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Generation of Thermal Energy: A Theoretical Approach

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Abstract—*Today's modern world is dependent on various types of advanced technological breakthroughs that are making our life more productive as well as comfortable. In simple terms, inexpensive and reliable electricity is critical to the sustained economic growth and security of any nation. Today's world is dependent on reliable, low cost and abundant energy.*

It is the power plant which provides this critical energy source. As an amazing fact, in the United Nations around 90% of the electricity is produced from the power plants that use steam as an energy source; with just 10% of the electricity produced from hydroelectric power plants. In other parts of the world as well, similar proportions are common for their electric production.
The power plant may be defined as a facility which transforms various types of energy into electricity or heat for some useful purpose. Based on the input mode to the power plant, the plant design will be drastically different for each energy source.

The forms of the input energy can be categorized as follows –
1. *The potential energy of an elevated body of water. In simple technical terms, it may be referred to as the hydroelectric power plant.*
2. *The chemical energy that is relatively from the hydrocarbons which are contained in the fossil fuels such as coal, oil or natural gas, which can be referred to as a fossil fuel fired power plant.*
3. *Now, comes the most amazing technology which is called as the Nuclear power plant. The energy developed is predominantly due to the separation or attraction of atomic particles.*

The present study is a humble effort towards the review of Thermal energy and the detailed theoretical investigation of the generation of this energy.

Keywords: *Energy, Rankine's Cycle, Carnot Vapour Cycle, Thermal Efficiency.*

1. INTRODUCTION

The growing concern for energy security is gradually becoming a major threat for a developing nation like INDIA. One of the most significant contributor to this has been the question of becoming self sufficient in power generation to meet the expontential demand of a growing nation.One of the most astonishing fact is that INDIA has been the 2nd best growing nation,even in the economic downslide of 2008-2009.Inspite of the current trend, one cannot overlook this fact that a regular supply of electricity is essential for a strong economic growth. An estimate shows that for every 1% economic growth, power generation capacity for INDIA needs to grow by 5-6 times to sustain the levels of growth for decades to come.

Nowadays most of the electricity produced throughout the world is from steam power plants.However electricity is being produced by some other power generation sources such as for example Hydropower, biogas power, solar cells etc. One newly developed method of electricity generation is the Magneto Hydro Dynamic Power Plant.

2. STEAM AND ITS IMPORTANCE:

Steam is one of the most important critical resource in todays industrial world. It is essential for the production of paper and other wood products, for the preparation and serving of foods for cooling and heating of large buildings, for driving equipments such as pumps and compressors and for powering ships. However the most important priority remains as the primary source of power for the production of electricity.

Steam is extremely valuable because it can be produced anywhere in the world by utilizing the heat that comes from the fuels that are available in the nearby area. Steam also has some unique properties that are extremely important in the production of energy. Steam is basically recycled, from steam to water and subsequently back to steam again in a manner which is non toxic in nature. The modern steam plants of today are a combination of some complex engineered system that work to produce steam in the most efficient manner that is economically feasible. In any kind of situation however the steam power plant must obtain the required amount of heat. This heat must come from an energy source which varies significantly based on the plant's location in the world. The sources of heat could be the following:

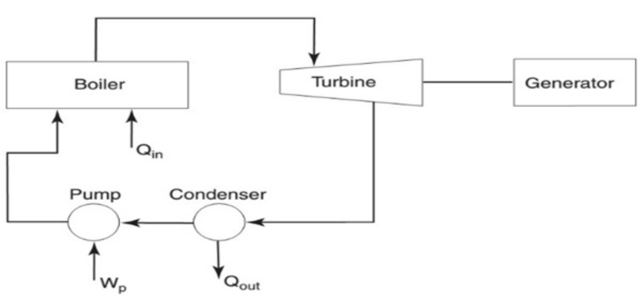
- A fossil fuel - coal, oil or natural gas.
- A nuclear fuel such as uranium.
- Other forms of energy which includes waste heat from exhaust gases of the gas turbines by product fuels such as Carbon Monoxide (CO), blast furnance gas (BFG) or methane, geo thermal energy and solar energy.

Each of the fuels contain potential energy in the forms of a heating value and this is measured by terms of british thermal units (B tus) per each pound or cubic feet of the fuel. Depending on whether the fuel is a solid or a gas. A British thermal unit is about equal to the quantity of heat required to raise one pound of water by one degree Fahrenheit. As the water is heated, it eventually changes its form by turning into steam. As the heat is continuously added, the steam reaches the desired temperature and pressure for the particular application.

3. DETAILED INVESTIGATION ON GENERATION OF THERMAL ENERGY:

The steam plant cycle:

The simplest steam cycle of practical significance is referral to as the Rankine's cycle. The steam cycle is important because it connects processes that allow heat to be converted to work on a continuous basis. This simple cycle was based on dry saturated steam being supplied by a boiler to a power unit such as a turbine that drives an electric generator. Dry saturated steam is at the temperature that corresponds to the boiler pressure, is not super heated and does not contain moisture. The steam from the turbine exhausts to a condenser, from which the condensed steam is pumped back into the boiler. It is also called a condensing cycle and a simple schematic of the system is shown in the figure:



The schematic diagram also shows heat (Q_{in}) being supplied to the boiler and generator connected to the turbine for the production of electricity. Heat (Q_{out}) is removed by the condenser and the pump supplies energy (Wp) to the feed-water in the form of a pressure increment to allow it to flow through the boiler.

A higher plant efficiency is obtained if the steam is initially superheated which subsequently means that less steam and less fuel are required for a specific output. (Superheated steam has a temperature that is above that of dry saturated steam at the same pressure and thus contains more heat content called "enthalpy". If the steam is reheated and passed through a second turbine, cycle efficiency also improves and moisture in the steam is reduced as it passes through the turbine. Due to this phenomena, the erosion of the turbine blades is subsequently reduced.

With the addition of superheat, the turbine transforms the additional energy into work without forming moisture and thus, energy is basically recoverable in the turbine.

By the addition of regenerative feed water heating, the original Rankine cycle was improved significantly. This is done by extracting steam from various stages of the turbine to heat the feed water as it is pumped from the condenser back to the boiler to complete the cycle. It is this cycle concept that is using in modern power plants.

4. APPLICATION OF THERMODYNAMICS:

Two important area of the application of thermodynamics are power generaton and refrigeration. Both power generation and refrigeration are usually accomplished by a system that operates on a thermo-dynamic cycle.

Thermodynamic cycle can be categorized as follows-

a) Power cycles
b) Refrigeration cycles.

5. BASIC CONSIDERATION IN THE ANALYSIS OF POWER CYCLES:

Actual cycle:

The cycles encountered in actual devices are difficult to analysize because of the presence of complicating effects, such as friction and the absence of sufficient time for establishment of the equilibrium conditions during the cycle.

Ideal cycle:

When the actual cycle is stripped of all the internal irreversibilities and complexities, a new cycle is formed that resembles the actual cycle closely but it is made of totally internally reversible process. Such a cycle is referred to as the ideal cycle.

Carnot Cycle:

The Carnot cycle is composed of four totally reversible processes

a) Isothermal heat addition at high temperature. (T_H).

b) Isentropic Expansion from high temperature to low temperature.

c) Isothermal heat rejection at low temperature.

d) Isentropic compression from low temperature to high temperature.

Thermal Efficiency of Carnot Cycle may be given by:

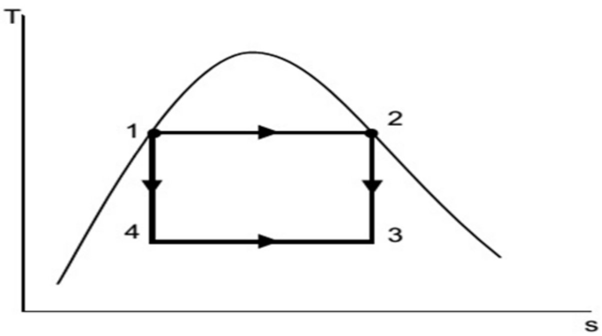
n_{th} ,carnot = 1-(T_L/T_H)

The carnot vapour cycle:

a) A steady flow carnot cycle executed with the saturation dome of a pure substance is shown in the figure:

The fluid is heated reversibly and isothermally in a boiler (Process 1-2) expanded isentropically in a turbine (Process 2-3), condensed reversibly and isothermally in a condenser (Process 3-4) and compressed isentropically by a compressor to the initial state (Process 4-1).

b) The carnot cycle is not a suitable model for vapour power cycle because it cannot be approximated in practice.

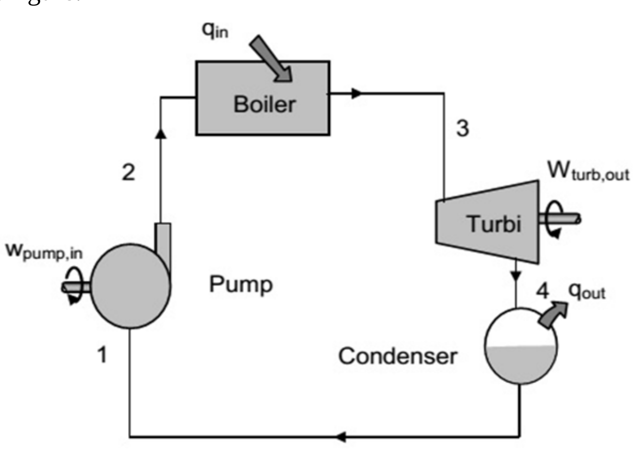


Rankine cycle:

The ideal cycle for vapour power cycle:

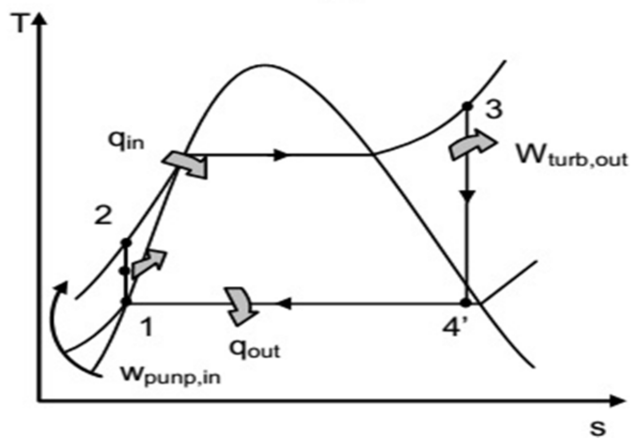
a) The impracticalities associated with carnot cycle can be eliminated by super heating the steam in the boiler and condensing it completely in the condenser. The resulting cycle is the rankine cycle which is the ideal cycle for vapour power plants.

The construction of power plant and Ts diagram is shown in the figure:



b) The ideal rankine cycle does not involve any internal irreversibilites.

c) The rankine cycle consists of the following four processes:



1-2 → Isentropic compression in pump.

2-3 → Constant pressure heat addition in boiler.

3-4 → Isentropic expansion in turbine.

4-1 → Constant pressure heat rejection in a condenser.

How can we increase the efficiency of the Rankine cycle?

The rankine cycle efficiency can be increased by increasing average temperature at which heat is transferred to the working fluid in the boiler or decreasing the average temperature at which heat is rejected from the working fluid in the condenser. That is the average fluid temperature should be as high as possible during heat addition and as low as possible during heat rejection.

The 3 ways by which the efficiency of the rankine cycle can be increased are:

a) Lowering the condenser pressure.

b) Superheating the steam to high temperature.

c) Increasing the boiler temperature.

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