Reusable Hydrometer for Human Specific Gravity Measurements

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ABSTRACT

Specific gravity is an approachable method to monitor daily outflow of urine for the purpose of preventing kidney stone formation. However, most specific gravity measurement devices are clinical research grade equipment and are not commercially available due to cost and technical experience to operate. Here described is our method for adapting a commercially available fish tank hydrometer to be utilized for human urine specific gravity measurements by fabricating an adapter attachment that not only increases the ease of use for our device but also increases the accuracy of it.

Introduction

Kidney stone formation has become a prevalent problem facing the onset of the obesity epidemic. It was found Ahmed et al. that epidemiologic studies have shown that incident renal stone risk increases with a body mass index[1]. Stones can form in any part of the urinary system, which consists of the kidneys, ureters, bladder, and urethra. Urine travels through the system and some of the waste product that urine consists of is left behind.

Moreover, the collection of these waste products forms stones[2]. There are four major types of kidney stones: calcium stones, struvite stones, uric acid stones, and cystine stones. These groups are separated by the chemical composition and the cause of formation. Calcium stones are the most common type; calcium that is not used by the bones and the muscles goes through the kidney which usually gets washed out with the urine. However, some calcium may be left behind that combines with other waste products to form a stone, which in most cases is a combination called calcium oxalate. Struvite stones are usually formed after an infection in the urinary system and are composed of the mineral magnesium and the waste product ammonia. A uric acid stone forms when the urine is too acidic. Cystine stones are rare, but can form when cystine, the building block of muscles, nerves, and other parts of the body, builds up in the urine[3].

A simple preventative to kidney stone formation is increased fluid intake. Studies have shown that increased intake of fluids decreases the concentration and acidity of urine[4]. Other studies have found that changing the pH of urine reduces kidney stone formation[5].

Furthermore, it has been found that the adequacy of a single 24-hour urine sample for evaluating patients for medical renal stone prevention[6]. However, the results found that single 24-hour sample is not sufficient for evaluating patients before metabolic treatment for stone prevention. Our client, Dr. Jhagroo, a nephrologist at the University of Wisconsin – Madison Hospital and Clinic, has found a methodical way to approximate a patient's previous 24-hour urine volume output by measuring the specific gravity of the patient's urine. From this information, Dr. Jhagroo can diagnose a potential formation of renal stones. He currently uses a fish tank hydrometer to measure specific gravity and a prevalent problem for him is the bubble formations. Bubbles in urine cling on the hydrometer needle and gives inaccurate readings. He requests a reusable device that can easily read specific gravity while reducing bubble formation, is easy to use for patients, and can be cleaned easily.

There are many ways to measure specific gravity. Currently, our client uses dipsticks with a refractometer that provides the specific gravity through a color indicator. Other devices that measure specific gravity include a densitometer, which are electronic devices commonly used in labs, and elaeometer, which is used for oils[7]. Hydrometers are instruments that measure the specific gravity of different solutions, or the ratio between the density of the solution and the density of water[8]. Commercially, they are used to test the specific gravity of fish tanks or car batteries. Hydrometers provide information such as the identification of a solution or the concentration of the solution. In our case, the client will be using the hydrometer to test the concentration of the urines.

There are two basic types of hydrometer: the standard hydrometer and the swing arm hydrometer. The standard hydrometer is composed of a sleek, glass instrument that is filled with a reference solution, which is calibrated to be the density of water. The instrument is placed into a container filled with the solution and, once the buoyant force (F_B) is equal to the weight ($m \times g$) of the instrument, it provides the specific gravity (**Figure 1**). At equilibrium, the buoyant force is equal to the pressure (P) on the object multiplied by the surface area (SA) of the instrument:

$$\frac{F_B}{SA} = P = \rho_{sol} \times h \times g$$

$$F_B = F_w = \rho_{sol} \times h \times g \times SA = m \times g$$

$$h = \frac{m}{\rho_{sol} \times SA}$$

This gives us an inverse relationship between the height (h) of object in the solution and the density (ρ_{sol}) of the solution. Analytically, this relationship agrees with what we would see. For example, if we place the object in syrup the height device will not sink very far in the solution and the height will be small.

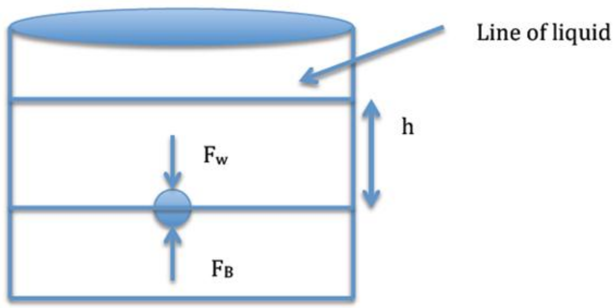


Figure 1: Standard hydrometer at equilibrium. The weight of the instrument is equal to the buoyant force acting on it.

The swing arm hydrometer is composed of a container that holds a needle, which is calibrated to be the density of water. When liquid is poured in, the needle rotates on a pin in a circular motion until the buoyant force is equal to the weight of the needle. This instrument works using moment: the density difference between the solution and the needle forces the needle to go up while the density difference between the weight and the solution forces it to go down (**Figure 2**).

$$\sum Moment = \rho V_1 \times l\cos(\alpha+\theta) + \rho V_2 \times l\cos(\alpha) - m_1 g \times l\cos(\alpha+\theta) - m_2 g \times l\cos(\alpha) = 0$$

$$\rho = \frac{m_1\cos(\alpha+\theta) + m_2 g\cos(\alpha)}{V_1 g\cos(\alpha+\theta) + V_2\cos(\alpha)}$$

Commercially, these are used to test the specific gravity of fish tank water.

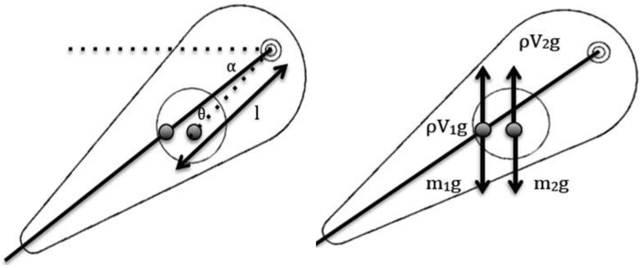


Figure 2: Swing arm hydrometer at equilibrium. The forces acting on the need occur at the center mass of the needle and the counterweight.

Design Process

Our group came up with three hydrometer designs for the purpose of testing the specific gravity of human urine: syringe, tube (swing arm), and funnel (swing arm).

The syringe hydrometer (**Figure 3**), involves two dynamic pieces: a simple syringe, and a pre-calibrated counter weight, which is the component that actually would determine the specific gravity of the solution. The syringe hydrometer works by the patient pulling in the desired liquid into the inner compartment of the syringe. At this point, the pre-calibrated weight would bob up and down until equilibrium is reached. Basically, it works on Archimedes Principle. The principle states that the weight of the counterweight equals the weight of the fluid that it displaces at equilibrium. In this case, when fluids of different densities are drawn into the syringe, the counterweight will displace different amount of solutions. To be more precise, the counterweight displaces less solution, thus floating higher if the solution has higher specific gravity.

Figure 3: Syringe Hydrometer. Includes pre-calibrated counter weight, and syringe components. Liquid is pulled in the syringe and the internal component would float at levels depending on the density of the liquid.

Some benefits of using this design are ease of portability, the ease of not needing a large volume of urine for testing, and easy cleaning. However, an inherent problem with the design is the difficulty associated with manufacturing the counterweight. Calibrating the internal piece to have water as a reference liquid would be incredibly difficult. Also, properly designating particular gradations on the counter weight is problematic. Lastly, having two separate pieces increases the possibility of losing one or the other, preventing any further measurements.

Our next design, the tube adapter hydrometer, utilizes a commercially available fish tank hydrometer (**Figure 4**).

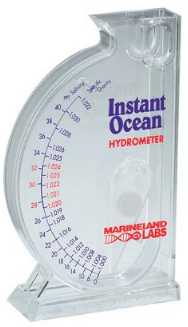


Figure 4: Commercially available fish tank hydrometer for specific gravity measurements.

To prevent urine from splashing and generating bubbles (disrupts data collection), we postulated fabricating a tube that runs the length of the hydrometer, until the bottom, allowing the flow to proceed at a leisurely pace (**Figure 5**).

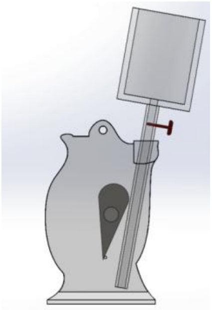


Figure 5: Tube-adapter hydrometer. Inserted into hydrometer to facilitate easier pouring and prevent bubble formation.

This design would work by urine being poured into the top portion. Once the funnel is filled to a particular line (which would be calculated), the stopcock is opened at the base of the funnel, allowing urine without bubbles to flow into the hydrometer. Once enough urine has filled the hydrometer, the stopcock would be closed, and the adapter would be removed from the hydrometer.

A positive aspect of this design is when used correctly, this design will minimize bubble formations drastically. However, this design still has two assembly pieces which complicates its use, and the act of closing the stopcock to prevent bubbles entering the hydrometer may prove difficult for some patients. Lastly, another drawback with this design is the potential for urine spilling.

Our final design is known as the funnel adapter (**Figure 6**) also uses the commercially available fish tank hydrometer. This design is an extension of the previous design and incorporates similar aspects.

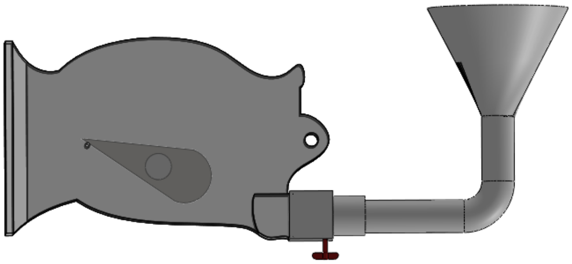
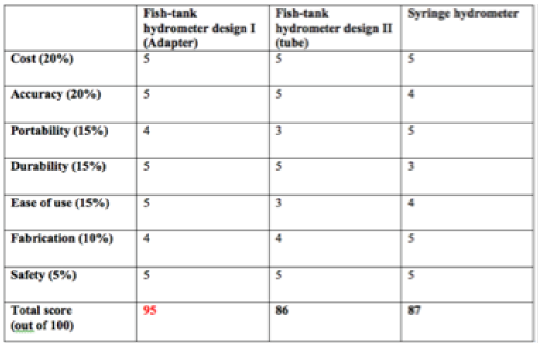


Figure 6: Funnel adapter design. Funnel is attached to hydrometer and urine is poured in this state. When finished pouring, the hydrometer is turned upright and measured.

The procedure to utilize this design is similar to the previous tube design. The hydrometer, with the associated adapter, is tilted 90 degrees toward the horizontal. The patient then pours urine into the adapter until a certain line, designated by the funnel, is reached. The stopcock is now opened and the urine proceeds into the hydrometer. Once a state of equilibrium is reached, the stopcock is closed and the hydrometer is tilted up 90° until it is vertical. The urine that is on the funnel's side after equilibrium will then collect in the long horizontal tubing, preventing urine spillage.

This design is the most beneficial to the patient. It allows the hydrometer and the adapter to be fitted together as one individual piece, rather than two separate pieces, and it allows the patient to easily pour in urine without having to worry about closing the stopcock. Furthermore this design takes more preventative measures against bubble formation. Having the hydrometer vertically assembled with the adapter allows for the passive flow of urine into the hydrometer at a slower rate than in the previous design.

With these design in mind, and after talking with our client, we constructed our design matrix (**Figure 7**).



	Fish-tank hydrometer design I (Adapter)	Fish-tank hydrometer design II (tube)	Syringe hydrometer
Cost (20%)	5	5	5
Accuracy (20%)	5	5	4
Portability (15%)	4	3	5
Durability (15%)	5	5	3
Ease of use (15%)	5	3	4
Fabrication (10%)	4	4	5
Safety (5%)	5	5	5
Total score (out of 100)	95	86	87

Figure 7: Design matrix. The choice of our final design was based on seven different categories, placing cost and accuracy as the most important considerations.

After much deliberation, our group decided on the funnel adapter design for the fish tank hydrometer. As the table shows, three alternative designs of hydrometer are compared through seven different categories: cost, accuracy, portability, durability, ease of use, fabrication, and safety. A total score of 100 is assigned into seven categories with different weights. The "cost" and "accuracy" both have the highest weights (20% each) since it is required to design a cheap hydrometer for patients to measure the specific gravity of their urines reliably. More specifically, a cheap design of urine specific gravity measurement system allows for more fabrications of prototypes to test the accuracy for different patients within the limited budget. The desirable cost for each hydrometer system is estimated to be less than 30 dollar. There are specific requirements for the accuracy for the specific gravity measurement. The design is aim to precisely measure the specific gravity to 0.001 and with a total range from 1.000 to 1.032. Since the design is used to monitor the specific gravity of patient's urine sample variation within a day, the device must remain accurate after multiple uses. It is also important for the design to be portable, easy to operate, and effective for certain duration; thus each of these categories has a 15% weight. The hydrometer system should be convenient for patients to carry with daily; therefore the size of the device is restricted to be no bigger than 25 cm by 15 cm by 5 cm and the optimal weight is roughly 1 kg. In this case the hydrometer system could be easily transported in a suitcase or luggage. The device is designed to be easy to operate and clean for patients. The patients would like to put less effort into using the hydrometer and getting the measurement results of urine quickly. The "fabrication" and "safety" categories both have a lower weights (10% and 5% respectively) than the rest since the fabrication process of each design is believed to be easy and all the potential hydrometers we are going to incorporate into the designs have smooth finishes.

In general, a score from 1 to 5 is assigned to each of design alternatives in each category. The fish tank hydrometer with tube has a low cost (scores 5), high accuracy (5), and is considered to be used for long time (5) while it is not portable (3) with the loose tube inside it. For the syringe hydrometer, it is the most portable (5) one among the three due to its small volume. Also, with the syringe being available, there is not much work of fabrication (5). However, its accuracy (4) largely depends on the calibration of counterweight and it has to change the syringe quite often. Lastly, the design of swing arm hydrometer incorporating adapter shows the advantage of being low cost (5), high accuracy (5), easy to use (5), and safe (5). It also achieves a balance of being portable (4) as well as durable (5). Overall, the swing arm hydrometer with adapter scored the highest (95) among the three, with the syringe hydrometer coming in second (87) and the swing arm hydrometer with tube coming in last (86). So at this stage, the swing arm hydrometer with adapter is the ideal one among all potential designs.

With the prototype design selected, it now became our goal to draft a design that we could utilize in the fabrication process. Our first idea was to simply create the adapter in one solid piece. We purchased foot long acrylic rods with a 50.8 mm (2”) diameter which, on one end, would be fashioned into a rectangular segment that would fit into the hydrometer, with a tapered section in the middle to provide an avenue in which we could insert the stopcock. We wanted to have a set volume of liquid to be held in the length of the hollowed rod from the stopcock to the funnel. Assuming a 38.1 mm (1.5”) inner diameter, we calculated that the required length to provide the set volume would be 87.63 mm (3.24”), which at the time was an excellent proposition. It would allow us to keep the adapter relatively close to the hydrometer without too much bulk. We purchased acrylic rods that were relatively cheap with the hope that we could begin fabrication the week before Thanksgiving.

However, when the design plans were discussed with the shop technicians they said that it would be quite impossible to fabricate the adapter the way we had planned. The design was just too intricate to really be feasible. They offered suggestions, such as simple attaching a ball valve to the end of a PVC pipe and using that as the rate limiting step for the liquid from adapter to hydrometer. Over Thanksgiving break our team discussed our options and decided to pursue the concept that was suggested by the shop technicians. We purchased 0.3048 m (1’) long PVC pipes with an inner diameter of 12.7 mm (1/2”), as well as several ball valves that would fit snugly with the PVC pipes. PVC edge pieces were also purchased to provide a place to mount the funnel (**Figure 8**).

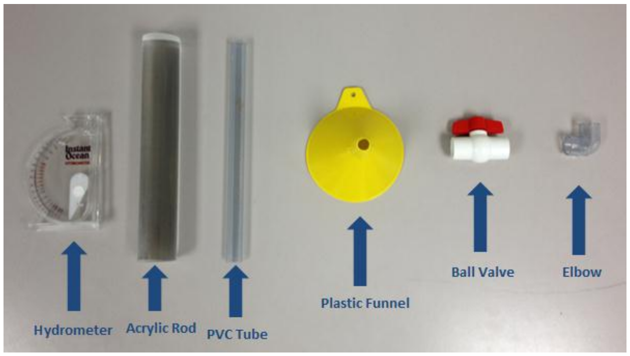


Figure 8: The materials required for fabrication of our fish-tank hydrometer adapter

The only question left was how to attach the PVC pipe with the ball valve into the hydrometer. We ultimately decided to utilize the purchased acrylic rods to make attachment pieces. We also wanted to build with the attachment piece an extension that would hook onto the hydrometer sealing the hole on the side preventing spills (**Figure 9**).

Figure 9: Design for the fish-tank hydrometer adapter utilizing a PVC pipe with a ball valve and the fabricated attachment piece. The extension (on the left side) would clip onto the hydrometer and block the hole on the side.

Fabrication of the extension from the adapter into the hydrometer to plug the hole also turned out to be too difficult, so we decided to extend the rectangular portion to cover up the alternative avenue (**Figure 10**).

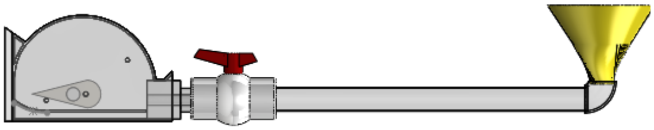


Figure 10: Our final design. Instead of having a bridge cover the gap, we will extend the rectangular adapter so that not only will it fit snugly with the sides of the hydrometer, it will be long enough to reach and block the hole.

Jerry and Matt were tasked with creating the rounded region that would fit into the ball valve. This required use of a mill in the student machine shop. They first started by "facing" the acrylic piece to establish a suitable, smooth surface. The piece was then cut down its length measuring the total length of the required round part (1.25" or 31.75 mm). They subsequently cut down the diameter in incremental strokes in order to reach the desired diameter that would fit into the ball valve (0.84" or 21.34 mm). Finally Jerry and Matt needed to drill into the piece to establish the hole that would connect the PVC pipe to the hydrometer. They began by using a center drill to initiate the drill hole and then followed suit with a 6.35 mm (1/4") drill bit. Once the hole was drilled to an appropriate length they then used a 9.525 mm (3/8") drill bit to drill the correct size.

After that part was complete, Jack and Steve were tasked to fabricate the rectangular piece that goes above the fabricated pipe. They started first by using a drop saw to cut off the piece from the rest of the acrylic rod. Then they used the mill to polish the top to a smooth finish with an 11.11 mm (7/16") end mill bit. They used a system of measurement using an end finder for both the x and y axis to determine the exact center of the piece and then started cutting the sides with the same end mill bit. At the end they milled a rectangle with 15.088 mm (0.594") width, 34.93 mm (1.375") height, and 31.75 mm (1.25") depth (**Figure 11**).

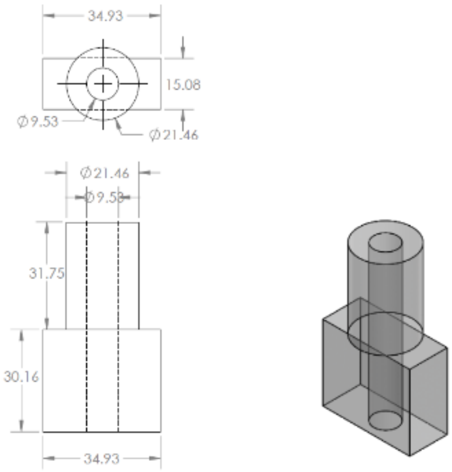


Figure 11: Design specifications for the acrylic attachment piece in mm.

Experimental Testing

After deciding on our design, our group researched various aspects of the hydrometer accuracy. We first tested temperature's effect on specific gravity measurement. When the temperature of a liquid is raised, the volume is also raised, causing the density to decrease. Since specific gravity is directly correlated to density, we expected increase in temperature would decrease specific gravity. We used tap water from the sink as our source and measured the specific gravity at room temperature, near boiling, and near freezing (**Figure 12**).

Temperature	Trial 1	Trial 2	Trial 3	Average
21 Celsius	1.003	1.004	1.003	1.003
90 Celsius	1.000	1.001	1.001	1.001
1 Celsius	1.000	1.000	1.000	1.000

Figure 12: Testing of water's specific gravity measurement at various temperatures.

At room temperature the specific gravity reading was on average 1.003. The reason it was not exactly 1.000 is due to the minerals in tap water which increases the overall mass and therefore density. The specific gravity measurements at room temperature and near-boiling match the idea that higher temperature gives lower specific gravity readings. Therefore it is plausible that lower temperatures give higher specific gravity readings. The specific gravity measurements near freezing, however, measured lower than that of room temperature and near boiling. We believe that error in measurement results from water's peculiar trait of having a lower density solid than liquid. Since we used a mixture of ice and water for our near freezing experiment, the ice's lower density may have affected the measurements. The calculated standard deviance is in the magnitude of millionth so it is negligible.

We then tested whether crystallization of urine would affect specific gravity measurements. If the patients were to not adequately rinse out the hydrometer, it is possible that residue of urine will crystallize on the needle and affect specific gravity measurements. Our client, Dr. Penniston, has been using a hydrometer to measure urine specific gravity for a few months and she only needs to rinse it out before and after each use. We took Dr. Penniston's hydrometer and a brand new Instant Ocean hydrometer and measured the specific gravity from the same set of urine (**Figure 13**).

Hydrometer	Trial 1	Trial 2	Trial 3	Average
Used	1.0225	1.0230	1.0225	1.0227
New	1.0245	1.0245	1.0240	1.0243

Figure 13: Testing of the urine specific gravity measurement with varying hydrometers

On average, the brand-new hydrometer had a higher reading of specific gravity than the used hydrometer, by a difference of 0.0016. Taking the brand-new hydrometer as the expected measurement and the used as the observed, we can calculate the percentage of error.

$$error = \frac{|expected - observed|}{expected} = \frac{1.0243 - 1.0227}{1.0243} = 0.156\%$$

The calculated error is quite negligible; our client Dr. Jhagroo confirmed that such a small percentage of error can be ignored for the specific gravity measurement. Our calculated standard deviance is negligible.

The difference in readings can be attributed to slight crystallization of urine on the hydrometer needle. The crystallization would increase the overall mass of the needle, which would increase the density of the calibrating needle. Since the specific gravity measurement is calculated from the density of the liquid over the density of the needle, an increase in the needle density (the denominator) would give an overall lower specific gravity measurement.

Once our final product was complete, our main concern was leakage the bridge and the face of the acrylic end piece. After our initial test, there was significant leakage at this point which was cause by the plastic-to-plastic face; it is not water sealed. However, one of the solutions this issue was to put Vaseline on the face of the end piece that will touch the bridge. This would create a somewhat water seal where the leakage occurred. After performing ten trials and applying Vaseline after each trial, there was no leakage in seven out of the ten trials. The trials that had leakage had only a few drops.

We performed a test to see if the adapter affected the specific gravity of the water. We performed three trials with water and no adapter and three trials with water plus the adapter. We used water from the same source (the sink) in order to minimize the amount of variables. With the trials that had no adapter, water was poured directly into the hydrometer from the sink. With the trials that had the hydrometer, the water was poured from the sink to the funnel and into the adapter; then, the valve was opened to let the flow of water in (**Figure 14**).

Situation	No adapter	Adapter
Trial 1	1.000	1.000
Trial 2	1.002	1.001
Trial 3	1.001	1.000
Averages	1.001	1.000

Figure 14: Testing of the product with tap water (top) and with soapy water (bottom)

Situation	No adapter	Adapter
Trial 1	1.000	1.000
Trial 2	1.000	1.000
Trial 3	1.000	1.000
Averages	1.000	1.000

The data shows that the adapter has negligible effect on the specific gravity of the liquid. Moreover, the Vaseline had no effect on the reading which was our biggest concern. During the soap test, we also noted the formation of bubble formation in each trial. With no adapter, there was bubble formation on the needle in each trial that slowed down the reading. When the adapter was applied, there was no bubble formation on the needle; therefore, the reading was faster. The standard deviance is also too small and therefore can be neglected.

One of the major issues that arose when testing the hydrometer was that cracks formed on the hydrometer when attaching the adapter multiple times. This would compromise the leakage of the adapter because it changed the inner dimensions of the hydrometer which takes away from the “snug” fit of the adapter.

Our main concern with the efficiency of our fabricated adapter was to prevent the propagation of bubbles into the fish-tank hydrometer, and by effect skewing specific gravity measurements. We ran a simple experiment to see if the bubbles that would reside in the adapter had the possibility of entering the hydrometer. A soap solution was made and poured into the adapter, and the adapter was allowed to lie prone allowing the bubbles to spread along its length (**Figure 15**). Then, following our designated procedure of use for our adapter, we tilted the adapter upwards allowing the bubbles to rise to the top of the adapter (**Figure 16**). After the bubbles stopped flowing upwards, the ball valve was opened gently and the liquid was allowed to flow into the hydrometer, closing the ball valve once bubbles came close to entering the hydrometer.

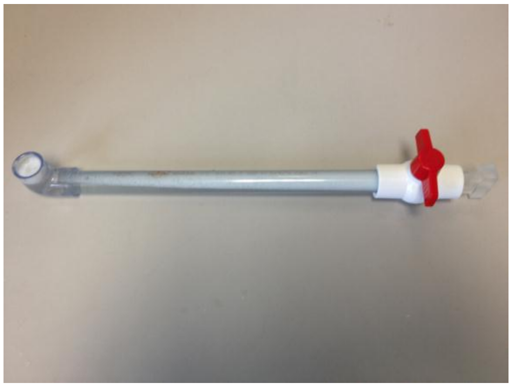
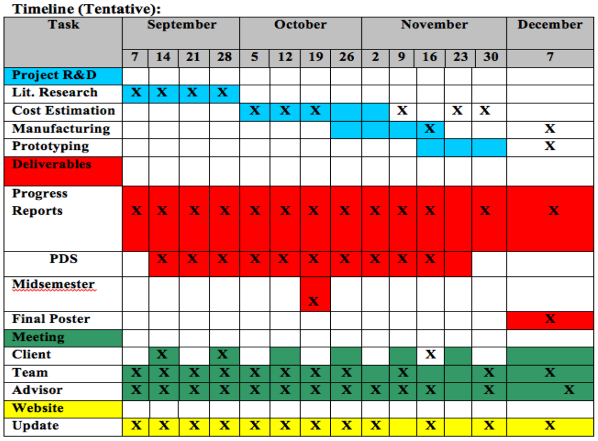


Figure 15: Adapter with soap solution within chamber lying prone to test adapter’s effect on bubble propagation into the hydrometer. Observe bubbles residing across length of adapter.

Figure 16: Adapter with soap solution tilted upwards. Observe bubbles no longer reside along the length of the adapter, rather at the top, and away from the hydrometer that would be situated beneath.

Timeline



Timeline (Tentative):

Task	September				October				November					December
	7	14	21	28	5	12	19	26	2	9	16	23	30	7
Project R&D														
Lit. Research	X	X	X	X										
Cost Estimation					X	X	X			X		X	X	
Manufacturing											X			X
Prototyping														X
Deliverables														
Progress Reports	X	X	X	X	X	X	X	X	X	X	X		X	X
PDS		X	X	X	X	X	X	X	X	X	X			
Midsemester							X							
Final Poster														X
Meeting														
Client		X		X							X			
Team	X	X	X	X	X	X	X	X		X			X	X
Advisor	X	X	X	X	X	X	X	X	X	X	X		X	X
Website														
Update	X	X	X	X	X	X	X	X	X		X		X	X

Figure 17: Proposed timeline for our group project. Completed tasks are designated with "X."

Our group as a whole has made a great effort staying close to the proposed timeline (**Figure 17**). Any deviations from the timeline can be seen specifically in not meeting with the client and a delay in beginning the cost estimation phase and manufacturing phase.

Our group has made a consistent effort to meet with our client when needed. The previous weeks have not needed a formal meeting with Dr. Jhagroo since all questions that our group had were answered via email.

The delay in the initiation of the cost estimation phase and the manufacturing phase is due to group member schedule difficulties. Those weeks were unforeseeably busy for each member of our team and consequently prevented our group as a whole from reaching the desired point in our research and development of our adapter.

The weeks following mid-semester brought us closer to the fabrication of our adapter with only some minor difficulties. As discussed in the design process section, prior to Thanksgiving break we had a conceptual idea of how to fabricate our adapter. However, due to some logistical problems, we were unable to see our prototype built. We collectively decided upon a new idea following Thanksgiving, and with the proper purchases were able to build our adapter. Waiting on purchases stock materials and creating a new design was the final problem that prevented us from matching our proposed timeline completely.

Budget

Date:	Item:	Cost:	Comments:
11.11.2012	3(Acrylic Rod: 2" diameter, 1 ft long)	63.06$	Acrylic rods for adapter fabrication.
11.25.2012	10(Ball socket valves) 10(Clear PVC: ½" diameter)	8.80$ 18.50$	New materials for adapter.
11.30.2012	5(Clear PVC Elbow Joints: 1/2" diameter)	33.18$	
12.3.2012	3(Plastic funnels)	5.60$	
	TOTAL:	129.14$	

Figure 18: Spent funds during the semester.

As proposed prior to mid-semester, much of the funds spent during the semester involved bulk plastics for fabrication of the adapter. The first purchase we made was the acrylic rods that were a part of our initial prototype design, which ended up being too difficult to fabricate. The materials purchased after the acrylic rods are a part of our final design. We utilized some of the stock acrylic to generate a connecting piece that joins the hydrometer and the ball valve. Ultimately we were pleased that our final prototype design turned out to be cheaper than the initial design (**Figure 18**).

Future Work

Generally, there are potentials to improve this design project in the future if more time is allowed. First of all, there could be enhancements of fish-tank hydrometer adapter. The purchased ball valve is slightly bulky; this causes the center of mass move away from the center of hydrometer body and makes the whole design heavier. A small and light ball valve with same inlet and outlet diameter would fit the design better. Besides, an ideal snap-fit adapter between fish-tank hydrometer and ball valve would both prevent the leakage and be easy to remove. The fabricated adapter we made use lathe and mill fit the outlet of ball valve and inlet of hydrometer inlet tightly but it is hard to remove sometimes. A snap-fit design with a “lock” would make the connection smoother.

Finally, a prototype of syringe hydrometer could be fabricated to compare with the current adapter design in terms of the accuracy of measuring the specific gravity. The majority of work would be done in selecting the proper material to fabricate the weight inside the syringe and calibrate it to accurately indicate the specific density of urine. Two 60 ml syringes were gotten to use as the parts of syringe hydrometer design while we encountered problems when selecting the suitable materials to make the inside weight. The original plan was to use make a wood rod with radius of 50 mm and height of 40 mm; a thin metal piece then attach to the bottom of the rod to make whole weight able to work. However, it’s hard to find the appropriate wood and metal material that would not potentially interact with urine and easy to clean. We suspended the syringe hydrometer in order to focus on the fabrication of fish-tank hydrometer adapter. If more time was allowed, a syringe hydrometer could be made to verify its feasibility by sending it to patient.

Conclusion

Kidney stones are a prevalent problem in American culture, and the only real means of preventative measure is to increase daily urine outflow. Measuring the specific gravity of an individual's urine can be extrapolated to measure if daily urine outflow needs to be increased. Our team has been tasked with designing a reusable hydrometer for the purposes of testing the specific gravity of human urine. With the help of Dr. Jhagroo, we have found that a commercially available product exists, but it is not adapted to interface with the human body. This fish tank hydrometer has the required scale to measure human urine specific gravity but application of urine into the device can result in bubble formation around the needle, skewing data. Our team has consequently designed an adapter that will reduce bubble formation and thus give more accurate data. Difficulties arose during the fabrication process, due to intricacy of our proposed design, and material characteristics. However, as an adaptive BME design team, we responded to those challenges accordingly. In the end we developed and implemented a prototype design that will aid Dr. Jhagroo is his research.

Bibliography

(1) Ahmed, M; Ahmed, H; Khalil, A. *Ren. Fail.* **2012**, 34, (10)

(2) Pearle, M. S.; Calhoun , E. A. *J Urol* **2005**, 173(3), (848-857)

(3) Worcester, E. M.; Coe, F. L. *N Engl J Med* **2010**, 363(10), (954-963)

(4) Vaamonde, C; Presser, J; Clapp, W. *J. Appl. Phys.* **1974**, 36.4, (434 – 439)

(5) Lu, X; Wang, J; Cao, X; Li, M; Xiao, C; Yasui, T; Gao, B. *Urol Ann.* **2011**, 3(2), (71-74)

(6) Parks, J. H.;E. Goldfisher *J Urol* **2002**, 167(4), (1607-1612)

(7) Paris, J.K.; Bennett, A.D.; Dodkin, S.J.; Gunn-Moore, D.A. *Vet Rec.* **2012**, 170(18), (463)

(8) Stuempfle, K; Drury, D. *J Athl Train.* **2003**, 38(4), (315-19)