Carbon Particle Generator

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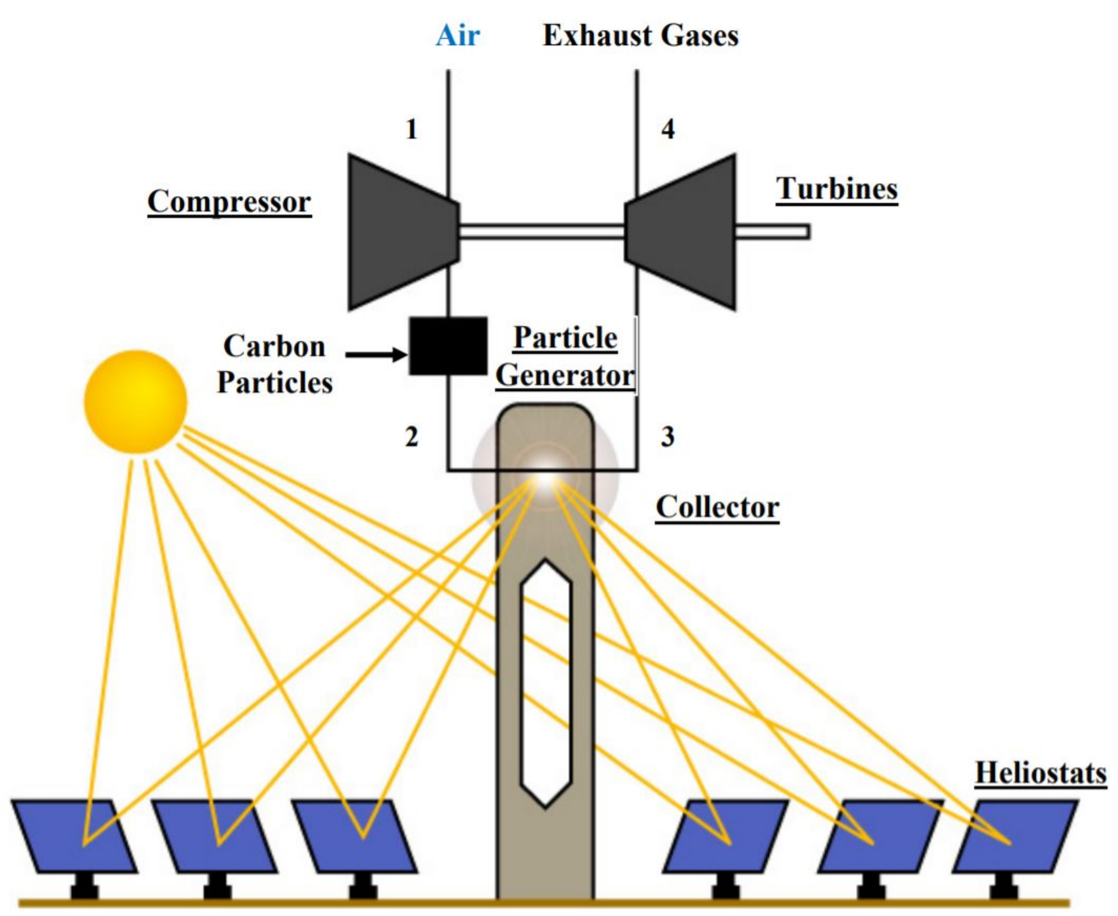
Background

According to the U.S. Energy Information Administration, 63% of the energy generated in the United States came from fossil fuels, with only 18% produced by renewable energy sources. As prices for coal and petroleum keep increasing, the need for cleaner and more efficient sources becomes clear. Prototypes for Brayton Cycles employing solar energy began in the 1980's by Dr. Miller and Dr. Hunt using carbon to absorb solar energy. This carbon is introduced through a carbon particle generator using pyrolysis, which is the decomposition of a substance by high temperatures in the absence of oxygen (prevents combustion). The latest iteration in Dr. Miller's lab is a large generator that uses a gas fuel to produce batches of carbon in low quantities. By using a liquid fuel, more carbon can be produced per unit mass of fuel, improving the efficiency of the generator.

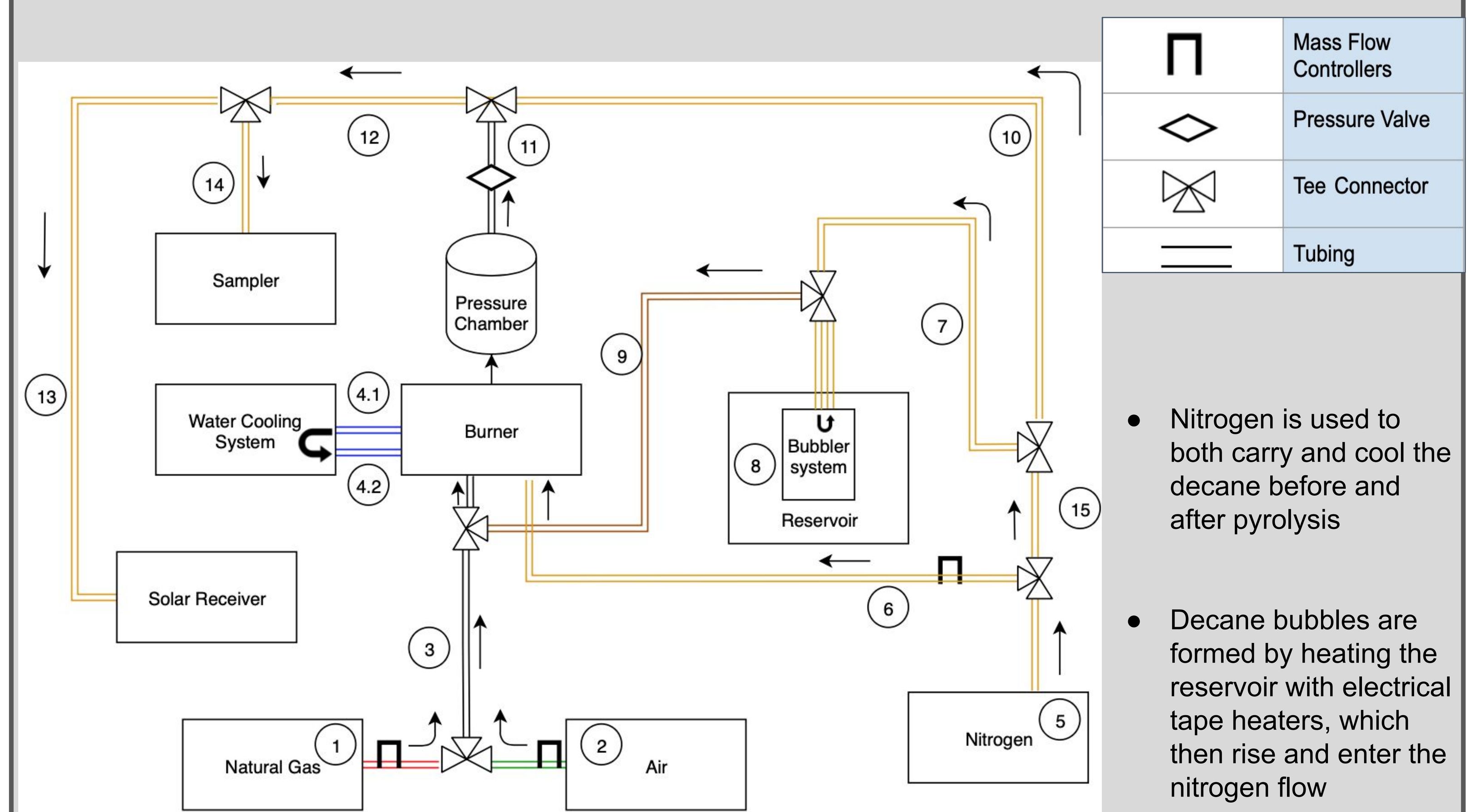


Objectives

- The new carbon particle generator should use a liquid hydrocarbon fuel
- The generator should be pressurized to match the pressure in the solar simulator
- There must be a constant production of carbon without interruption for extended hours
- The carbon particles should not agglomerate and maintain a diameter for optimal light absorption
- The generator should provide enough mass flow for efficient absorption of light and minimize energy wasted

Design Overview

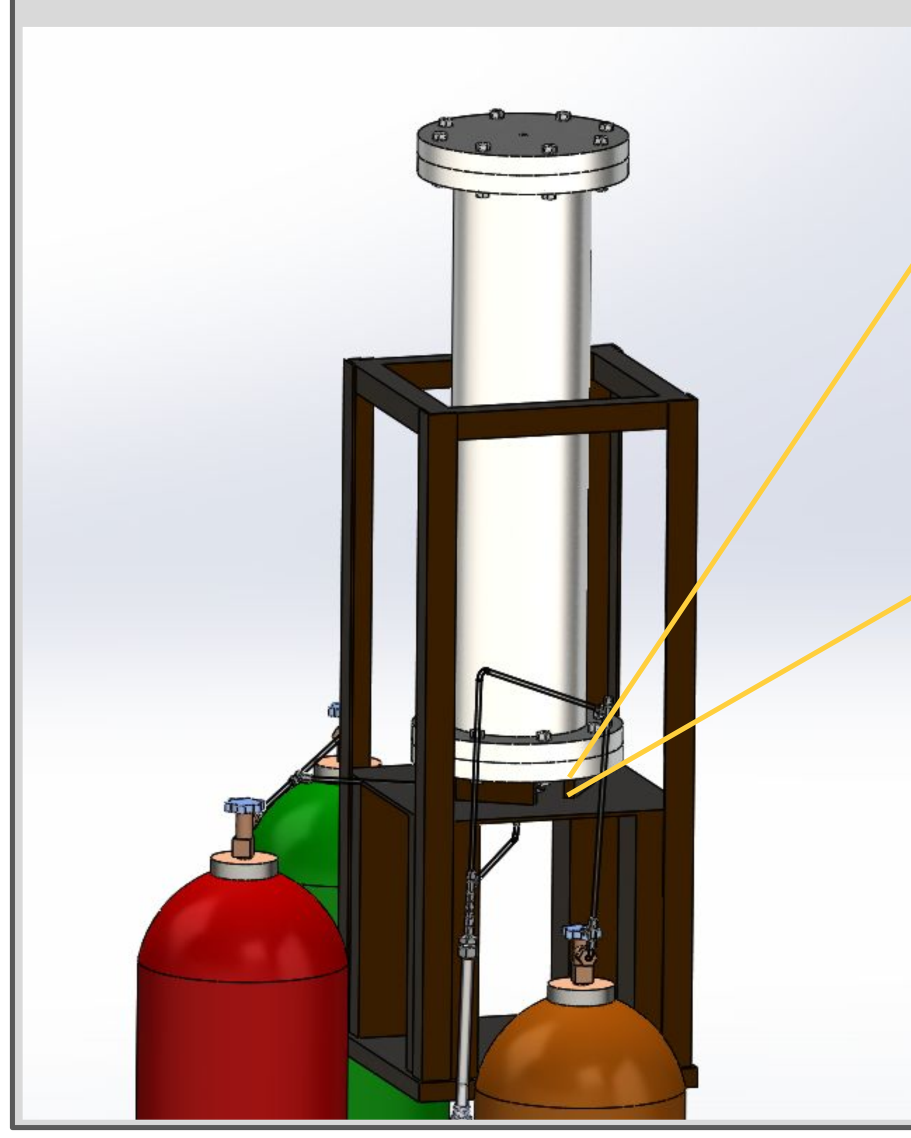
The final design incorporates a steel pressure chamber where liquid decane bubbles carried by nitrogen enter from the bottom **(9)**. A water-cooled porous burner is located inside the pressure chamber where it will decompose the liquid decane through pyrolysis **(4)**. This carbon is then carried upwards out of the pressure chamber through a nitrogen shroud included in the porous burner **(11)**. It will then travel into Solar Receiver to absorb solar energy **(13)**.

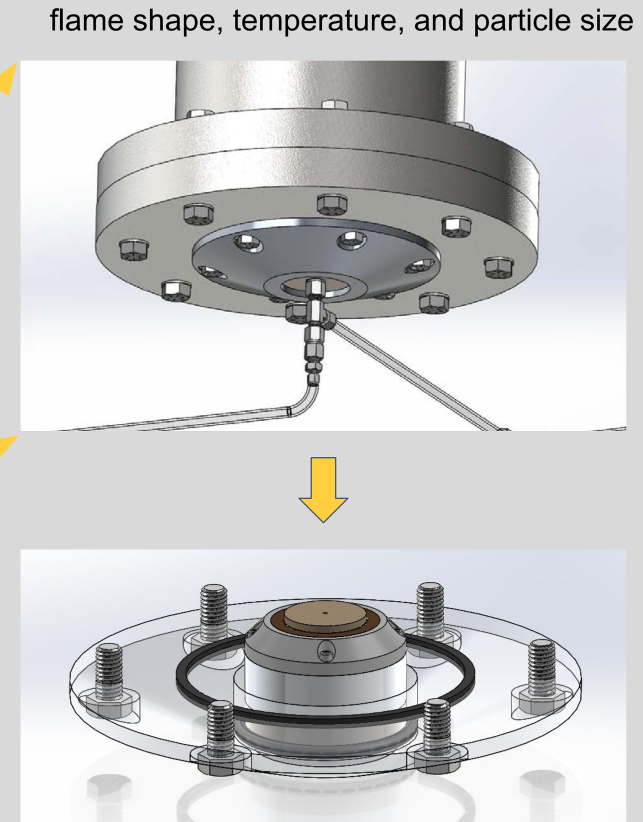


- Nitrogen is used to both carry and cool the decane before and after pyrolysis
- Decane bubbles are formed by heating the reservoir with electrical tape heaters, which then rise and enter the nitrogen flow

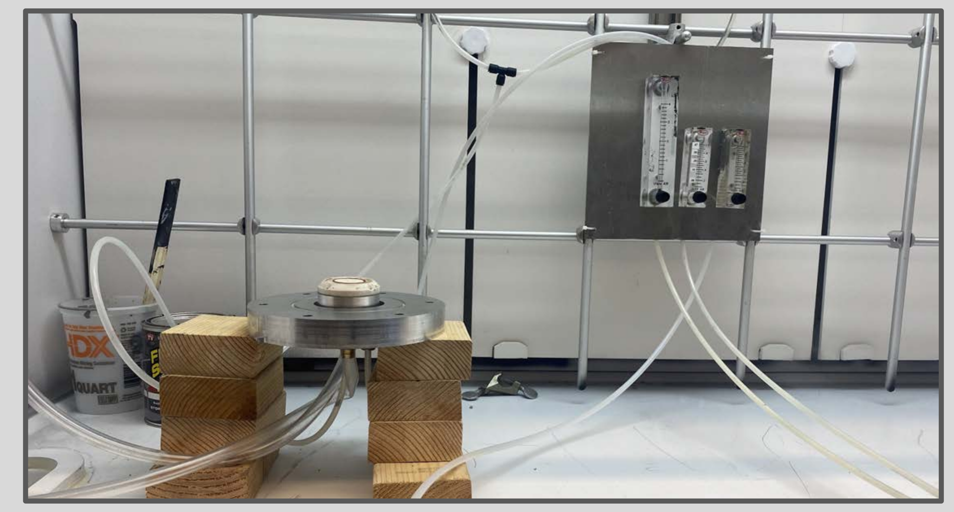
- The porous burner is water-cooled to reduce the likelihood of decane pre-pyrolyzing inside the burner before entering the chamber, which would clog the tubing
- A sampling system using a nozzle was included to analyze carbon particle size and shape under an electron microscope

- The most determining factor in the design was the porous burner, donated by Dr. Joaquin Camacho, which will offer higher temperatures than the electric heating used in the previous carbon particle generator
- The natural gas and air ratio must be accurately determined to produce the correct flame shape, temperature, and particle size





Testing Results



Porous Burner Testing: After several testing iterations due to leaking, it was determined that including an o-ring around the porous material would be necessary to avoid any potential leaking. The flame was not stable due to these leaks, but overall the burner was successful in combustion and passing nitrogen

Future Work

Due to the threat of COVID-19, on March 17, 2020 San Diego State University ordered all non-essential personnel from arriving on campus in accordance to federal law. All of the project's equipment and workspace was located in Dr. Miller's lab, bringing the project to a halt. Hands-on work ended during Porous Burner Testing and the team continued certain tasks virtually, including a Chemkin-Pro analysis of the carbon particle generator to simulate its behavior. A future work document with detailed instructions of how to complete the carbon particle generator was prepared for Dr. Miller to continue with another team. Some of these tasks include:

1) Finishing Porous Burner Testing with a stable flame and strong seal
2) Complete the Decane Reservoir Testing with appropriate decane flow and temperature
3) Assemble the entire carbon particle generator with all its subsystems (Porous Burner, Decane Reservoir, Pressure Chamber, and Sampling Valve)
4) Test the entire assembly by varying mass flow, decane temperature, and burner temperature until carbon particle samples show appropriate shape and diameter

Ackowledgements

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