COURSE FILE

THERMAL ENGINEERING 1
(Subject Code: C312)

III Year, I Sem B.TECH. (MECHANICAL ENGINEERING)

Submitted to

DEPARTMENT OF MECHANICAL ENGINEERING

BY

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NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING & TECHNOLOGY, HYDERABAD

DEPARTMENT OF MECHANICAL ENGINEERING

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3. VISION AND MISSION OF THE INSTITUTE

VISION

To impart quality technical education with strong ethics, producing technically sound engineers capable of serving the society and the nation in a responsible manner.

MISSION

M1: To provide adequate knowledge encompassing strong technical concepts and soft skills thereby inculcating sound ethics.

M2: To provide a conducive environment to nurture creativity in teaching- learning process.

M3: To identify and provide facilities which create opportunities for deserving students of all communities to excel in their chosen fields.

M4: To strive and contribute to the needs of the society and the nation by applying advanced engineering and technical concepts.

PROGRAM OUTCOMES (POs)

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate review research literature and analyze complex engineering problems reaching substantiated conclusions using first principle of mathematics, natural science and engineering science.
3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

4. VISION AND MISSION OF MECHANICAL ENGINEERING DEPARTMENT

VISION

To achieve excellence in Mechanical Engineering by imparting technical and professional skills along with ethical values to meet social needs via industrial requirements.

MISSION

M1: To offer quality education with the supportive facilities to produce efficient and competent engineers through industry-institute interaction.

M2: To prepare the students with academic excellence, professional competence, and ethical behaviour for a lifelong learning.

M3: To inculcate moral & professional values among the students to cater the needs of the society and environment.

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

- **PEO 1**: Graduates will apply their engineering knowledge and problem-solving skills to design mechanical systems and processes.
- **PEO 2:** Graduates will embrace leadership skills at various roles in their career and establish excellence in the field of Mechanical Engineering.
- **PEO 3:** Graduates will provide engineering solutions to meet industrial requirements there by full fill societal needs.

Course Objectives

- To apply the laws of Thermodynamics to analyze air standard cycles.
- To understand, evaluate and perform analysis of the major components and systems of IC engines, refrigeration cycles and their applications.

Course Outcomes:

At the end of the course, the student should be able to:

CO1	Understand the working principles of various types of IC engines and its supporting systems.
CO2	Distinguish between normal and abnormal combustion and evaluate the performance of IC engines with different operating conditions.
CO3	Recognize the types of compressors and evaluate their performance under different operating conditions.
CO4	Apply the laws of thermodynamics to assess the performance of refrigeration and design an air-conditioning system.

UNIT – V

Refrigeration: Mechanical Refrigeration and types – units of refrigeration – Air Refrigeration system, details and principle of operation – applications of air refrigeration, Vapour compression refrigeration systems – calculation of COP – effect of superheating and sub cooling, desired properties of refrigerants and common refrigerants- Vapour absorption system – mechanical details – working principle, Use of p-h charts for calculations Air- Conditioning: Concepts of Psychrometry – Properties of moist air – Usage of Psychrometric Chart – Calculation of moist air properties. Types of air – conditioning systems – Requirements - schematic layout of a typical plant.

TEXT BOOKS:

1. I.C. Engines / V. Ganesan / Mc Graw Hill
2. Thermal Engineering / Mahesh M Rathore / Mc Graw Hill

REFERENCE BOOKS:

1. Applied Thermodynamics for Engineering Technologists / Eastop / Pearson
2. Fundamentals of Classical Thermodynamics / Vanwylen G.J., Sonntag R.E. / Wiley Eastern

Syllabus

Course Code	Course Title				Core/Elective
C312	THERMAL ENGINEERING 1				Core
Prerequisite	Contact Hours per week				Credits
	L	T	P	D	
	4	1	0	0	4

UNIT – I

I.C. Engines: Classification - Working principles of Four & Two stroke engine, SI & CI engines, Valve and Port Timing Diagrams, Air – Standard, air-fuel and actual cycles - Engine systems – Carburetor and Fuel Injection Systems for SI engines, Fuel injection systems for CI engines, Ignition, Cooling and Lubrication system, Fuel properties and Combustion Stoichiometry.

UNIT – II

Normal Combustion and abnormal combustion in SI engines – Importance of flame speed and effect of engine variables – Abnormal combustion, pre-ignition and knocking in SI Engines – Fuel requirements and fuel rating, anti-knock additives – combustion chamber – requirements, types of SI engines. Four stages of combustion in CI engines – Delay period and its importance – Effect of engine variables – Diesel Knock– Need for air movement, suction, compression and combustion induced turbulence in Diesel engine – open and divided combustion chambers and fuel injection– Diesel fuel requirements and fuel rating

UNIT – III

Testing and Performance: Parameters of performance - measurement of cylinder pressure, fuel consumption, air intake, exhaust gas composition, Brake power – Determination of frictional losses and indicated power – Performance test – Heat balance sheet and chart Classification of compressors – Fans, blowers and compressors – positive displacement and Dynamic types – reciprocating and rotary types. Reciprocating Compressors: Principle of operation, work required, Isothermal efficiency volumetric efficiency and effect of clearance volume, staged compression, under cooling, saving of work, minimum work condition for staged compression

UNIT – IV

Rotary Compressor (Positive displacement type): Roots Blower, vane sealed compressor, Lysholm compressor – mechanical details and principle of working – efficiency considerations. Dynamic Compressors: Centrifugal compressors: Mechanical details and principle of operation – velocity and pressure variation. Energy transfer-impeller blade shape-losses, slip factor, power input factor, pressure coefficient and adiabatic coefficient – velocity diagrams

– power. Axial Flow Compressors: Mechanical details and principle of operation – velocity triangles and energy transfer per stage degree of reaction, work done factor – isentropic efficiency pressure rise calculations – Polytropic efficiency.

PROGRAM SPECIFIC OUTCOMES (PSOs)

- **PSO-1:** Implement new ideas on product design and development with the help of modern computer aided tools, while ensuring best manufacturing practices
- **PSO-2:** Impart technical knowledge, ethical values and managerial skills to make successful in career.
- **PSO-3:** Develop innovative attitude, critical thinking and problem-solving approach for any domains of mechanical engineering

MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

Sr. No.	Course Outcome	PO
1.	**CO1:** Understand the working principles of various types of IC engines and its supporting systems.	PO1, PO2, PO3, PO4, PO5, PO6, PO7, PO9, PO10 PO11, PO12, PSO1, PSO2, PSO3
2.	**CO2:** Distinguish between normal and abnormal combustion and evaluate the performance of IC engines with different operating conditions.	PO1, PO2, PO3, PO4, PO5, PO6, PO7, PO9, PO10 PO11, PO12, PSO1, PSO2, PSO3
3.	**CO3:** Recognize the types of compressors and evaluate their performance under different operating conditions.	PO1, PO2, PO3, PO4, PO5, PO6, PO7, PO9, PO10 PO11, PO12, PSO1, PSO2, PSO3
4.	**CO4:** Apply the laws of thermodynamics to assess the performance of refrigeration and design an air-conditioning system.	PO1, PO2, PO3, PO4, PO5, PO6, PO7, PO8, PO9, PO10 PO11, PO12, PSO1, PSO2, PSO3

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1:	3	2	1	1	1	2	2	0	1	1	1	2	1	1	1
CO2:	3	3	3	3	2	2	2	0	1	2	2	2	2	2	2
CO3:	3	3	2	3	2	1	1	0	1	1	2	2	2	2	2
CO4:	3	3	3	3	3	3	3	1	2	2	2	3	3	3	3

PRE-REQUISITES

1. Thermodynamics

Lecture schedule With Methodology Being adopted

SL. No	Unit No.	Total No. of classes	Date	Topic to be covered in One Lecture	Reg/ Additional	Teaching aids used PPT/BB
1	I	2	15/07/2019	Four & two stroke engine	Regular	BB
2		3	17/07, 18/07/19	SI & CI engines	Regular	BB
3		2	22/07/19	Valve and Port Timing Diagrams	Regular	BB
4		3	24/07/, 25/07/19	Fuel injection systems for SI engines	Regular	PPT
5		2	29/07/19	Fuel Injection Systems for CI engines	Regular	PPT
6		1	31/07/19	Ignition systems	Regular	PPT/BB
7		2	01/08/19	Cooling systems	Regular	PPT
8		2	05/08/19	Lubrication systems	Regular	PPT/BB
9		1	07/08/19	Fuel properties and Combustion	Regular	PPT/BB
10	II	2	08/08/19	Normal Combustion and abnormal combustion	Regular	PPT
11		3	1/08,14/08/19	Importance of flame speed and effect of engine variables	Regular	PPT
12		02	19/08, /19	Type of Abnormal combustion	Regular	PPT
13		01	21/08/19	pre-ignition and knocking	Regular	PPT
14		2	22/08/19	Fuel requirements and fuel rating, anti-knock additives	Regular	PPT
15		2	26/08/19	combustion chamber – requirements, types	Regular	PPT/BB
16		3	28/08/19	Four stages of combustion	Regular	PPT/BB
17		1	29/08/19	Delay period and its importance – Effect of engine variables	Regular	PPT/BB
18		2	02/09/19	Diesel Knock– Need for air movement, suction, compression and combustion induced turbulence	Regular	PPT/BB
19		1	04/09/19	open and divided combustion chambers and fuel injection	Regular	PPT
20		2	05/09/19	fuel requirements and fuel rating	Regular	PPT
21	III	2	09/09/19	Measurement of cylinder pressure, fuel consumption, air intake	Regular	BB
22		1	11/09/19	exhaust gas composition, Brake power –	Regular	BB
23		2	12/09/19	performance test-	Regular	BB
24		2	16/09/19	heat balance sheet and chart.	Regular	BB
				Assignment test-1		
				Mid Test-I		
25		1	18/09/19	Classification-fan, blower and compressors –	Regular	BB
26		2	19/02/19	positive displacement and dynamic types –	Regular	BB
27		3	23/09, 25/9/19	reciprocating and rotary types.	Regular	BB

SL.No	Unit No.	Total No. of classes	Date	Topic to be covered in One Lecture	Reg/ Additional	Teaching aids used PPT/BB
28	IV	2	26/09/19	Roots Blower, vane sealed compressor, Lysholm compressor	Regular	BB
29		3	30/09, 02/10/19	mechanical details and principle of working – efficiency considerations.	Regular	BB
30		2	03/10/19	Centrifugal flow Compressors: Mechanical details and principle of operation	Regular	BB
31		3	07/10, 09/10/19	velocity and pressure variation	Regular	BB
32		2	10/10/19	Energy transfer-impeller blade shape-losses, slip factor, power input factor	Regular	BB
33		2	14/10/19	pressure coefficient and adiabatic coefficient	Regular	BB
34		1	16/10/19	velocity diagrams – power.	Regular	BB
35		2	17/10/19	Axial Flow Compressors: Mechanical details and principle of operation	Regular	BB
36		2	21/10/19	velocity triangles and energy transfer per stage	Regular	BB
37		1	23/10/19	degree of reaction, work done factor - isentropic efficiency	Regular	BB
38		2	24/10/19	pressure rise calculations – Polytropic efficiency.	Regular	BB
39	V	3	28/10, 30/10/19	Refrigeration: Mechanical refrigeration and types-unit of refrigeration-air refrigeration system, details	Regular	BB
40		2	31/10/19	principle of operation-applications of air refrigeration	Regular	BB
41		3	04/11, 06/11/19	vapor compression refrigeration systems- calculation of COP	Regular	BB
42		2	07/11/19	effect of superheating and sub cooling	Regular	BB
43		3	11/11, 13/11/19	desired properties of refrigerants and common refrigerants	Regular	BB
44		2	14/11/19	vapor absorption system, mechanical details- working principle	Regular	BB
45		3	18/11, 20/11/19	Use of p-h charts for calculations.	Regular	BB
				Solving University papers		
				Assignment test-2		
				Mid Test-II		
		93	**TOTAL NUBER OF CLASSES**			

LESSON PLAN:

UNIT I

15/07/2019 to 07/08/2019:

I.C. Engines: Classification - Working principles of Four & Two stroke engine, SI & CI engines, Valve and Port Timing Diagrams, Air – Standard, air-fuel and actual cycles - Engine systems – Carburetor and Fuel Injection Systems for SI engines, Fuel injection systems for CI engines, Ignition, Cooling and Lubrication system, Fuel properties and Combustion Stoichiometry.

UNIT II

08/08/2019 to 05/09/2019:

Normal Combustion and abnormal combustion in SI engines – Importance of flame speed and effect of engine variables – Abnormal combustion, pre-ignition and knocking in SI Engines – Fuel requirements and fuel rating, anti-knock additives – combustion chamber – requirements, types of SI engines. Four stages of combustion in CI engines – Delay period and its importance – Effect of engine variables – Diesel Knock– Need for air movement, suction, compression and combustion induced turbulence in Diesel engine – open and divided combustion chambers and fuel

injection– Diesel fuel requirements and fuel rating

UNIT III

09/09/2019 to 25/09/2019:

Testing and Performance: Parameters of performance - measurement of cylinder pressure, fuel consumption, air intake, exhaust gas composition, Brake power – Determination of frictional losses and indicated power – Performance test – Heat balance sheet and chart Classification of compressors – Fans, blowers and compressors – positive displacement and Dynamic types – reciprocating and rotary types. Reciprocating Compressors: Principle of operation, work required, Isothermal efficiency volumetric efficiency and effect of clearance volume, staged compression, under cooling, saving of work, minimum work condition for staged compression

UNIT IV

26/09/2019 to 24/10/2019:

Rotary Compressor (Positive displacement type): Roots Blower, vane sealed compressor, Lysholm compressor – mechanical details and principle of working

– efficiency considerations. Dynamic Compressors: Centrifugal compressors: Mechanical details and principle of operation – velocity and pressure variation. Energy transfer-impeller blade shape-losses, slip factor, power input factor, pressure coefficient and adiabatic coefficient – velocity diagrams –power. Axial Flow Compressors: Mechanical details and principle of operation – velocity triangles and energy transfer per stage degree of reaction, work done factor - isentropic efficiency pressure rise calculations – Polytropic efficiency.

UNIT V

04/11/2019 to 20/08/2019:

Refrigeration: Mechanical Refrigeration and types – units of refrigeration – Air Refrigeration system, details and principle of operation – applications of air refrigeration, Vapour compression refrigeration systems – calculation of COP – effect of superheating and sub cooling, desired properties of refrigerants and common refrigerants- Vapour absorption

system – mechanical details – working principle, Use of p-h charts for calculations

Air-Conditioning: Concepts of Psychrometry – Properties of moist air – Usage of Psychrometric Chart – Calculation of moist air properties.

Types of air – conditioning systems – Requirements - schematic layout of a typical plant.

UNIT - I

UNIT - I

Engine:-

An engine is a device which transforms one form of energy into another form of energy.

Heat Engine:-

Heat engine is a device which convert heat energy of fuel into thermal energy by burning of fuels to produce Mechanical work.

Classification of Heat Engines:

i) Internal combustion Engines (I.C. Engines)

ii) External combustion Engines (E.C Engines)

i] Internal Combustion Engines:

In I.C engines combustion of fuel takes place inside the engine cylinder.

Ex: Petrol engine, Diesel engine, & gas engine

ii] External Combustion Engines:

In E.C engines combustion of fuels takes place outside the engine Cylinder.

Ex: Steam engine, Steam turbine.

*Steam engine: the fuel fed into the cylinder is in the form of steam which is already heated (or supr heated) and is ready for working in combustion cycle of the engine.

Classification of I.C Engines.

The IC engines may classified into following:

01. Type of fuel used

i) Petrol engine

ii) Diesel engine

iii) Gas engine.

02. Method of ignition used.

i) spark ignition engines (SI engines)

ii) Compression ignition engines (CI engines)

03. The number of strokes per cycle

i) Four stroke

ii) Two stroke

04 Cycle of operation used

i) Otto cycle. (constant volume Cycle) engines

ii) Diesel cycle (Constant Pressure Cycle) engines.

iii) Dual Combustion Cycle (semi Diesel Cycle)

05 Speed of engine used

i) High speed engines

ii) Medium speed engines

iii) Slow speed engines

06 Cooling system used

i) Air Cooled engines

ii) water cooled engines

iii) evaporative cooling engines

07. Method of fuel injection used

i) Carburettor engines

ii) Air injection engines.

08. Number of cylinders used

i) Single cylinder engine

ii) Multi cylinder engine

09. According to the arrangement of cylinders

i) Vertical engines

ii) Horizontal engines

iii) Radial engines

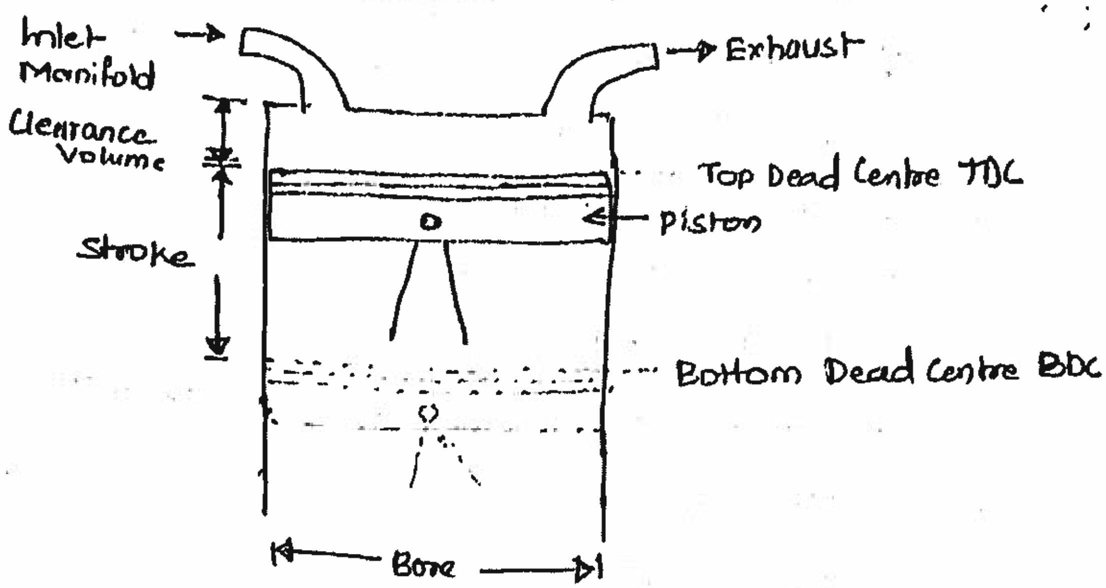
iv) In-line Multicylinder engines

v) V- type Multicylinder engines

vi) Opposite - Cylinder engines

vii) Opposite - Piston engines.

Terminology of IC Engine.



Bore:

The nominal inside diameter of the engine cylinder

Top Dead Centre TDC:

The extreme position of the piston at the top of the cylinder of the vertical engine.

→ in case of horizontal engines it is known as inner dead centre (IDC)

Bottom Dead Centre. BDC:

the extreme Position of Piston at the bottom of the cylinder of the vertical engine

In case of Horizontal engines, It is known as ODC, outer dead Centre.

Stroke:

The distance travelled by the Piston from TDC to BDC is called stroke.

In other words the maximum distance travelled by the piston in the cylinder in one direction is known as stroke

Clearance Volume (V_c) :

The volume contained in the cylinder above the top of the piston, when the piston is at top dead centre is called clearance volume

Swept Volume (V_s):

The Volume swept by the piston during one stroke is called the swept volume. or piston Displacement

$$\text{Swept Volume} = V_s = A \times L = \frac{\pi}{4} D^2 L$$

Compression Ratio (r_c) :-

Compression ratio is a ratio of the Volume when the piston is at bottom dead centre to the volume when the piston is at the top dead centre

$$\text{Compression ratio} = \frac{\text{Maximum Cylinder Volume}}{\text{Minimum Cylinder Volume}}$$

The compression ratio varies from 5:1 to 10:1 for Petrol engine
12:1 to 22:1 for Diesel engine

Working Principle of four stroke Engine

When a four stroke engine is working Continuously, the following strokes are carried out

1. Suction stroke
2. Compression stroke
3. Expansion stroke
4. Exhaust stroke.

In this engine, the working cycle is completed in four strokes of piston or two revolutions of crankshaft.

Working Principle of Four stroke Petrol Engine:

→ It consist of spark plug fitted at the top of the cover to initiate the ignition of the fuel air mixture supplied to the cylinder from the Carburettor

→ The petrol engine works on principle of Otto cycle known as constant Volume Cycle

→ The piston perform four strokes to complete one working cycle.

01. Suction stroke
02. Compression stroke
03. Expansion or Working or Power stroke
04. Exhaust stroke.

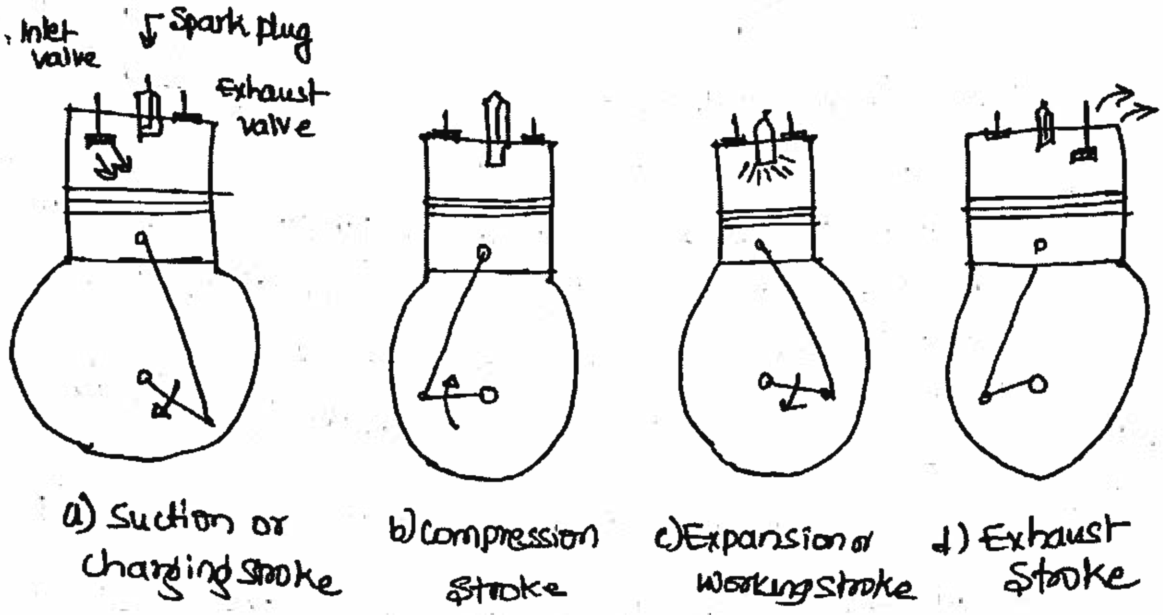


Fig:- Four stroke cycle Petrol engine.

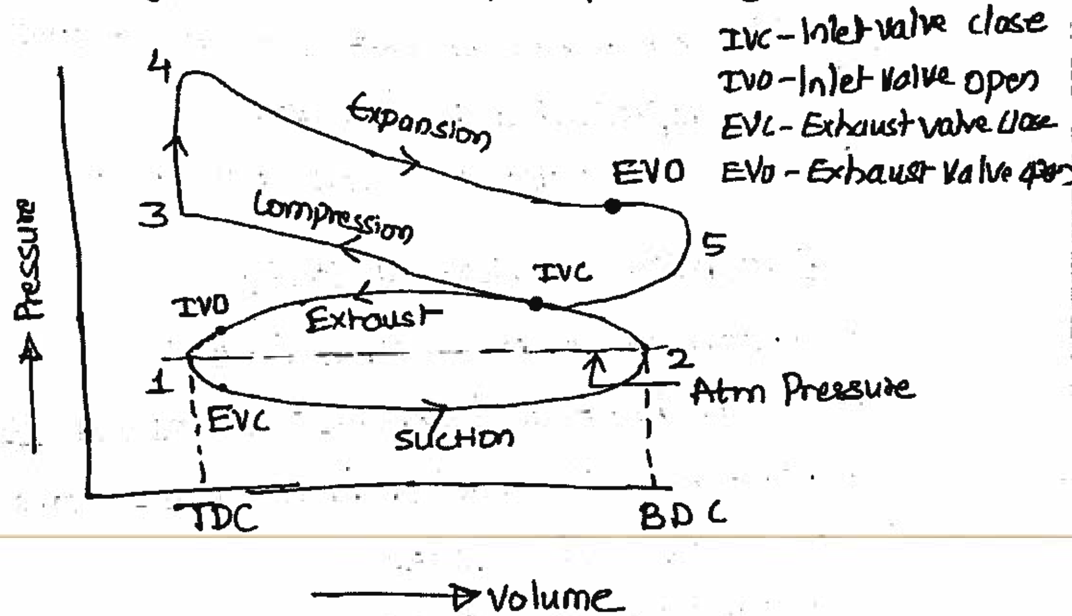


Fig:- Actual Indicator diagram for four stroke petrol engine.

01. Suction stroke:-

In this stroke

- Piston moves from TDC to BDC
- Inlet valve opens and charge (Air Petrol mixture) enters into the cylinder till the piston reaches BDC.
- At the end of stroke Inlet valve closes in fig(a) and and it is represented by line 1-2 in actual indicator dig.

ii] Compression stroke

→ Piston moves from BDC to TDC and both Inlet & exhaust valves are closed.

→ When piston moves up it compresses the air-petrol mixture, as a result of compression temprature and pressure of the mixture increases

→ as shown in fig B. and represented by line 2-3

→ The compression ratio ranges from 1:7 to 1:11

→ At the end of this stroke, the mixture is ignited by spark plug. the combustion of petrol releases hot gas which will increase pressure at constant volume it is represented by line 3-4

→ This completes one revolution of crankshaft

iii] Expansion or working stroke.

→ Piston moves from TDC to BDC

→ Both Inlet and exhaust valves are closed

→ The high pressure of burnt gases force the piston to perform this stroke

→ Expansion of hot gases takes place. During the expansion piston produces mechanical work which is transmitted to the crankshaft. as shown in fig C. and represented by line 4-5.

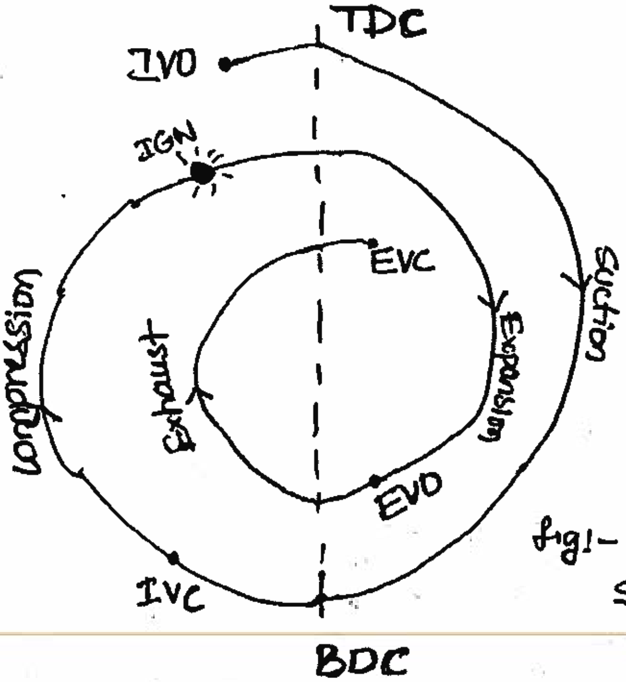
→ At the end of stroke exhaust valve opens and releases burnt gases to atmosphere.

→ The pressure in a cylinder reduces at a constant volume.

iv. Exhaust stroke.

→ Piston moves from BDC to TDC
→ the exhaust valve is opened and burnt gases releases to atmosphere.
→ at the end of stroke exhaust valve closes as shown in fig d and represented by line 5-1
→ This completes the cycle and engine cylinder is ready to suck the charge again.

Valve Timing Diagram for a Four-Stroke Petrol Engine



IVO - Inlet valve opens (10°-20° before TDC)
IVC - Inlet valve close (30°-40° after BDC)
IGN - Ignition (20-30° before TDC)
EVO - Exit valve opens (30-50° before BDC)
EVC - Exit valve closes (10-15 after TDC

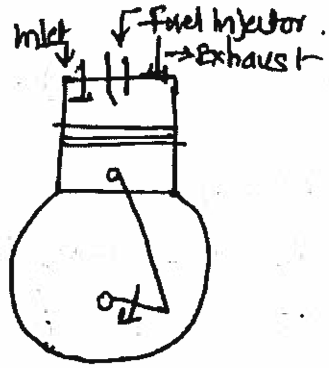
fig1 - Valve timing diagram for four stroke petrol engine.

→ Inlet valve opens before piston reaches TDC
→ Air-fuel suction takes place in suction stroke (crank revolves through 180° in theoretical valve timing dig)
→ Inlet valve closes and compression take's place
→ mixture is ignited with the help of spark plug before end of compression stroke.
→ Piston reaches TDC & burnt high pressure, temp gases push piston to downward and expansion takes place. Now exhaust valve opens before piston reaches BDC.
→ and piston moving to TDC and performs exhaust stroke

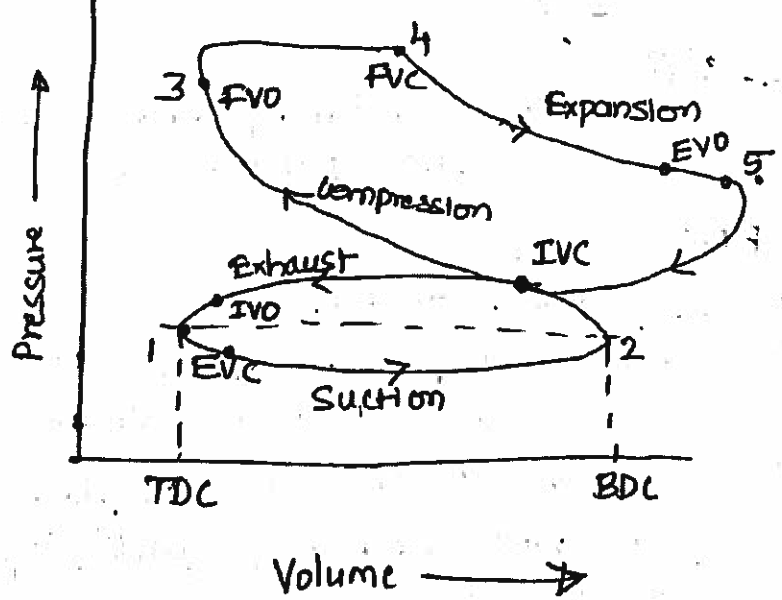
Four Stroke Diesel Engine: (Constant Pressure Cycle)

→ The basic construction of four stroke Diesel engine is same as that of petrol engine, except instead of spark plug, a fuel injector is mounted.

→ The fuel is supplied to the injector by means of fuel pump



Suction Stroke



FVO → Fuel valve open

FVC → Fuel valve closed

Fig: actual Indicator diagram for a four stroke cycle Diesel engine.

→ The Diesel engine work on the Principle of Diesel cycle known as constant Pressure (heat) addition cycle.

→ It is also known as C.I engines because the ignition takes place due to heat produced in the cylinder at the end of compression stroke.

i. Suction stroke

→ The Piston moves from TDC to BDC.

→ the Inlet valve opens and pure air enters into the cylinder till the piston reaches to BDC it is represented by line 1-2.

ii. Compression stroke.

→ In this stroke piston moves from BDC to TDC

→ both valves are closed.

→ as piston moves it compresses the air and increases the temperature and Pressure of the air. it is represented by line 2-3

→ at the end of stroke oil sprayed into the cylinder through fuel injector: the high temperature of the air ignites the diesel engine and combustion of fuel takes place.

→ This is the constant Pressure heat addition.

iii. Expansion or Working stroke.

→ In this stroke both valves are closed, (piston moves from TDC to BDC)

→ the burnt gases released by the combustion of diesel forces piston moves from TDC to BDC.

→ the expansion of burnt gases takes place at constant Pressure, it is represented by line 4-5

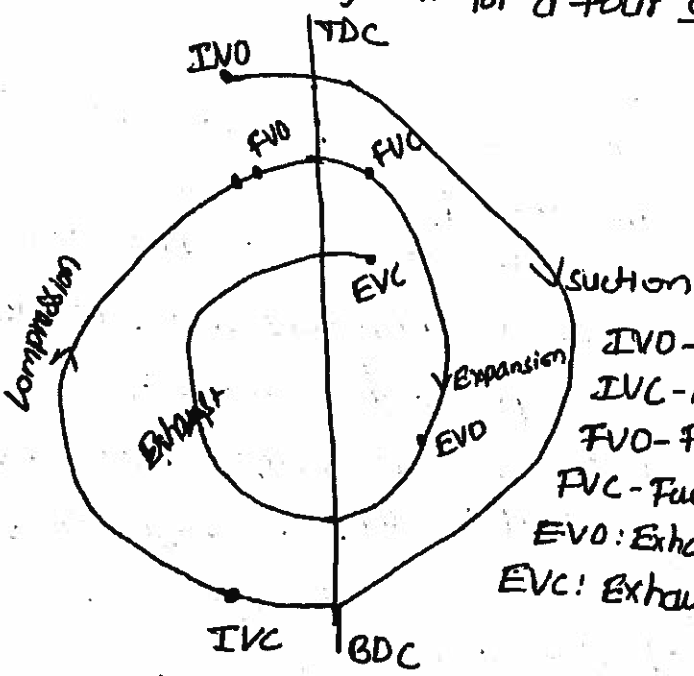
→ During the expansion stroke piston produces the Mechanical work which is transmitted to the Crankshaft

iv. Exhaust Stroke

→ In this stroke exhaust valve is opend and Piston moves from BDC to TDC

→ The movement of piston pushesh out the burnt gases to atmosphere. It is represented by line 5-1.

Valve Timing Diagram for a Four stroke Diesel engine.



IVO – Inlet valve opens (10-20° before TDC)
IVC – Inlet valve closes (25-40° after BDC)
FVO – Fuel valve opens (10°-15° before TDC)
FVC – Fuel valve closes (15-20° after TDC)
EVO: Exhaust valve opens (39°-50° bef TDC)
EVC: Exhaust valve closes (10°-15° after TDC)

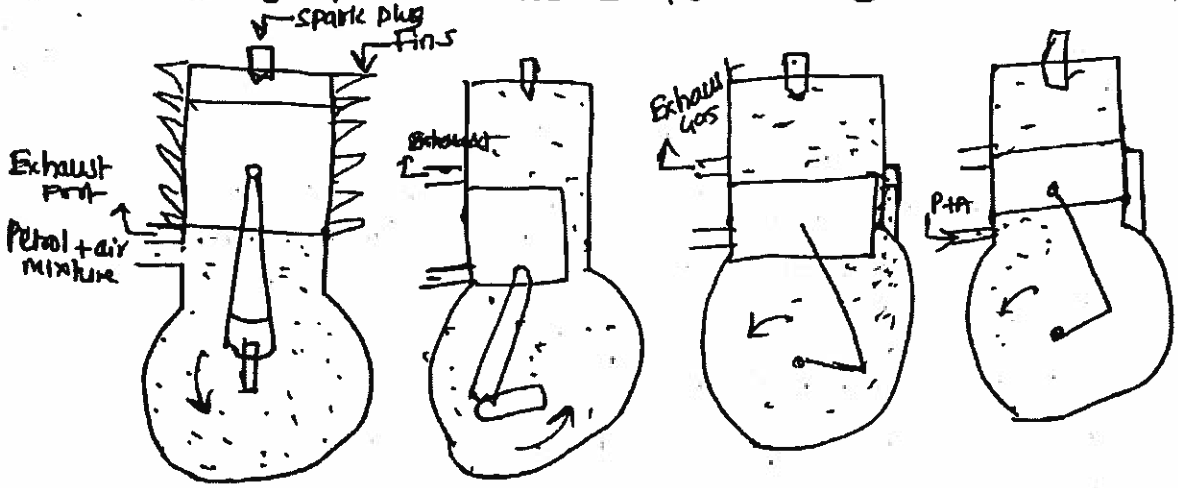
fig: Valve timing diagram for four stroke Diesel engine.

Comparision of Petrol and Diesel Engine

PETROL	DIESEL
→ It draws <u>petrol-air</u> mixture into the cylinder during suction stroke	It draws only <u>air</u> in to the cylinder during suction stroke.
→ It works on otto cycle	→ It works on Diesel cycle
→ It uses the spark plug ignition.	→ It uses the compression ignition.
→ Carburettor is used to mix the air and fuel	→ It uses the injector or automiser to inject the fuel.
→ compression pressure is about 10 bar	→ Compression pressure is about 30 bar
→ Easy starting	→ Starting is little diffcult
→ Lighter and cheaper	→ Heavier and costlier
→ High running cost	→ Low running cost
→ Low mentainance cost	→ High Mentainance cost.
→ Low initial cost	→ High Initial cost.
→ Thermal efficiency is about 26%	→ Thermal efficiency is about 40%.

Four stroke Engine	Two stroke Engine
→ Requires 4 stroke to complete one cycle	→ It requires 2 stroke to complete one cycle
→ the charge is directly entered into the engine cylinder	→ the charge first enters the crank case and then transfered into the engine cylinder
→ It consist of valve	→ It consist of port
→ less cooling required	→ greater cooling required.
→ High lubrication oil consumption	→ less lubrication oil consumption
→ Initial cost is High	→ Initial cost is low
→ High thermal efficiency	→ low thermal efficiency
→ Noise will be less	→ Noise will be More
→ Used for slow speed high power engines in truck, jeep, car etc.	→ Used in High speed low power engines - scooter, Motor cycle etc.

Working of Two stroke Petrol Engine. (SI engine) 08



a) Begining of first stroke

b) Piston uncovers exhaust & transfer port during the first stroke

c) transfer port covered.

d) compression commenced

FIRST STROKE SECOND STROKE

First Stroke

→ Two stroke petrol engine works otto cycle and requires only one revolution or two stroke to complete one working cycle.

First Stroke

→ Initially the Piston at TDC.

→ the spark plug ignites air-petrol mixture. the combustion of petrol releases the hot gases and increase the pressure on piston to move from TDC to BDC to perform power stroke until it opens exhaust Port

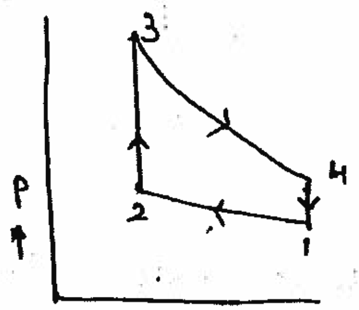
→ the hot burnt gases expand due to high speed of piston produces mechanical work.

→ At the end of power stroke the exhaust Port opens and high pressure burnt gases.

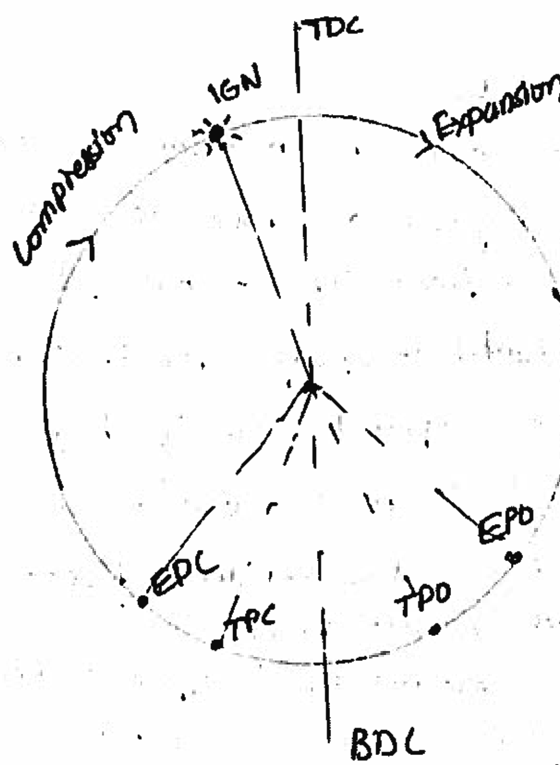
→ As piston moves down continuesly it open transfer Port and fresh petrol air mixture enters into cylinder.

Second Stroke:

- → piston moves from BDC to TDC.
- → As piston moves up, first closes the transfer port and cutoff the supply of petrol air mixture, and then its moves further up it closes exhaust port
- → further movement of piston will compress petrol air mixture in cylinder with
- → At the end of this stroke charge is ignited by spark plug & first stroke repeated.



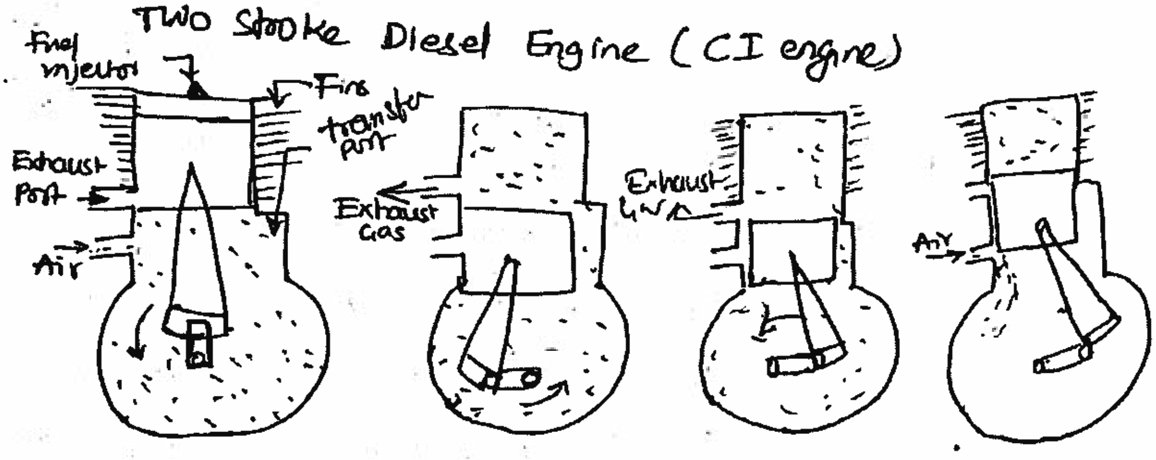
PV Diagram for two stroke petrol engine



EPO - Exhaust port open (35-50° before BDC)
TPO - Transfer port opens (30°-40° before BDC)
TPC - transfer port close (30°-40° after BDC)
EPC - Exhaust port close (30°-50° after BDC)
IGN - Ignition (15-20° before TDC)

Valve timing Diagram

TWO Stroke Diesel Engine (CI engine)



FIRST STROKE   SECOND STROKE

FIRST STROKE :

→ Initially piston at TDC, the diesel is injected into cylinder as a spray. the compressed air at high temperature ignites diesel.

→ the combustion of the diesel releases hot gases and increases the pressure on piston to move from TDC to BDC to perform power stroke until it opens exhaust port.

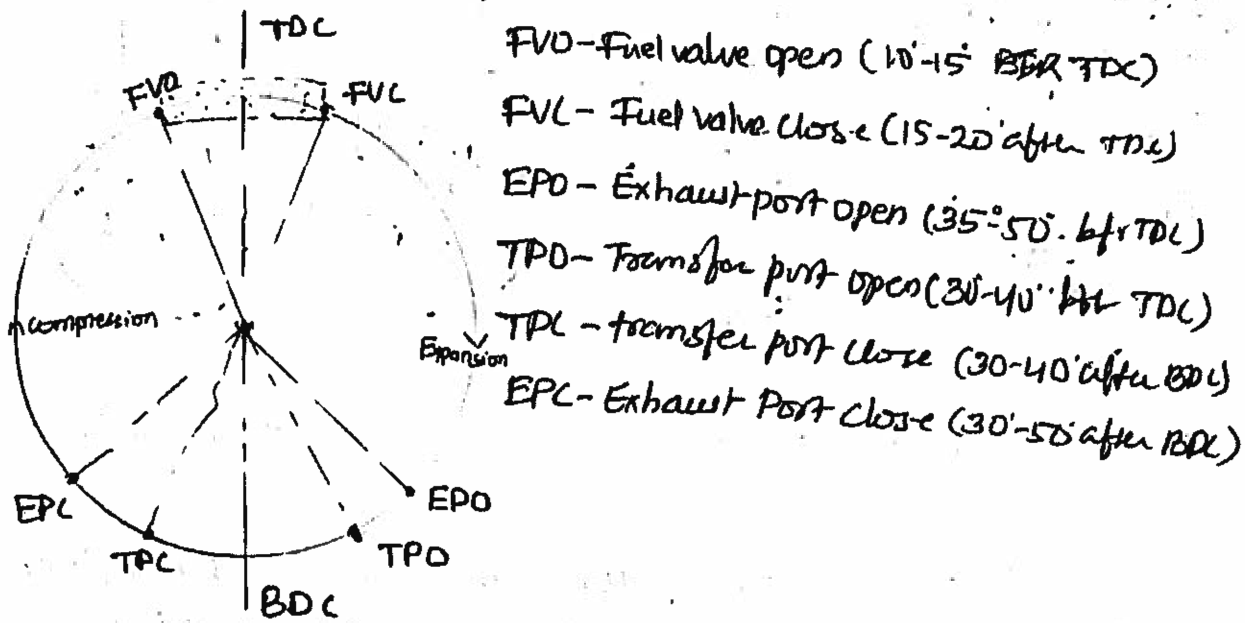
→ The hot burnt gas expands due to high speed of the piston produces the Mechanical work

→ At the end of the power stroke the exhaust port opens and high pressure burnt gases escape to the atmosphere.

→ As piston moves down continuosly it also opens the transfer port and freshe air enters into the cylinder from the crank case.

SECOND STROKE ·

→ piston moves from BDC to TDC. as the piston moves up, first it closes transfer port and cut off the supply of air from crank case. when it further moves up closes exhaust port



Valve timing Diagram for two stroke Diesel engine (CI engine)

→ Inlet port opens and allows the air to enter into the crank case through (Inlet port)
→ further movement of piston will compresses the air with the compression ratio 1:20 to 1:22
→ At the end of the compression stroke the diesel is injected in the form of spray into the cylinder. which is ignited by the high temperature of the compressed air.

2) Backflow or loop scavenging

In this method Inlet & outlet ports are situated on the same side of the engine cylinder. the fresh charge while entering into the engine cylinder, forms a loop and pushesh out the burnt gases

3) Uni flow scavenging

In this Method, the fresh charge while entering frome one or two sides of the engine cylinder pushesh out the gases through exit valve situated on the top of the cylinder.

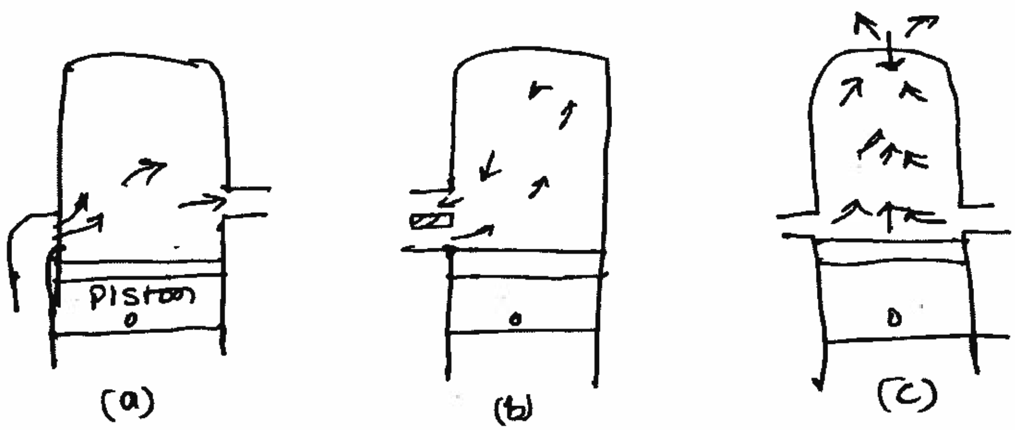
Scavenging of I.C Engines.

It is experianced that the burnt gases in the Cylinder are not completely exhausted before the Suction stroke. but a part of gases still remains inside the cylinder and mix with fresh air charge. As a result of this mixing, the fresh charge gets diluted and its Strength is reduces.

The Process of Removing burnt gases from the combustion chamber of the engine cylinder, is known as Scavenging.

types of Scavenging

1. cross flow Scavenging
2. Backflow or loop Scavenging
3. uniflow scavenging



01. cross flow scavenging:

In this method transfer port (inlet port) and exhaust port are situated on the opposite sides of the engine cylinder, the piston crown is designed into a particular shape so that the fresh charge moves upwards and pushes out burnt gases

Air standard Cycle (Thermodynamics Cycle)

→ Thermodynamic cycle or Air standard Cycle can be defined as the cyclic process consist of series of thermodynamic processes. which takes place in Particular order so that initial conditions are restored at the end of processes.

→ the air Standard cycles are used for heat engines, gas turbines, air motors. IC engines etc.

→ Following are the important Thermodynamic cycles

01. Carnot Cycle
02. Joule Cycle
03. Otto Cycle
04. Diesel Cycle
05. Dual Combustion Cycle

→ the basic objective of these cycle is to Convert maximum heat energy into useful work

→ Air standard Cycle it is understood how the thermal efficiency improved by increasing compression ratio.

Fuel-Air Cycle

→ In this cycle the Presence of fuel in the Cylinder is taken into account and accordingly the working medium was assumed to be Mixture of fuel & air.

→ By fuel air cycle analysis it will be possible to bring out the effect of fuel Air ratio on thermal efficiency and also study how the Peak pressure & temprature vary with respect to fuel Air ratio

Comparision of Air Cooling and Water Cooling System.

Air Cooling System	Water Cooling System
→ Design of the system is Simple & costly	→ Design of the system is Complicated & more costly.
→ mass of cooling system is very less	→ mass of cooling system is much more.
→ the fuel consumption is more	→ The fuel consumption is less.
→ Its Installation & mentainance is very easy and less costly	→ its Installation and Mentainance is difficult and More costly.
→ There is no danger of leakage or freezing of coolant	→ There is a danger of leakage or freezing of the coolant
→ It works Smoothly & Continously	→ If the System fails, it may cause Serious damage to engine.

Cooling of [redacted] IC Engines.

→ Due to combustion of fuel inside the engine cylinder of IC engine, intense heat is generated and heat is absorbed by engine cylinder, cylinder head, Piston and engine valves, so heating of parts have following effects

- → overheating causes thermal-stresses in engine Parts.
- → over heating reduces strength of the Piston.
- → over heating causes decomposition of lubricating oil
- → reduces volumetric efficiency, & increases tedency of detonation.

Cooling Systems for [redacted] IC engines.

01. Air cooled System
02. Water Cooling System

01. Air Cooled System

→ This is used in Motor cycles, Scooters, aeroplanes and Stationary installations.

→ In this System the heat is directly dissipated to atmospheric air by conduction through cylinder walls.

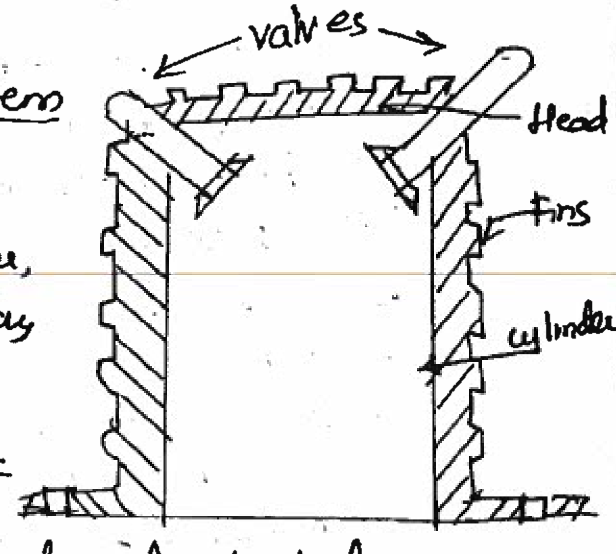


fig: Air Cooled System.

→ In order to increase the rate of cooling outer Surface area of cylinder and cylinder head is increased by providing radiating fins and flanges.

Water cooling System : (Thermosyphon System of cooling)

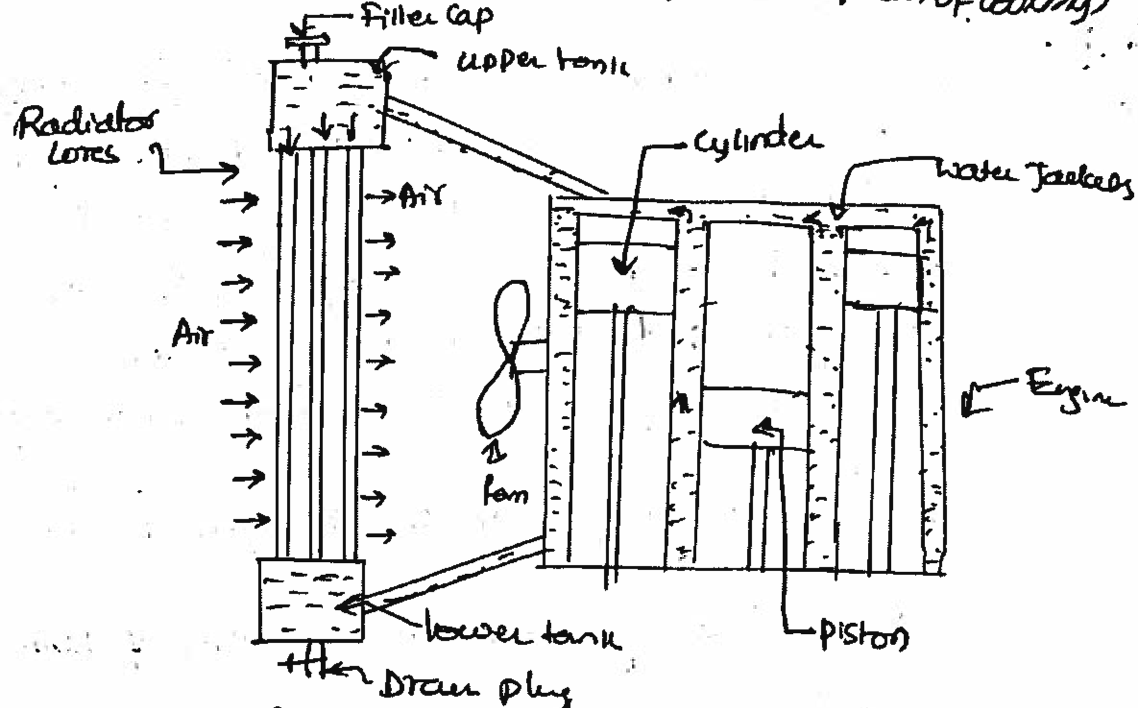


fig: water cooling system.

→ It is used in the engines of cars, buses, trucks etc. In this system the water is circulated through water Jackets around the combustion chamber, cylinder,
→ water is kept continuosly in motion by a centrifugal pump which is driven by a V-belt from the pulley on the engine crank shaft.
→ after passing through the engine Jackets in the cylinder block and heads, the water is passed through radiator.
→ In the radiator water is cooled by air draw through radiator by a fan, & fan and water pump are mounted and driven on a common shaft.
→ after passing through a radiator, the water is drained and delivered to the water pump through cylinder Inlet passage.
→ the water is again circulated through engine Jackets.

Ignition System of Petrol Engine..

01. Coil Ignition system
02. Magneto ignition system

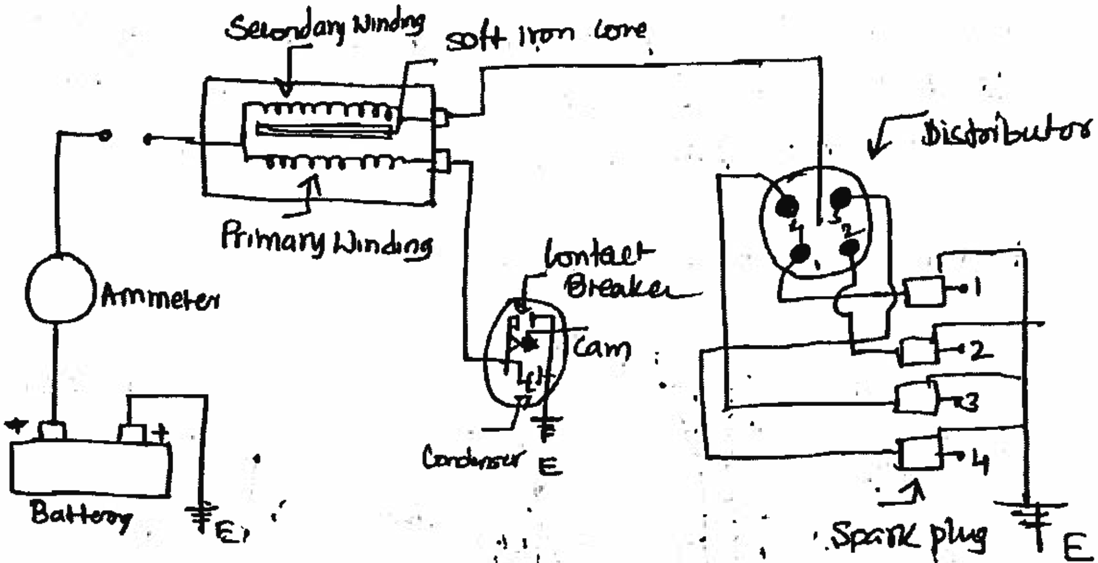


fig:- Coil ignition system

→ it is also called as battery Ignition system and has an Induction coil, which consist of two coils as primary and secondary coils wound on soft iron core,

→ The Primary coil consist of about 300 turns of wire the secondary coil is consist of about 20,000 turns

→ the one end of the primary coil is connected to a ignition switch, battery (6volt) and other end is connected to contact Breaker

→ the Secondary coil is Connected to the Distributor with central terminal of the spark plugs. the outer terminals of sparking plugs are earthed together,

→ In this ignition system the value of voltage depends on number of turns in each coil. The voltage required to produce a spark across the gap between the sparking point is 10,000 to 20,000 volts.

→ Since secondary coil has several thousand turns so it develops a sufficient high voltage to overcome the resistance gap of the spark plug.
→ This high voltage then passes to a distributor, it connects the spark plug in a rotation depending upon the firing order of the engine. hence the ignition takes place in all the engine cylinder.

Magneto Ignition System

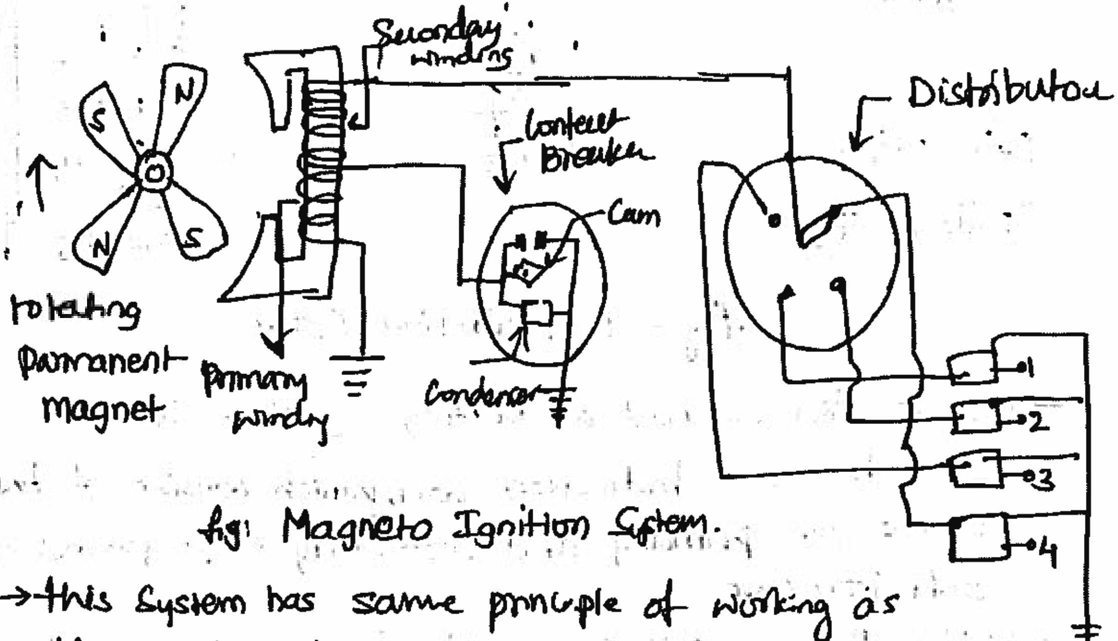


fig: Magneto Ignition System.

→ this system has same principle of working as that coil ignition system, except that no battery is required as the Magneto act as own generator.
→ It consist of either rotating magnets in fixed coils or rotating coils in fixed magnets
→ the current produced by magneto is made to flow to induction coil, which works in the same way as that of coil ignition system.
→ the high voltage current is then made to flow to the distributor, which connects the sparking plugs in rotation depending upon the firing order of engine.
→ It is used in such as, Scooters, Motor cycles

Fuel Injection System for Diesel engine.

→ In a constant Pressure cycle or (Diesel engine) only air is compressed at the cylinder and fuel is injected into the cylinder by means of fuel injection system

01. Air Injection system

02. Solid Injection System.

01. Air Injection System.

→ In this fuel injection system, fuel is forced into the cylinder by means of compressed air,

→ this system used little nowadays because it requires bulky Multi stage air compressor.

→ thus causes increase in engine weight and reduces the break power output further.

02. Solid Injection System

→ In this fuel injection system, the liquid fuel is injected directly into the combustion Chamber without aid of Compressed air.

→ hensce it is also called as airless Mechanical injection System or Solid Injection System.

→ Solid Injection system is further Classified into two types

a. Common rail System

b. Individual Pump System

a) Common rail System

→ In this system, Multi cylinder high Pressure Pump is used to Supply fuel at a high pressure to a common rail or header.

→ The high pressure in common rail forces the fuel to reach to nozzle located in the cylinder.

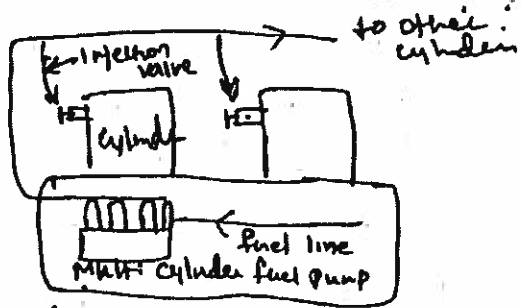


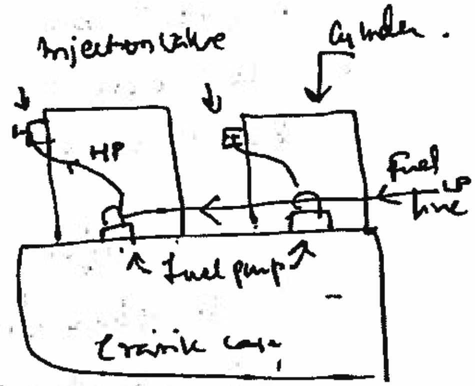
fig: common Rail system.

→ The pressure in common rail is kept constant with the help of high pressure relife Valve.

b) Individual pump Systems

→ In this system cylinder of the engine is provided with Individual Injection valve,

→ In this arrangement a saparate Metering & Compression pump is provided for each cylinder. The pump may be placed closed to the cylinder.



15

Lubrication System for IC Engines.

the lubrication is used to reduce friction and wear between the components engine.

advantages of lubrication of IC engines.

01. It reduces wear and tear of the moving Part
02. It dramps down the vibration of engine
03. It dissipates the heat genrated from moving Parts due to friction
04. It cleans the moving parts

TYPES

A. Wet sump lubrication B. Mist lubrication C. Dry Sump lubrication

01. Splash Lubrication
02. Forced lubrication.

} wet sump lubrication

01. Splash lubrication

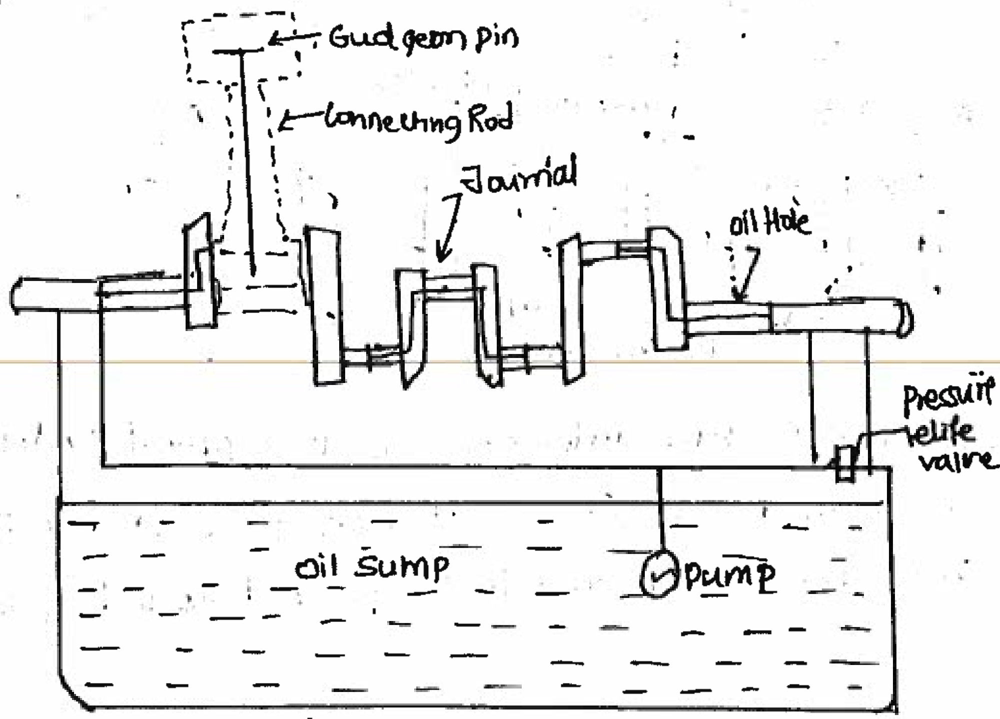


fig:- Splash Lubrication

→ In this Method oil sump is fixed to the bottom of the Crank shaft case and pump is immersed, in the lubricating oil

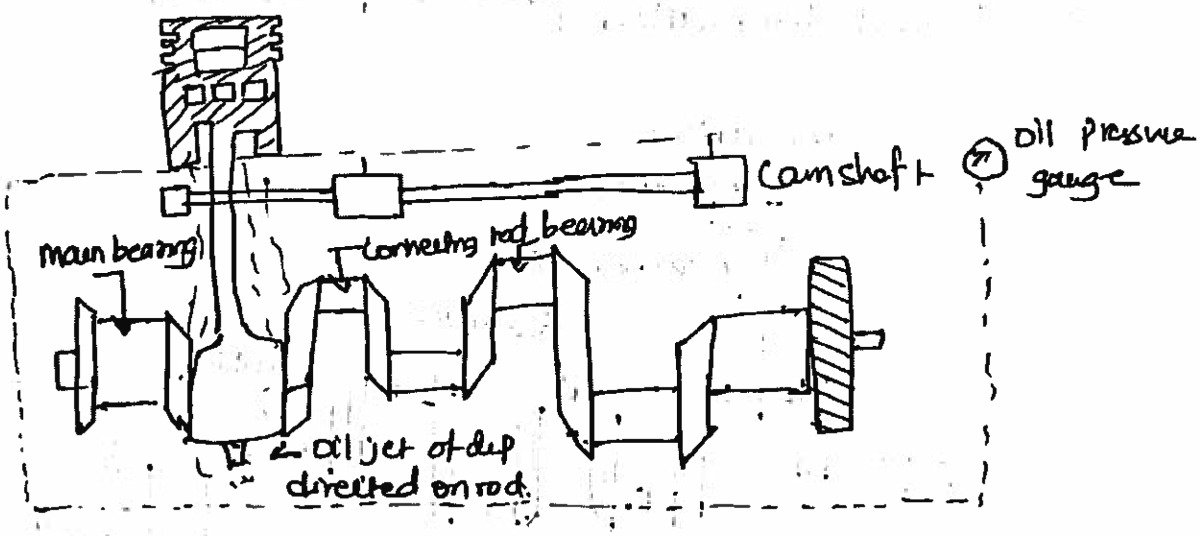
→ A small hole is drilled in crankshaft and the oil is forced through this to hole bearing

→ the oil is also forced along the connecting rod either through drilled ~~hole~~ rod, or small copper pipe to gudgeon pin and piston

→ the surplus oil is thrown out, in the form of a spray, from the bearings by centrifugal action.

→ the surplus oil lubricates the cams, tappets and valve systems, the whole oil is drained back into the sump (it is used small engines)

02. Forced lubrication (splash and pressure lubrication)



→ In this system lubricating oil is supplied under pressure to main and camshaft bearings and the oil is with the sump and it is pumped back by pump.

Mist lubrication system

→ This system is used where crankcase lubrication is not suitable

→ In two stroke engine, as the charge is compressed in the crank case, it is not possible to have the lubricating oil in the sump, hence lubricating adopted in this.

→ In such a engines, the lubricating oil is mixed with the fuel, the usal ratio being 3% to 6%.

→ The oil and fuel mixture are inducted through. the carburettor,

→ The fuel is vaporized and the oil in the form of mist goes via the crank case into the cylinder.

→ The oil which strikes the crank case walls. lubricates the main and connecting rod bearings. and rest of the oil lubricates the piston, piston rings and the cylinder.

C. DRY SUMP LUBRICATION SYSTEM

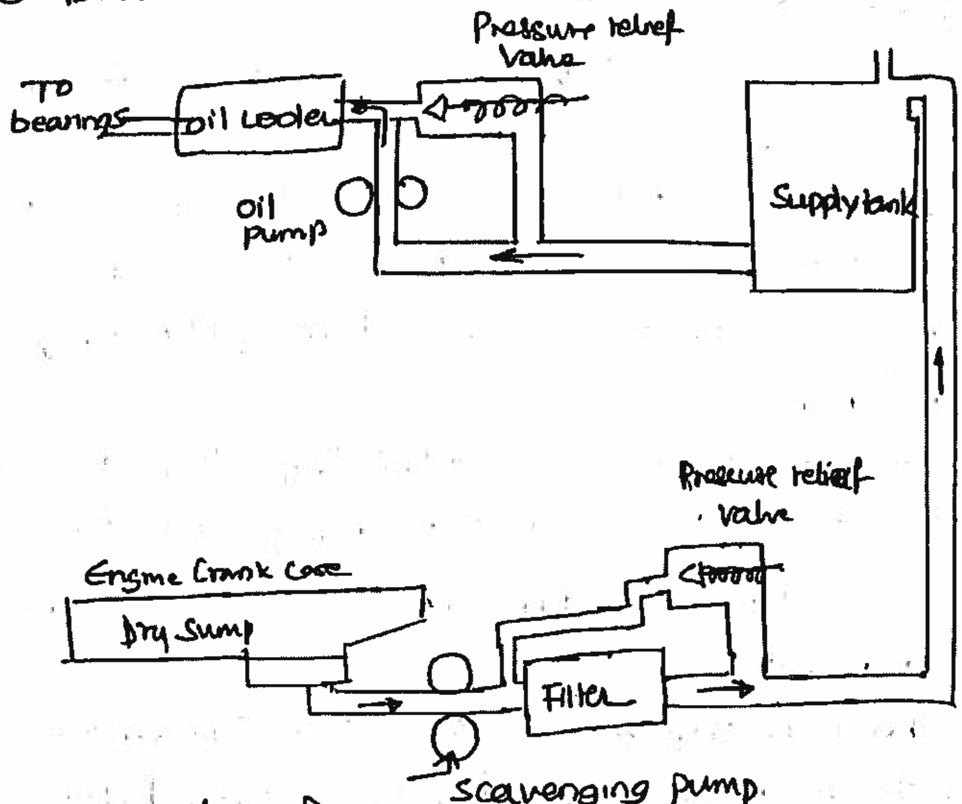


fig:- Dry sump Lubrication.

- In this system the supply oil is carried in an external tank
- An oil draws oil from the supply tank and circulates it under pressure to the various bearing of the engine
- Oil dripping from the cylinders and bearings into the sump is removed by a scavenging pump which in turn the oil is passed through a filter and is feed back to the supply tank
- Thus oil is prevented from accumulating in the base of the engine
- It is used in sports cars.

CARBURETION / CARBURETOR.

→ The process of formation of a combustible fuel air mixture by mixing the proper amount of fuel with air before admission to the engine cylinder is called carburetion. and the device which performs this job is called carburetor.

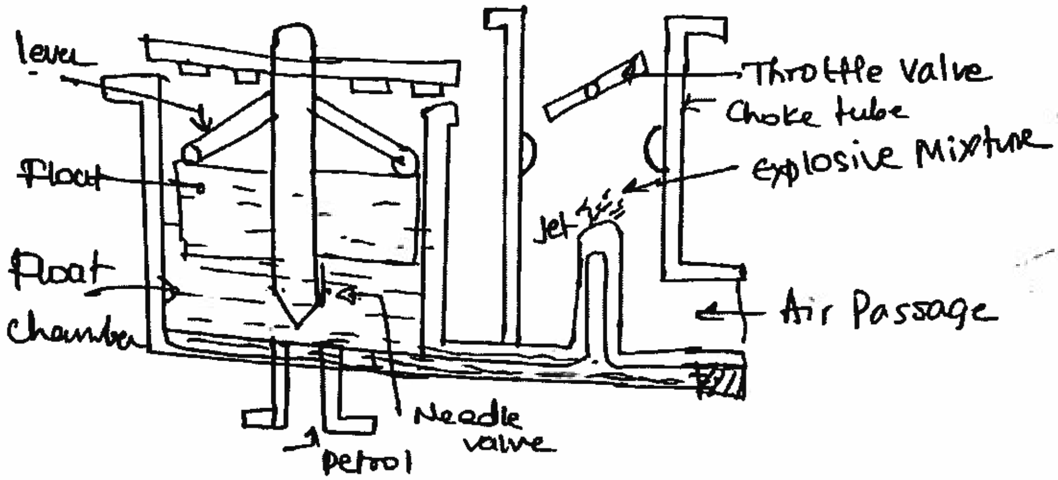


fig 1 Carburettor

→ It consist of fuel jet located in the centre of the choke tube.

→ A float chamber is provided for maintaining the level of the fuel in the jet and is controlled by a float and lever which operates its needle valve.

→ The suction produced by the engine draws air through choke tube the reduced diameter of choke tube increases the velocity of air and reduces pressure.

→ The high velocity and low pressure in the tube facilitate breaking up of fuel with air and a throttle valve controls the flow of mixture delivered to the engine cylinder

UNIT - II

Abnormal Combustion.

→ In normal combustion, the flame initiated by the spark travels across the combustion chamber in a fairly uniform manner.

→ Under certain operating conditions the combustion deviates from the normal course leading to a loss of performance and possible damage to the engine. This type of combustion is termed as abnormal combustion or knocking combustion.

Pre ignition:

→ The increase in rate of heat transfer to the walls may cause local overheating specially of the spark plug, which may reaches the temperature high enough to ignite the charge before the passage of spark plug. This phenomenon is called pre-ignition

→ Pre ignition is also caused by overheated exhaust valves or glowing carbon deposits in the combustion chamber

Surface ignition

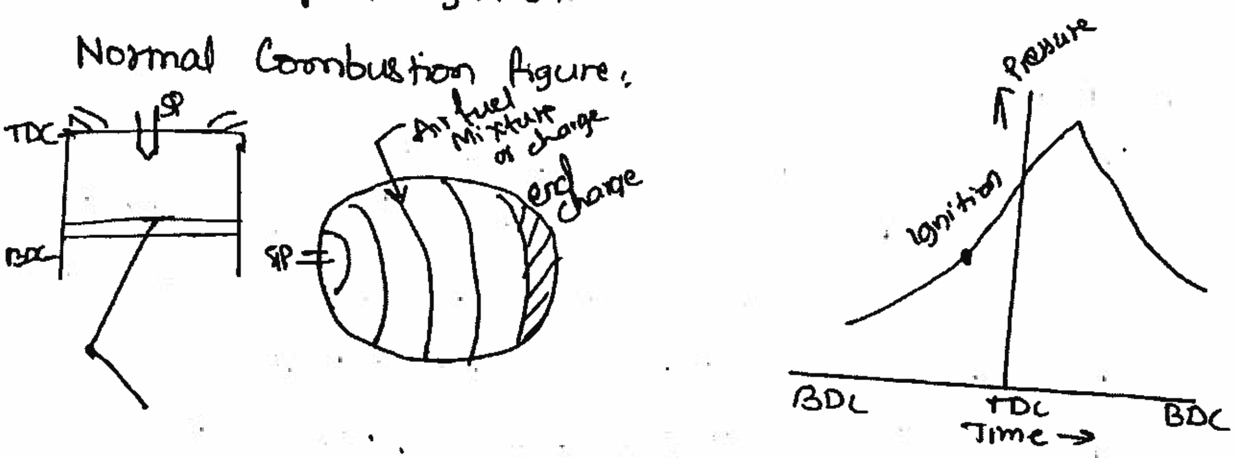
→ under certain conditions air fuel mixture is ignited by a hot spot cylinder

→ Initiation of flame front by a hot surface other than the spark plug is called surface ignition

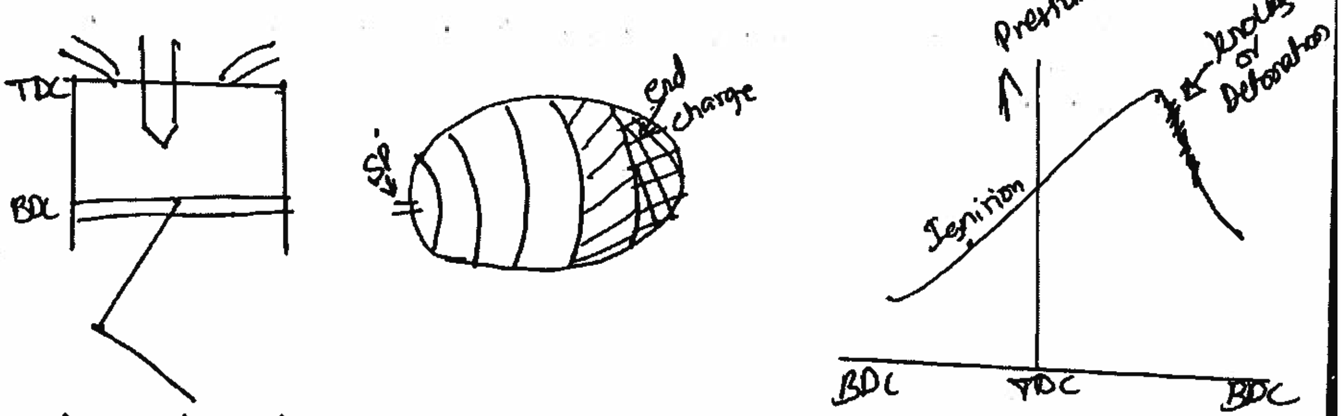
→ Surface ignition occouring before the spark is called pre ignition

→ Surface ignition occours after the spark is called post ignition

Normal Combustion figure:



Abnormal combustion



Normal combustion: It refers to a combustion process which is initated by spark plug and in which flame moves completely across the combustion chamber in uniform manner at normal velocity

Stages of Combustion in SI Engines

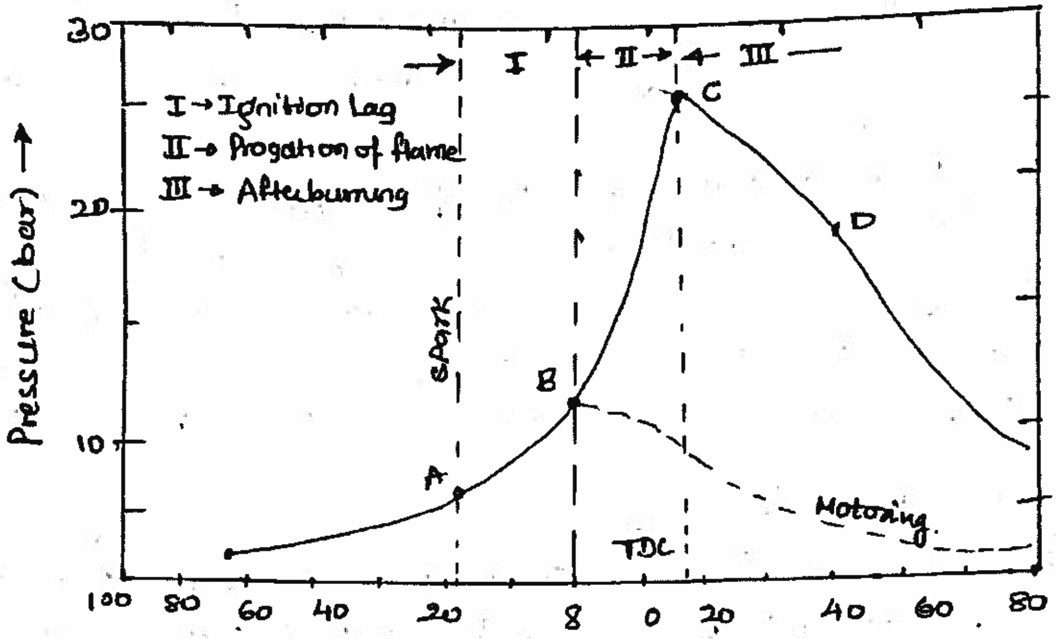


fig:- Stages of Combustion in an SI engine {(P-θ) diagram}

Stage-I: Ignition Lag or Preparation Phase

→ It is a chemical process which depends upon nature of fuel, temprature and Pressure, proportion of exhaust gas, rate of burning and temprature.

→ It is the growth and Development of a semi propogating nucleus of flame (at the moment spark discharge the temprature exceeds 10,000°C)

→ At the end of this stage, the first rise of Pressure (on the Indicator diagram) can be detected, it is the point where line of combustion departs from the compression line.

Stage II: Propogation of flame.

→ It is a simple and pure Mechanical Process, the starting point of the second stage is where first measurable rise of Pressure can be seen on the Indicator diagram, i.e the point where the line of the combustion departs from the compression line.

→ During the second stage the flame spreads throughout the combustion chamber. and second stage ends as maximum Pressure is reached.

Stage III: After Burning.

→ End of the second stage means completion of flame travel. but it does not result in complete heat release (burning of fuel)

→ Even after the passage of flame, Some chemical adjustments continue throughout the expansion Stroke near the walls and behind the turbulent flame front

→ Rate of combustion reduces due to Surface of flame front becoming smaller and reduction in turbulance

Effect of engine Variables on Flame Propagation.

Fuel Air ratio:

With Hydrocarbon fuels the maximum flame Velocities occurs when the mixture strength is 110% of Stoichiometric.

- lean (more air in A/F mixture) Mixtures releases less thermal energy resulting in a lower flame temperature and flame speed.
- Very rich mixtures have incomplete combustion (Some Carbon only burns to CO and not to CO_2) which results in production of less thermal energy and hence flame speed is again low.

Compression ratio:

A higher compression ratio increases the Pressure and temperature of working mixture and decrease the concentration of residual gases.

The High Pressure & temperature of the compressed also speed up the second phase of combustion. total ignition angle is reduced. maximum Pressure are increased.

Intake temperature and Pressure

Increase in the Intake temperature and Pressure increases the flame Speed

Engine load.

With increase in the engine load the cycle Pressure increases. hence the flame Speed increases

Turbulance:

The flame Speed is very low in non turbulent mixtures.

a turbulance motion of the mixture intensifies the process of heat transfer & mixing of burned and unburned portions in the flame front

these two factors cause the velocity of turbulance flame to increase pratically in proportion to the turbulance velocity. However excessive turbulance is also undesirable.

Engine Speed

the higher engine speed the greater turbulance inside the cylinder for this reason the flame speed increases almost linearly with the engine speed.

the Crank angle required for flame Propogation which is the main phase of combustion, will remain almost constant at all speed.

Knocking in SI (petrol) engine. (14)

Since air fuel mixture is added to SI engines Sometimes here the last charge left at the end of piston gets ignited due to high temperature and hence it generates flame front in opposite direction of the original one caused by the spark, these two flame fronts collide at a point and create a very high temperature zone and hence a pinging sound is heard. this phenomenon is called knocking in SI engine

Methods to reduce knocking in SI engine

* Decrease the Compression ratio
* Decrease the mass of charge
* Decrease the inlet temperature of charge
* provide coolant to the engine
* Spark retard
* Using rich air fuel mixture (only 10% rich, not more)
* Increase turbulance of charge inside the cylinder
* Increase engine speed
* Reducing distance of flame travel.

Anti knock Additives

→ Anti knock Additives / agents are chemical compounds added in small quantities (less than 1%) to motor fuel to improve the anti knock rating of fuel

→ Usualy added to gasoline to rise its octane value Higher octane value means gasoline will ignite high temperature and Pressure, it helps fuel to ignite at correct time reducing pre-detonation which can be harmful to engine the octane number of gasoline increase in order.

Paraffin → olefins → naphthene → Isoparafin → aromatics

Some of the antiknock agents are used are.

01. Tetraethyl lead and Tetramethyl lead (TEL/TML)

The addition of TEL/TML to gasoline called doping.

the addition of very small amount of TEL to gasoline of low anti knock value usualy increases the Octane number to a very considerable extent.

02. BENZOLE

a typical composition of benzole is benzene 75% Toleune 15% and Xylene 10%

As benzole contains large number of aromatics therefore, it is use as octane boosting agent.

03. METHYL TERTIARY BUTYL ETHER (MTBE)

MTBE is the most adaptable octane enhancing oxygenate available for blending with unleaded gasoline but is not widely used because of environmental concerns.

DETONATION

Very sudden rise of pressure during combustion accompained by mettalic hammer like sound is called Detonation

Effects of Detonation

* Noise and roughness
* Mechanical Damage
* Carbon deposits
* Increase in heat transfer
* Pre ignition

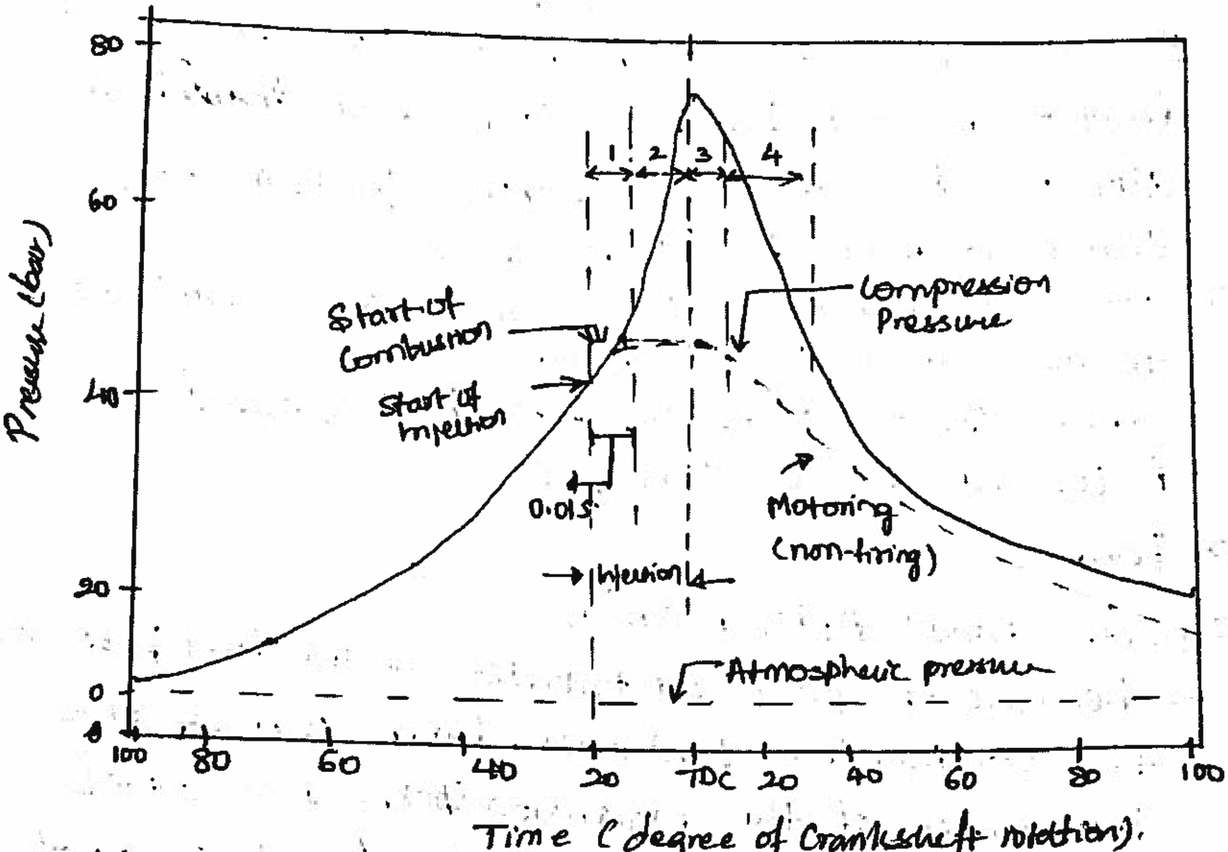
Control of Detonation

* Increase in engine rpm
* retarding spark.
* reducing pressure at inlet manifold
* Use of octane fuel can eliminate detonation

Factors affecting Detonation / Knocking

* Fuel choice :- A self ignition temperature promots knock
* Induction Pressure:-
  Increase of pressure decreases the self ignition temperature and induction period.
* Engine Speed:-
  low engine speeds will give low turbulence and low flame velocities and knock may occur at low speed
* Ignition timing:-
  Advanced ignition timing increases peak pressure and promotes knock.
* Compression Ratio:-
  High compression ratio increases cylinder pressure & promotes knock

Stages of combustion in C.I engine.



First Stage: Ignition Delay.

Ignition Delay period during which some fuel has been admitted but has not yet been ignited. the ignition delay is counted from the start of Injection to the point where P-θ curve separates from pure air compression curve.

Second Stage: Rapid or Uncontrolled Combustion

In this second stage pressure rise is rapid because during the delay period the ~~fuel~~ fuel droplet have had time to spread themselves over a wide area and they have fresh air all around them.

It is counted from the end of delay period to the Point of maximum pressure on P-θ diagram

About one third of the heat is evolved during this period

Third stage: Controlled Combustion

→ At the end of second stage, the temperature and pressure are so high so high that the fuel droplets injected during the last stage burn almost as they enter and further pressure rise can be controlled by injection rate.

→ It is counted from the point of maximum pressure to maximum cycle temperature
about 70 to 80% of the total heat of the fuel is evolved during this period.

→ Fourth stage: After burning.

→ because of poor distribution of the fuel particles, the combustion continues during part of the remainder of the expansion stroke. this after burning can be called the fourth stage of combustion.

→ the duration of after burning phase may correspond to 70-80 degree of crank travel from TDC.

→ Total heat evolved by the end of combustion process is 95 to 97% and 3 to 5% of heat goes as unburnt fuel in exhaust.

Ignition Delay Period in CI Engines.

→ Ignition delay is the period during which some fuel has been admitted but has not yet been ignited.

→ It is counted from the start of injection to the point where P-θ curve separates from pure air compression curve. The ignition delay can be roughly devided into two parts: Physical Delay and Chemical Delay

Physical Delay:-

The period of Physical Delay is the time between the begining of injection and attainment of chemical reaction conditions.

In physical delay period the fuel is automized vaporized, mixed with air. and rise in temprature

Chemical Delay:-

In this period pre flame reactions starts slowly and then accelarate until ignition takes place

At high temprature chemical reaction is quicker and physical delay is longer than chemical delay.

Factors affecting Ignition Delay Period.

Fuel:

lower self ignition temprature means a lower delay period. Higher Centane means a lower delay period and smooth engine operation.

Intake temprature:

Increase in intake temprature would result in increase in compressed air temperature and density

Type of combustion chamber:

A pre combustion chamber gives shorter delay compared to an open type combustion chamber.

Diesel Knock

If the ignition delay period is long, a large amount of fuel will be injected and accumulated in the chamber.

the auto ignition of this large amount of fuel may cause high rate of pressure rise and high maximum pressure which may cause knocking in diesel engine

methods for controlling Diesel knock.

→ ~~High charge temprature~~

The diesel knock can be controlled by reducing delay period. the delay is reduced by following

- → High charge temperature.
- → High fuel temperature
- → Good turbulance
- → A fuel with short induction period.
- → by using Ignition accelarators like Amyl Nitrate

SI engine Fuel requirments:

(Fc)

01. Volatility:

Gasoline is a mixture of different hydrocarbons, Volatility depends on the fractional composition of the fuel the usual practice of measuring the fuel Volatility is the distillation of the fuel in a special device at atmospheric pressure and the presence of its own vapour.

02. Operating range Performance:

In order to obtain good vapourization of the gasoline, low distillation temperatures are preferable in the engine operation range. better vapourization tends to produce more uniform distribution of fuel to the cylinders,

03. Crankcase Dilution:

liquid fuel in the cylinder causes loss of lubricating oil (by washing away oil from cylinder walls) which deteriorates the quality of lubrication and tends to cause damage to engine through increased friction to prevent this the upper portion of distillation curve Should exhibit Sufficiently low distillation temperatures to insure that all gasoline in the cylinder is vaporised by the time combustion starts.

04. Anti Knock Quality:-

the anti knock quality of or property of fuel depends on the self ignition characteristics of its mixture and vary largely with chemical composition and molecular Structure of the fuel, the good fuel have highest anti knocking property, Since it permits the use of higher compression ratios and thus thermal efficiency and power output can be greatly increased.

CI Engine Fuel Requirements

01. Knock characteristics:

Knock in the CI engine occurs because of an ignition lag in the combustion chamber. and ignition lag affects, the starting, warm up and leads to production of exhaust smoke in CI engines. the present day measure in the cetane rating the best fuel in general will have cetane rating sufficiently high to avoid knock.

02 Volatility:

the fuel should be sufficiently volatile in operating range of temperature to produce good mixing & combustion.

03 Starting Characteristics:

the fuel should help in the starting the engine easily. this requirement demands high enough volatility to form a combustible mixture readily and a high cetane rating in order that the self ignition temperature is low.

04. Viscosity:

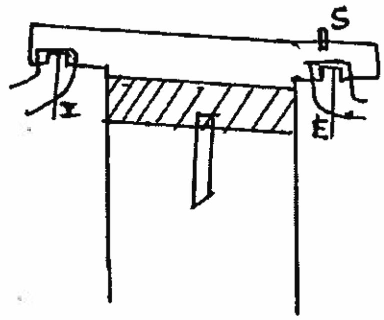
CI engine fuels should be able to flow through the fuel system and the strainers under the lowest operating temperatures to which the engine is subjected to.

05. Smoke and odour:

the fuel should not promote either smoke or odour in the engine exhaust, generally, good volatility is the first prerequisite to ensure good mixing and therefore complete combustion.

COMBUSTION CHAMBERS FOR SI ENGINES

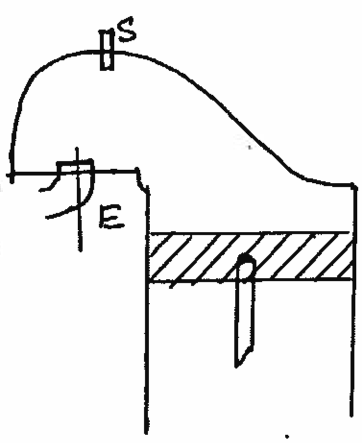
The design of the combustion chamber for SI engine has an important influence on the engine performance and its knocking tendencies. The design involves the shape of the combustion chamber, the location of spark plug and the location of inlet and exhaust valves. because of this importance, the combustion chamber design design has been a subject of considerable amount of research and development in the last fifty years.



T-head Type

i] T-Head Type:

T Head type combustion chambers were used in the early stage of engine development, Since the distance across the combustion is very long, knocking tendency is very high in this type of engines. it requires two camshafts.



L-head Type

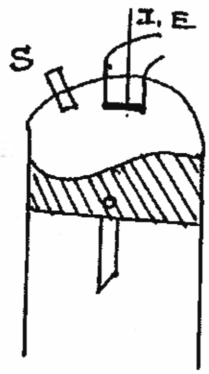
ii] L-Head Type.

A modification of the T-head type of combustion chamber is the L-head type which provides the two valves on the same side of the cylinder and the valves are operated by a single camshaft.

E - Exhaust Valve

I - Inlet Valve

S - Spark plug



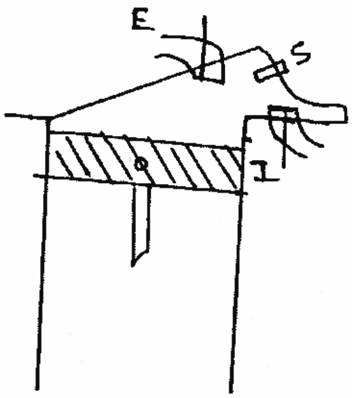
I- head type

I-Head type or Overalhead Valve.

The I-head type is also called the overhead valve combustion chamber in which both the valves are located on the cylinder head.

The overhead valve engine is superior to a side valve or an L-head engine at high compression ratios. Some of the important characteristics this type of valve arragment are

* less surface to volume ratio and therefore less heat loss.
* less flame travel length and hence greater freedom from knock.



F-Head type.

F-Head Type

The F-Head type of valve arrangement is a compromise between L-head and I-Head types, Combustion chambers in which one valve is in the cylinder head and the other in the cylinder block are known as F-Head combustion chamber.

COMBUSTION CHAMBERS FOR CI ENGINES

The CI engine combustion chamber is to provide proper mixing of fuel and air in a short time. In order to achieve this, an organised air movement called the air swirl, is provided to produce high relative velocity between the fuel droplets and the air. The fuel injected into the combustion chamber by an injector having a single or multihole orifices. The increase in the number of Jets reduces the intensity of air swirl needed

CI engine combustion chambers are classified into two categories.

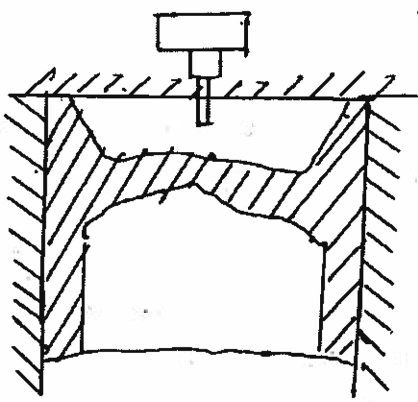
01. Direct Injection (DI) Type ("Open combustion chamber")

02. Indirect Injection (IDI) Type ("Divided combustion Chamber")

01. Open Combustion Chamber:

In this type the entire volume of the combustion chamber is located in the main cylinder and the fuel is injected into this volume.

An Direct Injection type / open combustion chamber in which combustion space is essentially a single cavity with little restriction from one part of the chamber to the other and hence with no large difference in pressure between parts of the chamber during the combustion process.



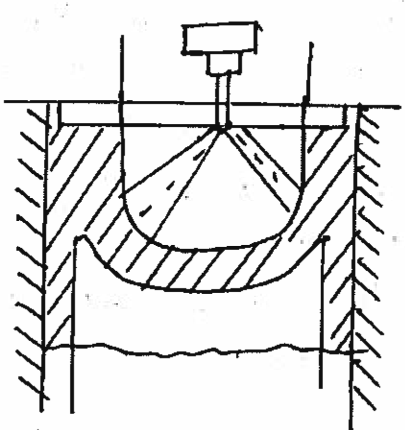
Shallow depth chamber

i) Shallow Depth chamber:

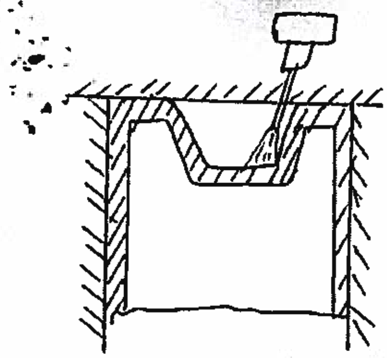
In this depth of the cavity provided in the piston is quit small. this chamber is usually adopted for large engines running at low speed. Since the cavity diameter is very large, the squish is negligible.

ii) Hemispherical Chamber

This chamber also gives small squish, However the depth to diameter ratio for a cylindrical chamber can be varied to give any desired squish to give better performance.



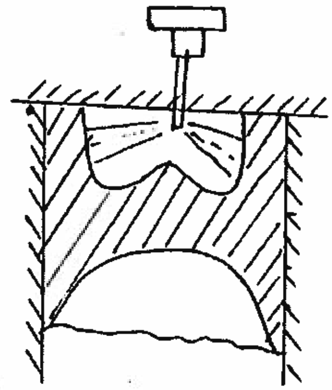
Hemispherical chamber



cylindrical chamber

iii] Cylindrical chamber:

this cylindrical chamber consist of a truncated cone with base angle of 30°, the swirl was produced by masking the valve for nearly 180° of circumference. Squish can also be varied by varying the depth.



Torodial chamber

iv] Torodial chamber.

Torodial chamber is used to provide a powerful squish along with the air movement, similar to that of the familiar smoke ring, within the torodial chamber. Due to powerful squish the mask need on inlet valve is small and there is better utilization of oxygen. the cone angle of spray for type of chamber is 150° to 160°

02. Divided Combustion chamber (Indirect injection chambers)

A divided combustion chamber is defined as one in which the combustion space is divided into two or more distinct compartments connected by restricted passages. this creates considerable pressure differences between them during the combustion chamber

01. Swirl chamber:

Swirl chamber consist of a spherical shaped chamber separated from the engine cylinder and located in the cylinder head. into this chamber about 50% of the air is transfered during the compression stroke.

A throat connects the chamber to the cylinder which enters the chamber in tangential direction so that the air is coming into this chamber is given a strong rotary movement inside the swirl

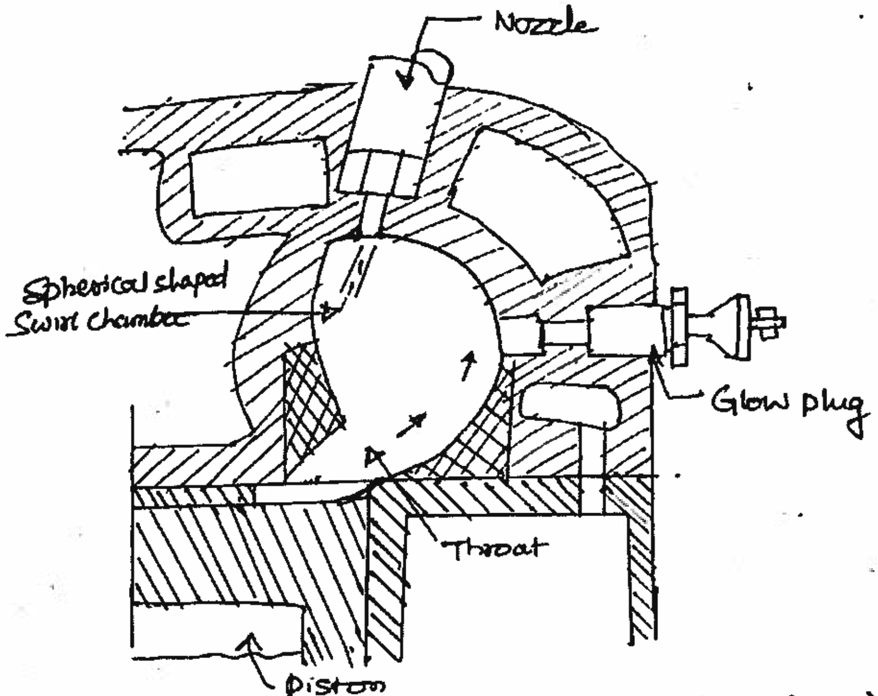


fig: Swirl chamber (Ricardo Swirl chamber)

chamber and after the combustion, the product rush back into the cylinder through the same throat at much higher velocity. This causes considerable heat loss to the walls of the passage which can be reduced by employing a heat-insulted chamber. However in this type of combustion chamber even with a heat insulted passage, the heat lose is greater than that in an open combustion chamber which employs induction swirl.

UNIT - III

Testing of Internal Combustion Engines.

Indicated Power:

It is the actual power developed in the engine cylinder.

$$IP = \frac{100\,K\,P_{mi}\,LAn}{60}\ \text{KW}$$

P_{mi} → Indicated mean effective pressure in bar

L → length of stroke in m.

A → area of piston in m^2

N → Speed of the engine rpm.

n → Number of working stroke per Minute

= N for two stroke engine

= $\frac{N}{2}$ for two stroke engine.

k → Number of Cylinders (for single cylinder k=1)

Break Mean Effective Pressure (BMEP) P_{mb}:

It is a constant pressure acts over a full length of stroke to produce the same amount of work from crank shaft.

$$\eta_{mech} = \frac{P_{mb}}{P_{mi}}$$

$$P_{mb} = \eta_{mech} \times P_{mi}$$

$$BP = \frac{100\,K P_{mb}\,LAn}{60}$$

$$P_{mb} = \frac{BP \times 60}{100\,KLAn}\ \text{bar}$$

Breake Power (BP):

It is the net power available at the crank Shaft.

→ It can be measured by means of Prony breake or rope brake Mechanism.

In case of Prony Brake.

$$BP = \frac{2\pi NT}{60} = \frac{2\pi N(WL)}{60} \text{ watts.}$$

W → Break load in N

l → length of arm in m

N → Speed of the engine in rpm

T → Torque in N-m = W×l

In case of rope brake.

$$BP = \frac{(W-S)\pi DN}{60} \text{ watts}$$ (without considering the dia of rope)

$$BP = \frac{(W-S)\pi(D+d)N}{60} \text{ watts}$$ (considering the dia of rope)

W → Dead load in N

S → Spring balance reading in N

D → Dia of brake drum in m

d → Dia of the rope in m.

N → Speed of the engine in rpm

Mean effective Pressure [Indicated Mean effective Pressure]

$$P_{mi} = \frac{a \times S}{l}$$

S → Scale of the Pressure or Indicator Spring in bar per mm

a → area of diagram

l → length of the diagram in mm.

Indicated thermal efficiency

It is the ratio of the heat equivalent to one KW hour to heat in the fuel per IP hour.

$$\eta_t = \frac{\text{Heat equivalent to one KW hour}}{\text{Heat fuel per IP hour}}$$

$$= \frac{3600}{\frac{m_f \times C}{IP}}$$

$$= \frac{IP \times 3600}{m_f \times C}$$

* where $\frac{m_f}{IP}$ is the specific fuel consumption per IP hour.

Brake Thermal efficiency.

It is the ratio of the heat equivalent to one KW hour to the heat in fuel per BP hour. It is also known as overall thermal efficiency

$$\eta_b = \frac{\text{Heat Equivalent to one KW hour}}{\text{Heat in fuel per BP Hour}}$$

$$= \frac{3600}{\frac{m_f \times C}{BP}}$$

$$\eta_b = \frac{BP \times 3600}{m_f \times C}$$

Where $\frac{m_f}{BP}$ is known as specific fuel consumption per BP per hour

P7

Mechanical efficiency:

It is the ratio of brake power to the Indicated power.

$$\eta_m = \frac{\text{Brake Power}}{\text{Indicated Power}} = \frac{BP}{IP} \%$$

→ BP is always less than IP because of loss of Power due to friction known as frictional Power (FP), therefore

$$FP = IP - BP$$

→ It is also noted that Mechanical efficiency is always less than unity.

Overall efficiency:

It is the ratio of work at crank shaft in a given time to the energy supplied by the fuel during the same time

∴ work at crank shaft/minute $= BP \times 60$ kJ

• BP in KW.

$1 KW = 1 \frac{KJ}{Sec}$

energy supplied by fuel/minute $= \frac{m_f \times C}{60}$ KJ

m_f → mass of fuel consumed in kg/hr

C → Calorific value of fuel in KJ/kg

overall efficiency $\eta_o = \frac{BP \times 3600}{m_f \times C} = \frac{BP \times 60 \times 60}{m_f \times C}$. ($\because 60 \times 60 = 3600$)

Air standard efficiency

$$\eta_{ase} = 1 - \frac{1}{r^{\gamma-1}} \quad \text{for petrol engine}$$

$$= 1 - \frac{1}{r^{\gamma-1}}\left[\frac{\rho^{\gamma}-1}{\gamma(\rho-1)}\right] \quad \text{for Diesel engine}$$

r = Compression ratio

γ = ratio of Specific heat

ρ = cut off ratio.

Relative efficiency

It is the ratio of indicated thermal efficiency to air standard efficiency

$$\text{Relative efficiency} = \frac{\eta_t}{\eta_{ase}}$$

* It is also known as efficiency ratio

Volumetric efficiency

It is the ratio of actual volume charge of charge admitted during suction stroke at NTP to the swept volume of the piston

$$\eta_v = \frac{V_a}{V_s}$$

Heat Balance Sheet :

Heat Balance sheet is a complete record of heat supplied and heat utilized during a particular time (say one minute) by an I C engine, is prepared in tabular form.

Following terms are used to complete the heat balance sheet

01. Heat Supplied by fuel $= m_f \times C$ KJ/min

$m_f \rightarrow$ Mass of fuel supplied in kg/min

$C \rightarrow$ lower calorific value of fuel in KJ/kg

02. Heat absorbed in I.P. Produced

$$IP = \frac{100\, P_{mi} L A n}{60} \text{ KW. (for single cylinder } K = 1)$$

Heat absorbed in IP/min $= 100\, P_{mi} L A n$ KJ/min $\left(1\,KJ = 1\, \frac{kJ}{sec}\right)$

03. Heat absorbed in BP Produced $= BP \times 60$ KJ/min

04. Heat rejected to cooling water $= M_w C_w (t_1 - t_2)$ KJ/min

$M_w \rightarrow$ mass of cooling water in kg/min

$C_w \rightarrow$ Specific heat of water $= 4.2$ KJ/kg K.

$t_1 \rightarrow$ Inlet temperature

$t_2 \rightarrow$ outlet temperature.

05. Heat Carried away by the exhaust gases $= m_g C_g t$ $\frac{KJ}{min}$

$m_g \rightarrow$ mass of exhaust gases in kg/min

$m_g = m_a + m_f = \left(\frac{A}{F} + 1\right) \times m_f$

$C_g \rightarrow$ specific heat of exhaust gases

$t \rightarrow$ rise in temperature.

06. Unaccounted Heat = Heat supplied − (Heat absorbed in BP + heat rejected in cooling water + heat carried away by the exhaust gases)

SL NO	Particulars	Heat KJ	Heat %	SL NO	Particulars	Heat KJ	Heat %
	Heat Supplied/min.	KJ	%			KJ	%
	Heat Supplied by the fuel	KJ	%	1	Heat absorbed in IP	–	–
				2.	Heat rejected to cooling water	–	–
				3.	Heat Carried away by the exhaust gases	–	–
				4.	Unaccounted Heat	–	–
	Total		100%		Total		100%

Q. A diesel engine uses 6.5kg of oil per hour of calorific value 30000 KJ/kg. If the BP of the engine is 22 KW and Mechanical efficiency 85% calculate i) Indicated thermal efficiency 2) Brake thermal efficiency 3) Specific fuel Consumption in kg/BP/hr

Given Data.

$m_f = 6.5$ kg/hr

$C = 30000$ KJ/kg

$BP = 22$ KW

$\eta_m = 85\% = 0.85$

01. $\eta_t = ?$ $\quad \eta_t = \frac{IP \times 3600}{m_f \times C}$

$IP = \frac{BP}{\eta_m}$

02. $\eta_b = ?$ $\quad \eta_b = \frac{BP \times 3600}{m_f \times C}$

03. Specific fuel Consumption $= \frac{m_f}{BP}$

01. Indicated thermal efficiency

WKT $\quad IP = \frac{BP}{\eta_m} = \frac{22}{0.85} = 25.88$ KW

$$\eta_t = \frac{IP \times 3600}{m_f \times C} = \frac{25.88 \times 3600}{6.5 \times 30000} = 0.48 = 48\%$$

02. Brake thermal efficiency

$$\eta_b = \frac{BP \times 3600}{m_f \times C} = \frac{22 \times 3600}{6.5 \times 30000} = 0.406 = 40.6\%$$

03. Specific fuel Consumption

$$= \frac{m_f}{BP} = \frac{6.5}{22} = 0.295 \text{ kg/BP/hr}$$

During the test on single cylinder oil engine working on the four stroke cycle and fitted with a rope brake, the following readings are taken,
effective diameter of brake wheel = 630mm, Dead load on brake = 200N, Spring balance reading = 30N, Speed = 450 rpm, area of Indicator diagram = 420mm², length of Indicator diagram = 60mm, Spring Scale = 1.1 bar per mm, Diameter of cylinder = 100mm, Stroke 150mm, Quantity of oil used = 0.815 kg/h, Calorific value of oil = 42000 KJ/kg
Calculate brake power, Indicated power, mechanical efficiency, brake thermal efficiency and brake specific fuel consumption.

Given Data

$K = 1$

$D = 630\,mm = 0.6\,m$

$W = 200\,N$

$S = 30\,N$

$N = 450\,rpm$

$a = 420\,mm^2$

$l = 60\,mm$

$s = 1.1\,bar/mm$

$D_c = 100\,mm = 0.1\,m$

$L = 150\,mm = 0.15\,m$

$m_f = 0.815\,kg/h$

$C = 42000\,KJ/kg$

find

i) $BP = \frac{(W-S)\pi D N}{60}$ kW

ii) $IP = \frac{100 K P_m L A n}{60}$ kW

$n = \frac{N}{2}$ for 4 stroke

to find $P_m = \frac{a \times s}{l}$ bar

iii) $\eta_m = \frac{BP}{IP}$ %

iv) $\eta_{bt} = \frac{BP \times 3600}{m_f \times C}$ %

v) $\frac{m_f}{BP} =$

A four cylinder two stroke ~~two stroke~~ cycle petrol engine develops 23.5 kW brake power at 2500 rpm. the mean effective pressure on each piston is 8.5 bar and the Mechanical efficiency is 85%. Calculate the diameter and stroke of each cylinder, assuming the length of stroke equal to 1.5 times the diameter of cylinder.

Solution:-

$K = 4$

$BP = 23.5\,kW$

$N = 2500\,rpm.$

$P_m = 8.5\,bar$

$\eta_m = 85\% = 0.85$

i) D_c & D_L

→ $IP = \frac{100\,K P_m L A n}{60}$

to find BP.

$IP = \frac{BP}{\eta_m}$

Area of Cylinder.

$n = N = 2500$ (engine works on 2 stroke)

$$A = \frac{\pi}{4}(D_c)^2$$

let D_c → Cylinder dia

L → length of stroke $= 1.5 D_c$

$$A = \frac{\pi}{4}(1.5 D_c)^2 = 0.7855 (D_c)^2$$

Now

$$IP = \frac{BP}{\eta_m} = \frac{23.5}{0.85} = 27.65\,kW$$

from

$$IP = \frac{100\,K P_m L A n}{60}$$

$$27.65 = \frac{100 \times 4 \times 8.5 \times 1.5 D_c \times 0.7855 (D_c)^2\, 2500}{60}$$

$$(D_c)^3 = 0.000165$$

$$D_c = 0.055\,m$$

$$D_c = 55\,mm.$$

$$L = 1.5 D_c = 1.5 \times 55 = 82.5\,mm.$$

i) BRAKE Power

$$BP = \frac{(W-S)\pi DN}{60} = \frac{(200-30)\pi \times 0.63 \times 450}{60} = 2.520 \text{ kW}$$

ii) Indicated Power.

$$IP = \frac{100 K P_m L A n}{60}$$ Now find P_m, A

to find $P_m = \frac{a \times s}{l} = \frac{420 \times 1.1}{60} = 7.7 \text{ bar}$

$$A = \frac{\pi}{4} D_c^2 = \frac{\pi}{4}(0.1)^2 = 7.855 \times 10^{-3} \text{ m}^2$$

for 4 stroke $n = \frac{N}{2} = \frac{450}{2} = 225$

$$IP = \frac{100 \times 1 \times 7.7 \times 0.15 \times 7.855 \times 10^{-3} \times 225}{60} = 3.4 \text{ kW}$$

iii) Mechanical efficiency

$$\eta_m = \frac{BP}{IP} = \frac{2.52}{3.4} = 0.7418 \text{ or } 74.18\%$$

iv) Brake thermal efficiency

$$\eta_{bt} = \frac{BP \times 3600}{m_f \times C} = \frac{2.52 \times 3600}{0.815 \times 42000} = 0.265 \times 100$$

$$\eta_{bt} = 26.5\%$$

v) Brake fuel consumption

$$= \frac{m_f}{BP} = \frac{0.815}{2.52} = 0.323 \text{ kg/BP/hr}$$

the Diameter and Stroke length of Single Cylinder two stroke gas engine working on constant volume cycle are 200 and 300mm respectively, with a clearance volume 2.78 liter. When the engine is running at 135 rpm the indicated mean effective pressure was 5.2 bar and the gas consumption is 8.8 m3/hour. If the Calorific value of the gas used as 16350 kJ/m3 find 1) air standard efficiency 2) Indicated Power developed by the engine 3. Indicated thermal efficiency of engine

$D_c = 200mm = 0.2m$

$L = 300mm = 0.3m$

$V_c = 2.78$ liter $= 0.00278\ m^3$

$N = 135\ rpm$

$P_m = 5.2\ bar$

$m_f = 8.8\ m^3/h$

$C = 16350\ kJ/m^3$

i) $\eta_{ase} = ?$

ii) $IP = \frac{100 P_m L A n}{60}$ kW

iii) $\eta_{it} = \frac{IP \times 3600}{m_f \times C}$

i) $\eta_{ase} = 1 - \frac{1}{r^{\gamma-1}}$

area of cylinder $A = \frac{\pi}{4} d^2 = \frac{\pi}{4} \times (0.2)^2 = 0.03142 m^2$

Stroke volume $V_s = A \times L = 0.03142 \times 0.3 = 0.009426 m^3$

Compression ratio $= \frac{\text{total volume of cylinder}}{\text{Clearance volume}} = \frac{V_c + V_s}{V_c} = 4.4$

$\eta_{ase} = 1 - \frac{1}{r^{\gamma-1}} = 1 - \frac{1}{(4.4)^{1.4-1}} = 1 - 0.553 = 0.447 = 44.7\%$

2. Indicated power developed by engine

$$IP = \frac{100 P_m L A n}{60} = \frac{100 \times 5.2 \times 0.3 \times 0.03142 \times 135}{60}$$

$$IP = 11.03 \text{ kW}$$

3. Indicated thermal efficiency

$$\eta_{it} = \frac{IP \times 3600}{m_f \times C} = \frac{11.03 \times 3600}{8.8 \times 16350} = 27.6\%$$

→ A single-cylinder, two-stroke cycle engine.

P_{mi} = 550 KPa
T = 628 Nm
N = 360 rpm
n = N = 360 rpm
d = 21 cm = 0.21 m
L = 28 cm = 0.28 m
m_f = 8.16 kg/h
CV = 42700 KJ/kg
k = 1

i) Mechanical efficiency
ii) Indicated thermal efficiency
iii) Brake thermal efficiency
iv) Brake specific fuel consumption.

i) $\eta_{mech} = \frac{BP}{IP}$

$IP = \frac{100\, P_m K L A n}{60} = 32.0 kW$

$BP = \frac{2\pi N T}{60} = 23.675 kW$

Mechanical efficiency

$\eta_{mech} = \frac{BP}{IP} = \frac{23.675}{32.0} = 0.7397 = 74\%$

ii) Indicated thermal efficiency

$\eta_{ith} = \frac{IP \times 3600}{m_f \times CV}$

$= \frac{32.0 \times}{\left(\frac{8.16}{3600}\right)}$

$\eta_{ith} = 0.330 = 33\%$

iii) Brake thermal efficiency

$\eta_{bth} = \frac{BP \times 3600}{m_f C_v}$

$\eta_{bth} = 24.4\%$

iv) Brake specific fuel consumption

$Bsfc = \frac{m_f}{BP}$

$= 0.3446$ kg/kWh

The following observations were recorded during a test on a single cylinder four stroke oil engine

Bore 300mm, Stroke 450mm, Speed 300rpm.
Imep 6 bar, brake load 1.5kN, brake drum diameter 1.8m, Brake rope diameter 2cm.

Calculate:- i) Indicated power.
ii) brake power.
iii) Mechanical efficiency.

Given Data

$d = 300mm = 0.3m$.
$L = 450mm = 0.45m$.
$N = 300rpm$.
$P_{mi} = 6bar = 600kPa$.
$W_{brake} = 1.5\ kN$
$D_{brake} = 1.8m$, $d_{rope} = 2cm = 0.02m$.
$K = 1$, $n = \frac{N}{2} =$

i) IP

$$IP = \frac{100KP_m LAn}{60}$$

$$= \frac{100 \times 1 \times 6 \times 0.45 \times \frac{\pi}{4} \times (0.3)^2 \times \frac{300}{2}}{60}$$

$IP = 47.71kW$

ii) $BP = \frac{2\pi NT}{60}$

T = brake load × effective brake radius

$$R_{brake} = \frac{D_{brake} + d_{rope}}{2} = \frac{1.8 + 0.02}{2}$$

$R_{brake} = 0.91m$

$T = 1.5 \times 0.91 = 1.365\ kNm$
$= 1365\ Nm$

$$BP = \frac{2\pi \times 300 \times 1365}{60,000}$$
$= 42.88kW$

iii) $\eta_{mech} = \frac{BP}{IP} = 89.8\%$

$V_s = \frac{\pi}{4}(D_c)^2 L$ ... 11

A four stroke diesel engine has a cylinder bore of 150mm and a stroke of 250mm. the crankshaft speed is 300rpm. and fuel consumption is 1.2kg/h, having a calorific value of 39900 kJ/kg. the indicated mean effective pressure is 5.5 bar. if the compression ratio is 15 and cutt of ratio is 1.8 calculate relative efficiency taking $\gamma = 1.4$.

Given Data

$D_c = 150mm = 0.15m$

$L = 250mm = 0.25m.$

$N = 300rpm$

$m_f = 1.2\ kg/h$

$C = 39900\ kJ/kg$

$P_m = 5.5\ bar$

$r = 15$

$\rho = 1.8$

$\gamma = 1.4$

i) $\eta_i = \frac{\text{Indicated thermal eff}}{\text{Air standard efficiency}} = 74.7\%$

$\eta_{it} = \frac{IP \times 3600}{m_f \times C} = 45.86\%$

$\eta_{ase} = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{\rho^{\gamma} - 1}{\gamma(\rho - 1)}\right]$

$= 61.4\%$

to find η_{it}

$IP = \frac{100\ P_m L A n}{60}$

$n = \frac{N}{2} = 150$ for 4stroke

$A = \frac{\pi}{4}(0.15)^2 = 0.0177m^2$

$IP = 6.1\ kW$

A four stroke petrol engine 80mm bore, 100mm stroke. It is tested at full throttle at constant speed. The fuel supply is fixed at 0.068 kg/min and the plugs of the four cylinders are successively short circuited without change of speed, brake torque being correspondingly adjusted. The brake power measurements are following

With all cylinders firing = 12.5 KW
With cylinder No. 1 cut off = 9 KW
" 2 " = 9.15 KW
" 3 " = 9.2 KW
" 4 " = 9.1 KW

Determine I.P of the engine under these conditions also determine the indicated thermal efficiency. Calorific value of the fuel is 44100 KJ/kg. Compare this efficiency with the air standard value. Clearance volume of one cylinder is $70 \times 10^3\ mm^3$

Given Data

$D_c = 80mm = 0.08m$

$L = 100mm = 0.1m$.

$m_f = 0.068\ kg/min = 4.08\ kg/h$

$B_p = 12.5\ KW$

$B_1 = 9\ KW$

$B_2 = 9.15\ KW$

$B_3 = 9.2\ KW$

$B_4 = 9.1\ KW$

$C = 44100\ kJ/kg$

$V_c = 70 \times 10^3\ mm^3$.

i) $\eta_{it} = \dfrac{IP \times 3600}{m_f \times C}$

ii) $\eta_{ase} = 1 - \dfrac{1}{r^{\gamma-1}}$; to find $r \rightarrow r = \dfrac{V_c + V_s}{V_c}$

$V_s = \frac{\pi}{4}(D_c)^2 L$

Indicated power of the engine.
IP produced in cylinder 1.

$$I_1 = B - B_1 = 12.5 - 9 = 3.5\ KW$$

$$I_2 = B - B_2 = 12.5 - 9.15 = 3.35\ KW$$

$$I_3 = B - B_3 = 12.5 - 9.2 = 3.3\ KW$$

$$I_4 = B - B_4 = 12.5 - 9.1 = 3.4\ KW$$

IP of the engine $I = I_1 + I_2 + I_3 + I_4 = 13.55\ KW$

i) Indicated thermal efficiency

$$\eta_{it} = \frac{IP \times 3600}{m_f \times C} = \frac{13.55 \times 3600}{4.08 \times 44100} = 0.271 = 27.1\%$$

ii) Air standard efficiency

$$\eta_{ase} = 1 - \frac{1}{r^{\gamma - 1}}$$

Now $r = \frac{V_c + V_s}{V_c} = \frac{\text{total Cylinder volume}}{\text{Clearance volume}}$

Now $V_s = \frac{\pi}{4} (D)^2 L = \frac{\pi}{4} (80)^2 100$

$$= 503 \times 10^3\ mm^3$$

$$r = \frac{(70 \times 10^3) + (503 \times 10^3)}{70 \times 10^3} = 8.18$$

$$\eta_{ase} = 1 - \frac{1}{r^{\gamma - 1}} = 1 - \frac{1}{(8.18)^{1.4-1}} = 56.9\%$$

Now
Ratio of η_{ase} to $\eta_{it} = \frac{0.569}{0.271} = 2.1$

So air Standard efficiency is 2.1 times the indicated thermal efficiency

An IC engine uses 6kg of fuel having calorific value 44000 kJ/kg in one hour. The IP developed is 18kW. the temperature of 11.5kg of cooling water was found to rise through 25°C per minute. the temperature of 4.2 kg of exhaust gas with specific heat 1 kJ/kgK was found to rise through 220°C. Draw the heat balance sheet for the engine

Given Data

$m_f = 6\,kg/h = 0.1\,kg/min$

$C = 44000\,kJ/kg$.

$IP = 18\,kW$

$m_w = 1.5\,kg/min$.

$t_2 - t_1 = 25°C$

$m_g = 4.2\,kg$.

$C_g = 1\,kJ/kgK$.

$t_g = 220°C$

01. Heat supplied by fuel

$= m_f \times C = 0.1 \times 44000 = 4400\,\frac{kJ}{min}$

02. Heat Absorbed in I.P Produced

$= 18\,kW = 18\,kJ/s = 1080\,\frac{kJ}{min}$

03. Heat rejected to cooling water

$= m_c C_w (t_2 - t_1)$

$= 11.5 \times 4.2 \times 25 = 1207.5\,kJ/min$

04 Heat lose to exhaust gases

$= m_g c_g t - 4.2 \times 1 \times 220 = 924\,\frac{kJ}{min}$

05 Unaccounted Heat

$= 4400 - (11080 + 1207.5 + 924)$

$= 1188.5\,kJ/min$

Sl NO	Particulars	Heat KJ	Heat %
	total Heat Supplied	4400	100
1.	Heat absorbed in IP	1080	24.55
2.	Heat rejected to cooling water	1207.5	27.44
3.	Heat carried by exhaust gases	924	21.00
4.	Unaccounted Heat	1188.5	27.01
	Total	4400	100

The following data were recorded during four stroke oil engine

Bore = 150mm

Stroke = 300mm

Speed = 18000 revolution/hour

Brake Torque = 200 Nm

Indicated mean effective Pressure = 7 bar

Fuel consumption = 204 kg/hr

Cooling water flow rate = 5kg/min

Cooling water temprature rise = 30°c

Air fuel ratio = 22

Exhaust gas temprature = 410°c

Specific heat of exhaust gases = 1KJ/kgK.

Room temperature = 20°c

Calorific value of fuel = 42 MJ/kg

Determine : Mechanical efficiency ii) BSFC & Heat Balance sheet

Given Data

$D_c = 150mm = 0.15m$

$L = 300m = 0.3m$

$N = 18000 R/h = \frac{18000}{60} = 300$ rpm

$T = 200 Nm$

$P = 7 bar$

$m_f = 204 kg/hr = \frac{204}{60} =$

$t_{w_1} = 30°C$

$m_w = 5 kg/min$

$A/F = 22$

~~exh~~ $T_E = 410°c.$

$C_g = 1 \cdot KJ/kgK$

$T_R = 20°C$

$C = 42 MJ/kg$

$= 42 \times 1000$

$= 42000 \frac{KJ}{kg}$

A]

i) $BP = \frac{2\pi NT}{60} = \frac{2\pi \times 300 \times 0.2}{60} = 6.28\ KW$

$n = \frac{N}{2}$ for 4 stroke

ii) $IP = \frac{100 P_m LAN}{60} = \frac{100 \times 7 \times 0.3 \times \frac{\pi}{4} \times (0.15)^2 \times \left(\frac{300}{2}\right)}{60}$

$IP = 9.28\ KW$

$\eta_{mech} = \frac{BP}{IP} = \frac{6.28}{9.28} = 0.676 = 67.6\%$

$BSFC = \frac{m_f}{BP} = \frac{204}{6.28} = 32.5\ kg/kWh$

i) Heat Supplied $= \frac{m_f}{min} \times CV = \frac{204}{60} \times 42{,}000 = 142{,}800\ KJ/min$

ii) Heat equivalent to IP $= \frac{100 PLAn}{60} = \frac{100 \times 7 \times 0.3 \times \frac{\pi}{4} \times (0.15)^2 \times 150}{60}$

or

$= 9.28\ kW.$

Heat equivalent to BP $= BP \times 60 = 6.28 \times 60$

$= 376.8\ KJ/min$

Heat loss due to friction $= (IP - BP) = (9.28 - 6.28)60$

$= 180\ KJ/min.$

or

$IP = IP \times 60 = 9.28 \times 60 = 556.8\ KJ/min$

iii) Heat loss due to cooling water $= M_w C_w (t_2 - t_1)$

$= 5 \times 4.2 \times 30$

$= 630\ KJ/min.$

$\frac{A}{F} = 22 \rightarrow A = 22F$

$M_{exhaust} = m_a + m_f$

$M_{ex.} = 22 m_f + m_f = 23 m_f$

iv) Heat carried away by exhaust gases $= M_g C_g (t_2 - t_1)$

$= 23 \times \frac{204}{60} \times 1 (410 - 20)$

$= 30498\ KJ/min.$

v) Heat unaccounted $= 142800 - (376.8 + 180 + 630 + 30498)$

$= 111113.4\ KJ/min$

: Heat Balance sheet

Sl No.	Particulars	KJ/min	%	
1	Heat Input	142800	100	
2.	a. Heat equivalent of IP OR Heat loss due to friction + Heat equivalent to BP	 180 376.8	~~26.78.88~~ ~~0.134%~~ 0.13 0.264	 0.13 0.26
	b. Heat loss to cooling water	630	21.4	0.44
	c. Heat carried away by exhaust gases	30498		21.4
	d. Heat unaccounted	111113.4		77.8
	Total	142800	100	

AIR COMPRESSORS

An air compressor is a machine which takes atmospheric air, compresses it with the help of some mechanical energy and delivers it at high Pressure.

→ An air compressor increases the Pressure of air by decreasing its specific volume

Classification of Air Compressor.

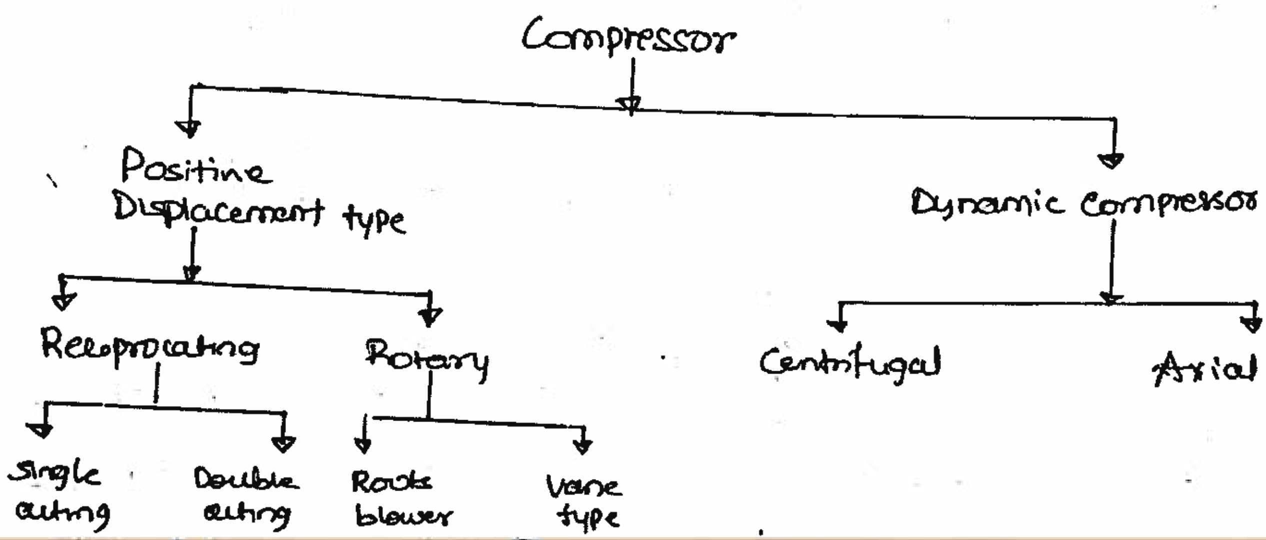


fig: classification of Air Compressor.

The Compressor are mainly classified as

i. Reciprocating compressors,

ii. Rotary Compressor.

01. Reciprocating Compressor:

→ it is used to produce high Pressure gas.

→ It uses the displacement of piston in the cylinder for compression,

→ It handles a low mass of gas and high Pressure ratio

02. Rotary Compressors:

→ The rotary compressors are used for low and medium Pressures.

→ they usually Consist of a blade wheel or Impeller that spins inside a circular housing & they handle large mass of Gas.

Technical terms Involved In Air Compressor.

01. Inlet Pressure: It is the absolute of air at the Inlet of Compressor.

02. Discharge Pressure: It is the absolute Pressure of air at the outlet of Compressor.

03. Compression ratio: (Pressure ratio)
It is the ratio of discharge pressure to the Inlet Pressure.
Since the discharge pressure is always more than the Inlet Pressure, therefore the value of compression ratio is more than unity

04. Compressor Capacity: It is the Volume of air delivered by the Compressor, and it is expressed in m^3/min or m^3/s.

05. free air delivery: It is the actual volume delivered by a Compressor when reduced to the normal temperature and Pressure conditions.

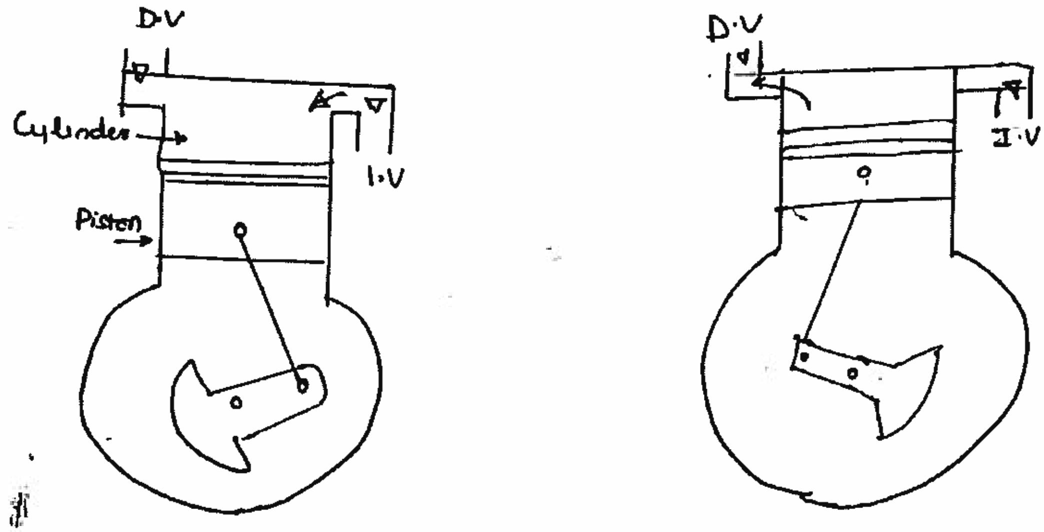
06. Swept Volume: It is the volume of air sucked by the Compressor during its Suction stroke.

$$V_s = \frac{\pi}{4} \times D^2 \times L$$

D → Diameter of cylinder bore

L → length of piston.

Working of Single Stage Reciprocating Air Compressor



a. Suction Stroke.   b. Delivery stroke

fig:- Single stage reciprocating compressor.

→ It consists of a cylinder, piston, inlet and discharge valves,

→ Suction Stroke:

* when piston moves downwards the pressure inside the cylinder falls below the atmospheric pressure. due to this pressure difference the inlet valve gets opened and air is sucked into the cylinder, at the inlet pressure until the piston completes suction stroke (outward stroke)

→ Delivery stroke

* When Piston moves upwards. the pressure inside the cylinder goes on increasing till it reaches the discharge pressure.
  At this stage discharge valve DV gets opened and air is delivered to container.
* At the end of this stroke, a small quantity of air at high pressure is left in the clearance space. As piston starts suction stroke, the air contained in the clearance space expands till its pressure falls below the atmospheric pressure.

* At this stage the inlet valve gets opened as a result of which fresh air is sucked into the cylinder and the cycle is repeated.

Work done by Single Stage Reciprocating Air Compressor Without clearance volume

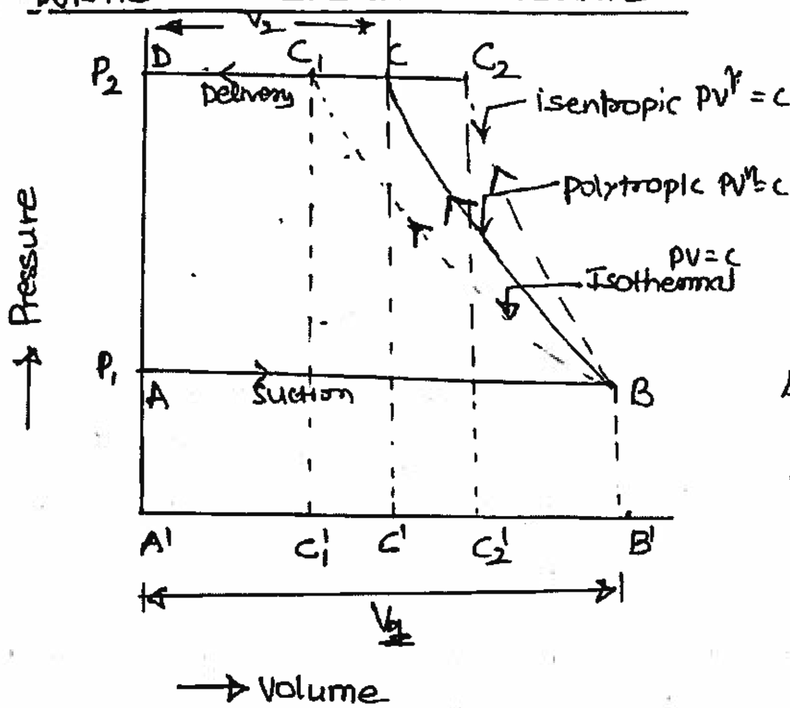


figure: P-V diagram without clearance volume

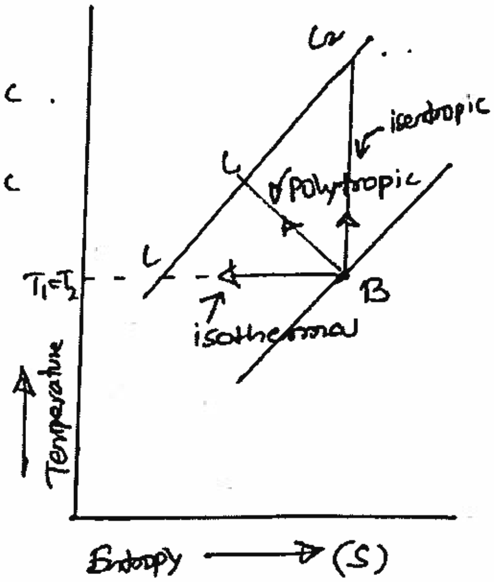


fig: T-S Diagram

* Consider a single stage reciprocating air compressor without clearance volume delivering air from one side of piston only

let P_1 = Initial Pressure of air before compression

V_1 = Initial volume of air before compression

T_1 = Initial temperature of air before compression

P_2, V_2, T_2 = Corresponding values for final conditions after delivery part

r = Pressure ratio (i.e $\frac{P_2}{P_1}$)

n = polytropic index for compression and expansion

V_c = clearance volume (i.e volume at point C)

V_s = Swept or stroke volume $= V_1 - V_c$

Q2. Workdone during isentropic Compression ($PV^{\gamma}=C$) " Adiabatic Compression 4.3

→ the isentropic Compression is shown by Curve BC_2. In this case the volume of air delivered V_2 is represented by the line C_2D

→ The workdone on the air cycle during Isentropic Compression may be worked out in the Similar way as polytropic compression. the polytropic index n is changed to isentropic Index γ in the previous result

$$W = \text{area } ABC_2D$$

$$= \text{area } A'C_2'C_2D + C_2BC_2'B' - AA'BB'$$

$$= P_2V_2 + \frac{P_2V_2 - P_1V_1}{\gamma-1} - P_1V_1$$

$$= P_2V_2 + \frac{P_2V_2}{\gamma-1} - \frac{P_1V_1}{\gamma-1} - P_1V_1$$

$$= P_2V_2\left[1 + \frac{1}{\gamma-1}\right] - P_1V_1\left[\frac{1}{\gamma-1} + 1\right]$$

$$= P_2V_2\left[\frac{\gamma - 1 + 1}{\gamma-1}\right] - P_1V_1\left[\frac{1+\gamma-1}{\gamma-1}\right]$$

$$= P_2V_2\left[\frac{\gamma}{\gamma-1}\right] - P_1V_1\left[\frac{\gamma}{\gamma-1}\right]$$

$$= \frac{\gamma}{\gamma-1}\left[P_2V_2 - P_1V_1\right] \quad \text{—(i)}$$

$$WD = \frac{\gamma}{\gamma-1} P_1V_1\left[\frac{P_2V_2}{P_1V_1} - 1\right] \quad \text{—(ii)}$$

WKT isentropic Compression

$$P_1V_1^{\gamma} = P_2V_2^{\gamma}$$

$$\frac{V_2}{V_1} = \left(\frac{P_1}{P_2}\right)^{\frac{1}{\gamma}} = \left(\frac{P_2}{P_1}\right)^{-\frac{1}{\gamma}} \quad \text{or} \quad \frac{V_2}{V_1} = \left(\frac{Y_2}{Y_1}\right)^{1/\gamma}$$

$$WD = \frac{\gamma}{\gamma-1} \times mRT_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}\right] \quad \text{—— (iii)}$$

the equation (1) may also written as —

$$WD = \frac{\gamma}{\gamma-1} \times (P_2V_2 - P_1V_1) \quad \text{—— (i)}$$

$$WD = \frac{\gamma}{\gamma-1} \times P_2V_2 \left[1 - \frac{P_1V_1}{P_2V_2}\right]$$

$$= \frac{\gamma}{\gamma-1} \times P_2V_2 \left[1 - \frac{P_1}{P_2}\left(\frac{P_2}{P_1}\right)^{1/\gamma}\right]$$

$$= \frac{\gamma}{\gamma-1} \times P_2V_2 \left[1 - \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}}\right] \quad J/s$$

$$= \frac{\gamma}{\gamma-1} \times mRT_2 \left[1 - \frac{T_1}{T_2}\right]$$

$$WD = \frac{\gamma}{\gamma-1} \times mR\,[T_2 - T_1] \quad \text{— iv}$$

WKT

$$\gamma = \frac{C_p}{C_v} \quad \text{and} \quad C_p - C_v = R.$$

$$R = C_p - C_v = C_p\left(1 - \frac{C_v}{C_p}\right) = C_p\left(1 - \frac{1}{\gamma}\right)$$

$$R = C_p\left(\frac{\gamma-1}{\gamma}\right)$$

workdone $W = \frac{\gamma}{\gamma-1} \times mR(T_2 - T_1)$

$$= \frac{\gamma}{\gamma-1} \times mC_p\left(\frac{\gamma-1}{\gamma}\right)(T_2 - T_1)$$

$$WD = m\,C_p\,(T_2 - T_1)$$

01. Work done during polytropic Compression (PV^n = Constant) (Without Clearance volume)

* The polytropic compression is shown by the line BC in figure. and CD represents the volume of air delivered V_2

Workdone = Area ABCD

$$= \text{Area } A'DCC' + \text{Area } CBB'C' - \text{Area } A'ABB'$$

$$= P_2V_2 + \frac{P_2V_2 - P_1V_1}{n-1} - P_1V_1$$

$$= P_2V_2 + \frac{P_2V_2}{n-1} - \frac{P_1V_1}{n-1} - P_1V_1$$

$$= P_2V_2 \left[1 + \frac{1}{n-1}\right] - P_1V_1\left[\frac{1}{n-1} + 1\right]$$

$$= P_2V_2\left[\frac{n-1+1}{n-1}\right] - P_1V_1\left[\frac{1+n-1}{n-1}\right]$$

$$= P_2V_2\left[\frac{n}{n-1}\right] - P_1V_1\left[\frac{n}{n-1}\right]$$

$$= \frac{n}{n-1}\left[P_2V_2 - P_1V_1\right] \quad \text{——(i)}$$

$$WD = \frac{n}{n-1}\left\{P_1V_1\left[\frac{P_2V_2}{P_1V_1} - 1\right]\right\} \quad \text{——(ii)}$$

WKT polytropic compression

$$P_1V_1^n = P_2V_2^n$$

$$\frac{V_2}{V_1} = \left(\frac{P_1}{P_2}\right)^{1/n} = \left(\frac{P_2}{P_1}\right)^{-1/n} \text{ or } \frac{V_2}{V_1} = \left(\frac{P_2}{P_1}\right)^{-1/n}$$

Substitute value of V_2/V_1 in equation(ii)

$$WD = \frac{n}{n-1} \times P_1V_1\left[\frac{P_2}{P_1}\left(\frac{P_2}{P_1}\right)^{-1/n} - 1\right]$$

$$WD = \frac{n}{n-1} \times P_1V_1\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

$$WD = \frac{n}{n-1} \times mRT_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right] \quad \text{—— (iii)} \qquad \because mRT_1 = P_1V_1$$

The equation (i) may also written as.

$$WD = \frac{n}{n-1} \times (P_2V_2 - P_1V_1) \quad \text{-(i)}$$

$$WD = \frac{n}{n-1} \times P_2V_2 \left[1 - \frac{P_1V_1}{P_2V_2}\right]$$

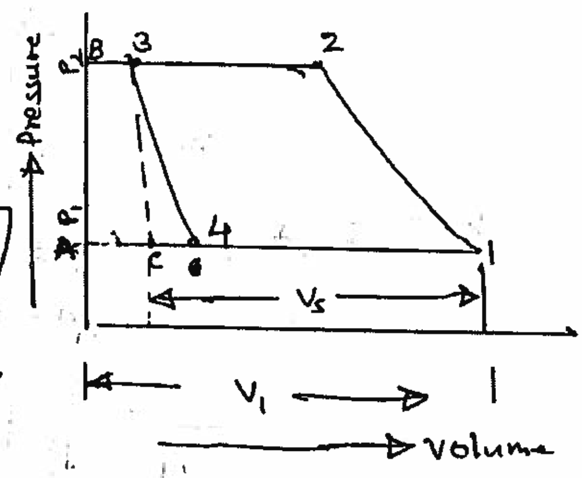
$$= \frac{n}{n-1} \times P_2V_2 \left[1 - \frac{P_1}{P_2}\left(\frac{P_2}{P_1}\right)^{1/n}\right]$$

$$= \frac{n}{n-1} \times P_2V_2 \left[1 - \left(\frac{P_1}{P_2}\right)^{\frac{n-1}{n}}\right] \quad J/s$$

$$= \frac{n}{n-1} \times mRT_2 \left[1 - \frac{T_1}{T_2}\right]$$

$$= \frac{n}{n-1} \times mR\,[T_2 - T_1] \quad \text{—— (iv)}$$

Workdone by Reciprocating air compressor with clearance volume.



W = Area 1-2-3-4

= (Area A-1-2-B) − (Area A-4-3-B)

$$= \frac{n}{n-1} \times P_1V_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right] - \frac{n}{n-1} P_1V_4 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

$$= \frac{n}{n-1} \times P_1(V_1 - V_4) \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

$$= \frac{n}{n-1} \times mRT_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

Two stage Reciprocating Air Compressor with Intercooler

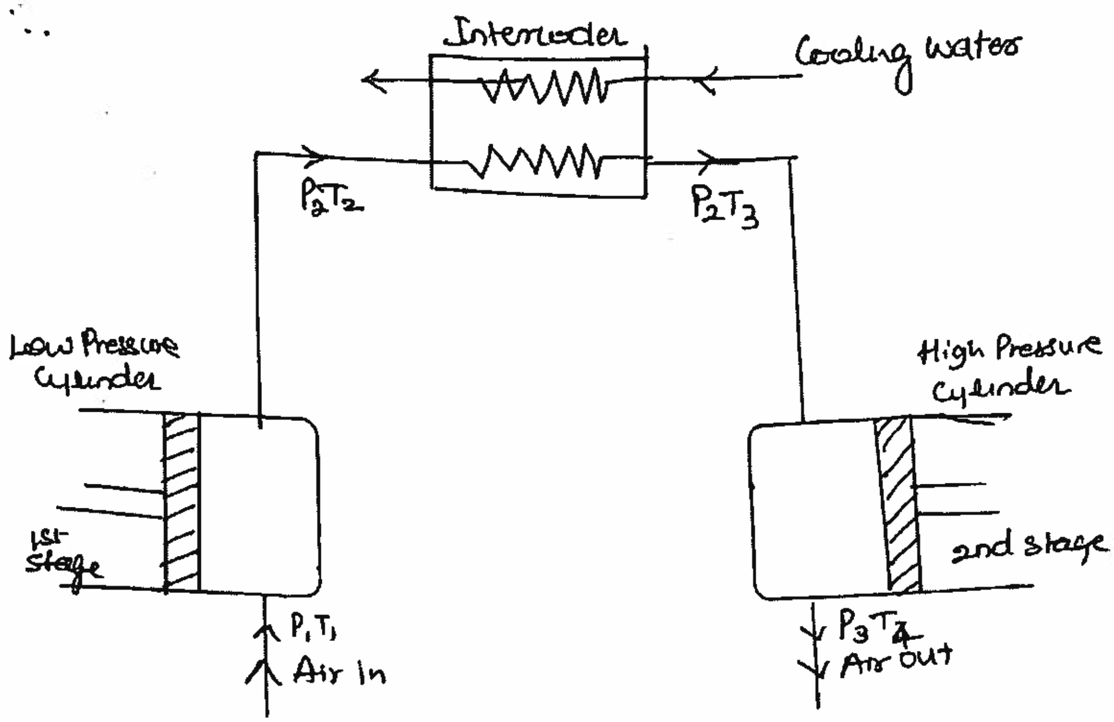


fig: Two stage reciprocating air compressor with intercooler.

→ Fresh air is sucked from the atmosphere in the low pressure (LP) cylinder during suction stroke at the intake pressure P_1 and Temperature T_1.

→ The air after compression in the low pressure cylinder (i.e first stage) from 1 to 2 delivered to the intercooler at pressure P_2 and the temperature T_2. Now the air is cooled in the intercooler from 2 to 3 at constant pressure P_2 and from temperature T_2 to T_3.

→ After that the air is sucked in the high pressure (H.P) cylinder during its suction stroke finally the air after further compression in the H.P cylinder (i.e second stage) from 3 to 4 is delivered by compressor at pressure P_3 and Temperature T_4.

Complete or perfect intercooling:

when the temperature of the air leaving the intercooler (T_3) is equal to original atmosphere air temperature. (T_1) then intercooling is known as complete or perfect intercooling.

Incomplete or Imperfect Intercooling:

the temperature of air leaving the intercooler (T_3) is more than original atmospheric temperature T_1 then the intercooling is known as incomplete intercooling

Case i: If intercooling is incomplete.

WD per cycle in LP Cylinder.

$$W_1 = \frac{n}{n-1} \times P_1 V_1 \left[\left(\frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right]$$

WD per Cycle in H.P cylinder

$$W_2 = \frac{n}{n-1} \times P_2 V_2 \left[\left(\frac{P_3}{P_2} \right)^{\frac{n-1}{n}} - 1 \right]$$

total workdone per cycle

$$W = W_1 + W_2$$

$$= \frac{n}{n-1} \times P_1 V_1 \left[\left(\frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right] + \frac{n}{n-1} P_2 V_2 \left[\left(\frac{P_3}{P_2} \right)^{\frac{n-1}{n}} - 1 \right]$$

$$= \frac{n}{n-1} \left[P_1 V_1 \left\{ \left(\frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right] + P_2 V_2 \left[\left(\frac{P_3}{P_2} \right)^{\frac{n-1}{n}} - 1 \right] \right]$$

Case ii: if intercooling is complete.

$$P_1 V_1 = P_2 V_2$$

$$W = \frac{n}{n-1} P_1 V_1 \left[\left(\frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right] + \frac{n}{n-1} P_2 V_2 \left[\left(\frac{P_3}{P_2} \right)^{\frac{n-1}{n}} - 1 \right]$$

$$W = \frac{n}{n-1} P_1 V_1 \left[\left(\frac{P_2}{P_1} \right)^{\frac{n-1}{n}} + \left(\frac{P_3}{P_2} \right)^{\frac{n-1}{n}} - 2 \right]$$

Power required to Drive two-stage Reciprocating air compressor

$$P = \frac{W \times N_W}{60} \text{ watts.}$$

$N_W \rightarrow$ No of working Strokes per minute

Two stage Reciprocating Air compressor

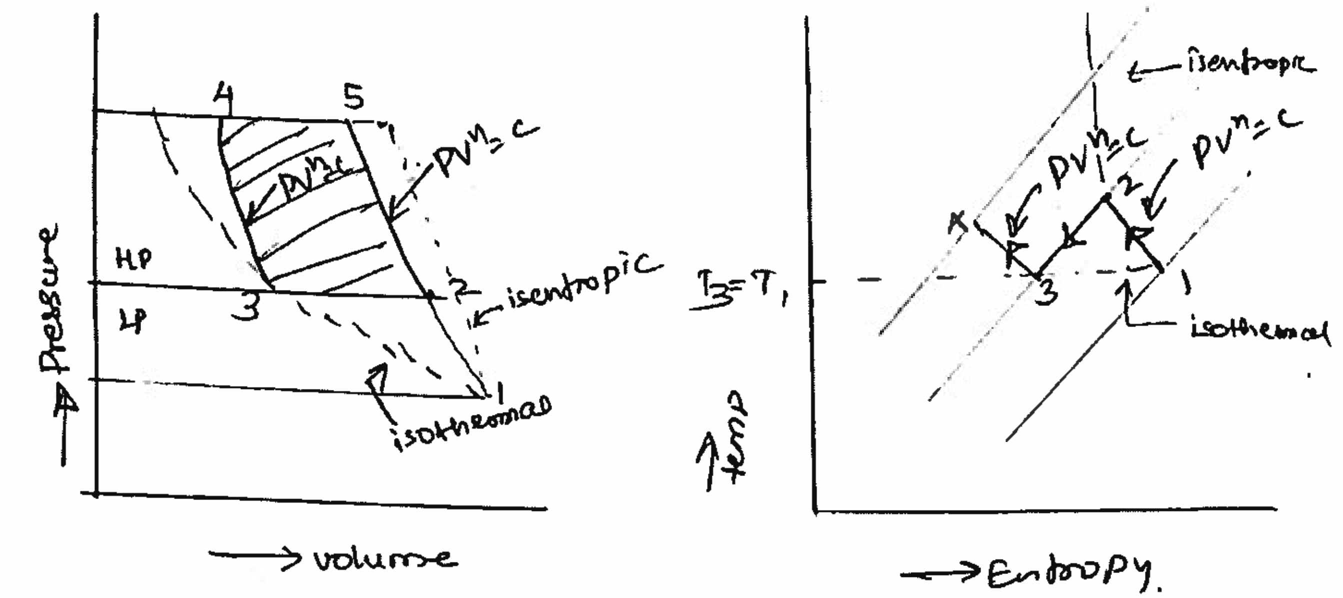


fig: Complete Intercooling of Air

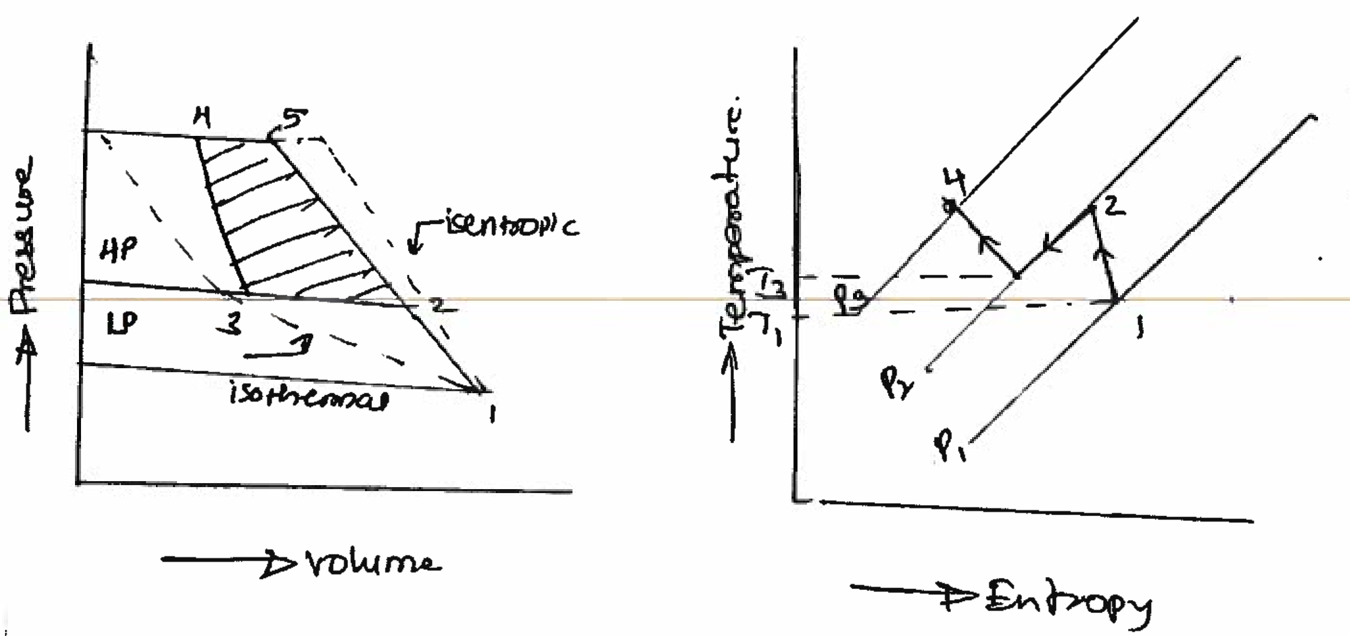


fig: Incomplete Intercooling of Air

03. Workdone during Isothermal Compression (PV = constant):

→ The isothermal compression and delivery of air is shown by graphs, BC_1 and C_1D respectively.

C_1D represent volume of air.

$$W = \text{Area } ABC_1D$$

$$= \text{Area } A'DC_1C_1' + \text{Area } C_1BB'C_1' - \text{Area } A'ABB'$$

$$= P_2V_2 + 2.3\, P_2V_2 \log\left(\frac{V_1}{V_2}\right) - P_1V_1$$

$$= 2.3\, P_1V_1 \log\left(\frac{V_1}{V_2}\right)$$

$$= 2.3\, P_1V_1 \log\left(\frac{P_2}{P_1}\right) \qquad \therefore P_1V_1 = P_2V_2$$

$$= 2.3\, P_1V_1 \log r \qquad \therefore T_1 = T_2$$

$$= 2.3\, mRT_1 \log r$$

Minimum work Required for two stage Reciprocating Air Compressor.

WKT workdone by two stage Reciprocating air compressor With Intercooling

$$W = \frac{n}{n-1} \times P_1 V_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} + \left(\frac{P_3}{P_2}\right)^{\frac{n-1}{n}} - 2 \right] \quad (1)$$

if P_1 & P_3 are fixed, Intercooling Pressure P_2 may be Obtained by differentiating above equation

$$\frac{dW}{dP_2} = 0$$

$$\frac{d}{dP_2}\left[\frac{n}{n-1} \times P_1 V_1 \left\{ \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} + \left(\frac{P_3}{P_2}\right)^{\frac{n-1}{n}} - 2 \right\}\right] = 0$$

Put $\frac{n-1}{n} = a$ as constant

$$\frac{d}{dP_2}\left[a P_1 V_1 \left\{ \left(\frac{P_2}{P_1}\right)^{a} + \left(\frac{P_3}{P_2}\right)^{a} - 2 \right\}\right] = 0$$

$$a P_1 V_1 \left[\left(\frac{1}{P_1}\right)^{a} a (P_2)^{a-1} + (P_3)^{a} (-a) (P_2)^{-a-1} \right] = 0$$

$$a (P_1)^{-a} (P_2)^{a-1} = a (P_3)^{a} (P_2)^{-a-1}$$

$$\frac{(P_2)^{a-1}}{(P_2)^{-a-1}} = \frac{(P_3)^{a}}{(P_1)^{-a}}$$

$$(P_2)^{a-1} (P_2)^{a+1} = (P_3)^{a} (P_1)^{a}$$

$$(P_2)^{2a} = (P_3 P_1)^{a} \qquad P_2^2 = P_3 P_1$$

$$P_2 = \sqrt{P_3 P_1}$$

in other words $\quad \frac{P_2}{P_1} = \frac{P_3}{P_2} = \left(\frac{P_3}{P_1}\right)^{1/2}$

Now substitute $\frac{P_3}{P_2} = \frac{P_2}{P_1}$ in equ (1)

$$W = \frac{n}{n-1} \times R V_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} + \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 2 \right]$$

$$= 2 \times \frac{n}{n-1} R V_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1 \right]$$

$$= 2 \times \frac{n}{n-1} P_1 V_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1 \right] \quad \text{——— (2)}$$

for two stage.

Now substitute $\frac{P_2}{P_1} = \left(\frac{P_3}{P_1}\right)^{1/2}$ in equ. (2)

$$W = 2 \times \frac{n}{n-1} \times P_1 V_1 \left[\left(\frac{P_3}{P_1}\right)^{\frac{n-1}{2n}} - 1 \right]$$

Similarly it can prove for three stage.

$$\frac{P_2}{P_1} = \frac{P_3}{P_2} = \frac{P_4}{P_3} = \left(\frac{P_4}{P_1}\right)^{1/3}$$

Minimum work required for three stage compressor

$$W = 3 \times \frac{n}{n-1} P_1 V_1 \left[\left(\frac{P_4}{P_1}\right)^{\frac{n-1}{3n}} - 1 \right]$$

$$W = 3 \times \frac{n}{n-1} mRT_1 \left[\left(\frac{P_4}{P_1}\right)^{\frac{n-1}{3n}} - 1 \right]$$

UNIT IV

Rotary Air Compressors:

Roots Blower

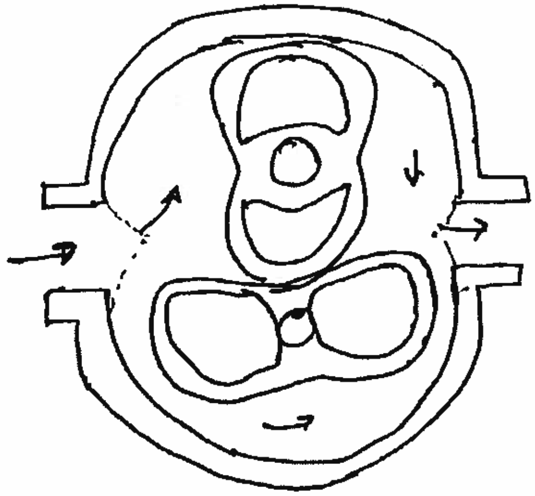
→ A root blower consist of two rotors with lobes rotating in a air tight casing. the casing has inlet and outlet on opposite sides

→ The lobes are so designed that they provide an air tight Joint at point of their contact.

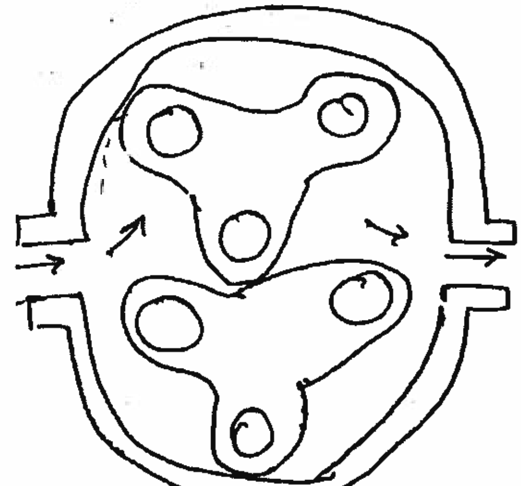
→ One of the rotor ~~rotates~~ is rotated by external means the other gear is driven by the first one

→ when the rotor rotates the air at atmosphere pressure is trapped in the pockets formed between rotors and casing. the rotary motion of the lobes delivers the entrapped air into the receiver

→ Thus more & more air delivered in to the receiver. this increases the pressure of air in the receiver. finally the air is used at required pressure from the receiver

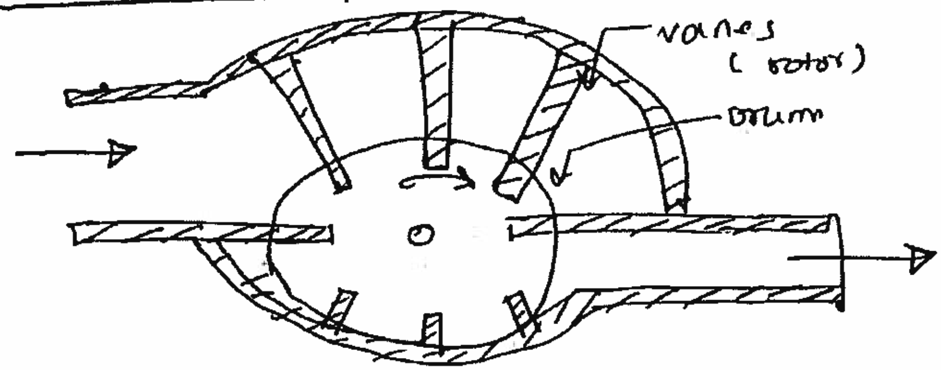


TWO LOBE



THREE LOBE

Vane Blower Compressor.



→ It consist of a disc rotating elentrically in an air tight casing with inlet and outlet ports, the disc has number of slots (generally 4 to 8) containing vanes.

→ When the rotor rotates the disc, the vane are pressed against casing due to centrifugal force and forms air tight pockets

→ The mechanical energy is provided to the disc from some external source. As the disc rotates, the air is trapped in the pockets formed between the vanes & casing.

→ First of all the rotary motion of the vanes compresses the air. When rotating vane uncovers the exit port, some air (under high pressure) flows back into the pocket in the same way.

Centrifugal Compressor.

→ It consist of a rotor or impeller, to which a number of curved vanes are fitted symmetrically.

The rotor rotates in an air tight volute casing with inlet and outlet points.

→ The casing for compressor is so designed that the kinetic energy of air is converted into pressure energy before it leaves the casing

→ The Mechanical energy is provided into the rotor from some external source. as the rotor rotates it sucks air through its eye, increase its pressure due to centrifugal force and force the air to flow over the diffuser.

The pressure of air is further increased during its flow over the diffuser.

→ finally the air at high pressure is delivered to the receiver. in this air enters the impeller radially and leaves the vane axially

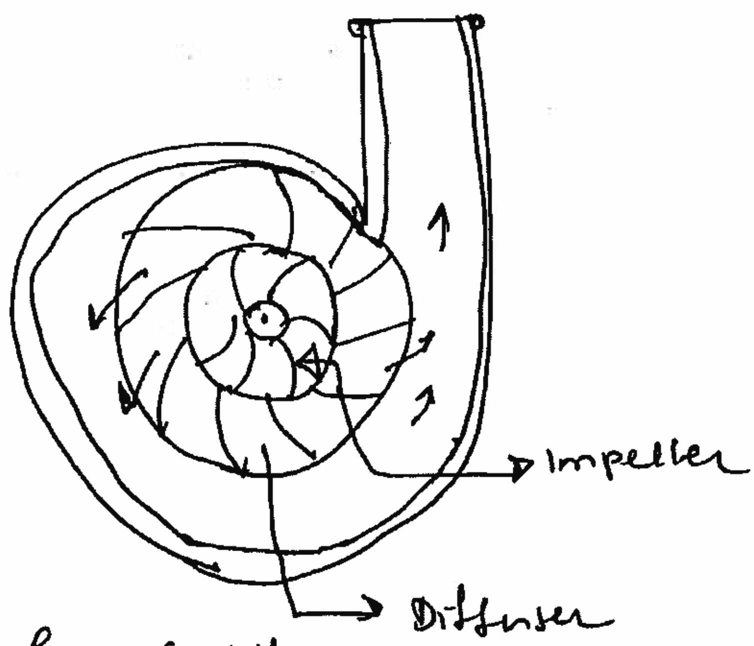


fig:- Centrifugal Compressor.

Workdone by Centrifugal Air Compressor.

$$W = 2.3\, P_1 V_1 \log\left(\frac{V_1}{V_2}\right) \quad \text{for isothermal}$$

$$= 2.3\, mRT_1 \log r \qquad r = \frac{V_1}{V_2} = \frac{P_2}{P_1}$$

$$W = \frac{n}{n-1} \times P_1 V_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right] \quad \text{for polytropic Compression}$$

$$= \frac{n}{n-1} \times mRT_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

$$W = \frac{\gamma}{\gamma-1} \times P_1 V_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right] \quad \text{for isentropic process}$$

Where P_1 → Initial Pressure of air

V_1 → Initial Volume of air

T_1 → Initial temperature of air

P_2, V_2, T_2 → Corresponding values for the final Condition

m → Mass of air Compressed per minute

n → polytropic Index

γ → Isentropic Index

C_p → Specific heat at Constant Pressure.

Axial Flow Compressors.

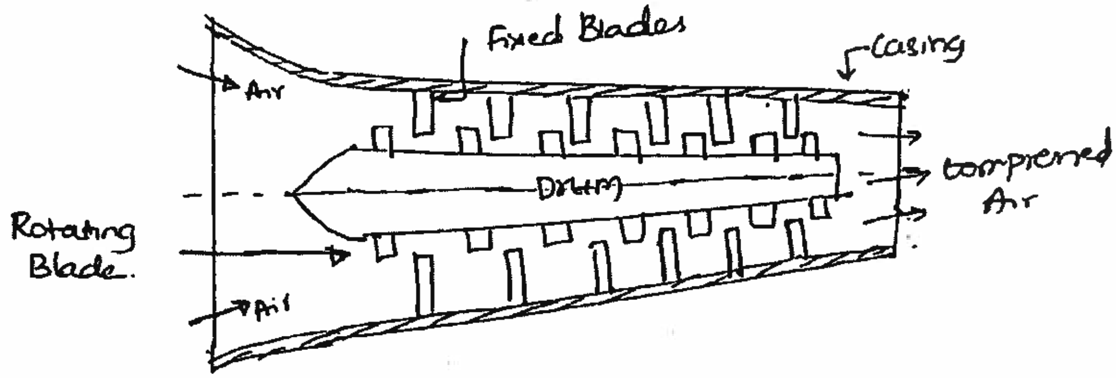


Fig: Axial flow compressor.

→ It consist of a number of rotating blade rows fixed to a rotating drum. the drum rotates inside an air tight casing to which are fixed stator blade rows,
the blades are made of aerofoil section to reduce the loss caused by turbulence and boundary separation

→ The Mechanical energy is provided to rotating shaft. which rotates the drum, the air enters from left side of the compressor.

→ As drum rotates the air flows through alternately arranged stator & rotor.

→ As the Air flows from one set of stator and rotor to another, it gets compressed.

Centrifugal Compressor	Axial flow Compressor
→ The flow of air is perpendicular to the axis of Compressor	→ The flow of air is parallel to the axis of Compressor
→ It has low manufacturing & running cost	→ It has high Manufacturing & running cost
→ It requires low starting torque	→ It requires high starting torque.
→ It is not suitable for Multistage	→ It is suitable for Multistage

Comparision of Reciprocating and Rotary Air Compressor

Reciprocating Air compressor	Rotary Air Compressor
→ Maximum delivery pressure may be as high as 1000 bar	→ The maximum delivery pressure is 10 bar only.
→ maximum free air discharge is about 300 m³/min.	The maximum free air discharge is about 300 m³/min.
→ They are suitable for low discharge of air at very high Pressure	They are suitable for large discharge of air at low Pressure.
→ Speed of air compressor is low	speed of air compressor is high
→ The air Supply is Intermittent	the air supply is continous
→ The size of air compressor is large for the given discharge	The size of air compressor is Small for the same discharge
→ The balancing is main problem	There is no balancing problem
→ Isothermal efficiency is used for all sort of calculations.	Isentropic efficiency is used for all sorts of calculations.

Estimate the minimum work required to compress 1 kg of air from 1 bar 27°C to 16 bar in two stages if the law of compress is $PV^{1.25}$ = constant and intercooling is perfect, take $R = 287\ J/kgK$

<u>Given Data</u>

$m = 1 kg. = \frac{1}{60}$ kg/sec

$P_1 = 1 bar = 1 \times 10^5 N/m^2$

$T_1 = 27° = 27 + 273 = 300K$

$P_3 = 16 bar$

$n = 1.25$

$R = 287\ J/kgK$.

For perfect intercooling intercooler pressure

$$P_2 = \sqrt{P_1 P_3} = \sqrt{1 \times 16} = 4 bar$$

Minimum work required to compress 1 kg of Air

$$W = 2 \times \frac{n}{n-1} P_1 V_1 \left[\left(\frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right]$$

$$= 2 \times \frac{n}{n-1} mRT_1 \left[\left(\frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right]$$

$$= 2 \times \frac{1.25}{1.25 - 1} \left(\frac{1}{60}\right) \times 287 \times 300 \left[\left(\frac{4}{1} \right)^{\frac{1.25-1}{1.25}} - 1 \right]$$

= 275090 ~~N-m~~ ~~[illegible]~~ KJ

(N·m [illegible])

Estimate the work done by a two stage reciprocating single acting air compressor to compress 2.8 m^3 of air per min at 1.05 bar and 10°c to find a final pressure of 35 bar. the intermediate receiver cools the air to 30°c and 5.6 bar pressure. For air take $n = 1.4$

Given Data

$V_1 = 2.8\, m^3/min$

$P_1 = 1.05\ bar = 1.05 \times 10^5\ N/m^2$

$T_1 = 10°C = 10 + 273 = 283\ K$

$P_3 = 3\,bar$

$T_3 = 30°C = 30 + 273 = 303 K.$

$P_2 = 5.6\ bar = 5.6 \times 10^5\ N/m^2$

$n = 1.4$

$$W = \frac{n}{n-1}\left[P_1V_1\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]\right\} + P_3V_2\left\{\left[\left(\frac{P_3}{P_2}\right)^{\frac{n-1}{n}} - 1\right]\right\} \quad \text{--- (1)}$$

to find V_2.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_3}$$

$$V_2 = \frac{P_1V_1T_3}{P_2T_1} = \frac{1.05\times10^5 \times 2.8 \times 303}{5.6\times10^5 \times 283} = 0.562\ m^3/min$$

Now equ (1)

$$WD = \frac{1.4}{1.4-1}\left[1.05\times10^5\times2.8\left\{\left(\frac{5.6}{1.05}\right)^{\frac{1.4-1}{1.4}} - 1\right\}\right] \cdot 5.6\times10^5\times0.562\left\{\left(\frac{35}{5.6}\right)^{\frac{1.4-1}{1.4}} - 1\right\}\right]$$

$= 13.9 \times 10^5\ Nm/min$

A single stage reciprocating air compressor is required to compress 1 kg of air from 1 bar to 4 bar. The initial temperature is 27°C. $R = 287\ J/kgK$. Compare the work requirement in the following cases.

i) isothermal compression ii) $PV^{1.2} = \text{constant}$.

iii) isentropic compression.

Given Data

$m = 1\ kg$

$P_1 = 1\ bar$

$P_2 = 4\ bar$

$T_1 = 27°C = 27 + 273 = 300 K$

$n = 1.2$.

01. isothermal compression

$$W = 2.3 P_1 V_1 \log \frac{P_2}{P_1} = 2.3 m R T_1 \log \frac{P_2}{P_1} \qquad P_1 V_1 = mRT_1$$

$$= 2.3 \times 1 \times 287 \times 300 \log\left(\frac{4}{1}\right) = 119230\ J$$

$$= 119.23\ kJ$$

02. Polytropic compression $PV^{1.2} = C$.

$$W = \frac{n}{n-1} \times m R T_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

$$= \frac{1.2}{1.2-1} \times 1 \times 287 \times 300 \left[\left(\frac{4}{1}\right)^{\frac{1.2-1}{1.2}} - 1\right] = 134320\ J$$

$$= 134.32\ kJ$$

03. Isentropic Compression

$$W = \frac{\gamma}{\gamma-1} \times m R T_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$$

$$= \frac{1.4}{1.4-1} \times 1 \times 287 \times 300 \left[\left(\frac{4}{1}\right)^{\frac{1.4-1}{1.4}} - 1\right]$$

$$= 146.63\ kJ$$

Problem: A single stage acting air compressor 30 cm bore and 40 cm stroke is running at a speed of 100 RPM. It takes in air at 1 bar and 20°C and compresses it to a pressure of 5 bar. Find the power required to drive it when the compression is i) isothermal ii) $PV^{1.2} = C$ and iii) Adiabatic. Also find isothermal efficiency for the cases iii) Neglect clearance volume

$N = 100 rpm$

$d = 30 cm = 0.3\ m$

$L = 40 cm = 0.4\ m$

$P_1 = 1 bar$

$T_1 = 20°c = 293 k$

$P_2 = 5 bar.$

Stroke, or swept volume

$$V_s = \frac{\pi}{4} d^2 L = \frac{\pi}{4} \times 0.3^2 \times 0.4 = 0.028\ m^3/cycle$$

Since clearance volume is neglected

$$V_1 = V_s = 0.028 \times \frac{100}{60} = 0.047\ m^3/s.$$

i) isothermal $PV = C$.

$$Power = P_1 V_1 \ln \frac{P_2}{P_1} = mRT_1 \ln \frac{P_2}{P_1}$$

to find m. $$m = \frac{P_1 V_1}{RT_1} = \frac{1 \times 10^2 \times 0.047}{0.287 \times 293} = 0.055\ kg/s$$

$$Power = mRT_1 \ln \frac{P_2}{P_1} = 0.055 \times 0.287 \times 293 \ln \frac{5}{1}$$

$$P = 7.56\ kW$$

ii) $PV^{1.2} = c$.

temperature after first stage

$$T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = 293 \left(\frac{5}{1}\right)^{\frac{1.2-1}{1.2}} = 383.14\ k$$

$$power = \frac{n}{n-1}(P_2V_2 - P_1V_1) = \frac{n}{n-1} mR (T_2 - T_1)$$

$$= \frac{1.2}{1.2} \times 0.055 \times 0.287 \times (383.14 - 293)$$

$$= 8.53\ kW$$

$$\text{isothermal efficiency} = \frac{\text{Isothermal Power}}{\text{Actual Power}}$$

$$= \frac{7.56}{8.53} = 0.8854$$

$$\eta_{isothermal} = 88.54\,\%$$

iii) Adiabatic $PV^{1.4} = C$

$$T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{1.4-1}{1.4}} = 293\left(\frac{5}{1}\right)^{\frac{1.4-1}{1.4}} = 464\ K$$

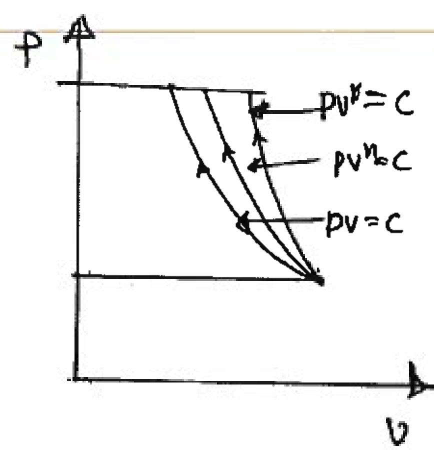
$$\text{Power} = \left[\frac{\gamma}{\gamma-1}\right] \times mR\,(T_2 - T_1)$$

$$= \frac{1.4}{1.4-1} \times 0.055 \times 0.287\,(467-293)$$

$$= 9.45\ kW$$

$$\eta_{isothermal} = \frac{7.56}{9.45} = 0.80$$

$$\eta_{iso} = 80\,\%$$



Problem: A single acting, single cylinder reciprocating air compressor has a cylinder diameter of 200mm and a stroke of 300mm. Air enters the cylinder at 1 bar. 27°C, It is then compressed polytropically to 8 bar according to the law $PV^{1.3}$ = Constant.
If the speed of the compressor is 250 rpm. Calculate the mass of air compressed per minute, and the power required in kW for driving the compressor

$d = 200mm = 0.2m$
$L = 300mm = 0.3m$
$P_1 = 1 bar = 100 kPa$
$P_2 = 8 bar$
$N = 250 rpm$
$T_1 = 27 + 273 = 300K$
$n = 1.3$

Find
01) m_a in kg/min
02) Power input to compressor.

* Neglect Clearance Volume
* Assume $R = 0.287$ kJ/kgK.

01) $m_a = \frac{P_1 V_1}{R T_1}$

to find V_1 the swept volume of cylinder per cycle

$$V_s = V_1 = \left(\frac{\pi}{4}\right) d^2 L$$
$$= \left(\frac{\pi}{4}\right) \times 0.2^2 \times 0.3$$
$$V_s = 9.424 \times 10^{-3} \, m^3$$

$$m_a = \frac{P_1 V_1}{R T_1} = \frac{100 \times 9.424 \times 10^{-3}}{0.287 \times 300} = 0.0109 \text{ kg/cycle}$$

the Mass flow rate of Air

$$m_a = \text{Mass of air} \times \frac{rpm}{min} = 0.0109 \times 250 = 2.74 \text{ kg/min}$$

Temperature of air after Compression

$$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = 300 \times \left(\frac{8}{1}\right)^{\frac{1.3-1}{1.3}}$$

$$T_2 = 484.75\ K$$

Work Input / Power Input to compressor.

$$P = \frac{n}{n-1} m_a R (T_2 - T_1)$$

$$= \frac{1.3}{1.3-1} \times 2.74 \times 0.287 \times (484.75 - 300)$$

$$= 629.56\ KJ/min$$

$$= 10.49\ kW$$

H-16

An ideal single stage, single acting air compressor has displacement volume of 14 litre and clearance volume of 0.7 litre. It receives the air at pressure of 7 bar. The compression is polytropic with an index of 1.3 and re-expansion is isentropic with an index 1.4. Calculate net indicated work of a cycle.

Given Data

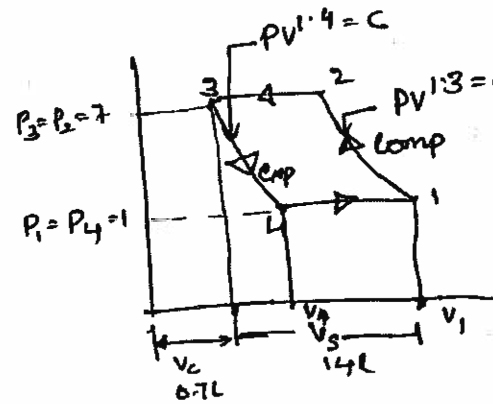
$P_1 = 1 \text{ bar} = 100 \text{ kPa}$, $P_2 = 7 \text{ bar} = 700 \text{ kPa}$

$V_s = 14$ litre

$V_c = 0.7$ litre

$n_c = 1.3$

$\gamma_e = 1.4$



$$WD = \frac{n_c}{n_c - 1} P_1 V_1 \left[\left(\frac{P_2}{P_1} \right)^{\frac{n_c - 1}{n_c}} - 1 \right] - \frac{\gamma_e}{\gamma_e - 1} P_1 V_4 \left[\left(\frac{P_2}{P_1} \right)^{\frac{\gamma_e - 1}{\gamma_e}} - 1 \right] \quad \text{—(1)}$$

total volume of cylinder.

→ $V_1 = V_s + V_c = 14 + 0.7 = 14.7 \text{ litre} = 0.0147 \, m^3$

→ the volume V_4 after re-expansion of compressed Air

$$V_4 = V_3 \left(\frac{P_2}{P_1} \right)^{\frac{1}{\gamma_e}} = 0.7 \left(\frac{7}{1} \right)^{\frac{1}{1.4}} = 2.81 \text{ litre}$$

$$= 0.00281 \, m^3$$

Now eqn (1) ⇒

$$= \frac{1.3}{1.3 - 1} \times 100 \times 0.0147 \times \left[\left(\frac{7}{1} \right)^{\frac{1.3-1}{1.3}} - 1 \right] - \frac{1.4}{1.4 - 1} \times 100 \times 0.00281 \times \left[\left(\frac{7}{1} \right)^{\frac{1.4-1}{1.4}} - 1 \right]$$

$$= 3.61 - 0.731$$

$$= 2.88 \text{ kJ/cycle}.$$

problem: The bore and stroke of a single acting air compressor are both 10cm. clearance volume 80cc (cubic centimeter). Index of compression and expansion 1·23, Suction pressure 1 bar, delivery pressure 7 bar Speed 400 RPM if the temperature at the beginning of compression is 22°c, find the amount of free air delivery with the compressor per minute at a pressure of 1·05 bar and temperature of 16°C.

$d = L = 10\,cm$

$V_c = 80\,cc = 0.00008\,m^3$

$P_1 = 1\,bar$

$T_1 = 22°C =\quad K$

$N = 400\,RPM$

$P_2 = 7\,bar$

$T_a = 16°C = \quad K$

$P_a = 1.05\,bar$

Mass of Air $= \frac{P_a V_a}{R T_a}$

to find V_a.

$$\eta_v = \frac{V_a}{V_s}$$

to find η_v volumetric efficiency

$$\eta_v = \frac{P_1 T_a}{P_a T_1}\left[1 + C - C\left(\frac{P_2}{P_1}\right)^{1/n}\right]$$

to find C

clearance ratio $= \frac{V_c}{V_s}$

to find Vs

$$V_s = \frac{\pi}{4} d^2 L$$

Swept volume $V_s = \frac{\pi}{4} d^2 L = \frac{\pi}{4} \times 0.1^2 \times 0.1 = 0.0007853\,m^3$

clearence ratio $C = \frac{V_c}{V_s} = \frac{0.00008}{0.0007853} = 0.1018$

volumetric efficiency $\eta_v = \frac{P_1 T_a}{P_a T_a}\left[1 + C - C\left(\frac{P_2}{P_1}\right)^{1/n}\right]$

$$= \frac{1 \times 289}{1.05 \times 295}\left[1 + 0.1018 - 0.1018\left(\frac{7}{1}\right)^{1/1.23}\right]$$

$$= 0.5659 = 56.59\%$$

$\eta_v = \frac{V_a}{V_s}$

Volume of free air $V_a = \eta_v \times V_s = 0.5659 \times 0.0007853$

$= 0.000444 \ m^3/cycle$

$= 0.000444 \times 400^{rpm}$

$= 0.17776 \ m^3/min.$

Mass of free Air $= \frac{P_a V_a}{R T_a} = \frac{1.05 \times 100 \times 0.1776}{0.287 \times 289}$

$= 0.225 \ kg/min$

A two stage single acting reciprocating air compressor draws in a air at a pressure of 1 bar and 17°C and compresses it to a pressure of 60 bar. after compression in the LP cylinder, the air cooled at constant pressure of 8 bar to a temperature of 37°C. the low pressure cylinder has a diameter of 150mm and both the cylinders have 200mm stroke, if the law of compression is $PV^{1.35} = C$ find the power of the compressor when it runs at 200rpm. Take R = 287 J/kgK

$P_1 = 1$ bar

$T_1 = 17°C + 273 = 290K$

$P_3 = 60$ bar

$P_2 = 8$ bar

$T_3 = 37 + 273 = 310K$

$D = 0.15m$

$L = 0.2m$

$n = 1.35$

$N = 200rpm.$

$R = 287 J/kgK$

$$P = \frac{W \times N_W}{60} = ?$$

$$W = \frac{n}{n-1}\left[P_1V_1\left\{\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right\} + P_2V_2\left\{\left(\frac{P_3}{P_2}\right)^{\frac{n-1}{n}} - 1\right\}\right] \quad \text{—(1)}$$

to find V_2

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \Rightarrow V_2 = \frac{P_1V_1T_3}{P_2T_1} \quad \text{—(2)}$$

$$V_1 = \frac{\pi}{4} \times D^2 \times L$$

$$= \frac{\pi}{4} \times 0.15^2 \times 0.2 = 0.0035m^3$$

Now (2)

$$V_2 = \frac{1 \times 10^5 \times 0.0035 \times 310}{8 \times 10^5 \times 290}$$

$$= 0.00047m^3$$

(1) →

$$W = \frac{1.35}{1.35-1}\left[1 \times 10^5 \times 0.0035\left\{\left(\frac{8}{1}\right)^{\frac{1.35-1}{1.35}} - 1\right\}\right] + \left[8 \times 10^5 \times 0.00047\left\{\left(\frac{60}{8}\right)^{\frac{1.35-1}{1.35}} - 1\right\}\right]$$

W = Nm

$N_W = N = 200$ bcz. single acting compressor

$$P = \frac{W \times N_W}{60} = \frac{1961 \times 200}{60} = 6540 \text{ kW}$$

A two stage compressor with perfect intercooling takes in air at 1 bar pressure and 27°c. the law of compression in both stages is $pV^{1.3} = C$. the compressed air is delivered at 10 bar from the HP cylinder to an air receiver. Calculate kg of air.

i). The Minimum work done

ii) Heat rejected in the intercooler

iii) The Minimum work done in a three stage compressor working under the same conditions.

Given Data

$P_1 = 1$ bar

$T_1 = 27°c$

$P_3 = 10$ bar

$m = 1kg$

$$P_1V_1 = mRT_1$$

$$V_1 = \frac{mRT_1}{P_1} = \frac{1 \times 0.287 \times 300}{1 \times 10^2}$$

$$V_1 = 0.861\ m^3$$

Minimum work done is

$$W = \frac{2n}{n-1} P_1V_1 \left[\left(\frac{P_3}{P_1}\right)^{\frac{n-1}{2n}} - 1 \right]$$

$$W = \frac{21.3}{1.3-1} \times 1 \times 10^2 \times 0.861$$

$$W = 227\ KJ/kg \text{ of air}$$

For perfect intercooling

$$P_2 = \sqrt{P_1P_3} = \sqrt{1 \times 10} = 3.162 \text{ bar}$$

$$T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = 300 \left(\frac{3.162}{1}\right)^{\frac{1.3-1}{13}}$$

$$T_2 = 391.28\ K$$

Heat rejected in Intercooler $= mC_p(T_2 - T_1)$

$= 1 \times 1.005(391.28 - 300)$

$= 91.74$ KJ/kg of air

A two stage reciprocating compressor delivers 150 m^3/hr of free air measured at 1.03 bar and 15°C. the final pressure is 18 bar. the pressure and temperature of the air in LP cylinder before compression is 1 bar and 30°C the diameter of LP cylinder is twice that of HP cylinder and air enters the HP cylinder at 40°C if compression follows the law $PV^{1.22} = C$ determine

i) Intermediate pressure and power required if the intercooling is imperfect

ii) Ratio of cylinder diameters and minimum power required for perfect intercooling.

$$V_a = 150\ m^3/s = \frac{150}{60 \times 60} = 0.02916\ m^3/sec.$$

$P_1 = 1$ bar, $T_1 = 30°C$

$P_a = 1.03$ bar, $T_a = 15°C$

$P_3 = 18$ bar, $T_2 = 40°C$ Neglect the effect of clearance.

i) Imperfect intercooling:-

$$P_1 V_1^{1.22} = P_2 V_2^{1.22}$$

$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{1.22} = \left[\frac{\left(\frac{\pi}{4} \times d_{LP}^2 \times L\right)}{\left(\frac{\pi}{4} \times d_{HP}^2 \times L\right)}\right]^{1.22}$$

workdone in a 3- Stage compressor working between same pressure limits.

$$W = \frac{3n}{n-1} P_1 V_1 \left[\left(\frac{P_3}{P_1} \right)^{\frac{n-1}{3n}} - 1 \right]$$

$$= \frac{3 \times 1.3}{1.3-1} \times 1 \times 100 \times 0.861 \left[\left(\frac{10}{1} \right)^{\frac{1.3-1}{3 \times 1.3}} - 1 \right]$$

$W = 216.89$ KJ/kg of Air

UNIT V

UNIT V REFRIGERATION

Refrigeration:-

Refrigeration is the process of providing and Maintaining temperatures of the system below that of the Surrounding atmosphere.

Unit of Refrigeration.

The common unit used in the feild of refrigeration is known as Ton of refrigeration

A ton of refrigeration is defined as the quantity of heat required to be removed to produce one tone (1000kg) of ice within 24 hours when the initial Condition of water is zero degree centigrade

(latent heat of ice in KJ/kg)

$$\text{Ton of Refrigeration} = \frac{1000 \times 335}{24 \times 3600} = 3.5 \text{ KJ/s}$$

- Consider a refrigerator of T ton capacity

$$\text{Refrigeration Capacity} = 3.5\,T \text{ kJ/s}$$

$$\text{Heat removed from refrigerator} = \text{Refrigeration effect KJ/kg} = RE \text{ (KJ/kg)}$$

$$\text{Mass flow rate} = \frac{\text{Refrigeration Capacity}}{RE} = \frac{3.5T}{RE}$$

Power of the compressor = work/kg of refrigerant x Mass flow rate

AIR REFRIGERATION SYSTEM

In air Refrigeration System, air is used as the refrigerant which always remains in the gaseous phase. the heat removed Consists only of censible heat and as result, the Co-efficient of performance (COP) is low.

Air Refrigeration system working on Bell-coleman cycle (Reversed Brayton cycle)

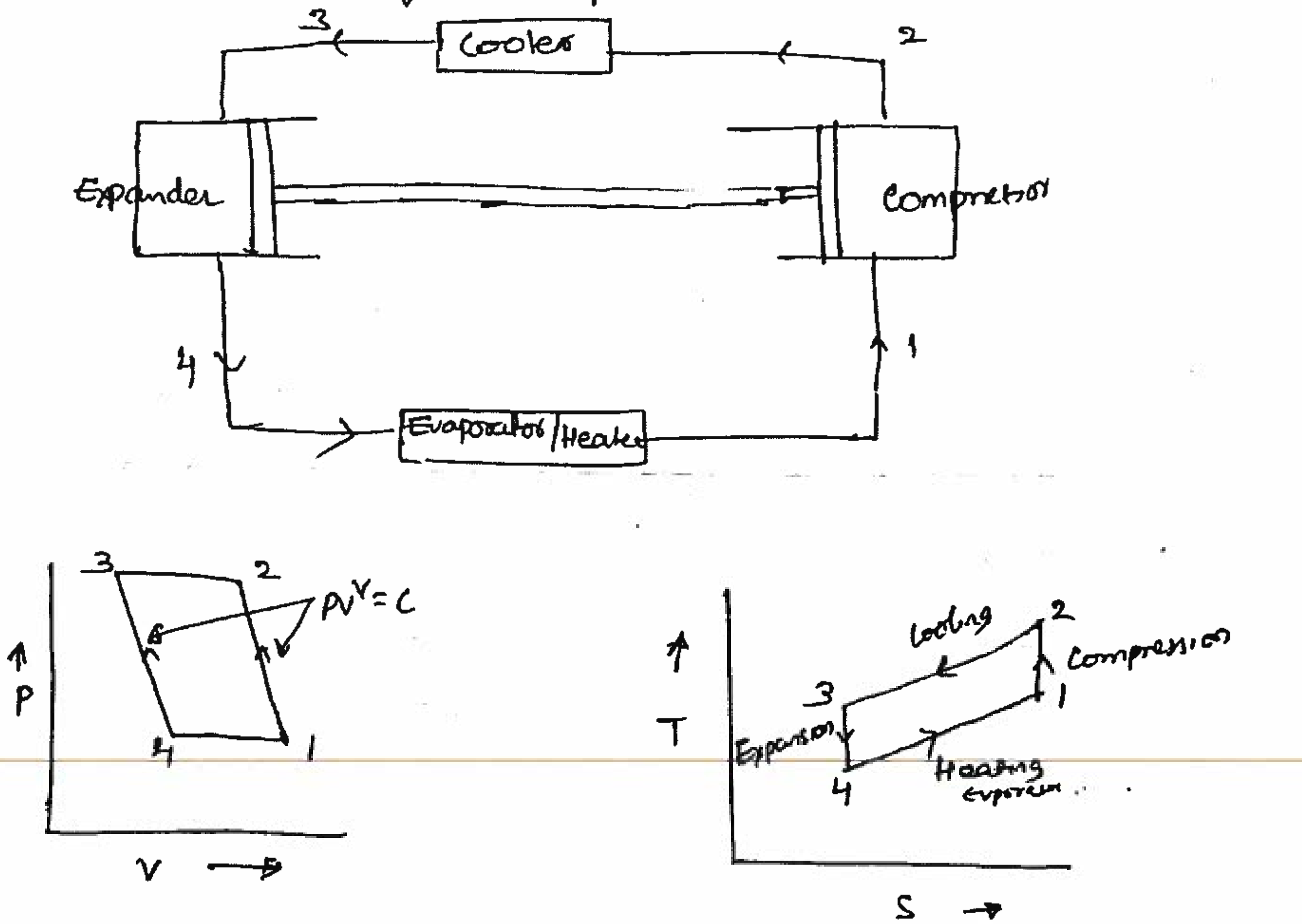


fig: Air Refrigeration System.

Process 1-2:

The air leaving the evaporator enters a compressor where it is compressed isentropically, to high pressure and temperature.

Process 2-3:

The high pressure and temperature air then enters a cooler where it is cooled at constant pressure to a lower temperature

Process 3-4: This high pressure, lower temperature air is then expanded in an expander to low pressure and temperature in a isentropic manner.

At point 4, the temperature of air will be lowest

Process 4-1:- The low temperature air is then passed through the heater coils where it absorb heat from the space to be cooled namely the refrigerator and the air gets heated back to the initial temperature, but in the process it cools the refrigerator. and the cycle repeats.

Expression for Co-efficient of Performance when compression and expansion are isentropic

RE = Refrigeration effect = heat removed from refrigerator.

$$= C_p (T_1 - T_4) \ KJ/kg$$

$$\text{Work Input} = W_C - W_E = \frac{\gamma}{\gamma-1}\left[P_2V_2 - P_1V_1\right] - \frac{\gamma}{\gamma-1}\left[P_3V_3 - P_4V_4\right]$$

$$= \frac{\gamma}{\gamma-1} R[T_2 - T_1] - R\,[T_3 - T_4]$$

$$W_{net} = \frac{\gamma R}{\gamma-1}\left\{(T_2 - T_1) - (T_3 - T_4)\right\} \quad (1)$$

$$\text{but } \frac{C_p}{C_v} = \gamma \ , \quad C_v = \frac{C_p}{\gamma}$$

WKT

$$C_p - C_v = R$$

$$C_p - \frac{C_p}{\gamma} = R$$

$$C_p\left[1 - \frac{1}{\gamma}\right] = R$$

$$C_p \frac{(\gamma-1)}{\gamma} = R$$

$$\frac{\gamma R}{\gamma-1} = C_p$$

Now equ ①

$$W_{net} = C_p\left[(T_2 - T_1) - (T_3 - T_4)\right]$$

$$COP = \frac{RE}{Work} = \frac{C_p (T_1 - T_4)}{C_p\left[(T_2 - T_1) - (T_3 - T_4)\right]}$$

$$COP = \frac{T_1 - T_4}{(T_2 - T_3) - (T_3 - T_4)} = \frac{1}{\quad} \quad \text{—②}$$

Process 1-2 : is isentropic

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = r^{\frac{\gamma-1}{\gamma}} \quad \text{—ⓐ}$$

Process 3-4 : is isentropic

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = r^{\frac{\gamma-1}{\gamma}} \quad \text{—ⓑ}$$

From equ ⓐ & ⓑ

$$\frac{T_2}{T_1} = \frac{T_3}{T_4}$$

$$\frac{T_2}{T_3} = \frac{T_1}{T_4}$$

$$\therefore \frac{T_2}{T_3} - 1 = \frac{T_1}{T_4} - 1$$

$$\frac{T_2 - T_3}{T_3} = \frac{T_1 - T_4}{T_4}$$

$$\frac{T_2 - T_3}{T_1 - T_4} = \frac{T_3}{T_4} \quad \text{— (c)}$$

Now. (c) & (2)

$$COP = \frac{1}{\frac{T_3}{T_4} - 1} = \frac{1}{r^{\frac{\gamma-1}{\gamma}} - 1}$$

$$COP = \frac{T_4}{T_3 - T_4}$$

Advantages of Air Refrigeration system

→ Air is cheap, easily Available

→ It is non flameable

→ for a given capacity, weight of air refrigeration system is less compared to other system hence it is widely used in aircraft cooling

Disadvantages

→ Since heat is removed by air consists of sensible heat, weight of air required is high

→ COP of the system is low compared to other systems

The following data refers to an air refrigerator system using air and working on Bell Coleman cycle

i. Pressure limits 4.5 bar and 1 bar

ii. Temperature of air entering the compressor and expander are 268K and 300K respectively.

What is the COP if the compression and expansion follow $pv^{1.2} = C$ and $pv^{1.4}$... & find the refrigeration effect in tons, if air is circulated at the rate of 10 kg/min.

$P_1 = 1$ bar

$P_2 = 4$ bar

$T_1 = 268K$.

$T_3 = 300K$

$RE = C_p(T_1 - T_4) = ?$

$COP = \frac{RE}{work} = ?$

$$work = \left(\frac{n}{n-1}\right)\left(\frac{\gamma}{\gamma-1}\right) C_p[(T_2 - T_1) - (T_3 - T_4)]$$

find T_2 & T_4.

$$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = 268\left(\frac{4.5}{1}\right)^{\frac{1.2-1}{1.2}} = 344.35\,k.$$

$$T_4 = T_3\left(\frac{P_3}{P_4}\right)^{\frac{k-1}{k}} = 300\left(\frac{1}{4.5}\right)^{\frac{1.2-1}{1.2}} = 233.48\,k$$

$$\text{Refrigeration effect} = C_p(T_1 - T_4)$$
$$= 1.005\ (268 - 233.48)$$
$$= 34.692\ kJ/kg$$

$$work = \left[\frac{1.2}{1.2-1}\right]\left[\frac{1.4-1}{1.4}\right] \times 1.005[(344.35 - 268) - (300 - 233.48)]$$
$$= 16.93\ kJ/kg.$$

$$COP = \frac{RE}{Work} = \frac{34.692}{16.93} = 2.048$$

Refrigeration Capacity = RE × mass of Air

$= 34.692 \times \frac{10}{60}$

$= 5.78$ kJ/s

$= \frac{5.78}{3.5} = 1.652$ tons of refrigerant

- An Air Refrigeration System works on an open air cycle is required to provide 20 tons of refrigeration with cooler Pressure of 12.5 bar and refrigerator pressure of 1.05 bar. the temperature of the air leaving the cooler is 20°C and leaving the cold chamber is −1°C. Assuming isentropic compression and expansion and neglecting clearance. find

a). weight of air circulated/min

b) COP of the system

c) Power required per ton refrigeration.

$P_1 = 1.05$ bar $\quad P_2 = 12.5$ bar

$T_1 = -1°C \quad T_3 = 20°C$

$$T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = 272\,(12.5)^{\frac{1.4-1}{1.4}} = 559.72\ K.$$

$$T_4 = T_3 \left(\frac{P_4}{P_3}\right)^{\frac{\gamma-1}{\gamma}} = 293 \left(\frac{1}{12.5}\right)^{\frac{1.4-1}{1.4}} = 142.28\ K$$

$$RE = C_p(T_1 - T_4) = 1.005\,(272 - 142.38)$$

$$= 130.26\ kJ/kg$$

$$work = C_p\{(T_2 - T_1) - (T_3 - T_4)\}$$

$$= 1.005\,[(559.72 - 272) - (293 - 142.38)]$$

$$= 137.7\ kJ/kg.$$

$$COP = \frac{RE}{work} = \frac{130.26}{137.7} = 0.945$$

Refrigeration capacity = 20 tons

$= 20 \times 3.5$

$= 70$ kJ/s

Weight of air circulated $= \dfrac{\text{Refrigeration Capacity}}{RE}$

$$= \frac{70}{130.26} = 0.537 \text{ kg/s}$$

Power = Work x weight of air/sec

$$= 137.7 \times 0.537 = 73.99 \text{ kW}$$

Power/ton of refrigeration $= \dfrac{73.99}{20}$

$$= 3.699 \text{ kW/ton of refrigeration}$$

Vapour Compression Refrigeration System.

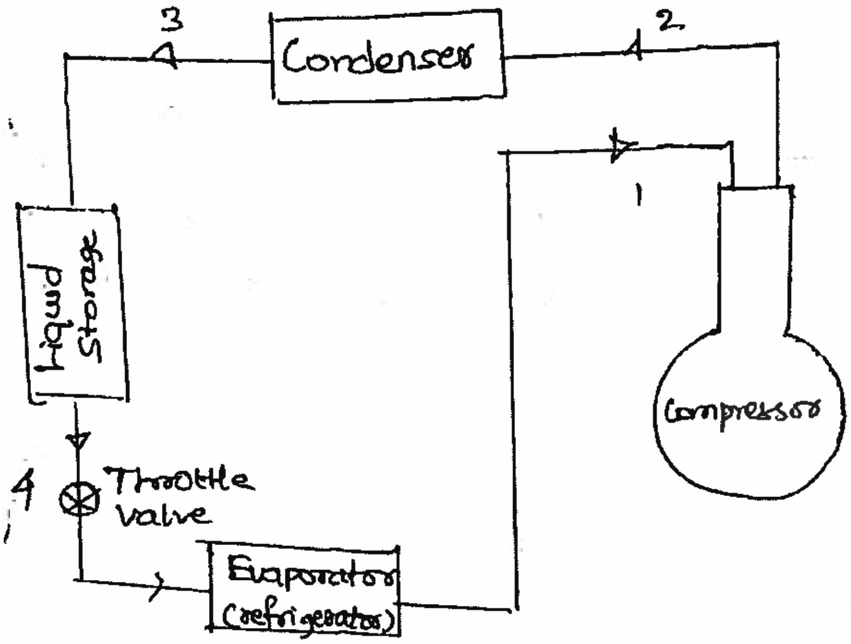
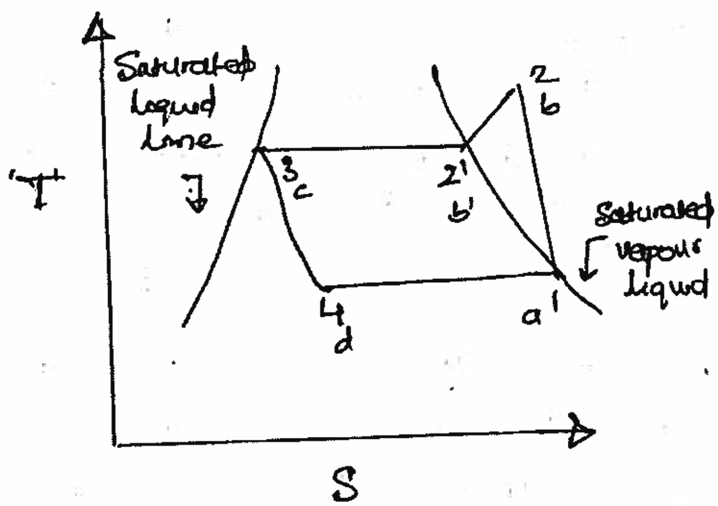
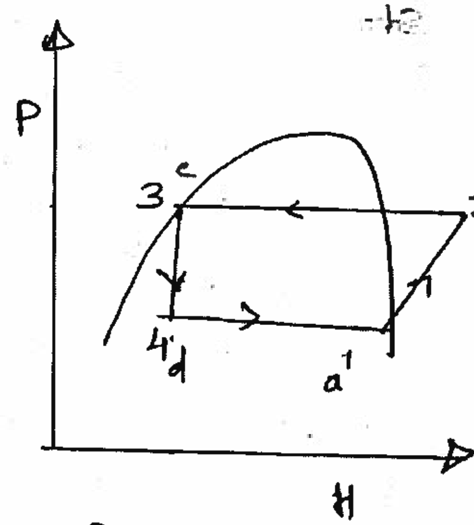


fig: Schematic Diagram of Vapour Compression Refrigeration System



TS Diagram



PH Diagram

In Vapour Compression System, the refrigerants used are ammonia, carbon dioxide, freons, etc.
the refrigerant alternately undergoes condensation and evaporation during the cycle, when refrigerant enters the evaporator it will be in liquid state and by

absorbing latent it becomes vapour. thus the COP of this system is always much higher than air refrigeration system.

Process 1-2:

The vapour refrigerant entering the compressor is compressed to high pressure and temperature in a isentropic manner.

Process 2-3:

The high pressure and temperature vapour then enters a condenser where the temperature of the vapour first drops to saturation temperature, and subsequently the vapour refrigerant condenses to liquid state.

Process 3-4:

This liquid refrigerant is collected in the liquid storage tank and later on its expanded to low pressure and temperature by passing it through the throttle valve. At point d we have low temperature liquid refrigerant with small amount of vapour.

Process 4-1:

This low temperature liquid then enters the evaporator where it absorbs heat from the space to be cooled namely the refrigerator and become vapour.

Refrigeration effect = $H_a - H_d$

(R.E) Refrigeration effect $= H_a - H_c$. (or $H_1 - H_3$)

Work done $= H_b - H_a$ (or $H_2 - H_1$)

$$COP = \frac{RE}{Work} = \frac{H_a - H_c}{H_b - H_a} \quad \left(\text{or} = \frac{H_1 - H_3}{H_2 - H_1} \right)$$

Effect of under cooling the liquid Refrigerant and Superheating the vapour Refrigerant

01]

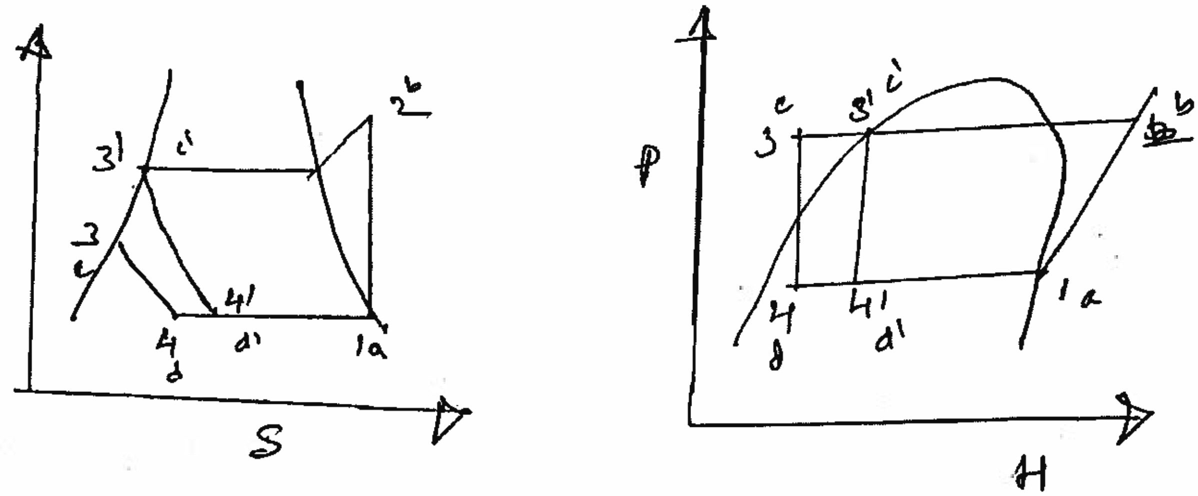


fig: effect of under cooling the liquid

→ cooling of liquid refrigerant below the saturation temperature is known as undercooling or Subcooling line (3'-3)

→ Refrigeration effect with undercooling is Ha − Hd. refrigeration effect without under cooling is Ha − Hd' since (Ha − Hd) > Ha − Hd' under cooling result in increase in refrigeration effect. Since the work input remains same, the COP increases

02]

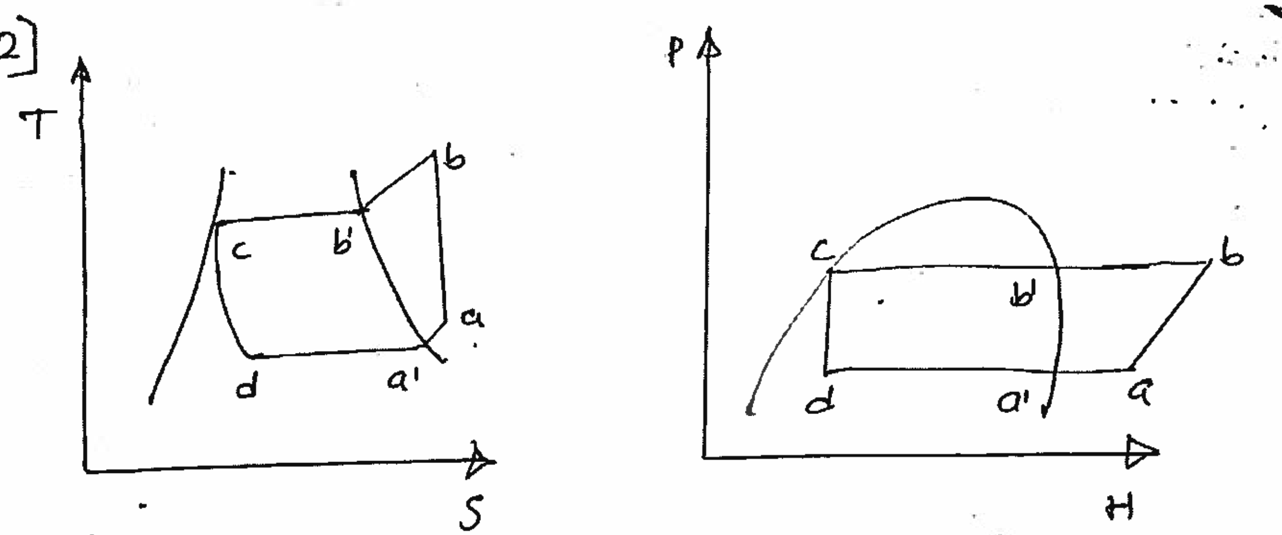


fig:- Effect of Superheating the Vapour

- When the temperature of vapour leaving the evaporator is more than the saturation temperature, then the vapour is said to be Superheated (line a'-a)
  Superheating also increases the refrigeration effect
- However there is a corresponding increase in work input and as result the effect on COP is negligible
  However Superheating ensures the presence of 100% vapour during compression which is always prefered

Advantages and Disadvantages of vapour Compression System over air refrigeration System

Advantages:

- Since the working cycle approaches closer to Carnot Cycle the COP is quite high.
- Operational cost of VCS is Just about 1/4th of Air refrigeration system
- Since heat removed consist of latent heat of vapour amount of liquid circulated is less as result size of evaporator is small

Disadvantages

- Initial investment High
- Prevention of leakage of refrigerant is major problem.

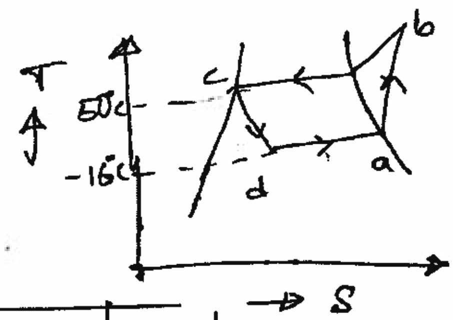
An NH_3 refrigerator operates between evaporating and condensing temperatures of $-16°c$ and $50°c$ respectively. the vapour is dry and saturated at the compressor inlet, the compression process is isentropic and there is no under cooling of the condensate. calculate.

i. The refrigerating effect/kg

ii The mass flow and power input per ton of refrigeration

iii COP of the refrigerator.

Take Cp of vapour refrigerant as 3.0013 KJ/kgK.



T	Pressure kPa	Enthalpy			Entropy			Cp
		h_f	h_{fg}	h_g	S_f	S_{fg}	S_g	
50 (b)	2032.62	421.7	1052	1473.7	1.5135	3.2561	4.7696	3.0013
-16 (a)	226.45	107.8	1316.5	1424.4	0.4343	5.1207	5.5600	

to find the temperature of the vapour at b

Entropy at b = entropy at a.

$$S_{g_b} + C_p \ln \frac{T_b}{T_b'} = S_{g_a}$$ $T_b' = 50+273 = 323$

$$4.7696 + 3.0013 \ln \frac{T_b}{323} = 5.5600$$

$$T_b = 420.31\ K.$$

$$H_b = h_{g_b} + C_p (T_b - T_b') = 1473.7 + 3.0013(420.31 - 323)$$

$$H_b = 420.31\ K.$$

$$H_a = h_{g_a} = 1424.4\ KJ/kg$$

$$H_c = h_{f_c} = 421.7\ KJ/kg$$

$RE = H_a - H_c = 1424.4 - 421.7 = 1002.7$ kJ/kg

$work = H_b - H_a = 1765.75 - 1424.4 = 341.35$ kJ/kg

$$COP = \frac{RE}{work} = \frac{1002.7}{341.25} = 2.93$$

Refrigeration Capacity = 1 ton = 3.5 kJ/s.

$$\text{Mass flow rate} = \frac{\text{Refrigeration Capacity}}{RE}$$

$$= \frac{3.5}{1002.7} = 0.00349 \text{ kg/s}$$

Power = work/kg × mass flow rate

$= 341.35 \times 0.00349$

$= 1.19$ kW/ton of refrigeration.

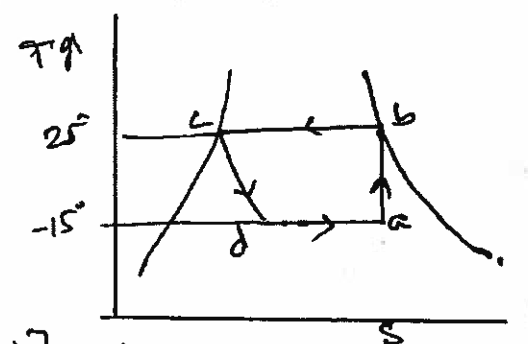
28 tons of ice from and at 0°C is produced per day from water at 20°C in an NH_3 refrigerator. The temperature range in the compressor is from 25°C to -15°C. The vapour is dry and saturated at the end of compression and expansion valve is used. Assuming a COP of 62% of theoretical, calculate the power required to drive the compressor. Take latent heat of ice = 335 kJ/kg

Properties of Refrigerant

Temp °C	Enthalpy kJ/kg		Entropy kJ/kg°C	
	Liquid h_f	Vapour h_f	Liquid S_f	Vapour S_f
25	100.04	1319.12	0.3473	4.4852
-15	-54.56	1304.99	-2.1338	5.0585

To find the condition of vapour at point A

Entropy at a = entropy at b



a-l
g-v

$$S_{f_a} + x_a S_{fg_a} = S_{g_b}$$

$$S_{fg_a} = (S_{f_v} - S_{f_l})$$

$$-2.1338 + x_a[5.0585 - (2.1338)] = 4.4852$$

$$x_a = 0.92$$

$$H_a = h_{f_a} + x_a h_{fg_a} = h_{f_a} + x_a(h_{fg} - h_{f_a})$$

$$= -54.56 + 0.92(1304.99 - (-54.56))$$

$$H_a = 1196.26 \text{ kJ/kg}$$

$$H_b = h_{fg} = 1319.22 \text{ kJ/kg}$$

$$H_c = h_{f_a} = 100.04 \text{ kJ/kg}$$

Refrigeration effect $RE = H_a - H_c$

$$= 1096.18 \text{ kJ/kg}$$

work $= H_b - H_a$

$$= 122.96 \text{ kJ/kg}$$

Ideal COP $= \frac{RE}{work} = \frac{1096.18}{122.96} = 8.91$

Actual COP $= 0.62 \times 8.91 = 5.52$

Heat extracted/kg of ice $= C_p(20-0) +$ latent heat of fusion of ice

$= 4.187(20) + 335$

$= 418.74$ kJ/kg

Mass of ice produced/sec $= \frac{28 \times 1000}{3600 \times 24} = 0.324$ kg/s

actual heat extracted/sec $= 4187.74 \times 0.324$

$= 135.7$ kJ/s

Actual COP $= \frac{\text{Actual heat extracted/sec}}{\text{Actual work/sec}}$

$= \frac{135.7}{5.525} = 24.58$

or power to drive compressor $= 24.58$ kW

7.5.5 Different Conditions During Compression

i) Wet Compression

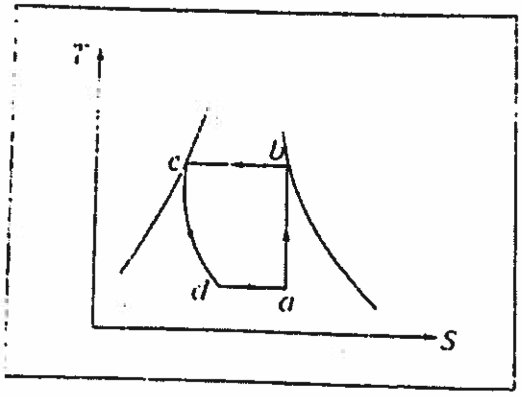


Fig 7.18

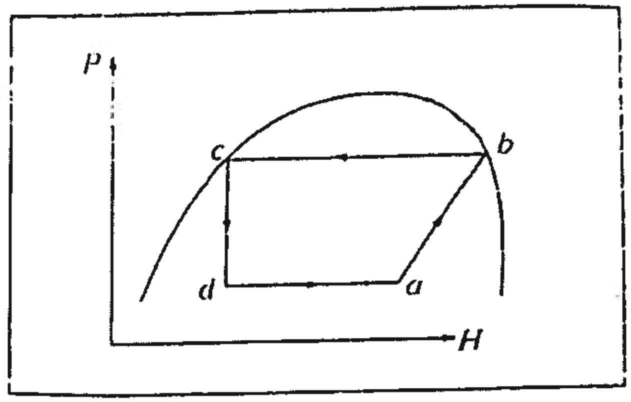


Fig 7.19

Here the vapour remains as wet vapour throughout compression process (Fig. 7.18 & 7.19). In other word even at the end of compression the vapour will still be wet. Generally this is not desirable.

ii) Dry Compression

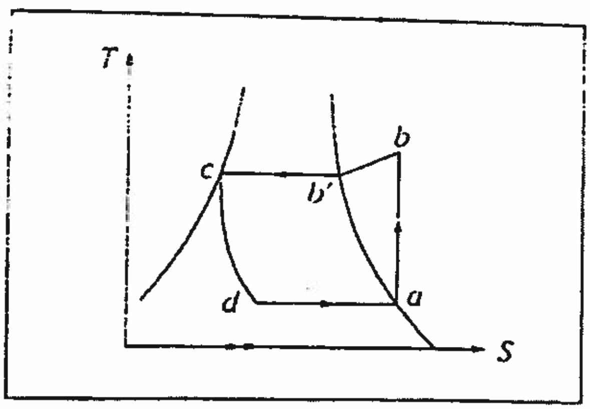


Fig. 7.20

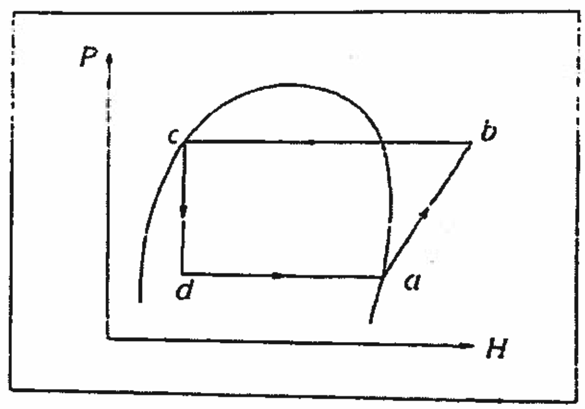


Fig 7.21

Here the vapour entering the compressor will be dry and saturated (Fig. 7.20 & 7.21). After compression, the vapour will be in the superheated state.

iii) Superheating

When the load on the refrigerator is more, the condition of refrigerant as it comes out of the evaporator will be superheated. Thus throughout the compression process, the vapour will be in the superheated state (Fig. 7.22 & 7.23).

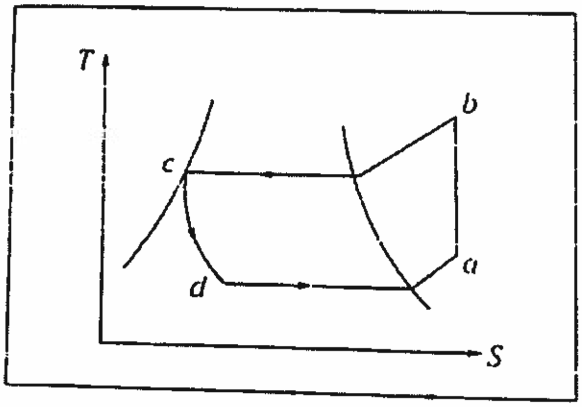


Fig 7.22

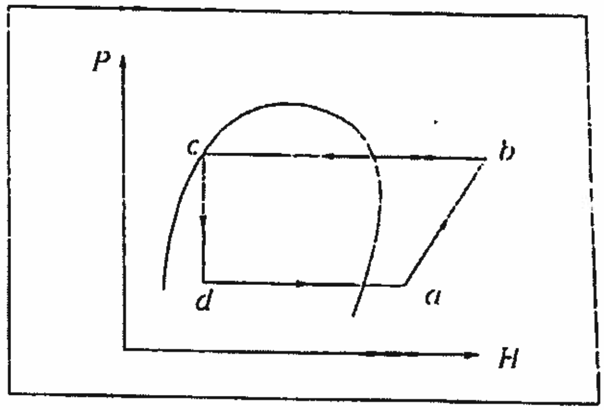


Fig. 7.23

iv) Under Cooling

During condensation in the condenser, sometimes the temperature of the liquid will drop down below the saturation temperature. (Fig. 7.24 & 7.25). In such a case, the liquid is said to have been under cooled. Under cooling always increases the refrigeration effect as well as C.O.P.

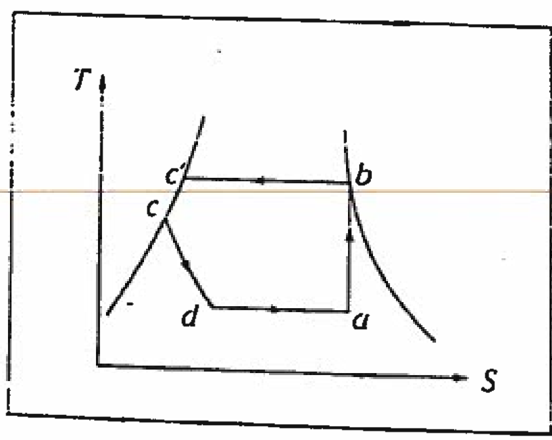


Fig. 7.24

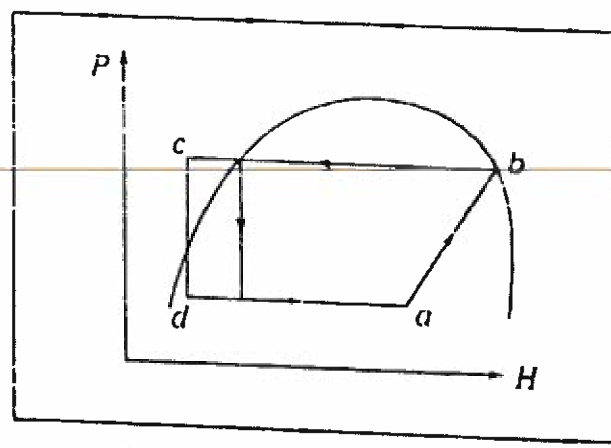


Fig.7.25

Ex

7.5.6 Refrigerant

A refrigerant is a fluid in a refrigerating system that by its evaporating takes the heat of the cooling coils and gives up heat by condensing the condenser. The common refrigerants with their chemical formula and molecular weights are as follows:

	Refrigerant Common name	Chemical formula	Molecular weight	Chemical name
1.	Ammonia	NH_3	17.03	Ammonia
2.	Freon –11	CCl_3F	137.37	Trichloro mono fluro methane
3.	Freon –12	CCl_2F_2	120.91	Dicloro difluro methane
4.	Freon –22	$CHClF_2$	86.47	Monochloro difluro methane
5.	Freon –113	$CCl_3F\text{-}CClF_2$	187.39	Trichloro trifluoro methane
6.	Methyl Chloride	CH_3Cl	50.48	Methyl chloride
7.	Sulphur dioxide	SO_2	64.06	Sulphur dioxide

Ammonia

Ammonia is one of the oldest and most widely used refrigerant. It is highly toxic and inflammable. It has a boiling point of $-33°C$ and a liquid specific gravity of 0.684 at atmospheric pressure. Its greatest application has been in large industrial and commercial reciprocating compression system where high toxicity is secondary. For industrial applications, it has been found valuable because of its low volumetric displacement, low cost, low weight of liquid circulated per ton of refrigeration, and high efficiency. It is also widely used as the refrigerant in absorption system.

Freon refrigerants

The entire group is clear and water white in colour and has a somewhat the ethereal odour similar to carbon tetrachloride. They are all nonflammable, and for all practical purposes nontoxic. Freon-11 is widely used for centrifugal refrigeration. Freon-12 is generally applied to reciprocating compressor. Freon-13 and 14 are intended for very low temperature usage.

Methyl chloride

Methyl chloride is a colourless liquid with a faint, sweet, nonirritating odour. It has a boiling point of −23°C and liquid specific gravity of 1.002. It is to a certain degree both inflammable and toxic. Methyl chloride has been used in domestic units with both reciprocating and rotary compressors and in commercial units with reciprocating compressors upto approximately 10 tons capacity.

Sulphur dioxide

Sulphur dioxide is a colourless gas or liquid, and is extremely toxic and has a pungent irritating odour. It is non-explosive and non-flammable and has a boiling point of −11°C and a liquid specific gravity of 1.36. It is widely used as a refrigerant in domestic systems. It has also been used to a considerable extent in small-tonnage commercial machines.

7.5.7 Identifying Refrigerants by Number

The present practice in the refrigeration industry is to identify refrigerants by numbers. The identifying system of numbering has been standardized by the American Society of Heating, refrigerating and Air conditioning engineers (ASHRAE), some refrigerants in common use are:

Refrigeration	Name and Chemical Formula	
R-11	Trichloromonofluoromethane	CCl3F
R-12	Dichlorodifluoromethane	CCl2F2
R-22	Monochlorodifluoromethane	CHClF2
R-717	Ammonia	NH3
R-114 (R40)	Methyl Chloride	CH3Cl
R-500	Azeotropic mixture of 73.8% (R–12) and 26.2%	(R–152a)
R–502	Azeotropic mixture of 48.8% R–22 and 51.2%	(R–115)
R–764	Sulphur Dioxide	SO_2

7.5.8 Properties of Refrigerants

The properties of refrigerants of importance in engineering are:

1) **Toxicity:** It is obviously desirable that the refrigerants have little effect on people.

2) **Inflammability:** Although refrigerants are entirely sealed from the atmosphere, leaks are bound to develop. If the refrigerant is inflammable and the system is located where ignition of the refrigerant may occur, a great hazard is involved. Inflammable should not be used except on small systems unless an operating engineer is present at all times.

3) **Chemical activity:** Refrigerants in their pure state must be chemically inert to the materials from which the system is made. In the absence of water, it is also desirable that they may be chemically inert.

4) **Effect on refrigerated produce:** The refrigerant should not have any effect on refrigerated produce. Ammonia readily reacts with fruits, vegetables etc. In small concentrations the effect of NH3 is mild, but excessive exposure will result in rot. Sulphur dioxide is not dangerous to foods. Methyl chloride vapours do not harm fruits, flowers and other household articles. Methyl chloride may flavour foods to a very slight extent, if they are sufficiently exposed to the vapours however, there is no danger in eating foods that have been exposed to methyl chloride vapours. Freons 11, 12, 22 and 113 are soluble in water only to a very limited extent. The vapours have therefore no effect on dairy products, meat and vegetables. They have, further no effect upon flowers, plant life, or the colour and structure of textiles and furs.

5) **Odour:** Odour may be an advantage or a disadvantage to a refrigerant. Leak can be easily detected if the refrigerant has a distinct odour. On the other hand, if a leak occurs in a refrigerated space, it may flavour the product and render it unusable. Refrigerants having irritating odours may cause panic where numerous people are involved and should not be used under such conditions.

6) **Oil solvent properties:** A refrigerant that is highly insoluble in oil offers fewer problems than one that is highly insoluble in oils, however the compressor will be better lubricated when oil solvent refrigerants are used. Ammonia is nearly insoluble in mineral lubricating oils. Freon–22 and sulphur dioxide have a limited solubility in mineral lubricating oil. The freons 11, 12 and 113 and methyl chloride are highly soluble in mineral oil.

7) **Pressure-volume-temperature characteristics:** The critical temperature and pressure of a refrigerant is the temperature and pressure at which the liquid and vapour have identical properties. A suitable refrigerant will have a critical temperature and pressure well above the condensing temperature and pressure of the refrigerating system. The freezing point shall be well below the lowest evaporating temperature at which the system operates.

8) **Power required per ton of refrigerant:** The theoretical power required per ton of refrigerant is nearly the same for all common refrigerants under a given set of temperature and operating conditions.

9) **Cost:** The cost of the entire system when using various refrigerants, is an item of major importance. Analysis of this item can be made only for separate installations.

10) **Specific heats:** The specific heats of refrigerants in their liquid and vapour phases are of importance in many heat transfer and thermodynamic computations. Specific heats of liquid refrigerants can be readily computed over a wide range of temperature from the enthalpy of the liquid in tables of thermodynamic properties of refrigerants.

11) **Viscosity** of a refrigerant is of importance in determining its heat transfer characteristics and its resistance to flow through pipes. A refrigerant having a low viscosity tends to have a good heat transfer characteristics and will flow through pipes with a minimum friction.

12) **Thermal conductivity:** The thermal conductivity of refrigerant liquids and vapours is important in calculating the film coefficient of heat transfer when the refrigerant is evaporating, condensing or flowing through a pipe.

13) **Enthalpy and entropy:** Enthalpy and entropy are of importance in determining the amount of refrigerant that must be pumped and the power required to do it.

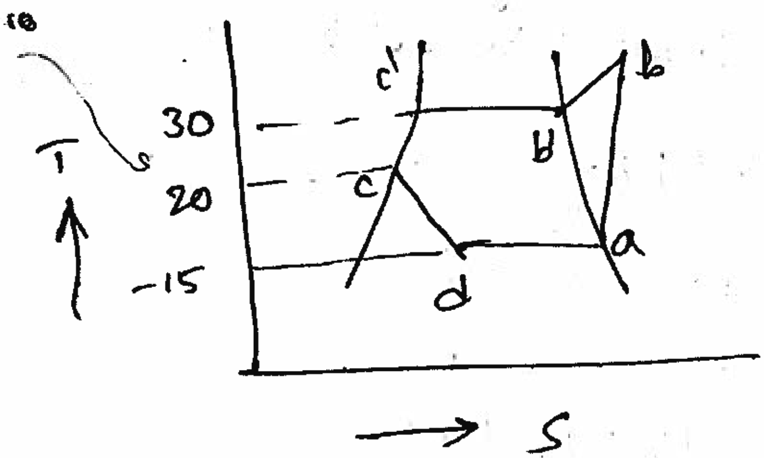
A Simple NH_3 vapour compression System has a "Condenser temperature of 30°c and evaporator temperature of −15°c. the liquid is "Subcooled" by 10°c calculate 1) Refrigerating effect

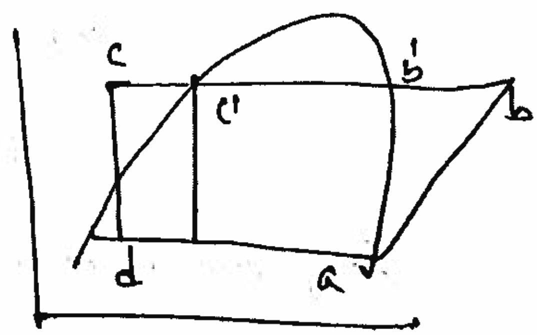
ii) Mass flow rate per ton of refrigeration

iii) COP iv) power per TR v) Represent on T-S & PH Diagram

$C_{PV} = 2.805$ kJ/kgk $C_{PL} = 4.606$ kJ/kgk.

T	Enthalpy		Entropy		Sp. vol m^3/kg
	h_f	h_g	s_f	s_g	
−15	112.3	1426.0	0.457	5.549	0.509
+30	323.1	1469.0	1.204	4.984	





to find T_b

Entropy at a = Entropy at b

$$S_{g_a} = S_{g_b} + C_{pv} \ln \frac{T_b}{T_b'}$$

$$5.549 = 4.984 + 2.805 \ln \frac{T_b}{303}$$

$$T_b = 370.613 \text{ K}$$

$$H_a = H_{g_a} = 1426 \text{ KJ/kg}$$

$$H_b = H_{g_b}' + C_{pv} (T_b - T_b')$$

$$= 1469 + 2.805 (370.61 - 303)$$

$$= 1658.65 \text{ kJ/kg}$$

$$H_c = h_{f_c}' - C_{pL} (T_c' - T_c) \quad = h_{fc}' - C_{pL}(T_c' - T_c)$$

(T_c → condenser temp; T_c' → condenser temp)

$$= 323.1 - 4.606 (30 - 20)$$

$$= 277.04 \text{ KJ/kg}$$

Refrigeration effect $= RE = H_a - H_c$

$$= 1426 - 266.04$$

$$= 1148.96 \text{ KJ/kg}$$

$COP = \frac{RE}{Work}$; Work $= H_b - H_a = 1658.65 - 1426$

$$= 232.65 \text{ KJ/kg}$$

$$COP = \frac{RE}{Work} = \frac{1148.96}{232.65} = 4.93$$

Refrigeration Capacity = 1 ton = 3.5 KJ/s

$$\text{Mass flow rate} = \frac{RC}{RE} = \frac{3.5}{1148.96}$$

$$= 0.0003046 \text{ kg/s}$$

$$= 10.96 \text{ kg/hr.}$$

Power / ton = work/kg x Mass of refrigerant/sec

$$= 232.65 \times 0.0003046$$

$$= 0.07 \text{ kW/ton}$$

A vapour compression refrigerator of 10 tonnes capacity using Freon-12 as the refrigerant has an evaporator temperature of −10°C and condensate temp of +30°C. Assuming saturation cycle, determine

i) Mass flow rate of refrigerant in kg/min

ii) Power input

iii) COP

Take $C_{pv} = 0.72$ kJ/kgK

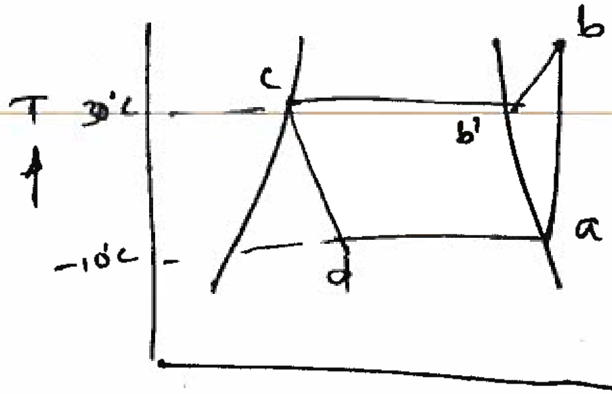
Sol:

Temp	h_f	h_{fg}	h_g	s_f	s_{fg}	s_g
30	64.539	134.93	199.47	0.2397	0.4451	0.6848
−10	26.851	156.20	183.05	0.1079	0.5936	0.7014

» In simple saturation cycle vapour will be dry & saturated at the beginning of compression

To find T_b

Entropy at b = entropy at a



$$S_{g_{b}}' + C_{pv} \ln \frac{T_b}{T_b'} = S_{g_a}$$

$T_b' = 273 +$ Condenser temp
$= 273 + 30 = 303$

$$0.6848 + 0.72 \ln \frac{T_b}{303} = 0.7014$$

$$T_b = 310.06\ K$$

$H_a = h_{ga} = 183.058$ kJ/kg

$H_b = h_{gb'} + C_{pv}(T_b - T_b')$

$= 199.475 + 0.72\,(310.06 - 303)$

$= 206.72$ kJ/kg.

$H_c = h_{fc} = 64.539$ kJ/kg

$RE = H_a - H_c = 183.058 - 64.539 = 118.519$ kJ/kg.

$Work = H_b - H_a = 206.72 - 183.058$ kJ/kg

$= 23.662$ kJ/kg

$COP = \frac{RE}{Work} = \frac{118.519}{23.662} = 5$

Refrigeration capacity $= 10$ tons $= 10 \times 3.5$

$= 35$ kJ/s

Mass flow rate $= \frac{RC}{RE} = \frac{35}{118.519} = 0.2953$ kJ/s

$= 0.2953 \times 60$

$= 17.71$ kJ/min.

Power input $= \frac{work}{kg\ of\ Air} \times$ mass of refrigerant/sec

$=$ ~~183.058 × 0.2953~~ 21.527×0.2953

$=$ ~~54.05~~ $= 6.3$ kW.

7.6 Vapour Absorption Refrigeration System

7.6.1 General

The absorption refrigeration system is a heat-operated unit which uses a refrigerant that is alternately absorbed and liberated by the absorbent.

7.6.2 Simple Absorption System

The minimum number of primary units essential in an absorption system include an evaporator, absorber, generator and condenser.

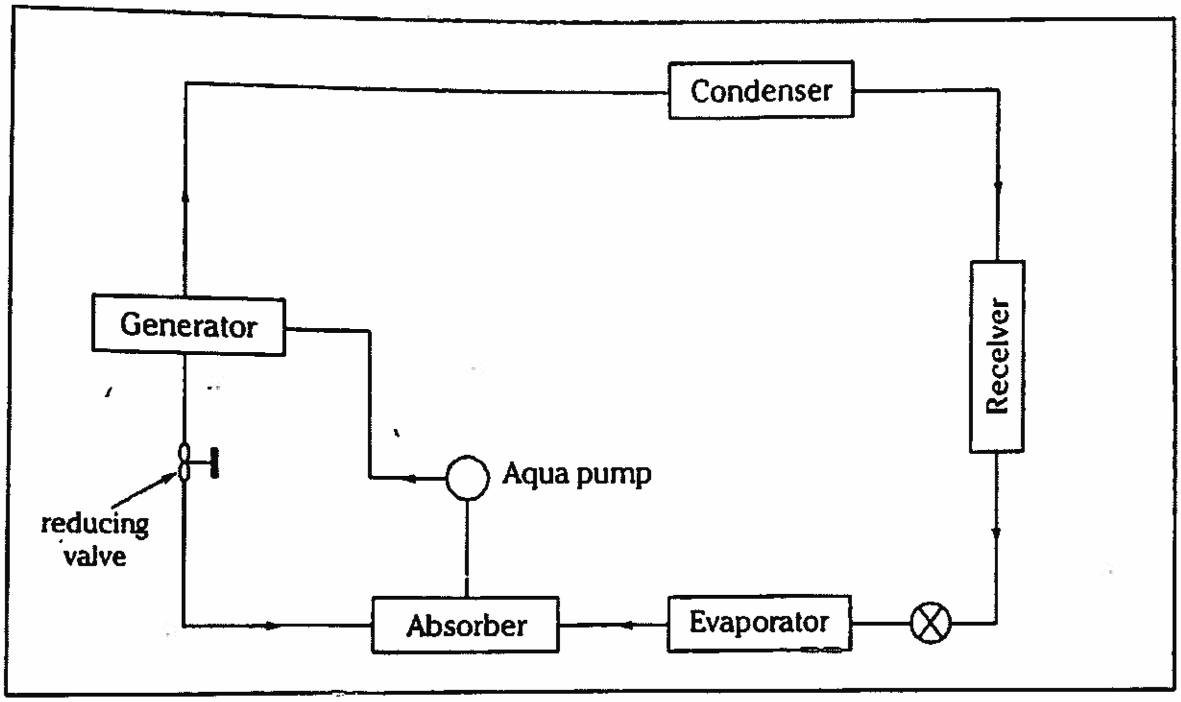


Fig. 7.59 Simple Absorption System

An expansion valve, pressure reducing valve, and a pump are used in a conventional two-fluid cycle, but the pump can be eliminated by adding a gaseous third fluid. A simple absorption cycle is shown in Fig. 7.59.

This cycle differs from a vapour compression cycle by the substitution of an absorber, generator, pumps and reducing valve for the compressor. Various combinations of fluids may be used, but that of ammonia and water is the most common. The solution is called aqua ammonia, a strong solution that contains about as much ammonia as possible; a weak solution contains considerably less ammonia.

8.15 Psychrometric Process

1. Sensible Heating

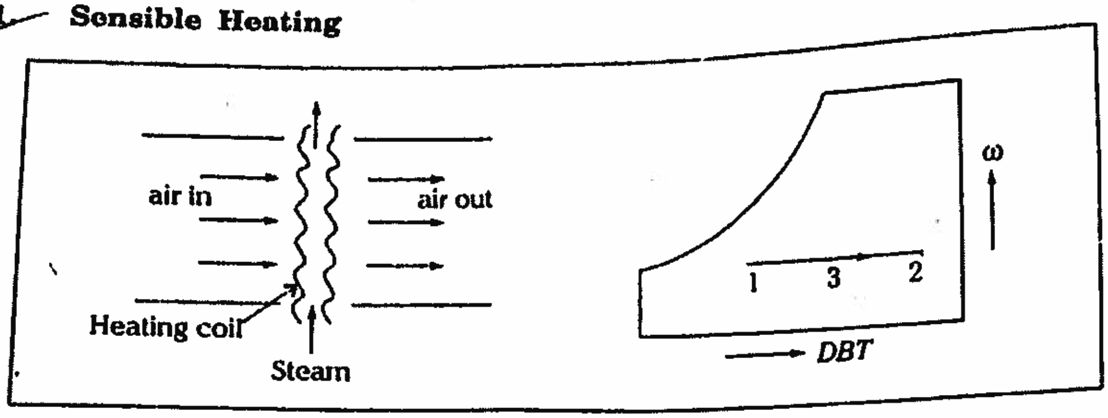


Fig. 8.4 Sensible Heating

Heating of air without addition or subtraction of moisture is called sensible heating. This can be achieved by passing the air over a heating coil like electrical resistance heater or steam coils. The heat added increases the *DBT* of air. This is useful in winter air conditioning.

2. Sensible Cooling

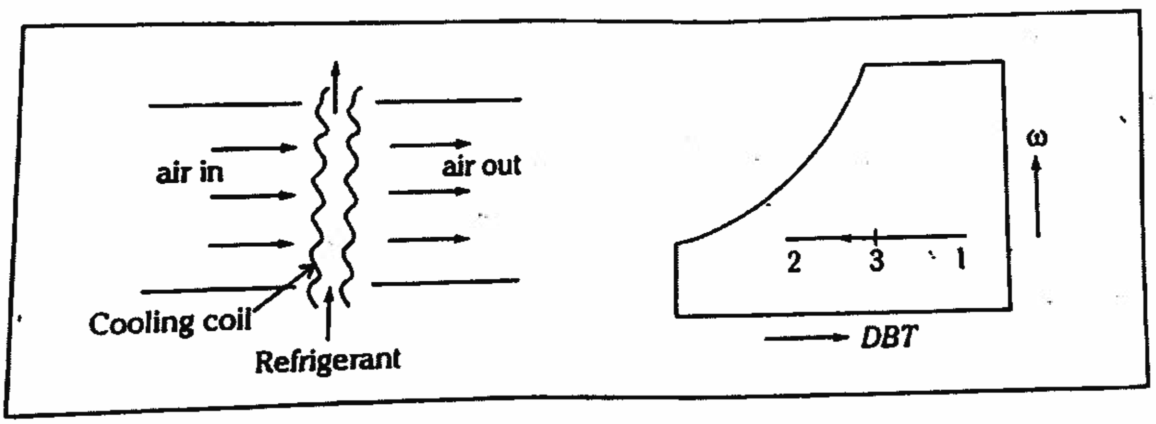


Fig. 8.5 Sensible Cooling

Cooling of air without adding or subtracting moisture is called sensible cooling. This can be achieved by passing air over cooling coil like evaporating coil of refrigeration cycle. This is useful in summer air conditioning.

By- Pass Factor:

It is observed that when air at temperature T_1 is passed over a coil at temperature T_2, the temperature of the air coming out of the coil will be less than T_2, say T_3, ($T_3 < T_2$).

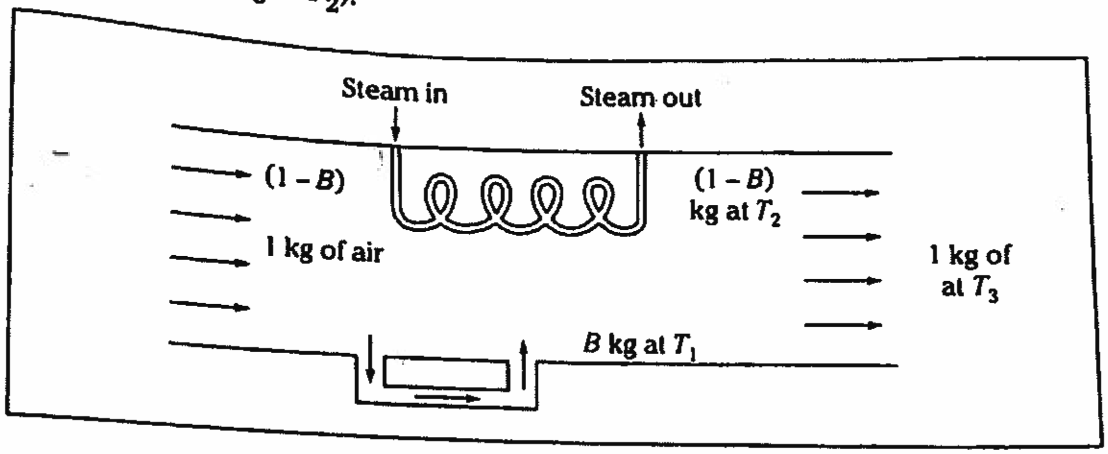


Fig. 8.6 By-pass Factor

When one kg of air at temperature T_1 is passed over the coil, it comes out at temperature T_2. Of this one kg, B kg is assumed to be by passed and remaining $(1 - B)$ kg of air is coming out with temperature T_2 (coil surface temperature) Balancing the enthalpies,

$$BC_{p_m} T_1 + (1 - B)C_{p_m} T_2 = 1 \times C_{p_m} T_3$$

$$BT_1 + T_2 - BT_2 = T_3$$

$$B(T_1 - T_2) = T_3 - T_2$$

$$\therefore \quad B = \frac{T_3 - T_2}{T_1 - T_2} \quad \text{or} \quad B = \frac{T_2 - T_3}{T_2 - T_1} = \frac{\text{Actual heating}}{\text{Ideal heating}}$$

Where, B is called by-pass of factor of the coil. $(1 - B)$ = Mass of air actually coming in contact with the coil and is called efficiency of the heating coil.

Contact factor = $1 - B$

8. Cooling and Dehumidifying

This process implies lowering both the air temperature and the specific humidity. Dehumidification is possible only when we cool the air below the dew point temperature (*DBT*) of the air. Thus it is necessary to maintain the coil surface temperature below the *DPT* of air.

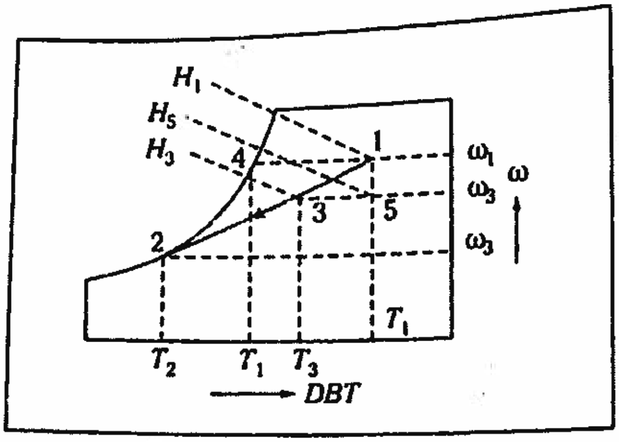


Fig. 8.7 Cooling and Dehumidifying

This is the process commonly used in summer air conditioning in which air is passed over cooling coil.

T_1 = Temperature of air entering the coil.

T_2 = Coil surface temperature.

T_4 = *DPT*.

T_3 = Temperature of air coming out of the cooling coil.

$$B = \frac{T_2 - T_3}{T_2 - T_1}$$

T_2 = *DPT* of the coil called as apparatus dew point temperature *ADP*

$$\therefore \qquad B = \frac{T_3 - ADP}{T_1 - ADP}$$

The process may be assumed to follow the path 1–5 and 5–3 as shown in the figure.

Then total heat removed = $H_1 - H_3$

$$Q_T = (H_1 - H_5) + (H_5 - H_3)$$

$$Q_T = Q_L + Q_S$$

$$Q_L = H_1 - H_5 = \text{Latent heat removed}$$

$$Q_S = H_5 - H_3 = \text{Sensible heat removed}$$

The ratio $\frac{Q_S}{Q_T}$ is called sensible heat factor or sensible heat ratio.

$$\text{SHR} = \frac{Q_S}{Q_S + Q_L}$$

The value of SHR varies from 0.6 to 0.9 depending on the type of building.

4. Cooling with Adiabatic Humidification of Air (Adiabatic Saturation Process)

The recirculated water is sprayed into the air in an insulated chamber. A part of it evaporates in trying to saturate the air. The heat required for evaporation of water is taken from the air itself, thus decreasing its temperature. As complete humidification is not possible, the effectiveness of the spray chamber is given by,

$$\epsilon = \frac{\text{Actual drop in DBT}}{\text{Ideal drop in DBT}} = \frac{T_3 - T_1}{T_2 - T_1} \qquad \text{Humidifying } \eta = 100\,\epsilon$$

If the air leaving the humidifier becomes saturated, then the temperature of air is called adiabatic saturation temperature.

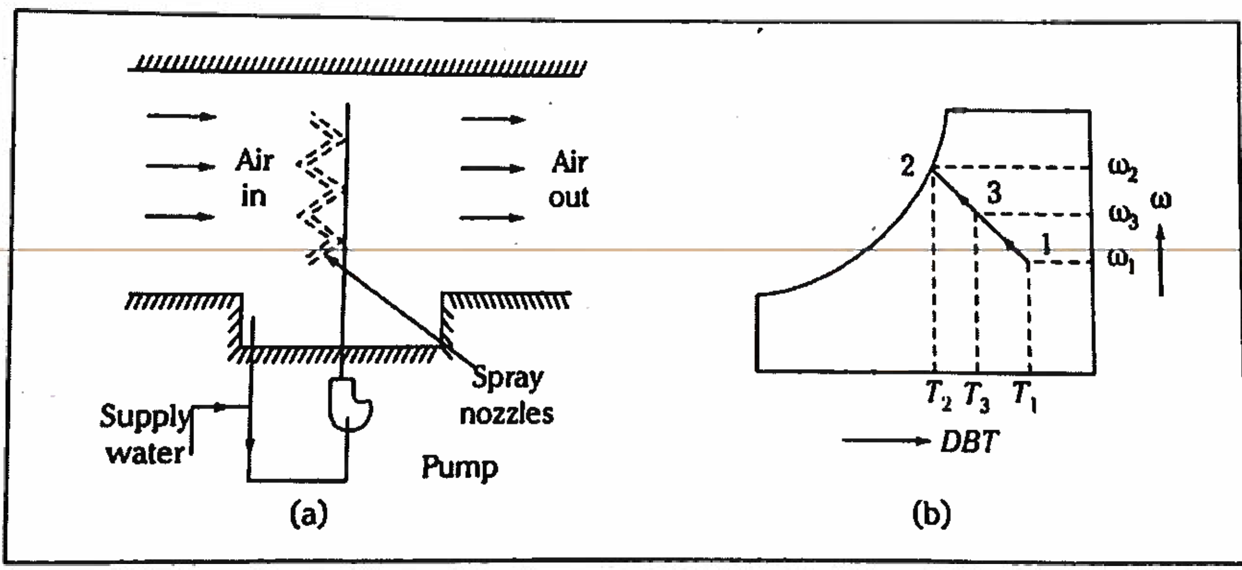
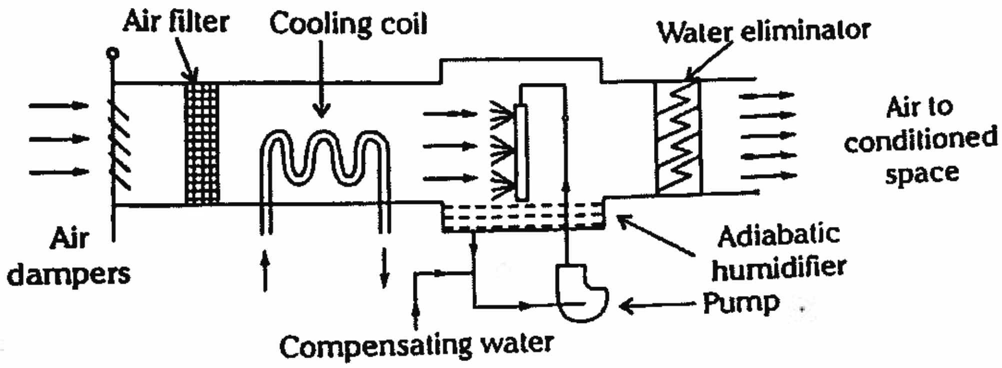


Fig. 8.8 Adiabatic Saturation Process

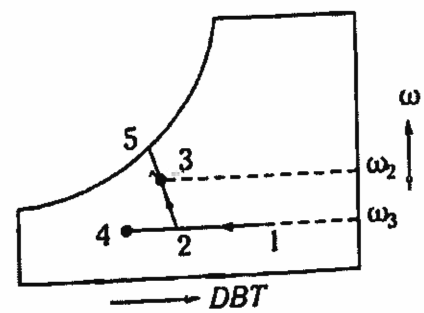
8.17 Air Conditioning Systems

I. Summer Air Conditioning System

a) Hot and Dry Outdoor Condition



(a) Schematic diagram



(b) Psychometry chart

Fig. 8.12 Summer Air Conditioning System

Consider a place in summer where the temperature is 40°C *DBT* and *RH* is 20%. The comfort condition required inside the air-conditioned space is 22°C *DBT* and 60% *RH*. The required condition can be achieved by first cooling using cooling coils and adiabatic humidification to get desired humidity.

Air is first cooled from outdoor condition (point 1) to point 2 by passing over a cooling coil.

$$\text{The Bypass factor of the coil } B = \frac{\text{Distance 4 - 2}}{\text{Distance 4 - 1}}$$

The air coming out of the coil at point 2 is passed into the adiabatic humidifier and the required conditioned air leaves the humidifier at point 3. The efficiency of the humidifier is given by,

$$\eta_h = \frac{T_3 - T_2}{T_5 - T_2} \times 100$$

Let V = quantity of air supplied in m^3/sec

Capacity of the cooling coil $= \frac{V}{V_s} = \frac{(H_1 - H_2)}{3.5}$ tons of refrigeration

Capacity of humidifier $= \frac{V}{V_s}\ (\omega_3 - \omega_2)$ kg/sec

b) Hot and Wet Outdoor Condition

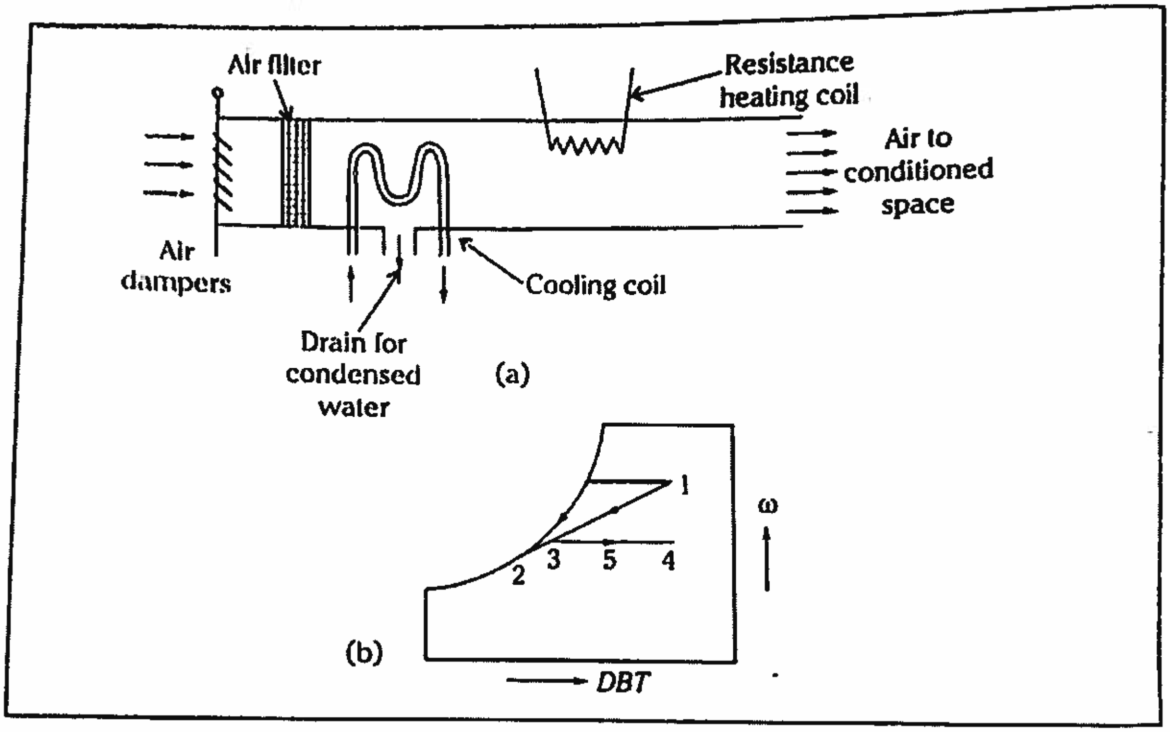


Fig. 8.13 Hot and Wet Outdoor Condition

Consider a place in summer where the temperature is 32°*DBT* and relative humidity 75%*RH*. The required comfort conditions are 22°C *DBT* 60% *RH*. The equipments required and their arrangements are shown in figure.

1 – outdoor condition.

5 – Required comfort condition.

2 – *DPT* of the cooling coil.

The outdoor air is first passed over the cooling coil so that it gets dehumidified and cooled and comes out of the coil at point 3. The By pass factor of the cooling coil is given by,

$$B_c = \frac{\text{Distance 2-3}}{\text{Distance 2-1}}$$

Capacity of the cooling coil $= \frac{V}{V_s}\frac{(H_1 - H_3)}{3.5}$ tone, where V is volume of air in m^3/s.

The air leaving the cooling coil is then passed over the resistance heating coil to get the required comfort condition.

The By pass factor of heating coil $B_h = \frac{\text{Distance 4-5}}{\text{Distance 4-3}}$

Capacity of the heating coil $= \frac{V}{V_s}(H_5 - H_3)\ kW$

2. **Winter Air Conditioning System**

Consider a place in winter where the temperature is 15°C and relative humidity 80%. The required comfort conditions are 22°C and 60% *RH*. The equipments required and their arrangement are shown in figure.

1 – Atmospheric condition

6 – Required comfort condition

The air is first passed over a resistance heater which is called preheater, it is then passed through the humidifier and finally through a second heater to achieve the desired indoor condition.

B_1 = By pass factor of preheating coil $= \frac{\text{Distance 2-3}}{\text{Distance 1-3}}$

Capacity of the preheating coil $= \frac{V}{V_s}(H_2 - H_1)$ kW

B_2 = By pass factor of the reheating coil $= \frac{\text{Distance 6-7}}{\text{Distance 4-7}}$

Capacity of reheating coil $= \frac{V}{V_s}(H_6 - H_4)$

$$\text{Efficiency of the humidifier} = \frac{\text{Distance 2-4}}{\text{Distance 2-5}}$$

$$\text{Capacity of humidifier} = \frac{V}{V_s}(\omega_4 - \omega_2)\ \text{kg/sec}$$

Where V = Volume of air per sec

V_S = Specific Volume

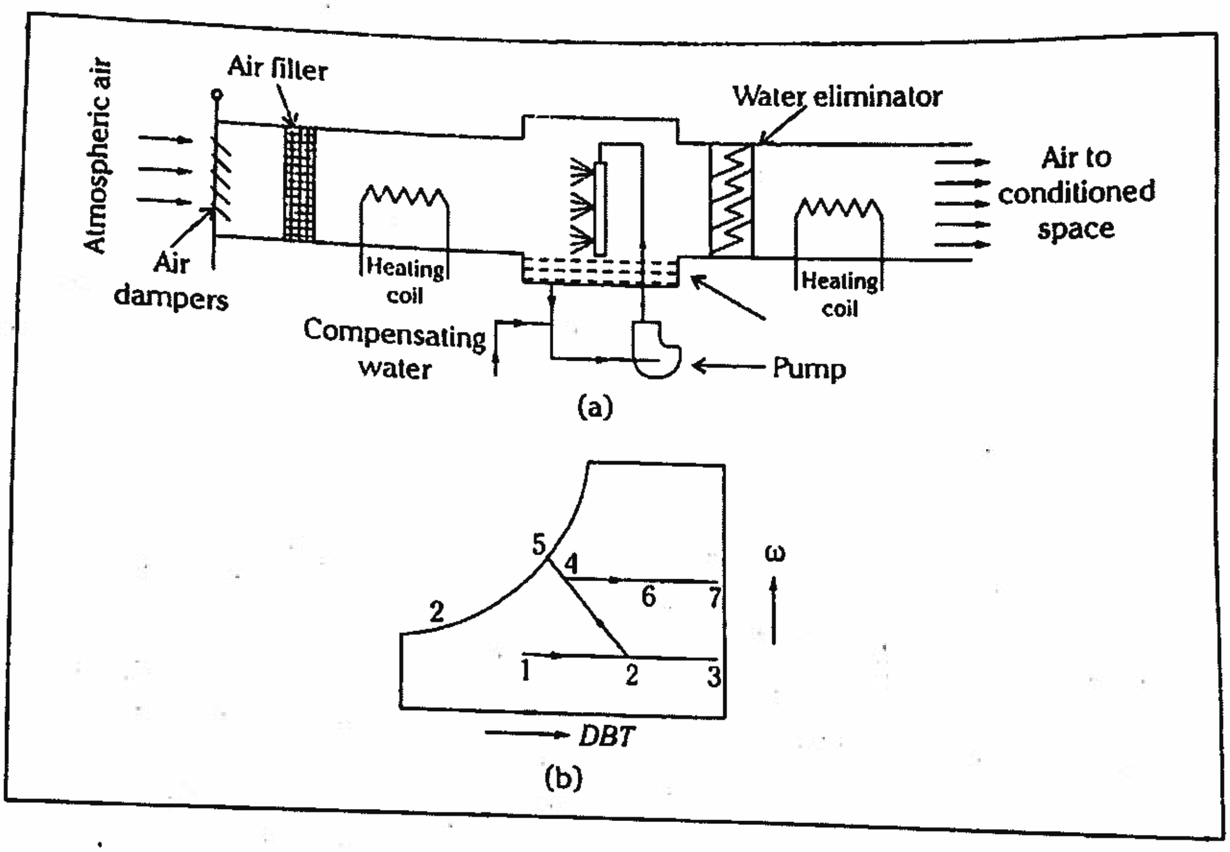


Fig. 8.14 Winter Air Conditioning

3. Year-Round Air-conditioning

It is seen that in many places both summer and winter are quite uncomfortable.

Hence it becomes necessary to have an air conditioning system which will provide comfort conditions throughout the year. Thus year round air conditioning system must be capable of maintaining the desired temperature

14.

Important Questions/Question Bank

1. Clearly explain the various types of lubrication systems?
2. (a) What is supercharging and turbocharging? How do these affect the performance of an engine?
(b) Differentiate between indicator diagram and valve timing diagram.
3. What are various types of SI engine cylinder designs, write in detail about them. (T type, L type, I type, F type etc.)
4. Explain various types of ignition systems.
5. The temperature of air at the beginning and end of compression of an Otto cycle are 310K and 600K. Calculate air standard efficiency of the cycle if engine develops 20Kw indicated thermal efficiency and relative efficiency. CV = 44MJ/Kg; Sp. gravity= 0.78.
6. (a) What are different factors affecting knock in SI engine?
(b) What are knocking limited parameters in SI engine?
7. Explain with a neat sketch working of simple carburetor, and label the parts of the same.
8. With the help of a neat diagram, explain the working of fuel injection system in CI engines.
9. (a) Give a detailed classification of IC engines based on cycle/ Fuel used/ Method of charging the same.
(b) Bring out differences in two stroke and four stroke engines, explain the same with aid of diagrams.
10. (a) With all minute details, explain the factors affecting the knocking including the fuel characteristics for S I Engines and C I Engines.
(b) What are the essential qualities of SI and CI fuels, how is the rating done?
11. List out various water-cooled systems and discuss them in detail.
12. A 4 cylinder 4 – stroke petrol engine having bore 6 cm and stroke 10 cm develops 65 N-m torque at 3000 RPM. Find the fuel consumption of the engine in kg/hr and brake mean effective pressure, if the relative efficiency of 50% and clearance volume is 60 cm^3. Take CV = 40 MJ/kg.
13. (a) With the help of diagrams, explain different combustion chambers used in CI engines
(b) What is meant by delay period and explain factors affecting the delay period.
14. Explain in depth what factors influence flame speed, during combustion, in SI engines.
15. Explain each stage of combustion process in SI and CI engine.
16. Define and classify of compressors
17. Explain the working principle of centrifugal compressor
18. Explain the working principle of reciprocating compressor with the help of indicator diagrams
19. Explain the working principle of Axial flow compressor
20. Derive the expression for efficiency of centrifugal compressor
21. Derive the expression for efficiency of reciprocating compressor
22. Derive the expression for efficiency of axial flow compressor
23. Define refrigerator and classify. Define Ton of refrigeration
24. Explain the working principle of Air refrigeration systems (Bell-Coleman) and derive the COP expression
25. Explain the working principle of Vapor compression refrigeration cycle and derive the COP expression
26. Explain the working principle of Vapor absorption refrigeration cycle and derive the COP expression

Course Time Tables

NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING & TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING
TIME TABLE

Acadmic year: 2019-2020 **Year-Semester:** III-I-A
Course: B.Tech **Room No. :** G-LH:4

	9:30 to10:20	10:20 to11:10	11:10 to 12:00	12:00 to12:50	12:50 to1:40	1:40 to2:30	2:30 to 3:20	3:20 to 4:10
MONDAY	TE-I				L U N C H			
TUESDAY	TE-I							
WEDNESDAY	TE-I							
THURSDAY					B R E			
FRIDAY					A			
SATURDAY					K			

THEORY:

THERMAL ENGINEERING I (TE-I)	Mr.VINAY KULKARNI
DESIGN OF MACHINE MEMBERS -I(DMM-I)	Mr.FAZAL MOHAMMED
METROLOGY AND MACHINE TOOLS(MMT)	Mr.SADAT ALI
FUNDAMENTALS OF MANAGMENT(FOM)	Ms.QIZER UNNISA
DISATER MANAGEMENT(DM)	Mr.MD RAFEEQ

LABS:

ENGGG METROLOGY LAB	Mr.SADAT ALI /Mrs. TASLEEM BANU
MACHINE TOOLS LAB	Mr.FAZAL MOHAMMED/Mr AQEEL
TE LAB	Mr.VINAY KULKARNI/Mr MD TAHER
PROFESONAL ETHICS(PE)	Mr.KHASIM

HOD PRINCIPAL

NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING & TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING
TIME TABLE

Acadmic year: 2019-2020 | Year-Semester: III-I-B

Course: B.Tech | Room No. : G-LH:5

	9:30 to10:20	10:20 to11:10	11:10 to 12:00	12:00 to12:50	12:50 to1:40	1:40 to2:30	2:30 to 3:20	3:20 to 4:10
MONDAY					L U N C H	TE-I		
TUESDAY								
WEDNESDAY								
THURSDAY					B R E	TE-I		
FRIDAY	TE-I				A			
SATURDAY					K			

THEORY:

THERMAL ENGINEERING I (TE-I)	Dr. MAGBUL HUSSAIN
DESIGN OF MACHINE MEMBERS -I(DMM-I)	Mrs. SARTAZ
METROLOGY AND MACHINE TOOLS(MMT)	Dr.SM HUSSAINI
FUNDAMENTALS OF MANAGMENT(FOM)	Ms.AZEEZA SHAHEEN
DISATER MANAGEMENT(DM)	Mr.M A MOYEED

LABS:

ENGGG METROLOGY LAB	Mr.SYED AMER/Mrs. SARTAZ
MACHINE TOOLS LAB	Mr.ABDUL RAHMAN KHAN/Mr. SHAIK ASIM
TE LAB	Mr.MD RAFEEQ/Mr. KHAJA ALI
PROFESONAL ETHICS(PE)	Ms. SABIHA KHATOON

HOD

PRINCIPAL

NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING & TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING
TIME TABLE

Acadmic year: 2019-2020 | Year-Semester: III-I-A

Course: B.Tech | Room No. : G-LH:4

	9:30 to10:20	10:20 to11:10	11:10 to 12:00	12:00 to12:50	12:50 to1:40	1:40 to2:30	2:30 to 3:20	3:20 to 4:10
MONDAY	TE-I		FOM		LUNCH BREAK	DMM-I		LIBRARY
TUESDAY	TE-I	MT LAB/ME /TE LAB				DM		DMM-I
WEDNESDAY	TE-I		FOM			PE		
THURSDAY	DMM-I		MMT			MT LAB/ME /TE LAB		
FRIDAY	MMT		DM			MT LAB/ME /TE LAB		
SATURDAY	SPORTS					LIABARY/TPO		

THEORY:

THERMAL ENGINEERING I (TE-I)	Mr.VINAY KULKARNI
DESIGN OF MACHINE MEMBERS -I(DMM-I)	Mr.FAZAL MOHAMMED
METROLOGY AND MACHINE TOOLS(MMT)	Mr.SADAT ALI
FUNDAMENTALS OF MANAGMENT(FOM)	Ms.QIZER UNNISA
DISATER MANAGEMENT(DM)	Mr.MD RAFEEQ

LABS:

ENGGG METROLOGY LAB	Mr.SADAT ALI /Mrs. TASLEEM BANU
MACHINE TOOLS LAB	Mr.FAZAL MOHAMMED/Mr AQEEL
TE LAB	Mr.VINAY KULKARNI/Mr MD TAHER
PROFESONAL ETHICS(PE)	Mr.KHASIM

HOD

PRINCIPAL

NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING & TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING
TIME TABLE

Acadmic year: 2019-2020 Year-Semester: III-I-B
Course: B.Tech Room No. : G-LH:5

	9:30 to10:20	10:20 to11:10	11:10 to 12:00	12:00 to12:50	12:50 to1:40	1:40 to2:30	2:30 to 3:20	3:20 to 4:10
MONDAY	DMM-I		FOM		L U N C H B R E A K	TE-I		DM
TUESDAY	FOM		DMM-I			DM		MMT
WEDNESDAY	DMM-I	MMT		DM		MT LAB/ME /TE LAB		
THURSDAY	MT LAB/ME /TE LAB			MMT		TE-I		MMT
FRIDAY	TE-I	MT LAB/ME /TE LAB				PE		
SATURDAY	SPORTS					LIABARY/TPO		

THEORY:

THERMAL ENGINEERING I (TE-I)	Dr. MAGBUL HUSSAIN
DESIGN OF MACHINE MEMBERS -I(DMM-I)	Mrs. SARTAZ
METROLOGY AND MACHINE TOOLS(MMT)	Dr.SM HUSSAINI
FUNDAMENTALS OF MANAGMENT(FOM)	Ms.AZEEZA SHAHEEN
DISATER MANAGEMENT(DM)	Mr.M A MOYEED

LABS:

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MACHINE TOOLS LAB	Mr.ABDUL RAHMAN KHAN/Mr. SHAIK ASIM
TE LAB	Mr.MD RAFEEQ/Mr. KHAJA ALI
PROFESONAL ETHICS(PE)	Ms. SABIHA KHATOON

HOD PRINCIPAL

Class Time Tables

Assignment Questions

UNIT-I: I.C. ENGINES

1	a	What are the merits and demerits of two stroke I.C. engines over the four stroke I.C. engines?
2	b	Differentiate S.I. and C.I. engines.
3	a	What is the need and requirement of cooling in I.C. engines? Will it be same for both S.I. and C.I. engines?
	b	For a petrol engine explain the fuel system with a line diagram. How does it help to control the load variation?
4	A	Explain the principle of working of a four stroke S.I. engine with a neat sketch.
	B	Why do you need lubrication in I.C. engines and name the types of lubrication.
	C	Explain the principle of working of a battery ignition system with a neat sketch.

UNIT-II: Combustion in S.I. & CI Engines

1	a	Describe phenomenon of pre-ignition in S.I. engines and discuss its effect on the performance.
	b	Explain the phenomenon of knock in a S.I. engine with p- diagram.
2		Show the phenomenon of detonation on pressure crank angle diagram and compare it with that of normal combustion.
3	a	Discuss the effect of rate of pressure rise on engine operation.
	b	What is flame speed in the normal combustion of S.I. engines and discuss its influence on combustion phenomenon.
4	a	Discuss the factors which promote pre-ignition.
	b	What is flame speed in the normal combustion of S.I. engines and discuss its influence on combustion phenomenon.
5		Discuss the desirable principles of combustion chamber design for S.I. engines.
6		Compare the normal combustion phenomena in SI and CI engines?
7		Explain the terms ‘delay period’ and ‘knocking’ as referred to CI engines.
8	a	Explain the effect of the following operating parameters on delay period in C.I. engines. (i) Speed (ii) Air –fuel ratio (iii) Injection timing.
	b	How C.I. engine fuels are rated? Explain the methodology.

UNIT-III: Testing and Performance

1		What is the significance of conducting the MORSE test? Explain the same in detail.
2	a	During the trial of a four stroke diesel engine the following observations were recorded: Area of the indicator diagram = 475 mm^2, Length of the indicator diagram = 62 mm Spring number= 1.1 bar/mm, Diameter of the piston= 100 mm Length of the stroke= 150 mm, Engine RPM= 375 Determine (i) indicated mean effective pressure (ii) indicated power in kW.
	b	The output of a single cylinder four stroke IC engine is measured by a rope brake dynamometer. The diameter of the pulley is 750 mm and rope diameter 50 mm. The dead load on the tight side of the rope is 400 N and the spring balance reading is 50 N. The bore is 150 mm and stroke is 190 mm. The engine consumes 4 kg/h of fuel at the rated speed of 1000 rpm. The calorific value of the fuel is 44 MJ/kg. Calculate the brake specific fuel consumption, BMEP and the brake thermal efficiency. If the mechanical efficiency is 80%, calculate the IP, IMEP, indicated specific fuel consumption and indicated thermal efficiency.
3	a	Why testing of engine is necessary? Describe the various methods for determination of indicated power of an engine.
	b	A single cylinder internal combustion engine gave the following results when put to a trial test. Area of the indicator diagram= 12 cm^2, Length of the indicator diagram= 8 cm Spring scale= 2.8,Diameter of the piston= 21 cmLength of the stroke= 28 cm,Engine speed = 370 RPM. Determine IP of the engine when (i) working on four stroke cycle and (ii) working on two stroke cycle.
4	a	Explain various methods of determining the brake power of an engine.
	b	A six cylinder, single acting internal combustion engine has the piston speed of 540 m/min, piston diameter 12 cm and stroke length 18 cm. While developing 60 kW BP, it gave mechanical efficiency equal to 80%. Mean effective pressure acting on the piston face is 4.063 bars. The specific fuel consumption per BP hour is 0.3 kg. If the calorific value of the fuel used is 42000 kJ/kg, determine (i) whether it is a two stroke or four stroke engine (ii) thermal efficiency of the engine based on brake power.

UNIT-III: COMPRESSORS

1		Explain the terms effective swept volume and displacement volume of the compressor.
2		A single acting compressor has zero clearance, stroke of 20 cm and piston diameter 15 cm. When the compressor is operating at 235 rpm and compressing air from 10 N/cm^2, 25 ^0C to 41 N/cm^2, find (i) the volume rate of air handled and (ii) the ideal power required.
3		Derive an expression for the isothermal efficiency of a compressor in terms of the pressure ratio.
4		A double acting compressor takes in air at 100 kpa and delivers it to the receiver at 1000 kpa. The speed is 200 rpm, diameter is 150 mm and the stroke length is 220 mm. Calculate the capacity of the motor required.
5		Air is to be compressed in a single stage reciprocating compressor from 101.3 kpa and 15 ^0C to 700 kpa. The free air delivery is 0.3 m^3/min when the compressor speed 1000 rpm. If the compressor is single acting and has a stroke/bore ratio of 1.2, calculate the bore size required

UNIT-IV: Rotary (Positive displacement type)

1		Discuss the merits and demerits of rotary compressor over reciprocating compressor.
2	a	List the various types of rotary compressors.
	b	Explain with a neat sketch, the working of a vane blower.
3		A centrifugal compressor receives air at the rate of 1400 m^3/min at 100 kpa and 35 ^0C and delivers at 350 kpa. It has an isentropic efficiency of 82%. Mechanical losses amount to 2.5% of the shaft power. Determine the power required and exit air temperature.
4		How does the working of centrifugal compressor differ from the axial flow compressor? Explain.

UNIT IV: Axial Flow Compressors

1	a	An 8-stage axial flow compressor takes in air at 20 ^0C at the rate of 180 kg/min. The pressure ratio is 6 and the isentropic efficiency is 0.9. Determine the power required.
	b	Explain with a neat sketch, the working of a axial flow compressor
2	a	Explain the term degree of reaction and point out the difference between the blading of a reaction turbine and that of an axial flow compressor.
	b	Define Polytropic efficiency and isentropic efficiency.
3		Explain the phenomenon of stalling of blades in axial flow compressors.

Code No: RT31035 **R13** SET - 1

III B. Tech I Semester Supplementary Examinations, October/November - 2020

THERMAL ENGINEERING – II

(Mechanical Engineering)

Time: 3 hours Max. Marks: 70

Note: 1. Question Paper consists of two parts (**Part-A** and **Part-B**)
2. Answering the question in **Part-A** is compulsory
3. Answer any **THREE** Questions from **Part-B**
4. Use of Steam tables with Mollier diagram is allowed

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PART –A (22 Marks)

1 a) Discuss the advantages of a regenerative feed heating in steam power cycle. [4M]
b) Explain the differences between internally fired and externally fired boilers. [3M]
c) Explain what is meant by critical pressure ratio of a nozzle? [4M]
d) Discuss t the factors which affect the vacuum efficiency of a condenser. [4M]
e) What are the disadvantages of a closed cycle gas turbine over open cycle gas turbine? [3M]
f) Explain thrust power and propulsion efficiency of a rocket engine. [4M]

PART –B (48 Marks)

2 a) What is adiabatic flame temperature? How flame temperature can be calculated? [7M]
b) A power generating plant uses stem as working fluid and operates at boiler pressure of 50bar, dry saturated and a condenser pressure of 0.1 bar. Calculate for thee limits: i) The cycle efficiency; ii) The work ratio and specific steam consumption of Rankine cycle. Take pumping work also into account. [9M]

3 a) What do you understand by feed check valve? Explain the working of a feed check valve with a near sketch. [7M]
b) The equivalent evaporation of boiler from and at 100^0C is 1300 kg/hr. Calculate the actual evaporation if the feed water is supplied at 110^0C and the steam is generated at a pressure of 15 bar and temperature 200^0C. If the efficiency of this boiler is 72% find: i) The fuel consumption per hour taking calorific value of coal as 25500 kj/kg, and ii) The grate area if the rate of evaporation is 100 kg/m^2 per hour. [9M]

4 a) Explain the functions of the convergent portion, the throat and the divergent portion of a convergent-divergent nozzle with reference to flow of steam. [7M]
b) A convergent-divergent nozzle is required to discharge 5 kg of steam per second. The nozzle is supplied with steam at 10bar and 200^0C and the discharge takes place against a back pressure of 0.34 bar. Estimate the throat and exit areas. Assume isentropic flow and take the index n=1.3. If the nozzle efficiency is assumed to be 85%, determine the exit area. [9M]

5 a) What is the fundamental difference between the operation of impulse and reaction turbines? Explain the same with neat sketches. [7M]
b) The vacuum at the bottom of a surface condenser is 65.4 cm of mercury (barometer 75.7 cm), the temperature at the air pump suction is 36.2^0C. If the rate of air leakage into the condenser is 1 kg per 1000 kg of steam, estimate the mass of air and vapour removed by the air pump per minute when the engine consumption is 136000 kg of steam/hr. [9M]
~~~~~~

6 a) Discuss the effect of Compressor inlet temperature and Turbine isentropic efficiency on the specific output and thermal efficiency of the open cycle gas turbine at different pressure ratios. [7M]

b) In gas turbine plant, the compressor takes air at 15^0C and compresses with pressure ratio of 4 with isentropic efficiency 82%. Then the air is heated in the heat exchanger using 75% of the available heat with exhaust gases and then heated in combustion chamber to 600^0C. Isentropic efficiency of turbine is 70%. Taking the properties of air and gases same, find work developed per kg of air flow and thermal efficiency of the cycle; Take effectiveness of heat exchanger as 0.75. [9M]

7 a) What is meant by thrust augmentation? When it is necessary? Describe any one method of thrust augmentation. [8M]

b) The effective jet exit velocity of a rocket is 3500 m/s, the forward flight velocity is 1250 m/s, and the propellant consumption if 75 kg/s. Calculate: i) The thrust; ii) The thrust power and iii) The propulsive efficiency. [8M]

*****

1	a	A boot strap cooling system of 10 tons is used in an aero plane. The temperature and pressure conditions of atmosphere are 20°C and 0.9 atm. The pressure of air is increased from 0.9 atm to 1.1 atm due to ramming. The pressures of air leaving the main and auxiliary compressor are 3 atm and 4 atm respectively. Isentropic efficiency of compressors and turbine are 0.85 and 0.8 respectively. 50% of the total heat of air leaving the main compressor is removed in the first heat exchanger and 30% of their total heat of air leaving the auxiliary compressor is removed in the second heat exchanger using removed air. Find: a) Power required to take cabin load b) COP of the system The cabin pressure is 1.02 atm and temperature of air leaving the cabin should be greater than 25°C. Assume ramming action to be isentropic.
	b	Determine the work of compression and cooling effect produced by the cycle.
2	a	.A R-12 plant has to produce 10 tons of refrigeration. The condenser and evaporator. A Carnot refrigerator using R12 as working fluid operates between 40°C and -30°C. temperatures are 40°C and - 10°C respectively. Determine a) Refrigerant flow rate b) Volume flow rate of the compressor c)Operating pressure ratio d) Power required to drive the compressor e) COP
	b	The operating temperatures of a single stage vapour absorption refrigeration system are: generator: 90 0C; condenser and absorber: 40 0C; evaporator: 0 0C. The system has a refrigeration capacity of 100 kW and the heat input to the system is 160 kW. The solution pump work is negligible. a) Find the COP of the system and the total heat rejection rate from the system. b) An inventor claims that by improving the design of all the components of the system he could reduce the heat input to the system to 80 kW while keeping the refrigeration capacity and operating temperatures same as before. Examine the validity of the claim.
3		An ideal refrigeration cycle operates with R134a as the working fluid. The temperature of refrigerant in the condenser and evaporator are 40°C and -20°C respectively. The mass flow rate of refrigerant is 0.1 kg/s. Determine the cooling capacity and COP of the plant.

Code No: 135BP R16

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

B. Tech III Year I Semester Examinations, May/June - 2019
THERMAL ENGINEERING – I

(Mechanical Engineering)

Time: 3 hours **Max. Marks: 75**

Note: This question paper contains two parts A and B.

Part A is compulsory which carries 25 marks. Answer all questions in Part A. Part B consists of 5 Units. Answer any one full question from each unit. Each question carries 10 marks and may have a, b, c as sub questions.

PART – A **(25 Marks)**

1.a) List out the differences between the SI engine and CI engine. [2]

b) What is valve overlap period? Explain its significance. [3]
c) List out various factors influencing delay period. [2]
d) Discuss about indirect injection combustion chambers. [3]
e) Define isothermal efficiency of air compressor. [2]
f) List out the advantages of reciprocating compressors [3]
g) Why the axial compressors are more suitable for gas turbines? Explain. [2]
h) Explain the concept of slip factor in centrifugal compressor. [3]
i) What is COP of refrigeration system? Explain the importance. [2]
j) What are the commonly used refrigerants in vapour compression system? [3]

PART – B **(50 Marks)**

2.a) Why the actual cycle efficiency is much lower than the air standard cycle efficiency? List the major losses in the actual engine.

b) What are the important requirements of fuel injection system in a C.I Engine? [5+5]

OR

3.a) Describe the evaporative cooling system with a neat sketch.

b) Describe the working of pressure feed lubrication system with a neat sketch. [5+5] 4.a) Discuss the various methods for improving the anti-knock quality of an SI engine.

b) With the help of graph, explain the factors which influence the flame speed in an S.I.engine. [5+5]

OR

5.a) What is Physical delay? Discuss the factors that affect the delay period in a C.I. engine.

b) Explain the phenomenon of knock in CI engine and compare it with SI engine knock. [5+5]

6.a) Explain Rope brake dynamometer to determine the brake power of an engine?

b) The following date was recorded during testing of a four-stroke cycle gas engine. Area of indicator diagram = 900 mm2; Length of indicator diagram = 70 mm; spring scale = 0.3 bar/mm; Diameter of piston = 200 mm; Length of stroke = 250mm; Speed = 300 rpm. Determine i) Indicated mean effective pressure ii) Indicated power. [5+5]

OR

7.a) Derive the expression for work done when compression is isentropic for a single stage reciprocating air compressor.

b) A single acting two stage reciprocating air compressor compresses 4.5 kg of air per minute from 1.013 bar and 15°C through a pressure ratio of 9. The intercooling is perfect and the law of compression and expansion $PV^{1.3}$ = constant. Assuming the clearance volumes of both stages 5% of their swept volume and the speed of compressor 300 rpm, calculate the indicated power and the cylinder swept volume. [5+5]

8.a) With a neat sketch explain the working of roots blower and derive the expression for roots efficiency.

b) A centrifugal air compressor having isentropic efficiency of 70% receives air at 17°C.

If the outer diameter of the blade tip is 1 m and the compressor runs at 5000 rpm find:(i) The temperature rise of the air and (ii) the static pressure ratio. [5+5]

OR

9.a) What is degree of reaction? Derive the expression for degree of reaction for axial flow compressor.

b) A multistage axial compressor is required for compressing air at 293 K through a pressure ratio of 5 to 1. Each stage is to be 50% reaction and the mean blade speed 275 m/s, flow coefficient 0.5, and stage loading factor 0.3, are taken, for simplicity, as constant for all stages. Determine the flow angles and the number of stages required if

the stage efficiency is 88.8%. Assume C_P =1.005 kJ/kg K and γ= 1.4 for air. [5+5] 10.a) Explain the working of Vapour compression refrigeration system with a neat diagram.

b) An ammonia refrigeration plant operates between a condenser temperature of 42°C and an evaporator temperature of −2°C. The vapour is superheated with a degree of

superheat 10°C at the end of end of compression. The specific heat of ammonia is

2.16 kJ/kgK. Calculate net refrigeration effect, work required and coefficient of performance. [5+5]

OR

11.a) What are the desirable properties of an ideal refrigerant? Explain.

b) A Bell-Coleman refrigerator works between 4 bar and 1 bar pressure limits. After compression, the cooling water reduces the air temperature to 17°C. What is the lowest temperature produced by the ideal machine? Compare the coefficient of performance of this machine with that of the ideal Carnot cycle machine working between the same pressure limits, the temperature at the beginning of compression being -13° C. [5+5]

Code No: 135BP R16

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

B. Tech III Year I Semester Examinations, November/December - 2018
THERMAL ENGINEERING – I

(Mechanical Engineering)

Time: 3 hours **Max. Marks: 75**

Note: This question paper contains two parts A and B.

Part A is compulsory which carries 25 marks. Answer all questions in Part A. Part B consists of 5 Units. Answer any one full question from each unit. Each question carries 10 marks and may have a, b, c as sub questions.

PART – A (25 Marks)

1.a) What is heat loss factor? [2]

b) What do you understand by supercharging? [3]
c) What are the different types of combustion chambers used in SI engine? [2]
d) Define specific fuel consumption. [3]
e) Draw the P-v and T-s diagram for a single acting reciprocating air compressor. [2]
f) What is heat balance sheet? [3]
g) What is the difference between rotary and reciprocating compressor? [2]
h) Differentiate between centrifugal compressor and axial flow compressor. [3]
i) What do you understand by effective room sensible heat factor? [2]
j) Distinguish sensible and latent heat loads. [3]

PART – B (50 Marks)

2.a) Discuss the various important qualities of a good ignition system.

b) Explain the differences between actual and ideal fuel air cycles of C.I. engines. [5+5]

OR

3.a) Derive an expression for air fuel ratio of a simple carburetor.

b) With a neat sketch, explain the battery ignition system. [5+5]

4.a) Discuss the desirable characteristics of a good combustion chamber for an SI engine.

b) Classify and explain the CI engine combustion chambers. [5+5]

OR

5.a) Discuss the various methods for improving the anti-knock quality of an SI engine.

b) Explain and discuss the phenomenon of diesel knock in CI engines and compare the same with detonation in SI engines. [5+5]

6.a) Explain Rope brake dynamometer to determine the brake power of an engine.

b) A six cylinder, four-stroke gasoline engine having a bore of 90 mm and stroke of 100 mm has a compression ratio 7. The relative efficiency is 55% when the indicated specific fuel consumption is 300gm/kW h. Estimate (i) the calorific value of the fuel and (ii) corresponding fuel consumption, given that imep is 8.5 bar and speed is 2500 rpm. [5+5]

7.a) Enumerate the various engine efficiencies. Explain.

b) A gasoline engine working on four stroke develops a brake power of 20.9 kW. A Morse test was conducted on this engine and the brake power (kW) obtained when each cylinder was made inoperative by short circulating the spark plug are 14.9, 14.3, 14.8 and 14.5 respectively. The test was conducted at constant speed. Find the indicator power, mechanical efficiency and bmep when all the cylinders are firing. The bore of the engine is 75 mm and the stroke is 90 mm. The engine is running at 3000 rpm. [5+5]

8.a) List out various rotary compressor. Write the advantages of rotary compressors over reciprocal compressors.

b) Explain the principle of operation of centrifugal compressor with neat sketch. [5+5]

OR

8. Explain the following terms for dynamic compressors.
a) Power input factor
b) Pressure coefficient
c) Adiabatic coefficient. [10]

9. A four rows coil with a face velocity of 150 m/min has a contact factor of 0.85. Calculate the contact factors for the following cases:
a) Face velocity 200 m/min and four rows.
b) Face velocity 100 m/min and four rows
c) Face velocity 150 m/min and eight rows
d) Face velocity 150 m/min and two rows. [10]

OR

11.a) A stream of moist air at 2oC dry bulb and 80 per cent relative humidity mixes with another stream of moist air at 30oC dry bulb and 10oC dew point in the ration by mass of one part of the first to two parts of the second. Calculate the temperature and specific humidity of the air after mixing.

b) Explain about year –round air conditioning system with a neat labelled diagram. [5+5]

Mid Question Papers

NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING & TECHNOLOGY

New Malakpet, Hyderabad-500024

III-B.TECH I-SEM MID-I EXAMINATION Sept - 2019

BRANCH: ME **DATE: 11.09.2019 AN**

SUBJECT: ThE-I **TIME: 02:00 PM TO 03.30 PM**

I Answer any two of the following 2x5=10

Q.No	Question	Bloom's Level
1.	Explain with a neat sketch magneto ignition system and Battery ignition system?	L1, L2
2.	Explain with neat sketch Air cooled and water cooled system	L2
3.	Explain with neat sketch Stages of combustion in SI engine	L2
4.	An IC Engine uses 6 kg of fuel having calorific value of 44000 kJ/kg one hour the IP developed is 18km the temperature of 11.5kg of cooling water was found torise through 25degree per minute the temperature of 4.2kg of exhaust gas with specific heat is 1 kJ/kgKwas found to rise through 220 degree draw the heat balance sheet for the engine	L3

NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING & TECHNOLOGY

III B.Tech. I Sem., I Mid-Term Examinations, SEPTEMBER – 2019

THERMAL ENGINEERING -I

Objective Exam

BRANCH: ME

Name: ______________________________ **Hall Ticket No.** | | | | | | A | | | | |

Answer All Questions. All Questions Carry Equal Marks. Time: 20 Min. Marks: 10.

1. **Choose the correct alternative:**
2. The working cycle in case of four stroke engine is completed in following number of revolutions of crankshaft ( )
   (a) ½ (b) 1 (c) 2 (d) 4

3. In a diesel engine, the fuel is ignited by ( )
   (a) spark (b) injected fuel
   (c) heat resulting from compressing air that is supplied for combustion (d) ignition

4. If the intake air temperature of SI. engine increases, its efficiency will ( )
   (a) increase (b) decrease
   (c) remain same (d) unpredictable

5. The air-fuel ratio of the petrol engine is controlled by ( )
   (a) fuel pump (b) governor
   (c) injector (d) carburettor

6. The actual volume of fresh charge admitted in 4-stroke petrol engine is ( )
   (a) equal to stroke volume
   (b) equal to stroke volume and clearance volume
   (c) less than stroke volume
   (d) more than stroke volume

7. Scavenging is usually done to increase ( )
   (a) thermal efficiency (b) speed
   (c) power output (d) fuel consumption

8. The air-fuel ratio in petrol engines-is controlled by ( )
   (a) controlling valve opening/closing (b) governing
   (c) injection (d) carburettion

9. A stoichiometric air-fuel ratio is ( )
   (a) chemically correct mixture (b) lean mixture
   (c) rich mixture for idling (d) rich mixture for over loads

10. Excessive Turbulence in SI engine will ( )
    (a)Decrease Efficiency (b)Decrease Power output
    (c)Increases Tendency of Knock (d)none of the above

11. Octane number of a fuel ( )
    (a)Resist the Detonation (b)Persist the knocking
    (c)Will increase the rate of pressure rise (d)None

I. Fill in the blanks:

1. A heat engine is a device which transforms the chemical energy of a fuel into thermal energy and uses this energy to produce ___________
2. The nominal distance through which a working piston moves between two successive reversals of its direction of motion is celled ___________
3. ___________charge consisting of fresh air mixed with the fuel is drawn into the cylinder due to the vacuum pressure created by the movement of the piston from TDC to BDC.
4. ___________ occurs when the un-burnt gases ahead of flame front spontaneously ignite causing a sudden rise in pressure accompanied by a characteristic pinging sound
5. Ignition systems are of 2 types: ___________
6. ___________is the ignition of the homogeneous mixture of charge as it comes in contact with hot surfaces, in the absence of spark.
7. ___________ is a measure of the resistance to flow or the internal friction of the lubricant.
8. ___________is the actual power available at the output shaft or crankshaft of an IC engine.
9. ___________ is the process of replacing burnt gases after a firing stroke with a fresh charge in the cylinders.
10. The ratio of brake power to indicated power is called as ___________

NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING & TECHNOLOGY

New Malakpet, Hyderabad-500024

III-B.TECH I-SEM MID-II EXAMINATION Nov - 2019

BRANCH: ME DATE: 21.11.2019 AN

SUBJECT: TE-I TIME: 02:00 PM TO 03.30 PM

I Answer any two of the following **2x5=10**

Q.No.	Question	Bloom's Level
1.	Derive an expression for work done in 2 stage reciprocating air compressor and also derive an equation for minimum work done	L2
2.	Calculate the power required and efficiency of vane compressor when it handles 6m^{3}of air per minute from 1 bar to 2.2 bar.The pressure rise due to compression in the compressor is limited to 1.6 bar take mechanical efficiency of compressor as 80%	L3
3.	Explain vapour compression refrigeration system with effect of supper heating and under cooling	L2
4.	An air refrigeration system works on an open air cycle is required to provide 20 tonne of refrigeration with cooler pressure of 12.5 bar and refrigeration pressure of 1.05 bar the temperature of the air leaving the cooling is 20^{0c} and leaving the cold chamber is -1^{0c} assuming isentropic compression and expansion and neglecting clearance find 1. Weight of air circulated/min 2. COP of the system 3. Power required per tonne of refrigeration	L3

NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING& TECHNOLOGY

III B.TECH I SEM., II MID-TERM EXAMINATIONS, November – 2019

THERMAL ENGINEERING - I

Objective Exam

BRANCH: ME

Name: ______________________________ **Hall Ticket No.** | | | | | | A | | | | |

Answer All Questions. All Questions Carry Equal Marks. Time: 20 Min. Marks: 10.

I Choose the correct alternative:

1. Work required to run the main compressor is minimum if the compression is ( )
   (a)Polytrophic (b) Adiabatic (c)Isothermal (d)Isobaric

2. Multistage compressor gives ( )
   (a)Higher Volumetric efficiency (b) lower isothermal efficiency
   (c)lower volumetric efficiency (d) higher exit temperature

3. for reason for adopting the axial flow compressor instead of centrifugal compressor in air craft turbine ( )
   (a)starting torque for axial flow compressor is high (b) the frontal area of axial flow compressor is considerable less
   (c)the efficiency and middle space required is higher (d) none of this

4. In centrifugal compressor an increase in speed at a given pressure ratio causes ( )
   (a)increase in flow (b) increase in efficiency
   (c)increase in flow and decrease in efficiency
   (d) decrease in flow and decrease in efficiency

5. In positive displacement compressor the increase in pressure is due to ( )
   (a) backflow of air (b)Dynamic effect
   (c) front flow of air (d) static effect

6. Which one of the following is positive displacement compressor ( )
   (a)centrifugal compressor (b)axial flow compressor
   (c)vane type compressor (d)none of them

7. The refrigerant used in reversed brayton or bell-coleman cycle is ( )
   (a) Air (b) Ammonia
   (c) Freon (d) Water
8. The heat transfer equivalent of one tonne of refrigeration is ( )
   (a)1000kg (b)3.5kw (c)1Kw (d) 3.5kg

9. Two fluid refrigeration system is ( )
   (a) vapour compression system (b)Vapour absorption sytem (c) Air refrigeartion (d) all

10. The refrigerant used in steam jet refrigeration is ( )
    (a)Ammonia (b)Feron (c)water (d)Air

I. Fill in the blanks:

1. The efficiency of vane type compressor as compared to roots air compressor for same pressure ratio is ___________
2. Rotary compressors are used for delivery of ___________quantity of air__________ pressure
3. The compressor generally used in air craft engine is _____________ ___________
4. Efficiency of vane blower is the ratio of _______________ and ____________
5. The ratio of delivery pressure to the inlet pressure is___________
6. The work required for the compression is minimum when the compression is___________
7. The commercial refrigeration system which is closer to reversed Carnot cycle is ________________
8. COP is defined as_____________
9. One tone of refrigeration is defined as ___________________________
10. In split air conditioning system________________________________

Student List

S.NO	H.T. NO	NAME OF STUDENT
1	17RT1A0301	ABDUL MANNAN BAIG
2	17RT1A0307	ARAFAT
3	17RT1A0308	BILAL MOHAMMED ATEEQ
4	17RT1A0311	HAMED BIN TAHER HARHARA
5	17RT1A0312	ISMAIL PASHA
6	17RT1A0319	MIRZA AFROZ BAIG
7	17RT1A0320	MIRZA AMAIR BAIG
8	17RT1A0321	MIRZA FARHAN BAIG
9	17RT1A0326	MOHAMMED ABDUL HADI
10	17RT1A0327	MOHAMMED ABDUL JALEEL
11	17RT1A0328	MOHAMMED ABDUL RAHMAN ALEEM
12	17RT1A0329	MOHAMMED ADNAN HUSSAIN
13	17RT1A0330	MOHAMMED ABDUL WAJID
14	17RT1A0331	MOHAMMED ABDUL WASY
15	17RT1A0332	MOHAMMED ABDULLAH GHORI
16	17RT1A0333	MOHAMMED ABIDULLAH ANSARI
17	17RT1A0334	MOHAMMED ABRAR HASSAN
18	17RT1A0336	MOHAMMED ASAD AHMED
19	17RT1A0338	MOHAMMED AZIZUDDIN
20	17RT1A0341	MOHAMMED HYDER AHMED
21	17RT1A0342	MOHAMMED ILYAAS AKBAR
22	17RT1A0343	MOHAMMED IMRAN
23	17RT1A0344	MOHAMMED INZEMAMUDDIN
24	17RT1A0346	MOHAMMED JUNAID
25	17RT1A0348	MOHAMMED KHADER JILANI
26	17RT1A0351	MOHAMMED MUHEEB UDDIN ASLAM
27	17RT1A0356	MOHAMMED SHAHBAZ HUSSAIN
28	17RT1A0357	MOHAMMED SHAHER YAR KHAN
29	17RT1A0360	MOHAMMED TAJ
30	17RT1A0361	MOHAMMED VASIUDDIN
31	17RT1A0362	MOHAMMED YASSER
32	17RT1A0366	MOHD ABDUL QAVI
33	17RT1A0367	MOHD ABDUL RAHMAN
34	17RT1A0368	MOAHD ABDUL RAHMAN
35	17RT1A0370	MOHD ARBAZ
36	17RT1A0374	MOHD FAISAL HUSSAIN
37	17RT1A0377	MOHD IMRAN UDDIN
38	17RT1A0378	MOHAMMED KHAJA
39	17RT1A0379	MOHD KHALEEL UR RAHEMAN
40	17RT1A0381	MOHD NADEEM
41	17RT1A0382	MD OMAIR AHMED
42	17RT1A0383	MOHD PARVEZ
43	17RT1A0386	MOHD SULEMAN UDDIN ALI KHAN
44	17RT1A0389	MUSAIB MOHIUDDIN
45	17RT1A0391	SALAH MOHD SOHAIL
46	17RT1A0393	SHAIK ABDUL OBAID
47	17RT1A0394	SHAIK ABDUL WASI
48	17RT1A0395	SHAIK ASHRAF ALI

49	17RT1A03A0	SHAIK SAMI UR RAHMAN
50	17RT1A03A2	SK MOHAMMED NAIF UDDIN
51	17RT1A03A5	SYED ALTAF UDDIN
52	17RT1A03A6	SYED ESA GIBRAN
53	17RT1A03A7	SYED FARDEEN ALI
54	17RT1A03A8	SYED HUSSAIN AHMED
55	17RT1A03B4	SYED MOHD NADEEM
56	17RT1A03B5	SYED MOHD LATEEF
57	17RT1A03B6	SYED NAIYYER HUSSAIN
58	17RT1A03B8	SYED NOOR MOHAMMED
59	17RT1A03C0	SYED SUFIYAN MOHAMMED
60	17RT1A03C1	SYED TALIB AZAM
61	**18RT5A0301**	ADIL MOHAMMED SAIFUL ISLAM
62	18RT5A0302	AHMED ABDUL HAQUE
63	18RT5A0303	CHEGONDI SIVALINGA RAJU
64	18RT5A0304	HABEEB AHMED
65	18RT5A0305	IBRAHIM BIN HASAN MOHAMMADI
66	18RT5A0306	KAMA NAVEEN
67	18RT5A0307	KHALEEL AHMED
68	18RT5A0308	M A WASEEM
69	18RT5A0309	MD AIJAZ UDDIN
70	18RT5A0310	M A MUNAWAR
71	18RT5A0311	MD SHOIEB KHAN
72	18RT5A0312	MOHAMMAD ABDUL RAHMAN
73	18RT5A0313	MOHAMMAD FARDEEN FARAZ
74	18RT5A0314	MOHAMMAD SUFIYAN OUSAF
75	18RT5A0315	MOHAMMED ABDUL KHALEEL
76	18RT5A0316	MOHAMMED ABDUL RAHMAN
77	18RT5A0317	MOHAMMED IBRAHIM
78	18RT5A0318	MOHAMMED SHOAIB HUSSAIN
79	18RT5A0319	MOHAMMED SHOAIB KHAN
80	18RT5A0322	MOHD AMIR
81	18RT5A0323	MOHD ASEEM UDDIN
82	18RT5A0324	MOHD AZMATH QUADRI
83	18RT5A0325	MOHD MOIZ UDDIN
84	18RT5A0326	MOHD SADIQ
85	18RT5A0327	MOHD SHOAIB ABBAS
86	18RT5A0328	SHAHEDA MAHREEN
87	18RT5A0329	SHAIK AWAIS
88	18RT5A0330	SHAIK BASHEER
89	18RT5A0331	SHAIK UMAR SHARIEF

Slow learners List

S.NO	H.T. NO	MID I
1	17RT1A0327	17
2	17RT1A0328	17
3	17RT1A0331	17
4	17RT1A0336	14
5	17RT1A0348	17
6	17RT1A0351	17
7	17RT1A0362	17
8	17RT1A0366	15
9	17RT1A0370	17
10	17RT1A0381	17
11	17RT1A0391	15
12	17RT1A0393	15
13	17RT1A0394	17
14	17RT1A0395	15
15	17RT1A03A2	15
16	17RT1A03A5	15
17	17RT1A03A8	17
18	17RT1A03B4	17
19	17RT1A03C0	17
20	17RT1A03C1	15
21	18RT5A0302	14
22	18RT5A0305	17
23	18RT5A0308	14
24	18RT5A0313	16
25	18RT5A0315	15
26	18RT5A0317	14
27	18RT5A0322	17
28	18RT5A0324	17
29	18RT5A0325	15
30	18RT5A0327	15

Advanced learners List

S.NO	H.T. NO	MID I
1	17RT1A0301	23
2	17RT1A0311	20
3	17RT1A0312	21
4	17RT1A0319	21
5	17RT1A0320	22
6	17RT1A0326	20
7	17RT1A0330	22
8	17RT1A0332	23
9	17RT1A0338	23
10	17RT1A0342	20
11	17RT1A0343	21
12	17RT1A0344	20
13	17RT1A0346	23
14	17RT1A0360	23
15	17RT1A0361	20
16	17RT1A0377	21
17	17RT1A0379	23
18	17RT1A0382	20
19	17RT1A0383	23
20	17RT1A0386	23
21	17RT1A0389	23
22	17RT1A03A0	23
23	17RT1A03A7	20
24	17RT1A03B5	20
25	17RT1A03B6	23
26	17RT1A03B8	20
27	**18RT5A0301**	23
28	18RT5A0307	20
29	18RT5A0309	20
30	18RT5A0314	23
31	18RT5A0318	21
32	18RT5A0326	22
33	18RT5A0328	23
34	18RT5A0330	23
35	18RT5A0331	23

ATTAINMENT FOR 2019-20

NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING AND TECHNOLOGY, JNTUH Hyderabad
DEPARTMENT OF MECHANICAL ENGINEERING

B.Tech. III YEAR, I SEM - ATTAINMENT CALCULATIONS - Academic Year: 2019-20

Subject: Thermal Engineering 1 **Subject Code:** C312 **Faculty:** MOHAMMED AHMAD HUSSAIN

S.No.	Hall Ticket No.	MID - 1											MID - 2											MID		SEE
		ASG-1 (2.5M)	ASG-2 (2.5 M)	Quiz-1 (10 M)		Q 1 (5 M)	Q 2 (5 M)	BEST OF Q1&Q2	Q 3 (5 M)	Q 4 (5 M)	BEST OF Q3&Q4	Mid-1 TOTAL (25 M)	ASG-3 (2.5M)	ASG-4 (2.5 M)	Quiz-2 (10 M)		Q 1 (5 M)	Q 2 (5 M)	BEST OF Q1&Q2	Q 3 (5 M)	Q 4 (5 M)	BEST OF Q3&Q4	Mid-2 TOTAL (25 M)	Average MID	TOTAL Marks	End Exam
		CO1	CO2	CO1	CO2	CO1	CO1	CO1	CO2	CO2	CO2		CO3	CO4	CO3	CO4	CO3	CO3	CO3	CO4	CO4	CO4		(25 M)	(100 M)	(75 M)
1	17RT1A0301	2.5	2.5	5	4	5		5	4		4	23	2.5	2.5	5	4		5	5	5		5	24	24	57	34
2	17RT1A0307	2.5	2.5	4	2	4		4	4		4	19	2.5	2.5	4	2	4		4		2	2	17	18	39	21
3	17RT1A0308	2.5	2.5	4	3		4	4		3	3	19	2.5	2.5	4	2	4	3	4	2		2	17	18	48	30
4	17RT1A0311	2.5	2.5	3	4	5	4	5	3		3	20	2.5	2.5	5	3	3		3	3		3	19	20	39	20
5	17RT1A0312	2.5	2.5	4	3	5		5	4		4	21	2.5	2.5	5	3	5		5	3		3	21	21	39	18
6	17RT1A0319	2.5	2.5	3	4		5	5	4		4	21	2.5	2.5	5	3		5	5		4	4	22	22	39	18
7	17RT1A0320	2.5	2.5	5	3	4		4	5		5	22	2.5	2.5	4	3		5	5		4	4	21	22	48	26
8	17RT1A0321	2.5	2.5	4	3	4		4	3		3	19	2.5	2.5	5	3		4	4	3		3	20	20	39	20
9	17RT1A0326	2.5	2.5	4	3	4	3	4		4	4	20	2.5	2.5	4	3	4		4		3	3	19	20	39	20
10	17RT1A0327	2.5	2.5	3	2		4	4	3		3	17	2.5	2.5	4	2		4	4	3		3	18	18	39	22
11	17RT1A0328	2.5	2.5	3	2	4		4	3		3	17	2.5	2.5	5	4	4		4		3	3	21	19	39	20
12	17RT1A0329	2.5	2.5	4	3		4	4	3		3	19	2.5	2.5	3	1		4	4	2		2	15	17	39	22
13	17RT1A0330	2.5	2.5	4	4		5	5	4	3	4	22	2.5	2.5	5	2	4		4	4		4	20	21	48	27
14	17RT1A0331	2.5	2.5	3	2		4	4		3	3	17	2.5	2.5	3	2	4	3	4	2		2	16	17	48	31
15	17RT1A0332	2.5	2.5	5	4	4		4		5	5	23	2.5	2.5	5	5	3	5	5		4	4	24	24	67	43
16	17RT1A0333	2.5	2.5	4	3	4	3	4	2		2	18	2.5	2.5	3	1	3		3	2		2	14	16	48	32
17	17RT1A0334	2.5	2.5	3	4	4		4	2		2	18	2.5	2.5	4	3		5	5		4	4	21	20	39	20
18	17RT1A0336	2.5	2.5	3	1	3		3	2		2	14	2.5	2.5	5	3	5	3	5	4		4	22	18	39	21
19	17RT1A0338	2.5	2.5	5	4		5	5		4	4	23	2.5	2.5	5	4	5		5	5	4	5	24	24	57	34
20	17RT1A0341	2.5	2.5	4	3		4	4	2		2	18	2.5	2.5	4	2	5		5	4		4	20	19	39	20
21	17RT1A0342	2.5	2.5	4	3		4	4	4		4	20	2.5	2.5	4	2		4	4	3		3	18	19	39	20
22	17RT1A0343	2.5	2.5	4	3	4		4	3	5	5	21	2.5	2.5	4	3	4		4		4	4	20	21	48	27
23	17RT1A0344	2.5	2.5	4	3		4	4		4	4	20	2.5	2.5	5	4		5	5	4		4	23	22	39	18
24	17RT1A0346	2.5	2.5	5	4	4		4	5	4	5	23	2.5	2.5	5	5	4		4	5		5	24	24	57	34
25	17RT1A0348	2.5	2.5	3	2		4	4	3		3	17	2.5	2.5	4	3	4		4	4		4	20	19	39	21
26	17RT1A0351	2.5	2.5	3	2	4		4		3	3	17	2.5	2.5	4	3		5	5	4		4	21	19	39	20
27	17RT1A0356	2.5	2.5	4	3	4	3	4	3		3	19	2.5	2.5	3	2	3	5	5	3		3	18	19	48	29
28	17RT1A0357	2.5	2.5	4	3	3	4	4		2	2	18	2.5	2.5	4	2	5		5		3	3	19	19	48	29
29	17RT1A0360	2.5	2.5	5	4	4		4	5		5	23	2.5	2.5	5	4		5	5	5		5	24	24	39	16
30	17RT1A0361	2.5	2.5	4	3		5	5	3		3	20	2.5	2.5	5	5	5		5	4		4	24	22	48	26
31	17RT1A0362	2.5	2.5	3	2	4	3	4	3		3	17	2.5	2.5	5	3	4		4	3		3	20	19	48	29
32	17RT1A0366	2.5	2.5	4	1	3		3		2	2	15	2.5	2.5	4	3		5	5	4	3	4	21	18	39	21
33	17RT1A0367	2.5	2.5	3	3	4		4	4		4	19	2.5	2.5	4	3		5	5		4	4	21	20	39	19
34	17RT1A0368	2.5	2.5	4	2		5	5		3	3	19	2.5	2.5	4	3	5		5		4	4	21	20	39	19
35	17RT1A0370	2.5	2.5	3	2	5		5		2	2	17	2.5	2.5	3	4		4	4	3		3	19	18	39	21
36	17RT1A0374	2.5	2.5	4	3		4	4		3	3	19	2.5	2.5	4	2		4	4	2		2	17	18	48	30
37	17RT1A0377	2.5	2.5	4	3	4		4	4	5	5	21	2.5	2.5	3	2		3	3	2		2	15	18	39	21
38	17RT1A0378	2.5	2.5	5	3	4		4	2		2	19	2.5	2.5	4	1	4		4		2	2	16	18	39	22
39	17RT1A0379	2.5	2.5	5	4		5	5		4	4	23	2.5	2.5	5	4	5	3	5	5		5	24	24	57	34
40	17RT1A0381	2.5	2.5	4	2	3	4	4	2		2	17	2.5	2.5	4	1	4		4	2		2	16	17	48	31
41	17RT1A0382	2.5	2.5	4	3	5		5	3		3	20	2.5	2.5	5	2	4		4	3		3	19	20	39	20
42	17RT1A0383	2.5	2.5	4	4		5	5	5		5	23	2.5	2.5	3	1		4	4		2	2	15	19	39	20
43	17RT1A0386	2.5	2.5	5	4	5		5	4		4	23	2.5	2.5	4	3		5	5	3		3	20	22	39	18
44	17RT1A0389	2.5	2.5	5	4	4		4	5		5	23	2.5	2.5	3	1		5	5	2		2	16	20	57	38
45	17RT1A0391	2.5	2.5	4	1		3	3		2	2	15	2.5	2.5	2	1		4	4		2	2	14	15	39	25
46	17RT1A0393	2.5	2.5	2	2		4	4	2		2	15	2.5	2.5	4	2		4	4	3		3	18	17	39	23
47	17RT1A0394	2.5	2.5	3	2	4		4	3		3	17	2.5	2.5	4	1	5		5	2		2	17	17	48	31
48	17RT1A0395	2.5	2.5	3	2		3	3	2		2	15	2.5	2.5	4	1		4	4	3		3	17	16	39	23
49	17RT1A03A0	2.5	2.5	5	4		5	5	4	3	4	23	2.5	2.5	4	2	5		5	3		3	19	21	48	27
50	17RT1A03A2	2.5	2.5	2	2		3	3		3	3	15	2.5	2.5	3	2	5	3	5	3		3	18	17	39	23

51	17RT1A03A5	2.5	2.5	3	1	3		3		3	3	15	2.5	2.5	3	1	4		4		2	2	15	15	39	24
52	17RT1A03A6	2.5	2.5	4	2	4	3	4	3		3	18	2.5	2.5	4	3	5		5	3		3	20	19	39	20
53	17RT1A03A7	2.5	2.5	3	4	4		4	4		4	20	2.5	2.5	3	2		4	4		3	3	17	19	48	29
54	17RT1A03A8	2.5	2.5	4	2	3		3	3		3	17	2.5	2.5	2	1	4		4	2		2	14	16	39	24
55	17RT1A03B4	2.5	2.5	3	2		4	4		3	3	17	2.5	2.5	5	4	5		5		4	4	23	20	39	19
56	17RT1A03B5	2.5	2.5	4	3		4	4	4		4	20	2.5	2.5	4	3	5		5	2		2	19	20	48	28
57	17RT1A03B6	2.5	2.5	5	4		5	5	4		4	23	2.5	2.5	5	4		5	5	5		5	24	24	39	16
58	17RT1A03B8	2.5	2.5	4	3		4	4	4		4	20	2.5	2.5	5	4	5		5		4	4	23	22	39	18
59	17RT1A03C0	2.5	2.5	3	2		4	4		3	3	17	2.5	2.5	5	4		5	5	4		4	23	20	48	28
60	17RT1A03C1	2.5	2.5	3	1	4		4	2		2	15	2.5	2.5	4	3	4		4	1		1	17	16	48	32
61	18RT5A0301	2.5	2.5	5	4		5	5		4	4	23	2.5	2.5	5	3	5		5		4	4	22	23	57	35
62	18RT5A0302	2.5	2.5	2	1	4		4	2		2	14	2.5	2.5	5	3		5	5	3		3	21	18	39	22
63	18RT5A0303	2.5	2.5	3	3		3	3		4	4	18	2.5	2.5	5	2	3		3	5		5	20	19	39	20
64	18RT5A0304	2.5	2.5	4	3	4		4	2		2	18	2.5	2.5	4	3		5	5	4		4	21	20	48	28
65	18RT5A0305	2.5	2.5	2	4	4		4	2		2	17	2.5	2.5	4	2	4		4		2	2	17	17	39	22
66	18RT5A0306	2.5	2.5	4	2		4	4		3	3	18	2.5	2.5	4	3	4	3	4	3		3	19	19	39	21
67	18RT5A0307	2.5	2.5	3	4	5	4	5	3		3	20	2.5	2.5	5	3	5		5	4		4	22	21	48	27
68	18RT5A0308	2.5	2.5	2	1	4		4	2		2	14	2.5	2.5	3	2	4		4	3		3	17	16	39	24
69	18RT5A0309	2.5	2.5	4	3		5	5	3		3	20	2.5	2.5	5	4		4	4		4	4	22	21	39	18
70	18RT5A0310	2.5	2.5	4	2	4		4	3		3	18	2.5	2.5	4	2	5		5	3		3	19	19	48	29
71	18RT5A0311	2.5	2.5	3	4	4		4	2		2	18	2.5	2.5	4	2	5		5		3	3	19	19	48	29
72	18RT5A0312	2.5	2.5	3	3	4	3	4		3	3	18	2.5	2.5	4	1	4		4	2		2	16	17	39	22
73	18RT5A0313	2.5	2.5	3	2		3	3	3		3	16	2.5	2.5	4	1		5	5		3	3	18	17	39	22
74	18RT5A0314	2.5	2.5	5	4	4		4	5		5	23	2.5	2.5	5	2	5		5	4		4	21	22	57	35
75	18RT5A0315	2.5	2.5	3	1		3	3	3		3	15	2.5	2.5	4	3		4	4	3		3	19	17	39	22
76	18RT5A0316	2.5	2.5	3	2		5	5		3	3	18	2.5	2.5	3	2	3		3		3	3	16	17	39	22
77	18RT5A0317	2.5	2.5	2	1		3	3		3	3	14	2.5	2.5	4	2	5		5	3		3	19	17	48	31
78	18RT5A0318	2.5	2.5	4	3	4		4		5	5	21	2.5	2.5	4	3		4	4	5		5	21	21	57	36
79	18RT5A0319	2.5	2.5	4	2	4	3	4	3		3	18	2.5	2.5	5	3	5	4	5	4		4	22	20	48	28
80	18RT5A0322	2.5	2.5	3	2	3		3	4		4	17	2.5	2.5	4	2	4		4	3		3	18	18	39	22
81	18RT5A0323	2.5	2.5	5	3	3		3	3		3	19	2.5	2.5	4	3		5	5	2		2	19	19	39	20
82	18RT5A0324	2.5	2.5	3	1		5	5		3	3	17	2.5	2.5	5	2	5		5	3		3	20	19	39	21
83	18RT5A0325	2.5	2.5	2	1		4	4	3		3	15	2.5	2.5	5	3	5		5	3	3	3	21	18	48	30
84	18RT5A0326	2.5	2.5	4	4		5	5	4		4	22	2.5	2.5	4	3	5	3	5		4	4	21	22	48	26
85	18RT5A0327	2.5	2.5	3	1	3		3	3		3	15	2.5	2.5	5	3	5		5		3	3	21	18	39	21
86	18RT5A0328	2.5	2.5	5	4	4		4	5		5	23	2.5	2.5	5	4	5		5	4		4	23	23	39	16
87	18RT5A0329	2.5	2.5	4	2		5	5	2		2	18	2.5	2.5	3	1		4	4		1	1	14	16	39	23
88	18RT5A0330	2.5	2.5	4	5	5	4	5		4	4	23	2.5	2.5	4	3	3		3		4	4	19	21	39	18
89	18RT5A0331	2.5	2.5	5	4	5		5	4		4	23	2.5	2.5	4	2		4	4		5	5	20	22	57	36
Average Marks		2.5	2.5	3.71	2.74	4.00	4.02	4.11	3.26	3.38	3.29	18.8539	2.5	2.5	4.16	2.60	4.36	4.25	4.45	3.25	3.25	3.25	19.4494	19.15	43.61	24.46

CIE (Mid Exam) CO Wise Percentage

COURSE OUTCOME	CO Wise Sum	CO Wise Percentage %
CO1	10.32	82.56
CO2	8.53	68.27
CO3	11.11	88.85
CO4	8.34	66.74
Average	9.58	76.61

CIE - CO Wise Sum Formula

CO1 = ASG(CO1) + Q1(CO1) + BestOfQ2&Q3(CO1)
CO2 = ASG(CO2) + Q1(CO2) + BestOfQ4&Q5(CO2)
CO3 = ASG(CO3) + Q1(CO3) + BestOfQ2&Q3(CO3)
CO4 = ASG(CO4) + Q1(CO4) + BestOfQ4&Q5(CO4)

CIE - CO Wise Percentage

CO1 % = (CO1 SUM/total CO1 Marks(12.5))*100
CO2 % = (CO2 SUM/total CO2 Marks(12.5))*100
CO3 % = (CO3 SUM/total CO3 Marks(12.5))*100
CO4 % = (CO4 SUM/total CO4 Marks(12.5))*100

Average Marks	24.46
Student Count >Avg	37
Total Students	89
Percentage	41.573

SEE (End Exam) CO Wise Percentage

CO1-CO4	24.46	41.57

SEE - CO Wise Percentage

CO1-CO4 = End Exam Avg Marks

SEE - CO Wise Percentage

CO1-CO4 % = (End Exam Avg Marks/75)*100

CO ATTAINMENT	Internal Marks %	Internal Attainment	External Marks %	External Attainment	DIRECT ATTAINMENT LEVEL
CO1	83	3	41.57	1	1.5
CO2	68	2	41.57	1	1.25
CO3	89	3	41.57	1	1.5
CO4	67	2	41.57	1	1.25
Average					1.375

INTERNAL EXAM ATTAINMENT LEVEL SCALE

Attainment Levels	0	<=49
	1	50-64
	2	65-79
	3	>=80

EXTERNAL EXAM / FINAL ATTAINMENT LEVEL SCALE

Attainment Levels	0	<=34
	1	35-44
	2	45-54
	3	>=55

Direct Attainment Level

CO1=(CO1IntAtn*0.25+CO1ExtAtn*0.75)
CO2=(CO2IntAtn*0.25+CO2ExtAtn*0.75)
CO3=(CO3IntAtn*0.25+CO3ExtAtn*0.75)
CO4=(CO4IntAtn*0.25+CO4ExtAtn*0.75)

CO-PO Matrix

Course	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	Attainment
CO1	3	2	1	1	1	2	2	0	1	1	1	2	1	1	1	1.5
CO2	3	3	3	3	2	2	2	0	1	2	2	2	2	2	2	1.25
CO3	3	3	2	3	2	1	1	0	1	1	2	2	2	2	2	1.5
CO4	3	3	3	3	3	3	3	1	2	2	2	3	3	3	3	1.25
Average	3.00	2.75	2.25	2.50	2.00	2.00	2.00	1.00	1.25	1.50	1.75	2.25	2.00	2.00	2.00	1.38

Final Attainment %

C01 = (DIRECT ATTAINMENT*0.8) + (INDIRECT ATTAINMENT*0.2)
C02 = (DIRECT ATTAINMENT*0.8) + (INDIRECT ATTAINMENT*0.2)
C03 = (DIRECT ATTAINMENT*0.8) + (INDIRECT ATTAINMENT*0.2)
C04 = (DIRECT ATTAINMENT*0.8) + (INDIRECT ATTAINMENT*0.2)

Course PO Attainments

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
[illegible]	1.38	1.26	1.03	1.15	0.92	0.92	0.92	0.46	0.57	0.69	0.80	1.03	0.92	0.92	0.92
[illegible]	1.38	1.32	1.23	1.26	1.15	1.15	1.15	0.92	0.97	1.08	1.09	1.20	0.99	1.15	1.15
[illegible]	1.38	1.27	1.07	1.17	0.96	0.96	0.96	0.55	0.65	0.76	0.86	1.07	0.93	0.96	0.96

PO ATTAINMENTS

DIRECT ATTAINMENT (PO1)= (Average of PO1*Average of CO Direct Attainment)/3
Similar for PO2 TO PO12 & PSO1 TO PSO3
INDIRECT ATTAINMENT (PO1) = (Average of PO1*Average of CO Direct Attainment)/2
Similar for PO2-PO12 & PSO1 TO PSO3
FINAL ATTAINMENT = (DIR ATNM-PO1)*0.8 + (INDIR ATNM-PO1)*0.2