UNIT–V: POWER CYCLES AND REFRIGERATION CYCLES

1. Thermodynamic Cycle

Definition

A **thermodynamic cycle** is a series of thermodynamic processes in which the working fluid returns to its initial state after completing all processes.

- Initial state = Final state
- Net change in internal energy = 0

Hence,

Net Work = Net Heat Transfer

Classification of Cycles

A) Power Cycles

Convert heat energy into mechanical work.

Examples:

- Otto Cycle
- Diesel Cycle
- Dual Cycle
- Brayton Cycle
- Rankine Cycle

B) Refrigeration Cycles

Require work input to remove heat from a low-temperature region.

Examples:

- Carnot Refrigeration Cycle
- Vapour Compression Refrigeration Cycle (VCRS)
- Vapour Absorption Refrigeration Cycle (VARS)

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2. Carnot Cycle

It is the **most efficient heat engine cycle** operating between two temperature reservoirs.

Processes

1. Isothermal Expansion
2. Adiabatic Expansion
3. Isothermal Compression
4. Adiabatic Compression

Efficiency

η=1−TLTH\eta = 1-\frac{T_L}{T_H}η=1−THTL

Where

- TH = Source temperature
- TL = Sink temperature

Advantages

- Maximum possible efficiency
- Reversible cycle

Limitations

- Difficult to implement practically
- Requires infinitely slow processes

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3. Otto Cycle (SI Engine)

Used in Petrol Engines.

Processes

1→2 Isentropic Compression

2→3 Constant Volume Heat Addition

3→4 Isentropic Expansion

4→1 Constant Volume Heat Rejection

Thermal Efficiency

$$\eta =1-\frac{1}{r^{\gamma-1}}$$

where

r = Compression ratio

γ = Cp/Cv

Applications

- Petrol Cars
- Motorcycles
- Small Generators

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4. Diesel Cycle (CI Engine)

Used in Diesel Engines.

Processes

1→2 Isentropic Compression

2→3 Constant Pressure Heat Addition

3→4 Isentropic Expansion

4→1 Constant Volume Heat Rejection

Efficiency

Depends upon

- Compression ratio
- Cut-off ratio

Diesel cycle efficiency is lower than Otto cycle for the same compression ratio.

Applications

- Trucks
- Buses
- Tractors
- Ships

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5. Dual Cycle

Combination of Otto and Diesel cycles.

Heat addition occurs

- Partly at Constant Volume
- Partly at Constant Pressure

Applications

Modern high-speed diesel engines.

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6. Brayton Cycle

Used in Gas Turbine Power Plants.

Processes

1. Isentropic Compression
2. Constant Pressure Heat Addition
3. Isentropic Expansion
4. Constant Pressure Heat Rejection

Applications

- Aircraft Engines
- Gas Turbine Plants

Efficiency

$$\eta =1-\frac{1}{r_p^{(\gamma-1)/\gamma}}$$

where

r_p = Pressure Ratio

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7. Rankine Cycle

Used in Steam Power Plants.

Processes

1. Pump
2. Boiler
3. Turbine
4. Condenser

Applications

- Thermal Power Plants
- Nuclear Power Plants

Main Components

- Boiler
- Turbine
- Condenser

- Feed Pump

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8. Refrigeration

Definition

Refrigeration is the process of removing heat from a low-temperature body and rejecting it to a high-temperature body.

Applications

- Refrigerator
- Air Conditioner
- Cold Storage
- Ice Plants

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9. Refrigeration Cycle

Main Processes

Compression

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Condensation

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Expansion

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Evaporation

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10. Vapour Compression Refrigeration System (VCRS)

Main Components

1. Compressor
2. Condenser
3. Expansion Valve
4. Evaporator

Working

Compressor

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High Pressure Vapour

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Condenser

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Liquid Refrigerant

↓

Expansion Valve

↓

Low Pressure Mixture

↓

Evaporator

↓

Cooling Effect

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Compressor

Advantages

- High efficiency
- Compact
- Widely used

Applications

- Domestic Refrigerator
- Air Conditioning
- Cold Storage

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11. Vapour Absorption Refrigeration System (VARS)

Uses heat instead of mechanical work.

Main Components

- Generator
- Absorber
- Condenser
- Evaporator
- Pump

Working Fluids

Ammonia–Water

or

Lithium Bromide–Water

Advantages

- Low electricity consumption
- Uses waste heat

Applications

- Hotels
- Large Buildings
- Solar Refrigeration

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12. Coefficient of Performance (COP)

Refrigerator

COPR=Refrigeration EffectWork InputCOP_R=\frac{\text{Refrigeration Effect}}{\text{Work Input}}COPR=Work InputRefrigeration Effect

Higher COP indicates better performance.

Heat Pump

COPHP=COPR+1COP_{HP}=COP_R+1COPHP=COPR+1

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13. Difference Between Heat Engine and Refrigerator

Heat Engine	Refrigerator
Produces work	Consumes work
Converts heat into work	Removes heat from low-temperature region
Efficiency is important	COP is important
Heat flows naturally	Heat transferred against natural direction

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14. Comparison of Power Cycles

Cycle	Heat Addition	Used In
Carnot	Isothermal	Ideal Engine
Otto	Constant Volume	Petrol Engine
Diesel	Constant Pressure	Diesel Engine
Dual	CV + CP	Modern CI Engine
Brayton	Constant Pressure	Gas Turbine
Rankine	Steam Cycle	Steam Power Plant

15. Important Formulae

- Carnot Efficiency:

  η=1−TLTH\eta =1-\frac{T_L}{T_H}η=1−THTL

- Otto Efficiency:

  η=1−1rγ−1\eta =1-\frac{1}{r^{\gamma-1}}η=1−rγ−11

- Refrigerator COP:

  COPR=QLWCOP_R=\frac{Q_L}{W}COPR=WQL

- Heat Pump:

  COPHP=COPR+1COP_{HP}=COP_R+1COPHP=COPR+1

Frequently Asked University Exam Questions (NR25)

2 Marks

1. Define thermodynamic cycle.
2. State Carnot theorem.
3. Define COP.
4. List the components of VCRS.