Groping in the dark?

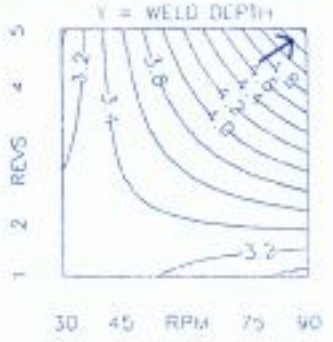
Are you dribbling away your R&D dollars in a series of stabs and guesses†?†?†?

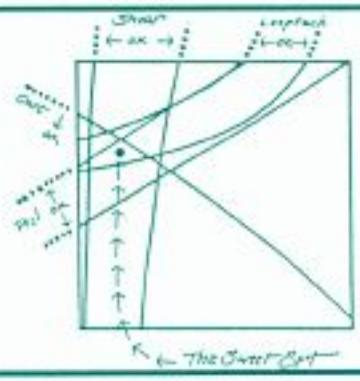
It's time to work smarter: turn on the light by using *Basic Experiment Strategies*

Bob Jordan needed better laser welding;
All welds were cracking and leaking.

He varied the laser settings, made this map, →
and found a better way to operate the laser.

He changed the process from all-parts-failing
to 100% passing: no more cracked parts.





Peter Tkaczuk needed a low-cost adhesive with adequate performance.

← This is his map of the OK-regions for peel, loop-tack, shear, and cost.

He found a sweet spot that met all four goals.

Bob and Peter turned on the light.
You can learn *Basic Experiment Strategies* from us.
We can turn on the light for you. Call us:

The Experiment Strategies Foundation: 800-732-7381

Bob Jordan's job is laser-welding development.

Friday October 19, 1990:

Bob: "I need your help on the YAG laser to weld some parts."

Bert: "I can't help you right now, Bob. We have to ship 60 accelerometers next week. We've spent weeks on this part and *we haven't made a crack-free part yet.* It's ship now or we lose the contract."

Bob: "I can help you with that. I took a *Basic Experiment Strategies* course in statistical experiment design. I know how to *design experiments to solve problems.*"

Bert: "We need the help. If you help us with the experiment design, we can help you with the YAG laser."

Bob: "We want better results, so we've got to make some bold changes. For power, let's try 200 to 375 watts; for rpm 30 to 90; and for revolutions 1 to 5."

Bert: "90 rpm! That's **way** faster than we've **ever** run. We've never run more than 2 revs.

Bob: "We've gotta be bold. We have to try big changes to get different results. Let's come in tomorrow and whip this out."

Next day, Saturday, October 20, 1990:

Bob: "I have laid out here a design for welding 10 pieces, to study power, rpm and revolutions."

Don (the operator): "I think changing lens type might also help reduce cracks. Maybe a 7.5 inch focal length lens as well as the 5 inch lens."

Bob: "You may well be right. Let's try both lenses as well as varying power, rpm and revolutions. We need all the factors in the design we can get. All four factors working together might stop cracks. Here's my modified experiment design for four factors."

Run Order	The Four Input Factors				Weld Depth
	Power	RPM	Revs	Lens	
1	290	60	3	5	3.5
13	200	30	1	7.5	1.9
6	375	90	1	5	3.2
7	200	30	5	5	1.7
5	290	60	3	7.5	3.1
15	375	30	1	7.5	3.5
9	375	30	5	5	1.7
8	290	60	3	5	3.1
17	375	90	1	7.5	2.8

Run Order	The Four Input Factors				Weld Depth
	Power	RPM	Revs	Lens	
10	200	90	5	5	2.2
11	290	60	3	5	1.4
16	200	90	1	7.5	0.6
2	200	30	1	5	2.1
14	290	60	3	7.5	2.9
12	375	90	5	5	5.6
4	200	90	1	5	1.7
3	375	30	1	5	4.3
18	290	60	3	7.5	2.4

Don: "This calls for 18 runs. Even so, I think we can do them all today."

Over the next seven hours the welds were made and tested. The weld depths were measured in mils, and entered in Bob's notebook as shown above.

Please turn the page →

This is Bob's solution to cracked welds.

Bert: "The weld penetration varies from 0.6 mils to 5.6 mils. We want maximum depth."

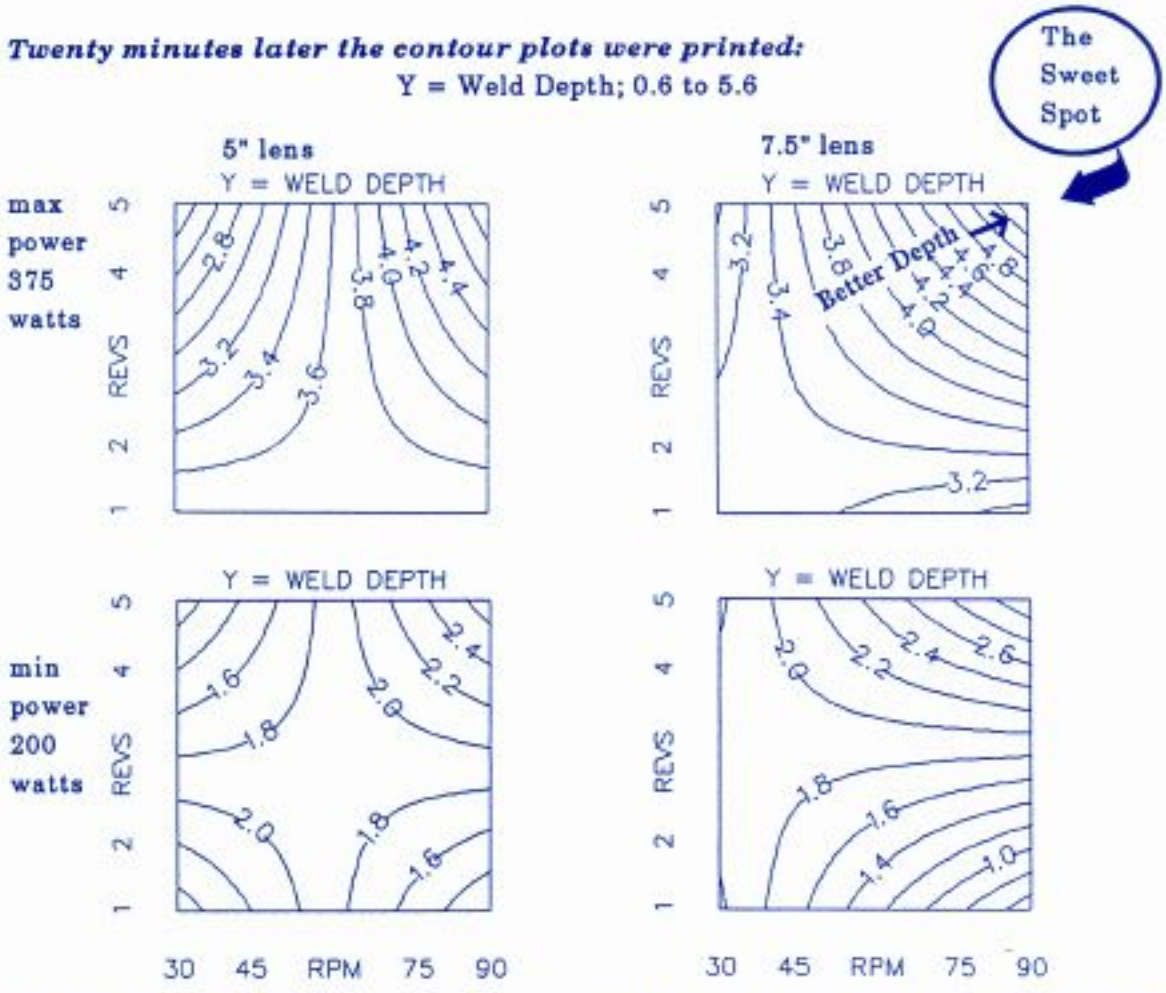
Bob: "I can make a map of weld depth. It's called a *contour plot*. That contour plot will show us the sweet spot."

Bert: "Let's do it. We need that sweet spot."

Bob: "We'll put the data through *regression analysis* and then make the *contour plots* on my PC using my copy of the *STRATEGY* software."

Twenty minutes later the contour plots were printed:

Y = Weld Depth; 0.6 to 5.6



Six test parts were made at this sweet spot.

No cracks!

Success!

The last available 60 parts were welded at these settings.

No cracks!

Success in one weekend!

All 60 parts went out on time. No cracks.

Monday, October 29, the Division Management wrote this letter:

. . . "Outstanding performance . . . previous attempts . . . caused cracked header leaks. . . . time had run out . . . Bob, Bert and Don spent a weekend and achieved a highly successful weld schedule . . . the schedule slippage [that we feared] did not occur. . . . We're proud of the teamwork!!"

Wednesday, July 10: Bob Jordan: "There's a difference between working hard and working smart. I want to work smart. This was my first use of *Basic Experiment Strategies*. In the 8 months since, I've done 6 more statistical experiment designs, each 2 to 4 factors, ***they were all successes***." Bob wrote an article for his company's newsletter, extolling statistical design of experiments; it's quoted on the back page.

To get the same Basic Experiment Strategies training, mail reply card (inside).

Peter Tkaczuk's job is development of adhesives.

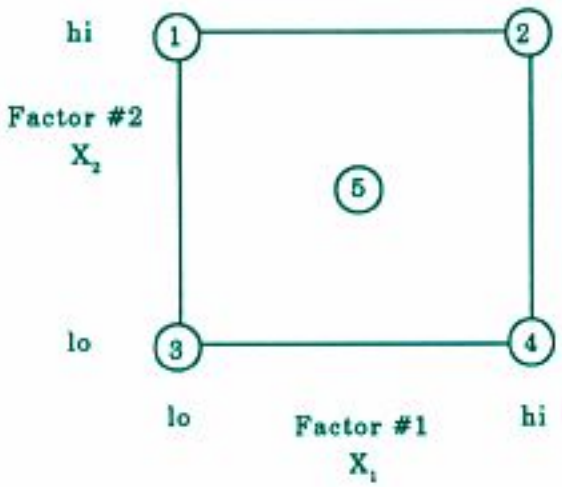
Marketing asked Peter for a pressure-sensitive adhesive to meet these goals:

1. Peel between 4.6 and 4.9
2. Loop tack between 4.0 and 4.3
3. Shear between 10 and 25
4. Cost below 14

Peter chose to vary two input factors.

(The names of these factors have been withheld for proprietary reasons.)

Five adhesives were prepared and tested:



Trials	X_1	X_2
1	lo	hi
2	hi	hi
3	lo	lo
4	hi	lo
5	mid	mid

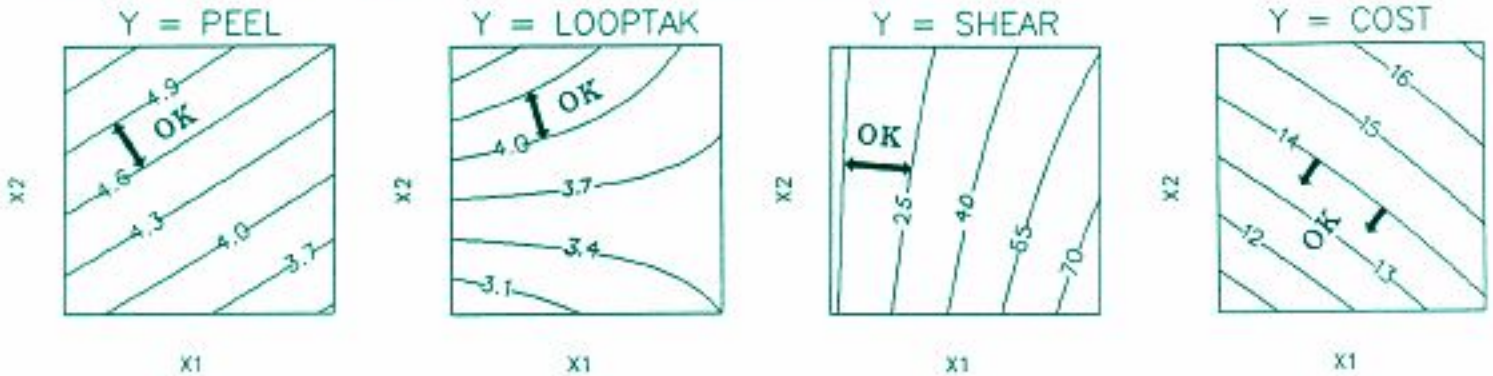
These 5 adhesives were tested for peel, loop tack and shear.

None of these five adhesives met the goals; but that's OK because:

Peter knew how to use a *regression program* to make *contour plots* for peel, loop tack, shear and cost.

He made the *contour plots* below and used them to predict the performance of all the other adhesives that can be made by varying these two factors within these limits.

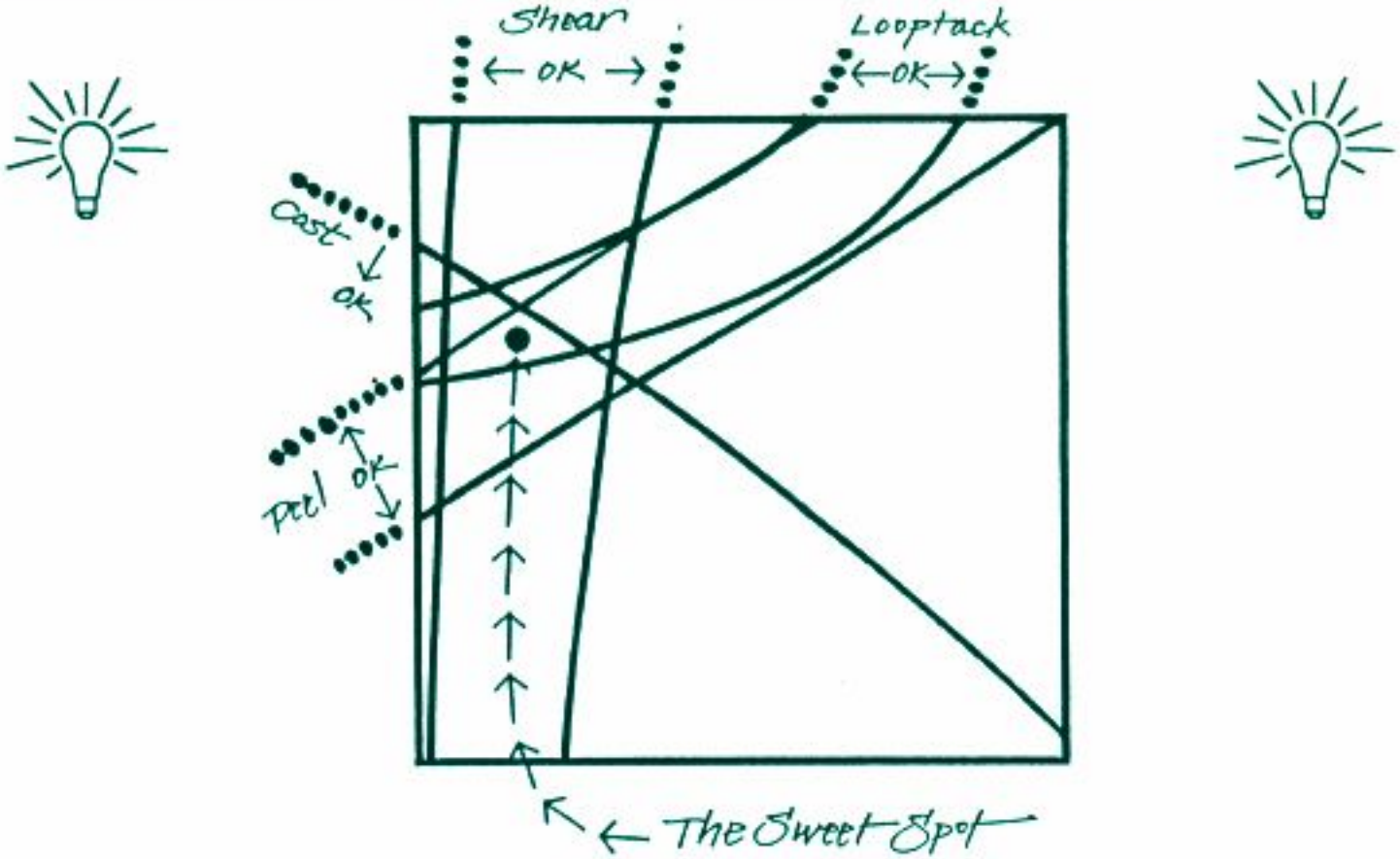
These are Peter's contour plots:



The arrows on his contour plots above show the settings of X_1 and X_2, for making adhesives that satisfy the goals.

There's more on the next page. →

This is Peter's method for developing a new adhesive.



These superimposed plots show the sweet spot where ***all goals were met***. **GridSearch** (in the software: *STRATEGY*) finds the sweet spot even more quickly than superimposing contour plots. **GridSearch** helps even more when more than two factors are being varied.

A Check Run was made at the sweet spot:

Peel = 4.7 meets the goals of 4.6 to 4.9; .....that's success for peel.

Loop tack = 4.3 meets the goals of 4.0 to 4.3; .....that's success for loop tack.

Shear = 18 meets the goals of 10 to 25;.....that's success for shear.

Cost = 13.7 meets the goal of cost: less than 14; .....that's success for cost.

Mission accomplished! . . . Marketing gets the adhesive they need.

You can read the whole story in Adhesives Age, August 1988: Tkaczuk, Peter; Formulating Solvent PSAs Using Designed Experiments. This paper was rated best paper at the Pressure Sensitive Tape Council's technical seminar in May 1988.

Contour plots are easy. You can learn how to get *contour plots* for your project in our training course: *Basic Experiment Strategies*. You can find sweet spots in the same way Peter did. Send in the enclosed card and take *Basic Experiment Strategies* training given by:

The Experiment Strategies Foundation: 800-732-7381

Does your job need Basic Experiment Strategies?

If you work in research, development or engineering, then you are changing the levels of input variables (factors) in an effort to make output measurements (responses) come out better.
Basic Experiment Strategies training helps you do that well.

You can learn what Bob Jordan and Peter Tkaczuk learned:
statistical experiment design and response surface methodology.

Take Part I of *Basic Experiment Strategies* training: ..... in 2-1/2 days to get the basic skills;

Or take the full training, Parts I and II: .....in 4 days: to get the basic skills and then more skills to handle a wider variety of applications. Details on the page to the right.

The schedule for *Basic Experiment Strategies* training is on the card below. You can attend one of our open sessions. If you prefer, we'll teach on-site, at your company. Call us at 800-732-7381, or put your name and number on the card below and drop it in the mail.

Turn on the light with
Basic Experiment Strategies training from
The Experiment Strategies Foundation

Basic Experiment Strategies training is offered in these cities:

· Seattle, WA · Palo Alto, CA ·· Boston, MA
· San Diego, CA · Chicago, IL · Cleveland, OH
·Los Angeles, CA · Research Triangle Park, NC
And in-house at your company. Call us for dates: 800-732-7381

The fee for the 4 day training is $1200. The fee for Part I, 2-1/2 days is $750.
To receive a package of more information about the training,
call The Experiment Strategies Foundation at 800-732-7381.
The discount for 5 to 9 from your company is 10%. For 10 or more: 15%.

Christine J. Roth, Sandia Nat'l Labs: *This is by far the most usable and understandable course on statistics and applications I've ever had.*

John Geremia, Professor, M.E., US Naval Academy: *Your computer program [STRATEGY] is a beauty. It is complete and simple to operate. Your course is very thorough because it also provides a program to go along with it. It does not leave the students in the cold and searching for a good program.*

Joel Martin, Sr. Res. Chemist, Phillips Petroleum: *I have heard about this approach for years. This course was the first presentation which balanced statistics with thinking. I'm no longer skeptical. I usually doze through classes -- Not this one!*

Owen Decker, Phillips Petroleum: *Without a doubt the most valuable training I've had since first grade.*

Connie Chocas, Sandia Nat'l Labs: *This class [had] more to do with quality than any quality assurance or quality management course I have taken.*

Basic Experiment Strategies Training

In 2-1/2 days we teach you the skills Peter used:

You learn how to prepare an experiment design for discovering **interactions** between the factors. **Factorial designs** and other newer designs are used in class.

You learn how to use *STRATEGY* to prepare **contour plots** for finding sweet spots in three real case histories. You collect data for simulated processes and products in class. You analyze the data and reach conclusions.

You learn how to test a contour plot to decide whether or not its predictions of product-performance are safe predictions to use.

You learn how to measure **lack-of-reproducibility** of data (standard deviation) and how to use the standard deviation to get **confidence limits** for every result. Confidence limits advise the user as to how much one can depend on a result.

In 4 days we teach you the skills Bob Jordan used:

You learn everything above plus how to prepare **screening** designs for **selecting the strongest** factors from a long list of potentially helpful factors. Screening cuts a project down to manageable size.

And you learn how to use **quadratic** experiment designs to prepare contour plots with domes or basins when properties are too complex to be mimicked by the interaction contour plot. Many applications need this additional complication for best results. You practice screening and quadratic designs in a real case.

This is what happens during the training:

In class, you work in teams of two, collecting realistic data from micro-computers in four applications. Each application provides practice of the strategies learned. The micro-computers serve as mini-labs and mini-factories. The applications studied are taken from R&D projects conducted by scientists and engineers on the job after they took this training.

You analyze the data and prepare, on a PC, for each property measured, a prediction equation and, from that equation, a contour plot. Using the contour plots you find the sweet spot. This practice on real problems gives you the confidence necessary to use the strategies in your own applications when you return to your job.

You will use the Experiment Strategies Foundation's software, *STRATEGY,* in class. Everything you learn is applied in class. Every strategy taught is demonstrated by means of real examples. Questions are welcome at all times. The specifics of applying the strategies learned to the your projects are discussed.

Anyone with training in science and/or engineering will understand this material without difficulty. Participants often wish they had discovered these strategies years earlier. No prior skills other than elementary algebra are needed. No work need be done outside of class time.

The Experiment Strategies Foundation: 800-732-7381

Bob Jordan wrote an article to tell his colleagues the benefits of design of experiments (DOE) that he learned in Basic Experiment Strategies training. Here are excerpts from that article.

Design of Experiments for Engineering Continuous Improvement

Design of Experiments (DOE) is a cost-saving, time-saving, effective method for identifying the optimum parameters for manufacturing and design processes. DOE has been around for a long time, but with canned computer software [*STRATEGY*], it is now an easily employed technique.

The well-designed experiment will provide the engineer, scientist, or researcher reliable results at minimum cost.

. . . DOE has been used to develop many laser welding schedules. Before DOE, engineers spent weeks working with new alloys and designs trying to weld them. After applying DOE techniques, weld schedules were developed in 2-5 days, and some schedules were developed in one day.

Another stellar application was the new oven-temperature indicator ("turkey popper"). DOE was used to define a metal alloy with a specific melting point. The experiment was a resounding success, and an alloy formulation was developed to satisfy the customer's requirement. Later, when the customer wanted an alloy that would melt at a different temperature, data from the original experiment was consulted and another alloy formulation was revealed.

THE OLD WAY: The engineer would change one factor at a time. Each run could only be evaluated on its own merit, not as part of the whole.

THE DOE WAY: A statistically-based design experiment allows the experimenter to bracket the boundaries of possibilities, forming an area or volume. Within this area or volume is the "sweet spot." The sweet spot is the best combination of parameter values to produce the optimum product (design or process).

The strength of DOE: Reliable, statistical predictions are made within a wide range of possibilities.

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800-732-7381 (voice)

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