SPEAKMAN®

SE-4000 Spray Arm and Valve Design

Team 11 – Phase 4

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Matt Jaskot
Jason McKnight
Project summary

Background

University of Delaware design team 11 has been tasked with redesigning the spray arm and valve assembly of the Speakman Company’s SE4000 portable eye wash unit. The current valve design is a complex brass structure with 38 parts and costing $55 to produce. The team’s constraints are to redesign this assembly to meet ANSI standards at a cost of under $15 for parts and assembly. Speakman also has requested that the team stay within a tooling and design cost which can be covered in less than a year at 2000 units per year ($90,000). The team generated 5 concept directions. Of these 5 directions, two were pursued to the point of rough initial prototypes. Upon analyzing these two prototypes it was determined the only the plate and nozzle design has potential to become the team’s final solution. The team is now moving forward with refining the plate and nozzle design.

Design Validation

In engineering the best possible design of the spray arm and valve mechanism, the concept must be clearly validated using the metrics. Detailed design development is validated by continuing to adjust and focus performance requirements, demonstrating an understanding of the technologies necessary for producing a prototype, and correlating the prototype performance with how the solution will be implemented in production. At this point in the design process, a single concept has been chosen based on continuous re-evaluation of the metrics and feedback from the Speakman Company. Several key obstacles have been encountered with the initially proposed ball-valve solution have come to light since the previous phase of design. Following is a description of the validation process that the team has used in evaluating previous design decisions, and will use to examine design decisions and prototypes moving forward.

When evaluating a design decision or concept, the first consideration of the team will be to verify that all projects constraints are met. They are as follows:

CONSTRANTS:
- This shall be done without violating any of the ANSI standards for eye washing devices.
  - Minimum flow of .4 gallons for 15 minutes
  - Hands free operation
  - Nozzles protected from airborne contaminants
  - On to off in less than 1 second
  - Nozzles at least 6” from nearest obstruction
  - Flow pattern meets guidelines
- The device must work every time it is needed (cannot fail to flow when operated, leak, or break under expected conditions).

In addition to these constraints, the Speakman Company would like to achieve a positive return on any capital expenditures made in less than one year based on 2000 units sold annually, and a current cost of $60 per valve. This results in a tooling and redesign budget of $90,000.

**METRICS:** While all design consideration must meet the project constraints listed above, there are a number of other desirable factors affecting the design decisions. In an attempt to quantify the tradeoffs associated with the design decisions, the team will use a relative ranking scale to relate our design metrics with respect to importance on a ten-point scale as validated by our sponsor, Speakman, during Phase 1:

<table>
<thead>
<tr>
<th>Performance Criterion</th>
<th>Importance (10 point scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>10</td>
</tr>
<tr>
<td>Number of Motions to Operate</td>
<td>6</td>
</tr>
<tr>
<td>Strength</td>
<td>5</td>
</tr>
<tr>
<td>Changes to Tank</td>
<td>5</td>
</tr>
<tr>
<td>Number of Parts</td>
<td>4</td>
</tr>
<tr>
<td>Customer Assembly</td>
<td>3</td>
</tr>
<tr>
<td>Aesthetic Rating (out of 10)</td>
<td></td>
</tr>
</tbody>
</table>

These results serve as the justification for pursuing the pull-off caps design. After reviewing a number of initial concepts with the sponsors, the team decided to move forward with the pull-off caps design because of its simplicity and its ability to be produced cheaply while still maintaining functionality. A functional prototype of the ball-valve concept has aided in validating the team’s decision to pursue a more refined pull-off caps design. Aesthetics came into play here as well as functionality; the sponsor was not satisfied with the way the ball-valve prototype looked. This decision was driven by a re-evaluation of the metrics, which strictly limit
the cost of the proposed design. An initial prototype of the caps design has shown promise functionally and is well-aligned with the metrics. It is apparent that cost is the driving factor; a more detailed cost analysis can be found in the appendix. The cost estimates used in this model were derived by assuming a 20% price reduction on all parts when bought in bulk; we took 80% of the prototype cost to estimate the cost when produced in quantity (2000 units yearly).

Design Details

Having made the decision to pursue the pull-off cap design, the team prepared the design details. The rough initial prototype of the plate and nozzle design showed a lot of potential. The team refined the design, however due to uncertainties in the manufacturing method, there were unresolved details. Two potential design routes were pursued, one being the stamping of a metal plate, and the second being to replace the metal plate with a hollow blow molded HDPE piece. Both blow molding and rotomolding appear to be viable routes, in which an aesthetically pleasing, rigid, functional design could be produced within the cost goal. A description of the prototyping process and subsequent validation of the plate design are presented in this phase. Detailed design drawings are in the appendix.

Metal Forming

The pull off cap design utilizes an aluminum plate that attaches the spray nozzles to the tank. This can be illustrated in the initial cap design prototype produced by the design team. The plate needs to be bent 90 degrees at its midpoint and contoured to the shape of the tank where it will be supported. These stamping operations can be executed through the use of a brake press. Finally, several holes must be drilled in the plate where the through bolts attach it to the tank and where the plate supports the spray nozzles.
Blow Molding

The spray arm that supports the nozzles may also be made of plastic. The thin, hollow features of this fixture would make it an ideal candidate to be produced through blow molding. In this process a short tubular plastic piece, known as a parison, is either extruded or injected into a larger mold cavity. A blow pin is then inserted into the parison and blasts in hot air at high pressures (50 to 100 psi) expending the plastic onto the walls of the mold cavity. This is the current method in which the tank is produced. Therefore the spray arm’s appearance would resemble that of the tank creating a smooth, elegant interface between the two components.

Because cost is the key performance criterion, it is helpful to compare the costs of the two manufacturing routes when making a decision about which to pursue:

<table>
<thead>
<tr>
<th>Material Costs of Plate with nozzles Design</th>
<th>(estimate)</th>
<th>(estimate)</th>
<th>(estimate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>steel stamping</td>
<td></td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>bolts/washers/nuts</td>
<td>each</td>
<td>0.2</td>
<td>3</td>
</tr>
<tr>
<td>screws</td>
<td>each</td>
<td>0.05</td>
<td>4</td>
</tr>
<tr>
<td>3/8 hose</td>
<td>foot</td>
<td>0.2</td>
<td>1</td>
</tr>
<tr>
<td>1/2 hose</td>
<td>foot</td>
<td>0.28</td>
<td>1</td>
</tr>
<tr>
<td>T barbed fitting</td>
<td>each</td>
<td>0.43</td>
<td>1</td>
</tr>
<tr>
<td>plate</td>
<td>each</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>spray heads</td>
<td>each</td>
<td>3.66</td>
<td>2</td>
</tr>
<tr>
<td>T handle</td>
<td>each</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Material cost $16.50 + $3.11 labor = $19.61
Based on this cost estimate, and a labor and overhead cost of $3.11 (derived in appendix), the total cost would be $19.61 per unit.

<table>
<thead>
<tr>
<th>Material Costs of Molded Plastic Caps Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>nut each</td>
</tr>
<tr>
<td>1/2 hose foot</td>
</tr>
<tr>
<td>T barbed fitting each</td>
</tr>
<tr>
<td>molded plastic fixture each</td>
</tr>
<tr>
<td>spray heads each</td>
</tr>
<tr>
<td>T handle each</td>
</tr>
<tr>
<td><strong>Material cost</strong></td>
</tr>
<tr>
<td>$1.75 labor = $14.25</td>
</tr>
</tbody>
</table>

Based on this cost estimate, and a labor and overhead cost of $1.75 (derived in appendix), the total cost would be $14.25 per unit.

While the cost difference between the two manufacturing routes is small and rough materials estimates are involved, blow molding at least has the potential to be competitive with a stamped plate design. The team feels that this is justification enough to prototype a plastic molded design as well as a stamped plate prototype. The following chart is a summary of the comparisons between the proposed and current designs:

<table>
<thead>
<tr>
<th>Performance Criterion</th>
<th>Current Design</th>
<th>Proposed Design (metal plate)</th>
<th>Proposed Design (molded plastic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>$55</td>
<td>$19.61 + stamping tooling</td>
<td>$14.25 + molding tooling</td>
</tr>
<tr>
<td>Number of Motions to Operate</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Strength</td>
<td>~25lb.</td>
<td>~15lb.</td>
<td>~10lb.</td>
</tr>
<tr>
<td>Changes to Tank</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Number of Parts</td>
<td>38</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Customer Assembly</td>
<td>0</td>
<td>5 minutes w/ tools</td>
<td>2 minutes w/o tools</td>
</tr>
<tr>
<td>Aesthetic Rating (out of 10)</td>
<td>10</td>
<td>6</td>
<td>8</td>
</tr>
</tbody>
</table>
Design iterations

After having made the decision to pursue the plastic molded route for the pull-off caps design, the team went through several iterations of detailed designs before settling on one which the sponsors felt was close enough to the finished product to justify the cost of rapid prototyping.

![Initial design](image1.png)

**Fig. 1**

The initial design, shown above (Fig. 1), consisted of a hollow molded shape with a threaded inlet on the back. A nut which would be threaded onto this inlet would hold the fixture in place during operation. The back contour of the piece was fitted to the contour of the tank in order to hold it in place more securely. The nozzles would be removed using a rigid T-handle attached to the nozzle caps. Existing nozzles and caps from another of Speakman’s products were to be used in this design.

![Fig. 2 and Fig. 3](image2.png)

**Fig. 2**      **Fig. 3**
After consulting with the sponsor, the team decided to make some changes, resulting in a new design iteration, shown above (Fig. 2). At this point it was decided that the T-handle was a weaker design idea than a rubber strap which would pull off of the nozzles. This decision was made due to the high forces necessary to remove the caps with the nozzles conducive to the T-handle design, as well as possible issues with leaking because these caps and nozzles were not designed for multiple uses. Because of the decision to use a rubber strap (Fig. 3) instead of a T-handle, the nozzles were moved further apart and angled in towards the center to allow enough room for someone to grab the rubber strap in between the nozzles. The rubber strap at this point was curved upwardly to allow more room for a user to reach underneath it to pull it off. New nozzles were also implemented which would clamp and seal into a hole in the fixture. These new nozzles worked well with the rubber strap idea and would create a good seal. The new nozzles were taken from an existing Speakman product and more could be ordered for use in a future product.

Data was determined experimentally using the new nozzles to predict the vertical flow height from the fixture (13 inches). At this point, calculations were made based on this experimental flow data to determine the correct angle between the nozzles and the horizontal plane so that the flow would meet the ANSI requirements.

The next design iteration, shown above in (Fig. 4), had a lower profile, such that the nozzles were at a lower level and therefore experienced greater pressure and a stronger flow. This changed the overall shape of the design so that it sloped downward more. This design change made it necessary to recalculate the flow height and the nozzle angles because the nozzles were lower. It was also decided that one attachment point with coarse threads (all that could be counted on from rotomolding) would not provide as much stability as two attachment points, so the inlet threads were removed and two holes were added in for bolts (Fig. 5) to attach the fixture to the tank. This resulted in greater labor cost for assembly (drilling two holes in the tank) but added to the value of the product significantly. Removing the threads also made the molding process much less complicated, especially for rotomolding.
Finally, one more design iteration resulted in the design which Speakman felt was close enough to the finished product to prototype. Shown in Figure 6, above, this design dealt with the air trapping issues in the fixture. Because the fixture is hollow and sealed at the nozzles, air would be trapped in the portion of the part above the inlet hole. To remedy this problem, the nozzles were moved below the inlet hole by angling the whole fixture downward slightly. This also increased the clearance between the user’s head and the tank. According to Speakman, most users mount the unit on a wall, so it was not a problem having the fixture extend below the base of the tank. The tank can still sit on the edge of a table with the fixture protruding off the edge. Again, because of the change in height of the nozzles, it was necessary to recalculate the angle of the nozzles with the horizontal plane to meet the ANSI requirements for flow.

Also, the holes in the fixture needed to be redesigned in order to be made with rotomolding. Instead of holes through a solid section, “tunnel” type holes were used through a hollow section; this made rotomolding feasible. The rubber pull-off strap was also modified (Fig. 7) after consulting with Plasticoid; the handle was made flat so that the piece could be molded in a two-piece mold without creating a parting line in the sealing region of the handle.

Prototyping
Testing

After the prototype was obtained, we subjected it to testing to make sure that all the ANSI requirements and projects constraints and wants were adequately met. The prototype was bolted to the tank, attached to the supply hose and the tank was filled with water. As the tank filled, we made sure that there were no issues with air trapping in the nozzles. There was air trapped in the region above the nozzles, but it did not affect the flow. Using the rubber strap we had, which had tolerances identical to the strap we designed, we were able to test the strap removal from the nozzles. We found that the strap was able to be easily removed with a minimum of force applied, while still maintaining a good seal on the nozzles when in place. The flow started immediately once the strap was removed, satisfying the requirement of one second activation.

Next, we filled the tank up and removed the strap, starting a stopwatch at the beginning of the flow. The spray pattern was checked using the gauge supplied to us by our sponsor, and the pattern was more than adequate to meet ANSI requirements. ANSI requirements state that the flow must meet or exceed 0.4 GPM and meet the required flow pattern for at least 15 minutes. We let the flow go for 15 minutes, and then measured the flow rate, which was calculated at 0.56 GPM after 15 minutes. We also checked the flow pattern and it did cover the test area on the gauge well also. We then let the unit keep going to see how long it would take before the flow requirements were no longer met. At 23 minutes, the measured flow rate dropped to 0.44 GPM and the flow pattern began to no longer cover the test area on the gauge completely. Based on our test results, approximately 23 minutes of flow meeting all ANSI requirements are provided by this prototyped design. Because of the fact that we were testing using an expensive prototype, we did not perform actual loading tests on the fixture; however, according to finite element analysis models and our engineering intuition, we expect the design
to be able to support sufficient loads during usage including someone leaning or pulling on the fixture.

Initial Flow          Flow at 15 minutes

Flow at 23 minutes
Summary of Cost

The overall cost of the proposed design is significantly less than the total cost of the current spray arm. Fewer parts, simple attachment, and ease of assembly are the main factors which contribute to this reduction. The cost is broken down below and summarized in “current-state / future-state” form to illustrate the improvement in cost permitted by our proposed design. The chart below presents a current-state / future-state overview regarding the current SE-4000 spray arm design with respect to the proposed rotomolded fixture.

Valve Mechanism - Current state

Parts: $54.80  
Labor/Assembly with overhead: $28.29  
Total: $83.09

Breakdown of cost:  
Valve assembly: $10.44  
Valve mechanism assembly: $0.46  
Spray head assembly: $1.11  
Dust Cap and chain: $1.85

Rotomolded Fixture - Future state

Parts: $18.66  
Labor/Assembly with overhead: $1.57  
Total: $20.23

Spray Heads - $2.87  
Rubber piece – $5.00 estimate

Additional cost and time for implementation of new design:  
Three-Piece cast aluminum mold with Teflon Coating: $7,194.00  
Secondary Fixture Costs: $420.00  
Tooling delivery: 6 - 7 weeks  
Tooling Capacity: 125 pieces per week  
Minimum releases of 125  
Cost of Molded piece $10.79 each

The current tank will be used for the future design.  
Tank cost: 42.41
<table>
<thead>
<tr>
<th>Cost</th>
<th>Current State</th>
<th>Future State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parts</td>
<td>$ 54.80</td>
<td>$ 18.66</td>
</tr>
<tr>
<td>Labor/Assembly</td>
<td>$ 28.29</td>
<td>$ 1.57</td>
</tr>
<tr>
<td>Total</td>
<td>$ 83.09</td>
<td>$ 20.23</td>
</tr>
</tbody>
</table>

**Implementing the Proposed Design**

The team has developed the design with the recommendation of manufacturing via the rotomolding process. The design has been fully reviewed by Trilogy plastics, and a favorable initial quote has been presented. If the Speakman Company determines that this proposal is an acceptable change for their SE-4000 eyewash, transition to manufacturing should be a rapid and easy process. Remaining steps to complete the manufacturing specifications and begin production include:

- Have the contour of the existing blue tank mapped by an electronic stylus and modify the fixture’s contour to match. Despite significant effort, the team has not been able to create an adequately matched contour through a physical measurement route. Electronic measurement of the contour is the only method to guarantee a highly precise match. Protocam or Trilogy may have these electronic measurement capabilities.

- Once the contour has been measured and the drawings modified, final specification can be submitted to Trilogy Plastics for an accurate quote.

- The cap strap design has been fully specified and submitted to Plasticoid for a firm quote. This quote is still being prepared. Once it is received, the part should only need approval by Speakman for production.
The remaining parts outlined in the design details section above are all available for purchase by the Speakman Company. They must be sourced and purchased.

The existing pull decal on the blue tank needs to be redesigned to reflect the new method of operation.

Packaging and product information must be updated to fit the new design.

Once these steps are complete, the revised design should be ready for implementation.

The team has prepared this design package with the rotomolding process in mind. However, blow molding is also a pursuable route. This would present a tradeoff between higher tooling cost and lower piece price. CY-Plastics prepared an initial quote for an early design iteration drawing. This design iteration required a simpler 2 piece mold rather than the three piece mold required for the current design. The initial quote from CY-Plastics is included in appendix C. The considerable addition of complexity since this early design leads us to estimate the costs associated with blow molding the part to be approximately $6/part, and $30,000 for tooling. Although this would reduce the piece price by nearly $5, it would increase the tooling costs by $22000. The additional tooling cost would require an additional 2+ years to recover when compared to a rotomolded route. The design team has made the assumption that this is not desirable to the Speakman Company, but felt it necessary to present as an option.
Appendix A

Initial quote from Trilogy plastics for rotomolding the yellow fixture:

Nate,

At your request we have ballparked the Speakman Fixture per the following request:

One Three-Piece cast aluminum mold with Teflon Coating: $7,194.00
Secondary Fixture Costs: $420.00

Tooling delivery: 6 - 7 weeks
Tooling Capacity: 125 pieces per week

Minimum releases of 125
$10.79 each

The above pricing is based upon yellow LLDPE material and a calculated molded weight of .85 pounds. Each part would be pressure tested and bulk packed. The mounting holes would be molded in, the others routed. Note that the angle of the nipple will need to be addressed in detail prior to tooling.

All prices are estimated, although we believe them to be accurate. Firm pricing would be available soon after the final design. With a final design we can likely reduce the mold cost.

If there are any questions or if there is something else we can do to be of assistance please do not hesitate to contact me.

Bruce Frank
Trilogy Plastics, Inc.
Appendix
QUOTATION

NUMBER: 7294
DATE: 11/20/07

University of Delaware

ATTN: Nathan Griffith

DESCR: Spray Face Mount
MATERIAL: HDPE Nat.

RELEASE QTY 2,000
PIECE PRICE – EA. $2.750

F.O.B. OUR PLANT

PIECE PRICES ARE QUOTED AT CURRENT RAW MATERIAL COSTS AND ARE SUBJECT TO MARKET Volatility Adjustment.

PIECE PRICE IS QUOTED AT PART WEIGHT 14 OZ. TO BE ADJUSTED IF NECESSARY.

TOOLING: Single Cavity Aluminum Blow mold per file provided.

$19,800.00

DELIVERY: 8 – 10 weeks from receipt of order and approved prints/geometry.

NOTES: Mold built with pulling cores both halves per design of part.

TERMS: NET 30

ADDITIONAL TOOLING TERMS: 50% REQUIRED WITH TOOLING ORDER.
2% PER MONTH OVER 30. 40% DUE UPON RECEIPT OF INVOICE
AFTER FIRST SAMPLES.
PURCHASER TO PAY ANY COSTS OF COLLECTION. BALANCE DUE NET 30 DAYS AFTER FIRST SAMPLES.

LEADTIME BEGINS WITH RECEIPT OF FINAL DRAWINGS AND CONDITIONS MET.

BY: PAUL E. SIRUS
RUN OR PRODUCTION.

FULL PAYMENT REQUIRED BEFORE ANY PILOT AND/OR MOLD DESIGN.
CY PLASTICS WORKS INC.

THIS IS AN ESTIMATE ONLY PENDING FINAL PART
NO OTHER ITEMS OR CONDITIONS APPLY