Wiped Film Evaporator Pilot Scale Experimental Design Data Analysis

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ABSTRACT & BACKGROUND

Abstract

- This report analyzes data collected from a previous pilot scale experiment of a Wiped Film Evaporator (WFE) used to reduce the amount of liquid from the waste of three stimulants with representative compositions of the U.S. Department of Energy's Hanford Site tanks.
- The data was studied by applying a linear regression model to the observations.
- Differences in the results obtained in two consecutive sets of data, lead us to suspect a delay in the reading of the specific gravity, influenced by the test configuration and the associated recording method. A new location for recording the response was proposed.
- The factors vacuum pressure, temperature and feed flow were significant in achieving higher values of specific gravity.
- These same factors were set to implement a Response Surface Methodology (RSM) in order to optimize the process.

Background

- Most of the waste generated at the Hanford site is stored in 177 underground tanks.
- Most of waste held in the tanks is subject to change as waste is retrieved from SSTs to DSTs.
- Double Shell Tanks do not have enough capacity to hold all the waste from SST retrieval processes.
- The 242-A Evaporator is the only evaporation system available to support waste retrieval projects.

PURPOSE & HYPOTHESIS

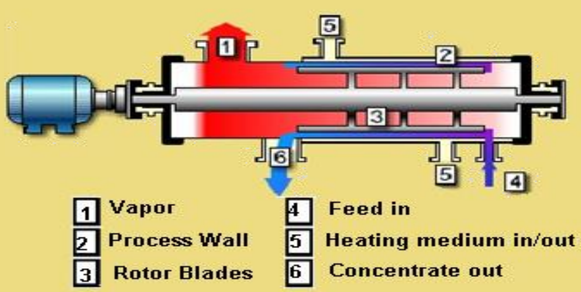
Purpose

- Columbia Energy proposes the use of a Wiped Film Evaporator to help in the process of liquid reduction present in the waste.
- Demonstrate that the hypothesized factors (vacuum pressure, feed flow and temperature) involved in the process were significant in achieving high specific gravity values in a short period of time.
- Create a Linear Regression Model in order to describe the data previously recorded and predict new changes in the specific gravity.

Hypothesis

- The test of significance of the model was based on the null hypothesis that the factors mentioned above were insignificant to the model. The alternative hypothesis was that at least one of the factors was significant.
- Mathematically expressed as: $H_o : \beta_1 = \beta_2 = ... = \beta_k = 0$, $H_1 : \beta_k \neq 0$

Wiped Film Evaporator Scale Design



MODEL SET UP & DATA ANALYSIS

The Linear Regression Model

This model was set to test the significance of the regression equation and its coefficients using an ANOVA method.

$$y_i = \beta_o + \beta_1 x_1 + ...\beta_k x_k + \varepsilon_i$$

$$\varepsilon_i = y_i - \left\{ \beta_o + \sum_{i=1}^{k} \beta_i x_i \right\}$$

$Least \cdot Square \cdot Method$

$$L = \sum_{i=1}^{n} \vec{\varepsilon}_i^{\,2} = \varepsilon^{'}\varepsilon \xrightarrow{differentiate} \frac{\partial L}{\partial \beta} = 0$$

$$\vec{\beta} = \left(X^{'}X\right)^{-1} X^{'}\vec{y}$$

$$SS_T = \sum_{i=1}^{n} y_i^2 - \frac{\left(\sum_{i=1}^{n} y_i\right)^2}{n} = \vec{y}^{'}\vec{y} - \frac{\left(\sum_{i=1}^{n} y_i\right)^2}{n}$$

$$SS_E = \sum_{i=1}^{n} \left(\vec{y}_i - \hat{\vec{y}}_i\right)^2 = \sum_{i=1}^{n} \left(\varepsilon_i\right)^2 = \varepsilon^{'}\varepsilon = y^{'}y - \vec{\beta}^{'}X^{'}y$$

$$SS_T = SS_R + SS_E \xrightarrow{then} SS_R = SS_T - SS_E = \vec{\beta}^{'}X^{'}y - \frac{\left(\sum_{i=1}^{n} y_i\right)^2}{n}$$

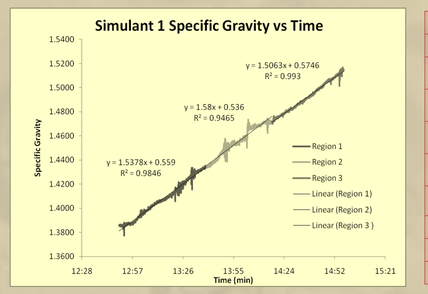
$$R^2 = 1 - \frac{SS_E}{SS_T}$$

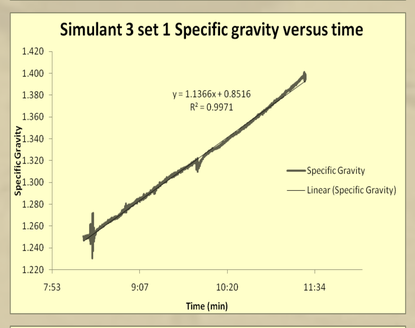
$$R^2_{adjust} = 1 - \left(\frac{N-1}{N-p}\right)(1-R^2)$$

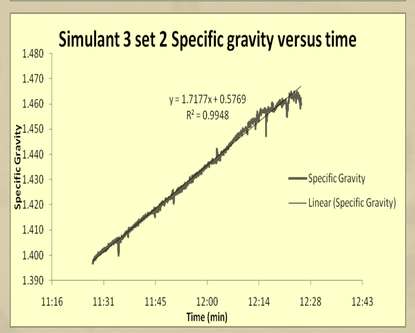
$$R^2_{prediction} = 1 - \frac{PRESS}{SS_T}$$

The data was arranged according to the model in which X represents the matrix of the parameters evaluated, y is a column vector representing the specific gravity, β is a column vector representing the regression coefficients and ε is a column vector representing the difference between the observed and the fitted values.

Data Analysis

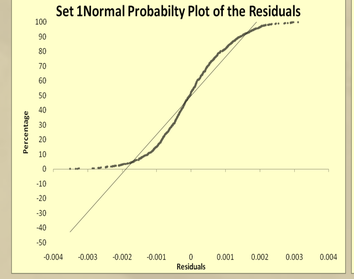


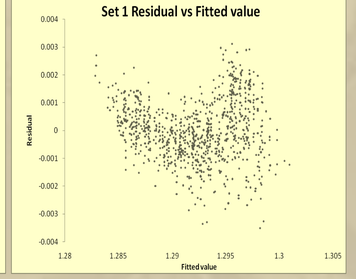




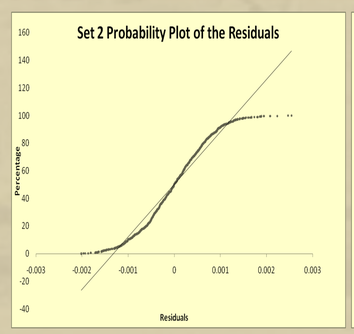
Linear Regression Model

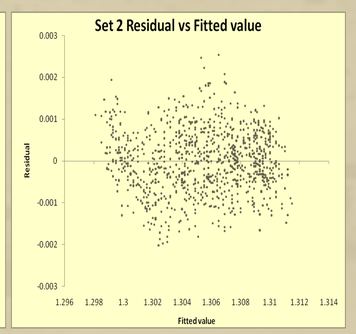
Analysis of Variance Set 1					
Source	**DF**	**SS**	**MS**	**F**	**P**
Regression	3	0.0147769	0.0049256	4363.42	<0.01
Residual Error	965	0.0010893	0.0000011		
Total	968	0.0158662			
	R=0.94	R-adj=0.90	R-Press=0.99	Significance	
Regression Coefficients	**Value**	**Partial Fo test**		**Yes**	**No**
Temperature	0.0003	16.98		X	
Pressure Vacuum	-0.0001	0.1421			X
Feed Flow	-1.03	9896		X	





Analysis of Variance Set 2					
Source	**DF**	**SS**	**MS**	**F**	**P**
Regression	3	0.0105324	0.0035108	6325.74	<0.01
Residual Error	965	0.0005356	0.0000006		
Total	968	0.011068			
	R=0.94	R-adj=0.92	R-Press=0.99	Significance	
Regression Coefficients	**Value**	**Partial Fo test**		**Yes**	**No**
Temperature	0.0007	32.26		X	
Pressure Vacuum	-0.2138	1926.8		X	
Feed Flow	-0.3876	1432.2		X	

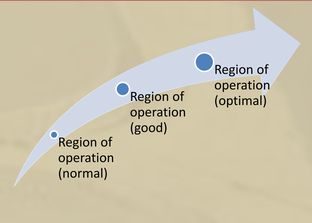


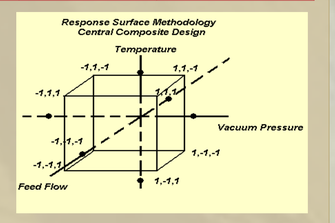


RESULTS

Nominal parameters		
P(psi)	**FF(gpm)**	**ΔT(F)**
-13.34	1.10	250.25

Operation Factors	Low level	Center value	High level
Feed Flow (gpm)	1.0	1.10	1.20
Temperature (F)	385	395	405
Vacuum Pressure (psi)	-13.58	-13.34	-13.10





CONCLUSIONS

1. Use of a Surface Response method is suggested as a future statistical tool to optimize variables involved in the scale process.
2. Additional proportional control valves need to be added to the model of the WFE to control temperature and vacuum pressure.
3. A second coriolis-meter should be added at a point between the Wiped Film Evaporator outlet and the feed tank.
4. According to the design of the WFE cycle:
   - If in the test configuration the concentrate goes back to the feed tank, then the responses (specific gravity and condensate flow) should be recorded as the slope of the graph of these responses versus time.
   - If in the test configuration the concentrate does not go back to the feed tank, then the responses mentioned above should be recorded as the mean value of each response during the observation time.

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