ROHINI COLLEGE OF ENGINEERING AND TECHNOLOGY

ME 3391 ENGINEERING THERMODYNAMICS DIGITAL NOTES

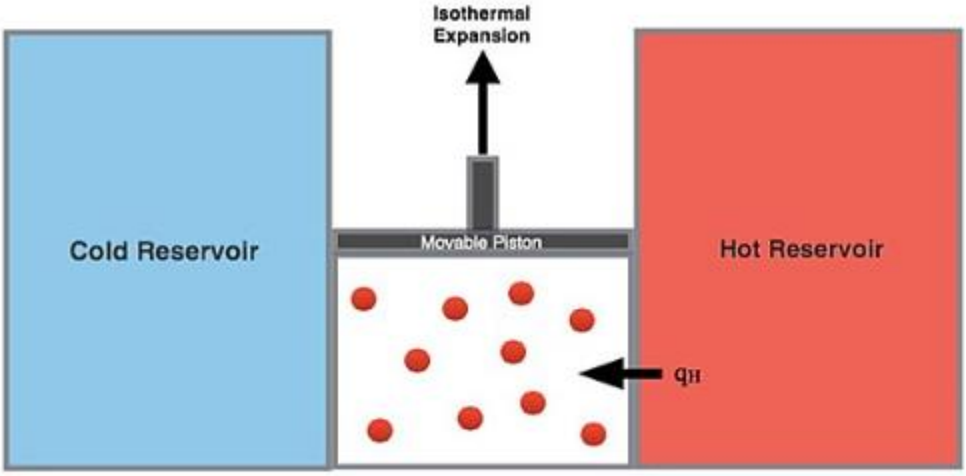
DIGITAL NOTES

CARNOT CYCLE

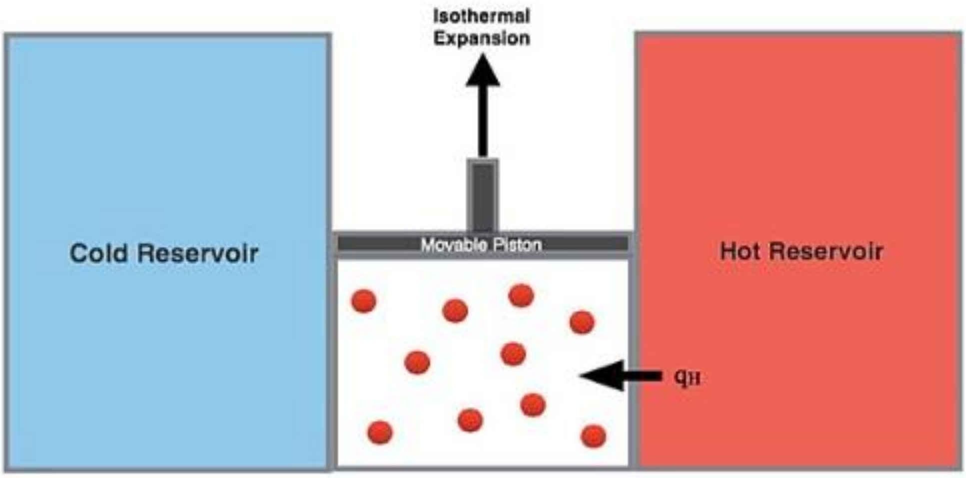
A Carnot cycle is defined as an ideal reversible closed thermodynamic cycle. Four successive operations are involved: isothermal expansion, adiabatic expansion, isothermal compression, and adiabatic compression. During these operations, the expansion and compression of the substance can be done up to the desired point and back to the initial state. . During these operations, the expansion and compression of the substance can be done up to the desired point and back to the initial state.

Stages

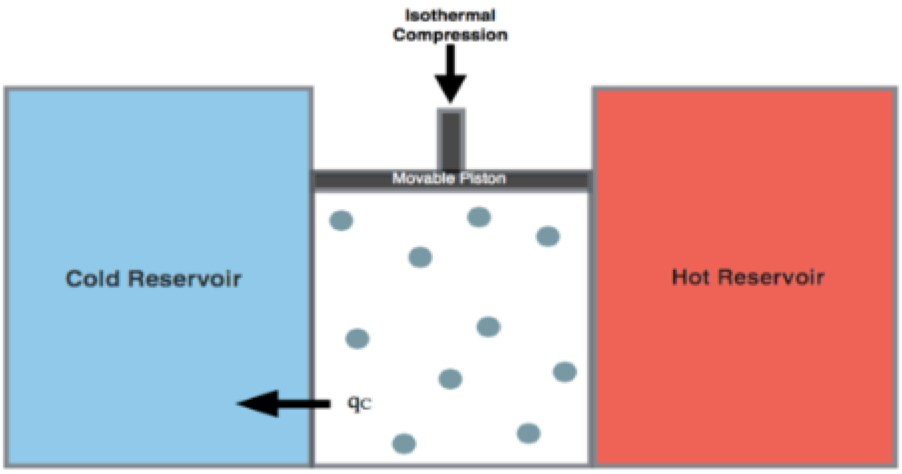
Isothermal expansion. Heat (as an energy) is transferred reversibly from hot temperature reservoir at constant temperature T_H to the gas at temperature infinitesimally less than T_H (to allow heat transfer to the gas without practically changing the gas temperature so isothermal heat addition or absorption). During this step, the gas is thermally in contact with the hot temperature reservoir (while thermally isolated from the cold temperature reservoir) and the gas is allowed to expand, doing work on the surroundings by gas pushing up the piston (stage 1 figure, right). Although the pressure drops from points 1 to 2 (figure 1) the temperature of the gas does not change during the process because the heat transferred from the hot temperature reservoir to the gas is exactly used to do work on the surroundings by the gas, so no gas internal energy changes (no gas temperature change for an ideal gas).



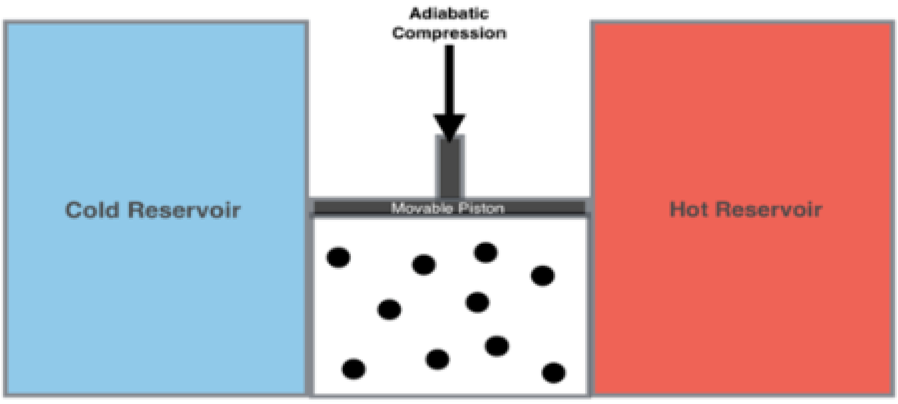
Isentropic (reversible adiabatic) expansion of the gas (isentropic work output). For this step the gas in the engine is thermally insulated from both the hot and cold reservoirs, thus they neither gain nor lose heat, an 'adiabatic' process. The gas continues to expand with reduction of its pressure, doing work on the surroundings (raising the piston; stage 2 figure, right), and losing an amount of internal energy equal to the work done. The gas expansion without heat input causes the gas to cool to the "cold" temperature (by losing its internal energy), that is infinitesimally higher than the cold reservoir temperature T_C. The entropy remains unchanged as no heat Q transfers ($Q = 0$) between the system (the gas) and its surroundings, so an isentropic process, meaning no entropy change in the process).

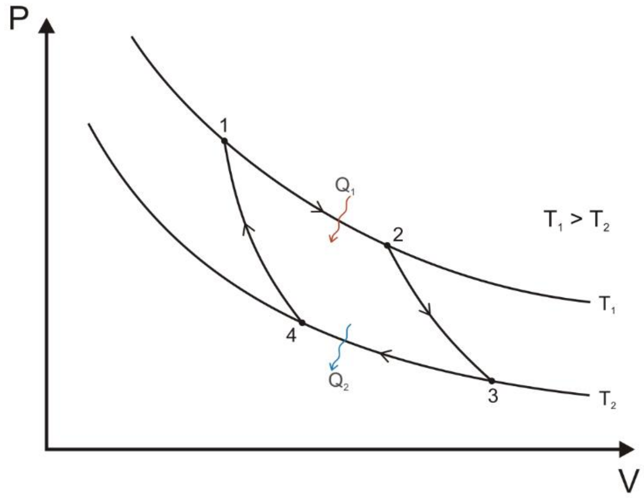


Isothermal compression. Heat transferred reversibly to low temperature reservoir at constant temperature T_C (isothermal heat rejection). In this step the gas in the engine is in thermal contact with the cold reservoir at temperature T_C (while thermally isolated from the hot temperature reservoir) and the gas temperature is infinitesimally higher than this temperature (to allow heat transfer from the gas to the cold reservoir without practically changing the gas temperature). The surroundings do work on the gas, pushing the piston down (stage 3 figure, right). An amount of energy earned by the gas from this work exactly transfers as a heat energy $Q_C < 0$ (negative as leaving from the system, according to the universal convention in thermodynamics) to the cold reservoir and entropy decreases due to compression.



Isentropic compression. Once again the gas in the engine is thermally insulated from the hot and cold reservoirs, and the engine is assumed to be frictionless and the process is slow enough, hence reversible. During this step, the surroundings do work on the gas, pushing the piston down further (stage 4 figure, right), increasing its internal energy, compressing it, and causing its temperature to rise back to the temperature infinitesimally less than T_H due solely to the work added to the system, but the entropy remains unchanged. At this point the gas is in the same state as at the start of step 1.





$$\Delta S_H + \Delta S_C = \Delta S_{\text{cycle}} = 0,$$

or,

$$\frac{Q_H}{T_H} = -\frac{Q_C}{T_C}.$$