

STAT 496, Spring 2009
Homework Assignment #7, Due by Friday, April 17

1. An experiment involving a wire bonder is reported in “How to Optimize and Control the Wire Binding Process: Part I” by Scheaffer and Levine, Solid State Technology, November, 1990. The five factors and levels are given below.

Factor	Level	
	Low (-)	High (+)
A: Constant Velocity	0.6 in./sec	1.2 in./sec
B: Temperature	150° C	200° C
C: Bond Force	80 g	120 g
D: Ultrasonic Power	120 mW	200 mW
E: Bond Time	10 ms	20 ms

The response variable, Y, was a force (in grams) required to pull wire bonds made on the machine under a particular combination of levels of the factors. The levels and responses for the 2^{5-1} fractional factorial experiment are given below.

Treatment Combination	Factor					Force, g
	A	B	C	D	E=ABCD	
e	-	-	-	-	+	8.5
a	+	-	-	-	-	7.9
b	-	+	-	-	-	7.7
abe	+	+	-	-	+	8.7
c	-	-	+	-	-	9.0
ace	+	-	+	-	+	9.2
bce	-	+	+	-	+	8.6
abc	+	+	+	-	-	9.5
d	-	-	-	+	-	5.8
ade	+	-	-	+	+	8.0
bde	-	+	-	+	+	7.8
abd	+	+	-	+	-	8.7
cde	-	-	+	+	+	6.9
acd	+	-	+	+	-	8.5
bcd	-	+	+	+	-	8.6
abcde	+	+	+	+	+	8.6

- a) Give the defining relation.
- b) What resolution is this design?
- c) Estimate the effect of each of the factors and interactions. For each estimated effect give the effect name and all aliases.
- d) Using a normal probability plot identify, with name and aliases, effects that appear to be significant.

- e) Suppose that in addition to the 16 points in the fractional factorial, 5 runs were made at constant velocity of 0.9 in./sec, a temperature of 175o C, a bond force of 100 g, a power of 160 mW and a bond time of 15 ms. The observed pull strengths at these points were: 8.1, 8.6, 8.0, 8.7, & 8.1. Use these to come up with a critical effect size. Which effects in (c) are significant?
- f) Each effect name has an alias. To what factor or combination of factors do you attribute each significant effect?
- g) Give a prediction equation using those effects deemed significant in (e) and identified in f). Be sure to define, explicitly, each variable in your equation.
- h) What would your recommendation be for the operating conditions of this machinery to obtain the highest pull force? Give a prediction and prediction interval for these operating conditions.
2. An engineer, who is planning a 2^{7-3} fractional factorial has in mind two separate choices of generators.

Choice 1: E=ABCD, F=ACD, G=BCD

Choice 2: E=ABC, F=BCD, G=ACD

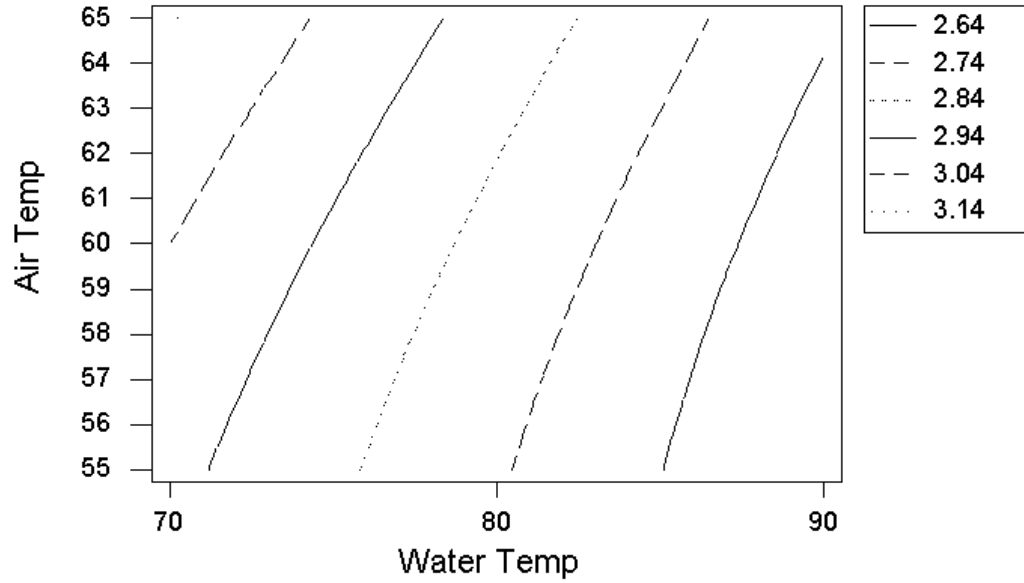
- a) Write out the entire defining relation for both each choice.
- b) Which choice is most appealing and why?
- c) Give the treatment combinations, in terms of -1's and +1's and the shorthand notation, e.g. (1), bc, etc. for your most appealing choice. You can use the attached sheet.
3. An experiment is conducted on the efficiency of a refrigeration system using R12, essentially Freon. In the experimental test stand, water temperature simulates the ambient temperature outside a house while air temperature simulates the ambient temperature inside a house. Three levels of each temperature are used in a full factorial. The data appear below.

Water Temperature (°F)	Air Temperature (°F)		
	55	60	65
70	2.99	3.07	3.16
	2.96	3.03	3.13
	2.96	3.02	3.13
80	2.76	2.82	2.90
	2.74	2.81	2.91
	2.72	2.80	2.92
90	2.55	2.59	2.67
	2.54	2.58	2.64
	2.53	2.57	2.64

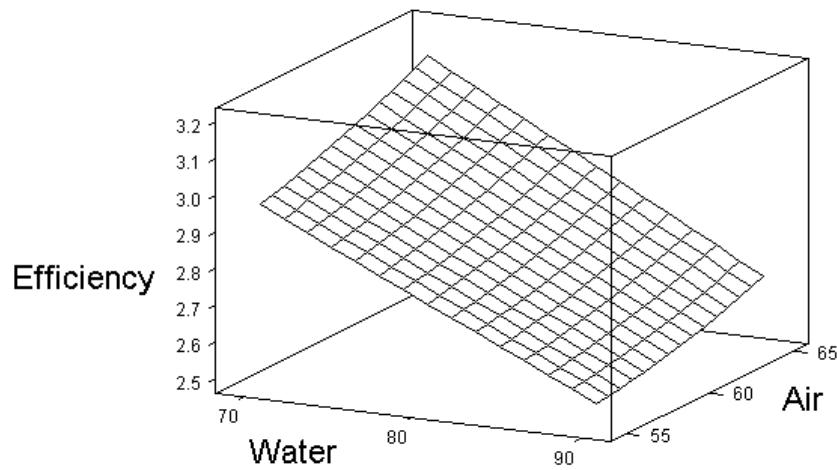
- a) Construct main effect and interaction plots and comment on the possible impact of each factor and the interaction. Comment on whether there appears to be a linear or curved response between each of the factors and the response.

- b) Fit a response surface model using orthogonal polynomials (JMP does not automatically use orthogonal polynomials to do the fit of a response surface. Therefore the output from JMP will not give you the analysis asked for in this question. If you enter the orthogonal polynomial coefficients as separate columns in JMP, use Fit Model and Add each column into the Construct Model Effects, the JMP output will match what is being asked for in this question). Give the prediction equation. Be sure to explicitly define all variables in the equation.
- c) Predict the efficiency for the test stand operating with a water temperature of 85 and an air temperature of 65.
- d) Reduce the model to include only those terms that are statistically significant. Again give the prediction equation and predict the efficiency for the test stand operating with a water temperature of 85 and an air temperature of 65.
- e) Contour and response surface (wireframe) plots of the full quadratic model and the reduced model are given on the next two pages. What do these plots indicate about the effects of water temperature and air temperature on the refrigeration test stand efficiency?

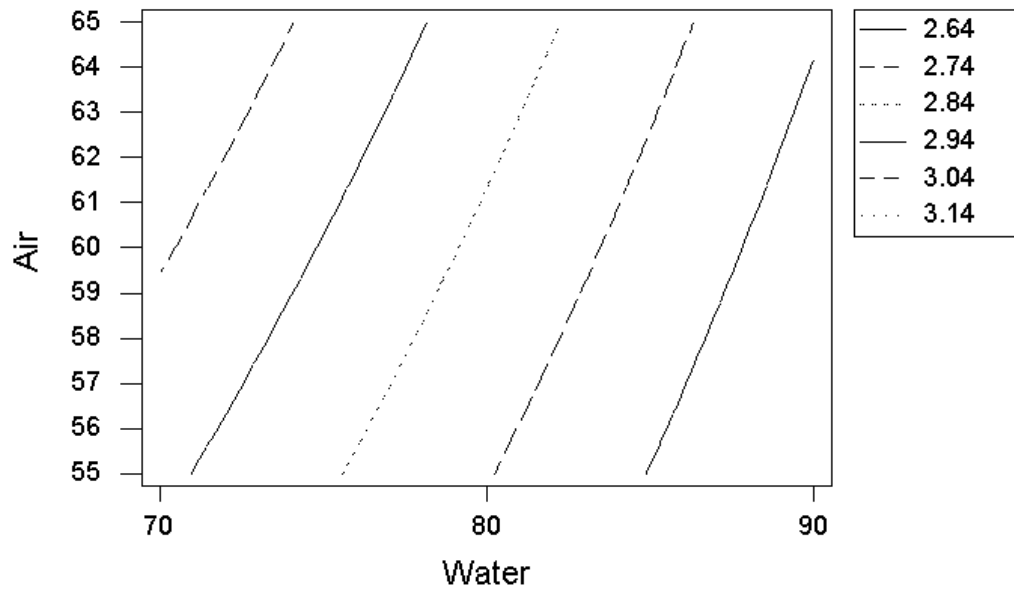
Contour Plot of Efficiency (full model)



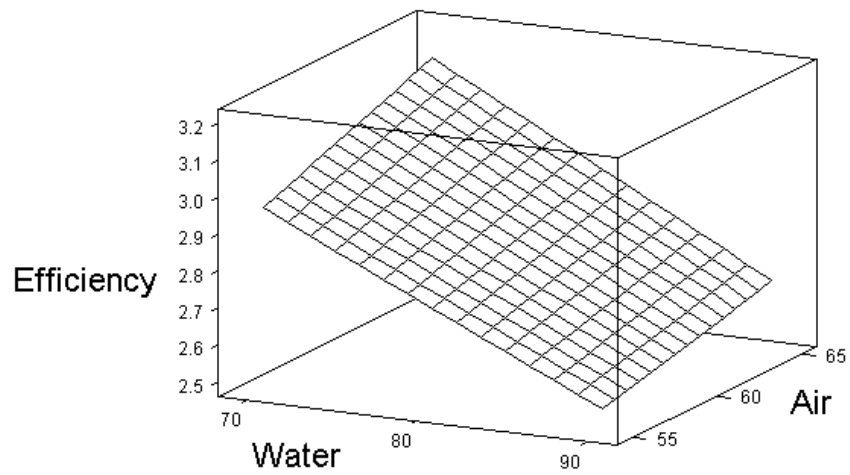
Wireframe Plot of Efficiency (full model)



Contour Plot of Efficiency (reduced model)



Wireframe Plot of Efficiency (reduced model)



run	Treatment Combination	A	B	C	Factor D	E	F	G
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								