

CHAPTER 2

DESIGN DEFINITION

Wizard Option

The Wizard is a powerful tool available in DOE Wisdom to help with the set-up and analysis of your Screening or Modeling experiment. The Wizard walks you through defining the factors, responses and design selection for your experiment. The Wizard also automatically analyzes your data and generates a final report that summarizes your entire experiment.

Simply click on the **Wizard** button to open the Wizard. Introductory DOE users find the Wizard especially helpful. More advanced users often use the Wizard to help generate their Screening and Modeling designs. If you would like to use the standard interface to generate your experiment, follow the directions below.



Design Definition Dialog Box

Double-click on the **Design** folder in the **Project** window or click



the **Design** button.

The Design Definition Dialog Box shown in Figure 2-1 will appear.

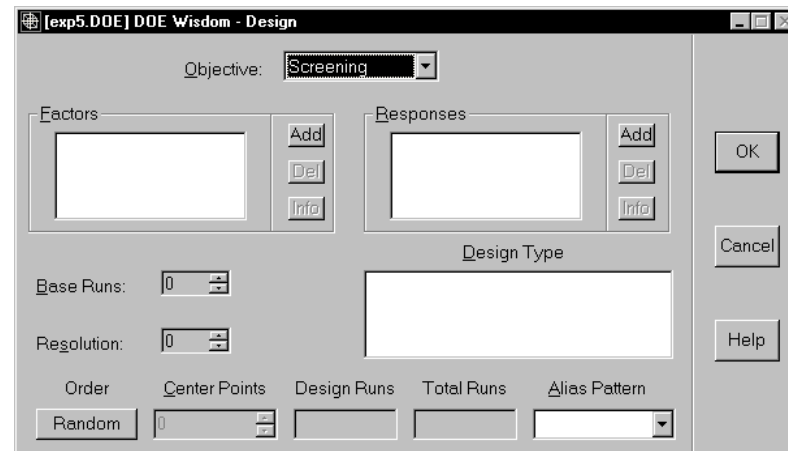


Figure 2-1

Objective

DOE Wisdom support five types of experimental objectives:

- **Screening**
- **Robust Designs**
- **Modeling**
- **D-Optimal**
- **Create Your Own**

Screening Designs

Screening designs are typically done before Robust™ or Modeling designs. Use this design type if you are unsure of the important factors affecting your process. Screening designs allow you to investigate a large number of factors to determine which are the most important. DOE Wisdom allows up to 12 factors for screening designs. The specific screening designs supported by DOE Wisdom are listed in Appendix I.

Robust™ Designs

The word “robust” means insensitive. Robust Designs™ are used when the experimental objective is to make your process insensitive to noise. When the Robust Design™ objective is selected, DOE Wisdom allows the user to utilize both inner and outer arrays. Control factors are placed in the inner array and noise factors are placed in the outer array. Robust Designs™ allow the selection of the best levels for control factors such that the product performance is insensitive to noise.

Robust Designs™ are used to find factor settings that minimize variability in the response as well as produce desired levels of the response. DOE Wisdom allows up to 12 control factors in the inner array and permits up to three noise factors in the outer array. The specific Robust Designs™ supported by DOE Wisdom are listed in Appendix II.

Modeling Designs

When the key control factors are known, modeling designs are used to model the relationship between those factors and the responses. Modeling designs allow the user to build a mathematical model to optimize the response. These models can be used to predict the levels of the responses at different factor settings. DOE Wisdom allows up to 7 factors for modeling designs. The specific modeling designs supported by DOE Wisdom are listed in Appendix III.

D-optimal Designs

When there is a mixture of quantitative and qualitative factors, many experimenters will use a D-optimal design. These designs are not typically orthogonal. In situations where it is too costly to use a fractional design which is orthogonal, the D-optimal may be used.

Create Your Own Design

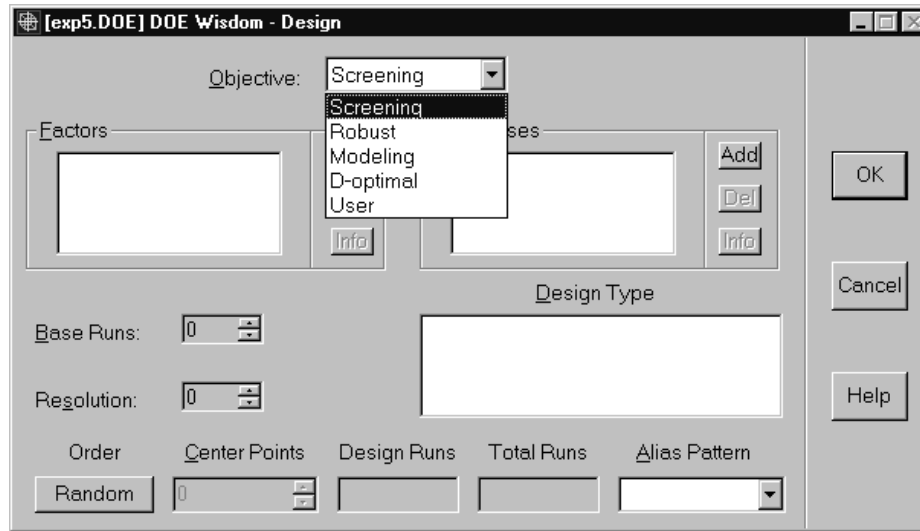
This option allows the user to enter any design type they would like. The user will be asked to enter the various levels for the factors in the Worksheet. The software also has a section titled “Treatment of Qualitative Factor.” If you are creating a standard orthogonal design (e.g. fractional-factorial, etc.), select **Standard**. If you are creating a non-orthogonal d-optimal design, select **D-optimal (effect coding)**. Because this option allows the user to enter any design, it assumes more user knowledge. The user must have a thorough understanding of the limitations of the design they choose to enter under “Create Your Own Design.”

Selecting an Objective

In the Design Definition Dialog Box, click on the arrow at the right of the drop-down **Objective** list box to display more objective types. Select the experimental Objective type you wish to create.

After the file has been created, the screen shown in Figure 1-2 will appear. DOE Wisdom presents the user with several views of the current project. Each of these views is used to look at the project from a different aspect, for example; the worksheet window views the design of the project in matrix form and the graph window can produce several different graphical views of the design, data, and analysis aspects of the project.

The windows available depend on the status of the project. The user always has a Message Log and Design window available. When a complete design has been entered, the Worksheet and Data windows also become available. Finally, when data is entered to complete the project the Graphics and Statistics windows are available.



Factors

Types of Factors

Control factors and noise factors can be entered in DOE Wisdom. Control factors are factors that can be controlled. Factors that you cannot or choose not to control are called noise factors. Additionally, control and noise factors may be quantitative or qualitative. Quantitative factors are those whose levels can vary over a continuous numerical scale. Time, temperature, and pressure are examples of quantitative factors. Qualitative factors have discrete levels. Qualitative factor levels cannot be arranged in order of magnitude. Material lot number and operator are examples of qualitative factors.

Adding Quantitative Factors

In the Factor Drop-Down List Box, choose Add. The window in Figure 2-3 will appear.

The screenshot shows a dialog box titled "Factor Definition". At the top, there are two buttons: "Quantitative" (which is highlighted) and "Qualitative". Below these are five input fields: "Name:", "Units:", "Low Level:", "High Level:", and "Precision:". Below the "Precision" field is a dropdown menu for "Ease Of Adjustment" with "Easy" selected. At the bottom left is a "Control" button. On the right side, there are three buttons: "OK", "Cancel", and "Help".

Figure 2-3

Click on the Quantitative button to switch back and forth between quantitative and qualitative factors . Select quantitative.

Enter the factor name.

Tab to move the insertion point to the **Units** section. Specify the units of measurement for the factor. For example, the factor name may be time and the units would be seconds.

Tab to the **Low Level** section. Enter the low level for the factor. Tab to the **High Level** section and enter the high level for the factor. (**NOTE:** DOE Wisdom only asks for a low and a high level for each factor. If a modeling design has been chosen, the software will automatically calculate the alpha and center points. These will appear on the worksheet.)

Tab to the **Precision** section. Enter the factor precision. The precision specifies how precisely a factor can be controlled. A precision of 1.0 indicates the factor can be measured within ± 0.5 units. The precision must be a power of 10.

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Click on the arrow at the right of the drop-down **Ease of Adjustment** list box to display the options. DOE Wisdom supports three levels for this attribute: Easy, Medium, and Hard. DOE Wisdom will generate the worksheet so that hard to vary factors are varied least often.

If you have selected a Robust Design™ in the objective section, the Control/Noise command button will be active. If the factor is a control factor for the inner array, select **Control**. If the factor is a noise factor for the outer array, click on the button and it will change to **Noise**.

Once all descriptions have been entered for a factor, choose **OK**. The factor will now appear in the Factor Drop-Down List Box..

To continue adding factors, simply select **Add**.

Adding Qualitative Factors

In the Factor Drop-Down List Box, select **Add**. The window in Figure 2-3 above will appear. Click on the Quantitative button to switch back and forth between quantitative and qualitative factors. When qualitative is selected, the window in Figure 2-4 will appear.

The image shows a dialog box titled "Factor Definition". It has a "Qualitative" button at the top. Below it are three input fields labeled "Name:", "Units:", and "Levels:". Below the "Levels:" field is an "Ease Of Adjustment" dropdown menu with "Easy" selected. At the bottom of the left pane is a "Control" button. On the right side of the dialog are three buttons: "OK", "Cancel", and "Help".

Figure 2-4

Enter the factor name.

Tab to move the insertion point to the **Units** section. Specify the units of measurement for the factor. The units attribute is optional.

Tab to the **Levels** section. Type in the factor level. For example, the factor name might be resin and the level might be Lot A. Press **Enter** to add additional levels. DOE Wisdom allows up to five levels for D-optimal designs.

Click the arrow at the right of the drop-down **Ease of Adjustment** list box to display the options. DOE Wisdom supports three levels for this attribute of a qualitative factor: Easy, Medium, and Hard. As with quantitative factors, DOE Wisdom will generate the worksheet so that hard to vary factors are varied least often.

Once all descriptions have been entered for a factor, choose **OK**. The factor will now appear in the Factor Drop-Down List Box.

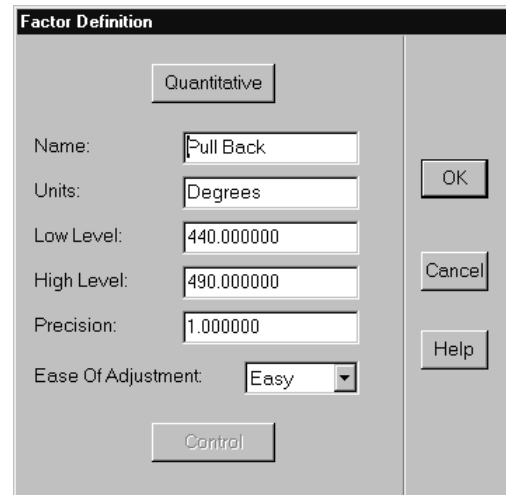
NOTE: All qualitative factors display which label is the -1 and which is the +1 label. On standard designs the user cannot change which is assigned -1 and which is assigned +1. For User Defined designs (with D-optimal coding) and D-optimal designs, the - and + identifies become active and the user can choose which label is - and which is + by dragging the button to point at the correct label.

Deleting Factors

Move the mouse pointer to the factor you wish to delete. Click the mouse button. The factor is now selected and will be highlighted. In the Factor Drop-Down List Box, select Del.

Factor Information

Select the factor for which you want to review information. The factor is now highlighted. In the Factor Drop-Down List box, select Info. Information on that particular factor will appear as shown in Figure 2-5. DOE Wisdom will allow you to modify the factor. Use the tab key to advance to the factor attribute you wish to modify. When all changes have been made, choose **OK**.



The image shows a dialog box titled "Factor Definition". It has a dark header bar with the title. Below the header, there are two buttons: "Quantitative" (selected) and "Control". The "Name:" field contains "Pull Back". The "Units:" field contains "Degrees". The "Low Level:" field contains "440.000000". The "High Level:" field contains "490.000000". The "Precision:" field contains "1.000000". The "Ease Of Adjustment:" field is a dropdown menu with "Easy" selected. On the right side of the dialog, there are three buttons: "OK", "Cancel", and "Help".

Figure 2-5

Types of Responses

Selecting the appropriate response or quality characteristic to measure is critical to successful experimentation. DOE Wisdom supports continuous responses. For example, thickness measurements are considered a continuous response. If the response is not continuous (e.g., poor, fair, good, very good, excellent) you can assign integers to the categories. For example:

- 1 = poor
- 2 = fair
- 3 = good
- 4 = very good
- 5 = excellent

Adding Responses

In the Response Drop-Down List Box, select Add. The window in Figure 2-6 will appear.

The screenshot shows a dialog box titled "Response Definition". It is divided into two main sections. The top section contains input fields for "Name:", "Units:", "Min:", "Max:", and "Replicates:". The "Replicates" field is a spinner box currently set to "1". To the right of these fields are three buttons: "OK", "Cancel", and "Help". The bottom section is titled "Desirability" and contains four radio button options: "None" (which is selected), "Increasing", "Decreasing", and "Tent".

Figure 2-6

Enter the response name.

Tab to the **Units** section. Enter the units. For example, the response may be thickness and the units might be inches.

Move to the **Min** section. Enter the minimum expected value for the response. Move to the **Max** section. Enter the maximum expected value for the response. During data entry, DOE Wisdom will verify that all responses fall within the specified region. This protects against some data entry mistakes. For example, if the thickness value range was specified between 10 and 100 and a value of 0.1 was entered, DOE Wisdom would warn the user that the value is out of range. If the value is correct, simply select **OK** at the warning prompt and the software will enter the value into the data entry sheet.

Click the arrows at the right of the **Replicates** section to indicate the number of replicates desired. This

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section defines how many response measurements you would like to record for each run. Repetition refers to completing a run more than once without resetting the factors. A replication occurs when runs are completed more than once and factors are reset each time. Replication will tend to provide a better estimate of experimental error, but it may be expensive to reset all factors for each run. DOE Wisdom performs the analysis the same, regardless of whether the multiple response values are based on repetition or replication.

Desirability Functions

Desirability functions are a mathematical means of conducting trade-offs between two or more responses from a designed experiment. Sometimes it is difficult to do trade-offs with overlapping contour plots for numerous responses particularly when responses have different degrees of importance. Desirability functions are often used in these situations.

DOE Wisdom allows the user to choose the following desirability functions:

None	No desirability function is required.
Increasing	The higher response value is desirable.
Decreasing	The lower response value is desirable.
Tent	A nominal response value is desirable.

Click on the appropriate desirability function. If “Tent” was selected, the window shown in Figure 2-7 would appear.

Response Definition

Name: response 2
Units:
Min: 0
Max: 350
Replicates: 1

OK
Cancel
Help

Desirability

None
 Increasing
 Decreasing
 Tent

Target:
Min:
Max:
Weight: 10

Figure 2-7

Determine the nominal, minimum, and maximum values “desired.” Use the mouse pointer or tab key to change the values. Suppose the following values were desired:

Nominal 100
Minimum 50
Maximum 150

The window shown in Figure 2-8 would appear.

Response Definition

Name: response 2

Units:

Min: 0.000000

Max: 350.000000

Replicates: 1

OK

Cancel

Help

Desirability

None

Increasing

Decreasing

Tent

Target: 100.000000

Weight: 10

Min: 50.000000

Max: 150.000000

Figure 2-8

The steps required for desirability functions are as follows:

1. Plan the experiment in the normal manner.
2. For each response, decide if the desired response is increasing, decreasing, or a tent.

If increasing, determine the minimum acceptable value and maximum value beyond which no further improvement would be obtained.

If decreasing, determine the minimum value below which no further improvement would be obtained and the maximum acceptable value.

If a tent, determine the nominal, minimum, and maximum desired values.

For each response, determine the importance weight. This is a value between 1 and 10. The higher the number, the more important that particular response is.

3. Conduct the experiment.

- Analyze the data using:

$$Desirability(D)=[(d_1)^{w_1}(d_2)^{w_2}\dots(d_n)^{w_n}]^{\frac{1}{\sum w_i}}$$

- Determine the settings for factors which maximize the desirability. DOE Wisdom will add the desirability function to the list of responses for appropriate graphs and statistics. For optimal results, the user should try to maximize the D(comp) value.

Deleting Responses

Move the mouse pointer to the response you wish to delete. Click the mouse button. The response is now selected and will be highlighted. In the Response Drop-Down List Box, select **Del**.

Response Information

Select the response for which you want to review information. The response will be highlighted. In the Response Drop-Down List box, choose **Info**. Information on that particular response will appear. DOE Wisdom will allow you to modify the response. Use the tab key to advance to the response attribute you wish to modify. When all changes have been made, choose **OK**.

Design Type Terminology

Full Factorial Design	A design matrix which tests all possible combinations of the factors and levels. This design type is capable of estimating the effect of all possible factor combinations on the response.
Fractional Factorial	A subset of the full factorial in which some factors are assigned to certain interaction columns of the design.
Taguchi Designs	Tabulated design matrices that originate from full factorials, fractional factorials, Plackett-Burman, Hadamard matrices, and Latin Square designs.

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Plackett-Burman	Designs developed by Plackett and Burman and used for screening a large number of factors to determine the important ones. These designs are based on Hadamard matrices. The number of runs in a Hadamard matrix is a multiple of 4. The two factor interaction effect does not bias just one main effect, but is parceled out over many main effects.
Box-Behnken Design	A 3-level design used to estimate all main, quadratic, and 2-way interaction effects.
Central Composite	A class of designs typically used for quantitative factors and designed to estimate all main effects plus desired quadratics and 2-way interactions. These designs contain a factorial portion, a center portion, and an axial portion.
Resolution III Design	A design which does not alias main effects with one another, but does alias main effects with 2-way interactions. 2-way interactions are aliased with each other.
Resolution IV Design	A design which does not alias main effects with one another or with 2-way interactions, but does alias 2-way interactions with other 2-way interactions. Main effects are also aliased with 3-way interactions.
Resolution V Design	A design that does not alias the main effects with other main effects or with 2-way interactions. 2-way interactions are not aliased with other 2-way interactions. 2-way interactions are aliased with 3-way interactions. Main effects are also aliased with 4-way interactions.

Design Types

When factors and responses have been entered, DOE Wisdom displays the permissible design types for the objective selected. The recommended design type is highlighted.

The Base Runs, Resolution, Design Type, and Total Runs sections are all interactive. If you select a different design type, the number of runs and the resolution will change. If you decrease the number of runs, the resolution and design type will change.

Using the mouse, select the desired design type.

Order

Standard vs Random

DOE Wisdom allows you to choose either Standard or Random order for your worksheet. Standard Order creates a worksheet in the textbook order of the design. Random Order creates a worksheet with all the runs in a randomized order. This assists in “averaging out” the effects of extraneous uncontrolled factors that may be present.

Selecting the Order

Click on the **Order** button to switch back and forth between Standard and Random Order. DOE Wisdom automatically defaults to Standard Order for Taguchi designs and designs with “Hard to Vary” factors. DOE Wisdom defaults to Random Order for factorial designs.

Center Points

Default Values

For Central Composite Designs, DOE Wisdom recommends the number of center points necessary to maintain orthogonality. The table below shows the alpha values that are recommended. If you choose to change the number of center points, DOE Wisdom will calculate and use new alpha values to maintain orthogonality.

Number of Factors	Alpha Value
2	1.414
3	1.682
4	2.000
5	2.378
6	2.828
7	2.828

Selecting the Number of Center Points

Use the arrows to the right of the Center Points section to increase or decrease the number of center points included in the design. Center points can be used in screening designs to test for curvature of the response surface. DOE Wisdom only uses the center points when plotting the scatter plots. They are not used in the ANOM or ANOVA statistics. **NOTE:** If you change the number of center points, the software will default to your new defined number for any other experiments generated from this design even if additional factors are added.

Alias Pattern

Aliasing

Terms that are aliased have the same (+) and (-) sequence in their columns. The result of aliasing is that the two terms cannot be evaluated separately.

Viewing the Alias Pattern

Click the arrow at the right of the drop-down Alias Pattern box to display the alias pattern for the design selected.

Click the arrow again to hide the display.

Accepting the Defined Design

Once the factors, responses, design type, order, and number of center points have been defined, simply choose the **OK** command button to accept this design.

Modifying an Accepted Design

Open the experiment file you wish to modify. Click on the **Design** button. Modify the factors, responses, design type, order, or number of center points. After all modifications have been made, simply choose **OK** to accept the modified design. DOE Wisdom will ask if a new project should be created. Select **Yes**. The software will then ask for a name for the new project. If you wish to give it the same name as the old project, type in that name. DOE Wisdom will ask if you want to overwrite the old file.

NOTE: If you do not wish to accept the changes, choose **Cancel**.