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Condenser Basics

The Rankine Cycle

The Rankine cycle is the standard for steam power plants that are built around the world. The basic Rankine cycle consists of four main components:

- Steam Generator
- Turbine
- Steam Condenser
- Pump

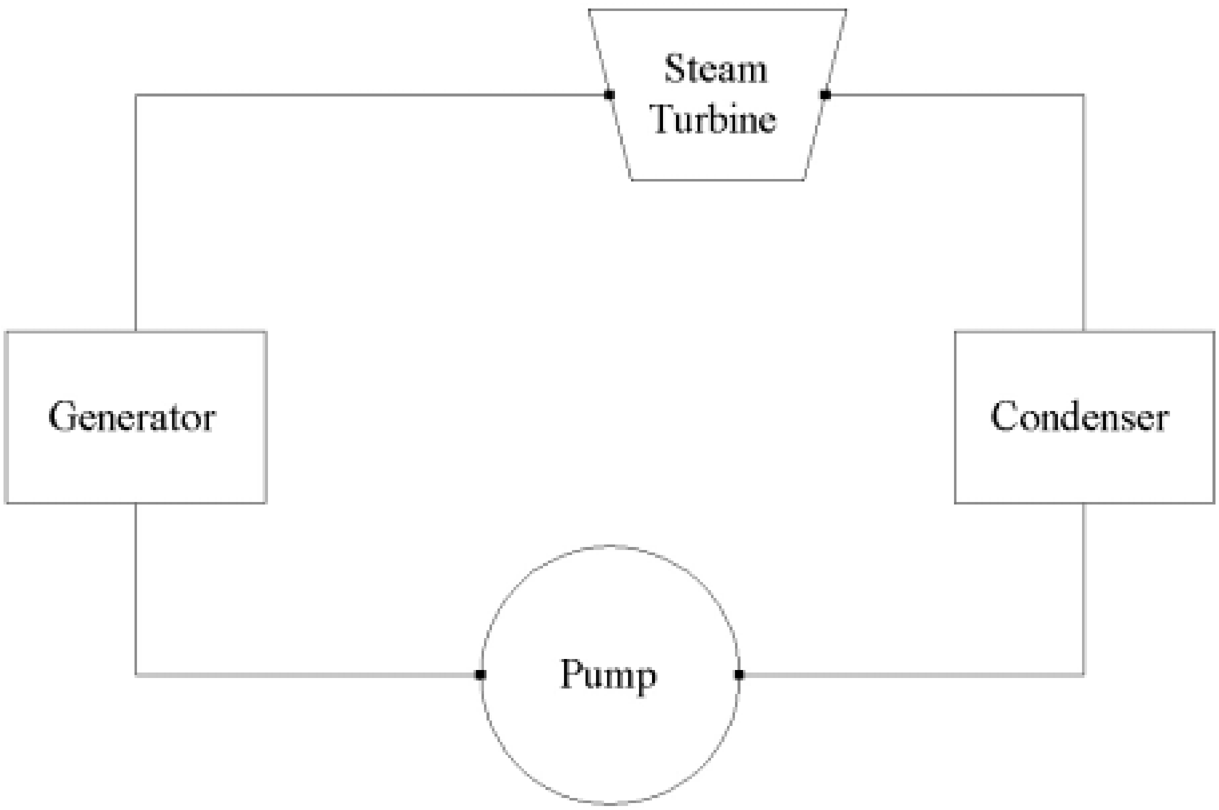

Figure 1

The actual Rankine cycle used in modern power plants has many more components, but the above four components are common to all power plants. In this cycle, water is heated in the steam generator to produce high temperature and pressure steam. This steam is then expanded in a turbine to produce electricity from a generator that is connected to the turbine. The steam from the turbine is then condensed back into water in the condenser. The pump then returns the water to the steam generator.

Thus, the main purposes of the condenser are to condense the exhaust steam from the turbine for reuse in the cycle and to maximize turbine efficiency by maintaining proper vacuum. As the operating pressure of the condenser is lowered (vacuum is increased), the enthalpy drop of the expanding steam in the turbine will also increase. This will increase the amount of available work from the turbine (electrical output). By lowering the condenser operating pressure, the following will occur:

- Increased turbine output
- Increased plant efficiency
- Reduced steam flow (for a given plant output)

It is therefore very advantageous to operate the condenser at the lowest possible pressure (highest vacuum).

CONDENSER TYPES

There are two primary types of condensers that can be used in a power plant:

1. Direct Contact
2. Surface

Direct contact condensers condense the turbine exhaust steam by mixing it directly with cooling water. The older type Barometric and Jet-Type condensers operate on similar principles.

Steam surface condensers are the most commonly used condensers in modern power plants. The exhaust steam from the turbine flows on the shellside (under vacuum) of the condenser, while the plant's circulating water flows in the tubeside. The source of the circulating water can be either a closed-loop (i.e. cooling tower, spray pond, etc.) or once-through (i.e. from a lake, ocean, or river). The condensed steam from the turbine, called condensate, is collected in the bottom of the condenser, which is called a hotwell. The condensate is then pumped back to the steam generator to repeat the cycle.

STEAM SURFACE CONDENSER OPERATION

The main heat transfer mechanisms in a surface condenser are the condensing of saturated steam on the outside of the tubes and the heating of the circulating water inside the tubes. Thus for a given circulating water flow rate, the water inlet temperature to the condenser determines the operating pressure of the condenser. As this temperature is decreased, the condenser pressure will also decrease. As described above, this decrease in the pressure will increase the plant output and efficiency.

Due to the fact that a surface condenser operates under vacuum, noncondensable gases will migrate towards the condenser. The noncondensable gases consist of mostly air that has leaked into the cycle from components that are operating below atmospheric pressure (like the condenser). These gases can also result from caused by the decomposition of water into oxygen and hydrogen by thermal or chemical reactions. These gases must be vented from the condenser for the following reasons:

- The gases will increase the operating pressure of the condenser. Since the total pressure of the condenser will be the sum of partial pressures of the steam and the gases, as more gas is leaked into the system, the condenser pressure will rise. This rise in pressure will decrease the turbine output and efficiency.
- The gases will blanket the outer surface of the tubes. This will severely decrease the heat transfer of the steam to the circulating water. Again, the pressure in the condenser will increase.
- The corrosiveness of the condensate in the condenser increases as the oxygen content increases. Oxygen causes corrosion, mostly in the steam generator. Thus, these gases must be removed in order to extend the life of cycle components.

STEAM SURFACE CONDENSER AIR REMOVAL

The two main devices that are used to vent the noncondensable gases are Steam Jet Air Ejectors and Liquid Ring Vacuum Pumps. Steam Jet Air Ejectors (SJAE) use high-pressure motive steam to evacuate the noncondensables from the condenser (Jet Pump). Liquid Ring Vacuum Pumps use a liquid compressant to compress the evacuated noncondensables and then discharges them to the atmosphere. (See the HEI Primer on Vacuum on the HEI Website, www.heatexchange.org, for further information about Steam Jet Ejectors and Liquid Ring Vacuum Pumps.)

To aid in the removal of the noncondensable gases, condensers are equipped with an Air-Cooler section. The Air-Cooler section of the condenser consists of a quantity of tubes that are baffled to collect the noncondensables. Cooling of the noncondensables reduces their volume and the required size of the air removal equipment.

Air removal equipment must operate in two modes: hogging and holding. Prior to admitting exhaust steam to a condenser, all the noncondensables must be vented from the condenser. In hogging mode, large volumes of air are quickly removed from the condenser in order to reduce the condenser pressure from atmospheric to a predetermined level. Once the desired pressure is achieved, the air removal system can be operated in holding mode to remove all noncondensable gases.

STEAM SURFACE CONDENSER CONFIGURATIONS

Steam surface condensers can be broadly categorized by the orientation of the steam turbine exhaust to the condenser. Most common are side and down exhaust. In a side exhaust condenser, the condenser and turbine are installed adjacent to each other, and the steam from the turbine enters from the side of the condenser. In a down exhaust condenser, the steam from the turbine enters from the top of the condenser and the turbine is mounted on a foundation above the condenser.

Condensers can be further delineated by the configuration of the shell and tube sides.

Tubeside

The tubeside of a steam surface condenser can be classified by the following:

- Number of tubeside passes
- Configuration of the tube bundle and waterboxes

Most steam surface condensers have either one or multiple tubeside passes. The number of passes is defined as how many times circulating water travels the length of the condenser inside the tubes. Condensers with a once-through circulating water system are often one pass. Multiple pass condensers are typically used with closed-loop systems.

The tubeside may also be classified as divided or non-divided. In a divided condenser, the tube bundle and waterboxes are divided into sections. One or more sections of the tube bundle may be in operation while others are not. This allows maintenance of sections of the tubeside while the condenser is operating. In a non-divided tubeside, all the tubes are in operation at all times.

Shellside

The shellside of a steam surface condenser can be classified by its geometry. Examples of types are:

- Cylindrical
- Rectangular

The choice of the above configuration is determined by the size of the condenser, plant layout, and manufacturer preference. Steam surface condensers can be multiple shell and multiple pressure configurations, as well.

See HEI *Standards for Steam Surface Condensers* for examples of shell and tube configurations and for additional information about steam surface condensers.