

# Outline

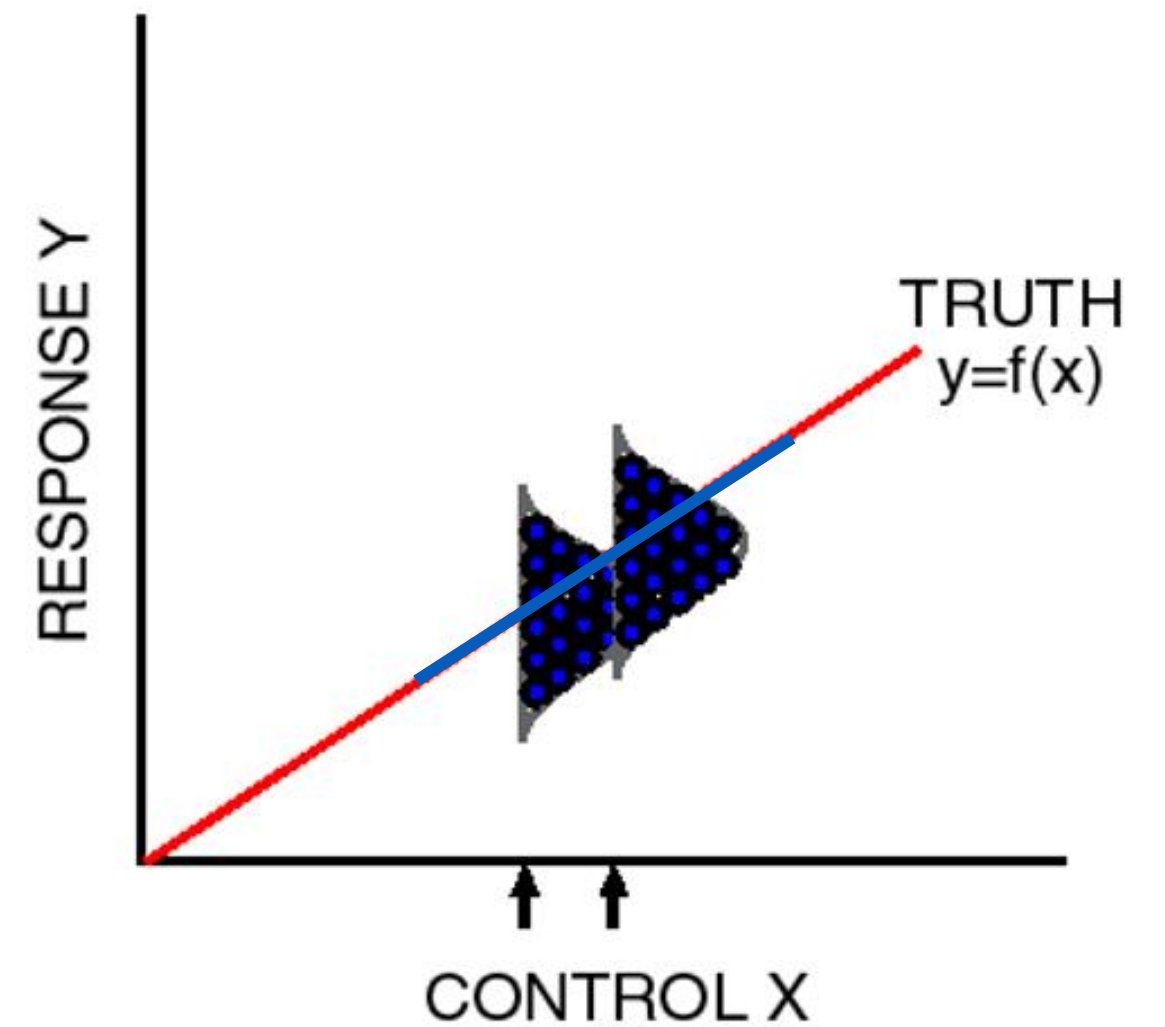
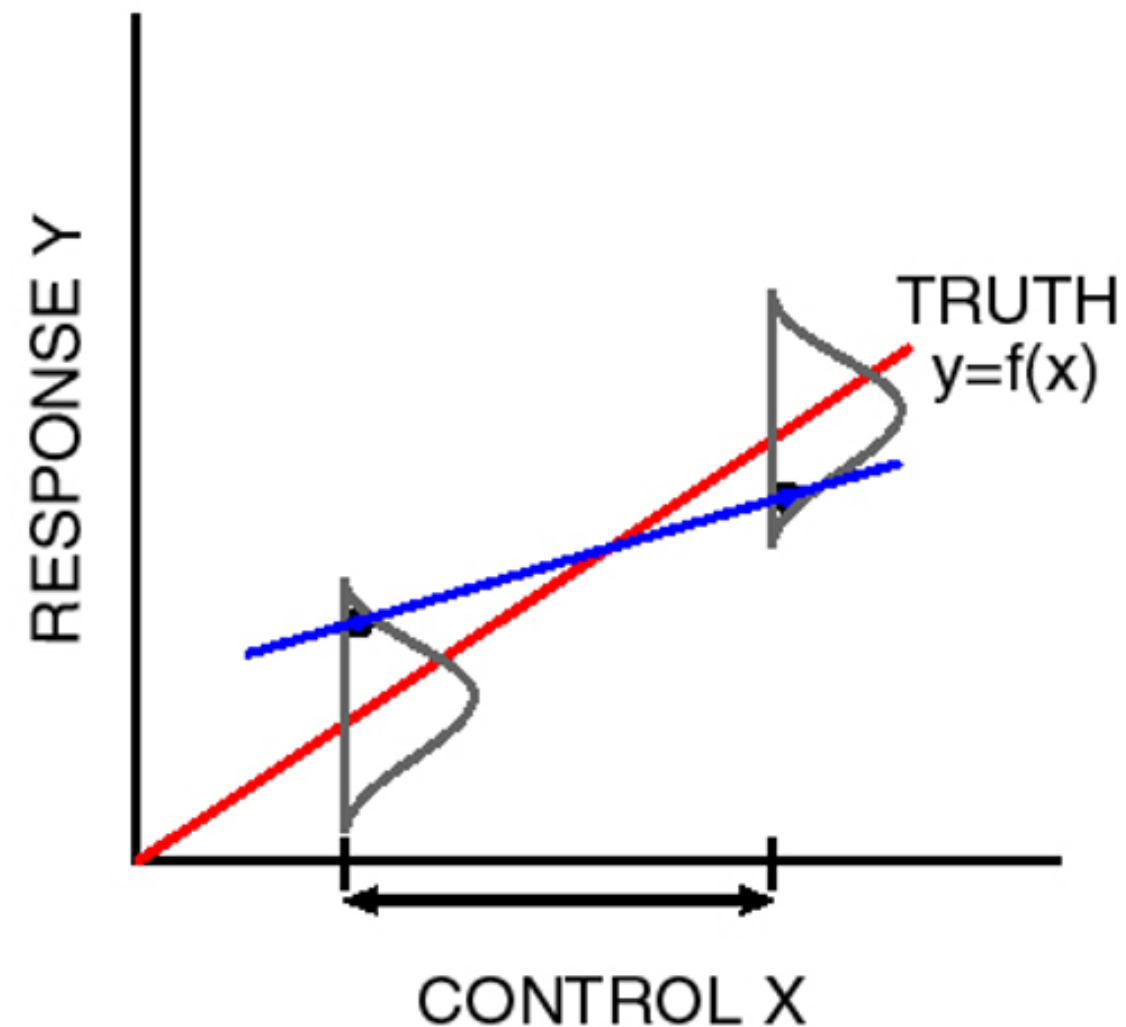
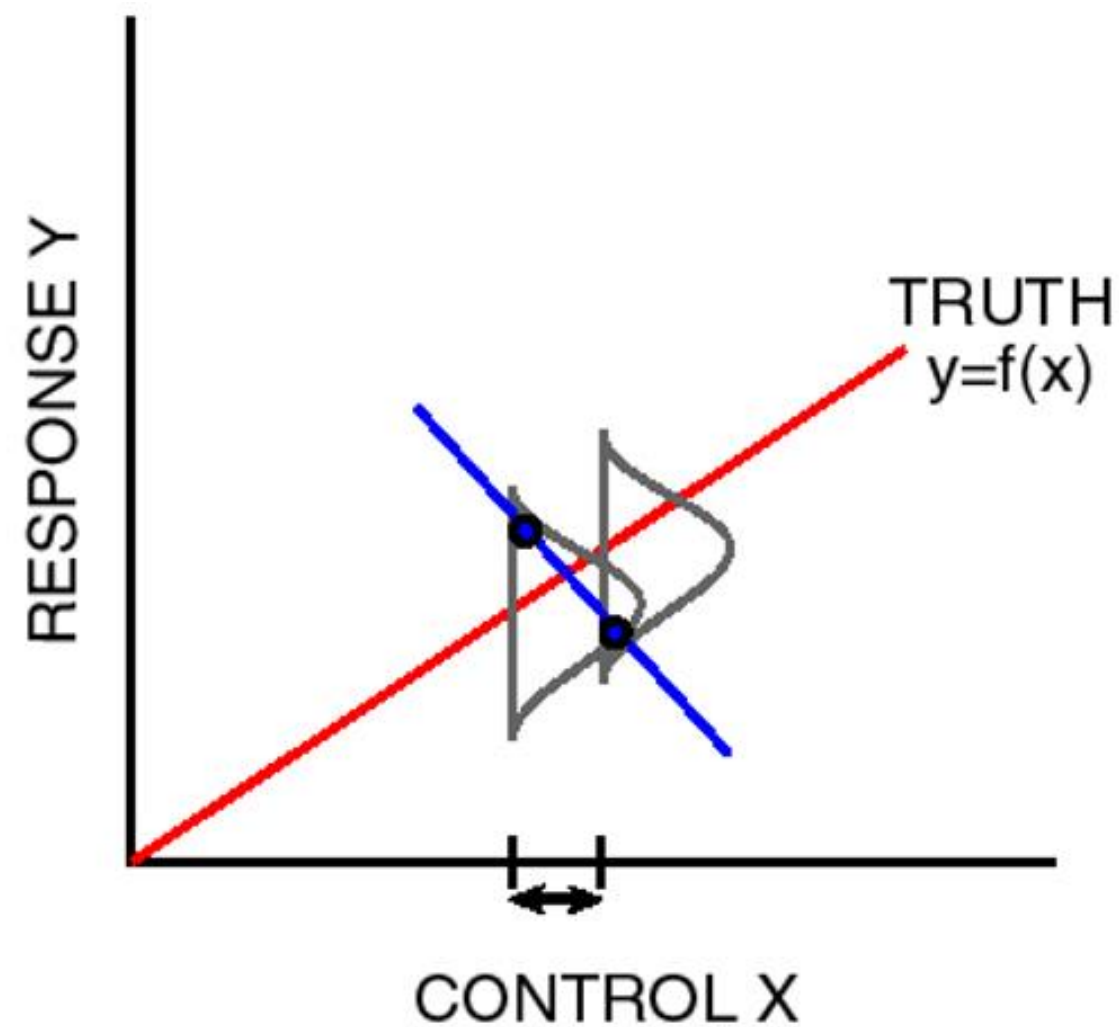
- Factor ranges – Timid vs. Bold
  - Be as bold as you can without changing the “physical mechanism”
  - Boldness helps to overcome need for large sample size
- Use subject matter expertise to set ranges boldly
  - DOE cannot blindly be slapped on a process ignorant of the science
- Still too bold? Somehow break design?
  - Create custom design but find out some trials don't work
  - Use **Augment Design with Constraints** to repair the design

# More than a few of my DOE trials don't work. Now what?

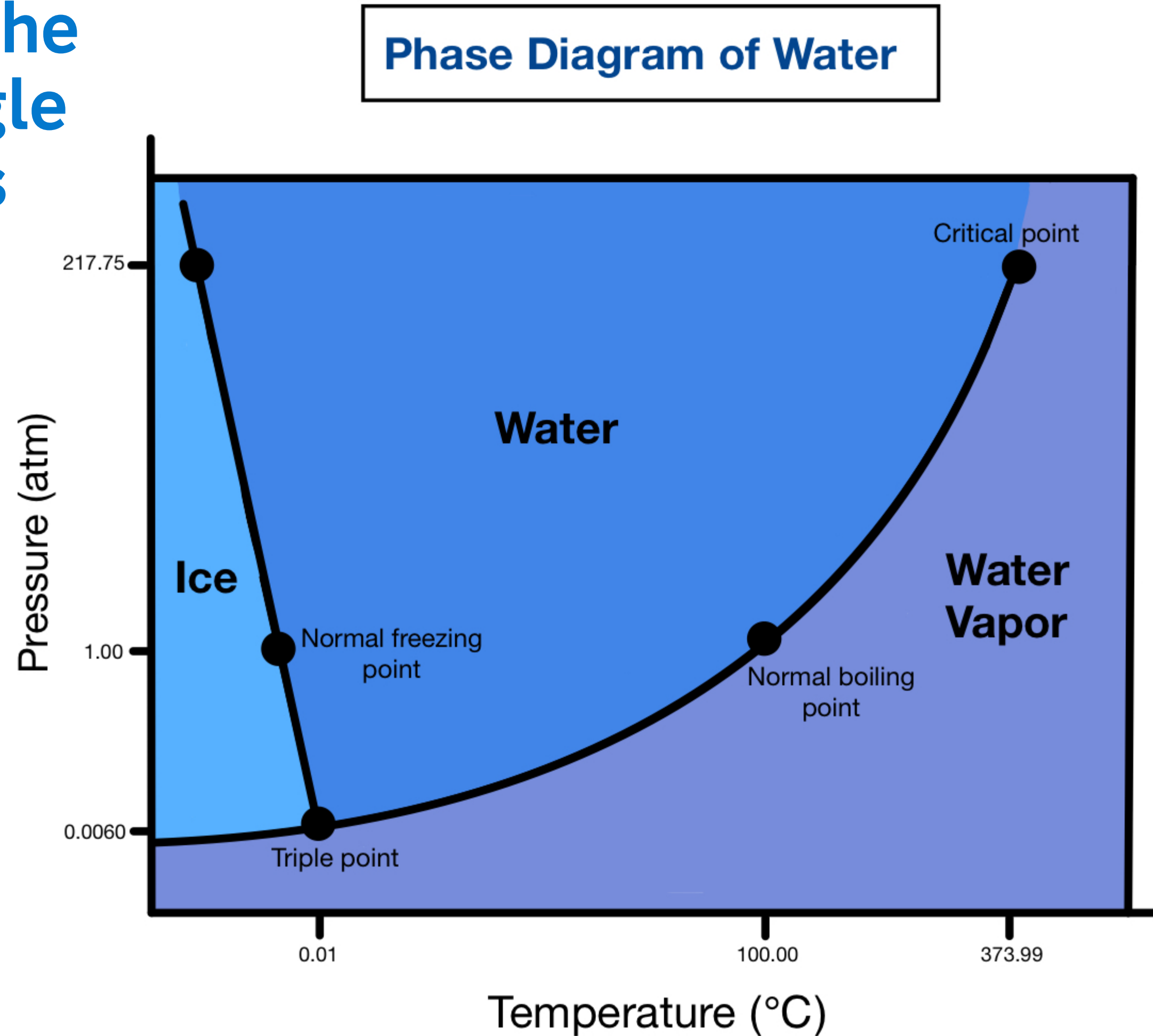
You've just started using DOE and are following the advice to be as **bold** as you can with factor ranges. But you have made your ranges so wide that certain factor combinations cause the process to “**break**.” You are unable to measure a useful response value for some trials, and now your **model won't run!** This session will show you how to **repair** your design using the **Augment Design** in combination with specifying **Constraints** option in the JMP's DOE platform.

# Timid vs. Bold Range Settings

Boldness overcomes the need for large sample size



# Keep Ranges in the Domain of a Single Physical Process



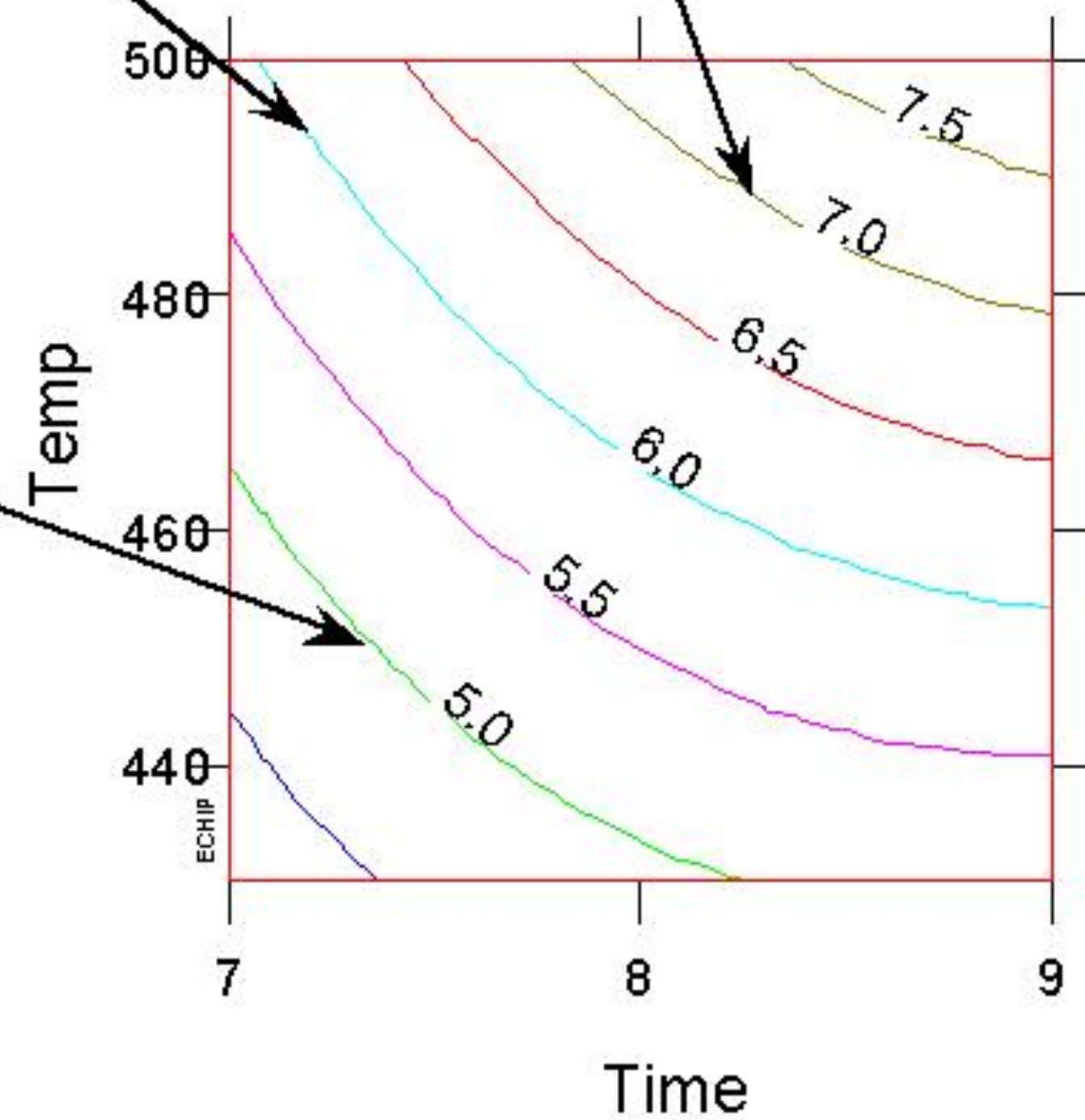
## Examples of “Breaking” the Process

- Injection molding press “flashing”
- Film thickness completely etched away
- Quenching of photoluminescence of ZnS doped with Mn beyond 5%
- Proportions of food ingredients too distasteful, oily, bitter, salty,...
- Proportions of mixture ingredients leads to “unreacted” components or “voids”
- Turning at too high a speed leads to structural failure
- Time & Temperature combinations put in too much energy or not enough





Cheese Colour



# 3 Different Factor Types

Create 24-trial RSM DOE for a Pizza Process

Continuous

- **Time:** 10 20

Continuous

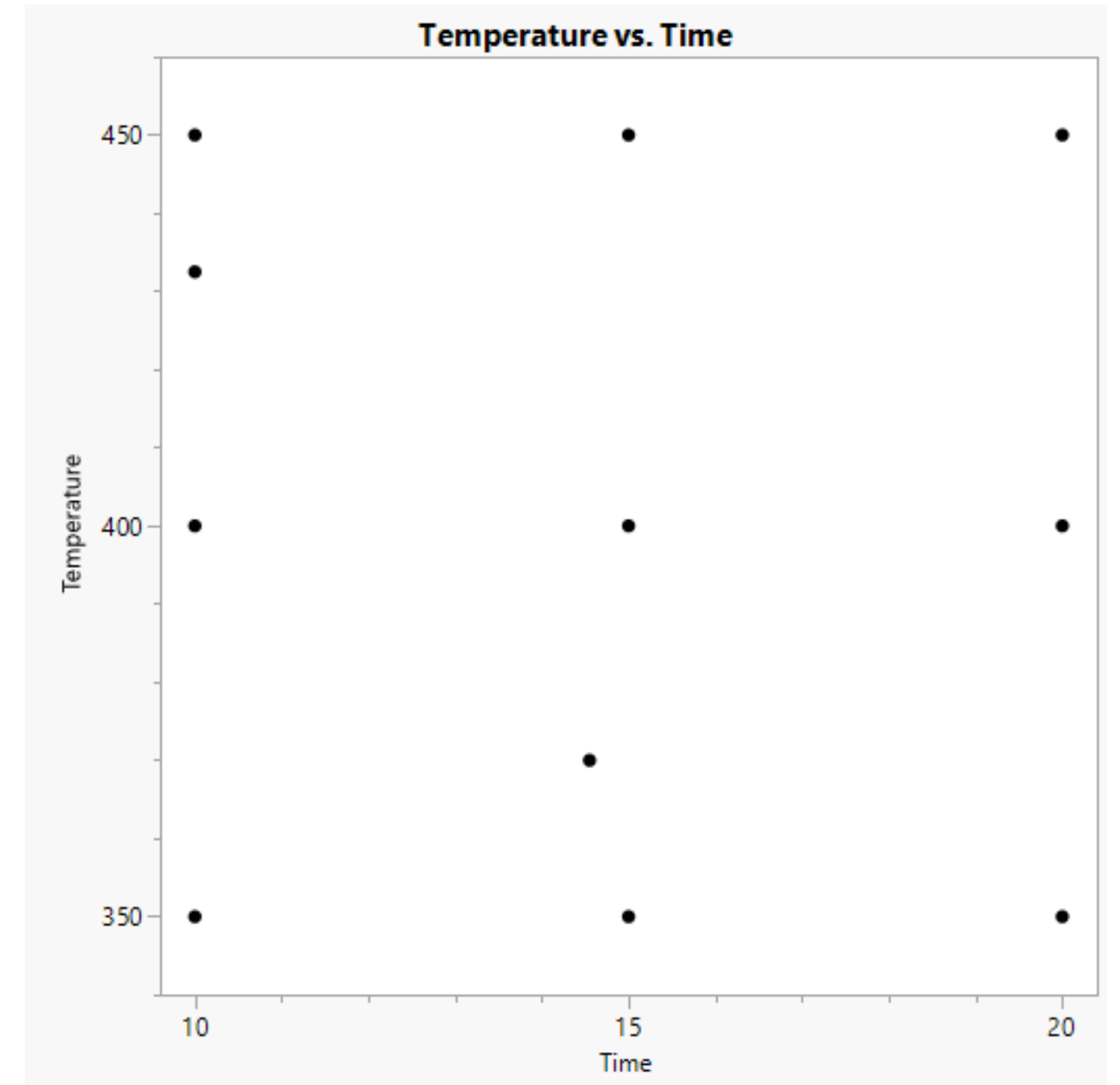
- **Temp:** 350 450

Discrete Numeric  
with 4 levels

- **Pizza Size:** 9, 12, 14, & 16

Categorical  
with 3 levels

- **Pizza Type:**
  - Cheese
  - Meats
  - Veggies



# 3 Different Factor Types

Lo-Lo Trials “Not DONE” & Hi-Hi trials “Burnt”

Continuous

- Time: 10 20

Continuous

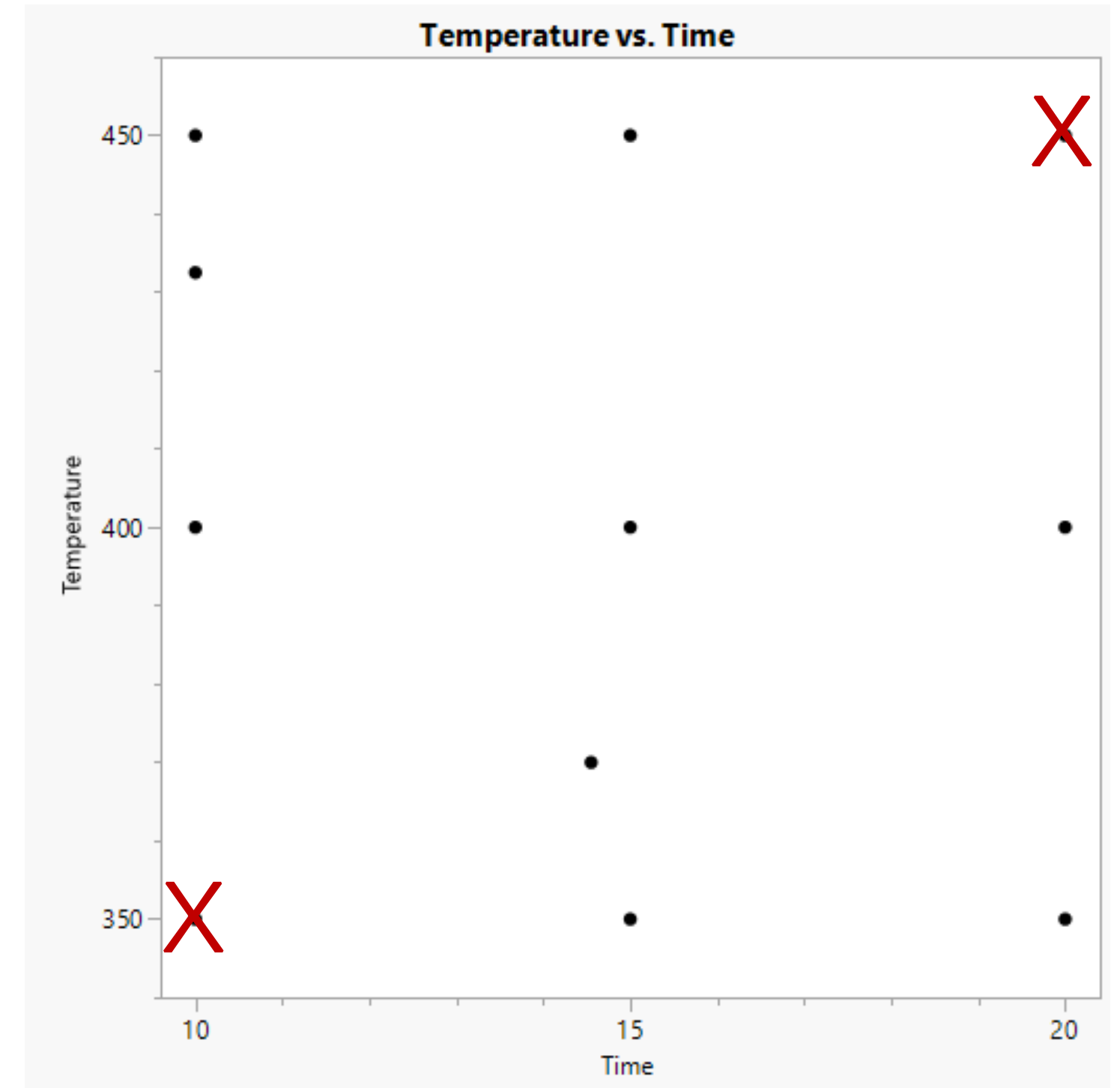
- Temp: 350 450

Discrete Numeric  
with 4 levels

- Pizza Size: 9, 12, 14, & 16

Categorical  
with 3 levels

- Pizza Type:
  - Cheese
  - Meats
  - Veggies



In this case 6-to-8 trials lost. Not enough support for original RSM model!



# Augment Working Trials Subject to Two Constraints

## Repair Broken Design for Pizza Process

Continuous

• **Time:** 10 20

Continuous

• **Temp:** 350 450

Discrete Numeric  
with 4 levels

• **Pizza Size:** 9, 12, 14, & 16

Categorical  
with 3 levels

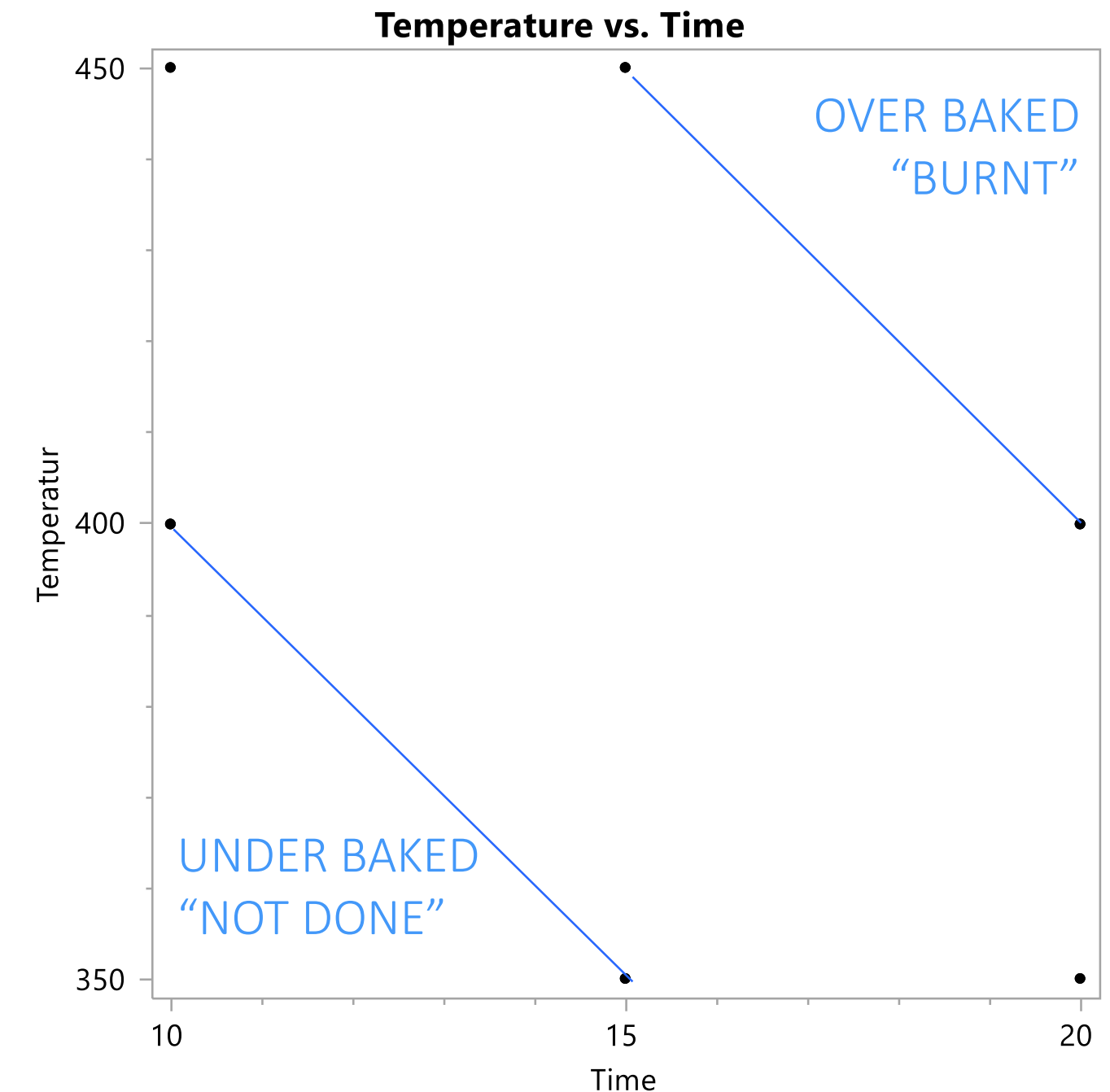
• **Pizza Type:**

- Cheese
- Meats
- Veggies

Hi + Hi = "Burnt"

Lo + Lo = "Not Done"

Graph Builder



# Repair Broken Design

## Steps for Using Augment Design Platform

1. Delete or exclude broken trials from data table
2. Follow this menu path: DOE → Augment Design → Choose Xs and Ys → OK
3. Check “Group new runs into a separate block.”

Generally, will want to block to see if any unknown factors have crept into the process.  
Blocking is a very inexpensive insurance policy.

4. Under Define Factor Constraints → Specify Linear Constraints → Enter Constraints

Constraints based on either subject matter expertise, or your best guess as to where you will avoid breaking the process again!

5. Click Augment button.
6. Choose total number of trials for repaired design. Default is 8 more than number of working trials.
7. Click Make Design button.

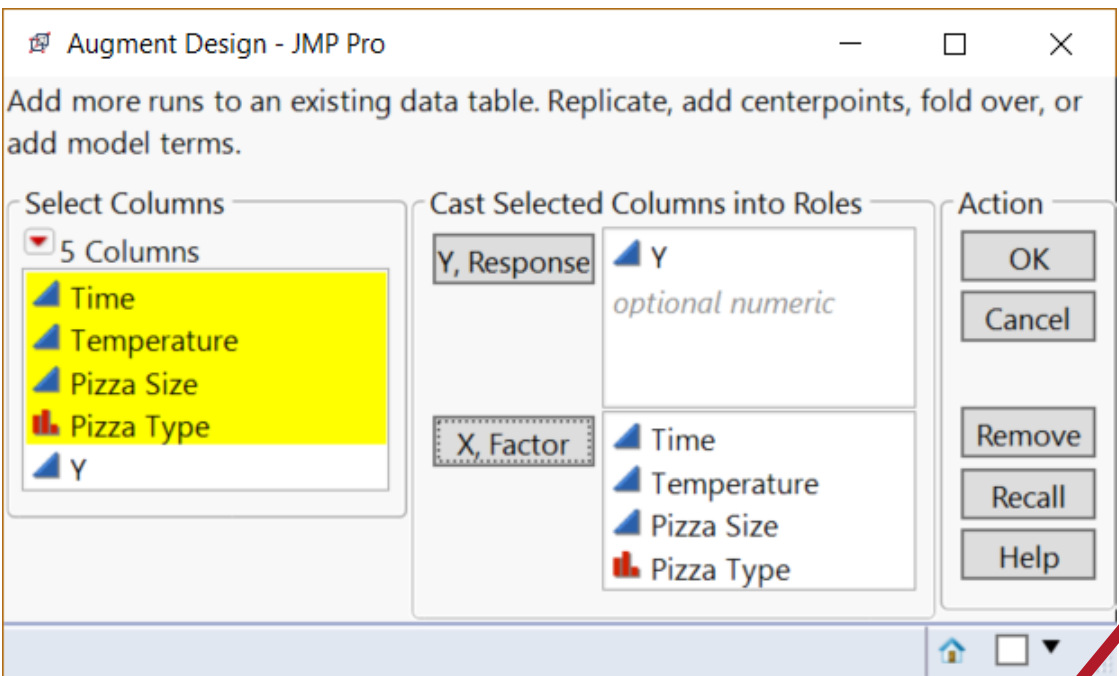
# Augment Design

## 3 Different Factor Types

## Plus 2 constraints

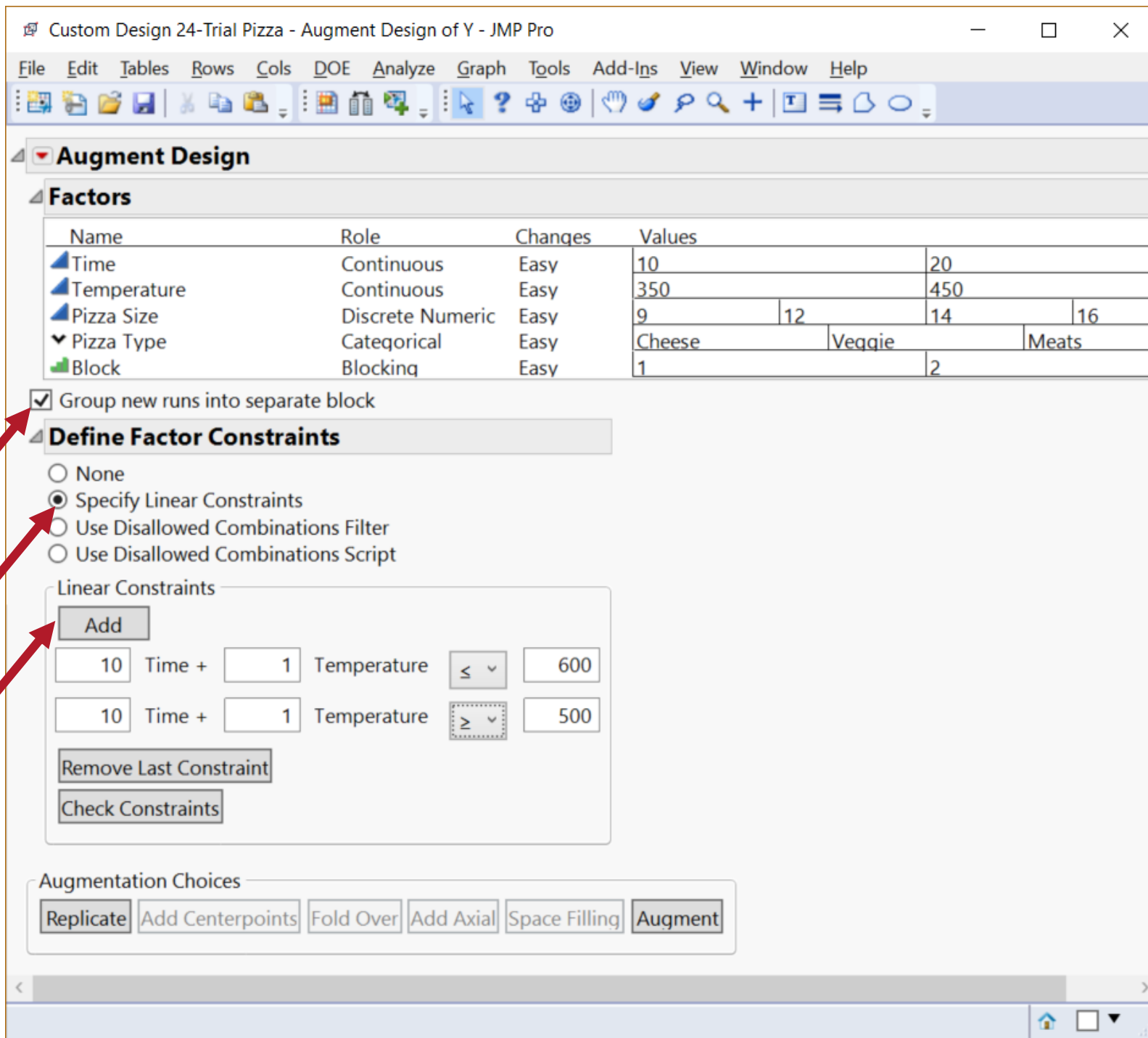
Repairing DOE for broken Pizza Process

	Time	Temperature	Pizza Size	Pizza Type	Y
1	15	450	9	Cheese	3
2	10	400	9	Meats	7
3	15	350	9	Meats	4
4	10	450	12	Meats	6
5	20	350	9	Veggie	3
6	15	400	12	Veggie	6
7	10	350	16	Meats	•
8	20	400	16	Meats	4
9	14.55	370	16	Cheese	3
10	20	450	16	Cheese	•
11	10	450	9	Veggie	1
12	20	350	16	Veggie	6
13	10	450	16	Veggie	4
14	15	400	12	Cheese	3
15	20	450	9	Meats	•
16	20	400	9	Cheese	5
17	20	350	14	Cheese	2
18	15	400	14	Veggie	6
19	20	450	12	Veggie	•
20	10	350	9	Cheese	•
21	15	450	14	Meats	3
22	10	432.5	14	Cheese	7
23	20	350	12	Meats	3
24	10	350	12	Veggie	•



Check “Group new runs into separate block.”

Select Specify Linear Constraints. Add two.

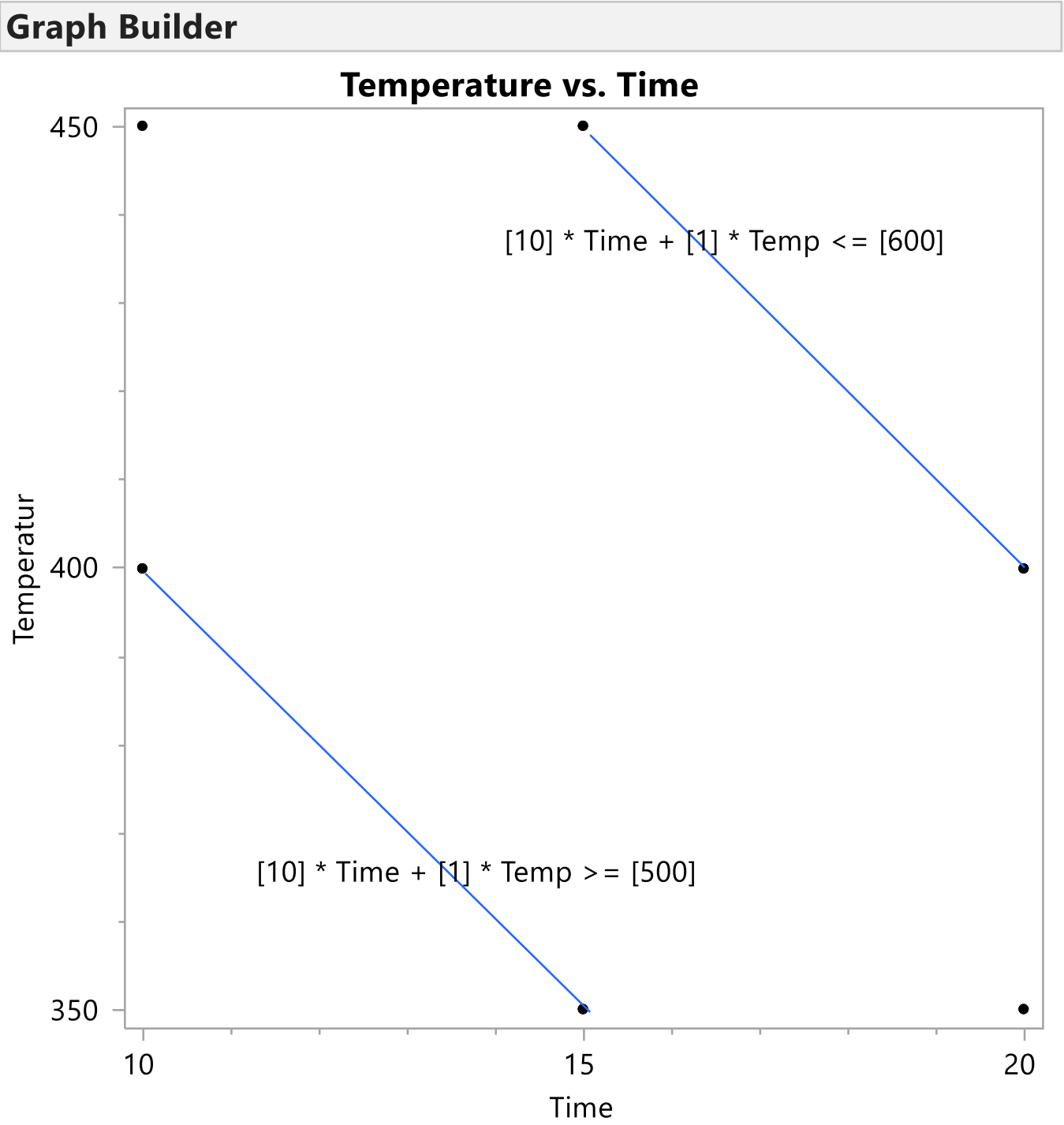


# Time & Temperature Inequality Constraints - Uncoded

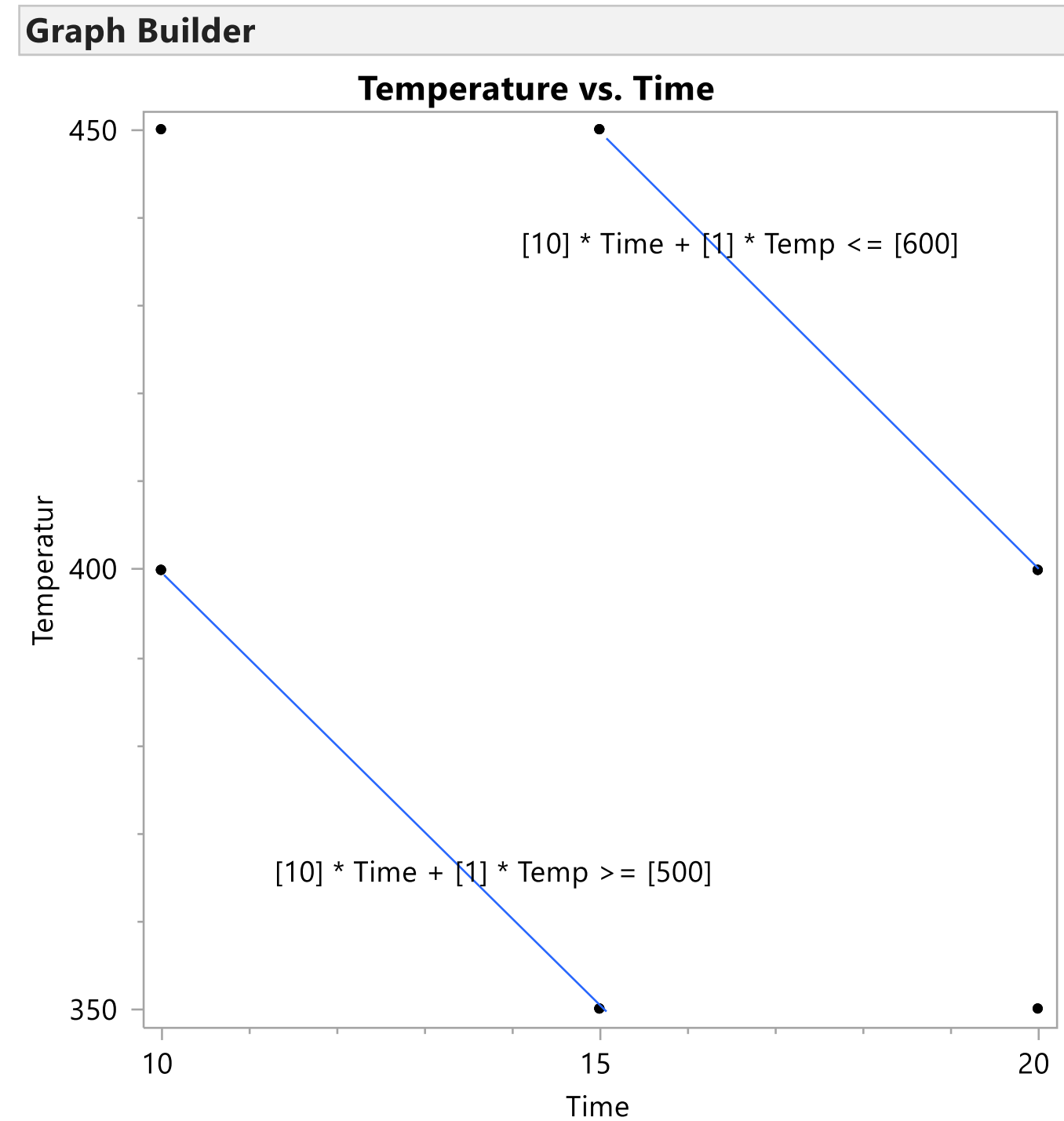
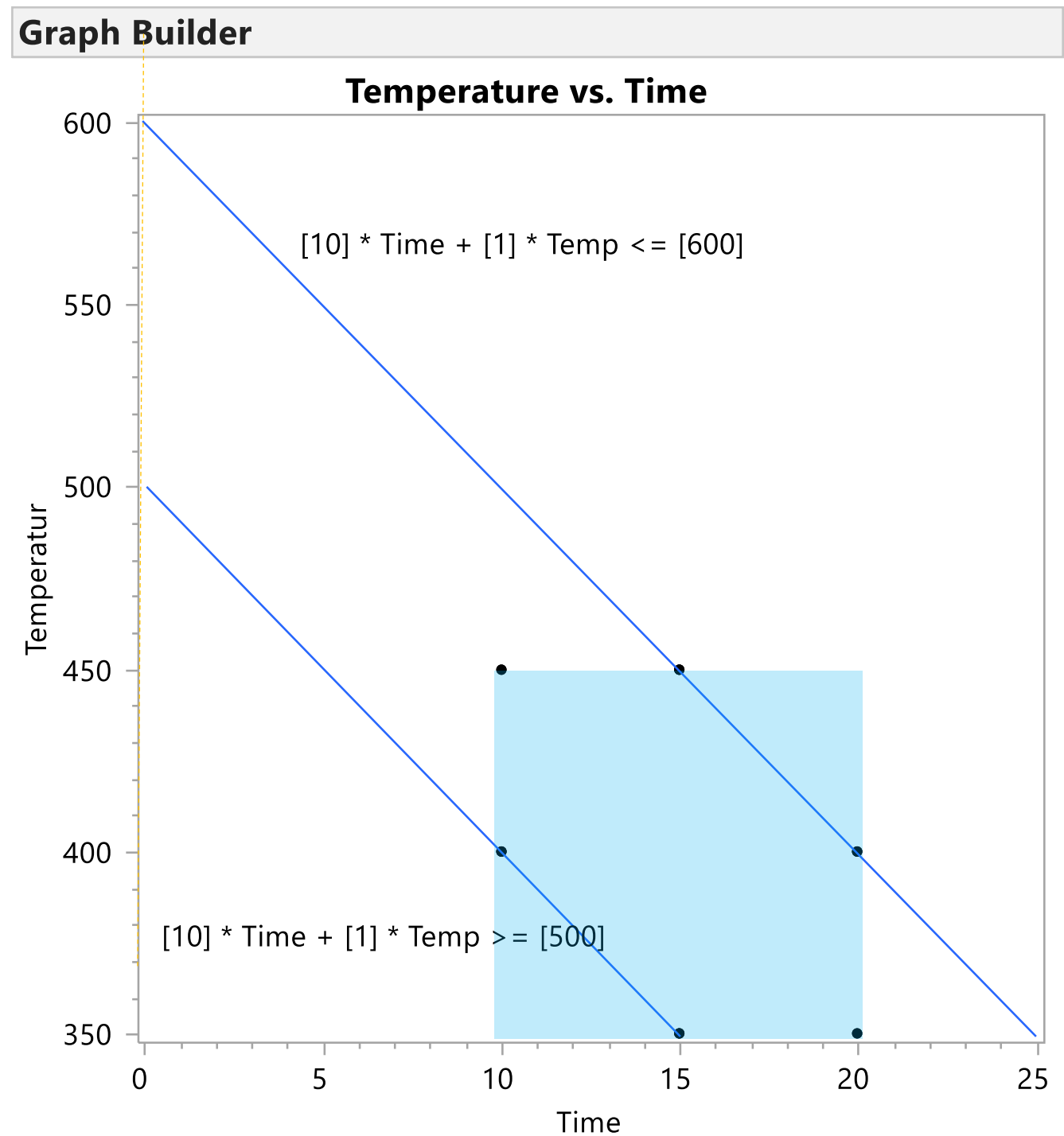
Define Factor Constraints

Add Constraint

10	Time +	1	Temperature	≤	600
10	Time +	1	Temperature	≥	500



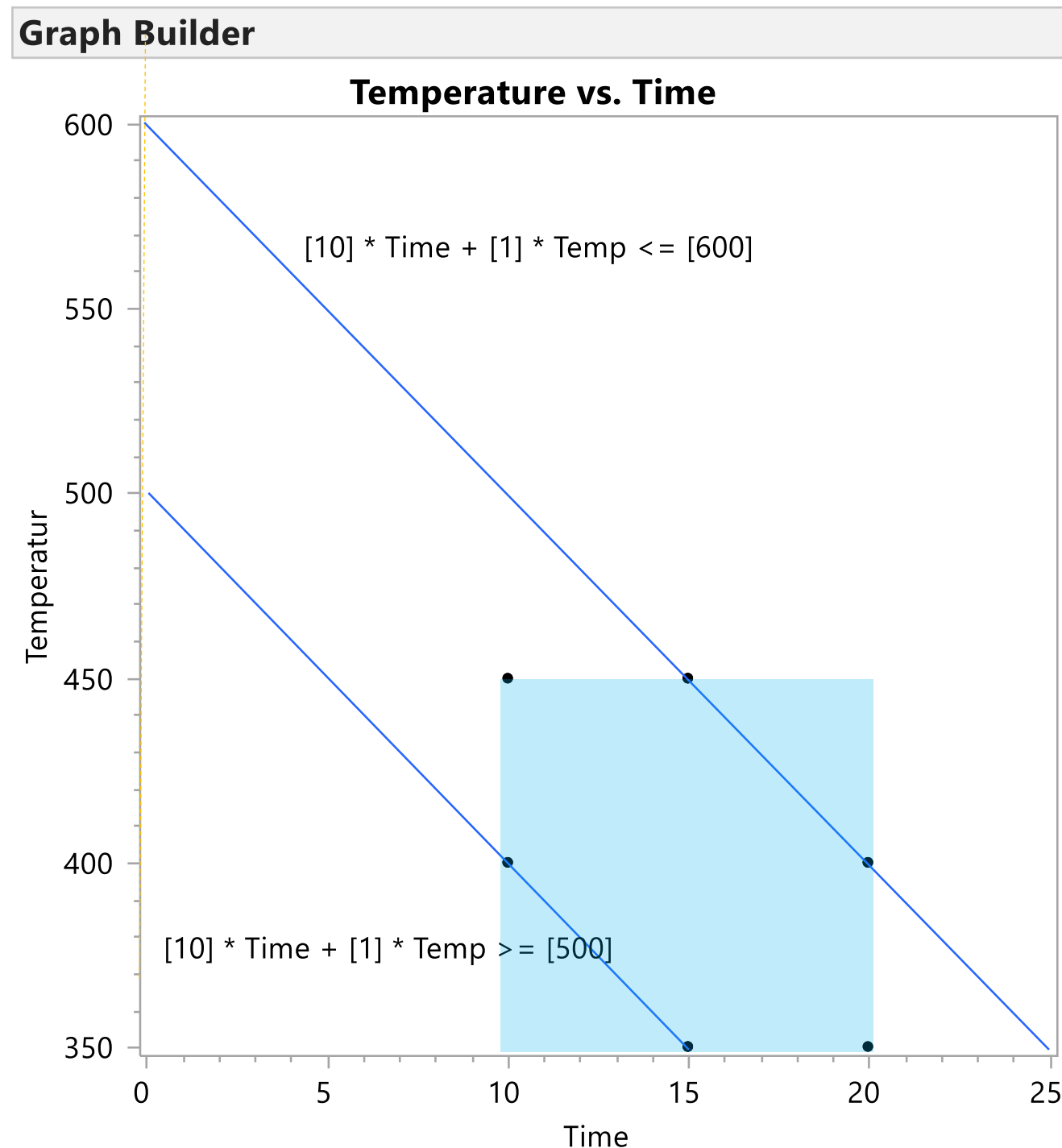
# Time & Temperature Inequality Constraints - Uncoded





# Time & Temperature Inequality Constraints - Uncoded

Slope =  $m$  = rise/run =  $-150/15$ ;  $m = -10$   
Intercept =  $b$  =  $y$  when  $x$  = zero;  $b = 600$



$$y = mx + b$$

$$\text{Temp} = m * \text{Time} + b$$

$$[1] * \text{Temp} = [-10] * \text{Time} + [600]$$

$$[10] * \text{Time} + [1] * \text{Temp} = [600]$$

$$[10] * \text{Time} + [1] * \text{Temp} \leq [600]$$

$$y = mx + b$$

$$\text{Temp} = m * \text{Time} + b$$

$$[1] * \text{Temp} = [-10] * \text{Time} + [500]$$

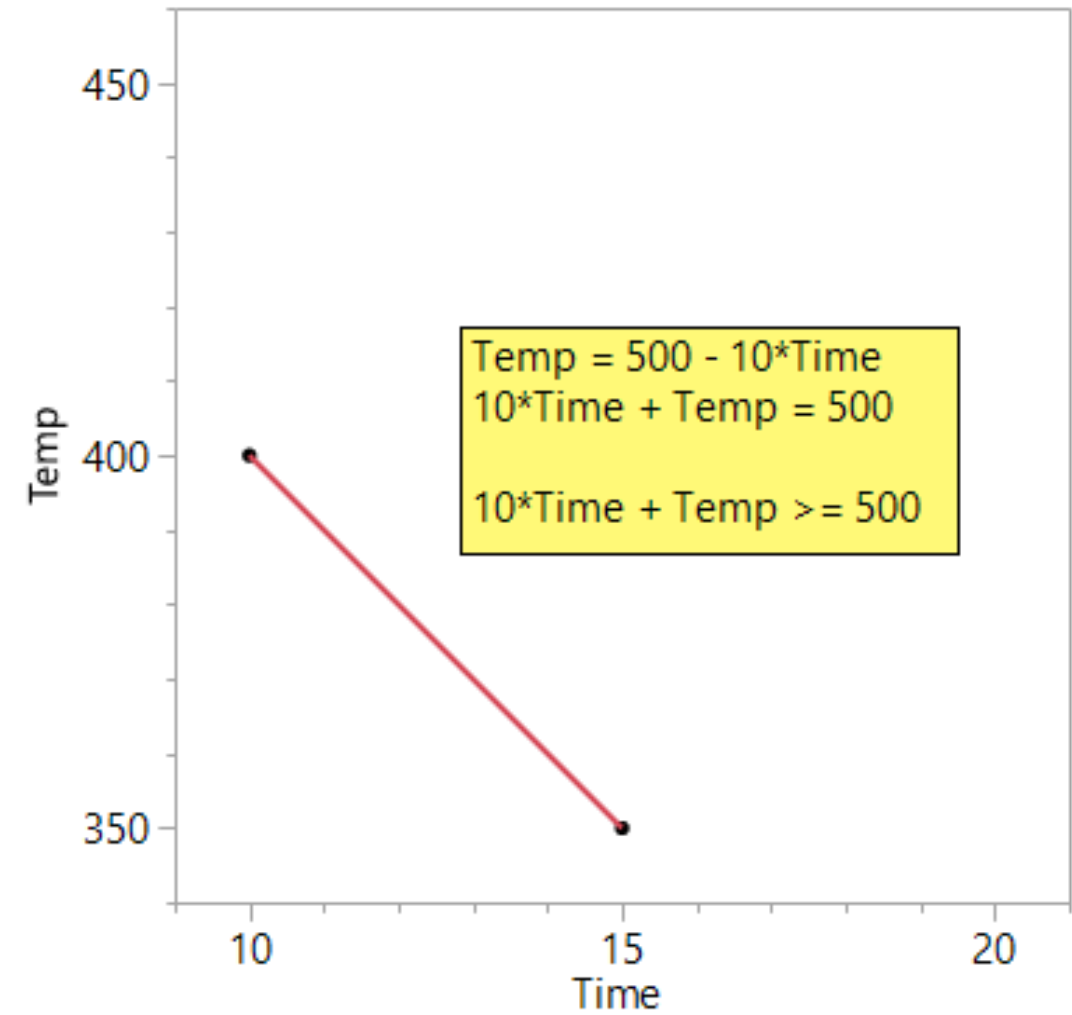
$$[10] * \text{Time} + [1] * \text{Temp} = [500]$$

$$[10] * \text{Time} + [1] * \text{Temp} \geq [500]$$

# Time & Temperature Inequality Constraints - Uncoded

	Time	Temp	Constraint Location
1	15	450	Upper
2	20	400	Upper
3	15	350	Lower
4	10	400	Lower

Bivariate Fit of Temp By Time Constraint Location=Lower



— Linear Fit

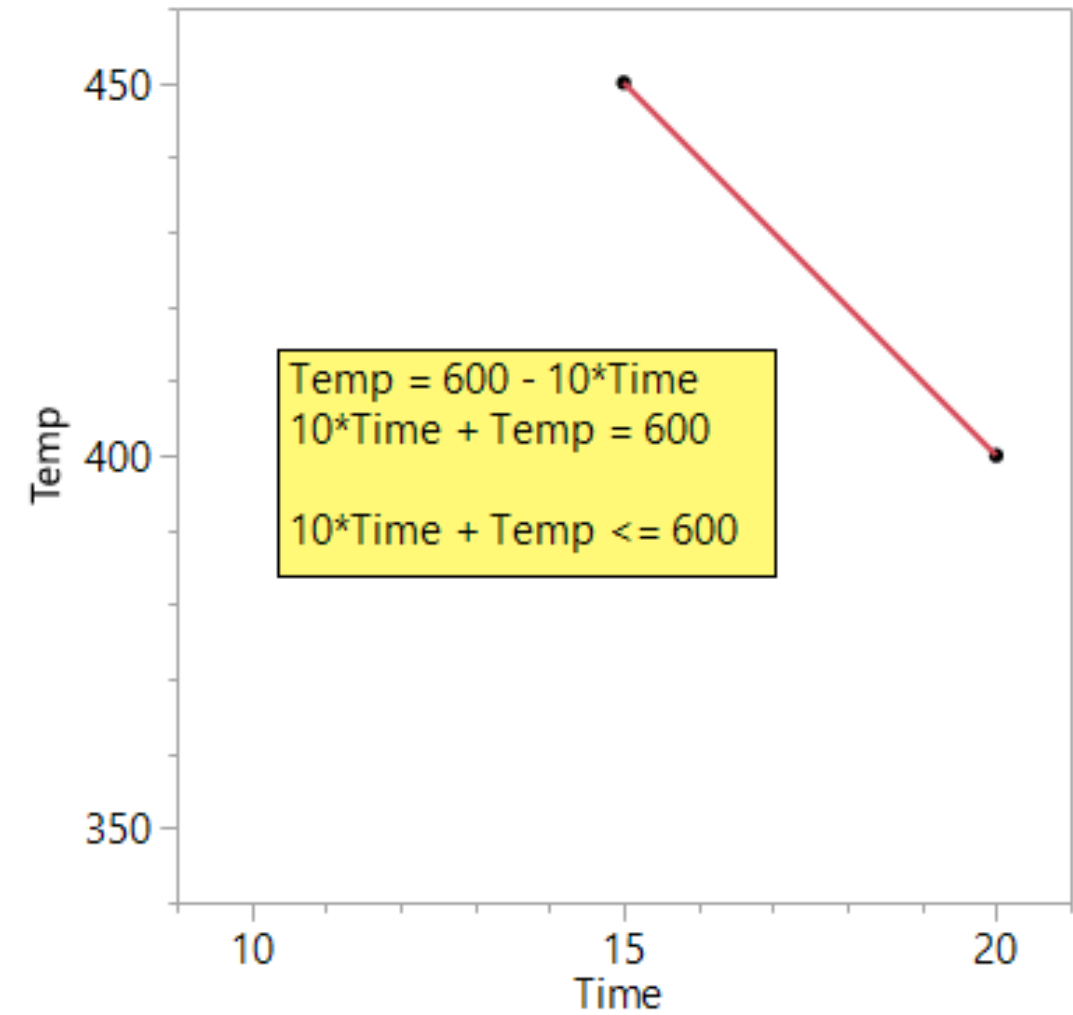
Linear Fit

Temp = 500 - 10\*Time

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	500	.	.	.
Time	-10	.	.	.

Bivariate Fit of Temp By Time Constraint Location=Upper



— Linear Fit

Linear Fit

Temp = 600 - 10\*Time

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	600	.	.	.
Time	-10	.	.	.

# Augment Design

## 3 Different Factor Types

### Plus 2 constraints

# Repairing DOE for broken Pizza Process

Custom Design 24-Trial Pizza - Augment Design of Y - JMP Pro

File Edit Tables Rows Cols DOE Analyze Graph Tools Add-Ins View Window Help

**Augment Design**

**Factors**

Name	Role	Changes	Values			
Time	Continuous	Easy	10	20		
Temperature	Continuous	Easy	350	450		
Pizza Size	Discrete Numeric	Easy	9	12	14	16
Pizza Type	Categorical	Easy	Cheese	Veggie	Meats	
Block	Blocking	Easy	1	2		

☒ Group new runs into separate block

**Define Factor Constraints**

☐ None  
☒ Specify Linear Constraints  
☐ Use Disallowed Combinations Filter  
☐ Use Disallowed Combinations Script

Linear Constraints

Add

10 Time + 1 Temperature ≤ 600

10 Time + 1 Temperature ≥ 500

Remove Last Constraint

Check Constraints

**Model**

Model

Main Effects

Interactions

RSM

Cross

Powers

Remove Term

Name	Estimability
Intercept	Necessary
Time	Necessary
Temperature	Necessary
Pizza Size	Necessary
Pizza Size*Pizza Size	Necessary
Pizza Type	Necessary
Time*Time	Necessary
Time*Temperature	Necessary

Alias Terms

Factor Design

Run	Time	Temperature	Pizza Size	Pizza Type	Block
1	15	450	9	Cheese	1
2	10	400	9	Meats	1
3	15	350	9	Meats	1
4	10	450	12	Meats	1
5	20	350	9	Veggie	1
6	15	400	12	Veggie	1
7	20	400	16	Meats	1
8	14.55	370	16	Cheese	1
9	10	450	9	Veggie	1
10	20	350	16	Veggie	1
11	10	450	16	Veggie	1
12	15	400	12	Cheese	1
13	20	400	9	Cheese	1
14	20	350	14	Cheese	1
15	15	400	14	Veggie	1
16	15	450	14	Meats	1
17	10	432.5	14	Cheese	1
18	20	350	12	Meats	1

Design Generation

Enter Number of Runs (counting 18 included runs):

26

Make Design

Default is number of existing trials plus eight.

Default is number  
of existing trials  
plus eight.

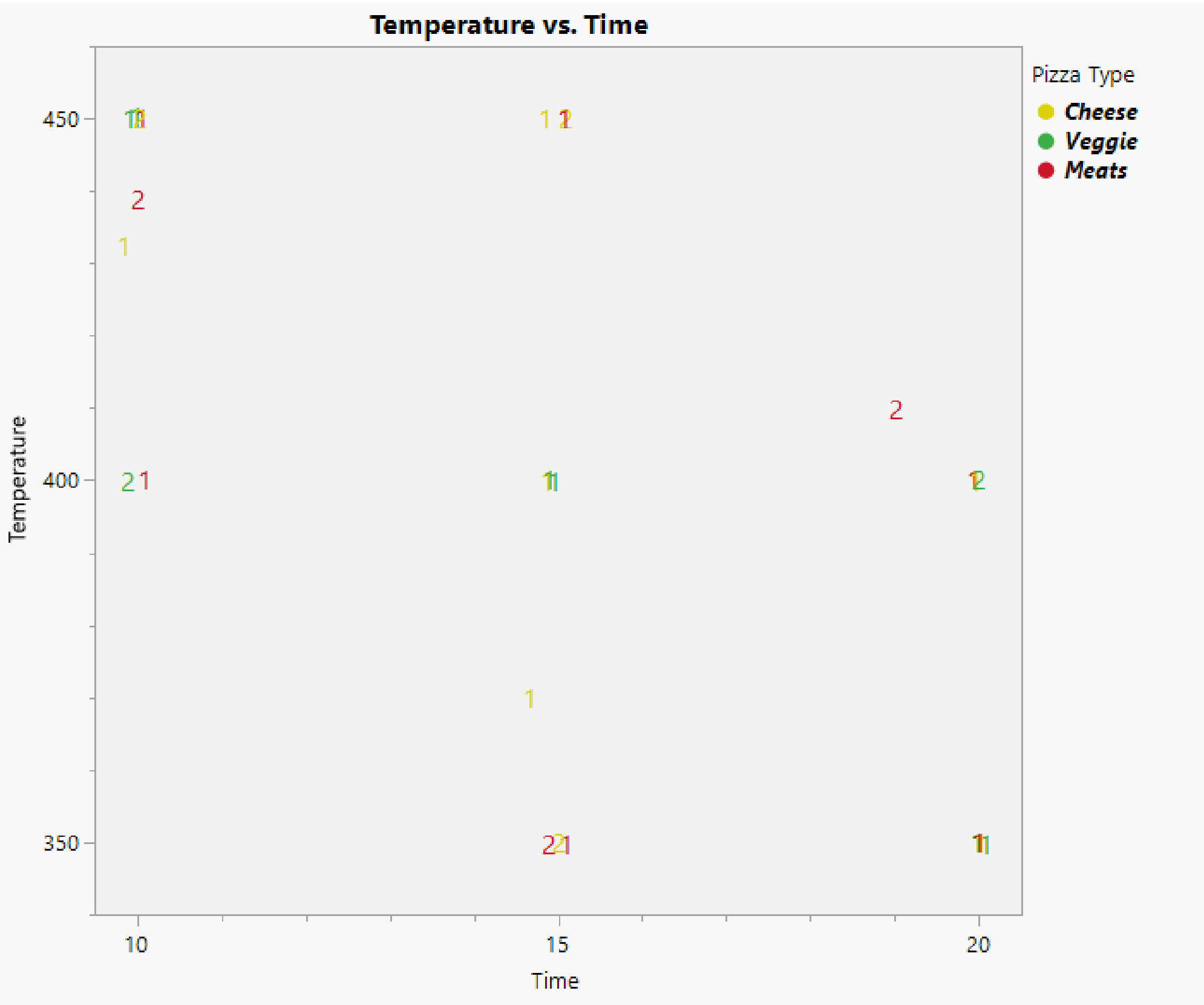
# Augment Design

## 3 Different Factor Types

## Plus 2 constraints

Repairing DOE for broken Pizza Process

	Time	Temperature	Pizza Size	Pizza Type	Block	Y
	20	450	16	Cheese	1	7
				Meats	2	
				Veggie		
	10	350	9			1
1	15	450	9	Cheese	1	3
2	10	400	9	Meats	1	7
3	15	350	9	Meats	1	4
4	10	450	12	Meats	1	6
5	20	350	9	Veggie	1	3
6	15	400	12	Veggie	1	6
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18	20	350	12	Meats	1	3
19	15	450	16	Cheese	2	•
20	20	400	12	Veggie	2	•
21	19	410	9	Meats	2	•
22	10	450	9	Cheese	2	•
23	15	350	16	Meats	2	•
24	10	439	16	Meats	2	•
25	10	400	12	Veggie	2	•
26	15	350	9	Cheese	2	•



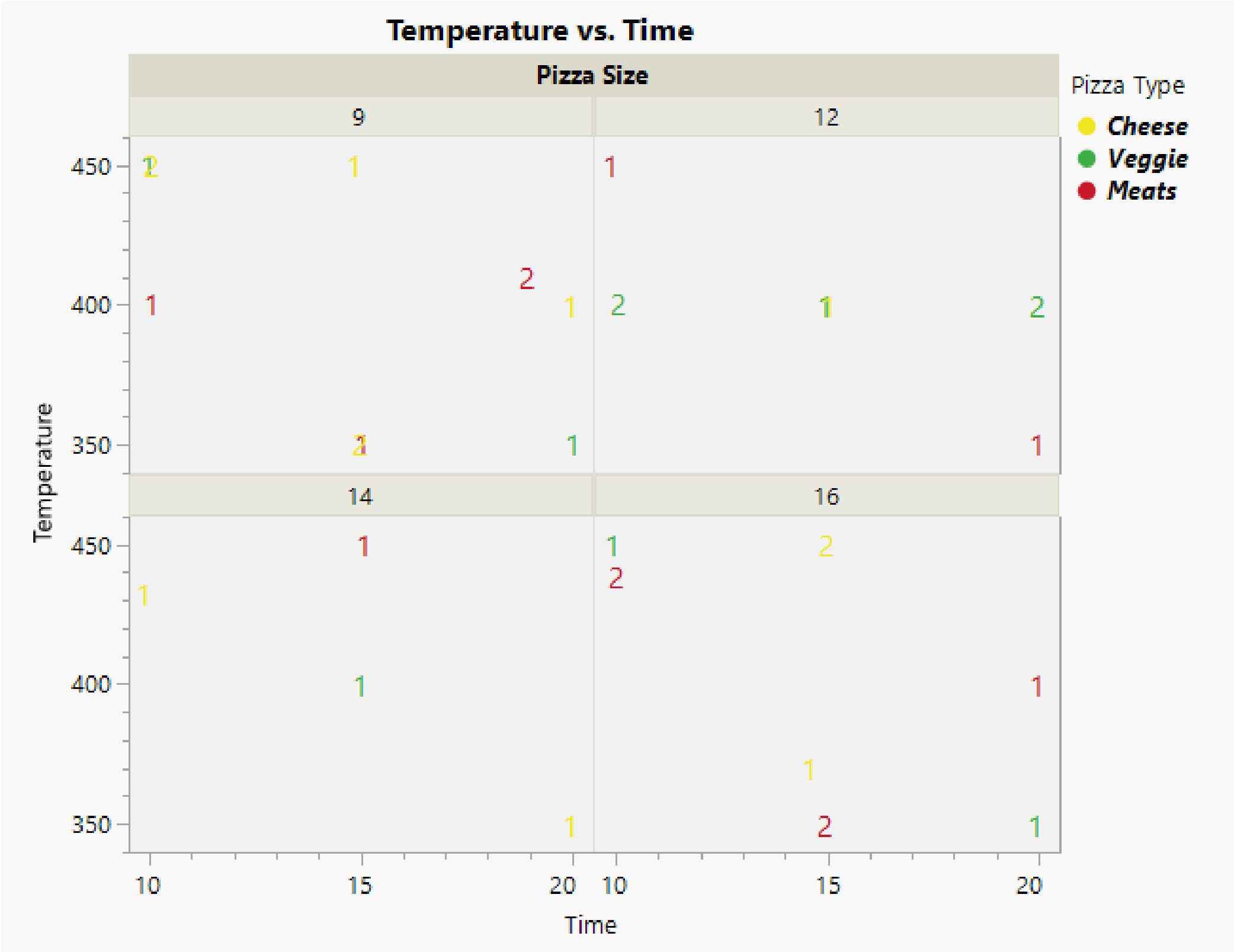
# Augment Design

## 3 Different Factor Types

## Plus 2 constraints

Repairing DOE for broken Pizza Process

	Time	Temperature	Pizza Size	Pizza Type	Block	Y
	20	450	16	Cheese	1	7
				Meats	2	
				Veggie		
	10	350	9			1
1	15	450	9	Cheese	1	3
2	10	400	9	Meats	1	7
3	15	350	9	Meats	1	4
4	10	450	12	Meats	1	6
5	20	350	9	Veggie	1	3
6	15	400	12	Veggie	1	6
7	20	400	16	Meats	1	4
8	14.55	370	16	Cheese	1	3
9	10	450	9	Veggie	1	1
10	20	350	16	Veggie	1	6
11	10	450	16	Veggie	1	4
12	15	400	12	Cheese	1	3
13	20	400	9	Cheese	1	5
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15	15	400	14	Veggie	1	6
16	15	450	14	Meats	1	3
17	10	433	14	Cheese	1	7
18	20	350	12	Meats	1	3
19	15	450	16	Cheese	2	•
20	20	400	12	Veggie	2	•
21	19	410	9	Meats	2	•
22	10	450	9	Cheese	2	•
23	15	350	16	Meats	2	•
24	10	439	16	Meats	2	•
25	10	400	12	Veggie	2	•
26	15	350	9	Cheese	2	•

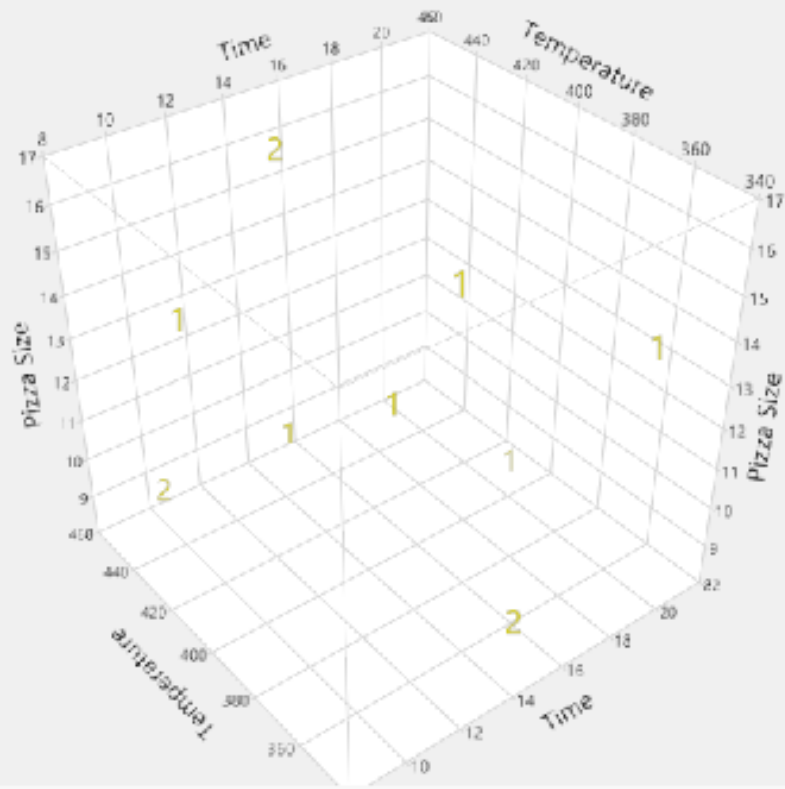




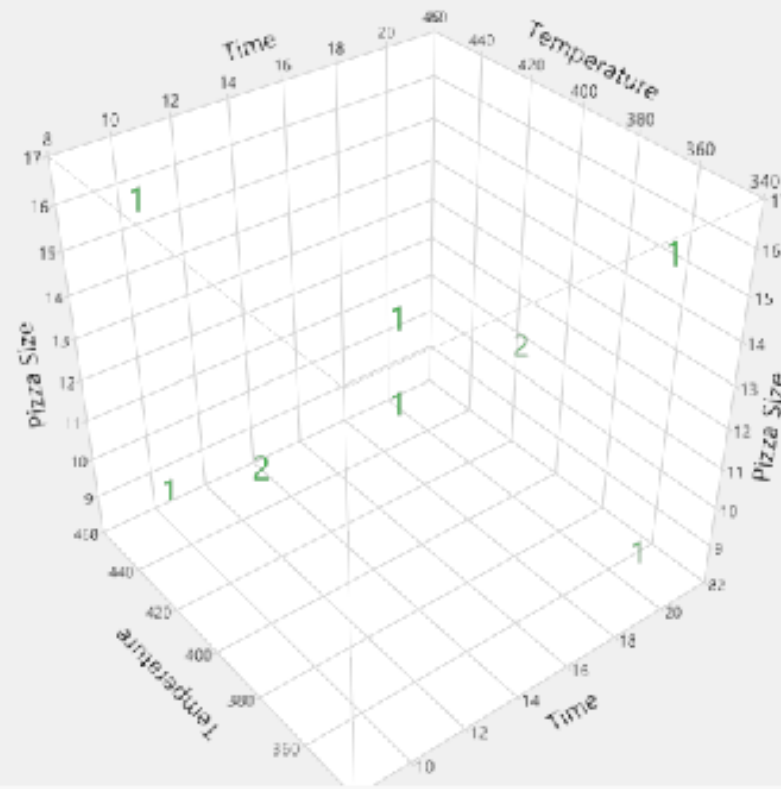
# 3-D Scatterplots; Time, Temperature, & Pizza Size by Pizza Type

## Bottom Row looking down on Time and Temperature axes

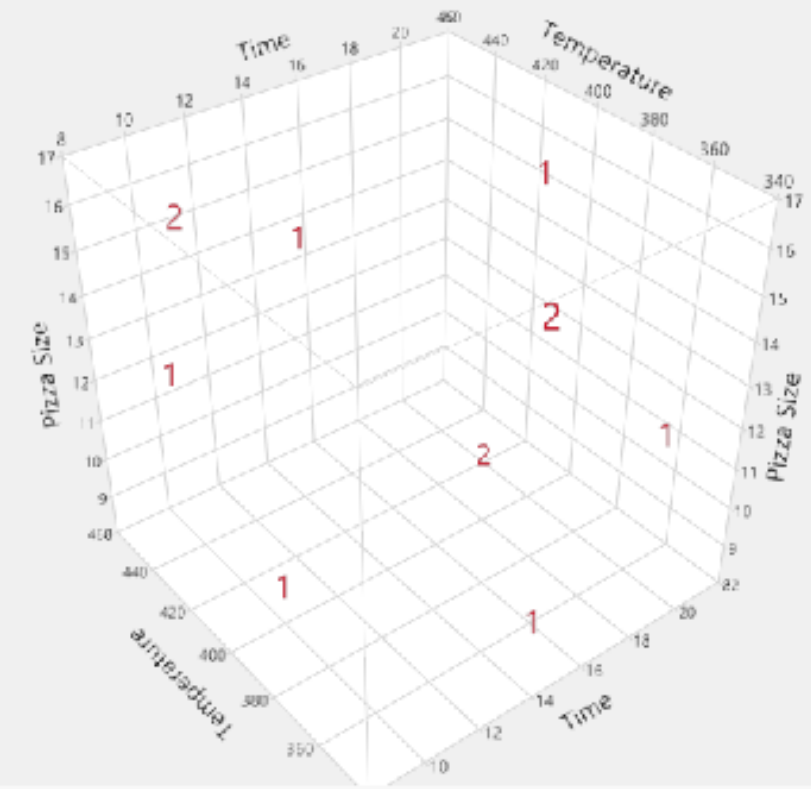
Scatterplot 3D Pizza Type=Cheese



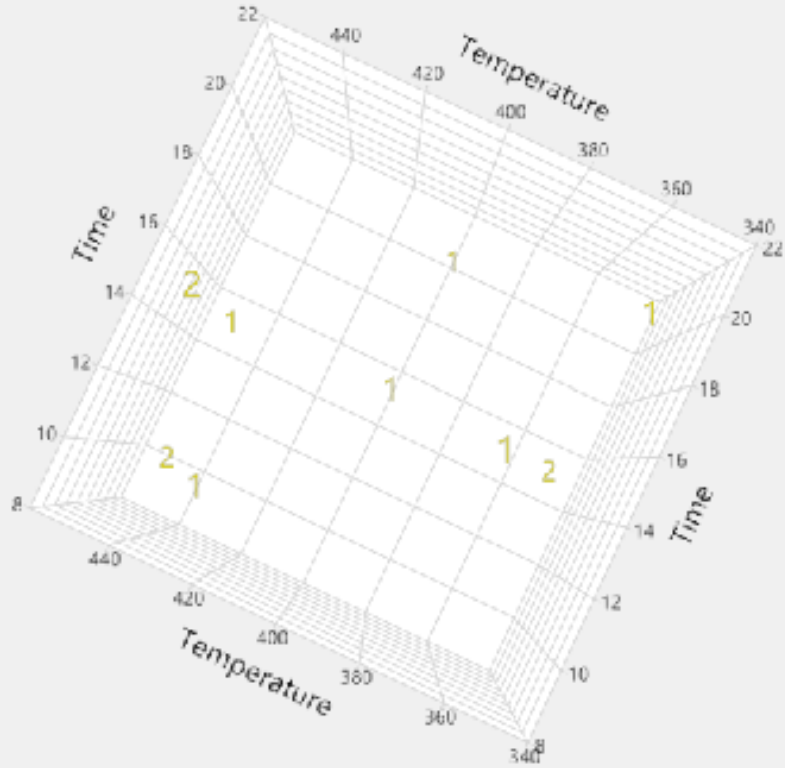
Scatterplot 3D Pizza Type=Veggie



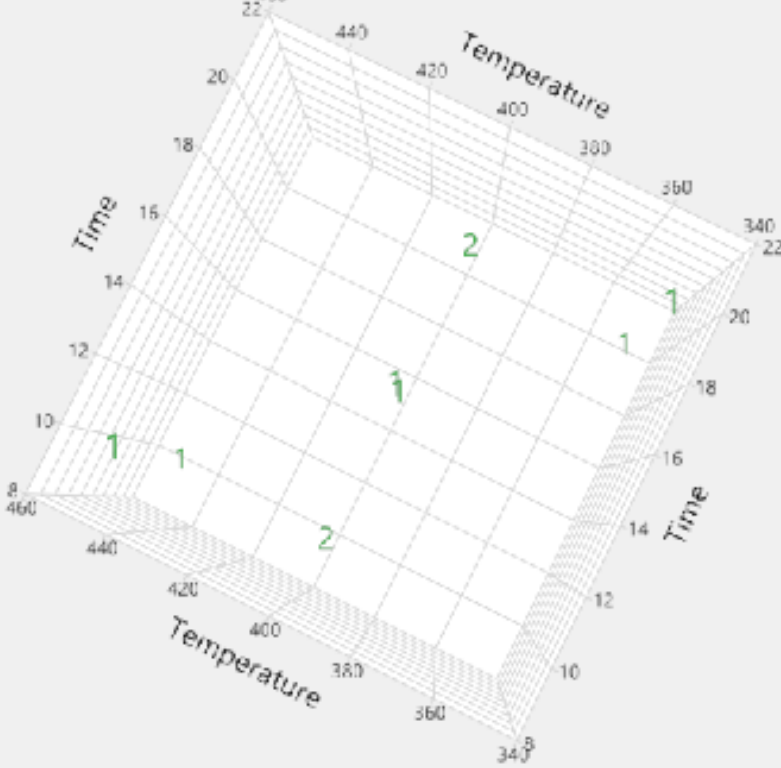
Scatterplot 3D Pizza Type=Meats



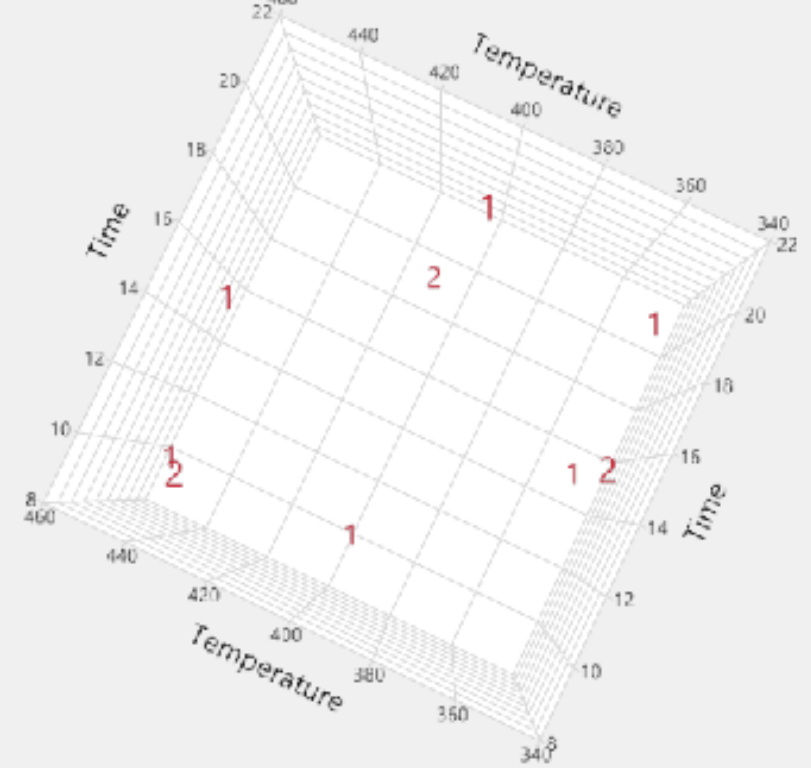
Scatterplot 3D Pizza Type=Cheese



Scatterplot 3D Pizza Type=Veggie



Scatterplot 3D Pizza Type=Meats



# Time & Temperature Inequality Constraints - Uncoded

Slope =  $m$  = rise/run =  $-150/15$ ;  $m = -10$   
Intercept =  $b$  =  $y$  when  $x$  = zero;  $b = 625$

$$y = mx + b$$

$$\text{Temp} = m * \text{Time} + b$$

$$[1] * \text{Temp} = [-10] * \text{Time} + [625]$$

$$[10] * \text{Time} + [1] * \text{Temp} = [625]$$

$$[10] * \text{Time} + [1] * \text{Temp} \leq [625]$$

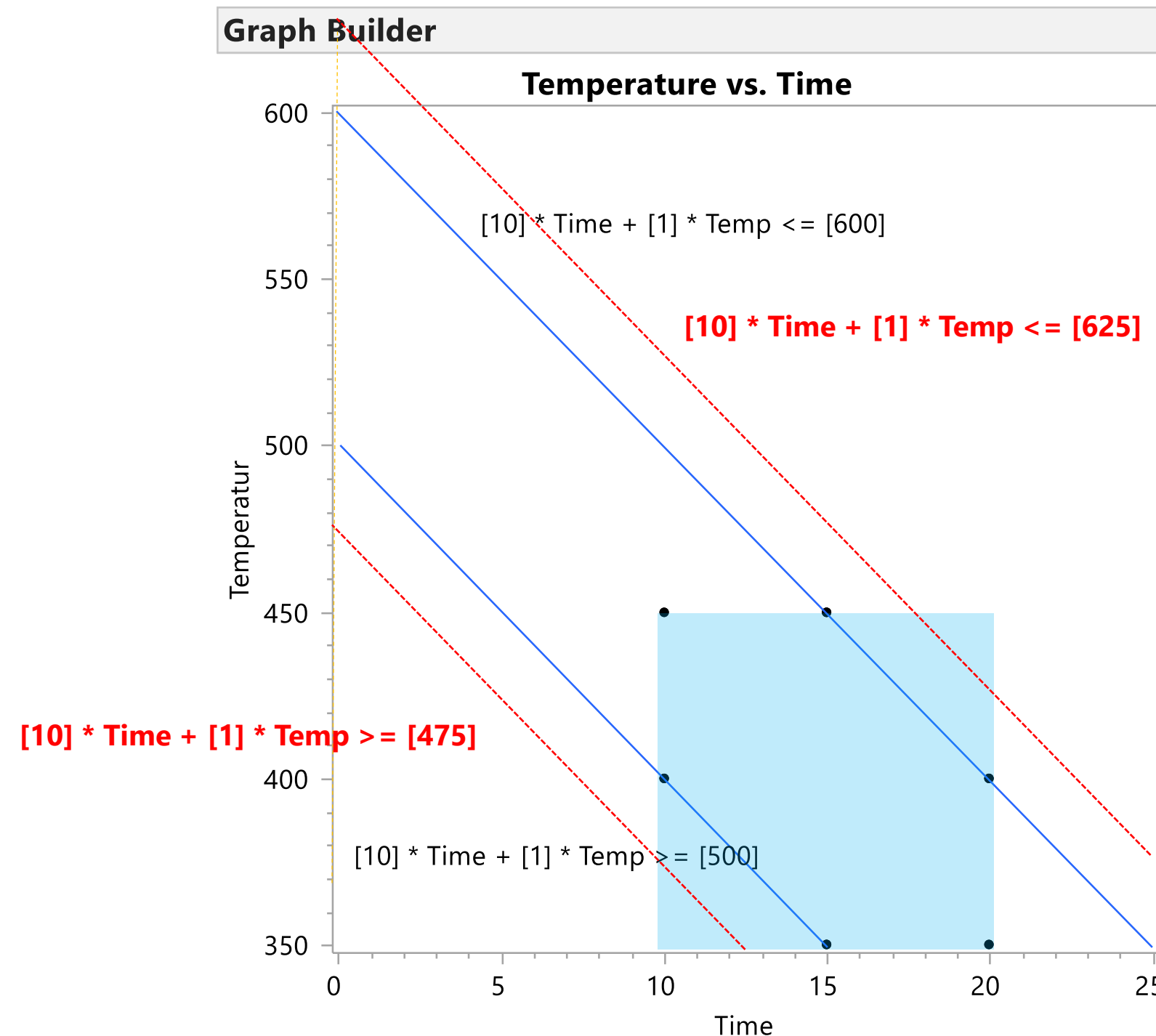
$$y = mx + b$$

$$\text{Temp} = m * \text{Time} + b$$

$$[1] * \text{Temp} = [-10] * \text{Time} + [475]$$

$$[10] * \text{Time} + [1] * \text{Temp} = [475]$$

$$[10] * \text{Time} + [1] * \text{Temp} \geq [475]$$

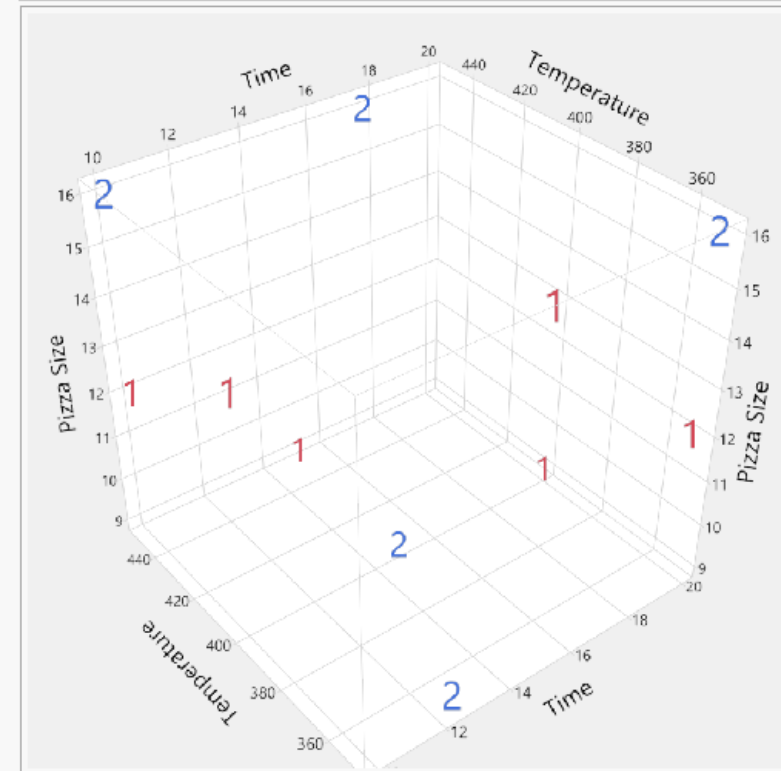


Alternate “Less Conservative” constraints in red. Talk to SMEs. Have data points on blue lines that work!

# 3-D Scatterplots; Time, Temperature, & Pizza Size by Pizza Type

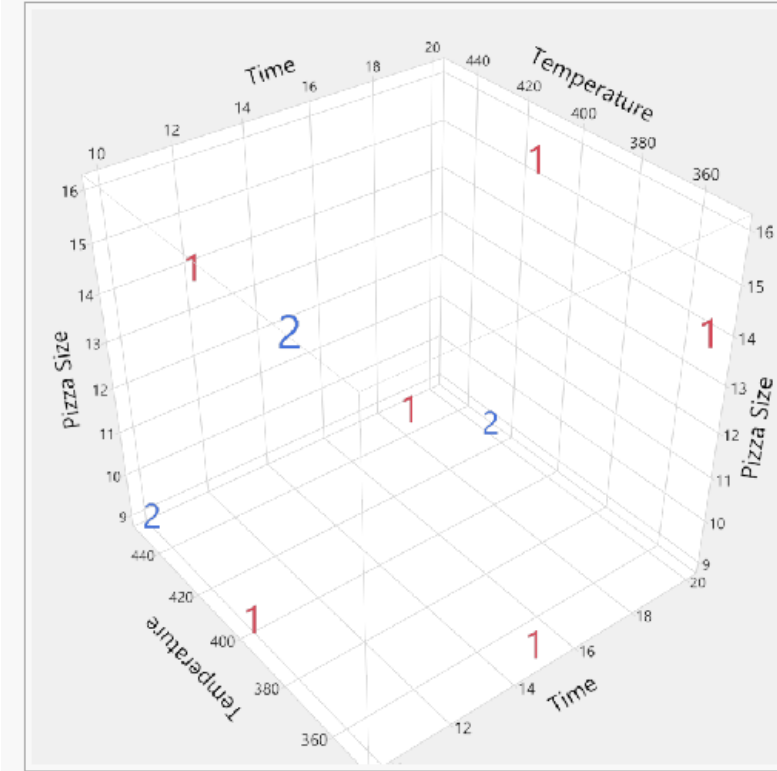
## Bottom Row looking down on Time and Temperature axes

Scatterplot 3D Pizza Type=Cheese



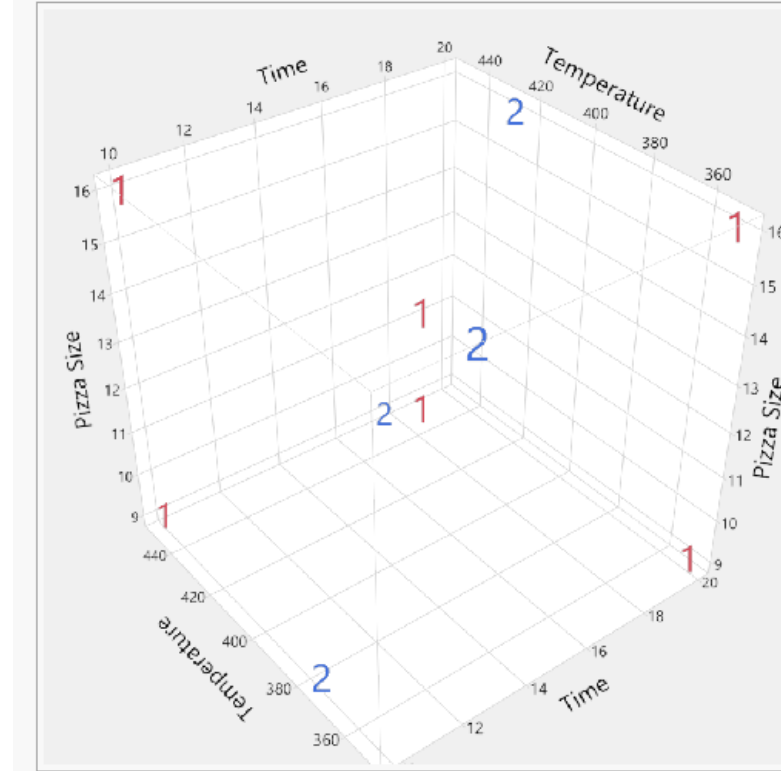
Data Columns Time Temperature Pizza Size

Scatterplot 3D Pizza Type=Veggie



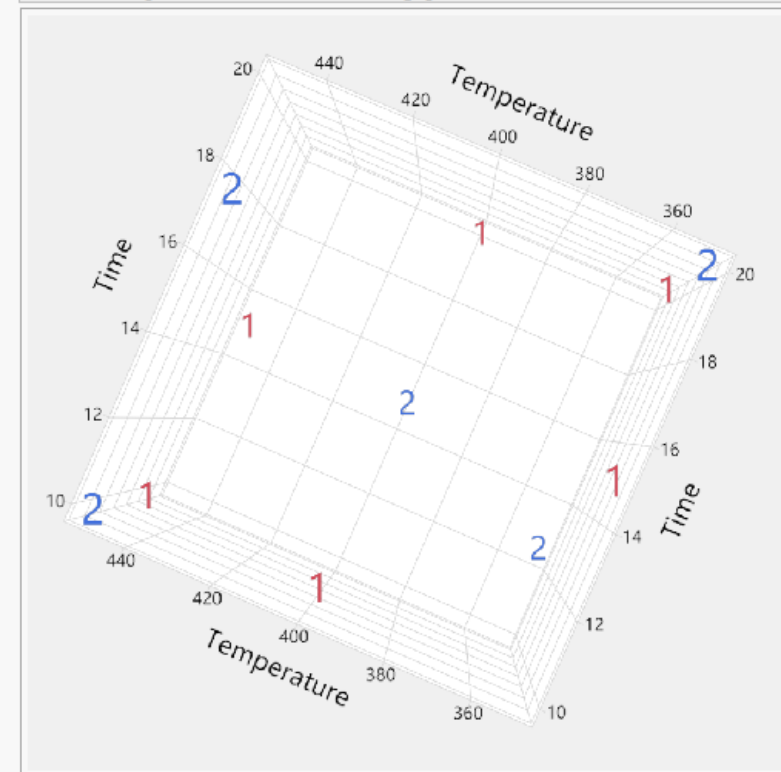
Data Columns Time Temperature Pizza Size

Scatterplot 3D Pizza Type=Meats



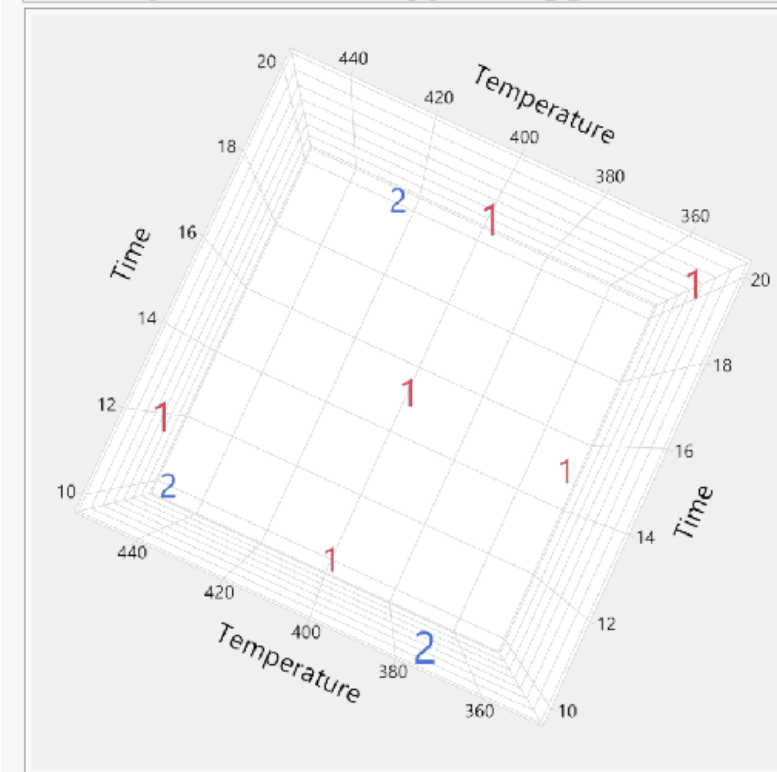
Data Columns Time Temperature Pizza Size

Scatterplot 3D Pizza Type=Cheese



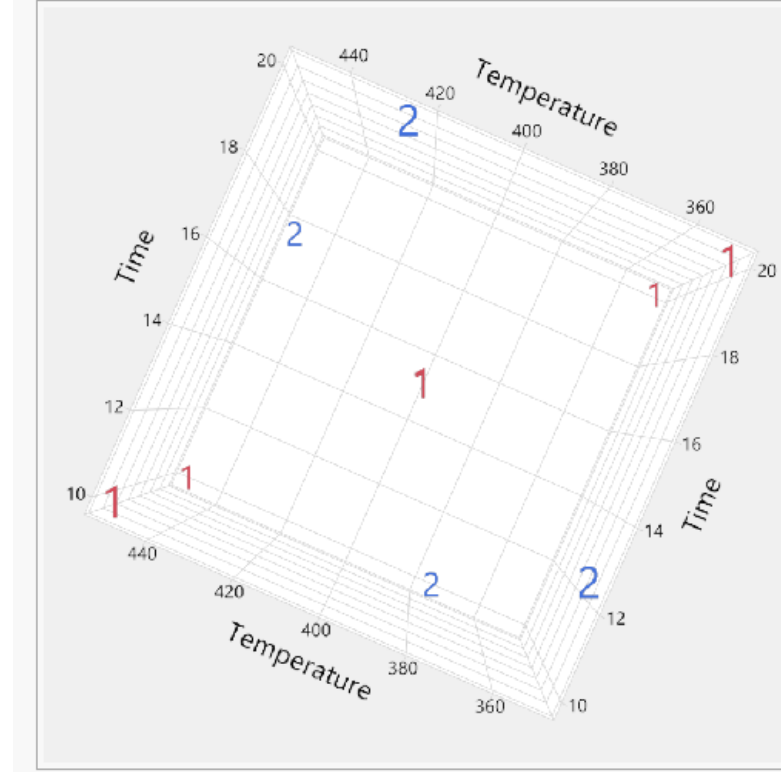
Data Columns Time Temperature Pizza Size

Scatterplot 3D Pizza Type=Veggie



Data Columns Time Temperature Pizza Size

Scatterplot 3D Pizza Type=Meats



Data Columns Time Temperature Pizza Size

# Outline

- Factor ranges – Timid vs. Bold
  - Be as bold as you can without changing the “physical mechanism”
  - Boldness helps to overcome need for large sample size
- Use subject matter expertise to set ranges boldly
  - DOE cannot blindly be slapped on a process ignorant of the science
- Still too bold? Somehow break design?
  - Create custom design but find out some trials don't work
  - Use **Augment Design with Constraints** to repair the design

