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Pede-Stool Design and Manufacturing Project

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IN CONJUNCTION WITH
Mechanical Engineering 203
Manufacturing and Design

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To: S.Dion, Product Manager

From: R.Warren, Product Designer,
Consumer Product Design Team

Date: November 1, 2006

Re: Pede-Stool Product Proposal and Budget Request

Overview

The Pede-Stool (see Figure 1) is an exciting innovation in stepping stool-design that is portable, lightweight, safe, easy-to-assemble, and aesthetically appealing. While still in its early stages of design, interviews with members of the product’s target market indicate that the product is seen as practical and value-added. An investment of $1,000 is now required to take this promising design to the next stages of product development, including design research, prototype construction and test marketing. Financial details, a timeline, and detailed product descriptions are summarized in this proposal. To ensure that we remain on target for our production goals, we request that you consider our project for approval by Monday, November 6.

Figure 1 – Folded View of Pede-Stool
Target Market

The Pede-Stool is intended primarily for use by children ages 5-10 in an indoor setting or on level ground. This product is small enough to fit into a backpack and light enough for children (or their parents) to carry easily. On a school field trip to a museum, for example, the students could carry their stools in their backpacks and unpack them when exhibits are too high to see. The flat top can also be used as a writing or drawing surface. The Pede-Stool is a great addition to a family trip to the zoo or a parade, where crowds and height limitations often make viewing difficult for children. Since the purchasing power of children is limited, parents and school teachers constitute the target market for the Pede-Stool. The durability and ease-of-use of this product should make it attractive to customers seeking a safe and reliable stool for their children.

Current Market Products

Currently most “foldable” stepping stools are designed for easy storage. They can be folded to only a few inches wide but still have large cross-sectional areas that make them difficult to carry (Figure 3). The Pede-Stool is unique because it is designed for portability. Made of aluminum, it is more durable than conventional plastic stools and lighter than the rubber-coated steel structures currently available on the market. Bright colors and rivets give the Pede-Stool a ‘cool’ futuristic aesthetic that will stand out against the bland white plastic of its competitors.
Design Details

The Pede-Stool is designed to be 1) portable, 2) lightweight, 3) safe, 4) easy to assemble, and 5) aesthetically appealing. The design elements used to achieve these five goals are outlined below:

1) Portable

Figure 2 provides dimensions for the “folded” and “unfolded” Pede-Stool. Each leg of the stool folds in half underneath the stool top. Two hinges on the stool top enable the Pede-Stool to become a compact carrying case. When folded, the Pede-Stool’s built-in handle allows for easy transportation. Small aluminum latches ensure that the stool remains folded while in transit.

2) Lightweight

The Pede-Stool is made of 6061-T6 Aluminum, a lighter alternative to steel which is typically used in stools. Ribs underneath the stool’s top surface increase strength with little extra material and the legs of the stool are hollow. Initial estimates place the Pede-Stool weight at 3 lbs.

3) Safe

From a statics analysis, the Pede-Stool is estimated to support a load of 300 lbs, a limit that is sufficient for use by children and most adults. Rubber soles on the bottom of each leg help to maintain overall sturdiness while grit paper on the stool top prevents the user from slipping on the metal surface of the stool.
4) **Easy to Assemble**

The Pede-Stool can be folded and unfolded with minimal effort from the user (no tools required). The joining mechanism in the legs and cross-beam of the stool are based on a “tent-pole” design that is intuitive and familiar to many people.

5) **Aesthetically appealing**

To increase its aesthetic appeal, the Pede-Stools will be anodized in a choice of 5 colors: green, blue, orange, purple and yellow.

**Budget & Timeline**

Tables 1 and 2 below outline the timeline and budget costs requiring approval for this project:

<table>
<thead>
<tr>
<th><strong>Project Milestone</strong></th>
<th><strong>Date Completed</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial design finalized</td>
<td>13 November 2006</td>
</tr>
<tr>
<td>Prototype Construction</td>
<td>20 November 2006</td>
</tr>
<tr>
<td>Test Marketing</td>
<td>4 December 2006</td>
</tr>
<tr>
<td>Final Design</td>
<td>18 December 2006</td>
</tr>
<tr>
<td>Production Begins</td>
<td>15 January 2007</td>
</tr>
</tbody>
</table>

**Table 2 – Project Budget**

<table>
<thead>
<tr>
<th><strong>Project Element</strong></th>
<th><strong>Cost ($)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Research</td>
<td>500</td>
</tr>
<tr>
<td>Prototype Materials &amp; Construction Costs</td>
<td>100</td>
</tr>
<tr>
<td>Test Marketing</td>
<td>400</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,000</strong></td>
</tr>
</tbody>
</table>
Figure 2 – Unfolded View of Pede-Stool

Figure 3 – Conventional Folding Stool
To: S.Dion, Product Manager

From: R.Warren, Product Designer,
Consumer Product Design Team

Date: November 15, 2006

Re: Pede-Stool Manufacturing System

Overview

This memorandum proposes a manufacturing system for the Pede-Stool that is designed to meet the demands of the San Francisco Bay Area market. The proposed system is semi-automated, with human operators loading the machines and performing assembly work and quality control checks. Custom parts will be fabricated, assembled and finished “in-house”, with some outsourcing of minor components. A Just-In-Time (JIT) batch process manufacturing system will eliminate excess inventory, while providing market flexibility for this new product. Potential challenges associated with this manufacturing system are outlined at the end of the memorandum. It is our goal to discuss these and other aspects of the proposed system at our upcoming meeting on Thursday, November 23, with the final version of the Pede-Stool manufacturing system approved by December 1.

Product description – Material Input; Product Output

All the required parts for the Pede-Stool are listed in Table 1 below. Initially, this product will be sold in the San Francisco Bay Area (population 7 million) with future plans for expansion to be determined. Predicting a 25% market share at 50,000 total stools sold per year, demand for the Pede-Stool is estimated to be approximately 13,000 stools per year, or an average of 36 stools per day. Necessary daily material input rates based on a conservative 80% first pass yield estimate are presented in Table 1.
Table 1 – Pede-Stool Parts

<table>
<thead>
<tr>
<th>Part</th>
<th>Number</th>
<th>“In-house” Manufacturing?</th>
<th>Material input rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stool top</td>
<td>1</td>
<td>Yes</td>
<td>6480 in² Al</td>
</tr>
<tr>
<td>Cross bar</td>
<td>2</td>
<td>Yes</td>
<td>900 in² Al</td>
</tr>
<tr>
<td>Diagonal support</td>
<td>2</td>
<td>Yes</td>
<td>180 in² Al</td>
</tr>
<tr>
<td>Leg</td>
<td>4</td>
<td>Yes</td>
<td>4320 in² Al</td>
</tr>
<tr>
<td>Pin</td>
<td>4</td>
<td>No</td>
<td>180 pins</td>
</tr>
<tr>
<td>Elastic chord</td>
<td>4</td>
<td>No</td>
<td>2160 in chord</td>
</tr>
</tbody>
</table>

Detailed design specifications for each of the above parts can be found in the CAD models included in the previous memorandum and are available upon request.

Manufacturing system

Five basic operations are needed to fabricate and finish the four custom-manufactured parts for the Pede-Stool: 1. cutting, 2. drilling, 3. bending, 4. welding, and 5. anodizing. The required machines for each of these procedures are described below. A manufacturing flow chart for these four parts is provided in Figure 1 (attached). Quality control checks are included throughout the manufacturing process to verify that each part meets specified design criterion. At a rate of 36 stools per day, these processes will be completed in batches.

1) & 2) Computer Numerical Control (CNC) Machine

A total of five CNC machines are used for both cutting and drilling in the Pede-Stool’s manufacturing system. These machines are accurate and reliable for high-quality manufacturing. Relatively simple to program, the CNC’s will allow easy inclusion of any necessary design changes.
3) *Sheet Metal Bender*

The sheet metal bender is a fast, simple tool for making the required 90° angles in the stool design. Due to its inherent ease of use, the sheet metal bender will be operated by hand.

4) *Automated TIG Machine*

For welding the stool top and legs, a *Liburdi Automation Products* automated TIG machine known as the “*Dabber*” will be used. Although expensive, automating the welding process will have a significant impact on increasing first-pass yield, ultimately lowering total production costs.

5) *Anodizer*

All aluminum parts of the Pede-Stool will be anodized using technology already employed in finishing many of our company’s other products.

**Required Personnel**

In this semi-automated manufacturing process, human operators are needed to load parts into the machines, to assemble the final product, and to ensure quality control throughout production. Estimated numbers of required personnel for each task are summarized in Table 2 for a production rate of 36 stools per day.

<table>
<thead>
<tr>
<th>Task</th>
<th>Number of personnel required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loading parts into machines</td>
<td>3</td>
</tr>
<tr>
<td>Operating the sheet metal bender</td>
<td>1</td>
</tr>
<tr>
<td>Assembly</td>
<td>1</td>
</tr>
<tr>
<td>Quality control</td>
<td>2</td>
</tr>
</tbody>
</table>
**Just-In-Time (JIT) Manufacturing**

The Pede-Stool’s manufacturing system is based on JIT manufacturing principles. Employing JIT manufacturing techniques will reduce material and inventory costs by keeping producing rates in line with demand. This is especially important in the early stages of Pede-Stool production, when selling rates are unknown. A JIT manufacturing system will also work well within the framework of our company as a whole, allowing resources and human capital to be distributed amongst products in response to market demands.

**Potential challenges**

Although an efficient use of resources, the Pede-Stool’s batch process JIT manufacturing system is susceptible to breaks in raw material supplies. Establishing strong relations with suppliers is therefore paramount to manufacturing success. Before the Pede-Stool is released on the market, process simulations should be run to test for bottle-necks and determine optimal lead time for materials. A future challenge will be expanding this manufacturing system when the Pede-Stool market extends beyond the Bay Area.
Figure 1 – Manufacturing Flow Chart

Sheet Al

Cut metal to size

Stool Top

Cut to shape
- Drill Holes
  - Quality control
    - Pass
      - Bend sides
        - Weld edges
          - Quality control
            - Fail
              - To Assembly
            - Pass
              - To Assembly
        - To Assembly
    - Fail
      - Recycle Bin
  - To Assembly

Cut to shape
- Extrude pin holes
  - Quality control
    - Pass
      - To Assembly
  - Angle & smooth edges
    - Quality control
      - Pass
      - To Assembly
    - Weld edges
      - Quality control
        - Pass
        - Cut to shape
          - To Assembly

Cut to shape
- Bend to shape

To Assembly
To: S.Dion, Product Manager

From: R.Warren, Product Designer,
     Consumer Product Design Team

Date: January 3, 2006

Re: Pede-Stool Production Evaluation

Introduction

The Pede-Stool is a light-weight, portable aluminum stepping stool designed for use by children in an indoor setting. The product has been out on the market for six weeks. This memorandum describes the strengths of the product and proposes design improvements based on feedback from sales, marketing and warranty repair data. Intended to address current weaknesses in Pede-Stool functionality, manufacturing procedures, and aesthetics, these design improvements will lower production costs while allowing variations in Pede-Stool strengths and heights to fulfill a wider range of customer needs. A review of the proposed improvements will take place during the Design Team meeting on January 8, at which time questions or comments relating to these changes will be addressed. Management support for this Pede-Stool successor model is requested by January 12 to ensure that stool production remains on target.

Summary

After only six weeks on the market, the Pede-Stool is exceeding sales targets and claiming 50% of the total market share. In its successor model proposed here, providing multiple levels of stool strengths and heights will allow customers to choose a product according to individual needs. Functionality improvements in the hinge, latch, and rubber pads require minimal, if any, additional manufacturing expenses to enhance reliability. With
respect to the product’s manufacturing system, substituting formed sheet metal for welded joints will increase first-pass yield while lowering associated energy and human costs. Exciting innovations in aesthetics targeted towards the product’s main users (children) include additional anodized colors and LED lighting. The proposed changes that constitute the Pede-Stool successor model will be implemented in stages during the next two years and are expected to increase profits and improve manufacturing efficiency.

**Product Strengths**

Pede-Stool sales over the past 6 months have been highly successful. As shown in Figure 1 below, the number of stools sold per week exceeded the target of 300 after only fifteen weeks on the market (product currently sold only within the San Francisco Bay Area). Furthermore, the general sales trend is continuing to increase.

![Figure 1 - Number of Pede-Stools Sold per Week during the first 6 months of Production](image)
Consumer reports have indicated customer satisfaction with the light-weight nature of the Pede-Stool. Indeed, this product is on average 50% lighter than similar-sized stools on the market. While it is still too early to determine the long-term durability of the product in the hands of consumers (the first stools were sold only 6 months ago), the metal of the Pede-Stool is predicted to outlast the plastic stools of competitors. A comparison of warranty-repair data (Figure 2 below) reveals the high quality of Pede-Stool manufacturing compared to competitor brands.

![Figure 2 - Comparison of Monthly Warranty Repairs by Pede-Stool and Competitors*](image)

* Competitor data obtained from annual reports

**Design Improvements**

Despite the many assets of the Pede-Stool and its production process, a number of improvements in product functionality, manufacturing process, and aesthetics are possible for the successor model. Table 1 outlines these proposed design changes and the product weaknesses they address. Each entry in the table is discussed in more detail below.
Table 1 – Pede-Stool Design Improvements

<table>
<thead>
<tr>
<th>Category for Improvement</th>
<th>Product Element</th>
<th>Weakness of Current Model</th>
<th>Design Change for Successor Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Functionality</td>
<td>a) Strength</td>
<td>Pede-Stool outsold by stools with higher load limits.</td>
<td>Use heat treating technology or switch to stronger aluminum alloy (6061-T6 or 3003).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b) Height</td>
<td>Pede-Stool not competitive with shorter or taller stools.</td>
<td>Produce Pede-Stool in 3 different heights: 5”, 10” (current height), 15”.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>c) Hinge</td>
<td>Reported incident of pin failure under loading.</td>
<td>Replace aluminum pins with more durable steel pins.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>d) Latch</td>
<td>Breaks easily with repeated use.</td>
<td>Replace mechanical latch with a magnetic latch.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>e) Rubber pads</td>
<td>Tend to fall off the stool.</td>
<td>Use a stronger epoxy and a tighter-fitting design.</td>
</tr>
<tr>
<td>3. Aesthetics</td>
<td>a) Color</td>
<td>Limited to 4 colors (silver, blue, green, yellow).</td>
<td>Increase available colors from 4 to 7.</td>
</tr>
<tr>
<td></td>
<td>b) Child appeal</td>
<td>Missing a ‘cool’ element to attract consumer attention.</td>
<td>Add LED lighting to stool top.</td>
</tr>
</tbody>
</table>

1. a) Pede-Stool Strength

Although the Pede-Stool controls 50% of the market share, stools with greater load capacities are consistently out-selling our product. To recover these lost sales, Pede-Stool strength must be improved using heat treatment, a stronger aluminum alloy, or a combination of these two methods. Three different stool strengths could be made: regular (current design, 1100 alloy), strong (3003 alloy), and extra strong (heat treated 3003 alloy). Stronger models would be more expensive to compensate for the extra production costs associated with these
design changes, but allow consumers more flexibility in the application of their stools. Table 2 below outlines the additional expenses associated with heat treatment and two stronger aluminum alloys. At present, heat treatment procedures would be outsourced, with a future switch to in-house treatment to be considered in the future.

<table>
<thead>
<tr>
<th>Pede-Stool Design Strength</th>
<th>Load Capacity (lb)</th>
<th>Manufacturing Cost per Stool ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular (1100 alloy)</td>
<td>80</td>
<td>10.00</td>
</tr>
<tr>
<td>Strong (3003 alloy)*</td>
<td>120</td>
<td>11.00</td>
</tr>
<tr>
<td>Extra strong (3003 alloy with heat treatment)**</td>
<td>150</td>
<td>13.50</td>
</tr>
</tbody>
</table>

* Based on a material price increase factor of 1.11 between 1100 alloy and 3003
** Based on typical heat treatment costs for outsourcing in bulk

b) **Height**

Since the Pede-Stool is currently only available in one size, consumers seeking a different stool height must buy from competitors. To capture a wider share of the market, two Pede-Stool sizes will be released in addition to the current 10” height: small (5” height) and large (15” height). As the same manufacturing processes can be used for these alternative sizes, the only costs incurred by this design change are due to higher amounts of raw material consumption in the case of the large stool. Sale prices will reflect the cost of raw materials associated with producing each size.

c) **Hinge**

During the first six months of production, a case of structural failure was reported when one of the pins composing the stool hinge broke in shear, causing the stool to collapse. At the time, the stool was supporting an estimated load of 100lb, which is well above the maximum specified load of 80lb. Although Pede-Stool is not responsible for failure
associated with improper use, replacing the aluminum pins in the hinge with steel pins will significantly increase the stool’s safety factor and protect consumers from injury. Since the pins are such a small fraction of total stool material, this change is estimated to produce only a $0.10 increase in cost per stool.

d) Latch

In the current design, an aluminum latch is used to secure the stool in its collapsed state. Due to the small, rather delicate nature of this part, it breaks easily and is the subject of almost 50% of warranty repair calls. Replacing this mechanical latch with a magnetic latch will reduce production costs by $1 and result in a more durable product (which in turn will reduce the cost of warranty repairs).

e) Rubber pads

Another common source of warranty repairs is the rubber pad on the bottom of each stool leg, which is currently held in place with epoxy and has a tendency to fall off. To solve this problem, a stronger epoxy will be used in conjunction with a tighter fitting design for the pad that wraps around the leg to 1” above the ground. Although the stronger epoxy and rubber pad design will result in an estimated $0.75 cost increase per stool, consumers have responded favorably to the presence of these pads (which reduce slipping of the stool and allow the Pede-Stool product to be used on nice floors without scratching) and they should remain part of the design.

2. a) Welding

The average first pass yield rate of 65% over 6 months for the manufacturing of the Pede-Stool is significantly lower than the 80% target goal. Most quality control failures have been associated with the welding process. In addition, this stage of the manufacturing
process, which is much slower than the bending and cutting, has been producing bottlenecks in the production line and an accumulation of inventory. After considerable design research, all welding processes associated with Pede-Stool manufacturing will be replaced by additional sheet metal that will be bent into the desired shape and position. The cost of this additional metal is negligible compared to savings on electricity, gas and equipment to be gained by eliminating the welding stage of production. This manufacturing change will also greatly increase first-pass yield results and reduce process flow times.

3. a) Color

Unlike most stepping stools on the market, the Pede-Stool is available in a variety of colors, including silver, blue, green, and yellow. Consumer response to these color choices has been positive, with sales of blue, green and yellow stools exceeding sales of the more typical silver color. Capitalizing on this unique attribute and to increase product variety, the stool will now also be sold in red, orange, and purple.

b) Child Appeal

The marketing success of the Pede-Stool depends highly on its appeal to children, the product’s target users. For children, aesthetics is especially important and the presence of a ‘cool’ new feature that appeals to their imaginations is essential. Special versions of the Pede-Stool will be manufactured that feature a border of multi-colored LED lighting on the stool top. These stools will be sold for a higher price than the regular product version to account for the higher manufacturing costs.
Timeline for Design Improvements

The design improvements described in this memorandum will be achieved in stages, beginning with critical structural improvements and finishing with aesthetic enhancements. A timeline for the implementation of the proposed changes is given in Table 3 below (numbering refers to Table 1).

Table 3 – Design Change Implementation Timeline

<table>
<thead>
<tr>
<th>Design Change</th>
<th>Implementation Time goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.c) Steel pins in hinge</td>
<td></td>
</tr>
<tr>
<td>1.d) Magnetic latch</td>
<td></td>
</tr>
<tr>
<td>1.e) Improved adhesive for rubber pads</td>
<td>Immediate</td>
</tr>
<tr>
<td>2. a) Eliminate welding from manufacturing process</td>
<td></td>
</tr>
<tr>
<td>1.a) Strong and Extra Strong versions available</td>
<td>Within 6 months</td>
</tr>
<tr>
<td>1.b) Small, Regular and Large sizes</td>
<td>Within 1 year</td>
</tr>
<tr>
<td>3. a) Increased number of anodized colors</td>
<td>Within 2 years</td>
</tr>
<tr>
<td>3. b) LED lights</td>
<td></td>
</tr>
</tbody>
</table>