ROHINI COLLEGE OF ENGINEERING AND TECHNOLOGY
ME 3391 ENGINEERING THERMODYNAMICS
DIGITAL NOTES
UNIT II

Heat Engines

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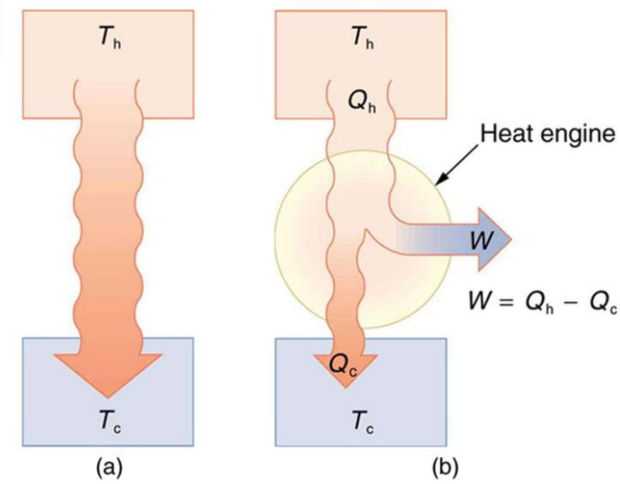
In thermodynamics, a heat engine is a system that performs the conversion of heat or thermal energy to mechanical work. Gasoline and diesel engines, jet engines, and steam turbines are all heat engines that do work by using part of the heat transfer from some source. Heat transfer from the hot object (or hot reservoir) is denoted as Q_h, while heat transfer into the cold object (or cold reservoir) is Q_c, and the work done by the engine is W. The temperatures of the hot and cold reservoirs are T_h and T_c, respectively.



Heat Transfer: (a) Heat transfer occurs spontaneously from a hot object to a cold one, consistent with the second law of thermodynamics. (b) A heat engine, represented here by a circle, uses part of the heat transfer to do work. The hot and cold objects are called the hot and cold reservoirs. Qh is the heat transfer out of the hot reservoir, W is the work output, and Qc is the heat transfer into the cold reservoir.

Heat Pumps and Refrigerators

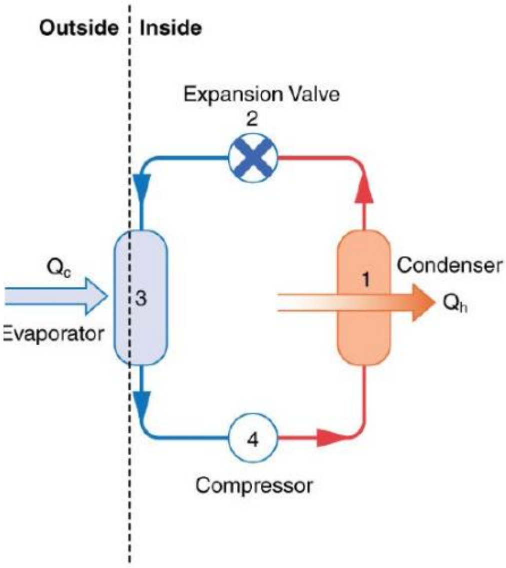
Heat pumps, air conditioners, and refrigerators utilize heat transfer from cold to hot. Heat transfer (Q_c) occurs from a cold reservoir and into a hot one. This requires work input W, which is also converted to heat transfer. Thus the heat transfer to the hot reservoir is $Q_h=Q_c+W$. A heat pump's mission is for heat transfer Q_h to occur into a warm environment, such as a home in the winter. The mission of air conditioners and refrigerators is for heat transfer Q_c to occur from a cool environment, such as chilling a room or keeping food at lower temperatures than the environment. Actually, a heat pump can be used both to heat and cool a space. It is essentially an air conditioner and a heating unit all in one. In this section we will concentrate on its heating mode.

Heat Pumps

A working fluid such as a non-CFC refrigerant is used in a basic heat pump. The basic components of a heat pump in are a condenser, an expansion valve, an evaporator and a compressor. In the outdoor coils (the evaporator), heat transfer Q_c occurs to the working fluid from the cold outdoor air, turning it into a gas. The electrically driven compressor (work input

W) raises the temperature and pressure of the gas and forces it into the condenser coils that are inside the heated space. Because the temperature of the gas is higher than the temperature inside the room, heat transfer to the room occurs and the gas condenses to a liquid. The liquid then flows back through a pressure-reducing valve to the outdoor evaporator coils, being cooled through expansion. (In a cooling cycle, the evaporator and condenser coils exchange roles and the flow direction of the fluid is reversed.)

The heat pump itself consists of a compressor, which moves a refrigerant through a refrigeration cycle, and a heat exchanger, which extracts heat from the source. The heat is then passed on to a heat sink through another heat exchanger. In buildings, the heat is delivered using either forced air or hydronic systems such as radiators or under-floor heating. Heat pumps can be connected to a tank to produce sanitary hot water or provide flexibility in hydronic systems. Many of the heat pumps can also provide space cooling in summer in addition to meeting space heating needs in winter. In industry, heat pumps are used to deliver hot air, water or steam, or to directly heat materials. Large-scale heat pumps in commercial or industrial applications or in district heating networks require higher input temperatures than in residential applications, which can be sourced from the waste heat of industrial processes, data centres or wastewater.



Simple Heat Pump: A simple heat pump has four basic components: (1) condenser, (2) expansion valve, (3) evaporator, and (4) compressor.

Coefficient of Performance

The quality of a heat pump is judged by how much heat transfer $Q_h$occurs into the warm space compared with how much work input W is required. We define a heat pump's coefficient of performance (COP_{hp}) to be

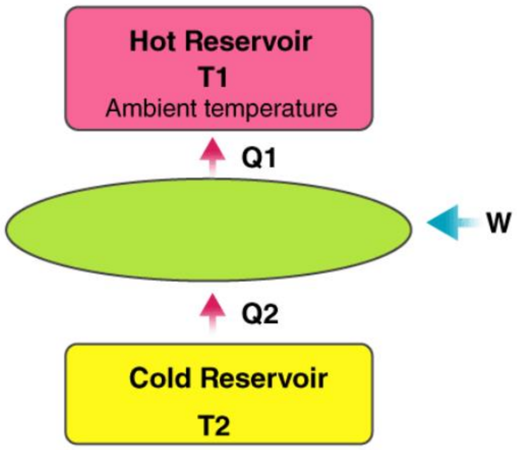
$$COP_{hp} = \frac{Q_h}{W}.$$

Since the efficiency of a heat engine is $Eff = W/Q_h$, we see that $COP_{hp} = 1/Eff$. Since the efficiency of any heat engine is less than 1, it means that COP_{hp} is always greater than 1—that is, a heat pump always has more heat transfer Q_h than work put into it. Another interesting point is that heat pumps work best when temperature differences are small.

Applications

- **Space heating:** Heat pump is used to heat an enclosed area such as a workspace, greenhouses, and houses.
- **Water heating:** Water in industries and households is heated using heat recovered from other reactions using the heat pump.
- **Process heating:** In industries, the heat pump is used to heat the process fluid before the reactions.
- **Heat recovery:** Heat pump is used to recover process heat from other reactions.

Refrigerator



In the refrigeration cycle, there are five basic components: a fluid refrigerant, a compressor, a condenser coil, an evaporator coil, and an expansion device. The compressor constricts the refrigerant vapour, raising its pressure, and pushes it into the coils on the outside of the refrigerator. When the hot gas in the coils meets the cooler air temperature of the kitchen, it becomes a liquid. Now, in liquid form at high pressure, the refrigerant cools down as it flows into the coils inside the freezer and the fridge. The refrigerant absorbs the heat inside the fridge, cooling down the air. Lastly, the refrigerant evaporates and then flows back to the compressor, where the cycle repeats itself.

Applications

- **Separation of gases:** Separation of air into its constituents by fractional distillation as different components of air liquefies at different temperatures.
- **Condensation of gases:** In industries, gases such as ammonia are condensed before storage and shipment.

- **Dehumidification of air:** Air is dehumidified by liquefying and separating the moisture present in it.
- **Cooling for preservation:** Vegetables, organic-chemical, and explosives are kept in cold storage for preservation.