NAU Mixing Valve Team

Rob Stevenson: Project Manager
Stephon Lane: Client Contact
Jorge Renova: Budget Liaison
Summer Johnson: Document Manager
Connor Mebius: Website Developer

Introduction and Project Description

- NAU Mixing Valve team is making a valve for General Atomics with the primary goal of reducing weight by as much as possible, with a goal of at least 96 lbs of total reduction. This will be done with the following:
  - Switch large parts of valve to titanium, which is significantly lighter
  - Thin walls of the valve
  - Remove flanges and excess material
  - Reduce inlets and outlets from four inches to three inches

Figure 1: Modified Valve

Johnson

Original System Cont.

- The Original System is purchased commercially from Armstrong and modified by General Atomics. GA reduced the weight of the valve by removing flanges.
- The temperature is specified by the user and the valve mixes two streams of water to create the outlet stream of water.

Figure 2: Modified Valve

Johnson

Black Box Model For Valve

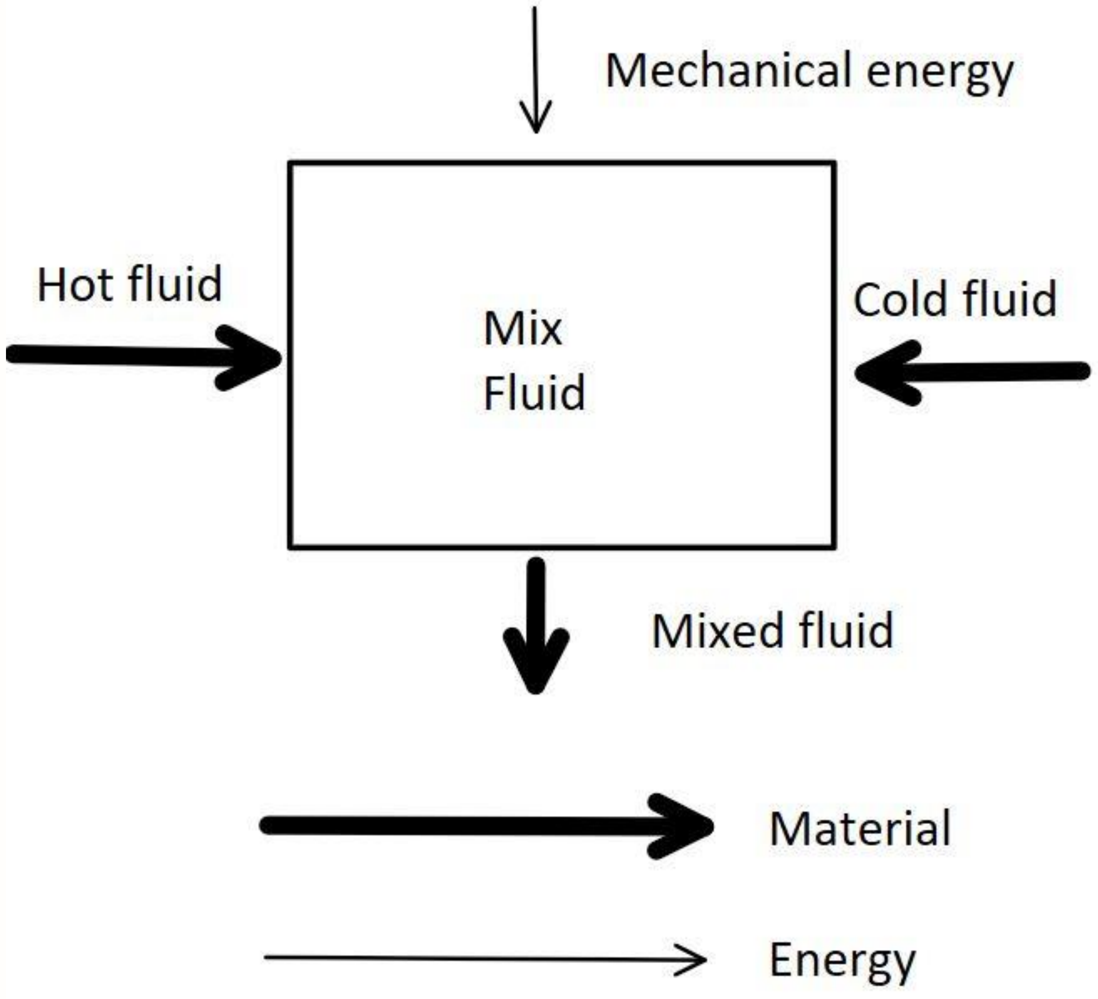


Figure 3: Black Box Model

Stevenson

Functional Model For Valve

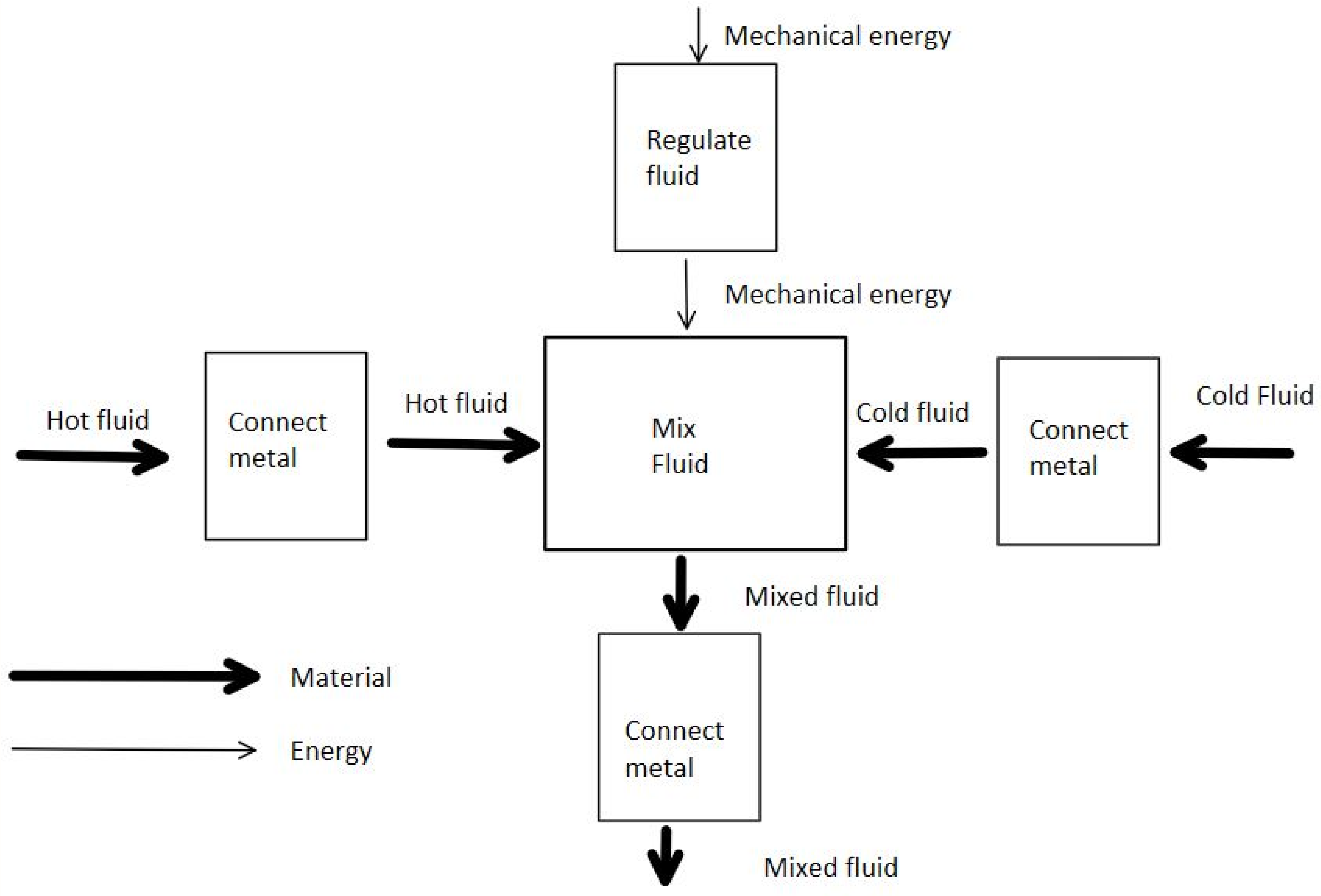


Figure 4: Functional Model

Stevenson

Design Selected – First Semester: 3 Inch Port Mixing Valve - Stainless Steel/Titanium

- 3 inch inlet/outlet ports
- Benefits from material change and can produce more weight savings than 4 inch valve
  - To be tested using SolidWorks Flow Simulation
- Does not need to use a size reducing Hydroflow Flange.
  - Using Hydrowflow Flange for 3-inch outlet to a 3-inch pipe.

Table 1: Pros and Cons of 3 Inch Stainless Steel-Titanium Mixing Valve

Pros	Cons
Titanium is 56% as dense as Stainless Steel	Not as much weight savings as a full titanium design
Titanium is non-corrosive because it produces an oxidized protective layer	Stainless Steel parts may not be compatitble with Titanium parts
Potential to use less material of titanium, thus redudcing weight.	Stainless Steel's modulus of elasticity is almost double the modulus of Titanium
Cost to switch is less than changing the entire valve to titanium	Titanium is more expensive to buy
Reduces chance of threatening the integrity of the design	Titanium is more expensive to machine
Provides good weight reduction	

Lane

Current Concept

- 3 inch inlet/outlet ports
- 316 Stainless Steel and Grade 5 Titanium
- Hydraflow Flanges
  - No flanges
  - Reduces weight
- Compatible with existing actuator
- Initial total weight reduction 79.6 lbs
  - Reduce Further

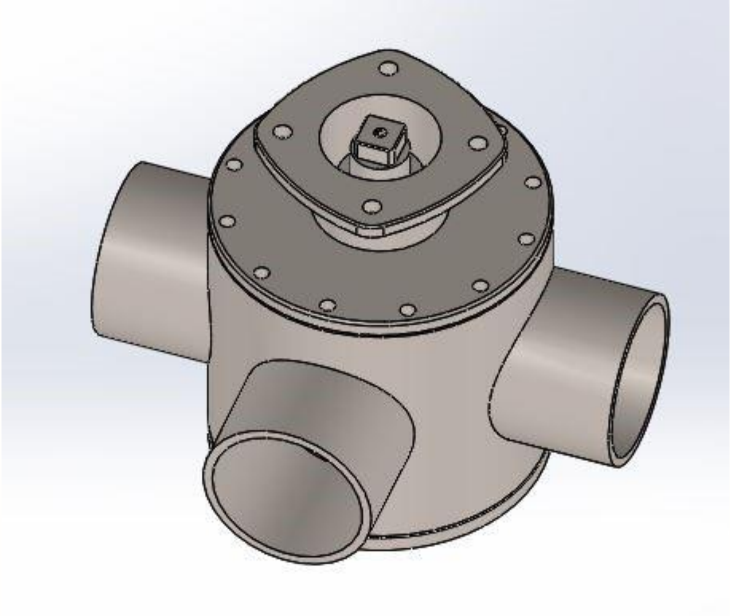


Figure 5: Valve Concept

Testing Procedure – SolidWorks Flow Simulation

- Flow will be characterized by using known values
  - Ambient conditions, flow type, materials, etc.
- Engineering Requirements can be tested and visualized using this software
  - SolidWorks Flow Wizard can plot different "Global Goals"
- Will be completed for designs (assemblies) created during summer term
- Testing takes time and thought, but can be done in a reasonable time-frame
  - The team expects to test the valve each time it is modified

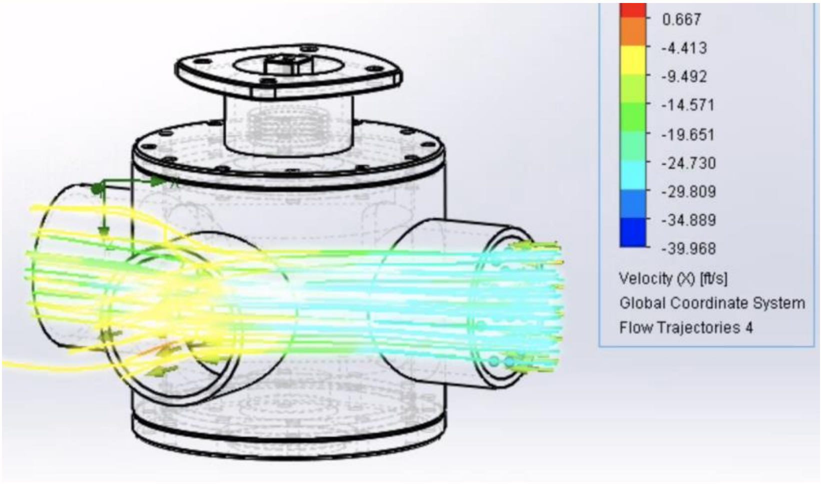


Figure 6: Flow Velocity Visualization (Example)

Lane

One Direction Flow Simulation (Example)

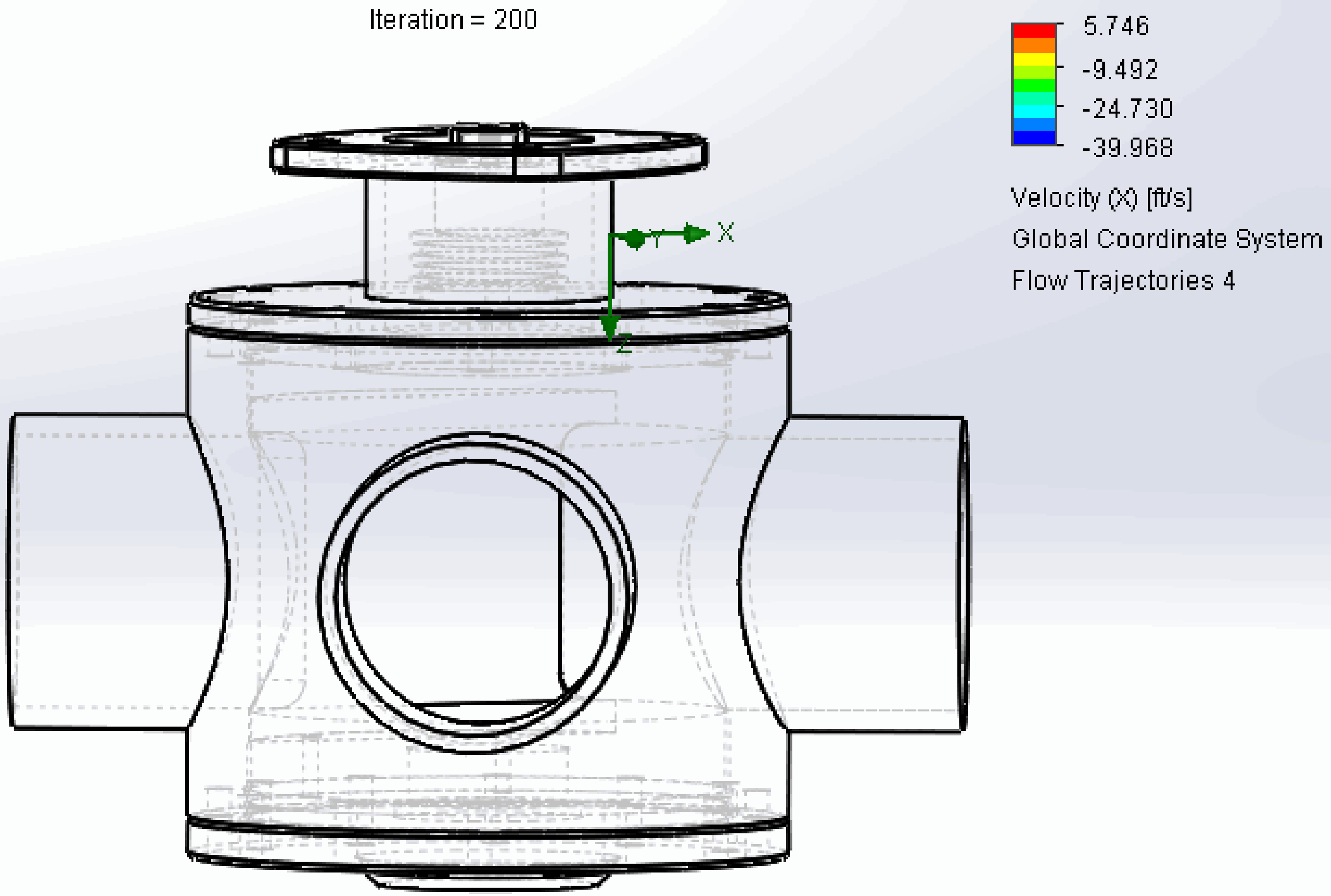


Figure 6: Flow Velocity Visualization Simulation

Potential Critical Failure 1: Effects of Thermal Expansion

- Same Conditions
  - 316 Stainless Steel expands twice as much as Grade 5 Titanium
- This may affect:
  - Tolerancing
  - Fits where Stainless Steel and Titanium interact
- With two fixed supports holding a different material:
  - Compression forces change
  - Titanium will not expand as much as Stainless Steel
    - Potentially causing a loss of necessary compression forces

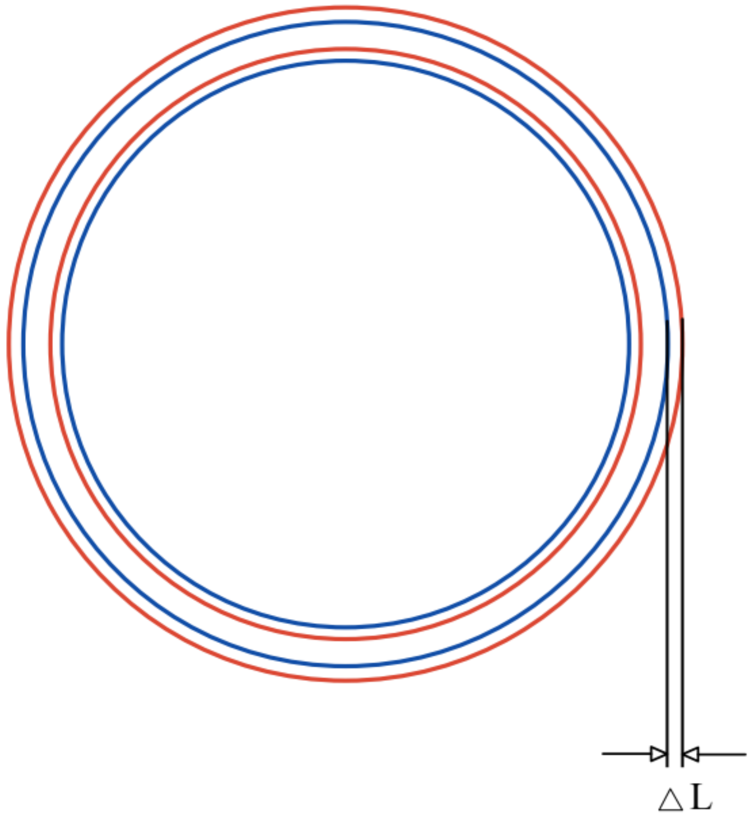


Figure 7: Change in Length Due to Thermal Expansion

Lane

Resulting Effects of Thermal Expansion

- Analyzing valve metals and Viton O-Ring
  - Increase of 15 Degrees Celsius
  - Assumed initial length: 3.0000 in [76.2 mm]

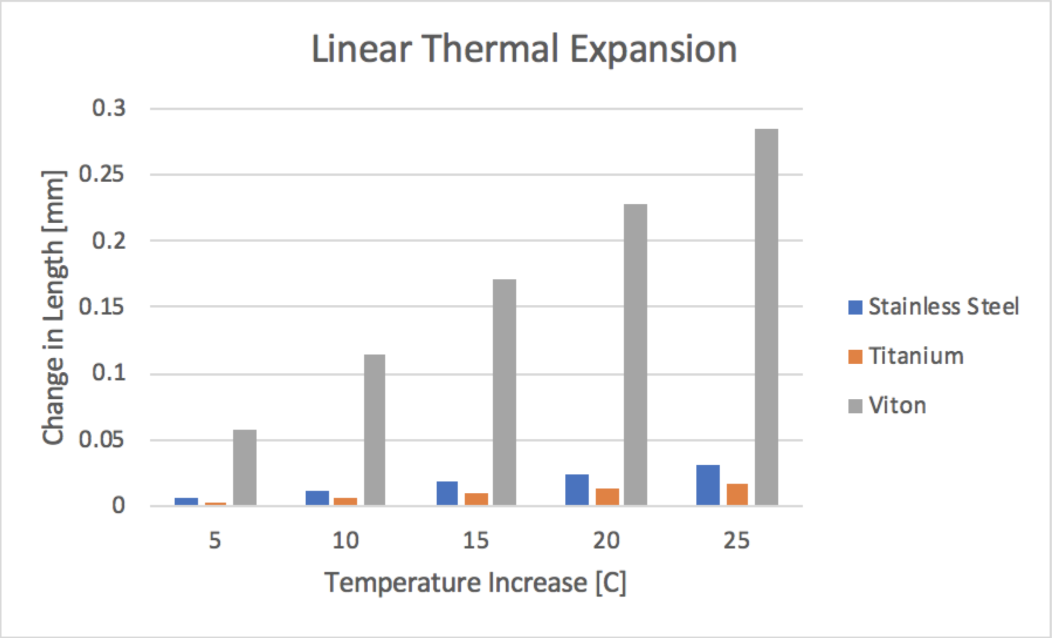


Figure 8: Linear Thermal Expansion Visual

Lane

Potential Critical Failure 2: Machining Titanium Concerns

- Machining Titanium can be dangerous due to fire hazards
- Machining tool get hotter and wear faster
- Machining chips to cut thick to thin can help reduce temperature in the tool and titanium
- General Atomics will be doing all the machining for the valve

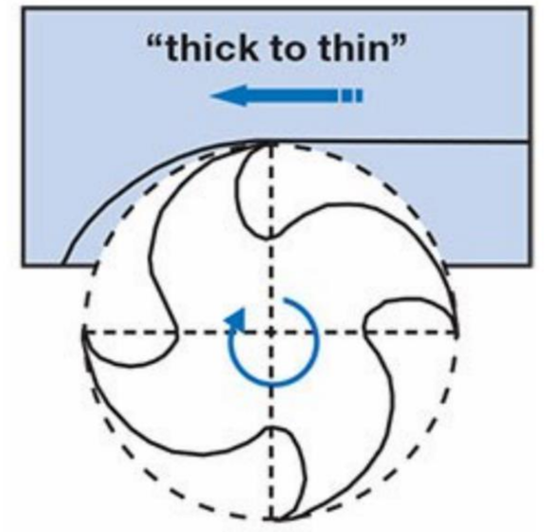


Figure 9: How to create metal chips thick to thin.

Potential Critical Failure 3:
Wall Thickness Pressure Analysis

- Modeled as a cylindrical pressure vessel
- MATLAB live script with input options for:
  - Max Pressure
  - Outer Diameter
  - If welded or not
  - Material selection between stainless steel and titanium

```
Command Window
What is the max design pressure? (psi)
185
What is the outter diameter of the valve? (inch)
8.66142
Will there be welds? (1=yes/2=no)
1
What material is the valve made of? (1=Ti/2=SS)
1
fx >>
```

Figure 10: Command window prompts for MATLAB live script inputs.

Wall Thickness Pressure Analysis Cont.

- MATLAB live script with outputs for:
  - Minimum wall thickness
  - Hoop stress
  - Axial stress
- Min wall thickness is 0.007374 in
- Roughly two sheets of paper thick
- Pressure is not a driving factor for wall thickness
- This wall thickness is impractical for design applications

```
The min wall thickness is 0.007374 inch

The hoop stress is 108689 psi
The axial stress is 5.434450e+04 psi
```

Figure 11: Outputs from MATLAB live script for thickness, hoop stress, and axial stress.

Potential Critical Failure 4: Chamber Wall Thickness

- Wall Thickness
  - Original cylinder wall is 22mm [0.8661in] thick
  - Corrected cylinder wall is 18mm [0.7087in] thick
- 316 Stainless Steel
  - Original mass is 36.91 lbs
  - Corrected mass is 29.68 lbs
  - Total mass reduction of 7.23 lbs
- Descaled Titanium
  - Original wall mass is 20.86 lbs
  - Corrected wall mass is 16.77 lbs
  - Total mass reduction of 4.09 lbs
- Overall mass reduction from switching materials is 20.14 lbs

Figure 12: Main Chamber

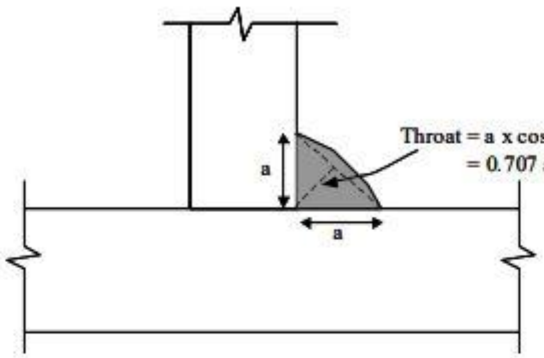
Failure 4 Cont: Top/Bottom Chamber Bolts

- Current bolts are F593C bolts
- 24 bolts for top and bottom plate combined
  - Mass for each bolt: 0.04798 lbs
  - Combined mass for 24 bolts :1.1516 lbs
  - Combined mass for 20 bolts: 0.9597 lbs
  - Total mass reduction: 0.1919 lbs
- Bolt quantity reduction not worth the stress risk
  - Total bolt mass reduction is minimal
- Reducing the bolt size is being considered

Figure 13: F593C Bolts

Critical Failure 5: Welding Analysis

- Transverse Fillet Weld
- Tensile strength of weld should match base material
- Minimum height of weld is 0.002 inches
  - In order to withstand max internal pressure



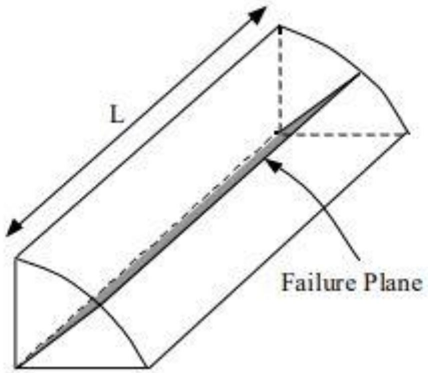


Figure 14: Transverse Fillet Weld

Bill of Materials

Table 2: Bill of Materials

Bill of Materials			
Part	Description	Quantity	Material
1	Nameplate	1	316 Stainless Steel
2	Wear Ring	2	Carbon Reinforced PTFE X
3	Gland Nut	3	316 Stainless Steel
4	Body Base Plate	1	Titanium
5	Body Base Plate	1	Titanium
6	Bonnet	1	316 Stainless Steel
7	Spindle	1	316 Stainless Steel
8	Turret Top Plate Disc	1	Titanium
9	Turret lower Plate Disc	1	Titanium
10	Turret Seal Support	1	Titanium
11	Turret Trunnion	1	316 Stainless Steel
12	Turret Seal	1	Glass Reinforced PTFE X
13	Turret Seal Bush	2	316 Stainless Steel
14	Mixer Insert	1	316 Stainless Steel
15	Needle Roller Thrust Bearing	1	Cr-C Steel X

Bill of Materials Cont.

Table 2: Bill of Materials

16	U Hammer Drive Screw	2	316 Stainless Steel
17	Spindle Cap Screw	4	316 Stainless Steel
18	Gland Nut Locking Screw	1	316 Stainless Steel
19	Bonnet/Base Plate/Body Bolt	24	316 Stainless Steel
20	Turret Seal Cap Screw	2	316 Stainless Steel
21	Turret Lower Plate Cap Screw	4	316 Stainless Steel
22	Turret Trunnion Cap Screw	2	316 Stainless Steel
23	O-Ring Gland External	1	EPDM 75 X
24	O-Ring Gland Internal	1	EPDM 75 X
25	O-Ring Spindle Seal	2	EPDM 75 X
26	O-Ring Body Seal	2	EPDM 75 X
27	O-Ring Turret Seat Seal	1	EPDM 75 X
28	Thrust Washer	2	C-Cr Steel X
29	O-Ring Mixer Insert	1	EPDM 75 X
30	Spindle Handle	1	316 Stainless Steel

Budget Planning

- $2500.00 available
- General Atomics will do all of our machining, so our budget will go to planning and prototyping 3D printed models
- No budget has been used at this time

Future Work

- Valve analysis using Flow Simulator
- Topology Optimization
    - Affects flow
    - Internal component redesign
- 3 inch port valve calculations
- Create drawing files of new valve for client
- Removing inlet/outlet flanges and weld coupling directly to valve
- Seal/O-ring studies
    - Thermal expansion
    - Material composition/characteristics
    - Alternative material options

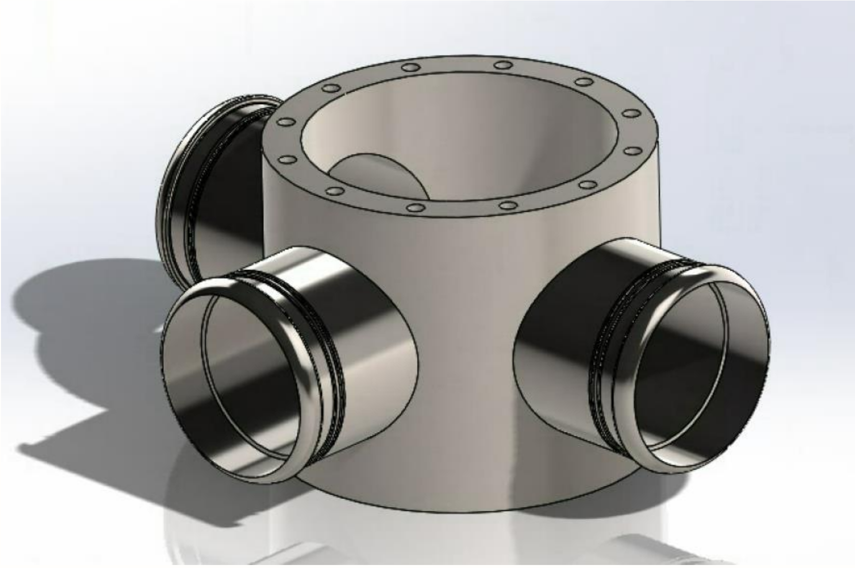
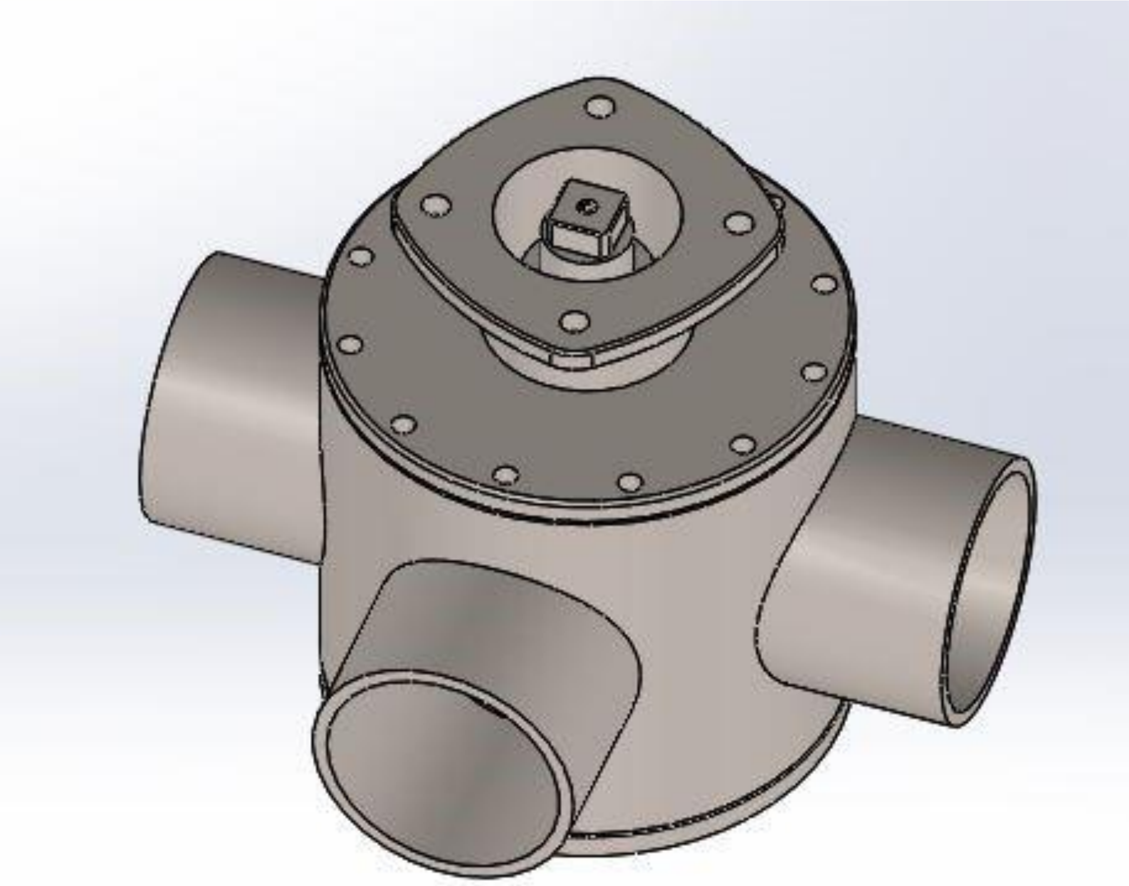


Figure 15: Valve Concept

Questions?



References

[1]"Actuators | Armstrong International", *Armstronginternational.com*, 2020. [Online]. Available: https://www.armstronginternational.com/products-systems/hot-water-industry/water-temperature-controls/emech®-digital-control-valves/actuators. [Accessed: 05- Feb- 2020].

[2] Armstrong International, Inc. “Emech® Digital Control Valves.” *Armstrong*, 2017, www.armstronginternational.com/sites/default/files/resources/documents/HW-430.pdf. [Accessed: 05- Feb- 2020].

[3] "Model E100WR | Armstrong International", *Armstronginternational.com*, 2020. [Online]. Available: https://www.armstronginternational.com/products-systems/hot-water-industry/water-temperature-controls/emech®-digital-control-valves/hot-cold-water/model-e100wr. [Accessed: 04- Feb- 2020]

[4] “Products Products” Watts. [Online]. Available: accessed: 06-Feb-2020].

[5] L. V. Company, "YouTube," February 2019. [Online]. Available: accessed Feb

References Cont.

[6] W. D. C. &. D. G. Rethwisch, Materials Science and Engineering, Wiley & Sons, 2018.

[7] B. Campus, "Thermal Expansions of Solids and Liquids," [Online]. Available: https://opentextbc.ca/physicstestbook2/chapter/thermal-expansion-of-solids-and-liquids/. [Accessed 28 March 2020].

[8] AmesWeb, "Linear Thermal Expansion Coefficient of Titanium," [Online]. Available: https://amesweb.info/Materials/Thermal_Expansion_Coefficient_of_Titanium.aspx. [Accessed 27 March 2020].

[9] T. E. Toolbox, "Coefficients of Linear Thermal Expansion," [Online]. Available: https://www.engineeringtoolbox.com/linear-expansion-coefficients-d_95.html. [Accessed 28 March 2020].

[10] "ASTM F593C Stainless Steel Bolts: ASTM F593 Stainless Steel Bolts." *TorqBolt* www.torqbolt.com/suppliers/astm-f593-specification/#specification. [Accessed 30 March 2020]

[11]U. Chaudhary, "YouTube," Technology Explore, 2 August 2018. [Online]. Available: https://www.youtube.com/watch?v=KqMI6fa-guU&t=538s. [Accessed April 2020].

[12]GoEngineer, "YouTube," 7 November 2013. [Online]. Available: https://www.youtube.com/watch?v=ZVnkVXKOW_Y. [Accessed April 2020].