Instructor's Guide

Simulator

Version 2.0

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Table of Contents

1   Answers to Exercises

Program Simulator comes with 5 simulations. Chapter 1 describes these simulations and how to optimize the performance of each simulation. The files associated with these simulations are automatically installed in the same directory as the software. These files can be modified and new files added as described in Chapter 2.

1.1   Heat Sealer

This simulation involves the development of a heat sealing process to form the top seal of a plastic bag. This is a good simulation to let the students attempt by trial and error. Only 4 of the 8 inputs are significant so it provides a good example for using a screening experiment. It also illustrates the importance of robust design. It is described in the book *Optimization and Variation Reduction in Quality* by Wayne A. Taylor and in the VarTran User manual.

Forming the top seal closes the bag sealing its contents inside. The top seal is a tear seal. It must be torn open to remove the contents of the bag. Of interest is the seal strength. Too weak a seal can result in the bag breaking open during shipping and storage. Too strong a seal makes the bag difficult to open. Spec limits for seal strength have been set at 20 and 32 pounds.

The developer would like to:

     °   Target the process at 26 pounds,
     °   Reduce the variability of seal strength, and
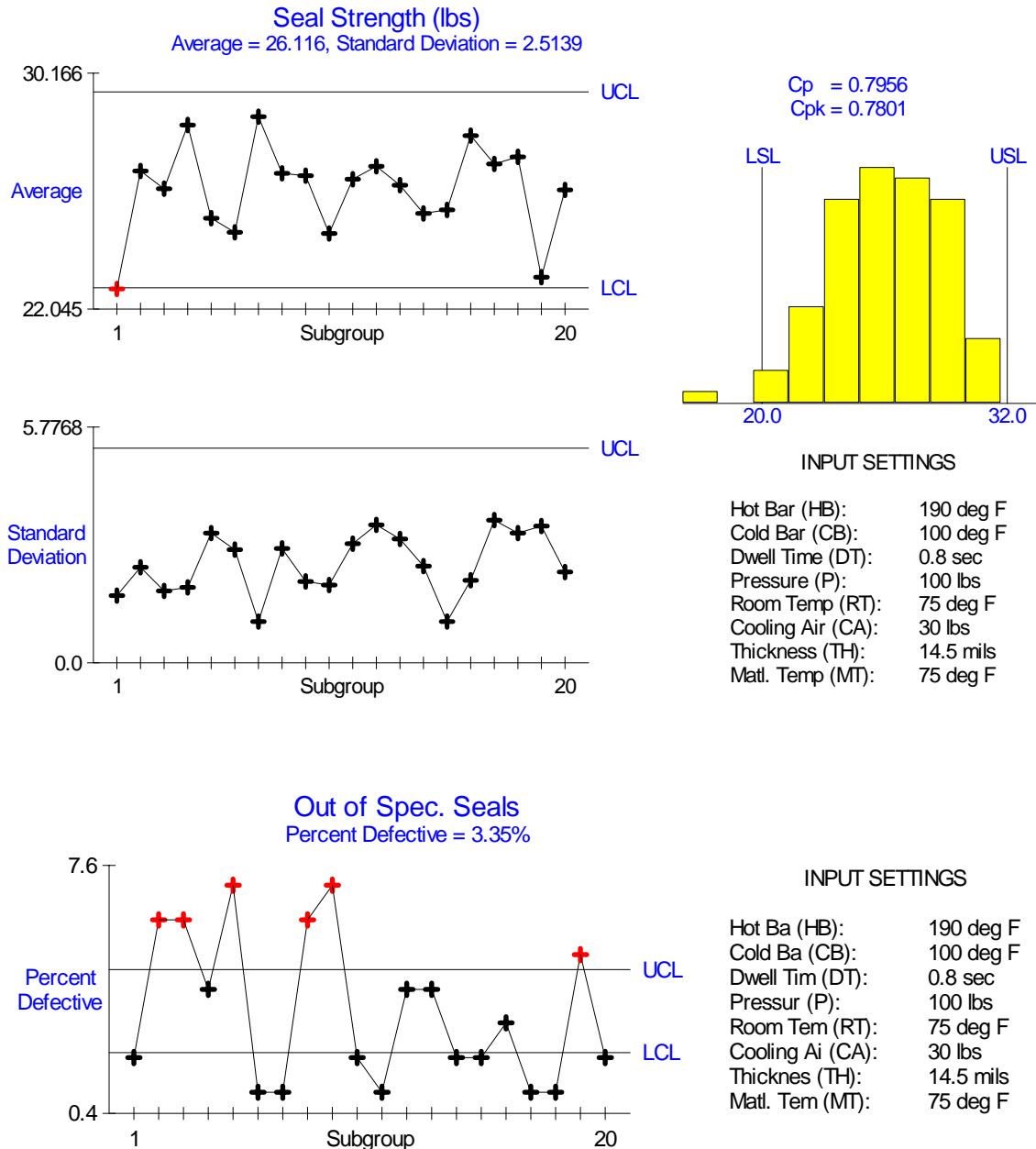   °   Establish a procedure for controlling the process.

The plant already has a heat sealer which is believed capable of performing the job. The manufacturer of the heat sealer has provided the following recommended cycle:

Temperature - Hot Bar	=	190 °F
Temperature - Cold Bar	=	100 °F
Dwell Time	=	0.8 seconds
Pressure	=	100 pounds
Cooling Air Pressure	=	30 pounds
Material Thickness	=	14.5 mils
Room Temperature	=	75 °F
Material Temperature	=	75 °F

The heat sealer works by clamping the material to be sealed between two bars. The top bar, called the hot bar, provides heat to melt the plastic material and cause them to flow together to form the seal. The top bar also moves up and down to allow the material to be moved. The bottom bar is stationary and has cooling water running through it allowing its

temperature to be controlled. When the top bar comes down to make contact with the material, it is lowered until it exerts a preset pressure on the material. It is then held there for a preset time. Before moving the material, cooling air is blown on the seal to facilitate hardening.

There are two outputs: seal strength and out of spec seals. They are actually the same test but reported on both an attribute and variable basis.

Seal Strength (lbs)
Average = 26.116, Standard Deviation = 2.5139

Cp = 0.7956
Cpk = 0.7801

INPUT SETTINGS

Hot Bar (HB):	190 deg F
Cold Bar (CB):	100 deg F
Dwell Time (DT):	0.8 sec
Pressure (P):	100 lbs
Room Temp (RT):	75 deg F
Cooling Air (CA):	30 lbs
Thickness (TH):	14.5 mils
Matl. Temp (MT):	75 deg F

Out of Spec. Seals
Percent Defective = 3.35%

INPUT SETTINGS

Hot Ba (HB):	190 deg F
Cold Ba (CB):	100 deg F
Dwell Tim (DT):	0.8 sec
Pressur (P):	100 lbs
Room Tem (RT):	75 deg F
Cooling Ai (CA):	30 lbs
Thicknes (TH):	14.5 mils
Matl. Tem (MT):	75 deg F

The process is averaging around 3% defective primarily due to excessive short-term variation. The focus should be on reducing the variation.

Of the 8 inputs, only four are actually key inputs (included in model). The targets selected for the other four inputs are entirely ignored. The four key inputs are:

HB   Hot Bar
DT   Dwell Time
P   Pressure
MT   Matl. Temp

The equation used to generate both output variables is:

$$\text{Seal Strength} = -403.5 + 3.6\,HB - 0.008\,HB^2 + 280.0\,DT - 80.0\,DT^2 - 0.96\,HB\,DT + 0.04\,P + 0.05\,MT + Err$$

Besides the 4 main effects, there are quadratic effects for HB and DT along with an interaction between them. In a screening experiment the group of interactions which includes the HB*DT interaction should test significant. Also, if center points are included you should detect significant curvature.

The model includes the following sources of variation:

HB   Hot Bar   Trial-to-trial standard deviation of 2.0 ºF
DT   Dwell Time   Unit-to-unit standard deviation of 0.08 sec
Err   Other Error   Unit-to-unit standard deviation of 0.8 pounds
                                 Each trial has 1/5 chance of shift with std. dev. 0.8 pounds

The variation within a trial is caused by DT and the error term. Further variation from trial-to-trial is caused by HB and the error term. This makes the process slightly unstable. However, the variation caused by dwell time dominates.

To make the process robust to dwell time, the target of dwell time can be adjusted (due to quadratic effect) and the target of hot bar can be adjusted (due to interaction). The targets of the other two key inputs will only affect the average. The effect of HB and DT's targets of the variation is shown below:

**CONTOUR PLOT OF
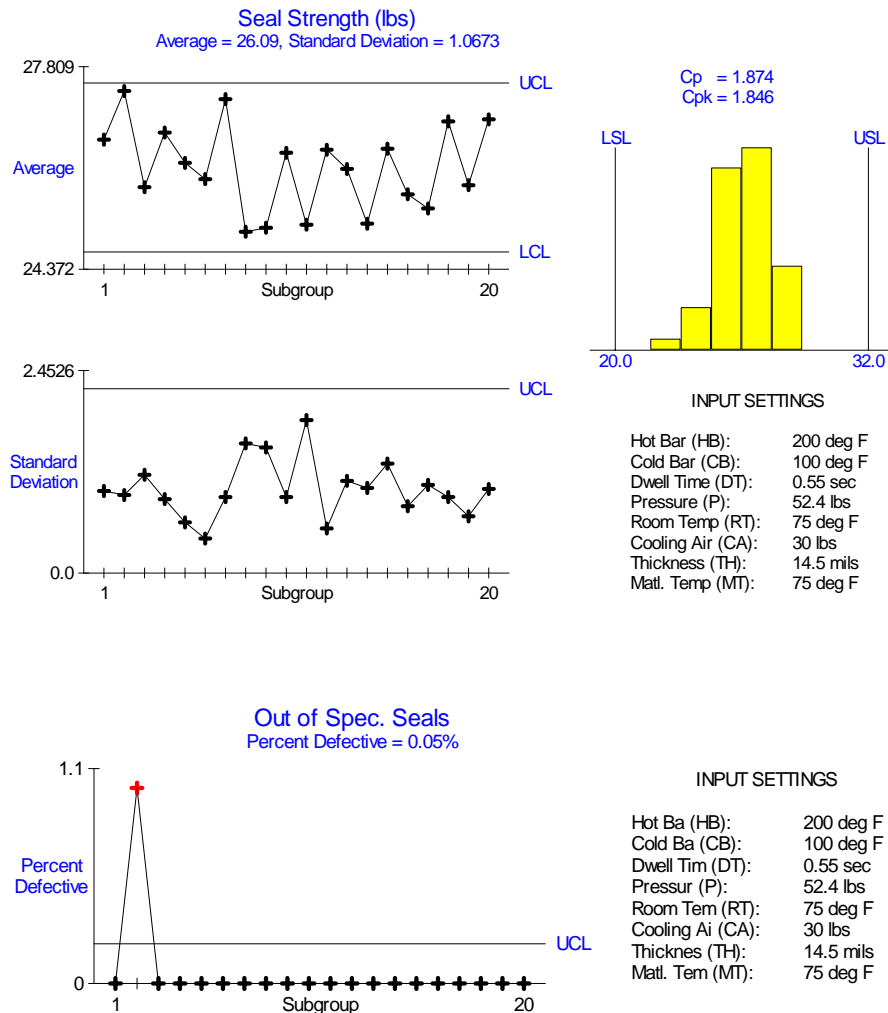SEAL STRENGTH STANDARD DEVIATION**
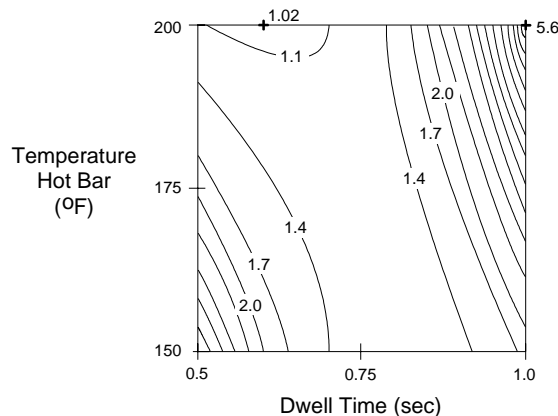
This leads to the following strategy:

> Adjust HB and DT to minimize variation
> Adjust P and MT to get on target
> Set targets of other 4 inputs to minimize cost (Ex: turn cooling air off).

Adjusting material temperature requires constructing a pre-heating chamber for the material. It will be fixed at 75 ºF since pressure can be used to adjust the average. The optimal tagets for the other inputs are:
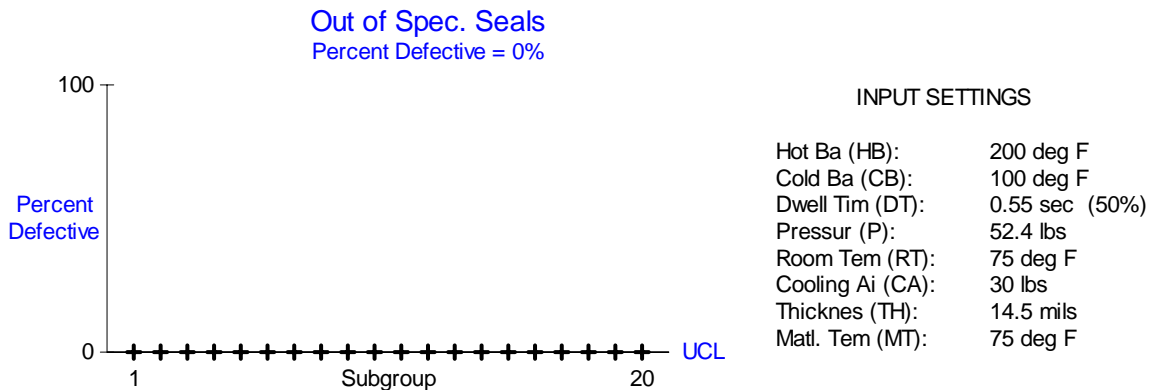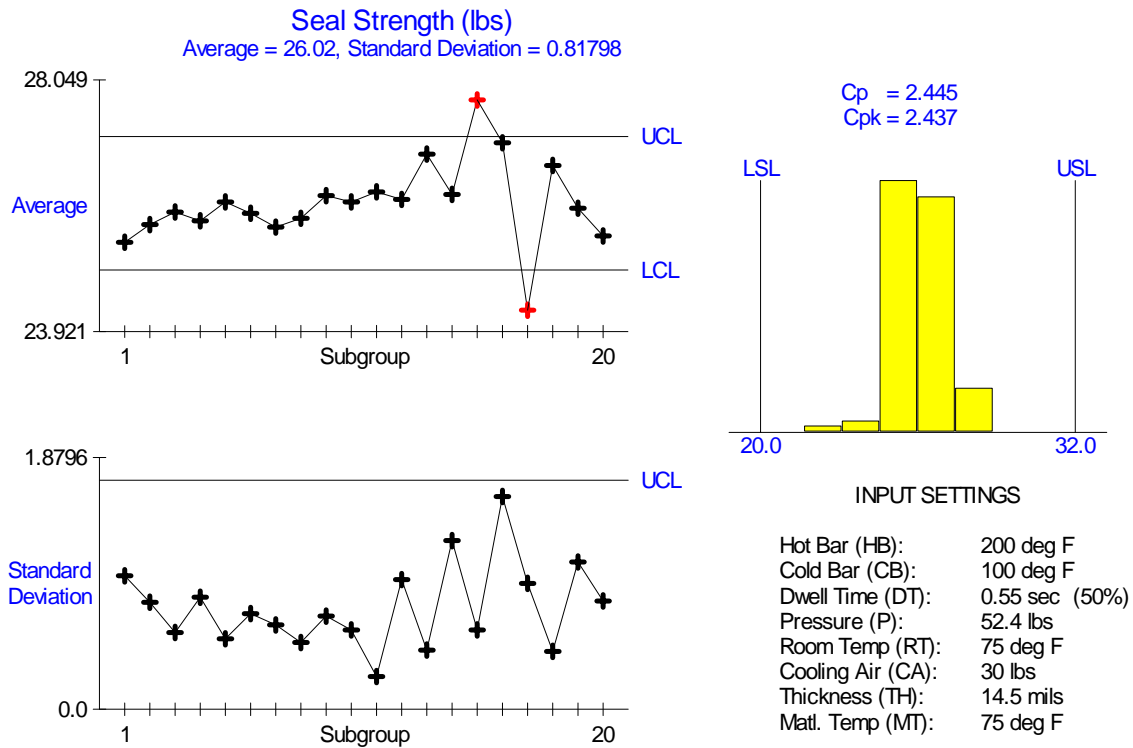
HB	Hot Bar	200 ºF
DT	Dwell Time	0.55 sec
P	Pressure	52.4 lbs.

The improved performance is shown below. The process is now averaging around 0.05% defective with a Cpk value of 1.874.

Seal Strength (lbs)
Average = 26.09, Standard Deviation = 1.0673

Cp = 1.874
Cpk = 1.846

INPUT SETTINGS

Hot Bar (HB):	200 deg F
Cold Bar (CB):	100 deg F
Dwell Time (DT):	0.55 sec
Pressure (P):	52.4 lbs
Room Temp (RT):	75 deg F
Cooling Air (CA):	30 lbs
Thickness (TH):	14.5 mils
Matl. Temp (MT):	75 deg F

Out of Spec. Seals
Percent Defective = 0.05%

INPUT SETTINGS

Hot Ba (HB):	200 deg F
Cold Ba (CB):	100 deg F
Dwell Tim (DT):	0.55 sec
Pressur (P):	52.4 lbs
Room Tem (RT):	75 deg F
Cooling Ai (CA):	30 lbs
Thicknes (TH):	14.5 mils
Matl. Tem (MT):	75 deg F

The operator should be restricted to using pressure to adjust the machine if it shifts off-target. Adjusting DT or HB with increase the variation.

Further improvements must be made by tightening tolerances. Tightening the tolerance of dwell time by 50% produces the following results. Now Six Sigma quality has been achieved.

Seal Strength (lbs)
Average = 26.02, Standard Deviation = 0.81798

Cp = 2.445
Cpk = 2.437

INPUT SETTINGS

Hot Bar (HB):	200 deg F
Cold Bar (CB):	100 deg F
Dwell Time (DT):	0.55 sec (50%)
Pressure (P):	52.4 lbs
Room Temp (RT):	75 deg F
Cooling Air (CA):	30 lbs
Thickness (TH):	14.5 mils
Matl. Temp (MT):	75 deg F

Out of Spec. Seals
Percent Defective = 0%

INPUT SETTINGS

Hot Ba (HB):	200 deg F
Cold Ba (CB):	100 deg F
Dwell Tim (DT):	0.55 sec (50%)
Pressur (P):	52.4 lbs
Room Tem (RT):	75 deg F
Cooling Ai (CA):	30 lbs
Thicknes (TH):	14.5 mils
Matl. Tem (MT):	75 deg F

For the student to determine which tolerance to tighten, they need to perform a tolerance analysis. The VarTran software package can be used to perform this purpose. It comes with a file for the heat sealer. The model in this file is slightly different than the model described above because it uses an equation obtained using a response surface study rather than the true equation. It also used a slightly different error structure. None of these differences are evident to the student.

1.2   Sheeting Extruder

This simulation involves optimizing a sheeting extrusion process. It is a simple example for starting out with. It has only four inputs, all of which are important, making it most suitable for a response surface study. It cannot be used to illustrate robust design.
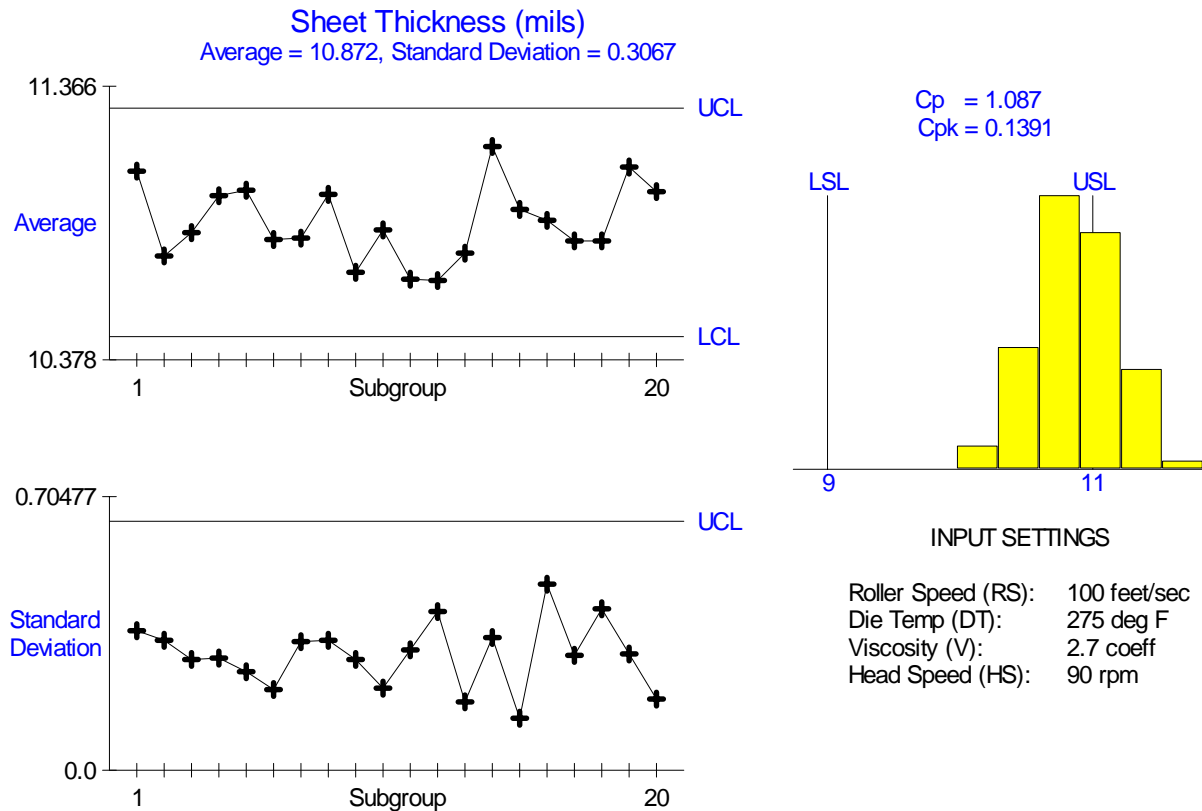
The output of interest is sheeting thickness. The target is 10.0 mils (thousands of an inch). The spec limits are 9.0 to 11.0 mils.

The current settings for the inputs are:

RS	Roller Speed	=	100 feet/sec
DT	Die Temp	=	275 ºF
V	Viscosity	=	2.7 coeff
HS	Head Speed	=	90 rpm

The extruder works by forcing molten plastic through a die. The material is first heated to the die temperature. Increasing head speed increases the pressure the material is forced out with. Roller speed is the speed at which the roller receiving the extruder sheeting is turning. Viscosity is a material property.

The current process is off-center:

Sheet Thickness (mils)
Average = 10.872, Standard Deviation = 0.3067

Cp = 1.087
Cpk = 0.1391

INPUT SETTINGS

Roller Speed (RS):   100 feet/sec
Die Temp (DT):   275 deg F
Viscosity (V):   2.7 coeff
Head Speed (HS):   90 rpm

The equation used to generate Sheeting Thickness is:

Thickness = $-64.93479 - 0.10766\ RS - 0.001058\ RS^{\wedge}2 + 0.48434\ DT -$
$0.001058\ DT^{\wedge}2 + 0.001084\ RS\ DT + 5.0\ V + 0.0075\ HS + Err$

Besides the 4 main effects, there are quadratic effects for RS and DT along with an interaction between them.

The model includes only a single source of variation:

Err   Other Error   Unit-to-unit standard deviation of 0.3 pounds

This simulation cannot be used to illustrate robust design. Changing targets does not affect the variation. The goal is to adjust the variables to get the average on target. There are numerous combinations of the four inputs that will center the process.

1.3 Sonic Sealer

This simulation involves optimizing a sonic sealing process. The model involved includes a three-way interaction making it difficult to model. It takes the right combination of the different inputs to get the process above the lower spec limit. A good final exam. It cannot be used to illustrate robust design.
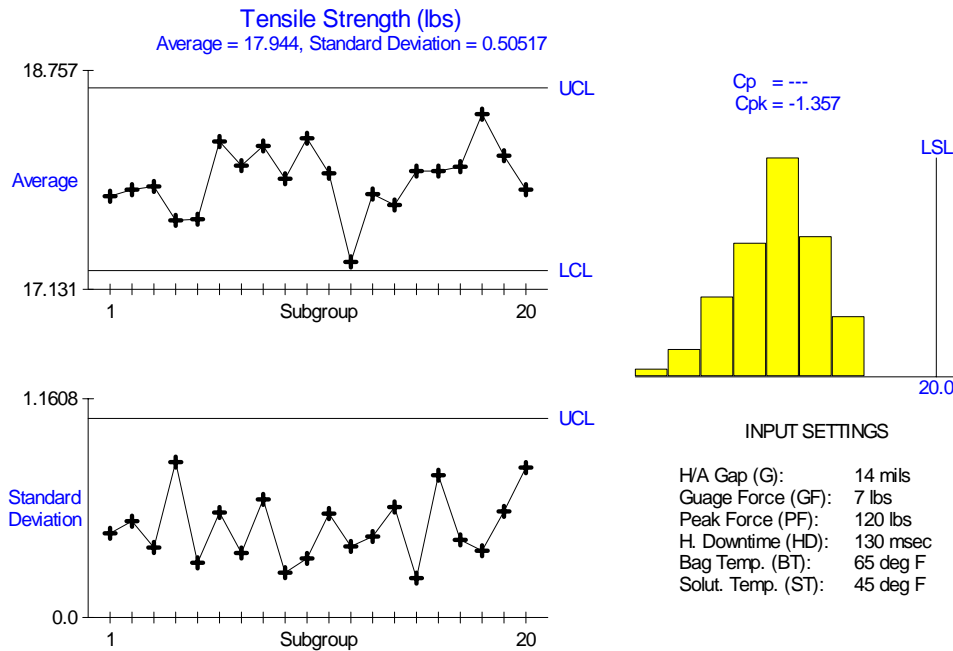
The output of interest is tensile strength. A small plastic disk is being sealed inside a hollow plastic tube. Tensile strength is the force required to pull the disk out. There is a lower spec limit of 20 pounds.

This is a new process. The goal is to demonstrate the feasibility of this approach. The inputs and one of the settings run are:

G	H/A Gap	=	14 mils
GF	Gauge Force	=	7 lbs
PF	Peak Force	=	120 lbs
HD	Horn Downtime	=	130 msec
BT	Bag Temp	=	65 ºF
ST	Solution Temp.	=	45 ºF

The sonic sealer works by focusing sound energy of the disk to get it to melt to the surrounding tube. The horn is the metal tooling inserted into the tube used to focus the sound energy on the disk. The tube has just been used to a fill sterile bag. The temperatures are the temperature of the bag before filling and the temperature the solution just placed in the bag.

Dozens of different settings like the one given above have been tried without success. The results always look like the capability study on the next page. Yes, that is the lower spec limit above all the values. The project is about to be canceled. However, since you have been exhorting the benefits of designed experiments, you are being given the weekend to run a study (true story). Nobody expects much, but at least it will keep you quite in the future. Don't expect to make the process Six Sigma, only to demonstrate feasibility.

Tensile Strength (lbs)
Average = 17.944, Standard Deviation = 0.50517

Cp = ---
Cpk = -1.357

INPUT SETTINGS

H/A Gap (G):	14 mils
Guage Force (GF):	7 lbs
Peak Force (PF):	120 lbs
H. Downtime (HD):	130 msec
Bag Temp. (BT):	65 deg F
Solut. Temp. (ST):	45 deg F

There are two outputs, tensile strength and number of below spec seals. The same equation is used for both. One presents the data in variable format and the other as an attribute. The equation is:

$$\text{Tensile Strength} = 39.2355 - 1.10625\ G - 0.25625\ HD - 1.1829167\ ST + 0.015625\ G\ HD + 0.07145833\ G\ ST + 0.01204166\ HD\ ST - 0.0007708\ G\ HD\ ST + Err$$

Only three of the inputs are in this equation: G, HD and ST. All 3 2-way interactions between these variables exist and there is even a three way interaction. There are no quadratic effects

The model includes only a single source of variation:

Err   Other Error   Unit-to-unit standard deviation of 0.5 pounds

This simulation cannot be used to illustrate robust design. Changing targets does not affect the variation. The goal is to adjust the variables to get the average above the lower spec limit.

Running a screening experiment on this example will generally result in identifying 4 key inputs. Three are the true key inputs and the other is whatever is confounded with the three way interaction. One will also pick up at least three groups of interactions. Despite this error in picking up an extra variable, careful use of the interaction plots will suggest 1 or 2 combinations of the inputs producing the optimal performance. If two, try them both.

Running a response surface study will correctly pick up the 3 key inputs and sort out interactions but will still not include the three-way interaction unless the students identified the highly interactive nature of the inputs and included it using a d-optimal design. Because there are no quadratic effects, the optimal must be a corner point. The setting that works is:

G	H/A Gap	=	12 mils
HD	Horn Downtime	=	150 msec
ST	Solution Temp.	=	60 ºF

Tensile Strength (lbs)
Average = 21.167, Standard Deviation = 0.53688

Cp = ---
Cpk = 0.7249
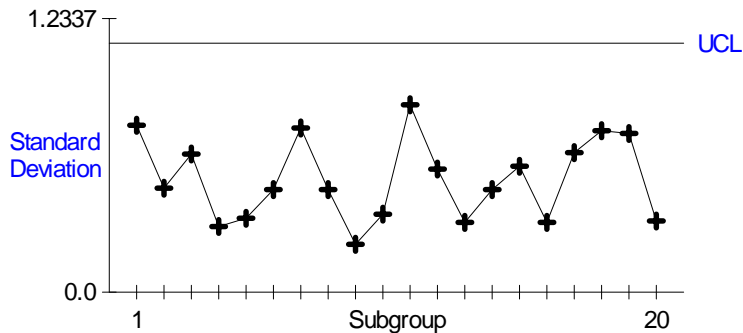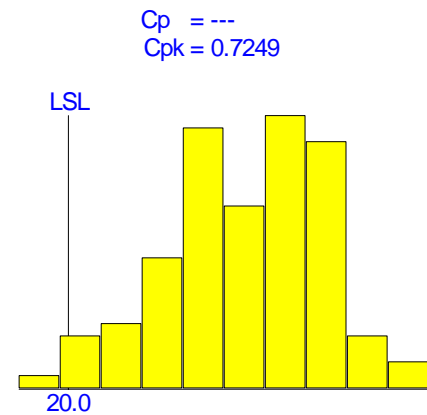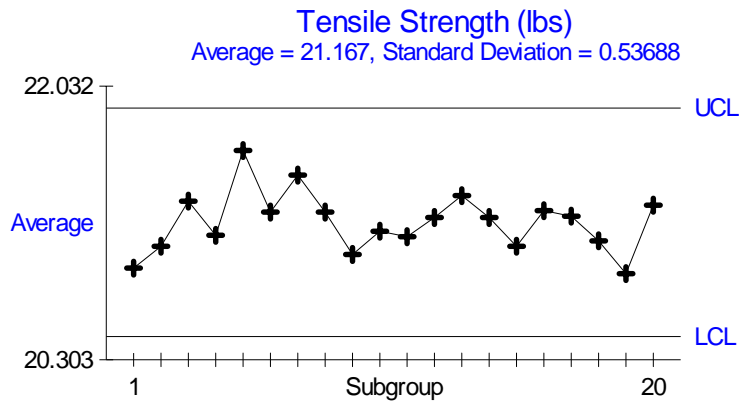
INPUT SETTINGS

|	
H/A Gap (G):	12 mils
Guage Force (GF):	7 lbs
Peak Force (PF):	120 lbs
H. Downtime (HD):	150 msec
Bag Temp. (BT):	65 deg F
Solut. Temp. (ST):	60 deg F

1.4 Flo-Former

This simulation involves optimizing a flo-former process. The model involves 8 candidate input variables which reduce to three key inputs. There are multiple sources of variation and interactions allowing for robust design. The full set of tools, including screening and response surface studies, robust design and selectively tightening tolerances, all apply to this simulation. This example is borrowed from Tom Barker's course on robust design.
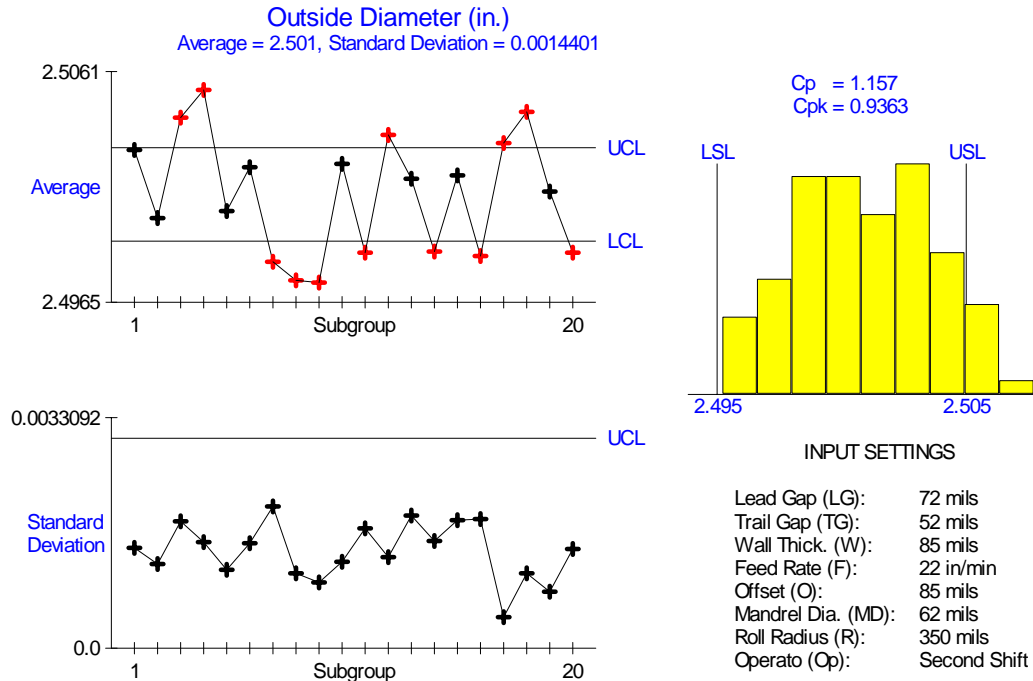
The flo-former process is used to crush an extruded metal tube called a mandrel to the right size. The output of interest is the finished outside diameter. The target is 2.5 inches +/- 0.005. The mandrel is originally extruded slightly larger than needed and then crushed. The inputs along with their current settings are shown below:

LG   Lead Gap   = 72 mils
TG   Trail Gap   = 52 mils
W   Wall Thickness   = 85 mils
F   Feed Rate   = 22 in/min
O   Offset   = 85 mils
MD   Mandrel Diameter   = 62 mils
R   Roll Radius   = 350 mils
Op   Operator   = Second Shift

Mandrel diameter and wall thickness are material properties. The remaining parameters are mostly machine settings. Many are setup related. The exception is the shift (operator). The mandrel is spun between several rollers that reduce the diameter. A diagram of the machine is given below:
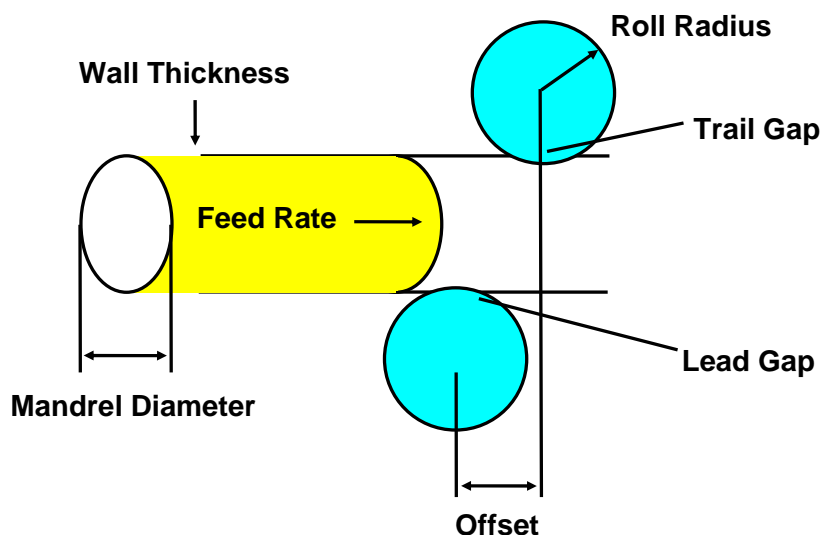
A capability study of the current at the current settings is shown below. The process is unstable with excessive short term variation.

Outside Diameter (in.)
Average = 2.501, Standard Deviation = 0.0014401

Cp = 1.157
Cpk = 0.9363

INPUT SETTINGS

Lead Gap (LG):	72 mils
Trail Gap (TG):	52 mils
Wall Thick. (W):	85 mils
Feed Rate (F):	22 in/min
Offset (O):	85 mils
Mandrel Dia. (MD):	62 mils
Roll Radius (R):	350 mils
Operato (Op):	Second Shift

There is one output, the outside diameter of the finished mandrel. The equation is:

$$\text{Outside Diameter} = 2.5 + (-466.3 + 5.19\,LG + 1.05\,TG + 4.15\,W - 0.051424\,LG\,W + Err) / 1000$$

Only three of the inputs are in this equation: LG, TG and W. There is a single 2-way interaction between LG and W. There are no quadratic effects

The model includes multiple sources of variation:

|		
LG	Lead Gap	Trial-to-trial standard deviation of 1.0 mils
TG	Trail Gap	Trial-to-trial standard deviation of 1.0 mils
W	Wall Thickness	Unit-to-unit standard deviation of 2.0 mils plus
		Trial-to-trial standard deviation of 4.5 mils
Err	Other Error	Unit-to-unit standard deviation of 1.0 mils

The setup parameters like trail and lead gaps only vary from trial-to-trial so may be the cause on instability. Changing targets affects the variation so robust design can be explored. The goal is to reduce the variation, both unstable and short term.

Running a screening experiment on this example will generally result in identifying the 3 key inputs and one interaction group. The inclusion of center points will identify no curvature. The correct interaction in the group can generally be identified based on which terms tested significant individually. From this a model can be fit without with going to a response surface study.

When analyzing the standard deviation as a response variable, only lead gap tests significant. A plot is shown below. The key to reducing the variation is setting lead gap to 80. This takes advantage of the LG*WT interaction and makes the process robust to material.
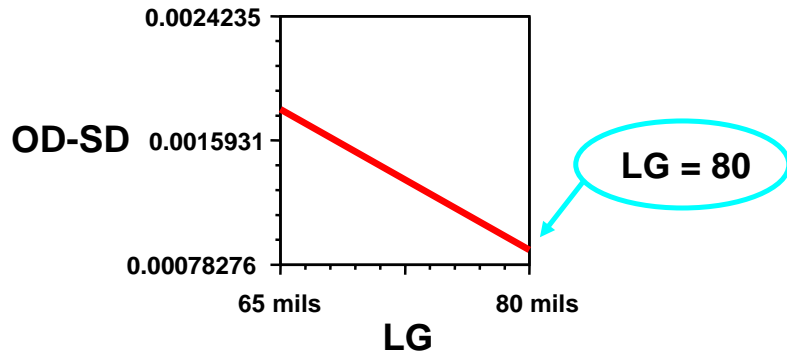
Setting LG to 80 minimizes the variation, MT is a material parameter that is more difficult to change so it will be left alone. Trail Gap affects only the average and will be used to adjust the average to 10 mils. A setting of 46 for TG centers the process. The results are shown below.
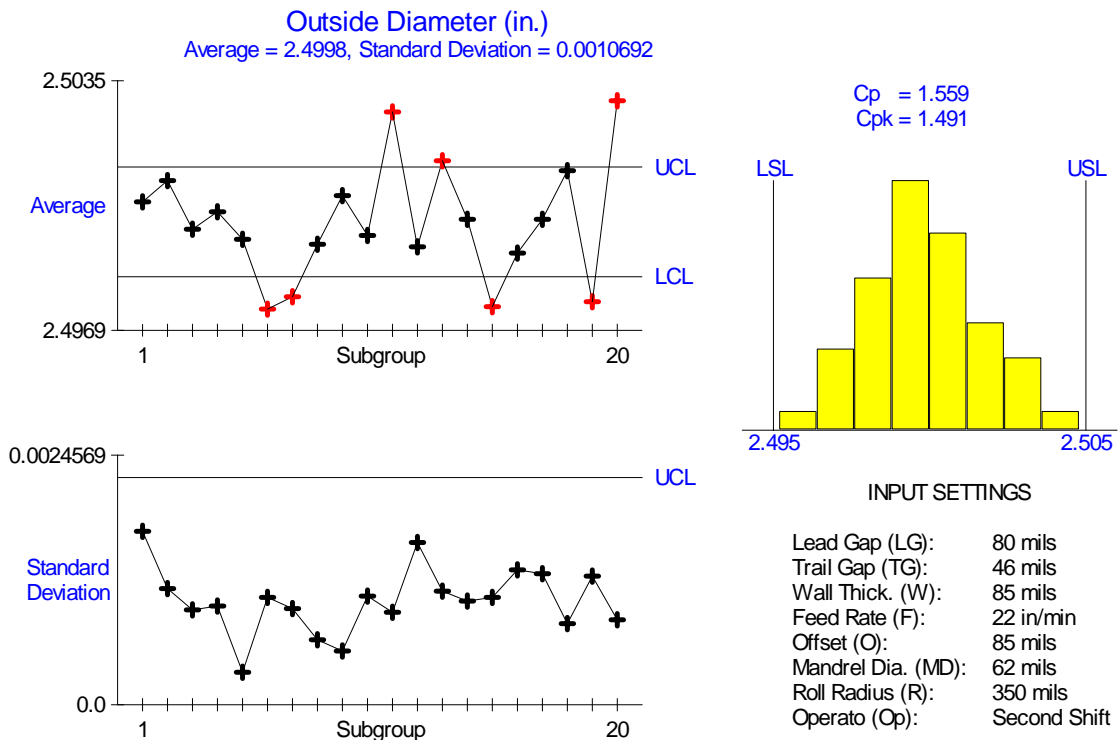
While this represents a big improvement, it is still not Six Sigma. Further improvements can only be obtained by tightening tolerances. Taking the equation into VarTran identifies LG as the primary cause of the variation. Cutting its tolerance by 50% improves the performance further as shown below.

Outside Diameter (in.)
Average = 2.5003, Standard Deviation = 0.00096178

Cp = 1.733
Cpk = 1.636
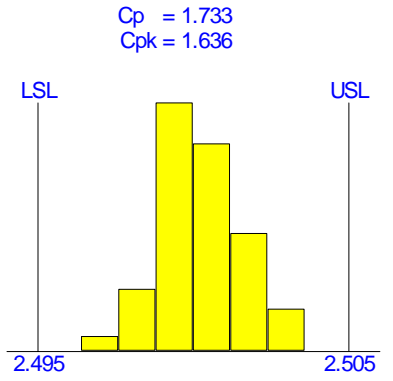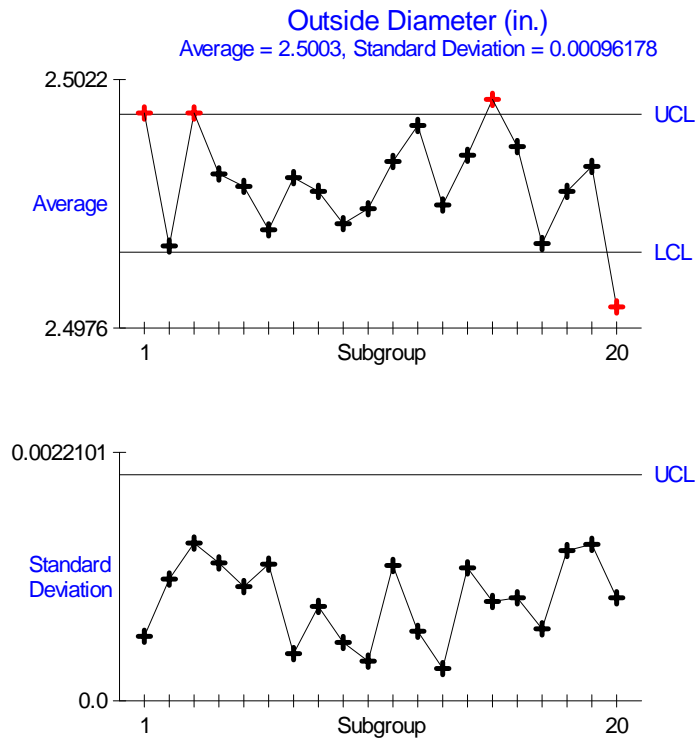
INPUT SETTINGS

Lead Gap (LG):	80 mils
Trail Gap (TG):	46 mils (50%)
Wall Thick. (W):	85 mils
Feed Rate (F):	22 in/min
Offset (O):	85 mils
Mandrel Dia. (MD):	62 mils
Roll Radius (R):	350 mils
Operato (Op):	Second Shift

1.5 Pump

This simulation applies to the design of a product rather than a process. It only involves 4 inputs so is best handled using a response surface study. It provides a great example relative to robust design and tightening tolerances.
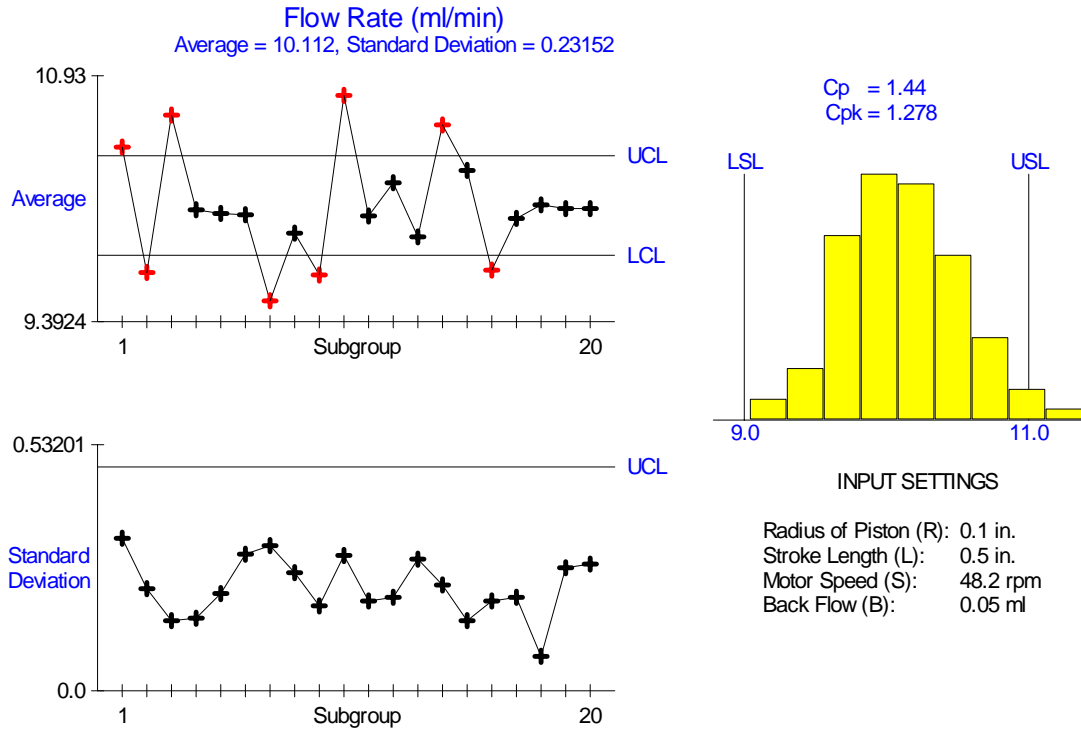
Design offers the first and best opportunity for reducing variation. To illustrate the strategies and tools required, consider the task of designing a new pump. Suppose that the pump must be capable of delivering solution at a constant rate of 10 ml/min. Customer usage requires that the flow rate remain between 9 and 11 ml/min. The first step is to develop a design concept. Taguchi calls this the system design. Suppose we decide to use a piston to push the solution. This concept requires a motor to drive the piston and a valve to control the direction of the flow. This is the creative part of design.

Now the work begins. We need to determine all the specifics such as "How far should the piston travel?" and "How fast should the motor turn?" To accomplish this task, we need to make a list of all the factors affecting flow rate. Three obvious factors are the piston radius (R), the stroke length (L), and the motor speed (S). Another possible factor is the amount of backflow through the valves (B). It is the output, flow rate, for which we want to optimize the average and reduce the variation. This is accomplished by establishing requirements and controls for the inputs.

Initial settings for the inputs are shown below:

R	Piston Radius	=	0.1 inches
L	Stroke Length	=	0.5 inches
S	Motor Speed	=	48.2 rpm
B	Back Flow	=	0.5 ml/stoke

A capability study of the current at the current settings is shown below. The process has excessive short term variation.

Flow Rate (ml/min)
Average = 10.112, Standard Deviation = 0.23152

Cp = 1.44
Cpk = 1.278

INPUT SETTINGS

Radius of Piston (R): 0.1 in.
Stroke Length (L): 0.5 in.
Motor Speed (S): 48.2 rpm
Back Flow (B): 0.05 ml

There is one output, the flow rate. The equation is:
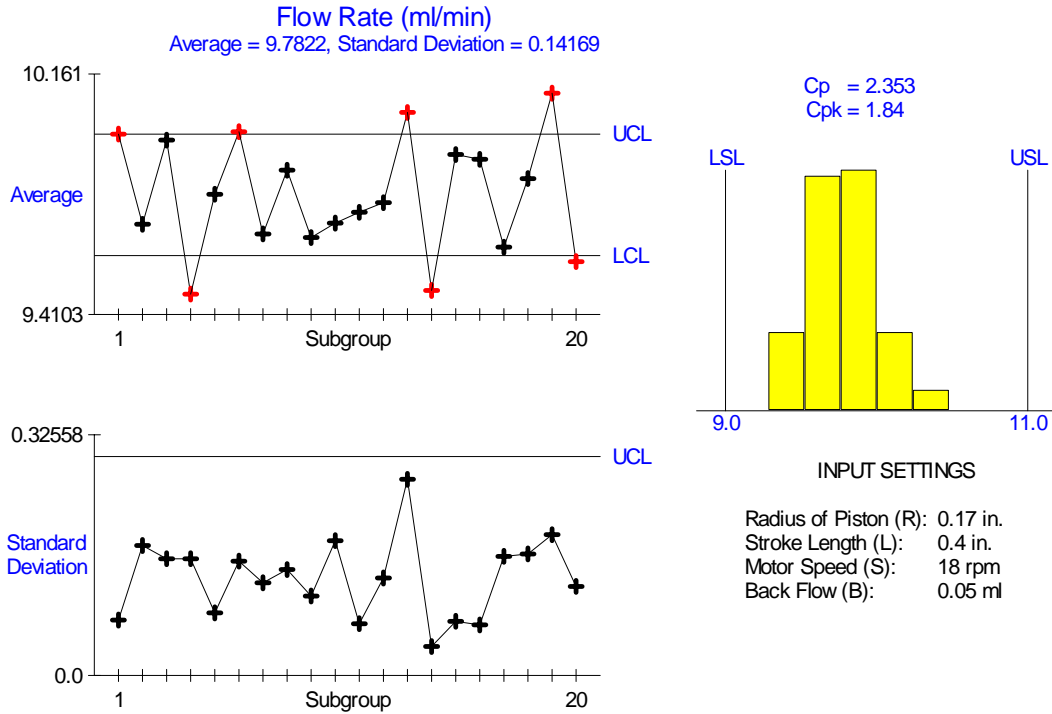
$$F = (16.388 \, \pi \, R^2 \, L - B) \, S$$

All four inputs are in the equation. The equation consists of two interaction B * S and the more complicated $R^2 * L * B$. This second interaction dominates leading to R, L, S, R^2, R*S, R*L and S*L all testing significant.
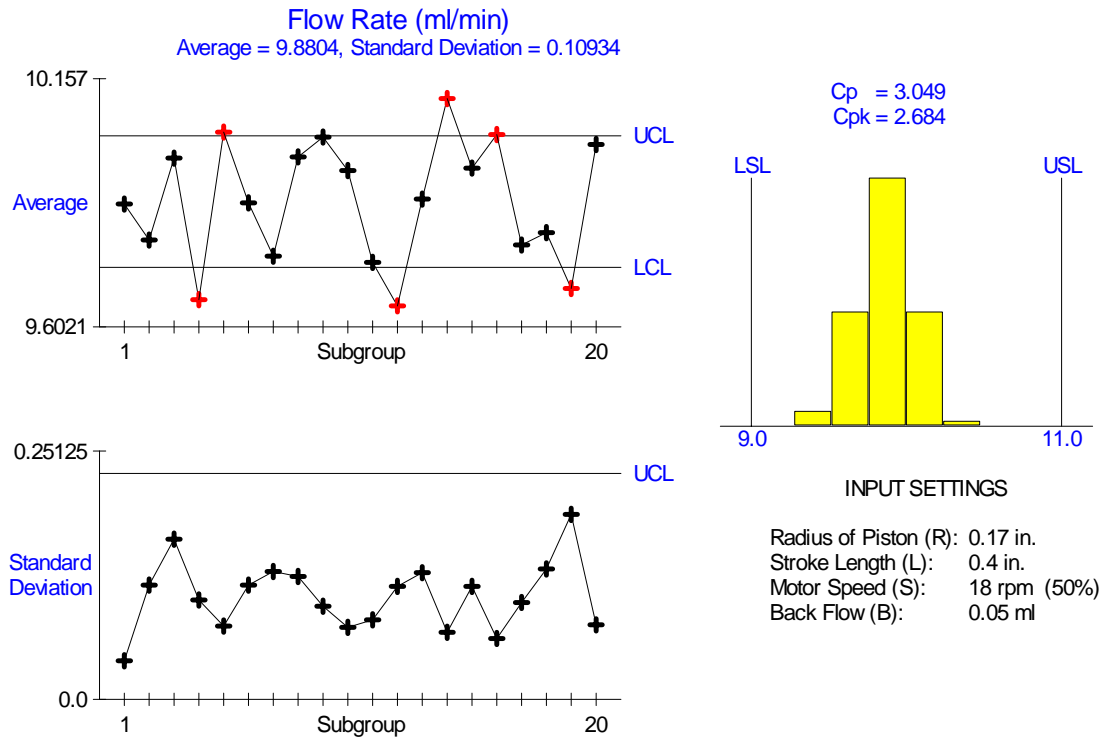
The model includes multiple sources of variation:

R	Radius	Unit-to-Unit Standard deviation of 0.00005 inches plus Trial-to-trial standard deviation of 0.000075 inches
L	Stoke Length	Unit-to-Unit Standard deviation of 0.00167 inches plus Trial-to-trial standard deviation of 0.0025 inches
S	Motor Speed	Unit-to-unit standard deviation of 0.167 rpm Trial-to-trial standard deviation of 0.25 rpm
B	Back Flow	Unit-to-unit standard deviation of 0.005 ml/stroke plus Trial-to-trial standard deviation of 0.0075 ml/stroke

Analyzing the log of the standard deviation identifies R, L, S, and R^2 all affect the variation. Plots of the R, L and S effect on the average and standard deviation can be used to identify the optimal settings. The optimization routines some DOE packages can also be used. Another alternative is to bring the design in VarTran for optimization. The optimal settings are:

R	Piston Radius	=	0.17 inches
L	Stroke Length	=	0.4 inches
S	Motor Speed	=	18 rpm

Flow Rate (ml/min)
Average = 9.7822, Standard Deviation = 0.14169

Cp = 2.353
Cpk = 1.84

INPUT SETTINGS

Radius of Piston (R): 0.17 in.
Stroke Length (L):   0.4 in.
Motor Speed (S):   18 rpm
Back Flow (B):   0.05 ml

Further improvements can only be obtained by tightening tolerances. Taking the equation into VarTran identifies motor speed as the primary cause of the variation. Cutting its tolerance by 50% improves the performance further as shown below.

Flow Rate (ml/min)
Average = 9.8804, Standard Deviation = 0.10934

Cp = 3.049
Cpk = 2.684

INPUT SETTINGS

Radius of Piston (R): 0.17 in.
Stroke Length (L):   0.4 in.
Motor Speed (S):   18 rpm (50%)
Back Flow (B):   0.05 ml

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2   Structure of Simulation Files

The simulations for version 2.0 of the program Simulator are set up using text files that can be easily edited and added or removed. When starting, Simulator checks the directory the program resides in for text files (i.e., having the extension txt). It reads each text file to see if it contains a simulation and displays the simulations found on the Startup dialog box.

2.1   File Structure

Each simulation file contains the name of the simulation, a graphic and then a description of the input and output variables. The file for the heat sealer simulation is shown below:

```
"Simulator" 2.0
"sealer.bmp" "sealer.rtf" 1
"Heat Sealer"
9
"HB"  "Hot Bar"      "deg F"  -5  "190"   "150"  "200"  "0.0"   "2.0"  "0.0"  "0.0"  "100" 1 1
"CB"  "Cold Bar"     "deg F"  -5  "100"   "80"   "120"  "0.0"   "0.0"  "0.0"  "0.0"  "100" 1 1
"DT"  "Dwell Time"   "sec"    -5  "0.8"   "0.5"  "1.0"  "0.08"  "0.0"  "0.0"  "0.0"  "100" 1 1
"P"   "Pressure"     "lbs"    -5  "100"   "50"   "150"  "0.0"   "0.0"  "0.0"  "0.0"  "100" 1 1
"RT"  "Room Temp"    "deg F"  -5  "75"    "70"   "80"   "0.0"   "0.0"  "0.0"  "0.0"  "100" 1 1
"CA"  "Cooling Air"  "lbs"    -5  "30"    "0"    "30"   "0.0"   "0.0"  "0.0"  "0.0"  "100" 1 1
"TH"  "Thickness"    "mils"   -5  "14.5"  "14"   "15"   "0.0"   "0.0"  "0.0"  "0.0"  "100" 1 1
"MT"  "Matl. Temp"   "deg F"  -5  "75"    "70"   "110"  "0.0"   "0.0"  "0.0"  "0.0"  "100" 1 1
"Err" "Other Error"  "lbs"    -5  "0"     "0"    "0"    "0.8"   "0.0"  "0.2"  "0.8"  "100" 0 0
0
2
"SS"  "Seal Strength"      "lbs"  -5
"-403.5 + 3.6 HB - 0.008 HB^2 + 280.0 DT - 80.0 DT^2 - 0.96 HB DT + 0.04 P + 0.05 MT + Err"
1  1  1  "32.0"   "20.0"  "26.0"  5    5
"OS"  "Out of Spec. Seals"  ""    -5
"-403.5 + 3.6 HB - 0.008 HB^2 + 280.0 DT - 80.0 DT^2 - 0.96 HB DT + 0.04 P + 0.05 MT + Err"
1  0  1  "32.0"   "20.0"  "26.0"  100  100
```

The file contains text strings and numbers. Text strings start and end with a quotation mark ("). Sometimes the text string will contain an expression as described in the last section. Numbers are of the form -XX.XXe-XX. The exponent, decimal point and signs are all optional. Any number of blank characters, tabs and line feeds can be inserted between text strings and numbers. Therefore the arrangement shown above could be changed to have all the values on one line or to have every value of a separate line.

The file is broken into 4 main sections:

- Header Information – first three lines above
- Input Variables – number followed by list
- Category Input Variables – number followed by list
- Output Variables – number followed by list

Simulator is as consistent as possible with the VarTran software package relative to its handling of the 3 types of variables. Each section is described separately.

2.2 Header Section

The Header section consists of the following lines:

```
"Simulator" 2.0
"sealer.bmp" "sealer.rtf" 1
"Heat Sealer"
```

There are six items which must be entered:

Name	Type	Description
Program Name	Text String	Must always be set to "Simulator". File will only be read if it starts with the text string Simulator. This prevents the program from accidentally reading other text files.
Version Number	Number	Files following the instructions in this document should have a version number of 2.0. This will allow future versions of the program to continue to read the file.
Graphics File	Text String	Name of a graphics file containing a picture to be displayed on the Startup dialog box and elsewhere. The file must be in the same directory as the program and simulation text files. If no graphic is provided, enter the blank text string "". The file should be in bmp, jpg, ico, emf, or wmf formats. 30 by 30 pixel files will appear without distortion. All other files will be automatically shrunk or expanded to fit the space provided.
Description File	Text String	Name of a rich text file containing a description of the simulation that is incorporated into the help system. The file must be in the same directory as the program and simulation text files. If no description file is provided, enter the blank text string "". The file should be in rtf format. It can be created in Word using the Save As menu item.
Sequence Number	Number	The sequence number is used to control the order that the simulations appear on the Startup dialog box starting with the smallest numbers. Simulations with the same sequence number sorted alphabetically by title.
Title	Text String	The name of the simulation as it is to appear on the Startup dialog box, Control panel, and windows displaying the results of the simulation.

2.3 Input Variables Section

The Input Variables section consists of the following lines:

```
9
"HB"  "Hot Bar"      "deg F"   -5  "190"  "150"  "200"  "0.0"   "2.0"  "0.0"  "0.0"  "100" 1 1
"CB"  "Cold Bar"     "deg F"   -5  "100"  "80"   "120"  "0.0"   "0.0"  "0.0"  "0.0"  "100" 1 1
"DT"  "Dwell Time"   "sec"     -5  "0.8"  "0.5"  "1.0"  "0.08"  "0.0"  "0.0"  "0.0"  "100" 1 1
"P"   "Pressure"     "lbs"     -5  "100"  "50"   "150"  "0.0"   "0.0"  "0.0"  "0.0"  "100" 1 1
"RT"  "Room Temp"    "deg F"   -5  "75"   "70"   "80"   "0.0"   "0.0"  "0.0"  "0.0"  "100" 1 1
"CA"  "Cooling Air"  "lbs"     -5  "30"   "0"    "30"   "0.0"   "0.0"  "0.0"  "0.0"  "100" 1 1
"TH"  "Thickness"    "mils"    -5  "14.5" "14"   "15"   "0.0"   "0.0"  "0.0"  "0.0"  "100" 1 1
"MT"  "Matl. Temp"   "deg F"   -5  "75"   "70"   "110"  "0.0"   "0.0"  "0.0"  "0.0"  "100" 1 1
"Err" "Other Error"  "lbs"     -5  "0"    "0"    "0"    "0.8"   "0.0"  "0.2"  "0.8"  "100" 0 0
```

It starts with the number of input variables. Then there are 14 items which must be entered for each input variable:

Name	Type	Description
Symbol	Text String	Symbol used to represent variable in equation for output. Must be unique, consist of only letter, digits and underscores and cannot begin with a digit.
Name	Text String	More descriptive name for the variable for use on the Control Panel and windows displaying the results of the simulation.
Units	Text String	Units of measure used for specifying current, minimum and maximum targets.
Precision	Number	Number used to specify precision for displaying numbers. A positive integer and zero indicates the number of digits after the decimal number to report. A negative integer represents the number of significant digits to report. Generally a value of -5 works well.
Initial Target	Text String Containing Constant Expression	The initial value to target the input at. It is frequently the current recommended setting used for process or the midpoint between the minimum and maximum targets. The value entered must be between the minimum and maximum targets. The initial target is entered as a text string that can contain a constant expression.
Minimum Target	Text String Containing Constant Expression	The minimum value the user can set the target to. The value entered must be less than the maximum target if the variable appears on the control panel. The minimum target is entered as a text string that can contain a constant expression.

Name	Type	Description
Maximum Target	Text String Containing Constant Expression	The maximum value the user can set the target to. The value entered must be less than the maximum target if the variable appears on the control panel. The maximum target is entered as a text string that can contain a constant expression.
Unit Standard Deviation	Text String Containing Expression	The standard deviation from unit-to-unit in the same subgroup or trial. The unit standard deviation is entered as a text string that can contain an expression containing the symbol **Target**. This allows the unit standard deviation to depend on the target selected. For example the expression "0.3 Target" causes the standard deviation be always be 3% of the target, i.e., sets the CV to 3%. The unit standard deviation must always be greater than or equal to zero.
Setup Standard Deviation	Text String Containing Expression	The standard deviation from subgroup-to-subgroup or trial-to-trial. The setup standard deviation is entered as a text string that can contain an expression containing the symbols **Target** and **UnitStandardDeviation**. This allows the setup standard deviation to depend on these two values. The setup standard deviation must always be greater than or equal to zero.
Probability of a Shift	Text String Containing Constant Expression	The probability that a shift in the average occurs between subgroups or trials. The probability of a shift is entered as a text string that can contain a constant expression. The probability of a shift must be between zero and one.
Shift Standard Deviation	Text String Containing Expression	Standard deviation of distance above or below target following a shift. Shifts are not cumulative. Each time a shift is determined to have occurred, a new distance from target is determined. This results in a stationary time series process that remains centered around the target. The shift standard deviation is entered as a text string that can contain an expression containing the symbols **Target** and **UnitStandardDeviation**. This allows the shift standard deviation to depend on these two values. The shift standard deviation must always be greater than or equal to zero.

Name	Type	Description
Percent Tolerance	Text String Containing Constant Expression	The standard deviations are all reduced by this quantity. Setting to 0% eliminates all variation of the input variable. This variable is generally set to 100 initially. The percent tolerance is entered as a text string that can contain a constant expression. The percent tolerance tightened must be between 0 and 100.
Display on Control Panel?	Number	A value of 1 causes this variable to be displayed on the control panel allowing its target to be adjusted by the user. A value of 0 hides this variable from the user. This allows sources of variation like measurement error to be added to the model that the user cannot adjust the target of.
Able to Tighten Tolerance?	Number	A value of 1 causes this variable to be displayed on the maintenance panel allowing the percent tolerance tightened to be adjusted. A value of 0 hides this variable from the user. If all are set to zero, the tighten tolerance panel will not be displayed.

2.4 Category Input Variables Section

The Category Inputs Variables section for the sealer file consists of the following line:

```
0
```

This indicates there are no category inputs in this simulation. When there are category input variables, the section would appear as follows:

```
2
"M"  "Material"  "type"    -5  2  "N" "New"  "O" "Old"  2
"C"  "Cavity"    "number"  -5  4  "_1" "Cavity 1"  "_2" "Cavity 2"
                                  "_3" "Cavity 3"  "_4" "Cavity 4"  1
```

It starts with the number of category input variables. Then there are 8 items which must be entered for each category input variable:

Name	Type	Description
Symbol	Text String	Symbol used to represent variable in an equation for an output variable. Must be unique, consist of only letter, digits and underscores and cannot begin with a digit.
Name	Text String	More descriptive name for the variable for use on windows displaying the results of the simulation.
Units	Text String	Units of measure. While this field must be entered for all variables, it is ignored for category input variables.
Precision	Number	Number used to specify precision for displaying numbers. While this field must be entered for all variables, it is ignored for category input variables.
Number of Categories	Number	Number of category or levels associated with variables. Must be at least 1.
Category Symbol	Text String	Symbol used to represent a category in an equation for an output variable. Must be unique, consist of only letter, digits and underscores and cannot begin with a digit. The category symbol and name are entered next to each other and then repeated for each category.
Category Name	Text String	More descriptive name for the category for use on windows displaying the results of the simulation.
Selected Category	Number	The selected category for performing simulations. Must be an integer between 1 and the number of categories.

2.5 Output Variables Section

The Output Variables section consists of the following lines:

```
2
"SS"  "Seal Strength"      "lbs"  -5
"-403.5 + 3.6 HB - 0.008 HB^2 + 280.0 DT - 80.0 DT^2 - 0.96 HB DT + 0.04 P + 0.05 MT + Err"
1  1  1  "32.0"   "20.0"  "26.0"  5    5
"OS"  "Out of Spec. Seals"  ""    -5
"-403.5 + 3.6 HB - 0.008 HB^2 + 280.0 DT - 80.0 DT^2 - 0.96 HB DT + 0.04 P + 0.05 MT + Err"
1  0  1  "32.0"   "20.0"  "26.0"  100  100
```

It starts with the number of output variables. Then there are 13 items which must be entered for each output variable:

Name	Type	Description
Symbol	Text String	Symbol used to represent variable in equation for another output. Must be unique, consist of only letter, digits and underscores and cannot begin with a digit.
Name	Text String	More descriptive name for the variable for use on windows displaying the results of the simulation.
Units	Text String	Units of measure used for calculated values.
Precision	Number	Number used to specify precision for displaying numbers. A positive integer and zero indicates the number of digits after the decimal number to report. A negative integer represents the number of significant digits to report. Generally a value of -5 works well.
Equation	Text String Containing Expression	Equation for output in format used by VarTran. Can contain numbers, symbols of other variables, operators and functions. The equation can reference any of the input variables and category input variables as well as other output variables. A complete description is given below.
Equation for Value?	Number	The value of 1 indicates the entered equation is for values of the output. The equation is then repeatedly evaluated as the inputs vary to generate data. A value of 0 indicates the equation is for the fraction defective. The equation is evaluated once for each trial to obtain the fraction defective and then the binomial distribution is simulated to obtain the data.

Name	Type	Description
Report Values?	Number	This item is only applicable to the case where Equation for Value is set to 1. A value of 1 causes the programs to report the average and standard deviation of the values generated. A value of 0 causes the program to only report the percentage of values in spec. There are two ways to generate attribute data: (1) enter an equation for the fraction defective using the previous variable or (2) enter an equation for values and specify 0 for this variable.
Display Results For?	Number	A value of 1 causes results to be displayed for this variable for trails and capability studies. A value of 0 causes no results to be displayed. This allows complex models to be entered were one output variable to be defined in terms of other intermediate output variables without having to display the results for the intermediate outputs.
Upper Spec Limit	Text String Containing Number or Blank	Upper spec limit for values. Only applicable if the Equation For Values is set to 1. Set to blank string "" if no upper spec limit.
Lower Spec Limit	Text String Containing Number or Blank	Lower spec limit for values. Only applicable if the Equation For Values is set to 1. Set to blank string "" if no lower spec limit.
Target	Text String Containing Number or Blank	Target for values. Only applicable if the Equation For Values is set to 1. Set to blank string "" if no target. When there are two spec limits, the target is frequently the midpoint.
Number of Samples Per Trial	Number	Specifies the number of samples to be generated for each trial. A value of 5 is common when values are generated and a value of 100 is common for attribute data.
Number of Samples Per Subgroup	Number	Specifies the number of samples to be generated for each subgroup of a capability study. A capability study always consists of 20 subgroups. A value of 5 is common when values are generated and a value of 100 is common for attribute data.

2.6 Expressions

An expression consist of numbers, operators, functions, variables and parenthesis as described below.

Numbers: Examples are "1", "1.0", ".1", "1.1 10^2", and "-1.1 10^-2".

Operators: Unary operators: - and +. Binary operators: +, -, *, /, and ^. If parenthesis are omitted, the operations are performed in the order determined by the operator precedence and association rules. Multiplication operators may be omitted. For example the expression "2 A Log[B C]" is interpreted as "2 * A * Log[B * C]".

Functions: Of form "function [param1, param2, ...]". The following functions are supported: Log, Log10, Exponential, SquareRoot, Sine, Cosine, Tangent, ArcSine, ArcCosine, ArcTangent, HyperbolicSine, HyperbolicCosine, HyperbolicTangent, Gamma, LogGamma, Beta, LogBeta, AbsoluteValue, Minimum, Maximum, NormalDistribution, InverseNormalDistribution, pi, and e. Most functions require one parameter. Exceptions are Beta, LogBeta, Minimum, and Maximum which require 2 and pi and e which require zero. Squared brackets must be used with functions.

Symbol: Can enter the symbol of any input variable or output variable. For output variables circular or recursive references are not allowed.

Category Input Variables: Of form "Symbol { Symbol }". Examples are: "SS{Average}", "Y{Standard Deviation}" and "O2{Cpk}". Properties are used to specify characteristics of output variable and categories of category input variables.

Rounded Parentheses: "(" and ")" are used to control the order that operations are performed. Without parentheses, the operations are performed in the order determined by the operator precedence and association rules. If in doubt about the order the operations will be performed, use parenthesis.

A constant expression is an expression which does not reference any symbols or variables.

Warning: Be sure to use rounded parenthesis for order of operation, square brackets for function calls and curved brackets for category input variables. "Log[A]" means to take the log of the variable A. "Log(A)" means to multiply the variables Log and A. "Log{A}" is the category A of the category input variable Log.