Syngas-Alaska Style

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Introduction

Alaska ranks as one of the most expensive states for electricity costs, second only to Hawaii. Alaska ranks 3rd highest in total energy expenditures per capita.[2] Conversely, Alaska is ranked 13th in energy production predominantly due to petroleum exports.[3] The point is, Alaska has a lot of energy, but it is not necessarily available for its residents at affordable prices. This is all about economics, but there is a lot more to the energy picture than money. Alaskans are fiercely independent by nature. Wood is the primary source of energy to which most Alaskans have access with few restrictions. In Alaska, wood in large part is used for heating, and to a much lesser degree for cooking. Wood gasification is not a new idea, but syngas production coupled with the most modern technologies can be a game changer in the future. This paper will describe a device and process that can change the way wood and other available energy resources are used by individuals. It is a pathway to energy independence.

Problem

Our ancestors have been using fire for at least 200,000 years and maybe a lot longer.[4] Not too much has changed about the process. Once wood is burning, it releases gas. This part of burning is pyrolysis. If there is enough heat and oxygen, the moisture is vaporized and the combustible gasses are burned up in the process. The product is heat, carbon dioxide, water vapor, and inorganic ash. There are few problems when all the conditions are right for complete combustion of wood; however, as soon as the conditions are no longer perfect, the problems start. Even Stone Age humans were plagued with smoke from their fires. Anthropologist believe that exposure to wood smoke caused early humans to develop resistance to the harmful components of the smoke.[5] Darwinism still has not fixed the problem in our species. Fairbanks, Alaska has been ranked the number one worst city for **fine particulate air pollution** in the United States.[6] Scientist believe the source of the fine particulate that is the source of this pollution is caused by burning wood for heat.[7]

There is no free lunch according to the second law of thermodynamics. Even if the firewood costs no money, burning wood is not free. Labor, environmental impact, resource depletion, hazards, and other factors must be considered. All of the costs associated with burning wood for heat can be reduced by using wood more efficiently. The EPA “Burn Wise” program states that modern wood burning appliances (post 2015) have efficiencies between 70-85%.[8] These numbers do not necessarily represent usable energy, but instead the amount of heat produced by burning the wood in the various appliances. The problem with wood burning appliances is the actual **efficiency of converting wood to usable energy**. The flash point of wood is 572 °F; however to achieve clean, efficient combustion the fire needs to exceed 1100 °F. The problem comes when the need for additional energy stops but the wood burning appliance does not stop producing heat. To maintain the high efficiency burn, the appliance often produces more heat than is needed for the application. Slow burning, cooler fires produce tar and particulate rich smoke that not only causes air pollution, but also is not an efficient use of the fuel. When considering the ultimate efficiency of burning wood, the numbers are often much less attractive.

Much of the world is almost completely reliant upon refined fossil fuels and electricity distributed by a grid. In large part, those who are not, have an energy crisis. **Dependence on centralized energy sources** and distribution systems that could be vulnerable to attack or severe depletion create a threat that is real and potentially catastrophic. People who live “off the grid,” whether by choice or lack of access to centralized power would be less affected by disruptions in these systems. Developing nations where centralized power infrastructure has not yet been developed would not have the problem; however due to lack of access to energy for refrigeration, water treatment, cooking, etc. there are other problems. More than 500 million people in Africa live without the grid.[12] According to World Energy Issues Monitor 2019, referring to Africa:

> "Decentralized systems are viewed as a solution to deliver socio-economic dividends faster and at lower costs than the conventional past solutions. They can offer an attractive option for closing the energy access gap in a faster way by contributing to meet the territorial energy demand, especially in remote and rural areas, through on-grid and off-grid systems.[10]"

In 1989, the Federal Emergency Management Agency (FEMA) published a report to address national security in the event of a significant petroleum shortage. The introduction to the reports is as follows:

> "This report is one in a series of emergency technology assessments sponsored by the Federal Emergency Management Agency (FEMA). The purpose of this report is to develop detailed, illustrated instructions for the fabrication, installation, and operation of a biomass gasifier unit (that is, a "producer gas" generator- also called a "wood gas" generator) which is capable of providing emergency fuel for vehicle such as tractors and trucks, in the event that normal petroleum sources were severely disrupted for an extended period of time. These instructions are prepared in the format of a manual for use by any mechanic who is reasonably proficient in metal fabrication or engine repair. "[9]

Wood was the "go to" source of energy for the United States in the late 1980s and may still be today.

Design

Background

To address the problems of air pollution, inefficiency, and the dependence on centralized energy systems, Renewable Energy Solutions Education and Technologies (RESET) has endeavored to modernize and adapt the downdraft gasifier. There are gasifiers in commercial production around the world. Most are based on the Imbert design.[14]

A nonprofit group from the University of California, Berkeley did much groundbreaking work in modernizing this technology. They offered a gasifier experimental kit (GEK) and shared their plans with the public via their nonprofit. Later, they started a for-profit company called All Power Labs to market a finished product. Another gasifier developer is Wayne Keith, a cattle farmer from Alabama who was featured by Mother Earth News magazine. Mr. Keith simplified the process and understood how to make gasification work for his situation. The GEK gasifier is designed to make electricity and the Keith design runs his farm truck. These are among the best and most successful gasifiers; one is more simple and the other very complex.

Originally, RESET was designing a larger, centralized system to produce 500 KW of electricity from syngas. Quickly, it became obvious that the real need was for a residential or small commercial gasifier that could provide heat as a primary product, and electricity as a by-product. RESET's goal was to design and test a unit for this purpose and to share the design with everyone who is interested.

Some of the problems RESET identified with other down draft gasifier designs included limited batch fueling, fuel bridging, open system ignition, condensate management, lack of monitoring and control, too much production for residential use, and other issues related to construction and materials. Many of these issues have been resolved in this design.

Components

There is little or no standardization for gasifiers and the components that make them up. RESET has its own names for these components, which may or may not be common to other gasifiers. The major components are as follows.

The frame – a welded mild steel angle iron frame to mount the other components and casters. The frame dimensions are 30 in. wide, 60 in. long and 56 in. tall.

The hopper – RESET uses a 55 gallon open-head drum with a lid. The hopper could be much larger and of various designs due to the fuel feed design used by this gasifier. The hopper is actually not a part of the gasifier unit itself. RESET's hopper includes a chip agitator to prevent fuel bridging. Bridging is a major problem with wood chips.

Auger system – fuel is fed into the gasifier by a 3 in. auger. The auger is powered by electric motors that are controlled by a programmable logic controller (PLC). The fuel feed system is unique to this gasifier design.

Reactor – the reactor is the syngas refinery. The reactor is made up of a fire tube, a conductive copper baffle, a mild steel baffle, an inner jacket, a feed tube, top plate, intake manifold, and an outer jacket. There are air injection nozzles in the fire tube and an ash grate at the bottom of the fire tube. The reactor vessel has a top access cap, thermocouple port, igniter ports, ash door, air intake port, gas outlet and condensate drain port. The intake port and condensate port have powered valves controlled by the PLC.

Heat exchanger – the heat exchanger is a set of liquid-to-air radiator cores. A gas inlet manifold connects the cores. The design allows for adding or subtracting cores. Currently, the RESET design is using three cores. The cores are attached to a condensate reservoir tank.

Condensate tank – the condensate tank receives all the condensate from the gasifier. The tank can be pumped to a bulk storage tank. The PLC manages the valves and condensate pump.

Filters – the primary filter is a 16-gallon open-head drum filled with hay or straw. The final filter is two automotive air filters contained inside the drum attached to a sealed lid.

Blower – the blower maintains flow through the gasifier; it is the primary means of initiating and maintaining the reaction. The blower is a regenerative blower that is controlled by a variable frequency drive and the PLC. The system is in a vacuum until this point.

Gas outlets – the gas is produced and forced out of the gasifier through a powered valve. This mode is for use when a manifold is used to distribute gas to appliances that do not pull the gas as an internal combustion engine would. The other outlet is before the blower and used by an engine for generating electricity or other purposes.

Controls and electronics – the gasifier is controlled by a PLC. The primary inputs are pressure in the outlet line or manifold, temperature in the reactor, and a fuel level-metering switch. The outputs include relays for the igniters that are turned on at startup and occasionally for restart, relays for the auger motors, relays for the inlet, outlet, and condensate tank valves, a relay for the condensate vacuum pump, and relays to start the grate rotator and chip agitator motors. The PLC also data logs the inputs. The system includes an inverter that converts 12 volt DC from an onboard battery to 110 volt AC for the VFD that controls the blower. The PLC manages the logic to shut down and seal the unit as needed. There are manual emergency shut downs as well.

Process

The RESET gasifier can be operated hands free via an application on any smart phone or from any personal computer that has Wi-Fi or Bluetooth. Once the hopper has been loaded with fuel the process can start.

Ignition – the process is started by pushing the START button on the screen. Once the process is initiated, the augers feed fuel until the fuel-metering switch is open. Next, the igniters start a heating process for 90 seconds. After the heating period, the air inlet and gas valves are opened and the blower starts. The fire tube (core) temperature is monitored to see that combustion is underway. Ignition is complete. This phase takes approximately two minutes.

Stabilizing the production - the ignition phase brings the core temperature to approximately 600 °F. The initial gas flow is lower temperature and contains long-string hydrocarbon tar gas. While combustible, this gas is not ideal for most appliances because of the tar residue. The first gas is flared outside of the gasifier until the core temperature reaches the optimal operating temperature (1500-1800 °F). This phase of the process takes approximately 2 minutes from the time ignition occurs. Combustion air enters the nozzles and heats the fuel very rapidly.

Production – the RESET gasifier design is unique because the rate of syngas production is controlled by coordinating the fuel feed and the blower pressure. The process includes maintaining a proper reduction bed temperature to allow for high quality refined syngas at a rate needed for the given application. The gas released from the fuel is drawn down through the hot reduction zone and the pyrolytic gases are cracked into hydrogen, carbon monoxide, and methane. After traveling through the column of hot charcoal, the gas begins to cool and much of the fly ash falls out of the flow in the chamber between the inner and outer jacket of the reactor. The gas is cooled as it travels through the heat exchanger and the heat that is extracted is used to preheat the incoming combustion air. As the gas cools, water is condensed and dropped into the condensate tank. The gas is pulled into the filter system where more moisture is condensed and other fine particulate matter is filtered before entering the blower. By this point in the process, the gas has cooled to near ambient temperature. The gas passes through the blower and exits through the gas outlet valve. Various types of manifolds can be used to distribute the gas depending on the needs of the user. In the cases where the gas is used by an internal combustion engine, the gas is extracted before entering the blower. Condensate and ash are periodically removed from the gasifier.

Shutdown – when there is no long a demand for gas, the blower and the fuel feed are stopped. The air inlet is and the gas outlet valves are closed. The reaction stops and core cooling begins.

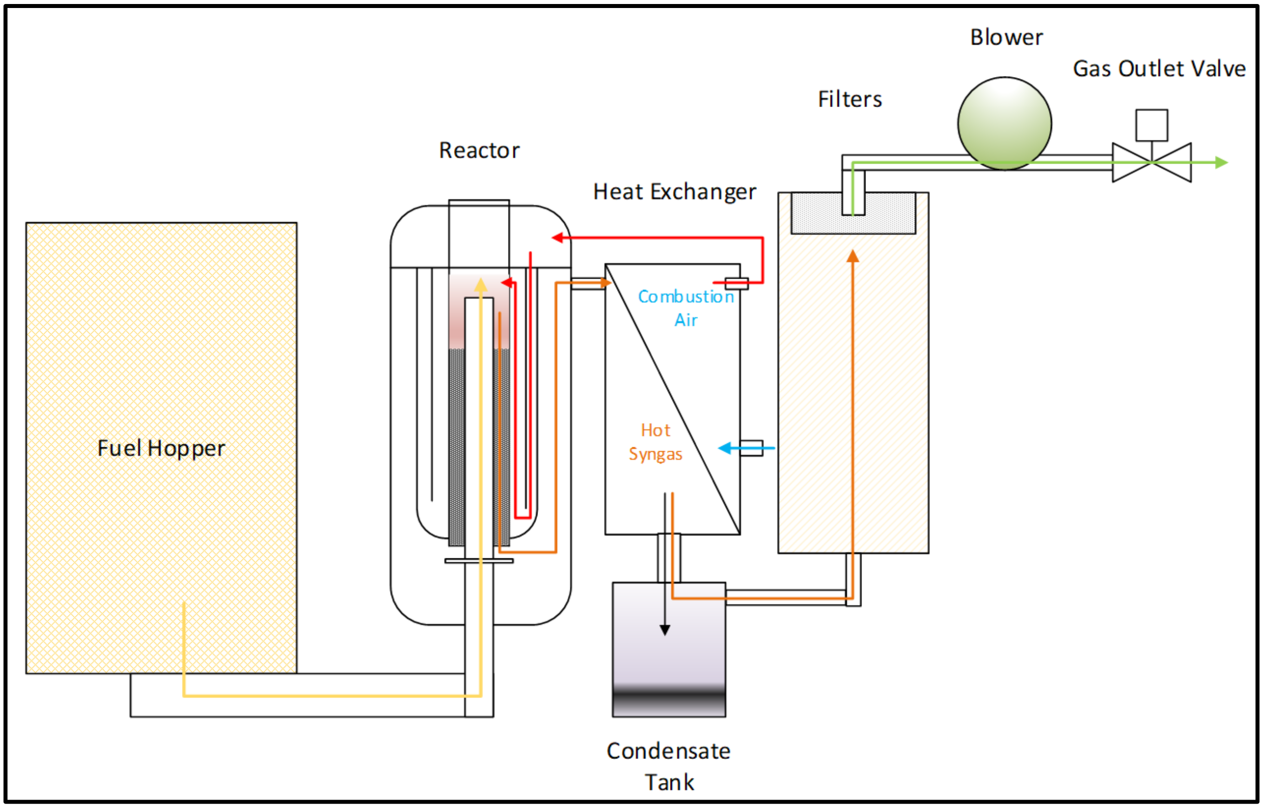

Figure 1. Diagram #1 Syngas Flow Diagram.

Solutions

Pollution – Converting wood chips and/or other carbon-rich, solid fuels into syngas is a giant step in the right direction. Controlled gasification allows for removing most of the particulates and refining the composition of the gas before it is combusted. The gas can be used in cleaner burning appliances.

Inefficiency – Producing syngas from wood chips consumes some of the energy in the process; therefore, the conversion of fuel to heat is less efficient than burning the wood at high temperature until it is completely combusted. However, the RESET gasifier design allows for syngas production practically on-demand. The process can start and stop very quickly. Since the syngas can be produced as it is needed, remaining fuel that would have been burned up in traditional wood burning appliances is still in the hopper. Additionally, the syngas can be used in high efficiency appliances.

Energy dependence – Using wood and/or other carbon-rich, solid fuels for energy will not work for everyone, everywhere. Two billion people use wood as their primary source of energy, yet that only accounts for 7% of the world's energy consumption.[13] Converting the same wood that is used by these 2 billion people to fuel that can be used for refrigeration, electricity, more efficient heating and cooking, could alleviate many health and welfare issues associated with poverty. These people are not dependent on centralized energy systems because they do not have access to them. Those who are dependent on others to provide their energy could become more independent by utilizing renewable energy sources that they can manage and operate on their own. Syngas produced from wood chips and/or other carbon-rich, solid fuels is only one source, but it is a reasonable source for many.

Conclusions

Wood and other carbon-rich solid fuels can be converted to syngas. The syngas can be refined to be a clean burning fuel, alleviating much of the pollution associated with burning wood. Controlling the production of syngas and combusting it in high efficiency appliances can result in better energy efficiency from wood fuel. A wood gasifier can be owned and operated by an individual. Utilizing available and renewable sources of fuel and refining the energy to do work in modern appliances can give individuals control of their energy. This can reduce or eliminate dependency on centralized energy systems.

Recommendations

1. The energy value of the syngas produced by the RESET gasifier should be tested.
2. Emissions from combustion of the syngas produced by the RESET gasifier should be analyzed for particulates and other pollutants.
3. Efficiency of energy conversion form various types of wood and other solid fuel sources should be determined.

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