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A NASA base on an asteroid has built a magnetic field generator in order to fire meteorites to impact. However, this has resulted in the asteroid base being surrounded by a gaseous shell, as well as large gaseous clouds. A prototype for these bridges should be built and tested. It should use cryogenic hydrogen, which is easier to capture than the comets (due to their gaseous nature). Given the specifications, the bridge would strike with 6-8 times the kinetic energy and would damage it on an acceleration of 60 Gs or greater occurs. The materials available on the asteroid are: timber and Elmer's glue.

2/16/11
Organize Dates and Timeline
- Deliverables Due Dates
  - Week 4: Morphological Charts - 2/16/11
  - Week 5: Preliminary Design Review - 2/25/11
  - Week 7: Turn in Final Development File - 3/14/11

2/16/11
Organize Groups: First Meeting via Email
- Sent out an e-mail to all group members requesting a meeting time and the best form of communication
- Group decided to meet at 3pm on Sunday, February 13th in Duffield Atrium.
- Group agreed that e-mail and texting were best ways to communicate.
- In addition to Sunday, group was available on Tuesdays and Thursdays

Contact Information for Group Members
- Jennifer Goss (jlg368) Phone: (314) 288-7584
- Chuan Yen Goh (cpg57) Phone: (607) 391-4682
- Lenny Perez (lpp20) Phone: (310) 538-7364

2/16/11
Group meeting at 3pm in Duffield Atrium to enter Phase 1 of design process.
- Tasks for the meeting: identify and prioritize customer needs, create numerical specifications, and optimize each task. Product needs matrix.
- Group agreed to think of ideas for morphological chart for next meeting on Thursday, 2/19/11.
Task: Identifying Customer Needs from Customer Statements
Below are numbered customer statements with the group's interpretation.

1. "The structure will be built entirely of fibrous materials, provided by the instructors and Glue's glue."
   - The materials used to construct the bridge are non-man-made materials. They are natural and have the characteristics of fibrous materials.

2. "The structure must be lightweight."
   - The structure minimizes material and maximizes strength so that it will not collapse due to its own weight.

3. "The structure must be simple to manufacture."
   - All steps for assembly are easy to follow and it is clear how the structure comes together.

4. "The structure must be able to catch a baseball."
   - The structure dissipates 3-4 joules of kinetic energy when struck from above.

5. "The structure must provide a margin of safety."
   - The structure reliably absorbs forces and energy which are a factor of the maximum.

6. "The structure must be innovative."
   - Proof of a detailed thought and decision making process leading up to the final design exist.

7. "The structure must be able to be used after catching the meteorite."
   - The structure can withstand at least 5° of deflection (see "back of envelope calculations") without critical damage.

8. "The prototype must span 21" x 14" and sit stably between two flat surfaces."
   - The prototype structure is scaled to span 21" x 14" and sit stably statically without extra support between two flat edges.

9. "The meteoroid must not damage on impact."
   - The final physical condition of the meteoroid is the same as the initial; it can be reused.

10. "Baseball is almost always hit to center of the bridge."
    - The structure is designed for impact close to the center of the structure.
0. "Some" specialty shipments of materials may be made, but requests must be 1 week in advance. This limits the shipment period for special materials as accounted for when considering the structure's design and testing.

1. "The meteorite cannot 'shatter on impact.' The energy of the meteoroid is dissipated slowly so that it maintains its original form.

<table>
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<th>Task: Priority Customer Statements/Needs</th>
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<tr>
<td>Priority</td>
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<tr>
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</tr>
<tr>
<td>Highest</td>
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<td></td>
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<td></td>
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<tr>
<td>Lowest</td>
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<table>
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<tr>
<th>Task: Assign Metrics to Various Specifications/Parameters</th>
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<tr>
<td>Metric</td>
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</table>
| Cost of Structure | 4 | Dollars ($)
| Structure Length | 1 | Inches (in)
| Mass | 4 | Ounces (oz)
| Force of Assembly | 9 | Subject
| Impact Location | 2 | Inches (in)
| Rate of Energy Dissipation | 3 | Pounds force-feet per second (lbf-s)
| Energy Absorbed | 2 | Pounds force-feet (lbf-ft)
| Maximum Deflection | 2 | Inches (in)
| Impact Point Safety Factor | 7 | Dimensionless (Actual/Target Nu.
| Planning & Organization | 5 | Percentage of Deadlines Met

- Task: Create a Needs vs. Metric Matrix to Focus Design Process Priorities. The matrix created by the group is found attached to the next page.

Meeting Adjourned at 5 p.m. The matrix is distributed to group via e-mail.
<table>
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<th>Needs</th>
<th>Concept 1</th>
<th>Concept 2</th>
<th>Concept 3</th>
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<tr>
<td>1. Structure is only made of natural and fibrous materials</td>
<td>x</td>
<td></td>
<td></td>
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<tr>
<td>2. Structure minimizes material and maximizes strength</td>
<td>x</td>
<td></td>
<td></td>
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<tr>
<td>3. All steps for assembly are easy to follow</td>
<td>x</td>
<td></td>
<td></td>
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<tr>
<td>4. Structure must be able to absorb 6-8 joules of kinetic energy when struck from above</td>
<td>x</td>
<td></td>
<td></td>
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<td>5. Structure absorbs forces and energy which is a factor of the maximum</td>
<td>x</td>
<td></td>
<td></td>
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<td>6. Proof of a detailed process leading up to the final design was</td>
<td>x</td>
<td></td>
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<tr>
<td>7. Structures can withstand at least 3° deformation without critical damage</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. The prototype must be scaled to scale 2/3 and verified without excess support</td>
<td>x</td>
<td></td>
<td></td>
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<tr>
<td>9. The final physical condition of the meteoroid is the same as the initial, can be reused</td>
<td>x</td>
<td></td>
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<tr>
<td>10. The bridge is designed for impact close to the center</td>
<td>x</td>
<td></td>
<td></td>
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<tr>
<td>11. The one week shipment period for special materials is accounted for when considering the structure's design and testing</td>
<td>x</td>
<td></td>
<td></td>
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<tr>
<td>12. The energy of the meteoroid is dissipated slowly so that it maintains its original form</td>
<td>x</td>
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Group 1: Needs-Metric Matrix
2/14/11 - Sketches Various Ideas Preliminary Brainstorming for Morphological Chart

Attachment Variations
- Side view of attachment
- Top view of component
- Side view of component
- Top view of attachment

Gripping Variations
- Simple net
- Support from trees
- Modified net
- Support from trees

Netting Variations (All Top Views)
- Repeated
- Linen style
- Repeated
- Repeated

Witnessed & Understood by me,
Rebecca Vandermolen
Date: 2/18/11
Invented by
Rebecca Vandermolen
Date: 2/18/11

Reinforced bottom
Meeting with Group at 4:30 in Duffield Atrium.
* Group discussed ideas & concepts for morphological chart & put the ideas into a list format

- List of Ideas for Morphological Chart
  - Fibers
    - Stir Sticks
    - Small Sticks
  - Natural
    - Notecards
    - Printer Paper
  - Plastic
    - Cotton String
    - Card Stock

- Materials
  - Wrap string around support
  - Build latching clip
  - Bar attached with rubber bands

- Latching Mechanism
  - Breakpoint with wooden sticks
  - Cover hole with thick paper
  - Layers of supporting raphia
  - Suspended bowl
  - Funnel-like structure
  - Paper balls at bottom for dissipation
  - Suspension bridge design
  - Curved ramped walls of net

- Nailing
  - Waxed paper
  - Diamond weaving
  - Lacrosse head weaving
  - Basket of paper strips

- Joints
  - Notched bars
  - Tying the bars together using string
  - Fold over paper on bars
  - Glue the joints together

- Top of Bridge
  - Truss-like structure on top
  - Tie the sides of the truss together

Using these ideas, a morphological chart complete with sketches was made. The morphological chart can be found in Jen Glass's notebook. (See page 27)

Group agreed to discuss further designs in lab section tomorrow, Friday, Feb. 18, 2011.

Questions to ask TA:
- What are the clips and small sticks on the materials list?
- What is meant by structural stability? Can we attach string to supports?
- What is the bridge's dimensions?
Additional Information Added to Problem Statement:
- Teams start with (at no cost) 100 3" x 5" stickers, 2 bottles of glue, 2 box small clips, 6 box med. clips
- Budget (not to be exceeded): $150

<table>
<thead>
<tr>
<th>Item</th>
<th>List Price</th>
<th>Cost</th>
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<tr>
<td>Napkins</td>
<td>499/500 ct.</td>
<td>$0.01 per</td>
</tr>
<tr>
<td>Notebooks 3 x 5</td>
<td>1.79/100 ct.</td>
<td>$0.02 per</td>
</tr>
<tr>
<td>5 x 8</td>
<td>3.99/100 ct.</td>
<td>$0.04 per</td>
</tr>
<tr>
<td>Paper 8.5 x 11</td>
<td>5.39/500 ct.</td>
<td>$0.01 per</td>
</tr>
<tr>
<td>Surf Sticks</td>
<td>2.98/500 ct.</td>
<td>$0.005 per</td>
</tr>
<tr>
<td>Small Sticks</td>
<td>1.00/500 ct.</td>
<td>$0.002 per</td>
</tr>
<tr>
<td>Letter String</td>
<td>4.99/400 ft.</td>
<td>$0.0012 per/ft</td>
</tr>
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Lab Section, 2pm, Taylor Design Studio - Team Synthesizers

Fossil Design/Morphological Chart Review (Below are post-it comments by our response)

- Fishing Sticks vs String (Gude)
  - Comment: What if it's in compression?
  - Perhaps using string bars vs stick bars to create suspension

- Suspended Ball
  - Comments: What if it bounces out? Can you create a suspended net?
  - Maybe a netting would work to better dissipate energy
  - More string for support of suspension

- Paper Balls in Bottom of Net
  - Comment: Would add to weight/cost?

- Netting
  - Complex to manufacture?

- Lump
  - Where on the bridge would the ball hit?

- Other good ideas? Scissor Jacks

We took biomimicry/morphic analysis' suggestions, supporting

Data Benchmarking

1/2 Stirrer

- 3 m in Diameter

Weight: 0.142 Kg = 5.06 oz

To Page No. 9
- Benchmarking: Supports

- Benchmarking: Stirrers (80 count)

- Data on Stirrers
  - Breaking when in paper shank: 7-8 N
  - At 20 N when ½ length
  - 0.05 lbs = 37 sticks
  - Curvable/plastic to a certain degree
  - When on side: 20% of strength
  - A lot of twisting: 1.75" from midpoint
  - One stick: 0.05 lbs

- Benchmarking: Mech. Clips (so that when we weigh in clips, we can determine actual weight)

\[ m = 0.05 \text{ lbs} \]

- Things for Next Time:
  - Preliminary Design Review (Presentations + Questions)
    - Ideas + Specs +
    - Morphological Chart +
    - Decision Matrix
    - 3 Complete Concepts

Testing: Test strength of paper next time

Witnessed & Understood by me:

Rebecca Vansant

Date: 1/18/11

Invented by

Recorded By: Rebecca Vansant

Date: 2/18/11
- Group meeting in Duksfield; at 3:30 pm
- Preparations for Meeting; Complete Decision Matrix; Come up with 3 Unique Concepts

- Decision for Safety Factor
  
  We decided to make the safety factor 5 because the standard safety factor for civil engineering is typically 5-10. Since this bridge is a structure typically associated with civil engineering, we picked a safety factor within the range of the civil engineering standard. We chose towards the lower end since we do not know much about the materials, except for that one pole weighs 800g. Since one pole weighs 800g and there are 4.5-5.0 units that need to be dissipated, we decided to use this safety factor.  

  "Basic of Envelope Calculations"
  
  \[
  \begin{align*}
  \text{weight of pole} &= \frac{0.125 \times 5}{2} = 0.3125 \text{ mg} \\
  \text{weight of materials} &= \text{weight of a big chip} \\
  \text{Fawkes} &= \text{weight of a stick length} \\
  \text{Costs} &= \text{we decided to compare material costs based on amount of material we could get for}\ 
  \\
  \text{Table of Envelope Calculations} & \\
  \text{Material} & \text{Amount} & \text{Material} & \text{Amount} \\
  \text{Napkin} & 1 & \text{Cotton string} & 3.5 \text{ ft} \\
  \text{Wooden rod (AS)} & 0.56 = \frac{0.56}{0.0125} & \text{Cotton string} & 3.5 \text{ ft} \\
  \text{Nylon string (5 x 8)} & 0.25 = \frac{0.25}{0.0125} & \text{Nylon string (5 x 8)} & 0.25 = \frac{0.25}{0.0125} \\
  \text{Shovel sticks} & 2 & \text{Small sticks} & 5 = \frac{5}{0.56}
  \end{align*}
  \]

- Decision Matrix

- 3 Concepts
  
  - Concept 1: 
    
  - Concept 2: 
    
  - Concept 3: 
    
  - At next meeting:

  3:30 pm - 2/24/11

Witnessed & Understood by:

 heleen Vendar

Date: 2/12/11

Invented by: Rebecca Ventimiglia

Date: 2/12/11
Sketches of Truss Ideas

- Reinforced beams towards the center
- Use stiffness of plates to hold up the string which supports truss

Reinforcement beams

Not good because weakest at force application point

- Synthesizer Meeting Thursday, 2/24/11 at 3:30 PM in Duffield
  - Start off meeting w/ re-evaluating decision matrix
  - Cost of string changed/updated so now only .83 ft can be bought with $1. We updated the matrix to reflect this.
  - Decision matrix on next page.
- After realignment, the top 6 designs/concepts to consider due to highest ratings on 5 pt scale
  1. Diamond weaving
  2. Net that breaks
  3. Stick breakpoint + net
  4. Composite Net
  5. Lacrosse Net
  6. Note card breakpoint + net

- Than we considered the designs based on scored & similarities in design to create 3 concepts that are unique:
  1) Composite Net, © Breakaway Sticks, © Note card Linking Breakpoint

Witnessed & Understood by: Rebecca Ventrmimg

Invented by: Rebecca Ventrmimg

Recorded by: Rebecca Ventrmimg

Date: 2/24/11
Next, we discussed various shapes and types of trusses in order to draw consistent sketches. We considered the cost of manufacturing each concept as a fixed cost because it would be standard for all the concepts. We looked up that for a material like wood, its tensile strength is larger than compressive strength. Therefore, the truss would be attached to the frame in a way that put the bars in tension. The structure decided on after discussion of stability, number of joints required, amount of material needed, etc., was chosen structure was:

![Truss Diagram]

**Truss Analysis:** Page 28

- Assignments of Tasks
  - Lecture - 30% of lecture on trusses/sketch concept
  - Jen - Sketch concept for scrap in morphological chart
  - Chen - PowerPoint w/Need for specs
  - Rebecca - Sketch & lock up properties of wood

For next time in lab, test:
- Give strength
- Manufacturing quality of design
- Twisting strength (tension)
- How angle of stick affects breaking strength.

*We will meet tomorrow. 4/22/11 during normal scheduled lecture to finalize plan and go through PPE.*

To Page No. 12
Composite Net Concept

Features:
- Node Diamond Weave net with piece of paper on top of net
- Supports underneath truss
- Truss over extends supports so that it may rest slowly

Research on Material Properties of Wood: Internet Sources

<table>
<thead>
<tr>
<th>Wood</th>
<th>Tensile Strength</th>
<th>Young's Modulus</th>
<th>Ultimate Tensile Strength (Compression)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pine</td>
<td>40 MPa, 35 GPa</td>
<td>4 GPa</td>
<td>Ultimate Tensile Strength, Young's Modulus</td>
</tr>
<tr>
<td>Oak</td>
<td>13 GPa</td>
<td>3 GPa</td>
<td>Young's Modulus</td>
</tr>
<tr>
<td>Doug Fir</td>
<td>2 GPa</td>
<td>1 GPa</td>
<td>Ultimate Tensile Strength (Compression), Young's Modulus</td>
</tr>
</tbody>
</table>

Witnessed & Understood by me:

Rebecca Vertimiglia

Date: 2/24/11

Invented by:

Rebecca Vertimiglia

Recorded by:

Rebecca Vertimiglia

Date: 2/24/11
<table>
<thead>
<tr>
<th>Timber</th>
<th>Ultimate Strength (MPa)</th>
<th>Modulus of Elasticity (GPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Douglas Fir</td>
<td>60</td>
<td>13</td>
</tr>
<tr>
<td>Spruce, Sitka</td>
<td>39</td>
<td>10</td>
</tr>
<tr>
<td>Shortleaf Pine</td>
<td>50</td>
<td>12</td>
</tr>
<tr>
<td>Western white pine</td>
<td>24</td>
<td>10</td>
</tr>
<tr>
<td>Ponderosa pine</td>
<td>35</td>
<td>9</td>
</tr>
<tr>
<td>White oak</td>
<td>36</td>
<td>12</td>
</tr>
<tr>
<td>Red oak</td>
<td>47</td>
<td>12</td>
</tr>
<tr>
<td>Western Hemlock</td>
<td>30</td>
<td>11</td>
</tr>
<tr>
<td>Sugar Maple, Hickory</td>
<td>63</td>
<td>15</td>
</tr>
<tr>
<td>Ash</td>
<td>65</td>
<td>9</td>
</tr>
</tbody>
</table>

*Note: About type of wood struts are made of...
4/25/11 - Meeting in Duffield (11:15 AM - 12:20 PM)
- Discussed drawings for presentation
- Reviewed PDE skeleton created by Chua
- Ran through slides to check for wordiness
- Went over what each person is to say during presentation
- Cleaned up PowerPoint
  * See PowerPoint at end (page indicated in Table of Contents)

4/25/11 - Lab Session: Taylor Design Studio (2:00 - 4:30 PM)
- Perfection - think of how much this is related to more...
- Stability of keeping beam in net
- Look into cost of materials
- Label colors on charts/put in key or chart
  * More design considerations to consider
  * (what we took away from PDE that we need)

*Materials Update: Birch wood is what coffee stirrers made out of (but don’t think it’s birch)*

*Online Research (Lecture)
  * Drone: Guiseff test the best!
  * Two Stirrers Flat Sandwich against a third stirrer to create strong joint.
  * We created a sample joint and tested it by seeing if the stirrer slid when pulled on.
  * Grip, hooks and joint is strong.
  * Case study research: out of the question.

- Tests during lab
  * Wide Guiseff Joint
  * Test Box and String
  * Fmax ~ 150 Newtons
  * Buckling Test
  * Max ~ 1.3 lbs
  * We tested buckling by placing stick vertically on a scale and pushing straight down it. Force reported after being taken off

Witnessed & Understood by:
Rebecca Ventriglia

Date: 4/25/11

Recalled by:
Rebecca Ventriglia

Date: 4/25/11
For Next Time:
- 10 Minute presentation (hard deadline)
- Poly design
- Outline design/why you picked it?
- Performance specs
- Weight factor
- Any changes since PDR
- Kelsey due week 7

At the end of lab, we decided to go with the breaking sticks idea because it was in the top set of ideas, innovative, analyzable, and easy to manufacture.

Sketch of Final Concept: Purposely Breaking Sticks Bridge:

```
[Diagram of a bridge with labeled parts and notes]
```

Key Features:
- Purposely Breaking Sticks in z-direction.
- Strings of different lengths so that nut moves w/ball when dissipating energy.
- Diamond weaves nut
- Pratt truss (puts more members in tension vs. the wood is stronger in tension). Only puts bars fartherest away from force application in compression with least amount of force.

Witnessed & Understood by me: [Signature] 2/25/11

Invented by: [Signature] 2/25/11

Recorded By: [Signature] 2/25/11
Since we went with the sticks breaking purposely concept, I decided to research net manufacturing (knit for tomorrow) group meeting at Duffield/Taylor Design Studio.

Knots: From www.4knottedknits.com (looking for energy dissipating/dynamic knots)

- Knot Allows for Sliding Along Axis

- When each string is pulled in forces in opposite directions, the knots collide/make contact

- The knot is loose to begin with, and then tightens around joint

- The knot is tied around an axis so that it can slide about the axis.

- The knot tightens and holds when force is applied to the string (there is enough tension in string)

Netting: Important to avoid knots in net so that strings of net "snort" to encase ball.

How to Make Diamond Weaving: Start with 3 loops. 1 to 2 strings in proximity to each other.

How to Make Hammock Weaving:

- String knot
- Loops around previous string

Witnessed & Understood by me:

Rebecca Ventimiglia

Date: 2/24/11

Invented by:

Rebecca Ventimiglia

Date: 2/24/11
Meeting in Durham at 11:30 AM → Taylor Design Studio

2/29/11

Meeting Dimensions (Back of envelope calculations)
- X = 44", Y = 46" (1.15m)² = 28.17 in² - Surface area of Bochall
- Side View
  - 6.3\(\theta\) = 7\(\theta\)
  - \(\theta\) = \(\frac{\pi}{3}\) m
  - \(\theta\) = \(\frac{\pi}{6}\) m

- Circumference = \(2\pi r = 2\pi (4.5\text{ in})\) = \(26.18\) in
- Area = \(\frac{\pi}{6}\) in²
- \(\theta\) = \(\frac{\pi}{6}\) in

- If square, net = \(L = 4.5\) in
  - \(A = L^2\)
  - \(28.17\text{ in}^2 = 4.5\text{ in} \times 4.5\text{ in}
  - \(6.28\text{ in} = L\)

- Hammer - Step backing
- Energy - Disappearing Cross

- 4" x 4" to be knot around joints
- 42 critical points - what string needed
  - 4 x 12 = 48 in (4 ft)
  - Cost string = \$5.56

- If more needed - 20 critical points
  - 4 x 20 = 80 in (6.67 ft)
  - Cost \$11.12

Witness & Understood by me,

Rebecca Vantumpria

Date: 2/29/11
Begin Construction:

- Tape used to keep knots stable and attached to bobbin during manufacturing.
- Taped to cutting board so that 45° angle is created.
- Strings looped out and run to previous triangle.
- All string portioned out and taped (so that the right amount of string was ensured).
- No knots around vertical/horizontal components.

Tested net after construction. Too much slip! There is no way that the size of the hole will be constant. The baseball falls right through the net. The fix is to add more loops in between triangles (to create more stiffness) and knots on outside to create more shape stability. Additional strings were added across the holes so that the initial hole size was smaller and less movement is likely amongst string members.

Net Design w/Improvements:

- At Joints, vertical string goes in between looped string as shown below.

This design is like the Lacrosse net which was originally turned down. Turns out that this type of net was easier to manufacture than expected and only cost $6 x .4 = $2.40. Extra for knots = $2 x $.02 = $.036.
3/4/11 - Test Day in Stairwell of Rhodes Hall! (Lab: 2:00-4:30 PM)

1. Team Pineapple - X (Failed) (Carried Over)
   - Force: ~652 (≈115 lb)
   - Cost: $1,052

2. The Symphonizers - ❌ (Failed) (Credit)
   - Force: 0, 7.154 lb
   - Cost: $88

3. Team Watson - X
   - Force: 0, 0.732 lb
   - Cost: $72

4. Pork Chops, Inc.
   - Weight: 180 kg
   - Cost: $1,156

5. Team KLAM
   - Weight: 0.124 kg
   - Cost: $8, $1.09

6. The Builder
   - Weight: 0.191 kg
   - Cost: $9.23

Sketch of Design

Witnessed & Understood by me:

Rebecca Vehicle

Date: 3/4/11
Invented by

Recorded By

Date: 3/4/11
- ZF/4/1W (continued) Taylor Design Studio

- Start Manufacturing of Truss

- We went off a template method so that parts could be prefabricated and standardized w/ little dimension. Also allows for simple, easy to follow fabrication/assembly.

- 12 parts were cut with an exacto-knife/sx cutter:
  - 12 for truss: 8 diagonals, 4 verticals, 4 horizontal
  - 14 cut-off pieces of various lengths

- Diagram/Specs of 5 Template Parts:
  - Verticals: ~6.5 in
  - Horizontal: 16.5 in
  - Diagonals: 16.5 in - 10.5 in

- Once proper amount of each template part was manufactured, assembly of one side of the truss began. In order to create strong joints, coffee stirrers were used to cover the joint on both the front and back of joints. Every section assembly was placed according to the Pratt truss design. Joints were held in place by glue.

- Isometric of Truss Segment Sketch

- Triple Beam Reinforcement

- Single Beam (for now)

- At the end of team meeting, one side of truss was created.
  - Pled to meet around 2 pm the next day.
- 2/27/11 - Meeting in Upson (2:00 pm)
  - While using the template and scissors to cut new members, the second half of the truss was constructed.
  - We noticed that our half of the truss had a slight curve that due to the truss' weight in the drying process. We flipped the truss around to let the weight of the truss bend it back into place.
  - On the 1st half of the truss, we glued another stick support to the outside of the farthest diagonal member. We did this in order to add extra support and prevent tension on the members with the most tensile force.

Players which are echoed at have double reinforcement.

- 3/1/11 - Meeting Taylor Design Studio (10:10 pm)
  - We next to finish the second truss and discuss how the two sides will be attached to each other. We decided to use alternating diagonal members, as shown below. Will manufacture the two beams.

Side View of Truss
Manufactured Supports in between truss sides using template method. We eyeballed the angle at which the supports should be cut by taking a full stick and placing it in the desired position in the truss, and tracing over the angle in pen. This piece was then used as the template. Other members were attached across the top.

- Support piece final manufacturing

- Once the glue had dried, the beams were tested with a preliminary setup as shown below. The ball was dropped from a height of 2 m and the truss structure's purposefully breaking beams broke. However, difficulty in getting the ball to land in the net led us to revise our net design so that it was larger.

- Test Set Up:

- Once the test was complete, we knew about how much force would be required to break the beams using our string net setup.

- Revised Net Design: 3/4" wider on each side, requires a string

- Calculation for String Needed

  6" + 1" on each side = 8"\times 32" = 256"  
  4 sides \times 7" for weaving on each side = 28"  
  28 + 32" = 60" of string = Set.

- Manufactured using tape method from before. A frame was created around the square net and another string was looped between the new and old frames to provide suspension. All strings secured with knots. Also contained 4 pull strings to better control placement of net on truss base for testing.
- The group used this day for more conclusive testing, we performed testing with the actual truss structure in order to again determine the amount of force required to break a beam.
- We decided to add more support at joints/connection point for each beam that would be breaking in order to ensure that the beams would break at the midpoint as planned. This extra support involved another stick glued to the top of the end of the beam at the joint and small squares glued to the side of the truss to keep the joints in place. We chose this over using string to secure joints because it was cheaper and would do the same job—keep joints in place so that force is applied in middle of beam.

- Results of Testing — We dropped heavy ball from heights, increasing by .2 m each time to determine when the sticks would break. Height measured from bottom of net upwards.

<table>
<thead>
<tr>
<th>Height (m)</th>
<th>Did it Break?</th>
</tr>
</thead>
<tbody>
<tr>
<td>.5 m</td>
<td>No</td>
</tr>
<tr>
<td>.7 m</td>
<td>No</td>
</tr>
<tr>
<td>1.0 m</td>
<td>No</td>
</tr>
<tr>
<td>1.2 m</td>
<td>No</td>
</tr>
<tr>
<td>1.4 m</td>
<td>No</td>
</tr>
<tr>
<td>1.6 m</td>
<td>No</td>
</tr>
<tr>
<td>1.8 m</td>
<td>No</td>
</tr>
<tr>
<td>2 m</td>
<td>Yes</td>
</tr>
</tbody>
</table>

- This data was used in our Matlab code (see page 29) in order to determine the number of breaking sticks needed.

- Matlab code determined that breaking sticks needed.
Net Attachment:
- Strings of approximately the same length attached each breaking stick to a point on the net. At this point was a group of knots coming from each string. These knots were glued into place for extra support. See diagram of top view of net below. This design allowed the net to still hang despite any non-breaking members.

Knots attaching net to beam were also glued for extra support.

**Final Design - The Destructor**

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
<th>Unit Cost</th>
<th>Total Cost/Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>① Sticks (green)</td>
<td>810</td>
<td>$0.05</td>
<td>$40.50</td>
</tr>
<tr>
<td>② Sticks (beige)</td>
<td>4</td>
<td>$0.05</td>
<td>$0.20</td>
</tr>
<tr>
<td>③ String (beige)</td>
<td>29 ft</td>
<td>$0.12/ft</td>
<td>$3.48</td>
</tr>
<tr>
<td>④ Paper (CRD)</td>
<td>1</td>
<td>$0.01</td>
<td>$0.01</td>
</tr>
</tbody>
</table>

Maintenance & Repair:
- 10 Sticks
  - $0.05 per metered

**Final Specs**
- Cost: $85.00
- Weight: 3.3 oz = 0.936 kg
- Length: 24"
- Height: 6"

*See FDE Page*

**Created FDE & assigned Students by group: Prepared to meet before lab for day run**

Witnessed & Understood by me:

Rebecca Venticuglia
Date: 3/10/19

Received By:
Date: 3/10/19
From Page No. 27

Physical Analysis/Force Equation Analysis: (From Linny's Notebook)

Initial: \( v_x = \frac{v_0}{\cos \theta} = 24 \text{ m/s}, \quad x_0 = 11 \text{ m}, \quad v_y = v_{y0} = -9.78 \text{ m/s}, \quad \Delta x = -0.5 \text{ m/s} \) (from deflection test)

\[
\frac{a}{\Delta t} = \frac{\Delta v}{\Delta t} = \frac{\Delta v}{\Delta t} = \frac{\sqrt{19} - 2 \Delta y}{\Delta t} = 0.823 \text{ s}
\]

\[
25 \sin \theta = m\frac{\Delta v}{\Delta t} \quad m = 1.142 \text{ kg} \quad \text{mass of baseball}
\]

\[
T \sin \theta = \frac{m v_0}{\Delta t} = 8.91 \text{ N}
\]

Final: We needed to find a more realistic \( \Delta x \) from testing

\[
m = 1.142 \text{ kg}, \quad v_0 = \frac{v_x}{\cos \theta}, \quad v_y = v_{y0} = -9.78 \text{ m/s} \quad \text{we will vary} \ h \ \text{to find} \ \Delta x \ \text{at which breaking occurs}
\]

\[
T \sin \theta = m \frac{v_0}{\Delta t} = 40 \text{ N} \quad \alpha = 25 \text{ m/s} \quad \frac{v_0^2}{2 \alpha} = -0.2 \text{ m/s}^2
\]

\[
\Delta y = \frac{v_x \Delta t^2}{2} = \frac{-24 \Delta t^2}{2} = -3 \Delta t^2
\]

\[
\Delta x = \frac{h}{2} = \frac{2 \Delta t}{4} = 0.1 \Delta t^2
\]

Using Engineering Equation: we found that our possible range of \( \Delta x \) was

\[
\Delta x = \frac{v_0^3 - v_{y0}^2}{2a}
\]

\[
v_0 = \sqrt{2gh} \quad v_{y0} = 0 \quad \Delta x = \frac{v_0^2}{2a}
\]
Calculates the velocity, acceleration, and force during/after each pair of
tracks breaks. Basically just calls a loop calculating the final velocities
after each break using the equation \( F = \text{mass} \times \text{acceleration} \) and then these values
are used to find the force on each stick breaking. The acceleration comes
directly from the experimental \( \text{mass} \times \text{acceleration} \) of each stick.

```matlab
function [max, alpha, gamma, v0, d] = breaks(v0, d, n)
    % v0 = initial velocity
    % d = distance
    m = 0.142;
    g = -10;
    % max = experimentally found.

    printf('Number of Breaks: %d

    | Break | Initial Velocity [m/s] | Final Velocity [m/s] | Max [m/s^2] | Vertical Tension [N] |
    |-------|------------------------|----------------------|------------|---------------------|
    |   1   | 10.06                  | 9.39                 | 42         | 55.76               |
    |   2   | 8.38                   | 7.64                 | 42         | 55.52               |
    |   3   | 7.25                   | 6.53                 | 42         | 50.99               |
    |   4   | 6.54                   | 6.13                 | 42         | 50.99               |
    |   5   | 5.74                   | 5.72                 | 42         | 50.99               |
    |   6   | 5.12                   | 5.15                 | 42         | 50.99               |

    % MATLAB Output:
    % Number of Breaks: 6
    % d = 3.5006 [m]
    % v0 = 10.00 [m/s]

    % Break 1:
    % Initial Velocity [m/s]: 10.06
    % Final Velocity [m/s]: 9.39
    % Max [m/s^2]: 42
    % Vertical Tension [N]: 55.76
```

Witnessed & Understood by me,

Rebecca Vincentina

Date: 3/10/11

Invented by

Rebecca Vincentina

Date: 5/14/11
Materials Bought/Purchases Made:

- 5 popsicle sticks
- 1 sheet of paper
- 8 ft of string
- 10 sticks
- 2 ft of string

Initial Truss Construction

- 13 sticks { 3/1/11
- 6 sticks { Truss construction
- 5 ft string { Net Beam
- 7 sticks { Truss Construction

- 2 ft string
- 5 ft string { Net Attachment
- 2 ft string

Totals: 91 sticks
29 ft of string
1 sheet of paper


Pareto Charts:

Pareto Chart: 1/Cost vs. 1/Force

Pareto Chart: 1/Weight vs. 1/Force

Witnessed & Understood by me,
Rebecca Ventimiglia

Invented by
Date: 3/10/11
Rebecca Ventimiglia

Recorded By
Date: 3/10/11
Design Considerations

- Safety Factor = 1.2
- Cost Analysis

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>5</td>
</tr>
<tr>
<td>Transmit Height</td>
<td>500</td>
</tr>
<tr>
<td>Tooth Width</td>
<td>5</td>
</tr>
<tr>
<td>Tooth Width</td>
<td>5</td>
</tr>
<tr>
<td>Overall Size</td>
<td>21 x 21</td>
</tr>
</tbody>
</table>

Decision Matrix

Concept No. 1

Concept No. 2

Concept No. 3

Witnessed & Understood by: Rebecca Ventriglia
Date: 3/10/11

Invented by: Rebecca Ventriglia
Date: 3/10/11

Recorded By: Rebecca Ventriglia
Date: 3/10/11
Final Design Review

The SYNTHESIZERS:
- Jan Cas, Lernay Pever, Rebecca Ventimiglia, Chia Yip ooh

The DISSIPATOR
- From Concept...
- To Deliverable

Design Overview
- Suspended Net
- Lattice/Diamond/Diamond-Diamond pattern
- Biaxial for suspension & energy dissipation

Analysis: Truss
- Pratt Truss:

Design Overview
- Pratt Truss
- Two Beam Types
- Gusset Joins
- Diaphragm beams: present & tension
- Reinforced members for stiffness
- Gusset joints: limit 90°

Analysis: MATLAB
- Equations Used:
  \[ T_{max} = \frac{F \cdot L}{A} \]
- MATLAB Output:

Witnessed & Understood by me.
Rebecca Ventimiglia
5/10/11

Recorded By
Rebecca Ventimiglia
3/10/11
Performance Specs
- Easy to manufacture
- Adjustable for style
- Strong triple reinforced beams
- Affordable
- Weight: 3.3 oz.
- Cost: 88 c

Ready for Mars
- Built of fibrous materials
- Lightweight
- Inexpensive
- Simple to manufacture
- Unique design
- Stable
- Dissipates meteorite energy effectively

Notes for "Ready for Mars Site"
- Built of wood, cotton string, glue
- Lightweight: approximately 3.3 oz., is less than 1 kg
- Inexpensive: cost less than a $1, total cost was only 20% of budget
- Pre-fabrication techniques allowed for easy to manufacture design
- Unique design with its own label
- Triple reinforced beams make it more stable, diagonal connections prevent tension
- Dissipation occurs as opposed to a dead stop.

The Synthesizers...
"In Trust We Trust"
Date: 3/4/2011 (Lab Section 2:00-4:30)

Today in lab we received our groups/partners for the windpump project. The names and contact info of my team members is listed below:

<table>
<thead>
<tr>
<th>Name</th>
<th>Net ID</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rebecca Ventimiglia</td>
<td>r488</td>
<td>(203) 695-7208</td>
</tr>
<tr>
<td>Catherine (Kai) Wong</td>
<td>kw358</td>
<td>(408) 896-0214</td>
</tr>
<tr>
<td>Andre Vasquez</td>
<td>aav28</td>
<td>(916) 434-7612</td>
</tr>
<tr>
<td>Ryan Westover</td>
<td>crw59</td>
<td>(732) 775-9742</td>
</tr>
<tr>
<td>Christian Segarra</td>
<td>cas397</td>
<td>(917) 406-2759</td>
</tr>
</tbody>
</table>

After exchanging contact information, we agreed to meet up during the following week. This meeting would be coordinated by e-mail.
Date: 3/14/2011 (Initial Team Meeting in Duffield - 9 pm to 10 pm)

While waiting for everyone to arrive, the topic of meeting times was discussed. The best days for the group to meet, based on schedules were Tuesdays, Thursdays, and Saturdays in the evening.

The schedule for the pump project was also looked over, in order to familiarize ourselves with deadlines:

- Team Assignment: Week 6 (3/4/11)
- Preliminary Design Review: Week 8 (3/18/11)
- Analysis: Week 9 (3/25/11) → Spring Break
- Final Design Review: Week 10 (4/1/11)
- Qualifiers: Week 12 (4/15/11)
- Pump Presentation: Week 13 (4/22/11)

The project statement was reviewed:

The team must create a water pump powered by a wind turbine. The prototype must be efficient, and be made of a piston and be compatible with supplied plate and speaker. Included specifications for the wind turbine are that it will spin at a speed of 760/5 and the blades have a radius of 0.5m.

Next, customer needs were translated:

1. The prototype should pump water from an input reservoir with water level at the height of the drive shaft to an output reservoir with water level at an elevation at least 1.5 m above the axis of the drive shaft at a rate of at least 1 L/min.

   The windmill can have water input at the height of its drive shaft and transport water to a height at least 1.5m above the shaft at a minimum rate of 1 L/min.

2. The cylinder bore diameter is fixed at 1.875", wall thickness 0.125", due to material availability.

   The water pump's cylinder will have a diameter of 1.875", wall thickness of 0.125" (so that the inner diameter is 1.5"), due to the material available.

Witnessed & Understood by me,

Rebecca Venturinigia

Date: 3/10/11

Invented by: 

Date: 3/10/11

Recorded By: Rebecca Venturinigia
"The pump must sit stably on a 3" x 7" horizontal plane supplied by customer."

The pump's center of mass coincides with the 7" x 7" horizontal plate's center of mass (supplied by customer, must also consider height of pump).

"The output drive shaft must be a 1/2" diameter rod extending 2 1/2" beyond the supplied face-plate (1/4" thick). Its axis will be located 5 1/2" above the horizontal plane. The pump will be attached to the face-plate by 4, 1/4" x 20 thread screws located on the face plate as shown on Blackboard."

The windpump's output drive shaft has a diameter of 1/2" extending 2 1/2" beyond the horizontal plate. The windpump's drive shaft axis is located between 9" and 7" above the horizontal plate. The windpump is attached to the face plate by 4, 1/4" x 20 thread screws.

"The overall dimension of the pump must be such that it fits into a volume no greater than 14" x 14" x 14". It will sit on the 7" x 7" horizontal plate (see sketch on Blackboard). The height of the horizontal plate is adjustable so that the distance from the horizontal plate to the drive shaft accommodates your motor within the range specified in the previous paragraph. The pump will be surrounded by ambient air, and placed in a tub to collect possible water leaks. Water will be fed to and from the pump through 3/8" lines connected to the input and output reservoir. The elevation of the input reservoir water level will be the same as the shaft's.

The volume of the windpump is at most 2.744 in³. The pump works in an open-air environment and can be connected to water lines of 3/8" diameter. The pump's operating height is within the specified requirements. The pump must also tolerate leaks and pump from an input height that is even with the shaft's height.

"The input torque will be provided by the customer-supplied wind turbine. You will have measured the torque-power characteristics of the turbine in weeks 7 or 8."

The windpump receives input torque from a customer-supplied wind turbine whose power and torque characteristics will be measured in weeks 7 or 8.

Next meeting: 4 pm on Saturday, March 12, 2011.
Date: 3/11/2011 (Lab Section 2:00-4:30 pm)

**Wind Turbine Testing**

**Procedure:**
1. Start: Obtain an rpm measurement device (Tachometer)
2. Zero out the springs in the testing setup.
3. Remove belt from around the flywheel and start the wind turbine.
4. Obtain the maximum number of RPM for the turbine while the belt is disconnected.
5. Add the belt to the wind turbine flywheel and record the RPM and the spring measurements for each spring. Be sure that these springs are not so tight that the turbine stalls.
6. Tighten the springs and repeat Step 5, add slight increments of spring tightening and continue to repeat until stalling.
7. Once a stall point is reached, take down measurements of the flywheel decreased and record.

**Testing Set-Up:**

**Table:**

<table>
<thead>
<tr>
<th>Data</th>
<th>Group 2:</th>
<th></th>
<th>Group 1:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spring 2 (n)</td>
<td>Spring 3 (n)</td>
<td>RPM</td>
</tr>
<tr>
<td>Max</td>
<td>12.00</td>
<td>12.00</td>
<td>15.00</td>
</tr>
<tr>
<td>10.5</td>
<td>11.00</td>
<td>11.00</td>
<td>11.00</td>
</tr>
<tr>
<td>9.5</td>
<td>10.5</td>
<td>10.5</td>
<td>10.5</td>
</tr>
<tr>
<td>8.5</td>
<td>9.5</td>
<td>9.5</td>
<td>9.5</td>
</tr>
<tr>
<td>7.5</td>
<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
</tr>
<tr>
<td>6.5</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
</tr>
<tr>
<td>6.0</td>
<td>6.5</td>
<td>6.5</td>
<td>6.5</td>
</tr>
<tr>
<td>5.5</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>

**Flywheel:**
- Diameter: 14.5 cm
- Radius: 7.25 cm

**Turbine:**
- Length: 3.0 inches
- Width of Blade: 3.0 inches
- Flat Top: 1.0 inch
- Flat Base: 0.5 inches

Witnessed & Understood by me,

Rebecca Ventrimiglia

Date: 3/11/11

Inscribed by

Rebecca Ventrimiglia

Date: 5/11/11
After obtaining the Wind Turbine Data, we decided to write a MATLAB m-file to plot the data and analyze it.

Pseudo code for Power Curve Analysis:
- Define constants (radius of turbine = .0725 m)
- Define vectors for rpm and forces on each spring
- Convert rpm to rps and then define w (angular frequency) = 2π rps
- Find delta for Torque (the difference between the forces on the springs) and then use this delta to find Torque (radius of turbine multiplied by frequency difference in springs)
- Calculate daily power (Torque multiplied by frequency)
- Plot frequency vs. power.

By the time the code was written, it was time to test the lab. The group agreed to set up a few meetings for the next week and to communicate through a Wiki page account. The next meeting would be on Saturday, March 12th, 2011 at 9 pm. Team members would prepare by reading through lecture notes on turbine performance.

function powerCurve()
    radius = .0725;
    rpm = [1210 1027 945 865 727 640 544 530]';
    rps = rpm / 60;
    w = 2 * pi * rps;
    T1 = [0 4 6 8 11 13 14 15.5]';
    T2 = [0 0 0 0.2 0.4 0.7 0.8 0.8]';
    delT = T1 - T2;
    Torque = delT * radius;
    Power = Torque .* w;
    hold on
    axis equal
    axis on
    plot(w, Power);

end
Date: 3/1/2011 (Meeting in Project Team Lab by Whiteboard Wall (4:50-6:30PM))

In order to get a better feel for the project and the way the turbine/pump works, we rederived the equations from lecture.

Diagram (for Reference):

Key:
- $\theta$: angle of crankshaft w/ horizontal
- $F_c$: Force of crankshaft
- $L$: length of driveshaft
- $F$: force of piston
- $R$: radius of crankshaft
- $\alpha$: angle of crankshaft w/ horizontal
- $I_s, I_p$: moment of inertia of connecting rod
- $\omega$: angular frequency
- $R_b$: radius of blade
- $V_T$: tangential velocity at sprocket 1
- $V_a$: tangential velocity at sprocket 2

Distance from Top (TDC) Center:

$$X = R + L - \left[ L \cos \theta + R \cos \theta \right]$$

$$X = R + L - \left[ R \cos \theta + \sqrt{L^2 - R^2 \sin^2 \theta} \right]$$

Speed of Piston:

$$\dot{x} = \frac{1}{2} \left[ -\sqrt{L^2 - R^2 \sin^2 \theta} - R \sin \theta \right]$$

$$\dot{x} = \frac{1}{2} \left( L^2 - R^2 \sin^2 \theta \right)^{1/2} \left( -2R \sin \theta \cos \theta \right) + R \sin \theta$$

$$\dot{x} = \frac{R \sin \theta}{\sqrt{L^2 - R^2 \sin^2 \theta}}$$

Note: We did not follow Prof. White assumption since we wanted to do our own work completely.

Witnessed & Understood by me, 3/12/11

Rebecca Ventimiglia

Invented by

Date 3/12/11

Recorded By

Rebecca Ventimiglia
Volume Flow Rate (Volume Pumped)

\[ Q = \frac{\pi}{V} \int_0^1 \left[ \frac{E_1 \sin\theta \left( \cos\theta - \frac{1}{2} \right)}{\sqrt{V^2 - R_s^2 \sin^2\theta}} \right] \, d\theta \]

\[ \dot{Q} = \frac{\pi}{V} \int_0^1 \frac{E_1 \sin\theta \left( \cos\theta - \frac{1}{2} \right)}{\sqrt{V^2 - R_s^2 \sin^2\theta}} \, d\theta \]

\[
\begin{align*}
\dot{Q} &= \frac{1}{2} \pi \frac{E_1}{V} \int_0^1 \frac{d\theta}{\sqrt{1 - \frac{R_s^2}{V^2} \sin^2\theta}} + \pi \frac{E_1}{V} \int_0^1 \sin\theta \, d\theta \\
\dot{Q} &= \frac{1}{2} \pi \frac{E_1}{V} \left[ -\frac{1}{R_s} \sqrt{1 - \frac{R_s^2}{V^2}} \right] + \pi \frac{E_1}{V} \left[ -\frac{1}{2} \cos\theta \right]_0^1 \\
\dot{Q} &= \frac{1}{2} \pi \frac{E_1}{V} \left[ -\frac{1}{R_s} \sqrt{1 - \frac{R_s^2}{V^2}} - \frac{\pi}{2} \right] \\
\dot{Q} &= 2 \pi \frac{E_1}{V} \left( \frac{R_s}{2} \right) \\
\dot{Q} &= \frac{\pi}{V} \frac{E_1}{2} R_s \theta \\
\end{align*}
\]

\[ \dot{Q} = \frac{\pi}{V} \frac{E_1}{2} R_s \theta \\
\]

Sprinkler connections

Between the two sprinklers, tangential velocities are the same, therefore the same between the shaft connections:

\[ \Omega = \frac{R_2}{R_1} \]

This can now be substituted into the equation for volumetric flow.

Power:

\[ P = F \dot{Q} = F \frac{\pi}{V} \frac{E_1}{2} R_s \theta \\
P = \pi gh \frac{\pi}{V} \frac{E_1}{2} R_s \theta \\
P = \pi gh \dot{Q} = \pi gh \left( \frac{V^2}{2} \right) \dot{Q} \\
\]

so the key variable is \( r \) because all other variables are constants.

By going through these proofs, it was realized that a mostly complete linear motion was desirable for efficiency. Also, we obtained ideas for materials and design. We would consider gears as well as a clutch action piston.

Other considerations: friction between sprocket drive shaft/flywheel, lack to maximize torque. Maximize resistance in overall motion equation:

\[
\begin{align*}
\left[ I_1 + I_s \left( \frac{E_1}{2} \right)^2 \right] \theta &= \left( \frac{E_1}{2} \right)^2 \text{Tm} \tan \left( 2 \pi \frac{1}{2} \right) \frac{V}{\text{F} \tan} - \text{Res} \left( \frac{E_1}{2} \right) \cos \theta \\
\end{align*}
\]
After analyzing the MATLAB program, which had been revised since our last meeting, the new code included a resonance region between 87-97 rad/s (Angular Frequency). This included a line for the power required for certain angular frequency. We decided that we should avoid the end of the resonance region of a little more. This is because we would minimize the power required and avoid resonance. The curve that we looked at is shown below.

![Turbine Power Curve](image)

**Turbine Power Curve**

- Group 1 Data
- Group 2 Data

**Angular Frequency (\( \omega \))**

**Power Output (W)**
Date: 3/14/2011 (Meeting at Project Team Whiteboard Wall: 7-9 PM)

Priority of Customer Needs/Functional Requirements

<table>
<thead>
<tr>
<th>#</th>
<th>Aspect of Pump</th>
<th>Importance (5&gt;2&gt;1)</th>
<th>Dimension Requirement</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A between drive shaft and output</td>
<td>**</td>
<td>A X 21.5m</td>
<td>Meters</td>
</tr>
<tr>
<td>2</td>
<td>Volume Flow Rate</td>
<td>** **</td>
<td>A &gt; 64 l/min</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Center of Mass</td>
<td>* **</td>
<td>Gear/Center of</td>
<td>Meter</td>
</tr>
<tr>
<td></td>
<td>Face plate</td>
<td></td>
<td>Vibration</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Distance from face plate</td>
<td>**</td>
<td>A x 12.25&quot;, length 2&quot;</td>
<td>Inches</td>
</tr>
<tr>
<td>5</td>
<td>Axis of output shaft</td>
<td>*</td>
<td>5 2&quot; above horizontal plate</td>
<td>Meter</td>
</tr>
<tr>
<td>6</td>
<td>Attachment</td>
<td>****</td>
<td>Compatible with face plate</td>
<td>Meter</td>
</tr>
<tr>
<td>7</td>
<td>Volume of Pump</td>
<td>14&quot; x 14&quot; x 14&quot;</td>
<td>Surface plate</td>
<td>Meter</td>
</tr>
<tr>
<td>8</td>
<td>Input/Output Dimension</td>
<td>**</td>
<td>9/16&quot; Diameter</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Power</td>
<td>***</td>
<td>Generate at V=3/4&quot;</td>
<td>Watts</td>
</tr>
<tr>
<td>10</td>
<td>Cost Efficiency</td>
<td>**</td>
<td>Total Budget $930</td>
<td>USD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Efficient Machinery</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Ease of Production</td>
<td>**</td>
<td>Minimize components &amp;</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Complicated Shapes</td>
<td></td>
</tr>
</tbody>
</table>

In the chart above, aspects with 3 stars were given the highest priority and aspects with 1 star were given the lowest priority.

Witnessed & Understood by me,

Rebecca Ventimiglia

Date: 3/14/11

Invented by

Rebecca Ventimiglia

Recorded By

Rebecca Ventimiglia

Date: 3/14/11
### Project No. 2

#### Date: 3/14/2011 (Continued)

**Generated Projects to Focus on for A Morphological Chart**

<table>
<thead>
<tr>
<th>Junctions</th>
<th>Sizes</th>
<th>Shapes</th>
<th>Positions</th>
<th>Operating Mechanism</th>
<th># of Pistons</th>
<th>Values</th>
<th>Crankshaft</th>
<th>Drive Mechanism</th>
<th>Position of Pistons</th>
<th>Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Date: 3/17/2011 - My Ideas for Morphological Chart (5-5:30 PM)

**Junctions:**
- **Y-Junction:**
- **Branching:**
- **Rubber/Seal:**
- **Hydraulic Taper/Teflon**

**Threads:**
- **Threaded:**
- **Furrowed Staggered**

**Sizes:**
- **Large to Small (Nozzle):**
- **Small Throughout:**

**Shapes:**
- **Tapered Holes:**
- **Flared End/Nozzled Ends:**

**Positions on Input/Output:**
- **(3/14/11)**

---

**Witnessed & Understood by me:**

Rebecca Ventimiglia

**Invented by:**

Rebecca Ventimiglia

**Recorded By:**

Rebecca Ventimiglia

Date: 3/14/11
From Page No. 4

Date 3/17/11 (continued)

Positions of Pistons

Values
Check Values

Flap Values (like a Heart)

Crank Shaft (can vary angles between members)

Drive Shaft Connections

Drive Mechanisms

Yoke
Gears
Cam Driven
Slider Crank

Stability Supports

Weights
Feet
Truss-Like

Witnessed & Understood by me,
Rebecca Ventimiglia

Date 3/17/11
Invented by
Rebecca Ventimiglia

Recorded By
Rebecca Ventimiglia

Date 3/17/11
Date: 3/17/2012 - Team Meeting in Duffield (6:30 PM - 9:15 PM)
At this meeting, we created our Morphological Chart and Decision Matrix.

**Morphological Chart:**

<table>
<thead>
<tr>
<th>ING</th>
<th>PIVOTING</th>
<th>TWO PISTON</th>
<th>COMBUSTION SIMULATOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANK</td>
<td>YOKE DRIVEN</td>
<td>PLANETARY GEARS</td>
<td>SPRING LOADED</td>
</tr>
<tr>
<td>ID</td>
<td>OFFSET AT 90° 90°</td>
<td>OFFSET AT 180°</td>
<td>180°</td>
</tr>
<tr>
<td></td>
<td>FLOATING BALL</td>
<td>SPRING LOADED</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X-SHAPED</td>
<td>CHANGE IN DIAMETER</td>
<td>MULTIPLE JUNCTIONS</td>
</tr>
<tr>
<td></td>
<td>WITH CLARPS</td>
<td>TRUSS SUPPORT</td>
<td>WEIGHTS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ZIP TIES</td>
<td></td>
</tr>
</tbody>
</table>

Witnessed & Understood by me,
Rebecca Ventimiglia

Date: 3/17/11
Inverted by
Rebecca Ventimiglia

Recorded By
Rebecca Ventimiglia

Date: 3/17/11
**Mach 5 Decision Matrix** (numbers highlighted represent top choices for each category).

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volumetric Flowage</td>
<td>0.3</td>
</tr>
<tr>
<td>Stability</td>
<td>0.2</td>
</tr>
<tr>
<td>Compatibility with Given-Dimensions</td>
<td>0.15</td>
</tr>
<tr>
<td>Amount of Material</td>
<td>0.2</td>
</tr>
<tr>
<td>Cost Efficiency</td>
<td>0.15</td>
</tr>
<tr>
<td>Ease of Production</td>
<td>0.1</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
</tr>
</tbody>
</table>

Ratings are on a 1 to 5 scale where 1 is the worst and 5 is the best. Ratings were based on prior experience and knowledge from previous courses.

From the results of our decision matrix, we decided on drawing the top 3 concepts for the PDR design review. The sketches of the 3 concepts are shown in the following pages.

Witnessed & Understood by me,

Rebecca Ventromiglia  
Date: 3/19/11

Invented by

Rebecca Ventromiglia  
Date: 3/19/11

Recorded By

Rebecca Ventromiglia  
Date: 3/19/11
Sketches of 3 concepts for PDR:

1. Yoke Driver
2. Sliding Crank / Point Pusher
3. Two Pistons

Date: 3/19/11

Witnessed & Understood by me,

Rebecca Ventringlia

3/17/11

Invented by

Date

Recarded by

Rebecca Ventringlia

3/17/11
Date: 3/18/2011 (Meeting in Duffield 1:00 - 1:30 PM)
We need to finalize the PDR and go over what we wanted to discuss with the PDE.

Slide 1:
Rebecca to talk about MANIT'S Speed intro

Slide 2:
Overview
- Mission Statement
- Customer Needs
- Morphological Chart
- Decision Matrix
- Design Concepts

Next

Slide 3:
Catherine to discuss the main customer requirements as interpreted from customer statements

Slide 4:
Catherine to show how to account for dimensional requirements from customer statements

Slide 5:
Catherine to discuss ideas which are unique to MANIT, but at least one item per row

Slide 6:
Rebecca to discuss criteria, priority weights, and the two-decision matrix, no values for stability

Customer Needs
- Dimensions
- Flow Rate
- Stable
- Volume
- Power

Numerical Specifications
<table>
<thead>
<tr>
<th>Aspect of Pump</th>
<th>Dimension</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design pressure and capacity</td>
<td>100 bar</td>
<td>psi</td>
</tr>
<tr>
<td>Volume: Core volume</td>
<td>500 liters</td>
<td>125 gallons</td>
</tr>
<tr>
<td>Cylinder bore diameter</td>
<td>3.5 inches</td>
<td>89 mm</td>
</tr>
<tr>
<td>Wall thickness</td>
<td>0.25 inches</td>
<td>6 mm</td>
</tr>
<tr>
<td>Center of mass</td>
<td>Centered with GOM of composed mass</td>
<td></td>
</tr>
<tr>
<td>Output shaft</td>
<td>0.5 inch diameter, length 6 inches</td>
<td>13 mm</td>
</tr>
<tr>
<td>Output diameter</td>
<td>0.375 inch bore horizontal plane</td>
<td>9.6 mm</td>
</tr>
<tr>
<td>Compatibility with screw</td>
<td>0.50 inch, with thread</td>
<td>12.7 mm</td>
</tr>
<tr>
<td>Volume of pump</td>
<td>1.4 cubic inches</td>
<td>23</td>
</tr>
<tr>
<td>Component with mass</td>
<td>3 lbs</td>
<td>1.36 kg</td>
</tr>
<tr>
<td>Power</td>
<td>Maximum speed of transmission</td>
<td></td>
</tr>
</tbody>
</table>

Decision Matrices

Witnessed & Understood by me,
Rebecca Ventimiglia

Date 3/18/11

Invented by
Rebecca Ventimiglia

Date 3/18/11
Slide 7:
Rebecca→
Again, explain why there are two matrices, top concepts will go with each top concept from previous decision matrix.

Slide 8:
Rebecca→
Describe yoke driven concept, explain drawing.

Slide 9:
Catherine→
Explain two pump design concept.

Slide 10:
Catherine→
Explain dual acting ability of this concept.

Slide 11:
Rebecca→
Explain pros & cons of each design.

Slide 12:
Closing/Field Questions

Moving Ahead:
- Yoke Driven
  - Pros: Simple to manufacture/operate
  - Pros: Cost is competitive
- Two Piston
  - Pros: Simple, part & tool manufacturing
- Slider Crank
  - Pros: Durable, compact
  - Cons: Difficult to manufacture and assemble.

Questions?

Witnessed & Understood by me: Rebecca Ventimiglia

Date: 3/18/11

Invented by: Rebecca Ventimiglia

Date: 3/18/11

Recorded By: Rebecca Ventimiglia

Date: 3/18/11
Essel Design/Concept Review from Peers/TA's
Below is the name of the concept and the feedback we received for the concept.

1) Slider Crank PIVL Piston
   - Hard to house?
   - Might be too unstable?
   - Seems hard to make advantageous?
   - Easy to break?
   - Angle is good for pumping out, - Naylor a vertical driver?
   - Harder for drawing in.

2) Two Piston Slider Crank
   - Watch corners for stress points.
   - How is shaft made?
   - Check for engine balance.

3) Yoke Drive
   - Where are these commonly used?
   - One piston, most effective use of energy?
   - Tricky to manufacture

4) Morphological Chart
   - Joints may be hard to manufacture
   - Branching & clever could help with pressure
   - We've already provided a foot.
   - What values are you using for each design?
   - Planetary gears are complicated.
   - Considering analysis of maybe different gear orientations.

We reviewed the comments given to us by our peers and considered their expressions and advice in our design process.
Date: 3/10/2011 (continued)

After PDR presentations were given (see pages 49 to 50 for PDR), we analyzed pumps from previous years.

1. 4-Bolt Yoke Drive Design
   - String middle joint
   - Alignment geometry are very significant!
   - Notches cause a lot of stress
   - Open bottom to reduce material/save money
   - Dampers for alignment
   - Bore out plates to hold pistons
   - Rotation w/cylinders

2. Dual Acting (Unsuccessful)
   - Rather pads are bad idea for sealing
   - Hardness compacted cylinders
   - Yoke in one direction→no rotation!
   - Washers used in spacing

3. Dual Acting (Successful) Yoke Drive
   - Must minimize gap
   - A lot of boring → easy to manufacture?
   - Washers for less friction

4. Antilla Bigle
   - Notched joints
   - Ball bearings = less friction
   - Pins to hold joints together
   - Additional extra strips to limit friction/all gaps

The group used the pros and cons of each design & design elements when designing the pump.
Date: 3/27/11  (Team Meeting in Durham: 11:00am-11:30pm)

At today's team meeting, we discussed different valve box ideas as well as different ideas of parts for ordering.

**Valve Box Idea:**

- Holes drilled through material (one for intake, and one for output). Valves work as swivels, rotate, and hole aligns with holes in box. Shaft powered by belt to crankshaft.

- Intake/output holes

- Hole for valve shaft

**Parts to Consider Ordering:**

1. O-Ring (for seal)
2. Belt (to drive our valve shaft)
3. End caps (to hold rods in place while rotating)
4. Hose fittings (to control fluids into hoses)
5. Gears/pulleys for making gears
6. Belt pulleys

Witnessed & Understood by me.

Rebecca Ventimiglia

3/27/11

Invented by

Rebecca Ventimiglia

3/27/11

Recorded By

Rebecca Ventimiglia

3/27/11
It was brought up that our original design for the valve box shaft may not work. This is because the valve would be open on both the intake and output stroke, as shown below. We need the valve to only be open on one part of the cycle for each rotation.

* In order to fix this, we came up with a new circular shaft idea that allowed for an open valve for only a quarter of the cycle.

* Another idea that we considered was manufacturing a Geneva gear, as shown below. This would only allow for the valve to be open for 1/4 of a cycle. The original valve shaft design would be used with this design so that the valve would only be open on intake or output, but not both.

* Decided to come to another team meeting tomorrow to draw parts, fully dimensioned in CAD. Members expected to create design with dimensions.

Witnessed & Understood by me:

Date: 3/30/11

Rebecca Vardinioglio
Date: 3/30/2011

The following are my original design concepts with dimensions. I took the list of provided materials and worked with it to create a design.

Provided Material:
- Stock: Aluminium 6061 T6 & Steel 1012
- 1.575" PVC Round Stock
- 2" OD, Aluminium Tubing, nominally 1.75" ID
- 1" x 2" Aluminium Flat Stock 10" long
- 1/2" Diameter Aluminium Rod

Cylinders/Pistons

- O-Ring

MATERIAL USED:
- 1 - O-Ring
- 8" Aluminium Cylinder/Tubing
- 2" PVC Piston Round Stock

*Note: Dimensions were not chosen yet because it was dependent on the geometry of the rod for the brackets connecting to the rod.

The brackets will be manufactured from remaining stock.

Witnessed & Understood by:

Rebecca Ventimiglia

Date Invented by

3/30/11

Recorded By

Rebecca Ventimiglia

Date

3/30/11
**Date:** 3/30/2011 (Continued)

**Valve Box Shaft**
- 6.5 in
- 5.3 in
- Width of side of frame
- Semi-circular area for valve opening and closing
- Width of frame

**Material Used:**
- 6" of ½" Aluminum Stock

**Crank Shaft**

→ Please see next page!
DATE: 3/30/11

MATERIAL USED:
1.5 ft from 1" x 2" Aluminum Stock
(1) 9" Piece of Aluminum Stock
(5) 1" Pieces of 1/2" Aluminum Stock
(1) 20" Piece from 1/2" Aluminum Stock

Joint Press

FRAME:

Back Plate will be bolted 4" to 6" for cylinders

For valve shaft

Material Used:
Gusset 1.25" x 4" x 10" Aluminum Stock
6 pieces of 2.4" x 2.4" x 10" Aluminum

Lever: Use extra cylinders to create feet.

Witnessed & Understood by me:
Rebecca Ventimiglia

Date: 3/30/11

Invented by:
Rebecca Ventimiglia

Date: 3/30/11
Date: 3/30/2011

Geometrical Analysis

\[
\tan 30^\circ = \frac{x}{12.5}\sin \theta = \frac{x}{20} \sin \theta
\]

What material is used where?

- 5/8 Aluminum Rod - Bar
- 1.25" PVC Stock - Pistons
- 2 OD Alum. Cylinder - 6" for Cylinder, 4" for studs
- 2x4x4x6 - Frame
- 2x2x2" 10" - Valve Box, Rods
- 4 x 1" x 10" - Crankshaft Joints
DATE: 3/21/11 Team Meeting in Upper Basement (8:30 - 11:30 AM)

- At today's meeting, we collaborated on our dimensionalized sketches in order to create a full working 3D model of our pump in SolidWorks. These dimensions are preliminary, and the pump was created in order to see how everything fits together. Also, it gives us a model we can manipulate, as well as a way we can visually see how changing dimensions affects the design.

- Also, we considered only using the cylinders as feet to the base. Since we are boring out a hole for the cylinder and piston head, then why don't we just use this hole as our piston cylinder as below. We will inquire about this.

- We also looked into the prices for buying e-clips, O-rings, pulleys, timing belts, and hose fittings.

- Picture of Internal Pump CAD.

Witnessed & Understood by me:

Rebecca Ventimiglia

Date: 3/30/11

Inventor:

Rebecca Ventimiglia

Date: 3/30/11
**Windpump Project**

**DATE**: 3/31/2011

MATLAB Analysis: Earlier in the week, I wrote a final MATLAB code to model our pump. The code is 5 pages long, so I will write the pseudocode here. We used this code to calculate T, Wp, and power for any given P and R values (dimensions which were at our discretion).

**Pseudocode**:

- Initialize variables (P, R, r, p, g, h, A, radius of crankshaft, length of rod)
- Calculate \( \omega \) and \( \text{rpm} \) net force from tabulated data
- Plot \( \omega \) vs. power (label axes, state key, identify resonance region)
- Plot a line representing power requirement for certain \( \omega \) (\( P = \frac{g}{h} \cdot \omega \))
- Plot position of piston head with \( \theta \) (use \( x = L + R \cdot \sqrt{L^2 - R^2 \cdot \sin(\theta)^2} + R \cdot \cos(\theta) \)) (label axes again)
- Plot position of piston head with time (use \( x = c + R \cdot \sqrt{L^2 - R^2 \cdot \sin(\theta)^2} + R \cdot \cos(\theta) \), \( \theta = 2\pi \cdot f \cdot t + \omega \cdot t \)) (label axes again)
- Plot volume pumped with time (label axes again)

**Plots from code:**

**Turbine Power Curve**

**Combined Power Requirement for Two Pistons Throughout Cycle**

---

**Witnessed & Understood by me:**

Rebecca Ventimiglia

**Date:** 3/31/11

**Invented by:**

Rebecca Ventimiglia

**Date:** 3/31/11

**Recorded By:**

Rebecca Ventimiglia

**Date:** 3/31/11
Date: 4/1/2011 (Lab Section: 2:00-4:30 PM)

- Signed up for 3 Mill Shots and 1 Lathe Shot for manufacturing
  + Saw most of work would be done on the mill, so we signed up for more shots
    on the mill.

- Attempted to look into dimensions on the CAD of the pump to associate dimensions
  with stock. Finalized the CAD. At this point, we have a working CAD model, so
  we just need to check that it is feasible.

- Looked at stock code so that it would be more accurate in terms of volume pumped.

- Also considered how to manufacture pulleys/purchase parts for belt.

**Preliminary Cost Analysis of Materials to Purchase from McMaster:**

<table>
<thead>
<tr>
<th>Material</th>
<th>Type</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-Clips</td>
<td>Magnetic Stainless Steel - 9400A306</td>
<td>$6.12</td>
</tr>
<tr>
<td></td>
<td>Non-Magnetic Beryllium Copper - 92725A560</td>
<td>$1.86</td>
</tr>
<tr>
<td>O-Rings</td>
<td>EPDM Standard</td>
<td>$5.21</td>
</tr>
<tr>
<td></td>
<td>Polyurethane Standard</td>
<td>$7.66</td>
</tr>
<tr>
<td>Pulley</td>
<td>Drive Pulley</td>
<td>$14.17</td>
</tr>
<tr>
<td>Pulley Timing Belt</td>
<td>Single Sided with Trapezoidal Teeth</td>
<td>$3.07</td>
</tr>
<tr>
<td>Hose Fittings</td>
<td>Barbed- 1/4”</td>
<td>$6.53</td>
</tr>
<tr>
<td></td>
<td>Barbed- 3/8”</td>
<td>$7.03</td>
</tr>
</tbody>
</table>

From our cost analysis, we realized our driving system for the valves might cost us a lot. Would have to look for cheaper alternative because on a $30 budget, pulleys alone
would take up entire budget.

Witnessed & Understood by me:

[Signature]

Date: 4/1/11

Invented by:

[Signature]

Date: 4/1/11

Recorded by:

[Signature]

Date: 4/1/11
### E-Clips - Magnetic and Non-Magnetic

<table>
<thead>
<tr>
<th>For Shaft</th>
<th>Dia.</th>
<th>Dia.</th>
<th>Width (A)</th>
<th>Thick.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1/4&quot;</td>
<td>0.375&quot;</td>
<td>0.046&quot;</td>
<td>0.8&quot;</td>
</tr>
</tbody>
</table>

### O-Rings

<table>
<thead>
<tr>
<th>AS568A Dash Number</th>
<th>Type</th>
<th>O-Ring Type</th>
<th>Cross Section Shape</th>
<th>System of Measurement</th>
<th>Width</th>
<th>Inside Diameter</th>
<th>Outside Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>014</td>
<td>O-Ring</td>
<td>Standard</td>
<td>Round</td>
<td>Inch</td>
<td>1/16&quot;</td>
<td>1/2&quot;</td>
<td>5/8&quot;</td>
</tr>
</tbody>
</table>

### Pulley

<table>
<thead>
<tr>
<th>Pulley Type</th>
<th>Drive Pulley</th>
<th>Number of Teeth on Pulley</th>
<th>Pulley Design</th>
<th>Outside Diameter</th>
<th>Bore Type</th>
<th>Bore Size (Inner Diameter)</th>
<th>W Dimension</th>
<th>X Dimension</th>
<th>Y Dimension</th>
<th>Z Dimension</th>
<th>V Dimension (Pitch Diameter)</th>
<th>Pitch</th>
<th>Pulley Material</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1375K53</td>
<td>90</td>
<td>Solid</td>
<td>1.13&quot;</td>
<td>Finished Bore</td>
<td>1/4&quot;</td>
<td>.16&quot;</td>
<td>.276&quot;</td>
<td>.531&quot;</td>
<td>1.222&quot;</td>
<td>1.528&quot;</td>
<td>.08&quot;</td>
<td>Aluminum</td>
<td>Includes a set of screws</td>
</tr>
</tbody>
</table>

### Timing Belt

<table>
<thead>
<tr>
<th>Timing Belt Type</th>
<th>Single-Sided with Trapezoidal Teeth</th>
<th>1375K53</th>
</tr>
</thead>
</table>

### Material

<table>
<thead>
<tr>
<th>Material</th>
<th>Neoprene</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cord Material</td>
<td>Fiberglass</td>
</tr>
</tbody>
</table>

### Number of Teeth

| 300 |

### Outer Circle

| 24" |

### Belt Width

| 1/8" |

### Pitch

| 0.08" |

### Barbed Hose Fittings

<table>
<thead>
<tr>
<th>Pipe Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4&quot; - 5346K29</td>
</tr>
<tr>
<td>3/8&quot; - 5346K31</td>
</tr>
</tbody>
</table>

### Shape

<table>
<thead>
<tr>
<th>Adapter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adapter</td>
</tr>
</tbody>
</table>

### Adapter Type

| Male Pipe Swivel Adapter |

### Material

| Brass |

### Thread Type

| NPTF (Dry Seal) |

### For Hose Inside Diameter

| 3/8" |

### Maximum Pressure at 72°F

| 250 psi |

### For Hose Type

| Reinforced Rubber |

### Clamp With

| Hose Ferrule and Worm-Drive Clamp |

---

Witnessed and Understood by me:

Rebecca Venticinna

Date: 4/1/11

Invented by:

Recorded by:

Rebecca Venticinna

Date: 4/1/11
Date: 4/2/2011  Group Meeting in Upon Lounge (6-8pm)

Stress Analysis (Catherine's Notebook)

1. **8-32 Screw**:
   - \( \sigma = 1109 \) N
   - Material: Steel
   - D = 2.65 in

2. **Aluminum**
   - Shear Strength: 11,400 psi
   - Yield Strength: 12,000 psi

3. **Unit Conversion**
   - \( 1 \text{ ft}^2 = 929.03 \text{ cm}^2 \)
   - \( 1 \text{ psi} = 6,894.75 \text{ kPa} \)
   - \( 1 \text{ kN} = 0.22481 \text{ lbf} \)

4. **Steel**
   - \( \sigma_{\text{steel}} = 41,400 \text{ MN/m}^2 \)
   - \( 305.3 \text{ GPa} \)

5. **Effect of**
   - \( F = 2.00 \times 10^4 \times \pi/4 \)
   - \( = 1665 \text{ lb} \cdot \text{in}/4 \)
   - \( = 15465 \text{ lb} \cdot \text{in} \)
   - \( = 18516 \text{ N} \)

6. **Area**
   - \( A = \pi d \) (cross-sectional area)

7. **For 1" screw**:
   - \( A = 1 \times 1.164 \text{ in}^2 = 1.164 \text{ in}^2 \) (cross-sectional area)
   - \( \sigma = 2 \times D \times L = 1.66 \text{ psi}/2 = 0.8325 \text{ in}^2 \) (area around the cross section)
   - \( A_i = 2 \times D \times L = 1.050 \text{ in}^2 \times 2 = 5.15 \text{ in}^2 \) (area inside the hole)
   - \( P = \pi (0.02)^2 - \pi (0.01)^2 = 0.0340 \text{ in} \)
   - \( \sigma = 1500 \times 0.0340 \times 10^4 = 5.04 \text{ lb} \cdot \text{in} = 2419 \text{ N} \times 10^4 \)
   - \( \sigma = 2419 \text{ N} \times 10^4 \)

**Max Shear**
- \( 5.03 \times 10^6 \times A = 297525 \text{ lb} = 2213103 \text{ N} \)

Witnessed & Understood by me,

Rebecca Ventmgl

Date: 4/2/11

Invented by

Recorded By

Date: 4/2/11
Torque Analysis (Ryan's Notebook)

\[ \tau = \frac{F_0 \cos \theta}{E} \]

max effective stress: \[ \sigma_{\text{eff}} = \frac{1}{\pi} \sqrt{\left( \frac{F_0 (L_1 + L_2)}{E_0 A} \right)^2 + \left( \frac{F_0 (L_1 + L_2)}{E_0 A} \right)^2} \]

values: \( L_1 = 2 \text{ ft}, L_2 = 1 \text{ ft}, A = 6.4 \text{ in}^2, P = 500 \text{ lb}, E = 30,000,000 \text{ psi} \)

\[ \tau_{\text{eff}} = \frac{1}{\pi} \sqrt{\left( \frac{5400 (4.505 + 6.375 + 6.4375 - 0.0234)}{9400 (0.327 m)} \right)^2 + \left( \frac{5400 (4.505 + 6.375 + 6.4375 - 0.0234)}{9400 (0.327 m)} \right)^2} \]

\[ \sigma_{\text{eff}} = 200 \text{ psi} \]

\[ \sigma = \frac{2 \times 10^6 \text{ psi}}{9400 (0.327 m)} = 2.54 \times 10^5 \text{ psi} \]

Worst case: assume full force applied 45° to crankshaft

1. Torques: applied torque (T_a), T_1 from arm 1, T_2 from arm 2, T_T = T_2

2. Assume friction is negligible at points that arms turn about and when crankshaft turns in the side plate bearing (Fe x e = 0 for torques)

1 + 2: we know that torque at \( I \) appears at the opposite end and from \( T_a \), so there, \( T_{\text{sum}} = T_a + T_T \)

\[ T_{\text{sum}} = T_a + T_T = \frac{F_0 L_1}{2} \]

\[ T_T = F_0 \frac{L_1}{2} \]

at this critical points: bending moment \( M = F_0 (L_1 - L_2) \)

\[ M = \frac{T_T L_1}{2} - \frac{T_T L_2}{2} = F_0 \frac{L_1}{2} - F_0 \frac{L_2}{2} \]

Witnessed & Understood by me:

Rebecca Ventimiglia

Date: 4/2/11

Invented by:

Rebecca Ventimiglia

Date: 4/2/11
Date: 4/4/11 (Group Meeting in Uprincipal Basement: 8-10 pm)

- Work on finalizing CAD → will we buy pulleys or a belt?
  - If belt, must manufacture pulleys, tension.
  - If pulleys, no extra money left in budget for other stock, valve fittings, etc. Which are critical to pump.

- Decide to manufacture pulleys + update CAD
  - Type of belt to buy
    - Flat = Simple, easy to machine for, but maybe not enough friction ≠ too much slip
    - V-Shaped = more contact, less slip but hard to accurately machine for all current time limits

- We decided to go with a flat belt, as long as there is a way to induce friction without slip. In order to do this, we added a tension to our design in order to ensure belt is tight at all times. It did, however, require too much additional stock which we want to avoid and practical with our design knowing that we are not experienced machinists.

- It was also realized that mounting for the pump would have to be added because as of currently, our design does not have a way to connect to the water supply.
Although CAD for our design is created, we still need to make sure we have enough material to produce the design and stay within the budget. We decided to add an extra 1/8” to each hole to ensure straight, parallel edges, and exact size to exact sizing. (6pn’s) not going to fit.

**Preliminary Material breakout:**

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
<th>Used For</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 3/4”dia. PVC Round Stock</td>
<td>2</td>
<td>Pistons</td>
</tr>
<tr>
<td>1” dia. 1/2” Steel Rod</td>
<td>2 Valve Seats, Crankshaft, Middle Rod, Piston Pins, Tensor Roller</td>
<td></td>
</tr>
<tr>
<td>1” x 2” x 10” Al Plate</td>
<td>2 Crankshaft Connectors, Tensor plate</td>
<td></td>
</tr>
<tr>
<td>2” x 1” x 10” Al Plate</td>
<td>2 Piston Head Attachments, 2 Linkages</td>
<td></td>
</tr>
<tr>
<td>2” dia. 1/2” Steel Rod</td>
<td>2 Valve Seats, Cylinder Enclosure</td>
<td></td>
</tr>
<tr>
<td>3/4” dia. 1/2” Steel Rod</td>
<td>Lower Back Hosing, 2 Side Housings, 2 Small Pulleys, Housings, Pulleys</td>
<td></td>
</tr>
<tr>
<td>1/2” dia. 1/2” Steel Rod</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

*Please refer to appendix for pictures (frames of parts) sized from stock.*

**Dimensions:**

\[
20.495" = 14.75" + 2.25" + 1.75" + 4.0075"
\]

- Valve Seat
- Crankshaft/Connecting Rod Side
- Crankshaft/Connecting Rod Side
- Piston Pins, Rod Rear

**Result:**

Given 1/2” of 1/2” Steel Rod

\[
- 14.75" + 2.25" + 1.75" + 4.0075" + 1.125" + (1.25 + 1.75 + 4.44") = 20.4925"
\]

- Valve Seat
- Crankshaft Face Plate
- Middle Rod
- Tensor Plate
- Space = 2.9425"

**Purchase:**

\[
(1.75 + 4.44") + 2(1.25 + 1.75 + 4.44") + 2(1.25 + 1.75 + 4.44") = 9.4444"
\]

- Crankshaft-Timing Belt Rods
- Intermediate Rods
- Tensor Roller
- To Space = 6.56"

**Total:** 19.944"

**Witnessed & Understood by me:**

Rebecca Ventimiglia

Date: 4/6/11
Dimensions → Continued

10" x 2" x 1.5\" Aluminum Plate:

\[ \left( A + V_b \right) + \left( A + \frac{1}{2}\V_c \right) \] = 8.25\" Used

(2) Cylinder Headings/Enclosures

Top Spots = 1.75\" for 4 connections

4.500" to space

1 x 2" x 10" Aluminum Plate:

\[ \left( \frac{V_a}{\text{ain}} + \frac{V_b}{\text{ain}} \right) + \left( \frac{V_c}{\text{ain}} + \frac{V_d}{\text{ain}} \right) \] = 1.75\" Used

(2) Long arm Bar, 8.25\" to space

1 x 1\" x 10\" Aluminum Stock:

\[ \left( \frac{V_a}{\text{ain}} + \frac{V_b}{\text{ain}} \right) + \left( \frac{V_c}{\text{ain}} + \frac{V_d}{\text{ain}} \right) + \left( \frac{V_e}{\text{ain}} + \frac{V_f}{\text{ain}} \right) \] = 9.75\" Used

Piston Adapters

\[ \frac{V_a}{\text{ain}} + \frac{V_b}{\text{ain}} \] = 9.125\" for length

2 x 1.75\" x 1.5\" Side Plates

3.75\" to space

(p) Used for Width

2 x 1.75\" x 1.5\" Side Plates

0\" to space

Bottom

\[ \left( \frac{V_a}{\text{ain}} + \frac{V_b}{\text{ain}} \right) + \left( \frac{V_c}{\text{ain}} + \frac{V_d}{\text{ain}} \right) \] = 5.625\" Used in Length

1.375\" = to space

2.5\" x 1.5\" + 1.75\" x 1.5\" = 3.0\" Used in width

3\" to space

135\" PVC Stock

2 x \[ \left( \frac{V_a}{\text{ain}} + \frac{V_b}{\text{ain}} + \frac{V_c}{\text{ain}} \right) \] = 15.5\" Used for PVC

(2) Top Housing Pistons

8.50\" to space

Witnessed & Understood by me.

Rebecca Ventimiglia

Date: 4/11/11

Invented by

Rebecca Ventimiglia

Date: 4/11/11

Recorded By
**Material Given:**

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
<th>Parts Manufactured</th>
<th>Stock Used</th>
<th>Stock to Spare</th>
<th>Cost per Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>16&quot; of 1/4&quot; Diameter Steel Rod</td>
<td>1.333</td>
<td>Valve Shaft, Crankshaft: Face Plate Side, Middle Rod</td>
<td>13.0075&quot;</td>
<td>2.9925&quot;</td>
<td>1.85</td>
<td>2.1958</td>
</tr>
<tr>
<td>2 3/8&quot; X 2 3/4&quot; X 10&quot; Aluminum Plate</td>
<td>1</td>
<td>2 Valve Cylinder Housings</td>
<td>8.25&quot;</td>
<td>1.75&quot;</td>
<td>11.79</td>
<td>11.79</td>
</tr>
<tr>
<td>1&quot;x2&quot;x10&quot; Aluminum Plate</td>
<td>1</td>
<td>4 Crankshaft Connectors, Tensor Plate</td>
<td>1.75&quot;</td>
<td>8.25&quot;</td>
<td>5.58</td>
<td>5.58</td>
</tr>
<tr>
<td>1/4&quot;x1&quot;x10&quot; Aluminum Plate</td>
<td>1</td>
<td>2 Piston Head Attachment Plate, 2 Linkages</td>
<td>10&quot;</td>
<td>0&quot;</td>
<td>1.83</td>
<td>1.83</td>
</tr>
<tr>
<td>1/4&quot;x4&quot;x10&quot; Aluminum Plate</td>
<td>1</td>
<td>Back Housing, 2 Side Housings, 2 Small Pulleys</td>
<td>9.125&quot;</td>
<td>0.875&quot;</td>
<td>5.03</td>
<td>5.03</td>
</tr>
<tr>
<td>9&quot; of 1.875&quot; PVC Round Stock</td>
<td>1</td>
<td>2 Pistons</td>
<td>1&quot;</td>
<td>8&quot;</td>
<td>6.8</td>
<td>6.8</td>
</tr>
<tr>
<td>12&quot; of 2&quot; O.D. Aluminum Tubing</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>- 0</td>
<td></td>
</tr>
</tbody>
</table>

**Material to Purchase:**

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
<th>Parts Manufactured</th>
<th>Stock Used</th>
<th>Stock to Spare</th>
<th>Cost per Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>16&quot; of 1/4&quot; Diameter Steel Rod</td>
<td>1</td>
<td>Crankshaft: Timing Belt Side, Intermediate Joints, 2 Piston Head Joints, Tensor Roller</td>
<td>9.44&quot;</td>
<td>6.56&quot;</td>
<td>1.66</td>
<td>1.66</td>
</tr>
<tr>
<td>1&quot; 8-32 Screws</td>
<td>32</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.0423</td>
<td>1.3558</td>
</tr>
<tr>
<td>Snap Rings</td>
<td>16</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.0015</td>
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<tr>
<td>Fitting</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.19</td>
<td>4.76</td>
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<tr>
<td>Timing Belt (5002x111)</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7.04</td>
<td>7.04</td>
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<tr>
<td>1/4-20 Threaded Rod</td>
<td>1</td>
<td>Connections for Mounts</td>
<td>-</td>
<td>-</td>
<td>1.41</td>
<td>1.41</td>
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<tr>
<td>1/4&quot;x4&quot;x10&quot; Aluminum Plate</td>
<td>1</td>
<td>Top Mount, 2 Bottom Mounts, 4 Fast, 1 Large Pulley</td>
<td>8.825&quot;</td>
<td>1.175&quot;</td>
<td>5.03</td>
<td>5.03</td>
</tr>
</tbody>
</table>

**NOTES:**

If the Steel Rod is sold by foot, we will buy 2 ft.

We have some stock on the 1" x 2" x 10" piece to create a corner stabilizer for the crankshaft. (approx. 7")

---

Witnessed & Understood by me,  
Date: 4/7/11  
Invented by  
Date: 4/7/11  
Recorded By  
Date: 4/7/11
Date: 4/7/11 - Group Meeting in Rectifier from 7:00 PM to 9:00 PM

- Must finish up design for FDR before the end.

- Relationship between crankshaft speed and valve shaft speed - in order for valve shaft to work, it must spin 2 times as fast as the crankshaft.
  \[ r_1 \omega_1 = r_2 \omega_2 \]  
  \[ \text{Crankshaft} \quad \text{Valve Shaft} \]  
  \[ \text{Wellbore velocity equal} \]  
  \[ r_1 \omega_1 = r_2 (2 \omega_2) \]  
  \[ \frac{r_1}{r_2} = 2 \]  
  \[ \frac{1}{2} r_1 = r_2 \]  
  Size of valve shaft must be \( \frac{1}{2} \) size of crankshaft pulley!

- It was decided that in order for the valve shaft to spin 2x as fast and still work, the slots on the shaft must be \( 90^\circ \) out of phase or perpendicular. This way, water is moving at all times.

- Assignment of tasks to complete for FDR was made: 1. Machining, 2. Timeline, 3. Draft (current Gantt Chart), 4. Finish up (add mounts/ take screen shots).
4/9/11: Meeting in Dufresne Continued

- CAD Cleanup: We added pulleys and mounting to our design. Originally, we planned on using the aluminum tubing for feet, but we had extra stock to create mounting.

- Mounting:
  - Height Requirement: Axis is 5" above horizontal plate
  - Top Mount 2"
  - Side Bar 1.606" 3.4375" > 3" ✓
  - Bottom Mount 2.606"

- Small Pulleys:
  - Check Radii for Speed Reduction Guarantee:
  - 2r = 1" 2(3.4375) = 6.875 9.375" = 9.375" ✓

- Large Pulleys:

Witnessed & Understood by me.

Rebecca Ventimiglia 4/9/11
<table>
<thead>
<tr>
<th>Part</th>
<th>Subpart</th>
<th>Quantity</th>
<th>Time (min)</th>
<th>Mill</th>
<th>Lathe</th>
</tr>
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<tbody>
<tr>
<td>Crankshaft</td>
<td>crankshaft-concetion</td>
<td>4</td>
<td>60</td>
<td>N/A</td>
<td>30</td>
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<td></td>
<td>crankshaft-Timing Belt</td>
<td>1</td>
<td>30</td>
<td>30</td>
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<tr>
<td></td>
<td>crankshaft-faceplate</td>
<td>1</td>
<td>30</td>
<td>30</td>
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<tr>
<td></td>
<td>crankshaft-intermediate cylinders</td>
<td>2</td>
<td>45</td>
<td>45</td>
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<tr>
<td></td>
<td>middle rod</td>
<td>1</td>
<td>45</td>
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<td>N/A</td>
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<tr>
<td>Piston</td>
<td>head</td>
<td>2</td>
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<td>45</td>
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<tr>
<td></td>
<td>pin</td>
<td>2</td>
<td>30</td>
<td>30</td>
<td>N/A</td>
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<tr>
<td></td>
<td>adaptor</td>
<td>2</td>
<td>75</td>
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<tr>
<td>Valve Box</td>
<td>enclosure</td>
<td>2</td>
<td>60</td>
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<td></td>
<td>valve shaft</td>
<td>1</td>
<td>75</td>
<td>45</td>
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<tr>
<td>Plates</td>
<td>back plate</td>
<td>1</td>
<td>60</td>
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<tr>
<td></td>
<td>side plates</td>
<td>2</td>
<td>75</td>
<td>75</td>
<td>N/A</td>
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<tr>
<td>Task Name</td>
<td>Duration</td>
<td>Start</td>
<td>Finish</td>
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<td>--------------------</td>
<td>----------</td>
<td>------------------</td>
<td>--------------------</td>
<td></td>
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<tr>
<td>Test data analysis</td>
<td>6 days</td>
<td>Sat 3/2/11</td>
<td>Fri 3/10/11</td>
<td></td>
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<tr>
<td>Functional require</td>
<td>1 day</td>
<td>Mon 3/14/11</td>
<td>Mon 3/14/11</td>
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<td></td>
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<tr>
<td>Morphological chart</td>
<td>5 days</td>
<td>Mon 3/14/11</td>
<td>Fri 3/10/11</td>
<td></td>
<td></td>
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<td>MATLAB analysis</td>
<td>14 days</td>
<td>Tue 3/15/11</td>
<td>Fri 4/1/11</td>
<td></td>
<td></td>
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<tr>
<td>Decision matrix</td>
<td>3 days</td>
<td>Wed 3/16/11</td>
<td>Fri 3/18/11</td>
<td></td>
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<td>3 days</td>
<td>Wed 3/16/11</td>
<td>Fri 3/18/11</td>
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<td></td>
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<tr>
<td>Pump design draft</td>
<td>14 days</td>
<td>Fri 3/18/11</td>
<td>Wed 4/6/11</td>
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<tr>
<td>Valve design draft</td>
<td>13.5 days</td>
<td>Mon 3/21/11</td>
<td>Tue 4/2/11</td>
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<td></td>
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<tr>
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<td>Tue 4/5/11</td>
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<tr>
<td>Cost analysis</td>
<td>6 days</td>
<td>Sat 4/1/11</td>
<td>Fri 4/8/11</td>
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<tr>
<td>Performance est.</td>
<td>6.5 days</td>
<td>Wed 4/6/11</td>
<td>Wed 4/8/11</td>
<td></td>
<td></td>
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<tr>
<td>Failure analysis</td>
<td>6 days</td>
<td>Tue 3/29/11</td>
<td>Tue 4/5/11</td>
<td></td>
<td></td>
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<tr>
<td>Final design (CAD)</td>
<td>5 days</td>
<td>Mon 4/4/11</td>
<td>Fri 4/8/11</td>
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<tr>
<td>Final design review</td>
<td>8.5 days</td>
<td>Fri 4/8/11</td>
<td>Wed 4/20/11</td>
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<td></td>
</tr>
<tr>
<td>Machining (crankshaft)</td>
<td>12 days</td>
<td>Wed 4/13/11</td>
<td>Fri 4/22/11</td>
<td></td>
<td></td>
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<tr>
<td>First pump testing</td>
<td>12 days</td>
<td>Sat 4/19/11</td>
<td>Mon 4/25/11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machining (piston)</td>
<td>10.5 days</td>
<td>Wed 4/13/11</td>
<td>Wed 4/27/11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machining (valve box)</td>
<td>9 days</td>
<td>Tue 4/12/11</td>
<td>Fri 4/22/11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design modification</td>
<td>11 days</td>
<td>Sat 4/19/11</td>
<td>Fri 4/29/11</td>
<td></td>
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<tr>
<td>Design presentation</td>
<td>12 days</td>
<td>Tue 4/14/11</td>
<td>Fri 4/29/11</td>
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<td></td>
</tr>
</tbody>
</table>
Date: 2/16/16 - Lab Session in Taylor Studio (2-4:30pm)
FDR Presentation

Overview
- Decisions, Decisions
- The Components
- Game Plan
- The Kraken
- Don't Stress!
- Great Expectations

Gantt Chart

Thinking It Over

Crankshaft

Valveshaft

We had changed our decision matrix since we had not thought of our valve shaft for FDR.

Witnessed & Understood by me.

Rebecca Ventimiglia

Date: 4/8/11

Invented By

Rebecca Ventimiglia

Date: 4/8/11

Recorded By

Rebecca Ventimiglia
We figured we could save material by machining or cut areas of surfaces by making our own cylinder.

Shows how the wall is mostly machined and how the clamping is most time consuming.

Factor of safety from spring analysis:

From Sandvik tool:

Factor of safety is not adequate, materials are not suitable.

**Number Crunch**
- Factor of safety = 2.04 x 10^5
- Weight = 6.95 lb
- Volume = 59.823 in^3

**Budget Plan**

**The Kraken**

**Valve Box**

**Machining Timeline**

**Fabrication Plan**

**Factor of Safety from Spring Analysis**

Witnessed & understood by me,

Rebecca Ventriglia

Date: 4/8/11 (FDE continued)

Date: 4/8/11

Invented by

Rebecca Ventriglia
AFTER FDR, we started to machine. We got our stock and realized that the number of stock issues was less than anticipated. Fortunately, there was enough stock to machine each piece so that we could still get the stock down to size, and then faced its teeth. Today’s shop was mostly spent cutting stock and facing parts.
Date: 9/7/11 - Group meeting in DuBelfield from 5:45 - 7 PM

- We decided to increase our L value and decrease our R value in order to reduce our power and because we saw that our Stock could allow for such a slight change. We changed our L value from 1.5” to 1” and increased R from 2.5” to 3”. This allowed for a greater L/R, which typically provides for smoother motion.

- We also discussed what we needed for the machine shop. Entering the machine shop, we had no idea what was necessary. We decided that we needed:
  - Drawings of each part with dimensions
  - A form of communication between machine shop times
  - L wrapped in blue paper was all done
  - L tape to identify cut stock
  - Chart to track progress
  - Organize signing up for more time slots
    - Monday & Wednesday mornings, Thursday afternoons - good!
    - More real time than lathe time needed

Witnessed & Understood by me:

Rebecca Ventriglia 4/11/11

Invented by

Rebecca Ventriglia 4/11/11
This chart was used to keep track of completed processes in the shop. Dates for the processes represent when it was completed.

**Machining Processes for Part**

<table>
<thead>
<tr>
<th>Component</th>
<th>Lathe</th>
<th>Mill</th>
<th>Processes</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame</td>
<td></td>
<td></td>
<td>Cut from Stock</td>
<td>Trim down, Screw holes, Face Plate Holes, Side Holes for Snap Rings, Side Holes for Tension</td>
</tr>
<tr>
<td>Top Mount</td>
<td></td>
<td></td>
<td>Cut from Stock</td>
<td>Trim down, Screw holes</td>
</tr>
<tr>
<td>Stays</td>
<td></td>
<td></td>
<td>Cut from Stock</td>
<td>Trim down, Screw holes, Side Holes for Snap Rings, Side Hole for Tension</td>
</tr>
<tr>
<td>Cylinder Housing</td>
<td></td>
<td></td>
<td>Cut from Stock</td>
<td>Trim down, Screw holes</td>
</tr>
<tr>
<td>Back Housing</td>
<td></td>
<td></td>
<td>Cut from Stock</td>
<td>Trim down, Screw holes</td>
</tr>
<tr>
<td>Connecting Rods</td>
<td></td>
<td></td>
<td>Cut from Stock</td>
<td>Trim down, Screw holes</td>
</tr>
<tr>
<td>Feet</td>
<td></td>
<td></td>
<td>Cut from Stock</td>
<td>Trim down, Screw holes</td>
</tr>
<tr>
<td>Small Pulleys</td>
<td></td>
<td></td>
<td>Cut from Stock</td>
<td>Trim down, Screw holes, Lathe to Circle, Groove for Belt</td>
</tr>
<tr>
<td>Large Pulley</td>
<td></td>
<td></td>
<td>Cut from Stock</td>
<td>Trim down, Screw holes, Groove for Belt</td>
</tr>
<tr>
<td>Valve Shaft</td>
<td></td>
<td></td>
<td>Cut from Stock</td>
<td>Trim down, Screw holes, 1/2 Cut Semi-Circles, Groove for Belt</td>
</tr>
<tr>
<td>Timing Gear</td>
<td></td>
<td></td>
<td>Cut from Stock</td>
<td>Trim down, Screw holes, Groove for Snap Rings</td>
</tr>
<tr>
<td>Connecting (R)</td>
<td></td>
<td></td>
<td>Cut from Stock</td>
<td>Trim down, Screw holes, Groove for Snap Rings</td>
</tr>
<tr>
<td>Middle Rod</td>
<td></td>
<td></td>
<td>Cut from Stock</td>
<td>Trim down, Screw holes, Groove for Snap Rings, Slot for Attachment</td>
</tr>
<tr>
<td>Fan Plate Rod</td>
<td></td>
<td></td>
<td>Cut from Stock</td>
<td>Trim down, Screw holes, Groove for Snap Rings</td>
</tr>
<tr>
<td>Intermediate Rod</td>
<td></td>
<td></td>
<td>Cut from Stock</td>
<td>Trim down, Screw holes, Groove for Snap Rings</td>
</tr>
<tr>
<td>Piston Head</td>
<td></td>
<td></td>
<td>Cut from Stock</td>
<td>Trim down, Screw holes</td>
</tr>
<tr>
<td>Piston Linkage (LL)</td>
<td></td>
<td></td>
<td>Cut from Stock</td>
<td>Trim down, Screw holes</td>
</tr>
<tr>
<td>Piston Head Attachment</td>
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<td></td>
<td>Cut from Stock</td>
<td>Trim down, Screw holes</td>
</tr>
<tr>
<td>Piston Head Joint</td>
<td></td>
<td></td>
<td>Cut from Stock</td>
<td>Trim down, Screw holes, Groove for Snap Rings</td>
</tr>
<tr>
<td>Timing Holes</td>
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<td>Cut from Stock</td>
<td>Trim down, Screw holes, Groove for Snap Rings</td>
</tr>
<tr>
<td>Taper Plate</td>
<td></td>
<td></td>
<td>Cut from Stock</td>
<td>Trim down, Screw holes</td>
</tr>
</tbody>
</table>

**Legend**

- D: Done
- WIP: Work in Progress
- R: Ready
- T: To be Reassembled
Date: 4/15/11
Gantt Chart
Date: 4/15/11

Today was the last day to order parts for the Windpump project: ordering parts pack dimensions. 

1. Timing Belt sized at 5/8" x 3/16" x 16" outer diameter → $37.04 (2 weeks to come in)
   4. Box of #6-32 Screws (50 ct.) → $9.10

Figuuring Belt Dimensions for Belt:

\[ a^2 + b^2 = c^2 \]
\[ s = 4.125" \]
\[ 15/16 + 14.125^2 + (15/16 + 15/16)^2 = c^2 \]
\[ a = 5.125" \]
\[ b = 14.125" \]
\[ c = 19.125" \]

Length of Belt = 3.1 + 1.8 + 2.6 + 1.4 + 2.8 = 10.9 inches

Witnessed & Understood by me:
Rebecca Ventriniglia

Date: 4/15/11

Invented by:

Date: 4/15/11

Recorded By:
Rebecca Ventriniglia
Below is a rough estimate of when we completed parts in our machining process & tabulated improvements.

<table>
<thead>
<tr>
<th>Date</th>
<th>Processes Accomplished/Worked On</th>
<th>Problems</th>
<th>Improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/14</td>
<td>Stock Cutting</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4/15</td>
<td>Stock Cutting, facing of crankshaft connections</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4/16</td>
<td>Grooves for Snap Rings on crankshaft pieces, facing on lateral, facing connections</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4/17</td>
<td>Hole in crankshaft rear</td>
<td>-</td>
<td>- Crankshaft - Shop/Track Parts better</td>
</tr>
<tr>
<td>4/18</td>
<td>Crankshaft Pieces Back Plate</td>
<td>-</td>
<td>- Alignment of holes in (crankshaft) boss</td>
</tr>
<tr>
<td>4/19</td>
<td>Holes in crankshaft connections</td>
<td>-</td>
<td>- Drilled largest holes last because they were far apart</td>
</tr>
<tr>
<td>4/20</td>
<td>Redo holes in nuclearizations</td>
<td>+</td>
<td>- Set to smaller fitting in drawings</td>
</tr>
<tr>
<td>4/21</td>
<td>Core on enclosure network</td>
<td>-</td>
<td>- Reconsider design earlier due machining difficulties</td>
</tr>
<tr>
<td>4/22</td>
<td>Remove cylinder from 1, pulley side, plate holes</td>
<td>-</td>
<td>- Reorganize CFD</td>
</tr>
<tr>
<td>4/23</td>
<td>Small fulcrums</td>
<td>-</td>
<td>- Think ahead!</td>
</tr>
<tr>
<td>4/24</td>
<td>Piston head, large arm bar, adapter</td>
<td>-</td>
<td>--Realign design points (mounting needed)</td>
</tr>
<tr>
<td>4/25</td>
<td>Drilled holes in 2 mount</td>
<td>-</td>
<td>- New holes &amp; dimensions</td>
</tr>
<tr>
<td>5/2</td>
<td>Beam crankshaft holes, bottom mounts</td>
<td>-</td>
<td>- Think Ahead!</td>
</tr>
<tr>
<td>5/3</td>
<td>Fitted up mounts, new holes in side plates, set threaded rod, bought bolting / sleeves, holes in cylinder bed for fittings &amp; feet</td>
<td>-</td>
<td>- Think Ahead!</td>
</tr>
</tbody>
</table>

Witnessed & Understood by me:
Rebecca Ventimiglia

Date: 5/3/11

Invented by:
Rebecca Ventimiglia

Date: 5/3/11
Date: 5/3/11 - Meeting at Diffred - 8 pm - 1115 pm

- We met to organize for the marketing & sales pitch.

- Brainstorm pros about pump: quality, machined, easy to adjust. For 2 cylinders, intuitive, how parts go together, convenient carrying handle! :)

- Divide up work

  CAD Changes: We decided to reduce our pump from one to two cylinders to make since the timing belt did not work in and because of machining difficulties (see previous page). We eliminated the valve block & second cylinder from the design & Ryan changed CAD to reflect this.

  Costing Analysis: Catherine

  Animation: Rebecca

  Analysis: Andre

  Presentation formatting/Coordination: Chris
Date: 5/4/11 - Group Meeting in Duffield from 8-10 pm
- Costing Analysis, CAD,simulation, Fan analysis all put together for presentation.
- Re-evaluated machining hours, costs for parts, and surfaces. Data for calculations is to follow.

Purchased Material:

<table>
<thead>
<tr>
<th>Material Given:</th>
<th>Quantity</th>
<th>Parts Manufactured</th>
<th>Stock Used</th>
<th>Stock to Spare</th>
<th>Cost per Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&quot; of 1/2&quot; Diameter Steel Rod</td>
<td>1.533</td>
<td>Valve Shaft, Crankshaft: Face Plate Side, Middle Rod</td>
<td>13.0075&quot;</td>
<td>2.9925&quot;</td>
<td>1.05</td>
<td>21.9995</td>
</tr>
<tr>
<td>2 1/2&quot; X 2 1/4&quot; X 10&quot; Aluminum Plate</td>
<td>1</td>
<td>2 Valve Cylinder Housings</td>
<td>6.25&quot;</td>
<td>1.75&quot;</td>
<td>11.79</td>
<td>11.79</td>
</tr>
<tr>
<td>1&quot;x2&quot;x10&quot; Aluminum Plate</td>
<td>1</td>
<td>4 Crankshaft Connectors, Tensor Plate</td>
<td>1.75&quot;</td>
<td>8.25&quot;</td>
<td>5.58</td>
<td>5.58</td>
</tr>
<tr>
<td>1/4&quot;x1&quot;x10&quot; Aluminum Plate</td>
<td>1</td>
<td>2 Piston 1 side Attachment Plates, 2 Linkages</td>
<td>10&quot;</td>
<td>0&quot;</td>
<td>1.83</td>
<td>1.83</td>
</tr>
<tr>
<td>10&quot;x4&quot;x10&quot; Aluminum Plate</td>
<td>1</td>
<td>Back Housing, 2 Side Housings, 2 Small Pulleys</td>
<td>9.125&quot;</td>
<td>0.875&quot;</td>
<td>5.03</td>
<td>5.03</td>
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<tr>
<td>9&quot; of 1/875&quot; PVC Round Stock</td>
<td>1</td>
<td>2 Pistons</td>
<td>1&quot;</td>
<td>8&quot;</td>
<td>6.8</td>
<td>6.8</td>
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Date: 5/17/19 - Final CG Report

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Overview
- Finally!
- What The Kraken Can Do For You
- Money, Money
- The Kraken Unleashed

Pro Performance
- Lightweight
- Compact
- Efficient
- Hydro Power

Final Costing Info
- Prototype - $26,122
- Per Thousand - $328
- Materials - $50
WE LOVE CHEAP.

Kraken In Motion
Final specs presented in presentation:

- Power Required: 15 Watts (from Matlab code with adjustment for 1 cylinder)
- Weight: 4.545 lbs
- Height: 5.475"
- Length: 9"
- Width: 5.5"
- Volume: 1 ft³
When putting the Knacken together, we noticed some tips for the user manual:

- Assemble the piston head in the cylinder first, then the side bars, then the back plate.
- Put screws in one at a time, tighten evenly
- When attaching the enclosure to the side plates, there is some give in the y-direction, so line up the bottom of the back plate with the bottom of the enclosure to ensure a smooth motion of piston head.
- Do not remove the connecting 3/8-20 rods from bottom mounts. It’s a very tight fit so have these pieces come attached.
- Knurled stab handle also come mostly assembled→ snap ring tool is not available to everyone, so account for ways to work around it.
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<td>Top Mount</td>
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<td>Connecting Rods</td>
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<tr>
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<td>Cut from Stock Trim down Screws holes</td>
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Status: D - Delivered, G - Good, B - Bad, S - Scratch, M - Missing, E - Extra, WIP - Work in Progress
Title: MAR-7250: Water Pump Project: Testing

Date: 5/15/2011 - Testing during Lab Section

**Group 1: Team Blaster**
- L: 1.5 L/min
- Cost: $201.65

**Group 2: No Pump**
- L: 0 L/min
- Cost: $65.35

**Group 3: Pump It!**
- L: 0 L/min
- Cost: $312.04

**Group 4: Mach 5**
- Pump, no results -> 0 L/min
- Cost: $32

Cost Chart:

<table>
<thead>
<tr>
<th>Group</th>
<th>Prototype Cost</th>
<th>Single Pump Cost</th>
<th>1000 Pump Cost</th>
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<tbody>
<tr>
<td>1</td>
<td>$216.86</td>
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<td>$201.65</td>
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<tr>
<td>2</td>
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<td>$2,581.06</td>
<td>$5,162.12</td>
<td>$3,252.22</td>
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</tbody>
</table>

Witnessed & Understood by me:

[Signature]
Right Side (First Phase) Explosion

- Tip Mount
- Hex Nuts
- 1/4-20 Rod
- Bottom Mount (Right)

Left Side Explosion

- Bottom Mount
- 1/4-20 Rod

Whitewash & Understood by me,

Rebecca Vantimuglin

Date: 5/6/11
Back Enclosure, Elevation

Final Assembly (The Kraken!)
Top View of Assembly

Top View of the Crane
Front View of Assembly

The Knob is assembled!
5/14/11 - Last Group Meeting - Suffield - 11 AM - 5:00 PM

- We came together to collaborate and finish our project development file.

- Honestly, I had a great time working with my group and the TAs and I wish Cornell would offer more courses like this one. Thanks for an awesome class - it truly was the best one I've taken at Cornell thus far.

- Updated the drawings for all parts, old and revised, that were ever a part of our Kraken design.