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REVIEW ARTICLE

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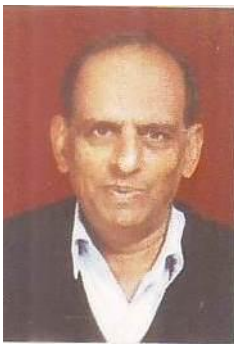
# AVAILABILITY, UNAVAILABILITY AND IRREVERSIBILITY

**Dr. LC SINGAL[1], SATISH KUMAR[2], Dr. RADHEY SHAM[3]**

[1,2]Department of Mechanical Engineering, Chandigarh Engineering College, Landran (Mohali), Punjab, India

[3]Department of Mechanical Engineering, Chandigarh College of Engineering & Technology, Chandigarh, India



**Dr. LC SINGAL**

**ABSTRACT**

The portion of low grade energy which can be converted into useful work is availability. The portion of low grade energy which cannot be converted into useful work is unavailability. The difference between total availability and useful work obtained is irreversibility. Irreversibility is inherent to every process. It is due to some kind of energy or potential loss or heat dissipation. There is internal as well as external irreversibility. Irreversibility is found in every day today process too like eating and cooking of food. Well known two statements of the Second law of Thermodynamics, by Planck's and Clausius, prove irreversibility in every process. Irreversibility can be reduced but cannot be eliminated altogether.



SYMBOLS AND ABBREVIATIONS

| | |
|---|---|
| *H* | *Total enthalpy, kJ* |
| *h* | *Specific enthalpy, kJ/kg* |
| *P* | *pressure, bars* |
| *S* | *Total entropy, kJ/K* |
| *s* | *Specific entropy, kJ/kg K* |
| *T* | *Absolute temperature, K* |
| *U* | *Internal energy, kJ* |
| *V* | *Volume, $m^3$* |
| *W* | *Work, kJ* |
| *w* | *Specific work, kJ/kg* |

## I. INTRODUCTION

There are different grades of energy available such as high grade and low grade. The amount of low-grade energy which can be converted into high grade energy is availability. The amount of low-grade energy which cannot be converted into high grade energy is unavailability. Availability has been considered between two reservoirs as well as between one finite source and the atmosphere. Irreversibility is the difference of total available energy and the actual useful work obtained. Every natural process is irreversible. Thus irreversibility is inherent to every process either due to heat dissipation or some loss of one kind or the other. Both Planck's and Clausius statements of the Second Law of Thermodynamics are the laws of irreversibility. It can be reduced but it cannot be eliminated altogether. A reversible process has zero irreversibility. But it is only a theoretical concept as it cannot be achieved in actual practice [1-11].

## II. GRADES OF ENERGY

There are two grades of energy available from the various sources [3-6].

*A. High grade energy*

High grade energy is that which can be fully converted useful work (Shaft Work) and is not governed by the Second Law of Thermodynamics [4-8].Examples of High Grade Energy are

i. Mechanical work
ii. Electrical energy
iii. Potential energy
iv. Kinetic energy
v. Wind energy
vi. Water energy

vii. Jet energy

(i) Tidal energy

*B. Low Grade Energy*

Low-grade energy is that which cannot be fully converted useful work (Shaft Work) and is governed by the Second Law of Thermodynamics. Examples of Low Grade Energy are

(i) Heat from nuclear fission or fusion

(ii) Heat from combustion of fossil fuels

(iii) Solar energy

(iv) Heat energy from any source

The high-grade energy is obtained from low-grade energy. The complete conversion of low grade energy into high grade (shaft work) is impossible i.e. there is irreversibility which varies from one process to another process.

**III. AVAILABILITY OR AVAILABLE ENERGY**

The amount of low-grade energy which can be converted into high grade energy is available energy.

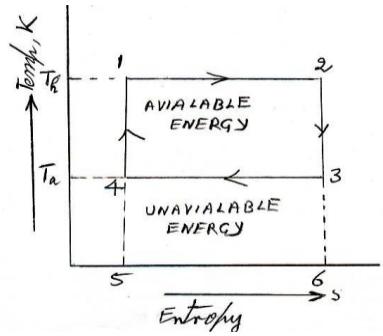



Fig. 1Availability and unavailability between Two Reservoirs (At Constant Temperatures)

Total availability = area 1-2-6-5-1

Availability = $W_{useful}$ = area 1-2-3-4-1

Unavailability = area 4-5-6-3-4

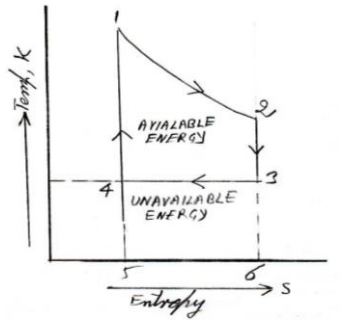



Fig. 2Availability and unavailability from a Finite Source

Total availability = area 1-2-6-5-1

Availability = $W_{useful}$ = area 1-2-3-4-1

Unavailability = area 4-5-6-3-4

IV. UNAVAILABILITY OR UNAVAILABLE ENERGY

The amount of low-grade energy which cannot be converted into high grade energy is unavailable energy.

$T_h$ is the absolute high temperature of a body and $T_a$ is the absolute atmospheric temperature in Fig.1.No energy can be converted into useful work below the atmospheric conditions. T1 and T2 are the absolute temperatures of a finite source and T4 is the absolute atmospheric temperature in Fig.2.

**V. AVAILABILITY FOR A NON-FLOW PROCESS**

Since availability is useful work. Therefore non flow process will be an expansion process up to atmospheric pressure $p_a$. Let $V_1$ and $V_a$ are the initial and final volumes of the system. Therefore work which could not be recovered will be = $P_a(V_a-V_1)$. Since it is a non-flow process, there will be no flow work. Hence only initial and final internal energies will be involved.

Availability= $W_{useful}= W_{max}—P_a(V_a-V_1)$

Availability per unit mass will be = $w_{useful}= w_{max} –T_a (s_a–s_1)$

For a non-flow process, $W_{max}= (U_1-U_a)-T_a (S_a-S_1)$

VI. AVAILABILITY FOR A FLOW PROCESS

In a flow process, flow work comes into existence. Thus enthalpies will be involved.

Availability =$W_{useful} = W_{max} = (H_1—H_a) – T_a (S_a—S_1)$

Availability per unit mass will be =$w_{useful}= w_{max =} (h_1 – h_a) –T_a (s_a–s_1)$

Availability energy is also called exergy or work potential of a system provided the body comes in equilibrium with the atmosphere after the process.

**VII. IRREVERSIBILITY**

It is the difference of total available energy and the actual useful work obtained. Every process in nature is irreversible. It is because of invisible or visible directional constraint. It is due to the reason that every process tends to acquire equilibrium. But the degree of irreversibility differs from one process to another process. It is because of different conditions, different causes and their varying magnitudes. In an irreversible process, both the

system and the surroundings cannot achieve the original condition. For example, fuel consumed by an automobile in going up a hill will not be returned while coming down a hill. Irreversibility is irrecoverability. Other examples are that fluid always flows from a higher pressure to a lower pressure. Heat always flows from higher temperature to lower temperature. Materials always diffuse from high concentration to low concentration. Moving vehicle is stopped by applying a brake which results in heat dissipation. When electric current passes through a cable, there is heat dissipation. Reverse of any of these never happens. Thus irreversibility is uni-directional. To make a process reversible, some external energy/force is to be used. Both Planck's and Clausius statements of the Second Law of Thermodynamics are the Laws of irreversibility.

**VIII. PLANCK'S STATEMENT OF SECOND LAW OF THERMODYNAMICS- AN IRREVERSIBILITY**

It states that there is no engine in the Universe which can convert certain amount of heat energy into equivalent work. But a certain amount of work can be converted into equivalent heat. Thus it talks of irreversibility in mutual conversion of heat and work.

IX. CLAUSIUS STATEMENT OF SECOND LAW OF THERMODYNAMICS- AN IRREVERSIBILITY

It states that heat cannot flow from a body at low temperature to a body at high temperature without the use of an external agent. But heat flows naturally from high temperature to low temperature by itself. Therefore Clausius statement talks of irreversibility in heat transfer between two bodies at different temperatures.

Irreversibility involves heat dissipation or increase of entropy or both. Irreversible processes happen under non equilibrium state. However thermodynamics deals with processes under equilibrium. There is no change in entropy or free energy at equilibrium. An irreversible process dissipates energy and entropy is created as a result of that. Thus for irreversible processes, the equations of classical thermodynamics become inequalities. An important aspect of sustainable development is the minimization of irreversibility's caused by the use of non-renewable like petrol and diesel. Free expansion is internally irreversible. Melting of ice is also irreversible.

**X. CAUSES OF IRREVERSIBILITY**

There are many reasons for a process to be irreversible.

**(i)** Friction
**(ii)** Plastic deformation under an external force
**(iii)** Free or unrestrained expansion
**(iv)** Heat transfer due to finite temperature difference
**(v)** Mass transfer
**(vi)** Fluid transfer
**(vii)** Momentum transfer
**(viii)** Current transfer
**(ix)** Mixing of two substances
**(x)** Magnetization
**(xi)** Polymerization
**(xii)** Spontaneous chemical reaction like combustion

**XI. TYPES OF IRREVERSIBILITY**

There are two types of irreversibility.

*A. Internal Irreversibility*

These occur within the working fluid. These are of further of two types.

(i) Internal mechanical irreversibility: Mechanical ir-reversibility **i**s due to friction and turbulence. It causes pressure drop, rise of temperature, increase of internal energy and increase in volume

**(ii)** Internal Thermal irreversibility**:** Thermal irreversibility is due to change of energy on mixing of two fluids. It is because of exothermic or endothermic nature of mixing of fluids. The internal irreversibility can be reduced but cannot be eliminated altogether.

*B. External Irreversibility*

These are external to the fluid. It is due to external friction between the moving parts such as friction in bearings and friction between cylinder walls and the piston. External ir-reversibility is between the system and the surroundings. It is due to friction between the moving /rotating parts and the atmosphere. External thermal irreversibility is

due to temperature difference. This irreversibility can be reduced but cannot be eliminated altogether.

**XII. PRACTICAL EXAMPLES OF IRREVERSIBILITY**

(i) Heat transfer due to temperature difference
(ii) Inelastic deformation
(iii) Work lost due to friction
(iv) Pressure drop due to friction
(v) Internal /external leakage
(vi) Flow of fluid due to pressure difference
(vii) Flow of current due to voltage difference
(viii) Mass transfer due to concentration difference
(ix) Free expansion
(x) Throttling expansion

**XIII. CONCLUSIONS**

- Availability is useful work obtained from low grade energy.
- Unavailability is that part of low grade energy which could not be converted into useful work.
- Difference between total availability and actual availability is irreversibility.
- Every process is irreversible.
- Irreversibility is inherent to every process due to some loss of one kind or the other.
- Planck's and Clausius statements of Second Law of Thermodynamic are the Laws of irreversibility.
- There is an internal as well as an external irreversibility.
- The internal as well as external irreversibility can be reduced but cannot be eliminated all together.
- Irreversibility exists every moment in each and every process. It may be cooking, eating, fluid flow or heat transfer.

**REFERENCES**

[1] Y. V.C. Rao, *Theory and Problems of Thermodynamics*, 1994, Wiley Eastern Ltd., New Delhi
[2] N.A .Gokcen and R.G.Reddy, *Thermodynamics,*1996,Plenum Press, New York
[3] C P Arora , *Engineering Thermodynamics*, 2001,Tata McGraw Hill
[4] J. Springer and Honerkamp,*Statistical Physics*, 2002, *p. 298.* ISBN978-3-540-43020-9
[5] Jones and Dugan, *Engineering Thermodynamics*, 2004, PHI, New Delhi
[6] E. Radhakrishnan, *Fundamentals of Engineering Thermodynamics,* 2005, PHI, New Delhi
[7] P K Nag, *Engineering Thermodynamics*, 2005, Tata McGraw Hill
[8] Cengel and Boles, *Thermodynamics : An Engineering Approach* - 2006, McGraw Hill Company
[9] B.K. VENKANNA and B.V.SWATI, *Thermodynamics*, 2010, PHI, New Delhi
[10] R.K.Rajput, *Thermal Engineering* , 2010,Laxmi Publications
[11] Bhavik R. Bakshi, Timothy G. Gutowski and Dusan P. Sekulic, *Thermodynamics and the Destruction of Resources*, Edited, 2011, Cambridge University Press