Squirting Balloon Toy Final Design Report

Sponsor: JumpSport

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Abstract

The main goal of the Squirting Balloon Toy project was to create a new toy that combined both a helium balloon and a squirting water component near the base of the balloon. The toy will be sold at theme parks, fairs, and to other retailers such as toy stores with the target audience of primarily children and their parents, or any individuals seeking a good laugh when they spray their unsuspecting target. As a result, the toy was designed to be both visually appealing and to have an element of surprise.

After testing and analyzing four different conceptual designs, two final designs were chosen to be further developed. Both use a helium filled balloon, connected to flexible tubing and a water container and trigger, similar to a spray bottle. The user squeezes the trigger, water travels up the tube, into a floating disk connected at the base of the balloon, through small channels in the disk, ultimately exiting four small holes spraying individuals in its range. The pump and reservoir are similar to a common spray bottle, however the pump is vertical instead of horizontal in order to allow water to flow straight up the tubing instead of horizontally when exiting the pump device. Both incorporate a disk design and can float (including the weight of the tubing and water in the tube) when the balloon is filled with helium. Although the main goal of the designs is for no extra support to be required to hold up the balloon, the non-spinning design can have a rigid support incorporated, so the toy does not require helium to be functional.

The only difference between the two toys is the design of the disk. For the spinning disk, there are four channels with two connecting at 90° angles. For the non-spinning disk, there are four channels that are straight, similar to spokes on a wheel.

The final toy designs are sturdy enough to be used either for a short period of time, such as a few days inside a theme park, or for a longer period of time, such as at someone's residence. The only maintenance required would be to change the balloon and refill the water reservoir, which can be done relatively quick and easy. Since the balloons are interchangeable, this also allows the toy to be sold to appear unique and entertaining depending on the event or occasion. The water reservoir is also interchangeable, allowing the user to change how they would like to disguise their device, such as in popcorn or candy cotton container. The reaction time of the water leaving the reservoir to where it exits the disk is also fast enough to provide an element of surprise in the design. As a result, it is believed that the two disk designs meet JumpSport's criteria for the Squirting Balloon Toy and will be a success when sold to customers.

Chapter 1: Introduction and Background

Currently balloons and water guns exist separately as toys, but there are no products that combine the two. The proposed product will combine the essence of a water gun with a balloon. At least two separate toys will be created, one that spins and one that does not. Both toys can be sold at fairs, theme parks, retail stores, and online.

The customer of the toys will be young children and their parents. To make the toy marketable toward children, it will be fun, visually appealing, and have an element of surprise. The design will ideally incorporate a floating balloon and squirt water near the base of the balloon. Both products will meet the California laws and regulations regarding toy safety, including: ASTM, the Consumer Product Safety Improvement Act, and the California Balloon Law (See Appendices E-G). A summary of potential design hazards is also included in the Conceptual Design Review Hazard Identification Checklist in Appendix D.

Design Requirements and Specifications

Two different toys will be made, spinning and non-spinning, in order to meet the project goal. The toys will be sold at fairs, theme parks, and/or to other retailers. Both toys will have a floating balloon, with water exiting near the base of the balloon. The user will hold the product and control when the water is released.

Water will either spin randomly out of the toy or shoot straight out from multiple ports. The user will be able to trigger when the water comes out of the toy and will be able to refill the product with more water as needed. The element of surprise is more important than accuracy, so the reaction time of the user pulling the trigger, to when the water is expelled from the toy, is desired to be less than five seconds. The water pressure must be high enough to spray someone standing within five feet of the Squirting Balloon Toy user. Enough water must come out of the toy in order to splash a person, but does not need to soak the intended target. The location of the water reservoir tank can either be at the top of the balloon, in the middle, or at the bottom of the toy by the user. If the tank is suspended in the air, it needs to be light enough for either the support device or the balloon to hold without causing the balloon to stop floating above the user.

The mechanical features of the toy, independent of the balloon, must have the lifetime of a typical water gun or toy. The design must allow the balloon to be replaced or refilled in order to extend the longevity of the toy. Overall, toy will be designed to have as few parts a possible in order to keep the per-unit final sale costs at a maximum of $20. All requirements listed above were developed from the QFD (See Appendix A) and a summary of the engineering requirements can be seen in Table 1 on the next page.

Table 1. Squirting Balloon Toy Requirements

Specification #	Parameter Description	Requirement /Target	Tolerance	Risk	Compliance
1	Balloon Durability	12 (hours)	Min	H	T, I
2	Trigger Durability for Fair/Theme Park	100 (cycles)	Min	H	A, T, I
3	Quantity of Squirt	0.5-2 (oz)	Min	H	T, S, I
4	Squirt Range	5 (ft)	Min	H	T, S, I
5	Reliability of Spinning or Aiming	65%	Min	H	T, I
6	Reaction Time	5 (s)	Max	H	T, I
7	Weight Balloon Can Hold	0.5 (oz)	Max	H	A, T, I
8	Per Unit Cost	$20	Max	H	A
9	Weight of Tank	5 (lbs)	Max	L	A, T, I

Project Management

Elizabeth was the main point of contact and was responsible for communicating with the sponsor, JumpSport. This included sending JumpSport important documents and arranging in-person and over the phone meetings. Rachael was the treasurer and was responsible for tracking any spending and making copies of receipts to be sent to JumpSport. Both team members were responsible for recording important information gathered from meetings and independent research.

Refer to Appendix B for a detailed list of tasks and deadlines detailed in a Gantt Chart. The Gantt Chart is broken up by winter, spring, and fall quarter for ease of viewing and new tasks will be added as required.

Chapter 2 Design Development

Brainstorming was compartmentalized into categories concerning the different elements of the product. These categories were taken from the customer requirements and engineering specifications listed in the QFD (See Attachment A). Some of these categories were broken into subcategories for more complex features. Two main design concepts were explored concerning the behavior of the product. The two concepts included one balloon that would spin when triggered and one that would aim toward a desired target area when positioned and triggered. Two design matrices with subcategories were drafted for the spinning and aiming design considerations. From each design matrix, 1-3 ideas were selected to model and test.

Design concepts that were selected to test:

- Trigger mechanisms:
  - Baster (Figure 1)
  - Syringe (Figure 1)
  - Electrical Water Gun (Figure 2)
- Tubing thickness
  - Large Tube with ID of 7 mm and OD of 12 mm (Figure 1-left tube)
  - Small Tube with ID of 3.5 mm and OD of 6 mm (Figure 1- right tube)
- Spinning Mechanisms
  - Pinwheel (Figure 2)
  - Wind Up Toy
- Weight Average Balloon Can Hold (Figure 3)

After testing trigger mechanisms, the syringe was found to have the best results, as it provided the most thrust for a steady stream with a greater projectile. As a result, a pump, similar to that of a spray bottle, was chosen for the trigger mechanism.

Figure 1. Baster and large tube, syringe and small tube tested for trigger mechanism.

For tubing, the thinner tube was found to be more lightweight and have a greater squirt range than that of the larger tube. Due to its small interior diameter, it produced a more concentrated stream with a higher velocity and a greater squirt range. As a result, thinner tubing, less than 0.5" was tested further.

To make the water spin as it exits the balloon, a pinwheel with various trigger mechanisms was tested. When the stream of water hit the pinwheel, a spray of water about 4 feet in diameter was produced. Due to the success of this mechanism, a pinwheel was incorporated into a design that will be prototyped for further testing. However, the pinwheel could potentially be too fragile and/or heavy for this design. As a result, a disk was thought to be incorporated in place of the pinwheel as another option to make the water spin when exiting near the floating balloon.

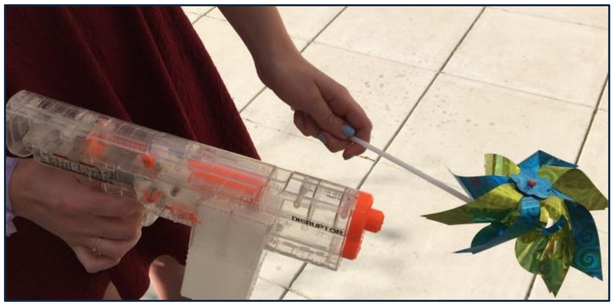

Figure 2. Electrical water gun and pinwheel combination test.

Finally, the weight an average balloon could hold was determined to be approximately 4 grams (See Appendix C for hand calculations). Since the weight of the mechanisms designed will exceed 4 grams, a larger balloon is necessary for the success of the Squirting Balloon Toy. Since the weight a balloon could hold was initially a high concern, a rigid rod, such as a balloon stick or spring-temper wire was selected to be used in designs where the balloon is unable to support the weight of the mechanism as a whole.

Figure 3. Testing weight balloon can hold.

Based on the decision matrices and testing, four designs were selected for prototyping (See Figures 4-8) and further testing in order to select two final designs for spinning and non-spinning.

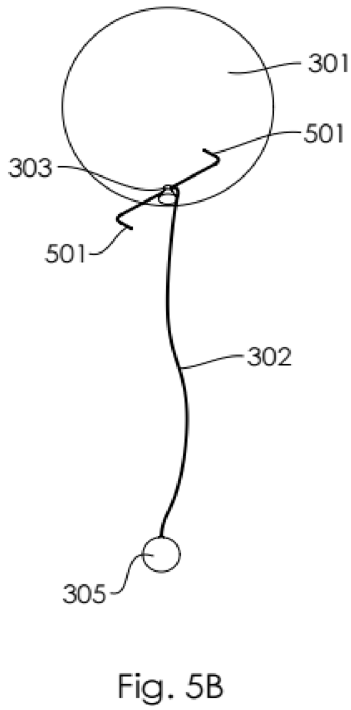

Figure 4. Spinning Rod design, JumpSport patent drawings (Appendix H).

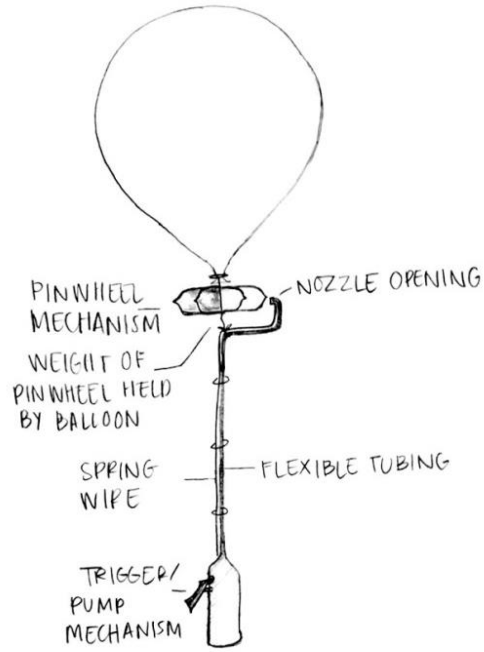

Figure 5. Pinwheel design, original sketch.

For all 4 designs, the balloon, reservoir, trigger,

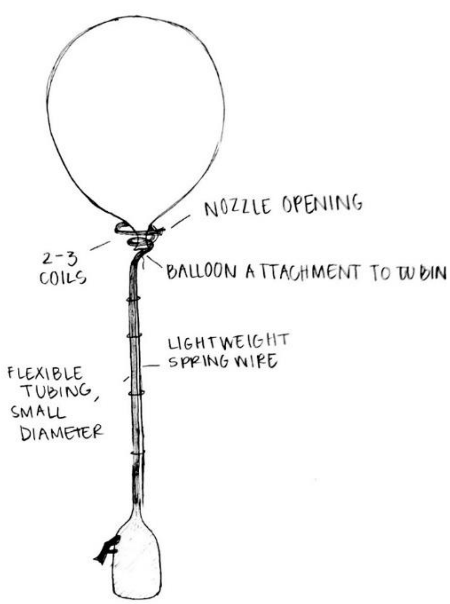

Figure 6. Vortex design, original sketch.

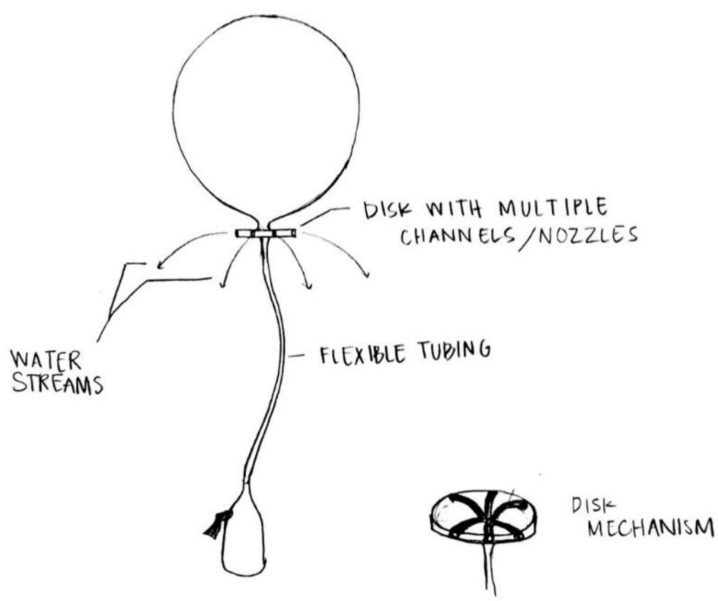

Figure 7. Disk design, original sketch.

and pump mechanism were the same. Initially a 32" Mylar balloon was tested in order to guarantee that it would float about 3-4 ft. above the user's head and to ensure it could hold the required weight for 12-24 hours.

Figure 8. Model of Pinwheel Design, original picture.

The pump and trigger mechanism were designed to resemble a spray bottle or squirt gun in order to allow the user to operate the toy with one hand. A trigger is connected to a piston cylinder which compresses a chamber filled with water, forcing the fluid into the tubing that leads up to the balloon and out the nozzle. The device was designed with the use of two one way valves, also referred to as check valves. One valve at the entrance, prevents water from flowing out of the chamber on the down stroke, and the other valve at the exit prevents air from being drawn into the chamber on the upstroke (intake). The trigger/pump mechanism was designed in order to ensure at least 0.5 oz. of water will exit out of the tube.

The water reservoir, for all designs, was decided to be held by the user at the bottom of the device. Since the balloon can hold very little weight, this was deemed the best place to put the water reservoir. The reservoir was also predicted to be about the same size and weight of an average water bottle or spray bottle to ensure the user is comfortable when holding the device. Allowing the balloon to float only about 3-4 ft. above the user's head will ensure the reaction time, from when the user presses the trigger to when the water exits, is reasonable since the length of the tubing will be similar to this distance.

A flexible tube, instead of a rigid tube, was chosen to transfer the water from the pump mechanism to the base of the balloon (for all four designs), in order to allow more flexibility and avoid possible crimping. Tubing of 3 different diameters were ordered to be tested. As found from initial testing, thin tubing allows a greater squirt range ensuring the prototypes would meet the minimum design requirement of a squirt range of 5 feet. To ensure the product remains under the retail price of $20, standard parts were anticipated to be most preferable.

The "Spinning Rod" design (Figure 4) consists of a thin flexible tubing that travels from the user holding the balloon to the base of the balloon. When the water exits by the balloon, it sprays out from two sides, creating a moment that results in a spinning motion. By using a thin light tube, the balloon was anticipated to support the tubing without additional support. If the balloon was unable to hold the weight of the tubing, spring-temper wire can be used to provide additional support.

The "Spinning Pinwheel" design (Figure 5) consists of a similar trigger/pump mechanism, balloon, and tubing setup as the "Spinning Rod". However, the water only exits at one point and hits a pinwheel attached underneath the floating balloon. When hit with water, the pinwheel spins, creating a circular spray of water above the user's head. Since the "Spinning Pinwheel" design is heavier than the "Spinning Rod" design, spring-temper wire was incorporated into the design to support the tubing. A model of the "Spinning Pinwheel" design is shown in Figure 8.

The "Vortex" design (Figure 6) is composed of spring temper wire and flexible tubing that will extend from the pump mechanism to the base of the balloon. The wire and tubing maintain a vertical composure until the base of the balloon, where it coils 2-3 times. The end of the coil is the nozzle, where the water exits. The wire provides support for the tubing and balloon by attaching to

the side of the tubing or rest inside the tubing, if spacing permits. The balloon sits inside of this vortex-like fixture, created by the coils, and attaches in the center with a thin, transparent string to resemble a floating Helium balloon. This design was beneficial in that the balloon does not need to be filled with Helium and could be used for aiming, as opposed to spinning.

The “Disk” design (Figure 7) resembles the “Spinning Rod” because the tubing is only supported by the balloon. The tubing runs from the trigger mechanism to the base of the balloon, where the water is directed into multiple channels that rest in a thin plastic disk mechanism about 2-3 inches in diameter and 1/16 inches thick. The disk is designed so that the water will exit in a spinning motion, similar to the “Spinning Rod”.

To build the four prototypes, standard parts were bought at local retail stores or online and made by hand or rapid prototyped as required. Testing was conducted and the final two designs were chosen based on the design requirements and specifications.

Supporting Preliminary Analysis

During testing, five standard latex balloons were found to be sufficient for supporting a rough prototype of the final design. This included the weight of the tubing and rapid prototype disk. It was assumed that the balloons were standard 11” diameter latex balloons and were spherical in shape. Furthermore, if exactly five standard 11” balloons were required for the purpose of this product, the next available standard balloon size that would displace as much volume was the 24” diameter latex balloon (See Appendix C). As a result, balloons under 24” were tested.

A rough estimate of the necessary pressure, provided by the stroke of the piston, was also performed and found to be around 17psia. This was with the assumption that the exiting velocity was 1 ft/s and the pressure was atmospheric. This initial pressure was also used to determine the necessary size of the piston. Standard grip forces for children was researched and the weakest force of roughly 20 lbf was used, in addition to the pressure found earlier, to determine the maximum diameter needed for the piston, 1.2” (See Appendix C). The piston diameter, however, is also limited by the desired quantity of the squirt. If the required quantity is 0.5 oz of water, then the minimum diameter of the piston (with a 1” stroke) is approximately 0.3”. Thus, the first prototype will have a diameter of 1”, a value in between the maximum and minimum limits.

Design Verification (Testing)

First, different types of balloons were tested. A 32” Mylar balloon was made using a mini iron and despite significant leaks, was able to hold 44 grams, not including the weight of the balloon (See Figure 12). However, due to the heaviness of the material (35.9 grams) a latex balloon was chosen instead. When tested, five latex balloons were able to hold the weight of the disk, tubing, and water in tube (See Figure 11), which equated to roughly a 24” balloon diameter. Next, the tubing length was determined by testing three tube sizes (1/32”, 1/16”, and 3/32” inner diameter). Five feet of tubing was tested for each size and it was found that each sized tubing was able to squirt water out at the base of the balloon in a reasonable time. However, after testing a 20” balloon and a 16” balloon, it was determined that five feet of tubing only worked with a 20” balloon, while four feet of tubing just barley worked with a 16” balloon. While the 16” balloon was able to displace the weight of the system with the 4 feet of tubing, it was unable to support the additional weight from the water in the tubing once the device was in use. As a result, it is recommend to use four feet of tubing with an 18” latex balloon as the design is able to remain free floating and the tubing length is

long enough to still allow the balloon to float over the user's head. A shorter tubing length also reduces the frictional losses in the system, ultimately reducing the overall pressure drop.

The pinwheel design was tested and determined to be too heavy and fragile to use as a final design. The one port design was not tested since we wanted to focus on a floating design aspect, but this idea may be developed in the future if a design with no Helium is desired.

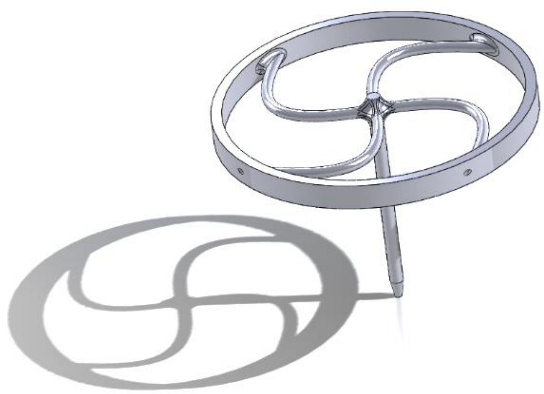

Figure 9. SolidWorks model spinning.

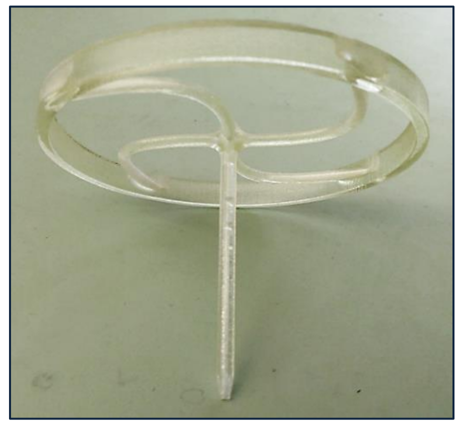

Figure 10. Rapid Prototype Spinning.

Figure 11. Five latex balloons holding weight of toy, original picture.

Figure 12: Handmade 32" Diameter Mylar Balloon, original picture.

Next, the spinning rod design (See Figure 4) was tested using the flexible tubing and Lightweight Aluminum Wire of 0.081" and 0.025" diameter. Both designs produced a circular spray when water

was pumped up to the balloon. However, a design with minimal manufacturing was desired, so a disk with a similar design of 90° bends was rapid prototyped (See Figure 9 and Figure 10). However, due to the sharp corners, the filler material from the rapid prototype machine was unable to be cleaned out of the channels and the prototype could not be tested. It was determined that this design was undesirable for testing and was not manufactural. A new design with channels that can be cleaned more easily was designed and rapid prototyped for testing (see Figure 13).

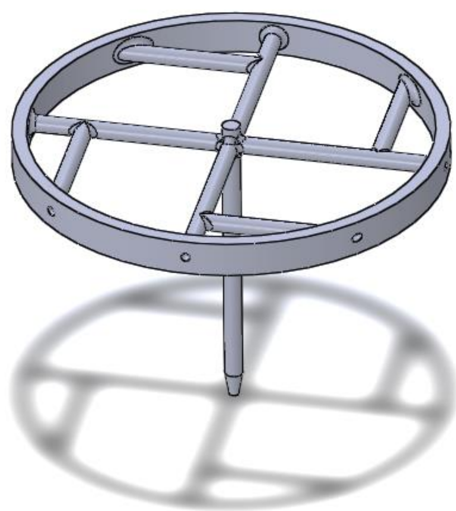

Figure 13: Spinning Disk design that was rapid prototyped and tested, original drawing.

The new design proved to be easily cleanable and all channels were cleared of unwanted material. Upon testing the design, the four straight ports were sealed with piping tape and the disk was connected to a 5 ft. length piece of tubing and a water filled syringe. This portion of the test was to see if the disk would indicate signs of spinning. While spinning was observed it was not significant enough to be seen as a successful and usable product. To improve the spinning motion two of the ports (180° apart) were sealed. This was to restrict the exiting area, allowing for a greater exiting velocity. While this proved to create a greater spin, it was still lacking in rotational speed.

To improve the design, it was determined that a bushing should be used to reduce torsional resistance caused by the tubing (Figure 21) and that the disk needed only two ports, as previously described, mimicking a sprinkler head (Figure 18). The small four inch disk did not deliver a great enough spray, so the disk diameter was increased to six inches in order to provide a five foot diameter spray. The bushing and new disk were rapid prototyped and tested with a syringe acting as the pump and proved to meet the design criteria (See Table 2). The bushing allowed the disk to freely rotate with very little resistance.

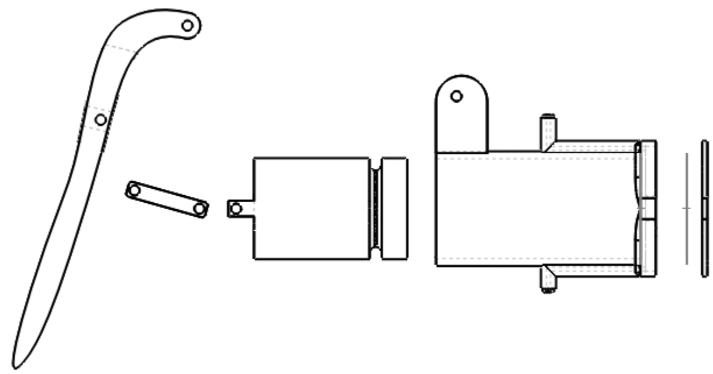

Figure 14: Exploded view of Pump Assembly, original drawings and mate

Figure 15: Screenshot of Pump Testing Video, original photo

The pump was rapid prototyped in five separate components for ease of manufacturability (Figure 14), including: the trigger, connecting rod, piston, body, and cover, respectively. The trigger, connecting rod, and piston were connected at their respective concentric holes by using the Aluminum Wire of 0.081" diameter and the pump cover was attached to the rear of the pump body with Epoxy. Initially the piston did not fit the cylinder in the pump body, so material was removed with fine grain sanding paper. Eventually the cylinder was able to fit in the chamber, however, upon testing did not provide a suitable seal. Upon the next design iteration, the piston diameter was reduced by 1/32" to provide enough clearance and a small groove was added to the rear of the piston to fit an O-Ring of 20mm ID and 26mm OD. Following the same assembly with the addition of the O-Ring, the two check valves were added to the connecting channels. After submerging the bottom channel in a water reservoir, the trigger was used to initiate the intake and compression strokes. Water was drawn into the chamber on the intake and was emitted vertically upward through the upper channel on the down stroke. Upon the first testing of the pump, the chamber did not fill entirely with water, however, on the second use the entire chamber was filled with water. See Figure 15 for the final pump prototype. After multiple cycles of testing, water appeared to leak around the piston – indicating an imperfect seal. Next, the pump was attached to the bushing and disk mechanism with the 5 feet of tubing. On the down stroke, water was forced into the tubing and eventually exited the disk's channels. While water exited the disk's channels, the pump was unable to provide enough pressure for the disk to spin. Although the pump was unable to produce spin in the disk, it worked well enough to provide proof of concept and met the criteria for the quantity of squirt. In addition, this design can be refined and improved in order to meet other design needs (see Conclusions and Recommendations section).

Critical criteria in Table 1 where tested and proved to meet or exceed expectations. A summary of key results are included in Table 2.

Table 2. Squirting Balloon Toy Requirements and Results

Specification #	Parameter Description	Requirement /Target	Final Result
1	Balloon Durability	12 (hours)	12 (hours)
3	Quantity of Squirt	0.5-2 (oz)	1.66 (oz)
4	Squirt Range	5 (ft)	5.5 (ft)
5	Reliability of Spinning	65%	100%
6	Reaction Time	5 (s)	< 5 (s)
7	Weight Balloon Can Hold	0.5 (oz)	> 10 (oz)
8	Per Unit Production Cost	$20	$12
9	Weight of Tank	5 (lbs)	< 5 (lbs)

Chapter 3: Final Design

Overall Description and Layout

The main premise of the two selected squirting balloon toy designs incorporates a tank, pump mechanism, tubing, a stationary or spinning disk, and a helium balloon. The pump is similar to that found in squirting guns and spray bottles, however is redesigned to have a vertical exit, as opposed to a horizontal one. The inlet and outlet channels will match the inner diameter of the tubing it will be attached to (3/32"). Also similar to many spray bottles, the pump mechanism will act as a cap to a variety of tanks. This will allow for flexibility in the tank design and provide opportunities for further camouflage and potentially a new element of surprise. Attaching to the pump exit will be the Tygon tubing. The tubing was selected because it is food and dairy safe, flexible, and lightweight. It will have an inner diameter of 3/32", an outer diameter of 5/32", and a length of four feet. The tubing acts as a way of guiding the fluid from the pump to the exit ports on the disk. The tubing attaches to the base of the disk, which has an inner diameter of 1/32" at the inlet. Due to the tee-like shape connection of the disk, the fluid flows through a 90 degree bend, and then diverges into 4 small 0.05" channels. Based on the design of the disk, the fluid will either exit in a linear or spinning motion. This entire mechanism is supported by an 18" helium filled latex balloon, which will attach to the top center of the disk. An approximate layout of the design is shown in Figure 16.

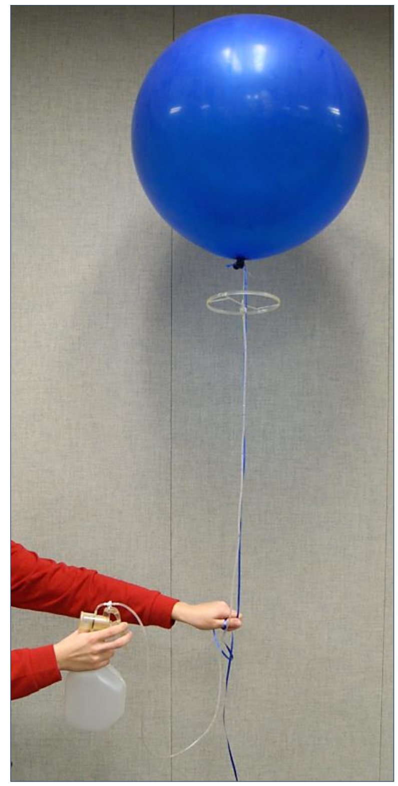

Figure 16: Final Prototype, original photo

All unique parts (disks, pumps, and water reservoirs), will be manufactured with injection molding using High-Density Polyethylene Plastic (HDPE).

Detailed Design Description, Analysis, and Manufacturing

Pump

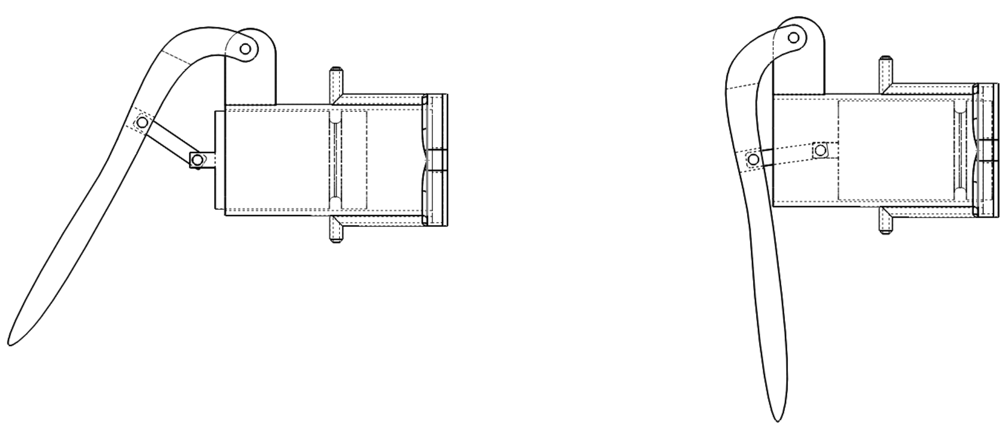

Figure 17: Pump Assembly illustrating the intake stroke (left) and down stroke (right)

The pump mechanism design is similar to a squirt gun and spray bottle. It has main features, including: 2 one way valves, a piston and cylinder, and a handle. The 2 one-way valves will be placed at the inlet and exit of the pump, via external attachment. These will be purchased from a vendor and sized to fit the chamber. They function so that on the intake stroke, the chamber can only fill with water and on the down stroke; the water is forced up the tubing, as opposed to returning to the tank (Figure 17). The cylinder is 1" in diameter and the piston is 31/32" in diameter, with a stroke of 1". The piston has a groove of 0.12" and is located 0.25" from the rear. This groove exists to house an O-Ring, which will provide the seal required for drawing and emitting water through the channels and chamber of the piston and cylinder mechanism. The pump is also designed so that in its resting position the handle is extended and when the piston is fully compressed the handle is vertically aligned. The trigger and cylinder connection will have three components: the trigger, connecting rod, and the piston. The connecting rod will function like a pin to enable changing radii of the device.

The pump will be made via injection molding with a reusable mold. In order to avoid undercuts, the back wall of the pump will be made separate and attached later. The channels of the pump will be created with core inserts, which is why the channels bend in a 90 degree fashion, as opposed to a curved radius. The pump mechanism will act as a cap in order to attach to the fluid tank, much like that of a commercial spray bottle. The tank will be a standard size (approximately 16 oz) and purchased from a vendor. However, unique tanks resembling other shapes, such as a popcorn container, can also be designed. Refer to Appendix J for SolidWorks files of the pump parts.

Disks

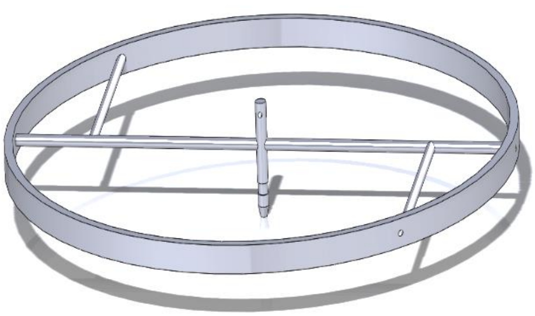

Figure 18: SolidWorks Spinning Model, original drawing.

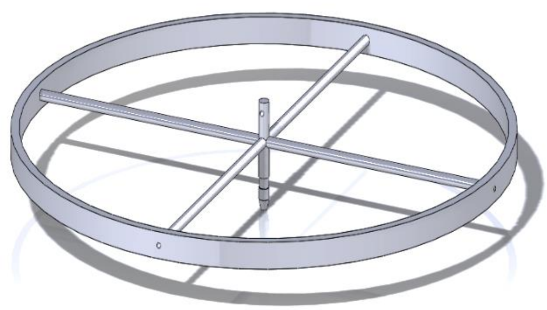

Figure 19: SolidWorks Non-Spinning Model, original drawing.

Both disk designs are made out of the same material, HDPE because most plastic toys on the market today are made of this material as well. The color of the disk can be varied, however if the desire is to surprise the target, a clear color is preferable. Refer to Appendix J for SolidWorks files of both disks.

The outer diameter of both disks is 6” and the width of the rim is 0.1” in order to make sure the disk is light enough to be supported by the floating balloon. The array of channels have an inner diameter of 0.05” and an outer diameter of 0.10” to ensure there is enough water that exits the toy, but the pressure is high enough to spray out five feet. The entrance hole of the disk has an inner diameter of 0.0375” and outer diameter of 0.125”. Near the entrance channel of the disk, a groove has been added for the bushing to fit into. There is also a 0.05 inch hole on the top of the part in order to easily connect the balloon and disk. Fillets on all connecting pieces help with the manufacturability of the part.

As mentioned earlier, the spinning disk has 90° channels, with four exit points. However, the exit points of the two longest channels will be plugged up after molding in order to create a spinning motion caused by the 90° bends. This allows the channels to be properly cleaned out before they are plugged, while still allowing the spinning motion. The spinning disk can be seen in Figure 18.

The non-spinning disk will be the same as the spinning disk, except it will only have four channels that are straight, similar to the spokes of a wheel (See Figure 19). This allows the fun aspect of water exiting multiple ports, while still allowing the channels to be cleaned properly.

Bushing

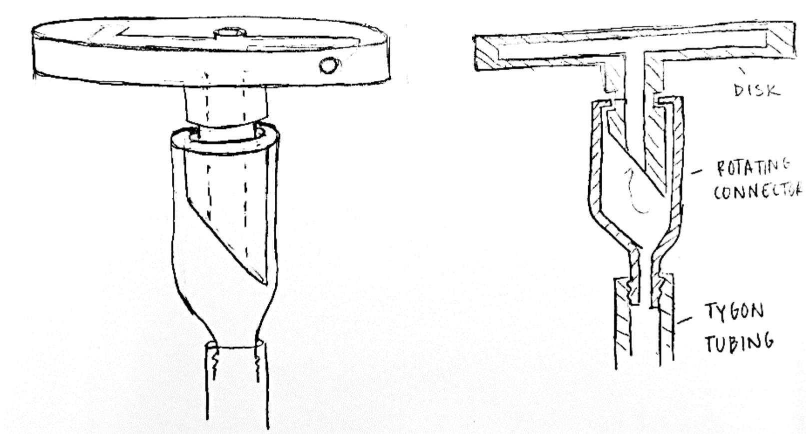

Figure 20: Bushing Mechanism, original sketch.

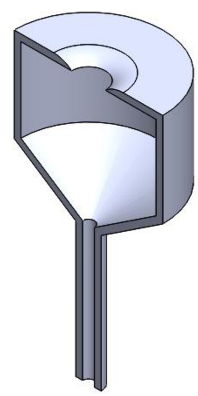

Figure 21: Bushing Connector, original drawing.

A bushing was created to allow free rotation of the spinning disk design. It is an additional piece to the disk that is separate and rests inside a groove of the entrance channel of the disk (see Figure 20). The part is designed to have very little clearance with the inner diameter of the groove on the disk in order to lubricate the disk with the water and allow free rotation, but not allow too much water from leaking out. As shown in Figure 21, the bushing would be manufactured in two halves and then clamped around the disk with an epoxy or other permeant process. See Appendix J for dimensions of the bushing.

Balloon

The balloon will be a standard size of 18" in diameter when filled. It will be composed of latex to minimize weight. Since the balloon is a standard size and material, it will be purchased in large quantities from a vendor. The balloon will be able to hold a minimum of 1.66 oz.

Tubing

As mentioned before, a flexible tube will be used to transfer the water from the pump mechanism to the base of the balloon, in order to allow more flexibility and avoid possible crimping. Four feet of Beverage Clear Tygon PVC tubing with in inner diameter of 3/32" and an outer diameter of 5/32" will be used. The tubing is wide enough to deliver the necessary amount of water to the disk, but still light enough to be supported by the balloon. Four feet of tubing was chosen, since combined with the height of the person standing up, this length will allow the balloon to float an average distance of 6-9 feet off the ground depending on the height of the person holding the toy.

Cost Analysis

An estimate of the material costs for the parts are as follows:

- Spinning Disk: $0.09
- Non-spinning Disk: $0.09
- Bushing: $0.01
- Pump and bottle: $0.90
- Tubing: $1.40
- Balloon: $0.40

<u>Total:</u> ~$3.00 per-unit

These prices do not include the price of molds or tooling. Using a multiplier of four to account for other hidden costs, such as shipping and handling, gives a finally estimate of approximately $12 per-unit to manufacture the product. Further cost breakdown can be found in the Bill of Materials (Appendix I).

Maintenance

Maintenance for this product is quick and easy for both designs. When water is running low in the reservoir, low enough that a steady stream is no longer exiting the toy, remove the cap of the bottle and refill with water. If the balloon is no longer floating in the air, either refill the balloon with helium or replace the balloon altogether.

Chapter 4: Conclusions and Recommendations

Balloon

Based on initial testing, it is recommended to use the product in areas with minimal wind, to prevent the balloon from moving around too much and increase the accuracy of the spray. In addition, latex is the most suitable material for the balloon as it is significantly more lightweight. With a lighter material, more of the buoyancy force of the balloon can support the mechanism (including the disk, tubing, and water), as opposed to the weight of the material, allowing a smaller balloon size to be used. Although a larger balloon may be used, an 18" balloon is optimal for the design.

Pump

The pump is designed to meet the requirements for the weakest anticipated user. The size of the piston is 1" diameter, and has a stroke distance of 1"-1.5". The pump design can be improved to supply a greater pressure by making the following changes: reducing the length of the tubing in order to reduce frictional losses, tightening the seal between the piston and cylinder by using an O-Ring thicker than 20mm ID and 26mm OD and enlarging the groove, and adding a compression spring in the cylinder chamber in order to improve the intake speed.

Tubing

Out of the tubing tested, the largest one was selected for use (inner diameter of 3/32" and an outer diameter of 5/32"). The larger tubing lowered the effect of friction losses in the tube, and allowed the connecting disk and pump channels to be of reasonable size.

Disks

Two 6" disk diameter designs were selected for the purpose of achieving a spinning and non-spinning effect. Both will resemble the shape of a disk, with one inlet at 0.0375" ID & 0.125"OD and four exits at 0.05" ID and 0.10" OD. The spinning design will be made with two additional channels attached to the main channels at an angle of 90 degrees to influence spinning motion. In addition, the ports with the two longer channels will be plugged after cleaning in order to force the fluid to make the 90 degree turn and produce the necessary couple to make the device spin. This design was chosen over the previous spinning mechanism, with curved channels, due to manufacturability.

To further improve the design, the thickness of the rim could be reduced and still maintain its structure. This would also reduce the weight of the disk and allow an increase in wall thickness of the channels to make them more robust and less likely to warp.

Bushing

The current bushing size allows enough water in its cavity to provide lubrication and allow the disk to freely spin. To further improve the design, the connecting piece of the bushing to the tubing could be reduced in length by about half the current size.

Manufacturing

The disk, pump, and bushing will be made out of HDPE using injection molding. The use of molds, removable cores, and post injection welding will be required. The initial tool costs are not included in the expected price analysis as per-unit price will vary depending on how many toys are sold. The Tygon tubing, O-ring, balloon, and tank can be purchased from large vendors and will not need to be specially made.

Appendices

A. QFD
B. Gantt Chart
C. Hand Calculations
D. Conceptual Design Review Hazard Identification Checklist
E. ASTM (Consumer Safety Specification for Toy Safety)
F. California Balloon Law
G. Consumer Product Safety Improvement Act
H. JumpSport Patent Drawings
I. Bill of Materials
J. SolidWorks Files