COMBINED CYCLE ENERGY PRODUCTION

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A combined cycle is characteristic of a power producing engine or plant that employs more than one thermodynamic cycle. Heat engines are only able to use a portion of the energy their fuel generates (usually less than 50%). The remaining heat from combustion is generally wasted. Combining two or more "cycles" such as the Brayton cycle and Rankine cycle results in improved overall efficiency.

In a combined cycle power plant (CCPP), or combined cycle gas turbine (CCGT) plant, a gas turbine generator generates electricity and the waste heat is used to make steam to generate additional electricity via a steam turbine; this last step enhances the efficiency of electricity generation. Most new gas power plants in North America and Europe are of this type. In a thermal power plant, high-temperature heat as input to the power plant, usually from burning of fuel, is converted to electricity as one of the outputs and low-temperature heat as another output. As a rule, in order to achieve high efficiency, the temperature difference between the input and output heat levels should be as high as possible. This is achieved by combining the Rankine (steam) and Brayton (gas) thermodynamic cycles. Such an arrangement used for marine propulsion is called Combined Gas (turbine) And Steam (turbine) (COGAS).

In a thermal power station water is the working medium. High pressure steam requires strong, bulky components. High temperatures require expensive alloys made from nickel or cobalt, rather than inexpensive steel. These alloys limit practical steam temperatures to 655 °C while the lower temperature of a steam plant is fixed by the boiling point of water. With these limits, a steam plant has a fixed upper efficiency of 35 to 42%.

An open circuit gas turbine cycle has a compressor, a combustor and a turbine. For gas turbines the amount of metal that must withstand the high temperatures and pressures is small, and expensive materials can be used. In this type of cycle, the input temperature to the turbine (the firing temperature), is relatively high (900 to 1,350 °C). The output temperature of the flue gas is also high (450 to 650 °C). This is therefore high enough to provide heat for a second cycle which uses steam as the working fluid; (a Rankine cycle).

In a combined cycle power plant, the heat of the gas turbine's exhaust is used to generate steam by passing it through a heat recovery steam generator (HRSG) with a live steam temperature between 420 and 580 °C. The condenser of the Rankine cycle is usually cooled by water from a lake, river, sea or cooling towers. This temperature can be as low as 35 °C

By combining both gas and steam cycles, high input temperatures and low output temperatures can be achieved. The efficiency of the cycles add, because they are powered by the same fuel source. So, a combined cycle plant has a thermodynamic cycle that operates between the gas-turbine's high firing temperature and the waste heat temperature from the condensors of the steam cycle. This large range means that the Carnot efficiency of the cycle is high. The actual efficiency, while lower than this is still higher than that of either plant on its own.

The thermal efficiency of a combined cycle power plant is the net power output of the plant divided by the heating value of the fuel. If the plant produces only electricity, efficiencies of up to 59% can be achieved. In the case of combined heat and power generation, the overall efficiency can increase to 85%.

The HRSG can be designed with supplementary firing of fuel after the gas turbine in order to increase the quantity or temperature of the steam generated. Without supplementary firing, the efficiency of the combined cycle power plant is higher, but supplementary firing lets the plant respond to fluctuations of electrical load. Supplementary burners are also called duct burners.

More fuel is sometimes added to the turbine's exhaust. This is possible because the turbine exhaust gas (flue gas) still contains some oxygen. Temperature limits at the gas turbine inlet force the turbine to use excess air, above the optimal stoichiometric ratio to burn the fuel. Often in gas turbine designs part of the compressed air flow bypasses the burner and is used to cool the turbine blades.

Combined cycle plants are usually powered by natural gas, although fuel oil, synthesis gas or other fuels can be used. The supplementary fuel may be natural gas, fuel oil, or coal. An integrated solar combined cycle power station is currently under construction at Hassi R'mel, Algeria.

References

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