

# Sealing Ring Testing and Characterization

## Final Presentation



### Team 1:

Tawakalt Akintola  
Richard Edgerton  
Erin Flagler  
Emilio Kenny  
Kenneth McCloud

**Sponsored by:** Cummins, Inc.  
**Advised by:** Dr. Oates and Dr. Alvi



# Outline



- Introduction
- Design Process
- Testing Procedure and Results
- Interface: How It Works
- Project Management
- What We've Learned
- Conclusion
- Future Work



# Introduction



- Cummins, Inc. designs and manufactures high-performance engines
- For a competitive, efficient product:
  - Leak-free joints
  - Sealing rings
- Sealing rings
  - Fit between mating parts
  - Resistant to harsh conditions
  - Wide variety of applications

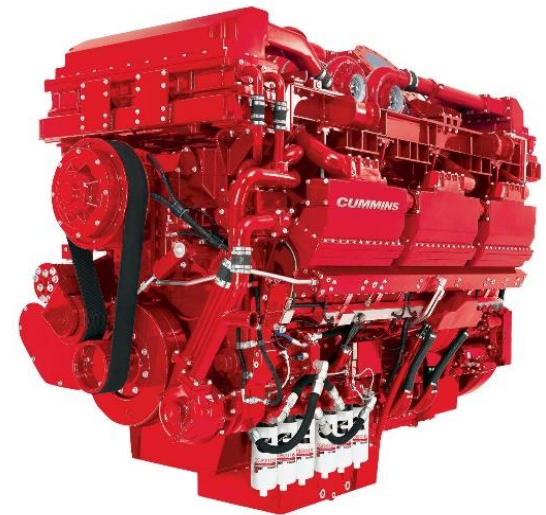


Figure 1: An engine produced by Cummins, Inc. [1]



# Background

- Sealing rings vary in size and shape
- Common material used is fluoroelastomeric rubber
- Current selection process involves
  - Finite element analysis
  - Time
  - Money

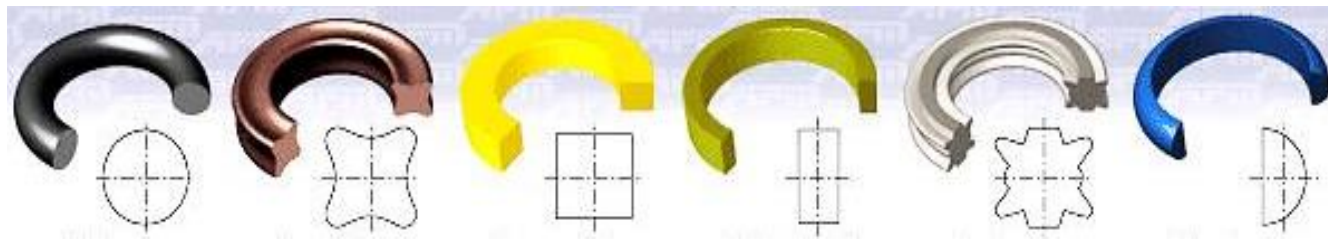


Figure 2: Examples of sealing ring cross-section variety [2]

# Motivation



- Current sealing ring selection process:
  - Complicated FEA
  - Time Consuming
  - Costly
- We aim to ***reduce the time, cost, and effort*** of selecting an appropriate sealing ring for application by identifying relationships between component properties



# Objectives



- Test selected sealing rings in static face-seal compression
  - Load
  - Displacement
  - Sealing pressure
- Define relationships between cross-section geometry, sealing pressure, and percent crush
  - Circular
  - Rectangular
  - Irregular
- Create a user interface to access data

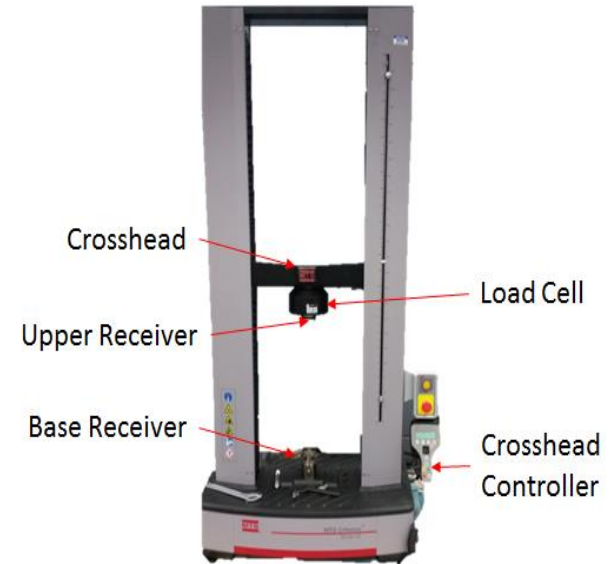


Figure 3: MTS Machine



Figure 4: Irregular Seals -  
Diamond and Pseudo-Diamond  
Cross-sections



# Test Fixture Prototypes

- Design Considerations
  - Rigidity
  - Groove plate interchangeability
  - Simplicity
  - Ease of use with existing equipment

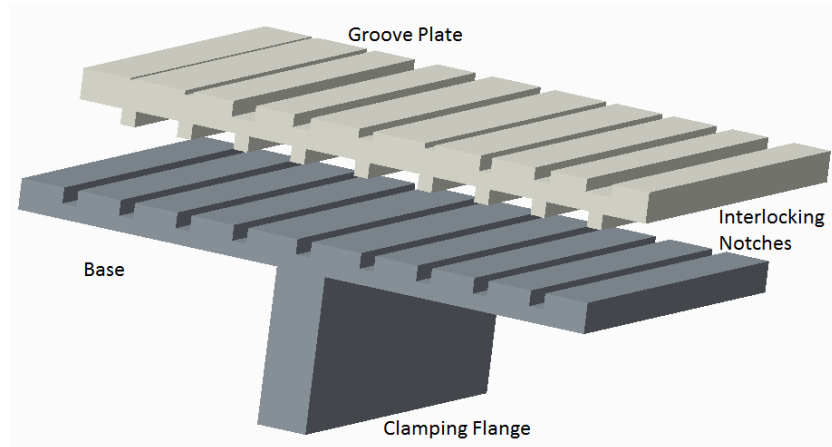


Figure 5: Centered Test Position

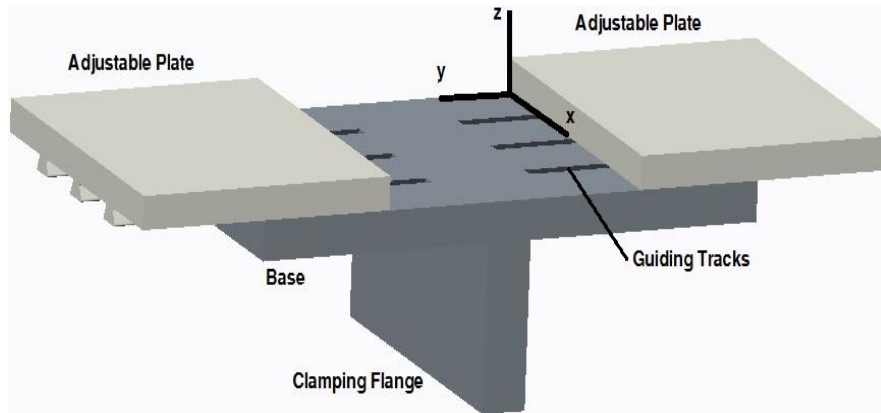


Figure 6: Adjustable Groove Plates

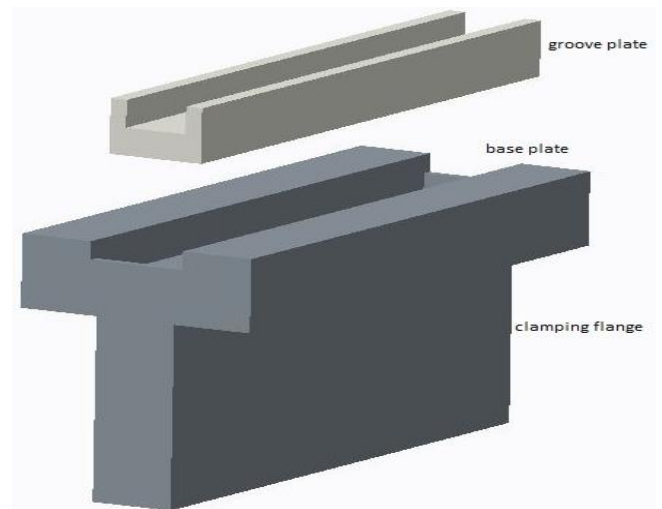


Figure 7: Individual Groove Plates

# Final Test Fixture Design



- Material: Aluminum 6061
  - Surface hardness
  - Machinability
  - Low cost

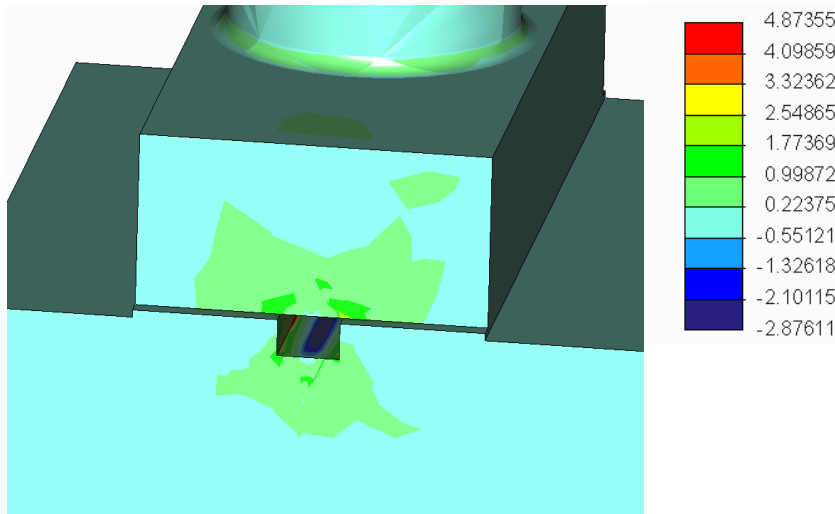


Figure 8: FEM Results (MPa)

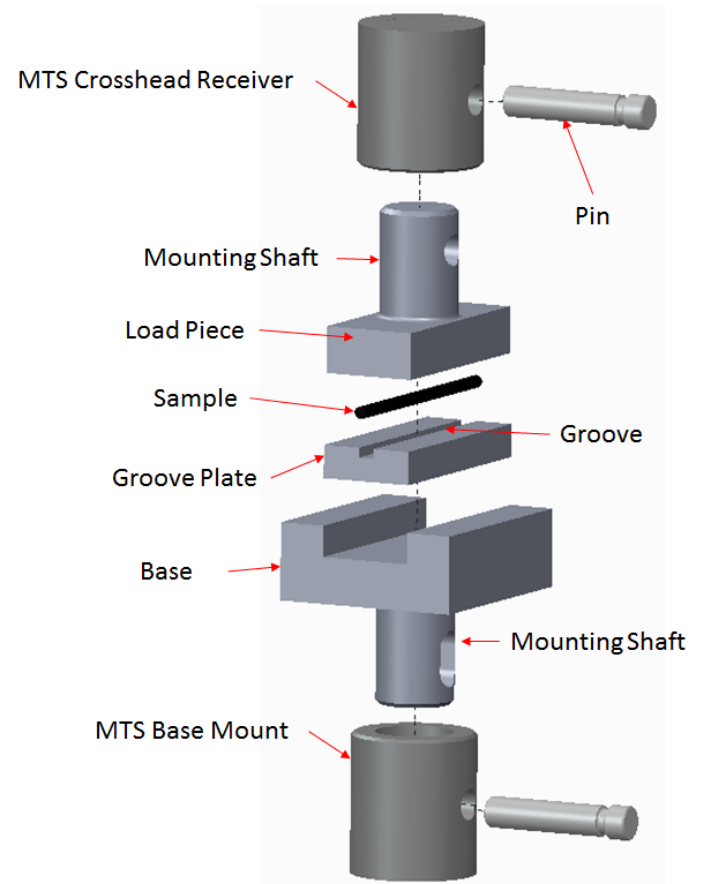


Figure 9: Mounted Test Fixture





# Test Procedure



- Mount sample and place film
- Input displacement corresponding to percent crush
  - 5%, 10%...40%
- Reset crosshead and exchange film
- Data Collection
  - Sealing pressure measured with Fujifilm Prescale
  - 3 sensitivities used (Low, Super Low, Ultra Low)

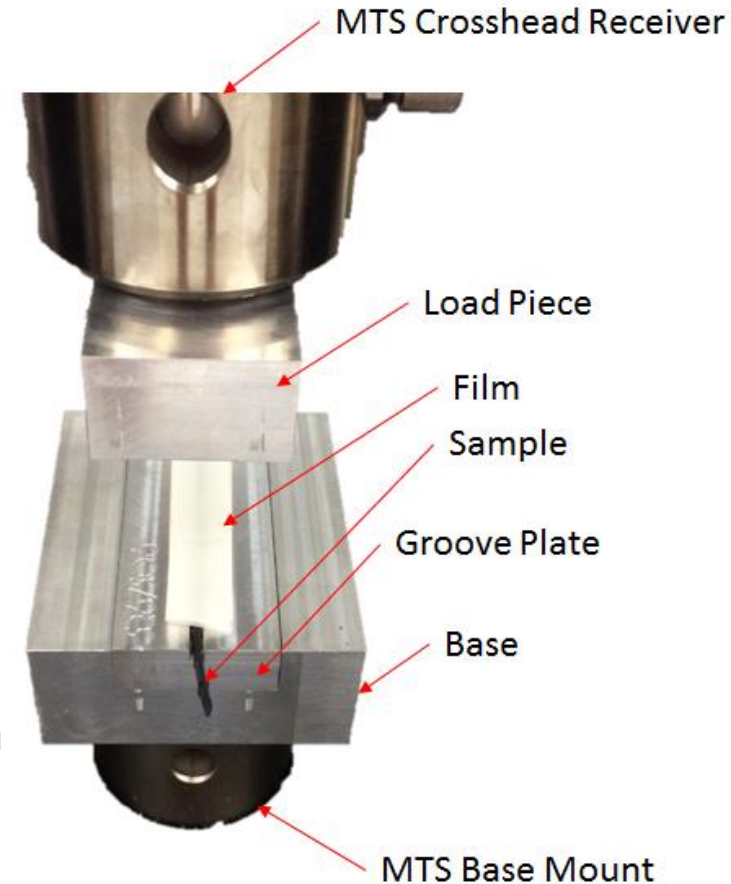


Figure 10: Test Fixture



# Testing Results



- Leaks occur when fluid pressure exceeds contact pressure
- Retrieved maximum continuous pressure of each seal

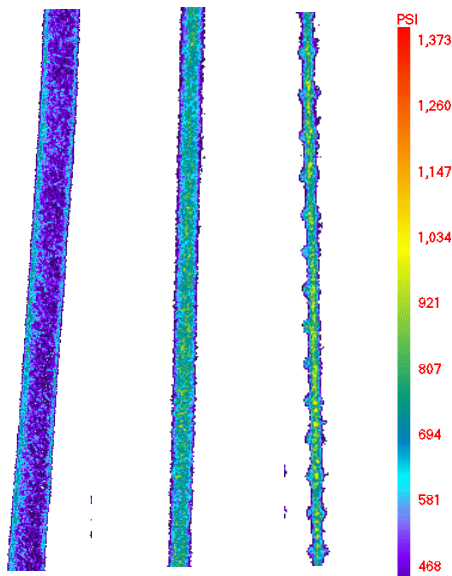


Figure 11: Sample Fujifilm

Circular Combined Exponential

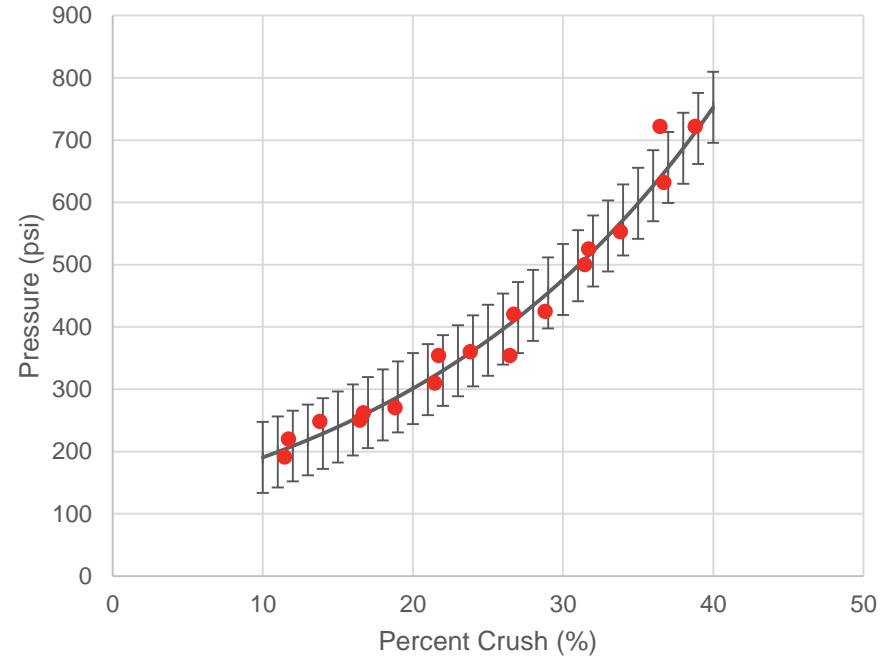


Figure 12: Sample Data



# Correlations



- Correlations between percent crush and pressure were found
- Cross-sectional scaling does not affect sealing pressures at the same percent crush

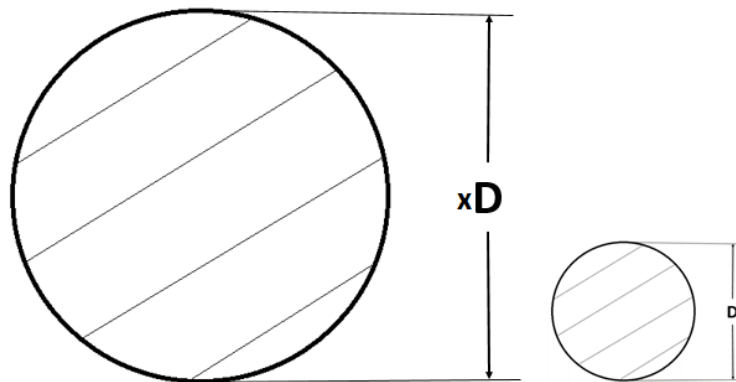


Figure 14: Scaling

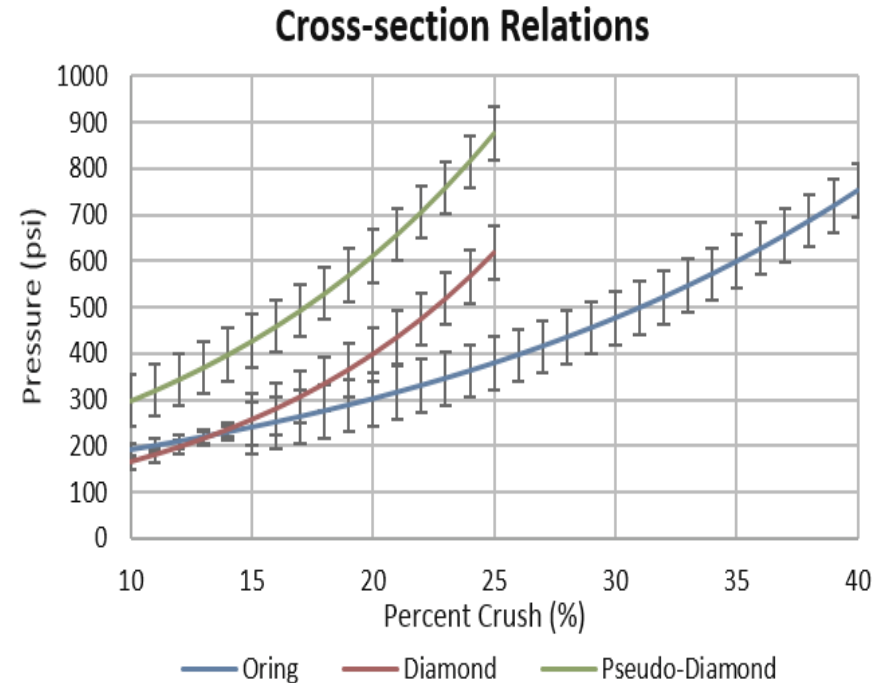


Figure 13: Correlations found



# User Interface: How It Works



The screenshot shows an Excel spreadsheet with the following content:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	<b>Welcome to the Interactive Sealing Ring Selector</b>																		
2	STEP 1: Select TWO known parameters, then press <b>Calculate!</b>																		
3	Groove Dimension <input type="checkbox"/>																		
4	Cross Section <input type="checkbox"/>																		
5	Pressure <input type="checkbox"/>																		
6	Percent Crush <input type="checkbox"/>																		
7	NEED TWO PARAMETERS																		
8	Next Step																		
9	Reset																		
10																			
11																			
12																			
13																			
14																			
15																			
16																			
17																			
18																			
19																			
20																			
21																			
22																			
23																			
24																			
25																			
26																			
27																			
28																			
29																			
30																			
31																			
32																			
33																			
34																			
35																			
36																			



# User Interface: How It Works



	A	B	C	D	E	F	G
1	<b>Welcome to the Interactive Sealing Ring Selector</b>						
2	STEP 1: Select TWO known parameters, then press <b>Calculate!</b>						
3	Groove Dimension	<input type="checkbox"/>					
4	Cross Section	<input type="checkbox"/>					
5	Pressure	<input type="checkbox"/>					
6	Percent Crush	<input type="checkbox"/>					
7	<b>Next Step</b>		<b>NEED TWO PARAMETERS</b>				
8							
9	<b>Reset</b>						
10			Select TWO known parameters				



# User Interface: How It Works



	A	B	C	D	E	F	G
1	<b>Welcome to the Interactive Sealing Ring Selector</b>						
2	STEP 1: Select TWO known parameters, then press <b>Calculate!</b>						
3	Groove Dimension	<input type="checkbox"/>					
4	Cross Section	<input type="checkbox"/>					
5	Pressure	<input type="checkbox"/>					
6	Percent Crush	<input type="checkbox"/>					
7	<b>Next Step</b>		<b>NEED TWO PARAMETERS</b>				
8							
9	<b>Reset</b>						
10							



Press Next Step



# User Interface: How It Works

	A	B	C	D	E	F	G	H	I	J	K
1	<b>Welcome to the Interactive Sealing Ring Selector</b>										
2	STEP 1: Select TWO known parameters, then press <b>Calculate!</b>										
3	Groove Dimension	<input checked="" type="checkbox"/>									
4	Cross Section	<input checked="" type="checkbox"/>									
5	Pressure	<input type="checkbox"/>									
6	Percent Crush	<input type="checkbox"/>									
7	<b>Next Step</b>		<b>PRESS NEXT STEP</b>								
8	Reset										
9											
10											
11											
12	<b>STEP 2: Input Parameters, then Press CALCULATE! Above</b>										
13	Groove Dimension	Value (in)									
14	Groove Height; A										
15	Clearance; C										
16											
17											
18											
19											
20											
21											
22	<b>Cross Section</b>										
23											
24	<b>Circular</b>			<b>Diamond</b>				<b>Pseudo-Diamond</b>			
25											
26	Dimension:			Dimensions				Dimension			
27	Value (in)			Value (in)				Value (in)			
28	D			K				E			
29				L				F			
30								G			
31								H			
32	Value (in)			Value (in)				Value (in)			
33											
34											
35											

Insert Known Parameters

# User Interface: How It Works

12 **STEP 2: Input Parameters, then Press CALCULATE! Above**

13 <b>Groove Dimension</b>	<b>Value (in)</b>
14 Groove Height; A	0.5
15 Clearance; C	0

22 **Cross Section**

24 **Circular**

32 <b>Dimension:</b>	<b>Value (in)</b>
33 D	0.75

24 **Diamond**

32 <b>Dimensions</b>	<b>Value (in)</b>
K	
L	

24 **Pseudo-Diamond**

32 <b>Dimension</b>	<b>Value (in)</b>
E	
F	



# User Interface: How It Works



userinterfaceFINAL - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW DEVELOPER ADD-INS

Clipboard Font Alignment Number Condition Formatting

H44

**Welcome to the Interactive Sealing Ring Selector**

STEP 1: Select TWO known parameters, then press **Calculate!**

Groove Dimension  
 Cross Section  
 Pressure  
 Percent Crush

Next Step      **PRESS NEXT STEP**

Reset      Calculate!

STEP 2: Input Parameters, then Press **Calculate!** Above

Parameter	Value (in)
Groove Dimension	
Groove Height; A	
Clearance; C	

**Cross Section**

Dimension	Value (in)
D	0.75

Dimensions	Value (in)
K	
L	

Dimension	Value (in)
E	
F	
G	

Sheet1



# User Interface: How It Works



userinterfaceFINAL - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW DEVELOPER ADD-INS PI DATALINK

Clipboard Font Alignment Number Conditional Formatting Styles Cell Styles Insert Delete Format AutoSum Fill Sort & Find & Filter Clear

H44

STEP 2: Input Parameters, then Press CALCULATE! Above

Groove Dimension	Value (in)	
Groove Height; A	0.5	
Clearance; C	0	

Cross Section

Circular

Dimension:	Value (in)
D	0.75

Diamond

Dimensions	Value (in)
K	
L	

Pseudo-Diamond

Dimension	Value (in)
E	
F	
G	
H	
I	
J	

Step 3: Results

Cross Section	Pressure (psi)	Cross Section	Percent Crush (psi)
Circular	554.6384276	Circular	33.33333333
Diamond		Diamond	
Pseudo-Diamond		Pseudo-Diamond	

Results Outputted



# User Interface: How It Works



Step 3: Results				
Cross Section	Pressure (psi)		Cross Section	Percent Crush (%)
Circular	554.6384276		Circular	33.33333333
Diamond			Diamond	
Pseudo-Diamond			Pseudo-Diamond	



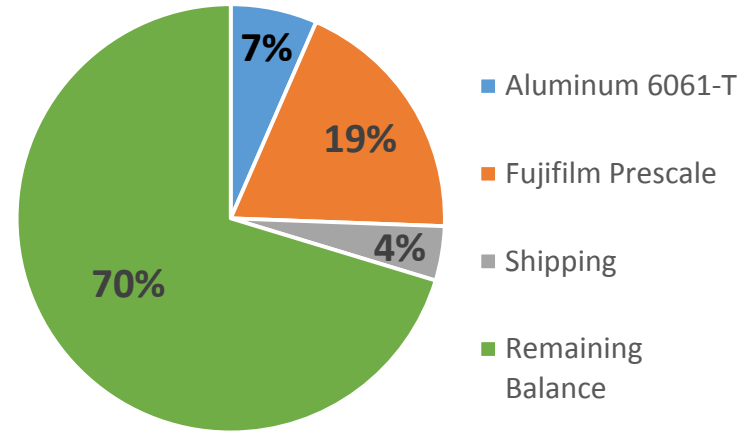
# Project Management



## Material Purchases

- Aluminum 6061-T6511
  - Test Fixture and Groove Plates
- Fujifilm Prescale
  - Low sensitivity
  - Super Low sensitivity
  - Ultra Low sensitivity

**\$2,000 Budget Allocation**



Item	Cost (\$)	Remaining (\$)
Fixture Material	130.71	
Fujifilm	380.99	
Shipping	82.17	
<b>Total</b>	<b>593.87</b>	<b>1406.13</b>



# What We Learned



- Project planning
  - The importance of proper scheduling and work planning
- Constant communication
  - Staying in touch with team members
- Job delegation
  - Utilizing the strengths of team members



# Summary



- We were unable to find a “universal” equation that relates the pressure-percent crush relationship between different cross-section geometries.
- The pressure-percent crush relationship is the same among sealing rings with the same cross-section geometry and independent of cross-section scale.
  - Ex. Circular sealing rings with diameters of 1 in and 2 in display the same pressure-percent crush relationship. The same is true for diamond seals with different dimensions.
- Sealing ring pressure values are dependent on the deformation of the contact area with percent crush. Contact area deformation differs significantly between different shaped sealing rings.



# Future Work



- Research programs to help with Fujifilm scan analysis
  - Currently very tedious, visual analysis
- Expand sealing ring database to include more cross-sectional geometries
- Research more parameters to monitor sealing ring deformation





# QUESTIONS? COMMENTS?





# REFERENCES



1. "Overview". *Cummins, Inc.* Web. 12 Feb. 2015. <<http://www.cummins.com/about-us/overview>>.
2. "Sterling Seal: O Ring Supplier, Kalrez Orings, Bonded Washers & Dowty Seals." *Sterling Seal: O Ring Supplier, Kalrez Orings, Bonded Washers & Dowty Seals.* Web. 9 Apr. 2015. <<http://eorings.com/>>.

