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Professor Timothy R. Cooley, PE, "CEO" of the Really Cool Engineering Company
MET 400 Mechanical Design "Honors" CAPSTONE, Fall 2019
Purdue University, Purdue Polytechnic New Albany
11 December 2019

Project Closure Report

Rocketcam Air Cannon Pneumatic Mortar Project

A Project Closure Report is typically the final project document and officially ends the project. The primary objective is to provide a complete picture of the deliverables within a framework of their primary constraints (scope/schedule/costs). It should include all important project information to help stakeholders, auditors, and future project managers clearly understand what was accomplished during the project as well as the constraints imposed on it at the time.

This document is the Project Closure Report for the Rocketcam Air Cannon Pneumatic Mortar Project, for the Really Cool Engineering Company. We overcame all engineering challenges, did it in 1/2 the time, and were under budget by 15.4%. Boiler Up!

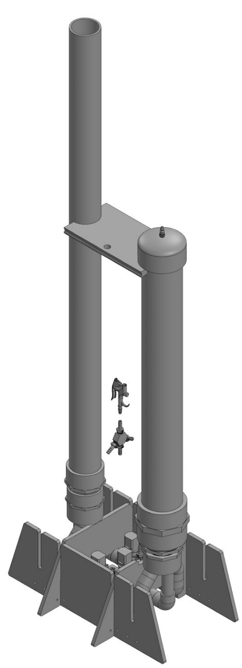

Fig. 1. SOLIDWORKS CAD Rendering of the Rocketcam Air Cannon.

Fig. 2. Photograph of the Rocketcam Air Cannon.

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The authors of this document wish to thank their family, Professor Timothy R. Cooley, Christy Snip, Paul Hagmann, Trina Ruby, Professor Rustin Webster, Professor Damon Sisk, Dani Reynolds, and Professor Joseph Dues for their help, knowledge, guidance, and patience with the successful completion of this MET 400 Mechanical Design "Honors" CAPSTONE project.

1. Overall

1.1 Project Constraints

Our team was tasked with engineering a solution for an improved pneumatic air cannon to launch a 3D printed rocket containing a GoPro camera. Below is the video on Youtube of the successful demonstration and photographic documentation of the design, prototype, test, build, and refinement of the project in 1/4 the time that other teams had in MET 401, and 1/2 the time other teams had in MET 400.

Purdue Students built an Awesome Rocketcam Air Cannon! - MET 400 CAPSTONE
https://youtu.be/xeTzhq9V3Eg

Senior Engineering Students at Purdue University, Purdue Polytechnic New Albany, Lukas W. DiBeneditto and Joseph Schoettmer, Jr. were tasked with creating an improved version of a pneumatic cannon, and wow did it turn out better than expected!

Fig. 3. The Youtube Title Card.

1.1.1 Scope

The main deliverables were to make it portable, the firing mechanism predictable, to reload faster, design for mass production, and to make the projectile reach a higher ceiling height than the original. Other than the original project for MET 400 being "killed" (when a decision is made by management or the team to end the project), the scope did not change.

Fig. 4. Previous Design Cannon Portion and Support.

Fig. 5. Previous Design Support and Pressure Vessel.

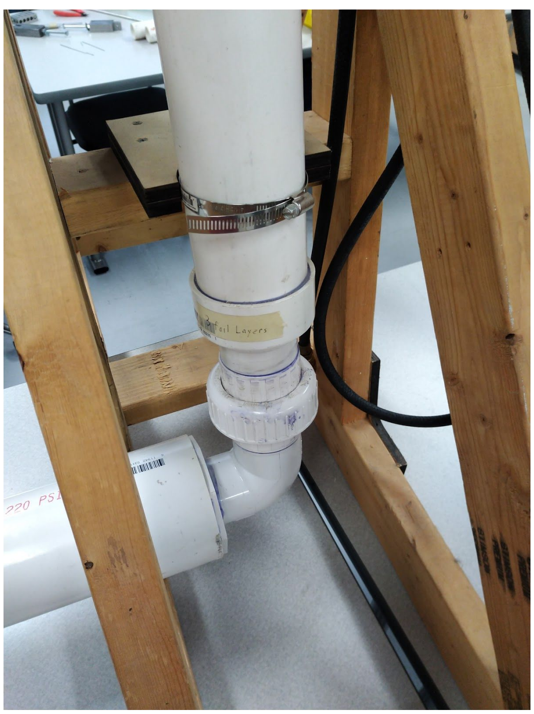


Fig. 6. Previous Design connection from pressure vessel to the cannon.

Fig. 7. Previous Design Aluminum Foil Burst Discs act as unpredictable valve.

1.1.2 Schedule

The normal semester is 16 weeks however, our first project was "killed", leaving only 8 weeks (1/2 the time) to design, prototype, test, build, and refine everything. We completed the project early, finished under budget, solved all design challenges, and exceeded all expectations. Boiler Up!

1.1.3 Costs

The initial starting budget amount was $1000, of which $227.41 was spent on testing, $618.67 and was spent on the build, for a total cost of $846.08 which is 15.4% under budget. This includes a total of 14 prototypes, of which some parts were swapped out to use on other prototypes, other parts when PVC solvent welded were a one time use, and the cost could not be recovered. The intention was always to spend the least amount of money to achieve our objectives. The actual cost for materials for 1 Rocketcam Air Cannon with support structure is estimated at $310.

While the cost may seem relatively high, that was due in part to ensure the added safety provided from making the engineering design decision to use Schedule 80 instead of Schedule 40 PVC pipe and fittings to decrease the risk of catastrophic pressure vessel explosion failure and the resulting danger to life and property. Every attempt was taken to minimize safety risk, including Lukas bringing in a valued $200+ 1/2 in thick polycarbonate blast shield repurposed from an old restaurant sign.

See also Section 2.1.3 Final Costs & Raw Materials List and Section 2.2 Manufacturing Process for manufacturing costs.

1.2 Team Members & Their Individual Responsibilities

1.2.1 Lukas W. DiBeneditto

Research, Experimental Design, Testing, Computer Networking, After Hours Lab Key Card Access for the Boilermaker Lab, Considerable Arduino Intra-Team Consultation, Arduino C++ Programming, Soldering, Electronic Circuit Design, Pressure Sensor System Implementation, Financial Procurement, Purchasing, Accounts Reconciliation, Most of the Financial Record Keeping, Company Credit Card Holder, Safety Validation, Metalworking and Fabrication, Welding, Laser Operation, Machine Shop Coordination, Pressure Vessel Validation, Manifold System Design, AutoCAD 2D CAD, SOLIDWORKS 3D CAD, Graphic Design, Cricket Vinyl Cutter Operation, Paint Prep, Paint, Hardware Assembly, Video editing, Youtube Video Posting, Google Docs Style Formatting, Final Product Breakdown Structure, Final Process Flow Diagram, 7 Prototypes, and Project Management.

1.2.2 Joseph Schoettmer, Jr.

Research, Experimental Design, Testing, Pressure Sensor System Implementation, Financial Procurement, Purchasing, Financial Accounts Reconciliation, Lathe Operation, Hardware Assembly, Pressure Vessel Validation, Piston Valve System, Launch Angle Device Prototype, 7 Prototypes, and Project Management.

1.3 Major Project Deliverables

See Section 2.1 Product and Section 2.2 Manufacturing Process below for the components, instructions, drawings, and process. See Table 1 (next page) for the major project deliverables.

Table 1. Comparing Existing Previous Design to Our New Design the Rocketcam Air Cannon.

Existing Previous Design	Our New Design
Not portable ● Heavy: 2 or more people needed ● Large footprint: ~28 ft^2 ● Takes ~15 minutes to set up	**Portable** ● Light: 1 person carry **50% improvement** ● Small footprint: ~4 ft^2 **85.71% improvement** ● Packaged for quick setup and disassembly ~5 minutes **66.7% improvement**
Firing Mechanism Unpredictable ● Aluminum foil discs fail at unpredictable pressures.	**Firing Mechanism Predictable** ● 3 inline 1" sprinkler valves to a 3 way brass manifold will **only fire when pneumatic trigger is pulled** at pressure specified by pressure regulator and dial indicator. ● **Adjustable pressure**
Slow Reload ● Usually takes ~10 minutes to unscrew PVC fittings, seat 3 layers of aluminum foil, and screw PVC fittings back together, load the rocket, and repressurize the 10 ft by 3 in pressure vessel.	**Fast Reload** ● ~15 seconds to reload **98.5% improvement** ● It's **immediately ready to fire after trigger is pulled**, drop in a new rocket, pressurize small 3 ft by 4 in pressure vessel.
Not Designed for Mass Production ● Custom designed frame	**Designed for Mass Production** ● See Section 2.1 Product and Section 2.1.4 Performance test results.
Lower Projectile Ceiling ● Neglecting air resistance, the data that we had was for 3 trial runs **~9.3 seconds** of flight time, an 80 degree launch angle, calculating a height of **348 ft**. [pro-mo-calc]	**Higher Projectile Ceiling** ● Neglecting air resistance, we have achieved a flight time of **11.108 seconds**, with a launch angle of 85 degrees, and calculating a height of **496 ft**, and a launch velocity of **122.3 mph**. [pro-mo-calc]
Not aesthetically pleasing	**Refined paint job and looks aesthetically pleasing. America!**

1.4 Major Issues Encountered and Their Resolutions

1.4.1 Pressure Test for Sprinkler Valve Timing and Selection

We didn't know how fast the irrigation sprinkler valves were, so we designed, prototyped, tested, built, refined a pressure testing system. We needed to know the fastest irrigation sprinkler valve to select it for use in the final design.

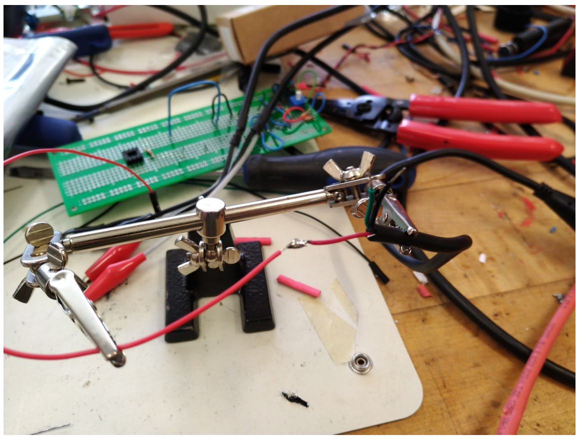


Fig. 8. Soldering wires for Arduino Pressure Sensor.

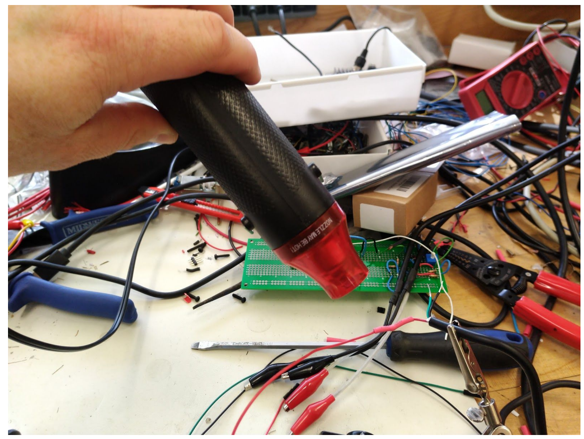


Fig. 9. Heat shrink tubing to prevent shorts for Arduino Pressure Sensor.

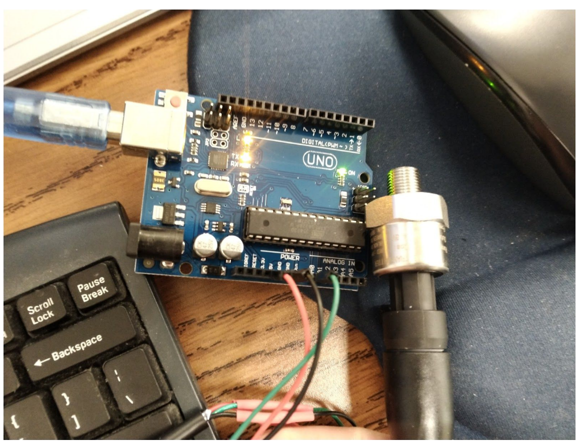


Fig. 10. Arduino Uno with selected pressure sensor.

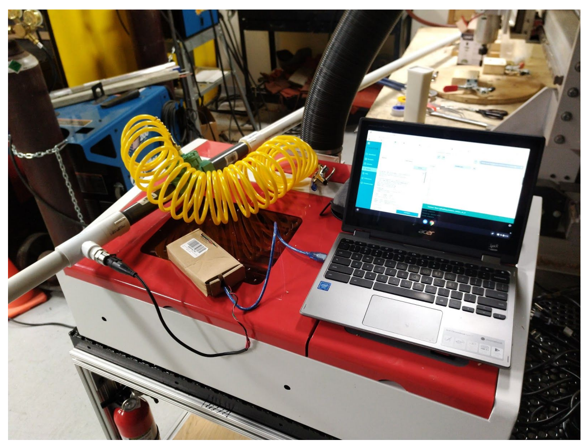


Fig. 11. Testing rig, laptop for recording data through Arduino Serial USB, pressure sensor connected to Arduino running custom programmed Arduino C++ code.

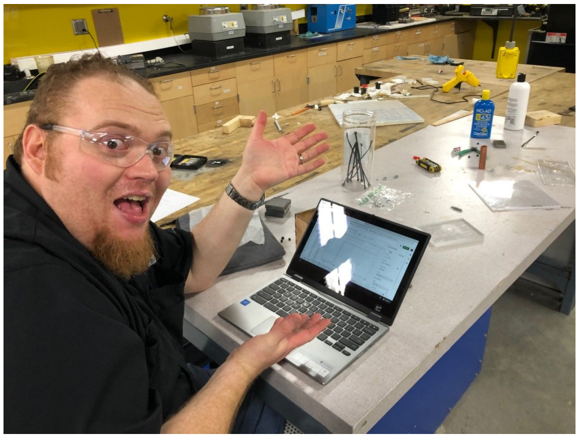


Fig. 12. Lukas DiBeneditto. We have data!

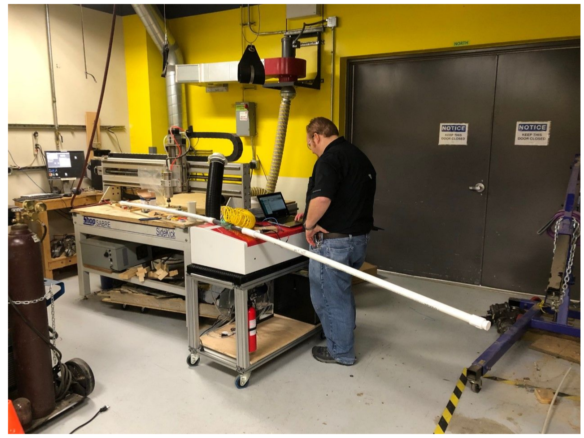


Fig. 13. Lukas DiBeneditto recording data. Like a Boss!

For Arduino code see Section 5. Appendix 1: Custom Arduino Code for Pressure Sensor Sprinkler Valve Testing and Selection System.

1.4.2 Sprinkler valve restriction - Shift to manifold system & piston valve

We did a proof of concept test with just a single 1" sprinkler valve. From observation, the water bottle did not achieve enough projectile thrust velocity sufficient for our needs. Basically we wanted the water bottle to come out faster, since the goal was for height.

We were concerned that a single 1" sprinkler valve would not supply the flow rate necessary by creating a flow rate restriction. So we added 2 additional 1" valves for a total of 3 all running in parallel, by designing a custom machined manifold wall and manifold system.

1.4.2.1 Air Flow Path

1. Shop air compressor
2. Shop hose
3. Pressure regulator and dial indicator
4. Pressure vessel
5. Machined Manifold Wall (our part 1)
6. Pressure side manifold
7. 3 Rain Bird CP100 1" Sprinkler Valves without Flow Control
    a. Signal Line Path
        i. Trigger hose
        ii. 3 way hex brass manifold (3 lines to 1 line)

    iii. Trigger hose
    iv. Trigger Air gun
    v. To atmosphere

b. Pressure Line Path
    i. Cannon side manifold
    ii. Machined Manifold Wall (our part 2)
    iii. Cannon barrel
    iv. To atmosphere

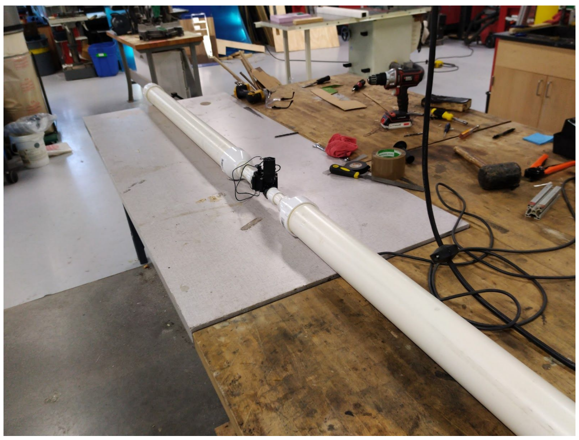


Fig. 14. Proof of concept test with 3 in pipe and only 1 1" sprinkler valve.

Fig. 15. Manifold wall milled out of 3/4" PVC thick sheet.

Fig. 16. 3/4" PVC sheet after milling, solvent welded inside 3" PVC Female Slip Female Threaded Adaptor and 3600 psi 2 part epoxy.

Fig. 17. Both the pressure side and cannon side, 3 Rain Bird CP100 1" sprinkler valves, and trigger assembly with 3 way hex manifold.

1.4.3 Parts order and procurement - Understand intercompany ordering process

Of note, we have a total of 32 receipts from all purchases and returns. Also Lukas (since he was designated by the "CEO" to manage the "company credit card") personally made over 10 trips to Plumbers Supply alone over 8 weeks for purchasing, waiting for parts, picking up parts, returning parts, and having to drive over to Kentucky to get parts.

Using the "company credit card" and interfacing with Professor Cooley, Trina Ruby (financial receipts, purchasing), Paul Hagmann (machine shop, lab manager) at Purdue Polytechnic New Albany respectively, Plumbers Supply, Lowes, Home Depot, Menards, and Harbor Freight in person was a great learning experience.

We had numerous returns, which were purchases "just in case they were needed" so that we could get everything done on time, which also required considerable paperwork on the back end. It was still the right choice, better to have it and not need it than to not have it, and need it right then.

2. Documents

2.1 Product

The product is a 3 hole custom machined manifold wall that is designed for mass production. The plan is to sell the machined part online. Also for future work we could make a CAD Drawing Package with "Plans to Build" which can be sold online to mitigate liability with pressure vessel certification. The material is a 3/4" Chemical Resistant PVC from McMaster-Carr. See Table 8. Raw Materials List for specific part.

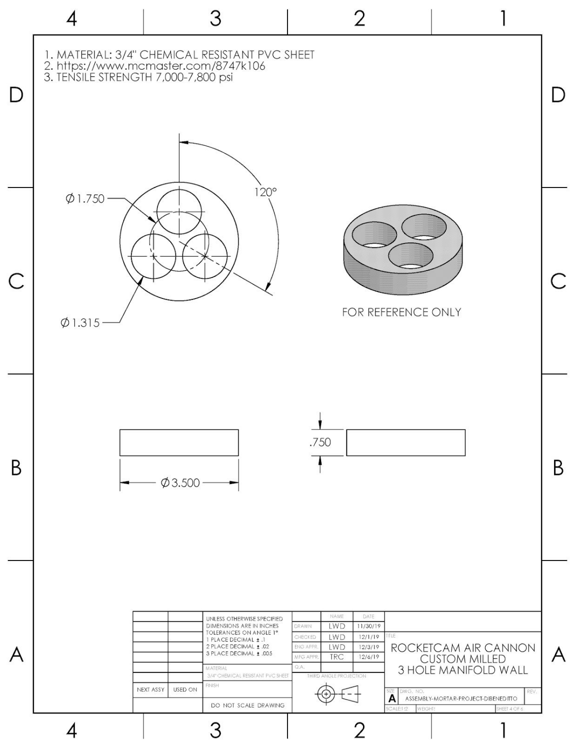


Fig. 18. CAD Drawing of Product Manifold Wall.

Fig. 19. Photograph of Product Machined Manifold Wall.

2.1.1 Product Breakdown Structure

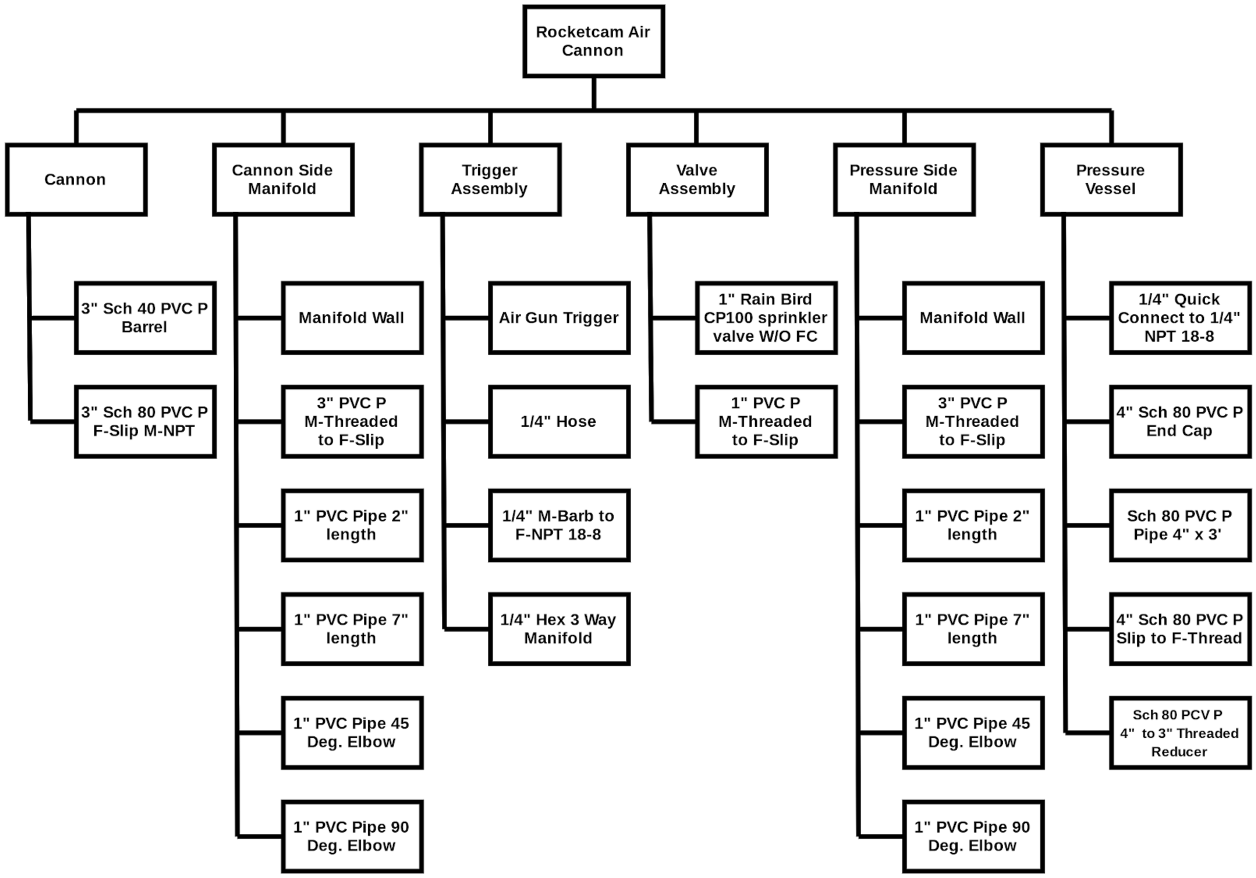


Fig. 20. Product Breakdown Structure

NOTE: We are considering the support structure and ramrod as extra add-ons, and were not included in this Product Breakdown Structure for clarification.

2.1.2 Drawing Package

See Section 7. Appendix 3: Drawing Package.

2.1.3 Final Costs & Raw Materials List

All receipts for the entire project have been provided in digital PDF form to Trina Ruby by email, organized into an overall spreadsheet broken down by business purchased from, date, invoice number, and amount. The difference between actual and build is based on 14 prototypes.

2.1.3.1 Receipts by the Numbers

- Amazon: 1
- Harbor Freight: 2
- Lowes: 11
- Menards: 4
- Plumbers Supply: 14
- **Total Receipts: 32**

Table 2: Final Costs

Total	**$846.08**
Test Subtotal	**$227.41**
Build Subtotal	**$618.67**
Individual Business Subtotal Sum Check	$846.08
Reimbursement to Lukas	$160.04

Table 3: Amazon Purchase

Date	Business	Invoice No.	Amount	Type/Notes	Credit Card
9/21/2019	Amazon	112-0719411-2545822	$29.74	Testing	Lukas MC 2301
		Subtotal	$29.74		

Table 4: Harbor Freight Purchases

Date	Business	Invoice No.	Amount	Type/Notes	Credit Card
11/1/2019	Harbor Freight Tools	03307905	$14.97	Build	Purdue MC 8893
11/1/2019	Harbor Freight Tools	03307905 Return	-$4.99	Build	Purdue MC 8893
		Subtotal	$9.98		

Table 5: Lowes Purchases

Date	Business	Invoice No.	Amount	Type/Notes	Credit Card
9/27/2019	Lowes	23180	$27.45	Testing	Purdue MC 0948
10/17/2019	Lowes	14791	$47.57	Build	Purdue MC 0948
10/18/2019	Lowes	14791 Return	-$5.99	Build	Purdue MC 0948
11/1/2019	Lowes	15035	$117.94	Build	Purdue MC 8893
11/06/2019	Lowes	09873	$26.73	Testing, Reimbursement, ReceiptTotal(46.73) - Personal($20.00) = ActualOwed($26.73)	Lukas MC 2301
11/07/2019	Lowes	11036	$20.28	Build, Reimbursement	Lukas MC 2301
11/08/2019	Lowes	05713	$4.62	Build, Reimbursement	Lukas MC 2301
11/21/2019	Lowes	18879 Return	-$28.79	Build, Reimbursement, Same Receipt 1, Back on Lukas MC 2301	Lukas MC 2301
11/21/2019	Lowes	18879 Return	-$23.61	Build, Same Receipt 1	Purdue MC 0948
11/21/2019	Lowes	18879 Return	-$43.24	Build, Same Receipt 1	Purdue MC 8893
11/26/2019	Lowes	07874	$40.49	Build, Reimbursement	Lukas MC 2301
		Subtotal	$183.45		

Table 6: Menards Purchases

Date	Business	Invoice No.	Amount	Type/Notes	Credit Card
10/18/2019	Menards	86005066363	$12.49	Build	Purdue MC 0948
10/24/2019	Menards	66087055958	$59.49	Testing, Reimbursement, ReceiptTotal($77.54) - [Personal($9.97+$6.89) * Tax(1.07)] = ActualOwed($66.86)	Lukas MC 2301
11/06/2019	Menards	80897089961	$19.12	Build, Reimbursement	Lukas MC 2301
11/21/2019	Menards	86147227171	-$11.64	Testing, Reimbursement, Back on Lukas MC 2301	Lukas MC 2301
		Subtotal	$79.46		

Table 7: Plumbers Supply Purchases

Date	Business	Invoice No.	Amount	Type/Notes	Credit Card
9/27/2019	Plumbers Supply Co.	9284084	$24.33	Testing	Purdue MC 0948
10/4/2019	Plumbers Supply Co.	9291826	$36.51	Testing	Purdue MC 0948
10/7/2019	Plumbers Supply Co.	9293414	$34.80	Testing	Purdue MC 0948
10/17/2019	Plumbers Supply Co.	9304516	$200.63	Build	Purdue MC 0948
10/17/2019	Plumbers Supply Co.	9304681	$251.04	Build	Purdue MC 0948
10/18/2019	Plumbers Supply Co.	9306494 Return	-$147.77	Build	Purdue MC 0948
10/18/2019	Plumbers Supply Co.	9306504 Return	-$20.35	Build	Purdue MC 0948
10/22/2019	Plumbers Supply Co.	9308724	$160.19	Build	Purdue MC 0948
10/22/2019	Plumbers Supply Co.	9308951	$144.71	Build	Purdue MC 0948
11/12/2019	Plumbers Supply Co.	9331674	$66.58	Build	Purdue MC 0948
11/21/2019	Plumbers Supply Co.	9342194 Return	-$102.11	Build, Same Receipt 2, Replaces Invoice 9342203	Purdue MC 0948
11/21/2019	Plumbers Supply Co.	9342194 Return	-$27.41	Build, Same Receipt 2, Replaces Invoice 9342203	Purdue MC 0948
11/21/2019	Plumbers Supply Co.	9342194 Return	-$77.70	Build, Same Receipt 2, Replaces Invoice 9342203	Purdue MC 0948
11/21/2019	Plumbers Supply Co.	9342203	$0.00	Build, Same Receipt 3, Replaced by Invoice 9342194, Orignal Credit $2.91	Purdue MC 0948
11/21/2019	Plumbers Supply Co.	9342203	$0.00	Build, Same Receipt 3, Replaced by Invoice 9342194, Original Credit $77.70	Purdue MC 0948
11/22/2019	Plumbers Supply Co.	9342194	$0.00	Build, Same Receipt 4, Duplicate of Invoice 9342194, Original Credit $71.97, note $71.97+$5.73=$77.70.	Purdue MC 0948
11/22/2019	Plumbers Supply Co.	9342203	$0.00	Build, Same Receipt 4, Duplicate of Invoice 9342194, Original Credit $5.73, note $71.97+$5.73=$77.70.	Purdue MC 0948
		Subtotal	$543.45		

Table 8. Raw Materials List

Item	Qty	Each Cost ($)	Sub-total ($)
Manifold wall, McMaster-Carr, Chemical-Resistant PVC Sheet 6" x 6" x 3/4" https://www.mcmaster.com/8747k106	2	9.72	19.44
1/4" Male to 1/4" NPT 18-8 Quick-Connect Air Coupler Plug	1	2.76	2.76
Sch 40 Pressure Pipe 3" x 5'	5	9.15/ft	45.75
Sch 80 Pressure Pipe 4" x 3'	3	9.05/ft	27.15
Sch 80 Pressure End Cap	1	13.01	13.01
Sch 80 Pressure Female Slip Male Thread	2	12.88	25.76
Sch 80 Pressure Threaded Bushing Reducer 4" to 3"	1	18.30	18.30
1" Sch 40 Pressure pipe 2" length	18	0.0445/in	1.60
1" Sch 40 Pressure pipe 7" length	3	0.0445/in	0.94
1" Sch 40 Pressure Slip Fitting	6	0.58	3.48
1" Sch 40 Pressure Slip Fitting	2	0.58	1.16
1" Rain Bird CP100 1" Irrigation Sprinkler Valve without flow control https://www.homedepot.com/p/Rain-Bird-1-in-In-Line-Irrigation-Valve-CP100/100197371	3	15.97	47.91
PVC Primer	1	6.85	6.85
PVC Solvent	1	6.94	6.94
Teflon Gas Tape	6ft	3.98	3.98
Harbor Freight CENTRAL PNEUMATIC 1/4 In. X 20 Ft. Coiled Nylon Air Hose, https://www.harborfreight.com/1-4-quarter-inch-x-20-ft-coiled-air-hose-97923.html	4	4.99	19.96
Menards Masterforce® 1/4" NPT Brass 3-way Hex Manifold Model Number: M1406 Menards® SKU: 2074691 https://www.menards.com/main/tools/power-tools/pneumatic-tools/air-tool-fittings/masterforce-reg-1-4-npt-brass-3-way-hex-manifold/m1406/p-1444451509797.htm	1	7.99	7.99
Plywood	4x8	22.78	22.78
1" Sch 40 Pressure 45 elbow	8	1.14	9.12
1" Sch 40 Pressure 90 elbow	6	1.00	6.00
Lowes Item # 1229768 Model # 50240H - JB Weld ClearWeld Clear Epoxy Adhesive https://www.lowes.com/pd/JB-Weld-ClearWeld-Clear-Epoxy-Adhesive/1000820870	1	15.98	18.98
Total	74*		**309.86****

* Including 4 Support Structure Boards, not including Ramrod.

** Not including Tax, since Purdue University is a Non-Profit.

2.1.4 Performance test results

The following data was gathered using the custom pressure sensor. See Section 5. Appendix 1: Custom Arduino Code for Pressure Sensor Sprinkler Valve Testing and Selection System.

Table 9. Response Time for Electrically Actuated vs. Pneumatically Actuated

1 inch black rain bird valve electrically actuated	
Test	Time (ms)
30	288.408
31	273.872
32	200.256
34	178.328
35	178.248
Sample size (n)	5
Sample mean (average, x bar)	223.8224
Median	200.256
Sample standard deviation	53.33480047
	223 ± 53 ms

1 inch green orbit valve electrically actuated	
Test	Time (ms)
26	114.832
27	208.928
28	134.552
29	122.232
Sample size (n)	4
Sample mean (average, x bar)	145.136
Median	128.392
Sample standard deviation	43.29882967
	145 ± 43 ms

1 inch black rain bird valve pneumatically actuated	
Test	Time (ms)
36	46.576
37	51.344
38	54.736
39	51.344
40	51.344
41	51.512
42	53.216
Sample mean (average, x bar)	51.0688
Median	51.344
Sample standard deviation	2.909502225
	51 ± 3 ms

The following data was gathered from analyzing the waveform patterns of the audio tracks associated with the video and matching launch and impact to duration of time of flight with the Videopad Video Editor software.

Table 10. Flight Data

Test	1	2	3	4
Projectile	Water Bottle	Water Bottle	Water Bottle	Rocketcam
Wadding	Paper Towels	Paper Towels	Shop Rag	None
Weight (oz)	16.9	16.9	16.9	8
Pressure Vessel (PSIG)	35	85	95	95
Time of Flight (s)	7.040	9.481	7.513	11.108
Angle of Launch	85	85	85	85
Initial Velocity (mph)	77.5127	104.3889	82.7206	122.3027
Initial Velocity (ft/s)	113.685	153.104	121.324	179.377
Maximum Height (ft)	199.3	361.5	227	496
Distance (ft)	69.8	126.5	79.4	173.7

Pressure Vessel	
Inside Diameter (in)	3.786
Inside Diameter (ft)	0.3155
Length (in)	36
Length (ft)	3
Volume (ft²) = π * h* (D/2)²	0.2345

Cannon (PSIG)	
Cannon Length (in)	60
Cannon Length (ft)	5

Implications for future designs: Step by step on "How to Build" instructional drawing package.

2.2 Manufacturing Process

According to the machine shop (Paul Hagmann) it took 1.5 hours to set up the CAD CAM and milling machine. In his expert opinion, a good estimate for an hourly rate for a machine shop is ~$75/hr for a total setup cost of $112.50. Also, it takes about 10 minutes to mill each part. With volume pricing, including material costs we estimate a cost of less than $15 per part. We can then sell the part for more than $40 per part.

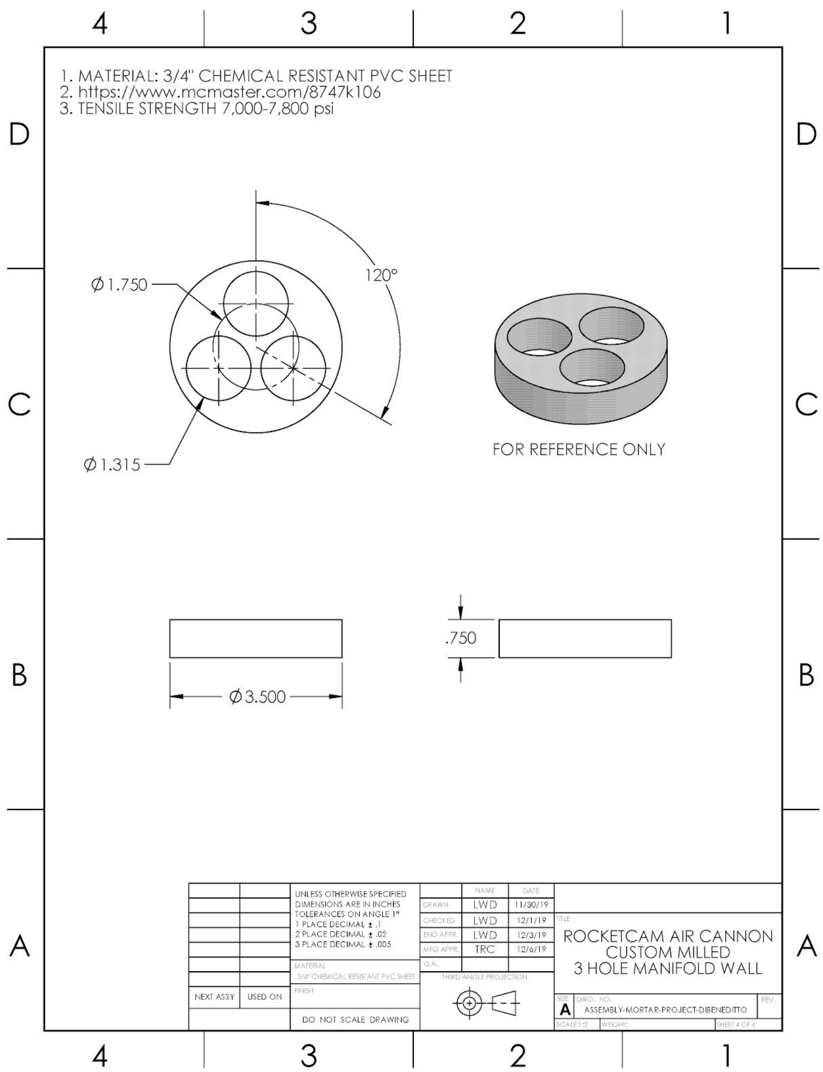


Fig. 21. The physical product: Machined 3/4" Chemical Resistant PVC Sheet from McMaster-Carr and CAD Drawing to manufacture.

2.2.1 Process Flow Diagram

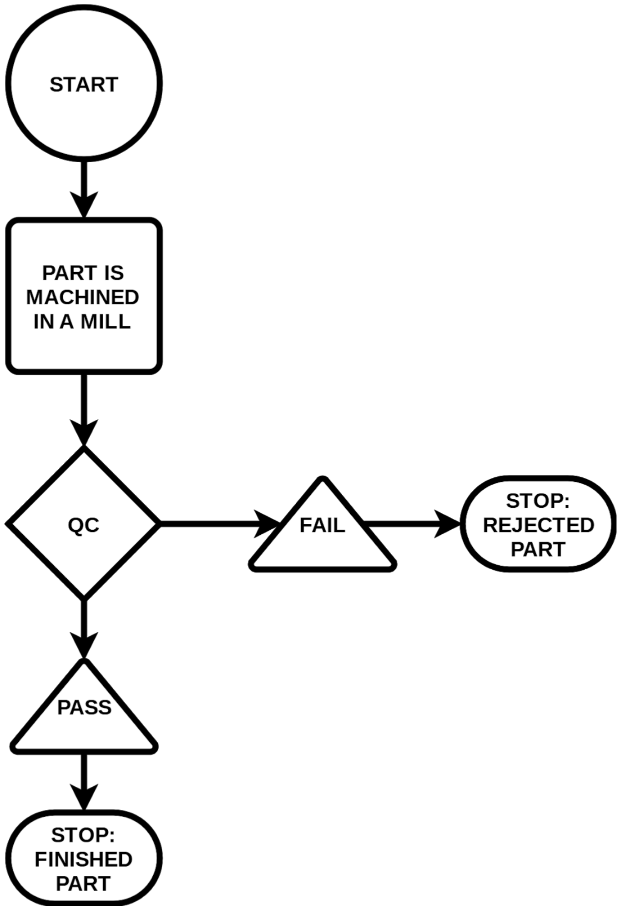


Fig. 22. Process Flow Diagram

2.2.2 Process Data Chart

Considering that we had 2 manifold walls machined, they worked perfectly, and were solvent welded, it is not possible to get the Upper and Lower Control limits for Process Data as per the textbook. [pmbok, p. 104]. With a larger sample size, we would be able to get this.

2.2.3 Anticipated product improvements

It may be possible to offer a value add to future customers by creating a PVC mold manufacturing process for the wall manifold and 3 in line 45 and 90 degree bends.

2.3 Project

2.3.1 Work Breakdown Structure

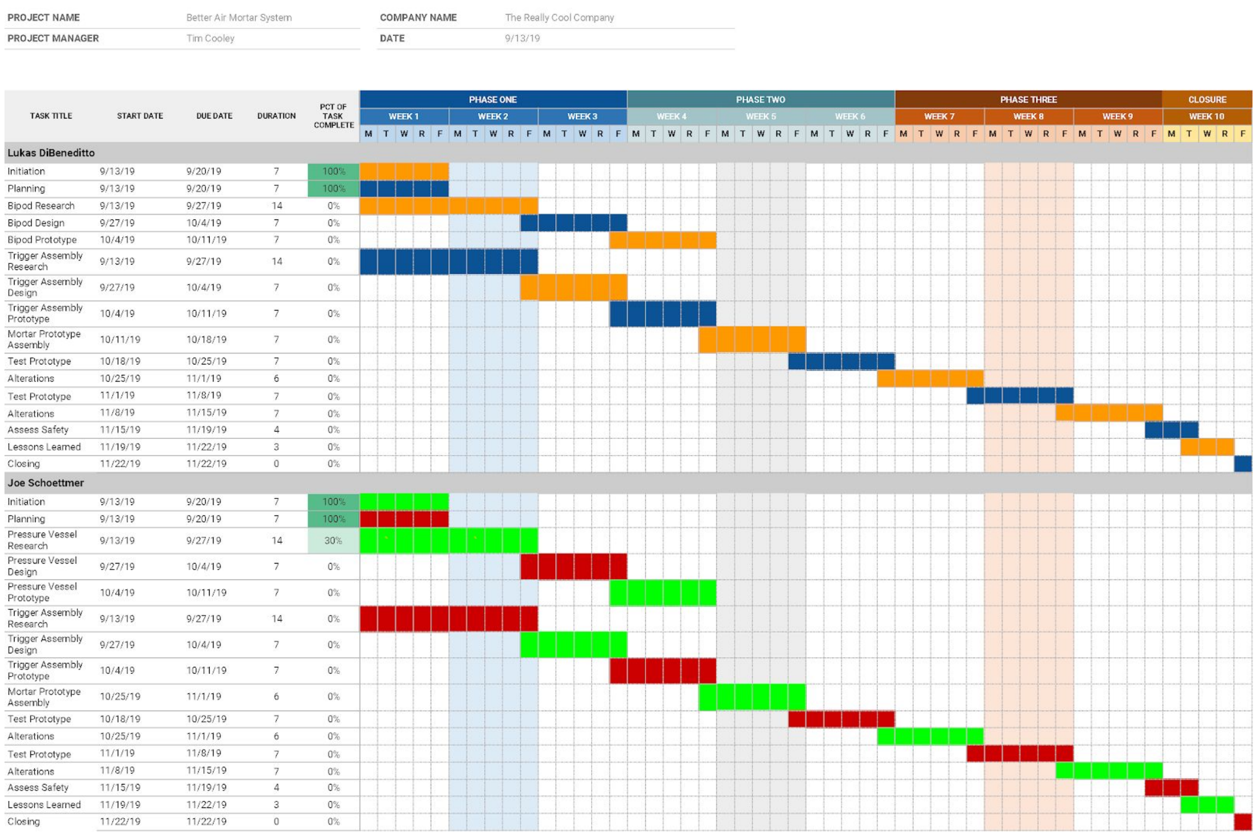
Table 11: Work Breakdown Structure

Week of	10/14		10/21		10/28		11/4		11/11		11/18		11/25		11/18		11/25		12/2		12/9	
	L	J	L	J	L	J	L	J	L	J	L	J	L	J	L	J	L	J	L	J	L	J
7 Prototypes	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y						
Accounts Reconciliation	y	y	y		y		y	y	y		y		y		y		y		y		y	
After Hours Lab Key Card Access for the Boilermaker Lab	y		y		y																	
Arduino C++ Programming	y		y		y		y						y								y	
AutoCAD 2D CAD	y						y						y		y							
Computer Networking	y		y																			
Considerable Arduino Intra-Team Consultation	y		y				y		y		y											
Cricket Vinyl Cutter Operation																					y	
Electronic Circuit Design	y		y																			
Experimental Design	y	y	y	y	y	y	y	y	y	y	y	y										
Financial Accounts Reconciliation	y	y	y		y		y		y		y		y		y	y	y	y	y	y	y	
Financial Procurement	y	y					y				y				y				y			
Google Docs Style Formatting												y	y		y	y	y	y			y	
Graphic Design	y																		y		y	
Hardware Assembly	y	y	y	y	y	y	y	y	y	y	y	y			y	y	y	y	y	y	y	y
Laser Operation															y	y	y				y	
Lathe Operation												y		y		y						
Launch Angle Device Prototype																y						
Machine Shop Coordination	y	y	y	y									y		y		y					
Manifold System Design									y		y		y		y							
Paint																			y		y	
Paint Prep																			y		y	
Piston Valve System	y	y	y	y	y	y	y	y		y		y		y		y		y		y		y
Pressure Sensor System Implementation	y	y	y	y	y	y	y		y		y				y		y		y		y	
Pressure Vessel Validation							y	y					y	y			y	y				
Project Management	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
Purchasing	y	y	y	y	y		y		y				y		y	y	y		y			

Research	y	y	y	y	y	y	y		y		y		y	y	y		y	y			y	
Safety Validation	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
Soldering	y		y		y						y											
SOLIDWORKS 3D CAD															y		y					
Testing	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y				
Video editing																			y		y	
Welding									y		y						y		y			
Youtube Video Posting																					y	

2.3.1 Gantt Chart

2.3.1.1 Initial Gantt Chart



PROJECT NAME	Better Air Mortar System	COMPANY NAME	The Really Cool Company
PROJECT MANAGER	Tim Cooley	DATE	9/13/19

TASK TITLE	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
Lukas DiBeneditto				
Initiation	9/13/19	9/20/19	7	100%
Planning	9/13/19	9/20/19	7	100%
Bipod Research	9/13/19	9/27/19	14	0%
Bipod Design	9/27/19	10/4/19	7	0%
Bipod Prototype	10/4/19	10/11/19	7	0%
Trigger Assembly Research	9/13/19	9/27/19	14	0%
Trigger Assembly Design	9/27/19	10/4/19	7	0%
Trigger Assembly Prototype	10/4/19	10/11/19	7	0%
Mortar Prototype Assembly	10/11/19	10/18/19	7	0%
Test Prototype	10/18/19	10/25/19	7	0%
Alterations	10/25/19	11/1/19	6	0%
Test Prototype	11/1/19	11/8/19	7	0%
Alterations	11/8/19	11/15/19	7	0%
Assess Safety	11/15/19	11/19/19	4	0%
Lessons Learned	11/19/19	11/22/19	3	0%
Closing	11/22/19	11/22/19	0	0%
Joe Schoettmer				
Initiation	9/13/19	9/20/19	7	100%
Planning	9/13/19	9/20/19	7	100%
Pressure Vessel Research	9/13/19	9/27/19	14	30%
Pressure Vessel Design	9/27/19	10/4/19	7	0%
Pressure Vessel Prototype	10/4/19	10/11/19	7	0%
Trigger Assembly Research	9/13/19	9/27/19	14	0%
Trigger Assembly Design	9/27/19	10/4/19	7	0%
Trigger Assembly Prototype	10/4/19	10/11/19	7	0%
Mortar Prototype Assembly	10/25/19	11/1/19	6	0%
Test Prototype	10/18/19	10/25/19	7	0%
Alterations	10/25/19	11/1/19	6	0%
Test Prototype	11/1/19	11/8/19	7	0%
Alterations	11/8/19	11/15/19	7	0%
Assess Safety	11/15/19	11/19/19	4	0%
Lessons Learned	11/19/19	11/22/19	3	0%
Closing	11/22/19	11/22/19	0	0%

Fig. 23. Initial Gantt Chart.

2.3.1.2 Final Gantt Chart

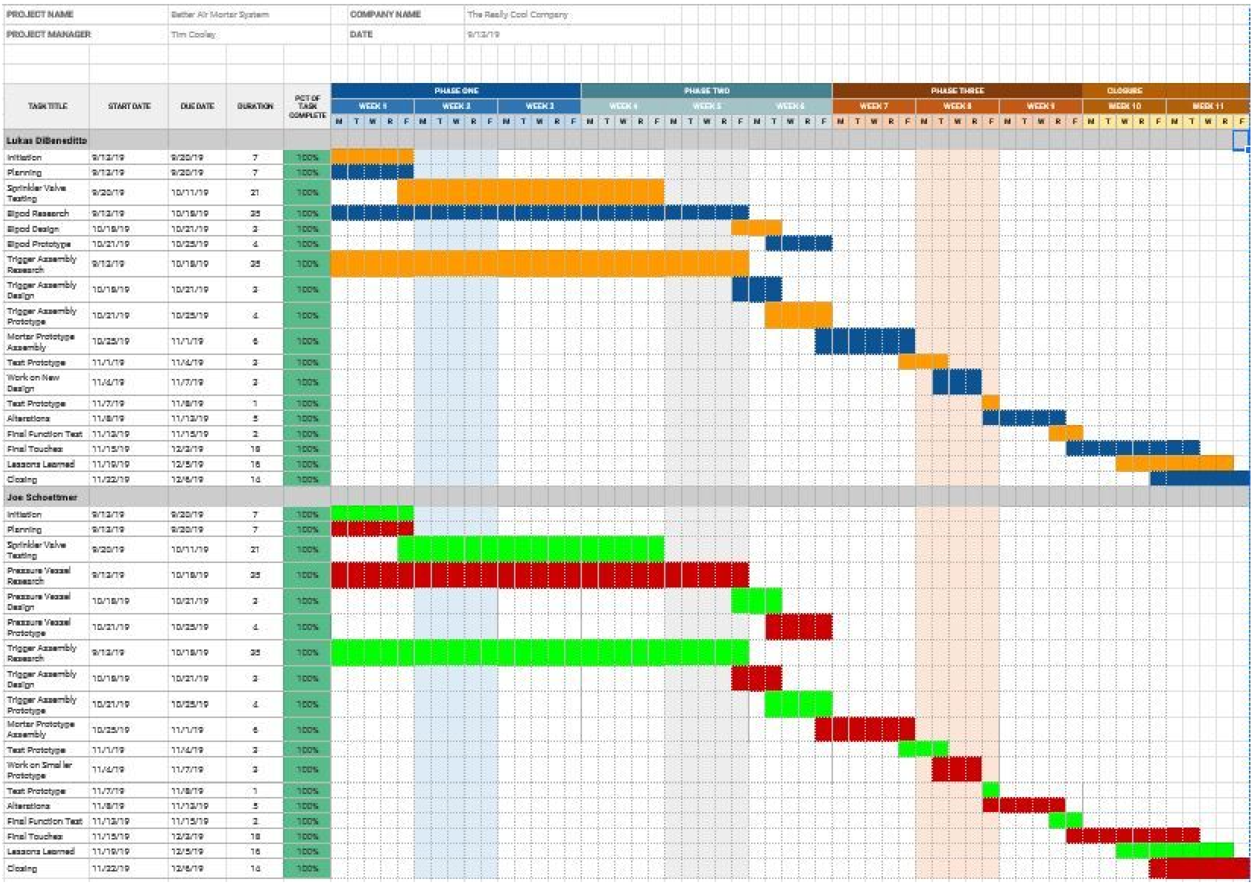


Fig. 24. Final Gantt Chart.

2.3.2 PERT Chart (final only)

1. 9/13

Previous project killed, new project assigned

A. Initiation, ideation, feasibility study, preliminary plan, define scope, time, cost, and anticipate risks

B. Research previous implementations

2. 9/20

C. Project work breakdown structure

D. Product work breakdown structure

E. Product breakdown structure

F. Risk Assessment

G. Gantt Chart

H. Research Pressure Transducer Sensor

I. Order Pressure Transducer
J. Research Arduino Code

3. 9/27
    K. Arduino Uno Pressure Transducer
    L. Initial test data of pressure transducer only
    M. Validation of pressure transducer
    N. Modify one inch butterfly valve, lab RFID access
4. 10/4
    O. One inch test system with Arduino Uno Pressure Transducer, Data with test with different combinations
    P. Presentation of results
    Q. Modified Code
    R. Evaluate Safety, electrical actuator
5. 10/11
    S. Two inch test system with Arduino Uno Pressure Transducer
    T. Modified Arduino Code
    U. Order Two inch adaptors, 4 inch pipe
    V. Report Financial Receipts
    W. Order sprinkler valve X2, PERT chart
6. 10/18
    X. Two inch retest with valve before sprinkler valve
    Y. Test second sprinkler valve
    Z. Analyze data
    AA. Determine modifications
    AB. Implement modifications of two inch sprinkler valve for both and test
    AC. Validation of pressure vessel
7. 10/25
    AD. Prototype one of 4 in pressure vessel
    AE. "U" adaptors valve with barrel
    AF. Iterate mortar design if necessary
    AG. Find test mortar/3D print, Soda can analog
    AH. Order metal to be welded
8. 11/1
    AI. Prototype stand
    AJ. Modification of stand
    AK. Iterate
    AL. Evaluate Safety
9. 11/8
    AM. Testing and iteration of overall design

AR. Manufacture Process Steps
AS. Procedure of Process Steps

10. 11/15
    AN. Testing and Iteration of overall design
    AT. Evaluation of manufacturing process
    AU. Validation of manufacturing process
11. 11/22
    AO. Final Presentation
    AP. Lessons Learned
    AQ. Closing
12. 11/29
    No School

2.3.3 Responsibility Assignment Matrix

See Section 1.2 Team Members & Their Individual Responsibilities.

2.3.4 Risk Matrix

2.3.4.1 Risk Matrix Initial

Table 12: Risk Matrix Initial

	Risks	**Triggers (symptoms or warning signs)**	**Workaround plans, corrective action, and other appropriate responses**
1	The modified trigger is not fast enough to meet requirements.	After modification, the 1 in Jar-Top In-Line Sprinkler Valve is unable to meet predicted performance Pressure vs. Time curves in during testing.	Team discussion, evaluate test procedure, confirm test procedure, iterate test procedure, and consult with fluid dynamics expert, consult with the project manager for alternatives.
2	The modified trigger suffers catastrophic failure due to excess pressure.	After modification, the 1 in Jar-Top In-Line Sprinkler Valve is unable to meet the 5 to 150 psi as listed on the product specifications,	Team discussion, evaluate test procedure, confirm test procedure, iterate test procedure, and consult with fluid dynamics expert,

		and/or cracks or fractures of material are observed.	consult with the project manager for alternatives.
3	The nest (bi-pod) does not fully stabilize the launch barrel.	During testing the nest (bi-pod) is shown to not stabilize or support the launch barrel, potentially causing a safety issue.	If we weld it out of steel this should not be an issue, we can also test and iterate to stabilize the nest (bi-pod) platform
4	The pressure vessel solvent welded PVC connections leak.	During testing, using dish soap to check for leaks.	Primarily this can be avoided by prepping the area to be solvent welded correctly. Leak stop, and various other leak mitigation strategies will be attempted.
5	The pressure vessel or pipe fittings suffer catastrophic failure due to excess pressure.	During testing is the Schedule 80 PVC pipe is unable to meet the 320 psi rating as listed on the product specifications, and/or cracks or fractures of material are observed.	Replace pipe with different schedule 80 PVC pipe. This is extremely unlikely because the building can only supply 95 psi. Team discussion, evaluate test procedure, confirm test procedure, iterate test procedure, and consult with fluid dynamics expert, consult with the project manager for alternatives.
6	Unsuccessful tests of trigger	Missed deadline	Team discussion, present manager w/ alternatives
7	Parts requested on backorder / out of stock	Delivery dates outside window of project	Team discussion, present manager w/ alternatives
8	Quickly draining budget	Budget depleted to 25%	Team discussion, present manager w/ alternative funding
9	Slow reaction time for evacuation	Mortar unable to achieve acceptable lift	Redesign elbow between pressure vessel and trigger in parallel with team discussion, followed by discussion with manager

10	Too quick of evacuation from pressure vessel	Mortar lift below target while actuation acceptable	Redesign pressure vessel parallel with team discussion, followed by discussion with manager

2.3.4.2 Risk Matrix Final "Reality"

Table 13: Risk Matrix Final "Reality"

Priority	Symptoms	Triggers	Responses
1	Unsuccessful Test of Trigger Mechanism	Missed Deadline	Team discussion, present manager with alternatives.
2	Leaks Between Joints	Unable to Maintain Pressure	Disassemble, inspect and add teflon or other components, discuss with team, add in manager if necessary.
3	Quickly Draining Budget	Budget Depleted to 25%	Team discussion, present manager w/ alternative funding.
4	Slow Reaction Time for Evacuation	Mortar Unable to Achieve Acceptable Lift	Redesign trigger in parallel with team discussion, followed by discussion with manager.
5	Launch Recoil Support Ineffective	Damage Noted to System	Team discussion, followed by discussion with manager.

3. Punchlist

3.1 Fabrications

Complete.

3.2 Testing

Complete.

3.3 Sign Offs

See Section 6. Appendix 2: Sign Off Sheet.

3.4 Financial closeouts

Lukas has submitted a reimbursement form (Purdue University Substitute W-9 Form) to Trina Ruby (Purdue University), all receipts for the entire project have been provided in digital PDF form to Trina Ruby by email, organized into an overall spreadsheet broken down by Business Purchased from, Date, invoice number, and amount.

4. Works Cited

[3d-printed-rocket] Spangler, Dan. "GoPro Cannon Cam. MAKE: PROJECTS". MAKE Community LLC. https://makezine.com/projects/make-39/cannon-cam/. Accessed 11 December 2019.

[lasco-fittings] LASCO Fittings, Inc. "Pressure Ratings of Plastics - Pressure Ratings of Thermoplastic Fittings". ND. https://www.lascofittings.com/pressureratingsofplastics. Accessed 11 Oct 201.

[pmbok] A guide to the project management body of knowledge (PMBOK guide. Newtown Square, Pennsylvania: Project Management Institute, 2000. Electronic.

[pro-mo-calc] Haponiuk, Bogna. Pamula, Hanna. "Projectile Motion Calculator - Omni". Omni Calculator sp. z o.o. https://www.omnicalculator.com/physics/projectile-motion. Accessed 11 December 2019.

NOTE: Some 3D models in the Drawing Package were obtained from mcmaster.com and grabcad.com and do not represent the work of the authors other than their use in the assembly for reference only.

5. Appendix 1: Custom Arduino Code for Pressure Sensor Sprinkler Valve Testing and Selection System

Note, the code does not currently account for timer drift, as this is a nonissue every time the Arduino Uno is plugged in. This is the 12th iteration (version). For greater accuracy, the time.h library and real-time clock could be implemented.

```
/*
  --------------------------------------------------
  Purdue MET 400, Programmer: "Lukas W. DiBeneditto"
    <lukas@dibeneditto.com>;
  Professor Timothy R. Cooley, 2019-12-11

  Arduino Uno code for Pressure Transducer
  Version 2.2

  NOTE: Baud rate for serial monitor should be set
  to 115200, not the normal 9600.

  NOTE: The Arduino needs to be unplugged from the USB
  and repowered after 1 hour otherwise it will provide
  incorrect time values.

  Pressure transducer, 0 to 100 psi, 0.5 to 4.5 v
  Autex Pressure Transducer/Sender/Sensor 100 Psi
  Stainless Steel For Oil, Fuel, Air, Water
  https://www.amazon.com/gp/product/B00NIK9E10/
  0 psi = 0.5v, 50 psi = 2.5v, 100 psi = 4.5v
  RED: IN+ = Arduino Uno 5V
  BLACK: Gnd = Arduino Uno GND
  GREEN: Out = Arduino Uno A0

  ASSUMPTION:
  Standard Atmospheric Pressure (STP) is
  equal to 14.7 psia.

  Pabs      = Pgage  + Patm
  PSIA      = PSIG   + PSI
  14.7 psia = 0 psig + 14.7 psi

  Pabs  = PSIA = Absolute Pressure
  Pgage = PSIG = Gage Pressure
  Patm  = PSI  = Atmospheric Pressure

  Instructions:
  Copy and paste the results into a spreadsheet
```

```
  to graph the results. Restart the time recording
  by pressing the reset button on the Arduino.
  --------------------------------------------------
*/

boolean runtimer = true;
unsigned long start = 0;
unsigned long current = 0; // for the timer

// the setup routine runs once when you press reset:
void setup() {
  // defines pin AO as input
  pinMode(A0, INPUT);

  // initialize serial communication at 115200 bits per second:
  Serial.begin(115200);
  while (!Serial) {
    ; // wait for serial port to connect. Needed for native USB
  }

  // output to serial
  Serial.println();
  Serial.println();
  Serial.println(F("--------------------------------------------------"));
  Serial.println(F("Purdue MET 400, Programmer: Lukas W. DiBeneditto"));
  Serial.println(F("  <lukas@dibeneditto.com>\;"));
  Serial.println(F("Professor Timothy R. Cooley, 2019-12-11"));
  Serial.println(F("Arduino Uno code for Pressure Transducer"));
  Serial.println(F("Version 2.2"));
  Serial.println();
  Serial.println(F("NOTE: The Arduino needs to be unplugged from the USB"));
  Serial.println(F("and repowered after 1 hour otherwise it will provide"));
  Serial.println(F("incorrect time values."));
  Serial.println();
  Serial.println(F("Pressure transducer, 0 to 100 psi, 0.5 to 4.5 v"));
  Serial.println(F("Autex Pressure Transducer/Sender/Sensor 100 Psi"));
  Serial.println(F("Stainless Steel For Oil, Fuel, Air, Water"));
  Serial.println(F("https://www.amazon.com/gp/product/B00NIK9E10/"));
  Serial.println(F("0 psi = 0.5v, 50 psi = 2.5v, 100 psi = 4.5v"));
  Serial.println(F("RED: IN+ = Arduino Uno 5V"));
  Serial.println(F("BLACK: Gnd = Arduino Uno GND"));
  Serial.println(F("GREEN: Out = Arduino Uno A0"));
  Serial.println();
  Serial.println(F("ASSUMPTION:"));
  Serial.println(F("  Standard Atmospheric Pressure (STP) is"));
  Serial.println(F("  equal to 14.7 psia."));
  Serial.println();
  Serial.println(F("Pabs      = Pgage  + Patm"));
```

```
  Serial.println(F("PSIA      = PSIG   + PSI"));
  Serial.println(F("14.7 psia = 0 psig + 14.7 psi"));
  Serial.println();
  Serial.println(F("Pabs  = PSIA = Absolute Pressure"));
  Serial.println(F("Pgage = PSIG = Gage Pressure"));
  Serial.println(F("Patm  = PSI  = Atmospheric Pressure"));
  Serial.println();
  Serial.println(F("Instructions:"));
  Serial.println(F("  Copy and paste the results into a spreadsheet"));
  Serial.println(F("  to graph the results. Restart the time recording"));
  Serial.println(F("  by pressing the reset button on the Arduino."));
  Serial.println();
  Serial.println(F("Time (us) is in microseconds, 1x10^-6 = 10E-6"));
  Serial.println(F("1000000 microsecond = 1 second"));
  Serial.println(F("--------------------------------------------------"));
  Serial.println();
  Serial.print(F("Time (us)"));
  t();
  Serial.print(F("Pgage = PSIG"));
  t();
  Serial.print(F("Pabs = PSIA"));
  t();
  Serial.print(F("Sensor Value"));
  t();
  Serial.println(F("Voltage"));

  // assign the current
  // per https://www.arduino.cc/reference/en/language/functions/time/micros/
  // micros()
  //   Returns the number of microseconds since the Arduino board began
  //   running the current program. This number will overflow (go back
  //   to zero), after approximately 70 minutes.
  start = micros();
} // end main setup

// the loop routine runs over and over again forever:
void loop() {
  while (runtimer == true) {

    // read the input on analog pin 0:
    int sensorValue = analogRead(A0);

    // get the time value
    current = micros(); // 1000000 microsecond = 1 second
    // time = millis(); // 1000 millisecond = 1 second

    // Convert the analog reading (which goes from 0 to 1023) to a voltage (0
to 5V):
```

```
    float voltage = sensorValue * (5.0 / 1023.0);

    // convert voltage to psig
    // formula: y = (100psig / 4.0v) * (x - 0.5v)
    // where y is psig and x is voltage
    float psig = (100.0 / 4.0) * (voltage - 0.5);

    // ASSUMPTION:
    //   Standard Atmospheric Pressure (STP) is
    //   equal to 14.7 psia.
    //
    // Pabs      = Pgage  + Patm
    // PSIA      = PSIG   + PSI
    // 14.7 psia = 0 psig + 14.7 psi
    //
    // Pabs  = PSIA = Absolute Pressure
    // Pgage = PSIG = Gage Pressure
    // Patm  = PSI  = Atmospheric Pressure
    float psia = psig + 14.7;

    // only for 2.5 seconds which seems to be the maximum buffer space
    // with this many lines for serial monitor
    if ((current - start) <=  (start + (2.5 * 1000000)) ) {
      // print out the value you read to serial monitor
      // format is "Time (µs)  Sensor Value  Voltage  Pgage = PSIG  Pabs =
PSIA"
      //   with tabs for the double spaces
      Serial.print(current - start); // display from zero start time
      t();
      Serial.print(psig);
      t();
      Serial.print(psia);
      t();
      Serial.print(sensorValue);
      t();
      Serial.println(voltage);
    } else {
      Serial.println(F("end 2.5 seconds"));
      runtimer = false;
    } // end if else
  } // end while
} // end main loop

// print a tab character
void t() {
  Serial.print(F("\t"));
} // end t function
```

6. Appendix 2: Sign Off Sheet Package

Lukas DiBeneditto and Joe Schoettmer transferred possession to Professor Damon C. Sisk (internal customer).

Documentation is in this report, including the Arduino Code for the Pressure Sensor, and the Drawing Package for the Manifold Wall.

This package contains:

1. Project Sign-Off Sheet
2. Training Sign-Off Sheet
3. Rocketcam Air Cannon Operating Instructions with Photographs

Please see next page.

Project Sign-Off Sheet

<table>
<tr><td>Project Name:
Rocketcam Air Cannon System</td><td>Project Team:
Lukas W. DiBeneditto Joseph Schoettmer, Jr.</td></tr>
<tr><td>Start Date:
9/13/2019</td><td>Completion Date:
12/6/2019</td></tr>
<tr><td>Project Duration:
84 Days</td><td>Sponsor:
Professor Timothy R. Cooley</td></tr>
<tr><td colspan="2">Project Goal: Our team was tasked with engineering a solution for an improved pneumatic air cannon to launch a 3D printed rocket containing a GoPro camera that is used by Purdue Polytechnic New Albany.</td></tr>
<tr><td colspan="2">Project Deliverables:
1. Portable
2. Quick Setup
3. Small Footprint
4. Predictable Launch
5. Fast Reload
6. Design to Manufacture
7. Sufficient Projectile Height
8. Custom Appearance</td></tr>
<tr><td>By signing this document, I acknowledge that I have delivered all the stated deliverables at the agreed to quality levels.</td><td>By signing this document, I acknowledge that I have received at the stated deliverables at the agreed to quality levels.</td></tr>
<tr><td>Signed:</td><td>Signed:</td></tr>
<tr><td>Printed Name:
Lukas W. DiBeneditto Joseph Schoettmer, Jr.</td><td>Printed Name:
Damon Sisk</td></tr>
<tr><td>Date:
12/19/2019 12/19/19</td><td>Date:
12/19/2019</td></tr>
<tr><td colspan="2">Remarks:</td></tr>
</table>

Training Sign-Off Sheet

Title:	**Rocketcam Air Cannon System**		
Document Number	PPNA.MET400.TRD1	**Date (Originated)**	12/6/2019
Version	0	**Revised Date**	
Status	Released	**Effective Date**	12/16/2019
Author(s)	Lukas DiBeneditto & Joseph Schoettmer		
Description	The use of a pressurized mortar system to launch a rocketcam mortar		
Safety Warnings	**DANGER** – The device can be pressurized above 100 psi, and must be monitored for fatigue after <u>EVERY</u> pressurization. **DANGER** – The device can be dangerous when pressurized, avoid the end of the barrel after pressurizing to reduce risk of injury. **DANGER** – Projectile can and will go hundreds of feet in the air, clear path for the projectile must be maintained to reduce risk from impaling by mortar upon return.		
Safety Equipment	Safety glasses and ear protection		
Training #	**Training Details**		
1	The recommended pressure is 100 psi for system. DO NOT EXCEED 120 psi, the maximum of the CP100 psi sprinkler valves.		
2	Do NOT use without the blast shield between the operator and the cannon.		
3	The pressure vessel has not been certified and is dangerous.		
4	This is not a toy, treat as a loaded firearm and always point the barrel in a safe direction.		
5	Check overhead for low flying planes / helicopters.		
6	Check downrange for a safe projectile firing path.		
7	Do NOT load a projectile with the system pressurized.		
8	Always remove ramrod before firing.		
Date	12/19/2019		
Print Trainee Name	Damon Sisk		
Sign Trainee Name	Damon Sisk		

Rocketcam Air Cannon Operating Instructions

Title:	**Rocketcam Air Cannon Mortar**		
Document Number	PPNA.MET400.WIS1	**Date (Originated)**	12/6/2019
Version	0	**Revised Date**	
Status	Released	**Effective Date**	12/16/2019
Author(s)	Lukas DiBeneditto & Joseph Schoettmer		
Description	The use of a pressurized mortar system to launch a rocketcam mortar		
Safety Warnings	**DANGER** – The device can be pressurized above 100 psi, must be monitored for fatigue after EVERY pressurization. **DANGER** – The device can be dangerous when pressurized, avoid the end of the barrel after pressurizing to reduce risk of injury. **DANGER** – Projectile can and will go hundreds of feet in the air, clear path for the projectile must be maintained to reduce risk from impaling by mortar upon return.		
Safety Equipment	Safety glasses and ear protection.		

Operating Instructions (See Photographs on next pages.)

Setup

1. The Rocketcam Air Cannon system can be picked up by 1 person, 2 person carry is recommended.
2. Set the base so that the desired angle is achieved for the barrel. Setup blast shield.

Set the Pressure Vessel, Clear cannon, and Release Pressure

1. Attach the pressure regulator to the pressure vessel.
2. Make sure the feed valve is closed.
3. Remove the airline hose, check, and clear any obstructions in the cannon barrel.
4. Move safely away from cannon barrel opening and attach airline feed to the pressure regulator.
5. Slowly open the valve to pressurize the system and observe pressure gauge.
6. Adjust the pressure regulator if necessary to desired psi. The higher the psi, the higher it will shoot.
7. Close the valve, and check that area is clear of bystanders.
8. Pickup the trigger and extend the trigger hose.
9. Release pressure by squeezing the trigger, to purge the system of pressure.

Loading the Cannon or Reloading

1. Verify gauge is set to 0 and that pressure has been released.
2. If the pressure gauge does not read 0, close the pressure valve and squeeze the trigger again.
3. Move spectators behind blast shield.
4. Load 3D Printed Rocket/Mortar or water bottle projectile into the top (stars end) of the barrel. The ramrod can be used to make sure the projectile is seated at the bottom of the cannon.
5. Remove the ram rod.
6. When safely clear of cannon barrel opening, open the pressure valve to pressurize the system.

Prepare for Launch

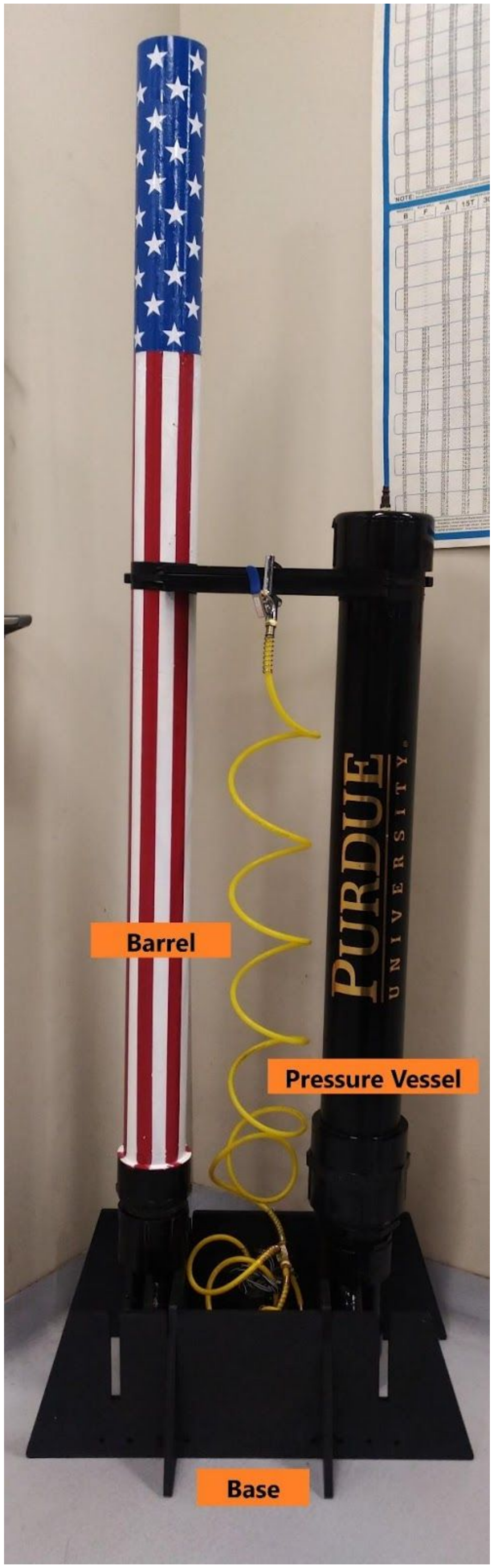
1. Step behind the blast shield with the trigger.

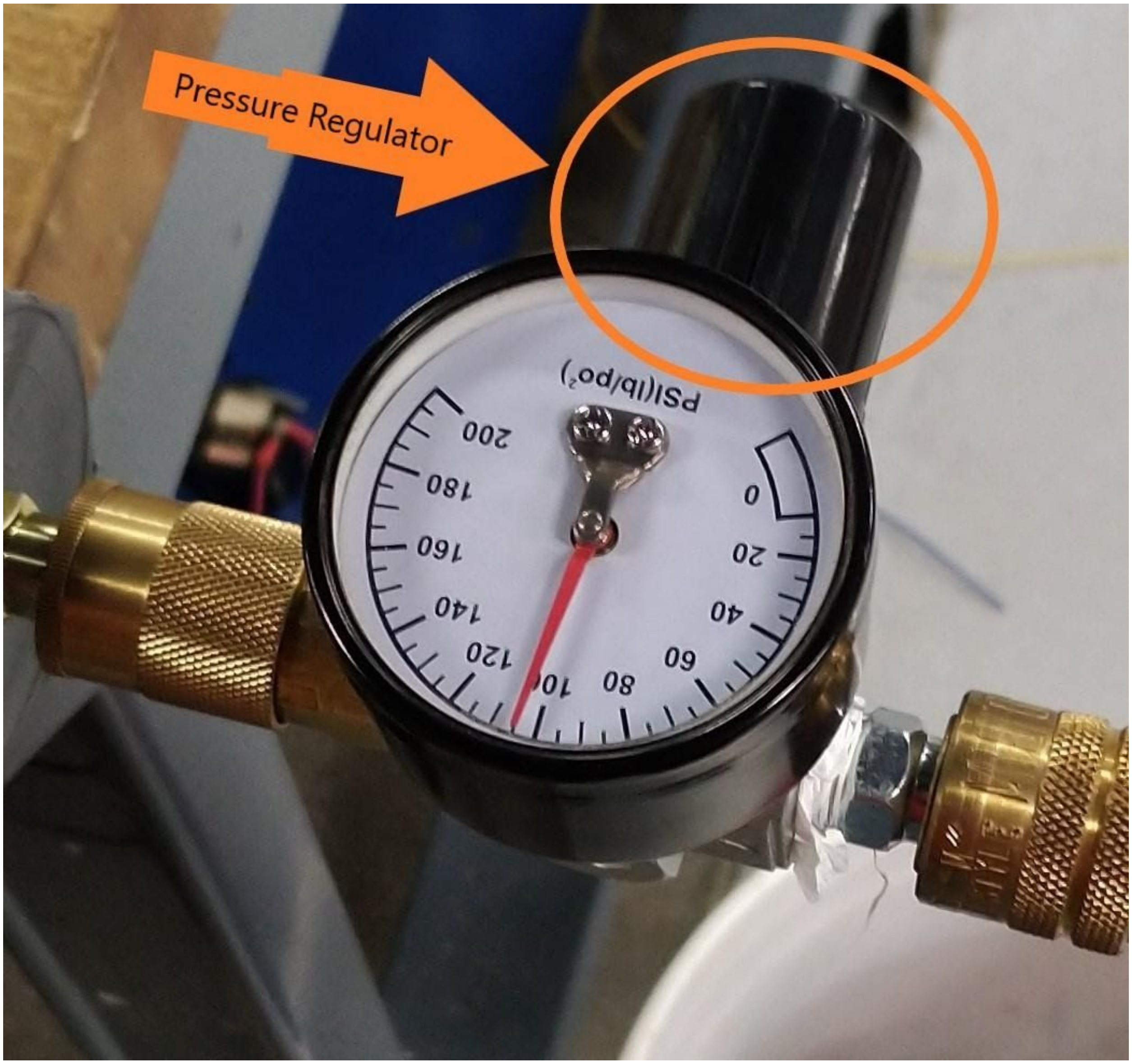
Launch

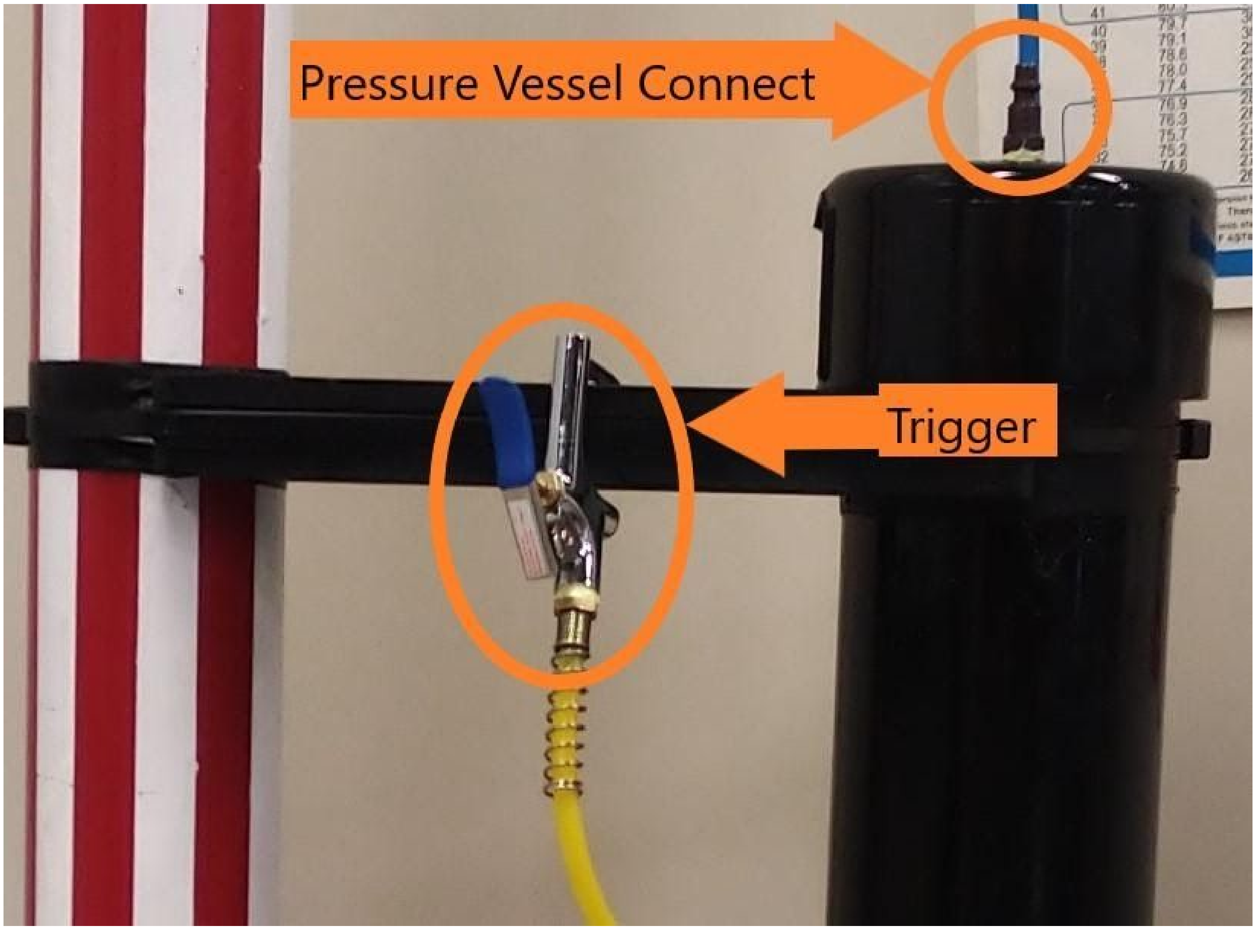
1. Check downrange that anticipated projectile trajectory is safe, and landing zone is empty of people.
2. Check downrange that if the projectile were to veer off course it is still safe to fire.
3. Initiate a countdown to launch and squeeze the trigger when ready to launch.

Takedown

1. Verify that pressure has been released by squeezing the trigger again, and disconnect the air hose.
2. The Rocketcam Air Cannon system can be picked up by 1 person, 2 person carry is recommended.

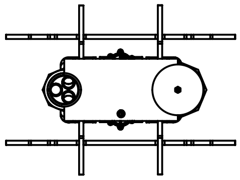

Barrel
Pressure Vessel
Base
PURDUE
UNIVERSITY


Pressure Regulator
PSI(lb/po²)
0
20
40
60
80
100
120
140
160
180
200


Pressure Vessel Connect
Trigger

7. Appendix 3: Drawing Package

Please see next page.



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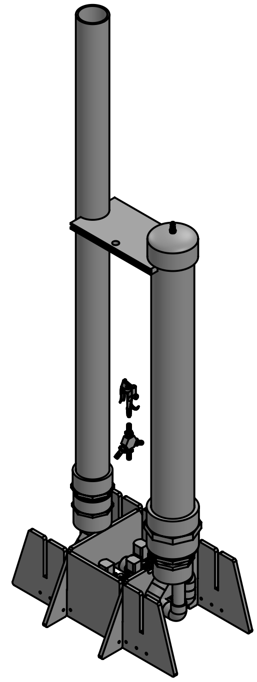

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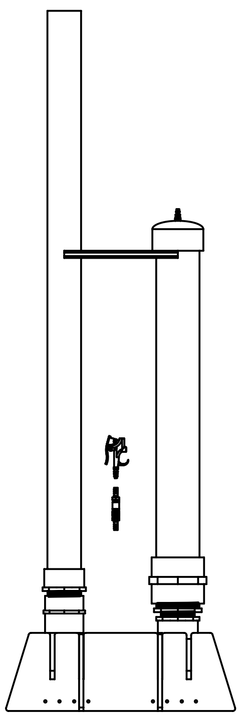

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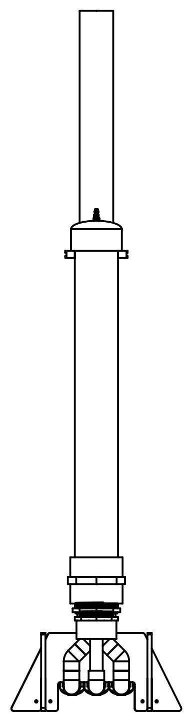


FOR REFERENCE ONLY

	NAME	DATE		
DRAWN	LWD	11/30/19		
CHECKED	LWD	12/1/19		
ENG APPR.	LWD	12/3/19		
MFG APPR.	TRC	12/6/19		
Q.A.				

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON ANGLE 1°
1 PLACE DECIMAL ± .1
2 PLACE DECIMAL ± .02
3 PLACE DECIMAL ± .005

MATERIAL

FINISH

DO NOT SCALE DRAWING

NEXT ASSY | USED ON

THIRD ANGLE PROJECTION

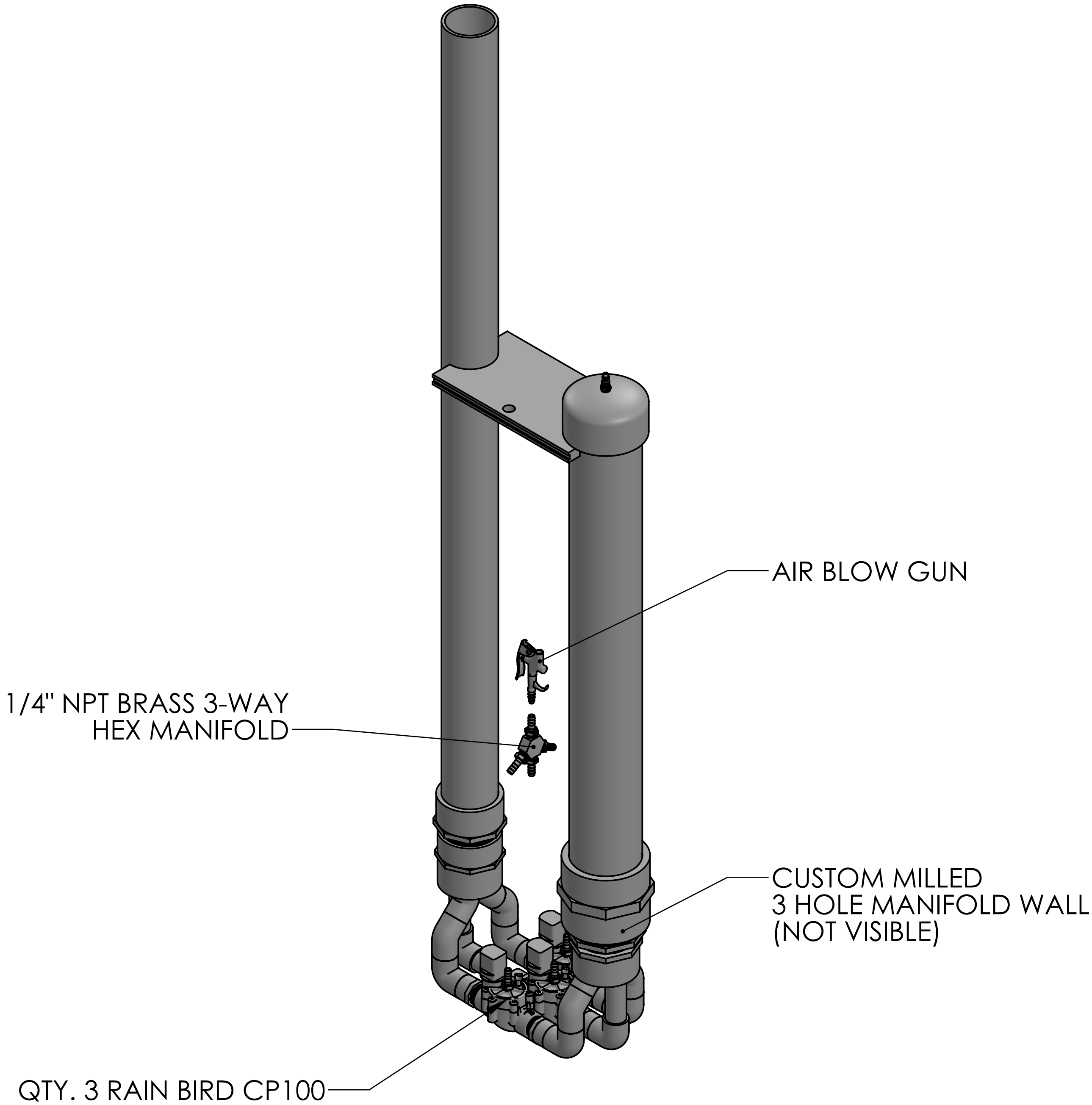
ROCKETCAM AIR CANNON

TITLE

PURDUE UNIVERSITY
MET 400 MECHANICAL
DESIGN CAPSTONE
MORTAR PROJECT

SIZE	DWG. NO.	REV.
A	ASSEMBLY-MORTAR-PROJECT-DIBENEDITTO	

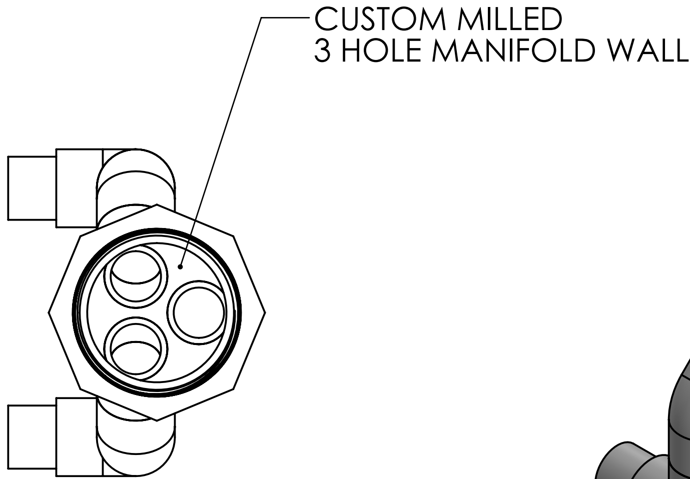
SCALE:1:20	WEIGHT:	SHEET 1 OF 6



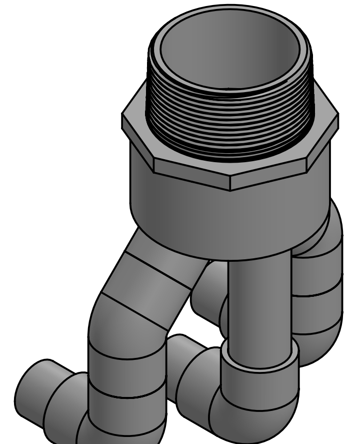
FOR REFERENCE ONLY

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON ANGLE 1° 1 PLACE DECIMAL ± .1 2 PLACE DECIMAL ± .02 3 PLACE DECIMAL ± .005		NAME	DATE		
	DRAWN	LWD	11/30/19		
	CHECKED	LWD	12/1/19	TITLE	ASSEMBLY ROCKETCAM AIR CANNON WITHOUT SUPPORT BASE
	ENG APPR.	LWD	12/3/19		
	MFG APPR.	TRC	12/6/19		
MATERIAL	Q.A.				
FINISH	THIRD ANGLE PROJECTION			SIZE A	DWG. NO. ASSEMBLY-MORTAR-PROJECT-DIBENEDITTO REV.
DO NOT SCALE DRAWING				SCALE:1:10	WEIGHT: SHEET 2 OF 6

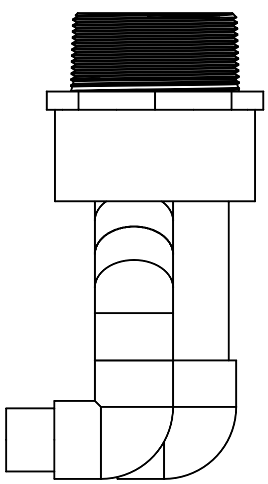
NEXT ASSY	USED ON



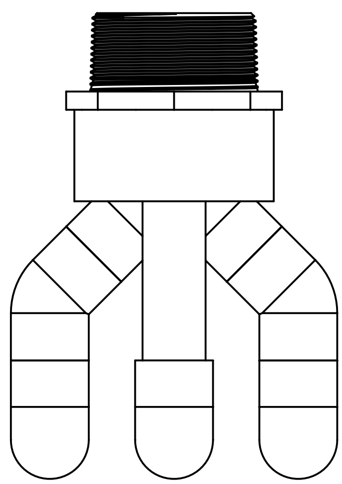
FOR REFERENCE ONLY



FOR REFERENCE ONLY



FOR REFERENCE ONLY



FOR REFERENCE ONLY

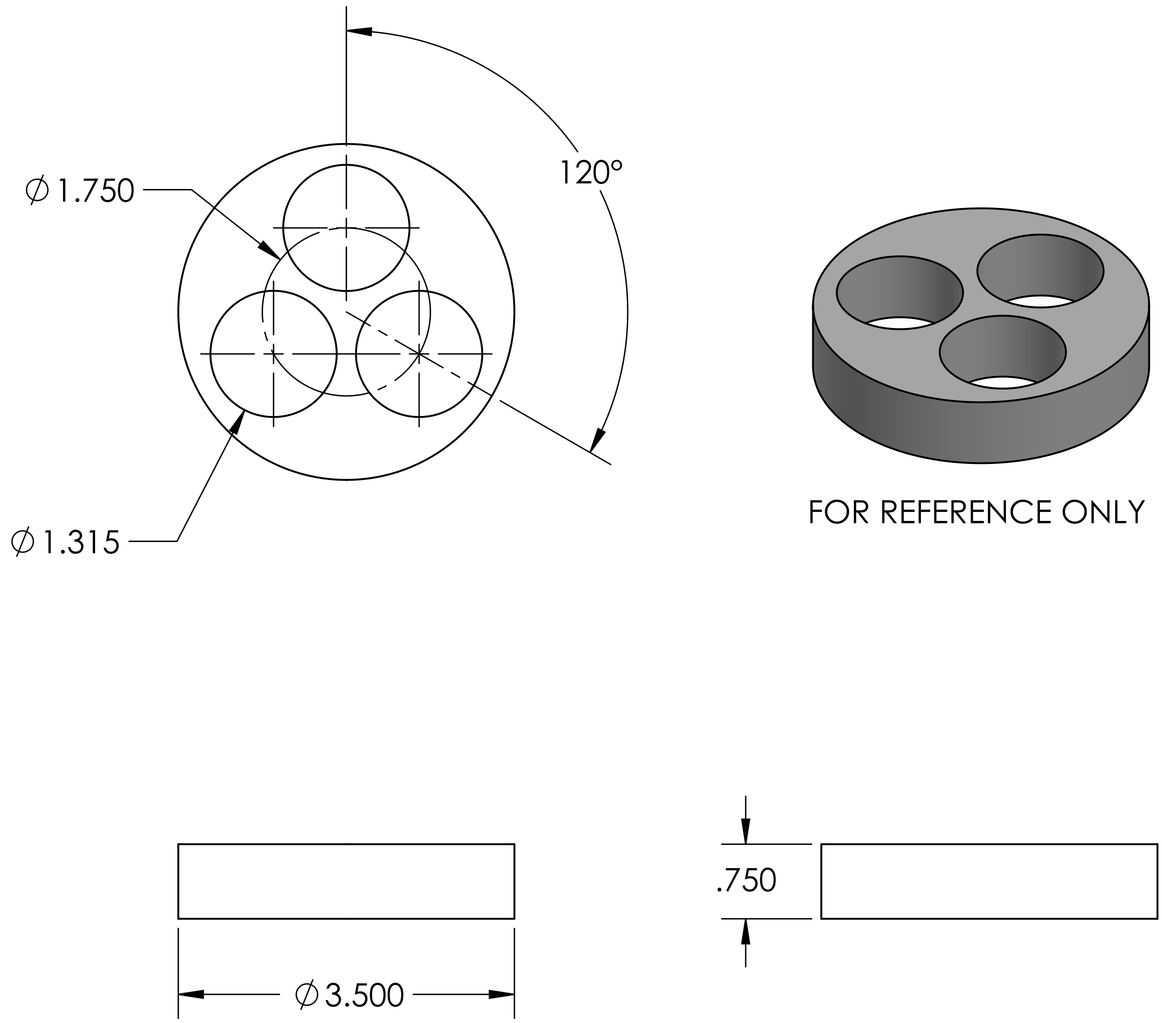
		UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON ANGLE 1° 1 PLACE DECIMAL ± .1 2 PLACE DECIMAL ± .02 3 PLACE DECIMAL ± .005		NAME	DATE
			DRAWN	LWD	11/30/19
			CHECKED	LWD	12/1/19
			ENG APPR.	LWD	12/3/19
			MFG APPR.	TRC	12/6/19
		MATERIAL	Q.A.		
NEXT ASSY	USED ON	FINISH	THIRD ANGLE PROJECTION		
		DO NOT SCALE DRAWING			

TITLE
ROCKETCAM AIR CANNON
ASSEMBLY PRESSURE SIDE

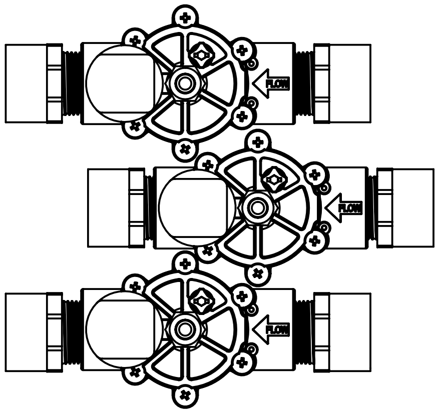
SIZE	DWG. NO.	REV.
A	ASSEMBLY-MORTAR-PROJECT-DIBENEDITTO	

SCALE:1:4	WEIGHT:	SHEET 3 OF 6

1. MATERIAL: 3/4" CHEMICAL RESISTANT PVC SHEET
2. https://www.mcmaster.com/8747k106
3. TENSILE STRENGTH 7,000-7,800 psi

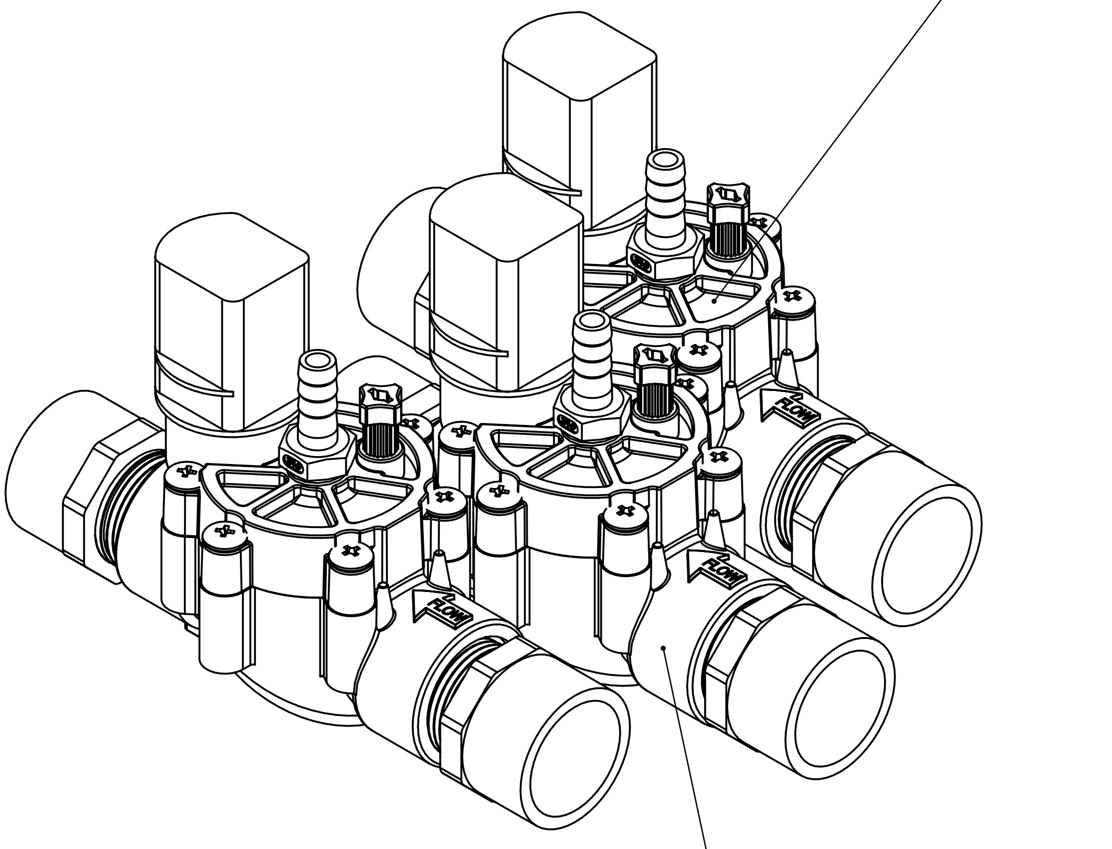


				NAME	DATE	
		UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON ANGLE 1° 1 PLACE DECIMAL ± .1 2 PLACE DECIMAL ± .02 3 PLACE DECIMAL ± .005	DRAWN	LWD	11/30/19	
			CHECKED	LWD	12/1/19	TITLE ROCKETCAM AIR CANNON CUSTOM MILLED 3 HOLE MANIFOLD WALL
			ENG APPR.	LWD	12/3/19	
			MFG APPR.	TRC	12/6/19	
		MATERIAL 3/4" CHEMICAL RESISTANT PVC SHEET	Q.A.			
			THIRD ANGLE PROJECTION			
NEXT ASSY	USED ON	FINISH				SIZE A DWG. NO. ASSEMBLY-MORTAR-PROJECT-DIBENEDITTO REV.
		DO NOT SCALE DRAWING				SCALE:1:2 WEIGHT: SHEET 4 OF 6



FOR REFERENCE ONLY

DRILL TAP AND THREAD 1/4" NPT 18-8
AT APPROXIMATE CENTER

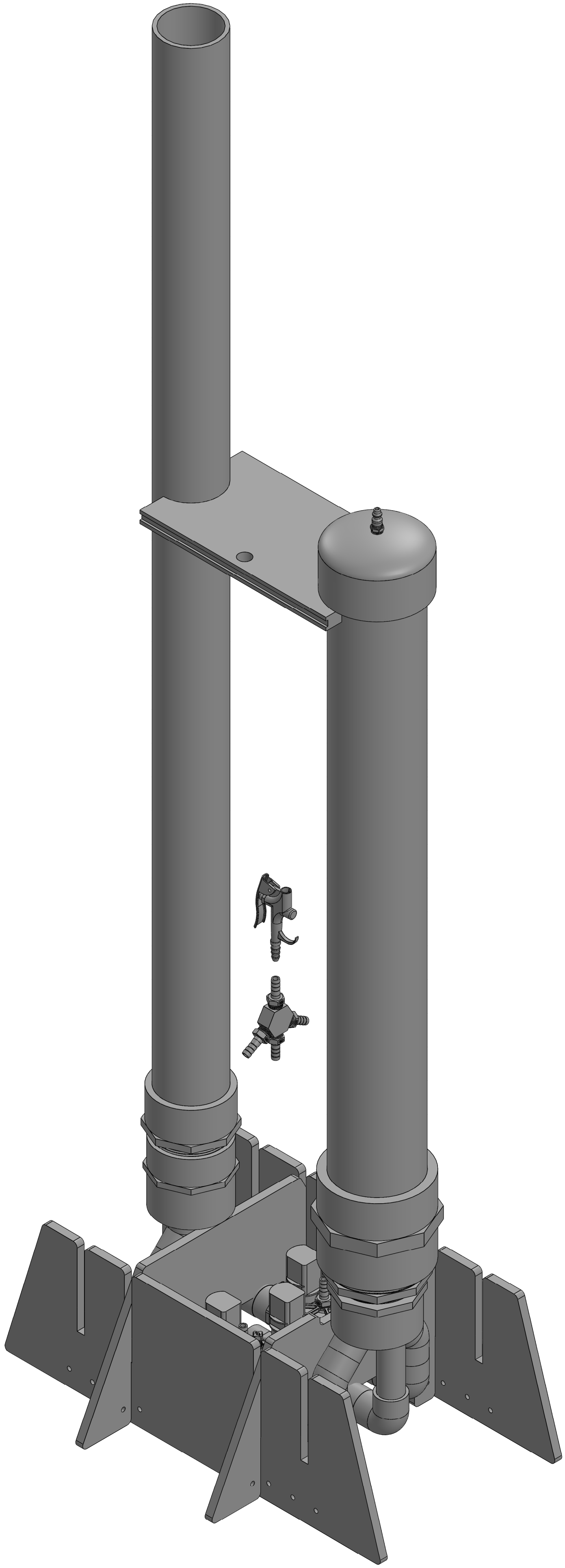


1" RAIN BIRD CP100 SPRINKLER VALVE

FOR REFERENCE ONLY

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON ANGLE 1° 1 PLACE DECIMAL ± .1 2 PLACE DECIMAL ± .02 3 PLACE DECIMAL ± .005		NAME	DATE		
	DRAWN	LWD	11/30/19	TITLE	
	CHECKED	LWD	12/1/19	ROCKETCAM AIR CANNON MODIFIED RAIN BIRD CP100 SPRINKLER VALVES	
	ENG APPR.	LWD	12/3/19		
	MFG APPR.	TRC	12/6/19		
MATERIAL 3/4" CHEMICAL RESISTANT PVC SHEET	Q.A.				
FINISH	THIRD ANGLE PROJECTION			SIZE A — DWG. NO. ASSEMBLY-MORTAR-PROJECT-DIBENEDITTO	REV.
DO NOT SCALE DRAWING				SCALE:1:8 — WEIGHT:	SHEET 5 OF 6

NEXT ASSY	USED ON



https://www.rainbird.com/products/cp-cpf-line-automatic-sprinkler-valves

CP & CPF In-line Automatic Sprinkler Valves

¾ in. or 1 in. irrigation valves with flow control option available

- Irrigation valve designed for in-line (below ground) installation with approved back flow prevention device (not included)
- ¾ in. or 1 in. female threaded inlet and outlet (use MPT threaded pipe adapters with Teflon tape)
- Top mounted, easy turn flow control option available to optimize flow to the zone for maximum efficiency
- 24 VAC, 50/60 Hz automatic operation or manual activation with bleed screw
- Buna-N diaphragm offers superior performance in harsh water environments
- Energy efficient, low power encapsulated solenoid with captured plunger for long lasting dependability
- Heavy duty construction with stainless steel screws

Features

This residential and light commercial grade in-line valve replaces Rain Bird and other irrigation valves installed below ground with ¾ in. or 1 in. female threaded inlets and outlets. It can be used with any 24 volt AC irrigation timer. Its unique

https://www.rainbird.com/products/cp-cpf-line-automatic-sprinkler-valves

reverse-flow design helps prevent flooding in the event of internal diaphragm failure, keeping the valve closed and saving water.

This valve can be used with all types of watering devices including Rain Bird spray heads and rotors as well as Drip zones when properly installed together with a pressure regulator and filter. Use in-line valves in locations where the use of a pressure vacuum breaker (PVB) or a double-check valve is required by code to protect against backflow. Check your local codes to determine what type of valve is required. After installation and before startup, always the flush system of dirt and debris manually using the valve's external bleed screw.

Optionally available equipped with adjustable flow control which helps prevent wasteful misting when water pressure is too high. A top mounted, easy turn flow control knob (CPF models only) allows you to optimize flow to the zone, permitting sprinklers to water at their most efficient rate for more uniform coverage.

- Buna-N diaphragm offers superior performance in harsh water environments
- Reliable, non-clogging design
- Reverse Flow design reduces stress on diaphragm for dependable operation
- In-line design minimizes pressure loss of dirt and debris during installation and system start-up
- Operates automatically or manually with manual bleed screw
- Works with any standard sprinkler timer
- Designed for below-ground installation, out of sight and away from playful hands
- Energy efficient, low power encapsulated solenoid with captured plunger

Additional Features (Flow Control Models Only):

- Easy-to-turn, pressure assisted flow control mechanism
- Reverse Flow design reduces stress on diaphragm for dependable operation

Specs

- Voltage: 24 VAC 50/60 Hz (cycles per second) solenoid

https://www.rainbird.com/products/cp-cpf-line-automatic-sprinkler-valves

- Inrush Current: 0.41A (9.9VA)
- Holding Current: 0.14A (3.43VA)
- Coil Resistance: 30-39 Ohms
- Pressure Range: 15-150 PSI
- Flow Range:
    - CP075 / CPF075: 0.2 GPM to 22 GPM
    - CP100 / CPF100: 0.2 GPM to 40 GPM
- Minimum Water and Ambient Air Temperature: 40° F (4° C)
- Water temperature: up to 110° F (43° C)
- Ambient temperature: up to 125° F (52° C)

			
CP-075 ¾" female pipe thread (FPT) inlet and outlet	**CP-100** 1" female pipe thread (FPT) inlet and outlet	**CPF-075** ¾" FPT inlet and outlet, with flow control	**CPF-100** 1" FPT inlet and outlet, with flow control

CP100 - 1 in. FPT Inline Irrigation Valve

- 1 in. female pipe thread inlet and outlet inline irrigation valve
- Buna-N diaphragm offers superior performance in harsh water environments
- Reliable, non-clogging design
- Reverse Flow design reduces stress on diaphragm for dependable operation
- In-line design minimizes pressure loss of dirt and debris during installation and system start-up
- Operates automatically or manually with manual bleed screw
- Works with any standard sprinkler timer
- Designed for below-ground installation, out of sight and away from playful hands
- Energy efficient, low power encapsulated solenoid with captured plunger

More Views

Product ID: **B60111**
Product Model: **CP100**

Regular Price: ~~$29.40~~
Special Price $18.18

Qty: 1 Add to Cart

+Add to Compare

Product Description | Specifications

Rain Bird manufactures only the highest quality In-Line valves. Use In-Line valves in locations where the use of a pressure vacuum breaker (PVB) or a double-check valve is required by city codes to protect against back flow. Check your local city codes to determine what type of valves are required.

In-Line valves are installed below ground in a valve box down stream from the main line from a PVB or doublecheck valve. In-Line valves will not prevent back flow on their own: they need the help of a back flow prevention device.

Frequently bought together

Customers who bought this product also commonly purchased the following combination of items.

- [x] This Item: CP100 - 1 in. FPT Inline Irrigation Valve
- [x] WPCONN10 - Waterproof Wire Connectors - 10 Pack Regular Price: ~~$7.71~~ **Special Price** $5.25
- [x] PTC1 - Spray Head Pull-Up Tool Regular Price: ~~$16.48~~ **Special Price** $10.47
- [x] 4252NZLPK - Rotor Nozzle Tree for 42SA+, 52SA & 5000+ Rotors Regular Price: ~~$2.12~~ **Special Price** $1.63
- [x] Rotor Screwdriver & Pull-up Tool Regular Price: ~~$5.30~~ **Special Price** $4.77

Total Price $40.30

Add All to Cart

Customers Who Bought This Item Also Bought

select all

WPCONN10 - Waterproof Wire Connectors - 10 Pack

Regular Price: ~~$7.71~~
Special Price $5.25

+Add to Compare

PTC1 - Spray Head Pull-Up Tool

Regular Price: ~~$16.48~~
Special Price $10.47

+Add to Compare

4252NZLPK - Rotor Nozzle Tree for 42SA+, 52SA & 5000+ Rotors

Regular Price: ~~$2.12~~
Special Price $1.63

+Add to Compare

Rotor Screwdriver & Pull-up Tool

Regular Price: ~~$5.30~~
Special Price $4.77

+Add to Compare

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Home → Valves → Sprinkler Valves → **CP100 - 1 in. FPT Inline Irrigation Valve**

Save 38%

CP100 - 1 in. FPT Inline Irrigation Valve

- 1 in. female pipe thread inlet and outlet inline irrigation valve
- Buna-N diaphragm offers superior performance in harsh water environments
- Reliable, non-clogging design
- Reverse Flow design reduces stress on diaphragm for dependable operation
- In-line design minimizes pressure loss of dirt and debris during installation and system start-up
- Operates automatically or manually with manual bleed screw
- Works with any standard sprinkler timer
- Designed for below-ground installation, out of sight and away from playful hands
- Energy efficient, low power encapsulated solenoid with captured plunger

More Views

Product ID: **B60111**
Product Model: **CP100**

Regular Price: ~~$29.40~~
Special Price $18.18

Qty: 1 Add to Cart

+Add to Compare

Product Description | Specifications

Valve Size	1 in
Valve Type	Inline
Material	Plastic
Valve Inlet/Outlet Configuration	NPT Female x NPT Female Threaded
Operating Temperature	Minimum Water and Ambient Air Temperature: 40° F (4° C) Water temperature: up to 110° F (43° C) Ambient temperature: up to 125° F (52° C)
Dimensions	Width: 4.75 in Height: 5 in Depth: 3.37 in
Electrical Specifications	24 VAC 50/60 Hz solenoid Inrush: .30 amp

	Holding: .19 amp
Flow Range	0.2 to 40 gpm *For flows below 3 GPM or drip line applications install a 200 mesh filter before the valve*
Operating Pressure	15 to 150 psi

Frequently bought together

Customers who bought this product also commonly purchased the following combination of items.

- [x] This Item: CP100 - 1 in. FPT Inline Irrigation Valve
- [x] WPCONN10 - Waterproof Wire Connectors - 10 Pack Regular Price: ~~$7.71~~ **Special Price** $5.25
- [x] PTC1 - Spray Head Pull-Up Tool Regular Price: ~~$16.48~~ **Special Price** $10.47
- [x] 4252NZLPK - Rotor Nozzle Tree for 42SA+, 52SA & 5000+ Rotors Regular Price: ~~$2.12~~ **Special Price** $1.63
- [x] Rotor Screwdriver & Pull-up Tool Regular Price: ~~$5.30~~ **Special Price** $4.77

Total Price $40.30

Add All to Cart

Customers Who Bought This Item Also Bought

select all

WPCONN10 - Waterproof Wire Connectors - 10 Pack

Regular Price: ~~$7.71~~
Special Price $5.25

+Add to Compare

PTC1 - Spray Head Pull-Up Tool

Regular Price: ~~$16.48~~
Special Price $10.47

+Add to Compare

4252NZLPK - Rotor Nozzle Tree for 42SA+, 52SA & 5000+ Rotors

Regular Price: ~~$2.12~~
Special Price $1.63

+Add to Compare

Rotor Screwdriver & Pull-up Tool

Regular Price: ~~$5.30~~
Special Price $4.77

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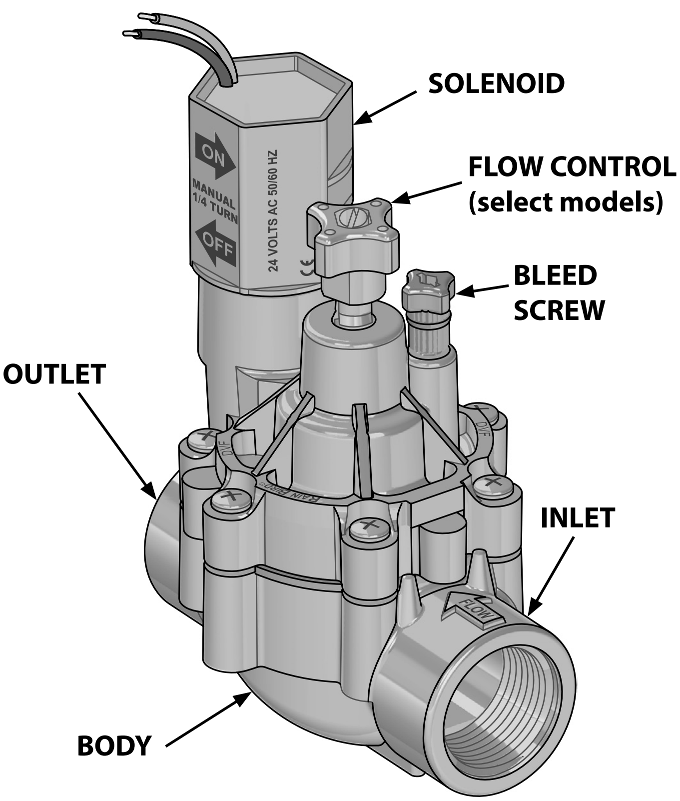
English

CP/CPF Series Valve Installation and Operation

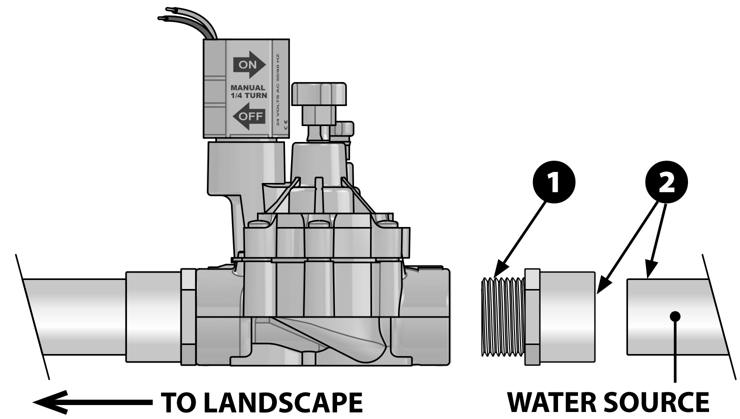


Before Installation

- Install master valves, pressure regulators and back-flow preventers as needed.
- A pressure regulator is required if water pressure exceeds 150 PSI (recommended over 80 PSI).
- Inline valves require a separate backflow preventer in the main line. Check local building codes.
- Flush the system thoroughly until water runs clear.
- Shut off the main water supply.

Connect Valve to Pipes

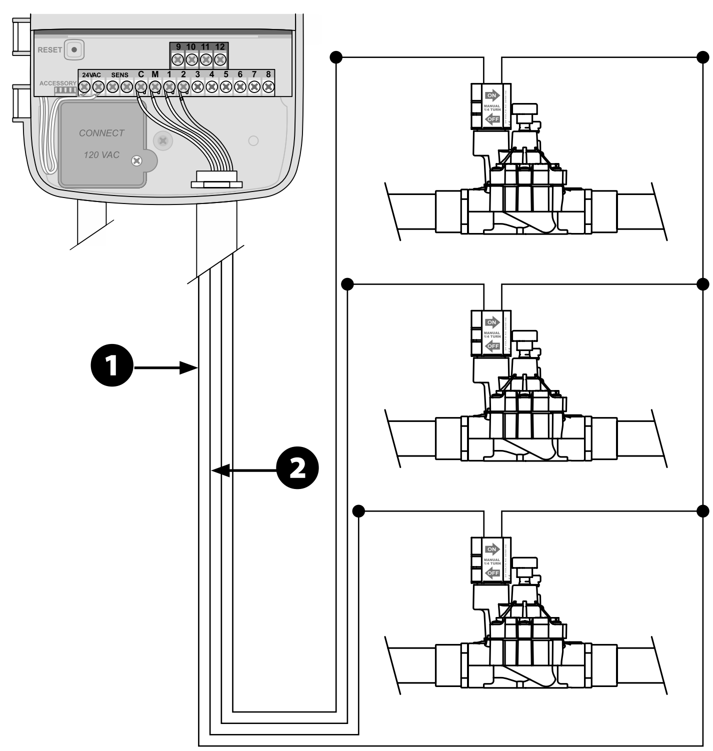
1. Apply PTFE thread-seal tape to the male threads on the adapters, screw into the valve and hand-tighten (do not use PVC glue or pipe dope on adapter threads).
2. Apply primer and then PVC cement to the ends of the pipe and inside the adapters per manufacturer's instructions.
3. Ensure the valve arrows face in the direction of water flow, and push valve onto inlet and outlet pipes until secure. Follow PVC cement instructions for cure time.



Connect Valve Wires

NOTE: Use watertight connectors and direct burial wire for all connections.

1. Connect one solenoid wire to a common wire (usually white). All valves can share the same common wire.
2. Connect the second solenoid wire to a power wire (usually colored).



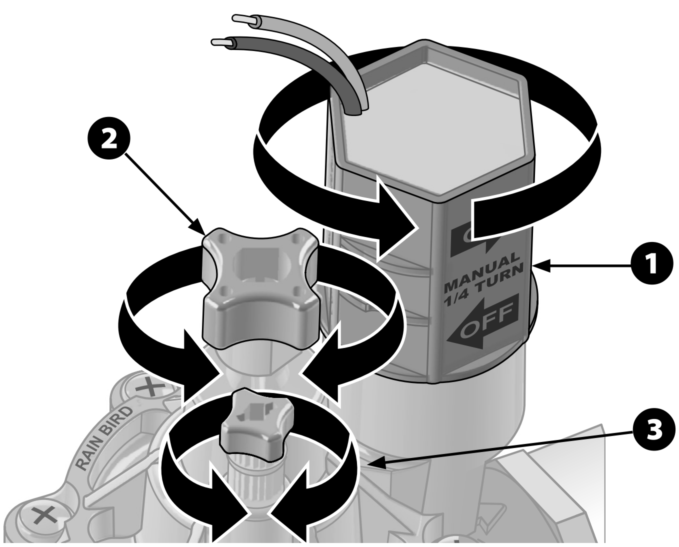
Valve Operation

Manual Operation:

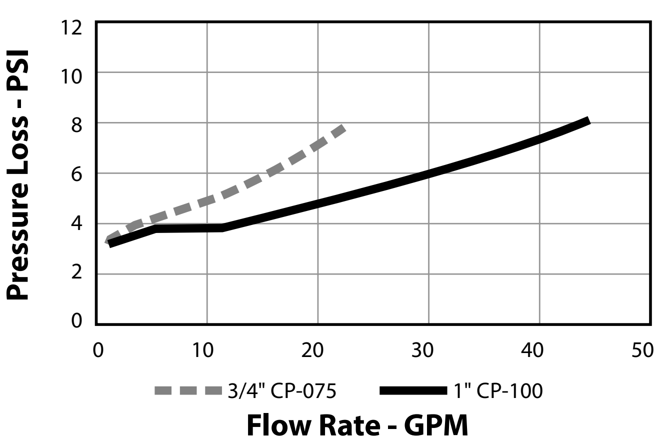
1. Manual on: Turn the solenoid counter-clockwise 1/4 turn. Do not unscrew completely. To close, hand tighten clockwise.
2. Flow control (select models only): Turn clockwise to restrict flow. Turn counter-clockwise to open flow.
3. Flush valve to clear debris: Turn the bleed screw counter-clockwise ONLY 1 turn. Flush one minute and turn clockwise to close.

First Use:

4. Open the main water supply and flush one minute with bleed screw to clear debris.
5. Test wiring by using the Manual Water feature on the irrigation controller.
6. Adjust the flow control to reduce over-spray. (select models).



Pressure Loss Chart



Operating Ranges

	075-CP / 075-CPF	100-CP / 100-CPF
Flow[2]	0.2 - 22 GPM	0.2 - 40 GPM
Pressure	15 - 150 PSI	15 - 150 PSI

NOTE: For flows below 3 GPM (0.75 m3/h), or any drip application, use a 200 mesh filter upstream and a pressure regulating filter downstream from the valve. 40 psi for 1" and 30 psi for 3/4" drip lines.

Troubleshooting

Symptom	Solution
Valve Won't Turn On when Solenoid is Turned	Make sure flow control is open (select models)
	Check that main water supply is on
	Make sure piping is connected properly and not blocked
Valve Won't Turn On at the Timer	Verify timer settings are correct
	Check and repair wiring and connections as needed
	Check and replace valve solenoid as needed
	Verify timer power output
Valve Won't Shut-off	Verify timer settings are correct
	Hand tighten solenoid and bleed screw if needed
Valve Won't Turn On at the Valve	Incorrect timer settings
	Check wiring
	Check solenoid
	Timer not supplying power to the valve
	Make sure the Flow Control stem is not turned all the way closed
Leaks at sprinkler heads	Clear debris by opening the bleed screw and flushing 1 minute
	Remove and clean the diaphragm. Replace if needed.
Leaks around the valve	Check pipe fittings connection and glue, repair or replace as needed
	Hand tighten solenoid and bleed screw if needed
	If vacuum breaker is leaking (anti-siphon models) remove cap, gasket, and internal piston gasket to clean and reassemble
	Turn off main water supply, relieve pressure on the valve by opening the bleed screw and tighten the jar top bonnet

NOTE: During winter, shutdown and drain the system to protect valves from freezing. Failure to properly drain the lines can result in damage to the valves, which is not covered under the customer satisfaction policy.

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Tucson, AZ 85756
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