EMISSIONS STUDY AND EQUIPMENT DESIGN/BUILD FOR STRIPPER WELL PRODUCTION

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ABSTRACT

Nowadays, concerns about global warming and the rise in greenhouse gasses grow each day. A major contributor to this is the hydrocarbon methane (CH_4) in natural gas. These concerns have caused government agencies, such as the United States Environmental Protection Agency, to require companies to reduce the amount of greenhouse gas emissions their oil wells release into the atmosphere. One such source of these gasses is small oil wells scattered across the United States. Eighty percent of US oil and natural gas production sites are low-production well sites. Low-production wells are a disproportionately large source of methane emissions, emitting 50% more than the total emissions from the Permian Basin, one of the world's largest oil and gas-producing regions. It is estimated that low-production well sites represent roughly half of all oil and gas well site methane emissions. Many of the standard methods of natural gas management are either too inefficient or too large a scale for the amount of methane produced. This is why this group has created a compact flaring tower to burn off the emitted methane, producing CO2 and water. The expected outcome is to yield a product that will aid in the reduction of greenhouse gasses emitted by small stripper well facilities

Keywords: Methane, Natural Gas Flaring, Emissions Study, Stripper Well Production

INTRODUCTION

The world humanity lives in faces an everyday increasing challenge, the urgent need to combat climate change and mitigate the adverse environmental impacts of industrial activities. In this search for sustainability, reducing greenhouse gas emissions, particularly methane, has emerged as a critical priority. Methane, a potent greenhouse gas, is a major contributor to global warming. It is released into the atmosphere through various sources, including, landfills, agriculture, and (what this project focuses on) oil and gas operations.

In the US, 80% of the total oil wells are considered to be small wells, meaning they produce <15 barrels of oil per day. During the process of collecting this underground oil, natural gas, such as methane is also pulled to the surface with the oil, and vented to the atmosphere. Due to the fact that these are small production wells, it is not financially feasible to store the methane pulled to the surface. Since methane is responsible for >25% of global warming we experience today, Mitigating methane emissions is crucial in curbing the planet's rising temperatures and safeguarding our environment for future generations.

One innovative solution in this battle against methane emissions is the design and implementation of flaring towers. Flaring towers, also known as flare stacks, represent a promising technology aimed at significantly reducing the release of harmful gasses into the atmosphere. These towering structures provide a controlled environment for the combustion of unwanted gasses, as seen in *Figure one*, converting them into less harmful substances such as carbon dioxide and water vapor. Flaring towers have become integral components of industries with emissions of volatile organic compounds (VOCs) and methane, as they offer a means to mitigate environmental impact while ensuring operational safety.

Other standard methods to manage the natural gas is to store it in a container next to the crude oil at a well's facility. An example of these tanks are seen in Figure two. This solution is used in instances when a well is found to have a substantial quantity of natural gas. This provides the owner or owners of the well to obtain another distributable resource from a single source point. The problem with gas storage facilities is that there needs to be a large quantity of said gas for this technique to be implemented.

The third method of managing natural gas at oil fields is to inject the gas back into the ground. This process is used when the pressure of a given well is waning, which decreases the amount of oil extracted over time. By injecting the gas back into the well, the waning pressure within the well starts to increase instead. With more pressure added into the system, the well would start increasing the rate of extraction of crude oil, increasing the production of barrels of oil per day in turn. This process is displayed in Figure three.

All companies that deal with oil and gas production have to take into account all of the methods and choose the course of action they deem to be the most ideal. One such company is Burk Royalty Co Ltd. With 1822 producing wells and an average estimated 5468 barrels of crude oil produced a day, Burk Royalty has to manage the natural gas output with heavy concern every day. Figure four shows a map which indicates the location of Burk Royalty's wells as well as pointing out these wells' current status. As a company stationed in Wichita Falls, Texas, with almost one hundred years of experience, Burk Royalty has reached out to the McCoy School of Engineering at Midwestern State University and has decided to sponsor our senior design project. They want our design group to find a way or design a device to manage the hydrocarbons being vented from their small oil wells. They have since aided our team by taking us to the oil well that will have since been taking data from as well as providing useful insight on certain factors to think about when designing mechanisms used on oil fields.

As stated before, smaller oil wells are just too small and do not have a high enough concentration of natural gas in order to use the standard methods of natural gas management. This is, unfortunately, why small oil well facilities must resort to venting the extracted methane into the atmosphere. In spite of that, this project aims to create a product or method that will manage the venting hydrocarbons coming out of Burk Royalty's small oil wells. Figure five is a picture taken of the specific oil well this project has been studying and will continue to study.

This research paper delves into the conception, design, and creation of a flaring tower, the overarching goal is to curb methane emissions and contribute to a greener and more sustainable future. As climate change becomes an increasingly pressing issue, the development of effective and efficient technologies to reduce methane emissions is crucial. This paper will explore the mechanics, benefits, and potential challenges of the design we choose to work with, aiming to shed light on their role as a vital tool in the fight against climate change and air pollution. Furthermore, it will discuss the potential implications and applications of this technology, not only for the industries in which it is employed but also for the global environment as a whole.

In order to start designing our project, the group needed to first identify several determining factors that would dictate whether or not the method or methods we chose could even be a possible method to manage methane unearthed by small pump jacks. One such factor is to find out how to separate the methane from all other materials, such as water and crude oil that are extracted from the well. This is important because the only objective the project is aimed towards achieving is the management of the excess natural gas emanating from a well. In addition to this, the concentration of methane is another variable that needs to be taken into account. Fortunately, some of these factors can be determined and measured with sensors, such as the ones made by Project Canary.

Suggested by the team of engineers at Burk Royalty Company, Project Canary is a climate technology company based in Denver, Colorado that offers companies a data platform that helps companies identify and measure their emissions. Project Canary's mission is to measure and quantify environmental risk assessments and emission profiles using software solutions to help companies improve and act on their emissions footprint. They do this by building high-fidelity sensors, ingesting data from various other technologies and sources, characterizing the accuracy of such emissions data, and deploying advanced physics-based AI-powered models to identify leaks and quantify emissions. The devices used in this project are the Canary X and the Canary Nubo. The Canary X sensor is specifically designed to track methane emissions and is able to localize and quantify emission sources and document these readings on the Canary dashboard. The Canary Nubo, or the Sensirion Nubo Sphere as it is labeled on Project Canary's website, is designed for versatility as well as being modeled for streamlined maintenance. Using a cartridge system that is exchangeable and being able to operate in tougher operating environments, the Nubo sensor is the ideal sensor for universal use. In addition to being a universally reliable sensor, the Nubo also integrates without a hitch into Project Canary's emissions dashboard.

The sensors implemented by Project Canary consist of three Canary Xs and one Canary Nubo. These sensors have been installed in the formation seen in Figure six, with the Canary Xs being placed at three points on the North side of the oil field and the Canary Nubo being placed South, adjacent to the wellhead. The primary objective of the Nubo is to measure the concentration of methane at the wellhead while the Canary Xs are measuring the same but near the facilities. This data was not immediately available. This is because the sensors need approximately a month to calibrate before the information is sent to the Canary dashboard. While the data was being gathered by the Canary sensors, the group worked on what they could with the information that they had. This includes creating rough designs of initial proposed methods for managing the methane, which will be discussed later in this introduction, as well as formulating equations and creating codes that provided useful information when the sensors eventually began to send their readings to the Canary dashboard. To clarify, the Canary dashboard is a web page in which all the data submitted by the Canary X sensors, as well as the Canary Nubo sensor, are sent to and quantified. Not only is the data quantified, but it also is put into graphs and charts to show the data in a visual display which allows the information to be shown in a streamlined fashion. When the group first gained access to the Canary dashboard, the information we were first able to obtain was the concentration of the methane, in parts per million (ppm), with respect to time. Figure seven shows this relation gathered by the Canary Nubo while Figure eight shows the relation gathered by the three Canary Xs. What is so helpful about the Canary Xs and the Canary Nubo is that these sensors send new data they record to the Canary dashboard every sixty seconds. In addition to constant reporting from the Canary sensors, the Canary dashboard also shows when the concentrations of methane were recorded starting from the initial recorded concentration up to the most recent value sent by the Canary sensors. These graphs are also able to be scaled down in order to see more clearly the times the methane concentration is the highest in a given week or day, as well as being able to be scaled up so that an entire month's worth of collected data can all be seen at once. After the initial brainstorming phase, the senior design group had to choose between two different ideas on how to manage the oil well's ventilation of methane. The two options the group had to pick between were either a compact flaring tower or a zeolite filtration system. The compact flaring system option would be to create a flaring tower that would be scaled down in size which then would be able to burn off the low concentrations of methane. The greatest question to consider with this hypothetical solution is if a flaring tower can even function when scaled down. The zeolite filtration method uses a cheap ceramic material called zeolite that has been enriched with a small amount of copper to increase the effectiveness of the zeolite's ability to absorb Methane and break it down into CO2 and weather (H2O). What is most notable about this method is that zeolite is a very inexpensive material, meaning that the cost for keeping this filtration system running would be a very low cost solution. The biggest issue with this theoretical solution is that as of the time of this project, there is not enough information on the zeolite filtration system that this senior design group found to warrant the use of this method. After a discussion period between peers, the design group chose to create a compact flaring tower in order to burn off the methane gas coming from small oil wells. While this project will not focus on the use of zeolite filtration as a method for managing the natural gas emissions of flaring towers, this does not mean that it should not be pursued outright. More research needs to be done by other parties in order to start a feasible way to take the zeolite filtration to the light.

The following sections will provide an in-depth analysis of the design principles, operational considerations, environmental impact, and economic viability of flaring towers. Additionally, we will explore the broader context in which these structures operate, addressing the evolving regulatory landscape and the imperative to balance industrial demands with environmental responsibilities. By understanding the science, technology, and policy dimensions of flaring towers, this research aims to contribute to a more sustainable future and a reduction in harmful emissions that imperil our planet.

APPARATUS DESCRIPTION

Initial Designs

Figure 9 is the first iteration of our design. It serves as the basis of our current design since it shares the same features and the intended purpose of it was to be a reference. This is because, after hours of research, the main ideas that we came up with were implemented into the initial design. It consists of a flaring tower where gas will be transferred up to be ignited, a water seal tank to create a layer between gasses to minimize the chances of a catastrophic explosion, and the inlet for the gas to go into the water seal tank.

Current Design

Our current design of the flaring tower, and all of the drawings can be found in the appendix. This design was updated from the initial one and more features were added to it to make it more practical, efficient, and safe. A stainless steel pipe will be used to serve as the flaring tower portion of this design. It will be roughly 3 feet tall and it is meant to serve as a pathway for the hydrocarbons to be ignited. It will be made of 310 stainless steel, which is more practical in high-temperature applications, due to its 25% chromium and 25% nickel content. In the top portion of the pipe, there will be a velocity seal welded on. This is a nozzle that will prevent outside air from proceeding down past the velocity seal to prevent explosions from occurring. This design was added due to air molecules possibly sticking to the inside of the pipe. The decrease in diameter size will also increase the velocity of the hydrocarbons at this outlet, which can be further studied using Bernoulli's Law. The bottom portion of the pipe will be connected to the water seal drum using a short pipe. This short pipe will be welded onto the water seal drum. On the end of the short pipe and flaring tower will be a flange welded onto each one. Therefore, flanges will be the method of connection for our design. These ½-inch thick stainless steel flanges will have four ⅝ inch cutouts for studs to go through. These flanges will be connected using fully threaded studs and hex nuts for a better clamping force than we had previously. The initial design used hex bolts and hex nuts, but after researching the proper connections, flanges typically use studs. In between these flanges, is a flange gasket to prevent the leakage of hydrocarbons. Our choice of material for the gasket was either neoprene or nitrile, but we went with nitrile, due to it being more environmentally resistant. Neoprene and nitrile are still both great candidates in terms of being the material of choice when being in contact with hydrocarbons. The water seal tank is to prevent explosions by creating a layer between the gas coming to be ignited from the well and the gas that is about to be ignited. If an explosion were to occur, only the gas passing the water boundary would be ignited since it wouldn't be in contact with the gas coming out of the inlet of the water seal tank. We also added a drainage system for the water seal drum. The purpose of this is to automatically drain the water using head pressure if the water level gets too high so it doesn't create the tendency to try and travel too far up the water seal drum inlet. The level of the drainage piping is set lower than the inlet to force water through it using head pressure if it is higher than that of the water in the piping. Since the tower is directly connected to the tank, occurrences such as rain would cause it to fill up unexpectedly, which is another reason why this design was implemented.

Electrical Circuit Design

For the gas to ignite, a standard spark plug is installed at the top of the tower. This plug is powered via a twelve-volt DC car battery that is connected to a solar panel in order to maintain the battery's charge. An emergency push button is the first node put into the circuit after the twelve volt as a safety measure. After the emergency push button, a toggle switch is added to act as the on/off switch. The next device in the circuit is a motion sensor which is used to determine if the spark plug needs to be sparking. The way that this is determined is by having the motion sensor placed under the pumpjack, while facing the walking beam. This makes it so that when the pumpjack is pumping, the sensor detects the movement of the walking beam and therefore allows the electric current to continue through the circuit. Once the current is able to pass through the sensor, it comes to an ignition coil. This coil acts as a step up transformer to raise the current's initial voltage of twelve volts (DC) to the necessary voltage required for the spark plug to activate, that being approximately twelve thousand volts. Once the current passes through the spark plug, it then goes through the ignition coil again, where the voltage is then brought back down to twelve volts, and then travels back all the way to the car battery, completing the circuit.

THEORY

Flare design is influenced by several factors, including the availability of space, the characteristics of the flare gas (namely composition, quantity, and pressure level) and occupational concerns. The sizing of flares requires the determination of the required flare tip diameter and height. The emphasis of this section will be to size a steam-assisted elevated flare for a given application.

Auxiliary Fuel Requirement

The flare tip diameter is a function of the vent gas flow rate plus the auxiliary fuel. The flow rate of the auxiliary fuel, if required, is significant, and must be calculated before the tip diameter can be computed. Some flares are provided with auxiliary fuel to combust hydrocarbon vapors when a flare gas stream falls below the flammability range or heating value necessary to sustain a stable flame. The amount of fuel required, F, is calculated based on maintaining the vent gas stream net heating value at the minimum of 300 Btu/scf required by rules defined in the Federal Register.

$$B_v + FBf = (Q + F)(300\ BTU/scf) \qquad (1)$$

where: Q = flow rate of the waste gas stream (scfm), F = Flow rate of the auxiliary fuel (scfm), B_v = Heat content of the waste gas stream (BTU/scf), Bf = Heat content of the auxiliary fuel (BTU/scf).Rearranging gives:

$$F(scfm) = Q((300 - B_v)/(Bf - 300)) \qquad (2)$$

The annual auxiliary fuel requirement, Fa , is calculated by:

$$F_a(Mscf/yr) = F\,(scfm)60(min/hr)8760(hr/yr) = 526F\ scfm/yr \qquad (3)$$

Typical natural gas has a net heating value of about 1,000 Btn/scf. Automatic control of the auxiliary fuel is ideal for processes with large fluctuations in VOC compositions. These flares are used for the disposal of such streams as sulfur tail gasses and ammonia waste gasses, as well as any low Btu vent streams.

Flare Tip Diameter

Flare tip diameter is generally sized on a velocity basis, although pressure drop must also be checked. Flare tip sizing for flares used to comply with EPA air emission standards is governed by rules defined in the Federal Register. To comply with these requirements, the maximum velocity of a steam-assisted elevated flare is given below:

Maximum Velocity of Steam-Assisted Elevated Flare

For a net heating value of vent stream B_v (BTU/scf) of 1000:

$$log_{10}(V_{max}) = ((B_v + 1{,}214))/852 \qquad (4)$$

By determining the maximum allowed velocity, $,V_{max}$ (ft/sec), and knowing the total volumetric flow rate, Q_{tot} (acfm), including vent stream and auxiliary fuel gas, a minimum flare tip diameter, D_{min} (in), can be calculated. It is standard practice to size the flare so that the design velocity of flow rate Q_{tot} , is 80 percent of V_{max} i.e.:

$$D_{\min}\,(in) = 12\surd((4/\Pi\ \ (Q_{\text{tot}})/(60(sec/min)))/(0.8\,V_{\max})) \qquad (5)$$

where, Q_{tot} = Q + F (measured at stream temperature and pressure)The flare tip diameter, D, is the calculated diameter, D = D_{min}, rounded up to the next commercially available size.

The minimum flare size is 1 inch; larger sizes are available in 2-inch increments from 2 to 24 inches and in 6-inch increments above 24 inches. The maximum size commercially available is 90 inches.

A pressure drop calculation is required at this point to ensure that the vent stream has sufficient pressure to overcome the pressure drop occurring through the flare system at maximum flow conditions. The pressure drop calculation is site specific but must take into account losses through the collection header and piping, the knock-out drum, the liquid seal, the flare stack, the gas seal, and finally the flare tip. Piping size should be assumed equal to the flare tip diameter. Schedule 40 carbon steel pipe is typically used.

If sufficient pressure is not available, the economics of either a larger flare system (pressure drop is inversely proportional to the pipe diameter) or a mover such as a fan or compressor must be weighed.

Flare Height

The height of a flare is determined based on the ground level limitations of thermal radiation intensity, luminosity, noise, height of surrounding structures, and the dispersion of the exhaust gasses. In addition, consideration must also be given for plume dispersion in case of possible emission ignition failure. Industrial flares are normally sized for a maximum heat intensity of 1,500-2,000 Btu/hr-ft2 when flaring at their maximum design rates. At this heat intensity level, workers can remain in the area of the flare for a limited period only. If, however, operating personnel are required to remain in the unit area performing their duties, the recommended design flare radiation level excluding solar radiation is 500 Btu/hr-ft2 . The intensity of solar radiation is in the range of 250-330 Btu/hr-ft2 . Flare height may also be determined by the need to safely disperse the vent gas in case of flameout. The height in these cases would be based on dispersion modeling for the particular installation conditions and is not addressed here. The minimum flare height normally used is 30 feet. Equation (1.6) by Hajek and Ludwig may be used to determine the minimum distance, L, required from the center of the flare flame and a point of exposure where thermal radiation must be limited.

$$L^2(ft^2) = (J\ f\ R)/(4\ \pi\ K) \qquad (6)$$

where: J = fraction of heat intensity transmitted, f = fraction of heat radiated, R = net heat release (Btu/hr), K = allowable radiation

The conservative design approach used here ignores wind effects and calculates the distance assuming the center of radiation is at the base of the flame (at the flare tip), not in the center. It is also assumed that the location where thermal radiation must be limited is at the base of the flare. Therefore, the distance, L, is equal to the required flare stack height (which is a minimum of 30 feet). The f factor allows for the fact that not all the heat released in a flame can be released as radiation. Heat transfer is propagated through three mechanisms: conduction, convection, and radiation. Thermal radiation may be either absorbed, reflected, or transmitted. Since the atmosphere is not a perfect vacuum, a fraction of the heat radiated is not transmitted due to atmospheric absorption (humidity, particulate matter). For estimating purposes, however, we assume all of the heat radiated is transmitted (i.e., r = 1). Table 1.1 is a summary of heat radiated from various gaseous diffusion flames:

In general, the fraction of heat radiated increases as the stack diameter increases. If stream-specific data is not available, a design basis of f = 0.2 will give conservative results. The heat release, R, is calculated from the flare gas flow rate, W, and the net heating value, B_v , as follows:

$$R(BTU/hr) = W(lb/hr)B_v(BTU/lb) \qquad (7)$$

Purge Gas Requirement

The total volumetric flow to the flame must be carefully controlled to prevent low flow flashback problems and to avoid flame instability. Purge gas, typically natural gas, N_2 , or CO_2 , is used to maintain a minimum required positive flow through the system. If there is a possibility of air in the flare manifold, N_2 , another inert gas, or a flammable gas must be used to prevent the formation of an explosive mixture in the flare system. To ensure a positive flow through all flare components, purge gas injection should be at the farthest upstream point in the flare transport piping. The minimum continuous purge gas required is determined by the design of the stack seals, which are usually proprietary devices. Modern labyrinth and internal gas seals are stated to require a gas velocity of 0.001 to 0.04 ft/sec (at standard conditions). Using the conservative value of 0.04 ft/sec and knowing the flare diameter (in), the annual purge gas volume, F_{pu}, can be calculated:

$$F_{pu}(Mscf/yr) = (0.04\ ft/sec)(\pi D^2/(4/144)\ ft^2)(3{,}600\ sec/hr)(8760\ hr/yr) = 6.88D^2(Mscf/yr) \qquad (8)$$

There is another minimum flare tip velocity for operation without burn lock or instability. This minimum velocity is dependent on both gas composition and diameter and can range from insignificant amounts on small flares to 0.5 ft/sec on greater than 60-inch diameter units.

Purge gas is also required to clear the system of air before startup, and to prevent a vacuum from pulling air back into the system after a hot gas discharge is flared. (The cooling of gasses within the flare system can create a vacuum.) The purge gas consumption from these uses is assumed to be minor.

Pilot Gas Requirement

The number of pilot burners required depends on flare size and, possibly, on flare gas composition and wind conditions. Pilot gas usage is a function of the number of pilot burners required to ensure positive ignition of the flared gas, of the design of the pilots, and of the mode of operation. The average pilot gas consumption based on an energy-efficient model is 70 scf/hr (of typical 1000 Btu per scf gas) per pilot burner. The number of pilot burners, N, based on flare size is:

The annual pilot gas consumption, Fpi is calculated by:

$$F_{pi}(Mscf/yr) = (70 \ sec/hr)(N)(8760 \ hr/yr) = (613 \, scf/yr)N \qquad (9)$$

Steam Requirement

The steam requirement depends on the composition of the vent gas being flared, the steam velocity from the injection nozzle, and the flare tip diameter. Although some gasses can be flared smokelessly without any steam, typically 0.01 to 0.6 pounds of steam per pound of flare gas is required. The ratio is usually estimated from the molecular weight of the gas, the carbon-to-hydrogen ratio of the gas, or whether the gas is saturated or unsaturated. For example, olefins, such as propylene, require higher steam ratios than would paraffin hydrocarbons to burn smokelessly. In any event, if a proprietary smokeless flare is purchased, the manufacturer should be consulted about the minimum necessary steam rate. A small diameter flare tip (less than 24 inches) can use steam more effectively than a large diameter tip to mix air into the flame and promote turbulence. For a typical refinery, the average steam requirement is typically 0.25 lb/lb, with this number increasing to 0.5 lb/lb in chemical plants where large quantities of unsaturated hydrocarbons are flared. For general consideration, the quantity of steam required, S, can be assumed to be 0.4 pounds of steam per pound of flare gas, W Using a 0.4 ratio, the amount of steam required is:

$$S(lbs/yr) = (0.4 \, (lb \ steam)/(lb \ flare \ gas))(W \ lb/yr)(8760 \ hr/yr) \qquad (10)$$

Operating a flare at too high a steam-to-gas ratio is not only costly, but also results in a lower combustion efficiency and a noise nuisance. The capacity of a steam-assisted flare to burn smokelessly may be limited by the quantity of steam that is available.

Knock-out Drum

The knock-out drum is used to remove any liquids that may be in the vent stream. Two types of drums are used: horizontal and vertical. The economics of vessel design influences the choice between a horizontal and a vertical drum. When a large liquid storage vessel is required and the vapor flow is high, a horizontal drum is usually more economical. Vertical separators are used when there is small liquid load, limited plot space, or where ease of level control is desired. It is assumed here that the drum is not sized for emergency releases and that liquid flow is minimal. Flares designed to control continuous vent streams generally have vertical knockout drums, whereas emergency flares typically have horizontal vessels. The procedure described below applies to vertical drums exclusively. A typical vertical knock-out drum is presented in Figure 12.

$$U(ft/sec) = G\sqrt{((p_l - p_v)/p_v)} \qquad (11)$$

Where: G= design vapor velocity factor, p_l and p_v = liquid and vapor densities (lb/ft3), Note that in most cases,

$$(p_l - p_v)/p_v = (p_l)/p_v \qquad (12)$$

The design vapor velocity factor, G, ranges from 0.15 to 0.25 for vertical gravity separators at 85% of flooding. Once the maximum design vapor velocity has been determined the minimum vessel cross-sectional area, A, can be calculated by:

$$A(ft^2) = (Q_n(ft/min))/((60 \, sec/min)(U \, ft/sec)) \qquad (13)$$

Where Q_n is the vent stream flow in actual ft³ /min, or Q adjusted to the vent stream temperature and pressure. The vessel diameter, d_{min}, is then calculated by:

$$d_{min} = \sqrt{(4/\pi A)} \qquad (14)$$

In accordance with standard head sizes, drum diameters in 6-inch increments are assumed so: d = d min (rounded to the next largest size). Some vertical knockout drums are sized as cyclones and utilize a tangential inlet to generate horizontal separating velocities. Vertical vessels sized exclusively on settling velocity (as in the paragraph above) will be larger than those sized as cyclones. The vessel thickness, t, is determined from the diameter as shown in Table 1.3. Proper vessel height, h, is usually determined based on required liquid surge volume. The calculated height is then checked to verify that the height-to-diameter ratio is within the economic range of 3 to 5. For small volumes of liquid, as in the case of continuous VOC vent control, it is necessary to provide more liquid surge than is necessary to satisfy the h/d > 3 condition. So for purposes of flare knock-out drum sizing: h =3d, Where, h = height (inches)   D = diameter

Gas Mover System

The total system pressure drop is a function of the available pressure of the vent stream, the design of the various system components, and the flare gas flow rate. The estimation of actual pressure drop requirements involves complex calculations based on the specific system's vent gas properties and equipment used. For the purposes of this section, however, approximate values can be used. The design pressure drop through the flare tip can range from 0.1 to 2 psi with the following approximate pressure drop relationships. The total system pressure drop ranges from about 1 to 25 psi.

CONCLUSION

Our aim has been to design a device capable of managing natural gas being emitted from small oil wells in a reliable fashion. After weeks of analysis, calculations, designing, and redesigning, our team has created a design for a compact flaring tower able to effectively flare low concentrations of methane affiliated to the target well sizes this project has been aimed towards. This process has been greatly aided and will continue to be aided by Project Canary's sensors collecting vital data on the methane concentration around the Burk Royalty oil well and its facility. Without this information gathered by the sensors, a great deal more time would have been needed to be set aside in order to quantify critical factors in designing the current design of this project's flaring tower.

What would be an ideal continuation of this project would be to enter the production phase and commence with the construction of an initial prototype of the compact flaring tower. Our goal for next semester is to discover the foremost method of gathering and/or crafting the components for our device in order to start the construction of the first prototype of our project. What our group needs to keep in mind is that Burk Royalty, as a company, works with numerous design projects and material allocation as a constant undertaking; therefore reaching out to the Company's engineers in order to ask for guidance on how and where to obtain the resources needed for our plans. Once a prototype has been constructed, we intend to transport it to the observed oil well and install it onto the system and observe the effect it has on the local concentration of methane around the site by checking the Project Canary dashboard for any changes in the patterns of the data recorded by the sensors.

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We would like to thank Burk Royalty for this amazing opportunity, and the rest of the McCoy School of Engineering faculty and staff at Midwestern State University.

APPENDIX

Table 1: Heat from Various Gaseous Diffusion Flames

Gas	Flare Tip Diameter (in)	Fraction of Heat Radiated (f)
Hydrogen	<1	.10
	1.6	.11
	3.3	1.6
	8.0	1.5
	16.0	1.7
Butane		
	<1	.29
	1.6	.29
	3.3	.29
	8.0	.28
	16.0	.30
Methane		
	<1	.16
	1.6	.16
	3.3	.15
Natural Gas		
	8.0	.19
	16.0	.23

Table 2: Number of Burners by Flame Tip Diameter

Flare Tip Diameter (in)	Number of Pilot Burners (N)
1-10	1
12-24	2
30-60	3
>60	4

Table 3: Vessel Thickness based on Diameter

Diameter, *d* (inches)	Thickness, *t* (inches)
d<36	0.25
36<d<72	0.37
72<d<108	50.5
108<d<144	0.75
d>144	1.0

Table 4: Design Pressure Losses through the Flare Tip

Equipment	Approximate Pressure Loss
Gas seal:	1 to 3 times flare tip pressure drop
Stack:	0.25 to 2 times flare tip pressure drop
Liquid seal and Knock out drum:	1 to 1.5 times flare tip pressure drop *plus* pressure drop due to liquid depth in the seal, which is normally 0.2 to 1.5 psi.
Gas collection system:	calculated based on diameter, length, and flow. System is sized by designer to utilize the pressure drop available and still leave a pressure at the stack base of between 2 and 10 psi.

Table 5: Gantt Chart

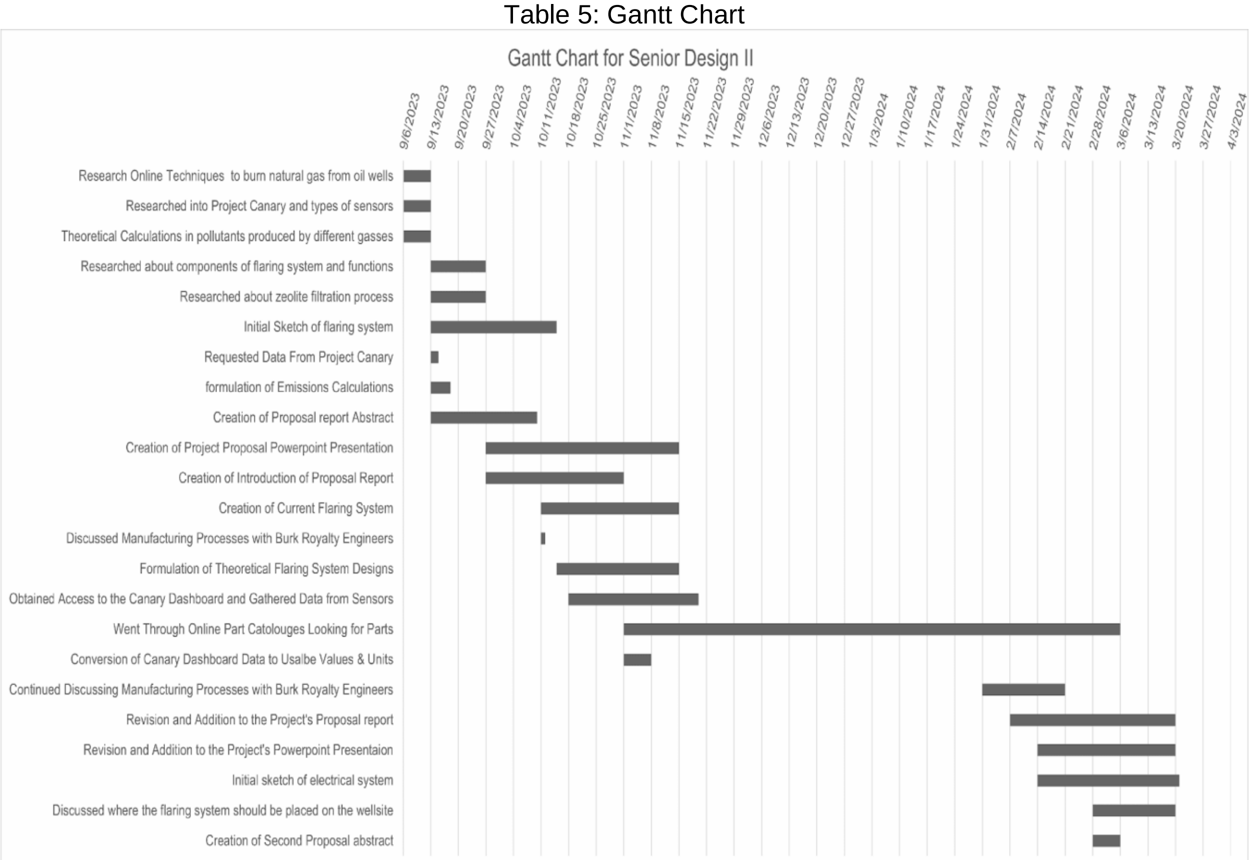

Figure 1: A standard on-site flaring tower

Figure 2: A Natural Gas Storage Tank

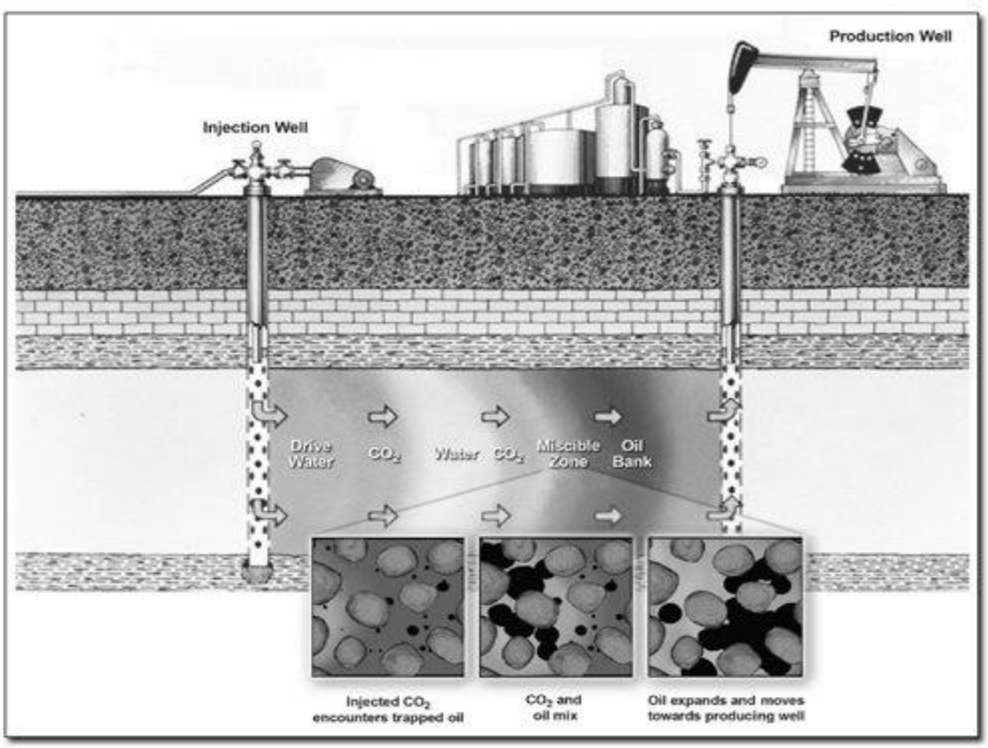

Figure 3: Graphic of the Process of Gas Injection

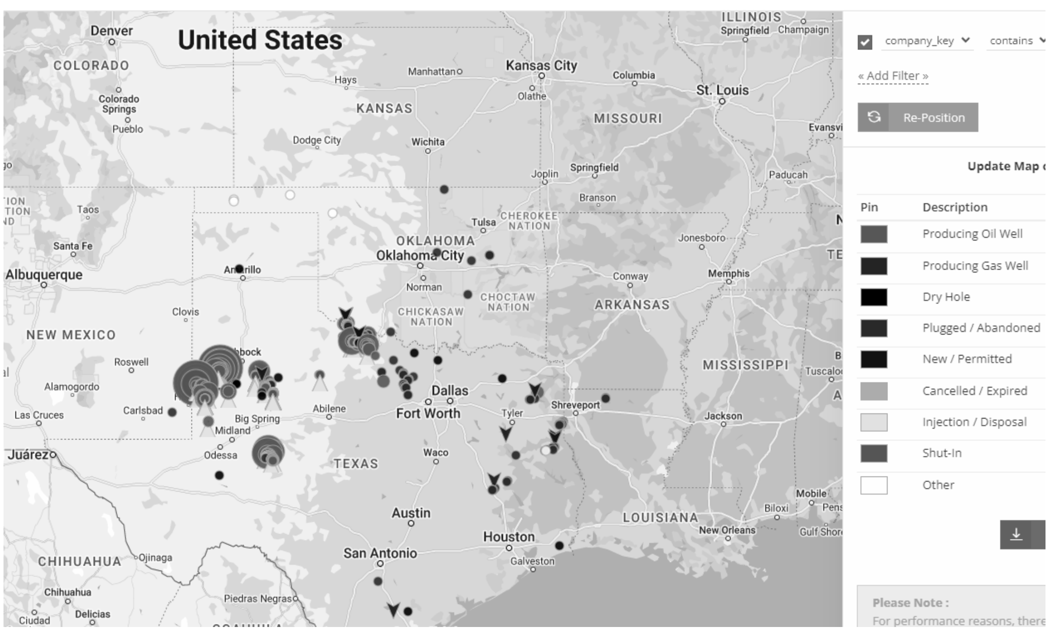

Figure 4: A Map Showing Burk Royalty’s Wells and Their Locations

Figure 5: The Pumpjack Located at the Observed Well at the Doneghy Facility

Figure 6: Map View of the Observed Oil Well from the Project Canary Dashboard

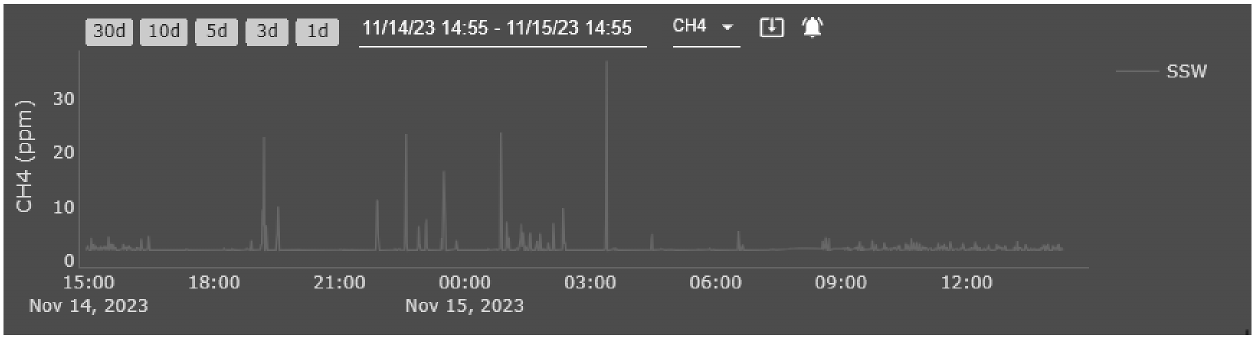

Figure 7: The Concentration of methane with respect to time gathered by the Canary Nubo

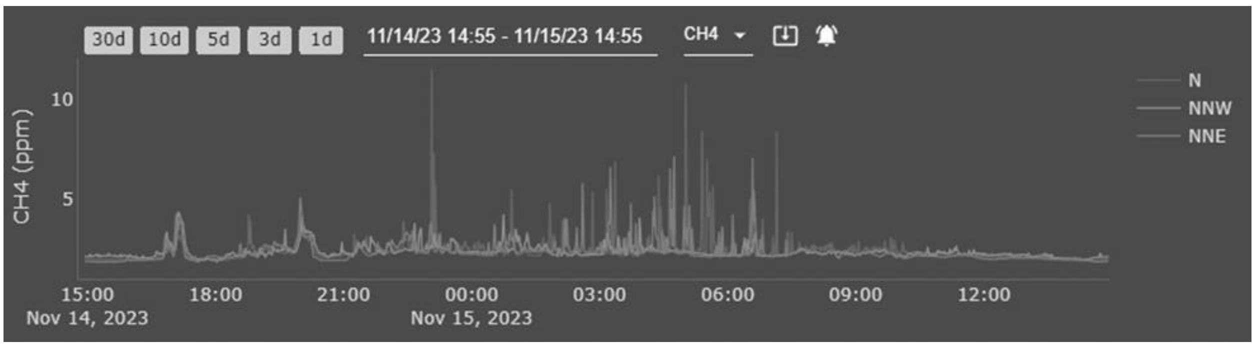

Figure 8: The concentration of methane with respect to time gathered by the three Canary Xs

Figure 9: Isometric View of Initial Design

Figure 10: Isometric View of Current Design

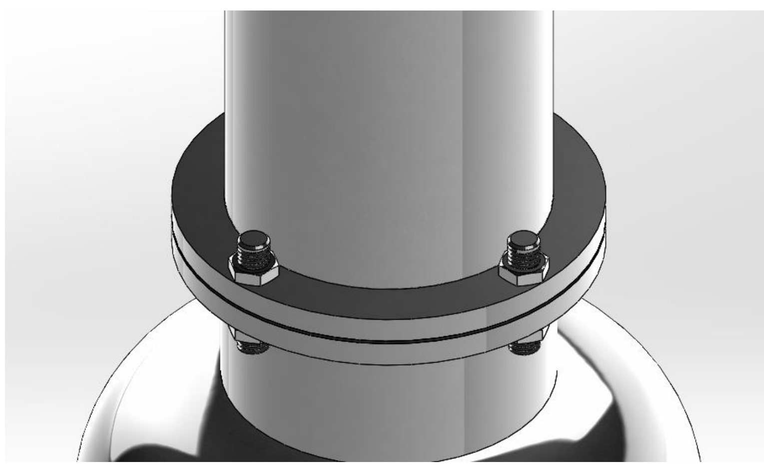

Figure 11: Zoomed-In View of Tower Connection

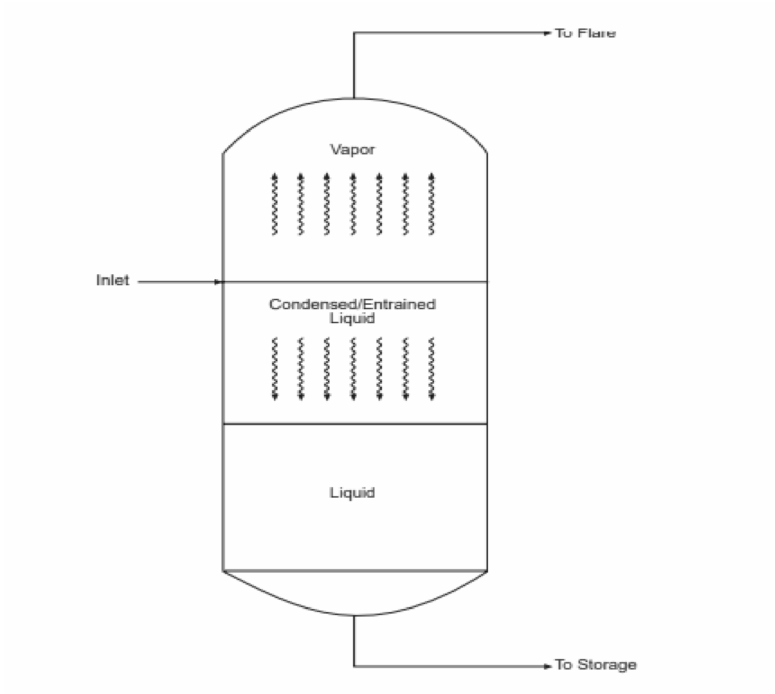

Figure 12: Typical vertical Knockout Drum

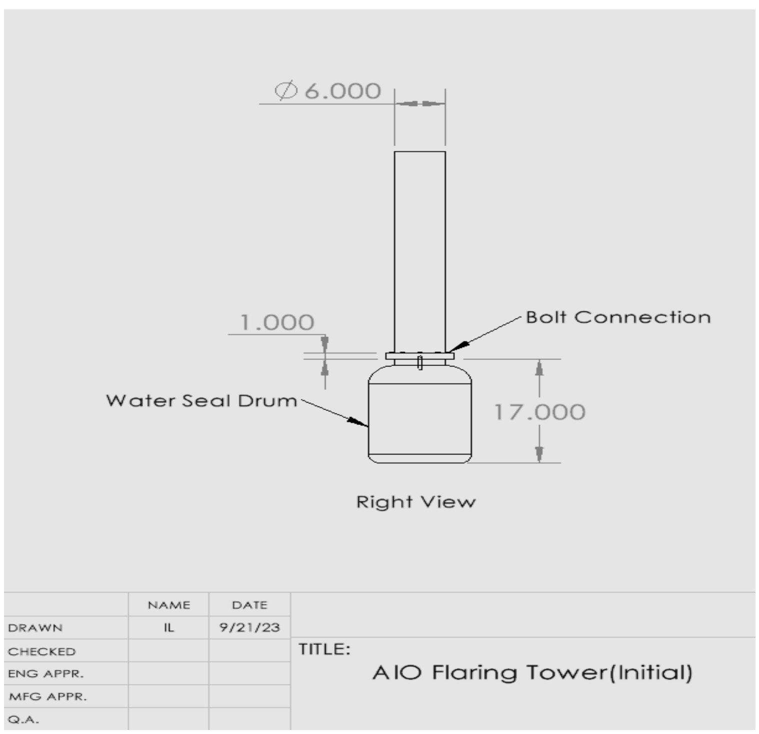

Figure 13: Right Side View of Initial Design Sketch

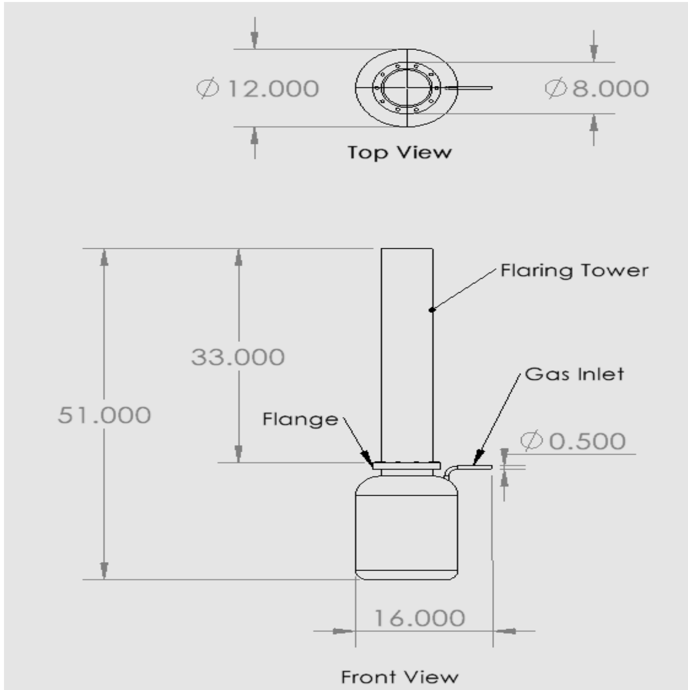

Figure 14: Top and Front View of Initial Design Sketch

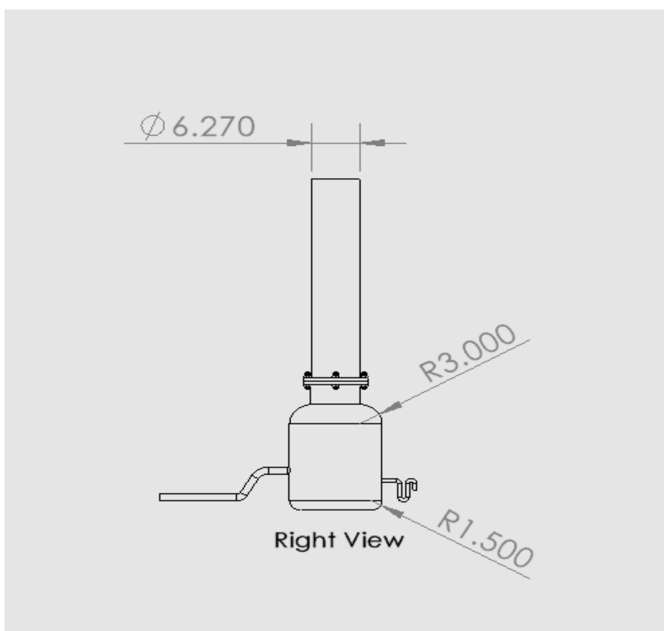

Figure 15: Right Side View of Current Design Sketch

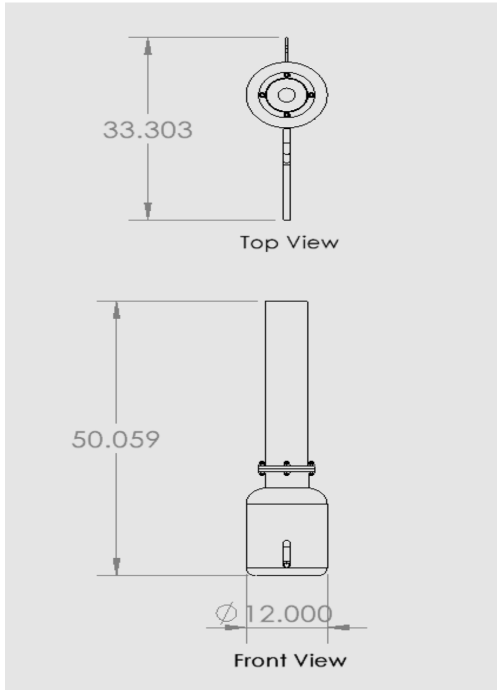

Figure 16: Top and Front View of Current Design Sketch

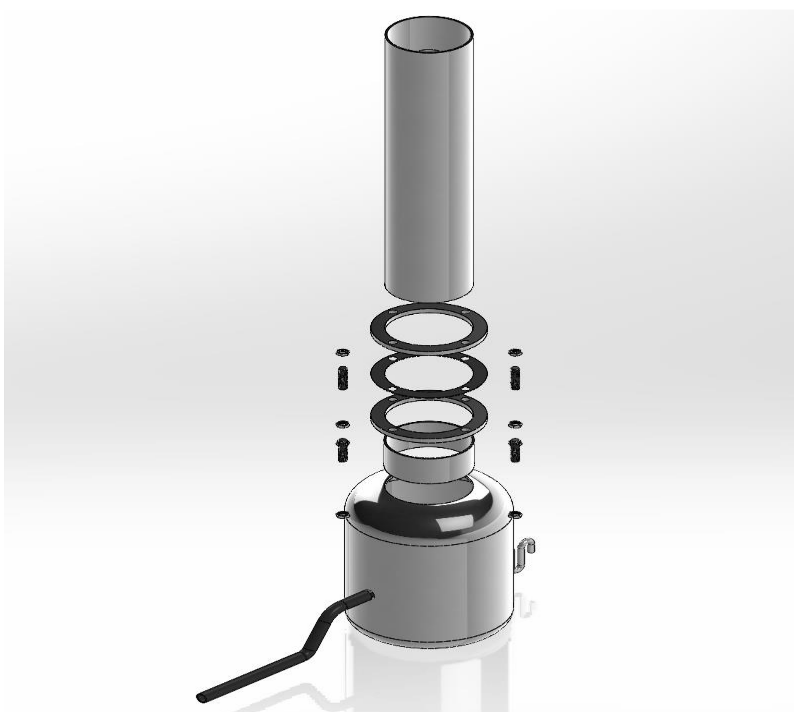

Figure 17: Exploded View of Current Design

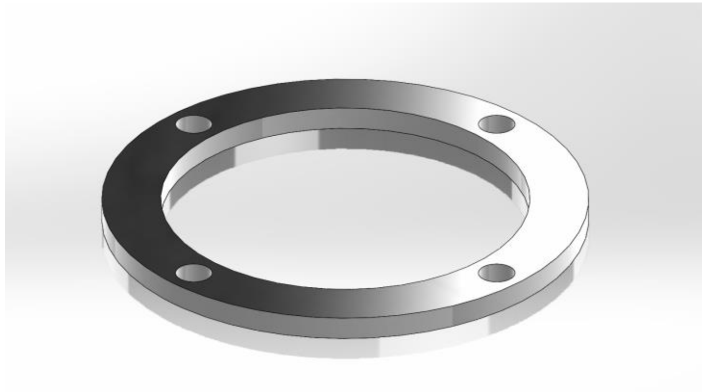

Figure 18: Flat Face Flange Design

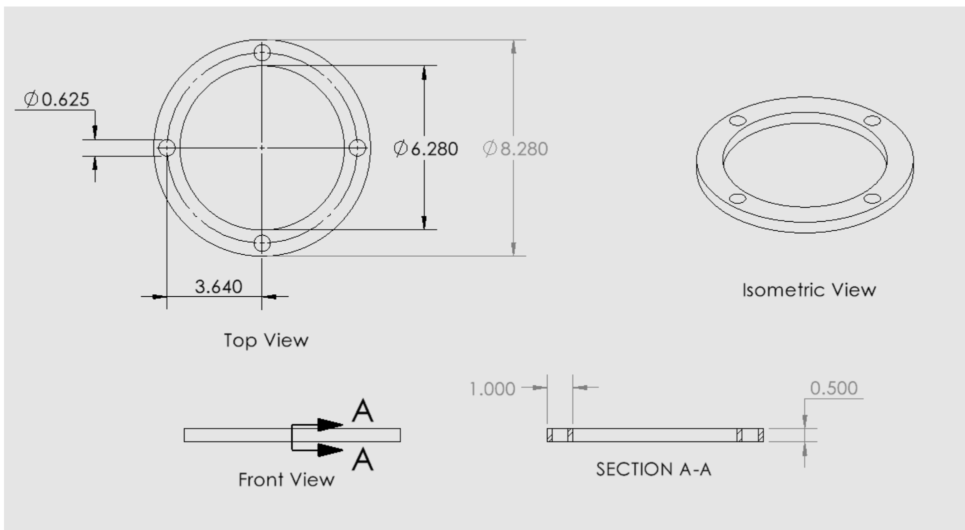

Figure 19: Sketch of Flat Face Flange

Figure 20: Flange Gasket Design

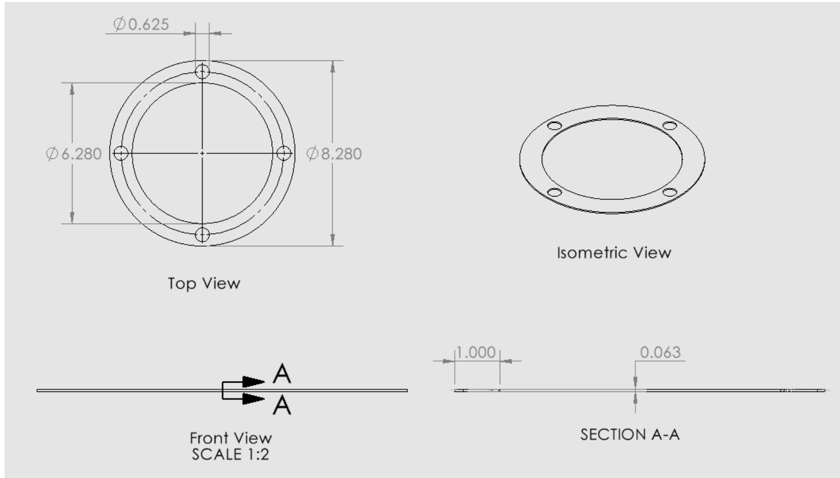

Figure 21: Sketch of Flange Gasket

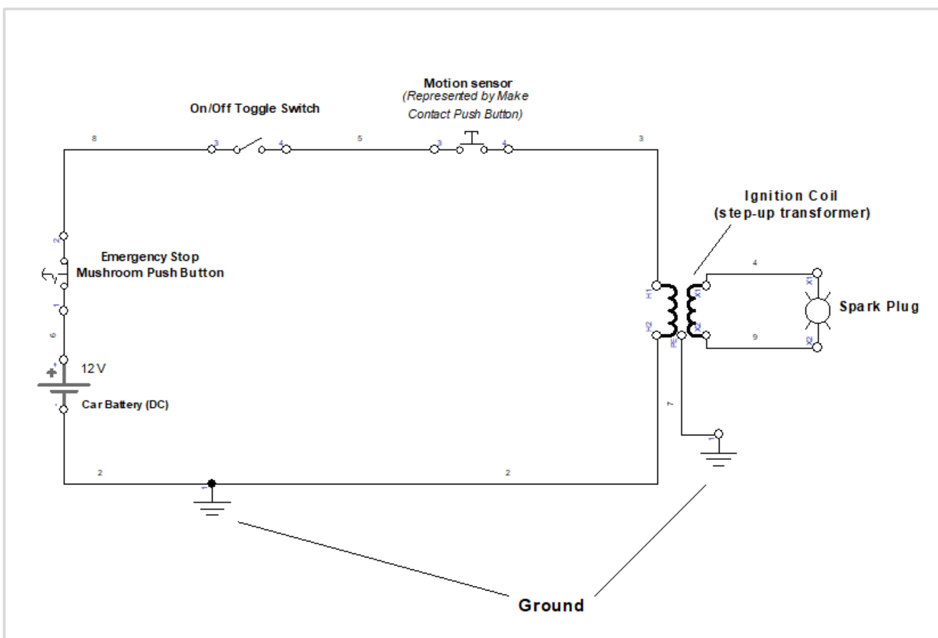

Figure 22: Simplified Version of the Electrical Ignition System