Shock Absorbing Motocross Handlebar Mount

by

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ABSTRACT

Motocross athletes are in very good shape and require high fitness levels in order to compete. Countless hours are spent training and preparing for their races. All this training and preparation can be wasted if the rider is unable to hold on to the motorcycle. This is a common problem for riders who can develop a symptom known as “arm pump” and struggle to hold on. Arm pump is lactic acid buildup in the forearms caused by the rider holding on too tightly to the handlebar. The current handlebar mounts are very rigid and transmit the shock not absorbed by the front suspension of the bike through the handlebar to the rider making it hard for the rider to hold on while riding over rough terrain.

By utilizing customer feedback various concepts were evaluated. The new design focused on building more absorption into the handlebar mount to lessen the amount of shock that is transmitted to the rider and help to reduce “arm pump.” The prototype was designed, built and tested in the following project. The testing results proved that the design works to reduce the amount of shock transmitted through the handlebar therefore helping to reduce “arm pump”.
TABLE OF CONTENTS

ABSTRACT ............................................................................................................................... I

TABLE OF CONTENTS .......................................................................................................... II

LIST OF FIGURES ................................................................................................................ III

LIST OF TABLES .................................................................................................................. III

PROBLEM STATEMENT AND RESEARCH ....................................................................... 1

  BACKGROUND AND PROBLEM STATEMENT................................................................. 1
  RESEARCH, TECHNOLOGY AND EXISTING PRODUCTS................................................. 3

CUSTOMER FEEDBACK, FEATURES AND OBJECTIVES .............................................. 7

  SURVEY ANALYSIS ........................................................................................................... 7
  PRODUCT FEATURES AND OBJECTIVES ......................................................................... 10

DESIGN ALTERNATIVES AND SELECTION .................................................................. 11

  ALTERNATIVE DESIGN # 1 ............................................................................................. 11
  ALTERNATIVE DESIGN # 2 ............................................................................................. 12
  ALTERNATIVE DESIGN # 3 ............................................................................................. 13
  SELECTION OF PREFERRED DESIGN ........................................................................... 14

CALCULATIONS .................................................................................................................. 15

  CALCULATING THE LOADING FORCE ON THE TOP PLATE ........................................ 15
  DETERMINING THE SPRING RATES ............................................................................... 18

COMPONENT SELECTION ................................................................................................. 18

FABRICATION AND ASSEMBLY .................................................................................. 19

  FABRICATION .................................................................................................................. 19
  ASSEMBLY ......................................................................................................................... 20

TESTING AND PROOF OF DESIGN .................................................................................. 21

  TESTING METHODS ......................................................................................................... 21
  TESTING RESULTS AND PROOF OF DESIGN ............................................................... 23
  RECOMMENDATIONS ...................................................................................................... 25
  PROOF OF DESIGN .......................................................................................................... 25

SCHEDULE AND BUDGET ................................................................................................. 26

  SCHEDULE ......................................................................................................................... 26
  BUDGET .............................................................................................................................. 26

BIBLIOGRAPHY ................................................................................................................... 27

APPENDIX A RESEARCH ................................................................................................ A

APPENDIX B SURVEY RESULTS ................................................................................... B

APPENDIX C QFD ............................................................................................................ C

APPENDIX D SCHEDULE ............................................................................................... D

APPENDIX E BUDGET ...................................................................................................... E
LIST OF FIGURES
Figure 1-(Triple Clamp) ........................................................................................................................................ 1
Figure 2-(Motocross Bike) ................................................................................................................................... 2
Figure 3-(Suspension Arm) ................................................................................................................................... 2
Figure 4-(Arm Pump Surgery) .................................................................................................................................. 2
Figure 5-(2004 Stock Yamaha) ................................................................................................................................ 3
Figure 6-(Topar Racing Triple Clamp) .................................................................................................................... 3
Figure 7-(Tag Metals Revolution Clamp) .................................................................................................................. 4
Figure 8-(Pro Taper triple clamp) ............................................................................................................................ 5
Figure 9-(RG3 triple clamp) ....................................................................................................................................... 6
Figure 10-(Hinge Design) .......................................................................................................................................... 11
Figure 11-(Linear Design) .......................................................................................................................................... 12
Figure 12-(Pocket Design) .......................................................................................................................................... 13
Figure 13-(Rider Free Falling) .................................................................................................................................. 16
Figure 14-(Top Clamp Base) .................................................................................................................................... 17
Figure 15-(Top Clamp Base) ...................................................................................................................................... 19
Figure 16-(Mounted on the Bike) ................................................................................................................................ 20
Figure 17-(Accelerometer Testing) .......................................................................................................................... 21
Figure 18-(Rider Test Session) ................................................................................................................................... 22
Figure 19-(HVM Results) ............................................................................................................................................ 23
Figure 20-(Test #2 Results) ........................................................................................................................................ 24

LIST OF TABLES
Table 1-(Customer Importance) ................................................................................................................................. 7
Table 2-(Customer Satisfaction) .................................................................................................................................... 8
Table 3-(Relative Weight from QFD) ........................................................................................................................... 8
Table 4-(Key Characteristics) ......................................................................................................................................... 9
Table 5-(Weighted Decision Matrix) .......................................................................................................................... 14
PROBLEM STATEMENT AND RESEARCH

BACKGROUND AND PROBLEM STATEMENT

The handlebar is the main contact point for the rider. Whatever shock not absorbed by the motorcycle suspension is transmitted through the top triple clamp to the handlebar and then to the rider. The triple clamp is used to secure the front forks (suspension) to the frame of the motorcycle along with providing a mounting point for the handlebar. (Figure 1) This shock contributes to the fatigue of the rider. A common fatigue that riders face is a problem known as “arm pump”. Arm pump is caused by the buildup of lactic acid in the forearms. This is a result of the rider holding onto the handlebar too tight. Some riders have gone to extreme measures to help eliminate arm pump such as surgery. A rider may not want to go as far as surgery and may opt for aftermarket products claiming to reduce arm pump. Motocross aftermarket companies discovered the triple clamp to be a component that could improve the feel of the motorcycle. The improvements have been minimal but the aftermarket triple clamp has become a popular purchase for the motocross rider who is looking for every advantage.
This design will focus on a triple clamp used on a motocross bike (Figure 2). The focus of this design project is to re-design the top triple clamp so that it lessens the amount of shock transmitted to the rider, reducing rider fatigue and “arm pump”.

Below it can be seen that the arm acts like a shock absorber (Figure 3) and some riders go to the extent of surgery (Figure 4) to alleviate the dreaded symptom known as “arm pump”.

![Motocross Bike](image)

![Triple Clamp](image)

![Suspension Arm](image)

![Arm Pump Surgery](image)
RESEARCH, TECHNOLOGY AND EXISTING PRODUCTS

The 2009 Yamaha YZ250 motocross bike comes stock with a solid mounted triple clamp. (Appendix A9) This triple clamp offers no absorption of any kind, but it does offer different handlebar positions. This is a small improvement over the 2004 YZ250 model which came with a solid mounted triple clamp and did not offer any adjustments (Figure 5).

Some of the aftermarket companies offer triple clamps with their only advantage being the bar adjustment and strength. One of these is the Applied Racing triple clamp (Appendix A6) which is a solid mounted clamp, which comes anodized, has adjustable bar mounts and claims to “provide superior strength” (1). The Topar Racing (Figure 6) triple clamp also offers a solid mounted design with four different bar positions, is anodized and claims to be “among the strongest on the market” (2) These clamps offer no absorption at all.
The next group of triple clamps incorporates an absorption system of some kind and recognizes this as an issue. The Tag Metals Revolution clamp (Figure 7) offers an innovative design using rubber mounts. The clamp comes in anodized black. The bar mounts are rubber mounted using a rubber bumper which extrudes above and below the triple clamp base. This clamp claims to “significantly improve the riding experience while dampening vibrations and impacts”. (3)

![Figure 7-(Tag Metals Revolution Clamp)](Image)

The Pro Circuit clamp (Appendix A2) also uses a rubber mounted system. This design uses rubber cones that provide some vibration and absorption to the bar mounts. The clamp also comes with metal cones that can replace the rubber cones if the rider wants. This is due to the fact that the rubber mount system is known to allow the handlebars to twist in the clamps in the event of a crash. The Pro Circuit clamp comes in anodized magnesium for a “Factory bike” look.
The Pro Taper triple clamp (Figure 8) offers a rubber mounted design using a “completely re-designed rubber mount system” (4). This system includes 3 durometers of cushions and also offers an aluminum rigid cushion.

![Figure 8-(Pro Taper triple clamp)](image)

The Pro Taper clamp is also very adjustable offering five different bar positions. The clamp comes in a satin black color. The Fly Racing design (Appendix A4) is similar to Pro Taper’s design. This is because the design is Pro Taper’s old design. Fly Racing bought the design from Pro Taper. It includes an elastomer damped top clamp with 3 different damper sets. It is also adjustable and comes black anodized. This clamp is said to “help dampen engine vibrations and reduces the shock from sharp jolts”. (5)
The RG3 triple clamp (Figure 9) is the most popular design. It utilizes a unique four post system that provides all the advantages of a rubber mounted system without the disadvantages. It is used by many Factory race teams. The clamp is used by top riders like Travis Pastrana, Mike Brown, Rodney Smith and Brian Deegan. The clamp claims “such performance benefits as lessened arm fatigue and pump, less transmitted vibration, much less harshness over square edged bumps and fewer hand blisters”. (6)

The existing triple clamps mentioned all offer small improvements over the stock clamp. Some of the designs claim to reduce the shock transmitted to the rider and reduce arm pump but the improvements are very minimal. The current clamps damping systems have very little movement and therefore offer very little in absorption.
CUSTOMER FEEDBACK, FEATURES AND OBJECTIVES

SURVEY ANALYSIS

Twenty five surveys were distributed, and fifteen of these were completed and returned. The surveys were given to a variety of riders including the typical motocross racer, the off-road racer and the just for fun trail rider (See Appendix B for full survey and customer results). The first half of the survey focused on customer importance and asked the surveyed person to rate the importance of each feature on a scale of 1-5 with 5 being the most important. Results are shown below in (Table 1) and have been sorted from most important to least important. It can be seen that reduced shock to rider and decreased arm pump rate as the highest importance.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Question surveyed</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reduced shock to rider</td>
<td>4.6</td>
</tr>
<tr>
<td>2</td>
<td>Decreased arm pump</td>
<td>4.5</td>
</tr>
<tr>
<td>3</td>
<td>Improved feel</td>
<td>4.2</td>
</tr>
<tr>
<td>4</td>
<td>Strength</td>
<td>4.1</td>
</tr>
<tr>
<td>5</td>
<td>Cost</td>
<td>4.0</td>
</tr>
<tr>
<td>6</td>
<td>Anti-twist</td>
<td>3.7</td>
</tr>
<tr>
<td>7</td>
<td>Adjustability</td>
<td>3.5</td>
</tr>
<tr>
<td>8</td>
<td>Easy to install</td>
<td>3.4</td>
</tr>
<tr>
<td>9</td>
<td>Appearance</td>
<td>2.1</td>
</tr>
</tbody>
</table>
The second half of the survey listed the same questions but asked the surveyed person how the current triple clamps available satisfied each feature listed. The satisfaction was ranked on a 1-5 scale with 5 being the most satisfied. Results are shown below in (Table 2) and sorted from least satisfied to most satisfied. It can be seen that the riders were least satisfied with the decreased arm pump and reduced shock to rider offered by the current triple clamp.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Question surveyed</th>
<th>Avg</th>
<th>Planned Satisfaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Decreased arm pump</td>
<td>2.4</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Reduced shock to rider</td>
<td>2.5</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Cost</td>
<td>2.9</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Adjustability</td>
<td>2.9</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Anti-twist</td>
<td>3.1</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Easy to install</td>
<td>3.1</td>
<td>3.1</td>
</tr>
<tr>
<td>7</td>
<td>Improved feel</td>
<td>3.3</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>Appearance</td>
<td>3.5</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>Strength</td>
<td>3.7</td>
<td>4</td>
</tr>
</tbody>
</table>

From the survey results a house of quality (Appendix C) was constructed. In the house of quality a planned satisfaction level (Table 2) was determined for each feature. The house of quality was used to come up with a correlation between the customer importance, current satisfaction and planned satisfaction. The results are displayed as a relative weight (Table 3) and show that reduced shock to rider and decreased arm pump are at the top of the list. This is consistent with the customer importance (Table 1) and customer satisfaction (Table 2) results which also list these features at the top of the list.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Question surveyed</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reduced shock to rider</td>
<td>17%</td>
</tr>
<tr>
<td>2</td>
<td>Decreased arm pump</td>
<td>17%</td>
</tr>
<tr>
<td>3</td>
<td>Improved feel</td>
<td>12%</td>
</tr>
<tr>
<td>4</td>
<td>Anti-twist</td>
<td>11%</td>
</tr>
<tr>
<td>5</td>
<td>Adjustability</td>
<td>11%</td>
</tr>
<tr>
<td>6</td>
<td>Strength</td>
<td>10%</td>
</tr>
<tr>
<td>7</td>
<td>Cost</td>
<td>9%</td>
</tr>
<tr>
<td>8</td>
<td>Easy to install</td>
<td>8%</td>
</tr>
<tr>
<td>9</td>
<td>Appearance</td>
<td>5%</td>
</tr>
</tbody>
</table>
The house of quality (Appendix C) was also used to determine the relative importance of each engineering characteristic. This was done using a strong to weak correlation to rank how each characteristic correlates with each customer feature. The results (Table 4) show that absorption type and amount of absorption are at the top of the list as the most important engineering characteristics.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Engineering Characteristic</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Absorption type</td>
<td>27%</td>
</tr>
<tr>
<td>2</td>
<td>Amount of Absorption</td>
<td>26%</td>
</tr>
<tr>
<td>3</td>
<td>Geometry</td>
<td>14%</td>
</tr>
<tr>
<td>4</td>
<td>Material</td>
<td>11%</td>
</tr>
<tr>
<td>5</td>
<td>Weight</td>
<td>7%</td>
</tr>
<tr>
<td>6</td>
<td>New Hinge Design</td>
<td>5%</td>
</tr>
<tr>
<td>7</td>
<td>Number of Componente</td>
<td>4%</td>
</tr>
<tr>
<td>8</td>
<td>Color</td>
<td>4%</td>
</tr>
<tr>
<td>9</td>
<td>Manufacturability</td>
<td>3%</td>
</tr>
</tbody>
</table>

With this evidence, new design concepts addressed these desirable features as the voice of the customer.
**PRODUCT FEATURES AND OBJECTIVES**

The product objectives come from the list of customer features on the survey (Appendix C). The list below ranks the features in order of customer importance followed in parentheses by the average response for each feature in the customer survey. Below each feature is the method or objective that will be used for the prototype design.

**Reduced shock to rider** (4.6)

a. Springs to absorb shock.
   b. Rubber bumpers to absorb shock.

**Decreased arm pump** (4.5)

a. Bar will move with rider.
   b. Bumpers on both sides of clamp to absorb downward motion as well as upward.

**Improved feel** (4.2)

a. Will aid suspension, eliminating solid mounted handlebar with harsh feeling.
   b. High quality elastomer used to get the correct stiffness.

**Anti twist** (4.1)

a. Design will not allow bar mounts to twist in moderate crashes.

**Adjustability** (4.0)

a. Bar mount will have a stiffness adjustment
   b. Different compounds of rubber bumpers

**Strength** (3.7)

a. Safety factor of 12 (Mott, Mechanics of Materials) will be provided to show that structural components of the attachment will not fail under repeated load.

**Cost** (3.5)

a. Higher end product, justified by outperforming other high end triple clamps. Final product cost less than $400.00.

**Easy to Install** (3.4)

a. Anyone with some mechanical knowledge, less than 1 hr required for assembly
DESIGN ALTERNATIVES AND SELECTION

ALTERNATIVE DESIGN # 1

The first design concept shown in Figure 10 will be referred to as the hinge design. This hinge design would be used in conjunction with rubber and spring bumpers. The bar mount would pivot on the hinge which is towards the back of the clamp. The spring and rubber bumpers would be in the front of the clamp and attached by a bolt that would ride in a clearance hole through the clamp. It seems this design would work quite well but the strength of the hinge is a concern. The attachment of the bolt was also an issue because it would be moving on a tangent to the hinge. This would require making a special bolt and mounting this would be difficult. This could also be accomplished using a straight bolt if the clearance hole in the clamp was large enough for the bolt to clear while pivoting.

Figure 10-(Hinge Design)
**ALTERNATIVE DESIGN # 2**

The second design concept shown below in Figure 11 uses a set of linear bushings that the bar mount will ride in. The design will be used in conjunction with spring and rubber bumpers to incorporate more absorption into the clamp.

![Diagram of Linear Design](image)

Figure 11-(Linear Design)
ALTERNATIVE DESIGN #3

The third design concept shown in Figure 12 would use a recessed pocket in which the bar mount would sit in. In the bottom of this recess springs would be used in the front and back as well as a rubber bottoming plate in the bottom of the pocket.

Figure 12-(Pocket Design)
**Selection of Preferred Design**

The three concepts were evaluated using a weighted decision matrix (Table 5) with a ten-point scale. The scores range from zero being inadequate to nine being excellent. The weighing factors from the nine design criteria were adjusted to total 1.00. The scores given for each criteria were multiplied by the weight factors and then added together to determine the total rating for each concept. The Linear Design (Design #2) was the clear choice as it scored much higher. This design will offer the most absorption of all the designs. It will also be strong and provide a positive feel at the handlebar.

<table>
<thead>
<tr>
<th>Design Criterion</th>
<th>Weight Factor</th>
<th>Units</th>
<th>Design #1</th>
<th>Design #2</th>
<th>Design #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced shock to rider</td>
<td>0.17</td>
<td>Experience</td>
<td>Good</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
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<td>8</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.36</td>
<td>1.53</td>
<td>0.85</td>
</tr>
<tr>
<td>Decreased arm pump</td>
<td>0.17</td>
<td>Experience</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.02</td>
<td>1.19</td>
<td>0.85</td>
</tr>
<tr>
<td>Improved feel</td>
<td>0.12</td>
<td>Experience</td>
<td>Good</td>
<td>Good</td>
<td>Fair</td>
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<td></td>
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<td></td>
<td>6</td>
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<td></td>
<td></td>
<td>0.72</td>
<td>0.84</td>
<td>0.48</td>
</tr>
<tr>
<td>Strength</td>
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<td>Experience</td>
<td>Fair</td>
<td>Good</td>
<td>Fair</td>
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<tr>
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<td>$</td>
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<td>Good</td>
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<td></td>
<td></td>
<td></td>
<td>0.36</td>
<td>0.54</td>
<td>0.36</td>
</tr>
<tr>
<td>Anti-twist</td>
<td>0.11</td>
<td>Experience</td>
<td>Poor</td>
<td>Good</td>
<td>Excellent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.33</td>
<td>0.55</td>
<td>0.99</td>
</tr>
<tr>
<td>Adjustable</td>
<td>0.11</td>
<td>in</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
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<td>6</td>
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<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.66</td>
<td>0.66</td>
<td>0.55</td>
</tr>
<tr>
<td>Easy to install</td>
<td>0.08</td>
<td>Experience</td>
<td>Poor</td>
<td>Good</td>
<td>Fair</td>
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<td></td>
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<td></td>
<td>3</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.24</td>
<td>0.48</td>
<td>0.32</td>
</tr>
<tr>
<td>Appearance</td>
<td>0.05</td>
<td>Experience</td>
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<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>7</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>0.15</td>
<td>0.35</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Table 5-(Weighted Decision Matrix)

<table>
<thead>
<tr>
<th></th>
<th>Design #1</th>
<th>Design #2</th>
<th>Design #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced shock to rider</td>
<td>1.36</td>
<td>1.53</td>
<td>0.85</td>
</tr>
<tr>
<td>Decreased arm pump</td>
<td>1.02</td>
<td>1.19</td>
<td>0.85</td>
</tr>
<tr>
<td>Improved feel</td>
<td>0.72</td>
<td>0.84</td>
<td>0.48</td>
</tr>
<tr>
<td>Strength</td>
<td>0.4</td>
<td>0.7</td>
<td>0.4</td>
</tr>
<tr>
<td>Cost</td>
<td>0.36</td>
<td>0.54</td>
<td>0.36</td>
</tr>
<tr>
<td>Anti-twist</td>
<td>0.33</td>
<td>0.55</td>
<td>0.99</td>
</tr>
<tr>
<td>Adjustable</td>
<td>0.66</td>
<td>0.66</td>
<td>0.55</td>
</tr>
<tr>
<td>Easy to install</td>
<td>0.24</td>
<td>0.48</td>
<td>0.32</td>
</tr>
<tr>
<td>Appearance</td>
<td>0.15</td>
<td>0.35</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Total Rating: 5.24, 6.84, 5.2
CALCULATIONS

CALCULATING THE LOADING FORCE ON THE TOP PLATE

The loading conditions were to be determined so that the triple clamp could withstand the weight of the bike and the rider falling from a height of 30 feet. The loading conditions were determined for a worst case scenario. The worst case scenario was determined to be if the bike and rider fell from 30 feet straight down. Some discussion on the best way to calculate this involved taking into effect the amount of absorption from the suspension and tires upon impact. One idea was to use conservation of energy and impulse and momentum equations from dynamics. This would require determining the amount of absorption upon landing. This was to be determined using high speed video footage to measure the amount. This idea was tried using footage of a bike and rider falling straight down from seven feet onto a slab of rock. This is again a worst case scenario, landing on a very solid surface. The bike did rebound slightly but it was determined that this was not enough to collect data from. The next approach used equations dealing with collision and impulse. It was determined the total force from the bike and rider falling would be 14,135 lbs. This force would be divided in half to account for both wheels. The force would then be divided between the four mounting points of the front suspension. Using this force the principal or max normal stress on the top clamp was determined to be 3,326 psi.
As stated above it was determined the best way to calculate the dynamic loading conditions would be using the collision and impulse equations below. This takes into account the 12” of suspension travel that the bike has.

- **Collision and Impulse**
- **Mass = Bike = 250lbs**  **Rider = 220lbs**
- **Total Mass = 470lbs = 213.63kg**
- **Height of fall = 30 ft. = 9.15m**
- \( \Delta KE = -\Delta PE \)
- \( \frac{1}{2}m^*v^2 - 0 = -m^*g^*(y-y_o) \)
- \( V = (2^*g^*(y_o-y))^\frac{1}{2} \rightarrow (2^*9.81^*(9.15))^\frac{1}{2} \)
- \( F\Delta t = \Delta p = p-po \rightarrow 0 - (213.6kg)(13.4m/s) \rightarrow -2,862.24N*s \)
- **Absorption from suspension = 12in. \rightarrow .0254m**
- **Vavg. = (13.4 +0)/2 \rightarrow 6.7m/s**
- \( \Delta t = (.3048m)/(6.7m/s) \rightarrow .0455s \)
- **F = (2,862/.0455) \rightarrow 62,901N \rightarrow 14,135lbs**
After calculating the force on the top clamp the stresses were then calculated using the equations below. In doing this the top plate was split in half due to the fact that each side is the same and would see the same loading conditions. This results in a principal or max normal stress of 3,326 psi and a shear stress of 1,164 psi.

- **Total Force = 14,000lbs**
- 14,000lbs / 2 = 7,000lbs on front wheel
- Force is distributed to Triple Clamp which has 4 mounting locations.
- 7,000lbs / 4 = 1750lbs of force

- **Stresses**
  - \( \sigma_{\text{max}} = \frac{MC}{I} \)
  - \( I = \frac{1}{12} \times (5.25\text{in}) \times (1.5\text{in})^3 = 1.48\text{in}^4 \)
  - \( M = 3.75\text{in} \times 1750\text{lbs} = 6562.5 \text{in}^4\text{lbs} \)
  - \( C = 1.5/2 = .75\text{in} \)
  - \( \sigma_{\text{max}} = \frac{(6562.5\text{in}^4\text{lbs}) \times (.75\text{in})}{1.48\text{in}^4} \rightarrow 3,326 \text{ psi} \)
  - \( \sigma_{P1} = \sigma_{P2} = 3,326 \text{ psi} \)
  - \( \sigma_{P3} = 0 \)
  - \( \tau = \frac{(V \times Q)}{(I \times t)} \)
  - \( Q = \frac{y}{1} \times Ap \)
  - \( Ap = t \times (h/2) \rightarrow 5.25 \times (1.5/2) \rightarrow 3.9375\text{in}^2 \)
  - \( y = .75\text{in}/2 \rightarrow .375\text{in} \)
  - \( Q = (3.9375\text{in}^2) \times (.375\text{in}) = 1.477\text{in}^3 \)
  - \( V = 1750\text{lbs} \)
  - \( \tau = \frac{(1750\text{lbs}) \times (1.477\text{in}^3))}{((1.48\text{in}^4) \times (1.5\text{in}))} \rightarrow 1.164.3 \text{ psi} \)

Figure 14-(Top Clamp Base)
DETERMINING THE SPRING RATES

The spring rates were determined considering that there would be two springs acting to absorb the force. The total force wanted to compress the handlebar was determined to be close to 200 lbs. and the travel was determined to be .75”. In order to accomplish this, a spring rate of 131 lb/in was used for the top spring. The springs used on the bottom side of the design were of a lighter spring rate (47 lb/in) so they would not put the top spring in compression. Other spring rates were also ordered so the rider can adjust the stiffness of the absorption. The other rates included 59 lb/in and 90 lb/in.

COMPONENT SELECTION

Because of the loading conditions and the design these materials were selected. The triple clamp itself along with the bar mounts and bar mount clamp are all made from 7075 T-6 Aluminum. This provides a high safety factor of 22 which is wanted for this application. The material for the bolts that pass through the linear bushing are made from 440 SST and have a Rockwell hardness of 60. This provides a very strong bolt and a smooth ride in the linear bushing. A linear bushing was used instead of a linear bearing as originally intended. The reason for this was because of space constraints with the linear bearings. The linear bushing provides a much smaller O.D. for the limited space in this area. The rubber bumpers are urethane and were trimmed down to the desired height. All other hardware was used as purchased.
FABRICATION AND ASSEMBLY

FABRICATION

The machining of the top clamp base seen below was done by Dave Webber at Webber Tech using a CNC mill. Webber Tech also cut the 440 SST shafts to the correct length and threaded both ends to 5/8-18 using a CNC mill. At first this was a concern because of the hardness of the shafts but ended up not being an issue as the threads cut nicely into the material. The other pieces of the design were machined by Chris Couch and myself using his dad’s machine shop C-Tek Tool. This included the top bar mounts and the top bar mount clamp. CNC machines were also used to machine these parts for a quality finish.

Figure 15-(Top Clamp Base)
**ASSEMBLY**

The assembly was fairly simple. The 440 SST shafts were threaded into the bar mounts using red lock tight to assure they do not come loose. Once the shaft was connected to the bar mount it was then inserted through the spring and rubber combination and through the bushing. The original design intention was to have the rubber on the bottom and the spring on top. When assembling it was realized that if the rubber was mounted on top of the spring below the bar mount that this would keep the shaft from riding through the rubber bumper. This configuration would prevent any friction between the rubber and shaft. So the design changed slightly as it was decided to go with this setup instead of the original. Once the shaft was inserted through the bushings the springs were placed on the bottom side of the clamp and a 5/8-18 nut was used to secure them. A cotter key was used on the end of the shafts to assure the nuts could not come loose.

The next step in assembly was to apply the clamp on the bike. This involved removing the handlebar, loosening the 10mm pinch bolts and the 26mm top nut which secures the clamp. Putting the new clamp on was a breeze as it went on smoother than the standard OEM clamp. The new clamp seemed to be a perfect fit seen below in Figure 11.
TESTING AND PROOF OF DESIGN

Testing Methods

Two different methods were used for testing. The first method was done using a Larson Davis HVM (human vibrations meter) supplied by The Modal Shop. This system seen below in Figure 11 recorded data from the 10mv/g accelerometers that were used. The accelerometers were mounted with one on the rigid plate of the triple clamp which would give the same results as the rigid bar mount. The other accelerometer was mounted on top of the new bar mount. This would give a direct comparison between the two and would make for an easy comparison.

Figure 17-(Accelerometer Testing)
The second test method involved six test riders (Figure 12) ranging from intermediate level to pro level. Four out of the six riders were Mechanical Engineers who were specifically chosen because of their background and ability to give technical feedback. The riders all rode the same bike on the same track under the same conditions. The riders were then asked to fill out a survey directly after testing. The survey asked five questions about the new triple clamp versus the old clamp.

Figure 18-(Rider Test Session)
**TESTING RESULTS AND PROOF OF DESIGN**

The testing results from the first method show that the new design reduces the amount of accelerations transmitted to the handlebar. The results show that over the smoother parts of the track the new design stays fairly consistent with the old design. This provides for a positive feel through the smooth parts of the track. Then as the rider starts hitting some of the bigger bumps it can be seen that the new design really starts to work and separates itself from the old design. These differences can be seen in the example below. Some of the bumps were reduced by 33 m/s^2 or 3.36 g’s of acceleration. This was the result from some smaller bumps while testing at higher speeds on larger bumps the difference was as high as 140 m/s^2 or 14.27 g’s of acceleration. This shows that the force transmitted to the rider is drastically reduced.

![Figure 19-(HVM Results)](image-url)
The results from the second test included answers from a survey that the riders completed directly after riding the new design. These results included very positive feedback as well as some negative feedback. All the riders did notice a big difference with the clamp saying that it worked as intended. Some riders were skeptical before riding but were surprised at how the clamp actually worked to reduce the shock transmitted to the rider’s hands. The negatives were that a small amount of play in the handlebar was noticed and one of the shorter riders noticed the increased bar height. The last question on the survey was “would you purchase this product” in which every test rider answered “yes”. Some of the quotes from the riders can be seen below.

<table>
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<th>TEST METHOD #2 RESULTS</th>
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<td>All riders noticed a difference in the new design</td>
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<tr>
<td>All riders answered yes to “would you purchase this product”</td>
</tr>
</tbody>
</table>

Quotes from Survey

- “Felt less bumps”
- “Choppy down hills feel much smoother”
- “Felt less choppy in rough sections making it easier to hold on”
- “Smoothes out choppy sections”
- “Bars felt more in control on rough down hills”
- “Bars feel like they have suspension”

Figure 20-(Test #2 Results)
RECOMMENDATIONS

Overall the testing results proved to be very good showing that the design was working as intended with a few drawbacks which is to be expected from a first prototype. The bushings used had .015” of play when brand new and this increased with wear. It was also found that the shaft was slightly (.03”) undersize of what was first expected. The combination of these two amounted to .018” of play and this could be felt at the handlebar. This also contributed to the bushings wearing during testing which made the bar have more play. New bushings have been ordered that will only allow .03” of play. Testing will be done to determine the correct amount of clearance so that the handlebar is solid while still allowing the shaft to ride freely through the bushings.

The issue with the added height is not a major concern. The added height is .75” and different handlebars can be purchased to accomplish a .75” lower height. The added height was liked by some of the taller riders as well. The other areas to improve on would be cutting down the weight and increasing durability once more testing is done to see how the design holds up to abuse.

PROOF OF DESIGN

<table>
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</tr>
<tr>
<td>Reduces overall fatigue for rider</td>
<td>yes</td>
</tr>
<tr>
<td>Lessens shock transmitted to rider</td>
<td>yes</td>
</tr>
<tr>
<td>Lower lap times</td>
<td>yes</td>
</tr>
<tr>
<td>Provides a positive feel at the handlebar</td>
<td>?</td>
</tr>
<tr>
<td>Will withstand constant abuse of motocross</td>
<td>?</td>
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SCHEDULE AND BUDGET

SCHEDULE

The project schedule began December 17th, 2008 with completing the Proof of Design Agreement. From this point the project timeline covered 24 weeks and ended June 5th, 2008 with the final report.

Key Dates:

- Proof of Design Agreement: Dec-17-08
- Design Freeze: Feb-4-09
- Oral Design Presentation: Feb-26-09
- Design Report Due: Mar-12-09
- Demo/Proof of Design: Apr-27-09
- Tech Expo: May-7-09
- Oral Presentation: May-25-09
- Final Report Due: June-5-09

BUDGET

A budget of expenses documents the costs associated with this project (Appendix E). All expenditures for this project are listed below. The highest cost was the machining cost at $550.00. The total cost of the prototype was $945.00. The cost will be much lower for future clamps now that the CNC programs are complete.

1. All purchased parts.
2. All raw materials needed for manufactured parts.
3. All machinery and labor costs for manufactured parts.
4. Use of computers and software for design and testing.

Budget

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<th>Item</th>
<th>Proposed Amount</th>
<th>Actual Amount</th>
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<tr>
<td>Bar Mount Material</td>
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<td>Total</td>
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<td>$945.00</td>
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BIBLIOGRAPHY


2. store.toparracing.com. [Online] [Cited: 9 29, 2008.]


9. dirtbike.off-road.com. [Online] [Cited: 11 20, 08.]

    http://www.sixsixone.com/Catalog_TagMetals.aspx?id=a0b293a3-8d9c-484b-bb1b-e699b30d4d53&product=b34cc413-88c8-4958-924c-a36ab6fd304b.


12. www.fernandezracing.co.uk. [Online] [Cited: 11 18, 2008.]
    http://www.fernandezracing.co.uk/gallery/003.jpg.
## APPENDIX A RESEARCH

<table>
<thead>
<tr>
<th>The Revolution Clamp</th>
<th>New dampening system</th>
<th>Anodized Black</th>
<th>Easy to Install</th>
<th>Minimal absorption</th>
<th>Bars can twist in mounts</th>
<th>Price: 449.99</th>
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</thead>
<tbody>
<tr>
<td>CNC-machined from cold-forged 7075 aluminum, to provide maximum strength and rigidity. TAG Revolution clamp is lightweight to ensure better racing performance and bolts right onto your motorcycle. Easy to install with its pre-pressed stem, seal and bearing, the Tag Revolution Clamp is designed for the ultimate racing performance. Tag's innovative design of its 7075-CNC rubber mounts and T-bone will significantly improve the riding experience while dampening vibrations and impacts. Bar mounts come in 1-1/8 inch I.D. and are black anodized for a longer lasting finish.</td>
<td><a href="http://www.tagmetals.cc/mx/productdetails.php?id=tripleclamps">http://www.tagmetals.cc/mx/productdetails.php?id=tripleclamps</a></td>
<td>9/29/2008</td>
<td>The Revolution Clamp</td>
<td><a href="http://www.tagmetals.cc">http://www.tagmetals.cc</a></td>
<td></td>
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</tbody>
</table>
All clamps are CNC-machined using 7075 aircraft-grade aluminum for increased strength and reduced weight. Clamps includes a pre-pressed steering stem, with all the bearings, seals and mounting cones needed for quick and easy installation. Replacement rubber cones are sold separately if needed.

Top Clamps/Honda
http://www.procircuits.com

Solid mount option
Rubber mount option
Anodized magnesium look
Price: $199.95
Pro Taper Triple Clamps
-one clamp for all applications
-cold-forged, then Machined from 6061 T6 aluminum; Much stronger than billet.
cold-Forged bar clamps with one piece accu-trax top clamp to resist “twisting”.
-5 front to back bar clamp positions.
-Completely re-designed rubber mount system includes 3 durometers of cushions (soft, medium, firm) and aluminum rigid mount cushion replacements.
-Complete kits feature the upper kit along with a fully assembled lower tripleclamp that includes stem, lower bearing and seal, and stem hardware.
-True bolt on. No special tools or presses required.
-Complete kit also includes a trick, two piece number plate mounted brake line guide.
satin black color

9/29/08
Pro Taper Accu-Trax Triple Clamp
http://www.protaper.com

Anti twist feature
New rubber mount
Easy to assemble
Adjustable
Minimal absorption
Price: $249.99 (top)
Elastomer Damped Adjustable Top Clamp Includes 2 damper sets: Firm (red), Medium (yellow), and Blue (soft)
Fits all 11/8” sized handlebars
The elastomer adjustable top clamp help dampen engine vibrations and reduces the shock from sharp jolts

9/29/2008

Rubber mounted
Anti-twist design
Minimal movement
Adjustable
Easy to assemble
Price: $200.99
RG3 triple clamps are the latest evolution in triple clamp technology. RG3 triple clamps utilize a unique, patented four post system that, unlike any other clamp on the market, provides all the advantages of a rubber-mounted system without the disadvantages. Rubber mount points stabilize the bar clamps while absorbing shock and vibration that would otherwise be transmitted to the rider's hands. This greatly reduces vibration and arm pump while increasing control and positive feel. Rider fatigue is greatly reduced as is the tendency to twist the bar mounts in the event of a fall or hard landing.

These are the clamps used by Travis Pastrana, Broc Hepler, Mike Brown, Rodney Smith, Nick Wey, Ryan Hughes, Mike Kiedrowski, JSR and numerous other professional and amateur riders, including elite freestyle riders such as Brian Deegan, Ronnie Faisst and Jeff Kargola (Ox).

These pro racers attest to such performance benefits as lessened arm fatigue and pump, less transmitted vibration, much less harshness over square-edged bumps and fewer hand blisters all while retaining a positive feel. Not only is arm pump and rider fatigue greatly reduced so is the tendency to twist the bar mounts after a fall or hard landing. Made from high quality aerospace grade aluminum and hard anodized this Patented product is available in your choice of bar mount size, position and clamp color. Lower clamps and offset options and stems are also available. Available for Suzuki, Honda, Yamaha, and Kawasaki models.

Available in Oversize or Standard bar size.

Customers say the benefits from these triple clamps are:

- Greatly reduced bar twisting that comes with conventional rubber mounted clamps.
- Less struggle to hang on due to fatigue and arm pump
- Faster lap times
- Can ride longer and still maintain control
- Less harshness over square edged bumps
- Reduced hand blisters
- Positive feel
- Better control
- Less shock and vibration in your hands and forearms
- Improved handling

Price: $309.95

http://www.rg3suspension.com/p_triple_clamps_2.php 9/29/08

Triple Clamps

http://www.rg3suspension.com

Popular design
Anti-twist design
Easy to assemble
Minimal absorption
Color options
This CNC machined Top Clamp Kit, made of billet aircraft aluminum, solid mounted, stock offset, provides superior strength and durability. The reversible bar mounts included in the Top Clamp Kit are available in different heights, to further tune the rider's position for a custom fit. Fork holes are bored, not honed, and are precision machined for a perfect fit and greater clamping surface. The Kit comes complete with an upper clamp, reversible bar mounts and all the necessary hardware. Made in the USA with a lifetime warranty to the original purchaser!

07-08 YZ125/250 YZF250/450 SLD MOUNT KIT  http://appliedrace.com

No dampening feature
Basic design
Anodized red
Easy to assemble
Price: $186.95

07-08 YZ125/250 YZF250/450 SLD MOUNT KIT

http://appliedrace.com/
Top Triple Clamp for and 2006 Yamaha YZ125, YZ250, YZ250F, and 06-07 YZ450F
Topar Triple Clamps are among the strongest on the market. This Top Triple Clamp Kit is machined from high-quality 6061 Aluminum and provides four different bar positions for the best comfort

9/29/08
Top Triple Clamp for and 2006 Yamaha YZ125, YZ250, YZ250F, and 06-07 YZ450F
http://store.toparracing.com

Solid mount
No dampening feature
Anodized black
Price: $85.95
No dampening feature  
No adjustments  
Price: $130.00 |
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http://www.yamaha-motor.com/sport/products/modelimagelib/30/15/1/1/image.asp x 11/20/08
### Interview with Rider, 9/21/2008
Brian Garrahan, Pro Racer, National Champion  
contact: (408) 857-5884 briangarrahant@msn.com  
Races for a living  
Deals with arm fatigue known as arm pump  
Has to run suspension extra soft to take some of the little jolts  
Has broken wrist and still bothers him  
Has tried other clamps but didn’t notice much difference

### Interview with Rider, 9/23/2008
Chris Couch, B class racer  
Riding is limited by his arm fatigue  
Currently runs rubber mounted clamps but doesn’t notice much

### Interview with Rider, 9/14/2008
Alan Westerfield, Kentucky Champion  
Has broken wrist pretty bad  
Makes it hard to hold onto rigid handlebar  
Wrist bothers him in rough races
APPENDIX B SURVEY RESULTS

Low Shock Triple Clamp
CUSTOMER SURVEY

I am a senior at the University of Cincinnati studying Mechanical Engineering Technology. The purpose of my senior design project is to lessen the impact that is transmitted to the rider through the handlebar. This will be done using a new triple clamp design. Please take a few minutes to answer the following questions.

How important is each feature to you for the design of a new triple clamp? Please circle the appropriate answer.  
1 = low importance  5 = high importance  

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How much would you be willing to pay for this product? $50(), $100(), $100-$200(7), $200-$300(6), $300-$400(2), $400-$500()

Thank you for your time.
### APPENDIX C QFD

9 = Strong  
3 = Moderate  
1 = Weak  

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## APPENDIX E BUDGET

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NMA-3

1.13
0.63
1.00
1.50
2.25
1.13
0.125
1.50
(0.38)
R0.13

5/8-18 UNF - 2B \( \downarrow \) 0.75
Might change to M16

1.25
0.63
0.28
1.69
3 x M8 \( \downarrow \) 0.75
R0.13

UNLESS SPECIFIED
TOLERANCES

DIMENSIONS ARE IN INCHES
DECIMALS ARE TO
CAGE CODE
OX693
SCALE: 1:1
SHEET 1 OF 1

CAGE CODE
OX693

DRAWN 4/7/09
CHECKED 4/7/09
MFG
ENGR

MATERIAL
7075 ALUMINUM
HEAT TREAT
FINISH

BAR MOUNT

APPENDIX F4
5/8-18 THREAD

1.00
5.00

0.75

0.38

0.1875

.125 Chamfer

BOLT

NMA-4

Appendix F5
APPENDIX G TESTING SURVEY RESULTS

QUESTIONS ASKED

1. Do you notice clamp?
2. Positive feedback?
3. Negative feedback?
4. Reduce Arm Pump?
5. Would you purchase this?

ANSWERS TO QUESTIONS ASKED

Rider #1

1. Yes
2. I felt less bumps compared to stock design.
3. The bars felt high.
4. I didn’t get any the time I spent on it.
5. Yes

Rider #2

1. Yes
2. Choppy downhill’s feel much smoother with the new clamp.
3. Play in the handlebars gives a choppy feel at low speeds.
4. Yes
5. Yes, if play in handlebar was eliminated.
Rider #3

1. Yes

2. Felt less choppy in rough sections making it easier to hold on.
3. Bars felt tall for me.

4. Yes

5. Yes, if bars were lower.

Rider #4

1. Notice effect of clamp on sharp edge bumps, reducing arm fatigue.

2. Smoothes out choppy straight-aways.

3. Slightly vague feel, may be from wear of surfaces.

4. Yes

5. Yes, if below $400.
## APPENDIX H BILL OF MATERIALS

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<th>BOM</th>
<th>Description</th>
<th>Qty.</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7076-T6 Aluminum (3”x12”x4”)</td>
<td>2</td>
<td>American Metal Supply</td>
</tr>
<tr>
<td>2</td>
<td>10mm pinch bolts</td>
<td>4</td>
<td>Cincinnati Fastener</td>
</tr>
<tr>
<td>3</td>
<td>5/8 -18 Nut</td>
<td>2</td>
<td>Cincinnati Fastener</td>
</tr>
<tr>
<td>4</td>
<td>Spring (47 in/lb)</td>
<td>2</td>
<td>Century Spring</td>
</tr>
<tr>
<td>5</td>
<td>Spring (59 in/lb)</td>
<td>2</td>
<td>Century Spring</td>
</tr>
<tr>
<td>6</td>
<td>Spring (90 in/lb)</td>
<td>2</td>
<td>Century Spring</td>
</tr>
<tr>
<td>7</td>
<td>Spring (131 in/lb)</td>
<td>2</td>
<td>Century Spring</td>
</tr>
<tr>
<td>8</td>
<td>Rubber Bumper with Washer</td>
<td>4</td>
<td>RG3</td>
</tr>
<tr>
<td>9</td>
<td>440 SST Linear Shaft (36”)</td>
<td>1</td>
<td>Pacific Bearing</td>
</tr>
<tr>
<td>10</td>
<td>5/8 I.D. Linear Bushing</td>
<td>2</td>
<td>Pacific Bearing</td>
</tr>
</tbody>
</table>
APPENDIX I MISC. PICTURES