NAU Mixing Valve Team

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Introduction and Project Description

- The NAU Mixing Valve Team was tasked with making a mixing valve that is significantly lighter than the mixing valve General Atomics is currently using
- General Atomics is currently purchasing valves commercially through Armstrong, and the NAU team's goal was to reduce the valve by 96 lbs.
- The NAU mixing valve team did this by changing the material, port sizes, and reducing the overall size

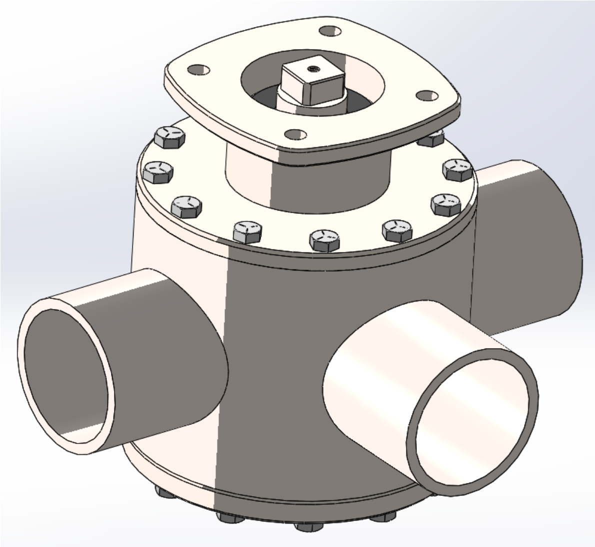

Figure 1: Valve Assembly

Engineering Requirements

- Max Internal Fluid Pressure: 125 PSIG
- Must be proof tested to 185 PSIG
- Max Flow rate: 450 GPM
- Balanced Port Design
- Accuracy of temperature requirements
- Specific operational fluids
- Allowable Materials: Electropolished Stainless Steel 316L; descaled titanium

Concept Generation

- The entire assembly was built in solidworks, and all parts were created independently then mated together in a large assembly
- Major Design Decisions
  - Switch Steel parts to titanium to decrease weight because titanium is 56% the density of steel.
  - Reduce parts' size by 20%, this will reduce the weight by 20%.
  - Switch from a 4 inch ports to a 3 inch to reduce weight

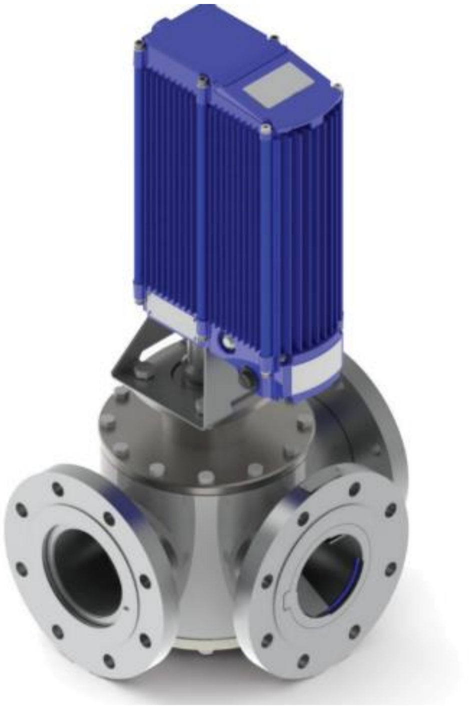

Figure 3: Mixing Valve

Major Design Decisions

Table 1: Pros and Cons of Major Design Decisions

Design Decision	Pros	Cons
Switch Steel Parts to Titanium	Titanium is 56% as dense as Steel, titanium is stronger than steel	Cannot weld steel to titanium, and titanium is expensive
Switch from a 4-inch port to a 3-inch port	Reduces weight	Could have effects on flow and pressurization
Reduce large parts' size by 20%	Reduces weight	Valve needs to fit actuator, so not all parts can be changed.

Manufacturing and Testing

- All analysis was done in SolidWorks Simulation
- General Atomics is doing all of the manufacturing and requested drawings.
- CR's met:
    - Weight Reduced under 46 lbs, the redesigned valve is 45.78 lbs
    - Hydraflow Flanges added
    - Designed to use Armstrong Actuator

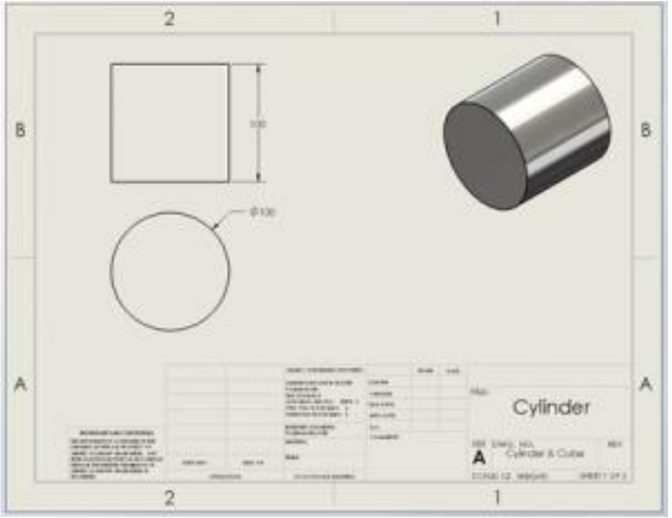

Figure 4: Example of a Solidworks drawing

RVTM: Requirement Verification Traceability Matrix

Table 2: RVTM with color coding

Requirement ID	Requirement Text	Verification method	Comments
Weight100	Reduce Valve weight by [redacted] pounds total	Analysis	Solidworks Props
Pressure100	Max operational internal fluid pressure = [redacted] PSIG	Analysis	Flow Analysis
Pressure200	Proof tested to [redacted] psig with no deformation	Analysis	Flow Analysis
Pressure300	Maximum pressure drop [redacted] psid at [redacted] gpm.	Analysis	Flow Analysis
Flow100	Max flow rate = [redacted] GPM	Analysis	Flow Analysis
Flow200	Balanced port design, constant flow through out valve swing	Analysis	Flow Analysis
Temp100	Accuracy from set point across step changes of [redacted] in hot let inlet	Analysis	From Actuator
Temp200	Set points programmable from [redacted] to [redacted]	Inspection	Actuator manual
Material100	Operational fluids = Water and possible others	Analysis	Check compatability
Material200	Allowable materials = Electropolished Stainless Steel 316L, descaled Titanium	Inspection	Solidworks Props
Material300	Allowable polymers = [redacted], [redacted]	Inspection	Purchase
Actuator100	If alternate actuator is selected, power and interfaces must be same as the G1 unit	Inspection	Using Old Actator
Actualtor200	Design may use EMECH/Armstrong G1 actuator or other design	Inspection	Using Old Actator
Assembly100	Reduce valve ports from four inches to three inches	Analysis	Pressure Analysis
CN	Fluid connections per [redacted] Hydraflow drawings	Analysis	
CN	Valve must fit original Bracket	Inspection	Solidworks
CN	Bolts must use helicoils	Inspection	
CN	Purchased Parts must fit in machined parts	Inspection	Purchase
CN	Drawings must be machineable	Inspection	From Client

Complete	Awaiting Verification	Incomplete

Testing: Internal Pressurization

- Verified max internal pressure did not cause yielding
- Pressure analysis was performed using SolidWorks SImulation
- Initial Conditions
    - Valve is fixed at bottom plate bolt holes
    - All internal surfaces pressurized to 185 PSI
    - Plate was added on bonnet to allow entire pressurization of upper surface
    - Titanium (Ti-6Al-4V)
    - All internal components removed

Testing: Internal Pressurization Cont.

- 185 PSI applied to all internal surfaces (red arrows)
- Assembly was fixed at bolt holes (green arrows)
- Test was conducted using the finest mesh in SolidWorks
    - Total Nodes: 109,998
    - Total Elements: 67,219

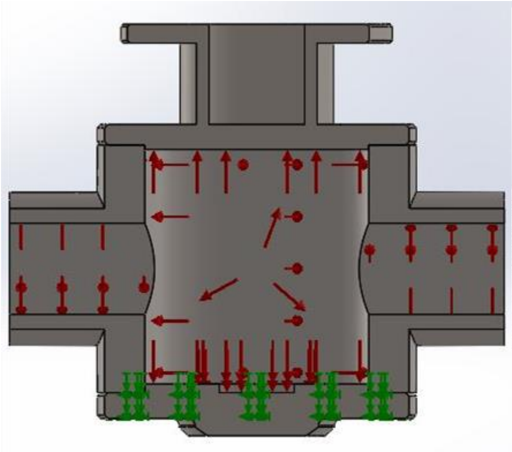

Figure 5: Fixture Section Cut

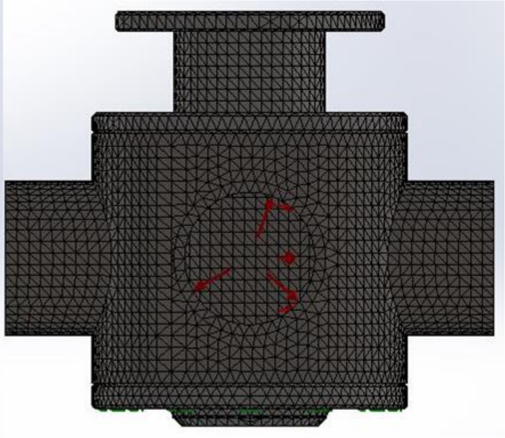

Figure 6: Mesh Quality

Testing: Internal Pressurization Cont.

- Maximum stress recorded was 54.6 MPa
  - Always occurred at bolt holes
- Nodes near maximum stress were probed to obtain average stress

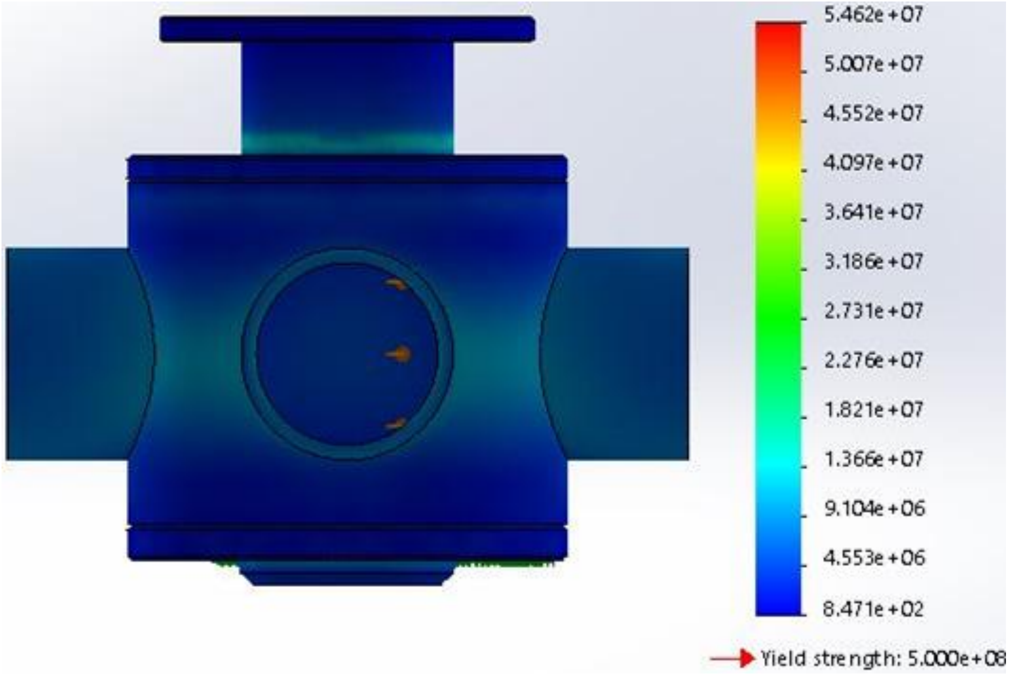

Figure 7: Valve Stresses

Testing: Internal Pressurization Cont.

- Nodes vs Stress
  - Analysis was performed 6 times under same conditions.
  - We expected an increase of stress with a finer mesh
  - Max stress fluctuated when mesh was refined (reason for probing).
  - Highest average stress occurs at highest mesh quality
- Lowest factor of safety obtained was 9.2

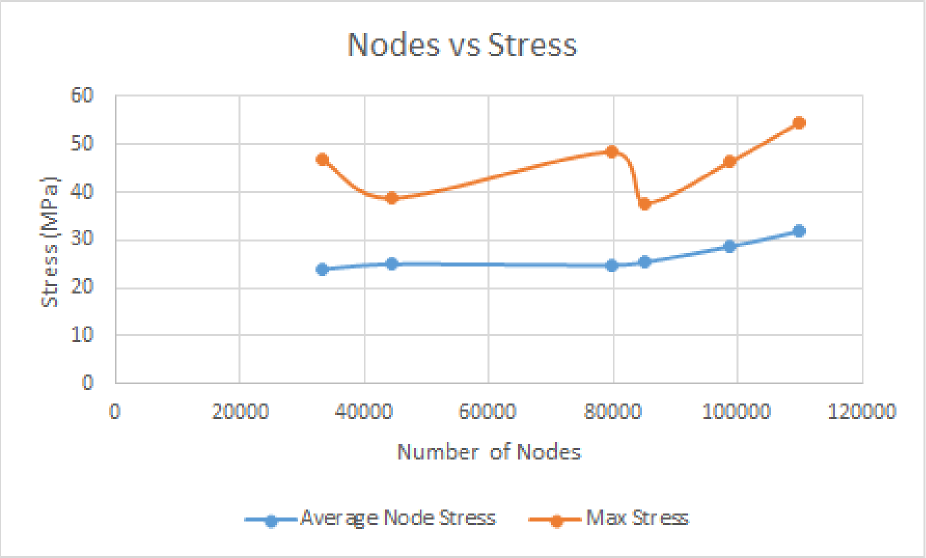

Figure 8: Nodes vs Stress

Testing: Pressure Drop

- Pressure Drop was tested in SolidWorks Flow Simulation
- Boundary conditions were set at the inlet ports and outlet ports
- Tests were done for two meshes: a lower mesh and higher mesh
  - Lower Mesh: 87,140 Cells
  - Higher Mesh: 160,852 Cells

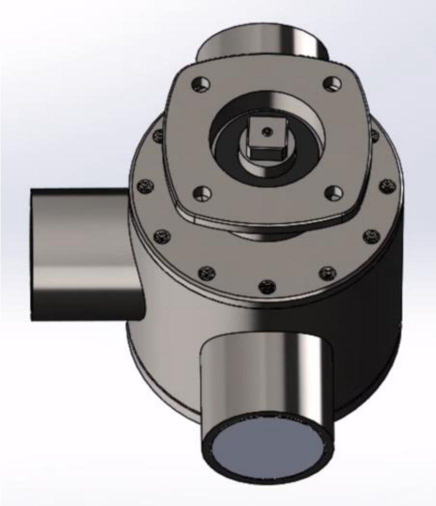

Figure 9: Isometric View Before Section Cut

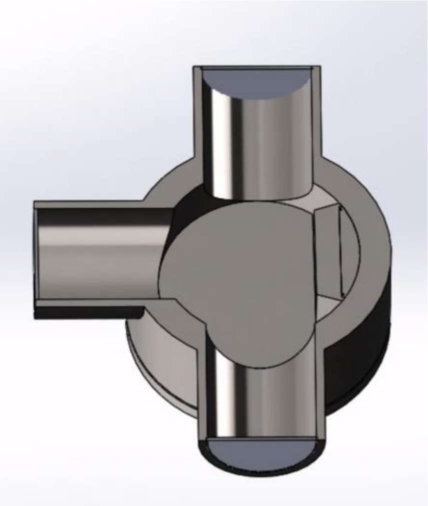

Figure 10: Isometric View After Section Cut

Testing: Pressure Drop Cont.

- Outlet flow set to 450 GPM
- Inlet flows set with total pressures of 20 PSI at cold and hot flows
- Ran internal flow simulation and created local goals
- Pressure drop obtained by taking the difference between largest and smallest pressure

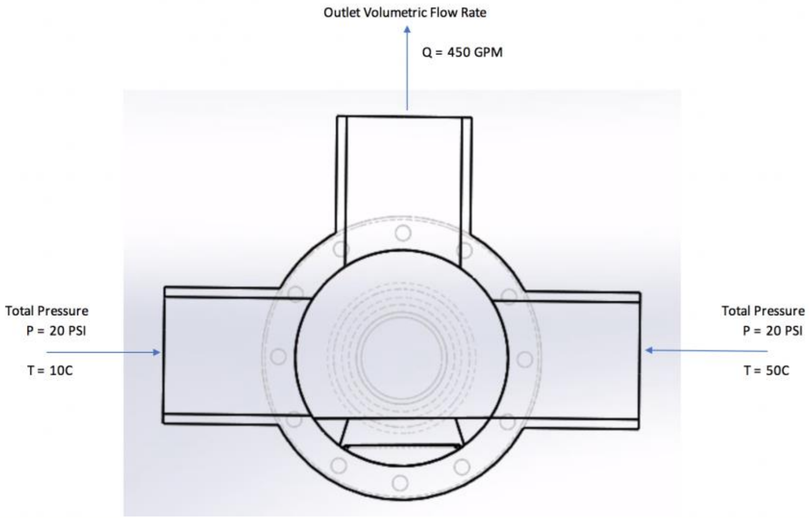

Figure 11: Boundary Conditions of Valve

Testing: Lower Mesh Pressure Results

- Pressure at the ports are shown in Figure 12. Total Pressure 1 shows the pressure value at the outlet. Total Pressures 2 & 3 show the pressure values at the inlet

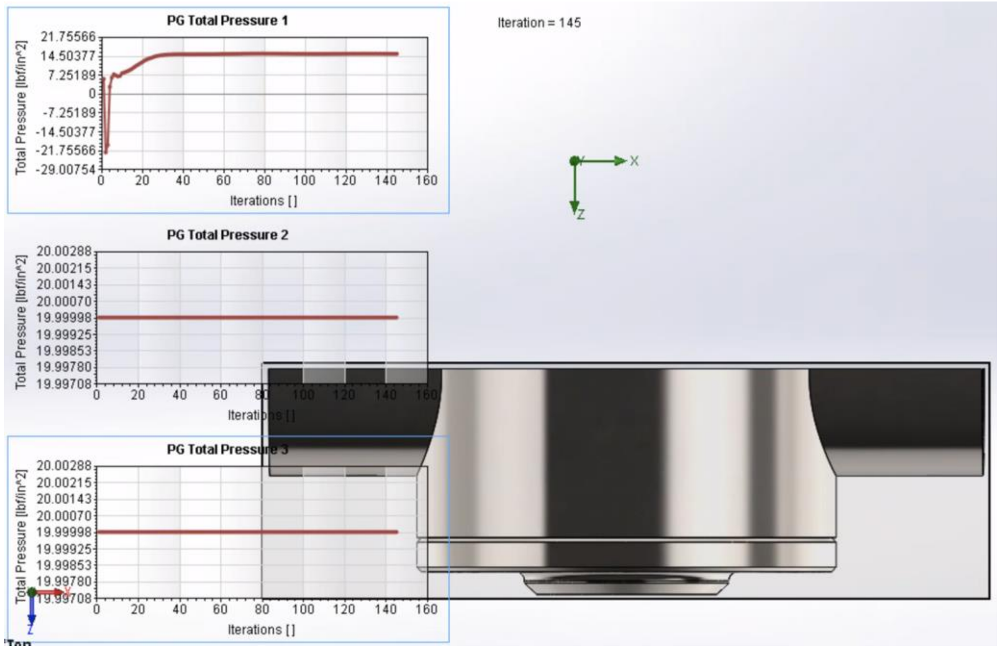

Figure 12: Lower Mesh Local Goal Plots

Testing: Higher Mesh Pressure Results

- Figure 13 shows the pressure values at each port for the higher mesh simulation
- Mesh details for lower and higher mesh can be found in Appendix A

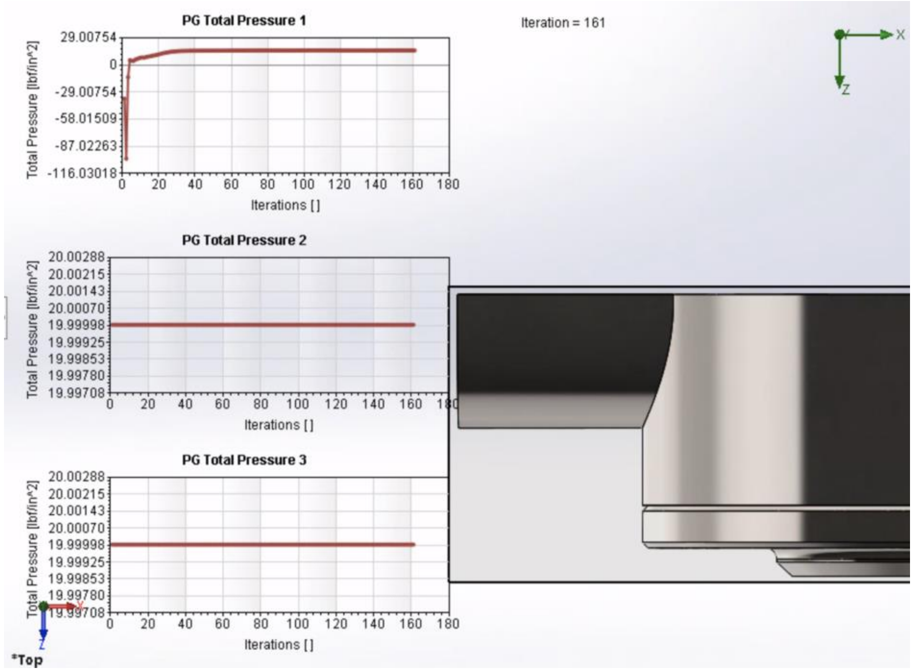

Figure 13: Higher Mesh Local Goal Plots

Testing: Pressure Drop Results

- Both mesh results gave the same outlet port pressure when exported to Excel (Figure 14)
- The calculated pressure drop was found by taking the inlet pressure value (20 PSI) and subtracting the outlet port pressure from it
  - Ultimately, the team found that the pressure drop in the designed mixing valve is 4.470 PSI (Figure 15)
  - Therefore, the mixing valve meets the 8 PSI maximum pressure drop requirement

Average Pressure Value (PSI)
15.530

Figure 14: Resulting Pressure at Outlet Port

Calculated Pressure Drop (PSI)
4.470

Figure 15: Resulting Pressure Drop

Testing: Pressure Drop Results

- General Atomics came to the conclusion that the pressure drop analysis could not be considered “satisfied” due to the fact that Flow Simulation would output pressure as ~14 PSI when run as a “Flow Trajectory” (Figures 16 & 17)
- The same result was reached each time Flow Simulation was run

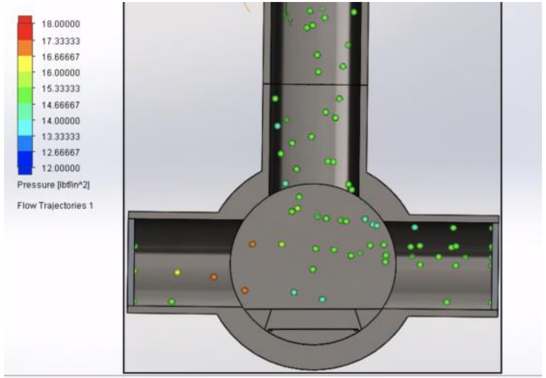

Figure 16: Lower Mesh Pressure Flow Trajectory

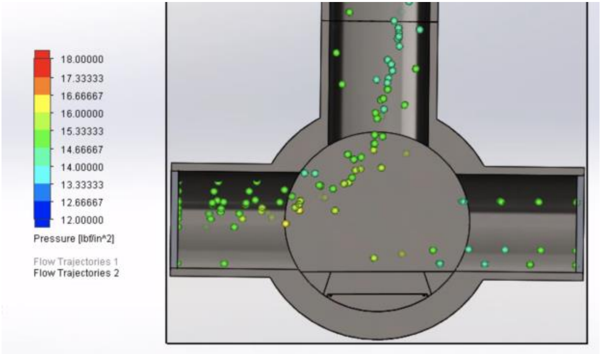

Figure 17: Higher Mesh Pressure Flow Trajectory

Testing: Pressure Drop Hand calculations

- Known:
  - V = 4.14 m/s
  - D= 3 in
  - Density = 1000 kg/m^3
  - K = 0.5
  - L= 2.5 ft

$$\Delta P = (\rho \frac{V^2}{2}) * (\frac{L}{D}) * K$$

$$\Delta P = ((1000 \frac{4.15^2}{2}) * (\frac{0.762}{0.0762}) * 0.5) Pa = 6.24 \ psi$$

- The average velocity from both inlets and the outlet was 4.15 m/s
- The outlet pressure drop of 6.24 psi would meet the 8 psi pressure drop requirement

Bolt and Screw Specifications

- All can be purchased on McMaster-Carr.com [1]
- All are 316 Stainless Steel
- Part 19 needs helicoils to prevent thread stripping on valve component
- Total Price for components: $96.49

Table 3: Bolt, Screw and Helicoil Specs

Part Number	Location	Quantity	Specifications	Price	McMaster-Carr Part Number
17	Spindle Cap Screw	4	5/16"-18 Thread Size, 3/4" Long	$6.05 Each	92488A457
18	Glan Nut Locking Screw	1	8-32 Thread Size, 1/2" Long	$3.01 per pack of 25	92185A194
19	Bonnet Base Plate/Body Bolt	24	3/8"-16 Thread Size, 1-3/8" Long	$13.09 per pack of 50	92865A253
	Bonnet Base Plate/Body Helicoil	24	3/8"-16 Right-Hand Thread, 0.938" Long	$8.12 per pack of 5	91732A747
20	Turret Seal Cap Screw	2	1/4"-20 Thread Size, 1" Long	$3.44 per pack of 10	92185A542
21	Turret Upper/Lower Plate Cap Screw	4	3/8"-16 Thread Size, 1-7/8" Long	$9.52 per pack of 10	92196A661
22	Turret Trunnion Cap Screw	2	1/4"-20 Thread Size, 1/2" Long	$2.63 per pack of 10	92185A537

Bill of Materials

Table 4: Bill of Materials

Bill of Materials									
Part	**Description**	**Quantity**	**Material**	**Price ($)**	**Part**	**Description**	**Quantit**	**Material**	**Price ($)**
2	Wear Ring	2	Carbon Reinforced	$200.00	16	U Hammer Drive	2	316 Stainless	TBD
3	Gland Nut	3	316 Stainless Steel	$570.70	17	Spindle Cap Screw	4	316 Stainless	$24.20
4	Body Base Plate	1	Titanium	TBD	18	Gland Nut Locking	1	316 Stainless	$0.48
5	Body Base Plate	1	Titanium	TBD	19	Bonnet/Base	24	316 Stainless	$13.09
6	Bonnet	1	Titanium	TBD	20	Turret Seal Cap Screw	2	316 Stainless	$3.44
7	Spindle	1	316 Stainless Steel	$2,660.60	21	Turret Lower Plate Cap	4	316 Stainless	$9.52
8	Turret Top Plate	1	Titanium	TBD	22	Turret Trunnion Cap	2	316 Stainless	$2.63
9	Turret lower	1	Titanium	TBD	23	O-Ring Gland External	1	EPDM 75 X	$200.00
10	Turret Seal	1	Titanium	TBD	24	O-Ring Gland Internal	1	EPDM 75 X	$200.00
11	Turret Trunnion	1	316 Stainless Steel	$258.40	25	O-Ring Spindle Seal	2	EPDM 75 X	$200.00
12	Turret Seal	1	Glass Reinforced	TBD	26	O-Ring Body Seal	2	EPDM 75 X	$200.00
13	Turret Seal Bush	2	316 Stainless Steel	TBD	27	O-Ring Turret Seat Seal	1	Titanium	TBD
14	Mixer Insert	1	316 Stainless Steel	TBD	28	Thrust Washer	2	C-Cr Steel X	$200.00
15	Needle Roller	1	Cr-C Steel X	$200.00	29	O-Ring Mixer Insert	1	EPDM 75 X	$200.00
								Total cost	$5,143.06

Budget

- The initial project budget was $2500
- Budget was increased to $4000 over the summer term
- The plan was to purchase parts to dimension and model from

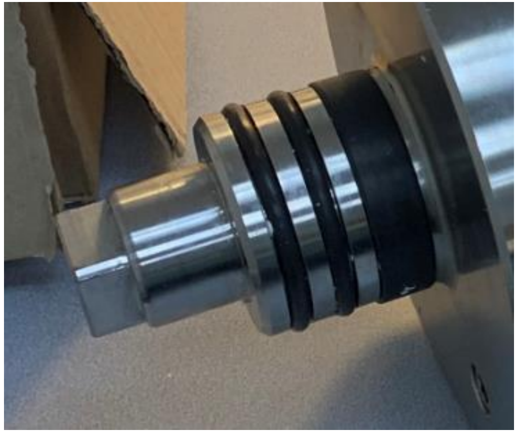

Figure 18: Spindle

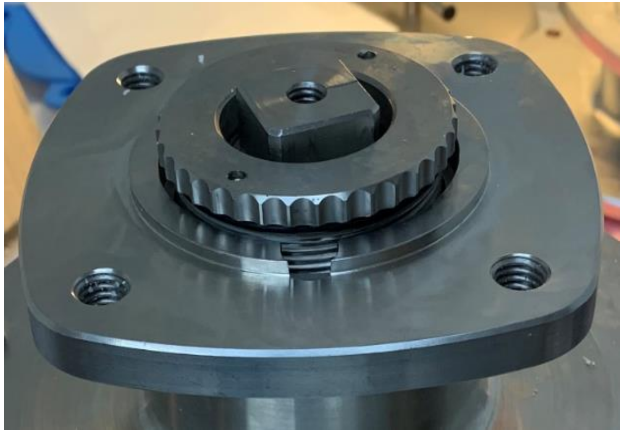

Figure 19: Gland Nut

Future Work

- The NAU valve team was unable to complete the drawings due to lack of required dimensions
- If work is to continue on the mixing valve the following Items must be purchased:
    - Spindle
    - Gland nut
    - Lock nut for gland nut
    - Trunnion
    - O-ring kit with 2x wear rings
    - Mounting bracket
- When these parts are acquired their dimensions must be taken and recorded.

Figure 20: Business Image

Future Work Continued

- Once dimensioned are known the following parts must be redimensioned as needed to fit the purchased parts:
  - Bonnet
  - Turret top plate
  - Turret bottom plate
  - Valve bottom plate
- It is recommended that the flow and pressure analysis are redone if any major changes are made
- The required hardware and O-rings can be found in the Bill of Materials
- When these changes are made GA can machine the titanium parts and assemble the mixing valve.

Works Cited

[1] “McMaster-Carr.” McMaster, https://www.mcmaster.com/92488A457/

[2] “McMaster-Carr.” McMaster, https://www.mcmaster.com/92185A194/

[3] “McMaster-Carr.” McMaster, https://www.mcmaster.com/92865A252/

[4] “McMaster-Carr.” McMaster, https://www.mcmaster.com/91732A747/

[5] “McMaster-Carr.” McMaster, https://www.mcmaster.com/92185A542/

[6] “McMaster-Carr.” McMaster, https://www.mcmaster.com/92196A661/

[7] “McMaster-Carr.” McMaster, https://www.mcmaster.com/92185a541

Appendix A - Pressure Drop Results

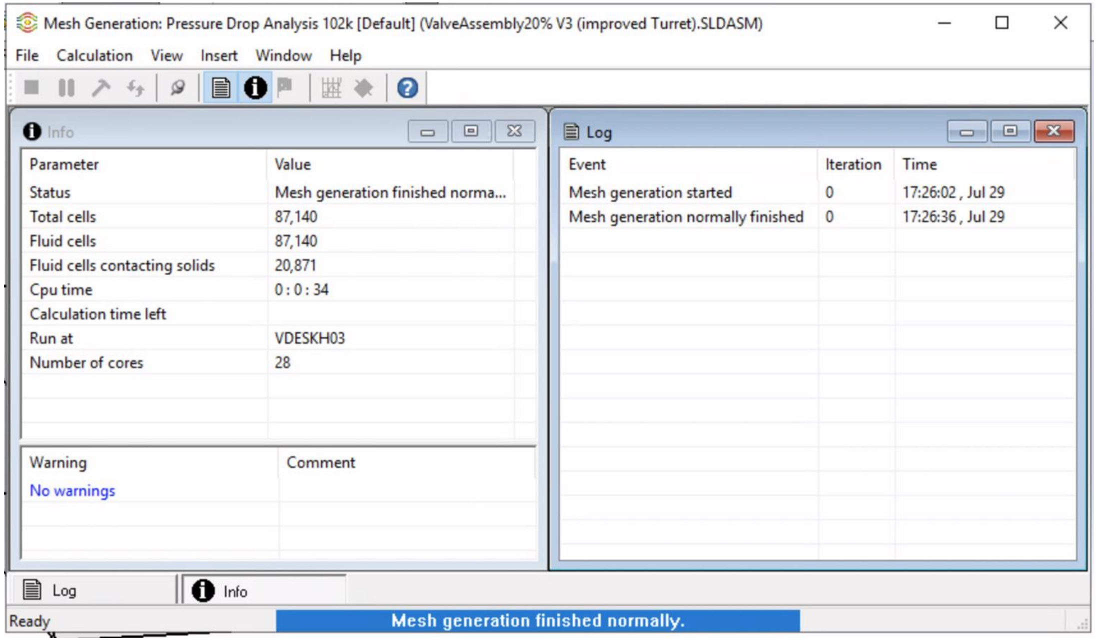

Figure A1: Lower Mesh Details

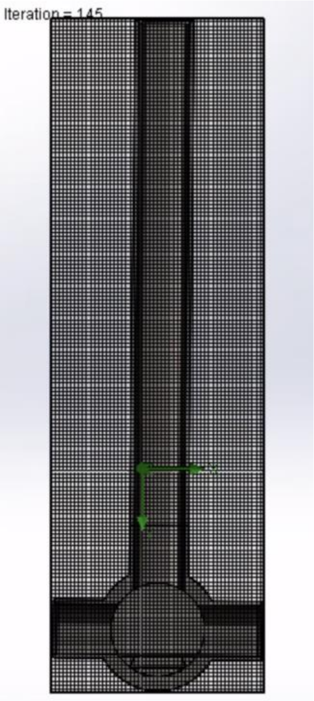

Figure A2: Mesh View

Appendix A - Pressure Drop Results Cont.

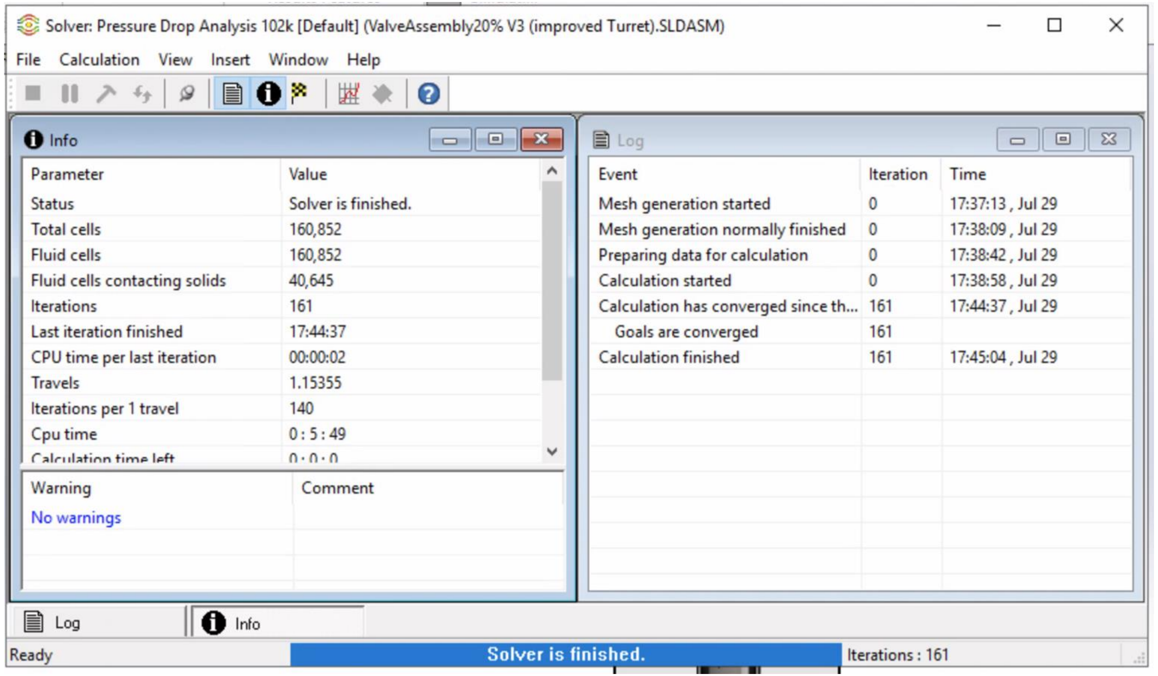

Figure A3: Higher Mesh Details

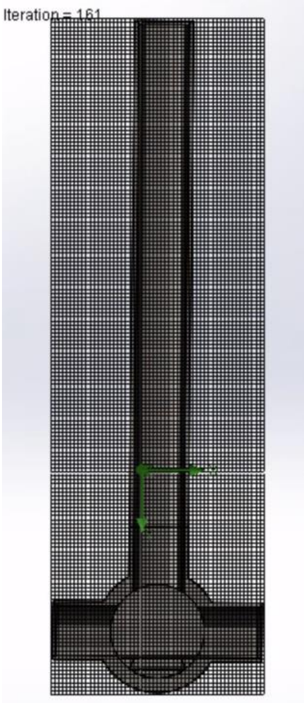

Figure A4: Mesh View