



Qualitek-4: Readme & Application Quick Reference

README File Contents (Version 0905)

General Installation and Practice Guide for Qualitek-4 software (32Bit W-XP)

Thank you for evaluating the Full Featured Working Model (DEMO) of our Qualitek-4 for Windows XP+ (32Bit) software. To install Qualitek-4, go to the RUN prompt in your Windows program and run the SETUP.EXE (or **QT4-Setup.exe**) from the directory (say C:\Downloaded Files) into which you unzipped the zipped files you downloaded. Make sure that you have NO OTHER APPLICATIONS running during the install process. This means that you might have to temporarily take anything that is in your STARTUP group out until after the installation (as you need to do while installing Microsoft Office).

When SETUP.EXE (or **QT4-Setup.exe**) runs and the program begins installing, you will then be prompted about the directory where you would like to install Qualitek-4 program. Once you select the directory, the it will proceed to install the program and create the Windows icons.

While installing you will need the registration number assigned to you. For evaluation/DEMO copy of the program, use the word "**DEMO**" as the registration number.

For distribution purposes and to share the program with others, copy SETUP.EXE or **QT4-Setup.exe** in a CD-ROM and label it as "Qualitek-4".

If you need more detail instruction on installation or program capabilities, review Qualitek-4 Reference Manual included with the program (electronic form on the original program CD-ROM or the hardcopy format)

Practice Session Using Qualitek-4 Software

1. Run Qualitek-4(QT4) program from your computer and click OK past the Registration Screen to the experiment configuration screen.
2. Notice that experiment file PISTON.Q4W is already loaded in memory. If not, OPEN file PISTON.Q4W.

Proceed to Review and Analyze Results of PISTON and other example experiments. There are over 50 example experiments of all sizes included with the program.

3. Click Analysis menu and select Standard Analysis. Since PISTON has three samples/results per trial, QT4 will remind you to perform S/N. Click OK to proceed. In the next screen check Bigger is Better Quality Characteristic and click OK.
4. Review results and click on Graph if you wish to view it. Click OK when done.



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5. While in the Main Effect screen, click Plot to view plots of Main Effect. Once you are in the graphics screen, click the "<<" or ">>" button at the bottom of the graph to display other factor plots. Click OK to return to Main Effect screen.

6. Click on Interaction button, to display interaction plots between any two factors. Select the Automatic option if you want QT4 to calculate interaction between all possible factors, even though you may not have thought about all the interactions or included them in your study. QT4 calculates $N(N-1)/2$ possible pairs of interactions for N factors and ranks them by Severity of their presence (Severity Index, 0 - 100%). Review the list to note the important pairs of interaction for future reference. Click OK or Cancel to return to Main Effect screen and click OK to proceed to ANOVA screen.

7. In ANOVA screen, try POOLING the factor with least amount of influence (last column). To POOL, double click on the factor description. At prompt, review % Confidence Level and click OK. Notice how the ANOVA table gets updated. You can also try one or more of the following tasks.

- a) Pool another factor with the least influence
- b) Reset ANOVA
- c) Pool all factors with less than 98.6% confidence level.
- d) Plot bar graph, pie chart, and Re-start ANOVA
- e) Review Pie diagram

Click OK or ANOVA button to move to the ANOVA screen

8. At the Optimum screen:

- a) Read expected response
- b) Convert this result to a real number when S/N analysis is used.
- c) Plot graph of factor contribution
- d) Find response for all factors at level 2
- e) Go back to ANOVA and pool all factors below 10% influence
- f) Determine 90% confidence interval of the optimum response
- g) Go to optimum screen

Click OK to return to the main screen. From the file menu select Open and select any other experiment file from the list of over 50 files. Analyze results by following steps 3 -8.

Experiment Designs

9. Prepare a list of factors and levels for a practice experiment (say 5 factors at 2-level each). Click on the DESIGN menu and select Manual Design. Check L-8 for your design. When in design screen, describe factors and their levels by assigning to any rows (which are columns of the array). Since you will be using five of the seven available columns, click on the UNUSED button to designate the two columns as unused. Click OK to move to the Orthogonal Array screen. Click OK to experiment file



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screen. Supply only the first eight characters of your file name. The file extension .Q4W is automatically added.

10. After design is completed, you may review the trial condition by clicking on REVIEW menu and selecting Trial Condition. Should you want to carry out these experiments, you may print some or all the trial conditions.

Result Entry

11. Once the experiments are carried out, you will need to enter the results by clicking on RESULT menu and then, selecting Enter Result option. If your result includes multiple evaluation criteria, you will select Multiple Criteria (OEC) option. Enter results/evaluation criteria as applicable. When done entering results, perform analysis following steps 3 - 8 as described above.

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Trouble shooting:

1. If the graphic server is not properly registered or the file is missing, the program may crash when graphic display button is clicked (Runtime Error ____). The problem can be eliminated by registering it following the procedure outlined.

Registering Graphic Servers - To unregister and register graphic servers, follow these commands:

```
From START - RUN in Widows 95(from \WINDOWS\SYSTEM in DOS)
Regsvr -u GRAPH16.OCX    to unregister the file
Regsvr GRAPHx16.OCX    to regiter another file
```

Also, if both GRAPH16.OCX and GRAPHX16.OCX are present in the \Windows\System directory, move GRAPH16.OCX to the \ Windows directory to avoid RUN TIME ERROR if experienced while displaying graphics.

2. Problem with TYPELIB.DLL in Windows 3.11 for Workgroups

If you are installing Qualitek-4 for Windows on Windows 3.11 for Workgroups, it is possible that program will be halted while trying to install file: TYPELIB.DLL. You will get a promp "The Windows version of TYPELIB.DLL is out of date. (This is a fault of Windows 3.11). If you experience this error when installing, abort the install (Select ABORT if you get an error message, otherwise the program should abort itself.) In order to fix this, move current TYPELIB.DLL out of the windows system directory, or rename it to something else. Then, Qualitek-4 for Windows setup program will install an updated version of TYPELIB.DLL and Windows will run as normal. (NOTE : We DO NOT suggest that you delete the old TYPELIB.DLL just for safety reasons. We have not run into any problems with using the new TYPELIB.DLL, however, you can never be to cautious. If you encounter any problems, please let us know via e-mail or phone call.)



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3. Problem due to REGIONAL SETTINGS

Qualitek-4 data file format requires English (United States) format. If your Windows is set to run in a non-English speaking European country, you may have difficulty with reading, display, and analysis of results. If you experience such problems with the default experiment file PISTON.Q4W, you do indeed have the problem. To correct the setting, do the following:

- a. From Windows 95 START, select SETTINGS, then CONTROL PANEL. Double click on the SETTINGS(Globe,Icon) and select English (United States).
- b. Select NUMBER tab and change Decimal symbol to (.) and Digit separator to (,)
- c. Restart your computer and run Qualitek-4.

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About Qualitek-4 (Early version)

The Qualitek-4 is a direct redesign and conversion from the DOS version of the program which was released in 1991. It is expected to have all major features of the DOS version and many more.

Computer: IBM/Compatibles 486 or better computers using Windows 95 or Windows 3.1, 8 Meg RAM and 10 Meg of Hard Disk space.

Printers: Will work with all Windows compatible B&W and color printers.

Program Capabilities:

- Factors - 2 - 63 factors
- Levels - 2, 3 and 4 levels of factors
- Inner array - L-4, L-8, L-9, L-64
- Outer array - L-4, L-8, L-9, L-64
- Dynamic Characteristics - 12 Signal levels, 10 Noise levels
- Results - Up to 120 sample/trial, Conversion, and multiple criteria evaluations reduced to Overall Evaluation Criteria(OEC)
- Analysis - Main Effect, ANOVA, Optimum studies using Std. or S/N analysis

Attractive Features for Experimenters:

Plan - You will have access to a large volume of reference materials from main screen pull down Help Menu. The content includes overviews on over 20 topics and hypertext subject index.

Tips on how to plan/brainstorm for Taguchi experiments is helpful



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Design - You will have option to let Q4W design the experiment or do it yourself. In automatic design, you simply indicate what are your factors and levels, it selects the array and assigns the factors to the appropriate columns. You also have a limited selection of interactions and outer array designs. 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.

Test - Once you are satisfied with your experiment design, Q4W readily describes the recipes for you to carry out the experiments. It also suggest the random order of conducting each of the experiment which are described in separate pages to resemble an 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.

Miscellaneous 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.

First Release Date: November 1, 1996

Order Single or Multiple user version from reseller or directly from Nutek.

Site License, Corporate Site License, and multiple users/Network version prices vary depending on the number of installations. The price quotations are available upon request.



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Quick Reference Manual (Text only)

For

Qualitek-4, Automatic Design and Analysis of Taguchi Experiments

Nutek, Inc. Bloomfield Hills, Michigan, USA. www.nutek-us.com (Last updated Jan. 2, 2007)

[This brief TEXT ONLY document is intended to be used for quick reference on the use of Qualitek-4 capabilities. For detail information, use the reference manual in the form of a hard copy or the electronic format.]

Content

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A. HOW TO: (Menu items referred are all in *experiment configuration* screen)

Design Experiment – Select *design* menu option to start all your experiment design tasks. Select *automatic design* when you want Qualitek-4 to decide the array and assign factors to the appropriate columns.

Create **Outer Array** – *Outer array* is included in the design you have already designed the inner array (using *manual design*). Select *outer array* from *design menu* and proceed as prompted.

Design for **Dynamic Characteristic** – Once the inner array is designed; you can proceed to include the signal and noise factor in the outer array by selecting *manual design – dynamic characteristic* from the design menu item.

Enter **Results for OEC** – To create OEC you must enter the originally collected observations for each criterion of evaluation in a special screen. From the *result* menu item, *select multiple criteria* (OEC) option. Before you proceed with your own data entry for OEC, you must make yourself familiar with the principles of OEC formulation (review www.rkroy.com/wp-oec.html and www.rkroy.com/wp-tec.html). To review an example POUND.Q4W included with the program.

Scale Results – To scale or transform results (up, down, Omega transformation, truncation, etc), select *edit results* from *edit* menu item. Click on the *transform* button and follow screen prompts.

Import Results – Importing results require you to prepare a text file containing the results. Follow the simple steps out lined in the *tips for importing* option in *analysis* menu item.



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B. Installing Qualitek-4 in Window XP+

To install Qualitek-4 program, you will need the program CD-ROM and your personal fifteen digit Registration number. If you do not have the correct registration number, the program will install as a “Demo” version allowing you to use it for designing experiments with L-8 array only.

You will install the program the same way as all other Windows program - just insert the CD-ROM into the drive run X:\SETUP (or SETUPQT4) (X = CD or floppy drive as applicable).

C. How to Start and Exit Program

You can use the Start button of Window 95 to start Qualitek-4 program. To start, click the Start button, and then point to Qualitek-4 program. If you are using Window 3.x, then double click the Qualitek-4 icon from the Window Program Manager screen.

D. On-line Application Support

The basic steps in the application process are as outlined below. Brief description and application guidelines are included on each of the application steps in the Qualitek-4 on-line help.

Select Project and plan Experiment

Look for simpler project to apply first. Arrange for the planning/brainstorming session. Determine:

- * Evaluation criteria and define a method to combine them
- * Control factors and their levels.
- * Interaction (if any)
- * Noise factors (if any)
- * Number of samples to be tested.
- * Experiment logistics.

Experiment Design

Design experiment & Describe trial conditions.

- * Determine the order of running the experiment
- * Describe noise conditions for testing samples if the design includes an outer array

Conduct Experiment

Carry out experiments

- * Note readings, calculate and record averages if multiple readings of the same criteria are taken.
- * Calculate OEC using the formula defined in the planning session.

Analyze Results

- * Determine factor influence (Main Effect)
- * Identify significant factors (ANOVA)



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- * Determine optimum condition and estimate performance
- * Calculate confidence interval of optimum performance
- * Adjust design tolerances based on ANOVA

Confirm Predicted Improvement

Run confirmation tests with multiple samples at the optimum condition. Compare the average performance with the confidence interval.

Although QT4 is designed mainly to help you accomplish your design and analysis tasks on command and not to teach you the method, there is a large volume of information available about the method and its application strategies in the *reference manual*. Most of the theory related items and general topics have been placed under HELP menu in the main screen. Discussion topics and search items are described in hypertext so that when a click on an item it takes you directly into the subject matter. To get some tips on what the content of the screen mean or how to interpret the data, click on the HELP button for help on the specific screen.

E. Experiment Planning

Experiment planning is a necessary and important first step in the application process. Of course planning/brainstorming for the project is done outside the program and before you come to use the program. But should you need some help with how to carry out the planning session or what to discuss in the planning session, a considerable amount of guidelines have been included in the main screen HELP in QT4. Remember it is the formal planning session, which supplies answers to the pertinent questions before an experiment is designed.

The main screen HELP in QT4 contains guidelines as follows:

PURPOSES OF BRAINSTORMING SESSION - Purposes of a brainstorming session are many:

- Identify factors, levels and derive other pertinent information about the experiment, collectively with all involved in the experiment.
- Develop team effort and achieve the maximum participation from the team members.
- Determine all experiment-related items by consensus decisions.

WHO SHOULD CONDUCT?

The session should be facilitated by a person who has a good working knowledge of the Taguchi methodologies. Engineers or statisticians dedicated to helping others apply this tool will make better facilitators.

WHO SHOULD HOST THE SESSION?

The team/project leader should host the brainstorming session.

WHO SHOULD ATTEND?



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The project team members consisting of all those who have first-hand knowledge and/or involvement in the subject under study should be included. For an engineering design or a manufacturing process, both the design and the manufacturing personnel should attend. If cost or supplier knowledge is likely factors, then persons from these disciplines should be encouraged to attend (group size permitting).

HOW MANY SHOULD ATTEND?

The more the better. The upper limit should be around 15. It can be as low as 2.

WHAT IS THE AGENDA FOR THE SESSION?

The meeting agenda need not be shared with all participants. The facilitator should try to complete all discussions within the meeting time, yet allowing enough time for item discussions.

TOPICS OF DISCUSSIONS

The following topics should be included in the agenda for the brainstorming session.

1. OBJECTIVE OF THE STUDY (What are you after?)

- What is the characteristic of quality? How do we evaluate the objective?
- How do we measure the quality characteristic? What are the units of measurement?
- What are the criteria (attributes) of evaluation for the quality characteristic?
- When there are more than one criterion or there are several attributes of the quality characteristic,
- How do we combine them into an Overall Evaluation Criterion (OEC)?
- How is the different quality criteria weighted?
- What is the sense of the quality characteristic?
- Lower is better, nominal is the best, etc.

2. DESIGN FACTORS AND THEIR LEVELS

- What are all the possible factors?
- Which ones are more important than others are (Pareto diagram)?
- How many factors should be included in the study?
- How to select levels for the factors? How many levels?
- What is the trade off between levels and factors?

3. "NOISE" VARIABLES (How to make a robust design?)

- What factors are likely to influence the objective function, but can not be
- Controlled in real life.
- How can the product under study be made insensitive to the noise factors?
- How are these factors included in the study?

4. INTERACTION STUDIES (Which factors are likely to interact?)

- Which are the factors most likely to interact?
- How many interactions can be included?



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- Should we include an interaction or an additional factor?
- Do we need to study the interaction at all?

5. TASK ASSIGNMENT AND DESCRIPTION (Who will do what, how and when?)

- What steps are to be followed in combining all the quality criteria into an OEC?
- What to do with the factors not included in the study?
- How to simulate the experiments to represent the customer/field applications?
- How many repetitions and in what order will the experiments be run?
- Who will do what and when? Who will analyze the data?

F. Experiment Design

Experiment design is the primary task you would want to accomplish by using QT4. The design task can only begin when you have completed the planning session and you have identified the factors and their levels and interactions. The size of your experiment will depend on the number of factors and levels you have. QT4 allows you to accomplish the experiment design two ways. The first option is for you to be in charge (Manual Design). Here you select the array for the experiment and also decide which factor goes to which column. The alternative way is to let QT4 prescribe the smallest design for your situation (Automatic Design).

Depending on your project your experiment design can have only and (a) Inner array, (b) Inner and Outer array, and (c) inner array and (c) Inner array and Dynamic characteristic. You can let QT4 design your experiments with Inner array only or experiments with outer array. But if you are studying Dynamic systems, you must add that to your inner array design manually.

(a) Simple Experiments

Simple experiments are those that are designed using only an inner array. Your experiment may indeed have noise factors; no formal outer array is utilized to define the noise conditions. You can design such experiments using the Manual or Automatic DESIGN options.

Manual design

3. Describe Factors and levels

Experiment design is accomplished in the Inner Array Design screen. Before start entering the description, you need to have a piece of paper where you have written the names of your factors and levels, and also identify which columns these factors are assigned.

Suppose that the factor you want to assign in column 1 is TIME. Highlight the CELL under Factor and row number 1 (rows in this table are columns of the Orthogonal array) by clicking with the right mouse button. Then type the description of the factor. For analysis reference purposes, it is a good idea to use a leader character designation like A, B, etc. So instead of typing TIME, type A: Time.

To describe the levels, click the CELL under Level 1 in the same row as the factor or press Shift+Right Arrow Key, then type the description of the level. Of course you have to have at least two levels for each factor. Also, while describing the level, if your level is 45 Seconds, type in 45



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Seconds, not just 45. If you entered only 45, QT4 will not complain, but it is a good idea to include characters and numbers both for description.

Reserve columns for Interaction studies

When your design includes interaction studies, you will need to reserve the appropriate columns for interaction. Suppose that you wish to reserve a column for interaction between factors (QT4 capabilities limited to interaction between 2-level factors only) A & B, you can do these two ways. If you already know the column for the interaction, from the Triangular Table, you can highlight the CELL under the Factor in the row number then click the COL.INT button at the bottom of the screen.

5. Identify unused columns

The columns that have no factors or interactions assigned are referred as unused columns. QT4 needs to know which columns, if any are determined by you as unused. To set a column as unused, highlight the CELL under Factor description in the line number corresponding the column by the mouse click, then click on the button UNUSED at the bottom of the Inner array design screen.

Your experiment design description is complete when you have addressed each and every column of the array, which are the rows identified by the number. For completeness, all columns must have a factor, an interaction, or be unused. In case of factors, there must be at least two levels described. QT4 will not allow you to proceed unless the description is complete. When ready, click OK to proceed.

6. Enter Project Descriptions

This screen allows you to attach four lines of description about your project. These items are optional and used only in printing reports when available. To set the Quality Characteristic appropriate for your experiment, click the pointer at the end of the line and make your selection. QT4 automatically puts the selected description.

Automatic Design

In automatic design, QT4 designs the experiment for you automatically. Given your experimental parameters such as number of factors at various levels and their descriptions, QT4 selects the most suitable array and assigns factors to the most desirable columns. Once the design is displayed, you can then modify the description, reassign the factors, and modify columns if necessary.

(b) Experiments with Outer Arrays

Outer arrays are used to formally incorporate the Noise factors into the experiment. Of course before an outer array is added to the experiment, the **inner array must be designed first**. Before proceeding to design the outer array, make sure that your Inner array is designed and that the desired experiment file is opened. If the file is not already opened, open the desired file by selecting the FILE menu from the main screen (Experiment Configuration).



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Manual design

After the Inner array design screen, QT4 will display the Outer design screens for your review, and when finished, you will have option to save the data under a file of your choice. The subsequent screens are the same as those shown in the previous section.

Description of Trial and Noise Conditions

After the experiment is designed, the trial condition can be described using the Factors and the array. The term TRIAL CONDITION is used to the combinations of control factor levels which are the prescriptions for different test conditions necessary to accomplish the experiment (all trial conditions). The term NOISE CONDITION, on the other hand, refers to the combinations of the Noise factor levels, which created the condition to which the trial conditions are exposed. In the example experiment an L-8 is used for the Inner array and an L-4 is used for the Outer array. Thus there will be eight Trial conditions and four Noise conditions. Experimenter should combine the Trial conditions and the Noise conditions as per the combinations required by the Outer array.

(c) Experiments with Dynamic Characteristics

Just as Outer arrays are used to formally incorporate the Noise factors, effect of Signal and Noise factors applicable to a Dynamic System is included in the experiment by this special design. There is no orthogonal array used for the outer array. Instead the levels of the Signal and the Noise factors are combined to form all the possible combinations are described. While conducting the experiment, each trial condition is exposed to these combinations of the Signal and the noise factors.

The Dynamic Characteristic can be added to the experiment only after the **inner array is designed first**. Before proceeding to design the outer array, make sure that your Inner array is designed and that the desired experiment file is opened. If the file is not already opened, open the desired file by selecting the FILE menu from the main screen (Experiment Configuration). To describe the Dynamic Characteristic (DC) design capabilities, the experiment DC-AS400.Q4W will be used. If you wish to redesign the DC for an existing experiment, you can work with a copy of the experiment file and proceed to redesign by first removing the existing DC design. To remove current DC, click on the EDIT menu item and select Remove Dynamic Characteristic option.

If you are working with an existing file which has results, QT4 will prompt you about the fact that the results will be erased. Click OK to proceed if you get this message. If you chose to keep the results, its size will be adjusted to suit the new DC design you are about to define.

Before any system information

Note:

How can you include multiple Signal factors?



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Suppose you have 3 Signal factors at two levels. Treat them like $3 \times 2 = 6$ levels of Signal factor. While describing the levels of the Signal factor, keep note and describe the levels to reflect your description.

You can treat multiple Noise factors in the same manner.

Cell represents a unique condition defined by combining Signal and Noise levels. There must be at least one sample tested in each cell. Depending on the levels of the Signal and Noise, the number of samples per Cell could be very large. QT4 is limited to 120 samples per trial condition. Which means that:

$$\# \text{ Signal levels} \times \# \text{ Noise levels} \times \# \text{ samples/Cell} = 120$$

Thus if $\# \text{ Signal levels} = 3$ and $\# \text{ Noise levels} = 2$, the number of samples per Cell could be as high as $120/(3 \times 2) = 20$.

Size of Experiment Calculation

In the example considered, total number of samples required is $3 \times 2 \times 2 \times 8 \text{ Trials} = 96$.

In case the number of levels of the Signal or Noise factors is larger than what the screen can accommodate, like other screens, a scroll bar will appear below the level description box. Scroll it to the right and complete descriptions of all levels before exiting the screen.

When you are done with describing Signal and noise factors, QT4 will return you to the P-diagram. Double click on Dynamic System to enter descriptions of the system. When available, clearly describe Symptom, Response, etc. for the Dynamic System under investigation.

Description of Signal and Noise Conditions

After experiment is designed, the combination of the Signal and the Noise levels to which the trial conditions are to be exposed can be described using REVIEW menu option from the main screen. These conditions are different from the description of the TRIAL CONDITIONS which are the combinations of control factor levels. The term NOISE CONDITION, on the other hand refers to the combinations of the Noise factor levels in case of OUTER ARRAY design, which represent the conditions under which the experiments are carried out. In the example experiment with Dynamic Characteristic, an L-8 is used for the Inner array and the three levels of Signal and the two levels of Noise creates six separate combinations(CELL). Since there are two samples tested in each cell, for each trial condition, two samples are exposed to each of the Signal and Noise combinations.

To review the Signal/Noise combination for experiment, click on the REVIEW menu item from the main screen and select Dynamic Characteristic. Review and Print descriptions using the screen buttons as desired. Note that the descriptions shown are applicable to all Trial conditions for the experiment.

G. Editing Factors, Arrays and Results



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Corrections and modifications of experiment design parameters can be done online, that is while entering descriptions or results, and also after input is complete. The EDIT option from the main screen allows modifications of the Factors, Levels, Arrays, Results, etc. already entered earlier or belonging to an existing experiment. To edit information, OPEN the experiment file desired unless you are already working with the file and it is currently being displayed in the main screen.

In addition to editing factors and arrays, you will use this menu option also to REMOVE OUTER ARRAY from your experiment when you need to do so. To totally exclude the Noise factors from your experiment, simply select the option from the EDIT menu. This action removes the Outer Array and your experiment is displayed without it. BE SURE TO SAVE YOUR EXPERIMENT FILE IF YOU WISH TO RETAIN THIS EXPERIMENT DESIGN.

Direct Input and Preparation of Results

In Design of Experiments (DOE) the term RESULT has special meaning. For the first part, as usual, results are numerical data representing the performance of the product/process under investigation for a specific test sample. To be noted also that results are only intermediate input to the DOE application process and not to be confused with the results of analysis or the whole process. So what is obtained from analysis of the designed experiments? Of course these are CONCLUSIONS and PREDICTIONS made from the analysis.

For the second part, results could reflect combined evaluations of several objectives. In this case result is a single number without any units which is a single quantity obtained by combining several numbers representing evaluations from multiple objectives/criteria. If your experiment requires evaluation of the performance under more than one criteria of evaluation, you need to prepare the results by combining multiple evaluations into an Overall Evaluation Criteria (OEC). No matter the number of criteria of evaluation criteria, you will always have one OEC for one sample. Thus the OEC's for the sample will constitute the results and should be used for analysis.

Direct Input of Results (Evaluation from Single Objective)

In case of single objective or when you wish to perform analysis using one evaluation at a time, you will enter the data directly in the result column. This is expected to be the case for most of your experiments. The number of columns of results, as always, will depend on the number of samples tested for each trial condition.

H. Preparation of Results (Combining Evaluation from multiple Objectives)

Background

Combining results is a necessary consideration when your experimental results are evaluated using more than one criterion of evaluations. In this regard the word "Results" take a special meaning in DOE application process. Of course result is an intermediate input to the whole process. The basic data collected as the experimental results may be better called as READINGS. Readings represent quantitative data representing an evaluation criterion. Each reading however, may be the average of many OBSERVATIONS of the same evaluation. Results can be a single READING or combination of multiple READINGS into a single index, as you as the experimenter wants it to be.

Practice of combining multiple criteria of evaluations into a single index is indeed common in academic, sporting and other competitive events. The grade point average we are so used to using, is nothing but a single quantity representing the average of all grades. The method of determining the best in the Olympic gymnastic events are determined in a scale of 0 - 6 by combining scores in



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several areas of performance like, jumping, style, balance, landing, etc. The scores in each of these criteria are averaged to calculate the final score.

If academic performance and sporting events can be determined by a single index, why scientific experiments and engineering projects can't be evaluated by a simplistic single index. There are good reasons. In the former cases, all evaluations have the same RANGE (low and high score) of evaluation. All evaluations also have the same units (mostly no units), same sense of desirability (Quality Characteristic/QC), same units of measurements, and same relative importance (weighting). This is not the case with scientific experiments. Thus attempts to meaningful combinations of evaluations from different criteria of evaluations, which most likely have different units of measurements and different importance, demands proper considerations of physics of the situation.

Why should you consider combining different evaluations into a single index?

When there are multiple objectives, each objective may be evaluated by different criteria of evaluations. Suppose that in the process of BAKING CAKE, the objectives are TASTE, MOISTNESS, and VOIDS. We can always analyze the results of the experiments by taking readings (single criteria reading as results) of each criteria separately and determine the best recipe for the cake. If the best recipes so determined by taking all criteria, one at a time, were the same, then there is no need to look at all the criteria collectively. But what if they are not? Which recipe then should we go for?

Just because two readings are expressed in numbers, they may not be added together to produce meaningful results. For instance, laws of physics will not allow us to combine one quantity expressed in terms of DEGREES FAHRENHEIT with another quantity expressed in terms of NEWTON METERS. The reason for this is obviously the units of measurement, which if unequal, addition is not allowed.

In addition to the units, the sense of desirability, that is the Quality Characteristic (QC) must also be of the same kind before two evaluations can be added together. Consider the case of two sportsmen who are both proficient in the game of Basketball and Golf.

Who is the better player? To answer this question, we will be grossly wrong if we simply compare their total scores. This is because, even though the two scores have the same unit of measurement, their sum does not produce meaningful numbers as they have different sense of desirability(or QC) since in the game of Basketball, the higher score is desirable, where as in the game of Golf, a lower score wins the match.

Measurements involved in engineering and science most often include evaluations which have different units of measurements and also different QC's. Combining them into a single index, called an Overall Evaluation Criteria (OEC), requires some adjustment to formula combining the individual criteria of evaluations. First the readings under individual evaluations must be NORMALIZED, that is freed from their units (dimensionless). Second, contribution from all reading must conform to the same QC, either Bigger or Smaller. Third, individual readings must be represented in proportion to the relative weightings (degree of importance) determined subjectively by the project team consensus. Consider the CAKE BAKING process and suppose that following were decided in the planning session convened for the experimental study.

Explanation of OEC equation

The Taste reading is a subjective evaluation and agreed to be a number between 0 to 12 with 12 being the best possible reading. The QC for this criteria is Bigger is better and since it carries a heavier relative weighting (55%), all other criteria will be made to conform to this QC.

$$X_{2b} - X_{2w}$$



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The individual criteria reading(X) are first subtracted by lowest magnitude of the best or worst readings ($X_{w/b}$). This quantity is then divided by the range of the reading (best - worst) to convert the quantity into a dimensionless number. The resultant is now multiplied by the relative weighting expressed in percentage which reflects the appropriate importance carried by these particular criteria.

The second criteria, Moistness measured in grams is such that a fixed volume measures 40 grams in ideal condition, and the range is expected between 25 and 50 grams. This constitutes a *Nominal is the best* QC. A nominal reading is equivalent to *smaller is better* reading when the nominal value is subtracted from the reading. But in order to add a *Smaller is better* reading with one that is *Bigger is better*, its QC is theoretically changed to *bigger is better* by subtracting its effect from 1. Again the whole quantity is multiplied by the relative weighting for the criteria.

The third criterion, Voids, is a count of number of voids ranging between 2 and 8. Since least number of voids is desirable, this criterion is also handled the same way by converting its influence to *Bigger is better* QC.

Qualitek-4 can prepare the OEC's which are considered as the RESULTS for the analysis when you describe the evaluation criteria table and enter the readings appropriately. To prepare the OEC from the reading under multiple criteria of evaluation follow these steps.

1. Describe Evaluation Criteria Table
2. Enter Evaluations for each sample under each Trial condition
3. Review OEC and accept (or reject) them as results.

3. Enter Evaluations (Original readings under each criteria of evaluation)

After the criteria are described, evaluations under each criterion are entered, for one test sample at a time. Each test sample tested is identified by a trial number and a run number. Each sample then will have as many evaluations (one reading for each evaluation criteria) as the number of criteria described and checked (Used column). The numbers 11, 44 and 3 shown in the screen(next page) represent the Taste reading(11), Moistness reading(44), and Voids(3) reading for the first sample(Run#1) of Trial 1. As evaluations are entered, the OEC values are calculated and placed in the proper trial # and run # locations.

Qualitek-4 requires that all trial condition have the same number of runs. Therefore, evaluations for all trial and the same run numbers for all trials must be entered before clicking OK, which makes QT4 accept OEC as results. The QC for the result now becomes the Quality Characteristic shown for the OEC (as decided by Qualitek-4 based on the relative weightings of the criteria)

Be sure to **SAVE** experiment file by selecting Save or Save as from the File menu option.

OEC SUMMARY

When the product/process is to satisfy more than one objective, performances of samples tested for each trial condition are evaluated by multiple criteria of evaluations. Such evaluations can be combined into a single quantity, called Overall Evaluation Criteria (OEC), which is considered as the result for the sample. Each individual criterion may have different units of measurements, quality



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characteristic, and relative weighting. In order to combine these different criteria, they must first be normalized (no units), QC aligned (either Bigger or Smaller), and weighted accordingly.

When multiple objectives are present, as always, results of the experiments can be analyzed by taking evaluations (which is considered results for analysis) of each criteria, separately. This way a complete analysis can be performed based on each criteria of evaluation. If all such analyses produce the same optimum design and the same trend of factor influences, there would be no need for an additional analysis. Should they differ, however, an additional analysis using OEC may produce some vital statistics reflecting the relative merits (weightings) of the individual criteria of evaluation as determined by the project team during the planning session.

Export and Import Results

Results of your experiments can be exported for use by other analysis software. Results also can be imported saving manual entry. This would particularly be helpful when your array is large and the number of samples per trial is also large.

For exchanging results with another statistical analysis program or simulation model, the data format has been kept to basic text format. The result file can be created using DOS EDIT or made using and word processor program then saving them as text file. In either case, the file format must be strictly followed. The result file must be named with an extension .RES. In other words, for PISTON.Q4W file, the result file will be PISTON.RES. The exact format of the file can be seen by reviewing any .RES file in your directory or by exporting PISTON.Q4W file which will create a PISTON.RES file automatically.

I. Analysis of Results

When all the trial conditions are tested and the results are entered into the experiment file, analysis of the results can now be performed. QT4 allows you to analyze the results in two ways: Standard Analysis is always performed when there is only one sample tested for each trial condition. In case of multiple samples per trial, Signal to Noise ratio (S/N) analysis is strongly recommended, but Standard analysis can be performed if desired. To demonstrate all major steps in analysis, the BRACKET example created earlier with one sample per trial will be considered.

Standard Analysis

You can view factor influence graph one factor at a time. Click the buttons at the bottom of that graph to view other factor graphs. The calculated values of the average effects used for the plot are shown on right. Click RETURN to go back to the Main Effect screen.

When you click the interaction button, QT4 allows the option to view interaction between selected pair of factors or let it calculate all possible interactions for your review. Click on MANUAL if you want to view interaction between any two factors, and then double click on the factors. If you want QT4 to calculate all possible interactions, select AUTO.

In AUTO option, QT4 calculates $n(n-1)/2$ interactions for n number of factors in the experiment. Thus if there were 15 factors, $15 \times (15-1)/2 = 105$ interactions are calculated. In the current example there are only 4 factors which give rise to 6 interactions.



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To rank the strength of these interactions in descending order, a quantity called SEVERITY INDEX (S.I) is calculated. The values of S.I. range between 0 - 100% corresponding to the angle between the interaction lines of 0 - 90 degrees.

To examine an interaction, double click the Interaction Factor descriptions. Click on the S.I. button if you want to examine the interaction pairs and their ranking.

If you happen to find an interaction which is already included in your experiment and it is found to be significant (in ANOVA), then the review of the interaction plot is important. The factor levels most desirable to incorporate the interaction effect into the prediction of the Optimum condition and the performance, are determined from this graph. If QC is *Bigger is better*, the desirable level is obtained by the levels represented by the highest pint in the graph. The opposite is true if the QC were *smaller is better*.

At end of interaction plot review, click return to get back to the Main effect screen, and click OK in that screen to proceed to ANOVA screen.

What to do when you are in ANOVA?

Pool a column item, double click the description. The screen displays the confidence level the factor or column has. Click OK if you wish to Pool it. The decision of whether to pool should be based on the Confidence level desired. The level of confidence one wants can be arbitrary. It is recommended that you always work with a fixed Confidence level (C.L) for the experiment, say 80%, 90% or 95%. Whether a factor/Interaction is significant or not depends on whether it has the confidence level you desire. But the calculation of C.L a column has, or the test of significance can only be done when the Degrees of Freedom (DOF) of the error term (the last line in ANOVA table) is non-zero. So when the error DOF is zero or small, the C.L may not be calculated and you may decide to pool the factor arbitrarily. Obviously, you should start pooling with the weakest column when available. How long should you pool? Continue to pool factors/Interactions as long as they are insignificant and the error DOF is closer to half the total DOF of the experiment.

Click on the C.I. button when you want to calculate the confidence interval. The C.I. is calculated for a given C.L. and only when the error DOF is non-zero. Thus if the error DOF is zero or too small, QT4 cannot calculate the C.I.

The C.I. is a number in the same units of measurement as the performance and it represent the accepted variation of the mean performance from a population tested at the Optimum condition. Thus the C.I. in combination with the estimate of performance forms the yardstick for confirmation of the prediction based on the experimental results.

When done with estimation, click OK to return to Optimum screen. At optimum screen click OK to return to the main screen. Now that the analysis is completed, you may enter into report option and print reports of the key analysis steps, cost savings and variation reduction reports.

Analysis of Multiple Sample Results (S/N ratios)



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When your experiments include multiple samples per trial condition, analysis using S/N ratios of the results is strongly recommended. This would be the case when there is an outer array or otherwise there are multiple samples per trial condition. In this analysis approach, S/N ratios of the trial results are used for analysis instead of the average of trial results in the Standard Analysis. All calculations for Main effect, ANOVA and Optimum condition are carried out with S/N ratios. You must remember to transform the Optimum performance back to the original units of result when interpreting the improvement or predicting expected performance.

Analysis using Dynamic Characteristic

Analysis of results from a dynamic system requires the use of Dynamic Characteristic. This is a special form of Nominal is the Best Quality Characteristic. The option to select Dynamic Characteristic (DC) will only be available when the experiment design is created using DC and the results are collected by conducting the test prescribed. However, QT4 will allow you to perform S/N analysis if for some reason you wish to carry out such analysis.

Estimate Savings and Variation Reduction

These two items may serve as good component of a management report at the conclusion of an experiment. Since the main reason for the experimental study should be to improve quality by reducing variations, its impact on the reduction of costs from reduced scraps and warranty is of immense interest to the management. These options allow you to produce graphical representations of the cost savings resulting from the corresponding variation reduction.

Calculation of Savings using Loss Function

The savings from improvement is calculated by using the analytical model (Loss Function) proposed by Dr. Genechi Taguchi. A company manufacturing and selling parts will always have scraps and warranty. Therefore, theoretically speaking it will always incur a loss. So it is the reduction of loss which is attributed as savings.

Printing Reports and Graphs

Reports for each individual experimental parameter such as Factors, Array, Results, etc. can be printed while creating or editing the information and it is on display. Additionally it can be printed from the REPORT menu option from the main screen.

J. Practice Session Using Qualitek-4 Software

- Run Qualitek-4(QT4) program from your computer and click OK past the Registration Screen to the experiment configuration screen.

Notice that experiment file PISTON.Q4W is already loaded in memory. If not, OPEN files PISTON.Q4W. Proceed to Review and Analyze Results of PISTON and other example experiments. There are over 50 example experiments of all sizes included with the program.

- Click Analysis menu and select Standard Analysis. Since PISTON has three samples/results per trial, QT4 will remind you to perform S/N. Click OK to proceed. In the next screen check Bigger is Better Quality Characteristic and click OK.



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- Review results and click on Graph if you wish to view it. Click OK when done.
- While in the Main Effect screen, click Plot to view plots of Main Effect. Once you are in the graphics screen, click the "<<" or ">>" button at the bottom of the graph to display other factor plots. Click OK to return to Main Effect screen.
- Click on Interaction button, to display interaction plots between any two factors. Select the Automatic option if you want QT4 to calculate interaction between all possible factors, even though you may not have thought about all the interactions or included them in your study. QT4 calculates $N(N-1)/2$ possible pairs of interactions for N factors and ranks them by Severity of their presence (Severity Index, 0 - 100%). Review the list to note the important pairs of interaction for future reference. Click OK or Cancel to return to Main Effect screen and click OK to proceed to ANOVA screen.
- In ANOVA screen, try POOLING the factor with least amount of influence (last column). To POOL, double click on the factor description. At prompt, review % Confidence Level and click OK. Notice how the ANOVA table gets updated. You can also try one or more of the following tasks.
 - Pool another factor with the least influence
 - Reset ANOVA
 - Pool all factors with less than 98.6% confidence level.
 - Plot bar graph , pie chart, and Re-start ANOVA
 - Review Pie diagram
- Click OK or ANOVA button to move to the ANOVA screen
- At the Optimum screens:
 - Read expected response
 - Convert this result to a real number when S/N analysis is used.
 - Plot graph of factor contribution
 - Find response for all factors at level 2
 - Go back to ANOVA and pool all factors below 10% influence
 - Determine 90% confidence interval of the optimum response
 - Go to optimum screen
- Click OK to return to the main screen. From the file menu select Open and select any other experiment file from the list of over 50 files. Analyze results by following steps 3 -8.
- Prepare a list of factors and levels for a practice experiment (say 5 factors at 2-level each). Click on the DESIGN menu and select Manual Design. Check L-8 for your design. When in design screen, describe factors and their levels by assigning to any rows (which are columns of the array). Since you will be using five of the seven available columns, click on the UNUSED button to



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designate the two columns as unused. Click OK to move to the Orthogonal Array screen. Click OK to experiment file screen. Supply only the first eight characters of your file name. The file extension .Q4W is automatically added.

- After design is completed, you may review the trial condition by clicking on REVIEW menu and selecting Trial Condition. Should you want to carry out these experiments, you may print some or all the trial conditions.
- Once the experiments are carried out, you will need to enter the results by clicking on RESULT menu and then, selecting Enter Result option. If your result includes multiple evaluation criteria, you will select Multiple Criteria (OEC) option. Enter results/evaluation criteria as applicable. When done entering results, perform analysis following steps 3 - 8 as described above.

K. Trouble shooting

1. If the graphic server is not properly registered or the file is missing, the program may crash when graphic display button is clicked (Runtime Error ____). The problem can be eliminated by registering it following the procedure outlined.

Registering Graphic Servers - To unregister and register graphic servers, follow these commands:

From START - RUN in Windows 95 (from \WINDOWS\SYSTEM in DOS) Regsvr -u GRAPH16.OCX to unregister the file Regsvr GRAPHx16.OCX to register another file

Also, if both GRAPH16.OCX and GRAPHX16.OCX are present in the \Windows\System directory, move GRAPH16.OCX to the \ Windows directory to avoid RUN TIME ERROR if experienced while displaying graphics.

2. Problem with TYPELIB.DLL in Windows 3.11 for Workgroups

If you are installing Qualitek-4 for Windows on Windows 3.11 for Workgroups, it is possible that program will be halted while trying to install file: TYPELIB.DLL. You will get a prompt "The Windows version of TYPELIB.DLL is out of date. (This is a fault of Windows 3.11). If you experience this error when installing, abort the install (Select ABORT if you get an error message, otherwise the program should abort itself.) In order to fix this, move current TYPELIB.DLL out of the windows system directory, or rename it to something else. Then, Qualitek-4 for Windows setup program will install an updated version of TYPELIB.DLL and Windows will run as normal. (NOTE: We DO NOT suggest that you delete the old TYPELIB.DLL just for safety reasons. We have not run into any problems with using the new TYPELIB.DLL, however, you can never be too cautious. If you encounter any problems, please let us know via e-mail or phone call.)

3. Problem due to REGIONAL SETTINGS



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Qualitek-4 data file format requires English (United States) format. If your Windows is set to run in a non-English speaking European country, you may have difficulty with reading, display, and analysis of results. If you experience such problems with the default experiment file PISTON.Q4W, you do indeed have the problem. To correct the setting, do the following:

- a. From Windows 95 START, select SETTINGS, then CONTROL PANEL. Double click on the SETTINGS (Globe, Icon) and select English (United States).
- b. Select NUMBER tab and change Decimal symbol to (.) and Digit separator to (,)
- c. Restart your computer and run Qualitek-4.

4. QT4 CD-ROM TROUBLESHOOTING (Problems with reading disc)

IN CASE YOU HAVE DIFFICULTY READING THE PROGRAM CD OR INSTALLING,
PLEASE READ AND FOLLOW THIS INSTRUCTION.

Open **System Properties** (under Control Panel) and select the **Performance tab**. Press the **File System** button and select CD-ROM tab. Under the “**Optimize Access Pattern...**”, select **no-read ahead**.

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