

Chapter 885

Response Surface Designs

Introduction

Response-surface designs are the only designs provided that allow for more than two levels. There are two general types of response-surface designs. The central-composite designs give five levels to each factor. The Box-Behnken designs give three levels to each factor.

An introduction to experimental design is presented in Chapter 881 on Two-Level Designs and will not be repeated here.

The Central-Composite designs build upon the two-level factorial designs by adding a few center points and star points. A factor's five values are: $-a$, -1 , 0 , 1 , and a . The value of a is determined by the number of factors in such a way that the resulting design is orthogonal. For example, if you are going to use either four or five factors, the value of a is 2.00.

The actual values of the levels are determined from these five values as follows:

1. The low-level value is assigned to -1 .
2. The high-level value is assigned to 1 .
3. The average of these two values is assigned to 0 .
4. The values of $-a$ and a are used to find the minimum and the maximum values.

For example, suppose we entered 50 for the low-level and 60 for the high level. Further, suppose there were four factors in the experiment. The levels would be

<u>Coded Level</u>	<u>Actual Level</u>
$-a$	45
-1	50
0	55
1	60
a	65

The values of a depend on the number of factors in the design:

<u>Factors</u>	<u>Value of a</u>
2	1.41
3	1.73
4	2.00
5	2.00
6	2.24

The Box-Behnken designs have two differences from the central-composite designs. First, they usually use fewer runs. Second, they only use three levels while the central-composite designs use five.

The actual values of the levels are determined in the same manner as the central-composite designs, except that the value of α is ignored.

Example 1 – Response Surface Design

This section presents an example of how to generate an experimental design using this program. **CAUTION: since the purpose of this routine is to generate data, you should always begin with an empty output spreadsheet.**

In this example, we will show you how to generate a three-factor central composite design with blocks.

Setup

If the procedure window is not already open, use the PASS Home window to open it. The parameters for this example are listed below and are stored in the **Example 1** settings file. To load these settings to the procedure window, click **Open Example Settings File** in the Help Center or File menu.

Design Tab	
Design Type.....	Central-Composite
Sort Order	Standard
Factor 1.....	-1 1
Factor 2.....	-1 1
Factor 3.....	-1 1
Factor 4.....	<Empty>
Factor 5.....	<Empty>
Factor 6.....	<Empty>
Store Data on Spreadsheet	Checked
Block Column.....	1
First Factor Column	2

Output

Click the Calculate button to perform the calculations and generate the following output.

Three-Factor Response-Surface Design

Experimental Design: Central-Composite

Row	Block	Factor 1	Factor 2	Factor 3
1	1	-1	-1	-1
2	1	1	-1	-1
3	1	-1	1	-1
4	1	1	1	-1
5	1	-1	-1	1
6	1	1	-1	1
7	1	-1	1	1
8	1	1	1	1
9	1	0	0	0
10	1	0	0	0
11	1	0	0	0
12	2	-1.73	0	0
13	2	1.73	0	0
14	2	0	-1.73	0
15	2	0	1.73	0
16	2	0	0	-1.73
17	2	0	0	1.73
18	2	0	0	0
19	2	0	0	0
20	2	0	0	0

The block and factor values were also produced on the spreadsheet.

These values are also generated on the spreadsheet. Note that there are three replicates of the center points in each block. Note the star points represented by -1.73 and 1.73.