UNIVERSITY OF ILLINOIS AT CHICAGO
Mechanical Engineering

IE 446
Solutions to Problem Set #10

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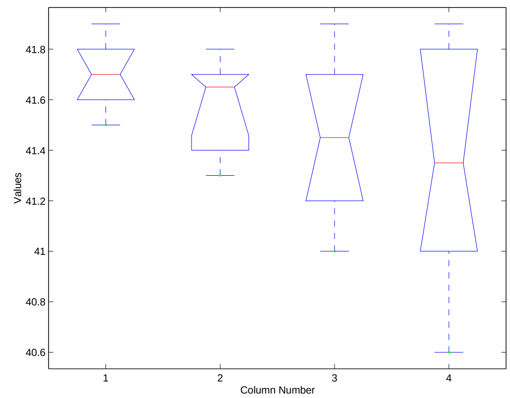
1. (Montgomery 10-7)

   (a) The analysis of variance has the following results:

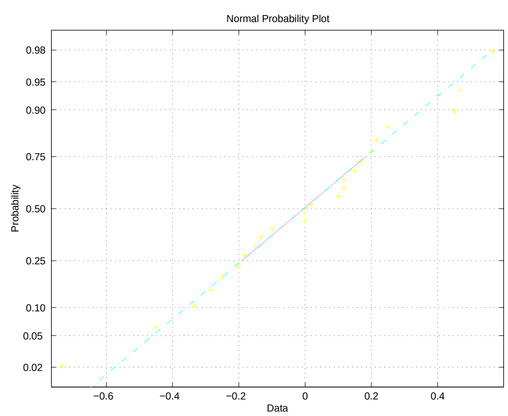
ANOVA Table

Source	SS	df	MS	F
Columns	0.4567	3	0.1522	1.452
Error	2.097	20	0.1048	
Total	2.553	23		



   which shows that firing temperature does not significantly affect density.

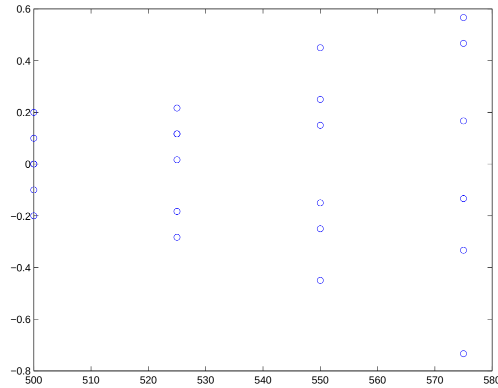
   (b) The residuals are computed against the average for each temperature (the row averages). The normal probability plot looks like this:



   so the normality assumption is reasonable.

   (c) The lowest temperature has the lowest variance; choose that.

2. (Montgomery 10-8) As shown below, variability seems to increase with temperature. Again, choose lowest temperature.

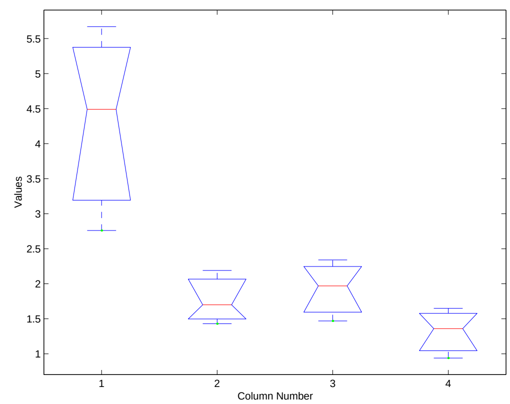


3. (Montgomery 10-11)

   (a) The analysis of variance for the wafers looks like this:

ANOVA Table

Source	SS	df	MS	F
Columns	16.22	3	5.407	8.29
Error	5.217	8	0.6522	
Total	21.44	11		



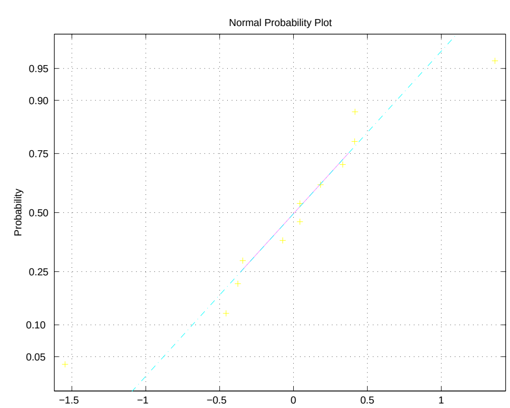
   Position 1 is different from 2, 3, and 4 at a significance level of $\alpha = 0.0077$, well below $\alpha = 0.05$.

   (b) The variability due to wafer position is σ_τ^2, estimated by:

$$\hat{\sigma}_\tau^2 = \frac{\mathrm{MS}_{\mathrm{factor}} - \mathrm{MS}_E}{n} = \frac{5.4066 - 0.6522}{12} = 0.3962$$

   (c) The total random error is $\hat{\sigma}_\tau^2 + \mathrm{MS}_E = 0.3962 + 0.6522 = 1.0484$.

   (d) These residuals are calculated by comparison to wafer position means. The normal probability plot is:



   The plot looks pretty good, but the two end points are perhaps questionable.

4. (Montgomery 10-12) For this problem we analyze both variability between tips and variability between coupons. The anova2 results look like this:

ANOVA Table

Source	SS	df	MS	F
Columns	0.385	3	0.1283	14.44
Rows	0.825	3	0.275	30.94
Error	0.08	9	0.008889	
Total	1.29	15		

(a) The tip type does affect hardness, at a significance level of $\alpha = 0.0009$.

(b) The residuals here are calculated against $\hat{y}_{ij} = \bar{y}_{i.} + \bar{y}_{.j} - \bar{y}_{..}$ (sum the row and column means, subtract the grand mean). The plot, which shows that the normality assumption is reasonable, looks like this: