SMALL SCALE BACKFLOW AND CROSS-CONNECTION EDUCATIONAL MODEL

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LETTER OF TRANSMITTAL

Mike Wentink, Training and Licensure Officer
Nebraska Department of Health & Human Services
301 Centennial Mall South, Lincoln, Nebraska 68509

Dear Mr. Wentink,

The enclosed report summarizes and explains the details of our *Small Scale Backflow and Cross-connection Educational Model*. Serving as a guide, the report depicts the design process, engineering background and construction of this model. Enclosed is a detailed explanation of the design objectives, constraints, criteria, alternative design features and final solution. This project is authorized and funded by the Department of Health and Human Services (DHHS) from December 1, 2009 to September 30, 2011. The design component of the project was also a part of the Biological Systems Engineering Senior Design Class.

You have reported that many small-town public water systems in Nebraska have insufficient backflow prevention programs to protect their piping infrastructure and fail to recognize the concerns related to potential cross-connections. It is your belief that his lack of awareness is addressed, sufficient public water system resources might be directed toward protecting the system from the potential public health threats associated with cross-connections. With the potential of this leading to serious public health threats, you have communicated with us your desire for a visual model to aide your educational efforts in this area. Thus, our purpose was to develop the concept for, design and construct a small-scale educational model to demonstrate potential cross-connection and backflow contamination dangers in public water systems. The model we have developed gives a visual representation of the dangers associated with backflow and will be a useful addition to your educational program influencing public water system representatives and other clients across Nebraska to take the appropriate action. To make a compelling argument, relevant situations are depicted in the model and proper engineering backup has been provided. In total, the deliverables for this project include three backflow models, complemented with appropriate supplemental material: operation and maintenance manual, construction instructions and a complete parts list.

To date each of the three models are complete and ready to be transported and put into use. Each of the models fits the criteria you have provided and we hope will act as a valuable visual complement to your current educational efforts.

As a senior design team, we are very grateful for the opportunity of working on this project. While working on the project, significant knowledge of the cross-connection issues facing small towns across the nation was gained. We were made aware of the importance of educational programs, such as those put on by DHHS, in addressing these issues.

The design team appreciates the help received from Bruce Dvorak, David Admiraal, and Dennis Schulte who acted as advisors throughout the project. Another useful resource was Jim Purzycki's backflow model which served as an introduction for the development of this model. Mike Florek also provided significant assistance in initial prototype and construction and draft revision. We would also like to recognize Scott Minchow for his help in the construction aspect of this project as well as the generous use of his workspace.

Lastly, would especially like to thank DHHS for their availability to provide feedback regarding design features while also providing guidance and resources. If there are any questions regarding the use or operation of this model please feel free to contact the backflow model design team.

Best Regards,

Scott Barker and Allison Potter

Scott Barker *Allison Potter*

EXECUTIVE SUMMARY

According to the Nebraska Department of Health and Human Services (DHHS), many small public water system owners/governing boards and water operators are unaware of the likelihood of backflow occurrence due to cross-connections commonly found within the distribution system. Small public water systems frequently operate on limited budgets where the implementation of a program for the effective detection and elimination of cross-connections does not receive sufficient resources or priority. DHHS has developed a project to educate representatives of small public water systems and their operators about the occurrence of backflow in the hopes that it will encourage Nebraska's small water systems to recognize the need for the diligent maintenance of an effective cross-connection control program. The small-scale backflow and cross-connection model is a tool designed to provide a visual recognition of the hazards associated with backflow, for use in the DHHS public water system educational programs.

In order to make a compelling argument, DHHS needs a visual representation of backflow scenarios which commonly occur in small towns across Nebraska. The models include realistic scenario situations such as: private water wells, boilers, water main breaks, fire-flow conditions, truck fill stations, submerged inlets in stock tanks, and subsurface contamination. A selection of four scenarios is represented in each model. The model is created mainly from clear acrylic sheets and pipe and receives water from an elevated water basin fed by a pump. Scenarios in the model consist of a series of ball valves, reservoirs, pumps, flexible tubing, and pressurized vessels. Each scenario is adorned with model miniatures to create a realistic environment for each backflow event. The model is designed to be easily demonstrated, cleaned, repaired and transported.

The educational demonstration of this model will create a persuasive argument for small towns in Nebraska to take action in the effective detection and elimination of potential cross-connections. DHHS will use this model as a resource to better the health and quality of life for citizens across the state.

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Problem Statement and Design Objective

Problem Statement

The existence of cross-connections and resulting backflow in distribution systems are major public health concerns. Technology and procedures have been developed which mitigate these concerns, yet implementation of these preventive measures has not been comprehensive. Our client, Nebraska DHHS, expressed that Nebraska public water systems have the legal responsibility for the safety of the drinking water within their distribution systems, and that many owners/representatives of small public water systems are unaware of the potential backflow hazards that can exist due to aged distribution systems and improper plumbing connections. The consequence of this lack of awareness is insufficient water system operations support and resources toward an effective cross-connection control program. DHHS believes that if representatives of small public water systems were presented a visual depiction of backflow hazards due to cross-connections and provided with available solutions, they would take the necessary steps to alleviate those public health hazards. DHHS plans to educate operators and owners/representatives of small public water systems through a presentation on the public health concerns relative to cross-connections, believing that this will persuade small public water systems to direct the necessary support and resources toward backflow prevention. Use of a demonstrational model will provide visual support to the client's educational programs.

Design Objective

The design objective was to design and construct three interactive tabletop models visually demonstrating backflow conditions that can occur from cross-connections commonly identified in public water systems. The models are for DHHS educational programs and are purposed to educate water operators and representatives of small public water systems on the dangers of cross-connections and backflow, and to encourage them to identify and eliminate such public health hazards within their systems. Each of the three table-top models should visually represent four unique scenarios where cross-connections commonly occur. The models were to be visually realistic of relevant small town scenarios and will be designed to be setup and run by a trained individual. The model will be supplemented with an operations manual, construction instructions and complete parts list.

MODEL REQUIREMENTS

Requirements given by DHHS for the model include that each model display a minimum of one of each of the types of backflow conditions, backsiphonage and back pressure, and that four total scenarios are represented in each model. The model was required have physical dimensions smaller than 42” x 32” x 18” and weigh (drained) less than 40 lbs. The model must be easily set up and disassembled. It is also required that the model be backed up with relevant engineering analysis to establish its effectiveness as an educational tool. The budget for the materials was $6,450 and $12,930 for labor.

DESIGN

The final solution is a small-scale water distribution system modeled with clear rigid tubing and enclosed in an acrylic case (Figure 1). The model is created from clear acrylic ¼" inner diameter tubing and utilizes several additional ball valves, tees, connectors and acrylic junctions. The model is designed to lie horizontally on a table surface and to allow interaction and observation from above.

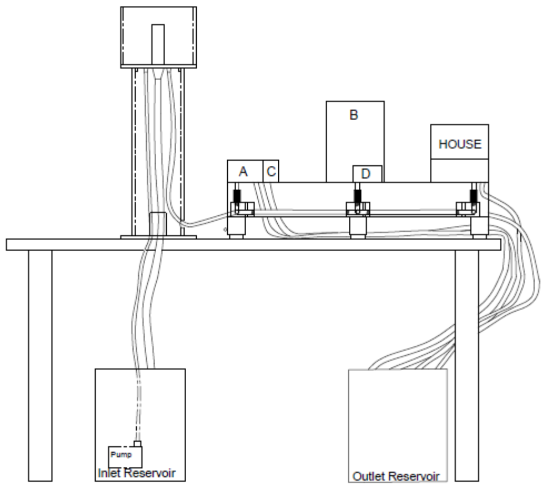

FIGURE 1. OVERVIEW OF THE MODEL

The model is gravity run from a water tower reservoir (Figure 2), which rests two feet above the model. This reservoir is refilled by a submersible fountain pump included with the model, which supplies water from a reservoir, stored under the presentation table as illustrated in Figure 1. The water tower has a built in overflow line to maintain the system at constant pressure.

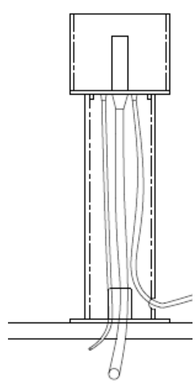

FIGURE 2. WATER TOWER OVERVIEW

The model's water supply flows through the main pipe, which runs along the periphery of the model with two backsiphonage scenarios and two backpressure scenarios connecting at various locations. Flow to each scenario is controlled through ¼" ball valves and each scenario can be attached or detached with quick disconnect fittings. A house is present on the model, where an outlet for water flow is located. Water pools in an open reservoir within the house acting as a bathtub which signifies a location where human contact or consumption takes place. Food coloring dye is used in each of the four scenarios to demonstrate the presence of contamination within the water system. When the dye enters the system, upon activation of a scenario, it will be seen within the clear acrylic tubing and ultimately within the house. Used water, including water colored by the contamination dye, will be collected in an outlet reservoir, also stowed under the table.

One scenario representing backsiphonage is achieved through loss of pressure in the system due to a water main break or a fire-flow incident. The water main break is demonstrated by disconnecting a small flexible section of tubing using quick disconnects. This creates a sudden drop in pressure in the lines. In order to 'repair' this leak, two ball valves are used to cut off the water flow to that portion of pipe. At this point the pressure in the main and lines connected to it has fallen to zero. This pressure loss siphons water contaminated with food dye located in the subsurface backsiphonage scenario. When the water main is fixed, the ball valves are returned to their original configuration and normal water flow resumes. As this takes place, the contaminated water infiltrates the clean water and fills the house.

The other backsiphonage scenario, a stock tank on a hill, is achieved due to loss of pressure in the system in an episode of upstream fire-flow. A fire-flow scenario is activated using a ball valve which siphons water from incoming flow. Due to this high water demand and resulting low pressure, the second backsiphonage scenario is activated and contaminated water from the stock tank will backsiphonage into the main system. For further explanation and diagrams on backsiphonage scenarios reference the construction and operations manual in Appendix A.

The backpressure scenarios utilize two separate mechanisms to create a high pressure relative to the system. In the first backpressure scenario, a pressurized container is connected to the system with flexible tubing and sealed with a ball valve. The pressurized vessel houses food coloring-contaminated water. It is manually pressurized by pumping a hand pump and allowed to overpower the system by opening the connecting ball valve. This scenario may represent any scenario with a pressurized vessel, but in this model is designed to represent a water boiler.

The second backpressure scenario uses a small fountain pump resting in a small container of dyed water. It is connected through flexible tubing and sealed with a ball valve attached to the system. When the system is running at normal pressure provided by the water tower, and the ball valve is opened, the contaminated water is forced into the system and contaminates the water line and eventually the house reservoir. For further explanation and diagrams on backpressure scenarios reference the construction and operations manual in Appendix A.

Model diorama parts and other visual cues will be used to visually adorn the model and demonstrate the location and context of each scenario.

The model is supplemented with construction, operation, and parts manuals, which can be found within this report and appendices. The construction, operation, and parts manuals gives detailed procedures of how to repair, maintain and clean the model. In addition, instructions and specs on how to machine any of the necessary acrylic components have been included.

The final model satisfies the initial criteria laid out by DHHS. The model will be easily transportable as it is encased in a padded hard shell case with carrying handles and wheels. The model can be easily set up and operated by one individual. The final dimensions of the model were measured to be 36” x 20” x 10”. Each model contains a representation of at least one backsiphonage and one backpressure example with a total of four scenarios to a model. In each scenario the signs corresponding to the applicable pressure differences are of the same sign that is found in real life scenarios and is provided by relevant engineering analysis. The majority of the materials were purchased through online order from McMaster-Carr and were received one business day after order submission making them readily available. The other materials used were ordered online from American Plastics or were common materials either located at a general grocer or a home and appliance store.

FINAL DESIGN SUMMARY

The final model design is ready for implementation. Accompanied by the operation, parts and maintenance manual, the design is a straight-forward model which can be used with initial training by any educator. The design consists of a 36” x 20” x 8” acrylic box ornamented with model miniatures to visually accompany our backflow scenarios modeled out of acrylic piping and ¼” valves and fittings. The model is of a horizontal orientation where piping infrastructure can be seen through the transparent acrylic surface of the model. The model is gravity-run from a water tower, which is supplied by a fountain pump. Four scenarios are represented in the model: backsiphonage from a stock tank and a truck fill station, and backpressure from a private water well and a water boiler. Each scenario is initiated by turning off and on water flow through a labeled ball valve. Dye is inserted into the system at a few key points, and as the operator initiates contamination, enters the system making a striking visual display. This is extensively explained in the operation section of the manual. It is our hope that this is a significant educational aid in convincing public water system representatives all over Nebraska to seriously evaluate their water systems and devote adequate resources for implementation of an effective cross-connection control program.

REFERENCES AND CITATIONS

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University of Southern California. *Manual of Cross-Connection Control 10th ed.* CA: Los Angeles, 2010. Print.

United States. Environmental Protection Agency. Office of Water. Office of Groundwater and Drinking Water. *EPA – Cross Connection Control Manual.* Washington: GPO, 2003. Print.

Florida. Department of Environmental Protection. *Cross Connection Control and Backflow Prevention Program.* Tallahassee: FL Dept. of Environmental Protection, 2008. http://www.dep.state.fl.us/water/drinkingwater/bfp.htm

APPENDICES

Appendix A: Operations Manual
Appendix B: Parts Manual
Appendix C: Instructions for Acrylic Machining Company
Appendix D: Design Alternatives
Appendix E: Engineering Analysis

Appendix A: Operations Manual

OPERATIONS MANUAL

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Operation, Set-up and Maintenance of Backflow Model

Correct procedures must be followed in the use of this model to ensure operational success and for maximum visual effect. The operations section includes step-by-step instructions on set-up, tear down, cleaning, inspection and storage

Before Departure

Before departure to each site it is important to understand the resources of the location you will be presenting in. Water, electricity and space availability are all important considerations to take into account. If water is not readily available you will have to fill the inlet reservoir container before departure and bring an additional carboy of water. If electricity is not available a small generator should be purchased to power the model. An extension cord may also be necessary to plug in the power strip if the nearest outlet is a large distance from the presentation space. If a level table is not provided for the presentation you should bring one at least 60" x 32" in size.

SET-UP OF THE MODEL

Place the model on a flat, level table clear of obstructions to the area where the audience will be viewing the model. You will need at least a 60"x 32" work space. There are several valves you will need to turn throughout the operation of the scenarios so you will want to keep the model at waist height.

Place the empty water tower on the table adjacent to the inlet of the model. It is important that these two components are level because the system is powered by gravity head from the water elevation in the tower. Next, fill the inlet reservoir and place the inlet and outlet containers in their respective locations as diagramed in Figure 1. The inlet reservoir should be on the floor next to water tower while the outlet reservoir should be near the main break at the opposite side of the model.

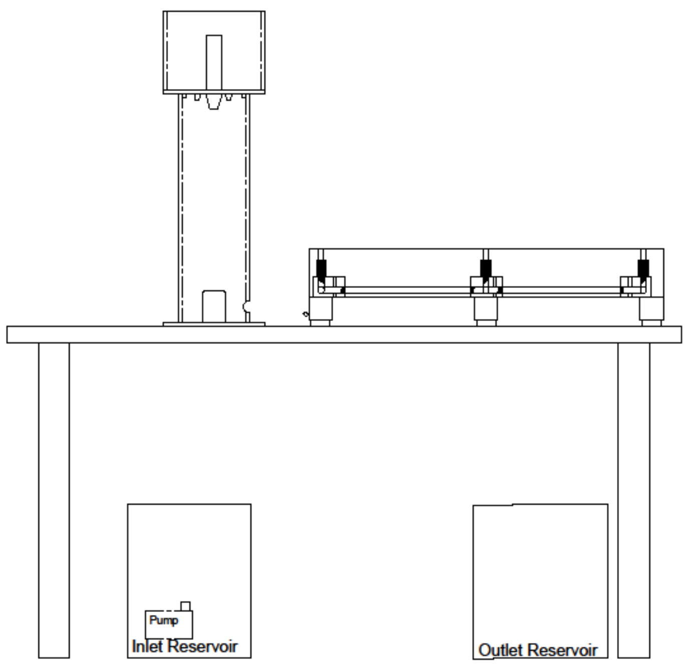

FIGURE 1. POSITION OF MODEL, WATER TOWER & RESERVOIRS

SET-UP OF WATER TOWER

The water tower consists of two major acrylic pieces: the stand and the reservoir, and a series of flexible tubing and quick disconnections. To assemble the water tower, place the reservoir on top of the stand. There should be three lengths of tubing inside the inlet reservoir bucket with labels signifying which socket they connect to. Thread the ¼" flexible tubing from the pump (Q2), and the ½" tubing (Q1) from the reservoir through the rectangular hole in the base of the water tower stand up to the bottom of the water tower reservoir and connect them to their respective quick disconnect sockets as is shown in Figures 2 and 3.

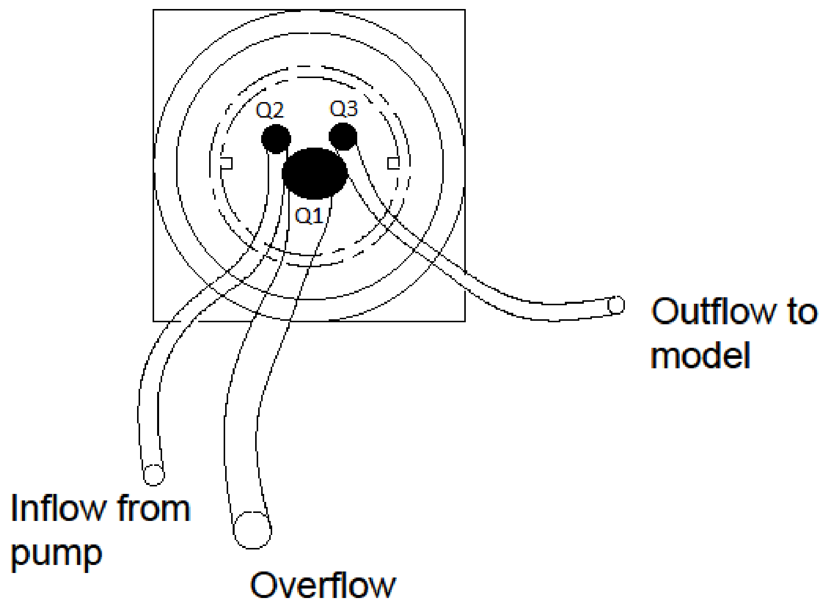

FIGURE 2. CONNECTING WATER TOWER INLETS (ABOVE VIEW)

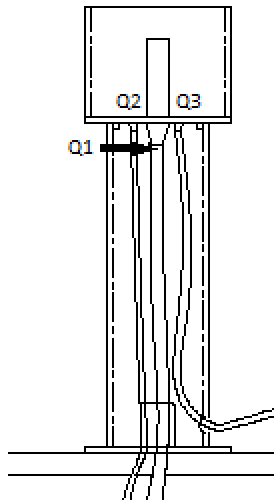

FIGURE 3. CONNECTING WATER TOWER INLETS (SIDE VIEW)

The last flexible tubing section in the inlet reservoir should be a ¼" flexible tubing segment (Q3). Connect one of its quick disconnects to Q3 on the base of the water tower reservoir and thread it down the water tower stand and through the small hole in the base of the water tower to later be connected to Q5 on the model. Once all tubes are connected to the water tower basin, stand the water tower upright and make sure each piece is secure and that the tubes are free from crimps.

The mechanism of the water tower works as follows: the pump in the reservoir bucket pumps water in through the ¼" line. It fills the reservoir and the "To Model" line. It will continue to fill the reservoir until the water level reaches the elevation of the overflow tube. Once the water reaches that level, it begins to overflow back to the inlet reservoir under the table. When the "To Model" ball valve is opened, water from the reservoir enters the system but the water level in the water tower remains constant providing a constant pressure to the model system. This is shown in Figures 4-7.

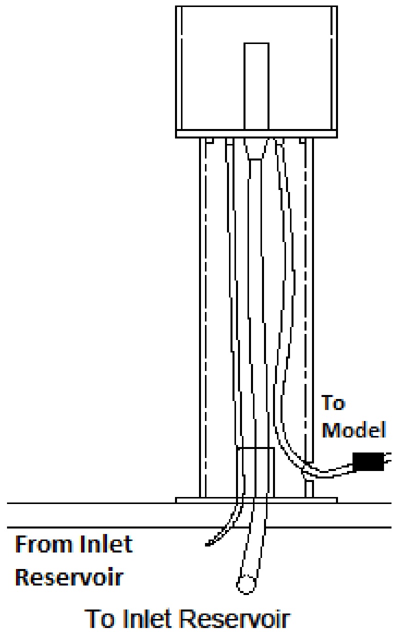

FIGURE 4. EMPTY WATER TOWER

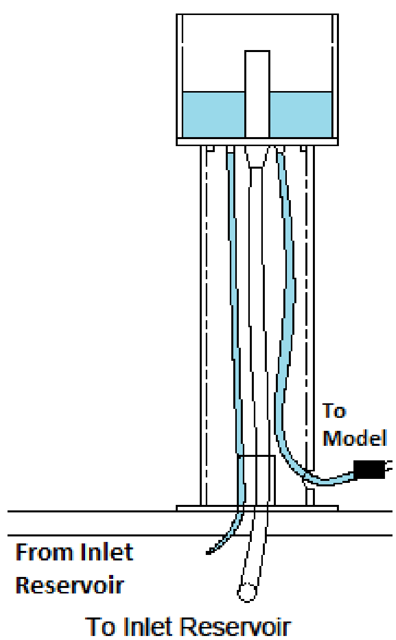

FIGURE 5. WATER TOWER FILLING

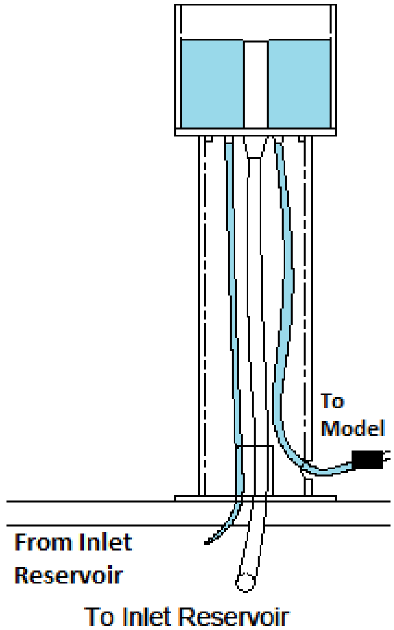

FIGURE 6. WATER LEVEL REACHING OVERFLOW

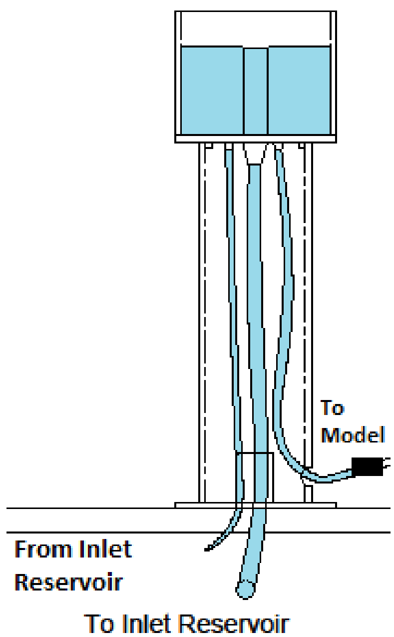

FIGURE 7. WATER OVERFLOWING

Connect the “To Model” line which exits the water tower through the small hole to the inlet quick disconnect (Q5) on the model.

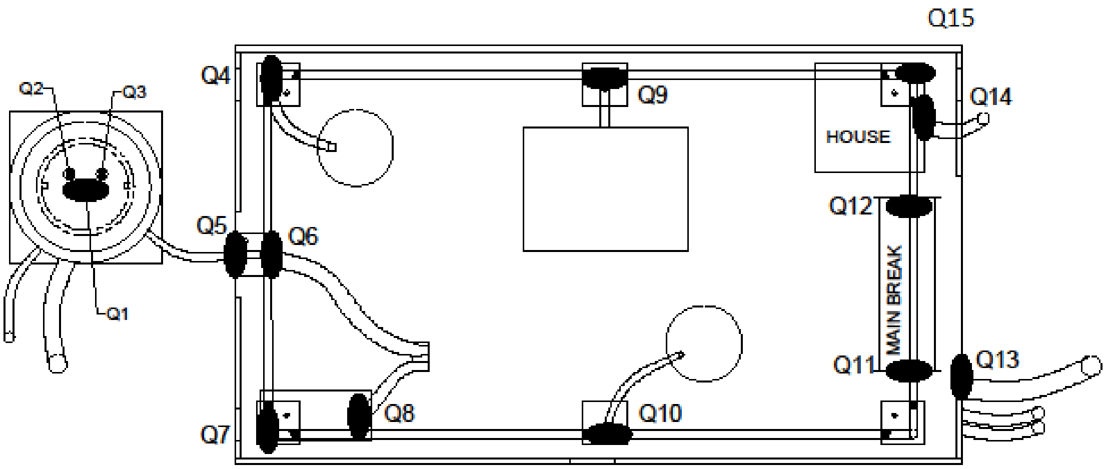

FIGURE 8. QUICK DISCONNECTS

Next gather the four remaining flexible tubing sections which are stored in the inlet reservoir. There should be two ¼” tubes (Q6 and Q8), one ½” tube(Q13) and one 3/8” tube (Q14). Thread both ¼” lines from through the hole in the bottom of the model to their matching quick disconnect sockets. Each tube and socket should be labeled. Q6 can connect immediately, but Q8 will not connect until the scenarios have been connected. The other two tubing and quick disconnect plugs connect at Q14 and Q13. Once each of these quick disconnects are locked, gather the opposite ends of the flexible tubing and insert them into the mouth of the outlet reservoir making sure there are no kinks in any of the tubes. Figures 8 and 9 give an overview of where each tube should run.

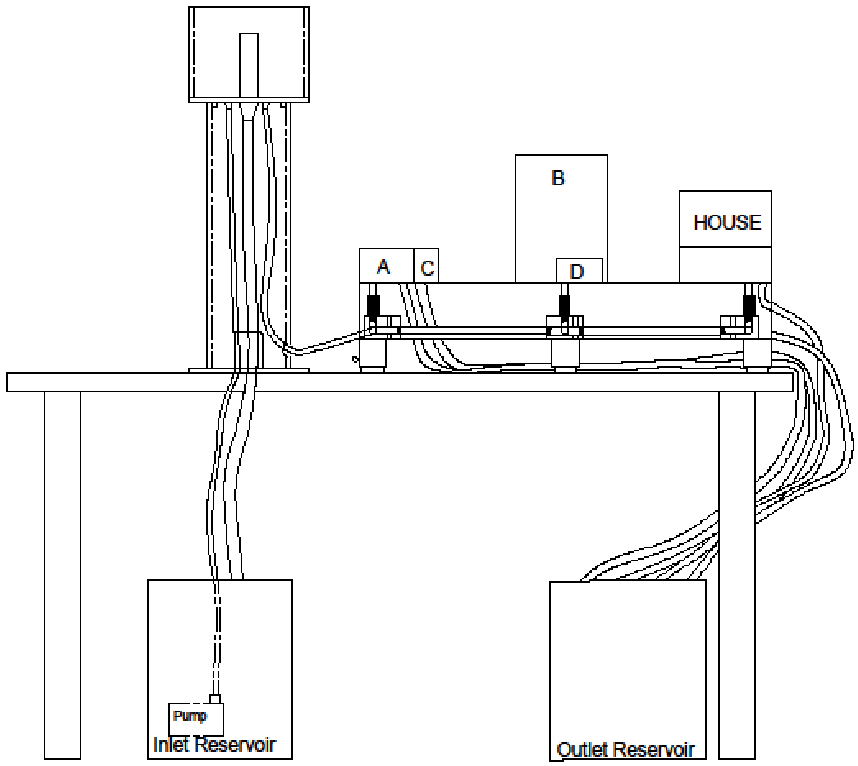

FIGURE 9. TUBING SET-UP SIDE VIEW

SET-UP OF SCENARIOS

Next, retrieve each scenario and the house from storage and connect to appropriate locations using the attached quick disconnect fittings. Appropriate locations for each scenario are shown in Figures 10 and 11. Once Scenario C is attached Q8 can be connected. Both Scenario A and D have Velcro pads to secure their reservoir. Make sure both scenarios are oriented correctly and secured with this Velcro connection.

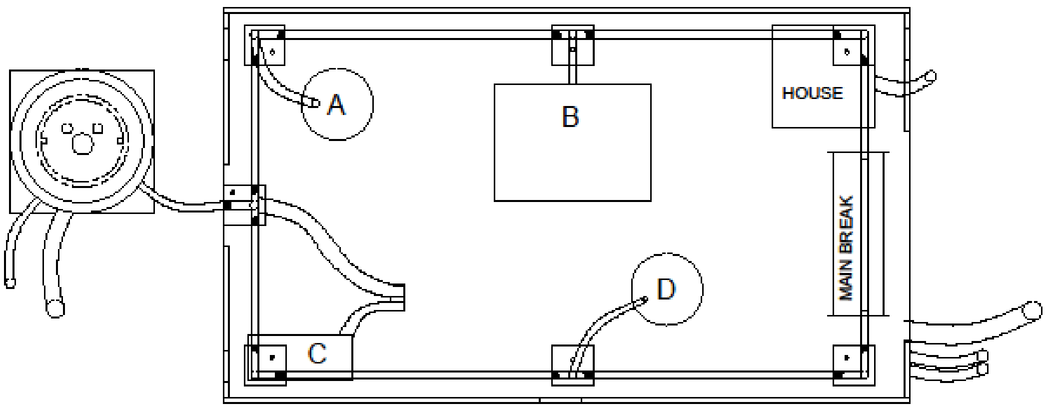

FIGURE 10. SCENARIOS (ABOVE VIEW)

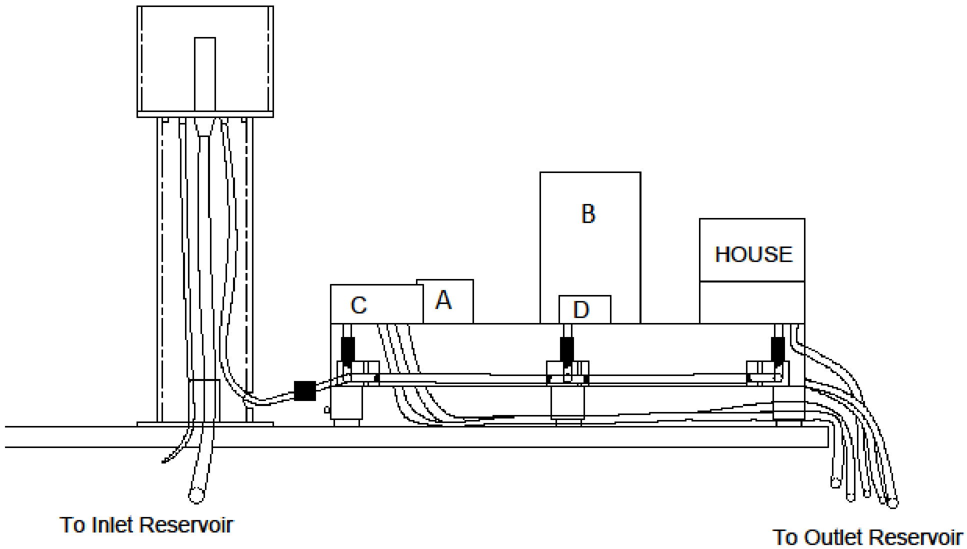

FIGURE 11. SCENARIOS (SIDE VIEW)

Scenarios:

A: Back-Pressure - Private Water Well Pump
B: Back-Pressure - Pressurized Vessel, Boiler in Office Building
C: Back-Siphon – Subsurface Cracked Pipes Contamination Scenario
D: Back-Siphon- Submerged Inlet at Cow Water Trough/Truck Fill Station

Set-up of Accessory Pieces

All of the decorative accessory pieces should be found in the large storage container accompanying the model. Photo 12 is provided to demonstrate appropriate placement of each piece. Each tree should have a Velcro patch on the bottom with a corresponding patch placed on the encasing's surface. The traffic set, cows, truck, fire hydrant and well all attach using sticky tack which should remain on the bottom of the piece and be placed on the Xs marked along the model. The greenery rings are to be placed on the reservoirs of scenario A and D.

Figure 12. Photo of Model Arrangement

Model Operation

To begin, make sure each of the ball valve is in its correct position as outlined in Figure 13.

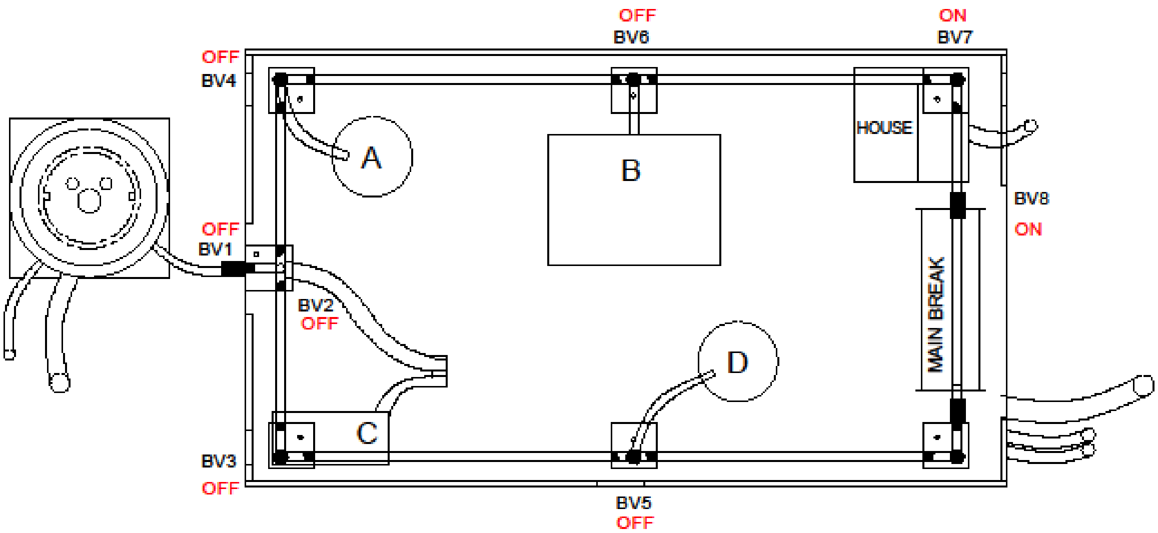

Figure 13. Set Up: Orientation of ball valves

A ball valve in the OFF position will have its handle perpendicular to the shaft of the valve. A ball valve in the ON position will have a handle in line with the shaft of the ball valve. Before using each scenario, familiarize yourself with the ways each ball valve turns. This is shown in Figures 14 and 15.

Figure 14. Set-Up: Ball Valve ON

FIGURE 15. SET-UP: BALL VALVE OFF

Once the ball valves are in their correct orientation, all quick disconnects have been connected and the inlet reservoir is full, plug in the main pump to the power strip and plug the power strip into the nearest outlet. The water tower will begin to fill at this point.

Once the water in the water tower has reached the overflow level, turn BV1 to the ON position to activate the model (Figure 16).

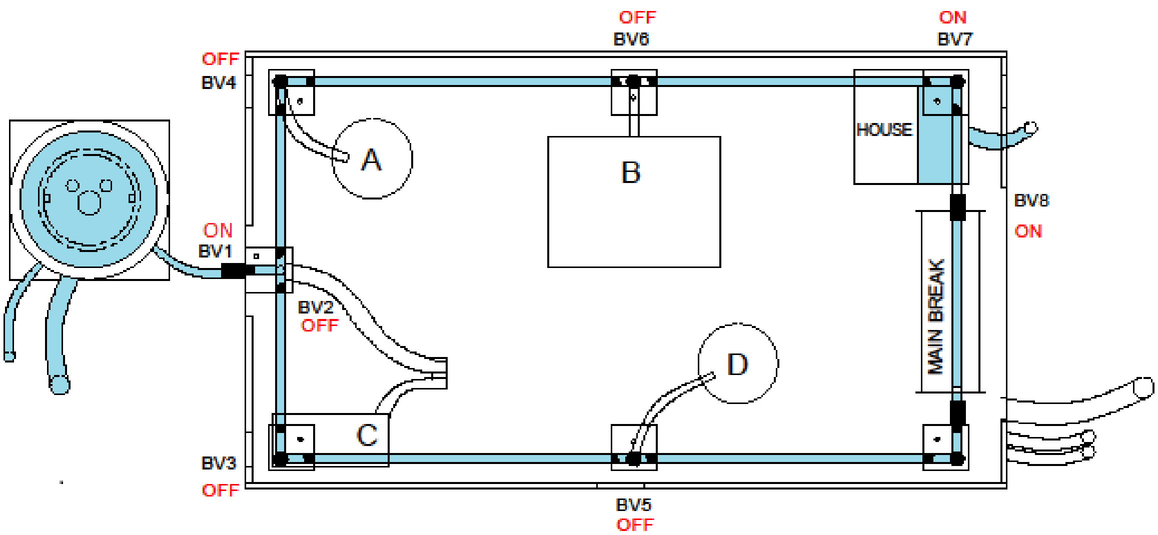

FIGURE 16. SET-UP: MODEL BASIC SET-UP WITH WATER

The acrylic tubing within the model should fill with water and the house should begin to fill and drain. At this point you will need to rid the system of air bubbles and flush each scenario. To do this close all ball valves. Slowly open BV7 on the house to barely let any water escape. Keeping the ball valve in this position gently tip the corner of the model with the house up so that all trapped air bubbles can exit through the house. Gently tap the model if necessary.

One by one open the ball valves leading to each scenario (BV4, BV3, BV5) to get water to fill the lines. It is not necessary to open BV6. Open BV5 and BV4 until water has filled ¾ of the reservoir. Fill the small reservoir on the subsurface back-siphon scenario (C) with water.

Adding Dye to Scenarios

In each of the reservoirs for scenarios A, C, and D add 5 drops of different colored food dye. Suggested colors are shown in Figure 17. Instructions for adding dye to scenario B are found in the following section.

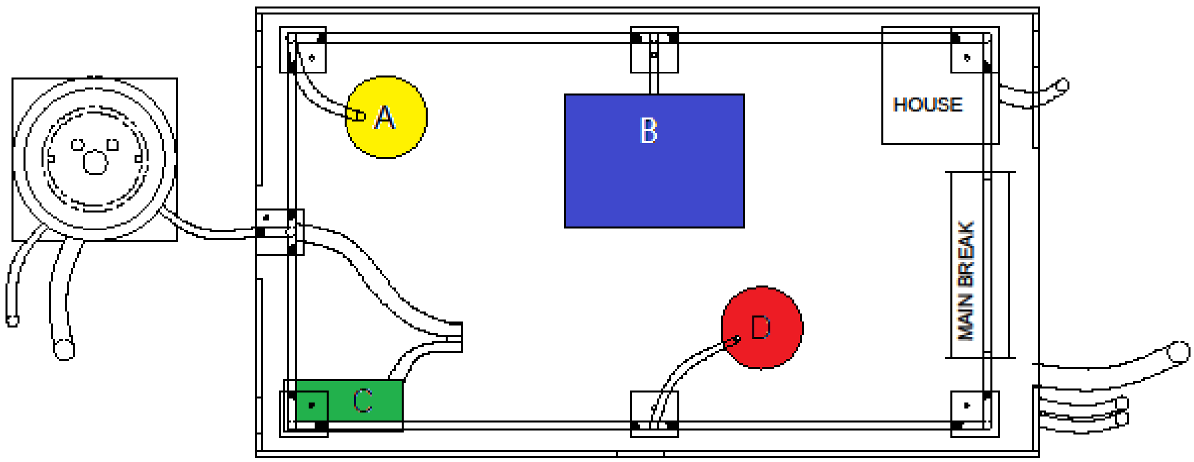

Figure 17. Set-Up: Suggested scenario dye colors

Filling Pressurized Vessel

Figure 18. Pressurized vessel

Before connecting the quick disconnects for Scenario B, the pressurized vessel in the office building, you will need to fill the vessel (Figure 18). This may not be necessary for each demonstration of the model, because once filled the reservoir should contain enough liquid for five demonstrations of the scenario. To fill the scenario, remove the sprayer tank from the office building. Unscrew the lid and fill the reservoir ¾ full. Add 10 drops of dye and recap the vessel. Put the vessel back in the office building and thread the flexible tubing through the hole in the office building and connect it to Q9. The pressurized vessel does not need to be flushed with water but simply pumped 4-5 times before its demonstration.

The model is now ready to use. The mechanics and instructions for each scenario are outlined below.

OPERATION OF EACH SCENARIO

The overall layout and scenario location is demonstrated in Figures 19 and 20.

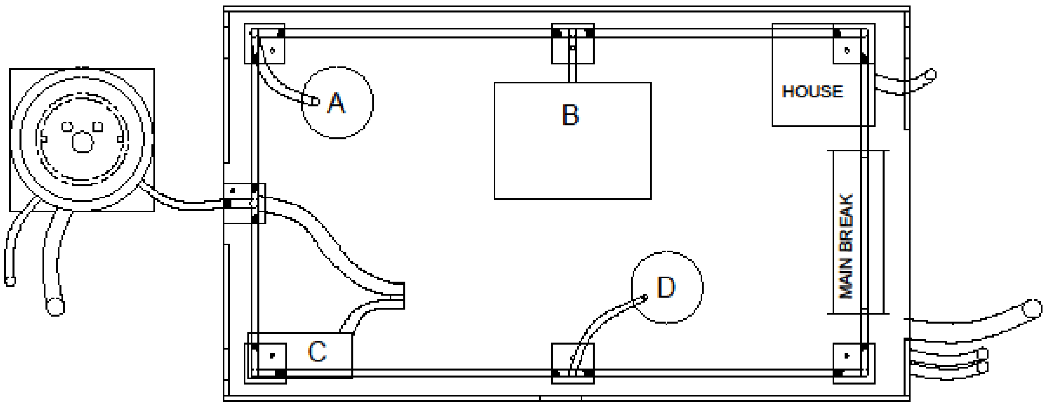

FIGURE 19. LOCATION OF SCENARIOS (ABOVE VIEW)

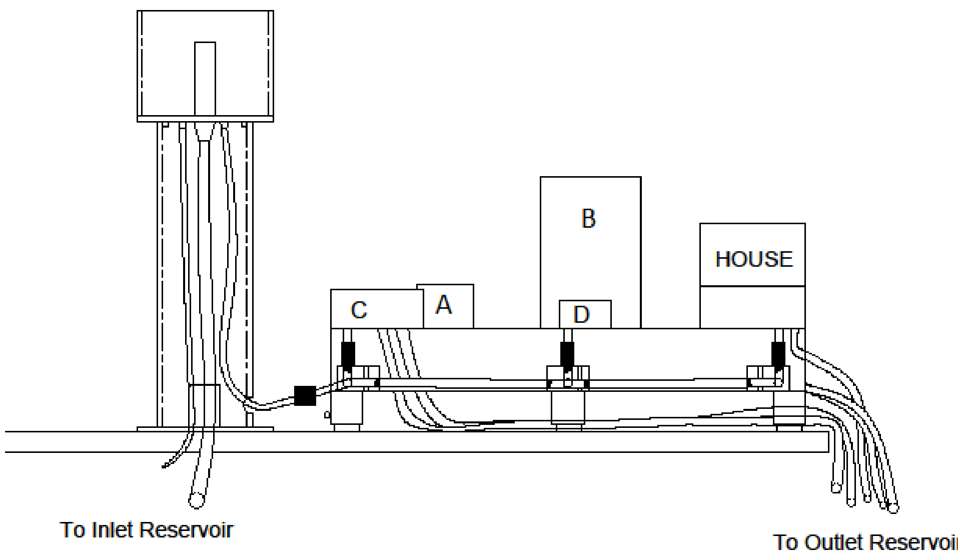

FIGURE 20. LOCATION OF SCENARIOS (SIDE VIEW)

Scenarios:

A: Back-Pressure - Private Water Well Pump
B: Back-Pressure - Pressurized Vessel, Boiler in Office Building
C: Back-Siphon – Subsurface Cracked Pipes Contamination Scenario
D: Back-Siphon- Submerged Inlet at Cow Water Trough/ Truck Filling Station

Normal Flow Conditions

First, a demonstration of the model in normal flow conditions without any scenarios activated is shown in Figures 21 and 22.

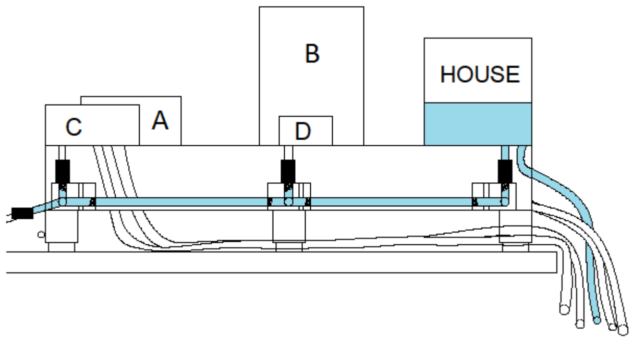

Figure 21. Normal Flow Conditions (Side View)

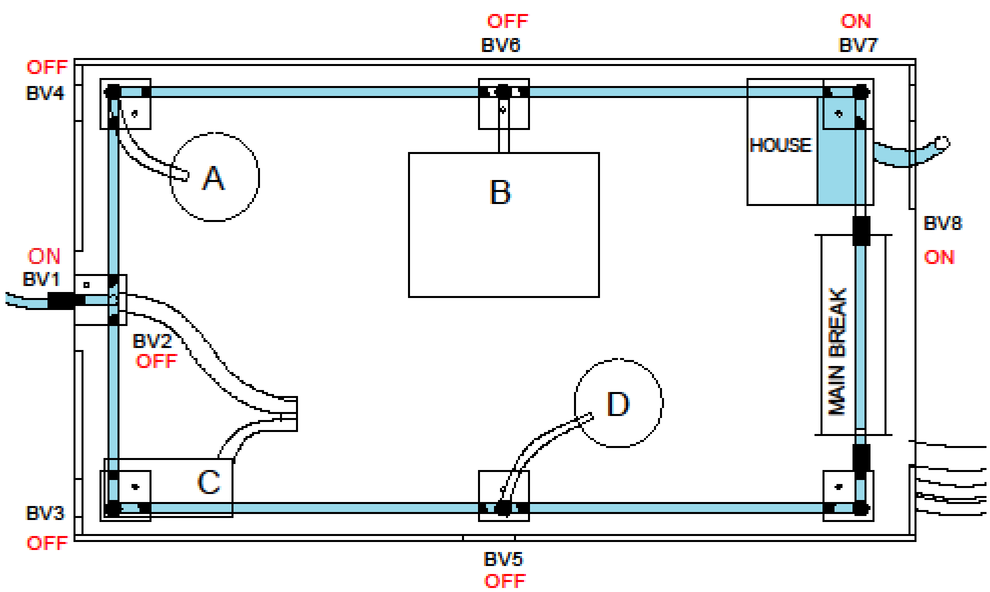

Figure 22. Normal Flow Conditions (Above View)

The scenarios can be presented in any order upon demonstration. Between demonstrations of scenarios sufficient time must be given for dye to flush fully from the house reservoir. This should take no longer than 30 seconds after scenario demonstration is complete. When presenting each scenario, it is best to do most of the explanation for the scenario before activating it, as each scenario can only run for roughly 45 seconds-1 minute.

Scenario A: Back-Pressure Contamination Through Private Water Well

Before running this scenario, please make sure all of the steps have been followed in the set-up section of the operation and parts manual. Also, check to make sure that ball valves, 1, 7, and 8 are open and that water is collecting and overflowing through the house outlet as diagramed in Figures 21 and 22.

Scenario A is a depiction of a back-pressure private water well scenario. To run the scenario, first plug in the pump. The pump can be plugged in at the initial setup of the model or right before running Scenario A. The pump should be plugged in to the supplied power strip which the main pump is also connected to. Turn BV4 to the open position releasing dyed water into the system. You should be able to see dye within the acrylic tubing and also entering the house reservoir. Figures 23-26 depict this scenario. After explaining the scenario, shut BV4 and allow the system to run until all dye has been flushed from the system. The scenario can be left on as long as there remains water in Reservoir A. Once the water level falls below the level of the pump, turn BV4 to the OFF position.

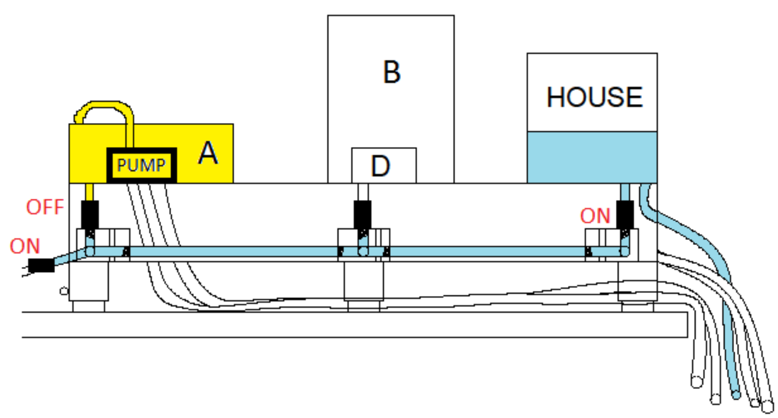

Figure 23. Scenario A: Set-up (Side View)

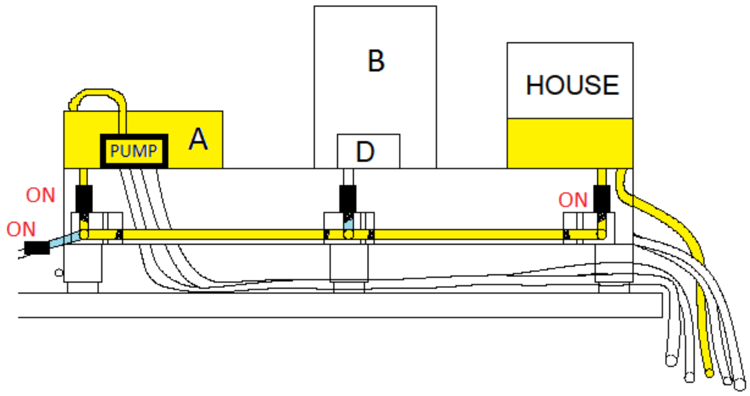

FIGURE 24. SCENARIO A: STEP 1 - TURN ON BV4

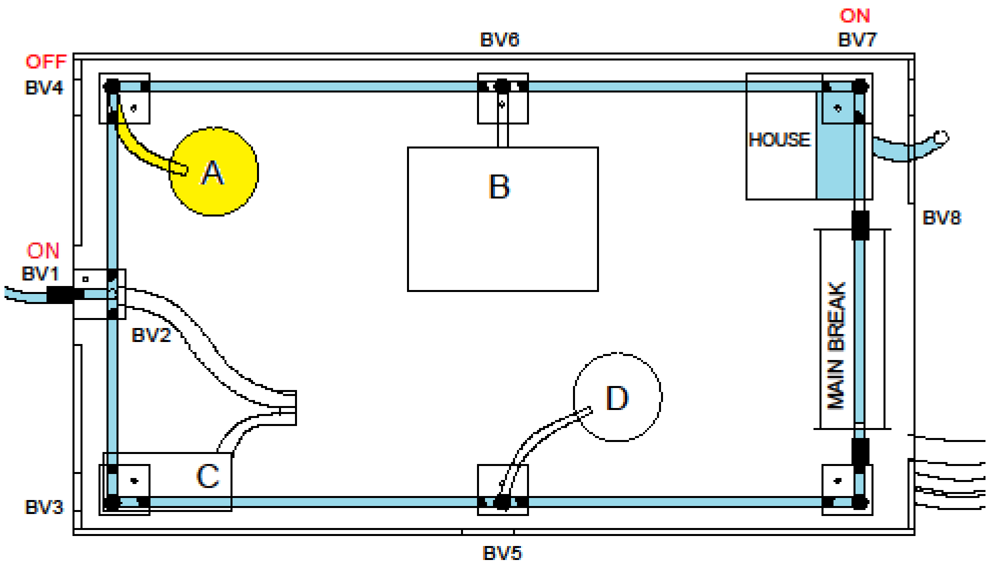

FIGURE 25. SCENARIO A: SET-UP (ABOVE VIEW)

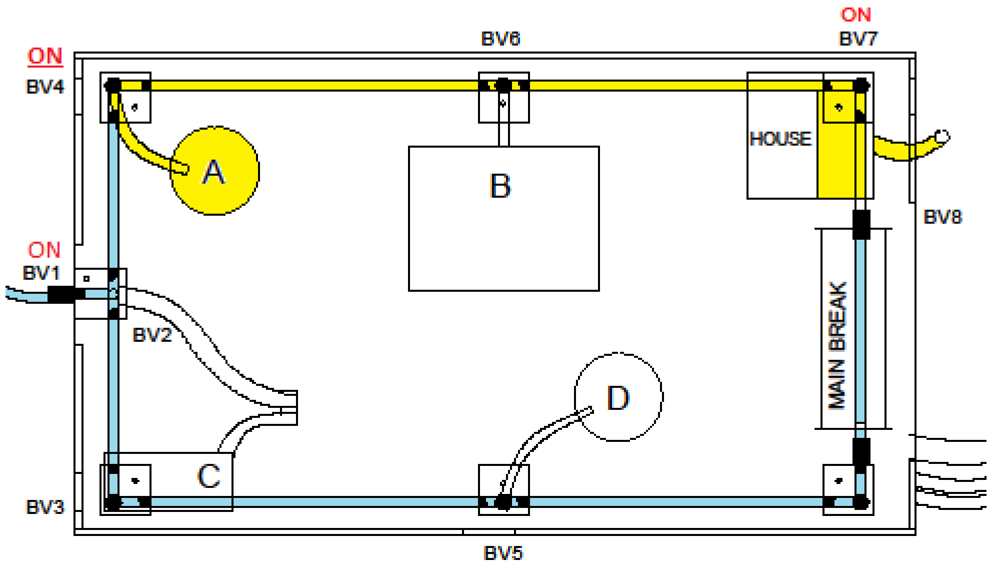

FIGURE 26. SCENARIO A: STEP 1 - TURN ON BV4

Scenario B: Pressurized Vessel, Boiler in Office Building

Before running this scenario, please make sure all of the steps have been followed in the set-up section of the operation and parts manual. Also, check to make sure that ball valves, 1, 7, and 8 are open and that water is collecting and overflowing through the house outlet as diagramed in Figures 21 and 22.

Scenario B is a depiction of a boiler in an office building which creates backpressure contamination into the main system. To run this scenario, first, make sure that the pressurized vessel has been filled and pumped 5 times. Do not pump the vessel more than 5 times. If the pressurized vessel has to high of a pressure, dye will enter the entire system and may make it into the water tower reservoir. Not only is this inaccurate for demonstrational purposes it could also affect future scenario demonstrations. If it has not been filled refer to page 14 on preparing the pressurized vessel. When ready to operate the scenario turn ON BV6 and dyed water will enter the system through the pressurized vessel. Allow the dye to enter the house reservoir and then close BV6. Permit all dye to flush from the system before moving to the next scenario. This should take no more than 30 seconds. Figures 27- 30 depict this scenario.

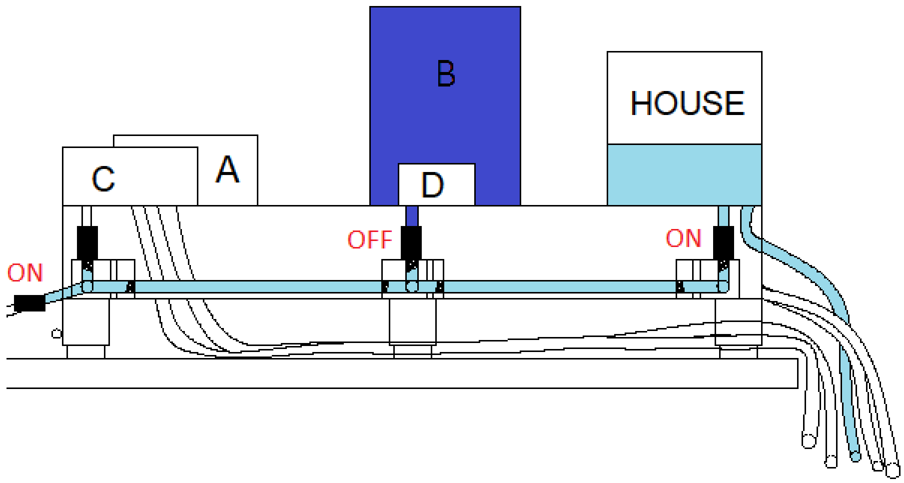

FIGURE 27. SCENARIO B: SET-UP (SIDE VIEW)

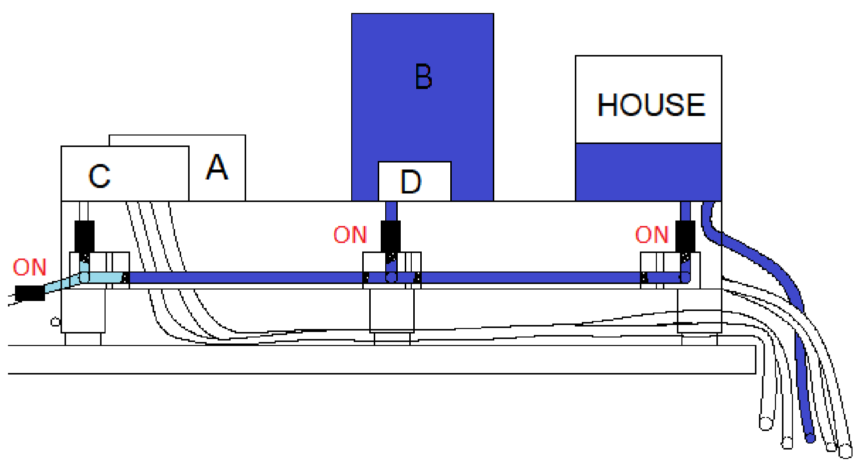

FIGURE 28. SCENARIO B: STEP 1- TURN ON BV6

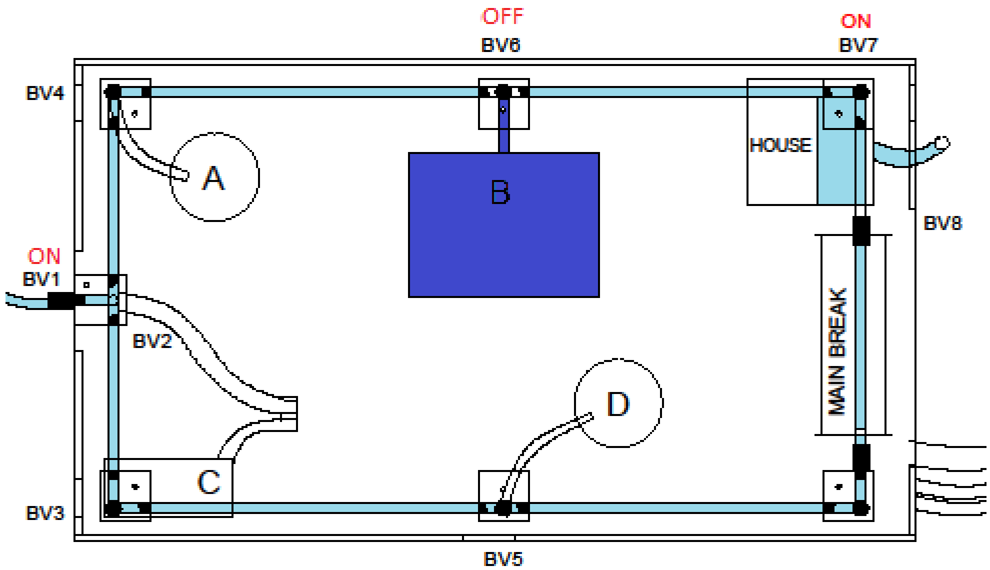

FIGURE 29. SCENARIO B: SET-UP (ABOVE VIEW)

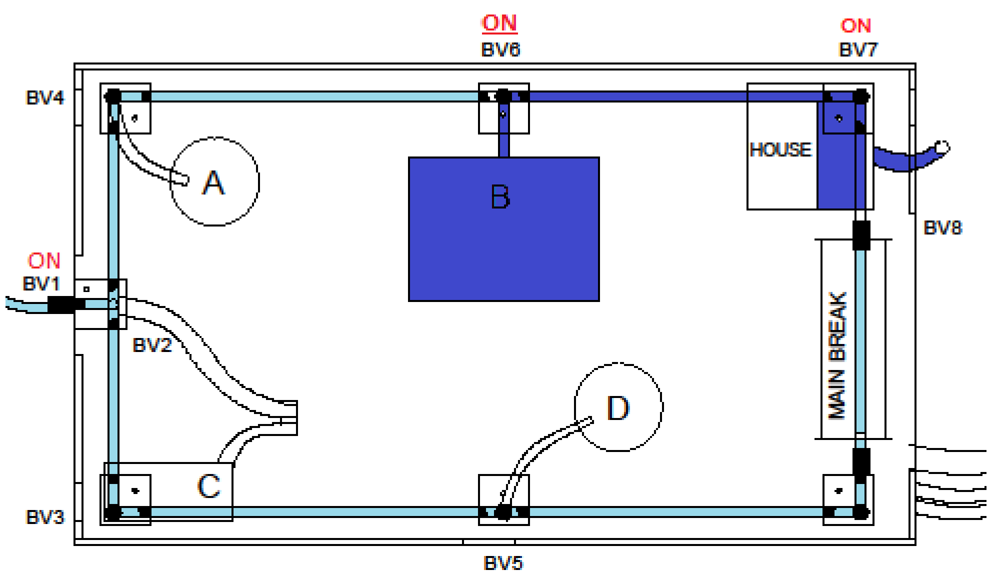

FIGURE 30. SCENARIO B: STEP 1- TURN ON BV6

Scenario C: Backsiphonage Subsurface Contamination through Pipe Leak & Main Break

Before running this scenario, please make sure all of the steps have been followed in the setup section of the operation and parts manual. Also, check to make sure that ball valves, 1, 7, and 8 are open and that water is collecting and overflowing through the house outlet as diagramed in Figures 21 and 22.

Scenario C demonstrates water contamination which occurs at the time of a main break from cracks in sanitary and sewage pipes through subsurface contamination. This is one of the more complex scenarios to demonstrate. To achieve a successful demonstration, steps should be followed exactly. The small reservoir on top of Scenario C should be filled with dyed water. To demonstrate the contamination within a sewage line turn the ball valve under the reservoir ON. At this point dye should enter the subsurface box and contaminate the entire box with dyed water. Turn ON BV3 and allow water to fill the box and drain through the overflow. As long as a higher pressure is kept in the drinking water line, no contamination should enter the system. Now it is time to simulate a break in the water main. To do this, disconnect the flexible tubing section in the main break area. The trough should begin to fill with water and drain. To allow for necessary maintenance on the main valves below and above the main break are closed. To demonstrate this turn OFF BV8 and BV1. This should prevent flow to the side of the model where Scenario C is located. After the main valves are closed, dye should flow from Scenario C into the main lines towards the main break. Once this takes place "fix" the main by reconnecting it and once it is reconnected turn ON BV8 and BV1. The dye within the lines should travel towards the house and contaminate the bathtub reservoir. These steps are shown in Figures 31-41.

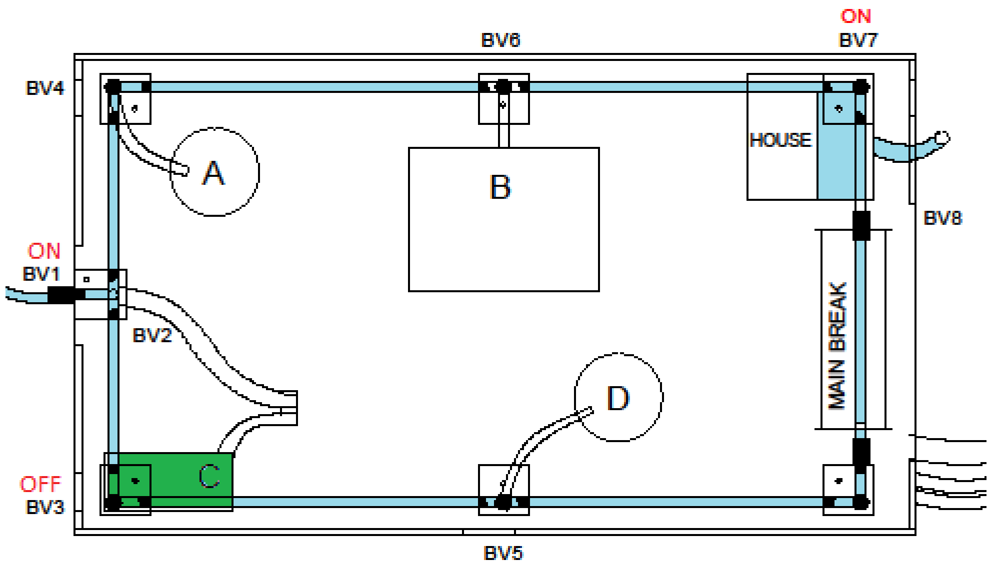

FIGURE 31. SCENARIO C: STEP 1- DYE ENTERING SCENARIO (ABOVE VIEW)

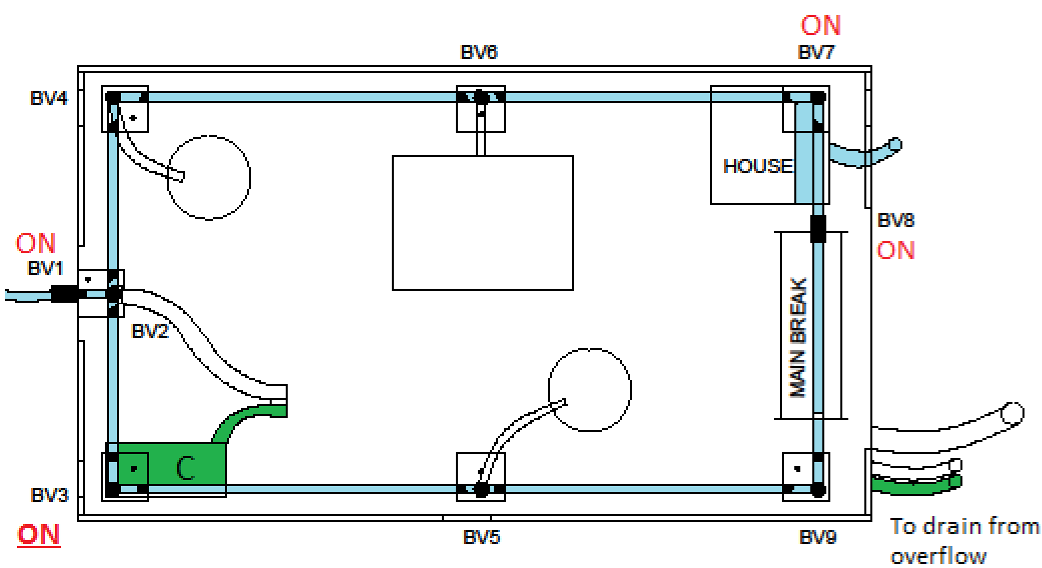

FIGURE 32. SCENARIO C: STEP 2 – DYE OVERFLOW IN SCENARIO (ABOVE VIEW)

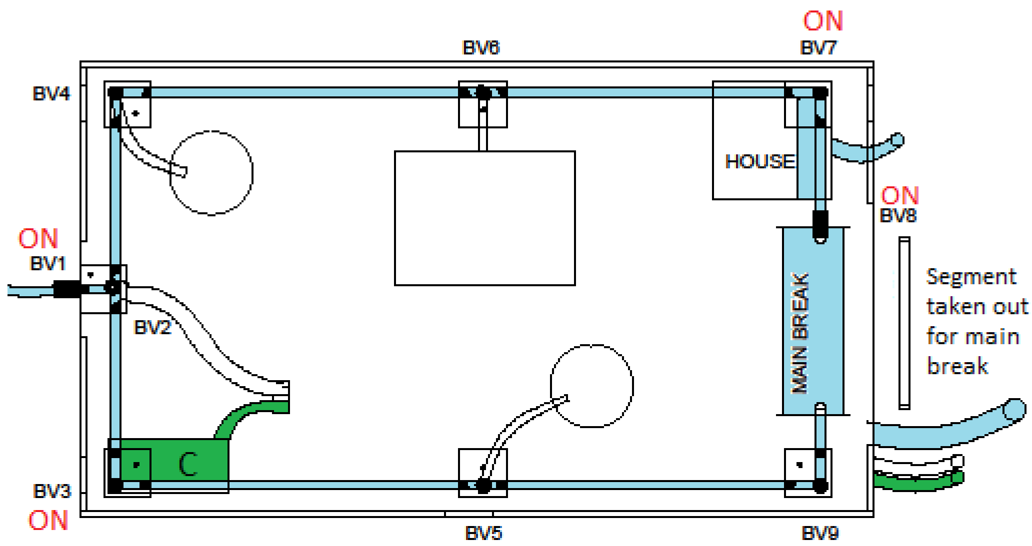

FIGURE 33. SCENARIO C: STEP 3 – REMOVE SEGMENT FOR MAIN BREAK (ABOVE VIEW)

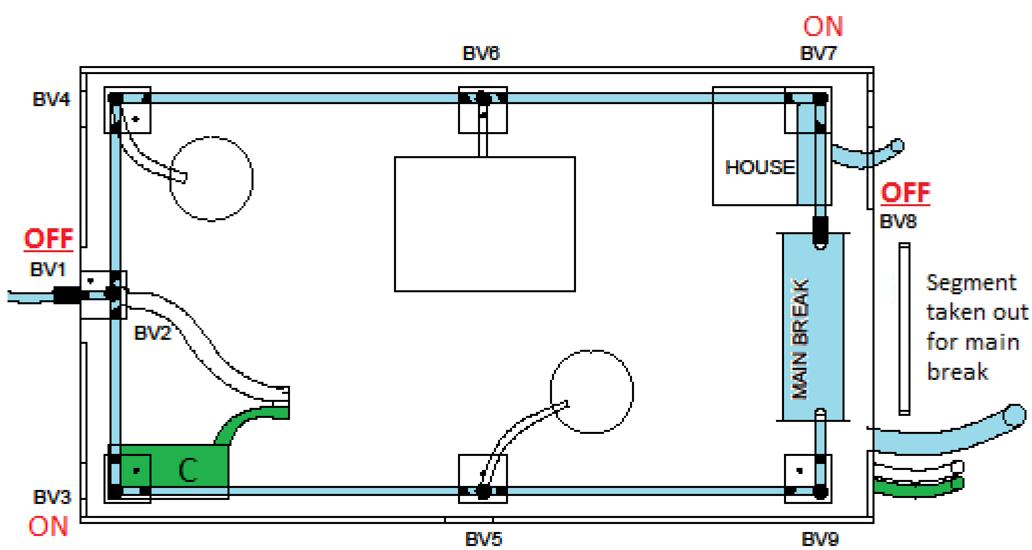

FIGURE 34. SCENARIO C: STEP 4 - TURN OFF BV1 & BV8 (ABOVE VIEW)

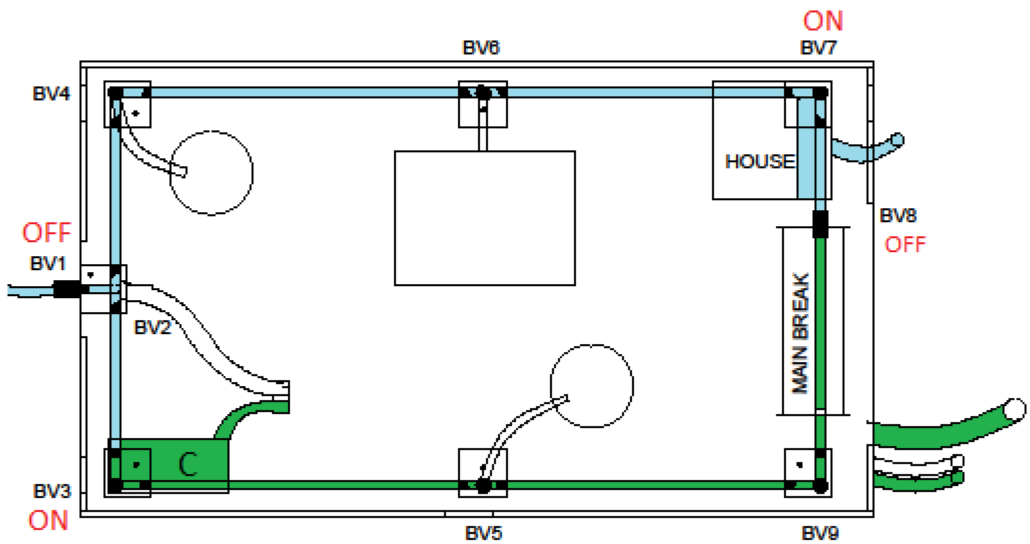

FIGURE 35. SCENARIO C: STEP 5 - REATTACH SEGMENT ("FIX" BREAK) (ABOVE VIEW)

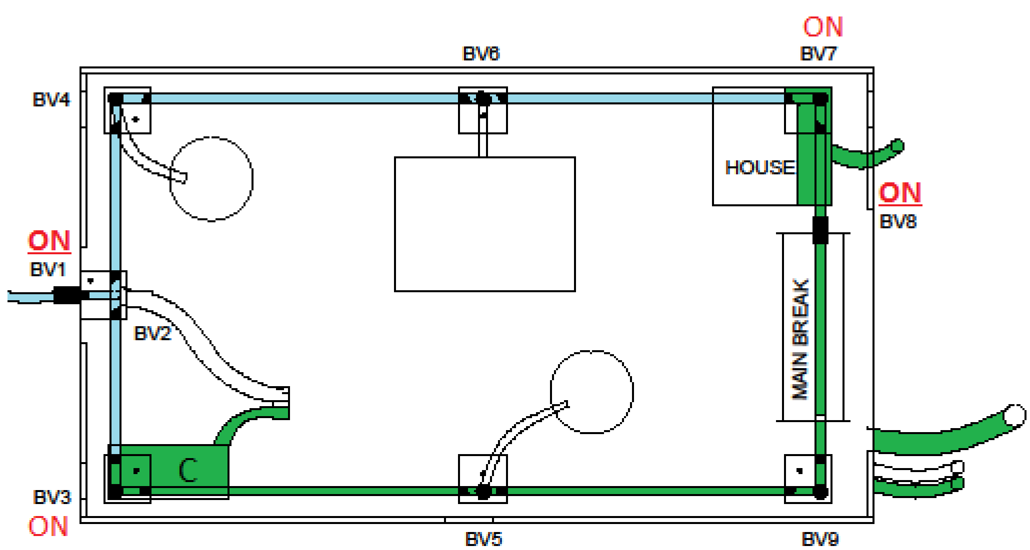

FIGURE 36. SCENARIO C: STEP 6 - OPEN BV1 & BV8 (ABOVE VIEW)

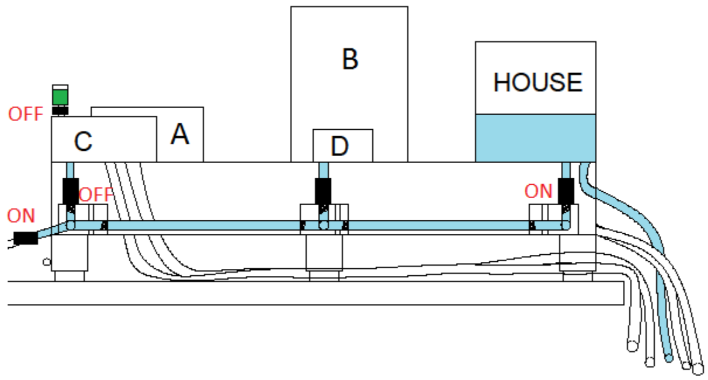

Figure 37. Scenario C: Set-up (Side View)

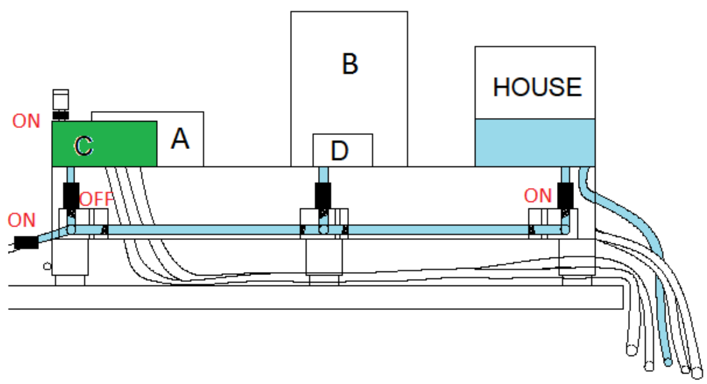

Figure 38. Scenario C: Step 1 - Dye Entering Scenario (Side View)

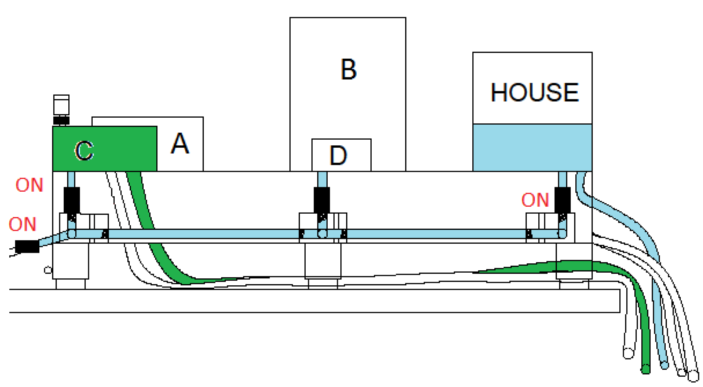

Figure 39. Scenario C: Step 2 - Dye Overflow in Scenario (Side View)

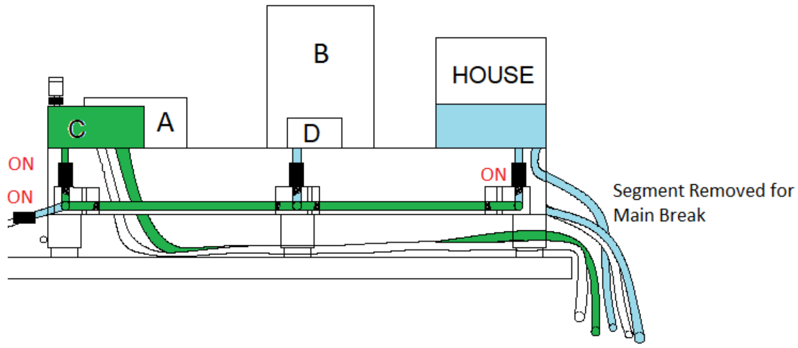

FIGURE 40. SCENARIO C: STEP 3 - REMOVE SEGMENT FOR MAIN BREAK (SIDE VIEW)

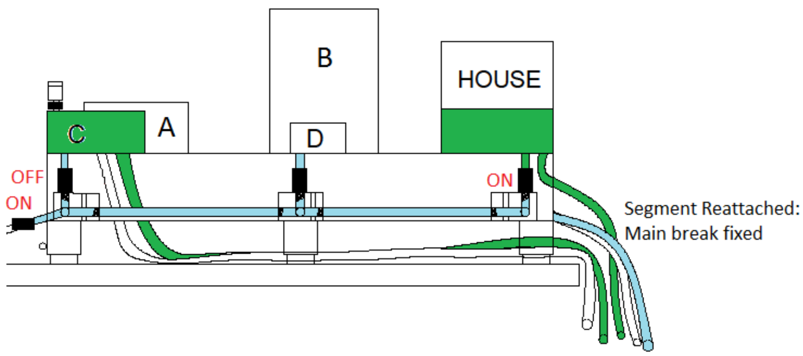

FIGURE 41. SCENARIO C: STEP 5 - REATTACH SEGMENT ("FIX" BREAK) (SIDE VIEW)

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Scenario D: Backsiphonage Through Submerged Inlet

Before running this scenario, please make sure all of the steps have been followed in the set-up section of the operation and parts manual. Also, check to make sure that ball valves, 1, 7, and 8 are open and that water is collecting and overflowing through the house outlet as diagramed in Figures 21 and 22.

This scenario demonstrates backsiphonage through a fire-flow incident coupled with a submerged inlet either on a stock tank or a truck fill station. To run this scenario, first open BV5 and allow water to enter the reservoir of Scenario D. During normal flow conditions the water pressure will not allow contamination in to the system through this submerged inlet. To simulate a fire-flow condition where a large water demand for firefighting is needed turn BV2 to the ON position. Water in the system will begin to drain to the outlet reservoir through this fire-flow line and contaminated water from Scenario D will enter the water lines. When sufficient dye has entered the water line close BV2 and BV5. Contaminated water should flow from the lines to the house and contaminate the bathtub reservoir. Step-by-step depictions of this can be found in Figures 41-48.

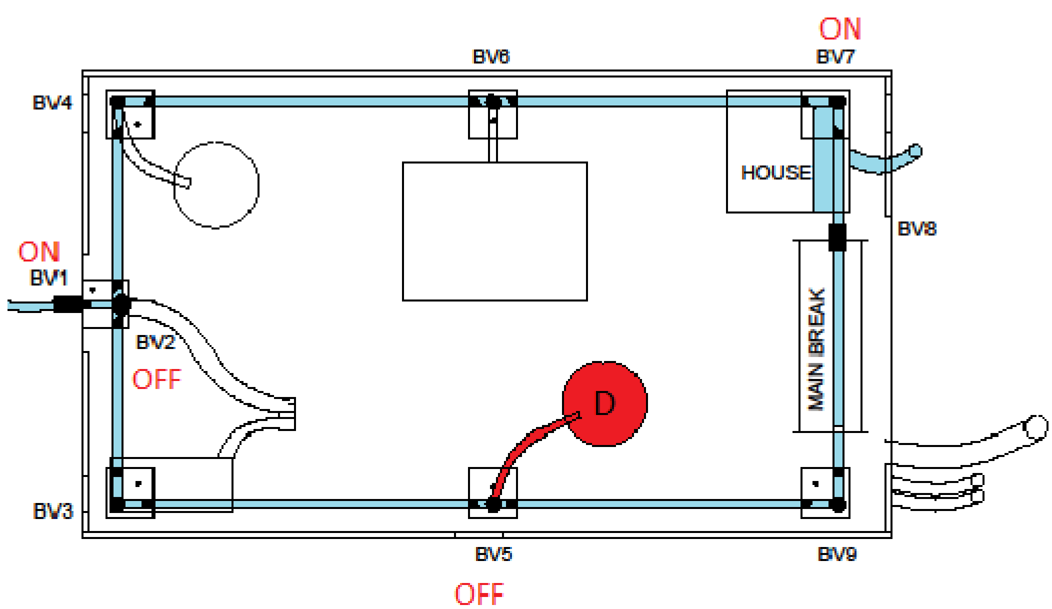


Figure 41. Scenario D: Set-up (Above View)

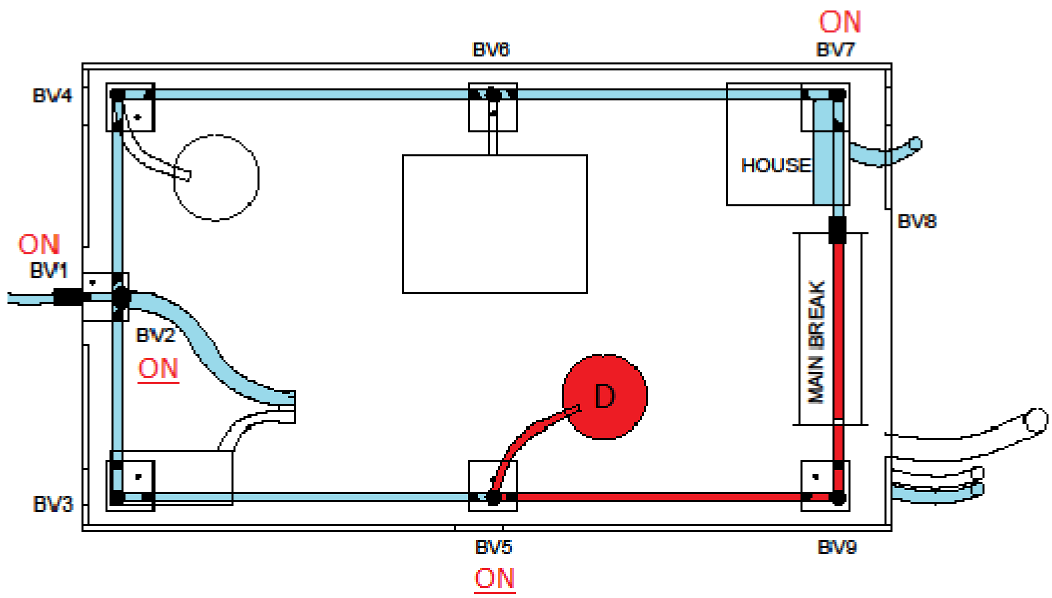


FIGURE 42. SCENARIO D: STEP 1- OPENING BV5 & BV2 (ABOVE VIEW)

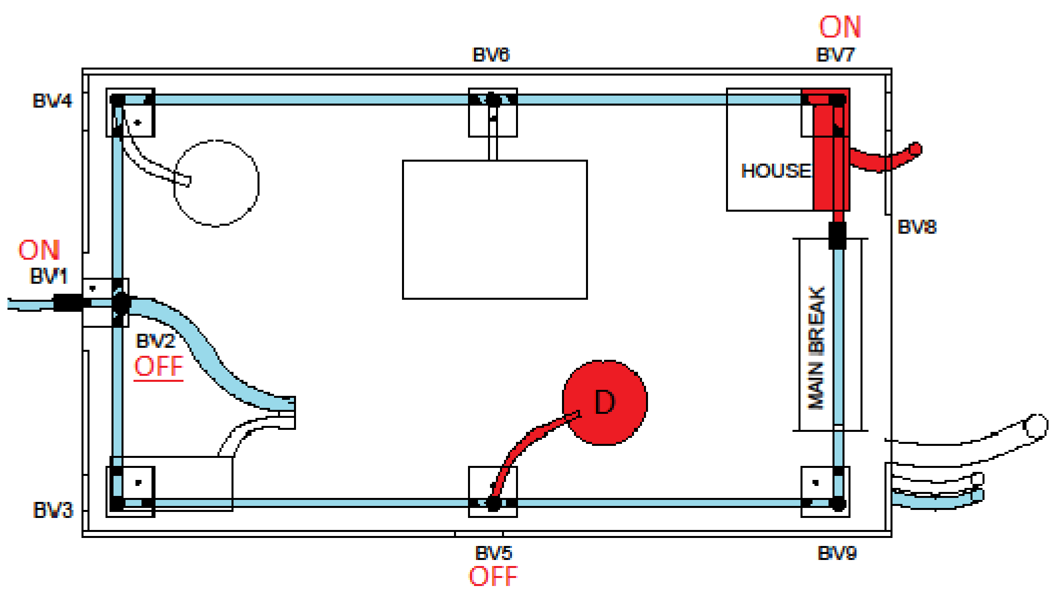


FIGURE 43. SCENARIO D: STEP 2 - CLOSING BV5 & BV2 (ABOVE VIEW)

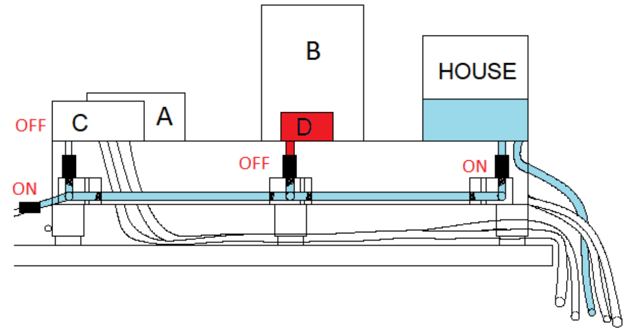


FIGURE 44. SCENARIO D: SET-UP - DYE IN RESERVOIR D (SIDE VIEW)

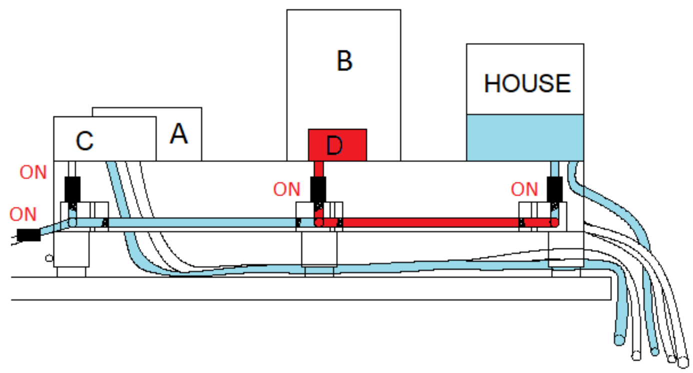


FIGURE 45. SCENARIO D: STEP 1- OPEN BV5 & BV2 (SIDE VIEW)

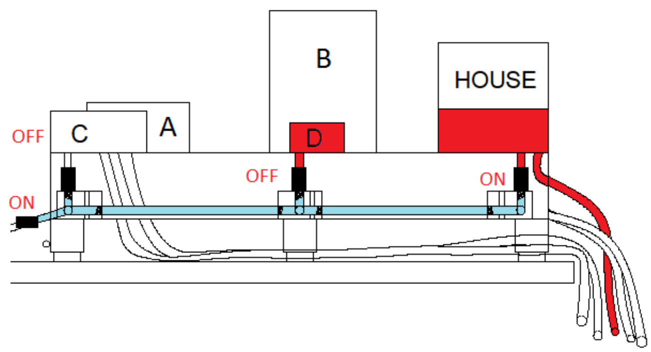


FIGURE 46. SCENARIO D: STEP 2 - DYE IN RESERVOIR D (SIDE VIEW)

Clean-up & Maintenance

After Use

1) The system must first be flushed to rid the piping and scenarios of any remaining dye. Run the system continuously after demonstration for at least one minute or until all traces of dye have visibly exited.

2) Unplug each pump from the power source.

3) Close the ball valve on the inlet line (BV1) connecting the water tower and the encased model. At this point the water tower will drain into the inlet reservoir. Figure 47 shows correct orientation for all ball valves for draining of model.

4) Make sure BV8 is open to allow a free drainage path within the acrylic pipe network.

5) Check to make sure each ball valve to a scenario is closed. (BV3, BV4, BV5, BV6). Keep the ball valve to the house unit open (BV7).

6) Disconnect the flexible tubing section which simulates the main break. All of the system's remaining water should be drained through this connection.

7) Gently lift the model on the side closest to the water tower to drain the remaining water in the acrylic lines to the main break trough.

8) Check to make sure water has drained from the house and each acrylic junction.

9) Empty each backsiphonage scenario by disconnecting the flexible tubing from the model. These scenarios can be cleaned separately. It is recommended to remove all dye and water from these scenarios.

10) The water tower should drain once the pump is unplugged but check to make sure it is cleared of water.

11) Water from both inlet and outlet reservoirs water may be disposed of.

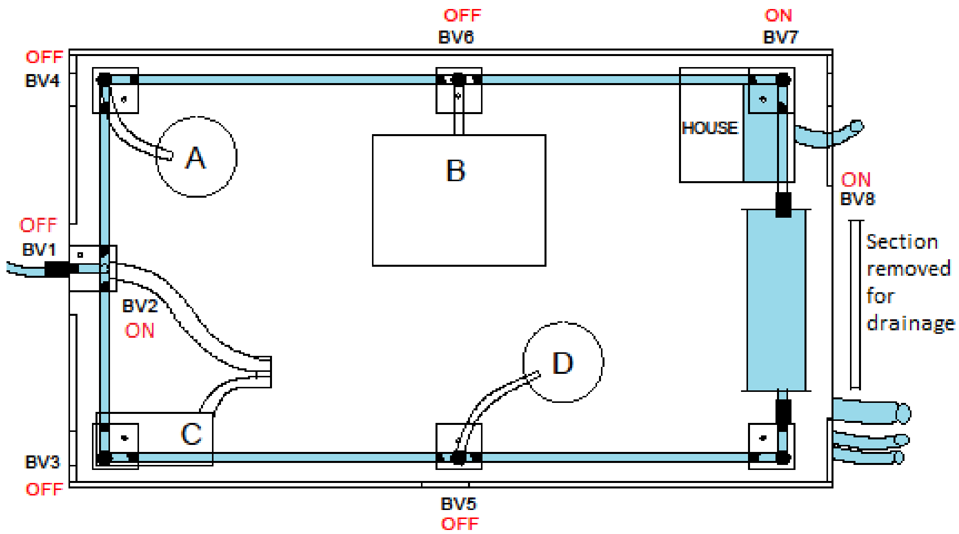


FIGURE 47. BALL VALVE ORIENTATION FOR DRAINING MODEL

CLEANING

The model should be cleaned before long-term storage (upwards of a month). It should also be cleaned after every five or six uses with a water and vinegar solution to avoid dye build up or bacteria. Cleaning the model involves filling the inlet reservoir with a water-vinegar mixture of one part vinegar to 5 parts water and running the entire model, making sure to activate each scenario. A total volume of one gallon of the vinegar cleaning solution is recommended. After cleaning, the model should be flushed with tap water and completely emptied.

It is not recommended to leave stagnant water within the system when the model is not in use. It is also not recommended to leave any dyed water within the system when not in use. This could lead to permanent discoloration of the acrylic infrastructure. An air tank can be attached to the inlet and used for more efficient drying.

If any discoloration of the system occurs follow the outlined cleaning procedure and if discoloration persists refer to Parts Manual to replace discolored model parts.

INSPECTION

It is recommended that model is examined after every 5 uses and joints are examined carefully. If a leak is detected within the acrylic/acrylic fittings, fusing the acrylic joints by applying acrylic glue is recommended for repairs. If any leaks are found at threaded junctions, it is recommended that clear silicone glue is applied to the threads and the seal retightened.

APPENDIX B: PARTS MANUAL

PARTS MANUAL

Contents

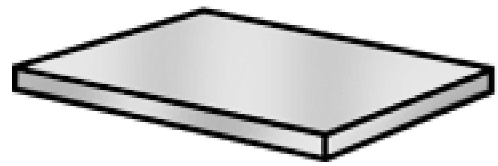
PARTS

MCMASTER-CARR

ACRYLIC SHEETS

1.25” CAST ACRYLIC SHEET

Length: 12”, Width: 12”, Height 1.25”
Part Number: 8560K381
$59.45 Each



¼” CAST ACRYLIC SHEET

Length: 8’ Width: 48” Height: ¼”
Part Number: 8560K437
$245.62 Each

ADAPTERS

FDA WHITE NYLON SINGLE BARBED TUBE FITTING ADAPTER

¼” Tube ID x ¼” NPT Male Pipe
Part Number: 5116K87
$2.99 per pack of 10

BALL VALVES

MINIATURE CHROME-PLATED BRASS BALL VALVE WEDGE HANDLE

1/4" NPT Female X Male Connections.
Part Number: 4912K72
$5.38 Each

HOSE CLAMPS

STAINLESS STEEL WORM DRIVE HOSE CLAMPS

For ¼” pipe
Part Number: 5321K14
$6.48 for a pack of 10

PIPE TAPE

COMMERCIAL GRADE PIPE THREAD SEALANT TAPE

50'L X 1/2" W, .0028" Thk, 0.5 G/CC Specific Gravity
Part Number: 4591K12
$1.65 per roll

FLEXIBLE TUBING

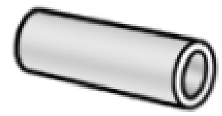
CLEAR PVC FLEXIBLE TUBING 3A

Sanitary, ¼” ID, 3/8” OD
1/16” Wall Thickness
Part Number: 5231K331
$0.30 per foot

CLEAR PVC FLEXIBLE TUBING 3A

Sanitary, 3/8” ID, ½” OD
Part Number: 5231K355

Rigid Tubing



Extruded Clear Acrylic Tubing

Inner diameter ¼”, Outer diameter ½”
Part Number: 8532K12
$5.00 for 6’

Extruded Clear Acrylic Tubing

3.5” ID 3.75” OD.
Part Number: 8486K529
$18.38/12”

Extruded Clear Acrylic Tubing

2.5” OD ¼” wall thickness.
Part Number: 8486K547
$24.01/1’ or $72.03/3’

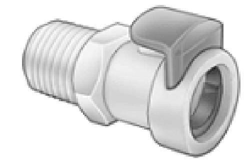
Extruded Clear Acrylic Tubing

OD: 6” wall thickness ¼”
Part Number: 8486K937
$34.09/12”

Extruded Clear Acrylic Tubing

OD: 4” wall thickness: ¼”
Part Number: 8486K574
$79.20/36”

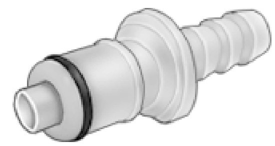
QUICK DISCONNECT PARTS

NPT PIPE X QUICK-DISCONNECT TUBE


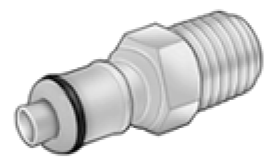
¼" with Shutoff valve
Part Number: 5923K23
$5.47 Each

NPT PIPE X QUICK-DISCONNECT TUBE


No shutoff valve ¼".
Part Number: 5923K21
$3.35 Each

BARBED QUICK-DISCONNECT PLUG


¼" with Shutoff Valve
Part Number: 5923K73
Cost/unit: $6.42

QUICK DISCONNECT PLUG X NPT PIPE


¼" with Shutoff Valve
Part Number: 5923K53
Cost/unit $6.71

QUICK-DISCONNECT X BARBED ¼" PLUG


¼" No shutoff valve
Part Number: 5923K72
Cost/unit: $1.28/unit

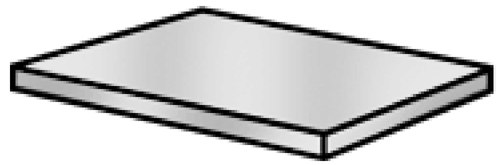
LEVELING FEET

POLYETHYLENE BASE WITH NICKEL-PLATED STEEL TOP


2 ¾" Long, 5/16" – 18 Thread.
Part Number: 23015T63
$3.38/ package of 4

AMERICAN PLASTICS

ACRYLIC SHEETS



¼" ACRYLIC SHEET

Price per sheet: $185
Shipping $30
American Plastics
Website: http://americanplastics.us/

CONTAINERS

RL FLO-MASTER 3 PT. HAND SPRAYER

Model # 56HD Store SKU # 764434 Store SO SKU # 317167
$6.87 Each

BLITZ USA 5-GALLON ENVIRO-FLO PLUS GAS CAN

Model # 81033 Store SKU # 539994
$12.48 Each

BUCKET BOSS 4 1/2 GALLON BUCKET

Model # 10002 Internet # 202332263
$7.98 Each

FILM PRODUCTS

GILA 4 FT. X 6-1/2 FT. FROSTED PRIVACY WINDOW FILM

Part Number: PFW486

$19.92 Each

GILA COMPLETE WINDOW FILM APPLICATION KIT

Part Number: RTK500SM

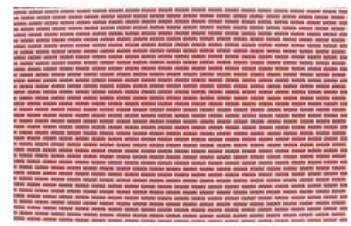
$8.49 Each

DECORATIVE ITEMS

PAPER MACHE HOUSE SHAPE SET

sku# 377218

$12.97/ Set



HOUSEWORKS RED BRICK VINYL SIDING

sku# 126276

Price: $6.99

DOLLHOUSE PORCELAIN BATHROOM

sku# 726216

$19.99/set

ASPHALT SHINGLES HEXAGONAL

sku# 345462

$8.99/ Roll

HOLSTEIN BULL

sku# 606178

$7.99 Each

Sun Kissed Trees

sku# 872507
$15.99 Each

Bushes

sku# 283689
$4.99/Bag

Miniature Wishing Well

sku# 961003
$2.99 Each

Fire Rescue Set

sku# 848325
$3.99 Each

Assembly Materials

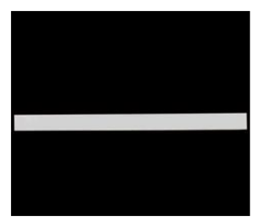
Stick-On Hook & Loops Strips

sku# 439703
Price: $2.99 Box

FolkArt Acrylic Paint
sku# 431627
Price: $1.27

Poster Tack
sku# 271056
Price: $2.49

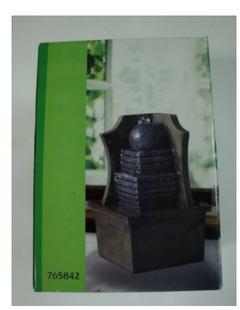
Craft Sticks All Temp Mini Glue Sticks
sku# 284836
Price: $3.99



High Temperature Glue Gun
sku# 222497
Price: $2.99

PUMPS

Submersible Aquarium Pump (in desk fountain)
PP-300, Fitting 5/16"
Maximum Head: 0.5 meters
Website: www.jebao.com
$17.99 Each



OTHER

DECORATIVE MATERIALS

FIRE HYDRANT METAL FIRE HYDRANT

Part Number: 1738
Price/Unit: $2.99
Website www.miniatures.com

DYE

FOOD COLORING DYE

Puchased at any grocer or craft store
$4.00 for a pack of four

PUMP

AQUARIUM PUMP

Ace Hardware
Crystal Pond Professional
Price/Unit: $39.99

CASE

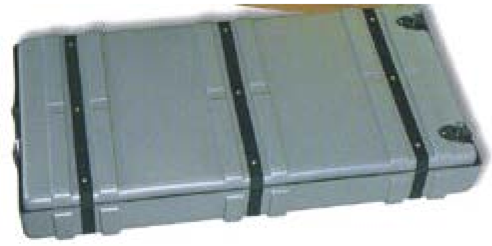
TRADE SHOW & EXPO CASE

Dimensions: 40x 26.5x10

Case #: OLE4026

Price/Unit: $285.94 (for 3-4)

Website: www.caseclub.com/tradeshow-exposition-cases.htm



APPENDIX C: INSTRUCTIONS FOR ACRYLIC CONSTRUCTION

INSTRUCTIONS FOR ACRYLIC MACHINING COMPANY

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ACRYLIC BLOCKS

The acrylic blocks are 1.25" cubes of clear acrylic with a centered 5/16"-18 threaded hole drilled top to bottom (Fig. 1). A total of six of these blocks will be glued to the bottom of the bottom piece of the encasing. Leveling feet will be screwed into each block and provide support for the model. A total of six are required per model.

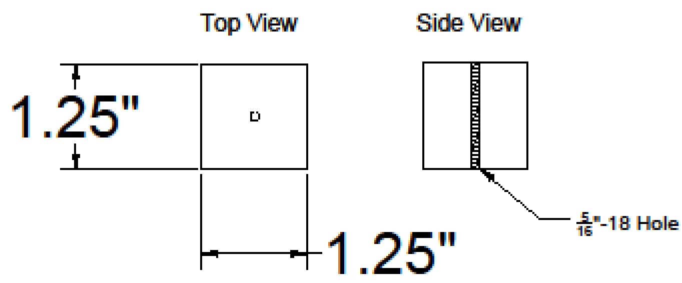

FIGURE 1. ACRYLIC BLOCKS

Acrylic Junctions

Each acrylic junction will be made from a 2" x 2" x 1.25" clear acrylic block. Seven total are needed for each model; four elbows, two vertical tees, and one 4-way tee (Quantities are also listed in respective blocks in Figure 2). These blocks will connect ¼"-18 acrylic pipe, so each hole in the block must be tapped with ¼"-18 threads. The exact placement of the holes is not crucial as long as it is consistent within the series. Suggested locations are marked in Figure 3. Through each block a 3/16" hole will also be drilled for later fastening the blocks to the model. The hole will run through the entire block top to bottom.

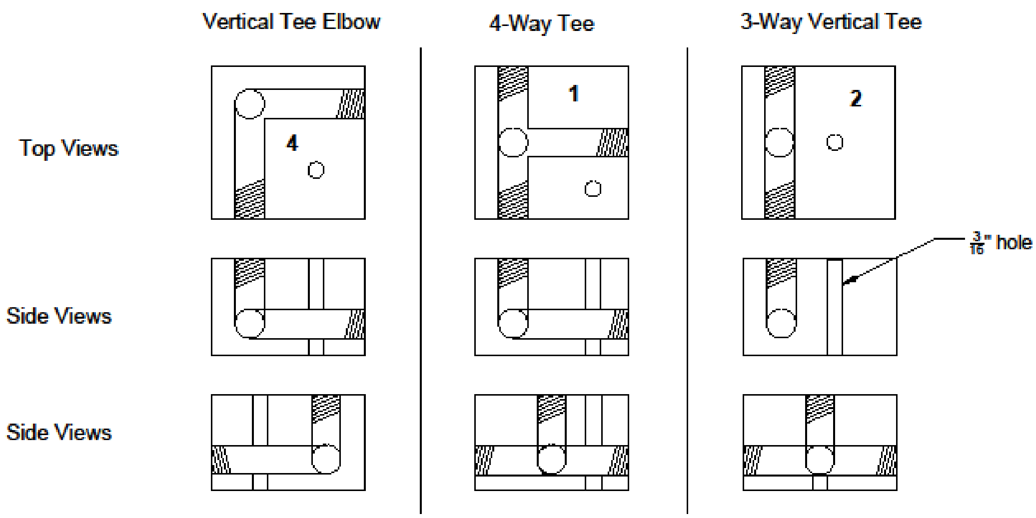

Figure 2. Acrylic Junctions

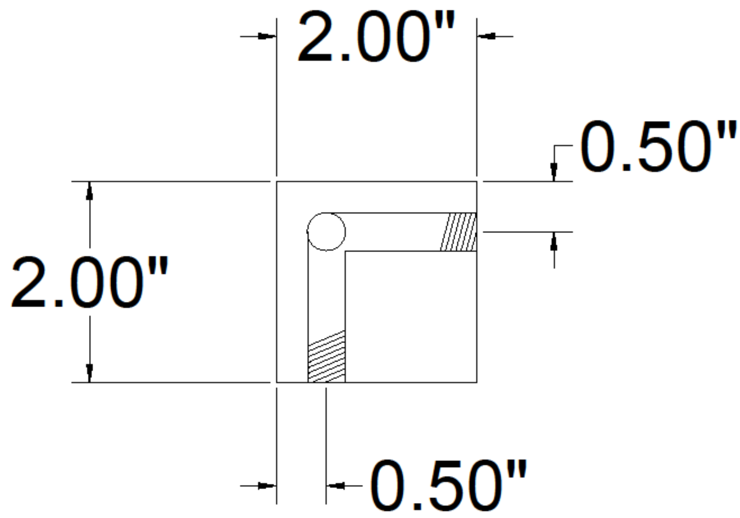

FIGURE 3. ACRYLIC JUNCTION: ELBOW (ABOVE)

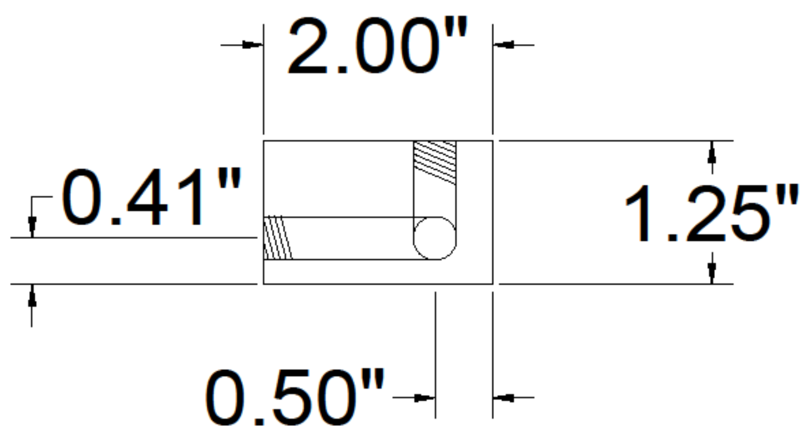

FIGURE 4. ACRYLIC JUNCTION ELBOW (SIDE)

SIDE WALLS

Each side wall is cut from ¼" clear acrylic and shown in Figures 5-8. Two copies of Side Wall 2 are to be made, and one each of Side Wall 1,3 and 4 to give a total of five pieces per model. These side walls will be glued to the outer ¼" along the outside edge of the top of the bottom piece.

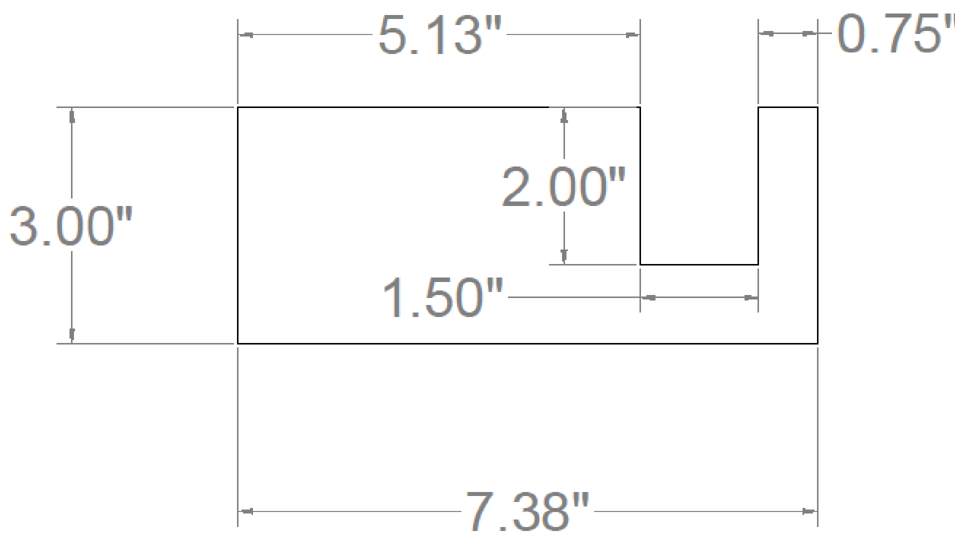

FIGURE 5. SIDE WALL 1

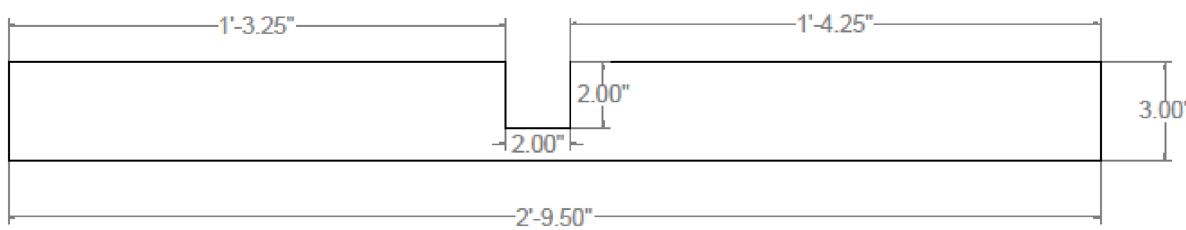

FIGURE 6. SIDE WALL 2

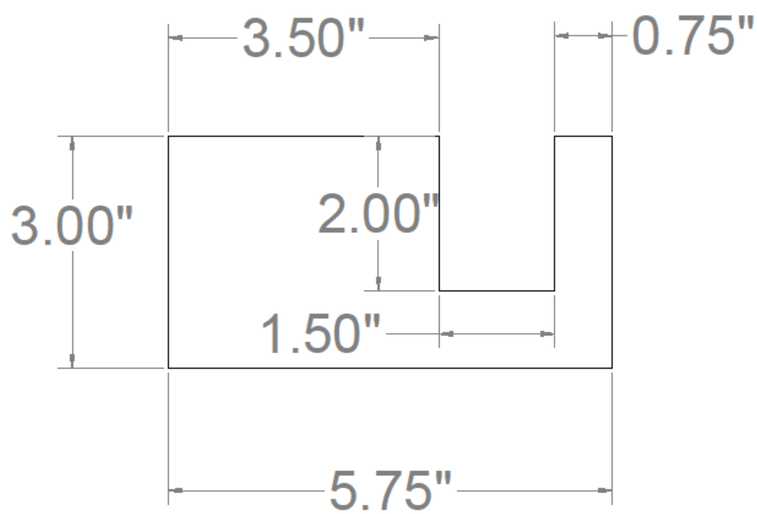

FIGURE 7. SIDE WALL 3

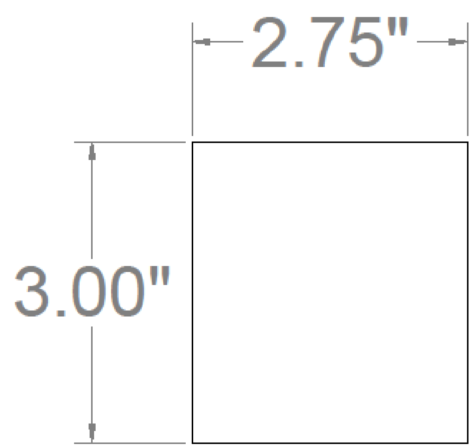

FIGURE 8. SIDE WALL 4

TROUGH

The trough is made from a 3" OD semicircular tube ¼" thick, which is capped on one end with ¼" acrylic. The other side is glued to a machined acrylic block which acts as an outlet elbow allowing water to drain through a ½" NPT tapped hole. The specifications of the block are not important as long as the end of the trough is sealed and water can exit to the right of the trough through a ½" NPT connection. The tunnel in the block should be large enough to allow for quick drainage. Specs and diagrams of the trough are shown in Figures 9-11.

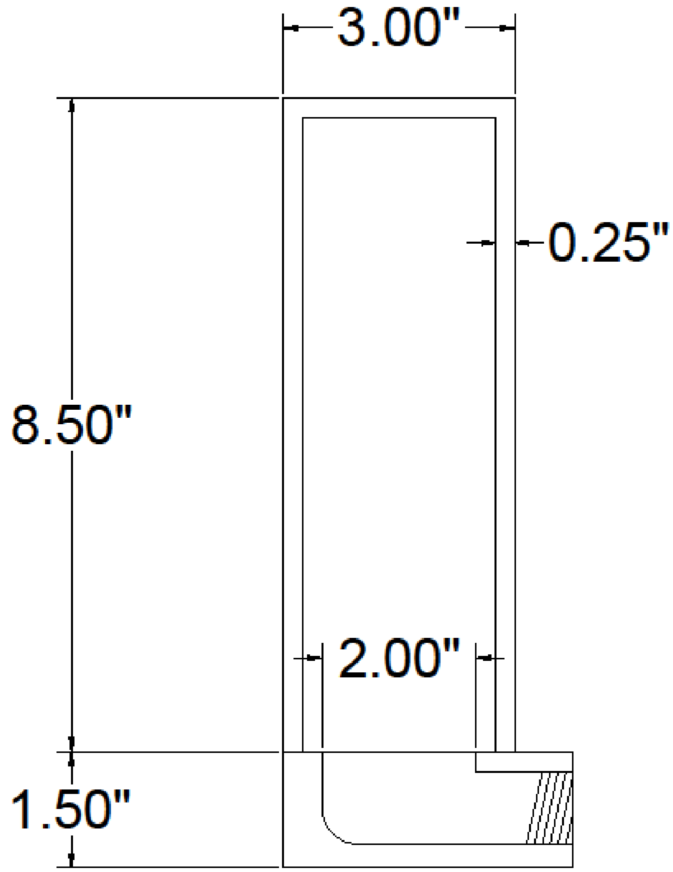

FIGURE 9. TROUGH (ABOVE)

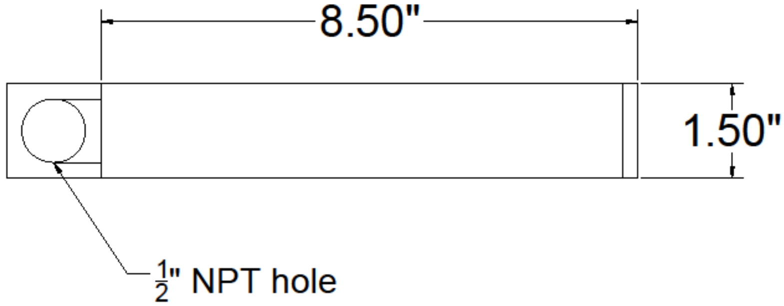

FIGURE 10. TROUGH (SIDE)

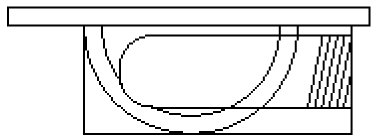

FIGURE 11. TROUGH (SIDE)

BOTTOM PIECE

The bottom piece is cut from a ¼" clear acrylic sheet. The bottom piece is 2'-9.50" in length and 1'-7.25" in width. From the bottom piece two rectangular holes will be cut out one 8" x 2.5" and the other 0.75" x 1.25". Exact placement of these are shown in Figure 12. A 0.5" radius hole will be drilled through the acrylic as shown in Figure 12. The trough piece (see Trough section) will be glued to the bottom of the bottom piece and will line up exactly with the 8" x 2.5" hole as shown in Figure 13. The side walls (see Side Wall section) will be glued to the outer ¼" edge of the top of the bottom piece. This is shown in Figure 14 where the corresponding side pieces are laid to the side to show placement.

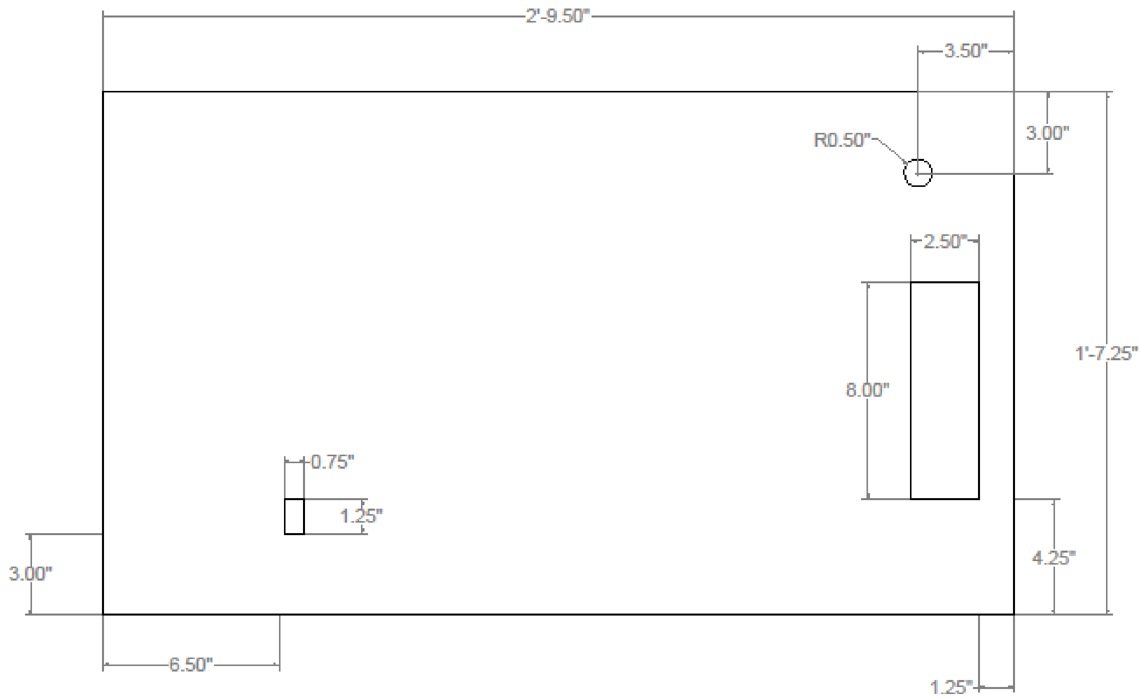

FIGURE 12. BOTTOM PIECE

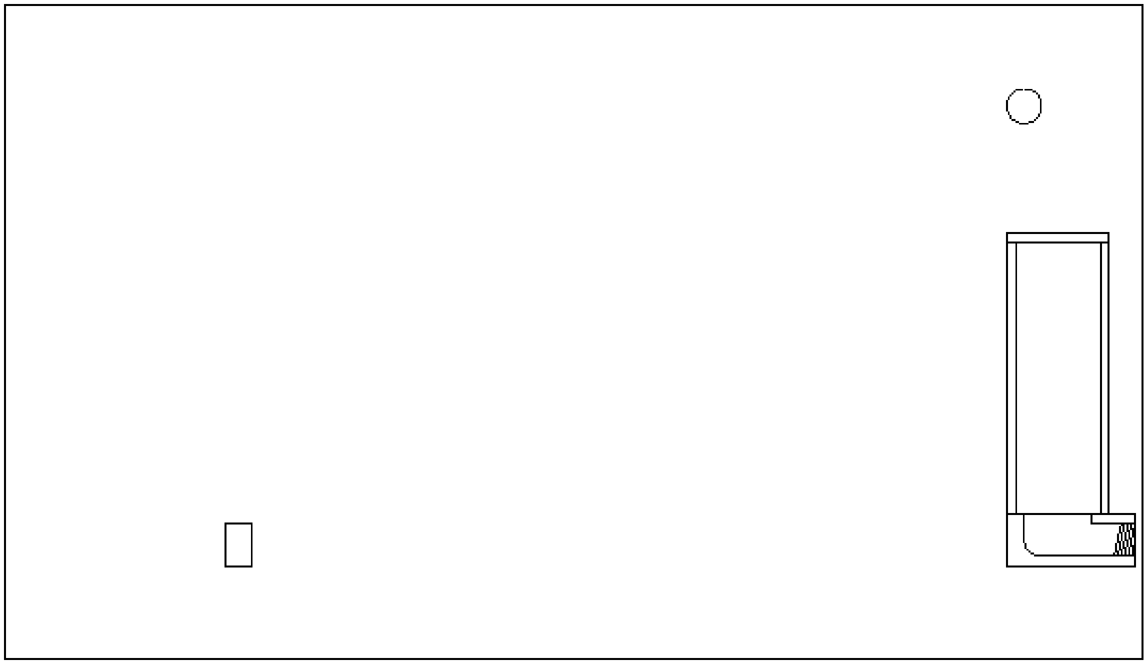

Figure 13. Bottom Piece with Trough

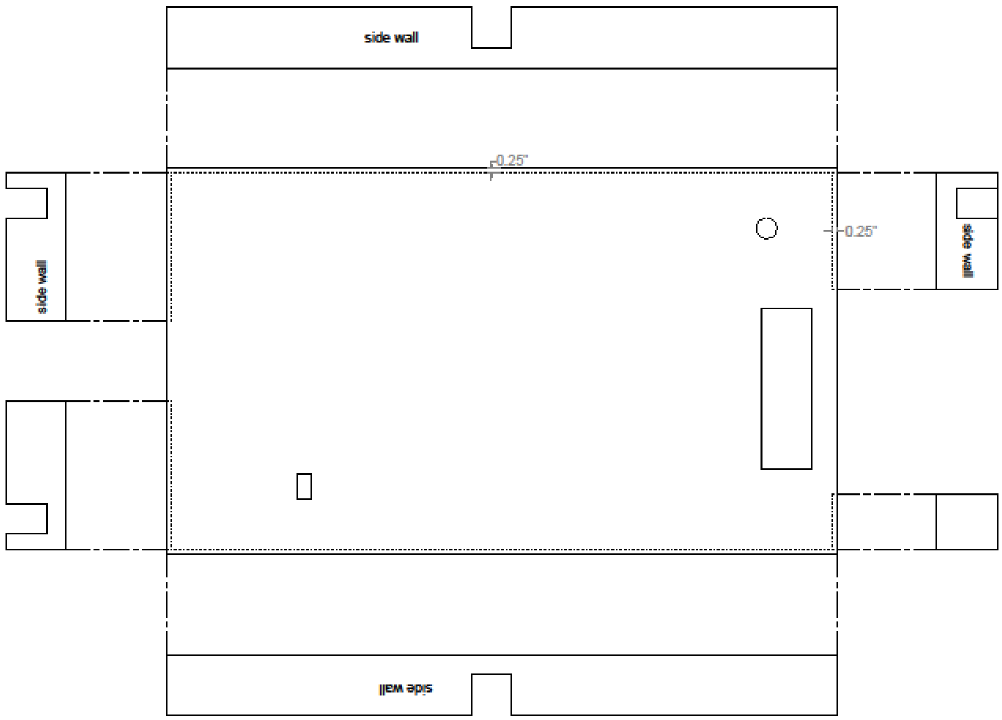

Figure 14. Bottom Piece with corresponding side walls shown

STABILIZERS

Stabilizers are ¼" x ¼" x 1.5" acrylic segments designed to secure and align the top piece of the encasing to the rest of the encasing acting as a lid. They will be glued to the underside of the top piece ¼" from the outer edge so as to set just inside the encasing side walls when the top piece is placed onto the rest of the encasing as a lid. The stabilizers are shown on the top lid in Figures 16 and 17.

TOP PIECE

The top piece is cut from a ¼” thick clear sheet of acrylic. It is 2’-9.50” in length and 1’-7.25” in width with many smaller cutouts from the edges. In addition two holes, both 0.5” in radius will be drilled in the locations shown in Figure 15. The stabilizers (see Pg. 13 on Stabilizers) will be glued as shown in Figures 16 & 17, ¼” in from the outer edge of the top piece. These will create a lip on the top piece that will fit into the side walls of the assembled bottom piece and walls.

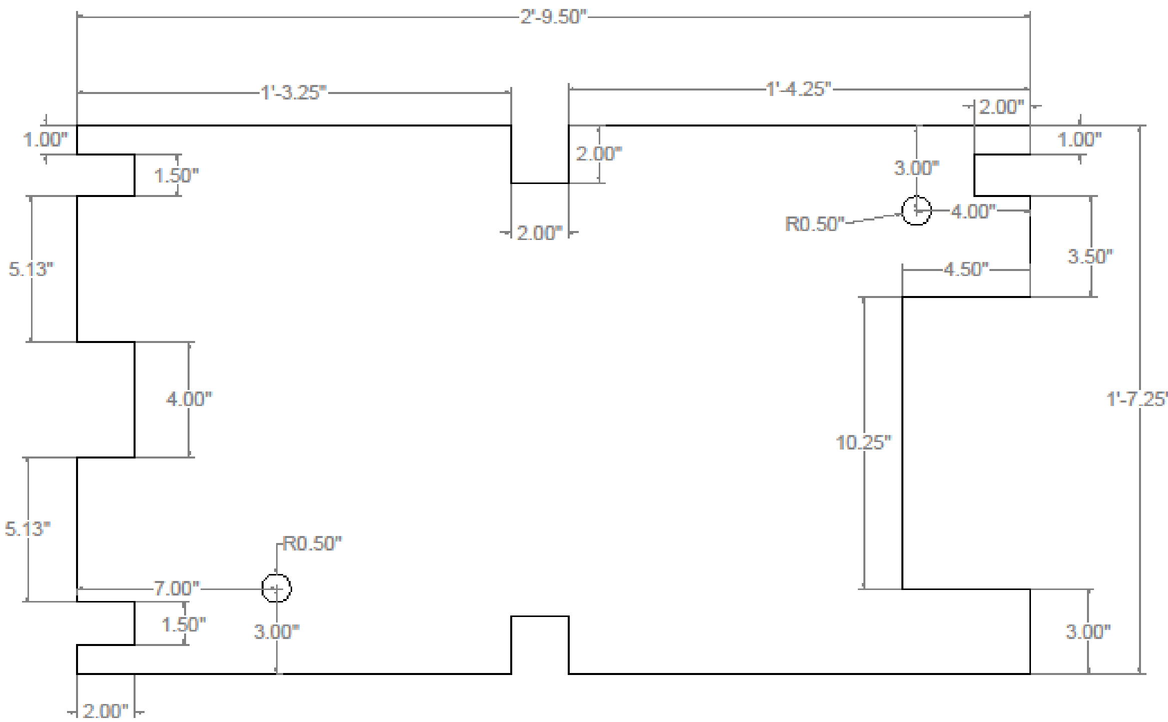

FIGURE 15. TOP PIECE

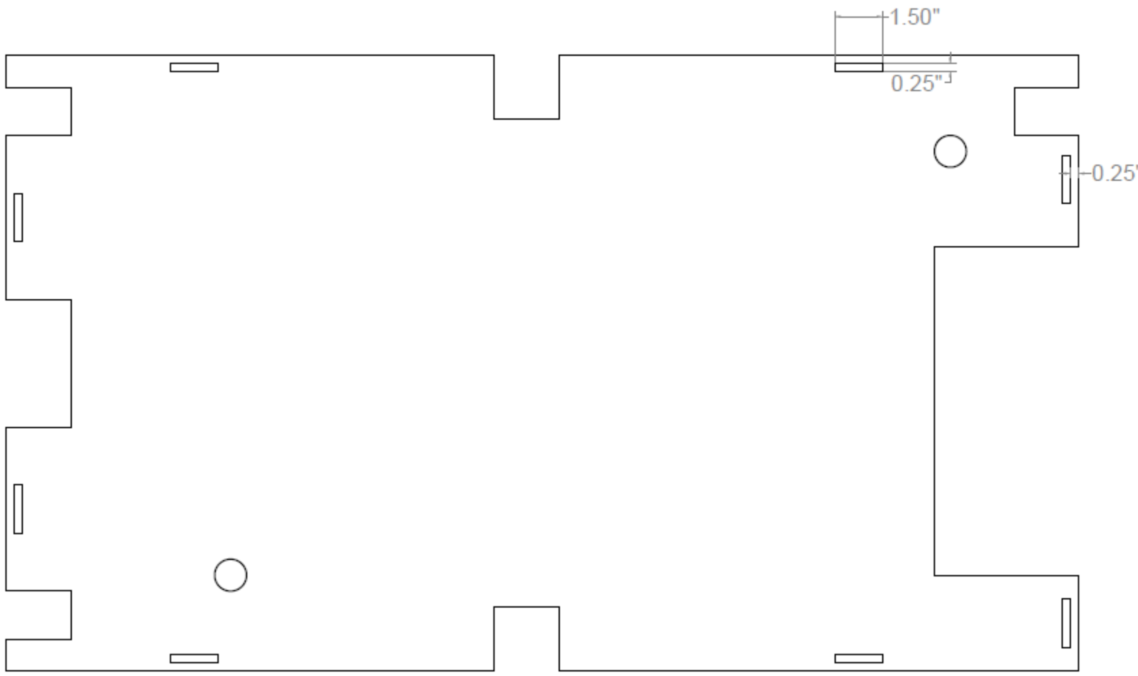

FIGURE 16. TOP PIECE WITH STABALIZERS (TOP)

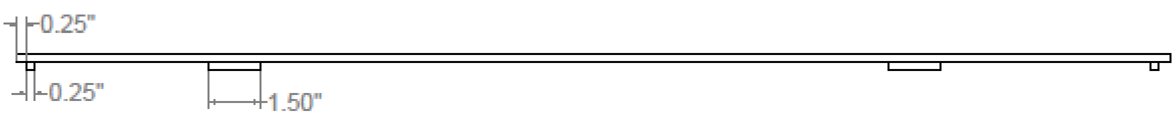

FIGURE 17. TOP PIECE WITH STABALIZERS (SIDE)

ASSEMBLED ENCASING

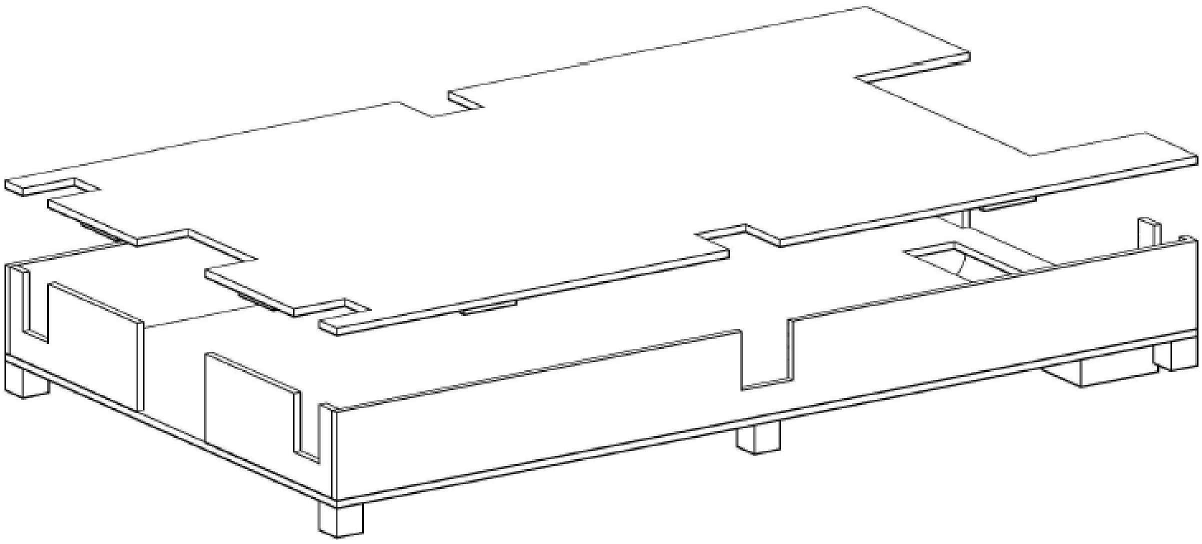

FIGURE 18. TOP, SIDE AND BOTTOM PIECES ASSEMBLED

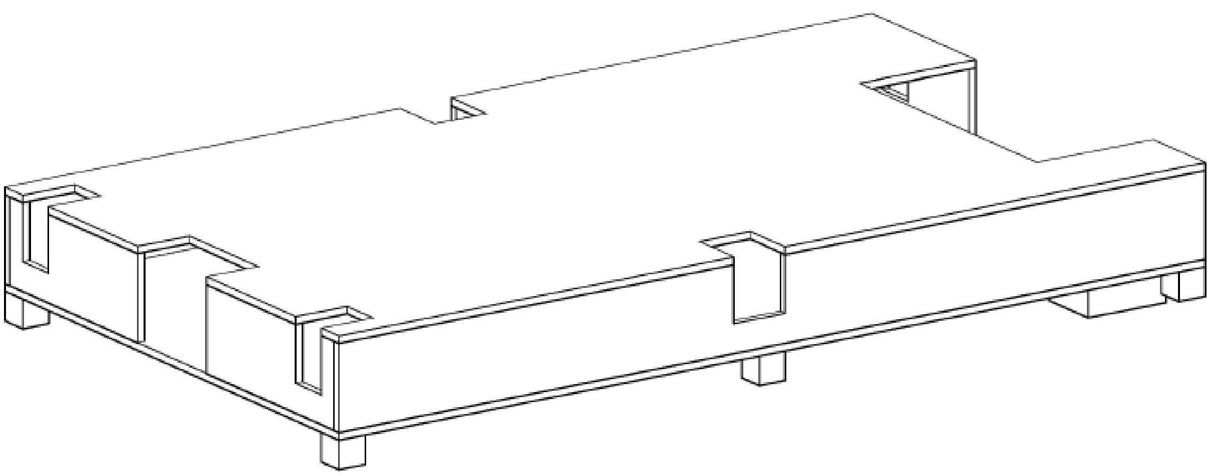

FIGURE 19. ENCASING ASSEMBLED WITH LID ON

HOUSE

The house is a clear lidless cube created from 5 clear acrylic rectangles ¼" thick: a 5" x 5" rectangle, two 5" x 4.75" rectangles, two 4.75" x 4.50" and one 2" x 4.5" rectangle. The 5" x 5" rectangle acts as the base and the other four large rectangles are glued on as sides. The remaining 2" x 4.5" rectangle acts as a divider in the middle of the house. Two tapped holes are made within the acrylic pieces. One ¼" NPT hole on one of the 4.75" x 5" rectangles, and the other a 3/8" NPT tapped hole on the 5" x 5" base. Upon assembly the hole in the base and the hole in the side wall should be located on the same side of the divider. Figures 20-23 show these details.

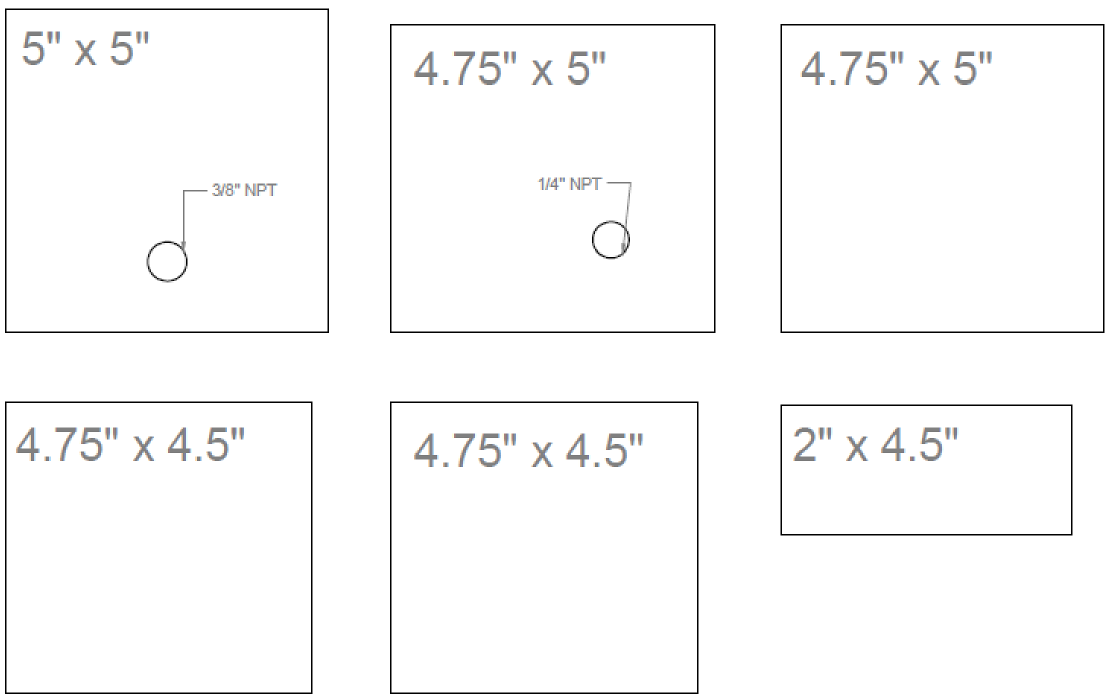

FIGURE 20. ACRYLIC PIECES OF HOUSE

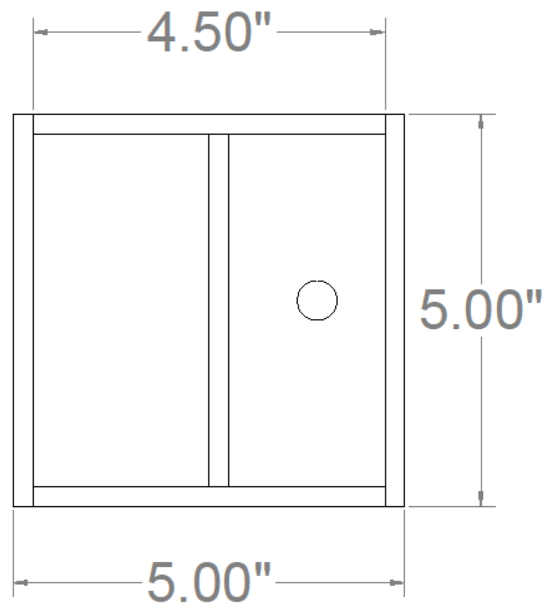

FIGURE 21. TOP VIEW OF ASSEMBLED HOUSE

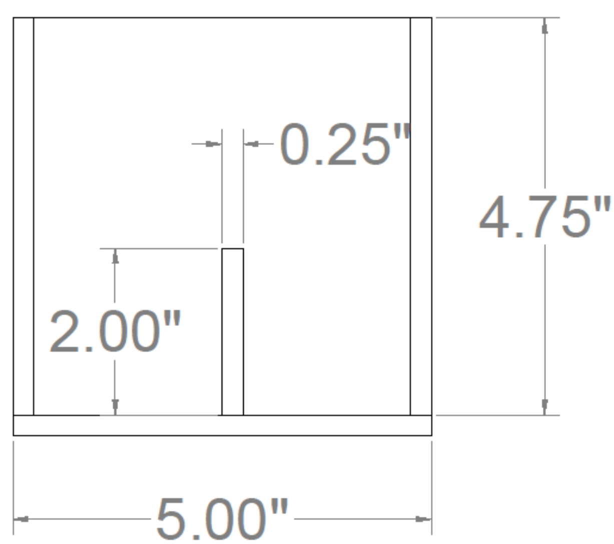

FIGURE 22. SIDE VIEW ONE OF ASSEMBLED HOUSE

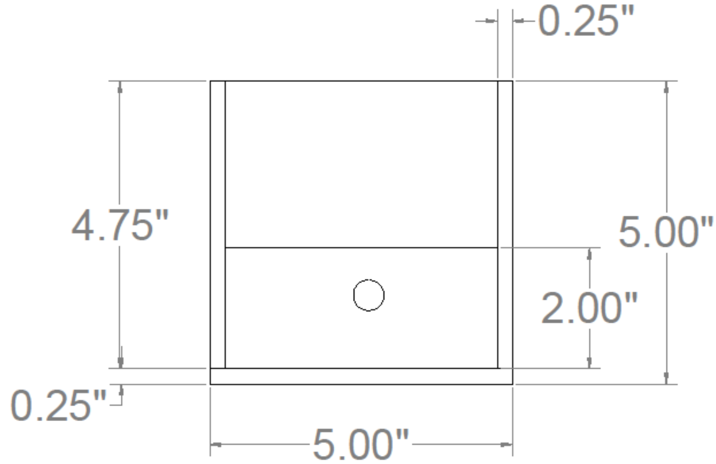

FIGURE 23. SIDE VIEW 2 OF ASSEMBLED HOUSE

Water Tower

The water tower is made from three separate pieces: the base, the tower and the basin. The base is a 6.5” x 6.5”rectangle of acrylic. On the base three small arced segments of acrylic are to be glued along a 2” OD circular path as shown in Figure 24. These small arcs will secure the tower as they will slide flush into the inside of the 4” diameter tower when it is placed on top.

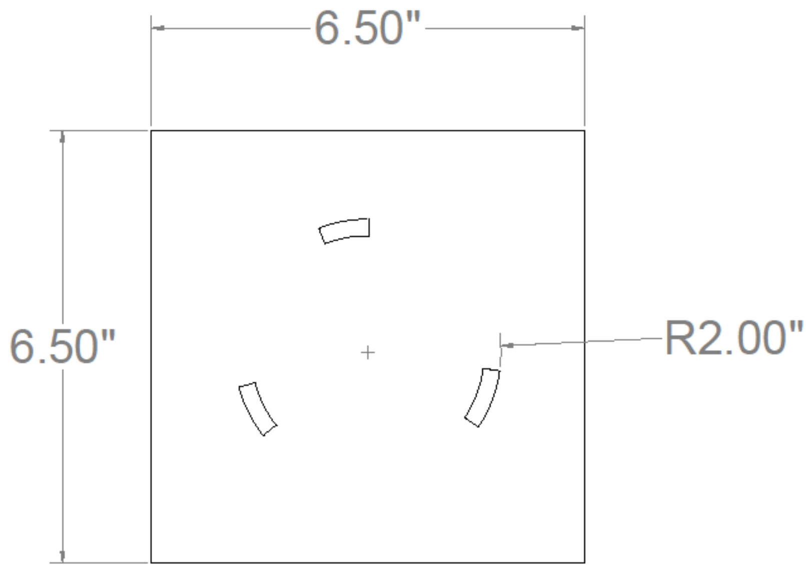

Figure 24. Water Tower Base

The tower, which has a 4” ID, is ¼” thick and 14.5” tall. The tower has two separate holes cut from the bottom portion of the tower. One hole is 0.75” in diameter and lies 1” from the base. The other, one quarter turn from the first hole, is a rectangular hole 2” x 1.5” of which one side is open to the base of the tower. This is more specifically outlined in figures 25 and 26.

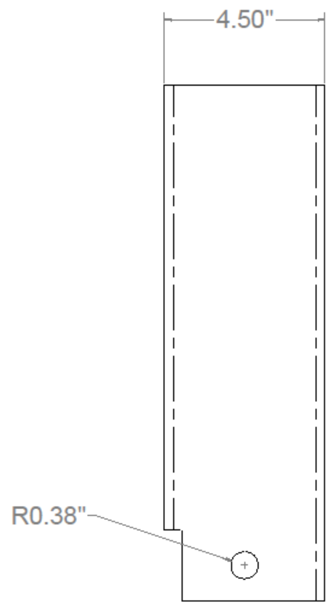

FIGURE 25. WATER TOWER TOWER (SIDE VIEW 1)

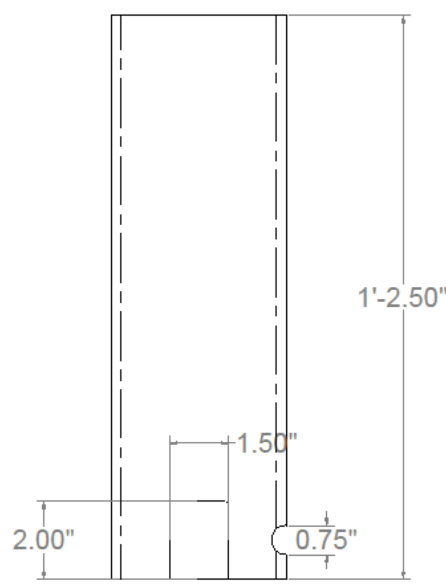

FIGURE 26. WATER TOWER TOWER (SIDE VIEW 2)

The tower should slide down onto the base and sit securely in place. The base and tower fit together as shown in figures 27 and 28.

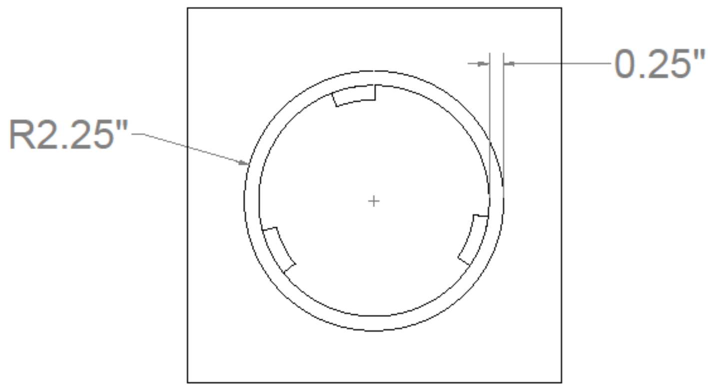

FIGURE 27. WATER TOWER BASE & TOWER (ABOVE VIEW)

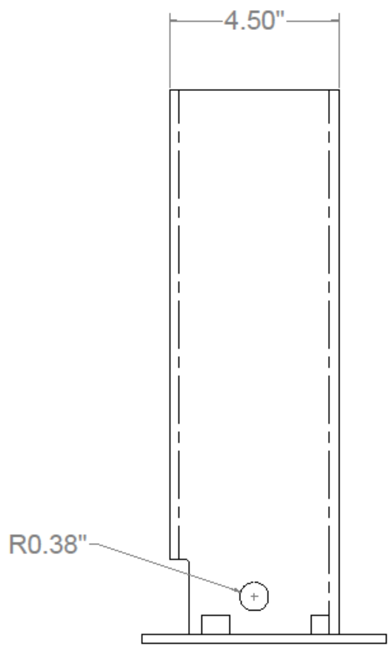

FIGURE 28. WATER TOWER BASE & TOWER (SIDE VIEW)

The water tower basin is made from a 6.5" OD tube of acrylic 5" deep and ¼" thick. A 6.5" ¼" acrylic disk is tapped with three holes and glued to the bottom of the tube as a base. Two of the holes are tapped ¼" NPT holes and one is a ½" tapped NPT hole. In a similar fashion to the base, three arced segments are glued in a 2" OD circle around the three holes. These will help secure the basin onto the tower as done with the base. This is shown in Figures 29 and 30.

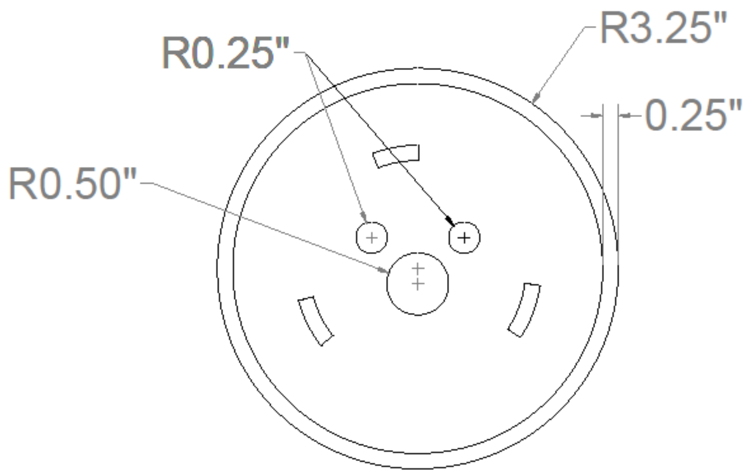

FIGURE 29. WATER TOWER BASIN (TOP VIEW)

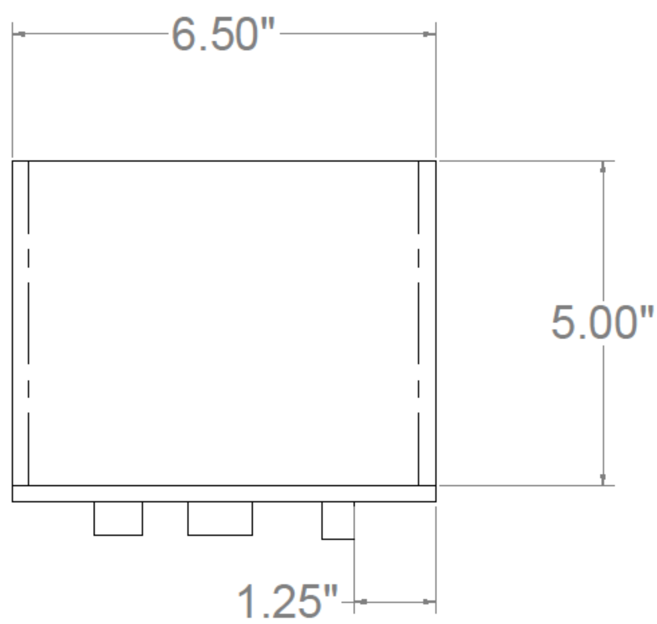

FIGURE 30. WATER TOWER BASIN (SIDE VIEW)

Once the three components are complete, they should fit into one another and sit secured due to the small arc spacers. Figures 31 and 32 demonstrate the completely assembled tower.

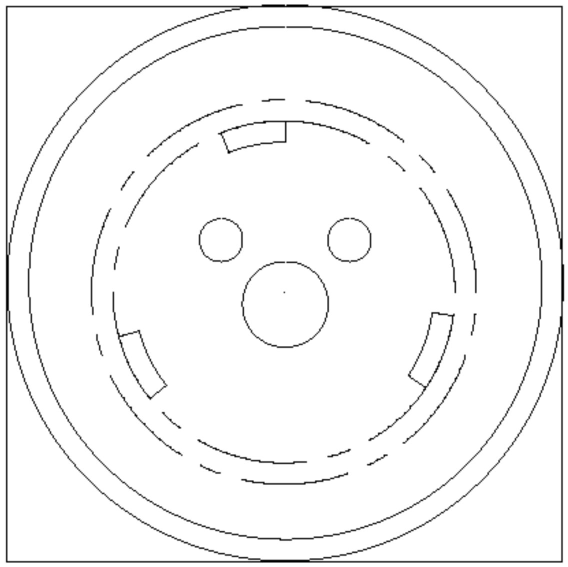

FIGURE 31. WATER TOWER PUT TOGETHER (TOP VIEW)

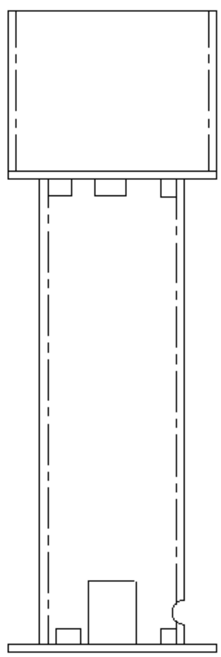

FIGURE 32. WATER TOWER PUT TOGETHER (SIDE VIEW)

APPENDIX D: DESIGN ALTERNATIVES

Throughout the design process multiple solutions to situations were discovered and evaluated. The alternatives were evaluated against the design criteria and constraints and chosen based on their fulfillment. Some of the design alternatives are explained below.

Model Orientation

Horizontal and vertical orientations of the model were initially considered. The benefits to a vertical model included that it would make viewing possible from a farther distance and would increase flexibility in demonstrating the model in classroom settings or for large groups. The benefits to a horizontal model included that it would more accurately represent a water distribution layout and would prevent varying pressure head differences in each of our scenarios. A horizontal model was chosen because it allowed for a more visually compelling and accurate representation. Although viewing a vertical model would be advantageous, it was found that this compromised the visual significance and accuracy of modeling a horizontal water distribution system.

Pressure Source

Another alternative was to create a model that is driven by gravity rather than a pump. The benefits to a gravity-run model included that it would decrease the complexity of the model making it more versatile, eliminating a need for electricity, and would also eliminate possibility of mechanical failure. The initial benefits of using the pump outweighed the gravity model due to the fact that the pump provided a constant high pressure throughout the system. It also initially provided high enough pressure differentials to represent backpressure, which was not possible with the gravity-run model. Upon further investigation, the pressures provided by this pump were too high for our system and the pump's large flow rate made our dye exit the system rapidly. This decreased the visible impact of many of our scenarios. The final model implements both pump and gravity mechanisms. A water tower provides gravity powered water pressure to the system but a pump is used to maintain the water tower at a constant pressure. This allowed us to represent the scenarios most effectively.

Tubing

Using flexible tubing, instead of rigid pipe was also an initial design alternative. Initially, the concept of flexible tubing was ideal because it was simple to assemble and disassemble and was much less expensive than rigid tubing. It also allowed for a physical rupture in the tubing to simulate a main break within the system. This design consideration was rejected, however, when flexible tubing failed to provide the rigidity in our model. The rigid tubing was also much more durable and would not require the degree of replacement and maintenance that the flexible tubing would. Rigidity and durability of the model increased the ease of transport, cleaning and maintenance as required by DHHS, so it was chosen as a final design feature.

Recirculation

A recirculation loop was also considered in the model. This loop would allow water to recirculate from the outlet reservoir to the inlet tank. The use of this loop would allow the model to run continuously without refill and would require less total water. Although recirculation is not a necessity for the model it minimizes space and would require less oversight of the model, but would also add complexity due to the separation of contaminated and clean water. Due to the hassle of keeping dyed and clean water separate, no recirculation loop was implemented.

Venturi Effect

An alternative mechanism for demonstrating scenarios was considered for the model. DHHS encouraged attempting to implement the Venturi effect to create pressure differences. The Venturi effect is a reduction in pressure when fluid flows through a constricted area. To model this scenario, 1/8" inner diameter tubing or smaller would be required as well as two extra joints. Representing the Venturi effect would reduce the amount of visible tubing and would likely not provide a significant pressure drop at such a small scale. This idea also limits the flexibility of the scenarios, as it is limited to modeling only one backflow scenario. Other more versatile representations allow several scenarios to be modeled using one setup. Given that the visibility of water flow is critical for the design and due to space constraints, the Venturi scenario will not be implemented.

APPENDIX E: ENGINEERING ANALYSIS

The characteristic attribute of an actual water system is the Reynolds number. The Reynolds number, shown in equation 1, compares the inertial forces to viscous forces in a fluid.

contamination (dye) will flow into the water supply and eventually to the house outlets. Calculating pressure head within the model is outlined below (Equation 4). This equation depicts the total pressure head in distribution system from a particular source without considering minor losses.