One-Factor-at-a-Time Versus Designed Experiments

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INTRODUCTION

- One-factor-at-a-time (OFAT) experiments, which vary only one factor or variable at a time while keeping others fixed.

- Statistically designed experiments that vary several factors simultaneously are more efficient when studying two or more factors.

ADVANTAGES OF DOE OVER OFAT EXPERIMENTS

- It requires less resources
- The estimates of the effects of each factor are more precise.
- The interaction between factors can be estimated systematically.
- There is experimental information in a larger region of the factor space.

EXAMPLES 1

- Two Factors in Three Runs
- An engineer planned an experiment to compare pressure and temperature for a standard gas anneal process and a new gas anneal process using three experimental runs:

1. Standard pressure and standard temperature;
2. standard pressure and new temperature; and
3. new pressure and new temperature.

One factor at a time

Table 1. OFAT experiment in two factors in three runs, with 16 of the 48 wafers at each run

	Temperature	
Pressure	*Standard*	*New*
Standard	16 wafers	16 wafers
New		16 wafers

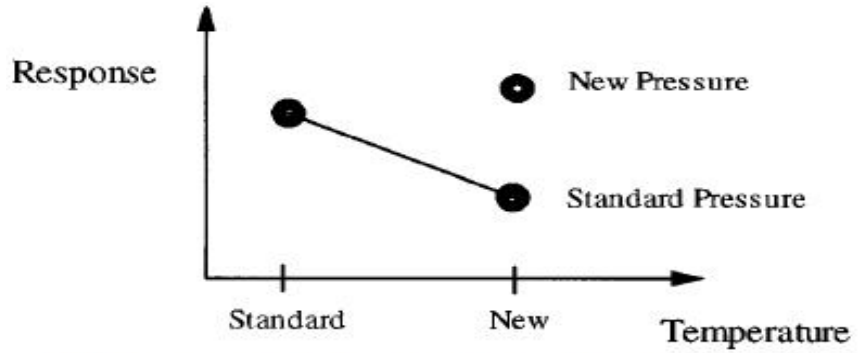


Figure 1. The interaction graph for temperature and pressure cannot be drawn for the OFAT experiment.

It is clear that there is no information at the new pressure with standard temperature.

2^2 full-factorial

Table 2. Full factorial designed experiment in two factors at two levels each in four runs, with 12 of the 48 wafers at each run

	Temperature	
Pressure	*Standard*	*New*
Standard	12 wafers	12 wafers
New	12 wafers	12 wafers

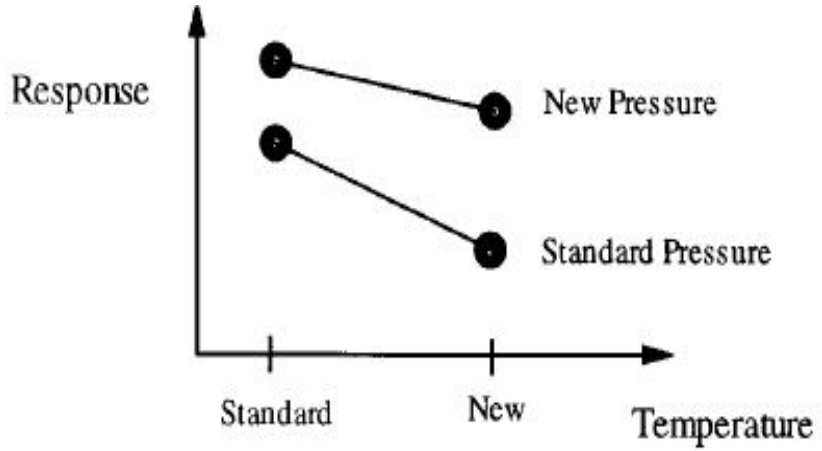


Figure 2. The interaction graph for temperature and pressure can be drawn for the designed experiment.

All 48 wafers are used to study the effect of temperature, and to estimate the interaction between temperature and pressure.

EXAMPLES 2

- Two Factors in Six Runs
- They wanted to study the sensitivity of the response sheet resistance to two factors ：

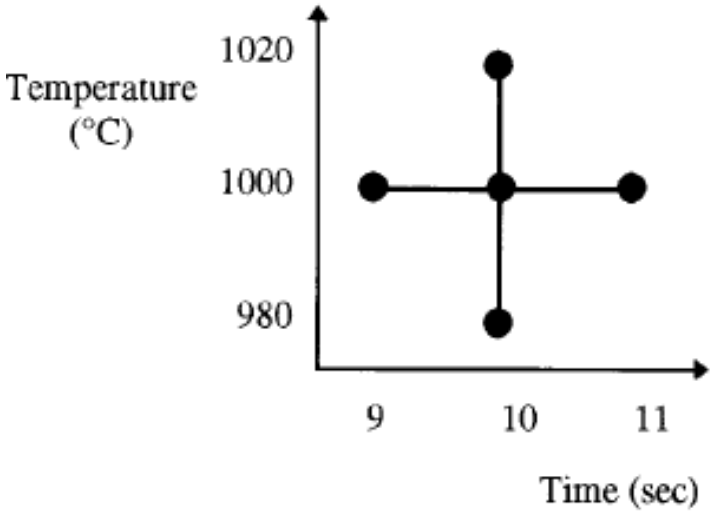
  time and temperature

One factor at a time

- Two Factors in Six Runs

Table 3. OFAT experiment in two factors in six runs

Time (sec)	*Temperature (°C)*
10	980
10	1000
10	1020
9	1000
10	1000
11	1000

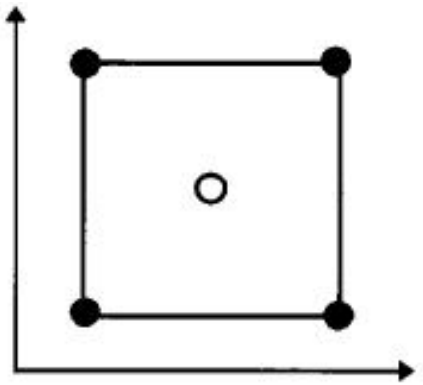


The interaction between time and temperature cannot be estimated.

2^2 full-factorial

Table 4. Full factorial designed experiment in two factors at two levels each in four runs

Time (sec)	*Temperature (°C)*
9	980
9	1020
11	980
11	1020



b) Designed experiment

All four runs are used to estimate the effect of time, the effect of temperature, and the interaction between time and temperature.

2^2 full-factorial v.s OFAT

- It requires less resources (four < six).
- The estimates of the effects of each factor are more precise.
- The interaction between the factors can be estimated.
- There is experimental information in a larger region of the factor space.

2^2 full-factorial v.s OFAT

- Time=10 seconds (along the vertical line of circles).
- Temperature= 1000℃ (along the horizontal line of circles.
- The center point is replicated twice, and can be used to estimate natural variability.

EXAMPLES 3

- Three Factors in 15 Runs
- Three factors：

  exhaust on time

  resist temperature

  environmental temperature.

One factor at a time

- Three Factors in 15 Runs

Table 5. OFAT experiment in three factors in 15 runs

Exhaust time (sec)	Resist temperature (°C)	Environmental temperature (°C)
2	23	21
4	23	21
8	23	21
12	23	21
16	23	21
2	21	21
2	22	21
2	23	21
2	24	21
2	25	21
2	23	19
2	23	20
2	23	21
2	23	22
2	23	23

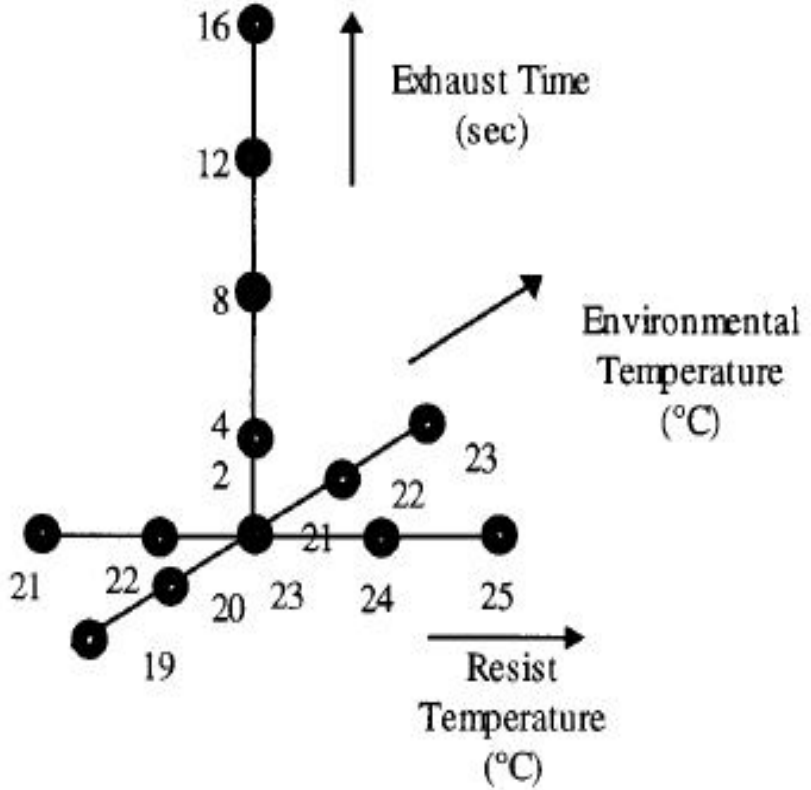


Figure 5. OFAT experiment in three factors in 15 different runs.

Box-Behnken

- Three Factors in 15 Runs

Table 6. Box–Behnken designed experiment in three factors in 15 runs

Exhaust time (sec)	Resist temperature (°C)	Environmental temperature (°C)
2	21	21
2	25	21
16	21	21
16	25	21
2	23	19
2	23	23
16	23	19
16	23	23
9	21	19
9	21	23
9	25	19
9	25	23
9	23	21
9	23	21
9	23	21

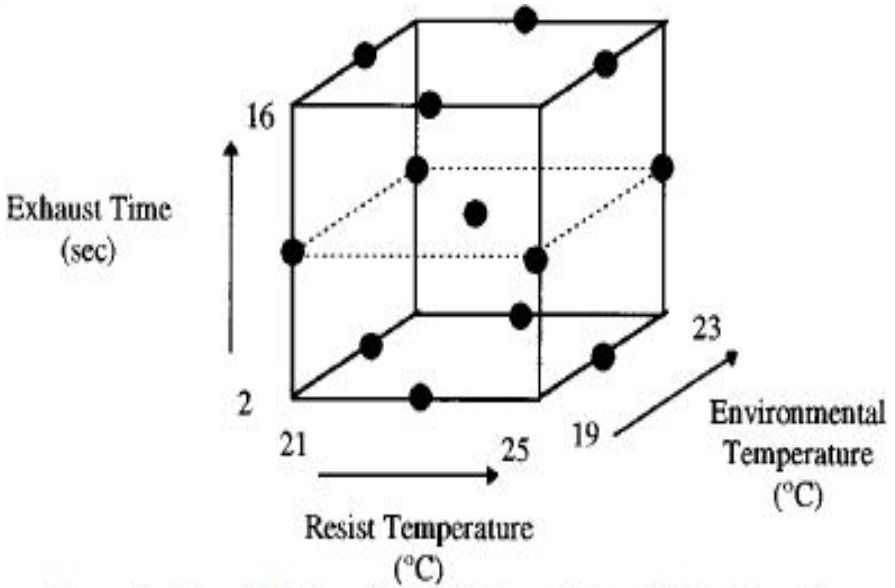


Figure 6. Box–Behnken design in three factors in 13 different runs: 12 runs at edge midpoints, and 1 run at center point.

Box is better than the OFAT

- The interaction between the factors can be estimated.

- The experimental runs are more evenly spread out in the factor space. (better prediction)

The optimization

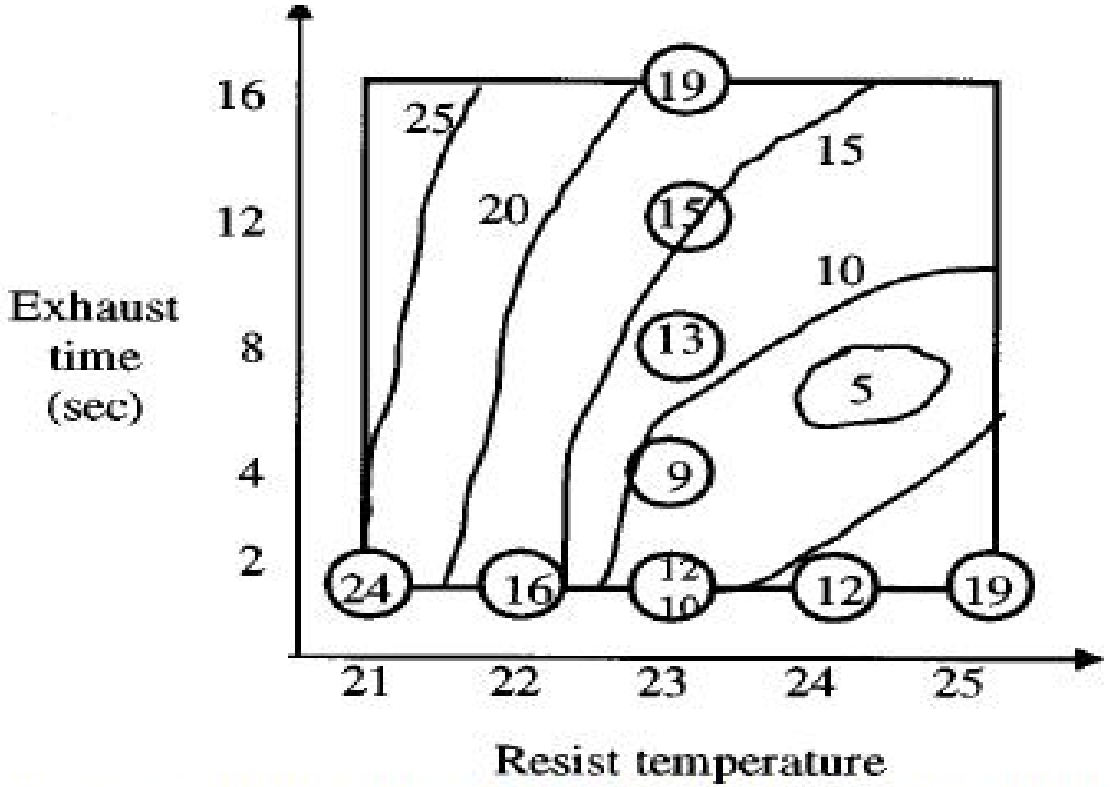


Figure 7. Invented contour plot of the response for the central composite designed experiment. Real response values are shown inside the circles. The response is not minimized along the two strings of circles of the OFAT experiment, but is minimized using the contour lines for the designed experiment.

SUMMARY

- The advantages of designed experiments over OFAT experiments.
- OFAT is important because many scientists and engineers continue to perform.
- The examples can be used in academic and industrial design of experiments classes.

- THE END THANKS