STEAM POWER UPDATE 2007

STATUS OF RENEWABLE AND SUSTAINABLE

GREEN STEAM POWER TECHNOLOGY

CONTENTS

Part 1 - What is Steam Power?

Steam power is, literally, the power derived from steam (generally pure water [H_2O]) expanding and cooling from high temperature and pressure to lower temperature and pressure. To derive power (and useful work) from steam, certain components are usually required to create a complete steam power system (a steam engine). The "typical" steam engine components are:

- Water – the working fluid that turns from liquid to steam (and maybe back to liquid over and over in a cycle)
- A water pump – to pressurize the water
- A heat (energy) source – to heat the water
- An expander – to extract the useful work as the water expands
- A condenser – to condense the steam back into liquid water and allow re-use of the water
- A tank or reservoir – to store the condensed water for re-use
- Controls – to start and stop the engine, adjust the heat input and steam flow, and maintain other operating parameters

The history of steam power is well documented and widely known, as are many of steam power's past contributions to modern society. Most people today view the steam locomotive as the most familiar steam powered machine. Steam locomotives still operate throughout the world today (and new ones are being built); large coal, oil, and natural gas fueled steam power plants and combined cycle power plants are the most common uses of steam power in the world today.

Steam powered automobiles (many of which remain operational today) were proven feasible, even with technology from the late 1800's. With the advent of low cost gasoline in the1900's, the internal combustion engine thrived and steam powered automobile technology development ended … until now.

Part 2 - What is “Green” Steam Power?

Green steam power is defined by the energy source that heats the steam. Steam power is “Green Steam Power” if the answers to the following questions are “Yes”.

- Is the energy source naturally renewable at the rate of energy use?
- Is the energy source renewable by human interaction at a rate that can be sustained indefinitely, without the depletion of natural resources?
- Does the use of the energy source reduce our dependence on oil and other fossil fuels?
- Does the use of the energy source result in reduced contamination of air (including net carbon emissions), water, and land?

Green steam power is being developed today to replace or reduce the use of gasoline and other oil-based technologies in the following industries:

- Automobiles, motorcycles, and buses
- Locomotives
- Ships
- Single family, multi-family, village, commercial, and utility scale electric generation
- Water purification and pumping
- Mechanical power for manufacturing and food processing

Part 3 – Developments in Steam Power: 2007

It took almost 100 years (from 1900 to 2000) for steam power technology development to regain momentum. The International Association for the Advancement of Steam Power (IAASP) has contacted engineers and scientists throughout the world who are advancing steam power technology today.

Here are a few of the technological developments in modern green steam power, which are being pursued around the globe today:

- A steam engine 1/20th the size of a human hair.
- Electric power without pollution.
- Automobiles, trains, airplanes, ships, buses, motorcycles that operate on clean, non-polluting, renewable fuels.
- Homes powered entirely by solar thermal electric energy.
- Quiet, clean, powerful, palm-sized steam engines operating on virtually any fuel, even hydrogen.
- Steam engines that recover excess engine heat and convert it to electricity and useful work.
- High efficiency steam engines that can operate without oil, underwater, or in outer space without air.

Unlike more mature green power technologies (such as wind and small hydroelectric), and unlike the fuel cell industry, the development of modern green steam power has remained predominantly the responsibility of a relatively few dedicated pioneers. These steam power pioneers, as a group, are being careful to limit their communications to what they choose to post on their websites, communicate in limited email replies, or private confidential communications. The latest available developments in steam power can be found at www.steampower.com.

Part 4 – "Green" and Sustainable Energy Sources

The steam engine's green and sustainable energy (heat) sources today are: solar thermal energy, waste heat, ethanol, methanol (wood alcohol), bio-fuel blends, bio-diesel, biomass, landfill gas, digester gas, industrial waste, municipal solid waste, and geothermal energy. Hydrogen has not yet become available from a non-fossil based renewable source. Note that hydrogen fuel derived from seawater using solar energy, although an ideal and seemingly unlimited potential steam engine fuel source, is **not** considered renewable by some organizations in the energy industry. The California Energy Commission is one of those organizations.

The following are brief descriptions of these green and sustainable energy sources for steam power.

Solar Thermal Energy

The intense direct energy of the sun (solar energy or solar thermal energy) is the ideal heat source for steam power. Among the first mechanical uses of the sun was a 20-square-meter, parabolic concentrating reflector that boiled water and produced steam. This steam was used in a steam-driven printing press at the 1878 World's Fair in Paris.

Solar energy can also generate useful work and electricity. Steam power systems using concentrating solar power can range in size from 5 to 10 kilowatts (for home or village) to grid-connected applications in the hundreds of megawatts. Steam power systems can store thermal energy for nights and cloudy periods. This allows them to continue to produce electricity when the sun is not shining. Combined with renewable fuels for longer periods without sun, the resulting "hybrid power plant" provides valuable, dispatchable electricity. These solar thermal steam-electric power systems have comparatively high efficiencies, making steam power an attractive renewable energy option in the sun-belt regions of the world.

These solar thermal power plants rely upon curved mirrored troughs that concentrate sunlight. The sun heats a liquid that creates steam to turn a traditional steam turbine. Solar PV panels register efficiencies ranging from 9 to 15 percent. The solar thermal trough steam cycle facilities are approximately 22 percent. These efficiency numbers are based on calculations that convert the sun's energy into the equivalent of British Thermal Units, a universally recognized measuring unit of energy commonly referred to as "BTU's". One BTU is the same quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit.

Solar thermal electric capacity is increasing worldwide. The cost of building, operating, and maintaining solar thermal electric systems has decreased dramatically -- in some cases by a factor of ten -- during the 1980s and 90s and is expected to continue dropping. Solar-thermal designs may be economically competitive with some conventional electricity-generating technologies. The California Energy Commission has predicted that by 2010, some solar thermal electric technologies could be producing electricity at $0.06 to $0.07 per kilowatt hour (kWh). This is comparable to the current cost of wind energy produced from the latest wind power sites in California.

Waste Heat

By nature, all thermal processes reject some of the process heat as “waste heat”. If this heat has a high enough temperature and sufficient volume to capture, a steam engine can utilize this heat as its primary or sole energy source. A waste heat recovery system is used for this purpose. For example, in a commercial building, potential sources of waste heat include space heaters, refrigeration/air-conditioner compressors, or manufacturing or other high temperature processes.

In automobiles, the gasoline or diesel engine produces waste heat that can power a steam engine. Here is a description of one such steam powered waste heat recovery system now under development by BMW. The following description is excerpted from Wikipedia at their website http://en.wikipedia.org/wiki/Turbosteamer: The BMW Turbosteamer is an alternative non-parasitic hybrid concept based upon a steam engine that converts waste heat energy from an internal combustion engine into supplemental power for the vehicle. The Turbosteamer device is affixed to the exhaust system. It salvages the heat wasted in the exhaust (as much as 80% of the heat energy) and uses a steam engine to relay that power to the crankshaft. The steam circuit produces 14 horsepower and 15 pound-feet of torque at peak (for a 1.8 liter four), yielding an estimated 15% gain in fuel efficiency. Unlike gas-electric hybrids, these gains increase at higher, steadier speeds. BMW has indicated that the technology could in their automobiles by 2015.

Ethanol

Ethanol, also known as ethyl alcohol or grain alcohol, is currently used either as an alternative fuel or as an octane-boosting, pollution-reducing additive to gasoline in internal combustion engines. Corn and other starches and sugars are only a small fraction of biomass that can be used to make ethanol. The U.S Department of Energy's Advanced Bioethanol Technology allows fuel ethanol to be made from cellulosic (plant fiber) biomass, such as agricultural forestry residues, industrial waste, material in municipal solid waste, trees, and grasses. This technology turns ordinary low-value plant materials such as corn stalks, sawdust, or waste paper into fuel ethanol. If used to fuel steam powered automobile engines, ethanol would dramatically cut air pollution and reduce dependence on foreign oil. To help improve this technology and ready it for commercial operation, the DOE researchers and their industrial partners use the DOE Bioethanol Pilot Plant, a fully integrated biomass-to-ethanol production facility, that can turn as much as one ton per day of corn stalks or other plant material into transportation fuels.

Biodiesel

Biodiesel is made by transforming animal fat or vegetable oil with alcohol and can be directly substituted for diesel either as neat fuel (100% biodiesel) or as an oxygenate additive (typically 20% biodiesel with the rest diesel fuel). In Europe, the largest producer and user of biodiesel, the fuel is usually made from rapeseed (canola) oil. In the United States, the second largest producer and user of biodiesel, the fuel is usually made from soybean oil or recycled restaurant grease. In 2002, 15 million gallons of biodiesel was consumed in the United States (The American Soybean Association). The National Biodiesel Board, a trade association for biodiesel producers, is a good source of additional information.

Biomass

Biomass consists of organic residues from plants and animals, which are obtained primarily from harvesting and processing agricultural and forestry crops. These are used as fuels in direct combustion steam-electric power plants. The biomass is burned producing heat that is used to create steam to turn turbines to produce electricity. The steam can often be used for another process -- such as drying of vegetables or used in a factory. This is called cogeneration.

Examples of some of the biomass residues that are utilized in direct combustion steam power plants are: forest slash, urban wood waste, lumber waste, agricultural wastes, etc. The components of biomass include cellulose, hemicelluloses, lignin, lipids, proteins, simple sugars, starches, water, hydrocarbons, ash and other compounds. The total estimated biomass resource potential of California is approximately 47 million tons.

Landfill Gas

When you bury trash at a landfill, you create an oxygen-free environment under the capping soil layer. With relatively dry conditions, landfill waste produces significant amounts of gas as it decomposes -- mostly methane. With Californians dumping 33 million tons of waste per year, the total amount of landfill gases produced in California is tremendous.

If these gases were just released to the atmosphere, they could add to global climate change problems. They could also potentially be a fire or explosion hazard if not collected and gotten rid of. So, a good solution to the landfill gas problem is to collect it and burn it to produce electricity.

The gas can be collected by a collection system, which typically consists of a series of wells drilled into the landfill and connected by a plastic piping system. The gas entering the gas collection system is saturated with water, and that water must be removed prior to further processing.

The typical dry composition of the low-energy content gas is 57 percent methane (natural gas), 42 percent carbon dioxide, 0.5 percent nitrogen, 0.2 percent hydrogen, and 0.2 percent oxygen. In addition, a significant number of other compounds are found in trace quantities. These include alkanes, aromatics, chlorocarbons, oxygenated compounds, other hydrocarbons and sulfur dioxide.

After the water is removed, the landfill gas can be used directly in reciprocating steam engines or steam turbine engines. The carbon dioxide can be removed with further refining and purer methane can be used for electricity generation applications.

Digester Gas

Anaerobic digestion is a biological process that produces a gas principally composed of methane (CH_4) and carbon dioxide (CO_2) otherwise known as biogas. These gases are produced from organic wastes such as livestock manure, food processing waste, etc.

Anaerobic processes could either occur naturally or in a controlled environment such as a biogas plant. Organic waste such as livestock manure and various types of bacteria are put in an airtight container called a digester, so the process could occur. Depending on the waste feedstock and the system design, biogas is typically 55 to 75 percent pure methane. State-of-the-art systems report producing biogas that is more than 95 percent pure methane.

Municipal Solid Waste

Municipal solid waste MSW can be directly combusted in steam powered waste-to-energy facilities as a fuel with minimal processing, known as mass burn. The MSW can undergo moderate to extensive processing before being directly combusted as refuse-derived fuel or it can be gasified using pyrolysis or thermal gasification techniques.

Each of these technologies can produce useful work and electricity as well as be an alternative to landfilling or composting the MSW. In contrast with many other energy technologies that require fuel to be purchased, MSW facilities are paid by the fuel suppliers to take the fuel (known as a "tipping fee"). The tipping fee is comparable to the fee charged to dispose of garbage at a landfill.

In small villages, this technology could be the only option for the development of electric power. Air, water, and solid residual products must be carefully controlled to avoid pollution.

Geothermal Energy

Geothermal energy is produced by the heat of the earth and is often associated with volcanic and seismically active regions. California has 25 known geothermal resource areas, 14 of which have underground water temperatures of 300 degrees Fahrenheit (149 degrees Celsius) or greater.

Hot water and, in some instances, steam can be used to make electricity in large steam power plants. Steam and hot water can also be put to direct use, such as driving machinery, and heating greenhouses or other buildings. The constant temperature below ground can also be tapped to warm and cool your home through a ground source heat pump.

*** Sources: Excerpted from the California Energy Commission's Renewable Program Website, 2002. Additional technical content by Dennis A. Dudzik, P.E., IAASP, December 2002. Technical content updated and revised by Dennis A. Dudzik, P.E., IAASP, November 2007.**