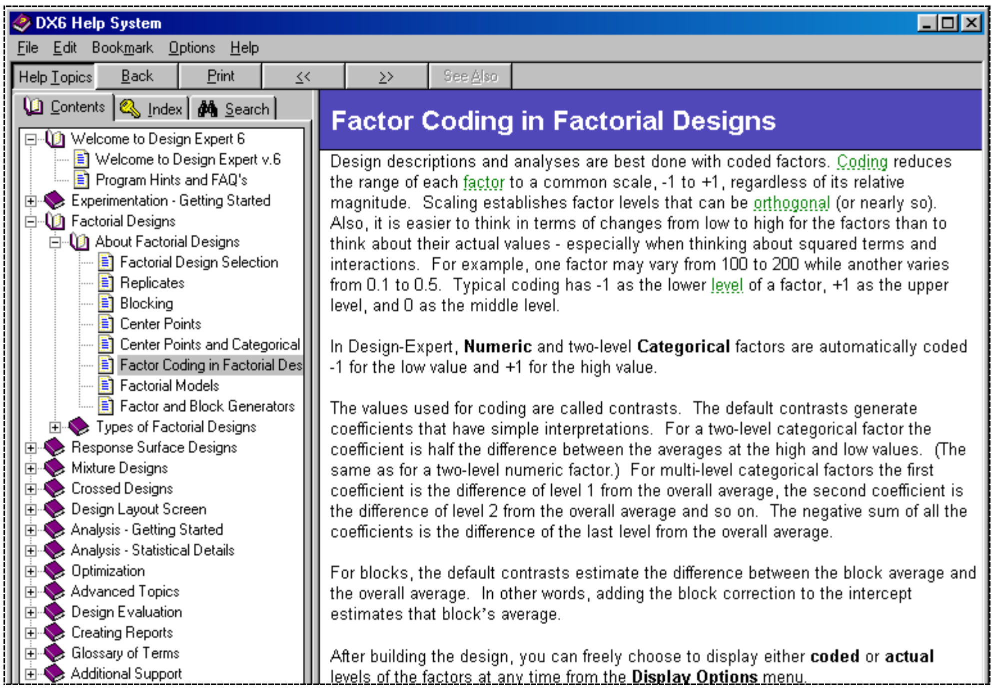
Section 13 – Program Tips

This section is a "catch-all" for features not described adequately elsewhere. Many of the interface features, such as file or print, will be well known to users of Windows, so no further description need be given. Many other features have already been exercised in the tutorials. Use the manual index as a reference. For more detailed program reference go to the Help system in the Design-Expert® software.

Help System

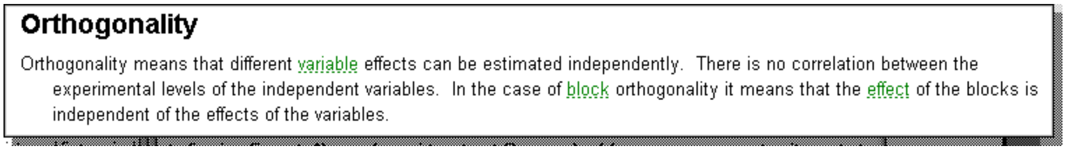
The Help menu gives you help on many program-related and statistical topics. You can access it from the main menu.

You may also be able to access context-sensitive or generic help with the F1 key. The initial list of topics will look something like the following screen. Click on the plus signs (+) on the tree structure of contents to get to the root topics, such as "Factor Coding in Factorial Designs."



Help Contents

The dash-underlined words in the text window represent hypertext, which you can link to with a mouse click. For example, if you click on the word "orthogonal" in the screen shown above, you will see the following explanation.

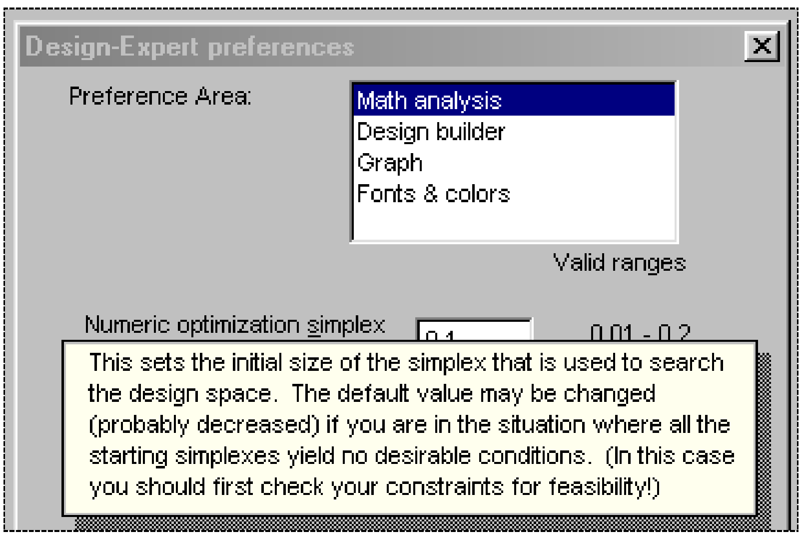


Help: Definition of Terms Obtained via Hypertext Link

This leads to several other terms that you can define via more hypertext links. You will find a wealth of information in the generic help system. Check it out!

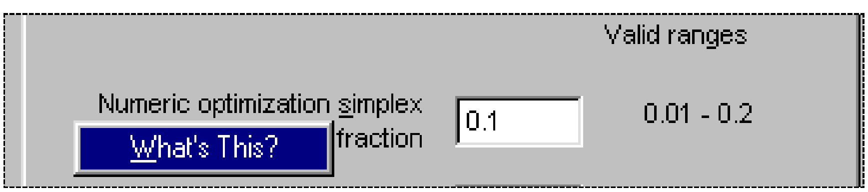
Context-Sensitive Program Help

By pressing F1 at many places in Design-Expert you can get context-sensitive program help. For example, you may want information about a particular user preference, such as Numeric Optimization, as shown in the following screen.



Context-Sensitive Help

The same information can be obtained by doing a right-click over the screen to get a "What's This?" option.



The "What's This?" Route to Help

You will find these features to be very informative on a "just-in-time" basis.

Statistical Help on Reports

By right clicking on a particular statistical output, you will get a menu, which often includes an active option for help. For example, you may want to get help on the probability statistic ("Prob > F") in the analysis of variance for a factorial model.

ANOVA for Selected Factorial Model

Analysis of variance table [Partial sum of squares]

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F
Model	5535.81	5	1107.16	56.74	< 0.00
A	*1870.56*	*1*	*1870.56*	*95.86*	*< 0.0*
C	*390.06*	*1*	*390.06*	*19.99*	*0.0*
D	*855.56*	*1*	*855.56*	*43.85*	*< 0.0*
AC	*1314.06*	*1*	*1314.06*	*67.34*	*< 0.0*
AD	*1105.56*	*1*	*1105.56*	*56.66*	*< 0.0001*
Residual	195.12	10	19.51		
Cor Total	5730.94	15			

Cut | Copy | Copy with Headings | Paste | Clear | Help

Right Mouse Click to Access Context-Sensitive Statistical Help

Then you will get information on the statistic, for example, probability.

Anova: Model Prob F

Probability > F: Probability of the observed F value if the null hypothesis is true (there are no factor effects). Small probabilities (less than 0.05) indicate that there is a model effect; large values (greater than 0.10) suggest no significant effect.

Help On Probability Statistic

You're likely to be presented with one or more underlined terms, which can then be explored via the hypertext links in the help system.

Interface

Design-Expert presents an innovative interface that offers:

- Standard menu bar at the top, and icon bar just below
- Node icons at left provide structure to design/analysis/optimization
- Wizard-like process for design building
- Progressive toolbar for statistical analysis
- Extensive availability of menus via right mouse clicks
- Interactive graphics

- Copy and paste of graphics and data
- Numerical tables and outputs in spreadsheet format
- Fixed pane with optional pop out view - updated by changes in data
- Optional user configurations for many features and outputs.

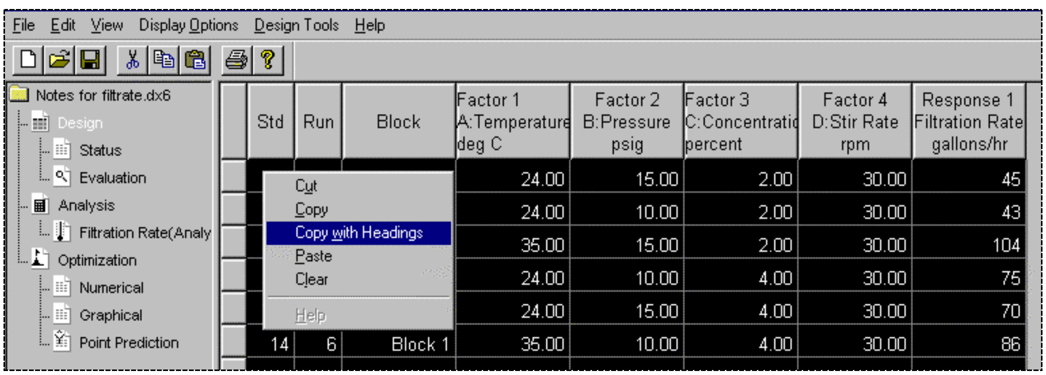
A brief description will be given on some of these features. The other features can be seen in one or more of the tutorials.

Like most Windows programs, Design-Expert presents a main menu bar at the top part of its screen. You select menu items, such a File or Edit, by clicking on the item. Underscored characters can be accessed via the keyboard by using the Alt key. Then press the Enter key to activate the command. The current state or context of the program determines which items are active or disabled (grayed out or in some other color as configured within Windows display options). The Edit Menu contains standard graphical interface edit commands, such as Copy and Paste, which can be applied to most windows in Design-Expert. The Copy and Paste functions can also be activated via the standard row of icons seen in most Windows software. Icons for Save and Print are also provided.

The main functions of the program are symbolized by node icons to the left of the main window. They come up in a tree view.

All numerical tables and outputs come in spreadsheet (column-row) format, which makes selection for copy and paste much more flexible. This feature makes the program very compatible with Windows word processors, presentation programs and spreadsheets.

Design-Expert makes extensive use of right-click menus, especially in the design layout. For example, select all design cells by clicking the blank square at the upper left corner. Then do a right click over any data cell and select Copy with Headings.

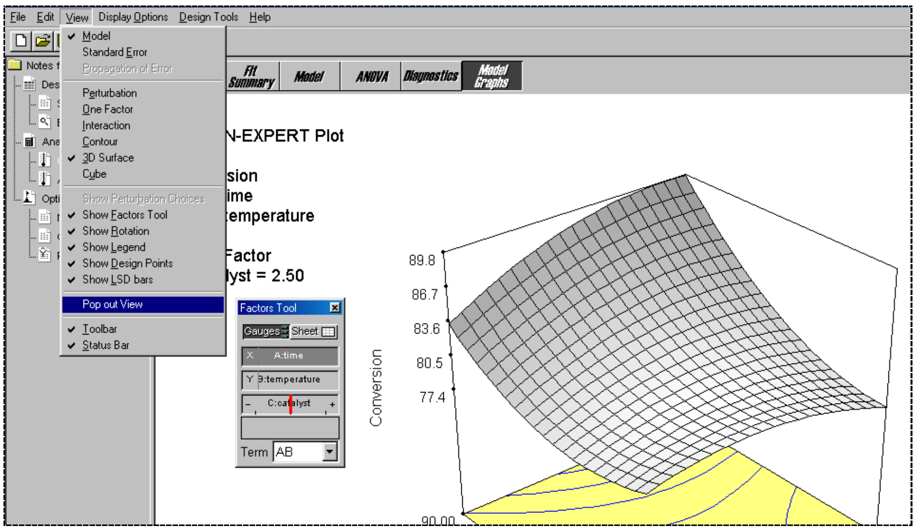


Example of a Right-Click Menu

Many of the right-click menus are demonstrated in the preceding tutorials. Be sure to work through these sections. Also, don't be shy about trying the right-click when you are seeking a screen-specific feature, such as changing characteristics of a graph. Experiment!

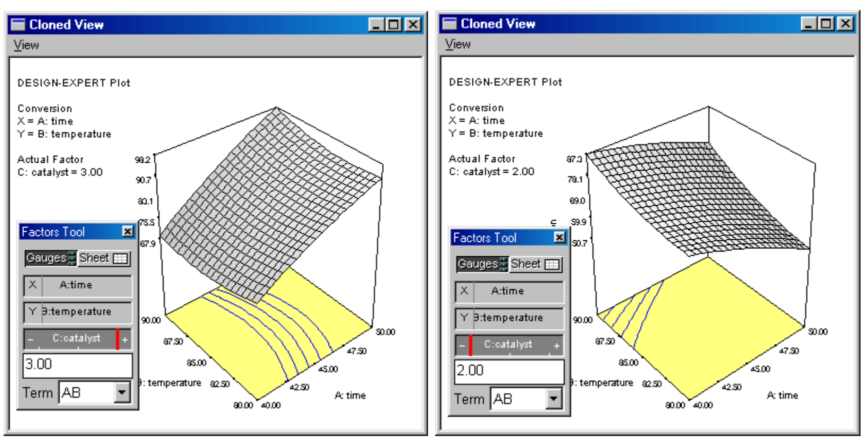
Fixed Pane versus Pop-Out View

By default, Design-Expert presents numerical and graphical output in a fixed window pane. This reduces screen clutter and prevents confusion. However, in some situations you may want to simultaneously view several screens. For example, in the tutorial on response surfaces you analyzed a design with three factors. (The file is on your disk under the name "Rsm-a.dx6.") Since only two factors can be seen at a time, you need to do slices on one of the factors. In this case it would be appropriate to click on View and select the Pop out View.



Selecting Pop Out View

Then you can push the slide bar on factor C to the highest setting at the right. Repeat View, Pop out View and set the C slice at its low level.



Viewing "Cloned" Graphs (C set high versus low) After Selecting Pop-Out View

The same approach could be used to simultaneously view different rotations of a 3D plot or many other options. (In some cases, such as a change from contour to 3D graphs, you may need to go back to the main window graph to make a change in the popped-out views.) The main output and all popped-out views will be updated if you make a change to the data or model.

To clean up the screen, just close out the popped-out windows.

User Preferences

You can make changes in configuration of outputs and screens via Edit, Preferences.

Here's a brief description of the "Math" options (first on the list):

- "Numeric optimization simplex fraction" changes the step size used by the program for its hill-climbing algorithm when it searches for optimums. See Statistical Details - Analysis for details on the algorithm for optimization. The default is 0.1 times the factor range.
- "Leverage limit" adjusts the level flagged by the program on the output from design evaluation, and in the case statistics that come after analysis of variance. It also affects the associated leverage graph accessed from the diagnostics palette. See the write-up on design evaluation towards the end of the Advanced Design Features section for details on leverage. The default is two times the average leverage. (If this value exceeds the theoretical limit of 1.0, then the limit will not be applied.)
- "Analysis outlier-t limit" changes the level flagged by the program on the output in the case statistics that come after analysis of variance. It also affects the limits placed on the associated residual plot. The default is 3.5.
- "Maximum actual equations with categorical factors" limits how many equations will be printed in the post-ANOVA output for designs with categorical factors. For example if two factors in a two-level DOE are categorical, you will get four equations that cover all combinations of categorical levels (2x2). As you increase the number of categorical factors and/or levels, the number of actual equations becomes excessive. The default limit is 4 equations, but you can print as many as 100.
- "Significance threshold" adjusts the significance level ("Prob>F" and the like) flagged by the program on the statistical outputs. The default of 0.05 can be adjusted down to 0.01 or up to 0.1.
- "Coefficient SS" changes the procedure for computing analysis of variance (ANOVA). The default of partial SS calculates each sum of squares (SS) corrected for all other terms in the model. If the design is not orthogonal, this procedure will generate a total SS that differs from the sum of all the individual SS values for the terms. The option of "sequential SS" corrects the individual sums of squares for those terms already included in the model. This avoids the problem noted above for non-orthogonal designs, but depending on the order that you add terms, individual sums of squares may vary.
- "Force precision" affects how numbers are reported in the statistical outputs, depending on what you enter for "Significant digits [2-10]."

- "Separated Pure Error on effect plot (DE3 Style)" changes the effects plot so that it plots the error effects and the factor effects against separate order statistics. Version 3 of Design-Ease (DE3) used this procedure.
- "Do not warn about aliased factorial models" turns off the warning message and options that come up when the ANOVA button is pressed for an aliased factorial model.

Press the Default button at the bottom of the Math dialog box to restore the original preferences that come with the program.

The next series of options comes under the heading of "Design."

- "D-optimal max exchanges" affects selection of candidate points for d-optimal designs. See Statistical Details - Design Selection for details on the algorithm used by Design-Expert. The default is five exchanges.
- "D-optimal random bootstraps" changes the number of times the d-optimal procedure will be repeated. This may result in slightly better designs. The default is four random bootstraps. If you are using a slow computer, we advise that you eliminate this procedure by choosing zero bootstraps.
- "Coded format" changes the number of digits displayed for coded factor levels. By default it will go to the third decimal place.
- "Maximum coded value" affects a check made by the program to prevent users from adversely coding factors. For example, you may accidentally type in actual levels when the design layout screen is displayed in coded form, thus creating nonsense levels. The default is five.
- "Do not display design description" when clicked will turn off text that appears on design screens. This may be necessary when working with screens set at low resolution (640x480). Otherwise the text crowds out the entry fields. The default is to display the text.
- "Allow orders higher than cubic for models" enables up to 6^{th} order terms, depending on the number of factors or components. See Help for details.

Press the Default button at the bottom of the Design dialog box to restore the original preferences that come with the program.

The next series of options fall under the heading of "Graph" preferences. This dialog box, which can be also be accessed via a right mouse click from within the affected plots, offers the following options:

- "3D graph drawing method" affects response surface plots. You can select from these three options:

  - "Wire frame" appears with see-through grid

  - "Shaded" (default) appears with shadows created by virtual lighting

  - "Hidden line" makes the grid opaque.

- "Contour graph shading" affects 2D contour plots. You have two options:

- "Std Error shading" (default) darkens regions with greater standard error of prediction.

- "Plain background" eliminates the standard error shading.

- "Graph resolution" affects the fineness of display. Choose:

  - "Normal" (default) looks best on VGA screens and lower resolution printers.

  - "High" resolution looks better on super VGA screens and printers with 600 dpi or better, but it may take significantly longer to display on computers with lower speed processors.

- "Horizontal Y-axis label" is an option that may be needed if vertical labels don't survive copy and paste operations, a common problem with Windows.

- "Draw lines on graphs" offers three options: thin (default), medium and thick. These options may produce better output from your specific printer.

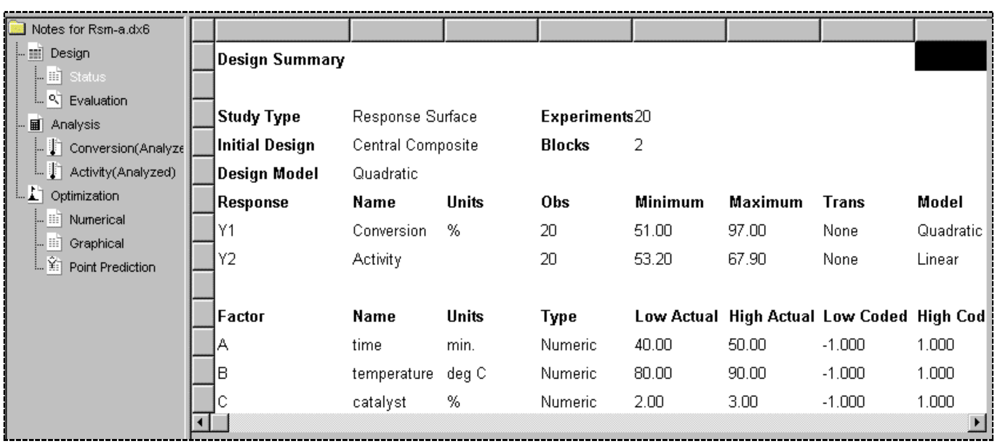
- "Draw dotted lines as" solid, dash, dot (default), dash-dot or dash-dot-dot.

The options presented in the next dialog box, "Fonts and colors," offer you a great deal of flexibility to change size and font for various screens and outputs, as well as colors for many screens and graphs. Check this out for yourself by selecting Edit, Preferences.

Miscellaneous Features

Design Status

The **Status** node under the design root will bring up a screen that provides information about the open data file. Here's what it says about the response surface data stored as "Rsm-a.dx6" on your disk.



Design Status Screen

(Note: we widened the first column by clicking it and dragging the border. You can do this with any spreadsheet-like output, and most of the windows within Design-Expert.

However, due to a peculiarity of Windows, it may be hard to grab the border. If at first you don't succeed, try again!)

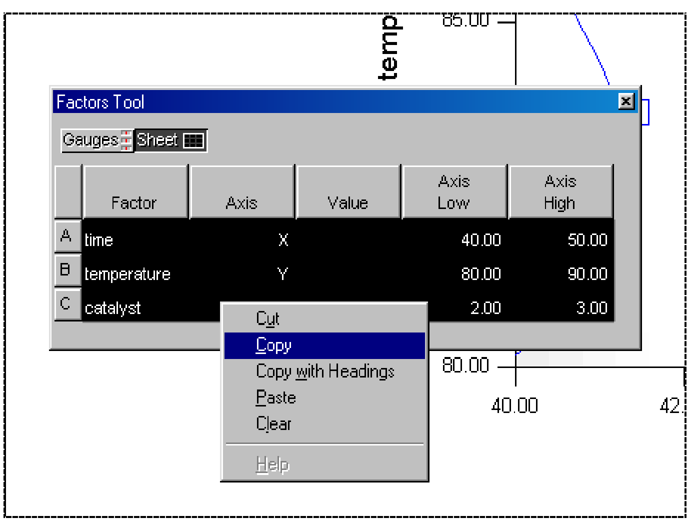
Factors Tool

The "Factors" control is a floating window that represents a "place" in the design space. This place can be either a specific point or a specific slice, depending on the context the control is used in. For example, in the point prediction node, the user needs to be able to specify a constant for each and every factor to make predictions from the response model. In this case, the factors control represents a point in design space. Another example occurs in a contour graph, where the user needs to specify what factors to use for X and Y axes, and what constants to use for all the other factors. The factors control here is representing a "slice" in design space.

The factor levels can be displayed as coded or actual according to your current choice in the "Display Options" menu. You may operate the factors control in two modes: "Gauges" or "Sheet."

The "Gauges" mode allows you to quickly change factor levels via a slide bar that you grab with your mouse. (Categorical factors cannot be continuously adjusted – they are activated by buttons at each discrete level.) If you want to set a factor level with more precision, you can click on the factor (to select it), then type the value in the edit field at the bottom of the control, and press Enter. You will see the red needle shift to the correct location. If the factor in question represents an axis on the current graph rather than a constant level, then the slide bar will be deactivated. By right-clicking over any specific factor, you can select it for a specific axis.

The "Sheet" mode offers a more precise numerical entry form for the factor levels and choice of axes. This view takes up more space on screen, but allows you to type in all the values for constant factors. You can also change the low and high ranges, or adjust the axes. If you have a specific position and axis orientation of a graph you wish to save, you copy it from "Sheet" mode. (Tip: click the button at the upper left to highlight all cells, then do a right click and select Copy.)



Copying the Graph Settings from "Sheet" Mode on Factors Tool

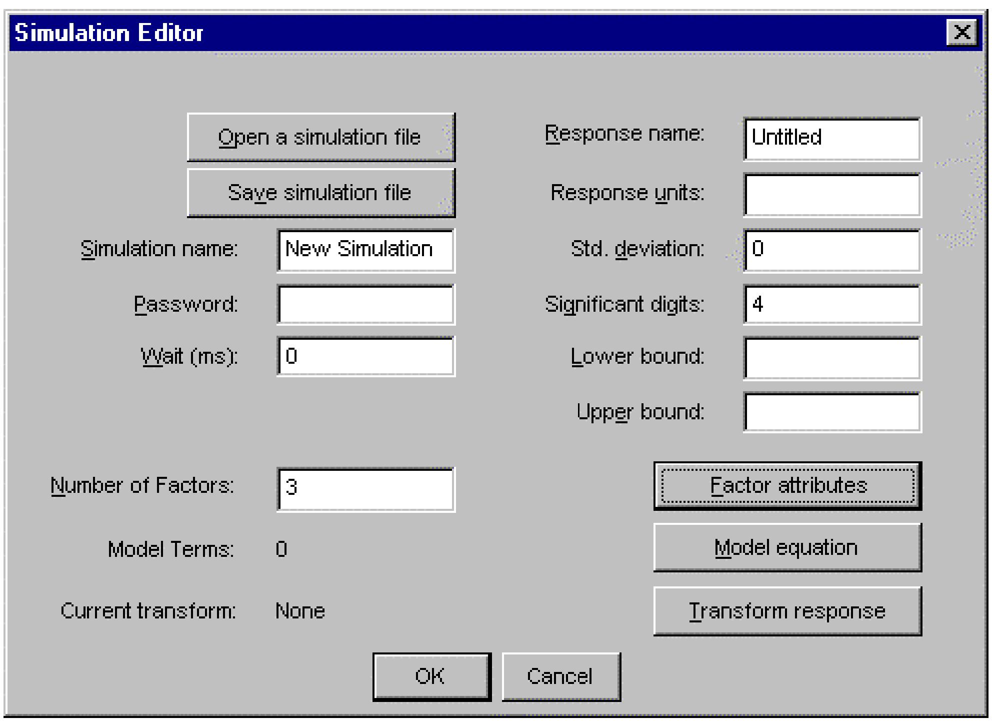
At a later time, you can paste that same data into the "Sheet" view of the factors control. This will restore all the values; changing your graph back to the same constant setting and axis choices.

Simulation Models

For classroom purposes, Design-Expert allows you to create simulations that include an element of random error. Here's a brief demonstration. Start by clicking on **Design Tools** and selecting the **Simulation Editor**.

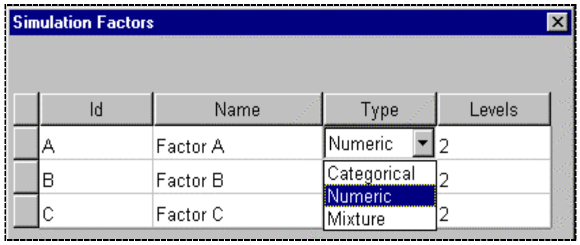
Creating a Simulation

You are now ready to create a model with a specified amount variation on the resulting response. Start by entering **Number of Factors**, **3**. Press the **Tab** key. The buttons for entering coefficients then become active.



Simulation Editor

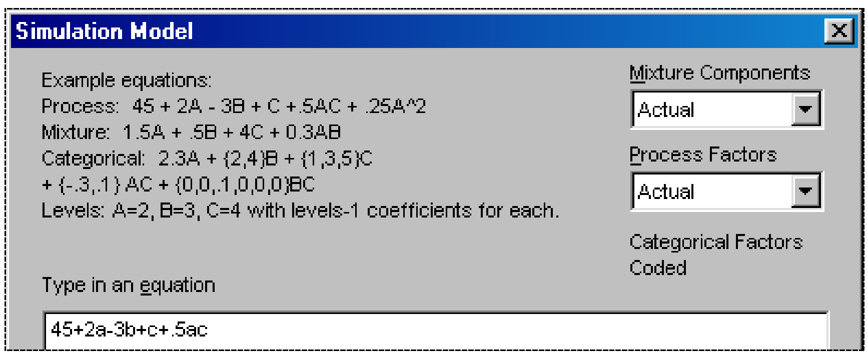
Press **Factor attributes** to specify the names, type of factor (categorical, numeric or mixture) and the number of levels.



Specifying Factor Attributes

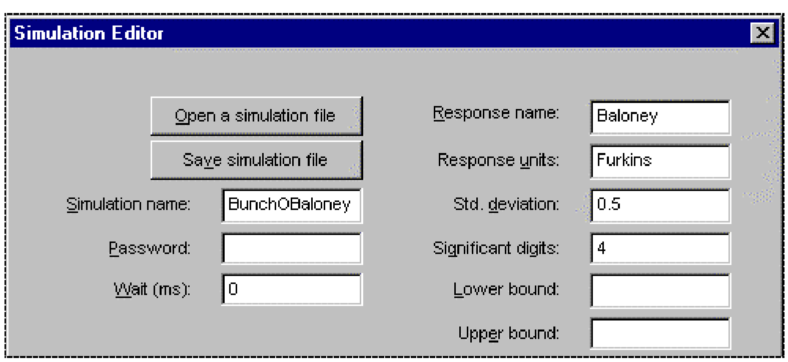
Leave all factors Numeric and press **Cancel**. Then, back at the main screen for the simulation setup, click on **Model Equation**.

You now are ready to enter in the coefficients in coded or actual form. Let's assume for demonstration purposes that we will simulate a process in terms of actual factors. This would be the most realistic approach for training purposes. The equation will be restricted to the two-factor interaction (2fi) order for purposes of training on two-level factorial design. Type in the equation as shown below.



Specifying the Equation

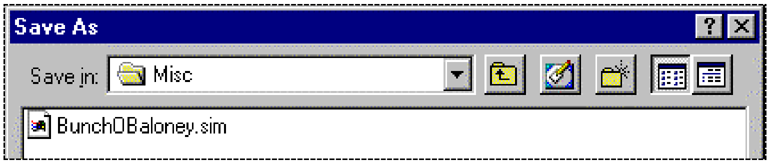
Press **OK** to get back to the main screen for entering simulation parameters. Put in a **Std. deviation** of 0.5. This will add realism to the results. The other fields can be left at their defaults or identified as you see fit.



Entering Standard Deviation and Other Fields

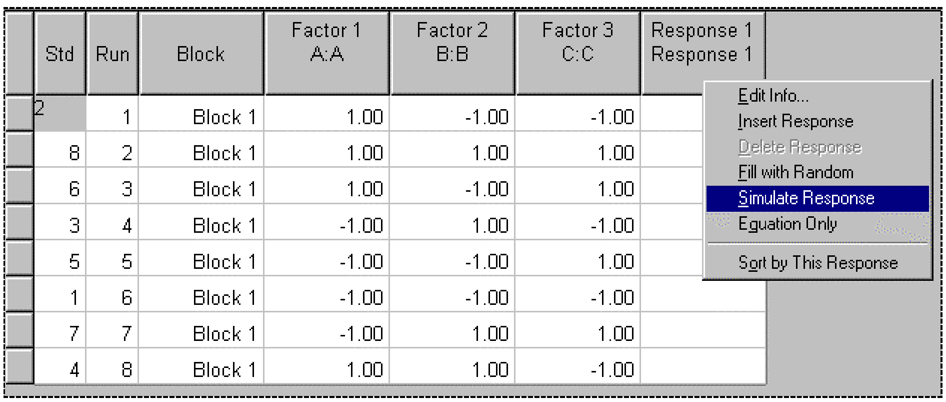
We left the fields for Lower bound and Upper bound blank, but you may want to fill these in as a precaution against students making gross errors in entering factors.

If you want to prevent students from accessing this simulation data, put in a Password. (We left this empty.) Then click **Save simulation file** to preserve the simulation. It will be saved as a **.sim** file.



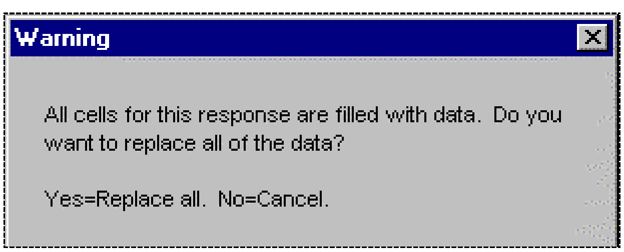
Saving the Simulation

To run the simulation, create a two-level factorial with three factors. Normally, we would make up a good story for a case study and recommend high and low ranges for suggested factors. Students can then do what they like. We won't bother with this here. If you want to see how the simulation turns out, just set up a generic two-level factorial with three factors, leaving all names and levels at their defaults. After creating the design, do a right click on the response column and select **Simulate Response**.



Running the Simulation

You will then be prompted to **Open** the simulation file. Double click on the simulation you just created. You should now see values entered as responses. Analyze the data if you like. Of course, results will vary, especially for the AC term, which tends to be obscured by the noise. You can repeat the simulation any number of times, but you will be warned first before Design-Expert replaces your data.



Warning Before Repeating Simulation

Simulations are very useful for classroom purposes. Not only can they add realism to case studies, but they save time on data entry.

Neat Tricks

Two-Level Factorial Analyzed as a Split Plot

Very often, experimenters set up two-level factorial designs with the best intentions of running it in random order, but they find that a given factor, such as temperature, cannot be easily changed. In this case, the analysis should be done by the split plot method discussed in Section 4 of this manual. For the special case of two-level factorial design, the handy half-normal plots for effect selection can be adapted to deal with the split plot structure. This will be illustrated very briefly via a case study.

From the **File** menu, click **Open Design** and then double-click on **Plasma.dx6**. This data comes from an experiment on a plasma treatment process aimed at making paper more susceptible to ink (Box, Bisgaard, et al, "Quality Quandries: Two-Level Factorials Run as Split Plot Experiments," *Quality Engineering*, 8(4), 705-708 (1996)). Scrolling down the design layout you will notice that there are five factors in 32 runs, so this is obviously a full two-level factorial (2^5). Notice that we've ignored a possible outlier at the low end of the response scale. More importantly, if you look carefully at the pattern of highs and lows, you will see that Factor E (paper type) is not randomized.

Std	Run	Block	Factor 1 A:Pressure	Factor 2 B:Power	Factor 3 C:Gas Flow	Factor 4 D:Gas Type	Factor 5 E:Paper Type	Response 1 Contact Angle
5	1	Block 1	-1.00	-1.00	1.00	Oxygen	E1	37.6
21	2	Block 1	-1.00	-1.00	1.00	Oxygen	E2	43.5
2	3	Block 1	1.00	-1.00	-1.00	Oxygen	E1	41.2
18	4	Block 1	1.00	-1.00	-1.00	Oxygen	E2	38.2
10	5	Block 1	1.00	-1.00	-1.00	SiCl4	E1	56.8
26	6	Block 1	1.00	-1.00	-1.00	SiCl4	E2	56.2

Two-Level Factorial (Run as Split Plot) Case Study Data (partially shown)

To save time, the experimenters set up their plasma reactor at the conditions specified by factors A through D (randomized), and then processed the two paper types (E) together. (The actual placement of paper in the reactor, right versus left, was randomized by a flip of a coin.) This forms a split plot design, broken down as follows:

- Whole-plot factors - A through D (and associated interactions)
- Subplot factor: E (and any interactions involving this factor)

The trick is to keep these groups separate for the analysis of variance, because the residual errors differ. Design-Expert makes this very easy, as you will see next.

Click the response node **Contact Angle** and press the ***Effects*** button. Select **View**, **Effects List**. Let's start by looking at the whole-plot terms. Right-click on factor E and choose **Ignore**. Do the same (ignore or "X") for all interaction terms involving E. (Suggestion: drag over the last few blocks of E terms to highlight them, and then right-click to change all of them to ignore.) You can leave ABCDE alone, which became aliased when we ignored the one run thought to be an outlier.

Term	Stdized Effects	Sum of Squares	% Contribution
Intercept			
A	10.25	746.64	13.99
B	2.65	40.80	0.76
C	-4.97	234.11	4.39
D	-13.52	1398.22	26.20
E	1.56	18.70	0.35
AB	-3.13	57.69	1.08
AC	3.97	164.95	3.09
AD	15.34	1854.08	34.74
AE	-4.80	199.88	3.75
BC	0.19	0.031	5.805E-004
BD	-4.31	141.12	2.64
BE	0.73	4.02	0.075
CD	0.62	3.54	0.066
CE	0.90	6.18	0.12
DE	-0.018	2.431E-003	4.556E-005
ABC	1.45	28.25	0.53
ABD	-1.87	48.48	0.91
ABE	-1.14	3.52	0.066
ACD	-0.93	19.80	0.37
ACE	-1.41	6.31	0.12
ADE	0.48	0.032	5.981E-004
BCD	2.42	34.98	0.66
BCE	-0.40	0.040	7.495E-004
BDE	1.07	5.67	0.11
CDE	1.55	18.62	0.35
ABCD	5.12	293.27	5.50
ABCE	0.50	0.48	9.070E-003
ABDE	0.38	0.13	2.530E-003
ACDE	-003	1.80	0.034
BCDE	0.82	5.18	0.097
ABCDE		Aliased	

Model
Block
Error
Ignore

Modeling Whole-Plot Factors and Associated Interaction Effects

Now, select **View**, **Half Normal Graph** and **View**, **Select by Lenth's M.E.**. The resulting display is reproduced on the next page (the graph on the left for whole-plot effects.) The effects of A, D and interaction AD stand out.

Click on the ***ANOVA*** button to verify the significance of these whole-plot effects. Do not look at the Diagnostics or the Model Graphs because the model is missing the subplot effects. The last step in the analysis will be to combine all of the terms, whole-plot and subplot, in one overall model. Only then you can get a proper view of diagnostic and model graphs.

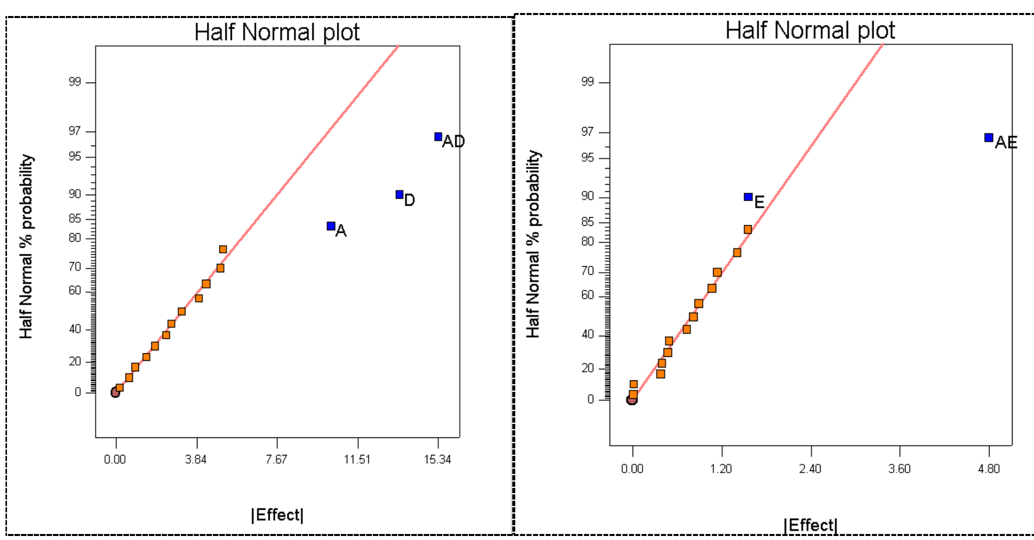
Let's move on to investigation of the subplot effects. Select **View**, **Effects List** once again. This time double click factor **E** and all interaction terms involving E for error (**e**). (Alternate approach: drag all of the terms to highlight them, then right-click and select Error.) Then right-click on whole plot factors **A**, **B**, **C** and **D,** plus all interaction terms involving these factors (not including E), and choose **Ignore** ("X"). (Alternate approach: drag over a block of terms to highlight them, then right-click and select Ignore.)

	Term	Stdized Effects	Sum of Squares	% Contribution
	Intercept			
	A	10.25	746.64	13.99
	B	2.65	40.80	0.76
	C	[illegible]	234.11	4.39
	D	[illegible]	1398.22	26.20
	E	[illegible]	18.70	0.35
	AB	[illegible]	57.69	1.08
	AC	[illegible]	164.95	3.09
	AD	15.34	1854.08	34.74
	AE	-4.80	199.88	3.75
	BC	0.19	0.031	5.805E-004
	BD	-4.31	141.12	2.64
	BE	0.73	4.02	0.075
	CD	0.62	3.54	0.066
	CE	0.90	6.18	0.12
	DE	-0.018	2.431E-003	4.556E-005
	ABC	1.45	28.25	0.53
	ABD	-1.87	48.48	0.91
	ABE	-1.14	3.52	0.066
	ACD	-0.93	19.80	0.37
	ACE	-1.41	6.31	0.12
	ADE	0.48	0.032	5.981E-004
	BCD	2.42	34.98	0.66
	BCE	-0.40	0.040	7.495E-004
	BDE	1.07	5.67	0.11
	CDE	1.55	18.62	0.35
	ABCD	5.12	293.27	5.50
	ABCE	-0.50	0.48	9.070E-003
	ABDE	0.38	0.13	2.530E-003
	ACDE	-9.007E-003	1.80	0.034
	BCDE	0.82	5.18	0.097
	ABCDE		Aliased	

Model
Block
Error
Ignore

Modeling Subplot Factors and Associated Interaction Effects

Now, select **View**, **Half Normal Graph** and **View**, **Select by Lenth's M.E.**. You will see the display shown at the right in the figures shown below.



Half-Normal Plot of Whole-Plot (left) versus Sub-Plot Effects (right – with E picked)

The interaction AE stands out. Look at the bottom axis of this graph versus the one done earlier for the whole-plot effects. Notice that the range is several-fold less for the sub-plot effects. This reflects the comparatively high variance between repeated whole plot reactor setups (factors A through D) versus the variance within the subplot factor (changing paper type E). After manually selecting **E**, click on the ***ANOVA*** button and say "**No**" to hierarchy to see the significance of the subplot effects. (By following this procedure you preserve hierarchy for the sub-plot effects. If asked to preserve hierarchy (by answering "Yes" to the warning prompt), the software incorrectly adds the whole plot effect of A to the sub-plot model.) Do not look at the Diagnostics or the Model Graphs because the model is missing the whole plot effects.

To investigate the whole and subplot effects, press the ***Effects*** button and select **View**, **Effects List**. Drag over all the terms to highlight them, then right-click and select **Error**. All terms should now be designated as error (except ABCDE, which remains aliased due to the ignored run in the design layout). Now select **A**, **D**, **E**, **AD** and **AE** as model terms.

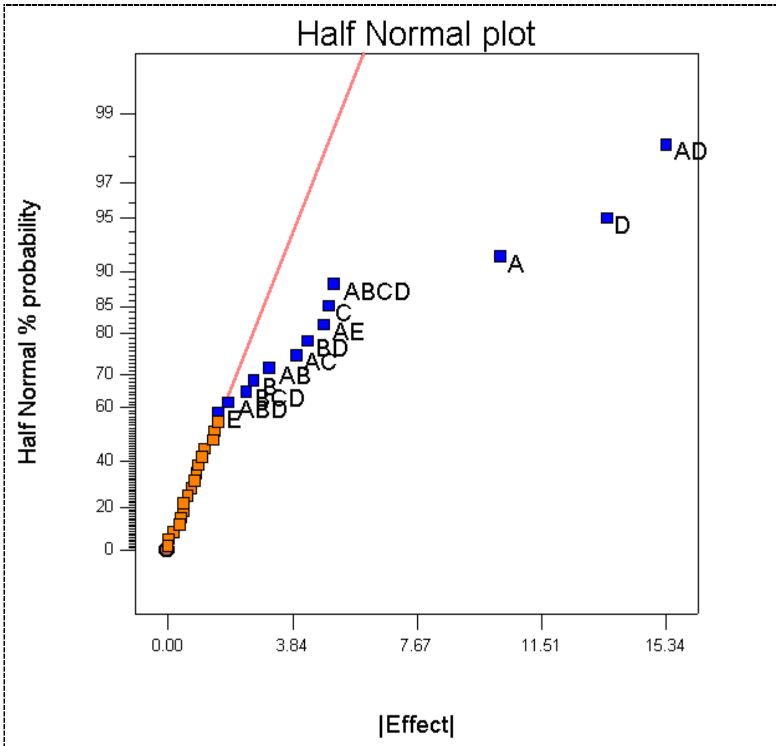
	Term	Stdized Effects	Sum of Squares	% Contribution
	Intercept			
M	A	10.25	746.64	13.99
e	B	2.65	40.80	0.76
e	C	-4.97	234.11	4.39
M	D	-13.52	1398.22	26.20
M	E	1.56	18.70	0.35
e	AB	-3.13	57.69	1.08
e	AC	3.97	164.95	3.09
M	AD	15.34	1854.08	34.74
M	AE	-4.80	199.88	3.75
e	BC	0.19	0.031	5.805E-004
e	BD	-4.31	141.12	2.64
e	BE	0.73	4.02	0.075
e	CD	0.62	3.54	0.066
e	CE	0.90	6.18	0.12
e	DE	-0.018	2.431E-003	4.556E-005
e	ABC	1.45	28.25	0.53
e	ABD	-1.87	48.48	0.91
e	ABE	-1.14	3.52	0.066
e	ACD	-0.93	19.80	0.37
e	ACE	-1.41	6.31	0.12
e	ADE	0.48	0.032	5.981E-004
e	BCD	2.42	34.98	0.66
e	BCE	-0.40	0.040	7.495E-004
e	BDE	1.07	5.67	0.11
e	CDE	1.55	18.62	0.35
e	ABCD	5.12	293.27	5.50
e	ABCE	-0.50	0.48	9.070E-003
e	ABDE	0.38	0.13	2.530E-003
e	ACDE	-9.007E-003	1.80	0.034
e	BCDE	0.82	5.18	0.097
~	ABCDE		Aliased	
	Lenth's ME	3.00		
	Lenth's SME	6.08		

Final Model Selection for Diagnostics and Effect Graphs

Click on ***ANOVA*** but ignore it. Press ahead to ***Diagnostics*** and ***Model Graphs***. Because the model is now complete, it's OK to use these tools for validation of the statistical assumptions and interpretation of the experimental outcome. See Section 4 for more details on the analysis of split plots.

The big question is: would the apparently significant effect of AE be obscured if the experimenters didn't recognize the split plot structure of their design? To determine the answer, select **View**, **Effects List** one more time and re-set all terms to **Error**. Then, select **View**, **Half Normal Graph**.

The sub-plot effect of AE is obscured by the variance between reactor setups (the whole plot)! Notice the split structure of the unchosen points at the left of the graph (the small effects). This reflects the dual error structure of the split plot design. As illustrated below, the AE effect is buried in the error terms of the whole plot (factors A through D).



Uncovering the AE Interaction

If you click on the points below (to the left) of the one labeled E, you will identify mostly sub-plot effects (interactions involving factor E), which exhibit less variance (steeper slope).

The manipulation of effect plots in this split-plot case uncovered a small but significant interaction that otherwise would've been obscured. In all likelihood, overlooking this effect makes no difference from a practical perspective, because the big breakthrough effects (AD, A, D) are revealed. For a more complete treatment of this case, attend Stat-Ease's Real-Life DOE workshop, presented only occasionally to the public, but always available for on-site presentation. There you will learn other tricks for manipulating Design-Expert for split plot design and analysis, such as:

- Sorting your design to restrict randomization
- Generating correct ANOVA statistics, residual analysis and effect graphs

If you think you need consulting help with a split-plot design, contact Stat-Ease. Details on how to reach us can be found at the end of the Introduction section of this manual.

Ratio Constraints

In many cases, especially for chemical mixtures, the level of one input depends on others in the form of a specified ratio. By application of relatively simple math, you can convert ratios to constraints accepted by Design-Expert. For example, let's look at the following composition (the current formulation):

- 50% of A (the key ingredient)
- 0.5% B (current stabilizer), based on a requirement that it be 1% of A
- 0.0% C (a new stabilizer not now used)
- 49.5% D (everything else)

The total is 100%. The formulator would like to determine the sensitivity of response to varying levels of the key ingredients and the addition of a new stabilizer:

- A to vary from 50% to 55%
- B to vary from 0% to 2% of component A
- C to vary from 0% to 2% of component A.
- (B + C) to vary from ½% to 2% of component A.
- D to make up the rest.

How do we set up a design to meet the above requirements?

The single component constraints are:

- 50% < A < 55%
- 0% < B < 1.1% (= 0.02*55%)
- 0% < C < 1.1% (= 0.02*55%)
- 0% < D < 100%

Notice the computations for stabilizers B and C to meet the ratio constraint with the main ingredient A. However, we still have not taken into account that the sum of the stabilizers must be kept within specified limits based on A. This must be done via a multilinear constraint, which can be expressed mathematically as:

$$0.005 < \frac{B+C}{A} < 0.02$$

This constraint requires some manipulation to get it into the proper format needed for entry into the software. Let's first work on the lower bound (0.005):

$$0.005 < \frac{B+C}{A}$$

$$0.005A < B+C$$

$$0 < -0.005A + 1B + 1C$$

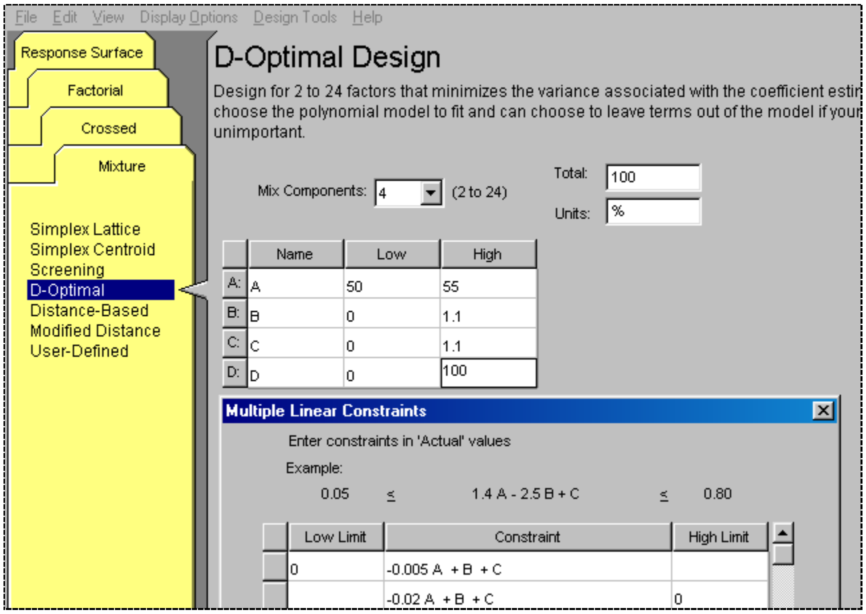
Next we need to address the upper bound (0.005) of the multilinear constraint:

$$\frac{B+C}{A} < 0.02$$

$$B+C < 0.02A$$

$$-0.02A + 1B + 1C < 0$$

We're now ready to set up the design. It must be done as a **Mixture** design with the **D-Optimal** option for **4** components. Enter the single component constraints into the fields on the main window (as shown below). Then press the **Edit Constraints** button and enter the multiple linear constraints.

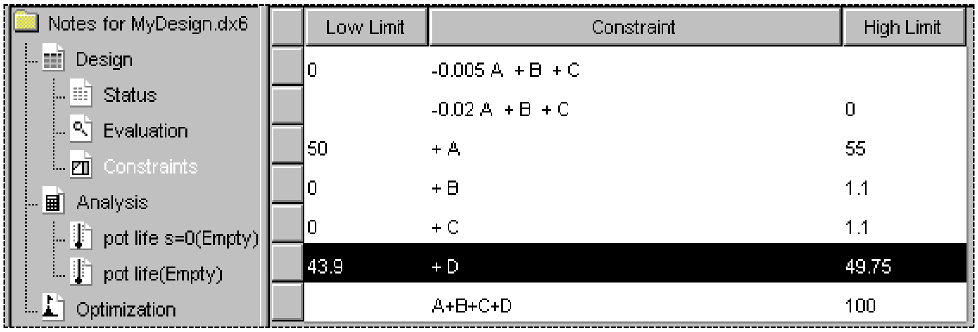


Entering Constraints for Ratio Problem

If you like, reproduce the design as shown above. Press **OK** for the multilinear constraints. You will then be warned as follows.

Warning After Entering Multiple Linear Constraints

Press **OK** to accept the adjustment and **Continue** a few times (with defaults accepted) until you see the design. To see the adjustments, click on the **Constraints** node.



Low Limit	Constraint	High Limit
0	-0.005 A + B + C	
	-0.02 A + B + C	0
50	+ A	55
0	+ B	1.1
0	+ C	1.1
43.9	+ D	49.75
	A+B+C+D	100

Final Constraints (adjusted by software)

Notice that component D has narrower limits. If you like, go back to the **Design** node and check the ranges of each component and you will find that they meet the ratio requirements originally specified for the formulation. That's it! For a more complete treatment of this case, attend Stat-Ease's Mixture Design for Optimal Formulations workshop.

Equality Constraints

Let's say you want to study four components in a formula. One component is a function of another, i.e., there is an additional equality constraint. How do you handle this?

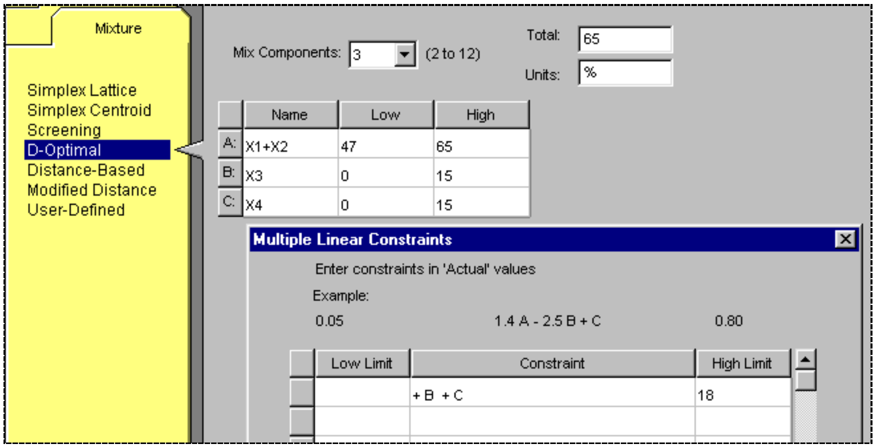
Assume that you must deal with the following constraints:

- X_1 varies from 15 to 25%.
- X_2 varies from 24 to 40%, subject to equality $X_2 = 1.6(X_1)$
- X_3 varies from 0 to 15%
- X_4 varies from 0 to 15%
- $X_3 + X_4 < 18\%$
- $X_1 + X_2 + X_3 + X_4 = 65\%$

Hint: For each equality constraint you lose a dimension. There are four components and two equality constraints. Therefore this is a two-dimensional problem. Picking the level of X_1 sets the level of X_2. Treat the mixture of X_1 and X_2 ($X_2/X_1 = 1.6$) as a single component. Therefore:

- A (X_1+X_2) varies from 39% (15+24) to 65% (25+40) where $X_2/X_1 = 1.6$.
- B (X_3) varies from 0 to 15%
- C (X_4) varies from 0 to 15%
- $B + C < 18\%$
- $A + B + C = 65\%$

These constraints could then be entered into the **Mixture** tab, **D-Optimal** design as shown below. (To add the multilinear constraint, press the **Edit Constraints** button.)



Constraint Entry for Problem with Equality Constraint

Go ahead and try this. Then press **OK** to accept the multilinear constraints and **Continue** a few times (with defaults accepted) to see the resulting design. You will find that the component ranges meet the requirements originally spelled out by the formulators. For a more complete treatment of this case, attend Stat-Ease's Mixture Design for Optimal Formulations workshop.