NAU Mixing Valve Team

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Introduction

- 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 96 pounds 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

Project Description

- Our project is a mixing valve for General Atomics. There are two inlet ports and one outlet port to produce water that is at a specific temperature.
- The temperature is specified by the user and the valve mixes two streams of water to create the outlet stream of water.
- The goal is to reduce the weight of their current valve by a total of 96 lbs

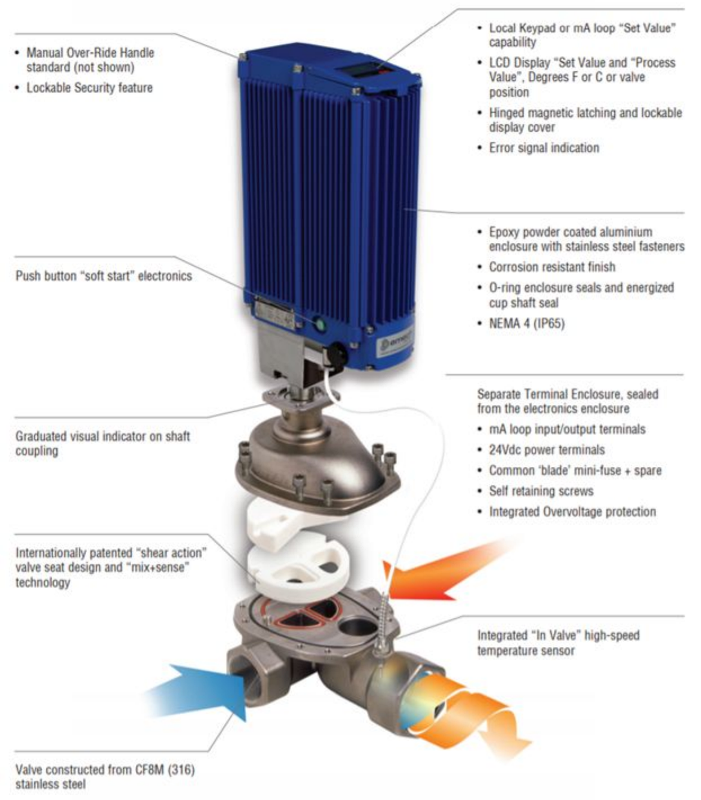

Figure 2: Modified Valve

Original System

- The original system was functional, however it is far too heavy for the application GA wants.

- The structure has an actuator on top of the valve to rotate it as needed, and it then accepts two streams of some incompressible fluid and releases a third stream that is a mixture of the first two streams to produce third accurate stream at the given temperature and flow rate.

Johnson

Original System Cont.

- The largest deficiencies of the original system is simply the weight, our goal is to reduce it significantly.
- The Original System is purchased commercially from Armstrong and modified by General Atomics. GA reduced the weight of the valve by removing flanges.

Black Box Model

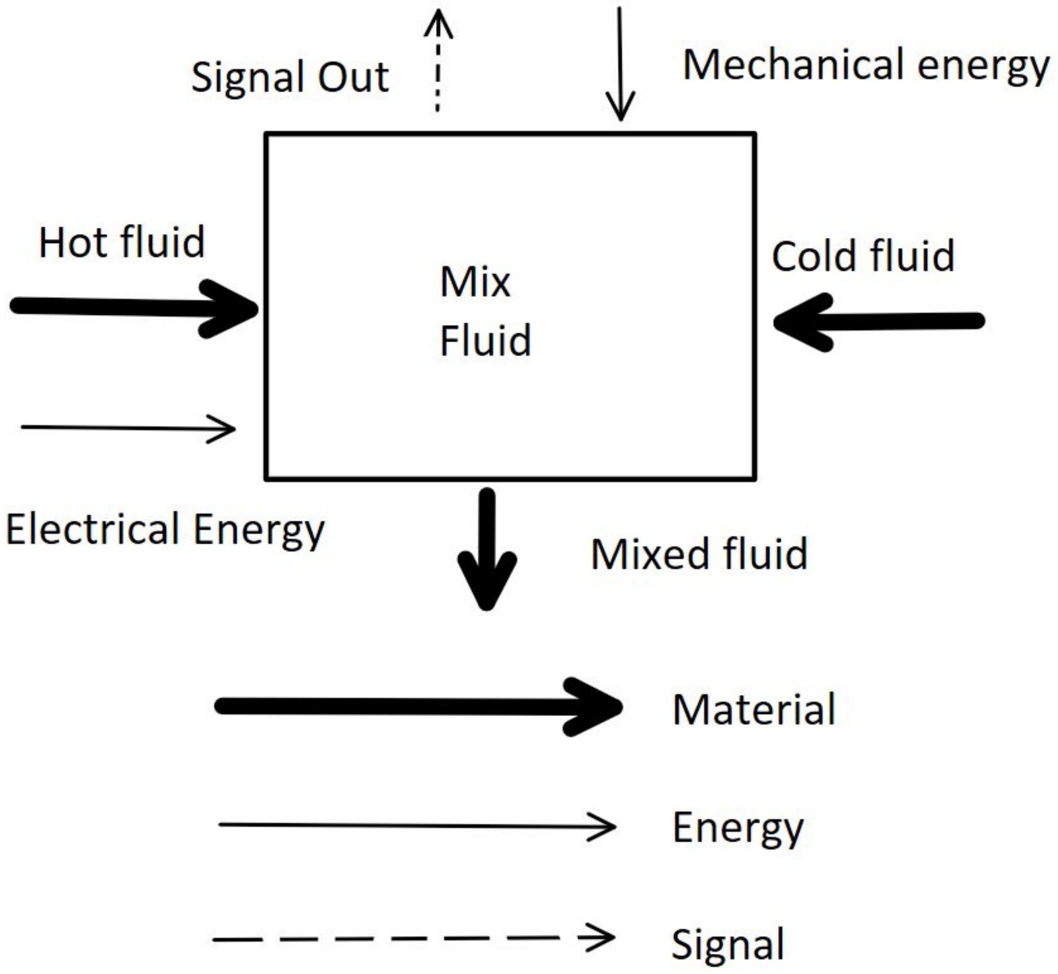

Figure 3: Black Box Model

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Functional Model

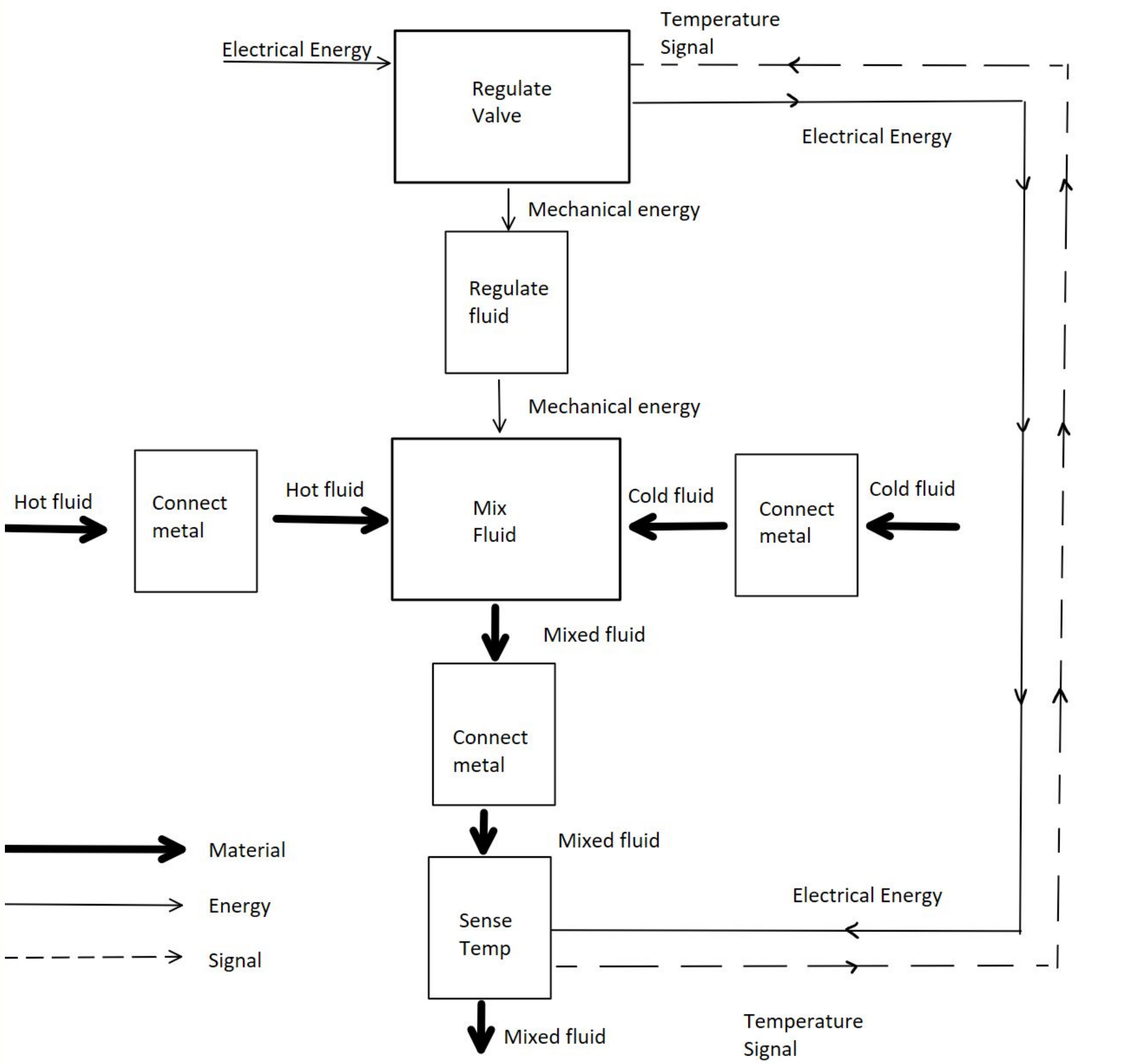

Figure 4: Functional Model

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Initial Concept Generation

- For Stainless Steel Valve 4 inch Body:
  - With Flanges: 102.7 lbs
  - Without Flanges: 41.2 lbs.
  - **Weight reduced: 61.5 lbs.**
- For Titanium Valve 4 inch Body:
  - With Flange: 57.9 lbs
  - Without Flange: 23.1 lbs
  - **Weight reduced: 34.8 lbs.**
- Total weight Reduction by switching to Ti and removing Flanges: 79.6 lbs

Material	Attachment Method
All Stainless Steel	Flanges
All Titanium	welds
Mix of Steel and Ti	Coupling/clamp

Figure 5: Concept generation freedom

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Why Switch to Titanium?

Pros:

- Potential to use less material if re-constructing valve
- Titanium is non corrosive because it produces and oxidized protective layer
- Titanium is 56% as dense as Stainless Steel

Drawbacks:

- Titanium has a modulus of 110[GPa], whereas Stainless Steel has a modulus of 190[GPa]
  - more material or re-structured part for same stiffness
- Titanium is more expensive
- Titanium is more difficult to machine

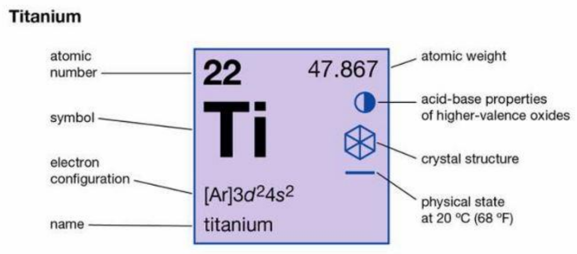

Figure 6: Titanium Information from Periodic Table

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Chamber Wall Thickness

- Wall Thickness
  - Reduced wall thickness from 22mm to 18mm
- 316 Stainless Steel
  - Original mass of 36.91 pounds
  - Corrected mass of 29.68 pounds
  - Reduced total mass 7.23 pounds
- Descaled Titanium
  - Original mass of 20.86 pounds
  - Corrected mass of 16.77 pounds
  - Reduced total mass of 4.09 pounds
- Total Weight Loss 20.14 Pounds
- Internal Pressure Not Driving Factor

Figure 7: Main Chamber

Top/Bottom Chamber Bolts

- Current Bolts are F593C Bolts
- 24 Bolts for Top and Bottom Plate Combined
  - Mass for Each Bolt: 0.04798 pounds
  - Combined Mass for 24 Bolts :1.1516 pounds
  - Combined Mass for 20 Bolts: 0.9597 pounds
  - Total Mass Reduction: 0.1919 pounds
- Bolt Quantity Reduction not Worth the Stress Risk
  - Total bolt mass reduction is minimal
- Descaling Bolts is Being Considered

Figure 8: F593C Bolts

Actuator Flange

- Currently the flange is 11 mm thick
  - Weighs 1.1 kilograms
- Reduction from 11 mm to 6.35 mm
  - Neither titanium or stainless steel will yield
  - Reduce mass to 0.62 kg if 316 stainless steel
  - Reduce mass to 0.35 kg if titanium
- Reducing thickness also reduces machining time and cost
- Additional tests for moments must be conducted

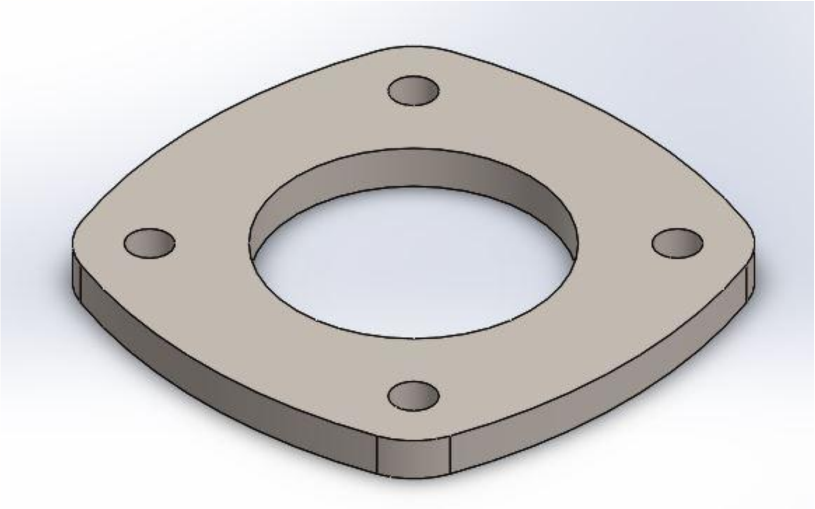

Figure 9: Actuator Flange

Why Switch to Hydraflow Flanges?

- Hydraflow flanges can be used instead of original flanges
    - Three Flanges at exit/inlets are heavy
    - Reduce valve body weight by 61.5 lbs for stainless steel
- Can not weld stainless steel to titanium so welding is not an option
    - Hydraflow flanges can be machined with both titanium and stainless steel
- Hydraflow flanges act more as a coupling (Figure 6)

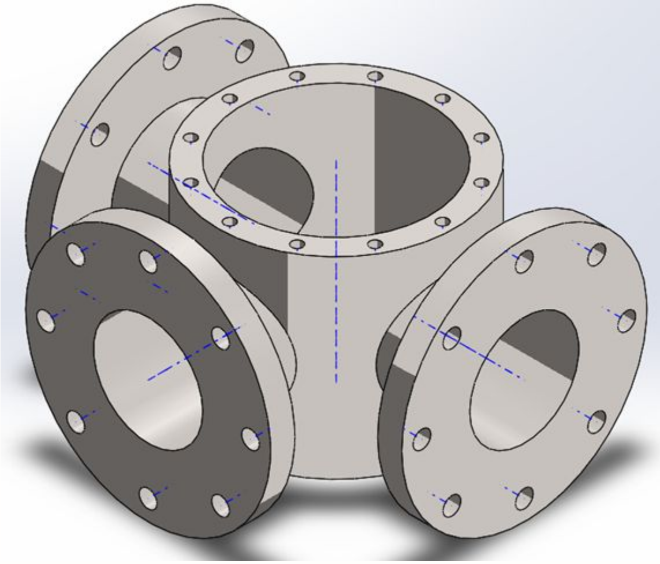

Figure 10: Un-Modified Valve

Figure 11: Example of Coupling Clamp

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Design 1: 4 Inch Mixing Valve Composed of Mostly Titanium

- Original sized valve is composed of mostly titanium for maximum weight reduction
- Could introduce deformation problems due to titanium being half as stiff as stainless steel.

Table 1: Pros and Cons of Switching to Titanium

Pros	Cons
Titanium is 56% as dense as Stainless Steel	Stainless Steel's modulus of elasticity is almost double the modulus of Titanium
Titanium is non-corrosive because it produces an oxidized protective layer	Switching could require a restructured valve to compensate for the modulus change
Potential to use less material of titanium, thus redudcing weight.	Titanium is more expensive to buy
	Titanium is more expensive to machine

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Design 2: 4 Inch Mixing Valve Composed of Stainless Steel and Titanium

- Instead of switching all components to titanium, Design 2 utilizes changing components selected by General Atomics (Figure 12).

Table 2: Pros and Cons of 4 Inch Valve with Stainless Steel and Titanium

Pros	Cons
Cost to switch is less than changing the entire valve to titanium	Not as much weight savings as a full titanium design
Reduces chance of threatening the integrity of the design	Stainless Steel parts may not be compatitble with Titanium parts
Provides good weight reduction	

Why Choose a mix of Steel and Titanium?

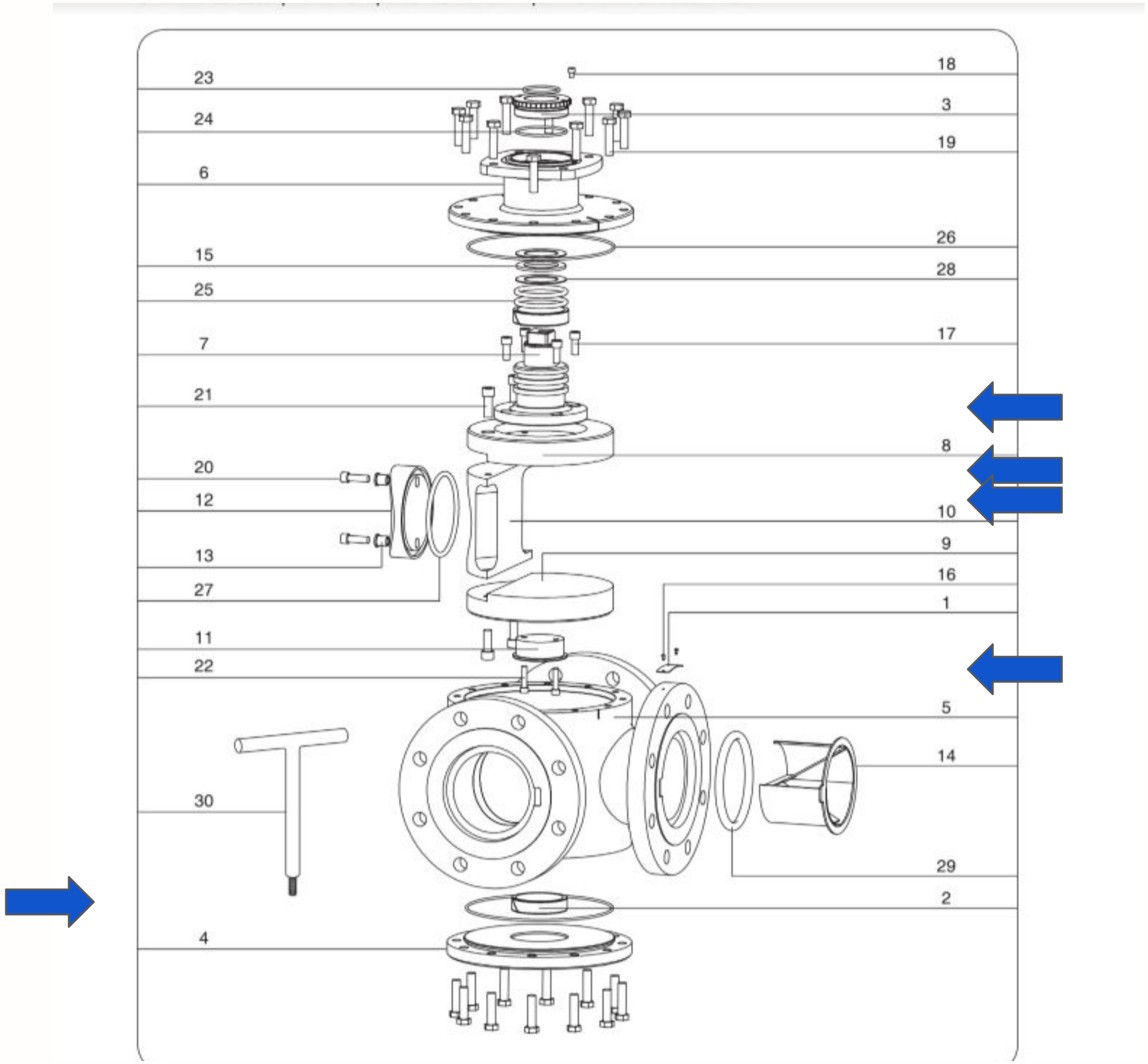

Figure 12: Current Candidates for Material Change

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Design 3: 3 Inch Mixing Valve Composed of Stainless Steel and Titanium

- Very similar to Design 3, except it is a 3 inch valve
- Benefits from material change and can produce more weight savings than 3 inch valve
- Does not need to use a size reducing Hydroflow Flange.

Table 3: 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	

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Effects of Thermal Expansion

- Same Conditions
  - 316 Stainless Steel expands twice as much as Grade 5 Titanium
- This affects:
  - 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

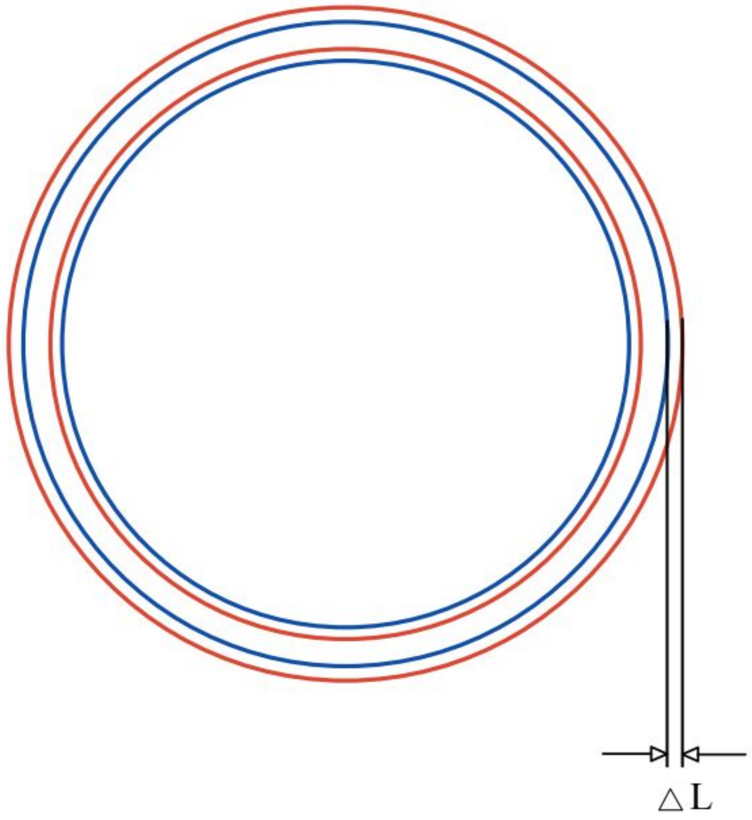

Figure 13: Change in Length Due to Thermal Expansion

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Effects of Thermal Expansion Cont.

- Assumptions
    - Increase of 15 Degrees Celsius
    - Outside diameter: 76.2 mm
    - Inside Diameter: 2.8125 mm
- Stainless Steel
    - Expands 0.00846 mm more than Titanium
    - Compressive Force
        - 25,182 N to 7,836 N

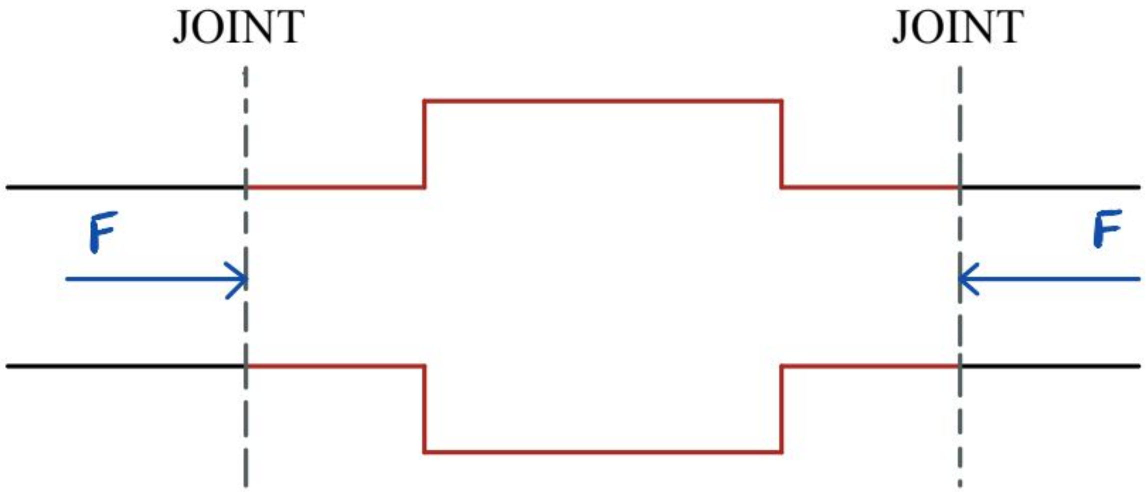

Figure 14: General Valve Schematic (Front)

Effects of Thermal Expansion Cont.

- Two main concerns are that the change in length, due to thermal expansion, will change when making the material switch, and that the compressive forces acting on the valve will change.
  - Change in length could cause leaks where titanium and stainless steel are mated. Titanium expands about 54% as much as stainless steel does under the same temperature change.
  - Compressive forces on the valve are less when titanium is used. Length may need to be added to the total length of the valve so that the compressive forces stay the same.

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Final Concept

- 3 Inch Valve with both 316 Stainless Steel and Grade 5 Titanium
- Hydro-pressure couplings
  - No flanges
  - Reduces weight
- Compatible with existing actuator
- Initial total weight reduction 79.6 lbs
  - Reduce Further

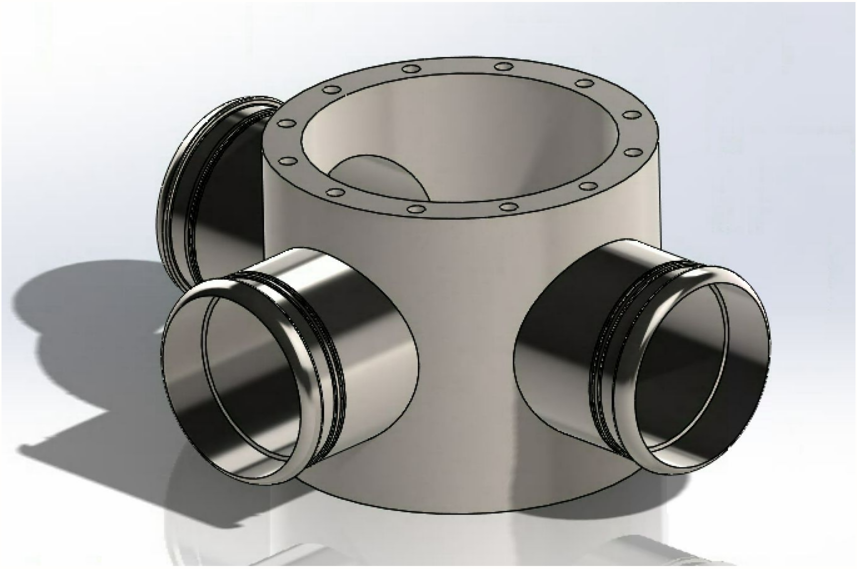

Figure 15: Valve Concept

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

- Perform simulated tests for flow rate and pressure drop
- Topology Optimization
  - Affects flow
  - Internal component redesign
- Descaling to 3 inch valve calculations
- Create drawing files of new valve for client
- Removing inlet/outlet pipes and weld coupling directly to valve

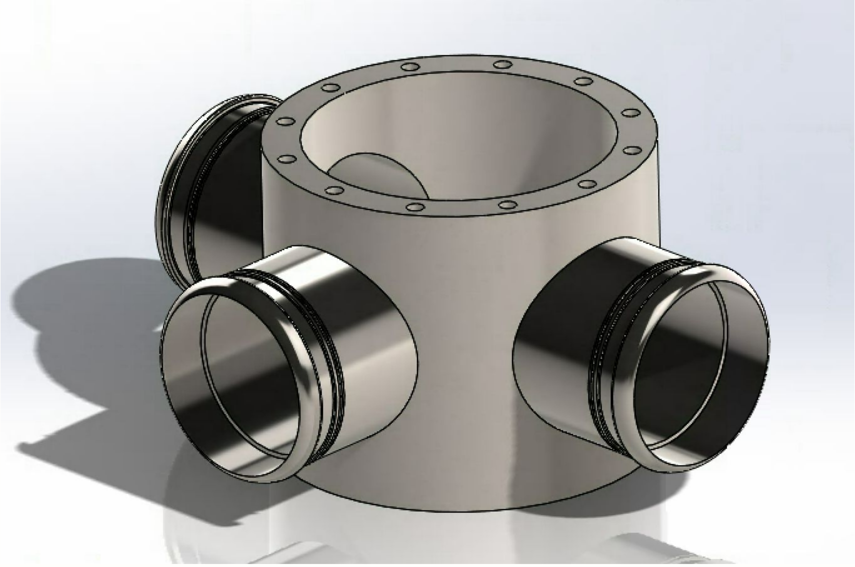

Figure 16: Valve Concept

Questions?

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