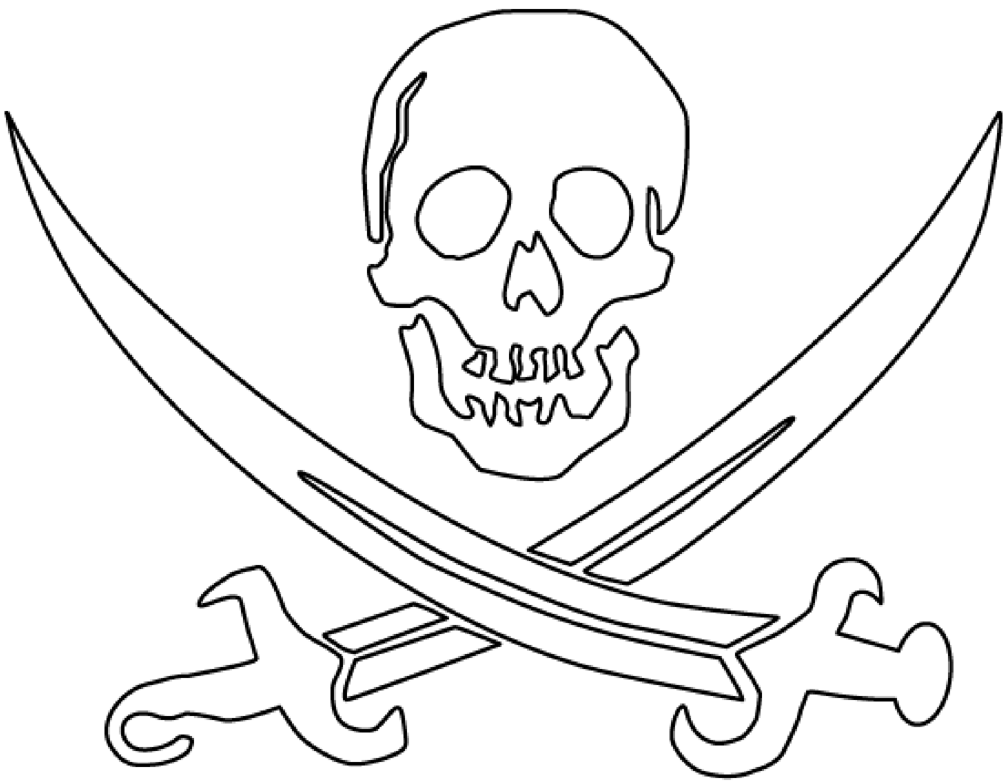
Marauder Marine

SPEARFISHING FLOAT DESIGN



Self-Sponsored

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EXECUTIVE SUMMARY

Marauder Marine is a free-dive spearfishing equipment company formed to design a new state-of-the-art float for spearfishermen. The float will be called the Pufferfish, and it will be the first spearfishing float designed to automatically deploy (inflate a bladder) when pulled underwater. In packed mode, the float has a streamlined cone shape that is easy to drag through the water and glides effortlessly through other obstacles such as kelp. The Pufferfish uses an increase in pressure from the water at depth to activate its triggering mechanism and inflate a bladder with CO_2. Once triggered, a bladder inflates and brings the float back to the surface of the water. This float is useful for spearfishermen when they spear a strong fish but the fish does not immediately die. When the fish begins to swim away or dive down, the float (which will initially be floating along the surface due to its inherent buoyancy) will be pulled underwater and deploy at a pre-determined depth. The inflated float has enough buoyant force to bring a medium sized fish to the surface. This product fulfills both the need for a low-drag float while still providing the buoyancy required to hold onto a speared fish.

INTRODUCTION

In spearfishing, a diver is required to have a flotation device attached to their speargun for several reasons. These reasons include: prevention of equipment loss, a marker for nearby boats and divers, and also to slow and tire a running fish after it has been shot. Many current floats on the market fulfill these needs, however they are large, hard to carry, and can easily get tangled up in kelp and other underwater obstacles.

The purpose of this project was to design and develop a new spearfishing float which will utilize an automatic deployment system to self-inflate. This new float is much smaller than current floats on the market allowing it to move through water and kelp much easier, but it will expand to provide the needed buoyant force when required.

There are already inflatable floats on the market for spearfishermen; however, they must be inflated before entering the water. The Pufferfish will be the first float on the market to automatically deploy once pulled down to a certain depth.

Although the target market is the spearfishing community, there may be other maritime industries that the device could be marketed to. These markets include treasure-hunting, item recovery, and search and rescue to name a few. Although all of these industries already have flotation devices used to keep items and people afloat, these devices are usually large and cumbersome making the compactness of our design appealing to each field.

The overall goal of this project was to design a revolutionary float that can be marketed to multiple industries with an emphasis on the spearfishing industry. Once a successful product is developed, one or more of our team members may pursue the start of a private business selling the product.

BACKGROUND

HISTORY

Spearfishing has been around for a very long time dating back to France 16,000 years ago (Gabriel & von Brandt). Originally spearfishing was used by hunters to spear fish in rivers and streams using sharpened sticks (Grahame, Anthony). In that day spearfishing was used primarily as a necessity to provide food; however, today it has evolved into a worldwide sport. In the 1920's people started spearfishing using only goggles and a spear gun. The method of spearfishing in which a diver does not use an oxygen tank is referred to as free-diving. Free-dive spearfishing grew in popularity so much that at one point enthusiasts tried to make it an Olympic sport. Within the several decades, spearfishing enthusiasts have formed private associations, many of which organize competitive spearfishing events.

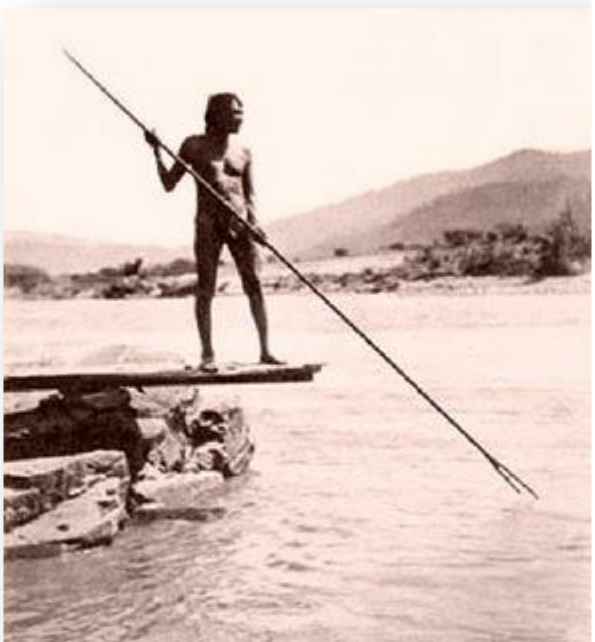


Figure 1: An old photo of a tribesman spearfishing using a pole spear from a dock.

Figure 2: An old advertisement for a speargun from the 20th century.

EXISTING PRODUCTS – SPEARFISHING FLOATS

There are many companies that currently produce and sell floats specifically for spearfishing. None of these companies offer a float that deploys automatically. Listed below are several of the floats currently available:

CARTER PERSONAL FLOAT WITH CO_2 INFLATOR: The closest thing on the market to our design is the Carter Personal Float with CO_2 Inflator. This float is deployed using replaceable CO_2 cartridges, but must be manually deployed using a rip-cord style system. We were not able to find a patent for the Carter Float using an online patent search. The Carter Float offers about 25 lbs of buoyant force and was not designed specifically for spearfishing, although many spearfishermen use it. This float is usually inflated outside of water, creating a lot of drag once in the ocean. ($72)

Figure 3: Carter CO_2 inflated float.

ROB ALLEN FOAM FLOAT: This float is the standard of durability in the current market. The foam filled hard plastic is extremely strong, and not at risk of popping or deflating. These floats are fairly hydrodynamic, but are limited by their bulky size and weight. These floats are buoyant enough to stay afloat when pulled by medium size fish but can easily be submerged by a larger, stronger fish. ($75)

Figure 4: Rob Allen foam float.

RIFFE INFLATABLE FLOAT: This is one of the most popular inflatable spearfishing floats. It is very large when inflated (40” length x 10” diameter), offering about 90lbs of buoyant force. Even with this large size, it travels well when un-inflated in a car or pack because it can be compressed or rolled up into a smaller, more compact shape. This float must be inflated orally or utilizing a pump, which can take a long time. After testing it in Morro Bay, we found that it creates a lot of drag through the water, due in part to its large size. ($179)

Figure 5: Riffe Inflatable Float.

NEPTONICS KELP CARROT: The kelp carrot is known in the spearfishing community as the best float for use in heavy kelp. It has a shape very similar to a carrot, and because of this it has very little drag and does not get caught up in kelp. However, the float is very small giving it a very low buoyant force. It would not be effective against large or strong fighting fish. From our research we have found that many users enjoy the low drag qualities of this float, leading us to believe that a shape similar would be useful in our design. ($62)

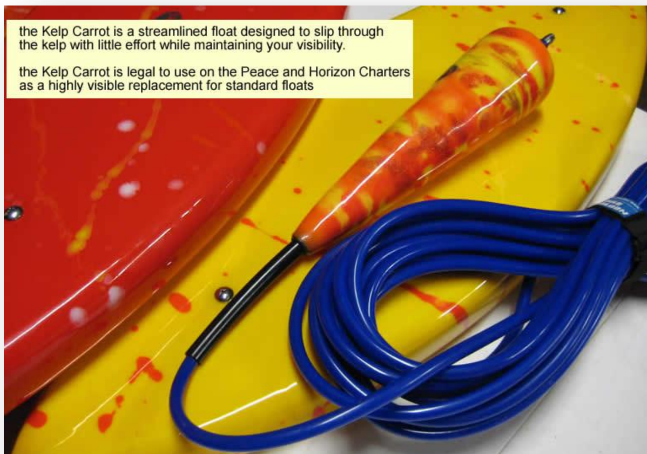


Figure 6: Neptonics Kelp Carrot.

OTHER PRODUCTS

During a patent search we discovered a few products relevant to our project. The most relevant is the Divers Buoyancy Vest (3,866,253). This is a safety vest worn around the neck; a rip-cord style deployment fills the vest from a CO_2 cartridge to provide inflation. There is no depth trigger mechanism. Searches for devices that deploy at depth returned next to nothing. One patent was found for controlling a divers' depth underwater (5,823,713), but this should not interfere with our product as it uses a buoyancy compensation device to slowly release compressed air from a SCUBA tank into the vest as the diver gets deeper and deeper.

MARKET RESEARCH

Our group generated an online survey to get the opinions of spear fishermen worldwide. We have received over 200 responses which have been very helpful in identifying customer needs/desires. Although many of the responses showed a satisfaction with their current float set-up, a majority also notes what they would like to see improved. From these comments we found that a design similar to the Kelp Carrot would be useful due to its hydrodynamic nature. We also discovered that many customers would enjoy having a more compact float that would be easy to carry to the ocean since many fishing locations require lengthy hikes.

MANUFACTURERS DATA

As a means to collect data on current spearfishing markets we contacted several manufacturers of spearfishing equipment. They helped us to determine the estimates below:

Today the world market for the spearfishing industry is between 20 and 30 million dollars annually, including close to 2 million in the U.S.A and approximately 500 thousand dollars spent in California alone. Based on the importance of a float to spearfishing as well as its relative cost compared to other spearfishing equipment, we believe the float market makes up approximately 15% of the spearfishing market. This means that our float design could potentially earn $75,000 annually in California alone and $300,000 annually to customers in the United States. Eventually upon production of a successful product our floats could be sold all over the world. This will cause sales to increase exponentially, as spearfishing is a much more popular in other parts of the world than in the United States.

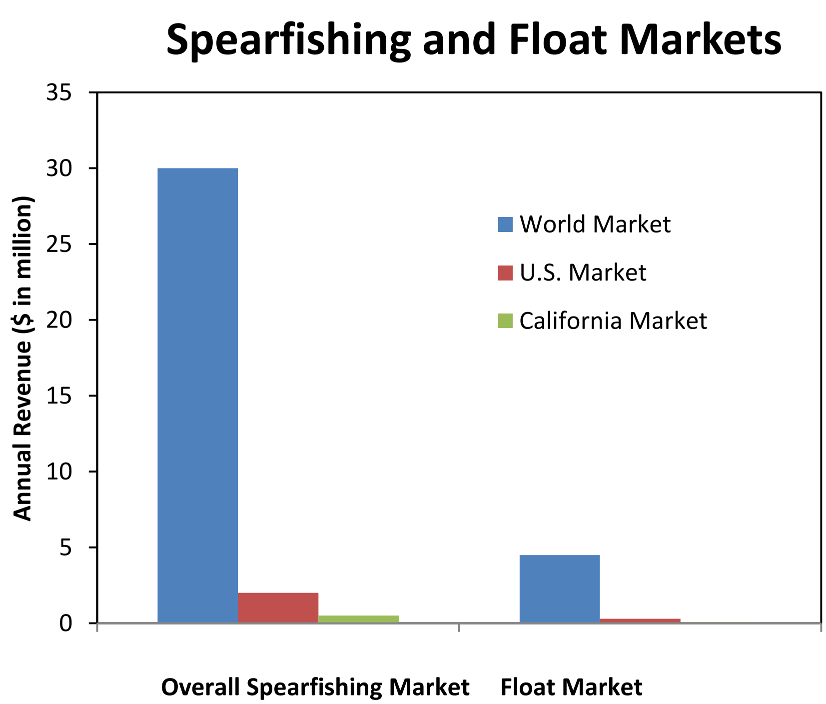


Figure 7: Spearfishing industry annual revenue, illustrating the potential for sales in the world market.

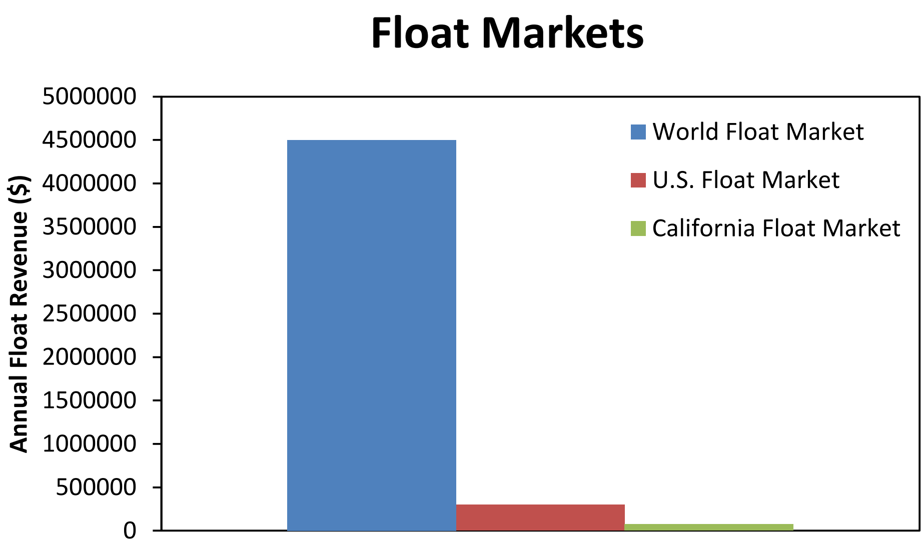


Figure 8: Float market annual revenue.

INTERVIEW WITH BRANDON WAHLERS

A professional spearfisherman and world record holder named Brandon Wahlers agreed to an interview with our team to discuss the project. The interview gave us very useful insight into the desires of competitive spearfishermen. He was very excited about the project and indicated he would buy/use the product if it makes it to market. In accordance with Brandon's wishes, explicit details from the interview will not be included in this report.

OBJECTIVES

Our goal as a team is to create a state-of-the-art inflatable float system for spearfishermen. Almost every float in the current market floats constantly on top of the water, whether it is an inherently buoyant object or is inflated by the diver before entering the water. This is inconvenient due to the drag these floats provide. Our team created a streamlined float with very little drag through the water which deploys when pulled below a certain specified depth. Although there are already a few CO_2 charged floats on the market, ours is much more streamlined and the first to automatically deploy at a certain depth in the water. This saves the user time and effort while swimming and hunting for fish. This float is able to work in all water conditions due to its streamlined body and is buoyant enough to fight against fish up to 50 pounds. In addition, our float was designed so that the spearfisherman can use multiple floats in series in case they would like to use it on larger fish. Our goal was to have this new self-inflating float revolutionize the float industry and provide divers a product that they cannot live without.

CUSTOMER DESIRES

The following list was produced from our market research:

- Reasonably priced **(Importance: Medium)**
- Size: small, lightweight **(Importance: High)**
- Reliable **(Importance: High)**
- Buoyant **(Importance: High)**
- Connection points for line (Easy to use underwater w/ gloves) **(Importance: Low)**
- Hydrodynamic (low drag) **(Importance: High)**
- Non-corrosive **(Importance: Medium)**
- Durable **(Importance: Medium)**
- Replaceable inflation cartridge **(Importance: Medium)**
- Easy to repackage after expansion **(Importance: Low)**
- Sleek, appealing look **(Importance: Medium)**

ENGINEERING REQUIREMENTS

Table 1: Engineering Requirements

	Parameter Description	Requirement or Target	Tolerance	Risk	Compliance
1	Weight	10 lbs	Max	L	A,T
2	Size	1'X6"X6"	Max	H	I,A
3	Our Cost to Create 1 Unit	$50	Max	H	I
4	Buoyant Force	45 lbs	Min	M	A,T
5	Time to Build 1 Unit	6 hrs	Max	M	T,S,I
6	Time to attach to Floatline	1 min	Max	L	T,S,I
7	Tensile Strength of Inflatable	50 psi	Min	M	A,T,I
8	Drag Force when not inflated	5 lbs	Max	H	A,T
9	Reliability of Deployment	99%	Min	H	T,I
10	Time to load cartridges	2 minutes	Max	L	T,S,I
11	Time to repack bladder	1 minute	Max	L	T,S,I
12	Depth of deployment	10 feet	Max	M	A,T
13	Size inflated	1 ft^3	Min	M	A,T,I
14	Internal bladder pressure	10 psi	Max	H	A,T,I

REQUIREMENTS: HIGH RISK

In order for our product to sell and be successful in the small market of spearfishing gear, the following high-risk requirements must be met.

DRAG-FORCE

The success of our project hinges on the ability to make spearfishing with a float easier and more streamlined. There are plenty of quality products already on the market that provide buoyancy, but we aim to improve from their bulkiness and tendency to tangle with other lines and kelp. This requirement basically states that we want our product to require less drag force to pull through the water than the current more buoyant products. We also want it to avoid tangling with kelp and lines.

SIZE

Our product needs to be easy to use and not present any significant hassles during use. A large float would get in the way and create problems, both during transportation and use. The bulkier the float is the more drag it will create being pulled through the water and the bigger inconvenience it will cause the user as far as carrying and packing. A small size float with a more aerodynamic shape would be less likely to catch in kelp, and would be easier to carry and maneuver. Therefore some of the main requirements for our float are that it be small, compact, and aerodynamic.

RELIABILITY OF DEPLOYMENT

A deployable float is worthless unless it has a high reliability of deployment. If a customer spears a fish and the float gets pulled more than10 feet underwater but fails to deploy, they may lose their fish, float, and gun; it is reasonable for them to get upset. The spearfishing community is rather small, and if there are problems with the dependability of our product, its reputation will dive-bomb and sales will suffer greatly.

COST

In order for our float to be competitive, we need to have a competitively low price. If our product performs twice as well as the competition, but comes with a price twice as high, it will be difficult to sell. We hope to minimize the cost by designing a simple mechanism, using common materials, and reducing manufacturing time. The bladder and casing will be cheaper than the triggering mechanism because we can use lower quality materials and less machining requirements.

INTERNAL BLADDER PRESSURE

One of the largest high-risk safety requirements for our float is that the bladder will not reach an internal pressure that would cause it to burst. Unlike the other requirements this one could potentially harm the user and it is very important that we hold the consumer's safety as a paramount concern. We must design and manufacture our float so that the internal pressure of the bladder once inflated by the five CO_2 cartridges will be low enough that the bladder does not burst.

CONCEPTUAL DESIGNS

TRIGGERING

The most important technical component of our float is the triggering mechanism, so that concept is where we invested the majority of our brainstorming time. To allow the float to deploy at depth, we decided early on to utilize that fact that a body air will compress and decrease in volume as it travels to greater depths. Most of our early concepts, and ultimately our final design, rely on this increase in water pressure to compress air and move a plunger.

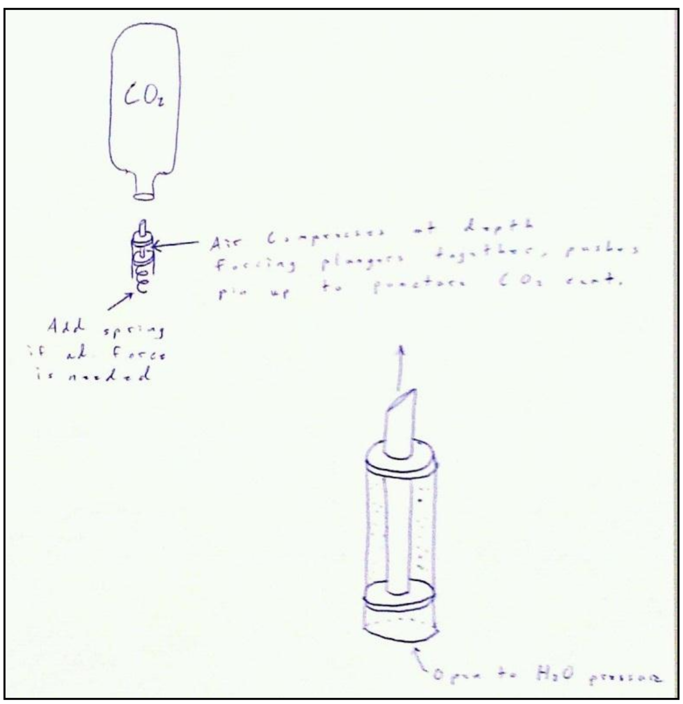


Figure 9: A pin/plunger assembly will be placed inside and air tight tube, as the volume of air decreases a pin will be forced upwards by a spring, eventually puncturing the canister.

We also explored other modes of triggering that did not rely upon the compression of air. One early concept uses a tube which had a floating cork attached to a string. When water fills the tube, the cork floats and pulls the string, which in turn pulls a pin and releases CO_2. This concept was dropped because a floating cork would not provide much force, requiring the pin to be easy to move. An easily moved pin would result in misfires, which is unacceptable in our opinion. The tube would also need to stay oriented so that the cork pulls in the right direction.

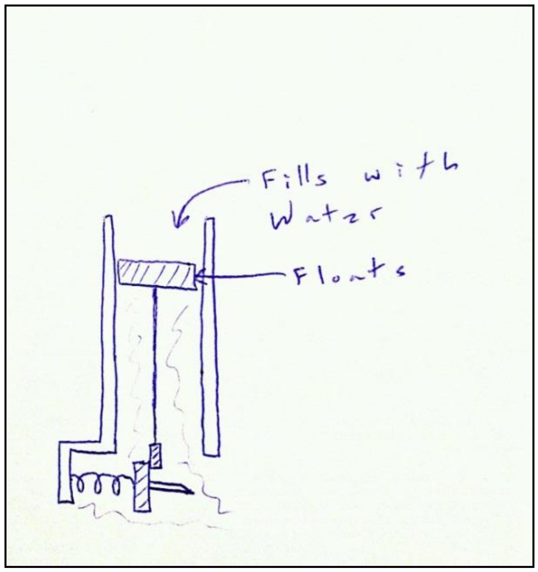


Figure 10: This concept utilizes a small floating "bobber" contained internally. When the entire assembly is pulled under water the mechanism floods forcing the "bobber" upward, this in turn releases a spring, which forces a pin into the CO_2 cartridge.

Another concept requires a fleeing fish to take the mechanism under the surface and pull it through the water. Once it generates enough velocity, the water flow over the propeller causes it to spin and winds up a string, which eventually pulls out a pin and releases a preloaded spring/puncture device.

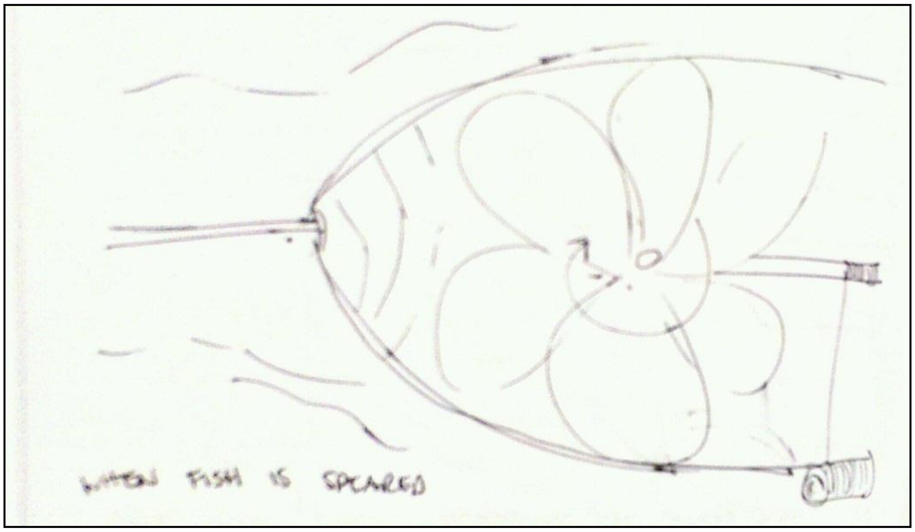


Figure 11: An internal propeller is exposed to water flow. When water flows through the mechanism it turns the propeller, winding a string. This string eventually hits a pre-determined point of travel which would trigger the device, likely using a pin and spring.

Once we decided to stick to the air compression concept, we explored different methods to puncture and release the CO_2. Most of these designs have some component that aids in the puncturing of the CO_2 cartridge.

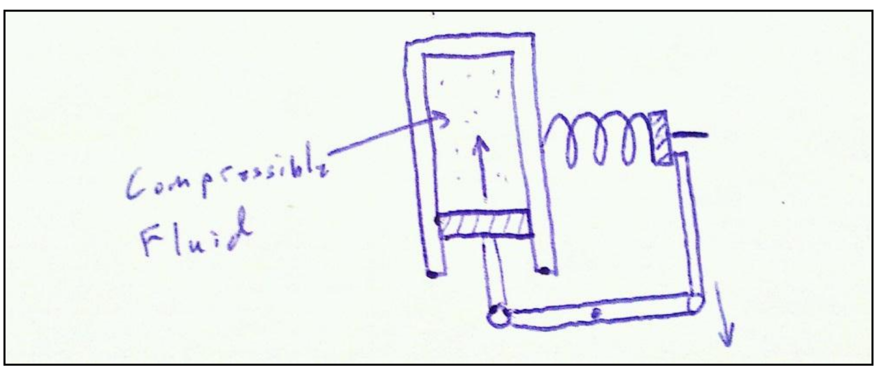


Figure 12: Compressing air moves a plunger, which in turn pulls a lever, releasing a pin-spring assembly. Once released the pin would be propelled by the spring into the CO_2 cartridge.

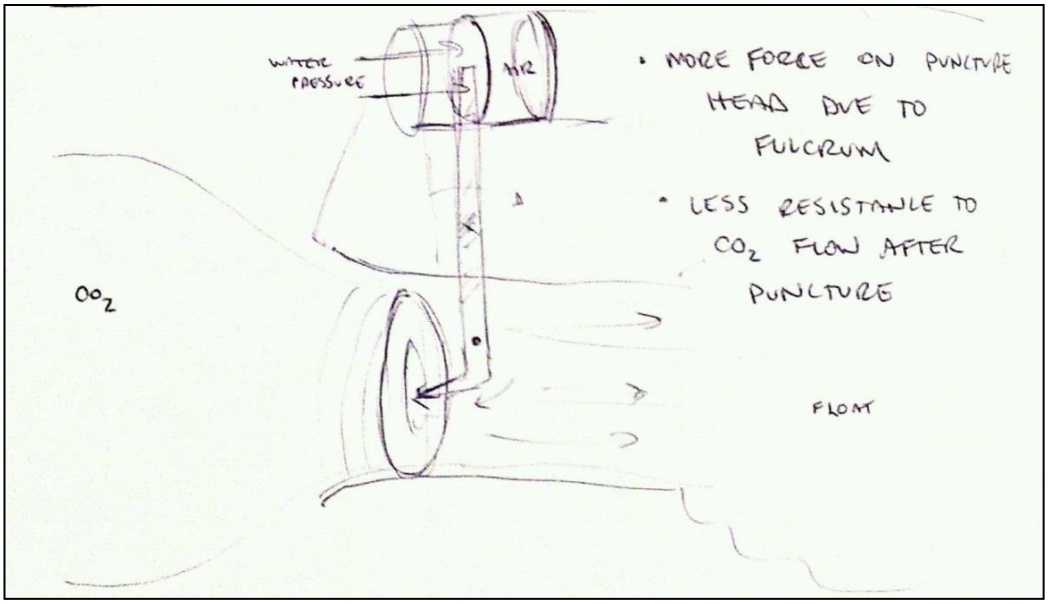


Figure 13: A variation of the air compression method, this concept again uses compressing air to move a plunger. In this concept the plunger motion moves a lever arm to increase force, in order to puncture the cartridge.

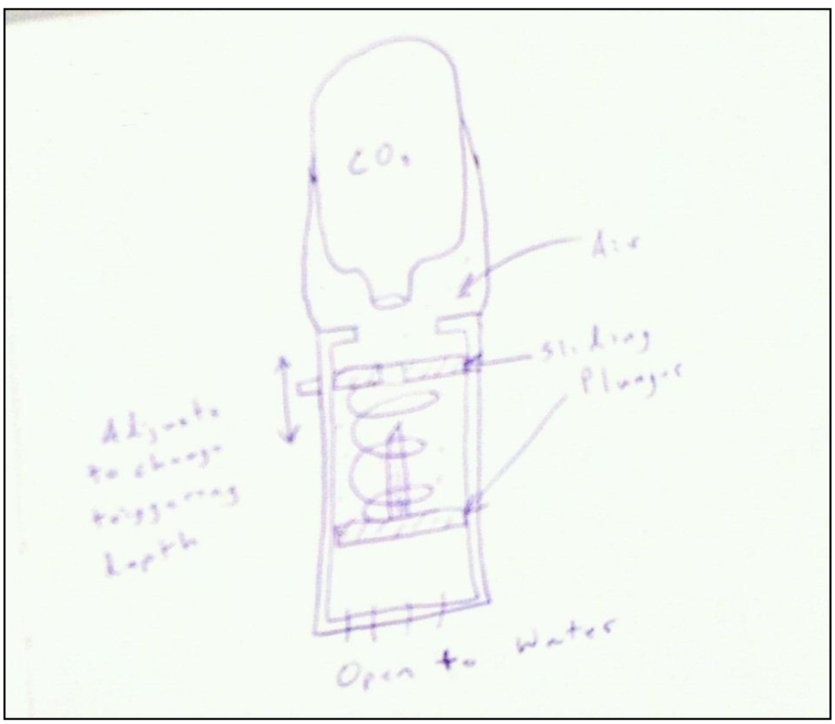


Figure 14: Similar to the spring behind plunger method, but this idea moves the spring to the front of the plunger. Rather than utilizing the spring for extra force, in this case it would be of adjustable compression. This would allow for an adjustable triggering depth

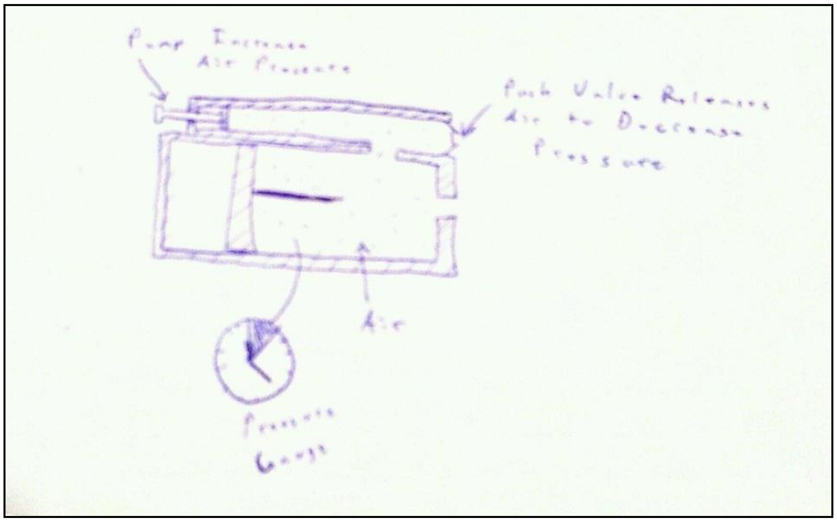


Figure 15: A pump is incorporated to adjust the air pressure in front of the plunger, inside the chamber. This would allow for an adjustable triggering depth.

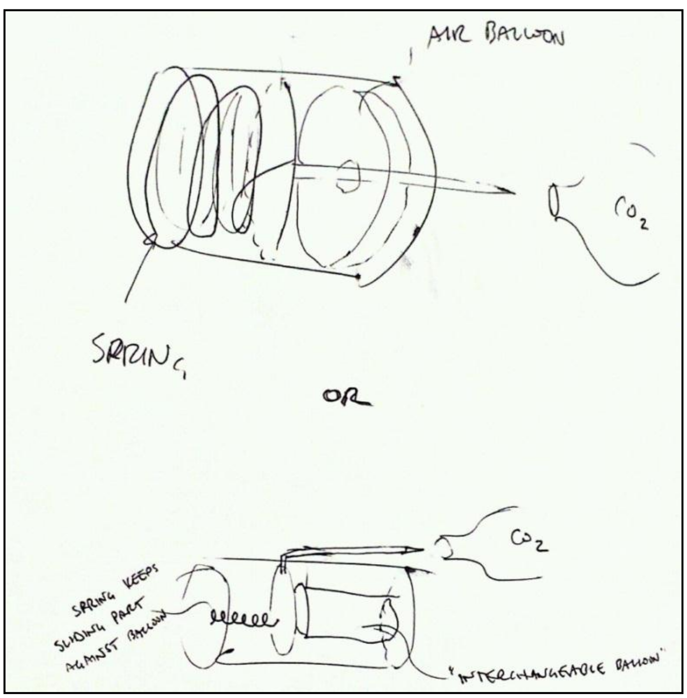


Figure 16: The internal pressure chamber is replaced with an air filled bladder, which would be interchangeable with bladders of different volume to allow deployment at different depths.

After considering all of these concepts, it occurred to us that it would be much easier and simpler to screw the CO_2 cartridge in beforehand and pre-puncture it. With this concept there is no need for complex spring or lever systems that attempt to pierce the metal canister underwater. This is the thinking that led us to our final design which is similar to our air-compression plunger idea.

BLADDER SHAPE

In considering the float bladder, we looked at the various designs and materials used in floats already on the market. We concluded that there is not much more improvement that can be made to this feature, so our bladder design differs little from floats that are currently available in dive shops or online. We did, however, consider various shapes for the bladder. A long skinny bladder would flow well through the water; but once inflated we want the float the provide resistance. A spherical bladder allows the most volume with the smallest surface; this is ideal because we want the most floatation with the least amount of money spent on materials. This shape may present an issue if the bladder provides too much resistance; if the fish pulls hard enough it can rip the spear out its body. If this becomes a problem it will be easy to change alter the bladder shape.

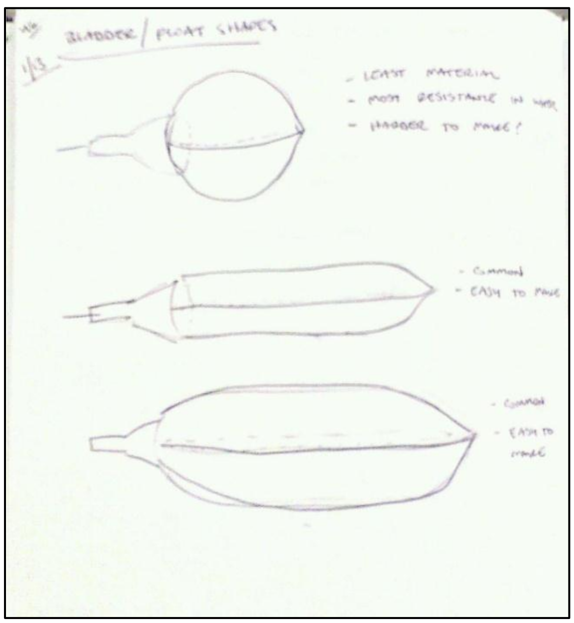


Figure 17: Considered bladder shapes.

SELECTING A CONCEPT

A Pugh Matrix was used to compare all above triggering concepts against each other in order to evaluate which ideas were the best. This complete table can be found in the Appendix at the back of this report. Four key categories, deemed by our team most important to our final design, were considered. From this it was apparent that our best concepts for this project were the Air Compression – Pump Adjust and the Air Compression – Interchangeable Balloons. Eventually after working on this project for some time and receiving outside advice, we added an air compression design using pre-punctured CO_2 canisters to our Pugh Matrix.

Table 2: Pugh Matrix for Triggering Methods

	Air Compression - Spring Behind Plunger	Air Compresion - Pin Through Plunger	Air Compression - Release Spring	Material Compression - Release Pin	Air Compression - Interchangeable Balloons (adjustable depth)	Floating Bobber - Pull Release	Air Compression - Spring in Front of Plunger (adjustable depth)	Air Compression - Pump Adjust (adjustable depth)	Air Compression - Lever	Air Compression - Pre punctured CO2 canisters
Can trigger at very shallow depths	-	-	+	-	D	+	-	S	S	+
Can trigger at deeper depths	S	S	S	S	D	-	S	S	S	S
Ease of Re-setting	S	S	-	-	D	-	S	S	S	S
Reliability / Can't trigger accidently (shaking / bouncing)	-	-	-	-	D	-	S	S	S	+
Sum +	0	0	1	0	D	1	0	0	0	2
Sum-	2	2	2	3	D	3	0	0	0	0
Sum S	2	2	1	1	D	0	3	4	4	2

With this concept there is no need for complex spring or lever systems that attempt to pierce the metal canister underwater. This is the thinking that led us to our final design which is similar to our air-compression plunger idea. This design will be more reliable and can use multiple CO_2 canisters to better inflate the bladder for more buoyancy force.

FINAL SELECTION

The process that it took for us to decide on our final design was not as simple as just making a Pugh matrix to find which idea would work best. Our original Pugh matrix helped to give us an idea of what style of triggering mechanism would work best. It showed us that using the compression of air in water at depth would be the best method we could use for triggering our device. However, we later came to the realization that that force would probably not be adequate to puncture a CO_2 canister. After some research and advice we decided that a better way for our device to work would be pre-puncturing the CO_2 canisters. This is the method that many devices use today including airsoft guns, paintball guns, and tire inflators. By pre-puncturing the canisters, we eliminate the force required to puncture the cartridges and the inherent unreliability with such an action.

Another concern that came in to our final idea was the issue of how many CO_2 canisters we wanted to use. When we originally began designing this float we had assumed that one CO_2 canister would be enough. However, after further calculations we discovered that in order to fully inflate our bladder under the increased underwater pressure, it would take five 16 gram CO_2 cartridges. This changed the shape of our design and the new shape will be shown in the description of the final design.

One of the most interesting things about our design process was the fact that our final concept was not even on the table as one of our original ideas. Instead we used different aspects of a few of our original ideas and combined them with ideas that came to us later to complete our design.

TRIGGERING CONCEPT 1 – DESIGN DESCRIPTON

The concept for this triggering method relies on the principals of Boyle's Law, which states that absolute pressure of a gas and its' volume are inversely proportional. More specifically, for our case, for every atmosphere of pressure increase the volume of air will be decreased by half. So, in sea water starting at sea level, for every 33 ft of depth, an amount of standard air will decrease in volume by half. In this first concept, this principal will be used to pull a plunger forward down a tube as the volume in front of this plunger decreases. The plunger will hold a pin which will puncture a pressurized CO_2 cartridge upon impact. This will release the pressure, and allow the CO_2 to escape, filling our inflatable. On this particular design a small pump has been added to the assembly in order to change the initial air pressure inside, the idea here is to change the volumetric decrease with depth, allowing for adjustments in triggering depth.

Parts are as labeled on drawing.

1. Trigger Case: The trigger case will act as the housing containing the triggering mechanism. The tolerances on this part will need to be very tight since it will have to contain moving parts and still remain air tight, even under heavy pressure. The material for this part has not yet been chosen. ABS plastic is being considered because of its manufacturing benefits; however, further analysis and testing must be done to establish whether it can meet the performance requirements.
2. Pump Plunger: The pump plunger's purpose is to force air into the chamber in order to increase pressure. This part will have a rubber disk on the end contained inside the tube; the rest will be made of plastic.
3. CO_2 Canister: An off-the-shelf CO_2 cartridge. These will be threaded 16 gram cartridges, which should provide approximately 12 lbs or floatation each at the surface.

4. Pin Plunger: The pin plunger sits inside the main chamber. The disks will be made of rubber, and the pin stainless-steel. The rubber disks will create a seal with the chamber walls, creating an air tight space. When the volume of this space decreases due to the principal described above the pin plunger will slide toward the CO_2 canister, and the stainless steel pin will puncture the Canister.

TRIGGERING CONCEPT 2 – DESIGN DESCRIPTION

The concept for this triggering method also relies on the principals of Boyle's Law. In this concept, a spring-loaded plunger slides along the inside of its cylindrical housing. A balloon filled with air or gas is placed inside the housing to restrict how far the plunger can move. As the device is submerged and reaches deeper depths, the pressure compresses the gas in the balloon component, allowing the plunger to slide further. Outside of the housing, there is an arm that attaches to the plunger. This arm has a sharp point that will puncture a CO_2 cartridge when the plunger/arm apparatus has traveled a certain distance. The spring ensures that the plunger slides as the balloon compresses, and also provides the force needed to puncture the CO_2 canister. One thing that is problematic about this design is finding a way to contain the CO_2 gas after the canister is punctured and directing it into the actual float bladder.

Parts are as labeled on drawing.

1. Trigger Housing: The trigger case will act as the housing containing the spring, plunger and compression balloon. The material for this part has not yet been chosen. Ideally it needs to be able to withstand the abusive ocean environment, and not wear with repeated rubbing from the plunger. ABS plastic is being considered because of its manufacturing benefits; however, further analysis and testing must be done to establish whether it can meet the performance requirements.
2. Plunger: The pump plunger's purpose is to travel as the balloon shrinks, and pull the puncture arm with it. It needs to be tough enough to resist wear from rubbing with the inside of the housing. The tabs of the plunger that protrude outside of the housing need to withstand bending induced from the tension loaded puncture arms.
3. Compression Balloon: A flexible container that will be filled with air or another gas. The balloon needs to be able to compress and shrink when water pressure increases. The pressure of the gas inside the balloon can be adjusted to permit just the right amount of compression for a given depth. This allows the device to be adjustable to activate at different depths.
4. Spring: The spring needs to provide at least 5 lbs of force at full extension, but ideally won't exert too much pressure on the balloon when on the surface or at shallower depths; we want the pressure of the water to compress the balloon, not the force from the spring.
5. CO_2 Canister: An off-the-shelf CO_2 cartridge. These will be threaded 16gram cartridges, which should provide approximately 12lbs or floatation each. Roughly five pounds of force is required to puncture the seal, depending on how sharp the puncture needle is.
6. Puncture Arm: This component fits onto the tabs of the plunger and is pulled when the balloon compresses and the plunger slides. The arm needs to hold the tension created when the puncture needle contacts the canister and the spring is pushing against the plunger.

FINAL DESIGN

The final design for our product is a result of our team weighing the strengths and weaknesses of each concept considered and implementing the strengths as best as possible into one final concept. We decided that relying on the compressive property of air was the most dependable and foolproof way to trigger the release of CO_2 at depth. We also came to the realization that instead of requiring a mechanism to puncture the cartridge(s), it would be much simpler and more effective to screw in the canisters and pre-puncture them, especially since multiple canisters are needed to fully inflate the bladder.

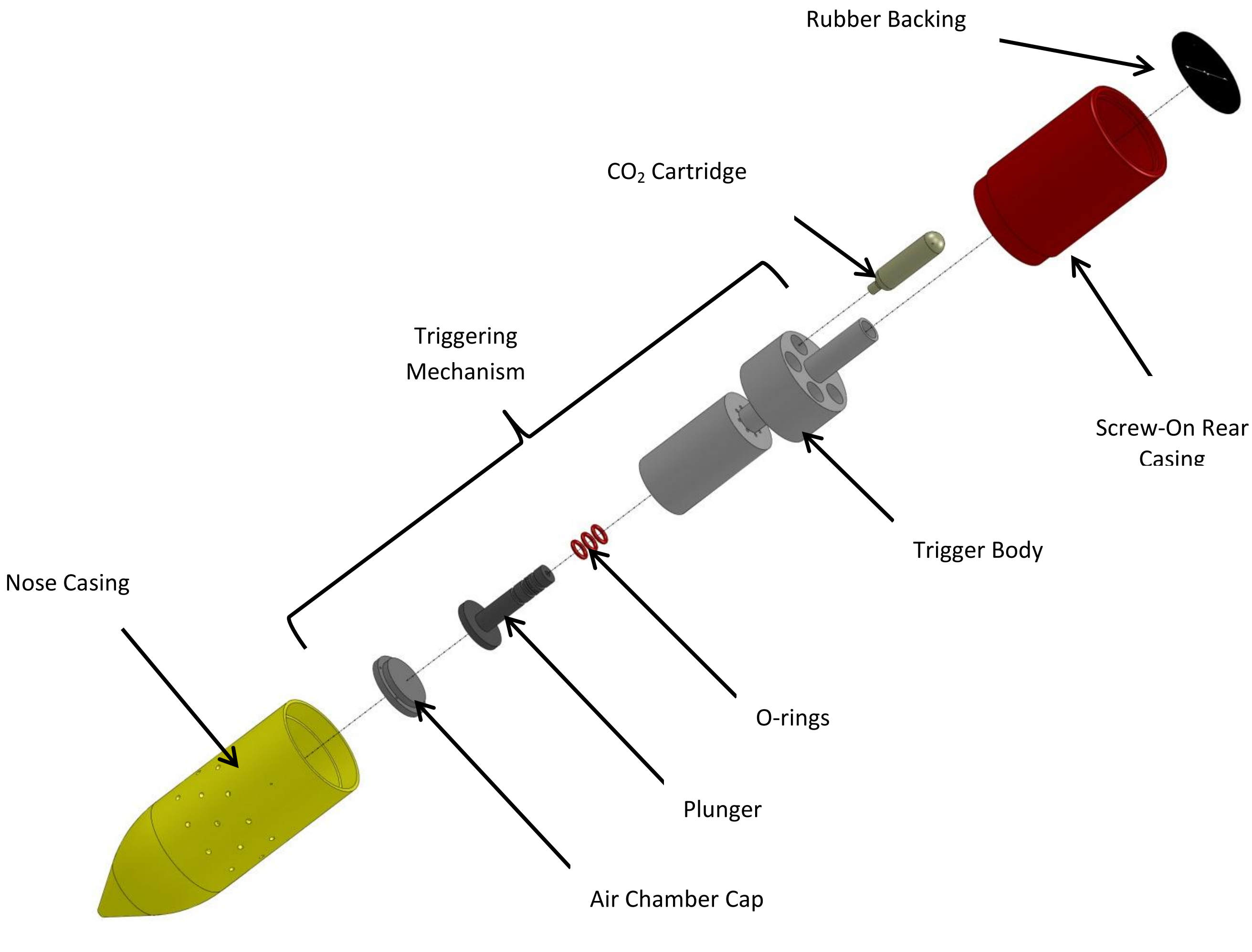
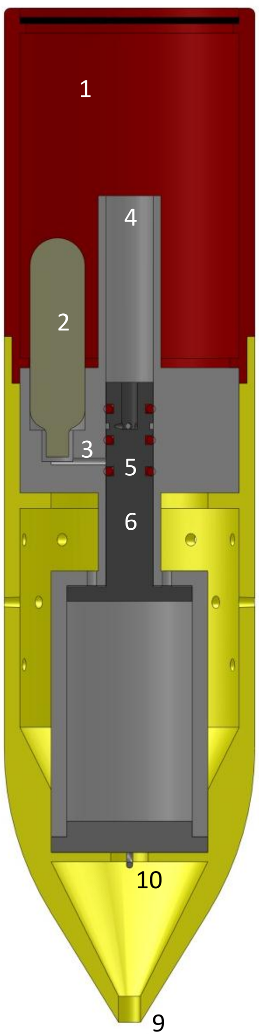


*Figure 18: Exploded view of the entire float system *Note: bladder, valves, and chamber O-rings not shown.*

The main features of the triggering mechanism include the air compression chamber, the plunger, the plunger barrel, and the valves into which the cartridges are inserted/punctured. O-rings ensure that the compression chamber is airtight and that the plunger prevents CO_2 flow into the bladder until a depth is reached desired. The entire triggering mechanism resides inside a casing, which is divided into two parts: the triggering mechanism is fit into the larger half of the casing, and the back half threads on to hold the trigger inside and protect the bladder. The back half of the casing has a large opening with rubber flaps to allow the bladder to expand out the back once it inflates. The nose (pointed part) of the casing has a hole to allow the user to secure their floatline through the casing directly to the triggering mechanism. The triggering mechanism is made of a stronger material than the casing, and is also what the bladder is attached to. The valves are off the shelf parts, and are manufactured with internal threads in which the user will screw in the CO_2 canisters; the valves also have external threads, which will hold the valves in the triggering body. The float is designed to use 16 gram cartridges, which are the most cost effective option for the user.

The user starts by unscrewing and removing the back of the casing (1). At this point the CO_2 valves are accessible. Once the CO_2 cartridges (2) have been installed into the valves and punctured, they pressurize ducts (3) that lead to the central pipe to the bladder (4); however, at the surface the plunger (5) blocks those passageways. Once the float is pulled underwater and reaches the desired depth, the air in the compression chamber (6) will compress and move the plunger. The ducts of compressed CO_2 will now be aligned with passageways (7) in the plunger, allowing inflation of the bladder. O-rings (8) ensure that no CO_2 escapes before the device reaches the desired depth. The user will insert their floatline through a hole the nose of the casing (9) and attach it to the hook which is part of the trigger (10). To reuse the float, the user simply discharges the pressure in the bladder with a release valve, replaces the cartridges and repacks the bladder.



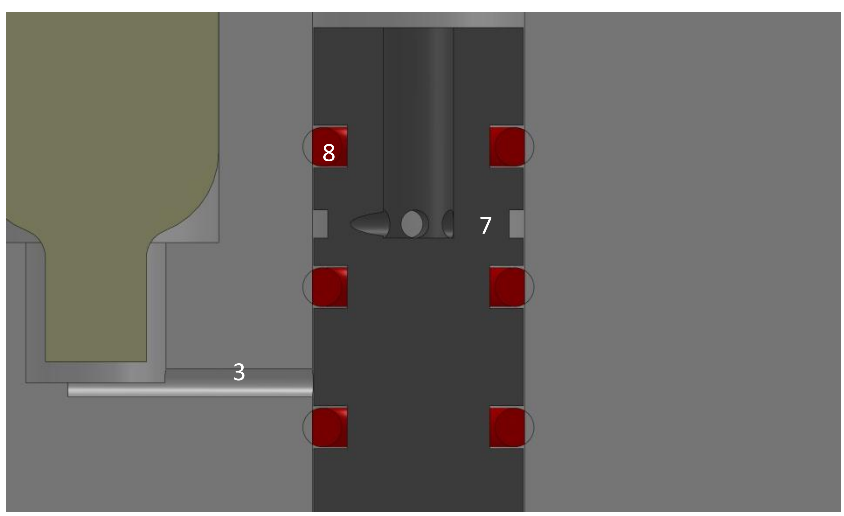


Figure 19: Above: section view displaying how components fit together. Right: detail view of plunger and CO_2 ducts.

PLUNGER MOVEMENT

To determine the dimensions for the air chamber pressure calculations were needed. We did these calculations for our desired triggering depth of 10 ft. According to Boyle's law, since the plunger is free-moving within the chamber it should position itself so that the water pressure on one side is equal to the air pressure on the other. Using the equations shown below we determined that a 2 in diameter and 4 in depth for the air chamber would yield the desired half inch of plunger movement.

$$p_1 V_1 = p_2 V_2$$

$$p_1 A_1 = p_2 A_2$$

$$p_2 \frac{A_2}{A_1} = p_0 \frac{V_0}{V_1}$$

For full calculations see Appendix C

INTERNAL PRESSURE

In order to keep costs low in manufacturing it is desirable to have the trigger body made from plastic. However, it is very important that this part is able to withstand the internal pressures created from the CO_2 cartridges that will be released into them. The average 16 gram CO_2 cartridge has an internal pressure of 1000 psi. We modeled the channel inside the trigger body at this pressure as a thick walled pressure vessel and found the related stresses. We determined the Hoop Stress to be the largest stress at approximately 995 psi. Therefore, a plastic like ABS 750, which has a yield strength of over 5,000 psi, would be more than sufficient for our design. For our prototype, to error on the side of caution, we have chosen to use Acetal with a yield strength of over 8,000 psi.

For internal pressure calculations see Appendix C.

BLADDER PRESSURE

Our bladder was sized based on the amount of water it would need to displace in order to provide the desired buoyant force. However, we also needed to decide how many CO_2 cartridges would be needed to fill this volume to a pressure greater than the external pressure presented by the sea water (at a depth of 10 ft this pressure is approximately 4.7 psi). Our calculations show that with a slight pre-fill in a bladder 5 cartridges will fill a volume of 0.9 cubic feet to a pressure of 5.1 psi, exceeding the external water pressure.

For bladder pressure calculations see Appendix C.

LINE ATTACHMENT

Our product must provide and easy method for the user to attach it to their own equipment. We have chosen to use a small loop of braided spectra core line which will protrude from the nose cone of our model. This line will be inexpensive, easy to install, and is available in many sizes with strengths greater than our needs. Having a simple loop in front of our casing should prevent entanglement and allow for easy attachment of a float line using a tuna clip (shown below), which is the standard of most float lines produced today. Inside the casing the spectra core will be attached to the chamber cap through a hole in the nose casing. For an extremely large force of 160 lb

applied to this line, we determined the stress in the plastic would be approximately 1630 psi, far below the yield stress of our material choices for manufacturing or our prototype. For Line attachment calculations see Appendix C

Figure 20: Tuna clips commonly used on float lines.

MATERIALS

In selecting materials for our float, we took into consideration many different factors; strength, manufacturability, cost, toughness, resistance to corrosion, weight, and aesthetics were the major concerns dictating which materials we decided to use.

The triggering mechanism needs to be strong to hold the pressure of the CO_2, but at the same time lightweight because it is the biggest component of the float and dictates the overall weight. It needs to endure extended periods of time in the harsh ocean environment and not rust or erode. This component is one of the only parts of the float that contains features requiring somewhat tight tolerances; the plunger has O-rings which fit inside the internal cylinder, and they need to fit right to ensure a proper seal. If the diameters of this duct or the plunger are out of tolerance, CO_2 may leak or the plunger may not move at all. We concluded that Delrin performed well when it came to these requirements. It will also be easy to machine Delrin bar stock on a lathe and mill. Three and a half inch diameter Acetal Delrin bar stock is available for about $58 per foot. Two inch diameter is about $16 per foot. One float requires 10.25” of 3.5” diameter bar stock and 3.5 inches of 2” diameter bar stock. This will produce the trigger body, the plunger, and the air chamber cap.

To decide what material to use for our bladder, we looked at what similar products already use. Many different life rafts, inflatable boats, and floats use different materials to accomplish the same goal so it took some time to narrow down our selection. In the end we decided to use a Pugh Matrix to choose our final material and decided to use polyurethane-coated nylon fabric due to its strength, flexibility, and cost. The Pugh Matrix can be found in

Appendix C. This nylon will only cost us $16.99 per foot of 59" wide fabric, allowing us to keep costs low for this portion of the float.

The casing will be composed of plastic. It needs to be tough to resist cracking if dropped on rocks, but does not necessarily need to be strong; the triggering mechanism carries the heavy forces. PVC is being considered for this component, but the material relies heavily on the manufacturing process that we decide to use. At this moment we are still debating how best to make the casing; whether we use a molding or casting process or attempt to machine the shape in a CNC mill.

The O-rings and valves are off the shelf parts. The O-rings generic, and are made of Buna-N, or Nitrile rubber. The valves were purchased from Genuine Innovations, who specialize in portable CO_2 inflators made to pump up bicycle tires. They are composed of steel and brass, and also utilize polymer O-rings of their own.

The rubber backing flaps will be cut from 1/8"sheets of ultra-strength silicone rubber. This material is tear-resistant, and also offers good resistance to sunlight, oxidation, and weather wear.

Selecting a bladder material that would fit our needs was important to our final design. Many different life rafts, inflatable boats, and floats use different materials to accomplish the same goal. We decided to use a Pugh Matrix to choose our final material and decided to use polyurethane-coated nylon fabric due to its strength, flexibility, and cost. The Pugh Matrix can be found in Appendix C. This nylon will only cost us $16.99 per foot of 59" wide fabric allowing us to keep costs very low for this portion of the float.

SAFETY CONSIDERATIONS

Our float design only has a few safety considerations to account for. Because all of the moving components of the float are contained inside of the casing there is no concern for any pinching or crushing of bodily parts; as long as the user is careful when screwing on the rear casing. The CO_2 canisters have their own safety concerns displayed on their packages which include advisement against leaving in sunlight or heat, as well as puncturing cartridges with no restraint. We will replicate these warnings in our user's manual. The float line is something that a spearfisherman must always watch out for; it can be easy to accidently get tangled within it. However, this is a hazard that applies to the sport as a whole, and is not specific to our float.

Our design comes with only two major safety concerns. The first is the possibility of an unanticipated deployment of the float. We will advise consumers not to install CO_2 cartridges until they are prepared to use them and that a loaded float should never be kept in a small confined space. However, our design is based on deployment due to increase in pressure so the float should not deploy unless it is under water or in a high pressure chamber. We will need to have a warning label to prevent people from taking our float anywhere that increased pressure could cause it to trigger. The second concern is the possibility that a user would unscrew a cartridge while the float is still "charged" with CO_2 pressure, causing the cartridge to shoot out and strike someone. We will put a warning label next to the valves and include a large warning in the manual to minimize the occurrence of this happening. This consideration may not even be a danger; the CO_2 may escape before the cartridge can be fully disengaged from the valve.

COST ANALYSIS

Table 3: Estimation of prototype cost.

Prototype - Component	Price
Plastic for triggering section	$100/ft
Polyurethane-Coated Nylon	$16.99/ft x 2 ft = $33.98
4 O-rings	$7 for package of 5
5 CO_2 Cartridges	$13.50 for package of 12
PVC for Case	$28.57/ft x 2 ft = $57.14
Rubber for Backing	$82/4ft^2 (36 parts)
Nylon Adhesive	$17
CO_2 Valves	$8
Labor	$0 (Personal Time)
Total Prototype	$182

Table 4: Estimation of costs for mass production.

Production Costs	
Machining of Triggering Section	\$17.57/hr (Machinist average wage)
High Frequency Welding Machine	\$999.00 (Branson 49012A Welder)
Machining of Casing	\$17.57/hr
Machining of Rubber Backing	\$17.57/hr
Plastic for Triggering Section	\$100/ft
Polyurethane-Coated Nylon	\$16.99/ft
O-rings	\$7/5 O-rings
CO_2 Cartridges	\$13.50/12 Canisters
PVC for Case	\$28.57/ft
CO_2 Valves	\$8/Valve
Assembly of Float System	\$15.30/hr (Mechanic average wage)
Total Production Cost	\$68/hr of labor, \$145.56/ft of raw material, \$999.00 in equipment, and \$28.50/set of pre-made items

Originally we had planned on a product in the \$140 range to keep the price on the low end for potential customers. However, once talking with Professor York and our business student teammates we realized that because we are producing a top-of-the-line product we have the capability to charge top-of-the-line price. Putting a price tag on our float in the \$200-\$300 range allowed us more flexibility on the cost of our components. Although the cost analysis for our prototype totaled \$180 we believe that once put into larger production each of the components will cost less for us to buy in bulk.

As we have yet to build our entire prototype model it is tough to predict the total machining and assembly time it will take to manufacture our float. Even after manufacturing the triggering mechanism it is difficult to say how long a single part would take, as we had to repeat several steps. The hourly wages we are using are based off of the National Pay Data for the past year. We may be able to cut costs on machining and assembly if we use injection molding for the machining and if the assembly is simple enough to use a lower-paid employee instead of a certified mechanic. As previously stated, our material costs should also decrease if put into mass production because we can buy all of these materials in bulk at a discounted price.

MANUFACTURING PLAN

In manufacturing our prototype, we planned to use fabrication techniques that are similar to the methods that will be used to create our final product in larger volume. This is to ensure that our prototype will have the same properties as our finished product. However, the methods that we have decided to use for our prototype are slightly different, mainly to keep the cost down. This is mostly apparent in fabrication of the bladder. We plan to use adhesive to join the bladder pieces that we cut; hot frequency welding is more efficient and desirable and would be used for large volume production; however, we aren't going to purchase a pricey welder just to make one prototype. We may use a high-frequency welder if there is one available on campus.

We are going to use a lathe to turn the triggering mechanism to its general shape from bar stock, then use a drill press and/or mill to cut the channels and the holes for the valves. The valves we purchased have exterior threads, so we will tap threads into the triggering body and screw in the valves. The casing will either be turned on a lathe from bar stock or somehow molded or cast to achieve its shape.

At this point we are more concerned with the functionality of the triggering mechanism. Once we have an operational trigger we will focus on the casing. The methods we are considering for forming the casing include casting or molding, or CNC machining.

PRODUCT REALIZATION

Figure 21: Trigger prototype with 3 CO2 cartridges installed.

MANUFACTURING PROCESSES

PISTON

The manufacturing process of the piston required the use of two machines: the lathe and the drill press.

The four tools used on the lathe in the manufacturing process were a turning tool, a parting tool, a drill, and a grooving tool. The Parting tool was used initially to cut the piston stock to the correct length needed. The turning tool was then used to turn the piston down to its correct diameters. Two different diameters were made using the turning tool, one which was a clearance fit for the main shaft of the trigger body (this had the tightest tolerances), and one for the air chamber that was to be compressed by water pressure. The drill was used to drill the CO_2 outlet hole in the piston shaft. Finally, we used the grooving tool to cut three grooves for o-rings on the main shaft, and one on the larger disk in order to create an air-tight seal with the trigger body.

The drill press was used for one feature of the piston: the CO_2 inlet holes around the shaft for the CO_2. The shaft was set up in a vise and positioned so that it was held for the holes to be drilled completely through the shaft, creating a total of 6 holes for CO_2 to enter and flow through the center of the piston shaft.

During the machining of the piston we realized that machining parts with tight tolerances is not as simple as plugging the numbers into a computer and removing the specified amount of material. We had to turn down the piston and groove out the O-ring channels multiple times little by little in order to ensure a proper fit into the trigger body. We attribute this to the expansion and contraction of the plastic as the temperature of the plastic changed.

THE TRIGGER BODY

The machining of the trigger body was the most complex part of our machining process and required the use of three different machines: the CNC lathe, the CNC mill, and a drill press.

The bulk of the machining took place on the lathe where we first drilled a ¾ inch hole through the center of our rod of Delrin that would serve as the main hole for our piston to slide through. Due to the tight tolerances around the piston-cylinder integration we then used a reamer to provide a smoother finish to the inner surface. The next portion of machining on the lathe was the turning down of the outer diameter of the rod. This portion took some time because there are 3 different diameters necessary at different points on the trigger body and precise fixturing of the rod was necessary. Finally, the last machining portion done by the lathe was to bore out the hole for the larger disk portion of the piston to slide through.

The CNC mill was used to drill the 5 holes needed for the CO_2 valves on top of the largest diameter portion of the trigger body. The trigger body was fixture directly in the center of the mill and appropriate X, Y coordinates were plugged into the CNC machine in order to ensure each individual hole was drilled in the correct location. We later tapped these holes using a tap and die set so that the valves would be able to easily thread in.

The drill press was used for two sections of the trigger body: the CO_2 inlet holes and the water inlet holes. The drill press is a very imprecise machine so it took a lot of measurements and tiny adjustments in order to get the holes lined up perfectly. Each CO_2 inlet hole needed to be perfectly in line with the holes drilled by the mill for the valves as well as at the proper height to line up with the piston. These holes were all plugged with dowel pins in order to prevent the CO_2 from escaping to the outside. Each water inlet hole needed to be at the correct height along the shaft so that the water would flow into the chamber above the disk of the piston and not just fill the sealed air chamber with water.

BLADDER

The manufacturing of the bladder was a simple process that only required the use of scissors and a special nylon glue called Tech-Bond.

First the bladder was cut into two identical rectangular pieces with a smaller attached rectangular piece extruding from one end to serve as a neck to attach to the trigger body. Next a bead of glue was applied along the outer edge of each nylon sheet. Finally the sheets were placed on top of each other with pressure applied to the outer edge to ensure a seal while the adhesive dried and held the two pieces together. This created a cylindrical bladder with a small neck to attach to the trigger body.

ASSEMBLY/PRE-MANUFACTURED PARTS

There were a few off-the-shelf parts that were purchased in order to complete the assembly of the triggering mechanism for the float. These parts included 5 CO_2 valves, 5 CO_2 cartridges, a hose clamp, a zip-tie, and some small screws. The CO_2 valves were secured into the trigger body using a socket set and their own threads, each of these valves are threaded and the CO_2 cartridges were subsequently threaded into them. The hose clamp was used to wrap around the large portion of the trigger body over the dowel-pin-plugged CO_2 inlet holes to provide extra holding so that the pressure from the CO_2 would not eject the pins. The zip tie was used to attach the bladder to the neck of the trigger body and the small screws were used to secure the cap of the air chamber to the body.

PROTOTYPE ALTERATIONS

Our prototype differs from our planned design mainly because of difficulties encountered during machining. For the trigger body, we decided to leave the Delrin bar stock thick in the middle to give the part more rigidity. This helps to keep the cylindrical faces of the piston duct and air chamber concentric, ensuring that the piston will be able to slide without interference. With this change, we had to relocate the holes that allow water to flow into the chamber to push on the piston. We changed the design to have the holes drilled in from the side of the air chamber, and as close as possible to inside face where the piston duct meets the air chamber. We also decided to forgo the bores into which the valves sit. We realized they don't really provide any benefit besides weight reduction, and since it is a time consuming machining step we decided to eliminate that part of the design. To eliminate the possibility of the dowel pins shooting out once under pressure, we tightened a hose clamp around the exterior. In our final product, this hazard would be controlled by either epoxying the pins in place or press-fitting a metal ring over the exterior.

The dimensions of the O-ring grooves varied slightly from the design. Initially, it was impossible to fit the piston into the body with the O-rings installed. We incrementally deepened the grooves until the piston could slide inside the body with reasonable resistance. We attribute this to the expanding and shrinking of the plastic as it heated and cooled.

We used zip ties to secure the bladder to the trigger body. We had originally planned to use a hose clamp, but the clamping mechanism built onto hose clamps protruded too far and interfered with the CO_2 cartridges.

RECOMMENDATIONS FOR FUTURE DESIGN

For the future, it would be beneficial to switch the body and piston to a material that is easier to machine and that holds tighter tolerances. We frequently encountered trouble when machining Delrin; our first prototype had to be scrapped because the inside duct completely melted during a reaming operation. The plastic also expanded and contracted depending on its temperature, causing interference between the piston and body. A metal that can resist corrosion from salt water and is lightweight, such as aluminum, would be more ideal for this application. Metal would be much easier to machine. Although more expensive, aluminum is stronger than plastic and we would require less raw material to achieve the same strength properties.

In manufacturing our body prototype, we determined that the best order of machining operations is turning of the largest outside diameter, drilling of the central hole, boring of the air chamber, drilling of the pressure water holes, and then turning of the piston-duct neck. The valve holes, CO_2 ducts, and cap can be machined after that in any

order. Drilling the through-hole and the bore first, when the piece is most rigid, ensures that these two features will be as concentric as possible.

To drill the valve holes, it was necessary to employ modular fixturing in conjunction with the CNC mill. A long threaded rod was placed inside the piston shaft with a nut tightened down on top, securing the piece onto the mill carriage. The CNC mill was especially useful because we were able to use coordinates to locate the valve holes, ensuring that they were evenly spaced.

The prototype was intentionally designed to be larger than a production model would be. This was so that the designers could really see what was going on in with the components, and to serve more as a proof of concept. In the future, the triggering mechanism should be made to be much smaller.

Cleaning and maintenance of the trigger body would be much easier with a threaded chamber cap as opposed to a cap with screws.

DESIGN VERIFICATION

TESTING PLAN

Table 5: Initial testing specifications

TEST PLAN			
Specification or Clause Reference	Test Description	Acceptance Criteria	Test Responsibility
Drag Force	Read force gage while pulling un-deployed float over surface of water.	< 4 lbs	group
Buoyancy Force	Hang weights from inflated float while in water until float sinks.	> 45 lbs	group
Time to Deploy	Time float to full deployment using either stopwatch or film.	< 3 sec	group
Line Attachment Strength	Tensile test using force gage or Instron machine. Line must not detach from or deform float case.	> 250 lbs	group
Bladder Burst Pressure	Use pump and psi gage. Must not leak or burst.	> 100 psi	group
Corrosion	Leave in seawater bucket. Should show no signs of rust or corrosion.	> 2 weeks	group
System Weight	Weigh with scale.	< 6 lbs	group
Reliability	Repeated Deployment Test. Must inflate within time limit with no leaking.	> 99%	group
Ease of Repacking	Random person must be able to repack deployed float using provided instructions.	< 1 minute	group

If the prototype is ever completely finished, these are the final tests that would be performed to gauge the performance of the float:

DRAG FORCE

Method: Use force gauge to pull float through water. Get a reading on drag force through saltwater and kelp. This will be done 10 times to get a solid average value from the readings for the drag force exerted on the float.

Equipment: force gauge, float, float-line, wetsuit.

BUOYANCY FORCE

Method: Attach weights to float in increasing amounts to pull float underwater to find the force required to submerge float which will be equal to the buoyancy force. If weights are found to be hard to acquire a waterproof fish scale may be used to determine force. This can be done in a pool or in the ocean.

Equipment: force gauge, float, goggles

TIME TO DEPLOY

Method: Pull float underwater and use a stopwatch to see how long it takes the CO_2 canisters to release their contents and inflate the bladder. An underwater camera will need to be used to record exact moment at which float begins deploying. This can be done in a pool or in the ocean.

Equipment: float, stopwatch

LINE ATTACHMENT STRENGTH

Method: We will tie the float line to the float using conventional methods and then pull the line using a high rated force gauge to see how much strength it takes to break the float line from the float. The float will need to be wedged behind a structure of sorts to prevent it from moving while we are pulling the line. If pull test does not return usable results we will use the Instron machine in building 192 to perform the test.

Equipment: force gauge, float, float Line, wedge structure to hold float.

BLADDER BURST PRESSURE

Method: Use pressurized CO_2 or air to inflate bladder until it bursts. Using a pressure gauge on the inflator we will be able to read the internal pressure at which the bladder bursts and breaks. Once bladder is fully inflated we will be required to stop inflation every 10 seconds in order to get a reading of the internal pressure

Equipment: float bladder, pressure gauge, compressed air tank/inflator.

CORROSION

Method: Rest float in bucket full of saltwater for one week. By the end of one week the float should show no signs of corrosion.

Equipment: float, bucket with lid, 1 gallon of saltwater.

SYSTEM WEIGHT

Method: Place float onto a scale and take a reading of the total weight for the float system.

Equipment: float, 3-beam balance.

RELIABILITY

Method: Drag float under water so that it deploys multiple times to see if the float is reliable and deploys on a consistent basis. This can be done in a pool or in the ocean.

Equipment: float.

EASE OF REPACKING

Method: Once float is deployed, release the air from inside the bladder and have a random individuals repack the bladder into the float case. Use a stopwatch to time repacking and ask for personal judgment about ease of repacking.

Equipment: float, stopwatch.

RESULTS

The main test required for the float was to test its ability to deploy. In order to test this we took our assembled triggering device out to the ocean and proceeded to submerge it under water deep enough for it to deploy. This test was designed to test for a few different qualities regarding our float. This test determined if our piston compressed at depth, if our CO_2 cartridges and trigger body leaked, if the bladder leaked, what depth the float deployed at, and how much buoyancy the inflated float provided. It took four rounds of testing and modifications to finally obtain reasonable results.

The first test returned results we were happy with but was mostly an unsuccessful mission. The first test showed us that the bladder did not leak, the air chamber for the piston did not leak, and most importantly that the piston moved when pulled to a depth of 25 feet. Although our desired depth was closer to 10 feet deep, the movement of the piston was still very encouraging to our team. What was not encouraging was the behavior of the CO_2 valves. The CO_2 valves leaked out their contents before it was possible for the bladder to be filled. The leaks occurred where the valves thread into the trigger body, but also where the canisters thread into the valves. Our team had not anticipated this leakage as the valves were pre-manufactured and we had assumed screwing them against the valve O-rings would create a strong enough seal, especially since the valve and canisters were purchased from the same company.

Figure 22: Test run #1. Compressed gas leaked out through valves, and the bladder was not inflated.

We conducted our second test once we had tightened the CO_2 valves more, but the outcome was similar to the first test. However, there were fewer valves that leaked this round, creating a slightly inflated bladder.

Figure 23: Test run #2. More gas made it into the bladder this time, although the valves continued to leak, as did the seal between the bladder and the trigger body.

Figure 24: Test run #3. Valves leaked again, but more gas was captured in float bladder. Seal between body and bladder held.

It was not until our fourth test, after ensuring proper seals between the valves and body with epoxy, did the bladder inflate to provide significant buoyant force. During the fourth test our product worked as specified except for the depth of deployment. This was something we could not manually adjust; it is a function of the air chamber size and friction caused by the O-rings. Grease had already been applied to the O-rings to eliminate as much friction as possible. In the future we would overcompensate for the force required to move the piston using a higher safety factor so that the float would be more likely to deploy at a shallow depth than a deeper one.

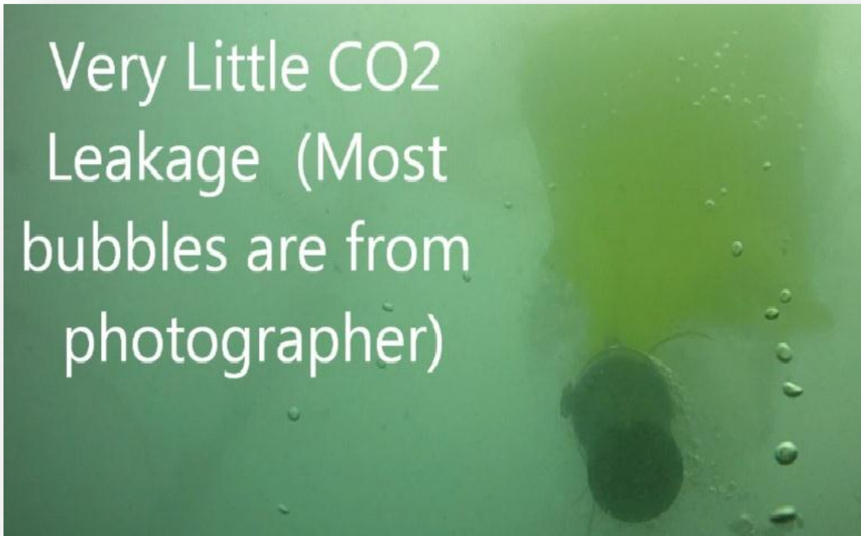


Figure 25: Test run #4. The float deployed at a depth of 25 ft, with the valves having very little leakage. Float is lifting a 15 lb anchor.

Figure 26: Test run #4. Float successfully lifted 15 lb boat anchor from 25 ft depth.

Table 6: Trigger body testing results

Specification	Requirement	Test 1	Test 2	Test 3	Test 4
Piston compresses at 10 ft depth	Piston must move 1/2" down for CO2 to inflate bladder	N	N	N	N
Piston compresses at 20 ft depth	Piston must move 1/2" down for CO2 to inflate bladder	Y	Y	N	N
Piston compresses at 25 ft depth	Piston must move 1/2" down for CO2 to inflate bladder	Y	Y	Y	Y
CO2 cartridge valves do not leak	Valves must not leak any CO2 from seams of threads	N	N	half	Y
Bladder does not leak	Bladder must not leak any CO2 from glued edges	Y	Y	Y	Y
Buoyant force	Once inflated float must float to surface of water	N	Y	Y	15 lbs.

We tested the trigger for 5 major capabilities: adequate piston compression when pulled under water, depth at which the piston compressed enough to release CO_2, CO_2 valve leakage, bladder leakage, and force needed from the inflated bladder to pull the float to the surface. As seen in the specification verification checklist above, we ran four separate tests, repairing problems along the way, in order to get our desired results. A major specification we were unable to obtain was to get the piston to compress at the shallow depth of 10 feet. Through this testing we also noticed that when the pressure was maintained within the trigger body by the CO_2 valves, it required the float to be pulled down five feet farther than when the CO_2 valves leaked. It also took quite a process of adjusting and epoxying the threaded valves to finally get them to not leak. The bladder never leaked and when CO_2 inflated the bladder it always rose to the surface. On our final test we even attached a 15 pound boat anchor to test the buoyant force of the bladder. In the future, additional testing with more weight and some minor leak adjustments could provide us with an exact buoyant force.

REVIEW/CONCLUSION

As Marauder Marine, we identified a need and potential niche in the spearfishing market for an auto-deploying streamlined float. After researching forums, surveying over 200 float users, and interviewing a professional spearfisherman, we developed specifications and requirements that we felt would lead to a successful product. Students from the Cal Poly business program aided in the market research and development of customer requirements. Using Quality Function Deployment and decision matrices, we were able to establish which aspects of the project carried the most importance, and which we needed to focus on to make our design competitive. After analyzing the results, it was apparent that the float had to be a sleek, streamlined design, and had to be very reliable. We aimed to produce a quality product with features no other float on the market possessed, and as such our business team advised that we would be able to sell it at a much higher price than many of the current floats on the market.

We then started the design of our float. We used several methods of brainstorming to come up with as many ideas as possible. Out of these spawned a few quality concepts, and we eventually centered on the idea of using the compressive properties of air at depth to trigger the release of pre-punctured CO_2 cartridges. We designed the product to be made of Delrin plastic which we thought would be ideal for the application. However, the plastic proved to be difficult to machine and also caused undesirable friction between sliding parts in the trigger mechanism. Manufacturing the prototype took longer than expected, and we ran into problems during nearly every process; because of these delays we were unable to create the outside casing for the float. Despite these setbacks we were able to construct a working prototype that performed well during testing. After a few runs our prototype deployed at 25 ft with minimal CO_2 leakage. For the next iteration, the prototype should be constructed out of a corrosion resistant metal to avoid several of the manufacturing and performance issues. The valves that

hold the cartridges should also be replaced with better performing valves. The O-rings that slide on the piston should also be reconsidered; research needs to be conducted to discover any other methods to minimize friction.

Overall, we feel this project was a great success. The prototype worked, and serves as a great proof of concept for an underwater depth trigger. This project helped lead one team member to a potential job with a float company; who knows, maybe the design will pop up in the spearfishing market in the future.

BIBLIOGRAPHY

Grahame, Anthony. “History of Spearfishing”. Web. February 23, 2011. http://www.ehow.com/about_6299852_history-spearfishing.html.

Gabriel, Otto; von Brandt, Andres. “Fish Catching Methods of the World”. ©2005.Blackwell Publishing.

Image Sources

Figure 1:

http://4.bp.blogspot.com/_VyXPbzemCTw/SW9ep_IL_5I/AAAAAAAABA8/PVI8WXrUnO0/s320/spearfishing.jpg

Figure 2:

http://thumbs1.ebaystatic.com/m/mzjR51qqC8R3-ZWgj_tgauw/140.jpg

Figure 3:

http://www.neptonicsystems.com/carter%20float.jpg

Figure 4:

http://frogdive.cart.net.au/images/merchant_files/5375/float-systems.jpg

Figure 5:

https://www.apnea.co.uk/images/Riffe_TorpedoFloat.jpg

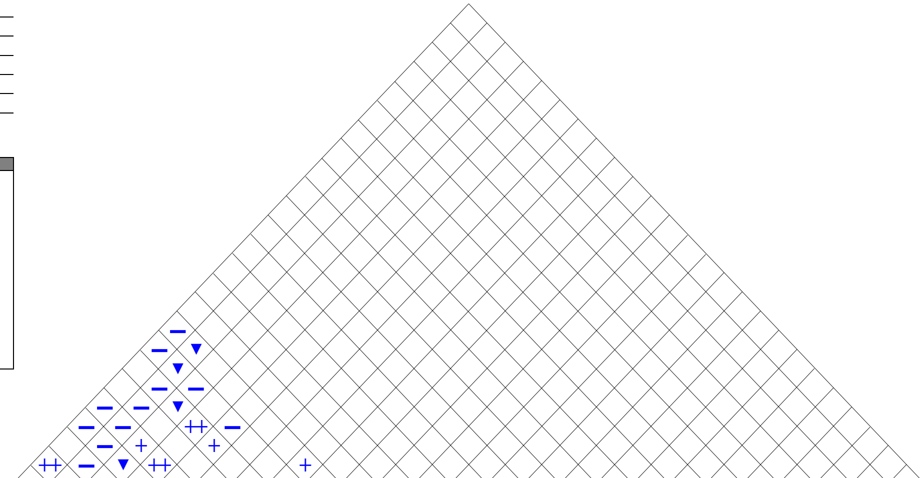
Figure 6:

http://www.neptonicsystems.com/kc6.jpg

APPENDIX A: Design Process

Title: QFD House - Spearfishing Group
Author: Kevin Glenn, Kyle Lancaster, Andrew Wickham
Date: 10/13/2010
Notes: Spearfisherman

Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
—	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
x	Objective Is To Hit Target	



Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)

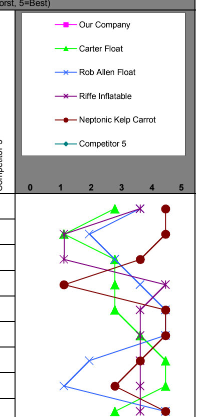
Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats") / Column #	1 Time to manufacture	2 Cost	3 Buoyant Force	4 Size	5 Weight	6 Time to attach	7 Drag Force (when not inflated)	8 Tensile Strength	9 Reliability
1	9	13.3	6.0	Low Drag while swimming through water			▲	Θ	▲		Θ		
2	9	8.9	4.0	Does not hang up in kelp			O	Θ	▲		Θ		
3	9	11.1	5.0	Low Cost compared to similar designs	Θ	Θ		▲	▲	▲		▲	▲
4	9	17.8	8.0	Strong buoyant force			Θ	Θ	O		▲	▲	O
5	9	4.4	2.0	Can withstand impact with sharp rocks		▲		O	O			Θ	O
6	9	20.0	9.0	Must deploy when necessary 99% of the time	O							▲	Θ
7	9	2.2	1.0	Lightweight and easy to carry	▲	O	▲	Θ	Θ		▲	▲	
8	3	15.6	7.0	More compact than current floats	▲	▲	O	O	O		▲	▲	▲
9	9	6.7	3.0	Easily replacable inflation cartridge	O	Θ	O	▲	O	Θ			O
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
24													
25													
				Target or Limit Value	<4hrs	50$	50lbs+	1'X6"X6"	<10lbs	<1 minutes	<5lbs	>30psi	99%
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)									
				Max Relationship Value in Column	9	9	9	9	9	9	9	9	9
				Weight / Importance	197.8	186.7	268.9	457.8	186.7	71.1	235.6	106.7	293.3
				Relative Weight	9.9	9.3	13.4	22.8	9.3	3.5	11.8	5.3	14.6

Columns 10–25: (empty)

Competitive Analysis (0=Worst, 5=Best)

Row #	Our Company	Carter Float	Rob Allen Float	Riffe Inflatable	Neptonic Kelp Carrot	Competitor 5
1		3	4	4	5	
2		1	2	1	5	
3		3	3	1	4	
4		3	4	5	1	
5		3	5	4	5	
6		4	5	4	5	
7		5	2	4	4	
8		5	1	4	3	
9		3	5	4	5	

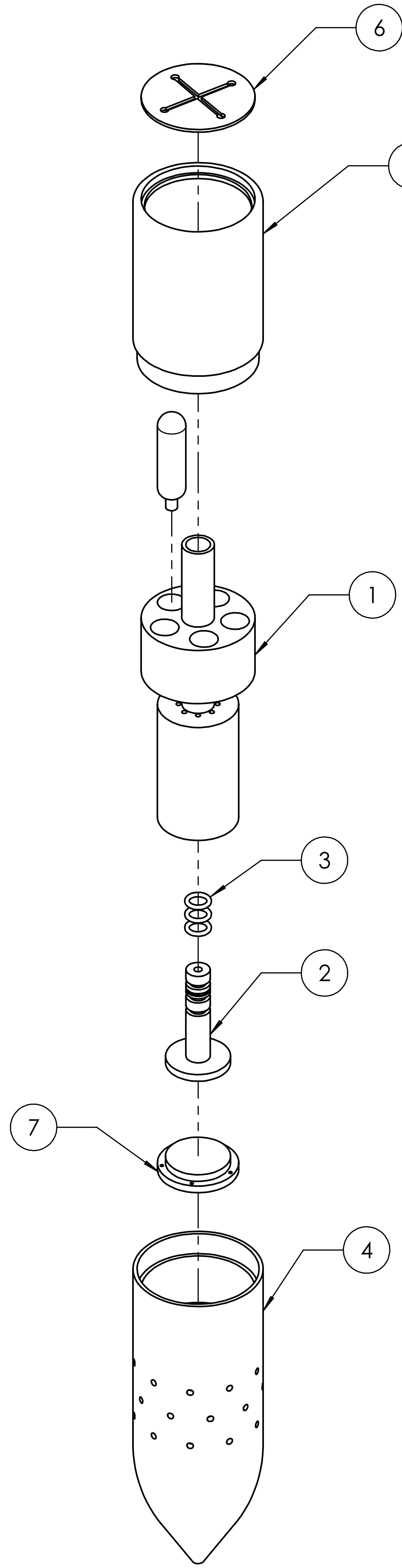


MARAUDER MARINE	Air Compression - Spring Behind Plunger	Air Compression - Pin Through Plunger	Air Compression - Release Spring	Material Compression - Release Pin	Air Compression - Interchangeable Balloons (adjustable depth)	Floating Bobber - Pull Release	Air Compression - Spring in Front of Plunger (adjustable depth)	Air Compression - Pump Adjust (adjustable depth)	Air Compression - Lever
Can trigger at very shallow depths	-	-	+	-	Datum	+	-	S	S
Can trigger at deeper depths	S	S	S	S	Datum	-	S	S	S
Ease of Re-setting	S	S	-	-	Datum	-	S	S	S
Reliability / Can't trigger accidently (shaking / bouncing)	-	-	-	-	Datum	-	S	S	S
Sum +	0	0	1	0	Datum	1	0	0	0
Sum-	2	2	2	3	Datum	3	0	0	0
Sum S	2	2	1	1	Datum	0	3	4	4

PUGH MATRIX: Bladder Material

	Polyester	PVC	Polyurethane Fabrics	Urethane Nylon	Hypalon	Neoprene
Low Drag	+	+	+	Datum	-	-
Low Rigidity	-	-	-	Datum	+	S
Low Cost	S	+	S	Datum	-	S
Tear Resistance	-	-	-	Datum	-	-
Sum +	1	2	1	Datum	1	0
Sum-	2	2	2	Datum	3	2
Sum S	-1	0	-1	Datum	-2	-2

APPENDIX B: Design Drawings



ITEM NO.	PART NUMBER	QTY.
1	Final Trigger	1
2	Final Plunger	1
3	207ring	3
4	Final Casing	1
5	Final Casing Top	1
6	Final Rubber Cap	1
7	Final Trigger Cap	1
8	CO2 Cartridge	1

NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	KEVIN	2/3/11
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

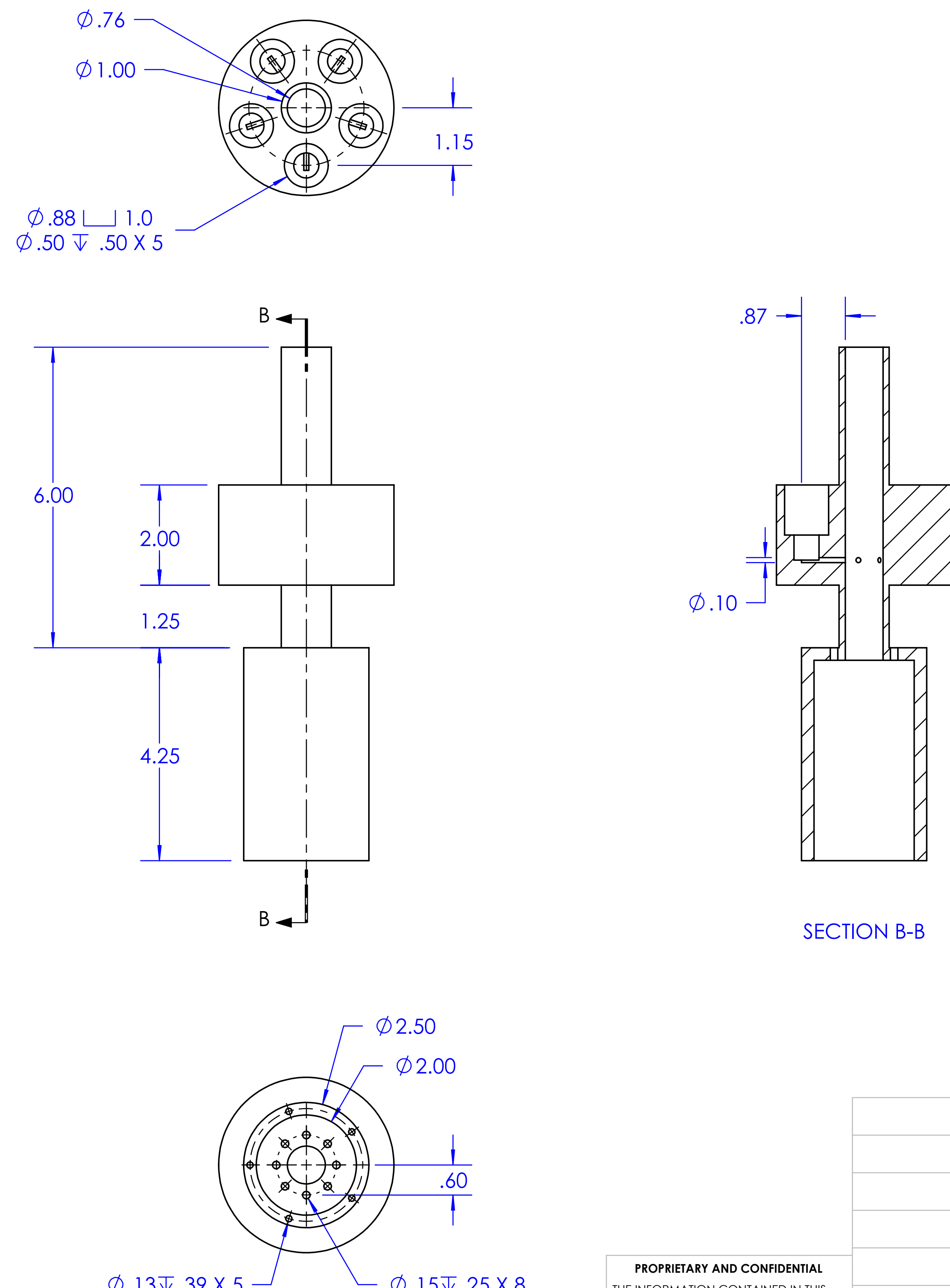
COMMENTS:

TITLE: ASSEMBLY VIEW OF FLOAT

NOTE: BLADDER NOT SHOWN

SIZE **B** DWG. NO. Final Design REV

SCALE: 1:5 WEIGHT: SHEET 1 OF 1



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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

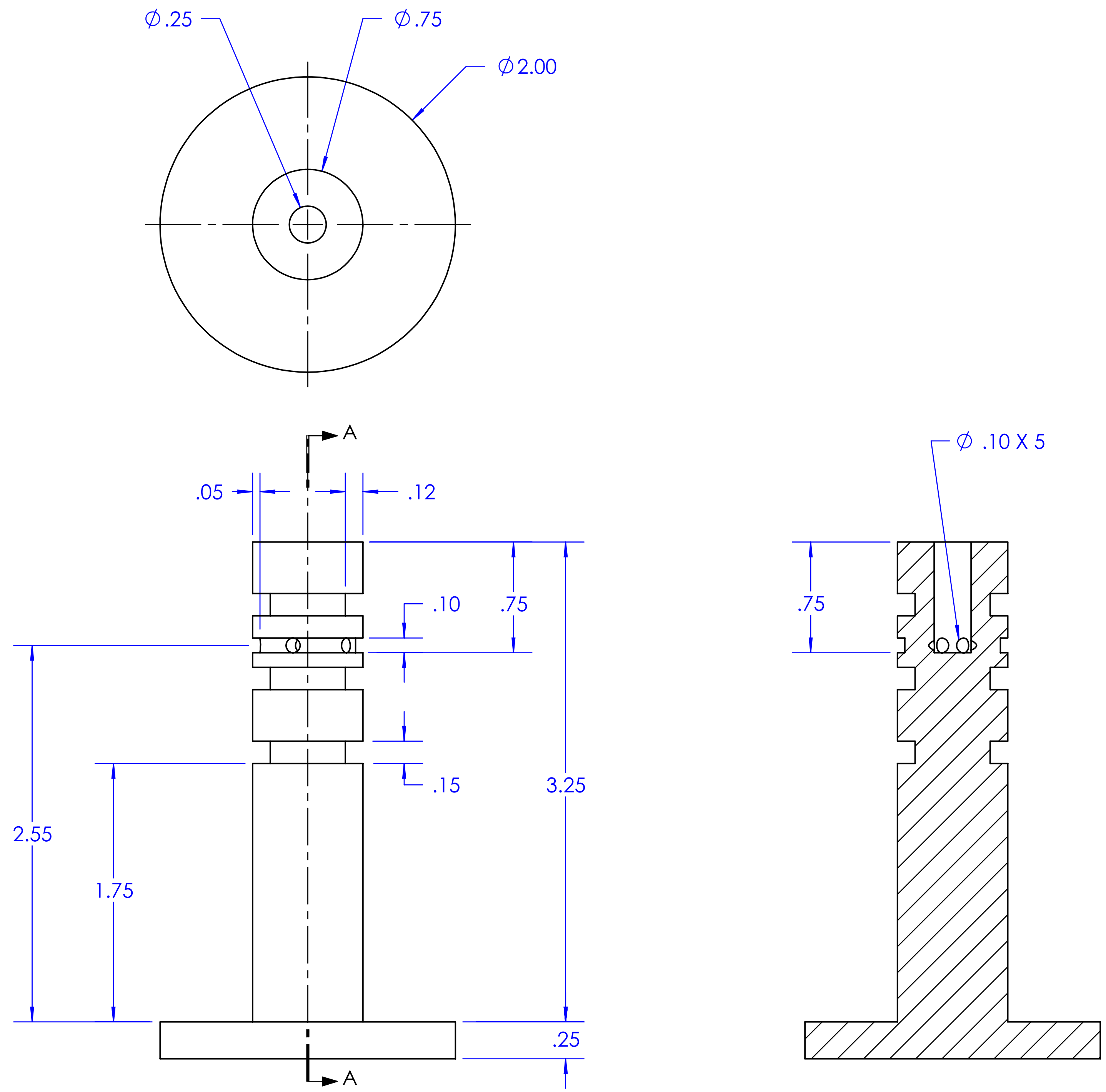
	NAME	DATE
DRAWN	Kevin	2/3/11
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

SIZE	DWG. NO.	REV
B	Final Trigger	1

SCALE: 1:3 WEIGHT: SHEET 1 OF 1



SECTION A-A

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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 0.01
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.001

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

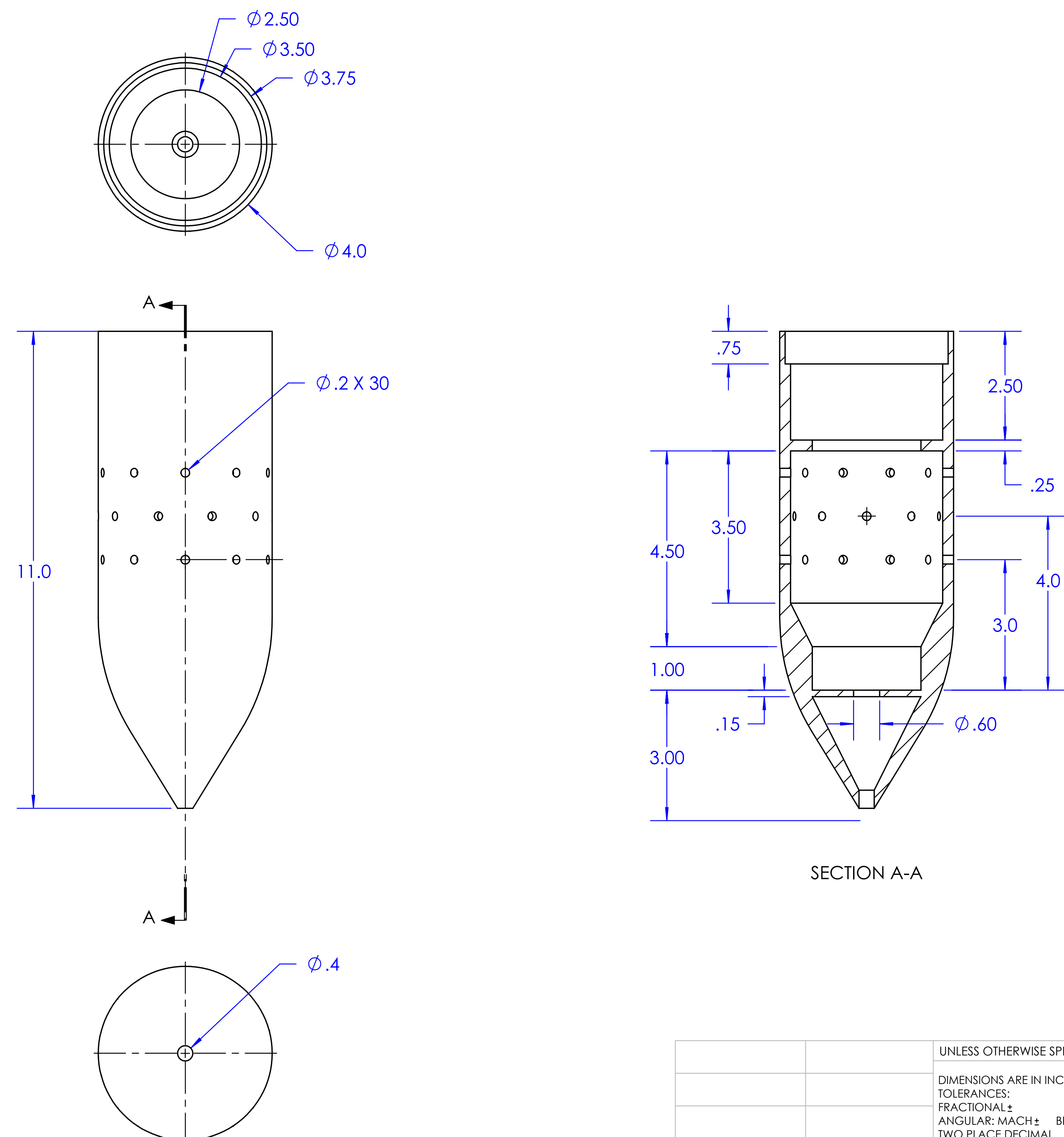
	NAME	DATE
DRAWN	Kevin	2/3/11
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

SIZE	DWG. NO.	REV
B	Final Plunger	1

SCALE: 1:1 WEIGHT: SHEET 1 OF 1



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NEXT ASSY | USED ON

APPLICATION

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

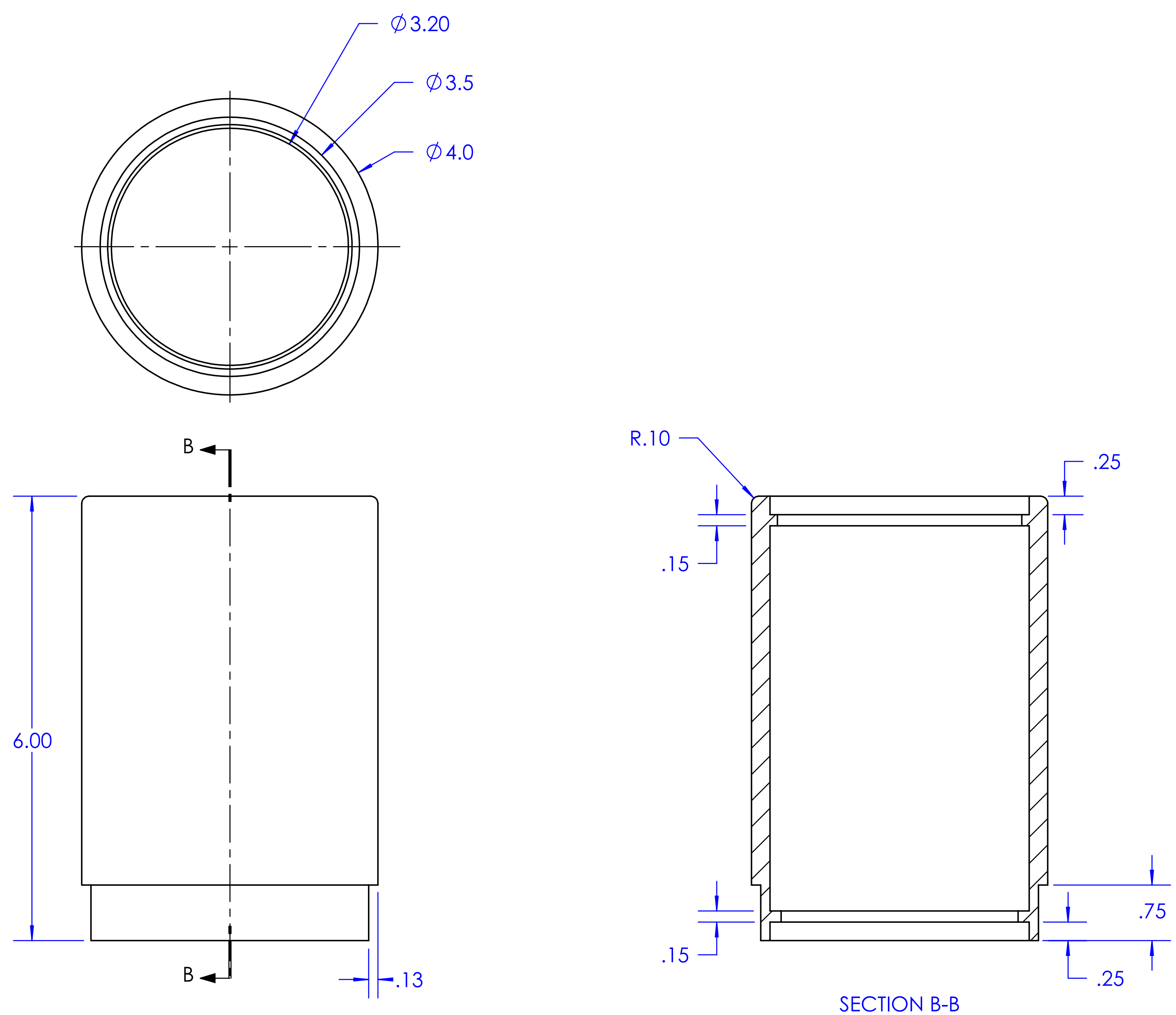
	NAME	DATE
DRAWN	Kevin	2/3/11
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

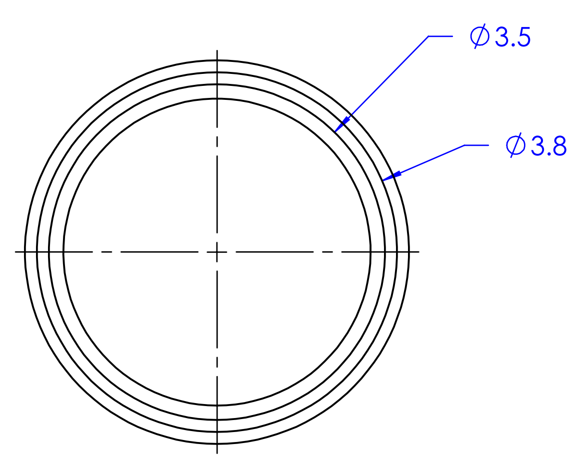
COMMENTS:

TITLE:

SIZE	DWG. NO.	REV
B	Final Casing	1

SCALE: 1:3 WEIGHT: SHEET 1 OF 1





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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

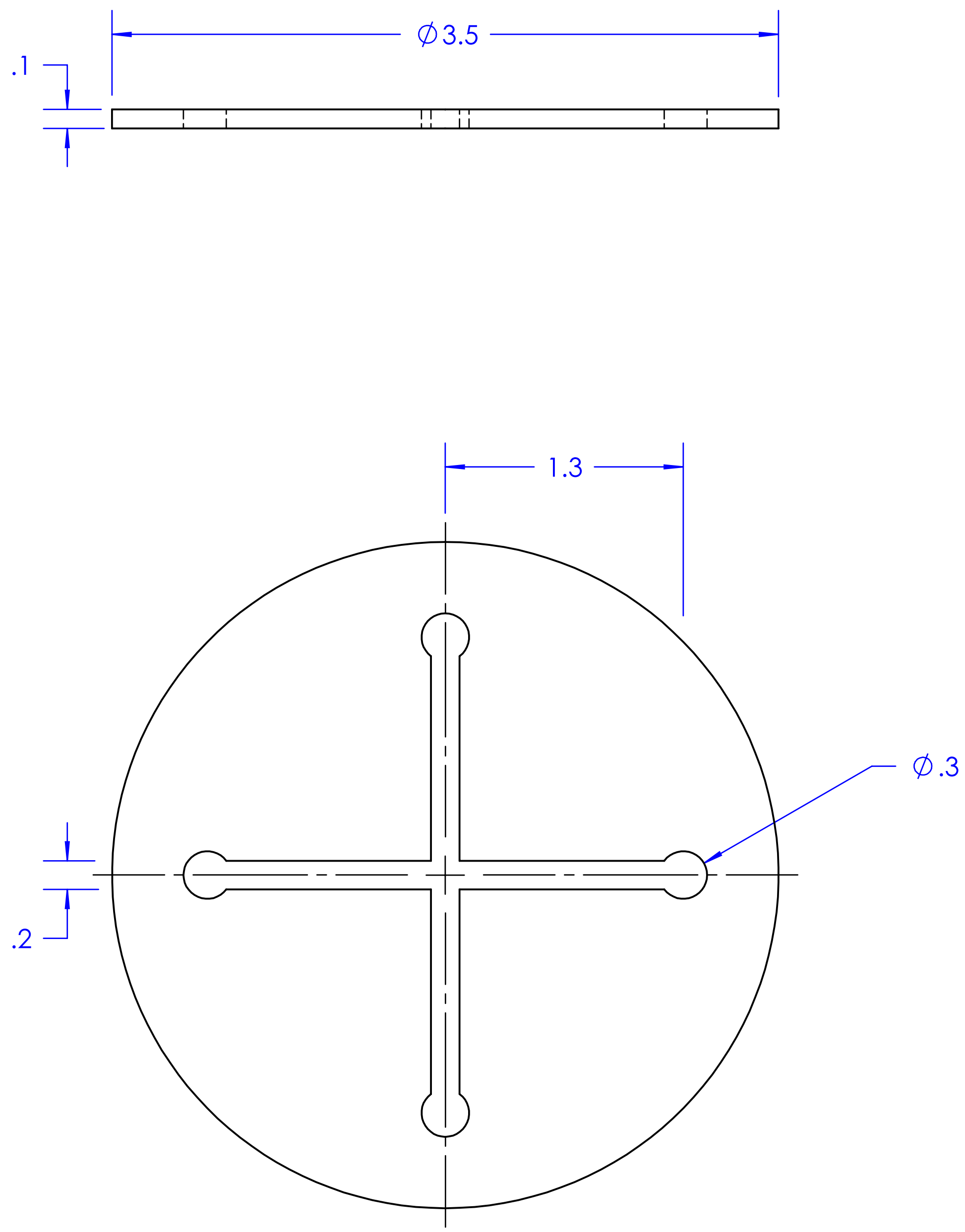
FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	Kevin	2/3/11
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE:

SIZE	DWG. NO.	REV
B	Final Casing Top	1
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	Kevin	2/3/11
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

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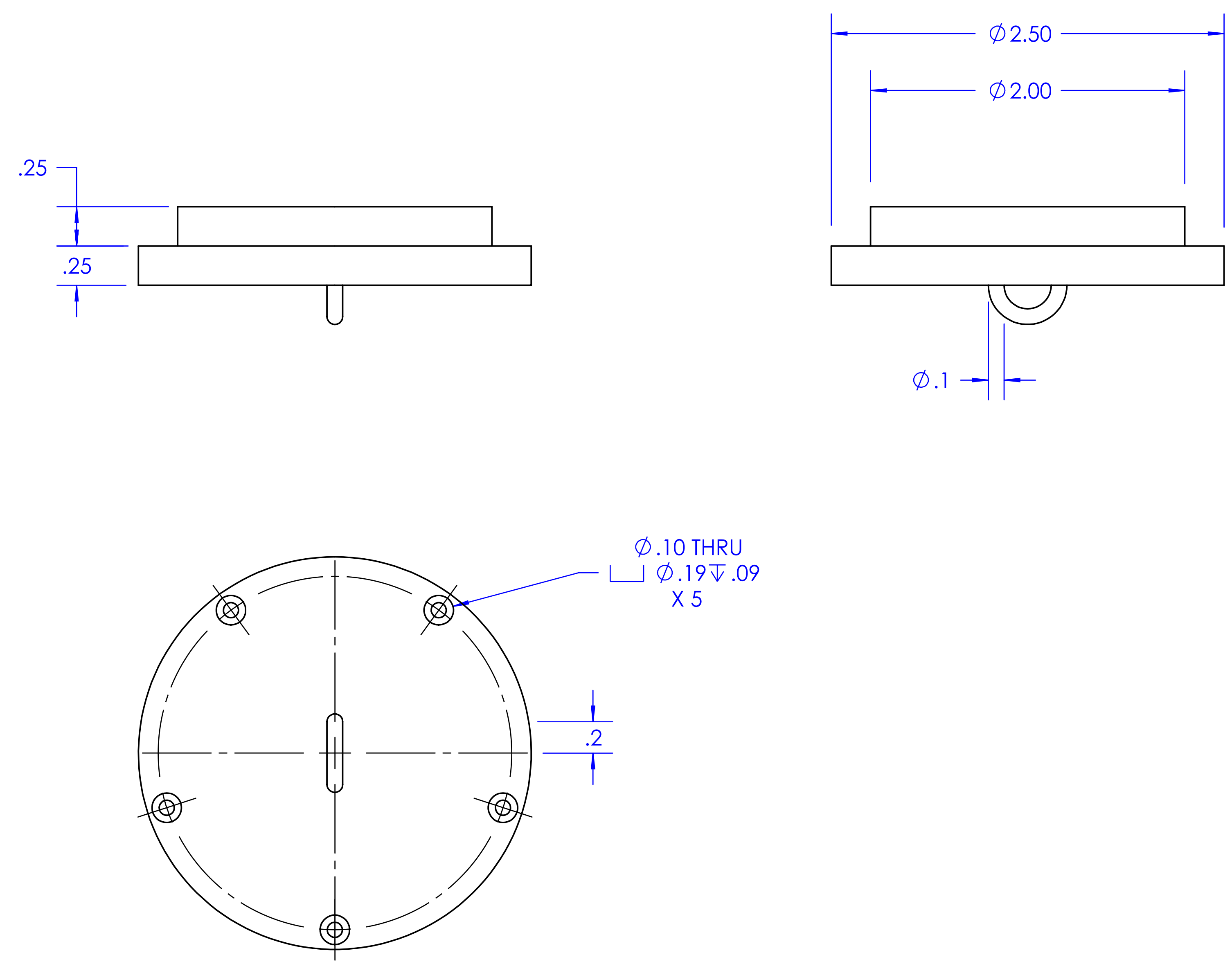
TITLE:

SIZE	DWG. NO.	REV
B	Final Rubber Cap	

SCALE: 1:1 WEIGHT: SHEET 1 OF 1



PROPRIETARY AND CONFIDENTIAL

NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	Kevin	2/3/11
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

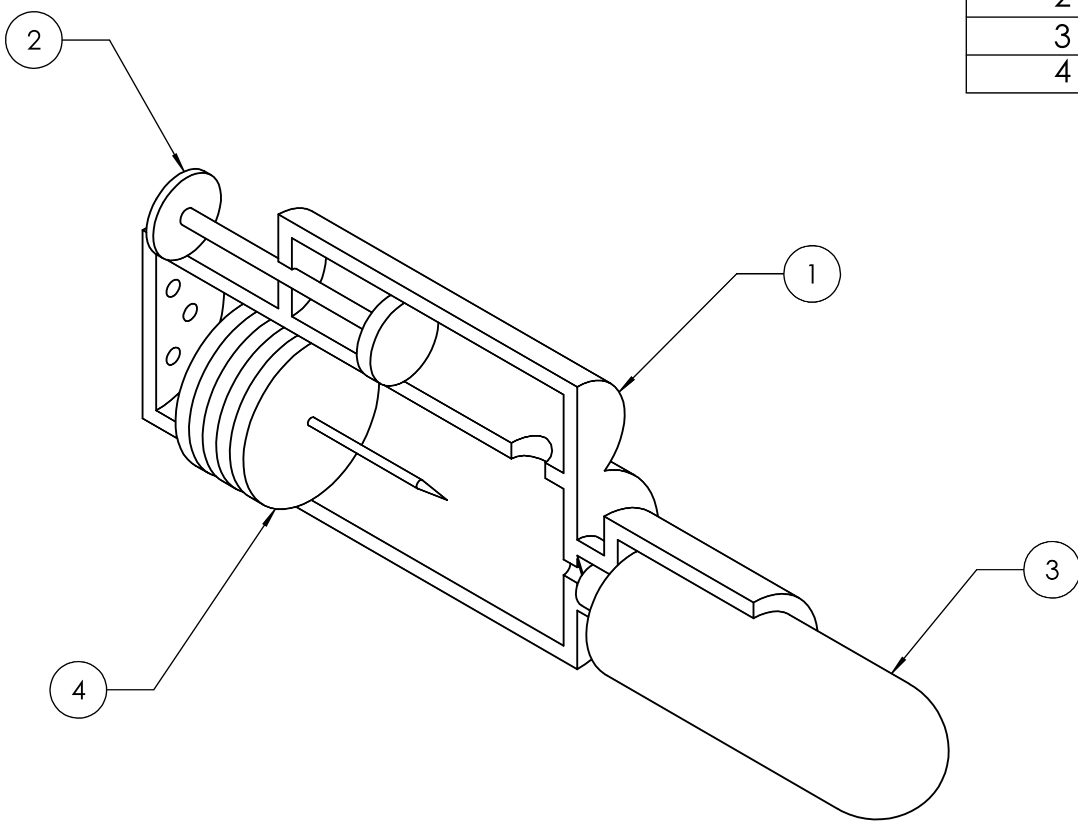
TITLE:

SIZE	DWG. NO.	REV
B	Final Trigger Cap	

SCALE: 1:1 WEIGHT: SHEET 1 OF 1

Preliminary Concept #1

ITEM NO.	PART NUMBER	QTY.
1	Trigger_Case	1
2	Pump_Plunger	1
3	CO2_Canister	1
4	Pin_Plunger	1



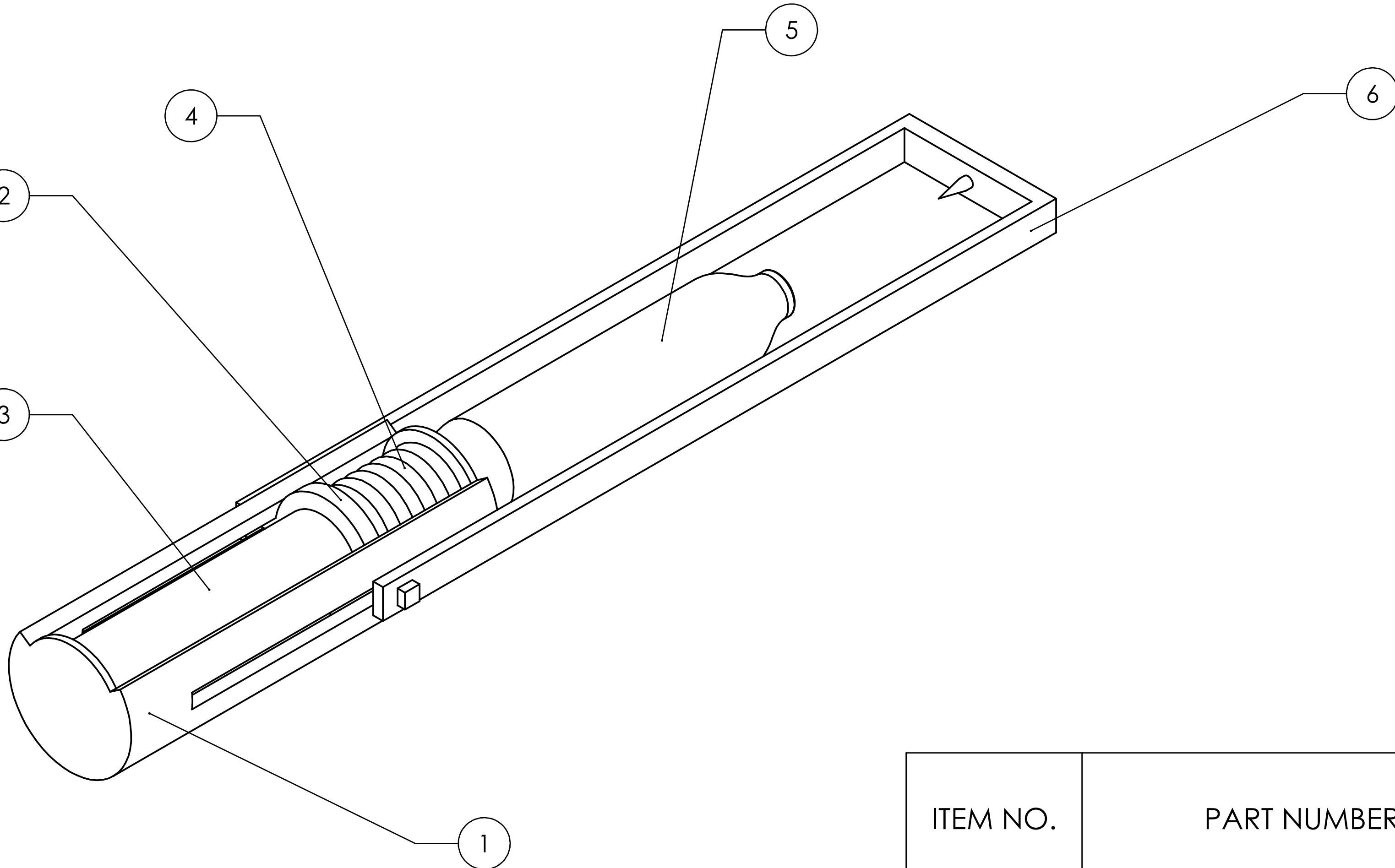
ME152 - FALL 2010

Mechanical Engineering CAL POLY

DATE: 11/20/10	UNITS:	MATERIAL:
TOLERANCE:	SCALE: ACTUAL	TITLE: TRIGGER CONCEPT 1
LEC SEC:	NEXT ASSY:	NAME: KEVIN GLEN
LAB SEC:	DRAWING #: 01	SIGNATURE:

5 4 3 2 1

Preliminary Concept #2



ITEM NO.	PART NUMBER	QTY.
1	trigger housing	1
2	plunger	1
3	balloon	1
4	spring	1
5	cartridge	1
6	arm	1

ME152 - FALL 2010	DATE: 11/20/10	UNITS:	MATERIAL:
Mechanical Engineering CAL POLY	TOLERANCE:	SCALE:	TITLE: TRIGGER CONCEPT 2
	LEC SEC:	NEXT ASSY:	NAME: Kyle Lancaster
	LAB SEC:	DRAWING #: 02	SIGNATURE:

5 4 3 2 1

APPENDIX C: Vendor Information

Vendor	Contact Info.	Component	Pricing
McMaster-Carr	mcmaster.com (592) 692-5911	Black Delrin Rod 3 1/2" diameter	$58.47
McMaster-Carr	mcmaster.com (592) 692-5911	White Delrin Rod 3" diameter	$31.64
Art's Cyclery	artscyclery.com (800) 626-3340	16g CO2 cartridge-threaded	$2.99
Genuine Innovations	genuineinnovations.com (520) 295-3936	CO2 valve-threaded	$5.99
San Luis Auto Parts	napaonline.com (805) 543-7287	O-rings	$0.79
McMaster-Carr	mcmaster.com (592) 692-5911	PU-coated nylon fabric	$4.35/ft
Tech-Bond Solutions	tech-bond.net (877) 565-7225	Nylon adhesive	$51.95

APPENDIX D: Supporting Analysis

2/8/11 Pressure Vessel Calcs

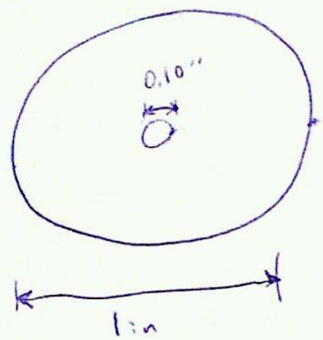
CO_2 pressure approximation 1000 psi

$V \approx 1.5\ in^3$

$m = 16\ g$

Cylindrical Pressure Vessel

r_1 = inside
r_2 = outside
r = point of interest



$\sigma_{max} = \frac{pr}{t}$ (Thin Walled?)

~~$\sigma_{max} =$ 1000 psi (~~

Thick Walled

$$\sigma_{max} = \frac{A + B}{r^2} = \frac{(p_1 r_1^2 - p_2 r_2^2)}{(r_2^2 - r_1^2)} + \frac{(p_2 - p_1) r_1^2 r_2^2}{r^2 (r_2^2 - r_1^2)}$$

$$\sigma_{max} = \frac{r_1^2 (r^2 - r_2^2)}{r^2 (r_2^2 - r_1^2)} p_1$$

$$= \frac{.05^2 (.05^2 - .5^2)}{.05^2 (.5^2 - .05^2)} (1000 psi)$$

$\sigma_{max_i} =$ 1000 psi

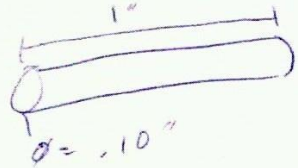
~~$\sigma_{max_o} =$~~

2/8/11 Pressure Vessel Calcs

$P_1 = 1000\,psi$ $V_1 = 1.5\,in^3$

$P_2 = ?$ $V_2 = AL + V_1$

$AL =$



$AL = \pi (.05)^2 (1) = .008\,in^3$

$P_1 V_1 = P_2 V_2$

$1000\,psi\,(1.5\,in^3) = P_2\,(1.508\,in^3)$

$P_2 = 995\,psi$

From Engineering Toolbox

$\sigma_{Axial} = -4.737\,psi$

$\sigma_{Hoop} = 991\,psi$

$\sigma_{radial} = -1000\,psi$

2/17/11 Pressure Calculations

Final Pressure in Bladder

$P_1 = 1000psi$

$V_{canister} = 1.5 in^3$

Assume $\frac{1}{4}$ pre-fill

$V_2 = 0.9 ft^3$

$P_1 V_1 = P_2 V_2$

$1000psi\,(1.5in^3 \times 5) = P_2\,(.75ft^3)$

$P_2 = 5.79\,psi$

↑ Bladder Internal Pressure after Inflation

Sea Water Pressure @ 10ft

$P \approx 4.7\,psi$

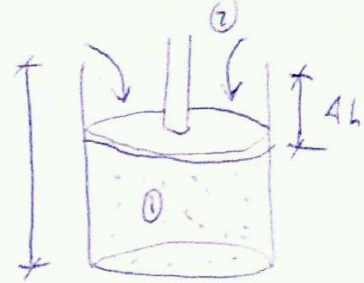
ABS

$1000psi\,(1.5in^3 \times 5) = P_2\,(.85ft^3)$

$P_2 = 5.106\,psi$

2/20/11 Distance Plunger Moves

inside chamber → $P_1 V_1 = P_2 V_2$ ← water filling against plunger



$P_1 = 1$ atm

$P_2 = 1.30237$ atm @ 10' deep

$V_1 = A_1(h - \Delta h)$

$V_2 = A_2(\Delta h)$

$A_1 = 3.142\ in^2$

$A_2 = 2.700\ in^2$

$1\ atm\ (3.142\ in^2)(h - \Delta h) = 1.30237\ atm\ (2.700$

~~$3.142h - 3.142\Delta h = 3.5164\Delta h$~~

~~$3.142h = 0.374399\Delta h$~~

$P_1 = P_2$ Free Moving Plung

$P_1 = P_2$ $P_1 = P_0 (V_0/V_1)$

$P_2 = P_1 = 1.30237\ atm = 19.1396\ psi$ @ 10' deep

$P_0 = 1\ atm$

$V_0 = Ah = 2\pi r^2 h = 3.142\ in^2\ h = 3.142\ in^2 (4) = 12.5664\ in^3$

$V_1 = ? = A(h - \Delta h)$

$P_2 = P_0 \left(\frac{A h_0}{A(h - \Delta h)} \right)$

$1.30237 = 1 \left(\frac{h}{h} - \frac{h}{\Delta h} \right)$

$1.30237 = 1 - \frac{h}{\Delta h}$

~~$\frac{h}{\Delta h} = -.30237$~~

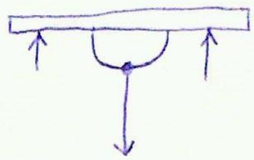
~~$h = -.30237\ \Delta h$~~

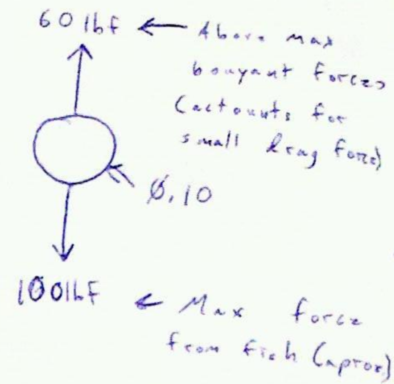
$P_2 = P_0 \left(\frac{A h_0}{A h_1} \right)$ $\frac{h_0}{h_1} = \frac{P_2}{P_0} = 1.30237$

$h_1 = \frac{h_0}{1.30237}$

$h_0 = 4\ in$ $h_1 = 3.0713\ in$

2/20/11 Line Attachment Calcs





$A = \pi r^2 = \pi(.05)^2 = 0.00785 \text{ in}^2$

$F = 60 + 100 = 160 \text{ lbF}$

$\sigma = \frac{F}{A} = \frac{160 \text{ lb}}{2(.00785)\text{ in}^2} =$ ~~20382.2~~ $\boxed{10191.1 \text{ psi}}$

↑ Not Sufficient

$\varnothing = .25 \text{ in} \quad A = 0.0491 \text{ in}^2$

$\sigma = \frac{160}{2(.0491)} = \boxed{1629.3 \text{ psi}}$ Acceptable

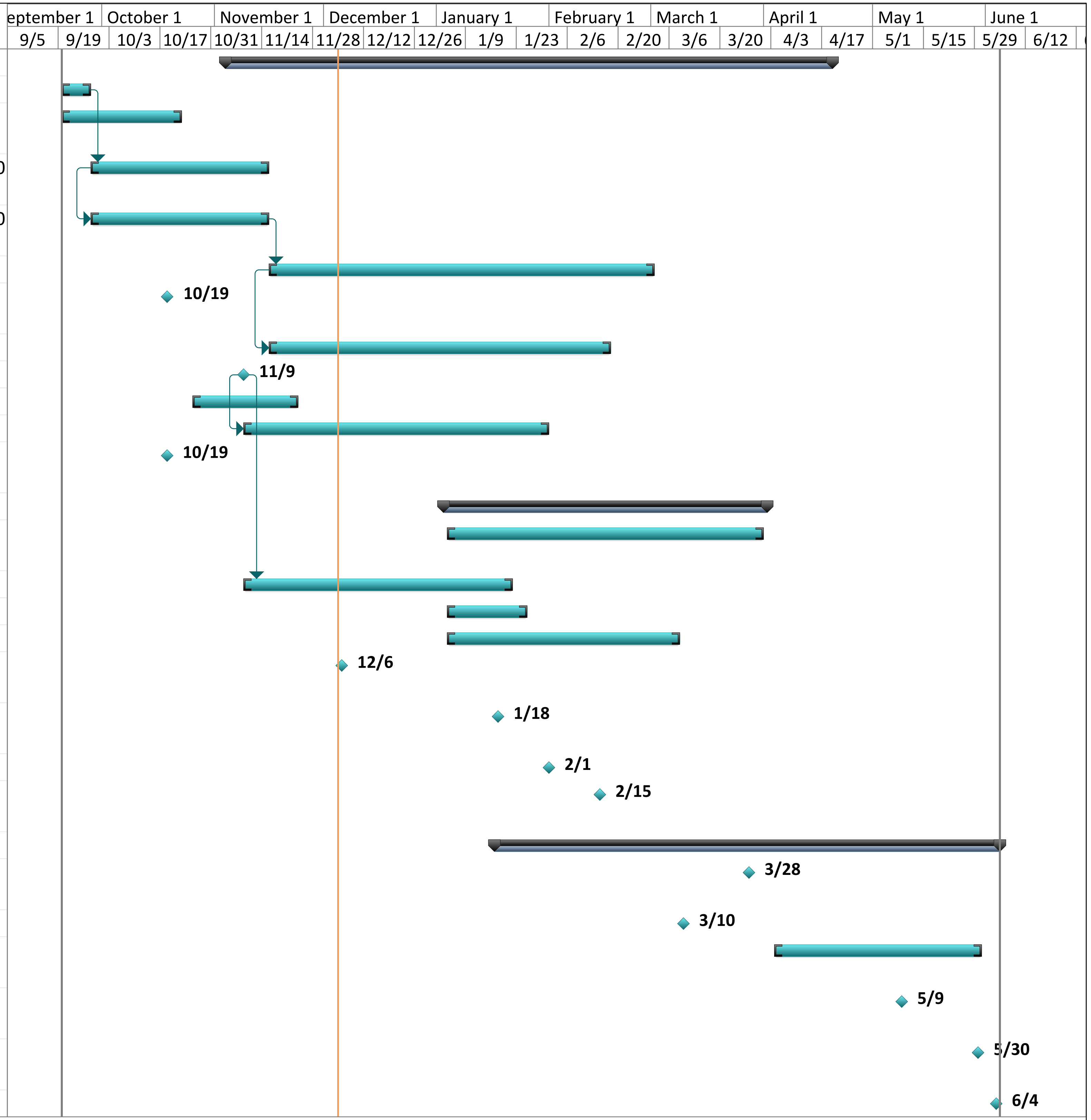
$\sigma_{yield\ (tension)} = 8{,}500 \text{ psi}$

Factor of Safety

$\boxed{n = 5.217}$

APPENDIX E: Gantt Chart

ID		Task Mode	Task Name	Duration	Start	Finish
1			**Design Work**	**119 days**	**Thu 11/4/10**	**Tue 4/19/11**
2			Form Engineering Teams	6 days	Mon 9/20/10	Mon 9/27/10
3			Add Business Student(s) to Team	25 days	Mon 9/20/10	Fri 10/22/10
4			Define Customer Requirements	35 days	Tue 9/28/10	Mon 11/15/10
5			Create Engineering Specifications	35 days	Tue 9/28/10	Mon 11/15/10
6			Generate Concept Ideas	76 days	Tue 11/16/10	Tue 3/1/11
7			Present Project Proposal to Advisor	0 days	Tue 10/19/10	Tue 10/19/10
8			Build Mock-Ups	68 days	Tue 11/16/10	Thu 2/17/11
9			Conceptual Model	0 days	Tue 11/9/10	Tue 11/9/10
10			Baseline Testing	21 days	Tue 10/26/10	Tue 11/23/10
11			Concept Testing	60 days	Tue 11/9/10	Mon 1/31/11
12			Conceptual Design Report	0 days	Tue 10/19/10	Tue 10/19/10
13			**Build**	**65 days**	**Mon 1/3/11**	**Fri 4/1/11**
14			Review/Improve Design	63 days	Tue 1/4/11	Thu 3/31/11
15			Generate 3D Models	54 days	Tue 11/9/10	Fri 1/21/11
16			Preliminary Analysis	16 days	Tue 1/4/11	Tue 1/25/11
17			Engineering Analysis	46 days	Tue 1/4/11	Tue 3/8/11
18			Conceptual Design Review	0 days	Mon 12/6/10	Mon 12/6/10
19			Design Presentation Day	0 days	Tue 1/18/11	Tue 1/18/11
20			Design Report	0 days	Tue 2/1/11	Tue 2/1/11
21			Team Ethics Presentation	0 days	Tue 2/15/11	Tue 2/15/11
22			**Testing**	**101 days**	**Mon 1/17/11**	**Sat 6/4/11**
23			Manufacturing and Test Review Presentation	0 days	Mon 3/28/11	Mon 3/28/11
24			Update Memo	0 days	Thu 3/10/11	Thu 3/10/11
25			Manufacturing of Final Product	41 days	Mon 4/4/11	Mon 5/30/11
26			Product Hardware Memo	0 days	Mon 5/9/11	Mon 5/9/11
27			Senior Design Presentation	0 days	Mon 5/30/11	Mon 5/30/11
28			Final Report	0 days	Sat 6/4/11	Sat 6/4/11



APPENDIX F: Survey Results

1. Where do you spearfish? Choose all that apply. (boat includes kayaks and jet-skis)

	Response Percent	Response Count
Shore dive - Reef/Sand	50.7%	109
Shore dive - Reef with Kelp	44.2%	95
Boat - Reef/Sand	**63.7%**	**137**
Boat - Reef with Kelp	37.7%	81
Boat - Kelp Paddies	20.5%	44
Boat - Blue water	33.0%	71
	answered question	**215**
	skipped question	**0**

2. To what depth do you typically dive?

	Response Percent	Response Count
0-15ft	2.8%	6
15-25ft	17.2%	37
25-35ft	**20.0%**	**43**
35-45ft	**20.0%**	**43**
45-65ft	15.8%	34
65-85ft	7.4%	16
85ft+	16.7%	36
	answered question	**215**
	skipped question	**0**

3. What set-up do you use (most often) when spearfishing?

	Response Percent	Response Count
Floatline with float(s)	**29.3%**	**63**
Floatline without float	20.5%	44
Reel	25.1%	54
Nothing attached to gun	25.1%	54
	answered question	**215**
	skipped question	**0**

4. If you use a float, what type of float do you use? (please specify exact brand/model if known)

	Response Percent	Response Count
Inflatable	46.4%	70
Solid	**53.6%**	**81**
Dive board	9.3%	14
	Brand/Model	104
	answered question	**151**
	skipped question	**64**

5. If you use a float or multiple floats, how much buoyancy does your set-up typically provide? (if unknown please guess) Ex) Carter float = 25lbs, Large Riffe inflatable = 90lbs

	Response Percent	Response Count
0-25lbs	**28.7%**	**45**
25-50lbs	23.6%	37
50-75lbs	23.6%	37
75-100lbs	21.7%	34
100-150lbs	6.4%	10
150-200lbs	0.6%	1
200lbs+	1.9%	3
	answered question	**157**
	skipped question	**58**

6. Have you ever lost equipment due to a fish? (i.e. speared fish swimming away with gun)

	Response Percent	Response Count
Yes	23.3%	50
No	**76.7%**	**165**
If Yes (please explain)		45
answered question		**215**
skipped question		**0**

7. Have you ever lost equipment while spearfishing for another reason?

	Response Percent	Response Count
Yes	**59.1%**	**127**
No	40.9%	88
If Yes (please explain)		106
answered question		**215**
skipped question		**0**

8. How much did your current float-line (including floats)/reel set-up cost?

	Response Percent	Response Count
0-50$	24.9%	44
50-100$	28.2%	50
100-200$	**40.7%**	**72**
200-400$	7.9%	14
400$+	1.1%	2
How much would you be willing to spend on a new float?		117
	answered question	**177**
	skipped question	**38**

9. Are you happy with your current float-line/reel set-up?

	Response Percent	Response Count
Yes	**82.4%**	**150**
No	18.1%	33
What would you change if you could?		86
	answered question	**182**
	skipped question	**33**

APPENDIX G: Patent Research

United States Patent [19]

Sinks et al.

[11] **3,866,253**

[45] **Feb. 18, 1975**

[54] **DIVERS BUOYANCY VEST**

[75] Inventors: **Allen J. Sinks,** Palatine; **Gordon T. Shearer,** Northbrook; **Vernon Pedersen,** Chicago, all of Ill.

[73] Assignee: **Dacor Corporation,** Northfield, Ill.

[22] Filed: **Jan. 8, 1973**

[21] Appl. No.: **321,963**

[52] **U.S. Cl.** **9/313,** 128/142

[51] **Int. Cl.** **B63c 9/08**

[58] **Field of Search** .... 9/342, 334, 335, 336, 337, 9/338, 339, 340, 341, 311, 333, 312, 313, 314, 315, 316; 137/493.9, 493.1; 128/145 R, 145 A, 142, 142.2, 142.3

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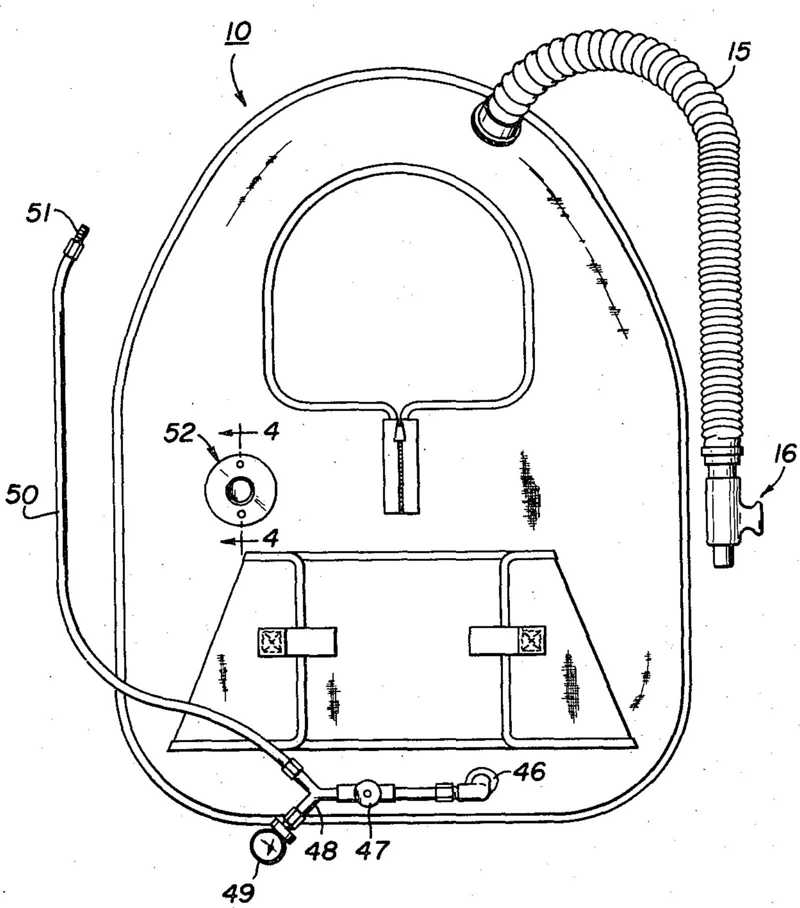
Primary Examiner—Robert J. Spar
Assistant Examiner—Donald W. Underwood
Attorney, Agent, or Firm—Edmond T. Patnaude

[57] **ABSTRACT**

A diver's buoyancy vest is provided with separate compartments for respective inflation with CO_2 gas and with air from either a pressurized air tank or from the lungs of the diver, the air pressure in the latter compartment being controllable by means of a pair of purge valves and the former being controllable by a separate purge valve mounted in the vest.

8 Claims, 6 Drawing Figures



PATENTED FEB 18 1975

3.866,253

SHEET 1 OF 2

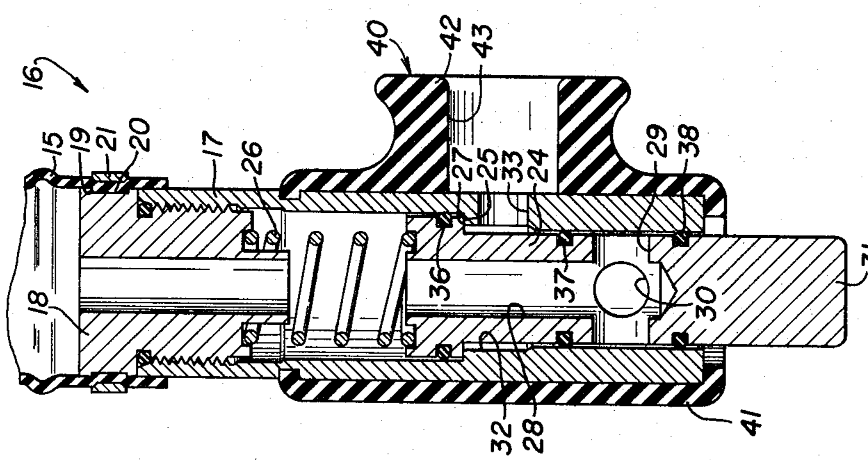


FIG. 3

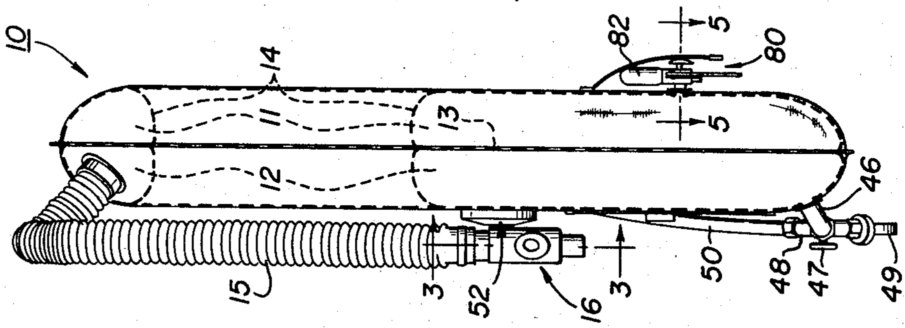


FIG. 2

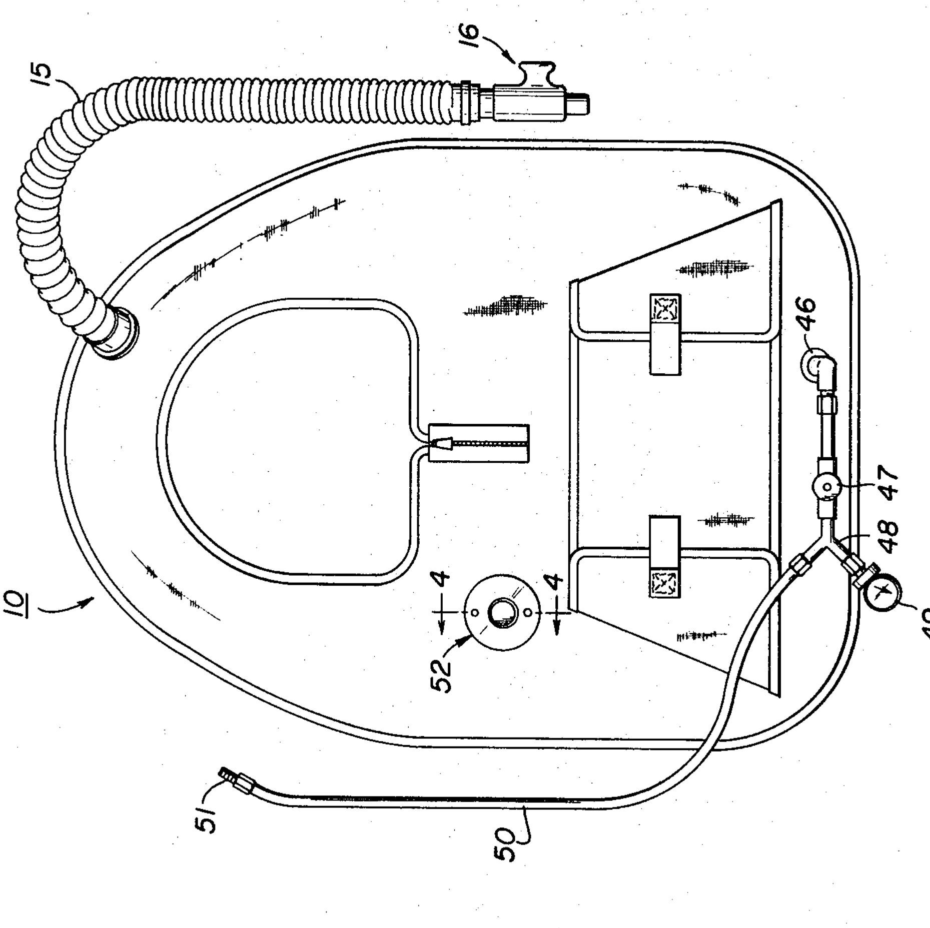


FIG. 1

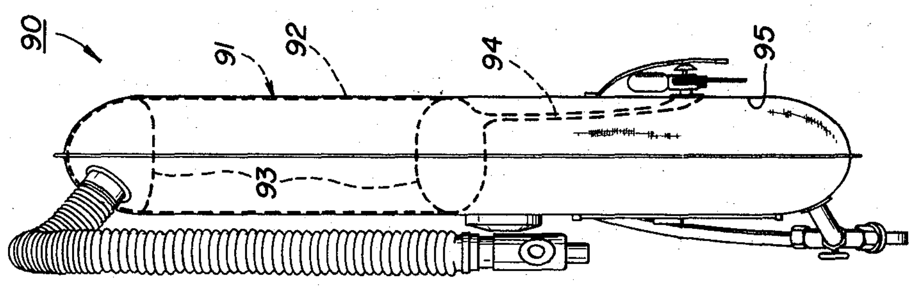


FIG. 6

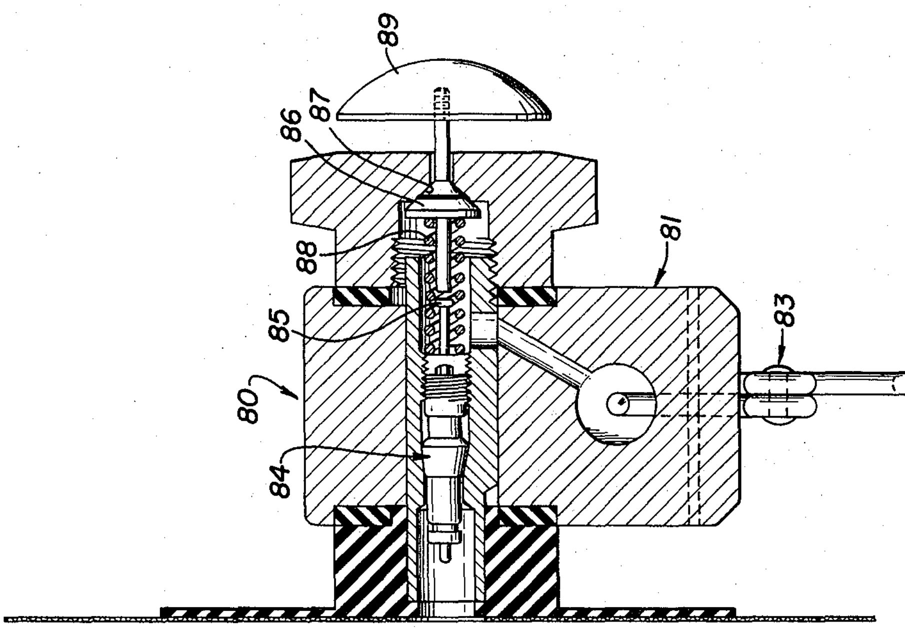


FIG. 5

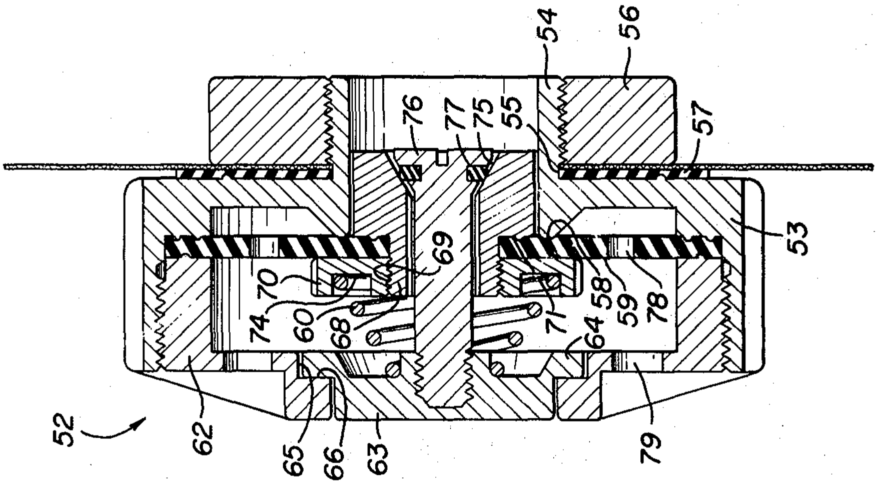


FIG. 4

DIVERS BUOYANCY VEST

The present invention relates in general to inflatable vests of the type used by SCUBA divers, and it relates more particularly to a buoyancy vest which is quickly inflatable in case of emergency from a CO_2 cartridge carried by the vest.

BACKGROUND OF THE INVENTION

In addition to being used by divers in cases of emergency, inflatable vests are also commonly used to control the buoyancy of the diver and his equipment by partially inflating the vest with air from the tank or by blowing into the vest. Moreover, the air in an inflated vest may be used for temporary breathing when necessary. Since the prior art vests include a single chamber inflatable by either CO_2 gas or air, there is the danger that the diver may inadvertently breath from a vest inflated with CO_2 gas.

Another problem associated with emergency breathing from the prior art type vest is that a substantial amount of water may be trapped in the mouthpiece and blown into the diver's lungs when he initially inhales from the vest. It would, therefore, be desirable to provide a mouthpiece and associated valve structure which substantially reduces the amount of water held therein.

When the vest is used as a buoyancy compensator, it is desirable that the diver be able to control the volume of gas in the vest. In the prior art vests, a relief valve is provided near the mouthpiece, but such valves have been difficult to operate because they are located at the distal end of a flexible tube. It would, therefore, be desirable to provide a more simply operable control valve mounted directly on the vest.

SUMMARY OF THE INVENTION

Briefly, an inflatable buoyancy vest embodying the present invention comprises two separate compartments respectively inflatable with CO_2 gas and with air. The air compartment is inflatable through a novel mouthpiece and control valve or from the air tank through a precision flow control valve. An automatic relief valve is provided to prevent over-inflation of the vest and incorporates a manually operable relief valve permitting the diver to control the buoyancy of the vest.

BRIEF DESCRIPTION OF THE DRAWINGS

Further objects and advantages and a better understanding of the invention may be had from the following detailed description taken in connection with the accompanying drawings, wherein:

FIG. 1 is a front view of an inflatable buoyancy vest embodying the present invention;

FIG. 2 is a side view of the vest of FIG. 1;

FIG. 3 is an enlarged cross-sectional view taken along the line 3—3 of FIG. 2 showing the details of the mouthpiece and associated purge control valve;

FIG. 4 is an enlarged cross-sectional view taken along the line 4—4 of FIG. 1 showing the details of the blow-off valve;

FIG. 5 is an enlarged, cross-sectional view showing the details of the CO_2 cartridge and purge valve assembly; and

FIG. 6 is a side view of another buoyancy vest embodying the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings and particularly to FIGS. **1** and **2** thereof, an inflatable buoyancy vest **10** comprises a pair of internal compartments **11** and **12** separated from one another by an imperforate partition **13.** The compartment **11** is at the rear of the vest and is adapted to be inflated with CO_2 gas while the compartment **12** at the front of the vest is adapted to be inflated with air. Both of the compartments **11** and **12** are generally ring-shaped to extend around an opening **14** which fits around the neck of the diver.

In order to permit controlled inflation and deflation of the compartment **12,** a flexible tube **15** is suitably connected thereto near the top of the vest for disposition behind the diver's neck and a mouthpiece and control valve assembly **16** is mounted over the distal end of the tube **15.** As best shown in FIG. **3,** the assembly **16** includes a tubular body member **17** in one end of which is mounted a sleeve **18** having an end portion **19** disposed at the end of the body member **17.** An annular groove **20** is provided in the end portion **19** for receiving the adjacent portion of the tube **15** into which the sleeve and associated end of the body member **17** are inserted. A clamp **21** compresses a portion of the tube **15** into the groove **19** to hold the assembly on the tube **15.** A valve sleeve **24** is slidable in the bore of the body member **17** and has an external annular shoulder **25** which is biased by a coil spring **26** against an internal annular shoulder **27** on the body member 17. An axial bore **28** extends part way through the sleeve **24** and a pair of transverse holes **29** and **30** extend through the sleeve in communication with the bore **28.** As shown in FIG. 3, the lower end of the sleeve **24** extends from the body member **17** to provide a manually actuatable button **31** for moving the sleeve **24** inwardly to align the transverse holes **29** and **30** with an annular chamber **32** with which a transverse opening **33** in the side of the body member **17** communicates. A pair of O-ring gaskets **36** and **37** are mounted in spaced apart annular grooves in the sleeve **24** for sealing the interior of the valve assembly from the opening **33** when the valve sleeve **24** is in the normally closed position as shown in FIG. **3.** A third O-ring gasket **38** is mounted in an external annular groove in the valve sleeve **24** near the outer end of the body member **17** for sealing the outer end of the valve assembly. An elastomeric mouthpiece **40** has a tubular body portion **41** which fits over the body member **17** and an integral mouth receiving portion **42** which extends from the side of the body portion **41** and is provided with a central bore **43** aligned with the hole **33.**

In order to orally inflate the vest **10,** the diver places the mouthpiece **42** in his mouth, depresses the button **31** and blows into the vest. Between breaths, he releases the button **31** to close the valve and prevent deflation of the vest. In order to purge air from the compartment **12** the button **31** is simply depressed while the mouthpiece **40** is out of the diver's mouth. The extent to which the button **31** is depressed controls the rate of flow of air from the vest. Where necessary, the diver may breath from the vest compartment **12** through the mouthpiece **40.** When so using the vest, only a very small amount of water will be blown into the diver's mouth when the button **31** is initially actuated, that being the water in the bore **43** and the hole **33.**

The compartment 12 may also be inflated with air fron the tank carried on the back of the diver. For this purpose, and as best shown in FIG. 1, an internally threaded fitting 46 is sealably mounted to the front of the vest near the left-hand bottom with a passageway therethrough communicating with the compartment 12. A quick disconnect, manually operated needle valve 47 is threadedly connected to the fitting 46. A Y-fitting 48 is connected to the valve 47 and a pressure gauge 49 is connected to one branch thereof. A flexible tube 50 is connected to the other branch and has a fitting 51 at the distal end for connection to the first stage regulator at the air tank (not shown). In order to inflate the vest from the air tank, the diver simply opens the valve 47 to admit the desired amount of air into the vest. The valve 47 is a precision type valve enabling a controllable low flow rate of the high pressure air from the tank. The quick disconnect feature of the valve 47 permits rapid scuttling of the tank, and check valves are incorporated in the separable parts thereof to prevent deflation of the vest when the valve 47 is disconnected therefrom.

In order to prevent over-inflation of the compartment 12 with a consequent rupturing of the vest, a safety relief blow-off valve 52 is mounted in the front of the vest. As shown in FIG. 4, the valve 52 includes a body 53 of generally cup-shaped configuration having a tubular portion 54 extending into the compartment 12 through an opening 55 in the front wall of the vest. The tubular portion 54 is externally threaded to receive a nut 56 which holds the valve 52 assembled to the vest. An hermetic seal is effected by an annular gasket 57.

An annular valve seat 58 is provided at the inner end of the tubular portion 54 and an elastomeric valve disc 59 is biased against the seat by a spring 60. Considered in greater detail, the valve disc 59 is held in place by means of an internal nut 62 which is threaded into the body 53 over the disc, and a manually actuatable purge button 63 is biased outwardly by the spring 60. An external, annular flange 64 on the purge button fits in an internal annular groove 65 in the nut 62 and rests against an annular seat 66 thereon. A sleeve 68 has an externally threaded portion 69 and a nut 70 is threaded thereon to sealably compress the disc 59 against an annular shoulder 71 on the sleeve. The nut 70 has an annular groove 74 receiving the inner end of the spring 60. The sleeve 68 has a conical valve seat surface 75 against which an outwardly flared valve steam 76 is adapted to seat. The stem 76 is resiliently biased into the closed position by the spring 60. As shown, a gasket 77 is carried by the stem for engagement with the seat 75.

In order to controllably purge the air from the compartment 12, the purge button 63 is depressed to move the valve stem 76 inwardly to unseat the gasket 77 from the seat 75. When the pressure in the compartment 12 exceeds a predetermined value as determined by the spring 60, the sleeve 68 and the disc 59 automatically move outwardly to unseat the gasket 77 from the seat 75 and also to unseat the valve disc 59 from its seat 58, whereupon air exits the vest through a plurality of openings 78 in the disc and a plurality of openings 79 in the nut 62.

Refer now to FIG. 5 wherein is shown the details of a CO_2 emergency inflation and purge valve 80 mounted on the back of the vest 10 as shown in FIG. 2. The valve 80 includes a body member 81 into which the neck of

a CO_2 cartridge 82 is threaded. When the seal in the cartridge neck is ruptured by a suitable trigger mechanism 83, CO_2 gas flows into the vest through a conventional check valve 84 having an outwardly biased actuating stem 85 which, when moved inwardly or to the left as shown in FIG. 5 opens the check valve to permit deflation of the vest compartment 11. A conical purge control valve member 86 is biased into a closed position against an annular seat 87 by a spring 88 and a button 89 is attached thereto for operation by the diver when he desires to purge the CO_2 compartment. As shown in FIG. 2, a flap is positioned over the cartridge 82 and the valve assembly 80 to protect the diver from possible irritation caused by direct contact with the cartridge or with the CO_2 gas exitting the valve assembly around the button 89.

Referring to FIG. 6, a vest 90 is provided with a separate bladder 91 disposed within an air compartment 95 therein. The bladder has a generally ring-shaped portion 92 which surrounds the neck opening 93 of the vest and a tubular portion 94 connecting to the CO_2 cartridge assembly. The vest 90 is used in the same manner as the vest 10.

While the present invention has been described in connection with particular embodiment thereof, it will be understood that those skilled in the art may make many changes and modifications without departing from the true spirit and scope thereof. Accordingly, the appended claims are intended to cover all such changes and modifications as fall within the true spirit and scope of the present invention.

What is claimed is:

1. An inflatable buoyancy vest for divers, comprising a flexible, hollow vest,
   - first and second mutually separate inflatable compartments in said vest,
   - first means for inflating said first compartment with CO_2 gas,
   - said first means including a holder attached to said vest for retaining a CO_2 cartridge,
   - second means for inflating said second compartment with air,
   - a manually operated control valve connected to said second compartment for purging air therefrom,
   - said control valve including
   - a first outwardly facing annular valve seat,
   - a first valve member movable against said seat,
   - a tubular member fixed to said first valve member and having an internal valve seat surface,
   - a second valve member axially mounted within said tubular member for movement against said valve seat surface, and
   - a spring urging said first and second valve members into sealing engagement with the respective valve seats.

2. An inflatable buoyancy vest according to claim 1, wherein
   - said first valve member is a flexible disc.

3. An inflatable buoyancy vest according to claim 2 wherein said control valve further including
   - a body having an opening therein aligned with said tubular member,
   - an actuating button secured to said second valve member and disposed in said opening, and
   - an internal abutment on said body for retaining said button therein against the force exerted thereon by said spring.

4. An inflatable buoyancy vest for divers, comprising
a flexible, hollow vest,
first and second separate and independent inflatable compartments in said vest,
first means for inflating said first compartment only with CO_2 gas,
said first means including a holder attachment to said vest for retaining a CO_2 cartridge,
second means for inflating said second compartment only with air,
a manually operated control valve connected to said second compartment for purging air therefrom,
said control valve including
a tubular body member having an opening in the side thereof,
a valve member slidable in said body member between a first position closing said opening and a second position communicating said opening to said second compartment,
spring means biasing said valve member into said first position,
a depressible manual actuator extending from one end of said tubular member for moving said valve against the force of said spring to said second position, and
a mouthpiece fitted over said body member and having a portion aligned with said opening for reception in the mouth of a diver.

5. An inflatable buoyancy vest according to claim 4, comprising
a flexible tubular member connected between said second compartment and said control valve.

6. An inflatable safety vest for use by a scuba diver carrying a reservoir of compressed air for use in underwater breathing, said vest having a neck receiving opening, the improvement comprising
first and second separate and independent inflatable compartments in said vest,
a conduit including a manually operable valve connected between said first compartment and said reservoir for inflating only said first compartment from said reservoir with air,
a flexible conduit having a mouthpiece at one end and connected at the other end to said first compartment,
said flexible conduit being sufficiently long to permit the mouthpiece to be placed in the mouth of the diver wearing said vest,
a manually operable valve connected in said flexible conduit for controlling the supply of air between said mouthpiece and said first compartment to permit said diver to orally inflate said first compartment and to breath air from said first compartment,
means including a CO_2 cartridge carried by said vest for inflating said second compartment only with CO_2 gas, and
manually and automatically operated purge valve means carried at the front of said vest substantially below said neck receiving opening to release air from said first compartment upon manual actuation or when the pressure within said first compartment exceeds the ambient pressure by a predetermined value.

7. An inflatable buoyancy vest according to claim 6, wherein
one of said first and second compartments is a bladder disposed in the other of said compartments.

8. An inflatable buoyancy vest according to claim 7 further comprising
a fitting on said vest connected to said first compartment,
said manually operable flow control valve connected to said fitting, and
said conduit including a flexible hose for connecting said manually operable flow control valve to a first stage regulator on said reservoir.

* * * * *