HydroPhysics - ABSTRACT

Historically, in the plains of the Midwest, flooding of basements devastates homes and disrupts activities, causing millions of dollars in property damage each year. Intense storms in the last decade have exacerbated the problem.

In flood prevention, a device which doesn't require energy, and one that will reliably prevent water from entering a basement is, astonishingly, absent!

It is for this reason that Team HydroPhysics decided to design our product "Anti-Flood Design" or AFD.

The physics of water teaches us that water will always attempt to reach the same level, regardless of volume or size of compartments. Using this, we designed a device that would allow water to enter our AFD and capture it in a non-flowableform.

After researching the topic, consulting water-proofing experts and conducting many experiments, we designed the final product. AFD was made from inexpensive materials, and was simple enough to eliminate the risk of malfunction associated with complexity.

The AFD requires no energy to maintain or "activate." In addition, Super-Absorbent Polymers harness the water in a flood, changing it to a non-flowable gel, adding weight to the AFD thereby strengthening the seal against the floor.

The AFD Final Design image shows how it harnesses the difference in volume-weight-time absorption behavior of different SAP types and puts it to use in strengthening the floor seal and preventing a flood. AFD is a highly effective, easily implementable and fool-proof device to solve the destructive problem of flooding with future applications in underground bunkers and encampments.

Mission Folder: View Mission for 'HydroPhysics'

State
Illinois
Grade
8th
Mission Challenge
Environment
Method
Engineering Design Process
Students

Legofan29
DaBoss9000
CURRYMAN

Team Collaboration

Uploaded Files:

- [**View**] **TeamCollaboration_HydroPhysics** (By: Advisor, 03/01/2015, .pdf)

  Description of Team Collaboration. File name: 01TeamCollaboration_HydroPhysics

(1) Describe the plan your team used to complete your Mission Folder. Be sure to explain the role of each team member and how you shared and assigned responsibilities. Describe your team's process to ensure that assignments were completed on time and deadlines were met.
See attached file 01TeamCollaboration_HydroPhysics.pdf

Engineering Design

Uploaded Files:

- [**View**] **02-01Question1** (By: Advisor, 03/01/2015, .pdf)

  Response to Engineering Design Process 02-01Question1
- [**View**] **02-01Question2** (By: Advisor, 03/01/2015, .pdf)

  Response to Engineering Design Process 02-01 Question 2
- [**View**] **02-01Question3** (By: Advisor, 03/01/2015, .pdf)

  Response to Engineering Design Process 02-01 Question 3
- [**View**] **02-02-1Question1** (By: Advisor, 03/01/2015, .pdf)

  Response to Engineering Design Process 02-02-1 Question1
- [**View**] **02-02-2Question2** (By: Advisor, 03/01/2015, .pdf)

  Response to Engineering Design Process 02-02-2 Question 2
- [**View**] **02-02-3Variables** (By: Advisor, 03/01/2015, .pdf)

  Response to Engineering Design Process 02-02-3 Variables
- [**View**] **02-03-1 Pictures_HydroPhysics** (By: Advisor, 03/01/2015, .pdf)

  Response to Engineering Design Process Question 02-03-1
- [**View**] **02-03-1Question1_HydroPhysics** (By: Advisor, 03/01/2015, .pdf)

Response to Engineering Design Process Question1 02-03-1

- [**View**] **02-03-2Question2** (By: Advisor, 03/01/2015, .pdf)

  Response to Engineering Design Process 02-03-2Question2

- [**View**] **02-03-2 Pictures** (By: Advisor, 03/01/2015, .pdf)

  Response to Engineering Design Process 02-03-2 Pictures SAP Experiment

- [**View**] **02-04-01Question1** (By: Advisor, 03/01/2015, .pdf)

  Response to Engineering Design Process Question 02-04-01

- [**View**] **02-04-02Question2** (By: Advisor, 03/01/2015, .pdf)

  Response to Engineering Design Process Question2-Data Analysis

- [**View**] **02-04-03Question 3** (By: Advisor, 03/01/2015, .pdf)

  Response to Engineering Design Process 02-04-03Question 3-Errors

- [**View**] **02-04 Pictures** (By: Advisor, 03/01/2015, .JPG)

  Response to Engineering Design Process Question 02-04 Pictures AFD Final Cross Section

- [**View**] **02-05 Drawing Conclusions** (By: Advisor, 03/01/2015, .pdf)

  Response to Engineering Design Process Question 02-05 Drawing Conclusions

Problem Statement

(1) What problem in your community did your team try to solve? Why is this problem important to your community?

See attached file 02-01 Question1_HydroPhysics.pdf

(2) List at least 10 resources you used to complete your research (e.g., websites, professional journals, periodicals, subject matter experts).

See attached file 02-01 Question2_HydroPhysics.pdf

(3) Describe what you learned in your research.

See attached file 02-01 Question3_HydroPhysics.pdf

Experimental Design

(4) Develop a design statement. Be sure to describe what exactly your device should be able to do. Do not describe HOW it's going to do what it needs to do.

See attached file 02-02-1Question1_HydroPhysics.pdf

(5) Determine the criteria for a successful solution and identify constraints for your design. Discuss what the device must have in order to accomplish its job and the restrictions of the device (i.e. the size, the cost, the weight, etc.).

See attached file 02-02-2Question2_HydroPhysics.pdf

(6) Identify the relevant variables you will use to test your prototype or model and explain how you will measure your variables.

See attached file 02-02-3Variables_HydroPhysics.pdf

Build Prototype or Model

(7) Develop a design and list the materials you used in your design. Include technologies you used (e.g., scientific equipment, internet resources, computer programs, multimedia, etc.).

See attached files:
02-03-1 Pictures_HydroPhysics.pdf
02-03-1Question1_HydroPhysics-materials.pdf

(8) Explain how you built your prototype(s) or model(s)? Include each of the steps in your process.

See attached files:
02-03-02 Pictures SAP Experiment No.7_HydroPhysics.pdf
02-03-2Question2-howbuiltmodel_HydroPhysics.pdf

Test Prototype

(9) Describe the data you collected and observed in your prototype testing (use of data tables, charts, and/or graphs are encouraged).
See attached file 02-04-01Question1- Datacollection_HydroPhysics.pdf

(10) Analyze the data you collected and observed in your prototype testing. Does your data support or refute your design statement? Do not answer with yes or no. Explain your answer using 'Our data supports/refutes the design statement because...'
See attached file 02-04-02Question2-DataAnalysis_HydroPhysics.pdf

(11) Explain any sources of error and how these could have affected your results
See attached file 02-04-03Question3-Errors_HydroPhysics.pdf

Drawing Conclusions

(12) Interpret and evaluate your results and write a conclusion statement that includes the following: Describe what you would do if you wanted to retest or further test your design. Evaluate the usefulness of your prototype or model. What changes would you make to your prototype or model for the future, if any?
See attached file 02-05DrawingConclusions_HydroPhysics.pdf

Community Benefit

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- [**View**] **Community Benefit** (By: Advisor, 03/01/2015, .pdf)

Description of project's benefit to the community

(1) How could your design help solve your problem and benefit your community? Describe next steps for further research/design and how you have or how you could implement your solution in the future.
See attached file titled, 03CommunityBenefit_HydroPhysics.pdf

Mission Verification

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- [**View**] **Abstract** (By: Advisor, 03/01/2015, .pdf)

Response to Mission Verification Question 3: Abstract

(1) Does your Mission Folder project involve vertebrate testing, defined as animals with backbones and spinal columns (which includes humans)? If yes, team must complete and attach an IRB.
No
(2) Did your team use a survey for any part of your project? If yes, team must complete and attach a survey approval form.
No
(3) You will need to include an abstract of 250 words or less. As part of the abstract you will need to describe your project and explain how you used STEM (Science, Technology, Engineering and Mathematics) to improve your community
See attached file "Abstract_HydroPhysics.pdf"

Our team, comprising of three 8th grade students, was well prepared when facing the task of roles and responsibilities. We strove for excellence with weekly meetings, a planned calendar of the upcoming months, and homework. These tactics were certainly an aiding factor to our team's progress and skill.

BUILDING CONSENSUS

At the start of the process, the team arrived at multiple potential problems for investigation and research. We created the factors we felt, as a team, were most important to us in the process of having fun together as a team experimenting and designing a product.

After comparing the Engineering Design Method to the Scientific Inquiry method, we agreed as a team that we will have more fun creating a product design and pursue the track of creating experiments to test the engineering design.

We created a multi-variate analysis matrix to rank our interests in various topics. We believed that agreeing and building consensus was important to keeping our enthusiasm high.

Possible ideas we researched:

- Wheelchairs that climb stairs,
- Motors that generate electricity from flowing flood water
- Preventing basement flooding in our local community
- Upcycling and recycling uses for old plastic bags
- Ergonomic shoe for seniors

Ranking characteristics

- Feasibility
- Tangibility
- Measurability
- Specificity (able to narrow down the design)
- Overall Fun factor opinion

We learned that using this process to drive cooperation and agreement was fun and useful!

PLANNING AND PROCESS

Each week, one of our members would hold a 2-hour meeting in their house. Each meeting would have been planned in advance, with a designated plan and schedule for that day. Usually, at the beginning of the meetings, we would present our homework to each other and begin with the day's plans. The homework often influenced the shape of the rest of the meeting. Our team would work out a plan for what we would research, experiment with, or test out during the meeting. At the end of each meeting, our team would assign each other homework to complete over the span of the next week to be ready for the upcoming meeting.

The homework often consisted of research, or having someone delve deeper into a topic than we could have done in our meeting. The weekly homework assignments were effective, and allowed us to progress through our project with much more velocity. To check up on our progress regarding the homework, we would often set up small 1-hour meetings during the week.

These meetings wouldn't actually be meetings - they were just conference calls. During the calls, we would often open up a shared google doc and work on it together. These calls were quick but also helpful - they let us coordinate our findings, work, and data with ease.

At the beginning of our project, we strove to set deadlines and a solid schedule for our the upcoming months. This layout was a simple chart, which plotted out our goals, and how we would achieve them. At first, it seemed tough to meet these goals in time, but as we progressed through, we got the hang of meeting our deadlines. This chart put our project into perspective, and gave us an idea of the time factor involved in the eCybermission competition.

BUILDING AND TESTING

We built things together. Using a saw, using glue on PVC, shopping for pipes and accessories and creating and making experiments was collaborative. Presentations to the Mayor of The Village of Lisle and the CETCO engineers and scientists were planned in advance with powerpoints and each of us picking assigned roles for sections of the project.

This has been a great team building exercise helping us build confidence in ourselves as a team.

What problem in your community did your team try to solve? Why is this problem important to your community?

Heavy rainfall and resulting flooding devastates homes and disrupts activities, especially in our community, causing flooded basements and millions of dollars in property damage. This has been a major problem for some time, but last year it expanded to hundreds of homes experiencing massive property damage. The increase in the frequency of 100-year storms in our community in the past 5 years is drawing significant attention amoung meteorologists, who believe that the current conditions will continue, if not grow worse.

3-Inches-Plus Storms in the Midwest							
	Trend in Annual Values 1961-2011	Average Changes by Decade Compared to 1961-1990					Top 10 Years 1961-2011 and Flooding Disasters(*)
		1961-1970	1971-1980	1981-1990	1991-2000	2001-2010	
Frequency of 3-Inches-Plus Storms	+103%	-14%	-3%	+17%	+20%	+52%	(1) 2008* (2) 1993* (3) 1982* (4) 2010* (5) 2011* (6) 2007* (7) 2000* (8) 2004* (9) 2002* (10) 1961* 7 in this century
Return Period (in years)	-	3.8	3.4	2.8	2.8	2.2	-
Amount of Precipitation from All 3-Inches-Plus Storms	+108%	-14%	-3%	+17%	+20%	+55%	(1) 2008 (2) 1993 (3) 1982 (4) 2010 (5) 2007 (6) 2011 (7) 2002 (8) 1986 (9) 1998 (10) 2004 6 in this century

Chart 1 rockymountainclimate.org
This chart shows the frequency and amount of increased precipitation of 3-Inches-Plus-Storms in the Midwest. The top 10 years of flooding disasters are also depicted.

We found numerous direct techniques to prevent basement flooding during heavy rains or power outages. The three most popular solutions are sump pumps, backup sump pumps, and backup power (i.e. battery backups and generators). In addition there are numerous other “quick-fix” techniques to abate basement flooding, however quick solutions are often overly-flawed. While there are alternative products, we have found that each has significant disadvantages. Sump pumps and backup sump pumps are not reliable enough, especially during a power outage. While many may say that backup power has numerous advantages, the disadvantages far outweigh the advantages. Backup power devices usually have a lifespan of about ninety minutes to maybe a few hours. Though many homeowners have generators in their garages that they can hook up to their sump pump, when residents go on vacation, an individual is still required to connect the generator. This causes constant anxiety and stress during travel. Consequently, many homeowners don't relax on vacations. Prices of generators with automatic transfer switches are exorbitantly high. In the field of flooding, a device, which doesn't require energy, and will effectively and reliably prevent water from entering, is astonishingly absent.

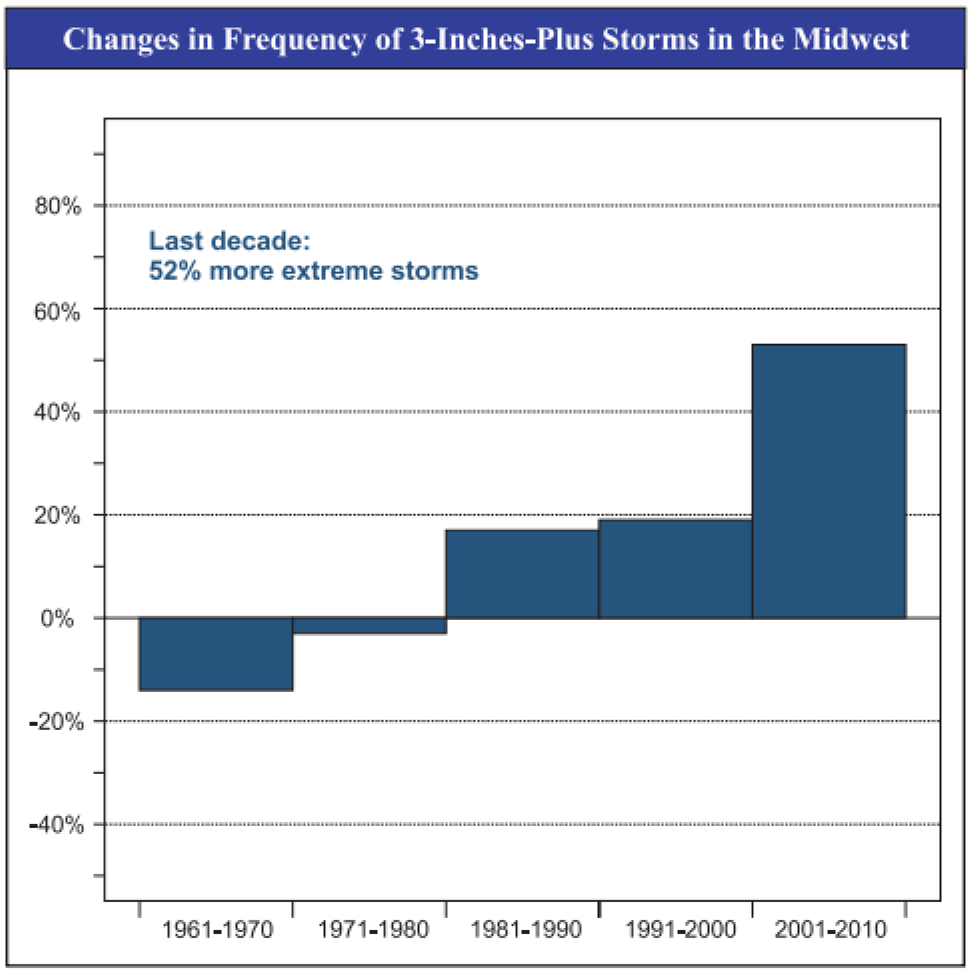

Chart 2 rockymountainclimate.org
This chart shows the changes in frequency of 3-Inches-Plus Storms in the Midwest.

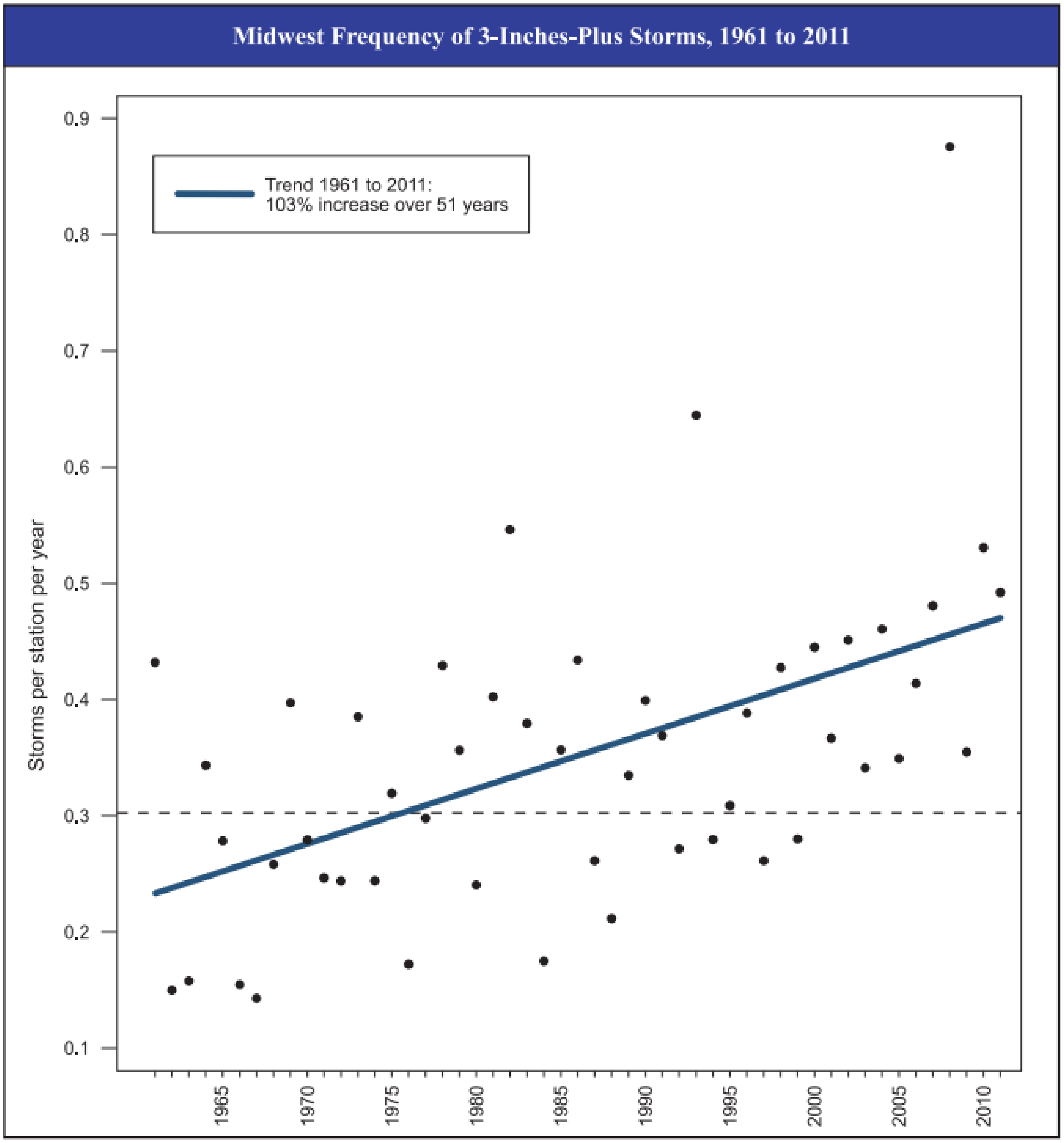

Chart 3 rockymountainclimate.org

This scatter plot shows the frequency of storms in the Midwest in storm stations.

List at least 10 resources you used to complete your research (e.g., websites, professional journals, periodicals, subject matter experts).

Intro

In our overall project, we used a variety of resources, from internet web pages to professional scientists. These resources proved valuable and elicited massive change in our project, and altered the course of our experiment many times over. In addition, our resources were drawn from a variety of sundry sources, which aided us with the assurance of trustworthy and in-depth information. We were always sure to double check if the data we were receiving from a source was 100% accurate and used foolproof methods to determine this.

Resources:

- ChatStep
- Sketchup
- PowerPoint
- Google Documents and Drive
- Google Hangouts
- USGS website
- NOAA website
- The Plumbing Info
- Basement Systems
- Physics Net
- http://www.rockymountainclimate.org/images/DoubledTroubleHigh.pdf
- Saunders, Stephen, Dan Findlay, and Tom Easley. "DOUBLED TROUBLE."*MORE MIDWESTERN EXTREME STORMS* (2012): 1-20.*Rockymountainclimate*. The Rocky Mountain Climate Organization, May 2012. Web. Jan.-Feb. 2015.
- www.reliabledrain.com
- Microsoft Word

While these were some of the internet resources we used, we also consulted a variety of scientists and even an official waterproofing company.

- Professional Architect, Ramu Ramachandran
- Certified Mechanical Engineer, Sumit Ray, PE - to understand basement water mechanics, basement pressures, water column weight, area, pressure at base, hydrostatic pressure.
- Certified Polymer Scientist, Udayakumar Bettakeri
- Manufacturing engineer and entrepreneur, Shailendra Verma
- Commercial waterproofing company, CETCO
- Village of Lisle officials: Marilyn Sucoe (stormwater engineer), Joe Broda (mayor), Tim Callahan (building official)
- Technical Bulletin 10-01

Although these are not all of the resources we used throughout our project, these are the primary ones that affected us the most. Without these we wouldn't be very far in our project.

In the next document, these resources will be explained thoroughly, our learnings will be revealed.

Describe what you learned in your research.

In our research, we learned about a multitude of things, from recycled plastic bags to automatic wheelchairs. While some of these were for our initial research for finding a viable topic, most of our research was centered upon the vast topic of basement flooding. Even within the allotted time, we were able to obtain and base conclusions on a large amount of information.

Udayakumar Bettakeri: When first researching high-absorbent polymers for our design, we decided to get our data straight from the source. We talked to a professional scientist, with a Major in bio-chemistry, about the different types of absorbent polymers. By the end of the call, our hopes had inflated. He said that although SAP's (super absorbent polymers) couldn't be reused, they are a hot topic in the economy at this moment, and show much promise if integrated into our experiment.

Sumit Ray: Sumit was one of the first professional scientists to give us input for our project. Without even thinking twice, this professional engineer okayed our project and assured us that the idea was solid and contained a lot of value.

Shailendra Verma: He was a very valuable asset in helping us with our calculations. Without him, we wouldn't have known the very basis of the rules of water pressure, and would have been struck down by our lack of knowledge.

Ramu R: From him, we learned a lot about teamwork and how to effectively get along with our teammates. In addition, he just gave us some overall data on the structural efficiency of a building and its leaking point. This information was priceless in helping us understand the layout of a basement, and it let us formulate the beginnings of our project. He also introduced us to the engineers at CETCO, a company with a strong focus of building waterproofing, advanced material sciences and research.

Cetco Meeting: The meeting with Cetco was definitely one of our most influential meetings in the whole project. Prior to this, we had some doubts about the materials and their capacities.

The meeting with Alex Labus and Kent Handler debunked a variety of myths that had formulated in our minds. For example, we were unsure about the strength of the basement walls, and the amount of pressure they would hold up to. But the meeting with Cetco confirmed that as long as the house was built in the last 50 years, the basement walls could withstand massive amounts of pressure. It was then almost certain that we had come to the correct place. They also confirmed our project, saying it was highly plausible, full of promise, and with a few minor modifications it could transform from a good idea to an amazing reality. While sitting down and discussing our project with them, they showed us some samples of their many waterproofing technologies. These waterproofing technologies were inserted directly between iron spikes driven into the ground and a vertical layer of concrete. Even this sample strip of waterproofing contained multiple layers comprising of Bentonite Clay, SAP, and air pockets. During our visit, we were also able to get a tour of their R&D lab, which was absolutely amazing. They showed us some of the products they made with SAP and Bentonite Clay, from kitty litter to commercial oil and water separators. In addition, they gave us access to their R&D lab. They showed us some amazing chemical reactions with SAP and Urethane. In addition, they even took time to explain each reaction so that we could easily understand the chemistry behind them. This display was truly awe inspiring to us, and it inspired us to continue on in our experiment. It was a great experience!

Village of Lisle meeting: In our meeting with the Village of Lisle, we discussed our project, and how it could be directly and properly implemented into the village. With them, we learned all about the different ways how our community has helped us with flooding. They have created designated areas called floodplains, and have assigned special rules for each different sector. These rules help to ensure and regulate flooding in these dangerous and arbitrary areas. In addition, they have compiled significant amounts of information on avoiding property damage with flooding, like ensuring your basement is safe from flooding. These small tips add onto their compilation of the community's flooding insurance. With all this information, a strong and steady background was built up and bolstered.

<u>Develop a design statement. Be sure to describe what exactly your device should be able to do. Do not describe HOW it's going to do what it needs to do.</u>

Our design was created to eliminate the risk of water flooding a basement through a sump pump pit.

When there is a power outage during a heavy rain, and sump pumps are no longer workable or their batteries are drained, the following scenario usually plays out:

The water level in the soil surrounding the house begins to rise. The drain tile around the house basement picks up the water and brings it into the sump pit. ***The water, in attempting to find its own level, will start filling the sump pit and eventually overflow and flood the basement.***

If we were successful, this design will be able to:

- Act without a reliance on electricity- whether main or backup.
- Allow the water to reach the same level as outside the house, but contain this water, keeping it from entering the basement.
- Effectively act as a plug to the sump well.
- Change the state of some of the water to use as weight to make a stronger seal
- Use possible water absorbent materials to reduce chance of leakage

We wish to call our final product the ANTI-FLOOD DESIGN or AFD

The purpose of the AFD is to prevent water from entering houses through the sump pit.

When fully implemented, it has the potential to save millions of dollars by preventing the property damage associated with floods, and it can offer a fool-proof, non-electricity based way to cease the dangers of flooding in the residential sector.

Lastly, the device should allow the harnessing of floodwater for personal use, such as watering plants, or studying the outside water for scientific purposes.

Q: Determine the criteria for a successful solution and identify constraints for your design. Discuss what the device must have in order to accomplish its job and the restrictions of the device (i.e. the size, the cost, the weight, etc.).

We used several criteria to help us develop the design of our prototype. While some of them helped us design the AFD shell, some others helped us choose related materials like fillers and seals. We observed that some are performance of design items while others were related to how easy it was to build or construct at home.

PRODUCT PERFORMANCE CRITERIA

- Capacity of product to hold water (Water-proof, durable, strong)
- Capacity of base of product to retain water (Sealant at base)
- Capacity of filler material within the product to absorb water (Absorbency, Super-absorbency)
- Capacity to strengthen seal by adding weight to assembly
- Speed of absorption (Time to absorb to full capacity)

PRODUCT DESIGN AND CONSTRUCTION CRITERIA

- Easily assembled within a basement
- Transportability (lightweight)
- Easily available materials
- Simplicity/complexity
- Easily available materials
- Non-toxic if using water-absorbing chemicals
- Cost-effective - less than $100
- Functionality (experiment vs. calculations)
- Clean and neat looking
- Limited by height of basement
- Diameter at base = size of sump pit approximately 18 inches
- Sustainability
- Upcycle at end of design life

Q: Identify the relevant variables you will use to test your prototype or model and explain how you will measure your variables.

The following variables were integrated into our experiments. These heavily influenced the outcome of our project, and have changed over time as we improved upon our designs.

INDEPENDENT VARIABLES:

- Capacity of filler material within the product to absorb water (Absorbency, Super-absorbency). This refers to the type of SAP (Super-Absorbent Polymer). Types of SAP are differentiated based on their capacity to hold water as measured on the basis of both weight and volume, and the time to absorb.
- Design of AFD - Shape decides Volume
- Materials of design of AFD - Material choice decides weight and this impacts the PRESSURE that the of final assembly will exert on the sealant at the base of the assembly.
- Choice of sealant - impacts effectiveness of seal

DEPENDENT VARIABLES:

- Weight after water is absorbed
- Volume after water is absorbed
- Time for complete absorption
- Pressure on seal at base of ring (based on both volume/weight of water+SAP combination and the resulting force on the bead of sealant at the base of the assembly

OTHER EVALUATION CRITERIA:

- Effectiveness/functionality (potential to fulfill all of the criteria) of the AFD
- Capacity of product to hold water (Water-proof, durable, strong)

See next page for MEASUREMENTS

VARIABLES DETERMINED BY EXPERIMENTAL MEASUREMENTS

- Absorptive capacity of SAP - WEIGHT
  - This is a ratio we called ***WEIGHT ABSORPTION EFFICIENCY OF SAP***
  - It is meant to show how effective each different SAP is in terms of how much water weight it is able to absorb compared to its own dry weight.
  - It is stated as Wg/Ws
  - Which is Weight of Gel (Wg) / Dry Weight of SAP crystals/powder (Wd)
  - Where, Wg = Weight of SAP including the weight of water it has absorbed as it turns into a gel
  - Measured in grams (g) using a weighing scale calibrated to tenth of grams.

- Absorptive capacity of SAP - VOLUME
  - This is a ratio we called ***VOLUME ABSORPTION EFFICIENCY OF SAP***
  - It is meant to show how effective each different SAP is in terms of how much volume of water it is able to absorb compared to its own dry volume. This shows us its expansion potential and informs us as to how much SAP needs to go into the absorption chamber in final product design.
  - It is stated as Vg/Vd; =Volume of Gel (Vg) / Dry Volume of SAP (Vd)
  - Final Vg is measured in Milli-Litres (mL) of volume using graduated cylinders and beakers.
  - How do we measure a volume of a gel that can be suspended in water?
  - To measure volume, a water displacement technique is used due the fact that the final SAP, after absorbency, is sometimes a gel and sometimes a partially crystallized gel
  - i.e., Vol. of Gel (Vg) = Total Volume (Vt) - Volume of water added (Vw)
  - This determines the maximum holding capacity in a given volume of the AFD design.

- Speed of Absorption - The time it takes for different SAPs to absorb the same amount of water measured using a stopwatch set to tenth of seconds.

VARIABLES DETERMINED BY THEORETICAL or CALCULATED MEASUREMENTS

- Maximum holding weight in given volume
  - Total Weight (Wt) = Weight of SAP/Water gel (Wg) + Weight of AFD product (Wp)
  - Wt = Wg + Wp; stated in Kg

- Pressure on base seal
  - Pressure = Weight / Area; Stated in psi
  - Weight = Volume of Water in AFD x Density of Water; Stated in Pounds

- where, Area = Area of flange of AFD in contact with floor through the use of a plumbers putty. Measured in Square Inches.

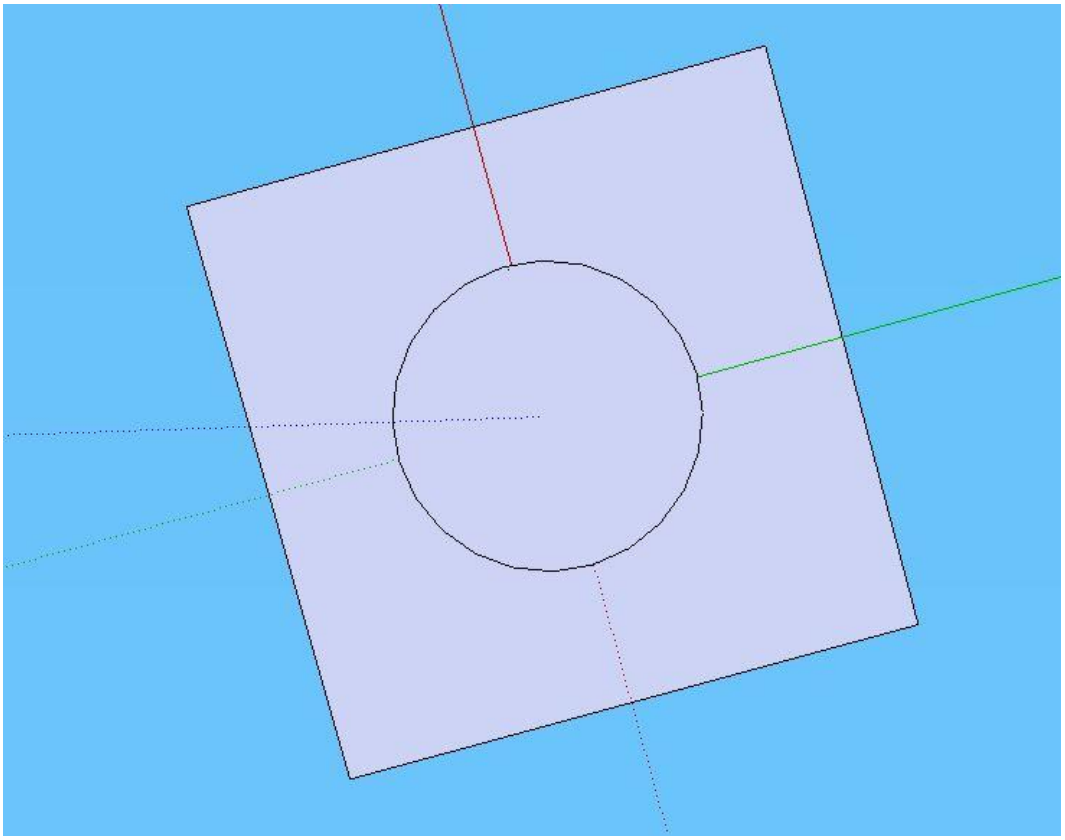

Figure 1 Bottom angle of a sump pit.

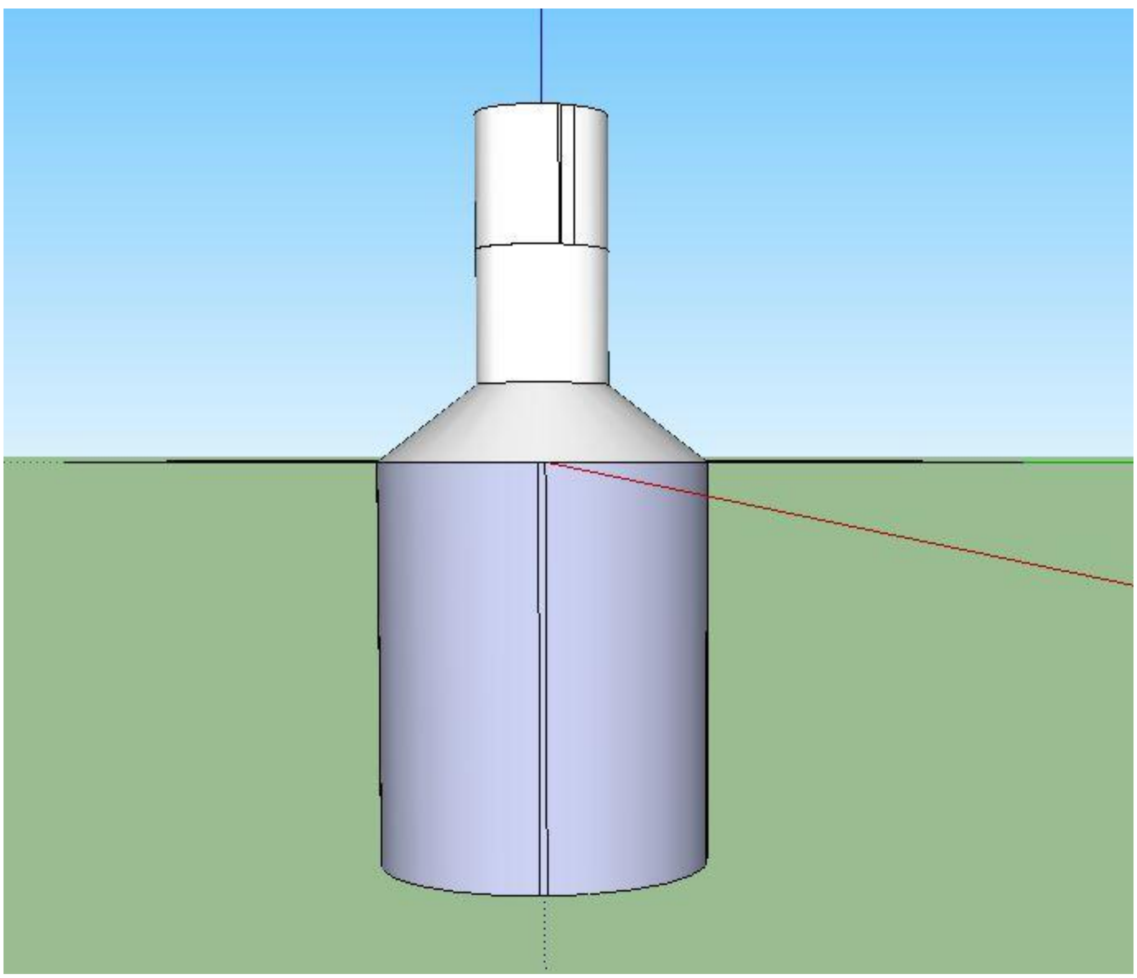

Figure 2 Side View of Design on Sump Pit

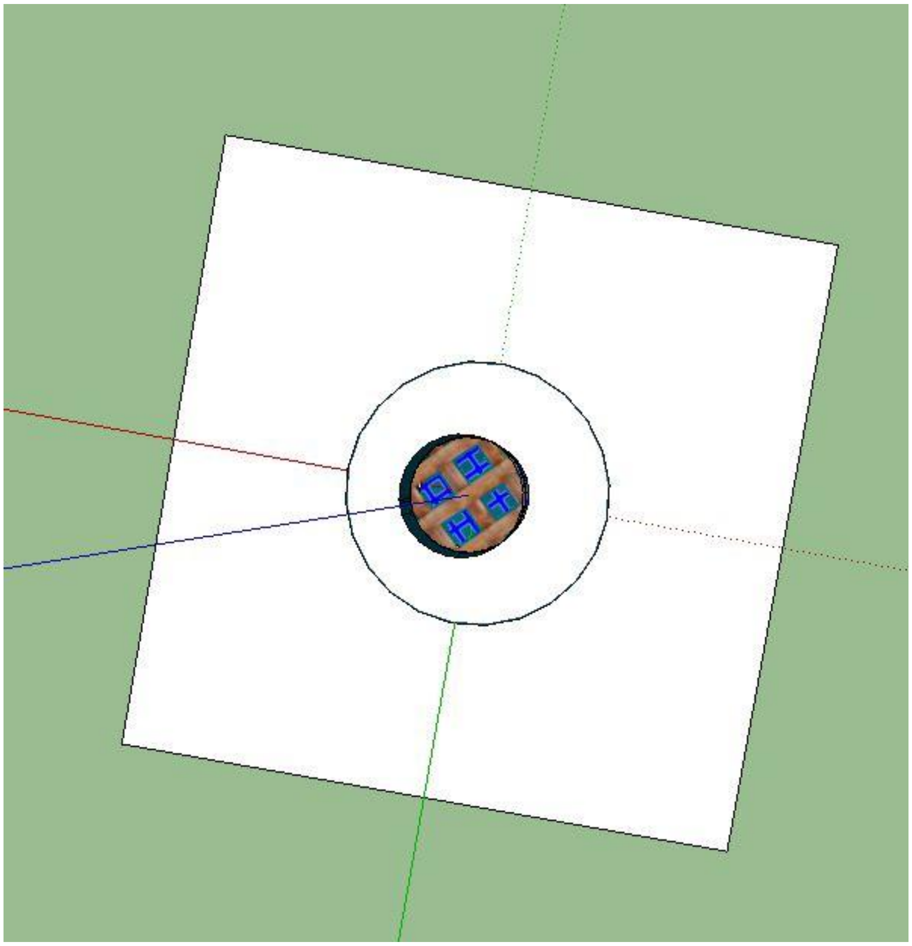

Figure 4 Top View of Design

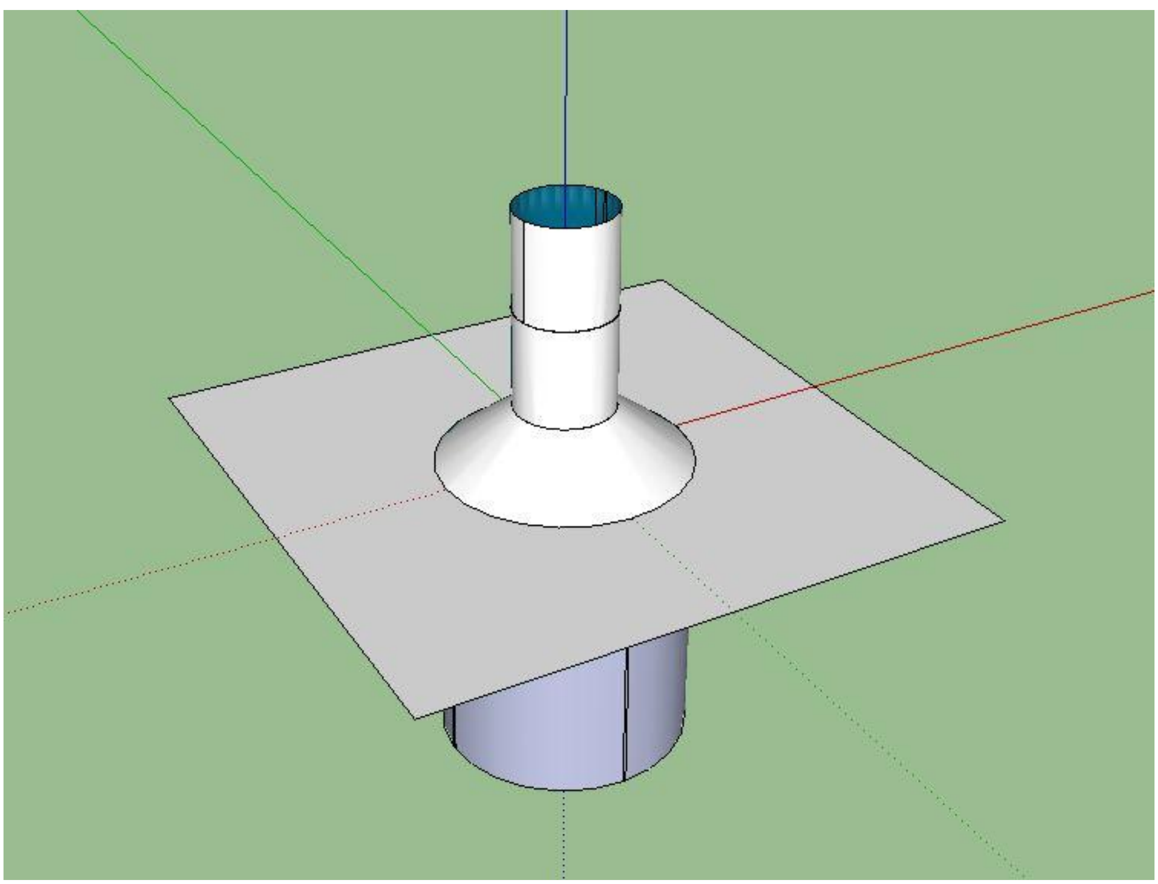

Figure 3 Top Angle of Design

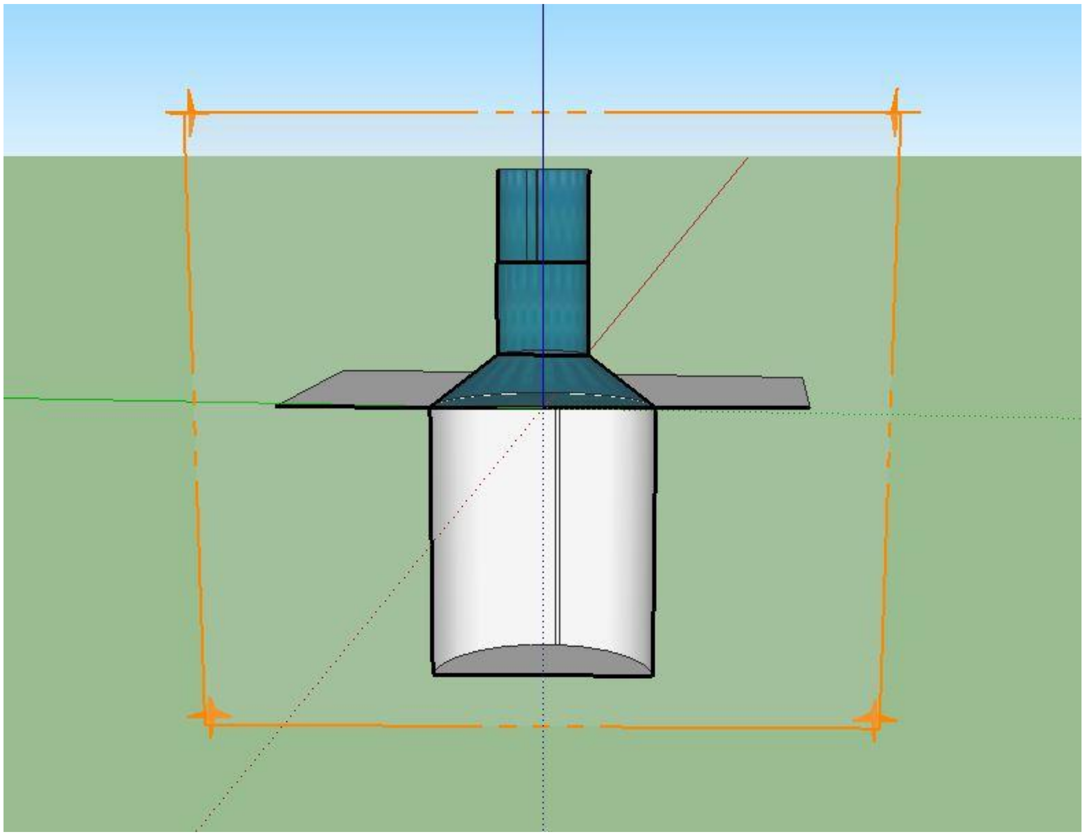

Figure 6 Side Cross-Section of Design

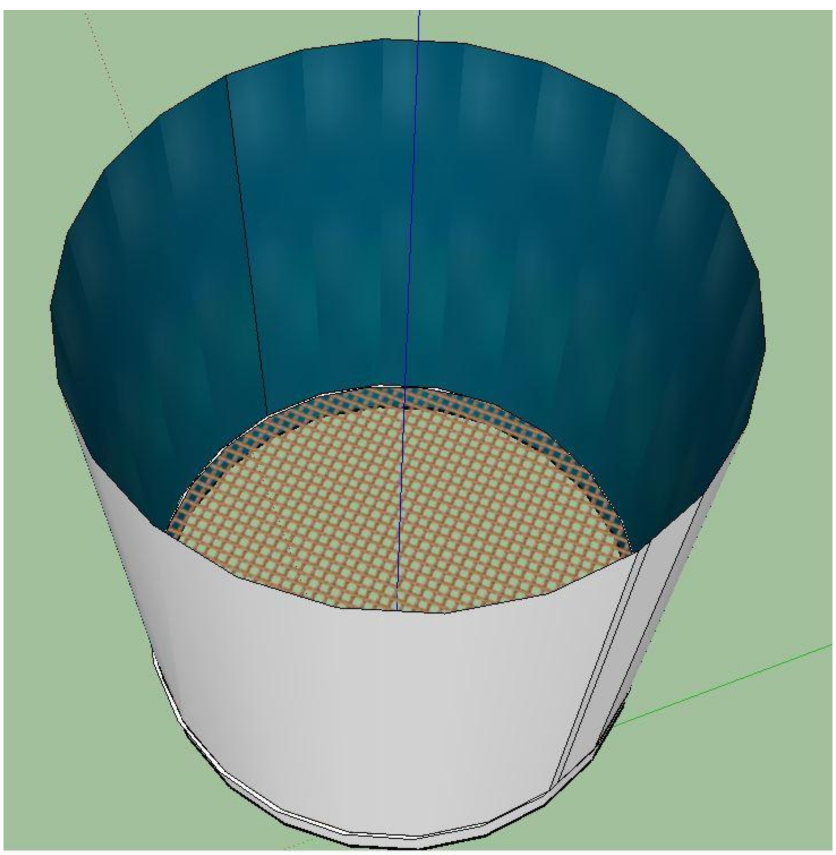

Figure 5 Top Chamber of Design

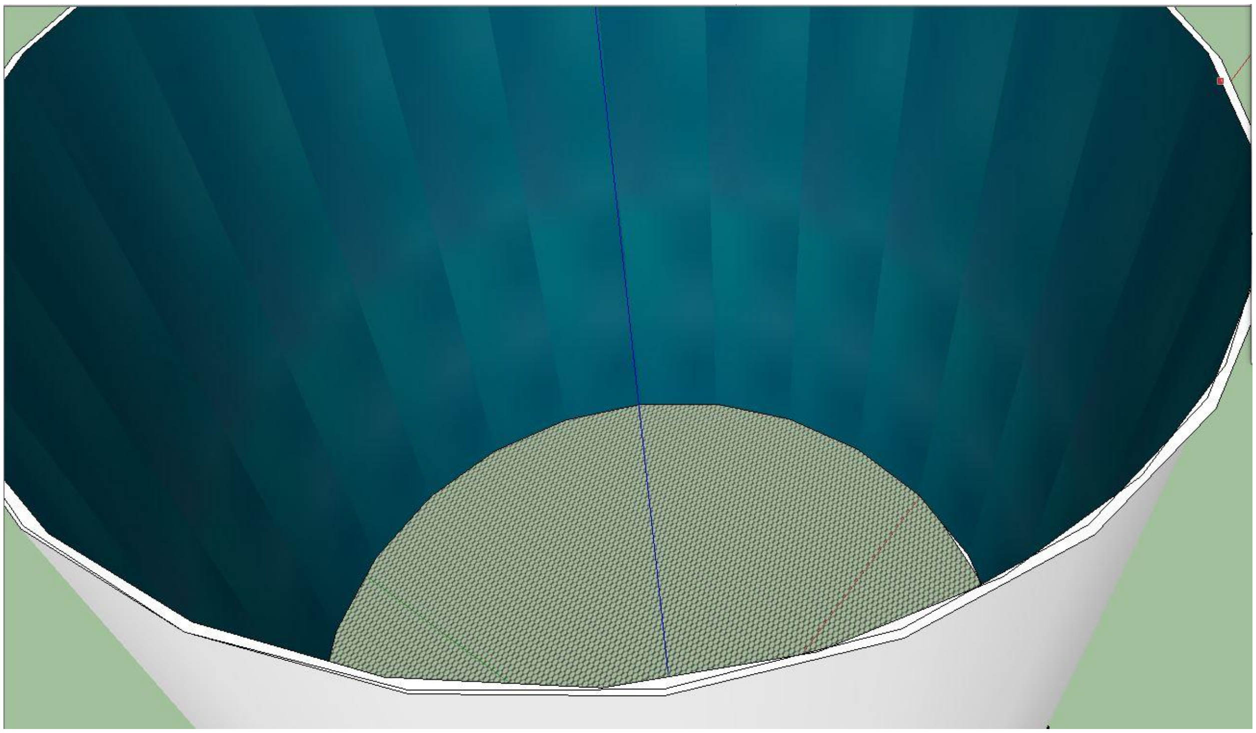

Figure 7 Lower Chamber of Design

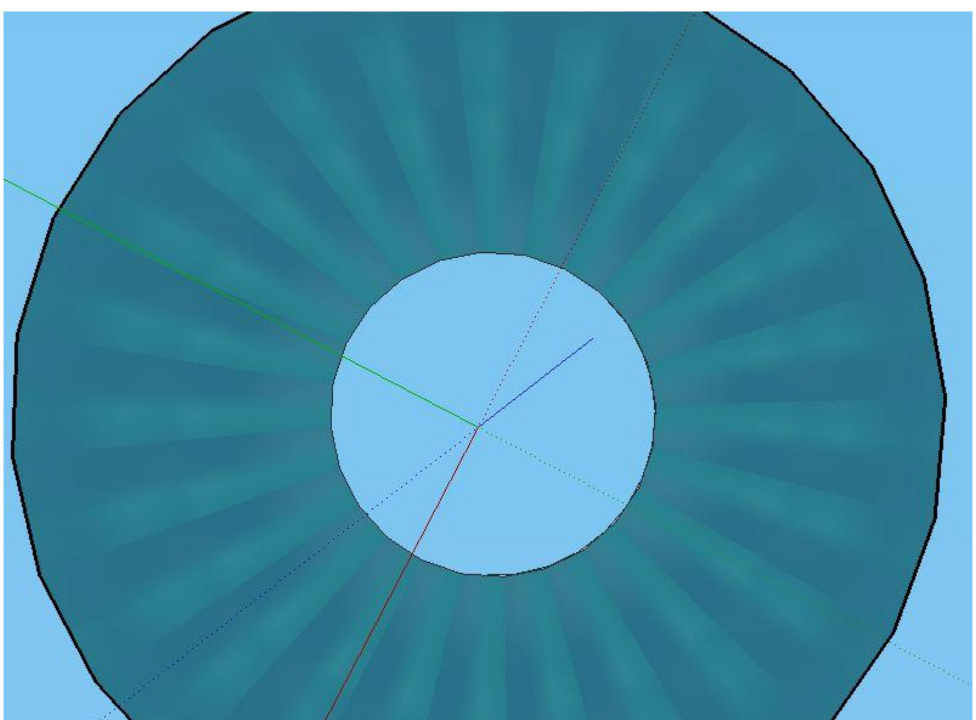

Figure 8 Water Containment Chamber

Q: Develop a design and list the materials you used in your design. Include technologies you used (e.g., scientific equipment, internet resources, computer programs, multimedia, etc.).

We looked at some of the key rules of water physics, and how water always tries to reach its same level. When we saw this, we realized that this simple rule could be easily applied to basements; rain water saturated in the soil surrounding the basement wants its water to reach the same level by filling up the basement to ground level. It will enter the basement through the sump pit, and instead of reaching its level by filling up the whole basement, it would only fill up a certain space (still reaching its level), but it would be contained by something like a cylinder.

We decided to use a funnel for many purposes. A funnel would allow us to effectively use a dual tube system, in which a filler absorbing substance could be easily incorporated. The inner tube would be directly connected to the lower chamber, and would have perforations leading to the outer tube. The outer tube would contain the filler material, and that material would add to the overall weight of the assembly. This weight would increase the efficiency of the seal that would be located between the assembly and the basement floor. With the seal now having two perpendicular forces acting upon it, it would definitely be more effective at keeping the water from leaking.

Charts:

	PVC	*Steel*	*Acrylic*
Lightweight	👍Y	👎N	👍Y
Durable	👍Y	👍Y	👍Y
Waterproof	👍Y	👍Y	👍Y
Rustproof	👍Y	👎N	👍Y
Transparent	👎N	👎N	👍Y
Easily workable	👍Y	👎N	👎N
Toxicity of Glue	👎N	👍Y	👍Y

	Bentonite	*SAP*	*Cotton*	*Sand*
Water Absorber	👍*Y*	👍*Y*	👍*Y*	👎*N*
Inexpensive	👎*N*	👍*Y*	👍*Y*	👍*Y*
Efficient	👍*Y*	👍*Y*	👎*N*	👎*N*
Expansion	👍*Y*	👍*Y*	👎*N*	👎*N*

	Plumber's Putty	*High Performance,High Capacity Industrial Seal*	*Commercial Seal*
Household Use	👍*Y*	👎*N*	👎*N*
High Strength	👎*N*	👍*Y*	👍*Y*
Reusability	👍*Y*	👎*N*	👎*N*

We chose PVC over metal, primarily because it was easy to work with, was relatively lightweight, durable, and rust+waterproof. In addition, we decided to use Plumber's Putty as the sealant. Although some commercial sealants would have been more effective at sealing the gap between the design and the floor, Plumber's Putty was reusable and did not pose as much of a safety hazard. But in a potential situation with a very deep basement, such as a large commercial project or even a military bunker, an industrial seal would easily survive the pressure.

When researching a filler material to reside in the outer tube, we came across a variety of natural and artificial absorbers. Through simple research, we narrowed the list down to Super Absorbent Polymers(SAP), Cotton, Sand, and Bentonite clay. The most effective (by far): SAP. It, in some variants, absorbed up to 90 times its own mass! After conducting a massive experiment on all the SAP's we had received from a valuable asset, we decided to use a combination of 2 different SAP's. We would use Poly-acrylamide Co-acrylate for the top layer, because it absorbed slowly, but absorbed large amount of water. On the bottom of the design, we would use a faster-absorbing SAP, the simple but effective Sodium Polyacrylate.

We have mentioned the variety of resources that we used in an earlier section of the mission folder. However we would like to reiterate the usefulness of particularly two resources. Firstly, Sketchup was instrumental in allowing us to visualize the form and the design of our experimental product and communicate to experts and city officials during our meetings. Secondly, our meeting with CETCO officials reaffirmed our experimental design and exposed us to various polymers that were super useful to our process.

Resources:

- Sketchup
- PowerPoint
- Google Documents and Drive
- Google Hangouts
- USGS website
- NOAA website
- The Plumbing Info
- Basement Systems
- Physics Net
- http://www.rockymountainclimate.org/images/DoubledTroubleHigh.pdf
- Saunders, Stephen, Dan Findlay, and Tom Easley. "DOUBLED TROUBLE."*MORE MIDWESTERN EXTREME STORMS* (2012): 1-20.*Rockymountainclimate*. The Rocky Mountain Climate Organization, May 2012. Web. Jan.-Feb. 2015.
- www.reliabledrain.com
- Microsoft Word

While we had a long list of resources on the internet as well as in real life, we also had to test out our complete experiments with some scientific measuring tools. These we did not have access to in our houses, especially the precise weighing scales or graduated cylinders. We located the scientific equipment in our school and, upon receiving permission from the teachers, retrieved the equipment from our teacher for a weekend and a day.

- Flinn Scientific Electronic Balance, 300 x 0.1-g
- Flinn Scientific Graduated cylinders
- Dry Measurement Kitchen Spoon

Explain how you built your prototype(s) or model(s). Include each of the steps in your process.

All of our prototypes included PVC tubes, putty or sealant, and PVC glue. In addition, all of our models included a Super-Absorbent Polymer, which helped the putty keep the water from leaking.

We built the first model of the anti-flood design (AFD) out of inner and outer PVC tubes, a PVC coupling, putty, PVC glue and a cap on the underside.

In order to build the AFD models, we had to stick a PVC pipe (ours was 6” tall, with an inner diameter of 2 1/16”) onto a base (ours was funnel-shaped). In our first experiment, we used a cap on the underside of the funnel, and attached a thinner PVC tube to the cap. In the second model, we put the cap at the same level as the inside of the base (see *Figure 1: funnel caps*).

KEY:

EX1	EX2	EX3	EX4	EX5	EX6	EX7
Theoretical simulation	1st Prototype funnel design	2nd Prototype funnel design	Water Pressure Test	Water Pressure Test #2	Seal Test - Search for Minimal Leakage	SAP experiment

Although some of our experiments had more qualitative aspects of data than quantitative, we will still describe the data collected from our 7 experiments.

Experiment 1:

Our first idea was to have a simple model to represent the flow of flooding from a river. We believed that we could create this simulation and develop a solution based on the flooding of a body of water. This experiment would include only very basic materials, such as; a water jug, some piping, the bottom of a water bottle, and some spare cardboard. We were satisfied with the setup, believing that it contained all the necessary elements to portray a success or failure of our idea. But after consulting others on our team and some scientists, we decided to switch to a more-feasible problem; flooding in the residential sector. In the long run, this experiment may not have had a major effect, however it was a useful exercise and helped us get ready to start our "real" experiments.

Experiment 2:

After multiple trips to different local hardware stores for the different parts of our experiment, we finally started to put together what was the first model of the Anti-Flood Design: the funnel.

The funnel comprised of inner and outer PVC tubes, a PVC coupling, putty, and a cap on the underside.

It was constructed of a PVC coupling, cap, and two different sized tubes. To connect and seal these together, we used Gorilla PVC glue. As you can see in the pictures, this first model of the AFD contained a cap on the underside of the funnel with a small hole drilled in it. This would allow the water to enter the inner tube. Once the water filled the inner tube to a certain level, two small holes, acting like perforations, would let the water into the outer tube.

The outer tube's purpose was to add more weight to the device, both by existence, and by harnessing the weight of the water into strengthening the putty. This turned a potential disadvantage into an advantage. By adding more force from above, the putty would be more effective. But unfortunately, we hadn't compensated for the air, which was trapped in the area of the funnel outside the cap on the underside. This trapped air acted as a flotation device for our assembly while it was submerged underwater, promptly tipping it over with its own buoyancy. While this in itself was a failure, the rest of the project appeared to have worked. Once replacing the assembly in the water sideways, the trapped air had been replaced by water. We continued our experiment with high hopes. Other than the air trapping issue, our overall second experiment was a useful learning experience, as the funnel trapped the water inside itself without letting it overflow.

Experiment 3:

This experiment was, in actuality, a success. 

Figure 1: funnel caps

In fact, the funnel experiment was redesigned to ensure maximum effectiveness. We got rid of the cap, and avoided the cavity where air would be trapped (See *Figure 1: funnel caps*). Without the cap, we theorized that the buoyancy wouldn't be enough to compromise the experiment, and we were right. In addition to changing the design, we also remodeled the simulation, using a plastic box to simulate the basement, and a larger box to simulate the outside water level. And we even colored the water entering the funnel, so you could see its level inside the funnel, or if any leaked from beneath the seal. From here, it seemed like an unflawed experiment. But unfortunately, we were unsure about whether the water pressure on the sides of the basement would build up. We had received many questions regarding the design itself, and whether the water pressure would be enough to override the leveled water inside the funnel and make water come gushing out like a funnel. So to summarize, this experiment confirmed that the design would be able to hold water without leaking, however it also raised more questions related to water pressure.

Experiment #4

This experiment contained major flaws that we needed to fix. While it would end up disproving one aspect, it would also show one of the major faults in another. We started this experiment by filling up a massive tub with water (see exact dimensions in **Data Collection**), and adding food coloring to it so that the water could be easily discerned. Then, we proceeded by placing our inner basement simulator into the water and added putty as a sealant. This experiment was solely meant to disprove the popular myth that high water pressure would cause water to spurt out of the funnel like a geyser. Unfortunately, although water did not spurt upwards, it did contain enough pressure to break through our seal. The leak in the seal grew fast, and in little time, compromised our experiment. Although this small error was a major and time consuming setback, it forced us to reconsider our current experimental plans and delve deeper into creating a strong seal.

Experiment #5

This experiment was an attempt at addressing and fixing the flaws in experiment 4. Since experiment 4 was a failure, we decided to redo the experiment, thinking that it wasn't the idea that was at fault, but rather the putty application. Therefore, we meticulously applied the putty, with a few grooves to help it firmly stick to both surfaces. This experiment was successful, and it showed us that our theory on water reaching the same level was accurate. Since the volume of water on the outside of the "basement" was much greater than that of the AFD, our theory maintained that the water wouldn't overflow into the basement, because it wouldn't go any higher than the water on the outside. However many people whom we consulted said that the water pressure would cause it to "spurt out" of the AFD, and into the "basement." Our experiment showed that this was not true, and the water would not be any higher inside the AFD than the level of water outside, regardless of relative volumes.

Experiment #6

The putty experiment was simply an experiment designed to test and find the best seal we could. We tried some ideas we had thought of previously, like putting a layer of SAP between two levels of putty. While the experiment was essentially effective in determining the best and most effective seal, it used a very similar setup to Experiment #5 and #4. The experiment consisted of the same setup with a large sized box simulating the outside of the basement and the small sized box simulating the basement itself. The primary difference was in the process of testing the seals against one another. Every time we would test the experiment with a different seal, to find the most effective seal. The smaller box had a hole drilled inside the bottom of it, simulating the sump pit, for water to enter the small box (basement). From there, the seal's design would effectively be tested, depending on whether or not it worked.

Experiment #7

In experiment #7, we tested a variety of SAP sample products against each other to discern the most effective and efficient absorber of the bunch. We would then use these in our prototype to add weight and make certain that no water would leak out. The construction of this experiment was simple: it consisted of a weighing scale, a variety of mugs and measuring tools, and the SAP itself. The measuring scale was almost always measuring one thing or another, whether it was a small collection of SAP powder, or a mug full of SAP-absorbed water. Once we put a measured amount of SAP in the mug, we would add water to it in increments of 50 mL. When the water was absorbed, we would add another 50mL. We would continue our experiment like this, noting down the amount of water we added. Once the SAP's capacity had been filled, we would measure its volumetric expansion through water displacement technique, and note the amount of water it absorbed in grams. See attached pdf "SAP Experiment #7 pictures".


Poly


FLINN
10.6 g
ZERO
ENTER
PRINT
CAL


FLINN
SCIENTIFIC, INC
4.1 g
ON / OFF
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PRINT
ENTER
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4.1 g
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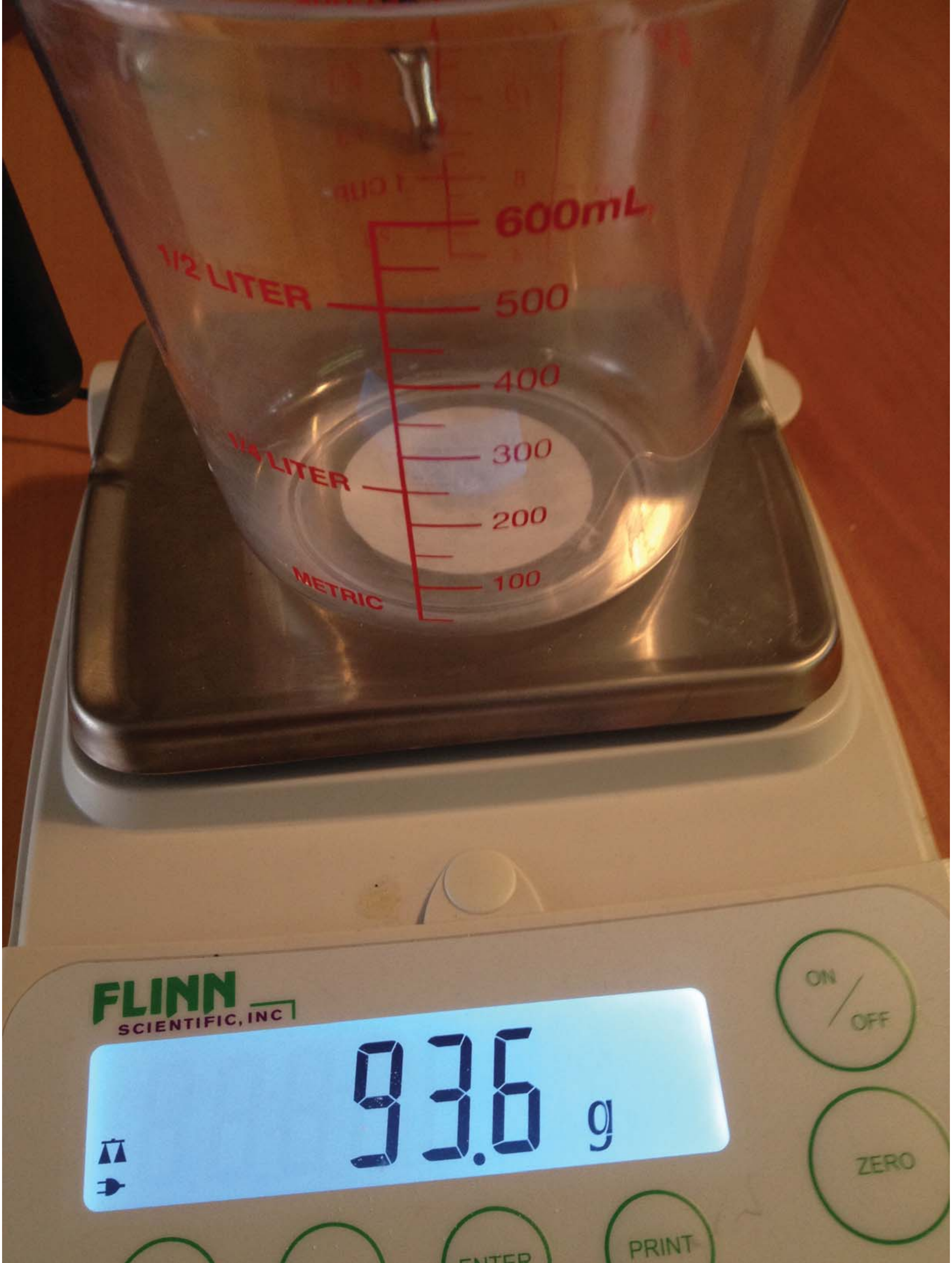
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1/2 LITER
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93.6 g
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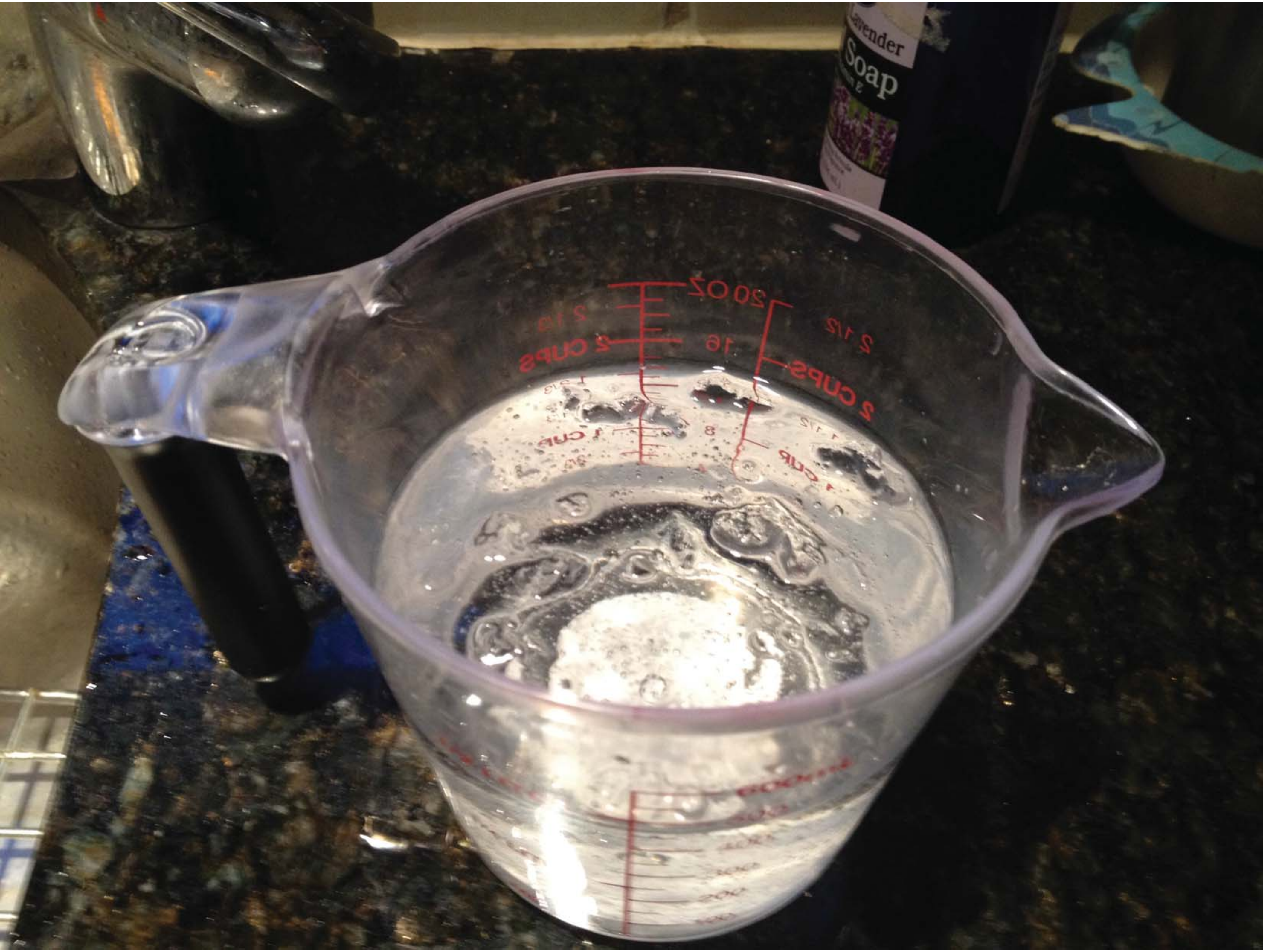
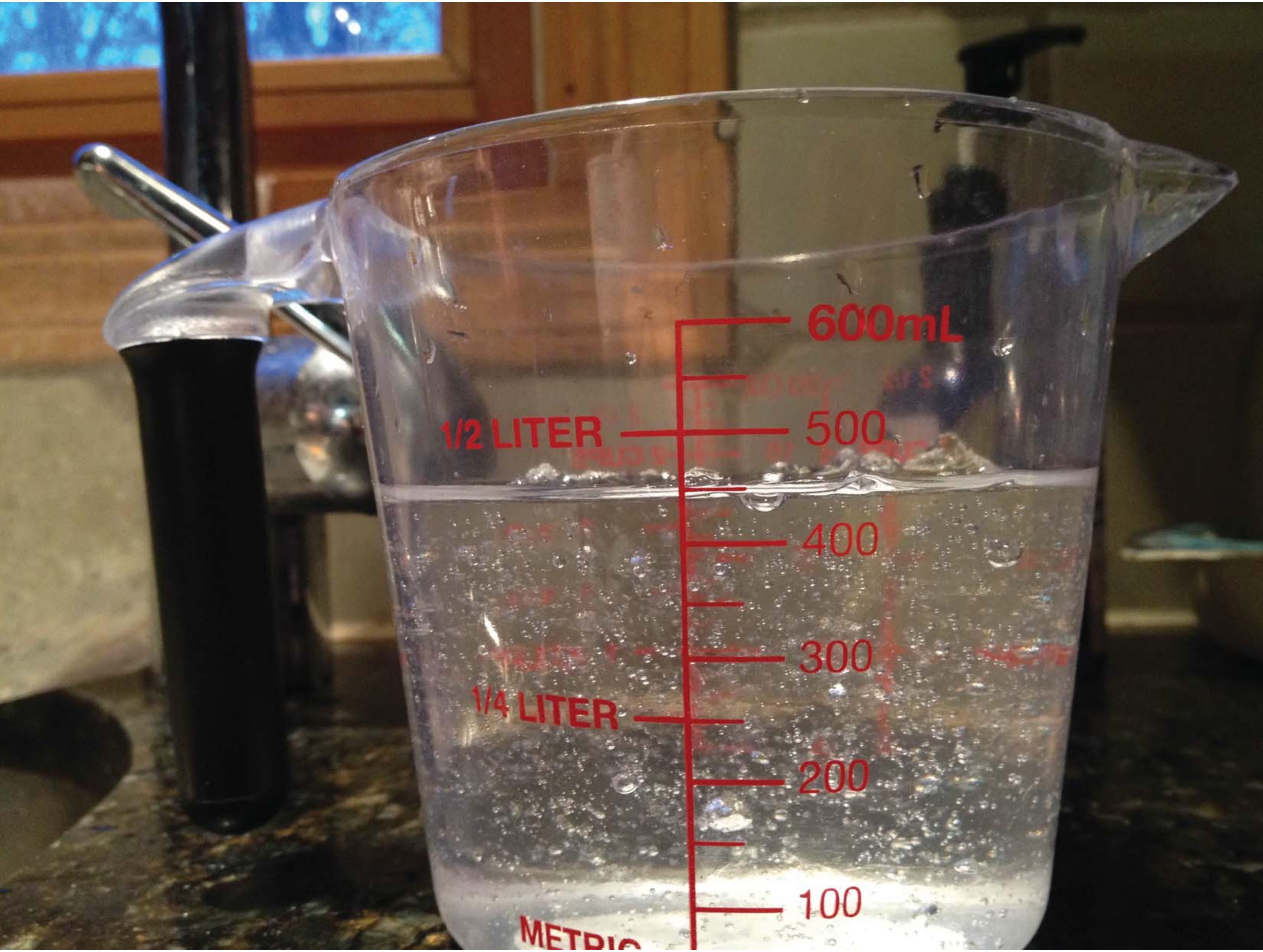

Lavender
Soap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1/2 LITER
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METRIC


600mL
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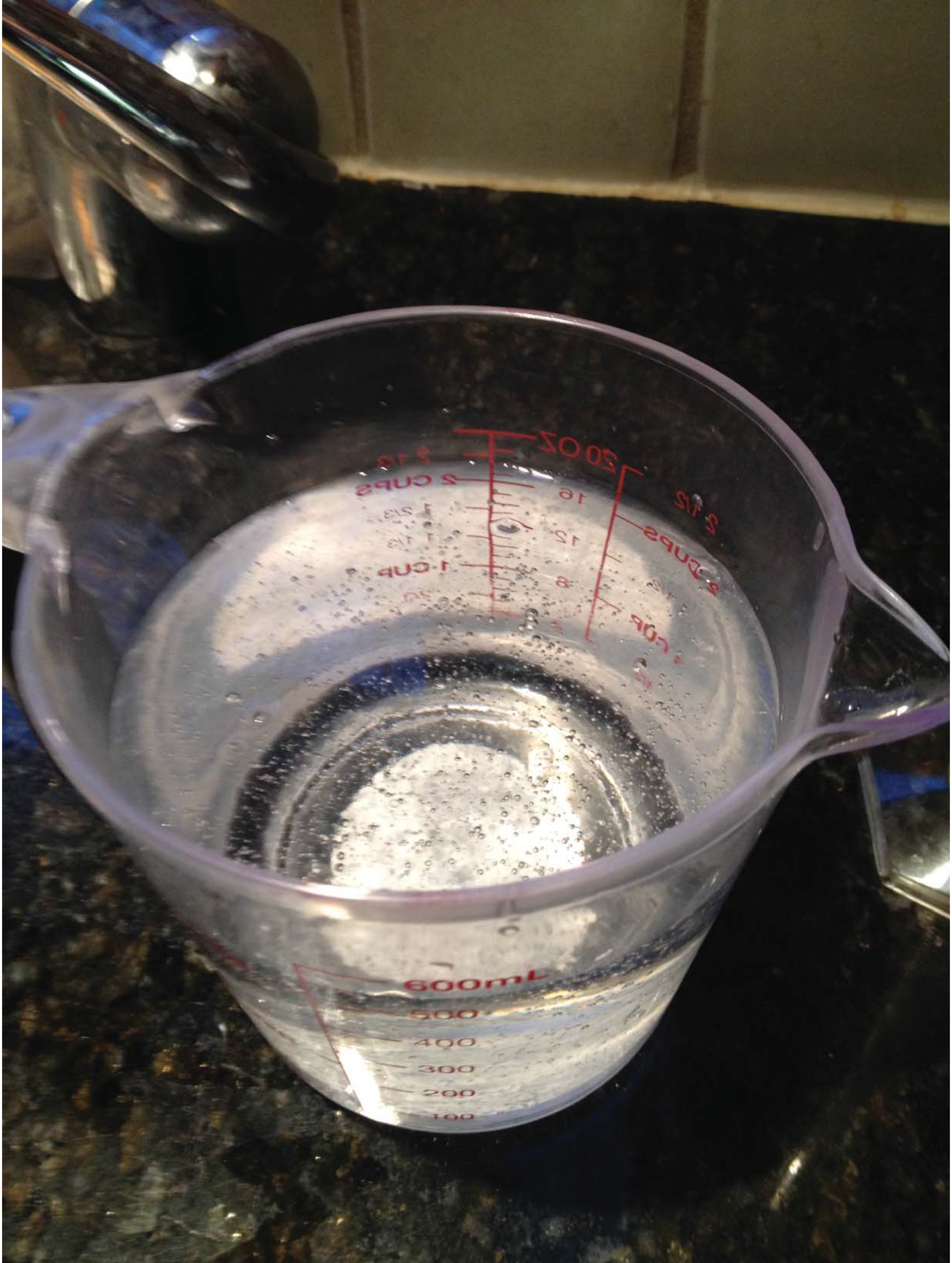
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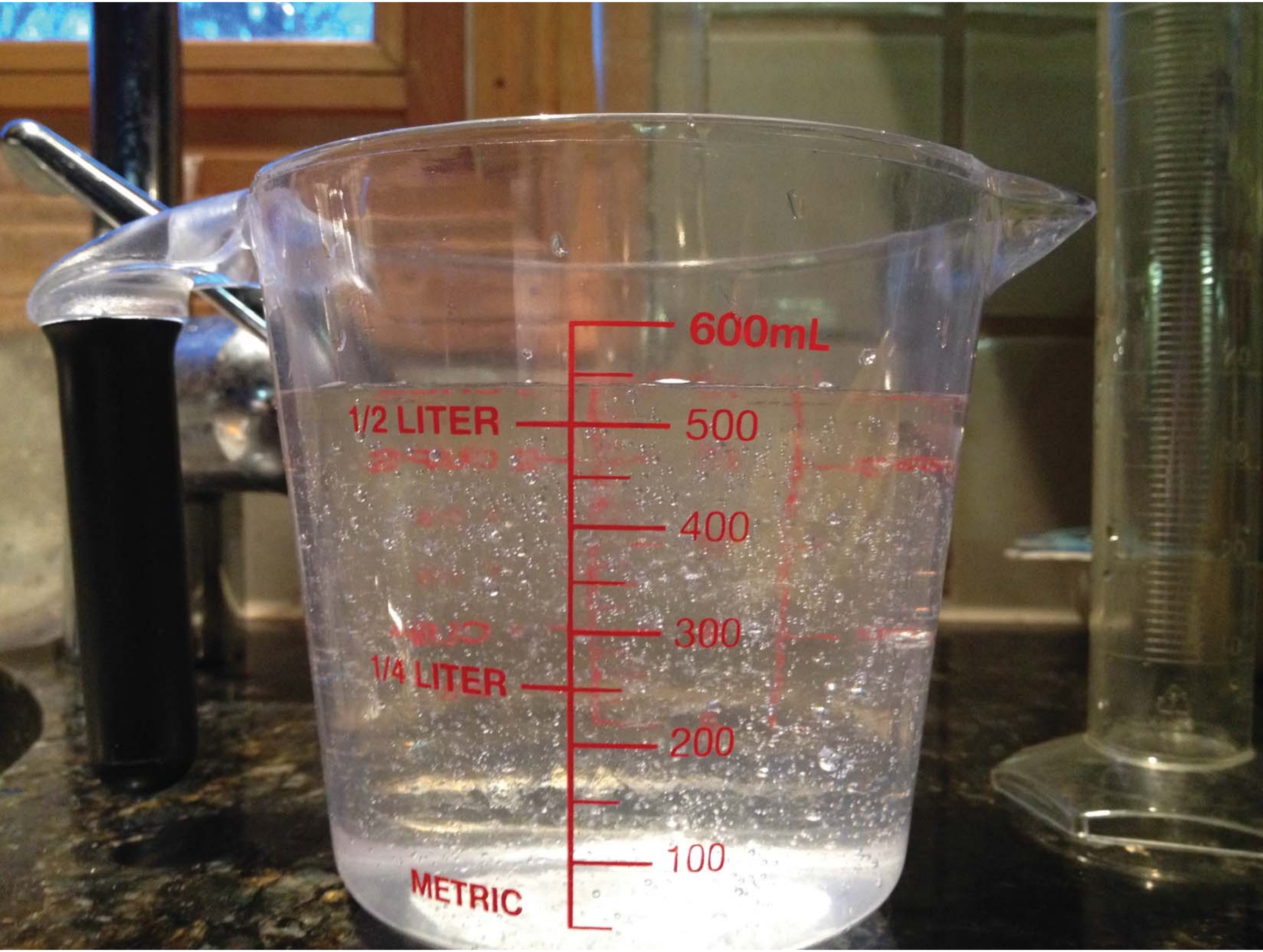
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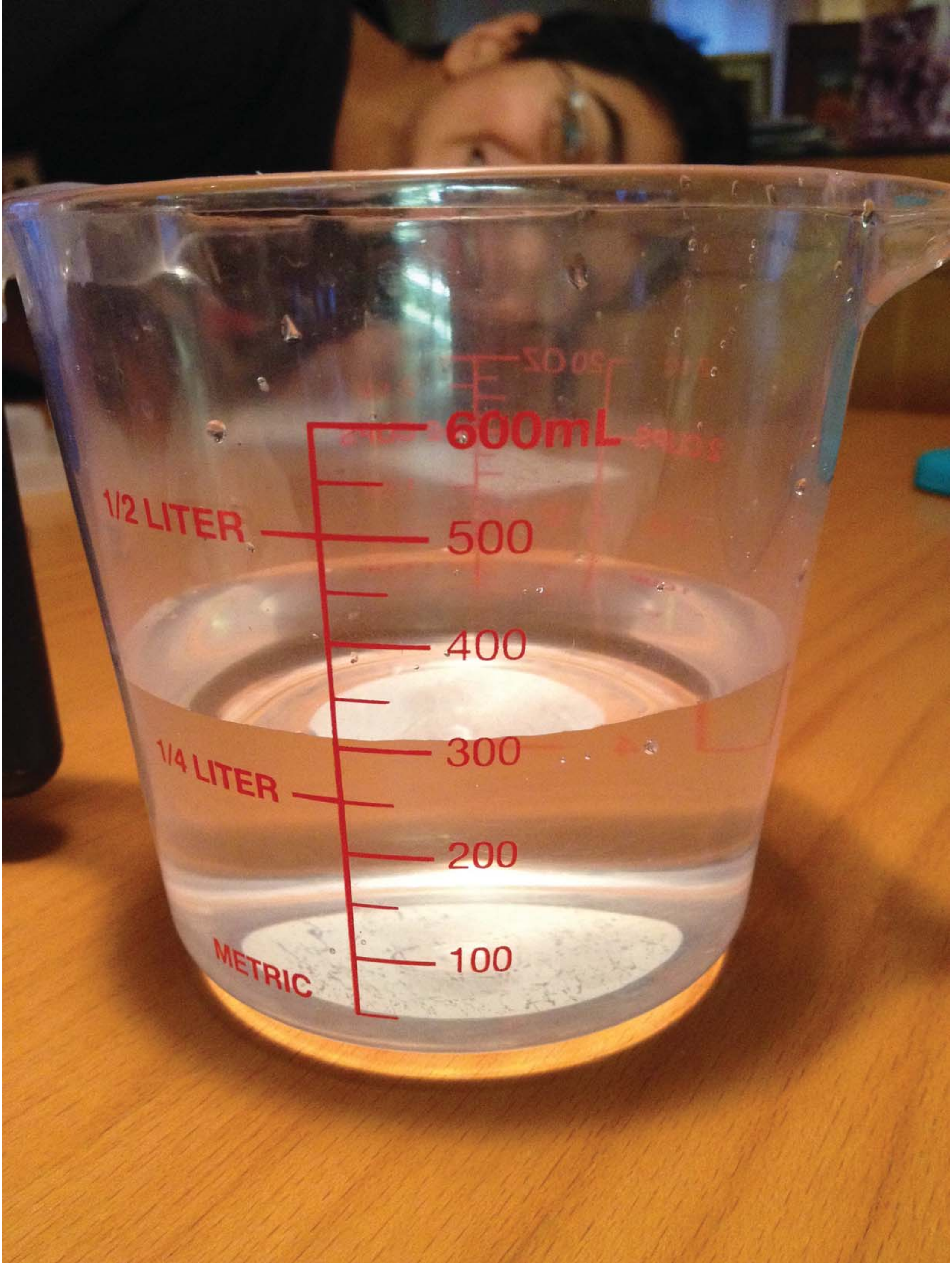
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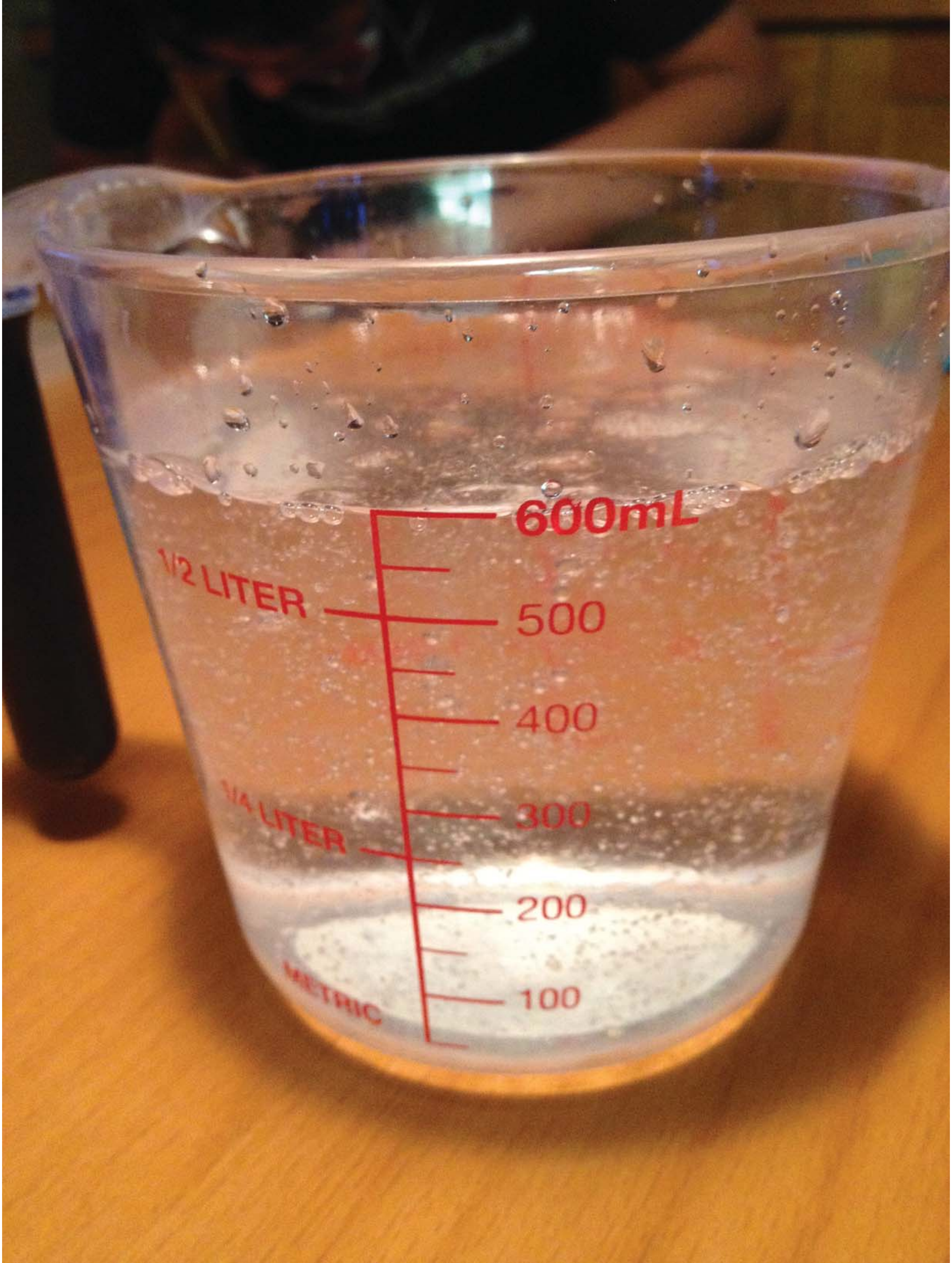

600mL
1/2 LITER
500
400
1/4 LITER
300
200
METRIC
100


20 Oz
16
2 1/2
2 Cups
8


Testing seal failure

KEY:

EX1	EX2	EX3	EX4	EX5	EX6	EX7
Theoretical simulation	1st Prototype funnel design	2nd Prototype funnel design	Water Pressure Test	Water Pressure Test #2	Seal Test -Search for Minimal Leakage	SAP experiment

Q. Describe the data you collected and observed in your prototype testing (use of data tables, charts, and/or graphs are encouraged).

Experiment #1: Simulation of flood
After collecting the necessary tools for our experiment, we discovered that most of them weren't compatible with each other. We also consulted each other and decided not to carry through with the experiment.

Experiment #2: 1st Funnel Prototype
The data we collected for this experiment was qualitative:
We found that using a dual-tube funnel was effective in holding water, however using a protruded cap created an air pocket, resulting in an upwards pressure which was too much stress for the putty and caused it to break. We learned that we needed to 1) put more weight on the putty, and 2) reduce the protrusion of the cap.

Experiment #3: 2nd funnel Prototype
We intentionally designed this experiment to be better suited to the situation, with a shorter height to fit the box, and a better model of the basement, outside soil, and sump pit.
In addition, we fixed the issue of buoyancy by using a different design. We had found that the protruding cap made it difficult for the air to escape, so we designed the new design so that the cap was shorter. This experiment was a success, in that it showed water would reach its level in a basement situation and confirmed the effectiveness of the seal.

Experiment 2 (left) vs. experiment 3 (right)

Experiment #4: Water Pressure Test

This experiment wasn't successful, because it lacked a proper seal. This was originally intended to disprove the notion that water pressure would overpower the design. While it didn't work completely, it brought to our attention the importance of the seal.

Experiment #5: Second Water Pressure Test

The fifth experiment was similar to the 4th in that it contained the same principles, but utilized a better constructed seal. Because of that, the experiment was successful in disproving the popular notion. But on the other hand, it increased our desire for testing out different versions of seal

Experiment #6: Seal Test

The putty experiment was simply an experiment designed to test and find the best seal we could. We tried some ideas we had thought of previously, like putting a layer of SAP between two levels of putty. While we were only able to test a limited amount of designs, we still got a sufficient amount of data.

	Simple Single Layer Putty	Dual layer Putty	Dual Layer Putty with SAP in between	Single External Putty w/ Internal SAP
Does it Work?	👎N	👍Y	👍Y	👎N

Data Collection: Experiment #7: Absorptive efficiency of SAP (SAP EXPERIMENT) :

We weighed everything three times + cartoon sketch, IV: SAP type, DV: amount of water absorbed

- Volumetric expansion is important to ensure that the SAP can be used to its fullest potential in the device

Quick Experiment Description: The purpose is to find the SAP with the most efficient water absorption.

Machine Test – Check!

Weight Chart

Weight of Beaker A (g)	Testing Mug	Weight of 9 oz (266 mL) test cup (g)	Weight of Beaker B (g)
40.6	96.3	10.6	39.2

Dry Density Chart

Type of SAP	Dry Volume (mL)	Dry weight (g)	Dry Density ratio (g/mL)
Sodium Poly-Acrylate	5	2.2	0.44
Linear	5	4.9	0.98
Polyacrylamide (SC)	5	4	0.8
Liquisorb 200	5	3.7	0.74
Macrofill	5	3.9	0.78
Polyacrylamide co-acrylate (LC)	5	4.1	0.82

Absorption + Expansion Chart

Type of SAP	SAP (mL)	Time to gel (sec)	Volumetric Expansion (mL)	Water Absorptio n (g)	Weight Absorption Efficiency[1]	Volume Absorptio n Efficiency[2]
Sodium Poly-Acrylate	5	8	247.5	545.8	249.091	49.5
Polyacrylamide co-acrylate (LC)	5	57600, or 16 hours	370	374.3	91.29	74

Leak Test

Type of SAP	Leaked? (Y/N)
Sodium Poly-Acrylate	N
Polyacrylamide co-acrylate (LC)	N

The success of the experiment is determined by the amount of water absorbed, and the time it takes to absorb.

[1] Weight of absorbed water/weight of SAP
[2] Volume of absorbed water/volume of SAP

Reconfirmation Experiment:

Determining extra water not absorbed by SAP

7.5mL of dry volume of SAP crystals were used to re-confirm earlier findings

Dry Paper Towel (g)	Wet Paper Towel (g)	Extra wetness in mug	Water not Absorbed
3.8	17.7	.5 g	14.5 g

Determining Weight

Weight of cups used (g)	Weight of SAP in cup A (g)	Weight of SAP in cup B (g)	Total Weight of SAP (g)
11.6	258	290.6	525.4

Volumetric Expansion

	Volume of Water added (mL)	Total Volume (mL)	Volume of SAP (mL)
Cup A	300	550	250
Cup B	300	550	250

Wg/Wd = (258+290.6)-(11.6x2)=525.4

Characteristics	SAP 1 (Sodium Polyacrylate)	SAP 2 (Polyacrylamide Coacrylate)
Weight of gel (Wg)	548 grams	378.4 grams
Weight of dry (Wd)	2.2 grams	4.1 grams
Wg/Wd Weight Absorption Efficiency	1 : 249.091	1 : 92.3
Volume of gel (Vg)	252.5 mL	375 mL
Volume of dry (Vd)	5 mL	5 mL
Vg/(Vd+Vwater) Volume Absorption Efficiency	1 : 50.5	1 : 75

Time to gel	8 seconds	57,600 seconds (16 hours)

Conclusion:

SAP 1 (Sodium Poly-Acrylate)- good for immediate absorption, low VAE (Volume Absorption Efficiency), high WAE (Weight Absorption Efficiency). Good for use in the lower chamber - comes into contact with water and acts immediately to absorb.

SAP 2 (PolyAcrylamide Co-Acrylate) - good for long term expansion, high VAE, low WAE. Good for use in the upper chamber, water level climbs slowly, this allows time to absorb and expand.

Analyze the data you collected and observed in your prototype testing. Does your data support or refute your design statement? Do not answer with yes or no. Explain your answer using 'Our data supports/refutes the design statement because...'
KEY:

EX1	EX2	EX3	EX4	EX5	EX6	EX7
Theoretical simulation	1st Prototype funnel design	2nd Prototype funnel design	Water Pressure Test	Water Pressure Test #2	Seal Test -Search for Minimal Leakage	SAP experiment

Experiment #2:
We found that using a dual-tube funnel was effective in holding water, however using a protruded cap created an air pocket, resulting in an upwards pressure which was too much stress for the putty and caused it to break. We learned that we needed to 1) put more weight on the putty, and 2) reduce the protrusion of the cap. These small changes could make or break our project.

Experiment #3:
This experiment was a success, in that it showed water would reach its level in a basement situation and confirmed the effectiveness of the seal.

Experiment #4:
This was experiment originally intended to disprove the notion that water pressure would overpower the design. While it didn't work completely, it demonstrated to us the importance of having an effective seal.

Experiment #5:
The fifth experiment was similar to the 4th in that it contained the same principles, but utilized a better constructed seal. Because of that, the experiment was successful in disproving the popular notion. But on the other hand, it increased our desire for testing out different versions of seals.

Experiment #6:
From this experiment, we learned a lot about the type of seal we should use. A simple single layer putty seal wouldn't work, and neither would any case when you exposed the actual SAP to the water. In the 1st case In the 2nd case, exposing SAP to water nullifies the SAP's purpose, and ends up

Experiment #7:
SAP:

We discovered that the Sodium-Polyacrylate was the fastest acting polymer, and it absorbed the most water, however it had a low expansion rate . On the other end of the spectrum, Poly-acrylamide Co-acrylate took the longest time, and didn't absorb much water, however it had the highest expansion rate. Both of these polymers were used in our final design, and we decided to create a 2-layer system of SAP. We would put the fastest acting SAP, Sodium Polyacrylate, near the bottom so that the rush of water during a flood would be absorbed, and would instantly add weight to the assembly, thus strengthening the putty for the rising water level. Then, we would add a layer of the expanding and slow acting SAP on the top, so that as the water slowly began to rise, the SAP would continue to absorb more water, continually adding more weight to the SAP, thus prevent the force of water from escaping. In addition, the high expansion rate would allow the Sodium-Polyacrylamide Coacrylate to seal any cracks and weak areas in the AFD, keeping all the water contained.

AFD:

We found that the best design would be a dual tube, PVC funnel design, with SAP layers in the outer layer. This design scored the highest in all of our criteria and experimentation, and has the potential to work very effectively on a larger scale.

Characteristics	SAP 1 (Sodium Polyacrylate)	SAP 2 (Polyacrylamide Coacrylate)
Weight of gel (Wg)	548 grams	378.4 grams
Weight of dry (Wd)	2.2 grams	4.1 grams
Wg/Wd Weight Absorption Efficiency	1 : 249.091	1 : 92.3
Volume of gel (Vg)	252.5 mL	375 mL
Volume of dry (Vd)	5 mL	5 mL
Vg/Vd Volume Absorption Efficiency	1 : 50.5	1 : 75
Time to gel	8 seconds	57,600 seconds (16 hours)

Pressure on the base seal (approx) of an idealized cylinder:

Volume of a cylinder - Assume a 5' tall x 9" dia AFD cylinder = 5'x0.44 SFT = 2.21 CuFT
Wt. of CuFT of water = 62.4 lbs
Weight of 2.21 CuFT of water = 137.8 lbs

Pressure at base is in the range of
Area of flange ring at base in contact with floor (Putty fill area) = 59.66 sq. in.
Pressure = Weight/Area = 2.31 pounds/Sq. in.

Our data supports our design statement because our design did effectively keep the water from entering the basement, and achieved nearly all of the goals of the design statement. It...

- Acted without a reliance on electricity- whether main or backup.
- Allowed the water to reach the same level as outside the house, but contained this water, keeping it from entering the basement.
- Effectively acted as a plug to the sump well.
- Changed the state of some of the water to use as weight to make a stronger seal (using the SAP)
- Used possible water absorbent materials to reduce chance of leakage (the SAP).

However there was one goal which our design did not fulfill. This goal was to harness the floodwater for personal use. Our device has the potential to be able to fulfill this demand, but in the time allotted, we weren't able to develop this idea enough (more about this in the community benefit area).

See attached image AFD Final Design to see how the the final design proposes to use the SAP1 and SAP2 at different vertical sections of the design in direct relation to their absorption capacities in terms of weight, volume and time.

Explain any sources of error and how these could have affected your results.

KEY:

EX1	EX2	EX3	EX4	EX5	EX6	EX7
Theoretical simulation	1st Prototype funnel design	2nd Prototype funnel design	Water Pressure Test	Water Pressure Test #2	Seal Test -Search for Minimal Leakage	SAP experiment

During our experiments, we experienced a variety of issues, ranging from small incongruencies to massive time consuming blunders. While most of these didn't affect us on a large scale, the prominent faults in our experiments are shown and explained here. These errors did *not* completely hinder our progress, but were enough to consume valuable time, and invalidate a minimal amount of data.

The upside to these failures was that they helped us refine our experiments and allowed us to see the weak points of our project and greatly improve upon them.

Experiment #1	**Experiment #2**	**Experiment #3**	**Experiment #4**	**Experiment# 5**	**Experiment #6**	**Experiment #7**
Proved to be a bad representation of the real situation at hand	Airtight seal worked too well	Not good representation of pressure	Putty failure results in flooding of 'basement' which gives inaccurate reading.	Simulated Water pressure well, but did not test seals	The putty experiment did not test a large selection of designs	The experiment skipped many of the SAP's in between and only got extremes

Experiment #1
Originally one of our team member's ideas, this experiment was only a very basic simulation of real life. It hardly resembled the actual real life situation of a flooded river. Consisting of a mug, some piping, and a plastic cup, this experiment was lacking in almost all fundamental aspects. After talking with a structural engineer's opinion, and attempting to construct the experiment, we abandoned the idea and turned toward residential flooding. This decision would lay the foundations of our entire project.

Experiment #2

In our original prototype of the funnel, the second experiment, there was an area above the cap that trapped air. Because the hole was located on the underside of the cap, air rose and got trapped in the area above the cap. This air had no outlet except for flowing up. Due to this characteristic, the air pushed upward, weakened the seal between the ground and the prototype, and forced the prototype into buoyancy. This proved our 2nd experiment ineffective. In addition, Experiment #2 was too tall for the box simulation setup that we had planned, and we were forced to test it out in a small bucket. This in itself was a faulty mistake, as it did not convey accurate data to us whatsoever. This however, really helped us in redesigning the experiment and see the results under Experiment #3.

Experiment #3

This experiment was, in actuality, a success. Read more about it in the **experiment descriptions page.** This experiment was measured out to the nearest centimeter so that its height wouldn't be an issue. In fact, the whole funnel prototype was redesigned to ensure that no air would be trapped. And we even colored the water entering the funnel, so you could see its level inside the funnel, or if any leaked from beneath the seal. From here, it seemed like an unflawed experiment. But unfortunately, we were unsure about whether the water pressure on the sides of the basement would build up. We had received many questions regarding the design itself, and whether the water pressure would be enough to override the leveled water inside the funnel and force water to gush out like a geyser. This made our team want to conduct another experiment to eliminate that doubt.

Experiment #4

This experiment contained major flaws that we needed to fix. While it would end up disproving one aspect, it would also show one of the major faults in another. We started this experiment by filling up a massive tub with water (see exact dimensions in **Data Collection**), and adding food coloring to it so that the water level could be easily discerned. Then, we proceeded by placing our inner basement simulator into the water added putty as a seal. This experiment was solely meant to disprove the myth that water pressure would cause water to spurt out of the funnel like a geyser. Unfortunately, although water did not spurt upwards, it did contain enough pressure to break through our seal. The leak in the seal grew fast, and in little time, compromised our experiment. Although this small error was a major and time consuming setback, it forced us to reconsider our current experimental plans and delve deeper into creating a strong seal.

Experiment #5

Surprisingly, the 5th experiment was not overly riddled with flaws. It consisted of the same setup and design details as the fourth, but was spot-checked multiple times to minimize the chances of error. In addition, we even video recorded it to get a hard copy of the evidence! One thing that we did want to improve was ideally focusing more of our time on the seal.

While the seal we had created for this experiment was sufficient, we strived to find the most effective seal possible.

Experiment #6

The putty experiment was simply an experiment designed to test and find the best seal we could. We tried some ideas we had thought of previously, like putting a layer of SAP between two levels of putty. While the experiment was essentially effective in determining the best and most effective seal, it did not test enough of a variety of ideas and designs for the seal. Once we had reached a seal that was effective, we stopped at that. But we could have continued going on, trying new ideas out, to get the best seal, but we chose not to, primarily because we were short on time.

We understood after talking to an architect that the commercial polyurethane based sealants are better for taller basements but take days to cure under dry conditions.

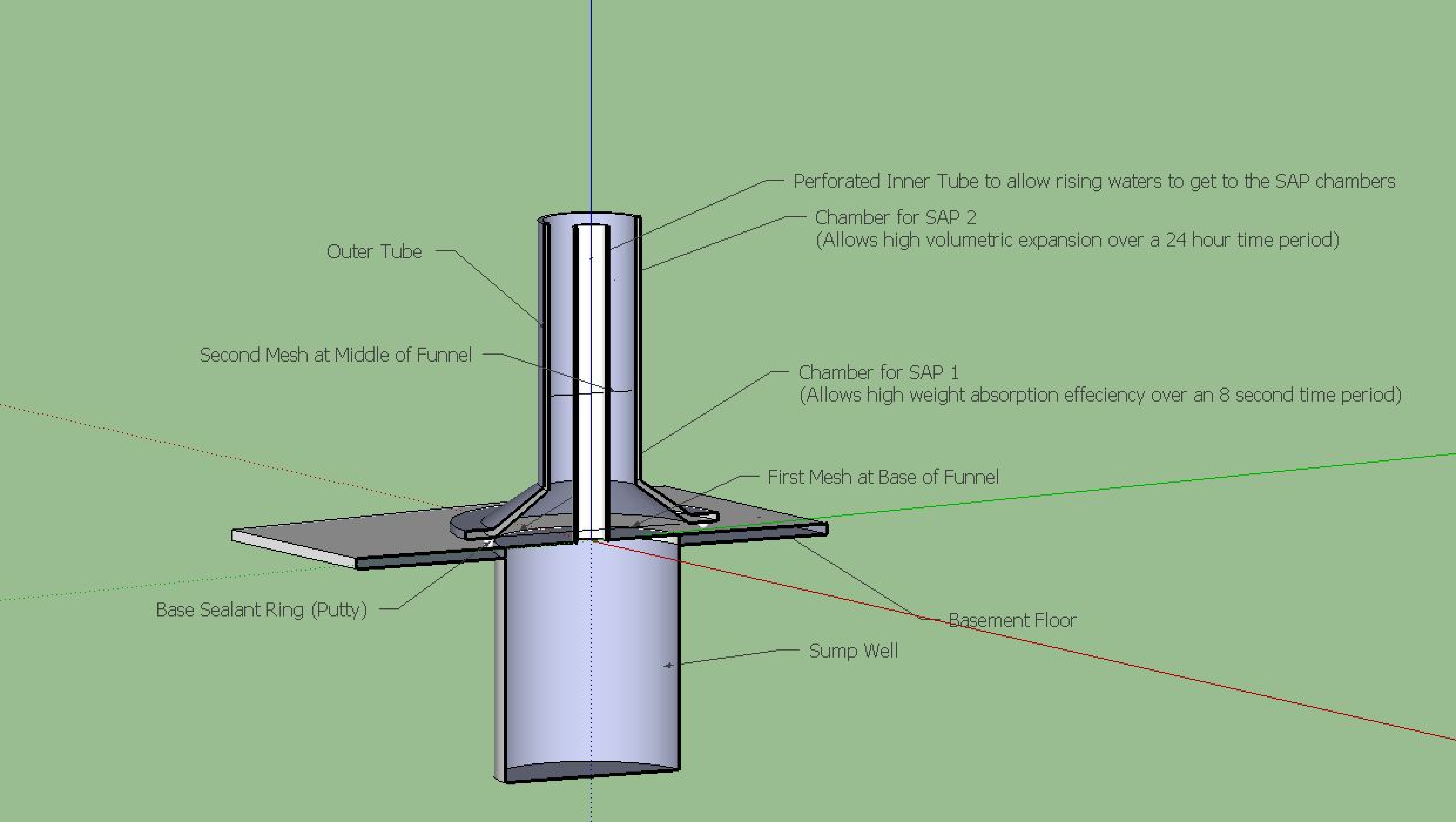
During our visit to CETCO labs, we understood that there are some very powerful structural 2-part urethane sealants that have expansion and sealing capacities in the presence of water (HYDROPHILIC). These may be better integrated into the base ring design in deeper commercial applications or in army underground bunkers.

Experiment #7

In experiment #7, we tested a variety of SAP sample products against each other to discern the most effective and efficient absorber of our collection. We would then use these in our prototype to add weight and make certain that no water would leak out. The only error we had was not having a precise dry measurement to measure the SAP. We were restricted to a dry measuring spoon in one of our teammate's kitchens.

We were limited to small jars of SAP crystals (of different sizes) obtained from CETCO labs and we ordered some available SAPs online. Due to the small amounts of material at hand, our dry volume measurements were somewhat limited in accuracy. Having greater amounts and bigger measurement vessels would have reduced error.

The SAP experiment helped us realize that the finest crystal was good for immediate absorption, a low VAE (Volume Absorption Efficiency), and a high WAE (Weight Absorption Efficiency). On the other hand, the thickest crystal was not good for immediate absorption, but good for long term absorption. It also has a high VAE and a low WAE.


Perforated Inner Tube to allow rising waters to get to the SAP chambers
Chamber for SAP 2
(Allows high volumetric expansion over a 24 hour time period)
Outer Tube
Second Mesh at Middle of Funnel
Chamber for SAP 1
(Allows high weight absorption effeciency over an 8 second time period)
First Mesh at Base of Funnel
Base Sealant Ring (Putty)
Basement Floor
Sump Well

Interpret and evaluate your results and write a conclusion statement that includes the following: Describe what you would do if you wanted to retest or further test your design. Evaluate the usefulness of your prototype or model. What changes would you make to your prototype or model for the future, if any?

Having completed the experimenting and testing of the product, and analysing the data and sharing it with experts and community officials, we are able to make the following conclusions:

The product design and the various super-absorbent polymer materials involved appeared to be **very feasible** to use in a real product in a residential application.

This definitely has the potential to work in real life situations. The task of **scaling the design up** to real-life sizes would be simple with some of the data we have already collected.

If we were to further test our design, we would focus on the **commercial and military applications**.

Commercially, we would expand our product to fit a deeper commercial basement. With more time, we would enjoy experimenting with transparent acrylic as the primary material for our design.

In an application like a sub-terranean military application or bunker, this **transparency of the AFD** would allow the user to visually observe the water quality, color, and turbidity of the groundwater surrounding the underground environment. The applications are almost endless!

Now, back to the residential application, **the non-toxicity of the SAP gel** and the passive design solution would require little maintenance after installation, and would eliminate worry form homeowner's minds.

One of the first things that we have wanted to do ever since we developed the idea was commercializing this. It is already a **very adaptable design**, and can be easily modified to fit almost any home's sump pit. With this, we can expand this to our community and make it easily available in home improvement chain stores in the local neighborhood.

The **cost effectiveness** and worry free passive design may make it very attractive to home-owners.

One thing that's certain is the **design's adaptability**. While it can already be easily adjusted to fit most sump pits in people's homes, it can also be modified many times over. In the future, we possibly want to integrate a tap so that the water collected inside the design could be utilized for simple jobs like watering the plants.

FUTURE IMPROVEMENTS

We wish to continue to experiment with the SAP's and sealants. The seal experiment was sufficient, but didn't test many different ideas for seals due to limitations of cure time and VOCs in a residential environment.

We could continue to explore some very interesting SAP characteristics in disposal and upcycling.

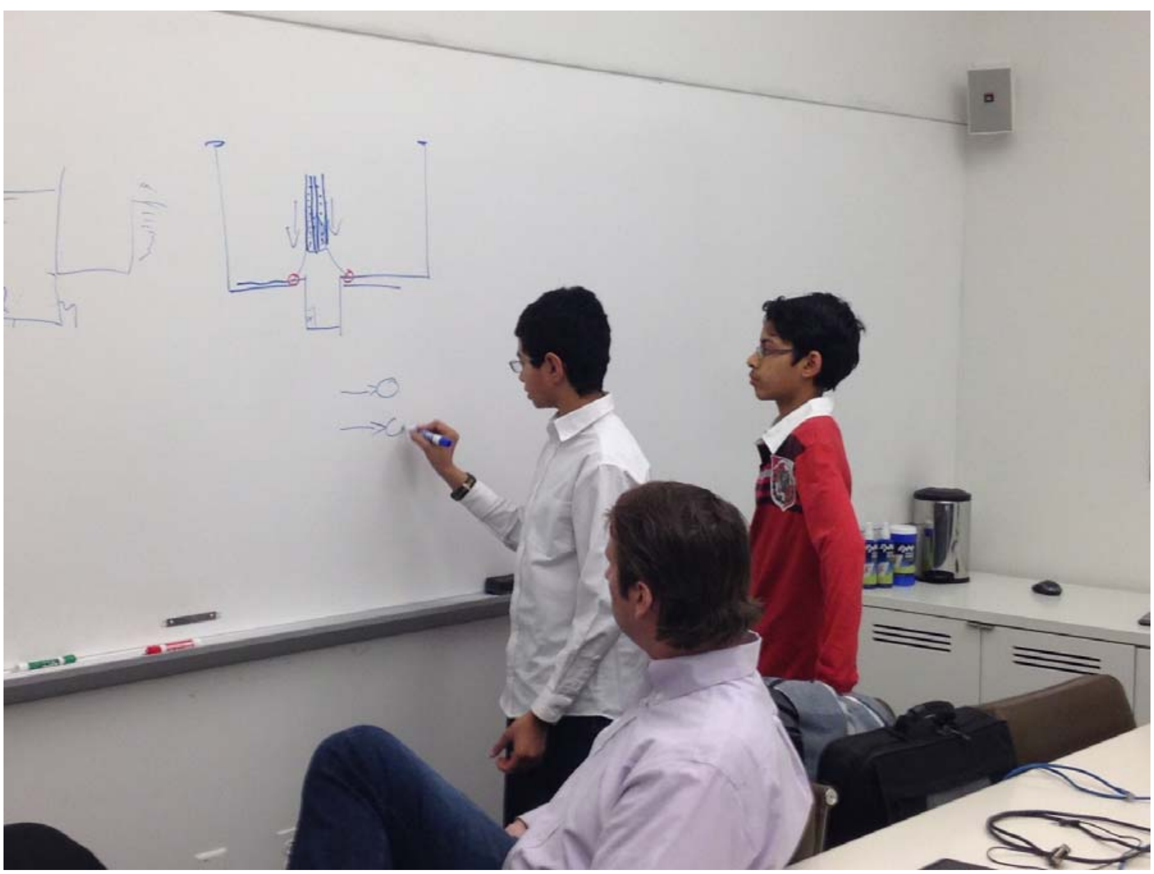
SAP’s are not only highly pertinent to our project, but are extremely fun to play with! And if there was one thing we learned from this project, it was that science can be tough… but fun!

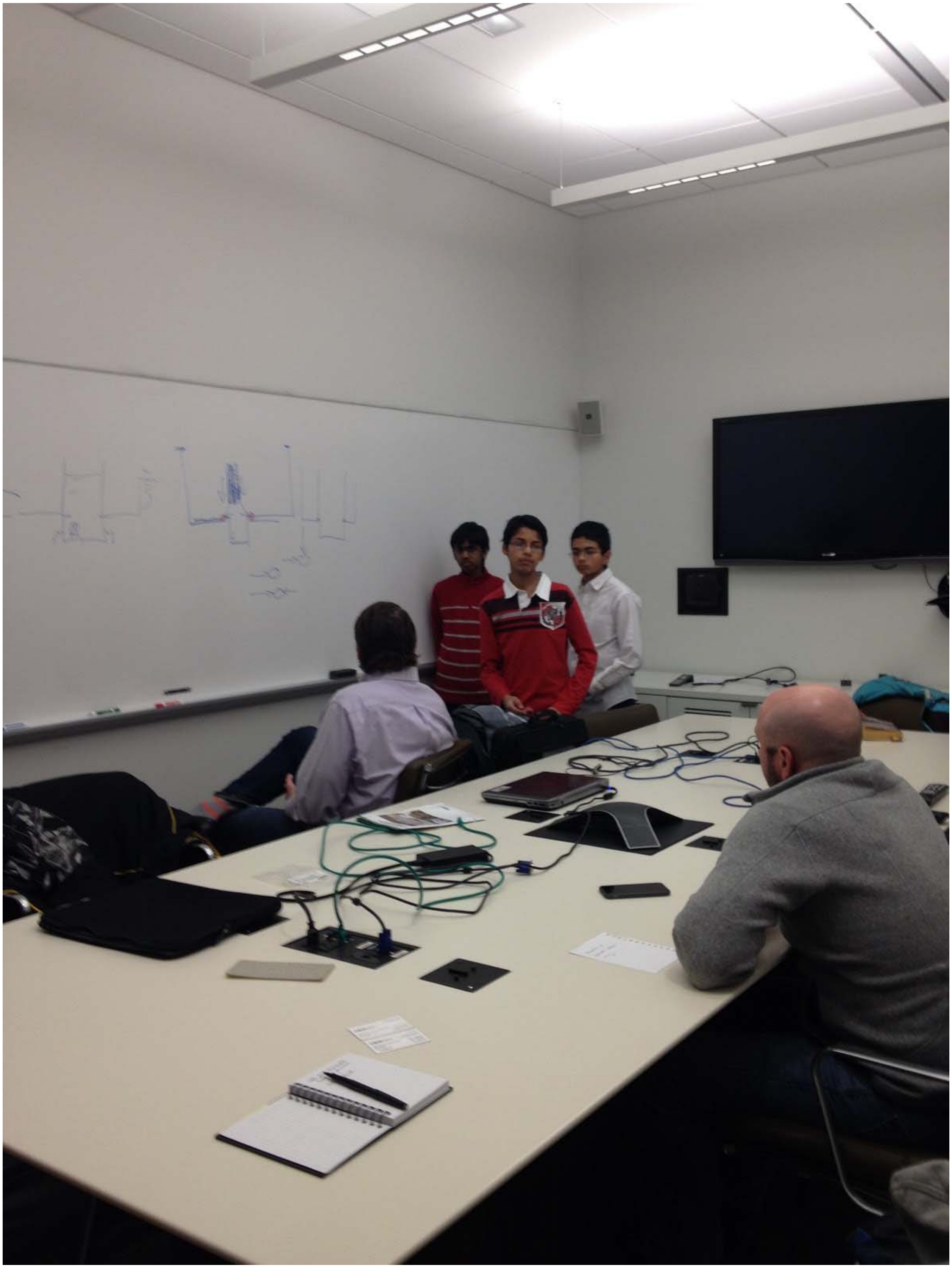
During our visit to CETCO labs, we understood that there are some very powerful structural 2-part urethane sealants that have expansion and sealing capacities in the presence of water (HYDROPHILIC). These may be better integrated into the base ring design in deeper commercial applications or in army underground bunkers.

We would also explore making the product available in sections and packaged in a bundle with the PVC pieces, glues and SAPs ready to assemble.

VALIDATION

At our meeting with CETCO, we felt that we received a reaffirmation that our direction, approach, design, material choice and calculations were good. the following pictures show us presenting ideas, discussing design, and learning about SAP product chemistry with the CETCO engineers and scientists. The meeting helped refine our design direction.






& PERSONAL CARE
SPECIALTY MATERIALS
BASIC MINERALS
Tide
Downy