Team 9 BattleBot

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1.0 PROJECT SCOPE

The scope of work for the 2002-2003 BattleBot senior design team will cover the following criteria. Improvements will be made on the BattleBot designed by the 2001-2002 senior design team. The BattleBot will be self-righting. The existing drive train will be redesigned for durability and higher performance. The primary and secondary weapon systems will be reevaluated with regards to effectiveness. The BattleBot weight will be optimized.

2.0 ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

The following list defines the acronyms, abbreviations, and definitions used in this document.

Robot/Bot	BattleBot fighting robot
Operator	Student or engineer responsible for environmental testing a UUT using a test facility.
Procedure	Detailed test facility operating instructions are designed to be a training tool and a reference document. The procedure can also be use for operator recertification.
Test Facilities	Facilities used to produce, control, and record the test environment.
Test Equipment	Equipment used to operate and monitor the UUT.
UUT	Unit under test

3.0 APPLICABLE DOCUMENTS

The documents listed in paragraphs 2.1 to 2.3 form a part of this procedure to the extent specified herein.

3.1 BattleBot Rules

BattleBot_Tech_Regs_v2.2
http://www.battlebots.com/download/BattleBots_Tech_Regs_v2.2.pdf

3.2 Event Procedures

BattleBots Tournament Rules and Procedures
http://www.battlebots.com/download/BattleBots_TR&P_v2.1.pdf

3.3 Judging Rules

BattleBots Judges' Guide
http://www.battlebots.com/download/Judges_Guide_Rev_0.9.pdf

3.4 ANSI Standards

Documents JIS 1801 and JIS 1802

4.0 BACKGROUND

The basis for this project was established by the Senior Design Team RAD in the 2001-2002 academic year. This team established the baseline for the current robot design. Team RAD BattelBot followed the design process and performed market research, objective and function analysis, specifications, concept generation, and concept selection to come up with their design. The final concept chosen was a wedge shaped robot with a pneumatic lifting arm on top of the robot, and a spinning drum weapon on the back. The Design by Team RAD had good intentions but failed during the BattleBot competition. The faults at hand were an ill thought out drive train construction and lack of consideration for overall robot weight. Due to weight problems, the pneumatic lifting arm had to be removed prior to competition creating a heavy reliance on the rotating drum weapon. The poor construction of the drive train caused a drive belt to misalign and snap on the competition floor causing immobilization and forfeiture.

5.0 NEEDS ASSESMENT

The BattleBot must meet the following Customer Needs:

- Move fast
- Quick acceleration
- Be able to push competitors around arena
- Agile and maneuverable
- Improve weapon effectiveness
- Improve durability
- Armor must protect Bot from other Bots and hazards
- Easy assembly/disassembly and battery recharging
- Must meet heavyweight division requirements
- Self righting

To confirm and validity and completeness of the customer needs and specifications, the needs and metrics were compared to ensure all needs were accounted for the all metrics were necessary. Table 5.1 shows that all the needs are associated with at least one metric and there are no metrics that do not relate to a customer need.

Table 5.1.– Needs/Metrics Matrix

	Needs \ Metrics	1 High top speed	2 Powerful drive train	3 Drive system must withstand constant direction and acceleration changes	4 Bearings must last through entire competition without needing replacement	5 Must operate at full power for entire match	6 Tires must resist punctures and cuts	7 Tires must have high traction	8 Must be highly maneuverable	9 Drive train must function under the weight of another Bot	10 Primary weapon must be able to function under weight of another Bot	11 Impact solid immoveable wall repeatedly at full speed and be fully functional	12 Must survive being tossed through the air	13 Armor must resist puncture from repeated blows by sharp object	14 Armor must protect entire robot	15 Armor must resist temporary encounters with saws	16 All repairs must be able to be made between matches	17 Power systems must be ready for each match	18 Entire Bot must make weight with all components installed	19 Self righting quickly
1	Move fast	•	•						•											
2	Quick acceleration		•						•											
3	Be able to push competitors around arena		•	•				•		•										
4	Agile and maneuverable			•				•	•											
5	Improve weapon's effectiveness									•	•									
6	Improve durability			•	•		•			•	•	•	•							
7	Protect Bot from other Bots and hazards						•							•	•	•				
8	Easy assembly/disassembly and recharging					•											•	•		
9	Must meet heavyweight division requirements					•								•	•	•	•		•	
10	Self righting																			•

6.0 SPECIFICATIONS

6.1 Target Specifications

The Target Specifications for the BattleBot are shown in Table 6.1. Specification importance (Imp,) is on a scale of 1 to 5 with 5 being the highest.

Table 6.1 – Target Specifications

	Metric	Imp.	Ideal Value	Acceptable Values	
				+	-
1	High top speed	4	10 mph	3	3
2	Powerful drive train	5	10 hp	2	4
3	Drive system must withstand constant direction and acceleration changes	5	100 cycles	40	20
4	Bearings must last through entire competition without needing replacement	3	10 matches	2	1
5	Must be highly maneuverable	5	turn within 1 length	0	0.5
6	Drive train must function under the weight of another Bot	3	300lbs	10	80
7	Must operate at full power for entire match	5	5 mins	0	2
8	Tires must resist punctures and cuts	4	75% functional at end of match	25	10
9	Tires must have high traction	4	full power from drivetrain w/o slip	0	10%
10	All repairs must be able to be made between matches	4	20 mins	0	5
11	Power systems must be ready for each match	4	20 mins	0	5
12	Entire bot must make weight with all components installed	5	220 lbs	0	10
13	Self righting quickly	3	7 secs	3	2
14	Primary weapon must be able to function under weight of another Bot	4	300lbs	50	80
15	Impact solid immoveable wall repeatedly at full speed and be fully functional	5	15 times	5	2
16	Must survive being tossed through the air	4	3 ft high drop	2	0
17	Armor must resist puncture from repeated blows by sharp object	4	20 times	10	2
18	Armor must protect entire robot	4	6 sides	0	1
19	Armor must resist temporary encounters with saws	3	3 secs, 4 times	2, 5	0

6.2 Final Specifications

The final specifications for BattleBot design are given in Table 6.2

Table 6.2 – Final Specifications

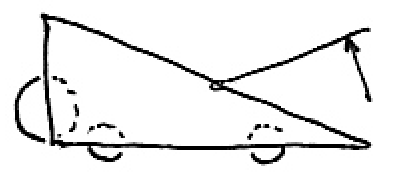
	Metric	**Ideal Value**
1	High top speed	8 mph
2	Powerful drive train	Two 1 hp
3	Drive system must withstand constant direction and acceleration changes	100 cycles
4	Bearings must last through entire competition without needing replacement	10 matches
5	Must be highly maneuverable	turn within 30 inches
6	Drive train must function under the weight of another Bot	300lbs
7	Must operate at full power for entire match	5 mins
8	Tires must resist punctures and cuts	75% functional at end of match
9	Tires must have high traction	full power from drivetrain w/o slip
10	All repairs must be able to be made between matches	20 mins
11	Power systems must be ready for each match	20 mins
12	Entire bot must make weight with all components installed	220 lbs
13	Self righting quickly	7 secs
14	Primary weapon must be able to function under weight of another Bot	300lbs
15	Impact solid immoveable wall repeatedly at full speed and be fully functional	15 times
16	Must survive being tossed through the air	3 ft high drop
17	Armor must resist puncture from repeated blows by sharp object	300 lbs, 20 times
18	Armor must protect entire robot	6 sides
19	Armor must resist temporary encounters with saws	3 secs, 4 times

7.0 CONCEPT GENERATION AND SELECTION

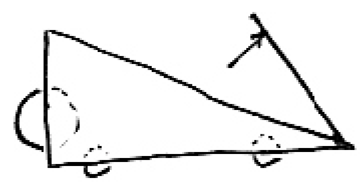
7.1 Concept Generation

The primary weapon system is mounted on the front of the Bot and will serve and the main method of attack. The concepts generated for the primary weapon system can be seen in Table 7.1.

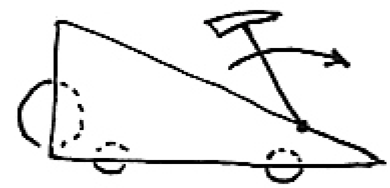
Table 7.1 – Primary Weapon System



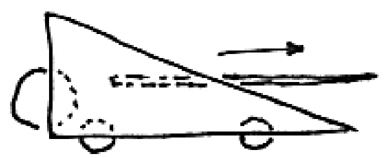
Flipper 1



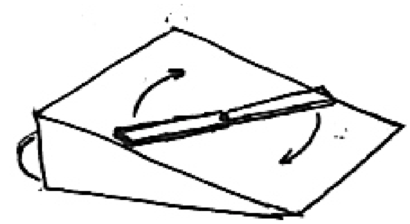
Flipper 2



Hammer Spike



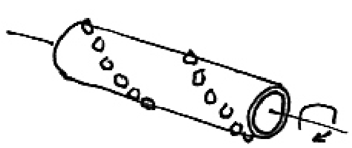
Projectile Spear



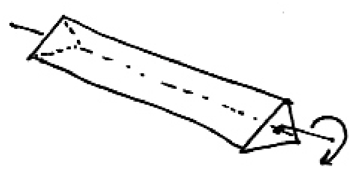
Spinning Blades of Death

The secondary weapon system will serve as another means of attack. It will also facilitate attack from multiple angles and directions as well as greater feasibility in attacking different types of Bots. The concepts generated for the secondary weapon system can be seen in Table 7.2

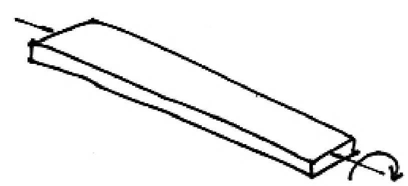
Table 7.2 – Secondary Weapon System



Helical Spikes



Triangular Bar

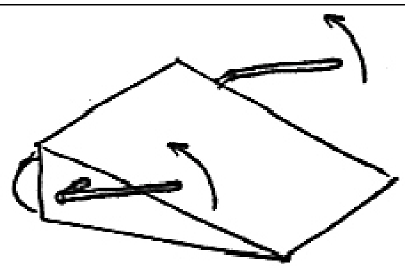


Rectangular Bar

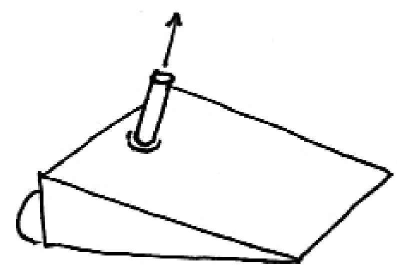
Existing Drum

In the event that the Bot is flipped, either by a hazard or another Bot, the self-righting mechanism will flip the Bot back on its wheels so it is not immobilized and therefore eliminated. Table 7.3 shows the concepts generated for the self righting mechanism.

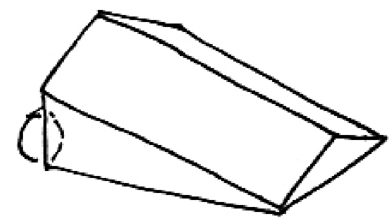
Table 7.3 – Self Righting Mechanism



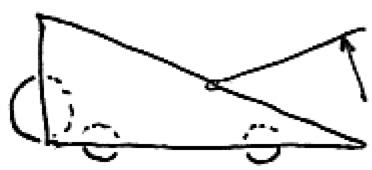
Flipping Arms



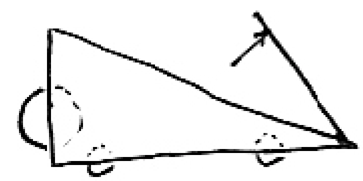
Flipping Rod



Geometric Balance



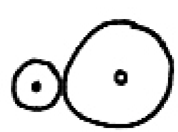
Flipper 1



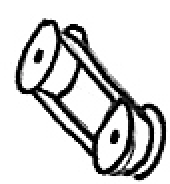
Flipper 2

The drive train must transmit power to the wheels and be able to stand up to the high loads and shocks from other Bots and the hazards in the arena. Concepts generated for the drive train can be found in Table 7.4.

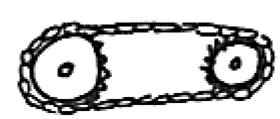
Table 7.4– Drive Train



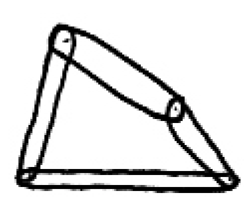
Gears



Belts



Chains



Linkages

7.2 Concept Selection

A rough comparison was made of the concepts in order to eliminate as many unfeasible solutions as possible. Each concept was given a plus (+), minus (-) or zero (0) according to whether it fulfilled the specification or not. By summing the pluses and minuses, the feasibility of each concept was determined. After careful consideration, some were eliminated. Table *7.5* shows the comparison matrix for the primary weapon system.

Table 7.5 – Phase 1 Matrix for Primary Weapon System

	Concepts				
Selection Criteria	**Flipper 1**	**Flipper 2**	**Hammer Spike**	**Projectile Spear**	**Spinning Blades**
Move fast	0	0	0	0	0
Quick acceleration	0	0	0	0	0
Be able to push competitors around arena	+	+	-	-	-
Agile and maneuverable	0	0	0	0	0
Improve weapon effectiveness	0	0	0	0	0
Improve durability	0	0	0	0	0
Armor must protect Bot from other Bots and hazards	+	+	-	-	0
Easy assembly/disassembly and battery recharging	0	0	0	0	-
Must meet heavyweight division requirements	+	+	-	-	-
Self righting	+	-	+	-	-
Low cost	-	-	-	-	-
Ease of machining	+	+	+	-	0
Feasibility of timely production	+	+	+	0	0
Use existing parts	+	+	-	-	-
Sum +'s	7	6	3	0	0
Sum 0's	6	6	6	7	8
Sum -'s	1	2	5	7	6
Net Score	6	4	-2	-7	-6
Rank	1	2	3	5	4
Continue?	yes	yes	no	no	no

After careful consideration, the Hammer Spike, Projectile Spear and Spinning Blades were eliminated. To narrow the selection further, the remaining two possibilities were tested by assigning a weight and value to the fulfillment of each specification and summing the numbers to get a total score. If it seemed that the concept with the highest score was the best, all other concepts were eliminated. If not, a more rigorous selection would have to be performed. Fortunately, this more rigorous selection process was not necessary. Table *7.6* shows the final concept selection for the primary weapon system.

Table 7.6 – Phase 2 Matrix for Primary Weapon System

		Concepts			
		Flipper 1		Flipper 2	
Selection Criteria	**Weight**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Move fast	3%	2	0.06	2	0.06
Quick acceleration	4%	2	0.08	2	0.08
Be able to push competitors around arena	12%	4	0.48	3	0.36
Agile and maneuverable	7%	4	0.28	4	0.28
Improve weapon effectiveness	11%	5	0.55	3	0.33
Improve durability	12%	3	0.36	3	0.36
Armor must protect Bot from other Bots and hazards	6%	3	0.18	4	0.24
Easy assembly/disassembly and battery recharging	5%	3	0.15	3	0.15
Must meet heavyweight division requirements	9%	4	0.36	4	0.36
Self righting	10%	5	0.5	3	0.3
Low cost	11%	3	0.33	3	0.33
Ease of machining	4%	2	0.08	2	0.08
Feasibility of timely production	3%	3	0.09	3	0.09
Use existing parts	3%	2	0.06	2	0.06
Net Score	100%		3.56		3.08
Rank			1		2
Continue?			yes		no

The Flipper 1 was determined to be the best concept and will be developed.

The same procedure was used to determine the concepts for all other categories. Table *7.7* shows the rough selection matrix for the secondary weapon system. It was determined that even though there was a difference in the scores, no concepts could be eliminated at this phase because they all showed possible merit.

Table 7.7 – Phase 1 Matrix for Secondary Weapon System

	Concepts			
Selection Criteria	**Helical Spikes**	**Triangular Bar**	**Rectangular Bar**	**Existing Drum**
Move fast	0	0	0	0
Quick acceleration	0	0	0	0
Be able to push competitors around arena	0	0	0	0
Agile and maneuverable	0	0	0	0
Improve weapon effectiveness	+	+	-	0
Improve durability	-	0	0	0
Armor must protect Bot from other Bots and hazards	0	0	0	0
Easy assembly/disassembly and battery recharging	0	0	0	0
Must meet heavyweight division requirements	0	+	+	0
Self righting	0	0	0	0
Low cost	0	0	0	+
Ease of machining	-	+	+	-
Feasibility of timely production	0	+	+	0
Use existing parts	-	-	-	+
Sum +'s	1	4	3	2
Sum 0's	8	9	9	10
Sum -'s	3	1	1	1
Net Score	-2	3	2	1
Rank	4	1	2	3
Continue?	yes	yes	yes	yes

All four concepts were ranked in the weighted matrix as seen in Table *7.8*. After careful consideration, including cost and use of existing parts, the existing drum was decided upon as the best concept.

Table 7.8 – Phase 2 Matrix for Secondary Weapon System

		Concepts							
		Helical Spikes		Triangular Bar		Rectangular Bar		Existing Drum	
Selection Criteria	**Weight**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Move fast	3%	3	0.09	4	0.12	4	0.12	4	0.12
Quick acceleration	4%	1	0.04	3	0.12	3	0.12	1	0.04
Be able to push competitors around arena	12%	3	0.36	3	0.36	3	0.36	4	0.48
Agile and maneuverable	7%	2	0.14	3	0.21	3	0.21	2	0.14
Improve weapon effectiveness	11%	4	0.44	4	0.44	4	0.44	5	0.55
Improve durability	12%	3	0.36	3	0.36	3	0.36	3	0.36
Armor must protect Bot from other Bots and hazards	6%	2	0.12	2	0.12	2	0.12	2	0.12
Easy assembly/disassembly and battery recharging	5%	3	0.15	3	0.15	3	0.15	4	0.2
Must meet heavyweight division requirements	9%	2	0.18	4	0.36	2	0.18	2	0.18
Self righting	10%	1	0.1	1	0.1	1	0.1	1	0.1
Low cost	11%	2	0.22	3	0.33	3	0.33	5	0.55
Ease of machining	4%	1	0.04	2	0.08	2	0.08	3	0.12
Feasibility of timely production	3%	3	0.09	3	0.09	3	0.09	3	0.09
Use existing parts	3%	1	0.03	1	0.03	1	0.03	5	0.15
Net Score	100%		2.36		2.87		2.69		3.2
Rank			4		2		3		1
Continue?			no		no		no		yes

The rough selection matrix for the self righting mechanism is shown in Table *7.9*. It was determined that using either of the flippers as the self righting mechanism was the best of the concepts.

Table 7.9– Phase 1 Matrix for Self Righting Mechanism

	Concepts				
Selection Criteria	**Flipping Arms**	**Flipping Rod**	**Geometric Balance**	**Flipper 1**	**Flipper 2**
Move fast	0	0	0	0	0
Quick acceleration	0	0	0	0	0
Be able to push competitors around arena	0	0	0	0	0
Agile and maneuverable	0	0	0	0	0
Improve weapon effectiveness	0	0	0	0	0
Improve durability	0	0	0	0	0
Armor must protect Bot from other Bots and hazards	-	-	+	+	+
Easy assembly/disassembly and battery recharging	-	-	+	0	0
Must meet heavyweight division requirements	-	-	-	0	0
Self righting	+	+	+	+	+
Low cost	-	-	-	-	-
Ease of machining	-	-	-	0	0
Feasibility of timely production	0	0	0	0	0
Use existing parts	-	-	-	0	+
Sum +'s	1	1	3	2	3
Sum 0's	7	7	7	11	10
Sum -'s	6	6	4	1	1
Net Score	-5	-5	-1	1	2
Rank	4	5	3	2	1
Continue?	no	no	no	yes	yes

The two flipping arms were carried over to the weighted matrix as seen in Table 7.10. The Flipper 1 concept was determined to be the best concept. Fortunately, the Flipper 1 concept was also determined as the best primary weapon system. Had this not been the case, the selection of both systems would have been revaluated.

Table 7.10– Phase 2 Matrix for Self Righting Mechanism

		Concepts			
		Flipper 1		Flipper 2	
Selection Criteria	**Weight**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Move fast	3%	2	0.06	2	0.06
Quick acceleration	4%	3	0.12	3	0.12
Be able to push competitors around arena	12%	2	0.24	2	0.24
Agile and maneuverable	7%	2	0.14	2	0.14
Improve weapon effectiveness	11%	4	0.44	2	0.22
Improve durability	12%	2	0.24	2	0.24
Armor must protect Bot from other Bots and hazards	6%	4	0.24	4	0.24
Easy assembly/disassembly and battery recharging	5%	2	0.1	2	0.1
Must meet heavyweight division requirements	9%	4	0.36	4	0.36
Self righting	10%	5	0.5	3	0.3
Low cost	11%	2	0.22	2	0.22
Ease of machining	4%	4	0.16	4	0.16
Feasibility of timely production	3%	4	0.12	4	0.12
Use existing parts	3%	3	0.09	3	0.09
Net Score	100%		3.03		2.61
Rank			1		2
Continue?			yes		no

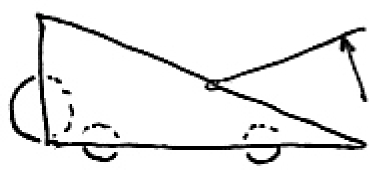
Finally, the drive system was evaluated using the rough selection matrix as seen in Table *7.11*. It was determined that chains would make the best drive system even though it did not win out decisively over belts. This decision was made due to the fact that the belts failed in the 2002 competition and that chains could be more durable.

Table 7.11 – Phase 1 Matrix for Drive Train

	Concepts			
Selection Criteria	**Gears**	**Belts**	**Chains**	**Linkage**
Move fast	0	0	0	0
Quick acceleration	0	0	0	0
Be able to push competitors around arena	0	0	0	0
Agile and maneuverable	0	0	0	0
Improve weapon effectiveness	0	0	0	0
Improve durability	+	-	+	-
Armor must protect Bot from other Bots and hazards	0	0	0	0
Easy assembly/disassembly and battery recharging	+	-	+	-
Must meet heavyweight division requirements	-	+	+	-
Self righting	0	0	0	0
Low cost	-	+	+	-
Ease of machining	-	+	+	-
Feasibility of timely production	0	+	+	-
Use existing parts	-	+	-	-
Sum +'s	2	5	6	0
Sum 0's	8	7	7	7
Sum -'s	4	2	1	7
Net Score	-2	3	5	-7
Rank	3	2	1	4
Continue?	no	no	yes	no

The final concept selections for all systems can be seen in Table 7.12

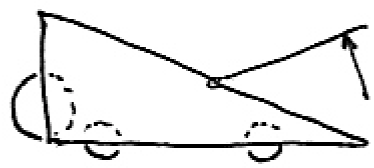
Table 7.12 – Final Concept Selections for all Systems



Primary Weapon - Flipper 1

Secondary Weapon – Existing Drum

Drive Train - Chains



Self Righting Mechanism – Flipper 1

8.0 DRIVE TRAIN

8.1 Theory

Chain drives transmit power from one shaft to another through a chain made of links, connected by rollers which are in mesh with teeth on sprockets attached to each shaft. Chain size is denoted by the chain pitch, or the distance between each link as seen in Figure 8.1[1].

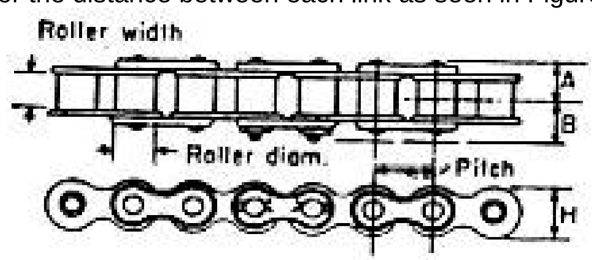


Figure 8.1 – Chain Pitch

The limiting factor on the design of the chain drives is the number of teeth on the small sprocket. This is based on the horsepower being transmitted and the RPM of the small sprocket. The more teeth there are on the small sprocket, the higher the power that can be transmitted. Manufactures of chain drive components have tabulated this data as seen in Table 8.1[1].

Table 8.1 – Table for Sprocket Sizing Based on Horsepower and RPM

ANSI Pitch No.	No. Teeth on Small Sprocket	Small Sprocket RPM									
		50	500	1200	1800	2500	3000	4000	5000	6000	8000
25	11	0.03	0.23	0.50	0.73	0.98	1.15	1.38	0.99	0.75	0.49
	15	0.04	0.32	0.70	1.01	1.36	1.61	2.08	1.57	1.20	0.78
	20	0.06	0.44	0.96	1.38	1.86	2.19	2.84	2.42	1.84	1.20
	25	0.07	0.56	1.22	1.76	2.37	2.79	3.61	3.38	2.57	1.67
	30	0.08	0.68	1.49	2.15	2.88	3.40	4.40	4.45	3.38	2.20
	40	0.12	0.92	2.03	2.93	3.93	4.64	6.00	6.85	5.21	3.38
35	11	0.10	0.77	1.70	2.45	3.30	2.94	1.91	1.37	1.04	0.67
	15	0.14	1.08	2.38	3.43	4.61	4.68	3.04	2.17	1.65	1.07
	20	0.19	1.48	3.25	4.68	6.29	7.20	4.68	3.35	2.55	1.65
	25	0.24	1.88	4.13	5.95	8.00	9.43	6.54	4.68	3.56	2.31
	30	0.29	2.29	5.03	7.25	9.74	11.50	8.59	6.15	4.68	3.04
	40	0.39	3.12	6.87	9.89	13.30	15.70	13.20	9.47	7.20	4.68
		Type I		Type II					Type III		

The RPM and horsepower are known, thus the number of teeth on the small sprocket can be read directly from the chart. It can be seen that heavier chains can not run at as high RPMs as smaller chains. Also, as the RPM increases, the power transmitted increases as would be expected. However, as the RPM gets higher, there is a point where the rollers impact the sprocket teeth so hard that the bushings are galled, resulting in a dramatic reduction in power transmitted. Thus, operating at the below this maximum power transmission will lead to the most efficient chain drive with the longest life.

The distance between the shafts is also important. As the distance decreases, the wrap of the chain around the larger sprocket increases while the wrap of the smaller sprocket decreases. Since it is better to have more teeth in mesh with the chain at one time, the center distance should be as great as possible. The recommended distance is 30-50 pitches[5].

8.2 Design Calculations

An overall gear reduction of between 5:1 and 6:1 was used last year and was satisfactory, so the chain drive was designed with this reduction. It quickly became apparent that a compound reduction would be necessary. With a minimum of 10 teeth recommended on the small sprocket, the large sprocket would have to have at least 50 teeth to accomplish the reduction directly. This meant that for #35 ANSI chain, the large sprocket would have to be approximately 7 inches in diameter. Since the wheels are only five inches in diameter, this would mean that the sprocket would stick out of the bottom of the robot and hit the ground. Thus, a compound reduction was necessary to keep the size of the large sprocket on the wheel shaft to a minimum.

The chain and sprockets for the drive train needed to be as light as possible while retaining high strength. In addition, the space constraints meant that the diameter of the sprockets could not be much larger than 3 inches. The power to be transmitted was approximately 1 horsepower.

8.3 Sprocket Size Calculations

After deciding on steel chain, the size was determined by examining the horsepower capacity as well as the size. As the size of the chain increased, the diameter of the sprockets did also. In addition, as the size increased, the maximum RPM decreased. The sizes near the operating range were #25, #35, and #40 ANSI chain. Using the information seen in Table 8.2[1], #35 ANSI chain was chosen because it gave plenty of strength, could operate at the high RPM at the motor, but was small enough that the sprockets would fit into the BattleBot.

Table 8.2 – Sprocket Sizing Table with Approximate Operating Ranges of Drive Train Highlighted

ANSI Pitch No.	No. Teeth on Small Sprocket	Small Sprocket RPM									
		50	500	1200	1800	2500	3000	4000	5000	6000	8000
25	11	0.03	0.23	0.50	0.73	0.98	1.15	1.38	0.99	0.75	0.49
	15	0.04	0.32	0.70	1.01	1.36	1.61	2.08	1.57	1.20	0.78
	20	0.06	0.44	0.96	1.38	1.86	2.19	2.84	2.42	1.84	1.20
	25	0.07	0.56	1.22	1.76	2.37	2.79	3.61	3.38	2.57	1.67
	30	0.08	0.68	1.49	2.15	2.88	3.40	4.40	4.45	3.38	2.20
	40	0.12	0.92	2.03	2.93	3.93	4.64	6.00	6.85	5.21	3.38
35	11	0.10	0.77	1.70	2.45	3.30	2.94	1.91	1.37	1.04	0.67
	15	0.14	1.08	2.38	3.43	4.61	4.68	3.04	2.17	1.65	1.07
	20	0.19	1.48	3.25	4.68	6.29	7.20	4.68	3.35	2.55	1.65
	25	0.24	1.88	4.13	5.95	8.00	9.43	6.54	4.68	3.56	2.31
	30	0.29	2.29	5.03	7.25	9.74	11.50	8.59	6.15	4.68	3.04
	40	0.39	3.12	6.87	9.89	13.30	15.70	13.20	9.47	7.20	4.68
		Type I		Type II					Type III		

Once the #35 chain was chosen, the next step was to size the sprockets. Since a compound train was to be used, the size of the sprockets, as well as the individual reductions of each train could be manipulated. The overall reduction was calculated using Equation 8.1 where N_1 – N_4 are the number of teeth on each sprocket and M_1 and M_2 are the reduction ratios.

$$M_{total} = (M_1)(M_2) = \frac{N_2}{N_1}\frac{N_4}{N_3} \qquad (8.1)$$

The gear locations are shown in Figure 8.2.

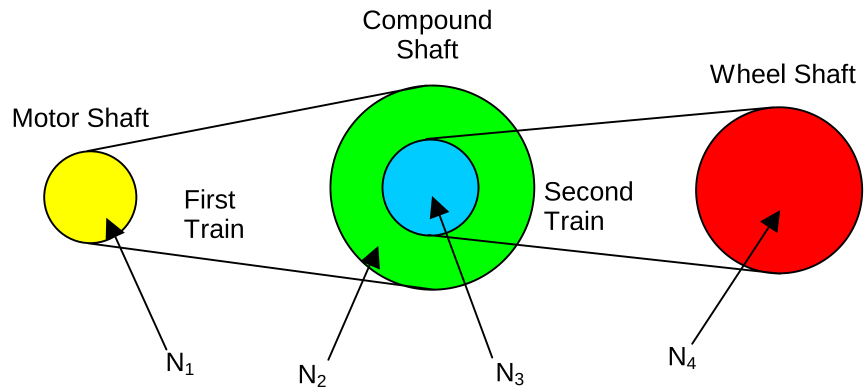


Figure 8.2 – Compound Gear Train

Using MathCad, many combinations of gear ratios and numbers of teeth were explored. From the geometry of the BattleBot, it was determined that the wheel sprocket could not be larger than 21 teeth. If it was any larger, it would hit the bottom of the body. This helped to reduce the number of variables in the problem. After many iterations, it was determined that the more even the reduction ratios were between the two trains, the better the overall design. This was due to the fact that as the first ratio was increased, the RPM of the second train's small sprocket was reduced, resulting in less power capacity as seen in Table 8.2. These calculations can be found in Appendix C.

After many iterations, the sprockets were finally sized and it was determined that they would fit into the BattleBot. The sizes are shown in Table 8.3.

Table 8.3 – Sprocket Sizes

Sprocket Number	Number of Teeth	OD (in)
1	10	1.38
2	25	3.19
3	10	1.38
4	21	2.71

The factors of safety for each train were also calculated. Since the weakest part of the drive train was the small sprocket, the factor of safety of each train was based on that part. Using Table 8.2, the factor of safety was calculated using Equation 8.2 where n was the factor of safety.

$$n = \frac{load_{capacity}}{load_{applied}} \qquad (8.2)$$

The load capacity was obtained from Table 8.2 and the load applied was equal to the horsepower of the motor, or 1 hp. The factor of safety for Train 1 was 2.5, and was 1.7 for Train 2. These calculations can be seen in Appendix C.

Sprockets 1 and 3 were made the same size to reduce the number of different parts required. The overall ratio, calculated using Equation 8.1, was found to be 5.25:1 which was within the tolerance.

Next, the length of chain needed to be calculated. This was done using Equation 8.3 where L is the length of chain in pitches, C is the center distance in pitches, N_1 is the number of teeth on the small sprocket, and N_2 is the number of teeth on the large sprocket.

$$L = 2C + \frac{N_2 + N_1}{2} + \frac{(N_2 - N_1)^2}{4\pi^2 C} \qquad (8.3)$$

The length of chain between the motor and compound shafts was found to be 23.25 inches, between the compound and front wheel shafts was 16.5 inches and between the front and rear wheel shafts was 27.375 inches. These detailed calculations can be found in Appendix C.

9.0 PRIMARY WEAPON SYSTEM / SELF RIGHTING MECHANISM

One major feature of the existing BattleBot that has been redesigned is the primary weapon system. The original primary weapon system was designed to be a flipping mechanism. However, the entire BattleBot would have to be wedged underneath the opponent for the weapon to be effective.

Concept generation and selection resulted in a new primary weapon system design. The new primary weapon system is arranged in such a way that it will serve as a self-righting mechanism, SRM. The primary weapon system / self-righting mechanism will now be referred to as the SRM. The new SRM design consists of a long beam-arm powered by a pneumatic piston. One end of the beam-arm is attached to the top-front of the BattleBot and rotates about the attachment.

9.1 Primary Weapon Functionality

For the new SRM to flip an opponent, the opponent must be positioned on top of the front edge of the SRM arm. The front edge of the SRM arm is spatula shaped to increase the chance of proper positioning. Figure 9.1 shows the redesigned BattleBot SRM linkage arrangement.

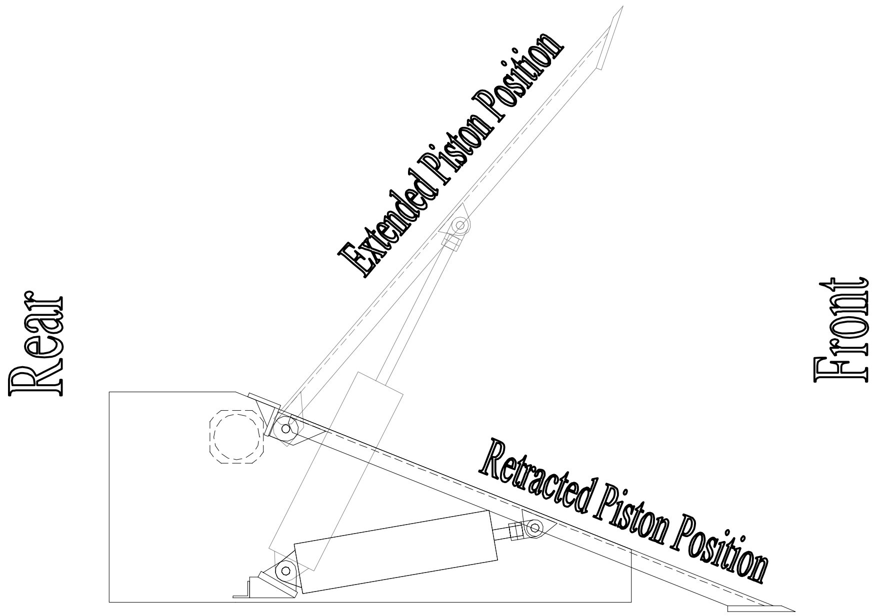


Figure 9.1: Redesigned BattleBot SRM

As shown in Figure 9.1, the retracted piston position gives the SRM-arm a low clearance. The intention of this design is to be able to scoop under an opponent. Once positioned properly, the piston will fire and the opponent will be toppled over by the SRM-arm. The SRM exerts about 323 pounds of force at the spatula end of the arm when the piston begins to extend from retracted position. An opponent's weight cannot exceed 220 lb since the BattleBot will compete in the heavyweight class. Therefore, the SRM will have ample force to extend. The total time for the SRM to fully extend is 0.267 sec, determined by the piston stroke length and extension rate.

If by chance the BattleBot becomes overturned, the SRM will take advantage of its 71.2 degrees of rotational freedom and set the Bot right side up. Instead of using complex dynamics calculations to verify the ability of the mechanism to function properly, a simulation program called Working Model was used. The weight, geometry, and similar forces were input to generate an accurate simulation. Figure 9.2 is a sequence of frames from the simulation program.

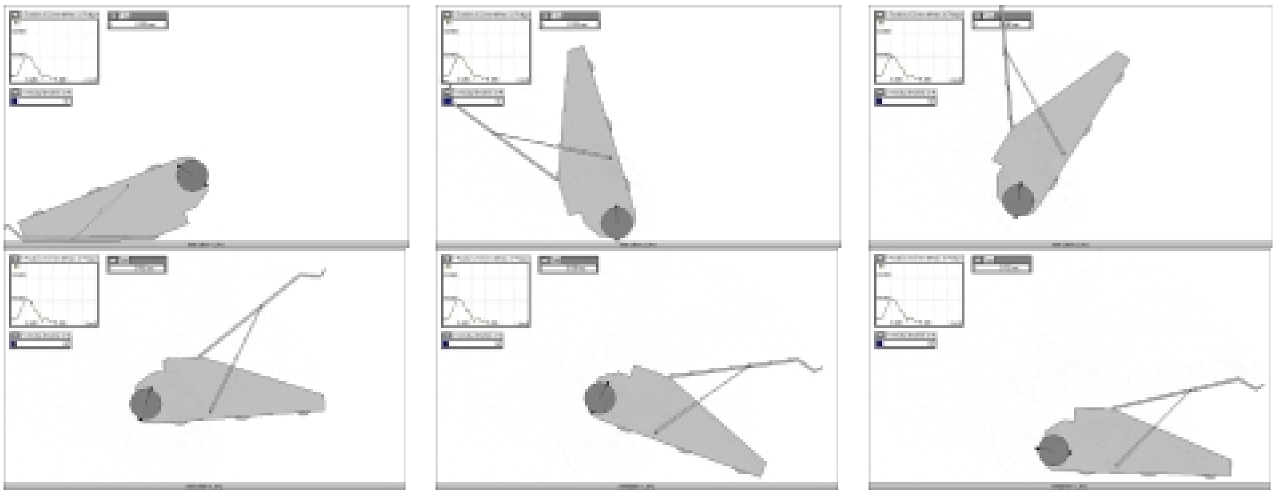


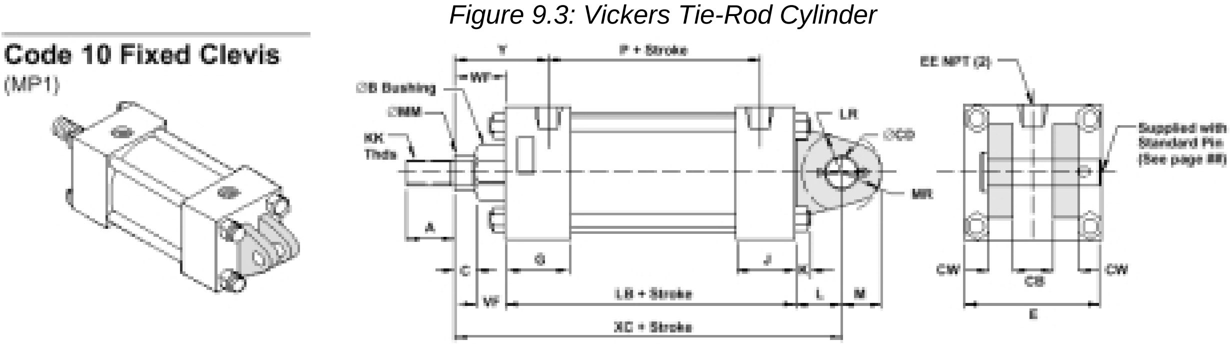
Figure 9.2: Working Model Simulation

9.2 Linkage Components

The two major components of the SRM are the arm and the piston. Most of the force and stress calculations are centered on these two parts. The other parts of the SRM require fabrication. These parts are brackets, the SRM saddle and flipper and the pins.

The piston is a VP series custom-made, non-lubricated tie-rod cylinder manufactured by Vickers. It has an 8” stroke length and measures 15” long retracted. With an operating pressure of 250 psi and a 2 ½” bore, the piston exerts 1227 lbf. The mounting style is shown in Figure 9.4 as cap fixed clevis.

Figure 9.3: Vickers Tie-Rod Cylinder



An NFPA Rod Eye is the type of attachment specified for the rod end and an NFPA Eye Bracket attaches to the clevis on the cap. The Rod Eye and Eye Bracket is shown in Figure 9.4:

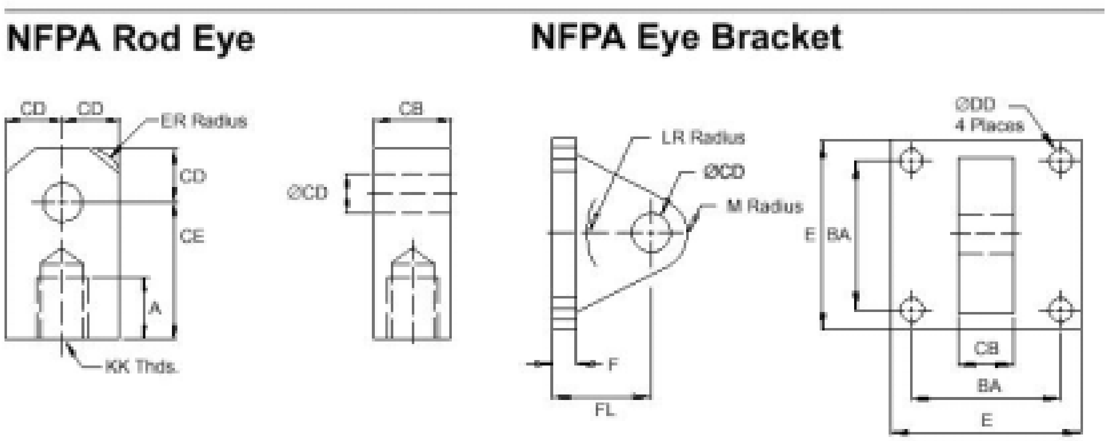


Figure 9.4: Vickers Tie-Rod Cylinder Attachments

The parts of the SRM that require fabrication are shown below in Figure 9.5:

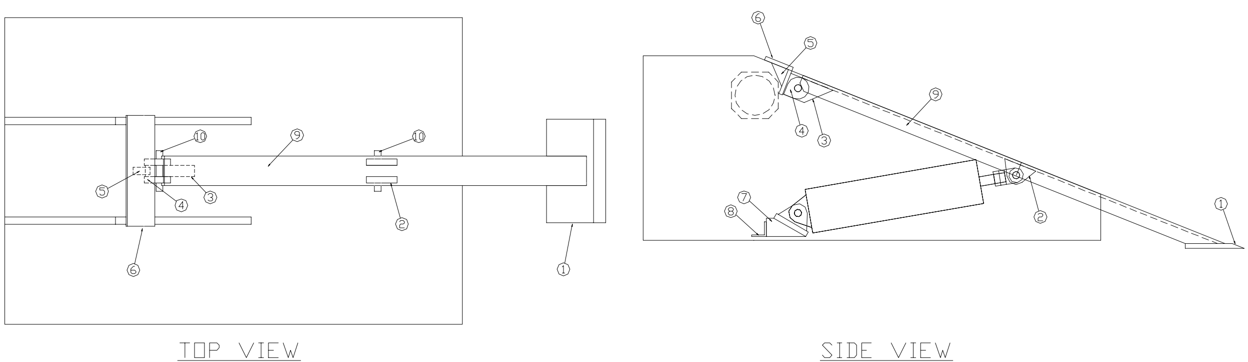


Figure 9.5: SRM Linkage Fabrication Parts

Parts 1, 2 and 3 are welded directly to the arm, part 9. Parts 4 and 5 are welded to part 6, but part 4 is also attached to 6 with screws. Parts 1 through 6 are all fabricated steel. Part 6 is the SRM saddle mount, cut from a steel angle. The saddle will be attached to struts located internally. The existing aluminum struts have been redesigned and new composite struts will be used instead. The method of attaching the saddle to the struts has yet to be designed.

Part 7 is a solid aluminum cylinder bracket mount and will be welded to the base of the BattleBot. A piece of angle is bolted to the bottom of the Bot behind the bracket mount for bracing. All pins used in the linkage are ½" diameter aluminum.

9.3 Pneumatics System

To power the pneumatic cylinder for the Primary Weapon System, an adequate pneumatics setup must be chosen. To power a pneumatic cylinder on a mobile and ungrounded system, a remote fluid reservoir is required. The fluid reservoir takes its shape as a containment tank connected to the pneumatic cylinder. From the reservoir to the cylinder, the fluid must be conditioned and controlled to provide proper cylinder operation.

BattleBot technical Regulation 8.2.1 restricts the allowable gas types used on a BattleBot to either Nitrogen (N_2), Carbon Dioxide (CO_2), or a mixture of both. The maximum allowable storage pressures for the gas types are: 2500 psi for nitrogen and 1000 psi for carbon dioxide (Tech. Reg. 8.2.2). Nitrogen was chosen as the working fluid in the pneumatics system.

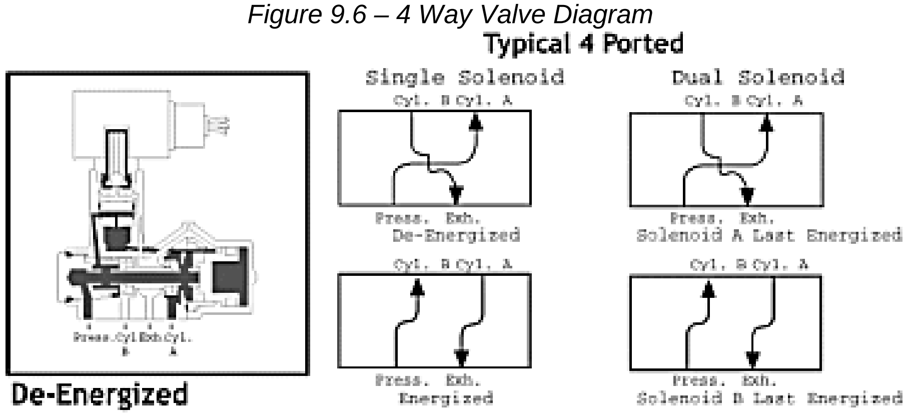
By using nitrogen some of the 2001-2002 BattleBot Team pneumatics system components could be reused. The working fluid for the previous setup was air, and being that N2 is an inert gas with no corrosive properties, the same reservoir tank could be used. Under the given storage conditions more N2 can be stored on the BattleBot than CO2, and with a limitation of 250 psi actuation pressure (BattleBot Technical Regulation 8.2.6 a higher amount of cylinder firings can be made per match.

9.4 Pneumatics Setup

To maximize the amount of nitrogen storable in a minimal volume, the highest allowable storage pressure of 2500 psi was chosen with use of the existing Luxfer Cylinders reservoir tank. With a reservoir pressure of 2500 psi and a cylinder operating pressure of 250 psi, a regulator must be used to step down the N2 pressure. Once the operating pressure is established, the flow must be controlled to the double acting pneumatic cylinder. The flow control can be performed by way of a valve.

There are two main types of valves that can be remotely operated to control flow in a pneumatic circuit, solenoid actuated valves and pilot actuated valves. A solenoid-actuated valve was chosen for the pneumatics setup for simplicity. A pilot actuated valve, in our case, would require the use of two extra solenoid valves to control it thereby further complicating the system, adding weight, and requiring further integration. A 4-way 2-position solenoid actuated valve is required to operate the double acting pneumatic cylinder that was chosen to allow exhaust gas to be vented from one end of the cylinder, while the other end is being energized, Figure 9.6.

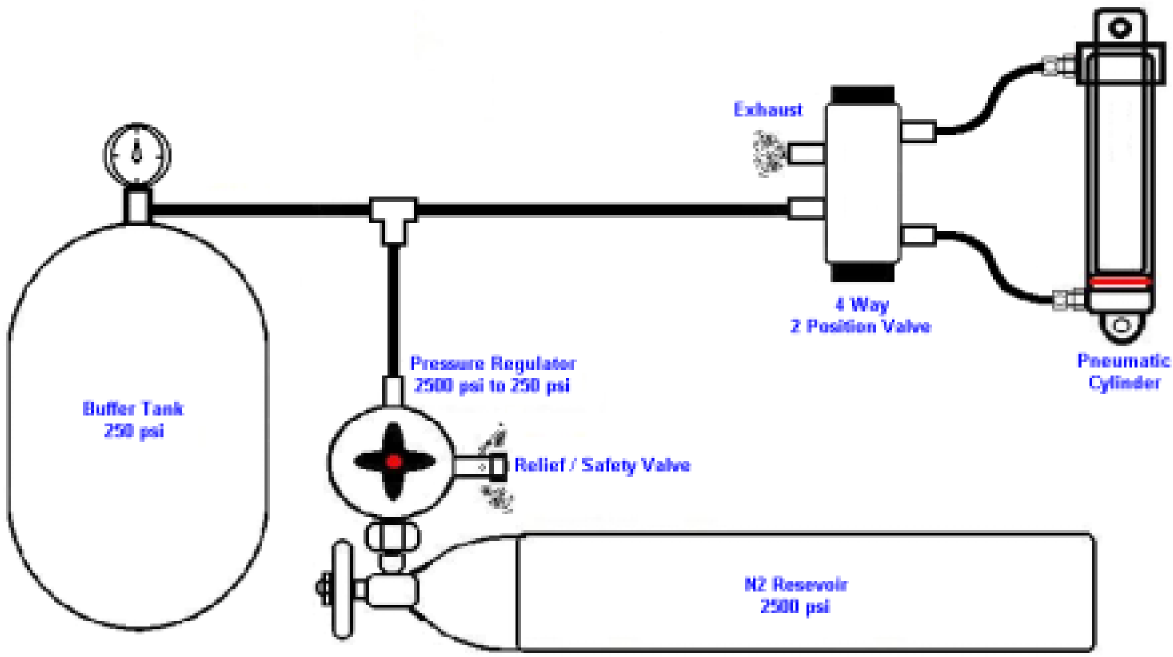
Figure 9.6 – 4 Way Valve Diagram



The 4-way 2-position solenoid actuated valve chosen was ASCO Piston/Poppet Single Solenoid Valve #8344G1. The valve was chosen for its sturdy solid construction and market availability.

A fault of the previous BattleBot design was the slow energizing of the pneumatic cylinder. A lack of pressure in the system and lag time from the regulator were believed to be at fault. To remedy this situation, a buffer tank was introduced into the pneumatic circuit to ensure that the circuit is always pressurized to the operating pressure of 250 psi and an ample volume of N2 available. A tank, smaller than the reservoir, was placed inline with the reservoir and valve to ensure the 250-psi operating pressure was maintained. The tank chosen, for compatibility with the reservoir tank on hand produced by Luxfer Cylinders, was Luxfer Cylinders N004. A layout diagram of the entire pneumatic circuit can be seen in Figure 9.7.

Figure 9.7 – Pneumatics Setup



10.0 SECONDARY WEAPON SYSTEM

The existing Secondary Weapon System consists of a 25-inch rotating steel drum armed with two horizontal edges mounted on the rear of the robot. The rotating drum is designed to inflict damage on opponents much like a saw. The drum is mounted on two large Aluminum (6061) brackets and is driven 1/3-hp 24-V Dayton Motor (4200rpm) on slipping V-Belt.

The design of the existing Secondary Weapon System was determined to be very effective on the previous BattleBot and primarily remains the same. The only aspects of the Secondary Weapon System that have been reworked are the mounts for the drum motor and the drum itself. The mounts for the motor were reworked to slightly reposition the motor within the robot assembly. The mounts for the rotating drum were redesigned to optimize the strength to weight ratio and is discussed in detail in Section 11.1 below.

11.0 STRUCTURAL ANALYSIS

11.1 Drum Bearing Bracket

One of the main problems of last year was that the bot was overweight. So weight reduction became a very important aspect of the design. The drum bearing blocks and the interior bulkheads were one of the main focus points for the weight reduction. With the aid of Pro-Engineering CAD software and ALGOR FEM package these parts were modeled and analyzed. Then different designs and materials were implemented and the results were compared. With the drum bearing blocks material was cut from the bulky brackets to make them lighter without loosing their rigidity. The final selection is shown in Figure 11.1 and Figure 12.14. Even though this one had the biggest displacement it was still extremely small and having the extra weight off was worth it.

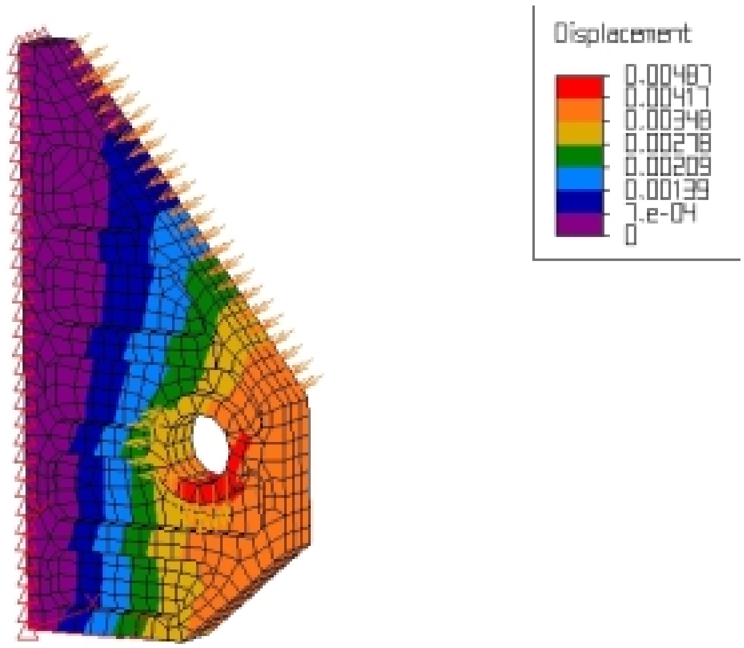


Figure 11.1: Final Drum Bearing Block Design

11.2 Bulkhead

For the bulkhead the decision was to leave the design the way it was because all the mounting points for different components were needed plus the flipping arm will attach to them. No strength could be sacrificed, so instead their material was looked into. Instead of Aluminum Alloy that has a tensile strength of 33ksi a high modulus carbon fiber with a tensile strength of 110 ksi was chosen. Because of the strength difference a smaller thickness was used from .5" to .375". Here is where a big chunk of weight was reduced. With the aluminum the two bulkheads weighed a combined 16.757 pounds, with the carbon fiber the weight dramatically reduces to 6.875 pounds. This was due to the differences in density (aluminum alloy 6061 .0975 lb/in^3, high modulus carbon fiber 0.061 lb/in^3). Bulkheads can be seen in Figure 12.10.

12.0 3D DESIGN AND DRAFTING

Many details of the BattleBot design had to go beyond pure calculations. Many issues, such as availability of parts, packaging, and weight all had large impacts on this design. 3-D modeling in Pro/E was invaluable in solving these problems. The entire BattleBot was created in the computer, down to the last detail, as seen in Figure 12.1.

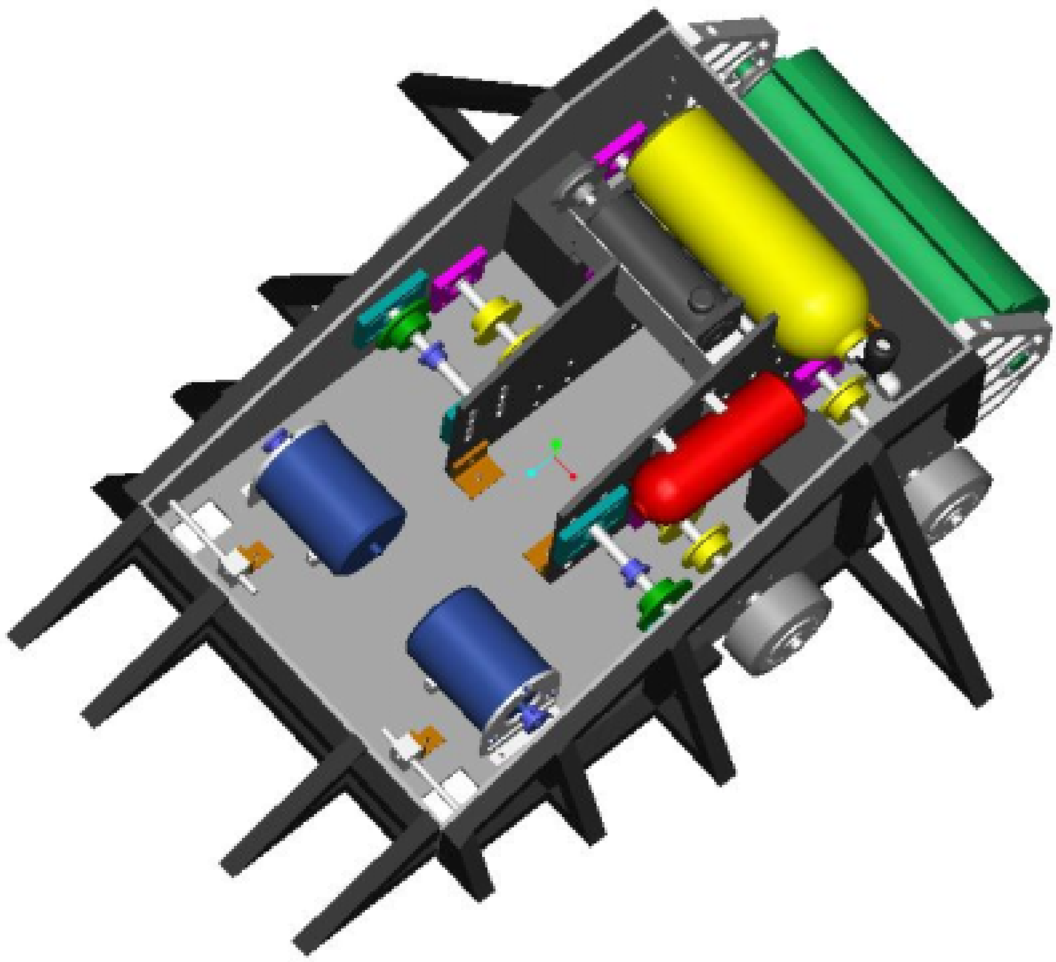


Figure 12.1 – Assembly of BattleBot

All of the practical considerations were examined, such as securing sprockets to shafts, mounting motors and holding tanks.

12.1 Drive Train Design

Many of the aspects of the original design were left as is, some were totally removed and some were modified. The main chassis of the robot was left mainly untouched. The armor struts, seen on the front and sides in black were left mostly alone. The front armor strut required slight modification to allow the lifting arm to extend to the front of the robot (not pictured here). The body shell, made of ¼ inch aluminum was also left alone aside from the few holes necessary for mounting new components.

The drive train was totally redesigned, except for the motors and wheels. The old belt system was totally removed and replaced with a chain drive. The locations of the wheels remained the same as well as the rough placement of the motors and shafts as seen in Figure 12.2.

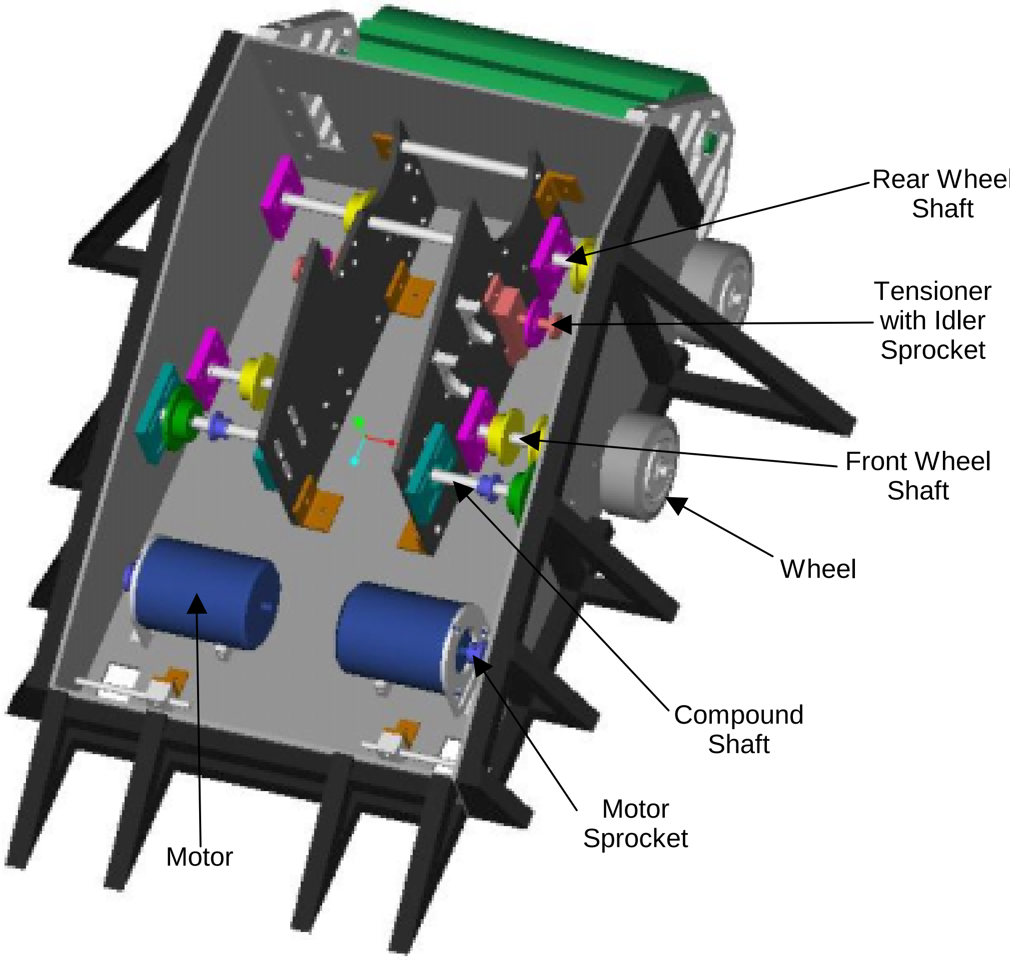


Figure 12.2 – Drive Train Components

The motor has a 10 tooth sprocket which is attached via the chain to a 25 tooth sprocket on the compound shaft (green sprocket). The 10 tooth sprocket on the compound shaft (blue) rotates with the green sprocket and is connected to a 21 tooth sprocket on the front wheel shaft (yellow). The front and rear wheel shafts are finally connected together by a 21 tooth sprocket on each shaft (yellow).

Tensioning the chain was a very important problem to solve. If the chain was too loose, it could fall off or cause severe rhythmic vibrations. Many different tensioning mechanisms were explored. One of the first ideas was to make one of the shafts moveable like on a bicycle rear tire. The shaft could be slid back until the chain was tight and then bolted down. The first problem encountered with this design was that the two wheel shafts could not be moved easily. However, this idea did seem to work well for the compound shaft or motor. The motor could either slide or rotate to tension the chain between it and the compound shaft. This did however present problems with mounting the motor securely and was discarded. The next idea was to move the compound shaft by cutting slots into its bearing blocks as seen in Figure 12.3.

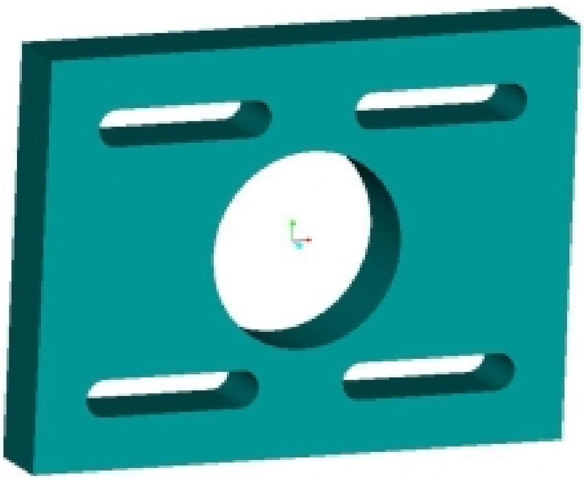


Figure 12.3 – Bearing Block to Allow Compound Shaft to Tension Chain

This would allow the whole compound shaft to slide up to tension the chain. This idea worked well for the chain between the motor and the compound shaft but made the chain between the compound shaft and front wheel shaft looser.

The next idea for the chain between the compound shaft and front wheel shaft was to let the adjustable bearing block slide in grooves vertically as well as horizontally as seen in Figure 12.4.

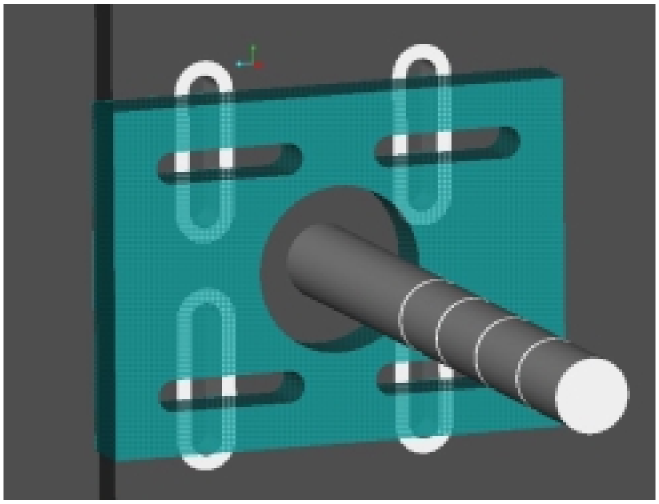


Figure 12.4 – Two-Way Adjustable Bearing Block

Thus, tension could be applied to both chains at the same time without adding extra weight or parts. Simply by giving the compound shaft two degrees of freedom, both chains could be tightened at once. Details of the bearing blocks can be found in Drawing 5 Sheet, 1.

This solution could not be applied to the chain between the two wheel shafts. The next idea for those shafts was to use a tensioner and idler sprocket as seen in Figure 12.5 to take up the slack in the chain.

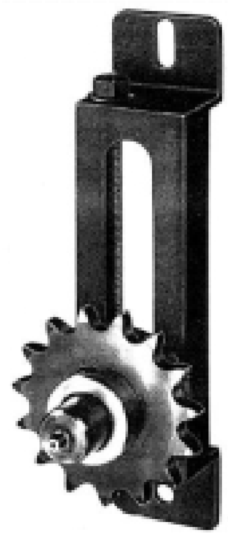


Figure 12.5 – Tensioner with Idler Sprocket

This particular tensioner applied force to the chain by screwing the bolt on the top which moved the idler up or down. Other types of tensioners work using springs or simply by having grooved mounting holes, but this seemed to be the most rugged and easiest to adjust. This tensioner worked well for the chain between the two wheel shafts but added weight to the design.

All of the drive train components can be seen in Figure 12.6.

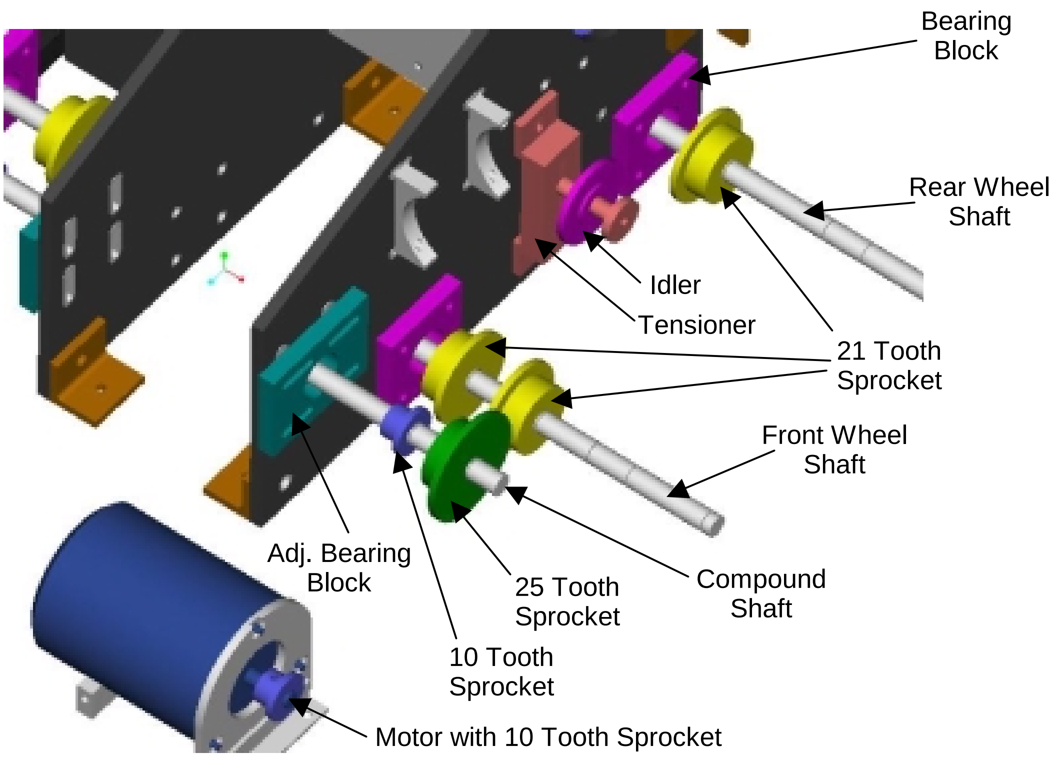


Figure 12.6 – All Final Drive Train Components

12.2 Shaft Design

Attaching the sprockets to the shafts and securing the sprockets into the bearings was a problem for the BattleBot last year. The sprockets were attached to the shafts using set screws and flats on the shafts. This was acceptable for normal driving, but the high impacts and constant direction changes made the set screws become loose. This resulted in one of the sprockets becoming misaligned and breaking the belt. For this years design, a much more rugged design was needed.

The diameter of the wheel shafts was 5/8 inch and was not a problem last year. This year, all three shafts were made the same diameter to cut down on different sizes of materials and parts. The shafts rode in bearings seated in bearing blocks. The inner bearing block was bolted to the bulkhead and the outer was bolted to the body. As seen in Figure 6. The wheel shafts were captured in place on the inside by the bulkhead wall, which was not cut out behind the bearing block. On the body side, an E-ring was used to secure the shaft. Dimensions for the E-rings can be found in Appendix B.

The compound shaft was captured on one side by the bulkhead and on the other by the body. Since neither the bulkhead nor the body was cut out behind the adjustable bearing blocks, the shaft could not slide.

Multiple methods were used to secure the sprockets to the shafts. For the motor sprocket, two set screws offset at 90º secured the sprocket to the shaft as seen in Figure 12.7.

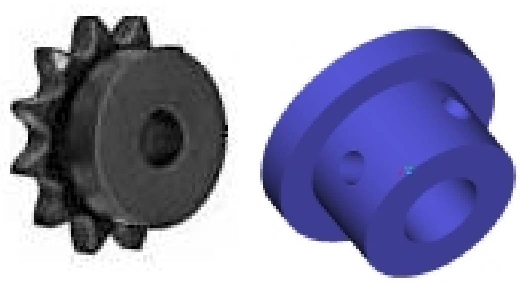


Figure 12.7 – Plain Bore Sprocket as Purchased and Finished Motor Sprocket with Bored Out Center and Two 90º Set Screws

Since the shaft diameter of the motor was metric (12mm), a plain bore sprocket was selected to be bored to the correct diameter. The set screw holes would then be tapped as seen in Drawing 5, Sheet 1. For all other sprockets, a keyway, E-rings and set screws were used. The sprockets chosen can be seen in Figure 12.8.

Figure 12.8 – Finished Bore Sprockets

Standard square keys were used for each sprocket. These standard sizes are based on shaft diameter and can be found in Table 12.1.

Table 12.1 – Standard Key Sizes

Finished-Bore Pulley Keyway Sizes

Bore Size	Keyway Wd. × Dp.
1/4" - 1/2"	1/8" × 1/16"
5/8" - 7/8"	3/16" × 3/32"
15/16" - 1 1/4"	1/4" × 1/8"
1 5/16" - 1 3/8"	5/16" × 5/32"
1 7/16"	3/8" × 3/16"

Since the key is square, half of the key protrudes into the shaft and the other half into the sprocket. Thus, the depth of the cut is half the width of the key. The keyway dimensions can be found in Drawing 5, Sheets 1 and 2.

The sprockets also come with two 90º offset set screws. These will be tightened for two reasons. First, it will help secure the sprocket from sliding laterally on the shaft. Also, it will take up any tolerance between the key and the slot, and help reduce backlash.

To further secure the sprockets and shafts, and E-ring will be placed 0.025 inches from either side of the sprocket as seen in Figure 12.9. The dimensions for the E-ring Slots can be found in Drawing 5, Sheets 1 and 2. Also, the manufacturers design information can be found in Appendix G.

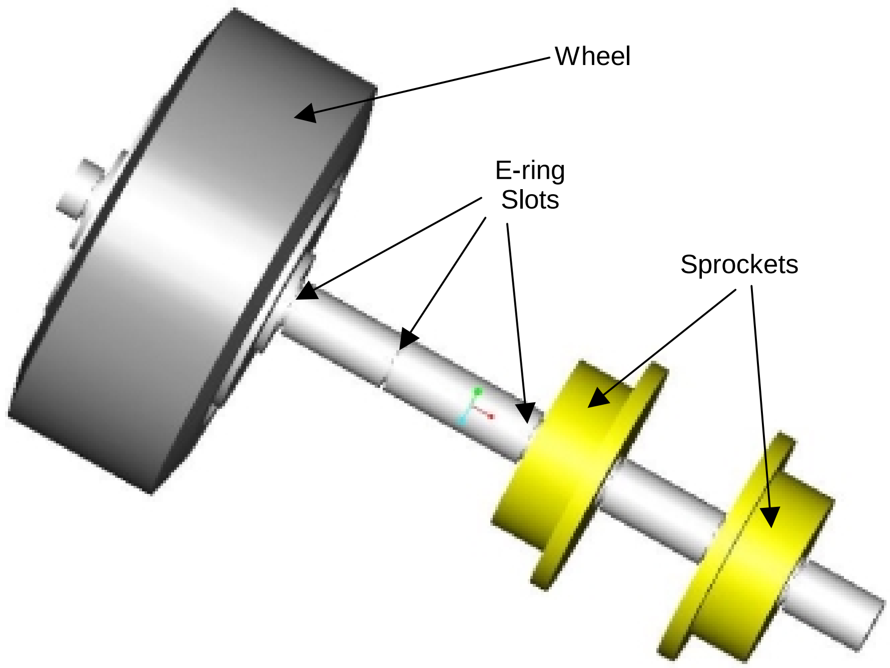


Figure 12.9 – Shaft Assembly Showing Sprocket and E-Ring Slots

Finally, wheels had to be secured to the shafts. Last year, a Woodruff key was used to keep the wheel from rotating. It was decided to eliminate the Woodruff key and use the same size keys throughout to keep the tooling and parts cost low. To keep the wheel from sliding laterally, the end of the shaft was threaded and the wheel secured with a nut. This idea was also scrapped because of the high machining costs and the fact that some of the threads were damaged during the match and made removing the nut very difficult. This year, the wheels were secured with an E-ring on each side as seen in Figure 12.9.

12.3 Bulkhead and Body Design

The Bulkheads, shown in Figure 1 were very important to the design of the BattleBot. Almost everything in the robot was attached to these two structures. Last year, they were made of 1/2 inch this aluminum plate. This year, to save weight, they will be made of carbon fiber sheet which is 3/8 inch thick. This alone caused some design problems. The carbon sheet could be crushed by the force of the bolts when they are tightened, so every screw hole in the bulkhead had to have an aluminum insert to keep the carbon fiber from collapsing. This can be seen in Figure 12.10.

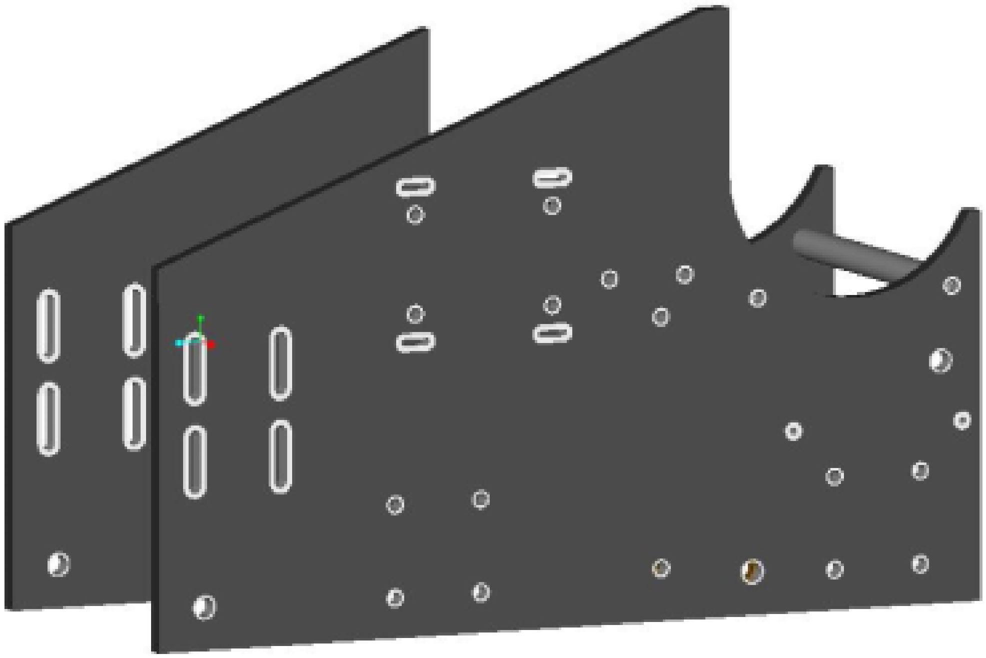


Figure 12.10 – Carbon Fiber Bulkheads with Inserts

3-D modeling was invaluable in designing the locations of all the screw holes on each bulkhead. All the parts that were attached were brought into the model and alignment of the screw holes was checked. Details of the bulkheads can be found in Drawing 4, Sheets 1-4. The bulkheads were secured to the body by 3/8 inch bolts that passed through tabs welded to the body as seen in Figure 12.11.

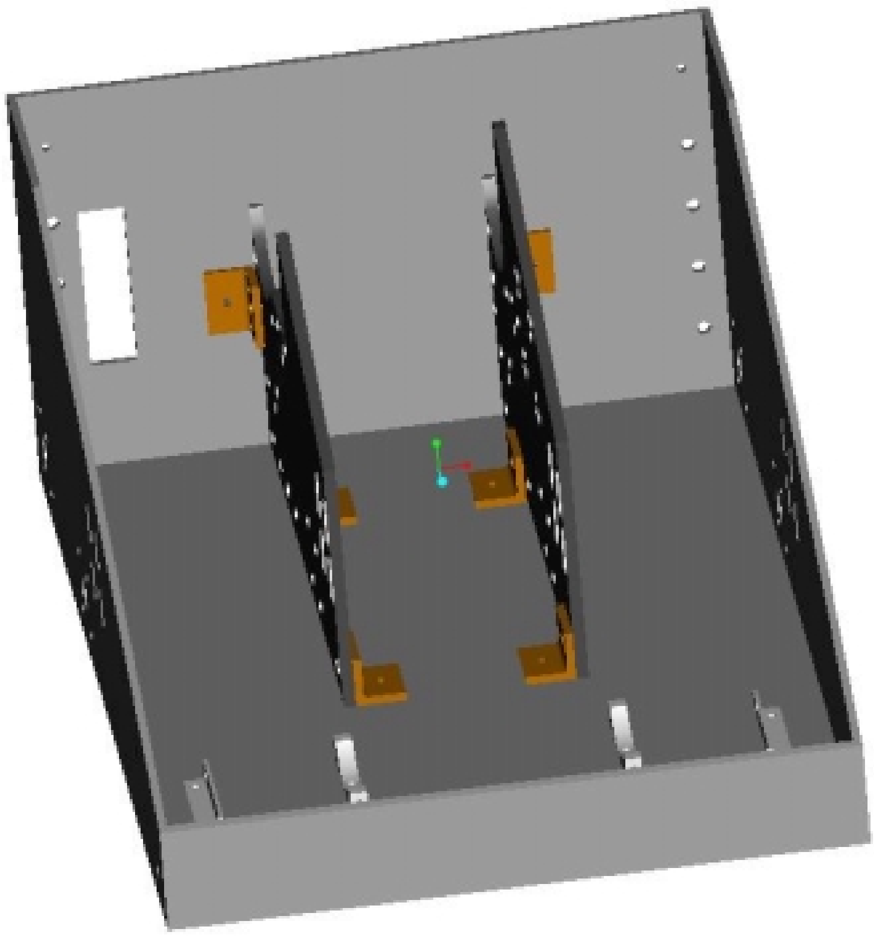


Figure 12.11 – Bulkheads Secured to Body by Tabs

Welding the tabs to the body was an improvement over last years design because it eliminated bolt heads on the bottom side of the BattleBot. Some of the bolt heads were severely damaged due to hazards and impacts and had to be drilled out. They could also catch the BattleBot on obstacles and stop it. The current design has eliminated all bolt heads from the bottom side. There are, however, still bolt holes to secure the tabs to the body. This was done so that the tabs could be bolted in place during welding, ensuring an accurate fit. After welding, they will be removed. Details of the body and tabs can be found in Drawing 3, Sheets 1-4.

12.4 Rotating Drum Design

The rotating drum system was left largely alone. The drum motor was left in its same place as last year with only minor modifications to fit it to the carbon fiber bulkheads as seen in Figure 12.12. The details of the drum motor mounts can be found in Drawing 6, Sheet 2.

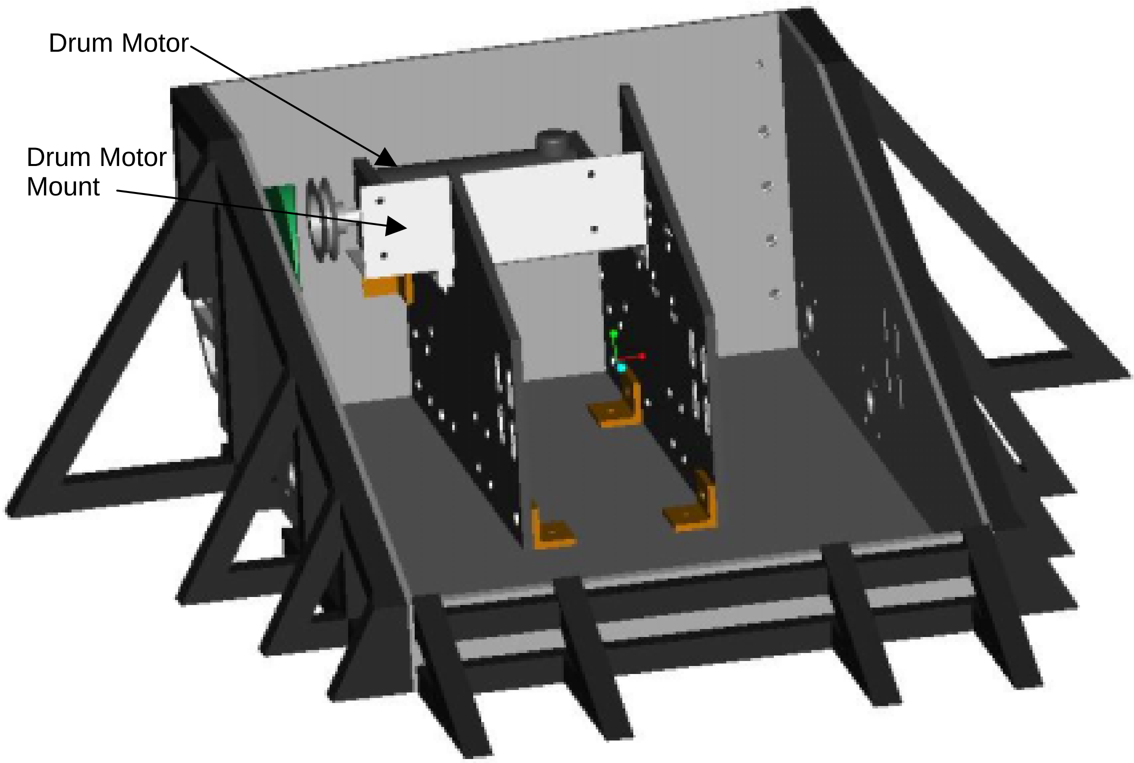


Figure 12.12 – Drum Motor Mounted in BattleBot

The drum itself was mounted to the body with two large drum mounts as seen in Figure 12.13.

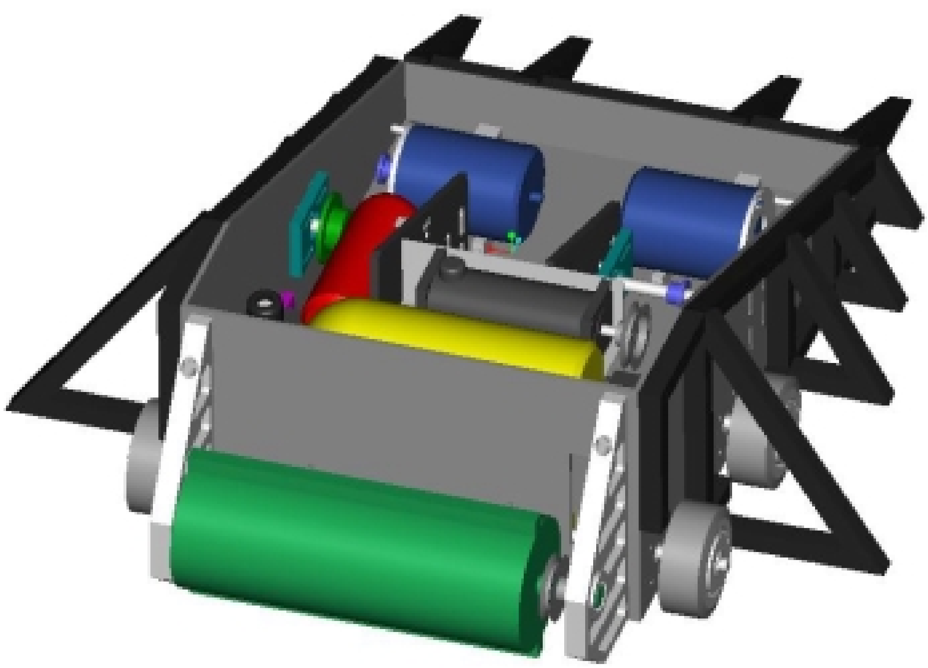


Figure 12.13 – Drum with Mounts

The only modification made to this setup was to try to reduce weight. The original drum mounts were made of 1 inch thick aluminum and weighed 4.7 pounds. After many different designs were examined with FEM analysis, the final design was created as seen in Figure 12.14.

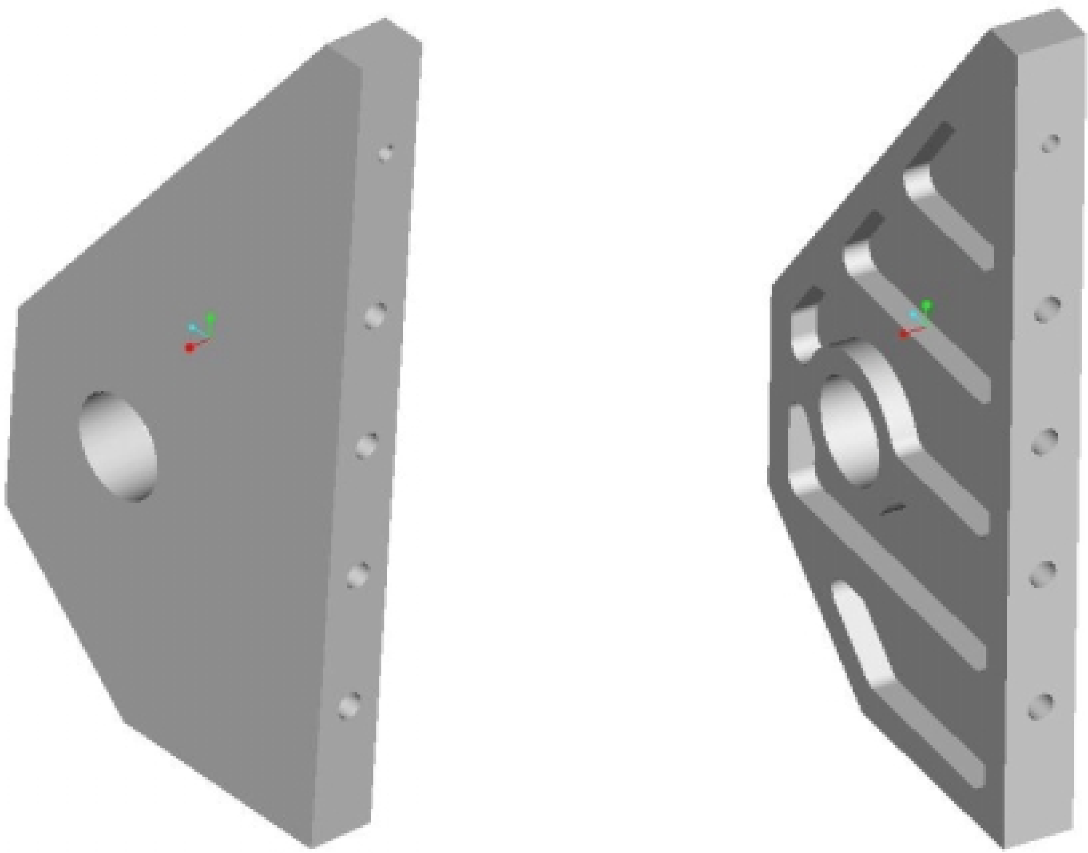


Figure 12.14 – Original Drum Mount and Modified Drum Mount

Material was cut out 3/8 inch deep on either side resulting in a weight reduction of 2.9 pounds. By creating the 3-D model, the ribs were able to be placed directly over the screw holes without worry of interfering with and threads. Also, the exact weight of each part was accurately approximated. The details of this mount can be found in Drawing 6, Sheet 1.

12.5 Internal Components

The BattleBot's systems have many internal components that had to be secured inside the body. Two of the most important were the nitrogen tank and buffer tank. The location of the nitrogen tank was kept the same as last year, but the method of securing it was changed. Last year it was enclosed in a box made of aluminum sheet. For this design, we decided to secure it with the bulkheads by pulling it down into a cradle as seen in Figure 12.15.

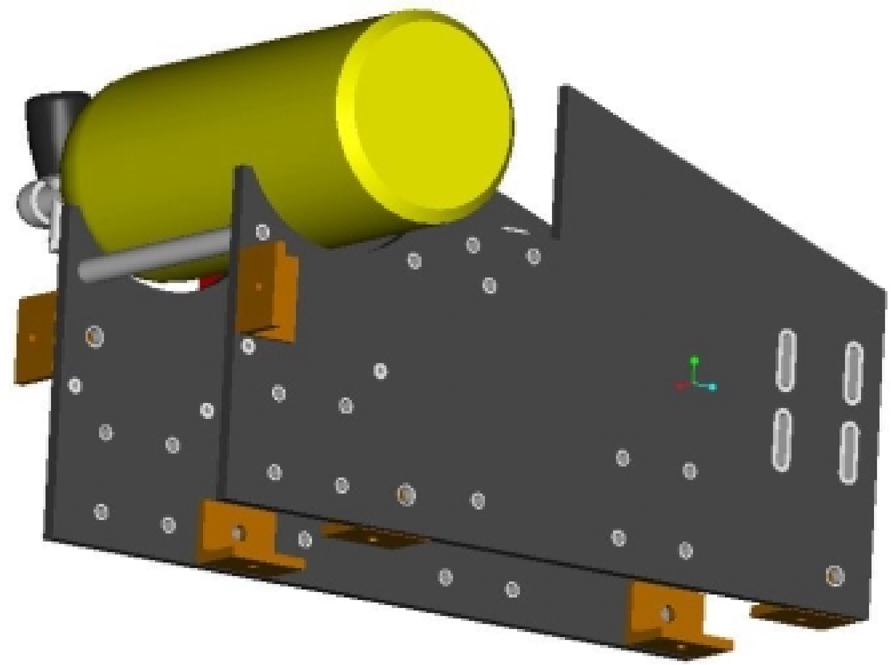


Figure 12.15 – Nitrogen Tank in Cradles

To keep the tank from damaging the bulkheads, the diameter of the cradles was made ¼ inch greater than the tank. This allowed for a rubber lining to fit between the tank and the bulkheads, thus preventing damage.

To pull down in the tank, many different ideas were explored including a split circle that could be bolted around the tank, to securing it with a simple sheet metal strap. It was finally decided that two large pipe clamps, as seen in Figure 12.16, would be wrapped around two bars under the tank, as seen in Figure 12.17, and then over the tank itself. The clamp could then be tightened to secure the tank.

Figure 12.16 – Large Diameter Hose Clamps for Securing Nitrogen Tank

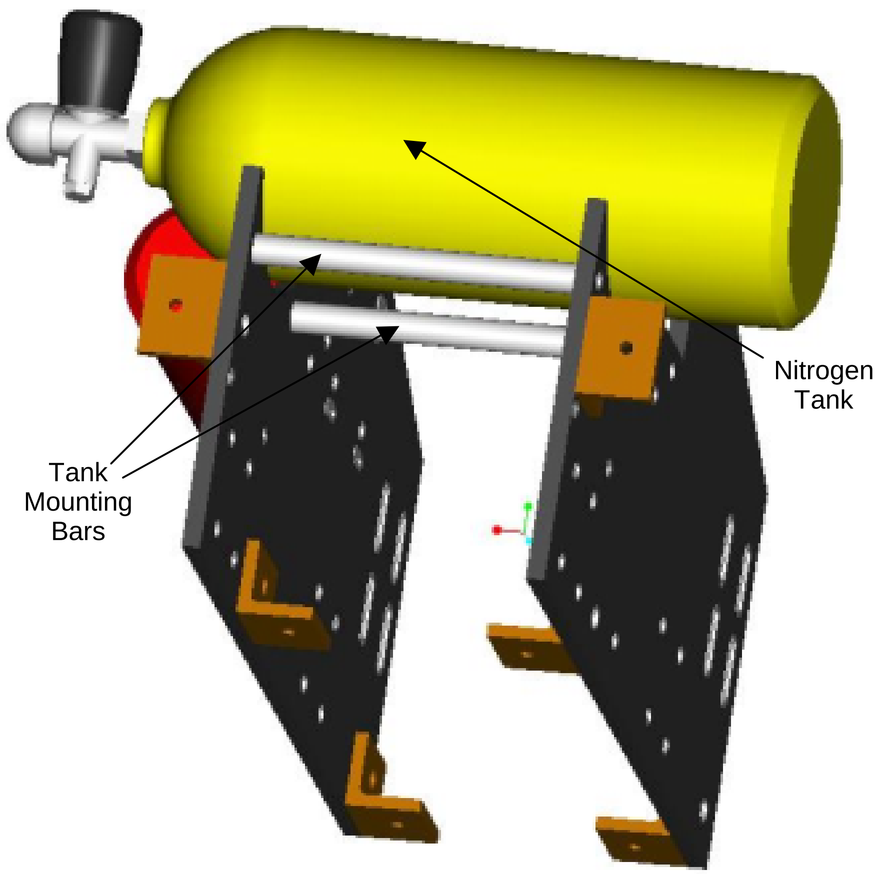


Figure 12.17 – Nitrogen Tank with Mounting Bars

This was an advantageous design because it was very light and also added stiffness and strength to the bulkheads. The details of these parts can be found in Drawing 6, Sheet 2.

The buffer tank was added to last years design, so no place existed for it in the robot. Using 3-D modeling, space for it was found on the right bulkhead above the chain drives as seen in Figure 12.18.

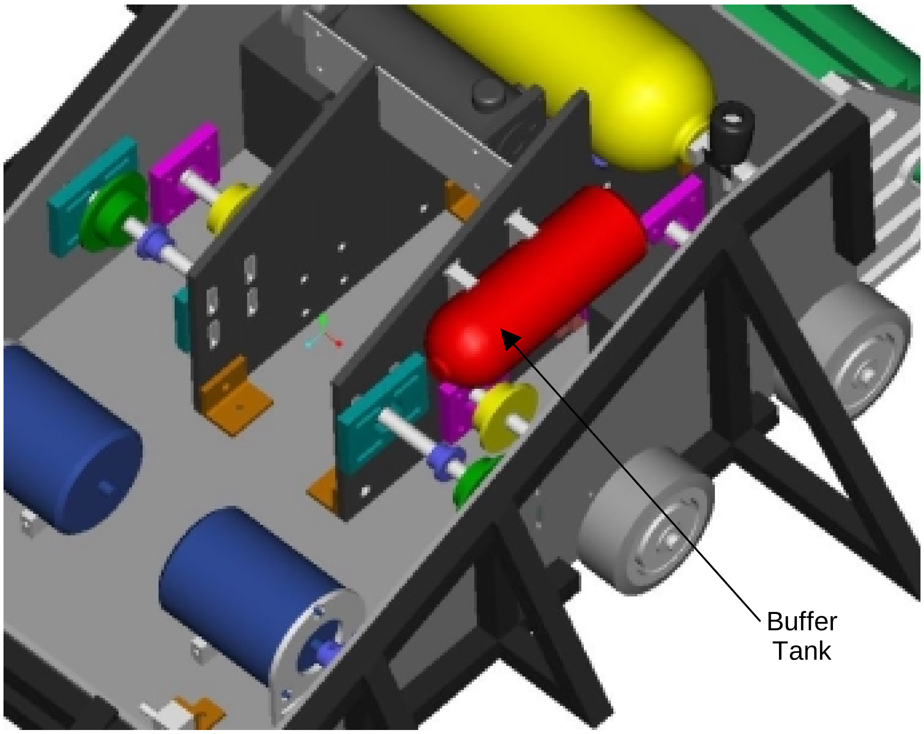


Figure 12.18 – Buffer Tank Location

This tank presented some problems for mounting because the round tank had to be mounted to the flat surface. Many of the same ideas were explored but a similar design to the nitrogen tank was designed. Two cradles were made from aluminum and screwed to the bulkhead. Then, slits were cut through the bulkhead to allow a hose clamp, similar to those on the nitrogen tank, to pass around the bulkhead and around the tank, thus securing it as seen in Figure 12.19.

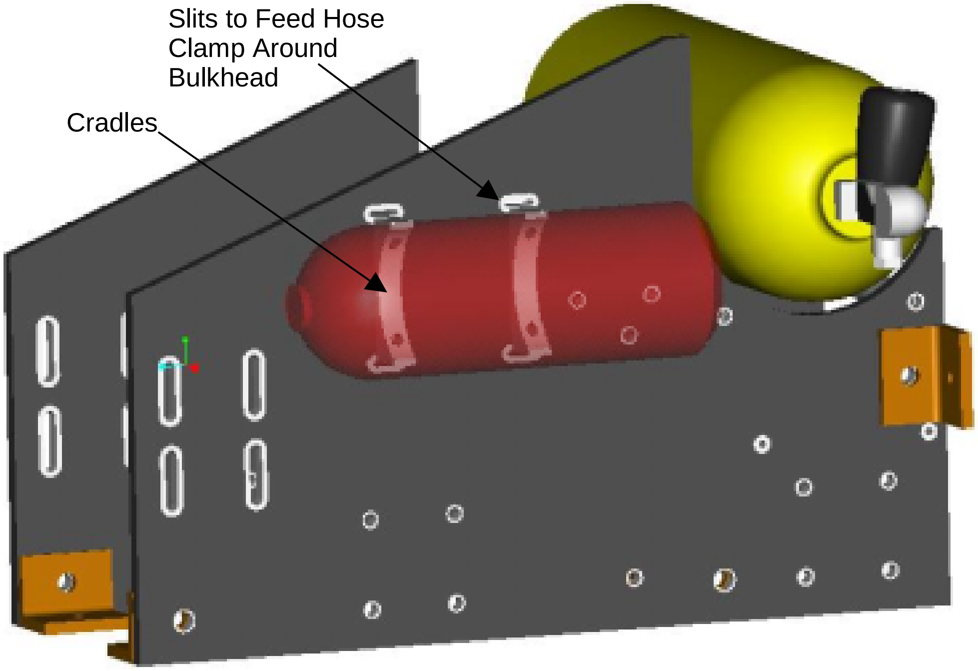


Figure 12.19 – Buffer Tank Mounting System

Another important component was the batteries. Two 12 volt batteries were required to power all the motors. Their location was not changed from last year and can be seen in Figure 12.20.

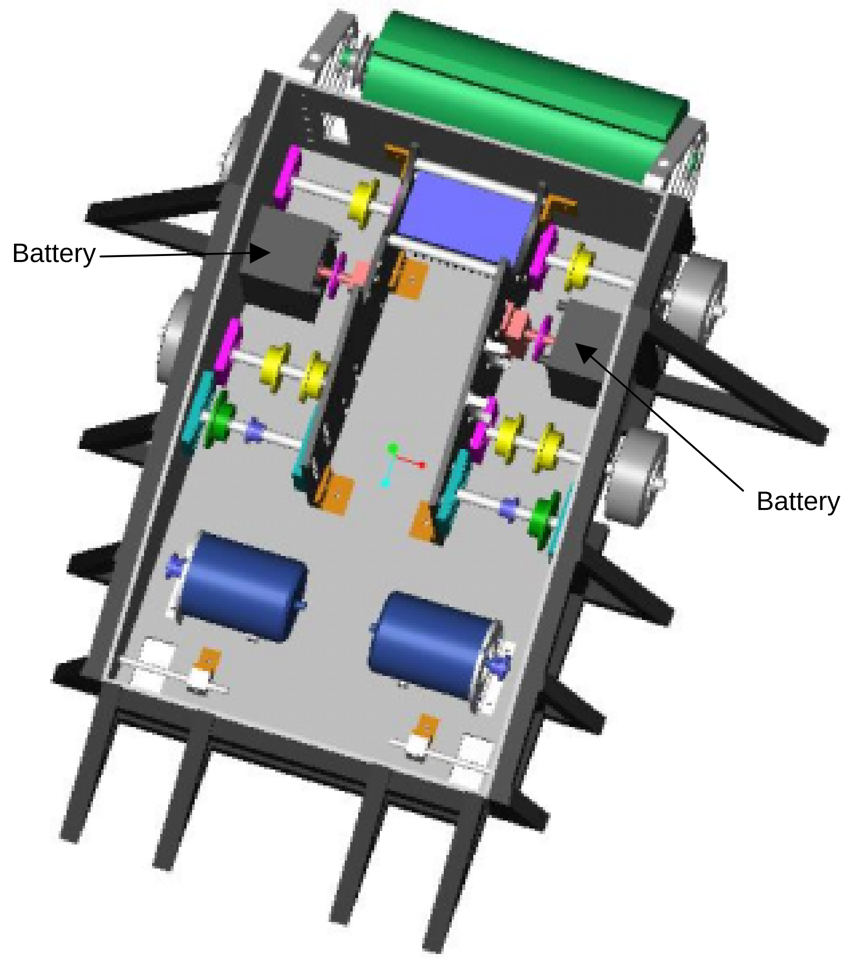


Figure 12.20 – Battery Mounting Location

The mounting system consisted of sheet metal straps and was deemed satisfactory to leave as is. The chain drives were designed to not interfere with the battery locations.

Finally, the brain of the drive system was the motor speed controller. This box full of electronics took inputs from the transmitter and output voltage to the motors. This controlled both the speed and the steering of the BattleBot. The location of this was not changed but the mounting design was changed slightly. The original design had the bulkheads spaced so the speed controller fit exactly between them. Bolts were screwed through the bulkheads into tapped holes in the speed controller. By using thinner bulkheads, a 1/8 inch gap was created on either side of the speed controller. This space was used to place a rubber washer between the bulkhead and speed controller to attenuate the vibration from shocks. Another washer was also placed under the screw head on the other side of the bulkhead to further reduce energy transfer. This helped to protect the electronics from damage when the BattleBot suffered impacts. The speed controller location can be seen in Figure 12.21.

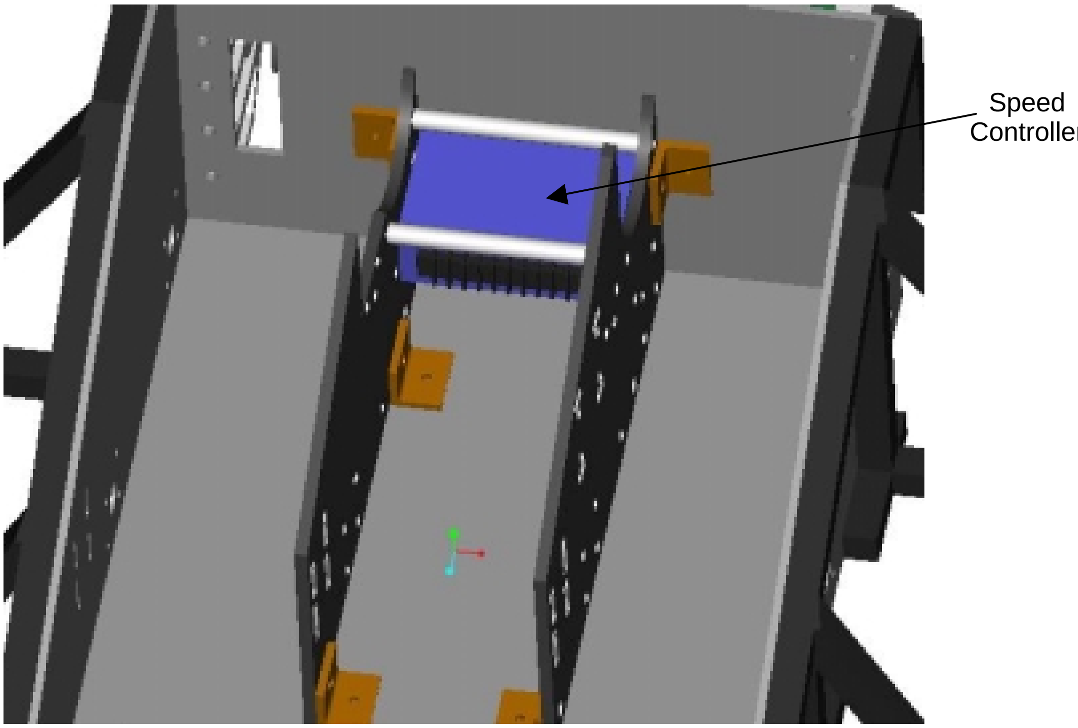


Figure 12.21 – Speed Controller Location

13.0 BUDGET ANALYSIS

13.1 BILL OF MATERIALS

Description	Vendor	Part #	Quantity	Price	Extended
10 tooth sprocket, #35 ANSI, 5/8 bore	McMaster	6280K112	2	6.56	13.12
21 tooth sprocket, #35 ANSI, 5/8 bore	McMaster	6280K124	6	12.06	72.36
25 tooth sprocket, #35 ANSI, 5/8 bore	McMaster	6236K22	2	13.40	26.8
10 tooth sprocket, #35, 3/8 unfinished bore	McMaster	6793K117	2	5.38	10.76
19 tooth idler sprocket, #35, 1/2 bore	McMaster	6663K22	2	14.68	29.36
Manually Adjustable Tensioner, 1/2 bore	McMaster	6265K5	2	43.60	87.2
Keys (pkg of 10) 3/16 square, 3/4 long	McMaster	98870A130	2 pk	2.86	5.72
E style retaining rings, 5/8 shaft (pkg 100)	McMaster	98407A140	1 pk	10.81	10.81
#35 ANSI Roller Chain (2 8-foot pieces)	McMaster	6261K531	16 ft	2.11	33.76
#35 ANSI Roller Chain Connecting Link	McMaster	6261K191	10	0.55	5.5
Chain Break for #25-60 Chain	McMaster	6051K15	1	17.63	17.63
2" x 2" x 1/4", 7.5" Long Steel Angle	Metal Supermarkets	ASTM - A36	1		
1" x 1" x 1/8", 2.5" Long Steel Angle	Metal Supermarkets	ASTM - A36	1		
1/2" x 1.75", 4" Long Cold Finished Steel Flat	Metal Supermarkets	ASTM - A36	1		
3/4" x 2", 3.5" Long Cold Finished Steel Flat	Metal Supermarkets	ASTM - A36	1		
5/16" x 2", 3" Long Cold Finished Steel Flat	Metal Supermarkets	ASTM - A36	1		
3/8" x 7", 4" Long Cold Finished Steel Flat	Metal Supermarkets	ASTM - A36	1		
1/2" Diameter, 9" Long Cold Finished Steel Round	Metal Supermarkets	ASTM - A36	1		
1.25" x 2.5", 3" Long Cold Finished Steel Flat	Metal Supermarkets	ASTM - A36	1		
Pneumatic Cylinder, 2.5" Bore, 8" Stroke, 250 psi	Vickers	VP10E6CA1FN08000	1	106.71	106.71
2" x 1" x 3/16", 31" Long Steel Channel	Metal Supermarkets	ASTM - A36	1		
NFPA Rod Eye, Small Male Cylinder Attatchment	Vickers	VP60008A or VP60008C	1		
NFPA Eye Bracket, Cylinder Clevis Attatchment	Vickers	VP62008A	1		
				Total	419.73

13.2 FUNDRAISING MONEY DISTRIBUTION

Many parts have already been ordered and received through Dr. Gielisse's Materila Selection Class. One whole set of drive train parts is in, two sheets of Lexan are on the way and there is a $500+ credit line at MetalSupermarkets as well as $600 at Grainger. The electrical engineers are working on other fundraising including getting a flight to San Francisco on a private jet. Other local fundraising is behind schedule.

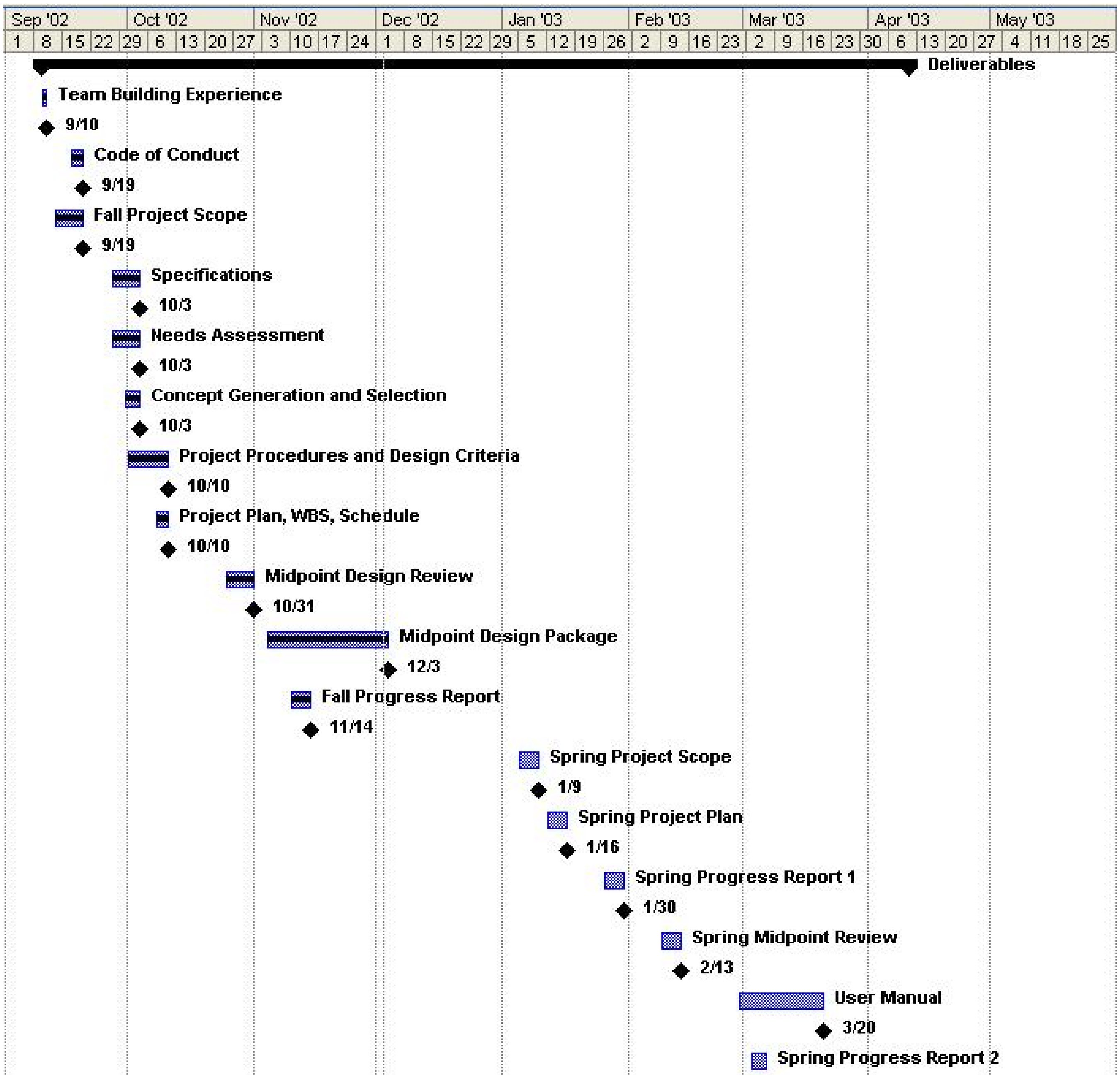
14.0 CONCLUSIONS

The design of the BattleBot is in its final stage and little work is left to be done before production can begin. The calculations and analysis of each individual system is complete. Systems integration of the entire robot is nearly complete, leaving only the lifting arm of the Primary Weapon System waiting to be modeled and pieced together. Many of the parts needed for each major sub system of the BattleBot have already been chosen.

Purchasing is ahead of schedule and ordering of parts has already begun for all of the systems. Many of the funds for the parts have already been allocated as well but Fundraising is still behind schedule. The Electrical Engineering students working along side of the Mechanical Engineering Department, however, have been soliciting local businesses within the Tallahassee area for funding.

15.0 APPENDICIES

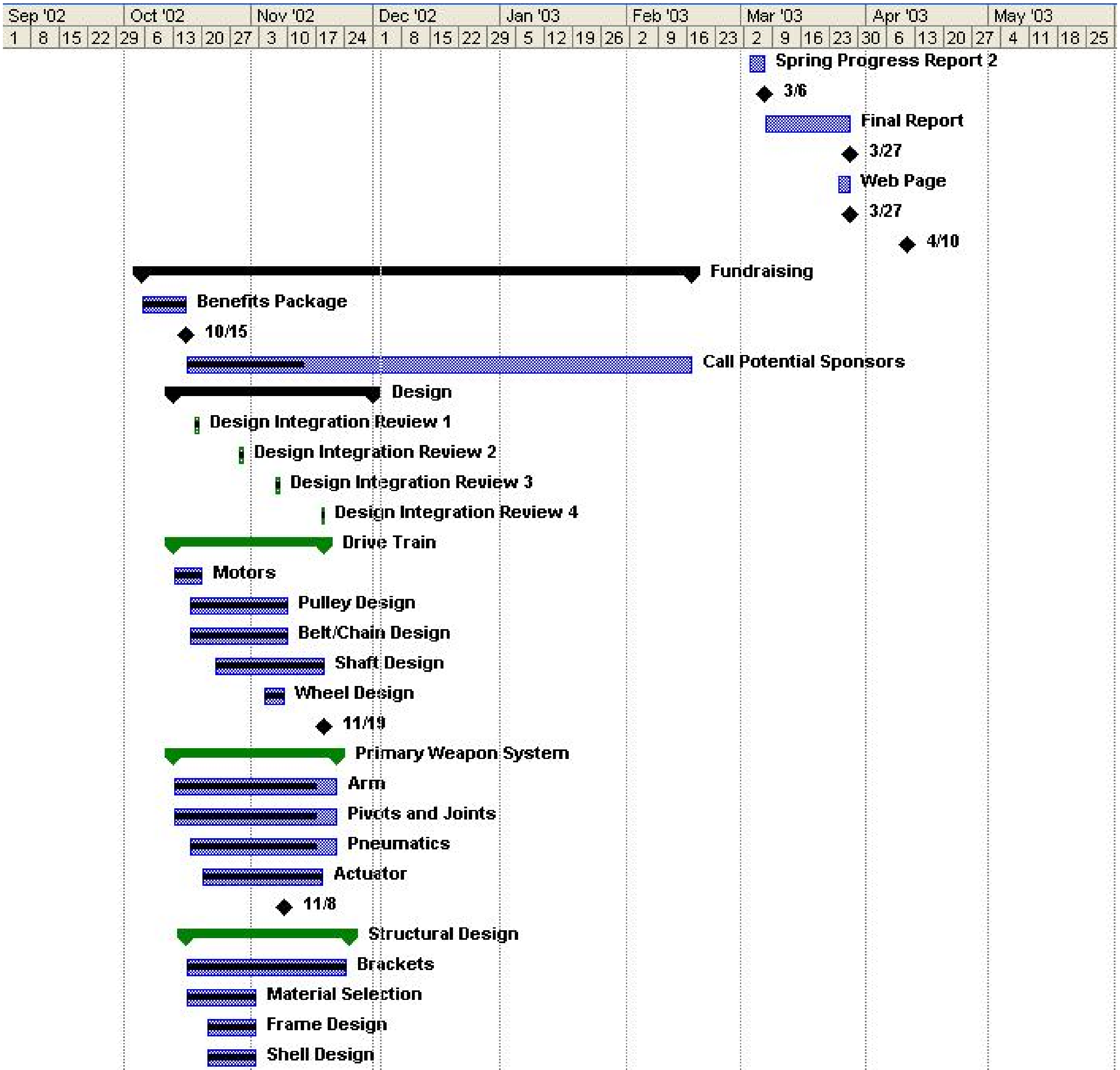
APPENDIX A. SCHEDULE REVISED SCHEDULE



Team 9 BattleBot

Florida State University
Tallahassee, FL

DATE 12/02/02	DOCUMENT NAME	Design Package REV -



Team 9 BattleBot

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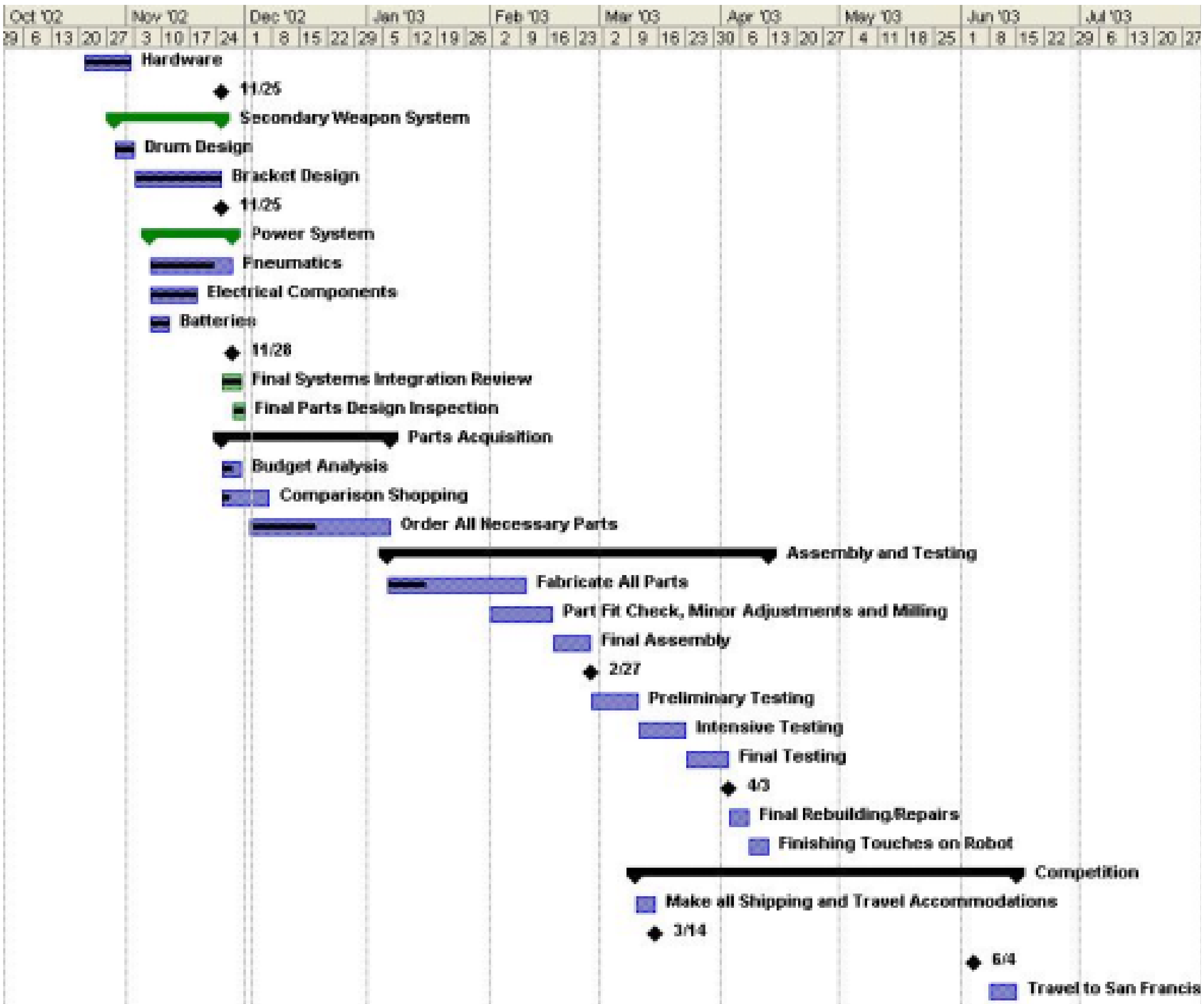
Tallahassee, FL

DATE 12/02/02	DOCUMENT NAME	Design Package REV -



APPENDIX B. CODE OF CONDUCT

1. All members are expected to perform actions when assigned and to completeness.
2. Members will be self motivated and not require motivation from the group.
3. All opinions and ideas will be respected.
4. All members will attend and be on time for meetings. If a member can not attend, an email or phone call will be made well in advance to let the group know.
5. Deconstructive arguing will not be tolerated.
6. No ideas are stupid.
7. All members will make the necessary sacrifices to complete deliverables and milestones on time.
8. Anything related to the project should be recorded in each member's data book.

APPENDIX C. DRIVE TRAIN CALCULATIONS

APPENDIX D. PRIMARY WEAPON SYSTEM CALCULATIONS

APPENDIX E. WEIGHT REDUCTION STRUCTURAL ANALYSIS

APPENDIX F. DRAWING PACKAGE

APPENDIX G. PART SPECIFICATIONS

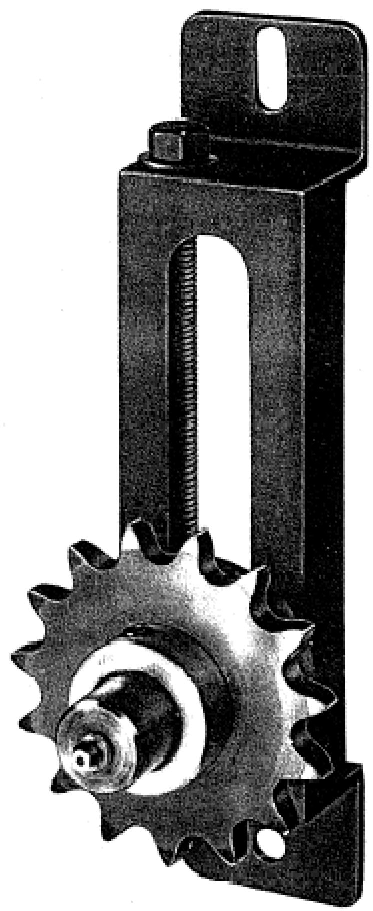
6265K SERIES

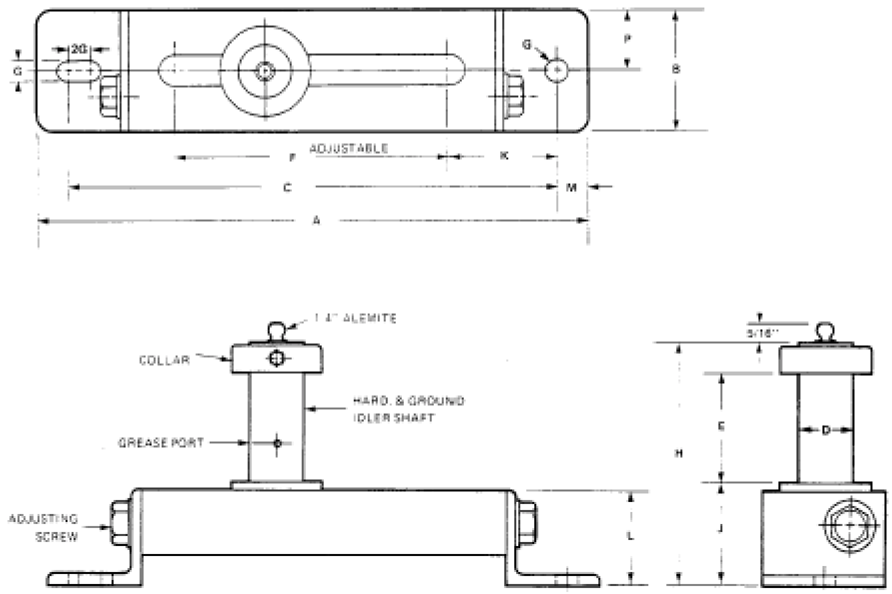
AJUSTO-SCREW TENSIONERS

The Adjusto-Screw, which is "slack-side" mounted, uses a screw to provide precise, easily-adjustable tension. The screw adjustment enables the user to set the precise tension necessary to provide maximum life for the sprocket and chain or belt. This is especially advantageous with heavy chains where slack is normally taken up by hand while making the adjustment. With the Ajusto-Screw, chain take-up and tension setting are both controlled with the screw. Ajusto-screw tensioners are useful on vertical drives, preventing lower sprocket disengagement. Constructed of structural steel (many competitive brands use cast iron), this patented tensioner is available in a wide range of capacities capable of handling up to RC 240 roller chain.

Many drive systems are enclosed, for safety reasons. With conventional tensioners, the enclosure must be removed for drive adjustment. With Ajusto-Screw, tension adjustments can often be made through a hole in the enclosure adjacent the head of the screw, substantially reducing costly maintenance and drive down-time. The screw is adjustable from either end of the tensioner.

All tensioners improve drive performance by eliminating whipping and slipping of loose drive chains and belts. They reduce vibration, noise and maintenance and provide additional life to drive components.





DIMENSIONS IN INCHES

SIZE	A	B	C	D	E	F	G	2G	H	J	K	L	M	P	Wgt.	SUGGESTED CHAIN
#0-B	5-7/8	1-1/2	5-1/4	.500	1	2-1/2	9/32	3/8	2-13/16	1-5/16	1-3/8	1-1/4	5/16	3/4	1 LB.	#35, 40, 41*
#1-B	9	2	8-1/8	.875	1-3/4	4-1/2	11/32	1/2	4	1-5/8	1-3/4	1-1/2	1/2	1	3 LB.	#40, 50, 60*
#2-B	13	3	11-7/8	1.125	2-7/8	6	9/16	3/4	5-1 1/16	2-5/32	2-7/8	2	5/8	1-1/2	7 LB.	#80, 100, 120*
#3-B	14	4	12-5/8	1.750	3-1/8	6	9/16	3/4	6-1/4	2-3/16	3-1/4	2	3/4	2	13 LB.	#140, 160, 200*
#4-B	22	6	19-3/8	2.500**	6-1/2**	7-1/2	1-1/16	1-1/8	11-3/16	3-11/16	5-5/8	3-1/2	1-1/2	3	50 LB.+Box	#200, 240

*Single-strand chain. For multiple-strand chain, use larger tensioner.

**Variable to suit required idler.

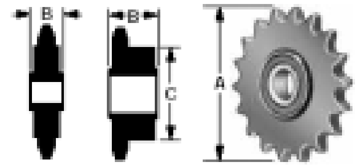
Roller Chain Idler Sprockets

The bearings or bushings in these sprockets allow them to rotate freely while controlling chain slack to maintain proper tension and prevent whip.

Steel sprockets have precision-cut teeth for longer chain life. Teeth on steel sprockets with plain bronze bearings and with needle bearings are also hardened to reduce sprocket wear. *Steel sprockets with plain bronze bearings* also have two plain washers and a hardened steel sleeve to protect the bearings.

UHMW polyethylene sprockets are self-lubricating, flexible, and resistant to abrasion and impact.

Bearing/Bushing Sprockets: *Ball bearings* are double-sealed and lubricated; *bronze bearings/bushings* are oil-impregnated; *needle bearings* have retainers separating the needle rollers to minimize internal friction and wear.



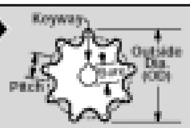
Style 1 *Style 2*

For ANSI Chain	Pitch	No. of Teeth	Bore	(A)	(B)		Each
Steel Sprocket with Ball Bearings—Style 1							
25	1/4"	20	3/8"	1.729"	5/16"	6663K11	$14.21
35	3/8"	19	3/8"	2.473"	3/8"	6663K21	14.68
35	3/8"	19	1/2"	2.473"	3/8"	6663K22	14.68
35	3/8"	20	0.640"	2.59"	0.72"	6663K23•	14.98
41	1/2"	18	1/2"	3.135"	7/16"	6663K31	16.53
41	1/2"	18	5/8"	3.135"	7/16"	6663K32	16.53
40	1/2"	18	1/2"	3.135"	7/16"	6663K41	16.53
40	1/2"	18	5/8"	3.135"	7/16"	6663K42	16.53
40	1/2"	17	0.640"	2.98"	0.72"	6663K43•	15.31
50	5/8"	15	0.640"	3.32"	0.72"	6663K44•	17.17
50	5/8"	17	1/2"	3.719"	7/16"	6663K51	17.00
50	5/8"	17	5/8"	3.719"	7/16"	6663K52	17.00
60	3/4"	13	0.640"	3.49"	0.72"	6663K53•	18.96
60	3/4"	15	1/2"	3.979"	7/16"	6663K61	16.59
60	3/4"	15	5/8"	3.979"	7/16"	6663K62	16.59
80	1"	12	3/4"	4.332"	39/64"	6663K63	27.19
UHMW Polyethylene Sprocket with Metal Ball Bearings—Style 1							
40	1/2"	17	1/2"	2.98"	0.72"	6663K101	44.74
40	1/2"	18	0.635"	3.14"	0.72"	6663K102	44.74
50	5/8"	18	0.635"	3.92"	0.72"	6663K104	48.36
60	3/4"	15	1/2"	3.98"	0.72"	6663K106	49.08
60	3/4"	16	0.635"	4.22"	0.72"	6663K107	50.50
80	1"	12	3/4"	4.33"	0.96"	6663K109	41.98

• Has hardened teeth.

For ANSI Chain	Pitch	No. of Teeth	Bore	(A)	(B)	(C)		Each
Steel Sprocket with Plain Bronze Bearings—Style 1								
35	3/8"	20	0.506"	2.59"	0.98"	—	6663K12	$10.85
41/40	1/2"	15	0.506"	2.65"	0.98"	—	6663K13	12.54
50	5/8"	15	0.506"	3.32"	0.98"	—	6663K14	14.60
60	3/4"	14	0.506"	3.74"	0.98"	—	6663K15	14.98
Steel Sprocket with Needle Bearings—Style 2								
25	1/4"	19	1/2"	1.65"	3/4"	1 7/32"	6663K71	38.67
35	3/8"	13	1/2"	1.75"	3/4"	1 13/32"	6663K72	43.59
35	3/8"	19	1"	2.47"	1"	1 13/16"	6663K73	43.59
41	1/2"	19	1"	3.28"	1"	2 3/16"	6663K74	50.92
40	1/2"	19	1"	3.28"	1"	2 3/16"	6663K75	50.92
50	5/8"	17	1"	3.72"	1"	2 5/8"	6663K76	57.28
60	3/4"	17	1"	4.46"	1"	2 5/8"	6663K77	66.55
80	1"	13	1"	4.66"	1 1/4"	2 5/8"	6663K78	79.88
Steel Sprocket with Bronze Bushings—Style 2								
35	3/8"	15	1/2"	1.990"	15/16"	1 1/8"	6663K81	13.98
35	3/8"	21	5/8"	2.713"	1 1/16"	2 1/8"	6663K82	18.89
41	1/2"	13	1/2"	2.329"	15/16"	1 9/16"	6663K83	19.58
41	1/2"	19	5/8"	3.296"	1 1/16"	2 7/16"	6663K84	24.54
40	1/2"	13	1/2"	2.329"	15/16"	1 9/16"	6663K85	19.99
40	1/2"	19	5/8"	3.296"	1 1/16"	2 7/16"	6663K86	26.06
50	5/8"	13	1/2"	2.911"	15/16"	2"	6663K87	21.65
50	5/8"	17	5/8"	3.719"	1 1/16"	2 5/8"	6663K88	29.30
60	3/4"	15	5/8"	3.979"	1 1/16"	2 11/16"	6663K89	36.88
60	3/4"	17	1 1/8"	4.462"	1 5/16"	2 7/8"	6663K91	49.63
80	1"	15	1 1/8"	5.305"	1 9/16"	3 1/2"	6663K92	61.08

ANSI Roller Chain Sprockets



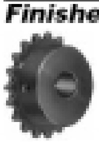
About Sprockets

In order for sprocket and chain to properly mesh, select a sprocket that matches your specific chain number and pitch. *Pitch* is the distance from one tooth valley to the next; this is where the centers of chain pins mesh with the sprocket. For ANSI chain, see pages 882-886. For standard ANSI keyway information, see page 1003.

No. of Teeth	Outside Diameter (OD) of the Sprocket					
	#25, 1/4" Pitch	#35, 3/8" Pitch	#40 and #41, 1/2" Pitch	#50, 5/8" Pitch	#60, 3/4" Pitch	#80, 1" Pitch
9	0.84"	1.26"	1.67"	2.09"	2.51"	3.35"
10	0.92"	1.38"	1.84"	2.30"	2.76"	3.68"
11	1.00"	1.50"	2.00"	2.50"	3.00"	4.01"
12	1.08"	1.63"	2.17"	2.71"	3.25"	4.33"
13	1.17"	1.75"	2.33"	2.91"	3.49"	4.66"
14	1.25"	1.87"	2.49"	3.11"	3.74"	4.98"
15	1.33"	1.99"	2.65"	3.32"	3.98"	5.30"
16	1.41"	2.11"	2.81"	3.52"	4.22"	5.63"
17	1.49"	2.23"	2.98"	3.72"	4.46"	5.95"
18	1.57"	2.35"	3.14"	3.92"	4.70"	6.27"
19	1.65"	2.47"	3.30"	4.12"	4.95"	6.59"
20	1.73"	2.59"	3.46"	4.32"	5.19"	6.91"
21	1.81"	2.71"	3.62"	4.52"	5.43"	7.24"
22	1.89"	2.83"	3.78"	4.72"	5.67"	7.56"
23	1.97"	2.95"	3.94"	4.92"	5.91"	7.88"

No. of Teeth	Outside Diameter (OD) of the Sprocket					
	#25, 1/4" Pitch	#35, 3/8" Pitch	#40 and #41, 1/2" Pitch	#50, 5/8" Pitch	#60, 3/4" Pitch	#80, 1" Pitch
24	2.05"	3.07"	4.10"	5.12"	6.15"	8.20"
25	2.13"	3.19"	4.26"	5.32"	6.39"	8.52"
26	—	3.31"	4.42"	5.52"	6.63"	8.84"
28	—	3.55"	4.74"	5.92"	7.11"	9.48"
30	2.53"	3.79"	5.06"	6.32"	7.59"	10.11"
32	—	4.03"	5.38"	6.72"	8.07"	10.75"
34	—	—	5.70"	7.12"	8.54"	11.39"
35	2.93"	4.39"	5.86"	7.32"	8.78"	11.71"
36	—	4.51"	6.02"	7.52"	9.02"	12.03"
38	—	—	6.33"	—	9.50"	12.67"
40	3.33"	4.99"	6.65"	8.32"	9.98"	—
42	—	5.23"	6.97"	8.72"	10.46"	13.94"
45	3.73"	5.59"	7.45"	9.31"	11.18"	—
48	—	5.95"	7.93"	9.91"	11.89"	15.86"
60	—	7.38"	9.84"	12.30"	14.76"	19.68"

Finished-Bore Steel Sprockets



Bores are finished so these sprockets are ready to mount. They have a standard keyway, except 3/8" and 1/2" bore sizes. Keyways are on the centerline of tooth. All include two set screws. Use sprockets with ANSI single-strand chain. Made of steel. **To Order:** Please specify bore size. Standard bore sizes are: 3/8", 1/2", 5/8", 3/4", 7/8", 1", 1-1/8", 1-3/16", 1-1/4", 1-3/8", 1-7/16" 1-1/2", 1-5/8", 1-3/4", 1-15/16", 2", 2-3/16", 2-7/16", and 2-11/16".

Additional Information: *Click here for the length through bore as well as hub diameter for these sprockets.*

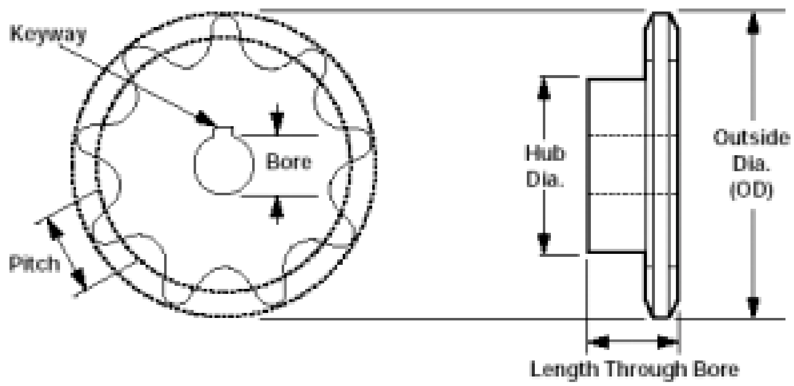
No. of Teeth	3/8" Pitch For #35 Chain: Bore Range		Each	1/2" Pitch For #41 Chain: Bore Range		Each	1/2" Pitch For #40 Chain	Each	5/8" Pitch For #50 Chain: Bore Range		Each	3/4" Pitch For #60 Chain: Bore Range		Each
9	3/8"	6280K311	$6.43	1/2"-5/8"	6280K142	$6.82	6280K189	$7.17	5/8"-3/4"	6280K247	$9.86	3/4"-1"	6280K101	$10.59
10	3/8"-5/8"	6280K112	6.56	1/2"-3/4"	6280K143	7.17	6280K191	7.43	5/8"-1"	6280K248	10.59	3/4"-1-1/4"	6280K102	11.05
11	3/8"-3/4"	6280K113	6.82	1/2"-7/8"	6280K144	7.43	6280K192	7.77	5/8"-1"	6280K249	11.05	3/4"-1-1/4"	6280K103	11.91
12	1/2"-3/4"	6280K114	7.04	1/2"-7/8"	6280K145	7.90	6280K193 ♦	8.51	5/8"-1-1/4"	6280K251	11.46	3/4"-1-5/16"	6280K104	13.25
13	1/2"-3/4"	6280K115	7.30	1/2"-1"	6280K146	8.16	6280K194	8.90	5/8"-1-1/4"	6280K252	11.91	3/4"-1-1/2"	6280K105	14.87
14	1/2"-3/4"	6280K116	7.30	1/2"-1-1/8"	6280K147	8.64	6280K195	9.38	5/8"-1-1/4"	6280K253	12.65	3/4"-1-5/8"	6280K106	17.41
15	1/2"-1"	6280K117	7.43	1/2"-1"	6280K148	9.38	6280K196 ▲	10.12	5/8"-1-1/2"	6280K254	13.25	3/4"-1-3/4"	6280K107	20.09
16	1/2"-1"	6280K118	7.90	5/8"-1-1/4"	6280K149	9.99	6280K197	10.72	5/8"-1-5/8"	6280K255	13.99	3/4"-1-13/16"	6280K108	22.36
17	1/2"-1"	6280K119	8.16	5/8"-1-1/4"	6280K151	10.72	6280K198	11.33	5/8"-1-5/8"	6280K256	15.68	1"-1-15/16"	6280K109	24.71
18	1/2"-1"	6280K121	8.64	5/8"-1-1/2"	6280K152	11.46	6280K199	11.91	5/8"-1-5/8"	6280K257	17.41	1"-1-15/16"	6280K201	27.26
19	1/2"-1"	6280K122	9.70	5/8"-1-1/2"	6280K153	12.52	6280K211	13.25	5/8"-1-5/8"	6280K258	19.36	1"-1-15/16"	6280K202	28.45
20	1/2"-1"	6280K123	10.85	5/8"-1-1/2"	6280K154	13.99	6280K212	15.20	5/8"-1-5/8"	6280K259	21.02	1"-1-15/16"	6280K203	29.80
21	1/2"-1"	6280K124	12.06	5/8"-1-1/2"	6280K155	15.46	6280K213	16.55	3/4"-1-1/2"	6280K261	25.31	1"-1-15/16"	6280K204	33.95
22	1/2"-1"	6280K125	13.12	5/8"-1-1/2"	6280K156	16.93	6280K214	18.15	3/4"-1-1/2"	6280K262	27.39	1"-1-15/16"	6280K205	36.35
23	1/2"-1"	6280K126	13.99	5/8"-1-1/2"	6280K157	18.62	6280K215	20.09	3/4"-1-1/2"	6280K263	29.53	1"-1-15/16"	6280K206	37.22
24	1/2"-1"	6280K127	14.87	5/8"-1-1/2"	6280K158	20.42	6280K216	21.56	3/4"-1-1/2"	6280K264	32.20	1"-1-15/16"	6280K207	39.77
25	1/2"-1"	6236K22	13.40	5/8"-1-1/2"	6236K28	18.56	6236K32	19.70	3/4"-1-1/2"	6236K42	28.54	1"-1-15/16"	6236K52	35.56
26	5/8"-1-1/4"	6236K1	17.00	5/8"-1-1/2"	—	—	6236K7	25.11	3/4"-1-1/2"	6236K16	33.26	1"-1-15/16"	6236K39	43.38
28	5/8"-1-1/4"	6236K2	19.38	5/8"-1-1/2"	—	—	6236K8	28.68	3/4"-1-1/2"	6236K17	36.64	1"-1-15/16"	6236K41	58.38
30	5/8"-1-1/4"	6236K23	16.65	5/8"-1-1/2"	6236K29	22.26	6236K33	26.17	3/4"-1-1/2"	6236K43	31.29	1"-1-15/16"	6236K53	39.97
32	5/8"-1-1/4"	6236K3	21.68	5/8"-1-1/2"	—	—	6236K9	31.87	3/4"-1-11/16"	6236K18	38.68	1"-1-15/16"	6236K48	48.81
34	—	—	—	5/8"-1-1/2"	—	—	6236K11	33.06	3/4"-1-11/16"	6236K19	39.96	1"-1-15/16"	6236K49	49.94
35	5/8"-1-1/4"	6236K69	18.02	5/8"-1-1/2"	6236K31	26.68	6236K34	27.92	3/4"-1-11/16"	6236K44	33.84	1"-1-15/16"	6236K54	42.10
36	5/8"-1-1/4"	6236K4	24.57	5/8"-1-1/2"	—	—	6236K12	33.94	3/4"-1-11/16"	6236K21	41.64	1"-2-3/16"	6236K51	51.77
38	—	—	—	5/8"-1-1/2"	—	—	6236K13	35.11	—	—	—	1"-2-3/16"	6236K57	54.32
40	5/8"-1-1/4"	6236K25	20.93	5/8"-1-1/2"	—	—	6236K35	30.18	3/4"-1-11/16"	6236K45	36.59	1"-2-3/16"	6236K55	47.45
42	5/8"-1-1/4"	6236K5	25.91	3/4"-1-1/2"	—	—	6236K14	36.85	3/4"-1-11/16"	6236K24	44.96	1"-2-3/16"	6236K61	59.87
45	5/8"-1-1/4"	6236K26	22.30	5/8"-1-1/2"	—	—	6236K36	31.29	3/4"-1-11/16"	6236K46	38.73	1"-2-3/16"	6236K56	53.59
48	5/8"-1-1/4"	6236K6	27.94	3/4"-1-1/2"	—	—	6236K15	38.74	1"-1-11/16"	6236K38	48.19	1"-2-3/16"	6236K62	69.26
60	5/8"-1-1/4"	6236K27	29.68	3/4"-1-1/2"	—	—	6236K37	36.31	3/4"-1-11/16"	6236K47	48.87	1"-2-3/16"	6236K58	56.77

♦ Max. bore size is 1". ▲ Max. bore size is 1-1/4".

1" Pitch, For #80 Chain

No. of Teeth	Bore Range		Each	No. of Teeth	Bore Range		Each	No. of Teeth	Bore Range		Each
9	1"-1-1/8"	6280K208	$17.89	19	1"-2-1/16"	6280K219	$47.48	30	1-1/4"-2-11/16"	6236K63	$62.03
10	1"-1-1/8"	6280K209	19.68	20	1"-2-1/16"	6280K221	50.34	32	1-1/4"-2-11/16"	6236K68	78.43
11	1"-1-3/8"	6280K131	21.95	21	1"-2-1/16"	6280K222	52.48	34	1-1/4"-2-11/16"	6236K71	81.81
12	1"-1-11/16"	6280K132	24.71	22	1"-2-1/16"	6280K223	59.46	35	1-3/16"-2-11/16"	6236K64	69.97
13	1"-1-11/16"	6280K133	27.26	23	1"-2-1/16"	6280K224	61.80	36	1-1/4"-2-11/16"	6236K72	86.13
14	1"-1-11/16"	6280K134	29.99	24	1"-2-1/16"	6280K225	62.52	38	1-1/4"-2-11/16"	6236K73	90.79
15	1"-2-3/16"	6280K135	32.00	25	1"-2-1/16"	6236K59	59.91	42	1-3/8"-2-11/16"	6236K74	105.57
16	1"-2-1/16"	6280K136	34.88	26	1-1/4"-2-13/16"	6236K65	66.49	48	1-3/8"-2-11/16"	6236K75	116.36
17	1"-2-1/16"	6280K217	41.78	28	1-1/4"-2-13/16"	6236K66	70.06	60	1-3/16"-2-11/16"	6236K67	128.12
18	1"-2-1/16"	6280K218	44.60								

More About Finished Bore Steel Roller Chain Sprockets



More About Finished Bore Steel Roller Chain Sprockets

	For #35 Chain, 3/8" Pitch					For #41 Chain, 1/2" Pitch					For #40 Chain, 1/2" Pitch				
No. of Teeth	Available Bore Sizes	OD	Length Through Bore	Hub Dia.		Available Bore Sizes	OD	Length Through Bore	Hub Dia.		Available Bore Sizes	OD	Length Through Bore	Hub Dia.	
9	[illegible]	1.20"	[illegible]	[illegible]*	6280K111	[illegible]	1.57"	[illegible]	[illegible]*	6280K142	[illegible]	1.67"	[illegible]	[illegible]*	6280K189
10	[illegible]	1.38"	[illegible]	[illegible]*	6280K112	[illegible]	1.84"	[illegible]	[illegible]*	6280K143	[illegible]	1.84"	[illegible]	[illegible]*	6280K191
11	[illegible]	1.50"	[illegible]	[illegible]*	6280K113	[illegible]	2.00"	[illegible]	[illegible]*	6280K144	[illegible]	2.00"	[illegible]	[illegible]*	6280K192
12	[illegible]	1.63"	[illegible]	[illegible]*	6280K114	[illegible]	2.17"	[illegible]	[illegible]*	6280K145	[illegible], 1"	2.17"	[illegible]	[illegible]*	6280K193
13	[illegible]	1.75"	[illegible]	[illegible]*	6280K115	[illegible], 1"	2.33"	[illegible]	[illegible]	6280K146	[illegible], 1"	2.33"	[illegible]	[illegible]	6280K194
14	[illegible]	1.87"	[illegible]	[illegible]	6280K116	[illegible], 1", [illegible]	2.49"	[illegible]	[illegible]	6280K147	[illegible], 1", [illegible]	2.49"	[illegible]	[illegible]	6280K195
15	[illegible], 1"	1.99"	[illegible]	[illegible]	6280K117	[illegible]	2.65"	[illegible]	[illegible]	6280K148	[illegible]	2.65"	[illegible]	[illegible]	6280K196
16	[illegible], 1"	2.11"	[illegible]	[illegible]	6280K118	[illegible]	2.81"	[illegible]	[illegible]	6280K149	[illegible]	2.81"	[illegible]	2"	6280K197
17	[illegible], 1"	2.23"	[illegible]	[illegible]	6280K119	[illegible]	2.98"	1"	[illegible]	6280K151	[illegible]	2.98"	1"	[illegible]	6280K198
18	[illegible], 1"	2.35"	[illegible]	[illegible]	6280K121	[illegible]	3.14"	1"	[illegible]	6280K152	[illegible]	3.14"	1"	[illegible]	6280K199
19	[illegible], 1"	2.47"	[illegible]	[illegible]	6280K122	[illegible]	3.30"	1"	[illegible]	6280K153	[illegible]	3.30"	1"	[illegible]	6280K211
20	[illegible], 1"	2.59"	[illegible]	[illegible]	6280K123	[illegible]	3.46"	1"	[illegible]	6280K154	[illegible]	3.46"	1"	[illegible]	6280K212
21	[illegible], 1"	2.71"	[illegible]	2"	6280K124	[illegible]	3.62"	1"	[illegible]	6280K155	[illegible]	3.62"	1"	[illegible]	6280K213
22	[illegible], 1"	2.83"	[illegible]	2"	6280K125	[illegible]	3.78"	1"	3"	6280K156	[illegible]	3.78"	1"	[illegible]	6280K214
23	[illegible], 1"	2.95"	[illegible]	2"	6280K126	[illegible]	3.94"	1"	[illegible]	6280K157	[illegible]	3.94"	1"	3"	6280K215
24	[illegible], 1"	3.07"	[illegible]	2"	6280K127	[illegible]	4.10"	1"	[illegible]	6280K158	[illegible]	4.10"	1"	[illegible]	6280K216
25	[illegible], 1"	3.19"	[illegible]	2"	6256K22	[illegible]	4.26"	1"	[illegible]	6256K28	[illegible]	4.26"	1"	[illegible]	6256K32

* Has recessed groove in hub for chain clearance.

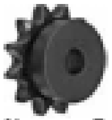
Continued

ANSI Roller Chain Sprockets

For information about sprocket OD and pitch, see page 892.

For the length through bore as well as hub diameter for the sprockets on this page, click on the Additional Information links below.

Plain Bore Steel Sprockets

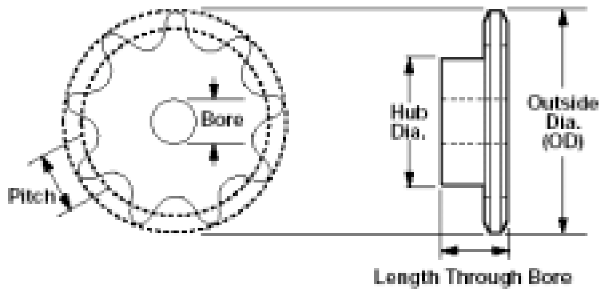


You can machine these plain bore sprockets to fit your application. They do not include keyways or set screws. Use with ANSI single-strand chain. Minimum bore size is the furnished size; you can enlarge bore to the maximum bore size.

Additional Information: *Click here (See top of page for details)*

No. of Teeth	For #35 Chain, 3/8" Pitch Bore Size Min.	Max.		Each	For #40 Chain, 1/2" Pitch Bore Size Min.	Max.		Each	For #50 Chain, 5/8" Pitch Bore Size Min.	Max.		Each	For #60 Chain, 3/4" Pitch Bore Size Min.	Max.		Each
9	3/8"	3/8"	6793K116	$5.04	1/2"	9/16"	6793K208	$6.28	5/8"	3/4"	6793K209	$8.55	3/4"	7/8"	6793K211	$9.52
10	3/8"	7/16"	6793K117	5.38	1/2"	3/4"	6793K141	6.41	5/8"	7/8"	6793K164	9.38	3/4"	1 1/8"	6793K212	10.27
11	3/8"	9/16"	6793K118	5.52	1/2"	7/8"	6793K142	7.03	5/8"	1"	6793K165	10.00	3/4"	1 5/16"	6793K213	10.90
12	1/2"	9/16"	6793K119	5.79	1/2"	1"	6793K143	7.52	5/8"	1 1/4"	6793K166	10.42	3/4"	1 3/8"	6793K187	11.65
13	1/2"	11/16"	6793K121	6.00	1/2"	1 1/16"	6793K144	7.66	5/8"	1 5/16"	6793K167	10.90	3/4"	1 1/2"	6793K188	12.69
14	1/2"	7/8"	6793K122	6.28	1/2"	1 1/8"	6793K145	7.66	5/8"	1 7/16"	6793K168	11.38	3/4"	1 3/4"	6793K189	13.66
15	1/2"	7/8"	6793K123	6.41	1/2"	1 1/4"	6793K146	7.66	5/8"	1 1/2"	6793K169	11.79	3/4"	1 7/8"	6793K191	15.79
16	1/2"	15/16"	6793K124	6.76	5/8"	1 3/8"	6793K147	8.00	5/8"	1 3/4"	6793K171	12.69	3/4"	2"	6793K192	17.79
17	1/2"	1 1/16"	6793K125	6.76	5/8"	1 7/16"	6793K148	9.38	5/8"	1 7/8"	6793K172	13.66	3/4"	2 1/4"	6793K193	18.69
18	1/2"	1 3/16"	6793K126	7.03	5/8"	1 1/2"	6793K149	10.00	5/8"	1 7/8"	6793K173	14.90	3/4"	2 3/8"	6793K194	19.93
19	1/2"	1 1/4"	6793K127	7.24	5/8"	1 3/4"	6793K151	11.38	5/8"	2"	6793K174	15.79	3/4"	2 3/8"	6793K195	22.69
20	1/2"	1 5/16"	6793K128	8.00	5/8"	1 7/8"	6793K152	13.03	3/4"	2"	6793K175	17.66	3/4"	2 5/8"	6793K196	24.28
21	1/2"	1 3/8"	6793K129	8.55	5/8"	1 7/8"	6793K153	14.41	3/4"	2"	6793K176	19.17	3/4"	2 3/4"	6793K197	25.04
22	1/2"	1 5/8"	6793K131	9.52	5/8"	1 7/8"	6793K154	15.79	3/4"	2"	6793K177	20.55	3/4"	2 3/4"	6793K198	26.97
23	1/2"	1 5/8"	6793K132	10.27	5/8"	2"	6793K155	17.38	3/4"	2"	6793K178	21.93	3/4"	2 3/4"	6793K199	27.79
24	1/2"	1 5/8"	6793K133	10.90	5/8"	2 1/4"	6793K156	18.28	3/4"	2"	6793K179	23.17	3/4"	2 3/4"	6793K201	30.07
25	1/2"	1 5/8"	6793K134	11.65	5/8"	2 1/4"	6793K157	19.17	3/4"	2"	6793K181	25.04	3/4"	2 3/4"	6793K202	32.34
30	1/2"	1 5/8"	6793K135	13.17	5/8"	2 1/4"	6793K158	22.69	3/4"	2 1/4"	6793K182	27.79	3/4"	2 3/4"	6793K203	36.97
35	5/8"	1 1/2"	6793K136	15.04	5/8"	2 1/4"	6793K159	24.28	3/4"	2 1/4"	6793K183	30.55	1"	2 3/4"	6793K204	39.24
40	5/8"	1 1/2"	6793K137	16.41	3/4"	2 3/8"	6793K161	26.90	3/4"	2 1/4"	6793K184	33.45	1"	2 3/4"	6793K205	45.24
45	5/8"	1 1/2"	6793K138	18.07	3/4"	2 3/8"	6793K162	27.79	3/4"	2 1/2"	6793K185	35.72	15/16"	2 3/4"	6793K206	51.72
60	3/4"	1 1/2"	6793K139	25.93	3/4"	2 3/8"	6793K163	33.31	1"	2 1/2"	6793K186	46.62	1 1/4"	2 3/4"	6793K207	72.55

More About Plain Bore Steel Roller Chain Sprockets



No. of Teeth	#35 Chain, 3/8" Pitch: OD	#35: Length Through Bore	#35: Hub Dia.	#35: Part No.	#40 Chain, 1/2" Pitch: OD	#40: Length Through Bore	#40: Hub Dia.	#40: Part No.	#50 Chain, 5/8" Pitch: OD	#50: Length Through Bore	#50: Hub Dia.	#50: Part No.	#60 Chain, 3/4" Pitch: OD	#60: Length Through Bore	#60: Hub Dia.	#60: Part No.
9	1.26"	5/8"	27/32"•	6793K116	1.67"	7/8"	1-1/32"•	6793K208	2.09"	1"	1-5/8"•	6793K209	2.51"	1-1/4"	1-29/32"•	6793K211
10	1.38"	5/8"	31/32"•	6793K117	1.84"	7/8"	1-1/4"•	6793K141	2.30"	1"	1-13/16"•	6793K164	2.76"	1-1/4"	1-15/16"•	6793K212
11	1.50"	5/8"	1-1/16"•	6793K118	2.00"	7/8"	1-3/8"•	6793K142	2.50"	1"	1-7/8"•	6793K165	3.00"	1-1/4"	2-1/16"•	6793K213
12	1.63"	5/8"	1-5/32"•	6793K119	2.17"	7/8"	1-15/32"•	6793K143	2.71"	1"	1-31/32"•	6793K166	3.25"	1-1/4"	2-3/8"•	6793K187
13	1.75"	5/8"	1-1/4"•	6793K121	2.33"	7/8"	1-19/32"	6793K144	2.91"	1"	1-7/8"•	6793K167	3.49"	1-1/4"	2-11/32"	6793K188
14	1.87"	5/8"	1-3/8"	6793K122	2.49"	7/8"	1-11/16"	6793K145	3.11"	1"	2-1/8"	6793K168	3.74"	1-1/4"	2-29/32"	6793K189
15	1.99"	5/8"	1-15/32"	6793K123	2.65"	7/8"	1-13/16"	6793K146	3.32"	1"	2-3/8"	6793K169	3.98"	1-1/4"	2-7/8"	6793K191
16	2.11"	5/8"	1-19/32"	6793K124	2.81"	7/8"	2"	6793K147	3.52"	1"	2-1/2"	6793K171	4.22"	1-1/4"	3-1/16"	6793K192
17	2.23"	5/8"	1-23/32"	6793K125	2.98"	1"	2-1/8"	6793K148	3.72"	1"	2-11/16"	6793K172	4.46"	1-1/4"	3-1/4"	6793K193
18	2.35"	5/8"	1-27/32"	6793K126	3.14"	1"	2-5/16"	6793K149	3.92"	1"	2-7/8"	6793K173	4.70"	1-1/4"	3-1/2"	6793K194
19	2.47"	5/8"	1-29/32"	6793K127	3.30"	1"	2-1/2"	6793K151	4.12"	1"	3"	6793K174	4.95"	1-1/4"	3-1/2"	6793K195
20	2.59"	5/8"	1-15/16"	6793K128	3.46"	1"	2-5/8"	6793K152	4.32"	1"	3"	6793K175	5.19"	1-1/4"	3-5/8"	6793K196
21	2.71"	7/8"	2"	6793K129	3.62"	1"	2-3/4"	6793K153	4.52"	1"	3"	6793K176	5.43"	1-1/4"	4"	6793K197
22	2.83"	7/8"	2"	6793K131	3.78"	1"	2-7/8"	6793K154	4.72"	1"	3"	6793K177	5.67"	1-1/4"	4"	6793K198
23	2.95"	7/8"	2"	6793K132	3.94"	1"	3"	6793K155	4.92"	1"	3"	6793K178	5.91"	1-1/4"	4"	6793K199
24	3.07"	7/8"	2"	6793K133	4.10"	1"	3-1/4"	6793K156	5.12"	1-1/8"	3"	6793K179	6.15"	1-1/4"	4"	6793K201
25	3.19"	7/8"	2"	6793K134	4.26"	1"	3-1/4"	6793K157	5.32"	1-1/8"	3"	6793K181	6.39"	1-1/4"	4"	6793K202
30	3.79"	7/8"	2"	6793K135	5.06"	1"	3-1/4"	6793K158	6.32"	1-1/8"	3-1/2"	6793K182	7.59"	1-1/4"	4"	6793K203
35	4.39"	7/8"	2-1/4"	6793K136	5.86"	1"	3-1/4"	6793K159	7.32"	1-1/8"	3-1/2"	6793K183	8.78"	1-1/4"	4"	6793K204
40	4.99"	1"	2-1/4"	6793K137	6.66"	1-1/8"	3-1/2"	6793K161	8.32"	1-1/4"	3-3/4"	6793K184	9.98"	1-1/4"	4-1/2"	6793K205
45	5.59"	1"	2-1/4"	6793K138	7.46"	1-1/8"	3-1/2"	6793K162	9.31"	1-1/4"	3-3/4"	6793K185	11.18"	1-1/4"	4-1/2"	6793K206
60	7.38"	1"	2-1/4"	6793K139	9.84"	1-1/8"	3-1/2"	6793K163	12.30"	1-1/4"	3-3/4"	6793K186	14.76"	1-1/4"	4-1/2"	6793K207

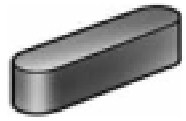
• Has recessed groove in hub for chain clearance.

Machine Keys

Made from plain C1018 steel. Tolerances: *Undersized:* −.002"; *Oversized:* +.002". Length tolerance is −.030" Tensile strength is 82,000 psi. Rockwell hardness is B85.

Keys with square ends are furnished in a package of 10.

Square End



Rounded End

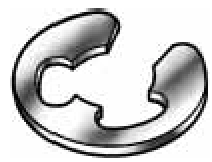
Lg.		Per Pkg.
Square Ends—*Undersized*		
1/8" Square		
3/4"	98870A100	$2.38
1"	98870A110	2.38
1 1/4"	98870A115	2.38
3/16" Square		
1/2"	98870A120	2.86
3/4"	98870A130	2.86
1"	98870A140	2.86
1 1/4"	98870A150	2.86
1 1/2"	98870A160	2.86
1 3/4"	98870A170	2.86
2"	98870A180	3.33
2 1/2"	98870A190	3.33
1/4" Square		
3/4"	98870A195	3.33
1"	98870A205	3.33
1 1/4"	98870A215	3.33
1 1/2"	98870A230	3.33
1 3/4"	98870A240	3.33
2"	98870A245	3.81
2 1/4"	98870A255	4.29
2 1/2"	98870A260	4.29
3"	98870A265	4.76
5/16" Square		
1 1/4"	98870A275	3.81
1 1/2"	98870A277	3.81
2"	98870A281	4.29
2 1/2"	98870A283	5.24
3/8" Square		
1 1/4"	98870A287	4.76
1 1/2"	98870A288	5.24
2"	98870A289	5.71
2 1/2"	98870A290	6.67
1/2" Square		
1 1/2"	98870A292	7.14
2"	98870A293	8.10
2 1/2"	98870A294	10.00
Square Ends—*Oversized*		
1/8" Square		
1/2"	98870A305	3.33
3/4"	98870A310	3.33
1"	98870A315	3.33
3/16" Square		
1/2"	98870A320	3.81
3/4"	98870A330	3.81

Lg.		Per Pkg.
Square Ends-*Oversized (Cont.)*		
3/16" Square (Continued)		
1"	98870A340	$3.81
1 1/4"	98870A355	3.81
1 1/2"	98870A365	3.81
1 3/4"	98870A370	3.81
2"	98870A375	4.29
1/4" Square		
3/4"	98870A385	4.29
1"	98870A395	4.29
1 1/4"	98870A405	4.29
1 1/2"	98870A415	4.29
1 3/4"	98870A420	4.29
2"	98870A430	4.29
2 1/4"	98870A435	4.76
2 1/2"	98870A440	4.76
3/8" Square		
1"	98870A450	4.76
1 1/4"	98870A455	4.76
1 3/4"	98870A460	5.24
2"	98870A465	5.24
2 1/4"	98870A470	5.71
2 3/4"	98870A475	6.19
1/2" Square		
1"	98870A480	5.71
1 5/8"	98870A485	7.62
2"	98870A490	8.10

Lg.		Each
Rounded Ends—*Oversized*		
3/16" Square		
1/2"	98870A560	$1.10
3/4"	98870A570	1.14
1 1/2"	98870A575	1.24
3/8" Square		
1"	98870A580	1.38
1 1/4"	98870A585	1.43
1 1/2"	98870A590	1.48
2"	98870A595	1.67
2 1/2"	98870A600	1.76
1/2" Square		
1"	98870A605	1.86
2"	98870A610	2.19
2 1/2"	98870A615	2.29
3"	98870A620	2.48
3 1/2"	98870A625	2.76

E-Style Retaining Rings

Snap rings directly into groove from the side of the shaft.



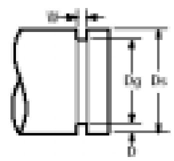
Additional Information: *Click here for detailed dimensions on Zinc-Plated Steel.*

Additional Information: *Click here for detailed dimensions on Stainless Steel.*

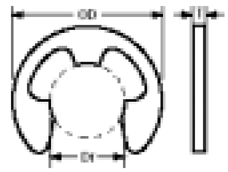
For Shaft Dia.	*Fits Groove* Dia.	*Fits Groove* Wd.	Pkg. Qty.	***Zinc-Plated Steel***	Per Pkg.	Pkg. Qty.	***Type PH 15-7 MO Stainless Steel***	Per Pkg.
1/16″	0.052″	0.012″	100	**98407A112**	$2.28	100	**98408A112**	$12.73
3/32″	0.074″	0.020″	100	**98407A114**	2.34	100	**98408A114**	13.03
7/64″	0.079″	0.020″	100	**98407A115**	2.56	100	**98408A115** ♦	17.49
1/8″	0.095″	0.020″	100	**98407A116**	2.44	100	**98408A116**	13.91
9/64″	0.102″	0.020″	100	**98407A117**	2.75	100	**98408A117**	13.91
5/32″	0.116″	0.029″	100	**98407A119**	2.89	100	**98408A119** ♦	16.11
11/64″	0.127″	0.029″	100	**98407A121**	3.33	100	**98408A121** ♦	16.41
3/16″	0.147″	0.029″	100	**98407A118**	3.33	100	**98408A118** ♦	16.57
7/32″	0.188″	0.029″	100	**98407A122**	3.69	50	**98408A122**	10.43
1/4″	0.210″	0.029″	100	**98407A120**	4.33	50	**98408A120**	11.38
5/16″	0.250″	0.029″	100	**98407A132**	4.14	50	**98408A132**	11.26
3/8″	0.303″	0.039″	100	**98407A134**	5.60	10	**98408A134**	3.43
7/16″	0.343″	0.039″	100	**98407A136**	6.40	10	**98408A136**	3.91
1/2″	0.396″	0.046″	100	**98407A138**	8.41	10	**98408A138**	4.81
5/8″	0.485″	0.046″	100	**98407A140**	10.81	10	**98408A140**	6.77
3/4″	0.625″	0.056″	50	**98407A152**	14.62	10	**98408A152**	11.14
7/8″	0.675″	0.056″	50	**98407A154**	10.30	1	**98408A154** ★	1.45
1″	0.835″	0.056″	50	**98407A156**	14.51	—	—	—
1 3/16″	1.079″	0.068″	25	**98407A158**	7.91	1	**98408A158** ★	2.70
1 3/8″	1.230″	0.068″	25	**98407A160**	11.64	—	—	—

★ Sold individually.

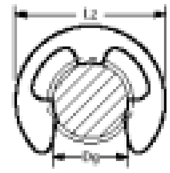
Zinc-Plated Steel E-Style External Retaining Rings



Shaft Diameter and Groove Size



Free Diameter, Thickness, and Free Outside Diameter

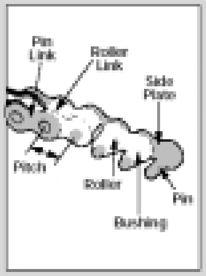


Clearance Diameter

	Shaft Diameter		*Groove Size*					*Ring Size*				*Clearance Dia.*	
	Dec.	*Frac.*	*Diameter*		*Width*		*Depth*	*Free Diameter*		*Thickness*		*Free Outside Diameter*	*Released In Groove*
	Ds	Ds	Dg	Tolerance	W	Tolerance	D	Df	Tolerance	T	Tolerance	OD	L2
98407A132	0.312"	5/16"	0.250"	+0.003"-0.000"	0.029"	+0.003"-0.000"	0.031"	0.243"	+0.002"-0.004"	0.025"	±0.002"	0.580"	0.520"
98407A134	0.375"	3/8"	0.303"	+0.003"-0.000"	0.039"	+0.003"-0.000"	0.036"	0.308"	+0.002"-0.004"	0.035"	±0.002"	0.660"	0.680"
98407A136	0.438"	7/16"	0.343"	+0.003"-0.000"	0.039"	+0.003"-0.000"	0.047"	0.337"	+0.002"-0.004"	0.035"	±0.002"	0.687"	0.710"
98407A138	0.500"	1/2"	0.396"	+0.003"-0.000"	0.046"	+0.003"-0.000"	0.052"	0.392"	+0.002"-0.004"	0.042"	±0.002"	0.800"	0.820"
98407A140	0.625"	5/8"	0.485"	+0.003"-0.000"	0.046"	+0.003"-0.000"	0.070"	0.480"	+0.003"-0.005"	0.042"	±0.002"	0.940"	0.960"
98407A152	0.750"	3/4"	0.625"	+0.003"-0.000"	0.056"	+0.003"-0.000"	0.062"	0.616"	+0.003"-0.005"	0.050"	±0.002"	1.000"	1.020"
98407A154	0.875"	7/8"	0.675"	+0.003"-0.000"	0.056"	+0.003"-0.000"	0.100"	0.668"	+0.003"-0.005"	0.050"	±0.002"	1.300"	1.320"
98407A156	1.000"	1"	0.835"	+0.003"-0.000"	0.056"	+0.003"-0.000"	0.082"	0.822"	+0.003"-0.005"	0.050"	±0.002"	1.500"	1.530"
98407A158	1.188"	1 3/16"	1.079"	+0.005"-0.000"	0.068"	+0.004"-0.000"	0.054"	1.066"	+0.006"-0.010"	0.062"	±0.003"	1.626"	1.670"
98407A160	1.375"	1 3/8"	1.230"	+0.005"-0.000"	0.068"	+0.004"-0.000"	0.072"	1.213"	+0.006"-0.010"	0.062"	±0.003"	1.875"	1.920"

ANSI Roller Chain

About Roller Chain



Roller chain consists of alternating pin links (two pins supported by side plates) and roller links (two rollers on bushings, also supported by side plates). The pins (all of which are riveted, except where noted) pivot inside the bushings. The rollers are free-turning to provide rolling contact with sprocket teeth. Chain sizes are distinguished by pitch, the distance between pin centers. Some smaller-pitched roller chain is actually rollerless, and is constructed of pins and bushings only. Use roller chain and sprockets with the same ANSI No. (For sprockets, see pages 892-897.)

Working load is the maximum load capacity that can be applied to the chain under normal operating conditions. ***Average tensile strength*** is the average load capacity at which the chain will break.

Extra Chain Links

Connecting Link Single-Strand · *Connecting Link Double-Strand* · *Roller Link Single-Strand* · *Roller Link Double-Strand* · *Offset Link Single-Strand* · *Offset Link Double-Strand*

Connecting Link—A special pin link that's easily disassembled: use to join the ends of a length of chain to make a continuous strand and to splice lengths together.

Roller Link—Add to chain to lengthen it. *Note:* Roller links for multi-strand chain are single links placed side-by-side.

Offset Link—A combination of a pin link and roller link. Standard chain has an even number of pitches; use an offset link to make a strand with an odd number of pitches.

Steel Roller Chain

Single Strand Riveted Roller Chain · *Double Strand Riveted Roller Chain* · *Single Strand Cotter-Pin Roller Chain* · *Double Strand Cotter-Pin Roller Chain*

This durable roller chain is the workhorse of drive chain.

All chain is offered in 1-ft. increments up to 10 ft., as well as in 20-, 50-, and 100-ft. lengths (except for the heavy single-strand chain which is not available in 100-ft. lengths). The 1-ft. through 20-ft. lengths include one connecting link. 50-ft. lengths include five connecting links, and 100-ft. lengths include 10 connecting links.

Heavy single-strand riveted roller chain has thick side plates that provide a higher load capacity.

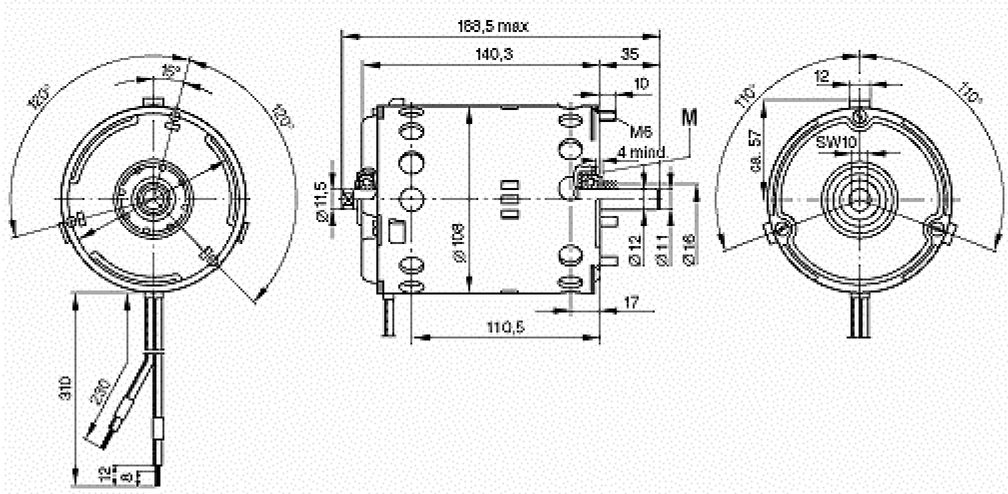
Cotter-pin roller chain has a cotter-pin construction that makes assembly and disassembly in the field easier than with riveted chain.

ANSI No.	Pitch (A)	Roller Dia. (B)	Roller Wd. (C)	Max. Working Load, lbs.	Average Tensile Strength, lbs.	ROLLER CHAIN	Per Ft. 1-9	Per Ft. 10-Up	EXTRA CHAIN LINKS: Connecting	Each	Roller	Each	Offset	Each
Riveted Roller Chain														
Single Strand														
25♦	1/4"	0.130"	1/8"	140	1,050	6261K107	$3.05	$2.54	6261K108	$0.66	6261K106	$0.40	6261K105	$1.38
35♦	3/8"	0.200"	3/16"	480	2,400	6261K531	2.56	2.11	6261K191	.55	6261K241	.45	6261K261	1.21
41•	1/2"	0.306"	1/4"	500	2,600	6261K532	2.72	2.27	6261K192	.85	6261K242	.51	6261K262	1.68
40	1/2"	0.312"	5/16"	810	4,300	6261K533	2.97	2.46	6261K193	.62	6261K243	.51	6261K263	1.36
50	5/8"	0.400"	3/8"	1,400	7,200	6261K534	3.81	3.07	6261K194	.72	6261K244	.72	6261K264	1.64
60	3/4"	0.469"	1/2"	1,950	10,000	6261K535	4.92	4.13	6261K195	.98	6261K245	1.02	6261K265	2.26
80	1"	0.625"	5/8"	3,300	17,700	6261K536	8.92	8.11	6261K196	1.74	6261K246	1.77	6261K266	3.60
100	1 1/4"	0.750"	3/4"	5,060	26,200	6261K137	14.73	13.35	6261K181	2.62	6261K211	2.87	6261K271	6.04
120	1 1/2"	0.875"	1"	6,800	37,700	6261K138	21.55	19.60	6261K182	4.28	6261K212	4.89	6261K272	9.34
140	1 3/4"	1.000"	1"	9,000	48,800	6261K139	26.35	23.95	6261K183	5.72	6261K213	7.43	6261K273	12.85
160	2"	1.125"	1 1/4"	11,900	62,200	6261K141	32.12	29.19	6261K184	8.00	6261K214	10.49	6261K274	17.77
Double Strand														
35-2♦	3/8"	0.200"	3/16"	810	4,800	6261K711	7.06	6.40	6261K221	1.45	6261K831	.93	6261K841	3.18
40-2	1/2"	0.312"	5/16"	1,370	8,600	6261K712	7.56	6.87	6261K223	1.51	6261K832	1.07	6261K842	3.33
50-2	5/8"	0.400"	3/8"	2,380	14,400	6261K713	9.90	9.00	6261K224	1.66	6261K833	1.51	6261K843	3.98
60-2	3/4"	0.469"	1/2"	3,315	20,000	6261K714	13.33	12.09	6261K225	2.32	6261K834	2.13	6261K844	5.60
80-2	1"	0.625"	5/8"	5,610	35,400	6261K715	21.47	19.50	6261K226	3.43	6261K835	3.69	6261K845	8.78
100-2	1 1/4"	0.750"	3/4"	8,600	52,400	6261K91	35.16	29.37	6261K922	6.53	6261K924	6.00	6261K923	15.31
Triple Strand														
40-3R	1/2"	0.312"	5/16"	2,025	12,900	6261K74	14.18	11.95	6261K752	2.58	6261K754	1.60	6261K753	5.31
50-3R	5/8"	0.400"	3/8"	3,500	21,600	6261K76	16.79	14.13	6261K722	2.80	6261K724	2.27	6261K723	6.22
60-3R	3/4"	0.469"	1/2"	4,875	30,000	6261K78	23.06	19.42	6261K762	3.84	6261K764	3.20	6261K763	8.64
80-3R	1"	0.625"	5/8"	8,250	53,100	6261K79	34.54	29.08	6261K717	6.02	6261K719	5.53	6261K718	13.69
Heavy Single Strand														
50H	5/8"	0.400"	3/8"	1,400	7,800	7265K4	8.60	7.12	7265K424	1.58	7265K426	1.38	7265K425	3.38
60H	3/4"	0.469"	1/2"	2,000	12,300	7265K5	7.12	5.89	7265K524	1.44	7265K526	1.31	7265K525	3.11
80H	1"	0.625"	5/8"	3,400	20,200	7265K6	12.04	9.96	7265K624	2.20	7265K626	2.20	7265K625	4.87
100H	1 1/4"	0.750"	3/4"	5,200	30,800	7265K7	19.70	16.31	7265K724	3.93	7265K726	4.44	7265K725	8.24
120H	1 1/2"	0.875"	1"	7,000	41,800	7265K8	28.31	23.43	7265K824	6.07	7265K826	6.64	7265K825	12.73
140H	1 3/4"	1.00"	1"	9,200	54,200	7265K9	34.20	28.31	7265K924	9.69	7265K926	10.20	7265K925	20.36
Cotter-Pin Roller Chain														
Single Strand														
80	1"	0.625"	5/8"	3,300	17,700	2322K1	11.77	10.19	6261K196	1.74	6261K246	1.77	6261K266	3.60
100	1 1/4"	0.750"	3/4"	5,060	26,200	2322K2	17.66	15.30	6261K181	2.62	6261K211	2.87	6261K271	6.04
120	1 1/2"	0.875"	1"	6,800	37,700	2322K3	24.60	21.13	6261K182	4.28	6261K212	4.89	6261K272	9.34
140	1 3/4"	1.000"	1"	9,000	48,800	2322K4	30.34	25.94	6261K183	5.72	6261K213	7.43	6261K273	12.85
160	2"	1.125"	1 1/4"	11,900	62,200	2322K5	38.47	32.66	6261K184	8.00	6261K214	10.49	6261K274	17.77
Double Strand														
80-2	1"	0.625"	5/8"	5,610	35,400	2322K6	26.55	23.15	6261K226	3.43	6261K835	3.69	6261K845	8.78
100-2	1 1/4"	0.750"	3/4"	8,600	52,400	2322K7	40.55	35.06	6261K922	6.53	6261K924	6.00	6261K923	15.31
120-2	1 1/2"	0.875"	1"	11,560	75,400	2322K8	56.94	48.87	2322K21	10.16	6261K212■	4.89	2322K31	22.27
140-2	1 3/4"	1.000"	1"	15,300	97,600	2322K9	69.64	59.38	2322K22	13.82	6261K213■	7.43	2322K32	29.82
160-2	2"	1.125"	1 1/4"	20,230	62,200	2322K11	86.47	73.21	2322K23	19.02	6261K214■	10.49	2322K33	41.25

♦ Rollerless chain. • Has thinner plates than No. 40 and is lighter in weight. ■ Two are required to connect chain.

Warning! ***Do not use the chain on this page for lifting applications or for moving people.***

Motor Schematic



Industrial Speciality Gas Cylinders

Specifications

Sales Part Number	Service Pressure psi	bar	Capacity N_2 cu ft	liters	Capacity O_2 cu ft	liters	Outside Diameter in	mm	Overall Length in	mm	Empty Weight lbs	kg	Min. Internal Volume cu in	liters	Min. Water Weight lbs	kg	Thread Size UNF
M004	2216	153	3.7	103.4	4.0	114.1	3.21	81.41	9.0	228.6	1.9	0.8	43	0.7	1.53	0.70	0.750-16 UNF-2B
M006	2216	153	5.3	150.7	5.8	164.5	3.21	81.41	11.8	299.0	2.2	1.0	62	1.0	2.24	1.01	0.750-16 UNF-2B
M007	2015	139	6.8	193.7	7.4	209.6	4.38	111.13	9.2	233.2	3.0	1.4	87	1.4	3.14	1.42	0.750-16 UNF-2B
M009	2015	139	8.1	229.4	8.8	249.4	4.38	111.13	10.6	269.9	3.7	1.7	103	1.7	3.71	1.68	0.750-16 UNF-2B
M011	2015	139	10.9	307.5	11.7	332.5	4.38	111.13	13.8	350.8	4.7	2.1	136	2.3	4.98	2.26	0.750-16 UNF-2B
M022	2216	153	20.9	591.9	22.9	647.1	5.25	133.35	17.1	435.1	8.8	4.0	244	4.0	8.80	3.99	0.750-16 UNF-2B, 0.750-14 NGT, 1.125-12 UNF-2B
M027	2216	153	25.3	716.5	27.6	782.2	5.25	133.35	20.2	513.5	10.4	4.7	295	4.8	10.64	4.83	1.125-12 UNF-2B
M033	2216	153	30.9	875.1	33.7	954.4	6.89	175.01	15.6	396.9	14.5	6.6	360	5.9	12.98	5.89	0.750-16 UNF-2B, 0.750-14 NGT, 1.125-12 UNF-2B
M042	2216	153	44.2	1252.0	48.2	1365.6	5.25	133.35	33.1	841.5	16.0	7.2	515	8.4	18.57	8.42	0.750-14 NGT
M060	2216	153	55.8	1580.3	60.9	1723.6	7.25	184.15	23.5	596.9	22.6	10.2	650	10.7	23.44	10.63	0.750-14 NGT, 1.125-12 UNF-2B, M25 x 2
M089	2216	153	82.4	2333.6	89.9	2545.7	7.25	184.15	32.9	835.0	30.7	13.9	960	15.7	34.62	15.70	0.750-14 NGT, 1.125-12 UNF-2B
M122	2216	153	111.8	3166.0	121.9	3452.5	8.00	203.20	36.3	922.3	40.0	18.1	1302	21.3	46.96	21.30	0.750-14 NGT, 1.125-12 UNF-2B
M150	2015	139	141.5	4007.6	153.2	4338.3	8.00	203.20	47.8	1214.5	48.1	21.8	1800	29.5	64.91	29.44	0.750-14 NGT, 1.125-12 UNF-2B
M155	1800	124	144.3	4086.6	154.8	4383.4	8.60	218.44	46.3	1176.7	50.6	22.9	2040	33.4	73.56	33.37	1.125-12 UNF-2B
M200	3000	207	179.2	5074.2	200.2	5669.9	8.60	218.44	40.7	1034.5	64.6	29.3	1590	26.1	57.32	26.00	0.750-14 NGT, 1.125-12 UNF-2B
M260	2216	153	243.0	6881.8	265.1	7506.9	9.80	248.92	51.5	1310.0	[illegible]	[illegible]	2831	46.4	102.08	46.30	0.750-14 NGT, 1.125-12 UNF-2B

3016 Kansas Avenue, Riverside, CA 92507 USA,
Tel: (909) 684 5110 or (800) 764 0366 Fax: (909) 781 6598

Luxfer Gas Cylinders

Pilot Operated

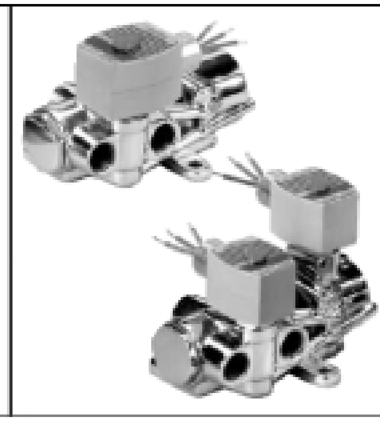
Piston/Poppet Solenoid Valves

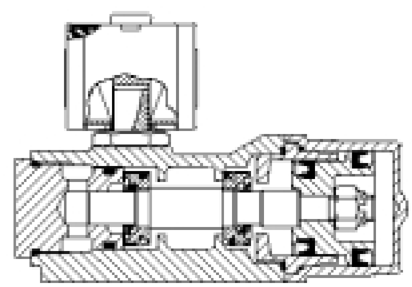
Brass Body • 1/4" to 1" NPT

4/2 SERIES 8344

Features

- Sturdy, solid construction.
- Piston-operated poppet design provides high flow.
- Can use air or water for piloting control valves.
- Wide range of sizes and flow rates.
- Single or dual solenoid construction.
- Dual solenoid can be shifted with a momentary signal and remain in position even if electrical power is lost.
- Mountable in any position.





Construction

Valve Parts in Contact with Fluids	
Body	Brass
Seals and Disc	NBR
Core Tube	305 Stainless Steel
Core and Plugnut	430F Stainless Steel
Springs	302 Stainless Steel and 17-7PH Stainless Steel
Shading Coil	Copper
Pilot Seat Cartridge and Disc-Holder	CA
Shaft Gasket	Lead/Copper

Electrical

Standard Coil and Class of Insulation	Watt Rating and Power Consumption				Spare Coil Part No.			
	DC	AC			General Purpose		Explosionproof	
	DC Watts	Watts	VA Holding	VA Inrush				
F	10.6	6.1	16	30	238210	238310	238214	238314
F	11.6	10.1	25	50	238610	238710	238614	238714
F	22.6	17.1	40	70	238610	238710	238614	238714

Dual Solenoid Operation: Minimum coil on-time for dual solenoid valves is 0.3 seconds on air service and 1.0 seconds on liquids.

Caution: Do not energize both solenoids simultaneously.
Refer to Engineering Section for details.

Standard Voltages: 24, 120, 240, 480 volts AC, 60 Hz (or 110, 220 volts AC, 50 Hz). 6, 12, 24, 120, 240 volts DC. Must be specified when ordering. Other voltages are available when required.

Solenoid Enclosures

Standard: Watertight, Types 1, 2, 3, 3S, 4, and 4X.
Optional: Explosionproof and Watertight, Types 3, 3S, 4, 4X, 6, 6P, 7, and 9. (To order, add prefix "EF" to the catalog number.)
See Optional Features Section for other available options.

Nominal Ambient Temperature Ranges:

AC: 32°F to 125°F (0°C to 52°C)
DC: 32°F to 104°F (0°C to 40°C)
Refer to Engineering Section for details.

Approvals:

CSA certified. Meets applicable CE directives.

Important:

A Minimum Operating Pressure Differential must be maintained between the pressure and exhaust ports. Supply and exhaust piping must be full area, unrestricted. ASCO flow controls and other similar components must be installed in the cylinder lines only.

4.07

SERIES
8344

ASCO®

Specifications (English units)

Pipe Size (ins.)	Orifice Size (ins.)	Cv Flow Factor Press.	Cv Flow Factor Exh.	Operating Pressure Differential (psi) ① Min.	Max. AC Air-Inert Gas	Max. AC Water	Max. AC Lt. Oil @ 300 SSU	Max. DC Air-Inert Gas	Max. DC Water	Max. DC Lt. Oil @ 300 SSU	Max. Fluid Temp. °F AC	Max. Fluid Temp. °F DC	Brass Body Catalog Number	Brass Body Constr. Ref. No.	Watt Rating/Class of Coil Insulation AC	Watt Rating/Class of Coil Insulation DC
SINGLE SOLENOID																
1/4	1/4	.80	1.0	10	150	125	125	125	125	125	180	150	8344G70	1	10.1/F	11.6/F
1/4	1/4	.80	1.0	10	250 ②	250 ②	250 ②	250 ②	250 ②	250 ②	180	180	8344G0	1	17.1/F	22.6/F
3/8	3/8	1.4	2.2	10	150	125	125	125	125	125	180	150	8344G72	2	10.1/F	11.6/F
3/8	1/4	.80	1.0	10	250 ②	250 ②	250 ②	250 ②	250 ②	250 ②	180	180	8344G1	1	17.1/F	22.6/F
1/2	3/8	1.4	2.2	10	150	125	125	125	125	125	180	150	8344G74	2	10.1/F	11.6/F
1/2	3/8	1.4	2.2	10	250 ②	250 ②	250 ②	250 ②	250 ②	250 ②	180	180	8344G27	2	17.1/F	22.6/F
3/4	3/4	5.2	5.6	10	150	125	125	125	125	125	180	150	8344G76	3	10.1/F	11.6/F
3/4	3/4	5.2	5.6	10	250 ②	250 ②	250 ②	250 ②	250 ②	250 ②	180	180	8344G29	3	17.1/F	22.6/F
1	3/4	5.2	5.6	10	150	125	125	125	125	125	180	150	8344G78	3	10.1/F	11.6/F
1	3/4	5.2	5.6	10	250 ②	250 ②	250 ②	250 ②	250 ②	250 ②	180	180	8344G31	3	17.1/F	22.6/F
DUAL SOLENOID ③																
1/4	1/4	.80	1.0	10	250	200	125	125	125	100	180	120	8344G44	4	6.1/F	10.6/F
3/8	3/8	1.4	2.2	10	250	200	125	125	125	100	180	120	8344G80	6	6.1/F	10.6/F
3/8	3/8	1.4	2.2	10	300	300	200	-	-	-	180	-	8344G50	7	10.1/F	-
1/2	3/8	1.4	2.2	10	250	200	125	125	125	100	180	120	8344G82	6	6.1/F	10.6/F
3/4	3/4	5.2	5.6	10	300	300	200	125	125	100	180	120	8344G84	8	10.1/F	10.6/F
1	3/4	5.2	5.6	10	300	300	200	125	125	100	180	120	8344G86	8	10.1/F	10.6/F

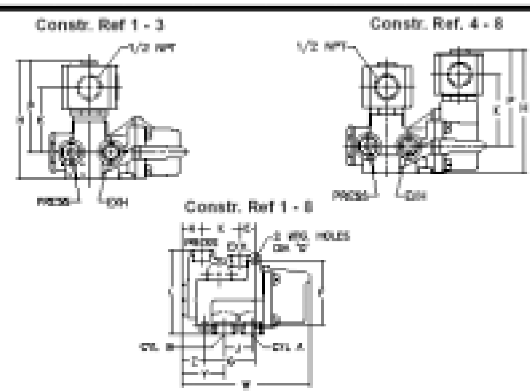
Notes: ① 25 psi (1.7 bar) minimum on light oil service. ③ On 50 hertz service, the watt rating for the 6.1/F solenoid is 8.1 watts.
② For best results, do not use valve rated 250 psi (17 bar) on mainline pressure of less than 125 psi (9 bar).

Specifications (Metric units)

Pipe Size (ins.)	Orifice Size (mm)	Kv Flow Factor (m3/h) Press.	Kv Flow Factor (m3/h) Exh.	Operating Pressure Differential (bar) ① Min.	Max. AC Air-Inert Gas	Max. AC Water	Max. AC Lt. Oil @ 300 SSU	Max. DC Air-Inert Gas	Max. DC Water	Max. DC Lt. Oil @ 300 SSU	Max. Fluid Temp. °C AC	Max. Fluid Temp. °C DC	Brass Body Catalog Number	Brass Body Constr. Ref. No.	Watt Rating / Class of Coil Insulation AC	Watt Rating / Class of Coil Insulation DC
SINGLE SOLENOID																
1/4	6	.69	.86	0.7	10	9	9	9	9	9	81	65	8344G70	1	10.1/F	11.6/F
1/4	6	.69	.86	0.7	17 ②	17 ②	17 ②	17 ②	17 ②	17 ②	81	81	8344G0	1	17.1/F	22.6/F
3/8	10	1.2	1.89	0.7	10	9	9	9	9	9	81	65	8344G72	2	10.1/F	11.6/F
3/8	6	.69	.86	0.7	17 ②	17 ②	17 ②	17 ②	17 ②	17 ②	81	81	8344G1	1	17.1/F	22.6/F
1/2	10	1.2	1.89	0.7	10	9	9	9	9	9	81	65	8344G74	2	10.1/F	11.6/F
1/2	10	1.2	1.89	0.7	17 ②	17 ②	17 ②	17 ②	17 ②	17 ②	81	81	8344G27	2	17.1/F	22.6/F
3/4	19	4.5	4.80	0.7	10	9	9	9	9	9	81	65	8344G76	3	10.1/F	11.6/F
3/4	19	4.5	4.80	0.7	17 ②	17 ②	17 ②	17 ②	17 ②	17 ②	81	81	8344G29	3	17.1/F	22.6/F
1	19	4.5	4.80	0.7	10	9	9	9	9	9	81	65	8344G78	3	10.1/F	11.6/F
1	19	4.5	4.80	0.7	17 ②	17 ②	17 ②	17 ②	17 ②	17 ②	81	81	8344G31	3	17.1/F	22.6/F
DUAL SOLENOID ③																
1/4	6	.69	.86	0.7	17	14	9	9	9	7	81	48	8344G44	4	6.1/F	10.6/F
3/8	10	1.2	1.89	0.7	17	14	9	9	9	7	81	48	8344G80	6	6.1/F	10.6/F
3/8	10	1.2	1.89	0.7	21	21	14	-	-	-	81	-	8344G50	7	10.1/F	-
1/2	10	1.2	1.89	0.7	17	14	9	9	9	7	81	48	8344G82	6	6.1/F	10.6/F
3/4	19	4.5	4.80	0.7	21	21	14	9	9	7	81	48	8344G84	8	10.1/F	10.6/F
1	19	4.5	4.80	0.7	21	21	14	9	9	7	81	48	8344G86	8	10.1/F	10.6/F

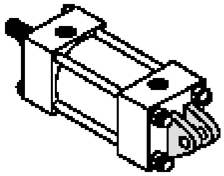
Dimensions: inches (mm)

Constr. Ref. No.		ØD	E	F	G	H	J	K	L	N	P	W	X	Y	Z	Exhaust Pipe Size
1	ins.	Ø.28	.56	2.41	1.88	4.09	1.03	2.15	3.13	.72	3.12	4.75	1.41	1.56	.81	3/8
	mm	Ø7.1	14	61	48	104	26	55	80	18	79	121	36	40	21	3/8
2	ins.	Ø.34	.75	3.12	2.63	4.06	1.50	1.97	3.18	.83	2.94	6.06	1.88	1.90	.84	1/2
	mm	Ø8.6	19	79	67	103	38	50	81	21	75	154	47	48	21	1/2
3	ins.	Ø.34	1.24	3.81	3.88	4.86	2.09	2.34	4.56	1.50	3.31	8.25	2.13	2.63	1.16	1
	mm	Ø8.6	34	97	99	123	53	59	116	38	84	210	54	67	30	1
4	ins.	Ø.28	.56	2.41	1.88	4.34	1.03	2.52	3.13	.72	3.38	4.81	1.41	1.56	.81	3/8
	mm	Ø7.1	14	61	48	110	26	64	80	18	86	122	36	40	21	3/8
6	ins.	Ø.34	.75	3.12	2.63	4.50	1.50	2.52	3.18	.83	3.38	6.06	1.88	1.90	.84	1/2
	mm	Ø8.6	19	79	67	114	38	64	81	21	86	154	47	48	21	1/2
7	ins.	Ø.34	.75	3.12	2.63	4.69	1.50	2.59	3.18	.83	3.56	6.06	1.88	1.90	.84	1/2
	mm	Ø8.6	19	79	67	119	38	66	81	21	90	154	47	48	21	1/2
8	ins.	Ø.34	1.24	3.81	3.88	5.56	2.09	3.03	4.56	1.50	4.00	8.25	2.13	2.63	1.16	1
	mm	Ø8.6	34	97	99	141	53	77	116	38	102	210	54	67	30	1



4.08

Code 10 Fixed Clevis
(MP1)

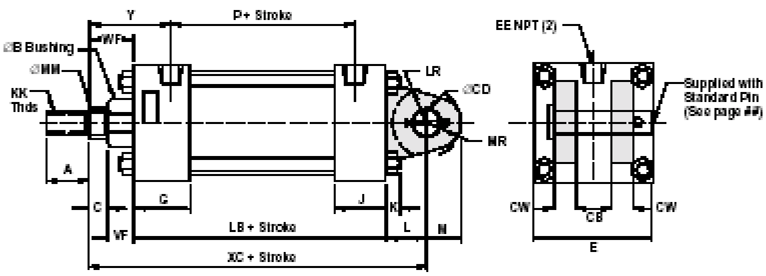


These mounts can be used both in compression (push) and tension (pull). Care must be exercised to prevent rod buckling in compression applications with long strokes.

NOTE

For strokes in excess of 30 inches, see "Stop Tube Selection" on page 45.

The centerline of the machine member that attaches to the swivel pin must be perpendicular to the centerline of the piston rod and the curved path must be in one place only. Any misalignment will cause excess side loading on the bearing and piston. This could lead to premature failure.



Dimension		1½" Bore (38.10)	2" Bore (50.80)	2½" Bore (63.50)	3¼" Bore (82.55)	4" Bore (101.60)	5" Bore (127.00)	6" Bore (152.40)	7" Bore (177.80)	8" Bore (203.20)
ØRod	Std.	5/8" (15.88)	5/8" (15.88)	5/8" (15.88)	1" (25.40)	1" (25.40)	1" (25.40)	1-3/8" (34.93)	1-3/8" (34.93)	1-3/8" (34.93)
	O.S.	1" (25.40)	1" (25.40)	1" (25.40)	1-3/8" (34.93)	1-3/8" (34.93)	1-3/8" (34.93)	1-3/4" (44.45)	1-3/4" (44.45)	1-3/4" (44.45)
A	Std.	.750 (19.05)	.750 (19.05)	.750 (19.05)	1.125 (28.58)	1.125 (28.58)	1.125 (28.58)	1.625 (41.28)	1.625 (41.28)	1.625 (41.28)
	O.S.	1.125 (28.58)	1.125 (28.58)	1.125 (28.58)	1.625 (41.28)	1.625 (41.28)	1.625 (41.28)	2.000 (50.80)	2.000 (50.80)	2.000 (50.80)
B $^{+.000}_{-.002}$	Std.	1.124 (28.55)	1.124 (28.55)	1.124 (28.55)	1.499 (38.08)	1.499 (38.08)	1.499 (38.08)	1.999 (50.78)	1.999 (50.78)	1.999 (50.78)
	O.S.	1.499 (38.08)	1.499 (38.08)	1.499 (38.08)	1.999 (50.78)	1.999 (50.78)	1.999 (50.78)	2.374 (60.30)	2.374 (60.30)	2.374 (60.30)
C	Std.	.375 (9.53)	.375 (9.53)	.375 (9.53)	.500 (12.70)	.500 (12.70)	.500 (12.70)	.625 (15.88)	.625 (15.88)	.625 (15.88)
	O.S.	.500 (12.70)	.500 (12.70)	.500 (12.70)	.625 (15.88)	.625 (15.88)	.625 (15.88)	.750 (19.05)	.750 (19.05)	.750 (19.05)
CB		.750 (19.05)	.750 (19.05)	.750 (19.05)	1.250 (31.75)	1.250 (31.75)	1.250 (31.75)	1.500 (38.10)	1.500 (38.10)	1.500 (38.10)
CC	Std.	1/2 – 20	1/2 – 20	1/2 – 20	7/8 – 14	7/8 – 14	7/8 – 14	1-1/4 – 12	1-1/4 – 12	1-1/4 – 12
	O.S.	7/8 – 14	7/8 – 14	7/8 – 14	1-1/4 – 12	1-1/4 – 12	1-1/4 – 12	1-1/2 – 12	1-1/2 – 12	1-1/2 – 12
CD		.500 (12.70)	.500 (12.70)	.500 (12.70)	.750 (19.05)	.750 (19.05)	.750 (19.05)	1.000 (25.40)	1.000 (25.40)	1.000 (25.40)
CW		.500 (12.70)	.500 (12.70)	.500 (12.70)	.625 (15.88)	.625 (15.88)	.625 (15.88)	.750 (19.05)	.750 (19.05)	.750 (19.05)
D	Std.	.500 (12.70)	.500 (12.70)	.500 (12.70)	.813 (12.70)	.813 (12.70)	.813 (12.70)	1.125 (15.88)	1.125 (15.88)	1.125 (15.88)
	O.S.	.813 (20.64)	.813 (20.64)	.813 (20.64)	1.125 (28.58)	1.125 (28.58)	1.125 (28.58)	1.500 (38.10)	1.500 (38.10)	1.500 (38.10)
E		2.000 (50.80)	2.500 (63.50)	3.000 (76.20)	3.750 (95.25)	4.500 (114.30)	5.500 (139.70)	6.500 (165.10)	7.500 (190.50)	8.500 (215.90)
EE		.375 (9.53)	.375 (9.53)	.375 (9.53)	.500 (12.70)	.500 (12.70)	.500 (12.70)	.750 (19.05)	.750 (19.05)	.750 (19.05)
FF	Std.	5/8 – 18	5/8 – 18	5/8 – 18	1 – 14	1 – 14	1 – 14	1-3/8 – 12	1-3/8 – 12	1-3/8 – 12
	O.S.	1 – 14	1 – 14	1 – 14	1-3/8 – 12	1-3/8 – 12	1-3/8 – 12	1-3/4 – 12	1-3/4 – 12	1-3/4 – 12
G		1.500 (38.10)	1.500 (38.10)	1.500 (38.10)	1.750 (44.45)	1.750 (44.45)	1.750 (44.45)	2.000 (50.80)	2.000 (50.80)	2.000 (50.80)
J		1.000 (25.40)	1.000 (25.40)	1.000 (25.40)	1.250 (31.75)	1.250 (31.75)	1.250 (31.75)	1.500 (38.10)	1.500 (38.10)	1.500 (38.10)
KK	Std.	7/16 – 20	7/16 – 20	7/16 – 20	3/4 – 16	3/4 – 16	3/4 – 16	1 – 14	1 – 14	1 – 14
	O.S.	3/4 – 16	3/4 – 16	3/4 – 16	1 – 14	1 – 14	1 – 14	1-1/4 – 12	1-1/4 – 12	1-1/4 – 12
L		.750 (19.05)	.750 (19.05)	.750 (19.05)	1.250 (31.75)	1.250 (31.75)	1.250 (31.75)	1.500 (38.10)	1.500 (38.10)	1.500 (38.10)
LB		3.625 (92.08)	3.625 (92.08)	3.750 (95.25)	4.250 (107.95)	4.250 (107.95)	4.500 (114.30)	5.000 (127.00)	5.125 (130.18)	5.125 (130.18)
LR		.750 (19.05)	.750 (19.05)	.750 (19.05)	1.250 (31.75)	1.250 (31.75)	1.250 (31.75)	1.500 (38.10)	1.500 (38.10)	1.500 (38.10)
M		.500 (12.70)	.500 (12.70)	.500 (12.70)	.750 (19.05)	.750 (19.05)	.750 (19.05)	1.000 (25.40)	1.000 (25.40)	1.000 (25.40)
MM	Std.	.625 (15.88)	.625 (15.88)	.625 (15.88)	1.000 (25.40)	1.000 (25.40)	1.000 (25.40)	1.375 (34.93)	1.375 (34.93)	1.375 (34.93)
	O.S.	1.000 (25.40)	1.000 (25.40)	1.000 (25.40)	1.375 (34.93)	1.375 (34.93)	1.375 (34.93)	1.750 (44.45)	1.750 (44.45)	1.750 (44.45)
MR		.625 (15.88)	.625 (15.88)	.625 (15.88)	.938 (23.81)	.938 (23.81)	.938 (23.81)	1.188 (30.16)	1.188 (30.16)	1.188 (30.16)
P		2.313 (58.74)	2.313 (58.74)	2.438 (61.91)	2.625 (66.68)	2.625 (66.68)	2.875 (73.03)	3.125 (79.38)	3.250 (82.55)	3.250 (82.55)
VF	Std.	.625 (15.88)	.625 (15.88)	.625 (15.88)	.875 (22.23)	.875 (22.23)	.875 (22.23)	1.000 (25.40)	1.000 (25.40)	1.000 (25.40)
	O.S.	.875 (22.23)	.875 (22.23)	.875 (22.23)	1.000 (25.40)	1.000 (25.40)	1.000 (25.40)	1.125 (28.58)	1.125 (28.58)	1.125 (28.58)
WF	Std.	1.000 (25.40)	1.000 (25.40)	1.000 (25.40)	1.375 (34.93)	1.375 (34.93)	1.375 (34.93)	1.625 (41.28)	1.625 (41.28)	1.625 (41.28)
	O.S.	1.375 (34.93)	1.375 (34.93)	1.375 (34.93)	1.625 (41.28)	1.625 (41.28)	1.625 (41.28)	1.875 (47.63)	1.875 (47.63)	1.875 (47.63)
XC	Std.	5.375 (136.53)	5.375 (136.53)	5.500 (139.70)	6.875 (174.63)	6.875 (174.63)	7.125 (180.98)	8.125 (206.38)	8.250 (209.55)	8.250 (209.55)
	O.S.	5.750 (146.05)	5.750 (146.05)	5.875 (149.23)	7.125 (180.98)	7.125 (180.98)	7.375 (187.33)	8.375 (212.73)	8.500 (215.90)	8.500 (215.90)
Y	Std.	1.875 (47.63)	1.875 (47.63)	1.875 (47.63)	2.438 (61.91)	2.438 (61.91)	2.438 (61.91)	2.813 (71.44)	2.813 (71.44)	2.813 (71.44)
	O.S.	2.250 (57.15)	2.250 (57.15)	2.250 (57.15)	2.688 (68.26)	2.688 (68.26)	2.688 (68.26)	3.063 (77.79)	3.063 (77.79)	3.063 (77.79)

All dimensions in inches (mm)

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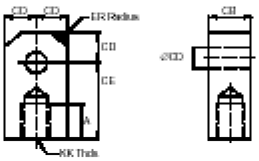
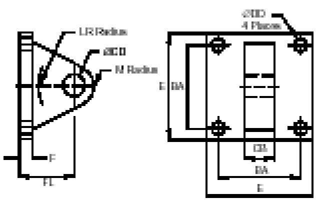
NFPA Rod Eye



	VP60008A	VP60008C	VP6000CA	VP60010A	VP60016A
CB	.750 (19.05)	.750 (19.05)	1.250 (31.75)	1.500 (38.10)	2.000 (50.80)
CD	.500 (12.70)	.500 (12.70)	.750 (19.05)	1.000 (25.40)	1.375 (60.33)
CE	1.500 (38.10)	1.500 (38.10)	2.375 (60.33)	3.125 (79.38)	4.125 (104.78)
ER	.5]	.500 (12.70)	.750 (19.05)	1.000 (25.40)	1.375 (60.33)
L	.750 (19.05)	.750 (19.05)	1.250 (31.75)	1.500 (38.10)	2.125 (53.98)

NFPA Eye Bracket



	VP62008A	VP62008B	VP6200CA	VP62010A
BA	1.625 (41.28)	2.562 (65.07)	3.250 (82.55)	3.812 (96.82)
CB	.750 (19.05)	1.250 (31.75)	1.500 (38.10)	2.000 (50.80)
CD	.500 (12.70)	.750 (19.05)	1.000 (25.40)	1.375 (60.33)
DD	.406 (10.31)	.531 (13.49)	.656 (16.66)	.656 (16.66)
E	2.500 (63.50)	3.500 (88.90)	4.500 (114.30)	5.000 (127.00)
F	.375 (9.53)	.625 (15.88)	.750 (19.05)	.875 (22.23)
FL	1.125 (28.58)	1.875 (47.63)	2.250 (57.15)	3.000 (76.20)
LR	.750 (19.05)	1.250 (31.75)	1.500 (38.10)	2.125 (53.98)

Cylinder Force and Volume Charts

Extend Forces in pounds (newtons)

Bore	Piston Area in^2 (cm^2)	psi (bar)						Vol. Cu. Ft. (cm^3) **Displacement** Per Stroke Inch
		40 (3)	60 (4)	80 (6)	100 (7)	150 (10)	200 (14)	
$1^1/_2$"	1.77 (11.40)	71 (315)	106 (472)	142 (629)	177 (786)	266 (1179)	353 (1570)	.00102 (29)
2"	3.14 (20.27)	126 (559)	189 (839)	251 (1119)	314 (1398)	471 (2097)	628 (2793)	.00182 (52)
$2^1/_2$"	4.91 (31.67)	196 (874)	295 (1311)	393 (1748)	491 (2185)	737 (3277)	982 (4368)	.00284 (80)
$3^1/_4$"	8.30 (53.32)	332 (1477)	498 (2215)	664 (2953)	830 (3692)	1245 (5538)	1659 (7379)	.00480 (136)
4"	12.57 (81.07)	503 (2237)	754 (3355)	1005 (4473)	1257 (5592)	1886 (8388)	2513 (11178)	.00727 (206)
5"	19.64 (126.71)	785 (3491)	1178 (5240)	1571 (6988)	1964 (8736)	2946 (13104)	3928 (17472)	.01137 (322)
6"	28.27 (182.39)	1130 (5026)	1696 (7544)	2262 (10061)	2827 (12574)	4240 (18860)	5654 (25149)	.01837 (520)
8"	50.26 (324.26)	2010 (8940)	3015 (13411)	4020 (17881)	5026 (22356)	7539 (33533)	10052 (44711)	.02227 (631)

Deduct these Forces for Retract Strokes

Bore	Piston Area in^2 (cm^2)	psi (bar)						Vol. Cu. Ft. (cm^3) **Displacement** Per Stroke Inch
		40 (3)	60 (4)	80 (6)	100 (7)	150 (10)	200 (14)	
$^5/_8$"	.307 (1.98)	12 (53)	18 (80)	25 (111)	31 (138)	46 (205)	61 (271)	.00018 (5)
1"	.785 (5.06)	31 (138)	47 (209)	63 (280)	70 (351)	118 (525)	157 (698)	.00045 (13)
$1^3/_8$"	1.485 (9.58)	59 (262)	89 (396)	119 (529)	118 (525)	222 (997)	297 (1321)	.00086 (24)
$1^3/_4$"	2.404 (15.51)	95 (423)	144 (641)	192 (854)	240 (1068)	360 (1601)	480 (2135)	.00139 (39)