Qualitek-4 is a Windows based software that helps you design experiments and analyze the results of the experiments. This guide helps you learn how to plan your experiments and accomplish the design & analysis tasks. (Text description in the guide is kept to a minimum for readability. Please refer to User Reference Manual for more description of capabilities.)
Qualitek-4 (QT4)
Automatic Design and Analysis of Taguchi Experiments

The Taguchi method of experimental design is a popular statistical technique utilized by the manufacturing industry today. Qualite-4 is designed to automatically design and analyze results of Taguchi experiments. Using its enhanced design capabilities, experienced users can layout experiments in a matter of minutes. When results are entered and the type of analysis indicated, QT4 readily computes main effect, performs ANOVA, determines optimum condition, and prints presentation quality reports.

Experiment Planning – While there is not much computations involved in experiment planning that Qualitek-4 performs, it provides users with detail descriptions of the process recommended by expert practitioners. Whether you are working as a single person project or a team comprising of larger number of participants, you would benefit by following the steps recommended in PLAN menu item in the software.

Experiment Design - To help you design your experiments, QT4 allows you to do it yourself or in automatic design option, lets you simply indicate what are your factors and levels, and then it selects the array and assigns the factors to the appropriate columns. While automatic design can handle most of your common experiment designs, the manual design option allows you to create the special designs to suit your needs. Once you are satisfied with your experiment design, QT4 readily describes the recipes for you to carry out the experiments. It also suggests the random order of conducting each of the experiments, which are described in separate pages to resemble a work order.

Analysis - The three basic steps in analysis; Main Effect, ANOVA, and Optimum studies are carried out in sequence with click of OK buttons. Analyses can be performed using Standard or S/N for Smaller, Bigger, Nominal or Dynamic Characteristics.

Additional Attractive Features - Automatic test of presence of interaction, Plot of interaction between two, three and four level factors, Least Squares quadratic curve fitting between average effects for three and four level factors, plot of Main Effects, Bar graph and Pie diagram for ANOVA results, Stacked diagram for factor contributions to Optimum, etc.
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To find Qualitek-4 software, search in GOOGLE or YAHOO using **keywords: Taguchi Experiment Software**.
This section contains information about from where to get Qualitek-4 software and how to install it in your computer.

a. Sources of Qualitek-4

For evaluation purposes, you should always find it convenient to download the demo copy of the software from our site: http://nutek-us.com/wp-q4w.html. Follow the link for DEMO DOWNLOAD, register with us and download a zipped file.

If you purchase the regular version of our software from us (Nutek) or our distributors, you will receive the software in a CD-ROM.

You may also prefer to download the software directly from our site using the URL: http://nutek-us.com/q4wxpdemo.zip.

No matter how you receive the copy of our software, it will always allow you to install and run it DEMO unless you have a valid registration number.

The DEMO version of Qualitek-4 software allows you to run experiments designed using only L-8 array for indefinite period.

b. Method of Installation

If you downloaded software from the web, you must first UNZIP it before proceeding to install. You do not need to do that if you have a CD-ROM. To install Qualitek-4, run SETUP.EXE.
c. User License

Your license to use the software is a 15-digit REGISTRATION #. You would need to type-in this number when prompted during installation process. If you do not have a registration number, you will leave this space blank which makes the software be installed and run as DEMO version.

![Registration Information](image)

Put your own or company name and follow through with other installation information as requested. Generally, just click OK to proceed with the default selection of directories and sub-directory selections.
Qualitek-4 Capability Overview

For all experiments, you should follow the three basic steps outlined below. Whenever we utilize QT4’s design and analysis capabilities, it would be assumed that you have completed the planning session and have all necessary information related to the experiment.

**PLAN**
Follow the steps prescribed in the online (Qualitek-4, PLAN menu)

.. Determine objectives

.. Select factors & levels

.. Select Orthogonal Array and assign factors to columns (for Manual design)

**DESIGN**
Select Manual or Automatic design option from DESIGN menu.

.. Select array (Manual design option)

.. Describe factor and levels

**ANALYZE**
Select analysis option from ANALYSIS menu.

.. Select quality characteristic (QC)

.. Review results

.. Analyze results
  - Main Effects
  - ANOVA
  - Optimum
The first step in carrying out your experimental study is to hold an experiment planning discussions. This is particularly important if you are running this study as a team. If you happen to be alone in this effort, you should definitely take the time to think through and collect all the information necessary to design the experiments you wish to run. To help you with experiment planning, you may utilize different sources available to you.

a. Online planning guide
You ready source for experiment planning is contained under PLAN menu in the software from Experiment Configuration screen (main screen) shown below. Once installed, you should run Qualitek-4 and be in this screen. You need not have a specific experiment file to review this Planning Guide.

Follow the suggested steps and establish the key information you need for your experiment before proceeding to DESIGN phase.
As an alternate source, or when you are away from Qualitek-4 software, you may visit our web site (http://nutek-us.com/wp-exptplanning.html) to carry out your planning process.

There are a number of planning details described in these steps. The main purpose is for you to exercise a thorough evaluation of your objectives and system before deciding on experimental factors.
b. Key data from planning

Regardless of the size of your team or complexity of your experiments, you should collect information about your projects such that you can complete the following summary data table.

<table>
<thead>
<tr>
<th>Project Title</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.</td>
</tr>
<tr>
<td></td>
<td>2.</td>
</tr>
<tr>
<td></td>
<td>3.</td>
</tr>
<tr>
<td></td>
<td>4.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Criteria Description</th>
<th>Worst Value</th>
<th>Best Value</th>
<th>QC</th>
<th>Rel. Weighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>etc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Your OEC Equation (if planned)

\[ \text{OEC} = (x) \times + (y) \times + (z) \times + (w) \times \]

Example:

<table>
<thead>
<tr>
<th>FACTORS</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>etc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

List interactions and noise factors you wish to include in your study.

Proposed Experiment Design: Indicate the inner and outer arrays used for the experiment design and how the control factors and noise factors will be assigned to the columns of the arrays. Based on the proposed design, indicate the test sample size requirements.

All experiments must have at least one criterion of evaluation (result). Of course, if you have multiple criteria of evaluation (For evaluation of multiple objectives), you may decide to create the Overall Evaluation Criteria (OEC) for analysis of results.
C. Manual and Automatic designs

To complete your planning process, you must select the orthogonal array appropriate for your design and identify and assign factors to the column. Bare in mind that Qualitek-4 offers you option to pursue experiment design either by Manual Design, or Automatic Design. Should you decide to go for Automatic Design option and let Qualitek-4 determine the array and assign columns, you will only need to provide the factor and its level information. If you are a beginner user, you should follow the Manual Design option.

The size of the experiment you can afford to run (Time & money available for the study) helps you select the array. Your selection of the array limits the number of factors you can include in the study. Once you identified a list of factors for the study, you should always have an idea about the array you would need and where the factors are assigned. This way, even when you elect the Automatic Design option, you will be able to confirm the design Qualitek-4 creates for you.
Qualitek-4 is designed mainly to help you accomplish your experiment DESIGN and ANALYSIS tasks. Naturally, you will utilize the software after you have finished planning discussions.

Depending on the type of factors you want to study and the nature of results you collect, you will have different variations in experiment designs and in analysis of the results. This section is dedicated to showing you simplest form of DESIGN and ANALYSIS that you would often encounter.

**a. One or more samples tested in each Trial Condition**

This would be the type of experiments you will do most often. For your practice purpose, we will see how experiment PISTON.Q4W is designed and analyzed. This is an example experiment file that comes with QT4.

**DESIGN EXPERIMENT**

Let’s assume that you and your team already planned the experiment involving piston head in automotive engine and determined the following:

Title: Piston Bearing Design Optimization
Results Measured: Loss of internal pressure (Quality Characteristic is Smaller …)

<table>
<thead>
<tr>
<th>Factors</th>
<th>Level - 1</th>
<th>Level - 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>2000 RPM</td>
<td>2500 RPM</td>
</tr>
<tr>
<td>Oil Viscosity</td>
<td>Low Temp.</td>
<td>High Temp.</td>
</tr>
<tr>
<td>Clearance</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Pin Straightness</td>
<td>Perfect</td>
<td>Depressed</td>
</tr>
</tbody>
</table>

With the above minimum information, you are ready to proceed.

- Run QT4 by double clicking the icon shown below or from the START (All Program) menu button.
- Click OK on Program screen and on Registration screen to be in the

![QT4 Icon]
Experiment Configuration screen. We would always call this screen as the main screen of QT4.
- Take a few moments to review all menus and displayed text in this screen. Notice that experiment file PISTON.QW is automatically selected by QT4 for demonstration.
- Click on the DESIGN menu and select Manual Design – Inner Array option. Since you are creating a new design, click OK to proceed.
- Select L-8 array in the next screen and click OK to proceed.

When you are in the Inner Array Design screen, enter factors and levels as you determined suitable for your design or as shown below. In this case, you could assign the four factors to any of the seven columns (Discussions of principles and concepts involved in the design of experiment technique is beyond the scope of this Guide). Note that the numbers in the left column
in this screen represents the corresponding columns of the orthogonal array (L-8 in this case) used for the design.

- When you are done entering factors and levels, place CURSOR on the empty blank/unused rows (rows 3, 6 & 7) and click UNUSED button.

- Click OK when done. QT4 will not let you proceed to next screen until you decided about each row (columns of array) in this screen. Each column MUST have a factor, reserved to study interaction, or be identified as UNUSED or UPGRADED.
- In the Description of Project screen, type project title and other information in the spaces provided (all items are optional). Click OK when done.

- In Edit Inner Array screen, you simply review the array to make sure that the columns are correct. When a column is identified as UNUSED/UPGRADED, QT4 automatically turns it into zeros (null column, columns 3, 6 and 7 in this case). In case the
columns do not look all right to you, click on RESET COLUMN or RESET ARRAY to correct the situation.

- In the Save File AS screen, assign a name for the experiment file you are creating, PISTON2. Note that you need not type the file extension “.Q4W”. Also, note that the file name is restricted to 8 characters only. By default, the experiment files you create will be saved under Q4W32\usrFiles sub-directory under Program Files directory in C: drive. Click OK when done and be in the main screen.

![Save File As...](image)

**PRINT TRIAL CONDITIONS**

- Once you are done designing the experiment, you will need to describe the 8 (for L-8 array) experiments (called Trial Conditions) you will need to run. To get the description of the Trial Conditions, select Trial Condition from CONDITION menu items.
- Description of Trial Conditions screen allows you to review all trials, one at a time, and also print or save descriptions. To review trials, click on Next Cond. Note that QT4 also shows the random order of running this trial as shown next to trial number in title.

It is a good idea to save description in a text file that you will be able to insert in WORD document and format and print as convenient. Click on the Save All Trial Conditions button to save in a file.

- In the Notes screen shown below, you have the option to enter information about the experiments as well as some instruction on who and how to run the experiment. You may also include some notes on how the results should be collected and what to do with it.

- Information in the box is strictly optional. Click on PROCEED button to go to the next screen.
You have option to name this file. By default, QT4 names this file the same as your experiment file, but assigns a different extension (TRL). To change name, type over PISTON2. Click on OK button to return to the main screen.

- You now have the description of all the experiments you will need to run. (Click Return in Trial Condition screen to be in the main menu.)

It is good idea to print each trial condition separately and enclose instruction on how to run the experiments and collect data.
CARRY OUT EXPERIMENTS …..

ENTER RESULTS (input to QT4)
- Run QT4, be in the main screen, load experiment file from FILE menu option.

- Suppose that you completed all 8 trial conditions with 3 samples tested in each condition and you collected the following results.

<table>
<thead>
<tr>
<th>Trial#</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>45</td>
<td>56</td>
<td>64</td>
</tr>
<tr>
<td>2</td>
<td>34</td>
<td>45</td>
<td>53</td>
</tr>
<tr>
<td>3</td>
<td>67</td>
<td>65</td>
<td>60</td>
</tr>
<tr>
<td>4</td>
<td>45</td>
<td>56</td>
<td>64</td>
</tr>
<tr>
<td>5</td>
<td>87</td>
<td>81</td>
<td>69</td>
</tr>
<tr>
<td>6</td>
<td>78</td>
<td>73</td>
<td>68</td>
</tr>
<tr>
<td>7</td>
<td>45</td>
<td>56</td>
<td>52</td>
</tr>
<tr>
<td>8</td>
<td>42</td>
<td>54</td>
<td>47</td>
</tr>
</tbody>
</table>

With these results at hand, you will now run QT4 to enter it in the program.

- When at the main screen, select Enter Results from RESULT menu items.
Experimental Results screen allows you to enter results of your experiments. Enter one result at a time for each trial condition. QT4 allows up to 120 sample results in each trial condition. Of course when sample size is large, you may prefer to IMPORT results from spreadsheet or WORD document.

While in this screen, you may explore Transform Data button for future use. There will be situation when you may need to transform results before analyses.

The Dummy Data button allows you to quickly insert some arbitrary data for evaluation purposes. This feature may be useful to you when you wish to demonstrate software analysis capabilities without regard to accuracy.

Complete entering all results and click OK to save data.
- The Save File As screen next gives you opportunity to update the experiment file with the results you just entered or save it under a different name.

**ANALYZE RESULTS**

- With all results entered, you are now ready to proceed to perform analysis. To analyze results, select Standard Analysis – Using Average of Results from ANALYSIS menu as shown below.

Analysis using average will always be your choice when you have either single sample or multiple samples of results (columns of results). Incase the sample tested in each trial is two or more, you will have option to analyze using standard deviation, and also using Signal to Noise Ratio (R/N).
- The preferred way to analyze multiple sample results, however, is to use S/N ratios. Click YES when you see the screen below.

- In the Quality Characteristic Selection screen, you will need to check one of the three QC’s. For analysis purposes, you may select any one and perform analysis. Generally, of course, you will select the QC that is consistent with your project objective (Smaller is better, in this case).
- The Experimental Results screen offers you an opportunity to review results to make sure that they are correct before you proceed with analysis. There area number of items for you to confirm.
  ▪ Check that Data Type and QC Type are OK.
  ▪ Examine all results for accuracy (Scroll right & down if appropriate). Look for any values of unusual magnitudes that may be due to typographical errors.
  ▪ Notice the computed values of average and standard deviation.
  ▪ Click on the Graph Result button if you wish to view the variation of results in graphical form. This could give you an indication of variabilities of results within and between experiments.
  ▪ Review the TEXT box for any additional information or actions you may benefit from.
  ▪ Click OK to proceed
Main Effects screen is the first of the THREE screens (Main Effect, ANOVA & Optimum) that helps you complete analysis of results. Once you become familiar with QT4’s analyses capabilities, you will simply click OK in this and the next screen to complete the analysis process and view the OPTIMUM CONDITION. But for starting users, there are a number of outputs to review.
Since the factors studied in this case are all at 2 levels, QT4 has created two columns to show the calculated average factor effects. For example, 54.5 is the average effect of SPEED at level 1. The last column shows the difference between the two average effects and is an indication of the slope of the main effect.

You have two options to view the main effects. Click on the Multi Plot button to view several interactions in the same screen (shown below). You can also view each plot separately by clicking on the Single Plot button. Click on either ANOVA or OK buttons to proceed.

When in ANOVA Table screen, you have a number of actions to exercise. Your minimum action in this case may be:

- Pool factor Pin Straightness that shows 0 percent influence by double clicking on the factor description. This action will revise ANOVA table (Do not be alarmed by higher number as ERROR term as it is not uncommon.).
_Click YES when asked for permission to POOL. (Discussions of ANOVA principles and rationale for POOLING factors based on test of SIGNIFICANCE are beyond the scope of this Guide. For details, refer to textbooks on the subject: www.nutek-us.com/wp-txt.html)

_Click on the Bar Graph and Pie Chart to view the relative percentage influence of the factors in graphical forms. These graphs are a better way to communicate results from analysis to people not familiar with ANOVA. Click OK, RETURN, or OPTIMUM button when finished reviewing ANOVA to proceed to the third screen in analysis. (Click on Main Effect button if you need to go back to the main effect screen.)
Optimum Condition and Performance screen shows the combination of factor levels that is likely to offer the most desirable performance.
The last line in the screen represents the expected performance when the prescribed optimum condition is set and confirmation tests are conducted. As rule, you should carry out confirmation tests before releasing the new design parameters.

You may want to obtain some additional information available from this screen:

- Click on the C.I. (Confidence Interval) button to calculate confidence interval at a given CONFIDENCE LEVEL (say 95%, subjective selection. 80-99% are common range). Enter the confidence level value (85, 90, 95, etc.) you desire and click OK to proceed.

```
Confidence Interval (C.I) is the expected variation of the mean performance at the optimum condition for a given Confidence Level (C.L). C.L values of 90% and 95% are commonly used, but may range between 70 - 99% for industrial experiments.

Enter the Confidence Level (C.L) : [95] %
```

- Confidence Interval shown (+/- 9.343) represents the limits of variability that can be expected from the MEAN performance of samples tested at the optimum condition. Click RETURN button to return to the Optimum screen.

```
Expression : C.I. = sqr. Root((F(1,n2)^2 Ve) / Ne)
Where : F(n1, n2) = 3.5 (Computed Value)
      n1 - 1 Error DOF, n2 = 20
      Ve  =  Error Variance  = 14961645
      Ne  =  Effective Number of Replications = 6.0
      [Factor DOF's Included in the Estimate = 3]

Confidence Level  = 95
Confidence Interval = +/- 9.343

Expected Results at Optimum = 46.666 +/- 9.343
                            (Low Value = 37.323, High Value = 56.007)
```
When it is not possible to set all the factors as prescribed in the optimum condition, you may want to study the effects of setting one or more factors to a fixed level. You can study such WHAT IF scenarios by ESTIMATE option. Click on ESTIMATE button to find out what happens when, say, factor Pin Straightness is set to level 1 instead of level 2 as prescribed by optimum recipe. Click (place cursor) on Level column and type 1 in place of 2 for Pin Straightness. Notice that the Expected Results changes from 46.665 to 47.998. This way, you can study the effect of levels different than those prescribed by optimum for all factors. You may also see the effects of absence of a factor by placing ‘0’ for the level for that factor. Click on RETURN to go back to the optimum screen.

The GRAPH button in the optimum screen offers option to view how different factors contribute to the improvement in the optimum performance. Since QC = Smaller is better in this case, the average performance is diminished by the contribution made by the factors when it is adjusted to the optimum level. Click RETURN when done and be back to the optimum screen.
If you need to go back to ANOVA table, click on ANOVA button.

This completes basic and simple analysis of common experiments you will run. Click OK at the optimum screen to return to the main screen.

b. Experiments to study Interactions

Suppose that for the same experiment you ran before, you wish to learn about interactions between the two factors placed in column 1 and column 2.

Title: Piston Bearing Design Optimization
Results Measured: Loss of internal pressure (Quality Characteristic is Smaller …)

<table>
<thead>
<tr>
<th>Factors</th>
<th>Level - 1</th>
<th>Level - 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>2000 RPM</td>
<td>2500 RPM</td>
</tr>
<tr>
<td>Oil Viscosity</td>
<td>Low Temp.</td>
<td>High Temp.</td>
</tr>
</tbody>
</table>
Clearance Low High
Pin Straightness Perfect Depressed
Interaction: Speed x Oil Viscosity

EXPERIMENT DESIGN
Since you already have this experiment designed and save as PISTON2.Q4W, you can simply modify the design to study the interaction effect. Open this file. Then, from the main screen, select Factor & Levels option from the EDIT menu items.

When you are in Inner Array Design screen, you will have two ways (Buttons Col. Inter & inter Table) to incorporate interactions in your design. To reserve column 3 to study interaction between factors in columns 1 & 2 (Assuming you know where the interaction will go.),

_ Place cursor on the third row and click Reset Col button
_ While the cursor in third row, click on Col Inter button.
This action will require you to select the interaction pair of interest to you from Interaction Columns Selection screen. Select 1x2 => 3 (if it is not already highlighted), then click OK to return.

In the other way of setting up interaction study, you do not need to know the interaction column or read the Triangular Table.

_ Place cursor on the third row and click **Reset Col** button (the row must be blank)
_ Place cursor any where (need not be in third row), click on **Inter Table** button.
This action brings up Interaction Table screen and allows you to indicate the interacting factor columns (1 & 2 in this case) and click on View Inter to show the interaction column.

Be sure now to *Check box to set interaction* to let QT4 identify the column as the one reserved for interaction study. Click OK to return to Inner Array design screen which shows the column 3 of the array as reserved to study interaction between factors in column 1 & 2.
Click OK to move to Description of Project screen. Edit any item as needed.

Click OK to move to Edit Inner Array screen. Make sure the third column of the array has the original level numbers. If not, click on anywhere in the column, then click Rest Col button. This action resets the column to original state.

Click OK to Save File As screen. Click OK or name file which return you to the main screen.

Since interaction columns do not affect your experiment design, there is no change in the trial condition or the results you collected before.
ANALYSIS OF RESULTS

As you are already familiar with standard designs covered earlier, only analyses that relate to interaction studies will be described in this section.

Run QT4; be in the main screen and open file PISTON2.Q4W which has the same result as before. Proceed with standard analysis using average of results and Smaller is better QC. Click OK when done.

Most information calculated on interactions is available from Main Effects screen. Two types of interaction data are of common interest. First, the relative influence of the interest effect that is obtained from the column reserved to study it.
Click of Single Plot and view effects of interaction between factors in columns 1 & 2 by clicking forward as shown below. The slope of the line represents the relative magnitude of influence of the interaction as such plots do for factors (Also called as column effect). This type of information (represents SIGNIFICANCE) is only available for interactions which were selected for studies and columns were reserved to do so. Click RETURN when done.

From Main Effects screen, click INTERACTION button to review the second type of computed information on the strength of presence of interactions. This information is available on all possible interaction between TWO 2-level factors.
In interaction calculation method selection, click on AUTO option.

The Automatic Test for Presence of Interaction screen shows the strength of presence of interaction and orders them in descending order. QT4 computes a number called SEVERITY INDEX (0 – 100%) to represent the strength. It so happens that the interaction selected for the study, Speed x Oil Viscosity, is the most severe (68.75%) in this case. Since there are 4 2-level factors, the number of possible interaction is 4x (4-1)/2 = 6.

To view plots of individual interaction, DOUBLE click on the description (see arrow in screen shown above). Click on the highlighted word HERE to see the data used for this plot. Note that the factor levels corresponding to smallest value (49.33, QC = Smaller) indicates that
level 2 of speed and level 2 (X2Y2) of Oil Viscosity are desirable due to this interaction if found significant. Click RETURN when done.

To view relative strength of presence of interaction, click on the SI Graph in this screen as shown below.

Interaction Severity Index plot captures the ordered strength information that may be useful to you for future experiments.
Click RETURN in this and the next screen to be back to the Main Effects screen. Click ANOVA or OK button to move to ANOVA screen.

In ANOVA screen you review interaction for its significance and pooling treating it just you would a factor assigned to any column. Since interaction (one in column 3 only) is very significant and (47.553) should not be POOLED. Click OK when done.

When interaction is found to be significant (only those that appear in ANOVA table), you may need to alter the OPTIMUM condition that QT4 identifies. You can study this possibility in the optimum screen below.
Observe that the optimum levels for factors speed are 1 and that for oil viscosity is 2. But, since the interaction between them is significant, we recognize the levels of these two factors dictated by interaction severity plots (from Main Effects screen option) were level 2 for speed and 2 for oil viscosity. For final observation and release, you can estimate the optimum performance by using the ESTIMATE button as shown in the screen below.

Notice now the optimum condition is modified as dictated by the interaction and the expected value is changed from 36.164 to 44.331.
Mixed-Level Experiment Designs

To accommodate mixed-level factor designs, QT4 allows you to modify columns of the orthogonal array used for the design. This section is dedicated to demonstrate how the orthogonal arrays are modified by UPGRADING and DOWN GRADING the columns. In Manual Design option, you are in charge and must know the principles behind array modification. Of course, in Automatic Design option, users need not be familiar with the process.

a. Designs with Columns Upgraded

To demonstrate column level UPGRADING, we will take an example experiment.

_ Run QT4 and open file GEN. Q4W from the main screen._
_ Select Inner Array from EDIT menu items._

This experiment has 1 4-level factor and 4 2-level factors. The design is accomplished by modifying the first column of an L-8 array to form a 4-level column using columns 2 & 3 for upgrading.

Suppose that the 4-level factor, Casement Structure, has 4 levels as 200RPM, 2500RPM, 3500RPM and 5000RPM as shown.

<table>
<thead>
<tr>
<th>Factors</th>
<th>L-8</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casement Structure</td>
<td>2000 RPM</td>
<td>2500 RPM</td>
<td>2500 RPM</td>
<td>5000 RPM</td>
<td></td>
</tr>
<tr>
<td>COLUMN Upgrades</td>
<td><em>UNUSED</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COLUMN Upgrades</td>
<td><em>UNUSED</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clearance</td>
<td>Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pm. Straightness</td>
<td>Present</td>
<td>Dip</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contact Brush</td>
<td>type1</td>
<td>type2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor Design</td>
<td>present</td>
<td>epoxy</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

After all factors are described, be sure to identify columns 2 & 3 as UPGRADED using/clicking the button. Click OK in this and the next screen to move to the Edit Inner Array screen. Modify the first column to a 4-level column by typing 1, 2, 3, & 4 in the order shown (Reset column and type over if it is already modified). Column 2 & 3 are
automatically set to zero by QT4. No other columns need to be modified. Click OK in this and the next screen to finish editing this design (The process is the same if started with a new design).

![Edit Inner Array](image)

**Analysis** of this experiment follows the same steps shown before.

**b. Designs with Columns Downgraded**

To demonstrate column level DOWNGRADING, we will use an example experiment.

1. Run QT4 and open file ENGINE. Q4W from the main screen.
2. Select Factors and Levels from EDIT menu items.

This experiment has 1 4-level factor, 2 3-level factors and 6 2-level factors. The experiment is designed using an L-16 array modified to accommodate the factors with levels larger than 2. Columns 7, 9 & 14 are combined to form a 4-level column (Col. 1). Columns 1, 2 & 3 and columns 4, 8 & 12 are first combined to make 2 4-level columns, and then DOWNGRADED to form 3-level columns (columns 1 and 4). The factors are described in the appropriate column. Click OK when done and move to the Edit Inner Array screen.
The two 4-level columns 1 and 4 are DOWNGRADED by replacing all 4's with 1 as shown below (You may reset these columns and type over).

Analysis of this experiment follows the same steps shown before.
Many experiments are designed to determine optimum parameter combination to satisfy multiple objectives. These objectives may have evaluation criteria that have different units of measurements and quality characteristics. To analyze results, often needs special reduction of results. QT4 allows you to combine multiple evaluation criteria into a single index called Overall Evaluation Criterion (OEC). Example experiment POUND.Q4W will be used to demonstrate OEC formulation and analysis. (Review textbook by R. Roy or visit [http://Nutek-us.com/wp-oec.html](http://Nutek-us.com/wp-oec.html) for OEC formulation and background)

a. Formulation of OEC (Single Index)
   _ Run QT4 and open file POUND. Q4W from the main screen.
   _ Select Factors and Levels from EDIT menu items. Review factors and array used for this experiment.

This experiment has 5 2-level factors and 2 interactions included in the study. It has three objectives evaluated by different criteria as shown below. Since you are already familiar with design and analysis tasks, the focus here will be to show you how to create OEC for analysis.

<table>
<thead>
<tr>
<th>Evaluation Criteria</th>
<th>Worst Value</th>
<th>Best Value</th>
<th>QC</th>
<th>Relative Weight</th>
<th>Sample Reading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taste of Cake</td>
<td>0</td>
<td>12</td>
<td>B</td>
<td>55%</td>
<td>11</td>
</tr>
<tr>
<td>Moistness (gm)</td>
<td>25</td>
<td>-70</td>
<td>N</td>
<td>30%</td>
<td>44</td>
</tr>
<tr>
<td>Voids</td>
<td>8</td>
<td>2</td>
<td>S</td>
<td>15%</td>
<td>3</td>
</tr>
</tbody>
</table>

Depending upon your experiment planning discussions, you will create your own data collection scheme and document sample evaluations as shown below for the POUND experiment.

<table>
<thead>
<tr>
<th>Trial#</th>
<th>Sample 1</th>
<th>Sample 2,.... Etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Taste</td>
<td>Moistness</td>
</tr>
<tr>
<td>1</td>
<td>11</td>
<td>44</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>43</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>28</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>29</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>37</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>44</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>39</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>33</td>
</tr>
</tbody>
</table>
After running one sample in each trial condition, the sample was evaluated by three different criteria (Taste, Moistness and Voids) of evaluation as shown above. Evaluations from the sample at first are shown under Sample reading in the table above.

Once all tests are conducted and you have evaluation ready, you will run QT4 for analysis. However, if you have multiple objectives, as it is in this case, you will need to follow a special QT4 capability to enter results/evaluations and combine into OEC first before proceeding with analysis.

To re-enter evaluation or edit OEC, select Evaluation Criteria from EDIT menu options. Of course, when you wish to create OEC for your own experiment, you will select Multi Criteria (OEC) from RESULT menu options. Even when you are creating OEC for your own experiments, it is good idea to review POUND.Q4W example experiment for your benefit.

In Overall Evaluation Criteria screen, you must first work in area #1 (shown in screen-shot below) and describe the evaluation criterion, one at a time. Type in Taste, Worst value, Best value, QC and Relative weight (Data entry comes later). You will enter sample evaluations in area #2 only after you completed area#1.

In area #1, the USED column must have ‘X’ to be included. Click on QC value to change B=>S=>N etc. Make sure that the Relative weight (%) you entered add up to 100.
area #3 is for display of OEC. You may scroll the slider bar in this area to select Trial condition. Select Data Creation Button from area#4 if need to review steps.

You are now ready to enter evaluation data you collected. Enter evaluation for trial#1, Sample 1 (only one sample in this case). Enter, 11, 44, and 3 as shown below. After entering all data, click at any other cell in area#2. You will notice that OEC is calculated (91.41) and displayed at bottom of the column as well as in area #3.

Now enter rest of the evaluations for the remaining samples in the same way. Click RETURN when you are finished with OEC.

Results you now see under RESULT column in the main screen are the calculated OEC values for each sample (results). Remember that OEC is a single quantity representing the combined effect of the these criteria of evaluations use to quantify performance of a sample.
You may now proceed to analyze the results (OEC’s in this case) using the ANALYSIS option as you would for normal results. Just remember to interpret the expected performance at the optimum condition to be in the same unit, which is in OEC (theoretical number, no units).

b. Analysis with OEC

Analysis with OEC results (one or more samples per trial) follows the same QT4 options as under normal situations. The only difference will be in the interpretation of the predicted performance at optimum condition.

From main screen, select Standard Analysis (Average) and continue with analysis using Bigger is Better QC (QC for OEC is defined to be always as Bigger is better) to obtain the optimum condition shown below (All column effects are considered significant, No POOLING).

The expected result (104.593), theoretical OEC) represent the OEC value. Statistically put, it represents the expected MEAN of OEC’s of many samples tested at the optimum condition.
Analysis of Results with S/N Ratios

Analysis using S/N ratio is highly recommended when you have multiple samples in each trial conditions. The specific observations like factor influence, optimum condition, etc. may indeed differ from that which you find by performing the Standard analysis, but you should rely more on the S/N analysis.

**a. Analysis with Bigger or Smaller QC**

You should perform S/N analysis when there are multiple columns of results (or OEC). To demonstrate how S/N analysis is performed, we will make use of the example experiment PISTON.Q4W.

- Run QT4 and open file PISTON. Q4W from the main screen.
- Select S/N Analysis from ANALYSIS menu items. Review this experiment and see that it is the same one you used earlier (4 2-level factors, one interaction, 3 samples/results in each trial condition.

When in Quality Characteristic Selection screen, check the SMALLER QC and click OK. Take time to review formulas for S/N ratio by clicking in the S/N Equation button shown.
The experimental Result screen, in this case, shows S/N ratios of individual trial results and the average of their average value (-35.249). Note that the S/N values may be negative or positive depending on the quality characteristic and the magnitude (smaller or larger than 1) of results.

The Main Effects screen below shows the calculated values of average effects in the transformed S/N values. All observations about main effect plots and interactions may be made as done before. Remember always, however, that S/N values range between $-\alpha$ to $+\alpha$ and that QC for S/N is always Bigger is better.

Click OK or ANOVA button when done.
In ANOVA screen, you may want to POOL the factor in Column 5 by double clicking as before (Click on YES at prompt). If you POOLED, you also reset ANOVA by clicking on UNPOOL ALL button as shown below. Click OK or OPTIMUM button when done.

Optimum Condition screen shows the optimum condition selected from main effects based on Bigger QC since S/N ratios are used for analysis. Calculated in the same manner as Standard Analysis, the expected optimum performance (-32.08) is also expressed in terms of S/N ratio.

Click on TRANSFORM button to see the expected performance in the original units of the results.
Transformation of Performance screen converts the expected performance in the original units of results. This is the number you should use to report expected performance to all. To see how this transformation works for other QC, you should repeat analysis using different QC and review the transformation from this screen. Click RETURN to get back to the Optimum Conditions screen.

Just as in the Standard Analysis, you can determine the confidence interval (C.I.) on the expected performance in this case too. Remember that the C.I. can be reliably calculated only when the degrees of freedom
of the error term is 3 or more. Click the C.I. button to calculate C.I in terms of S/N.
AT User Supplied Confidence Level screen, enter 85 (Higher value will not work for lower degrees of freedom for error term). Click OK to proceed.

The Confidence Interval screen displays the expected range of S/N ratios from samples tested at the optimum condition. The low and the high values of S/N can be transformed into original results by using the Transform High/Low S/N buttons. Click on Transform High S/N button to review transformed values.

Transformation of C.I. in S/N screen coverts the limits of S/N values into the original units of results. Understand that, smaller negative values of S/N (-31.7336) is actually considered larger. Be sure to review the on-
screen HELP text provided. Click RETURN when done and try transforming the lower limit of the S/N. Be in the optimum screen when done.

When you perform analysis using S/N, you will have option to display a graph (Variation Diagram) showing improvement in terms of variation reduction along with a few indices (Standard Deviation, Cpk, Loss in$, etc.) which expresses improvements. Click on VARIATION button from the Optimum Conditions screen.

Input for Variation-- screen allows you to modify the values (DEFAULT) QT4 selected for your graph. Generally, until you are fully familiar with the concepts, you may accept the default values and
proceed to display graph. Review on-screen texts to learn about what QT4 assumes. Click on the PLOT button to display Variation Reduction Plot.

The Variation Reduction Plot shown below compares the theoretical distributions (created from Std. Dev. And Mean values) before and after (expected performance at optimum) experiment. It also shows the corresponding changes in some of the other common performance characteristics. Most importantly, it also calculates the expected savings that is expected to result from the improvement in terms of pennies saved from a dollar loss before (51.7cent/$Loss).

When you build confidence in how to compose the Variation Plot, you may use it as a single page summary of your experiment for higher level management presentation.

Click RETURN in this and the next screen to get back to the Optimum Conditions screen.
Click OK at the Optimum Conditions screen to return to the *main screen*.

**b. Analysis with Nominal QC**

Analysis using S/N ratios with Nominal QC offers you several options for defining the S/N values. You may want to perform analysis with Nominal QC when the performance is desired close to a desired TARGET value. Suppose that for PISTON.Q4W experiment, you desire performance close to 40 (Target value), you would then want to analyze results with 40 as the target and determine the optimum condition.

_ Run QT4 and open file PISTON.Q4W from the *main screen._
_ Select S/N Analysis from ANALYSIS menu items and be in the Quality Characteristic Selection screen._

Check Nominal is the best QC and be in the S/N Based on Target screen. Here you can review S/N formula and decide which of the S/N definition you prefer. Note that S/N based on MSD is the common practice and is the only one that requires a TARGET/NOMINAL value (other definitions used average as the target).
Click on the Review S/N Definition – button to see the formulas for S/N.

The S/N Equations for Nominal QC screen shows different choices of definitions for S/N under Nominal QC. Click RETURN to return to S/N Based on Target screen, and then click on OK to go to the Target Value screen.
Enter 40 for target value in the screen below. Click OK when done.

Proceed with analysis that follows the same steps covered earlier.
The formal way of incorporating effects of noise factors is to utilize an Outer Array in your design. You should follow this strategy if you going for ROBUST DESIGN. The time to include Outer Array in your design is:

- Just after you completed designing your experiment with control factors (Inner Array design)
- Before you describe trial conditions or carry out your experiments.

To practice creating Outer Array in your design:

_ Run QT4 and open file PISTON2. Q4W from the main screen. Recall that you created this design. You may also open PISTON.Q4W and save it as PISTON2.Q4W before proceeding with the steps below.

To include Outer Array in your design (just after Inner Array design), select Manual Design – Outer Array from DESIGN menu items as shown below.

Since this MUST be done before you carry out experiments, QT4 asks permission to clear results. Of course, for new experiments, you will not have results and you will not be asked about results. Click YES when prompted.
a. Experiment Design considerations

The size of the Outer Array depends on the number of noise factors selected for the study. Since the size of the array dictates how many samples you will need to run in each trial condition, the number and levels of the noise factors, you should carefully deliberate and decided these items in the experiment planning session. Suppose that the noise factors you chose to include in the experiment are these.

<table>
<thead>
<tr>
<th>Noise Factors</th>
<th>Level -1</th>
<th>Level -2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lubricant</td>
<td>Low Viscosity</td>
<td>High Viscosity</td>
</tr>
<tr>
<td>Room Temperature</td>
<td>Low Temp.</td>
<td>High Temp.</td>
</tr>
<tr>
<td>Radial Load</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

As you proceed with the Outer Array design, at Select Outer Array, check the box for Array L-4 and click OK to proceed.
In the Outer Array Design screen below, enter description the three noise factors and their levels. Click OK when done.

Following description of the noise factors, review/modify Description of project input screen and the Edit Outer Array screen. Click on file saving screen.
When you are main screen, you are done with an experiment design that has both inner and outer array. You are now ready to describe the trial conditions and proceed to carry out the experiments.

The noise conditions, to which each trial conditions are exposed while running the experiment, can be described in the manner similar to that for the trial condition. While in the main screen, select Noise Conditions from DESIGN menu items as shown below.

Print, review or save file containing the descriptions of the noise conditions from the Description of Noise Conditions screen shown below.
Print and utilize both the trial and noise condition descriptions to prescribe the conditions of the tests to be conducted.

b. Analysis of Noise effects

When noise factors are studied using OUTER ARRAY design, in addition to determining the ROBUST DESIGN condition, you will have option to find out about the nature of influence (Main effects) of the noise factors.

To learn how to obtain information about the noise effects, we will use an example file: PISTON1.Q4W.

_ Run QT4 and open file PISTON1.Q4W from the main screen.
_ Select S/N Analysis from ANALYSIS menu items and proceed to the Main Effects screen by selecting Smaller QC (For Noise Effect, selection QC is immaterial).

You would be at the Main Effects screen as part of your routine analysis and may proceed to complete the two steps (ANOVA and Optimum) next. Our objective at this time, however, is to learn how QT4 allows calculation of the effects of the noise factors included in the study.

To proceed with calculation of noise effects, click on the NOISE EFFECTS button as shown above.
Read the note displayed and click OK to proceed.

In the Experimental Results for Noise Effects screen, you have an opportunity to review results and confirm before proceeding with analysis. Verify that for noise factor effects, you are now analyzing an L-4 experiment (Experiment with L-8 inner and L-4 Outer arrays) with 8 results in each trial condition. This means that the original result matrix (8x4) is now transposed (becomes 4x8). Scroll RIGHT to review all results.

Notice also that the results and the average values are all in its original units of measurement. This would always be the case (Even if you perform S/N analysis for Inner array) as we are interested in effects based on the mean performance/influence of the noise factors.

Click OK when done and be in the Average Effects of Noise Factors screen.
You can now click on PLOT MULTIPLE NOISE FACTOR EFFECTS button and view the plot as shown below. Click OK to return.

Similarly, PLOT SINGLE NOISE FACTOR EFFECT button allows you to display single noise factor effect at a time.
Click RETURN to get back to the Noise Effects screen.

While at Experimental Results for Noise Effects screen, click OK. Observe that this action puts you back Quality Characteristic Selection issue to proceed with the analysis of the control factors (Inner array).

Proceed with analysis as usual, or click CANCEL to return to the main screen.
QT4’s automatic design capability is one of its major attractiveness. When you opt for this capability, you need not know or decide which orthogonal array to use for the experiment design or how to assign factors & interactions to the columns. QT4 has built-in intelligence to decide these for many common (over 500) experimental situations.

To try the automatic design option, run QT4 and be in the main screen. It does not matter which experiment file you have open as you are going to create new ones.

**a. Experiment Designs with Standard Orthogonal Arrays**

Suppose that you wish to study 10 2-level factors for which you have descriptions (factors and their levels). Be in the main screen and select Automatic Design option from DESIGN menu items.

Click YES when prompted.
In Automatic Experiment Design screen, check the Number of 2-Level Control Factors and then put 10 in the box at right (scroll up). Later, you will see alternate ways of designing experiments when all factors are at two levels. Click OK when done.

Review the orthogonal array selected by QT4 and click YES if you agree with the selection. (Click NO if you wish to adjust number of factors and try again.)

In 2-Level Factor Description screen, enter the factor and their level descriptions. Click OK when done. (For
practice purposes, you may try DEFAULT TEXT button to quickly demonstrate the capability.)

When you click OK after entering descriptions, QT4 will show you the DESIGN (factors assigned to the column). Follow the steps performed in Manual Design to complete the experiment design.

Below is an experiment design with 1 2-level factor and 7 3-level factors (Automatic Design). Enter number of factors appropriately and accept the L-18 array. QT4 offers you screens to enter description of factors; 2-level first, then the 3-level factor.
Here is another for 1 4-level factor and 4 2-level factor. Click YES to proceed to describe factors. As you continue, notice how QT4 has automatically modified the array (You do not need to modify orthogonal array.)

![Automatic Experiment Design](image)

**b. Experiments to Study 2-Level Factor Interactions**

In many situations you will deal with all factors at 2 levels and interactions between pairs of these factors. In this case, you would find it convenient (recommended) to use the QT4 options demonstrated below.

Suppose that you have 10 2-level factors (A, B, C,….H, I, &J) and 5 interactions (AxB, CxD, etc) between several pairs of them. To try this capability, run QT4 and be in the *main screen* and select Automatic Design option from DESIGN menu items.

At Automatic Experiment Design screen, check the box as shown below.
You can either type in the description of the factors and their levels here or click on ENTER DUMMY DATA button to save time for demonstration purposes (Shown below).

Input 10 and click OK when done.
Once the factors are described and you accept it (Click YES when prompted), you will identify the interacting pairs of factors (between two factors only). To select the two interacting factors (Say AxB), DOUBLE CLICK on factor A first (Factor A becomes invisible temporarily) and then DOUBLE CLICK on factor B. QT4 acknowledges your selection by putting this pair on the right column under INTERACTIONS.

Continue identifying other 4 pairs of interacting factors in the same manner. Once interactions are identified, you may move any pairs up or down by using the MOVE UP and MOVE DOWN buttons. QT4 assumes the first one in the list to be most important and the last one the least. Click OK when done.
The Placement of Interaction and Factors screen shows the array QT4 has selected and how the factors and interactions are assigned to the column (You are not required to know about the Interaction Table or know which array to select). Click OK when done.

![Placement of Interactions and Factors]

At this point QT4 has already completed the design for you. To continue with inputting the other information about the experiment, QT4 shows the Inner Array Design screen in the format you are familiar with from the Manual Design steps.

![Inner Array Design]
Proceed inputting the experiment information and review of the orthogonal array to complete the experiment.

c. Experiment Design with Mixed level factors

When all factors you wish to study have the same number of levels, your experiment design becomes slightly complex as you may need to modify the orthogonal array. You would appreciate the benefit of QT4’s automatic design capability even more.

Suppose that you wish to design an experiment to study TWO 3-level factors, ONE 4-level factor, and SIX 2-level factors. To design this experiment, run QT4 and be in the main screen and select Automatic Design option from DESIGN menu items (You do not need to open/load any specific experiment file.).

When in Automatic Experiment Design screen, check the factor boxes and enter the number of factors in each, as shown below.

In the Condition screen, review the orthogonal array QT4 has selected. Click YES when ready to proceed.

![Automatic Experiment Design Screen](image)

Describe the factors starting with the 2-level ones first. Use DEFAULT TEXT button for practice. Otherwise enter the description of the actual factors.
QT4 shows you the complete design in formation in the Inner Array Design screen as shown below.

Notice how QT4 designed the experiment (Programmed to follow some specific structure). It modified column 1 using columns 1 & 2 and assigned the 4-level factor. The TWO 3-level
factors are assigned to columns 4 and 7. The remaining 2-level factors assigned arbitrarily to the available columns.

This experiment is similar to the example ENGINE.Q4W experiment which you may open and compare. Note that the design QT4 prescribed may be slightly different than when you follow the manual design or what it shows in the example experiment. But, be assured that both designs are correct.

Click OK to continue with other experiment information and be in Edit Inner Array screen. Notice that QT4 has already modified the L-16 array used for the experiment without any additional input from you.

![Edit Inner Array](image)

Review the array for accuracy and click OK to proceed with saving file to complete the experiment design process.

d. Experiments with Outer Array Designs

If your experiment includes NOISE FACTORS and you wish to include them in the design utilizing an OUTER ARRAY, QT4 can design such experiments.
Suppose that you wish to design an experiment to study TEN 2-level factors and FIVE 2-level NOISE factors. To let QT4 design this experiment, run QT4 and be in the main screen and select Automatic Design option from DESIGN menu items.

When in Automatic Experiment Design screen, check the CONTROLFACTOR and NOISE FACTOR boxes and enter the number of factors in each, as shown below.

As you click OK, review the arrays QT4 selected for INNER and OUTER array designs. Click OK to proceed.

Describe the control factors or use the dummy data as before. Click OK when done.

Enter the description of the NOSE FACTORS in the Noise factor Description screen or click on the DEFAULT TEXT button. Click OK when done.
As you proceed, the information for the control factors and the inner array is shown first, and then comes the screens with NOISE FACTRS and the outer array as shown below.

Click OK when done and complete the experiment design process by saving the experiment file.
Experiment Designs with Dynamic Characteristics

QT4 has capability to allow you to design and analyze experiments with DYNAMIC CHARACTERISTICS. (This capability will be included in this guide in future update)

a. Identification of Signal and Response
b. Selecting Optimization index (Linearity or Slope)
c. Steps in analysis

To review an experiment with DYNAMIC CHARACTERISTIC, open file DC-AS400.Q4W and select Dynamic Characteristic option from ANALYSIS menu items.

(More about this type of experiment design and analysis will be covered in future versions of this guide.)
Once you carry out a successful experiment, there would always be an expectation of financial benefits by implementing the recommended from the outcome (optimum condition). Fortunately, if you performed S/N analysis and have full knowledge of the status of performance before and after improvement/experiments, you can use the Loss Function capabilities of QT4 to generate such information. Using the Loss Function concepts, the performances can be expressed in terms of monetary loss, and the savings can be computed from the difference between the losses before and after improvement.

1. Case of Characteristic with Nominal value

You would use this option when you have a target value and only after you have completed your experiments and analyze results using S/N ratios.

Suppose that you completed an experiment and confirmed the expected performance. Let’s use the theoretical experiment SEM-EX09.Q4W to take some calculated values from analysis. From main screen, open this file. Check to see that this is an experiment with L-8 array and has THREE results in each trial condition. Using the ANALYSIS option, perform S/N analysis with Nominal QC with target value 42 as shown below.
Be in the Experimental Result screen and find that the average of S/N of all trials (S/N’s) is -18.88 as shown below. We will use this as the representative performance of current production process (You would have to test actual samples to get this number.)

As you proceed with analysis (QC = Nominal), clock OK in Main Effects and ANOVA screen and be at the Optimum Condition screen. Note the expected performance is -10.029 as shown below. In absence of actual confirmation test data, we will this estimated value for calculation of loss.

Once you have these two performance data at hand (either from test or calculated as shown above), you are ready to make use of QT4 to help
you compute expected saving from the improved design (Optimum condition)

Run QT4 and be in the *main screen* and select Loss – Nominal Case from the LOSS/SAVINGS menu items as shown below.

In addition to your knowledge about the target value (42), you will need to gather a few production data to compute loss. The most important parameter you will need is to estimate the customer tolerance of the quality characteristic. In other words, you need to gather field/performance data to determine range of variation (+/- 12.5 assumed) from nominal performance which will cause rejects. Suppose also that the cost of reject is $18 and the monthly production is 15,000 units.

In Computation of Dollar Loss screen, enter (type over the default values) the production and S/N (before and after performance data, –18.88 and –10.029) values as shown below. Realize, of course, that –10.029 is greater than -18.88 which reflects an improvement (Gain) of about 9 decibels (S/N, a Log to the base 10 value).

Correctly enter data and click OK when done (NOTE: These production data cannot be arbitrary to produce meaningful calculated values of saving/loss)
The Estimate of Loss screen below shows the calculated loss before and after experiments. Based on the production volume, QT4 is able to calculate the monthly savings ($116,022.6 per month) as shown below.

Click **PLOT LOSS** (screen above) to show plot of the loss function (or click **CANCEL** to try calculation with different production data).
Click RETURN when done reviewing the plot and then plot OK to return to the main screen.

2. General QC Case

You would use this option when you do not know the target or QC is Bigger or Smaller, but you completed the experiments and analyze results using S/N ratios. In this case, you must know the current loss in $ per part which is used to calculate the future loss.

Using the results from theoretical experiment SEM-EX09.Q4W, that is, S/N before experiment = -18.88 and S/N after experiment = -10.029, it is possible to calculate loss after experiment (improvement if the current loss is known.

Assume that:

- Current Loss = $8.9/part, and
- Production Volume = 15,000 per month.

Run QT4 and be in the main screen. Then select Loss – General Case (all types of QC) from the LOSS/SAVINGS menu items as shown below.
Enter the current loss and production volume by typing over the default values. Also, enter the current and future S/N values. Click OK to calculate loss.

Estimate of Loss screen below shows the loss calculation before and after experiments and the savings expected for the monthly volume of production (Savings = $116,103.3 per month, see screen below). If you wish to repeat calculation with different current loss or production volume, click CANCEL.
If you are satisfied with the results, click on the PLOT LOSS button (above screen) to view plot of the loss function (or OK to return to main screen).

Click RETURN when done reviewing the plot and then plot OK to return to the main screen.
QT4 contains some additional capabilities that are not part of the Taguchi experimental design technique, but are helpful in manipulating experimental results. A few such QT4 capabilities are briefly discussed in this section.

Run QT4 and be in the main screen. It does not matter which file you have loaded in memory.

**a. Variation Diagram - *Summary Improvement Graph***

You have seen variation Diagram that you generated upon completion of S/N analysis before. You can also generate the same diagram if you know the performance status from any arbitrary system (need not be from DOE study).

Select Variation Reduction from the LOSS/SAVINGS menu items as shown below. (Click OK at the message prompt. Not shown)

To make yourself familiar with how the option works, click on Example 1 button to use some existing data. Be sure to read the application tips and try your own data (if you have). Remember, you cannot put ANY input parameters and expect meaningful variation output calculations.
The data you enter must be observed test values. Click on PLOT to see the variation plot.

When you are done reviewing the Performance Distributions screen, click RETURN.

Practice with the other two examples or your own data, and then click RETURN to return to *main screen*.

**b. Population Statistics**

This option allows you to calculate some popular statistics from any arbitrary observations (Measure/performance data).
Select Population Statistics from the LOSS/SAVINGS menu items as shown below.

Suppose that the average number of visitors/day over last 12 weeks to a web site developed to introduce a new product is as shown below.

Visitors (x1000): 8.2, 7.5, 9.3, 7.9, 9.0, 8.4, 10.5, 8.7, 9.6, 9.8, 8.1 and 7.0

To calculate some of the useful statistics, enter data one at a time, then check Bigger is Better QC and click CALCULATE.
Click on the PLOT NORMAL DISTRIBUTION to show graph of the distribution plot (Theoretical plot based on calculated mean and standard deviation. Not shown).

c. Loss Plot Manipulations
As performance indices of the same data, the characteristics such as Loss, Std. Dev., MSD, S/N, etc. bear relations to each other. Use this option to see how they are calculated and their nature of relationships among them. THERE ARE A LARGE NUMBER OF CAPABILITIES UNDER THE LAST 4 OPTIONS IN THIS MENU. Explore these options when convenient (only limited screen shots are shown).

Select Loss Plot Manipulation from the LOSS/SAVINGS menu items as shown below.

In Quality Loss Function Manipulation screen, you can review BACKGROUND and COMPUTE many relationships among indices. Try entering your own data (default values are already entered) and click COMPUTE to see results. For loss plot, check Plot Loss Function (bottom-right) and click PLOT LOSSS button. Click RETURN when done.
d. Relationships Among Performance Criteria

The relationships among the different data attributes can be displayed in graphical form by using capabilities under this option.

Select Loss, StDev, MSD and S/N Relations option from the LOSS/SAVINGS menu items as shown below.

Be sure to check the box, modify input (default values are already shown) before clicking CALCULATE AND PLOT button in the screen below.
Some of the various relationship graphs you may obtain are shown below (Default data use).

e. Capability Relation Graphs
This option allows you to see the graphical relationships between Average & Stand. Dev. and the popular capability indices (Cp & Cpk).
Select **Capability Relation (Cpk) Graphs** option from the LOSS/SAVINGS menu items as shown below.

In capability Statistics and Plots screen, check the desired graph, modify input if desired, and then click **CALCULATE AND PLOT** button.
Plot of the capability index, Cpk, is shown below. Click RETURN when done. Click on REFRESH and repeat display if desired.

f. Normal Distribution Growth Plots
This option allows you to show improvements, before and after experiments, in terms of assumed normal distribution plots.

Select Capability Relation (Cpk) Graphs option from the LOSS/SAVINGS menu items as shown below.
In Norma Distribution Plot screen, you can enter your own data (Avg. & Std.Dev.) and plot graphs of a single distribution or two distributions showing improvement in graphical form.

Click on the PLOT ND for single normal distribution plot based on the input provided. You may click REFRESH, modify input and plot graph again.

For graphs of improvement in terms of distribution, click on ND GROWTH PLOTS button, modify data for before improvement and
current values, and then click on DRAW GRAPHS. A sample set of plot is shown below.

![Normal Distribution Graph](image)

**g. Online Tips**
QT4 contains tips on several topics & capabilities that can be helpful. While in main screen, select these tips from PRACTICE TIPS menu items as shown below.

![Experiment Configuration](image)
h. Conversion of Results

You can use QT4 to transform results to a format suitable for analysis. There are a large number of conversion routines provided for your use.

To try this option, run QT4, open file PISTON1.Q4W. Be in the main screen and select Results from EDIT menu items as shown below.

Suppose that before proceeding with analysis, you wish to clean up the data by converting them all to INTEGER values.
Click on TRANSFORM DATA button and then click the OK button in the Transform Result screen. Try other option in the Transform Result screen as convenient. In the Experimental Results screen, click OK to proceed to save/update file. To avoid altering the data in PISTON1.Q4W file, either same data in a different file or click CANCEL to return to main screen.

i. Result Export/Import

**EXPORTING RESULTS**
You can save results of your experiment file in a text file. You can archive or read & edit this file using Microsoft WORD.

To see how QT4 creates this file, open any experiment file (say PISTON1.Q4W). From main screen, select Export Results from the RESULT menu items.
As default feature, this file is saved as the original file name with “RES” as the extension (PISTON1.RES). However, you may name this file with 8 character file name of your choice.

**IMPORTING RESULTS**

If you collected and saved your experiments results using a different program (Text format or) say, Microsoft Excel, you may find it convenient to use QT4’s Copy & Paste capability. To import results, select Transfer Result option under RESULTS menu items as shown below.

To transfer a matrix of 8x10 sample results (L-8 array with 10 results in each trial condition), PASTE the results you copied from EXCEL (or WORD) inn the DOE Result Transfer screen as shown below. When you are done entering or pasting data, click on the PROCEED-EDIT and SAVE DATA button.
You will get warnings about the data and its format. Be sure that you have the format correctly and it is compatible with your experiment set up.

In Experimental Results screen (not shown), you will have the option to edit data and proceed to update/save experimental file.

**j. Qualitek-4 Working DEMO Capabilities**

QT4 demo software that you can freely download, allows you to use the software to design your own experiment using the L-8 orthogonal arrays. There is no time limit and you can design over 15 different types of experiments using the L-8 array.

Here are the types of experiments:

<table>
<thead>
<tr>
<th>L-8 Array’s Experiment Design Capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Four 2-Level factors</td>
</tr>
<tr>
<td>2. Five 2-Level factors</td>
</tr>
<tr>
<td>3. Six 2-Level factors</td>
</tr>
<tr>
<td><strong>4. Seven 2-Level factors</strong></td>
</tr>
<tr>
<td>5. Four 2-Level factors + Three interactions</td>
</tr>
<tr>
<td>6. Five 2-Level factors + Two interactions</td>
</tr>
<tr>
<td>7. Six 2-Level factors + One interaction</td>
</tr>
<tr>
<td>8. Four 2-Level factors + One 4-Level factor</td>
</tr>
<tr>
<td>9. Three 2-Level factors + One 4-Level factor</td>
</tr>
<tr>
<td>10. Two 2-Level factors + One 4-Level factor</td>
</tr>
<tr>
<td>11. One 2-Level factors + One 4-Level factor</td>
</tr>
<tr>
<td>12. Four 2-Level factors + One 3-Level factor</td>
</tr>
<tr>
<td>13. Three 2-Level factors + One 3-Level factor</td>
</tr>
<tr>
<td>14. Two 2-Level factors + One 3-Level factor</td>
</tr>
<tr>
<td>15. One 2-Level factors + One 3-Level factor</td>
</tr>
</tbody>
</table>

The textbooks (find them in [www.nutek-us.com/wp-txt.html](http://www.nutek-us.com/wp-txt.html)) by R. Roy corresponds 100% with the software. If you are an instructor, you may
consider using one or both books when you plan to use the software for the class.

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