansion)					
Velocity in outlet piping	$\left\{ \begin{array}{l} \text{ft/hr} \\ \text{ft/sec} \end{array} \right.$	74,700 20.8	75,000 20.8	79,200 22.0	82,600 22.9
Velocity head	ft	6.70	6.70	7.52	8.16
Reynold's number		64,000	351,000	3,230,000	5,670,000
Friction factor		0.006	0.0049	0.0040	0.004
<u>Pressure drop</u> thru elbow	psi	0.00107	0.00477	0.0381	0.0695
<u>Pressure drop</u> - outlet	psi	0.00372	0.0204	0.178	0.362
Total resistance to flow	psi	0.01507	0.07296	0.64471	1.205
Head available for circulation	psi	1.18	1.18	1.18	1.180

703 009

Recommendations

The proposed arrangement of evaporator and dump-tank combination shown herein apparently satisfies the requirements of the system enumerated as follows;

- 1) Normal evaporation 1/2 gpm
- 2) Maximum evaporation 1 gpm
- 3) Eversafe storage 80 liters (50 liters is the minimum)
- 4) Solution agitation 85 gpm/tank

However, it is recommended that a full scale mockup of one section of the dump tank and evaporator system shall be fabricated for performance tests. The test set-up may be expanded to include the following;

- 1) Evaporation rate at various jacket steam pressures up to 100 psig.
- 2) Heat balance and overall heat transfer coefficient.
- 3) Recirculation rate through evaporator and dump tank.
- 4) Outlet vapor-liquid velocity.
- 5) Moisture content from dump tank gas vapor outlet.
- 6) Differential thermal stresses in steam jacket and evaporator pipe.
- 7) Dump tank contents by weigh cell.
- 8) Efficiency of proposed centrifugal mesh type entrainment separator.
- 9) Effect of concentration on evaporation rates and heat transfer coefficients.

703 010

DECLASSIFIED