



# STUDENT HAND BOOK

Bachelor of Technology

Semester- 7<sup>th</sup>

Study Scheme- 2011 onwards

DEPARTMENT OF MECHANICAL  
ENGINEERING

**ASRA COLLEGE OF ENGINEERING &  
TECHNOLOGY**

**BHAWANIGARH (SANGRUR)**

**Department of Mechanical Engineering**

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## **BTME 801 INDUSTRIAL ENGINEERING & MANAGEMENT**

**1. Introduction:** Definition and scope of industrial engineering, Functions of industrial engineering department and its organization, Qualities of an industrial engineer, concept of production and productivity.

### **2. Concepts of Management:**

Functions of Management, Evolution of Management Thought : Taylor's Scientific Management, Fayol's Principles of Management, Douglas Mc-Gregor's Theory X and Theory Y, Mayo's Hawthorne Experiments, Herzberg's Two Factor Theory of Motivation, Maslow's Hierarchy of Human Needs – Systems Approach to Management.

**3. Designing Organizational Structures:** Concept, Importance and characteristics of organization, Types of organization - Project, matrix and informal organization. Span of control, Delegation of authority.

**4. Management Planning, Decision Making and Control:** Steps, hierarchy, principles and dimensions of planning function, Approaches to decision making, Decision support systems, Basic control process, control parameters, principles of control.

**5. Plant Location & Layout:** Plant location: definition, factors affecting the plant location, comparison of rural and urban sites-methods for selection. Plant layout: Needs for a good layout, Different types viz. Product, process and combination layouts, Introduction to layouts based on the GT, JIT and cellular manufacturing systems, Development of plant layout.

**6. Productivity:** Definition, reasons for low productivity, methods to improve productivity, relation between work-study and productivity.

**7. Work Analysis:** Definition, need and scope of Work Analysis. Method-study: Definition, objectives, step-by-step procedure, questioning techniques, charts and diagrams for recording data. Principles of motion economy; Development and installation of new method. Work-measurement: Definition, various techniques of work-measurement such as work-sampling, stopwatch time study & its procedure, Job selection, Equipment and Forms used for work measurement, need for rating operator, methods of rating, allowances and their types, standard time. Standard data techniques.

**8. Value Engineering:** Definition, Types of values, concept, phases and application of value engineering.

## **BTME 802 REFRIGERATION AND AIRCONDITIONING**

**1. Basic Concepts:** Definition of Refrigeration and Air conditioning; Difference between Refrigeration and cooling; Difference between Refrigeration and Air conditioning; Brief history of Refrigeration and Airconditioning; Natural and Mechanical Refrigeration; Applications of Refrigeration and Airconditioning; Definitions of refrigerant, cooling/ Refrigeration effect, cooling capacity, heating effect, heating capacity; Units of refrigeration; Coefficient of performance and Energy Efficient Ratio; COP of a refrigerator; and COP/EPR of a heat pump; Single Phase Reversed Carnot cycle and its limitations; Two Phase Reversed Carnot cycle and its limitations; Methods of Refrigeration; Numerical.

**2. Gas Cycle Refrigeration and Aircraft Refrigeration & Air conditioning:** Bell Coleman/Reversed Brayton/ Reversed Joule Cycle and its analysis; Numerical; optimum COP and pressure ratio (No mathematical Analysis); Applications of Gas Cycle Refrigeration; Necessity of aircraft refrigeration and air conditioning; Classification of aircraft refrigeration and air conditioning systems; Simple/basic aircraft refrigeration and air conditioning system (with and without evaporative cooler); Need of evaporator cooler; Boot Strap aircraft refrigeration and air conditioning system (with and without evaporative cooler); Regenerative aircraft refrigeration and air conditioning system; Reduced Ambient aircraft refrigeration and air conditioning system; Dry Air Rated Temperature (DART); Comparison of different aircraft refrigeration and air conditioning systems; Numerical.

**3. Vapour Compression Refrigeration Cycle:** Vapour compression refrigeration system and its basic components; Representation of Simple/Theoretical vapour compression refrigeration cycle on P-v, T-s and P-h diagrams; Dry versus wet compression; expansion versus throttling of liquid refrigerant; Analysis of Simple/Theoretical vapour compression refrigeration cycle; Introduction of P-h diagram/chart and Refrigeration Tables; Determination of properties of sub cooled, saturated and superheated refrigerant by using saturated properties & specific heat tables/saturated & superheated properties tables and P-h diagram; Compressor work and volumetric efficiency; Effect on performance and cooling capacity due to change in evaporator pressure, condenser pressure, subcooling of liquid refrigerant, super heating of suction vapours, use of liquid - vapour regenerative heat exchanger; Effect on performance and cooling capacity due to heat exchange of vapours with compressor cylinder walls, pressure drop in suction (wire drawing) and discharge valves, pressure drop in evaporator and condenser; Actual vapour compression refrigeration cycle on T-s and P-h diagrams (No mathematical analysis); Numericals. Flash gas, its advantages and disadvantages, and its removal: flash chamber, liquid sub-cooler; Brief introduction (no mathematical analysis) to compound (multistage) compression, its advantages, schematic representation of these systems with use of flash chamber, water intercooler, flash intercooler, liquid sub-cooler (independent and combination of these); Brief introduction (no mathematical analysis) to multiple evaporator systems, schematic representation

of these systems with use of individual and multiple expansion valves arrangements, with single and multiple (individual and compound) compressor.

**4. Vapour Absorption Refrigeration Cycle (No Mathematical Analysis):** Principle of vapour absorption refrigeration; basic components of the vapour absorption refrigeration system; Desirable properties of absorption system refrigerant and absorbent; Aqua-ammonia vapour absorption refrigeration system; Lithium Bromide - water absorption system (Single and double effect); Electrolux refrigeration system; comparison between vapour absorption and compression systems.

#### **5. Refrigerants:**

Classification and nomenclature of refrigerants; Desirable thermodynamic, chemical and physical properties of refrigerants; comparative study of commonly used refrigerants and their fields of application; Azeotropes; Zeotropes; Effect of moisture and oil miscibility; Refrigerants dyeing agents and antifreeze solution; leak detection and charging of refrigerants; environmental aspects of conventional refrigerants; Ecofriendly refrigerants and action plan to reduce ecological hazards.

**6. Alternative Refrigeration Systems and Low Temperature Refrigeration:** (No Mathematical Analysis) Steam Jet Refrigeration; Mixed Refrigeration Systems; Vortex Tube Refrigeration, Thermoelectric cooling; Transcritical Carbon Dioxide Compression Refrigeration; Cascade Refrigeration System; Linde and Claude cycles, cryogenics and its engineering applications.

**7. Air Conditioning Concepts and Applications:** Psychrometry; Dry Air; Moist Air; Basic laws obeyed by Dry Air and Moist Air; Psychrometric properties of air: Dry bulb, wet bulb and dew point temperatures, Relative and specific humidity, degree of saturation adiabatic saturation temperature, enthalpy of air and water vapours; Psychrometric chart and its use; Adiabatic mixing of moist air streams without condensation and with condensation; Numerical. Human requirement of comforts; effective temperature and comfort charts; Industrial and comfort air conditioning.

**8. Psychrometric Processes:** Basic psychrometric processes; Sensible heat process; Latent heat process; Total heat process; Sensible heat factor; Evaporative cooling; cooling with dehumidification; Heating with dehumidification; chemical dehumidification; By-pass factor; Contact factor; Psychrometric processes in air conditioning equipment: Cooling coils, Heating coils, cooling and dehumidification coils, Evaporative coolers, Adiabatic dehumidifiers, Steam injection, Airwasher; Numerical.

**9. Calculations for Air conditioning Load and for Rate and state of Supply Air:** Sources of heat load; sensible and latent heat load; Cooling and heating load estimation; Apparatus dew point temperature; Rate and state of supply air for air conditioning of different types of premises; Numerical

**10. Refrigeration and Air Conditioning Equipment:** Brief description of compressors, condensers, evaporators and expansion devices; Cooling towers; Ducts; dampers; grills; air filters; fans; room air conditioners; split units; Package and central air conditioning plants.

## **BTME 803 MECHANICAL VIBRATIONS**

**1. Introduction:** Basic concepts, Types of vibration, Periodic & Harmonic vibrations, Methods of vibration analysis

**2. Vibration of Single Degree of Freedom System:** Undamped free vibrations, damped free vibrations and damped force vibration system, Modelling of stiffness and damping (both viscous and coulomb), estimation of damping by decay plots, vibration isolation transmissibility, vibration measuring instruments.

**3. Two degrees of Freedom systems:**

a) Principal modes of vibrations, natural frequencies, amplitude ratio, undamped free, damped free, forced harmonic vibration, semi-definite systems, combined rectilinear & angular modes; Lagrange's equation.

b) Application to un-damped and damped absorbers: Vibration absorber – principle; centrifugal pendulum vibration absorber, torsional vibration damper, untuned dry friction and viscous vibration damper, torsional vibration absorber.

**4 Multi-degree of freedom systems:** Undamped free vibrations, influence coefficients, Generalised coordinates, orthogonality principal, matrix iteration method, Rayleigh and Dunkerley, Holzer's, Stodola method, Eigenvalues and eigen vectors

**5. Continuous systems:** Lateral vibrations of a string, longitudinal vibrations of bars, transverse vibrations of beams, Euler's equation of motion for beam vibration, natural frequencies for various end conditions, torsional vibration of circular shafts

## **HU-251 HUMAN RESOURCE MANAGEMENT**

**Introduction:** Introduction to Human Resource Management and its definition, functions of Human Resource Management & its relation to other managerial functions. Nature, Scope and Importance of Human Resource Management in Industry, Role & position of Personnel function in the organization.

**Procurement and Placement:** Need for Human Resource Planning; Process of Human Resource Planning; Methods of Recruitment; Psychological tests and interviewing; Meaning

and Importance of Placement and Induction, Employment Exchanges (Compulsory Notification of vacancies) Act 1959, The Contract Labour (Regulation & Abolition) Act 1970.

**Training & Development:** Difference between training and Development; Principles of Training; Employee Development; Promotion-Merit v/s seniority Performance Appraisal, Career Development & Planning.

**Job analysis & Design: Job Analysis:** Job Description & Job Description, Job Specification.

Job Satisfaction: Job satisfaction and its importance; Motivation, Factors affecting motivation, introduction to Motivation Theory; Workers ' Participation, Quality of work life.

**The Compensation Function:** Basic concepts in wage administration, company's wage policy, Job Evaluation, Issues in wage administration, Bonus & Incentives, Payment of Wages Act-1936, Minimum Wages Act-1961

**Integration:** Human Relations and Industrial Relations; Difference between Human Relations and Industrial Relations, Factors required for good Human Relation Policy in Industry; Employee Employer relationship Causes and Effects of Industrial disputes; Employees Grievances & their Redressal, Administration of Discipline, Communication in organization, Absenteeism, Labour Turnover, Changing face of the Indian work force and their environment, Importance of collective Bargaining; Role of trade unions in maintaining cordial Industrial Relations.

**Maintenance:** Fringe & retirement terminal benefits, administration of welfare amenities, Meaning and Importance of Employee Safety, Accidents-Causes & their Prevention, Safety Provisions under the Factories Act 1948; Welfare of Employees and its Importance, Social security, Family Pension Scheme, ESI act 1948, Workmen's Gratuity Act 1972, Future challenges for Human Resource Management.

## **DE/PE-2.0 Non Traditional Machining Processes**

Internal Marks: 40 External Marks: 60 Total Marks: 100

### **1. Introduction:**

Latest trends in Manufacturing, Introduction to Flexible manufacturing system, Introduction to computer integrated manufacturing, Limitations of conventional machining processes, Development of Non conventional machining processes, their classification, advantages and major applications

### **2. Advanced Mechanical Processes:**

Ultrasonic machining, Water Jet Machining and Abrasive Flow Machining-elements of process, Applications and limitations

### **3. Electrochemical & Chemical Removal Processes:**

Principle of operation, elements and applications of Electrochemical Machining, Electrochemical grinding, Electrochemical deburring, Electrochemical honing, Chemical Machining, Photochemical machining

### **5. Thermal Metal Removal Processes:**

Electric Discharge Machining- Mechanism of metal removal, electrode feed control, dielectric fluids flushing, selection of electrode material, applications. Plasma Arc Machining- Mechanism of metal removal, PAM parameters, Equipment's for unit, safety precautions and applications. Laser Beam machining- Material removal, limitations and advantages. Hot machining- method of heat, Applications and limitations. Electron-Beam Machining-, Generation and control of electron beam, process capabilities and limitations

### **6. Hybrid Machining Processes:**

Concept, classification, application, Advantages

## **BTME 804 REFRIGERATION AND AIRCONDITIONING LAB**

1. Study of various elements of a vapour compression refrigeration system through cut sections models / actual apparatus.
2. Study and performance testing of domestic refrigerator.
3. Study the performance testing of Electrolux refrigerator.
4. Study and performance testing of an Ice plant.
5. Calculation/ Estimation of cooling load for a large building.
6. Visit to a central Air conditioning plant for study of processes for winter and summer air conditioning
7. Visit to a cold storage for study of its working.
8. Study and performance testing of window type room air conditioner.
9. Study and performance testing of water cooler.

## **Mechanical Vibration Lab**

### **LIST OF EXPERIMENTS**

1. To verify the relation of simple pendulum.
2. To determine the radius of gyration 'k' of a given compound pendulum.
3. To determine the radius of gyration of given bar by using bi-flier suspension.
4. To study the torsional vibrations of single rotor system.
5. To study the free vibration of two rotor system and to determine the natural frequency of vibration theoretically & experimentally.
6. To study the damped torsional oscillation & to determine the damping coefficient.
7. To verify the Dunkerley's Rule Viz.
8. To study the longitudinal vibration of helical spring and to determine the frequency and time period of oscillation theoretically and actually by experiment.
9. To study the undammed free vibration of equivalent spring mass system.
10. To study the forced damped vibration of equivalent spring mass system.
11. To study the forced vibration of the beam for different damping.

## **BTME 801 INDUSTRIAL ENGINEERING & MANAGEMENT**

### **Assignment No. 1**

1. What should be the qualities of an industrial engineer?
2. What are the various functions of industrial engg. Department?
3. Enlist various strategies of improving productivity and discuss any four.
4. What are the advantages of higher productivity? Alos explain the reasons for low productivity.

### **Assignment No.2**

1. Discuss the procedure of method study.
2. Explain the following recording techniques along with their significance, construction and applications?
  - (a) Flow chart process
  - (b) Man-machine chart

- (c) Travel chart
- (d) Two hand process chart
- 3. Explain how the standard time is calculated.
- 4. Explain the various techniques of work-measurement and their applications.

### **Assignment No.3**

- 1. Define value. What are various types of values? Give examples.
- 2. Discuss various types of plant layouts.
- 3. Compare rural and urban site methods for selection of plant location?
- 4. What is group technology?

### **Assignment No. 4**

- 1. What are Fayol's principles of management?
- 2. Discuss Maslow's Hierarchy of human needs.
- 3. Discuss Douglas Mc-Gregor's Theory X and Theory Y.

### **Assignment No.5**

- 1. Explain various types of organizations?
- 2. What are the various steps and principles of planning functions?
- 3. What is the basic control process and its parameters?
- 4. What are the various approaches to decision making?

## **BTME 802 REFRIGERATION AND AIRCONDITIONING**

### **Assignment no. 1**

- 1. Define the following terms
  - a) Refrigeration
  - b) Natural and mechanical refrigeration
  - c) Tonne of refrigeration
  - d) Refrigeration effect
  - e) COP
- 2. Drive the expression for the C.O.P of Bell Coleman cycle when the process is carried out polytropically?

3. Write the limitations of reversed Carnot cycle?
4. Differentiate bet'n the following
  - a) Air refrigeration system & Vapour compression refrigeration system
  - b) Heat engine and heat pump.
  - c) Open cycle and closed refrigeration system.
5. Describe with a sketch a boot strap cycle of air refrigeration system.
6. Describe with the sketch a regenerative air cooling system.

**Assignment no. 2**

1. Describe the mechanism of a simple Vapour compression refrigeration system along with the P-H & T-S diagram?
2. 28 tonnes of ice from and at 0°C is produced per day in an ammonia 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 an expansion valve is used. Assuming the COP of 62% of the theoretical calculate the power required for driving the compressor.

Temp. °C	Enthalpy(k J/kg)		Entropy of liquid	Entropy of Vapour
	Liquid	Vapour	kJ/kg K	kJ/kg K
25	100.0	1319.22	0.3473	4.4852
-15	-54.56	1304.99	-2.1338	5.0858

Take the latent heat of ice = 335 KJ/Kg

3. Describe with the help of schematic & P-H Diagram the working of two stage compression system with water intercooler, liquid intercooler & liquid flash chamber?
4. A two stage compression ammonia refrigerating system with intercooler working between the pressure limits of 1.55 bar and 14 bar, is used to take a load of 50TR. The intercooler pressure is 4.92 bar. The ammonia is cooled to 32°C in water intercooler and sub cooled as liquid to 30°C. find
  - a. The rate of ammonia circulation per minute
  - b. Power required to drive the compressors
  - c. C.O.P. of the system
5. A single compressor system using R-12 as refrigerant has three evaporators of capacity 20 TR, 30 TR and 10 TR. The temperature in the three evaporators is to be maintained at -5°C, 0°C and 7°C respectively. The system is provided with multiple expansion valve and back pressure valve. The condenser pressure is 9.609 Bar. The liquid refrigerant leaving the condenser is sub-cooled to 30°C. the Vapour leaving the evaporator are dry and saturated. Assuming isentropic compression , find
  - a. Mass of refrigerant flowing through each evaporator
  - b. Power required to drive the compressor
  - c. C.O.P. of the system.
6. Draw and explain the schematic diagram of a refrigerating system having three evaporators at different temperature with single compressor, multiple expansion valve and back pressure valve. Explain its working with the help of P-H Diagram.

### **Assignment no. 3**

1. Compare VAR system with VCR System
2. Explain with a neat sketch of the working of  $\text{NH}_3\text{-H}_2\text{O}$  VAR system & Write its applications.
3. Define refrigerant. Write the desirable properties of ideal refrigerant.
4. Write the short note on R-12 and R-22 as a refrigerant.
5. What is an azeotrope? Give some example to indicate its importance.
6. Draw the neat diagram of lithium bromide water absorption system & explain its working. List the major field applications of this system.
7. Enumerate the various leak detection techniques of the refrigerant.

### **Assignment no. 4**

1. Draw the neat sketch of Linde and Claude cycles and compare both cycles in their construction.
2. Explain with a neat sketch the working of thermostatic expansion valve.
3. Give the brief description of any two of the following refrigeration and air conditioning equipment: (a) Rotary compressors, (b) Flooded expansion valve, (c) Natural draft cooling towers.
4. Give the brief description of any two of the following refrigeration and air conditioning: (a) Hermetically sealed Reciprocating compressors, (b) Shell and Tube condensers, (c) Package air conditioning units.
5. Write a short note on the following: (a) Expansion devices .(b) Window & Package air conditioning system
6. Explain Cascade refrigeration system and also give its advantages.
7. Discuss in detail the role of ducts, dampers and air filters in air conditioning system.

### **Assignment no.5**

1. Define the following terms
  - a. Dry air
  - b. Moist air
  - c. Saturated air
  - d. Degree of saturation
  - e. Humidity
  - f. Absolute humidity
  - g. Relative humidity
2.  $40 \text{ m}^3$  of air at  $35^\circ\text{C}$  DBT and 50% RH is cooled  $25^\circ\text{C}$  DBT maintaining its specific humidity as constant. Calculate the (a) Relative humidity (RH) of cooled air. (b) Heat removed from air.
3. One kg of air at  $40^\circ\text{C}$  dry bulb temperature and 50% relative humidity is mixed with 2 kg of air at  $20^\circ\text{C}$  dry bulb temperature and  $20^\circ\text{C}$  dew point temperature. Calculate the temperature and specific humidity of the mixture.
4. Discuss in detail the various factors affecting the human comfort.
5. A small office hall of 25 persons capacity is provided with summer air conditioning system with the following data:

Outside conditions	= $34^\circ\text{C}$ DBT and $28^\circ\text{C}$ WBT
Inside conditions	= $24^\circ\text{C}$ DBT and 50% RH

Volume of air supplied =  $0.4 \text{ m}^3/\text{min}/\text{person}$   
Sensible heat load in room =  $125600 \text{ KJ/h}$   
Latent heat load in room =  $42000 \text{ KJ/h}$   
Find the sensible heat factor of the plant.

6. A hall is to be maintained at  $24^\circ\text{C}$  dry bulb temperature and 60% relative humidity under the following conditions:

Outdoor conditions =  $38^\circ\text{C}$  DBT and  $28^\circ\text{C}$  WBT

Sensible heat load in the room =  $46.4 \text{ KW}$

Latent heat load in the room =  $11.6 \text{ KW}$

Total infiltration air =  $1200 \text{ m}^3/\text{h}$

Apparatus dew point temperature =  $10^\circ\text{C}$

Quantity of recirculated air from hall = 60%

If the quantity of recirculated air is mixed with the conditioned air after the cooling coil. Find the following:

- The condition of air leaving the conditioner coil and before mixing with the recirculated air
- The condition of air before entering to the hall.
- The mass of air entered the cooler.
- The of total air passing through the hall.
- The by-pass factor of the cooling coil.
- The refrigeration load on the cooling coil in tonnes of refrigeration.

## **BTME 803 MECHANICAL VIBRATIONS**

### **ASSIGNMENT NO. 1**

Q.1 What is the importance of vibration

Q.2 Explain different methods of vibration analysis

Q.3 Explain the different types of vibration

Q.4 Derive the relation for the work done by the harmonic force

### **ASSIGNMENT NO. 2**

Q.1 What do you mean by undamped free vibration

Q.2 Derive the relation for the frequency of spring mass system in vertical position

Q.3 What is damping and classify different types of damping

Q.4 Define proportional damping and modal damping ratio

### **ASSIGNMENT NO. 3**

Q.1 What are forced vibration

Q.2 Derive that relation for displacement transmissibility in case of support motion

Q.3 Write short notes on

1) vibrometer

2) Accelerometer

Q.4 Prove that natural frequency of centrifugal pendulum absorber is always proportional to the speed of rotating body

### **ASSIGNMENT NO. 4**

Q.1 Define the term Influence coefficient

Q.2 Explain Dunkerley's method

Q.3 Explain Holzer method

Q.4 What is orthogonality principle

Q.5 Explain Rayleigh's method

### **ASSIGNMENT NO. 5**

Q.1 Define the continuous system

Q.2 Derive suitable expression for longitudinal vibration for a rectangular uniform cross-section bar of length  $L$  fixed at one end and free at other end

Q.3 Derive the frequency equation for longitudinal vibration for a free-free beam with zero initial displacement

Q.4 Derive the frequency equation for torsional vibration for a free-free shaft of length  $L$

## **HU-251 HUMAN RESOURCE MANAGEMENT**

### **ASSIGNMENT NO. 1**

1. Define HRM & discuss the difference between Personnel management and HRM.
2. Discuss the importance of HRM and explain the role of HR manager.

3. What is the nature of HRM? Also explain the scope of HRM.
4. Explain the objectives of manpower planning.

#### **ASSIGNMENT NO. 2**

1. Discuss the Principles of interviewing.
2. Explain the term training in HRM in detail.
3. Explain various phases of training.
4. What is management development? Briefly describe the techniques used in this programme.
5. Discuss interview process.
6. Discuss various characteristics of a good recruitment policy.

#### **ASSIGNMENT NO. 3**

1. What is job analysis? Describe the importance. Discuss the procedure of job analysis.
2. Explain job evaluation and its methods in detail.
3. Define wages. How do they differ from salary?
4. Discuss financial and non-financial incentives.
5. Define motivation. Discuss the nature and characteristics of motivation?
6. Write a short note on the minimum wages act, 1948.
7. Write a short note on the payment of wages act, 1948.

#### **ASSIGNMENT NO. 4**

1. What are the causes of absenteeism?
2. Define labour turnover. What are its causes? How can it be controlled?
3. What do you understand by industrial relations? Discuss the importance of good industrial relations.
4. Write a short note on 'the contract labour act, 1970'.
5. What is meant by employee safety? Give causes of industrial accidents.

6. Define industrial disputes. Explain the different causes & effects of industrial disputes in india.

## **DE/PE-2.0 Non Traditional Machining Processes**

### **ASSIGNMENT:-1**

1. Tabulate the Material application for various non traditional machining processes.
2. Brief about material removal volume in brittle and ductile materials.
3. Differentiate the characteristics of conventional and non traditional machining process.
4. What is the need for non traditional machining process?

### **ASSIGNMENT:-2**

1. Write the MRR for ultrasonic machining process.
2. Explain the effect of operating parameters on ultrasonic machining process.
3. Draw the Abrasive Jet Machining equipment and explain its working process.
4. Write the Abrasive Jet Machining process variables.
5. Derive the material removal rate (MRR) in Abrasive Jet Machining

### **ASSIGNMENT:-3**

1. Explain Principle of operation, elements and applications of Electrochemical Machining.
2. Explain Electrochemical grinding
3. Explain Electrochemical deburring,
4. Define Electrochemical honing.
5. Explain Chemical Machining

### **ASSIGNMENT:-4**

1. Explain Photochemical machining with diagram
2. Explain in detail Electric Discharge Machining with neat diagram.
3. Explain Plasma Arc Machining and leaser beam machine.
4. Explain Electon-Beam Machining

### **ASSIGNMENT:-5**

1. Explain Hybrid Machining Processes:
2. Classification of Hybrid Machining Processes
3. Application of Hybrid Machining Processes
4. Advantages and dis-advantage Hybrid Machining Processes

## BTME 805 Mechanical Vibration Lab

### EXPERIMENT NO. 1

**OBJECTIVE:** TO VERIFY THE RELATION OF SIMPLE PENDULUM

$$T = 2\pi\sqrt{L/g}$$

Where T= Periodic time in sec.

L= Length of Pendulum in cm.

### DESCRIPTION:

For conduction the experiment, a ball is supported by nylon thread into a chuck. It is possible to change the length of pendulum. This makes it possible to study the effect of variation of length on periodic time. A small ball may be substituted by large ball to illustrate that period of oscillating that period of oscillation is independent of the mass of ball.

### UTILITIES REQUIRED:

- Pace Required : 0.90 \* 1.30m
- Power supply: 220volt, single phase, 5Amp. Socket

### EXPERIMENTAL PROCEDURE:

- Attach the ball to one end of the thread.
- Allow ball to oscillate and determine the periodic time T by knowing the time for say 10 oscillations.
- Repeat the experiment by changing the length.
- Complete the observation table given below.

### Standard Data:

Acceleration due to gravity,  $g = 9.81\text{m/s}^2$

Formulae:

1. Time Period,  $T_{\text{actual}} = t/n$  sec.
2. Time Period,  $T_{\text{theo.}} = 2\pi\sqrt{L/g}$  sec.

Where

- T = Time taken by 'n' oscillations.
- N = Nos. of oscillation.
- L = Length of the pendulum.

### OBSERVATION AND CALCULATION TABLE:

Sr. No.	L cm.	No. Of Osco 'n'	Time for n Osco. 'T' Sec.	T sec. (Act.) t/n	T Sec. (Theo)
1.					
2.					
3.					
4.					

## EXPERIMENT NO. 2

### OBJECTIVE:

- TO DETERMINE THE RADIUS OF GYRATION 'K' OF A GIVEN COMPOUND PENDULUM.
- TO VERIFY THE RELATION OF COMPOUND PENDULUM.

$$T = 2\pi\sqrt{(k^2 + (OG)^2/g (OG))}$$

Where

- T = Periodic time in sec.
- K = Radius of gyration about the C.G in cm.
- OG = Distance of C.G. of the rod from support.
- L = Length of suspended pendulum.

### DESCRIPTION:

The compound pendulum consists of a steel bar. The bar is suspended by knife – edge. Two pendulums of different lengths are provided with the set – up.

### EXPERIMENTAL PROCEDURE:

- Support the rod on knife - edge.
- Note the length of suspended pendulum and determine T by knowing the time for say 10 oscillations.
- Repeat the experiment with different length of suspension.
- Complete the observation table given below.

Standard Data:

Length of compound pendulum (1) = \_\_\_\_\_ cm.

Length of compound pendulum (2) = \_\_\_\_\_ cm.

Formulae:

1. Actual time period,  $T_{act} = t/n$

2. Actual radius of gyration,  $k_{act}$  from the equation

$$2\pi\sqrt{(k^2 + (OG)^2/g (OG))}$$

3. Theoretical radius of gyration,  $k_{Theo} = L/2\sqrt{3}$

T =

**OBSERVATION AND CALCULATION TABLE:**

Sr. No.	L cm.	OG	No. Of Osco N	Time for Osco.	T sec. act.	K act.	K Theoretical
1.							
2.							
3.							
4.							

**EXPERIMENT NO. 3**

**OBJECTIVE:** TO DETERMINE THE RADIUS OF GYRATION OF GIVEN BAR BY USING BI-FLIER SUSPENSION

**DESCRIPTION:**

A uniform rectangular section bar is suspended from the pendulum support frame by two parallel cords. Top ends of the cords pass through the two small chucks fitted at the top. Other ends are secured in the Bi-Flier bar. It is possible to adjust the length of the cord by loosening the chucks. The suspension may be used to determine the radius of gyration of any body. In this case the body under investigation is bolted to the center. Radius of gyration of the combined bar and body is then determined.

**EXPERIMENTAL PROCEDURE:**

- Suspend the bar from chuck, and adjust the length of the cord 'L' conveniently. Note the suspension length of each cord must be same.
- Allow the bar to oscillate about the vertical axis passing through center and measure the periodic time T by knowing the time for say 10 oscillations.
- Repeat the experiment by mounting the weights at equal distance from center.
- Complete the observation table given below.

Standard Data:

Distance between the 2 cords (2a) = 46cm.

1. Actual time period,  $T_{act}$  = t/n sec.

2. Actual radius of gyration,  $k_{act}$  from equation  

$$T = 2\pi \sqrt{\frac{k^2}{a^2} + \frac{L}{g}}$$

3. Theoretical radius of gyration,  $k_{Theo}$  =  $L/2\sqrt{3}$

Where

- N = nos. of oscillation  
 T = time taken by 'n' oscillation  
 L = length of the suspended string  
 2a = distance between the two string  
 g = acceleration due to gravity

k = radius of gyration of Bi-Flier suspension.

**OBSERVATION AND CALCULATION TABLE:**

Sr. No.	L cm.	2a cm.	No. Of Oscial	Time of Oscial.	T <sub>act.</sub>	k <sub>act.</sub>	k <sub>Theo</sub>
1.							
2.							
3.							
4.							

**EXPERIMENT NO. 4**

**OBJECTIVE:** TO STUDY THE TORSIONAL VIBRATIONS OF SINGLE ROTOR SYSTEM.

**DESCRIPTION:**

In this experiment one end of the shaft is gripped in the chuck and heavy flywheel free to rotate in ball bearing is fixed at the other end of the shaft. The bracket with fixed end of the shaft can be clamped at any convenient position along beam. Thus length of the shaft can be varied during the experiments. The ball bearing housing is fixed to side member of the main frame.

**EXPERIMENTAL PROCEDURE:**

- Fix the bracket at convenient position along the lower beam.
- Grip one end of the shaft at the bracket by chuck.
- Fix the rotor on the outer end of the shaft.
- Twist the rotor through some angle and release.
- Note down the time required for 10, 10 oscillations.
- Repeat the procedure for the different length of shaft.

Standard Data:

- a). Shaft Dia. = 3mm
- b). Dia. of Disc, D = 190mm
- c) Wt. of the Disc, w = 2.1kg.
- d) Modulus of rigidity for Shaft =  $0.8 \times 10^6 \text{ Kg/Cm}^2$
- e) Acceleration due to gravity,  $g = 9.81 \text{ m/s}^2$

- 1). Torsional stiffness,  $k_1 = GIp/L$
- 2). Theoretical Time period,  $T_{\text{Theo}} = 2\pi\sqrt{I/kt}$
- 3). Moment of inertia of disc,  $I = w/g \cdot d^2/8$
- 4). Actual time period,  $T_{\text{exp}} = t/n$

5). Theoretical Frequency,  $f_{\text{theo}} = 1/T_{\text{theo}}$

6). Actual frequency,  $f_{\text{Exp}} = 1/T_{\text{exp}}$

Where

L = Length of shaft

$L_p = \text{Polar M.L. of shaft} = d^4/32$

D = Dia. Of shaft.

G = Modulus of rigidity of shaft =  $0.8 \times 10^6 \text{ Kg/Cm}^2$

W = Weight of the disc in Kg

D = Diameter of disc.

**OBSERVATION TABLE:**

Sr. No.	Length of shaft-L cm.	No. of Osco. N	Time for n osco. T sec	Periodic time T = t/n(act.)
1.				
2.				
3.				
4.				

**CALCULATION TABLE:**

Sr. No.	Length of shaft cm.	$K_t$	$T_{\text{Theo. sec}}$	$T_{\text{act. sec}}$	$F_{\text{Theo. hz}}$	$F_{\text{act. hz}}$
1.						
2.						
3.						
4.						

**EXPERIMENT NO. 5**

**OBJECTIVE:** TO STUDY THE FREE VIBRATION OF TWO ROTOR SYSTEM AND TO DETERMINE THE NATURAL FREQUENCY OF VIBRATION THEORETICALLY & EXPERIMENTALLY.

**DESCRIPTION:**

In this experiment two discs having different mass moments of inertia are clamped one at each of the shaft by means of collect and chucks. Attaching the cross lever weights can be changed

Mass moment of inertia of an disc. Both discs are free to oscillate in ball bearing. This provides negligible damping during experiment.

### EXPERIMENTAL PROCEDURE:

- . Fix two discs to the shaft and fit the shaft in bearing.
- . Deflect the disc in opposite direction by hand and release.
- . Note down the required for particular number of oscillations.
- . Fit the cross arm to one of the discs says B and again notr down the time.
- . Repeat the procedure with different equal masses attached to the ends of cross arm and note down the time.

### Standard Data

1. Dia. Of Disc A = 225 mm
2. Dia. Of Disc B = 190 mm
3. Weight of Disc A = 2.5 kg
4. Weight of Disc B = 2.1 kg
5. Length of Cross Arm = 150mm
6. Dia. of Shaft = 3mm
7. Length of shaft between Rotors  $-L = 957$  mm

### FORMULAE:

- 1). Torsional stiffness,  $k_1 = GIP/L$
- 2). Polar moment of inertia,  $I_p = \pi d^4/32$
- 3). Moment of inertia of disc A,  $I_A = W_A/g * D_A^2/8$
- 4). Moment of inertia of disc B,  $I_B = W_B/g * D_B^2/8 + 2W_1/g * R^2/8$
- 5). Therotical Time period,  $T_{theo} = 2\pi \sqrt{I_A I_B / kt(I_A + I_B)}$  sec
- 6). Actual Time period,  $T_{ext} = t/n$  sec
- 7). Therotical frequency,  $f_{theo} = 1/T_{theo}$  Hz
- 8). Actual frequency,  $f_{exp} = 1/T_{exp}$  Hz

where

$G =$  modulus of rigidity of shaft  $= 0.8 * 10^6 \text{ Kg/cm}^2$

$I_A =$  M.I of disc A

$I_B =$  M.I of disc B

$d$  = shaft dia

$L$  = length of the shaft

$W_1$  = weight attached to the cross arm

$R$  = radius of the fixation of weight on the arm

Sample Calculation

**OBSERVATION TABLE:**

Sr. No.	No. of oscillations $N$	Time for $n$ Oscos. 'T' Sec.	Weight Attached (kg)	Radius of weight (cm)	$I_a$	$I_b$	T act. t/n sec.
1.							
2.							
3.							
4.							

**CALCULATION TABLE:**

Sr. No.	$I_a$ kg cm <sup>2</sup>	$I_b$ kg cm <sup>2</sup>	$T_{Theo}$ sec.	$F_{Theo}$ hz	$T_{exit}$ sec.	$F_{exit}$ sec.
1.						
2.						
3.						
4.						

**EXPERIMENT NO 6**

**OBJECTIVE:** TO STUDY THE DAMPED TORSIONAL OSCILLATION & TO DETERMINE THE DAMPING COEFFICIENT.

**OBJECTIVE**

**DESCRIPTION:**

This experiment consists of a long elastic shaft gripped at the upper end by chuck in the bracket. The bracket is clamped to the upper beam of the main frame. A heavy steel flywheel is clamped at the lower end of the shaft suspended from the bracket. A damping drum is fixed to the lower face of the flywheel. This drum is immersed in water, which provides damping. The rotor can be taken up and down for varying the depth of immersion of the damping drum.

Recording drum is mounted to the upper face of the flywheel. Paper is to be wrapped around the recording drum. Oscillations are recorded on paper with the help of specially designed piston of dashpot. This piston carries the attachment for fixing sketch pen.

### EXPERIMENTAL PROCEDURE:

- . With no water in the container allow the flywheel to oscillate & measure the time for say 10 oscillations.
- . Put thin mineral oil (no. 10 or 20) in the drum and note the depth of immersion.
- . Put the sketch pen in its bracket.
- . Allow the flywheel to vibrate.
- . Allow the pen to descend. See that the pen always makes contact with paper & record oscillation.
- . Determine i.e. amplitude at any position & Entry. amplitude after 'r' cycle.
- . After complete the experiment drain the water.

### STANDARD DATA:

G = Modulus of rigidity of shaft =  $0.8 \times 10^6 \text{ kg/Cm}^2$   
d = Shaft dia. = 3 mm  
l = Length of suspension of shaft Cm.  
W = Weight of disc. 9.500 Kg.  
D = Dia. Of disc = 25 cm.

### FORMULAE

- 1). Torsional stiffness,  $k_1 = GI_p/L$
- 2). polar moment of inertia of shaft  $I_p = \pi d^4/32$
- 3). Time period,  $T(\text{act}) = t/n$
- 4). Time period,  $T(\text{tho}) = 2\pi\sqrt{I/K_1}$
- 5). Moment of inertia of fly wheel,  $I = W/G \cdot D^2/8$
- 6). Critical damping factor,  $C_{tc} = 2W/g\sqrt{k_t/I}$
- 7). Logarithmic decrement,  $= 1/r \log_e [X_n/X_{nr}]$

Where

T = Periodic time of oscillation.

$X_n$  = Amplitude of Vibe . At the beginning of measurement to be found for record.

$X_{nr}$ . Amplitude of Vib. After 'r' cycles for record.

Sample Calculation

**OBSERVATION AND CALCULATION TABLE:**

Sr. No.	Length of suspension shaft - cm	of of	Xn (cm.)	Xntr (cm.)	No. of cycles(r)	No. of 'n' oscillations	Time of 'n' oscillations
1.							
2.							
3.							
4.							

Sr. No.	Kt	T act.	T tho.	ctc		Damping co-efficient, C <sub>t</sub>
1.						
2.						
3.						
4.						

**EXPERIMENT NO 7**

**OBJECTIVE:** TO VERIFY THE DUNKERLEY'S RULE VIZ.

$$1/F^2 = 1/F_1^2 + 1/F_b^2$$

Where:-

F = Natural frequency of given beam (considering the weight of beam) with central load W.

F<sub>L</sub> = Natural frequency of given beam (neglecting the weight of beam) with central load W.

$$F_L = \frac{1}{2\pi} \sqrt{48E.I.g/L^3W}$$

F<sub>ib</sub> = Natural frequency of the beam.

**DESCRIPTION** At rectangular bar is supported in trunion fitting at each end. Each trunion is provided in a ball bearing carried in housing. Each bearing housing is fixed to the vertical frame member. The beam carries at its center a weight platform.

### Experimental Procedure:

- . Arrange the set – up as shown in fig 10 with some wt. W clamped to wt platform.
- . Pull the platform & release it to set the system in to natural vibrations.
- . Find periodic time T & frequency of vibration F by measuring time for some oscillations.
- . Repeat experiment by putting additional masses on weight platform.
- . Plot graph of  $1/F^2$  Vs. W.

### Standard Data:

1. Length of Beam = L=105.5 cm.
2. Weight per cm of the beam = W/L
3. section of the beam = Small – 2.2 x 0.6 cm.
4. weight of the beam = Small – 1.26 Kg

### Formulae:

1. Frequency of beam  $F_L = \frac{1}{2\pi} \sqrt{48E.I.g/L^3W}$

2. Natural frequency of the beam,  $F_b = 2\pi \sqrt{g.E.I/WL^4}$

3. Moment of inertia os beam section,  $I = bh^3/12$

4. Actual Time Period,  $T_{act} = t/n$

5. Actual frequency,  $f_{acts} = 1/T_{act}$

where

w = weight os beam per unit length = 0.0119 kg/cm

E = Central load of the beam, OR weight attached.

L = Length of the beam.

B = width of beam

H = thickness of beam

### OBSERVATION AND CALCULATION TABLE:

Sr. No.	Wt. attached	No. of osc n	Time for n Osc, 't'	T act = t/n (sec)	Frequency Fact hz	F	T act. t/n
---------	--------------	-----------------	------------------------	----------------------	----------------------	---	---------------

							sec.
1.							
2.							
3.							
4.							

### EXPERIMENT NO.8

**OBJECTIVE:** TO STUDY THE LONGITUDINAL VIBRATION OF HELICAL SPRING AND TO DETERMINE THE FREQUENCY AND TIME PERIOD OF OSCILLATION THEORETICALLY AND ACTUALLY BY EXPERIMENT.

**DESCRIPTION:**

One end of open coil spring is fixed to the nut having a hole with itself is mounted on a MS strip fixed on one side of the main frame. The lower end of the spring is attached to the platform carrying the weights. The stiffness of the spring can be find out by varying the weight on the platform and by measuring the nos. of oscillation and time taken by them.

**EXPERIMENTAL PROCEDURE:**

- . Fix one end of the helical spring to upper screw.
- . Determine free length.
- . Put some weight to platform and note down the deflection.
- . Stretch the spring through some distance and release.
- . Count the time required in Sec. for say 10,20 oscillations.
- . Determine the actual period.
- . Repeat the procedure for different weights.

Standard Data.

- 1) Weights = 0.5 Kg and 1.0 kg (One each)  
 2) g = 9.81 m/Sec<sup>2</sup>

Formulae :

- 1). Stiffness,  $k = w/\Delta$  kg/cm
- 2). Mean stiffness,  $k_m = (k_1+k_2+k_3)/3$  kg/cm
- 3). Theoretical time period,  $T_{theo} = 2\pi\sqrt{W/k_m g}$
- 4). Theoretical frequency,  $f_{theo} = 1/T_{theo}$  Hz
- 5). Actual time period,  $T_{act} = t/n$  sec

6). Actual frequency,  $f_{act} = 1/T_{act}$  Hz

Where:

K = Stiffness of the spring  
 W = Weight applied  
 K m = Mean Stiffness.  
 G = Acceleration due to gravity =  $9.81 \text{ m/S}^2$   
 N = No. of oscillations.  
 T = Time taken by 'n' oscillation

**OBSERVATION & CALCULATION TABLE-1**

S.NO	Wt.Attached w kg	Deflection in spring	Stiffness k	Mean stiffness

**OBSERVATION & CALCULATION TABLE – 2**

S.NO	WT.ATTACHED Kg	W	NO. OF OSC	TIME REQD FOR OSC	N	T theo (sec)	T expt (sec)	F theo (Hz)	F expt (Hz)

**EXPERIMENT NO 9**

**OBJECTIVE:** TO STUDY THE UNDAMPED FREE VIBRATION OF EQUIVALENT SPRING MASS SYSTEM.

**DESCRIPTION:**

The equipment is designed to study free damped and undamped vibration. It consists of M.S rectangular beam supported at one end by a trunion pivoted in ball bearing. The bearing housing is fixed to the side member of the frame. The other end of beam is supported by the lower end of helical spring, upper end of the spring is attached to screw, which engage with screwed hand wheel. The screw can be adjusted vertically in any convenient position and can be clamped with the help of lock nut.

The exciter unit can be mounted at any position along the beam. Additional known weights may be added to the weight platform under side exciter .

### EXPERIMENTAL PROCEDURE :

- . Support one end of beam in the slot of trunion and clamp it by means of screw.
- . Attached the other end of the beam to lower end of spring.
- . Adjust the screw to which the spring is attached with the help of hand wheel such that beam is horizontal in position .
- . Weight the exciter assembly along with discs, bearing and weights platform.
- . Clamp the assembly at any convenient position.
- . Measure the distance  $L_1$  of the assembly from pivot. Allow system to vibrate freely.
- . Measure the time for any 10 oscillation and periodic time and natural frequency of vibration.
- . Repeat the experiment by varying  $L_1$  and also putting different weights on platform.

### Standard Data

W	=	18.5kg.
w	=	0.5kg and 1.0kg(one each)
k	=	5kg/cm
L	=	93.5 cm.
g	=	9.81 m / sec <sup>2</sup>

Weight of weight pan : 1 kg

Other weight : 0.5kg , 1 kg

Formulae

1). Time period,  $t = 2\pi\sqrt{m_e/k}$

2). Equivalent mass at the spring,  $m_e = m [L_1^2/L_2]$

3).  $m = W+w/g$

4). Actual time period,  $T_{act} = t/n$

Where

W = Weight of exciter assembly along with wt. Platform = 18.5 kg.  
 w = Weight attached on exciter assembly.  
 L1 = Distance of w from pivot.  
 k = Stiffness of spring = 5 kg/cm.  
 L = Distance of spring from pivot = Length of beam = 93.5 cm.  
 g = 9.81 m / sec<sup>2</sup>

**OBSERVATION & CALCULATION TABLE:**

Wt (kg)	LI (cm)	No. of osc	Time for n osc	T act = t/n	Freq	T <sub>theo</sub>	F <sub>theo</sub>

**EXPERIMENT NO. 10**

**OBJECTIVE:** TO STUDY THE FORCED DAMPED VIBRATION OF EQUIVALENT SPRING MASS SYSTEM

**DESCRIPTION:-**

It is similar to that described for expt. no. 9. The exciter unit is coupled to D.C. variable speed motor. RPM of motor can be varied with the speed control unit. Speed of rotation can be known from the RPM indicator on the control panel. It is necessary to connect damper unit to the exciter. Amplitude of vibration can be recorded on strip chart recorder.

**DAMPING ARRANGEMENT:-**

- ❖ Close the one hole of the damper for light damping.
- ❖ Close the two holes of the damper for medium damping.
- ❖ Close all the three holes of damper for heavy damping.

**EXPERIMENTAL PROCEDURE:-**

- ❖ Arrange the set-up as described in expt. no.9.
- ❖ Start the motor and allow the system to vibrate.
- ❖ wait for 1 to 2 minutes for amplitude to build the particular forcing frequency.
- ❖ Adjust the position of strip chart recorder. Take the recorder of amplitude  $v_s$ . time on strip chart recorder by starting recorder motor. Press recorder platform on the pen gently. pen should be wet with ink. Avoid excessive pressure to get good result.
- ❖ Take record by changing forces frequencies.
- ❖ Repeat the experiment by adjusting the holes on the piston of damper can change different damping.
- ❖ Plot the graph of amplitude  $v_s$ . frequency for each damping condition.

**OBSERVATION TABLE:-**

FORCING FREQUENCY (Hz)	AMPLITUDE (mm)

**EXPERIMENT NO. 11**

**OBJECTIVE:** TO STUDY THE FORCED VIBRATION OF THE BEAM FOR DIFFERENT DAMPING.

**DESCRIPTION:-**

In this experiment a slightly heavy rectangular section bar than used in expt. no. 10 is supported at both ends in trunion fittings. Exciter unit with the weight platform can be clamped at any conventional position along the beam. Exciter unit is considered to the damper, which provides the necessary damping.

**DAMPING ARRANGEMENT:-**

- ❖ Close the one hole of the damper for light damping.
- ❖ Close the two holes of the damper for medium damping.
- ❖ Close all the three holes of damper for heavy damping.

**EXPERIMENTAL PROCEDURE:-**

- ❖ Arrange the set-up as shown in fig 11.
- ❖ Connect the exciter motor to control panel.
- ❖ Start the motor and allow the system to vibrate.
- ❖ Wait for 5 minutes for amplitude to build up for particular forcing frequency.
- ❖ Adjust the position of the strip chart recorder. Take the recorder of amplitude  $v_s$ . time on strip chart recorder by starting recoeder motor.
- ❖ Take record by changing forcing frequency for each damping.
- ❖ Repeat the experiment for different damping.
- ❖ Plot the graph of amplitude  $v_s$  frequency for each damping.

**OBSERVATION TABLE:-**

FORCING FREQUENCY (Hz)	AMPLITUDE (mm)

## **BTME 804 REFRIGERATION AND AIRCONDITIONING LAB**

### **EXPERIMENT NO. 1**

Study various elements of mechanical refrigeration system through cut sections models/actual apparatus.

#### **Introduction:**

The refrigeration system consists of four basic components—the compressor, the condenser, the liquid receiver, the evaporator, and the control devices. These components are essential for any system to operate on the principles previously discussed. Information on these components is described in the following sections.

#### **Compressors**

Refrigeration compressors have but one purpose—to withdraw the heat-laden refrigerant vapor from the evaporator and compress the gas to a pressure that will liquefy in the condenser. The designs of compressors vary, depending upon the application and type of refrigerant. There are three types of compressors classified according to the principle of operation— reciprocating, rotary, and centrifugal.

Compressors will not be explained further here except to discuss the special methods used to seal compressors to prevent escape of refrigerant. Many refrigerator compressors have components besides those normally found on compressors, such as unloaders, oil pumps, mufflers, and so on. These devices are too complicated to explain here. Before repairing any compressor, check the manufacturer's manual for an explanation of their operation, adjustment, and repair.

**External Drive Compressor.**—An external drive or open-type compressor is bolted together. Its crankshaft extends through the crankcase and is driven by a flywheel (pulley) and belt, or it can be driven directly by an electric motor. A leak proof seal must be maintained where the crankshaft extends out of the crankcase of an open-type compressor. The seal must be designed to hold the pressure developed inside of the compressor. It must prevent refrigerant and oil from leaking out and prevent air and moisture from entering the compressor. Two types of seals are used—the stationary bellows seal and the rotating bellows seal.

An internal stationary crankshaft seal shown in figure 6-15 consists of a corrugated thin brass tube (seal bellows) fastened to a bronze ring (seal guide) at one end and to the flange plate at the other. The flange plate is bolted to the crankcase with a gasket between the two units. A spring presses the seal guide mounted on the other end of the bellows against a seal ring positioned against the shoulder of the crankshaft. As the pressure builds up in the crankcase, the bellows tend to lengthen, causing additional force to press the seal guide against the seal ring. Oil from the crankcase lubricates the surfaces of the seal guide and seal ring. This forms a gastight sea whether the compressor is operating or idle.

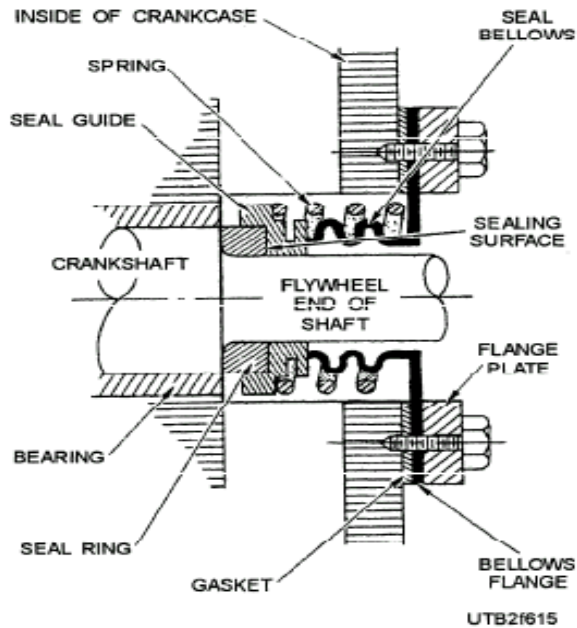


Figure 6-15.—An internal stationary bellows crankshaft seal.

An external stationary bellows crankshaft seal is shown in figure 6-16. This seal is the same as the internal seal, except it is positioned on the outside of the <http://www.sweethaven02.com/MechTech/Refrig01/crankcase>.

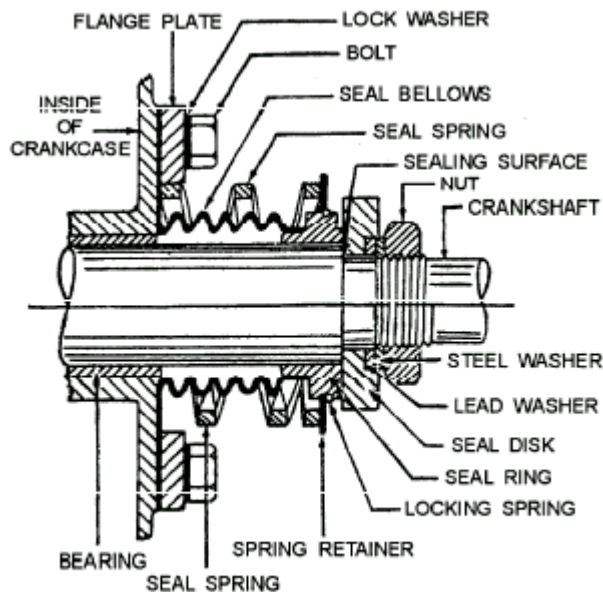


Figure 6-16.—An external stationary bellows crankshaft seal.

An external rotating bellows crankcase seal is shown in figure 6-17. This seal turns with the crankshaft. This seal also consists of a corrugated thin brass tube (seal bellows) with a seal ring fastened to one end and a seal flange fastened to the other. A seal spring is enclosed within the bellows. The complete bellows assembly slips on the end of the crankshaft and is held in place

by a nut. The seal ring that is the inner portion of the bellows is positioned against a nonrotating seal fastened directly to the crankcase.

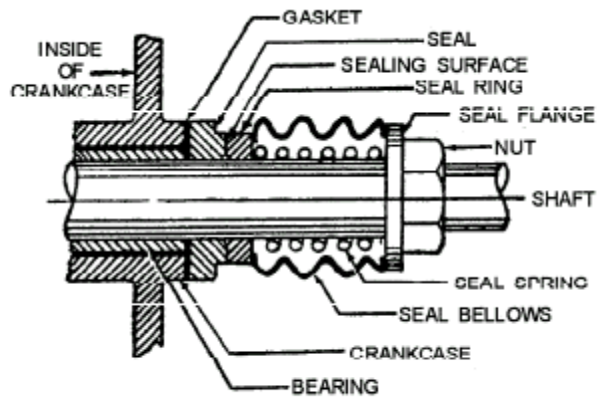


Figure 6-17.—An external rotating bellows crankcase seal.

During operation, the complete bellows assembly rotates with the shaft, causing the seal ring to rotate against the stationary seal. The pressure of the seal spring holds the seal ring against the seal. The expansion of the bellows caused by the pressure from the crankcase also exerts pressure on the seal ring. Because of this design, double pressure is exerted against the seal ring to provide a gastight seal.

**Hermetic Compressor**—In the hermetically sealed compressor, the electric motor and compressor are both in the same airtight (hermetic) housing and share the same shaft. Figure 6-18 shows a hermetically sealed unit. Note that after assembly, the two halves of the case are welded together to form an airtight cover. Figure 6-19 shows an accessible type of hermetically sealed unit. The compressor, in this case, is a double-piston reciprocating type. Other compressors may be of the centrifugal or rotary types.

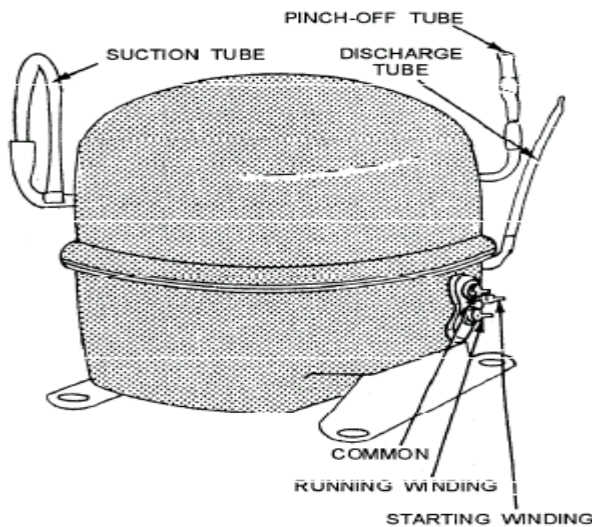
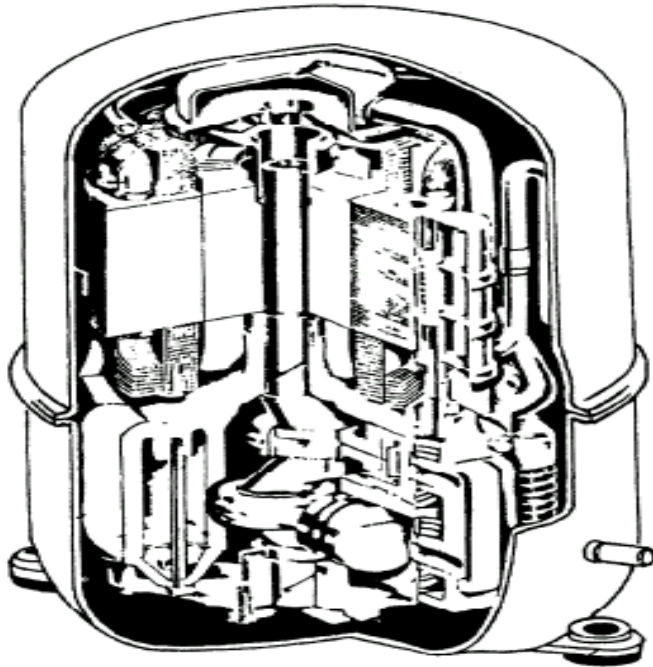


Figure 6-18.—Hermetic compressor.



**Figure 6-19.—A cutaway view of a hermetic compressor and motor.**

Cooling and lubrication are provided by the circulating oil and the movement of the refrigerant vapor throughout the case.

The advantages of the hermetically sealed unit (elimination of pulleys, belts and other coupling methods, elimination of a source of refrigerant leaks) are offset somewhat by the inaccessibility for repair and generally lower capacity.

### **Introduction:**

In systems involving heat transfer, a **condenser** is a device or unit used to condense a substance from its gaseous to its liquid state, typically by cooling it. In so doing, the latent heat is given up by the substance, and will transfer to the condenser coolant. Condensers are typically heat exchangers which have various designs and come in many sizes ranging from rather small (hand-held) to very large industrial-scale units used in plant processes. For example, a refrigerator uses a condenser to get rid of heat extracted from the interior of the unit to the outside air. Condensers are used in air conditioning, industrial chemical processes such as distillation, steam power plants and other heat-exchange systems. Use of cooling water or surrounding air as the coolant is common in many condensers.

## Types of condensers:

- A **surface condenser** is an example of such a heat-exchange system. It is a shell and tube heat exchanger installed at the outlet of every steam turbine in thermal power stations. Commonly, the cooling water flows through the tube side and the steam enters the shell side when the condensate occurs on the outside of the heat transfer tubes. The condensate collects at the bottom, often in a built-in pan called a *hotwell*. The shell side often operates at a vacuum or partial vacuum, often produced by attached air ejector.
- In chemistry, a condenser is the apparatus which cools hot vapors, causing them to condense into a liquid. See "Condenser (laboratory)" for laboratory-scale condensers, as opposed to industrial-scale condensers. Examples include the **Liebig condenser, Graham condenser, and Allihn condenser**. This is not to be confused with a condensation reaction which links two fragments into a single molecule by an addition reaction and an elimination reaction.

In laboratory distillation, **reflux, and rotary evaporators**, several types of condensers are commonly used. The Liebig condenser is simply a straight tube within a cooling water jacket, and is the simplest (and relatively least expensive) form of condenser. The Graham condenser is a spiral tube within a water jacket, and the Allihn condenser has a series of large and small constrictions on the inside tube, each increasing the surface area upon which the vapor constituents may condense. Being more complex shapes to manufacture, these latter types are also more expensive to purchase. These three types of condensers are laboratory glassware items since they are typically made of glass. Commercially available condensers usually are fitted with ground glass joints and come in standard lengths of 100, 200, and 400 mm. **Air-cooled condensers** are unjacketed, while **water-cooled condensers** contain a jacket for the water.

- Larger condensers are also used in industrial-scale distillation processes to cool distilled vapor into liquid distillate. Commonly, the coolant flows through the tube side and distilled vapor through the shell side with distillate collecting at or flowing out the bottom.
- A **condenser unit** used in central air conditioning systems typically has a heat exchanger section to cool down and condense incoming refrigerant vapor into liquid, a compressor to raise the pressure of the refrigerant and move it along, and a fan for blowing outside air through the heat exchanger section to cool the refrigerant inside. A typical configuration of such a condenser unit is as follows: The heat exchanger section wraps around the sides of the unit with the compressor inside. In this heat exchanger section, the refrigerant goes through multiple tube passes, which are surrounded by heat transfer fins through which cooling air can move from outside to inside the unit. There is a motorized fan inside the condenser unit near the top, which is covered by some grating to keep any objects from accidentally falling inside on the fan. The fan is used to blow the outside cooling air in through the heat exchange section at the sides and out the top through the grating. These condenser units are located on the outside of the building they are trying to cool, with tubing between the unit and building, one for vapor refrigerant entering and another for

liquid refrigerant leaving the unit. Of course, an electric power supply is needed for the compressor and fan inside the unit.

- **Direct contact condenser**

In this type of condenser, vapors are poured into the liquid directly. The vapors lose their latent heat of vaporization; hence, vapors transfer their heat into liquid and the liquid becomes hot. In this type of condensation, the vapor and liquid are of same type of substance.

## **EXPERIMENT NO.2**

**OBJECTIVE:** STUDY AND PERFORMANCE OF DOMESTIC REFRIGERATOR.

**APPARATUS:** Refrigerator test rig. (Vapour compression cycle)

**THEORY:** The refrigerator cycle in vapours forms finds application in countless industrial and domestic situations through out the world. For examples, the storage and transport of perishable food stuffs and drugs would be extremely difficult if not impossible without refrigeration's. Similarly the efficient operations of offices and factories in many part s of the world would be impossible without the use of refrigeration plants in air conditioning.

It is for this reason that engineers of many disciplines must have a good working knowledge of the refrigeration's cycle .a refrigerator is defined as a machine whose prime function is to remove heat from a low temperature region. Since the energy extracted cannot be destroyed, it follows that this energy required to operate the machine, must be rejected to the surrounding at a higher temperature, if the temperature of the rejections is high enough to be useful and this is the prime object of the machine, then the machine is called a HEAT PUMP.

The clausius statement of the second law of the thermodynamics states that heat will not pass from a cold to a hotter region without an "external agency" being employed. This external agency may be applied in the form of high-grade energy input of either "work" or a high-grade heat input. The high-grade heat input may take the form of either high temperature combustion products, electrical energy (in the form of heat) or solar energy.

The most common type of refrigerator or heat pump operates on the compression cycle and requires a work input. The vapour compression refrigeration test rig has been designed to enables students to safety study in the cycle in details. The test rig requires 220v ac,50c/s supply and fresh water supply connections.

REFRIGERANT USED	-	R12
REFRIGERATION RATE	-	1400w maximum, but varies with the evaporating.
CONDENSATING TEMP.	-	50° MAXIMUM
EVAPORATING TEMP.	-	-20°C TO +10°C. Variable by adjustment of load and cooling water temp.

COMPRESSOR	-	hermetically sealed 314l kirloskar
CONDENSER	-	shell and coil type
EVAPORATOR	-	compact once through concentric tube with refrigeration load supplied by separate concentric heating elements
EXPANSION VALVE	-	automatic expansion valve with two bypass capillary circuits.

### TERMODYNAMIC ASPECTS OF REFRIGERATIONS:

The second law of thermodynamic includes the statements, "it is impossible to transfer heat from a region at a low temperature to another at a higher temperature without the aid of an external agency".

Refrigerator and heat pumps are examples of machines, which transfer heat from a low to a high temperature region, and the "external agency" employed, may be either work or high-grade heat.

The first law of thermodynamics states in a cycle the net heat transfer is equal to the network transfer. Thus for a refrigerator, heat transfer at low temperature + heat transfer at high temperature = work done.

In the case of the refrigerator (or heat pump) using a work input, it follows that heat transfer at low temperature + work input = heat transfer at high temperature .if the external agency is high grade heat, the heat transfer at low temperature + heat transfer at high temperatures = 0

- A machine whose prime function is to remove heat from a low temperature region is called the refrigerator.
- A machine whose prime function is to deliver heat from a high temperature region is called the heat pump. From the first law of thermodynamics, it is apparent that a refrigerator must reject heat at a higher temperature and the heat pump must take in heat at a lower temperature. Thus, there is very little difference between the two plants, and both useful affects can be obtained from the same unit.
- COP:
 
$$= \frac{\text{Refrigerating effect}}{\text{Work done}}$$

**REFRIGERATION LOAD:** This is determined by the input to the electric heating element in the evaporator and is controlled by the heat input control setting. The product of the voltmeter and ammeter reading gives the evaporator heat input rate.

**CONDENSER PRESSURE:** The cooling water flow rate and its inlet temperature controls condensor motor. Reduce the cooling water flow rate to increase the condenser pressure.

**ELECTRIC INPUT:** the voltmeter and ammeter indicates the input to the compressor motor. The electric power input is in the products of volts, amps, and the power factor applicable (0.8).

**TEMPERATURE INDICATORS:** the temperature may be measured at six points in the circuit by selecting station 1-6 and the appropriate temperature scale.

**PROCEDURE:**

- 1) Ensure that the operation of the plant is clearly understood.
- 2) Start the unit and adjust the evaporator heat input control and, to set the evaporating pressure adjust the condenser cooling water to give the required condenser pressure and hence saturation temperatures.
- 3) For performance curves start with a small duty, say 250w and increase this in increments of about 25w until the maximum duty is reached. The unit will respond quickly after the load change and stabilise within 15 minutes, although it may take a little longer at light loads. Stability is reached when changes in pressure temperature, flow, etc have ceased.
- 4) Reduce the refrigerator load. Switch off mains switch and turnoff the cooling water.
- 5) The unit should be started and allowed to stabilise with a refrigeration load of about 250w.
- 6) In the evaporator, the pressure and temperature are high and the heat has been a heat input from the electric heating element.
- 7) In the condenser, the pressure and temperature are high and the heat has been given up to the cooling water, which has been given up to the cooling water, which has become warmer.
- 8) The compressor increases both the pressure and temperature and that the compressor requires a work input to-do this.
- 9) Both the pressure and temperature fall across the expansion valve and that no work transfer involved.

**PRECAUTIONS:**

- 1) Do not touch the compressor or the pipelines, which may be hot or cold.
- 2) Final readings be recorded after steady conditions have reached say after running for at least 30 minutes at a particular setting of water flow rate and heater evaporator load.
- 3) Ensures that water is continuously flowing through the condenser under all conditions of compressor working.

- 4) The flow of water should not be permitted to fall below 11pm.
- 5) High pressure and low pressure cut out set to shut off all electrical supplies to motor and evaporator heaters if condenser pressure exceeds 1400 KN-M2.

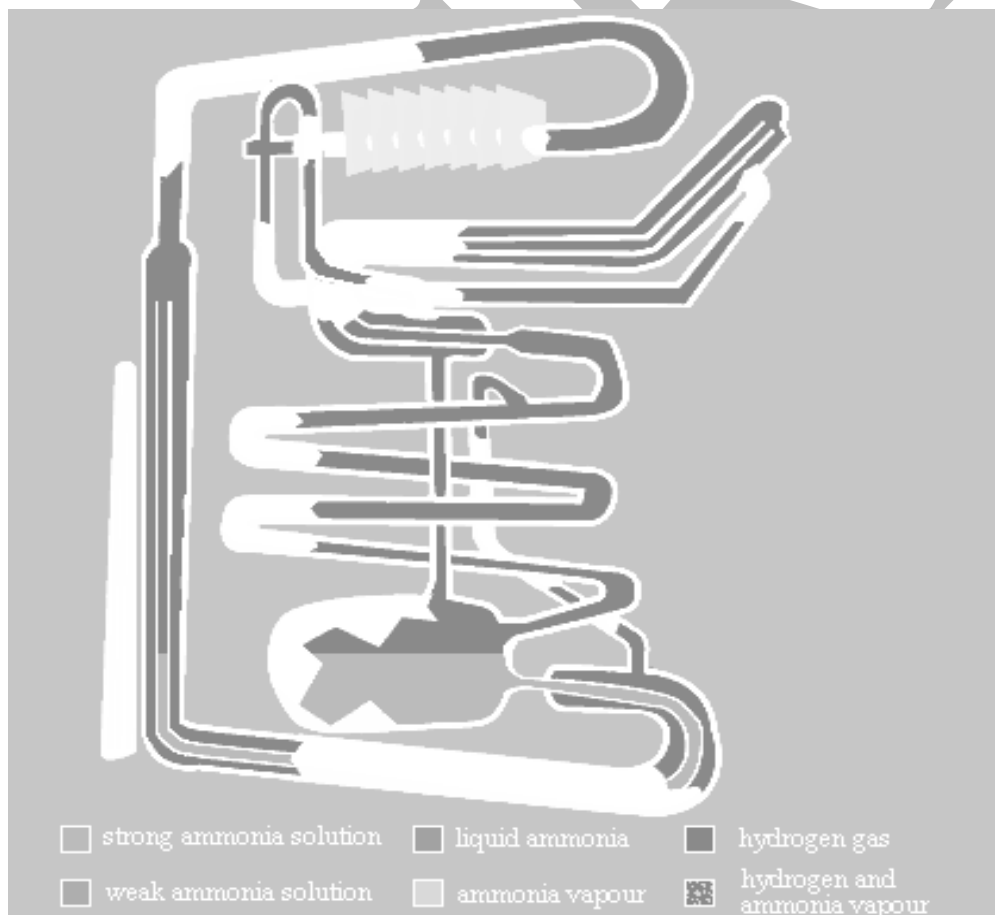
Reduce the refrigeration load (evaporator heat input control) switch off mains switch and turn off the cooling water.

### EXPERIMENT NO.3

#### OBJECTIVE:

STUDY THE PERFORMANCE OF ELECTRO-LUX-REFRIGRATOR.

**THEORY:** This type of refrigerator is generally used for domestic purposes as it is more complicated in its instructions and work. This type of refrigerator was developed first in 1925 by Munters and Boltzervon when they were at Royal Institute of Technology. This type of refrigerator is known as three fluids absorptions system.



The elimination of aqua pump from the absorption machine would produce a system with a complete absence of moving parts and working input. The main purpose to eliminate the pump is to make the machine noiseless. It uses a refrigerant, a solvent and an inert gas for working of system.

This inert gas is confined to low side of the system only by this absence. It is possible to maintain the uniform pressure throughout the system and at the same time permitting the refrigerant to evaporate at low temperature. Corresponding to its partial pressure. In high pressure side of the system, there exists only the refrigerant which is subjected to total pressure of the system so that it is condensed by using the normal cooling the water or air as it is done in other system. In low system side of system, the total pressure is the sum of partial pressure of ammonia vapor and the partial pressure of hydrogen which is used as inert gas. The liquid ammonia which comes into the evaporator evaporates at the partial pressure of ammonia.

**WORKING:** The strong aqua ammonia solution is heated in generator by the application of external heat source and  $\text{NH}_3$  vapor is removed from the solution the water vapor caused with the  $\text{NH}_3$  vapor is passed in the condenser and it is condensed by using the external cooling of source. The liquid  $\text{NH}_3$  from under gravity to evaporator and it is evaporated in the presence of hydrogen atmosphere absorbing the heat from the evaporator and it maintains low temperature in the evaporator. This mixture of hydrogen and ammonia vapor is passed into the absorber and the work solution of the aqua ammonia solution comes in contact with the hydrogen and ammonia vapor and it absorbs only ammonia, making the solution rich in ammonia and hydrogen is separated as shown in fig this strong solution is further passed to the generator and it completes the cycle.

There is pump to create the pressure differential between condenser and evaporator or not as expansion valve. The evaporator side is charged with  $\text{H}_2$  so that total pressure is same as that of condenser side. The cycle operates on the principle of Dalton's law where  $\text{pr.}(\text{NH}_3) + \text{pr.}(\text{H}_2) = \text{Constant}$ , so that the total pressure is same throughout the system. Due to the presence of  $\text{H}_2$  in the low side of the system, pressure of  $\text{NH}_3$  will be below that of  $\text{NH}_3$  on the condenser side. Thus the  $\text{NH}_3$  can evaporate at low pressure while  $\text{H}_2$  takes no part in the process except to supply its partial pressure to maintain the balance.  $\text{H}_2$  is prevented entering into the condenser side by strong solutions forming a trap absorber and liquid  $\text{NH}_3$ . U-trap at the condenser outlet. The  $\text{H}_2$  returns to the evaporator having no affinity for the absorbent. The  $\text{H}_2$  is held in this position by the U tube.

Due to the small pressure difference in this system, solution is circulated through absorber and generator by the thermal action. The parts are so arranged that the liquid refrigerant flows to the evaporator by the gravity action only. Care is taken to keep the hydrogen isolated in the proper parts of the system. Otherwise the pressure will be unbalanced and machine will stop.

The liquid  $\text{NH}_3$  also evaporates in the presence of air or other inert gases, but lightest the gas, the faster. The evaporation takes place, since  $\text{H}_2$  is the light gas and readily available and is also non-corrosive and insoluble in water, it is generally used for this type of refrigeration system.

## **EXPERIMENT NO.4**

**OBJECTIV:** STUDY OF AN ICE PLANT.

**THEORY: Introduction**

This note briefly describes the design and operation of icemaking plants. Space, power and refrigeration requirements are discussed, and the main types of icemaker are described. Methods of handling, transporting and storing ice are outlined.

### **Classification of ice plants**

The term ice plant is used in this note to mean a complete installation for the production and storage of ice, including the icemaker itself that is the unit that converts water into ice together with the associated refrigeration machinery, harvesting and storage equipment, and the building.

Ice plants are usually classified by the type of ice they produce; hence there are **block iceplants, flake ice plants, tube, slice or plate ice plants** and so on. Ice plants may be further subdivided into those that make dry or wet ice. Dry ice here means ice at a temperature low enough to prevent the particles becoming moist; the term does not refer in this note to solid carbon dioxide. In general, dry subcooled ice is made in plants that mechanically remove the ice from the cooling surface; most flake ice plants are of this type. When the cooling surface of an icemaker is warmed by a defrost mechanism to release the ice, the surface of the ice is wet and, unless the ice is then subcooled below 0°C, remains wet in storage; tube ice and plate ice plants are of this type.

### **Types of icemaker**

#### ***Block ice***

Tapered rectangular metal cans filled with water are immersed in a tank containing refrigerated sodium chloride brine. The dimensions of the can and the temperature of the brine are usually selected to give a 24 hour production time, and batches of cans are emptied and refilled in sequence during that period. Ice block weight can range from 12 to 150 kg depending on requirements; 150 kg is regarded as the largest size of block one man can conveniently handle. A block ice plant requires continuous attention and is labour intensive. The icemaker and the store require a good deal of floor space and impose heavy loads on the building structure. For these reasons block ice plants are going out of use, and more modern automatic plants are replacing them.

#### ***Rapid block ice***

It is possible to reduce the freezing time for blocks considerably, and thus reduce the space required for the icemaker. This is done by reducing the thickness of ice to be frozen; in one type of rapid icemaker this is achieved by passing refrigerant through tubes around which the ice forms and fuses into a block. The blocks can be released by defrosting and harvested automatically, thus markedly reducing the labour requirement, but the storage space required is



defrosting the tubes automatically, and are chopped into pieces about 50 mm long by a rotating cutter as they slide out. The cylindrical pieces can be subcooled by storing them at - 5°C, but they may require further crushing before being suitable for some applications in the fish industry.

### ***Plate ice***

Water is frozen on one face of a vertical refrigerated plate, and the sheet of ice is released by running warm water on the other face of the plate. The size of ice particle is variable, but the optimum thickness is 10-12 mm. The plates are usually mounted in banks, often above the refrigeration machinery, to form a self contained unit. Water for defrosting has to be heated if its temperature is below 23°C. Like most other icemakers the plate ice machine will operate unattended on an automatic timing cycle.

### ***Other icemakers***

Machines are available that make ice by methods other than those described here, but the size of unit is usually small, producing at the most only a few hundred kilograms of ice a day; these are suitable for retail and catering services, but are unlikely to be of interest to those providing icemaking services to the catching and processing sectors of the fish industry.

### **Capacity of ice plants**

Manufacturers usually quote a wide range of daily output for specific icemaker units, because their capacity can be affected by a number of factors, but this flexibility usually exists only at the planning stage; once the icemaker has been matched to suitable refrigeration machinery under given operating conditions, there is little scope for changing the capacity of the installed unit. Changes in demand are best catered for by reducing running time or by installing multiple units and operating only as many as are needed.

Since the capacity of both the icemaker and the refrigeration machinery is lower in warmer weather, the size of the plant should be selected for warm weather operation, when demand for ice is also likely to be greatest.

### **Ice plant requirements**

#### ***Space***

Modern icemakers are compact in comparison with block ice equipment, but it is not always possible to compare directly the space occupied by different types; for example they may not be available in the same unit sizes. However some guidance on the space requirements for icemakers with a nominal capacity of 50 tonnes a day is given in Table 1; the figures are for icemakers only, and the space for refrigeration machinery, handling and storage will usually amount to far more than for the ice-maker.

**Table 1** *Space required for an icemaker producing 50 t/day*

<b>type of ice</b>	<b>floor area m<sup>2</sup></b>	<b>height m</b>
block	190	5.0
rapid block	30	3.5
tube	3.3	6.6
flake	2.7	3.7

### ***Power***

Average power and peak power requirements may be different, and both have to be considered at the planning stage. The average power relates to the energy consumed in making a tonne of ice, and this is important in calculating operating cost. Peak power is important to the designer since it will determine what electrical supply is required, and may also affect operating cost if a peak demand factor is applicable.

The energy required to make a tonne of ice is not constant. It varies widely depending on a number of factors, the most important of which are

- Type of icemaker
- Operating temperature
- Make-up water temperature
- Cooling water temperature
- Air temperature
- Size of plant
- Utilization of plant
- Method of refrigeration

### ***Water***

In addition to water for making ice, water may be required for cooling, as in a refrigeration plant condenser, or for heating, as in a warm water defrosting system.

The amount of water required for making ice is roughly equal to the amount of ice being produced plus some allowance for wastage and for prevention of build up of solids in the water circulating system.

Fresh water for making ice for use with fish must satisfy the requirements for drinking water. In addition, the chemical composition of water for making ice must meet the equipment manufacturers' requirements; hard water containing excessive amounts of solids may foul the icemaker and may also yield a soft wet ice. On the other hand pure water may cause problems, particularly in flake ice plants, because the ice sticks hard to the drum; the remedy is to fit a

dosing device that puts 200-500 g salt into each tonne of water to improve release of the ice without making the ice detectably salty when used on fish.

It is inadvisable to use shell and tube condensers in a refrigeration system where cooling water is run to waste, unless a plentiful supply of cheap water is available, independent of the domestic drinking water supply; otherwise water costs may be prohibitive, since 15 tonnes of cooling water at 10°C or 60 tonnes at 25°C are required for each tonne of ice produced. Other factors can affect cooling water consumption, and manufacturers' precise figures should be used at the detailed planning stage.

Air cooled condensers can be used on small plants, but for most commercial installations evaporative condensers, or shell and tube condensers with a cooling tower, are more likely to be supplied. Evaporative condensers and cooling tower cooling systems normally use less than 1/2 tonne of water for each tonne of ice, plus some small additional allowance if an overflow is necessary to prevent build up of solids in the recirculated water.

Water for defrosting plate icemakers has to be of the same high quality as water for making ice. About 2 tonnes of water is required for each tonne of ice if the water is run to waste, but consumption can be reduced to almost nothing by making a closed circuit and reheating the water between defrosts.

### **The refrigeration system**

Most modern icemakers are designed to work unattended 24 hours a day with only routine inspection and maintenance. The system is therefore designed for reliability, with safeguards against failure or malfunction. Most manufacturers recommend the refrigeration system best suited to their icemakers, but where local installation engineers propose a system, the purchaser should ensure that the contractor is aware of the need for continuous automatic running and for rapid repair after breakdown.

The refrigeration system for an icemaker should be independent of any other refrigeration requirement; it should not be shared for example with a freezer or a cold store. The only exception to this rule is when a complex system is installed and a competent engineer is in fulltime attendance. Manufacturers often recommend a separate system for each icemaking unit, so that in a multiple unit installation there is considerable flexibility, and a reasonable guarantee that at least some of the units are always in production. Choice of refrigeration machinery and of refrigerant is a job for the refrigeration expert, and the advice of the ice plant manufacturer or competent consultant should be sought before making any decision.

### **Storage of ice**

Manufacture of ice can seldom be matched to meet immediate demand; therefore storage is necessary to cater for peak demand and to allow the icemaker to be operated continuously. Storage also acts as a buffer against interruption of production due to breakdown or routine maintenance.

The size of store required will depend on the pattern of operation, but it is never advisable to store less than 2 days' production, and in most installations it is useful to be able to store 4-5 times the daily production.

Stowage rates vary with the kind of ice being made, and Table 3 gives the storage space required for the principal types.

**Table 2 Storage space for ice**

<b>type of ice</b>	<b>space m<sup>3</sup>/tonne</b>
flake	2.2-2.3
plate	1.7-1.8
tube	1.6-2.0
crushed block	1.4-1.5

The type of ice storage may range from a simple insulated bin to a large refrigerated silo or bin with automatic loading, unloading and weighing of ice.

### ***Silo Storage***

Silos are generally used only for freeflowing subcooled ice, such as flake ice, and an independent refrigeration system for the silo is essential to keep the ice sub-cooled in storage.

It is usual to provide an air cooler to refrigerate the jacket space between the inner lining of the silo and the outer insulated structure; typically the air cooler is located next to the icemaker on top of the silo, and cold air either falls by gravity into the jacket or is circulated by fan.

Ice is removed from the bottom of the silo, gravity flow being assisted by an agitator, usually a rotating chain; this means the oldest ice is always used first. Ice adhering to the silo wall needs to be freed periodically; otherwise this wall of ice becomes permanent, and only the central core of ice in the silo remains freeflowing.

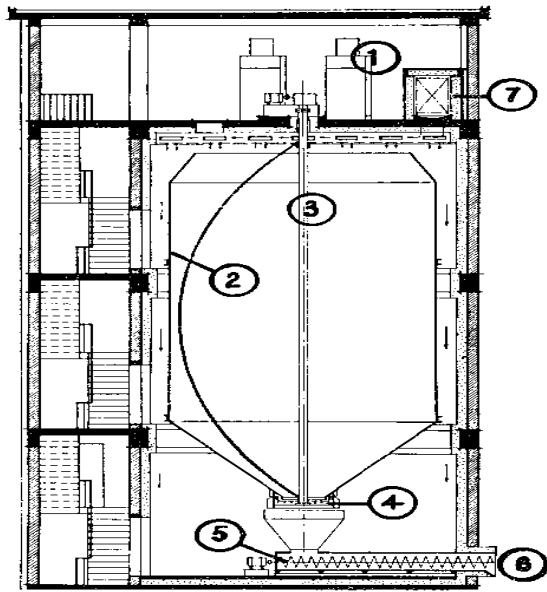
Silo storage is expensive for small amounts of ice; units have been made to hold as little as 10 tonnes, but silos are best suited for storing 40-100 t.

### ***Bin storage***

Bins can be used to store any kind of fragmented ice, and may be of any size from a simple box to hold 1/2 tonne to an installation holding 1000 t or more. Refrigeration of the bin is not always essential but, whatever the size, adequate insulation is necessary to reduce meltage; 100-150 mm of cork, or an equivalent thickness in many other suitable insulating materials, should be used.

A simple bin system is suitable for factories making ice for their own use. The icemaker can be mounted above the bin, so that ice flows by gravity to a take off point at the bottom of the bin; thus the oldest ice is used first. Where ice has to be distributed to customers, bins with a capacity of up to 50 tonnes can be made with a sloping floor and so mounted that rapid discharge direct to lorry or conveyor is possible. Some means of access to the bin is advisable in order to be able to dislodge any compacted ice.

**FIG 2. Silo ice store for 10-100 tonnes.**

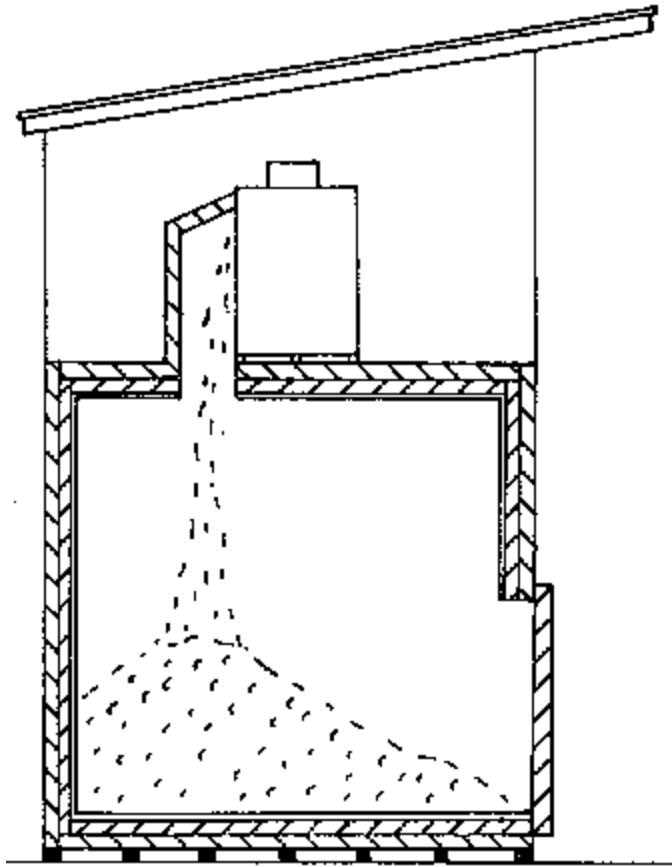


Key:

- |    |                     |            |
|----|---------------------|------------|
| 1. | Ice                 | makers.    |
| 2. | Concrete            | or         |
| 3. | Agitator            | with       |
| 4. | Sliding             | steel      |
| 5. | Screw               | silos      |
| 6. | Ice                 | chain      |
| 7. | Jacket cooler unit. | hatch.     |
|    |                     | conveyor   |
|    |                     | discharge. |

Depth of ice storage in a bin is limited to about 5 m to avoid fusion of ice under pressure; therefore large bins occupy considerable floor space, and usually require some mechanical means of unloading. Rakes, mechanical shovels and movable screw conveyors have all been used to remove ice from large bins. Rakes and shovels normally remove the topmost layer of ice in the bin, leaving older ice untouched at the bottom. It is therefore necessary to clear the bin periodically to remove all the old ice. Screw conveyors work at the bottom of a bin and remove oldest ice first, but an additional mechanism is required to distribute ice uniformly throughout the bin, and the screw drive takes up some space outside the bin area.

**FIG. 3. Small ice store for 5-15 tonnes.**



### ***Block ice storage***

Block ice can be crushed and stored in the same way as other fragmented ice, but it is more usual to store the blocks and crush them as required before delivery of the ice. Because of their weight and shape it is difficult to store blocks other than in a single layer; thus a considerable floor area is required. However there is usually some extra storage available in the icemaker itself, since all of the ice cans are normally kept full.

### **Handling, conveying and weighing**

Icemakers located directly above the store feed the ice by gravity. Where an ice-maker produces wet ice, it is advisable to drain off excess water before storing it; this is normally done on a conveyor between icemaker and store. Large bins require some means of distributing ice evenly throughout the storage space; silos and small bins do not require such an arrangement.

Both dished belt and screw conveyors are used extensively for transporting ice. Screws allow both horizontal and vertical movement, but can operate only over a limited distance. Belts are generally used for long hauls, and special ribbed belts can be used on an incline. Delivery into lorry or fishing vessel is by means of a chute that can be moved to distribute the ice evenly.

Pneumatic systems have been used for moving ice, but the method is unsuitable for ice that is to be stored again. The energy used in moving the ice is dissipated as heat which can cause some meltage, and more heat is transferred to the ice from the blown air, unless the air is precooled. In addition the ice is broken down into smaller particles by impact on the duct walls, so that a proportion of the ice at the delivery point appears as wet snow that cannot be stored, for example in a trawler fishroom. The use of pneumatic systems should therefore be confined to distributing ice to the point of use, for instance into fish boxes.

Ice can be weighed automatically on a conveyor belt to within  $\pm 2$  per cent. Elsewhere ice is usually measured by volume, the contents of a standard container having been weighed to determine the density. Weight of crushed block ice supplied is checked by counting the number of blocks delivered to the crusher.

### **Cost of ice plant**

It is impossible to generalize about cost of ice plant, since so much depends on local conditions. When a new installation is being planned, it may be necessary to take into account cost of land, buildings, roads, electrical and water supplies, drainage and so on as well as the cost of the icemaking and storage equipment. Annual fixed costs are likely to include depreciation, maintenance, interest on capital, tax, insurance and other overheads, while the main operating costs will include power, labour, water and possibly transport.

Cost estimating at an early stage may well influence the choice of plant size, since many of the costs are largely independent of size, and it may prove more economic for the plant operator to make more than he needs himself and become a supplier.

Maintenance cost may be of great importance in remote areas; although modern plants operate with minimum attention, regular professional maintenance is necessary. Direct comparison of capital and running cost of different types or makes of ice plant is not possible except on so general a basis as to be of little value to a prospective purchaser; each particular project has to be costed individually, using current prices.

## EXPERIMENT NO.5

**OBJECTIVE:** CALCULATION/ESTIMATION OF COOLING LOAD FOR LARGE BUILDING.

### PROCEDURE FOR COOLING LOAD ESTIMATION:

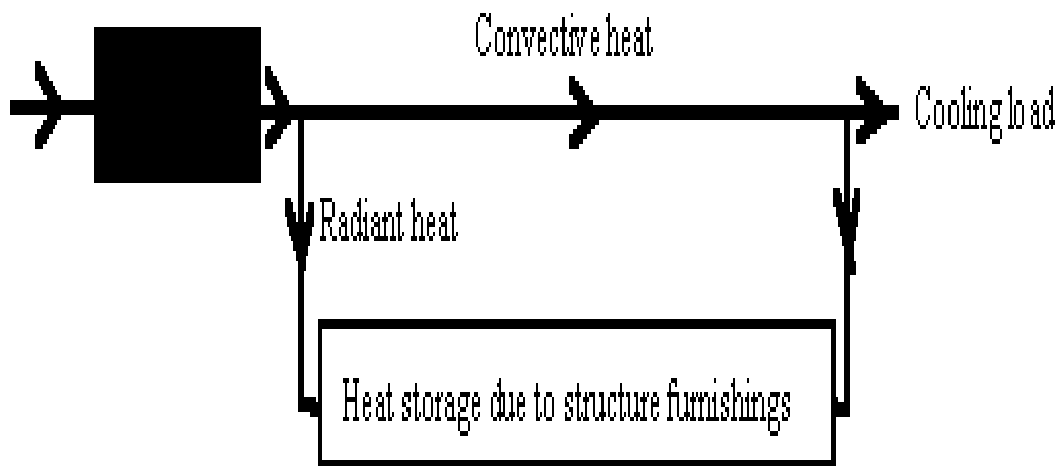
There are no. of factors which effects the cooling load calculation for a large building. To estimate the total cooling load we have to take many factors into consideration which are enumerated below:

#### 5.1 Space Heat Gain and Space Cooling Load

Space heat gain is the rate at which heat enters a space, or heat generated within a space during a time interval.

Space cooling load is the rate at which heat is removed from the conditioned space to maintain a constant space air temperature.

Figure 5.1 shows the difference between the space heat gain and the space cooling load. The difference between the space heat gain and the space cooling load is due to the storage of a portion of radiant heat in the structure. The convective component is converted to space cooling load instantaneously.



*Figure 5.1 Differences between Space Heat Gain and Space Cooling Load*

#### 5.2 Cooling Load Temperature Difference (CLTD) and Cooling Load Factor (CLF)

Cooling load temperature difference and cooling load factor are used to convert the space sensible heat gain to space sensible cooling load.

##### 5.2.1 Cooling Load Temperature Difference

The space sensible cooling load  $Q_{rs}$  is calculated as:

$$Q_{rs} = A \cdot U \cdot CLTD \quad (1)$$

where  $A$  = area of external wall or roof

$U$  = overall heat transfer coefficient of the external wall or roof.

CLTD values are found from tables, as shown in Tables 1 and 2, which are designed for fixed conditions of outdoor/indoor temperatures, latitudes, etc. Corrections and adjustments are made if the conditions are different.

### 5.2.2 Cooling Load Factor

The cooling load factor is defined as:

$$CLF = \frac{\text{sensible cooling load}}{\text{sensible heat gain}} = \frac{Q_{rs}}{Q_{es}} \quad (2)$$

CLF is used to determine solar loads or internal loads. Some CLF values are shown in Table 3.

*Table 1 Cooling Load Temperature Difference for Conduction through Window Glass*

Solar time, hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
CLTD, °C	1	0	-	-	-	-	-	0	1	2	4	5	7	7	8	8	7	7	6	4	3	2	2	1
			1	1	1	1	1																	

The values are calculated for an inside temperature ( $T_i$ ) of 25.5°C and outdoor daily mean temperature ( $T_{om}$ ) of 29.4°C.

$$\text{Correct CLTD} = CLTD + (25.5 - T_i) + (T_{om} - 29.4)$$

*Table 2 Cooling Load Temperature Difference (40 degree North Latitude in July) for Roof and External Walls (Dark)*

Solar time, hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
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North	08	07	06	06	07	73	66	65	73	80	86	89	89	86	82	75	78	91	24	18	15	13	11	10
North-east	0.03	0.02	0.02	0.02	0.02	0.56	0.76	0.74	0.58	0.37	0.29	0.27	0.26	0.24	0.22	0.20	0.16	0.12	0.06	0.05	0.04	0.04	0.03	0.03
East	0.03	0.02	0.02	0.02	0.02	0.47	0.72	0.80	0.76	0.62	0.41	0.27	0.24	0.22	0.20	0.17	0.14	0.11	0.06	0.05	0.05	0.04	0.03	0.03
South-east	0.03	0.03	0.02	0.02	0.02	0.30	0.57	0.74	0.81	0.79	0.68	0.49	0.33	0.28	0.25	0.22	0.18	0.13	0.08	0.07	0.06	0.05	0.04	0.04
South	0.04	0.04	0.03	0.03	0.03	0.09	0.16	0.23	0.38	0.58	0.75	0.83	0.80	0.68	0.50	0.35	0.27	0.19	0.11	0.09	0.08	0.07	0.06	0.05
South-west	0.05	0.05	0.04	0.04	0.03	0.07	0.11	0.14	0.16	0.19	0.22	0.38	0.59	0.75	0.81	0.81	0.69	0.45	0.16	0.12	0.10	0.09	0.07	0.06
West	0.05	0.05	0.04	0.04	0.03	0.07	0.11	0.14	0.16	0.19	0.22	0.38	0.59	0.75	0.81	0.81	0.69	0.45	0.16	0.12	0.10	0.09	0.07	0.06
North-west	0.05	0.05	0.04	0.04	0.03	0.06	0.09	0.11	0.13	0.15	0.16	0.17	0.31	0.53	0.72	0.82	0.81	0.61	0.16	0.12	0.10	0.08	0.07	0.06
Horizontal	0.05	0.04	0.04	0.03	0.03	0.07	0.11	0.14	0.17	0.19	0.20	0.21	0.22	0.30	0.52	0.73	0.82	0.69	0.16	0.12	0.10	0.08	0.07	0.06
	0.06	0.05	0.04	0.04	0.03	0.12	0.27	0.44	0.59	0.72	0.81	0.85	0.85	0.81	0.71	0.58	0.42	0.25	0.14	0.12	0.10	0.08	0.07	0.06

### 5.3 Space Cooling Loads

Space cooling load is classified into three categories:

#### 5.3.1 External Cooling Loads

External cooling loads have the following components:

##### 5.3.1.1 Solar Heat Gain through Fenestration Areas, $Q_{fes}$

$$Q_{fes} = (A_s \cdot \max. SHGF + A_{sh} \cdot \max. SHGF_{sh}) \cdot SC \quad (3)$$

where  $A_s$  = unshaded area of window glass

$A_{sh}$  = shaded area of window glass

$\max. SHGF_{sh}$  = maximum solar heat gain factor for the shaded area on window glass (Table 4)

$\max. SHGF$  = maximum solar heat gain factor for window glass (Table 5)

SC = shading coefficient (Table 6)

The corresponding space cooling load  $Q_{fs}$  is:

$$Q_{fs} = Q_{fes} \cdot CLF \quad (4)$$

Table 4 Maximum Solar Heat Gain Factor of Shaded Area

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
SHGFs <sub>i</sub>	98	107	114	126	137	142	142	133	117	107	101	95

Table 5 Maximum Solar Heat Gain Factor for Sunit Glass on Average Cloudness Days

Month	Maximum solar heat gain factor for 22 degree north latitude, W/m <sup>2</sup>					
	North	North-east / north-west	East / west	South-east / south-west	South	Horizontal
January.	88	140	617	789	696	704
February.	97	265	704	759	578	808
March.	107	404	743	663	398	882
April	119	513	719	516	210	899
May	142	572	687	404	139	892
June	180	589	666	355	134	880
July	147	565	671	391	140	877
August	123	502	694	496	223	879

September	112	388	705	639	392	854
October	100	262	676	735	563	792
November	88	142	606	786	686	699
December	84	101	579	790	730	657

ASPR



Clear out-clear in SCa=0 .84	6	0.80	0.57	0.51	0.60	0.25	0.56	0.42
Heat absorbing out-clear in SCa=0 .55	6	0.56	0.39	0.36	0.40	0.22	0.43	0.35
Reflective SCa=0 .20 SCa=0 .30 SCa=0 .40	6	0.80	0.19 0.27 0.34	0.18 0.26 0.33			0.18 0.27 0.36	0.16 0.25 0.29

Table 6 Shading Coefficient for Window Glasses with Indoor Shading Devices

Window Glass								
	Summer (outdoor wind velocity = 3.33m/s)							
	3 mm	5 mm	6 mm	12 mm	3 mm	5 mm	6 mm	
	thickn ess	thickn ess	thickn ess	thickness	thickn ess	thickn ess	thickn ess	

Single-glazed	5.4	5.2	5.0	4.3	6.1	5.7	5.4
Reflective			4.7				5.0
Double-glazed 6mm airspace	3.2	3.0	2.9		3.1	2.9	2.8
Double glazed 12mm airspace	2.8	2.7	2.6		2.7	2.6	2.4

a Shading coefficient with no shading device.

b Open weave means 40% openness, and closed weave indicate 3% openness.

*Table 7 Overall Heat Transfer Coefficients for Window Glasses*

#### 5.3.1.2 Conduction Heat Gain through Fenestration Areas, $Q_{fe}$

The space cooling load due to the conduction heat gain through fenestration area is calculated as:

$$Q = A \cdot U \cdot CLTD \quad (5)$$

where A = fenestration area

U = overall heat transfer coefficient for window glass (Table 7)

CLTD = cooling load temperature difference (Table 1)

#### 5.3.1.3 Conduction Heat Gain through Roofs ( $Q_{rs}$ ) and External Walls ( $Q_{ws}$ )

The space cooling load due to the conduction heat gain through roofs or external walls is calculated as:

$$Q_{rs} \text{ (or } Q_{ws} \text{)} = A \cdot U \cdot CLTD \quad (6)$$

where A = area for external walls or roofs

U = overall heat transfer coefficient for external walls or roof

CLTD = cooling load temperature difference (Table 2)

#### 5.3.1.4 Conduction Heat Gain through Interior Partitions, Ceilings and Floors, $Q_{ic}$

The space cooling load due to the conduction heat gain through interior partitions, ceilings and floors is calculated as:

$$Q_{ic} = A \cdot U \cdot (T_b - T_i) \quad (7)$$

where  $A$  = area for interior partitions, ceilings or floors

$U$  = overall heat transfer coefficient for interior partitions, ceilings or floors

$T_b$  = average air temperature of the adjacent area

$T_i$  = indoor air temperature

#### 5.3.2 Internal Cooling Loads

##### 5.3.2.1 Electric Lighting

Space cooling load due to the heat gain from electric lights is often the major component for commercial buildings having a larger ratio of interior zone. Electric lights contribute to sensible load only. Sensible heat released from electric lights is in two forms:

(i) convective heat from the lamp, tube and fixtures.

(ii) radiation absorbed by walls, floors, and furniture and convected by the ambient air after a time lag.

The sensible heat released ( $Q_{les}$ ) from electric lights is calculated as:

$$Q_{les} = \text{Input} \cdot F_{use} \cdot F_{al} \quad (8)$$

where  $\text{Input}$  = total light wattage obtained from the ratings of all fixtures installed

$F_{use}$  = use factor defined as the ratio of wattage in use possibly at design condition to the installation condition

$F_{al}$  = special allowance factor for fluorescent fixtures accounting for ballast loss, varying from 1.18 to 1.30

The corresponding sensible space cooling load ( $Q_{ls}$ ) due to heat released from electrical light is:

$$Q_{L_s} = \text{Input} \cdot F_{\text{use}} \cdot F_{\text{al}} \cdot \text{CLF} \quad (9)$$

CLF is a function of

- (i) number of hours that electric lights are switched on (for 24 hours continuous lighting, CLF = 1), and
- (ii) types of building construction and furnishings.

Therefore, CLF depends on the magnitude of surface and the space air flow rates.

### 5.3.2.2 People

Human beings release both sensible heat and latent heat to the conditioned space when they stay in it. The space sensible ( $Q_{ps}$ ) and latent ( $Q_{pl}$ ) cooling loads for people staying in a conditioned space are calculated as:

$$Q_{ps} = n \cdot \text{SHG} \cdot \text{CLF} \quad (10)$$

$$Q_{pl} = n \cdot \text{LHG} \quad (11)$$

where  $n$  = number of people in the conditioned space

SHG = sensible heat gain per person (Table 8)

LHG = latent heat gain per person (Table 8)

Adjusted values for total heat shown in Table 8 is for normal percentage of men, women and children of which heat released from adult female is 85% of adult male, and that from child is 75%.

CLF for people is a function of

- (i) the time people spending in the conditioned space, and
- (ii) the time elapsed since first entering.

CLF is equal to 1 if the space temperature is not maintained constant during the 24-hour period.

*Table 8 Heat Gain from Occupants at Various Activities (At Indoor Air Temperature of 25.5 oC)*

Activity	Total heat, W		Sensible heat, W	Latent heat, W
	Adult, male	Adjusted		
Seated at rest	115	100	60	40
Seated, very light work, writing	140	120	65	55
Seated, eating	150	170 <sup>b</sup>	75	95
Seated, light work, typing,	185	150	75	75
Standing, light work or walking slowly,	235	185	90	95
Light bench work	255	230	100	130
Light machine work	305	305	100	205
Heavy work	470	470	165	305
Moderate dancing	400	375	120	255
Athletics	585	525	185	340

b Adjusted for latent heat of 17.6W person released from food.

### 5.3.2.3 Power Equipment and Appliances

In estimating a cooling load, heat gain from all heat-producing equipment and appliances must be taken into account because they may contribute to either sensible or latent loads, and sometimes both. The estimation is not discussed in this lecture note. For more information, Chapter 26 of ASHARE Handbook - 1993 Fundamentals can be referred.

### 5.3.3 Loads from Infiltration and Ventilation

Infiltration load is a space cooling load due to the infiltrated air flowing through cracks and openings and entering into a conditioned room under a pressure difference across the building envelope. The introduction of outdoor ventilation air must be considered in combination with the infiltrated air. Table 9 shows the summer outdoor design dry bulb and wet bulb temperatures at 22 degree north latitude.

Table 9 Summer Outdoor Design Dry Bulb And Wet Bulb Temperatures At 22 Degree North Latitude

Solar time, hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Dry bulb temp. oC	28.4	28.3	28.2	28.1	28.0	28.0	28.2	29.0	29.9	30.8	31.8	32.2	32.8	33.0	32.7	32.5	31.8	31.1	30.4	29.7	29.1	28.8	28.6	28.4
Wet bulb temp. oC	25.8	25.7	25.7	25.6	25.6	25.5	25.7	26.4	26.7	27.0	27.5	27.6	27.8	28.0	27.9	27.6	27.4	27.1	26.8	26.7	26.5	26.3	26.1	25.9

TOTAL COOLING LOAD = SUM OF ALL THE LOADS

### EXPERIMENT NO.6

**OBJECTIVE:** VISIT TO A CENTRAL AIR CONDITIONING PLANT FOR STUDY OF PROCESSES FOR WINTER AND SUMMER AIR CONDITIONING.

**THEORY:**

During the visit the students will study the following components/parameters in central air conditioning plant:

1. Draw a detailed block diagram of the plant(s).
2. Construction of the main components of air conditioning systems.
3. Note down the capacity of each unit i.e. evaporator coil(s), compressor condenser etc.
4. Type of evaporator coil(s), condenser(s), compressor(s), expansion valves, control Valves, ducts, fans and materials used in construction.
5. Name of refrigerants and flow rates.
6. Temperature and pressure variation in evaporators and condensers.
7. Comparison between theoretical and actual COP of the system.

8. Capacity control of the plant under various load conditions in summer and winter.
9. Types of insulation materials used.
10. Suggest various methods to improve plant performance.

## **EXPERIMENT NO.7**

### **OBJECTIVE: STUDY AND PERFORMANCE OF WINDOW AIR-CONDITIONER**

**THEORY:** Air condition is defined as simultaneous control over the air, regarding its temperature, humidity, motion and purity. Window type room air conditioner is used to condition the air of a particular space. Such as office room, bedroom of a house, drawing office, room etc. it cools the air and sometimes dehumidifies it. It operates automatically once it is put into operation.

Charge the refrigerant in Air-conditioner through the charging pipe of compressor with Suction Pressure 70 to 75psi and discharge pressure 250 to 270 psi. The compressor compresses the refrigerant with high pressure and high temperature to send it through discharge pipe to condenser, which the temperature of refrigerant to convert into liquid form.

High pressure liquid flow through filter and capillary to evaporator when liquid enters after capillary the refrigerant expands and change liquid to vapor by air of room, when room air through heat transfer to its evaporator becomes cool and flows in room by the grille. The vapor goes back to compressor and is again compressed. The refrigerant cycle continues the fan motor fitted in the centre of air conditioner with one side fitted with propeller type fan blade ( condenser side ) and one side blower of evaporator 9 room side ). The air through fan condenses the refrigerant. The room air passes over evaporator and become cool and flow the cool air through grille louvers.

### **SPECIFICATIONS:**

- |    |                          |   |   |
|----|--------------------------|---|---|
| a) | Fan Capacity             | : | 177lps                                  |
| b) | Compressor               | : | 1.0 Ton (3.52 kW), Kirloskar make       |
| c) | Refrigerant              | : | R-22                                    |
| d) | Heater1, 2, 3 & 4        | : | each of 500 W                           |
| e) | Kettle Load              | : | 500 W                                   |
| f) | Moisture Content         | : | 2257kj/kg of water evaporated in kettle |
| g) | Electric tube Load       | : | 18 W                                    |
| h) | Power Factor $\cos \phi$ | : | 0.8                                     |
| i) | Pressure Gauge           | : | psin                                    |
| j) | Compound Gauge           | : | psin                                    |
| k) | Temperature Sensor       | : | Copper Constantan                       |

### **Experimental Procedure**

Step1: fill water in the DBT/WBT Thermometer cassette.

Step2: Fill 500ml of water in the electric kettle.

Step3: Set the thermostat knob of the A/C at particular temperature. And run the A/C for nearly10 minutes.

Step4: Load the chamber by switching ON a heater(of predetermined load).

Step5: Add moisture from electric kettle by feeding regulated power to match the desired latent heat load.

**Measurements**

1. Note down the chamber load from the heater.
2. Note down the DBT & WBT from thermometer mounted near window gives room /chamber temperature.
3. Note down the input Amp &Volts of refrigeration units.
4. Note down the suction and discharge pressures (average during operation)
5. Note down the thermocouple temperatures in C at
  - (a) Ambient Air.
  - (b) Outgoing air from condenser.
  - (c) Evaporator air at inlet and
  - (d) Air leaving the evaporator at grille.

**OBSERVATIONS:**

Name of Experiment : Window A/c test rig.

Name of student                      Semester                      Batch                      Session

Refrigerant                                      : R-22  
 Heater 1,2,3,&4                                : Each of 500W  
 Kettle load                                        : 500W  
 Moisture Content                                : 2257 kJ/kg of water evaporated in kettle  
 Electric Tube Load                              : 18W  
 Power factor cos                                 : 0.8  
 Conversion factor 1 kPa                        : psig x 6.89s

Run no	Latent HI (W)	Heater Load(W)	Thermometer		Compressor		Suction pr. (psi)	Discharge pr.(psi)	Temp. °C				
			Wbt (°C)	Dbt (°C)	V Volt	I Amp			1	2	3	4	

**CALCULATIONS:**

1. Room sensible heat load (SHL) can be found out by the summation of Heater load and Tube light load

Room Sensible Heat Load= Heater Load+Tube Light load in kJ/s or J/s or in watt.

2. Room latent heat load (LHL) can be found out from the moisture/steam generating capacity by the electrical kettle.
3. Room total heat load (THL) can be found out by the summation of room sensible heat load and room latent heat load.

$$THL=SHL+LHL$$

4. sensible heat factor (SHF ) can be found out by the ratio of room sensible heat load and room total heat load.

$$SHF= SHL/ THL$$

5. Apparatus dew point (ADP) can be obtained from the Psychometric chart supplied in the manual.
6. Dehumidified air is the amount of air being cooled and dried circulated by evaporator.

Dehumidification rise= Temperature of Evaporator air into it – Temperature of Evaporator air at grill.

Dehumidification air= SHL/ 1.23x Dehumidifier rise in lps

7. Coefficient of Performance of a Refrigerator (C.O.P) or EER  
= refrigerator rate or Duty/ Power Input to the compressor

#### **PRECAUTIONS:**

1. Run the apparatus for about 5 minutes without any load.
2. Fill the kettle with 500ml of water and estimate the moisture load.
3. operate the apparatus for 25-30 minutes only. Or add more water for generation of latent heat.
4. Do not touch the heater or the pipeline, which may be hot/cold.