FINAL DESIGN REPORT

The complete design of the toilet system developed by Sodhana Environmental

California Polytechnic State University, San Luis Obispo

Mechanical Engineering | December, 2013

| Sponsored by Mr. Harish Bhutani | Advised by Dr. Mohammad Noori | Sodhana Environmental is Eric Taylor (ME), Corissa Bellis (ENVE), Cody Perez (ME), and Cameron Zeller (CE)

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1.0 Introduction

In 2012, 2.6 billion people worldwide had no access to a toilet, resulting in water-borne diseases, infections, illnesses, and the mistreatment of women. As an attempt to eliminate this problem, this project plans to develop and design a household toilet requiring no water, no electricity, and minimal maintenance. Currently technologies exist but are too complex, expensive, or maintenance-intensive; these setbacks lead to abandonment of the toilets when they become too much of a burden to the users.

The proposed design shall incorporate the following key design elements and constraints:

- Low cost - funds are often not readily available in the intended design location
- No specialized equipment - limited repair capabilities and access to parts
- No water - toilets that require water are often burdensome to their patrons
- Self-sustaining - little to no energy is available for operation
- Monthly maintenance or less required - constant care can become a nuisance, leading to neglect
- Adaptability to diverse climates and cultures - sanitation is a worldwide problem
- Decrease illness and disease

Successful solutions will come from innovative and creative concepts. Producing a system with minimal resources will require a wide range of engineering knowledge. Sodhana Environmental is composed of mechanical, civil, and environmental engineering students and each member's specialized knowledge is crucial to design a globally applicable final product. It is the goal of this project to help others by creating a functional design: improving the quality of life through quality engineering.

Primary stakeholders for this project include Mr. Bhutani, Kiran Rami, Dr. Noori, various communities in India, and the Cal Poly College of Engineering. Mr. Bhutani, Kiran Rami, and Dr. Noori's passion has greatly inspired Sodhana Environmental to create an innovative design. Years of communication between Mr. Bhutani and Dr. Noori went into developing this project's goals and logistics. This design team hopes to fulfill and expand on their expectations.

2.0 Background

2.1 Competitors/Similar Systems

Many solutions and technologies have already been developed to improve sanitation. Each system is unique, but not always feasible for rural use. Many modern technologies are effective in treating waste, but too complex to maintain without ample resources. To evaluate their design and practicality, we have researched four modern approaches: the Sulabh International two-pit system, the Gendarme Ecological Sanitation System, Ecoloove, and Peepoo.

2.1.1 Two-Pit System by Sulabh International

One current solution is the two-pit system designed by Sulabh International as shown in Figure 1. In this system, two pits, with dimensions based on the number of users, are dug into the ground. A diverting flushing system requiring little water (1.5 to 2 liters) is built into the openings of the pits that allows the excrement to fill up one pit, then diverts the excrement to the other once the first pit is full (a process designed to take about 3 years). The excrement in the filled pit is digested (treated) and dried by naturally occurring processes. Users alternate between the two pits every three years resulting in an odorless, digested sludge that can be used as a soil supplement. This design's strengths include producing usable manure, needing only two pits, extremely low maintenance, and eliminating pathogens as a result of drying and digesting waste. Weaknesses include the need for water, an extremely precious resource in India's rural villages, and the work required to clean out the pits [1].

Figure 1: Sulabh's Two-Pit System [1]

2.1.2 Ecological Sanitation System by Gendarme

Another method for handling waste is the Gendarme Ecological Sanitation System. This process eliminates waste through anaerobic digestion into a two-bucket system shown in Figure 2. A flushing unit moves the waste from sight into the main digester tank. An internal agitating pump circulates the digester contents, helping break down the solids. Solids deposited into the toilet bowl when flushed will move to the second bio-filter bucket, where tiny suspended particles are trapped before the water is discharged. A fine silt residue composed of indigestible material such as grit, plastic, and bone remains at the tanks bottom. Positive design aspects include self-flushing, adaptability to any household, and disease prevention. Setbacks include the need for water and regular cleaning. It is more costly with a pump and potential electricity needs.

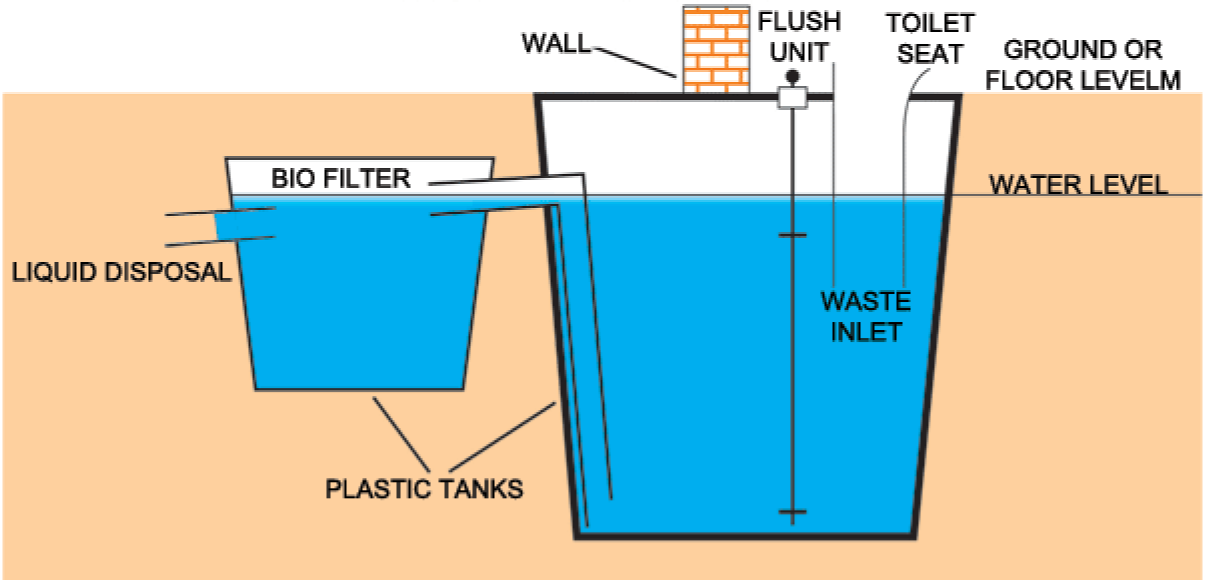

Figure 2: The two-bucket system incorporates anaerobic digestion into a self-flushing design [2]

2.1.3 Ecoloove

Ecoloove incorporates a Port-a-Potty like system that has an ongoing business advantage. As Figure 3 shows, a bamboo toilet room, with a simple urine diversion squatting pan, is mounted on a three-wheel bicycle. Users climb into the Ecoloove, relieve themselves, and the feces is collected in a bucket underneath. The urine is diverted via a pipeline into a black container designed to dehydrate the fluid. Sawdust, currently donated for free, is used to dilute the feces. The company providing the toilets takes away the full unit, replaces it with a fresh one, and sells the compost. Benefits include employment opportunities, no need for water, and the producing 100% biologic fertilizer. Setbacks include the toilet's temporary nature; and serves as a community restroom, rather than for an individual home.

Figure 3: Ecoloove's mobile toilet room prevents buildup of human waste in poor villages [3]

2.1.4 PeePoo

The PeePoo provides maximum hygiene and convenience with minimal material. It is a biodegradable bag with an inner layer, unfolding to form a wide funnel. The user defecates and urinates directly into the bag and ties it shut, as shown in Figure 4. The urine crystals inside the PeePoo deactivate harmful pathogens within two to four weeks and the bag does not start to break down until its contents are completely sanitized. PeePoo takes back the bags or they are buried in agricultural fields and gardens; PeePoo transforms into high-value fertilizer when molecules that make up the bag break down into carbon dioxide, water, and biomass. This system's advantages include low costs, versatility, no need for collection or disposal services, no environmental contamination, and odor containment for at least 24 hours. Disadvantages include the PeePoo's temporary nature (it is designed to be used once), and the lack of a physical structure to provide privacy.

Figure 4: The PeePoo provides maximum hygiene and convenience with minimal material [4]

2.2 Standard Testing and Sample Regimes

Testing of a toilet system requires pathogen testing for feces and urine that exit the system. Additionally, urine being disposed onto plants can be tested for nutrients; this will allow us to anticipate its effectiveness as a plant fertilizer.

2.2.1 Fecal Testing

Existing testing procedures for fecal matter look for fecal coliforms. Fecal coliforms are a form of coliform bacteria that exist in fecal matter and are used as an indicator organism. A larger presence of fecal coliforms indicates a higher potential for the presence of other harmful pathogens.

Standard testing procedures begin by taking several samples of fecal matter from multiple locations in a pile of feces and then incubating them for a couple of days. Once the incubation period is complete, the number of coliform forming units (CFUs) is counted and recorded as a fraction of the number of grams of sample. This process is completed at specific time intervals to capture the disappearance of CFUs as the feces pile ages [5].

2.2.2 Urine Testing

Many previous experiments have been conducted regarding the use of urine as plant fertilizer. It has been found that urine is a helpful fertilizer to increase plant growth. “Urine is packed with the nutrients plants need. In 22 gallons (100 liters), there are more than 10 oz (300 g) of nitrogen, 6 oz (170 g) of phosphorus, and 5.6 oz (160 g) of potassium.” Urine is a sterile fluid when leaving the body, but to avoid potential contamination it will be applied at the roots of the plants directly into the soil. This way the leaves will not come into contact with the urine. Tests have proven that plants fertilized with urine do not show changes in the chemical compositions of the crops.

Grasses and reeds require a high nitrogen content, and the growth will be tested in response to urine application. The mineral uptake of plants with respect to the area of the design’s location will be important factors in the final design. Ideally plants used will be native to the region and provide benefits to the patrons. Vegetables and other crops are ideal for the business model aspect of the design.

3.0 Design Requirements and Specs

Mr. Bhutani established specific requirements to guide the design of an applicable and affordable toilet system that will decrease illness and disease in poor rural villages. As funds are not readily available in the intended design locations, the toilet must not require high initial or maintenance costs; ideally, the system would have an operating cost of 5 cents per day per person. Building off of this requirement, Mr. Bhutani asked for a design that does not use specialized equipment. Poor villages have very limited repair capabilities, and even more limited access to parts. In order to avoid inconveniencing the user, the toilets must use no water and require monthly maintenance *at most*. Current solutions that do need water and regular upkeep often become a burden to the patrons, ultimately leading to abandonment of the toilet. The next specification set forth by Mr. Bhutani is that the system be self-sustaining; based on the level of poverty of the applicable villages, little to no energy will be available to operate the toilet. The system must also be adaptable to all climates and cultures; lack of sanitation is a widespread problem, and Mr. Bhutani prefers a design applicable to poor villages throughout the world. Preferably the design will provide a business opportunity for the users and owners.

3.1 Top Concepts/Designs

The proceeding concepts are distinct from one another and it is anticipated that only one of the three will be selected to be developed into the final prototype design. For this reason they are not fully developed but rather fully conceptualized. It is the hope of Sodhana Environmental that project advisor and sponsor input will help determine which concept is the best candidate for prototyping.

3.1.1 Garden Composter

The Garden Composter incorporates organic gardening methods with human waste treatment. Urine acts as a "compost tea" to water the plants growing in a Trickling-filter Flower Bed. Much of the urine is used to keep the soil moist, while the excess fluid that is not used by the plants evaporates into the atmosphere. Feces is separated by the Urine Diverting Dry Toilet (UDDT) seat and is collected in an aerated compost bin beneath the restroom. The collection bin has a ventilation system to increase the airflow promoting a dry composting method. Ash, sawdust, or toilet paper can be added to decrease the moisture content in the fecal waste. At the base of the composting bin there is trap door to allow the owner to remove the composted waste. Only the bottom waste should be removed as it has enough time to digest (pathogens and harmful bacteria neutralized/killed). The waste can be removed with a shovel from the hatch and added to the garden trickling filter if additional soil is needed.

The structure will be raised, housing the compost container beneath. A ventilation chimney will reach from the composting bin up through the restroom and out the roof. The urine will be diverted from the UDDT pan to a slanted trickling filter garden bed that will be located on the side of the structure reaching the ground. Side walls of the housing structure will be made of wooden slats that allow for airflow while keeping out rodents and other pests. Steps will necessary for the patron to reach the toilet.

Figure 5: Garden Sketch I

This depicts the raised structure with the garden trickling filter on the left. Our final design will not have a raised trickling filter and instead the urine will flow through a garden with an incorporated trickling filter. This mitigated complexities of pumping the urine up into the filter.

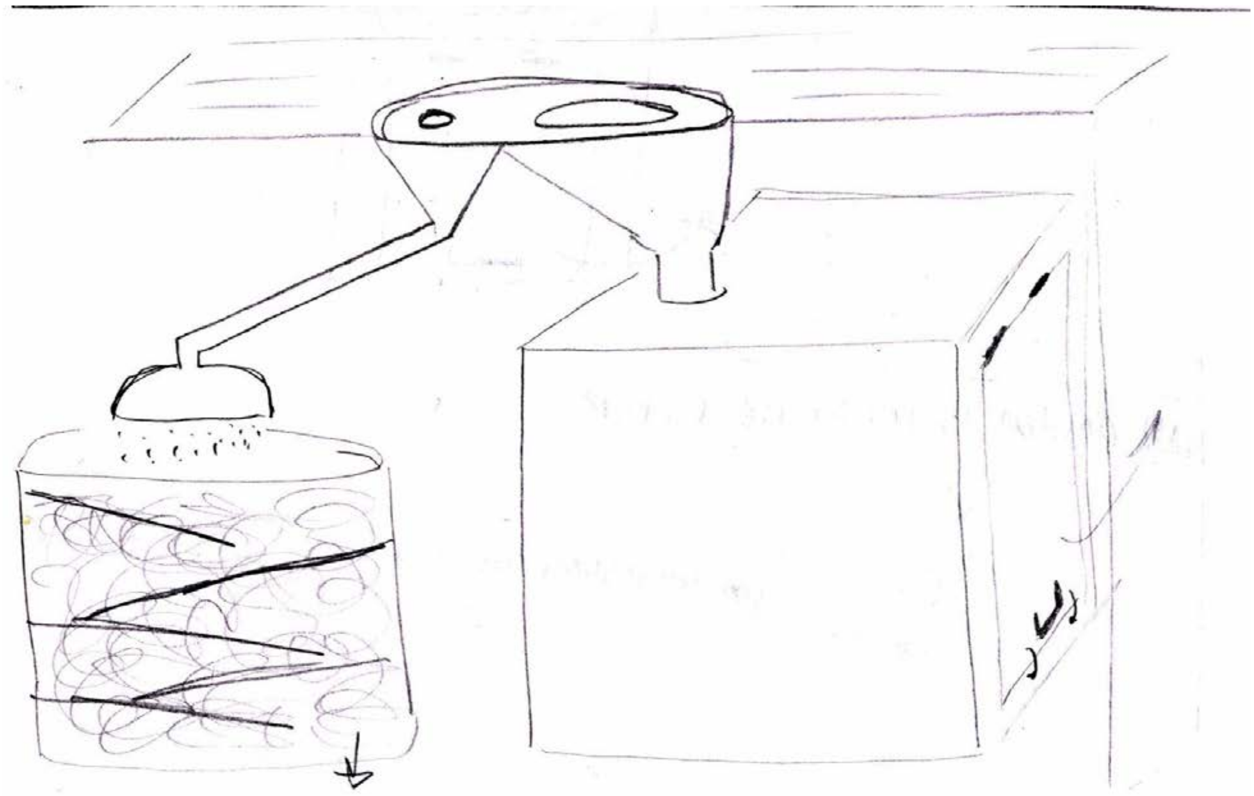

Figure 6: Garden Sketch II

This picture shows the diverting toilet seat. Urine is directed to the left into the trickling filter, and the feces is collected in the bin on the right.

Plants grown in the garden will be determined by the regional climate. Plants that are easily grown and not nutritionally fastidious are optimal for the treatment of urine. Crop producing plants are a viable option to increase the return produced by the system. Crops can be harvested and either consumed by the family or sold. Oral ingestion of potential urine pathogens is decreased because the urine is applied to the soil and roots, not on top of the plant themselves.

There are no specialized materials needed in the design. Basic carpentry and building supplies are required--prices will be determined using rates posted by the Indian Government [6].

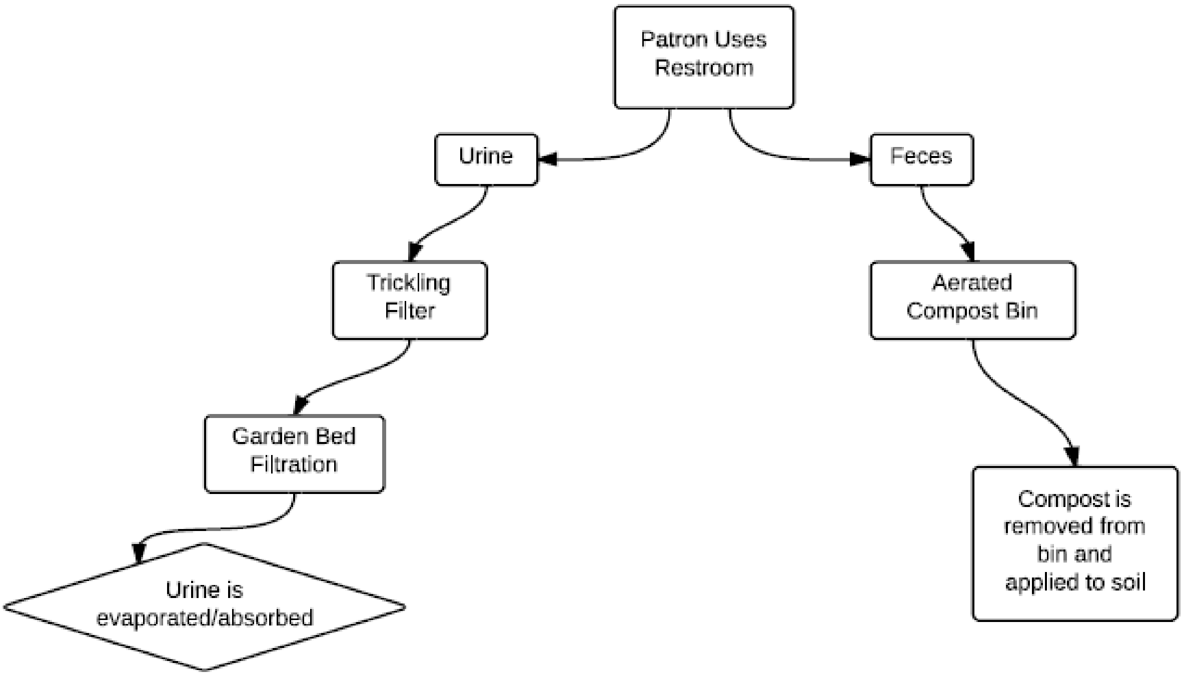

Figure 7: Flow Chart Illustrating the Garden Composter Concept

3.1.2 Poo Puck

The Poo Puck will separate urine and feces, and then convert the feces into a fire starter. The user will enter a square structure and squat over a toilet hole, facing the back wall. There will be a urine trap at the front of the toilet hole to divert urine, which will then run down a length of pipe to a French drain, located just behind the outhouse. The person's feces will be collected into a burlap sack and the fluids will drain from the sack over time. When the bag is full, a squeezing mechanism will be used to squeeze the fluid from the feces. After further dehydration using solar heat, the bag of feces will eventually transform into a dry brick or puck shape. Once the bag and poop are dry, the mass can be used as a fuel for fire.

The roof of the structure will be slanted to allow rainfall to also run down into the French drain. The front of the structure will be open to allow proper ventilation, but designed to keep rainwater out. Louvers located at the base of the side walls will allow natural airflow to circulate up through the structure and out the vent.

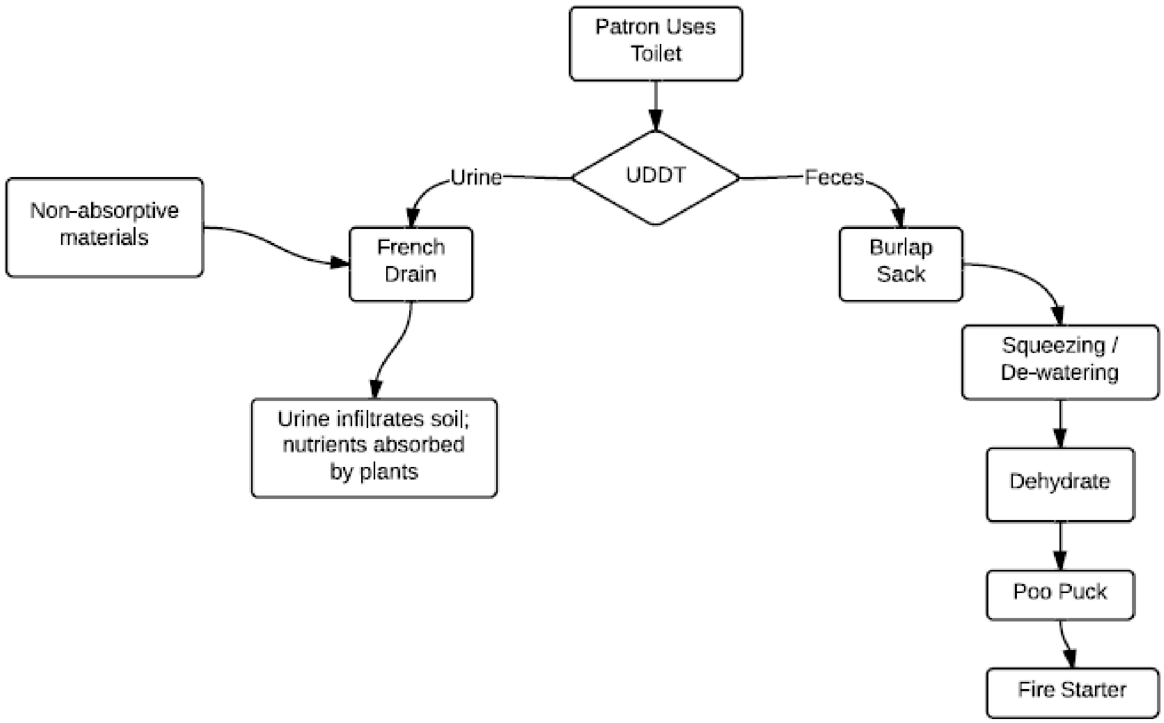

Figure 8: Flow Chart Illustrating the Poo Puck Concept

3.1.3 Existing Solution Combination

This concept is a synthesis between two existing solutions, namely the PeePoo bag and the two-tank system developed by Sulabh International (See the Background Section for more information). The fundamental idea is that the PeePoo is undesirable because it requires direct handling of the waste and the two-tank system is flawed because it requires the use of water.

With the combination solution the user will use the toilet and the feces will drop into a PeePoo bag. The PeePoo bag will be held in place by a railing system that will also suspend the bag on a conveyor belt. The user will turn a mechanical crank in the toilet structure to mechanically power the conveyor belt system. The conveyor will pass the bag along the rails through a bag sealing device to seal the bag. Finally, the sealed PeePoo bag falls into a tank to be composted. The result is a valuable compost.

Two tanks will be utilized in the same fashion as the Sulabh two-tank system such that only one tank is used at a time while the other tank is composting. The only user interaction required in this concept is some type of bag loading operation and the turn of the mechanical crank. No electricity or water is required because all mechanical processes are manually powered.

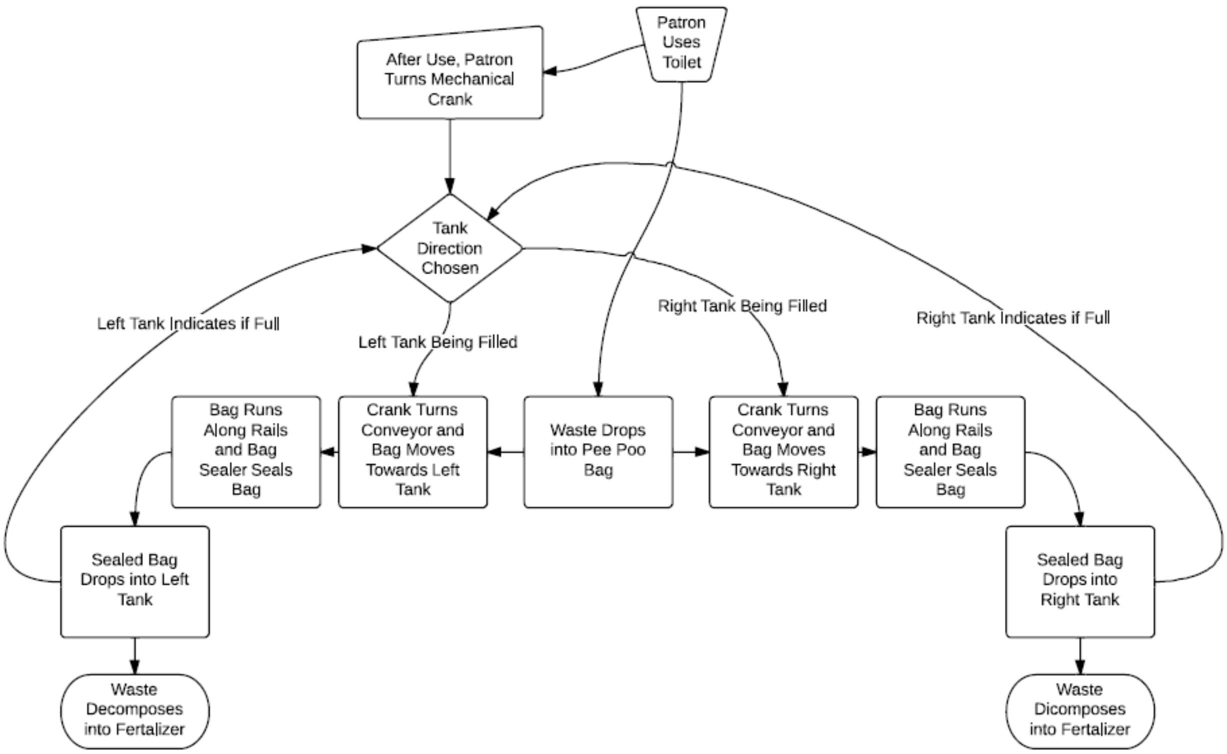

Figure 9: Flow Chart Illustrating the Combined Concept

3.2 Design Selection Description

Sodhana Environmental constructed a weighted decision matrix using Mr. Bhutani's response to a survey we created. The survey consisted of questions relating to the importance of design specifications and each was given a rating from 1 to 5, 1 being not important and 5 being extremely important. Each of the three preliminary designs, the Garden-Composter, the Poo-Puck, and the Combination, were rated on how well they meet each of the design specifications on a scale from 1 to 3. Completing the matrix produced final scores of 159, 153, 143, for the three designs, respectively. These results contributed to our final design decision. Sodhana Environmental unanimously chose the Garden Composter as the final design. Please refer to the Weighted Decision Matrix in Appendix A.

3.3 Satisfying Specifications

As previously stated the sponsor, Mr. Bhutani has requested a design with no water, no electricity, and monthly maintenance. The design will satisfy the specifications to the best of Sodhana Environmental's ability without minimizing creativity and originality. A creative and original design will compliment a successful business model.

3.4 Final Concept Design Details

The final design concept is the garden composter. As previously stated it will be a raised structure that will house a composting bin beneath with a latched opening for compost removal. This will be located at the bottom of the bin so that only the composted material will be taken out. The exact geometries of this design are still being calculated. The urine, separated in the diverting toilet seat, will fall through a trickling filter. The trickling filter will treat the urine, which is already 95% pathogen free when exiting the body. The media and design of the filter and garden structure is still under construction. Soil, sand, plastics, and rocks are viable contenders for the media, and the final design will be a combination. The plants chosen for the garden will be chosen based on the region of implementation.

3.4.1 Geometries

The toilet system will consist of a rectangular hut that houses one toilet. The small structure will be raised to allow the urine to flow down through the trickling filter. Building the structure above ground will also allow easy access to the feces composting system that will be collected directly below the toilet in a bin. To provide natural air ventilation to the interior space, the walls of the unit will have air intake louvers at the base and exhaust openings near the roof.

3.4.2 Materials

Simple and readily available materials are needed for the design. They must be found in rural communities around the world. Wood or metal will be the material used in the structure. Cement is needed for the base and constructing the Urine Diverting Dry Toilet pan. Additionally wood, plastic, or metal is needed to construct the garden trickling filter bed. There are many options for media in the trickling filter and ideally it would consist of waste plastics, local soil, sand or rocks to decrease the design cost. Hinges for the door, and a compost bin hatch are necessary along with nails and screws for construction. Steps up to the raised hut require wood for construction. Regional plants will be implemented in the garden.

3.4.3 Manufacturing Process

Design construction will be implemented in the rural communities that our sponsor has chosen. Minimal specialized labor or manufacturing processes will be required. Cost estimates for general labor, and materials for the trickling filter, garden, and compost pit will be based on the prices listed in the *Analysis of Rates for Delhi* document produced by the Indian Government's Central Public Works Department. These prices are estimates and may differ from the actual costs in the rural communities but will be adequate for preliminary price estimates. Ideally, the purchasing family will provide the general labor to mitigate the cost of their toilet.

4.0 Description of the Final Design/Layout with labeled solid model

The Sodhana Environmental Composting Toilet will utilize urine diversion and feces composting to treat human waste. Both effluents will become valuable resources for future profit and farming applications. The patron will use the Urine Diverting Dry Toilet pan (UDDT) that will separate the solids and liquids; urine and wash water through a peat filter to reduce the pathogenic load, and the feces into a ventilated composting bin. The toilet utilizes a two bin system that will fill one side then switch to the other while the first is composted completely. The bin size is designed for 2 years based on an average household of 5. The design is based on biological systems that produce a valuable crop. Thus it is a great business opportunity for the toilet owners to utilize the fertilizer produced.

4.1 Detailed Design Description

The Sodhana Toilet consists of a naturally ventilated structure, a two pit composting bin system, and a urine diverting dry toilet seat. The urine and anal cleansing water are treated by a Single Pass Peat Filter and collected weekly. The composted feces is removed and used for farming every two years. Waste removal and structural maintenance is performed by a Sodhana Environmental employee. The following sections describe each part of the design in detail. Drawings of each part are included in the Appendix B.

Table 1: Average Composition of Human Feces and Urine [8]

	Feces	Urine
Calcium	4.5	4.5 - 6
Carbon	44 - 55	11 - 17
Nitrogen	5 - 7	15 - 19
Organic Matter	80 - 97	65 - 85
Phosphorus	3 - 5.4	2.5 - 5
Potassium	1 - 2.5	3 - 4.5

4.1.1 Structure/Ventilation System

The composting pits are composed of cinder block walls built on top of a concrete foundation, all reinforced with steel rebar. Existing soil, slightly compacted to help prevent groundwater infiltration, makes up the floor of the pits. The toilet space is built directly on top of the composting pits and separated by two square panels of ¾" plywood. The walls of the toilet space are made out of plywood, unless local residents have a cheaper and/or simpler material that they prefer. The slanted roof of the structure, as well as the removable back panels separating each pit from the ambient, are constructed with corrugated metal (Drawing Number[1] U000180).

The toilet system will incorporate two ventilation systems: one system will ventilate the toilet room and the other system will ventilate the composting pits.

Wind-driven ventilation is used to bring fresh air into the toilet room, providing a more comfortable experience. Wind blowing towards the structure's windward side creates a positive pressure zone, while wind blowing away from the structure's opposite side creates a negative pressure zone. Strategically placed ventilation holes cut into the walls take advantage of the pressure differential- fresh air enters the space through the windward openings, and exhaust air exits the space on the opposite side. In order to maximize air mixing within the space, the vents are skewed along the walls- you cannot see through the structure by looking through any of the vents, and therefore the outside air will not pass straight through the space without mixing with the other air. Intake vents incorporate scoops in order to ensure fresh air intake even when the wind is blowing parallel to the openings. The intake vents are located along the bottom of the walls, while the exhaust is at the top of the room; this allows buoyancy-driven air flow (described in the next paragraph) to ventilate the space when the wind is not blowing. In order to maximize the airflow rate, the roof is angled upwards and the exhaust is at the highest point, allowing

[1] Drawing Number will henceforth be referred to as DN

all of the air that rises to flow out of the space. DN S000005 and SA0004 show the location of the intake and exhaust vents.

Solar chimneys (DN S000004) take advantage of buoyancy-driven air flow and ventilate the composting pits in order to accelerate the composting process. Buoyancy results from a density difference. With air, density is a function of temperature- at the same humidity; warmer air is more buoyant than cooler air. Sodhana's solar chimneys are specially designed to take in heat radiated from the sun and convect heat to the air within the column. The warm air rises and creates a negative pressure zone at the system's intake. The solar chimney's intake vent is located at the wall separating the composting pit and the ambient air. Fresh air flows in through the vent, aerates the compositing pit, and then flows out through the exhaust. In order for the solar chimney to take full advantage of the sun's radiated heat, the outer surface of the chimney is painted matte black and the entire toilet structure is oriented so that the chimney receives the maximum amount of sunlight. The solar chimney rises 2 feet above the roof (DN SA0004), allowing solar radiation to heat the exhausting air all day.

4.1.2 Urine Treatment

The urine is piped from a UDDT pan into a Single Pass Peat Filter (SPPF). Once it passes through the SPPF (DN US00001 and US00002), the urine is stored in a 55 gallon drum until it is collected. Please refer to Drawing Number US00004 for the Urine Collection Tank (Appendix B). The volume of the SPPF is based on an assumed maximum daily flow of 4.5 L/person/day with a factor of safety of 3, resulting in 22.5 liters of urine per day for a household of 5 people. The Full Urine Assembly and Urine Piping Assembly drawings are found in DN UFA003 and DN UPA005, respectively. A complete list of part drawings can be found in Appendix B.

The SPPF reduces pathogens in disease-laden urine the anal cleansing water (ACW). Using organic material as the filter media increases the range of biomass that treats the waste; organic materials host more biomass than plastic, rock, and other media types. Peat moss is a fibrous plant that is used as a filtering material. Sodhana Environmental has chosen peat moss because it is an organic material that can support a high microbial load. The peat moss can be purchased at local hardware and gardening stores. If peat moss is not available, hay, pine needles, leaves, or wood chips are viable alternatives. The column is a PVC pipe with a diameter of 11 cm and a height of 65cm. The media height is 60 cm with a 5 cm tall holding space above. The holding basin is designed to hold 5 consecutive uses (based on family size) to ensure no backup in the lines, with a factor of safety of 3.

Table 2: Pathogens that may be excreted in urine and their importance with respect to urine as a transmission route [9]

Pathogen	Transmission in urine	Importance
Leptospira interrogans	Usually through animal urine	N/A
Salmonella typhi and Salmonella paratyphi	Probably unusual, excreted in urine if systemic infection	Low compared to other transmission routes
Schistosoma haematobium	Not directly but indirectly, larvae infect humans in fresh water	Need to be considered in endemic areas where freshwater is available
Mycobacteria	Unusual, usually airborne	Low
Viruses: CMV, JCV, BKV, adeno, hepatitis	Not recognized other than single cases of Hep. A and suggested for Hep. B	Low
Microsporidia	Suggested but not recognized	Low
Vernereal disease causing	No, do not survive outside the body	-
Urinary tract infecting	No, no environmental transmission	-

Traditionally, peat filters under regular use need to be changed after about one year, depending on climate and loading. Typically, peat filters are used for full strength wastewater that contains both diluted feces and urine. The peat filter in the Sodhana Toilet is treating the ACW-Urine mixture, no feces. The urine's high nutrient concentration may degrade the peat faster and increase biological growth, potentially leading to clogging earlier. This will require the peat in the filter to be changed every 3-4 months.

The nutrients in urine, primarily nitrogen in the form of ammonia and ammonium ions, promote biomass growth and improve treatment, but also clog the filter. When a filter becomes clogged it is emptied into the composting feces bin and new peat is added. The testing phase will determine how many uses it takes to clog a filter. The PVC pipes are easy to take apart so replacing degraded peat moss is not a burden. Used peat moss is discarded in the composting bins. Biomass and peat will aid the feces composting and pathogen removal.

Single Pass Peat filters help maintain a low pH as the urine is passing through. A lower pH is desired to keep the nitrogen composition as ammonium ions (NH_4^+); ammonia (NH_3) is more easily volatilized and is a product of an alkaline pH (typically above 7). Ammonia volatilization increases odor and reduces the amount of nitrogen in the fertilizer. The fertilizer will consist of nitrogen, potassium, phosphorus, and calcium.

Table 3: Quantities of Constituents of Human Urine

Organic		Inorganic	
Nitrogen	23 – 35 g	Chloride	6 – 9g
Urea	25 – 30 g	NaCI	10 – 15g
Creatine	60 -150 mg	Phosphate	0.8 – 1.3 g
Creatinine	1.2 1.7g	Sulphate	0.8 – 1.3 gm
Ammonia	0.3 – 1.0 g	Potassium	2.5 – 3.0 g
Uric acid	0.5 – 0.8 g	Sodium	4.5 g
Hippuric acid	0.1- 1.0 g	Calcium	0.1- 0.3g
Oxalic acid	10 – 30 mg	Magnesium	0.1 – 0.2 g
Amino acid	150 – 200 mg	Iodine	50 – 250µg
Allantion	traces	Arsenic	50µg
Vitamins & hormones	traces	Lead	50µg

The urine and ACW mixture is collected and sold as a liquid fertilizer called Plant Whiz. The owners of Sodhana Toilets will receive a discounted price on the fertilizer. Please refer to the Business Model (section 6.1) for more information.

4.1.3 Feces Treatment

The purpose of feces treatment is to destroy feces-borne pathogens present in excrement, thereby preventing the spread of disease. Sodhana's Toilet employs a two pit system (DN S000001) constructed from cinder blocks (see Structure/Ventilation System: Section 4.1.1). The Sodhana two pit system uses two identically sized pits (each with a 40 inch by 40 inch base and measuring 4 feet tall) to hold human feces until it is composted. While one pit is in use (people are actively pooping into it), the feces in the other full pit will be composting. The composting process relies on pathogen-consuming bacteria that exist naturally in feces. While this process can take as little as a couple of weeks at certain temperatures, Sodhana Toilets are designed for a two-year composting period to ensure user safety and reduce the amount of system maintenance required.

Table 4: Typical Pathogen Survival Times in Various Environments [10]

Survival Time, Days			
Pathogen	**Wastewater**	**Crops**	**Soil**
Bacteria			
Fecal coliforms	<60 but usually <30	<30 but usually <15	<120 but usually <50
Salmonella (spp.)	<60 but usually <30	<30 but usually <15	<120 but usually <50
Shigella	<30 but usually <10	<10 but usually <5	<120 but usually <50
Vibrio cholerae	<30 but usually <10	<5 but usually <2	<120 but usually <50
Protozoa			
E. histolytica cysts	<30 but usually <15	<10 but usually <2	<20 but usually <10
Helminths			
A.lumbricoides eggs	Many months	<60 but usually <30	< Many Months
Viruses			
Enteroviruses	<120 but usually <50	<60 but usually <15	<100 but usually <20

The two pit system is handled in the following manner:

4.1.3.1 Pit Preparation

Just before its first use, five bamboo poles are placed in pre-prepared holes in the ground inside of the pit (explained later in this section). To place the poles, the user opens the toilet floor panel and inserts the poles from above. Next, a 1 inch layer of straw is laid on the floor of the pit, again accessed from the top. Feces is composed of 75% water that seeps out of the feces over time and infiltrates the ground. The layer of straw serves as a basic filter to capture pathogens before they contaminate groundwater. The straw eventually decomposes and becomes part of the useful compost product created by Sodhana Toilets. Once the bamboo poles and straw are in place the floor of the restroom area is shut.

4.1.3.2 Use

When the pit is ready for use, the Sodhana Toilet is used in the same way as other toilets common to India. Poop falls directly into the toilet and the user pours a layer of carbon-rich material over their excrement. The carbon-rich material is an essential form of food for the pathogen-consuming bacteria that expedite the composting process.

After approximately two years, the full pit is retired for composting and the other pit is used. The bamboo poles are removed from the full pit, creating aeration columns. These columns allow oxygen to enter the pile, feeding the bacteria as well as oxidizing carbon to create heat. The pile is left alone for two years. Although the composting process can take as little as a few weeks if high temperatures are reached, composting for two years ensures death of all potential pathogens. The final product is a useful fertilizer that is sold by a Sodhana Toilet Employee (see Business Plan).

All actions pertaining to the pit switching are performed by a Sodhana Toilet Employee. This reduces the burden on the patrons, increasing their incentive to use the Sodhana Toilet. Having a trained employee also reduces the potential for human-fecal contact and contamination. Please refer to the Business Plan and Safety Consideration Sections for more information.

4.2 Analysis Results

4.2.1 Cost Analysis

Pricing for the Sodhana Toilet is based on material costs in the United States. The total price has been calculated to be $700 US dollars. This is an upper limit capital cost for a 40 year lifetime. This lifetime price breaks down to 5 cents per family per day. It is assumed that the materials can be found in India and other countries at comparable prices, if not cheaper. The price presented includes all capital costs for a Sodhana Toilet. However, it is a preliminary assessment and will be adjusted after the testing and prototyping phases are complete. Additional costs for replacing the peat filter should be accounted for on a yearly basis. The peat filter needs to be replaced on an as-needed basis (approximate frequency to be determined through testing). According to an assumption of 15 quarts of peat per year, 1.5 bags are needed per year. All other materials are one-time costs. The Bill of Materials does not cover any maintenance and/or repair costs. Please refer to the table in Appendix C for a list of parts and pricing.

4.2.2 Material, Geometry, Component Selection

Material for the Single Pass Filter was determined based on microbial and nutritional load. Urine is very high in nutrients that aid fast biomass growth, resulting in filter clogging. Peat moss is the best selection because it can be added to the composting pile after clogging. Clogging is inevitable and creating an additional waste is taking a step backwards in the design. Compared to gravel or sand (other common filter media), peat is easily biodegradable and enhances the composting feces. The additional biomass load can expedite the composting process. The amount of additional biomass required will be determined during the testing phase.

The piping in the Sodhana Toilet is built from PVC. PVC was chosen because it is easy to install and is found worldwide. Please refer to DN UPA005 for the Urine Piping Assembly Drawing. Removal of filter material requires a system that is easily disassembled, and PVC satisfies this criteria (Refer to DN UFSA01 and UFA003 for Filter Sub Assembly and Full Urine Assembly, respectively). In addition, the 55 gallon drum for the ACW/urine collection was chosen based on availability. The drums are compatible with piping installation procedures and lightweight, simplifying installation and removal. Sturdiness and reliability of the piping and holding basin are important; unreliable materials can leak untreated waste onto the ground, resulting in contaminated soil and groundwater.

The structure around the composting bin is built from cinder blocks due to their availability, ease of construction, and resistance to corrosion. Each pit has a 40”x40” base because of the standard size of cinderblocks (8 inches wide by 16 inches long). The 4’ height of the compost bin was chosen to accommodate 2 years’ worth of feces. The quantity of feces produced in two years was calculated based on the following assumptions:

- 1 oz of poop/12 lbs of human weight/day
- 2 x 140 lb adults per household
- 3 x 85 lb children per household.

Bamboo was chosen for aeration because of its availability, although any similar-shaped object can be used as long as it can fit inside the bin with the lid shut. The floor's straw filter was also selected based on availability, but can be replaced by peat moss or other carbonaceous organic material.

4.2.3 Flow charts

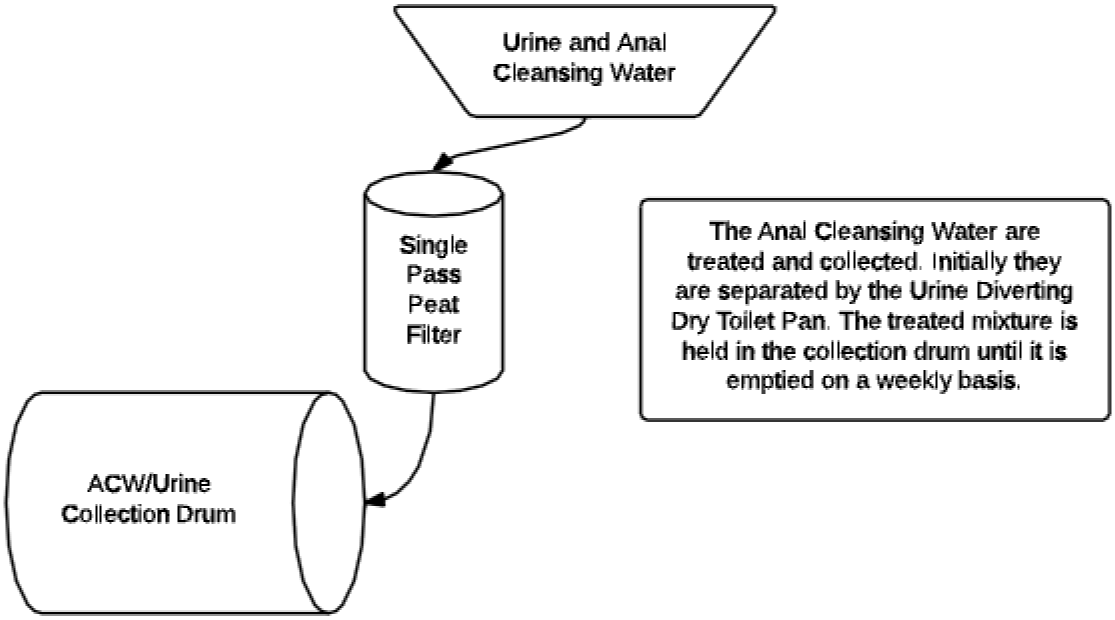

Figure 10: Single Pass Peat Filter Flow Chart

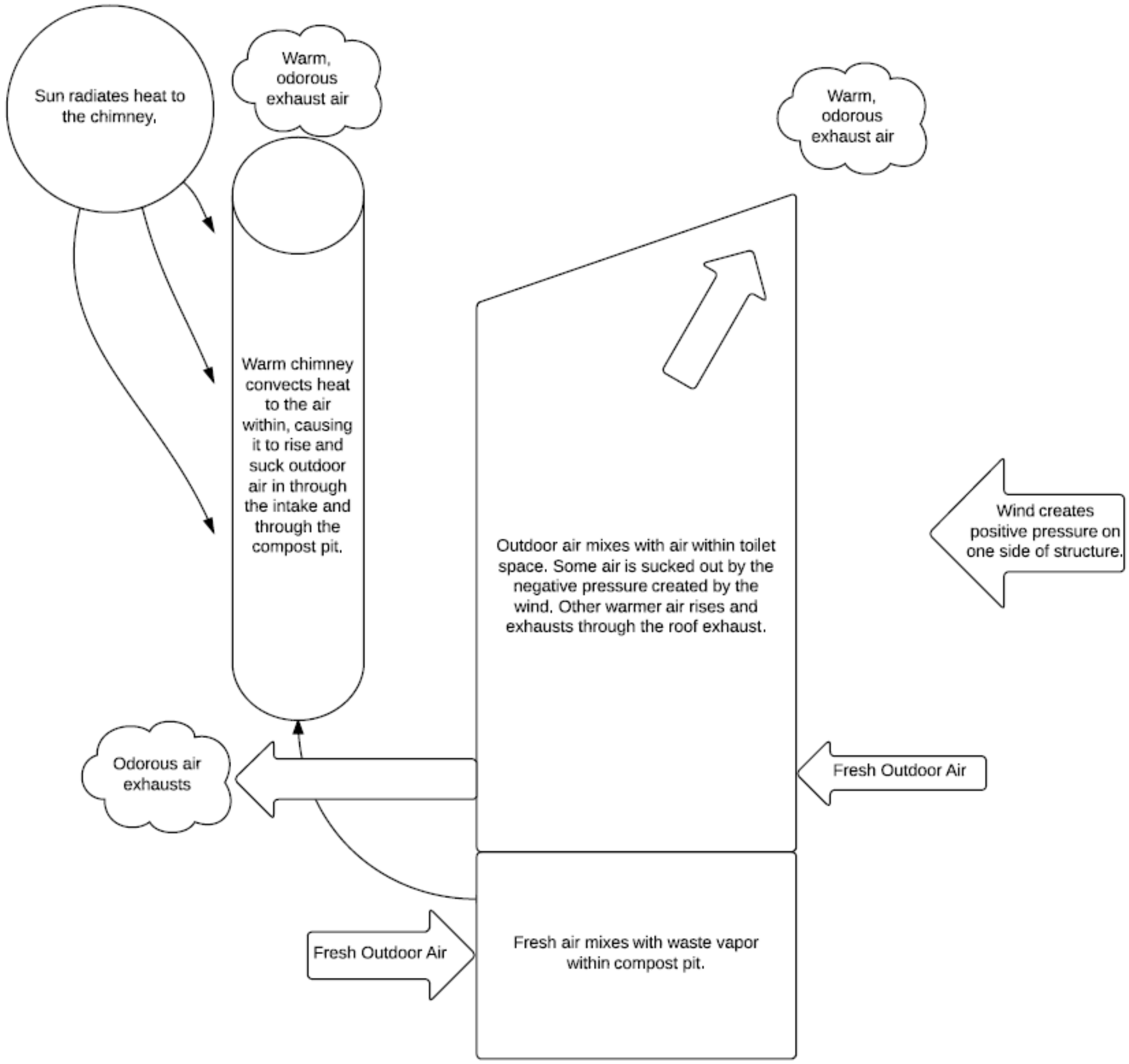

Figure 11: Natural Ventilation Flow Chart

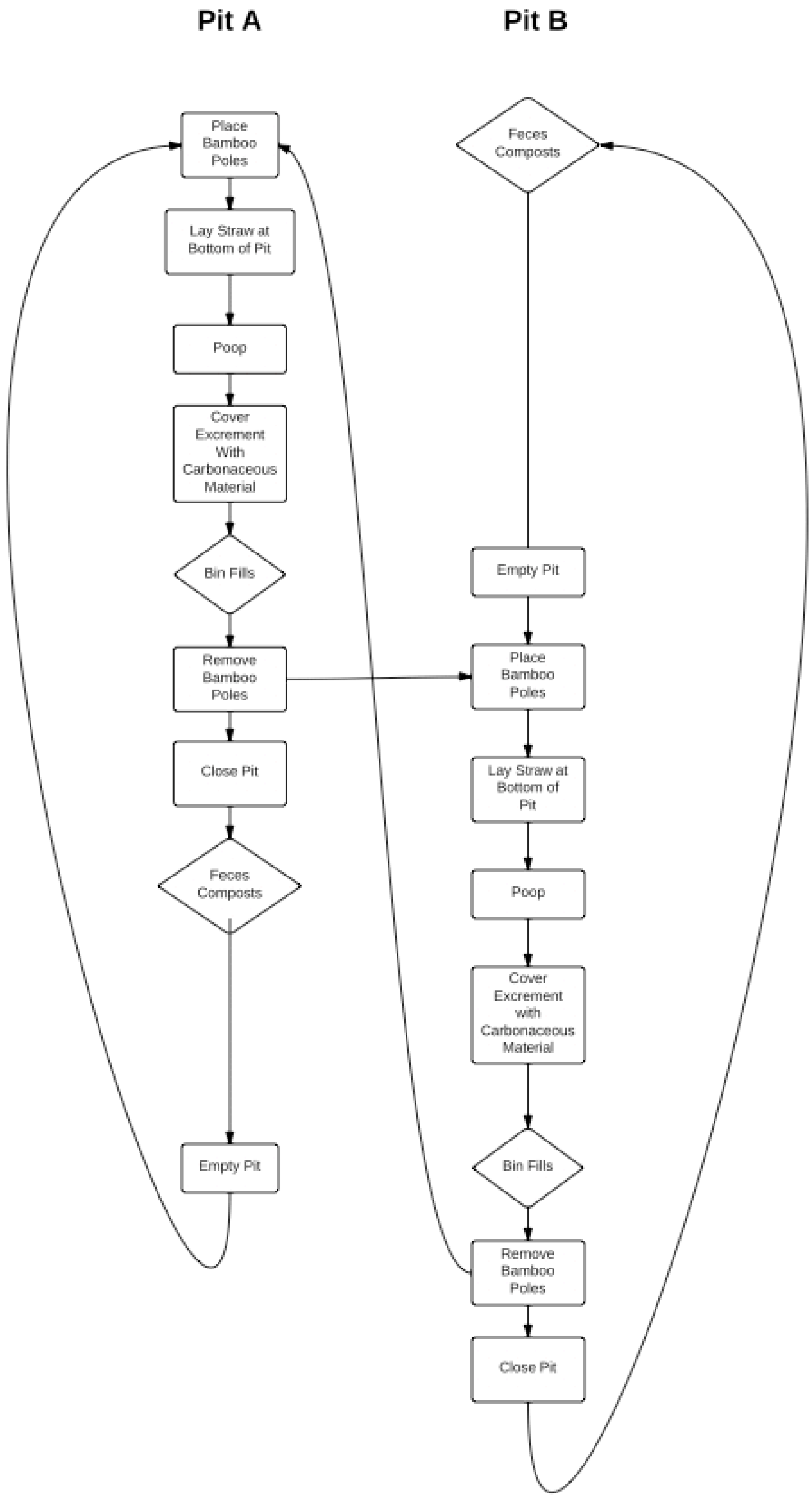

Figure 12: Composting Flow Chart

4.2.4 Manufacturing Drawings

Drawings for the Sodhana Toilet are included in Appendix B. Please refer to these drawings for specific parts and sub-sections of the design. There are full and sub-assembly drawings included. The drawings will be helpful for construction and implementation.

4.3 Safety considerations

Human waste contains harmful pathogens before it is properly treated. Patrons should not handle treated feces or the ACW/urine mixture to avoid exposure to raw sewage. Safety should be considered during all maintenance procedures for the Sodhana Toilet, including wearing proper personal protective equipment (PPE).

Gloves shall be worn while performing the following procedures:

- Switching the UDDT seat from one side of the toilet space to the other
- Transferring the ACW/urine fertilizer from the barrel to the distribution bottles
- Disposing of used SPPF material into the composting bins
- Applying Plant Whiz to crops

Glasses should be worn when removing the bamboo poles from fresh feces and extracting finished compost. Plant Whiz shall be applied directly to the soil no less than two weeks prior to harvesting. All crops fertilized with Plant Whiz should be washed prior to consumption.

In addition to taking the precautions mentioned above, patrons should wash their hands after any interaction with the Sodhana toilet and its bi-products.

4.4 Maintenance and Repair Considerations

The Sodhana Toilet requires minimal maintenance, as specified by our sponsor, Mr. Bhutani. Maintaining a clean atmosphere inside of the structure is the owner's responsibility. Any spills inside of the structure should be cleaned to increase the longevity of the toilet and reduce odors and flies. Closing the lid after each use will help maintain a clean atmosphere.

The SPPF needs to be replaced when the peat has degraded or the filter is clogged. When this happens, a Sodhana Toilet Employee removes the filter material from the piping and the degraded peat and biomass are emptied into the composting bin through the UDDT seat. New peat is added to the filter column. All parts are replaced and water is run through the system to check for any leaks.

Active use of the compost bins alternates every two years. When one pit fills with feces it is closed off and the UDDT seat is moved to the other pit. The other pit will have just finished composting and been emptied by a Sodhana Toilet Employee. The Employee will shovel the finished compost out of the back hatch of the bin and sell it as fertilizer. Please refer to the business plan for more information.

Maintenance pertaining to the ACW/Urine collection drum is minimal. If the flow slows or a clog forms the tank should be removed and flushed with water. Solids and minerals may collect around the spout. The spout should be kept closed when not draining to avoid leakage.

5.0 Design Verification Plan

Testing and prototyping will be performed during Fall Quarter 2013. Regular usage is crucial for testing. The testing site is still to be determined. It is proposed to have a testing period of 3 months to confirm that the Sodhana Toilet works properly.

5.1 Test Descriptions and Necessary Equipment

Necessary testing equipment includes building materials for the structure, the filtration system, and the composting pits. Please refer to the Bill of Materials for a detailed list and price points for each component. Additionally, regular use of the prototype is necessary to test the loads on the filter and composting system. Cultural differences between the testing site (United States) and proposed design location (India) include the UDDT pan, anal cleansing water (ACW) and toilet paper. To mitigate these differences no additional dry material (sawdust, ash, peat) will be added the composing pits. In this case the SPPF will filter only urine; ACW will not be used. Special instructions for using the UDDT pan will be included inside the structure.

The Sodhana Toilet will be tested for three months. After the testing period, all problem areas will be considered for re-designing, including, but not limited to, the ACW/Urine filter, size of the composting bins, ventilation system, and structural design. Application of the urine to crops will not be tested. Tests proving that urine is a nutritious fertilizer have already been performed in Sweden, Africa, and other locations. Please refer to the table for information regarding growth increases due to urine application. Urine has proved safe for plants when handled cautiously.

Table 5: Average yields in plant trials with urine as a fertilizer to vegetables in Zimbabwe [11]

Plant, growth period ad number of repetitions (n)	Unfertilized plants (g)	Fertilized, 3:1 water/urine application 3x per week (g)	Relative yield fertilized to unfertilized
Lettuce, 30 days (n=3)	230	500	2.2
Lettuce, 33 days (n=3)	120	345	2.9
Spinach, 30 days (n=3)	52	350	6.7
Covo, 8 weeks (n=3)	135	545	4
Tomato, 4 months (n=9)	1680	6084	3.6

Testing humanure is difficult due to time restraints. For fecal matter to compost completely it would take longer than 1 year. The testing period is only three months so the complete degradation of pathogens cannot be assessed. Sodhana Environmental has used the recommendations from *The Humanure Handbook* stating that feces are composted fully after 2 years. Using the Sodhana Toilet will test the composting bins' foundation, ventilation, and odor control. Analyzing the moisture content in the feces will give insight into the ventilation system's effectiveness. If necessary, Sodhana Environmental can perform fecal coliform tests to determine the pathogenicity of the compost. Lingering odors and unwanted flies will test the effectiveness ventilation of the structure and bins. Maintaining a sanitary environment is imperative to in encouraging villagers to use the Sodhana Toilet.

6.0 Project Management Plan

Development of Sodhana Environmental's toilet is based on a sustainable business plan. An effective business plan will create incentives to buy and use the toilet. The Sodhana Toilet produces valuable byproducts while improving sanitation and reducing groundwater and soil contamination. Sodhana proposes a staff of one to two persons (depending on the number of toilets in the area) to complete the following tasks.

The treated urine and ACW mixture is a valuable fertilizer for crops and is collected in the 55 gallon drum. The Sodhana Employee empties and splits the fertilizer between him/her and the Sodhana Toilet owners. When the fertilizer is collected, the Employee sells it to farmers in the form of *Plant Whiz Liquid Fertilizer*. The employee will earn a commission on the Plant Whiz that he/she sells.

Every two years (more or less depending on the feces loading), the pits need to be switched. After the initial change, there will be composted humanure ready for removal. It is the employee's job to check the fill level when removing the ACW/urine fertilizer on a weekly basis. Once full, they will remove the humanure and sell it. The toilet owner will divide the compost with the Sodhana Employee. The profits from selling the Plant Whiz Liquid Fertilizer and composted humanure will make up the employee's salary.

Reducing the owner's contact with the fecal matter will increase ease of use. The Sodhana Toilet will not become a burden, so the owner will be motivated to continue to use it. Free fertilizer is an additional incentive to use the restroom. The organic fertilizer sold by Sodhana Employees should be cheaper than that sold in stores, but the market price is not yet determined.

7.0 Testing and Results

Fecal coliform sampling for the single pass peat filter was performed on November 14, 2013. Three different sources of urine were run through the filter after an initial percolation of tap water from California Polytechnic State University building 192. The IDEXX Quanti Tray 2000 and Colilert 18 method for determination of the MPN (most probable number) of fecal coliforms was utilized. To understand this method, refer to the method composed by IDEXX in section 10.0 Supplemental Documentation. The Colilert 18 reagent tests for *E.coli* (fecal coliform) and natural coliforms was also utilized. In this method, squares in the Quanti Tray 2000 that are dark yellow are indicators of CFUs (coliform forming units). The MPN of CFUs present in the 100mL sample of filtered urine was determined using the IDEXX table (See attached table in section 10.0 Supplemental Documentation). The results from the experiment are listed below in Table 6.

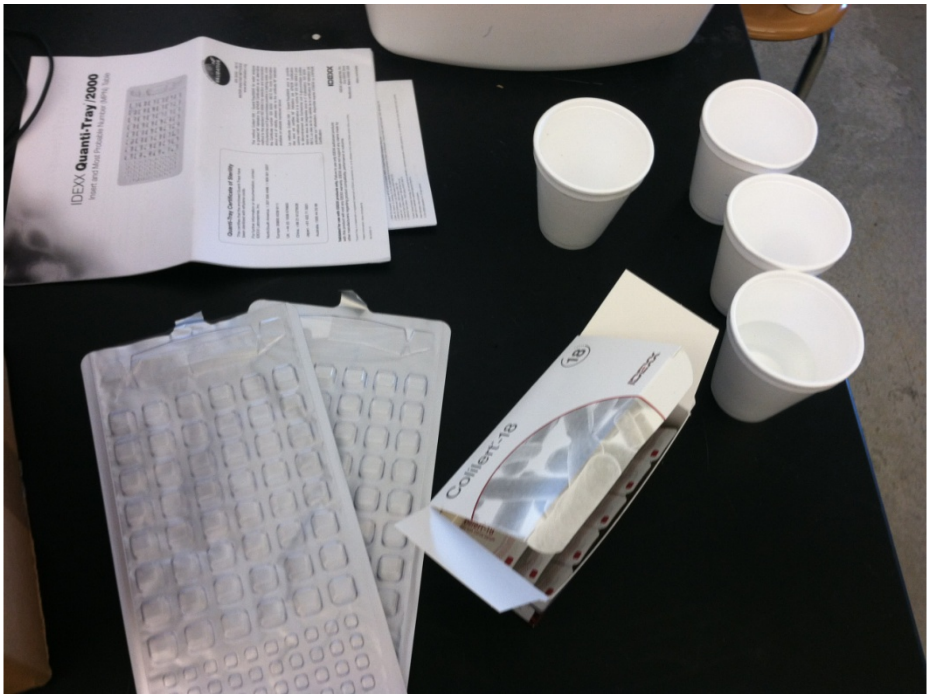

Figure 13: Quanti Tray 2000 and Colilert-18 ready for fecal coliform testing. 100mL goes into each Quanti Tray then is vacuum sealed so each well is filled and the tray is closed.

Table 6: IDEXX Testing Results

IDEXX Quanti Tray 2000 and Colilert 18 Fecal Coliform Testing of the Single Pass Peat Filter per 100mL sample						
Tray Description		Coliform		Fecal Coliform		Fecal Coliform MPN
		Positive Large Wells (of 48)	Positive Small Wells (of 48)	Positive Large Wells (of 48)	Positive Small Wells (of 48)	
Tap Water	Blank #1	1	0	0	0	<1
Tap Water	Blank #2	2	0	1	0	1.0
Filter Test	Water #1	48	41	0	0	<1
	Water #2	48	34	0	0	<1
No Filter	Urine #1	0	0	0	0	No Filter
Urine Through Filter	1	48	8	5	1	5.2
	2	41	7	0	1	1.0
	3	43	6	6	1	6.3
	4	48	10	7	3	10.7
	5	47	6	3	1	4.1
	6	48	8	2	1	3.0
	7	44	7	3	2	5.1
	8	45	9	2	1	3.0
	9	38	9	2	1	3.0
	10	48	10	6	1	7.4
					Average	4.9

As determined by the results of the experiment the filter's ability to remove fecal coliform was unacceptable. With a target of complete reduction of fecal coliforms the average MPN of 4.9 was above our target. Both of the water tests resulted with less than one fecal coliform. The pure urine sample, without running through the filter, also had less than one fecal coliform (no wells fluoresce).

Future testing is necessary on urine that has not passed through the filter. Another experiment that includes a urine sample before and after the filter will be necessary to further analyze the SPPF's efficiency. The MPN were supposed to be counted after the 18-24hr incubation time. Due to conflicting schedules the trays were not counted until 54 hours after the event. Thus, data was recorded 30 hours after they were ready allowed more growth in the wells, decreasing the test's accuracy.

The filter was not inoculated with any microbes that will treat the urine as it passes through. When implemented, the filter will have microbial growth inside of the filter as it naturally occurs when nutrients, such as the nitrogen in urine, are available. Thus, the treatment process will increase in efficiency. In addition to increased biomass inside the filter, the 55 gallon holding tank will also help kill any CFU (coliform forming units). The holding tank is a successor to the filter to kill any CFUs that have passed through.

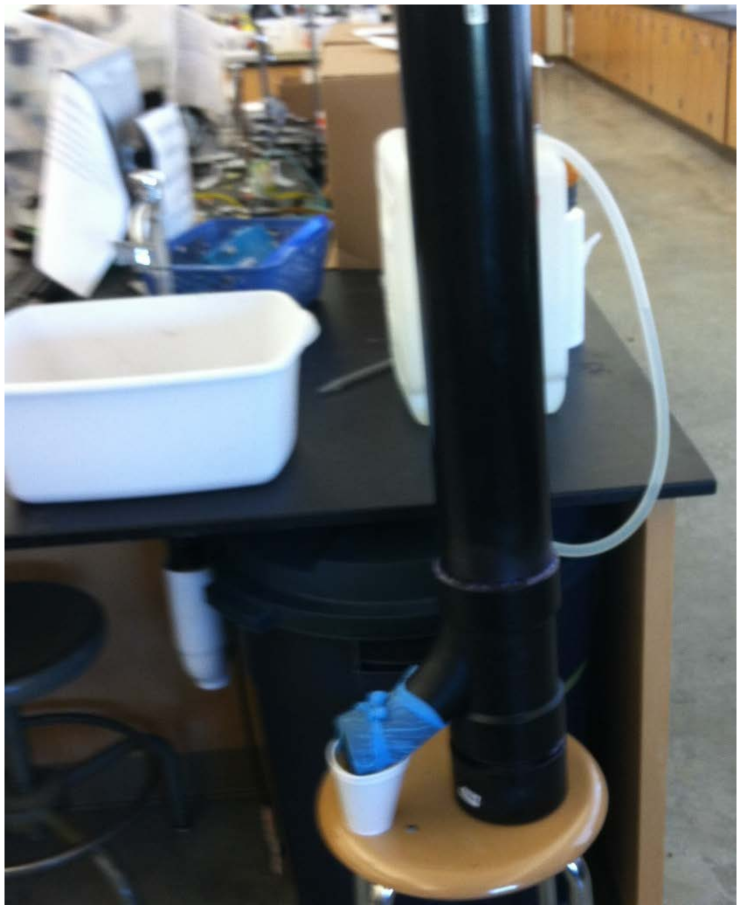

Figure 14: The Single Pass Peat Filter Ready for Testing

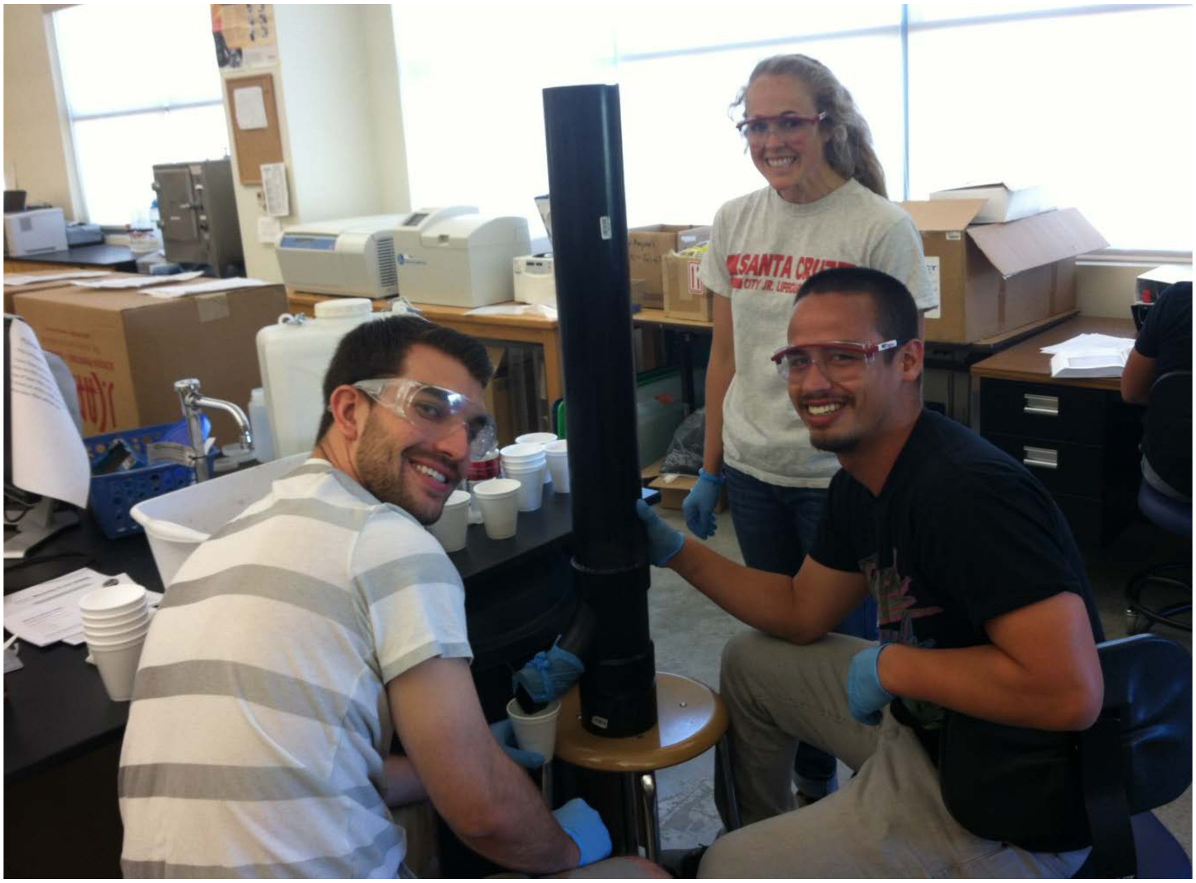

Figure 15: Sodhana Environmental hard at work in Cal Poly's Vista Lab testing the filter for fecal coliform E.coli

8.0 Conclusions and Recommendations

Sodhana Environmental is proud of the Sodhana Toilet design: it utilizes human waste as an organic fertilizer while improving sanitation and reducing contamination. The structure is designed to decrease grotesque toilet room conditions with natural ventilation. It keeps cultural and social practices in mind by including a squatting urine diversion dry toilet seat and an enclosure for the safety of women. The toilet is easy to use and includes a maintenance service provided by Sodhana Toilet personnel. It is crucial that the users are not burdened by the toilet to ensure continual use. In addition, the business plan surrounding the toilet will produce profits and incentive for use. Sodhana Environmental will try to hire persons whose current job is scavenging as a way to increase their income and eliminate the inhumane practice. Sodhana Environmental foresees that their design has the potential to reduce illness by improving sanitation and providing jobs.

After initial testing of our Urine Diverting Dry Toilet with the Single Pass Peat Filter, Sodhana Environmental has concluded that the system requires further improvement before implementation. In order to confirm sufficient performance for use in rural India, we suggest re-evaluation of the following elements of the testing process:

- Increase quantity of test samples - after our first run of tests, we recommend testing at least double the amount of 100 mL urine samples
- Improve consistency of urine that we test - rather than run one set of tests on urine samples from different people, run a set of tests on a uniform mixture of different peoples urines
- Optimize incubation time/dead time between incubation and testing - in order to ensure consistency, leave all samples in the incubator for the exact amount of time within the suggested 18-24 hour time period, and test for fecal coliforms immediately after incubation
- Test various peat moss mixtures for ideal coliform levels - prior to testing urine that has passed through filter, test pure water that has run through different mixtures of peat moss to confirm that the media does not contain fecal coliforms
- Investigate other medium - look into equally inexpensive materials that can effectively filter the urine and anal cleansing water.

The structure and ventilation systems were not tested due to the two year lag time for fecal composting. However, prior implementations of different elements of our structure and ventilation design have proven their effectiveness. Before final implementation into Indian culture, we believe that testing in India would be very beneficial, as their customs are different than here in the United States.

In summary, Sodhana Environmental has brought this project through the design, build, and testing phases of the design cycle and is pleased with the end result. It's our hope that subsequent teams continue to develop this design to completion.

9.0 Appendices

Appendix A: Weighted Decision Matrix

Table 7: Weighted Decision Matrix

	Design Constraints					Environmental Constraints				Health and Safety			Marketability		Creativity Constraints		
	No water	No electricity	Amount of maintenance required	Simple design	Easy to use	Can be used in any culture	All climates	Accommodates cultural stigmas	Eliminates the societal role of a scavenger	Can be used as a single device per household	Reduces disease and illness	Waste isn't handled directly	Creates a job opportunity	Low cost	Makes use of a brand new idea	No advanced technology is used	
Weight	3	3	2	1	2	3	3	1	3	2	3	1	1	2	3	3	Sum
Garden	5	5	3	4	5	5	4	5	5	5	5	3	2	4	4	4	159
Poo Puck	5	5	2	3	4	5	4	5	5	5	5	2	3	2	5	4	153
Combined	5	4	4	1	4	5	5	5	5	5	5	4	3	1	2	3	143

Appendix B: Bill of Materials, List of Vendors, Contact Information and Pricing

Table 8: Supplier Contact Information

Blain Supply Inc. farmandfleet.com 1-800-210-2370	Lowe's lowes.com 1-800-445-6937
Eco-Solutions eco-solutions.org ecopan@eco-solutions.org 1-888-978-7759	PVC Fittings Online pvcfittingsonline.com 1-803-328-2480
Hardware and Tools Corp. hardwareandtools.com 1-540-572-4000	US Plastic usplastic.com 1-800-809-4217
Home Depot homedepot.com 1-800-466-3337	True Value idealtruevalue.com 1-870-304-2944

Table 9: Bill of Materials

Parts	Quantity Needed	Price	Price Unit Length	Vendor	Notes
Urine Filter/Piping					
55 gallon collection tank	1	$58.95	1	Global Industries	
PVC Filter Column (4")	2.13"	$17.50	5'	PVC Fittings Online	4" Schedule 40 PVC Pipe 4004-040AB
Filter Column Plug	1	$5.33	1	PVC Fittings Online	4" Schedule 40 PVC Spg Plug 449-040
Filter Exit Screen	1	$3.44	1	US Plastic	1" Spigot PVC Compact Foot Valve Screen
UDDT Pan	1	$50.00		Eco-Solutions	Sustainable Technologies in the Community 49 Asan Nagar, Vallakkadavu, Trivandrum- 695008, Kerala, India.
1.5' PVC piping	1	$8.19	9'	PVC Fittings Online	
Liquid removal ball valve	1	$1.99	1	Hardware and Tools	Mueller 107-634 Ball Valve Pvc 3/4 Solv
Collection Bucket	2	$10.00	5 gallon	Blain Supply Inc.	Coleman Water Carrier
Peat Moss	15 qt/yr	$3.18	10 qt	True Value	10 QT, Sphagnum Peat Moss, Premium Grade Of Coarse Canadian Peat Moss,
Piping 1.5' elbow (45)		$0.98	1	PVC Fittings Online	1-1/2" Schedule 40 PVC 45 Elbow SxS 417-015

Piping 1.5' elbow (90)		$0.69	1	PVC Fittings Online	1-1/2" Schedule 40 PVC 90 Elbow 406-015
Estimated Cost		$160.25			
Structure/Ventilation					
Ventilation Pipe	2 @ 6"x10'	$6.10	5'	Global Industries	Round Pipe - 6 x 60 Button Lock Cartons
Pipe Elbow	2	15.5	1	Global Industries	Speedi-Boot Torpedo End Register Vent Boot Adj. Hangers SBH-2126 EB 2" X 12" X 6"
Hole Cover	1	$13.28	1/4"x4"x8'	Lowe's	1/4 x 4 x 8 Hardwood Underlayment Plywood
Door Hinges	3	$7.98	3	Lowe's	Gatehouse 3-1/2-in Oil-Rubbed Bronze Entry Door Hinge
Floor Hinges	4	$2.78	1	Lowe's	Gatehouse 3-1/2-in Oil-Rubbed Bronze Entry Door Hinge
Vent Screen	4	$3.00			Material dependent on building location
Structure Material	168 ft2	$100-$200	8'x4'		Material dependent on building location
Floor Wood		$45.00	3/4"x4"x8'	Lowe's	Material dependent on building location
Steps		$20-$100			Material dependent on building location
Sheet Metal Roofing		$41.80	8'x4'	delhi.gov.in	Price From New Delhi Price Sheet
Door	1	$15.00	1		Material dependent on building location
Estimated Cost		$512.54			
Composting Bin					
Concrete	1	$4.72	50 lb	Home Depot	
Cinder Blocks	102	$0.97	16"x8"x8"	Home Depot	
Removal Hatch	2	$5.00			Grouped Price
Bamboo	5 @ 3.5'	$2.40	10'		Bundle of 25 1" diameter, 6' tall poles
Estimated Cost		$20.49			
Total Cost		$693.28			

Appendix C: Detailed Supporting Analysis

The following tables already presented in previous sections provide the supporting analysis for the design.[2]

Table 1: Average Composition of Human Feces and Urine [8]

Table 2: Pathogens that may be excreted in urine and their importance with respect to urine as a transmission route [9]

Table 4: Typical Pathogen Survival Times in Various Environments [10]

Table 5: Average yields in plant trials with urine as a fertilizer to vegetables in Zimbabwe [11]

[2] If viewing this document electronically, you may control click each table heading to jump to it

Appendix D: References

[1] International, Sulabh. "Two-pit System." n.d. *Sulabh International Social Service Organisation.* http://www.sulabhinternational.org/?q=content/two-pit-system. January 2013.

[2] Gendarme. "How the System Works." n.d. *Gendarme ecological sanitation systems.* http://www.gendarme-systems.com/index.php/product/technical-info. January 2013.

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[8] Depledge, Derrick. Design Examples of Waterless Composting Toilets. Rep. no. 249. N.p.: n.p., n.d. SOPAC Miscellaneous. SOPAC. United Nations Development Program. Web. 10 Mar. 2013.

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[10] Water Efficiency Technology Fact Sheet: Composting Toilets. Rep. no. EPA 832-F-99-066. United States Environmental Protection Agency, Sept. 1999. Web. 16 Apr. 2013. <http://water.epa.gov/aboutow/owm/upload/2005_07_14_comp.pdf>.

[11] Jonssson, Hakan, Anna R. Stinzing, Bjorn Vinneras, and Eva Salomon. Guidelines on the Use of Urine and Faeces in Crop Production. Rep. 2nd ed. Stockholm: Stockholm Environment Institute, 2004. Ser. 2004. EcoSanRes Programme. Stockholm Environment Institute. Web. 18 Apr. 2013.

10.0 Supplemental Documents

Ghant Chart

See attached Ghant chart document

Design Packet

See attached Design Packet document

IDEXX Testing Methodology

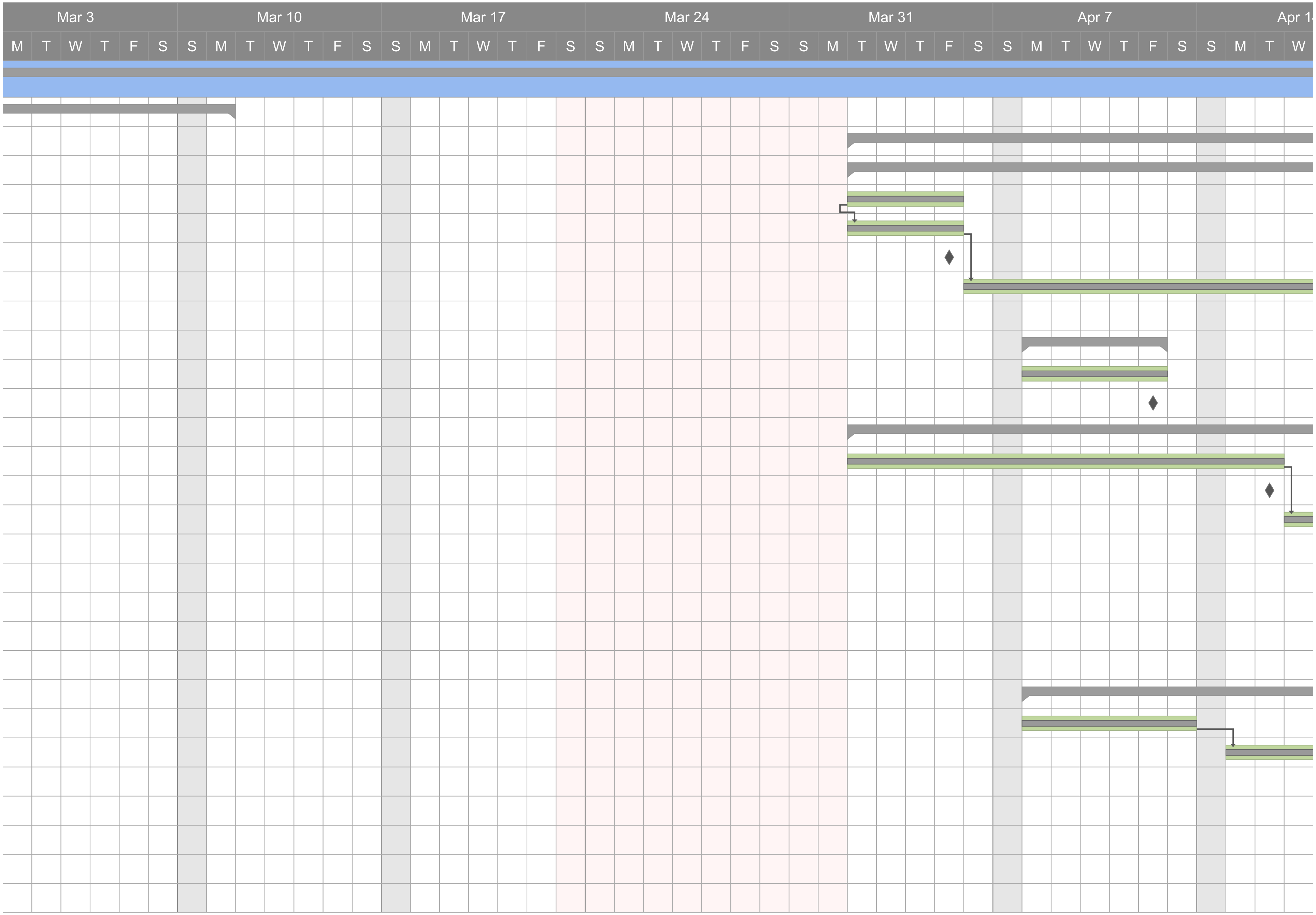
See attached testing methodology documentation

IDEXX Table

See attached IDEXX table document

Sodhana Environmental Gantt Chart

	Task Name
1	Sodhana Environmental Senior Projec
2	Winter 2013 Quarter
11	Spring 2013 Quarter
12	Analysis, Drawing, BOM
13	Work on Analysis
14	Work on Drawing
15	Analysis, Drawing, BOM Review
16	Decide on Long Lead Items
17	Long Lead Items on Order
18	Test Plan Development
19	Plan Testing
20	Test Plan Review
21	Ethics
22	Decide Individual Ethics Topic
23	Individual Ethics Memo Topic Due
24	Individual Ethics Memo Rough Draft
25	Individual Ethics Memo Final Draft
26	Individual Ethics Memo Due
27	Team Ethics Presentation Rough Draft
28	Team Ethics Presentation Practice
29	Team Ethics Presentation
30	Mid-Quarter Design Check
31	Design Report Outline
32	Design Report Rough Draft 1
33	Design Report Rough Draft 2
34	Design Report Final Draft
35	Design Report Due
36	CDR Presentation Outline
37	CDR Presentation Slides Finished


Mar 3
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Mar 17
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Apr 7
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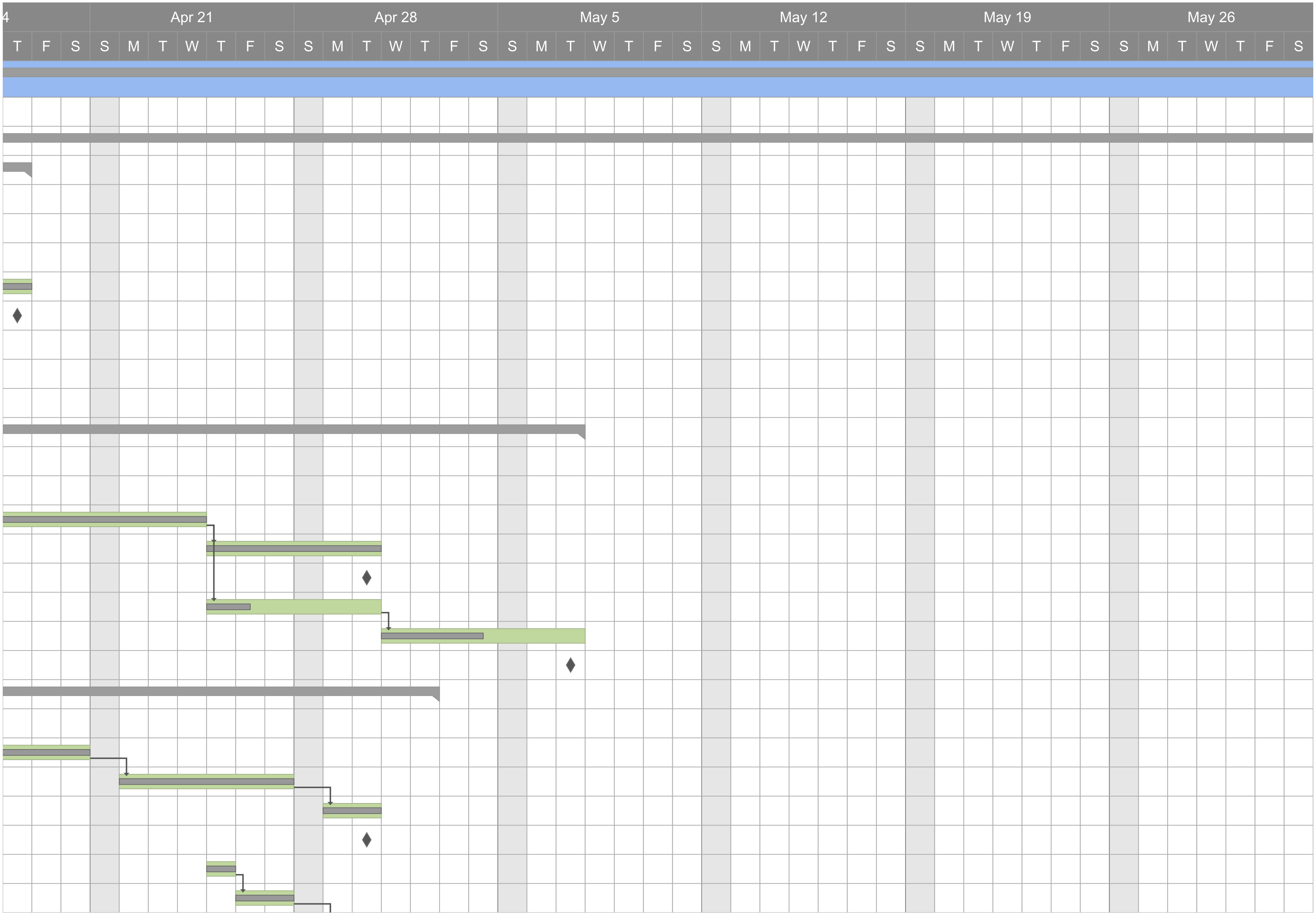
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Apr 21
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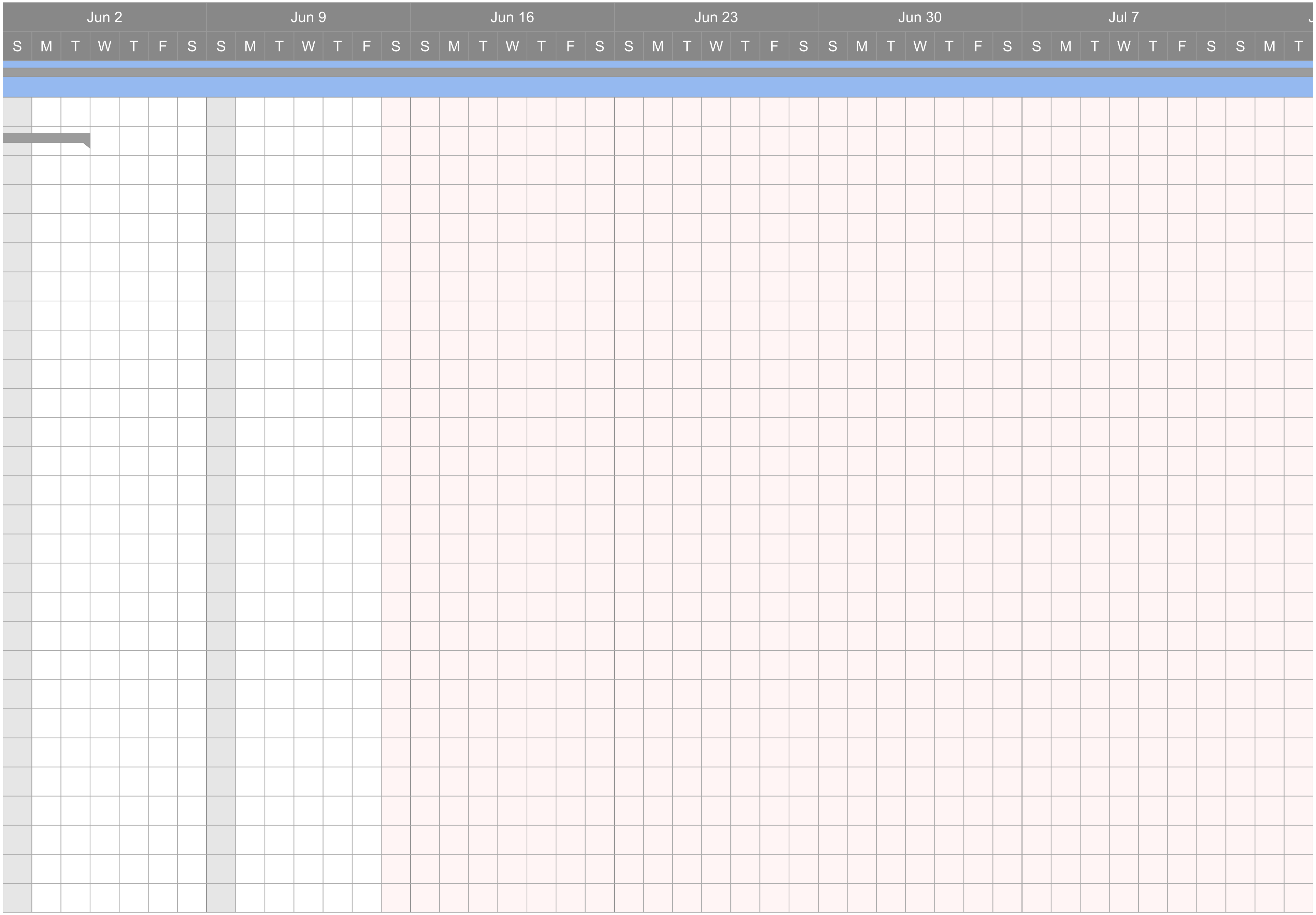
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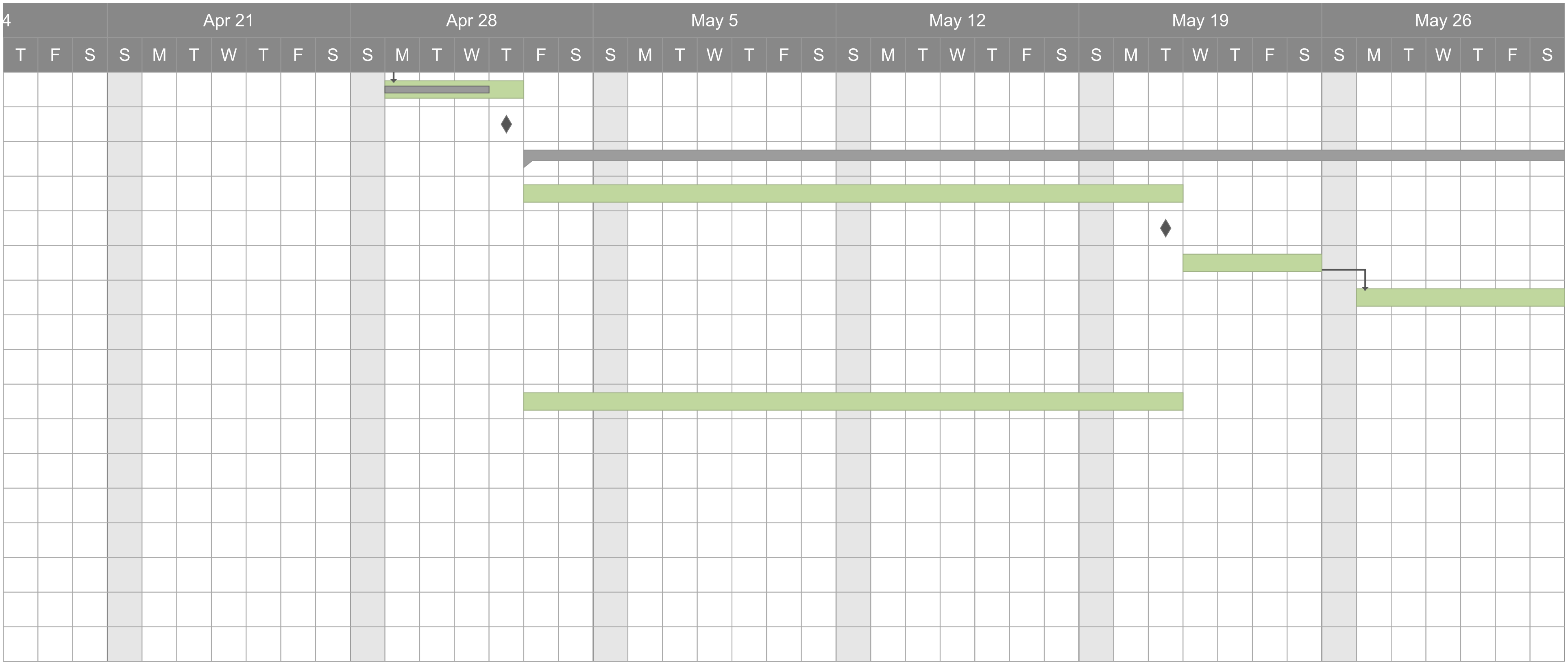
	Sep 1							Sep 8							Sep 15							Sep 22							Sep 29							Oct 6								
S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M

Oct 13					Oct 20							Oct 27							Nov 3							Nov 10							Nov 17							Nov 24				
T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T

		Dec 1						
F	S	S	M	T	W	T	F	S

	Task Name	Feb 3							Feb 10							Feb 17							Feb 24							
		S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
38	CDR Presentation Practice																													
39	Critical Design Review with Sponsor																													
40	End-Quarter Deliverables																													
41	Work On Manufacturing and Test Plan																													
42	Manufacturing and Test Review																													
43	End of Quarter Outline																													
44	End of Quarter Rough Draft																													
45	End of Quarter Final Draft																													
46	End of Quarter Report Due																													
47	Senior Project Design Exposition Poster (CE)																													
48	Fall 2013 Quarter (Summer?)																													
49	Project Update Memo to Sponsor																													
50	Senior Exit Exam																													
51	Project Hardware/Assembly Demo																													
52	Complete Senior Survey																													
53	Senior Project Design Exposition (ME)																													
54	Final Reports Due																													

Mar 3						Mar 10							Mar 17							Mar 24							Mar 31							Apr 7							Apr 1			
M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W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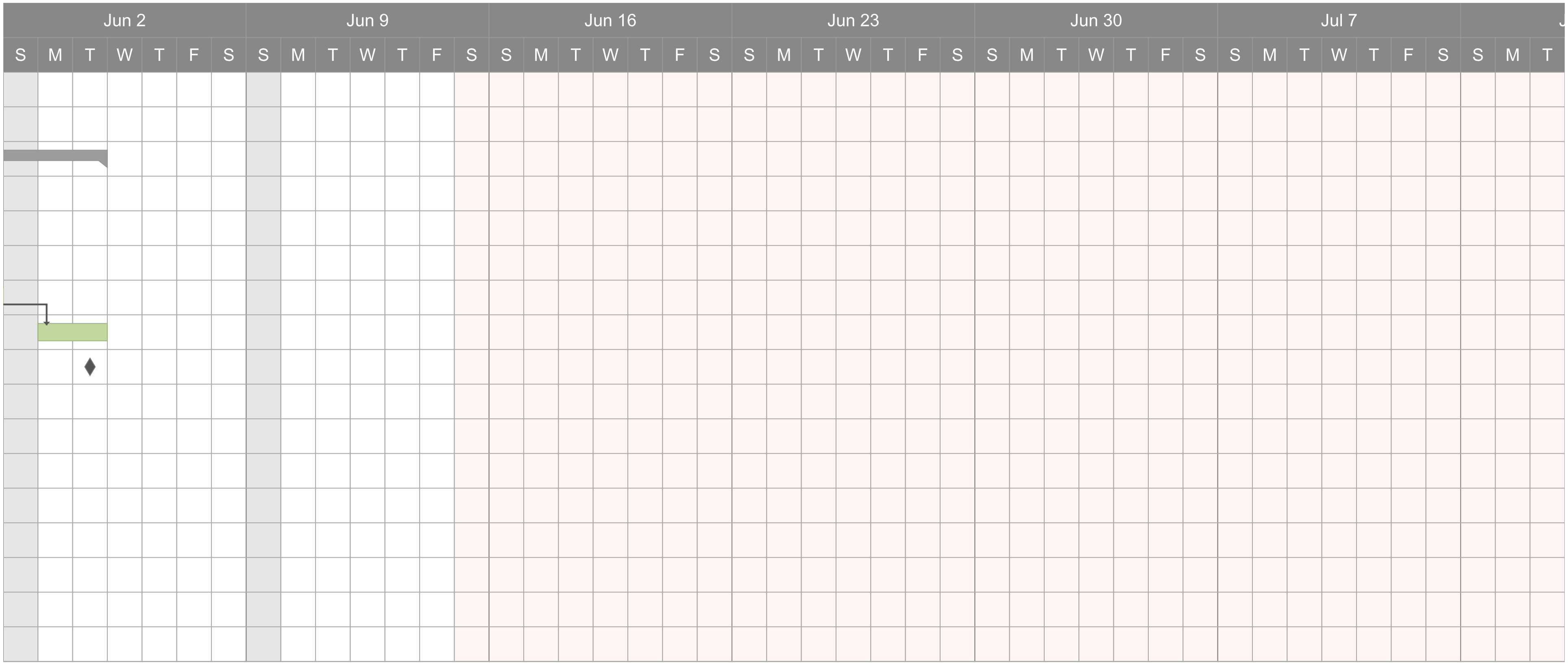
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Jul 14				Jul 21							Jul 28							Aug 4							Aug 11							Aug 18							Aug 25					
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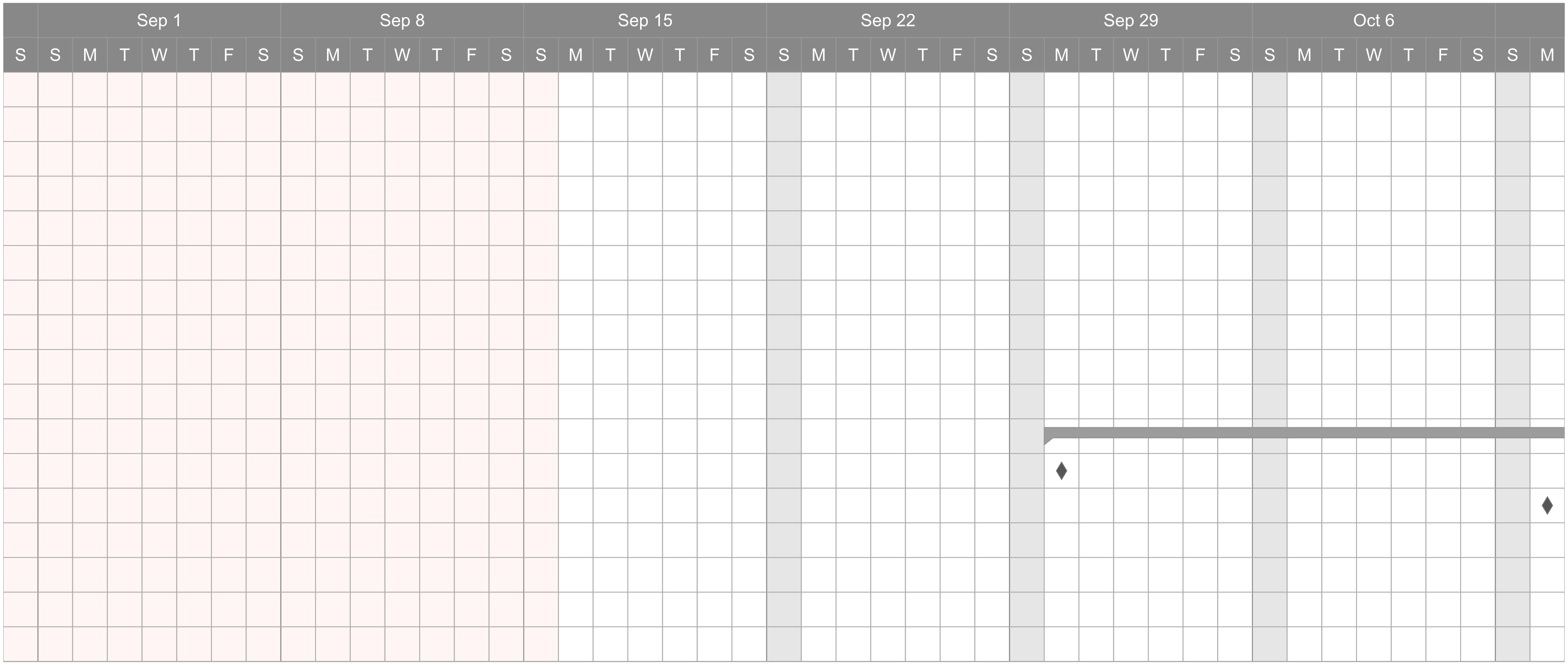
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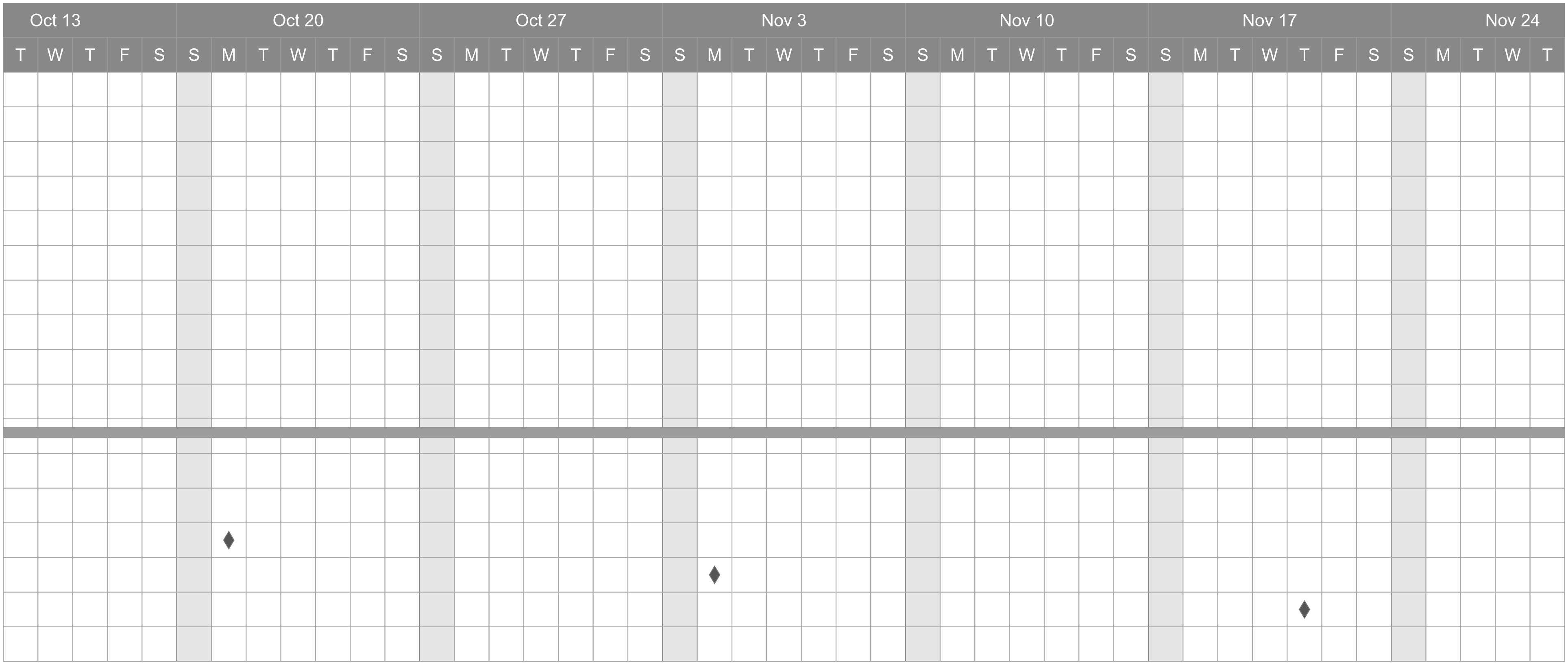
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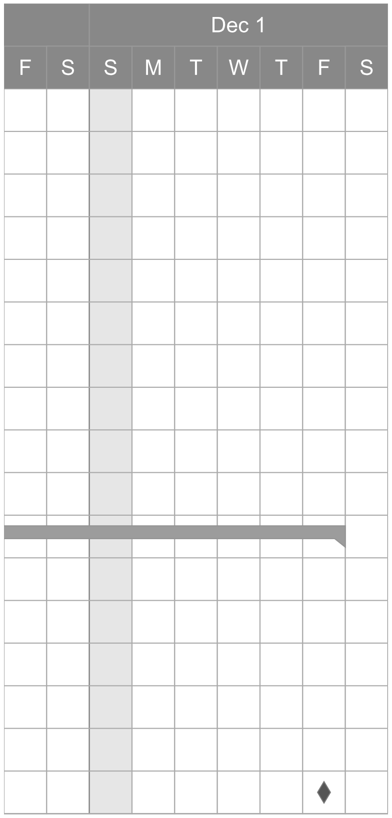
Dec 1
F S S M T W T F S

CRITICAL DESIGN REPORT: DESIGN PACKET

The complete set of detail design drawings of the toilet system developed by Sodhana Environmental

ME-429 | Spring 2013 | Sponsored by Mr. Harish Bhutani | Advised by Dr. Mohammad Noori | Sodhana Environmental is Eric Taylor (ME), Corissa Bellis (ENVE), Cody Perez (ME), and Cameron Zeller (CE)

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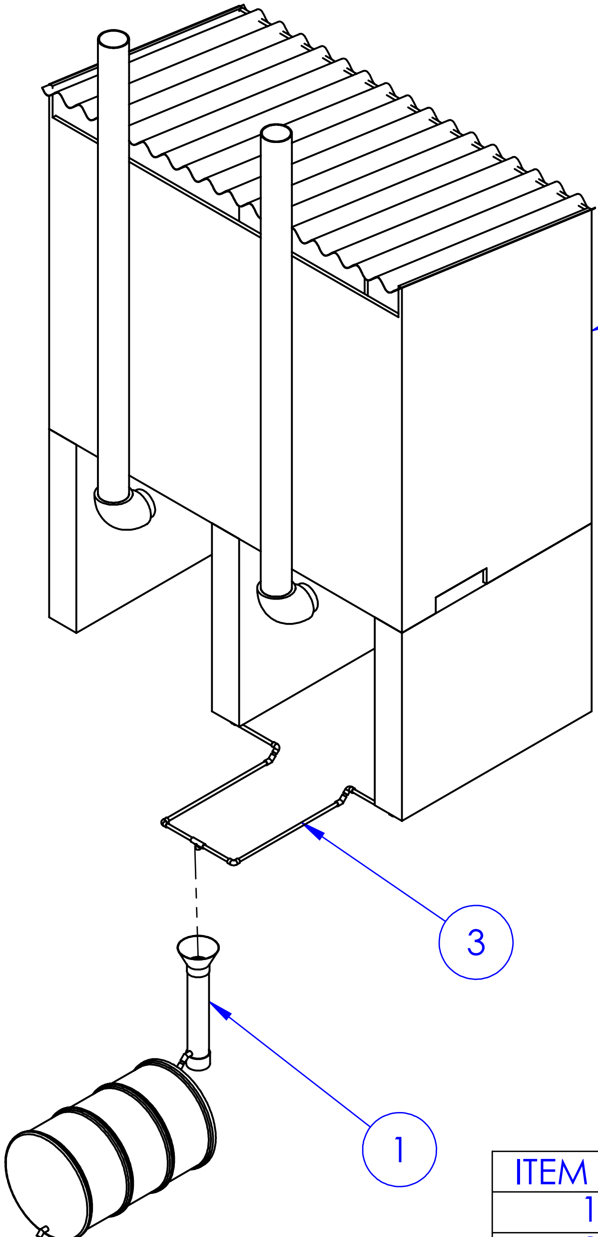
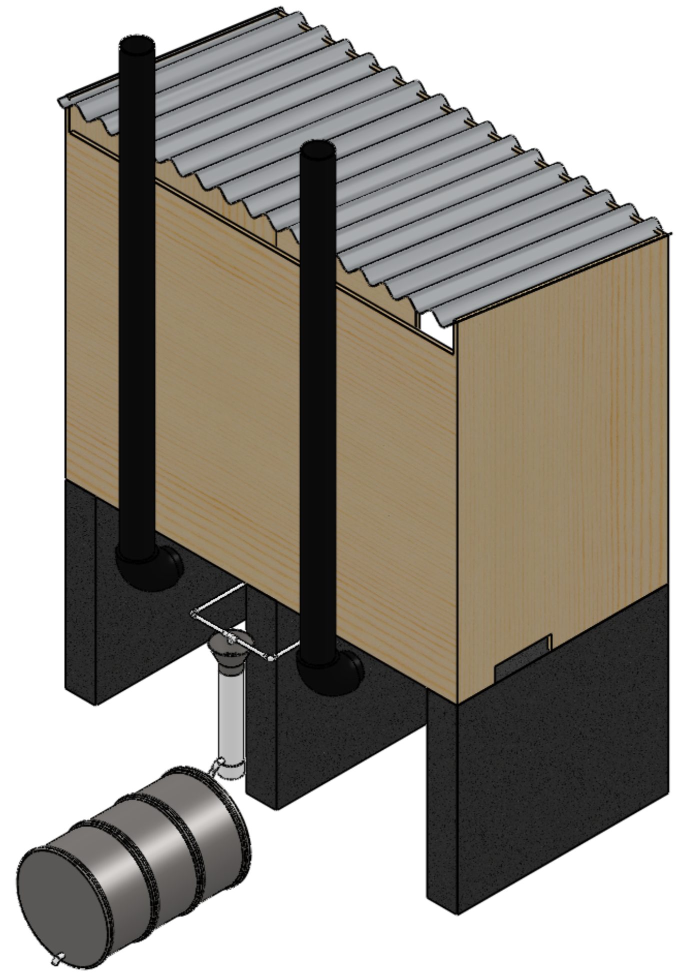
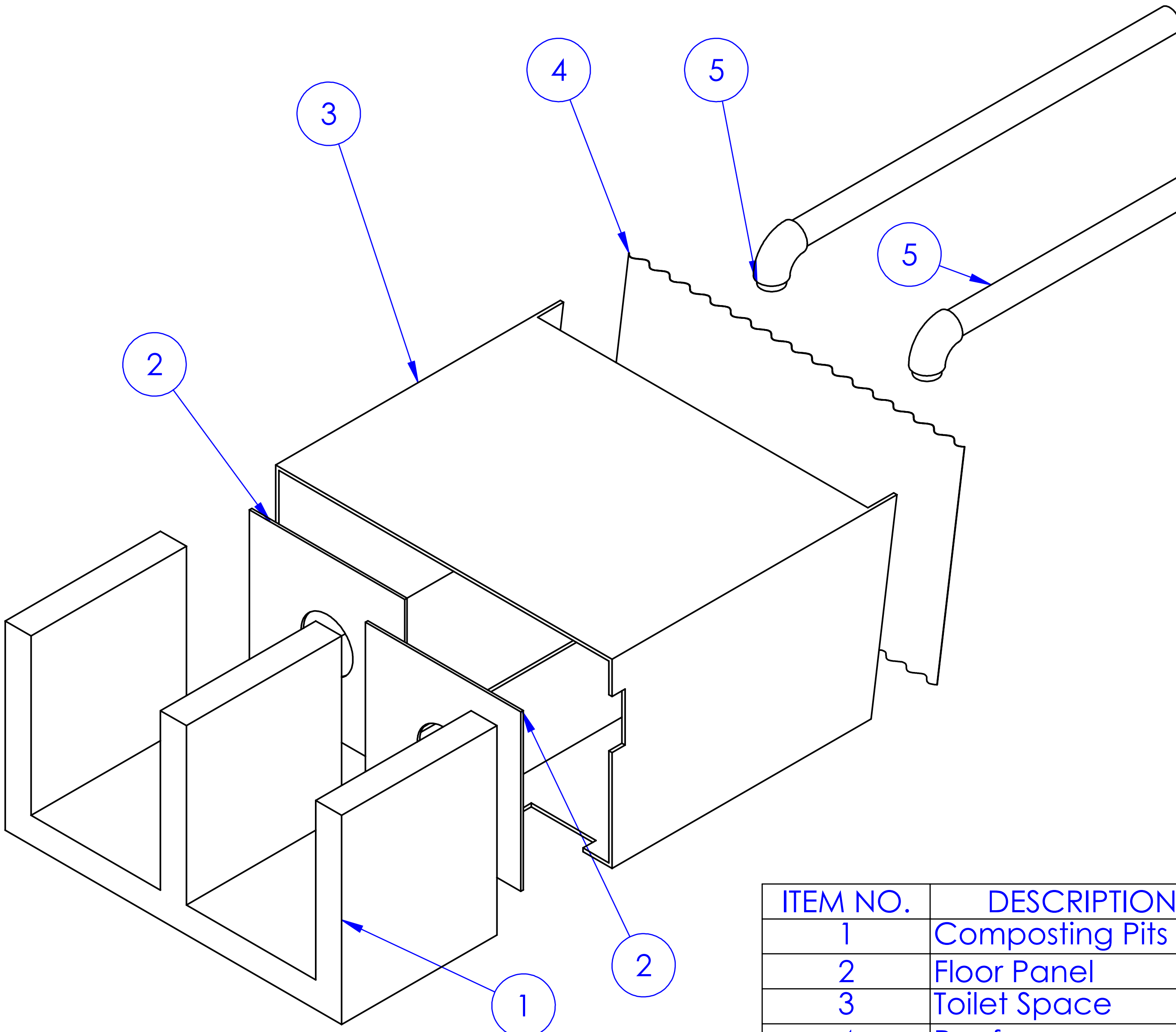
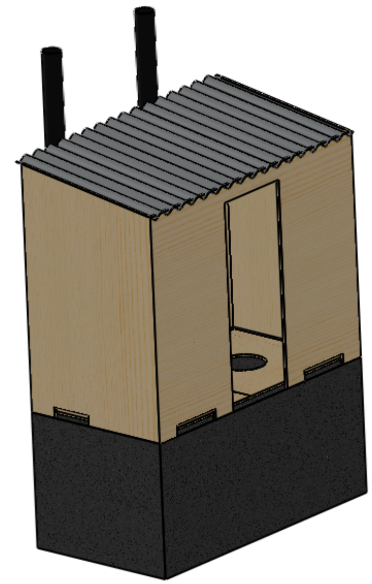




ITEM NO.	DESCRIPTION	PART NUMBER	QTY.
1	Full Urine Assembly	UFA003	1
2	Structure Assembly	SA0004	1
3	Urine Piping Assembly	UPA005	1

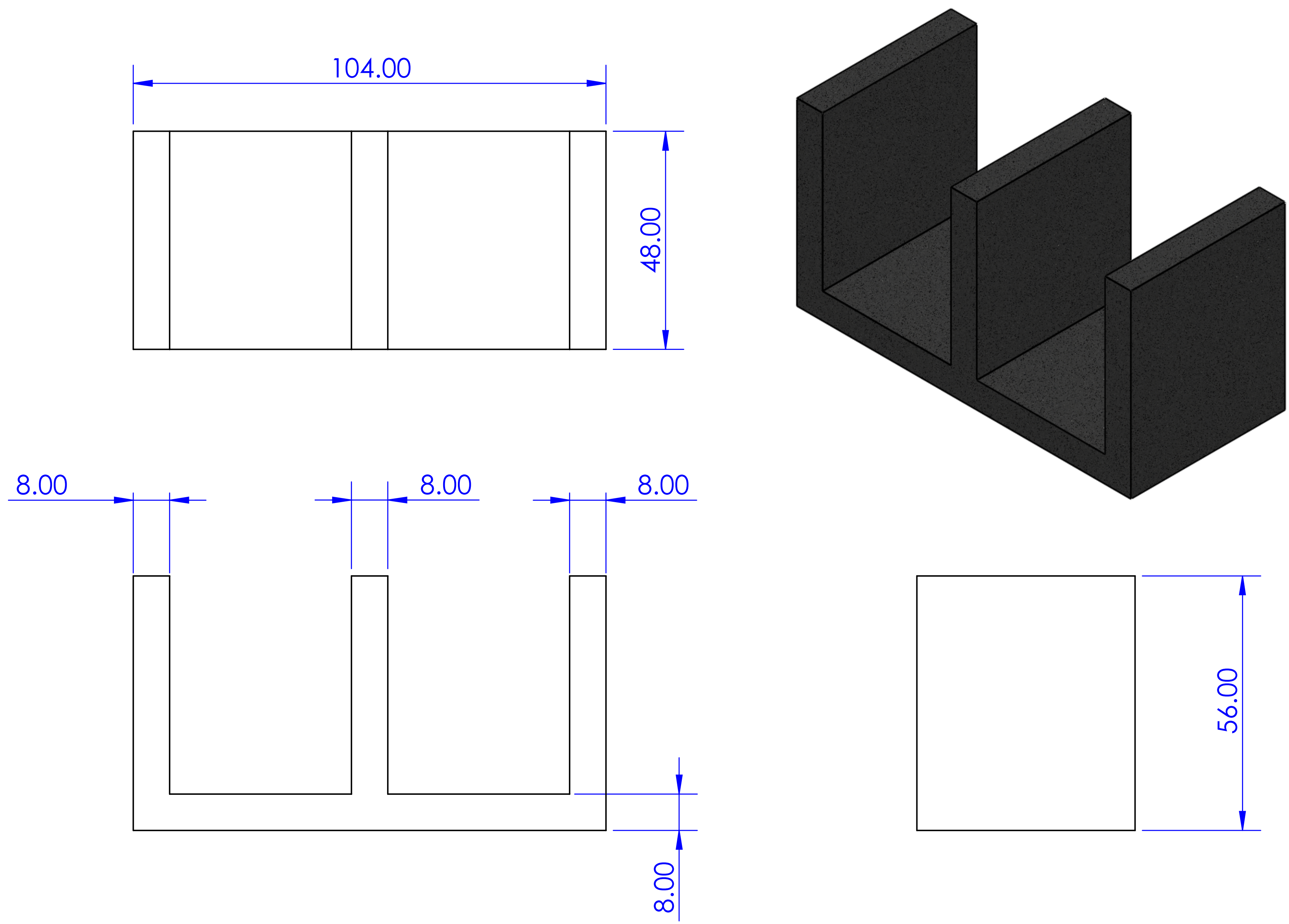
Cal Poly Mechanical Engineering Sodhana Environmental	ME-429	Units: Inches	Title: Full Assembly	Drwn. By: Eric Taylor
	Dwg. #: USFA02	Nxt Asb: N/A	Date: 5/2/13 | Scale: 1:40	Chkd. By:



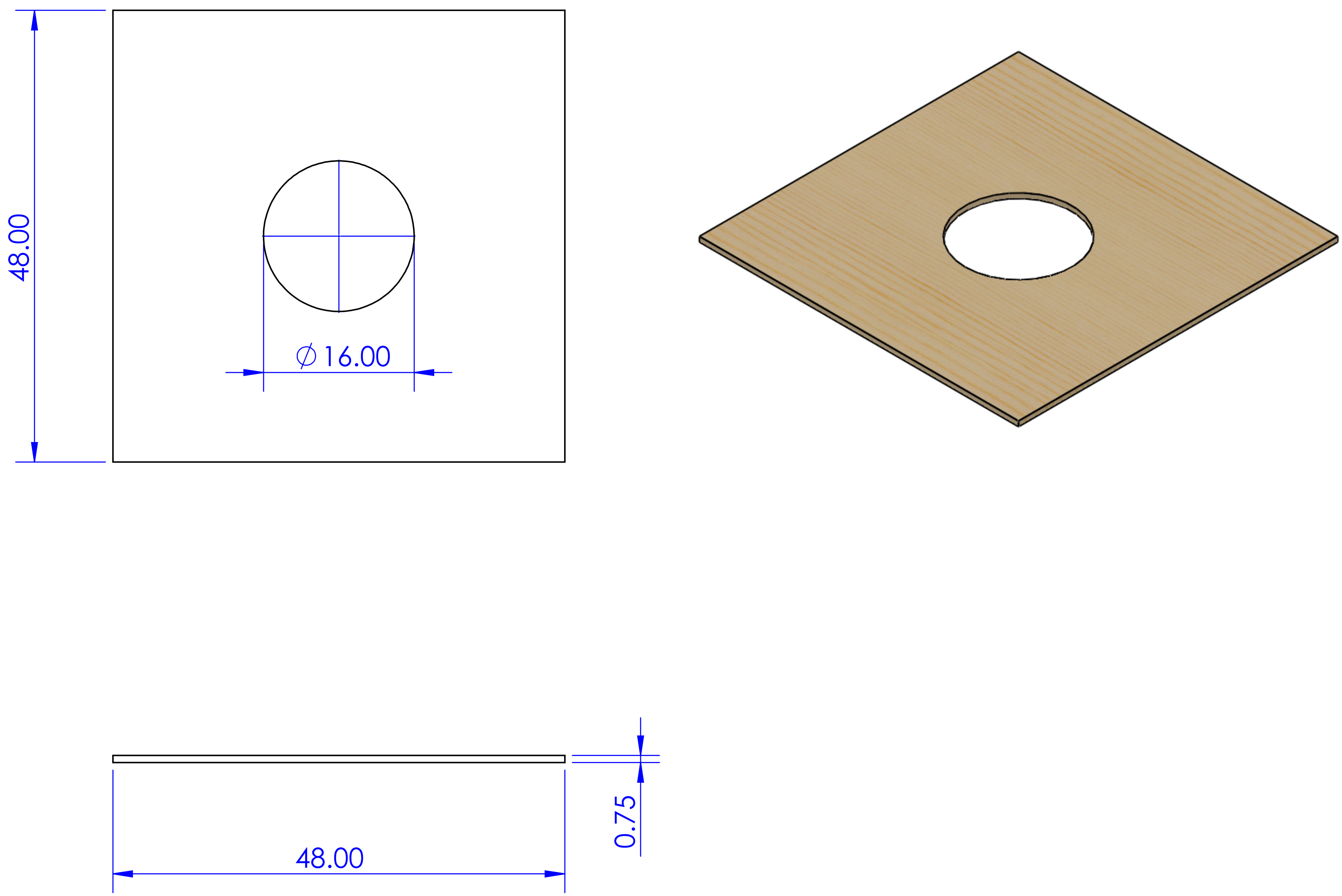


ITEM NO.	DESCRIPTION	PART NUMBER	QTY.
1	Composting Pits	S000001	1
2	Floor Panel	S000002	2
3	Toilet Space	S000005	1
4	Roof	S000003	1
5	Solar Chimney	S000004	2

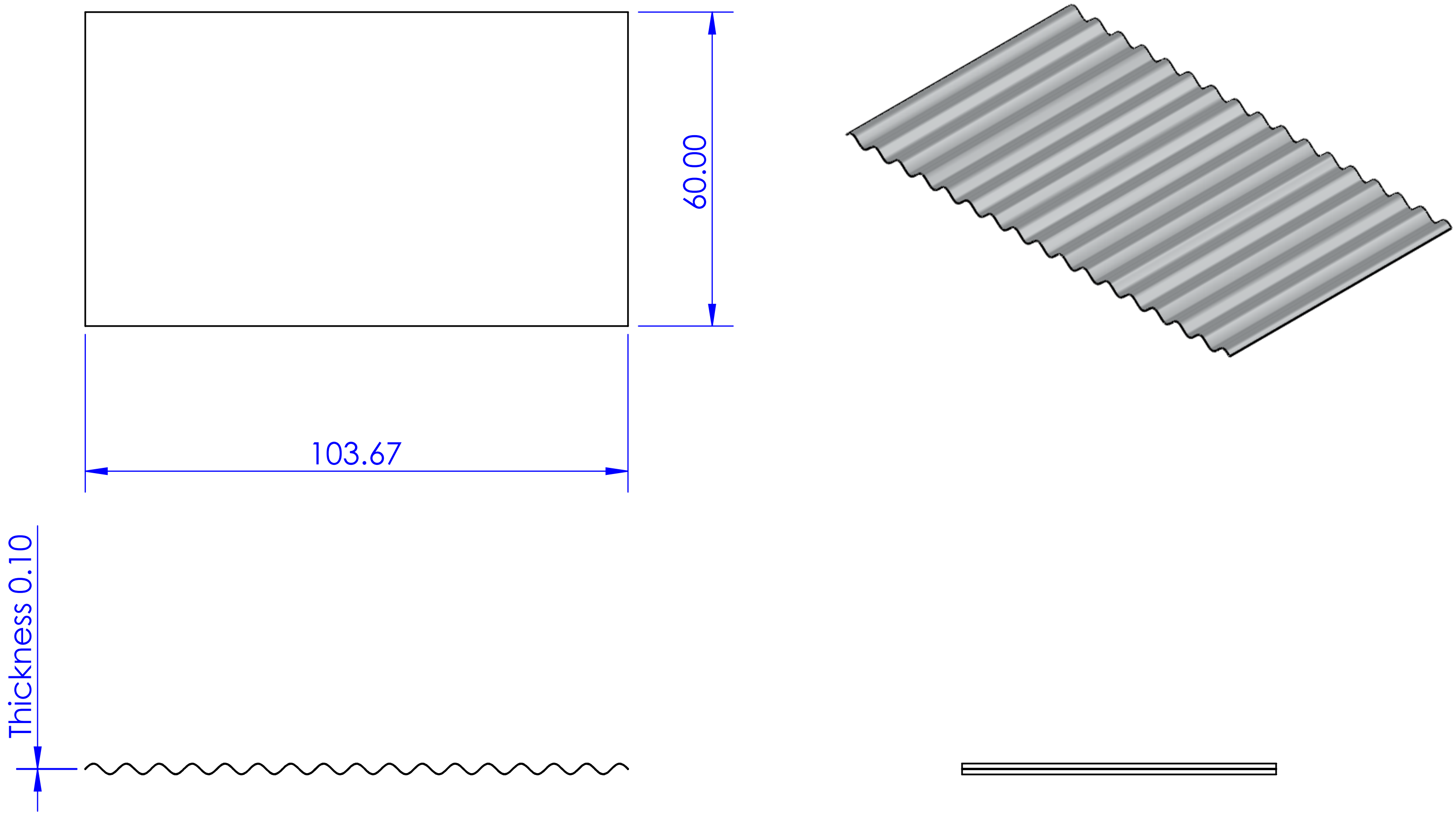
Cal Poly Mechanical Engineering	ME-429	Units: Inches	Title: Structure		Drwn. By: Eric Taylor
Sodhana Environmental	Dwg. #: SA0004	Nxt Asb: USFA02	Date: 5/2/13	Scale: 1:36	Chkd. By:



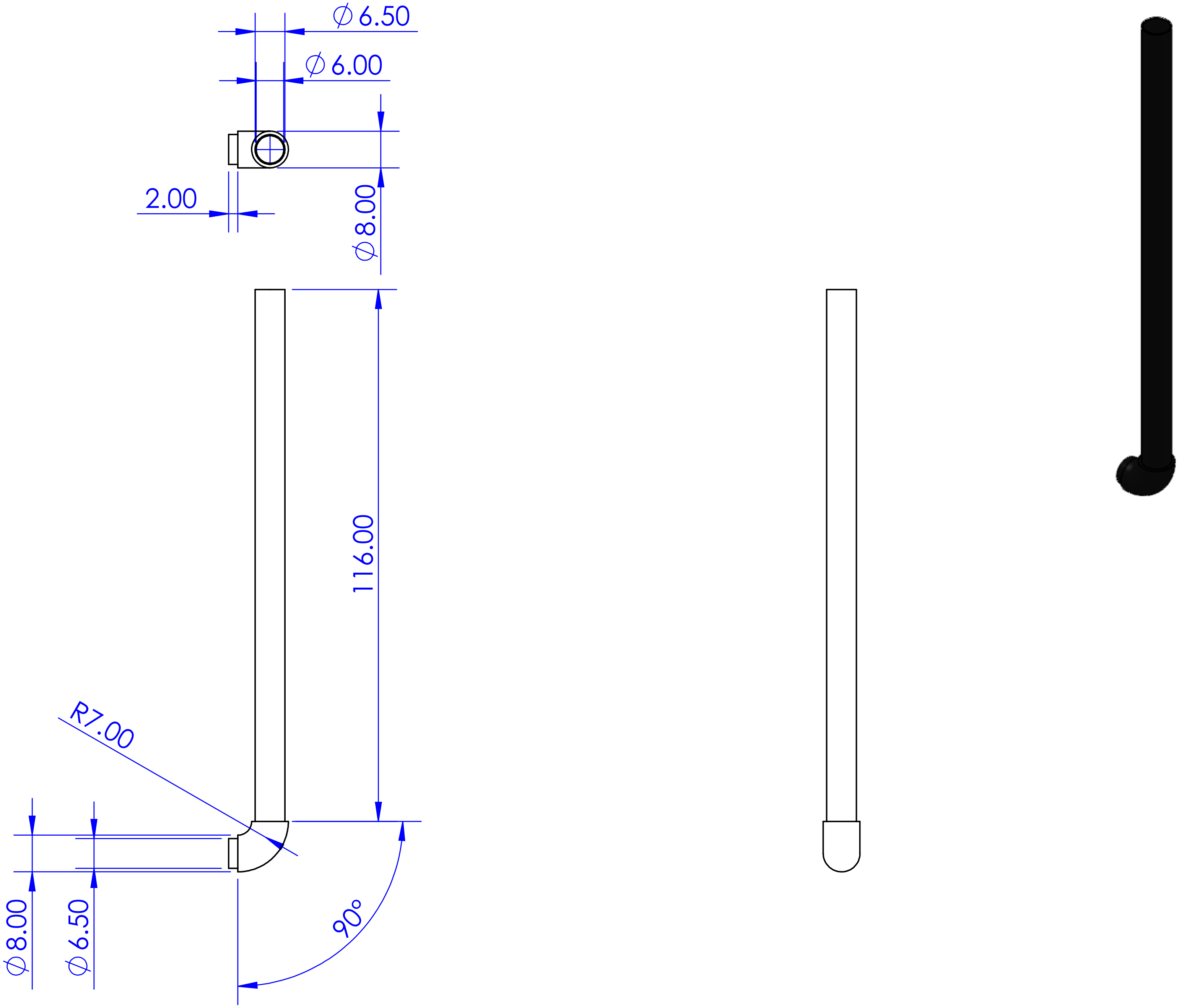
Cal Poly Mechanical Engineering	ME-429	Units: Inches	Title: Composting Pits		Drwn. By: Eric Taylor
Sodhana Environmental	Dwg. #: S000001	Nxt Asb: SA0004	Date: 5/2/13	Scale: 1:32	Chkd. By:



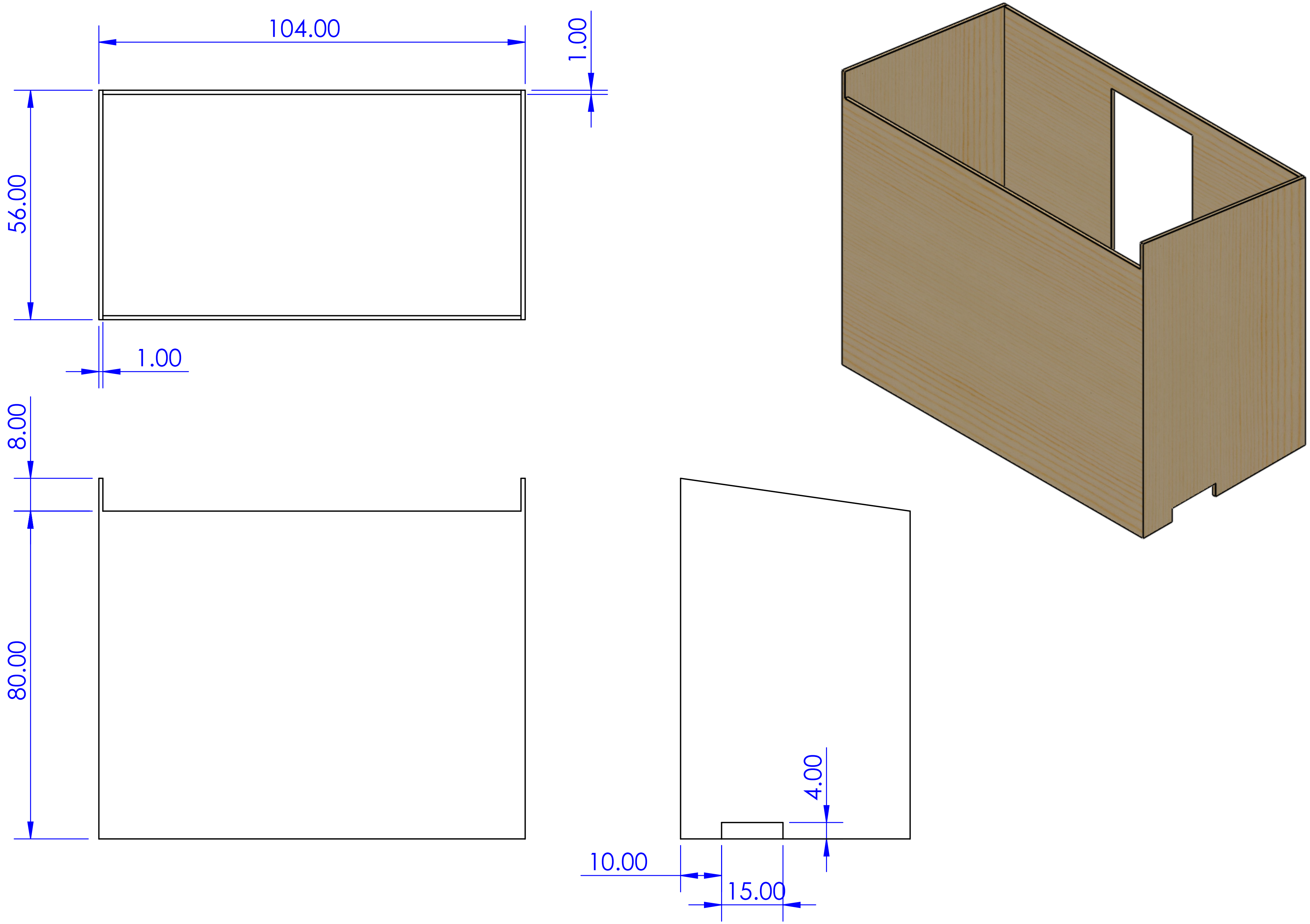
Cal Poly Mechanical Engineering	ME-429	Units: Inches	Title: Floor Panel	Drwn. By: Eric Taylor
Sodhana Environmental	Dwg. #: S000002	Nxt Asb: SA0004	Date: 5/2/13 / Scale: 1:16	Chkd. By:



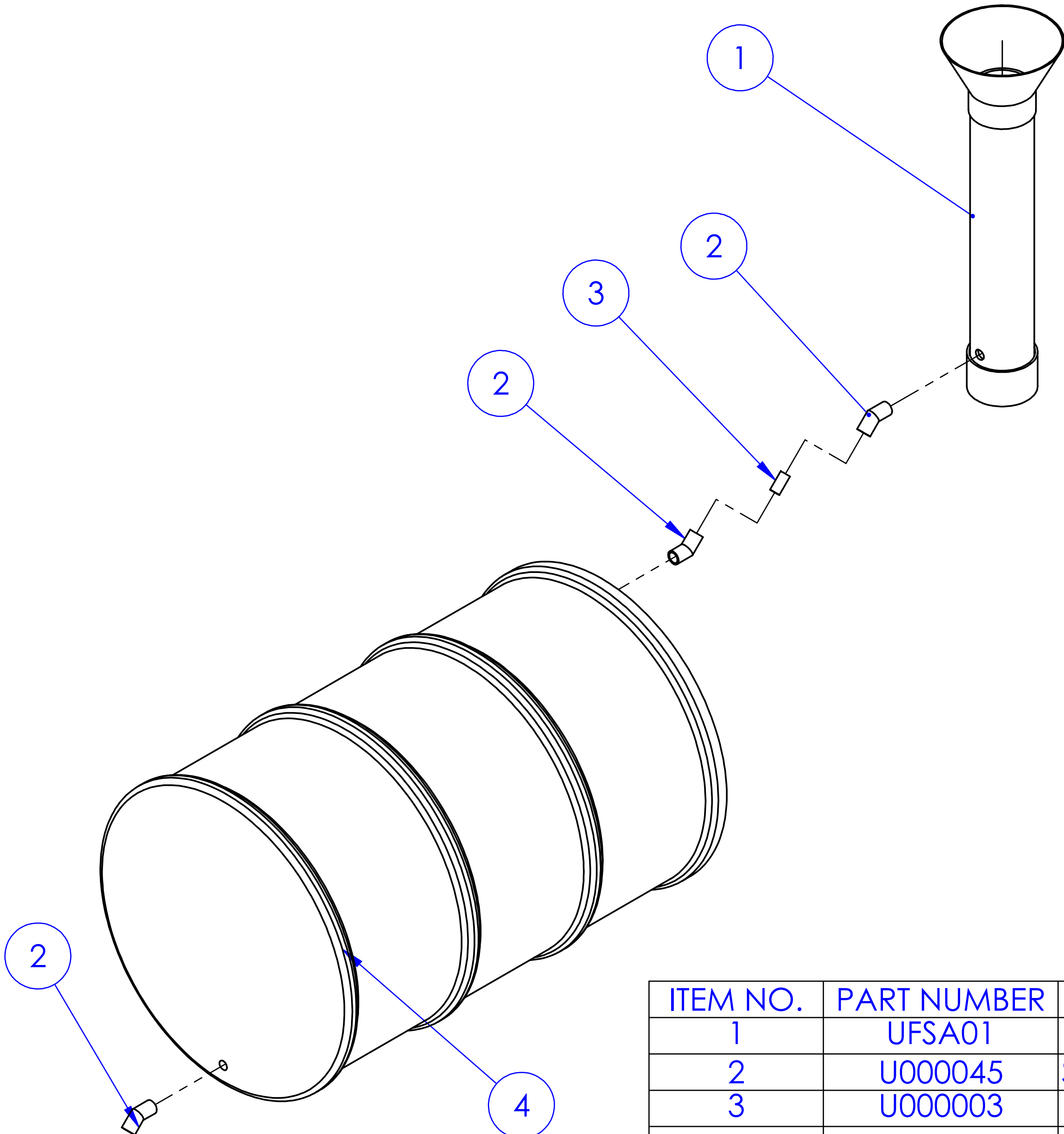
Cal Poly Mechanical Engineering	ME-429	Units: Inches	Title: Roof		Drwn. By: Eric Taylor
Sodhana Environmental	Dwg. #: S000003	Nxt Asb: SA0004	Date: 5/2/13	Scale: 1:32	Chkd. By:

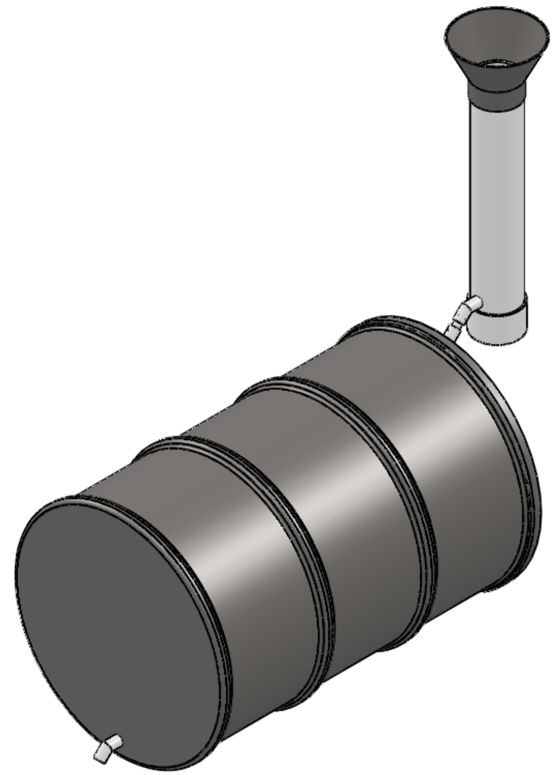


Cal Poly Mechanical Engineering	ME-429	Units: Inches	Title: Chimney	Drwn. By: Eric Taylor
Sodhana Environmental	Dwg. #: S000004	Nxt Asb: SA0004	Date: 5/2/13 / Scale: 1:32	Chkd. By:



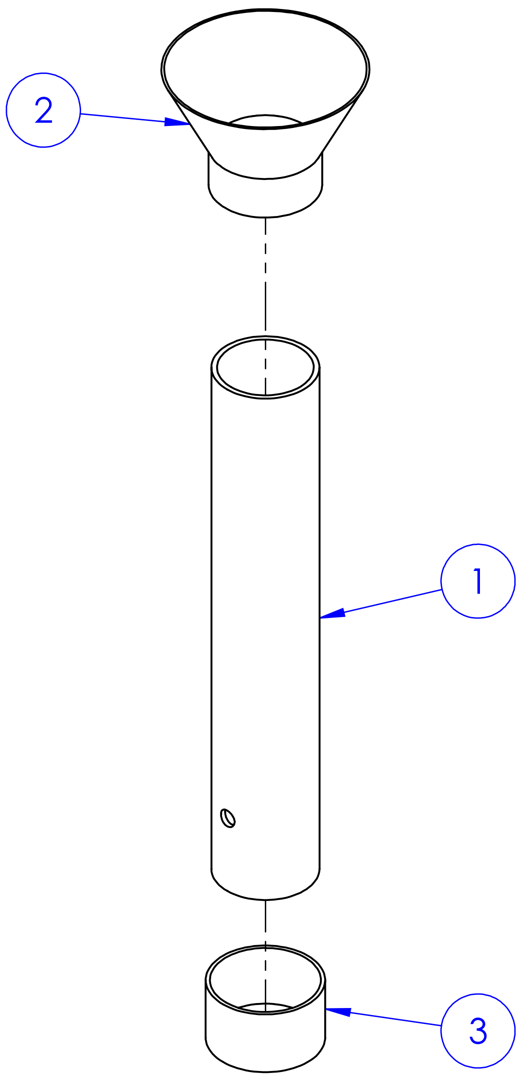
Cal Poly Mechanical Engineering	ME-429	Units: Inches	Title: Space for Toilet		Drwn. By: Eric Taylor
Sodhana Environmental	Dwg. #: S000005	Nxt Asb: SA0004	Date: 5/2/13	Scale: 1:32	Chkd. By:

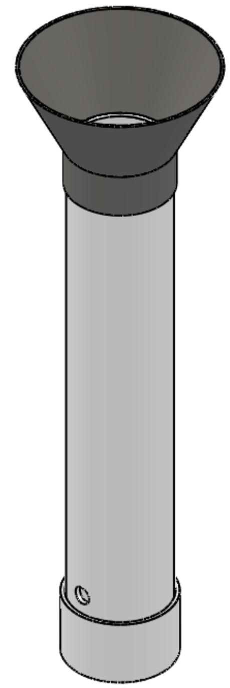




ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	UFSA01	Filter Sub Assembly	1
2	U000045	Slanted PVC Elbow	3
3	U000003	PVC Pipe (3in)	1
4	US00004	Urine Collection Tank	1

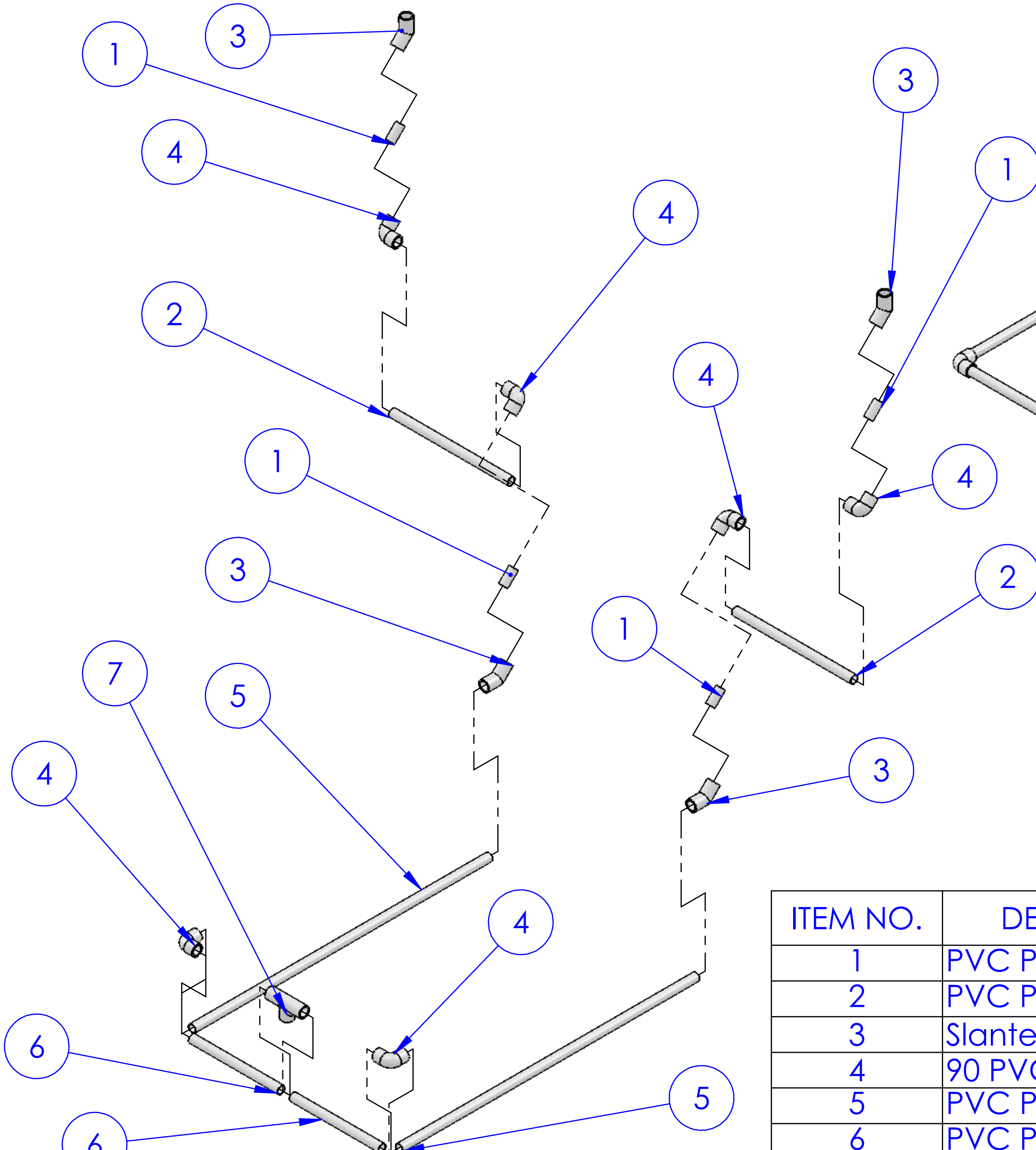
Cal Poly Mechanical Engineering	ME-429	Units: Inches	Title: Full Urine Assembly		Drwn. By: Eric Taylor
Sodhana Environmental	Dwg. #: UFA003	Nxt Asb: USFA02	Date: 5/2/13	Scale: 1:12	Chkd. By:

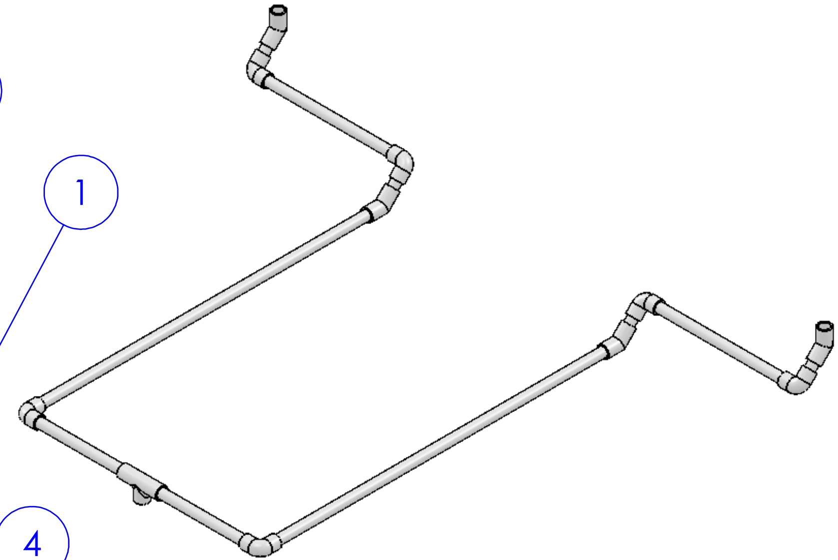




ITEM NO.	DESCRIPTION	PART NUMBER	QTY.
1	Soil Sand Filter Column Housing	US00002	1
2	Soil Sand Filter Diffuser	US00003	1
3	Soil Sand Filter Column End Cap	US00001	1

Cal Poly Mechanical Engineering	ME-429	Units: Inches	Title: Full Urine Filter		Drwn. By: Eric Taylor
Sodhana Environmental	Dwg. #: UFA003	Nxt Asb: USFA02	Date: 5/2/13	Scale: 1:8	Chkd. By:

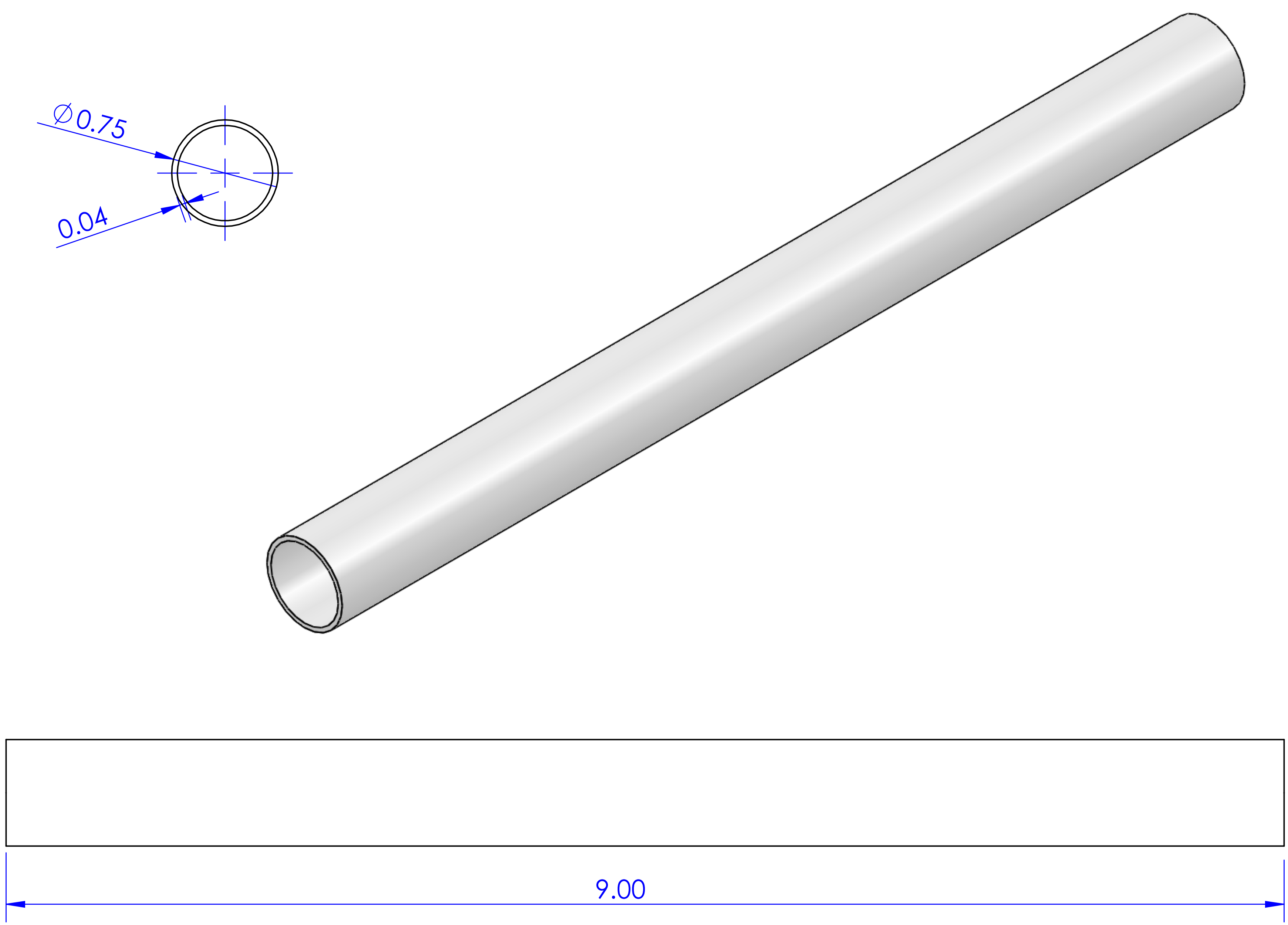




ITEM NO.	DESCRIPTION	PART NUMBER	QTY.
1	PVC Pipe (3in)	U000003	4
2	PVC Pipe (2ft)	U000024	2
3	Slanted PVC Elbow	U000045	4
4	90 PVC Elbow	U000090	6
5	PVC Pipe (5ft)	U000060	2
6	PVC Pipe (10in)	U000120	2
7	PVC T	U000180	1

Cal Poly Mechanical Engineering	ME-429	Units: Inches	Title: Full Urine Piping		Drwn. By: Eric Taylor
Sodhana Environmental	Dwg. #: UPA003	Nxt Asb: USFA02	Date: 5/2/13	Scale: 1:12	Chkd. By:

Standard Schedule 40 3/4in PVC Pipe



Cal Poly Mechanical Engineering	ME-429	Units: Inches	Title: 10in PVC Pipe		Drwn. By: Eric Taylor
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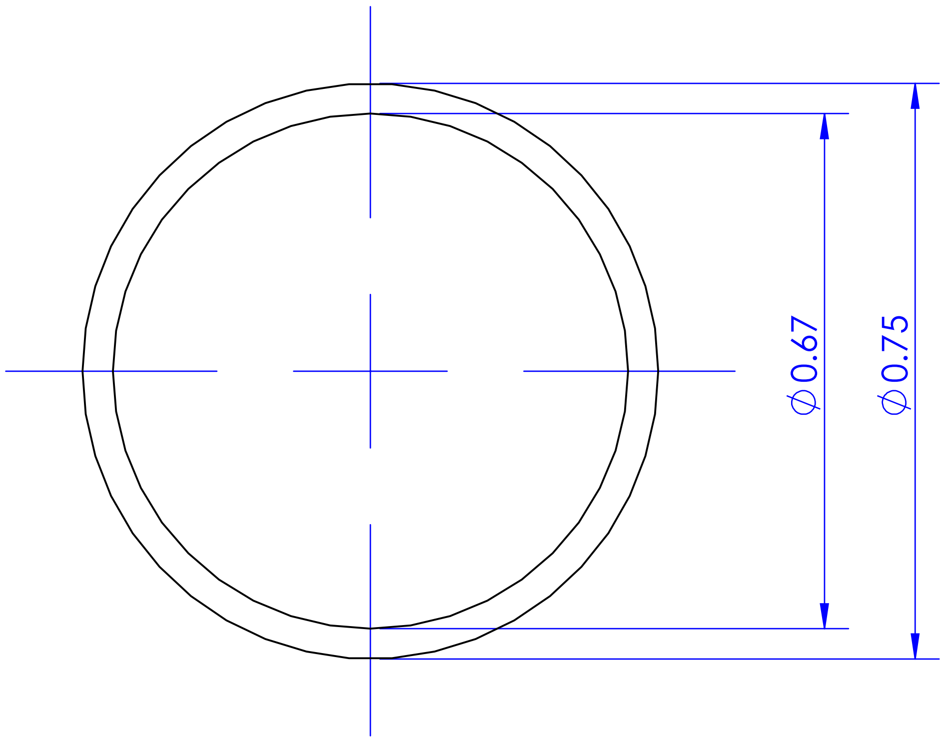
Standard Schedule 40 4/3in PVC Pipe



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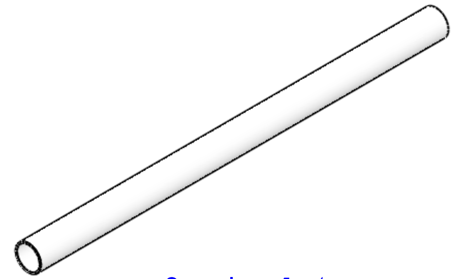

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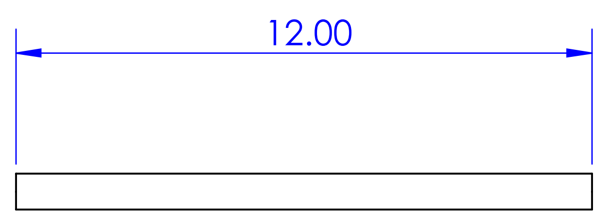
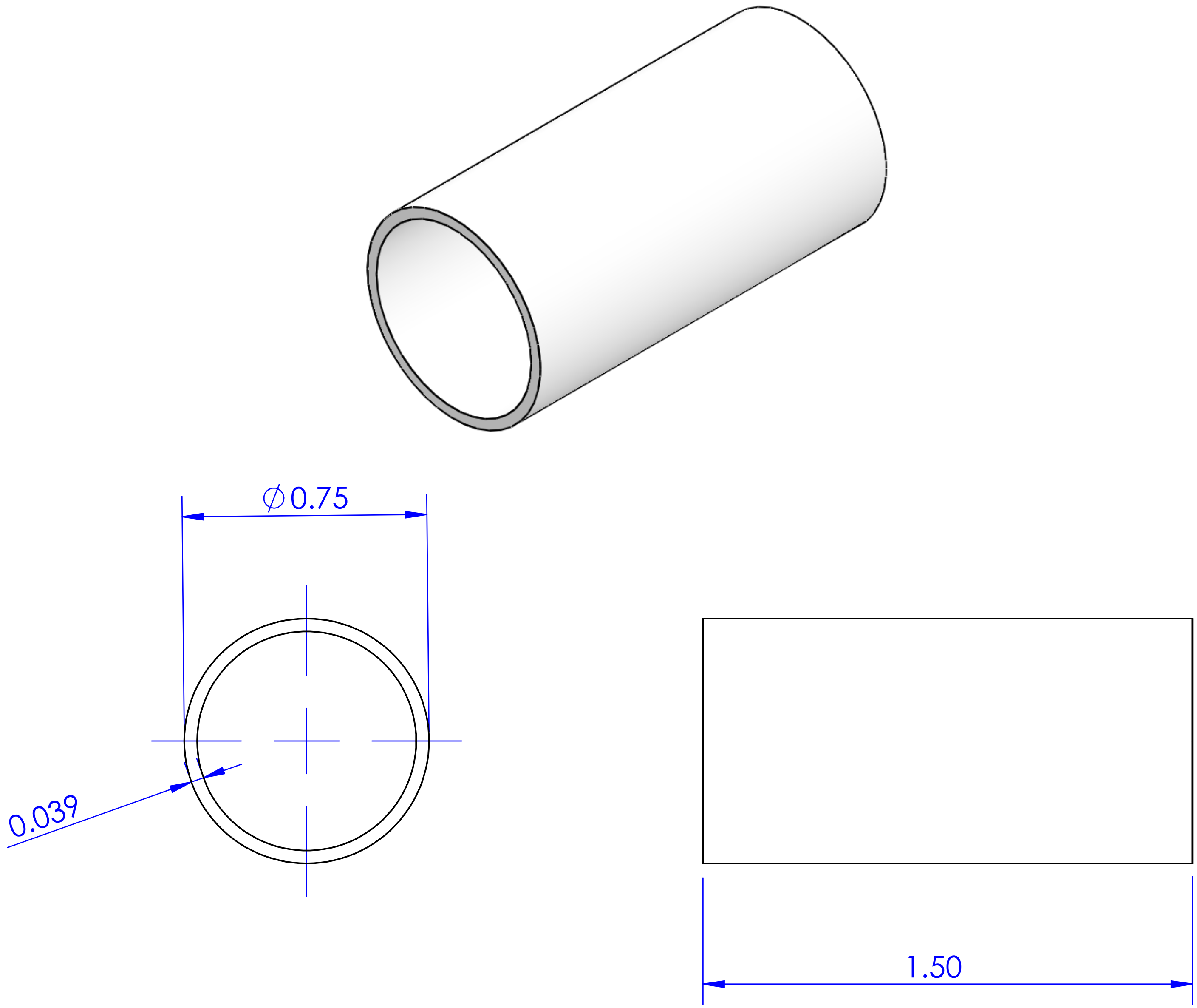


Scale: 1:4

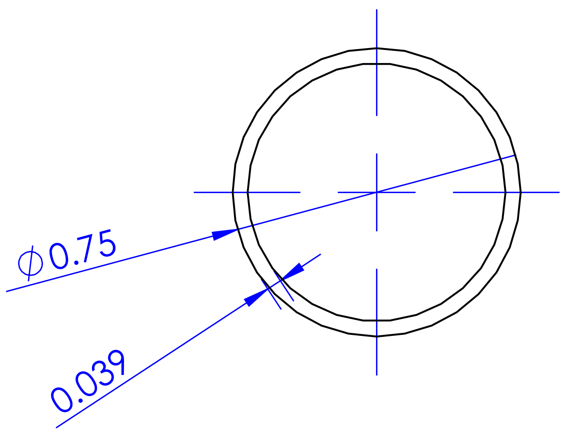
Cal Poly Mechanical Engineering	ME-429	Units: Inches	Title: 2ft PVC Pipe		Drwn. By: Eric Taylor
Sodhana Environmental	Dwg. #: U000024	Nxt Asb: UPA005	Date: 5/2/13	Scale: 4:1	Chkd. By:

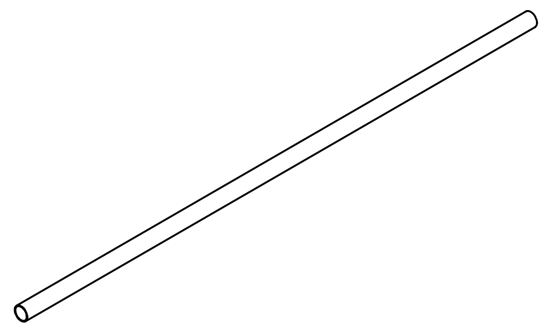
Standard Schedule 40 3/4 in PVC Pipe



Cal Poly Mechanical Engineering	ME-429	Units: Inches	Title: 3in PVC Pipe	Drwn. By: Eric Taylor
Sodhana Environmental	Dwg. #: U000003	Nxt Asb: UFA003	Date: 5/2/13 / Scale: 2:1	Chkd. By:

Standard Schedule 40 3/4in PVC Pipe





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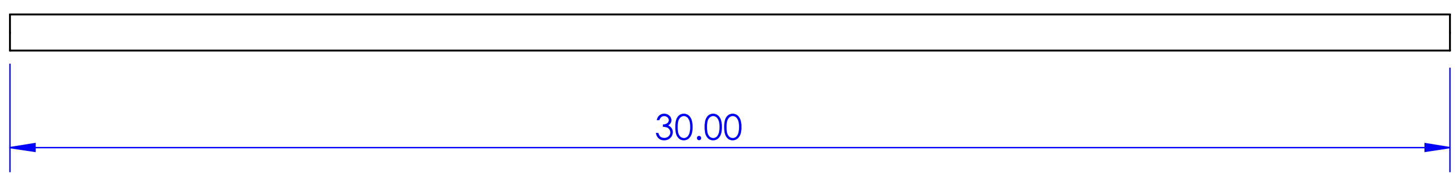
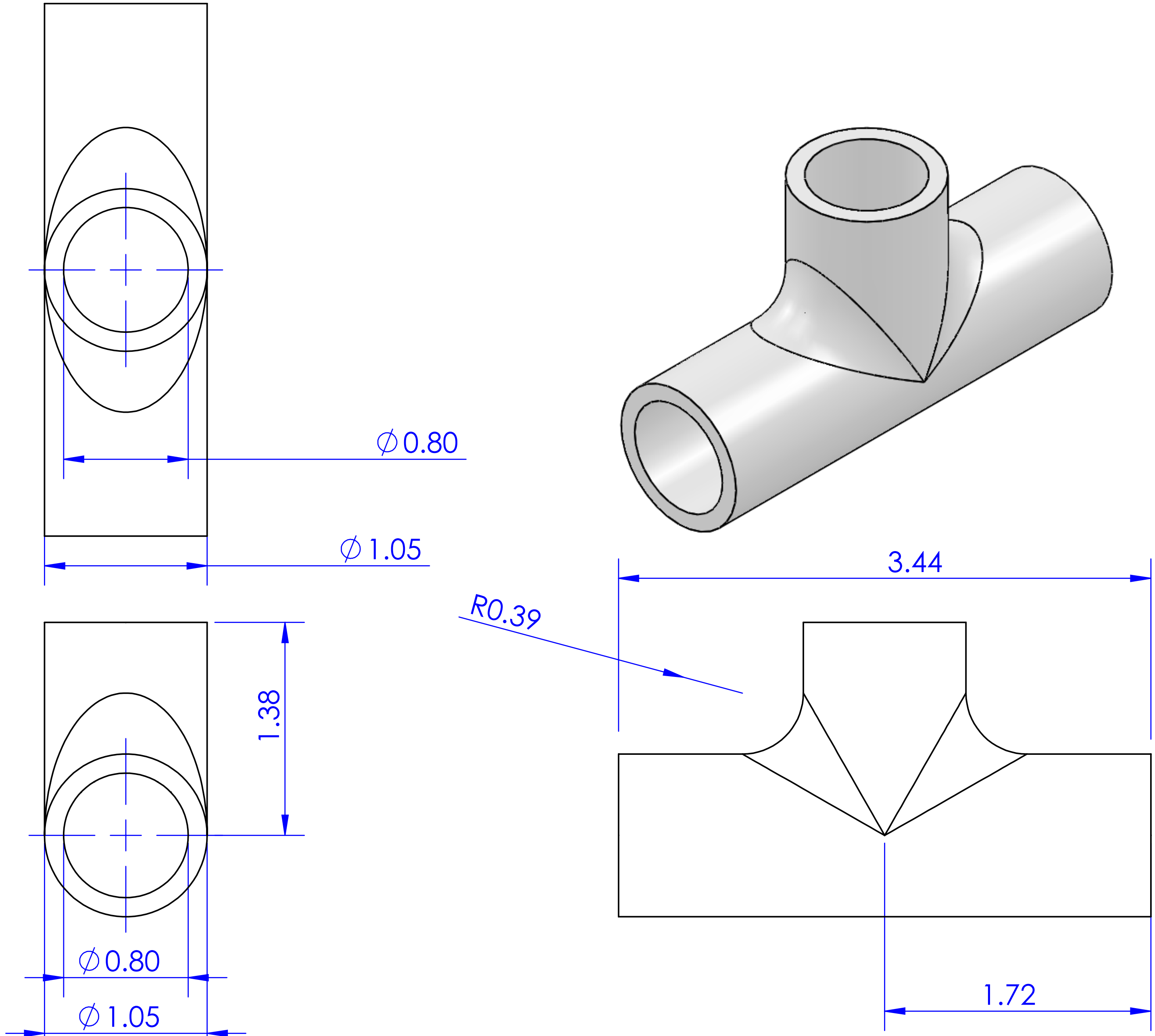


Scale 1:4

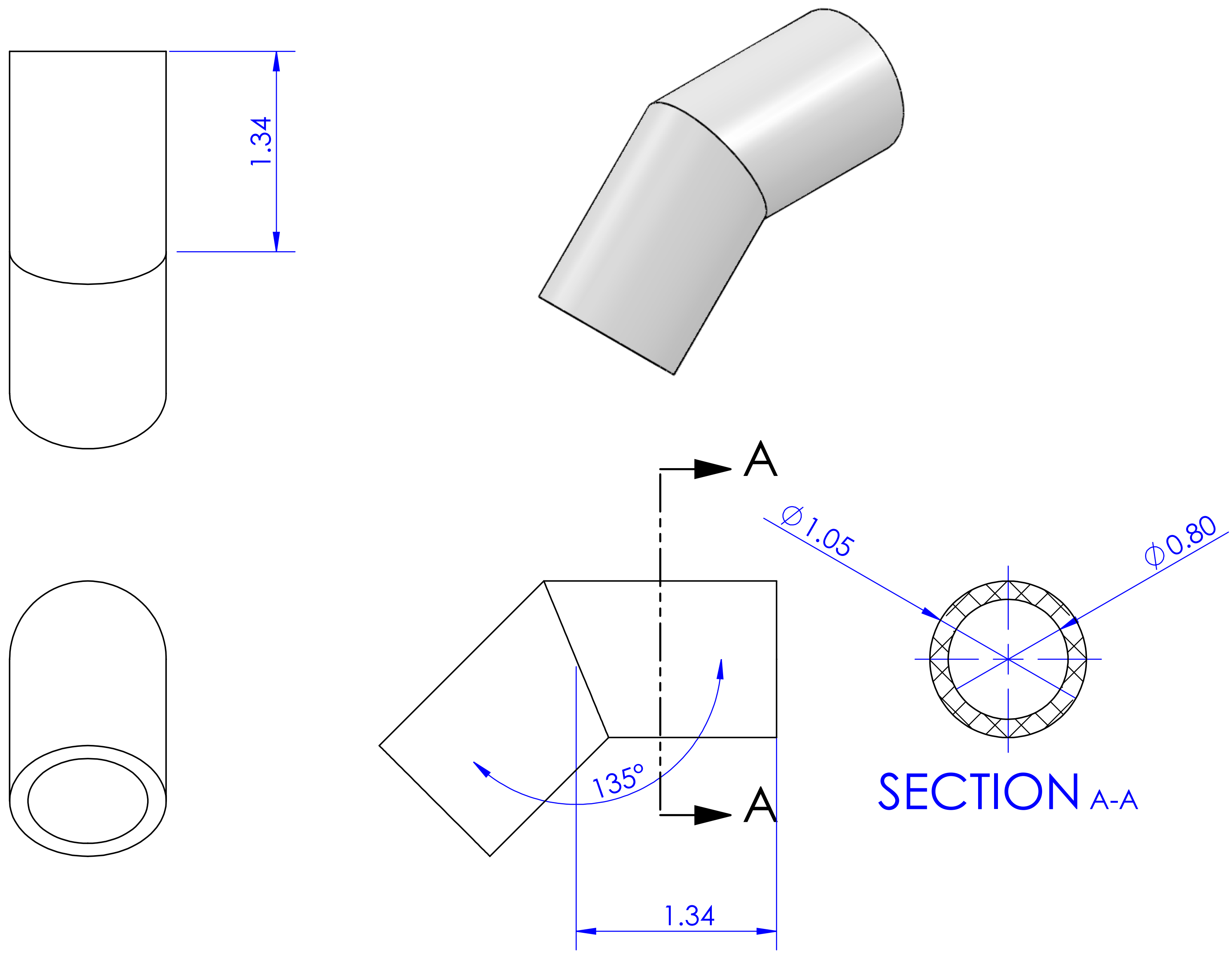
Cal Poly Mechanical Engineering	ME-429	Units: Inches	Title: 5ft PVC Pipe	Drwn. By: Eric Taylor
Sodhana Environmental	Dwg. #: U000060	Nxt Asb: UPA005	Date: 5/2/13 / Scale: 2:1	Chkd. By:

Standard Schedule 40 3/4in PVC T Joint



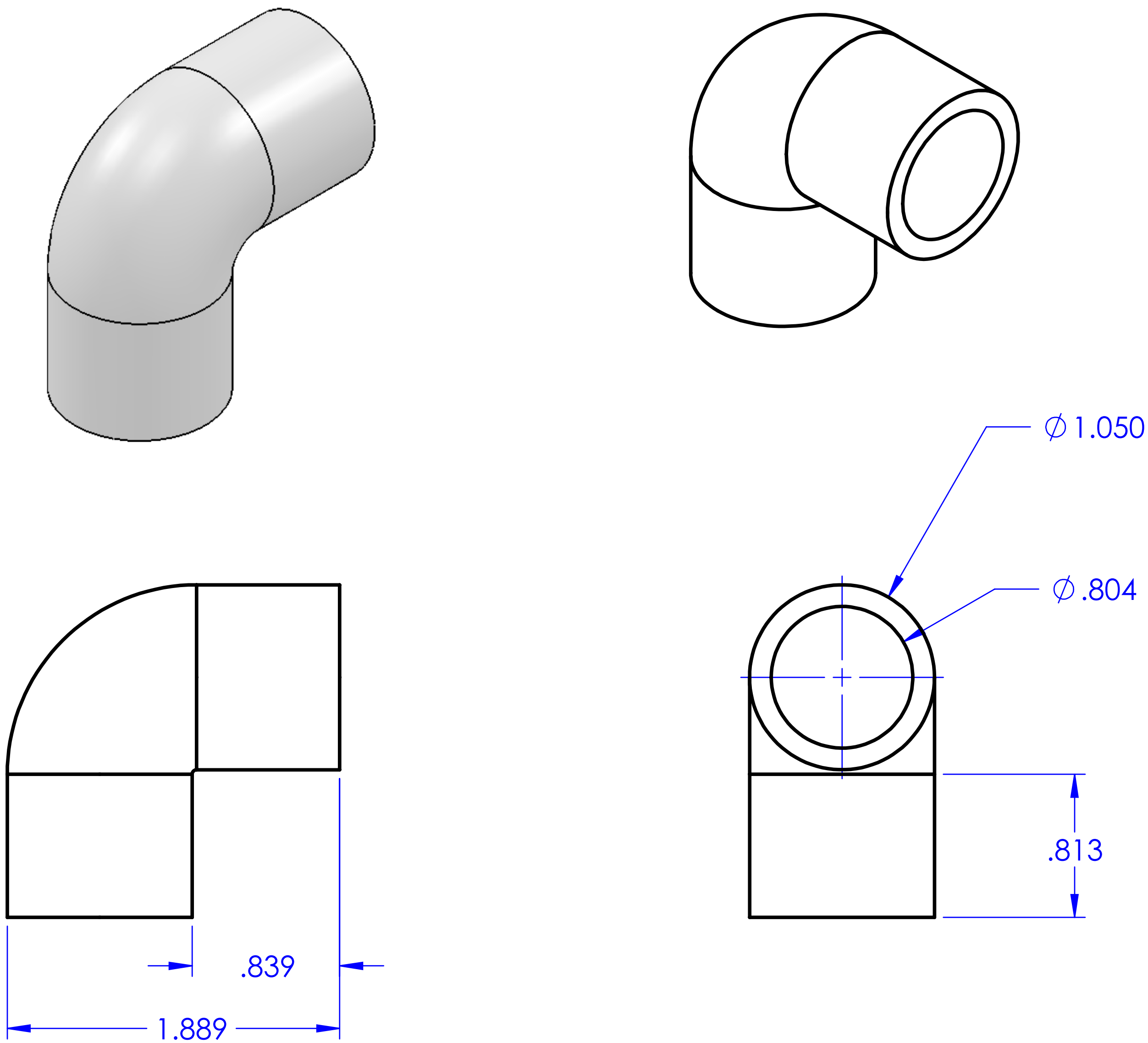
Cal Poly Mechanical Engineering	ME-429	Units: Inches	Title:PVC T-Joint		Drwn. By: Eric Taylor
Sodhana Environmental	Dwg. #: U000180	Nxt Asb: UPA005	Date: 5/2/13	Scale: 1:1	Chkd. By:

Standard Schedule 40 3/4in 45deg PVC Elbow



Cal Poly Mechanical Engineering	ME-429	Units: Inches	Title: 45 Degree PVC Elbow		Drwn. By: Eric Taylor
Sodhana Environmental	Dwg. #: U000045	Nxt Asb: UFSA01	Date: 5/2/13	Scale: 1:1	Chkd. By:

Standard Schedule 40 3/4" PVC Pipe Elbow



Cal Poly Mechanical Engineering	ME-429	Units: Inches	Title: PVC 90 Degree Elbow		Drwn. By: Eric Taylor
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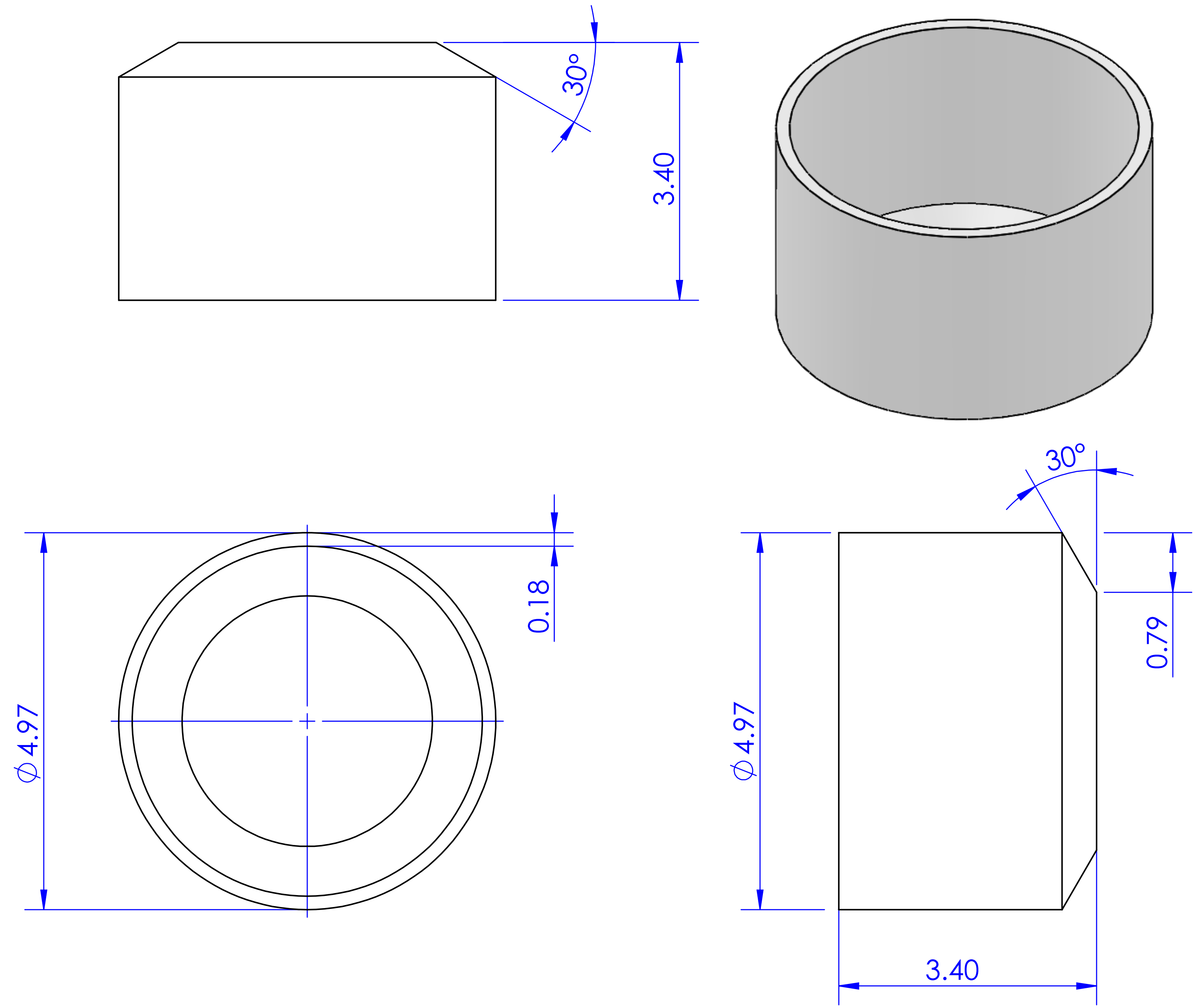
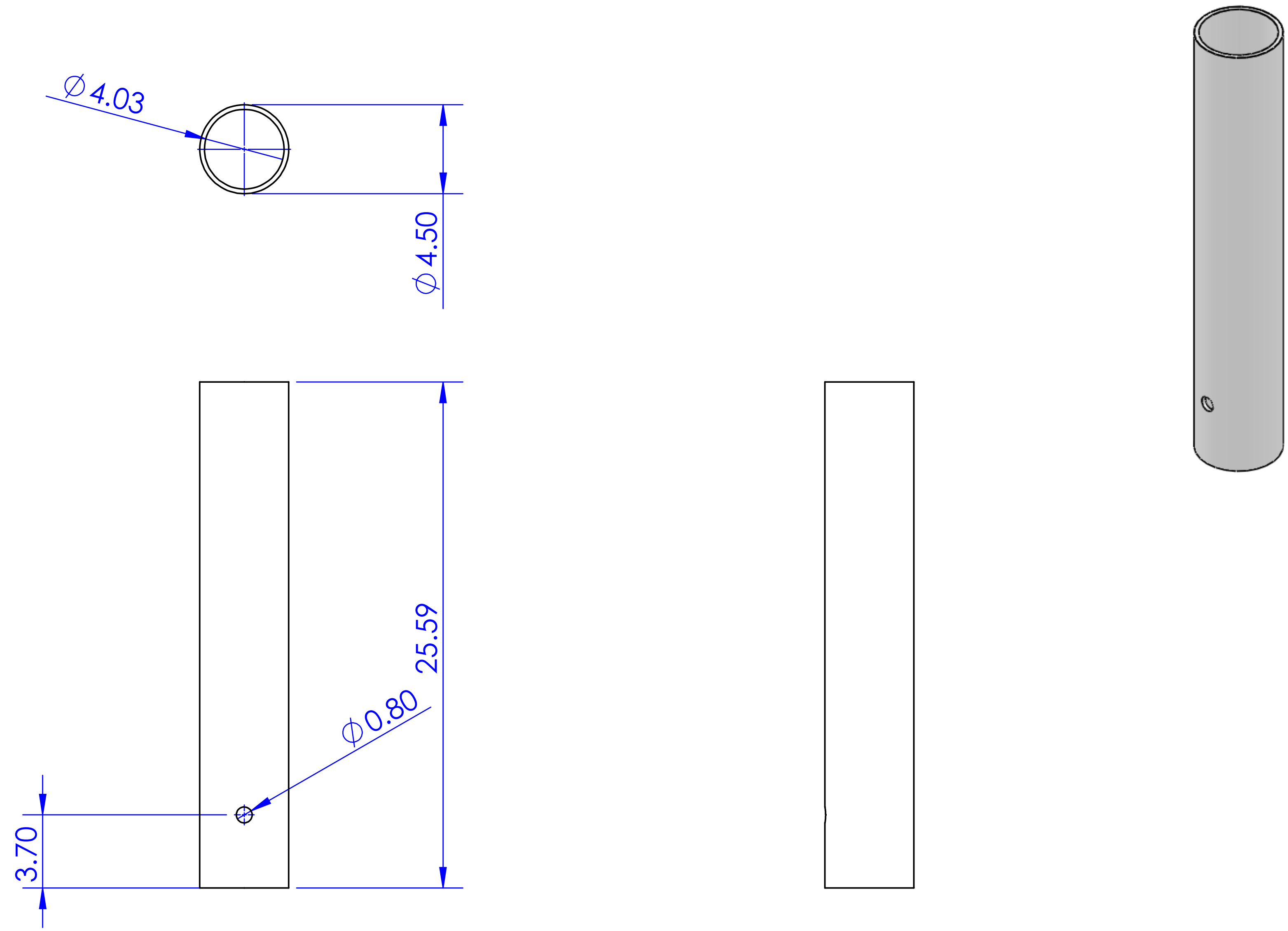


Cal Poly Mechanical Engineering	ME-429	Units: Inches	Title: Filter End Cap		Drwn. By: Eric Taylor
Sodhana Environmental	Dwg. #: US00001	Nxt Asb: UFSA01	Date: 5/2/13	Scale: 1:2	Chkd. By:



Cal Poly Mechanical Engineering	ME-429	Units: Inches	Title: Filter Housing		Drwn. By: Eric Taylor
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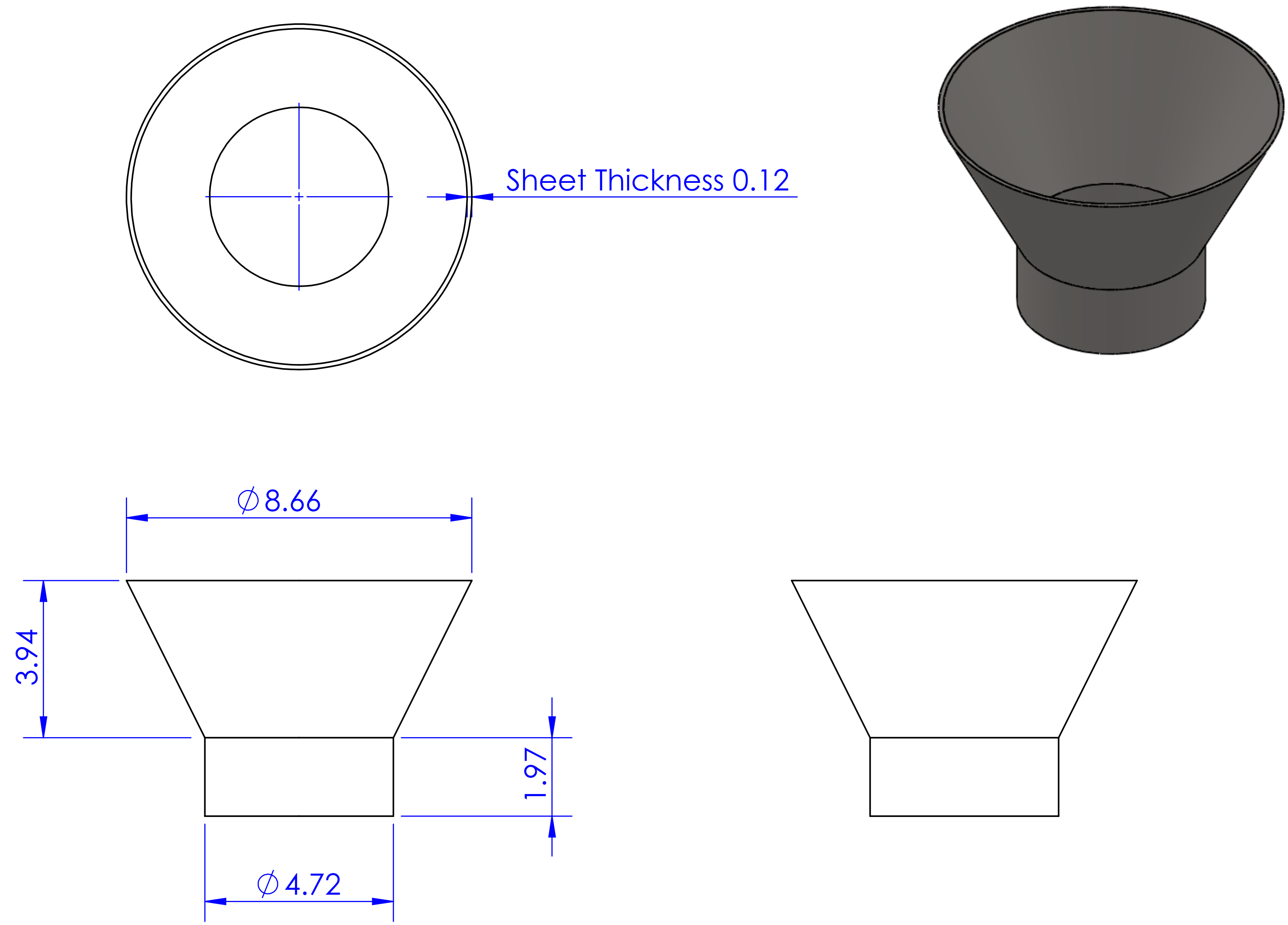
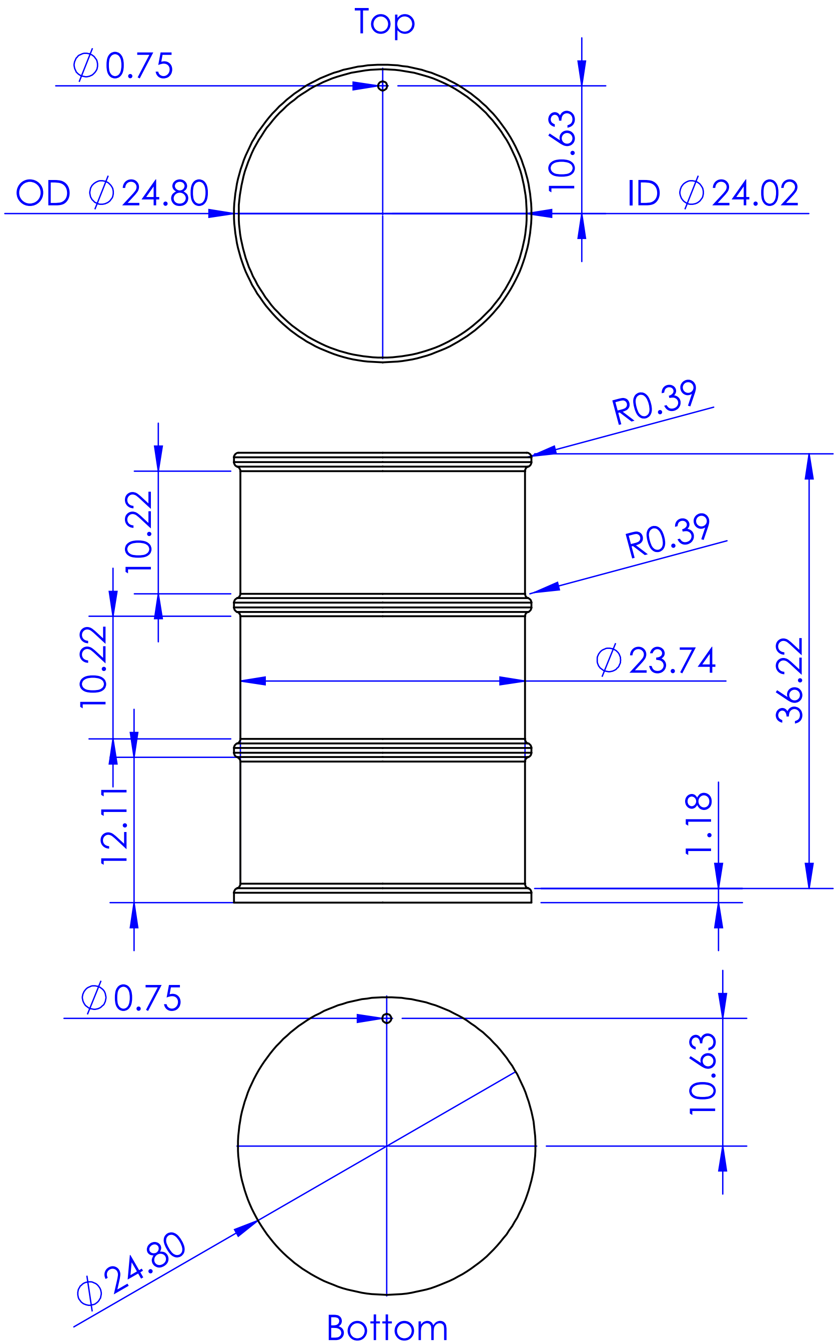
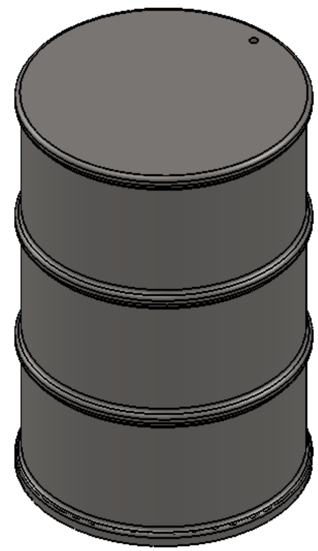


Cal Poly Mechanical Engineering	ME-429	Units: Inches	Title: Filter Diffuser	Drwn. By: Eric Taylor
Sodhana Environmental	Dwg. #: US00003	Nxt Asb:UFSA01	Date: 5/2/13 Scale: 1:4	Chkd. By:

Standard 55 Gal Drum





Cal Poly Mechanical Engineering	ME-429	Units: Inches	Title: Urine Collection Tank		Drwn. By: Eric Taylor
Sodhana Environmental	Dwg. #:US00004	Nxt Asb: UFSA01	Date: 5/2/13	Scale: 1:16	Chkd. By:

IDEXX Summary 15C

Topic Testing for Fecal Coliforms in Wastewater Using Colilert*-18

Title ***IDEXX Colilert*-18 and Quanti-Tray* Test Method for the Detection of Fecal Coliforms in Wastewater***

Source Gil Dichter

Date October 2011

Highlights

- The Colilert-18 method can be used to test for fecal coliforms in wastewaters when used with the Quanti-Tray system.
- In this method, fecal coliform bacteria are defined as bacteria that produce a yellow color after 18-22 h incubation at 44.5° +/- 0.2° C. Positive results are visualized only by color change, not fluorescence.
- Quality control should be conducted on each lot of Colilert-18, or more often as regulations require. Quality control procedures are identified in the product package insert (06-02027-19).
- The U.S. EPA has determined that Colilert-18 is a suitable method for the detection of fecal coliforms in wastewater when incubated at 44.5° C. See article 15A.

*Colilert and Quanti-Tray are trademarks or registered trademarks of IDEXX Laboratories, Inc. or its affiliates in the United States and/or other countries.

IDEXX COLILERT® -18 TEST and QUANTI-TRAY® METHOD FOR THE DETECTION OF FECAL COLIFORMS IN WASTEWATER

IDEXX Colilert® -18 and Quanti-Tray® Test Method For The Detection Of Fecal Coliforms In Wastewater

1.0 Scope and Application

1.1 This method is intended for use in the detection and confirmation of fecal coliforms in wastewater.

1.2 The minimum, non-zero number of bacterial counts detectable with this method is a function of the dilution scheme used when processing the sample.

1.3 The Colilert-18 method can be applied to test for fecal coliforms in wastewaters with the Quanti-Tray® system (see package insert) (20.1).

1.4 Since there can be a wide range of fecal coliform levels in wastewaters, dilutions can be used with this method for detecting and enumerating the actual level.

2.0 Summary of Method

2.1 The method is based on Defined Substrate Technology®. The product utilizes a nutrient indicator (ONPG) that produces a yellow color when metabolized by fecal coliforms at 44.5ºC. When the reagent is added to the sample and incubated, it can detect these bacteria at 1 CFU/ml at 18 hours and up to 22 hours.

3.0 Definitions

3.1 In this method, fecal coliform bacteria are those bacteria which produce a yellow color after incubation at 44.5 ±0.2°C at 18 hours and up to 22 hours.

3.2 Fecal coliform detection is based on the presence of the enzyme ß-D-galactosidase which is known to be present in fecal coliform bacteria.

3.3 For the detection of ß-D-galactosidase, Colilert-18 utilizes the chromogenic nutrient indicator ortho-nitrophenyl-ß-D-galactopyranoside (ONPG) which produces a distinct yellow color when hydrolyzed by ß-D-galactosidase.

4.0 Interferences

4.1 Some samples containing humic material may have an innate color and a control blank of the same water sample may be required for comparison to the inoculated sample.

5.0 Safety

5.1 The analyst/technician must know and observe the appropriate safety procedures required in a microbiology laboratory preparing, using, and disposing of samples, reagents and materials, and while operating equipment.

6.0 Equipment and Supplies

6.1 Pipettes, sterile, T.D. bacteriological or Mohr, glass or plastic of appropriate volume.

6.2 Sterile vessels, glass or plastic containing sodium thiosulfate to neutralize up to 15 mg/L of chlorine. Vessels should be at least120 mL to hold 100 mL of sample**.**

6.3 Quanti-Tray (51 well) or Quanti-Tray/2000

6.4 Quanti-Tray Sealer

6.5 Incubator maintained at 44.5 ±0.2°C. (Dry incubator or water bath that can maintain the required temperature tolerance).

7.0 Reagents

7.1 Sterile deionized water or distilled water. Water conforming to specification D1193, “Reagent water conforming to Type II, Annual Book of ASTM Standards” (2). Autoclave at 121°C (15 -lb pressure) for 15 minutes or sterile filter using a 0.22 micron filter into a sterile container. (20.2)

7.2 Colilert-18, stored at 2 -25°C away from light. The expiration date is indicated on the package (15 months from the date of manufacture).

7.3 Quanti-Tray or Quanti-Tray/2000 Comparator

7.4 Antifoam reagent

7.5 Sodium thiosulfate reagent (Standard Methods for the Examination of Water and Wastewater, [20.3 & 20.4]) or sterile vessels containing sodium thiosulfate to neutralize up to 15mg/L chlorine

8.0 Sample Collection, Preservation and Storage

8.1 Sampling procedures as described in detail in Standard Methods for the Examination of Water and Wastewater (20.3 & 20.4).

8.1.1 Storage Temperature and Handling Conditions: Ice or refrigerate bacteriological samples at a temperature less than 10°C (2-10°C) during transit to the laboratory. Use insulated containers to assure proper maintenance of storage temperature. Ensure the sample vessels are not totally immersed in water during transit.

8.1.2 Holding Time Limitations: Examine samples as soon as possible after collection. The required hold time of samples is 6 hours from collection to initiation of testing (20.7).

9.0 Quality Control

9.1 Quality control should be conducted on each lot of Colilert-18 or more often as regulations requires or accept the IDEXX Certificate of Quality (obtained from the website; www.idexx.com/water) . Inoculate 100 ml of sterile water with Quanti-Cult™ or American Type Culture Collection (ATCC) listed below or equivalent. Follow the procedure in section 11.0

Bacteria spp.		Expected Result
E.coli	ATCC 11775 or Quanti-Cult™ Organism (from IDEXX	Yellow
Pseudomonas aeruginosa	ATCC 10145 or 27853 or Quanti-Cult™ Organism (from IDEXX	Colorless

10.0 Calibration and Standardization

10.1 Check the temperature in the incubators daily as a minimum to insure it is within the stated limits. It is preferable to check the temperature in the morning and in the late afternoon. Record the date, temperature, time of reading and initial.

10.2 Check thermometers at least annually against NIST certified thermometer or one that meets the requirements of NIST Monograph SP 250-23 (20.3).

11.0 Quantification Procedure [follow package insert for quantification] (20.5)

11.1 Colilert-18 and the IDEXX Quanti-Tray System with either the 51 Well Quanti-Tray or the Quanti-Tray/2000.

11.2 Carefully separate one blister pack from the strip taking care not to accidently open the adjacent pack.

11.3 Ensure the powder is at the bottom of the blister pack.

11.4 Hold the blister pack face down (paper side up) at the top and towards the back and snap back the scoreline forming a "v" with the opening facing the open vessel.

11.5 Allow the powder to fall into the vessel containing the room temperature sample. Mix the sample well to dissolve the reagent.

11.6 If a dilution is necessary, use sterile deionized or distilled water, not buffered water for making the dilution prior to adding Colilert-18. Colilert-18 should be added to the diluted sample.

11.7 The use of IDEXX Antifoam reagent may be necessary to reduce foaming and eliminate excess bubbles in the wells of the Quanti-Tray. Alternatively, let the sample sit for a few minutes to allow the foam to dissipate.

11.8 Remove the sterile trays from the plastic bag by opening the bag at the green line (follow the package insert). Reseal the bag with tape or a clip. Pour the sample/reagent mixture into a Quanti-Tray or Quanti-Tray/2000 by squeezing the top (see package insert) and seal with the IDEXX Quanti-Tray Sealer.

12.0 Incubation:

12.1 Place the sealed tray in a 44.5 ±0.2˚C incubator for 18 hours and up to 22 hours (prewarming to 35˚C is not required). For incubation in a water bath, submerge the Quanti-Tray, as is, below the water level using a weighted ring or a bungee cord or metal rack. (do not use a rock or a bottle containing water to hold down the trays).

13.0 Results Interpretation:

13.1 Read results according to the Result Interpretation Table. Count the number of positive wells and refer to the MPN Table provided with the Quanti-Tray to obtain a Most Probable Number.

13.2 Less yellow than the comparator when incubated at 44.5 ±0.2°C is negative for fecal coliforms.

13.3 Yellow equal to or greater than the comparator when incubated at 44.5 ±0.2°C is positive for fecal coliforms

13.4 If a dilution is required, use sterile deionized or distilled water, not buffered water for making the dilutions. Always add Colilert-18 to the final 100ml diluted sample only.

13.5 Colilert-18 results are definitive at 18–22 hours. In addition, positives for fecal coliforms observed before 18 hours and negatives observed after 22 hours are also valid.

14.0 Data Analysis and Calculations

14.1 Follow the same interpretation directions from section 13.0; Count the number of positive wells. Refer to the Quanti-Tray MPN table provided by IDEXX to determine the most Probable Number (MPN) for total coliforms (yellow wells) in the sample. Correct the MPN value for any dilution made. The color of positive wells may vary. Use the appropriate Quanti-Tray MPN comparator following the instructions as indicated.

15.0 Method Performance-40CFR136.3 ATP evaluation (20.6)

15.1 Colilert-18 found to be equally sensitive to m-FC

15.2 Variances across the ten sites were similar using the Bartlett's test with Colilert-18 having a p-value (>0.05) of 0.308

15.3 False positives = 0%; False negatives = 7%

15.4 The EPA determined that Colilert-18 is a suitable method for the detection of fecal coliforms in wastewater when incubated at 44.5°C.

16.0 Reporting Results

16.1 Report results as MPN/100mL for fecal coliforms

17.0 Verification Procedure

17.1 Not applicable

18.0 Pollution Prevention

18.1 The solutions and reagents used in this method pose no threat to the environment when recycled and managed properly.

18.2 Solutions and reagents should be prepared in volumes consistent with laboratory use to minimize the volume of expired materials to be disposed.

19.0 Waste Management

19.1 It is the laboratory's responsibility to comply with all federal, state and local regulations governing waste management, particularly the biohazard and hazardous identification rules and land disposal regulations. Compliance with all sewage discharge permits and regulations is also required.

19.2 Samples, reference materials and equipment known or suspected to have viable bacteria attached or contained must be sterilized prior to disposal.

20.0 References

20.1 Colilert-18 Package Insert from IDEXX.

20.2 Annual Book of ASTM Standards, Vol. 11.01, American Society for Testing Materials, Philadelphia, PA 19103, (2005)

20.3 Bordner, R., J.A. Winter and P.V. Scarpino (eds.) Microbiological Methods for Monitoring the Environment, Water and Wastes, EPA-600/8-78-017. Office of Research and Development, USEPA. (December 1978)

20.4 Clesceri, L.S., A.E. Greenberg, A.D. Eaton (eds.). 1998 Standard Methods for the Examination of Water and Wastewater, 20th Edition, American Public Health Association, Washington, DC.

20.5 Quanti-Tray Package Insert from IDEXX.

20.6 ATP summary report and letter from EPA

20.7 Federal Register/Vol72, NO 47, Monday March 12, 2007 Page 11236, Table Holding Time

IDEXX Quanti-Tray®/2000 MPN Table *(per 100ml)*

# Large Wells Positive	# Small Wells Positive 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0	<1	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.1	15.1	16.1	17.1	18.1	19.1	20.2	21.2	22.2	23.3	24.3
1	1.0	2.0	3.0	4.0	5.0	6.0	7.1	8.1	9.1	10.1	11.1	12.1	13.2	14.2	15.2	16.2	17.3	18.3	19.3	20.4	21.4	22.4	23.5	24.5	25.6
2	2.0	3.0	4.1	5.1	6.1	7.1	8.1	9.2	10.2	11.2	12.2	13.3	14.3	15.4	16.4	17.4	18.5	19.5	20.6	21.6	22.7	23.7	24.8	25.8	26.9
3	3.1	4.1	5.1	6.1	7.2	8.2	9.2	10.3	11.3	12.4	13.4	14.5	15.5	16.5	17.6	18.6	19.7	20.8	21.8	22.9	23.9	25.0	26.1	27.1	28.2
4	4.1	5.2	6.2	7.2	8.3	9.3	10.4	11.4	12.5	13.5	14.6	15.6	16.7	17.8	18.8	19.9	21.0	22.0	23.1	24.2	25.3	26.3	27.4	28.5	29.6
5	5.2	6.3	7.3	8.4	9.4	10.5	11.5	12.6	13.7	14.7	15.8	16.9	17.9	19.0	20.1	21.2	22.2	23.3	24.4	25.5	26.6	27.7	28.8	29.9	31.0
6	6.3	7.4	8.4	9.5	10.6	11.6	12.7	13.8	14.9	16.0	17.0	18.1	19.2	20.3	21.4	22.5	23.6	24.7	25.8	26.9	28.0	29.1	30.2	31.3	32.4
7	7.5	8.5	9.6	10.7	11.8	12.8	13.9	15.0	16.1	17.2	18.3	19.4	20.5	21.6	22.7	23.8	24.9	26.0	27.1	28.3	29.4	30.5	31.6	32.8	33.9
8	8.6	9.7	10.8	11.9	13.0	14.1	15.2	16.3	17.4	18.5	19.6	20.7	21.8	22.9	24.1	25.2	26.3	27.4	28.6	29.7	30.8	32.0	33.1	34.3	35.4
9	9.8	10.9	12.0	13.1	14.2	15.3	16.4	17.6	18.7	19.8	20.9	22.0	23.2	24.3	25.4	26.6	27.7	28.9	30.0	31.2	32.3	33.5	34.6	35.8	37.0
10	11.0	12.1	13.2	14.4	15.5	16.6	17.7	18.9	20.0	21.1	22.3	23.4	24.6	25.7	26.9	28.0	29.2	30.3	31.5	32.7	33.8	35.0	36.2	37.4	38.6
11	12.2	13.4	14.5	15.6	16.8	17.9	19.1	20.2	21.4	22.5	23.7	24.8	26.0	27.2	28.3	29.5	30.7	31.9	33.0	34.2	35.4	36.6	37.8	39.0	40.2
12	13.5	14.6	15.8	16.9	18.1	19.3	20.4	21.6	22.8	23.9	25.1	26.3	27.5	28.6	29.8	31.0	32.2	33.4	34.6	35.8	37.0	38.2	39.5	40.7	41.9
13	14.8	16.0	17.1	18.3	19.5	20.6	21.8	23.0	24.2	25.4	26.6	27.8	29.0	30.2	31.4	32.6	33.8	35.0	36.2	37.5	38.7	39.9	41.2	42.4	43.6
14	16.1	17.3	18.5	19.7	20.9	22.1	23.3	24.5	25.7	26.9	28.1	29.3	30.5	31.7	33.0	34.2	35.4	36.7	37.9	39.1	40.4	41.6	42.9	44.2	45.4
15	17.5	18.7	19.9	21.1	22.3	23.5	24.7	25.9	27.2	28.4	29.6	30.9	32.1	33.3	34.6	35.8	37.1	38.4	39.6	40.9	42.2	43.4	44.7	46.0	47.3
16	18.9	20.1	21.3	22.6	23.8	25.0	26.2	27.5	28.7	30.0	31.2	32.5	33.7	35.0	36.3	37.5	38.8	40.1	41.4	42.7	44.0	45.3	46.6	47.9	49.2
17	20.3	21.6	22.8	24.1	25.3	26.6	27.8	29.1	30.3	31.6	32.9	34.1	35.4	36.7	38.0	39.3	40.6	41.9	43.2	44.5	45.9	47.2	48.5	49.8	51.2
18	21.8	23.1	24.3	25.6	26.9	28.1	29.4	30.7	32.0	33.3	34.6	35.9	37.2	38.5	39.8	41.1	42.4	43.8	45.1	46.5	47.8	49.2	50.5	51.9	53.2
19	23.3	24.6	25.9	27.2	28.5	29.8	31.1	32.4	33.7	35.0	36.3	37.6	39.0	40.3	41.6	43.0	44.3	45.7	47.1	48.4	49.8	51.2	52.6	54.0	55.4
20	24.9	26.2	27.5	28.8	30.1	31.5	32.8	34.1	35.4	36.8	38.1	39.5	40.8	42.2	43.6	44.9	46.3	47.7	49.1	50.5	51.9	53.3	54.7	56.1	57.6
21	26.5	27.9	29.2	30.5	31.8	33.2	34.5	35.9	37.3	38.6	40.0	41.4	42.8	44.1	45.5	46.9	48.4	49.8	51.2	52.6	54.1	55.5	56.9	58.4	59.9
22	28.2	29.5	30.9	32.3	33.6	35.0	36.4	37.7	39.1	40.5	41.9	43.3	44.8	46.2	47.6	49.0	50.5	51.9	53.4	54.8	56.3	57.8	59.3	60.8	62.3
23	29.9	31.3	32.7	34.1	35.5	36.8	38.3	39.7	41.1	42.5	43.9	45.4	46.8	48.3	49.7	51.2	52.7	54.2	55.6	57.1	58.6	60.2	61.7	63.2	64.7
24	31.7	33.1	34.5	35.9	37.3	38.8	40.2	41.7	43.1	44.6	46.0	47.5	49.0	50.5	52.0	53.5	55.0	56.5	58.0	59.5	61.1	62.6	64.2	65.8	67.3
25	33.6	35.0	36.4	37.9	39.3	40.8	42.2	43.7	45.2	46.7	48.2	49.7	51.2	52.7	54.3	55.8	57.3	58.9	60.5	62.0	63.6	65.2	66.8	68.4	70.0
26	35.5	36.9	38.4	39.9	41.4	42.8	44.3	45.9	47.4	48.9	50.4	52.0	53.5	55.1	56.7	58.2	59.8	61.4	63.0	64.7	66.3	67.9	69.6	71.2	72.9
27	37.4	38.9	40.4	42.0	43.5	45.0	46.5	48.1	49.6	51.2	52.8	54.4	56.0	57.6	59.2	60.8	62.4	64.1	65.7	67.4	69.1	70.8	72.5	74.2	75.9
28	39.5	41.0	42.6	44.1	45.7	47.3	48.8	50.4	52.0	53.6	55.2	56.9	58.5	60.2	61.8	63.5	65.2	66.9	68.6	70.3	72.0	73.7	75.5	77.3	79.0
29	41.7	43.2	44.8	46.4	48.0	49.6	51.2	52.8	54.5	56.1	57.8	59.5	61.2	62.9	64.6	66.3	68.0	69.8	71.5	73.3	75.1	76.9	78.7	80.5	82.4
30	43.9	45.5	47.1	48.7	50.4	52.0	53.7	55.4	57.1	58.8	60.5	62.2	64.0	65.7	67.5	69.3	71.0	72.9	74.7	76.5	78.3	80.2	82.1	84.0	85.9
31	46.2	47.9	49.5	51.2	52.9	54.6	56.3	58.1	59.8	61.6	63.3	65.1	66.9	68.7	70.5	72.4	74.2	76.1	78.0	79.9	81.8	83.7	85.7	87.6	89.6
32	48.7	50.4	52.1	53.8	55.6	57.3	59.1	60.9	62.7	64.5	66.3	68.2	70.0	71.9	73.8	75.7	77.6	79.5	81.5	83.5	85.4	87.5	89.5	91.5	93.6
33	51.2	53.0	54.8	56.5	58.3	60.2	62.0	63.8	65.7	67.6	69.5	71.4	73.3	75.2	77.2	79.2	81.2	83.2	85.2	87.3	89.3	91.4	93.6	95.7	97.8
34	53.9	55.7	57.6	59.4	61.3	63.1	65.0	67.0	68.9	70.8	72.8	74.8	76.8	78.8	80.8	82.9	85.0	87.1	89.2	91.4	93.5	95.7	97.9	100.2	102.4
35	56.8	58.6	60.5	62.4	64.4	66.3	68.3	70.3	72.3	74.3	76.3	78.4	80.5	82.6	84.7	86.9	89.1	91.3	93.5	95.7	98.0	100.3	102.6	105.0	107.3
36	59.8	61.7	63.7	65.7	67.7	69.7	71.7	73.8	75.9	78.0	80.1	82.3	84.5	86.7	88.9	91.2	93.5	95.8	98.1	100.5	102.9	105.3	107.7	110.2	112.7
37	62.9	65.0	67.0	69.1	71.2	73.3	75.4	77.6	79.8	82.0	84.2	86.5	88.8	91.1	93.4	95.8	98.2	100.6	103.1	105.6	108.1	110.7	113.3	115.9	118.6
38	66.3	68.4	70.6	72.7	74.9	77.1	79.4	81.6	83.9	86.2	88.6	91.0	93.4	95.8	98.3	100.8	103.4	105.9	108.6	111.2	113.9	116.6	119.4	122.2	125.0
39	70.0	72.2	74.4	76.7	78.9	81.3	83.6	86.0	88.4	90.9	93.4	95.9	98.4	101.0	103.6	106.3	109.0	111.8	114.6	117.4	120.3	123.2	126.1	129.2	132.2
40	73.8	76.2	78.5	80.9	83.3	85.7	88.2	90.8	93.3	95.9	98.5	101.2	103.9	106.7	109.5	112.4	115.3	118.2	121.2	124.3	127.4	130.5	133.7	137.0	140.3
41	78.0	80.5	83.0	85.5	88.0	90.6	93.3	95.9	98.7	101.4	104.3	107.1	110.0	113.0	116.0	119.1	122.2	125.4	128.7	132.0	135.4	138.8	142.3	145.9	149.5
42	82.6	85.2	87.8	90.5	93.2	96.0	98.8	101.7	104.6	107.6	110.6	113.7	116.9	120.1	123.4	126.7	130.1	133.6	137.2	140.8	144.5	148.3	152.2	156.1	160.2
43	87.6	90.4	93.2	96.0	99.0	101.9	105.0	108.1	111.2	114.5	117.8	121.1	124.6	128.1	131.7	135.4	139.1	143.0	147.0	151.0	155.2	159.4	163.8	168.2	172.8
44	93.1	96.1	99.1	102.2	105.4	108.6	111.9	115.3	118.7	122.3	125.9	129.6	133.4	137.4	141.4	145.5	149.7	154.1	158.5	163.1	167.9	172.7	177.7	182.9	188.2
45	99.3	102.5	105.8	109.2	112.6	116.2	119.8	123.6	127.4	131.4	135.4	139.6	143.9	148.3	152.9	157.6	162.4	167.4	172.6	178.0	183.5	189.2	195.1	201.2	207.5
46	106.3	109.8	113.4	117.2	121.0	125.0	129.1	133.3	137.6	142.1	146.7	151.5	156.5	161.6	167.0	172.5	178.2	184.2	190.4	196.8	203.5	210.5	217.8	225.4	233.3
47	114.3	118.3	122.4	126.6	130.9	135.4	140.1	145.0	150.0	155.3	160.7	166.4	172.3	178.5	185.0	191.8	198.9	206.4	214.2	222.4	231.0	240.0	249.5	259.5	270.0
48	123.9	128.4	133.1	137.9	143.0	148.3	153.9	159.7	165.8	172.2	178.9	186.0	193.5	201.4	209.8	218.7	228.2	238.2	248.9	260.3	272.3	285.1	298.7	313.0	328.2
49	135.5	140.8	146.4	152.3	158.5	165.0	172.0	179.3	187.2	195.6	204.6	214.3	224.7	235.9	248.1	261.3	275.5	290.9	307.6	325.5	344.8	365.4	387.3	410.6	435.2

IDEXX Quanti-Tray®/2000 MPN Table *(per 100ml)*

# Large Wells Positive	# Small Wells Positive 25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
0	25.3	26.4	27.4	28.4	29.5	30.5	31.5	32.6	33.6	34.7	35.7	36.8	37.8	38.9	40.0	41.0	42.1	43.1	44.2	45.3	46.3	47.4	48.5	49.5
1	26.6	27.7	28.7	29.8	30.8	31.9	32.9	34.0	35.0	36.1	37.2	38.2	39.3	40.4	41.4	42.5	43.6	44.7	45.7	46.8	47.9	49.0	50.1	51.2
2	27.9	29.0	30.0	31.1	32.2	33.2	34.3	35.4	36.5	37.5	38.6	39.7	40.8	41.9	43.0	44.0	45.1	46.2	47.3	48.4	49.5	50.6	51.7	52.8
3	29.3	30.4	31.4	32.5	33.6	34.7	35.8	36.8	37.9	39.0	40.1	41.2	42.3	43.4	44.5	45.6	46.7	47.8	48.9	50.0	51.2	52.3	53.4	54.5
4	30.7	31.8	32.8	33.9	35.0	36.1	37.2	38.3	39.4	40.5	41.6	42.8	43.9	45.0	46.1	47.2	48.3	49.5	50.6	51.7	52.9	54.0	55.1	56.3
5	32.1	33.2	34.3	35.4	36.5	37.6	38.7	39.9	41.0	42.1	43.2	44.4	45.5	46.6	47.7	48.9	50.0	51.2	52.3	53.5	54.6	55.8	56.9	58.1
6	33.5	34.7	35.8	36.9	38.0	39.2	40.3	41.4	42.6	43.7	44.8	46.0	47.1	48.3	49.4	50.6	51.7	52.9	54.1	55.2	56.4	57.6	58.7	59.9
7	35.0	36.2	37.3	38.4	39.6	40.7	41.9	43.0	44.2	45.3	46.5	47.7	48.8	50.0	51.2	52.3	53.5	54.7	55.9	57.1	58.3	59.4	60.6	61.8
8	36.6	37.7	38.9	40.0	41.2	42.3	43.5	44.7	45.9	47.0	48.2	49.4	50.6	51.8	53.0	54.1	55.3	56.5	57.7	59.0	60.2	61.4	62.6	63.8
9	38.1	39.3	40.5	41.6	42.8	44.0	45.2	46.4	47.6	48.8	50.0	51.2	52.4	53.6	54.8	56.0	57.2	58.4	59.7	60.9	62.1	63.4	64.6	65.8
10	39.7	40.9	42.1	43.3	44.5	45.7	46.9	48.1	49.3	50.6	51.8	53.0	54.2	55.5	56.7	57.9	59.2	60.4	61.7	62.9	64.2	65.4	66.7	67.9
11	41.4	42.6	43.8	45.0	46.3	47.5	48.7	49.9	51.2	52.4	53.7	54.9	56.1	57.4	58.6	59.9	61.2	62.4	63.7	65.0	66.3	67.5	68.8	70.1
12	43.1	44.3	45.6	46.8	48.1	49.3	50.6	51.8	53.1	54.3	55.6	56.8	58.1	59.4	60.7	62.0	63.2	64.5	65.8	67.1	68.4	69.7	71.0	72.4
13	44.9	46.1	47.4	48.6	49.9	51.2	52.5	53.7	55.0	56.3	57.6	58.9	60.2	61.5	62.8	64.1	65.4	66.7	68.0	69.3	70.7	72.0	73.3	74.7
14	46.7	48.0	49.3	50.5	51.8	53.1	54.4	55.7	57.0	58.3	59.6	60.9	62.3	63.6	64.9	66.3	67.6	68.9	70.3	71.6	73.0	74.4	75.7	77.1
15	48.6	49.9	51.2	52.5	53.8	55.1	56.4	57.8	59.1	60.4	61.8	63.1	64.5	65.8	67.2	68.5	69.9	71.3	72.6	74.0	75.4	76.8	78.2	79.6
16	50.5	51.8	53.2	54.5	55.8	57.2	58.5	59.9	61.2	62.6	64.0	65.3	66.7	68.1	69.5	70.9	72.3	73.7	75.1	76.5	77.9	79.3	80.8	82.2
17	52.5	53.9	55.2	56.6	58.0	59.3	60.7	62.1	63.5	64.9	66.3	67.7	69.1	70.5	71.9	73.3	74.8	76.2	77.6	79.1	80.5	82.0	83.5	84.9
18	54.6	56.0	57.4	58.8	60.2	61.6	63.0	64.4	65.8	67.2	68.6	70.1	71.5	73.0	74.4	75.9	77.3	78.8	80.3	81.8	83.3	84.8	86.3	87.8
19	56.8	58.2	59.6	61.0	62.4	63.9	65.3	66.8	68.2	69.7	71.1	72.6	74.1	75.5	77.0	78.5	80.0	81.5	83.1	84.6	86.1	87.6	89.2	90.7
20	59.0	60.4	61.9	63.3	64.8	66.3	67.7	69.2	70.7	72.2	73.7	75.2	76.7	78.2	79.8	81.3	82.8	84.4	85.9	87.5	89.1	90.7	92.2	93.8
21	61.3	62.8	64.3	65.8	67.3	68.8	70.3	71.8	73.3	74.9	76.4	77.9	79.5	81.1	82.6	84.2	85.8	87.4	89.0	90.6	92.2	93.8	95.4	97.1
22	63.8	65.3	66.8	68.3	69.8	71.4	72.9	74.5	76.1	77.6	79.2	80.8	82.4	84.0	85.6	87.2	88.9	90.5	92.1	93.8	95.5	97.1	98.8	100.5
23	66.3	67.8	69.4	71.0	72.5	74.1	75.7	77.3	78.9	80.5	82.2	83.8	85.4	87.1	88.7	90.4	92.1	93.8	95.5	97.2	98.9	100.6	102.4	104.1
24	68.9	70.5	72.1	73.7	75.3	77.0	78.6	80.3	81.9	83.6	85.2	86.9	88.6	90.3	92.0	93.8	95.5	97.2	99.0	100.7	102.5	104.3	106.1	107.9
25	71.7	73.3	75.0	76.6	78.3	80.0	81.7	83.3	85.1	86.8	88.5	90.2	92.0	93.7	95.5	97.3	99.1	100.9	102.7	104.5	106.3	108.2	110.0	111.9
26	74.6	76.3	78.0	79.7	81.4	83.1	84.8	86.6	88.4	90.1	91.9	93.7	95.5	97.3	99.2	101.0	102.9	104.7	106.6	108.5	110.4	112.3	114.2	116.2
27	77.6	79.4	81.1	82.9	84.6	86.4	88.2	90.0	91.9	93.7	95.5	97.4	99.3	101.2	103.1	105.0	106.9	108.8	110.8	112.7	114.7	116.7	118.7	120.7
28	80.8	82.6	84.4	86.3	88.1	89.9	91.8	93.7	95.6	97.5	99.4	101.3	103.3	105.2	107.2	109.2	111.2	113.2	115.2	117.3	119.3	121.4	123.5	125.6
29	84.2	86.1	87.9	89.8	91.7	93.7	95.6	97.5	99.5	101.5	103.5	105.5	107.5	109.5	111.6	113.7	115.7	117.8	120.0	122.1	124.2	126.4	128.6	130.8
30	87.8	89.7	91.7	93.6	95.6	97.6	99.6	101.6	103.7	105.7	107.8	109.9	112.0	114.2	116.3	118.5	120.6	122.8	125.1	127.3	129.5	131.8	134.1	136.4
31	91.6	93.6	95.6	97.7	99.7	101.8	103.9	106.0	108.2	110.3	112.5	114.7	116.9	119.1	121.4	123.6	125.9	128.2	130.5	132.9	135.3	137.7	140.1	142.5
32	95.7	97.8	99.9	102.0	104.2	106.3	108.5	110.7	113.0	115.2	117.5	119.8	122.1	124.5	126.8	129.2	131.6	134.0	136.5	139.0	141.5	144.0	146.6	149.1
33	100.0	102.2	104.4	106.6	108.9	111.2	113.5	115.8	118.2	120.5	122.9	125.4	127.8	130.3	132.8	135.3	137.8	140.4	143.0	145.6	148.3	150.9	153.7	156.4
34	104.7	107.0	109.3	111.7	114.0	116.4	118.9	121.3	123.8	126.3	128.8	131.4	134.0	136.6	139.2	141.9	144.6	147.4	150.1	152.9	155.7	158.6	161.5	164.4
35	109.7	112.2	114.6	117.1	119.6	122.2	124.7	127.3	129.9	132.6	135.3	138.0	140.8	143.6	146.4	149.2	152.1	155.0	158.0	161.0	164.0	167.1	170.2	173.3
36	115.2	117.8	120.4	123.0	125.7	128.4	131.1	133.9	136.7	139.5	142.4	145.3	148.3	151.3	154.3	157.3	160.5	163.6	166.8	170.0	173.3	176.6	179.9	183.3
37	121.3	124.0	126.8	129.6	132.4	135.3	138.2	141.2	144.2	147.3	150.3	153.5	156.7	159.9	163.1	166.5	169.8	173.2	176.7	180.2	183.7	187.3	191.0	194.7
38	127.9	130.8	133.8	136.8	139.9	143.0	146.2	149.4	152.6	155.9	159.2	162.6	166.1	169.6	173.2	176.8	180.4	184.2	188.0	191.8	195.7	199.7	203.7	207.7
39	135.3	138.5	141.7	145.0	148.3	151.7	155.1	158.6	162.1	165.7	169.4	173.1	176.9	180.7	184.7	188.7	192.7	196.8	201.0	205.3	209.6	214.0	218.5	223.0
40	143.7	147.1	150.6	154.2	157.8	161.5	165.3	169.1	173.0	177.0	181.1	185.2	189.4	193.7	198.1	202.5	207.1	211.7	216.4	221.1	226.0	231.0	236.0	241.1
41	153.2	157.0	160.9	164.8	168.9	173.0	177.2	181.5	185.8	190.3	194.8	199.5	204.2	209.1	214.0	219.1	224.2	229.4	234.8	240.2	245.8	251.5	257.2	263.1
42	164.3	168.6	172.9	177.3	181.9	186.5	191.3	196.1	201.1	206.2	211.4	216.7	222.2	227.7	233.4	239.2	245.2	251.3	257.5	263.8	270.3	276.9	283.6	290.5
43	177.5	182.3	187.3	192.4	197.6	202.9	208.4	214.0	219.8	225.8	231.8	238.1	244.5	251.0	257.7	264.6	271.7	278.9	286.3	293.8	301.5	309.4	317.4	325.7
44	193.6	199.3	205.1	211.0	217.2	223.5	230.0	236.7	243.6	250.8	258.1	265.6	273.3	281.2	289.4	297.8	306.3	315.1	324.1	333.3	342.8	352.4	362.3	372.4
45	214.1	220.9	227.9	235.2	242.7	250.4	258.4	266.7	275.3	284.1	293.3	302.6	312.3	322.3	332.5	343.0	353.8	364.9	376.2	387.9	399.8	412.0	424.5	437.4
46	241.5	250.0	258.9	268.2	277.8	287.8	298.1	308.8	319.9	331.4	343.3	355.5	368.1	381.1	394.5	408.3	422.5	437.1	452.0	467.4	483.3	499.6	516.3	533.5
47	280.9	292.4	304.4	316.9	330.0	343.6	357.8	372.5	387.7	403.4	419.8	436.6	454.1	472.1	490.7	509.9	529.8	550.4	571.7	593.8	616.7	640.5	665.3	691.0
48	344.1	360.9	378.4	396.8	416.0	436.0	456.9	478.6	501.2	524.7	549.3	574.8	601.5	629.4	658.6	689.3	721.5	755.6	791.5	829.7	870.4	913.9	960.6	1011.2
49	461.1	488.4	517.2	547.5	579.4	613.1	648.8	686.7	727.0	770.1	816.4	866.4	920.8	980.4	1046.2	1119.9	1203.3	1299.7	1413.6	1553.1	1732.9	1986.3	2419.6	>2419.6

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