Civacon VC3022 Valve Tester

A Baccalaureate thesis submitted to the
Department of Mechanical and Materials Engineering
College of Engineering and Applied Science
University of Cincinnati

in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

William Holstrom

May 2019

Thesis Advisor:

Muthar Al-Ubaidi, Ph.D.

TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

Civacon tasked me with the design and manufacture of a vacuum decay tester for one of their products. Their current way of testing allowed for human error allowing bad parts to be shipped to customers. The productivity in the cell was also low due to their current testing methods having a long cycle time. My solution would have addressed all these issues and worked very well for them in theory. Before I could begin the process of building this tester Civacon had had a bad quarter and had to drop the funding for the project.

Being an avid camper, I pivoted and decided to design and manufacture a minimalistic wood bringing camping stove. I knew that current products required level ground to function, so I had the idea to stick it in the ground and the slope wont matter. I needed a light weight and compact design that was rugged enough to work in the wilderness. My solution met all these requirements and is simple and cheap to produce too.

PROBLEM DEFINITION AND RESEARCH

PROBLEM STATEMENT

The current way of testing valves allows for human error causing approximately 5 customer quality complaints a month. In addition, currently the takt time is 6 minutes per coupler with 1 minute of testing time, slowing down the efficiency

BACKGROUND

Civacon is a company that specializes in products and systems to safely load, monitor and unload petroleum, dry bulk and petrol chemical cargo tanks, for the road and rail industries. (1) For the unloading or loading of dry bulk materials they produce a 3” aluminum check valve. This valve allows a high flow rate with less pressure drop for a faster unloading time. The main feature of this valve is a large poppet that is built to release any dangerous amounts of excess pressure. This way the poppet has a controlled fail which is much safer than if a pipe was to fail anywhere else and prevents other more expensive applications from failing. Each valve must me manufactured and tested within ISO 9001 standards.

The seal of this poppet must be tested to ensure quality and to meet these ISO standards. According to Watco Companies there are three main reasons to test for valve leaks, “Economic; to prevent material loss that interferes with system operation. Safety; Prevent explosive failures and environmental contamination. Reliability; Detect unreliable components, and those with leakage rates that exceed standards.” (1) The biggest issue that we have from the field is that the poppet seal will not be tight enough causing a loss in pressure. This will create a longer loading time and possibly cause backups within the system. Ensuring this seal is adequate is very crucial to the quality of this product which is why we test this seal.

Currently there are two main ways of testing for leaks in valves, internal and external. According to Valvemagazing.com, “internal testing tests for a leakage around the valve seat or through the closure member when the valve is closed.” (2) Civacon is currently performing an internal testing this seal through bubble testing. Bubble testing consists of pressurizing a system and looking for air escaping. The way they do this test is by attaching the valve to a pressurized system and then submerging the system into a tub of dyed water. If there are any leaks around the poppet seal bubbles of air will come from the spot where a leak is located. An associate must perform this test. It is up to them to visually see the bubbles to confirm if there is a leak or not.

RESEARCH

SCOPE OF THE PROBLEM

The scope of this project is to design a new tester to test the seal integrity of the seal on the valve. The current way of testing is allowing for human error in the leak detecting process. This means that valves that should not be passing the test because they are leaking are being sent out for customer use. Letting bad products out into the world is bad for business. Civacon will look bad compared to other competitors whose products work when they are shipped out. Most of all this is a valve that will allow a system to fail in a safe manor. If this valve malfunctions the end users could be injured.

CURRENT STATE OF THE ART

There are several ways of looking for these leakages. The simplest way of doing this is to do a basic soapy water bubble test. This test is where you apply a soapy water mixture to the outside of a pressurized valve. Where there are leaks you will see bubbles to form. The benefit of this test is that it is very simple to perform, and you can locate exactly where a leak is occurring. Some drawbacks of this type of testing are that it is inaccurate. This type of testing requires a person to apply the soap water mixture. If they miss an area of the valve when they apply you will not see any leaks there. The person also must identify if the soap created a bubble due to a leak or just the soap creating a bubble due to the way that it is applied. Also, if the leak is very small it may be difficult for the person to see.

Submerged bubble testing is how Civacon is currently testing for leaks. This is where you pressurize the valve in a system, and then submerge the system into a water bath. If there are any leaks air bubbles will emerge from the area and rise to the surface. This allows the entire valve to be tested very quickly. It is also easy to see exactly where the leak is coming from. One of the main drawbacks form this type of testing is that it still requires a person to visually confirm that there are bubbles occurring. Bubbles may be difficult to see and when you submerge anything bubbles naturally occur. The person must decide if the bubbles are natural or if they are from a leak. This may take valuable time for the person to sit over the water bath staring for bubbles increasing the takt time for the product.

The final way to test for leaks is through mass flow or pressure decay testing. This uses an electronic tester that can measure for changes in pressure caused by a leak. This is the most accurate way for testing because it removes all human error in testing for a leak. It can also detect much smaller leaks that may not produce bubbles that are noticeable. It can also perform this test much more reliably in a shorter span of time, allowing for a faster product takt time. This type of testing is the most expensive type of testing. There is also no off the shelf tester that you can go out and buy. Due to the many different types and sizes of valves companies only sell the parts to make a tester, and you must build your own. Or if you lack the knowledge of how to build your own you will have to contract someone to build one for you.

END USER

My project has two different end users. The persons who are purchasing the tester, and the line associate that will be using the tester. The person who is purchasing the tester is will be an engineer, operations manager, or supervisor that oversees the cell where its product is being made. They will put safety first, but they will be more interested in the quality of the test and how accurate it is as well as how quickly this test can be performed. They want to maximize revenue out of the cell. They will do this by ensuring the quality of the valve and decreasing the takt time for the valve.

The second end user is the person that will be using the tester repetitively throughout the day. This person can have a varying background of education from high school drop out to a high-level college student. They will often be mindlessly using the tester as they must perform the test many times throughout the day. They will not care how the tester works, they just want to know if the valve passes or fails the test. This makes safety their number 1 concern. They do not want to have a mental lapse for a second and wind up losing a finger. The second most important thing for them is the ease of use for the tester. The less they must do and the less steps they must remember the better. Also, an easy way to tell is the valve passes or fails is important. This way they can move on from the test quickly and keep their production numbers up.

CONCLUSIONS AND SUMMARY OF RESEARCH

From my research I found that the way Civacon is testing their valves leaves room for human error and causes a high cycle time for the tester. I found that the resources for a pressure decay tester are available on the market, but there is no tester that you can go out and buy. Therefore, Civacon has tasked me with designing one for them. I talked to managers, supervisors and line workers in the cell and found out what they all want the most in this tester. They put a high priority on safety, then quality, then ease of use and decreased cycle time.

CUSTOMER FEATURES

From My interviews with management and cell employees they all stated that their priorities for this tester followed SQDC. They listed their priorities as from most important at the top to least important at the bottom:

1. Safety
2. Quality
3. Delivery
4. Cost

Which I will elaborate on below:

They all said that the safety of the cell worker is the most important part of the design. Currently in their factory they are using a two-finger switch system to start other machines to ensure employees cannot have their hands in the machines when they are starting. They also have either a light curtain, or a door that closes before the machine starts ensuring no one can reach inside the machine while it is being used.

Quality is the next most important feature for them. This ensures that every product they produce meets their standards. This tester must be accurate at finding leaks to ensure no leaky products make it out to customers.

Delivery is the next most important feature. This would be the cycle time for the tester. A quick cycle time allows more products to be produced allowing us to meet customer demands.

Finally, cost is final in importance. This would be the materials, and parts that the tester is made out of. If the cost for building the tester is higher than the value it will add in production, then this project would not be worthwhile.

PRODUCT OBJECTIVES

By going through the interviews and assessing what the company is already using in their factory I have laid out the following product objectives. They are listed below and given a weighted importance.

1. Safety 50%
2. Quality 20%
3. Cycle time 10%
4. Seal integrity 15%
5. Cost 5%

To ensure that the tester will be safe for a worker to use I will employ two fingers start switches that will close a door to start the testing. This will make sure that an employee's hands and fingers will be out of the working space of the tester thus they will be safe. The second most important feature is quality. I will first need a pressure decay tester. This will eliminate any and all human factors with deducting leaks. We will also be able to set it to parameters that we choose like what leak rate is acceptable and what pressure to perform the test at. Next most important is the cycle time speed. This pressure decay tester will also speed up the cycle time for the test. The tester will also have to form an adequate seal around the valve in order to test it properly. To do this I will use a pneumatic cylinder to press down a sealing plate once the valve had been inserted and the worker starts the tester. Finally, for the cost I will have a budget provided by the company that I will have to work within.

QUALITY FUNCTION DEPLOYMENT

			Engineering Requirements (units)														Customer Satisfaction Rating (0.00 - 1.00)			
		Importance wt.	Size (Inch)	Pressure (PSI)	Time (Sec)	Pressure Decay (Normal														
	Customer Requirements		1	2	3	4	5	6	7	8	9	10	11	12	13	14	CP	A	B	C
1	Able to detect leaks	0.60		1		9											6			
2	Creates an adequate seal	0.30		9													3			
3	Decreases cycle time	0.25			9												2			
4	Easily fits into current cell	0.10	3														0.3			
5	Dedcting the Location of a leak	0.05	3														0.2			
6																				
7																				
8																				
9																				
10																				
	Total Importance	1.00																		
	Engineering requirement importance		6	10	9	9														
Performance	Current Product																			
	competitor A		1	9	3	0														
	competitor B		9	3	1	0														
	competitor C		1	3	3	0														
	New Product Targets		11	15	7	0														

Interaction Matrix

	Engineering Requirements	Size (Inch)	Pressure (PSI)	Time (Sec)	Pressure Decay (Normal.Liter	0	0	0	0	0	0	0	0	0	0
Engineering Requirements		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Size (Inch)	1	-													
Pressure (PSI)	2		+												
Time (Sec)	3			-											
Pressure Decay (Normal.Liters pe	4				-										
0	5														
0	6														

Figure 1

DESIGN

Concepts Drawings

1. Tester that uses one pneumatic cylinder to lower an upper sealing plate on to the top of the valve to create the seal.

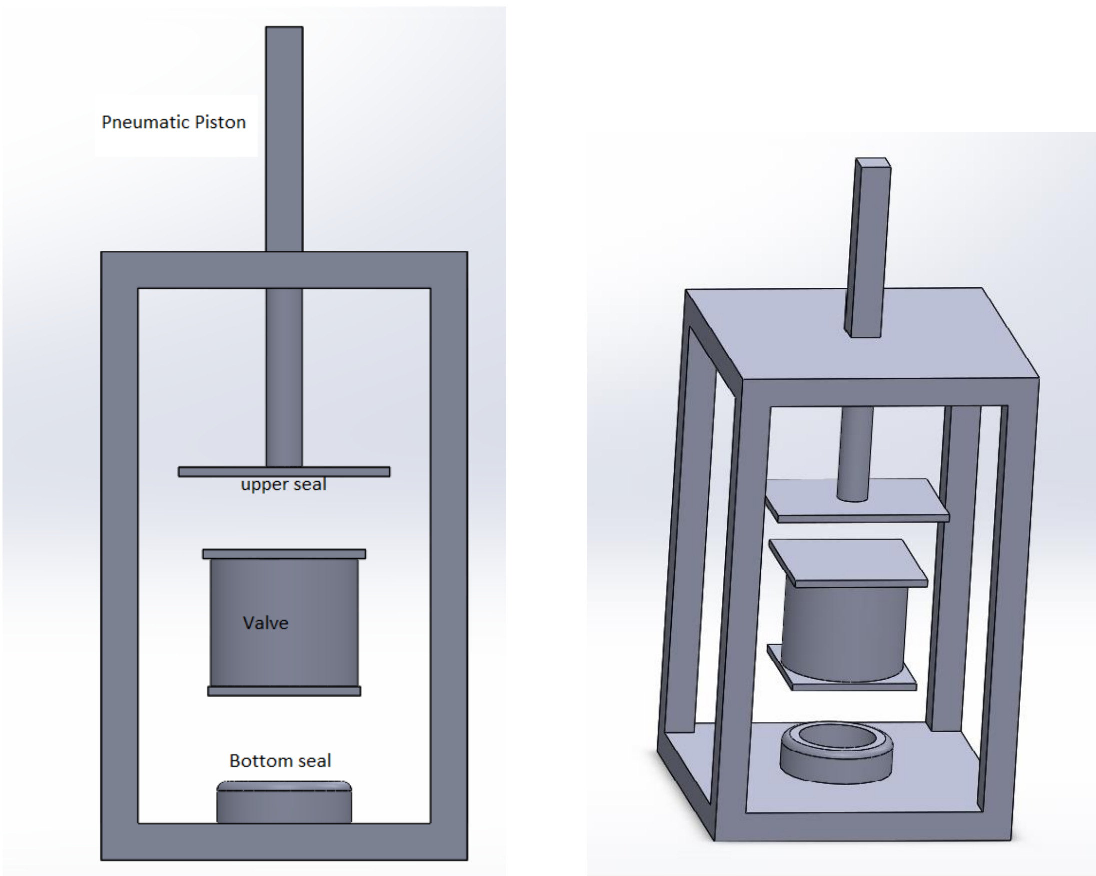


Figure 2

2. A pneumatic cylinder attached to a hinge sealant plate lowers the piston down creating a seal for testing

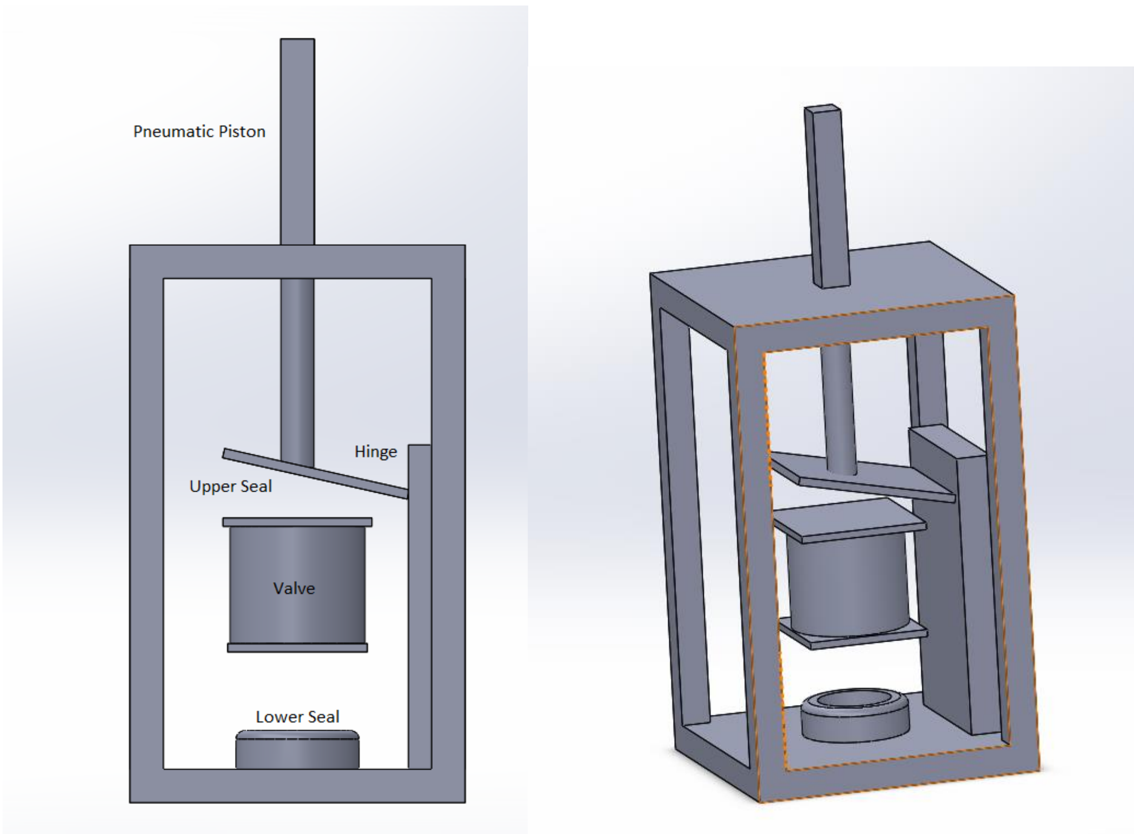


Figure 3

3. Two pneumatic cylinders come in from each side creating a right and left seal for testing while the valve is held in a fixture

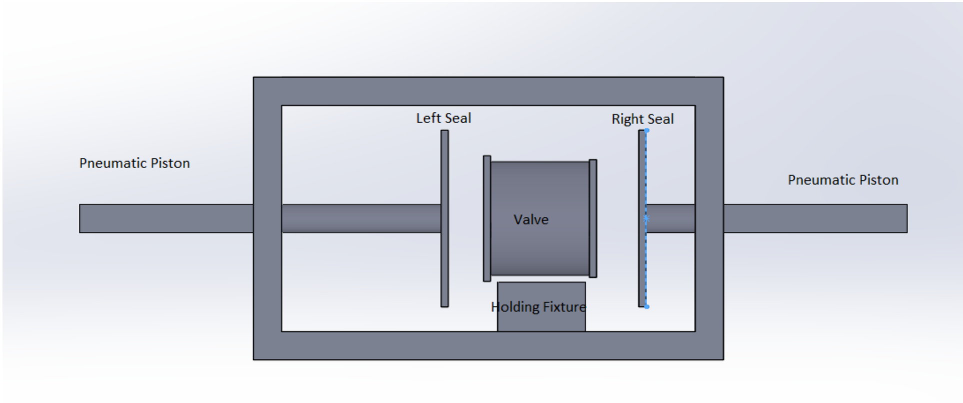


Figure 4

FINAL DESIGN

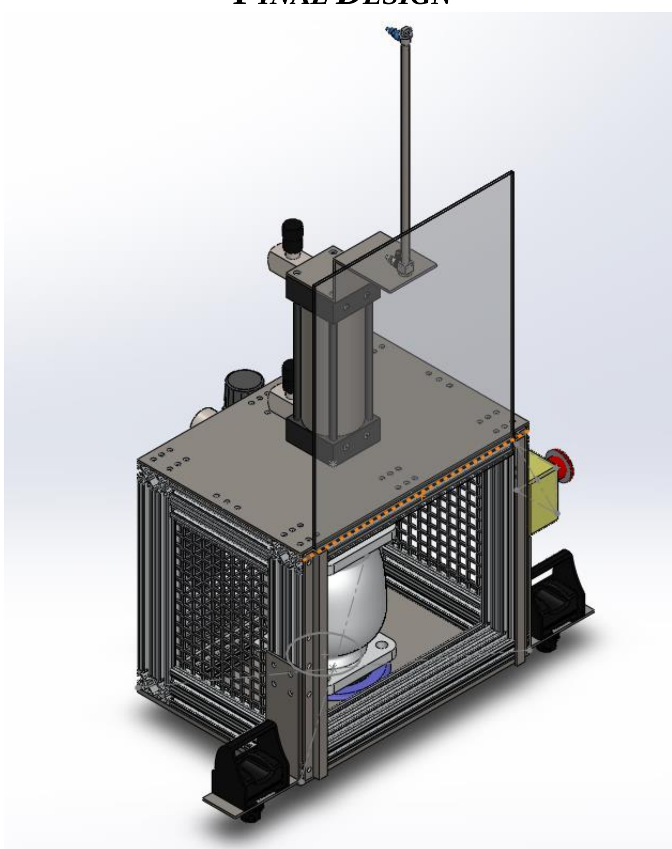


Figure 5

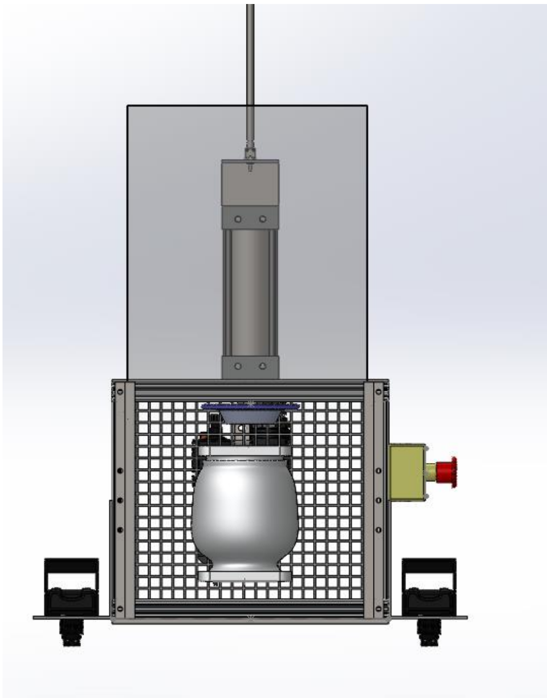


Figure 6

CALCULATIONS

FORCE NEEDED TO SEAL VALVE

F=PA

P=35 PSI

$A = \pi r^2$

r= 1.63

$A = 8.35\ in^2$

F=292.41 lbs.

SIZE OF CYLINDER NEEDED

House Pressure at Civacon=100 PSI

Force needed=307.03 lbs.

307.03= $(\pi r^2) * 100\ PSI$

r =.98

Options:

2 in bore: 314.16 lbs. @100PSI

2.5 in bore: 491 lbs. @100PSI

Cylinder with a 2.5 in Bore

TOP AND BOTTOM PLATE CALCULATIONS

Using A36 Structural Steel

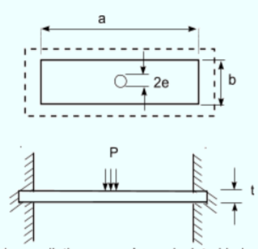
7.5x10^10 N/m^2 = Ultimate shear stress

Factor of Safety = 5

7.5x10^10 N/m^2 /5= 1.5x10^10 N/m^2

Rectangular Flat Plate , concentrated load at centre, edge clamped

t=.00635 m
a=.3566 m
b= 0.254 m
P=2187 N
v=.26
E=2x10^11 N/m^2
e'=1.01836



If e is small then use e' as calculated below

$e' = \left(\sqrt{1{,}6e^2 + t^2}\right) - 0{,}675t$ if e <0,5t else use e' = e

$\sigma_{mc} = \frac{1{,}5P}{\pi t^2}\left((1 + \nu)\ \ln\left(\frac{2b}{\pi e}\right) + k_3\right)$ At centre

$\sigma_m = k_2 \frac{P}{t^2}$ Middle of edge a

$y_m = k_1 \frac{Pb^2}{Et^3}$ At centre

	a/b						
	1,0	1,2	1,4	6	1,8	2,0	3 ->
k_1	0,061	0,071	0,076	78	0,0786	0,0788	0,0791
k_2	0,754	0,894	0,962	91	1,000	1,004	1,008
k_3	-0,238	-0,0078	0,011	53	0,068	0,067	0,067

Figure 7

MAXIMUM SHEAR STRESS AT CENTER

t=.00635 m

a=.3566 m

b= 0.254 m

P=2187 N

v=.26

E=2x $10^{11}\ N/m^2$

e'=1.01836

K3=.011

$$\sigma_{mc} = \frac{1.5P}{\pi t^2}\left((1+\nu)\ \ln\left(\frac{2b}{\pi e}\right) + k_3\right)$$

$$\frac{1.5(-2187)}{\pi\left(.00635^2\right)}\left((1+.26)\,ln\left(\frac{2(.254)}{\pi 1.01836}\right) + .011\right)$$

$$=5.9\text{x}10^7$$

MAXIMUM STRESS AT EDGE OF SIDE A

$$\sigma_m = k_2 \frac{P}{t^2}$$

$$= .962\left(\frac{2187}{.00635^2}\right)$$

$$=1.8\text{x } 10^8$$

Maximum Deflection at Center of Plate

$$y_m = k_1 \frac{Pb^2}{Et^3}$$

$$.076\left(\frac{2187\left(.254^2\right)}{2\cdot 10^{11}\left(.00635^3\right)}\right)$$

=.00021 m for one plate

Or 0.008 in

Shear Stress of Screws

$$Shear\ Stress\ Average = \frac{F}{\pi r^2}$$

$$Shear\ Stress\ Average = \frac{491}{\pi .125^2}$$

=10002.56 PSI

$$Bearing\ Area\ Stress = \frac{F}{t\ d}$$

$$Bearing\ Area\ Stress = \frac{491}{.18(.25)}$$

=10911.11 PSI

Ultimate Tensile Strength of Screws

$$t_{min} * \alpha = s_{tensile}$$

$\alpha = Tensile\ Stress$ Area

.031 in^2

$t_{min} = Minimum\ Tensile\ Strength$

80,000 PSI

80,000*.031=1860 lbs.

1860/5= 496 lbs. With Factor of Safety

40-4080 MAXIMUM DEFLECTION X

Moment of Inertia I=2.35 in^4

Load 491 lbs. at center

E=10200000 lbs./sq.in.

$$\frac{Force * Length^3}{192 * E * I}$$

12 in length = .00018 in

10 in Length = .00011 in

6 in Length = .00002 in

40-4080 MAXIMUM DEFLECTION Y

Moment of Inertia I = 0.608 in^4

Load 491lbs at center

E=10200000 lbs./sq.in.

Equation

$$\frac{Force * Length^3}{192 * E * I}$$

12 in length = .00713 in

10 in Length = .00412 in

6 in Length = .00089 in

40-4080 Maximum Bending Moment

$$\frac{Force * Length}{4}$$

Force=491lbs

Length 12 in= 1473 lbf

Length 10 in= 1227.5 lbf

Length 6 in= 736.5 lbf

40-4080 Elongation

$$\frac{Force * Length}{Area * E}$$

Force= 491 lbs.

Area= 2*1=2

E=10200000 lbs./sq.in.

12 in length = .00029 in

10 in Length = .00024 in

6 in Length = .00014 in

Leak Rate Calculation

$$LR = \frac{V\Delta P(60\text{sec})}{t.14.7}$$

LR=Leak Rate (scc/m)

V=internal volume (cc)=1469.10

ΔP=.02 PSI (Recommended by CTI)

t=Time in tester (sec)

14.7 PSI atmosphere

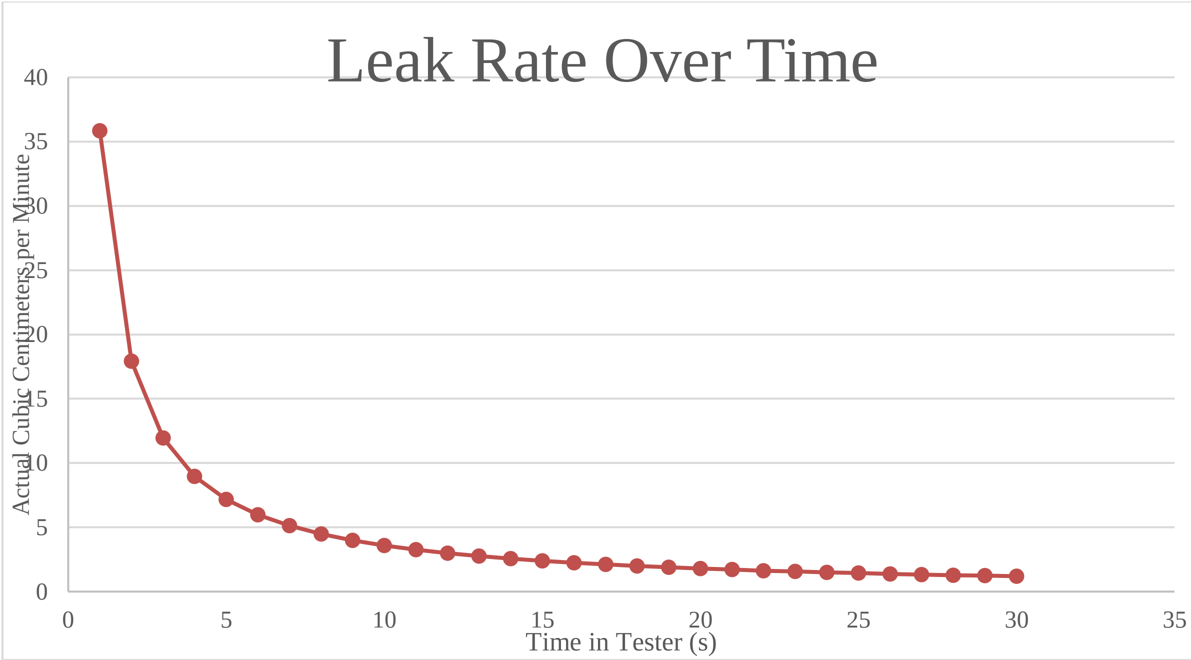


Figure 8

Safety Considerations

Dual Finger Switches

- An infrared light beam senses the lightest finger contact to switch a circuit on or off. The included guard prevents accidental activation.
- An indicator lights up to confirm that switches are actuated
- 15.51 in apart
- Too far to activate both with one hand

Acrylic sliding door

- Closes prior to main cylinder activating
- Ensures hands and other body parts from being crushed or pinched during testing

<u>Air Control Valves</u>

- Control Air flow to cylinders controls speed at which cylinders open and close
- Top rated to 145 PSI
- Bottom Rated to 2000 PSI

<u>Emergency Stop Button</u>

- Immediately cut power with a single push.
- All have positive force contacts that will open a circuit when actuated even if a spring fails or the contacts stick.

<u>Safety screens</u>

- 0.5 in holes
- Prevent hands and fingers from entering the work area while testing

PROJECT MANAGEMENT

BUDGET, PROPOSED/ACTUAL

Civacon is requesting the amount of $10,000 for a new pressure tester for the 3” Aluminum Swing Check Valve. In our current situation we are submerging the valve to in water, applying an internal pressure, and having an employee watch for bubbles from a leak. By using a pressure leak tester, we are eliminating the human error from this process. This will increase the quality of the products we are producing and create a safer product for our customers.

PROJECT BUDGET LIMIT

CTS Single Pressure Tester	$6,000

Tooling and Fixtures	$2,000
Labor (80 hours)	$2,000
Total Budget	$10,000

ACTUAL BUDGET AND BILL OF MATERIALS

Item	Product #	Price	Quantity	Total
Main Cylinder	6491k169	$ 143.40	1	$ 143.40
Saftey Shield Cylinder	6498k644	$ 54.84	1	$ 54.84
Finger Switches	6785K21	$ 41.92	2	$ 83.84
E-Stop Button	6785K21	$ 41.92	1	$ 41.92
Easy-Set Precision Flow-Adjustment Valve	46425K13	$ 49.82	2	$ 99.64
Elbow Air Flow Control Valves	62005K211	$9.73	2	$ 19.46
40-4080	47065T107	$ 50.38	10 ft	$ 50.38
Saftey Mesh	47065T291	$ 88.85	1	$ 88.85
Sentinel I28 Leak Detection System		$ 6,000.00	1	$ 6,000.00
Acrylic Plastic	47065T321	$ 40.96	1	$ 40.96
Brackets	47065T262	$ 9.26	12	$ 111.12
Screws (4 pack)	47065T142	$ 2.30	48	$ 110.40
Total				$ 6,844.81
				Budget:
CTS Single Pressure Tester				$6,000
Tooling and Fixtures				$2,000
Labor (80 hours)				$2,000
Total Budget				$10,000
			Difference	$3,155.19

Figure 9

SCHEDULE, PROPOSED /ACTUAL

- 2/11/19
  - Order parts
- 2/18/19
  - Machine parts and start assembly
- 3/17/19
  - Start testing
    - Leak Rate Testing
    - Cylinder speed testing
    - Switches testing
- 4/8/19

- Finish project

I was un-able to follow this schedule at all. Due to the changing market and financial forecasts of Civacon's business they were unable to fund my project. I was unable to take any part in finalizing the design or constructing the tester.

CONCLUSIONS

Because of this unforeseen issue with funding I stopped work on the valve tester. I believed that this would have been a successful design and had I been able to move forward with it, it would have accomplished all the goals I was tasked with.

Instead of being tasked with the completion of the tester I was able to design and build a Minimalistic Wood-Burning Camp Stove. In the coming pages I will talk about the design, project management and conclusions of that project.

MINIMALISTIC WOOD-BURNING CAMP STOVE DESIGN

<u>Problem Statement:</u> Light weight camping stoves need level ground in order to function, which may be hard to find while in the wilderness

Final Design

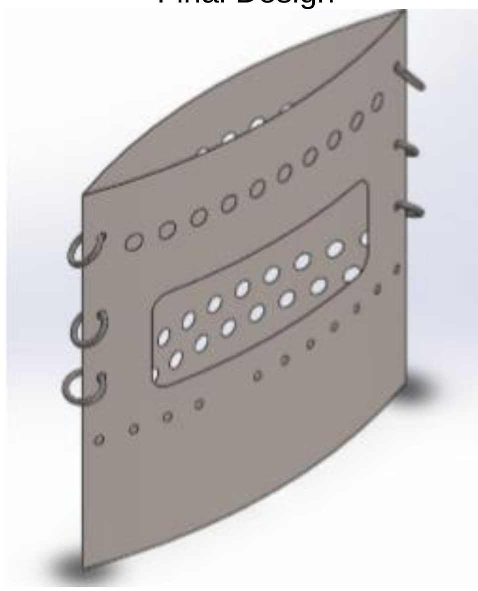


Figure 10

Closed

Figure12

Open

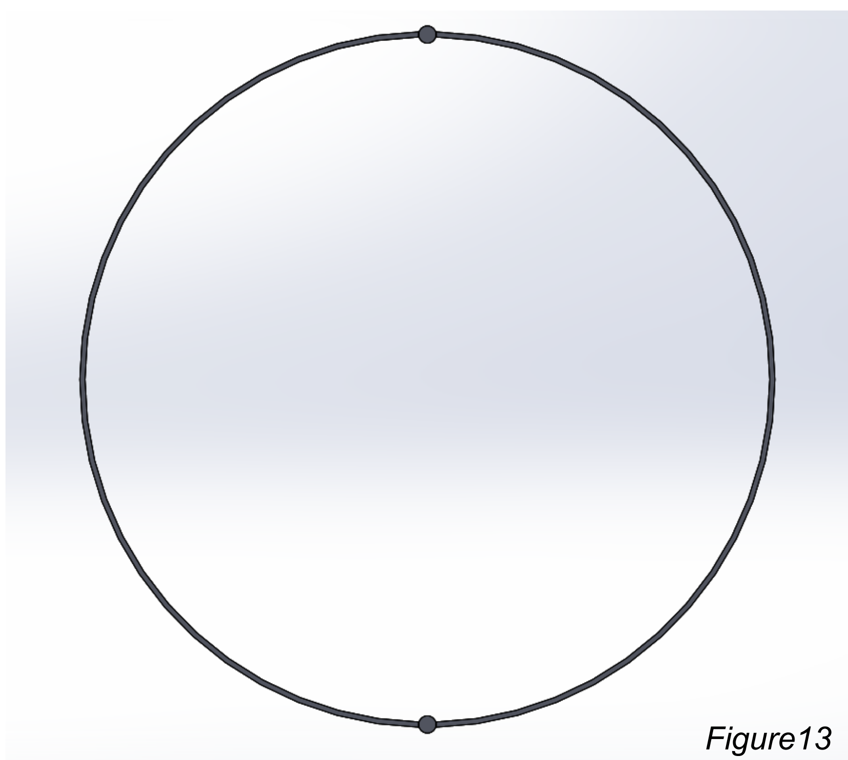


Figure13

CALCULATIONS:

THERMAL EXPANSION OF PIN DIAMETER

$$\frac{\Delta L}{L} = \alpha \Delta T$$

$$\frac{\Delta L}{0.1} = 32.3 * 10^{-6}(1112 - 0)$$

ΔL=.0003 in

THERMAL EXPANSION OF PLATE

$$\frac{\Delta L}{L} = \alpha \Delta T$$

$$\frac{\Delta L}{6.25} = 32.3 * 10^{-6}(1112 - 0)$$

ΔL=.22 in

THERMAL EXPANSION OF HINGE PINS

$$\frac{\Delta L}{L} = \alpha \Delta T$$

$$\frac{\Delta L}{1.75} = 32.3 * 10^{-6}(1112 - 0)$$

ΔL=.06 in

THERMAL STRESS OF HINGE PIN DIAMETER

$$\frac{F}{A} = Y \frac{\Delta L}{L_0}$$

$$\frac{F}{.00785} = 10^6 \frac{.0003}{0.1}$$

F=23.55 PSI

THERMAL STRESS OF HINGE PLATE

$$\frac{F}{A} = Y \frac{\Delta L}{L_0}$$

$$\frac{F}{.1875} = 10^6\frac{.22}{6.25}$$

F=6600 PSI

Thermal Stress of Hinge Pin Length

$$\frac{F}{A} = Y\frac{\Delta L}{L_0}$$

$$\frac{F}{.175} = 10^6\frac{.06}{1.75}$$

F=6000 PSI

Budget and Production Costs

Production: Flow Jet

304 Steel 48" x 96", 0.024" Thick: **$187.82**

Cycle Time

- Time to Cut Front Panel
  - 20 Sec x 51 Units= **17 min**
- Time to Cut Back Panel
  - 15 Sec x 51 Units= **12.75 min**
- Total Cutting Time
  - 29.5 min for 102 Units
  - 6.92 Min Per unit (Front and Back)
- Ring Assembly
  - 1 min
- Total Time
  - **7.92 minutes per unit**

- **<u>Production Cost:</u>**
    - 51 Front Sheets: **$1.79 ea.**
    - 51 Back Sheets: **$1.79 ea.**
- Steel Ring
    - .91 Cents Each
    - X 3 per unit= **$2.73**
- Total Cost Per Unit
    - $1.79 x 2 + $2.73= **<u>$6.31</u>**

SCHEDULE

- 2/11/19
    - Build model of stove and test different sizes
    - Select steel thickness
- 2/18/19
    - Test different hinge types
    - Start on full assembly
- 3/11/19
    - Test airflow
    - Test how stove behaves on different surfaces
- 4/15/19
    - Finish Project

Once I got this project up and running after the loss of funding on my pervious predesign project it went very smoothly. I was able to follow my schedule as it is show exactly above.

The first step that I took is I cut out different sizes of rectangles out of poster board. I used this to experiment with the different sizes of stoves I could create with the different lengths. I knew that I wanted to be able to fit both a large skillet as well as smaller pots and pans. I decided on a 6in by 6in square for the best results.

Next, I went to choose a metal that would work best for this stove. I went to a store that sold sheet metal. I picked up different thicknesses of sheet metal and bent them in my hands to find one suitable for the stove application. I wanted a metal that would stand up to the heat of the fire and be able to be bent multiple times without damage from the bending stress. I also wanted a thickness that was not too hard to bend. I wanted the product to be simple and safe for people to use.

I then went to decide how I would make the hinges attaching the two plates together. I spent some time trying to roll the steel into a circle at the ends so I could put a pin through and make a traditional door hinge. This proved to be very difficult and I went with a simpler solution by using a ring to attach the two.

Before I attached the two, I needed to cut holes into the steel plates to allow for air to breathe through and not smother the fire. I also needed to cut an opening on one side so you could add fuel to the fire to keep it burning. I made the opening big enough to put sticks through. For the smaller holes I just used a drill to cut through the steel plate. I then used a jig-saw to cut the larger opening. Finally, I assembled the two halves together by attaching the rings.

I then went and tested the stove. I went outside and started sticking it into uneven ground of multiple compositions. I noticed that the bottom of the stove had no trouble sticking into the ground. I then went and built a fire within the stove and cooked an egg on a very uneven surface. The stove had no problem making itself level on the ground and supporting the pan.

Once I got the fire going, I would add fuel in the form of sticks through the large hole I created. This all worked perfectly.

Once I had finished cooking cleanup was very simple. I removed the pan and simply kicked the stove over. I then placed it in the creek to cool it off and remove any excess soot. I then returned it to the flat orientation and packed it away.

CONCLUSION

This stove worked very well for being a prototype. It is light weight and compactable which is perfect for any backpacker. It was able to allow a person to cook on an unlevel ground exactly as designed.

I do have several recommendations for further development of this stove. First, I would like to use a 304 stainless steel. I used a low grade 1010 steel that did not spring back to its original shape as much as I would have liked. I had to brute force the steel into a round position and then again back to flat. Next, I used too much material. There was a large gap between the top of the fire and the pan. This caused the pan to heat us slowly. If I were to remove a half an inch from the top of the two steel plates this would have allowed for a faster heating time. Finally, I do not recommend using a hand drill and jig-saw for the stove’s construction. This method was highly inaccurate and did not lead to the finish product looking as nice as I would have liked. More importantly this was not a safe option. In my cycle time and production calculations I calculated them if I were to use a Flow-Jet for the cutting of the steel. This is much more safe, accurate and cost effective.

WORKS CITED

BIBLIOGRAPHY

1. **Home.** ***http://www.opwglobal.com/civacon.*** **[Online] Civacon. [Cited: 09 13, 2018.] http://www.opwglobal.com/civacon.**

2. Gamblin, Christopher. Leak Test For Plant Operators. [Online] Watco Company. [Cited: 09 13, 2018.] file:///C:/Users/holstrwc/Downloads/Leak%20Test%20for%20Plant%20Operators%20-%20Christopher%20Gamblin.pdf.

3. Bayreuther, David. Mistakes and Misconceptions in Valve Leak Testing . ***Valvemagazine.com.*** **[Online] March 02, 2016. [Cited: 09 13, 2018.] http://www.valvemagazine.com/magazine/sections/features/7388-mistakes-and-misconceptions-in-valve-leak-testing.html.**

APPENDIX A

An interview was conducted on Civacon management and line workers to determine the wants and needs of the customer