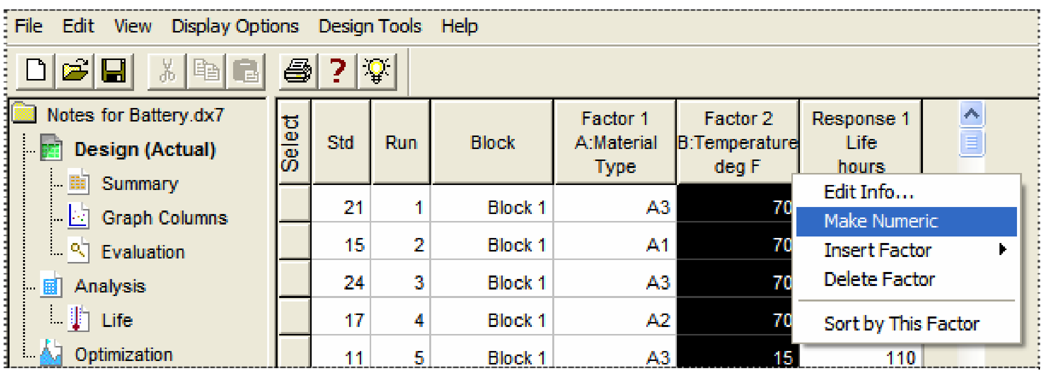
General Factorial Tutorial (Part 2 – Making Factors Numeric)

Continued – A Case Study on Battery Life

In the preceding General Factorial Tutorial – Part 1 you treated all factors as categorical. However, in this battery case, temperature is really a continuous numeric factor. In hindsight, this design might be constructed better by going to the Response Surface tab in Design-Expert® software and doing a one-factor design on temperature, with the addition of one categorical factor at three levels for the material type. Response surface methods (RSM) like this will be detailed from the ground up later: Refer to the Response Surface Tutorials. To see how you can make this change in Design-Expert after-the-fact, click on the **Design** node for the battery data from Part One, or re-open the file you saved earlier, named Battery.dx7. The main purpose of this exercise will be to make a better-looking and more accurate effects graph.

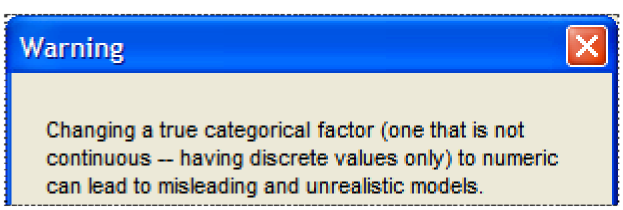
Changing a Factor from Categoric to Numeric

Place your cursor on the **B:Temperature** factor column heading and do a right click. You should now see the menu shown below.



Options for editing a factor

Choose **Make Numeric** to let the program know that the factor is not categorical. The software then warns you not to do this if the factor really should be considered categorical.

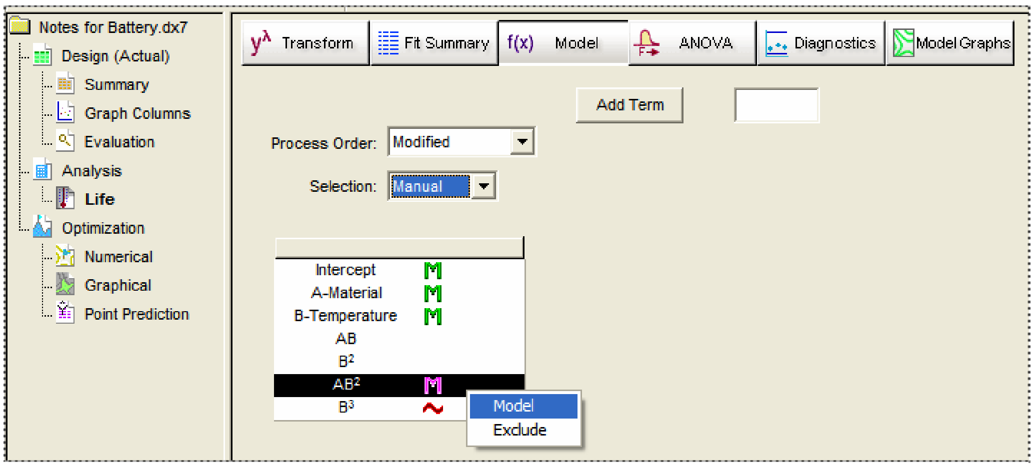


Warning on changing categorical factor to numeric

To complete the command, click on the **OK** button at the bottom of the warning message.

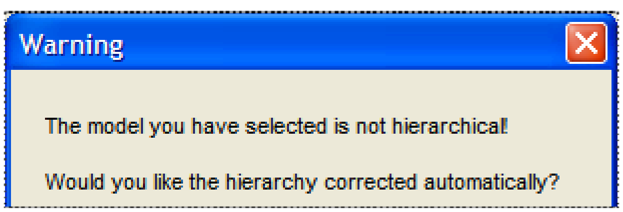
Re-Analyzing the Results

To re-analyze the data, click on the analysis node labeled "**Life**." Then click on the ***Fit Summary*** button. Let's not dwell on the output here, because this data comes from a hybrid combination of categorical versus numeric factors, which creates difficulty in interpretation. Go ahead and click on the ***Model*** button. To get a model that's equivalent to that used in Part 1 of the case study, you must choose the AB^2 term for the model. (You will see why after doing the ANOVA in just a moment.) Do this by double-clicking on the **AB^2** term, or via a right click and choice as **Model** as shown below.



Model selection screen

Click on the ***ANOVA*** button. You will get a warning about hierarchy.



Hierarchy warning

This warning arises because you chose a higher order term without support by parent terms, in this case: AB and B^2. Again, without getting into all the details statistically, it's best to just click **Yes** and move on.

The ANOVA report now displays in whatever view (annotated or not) that you used last. By comparing this output with the ANOVA done in Part One, you will see that the lines for the model and residual come out the same, but the terms involving B differ. In Part One we treated factor B (temperature) categorically, albeit in an ordinal manner. Now that this factor is recognized explicitly as numeric, what was B is now broken down to B and B^2, and AB becomes AB plus AB^2. Remember that the whole purpose of this exercise is to make a better-looking and more accurate effects graph, so let's get on with the process rather than belaboring the statistics.

Transform | Effects | ANOVA | Diagnostics | Model Graphs

Response 1 **Life**

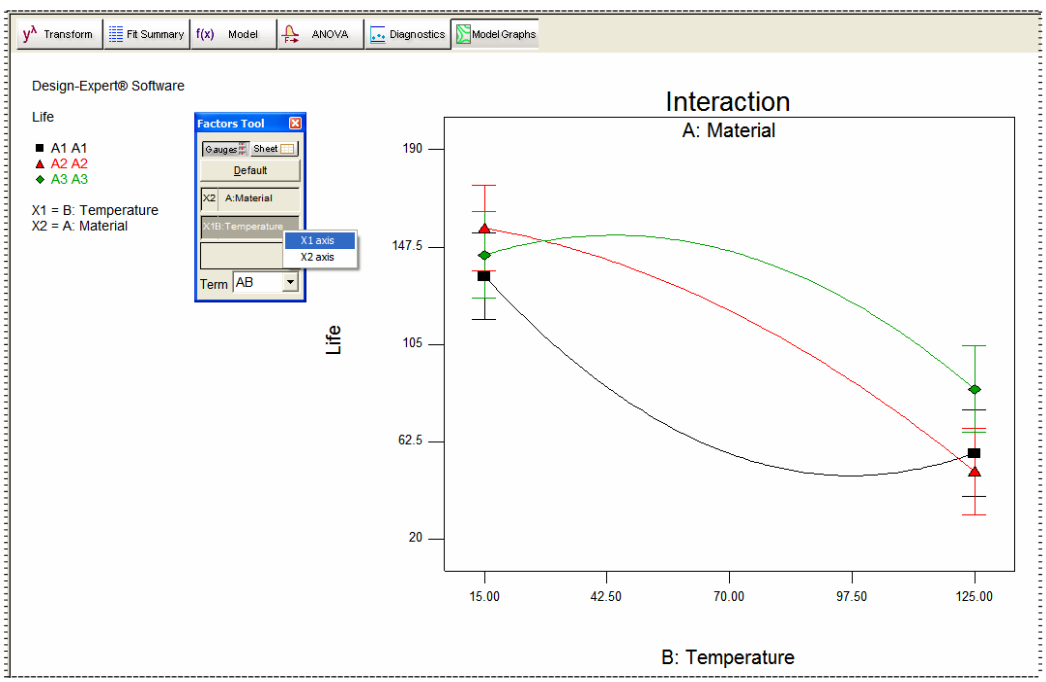
ANOVA for selected factorial model

Analysis of variance table [Classical sum of squares - Type II]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F
Model	59416.22	8	7427.03	11.00	< 0.0001
A-Material	*10683.72*	*2*	*5341.86*	*7.91*	*0.0020*
B-Temperature	*39118.72*	*2*	*19559.36*	*28.97*	*< 0.0001*
AB	*9613.78*	*4*	*2403.44*	*3.56*	*0.0186*
Pure Error	18230.75	27	675.21		
Cor Total	77646.97	35			

ANOVA output

Click on the ***Diagnostics*** button and examine the diagnostic graphs. These look OK, so go ahead and click on the ***Model Graphs*** button. Go to the Factors Tool and right-click on **B** (Temperature) and change it to the **X1 Axis**.



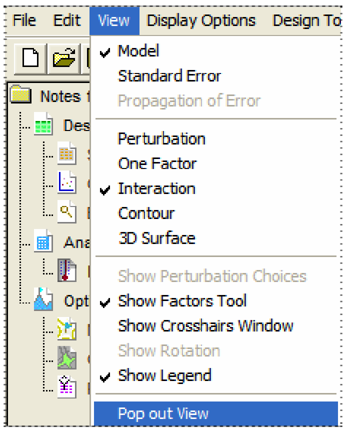
Viewing the interaction with temperature on X-axis

You now have a plot that looks similar to the one shown in Part One of this ongoing case study, except that the lines are now continuous with temperature, whereas in Part One they were displayed as discrete (categorical) segments. Notice that the curves by temperature (modeled by B^2) depend on the type of material (A). This provides graphical verification of the significance of the AB^2 term in the model.

The conclusions remain the same as before: Material A3 will maximize battery life with minimum variation in ambient temperature. However, by treating temperature numerically, a more accurate prediction can be made at values between those tested. Of course, these findings are subject to confirmation tests.

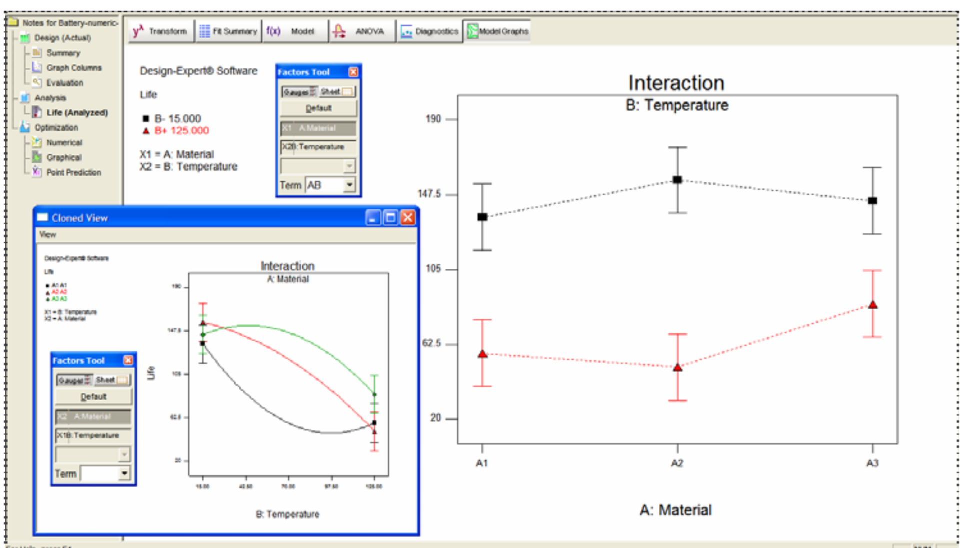
Postscript: Demo of "Pop out" View

Before exiting Design-Expert at this point, give this a try: **View**, **Pop out View**.



Pop out View

This pushes that current graph out of its fixed Windows pane into a 'clone' that floats around on your screen. Now on the **Factors Tool** right click on **A** (Material) and return it to the **X1 Axis**. Then do an Alt-Tab to bring back the clone of the previous view back on your current window.



Two ways of viewing the battery life results

Now you can present the Design-Expert outputs both ways for your audience:

- Curves for each material as a function of temperature on the X1 axis, or

- Two temperature lines connected to the three discrete materials as X1.

Be careful though, the pop out views can get confusing if you get carried away with them. A safer way to capture alternative graphs is to copy and paste them into a word-processor, spreadsheet or presentation program. Then you can add annotations and explanation for reporting purposes.