ROHINI COLLEGE OF ENGINEERING AND TECHNOLOGY

ME 3391 ENGINEERING THERMODYNAMICS

DIGITAL NOTES

UNIT III

SECOND LAW EFFICIENCY

The second law efficiency, of a process is defined as the ratio of the minimum available energy (or exergy) which must be consumed to do a task_ divided by the actual amount of available energy (or exergy) consumed. in performing the task.

Efficiency = Minimum exergy intake to perform the given task/ actual exergy intake to perform the same task.

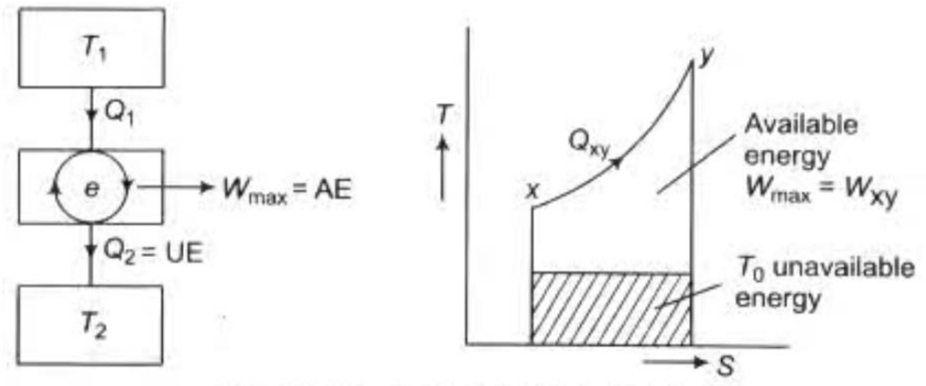
Efficiency = A_{min}/A

AVAILABILITY AND IRREVERSIBILITY

In thermodynamics, availability and irreversibility are closely related. Irreversible processes inevitably lead to a decrease in the availability of energy, as some of the energy that enters the system is inevitably lost as waste heat. This limits the efficiency of energy conversion processes, as some of the energy that could be used to do useful work is lost. Conversely, reversible processes are characterized by zero irreversibility and maximum availability, meaning that all the energy that enters the system can be used to do work. The concept of availability was first introduced by the physicist and mathematician Lord Kelvin in the mid-19th century as a measure of the maximum amount of work that could be extracted from a given system.

Since then, it has become a key concept in thermodynamics, used to evaluate the efficiency of energy conversion processes in a wide range of fields, from engineering and physics to environmental science and economics. Despite its importance, the concept of availability is often misunderstood or misapplied. Many people assume that availability is equivalent to energy, or that it is a measure of the total amount of work that can be extracted from a system. In reality, availability is a much more complex concept that takes into account factors such as temperature, pressure, and entropy, as well as the irreversibility of energy conversion processes. Understanding the relationship between availability and irreversibility is therefore essential for anyone seeking to design, optimize, or evaluate energy systems.

The availability of a system is always less than its total energy, as some energy is lost as heat due to irreversibilities such as friction and heat transfer. In order to maximize the availability of a system, engineers and scientists seek to minimize these irreversibilities and optimize the design and operation of the system. This can lead to more efficient and cost-effective systems that have less environmental impact. When a system is subjected to a process from its original state to its dead state the maximum amount of useful work that can be achieved under ideal conditions is known as available energy or availability of the system.



Availability and unavailability of energy

W_{max} =AE = $Q_{xy} - T_0(S_y\text{-}S_x)$

Unavailable Energy: UAE = $T_0(S_y\text{-}S_x)$

EXERGY IN CLOSED SYSTEM

Exergy is a thermodynamic property that measures the maximum amount of useful work that can be extracted from a system as it approaches a state of thermodynamic equilibrium with its surroundings. In a closed system, the exergy is a measure of the maximum amount of useful work that can be obtained from the system if it were brought into thermodynamic equilibrium with its surroundings. The exergy of a closed system is also known as the available work or the maximum work.

The exergy of a closed system is determined by its state variables, such as temperature, pressure, and composition, and the state variables of its surroundings. The surroundings include the external work that can be done on the system and the heat that can be transferred between the system and its surroundings. The exergy of a closed system can be calculated using the first and second laws of thermodynamics.

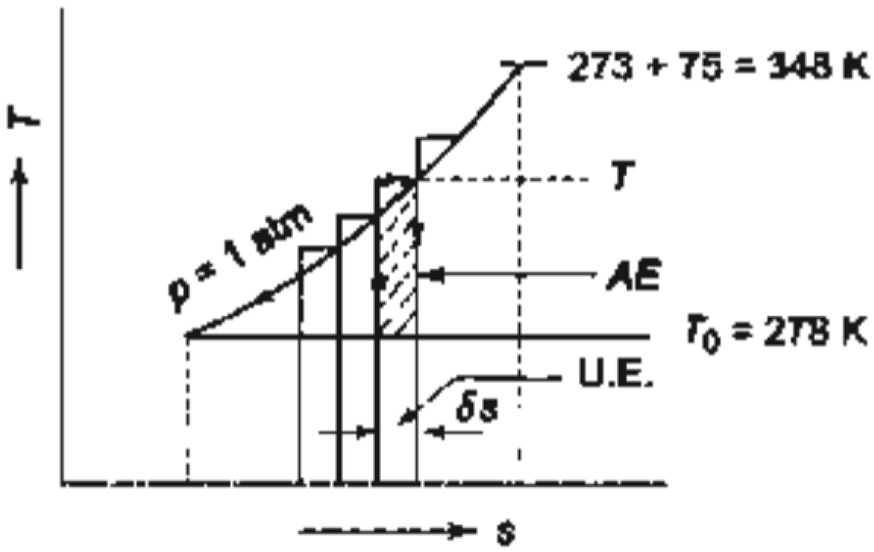
Calculate the available energy in 40 kg of water at 75°C with respect to the surroundings at 5°C, the pressure of water being I atm.

Solution

If the water is cooled at a constant pressure of 1 attn from 75°C to 5°C lbe heat given up may be used as a source for a series of Carnot engines each using the surroundings as a sink. It is assuned that the amount of energy received by any engine is small relative to that in the source and the temperature of the source does not change while heat is being exchanged with the engine.

Let us consider that the source has fallen to temperature T, at which level there operates a Carnot engine which takes in heat at this temperature and rejects heat at T0 = 278 K. If 8s is the entropy change of water, the work obtainable is t where 8s is negative.

With a very great number of engines in the series, the total work (maximum) obtainable when the water is cooled from 348 K to 278 K



$$W_{(max)} = \text{A.E.} = -\lim \sum_{348}^{278} 40 c_p \left(1 - \frac{T_0}{T}\right) \delta T$$

$$= \int_{278}^{348} 40 c_p \left(1 - \frac{T_0}{T}\right) dT$$

$$= 40 c_p \left[(348 - 278) - 278 \ln \frac{348}{278}\right]$$

$$= 40 \times 4.2\ (70 - 62)$$

$$= 1340 \text{ kJ}$$

$$Q_1 = 40 \times 4.2\ (348 - 278)$$

$$= 11{,}760 \text{ kJ}$$

$$\text{U.E.} = Q_1 - W_{(max)}$$

$$= 11{,}760 - 1340 = 10{,}420 \text{ kJ}$$