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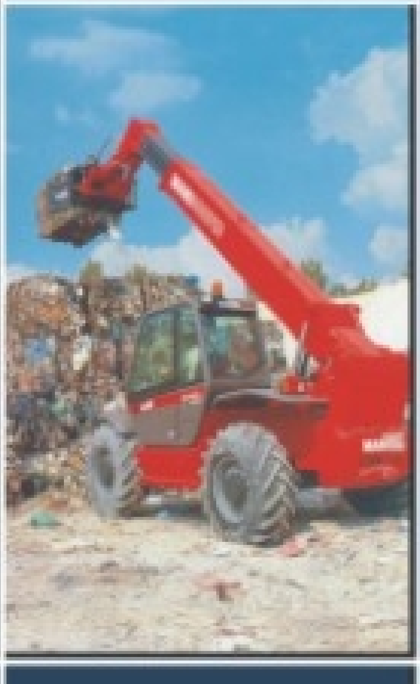
INTRODUCTION TO MATERIALS HANDLING



SIDDHARTHA RAY

NEW AGE INTERNATIONAL PUBLISHERS

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MATERIALS HANDLING

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PUBLISHING FOR ONE WORLD

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DEDICATION

This book is dedicated to the memory of my father

Benoyendra Narayan Roy,

a brilliant engineer, innovator and a noble hearted man.
He remains as the main source of inspiration in my life.

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PREFACE

Author of a book would like to explain to his readers why he has authored the book. If the book happens to be a textbook, the explanation almost becomes obligatory. At least, I feel that way.

During the final year of our engineering course, we had one full paper on "***Materials Handling***". At the time we had barely two foreign textbooks on the subject of western origin and prices of these were beyond a commoner's reach. Fortunately, three more textbooks of Russian origin came to the market around that period, which were rich in their contents and also very reasonable in price. I am talking about 38years back from today.

During thirty years of my industrial career in different industries at various levels, I came to appreciate the importance of materials handling in any production system, second to the production process only. I am sure, any practicing engineer/manager in an industry will readily agree with me. The importance of the subject is recognized by the fact that it is included as a separate subject in mechanical, production and industrial engineering curricula in both undergraduate and postgraduate levels in India and abroad. It is being taught in the postgraduate level in ***Manufacturing Technology*** course in my present institute.

During my long years in industry and last five years in academics, I came across a few text and handbooks on the subject of foreign origin, but unfortunately hardly any from Indian publishers.

Apart from a few handbooks, which are expensive and hence out of reach of an engineering student or a young practicing engineer, the textbooks which are now available to Indian students/ engineers are somewhat specialised in nature and can be classified mainly in two groups. The first group of books deal more on the management aspect of materials handling system, giving little stress on the use, application and design of large variety of materials handling equipment. The other group of books mainly stresses on the design aspects of a single or a narrow range of equipment. The three Russian books, which I mentioned earlier, were exceptions, but unfortunately no more available in India. The literatures published by the various equipment manufacturers mainly stress on the operating specifications and special features of their respective products, which are definitely useful for an experienced material handling engineer, but may not be as helpful to a student or a young engineer.

These have prompted me to write a textbook in the subject of Materials Handling. In this book, I have tried to draw a balance between the two extremes. It refers to the basic features of management of materials handling system. It also includes a wide range of material handling equipment with their use, selection criteria and operational details. It includes basic design concept of a few of these equipment. Sufficient illustrations of different types of materials handling equipment have been included in the book for easy understanding of these equipment.

In preparing the book, I have taken help of some specialised books and handbook written and edited by experts and literatures of equipment manufacturers. Acknowledgement and references of such books and literatures have been made in appropriate places.

References have also been made to various relevant BIS specifications which will help a student/engineer to prepare the buying specifications and to design some of these materials handling equipment.

The book is intended to cover various diploma, undergraduate and postgraduate engineering curricula for materials handling course in India. The book is also meant to be a ready reference for materials handling practitioners in industry.

At the end of the book, a small list of some of the Indian materials handling equipment manufacturers with their products and present addresses has been appended. This can be a ready reference, for such equipment, for practicing engineers and potential buyers.

— Author

Acknowledgement

While writing this book I have received help, suggestions and encouragement from various organizations and persons. I gratefully acknowledge that.

At the outset, I would like to express my appreciation to my M. Tech. students of Manufacturing Technology course in National Institute of Technical Teachers' Training and Research, Kolkata, who have an one semester paper in Materials Handling. While teaching and discussing the subject to them, I got impetus to undertake to write the present book. I am deeply indebted to them.

I have received help and encouragement from a number of Materials Handling Equipment designers/manufacturers in the form of technical information pertaining to their products and kind permission to use some of the photographic illustrations in the book. I acknowledge their kind gesture and would like to note my thanks to them named below:

(*i*) Jessop & Co. Ltd., Kolkata; (*ii*) TRF Ltd., Kolkata; (*iii*) Sandvik Asia Ltd., India, Kolkata; (*iv*) Godrej & Boyce Mfg. Co. Ltd., Mumbai; (*v*) Voltas Ltd, Mumbai; (*vi*) International Combustion (India) Ltd., Kolkata; (*vi*) Fanuc India Ltd., Bangalore.

I would particularly like to convey my thanks and gratitude to the following persons:

Mr. A.K. Sinha, Head Operations, Sandvik Asia Ltd., and a leading expert in the field of Bulk Handling Equipment for helping me in drafting and arranging the matter on bulk handling equipment and systems; Mr. P. Burman Ray, Vice President, Jessop & Co. Ltd., for his encouragement; Mr.Shibaji Dasgupta, TRF Limited and Mr. Ashim Ghosh, Stewarts & Lloyds of India Ltd. for helping me in making the list of names of equipment manufacturers. I am also thankful to Dr. B. K. Basak, V.P., The Wesman Engg. Co. Ltd., Dr. Samir Kr. Saha, Professor, Mech. Engg. Dept., Jadavpur University, Dr. J. Saha, Prof., Production Engg. Dept., Jadavpur University and Mr. S. Mukherjee, consultant & other colleagues at NITTTR, Kolkata for advising and encouraging me throughout the preparation of the book.

I am thankful to Mr.Kingshuk Ghosh, the DTP operator of my department, who untiringly finished the entire manuscript, working beyond his working hours and at home.

I am grateful to my wife Smt.Dipali Ray and my other family members for their constant encouragement and sacrifices during preparation of the book.

Finally, my thanks are to M/s New Age International (P) Ltd., Publishers, for readily accepting to publish the book in a professional manner.

Dr. Siddhartha Ray

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CONTENTS

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CHAPTER

Introduction to Materials Handling 1.0

1.1 DEFINITION AND SCOPE OF MATERIALS HANDLING

Expressed in simple language, **materials handling** is loading, moving and unloading of materials. To do it safely and economically, different types of tackles, gadgets and equipment are used, when the materials handling is referred to as **mechanical handling of materials**.

Since primitive men discovered the use of wheels and levers, they have been moving materials mechanically. Any human activity involving materials need materials handling. However, in the field of engineering and technology, the term **materials handling** is used with reference to industrial activity. In any industry, be it big or small, involving manufacturing or construction type work, materials have to be handled as raw materials, intermediate goods or finished products from the point of receipt and storage of raw materials, through production processes and up to finished goods storage and dispatch points.

Materials handling as such is not a production process and hence does not add to the value of the product. It also costs money; therefore it should be eliminated or at least reduced as much as possible. However, the important point in favour of materials handling is that it helps production. Depending on the weight, volume and throughput of materials, mechanical handling of materials may become unavoidable. In many cases, mechanical handling reduces the cost of manual handling of materials, where such materials handling is highly desirable. All these facts indicate that the type and extent of use of materials handling should be carefully designed to suit the application and which becomes cost effective.

Based on the need to be of optimum design and application specific to different type of industries, materials handling can be as diverse as industries themself. As a consequence, unfortunately, there is no universally accepted definition of materials handling. One of the definition adopted way back by the American Materials Handling Society is: **Materials handling is the art and science involving the moving, packaging and storing of substances in any form**[(1)*].Some of the other definitions are:

- Materials handling is the movement and storage of materials at the lowest possible cost through the use of proper methods and equipment.
- Materials handling is the moving of materials or product by any means, including storage, and all movements except processing operations and inspection.
- Materials handling is the art and science of conveying, elevating, positioning, transporting, packaging and storing of materials.

There are other definitions also, but above few jointly bring out the salient features of materials handling. It is referred to as an art and science because to most of the materials handling problem no unique solution exists and more than one solution may be prescribed. Lot of subjective considerations of the materials handling engineer go into it. At the same time many scientific factors are also considered to arrive at the solution. In one of the definitions, all the functions of materials handling have been refered

*Number within bracket indicates the serial number of the Reference given at the end of respective chapter.

to which are conveying, elevating, positioning, transporting, packaging and storing. Storage or warehousing is very much a part of materials handling. Materials handling uses different equipment and mechanisms called **Materials Handling Equipment**. Though in one of the definitions, processing operations and inspection have been specifically excluded from scope of materials handling operations, it is worth mentioning that in specific cases processing or inspection of materials may be accomplished simultaneously with handling activity. One definition also covers the important objective of materials handling which is **lowest cost solution**.

The essential requirements of a good materials handling system may be summarized as:

(*i*) Efficient and safe movement of materials to the desired place.

(*ii*) Timely movement of the materials when needed.

(*iii*) Supply of materials at the desired rate.

(*iv*) Storing of materials utilising minimum space.

(*v*) Lowest cost solution to the materials handling activities.

Functional scope of materials handling within an industry covers the following:

(*i*) Bulk materials as well as unit materials handing. Bulk handling is particularly relevant in the processing, mining and construction industries. Unit materials handling covers handling of formed materials in the initial, intermediate and final stages of manufacture.

(*ii*) Industrial packaging of in-process materials, semi finished or finished goods, primarily from the point of view of ease and safety of handling, storage and transportation. However, consumer packaging is not directly related to materials handling.

(*iii*) Handling of materials for storage or warehousing from raw materials to finished product stage.

Often materials handling extends beyond the boundary of the industry in the form of movement of raw materials from the sources to the plant or in the form of finished goods from the plant to the points of consumption. These long distance movements of materials are generally termed as **transportation of materials** through various modes of transport like, road, rail, ship or air. Transportation is generally excluded from the scope of materials handling. However, at each of the sources and destinations, loading and unloading of materials is necessary and these are referred to as materials handling of these locations.

Some production equipment are fitted with facilities for handling of the materials being processed. Such materials handling equipment are generally considered to be an integral part of the production equipment. A few typical examples are : (*i*) the feeding mechanism in an automatic machine, (*ii*) coiler and de-coiler in a strip rolling mill or (*iii*) paper feeding and transportation arrangement in a multi-station printing machine. Essentially these are special material handling devices, but when integrated with specific production machines, they become specialized parts of those machines. Such special devices and their functions are generally not considered to be within the scope of materials handling. However, materials handling at the workplace is an area which is drawing greater attention after introduction of concepts of machining cells fitted with robotic handling devices. This aspect has been further discussed under chapter 9 titled ‘‘Robotic Handling System’’.

1.2 IMPORTANCE OF MATERIALS HANDLING

The foremost importance of materials handling is that it helps productivity and thereby increases profitability of an industry. Many enterprises go out of business because of inefficient materials handling practices. In many instances it is seen that competing industries are using same or similar production equipment, and one who uses improved materials handling system stays ahead of their competitors.

A well designed materials handling system attempts to achieve the following:

(*i*) Improve efficiency of a production system by ensuring the right quantity of materials delivered at the right place at the right time most economically.

(*ii*) Cut down indirect labour cost.

(*iii*) Reduce damage of materials during storage and movement.

(*iv*) Maximise space utilization by proper storage of materials and thereby reduce storage and handling cost.

(*v*) Minimise accident during materials handling.

(*vi*) Reduce overall cost by improving materials handling.

(*vii*) Improve customer services by supplying materials in a manner convenient for handlings.

(*viii*) Increase efficiency and saleability of plant and equipment with integral materials handling features.

Apart from these, for certain industries, like process industries, heavy manufacturing industries, construction industries, mining industries, shipbuilding or aircraft industries etc., the materials are so large and heavy that these industries just can not run without appropriate materials handling system.

All the above points clearly show the importance of materials handling in an industry or a material transportation system. However, the negative aspects of materials handling should also not be overlooked. These are:

(*i*) Additional capital cost involved in any materials handling system.

(*ii*) Once a materials handling system get implemented, flexibility for further changes gets greatly reduced.

(*iii*) With an integrated materials handling system installed, failure/stoppage in any portion of it leads to increased downtime of the production system.

(*iv*) Materials handling system needs maintenance, hence any addition to materials handling means additional maintenance facilities and costs.

1.3 SYSTEMS CONCEPT

In the previous sections materials handling has already been referred to as a system, and it will be repeated many times in future. It is, therefore, important to understand the **systems concept of materials handling**.

The term ''system'' has many meaning depending on the field where applied. A general definition of the term could be: **a complex unity formed of many often diverse parts subject to a common plan or serving a common purpose**. The important characteristics of a system is that the parts, called subsystems, are interrelated and guided by an objective for which the system exists.

In an industry, materials handling is a subsystem (or part) of the production system. Materials handling itself can also be considered to be a system whose subsystems are (*i*)design or method to be adopted, (*ii*) types of materials handling equipment to be used, (*iii*) different operations like packing /unpacking, movement and storage involved, (*iv*) maintenance required for the equipment employed, (*v*) mode of transportation by the raw materials suppliers, distributors / customers, waste / scrap collectors etc. The common objective by which the different subsystems are guided is the lowest cost solution of the materials handling system for that industry.

In actual practice, the system concept of materials handling means the different types of materials handling needed at different parts of an industry and associated suppliers' and customers' end are to be considered in totality. Only this approach will ensure an overall cost effective materials handling solution for the industry.

From a traditional point of view, a materials handling engineer may consider the materials handling problem of a particular area as an individual, isolated case and produces the solution. He may have produced the most economic solution for that problem alone, but it may not lead to the overall lowest cost solution for the entire plant. There are many industries who are using more than hundred sizes of containers/boxes within the same plant! This is the result of solving materials handling problems of different areas in isolation. From systems point of view, the materials handling problem of a plant along with its associated suppliers' and customers' problems should be considered as one system and the subsystems have to be designed and operated accordingly. This systems concept is a logical approach which can achieve the objective of any materials handling scheme which is lowest cost solution.

1.4 CHARACTERISTICS AND CLASSIFICATION OF MATERIALS

Method to be adopted and choice of equipment for a materials handling system primarily depends on the type of material/s to be handled. It is, therefore, very important to know about different types of materials and their characteristics which are related to methods and equipment used for their handling.

As innumerable different materials are used and need to be handled in industries, they are classified based on specific characteristics relevant to their handling.

Basic classification of material is made on the basis of **forms**, which are **(*i*) Gases, (*ii*) Liquids, (*iii*) Semi Liquids and (*iv*) Solids**.

Following characteristics of gases, liquids and semiliquids are relevant to their handling.

For gases it is primarily pressure, high (25 psi and more) or low (less than 25 psi). Chemical properties are also important.

For liquids the relevant characteristics are density, viscosity, freezing and boiling point, corrosiveness, temperature, inflammability etc. Examples of common industrial liquids are: water, mineral oils, acids, alkalies, chemicals etc. Examples of common semi-liquids are: slurry, sewage, sludge, mud, pulp, paste etc.

Gases are generally handled in tight and where required, pressure resisting containers. However, most common method of handling of large volume of gas is through pipes by the help of compressor, blower etc. This process is known as **pneumatic conveying**.

Liquids and semiliquids can be handled in tight or open containers which may be fitted with facilities like insulation, heating, cooling, agitating etc. as may be required by the character of the liquid. Large quantity of stable liquids/semiliquids are generally conveyed through pipes using suitable pumps, which is commonly known as **hydraulic conveying**.

Solids form the majority of materials which are handled in industrial situation. Solids are classified into two main groups: **Unit load** and **Bulk load (materials)**.

Unit loads are formed solids of various sizes, shapes and weights. Some of these are counted by number of pieces like machine parts, molding boxes, fabricated items. Tared goods like containers, bags, packaged items etc. and materials which are handled en-masses like forest products (logs), structurals, pig iron etc. are other examples of unit loads. The specific characteristics of unit loads are their overall dimensions, shape, piece-weight, temperature, inflammability, strength/fragility etc. Hoisting equipment and trucks are generally used for handling unit loads. Certain types of conveyors are also used particularly for cartons/packaged items and metallic long products like angles, rods etc.

Unit loads have been classified by Bureau of Indian Standards' (BIS) specification number IS 8005:1976[(2)]. The classifications are based on:

(*a*) **Shape of unit loads** - (*i*) basic geometric forms like rectangular, cylindrical, pyramidal/conical and spherical; (*ii*) typical or usual forms like pallets, plate, containers, bales and sacks; (*iii*) irregular forms like objects with flat base dimension smaller than overall size, loads on rollers/wheels and uneven shapes.

(*b*) **Position of C.G. (stability) of load.**

(*c*) **Mass of unit load** in 10 steps from 0-2.5 kg to more than 5000 kg.

(*d*) **Volume per unit** in 10 steps from 0-10 cm^3 to more than 10 m^3.

(*e*) **Type of material** in contact with conveying system like metal, wood, paper/cardboard, textile, rubber /plastics, glass and other materials.

(*f*) **Geometrical shape** (flat, concave, convex, irregular/uneven, ribbed etc.) and **physical properties** (smooth, slippery, rough, hard, elastic etc) **of base surface of unit load.**

(*g*) **Specific physical and chemical properties** of unit loads like abrasive, corrosive, dust emitting, damp, greasy/oily, hot, cold, fragile, having sharp edges, inflammable, explosive, hygroscopic, sticky, toxic, obnoxious, radioactive etc.

(*h*) **Loads sensitive** to pressure, shock, vibration, turning/tilting, acceleration/deceleration, cold, heat, light, radiation, damp etc.

Bulk materials are those which are powdery, granular or lumpy in nature and are stored in heaps. Example of bulk materials are: minerals (ores, coals etc.), earthly materials (gravel, sand, clay etc.) processed materials (cement, salt, chemicals etc.), agricultural products (grain, sugar, flour etc.) and similar other materials.

Major characteristics of bulk materials, so far as their handling is concerned, are: lump-size, bulk weight, specific weight, moisture content, flowability (mobility of its particles), angles of repose, abrasiveness, temperature, proneness to explosion, stickiness, fuming or dusty, corrosivity, hygroscopic etc.

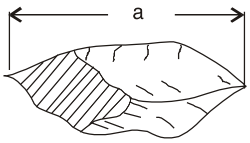


Fig. 1.4.1. Size of a particle

Lump size of a material is determined by the distribution of particle sizes. The largest diagonal size '*a*' of a particle in mm (see Fig.1.4.1) is called the particle size. If the largest to smallest size ratio of the particles of a lumpy material is above 2.5, they are considered to be unsized.

The average lump size of sized bulk material is

$$= \frac{1}{2} \text{ (maximum particle size + minimum particle size)} = \frac{1}{2} (a_{max} + a_{min})$$

Bulk weight or bulk density of a lumpy material is the weight of the material per unit volume in bulk. Because of empty spaces within the particles in bulk materials, bulk density is always less than density of a particle of the same material. Generally bulk load can be packed by static or dynamic loading. The ratio of the bulk density of a packed material to its bulk density before packing is known as the **packing coefficient** whose value varies for different bulk materials and their lump size, from 1.05 to 1.52. Bulk density is generally expressed in kg/m^3.

Mobility not flowability of a bulk material is generally determined by its **angle of repose**. When a bulk material is freely spilled over a horizontal plane, it assumes a conical heap. The angle 'ϕ' of the cone with the horizontal plane is called the angle of repose. Less is 'ϕ', higher is the flowability of the bulk material. If the heap is shaken, the heap becomes flatter and the corresponding angle of repose under dynamic condition is referred to as dynamic angle of repose ϕ_{dyn}, where ϕ_{dyn} is generally considered to be equal to 0.7ϕ.

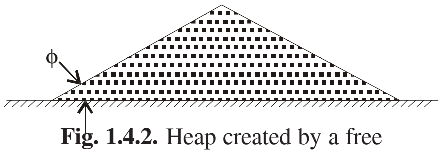
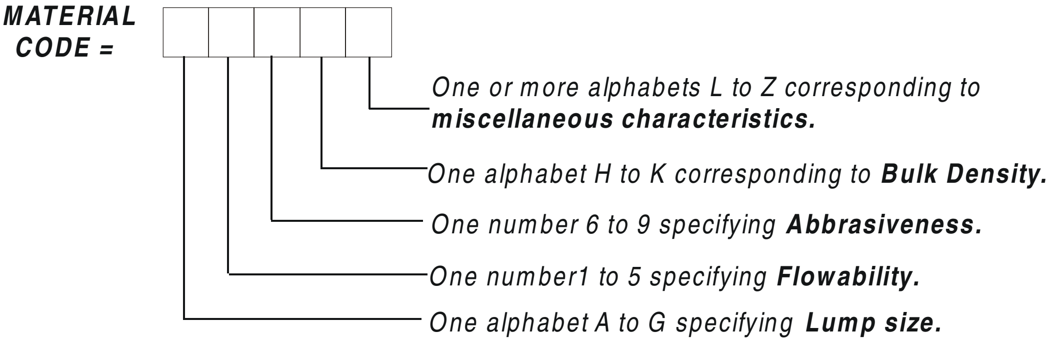


Fig. 1.4.2. Heap created by a free flowing material

Classification and codification of bulk materials based on lump size, flowability, abrasiveness, bulk density and various other characteristics have been specified by the BIS specification number **IS:8730:1997[3].** The alphanumeric codification system as per this specification is shown below:



In this material code, if any of the above characteristics is not known, corresponding number or alphabet is dropped from the material code.

Table 1.4.1 shows the descriptions and limits of the different classes of material characteristics.

Table 1.4.1 Classification of Bulk Materials

Material Characteristics	Description of characteristics with Typical Examples	Limits of Characteristics	Class
1. Lump size	Dusty material (cement)	"a_{max}" upto 0.05 mm	A
	Powdered material (fine sand)	"a_{max}" upto 0.05 to 0.50 mm	B
	Granular material (grain)	"a_{max}" upto 0.5 to 0.10 mm	C
	Small sized lumpy (iron ore)	"a_{max}" upto 10 to 60 mm	D
	Medium sized lumpy (chipped wood)	"a_{max}" upto 60 to 200 mm	E
	Large lump materials (boulder)	"a_{max}" upto 200 to 500 mm	F
	Especially large lump size	"a_{max}" over 500 mm	G

2. Flowability	Very free flowing (cement, dry sand)	Angle of repose: 0°-20°	1
	Free flowing (whole grains)	Angle of repose: 20°-30°	2
	Average flowing (anthracite coal, clay)	Angle of repose: 30°-35°	3
	Average flowing (bituminous coal, ores, store)	Angle of repose: 35°-40°	4
	Sluggish (wood chips, bagasse, foundry sand)	Angle of repose:>40°	5
3. Abrasiveness	Non-abrasive (grains)	-----	6
	Abrasive (alumina)	-----	7
	Very abrasive (ore, slag)	-----	8
	Very sharp (metal scraps)	Cuts belting of coveyors.	9
4. Bulk density	Light (saw, dust, peat, coke)	Upto 0.6 t/m^3	H
	Medium (wheat, coal, slag)	0.6 to 1.6 t/m^3	I
	Heavy (iron ore)	1.6 to 2.0 t/m^3	J
	Very heavy	2.0 to 4.0 t/m^3	K
5. Miscellaneous characteristics	Aerates and develops fluid	-----	L
	Contains explosive (or external) dust	-----	M
	Sticky	-----	N
	Contaminable, affecting use or saleability	-----	P
	Degradable, affecting use or saleability	-----	Q
	Gives off harmful fumes or dust	-----	R
	Highly corrosive	-----	S
	Mildly corrosive	-----	T
	Hygroscopic	-----	U
	Oils or chemicals present	May affect rubber products	W
	Packs under pressure	-----	X
	Very light and fluffy (or very high flowability and dusty)	May be swept by wind	Y
	Elevated temperature	-----	Z

Table 1.4.2 lists a few of the typical materials, which are handled in bulk, with their average bulk density, angle of repose and classification code as per IS:8730:1997. This BIS specification lists 486 different bulk materials, with their bulk densities, flowability properties and codes.

Table 1.4.2 List of a Few Typical Bulk Materials with Codes

Sl.No.	Material	Average Bulk Density, kg/m^3	Angle of Repose, degrees	Code*
1	Alumina	800–1040	22	B27M
2	Bauxite, crushed, 75mm and under	1200–1350	---	D38
3	Cement, Portland	1500	39	A27M
4	Coal, anthracite, sized	960	27	C27
5	Iron ore	1600–3200	35	D37
6	Lime, hydrated	560–720	40	---
7	Rice, hulled or polished	720–768	20	B16
8	Sand, foundry, prepared	1440	39	D38
9	Slag, blast furnace, crushed	1280–1440	25	A28
10	Stone, crushed	1360–1440	–	–
11	Wheat	720–768	28	C26N
12	Wood chips	290–320	–	E56WY

* Code of the materials may vary according to exact condition of the materials during handling.

Bulk materials are generally handled by belt-conveyor, screw conveyor, pneumatic conveyor, bucket elevator, grab bucket, skip hoist, stacker-reclaimer, dumper-loader etc. It can be handled by cranes / trucks when collected in containers or bags. Small lump (powdered / granular) materials can be handled pneumatically or hydraulically. Bulk materials are generally stored on ground / floor in the open or under shed, and also in bunkers / silos.

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CHAPTER

Principles of Materials Handling

2.0

The word principle means, in the context of materials handling, a prescribed rule or guide to accepted procedures, established through past experience, which is taken for granted or accepted as authoritative by practitioners.

Certain fundamental principles for analyzing and designing solutions to materials handling problems have been developed over a period of time based on experience of many materials handling experts. These can be used as general guide by any fresh materials handling practitioner, for analyzing a materials handling problem and arriving at a solution to same. Many of the materials handling problems may be initially treated by these principles before undertaking detailed technical analysis. In certain materials handling problems, these principles may become the only resort to an acceptable solution where the exact analysis is too costly or difficult.

Principles of materials handling were first published by Harry E.Stocker[1] which were further developed by spcialists like Footlik and Carle, Day, Hall and others.

It will be seen that each principle applies to a particular aspect of materials handling and helps in achieving one or more objectives of materials handling. A set of twenty principles of materials handling, (prepared by H.H.Hall[2]) is stated and briefly explained below. Certain specific suggestions have also been added for carrying out the respective principles into practice.

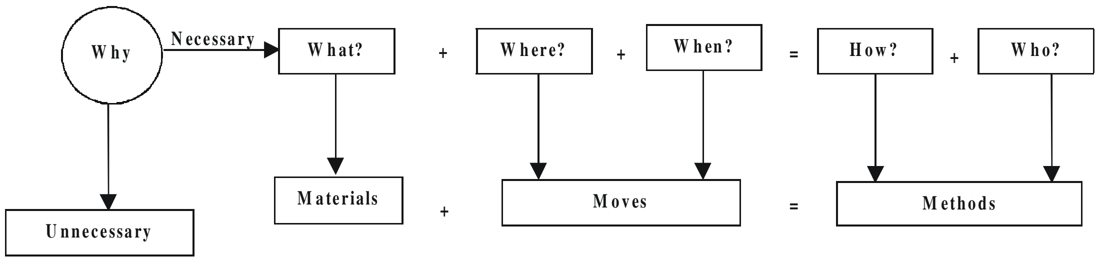
As these principles cover different aspects of industrial materials handling problem, some of the suggestions under different principles may be even contradictory to each other. Under such circumstances, the relative importance of the principles is to be very carefully understood and the relevant suggestion may be considered. Therefore, these principles are to be considered judiciously in context of the specific problem and to be applied with care.

2.1 PLANNING PRINCIPLE

All handling activities should be planned. This is the most basic principle which is in line with the Materials Handling Equation (see block below).

Suggestions for carrying out planning principles are:

- Consider the plant layout before equipment / system design.
- Plan correct location for materials supply and disposal. Plan for scrap removal.
- Assure adequate storage space at the workplace.
- Avoid placing materials directly on the floor. Place product on a pallet, skid etc. at the beginning of the process.
- Use same container throughout the materials movement, as far as practicable.
- Observe principles of motions economy.
- Plan productive operations and inspections during material movement, if possible.
- Use judicious amount of manual handling.



Materials Handling Equation

A simple but useful way of planning and designing a materials handling problem is described by the **materials handling equation**: If Materials Handling is necessary, then MATERIALS + MOVES = METHODS. This is represented by the Fig. 2.1.1 below, as adopted from Apple(3). The planning starts with the question ''why'' at all the contemplated materials handling is needed? If the necessity is clearly established then only a new handling system is to be considered. Next question is ''what'' type of materials to be moved to ''where'' and ''when'' ? Answer to this question leads to the method to be deployed *i.e.* ''How'' and by ''whom'' (manpower/operator) the materials handling will be effected. In effect, the equation emphasizes the necessity of carefully analyzing both the MATERIALS to be handled and MOVES to be made before selecting the METHODS.

Fig. 2.1.1. Materials handling equation

2.2 SYSTEMS PRINCIPLE

Integrate as many handling activities as possible encompassing full scope of operations like receiving, storage, production, inspection, packaging, warehousing, shipping/transportation.

Suggestions:

- Consider the entire scope of the handling activities, beyond the scope of immediate concern.
- Integrate operations into handling systems like processing, inspection, packaging etc.
- Avoid/ minimize intermediate storage.
- While designing a materials handling system, the practices/requirements of the suppliers, clients and transporters are to be considered.
- Allow necessary flexibility considering future requirements/emergencies.

2.3 MATERIAL FLOW PRINCIPLE

Plan operations sequence and equipment arrangement to optimize material flow.

Suggestions:

- Eliminate obstacles from material flow.
- Plan material movement in a direct path (avoid backtracking, zig-zag movements etc.)
- Use product layout whenever possible.
- Keep related work areas close together.

- Combine operations to reduce material movement.
- Minimize movement between floors.
- Move bulky / weighty materials the least distance.
- Process heavy / bulky materials close to receiving.

2.4 SIMPLIFICATION PRINCIPLE

Reduce, combine or eliminate unnecessary movement and/or equipment. It increases efficiency of materials handling.

Suggestions:

- Apply principles of motions economy. Avoid unnecessary handling. Eliminate re-handling as much as possible.
- Plan direct moves. Reduce or eliminate long, awkward or complicated moves.
- Deliver materials at correct location first time.
- Use material out of original container.
- Avoid use of variety of equipment types, sizes and makes.
- Plan adequate material handling equipment capacity.
- Do not mechanize unnecessarily.

2.5 GRAVITY PRINCIPLE

Utilize gravity to move material whenever practicable.

Suggestions:

- Use roller conveyors, slides, chutes between equipment/processes.
- Use ramps between varying work or floor levels.
- Use sloping floor when materials movement by hand truck is mainly in one direction.
- Use spiral chutes to feed machines at different floors.

2.6 SPACE UTILIZATION PRINCIPLE

Make optimum use of building volume.

Suggestions:

- Space equipment/processes close together.
- Eliminate or reduce temporary storage of materials.
- Stack materials to use building height.
- Use racks to permit higher stacking.
- Use stacking containers to permit stacking.
- Exercise economic order quantities to reduce inventory.
- Clean storage areas and dispose scrap regularly.
- Use narrow aisle handling equipment to reduce aisle width.

2.7 UNIT SIZE PRINCIPLE

Increase quantity, size, weight of loads handled.

Suggestions:

- Examine possibility of unitization of loads.
- Use containers for unitization of loads.
- Procure materials in larger units.
- Design load size to make optimum use of handling equipment capacity.

2.8 SAFETY PRINCIPLE

Handling methods and handling equipment use must be safe.

Suggestions:

- Provide adequate guards & safety devices on materials handling equipment.
- Do not overload materials handling equipment.
- Maintain floor in good condition.
- Provide adequate shop lighting.
- Provide good housekeeping.
- Use mirror at aisle intersections.
- Materials handling equipment operators should be properly trained.
- Stack / unstuck materials safely.
- Keep materials handling equipment in proper condition and do not use defective equipment.
- Use mechanical handling equipment for difficult handling activities and to handle dangerous/ hazardous materials.
- Use proper personal protective gears during handling materials.

2.9 MECHANIZATION/AUTOMATION PRINCIPLE

When appropriate, use mechanized or automatic materials handling equipment.

Suggestions:

- Consider mechanized system in the following cases:

  (*a*) Large quantities or volumes of materials, (*b*) Repetitive movement, (*c*) Long moves, (*d*) Hazardous move/materials, (*e*) Two man lifting, moving tasks, (*f*) Excess manual handling, (*g*) Replacing large number of persons involved in handling, (*h*) Heavy materials, (*i*) Scrap removal, (*j*) Feeding/unloading of high speed automated production machines.
- Do not over mechanize.

2.10 EQUIPMENT SELECTION PRINCIPLE

Before selecting materials handling equipment, consider all aspects of materials handling, e.g., materials to be handled, moves to be made, methods to be utilized.

Suggestions:

- Select versatile equipment.
- Select standardized equipment.
- Consider unitization of load for handling.
- Select capacity judiciously. Provide additional capacity based on future plan.
- Compare alternatives based on cost of handling.

2.11 STANDARDIZATION PRINCIPLE

Materials handling methods and equipment should be standardized to the extent possible.

Suggestions:

- Use standardized containers.
- Purchase standard types and sizes of equipment.
- Use standard sizes of pallets to fit products, bay sizes, equipment and transport trucks.

2.12 FLEXIBILITY PRINCIPLE

Use methods and equipment, which can perform different tasks and applications.

Suggestions:

- Buy flexible equipment like Fork Lift Truck, Conveyor etc.
- Use variable speed drives.
- Make use of attachment & accessories.
- Use four ways pallets, skids and containers.
- Utilize mobile in favour of fixed equipment (e.g. trucks in favour of fixed conveyors)

2.13 DEAD-WEIGHT PRINCIPLE

Reduce the dead-weight movement.

Suggestions:

- Movable materials handling equipment should be made of lightweight materials like aluminum, magnesium etc.
- Use lightweight, pallets, skids, containers etc.
- Consider expendable pallets, containers etc.
- Select lightweight equipment for light load.

2.14 MOTION PRINCIPLE

Stoppage of mobile equipment should be minimum.

Suggestions:

- Reduce loading/unloading time.
- Load/unload while materials handling equipment is in motion, if possible.
- Use mechanized loading/unloading equipment.

- Use self-loading/unloading equipment like lift truck.
- Plan materials movement on both ways movement of materials handling equipment.
- Use equipment where carrying device is attached to motive unit like platform-type trucks, trailers etc.
- Use pallets, skids etc. to hasten loading/unloading.
- Use devices like tipplers, bottom discharge containers etc.

2.15 IDLE TIME PRINCIPLE

Reduce idle or unproductive time of both materials handling equipment and manpower.

This principle is similar to motion principle, so far as materials handling equipment are concerned, hence same suggestions are applicable. Additional suggestions for ''manpower'' are:

- Deliver materials at proper rate so that operators are not idle for materials.
- Use indirect labour for materials handling.
- Install handling equipment to reduce labour.
- Combine jobs i.e. one man handles two or more machines or jobs.

2.16 MAINTENANCE PRINCIPLE

Do schedule maintenance and repair work of all materials handling equipment to minimize outage.

Suggestions:

- Train operators/maintenance personnel properly.
- Follow maintenance procedures as per manufacturers' recommendations.
- Operators should check conditions daily and report.
- Do repair/maintenance to avoid breakdowns.
- Establish preventive maintenance programme.
- Maintain adequate spares.
- Standardize equipment to reduce spares.
- Avoid over maintenance.
- Avoid over loading of materials handling equipment.

2.17 OBSOLESCENCE PRINCIPLE

Replace obsolete handling methods and equipment by more efficient methods or equipment to improve operations.

Suggestions:

- Establish a definite replacement policy.
- Rent or lease new equipment to tryout.
- Keep up-to-date as to what is new in the market through books, journals, expositions, factory visits, conference, manufacturers' representatives etc.

2.18 CONTROL PRINCIPLE

Use materials handling equipment to improve production & inventory control and order handling.

Suggestions:

- Move materials in lots, batches, containers of a predetermined quantity and size.
- Use containers with wire mesh for visual checking/counting.
- Synchronize materials handling with production.
- Coordinate materials handling programme with purchasing and production.
- Use mechanized handling.

2.19 CAPACITY PRINCIPLE

Use Materials Handling so that full production capacity can be achieved.

Suggestions:

- Use mechanical handling systems for uniform flow of materials.
- Operate equipment at optimum rate.
- Plan to utilize return run of the materials handling equipment.
- Make full use of building volume.
- Change size, shape of unit load to utilize space, equipment and manpower.
- Use outdoor or rented storage space, when necessary.
- Widen aisle ways to speed materials movement.

2.20 PERFORMANCE PRINCIPLE

Select materials handling systems with higher efficiency, measured in terms of expenses per unit load handled.

Suggestions:

- Identify all possible units, which could be used as a basis for comparison.
- Select common, convenient, standard equipment.
- Use versatile equipment.

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CHAPTER

3.0 Unit Load Concept

3.1 DEFINITION OF UNIT LOAD

Unitization of load is an important concept in Materials Handling. The basic concept is to move maximum load at a time so that the number of moves for a definite quantity of load to be moved is minimum and so is the cost of handling. The concept is practiced, wherever, possible, almost universally. The same concept is expressed by the ''Unit size principle'' referred in previous chapter.

A question may be asked as to what would be the right size of such a unitized load? The optimum size of a unitized load is that maximum load which can be safely and efficiently handled by the existing handling equipment in that industry.

There are many materials which by virtue of their size and weight need to be moved individually and are called **unit loads**. However, there are many materials whose individual size and weight is small, but are required to be moved in large quantities. Such materials, and also bulk materials which are needed in specific quantities, are generally gathered together to form a load of a definite weight, and then moved as an unit load. This is called Unitization of load. In the words of Professor James R.Bright, **unitized load** may be defined as: ''A number of items, or bulk material, so arranged or restrained that the mass can be picked up and moved as a single object, too large for manual handling, and which upon being released will retain its initial arrangement for subsequent movement. It is implied that single objects too large for manual handling are also regarded as unit loads.''

Often the two terms ''unit-load'' and ''unitized load'' are used interchangeably. However, in this chapter, unit load will mean a single object where unitized load will mean collection of objects which are being treated as an unit load for handling it.

A few examples of unitized load are:

(*i*) Bundle of stricks tied together.

(*ii*) Small castings put inside a container.

(*iii*) A stack of bricks on a pallet.

(*iv*) A trailer full of sand etc.

A distinction should be made here between unitized load and packaged loads. Loads are unitized for handling large volume of small/loose materials, for a comparatively short distance within a plant. Loads may get unitized sometimes by packaging also, but it is generally meant for protection of loads during storage and movement over long distances. Packaging is separately discussed in section 3.6.

3.2 ADVANTAGES AND DISADVANTAGES

The major advantages of unitization and handling of unit loads are:

(*i*) It permits handling of larger loads at a time and thereby reduces handling and transportation costs.

(*ii*) Loading and unloading time of unit load is substantially less than when handled as loose/individual material.

(*iii*) Unitized loads are less susceptible to damage and loss during movement from one place to another.

(*iv*) It offers safer handling and transportation compared to those of loose materials.

(*v*) Unitized load, even made of irregular shaped items, generally become stable and well shaped. This offers a number of advantages like stable storage, uniform stacking to greater heights and increased storage space utilization.

(*vi*) For unitized load, individual item labeling may be avoided.

(*vii*) The process of unitization often protects loads from foreign elements.

(*viii*) Unitization generally provides a basis for standardization of handling system and equipment within the plant as well as at the receiving and shipping points for transportation.

There are also disadvantages associated with unitization of loads. These are:

(*i*) There is a cost of unitization and de-unitization.

(*ii*) Unitization generally involves additional support and material for restraining the loose articles. These unitization medium increase the weight of the final load to be handled.

(*iii*) Unitization essentially means deployment of equipment, which necessitates capital investment.

(*iv*) Containers are often used for unitization. Movement of the empty containers results in additional handling cost and problem.

(*v*) There is possibility of damage due to mishandling of large amount of load.

(*vi*) Movement of unitized materials may get hampered due to absence of transfer equipment.

3.3 LOAD UNITIZATION PROCESSES AND HANDLING METHODS

As unitized load is generally of fairly large weight and volume, the method of handling them, i.e. how to hold, lift and carry them is an important issue. The basic methods of handling an unit load are:

(*i*) Putting a lifting device under the load like pallet, skid, tray, rack etc., and then handling this device along with the load.

(*ii*) Inserting a lifting element into the body of the unit load. This method is particularly suitable for lifting circular shaped loads, with a hole in it, like coils, wheels, pipes etc. The lifting element may be a ram type attachment of a forklift truck, or may be simply a rod or log inserted through the hole of the object.

(*iii*) Squeezing the load between two adjustable surfaces. This is equivalent to carrying an object by squeezing it between two fingers, between fingers and palm or between palms of two hands by a man. This action is simulated by carton-clamp, or grabbing attachment of a lift truck or self-closing tong of a lifting equipment.

(*iv*) Suspending the load. This can be done by hooking the object, looping slings around the load, gripping the load with a clamp, using a magnet for magnetic load, using vaccum cups for handling large flat fragile/delicate object made from glass, plastics etc.

Based on the process of unitizing and methods employed for handling, unitized loads are generally grouped into following five basic types:

(*i*) **Unit load on a platform:** When the load is arranged on a platform which can be lifted and carried as unit load. Generally two types of platform are used in industry - **pallet** and **skid** (see section 3.4 for further details on pallets and skids).

(*ii*) **Unit load in a container:** When small sized articles are put inside a box like container, which can be carried easily by trucks, cranes etc. This is a type of unitized load which is very popularly practiced in manufacturing industries. Different sizes and designs of containers are used like box, bin, crate, carton, sack / balloon etc. (see section 3.4 for further details on containers).

(*iii*) **Unit load on a rack:** Specially designed racks are used to hold different types of parts in desired orientation or relationship to each other. The racks may be provided with inserts, pegs, or holes to orient parts or to form dividers between layers for easy handling, counting, inspection etc. Long products like pipes, bars etc. are essentially stored in racks. Racks may be provided with wheels for movement in planes or may be provided with hooks for lifting. Following figure 3.3.1 illustrates a few typical unitized load on racks.

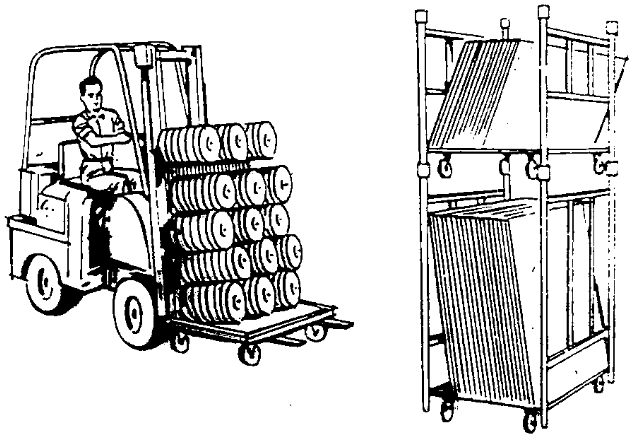


Fig. 3.3.1 Unitized load on special racks with wheels which can be moved by forklift truck or by hand

(*iv*) **Unit load on a sheet:** Unitization is possible on a sheet material and the shape of the load depends on the character and way the sheet material is used. Flat sheets like cardboard, chipboard or plywood may be used for unitization of load on it. Specially formed molded sheets are used for unitization of bulk materials. In these formed sheets, provisions are kept for fork entry of lift trucks. A flexible sheet may be used as sling particularly for odd shaped unit loads, bulk materials or materials packed in bags.

(*v*) **Self contained unit load** (not requiring major auxiliary aids)**:** Different kinds of self contained unitized loads are practiced in industry and in everyday use. There are:

(*a*) **Bundle:** Long pieces of unequal shapes tied together by a rope, wire, elastic band etc. for ease of handling.

(*b*) **Bale:** Materials like scrap paper, sheet metal trimmings etc. are compressed in a bailing press to make the loose materials into a single compact load of reduced size.

(*c*) **Fastened unit load:** Loose items fixed in position by materials like wrapper, tape, glue etc.

Shrink-wrapping and **Stretch-wrapping are** two very popular processes which are used more for packaging than unitization. These processes have been discussed in section 3.6.

(*d*) **Interlocked unit load:** Load which consists of individual pieces so shaped by design that they can be arranged in a fashion to make the assembly interlocked and self re-strained. For example cast aluminum pigs interlocked to build a stack.

(*e*) **Unrestrained Load:** Items stacked on a lifting device without any restraining member, such that it can be stored as an unit, but requires extra care for lifting or moving. Stack of bricks or cartons on a pallet are examples of unrestrained load.

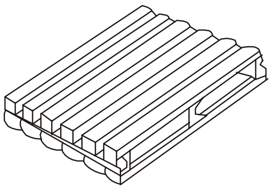
3.4 PALLETS, SKIDS AND CONTAINERS

Pallets, skids, and containers are the most commonly used unitization devices, referred in the previous section. Both pallets and skids are platform type devices used for forming **''Unit load on platform''.**

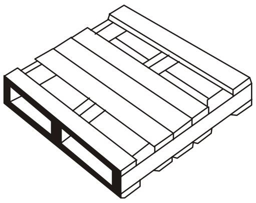
Pallet**:** It is essentially a platform used for assembling, storing and handling of materials as a unit load. Essential feature of a pallet is that the forks of a lift truck can be inserted at the bottom side of the platform, while the pallet is resting on floor and thus can raise the pallet with load and move it to desired place. Pallets, when not in use, can be stacked one above the other.

Skid**:** It is essentially a platform provided with legs so that a platform truck may get inside it and raise it from ground. Skids are thus single-faced and non-stackable.

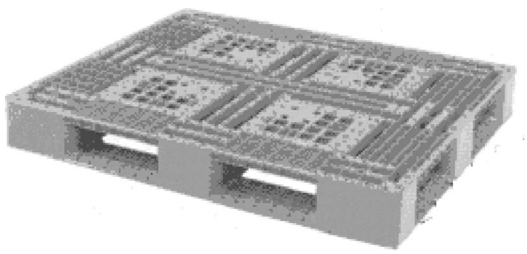
Pallets and skids may be classified as flat, box or post type. Post type are having either fixed or removable corner posts to help restrain the load. These different designs of pallets and skids are commonly made of lighter materials like, wood plywood, chipboard, aluminum, plastics, rubber and rarely by steel. Construction may be rigid or collapseable to permit easy return. Pallets and skids of different types are shown in Fig.3.4.1.



Pallet-aluminum



Pallet-wood



Pallet-Plastic

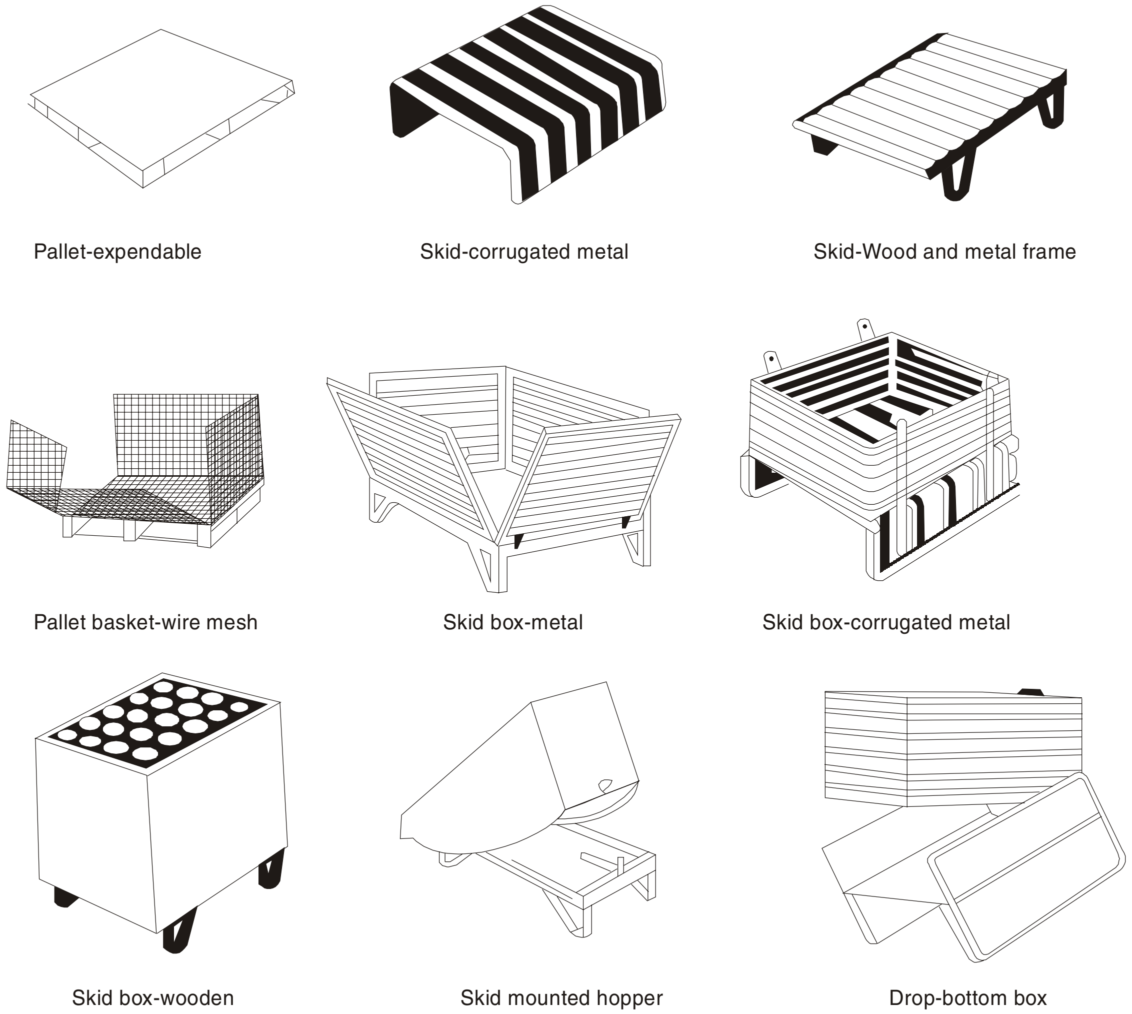


Fig. 3.4.1. Pallet and skids of different design

Pallets of different designs, size and constructional features are used in different industries. These can be single faced or double-faced, reversible or non-reversible, two-way or four-way entry. BIS standards IS 7276:1989 and IS 9340:1993 give various design and constructional inputs for non-expendable and expendable pallets respectively.

Non-expendable pallets are meant for repeated use while expendable ones are inexpensive and generally suitable for one time use only. As per the above BIS specifications, the overall plan dimensions of the pallets for use in plant materials handling are as follows:

Length, mm	Width, mm
800	1200
1000	1200
1100	1100
1200	1200
1200	1800

The specifications also specify the length and height of the gaps for entry of the forks of pallet trucks/fork lift trucks. The specifications also specify the followings:

(*i*) nominal load rating of the pallets, (*ii*) material requirements, (*iii*) constructional details, (*iv*) testing of pallets, (*v*) recommended timber species and various defects, if wood is used as pallet material.

IS 11982:1987 provides guidance on the relationship between the design rating of a pallet and its safe working load in actual use, which depends on the nature of the load (*viz.*, point, concentrated, uniformly distributed, uniformly placed, solid etc.) being carried.

Figure 3.4.2 illustrates a few designs of wooden pallets. Generally, same or similar item of fairly regular shape and size are put on pallet/skid for unitization. Items are generally kept in layers in definite arrangements. Placement of goods in such arrangements is called ***pallet pattern*.** Figure 3.4.3 shows a few of these pallet patterns referred to as **block, brick, row** and **pin-wheel.** The choice of a particular pattern depends on a number of factors like pallet type and size; dimensions, shape, fragility, weight, container used etc. of the item; container dimension, shape, strength, amount of interlock etc.; handling equipment and attachment used; Warehouse layout and type of movement. IS 13823:1993 recommends the procedure to be followed for palletization of different type and nature of cargoes for break bulk or container loading in regard to stacking, strapping and wrapping of the load on the pallet.

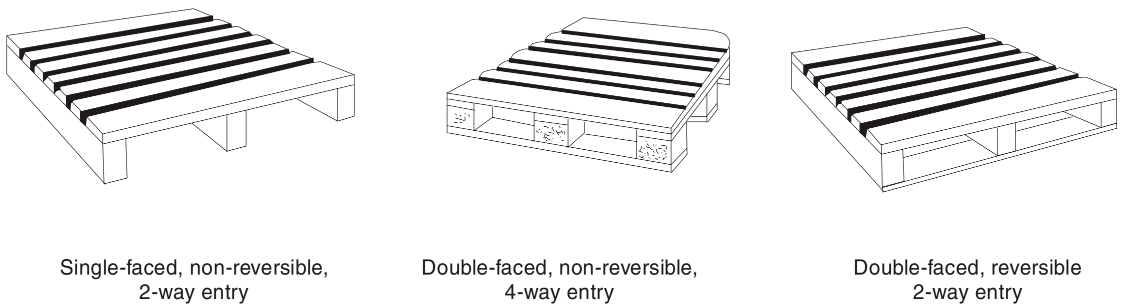
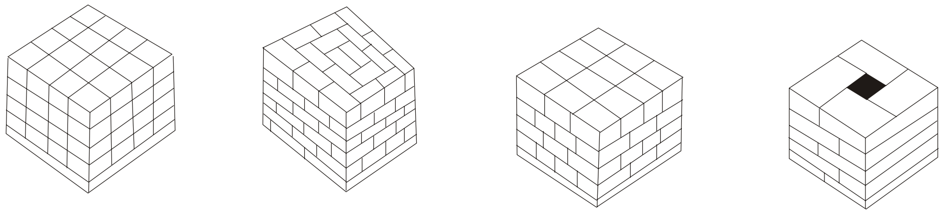


Fig. 3.4.2. Common designs of wooden pallet



Block Brick Row Pinwheel

Fig. 3.4.3. Typical pallet patterns

Container: Different types of containers of various sizes from small to large made out of diverse materials like sheet metal, wire net, wood, plastics, rubber, paper etc. are used for unitization of loads in industry. The term container includes parts bin, tote pan, tote box, pallet box, bulk container, cargo container, van/shipping container etc. Containers are of different designs. These may be top open, covered, hinged/gated bottom for easy discharge, on legs or on wheels for easy movement through equipment or manual effort etc. Small containers are generally handled manually and moved on platform trucks, while large containers are handled and moved by fork-lift trucks, tractors or cranes. Many containers are so designed that they can be stacked one above the other, while empty or even loaded. Following Figure. 3.4.4 shows some of the typical containers used in industries and services, and handling of the bulk/shipping containers. Constructional and dimensional details of metallic containers are available in BIS standards IS 9273:1979 and IS 6093:1985.

Plastic tote boxes

Containers with wheels

Metallic Pallet Box

Plastic pallet box

Container handling by forklift truck

Transportation of container

Loading of a shipping container

Fig.3.4.4. Typical containers and their handling.

3.5 ALTERNATIVE METHODS OF HANDLING

There are alternative methods of handling unitized loads without using unitizing devices like pallet, skids, containers and racks. These alternative methods make use of different attachments used in conjunction with materials handling equipment like forklift truck, crane etc. The unit load which are handled by these methods are generally single items or unitized loads of regular size and shape like rolls, bales, cartons, bags etc.

Circular shaped loads with a hole in it like a coil, wheel, pipe etc may be lifted by a ram type attachment of a forklift truck. Alternatively a sling round the load may be made by a rope/chain passing through the hole, and then suspending it from the sling by a forklift truck or crane. Cylindrical loads like paper rolls, drum etc. may be picked up using cylindrical clamp type attachments on forklift truck. Loads like cartons, bales etc. can be handled by squeezing action of straight clamp attachments. Some of these attachments have been discussed and illustrated in chapter 5 under forklift truck attachment.

Different types of tongs are used in conjunction with crane for lifting and moving many types of unit loads as illustrated in Fig.3.5.1.

Advantages of using these alternative methods are:

(*i*) No need of moving weighty and bulky devices like pallets, containers etc.

(*ii*) Lower operating cost.

(*iii*) Flexibility in storage as warehouses are not limited to a few size of palletized / containerized loads.

There are also some disadvantages of these methods:

(*i*) These are not suitable for less than unit loads.

(*ii*) Mixed size loads cannot be stacked effectively.

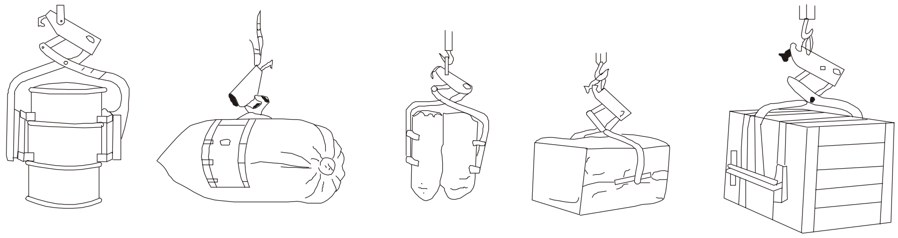


Fig. 3.5.1. Self closing tongs for handling different unit loads

In practice the actual method of handling of unit / unitized load is dictated by the cost of such handling.

3.6 PACKAGING FOR MATERIALS HANDLING

Packaging of materials has two major aspects. The one is to package individual product/item to promote sale of soft goods. The other is to protect the materials, individual or bulk, during storage and transportation of these packaged materials.

The first type of fancy sales packaging which promote the attractiveness of the articles to the consumer is not directly related with the subject of materials handling. However, the second type of packaging for protection of the materials including protection of the sales packaging, has close relationship with some of the materials handling functions like storage and transportation, and thus forms a part of Materials Handling System. This type of packaging is called **Industrial Packaging** or **Packing**. Both of the terms are used interchangeably.

Packing is to provide protection for an article or group of articles against physical damage during shipment/transportation. Such packing/packaging is accomplished by placing articles in a container and blocking, bracing and cushioning them when necessary, or by strapping, wrapping the articles or containers on a pallet or skid.

Raw materials from suppliers are often received as unitized load in packed condition. Similarly the finished goods from an industry is suitably packed and kept in warehouse prior to shipment to the consumer. The major purpose of packing is to protect the goods during storage as well as transportation to point of use. A secondary purpose of such packing is to allow easy/safe handling of some finished goods. There are many products which are not safe to be handled without suitable packing even by sophisticated materials handling equipment. For such goods, suitable packing is prerequisite for any type of handling. These packages often contain more than one goods/components, and thus serve the purpose of unitizing of load also.

Different types of industrial packaging are practiced in industries, depending on the items/goods to be packed. Some of these are: (*i*) wooden boxes, (*ii*) wooden crates, (*iii*) corrugated paper cartons, (*iv*) shrink-wrapping or stretch-wrapping etc.

The packaged units are necessarily handled mechanically. Therefore, suitable provisions are made in the packages to enable handling by trucks, cranes etc.

As the packed units have to be handled at both producers' and users' ends, the type, size and weight of these industrial packing are standardized based on discussions between both sides.

Wooden Boxes/Crates

Most of the finished engineering goods are packed in nailed wooden boxes or crates. By definition Wooden case or box is a framework whose base is based on a sill or skid, and all the other five sides are covered by sheathing made of wooden planks or plywood, used as a container to transport articles providing complete protection to the articles. Wooden crate is a framework used as a container in the transportation of articles which do not require complete protection afforded by a wooden case or box. In a crate, the faces are only partly covered by spaced battens and struts.

Specification of wooden crates to carry up to 500 kg articles is specified in IS 3071:1981. It illustrates different styles of crates specifying the constructional details, class of timber and nails to be used, dimensions of different members to be used based on weight and type of load which is classified in six classes (A to F)—"A" being for light load up to 50 kg and "F" for loads between 252 to 500 kgs. IS 10687:1983 gives the guidelines for nailing of large framed wooden containers (boxes).

The goods inside a box or crate may be covered by plastic sheets or waterproof paper to protect the goods from water, supported by stays and cushioned by cushioning materials as required. The boxes/crates are often cleated by steel angles for strengthening the boxes. The boxes may be provided with hooks fitted at the top for lifting by cranes. Large and heavy boxes are often marked at the positions of safe slinging. The box/crates are provided with shipping labels containing the information about the gross weight of the box amongst other shipping information. Boxes and crates may be wirebound to reduce wood requirements and to facilitate ease of assembly of the prefabricated faces.

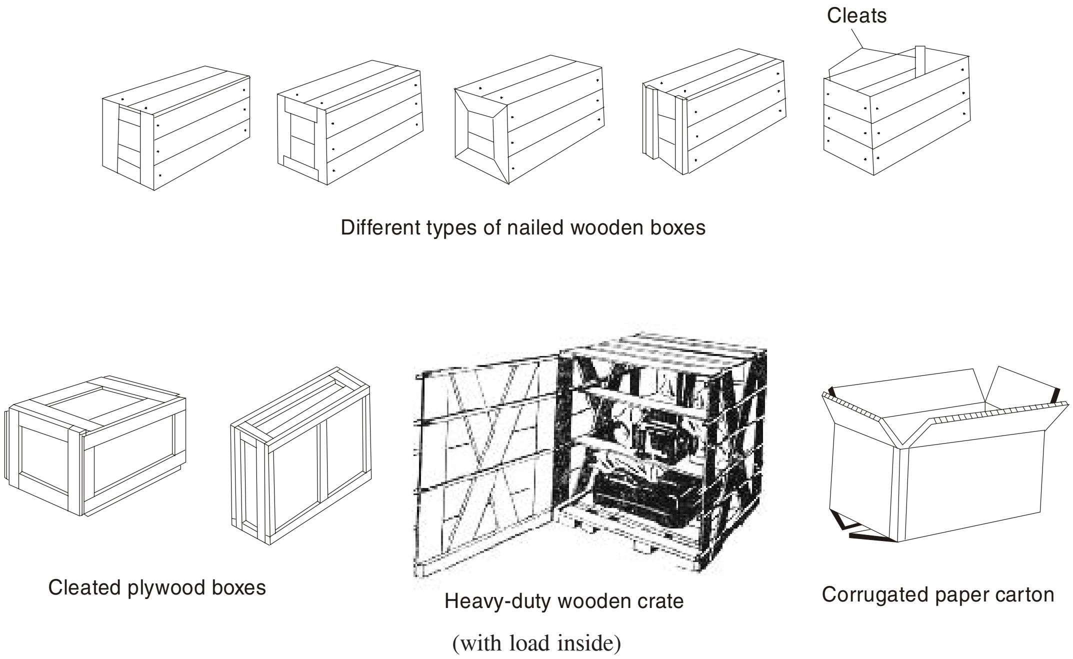


Fig. 3.6.1. Wooden boxes, crates and paper cartons

Cartons: Cartons, made of corrugated paper or plastic materials or solid fibreboard are used for packing a number of smaller goods with or without soft sales packaging. Cartons are sealed by gummed tapes at the corners of the cartons and the inner sides may be provided with blown plastic (thermocole) cushions.

Shrink wrapping and **stretch wrapping** are two much used processes of unitizing / packaging loads in industry. In shrink-wrapping, polyvinyl chloride (PVC) or polyethylene (PE) film of 50-350 micron thickness, is used to wrap the load arranged over a pallet and then heated by a portable hot air gun or some heat source at a temperature range of 350°C from a distance of about 300mm. With the application of heat the film shrinks and wraps the loads together to form a stable unit load. Major advantages of shrink-wrapping are:

- Can be used for articles almost of all shapes
- Stable pallet loads are formed
- Protects unitized load from dust, dirt and even moisture
- Protects articles from damage and loss
- Relatively low cost method of unitization and packaging
- Transparent film allows the wrapped articles visible

Stretch wrapping is the latest and most cost-effective method of unitizing pallet loads. Here high stretchable polyethylene film is wrapped under tension round the loads. Multiple wraps are generally employed, when the film gets attached to the load surfaces and make it an unitized load. However, additional advantages over those of shrink wrapping are:

- Costs less
- Requires less energy
- Holds piece loads together
- Can be used for heat sensitive products.

However, this method is particularly good if only four sides of the load need to be protected. Whereas shrink-wrapping is better if five or six sides are to be protected. Shrink wrapping done by film having UV ray retarding additives, is better for light sensitive loads for outdoor storage. Shrink wrap conforms better to odd shapes particularly sharp edges, or shapes with humps and voids. Shrink wrapping is also better for pressure-sensitive loads.

Both shrink and stretch wrapping can be done manually or by help of specially designed small as well as large shrink wrapping machines and stretch wrapping machines. A few typical industrial machines are shown in following photographs.

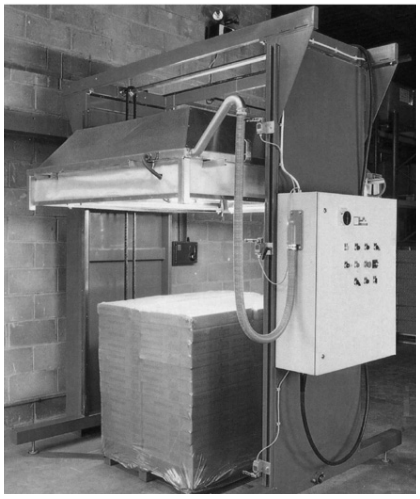


Fig. 3.6.2. Semi-automatic shrink wrapping machine with infra-red heating

Fig. 3.6.3. Automatic multi layer shrink wrapping machine

Fig. 3.6.4. Stretch wrapping machine. The pallet load is wrapped by a roll of film attached with rotating arm

Fig. 3.6.5. Stretch wrapping machine for covering six sides of the load

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CHAPTER

Classification of Materials Handling Equipment

4.0

4.1 BASIC EQUIPMENT TYPES

The nature of industries, manufacturing processes involved and types / designs of machines & plants in operation are innumerable, consequently the variety of materials handling equipment and systems used in industry is also very large in number and diverse in concept and design. New equipment are being designed and manufactured continuously. It is difficult even to mention about all types of materials handling equipment being used, detailed discussions on their functions and design aspects is just impossible within the limited span of the present book.

It is therefore, essential to classify such large number of materials handling equipment into a few ''basic types'' for meaningful discussion of these equipment. There has been many attempts by stalwarts in the field of materials handling to classify equipment in different ways. However, in the present book, classification based on the following basic types of equipment will be followed, which is in line with that followed by many practitioners and authors:

(*i*) Industrial Vehicles/Trucks.

(*ii*) Conveyors.

(*iii*) Hoisting Equipment.

(*iv*) Bulk Handling Equipment/System.

(*v*) Robotic handling system.

(*vi*) Containers and Supports.

(*vii*) Auxiliary Equipment.

In above classification the ''transportation equipment'' group has been excluded. However, it is to be noted that some of the road and railroad transportation equipment may often be used as common materials handling equipment inside a large industry or construction site.

There are sub-classifications under each type and there are different individual equipment under each of these sub classifications, with their individual utility and design features. However, since classification into above types form a convenient basis for discussing materials handling equipment, these are briefly described below, while the sub-classifications and examples of a few widely used individual equipment are listed in section 4.2. It is to be noted that there are equipment which may not quite fit in the above scheme of classification or may be classified under more than one category.

Industrial Vehicles/Trucks

These are manual or power driven vehicles suitable for movement of mixed or unitized load, intermittently, where primary function is **maneuvering** or **transporting**. The vehicle/truck is physically moved along with the load from one point to another via a flat or slightly inclined route. This classification excludes highway vehicles, railroad cars, marine carriers and aircrafts.

Conveyors

These are gravity or powered equipment commonly used for moving bulk or unit load continuously or intermittently, uni-directionally from one point to another over fixed path, where the primary function is **conveying** of the material by the help of movement of some parts/components of the equipment. The equipment as a whole does not move.

Hoisting Equipment

These equipment are generally utilized to lift and lower and move unit and varying loads intermittently, between points within an area known as the reach of the equipment, where the primary function is **transferring**. A hoisting equipment may also be mounted on a powered vehicle when the movement of the lifted load is not limited within a fixed area of operation.

Bulk Handling Equipment/System

In the large process industries and constructional projects, a wide range of heavy equipment are used for handling and storage of large amount of bulk solids. These are called bulk handling equipment.

Robotic Handling System

Specially designed robots are increasingly being used in materials handling application, particularly in loading and unloading of jobs to and form a machine or a machining cell.

Containers and Supports

This classification generally includes all types of secondary devices and aids which are utilized for storing, unitizing and movement of materials. Different types of pressure, tight, loose, closed and open-top containers; platforms and coil supports and different securements such as strapping, cinches (chain, rope, cables with tighteners), bulkheads, dunnage etc. are examples of secondary devices and aids.

Auxiliary Equipment

A large number of equipment and attachments which cannot be classified under above heads, but are frequently used independently or in conjunction with some other materials handling equipment, are classified in this type.

4.2 CLASSIFICATION OF HANDLING EQUIPMENT

The major sub classifications and some of the common individual equipment under these sub-classifications are mentioned in the following lists:

I. Industrial Vehicles / Trucks

A. Non-Powered	B. Powered
1. dolly	1. fork lift truck
2. wheelbarrow	2. front-end truck
3. 2-wheel hand truck	3. narrow aisle truck

4.4-wheel hand truck
(*a*) box
(*b*) platform
(*c*) special
5. hand lift (jack) truck
(*a*) pallet
(*b*) skid
(*c*) special.
6. lift table
7. semi-live skid
8. trailer

(*a*) pallet
(*b*) skid
4. platform truck
5. platform lift truck
6. reach truck
7. side loader truck
8. straddle truck (out-rigger)
9. straddle carrier
10. walkie
11. tractor
12. industrial car
(*a*) mine and quarry car.
(*b*) furnace and oven car.
(*c*) hot metal and ladle car.
13. truck (road)
14. locomotives

II. Conveyors

A. Belt Conveyor
1. flat
2. trough
3. closed
4. metallic
5. portable
6. telescoping

B. Chain Conveyor
1. apron or pan
2. slat
3. cross-bar or arm
4. car type/pallet
5. en-mass
6. carrier chain and flat-top
7. trolley
8. power and free
9. suspended tray or swing-tray

C. Haulage Conveyor
(A special class of chain conveyor in which load is pushed or pulled and the weight is carried by stationary troughs, surfaces or rail.)
1. drag chain
2. flight
3. tow
(*a*) over-head
(*b*) flush-floor
(*c*) under-floor

D. Cable Conveyor

E. Bucket Conveyor
1. gravity discharge
2. pivoted bucket
3. bucket elevator (also included under III)

F. Roller Conveyor
1. gravity
2. powered/driven
3. portable

G. Screw Conveyor

H. Pneumatic Conveyor

1. pipe line
2. air-activated gravity (airslide)
3. tube

I. Hydraulic Conveyor

III. Hoists, Elevators and Cranes

A. Hoist

1. chain
2. powered

B. Winch

C. Elevator

1. bucket
   (*a*) centrifugal discharge
   (*b*) positive discharge
   (*c*) continuous discharge
2. skip hoist
3. freight
4. lift

D. Crane

1. jib
   (*a*) fixed pillar
   (*b*) travelling
   (*c*) fixed-tower hammerhead
2. travelling (on rail runways)
   (*a*) bridge
   (*b*) gantry
3. wharf
4. pillar
5. tower

IV. Bulk and Miscellaneous Handling Equipment

A. Excavator

B. Belt wagon/mobile transfer conveyor

C. Spreader

D. Stacker, Reclaimer and Stacker reclaimer

E. Ship loader and unloader

F. Container handling crane

G. Dumper and Loader

H. Tippler truck, Wagon tippler etc.

V. Robotic Handling Systems

6. mobile
   (*a*) crawler
   (*b*) truck and wagon
   (*c*) railroad/locomotive
   (*d*) floating
7. derrick

VI. Containers and Supports

A. Shop Containers

1. bag
2. box and container
3. craton
4. crate
5. pallet box
6. skid box
7. tote box, pan and basket
8. tray

B. Bulk Containers

1. barrel
2. drum
3. tank
4. bin and silo, bunker, hopper.
5. ladle

C. Shipping Containers

1. bulk
2. freight
3. liquid

D. Supports

1. pallet
2. skid
3. tables and tray
4. rack
5. reel, spool, cone, core
6. securing devices (strappings, cinches, bulkheads etc.)

VII. Auxiliary Equipment

A. Gates

B. Feeders

C. Chutes

D. Positioners

E. Ball table

F. Weighing and Controlling Equipment

G. Pallet Loaders and Unloaders

H. Forklift Truck Attachment

I. Crane Attachment

J. Packaging Equipment

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CHAPTER

5.0

Industrial Vehicles/Trucks

Industrial vehicles/trucks is one of the most common group of materials handling equipment used in industry as well as in day to day distribution of goods in warehouses, large stores, transport depots etc. Basic definition of industrial trucks and their classifications have already been discussed in chapter 4. In this chapter, operation and constructional features of some of the common types of industrial trucks will be discussed. The adjective ''industrial'' used before this group of vehicles / trucks is to distinguish these from other group of vehicles like bus, lorry, truck etc. used for transportation of man, live stock or goods.

The entire range of industrial vehicles/trucks are generally sub-classified into two groups viz. **non-powered truck**, (also called **hand trucks)** and **powered trucks**.

The powered trucks can be further subdivided into following three subgroups, for convenience of discussion:

(*a*) Power Truck.

(*b*) Forklift Truck.

(*c*) Tractor.

5.1 HAND TRUCKS

Hand trucks, as the name implies, have no source of motive power, these are generally moved manually or are attached to other powered moving equipment/units. Hand trucks are classified into three sub groups (*i*) **2-Wheel hand truck**, (*ii*) **multiple-wheel hand truck** and (*iii*) **Hand lift truck**.

5.1.1 Two-wheel Hand Trucks

These are generally used for moving unit or unitized loads like bags, barrels, boxes, cartons, bales, cylinders etc. by pushing the truck manually.

Basically it consists of two long handles fixed by a number of cross bars which from the frame to carry the load. Two wheels mounted on an axle is fixed on far end of the frame. Two short legs are generally fixed to the two handles at the other end to allow the hand truck to stay in a horizontal position during loading and unloading of the truck. Constructional feature of a common 2-wheel hand truck is shown in Fig. 5.1.1.

1. Handle 2. Side rail 3. Leg 4. Leg brace 5. Top crossbar 6. 3rd crossbar 7. 2nd crossbar 8. 1st crossbar 9. Nose 10. Axle brace 11. Axle 12. Pressed steel wheel 13. Retaining ring 14. Axle bracket 15. Nut, bolt and lock washer

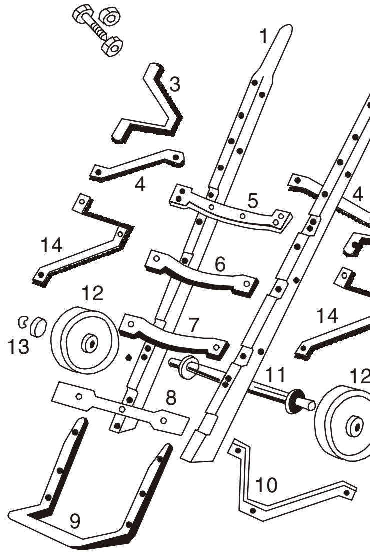


Fig. 5.1.1. Parts of common 2-wheel hand truck

Different varieties of 2-wheel trucks are in use based on the type of loads to be handled. Some of these, which are variations of the basic design, are illustrated in Figure 5.1.2 below indicating the type of load they are used for.

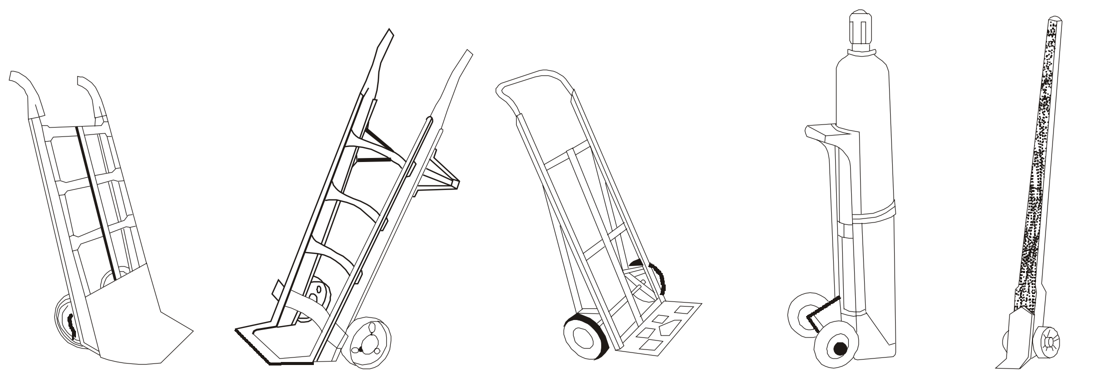


Fig. 5.1.2. Different types of 2-wheel hand trucks

Pry trucks having a crowbar nose, pry up a heavy load and roll it away. These are used for loads too heavy for ordinary 2-wheel trucks. They are often used in pairs by two men.

5.1.2 Multiple-wheel Hand Trucks

These trucks generally consists of a platform or framework mounted on 3 or 4 or more number of wheels. The truck is generally provided with a handle for pushing or pulling the platform. Certain trucks are provided with no handle or detachable handle.

Trucks under this subgroup can be classified in the following individual equipment:

Dollies: These units consists of a wooden or metallic low platform or frame of different shapes (rectangular, triangular or circular) and sizes depending on the load to be carried. The frames are provided with different numbers of wheels, fixed and / or swivel caster type. No handle is provided. These are moved by pushing the load itself. Fig. 5.1.3 shows some of the different design of dollies.

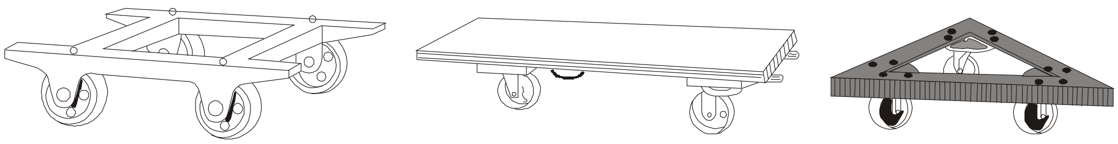


Fig. 5.1.3. Different designs of dollies

Platform Trucks: These are basically larger version of dollies in which metallic frames are generally of rectangular shape and produced in many sizes in light, medium and heavy-duty construction. Handle at one or both ends are provided for pushing. There are two basic chassis construction from the point of view of wheel arrangement: (*a*) **tilt or balance type** which have rigid wheels at the center of the platform and set of one or two swivel casters located at two ends of the platform permitting maneuverability. (*b*) **non tilt type** where the rigid wheels are at one end and the swivel casters, usually smaller in size, located at the other end, so that all the wheels are active always (Fig. 5.1.4). The platform may be provided with corner posts or various types of steel slat racks and frames to avoid slippage / spilling of the load (Fig. 5.1.5). Platform trucks may be built with extra reinforcement and provided with suitable coupler so that they may be used for light-duty trailer service or towline conveyor system.

Fig. 5.1.4. Not tilt type platform truck

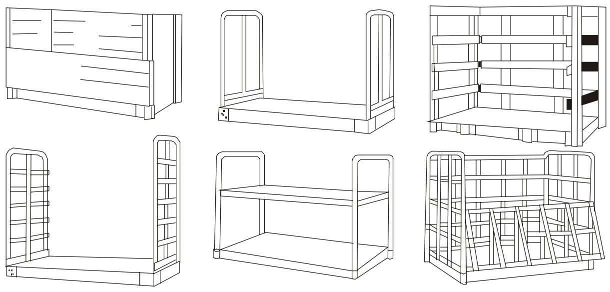


Fig. 5.1.5. Various types of rack bodies used on platform trucks

Semi-live skid platform: These are basically flat platforms with two load wheels on one end and two legs at the other. The skid platform with load is activated by a lift jack, which is a long handle with a pair of wheels and a hook. The hook engages with a coupling at the leg end of the platform and gives a jacking or prying action to lift the legs from ground/floor. The unit thus becomes a 3 wheel platform truck. Fig. 5.1.6 illustrates a semi-live skid platform.

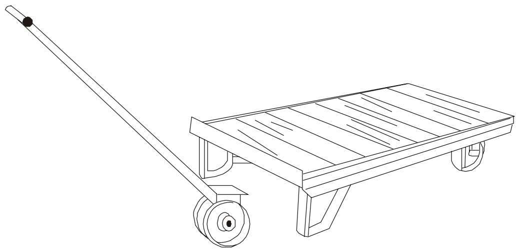


Fig. 5.1.6. Semi-live skid platform

5.1.3 Hand Lift Trucks

These hand trucks are provided with a mechanism of lifting its platform, which can be rolled under a pallet or skid, and raised to lift the pallet or skid with load to clear the ground and then move this load from one place to another. Depending on the lifting mechanism, these are grouped into hydraulic or mechanical type. Hand lift trucks are widely used in small to medium sized manufacturing industries using pallets, skids and/or containers.

Hydraulic lifting mechanism: This consists of a hydraulic ram (single acting cylinder), an oil storage vessel and a plunger pump. The handle of the truck is connected to the plunger of the pump though suitable mechanism, such that when the handle is moved up and down, the pump forces a certain quantity of oil into the ram which through suitable linkage mechanism raises the platform with load. Capacity range of hydraulic hand lift trucks vary between ½ ton to 10 tons. The platform is lowered by releasing a flow control valve to allow the pressurized oil to go back to tank, and the ram is retracted by the load itself.

Mechanical lifting mechanism: This mechanism is operated by a system of levers. The platform is raised by actuating a handle, which in turn, raises a pawl that falls into a slot or groove. Lowering is accomplished by releasing the pawl. There are single stroke, low-lift mechanisms also. Capacity of mechanical hand lift trucks is generally limited to 1 ton.

Both hydraulic and mechanical hand lift trucks are further classified, based on general constructional features, into: (*a*) **pallet,** (*b*) **platform** and (*c*) **special types.**

(*a*) A **hand pallet truck** is used for handling pallets. It consists of two strongly built metallic fingers, popularly called forks, connected at one end to give a U-shape. The lifting mechanism is housed at this end. At the outer ends of each fork a wheel is provided, which acts in accordance with the lifting system. The connected end is mounted on a pair of large sized wheels which can be steered. Fig. 5.1.7 shows photographic view of hydraulic hand pallet trucks. The Fig. 5.1.8 shows typical operation of the truck where the forks are introduced inside a pallet and the forks are raised with the pallet. Fig. 5.1.9 shows line diagram with important dimensions of such a truck. IS:5007-1988 lays down recommended dimensions of fingers (forks) of hand pallet trucks in line with recommended pallet dimensions.

(*a*) (*b*)

Fig. 5.1.7. Hydraulic hand pallet truck : (*a*) low-lift (*b*) high-lift

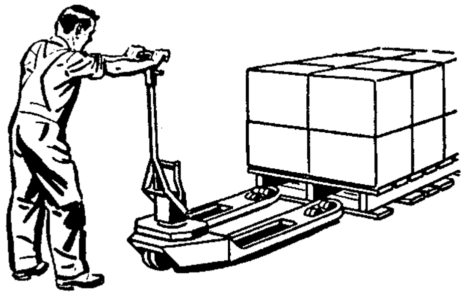


Fig. 5.1.8. Operation of a pallet truck

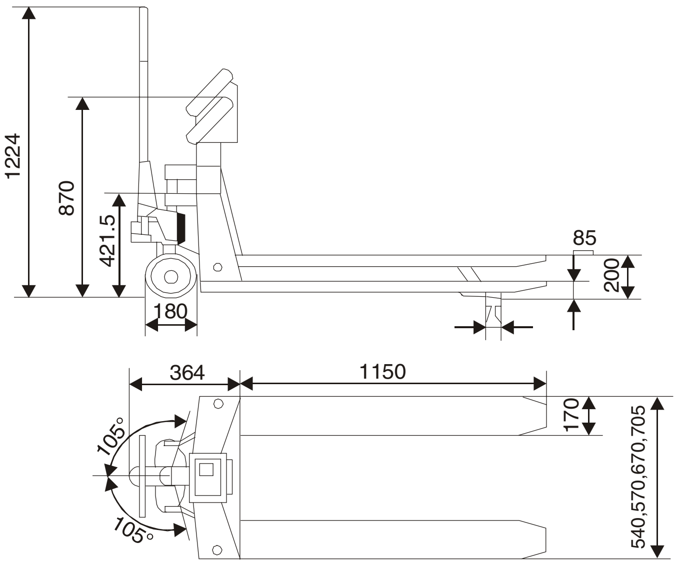


Fig. 5.1.9. Typical dimensions of a pallet truck

(*b*) **Platform lift truck** is similar to a pallet truck excepting that instead of two forks it has a platform, which can be raised. The platform may be solid or of open frame structure. These trucks are generally used with skids. Load capacity and nominal sizes of standard trucks of this kind vary within ranges : ½ ton to 3 tons, 450 mm to 680 mm width, 750 mm to 1800 mm length and lift heights from 150 mm to higher values (see Fig. 5.1.10).

(*a*) (*b*)

Fig. 5.1.10. Scissor design platform lift trucks : mechanical type (*a*) or hydrautic type (*b*)

(*c*) Lifting feature has been utilized in designing various types of lifting trucks for handling various specialized load in industries. All these are called **special hand lift trucks** as a group. A coil (reel) handling hydraulic lift truck is an example.

5.2 POWER TRUCKS

When a vehicle / truck contains its own source of motive power, it is called a power truck. Power trucks are divided into several categories of equipment. The wide varieties of powered industrial trucks have been classified into the following six groups in BIS specification number IS 7217:1990 and IS 4660:1993:

(*i*) mode of action
(*ii*) power source
(*iii*) type of wheel
(*iv*) mode of control
(*v*) height of lift
(*vi*) mode of travel

Functions with sketches of different classes of fixed and lift powered trucks have been described in specification no. IS 4660:1993, while various nomenclatures pertaining to powered industrial trucks are available in the other specification IS 7217:1990.

Out of these, a few common categories have been discussed below:

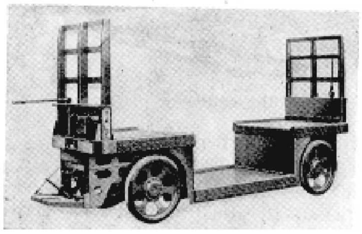
5.2.1 Fixed Platform Truck (powered)

These are powered (battery, diesel or gas operated) industrial trucks having a fixed level, non-elevating platform for carrying load. Materials to be moved have to be loaded and unloaded to and from the platform by hand, hoist or carne. Capacities of these trucks can go upto 40 tons. Smaller capacity models are called **load carriers**. Operator normally stands on the truck and runs it. Platform trucks are particularly useful for occasional handling of heavy loads.

Variations of normal platform truck are (*i*) **drop platform truck,** (*ii*) **drop center baggage truck** in which the central platform between two sets of wheels is very close to floor. Fig. 5.2.1 shows photographic views of different types powered platform trucks.

Flat bed gasolline truck

Drop platform truck



Drop-centre baggage truck

Fig. 5.2.1. Different designs of platform truck.

5.2.2 Platform Lift Truck (powered)

These equipment are a particular type of powered platform truck, whose platform can be raised and lowered to handle loads on skids. Range of lift of the platform may be ‘‘low-lift’’, upto 300 mm or ‘‘high-lift’’, over 300 mm.

5.2.3 Pallet Lift Truck (powered)

These are similar to platform lift truck in which the platform is replaced by forks to work also with loads on pallets. These are basically forenummer of fork-lift trucks. Low-lift models (Fig. 5.2.2) are used for movement of materials only while the high-lift models are used for stacking of pallet/skids one over another or in storage racks. Different variations of high-lift truck have been built. Some of these are:

Fig. 5.2.2. Pallet lift truck (battery)

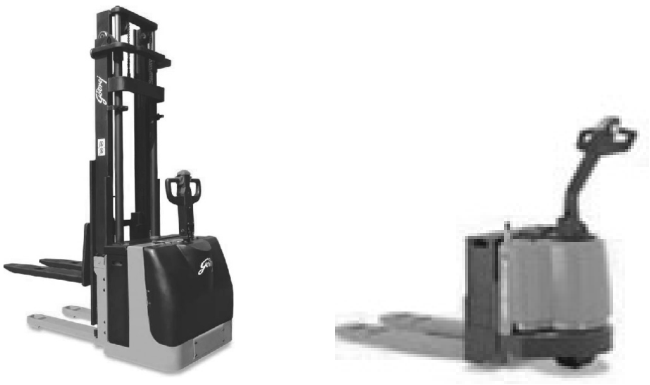
(*a*) Reach truck: In this design the forks can reach out on a pantographic mechanism which permits the forks to travel forward to engage load, lift it, and then retracts towards the mast before travel starts. These are of great use for warehousing and loading/unloading vehicles.

(*b*) Side loader truck: In this design the operational direction of the forks is at right angles to the movement of the truck. The major benefit of the design is that the truck need not turn into the load. The truck can move along a narrow aisle of a warehouse, and the fork can load / unload from the rack directly. These are particularly used for narrow aisle working and also for storing long loads (pipes, structural steel, logs etc.). Fig.5.2.3 shows a side loader truck. It needs specially trained operator.

Fig. 5.2.3. Narrow aisle side loader

5.2.4 Walkie Truck

This term implies different types of powered trucks described above, when the operator walks with the truck and operates it by means of controls available on the truck handle. Fig. 5.2.4 shows a walkie pallet truck and a walkie stacker truck.



Walkie stacker Walkie pallet

Courtesy : Godrej & Boyce Mfg. Co. Ltd., Mumbai.

Fig. 5.2.4. Walkie trucks

Walkie trucks are smaller, lighter and slower than rider-types, generally powered by battery. These are designed to fill the gap between hand trucks and powered rider-trucks in which the operator stands/sits on the truck.

5.2.5 Straddle Carrier

This is a self-loading powered truck for movement of long and heavy loads including shipping containers. The truck consists of a inverted "U" shaped frame having wheels mounted on outside of the frame. The truck can straddle a load / loads, picks it up with hydraulically operated load carrying shoes, mounted inside the frame, and then move with the load and unload it very quickly at a desired location. Capacities up to 40 tons is common (Fig. 5.2.5).

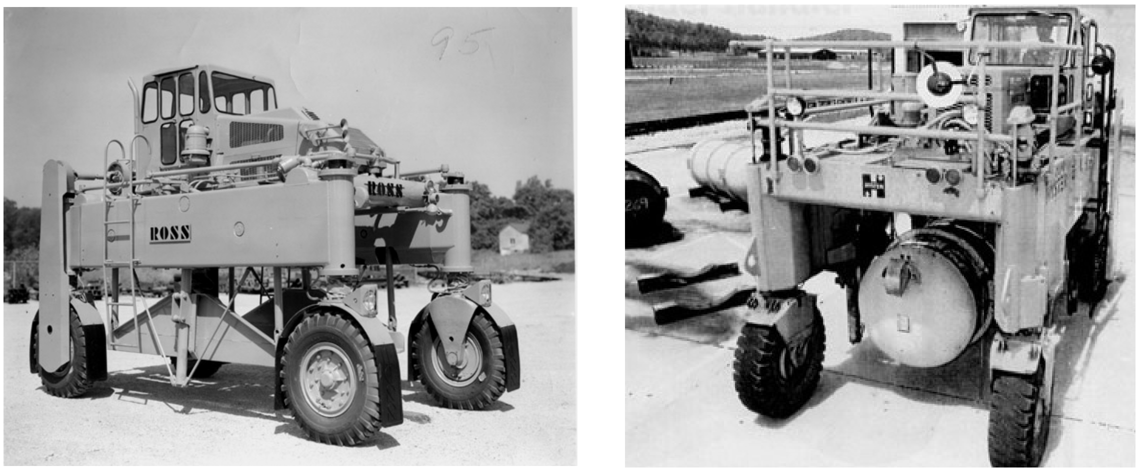


Fig. 5.2.5. Straddle carrier

5.3 FORK LIFT TRUCKS

Amongst the powered industrial vehicle/truck family, most versatile, useful and widely used equipment is industrial lift trucks, popularly called forklift trucks (FLT in short). These are self loading, counterbalanced, powered, wheeled vehicles, with the operator seating on the vehicle, designed to raise, move and lower load on forks or other attachments fastened to a mast which is fixed in front of the vehicle to allow lifting and stacking of loads. forklift trucks are used for lifting, lowering, stacking, unstacking, loading and unloading and maneuvering of medium to large weight, uniform shaped unit loads, intermittently. However, the limitations of these equipment are (*i*) usually requires pallet/skid/container, (*ii*) requires skilled operator, (*iii*) equipment needs maintenance facility, (*iv*) capacity of these equipment vary from 1ton upto about 60 tons, (*v*) slow travel speed (10-15 kmph) , (*vi*) suitable for short hauls (hundreds of meters).

Other features of a forklift truck are:

(*i*) The source of power is petrol/diesel or LP gas engine or a battery driven motor.

(*ii*) The mast may be tilted forward or backward within a range, for better stability during movement with load and also to facilitate loading and unloading. In a particular design the mast may be moved outboard and inboard on tracks laid over the chassis of the truck.

(*iii*) The mast may be a single mast or may be telescoping in design which allows high lifting of the load for trucks that must run through limited head room areas.

(*iv*) In certain designs, the forks are independently retractable outboard and inboard through pantograph mechanism. Loads are picked up and placed while forks are outboard but are moved inboard for greater stability during movement.

(*v*) The operation of the mast and movement of the forks (or any other attachment) are through a hydraulic power pack.

(*vi*) The body of the truck is purposely built heavy which act as counter load while lifting loads on forks/attachments.

(*vii*) Solid rubber tyres are provided for operation in different floor conditions. The rear two wheels are steered for manipulation of the forks/attachment fixed in front of the truck.

Fig. 5.3.1 is a line diagram showing major parts of a forklift truck.

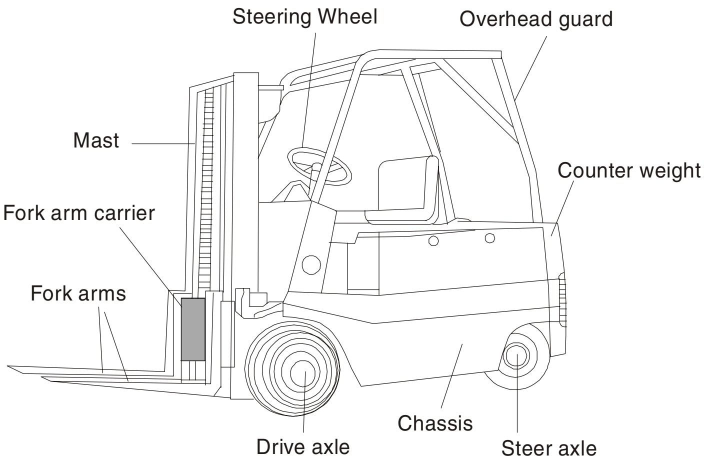


Fig. 5.3.1. Parts of a forklift truck

Fig. 5.3.2 shows photographs of a few designs of Forklift Trucks and their use.

Diesel operated FLT

Single mast FLT, forks raised

12 tons tilting mast diesel operated FLT

Battery operated FLT with single rear wheel

Heavy duty FLT with two pairs of forks

FLT with telescoping mast handling container

FLT loading a container truck

Fig. 5.3.2. Forklift trucks

5.3.1 Specifications of FLT

There are different operating parameters or specifications based on which suitability of a particular FLT is determined. The following is a list of major specifications from operational point of view:

(*a*) Rated capacity (1000 kg, 2000 kg etc.) at specified load center.

(*b*) Power sources (gas, diesel, battery etc.)

(*c*) Turning radius.

(*d*) Physical dimensions (length, width, height)

(*e*) Mast height

(*f*) Lift height.

(*g*) Mast specification (single or telescoping, tilting or non-tilting, retractable or not.)

(*h*) Travel speed.

(*i*) Lifting speed.

(*j*) Floor clearance.

(*k*) Free lift (movement of fork without mast movement).

(*l*) Retractable fork or not.

(*m*) Fork size (length, width, maximum gap between forks etc.)

(*n*) Attachments provided.

Other important technical specifications are : (*i*) motive power (h.p. rating), (*ii*) power transmission system (disc clutch, fluid coupling etc.), (*iii*) tyre specifications, (*iv*) battery and charger specification etc.

5.3.2 Capacity rating of FLT

FLT's are specified for a rated capacity at a specified load centre. Load centre is the distance from the heel (vertical face) of the forks to the assumed c.g. of the load. However, if the actual c.g. of the load goes beyond the specified load centre, the loading capacity of the truck has to be reduced accordingly, so that the moment of the load about the front wheel does not exceed that of the counter-loaded body of truck, and the rear wheels do not loose contact with ground.

For example (see Fig 5.3.3), let rated capacity of the FLT is 2000 kg and load centre is 450 mm. Let the distance between front wheels to heel of the fork (distance A to B) is 350 mm. Then true capacity of the FLT is =2000 × (load centre + distance A to B) = 2000 × (450 +350) = 16 × 10^5 kg.mm.

Now, if a load is to be carried whose c.g. "C" is at a distance of 550 mm from the heel of the forks (distance B to C = 550), then the maximum safe weight "W" that can be carried is given by the equation:

$$W \times (550 + 350) = 16 \times 10^5$$

or $$W = \frac{16\times10^5}{900} = 1777 \text{ kg}$$

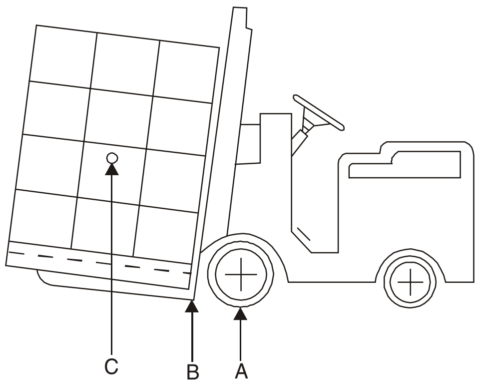


Fig. 5.3.3. Capacity rating of FLT

The stability of a fork lift truck at the rated capacity is of paramount importance from the point of view of safe operation. Indian standard number IS 4357:2004 titled ''methods for stability testing of fork lift trucks'', specifies basic tests to verify the stability of counterbalanced fork lift trucks, of rated capacity up to and including 50,000 kg.

5.3.3 Turning Radius and Aisle Width

A FLT can move freely through an aisle having its width atleast 300 mm more than the max width of the load or the FLT, whichever is higher. However, if the FLT has to work across the length of an aisle, like stacking or unstacking into racks in a warehouse, the minimum aisle width requirement can be determined from the following factor, as illustrated in Fig. 5.3.4.

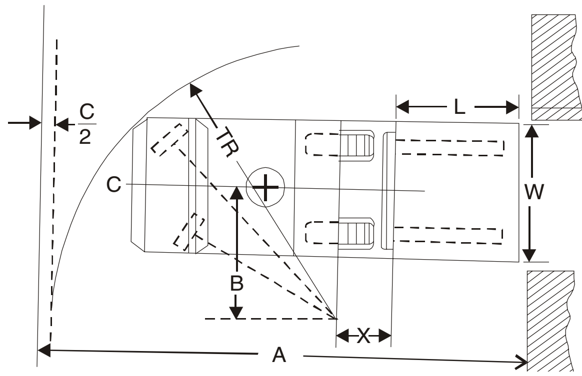


Fig. 5.3.4. Minimum turning radius of FLT

Let A = width of the aisle.

B = distance from center line of truck to the point about which truck turns when wheels are turned to extreme position (minimum turning radius condition). Centre of turning is designed to lie on front wheel centre line

TR = minimum turning radius

L = Length of weight resting on fork

X = distance between center line of drive (front) wheel to face of fork

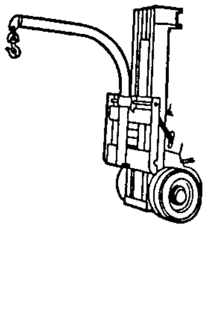
C = clearance (may be 150mm).

Then minimum aisle width A is given by the formula, A = TR + X + L + C

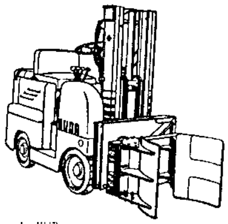
5.3.4 FLT Attachments

Forks of a forklift truck are one of the most common attachments. A pair of forks is used for working with skids, pallets, containers and box shaped loads resting on legs/ packers. However, a wide variety of devices have been designed for attaching to lift trucks to make them useful for many different tasks. Some of the common types of attachments are listed below with their names, short description of their special use and with some of their sketches.

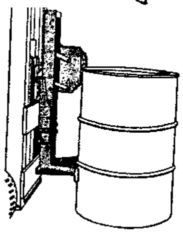
(*i*) *Boom:* This attachment is fixed with respect to the fork carrier. At the end of the boom, a chain pulley block is provided for lifting loads using the hook and slings.



(*ii*) *Clamp:* These are hydraulic devices for picking up loads like bales, barrels, cartons etc. by gripping them with opposing adjustable plates.



(*iii*) *Drum grab:* For drum-handling in vertical position.



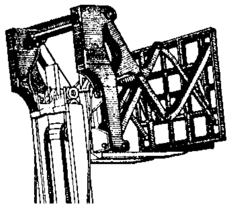
(*iv*) *Crane:* A crane mechanism is attached to FLT.

(*v*) *Die handler:* Platform for carrying heavy load.

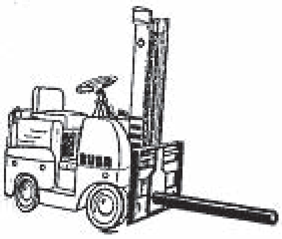
(*vi*) *Drop-bottom container*

(*vii*) *Load inverter cum pusher*

(*viii*) *Load pusher* (pallet un-loader)

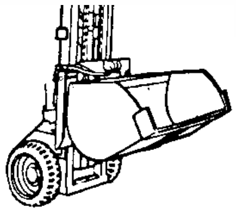


(*ix*) *Ram:* Fitted to the lift carriage for lifting cylindrical load with a hole (coil etc.)

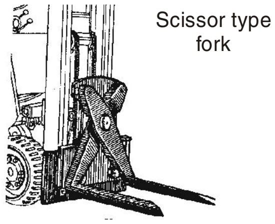


(*x*) *Roller platform*

(*xi*) *Shovel (scoop):* A scoop fitted to the carriage for scooping and carrying loose load.

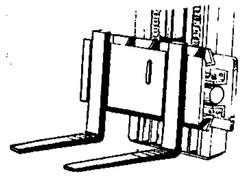


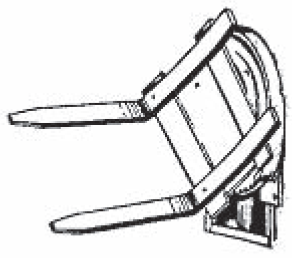
(*xii*) *Special forks:* (*a*) brick, (*b*) block, (*c*) extended,(*d*) scissor, (*e*) retractable.



(*xiii*) *Vacuum:* For handling light and fragile objects by a set of suction pods.

(*xiv*) *Side-shifter:* With this attachment, a load on truck can be moved from 100 to 150 mm on each side. This helps enormously in storing loads, without any damage to storage racks and merchandise.





(*xv*) *Rotator:* This is used in conjunction with a clamp or fork attachment to rotate load or for safer grip during movement with load.

BIS specification number IS 7570:1975 covers glossary of terms relating to fork arms and attachements, including their function, for forklift trucks.

5.3.5 Batteries for FLT

Engine driven trucks are comparatively cheaper than battery operated truck. Moreover, engine driven trucks can be used almost without the need of electricity. Despite all these, the number of battery trucks continues to increase, particularly for capacities upto 3 tons due to factors like overall lower maintenance cost and lack of smoke, fume and noise. Battery operated trucks are particularly suitable for warehousing and operations in confined areas. However, pre-requisite to using battery-operated trucks is availability of electricity and battery charging facility.

Types of batteries: Batteries may be either of **lead acid** or **nickel alkaline** type of sufficient ampere-hour capacity to insure at least one full day's operation.

Advantages of lead-acid battery are: lower cost, greater energy (kw-hr) capacity in a given space, lower internal resistance.

Benefits of nickel-alkaline battery are: longer life, better mechanical strength, noncorrosive electrolyte (KOH) which does not freeze, shorter recharge period (7 Hrs) and noncritical control of the charging current.

Battery voltage: The battery voltage has largely been standardized by industrial truck manufacturers. Table 5.3.1 below shows the types and capacities of battery operated trucks and average voltage employed for their operation:

Table: 5.3.1 Average Battery Voltage of Various Industrial Trucks [1]

	Truck Capacity (Tons)				
Type of truck	0.5 to 3.0	3.5 to 5.0	Over 5.0 to 8.0	Over 8.0 to 20.0	Over 20.0
Hand trucks (powered)	12 V	—			
FLT	24/36 V	36 V	—		
Platform trucks	24/36 V	36 V	36/48 V	48 V	72 V

Battery rating: It is essential that sufficient battery capacity be provided to allow uninterrupted operation of the truck during normal operation period. Capacity of a battery is rated in ampere-hour for a six hours discharge period. This rating, divided by six, gives the current draw in amperes, which, if continued six hours, will completely discharge the battery. The average voltage multiplied by the ampere-hours rating gives the total energy capacity of the battery in watt-hour. The battery sizes for trucks of various capacities have been standardized by the manufacturers.

Battery selection: Battery selection is based on energy rating for a proposed duty cycle of the truck within a given period between two battery changes. Energy calculations for different operations are based on certain charts and formulae adopted by the "Electrical Industrial Truck Association" in 1950 standardized through field study.

Energy calculation: Table 5.3.2 shows average watt-hours of energy required to accelerate and drive a truck over level distances. For intermediate distances, the data may be interpolated. The energy consumptions for other operations of FLT are given by following set of equations:

(*i*) *Travel up the grade:* Extra energy in watt-hours required in addition to that required for level running = total tons (truck + load) × length of grade in feet × % grade × 0.013 (where grade = tan θ). Going down grade steeper than 2% requires no power, and distance down grade may be subtracted from length of run.

(*ii*) Lifting energy in watt-hours = tons of load lifted × feet of lift × 2,

for empty lift = $\frac{1}{3}$ × load capacity in tons × feet of lift × 2.

(*iii*) Tilting energy (watt-hours) = tons of load × 1,

for empty tilt = $\frac{1}{3}$ load capacity in tons × 1

Table 5.3.2: Approximate Watt Hours Required by Fork Trucks to Travel on Level Concrete [1]

Weight (Truck plus load in pounds)	Length of Run (Feet)											
	50	100	200	300	400	500	600	700	800	900	1000	1100
1,000	1.8	2.5	4	5.5	7	8.5	10.5	12	13.5	15	16.5	18
2,000	3.5	6	8	11	14	17	21	24	27	30	33	36
4,000	7	10	16	22	28	34	42	48	54	60	66	72
6,000	10.5	15	24	33	42	51	63	72	81	90	99	108
8,000	14	20	32	44	56	68	84	96	108	120	132	144
10,000	17.5	25	40	55	70	85	105	120	135	150	165	180
12,000	21	30	48	66	84	102	126	144	162	180	198	216
14,000	24.5	35	56	77	98	119	147	168	189	210	231	252
16,000	28	40	64	88	112	136	168	192	216	240	264	288
18,000	31.5	45	72	99	126	153	189	216	243	270	297	324
20,000	35	50	80	110	140	170	210	240	270	300	330	360

Example: A battery operated FLT weighs 4000 pounds including weight of battery and operator. It is carrying a weight of 2000 pounds. The truck lifts the load to 2 ft and carries the load to a distance of 200 ft of which 170 is along level road and balance 30 ft on an upgrade of 6%. After discharging the load it returns over same route. Calculate total watt-hours of energy spent by the truck. Select suitable battery if the truck has to make 200 such trips daily.

The total energy can be calculated by summing up energy spent for the following elements of activity:

(*i*) Total run with load.

(*ii*) Extra power for 30 ft of inclined travel at 6% grade.

(*iii*) Return empty run deducting the downgrade run.

(*iv*) Lifting of load.

(*v*) Tilting of mast.

Calculations:

(*i*) *Energy for total run with load:* Total weight of the truck with load is 6000 pounds. From chart we find the energy required for a 200 ft run = 24 watt-hours.

(*ii*) *Extra power for going up grade* = $\frac{6000}{2000} \times 30 \times 6 \times .013 = 7.02$ w-hrs.

(*iii*) *Energy for empty run:* To be calculated for (200 – 30)= 170 ft, (energy spent during downward movement being zero) from chart it is interpolated as 10 + (16-10) × .7= 14.2 w-hrs

(*iv*) *Lifting energy* = $\frac{2000}{2000} \times 2(\text{lift}) \times 2 = 4$ w-hrs.

(*v*) *Tilting energy with load* = $\frac{2000}{2000} \times 1 = 1$ w-hrs.

Tilting energy without load $= \frac{1}{3} \times \frac{2000}{2000} \times 1 = \frac{1}{3}$ w-hrs.

Assuming 2 tilts with load and 1 tilt without load, total energy of tilting

$$= 2 \times 1 + \frac{1}{3} = 2\frac{1}{3} \text{ w-hrs.}$$

Thus estimated total energy for the above duty cycle

$$= 24 + 7.02 + 14.2 + 4 + 2.33 = 51.55 \text{ watt-hrs.}$$

For 200 trips, total energy requirement = 200 × 51.55= 10,310 watt-hrs. If we choose the voltage of the battery to be 36 volts, then total ampere hour capacity of the battery between two charges should be =10,310 ÷ 36 = 286.39.

Therefore, a 36 volts battery having ampere-hour rating of nearest figure above 286.39 should be the minimum size battery to be considered for the duty cycle.

Battery charging: Charging of used up batteries is an essential facility for battery operated FLTs. Industrial batteries used in forklift trucks are intended to be recharged approximately 300 times per year or once in 24 hours on an average. More frequent recharges generally reduce the overall life of the batteries.

The lead-acid batteries, for 8-hrs. charging period, requires a high rate (about 25amps per 100 amp-hr of battery capacity) of charging at the beginning and a low finishing rate (20% of initial rate) at the end.

A nickel-alkaline battery with a 7-hrs. charging period, needs a charging voltage of 1.5 times its normal voltage rating. Each size of nickel-alkaline cell has a specified current charging rate. At the beginning it should be about 140% of this specified rate and gradually it should taper down so that the average charging rate is approximately equal to the specified rate of the cell.

The battery charging unit, may be (*i*) motor-generator type or (*ii*) dry-plate rectifier type. However, each of these is provided with above charging sequence control features. The battery chargers may be suitable for a single battery or multiple batteries charging simultaneously. It should automatically stop charging when each battery gets fully charged.

5.4 TRACTORS

Tractor is a vehicle, having its own source of motive power, used as a prime mover to haul i.e. to give motion to another or a group of other vehicles which do not have their own motive power, such as trailers, semitrailers, transfer cars etc.

Tractors are used in a wide field of activities, starting from agriculture to earth-moving, municipal waste handling, construction and industries. A tractor may be fitted with different attachments to do different jobs like sweeping sidewalks, plough snow, excavate ground, scoop loading, bull dozing etc.

5.4.1 Industrial Tractor

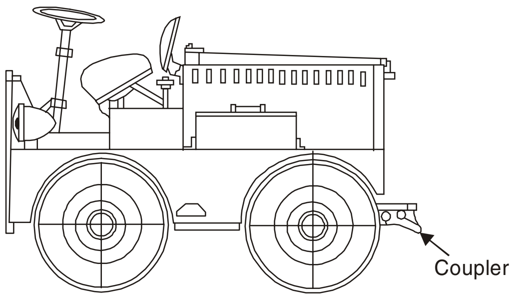
The industrial tractors are generally grouped into (*i*) wheel type which are primarily used for movement of one or more trailers for interplant or intraplant transportation, and (*ii*) crawler type which are mostly used in outdoor and storage yard service at slow speeds and for short hauls.

The most important specification of a tractor is it's **draw-bar pull rating.** According to this rating, they are classified as small (100 kg normal to 500 kg), medium (250 kg normal to 750 kg), large (1.0 tons normal to 5 tons maximum) and extra large (up to 35 tons). Other specifications are physical dimensions, weight, horse-power, number of wheel drive, front or rear wheel-steer, walkie or rider type etc.

The small and medium tractors are often battery operated walkie type. However, an ''electronically guided type'' of tractor requires no operator which follows a white line painted or a wire embedded in the floor. These are used for point to point pick-up and delivery of trailers. These may be programmed for automatic decoupling of trailers and give signals of arrival at two ends. Large and extra large tractors are powered by an internal combustion engine fueled by diesel or gas and are essentially rider type. A two-wheel tractor depends on working in conjunction with the attachments or load carrier for balance. Steering of these tractors is done by pivoting about one of the two wheels, thereby resulting in very small turning radius *i.e.*, high maneuverability of these tractors.

A coupler is secured to the rear of the tractor body for quick coupling and uncoupling of the trailers/ transfer cars.

Tractors are preferred over FLT when large volume of materials of different types of loads which can be carried on specifically designed trailers, need to be handled. In Fig. 5.4.1 view of a few tractors is illustrated.



Battery operated tractor without cabin

Typical farm tractor

Tractor fitted with attachments on both ends

Crawler tractor bulldozer

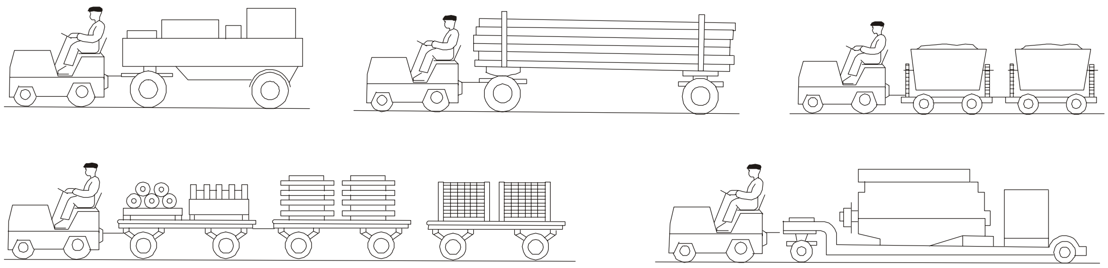
Fig. 5.4.1. Tractors

5.4.2 Trailer

Trailers are load bearing wheeled vehicles or cars without any motive power, designed to be drawn by a tractor or truck. Trailers are classified as semitrailer and full trailers.

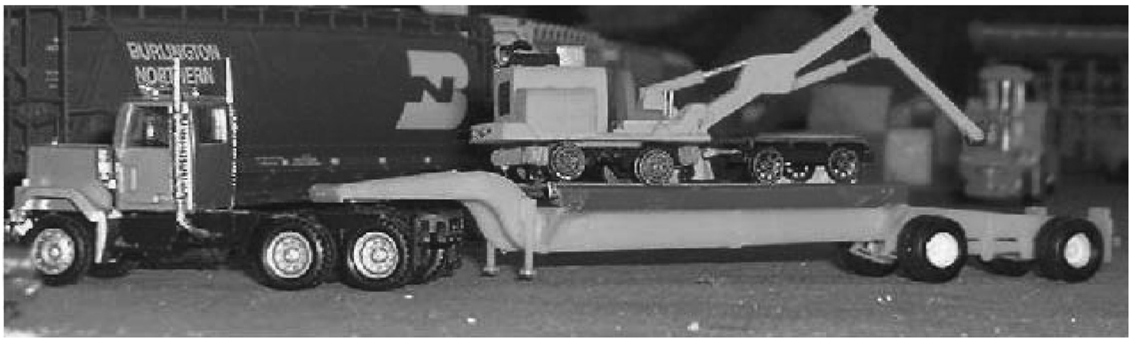
A semi trailer is a truck-trailer having one or more axles and constructed so that a part of its weight is carried by the truck/tractor. A full trailer is constructed to carry almost all its weight on its own wheels. Number of axles may be one or more. The tractor has to give only the pulling force for its motion.

More than one trailer may be pulled at a time by a tractor when it is called as a tractor-trailer train. Trailers can be of different shapes and sizes. Figure 5.4.2 shows a few types of trailers:



Use of tractors with different trailers

Single axle box type trailer



Tractor with semitrailer

Tractor pulling trailer train

Fig. 5.4.2. Trailers

Courtesy : Godrej & Boyce Mfg. Co. Ltd., Mumbai

Fig. 5.4.3. Heavy diesel forklift truck

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CHAPTER

6.0 Conveyors

Different classes of conveyors forming the **conveyor** group is by far the most frequently used materials handling equipment primarily for conveying bulk materials in process industries and also for conveying certain types of unit loads in large quantities. Basic definition of a conveyor and its classifications have already been given in chapter 4. In the present chapter, definition / description and operational characteristics of the different classes of conveyors have been discussed. Special features and use of some of the commonly used conveyors under each of these classes have been included. Certain design aspects of a few classes of conveyors have also been touched upon.

6.1 BELT CONVEYORS

6.1.1 Definition / Description

A belt conveyor consists of an endless flat and flexible belt of sufficient strength, made of fabric, rubber, plastic, leather or metal, which is laid over two metallic flat pulleys at two ends, and driven in one direction by driving one of the two end pulleys. Material is placed on this moving belt for transportation. The active half of the belt is supported by idler rollers or slider bed. The return half of the belt may or may not be supported, as it generally does not carry any additional load other than its own weight. The endless belt is kept taught by a belt tensioning arrangement.

6.1.2 General Characteristics

(*i*) Belt conveyors operate in one vertical plane, horizontally or with an inclination (up or down) depending on the frictional property of the load conveyed.

(*ii*) For changing direction of the materials being conveyed, in the horizontal plane, more than one belt conveyors are needed.

(*iii*) Conveying capacity of a conveyor can be controlled by changing belt speed.

(*iv*) Belt conveyors are generally employed for continuous flow of materials.

(*v*) Metal/special belts can carry hot, abrasive or reactive materials.

6.1.3 Types of Belt Conveyors

(*a*) **Flat Belt Conveyor:** In this conveyor, the active side of belt remains flat supported by cylindrical rollers or flat slider bed. The conveyor is generally short in length and suitable for conveying unit loads like crates, boxes, packages, bundles etc. in manufacturing, shipping, warehousing and assembly operations. Flat belts are conveniently used for conveying parts between workstations or in an assembly line in mass production of goods. Fig. 6.1.1 shows a flat conveyor.

Fig. 6.1.1. A flat belt conveyor with drive control

(*b*) **Troughed Belt Conveyor:** In this conveyor, comparatively wide flat belt is supported on troughed carrying rollers or shaped supporting surface so that the two edges of the active side of the belt are elevated from the middle part to form a trough. This provides a greater carrying capacity than a flat belt of equal width for conveying bulk materials or those materials which would slide off flat belts. These conveyors are used in handling bulk materials of different classes. The return side of the belt is generally kept flat supported on cylindrical rollers.

The troughed conveyors which are used within a plant for moving bulk materials from one point to another, are generally termed as ''normal'' or ''transfer'' conveyors. These are comparatively of shorter lengths, and path of movements are in straight line in a horizontal or an inclined plane. The stresses in the belts being within limits of cotton fabric belts.

However, troughed belt conveyors are often used for transportation of bulk materials over long distances, by means of a series of conveyors, over paths that are combination of inclines, declines and horizontal sections, following the natural contours of the ground. These are generally termed ''long-centre'' conveyors. There is no clear demarcation between a normal or long-centre conveyor. Long center conveyors are those where belt tension is high warranting use of high tension quality belts with less belt stretch, and low acceleration through gradual starting controls for the drive. By using a number of conveyors in series, it is possible to change the direction of materials movement at the junction of two conveyors, called ''transfer terminal''.

Long-centre conveyors are used for jobs like: (*i*) transportation of the output of mines to the processing plants, (*ii*) materials from shipping ports to the storage/transport loading sites, (*iii*) materials from outdoor storage yards to inside plants, (*iv*) movement of materials between plants etc.

(*c*) **Closed Belt Conveyor:** In a closed belt conveyor, the specially fabricated belt, after being loaded with the material, can be wrapped completely around the load. It essentially forms a closed tube moving along with the material. The advantages of a closed belt conveyor are: (*i*) it can handle fragile materials safely and without breaking by reducing inter particle collision, (*ii*) it can handle fine bulk materials without being swept by air (however, it is not really air tight at loading and unloading points), (*iii*) ability to handle corrosive and reactive materials without contamination and (*iv*) the tubed belt can travel around bends in more than one plane and hence versatile in layout.

The lengths of these conveyors are generally limited. Different designs of closed belts have been manufactured and used in different countries. In the following Fig. 6.1.2, a type called Zipper Conveyor is shown. Fig. 6.1.3 shows how the belt is closed after the belt is filled up at its flat configuration. Different designs for closing two ends of the belt have been developed by different manufacturers.

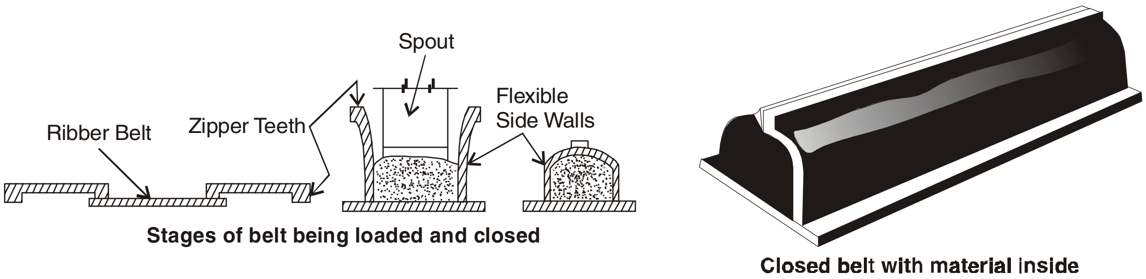


Fig. 6.1.2. Endless zipper belt

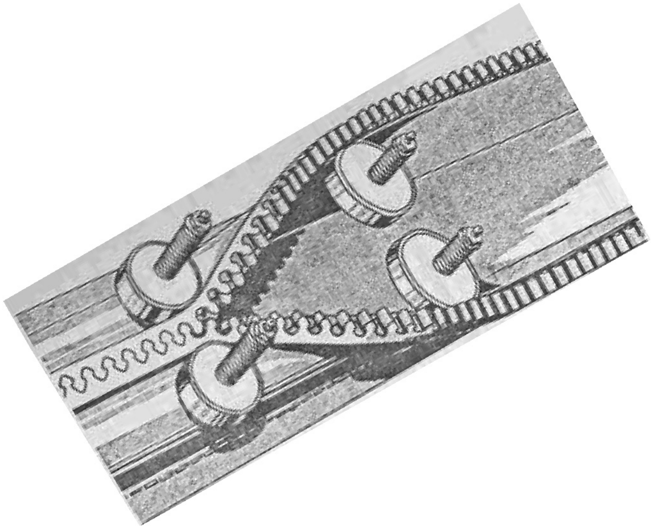


Fig. 6.1.3. Spreading, filling and locking of a closed conveyor

(*d*) **Metallic Belt Conveyor:** This is a flat belt conveyor where the flexible belt is replaced by a cold rolled carbon or stainless steel strip belt of thickness from 0.6 mm to 1.2 mm. The ends of the steel strip are lap joint riveted with a single row of special wide flat head rivets. A steel belt runs flat on cylindrical idlers or runs troughed on resilient idlers (made by suitable length of springs). Apart from all rolled strip steel belts, wire-mesh, belts of different designs have been used. The entire length is made up of short length sections. One of the designs is made up of flat wire spiral sections, shown in Fig. 6.1.4. The wire-mesh belts are more flexible and the design considerations are similar to a rubberized textile belt conveyors.

Metallic strip belt conveyors are used in food, chemical industry and for conveying hot and reactive loads. Wire-mesh belts are being widely used to handle unit and lump materials through furnaces (up to 1000°C temperature), as mobile base for baking industry and also for wetting, cooling, dehydrating and similar operations.

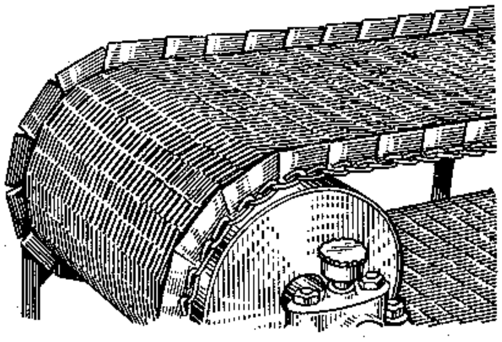


Fig. 6.1.4. Metallic belt conveyor

(*e*) **Portable Conveyor:** Short length flat conveyors carried on a wheeled structure is termed portable conveyor. These are particularly useful for loading and unloading of trucks / transport vehicles. The inclination of the conveyor can generally be adjusted to suit application.

Apart from above mentioned major types of belt conveyors, there are a few special types worth mentioning. These are:

(*f*) **Chain or Rope Driven Belt Conveyor:** In which the specially designed belt is driven by a moving chain or rope, where belt only serves as load carrier, and motion is by a chain or rope conveyor (refer section 6.2).

(*g*) **Submerged Belt Conveyor:** In which a portion of the belt moves through a metallic trough (casing) which is filled with free flowing, powdered material at the loading end. The moving belt with holes, makes the material flow to the unloading end of the trough. Fig. 6.1.5 shows a line drawing of a submerged belt conveyor.

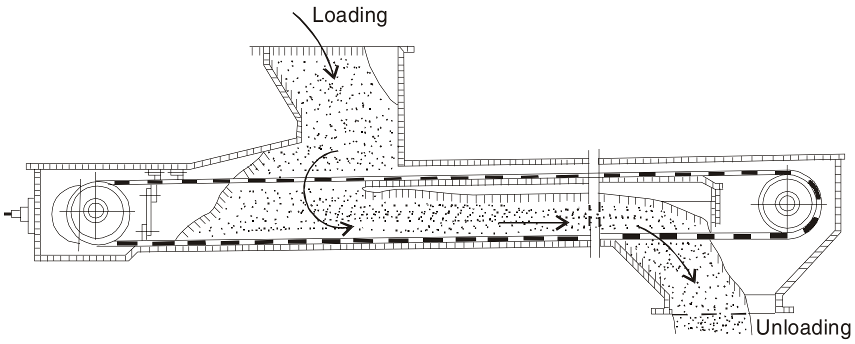


Fig. 6.1.5. A typical submerged belt conveyor

6.1.4 Parts of a Belt Conveyor

(*a*) **Conveyor Belts:** Belt, which supports and conveys the load, is the essential and most important component of any belt conveyor. Most common type of conveyor belting is rubber/plastics covered textile belting - the internal carcass of woven fabric gives the longitudinal strength of pulling the loaded belt and transverse strength for supporting the load, and the cover of rubber and/or plastics protects the carcass from damage. Specification, requirements and testing procedures of rubber/plastics, covered textile belting for conveyor (and elevator) has been given in IS 1891:1994, part I to V. Part I[(1)] covers the ''general purpose belting'' while the subsequent parts cover ''heat resistant belting'', ''oil resistant belting'', ''hygienic belting'' and ''fire resistant belting for surface application'' respectively.

Belt Construction: Cotton fabric ply constructed rubber covered belting is the mostly used belt for flat and troughed conveyor. The carcass consists of one or more plies of woven fabric or of solid woven fabric impregnated with a rubber or plastic mix, which after vulcanization binds the plies together. The fabric used is made of threads of cotton or polyamide or any other synthetic material or combination thereof, evenly and firmly woven. The carcass is covered by special wear and impact resisting rubber compounds / plastics. For the protection of the carcass, layer or layers of open-mesh or cord fabric, termed as ''breaker'' may be placed between the cover and the carcass, or may be embedded in the cover. Number of fabric plies varies from 3 for shorter belt widths (300mm and above) to a maximum of 12 to 14 plies for belt width of 2000mm. Number of plies can vary within a range for a specific belt width. Steel cord belting is used when good troughability, high operating tensile strength and small elongation are desired. Fig 6.1.6 shows a typical belt cross section.

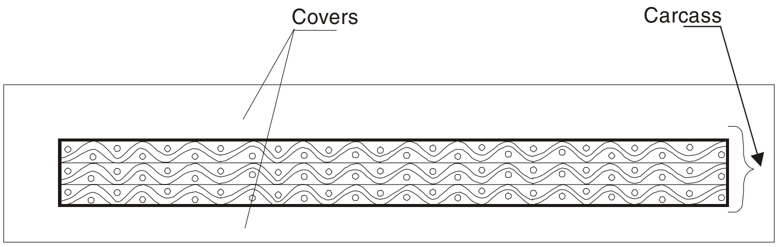


Fig. 6.1.6. Construction of a textile belt

Belt Covers: The primary purpose of the cover is to protect the belt carcass against damage. The requirements of the cover is to work satisfactorily in contact with the materials to be carried by the belt. For this purpose, sufficient thickness (not less than 1.0 mm) of top and bottom surface covers of different rubber compounds and plastics are used. Covers in the following grades are available:

(*i*) *Grade M24:* Natural rubber compound with superior resistance to cutting, gauging and abrasion.

(*ii*) *Grade N17:* Compound rubber with high abrasion resistance with inferior cutting and gauging resistance compared to M24 grade.

(*iii*) *Grade N17(Synthetic):* Composed mainly of synthetic rubber with higher abrasion resistance. Belt made of carcass with chemical or other superior bonding system should be used for this grade.

(*iv*) *Grade HR:* Suitable for handling load at high temperatures, upto 150°C for lumps or 125°C for powdered materials.

(*v*) *Grade FRAS:* Used for underground mining and processes where fire resistance and antistatic charge properties, are required.

(*vi*) *PVC Grade:* Used in fire resistance, oil resistance and hygienic belting.

Belt Designation: As per IS 1891 (Part I): 1994, belts are designated by IS No., grade of the cover, the ''type'' of belting defined by the full thickness breaking strength in KN/m and number of plies. For example, a conveyor belt with cover grade N17 and type 250 having 4 plies shall be designated as: Conveyor Belt IS 1891 (Part I) N17-250/4.

Steel cord belting is designated by prefix ''ST'' followed by the full thickness breaking strength in KN/m. Example ST-1800.

Belt Width: Unless otherwise agreed between the manufacturer and buyer, the standard widths of belting as per IS specification are:

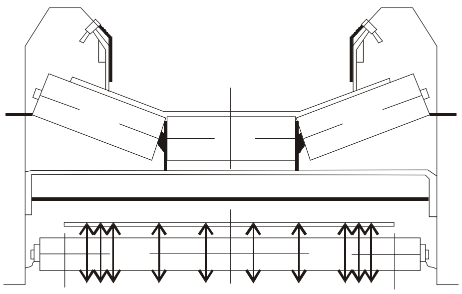
300, 400, 500, 600, 650, 800, 1000, 1200, 1400, 1500, 1600, 1800 and 2000 mm with a tolerance of ±5 mm upto 500mm width and ±1% of belt width for widths higher than 500 mm.

Belt Splicing: Two ends of a belt may be joined either by metallic belt fastners or by vulcanization. Metal fastner joining is easier and acceptable for flat belt conveyors. Vulcanized belt splicing is a superior technique suitable for troughed belt conveyors. The later is a stepped, lapped splice in which several plies of two ends of the belt are vulcanized together to make a joint of strength almost equal to the solid belt. Skilled operator and vulcanizing equipment are necessary for such splicing at coveyor site.

(*b*) **Idlers:** The rollers used at certain spacing for supporting the active as well as return side of the belt are called idlers. Accurately made, rigidly installed and well maintained idlers are vital for smooth and efficient running of a belt conveyor.

There are two types of idlers used in belt conveyors:

(*i*) straight carrying and return idlers, which are used for supporting active side of the belt for a flat belt conveyor and also for supporting the return belt in flat orientation in both flat or troughed belt conveyor.



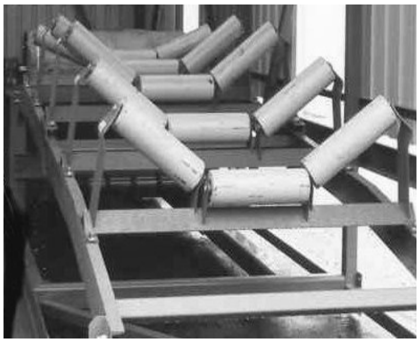


Fig. 6.1.7. Three roll idler : Sketch shows three roll carrying idler with straight return idler in same frame, and photograph shows set of assembled idlers

(*ii*) troughing idler set consisting of 2, 3 or 5 rollers arranged in the form of trough to support the belt in a troughed belt conveyor. Fig. 6.1.7 shows sketch and photograph of a 3-roll idler.

Idler construction: Idlers are generally made from steel tubes conforming to IS 9295:1983, uniformly machined all over at the outer diameter and at the two ends of the inner diameter. The tubes are mounted on antifriction bearings over a fixed steel spindle. The ends of the spindles are flat machined to standard dimensions for quick fixing in slots of idler structure. The idlers may be made of heavy steel tubes for severe service condition (like in material loading section) or cast iron in corrosive application (handling coke etc.). Fig. 6.1.8 shows different designs of roller mountings on antifriction bearings.

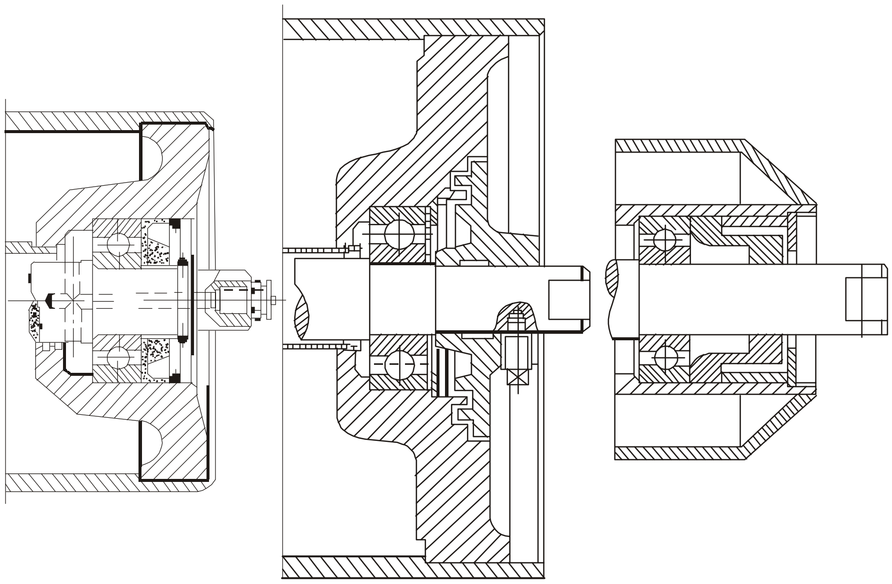


Fig. 6.1.8. Different mountings for idler roller.

Idler dimensions: Diameter, length and troughing angle have been standardized by BIS in IS 8598 :1987[(2)]. The carrying and return idler diameters in mm are : 63.5, 76.1, 88.9, 101.6, 108, 114.3, 127, 133, 139.7, 152.4, 159, 168.3 and 193.7. The maximum diameter of 219.1mm is used for carrying idler only. These sizes correspond to the available tube sizes. Selection of roller diameter depends on factors like bulk weight of load in kg per cubic meter, particle size and belt speed. Higher are these factors, higher is the roller size to be selected. Length of the idlers vary from 100 mm up to 2200 mm. The smaller lengths are generally made in smaller diameters while longer lengths are made in larger diameters. Troughed idler sets are made with troughing angle (the angle made by the inclined roller with horizontal) of 15°, 20°, 25°, 30°, 35°, 40° and 50°. Troughing angle of 15° is applicable only to two roll troughed idlers. The value of troughing angle of troughed return idlers are selected from 0°, (*i.e.*, straight idler), 10° and 15° for all widths of belt.

The length of the straight or troughed idler set is based on the selected width of belt, and desirable edge clearance between belt and roller edges. Table 6.1.1 shows the recommended edge clearances.

Table 6.1.1. Edge Clearance

Belt Width	Edge Clearance		
B	Flat idler	2-roll idler	3-roll idler
400	50	40	35
500	50	40	40
650	50	50	50
800	75	75	70
1000	75	75	70
1200 to 2000	100	100	100

Idler spacing: Spacing of idlers in the loaded run is a function of bulk weight of materials and width of belt. Selection of idler spacing has been further discussed in section 6.1.5(e).

(*c*) **Conveyor Pulleys:** At each of the two ends of a belt conveyor, one large diameter pulley is installed against which the belt turns and changes direction. These pulleys are called terminal or bend pulley. Drive is imparted to the belt through friction by one of the terminal pulleys called drive pulley. As the conveyor belt passes around these bend pulleys, the plies of the belt are elongated in proportion to the distance of the ply form center of the pulley. The differential elongation of one ply over the other is taken up by the rubberized bonding between two plies. Larger the pulley, less is differential elongation between the plies hence less tendency to ply separation. This is the reason the bend pulleys are made large.

The conveyor pulleys are either fabricated from rolled steel plates or of cast iron construction. The central steel shaft is keyed into the pulley drum and then the finished dimensions are machined. The pulleys are generally given a crowning at the face for keeping the belt at the centre of the pulley. The face length is generally 100 mm to 200 mm more than the belt width.

The surface of the pulley may be left bare smooth, or may be covered up to a thickness of 6 to 12 mm by rubber, polyurethane or ceramic layer with herringbone patterned grooves to increase the friction between the pulley and belt.

The pulleys are mounted on heavy duty antifriction bearings in suitable bearing housings.

(*d*) **Drives for Belt Conveyors:** The belt conveyors are generally driven at the head end pulley, where material is discharged. The drive pulley is connected to the drive motor through suitable speed reduction gear box and flexible shaft couplings. Drive of an inclined conveyor necessarily includes a braking device which prevents downward movement of the loaded belt in case of power failure of the motor.

(*e*) **Take-ups** or **Belt Tensioning Devices:** Endless conveyor belt after being threaded through the entire length of the conveyor need to be tightened so that sufficient frictional force is developed between the drive pulley and the belt, to make the belt move. Belts working under tension invariably gets elongated with time, which needs to be taken-up to maintain the desired tension in the belt. A belt conveyor generally have a screw-type (mechanical) or a gravity-type counterweighted take-up unit, also termed as belt tensioning device.

In the screw-type take-up, the bearing blocks for the tail end pulley are located in guide ways, so that these may be moved by rotating two screws as and when belt tension needs to be increased.

In gravity take up, the tail end pulley is mounted on a movable carriage which is pulled backwards along the length of the conveyor by a vertically hanging counterweight connected through a steel rope and deflecting pulleys. In an alternate design, the return side of the belt passes by the bottom of a counter-loaded deflictor roll which is free to move down to keep the belt taught. Fig. 6.1.9 illustrates the two gravity take-up arrangements.

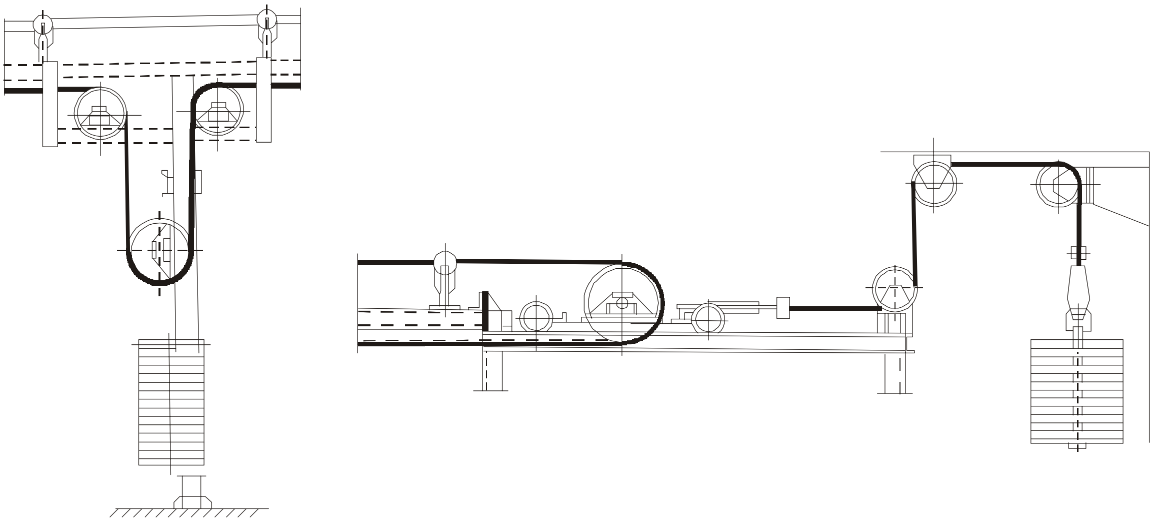


Fig. 6.1.9. Typical gravity take-up arrangements.

(*f*) **Loading and unloading devices:** Free flowing material may be directly delivered from a hopper, bin or storage pile through a chute, the delivery rate being controlled by a regulating gate at the hopper / bin output. For non free flowing materials a suitable feeder unit with a chute is used for loading the material centrally onto the belt as evenly and gently as possible. Side boards or skirt plates, extending a considerable length (2 to 3 m), is generally attached to the conveyor structure to be placed centrally to the belt, covering 2/3rd to 3/4th width of the belt, and maintaining a small clearance with the moving belt.

For unloading of materials at the end of the head pulley, no device is required excepting proper chutes to guide the discharged materials. For discharging at any point along the length of the conveyor, a plough or a belt tripper is used. A plough consists of a rubber tipped blade extending across the belt width at an angle of 60°. The plough may be one-side discharge or a V-shaped blade for two-side discharge. The belt carrying material must be made flat passing over a slider plate at the plough to allow close contact between the belt and rubber tipped blade. Plough is pivoted so that its position can be adjusted above the belt to allow control of material being discharged.

A belt tripper is an unloading device which consists of two pulleys, of comparable size of the head pulley, supported in a fixed or movable frame. One pulley serves to elevate the belt a sufficient height from carrying rollers to permit a discharge chute to be set under the pulley. The chute receives the entire amount of material flowing over the pulley and discharge it on one or both sides of the conveyor. The belt passes around the second pulley and beneath the chute, to resume its position on carrying rollers.

(*g*) **Belt Cleaners:** For cleaning the outer surface of the belt a wiper or scraper blade is used for dry particles adhering to the belt. A rotary brush type cleaner is used for wet and sticky materials. To clean the inner surface of belt, if warranted, a scraper is placed near the end of return run before the tail end pulley.

(*h*) **Training idlers:** For various reasons like eccentric loading, sticking of material to belt or idlers etc., particularly for a long-centre conveyor, the belt may tend to move out of centre line. To prevent this tendency, belt training idlers are used which automatically maintain belt alignment.

The belt training idler consists of an ordinary troughed idler which is mounted on its base by pivot shaft about which it can swivel within a limited angle. Two short vertical rollers, mounted on bearings are fixed at the two ends of the idler, such that they are perpendicular to the belt edges. The vertical rollers are placed slightly ahead of the idler centre line.

When the belt shifts off centre, it makes contact with one of the vertical rollers which makes the entire idlers frame to swivel through an angle. This skewed position of the idler creates a force which tends to bring the belt back to its central position.

In a long conveyor, such trainer idlers may be spaced at about 30 meters. Fig. 6.1.10 shows such a troughed belt training idler.

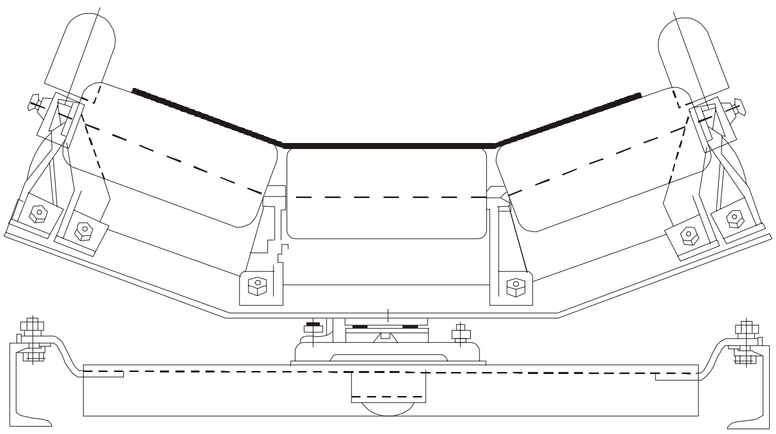


Fig. 6.1.10. Troughed belt training idler

To align belt travel, at times, troughed idlers having its side idlers tilted to a small angle not more than 3°, are used. However, this tilted rollers cause the belt to wear rapidly, hence should be used with caution.

(*i*) **Conveyor structure:** The structure supporting the pulleys and idlers consists of suitable sized channel stringers, with supporting legs to the main structure or floor. For long conveyors, lightweight truss sections are used that permit longer spans between supporting legs, and economical structural cost. A decking is provided to allow return run of the belt which also lends lateral rigidity to the structure. For long centre conveyors, sidewalk ways are provided for inspection and adjustment to idlers. The structures are often covered by tin plate at the top and sides to protect the materials being conveyed under the sky outside the plant. Fig. 6.1.11 shows photographs of two long centre conveyors with their covered structures, side walks etc.

Fig. 6.1.11. Photographs of long centre conveyors with their structures

(*j*) **Transfer terminals:** In a long-centre conveyor, direction of the conveyor is changed in a transfer terminal where materials from one conveyor is transferred into another conveyor. The second conveyor is laid out at certain angle (generally 90°) to the first one. The discharge from first conveyor takes place at a higher point, and materials is directed to the second conveyor situated at a lower height, through properly shaped and sized transfer chute. This transfer is a critical operation. The transfer terminal is enclosed within a structural framework, covered in all sides, called a junction tower.

6.1.5 Aspects of Belt Conveyor Design

The major points in selection and design of a belt conveyor are:

(*a*) Checking/determining capacity of a conveyor.

(*b*) Calculating maximum belt tension required to convey the load and selection of belt.

(*c*) Selection of driving pulley.

(*d*) Determining motor power.

(*e*) Selection of idlers and its spacing.

Above points have been discussed below in respect of flat as well as troughed belt conveyor. Necessary references have been made to IS 11592:2000 which provides guidance for selection and design practices to be followed for belt conveyors of sizes ranging from 300 mm to 2000 mm width of belt.

(*a*) **Checking/Determining Conveyor Capacity**

This basically means to check at what rate (tons/hrs. or units/min) a belt conveyor of a given belt width and speed can convey a particular bulk material or unit loads. Conversely, it is to find out the size and speed of the conveyor to achieve a given conveying rate.

Belt Width: (*i*) On a flat belt, free flowing materials will assume the shape of an isosceles triangle (Fig. 6.1.12 [*a*]). The angle of dynamic repose "φ_1" may be considered to be equal to 0.35φ, where "φ" is the static angle of repose for the material. To avoid spillage, the belt width "B" is taken at least 25% more than the base of triangle "*b*". Thus $b = 0.8$B. As per table 7 and 8 of IS 11592, $b = 0.9$B-0.05 m for B $\leq$ 2 m. Therefore, the assumption $b = 0.8$B is more conservative for B > 500 mm.

Referring to Fig. 6.1.12(*a*), the cross sectional area of the load on a flat belt is :

$$F_1 = \frac{bh}{2} = \frac{1}{2}\ (0.8B \times 0.4B\ \tan\varphi_1) = 0.16B^2 \tan(.35\varphi) \qquad ...(i)$$

Therefore, the conveying capacity "Q_f" of a flat belt conveyor is given by

$$Q_f = 3600F_1 \times V \times \gamma = 576B^2\ V\gamma \tan(0.35\varphi),\ \text{tons / hr} \qquad ...(ii)$$

where,

γ = bulk density of material in tons /m^3, and

V = velocity of belt in m/sec.

B = Belt width in metres.

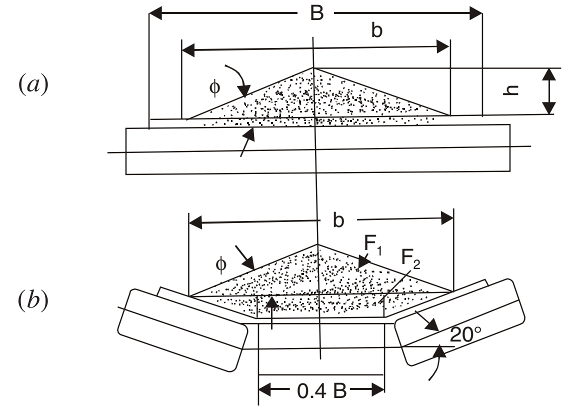


Fig. 6.1.12. Bulk load on flat and troughed belt conveyor

(*ii*) For a three roller troughed belt conveyor (Fig. 6.1.12 [*b*]), where the length of the carrier rollers are equal, the length of each roller l_r can be taken as a $l_r = 0.4$B. Let the trough angle be "λ". Then, cross sectional area of the load, F = $F_1 + F_2$.

The trapezoidal area

$$F_2 = \frac{1}{2}(0.4B+0.8B) \times 0.2B \tan\lambda = 0.12B^2 \tan\lambda \qquad ...(iii)$$

This is based on the assumption that the base "*b*" of top triangular area is given by $b = 0.8$B, as considered in (*i*) earlier.

$$\therefore \qquad F = 0.16B^2 \tan(.35\varphi) + 0.12B^2 \tan\lambda = B^2[0.16 \tan(.35\varphi) + 0.12 \tan\lambda]$$

The conveying capacity "Q_{tr}" of the troughed conveyor is

$$3600FVv = B^2Vv\ [576 \tan(.35\varphi) + 432 \tan\lambda],\ \text{tons/hr} \qquad ...(iv)$$

(*iii*) In case of flat belt carrying unit (box shaped) load the belt width B is taken to be ≅ width of the load + 200 mm. The capacity of the conveyor in terms of number of unit loads conveyed per unit time depends on orientation of unit loads on belt and speed of belt. Orientation of load depends on strength of the belt to carry unit load as well as on stability of the load on conveyor. This can be explained by an example given below.

Example:

Boxes of size 220 mm × 180 mm × 100 mm have to be conveyed by a belt conveyor of sufficient belt strength, at the rate of 2000 boxes per hour. What will be the size and speed of the conveyor?

Solution:

For stability, the boxes should be conveyed with their 100mm side as height. For safe conveying of boxes without moving off the belt, the belt width should be suitable for conveying the boxes with 220 mm side as width on the belt. So belt width should be 220 + 2 × 100 = 420 mm or its nearest higher standard size. With 420 mm belt width, even the maximum corner dimension of the box $\sqrt{220^2 + 180^2}$ = 284 mm will leave a side clearance of $\frac{1}{2}$ (420 – 284) = 68 mm. As per IS 1891:1994 (part I), the next higher standard size of 500 mm wide belt is chosen.

If the boxes are placed with a gap of say 200 mm between two boxes, then the maximum speed of conveyor "V" = $\frac{2000 \times (180 + 200)}{60 \times 1000}$ =12.67 m/min, which is quite a low speed for a 500 mm belt conveyor, hence acceptable.

In this problem, it is to be noted that, delivery of 2000 boxes per hour means same number of boxes to be loaded also *i.e.*, at a rate of $\frac{3600}{2000}$ =1.8 seconds per box. This may not be possible by manual loading and some type of automatic loading device needs to be incorporated.

IS: 11592:2000 has detailed out the maximum sectional area of materials on flat, two roller troughed and triple roller troughed belts for different belt widths, surcharge angles (dynamic angle of repose) and trough angles. These data may be interpolated for intermediate values of trough angles and dynamic angle of repose for different bulk materials as specified in IS:8730.

Belt Speed: Recommended belt speed depends on the width of the belt as well as lump size factor of the bulk material, its air borne factor and also its abrasiveness factor. IS: 11592:2000 gives the maximum recommended belt speeds for different sizes of belts based on "speed factor" (speed factor = lump size factor + air borne factor + abrasiveness factor). Tables 6.1.2 and 6.1.3 give the above factors and Table 6.1.4 shows the recommended maximum belt speeds. Higher belt speeds may be considered under special design conditions only.

Table 6.1.2. Lump size factor

Material	Lump Size	Lump Size Factor	Air Borne Factor
Fine Grain to Dust	< 10 mm	0	4
Granular	< 25 mm	1	0
Sized and Unsized	Quantity of largest lump is < 20 per cent of maximum permissible lump size (for the selected belt width)	2	0
Sized	Quantity of largest lump is < 60 per cent of maximum permissible lump size (for the selected belt width)	3	0
Unsized	Largest lump does not exceed maximum permissible lump size (for the selected belt width)	4	0

Table 6.1.3. Abrasiveness Factor

Abrasiveness	Type of Material	Abrasiveness Factor
Non Abrasive	Free flowing materials, such as cereal grains, wood, chips, wood pulp, fullers earth, flue dust, soda lime, char, loam sand, ground gravel.	1
Mildly Abrasive	Materials, such as aggregate, run-of-bank sand and gravel, slate, coal, salt, sand stone.	2
Abrasive	Materials, such as slag, spar, limestone concentrates, pellets.	3
Very Abrasive	Iron ores, taconite, jaspar, heavy minerals, flint rock, glass cullet, granite, traprock, pyrites, sinter, coke etc.	4

Table 6.1.4. Maximum Recommended Belt Speeds (m/s)

Belt Width, mm / Speed Factor	Upto 500	600 to 650	750 to 800	950 to 1050	1200 to 2000
1	2.50	3.00	3.50	4.00	4.50
2	2.30	2.75	3.20	3.65	4.12
3-4	2.00	2.38	2.75	3.15	3.55
5-6	1.65	2.00	2.35	2.65	3.00
7-8	1.45	1.75	2.05	2.35	2.62

For a conveyor sloping up (ascending), a slope factor ‘k’ is multiplied with the calculated conveyor capacity to get the actual capacity. The ‘k’ factors with angle of inclination is given in following table:

Degrees	0-2	4	6	8	10	12	14	16	18	20
'k' factor	1	0.99	0.98	0.97	0.95	0.93	0.91	0.89	0.85	0.81

(*b*) **Belt Tension**

In belt conveyor, the motive force to draw the belt with load is transmitted to the belt by friction between the belt and the driving pulley rotated by an electric motor.

From Euler's law of friction drive, considering no slip between the belt and pulley,

$$\frac{T_1}{T_2} = e^{\mu a}, \quad \text{...}(v)$$

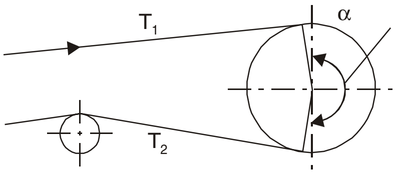


Fig. 6.1.13. Tensile forces on belt

where, T_1 = Belt tension at tighter side

T_2 = Belt tension at slack side

α = Wrap angle in radian

μ = Coefficient of friction between pulley and belt

$T_1 - T_2$ = "T_e" is the effective pull in the belt which is pulling the loaded belt against all resistances against the belt movement.

From eqn.(*v*), $T_e = T_1 - T_2 = T_2(e^{\mu\alpha} - 1)$ ...(*vi*)

Estimation of effective pull T_e: "T_e" is the sum total of all the resistive forces against the motion of belt carrying the load. The various components of resistances are as under:

Main resistance "R" comprising of :

(*i*) The resistance force caused by rolling friction in the bearings and seals of the carrying and return idlers.

(*ii*) The belt advancement resistance caused due to sagging of belt between idlers. *i.e*. due to recurrent flexing of belt and material over idlers.

Secondary resistance "R_s" comprising of :

(*i*) The inertial and frictional resistances R_a due to the acceleration and friction of the material at loading area.

(*ii*) The force R_w required for bending (or wrapping) of the belt over pulleys.

(*iii*) Resistance R_{ska} due to sliding friction between belt and side walls of the skirt at loading area.

(*iv*) Bearing resistance R_b of pulleys (with the exception of driving pulley, which is overcome directly by driving motor).

Special main resistance "R_{sp1}" comprising of:

(*i*) Drag due to forward tilt of idlers.

Special secondary resistance "R_{sp2}" comprising of:

(*i*) Resistance from belt cleaners.

(*ii*) Resistance from discharge ploughs and belt trippers.

Slope resistance "R_{sl}", which is the vertical component of the loaded belt when the conveyor is inclined to horizontal by an angle "δ".

Thus effective pull "T_e" can be written as:

$$T_e = fLg\,\{m_c + m_r + (2m_b + m_G)\cos\delta\} + R_s + R_{sp1} + R_{sp2} + m_G gL\sin\delta \qquad ...(vii)$$

where f = artificial coefficient of friction taking care of rolling resistance of idlers and belt advancement resistance.

The value of 'f' = 0.02 for horizontal belt conveyor.

= 0.012 for a down hill conveyor requiring a brake motor.

L = length of the conveyor, m.

m_c = moving mass of carrying idlers per metre, kg/m.

m_r = moving mass of return idlers per metre, kg/m.

m_b = mass of belt per meter, kg/m.

m_G = mass of load per metre of belt length, kg/m.

δ = angle of inclination.

L Sin δ = lift of conveyor between loading and discharge point.

Calculation of secondary resistance is based on, $R_s = R_a + R_w + R_{ska} + R_b$

where, R_a is inertial and frictional resistance of material at loading area.

$$= Q \times 1000 \times \rho(V - V_0) \qquad \ldots(viii),$$

where Q = Volumetric conveyor capacity, m^3/s.

ρ = bulk density, tonnes/m^3.

V = vel. of belt, m/sec.

V_0 = vel. of material at the point of loading, m/sec.

R_w is wrapping resistance between belt and pulley, generally calculated from the formula.

$$R_w = 9B\left[140 + 0.01\frac{Tav}{B}\right]\frac{t}{D} \qquad \ldots(ix)$$

for fabric carcass belt, or

$$R_w = 12B\left[200 + 0.1\frac{Tav}{B}\right]\frac{t}{D} \qquad ...(x)$$

For steel cord belt.

where, $T_{av} = \dfrac{T_1 + T_2}{2}$, Newton

t = belt Thickness, mm

D = pulley dia., mm

B = belt width, m

However, the wrapping force is approximated as a percentage of maximum belt tensions on tight and slack side. Following values of R_w may be assumed as a thumb rule.

Location of pulley	*Degree of wrap*	*Wrap resistance, Newton*
Tight side	150° to 240°	230
Slack side	150° to 240°	175
All other pulleys	—	140

The other resistances R_{ska} and R_b under secondary resistance and other special resistances R_{sp1} and R_{sp2}, can be calculated based on different formulae given in sections 8.5.1.3 and 8.5.1.4 of IS:11592, which are either small in values or not always applicable.

Once 'T_e' is estimated, tensions at the tight side (T_1) and slack side (T_2) are worked out using eqns. (*vi*) and (*v*).

The coefficient of friction between belt and driving pulley under different operating conditions can be in considered as given in Table 6.1.5.

Table 6.1.5. Friction Coefficient between Driving Pulley and Rubber Belting

Pulley Surface / Operating conditions	Smooth Bare Rim Steel Pulley	Rubber Lagging with Herringbone Patterned Grooves	Pulyurethane Lagging with Harringbone Patterned Grooves	Caramic Lagging with Harringbone Patterned Grooves	PVC Belt Type
Dry condition operation	0.35 to 0.4	0.4 to 0.45	0.35 to 0.4	0.4 to 0.45	0.25 to 0.35
Clean wet condition (water) operation	0.1	0.35	0.35	0.35 to 0.4	0.15 to 0.30
Operation under wet and dirty (clay or loam) conditions	0.05 to 0.1	0.25 to 0.3	0.2	0.35	Less than 0.25
Operation under very wet and dirty condition	0.05	0.25	0.2	0.3	0.15

Checking for belt sag : The minimum tensile force 'T_{min}' which should be exerted on the belt to limit belt sag between two sets of idlers is calculated by the formula:

$$T_{c\,min} \geq \frac{l_c^2 (m_b + m_G) g}{8S} \text{, for carrying side} \qquad ...(xi)$$

$$T_{r\,min} \geq \frac{l_r^2 m_b g}{8S} \text{, for return side,} \qquad ...(xii)$$

where l_c, l_r are idler spacing in meters,

and S = maximum allowable belt sag = .005 to .02 m.

If the $T_{c\,min}$ and $T_{r\,min}$ are higher than the tensions T_1 and T_2 calculated from total resistance consideration, these higher values of belt tensions should be achieved through proper belt tensioning and should be considered in calculation of different design parameters.

In order to increase the effective pull without slippage, the wrap angle of belt over driving pulley or pulleys is generally increased. Fig. 6.1.14 below shows the different drive arrangements for achieving higher value of wrap angle 'α'.

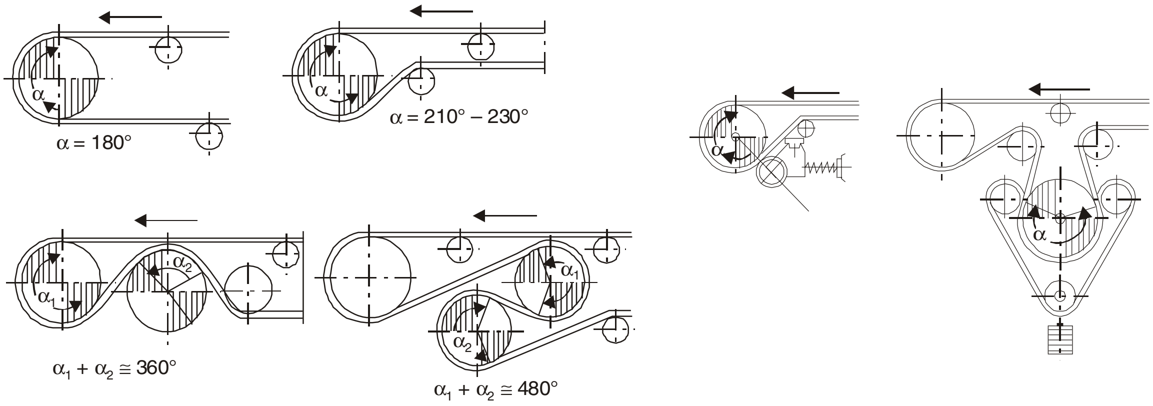


Fig. 6.1.14. Different belt drive arrangements

Selection of Belt Carcass : Maximum peripheral force "Te_{max}" often occurs when starting up the completely loaded conveyor from rest. The ratio "ξ" between Te_{max} and T_e depends on the type of drive selected, which varies from 1.8 -2.2 for direct on line start of motor connected by a pin bush type coupling, to a lower value of 1.2 for start-delta starting of a slip ring motor connected by flexible coupling or a 3 phase squirrel cage motor connected with a fluid coupling with delayed chamber filling.

Taking this maximum effective pull, $Te_{max} = \xi Te$, T_{1max} should be calculated where $T_{1max} = T_e \xi \left(\frac{e^{\mu a}}{e^{\mu a} - 1}\right)$. Based on this maximum tensile force in belt, the belt carcass should be selected from manufacturers' catalogues having sufficient breaking strength to withstand this maximum tensile force.

(c) **Selection of Driving and Other Pulleys**

The large diameter driving and tail end pulleys are generally fabricated from steel plates. The pulley shafts are made integral with the barrel. The barrel and journal portions are machined in one setting to make them concentric. The pulley faces are given a ''crown'' of around 0.5% of the pulley diameter, but not less than 4mm.

Diameter of pulley is selected based on the construction (number of plies which is proportional to carcass thickness) of the belt used. The recommended values of minimum pulley diameters based on carcass thickness and fibre materials is given in Indian standard IS: 1891 (part I).

However, as a thumb rule, diameter 'D' can be approximated from the relation, $D \geq ki$, where i = number of plies of belt, and k = 125 to 150for i between 2 to 6, and k = 150 for i between 8 to 12. Calculated 'D' is rounded off to the larger standard sizes of 250, 315, 400, 500, 630, 800,1000,1250,1400,1600, 1800 and 2000 mm.

The length of the barrel is kept 100mm to 200 mm more than the belt width.

The drive pulley may be covered (lagged) with a layer of suitable material like rubber, polyurethane, ceramics etc, whenever necessary, to increase the coefficient of friction between the pulley and belt. The thickness of such lagging may vary between 6 to 12 mm, and having a hardness between 55 to 65 shore A scale. However, the lagging on other pulleys like snub and bend pulleys, the hardness chosen is much less (35 to 45 shore A) to protect damage to the surface covering of the belt.

Courtesy : Sandvik Asia Ltd., India

Fig. 6.1.15. Two belt conveyors carrying ores, capacity 11,000 tph each, 13.8 km long

(*d*) **Motor Power**

The power required at the driving pulley just for driving the belt is given by the formula:

$$P_d = \frac{T_e \times V}{1000} \text{ kW, where } T_e = \text{effective tension} = (T_1 - T_2) \text{ in Newton}$$

V = belt speed, m/sec

P_d = driving power, kW

However, the actual power requirements, considering the wrap resistance between belt and driving pulley, and driving pulley bearings resistance, the actual motor power, P_A is given by

$$P_A = \frac{T_e V}{1000} + \frac{(R_{wd} + R_{bd})V}{1000} \text{ kW, where}$$

R_{wd} = wrap resistance between belt and driving pulley.

R_{bd} = driving pulley bearing resistance.

Additional power requirements should be taken into considerations for each belt tripper, and belt cleaner used with the conveyor.

The final motor power "P_M" is calculated based on efficiency "η" of the transmission system used consisting of gear box, chain / belt drive, coupling etc. Thus, $P_M = \frac{P_A}{\eta}$.

Actual motor is chosen with a power rating of 15% to 20% greater than the calculated power 'P_M'.

(*e*) **Selection of Idlers**

Depending on the type of belt conveyor, the carrying idlers can be troughed or straight, while the return idlers are generally always straight. The major selection criteria are the roller diameters and spacing of these idlers.

The range of idler diameters to be selected depends on belt width, maximum belt speed and type of materials to be conveyed. Based on these, the idlers are classified into following six series as specified in IS:11592:2000 and given in Table 6.1.6 below:

Table 6.1.6. Idler Classification

Idler Series	Roller Diameter	Belt Width	Maximum Belt Speed, m/s	Suitable for
I.	63.5 to 101.6	300-800	2.5	Fine material with small lumps-Nonabrasive, intermittent duty.
II.	88.9 to 139.7	400-1000	4.0	Fine material, small sized lumps, slightly abrasive, continuous duty.
III.	101.6 to 139.7	500-1200	4.0	Unsized medium lumps, mixed with fine sized small lumps, moderately abrasive, continuous duty.

IV.	127 to 139.7	500-1400	4.0	Unsized, large lumps, mixed with small sized medium lumps moderately abrasive continuous duty.
V.	139.7 to 219.1	800-2000	5.0	Large size lumps, highly abrasive, critical duty.
VI.	168.3 to 219.1	1600-2000	4.0	Large capacity conveyor with lumps.

Spacing for carrying and return idlers also depends on belt width, and bulk density of the material to be conveyed. The recommended spacing as per IS:11592:2000 is given in table 6.1.7 below.

Table 6.1.7 Recommended Idler Spacing

Belt Width	Troughed Belt		Flat Belt	Return Idler Sets
	Carrying Idler Sets for Materials of Bulk Density (t/m^3)			Troughed and Flat Belt
	0.40 to 1.20	1.20 to 2.80		-
	Recommended Spacings, mm			
300 400 500 650	1500	1200	1000	3000
800 1000	1200	1000		
1200 1400 1600 1800 2000	1000	1000	750	

6.2 CHAIN CONVEYORS

6.2.1 Definition / Description

The term chain conveyor means a group of different types of conveyors used in diverse applications, characterised by one or multiple strands of endless chains that travel entire conveyor path, driven by one or a set of sprockets at one end and supported by one or a set of sprockets on the other end. Materials to be conveyed are carried directly on the links of the chain or on specially designed elements attached to the chain. The load carrying chain is generally supported on idle sprockets or guide ways. The endless chains are kept taught by suitable chain tensioning device at the non-driven end.

6.2.2 General Characteristics

Different types of chain conveyors are used in wide varieties of applications. It is, therefore, not possible to have a set of common characteristics for all these chain conveyors. Special characteristics of individual type of chain conveyors have been described while discussing them.

Chain, compared to belts of a belt conveyor, have certain advantages as well as disadvantages. The major advantages are that the chain easily wraparound sprockets of small diameter, and the drive is positive i.e. no slippage takes place between chain and sprocket. The chain stretch is also little. The disadvantages of chain are its high weight, high initial cost, higher maintenance cost and most importantly, limited running speed because of dynamic loading that come into play in chain-sprocket drive causing intensive wear at high speeds (dynamic chain loading has been discussed in section 6.2.5.). Maximum length and maximum lift of chain conveyors are limited by the maximum allowable working tension of the chain used.

6.2.3 Types of Chain Conveyors

(*a*) **Apron or Pan Conveyor:** This is the most common type of chain conveyor. It consists of one or more strands of endless chain, usually link plate roller type, running in steel guides. Rollers ensure minimum pulling effort in the chain, while roller guides supported on the superstructure of the conveyor, carry the entire load of the materials and chains. The carrying surface of the conveyor is composed of a series of plates or shapes called **apron**, which are attached to the links of the chains through cleats. The bed created by the aprons is used for carrying bulk materials as well as unit loads. When the conveyor aprons have vertical flanges on all sides to form a pan like shape, if is specifically called a **pan conveyor**. Materials carried by the apron is discharged over the sprockets at the driven end, and the conveyor chain with aprons comes back empty on its return Journey. These are generally slow speed conveyors with a speed range of 20 to 35 mpm. Arrangement of a typical apron conveyor is shown in Fig. 6.2.1.

Courtesy : TRF Ltd., Kolkata

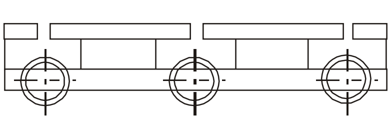
Fig. 6.2.1. Photographs of typical apron conveyor

Applications: Generally apron and pan conveyors are used to perform severe duties of conveying large quantities of bulk load such as coal, ore, slag, rock, foundry sand etc. These are frequently used for feeding materials to large crushers, breakers, grinders and similar machines. Specially designed aprons are used for conveying unit loads, coils, hot forgings. Part of an apron conveyor may be run through a liquid or water bath for washing of the materials and then allow drainage of liquid from wet materials. Apron conveyors can have flexible layout to follow combined horizontal and inclined movement in the same vertical plane.

Apron/pan design: Depending on the nature of materials to be conveyed, different designs of apron and pan are used. Some of the common designs are:

(*i*) **Flat, spaced apron:** Conveyor with rectangular shaped flat steel or wooden slat aprons with small gaps between them, providing a flat surface for carrying unit loads are specifically called "**slat conveyor**" [Fig. 6.2.2 (*a*)]. Some other designs of flat and spaced aprons with cleats for carrying different shaped object are shown in Fig. 6.2.2 (*b*) and (*c*).


(*a*) Slat Conveyor


(*b*)

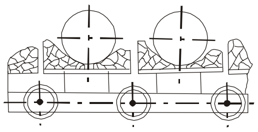

(*c*)

Fig. 6.2.2. Flat spaced apron conveyor

(*ii*) **Corrugated apron:** These are the most common type of apron, made of formed steel, with front and rear edges beaded so that one overlaps the other to form a continuous bed or trough. The overlaps are so made that during turning of the chain over sprockets, the apron ends move relative to each other without creating a gap for leakage of materials or a jamming of adjoining aprons or pans. Fig. 6.2.3 shows corrugated aprons of different styles. Some of the aprons are plain while some are provided with overlapped vertical end plates to form pans. Corrugated aprons or pans may be fabricated or cast from gray or malleable iron. The pans are designated as leakproof (for carrying fines), shallow, deep and hinged (for carrying chips, trimmings, scrap etc.). Deep pans may be used for carrying materials at an inclination of upto 45°.

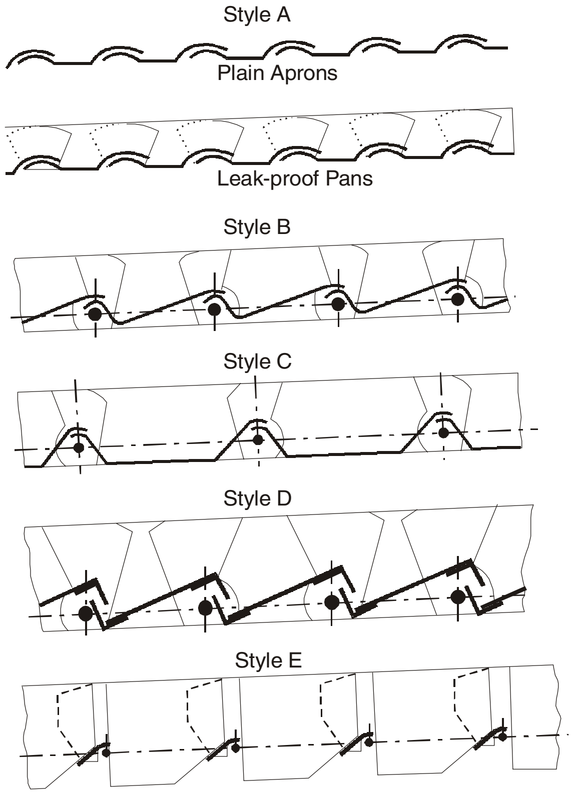


Fig. 6.2.3. Corrugated aprons of different styles

(*iii*) **Special types:** These are used in special applications and are too numerous to be discussed in limited space. Some of the typical examples are the four compartment cast-metal pans used for pig casting. Beaded aprons are used in sugar mills. When deep loads are carried on an apron conveyor, stationary side plates called skirt plates are provided on both sides, fixed to the conveyor frame.

(*b*) **Cross-Bar or Arm Conveyor:** This type of conveyor consists of a single or two strands of endless chain, to which are attached spaced, removable or fixed arms (or cross members) from which materials are hung or festooned. The arms may be replaced by shelves/trays to support packages or objects to carry them in a vertical or an inclined path.

Special arms are designed to suit specific load configuration. Depending on the design of arms, they are called by different names, some of which are: (*i*) pendent conveyor, (*ii*) pocket conveyor (shown in Fig 6.2.4), (*iii*) wire mesh deck conveyor, (*iv*) removable-crossbar conveyor, (*v*) fixed cross-bar (or arm) conveyor, (*vi*) swing tray conveyor.

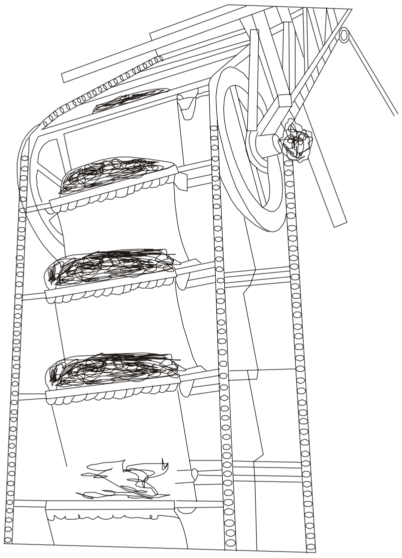


Fig. 6.2.4. Pocket type arm conveyor

Applications: Crossbar conveyors are used for conveying and elevating or lowering unit loads like barrels, drums, rolls, bags, bales, boxes etc. The conveyors may be loaded/unloaded manually or at automatic loading / discharging stations. Cross-bar conveyors are also used in a wide range of process applications such as dipping, washing, spraying, drying and assembly etc.

(*c*) **Car-Type Conveyor:** This type of conveyor consists of a series of small platform cars, propelled by an endless chain, running on a closed track. Car-type conveyors may have vertical runarounds over sprockets having horizontal axis. However, more often they are designed with horizontal runarounds (carousels) over sprockets (or sheaves for rope drive) with vertical axis. This type of conveyor is also called a **carousel conveyor** or a **pallet-type conveyor**.

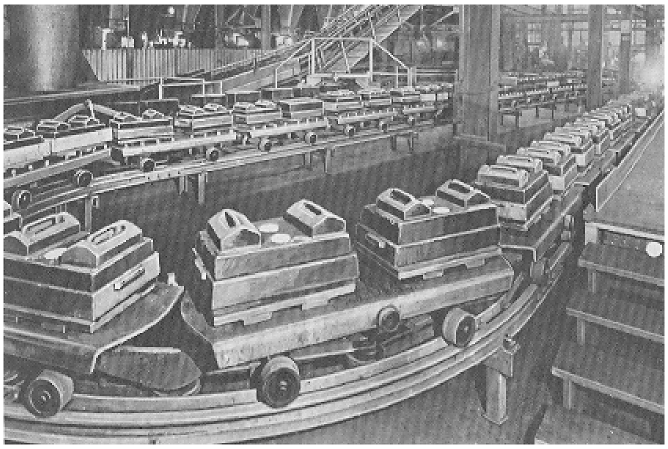


Fig. 6.2.5. Photographic view of car conveyor

The track is placed more or less in a horizontal plane. The cars may either be permanently attached to the driving chain (or cable) or may be propelled by pusher dogs on chain or rope against lugs on cars. The driving chain is generally positioned at the bottom side of the cars, between the two track rails. Loads may be manually loaded / unloaded, or may be designed for automatic loading, and unloading through tilting of car top at unloading point. Fig. 6.2.5 shows a typical car-type conveyor.

Applications: Car-type chain conveyors are particularly used for carrying heavy or irregular shaped large objects like moulds in foundries, coils for rolling plants etc.

These conveyors are conveniently used to combine different processing operations during transportation of the loads. Rolled coils may be cooled, molten metals may be solidified in moulds, assembly of components may be achieved, testing inspection may be performed etc.

The conveyors with horizontal runarounds can be arranged to move in any straight or irregular shaped path in the same horizontal plane, hence called contour type, which makes them very suitable for use in different process plant for picking up and delivery of materials from and to desired locations of the plant. On horizontal runarounds, a load not removed will continue to move with the conveyor. This gives an obvious advantage of using a short conveyor for accomplishing long duration processes (drying, cooling etc.) and irregular processes (foundry, testing etc). Horizontal carousel conveyor usually occupies larger floor space.

(*d*) **Carrier chain & Flat-top chain conveyor:** Carrier chain conveyor consists of one or more number of endless chains to which may be attached one of the many different attachments for the purpose of carrying unit materials or objects. In many cases, the materials are conveyed while being directly in contact with the chain/chains.

These conveyors have a broad application in practically all fabricating and processing industries. Different designs of attachments are used for different types of materials.

Carrier chain conveyors are generally classified into two basic types:

(*i*) *Rolling-type carrier chain conveyors:* In this class of conveyor, the chains are provided with rollers moving on tracks for minimum of friction. The materials are supported on the attachments. In a variation of this type of conveyor, the rollers may be used for supporting the objects while the chain acts as the connecting and propelling link for the rollers. The rollers may be shaped to accommodate curved faced objects or may be flat-faced to carry objects with flat surfaces. Rotation of the carrying rollers often causes the objects to move at a higher velocity than that of the chain.

(*ii*) *Sliding-type carrier chain conveyor:* In this class of conveyor, the loads are carried directly on one or more chains, while the individual chain slides on a track or surface or a trough. Attachments or specially designed links may be used to suit the loads.

Fig. 6.2.6 shows different designs of rolling type carrier chain conveyors.

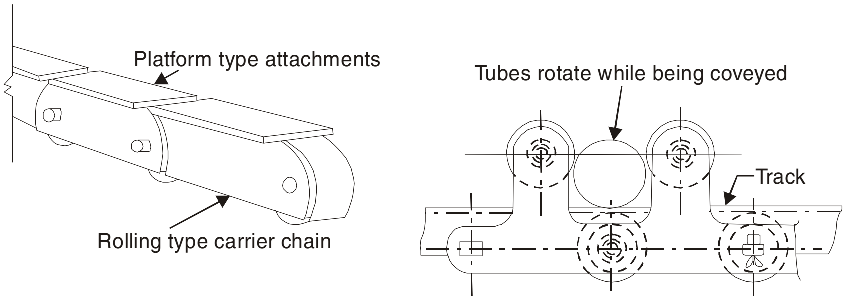


Fig. 6.2.6. Different rolling type carrier chain conveyors

Flat-Top chain Conveyor is a particular group of carrier chain conveyors, may be rolling or sliding type, with specially designed chain links or with flat plate attached to the chain links so as to provide a continuous, smooth, level top surface to carry small articles like bottles, cans, etc. at a high speed. These conveyors are widely used in canning and bottling plants.

Different types of chains and/or attachments are used such as hinged-joint continuous flat-top sliding type (Fig. 6.2.7), plate-top sliding or rolling type, crescent-shaped plate top type. The crescent plate design is particularly suitable for carousel-type operation to turn in a horizontal curve, a typical example being the baggage handling conveyors in the arrival section of an airport.

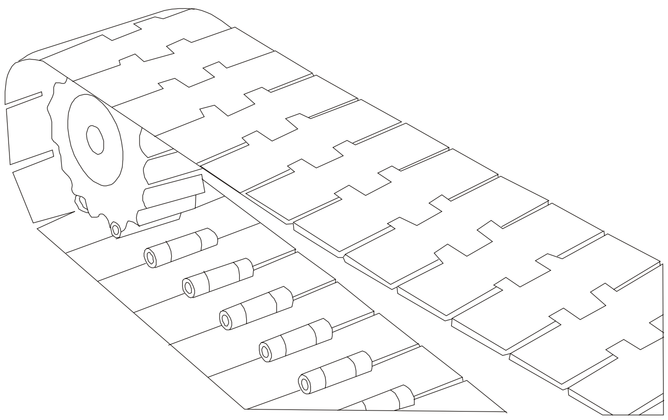


Fig. 6.2.7. Hinged joint continuous flat-top sliding conveyor

The above figure shows a variation of flat-top conveyor which consists of flat hinged plates so designed that the hinge barrels are driven by the specially designed sprocket. No actual chain is used in this conveyor which is widely used in canning and bottling plants.

(*e*) **Trolley Conveyor:** These conveyors consist of a series of trolleys supported from an overhead endless track and propelled by an endless chain or cable, with the loads usually suspended from the trolleys. This is one of the most versatile type of chain conveyors which can work in horizontal and inclined paths, vertical curves and horizontal turns to follow complicated routes.

Different structural members are used as track for overhead trolley-conveyor which include I-beam, double angles, T-rails, steel bars, pipes and fabricated sections. However, I-beam is the most common track. These tracks are laid at a higher level, suspended from roof, building structures or hung from floor-mounted columns, and routed around obstacles. Overhead operation allows free floor space and no interference with equipment or traffic at the floor level. For this reason, trolley conveyors are also called **overhead conveyors**. Generally two wheeled trolleys or more wheeled trolleys with load bar between them for handling large loads, are used. Loads are suspended from carriers bolted to the trolley bracket. Hooks and trays are the most common carriers.

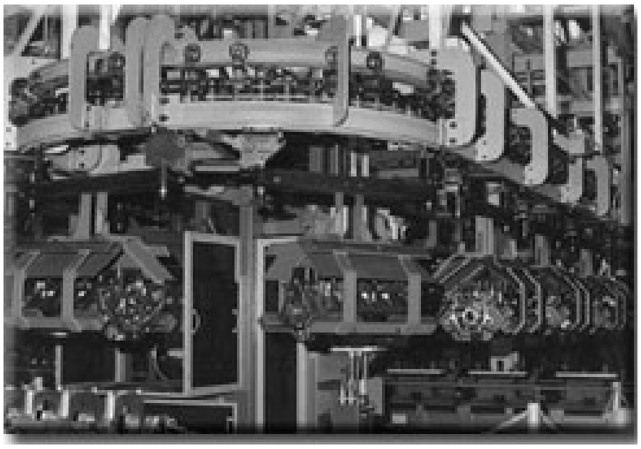


Fig. 6.2.8. View of a trolley conveyor

As the trolleys can move in three dimensions, this type of conveyor is extensively used for carrying materials continuously through different processes, like cleaning, washing, painting, drying, baking, degreasing, sand blasting etc. These conveyors may be, and usually are, used as a storage conveyor, at the same time as a processing and delivery conveyor.

The carriers can be loaded and unloaded en route, at one or more points of the conveyor run, either manually or automatically.

According to the method by which load is conveyed, trolley conveyors are further classified into following three types:

(*i*) *Load-carrying trolley conveyor:* Which is the main type, in which the trolley and the load carriers are permanently fixed to the pulling chain [Fig. 6.2.9 (*a*)].

(*ii*) *Load-propelling trolley conveyor:* In which the trolleys with load carriers travel on track being pushed by pusher dogs attached to the pulling chain or chain trolley [Fig. 6.2.9 (*b*)]. The special advantage of this load-propelling conveyor (also called **pusher trolley conveyor**) is the capacity to divert the load carriers from the main track to a branch track for achieving different operational requirements.

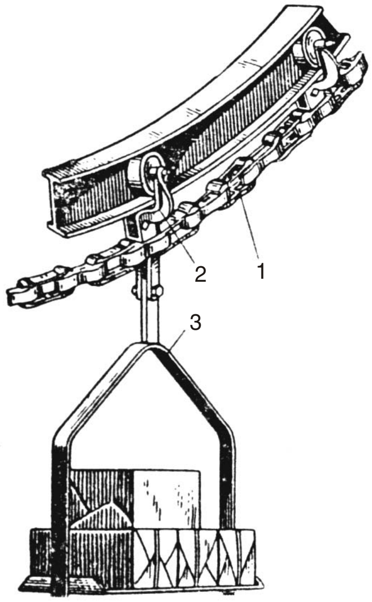


Fig. 6.2.9. (*a*) Load carrying trolley conveyor **Fig. 6.2.9.** (*b*) Chain trolley with dog

(*iii*) *Load towing trolley conveyor:* in which the trolleys are permanently secured to the pulling member, and specially designed hooks or rods from the trolley engage and tow floor mounted trucks carrying the load. In this case the conveyor may be made very light as the load in basically carried on the floor, but the advantage of free floor / working space is lost. This particular type of trolley conveyor is also classified as **overhead tow conveyor** (refer section 6.3 for further details). Fig. 6.2.10 shows schematic view of a load towing trolley conveyor.

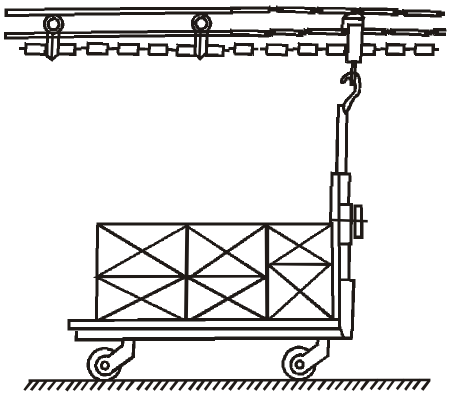


Fig. 6.2.10. Load towing trolley conveyor

At horizontal turns or vertical curves, where the trolley conveyor changes direction, special care is taken to keep the pulling chain from becoming slack or making kink. At turns, the chain may be supported by a series of rollers or by a suitable sized sprocket. At vertical curves, generally the slope is limited to 30° and while going down it starts with a dip down (that is gradually changing slope to the desired angle) and the opposite requires a dip up. At vertical curves, **stops** are sometimes used to prevent runaway of trolleys and loads if the chain breaks.

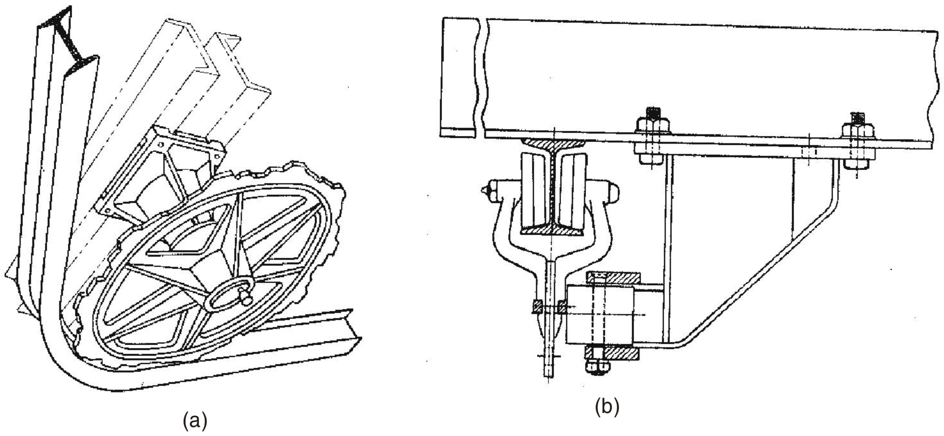


Fig. 6.2.11. Horizontal turn : (*a*) with sprocket, (*b*) roller supported

The advantages of an overhead trolley conveyor may be summarised as follows: movement is three dimensional and easily adopted to changes in direction; large length with one or multiple drives; free floor space; small power consumption; little maintenance and high salvage value.

(*f*) **Power and Free Conveyor:** These conveyors are basically a special design of the **Load-propelling or pusher trolley conveyors**. In a normal pusher trolley conveyor the non-powered trolleys, supported from a monorail, carry the load and are pushed by dogs/pushers attached to the chain trolleys mounted on a separate track. A power and free conveyor is one in which the power trolleys run directly above the free trolleys, which run in double channel track, and arrangements are made such that at desired points the non-powered load carrying trolleys may be engaged to or disengaged from the power trolleys.

The power trolley dogs/pushers are rigid attachments on the trolleys or chain. They engage or disengage with the free trolleys by switching them in from a branch line to the mainline, and by horizontal turns and vertical curves in the power line. The switching operations can be made mechanically or through actuation of pneumatic cylinder synchronous with movement of power trolleys.

Schematic diagram of a typical power and free conveyor is shown in the following (Fig. 6.2.12):

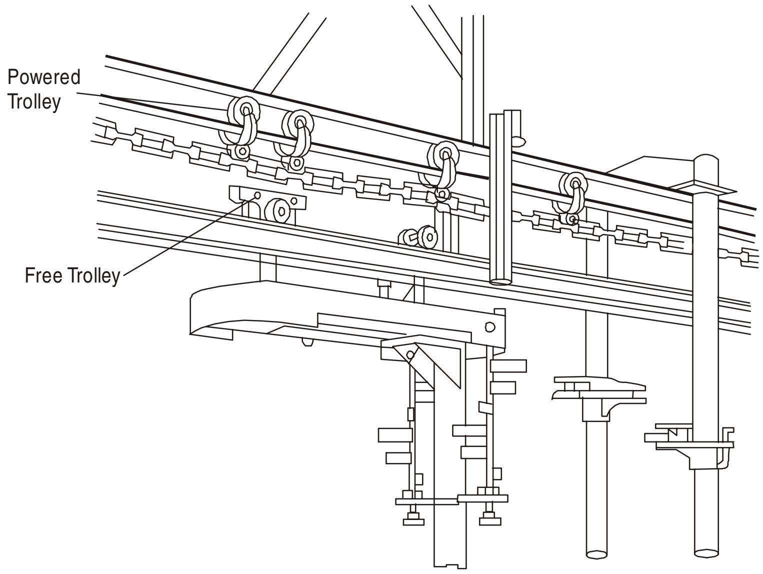


Fig. 6.2.12. Power and free conveyor

Unlike in a load-propelling conveyor, where the side pusher must be so arranged that switching is always done on the side away from the power conveyor pusher arm, the power and free conveyor can switch load on both sides of the power trolley track.

Through power and free conveyor, it is possible to switch off loads to branch lines, to alter load spacing in various sections of the conveyor, to stop the loads for making inspection, work repair or storage etc. Another advantage of this conveyor is that the power conveyor can often be kept out of the processing zone like oven, painting booth or other undesirable location.

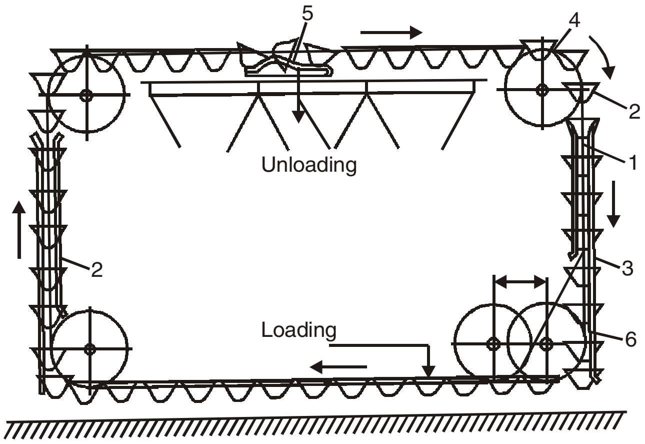
The special features of automatic dispatching, switching and transfer have resulted in remarkable savings in labour and manufacturing cost in host of different process industries like automobiles, foundry, graphite anode handling in aluminium pot shop etc.

From design point of view, one interesting aspect is the mechanism used for engagement and disengagement of the pusher and the free trolley. A popular design provides two counterweighted tilting dogs at the top of the free trolleys, so that as the power pusher attachment approaches the free trolley, it pushes one dog down to pass over it and engages the second dog. When first dog is released, it tilts back to its initial position and becomes a holdback. Depending on the direction of travel or the inclination of the track, either of the dogs may become pusher or holdback. In certain designs, the pusher units are supported against springs, which have sufficient rigidity to push a loaded carrier. However, when the carriers are stopped against a manual or automatic stop, the pusher spring is compressed and the pusher slides over the dogs on the free trolleys. This design of a pusher is called reversing spring pusher.

Fig. 6.2.13. An engagement mechanism between pusher and free trolley

(*g*) **Suspended Tray Conveyor** also known as **Swing-Tray Conveyor:** These conveyors consist of two strands of chains between which are pivot mounted a series of trays to carry in-process movement of various unit loads (forged components, boxes etc.) along complex contours comprising horizontal and vertical paths in one vertical plane. As the trays are pivot mounted from the links of the chains, the trays along with their loads always remain suspended vertically irrespective of the path of the chain.

Suspended tray conveyors are loaded on vertical sections manually or automatically by specially designed loading devices. These conveyors are particularly used for raising /lowering of loads between floors, convey materials between processing equipment, carry loads without transfer between interlinked horizontal and vertical sections. The conveyor may be used for carrying load through processing stations like drying, pickling chambers etc. Fig.6.2.14 illustrates a typical layout of a pivoted bucket conveyor showing different components of the conveyor.



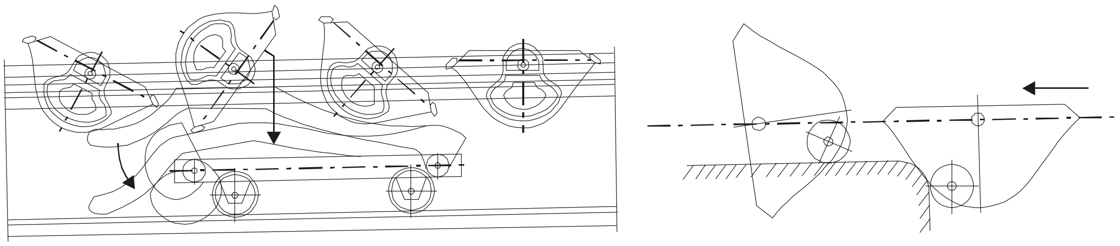
1. Pulling chain, 2. buckets, 3. vertical guides (to prevent oscillations), 4. driving sprocket,

5, take-up sprocket, 6. tipping divice.

Fig. 6.2.14. Layout of a pivoted bucket conveyor

The design of the trays are adapted to the requirements of loads and method of loading / unloading. The trays may be flat or curved. When the trays are made of steel plates in the shape of buckets for carrying powdered or granular bulk load, the particular conveyor is called **pivoted bucket**

conveyor. The bulk material is fed into the buckets on the lower horizontal section and carried through various sections without transfers, and hence is not crushed en-route. The pivoted buckets are discharged at the upper horizontal section automatically by tippers or dischargers. The buckets are fitted with projecting curved cams or guide rollers, which on coming in contact with the arms of tippers, tip the buckets. Fig.6.2.15 shows the two common schemes of bucket tipping devices. Pivoted bucket conveyors are used in power plants in carrying coal and ashes, in cement mills, ceramic industry, stone crushing plants etc..



(a) (b)

Fig. 6.2.15. Tipping devices of pivoted bucket conveyor (*a*) movable device with elevating lever and cam on buckets; (*b*) guide rollers on buckets.

6.2.4 Components of Chain Conveyor

The major components of a chain conveyor are : (*i*) Pulling chain, (*ii*) Sprocket to drive and support the chain, (*iii*) Take-up arrangement, (*iv*) Drive arrangement and (*v*) Various other components specific to various type of chain conveyors.

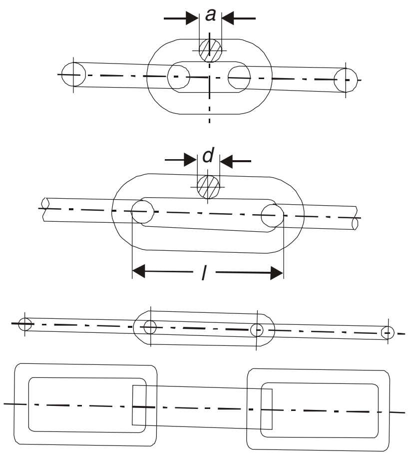
(*a*) **Pulling Chains:** Different types of chains are used in chain conveyors, which have their merits and demerits, briefly discussed below:

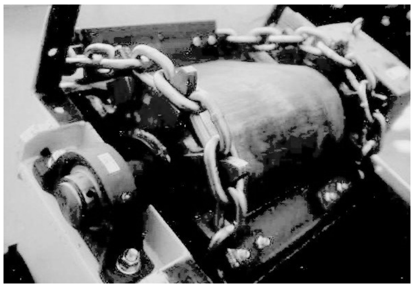
(*i*) *Round-link chains* (Fig. 6.2.16) are low in cost and high flexibility in all directions. This have flexibility which is particularly desirable in trolley conveyors. However, limitations of this chain are less contact area, high stretch under load and rapid wear.

(*a*)

(*b*)

(*c*)





Short or long-linked welded Round-link chain being driven by sprocket

Fig. 6.2.16. Round-link chain

(*ii*) *Combination chains* (Fig. 6.2.17) are widely used in many different conveyors. The links are generally of cast malleable iron construction with machined steel pins and may be with or without roller.

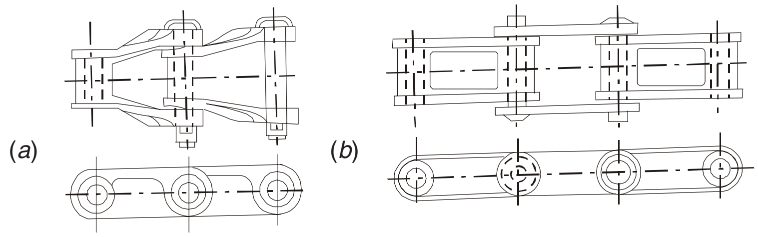
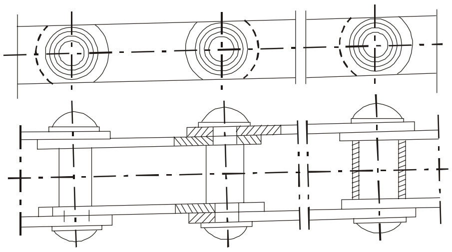


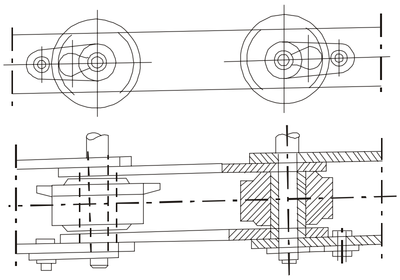
Fig. 6.2.17. Combination chain (*a*) without rollers, (*b*) outer link plates of steel

(*iii*) ***Link-plate chains*** (Sometimes called leaf chain) are the most common type used in chain conveyors. The link plates allow different types of attachments to be fitted in the chains. The pitch of the chain may be made large enough (pitch usually vary from 65 mm to 1250 mm) by making the links from steel plates.

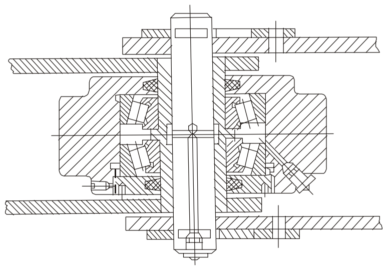
Constructionally the link-plate chains may be bush-less chain with or without rollers, and bushed chain with or without rollers, as shown in Fig. 6.2.18. The bushes decrease the wear at the link joints. The rollers fitted with bushes or with antifriction bearing for large size chain (Fig. 6.2.18) generally run on guided tracks or toughs which carry the entire weight of the chain and load being carried, thereby reducing the pull in the chain. Because of these advantages, chain with bush and roller are the preferred ones.



Bushless with or without roller



Bushed with roller



Antifriction bearing roller assembly

Fig. 6.2.18. Link plate chains

Chain selection is based on largest practical pitch (being cheaper than the shorter pitch chain of equal strength), allowable tension load, capital cost and degree of maintenance needed.

(*b*) **Sprockets:** The sprockets are made of good grade cast iron with chilled hardened teeth or from cast steel or plate steel. The teeth are machined to suit type of chain used. The advantage of using a large sized sprocket with greater number of teeth is to obtain smoother operation. However, larger the size of sprocket, costlier it is and taking larger space. Thus a compromise is made in selecting the size of a conveyor sprocket. (The pulsating motion of a conveyor chain is explained in section 6.2.5).

(*c*) **Take-up arrangements:** The most common type of take-ups is ***adjusting screw type*** for positioning the bearing blocks supporting the takeup sprocket shaft. The range of adjustment should be sufficient to permit initial slack-off of the conveyor chains for joining of two links to make them endless and ample adjustment for initial stretch and subsequent wear / elongation.

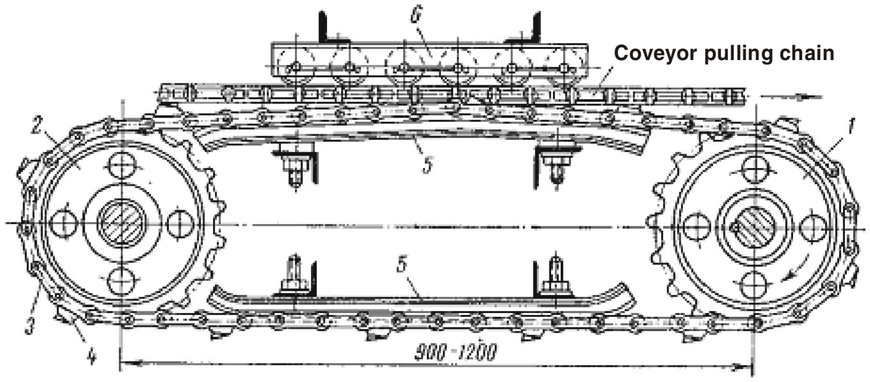
The alternative design is ***counterweighted-type***, providing automatic constant tension in chain. This type provides constant chain tension under variable temperature conditions also.

(*d*) **Drive arrangement:** Drive for a conveyor generally consists of an electric motor coupled to a speed reduction gear unit which in turn is coupled to the driving sprocket. For a conveyor having a simple configuration (as in an apron conveyor), the drive is located at the sprocket at the end of loaded strands of chain. For conveyors like trolley, car, tray etc. having a complicated path of motion, the drive location is determined by analysis of tension variation in the path of conveyor motion.

Drives may have fixed or variable speed. Variable speed may be achieved by using a variable speed gear box or change speed gear box or multiple speed motor or by having an electrical speed control system.

For a long chain conveyor, synchronously working multiple motor drives at different sections are employed which decrease the total tension in the chain.

A **crawler drive** is employed for giving drive to a straight portion of the pulling chain. The crawler drive arrangement is shown in Fig. 6.2.19. Straight portion of the conveyor chain, supported by the set of supporting rollers, is driven by the dogs of the drive chain.



1-drive sprocket, 2-tail sprocket, 3-drive chain, 4-driving dogs, 5-back-up bars, 6-support rollers.

Fig. 6.2.19 Crawler drive

(*e*) **Frame structures:** Frame structures supporting the entire conveyor, chain guide rails or troughs, skirt plates are the other components which are common to most type of chain conveyors.

Frame structures are generally custom designed to suit the location and application. The frames may be floor supported, set below the floor, be hung from the roof or bracket from wall / columns, as required by the different types of conveyor.

Different types of chain conveyors may need other specific components and structural arrangements, which have been mentioned in the discourse on the individual type of conveyor.

6.2.5 Aspects of Chain Conveyor Design

(*a*) **Dynamic Phenomena in Chain Conveyors :** In a chain-sprocket drive, engagement of sprocket to chain being discontinuous in nature, the linear velocity of the chain between two successive engagements with sprocket teeth becomes non-uniform. The reason for this is that the chain does not wrap around the driving sprocket on the pitch circle, but traces a pitch polygon, a phenomenon known as *chordal action*. The period of irregularity is equal to the time taken by the sprocket between two successive engagements (*i.e.* time taken by the sprocket to rotate by one pitch), $t_0 = \dfrac{2\pi}{\omega z}$

where , ω = angular velocity = $\dfrac{2\pi n}{60}$

z = number of sprocket teeth

n = rpm of sprocket

Fig. 6.2.20 shows a chain running on a sprocket. In the position pictured in the diagram, the pull is transmitted by the tooth 1, is in mesh with chain link 1′. As the sprocket rotates clockwise, tooth 2 engages with link 2′, then tooth 3 with link 3′ etc.

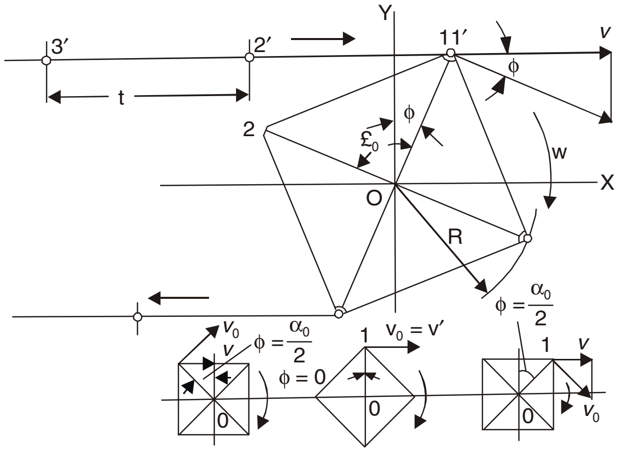


Fig. 6.2.20. Analysis of chain movement over sprocket

At constant angular velocity of the sprocket, the peripheral speed of the tooth remains constant ie $v_0 = \omega R$ while the chain translatory speed in the direction of the chain movement will be $v = v_0 \cos \phi = \omega R \cos \phi$, where ϕ is the variable angle formed by the contacting tooth radius O1 with vertical axis OY.

Thus the chain speed v during period t_0 required by the sprocket to turn by one pitch α_0, is represented by section of cosine curve, as shown in Fig 6.2.21.

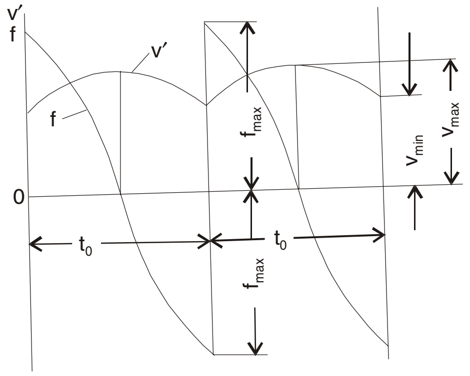


Fig. 6.2.21. Diagram of chain speed and acceleration

The chain speed reaches its peak value, $v_{max} = v_0 = \omega R$ when $\varphi = 0$, and its minimum when

$$\varphi = -\frac{\alpha_0}{2} \text{ and } \varphi = \frac{\alpha_0}{2}.$$

The acceleration 'f ' of the chain can be determined as the first derivative of the speed with time, or as the projection of centripetal acceleration $f_0 = R\omega^2$ to the direction of chain travel (tangential acceleration being zero). $f = f_0 \sin \varphi = R\omega^2 \sin \varphi$.

Acceleration diagram is also shown in Fig. 6.2.21. It becomes zero when $\varphi = 0$ and reaches its peak value at

$$\varphi = -\frac{\alpha_0}{2} \text{ and } \frac{\alpha_0}{2}. \quad \therefore \quad f_{max} = \pm R\omega^2 \sin \frac{\alpha_0}{2}.$$

Fig. 6.2.21 also shows that at the point of next sprocket 2 engaging the chain, the acceleration changes abruptly from $-f_{max}$ to $+f_{max}$. If 'M' is the reduced mass of the moving parts of the conveying machine and the load, the inertial force at the moment is $2Mf_{max}$. As the force is applied instantaneously, the dynamic inertial force $F_A = 2 \times 2Mf_{max} = 4Mf_{max}$. This inertial force is to be added to the static tight side tension of the chain to obtain the total theoretical tensile effort, the chain is subjected to.

To keep the variation of tension in the chain to a tolerable limit, the speed of the chain conveyor is kept low. Chordal action of chain links when going round the sprocket also imparts a pulsating motion at right angles to direction of chain, to the conveyor chain. This is more pronounced when sprockets with fewer teeth i.e. increased pitch angle α_0 is used. When conveyor centre distance is short, the pulsation is less noticeable.

(*b*) **Chain Pull and Conveyor Horsepower:** The entire weight of materials and the moving parts of a chain conveyor is pulled by the chain or chains employed. It is, therefore, important to calculate the tension of each chain and select the chain with adequate strength to work safely under the working pull, the chain will be subjected to.

The tension or pull necessary to move conveyor chains is sum total of live load *i.e.* the force required for conveying the material plus the dead load and the resistance to the movement of conveyor parts.

Thus, the total chain pull = Force required to raise material up an inclination + Force required to raise conveyor parts up the inclination + Frictional resistance to the movement of loaded conveyor parts in the carrying run + Frictional resistance of empty conveyor parts during return run.

If the various factors are represented with following notations:

T = Total chain pull, Newton

f = Coefficient of friction of moving chain on runways.

L = Length of conveyor centers, m.

H = Horizontal projection of the conveyor, m.

V = Vertical projection of the conveyor, m.

m_G = Mass of load per meter of conveyor, kg/m.

m_C = Moving mass of conveyor per meter, kg/m.

S = Velocity of conveyor, m/min.

Then,

$$T = m_G.g.V + m_c.g.V + m_Gg.fH + 2m_c.g.f.H - m_c.g.V$$
$$= m_G.g(V + f.H) + m_c.g.(V+f.H) + m_c.g.(f.H - V) \quad ...(i)$$

If V in the quantity m_cg (fH – V) exceeds fH, the conveyor return run will move down the inclination owing to the gravitational pull overcoming the frictional resistance of the return run. In this condition the term $m_cg(fH - V)$ is taken to be zero. If fH > V, then this additional pull is necessary to pull the return part of the conveyor.

If 'C' is capacity of the conveyor in tonnes /hr, we can write $m_G = 16.66\frac{C}{S}$, kg/m

Thus eqn. (*i*) may be rewritten as,

$$T = 16.66 \times \frac{C.g}{S}(V + f.H) + m_c.g(V + f.H) + mc.g(f.H - V) \quad ...(ii)$$

The frictional coefficient 'f' depends whether the chain is sliding or rolling. For non-roller flat linked chain, sliding on steel track or trough, the value of 'f' may be taken as 0.2 and 0.33 for well lubricated and dry run respectively. The rolling friction depends on roller size, condition of track etc. For 50mm diameter it is 0.15 while for 150mm it can be taken as 0.06.

When the load on conveyor passes through stationary skirt plates as in a deep apron or pan conveyor, additional frictional pull due to rubbing, must be added to the chain pull 'T' obtained from above formula. If this pull is "Y" in Newton per meter length of skirt plate, then

$$Y \cong 2.3h^2/k,$$

where h = height of materials rubbing in skirt in cm,

and k is a factor depending on material as given in the Table.

Materials	K
Iron ore, crushed	4
Cement clinker	8
Gravel or stone	8
Coal, fines and lumps mixed	30
Chips, pulpwood	48
Sugar cane	80

The basic power for driving the conveyor is calculated by the formula:

$$P = \frac{1.15 \times S \times [\text{Total chain pull} - m_{c.g}\ (v - fH)]}{1000 \times 60},\text{kw}$$

This formula takes care of 10% headshaft and 5% tailshaft friction. However, for actual motor power calculation, the efficiency of the drive system consisting of gearbox, pulley and belt, coupling etc. have to be considered.

The drive is generally applied to the delivery end. The required power is practically same if drive is applied to the tail end. The advantage of a head-end drive is that, only the active side of the chain is under maximum load. A tail end drive will put the entire length of the chain under this maximum tension and this causes greater friction at the head shaft and greater wear of the chain.

6.3 HAULAGE CONVEYORS

6.3.1 Definition/Characteristics

Haulage conveyor is a special group of chain conveyors. As the name implies, the material is dragged, pushed or towed by means of a chain or chains, making use of flights or surfaces which are parts of the chain themselves. The weight of the material is generally carried by stationary troughs, surfaces, or wheeled trucks/dollies on rails/floor. In certain designs, the chain may be replaced by cables. These conveyors are run at slow speed (15 to 60 mpm) and being built for heavy duty need little maintenance. However, the chains undergo wear under heavy tension and work in one direction only.

6.3.2 Types of Haulage Conveyors

Haulage conveyors are generally classified into drag conveyor, flight conveyor and tow conveyor.

(*a*) **Drag chain conveyor:** It is a conveyor having one or more endless chains, which slides in a track or tracks, resting at the bottom of a trough, and materials resting directly on the chain are carried by the chain links. The layers of materials above the chain level are moved by the cohesiveness with the material below.

The troughs or sliding base surface may be made of steel, concrete or even wood. The chain tracks are often made from steel channels.

These conveyors generally work in the same horizontal plane with little inclines, for movement of bulk materials, hot materials, abrasive materials, logs/timber, packages etc. Even cars may be moved in a car assembly line by putting two wheels on one chain.

A few of the typical designs of drag chain conveyors are mentioned below:

(*i*) *Multiple strands drag chain conveyor :* The multiple parallel chains may be spaced widely upto a few meters apart and may be used to transfer long objects like lumber, hot steel sections etc. placed across multiple strands. This type of conveyor is widely used in transferring hot steel sections in hot bar and section rolling mills. All chains move at same speed.

(*ii*) *Pusher-bar conveyor :* Consists of two strands of sliding endless chains connected by spaced crossbars. Unit loads resting on a slider bed are pushed by these cross bars. Fig. 6.3.1 is a schematic view of a pusher-bar drag conveyor.

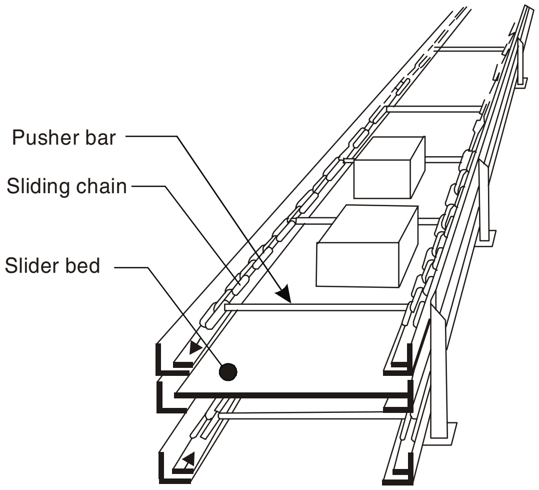


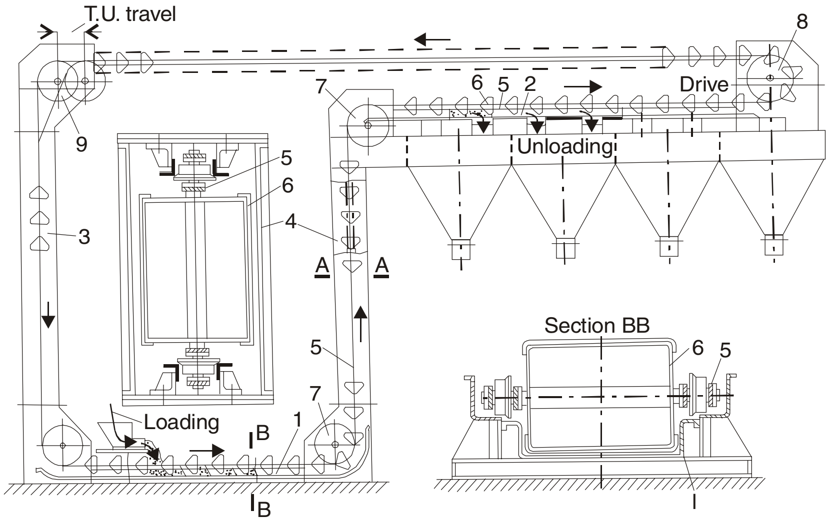
Fig. 6.3.1. Schematic view of a pusher-bar drag conveyor

(*iii*) *Wide-chain drag conveyor :* It consists of a single strand large width chain which can move a bed of bulk materials along a troughed path. The space between one set of link and bottom sliding plate form individual pockets for the bulk materials. These conveyors are widely used for handling refuse materials like clinkers, ashes, sawdust, and also bulky materials like wood chips, coal etc.

(*b*) **Flight Conveyor:** A conveyor comprising of one or more endless strands of chain with spaced transverse flights or scrapers attached which push granular bulk material along a shaped trough. The material can be loaded at any point into the trough and discharge can also be effected at various points through openings in the trough floor, closed by sliding gates. Both upper and lower strand may be used for transporting materials in opposite directions. These conveyors generally work at speed range of 30 to 50 mpm to handle free flowing materials of small to moderate size to move them in both direction. These are used for handling coal, ashes, sand, gravel, ore, wood chips, saw dust, chemicals, grains, cereals, generally for loading bunkers and bins and also used under floor for removal of metal chips/cut pieces.

One flight conveyor can handle two or more materials simultaneously by making two or more material flow troughs/channels side by side and designing the flights to match individual troughs. These conveyors are built rugged for long life and low maintenance.

When a two-chain flight conveyor have flights made in the shape of fixed buckets, such a flight conveyor is called **gravity discharge bucket conveyor**, also called **V-bucket conveyor**. These can fill up buckets in the horizontal section, move through vertical sections carrying bulk material and then discharge the material in another horizontal trough section at a higher level for filling up of bins etc. Scheme of such a V-bucket flight conveyor is shown in Fig. 6.3.2.



1,2- horizontal trough; 3,4-casing of vertical sections; 5-chain; 6-buckets; 7-turning sprockets; 8-driving sprocket; 9-take-up sprocket.

Fig. 6.3.2. V-bucket flight conveyor

(*c*) **Tow Conveyor:** This consists of a single strand endless chain which tows floor/ track mounted trucks, dollies or cars on which the materials are placed. Tow conveyors are generally used for handling of unit loads like boxes, barrels, crates, cartons, in the warehouse, in assembly lines and for intra-plant movement. Though the tow conveyors follow a fixed path, the carts can be detached easily from the conveyor and moved to other points.

Tow conveyors are classified into following three groups.

(*i*) *Overhead tow conveyor :* This type has already been described as ''*load towing trolley conveyor*'' under ''*trolley conveyor*'' in section 6.2.3(e).

(*ii*) *Flush-floor tow conveyor :* In this conveyor the materials are transported on rail bound carts, moved by one strand of endless chain moving in a fixed guide flushed with the floor. The carts are connected to the conveyor chain by removable link like chain with hook, removable dog and rigid drawbar which engage the trolleys and push them.

(*iii*) *Underfloor tow conveyor :* In this conveyor an endless chain is installed below floor level either supported by trolleys or sliding in a channel or angle track. The floor mounted carts are connected to the conveyor by retractable pin through a narrow slot in the floor, to pick up connecting device on the chain.

Underfloor tow conveyors work at higher speeds than overhead ones. These are widely used in variety of applications including moving automobiles, wash racks, in manufacturing assembly lines, warehouses, freight handling terminals etc.

The major limitations are track clogging with refuse and difficult access to maintenance. These conveyors have to be planned before constructing the new building where they have to be installed. Fig. 6.3.3 shows schematic arrangement of an underfloor tow conveyor.

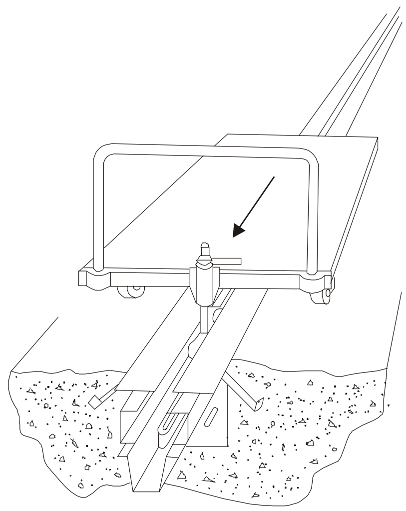


Fig. 6.3.3. Underfloor tow conveyor

6.4 CABLE CONVEYORS

6.4.1 Definition, Description and General Characteristics

These conveyors form a distinct group of materials handling equipment to transport people and bulk materials in load carrying buckets, using overhead moving cables and/or wire ropes and are composed of one or more spans from the loading point to the discharge point/points covering long distances upto several kilometers. These conveyors are also known as **ropeways** or **aerial tramways**.

The characteristic features and advantages of these conveyors are:

(*i*) As loads are moved at a substantial height from the ground, shortest route between the terminals can be followed independent of the ground contour.

(*ii*) Wide varieties of materials including human passengers may be transported. These are commonly used for carrying minerals from mines to their processing stations.

(*iii*) Cost of operation is comparatively less than other transportation systems.

(*iv*) Materials are moved between distantly located points without the need of re-handling.

(*v*) Materials can be automatically discharged at the desired point, hence eliminating use of an auxiliary discharging system.

6.4.2 Classification

From design point of view there are primarily two distinct systems of aerial tramways/ropeways, the **bicable** and the **monocable** system.

In the bicable system one or more (commonly two) stationary high-tensioned track cables are used over which carriers are placed from which hang the load carrying buckets. For a continuous bicable system, two stationary cables are needed. The carriers are pulled by one endless traction or pulling rope moving continuously in one direction. The loaded carriers move from the loading terminal to the discharge terminal, while the empty ones move in the opposite direction. For reversible bicable system one track cable is sufficient.

In the monocable tramways system, one endless moving wirerope is used for supporting as well as moving the carriers.

Monorail Tramways is another type of cable conveyor in which the load carriers run on suspended rails, and moved by a moving wire rope. This is essentially a trolley chain conveyor where the traction chain is replaced by a wire rope. These are used for towing load between much shorter distances.

6.4.3 Components of a Cable Conveyor

A cable conveyor basically consists of (*i*) one or more cables/wireropes, one of which is driven which pulls the load; (*ii*) a number of load carrying buckets or carriers which are hung through hangers from wheeled (2-wheel or 4-wheel type) carriages; (*iii*) loading and discharge terminals; (*iv*) intermediate towers for supporting the cable/rope and (*v*) drive arrangement.

Selection of size of traction rope or carriage supporting static rope is based on the estimated maximum tension in the rope. The construction of rope is selected such that it provides a smooth wearing surface for the carriage wheels, provides better gripping of the carrier with the rope and whose outer layers of wires do not unlay and get loosened. 6×7 or 6×19 lang lay construction with hemp center is customarily used. Constructional details and breaking strengths, for steel wire ropes for general engineering purposes, is given in Indian Standard IS:2266:1989.

The carriages are generally of 2-wheel or 4-wheel type, the later being used for heavier load. The rigid hangers are connected with traction rope through grips. These grips may be of (*i*) *compression type* which operate on toggle principle, (*ii*) *screw type* or (*iii*) *weight-operated* type which depends on the weight of the loaded carriers for its gripping capacity. The carriers are generally buckets of different types to suit specific nature of the load. The usual bucket designs are: (*i*) trunion mounted *rotary dump* buckets which may be overturned easily for discharging, (*ii*) *end dump buckets* for discharging load from one end and (*iii*) *bottom dump buckets* for discharging load from the bottom. Fig. 6.4.1 shows a monocable carrier.

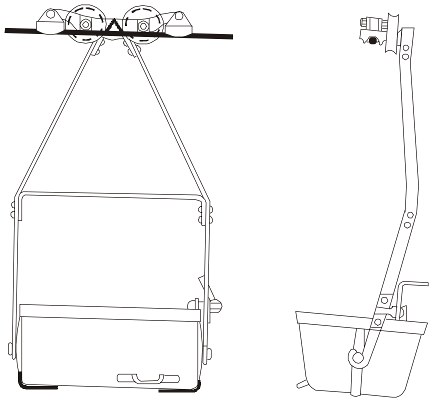


Fig. 6.4.1. Monocable carrier with rope grip, of the rotary dump bucket type

Loading or discharge terminals are structural platforms built at the height of the cables/ropes, where arrangements are provided for detaching and attaching the carrier from and to the traction rope by operating the grips, and taking them onto a loop of rail on the platform. At the loading terminal the empty buckets are loaded automatically from storage bins through proper feeders, while at the unloading terminal the buckets are emptied. Rope tensioning arrangement is provided at the discharge terminal while rope driving system is placed at the loading terminal. Fig. 6.4.2 shows the layout of a typical monocable discharge terminal.

Cable conveyor drive consists of a suitable power unit coupled to a speed reduction gear box and the driving sheave. The diameter of the driving sheave depends on the rope size and pressure of the rope on the sheave groove. Driving sheave may be rubber-lined. Grip sheaves with toggle jaws spaced around a segmented rim have been used for increasing driving power of the sheaves.

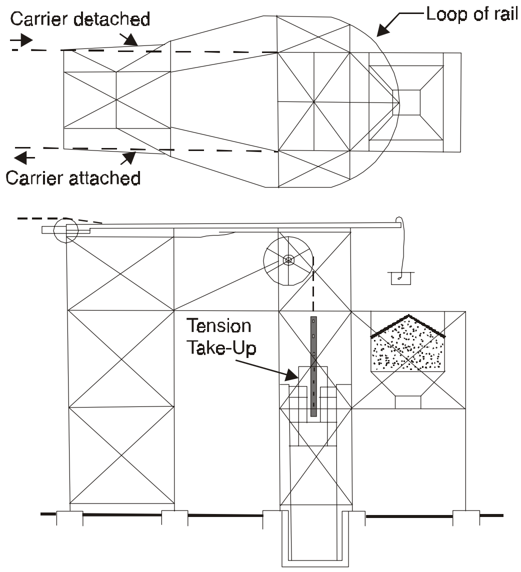


Fig. 6.4.2. Typical monocable discharge terminal

6.5 BUCKET CONVEYORS

These conveyors convey bulk loads in bucket shaped vessels which are attached to a system of moving chains or belt. These are generally classified as (*a*) Gravity discharge bucket conveyor, (*b*) pivoted bucket conveyor and (*c*) bucket elevator.

Gravity discharge bucket conveyor also called V-bucket conveyor has been discussed under Flight Conveyor in section 6.3.2(*b*) and pivoted bucket conveyor has been discussed under Suspended Tray Conveyor in section 6.2.3 (g).

Bucket elevators are used for conveying bulk materials from a lower level to a higher level, and as such has been included under Elevators in Chapter 8.0.

6.6 ROLLER CONVEYORS

6.6.1 Definition and Characteristics

A roller conveyor supports unit type of load on a series of rollers, mounted on bearings, resting at fixed spacings on two side frames which are fixed to stands or trestles placed on floor at certain intervals. A roller conveyor essentially coveys unit loads with at least one rigid, near flat surface to touch and maintain stable equilibrium on the rollers, like ingots, plates, rolled stock, pipes, logs, boxes, crates, moulding boxes etc. The spacing of rollers depend on the size of the unit loads to be carried, such that the load is carried at least by two rollers at any point of time.

Roller conveyors are classified into two groups according to the principle of conveying action. These are:

1. Unpowered or Idle Roller Conveyor.
2. Powered or Live Roller Conveyor.

In an unpowered roller conveyor, the rollers are not driven or powered from an external source. The loads roll over the series of rollers either by manual push or push from an endless moving chain or rope fitted with pusher dogs, rods or clamps. Generally these conveyors operate at horizontal plane, but at times a gentle slope is given to these coveyors to aid motion of the loads. An inclination of 1.5% to 3% ensures that the load will roll by gravity. Such conveyors are termed **"gravity roller conveyor"**.

In a powered roller conveyor, all or a selected number of rollers are driven by one or a number of motors depending on the selected drive arrangement. The driven rollers transmit motion to the loads by friction. The powered roller conveyors may be installed at a slightly inclined position, up to 10° up or up to 17° down. The load can be moved in either directions by changing the direction of rotation of the rollers, where these are called reversing conveyors.

Roller conveyors are used for conveying almost any unit load with rigid riding surface that can move on two or more rollers. These are particularly used between machines, buildings, in warehousing as storage racks, docks, foundries, rolling mill plants, manufacturing, assembly and packaging industry. They are also used for storage between work stations and as segment of composite handling system.

However, the limitations of rollers conveyors are that they can be best used for objects with rigid flat surfaces, and for movement to relatively short distances. Needs side guards to retain the loads from falling off. Gravity roller conveyors have the risk of accelerating loads.

6.6.2 Types of Roller Conveyor

(*a*) **Unpowered Roller Conveyor**

Introduction : An unpowered roller conveyor consists of series of rollers, the frame on which the rollers are placed and the stands also called the *trestles*, on which the framework rests. Because of simplicity of design, competitive cost and trouble free operation, these conveyors are used extensively in handling unit loads in workshops or process plants to convey articles from one working station to another. Unpowered roller conveyors are often used as a storing platform and as such are often termed as **roller table**. These are also used in stores as storing racks and in loading bays for loading / unloading materials from carriages. A gentle slope may be provided in the conveyor to aid movement of the loads on idle rollers. These **gravity roller conveyors** are used to convey load in one direction only. The conveyors can have a curved section to change direction. Material movement between two levels may be done by an inclined or a spirally formed gravity roller conveyor. The spiral form increases the length of the conveyor and thereby controls the velocity of the articles moving down the conveyor. A typical unpowered roller conveyor is shown in Fig. 6.6.1.

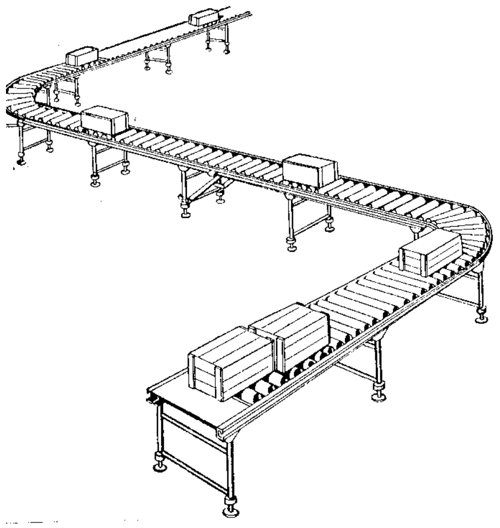


Fig. 6.6.1. General view of an unpowered roller conveyor

Parts of unpowered roller conveyor

(*i*) *Rollers:* Cylindrical rollers are generally used which are made from ERW steel pipes with cast or fabricated end flanges to accommodate the antifriction bearings (usually ball bearings). The through axles are stationary and roller barrels can rotate freely. These rollers are called idler rollers.

For conveying cylindrical objects (drums, pipes, round steel bars etc.), double tapered rollers or wheel rollers are used (Fig. 6.6.2).

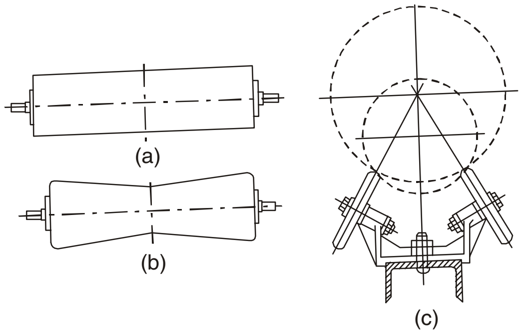


Fig. 6.6.2. Types of unpowered conveyor rollers
(*a*) cylindrical; (*b*) double tapered; (*c*) wheel

The diameter of the rollers depend on the diameter of standard steel pipes available, and vary from about 20 mm to max 155 mm. Heavier the load to be conveyed, larger diameter and heavier wall thickness of the rollers are chosen. Typical sizes of some of the rollers and their weight carrying capacities are given in the following table:

Roller Parameters	**Type of Roller**		
	Medium	**Heavy**	**Extra Heavy**
Roller diameter, mm	73	105	155
Maximum load per roller, kg.	300	600	1200
Axle dia at the journal, mm	20	30	45

Roller pitch depends on the length and weight of the load handled. The unit load should be supported at least by two rollers, thus the maximum pitch should be $\leq \frac{1}{2}$ of the load length. For goods vulnerable to jerks/ shaking, roller pitch equal to $\frac{1}{4}$ to $\frac{1}{5}$ of length of load to be considered.

(*ii*) *Frame:* Frame is that part of the conveyor on which the roller axles rest and are fixed to. The conveyor frame is fabricated from angle or channel sections. The roller axles are held in slots cut in the flanges of the frame. The axles are flat machined at the ends so that the axles do not rotate in the slots. Axial movement of the axles are prevented by using split pins or lock plates. For heavy rollers, the axles may be fixed on the frame by clamps. Typical idle rollers with bearing fittings and their attachment to the frame is shown in Fig. 6.6.3.

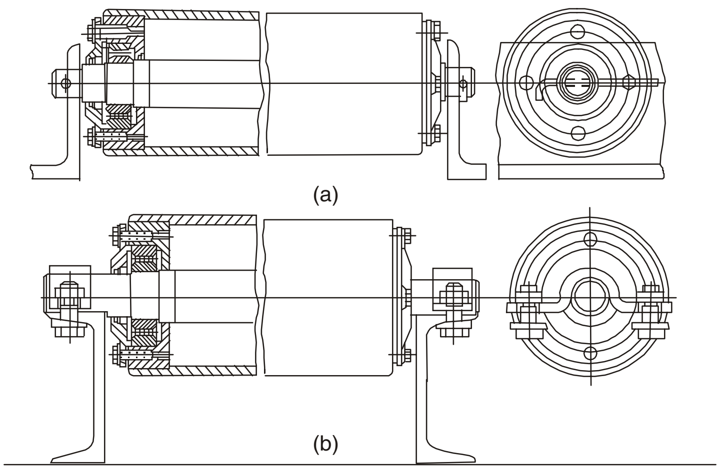


Fig. 6.6.3. Rollers of (*a*) heavy and (*b*) extra heavy type

Side guards may be provided along two edges of the frame to prevent movement of the loads beyond the roller span. Side guards are particularly necessary at the curved sections of a conveyor.

(*iii*) **Stands or Trestles:** Stands or trestles support the conveyor frames with roller assemblies, from the ground. Stands are generally fabricated from pipes or structural sections, with provision for grouting on the floor. Height of stands are chosen to keep the articles at a convenient level on the conveyor.

Small **portable conveyors** often have telescoping legs for the stands, such that the inclination of the conveyors can be suitably adjusted *in situ.*

Special designs/features

A number of features can be incorporated in an unpowered conveyor to satisfy different functional requirements. Some of these are described below.

(*i*) **Double-row roller conveyor:** This design is used to convey wide and heavy loads. In place of one long and proportionately large diameter roller, two smaller diameter rollers with lengths less than half of the larger roller are used. To support the inner ends of the pair of rollers, additional support frame is required. This design works out to be cheaper than the same width conventional single row conveyor with longer and larger rollers.

(*ii*) **Curved sections:** These are used for changing direction of the conveyor in the horizontal plane. In this section rollers are arranged radially. Two or more number of cylindrical rollers are used in place of one roller to reduce sliding action of the load on rollers (see Fig. 6.6.4). Minimum sliding action of the load on rollers can be achieved by using single tapered roller (V-roller), but as these are to be made from solid casting or forged section, are costly and seldom used.

(*iii*) **Switches:** Devices used in a roller conveyor to change the normal direction of the load or divert the load from the conveyor are called switches.

Different types of switches are employed, some of which are as follows:

A *turn-table* (see Fig. 6.6.4) is used for transferring a load from one roller conveyor to a sliding runway or to a perpendicular roller conveyor. This consists of a small length (equal or slightly smaller than the width of the main conveyor) of roller conveyor mounted on a base frame which is fixed on a vertical shaft mounted on bearings. Once the load comes on the turn-table, the turn table can be rotated (manually or by proper mechanism) to the desired angle and the load can be rolled over to the desired runway.

A *hinged section* (Fig. 6.6.4) is a small section of the conveyor which is hinged at one end with the frame/stand of the main conveyor, and can be lifted up to make a passage way through the conveyor line.

An array of *wheel rollers* on *swiveling heads* (castor wheel) are used independently or as a part of a roller conveyor where it is necessary to move the load in many directions.

Deflector is a flat or angle like section placed longitudinally over the conveyor making an angle (may be adjustable or fixed) with the conveyor axis. This acts as an obstruction to the movement of the load and deflects them to one side of the conveyor axis. *Manipulator* consists of one pair of deflectors to bring the loads at the middle section of the conveyor axis. Deflector or manipulator is used on idle conveyors and more commonly with powered roller conveyors with chain/rope pushing facility.

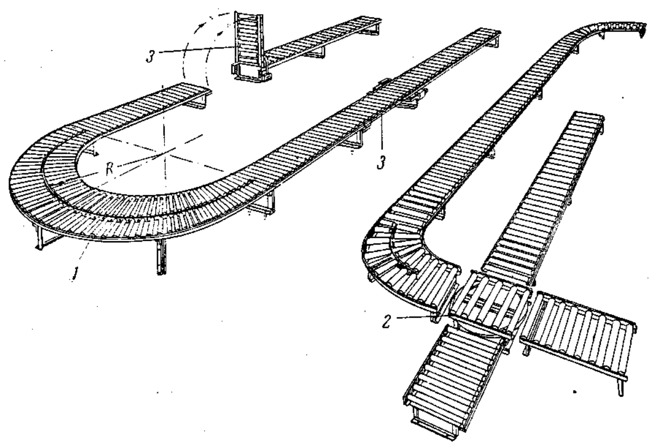


Fig. 6.6.4. Unpowered roller conveyors with curved section1, turn-table 2, hinged section 3

(*iv*) **Stops:** These are placed at the end of the conveyor to physically stop the moving loads from falling off the conveyor end. **Disappearing stops** may be placed at desired intermediate points in the path of a roller conveyor to stop the moving articles at such points, if required. The stops are simple flat steel plates fixed on rigid legs or fixed to conveyor structure. Disappearing stops may be moved up or down from the top level of the roller by suitable mechanism.

(*b*) **Powered Roller Conveyor**

Introduction: In a powered roller conveyor, also called *Live Roller Conveyor*, all or a few of the rollers are driven by one or multiple motors through associated transmission system.

The loads on the roller conveyor are moved by the frictional force caused between the loads and the driven rollers supporting the loads.

Powered roller conveyors are intensively used in heavy process plants like rolling mills to feed heavy and at times hot metal to or take delivery from the mill and to various other process equipment.

The roller conveyors can be *reversing* type to suit the process or may be Non-reversing type which transport materials within the shop.

Parts of powered roller conveyors

(*i*) **Rollers:** The rollers of a powered conveyor is fundamentally different from those of an unpowered conveyor in that the barrel and the shaft portion are integral so that they can be driven by connecting power to their shaft ends. The integral shafts are mounted on bearings housed in the frames at two sides. These are termed as **driven rollers**.

The driven rollers are generally subjected to considerable impact load (specially the reversing type processing conveyors) and hence they are made stronger.

The rollers can be made from solid steel forgings or castings or can be fabricated from heavy section of tubes and solid shafts, machined all over for proper static and dynamic balancing. The diameters can be varying between 400 to 600 mm for roller tables used in heavy slab or blooming mills, down to 250 to 350 mm for general duty transporting conveyors.

Roller pitch is so selected that the load is supported by at least two driven rollers. To prevent sagging of the load between two driven rollers, non powered (idle) rollers may be introduced between two driven rollers.

(*ii*) **Frames:** The rollers are supported at their journals on two set of frames at two ends. The frames are connected by heavy tie rods to make a composite frame structure suitable for grouting the conveyor frame on its foundation. For a heavy duty conveyor, the framework is usually made from cast steel, and for a lighter duty conveyor, the frames may be fabricated from rolled steel plates and sections. Design of the frames largely depend on the drive system employed.

(*iii*) **Drive arrangement:** Major classification of powered roller conveyor is based on the type of drive arrangement employed.

When one motor drives more than one or all the driven rollers, it is called **Group** or **Multiple drive**. In group drive, generally only one motor with suitable transmission arrangement is used to drive all the driven rollers. For a long conveyor, or from other considerations, more than one motor may be used, each driving a group of rollers in different sections of the conveyor. The transmission of power from the motor to the rollers vary widely depending on use. In a heavy duty non-reversing conveyor, bevel gear transmission arrangement may be used. The motor, through a gear box drives a shaft placed along the length of the drive side of the conveyor. Power to all the rollers are through set of two bevel gears as shown in Fig. 6.6.5. The drive shaft with supporting bearings and the bevel gears are housed in the box frame, and partially immersed in oil for lubrication. In an alternative design the transmission of power may come to one roller, and the other driven rollers may be connected to this driven roller by series of sprockets and chains.

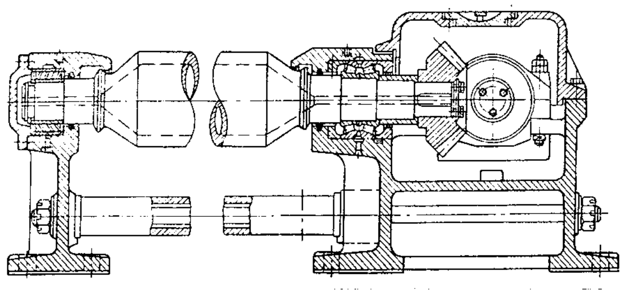


Fig. 6.6.5. Roller conveyor with multiple drive through bevel gears

In a light duty powered roller conveyor, the rollers may be driven by one endless flat belt driven below the rollers, and supported by idle rollers such that the belt touches all the rollers and transmit power to them by friction. This is, unlike others, not a positive drive.

When each of the driven rollers are driven by an individual motor, it is called **individual drive**. These motors may be high speed motors transmitting motion through a reducing gear (Fig. 6.6.6). Alternatively, specially designed slow speed hollow rotor shaft motors are used which are directly coupled to the roller shaft. With the availability of better electrical control systems, individually driven roller conveyors are getting more popular particularly for reversing duty.

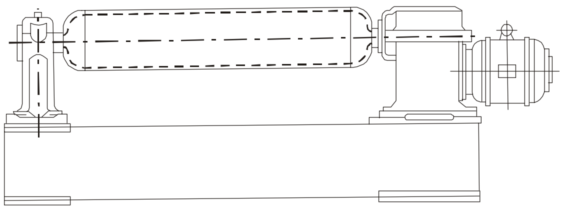


Fig. 6.6.6. Individual drive from flanged motor coupled to gear box

(*c*) **Portable Roller Conveyor**

It is a short (up to 7 m) section of roller conveyor mounted on legs and at times with wheels. These may be shifted from one place to another and adjusted in height or inclination for loading and unloading of trucks. The portable roller conveyor may be idle or driven. Drive is often through an endless belt described above.

6.6.3 Aspects of Roller Conveyor Design

(*a*) **Unpowered Roller Conveyors**

The major design calculations involved are to determine the force required to overcome the resistance to motion of the loads and the angle of inclination required for a gravity conveyor.

Total resistance to motion is made up of:

(*i*) Resistance to rolling of the load on rollers due to friction.

(*ii*) Frictional resistance in the roller bearings.

(*iii*) Resistance due to sliding of the load on the rollers and force required for imparting kinetic energy to rollers.

(*i*) **Resistance to rolling** of the total load "G" on the rollers is given by

$$F_1 = G.\frac{k}{R} \qquad ...(i)$$

where k = rolling friction factor also called coefficient of rolling resistance, cm

R = roller radius, cm

(*ii*) **Frictional resistance** on roller journals is expressed by

$$F_2 = (G + wn') \frac{\mu r}{R} \qquad ...(ii)$$

Where, w = weight of rotating part of each roller.

n′ = number of rollers supporting total load, and hence in motion.

μ = coefficient of friction at the journal.

r = journal radius.

(*iii*) When a moving load comes over a static roller, it slides over the roller and starts accelerating the roller till the roller attains the surface speed equal to speed of the load. When the load leaves the roller, it starts decelerating and eventually stops until it is accelerated by the next load. This phenomena is shown in Fig. 6.6.7.

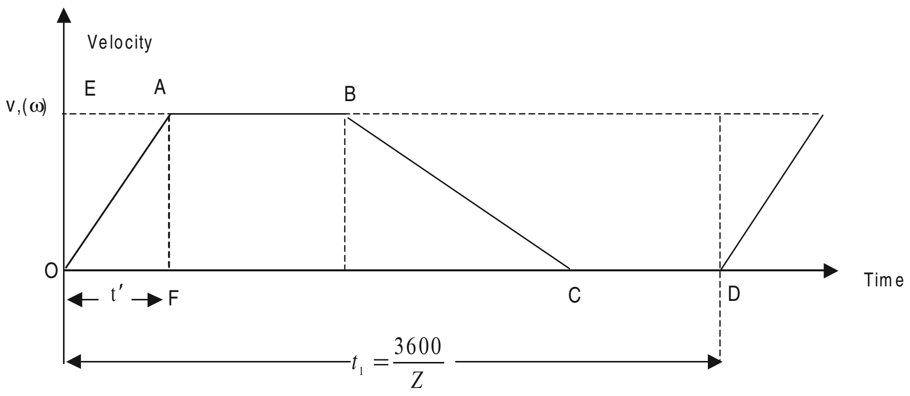


Fig. 6.6.7. Velocity diagram of a roller

O is the point of time when a moving load touches a static roller. Till time t; the load rolls and slides over the roller. The surface or rotational velocity of the roller is under acceleration., expressed by line OA. From A upto B, the load rolls over the roller, and at B it leaves the roller.

If the conveyor is conveying Z pieces of load per hour, then the cycle period will be $t_1 = \dfrac{3600}{Z}$ seconds.

If G′ is part of weight of each load carried by each roller and μ_0 the kinetic coefficient of friction, the frictional sliding force between the load and roller during time t′ is $= G' \mu_0$ and the work done by the load = $G'\mu_0 vt'$ where v linear velocity of the load, and vt′ is the distance moved by the load in time t′, represented by the area OEAF in Fig. 6.6.7.

The distance travelled by any point on the periphery of the roller during this time will be $\dfrac{v}{2}t'$(area OAF), which is also the sliding path. This shows that half of the work done by load is spent in overcoming the friction, and the other half is used in imparting kinetic energy to the roller.

If 'w' is the weight of the rotating part of the roller, then its kinetic energy = $\dfrac{1}{2}\dfrac{w}{g}v^2q$.

Where q is a factor of value between 0.8 to 0.9, because not all the mass of the roller moving parts is on the periphery, and thereby not moving with velocity v.

Therefore, the work done due to sliding and acceleration of one roller is given by

$$2 \times \frac{1}{2}\frac{w}{g}v^2q = \frac{wv^2}{g}q$$

If there are 'n' number of rollers in a total length of 'L', then the total work done in 'n' number of rollers will be = $\dfrac{nwv^2q}{g}$ for moving one load throughout the length of the conveyor. Hence the average resistance to motion on one load due to sliding and acceleration will be given by,

$$F_3' = \frac{nwv^3q}{gL} \quad ...(iii)$$

If there are Z_0 numbers of loads moving simultaneously on the conveyor, then average total resistance due to sliding and acceleration will be,

$$F_3 = \frac{Z_0 nwv^2q}{gL} \quad ...(iv)$$

Therefore, total resistance to motion of the loads, which is the force required to move the loads on a horizontal unpowered conveyor is

$$F = F_1 + F_2 + F_3 = G\frac{k}{R} + (G + wn')\frac{\mu r}{R} + q.\frac{Z_0 nwv^2}{gL} \quad ...(v)$$

We can define the equivalent resistance to motion factor 'f' by an equation, F = Gf.

$$\therefore \qquad f = \frac{F}{G} = \frac{2k}{D} + \left(1 + \frac{wn'}{G}\right)\frac{\mu d}{D} + q\frac{Z_0 nwv^2}{gLG} \quad ...(vi)$$

where, D = roller Diameter = 2R

d = journal diameter = 2r

However, for calculating the minimum inclination angle 'β' of a gravity conveyor, which will allow movement of a load due to gravity only, resistance to only one load need to be considered, which should be overcome by the component of the gravitational force on the load along the inclination of the conveyor. Thus,

$$f = \tan\beta = \frac{F}{G'} = \frac{2k}{D} + \left(1 + \frac{wn''}{G'}\right)\frac{\mu d}{D} + q\,\frac{nwv^2}{gLG'} \qquad ...(vii)$$

where, n″ = number rollers supporting each load = $\frac{n'}{Z_0}$

G′ = weight of each load = $\frac{G}{Z_0}$

Therefore,

$$\frac{n''}{G'} = \frac{\frac{n'}{Z_0}}{\frac{G}{Z_0}} = \frac{n'}{G}$$

and we find expression (*vi*) and (*vii*) are exactly same. This essentially means, that in a gravity roller conveyor, with requisite inclination angle 'β', one or many loads placed on the conveyor will move unaided due to gravity.

(*b*) **Powered Roller Conveyors**

Transport conveyor

The rollers of a group driven transport conveyor are rotated continuously in one direction irrespective of loads being on the conveyor or not.

If the conveying rate is Q tons/hr, 'V' and 'L_h' are vertical and horizontal components of the length 'L' of the conveyor in meters, n= number of rollers and 'w' is weight in kg of rotating parts of each roller and the conveying speed is 'v' m/sec.; then the motor power 'P' in kW will be sum total of power requirements for (*i*) raising the load through the vertical distance, (*ii*) rolling the load on the rollers and (*iii*) rotating the rollers against journal resistance.

Thus,

$$P = \left(\frac{QV}{367} + \frac{QL_h}{367}\left\{\frac{2K}{D} + \frac{\mu d}{D}\right\} + \frac{nwv}{102}\frac{\mu d}{D}\right) \times \frac{1}{\eta}, \text{ kW} \qquad ...(i)$$

where η = efficiency of the drive system.

For a horizontal conveyor, V = 0, and L_h = L, hence

$$P = \left(\frac{QL}{376D}\{2k + \mu d\} + \frac{nwv\,\mu d}{102D}\right)\frac{1}{\eta}, \text{ kW} \qquad ...(ii)$$

If the weight G′ of each load in kgs and number of pieces 'Z' transported per hour is given, then expression (*ii*) takes the following form :

$$P = \left(\frac{G'ZL}{367000D}\{2K + \mu d\} + \frac{nwv\,\mu d}{102\ D}\right)\frac{1}{\eta}, \text{ kW} \qquad ...(iii)$$

If the unit loads are fed uniformly, then the interval between two loads is given by $t = \frac{3600}{Z}$ seconds and time through which each load moves in conveyor is given by $T = \frac{L}{v}$ seconds.

Hence the number of loads moving simultaneously on the conveyor will be $Z_0 = \frac{T}{t} = \frac{ZL}{3600v}$ pieces.

Therefore, the required motor power for a horizontal conveyor will be

$$P = \left(\frac{Z_0 G' v}{102}\left\{\frac{2k}{D} + \frac{\mu d}{D}\right\} + \frac{nw\,\mu dv}{102D}\right)\frac{1}{\eta}, \text{ kW.}$$

$$= \frac{(Z_0 G'\{2k + \mu d\} + nw\,\mu d)v}{102D\eta}, \text{ kW} \quad ...(iv)$$

Reversing conveyor

In a reversing processing conveyor, the direction of rotation of the driven rollers are changed frequently. Consequently this additional inertial forces for accelerating or decelerating the rollers and the load have to be taken into consideration.

The maximum peripheral acceleration, 'a' of the roller is kept within limits, such that the load weighing 'G', moves on rollers without sliding (also called skidding). There will be no sliding when the frictional force between roller and load is more than the inertial force required to accelerate the load. If 'μ_0' is the static coefficient of friction then,

$$G\mu_0 \geq \frac{G}{g} a$$

so that $a_{max} = \mu_0 g$

the corresponding maximum angular acceleration 'α_r' of roller is

$$\alpha_{r\,max} = \frac{a_{max}}{r} = \frac{2a_{max}}{D} = \frac{2\mu_0 g}{D} \quad ...(v)$$

When a driven roller is accelerated, the load it carries is also accelerated, and this load can be considered as a rotating mass at the periphery of the roller being accelerated. This mass is $\frac{G}{g}$.

However, The acceleration of the motor $\alpha_m = i\alpha_r$, where i = transmission ratio.

Thus the inertial torque on the motor shaft

$$T_{im} = \left(I_r n + \frac{G}{g}\frac{D^2}{4}\right)\frac{\alpha_r}{i\eta} + I_m \alpha_m \quad ...(vi)$$

Where, I_r = moment of inertia of each roller.

I_m = moment of inertia of rotational part of motor.

The total torque required at the motor end is sum of inertial torque and static torque required for overcoming the journal friction at rollers and the torque required for rolling of the load over rollers.

Static torque at roller end is given by

$$T_{sr} = (G + nw)\,\mu\,\frac{d}{2} + Gk. \qquad ...(vii)$$

Static torque at motor end will be

$$T_{sm} = \frac{T_{sr}}{i\eta} \qquad ...(viii)$$

So total torque at motor end will be

$$T_m = T_{sm} + T_{im}$$

$$= \left[(G + nw)\frac{\mu d}{2} + Gk + I_r n\alpha_r + \frac{GD^2}{4g}\alpha_r\right]\frac{1}{i\eta} + I_m\alpha_m \qquad ...(ix)$$

The maximum torque of a reversing conveyor drive motor is so chosen that the motor does not stall even if the load does not move, i.e. the rollers can skid under the static load.

The skidding forque T_{skid} is

$$T_{skid} = \left[(G + nw)\frac{\mu d}{2} + G\mu_{st}\frac{D}{2}\right]\frac{1}{i\eta}$$

6.7 SCREW CONVEYORS

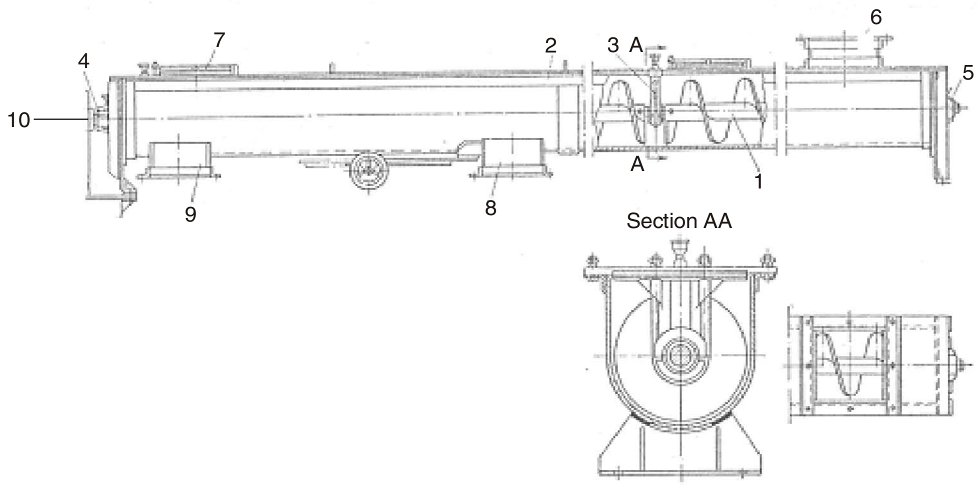
6.7.1 Definition, Characteristics and Use

A screw conveyor consists of a continuous or interrupted helical screw fastened to a shaft which is rotated in a U-shaped trough to push fine grained bulk material through the trough. The bulk material slides along the trough by the same principle a nut prevented from rotating would move in a rotating screw. The load is prevented from rotating with screw by the weight of the material and by the friction of the material against the wall of the trough.

A screw conveyor is suitable for any pulverized or granular non viscous material, and even at high temperature. The conveyor is particularly suitable for mixing or blending more than one materials during transportation, and also for controlling feed rate of materials in a processing plant. Abrasion and consequently certain amount of degradation of the material is unavoidable, hence it is not suitable for brittle and high abrasive materials. It is also not suitable for large-lumped, packing or sticking materials.

6.7.2 Descriptive Specifications

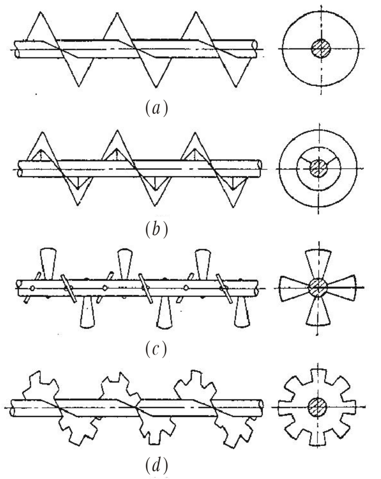
A typical screw conveyor is shown in Fig. 6.7.1. The screw shaft, if short (up to 5 meters), is supported at two ends. But for longer shafts (upto 40 to 50 m), they are supported by bearing hangers, at intermediate points. The shaft may be solid or hollow. Hollow shafts are lighter and can be easily joined to make a long shaft. The screw shaft is driven at one end, and the design may permit discharge of material from the bottom or one end. Opposite handed screw at two sides will cause the center discharge. The U-shaped fabricated trough are generally covered at the top to avoid particulate pollution. The bottom portion of the trough is of circular cross section matching the diameter of the screw. Generally a radial gap of 10 mm to 20 mm is kept between the screw and the trough, depending on size of the screw.

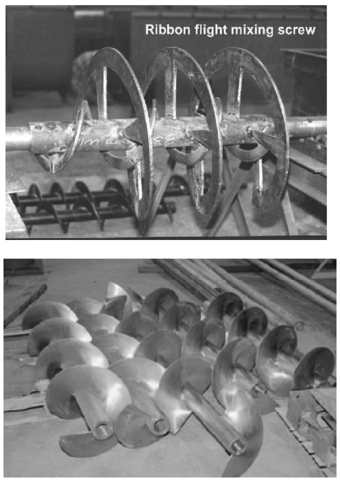


1-shaft with screw; 2-trough; 3-Intermediate hanger bearings; 4-front bearings; 5-terminal bearing; 6-feed hopper; 7-sight glass; 8-Intermediate discharge spout with gate; 9-terminal discharge hopper (open); 10-drive system (motor, gear box and coupings).

Fig. 6.7.1. Arrangement of a screw conveyor

Screws of different constructional design and style are used, which are shown in Fig. 6.7.2. Continuous screws are generally made from 4 to 8 mm sheet steel circular section with a hole corresponding to the size of the shaft. One radial slit is made in this section, and then formed into one pitch of the screw. The section is welded to the shaft and welded or riveted to each other to form the entire length of the screw. The screw may also be cast integral with the shaft. The paddle type flights consist of cast straight or curved segments fixed to the shaft. A ribbon screw is fixed to the shaft by means of radial rods.





(*a*) solid, continuous; (*b*) ribbon; (*c*) paddle-flight; (*d*) cut-flight

Photographs of different types of screw

Fig. 6.7.2. Types of screw used in screw conveyor

The drive unit comprises of an electrical motor, gear box and couplings.

Material is fed through the feed hopper fixed on the trough cover. A number of discharge sprouts with rack gears for closing and opening as required, are provided.

Screw conveyors are generally operated horizontally or at a small inclination (10° to 20°). However, there are special designs where the load is moved vertically up or at a small angle to vertical. These are called vertical screw conveyors.

6.7.3 Aspects of Screw Conveyor Design

(*a*) **Recommended Dimension of a Screw Conveyor:** The dimensions of principal components of a screw conveyor are nominal diameter of the helical screw, pitch of the screw, diameter of screw shaft, width of trough determining the gap between trough and screw, trough height from center of screw shaft, thickness of trough material and nominal thickness of screw flights.

Indian standard specification IS:5563:1985 has specified the standard dimensions for all above components. The recommended dimensions as per above IS is given in Table 6.7.1. The notations used in the table are shown in Fig. 6.7.3.

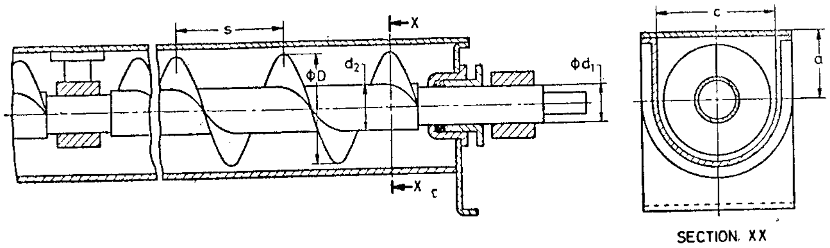


Fig. 6.7.3. Explanatory sketch for table 6.7.1.

Table 6.7.1, however, does not include the standard values of screw pitches. There are given below in mm.

80	100	125	160	200	250	315	400	500	600

Value of screw pitch ‘S’ generally varies between 0.8 to 1.0 time diameter 'D' of the screw. Screw pitch equal to the screw diameter is commonly used.

Table 6.7.1. Recommended Dimensions of Screw Conveyors

Nominal size D	Trough Height from Centre of Screw Shaft to Upper Edge of the Trough (a)	Trough Width C	Thickness of Trough			Tubular Shaft d_2) × Thickness*	Outside Diameter of Solid Shaft	Coupling Shaft Diameter	Nominal Thickness of Helical Screws					
									Segmental root			Continuous root		
			Heavy Duty	Medium Duty	Light Duty				Heavy	Medium	Light	Heavy	Medium	Light
100	63	120	----	2.0	1.6	33.7 × 2.5	30	25	----	3.15	2.0	----	5.0	3.15
125	75	145	----	2.0	1.6	33.7 × 2.5	30	25	----	3.15	2.0	----	5.0	3.15
160	90	180	5.0	3.15	1.6	42.4 × 2.5	35	40	5.0	3.15	2.0	7.0	5.0	3.15
200	112	220	5.0	3.15	2.0	48.3 × 3.5	40	40	5.0	3.15	2.0	7.5	5.0	3.15
250	140	270	5.0	3.15	2.0	60.3 × 4.0	50	50	6.0	5.0	3.15	10.0	7.0	5.0
315	180	335	5.0	3.15	----	76.1 × 5.0	60	50	7.0	5.0	3.15	10.0	7.0	5.0
400	224	420	5.0	3.15	----	76.1 × 5.0	60	75	8.0	6.0	5.0	12.0	10.0	7.0
400	224	420	5.0	3.15	----	88.9 × 5.0	70	75	8.0	6.0	5.0	12.0	10.0	7.0
500	280	530	5.0	3.15	----	88.9 × 5.0	70	75	8.0	7.0	5.0	----	----	----
500	280	530	5.0	3.15	----	114.3 × 5.5	80	75	8.0	7.0	5.0	----	----	----
630	355	660	6.0	5.0	----	114.3 × 5.5	80	100	10.0	8.0	----	----	----	----
630	355	660	6.0	5.0	----	139.7 × 6.0	90	100	10.0	8.0	----	----	----	----
800	450	830	6.0	5.0	----	139.7 × 6.0	90	100	10.0	8.0	----	----	----	----
800	450	830	6.0	5.0	----	152.4 × 7.0	100	100	10.0	8.0	----	----	----	----
1000	560	1040	7.0	5.0	----	152.4 × 7.0	100	125	12.0	10.0	----	----	----	----
1000	560	1040	7.0	5.0	----	193.7 × 8.0	110	125	12.0	10.0	----	----	----	----
1250	710	1290	7.0	5.0	----	193.7 × 8.0	110	150	12.0	10.0	----	----	----	----

**Tubular shaft diameter d_2 has been taken preferably from IS:3501:1966*

all dimensions in mm

(*b*) **Effect of Lump Size**: The selection of size of a screw conveyor basically depends on two factors. (*i*) the conveying capacity required and (*ii*) the lump size of the materials to be conveyed.

The lump size of materials determines the minimum size of the screw diameter 'D' to be chosen. D is recommended to be at least 12 times the lump size of a sized material or at least 4 times the largest lumps of an unsized material.

(*c*) **Capacity of Screw Conveyor:** The volumetric capacity 'V' in M^3/Hr depends on screw diameter 'D' in meters, screw pitch 'S' in meters, its rotational speed 'n' rpm and the loading efficiency of the vertical cross sectional area 'ϕ'.The tonnage capacity 'Q' in tons/hr is given by:

$$Q = V\gamma = \frac{\pi D^2}{4} S\ 60 n \phi \gamma C \text{ tons/Hr.}$$

where γ = bulk density of material in tons per m^3

C = factor depending on inclination of conveyor.

In a typical design , S = D to 0.8 D.

φ varies with flowability of the material as under:

Material Characteristics	Value of φ
1. Slow flowing, abrasive (clinker, ash)	0.125
2. Slow flowing, mild abrasive	0.25
3. Free flowing, mild abrasive (sand)	0.32
4. Free flowing, non-abrasive (grain)	0.4

Value of 'C' varying with inclination angle β is related as shown in following chart.

β	0°	5°	10°	15°	20°
C	1.0	0.9	0.8	0.7	0.65

The screw diameter and speeds vary widely depending on the designed capacity of the conveyor and the nature of the material handled. However, the speed is generally reduced as the diameter goes up, as shown in following table:

Screw dia, mm	160	200	250	300	400	500	630
Maximum rpm	150	150	120	120	95	90	75
Minimum, rpm	25	25	20	20	20	15	10

(*d*) **Power Requirements of Screw Conveyor:** IS:12960:1990 "Determination of Power Requirement of Screw Feeder—General Requirements", has recommended the method for calculation of power requirement of a screw conveyor.

The driving power of a loaded screw conveyor may be estimated by the formula:

$$P = P_H + P_N + P_{st}$$

where, P_H = power necessary for conveying the material.

P_N = driving power of the conveyor at no load.

P_{st} = power requirement for inclination of the conveyor.

Power necessary for conveying the material: P_H in kW is the product of the mass flow rate 'Q' of the material, the length 'L' of material movement in the conveyor and an artificial frictional coefficient 'λ', also called progress resistance coefficient.

$$\therefore \quad P_H = \frac{QL'}{3600}\lambda g, \text{ kW} = \frac{QL'\lambda}{367}, \text{ kW}$$

where,

Q = mass flow rate in t/hour.

L′ = length of material movement in conveyor in m.

λ = progress resistance coefficient.

λ depends on the material and its size. It is generally of the order of 2 to 4. It should be noted that during progress of material, over and above of sliding between the material, trough and screw, the material particles slide against each other which results in internal friction. Therefore, λ is naturally expected to be more than normal coefficient of friction for the material.

Drive power of the screw at no load, P_N is comparatively low. It is proportional to the screw diameter and total length of the screw. The recommended formula is

$$P_N = \frac{DL}{20}, \text{ kw}$$

Where, D = Nominal screw diameter, m

L = Length of screw, m

Power due to inclination, P_{st}. This power requirement is the product of the mass flow rate and height to which the material is being conveyed. Thus

$$P_{st} = \frac{QHg}{3600} = \frac{QH}{367}, \text{ kW}$$

Where, Q = mass flow rate in t/hr.

H = height in m.

If material is moving down the inclination, H is to be taken as negative.

So, total power requirement is

$$P = \frac{Q(\lambda L' + H)}{367} + \frac{DL}{20}, \text{ kilowatts.}$$

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CHAPTER

7.0

Pneumatic and Hydraulic Conveyors

Pneumatic and hydraulic conveying of materials, mainly granular bulk materials or small sized unit materials enclosed in special carriers, is a departure from other conveying methods, in concept as well as in constituting plant and equipment used. However, the two methods have lot of similarity in both score, and hence they have been brought together in this chapter.

7.1 PNEUMATIC CONVEYORS

7.1.1 Definition

Pneumatic conveying is the process of conveying granular / powdered materials by floating the materials in a gas, primarily air, and then allowing it to flow to the destination through a closed pipe. The operating principle common to all types of pneumatic conveying is that motion is imparted to the material by a fast moving stream of air.

Thus any pneumatic conveyor consists of an air supply equipment (blower or compressor), pipelines, product storages, air lock feeders and dust filters.

7.1.2 Advantages and disadvantages of Pneumatic Conveying

Pneumatic conveying system is used for delivery of non-sticky, dry materials via pipelines to various storage or process points which are economically inaccessible by conventional conveyors. The major advantages of using pneumatic conveying system are as follows:

(*i*) Materials can be picked from one or more points and can be delivered to one or more points in a plant or even outside to a different plant.

(*ii*) The conveying of materials take place through air tight piping and auxiliary system and hence neither pollutes the environment nor the materials get contaminated with foreign materials.

(*iii*) It offers plant and operator safety in handling fine powdery materials which may be toxic in nature or fire prone.

(*iv*) If offers a flexible system. The conveying pipe lines can be routed and rerouted with little efforts as per demand of the operations.

(*v*) It makes possible unloading of materials from ships, barges, transport vessels directly to storage bins.

(*vi*) It is self cleaning system, preventing accumulation of materials in the conveying system. Because of this, the same installation may be used for conveying different materials.

(*vii*) If offers a low maintenance cost system. It also offers a lower cost materials handling system compared to handling and storage of bulk materials in bags or small containers.

(*viii*) A pneumatic system can be operated automatically and can easily be integrated into manufacturing processes as feeders.

Despite many advantages cited above, there are certain limitations/disadvantages of pneumatic conveying systems. These are:

(*i*) The types of materials suitable for pneumatic conveying is limited to materials which are dry, granulated, pulverized, crushed etc. and essentially free flowing.

(*ii*) Friable or too abrasive materials are not suitable to be transported by pneumatic conveyors.

(*iii*) The movement of transportation is fixed (uni-directional).

(*iv*) Relatively high energy consumption per unit weight of materials transported.

(*v*) The length of pneumatic conveyors are limited. Vacuum systems are limited to 500 m while high pressure systems up to 2 kms or marginally more.

7.1.3 Types of Pneumatic Conveyors

Pneumatic conveyors are broadly classified into following three groups, based on application:

A. Pipeline Conveyor.

B. Air-activated Gravity Conveyor (Airslide).

C. Tube Conveyor.

A. Pipeline Conveyor

Further classification of pipeline conveyors are made on the basis of air pressure used. As per IS:8647-1977 ‘‘Design Criteria for Pneumatic Conveying Systems’’, the following classifications may be made:

(*a*) **Low pressure system,** in which the operating air pressure is normally limited to 1 atomsphere (760 mmHg) gauge, supplied by a positive displacement lobe type blower (roots blower). These systems are restricted to short distances (up to 500 m) and small flow rate. These systems are further sub-classified into:

(*i*) Positive pressure system.

(*ii*) Negative pressure (or suction) systems.

(*iii*) Combined negative-positive pressure (or combination) system.

(*b*) **Medium Pressure System,** with air pressure form 1 to 3 atmospheres, gauge.

(*c*) **High Pressure System** with air pressure from 4 to 7 atmospheres, gauge .

Medium and high pressure systems are essentially positive pressure type systems.

Positive pressure system: A positive low pressure pipeline system is one in which a positive air flow, created by a positive displacement blower, effectively transport slow flowing materials over a distance up to 500 meters.

The major characteristics of this system is that it can pick up material from one source and discharge the same to more than one points. Fig. 7.1.1 illustrates a typical positive pressure system. Referring to this figure, the basic principle of operation can be explained as follows:

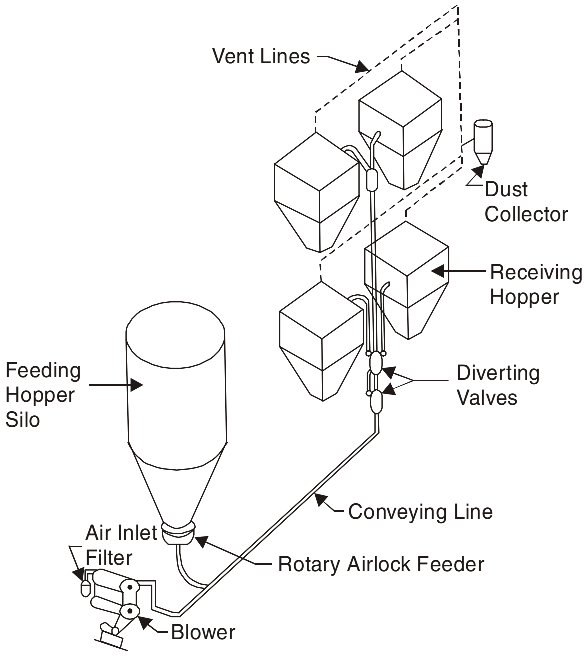


Fig. 7.1.1. A typical positive pressure system

A positive displacement blower (lobe type or roots blower) sucks air from the atmosphere through a suction filter and delivers pressurized air into the conveyor pipe line. Materials to be conveyed are introduced into the pipelines from the feeding bin/hopper through different types of **air lock feeder** at controlled rate. Air lock feeders are used at the outlet port of the feeding silos for discharge of materials into the pipeline, without being blown out from the top of such silos because of high air pressure. The materials so introduced are immediately air laden and blown to one or a number of receiving bins / silos through **diverting valves**, also called **change over valves**.

The diverting valves are generally designed for one inlet and two outlets, but multiple outlets are also possible. The valves are operated either manually or through remote controlled actuator. The air, after the material get discharged at the receiving hoppers, is made to pass through an appropriate dust removal system, before it is allowed to escape back to atmosphere.

The principal advantage of this system is that the blower does not handle dusty air. However, the major disadvantage of the system is the possible leakage of high pressure air along with materials to the surroundings.

Negative pressure (or **suction) system:** In this type of conveyor, a positive displacement blower creates a vacuum in the conveyor pipe line, which causes the material to be sucked through one or multiple nozzles and conveyed to a receiving hopper. The conveyed material is separated from the air stream and collected in the hopper. The air is generally made to pass through a dust collector to be freed from remaining finer particles of materials and then released to the atmosphere. Schematic view of a negative pressure pipeline conveyor is shown in Fig. 7.1.2. Easy flowing materials like cereals, grains, powdery materials etc. are conveyed in suction conveyors. In this system, materials from multiple storage points may be collected and transported to a single storage point.

The major advantage of this system is that at leakage points, air from surroundings enters the system, and hence air pollution through materials leakage is virtually nil. Therefore, this system is particularly useful for toxic and very fine powdered materials. However, the major limitation is that, if the air is not totally separated from the conveyed materials, dust laden air passes through the blower and tends to damage it. Moreover, the distance and volume of conveying is also limited because the actual vacuum created inside the pipeline is often not below 0.3 atmosphere (230 mmHg), absolute.

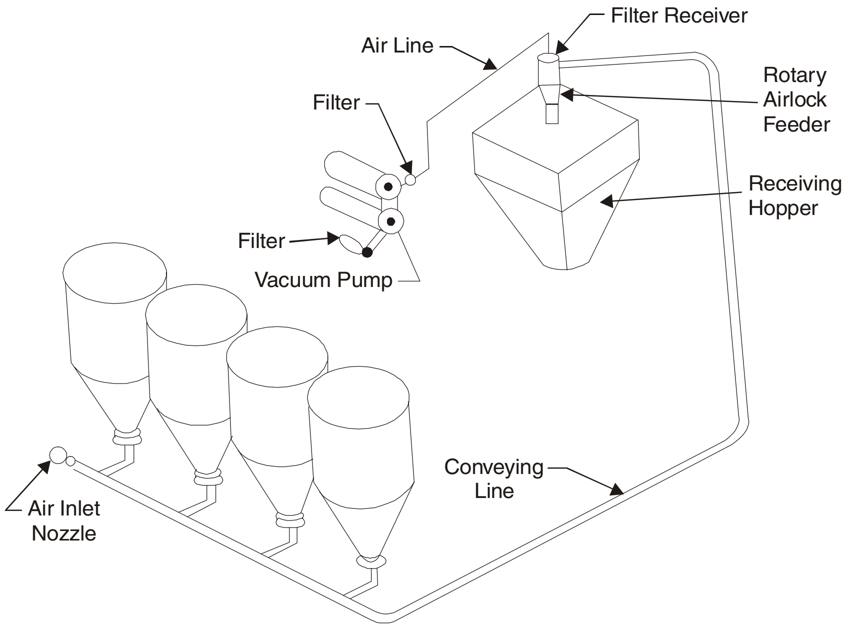


Fig. 7.1.2. Negative pressure system

Combined negative-positive pressure (or **combination) system:** In this system the principles of both positive pressure system and suction system are employed. This type of pneumatic conveyor is particularly employed when materials from more than one points have to be picked up and simultaneously delivered to multiple delivery points. For this system generally one positive delivery blower is used. Two separate blowers may also be used for the suction line and pressure line of the combination system. The suction side of the blower conveys material from the storage points to an intermediate receiving station. The suction air passes through this intermediate receiving station and then through a cyclone separator and a further dust cleaner, if required, and enters the blower. The compressed air is then thrown into the pressure delivery pipe line, into which the material from the intermediate storage is discharged through necessary air lock feeder. From there, material is conveyed to the multiple storage silos as per a positive pressure system already discussed. A typical scheme of the system is exhibited in Fig. 7.1.3.

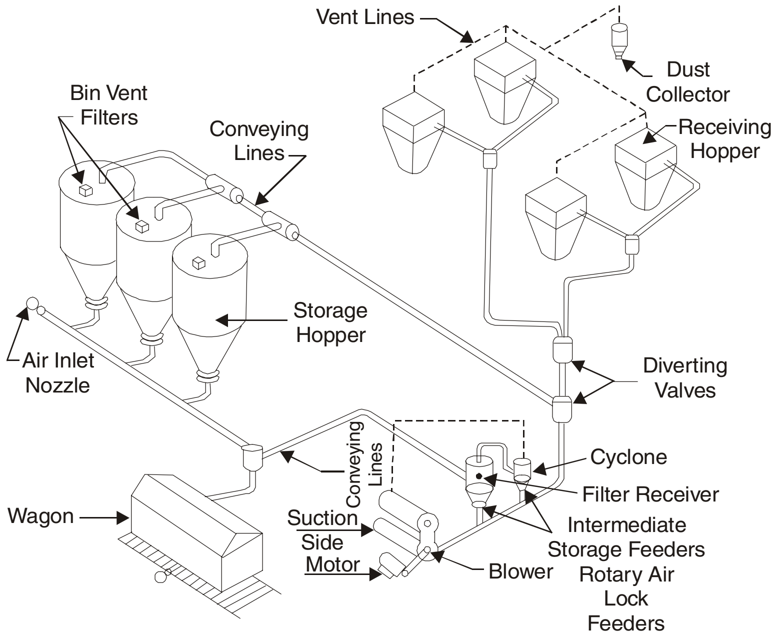


Fig. 7.1.3. Positive-negative pressure system

The three figures 7.1.1, 7.1.2 and 7.1.3 are based on figures in IS:8647-1977.

Medium and high pressure systems: These systems are basically similar to a positive pressure system in its operational principles. The difference is the range of air pressure used. Because of use of increased air pressure, the medium and high pressure systems principally differ from a low pressure system in two aspects. Firstly, the type of air supply equipment will vary according to the pressure selected. Secondly, the feeding devices used will be different to make the system leakproof.

A single stage rotary compressor is used for a medium pressure pneumatic conveying system while a double stage rotary compressor is normally used for a high pressure system. The medium pressure system generally operate continuously while a high pressure systems may be used for continuous, intermittent or batching operations.

In medium pressure system generally **screw feeder** (also termed **screw pump**) is used for feeding materials from the feeding hopper / silo to the conveyor pipe. Screw feeders are suitable for safe (no leakage of air through hopper) operations upto an air pressure of 2.5 to 3.0 atmospheres, gauge. For high pressure system, feeding of material is done through **blow tank** (also called **chamber feeder**) type line charger.

In these medium and high pressure systems, the materials flow takes place in the **dense phase** *i.e.* the mass flow ratio of material particles to air is over 15. The low pressure systems operate at **dilute phase** *i.e.* mass flow ratio being less than 15.

Selection of pneumatic handling system depends on properties of materials like bulk density, particle size; material characteristics like moisture content, abrasiveness, corrosiveness, fragility etc. and other factors like distance of conveyance, environmental considerations etc. IS:8647-1977 has suggested a list of choice of different types of pneumatic conveying system based on 79 specific materials. Table 7.1.1 shows the recommended selection of type of system for a few materials based on the table given in the above mentioned IS specification.

Table7.1.1. Selection of Pneumatic Conveying System

Materials	Type of System				
	Low Pressure			Medium Pressure	High Pressure
	Negative	Positive	Negative –Positive		
Alum	x	x	–	–	–
Aluminium oxide	–	x	–	–	–
Asbestos dust	x	–	–	–	–
Bauxite	x	–	–	x	–
Bentonite	x	x	x	x	x
Carbon, activated	x	x	x	x	–
Cement, Portland	–	–	–	x	x
Cereals	x	x	–	–	–
Coal, pulverized	–	–	–	x	x
Dolomite	–	–	–	x	x
Flour, wheat	x	x	–	–	–
Fly ash	–	–	–	x	-
Grain, whole	x	x	–	–	–
Graphite	x	x	–	–	–
Limestone, pulverized	–	–	–	x	–
Milk, dried	x	x	–	–	–
Ores, pulverized	–	–	–	x	x
Wood chips	–	x	–	–	–

***Note*: x indicates suitability.**

The air velocity necessary for pneumatic conveying depends on the bulk density and size of the material. Following table 7.1.2 indicates the minimum air velocity necessary for a few selected materials. However, actual air velocity employed is much more than these minimum velocities.

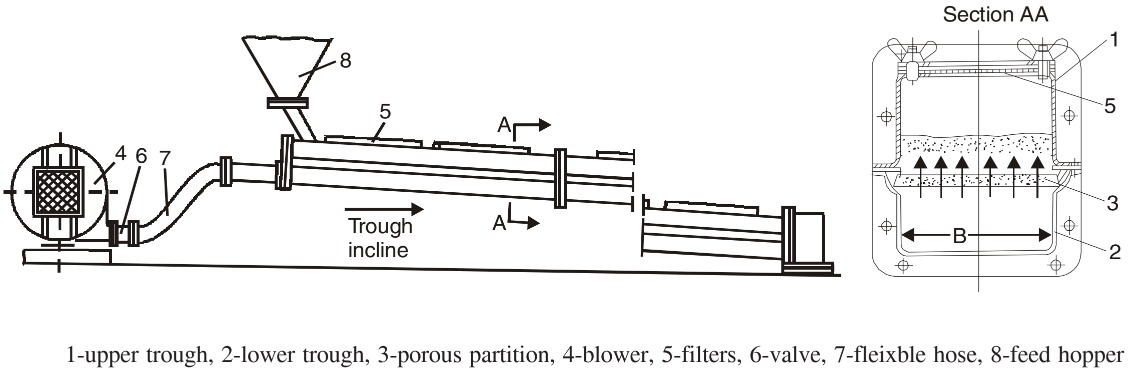
Table 7.1.2. Minimum Air Velocity

Material	Average bulk density (kg/m^3)	Approximate size (mm)	Minimum air velocity flow (m/s)
Alumina	930	106 mesh	1.5
Bentonite	900	75 mesh	1.5
Cement	1400	90 mesh	1.5
Coal	720	13	12.0
Coal	720	6	9.0
Common salt	1360	150 mesh	3.0
Ground Bauxite	1440	106 mesh	1.5
Polythene cubes	480	3	9.0
Pulverized ash	720	150 mesh	1.5
Pulverized coal	720	75 mesh	1.5
Silica flour	880	106 mesh	1.5
Soda ash	560	106 mesh	3.0
Wheat	753	5	9.0

B. Air-activated Gravity Conveyors (Airslide)

Dry powdered materials, when aerated acquires fluidity and can move along a plane having a slope of only 4% to 5%. This principle is adopted in an airslide for short distance movement of powdery materials at a fairly controlled rate.

An airslide consists of an inclined covered metallic trough with a longitudinal porous partition in between. Over the partition the material moves. Low-pressure air is allowed to enter from the bottom of the porous partition. The air fluidizes the powdered / pulverized material and makes it flow along the inclined partition due to gravity. Schematic diagram of an airslide is shown in Fig. 7.1.4.



1-upper trough, 2-lower trough, 3-porous partition, 4-blower, 5-filters, 6-valve, 7-fleixble hose, 8-feed hopper

Fig. 7.1.4. Schematic views of an airslides

Airslides are generally used for controlled movement of materials *i.e*. as feeders. For their simple design, low costs, low power consumption, high handling capacity combined with small overall dimensions, simple erection & adjustment and absence of moving and wearing parts, they are, in many cases, preferred over screw or vibrating feeders. Materials such as cement, ash, coal dust etc. can be effectively conveyed by airslides.

C. Tube Conveyor

When small piece goods in standerdised containers, called carriers, are transported pneumatically over short distance through pipe, it is called **Tube conveyor**. This type of transportation of piece goods are used in telegraph offices, banks, stores, newspaper offices and also in industries. The pipes of these installations may be round (up to 100 mm diameter) or elliptical. The carriers are moved at speeds range of 6 to 12 mps.

7.1.4 Parts for Pipeline Conveyor

Different parts/accessories making up different types of pipeline conveyors are the suction nozzle, feeding or intake unit for introduction of material into pipeline, changeover/diverting valves, separator (receiver) and dust collector (filter). The other components are the airdelivery system, pipes and automatic control systems.

Operation and constructional details of some of these parts are briefed below:

(*a*) **Suction nozzle:** These are used for sucking materials into the pipe of suction conveyors. It is basically a piece of pipe connected with the main conveying pipe through flexible hose. Part length of this pipe is jacketed by another concentric tubular piece. The jacket is closed at the bottom with inner pipe, while it is open at the top. Number of holes are created at the bottom side of the inner pipe. When this assembly is dropped into the material, part of the nozzle end gets buried into heap of the material. When the suction blower is switched on, air enters between the jacket and the inner pipe through opening at the top, passes through the holes at the bottom part of the inner pipe, through the materials and picks up the particles up the nozzle into the conveying pipe. Fig. 7.1.5 shows the scheme of a suction nozzle.

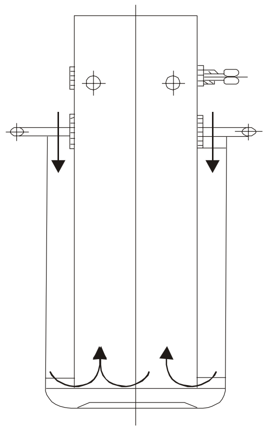


Fig. 7.1.5. Suction nozzle

(*b*) **Feeding or Intake units**

(*i*) **Air-lock gate** of different designs are used in low pressure pipeline system, for pressure up to 1.4 atmospheres, gauge for introduction of materials from storage hoppers/silos into the conveying pipe.

Rotary gate (Fig. 7.1.6) is one such air lock gate. The material is fed from the top funnel. The partitioned rotary durm (item 2) takes this material and discharge at the bottom by gravity. The drum is closely fitted with casing which prevents air to pass from outside to inside.

Another type of air lock is the **multiple-door air lock** which operates on the principle of closing and opening of a series of flap doors through the stationary feeder.

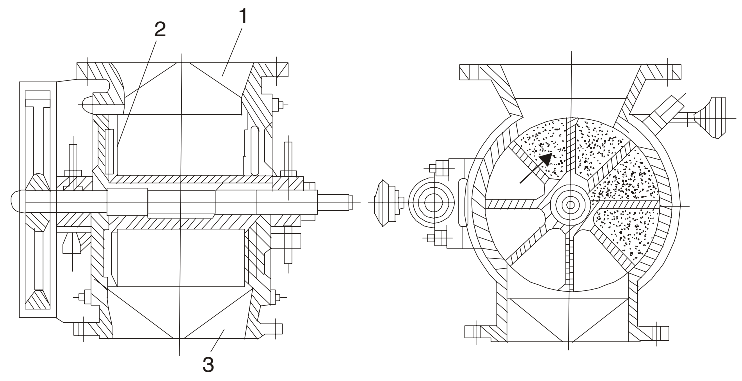


Fig. 7.1.6. Rotary air-lock gate

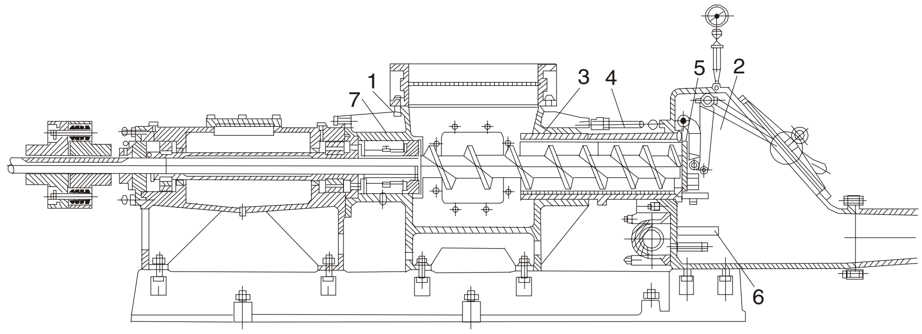
1-entry funnel, 2-rotary drum, 3-discharge hopper.

(*ii*) **Screw feeders** are used for feeding materials into pipelines working under medium pressure systems (up to about 3.0 atm, gauge pressure).

Screw feeders are short length screw conveyors with screws having differential pitch decreasing in the direction of load discharge. This feature makes the load to pack at the discharge end and prevents the high pressure air to escape through the feeding mouth of the feeder.

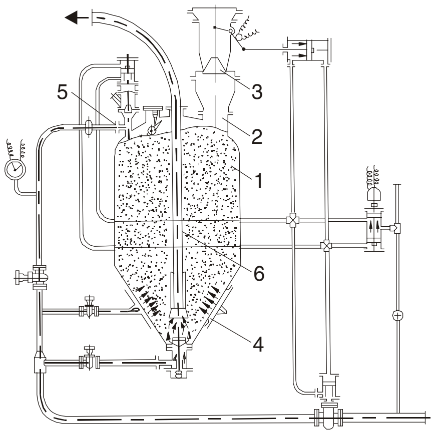
The material is discharged into a mixing chamber in which the pressurized air enters through a series of nozzles. The jet of air loosens the fed materials and carries it along the conveying pipe to the discharge point.

Fig. 7.1.7 shows a stationary screw feeder. Screw feeders are widely used for cement and other powdered materials.



1-feed funnel, 2-mixing chamber, 3-screw, 4-cylindrical casing, 5-front closing valve, 6-air nozzle, 7-bearing seal

Fig. 7.1.7 Stationary screw type pneumatic feeder (*iii*) **Blow tank** or **chamber feeders** are used for charging powdered materials into the pressure line. Fig. 7.1.8 shows schematic drawing of a pneumatic chamber feeder. Such feeders consist of a cylindrical vessel with conical bottom. The material is fed into the upper part of the chamber through a port and after filling the vessel, it is shut off. Then compressed air is introduced into the lower part to aerate the material, and also at the top of the vessel to force the loosened material to move though the feeding pipe into the main line of the pressure conveyor.



1-conical bottom chamber, 2-feeding port, 3-cone valve, 4-air entry jacket, 5-air entry at chamber top, 6-feed pipe.

Fig. 7.1.8. Blow tank or chamber feeder

(*c*) **Change-over** or **diverter valves :** These valves allow pneumatically conveyed material in a pressure system, to be delivered to a specific point out of the multiple storage points. These valves consist of a CI body having one flanged inlet and more than one flanged outlets. At the junction of the multiple outlets, a disk valve or flap is provided, which can be adjusted from outside, and which closes all but one of the outlets at predetermined settings.

(*d*) **Separator/receiver :** These are equipment used for separation of solid materials from the air which conveys it. Types of separators, used in pneumatic conveying can be broadly classified, based on principle of operation, into (*i*) **gravity** and **inertial** type and (*ii*) **cyclone** type.

In the **gravity** and **inertial type**, the solid laden air is admitted into a large volumed chamber, called the gravity chamber, in which the high velocity air losses its velocity within a range of 0.2 to 0.8 mps, and the solid falls due to gravity. In certain designs, the air is passed through a number of baffle plates, where the air has to abruptly change direction, and solid being heavier cannot change its inertia proportionately and separates out.

Cyclone separator is basically a conical bottom container or hopper provided with a suitable discharge valve at the bottom. Materials laden air enters tangentially at the upper part of the separator, moves along the outer wall of the equipment and looses its velocity and pressure, when the material separates from the air stream and falls at the bottom. The air escapes to the top from the cyclone separator through a pipe placed centrally and projecting down upto certain length of the hopper.

(*e*) **Dust collector (filter) :** The air that escapes from a separator of a storage silo after depositing the bulk of conveyed material, may still contain some amount of fines/dust. To prevent atmospheric pollution, and ingress of such fines though the blower of a suction system, often dust collectors are provided at the output end of a separator/storage silo. Various types of dust collectors are used to separate dust. Some of these are: bag filters, wet filters, electrostatic precipitators (esp) etc. According to the degree of cleanliness of air, filters are classified as coarse and fine.

7.2 HYDRAULIC CONVEYORS

7.2.1 Definition and Uses

Moving bulk materials along pipes or channels (troughs) in a stream of water is called **Hydraulic conveying**. The mixture of materials and water is termed as **pulp**. Pump is used for conveying of pulp through pipe under pressure. In channels the conveying takes place down the inclination due to gravity.

A hydraulic conveying system generally consists of a **mixer** where the material and water is mixed to form the requisite pulp. Depending on starting size of the bulk material, the materials may have to be **crushed / ground** in a **crushing plant** and **screening facility**. The prepared pulp is then pumped by a suitable **pumping** and **piping system**. In certain installation a suitable **recovery system** may be incorporated at the delivery end for dewatering the material.

Hydraulic conveyors are used in many industries, mining operations and construction works. Some of the popular uses are to dispose ash and slag from boiler rooms, deliver materials from mines and sand and water to fill up used mines, to remove slag from concentration plants, to quench, granulate and convey furnace slag to disposal points, to move earth and sand in large construction projects and for land filling etc. A typical hydraulic conveying arrangement is shown in Fig.7.2.1.

7.2.2 Advantages and Disadvantages

The advantages of using hydraulic conveyors are:

(*i*) High capacity of materials can be conveyed over a considerable length (tens of kilometers).

(*ii*) Comparatively simple and low running cost equipment are used.

(*iii*) Conveying can be combined with other processes like cooling, quenching and granulating of molten slags, washing etc.

(*iv*) Flexibility in selection and subsequent modifications to route.

(*v*) The conveying process is generally safe and easily controllable.

(*vi*) Low maintenance costs.

However, there are a few limitations and disadvantages associated with a hydraulic conveyor. Some of the major ones are:

(*i*) The materials that can be handled are quite limited, only smaller sized bulk materials which do not react or get dissolved in water can be conveyed in a hydraulic conveyor.

(*ii*) Cannot be used in cold conditions when water may freeze.

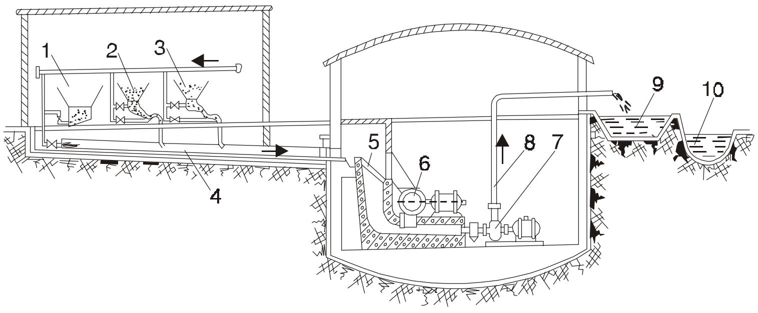
(*iii*) Increased humidity when operating in close environment.

(*iv*) Disposal or recirculation of water is often difficult and / or costly.

(*v*) Crushing and mixing are added power intensive operations.

(*vi*) Degradation of some materials due to attrition.

(*vii*) Choking of pipelines particularly at bends / fittings.



1-slag hopper; 2 and 3-ash hoppers, 4-trough, 5-grid, 6-slag crusher, 7-pump,8-pulp line, 9-dump tank, 10-water basin

Fig. 7.2.1. Arrangement of hydraulic installation for slag and ash disposal from power station boiler room

7.2.3 Design Considerations for Hydraulic Conveyor

The most important consideration in a hydraulic conveying system is that the material should not get settled and choke the pipeline. Settling velocity in M/sec for spherical particles in pipes is given by the relation: $V_p = 0.55\sqrt{a'(\nu' - 1)}$ where a′= particles size in cm, and ν′ = specific weight in tons /m^3. The working velocity 'V' is taken as 3 to 4 times V_p. The working velocity for conveying earth of different particle sizes through different pipe diameters are given in the following table:

Particle Size a′, mm	Velocity V (m/sec), for different pipe diameters, (mm)			
	200	**300**	**400**	**500**
0.5	1.63	2.00	2.28	2.53
1.0	1.95	2.39	2.73	3.03
5.0	2.34	2.84	3.26	3.62
15.0	2.60	3.15	3.62	4.01

Volume of water is generally 2 to 5 times volume of bulk material.

The water head in the pipe line is made up of the head required to overcome the resistance to motion of the pulp in the pipe line and velocity head required to impart velocity V to the moving mass.

$$H = L\,\frac{\lambda}{d_p}\frac{v^2}{2g} + \frac{v^2}{2g} = \left(\frac{L\lambda}{d_p} + 1\right)\frac{v^2}{2g}\text{, meters of water.}$$

Where,

L = length of pipe, m

λ = hydraulic loss factor

v = pulp velocity, m /sec

d_p = pipe diameter, m

The value of λ for a small-lumped material is given by the eqn.: ...(*i*)

$$\lambda = \left(0.03 + \frac{0.018}{\sqrt{vd_p}}\right) \nu'_p$$

where ν'_p = specific weight of pulp.

Value of λ may be taken as 0.04 to 0.045, for normal velocity and pulp concentration.

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CHAPTER

8.0 Hoisting Equipment

Hosting equipment are usually powered equipment used for lifting and lowering unit and varying loads intermittently. In certain equipment while lifting and lowering, shifting of the load can also be accomplished, within an area known as the reach of the equipment. The primary function of hoisting equipment is *transferring* through lifting and lowering operations.

A variety of equipment fall under the heading of hoisting equipment starting from hoists, different types of elevators and cranes. Excepting for elevators, these equipment generally utilize a drum, wire rope, pulleys and load lifting attachments for performing the lifting and lowering (i.e. hoisting) motions.

Hoisting equipment can be stationary, portable or travelling type. Often hoisting equipment are mounted on powered vehicles like truck, rail or ship, when the movement of the lifted load is not limited to a fixed area of operation.

8.1 PARTS OF HOISTING EQUIPMENT

It has already been stated that most of the hoisting equipment utilize common type of parts like chain, wire rope, chain or rope drums, pulleys, lifting attachments like hook, grabs etc. A brief discussion of these parts have been included in this section. However, the parts used in elevators are different, and have been discussed under the chapter on elevators. Similarly other specific parts associated with individual equipment have been discussed along with discussion of the respective equipment.

8.1.1 Chain and Chain Sprockets

The types of chains used in hoisting equipment are (*i*) welded load chains and (*ii*) roller chains. **Welded chains** are used in low capacity hoisting machines (hoists, winches, hand operated cranes etc.) as the main lifting appliance as slings for suspending load from the hook or other lifting attachments. Welded calibrated chains are employed as hand operated chain for driving the traction wheels of hoists and hand operated overhead cranes (hoists and cranes are referred in sections 8.2 and 8.5 respectively).

Welded chains are manufactured by joining one gap of individual chain links by hammer hot forging or by resistance welding of two half links. Resistance welded chains are more accurate and have increased strength. Disadvantages of the welded chain are their (*i*) heavy weight, (*ii*) susceptibility to jerks and overloads, (*iii*) heavy wear of the links, (*iv*) low safe speed of movement, (*v*) sudden failure without previous indication etc. On the other hand the advantages are their (*i*) flexibility in all directions, (*ii*) possibility of using small sized pulleys and drums, (*iii*) simple design and manufacturing process etc.

The diameter of welded chain pulleys or drums are, however, should not be less than 20d, where d is the diameter of rod of each link.

Roller chains are composed of plate links, hinge-jointed by pins. Chains may be made with two plates or for heavier duty with upto twelve plates.

Roller chains are used for both hand operated hoists as well as electrically driven equipment like hoists or winches for lifting heavy load at slow speeds (about 15 mpm) and in guideways.

Roller chains are superior to welded chains in many ways namely in reliability as links are made from solid plates. Roller chains have high flexibility in the plane of rotation and hence sprockets of smaller diameter may be used. The friction in the joints are also less hence more efficient.

However, the major limitation of roller chain is that it cannot be used to carry weight at an angle to the plane of rotation of the links. In such a case excessive bending load of the plates tend to damage/break the pins. It is because of this drawback, the roller chains have largely been replaced by steel wire ropes in the power driven hoisting equipment.

Sprockets for welded chains

These sprockets are used in hand operated hoists and winches for driving the mechanism for hoisting load and travelling of the hoist trolleys.

These are generally made of gray cast iron and, in special cases, steel casting. Around the periphery of the sprocket, as – cast pockets are provided which conform in shape and size to the links of the chain used. Alternate links sit at right angles to each other, as shown in Fig. 8.1.1, and pull in the chain is transmitted through the partitions between pockets, to the sprocket. Sprockets are made with minimum number of teeth ensuring compactness and low cost. The minimum number of teeth is 4. The arc of contact between the chain and sprocket should be at least 180° to avoid jumping off of the chain. If arc of contact is less, **chain guide**, as shown in Fig. 8.1.2 or a **guide block** is provided. Both chain and sprocket need to be lubricated to reduce frictional resistance.

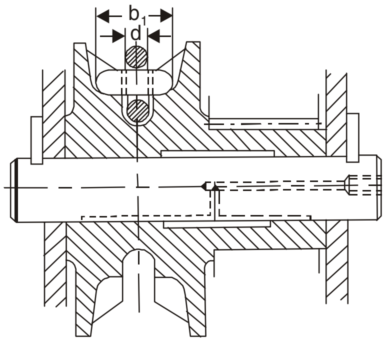


Fig. 8.1.1. Chain sprocket

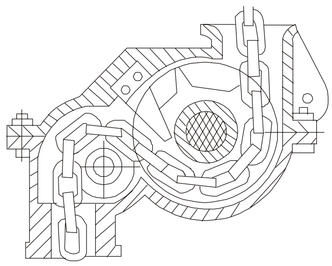


Fig. 8.1.2. Chain guide

Sprockets for roller chains

These sprockets are also used for hand-operated hoists and winches over 10 tons capacity. Materials used are cast iron, forged steel or steel castings. The teeth are machined in milling machine. Minimum number of teeth used is usually 8. To prevent the chain from slipping off the sprocket, and to ensure safe working, sometimes the sprocket with chain is enclosed in a housing, as shown in Fig. 8.1.3.

When load is lifted very high by means of a winch where chain is the pulling member, a chain collector is generally used to collect long end of the chain.

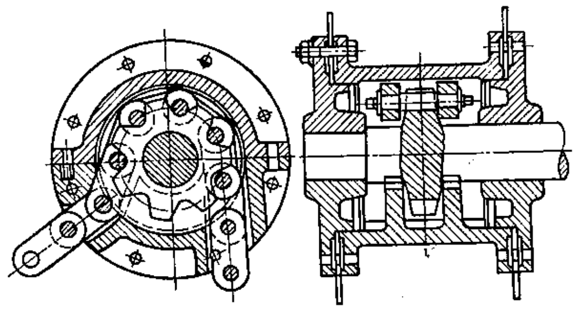


Fig. 8.1.3. Sprocket with chain is enclosed in a housing

8.1.2 Steel Wire Ropes and Drums

Steel wire ropes are extensively used as a flexible lifting media in hoisting machinery. The major advantages of using steel wire ropes compared to chains are the following:

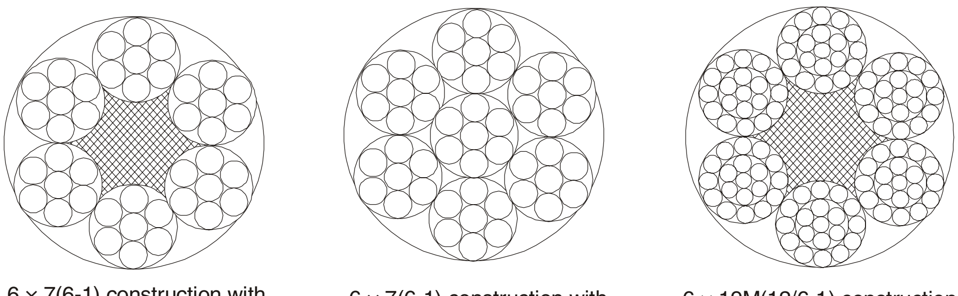
(*i*) Lighter weight

(*ii*) Flexibility of operation. Load can be lifted with connecting ropes making large angles with the vertical.

(*iii*) Greater reliability of operation. Rope does not give away suddenly without any notice. The outer layers of the wire ropes undergo intensive wear and always break from outside. This gives prior warning for changing of the rope before complete failure.

(*iv*) Wire rope is less susceptible to damages from jerks which is very common in hoisting operations.

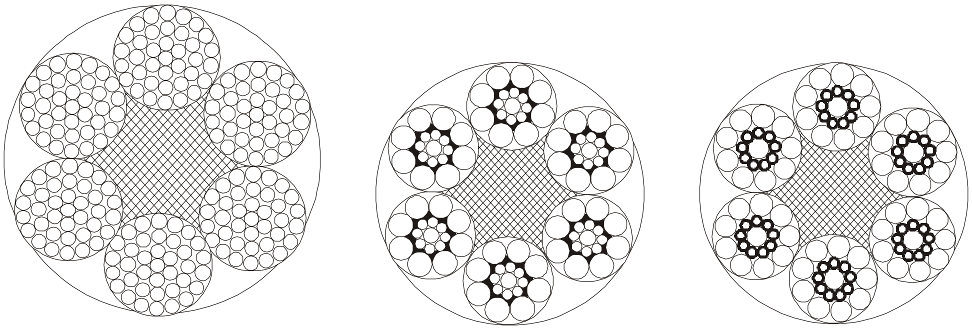
Wire ropes are made from steel wires, cold drawn and specially heat treated to an ultimate strength of 130 to 200 kg/mm^2. Number of steel wires are twisted to make into a strand and number of such strands are twisted over a core made of hemp, asbestos or wire of softer steel. Constructional details and breaking strength of steel wire ropes are specified in Indian Standard IS:2266:1989, ''Steel Wire Ropes for General Engineering Purposes-Specification''. Cross section of a few selected wire ropes as per above IS is shown in Fig. 8.1.4.



6 × 7(6-1) construction with Fibre Core (CF) 8 to 12 mm diameter

6 × 7(6-1) construction with Steel Core (CWF) 8 to 12 mm diameter

6 × 19M(12/6-1) construction with Fibre Core (CF) 8 to 52 mm diameter



6 × 37M(18/12/6-1) construction with Fibre Core (CF) 8 to 64 mm diameter

6 × 17 S (8-8-1) with Fibre Core (CF) 8 to 52 mm diameter

6 × 19 S (9-9-1) with Fibre Core (CF) 8 to 52 mm diameter

Fig. 8.1.4. A few selected wire ropes as per IS:2266:1989

Regular lay ropes, where directions of twist of the wires in the strand is opposite to the twist of the strands, are most commonly used. In a **parallel (Lang) lay** rope, the twist of the wires are in same direction as those of the strands. These ropes are more flexible, less susceptable to wear, but they tend to spin when hanging freely with a load. The parallel lay ropes are generally used in lifts and hoists working in guideways (*i.e.* the loads cannot spin) and also as haulage ropes. Rope constructions 6 × 19, 6 × 37, 6 × 61 and 18 × 19 are commonly used for cranes and hoists.

Rope drums

The purpose of a rope drum is to store length of wire rope on the face of the drum. Wire rope under tension from the weight of the load being lifted, can be coiled in by rotating the drum, and uncoiled by rotating the drum in opposite direction.

Life of wire rope depends on the $\frac{D}{d}$ ratio and number of bends the rope has to undergo.

D = drum diameter and d = diameter of the rope. The diameter 'd' of rope is measured over a pair of opposite strands.

The minimum permissible diameter of a rope drum or pulley is found from the relation:

$$D \geq e_1 e_2 d,$$

Where, D = drum/pulley diameter measured over the bottom of the rope groove, mm

d = rope diameter, mm

e_1 = factor depending on the type of hoisting equipment and its service

e_2 = factor depending on rope construction. It is generally taken to be 1for cross lay and 0.9 for parallel lay.

Table. 8.1.1. Minimum permissible Values of Factors k and e_1

Type of hoisting mechanism	Drive	Operating conditions	Factor K	Factor e_1
I. Locomotive, caterpillar-mounted, tractor-and truck-mounted pillar cranes (including excavators operating as cranes), cranes and hoisting mechanisms at construction sites and temporary jobs.	Hand Power Power Power	Light Light Medium Heavy to very heavy	4 5 5.5 6	16 16 18 20
II. All other types of cranes and hoisting mechanisms.	Hand Power Power Power	Light Light Medium Heavy to very heavy	4.5 5 5.5 6	18 20 25 30
III. Hand-operated winches with a load-lifting capacity of up to 1 ton mounted on various automotive vehicles (automobiles, trucks, etc.)	–	–	4	12
IV. Trolley hoists	–	–	5.5	20
V. Clamshell mechanism (except for pulleys in grabs) for hoisting mechanisms of item I.	–	–	5	20
VI. Ditto, for hoisting mechanisms of item II.	–	–	5	30

Note: $K = \text{Factor of safety} = \dfrac{\text{Breaking strength, kg}}{\text{Max tension in rope, kg}}$

The drums for steel wire rope are generally made of cast iron, but may also be made from steel casting or fabricated from steel plate. The drum diameter depends on the diameter of the rope chosen. When the drum is rotated by a motor, helical grooves are provided on the face of the drum so that the rope winds up uniformly and with minimum wear. The size and pitch of the grooves are selected such that there is no jamming or overlaying of wire rope. Table 8.1.2 gives the normal dimensions of grooves on drum.

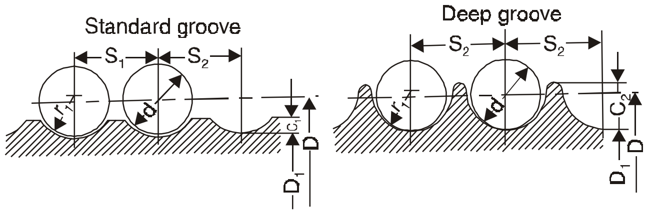


Table: 8.1.2. Dimension of drum grooves

Rope dia d	r_1	Standard groove		Deep groove			Rope dia d	r_1	Standard groove		Deep groove		
		s_1	c_1	s_2	c_2	r_2			s_1	c_1	s_2	c_2	r_2
4.8	3.5	7	2	9	4.5	1.0	19.5	11.5	22	5	27	13.5	2.0
6.2	4.0	8	2	11	5.5	1.5	24.0	13.5	27	6	31	16.0	2.5
8.7	5.0	11	3	13	6.5	1.5	28.0	15.5	31	8	36	18.0	2.5
11.0	7.0	13	3	17	8.5	1.5	34.5	19.0	38	10	44	22.0	3.0
13.0	8.0	15	4	19	9.5	1.5	39.0	21.0	42	12	50	24.5	3.5
15.0	9.0	17	5	22	11.0	2.0							

Drums with one coiling rope have one right handed helical groove. However, drums designed for two ropes, which is more common to accommodate **multiple pulley system** (refer to section 8.1.3), are provided with two helices—right hand and left hand.

The number of turns of rope on the drum for one rope member is given by the formula:

$$Z = \frac{Hi}{\pi D} + 2,$$

where,

i = ratio of pulley system

H = Max height to which the load is to be raised

D = drum diameter

The number 2, in above formula, is added to account for extra turns to hold the rope on the drum.

The length "L" of the grooves on the drum then becomes L = Zs, where "s" is the pitch of grooves.

Allowing a length of 5s for accommodating fixture for fastening the rope and for both side flanges, the full length of the drum becomes:

$$L = \left(\frac{Hi}{\pi D} + 7\right)s$$

If two rope members are coiled on the drum (multiple pulley system), the full length of the drum is given by the formula:

$$L = \left(\frac{2Hi}{\pi D} + 12\right)s + l_1$$

where l_1 is the space in middle of drum, between the two helices.

The wall thickness 't' of a cast iron drum can be approximated by the empirical relation:

$$t = 0.02D + (0.6 \text{ to } 1.0) \text{ cm, where } D = \text{drum diameter in cm.}$$

Fastening arrangement of the end of rope on drum is an essential feature. Various methods are available, but the popular method is to fix two turns of the rope by a steel plate which is pressed towards the drum by means of screw or stud. The steel plate is provided with part grooves made on the bottom side to fit on the two turns of rope.

8.1.3 Pulleys and Pulley Systems

Pulleys can be of two designs—**fixed** and **movable**. Fixed pulleys having fixed axles are also called guiding pulleys as they help to change the direction of the flexible element (wire rope in the case of hoisting equipment).

Use of each pulley increases the pull or effort on the rope, because of the resistance offered by the pulleys. Pulley resistance arises out of resistance of the rope to bending over the pulley and frictional resistance in the pulley bearings.

Moveable pulleys have movable axles to which either a load or effort is applied. Accordingly, there are two applications of movable pulleys, firstly for a gain in force and secondly for a gain in speed. The two applications of movable pulley have been shown in Fig. 8.1.5.

For the figure shown in 8.1.5(*a*), the distance 'S' traveled by the point in rope where effort 'Z' is applied is equal to twice the height 'h', to which the load 'Q' is raised.

$$S = 2h \text{ and } c = 2v.$$

where c = speed rope and v = speed of load.

The effort $Z = \in S_o$, where $\in$ is called **pulley factor of resistance.**

We have $Z + S_0 = Q$ and $2Z_0 = Q$.

or $$Z + \frac{Z}{\in} = Q = \frac{Z(1+\in)}{\in}$$

or $$Z = \frac{\in Q}{1+\in}$$

Efficiency 'η' of the pulley is given by

$$\eta = \frac{Z_0}{Z} = \frac{Q}{2} \times \frac{(1+\in)}{\in Q} = \frac{1+\in}{2\in}$$

If $\in \cong 1.05$, then $\eta \cong 0.975$

For the figure shown in 8.1.5(b), $S = \frac{h}{2}$ and $c = \frac{v}{2}$

The efficiency η can be shown to be $= \frac{2}{1+\in}$

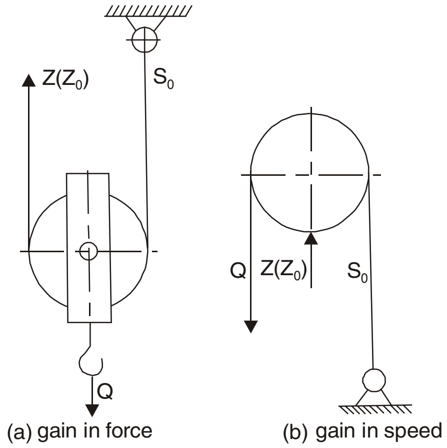


Fig. 8.1.5. Moveable pulleys

Pulley systems

Combination of several movable and fixed pulleys or sheaves, intended to achieve a gain in force or gain in speed, is called a pulley system. Fig. 8.1.6 shows a few pulley systems employed for gain in force. In a simple pulley system, a single pulley is mounted one one shaft.

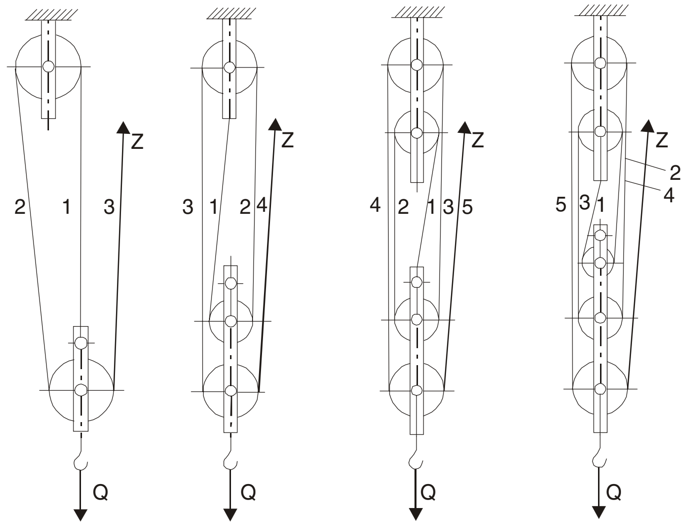


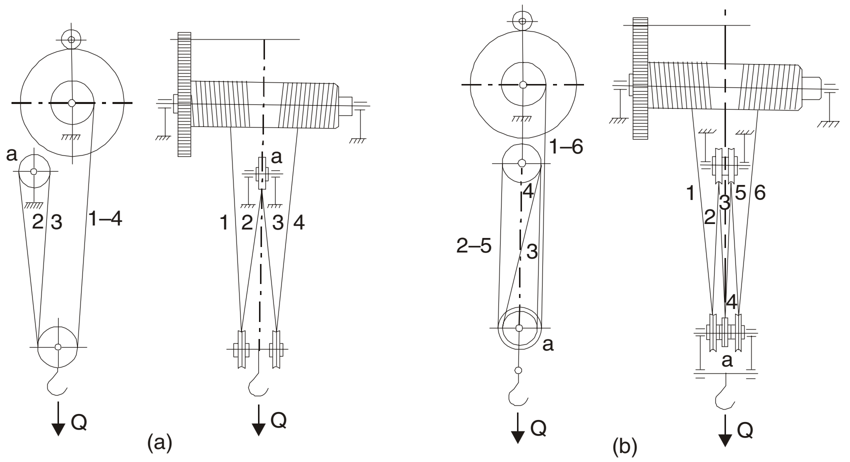
Fig. 8.1.6. Simple pulley systems employed for gain in force

The shortcomings of directly suspending a load from the rope end or from employing simple pulleys for gain in force during hoisting the load are:

(*i*) The different parts of rope are in one plane and this may allow load to sway freely at right angles to the plane of rope.

(*ii*) Because of coiling of rope in drum along its length, the load also moves in a horizontal direction.

By using **multiple pulley systems**, these shortcomings can be avoided, specially in electrically driven winch or crane hoisting mechanism. The load is raised in a strictly vertical direction and with much less tendency of sway. With use of multiple pulley systems, the force acting on the ropes are reduced and size of rope and consequently size of drum can be reduced. This reduces the size, weight and cost of the entire mechanism. Fig. 8.1.7 illustrates multiple pulley systems used for gain in force. In multiple pulley system, Load is hung from more than one pulley mounted ona common shaft.



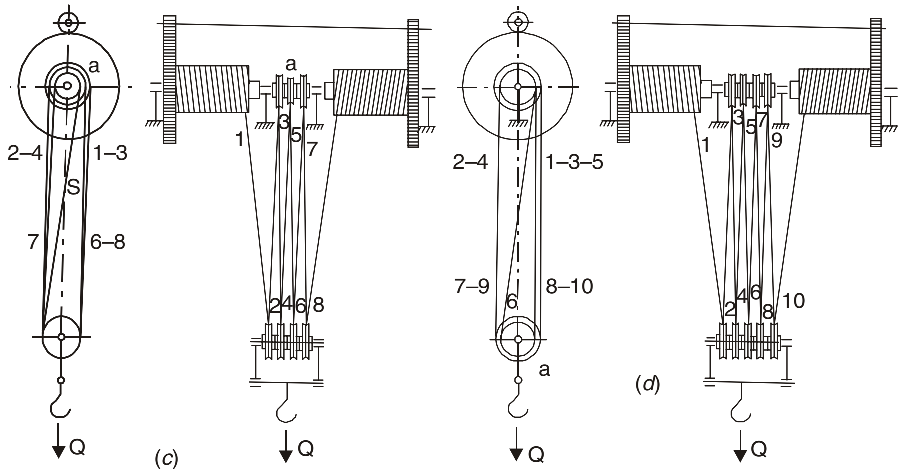


Fig. 8.1.7. Multiple pulley systems used for gain in force

In these systems, the two ends of the wire rope are fixed on a drum or on two drums with right and left hand helical grooves. The rope passes from one half of the pulley system to the other by means of a compensating pulley 'a' (this is a slightly smaller pulley put in between a multiple pulley system with odd number of pulleys) which simultaneously equalises the lengths of rope parts when they stretch non-uniformly.

Fig. 8.1.7(*a*) shows a multiple pulley system with four parts of rope, which are generally used to carry upto 25tons. The transmission ratio i =2 as the length of rope being wound around each half of the drum is 2h, where h is the lifting height. The rope speed is c = 2v. The system efficiency is about 0.94.

The figures b, c, d are different multiple pulley systems with following particulars:

Figure	rope parts	i	load limit, tons	efficiency, η
Fig. (b)	6	3	50	0.92
Fig. (c)	8	4	75	0.9
Fig. (d)	10	5	100	0.87

8.1.4 Arresting Gears and Brakes

In hoisting equipment, use of arresting gears or brakes is of paramount importance to prevent the raised load from getting lowered of its own weight, when the raising effort is withdrawn.

Arresting gear is used to hold the load lifted by winches. The common arresting gears are

(*a*) **Pawl and ratchet** mechanism *i.e.* ratchet gearing. This comprises of ratchet wheel and a pawl. The ratchet teeth can be arranged external or internal to the wheel. The teeth are so designed that the ratchet wheel runs free over the pawl when the load is being raised, but the pawl gets engaged with ratchet tooth when the ratchet wheel tries to rotate in opposite direction (lowering direction of load). During lowering of load, the pawl has to be kept deliberately away from ratchet path.

(*b*) **Roller ratchet** or roller clutch is used as an arresting gear in combination with a brake.

Brakes are used for dual purpose of holding the suspended load at rest and for controlling the speed of lowering of load.

Some of these brakes are to be operated while some are automatic. Operated brakes include shoe, band, cone, disk brakes etc. Centrifugal brakes and brakes applied by weight of the load are the automatic types.

Actuation of the operated brakes may be through pulling a handle or by pressing a pedal which are termed as mechanical brakes. Actuation can be through energizing magnet by AC or DC electricity (**electromagnetic brakes**) or may be by hydraulic means (**electro-hydraulic thrustor brakes**).

The electromagnetic brakes and electrohydraulic thrustor brakes can be used as controlled brakes. Moreover, these brakes can also be used as fail safe device. Normally these are in open condition (brake is not engaged), but actuates when the power fails. Fig. 8.1.8 shows line diagrams of an electromagnetic brake and a thrustor brake.

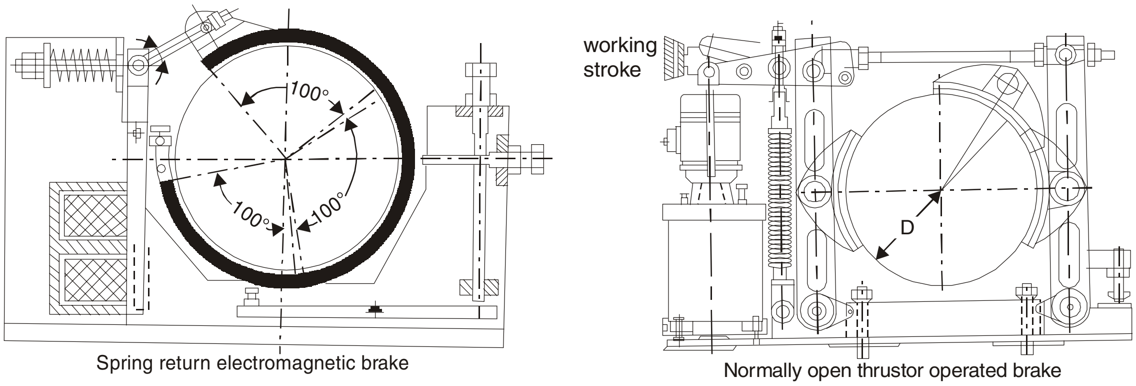


Fig. 8.1.8. Line diagrams of an electromagnetic brake and a thrustor brake

8.1.5 Load Handling Attachments

The common attachments used with various hoisting equipment are (A) **hooks**, (B) **grabs** of different types, (C) **grab buckets** for bulk load, (D) **ladles** for liquid materials, (E) **electro magnets** etc.

These different attachments are discussed below:

(A) **Hooks:** The common method of lifting unit load by hoisting equipment is to sling the load by chain or rope and suspended it from the hook of the hoisting equipment. To facilitate handling of loads by hook, many manufactured goods or packages are provided with hooking facilities (rings, bails, holes etc. through which a hook may be readily introduced).

After forging and machining operations, the hooks are annealed. The inner diameter of the hook should be sufficient to accommodate two strands of chain or wire rope. The load is always carried by four elements sling with two loops. The body of the hook is generally of trapezoidal section while it ends at the top in a round section working under tension. The top part of the shank is threaded for suspension from a **crosspiece**. Hooks are mandatorily to be tested under testing load and got certified before use.

Some of the common types of hooks are as follows:

(*i*) **Standard hooks** are the most commonly used hooks which have a single curved horn.

(*ii*) **Ramshorn hooks** have two horns like that of a ram. Saddles of each horn is smaller than the saddle of a standard hook of same capacity.

(*iii*) **Solid triangular eye hooks** are used in cranes of capacity over 100 tons. The disadvantage of these hooks is that the sling rope must be passed through the eye first, before they are attached to the load.

(*iv*) **Hinged triangular hooks** are made up of a few components, and are much simpler to produce.

Fig. 8.1.9 shows line diagrams of standard, ramshorn and hinged triangular hooks.

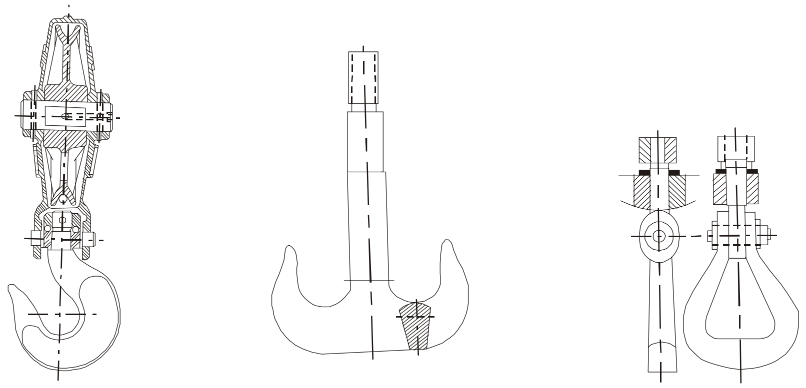


Fig. 8.1.9. Standard, ramshorn and hinged triangular hooks

Suspension of hooks

The cylindrical shank portion is generally fitted to a **crosspiece** provided with machined turnions at the ends. If the hook is fitted with a thrust bearing resting on crosspiece top, the hook may be rotated freely even with load. The crosspiece is pivoted in the side plates of casings usually reinforced with straps or shackles made of plate steel. Two or more rope pulleys/sheaves may be mounted on the extended trunnions of the crosspiece or multiple pulleys may be fitted in the casings. Fig. 8.1.10 shows a few of the many different arrangements of suspending hooks with crosspieces and casings with sheaves.

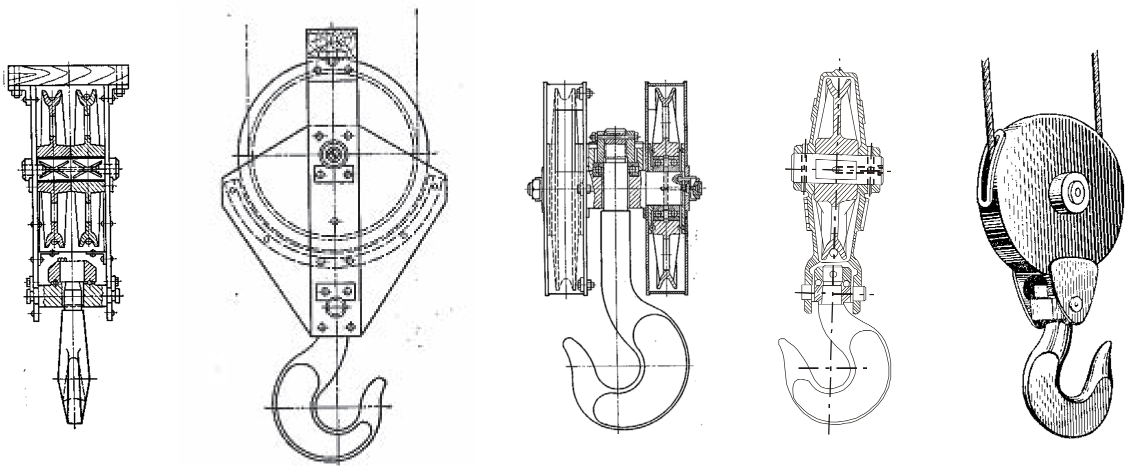


Fig. 8.1.10. Different arrangements of suspending hooks with crosspieces and casings with sheaves

(B) **Grabs:** For quick suspension and release of typical types of loads, certain specific grabs are used. The special performance requirements of these grabs are:

(*i*) conformation to the shape and properties of the load.

(*ii*) quick grabbing and releasing.

(*iii*) adequate strength and reliability.

(*iv*) safety to men and loads.

(*v*) convenience of use.

(*vi*) low weight.

Some of the common grabs in use are briefed below:

(*a*) **Carrier beams** are employed to lift long and heavy loads. Fig. 8.1.11 shows a carrier beam with adjustable shackles from which the loads are suspended.

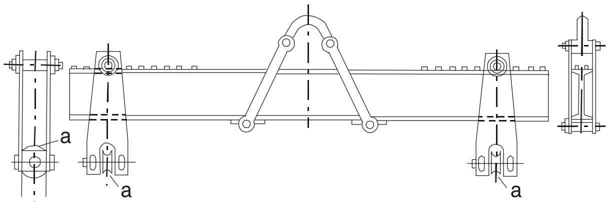
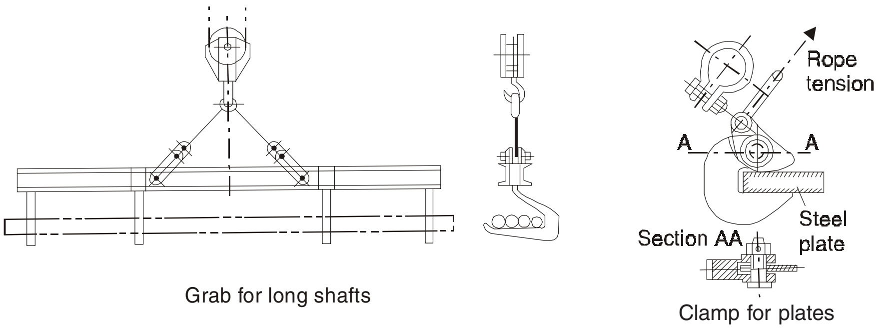


Fig. 8.1.11. Carrier beam with adjustable shackles for a foundry crane

(*b*) **Crane grabs and clamps** of different styles are used for handling different types of load.

(*i*) carrier type grabs are used for carrying short or long shafts. (*ii*) Clamps are used to grip sheet or plate type loads.

Following Fig. 8.1.12 exhibits a few types of grabs and clamps



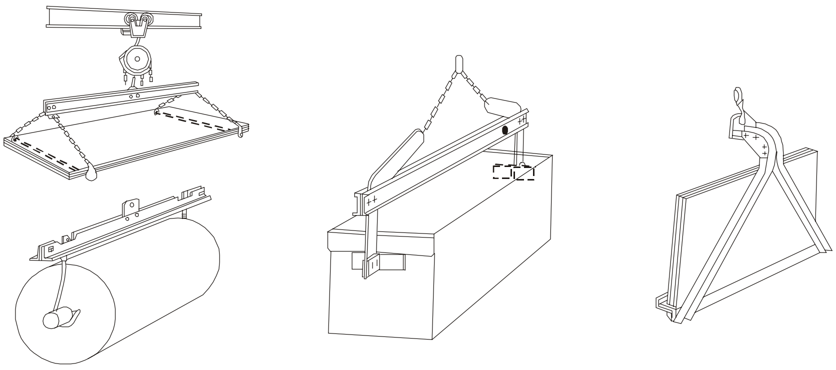


Fig. 8.1.12. Grabs and clamps

(*c*) **self closing tongs** are used for automatic grabbing of different shapes. The tongs are made self closing to avoid manual intervention during grabbing. Fig. 8.1.13 shows a few self closing tongs.

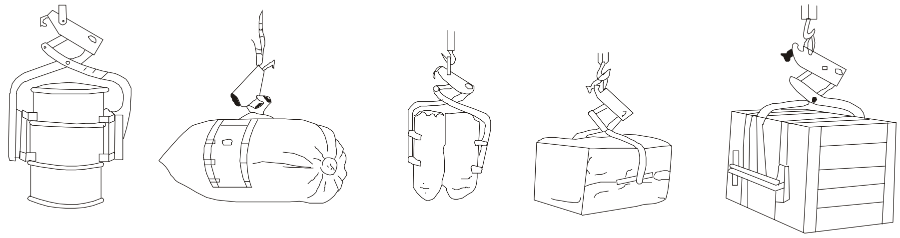


Fig. 8.1.13. Self closing tongs

(C) **Grabbing attachments** are used for lifting loose/bulk materials by means of a crane and transferring them. There are basically two types of these grabbing attachments for loose materials:

(*a*) **Tubs:** These are box type structures made from steel sheets. The tubs are provided with doors at the bottom or sides which can be opened by pulling a rope from the crane for automatic dumping of the contents inside the tub. However, these tubs have to be filled up manually or by using some other materials handling equipment. The tubs are provided with bails for suspending them from a crane hook.

(*b*) **Grab buckets:** These are specially designed bucket attachments which scoop loose materials and dump them mechanically through manipulation of ropes from the crane. Grab buckets are used for handling large amount of loose materials through cranes.

The bucket essentially consists of two clam shell like scoops with rounded bottoms which are hung by four rods from a top cross-member. The inner ends of the scoops are also hung from another movable cross-member. All the joints are provided with pins for pivot action. The top and bottom cross-members are suspended through ropes from a crane.

The principle of operation of a double-rope grab bucket is shown in Fig. 8.1.14. When the rope S_1 for bottom cross-member is loose, the grab buckets open up due to its own weight. At this position the bucket is lowered until the two scoops gets into the material. The rope S_1 is then tightened when the lower cross-member moves up and closes the scoops with material inside. In this closed condition the grab bucket is transferred, and at desired point, the rope S_1 is again loosened when the buckets open on its own and scooped materials' weight and discharges the materials.

There are many designs of clamshell buckets where number of ropes may be 1, 2 or 4, or scoops are operated by special mechanisms. Fig. 8.1.14 also shows an asymmetric grab bucket design which are simple in design and close the scoop edges well.

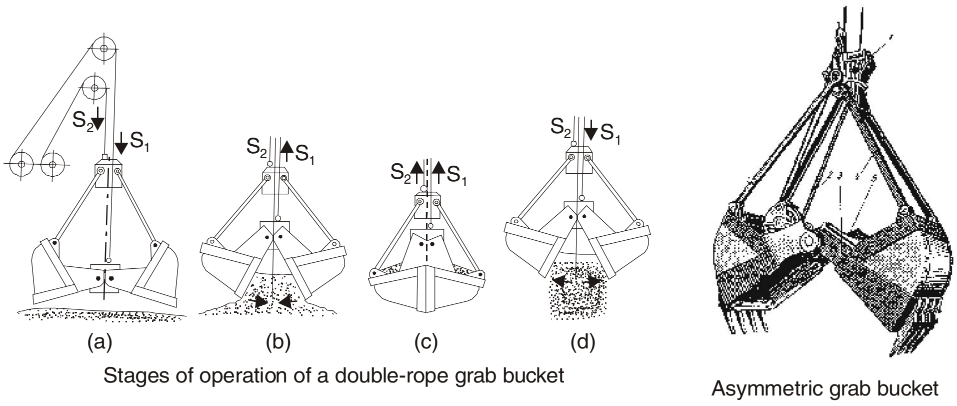


Fig. 8.1.14. Grab bucket

(D) **Ladles:** Ladles made from plate steel and having a refractory lining are used for carrying hot liquid metal. Small ladles or crucibles may be handled manually. But large ladles are conveyed in ladle cars, but more commonly by cranes. A crane ladle essentially has a bail. Smaller ladles may be tilted (for pouring) manually and medium size ladles by hand wheel actuated mechanism. However, large ladles are tilted by special devices actuated from the crane itself.

(E) **Electromagnets:** Electro lifting magnets are used to handle magnetic materials of different shapes and sizes like ingots, steel structurals (beams, rails etc.), plates, scraps, pigs, metal chips etc. The particular advantage of using magnets for lifting is that it does not need any time for fixing or releasing of the load. It is also very convenient for stacking of such items to a large height without labour. However, electromagnet has the risk of materials falling off in the event of a power failure. The other disadvantage is the large weight of the magnet itself which reduces the capacity of the hoisting crane.

Electromagnets are particularly popular in steel plants, fabrication yards and scrap yards. The magnets are generally hung from the crane hook through chain slings.

8.2 HOISTS

8.2.1 Definition, Characteristics and Uses

Hoist is an apparatus for raising or lowering a load suspended from a hook on the end of a chain or wire rope. A hoist may be fixed i.e., stationary, base mounted or supported from overhead by a clevis or hook. It may be travelling type mounted on a track (Fig. 8.2.1).

Hoists are rugged, dependable, simple to operate and inexpensive. Their installation is easy. Operation of a hoist can be by hand through pulling of chain, compressed air or electricity (operated by pendant switch box).

Hoists are truly the basic hoisting equipment. These are extensively used in manufacturing industry, workshop, godown, truck terminal, construction & erection site and even in small garage for handling relatively light loads. These are used for loading and unloading of varying jobs from machines, transfer of loads between work places. Hoists supplement overhead travelling cranes, when put on a monorail.

Limitations of hoists are that they are used for relatively lighter loads (2 to 3 tonnes), they are relatively slow, have limited travel distance and fixed direction determined by the track.

(a) (b)

Fig. 8.2.1. (*a*) Fixed hoist, (*b*) travelling electric hoist

8.2.2 Constructional Features

(A) **Hand operated Hoists:** A hand operated hoist essentially consists of a large diameter welded chain sprocket which is rotated by pulling of an endless chain. The sprocket is connected to another smaller chain sprocket through a system of gearing with large speed reduction. The gearing may be planetary spur gear system or may be worm-worm wheel arrangement. For this gearing system, the torque applied at the input sprocket is multiplied at the output sprocket, and a heavy load may be lifted with comparatively lighter pull at the input chain. When a worm-worm wheel is used, the gearing system is self locking, but in spur gearing system an arresting arrangement (generally ratchet-pawl) is provided to avoid descend of the load by its own weight. The entire sprocket and gearing system is enclosed in a frame.

In case of a travelling hoist, the main hoist frame is fixed to the bottom of a 4 wheeled trolley frame. The wheels are supported on the track. The bottom flanges of an I-beam is the most commonly used track. Pair of wheels on one side are provided with two spur gears which are connected by a smaller gear in the middle. On the shaft of this small gear is fitted a chain sprocket. On rotating this sprocket by pulling of an endless chain, the trolley moves on its track, and carries the load to the desired point. Fig. 8.2.2 shows the constructional features of a typical hand operated worm-geared trolley hoist.

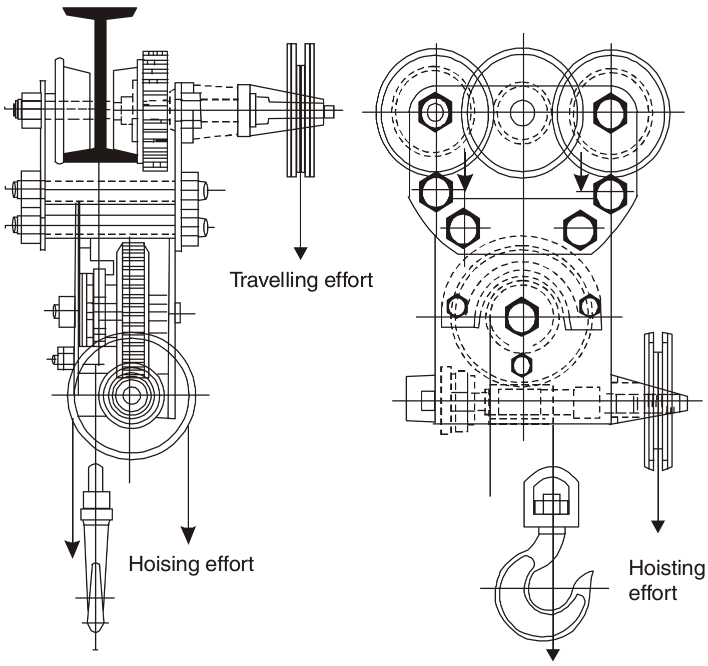


Fig. 8.2.2. Constructional features of a typical hand operated worm-geared trolley hoist

In smaller capacity hoists, the trolley may be moved by simply pulling it by a chain. These are termed as hand pushed trolley hoist.

(B) **Electric hoists:** An electric motor driven hoist has one or two rope drums for coiling and uncoiling the hoisting wire rope. The hoisting motor drives the drum through a planetary gearing system. The gearing system with high reduction ratio serves dual purpose of increasing torque as well as reducing speed of hoisting. 2-speed motors may be used for obtaining two hoisting speeds. The lower speed is employed at the start of hoisting or at the finishing stage of lowering the load, to avoid heavy jerk on the rope and pulley system or impact of the load with the floor. The rope is connected with a hook (see Fig.8.1.10).

The trolley for travelling hoist may also be powered by another motor. Motion from the motor is generally transmitted to the wheel through three pairs of spur gears. The motors of an overhead electric hoist is controlled by a pendant switch box hanging from the hoist frame at a convenient height for operation from floor level.

8.2.3 Specifications

Irrespective of its type (hand or electric or pneumatic), the most important specification of a hoist is its maximum load hoisting capacity. The next important specification is maximum operational lift or height. For travelling hoist, the important specifications are the size of I-beam track and the minimum radius of curvature through which the trolley can be maneuvered. For electric hoist, the hoisting speed/s and travelling speed are two important specifications. Overall size of the hoist, chain or wire rope size etc. are the other specifications an user will be interested in.

Hoist manufacturers manufacture different types of hoists in different standard capacities and lifts and all the relevant specifications are indicated in their product catalogues.

8.3 WINCHES

8.3.1 Definition and Uses

Winch is an equipment for pulling a heavy load by winding one or two ropes on a rope drum. It is a stationary equipment which is fixed to the floor or wall.

Winches, like hoists, are rugged and simple equipment with minimum maintenance. Winch may be hand operated or motor powered.

Winches are used as an independent pulling equipment at construction sites. However, they are also used as an integral part of various other equipment like skip hoist, certain types of cranes etc.

8.3.2 Constructional Features

The main component of a winch is the rope drum, supported by bearings at two ends mounted on the winch frame. The frame may be made of cast iron or fabricated from steel plate. The rope drum is generally single and plain, where rope is wound in multiple layers. In sophisticated application as in a carne, the drum is grooved in two halves (double drum) for winding two ropes simultaneously. Suitable mechanism is provided for guiding the rope for proper laying on grooves during winding. The drum is connected to input effort through a series of gearing of suitable reduction ratio, which determines the ultimate pull in the rope corresponding to the torque applied at the input. In hand operated winch, the torque is applied by a handle of suitable arm length. A ratchet-pawl type arrestor mechanism is an essential feature for a winch. The arrestor ensures no unwinding of the drum when the input effort is withdrawn. In power-operated winch, a motor of suitable power-torque capacity is connected to the gear train through a coupling. In an electrically driven winch, a magnetic or thrustor brake is used inplace of pawl-ratchet mechanism for parking as well as controlling load lowering. The coupling between the motor and drive system is used as a brake drum on which the brake is applied. Such couplings are called **brake-drum coupling**.

Multiple -drum winches: when a winch is an integral part of a crane or derrick, a multiple-drum winch may be used. The number of drums is determined by the number of independent operations used in the crane or derrick. One drum is required to handle the main load. Another drum may be added when the main load is double-reeved and two drums lift the load simultaneously by winding two ends of the wire rope. Another drum is used where a crane or derrick boom needs to be raised or lowered. Line diagram of a typical double-drum hand operated winch is shown in Fig. 8.3.1.

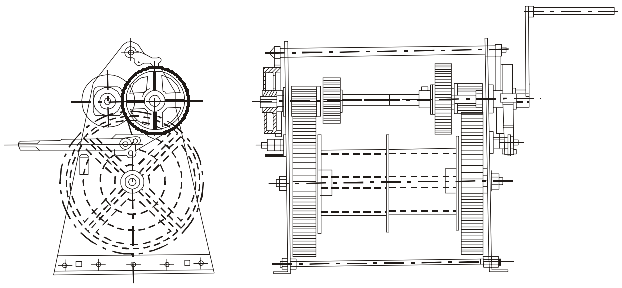


Fig. 8.3.1. Double-drum hand operated winch

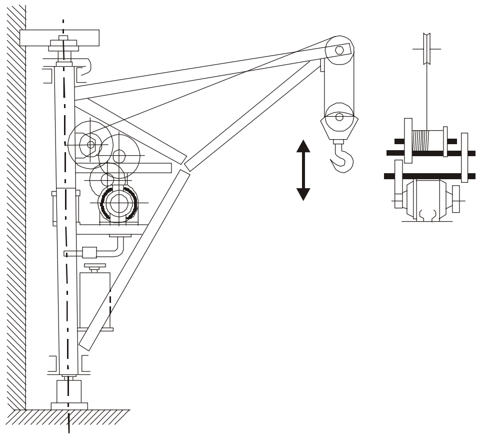


Fig. 8.3.2. Use of a winch in a stationary rotary pillar crane

Fig. 8.3.2 shows the use of a winch in a stationary rotary pillar crane.

Major specifications of a winch are: pulling capacity, length of rope, rope speed (for motorised winch) and number of drum used (single or double drum). The other specifications include overall dimensions, rope size, drum size, motor power etc.

8.4 ELEVATORS

The term **elevator** is used to signify a group of materials handling equipment which carries materials up or down. The group includes a number of diverse type of equipment like bucket elevators, skip hoists, freight elevators, lifts etc. Some of these equipment have been discussed in this section.

8.4.1 Bucket Elevators

(A) **Definition, descriptive specifications and use:** These are powered equipment for conveying bulk materials in a vertical or steep inclined path, consisting of an endless belt, or chain/s to which metallic buckets are fixed. With the flexible belt/chain, the buckets move unidirectionally within a casing and collects bulk materials at bottom end of the equipment and delivers it at the top end.

A typical bucket elevator with different constructional parts is shown in Fig. 8.4.1. The different major parts constituting a bucket elevator are as follows:

(*i*) An endless pulling member- flat belt or chain.

(*ii*) Driving and take up pulleys or sprockets at top and bottom respectively, mounted on bearings and blocks.

(*iii*) Metal casing covering the entire elevator. It consists of **head** at the top, **boot** at the bottom and intermediate sections, all joined at flanges by fasteners.

(*iv*) Buckets, generally made out of sheet metal, which are attached at definite pitch to the pulling member by fastners (screw and nuts, riveted etc.)

(*v*) Drive at the top consisting of an electric motor, gearbox, and couplings.

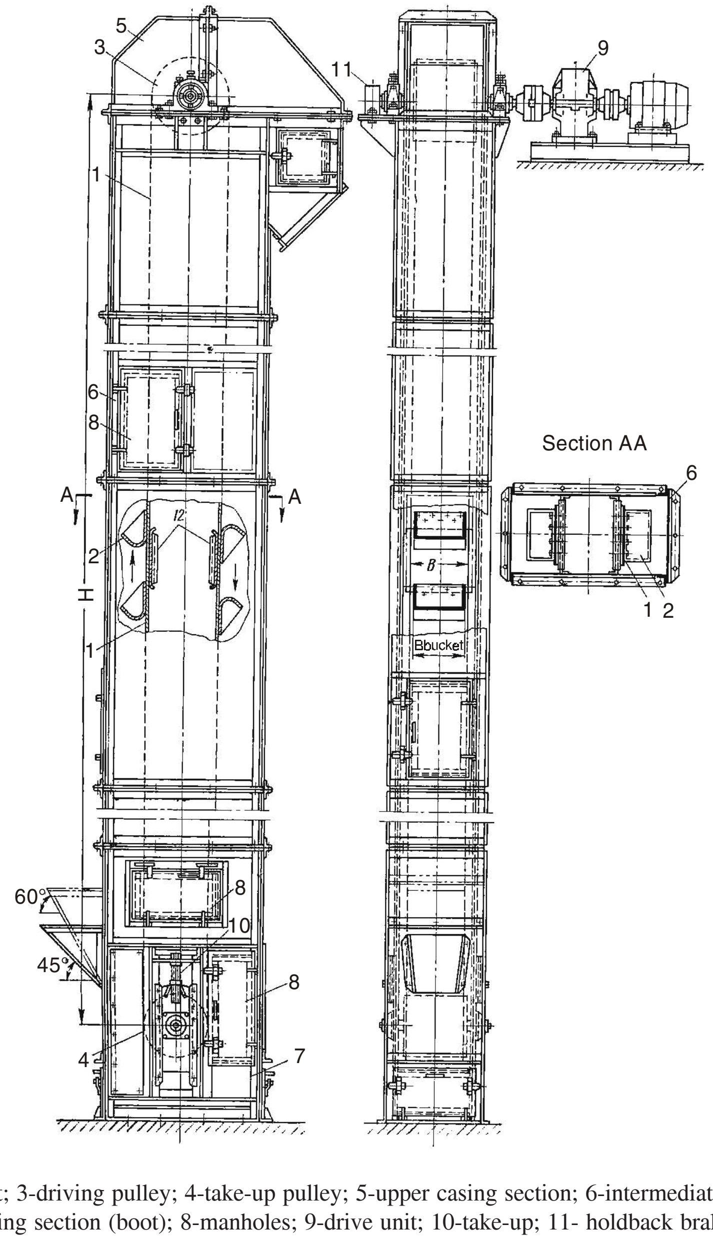
(*vi*) Hold back brake attached to the top pulley/sprocket shaft, to prevent reverse motion of the elevator when drive is stopped.

(*vii*) Feed hopper attached to the boot for feeding materials to the elevator.

(*viii*) Delivery/ discharge spout fixed with the top part of the casing, through which the material is discharged.

(*ix*) Manholes are provided at the casing to check operations of the elevator.

(*x*) Guides and guide sprockets are provided for belt and chain respectively to keep them in a straight path.



1-belt; 2-bucket; 3-driving pulley; 4-take-up pulley; 5-upper casing section; 6-intermediate casing sections; 7-lower casing section (boot); 8-manholes; 9-drive unit; 10-take-up; 11- holdback brake; 12-guides.

Fig. 8.4.1. A vertical belt-and-bucket elevator

Bucket elevator is a simple and reliable equipment widely used in process plants for lifting of bulk materials like lime stone, foundry sand, coke, coal, grain, dry chemicals and many more. Bucket elevators are generally low cost equipment requiring little floor space.

However, bucket elevator is not suitable for large sized (100mm or above), hot or sticky materials because buckets are generally loaded by scooping action in the **boot** section and discharge from the buckets by centrifugal force or gravity. Chain type, with one or two chain, elevators are suitable for a speed range of 0.6 to 1.55 mps, while belt type are recommended to be used in a speed range of 1.15 to 2.85 mps.

(B) **Types of bucket elevators:** Bucket elevators are classified based on bucket spacing and mode of discharge of materials. As per IS:7167-1974, ''Code for Selection and Use of Bucket Elevators,'' they are classified into following three basic types.

(*i*) **Centrifugal discharge elevators (designated as type I):** In a centrifugal discharge elevator, the buckets are spaced at a regular pitch to avoid interference in loading and discharging. The charging of buckets is by scooping action and the discharge is by centrifugal action. These elevators are generally used in vertical configuration and used for practically all types of free flowing, small lump materials like grain, coal, sand, clay, sugar, dry chemicals etc. Both belt and chain may be used and the speed of these elevators range between 1.1 to 2 mpm. Buckets of the type A_1, A_2, A_3 and A_4 as per IS:6833-1973 are generally used. Fig. 8.4.2 illustrates the charging and discharging of buckets of this type of elevator.

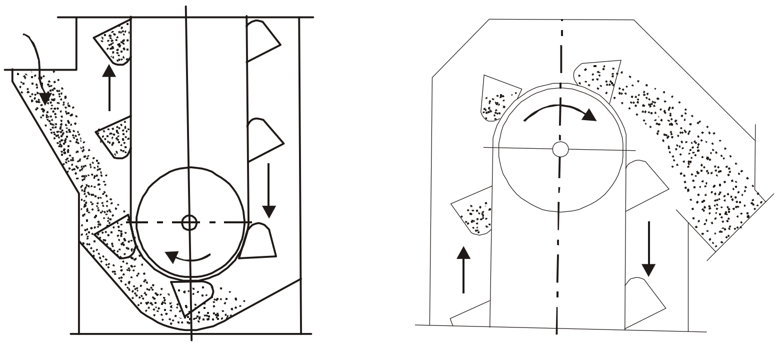


Fig. 8.4.2. Charging and discharging of buckets of centrifugal discharge elevator

(*ii*) **Positive discharge elevators (designated as type III):** These are similar to centrifugal discharge type excepting that the buckets are side-mounted on two strands of chains (i.e. buckets lie between two strands of chains), and are provided with a pair of two snub sprockets under the head sprockets to invert the buckets for complete discharge. The speed of the elevator may be slow in the range of 0.6 to 0.67 mpm. These elevators are used for light, fluffy, sluggish and slightly sticky materials. The feeding is through scooping or digging by the buckets. Fig. 8.4.3 shows the discharging of these elevators. An inclined elevator is particularly suitable for perfect gravity discharge.

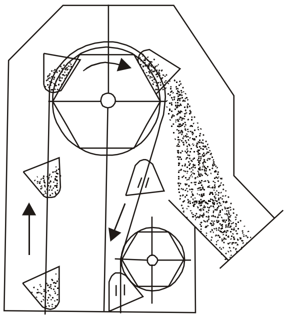


Fig. 8.4.3. Discharging of positive discharge elevator

(*iii*) **Continuous discharge elevators (designated as type II):** In these elevators, V-type buckets are used without any gap between them. These elevators are employed for handling larger lumps and materials that may be difficult to handle by centrifugal discharge. The charging of the buckets are by direct filling. The discharge is by directed gravity i.e. when the buckets pass over head wheel, the flanged end of the preceding bucket act as a chute to deliver materials gently to the discharging spout. This type of charging and dischargeing is particularly effective for handling fragile materials. Bucket type B_1, B_2, B_3 and B_4 as per IS:6833-1973 is used for these elevators. Both belt and chain are used as pulling medium. Speed is generally kept low. These elevators are used vertically or inclined. When inclined, special supports are provided for belt/chain in the return run, and wider casing is provided to allow for return run sag. Fig. 8.4.4 shows the charging and discharging of a continuous bucket elevator.

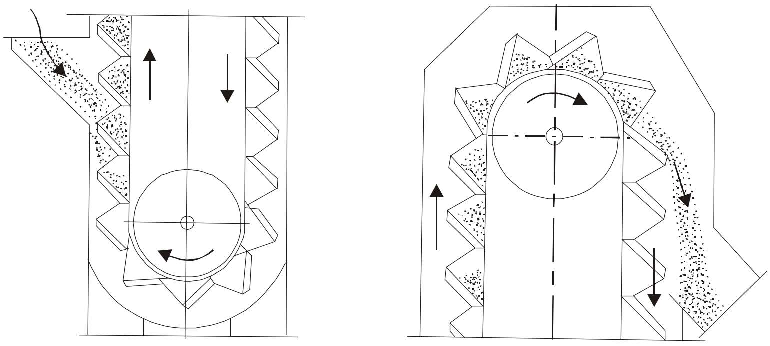


Fig. 8.4.4. Charging and discharging of a continuous bucket elevator

Fig. 8.4.5 shows photograph of head section (with part of cover removed) of a working bucket elevator.

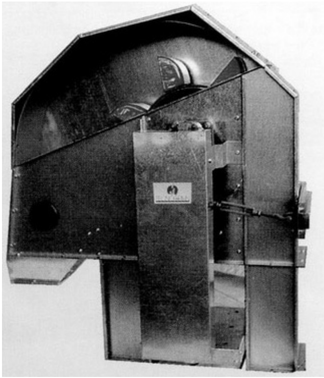


Fig. 8.4.5. Part cover removed head section of a bucket elevator

Selection of type of elevator: Selection of type of bucket elevator depends primarily on materials to be handled. IS:7167-1974 recommends an elaborate list of different materials (123 in number) with the corresponding type of elevator to be selected and whether belt or chain to be used. Recommendation for only a few materials is shown in Table 8.4.1.

Table. 8.4.1. Recommendation for Selection of Bucket Elevators

Materials	Bulk density, kg/m^3	Belt /chain	Type of elevator (see note)
Alum, lumpy	800-960	Chain	I, III
Aluminum ore	1200-1350	Chain	I, III
Ashes	560-640	Chain	I
Bauxite, crushed and dry	1200-1350	Chain/belt	I, III
Carbon, black pelletized	320-400	Chain	III
Carbon, black powder	65-100	Chain	II
Cement, Portland	1200-1350	Chain	I, III
Chalk, pulverized	1120-1200	Belt / Chain	III
Coal anthracite	960	Chain/belt	I, III
Coke, loose	370-510	Belt	I
Gypsum calcined	880-960	Chain	I, III
Lime, ground	960	Chain	I, III
Lime, hydrated	560-720	Chain/belt	III
Malt, dry ground	320-335	Belt/ Chain	I, II
Rice, bran	320	Belt/ Chain	I
Salt, dry coarse	720-800	Belt/ Chain	I, III
Sand, damp	1760-2080	Belt/ Chain	I
Sand dry	1440-1760	Belt	I
Sugar raw	880-1040	Chain/belt	I
Talc	800-960	Belt	I

Note to Table 8.4.1 :

I = Centrifugal discharge bucket elevator.

II = Positive discharge bucket elevator.

III = Continuous bucket elevator.

(C) **Buckets for bucket elevator:** The different components of a bucket elevator have been mentioned under ‘‘descriptive specification’’ in section 8.4.1 (A). The buckets used in a bucket elevator needs further elaborations.

The buckets used are made as per BIS specification number IS:6833-1973 (reaffirmed 1996),‘‘Specification for Buckets for Bucket Elevators’’. The buckets are manufactured from suitable steel, aluminum or stainless steel sheet. The buckets may be cast also from malleable cast iron (IS:2107-1962 or IS:2108 -1962), cast steel, aluminum or even stainless steel castings.

Buckets are classified into two types from consideration of their shape: Rounded bottom buckets are used in spaced bucket elevators and are classified as A_1, A_2, A_3 and A_4 type. V-type buckets are used in continuous bucket elevators, and are classified as B_1, B_2, B_3 and B_4 type. Fig. 8.4.5 illustrates geometrical features of the various types of buckets.

Specified dimensions of these buckets namely length, projection, depth and capacity of the individual buckets are given in IS:6833-1973. Table 8.4.2 below indicates only the range of recommended dimensions of such buckets.

Table 8.4.2. Range of dimensions for buckets.

Bucket Type	Range of Bucket Size, mm			Capacity, litres	
	Length, mm	Projection, mm	Depth, mm		
A_1	150 to 1000	95 to 250	100 to 260	0.87 to 36.50	
A_2	150 to 1000	100 to 255	110 to 270	0.85 to 38.00	
A_3	150 to 410	90 to 165	130 to 230	0.71 to 6.80	
A_4	150 to 410	115 to 180	100 to 140	0.735 to 4.47	**S dimension**
B_1 and B_4	150 to 610	75 to 300	145 to 460	0.81 to 41.0	20 to 50 for B_1
B_2	150 to 610	75 to 300	145 to 460	0.81 to 41.0	20 to 50
B_3	150 to 610	75 to 300	145 to 460	0.93 to 45.6	

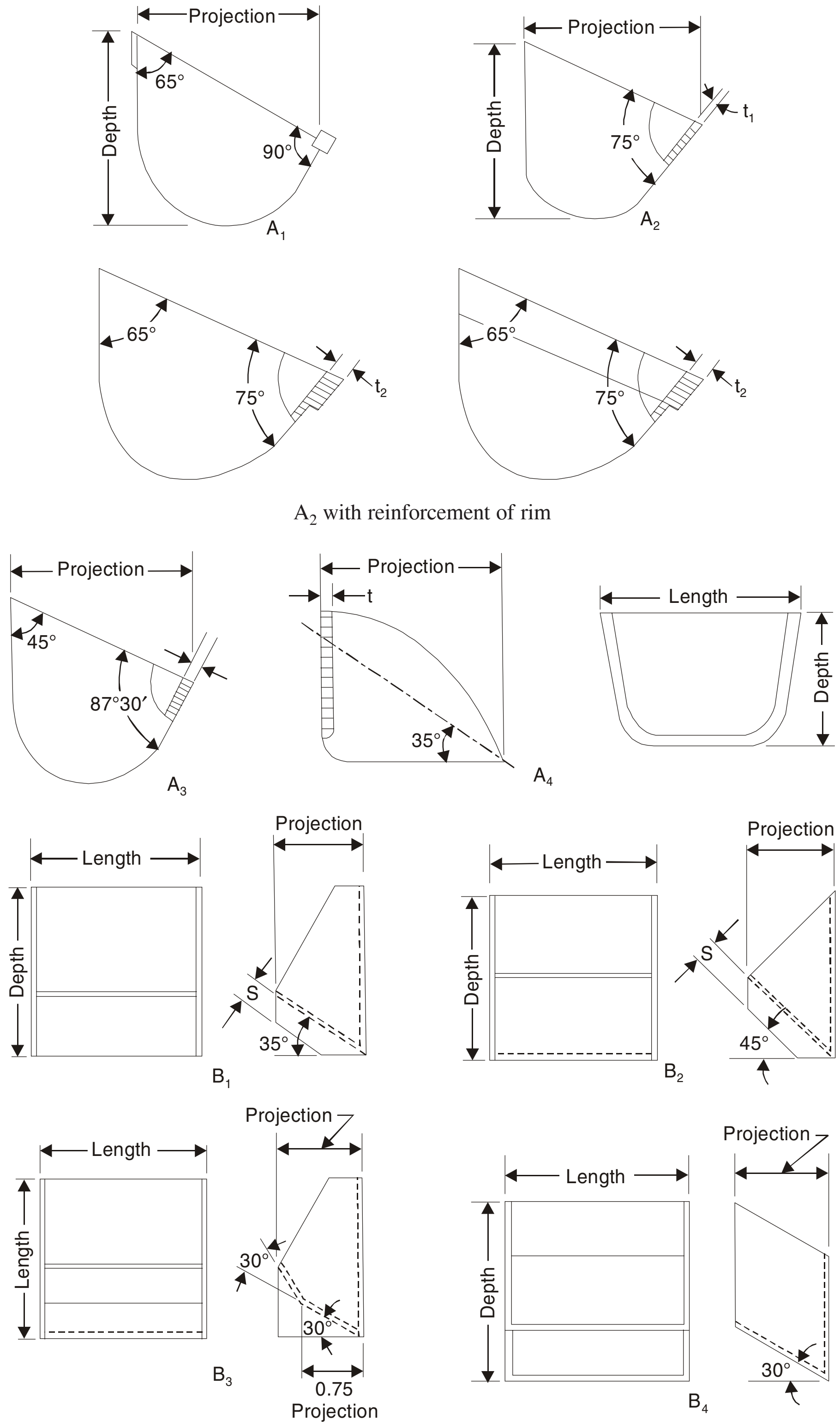
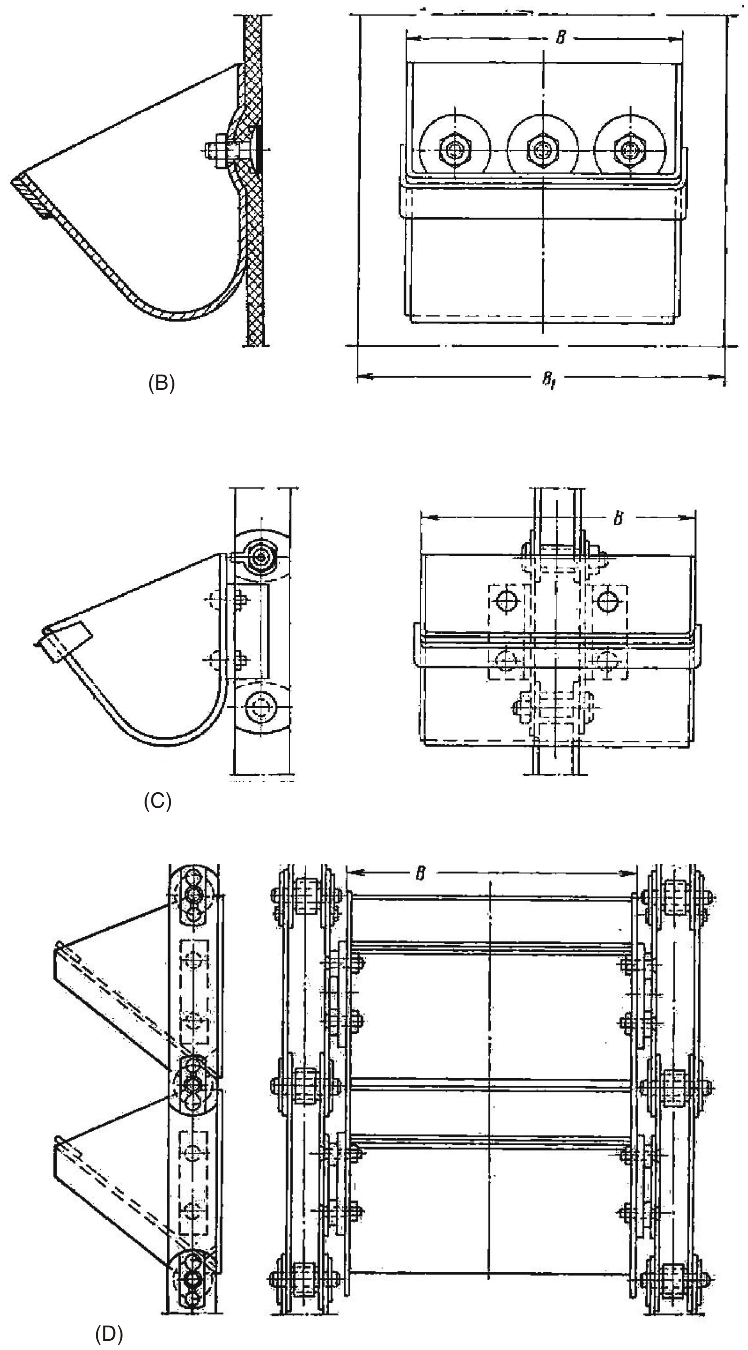


Fig. 8.4.5. Geometrical features of various types of buckets

Types A_1, B_1, B_2, B_3, B_4 buckets are fabricated from sheet metal with joints welded or pressed. Types A_2, A_3 and A_4 buckets are cast.



B-to belt; C-single chain; D-two chains to bucket side walls.

Fig. 8.4.6. Typical bucket fixing arrangement

Fixing arrangement of buckets: The method of fixing of buckets to belt or chain is specified in IS:6930-1973 (reaffirmed 1996)- "Fixing Arrangement of Buckets for Bucket Elevators".

The methods are designated by letters B, C and D as per following norms:

(*i*) Fixing of buckets to belt - B.

(*ii*) Fixing of buckets to chains passing through back of buckets - C

(*iii*) Fixing of buckets to chains passing through side of buckets - D

Typical bucket fixing arrangements are shown in Fig. 8.4.6.

Selection of type of buckets: The selection is based on the discharging method and materials to be conveyed. Recommendation of IS:7167-1974 is as given in the following table 8.4.3.

Table 8.4.3. Selection of Bucket

Type of elevator discharge	Type of bucket IS:6833	Recommended Application
Centrifugal and positive discharge	A_1	For powdered and free flowing material.
	A_2	For cement, coal, sand, gravel, stone, ores, fertilisers.
	A_3	For wet, stingy materials. Also for coarse broken materials.
	A_4	Sugar, clay, salt, wet ores.
Continuous discharge	B_1	For pulverized and sluggish materials that stick.
	B_2	For average materials.
	B_3	For large lumps and extra capacity.
	B_4	For inclined elevators.

(D) **Capacity calculation:** The discharge capacity 'Q' in tonne/hr. of a bucket elevator is given by the formula:

$$Q = \frac{C \times F}{1000} \times \frac{3600v}{s} \times \frac{\rho}{1000} \text{ tph}$$

where, C = capacity of each bucket, litres

F = bucket filling factor, a constant.

v = elevator speed, m/sec

s = bucket spacing, m

ρ = material bulk density, kg/m^3.

Bucket filling factor indicates both loading and discharging efficiency of buckets for a particular application. Bucket filling factor 'F' varies between 0.85 for powdered materials to 0.4 for sluggish, moist materials. Following table 8.4.4, gives the values of 'F' to be considered in the above calculation, as recommended by IS:7167-1974.

Table 8.4.4. Bucket Filling Factor, F

Material Characteristics	Type of Bucket Elevator	F
Powdered (ground) *e.g*. coal dust, cement, chalk, phosphate fertiliser etc.	Positive discharge Centrifugal discharge	0.85 0.75
Granular and small lumped (60 mm) mildly abrasive *e.g*. saw dust, dry clay in lumps, coal peat, grain, etc.	Centrifugal discharge	0.7 to 0.8
Granular and small lumped (60 mm) highly abrasive *e.g*. gravel, ore, slag, sand, ash, earth, rock, etc.	Continuous discharge Centrifugal discharge	0.7 to 0.85 0.5 to 0.7
Medium and large lumped (60 mm) highly abrasive *e.g*. crushed ore, stone, slag	Continuous discharge	0.6 to 0.8
Lumped, fragile, down graded by crushing *e.g*. charcoal, coke etc.	Continuous discharge	0.6
Slugglish, powdered and granular, moist *e.g*. moist chemicals, fluffed peat, earth, wet sand, wet powdered chalk etc.	Positive discharge Centrifugal discharge	0.4 to 0.6 0.4 to 0.6

The recommended bucket spacing 's' is also specified in IS:7167-1974, based on method of discharge and size of bucket used. For centrifugal discharge bucket elevators, it varies approximately between 2 to 3 times the depth of the buckets, while for positive discharge bucket elevators, it can vary between 3 to 5 times approximately. However, for continuous discharge elevators, it is kept marginally (10 to 20 mm) more than bucket depths, just necessary for fixing and to do maintenance to the buckets.

8.4.2 Skip Hoists

This is a very special type of elevators which is primarily used for charging of ores and other materials into tall furnaces like blast furnace, lime calcination furnace etc. and to carry other process materials.

A skip hoist consists of an open ended wheeled steel car called **skip**, which moves in two sets of rail tracks fixed to a fabricated structure called **skipbridge** or **skipway**. A winch is employed to pull the loaded skip up the steep incline of the skipway by means of a rope guided on a series of sheaves. Fig. 8.4.7 shows the conceptual details of a vertical skiphoist.

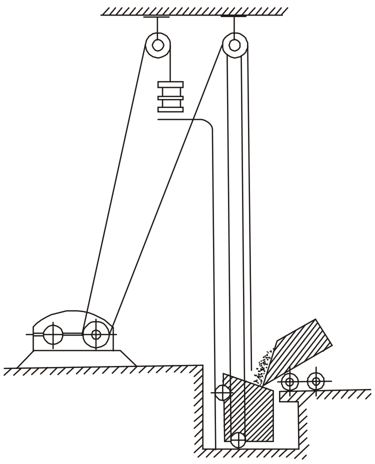


Fig. 8.4.7. The conceptual details of a vertical skip hoist

The skips are loaded at the ground or below ground level by appropriate loading devices. When the loaded skip reaches the top level, it gets automatically tilted at the end of the travel and discharges the material into the furnace through the open end. Tilting is actuated by laying two pairs of rails on the skipway. The front wheels of the skip rest on one pair while the rear wheels rest on another pair of rails. The rail carrying the front wheels are curved at their extreme ends so that the skips get automatically tilted at the end of their top travel.

For blast furnaces, generally two skips operate side by side on the same skip bridge. While one goes up with material, the other comes down to be filled with material. The capacities of each skip can be in the order of 20 tons or more. For other furnaces smaller capacity skip hoists are used. For the purpose of safety, generally the large capacity skips are connected with two pulling ropes, each being strong enough to pull the load. The length of travel for a typical blast furnace skip hoist is in the range of 80 meters, and speed is in the range of 130–150 mpm.

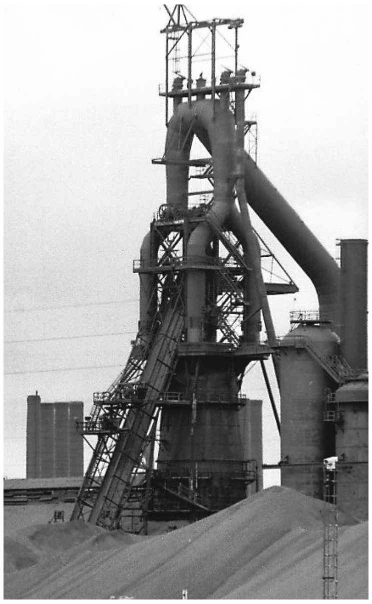


Fig. 8.4.8. Skip hoist in front of blast furnace

The winch used for a skip hoist is a grooved single drum winch, generally powered by two electric motors.

The entire operation of skip hoists is generally automated through proper electronic controls.

8.4.3 Freight Elevators / Lifts

For vertical movement of materials and men between different floors of a multistoried factory or building, freight elevators or lifts are used.

Such a freight elevator/lift consists of a box type **cage** or **car**, which moves vertically up and down through the designed opening kept in the floors, called shaft of the elevator. The movement of the car is guided by guide rails laid vertically in the shaft. The car is suspended from and moved up and down by a hoisting mechanism, located at the top of the shaft. The hoisting mechanism may either be (*i*) drum winch type or (*ii*) traction-type, as shown in Fig. 8.4.9. In the drum-type, one end of wire rope is firmly attached to the drum, and the other end to the elevator car top. A counterweight, usually equal to the weight of empty car plus one third of the duty load, is used for increasing the load lifting capacity of the winch motor of given rating.

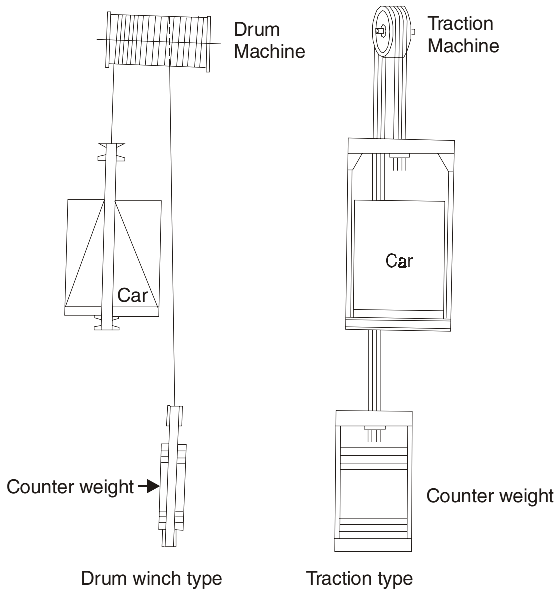


Fig. 8.4.9. Elevator hoisting mechanism

However, winch type mechanism is bulky and may pose difficulty in accommodating the winch at shaft top. In such cases, the traction-type mechanism consisting of multiple rope and multiple groove sheave, driven by a motor through gear box is used.

Beneath both the car and counterweight, spring type buffers are provided for shock absorption. Proper drive controls and indication instruments for knowing position of the car are provided. Freight elevator/ lift is provided with automatic brake which operates if the rope snaps and the car develops high acceleration.

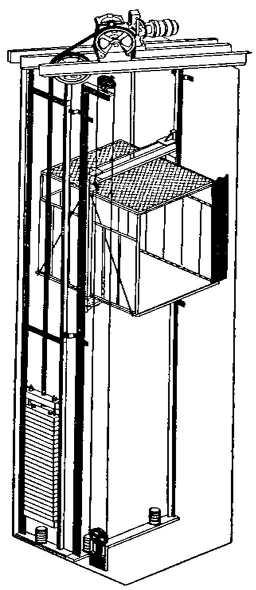


Fig. 8.4.10. Schematic view of an elevator

The speed of freight elevators are kept low, while the passenger lifts in high rises are quite fast (500 mpm or higher).

Cars of a freight elevator may be designed to suit type of materials they have to carry and for automatic loading by devices like:

(*i*) fork lift truck or platform truck

(*ii*) tow truck or trailers

(*iii*) roller conveyor

(*iv*) overhead monorail conveyor etc.

Fig. 8.4.10 shows a schematic view of an elevator showing the car supported in guide, the traction-type hoisting mechanism, counterweight and buffer springs.

8.5 CRANES

Crane is a materials handling equipment for lifting or lowering a load by a hook and moving (transferring) it horizontally, in which the hoisting mechanism is an integral part of the equipment. A crane may be driven manually or by power and may be fixed or mobile. Equipment like stackers, lift trucks, power shovels, backhoes, excavators and other hoisting equipment not discussed in this chapter are not included in the category of crane.

A crane essentially consists of (*i*) a steel structure, (*ii*) a hoisting mechanism or a winch mechanism with its pulley and pulley system, (*iii*) suitable load handling attachment /s and (*iv*) drive and controls.

The major classification of cranes is based on whether they are stationary or mobile. However, it is to be noted that, even for the stationary cranes, some structural component of the crane is capable of movement for transferring the load within reach of its movement. Movements of components of these stationary cranes may be linear, revolving or combination of both.

Revolving cranes: The characteristic feature of these cranes is presence of a structural arm called **boom**, which can be rotated through 360° about a vertical axis. These cranes are also called **rotary crane** or **slewing crane**. Boom may be strut or struss type. The lower end of the boom is affixed to a mast, base, carriage or support against which it can be pivoted and moved up and down which is called **luffing** or **booming**. The upper end of the boom supports a hook or other end attachments for lifting of load. Different types of cranes are grouped under this classification.

Mechanism employed for rotating the boom is called **slewing mechanism**. Usually three different types of slewing mechanisms are used which are:

(*i*) Crane superstructure revolves together with the pillar or column which is mounted on bearings. Jib cranes generally fall under this category.

(*ii*) The boom rotates about a pillar fixed on a foundation or in the crane truck.

(*iii*) The entire crane superstructure is mounted on **turntable** which rotates about and secured to its non revolving part. The turntable of the crane rests on a number of rollers running or a circular rail erected on the foundation or on the crane truck. Rack and pinion or cogwheel drives are generally employed for rotating the turntable.

Luffing is another important motion of the boom of a crane. It is the up and down motion of the boom about a pivot joint at the inner (base) end of the boom. Luffing motion of the boom can be imparted by applying various mechanism like (*i*) rack and pinion, (*ii*) nut and screw, (*iii*) segment gears, (*iv*) crank and link, (*v*) hydraulic cylinder and (*vi*) hoist drum and rope reeving system. Luffing motion is very important to reach loads lying at different distances from a stationery crane. It is to be noted that the capacity of a crane varies at different boom angles, which are indicated by the crane manufacturers.

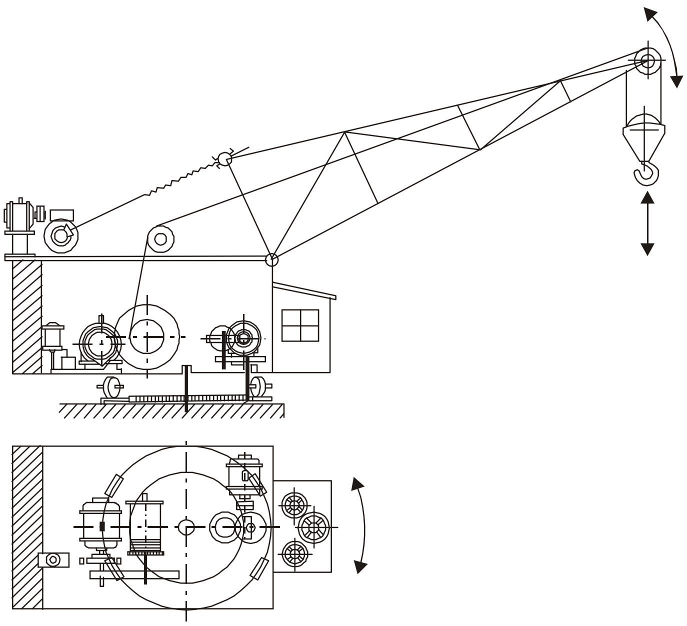


Fig. 8.5.1. Rotation and luffing motion of a turn table crane

Types of cranes

There are different types of cranes under each classification, based on their constructional features and specific uses. Some of the common types are:

Stationary Cranes

(*i*) Jib crane
(*ii*) Overhead Travelling crane (also called Bridge crane)
(*iii*) Gantry crane

Stationary Revolving Cranes

(*i*) Wharf crane
(*ii*) Pillar crane
(*iii*) Tower crane

Mobile Cranes

(*i*) Truck/wagon mounted crane
(*ii*) Crawler crane
(*iii*) Railway/Locomotive crane
(*iv*) Floating crane

Definition, descriptive specifications, characteristics, features & uses and some of the design variations of the above types of cranes are discussed below.

8.5.1 Jib Cranes

It is a stationary crane consisting of a vertical member (called pillar or column) from which extends a horizontal swinging arm called **jib**, carrying a trolley hoist or other-hoisting mechanism.

The jib is generally made from a standard I-beam section, and can rotate in a horizontal plane (i.e. no luffing motion) between 180° up to 360°, so that loads can be lifted and deposited within the sector of circle having its radius equal to the length of the boom. The extreme end of the arm is often supported from the vertical member by a tie rod.

Above description matches with other types of crane like tower cranes, pillar crane etc. However, the difference is basically in terms of size and capacity and thus in specific applications. A normal jib crane is generally limited to a jib length of 8meters and hoist capacity of 15tons. A typical jib crane is shown in Fig. 8.5.2.

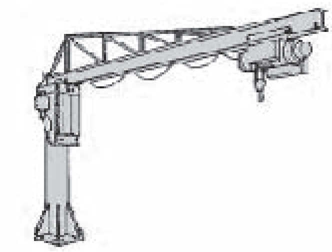


Fig. 8.5.2. A jib crane

Jib cranes are inexpensive and widely used in manufacturing industries for:

(*i*) serving individual or a group of work places in machine shops.

(*ii*) loading and unloading of vehicles.

(*iii*) handling ladle, casting and mould in a foundry.

(*iv*) moving loads across shop bays and thus supplementing on overhead traveling crane.

Different design variations of a jib crane is possible which are as follows:

(A) **Revolving pillar jib crane** in which the pillar or vertical column consists of a structural pipe. On the top of the column a thrust bearing of sufficient capacity is mounted, on which the jib constructed from a standard I-beam is mounted. The jib can rotate by 360° on the fixed column. The column base is bolted to the floor/ foundation or directly grouted in foundation. A manual or powered trolley type hoist is mounted on the jib. Stops are provided at the end of the track to prevent over travel. Fig. 8.5.3 shows photograph of such a jib crane.

Fig. 8.5.3. Revolving pillar jib crane

(B) **Swinging pillar jib crane** in which the jib and it's tie rod are connected to the vertical column through swinging fitting supports, welded with the column. The fittings allow swinging of the jib and the tie by about 180° about the fixed column.

(C) **Swinging bracket supported jib crane** is similar to a swinging pillar jib crane, excepting that there is no independent vertical column. Instead, the swinging fittings are wall-bracket type which are fixed on a vertical wall. This jib crane has maximum 180° rotation.

(D) **Revolving mast jib crane** is one in which the vertical column or mast is supported at the top and bottom on bearings. The jib is bolted or welded to the column. The jib is supported by tie rod. The jib can rotate along with its supporting column. Fig. 8.5.4 shows such a jib crane.

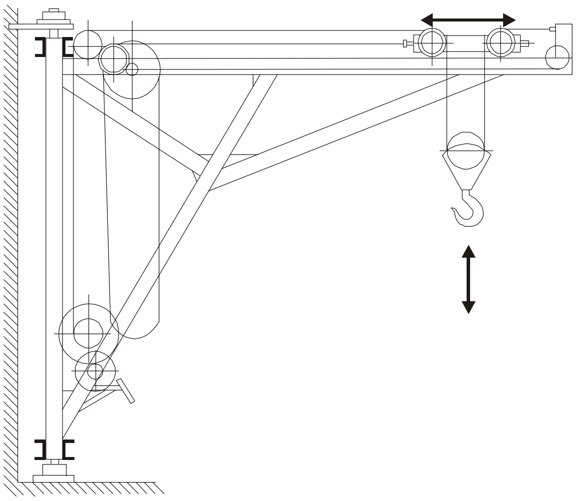
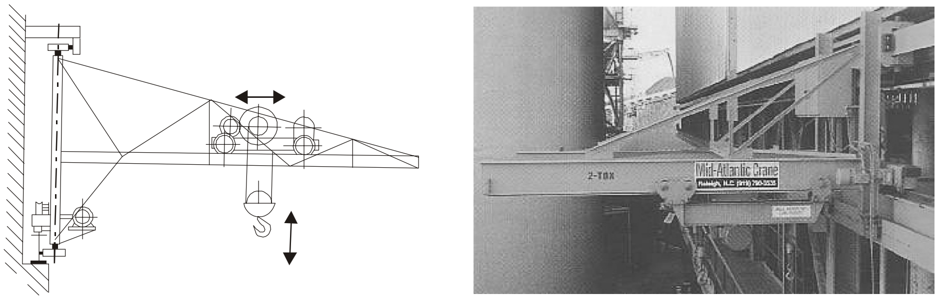


Fig. 8.5.4. Revolving mast jib crane

(E) **Rotary girder jib crane** is similar to a swinging bracket supported jib crane without a tie rod. Instead, the end of the jib is supported from a trolley by a chain, while the trolley is supported from a circular girder fixed to the roof or roof strusses.

(F) **Travelling jib crane** is a special type of jib crane which consists of a cantilevered arm similar to the bridge girder of a overhead traveling crane. One end of the girder is held from the side wall, and supported over wheels on rails laid parallel to the wall. A motorised arrangement drives the wheel and makes the arm to travel along the wall. The hoisting device travels along the arm. Travelling jib crane serves the purpose of a bridge crane for lighter loads. Fig. 8.5.5 shows the schematic diagram as well as a photograph of such a crane.



(a) Schematic view (b) Photographic view

Fig. 8.5.5. Traveling jib crane

(G) **Fixed-tower hammerhead jib crane** is a special type of jib crane, which is built in capacities from 6 te to as high as 350 te. The jib of this crane is of struss structure and looks like the head of the hammer, hence the name. The jib is mounted on a fixed tower. The front portion of the jib supports rail upon which one, two or three crane trolleys travel, and the rear portion of the jib houses the machinery for hoisting, trolley travel and slewing arrangement as well as necessary counterweight. When two trolleys are used, they are arranged to be operated individually or simultaneously. Fig. 8.5.6 shows a hammarhead jib crane.

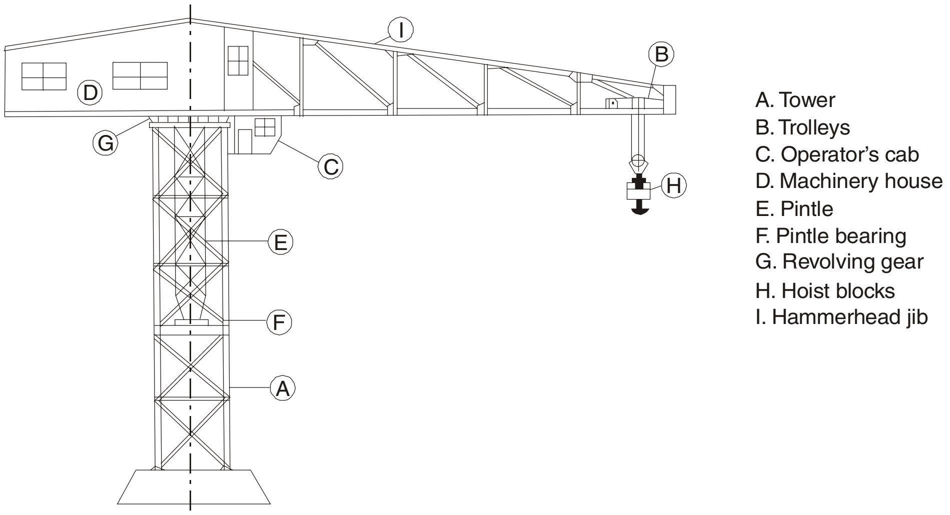


Fig. 8.5.6. Fixed-tower hammerhead jib crane

8.5.2 Overhead Travelling Cranes or Bridge Cranes

Definition & descriptive specifications

These cranes essentially consists of one or more hoisting devices mounted on a bridge consisting of one or two horizontal girders, which are supported at each end by trucks riding on elevated runways installed at right angles to the bridge. Runways are installed on building columns, overhead strusses or frames, much above floor level. The hoisting device moves along the bridge while the bridge moves along the runway.

Depending on the lifting capacity of these cranes, the hoisting device may be a hand operated trolley type hoist, an electric hoist or a drum-type **crane trolley or crab**. Crane trolley is an independent machine consisting of the drum-type hoisting equipment built on a framework, which is fitted with runner wheels, and driven by a motor through gearings. The hoisting motion is also motorised. Fig.8.5.7 is a line diagram of crane trolley. The long travel of a bridge may also be manual through chain operation or motorised.

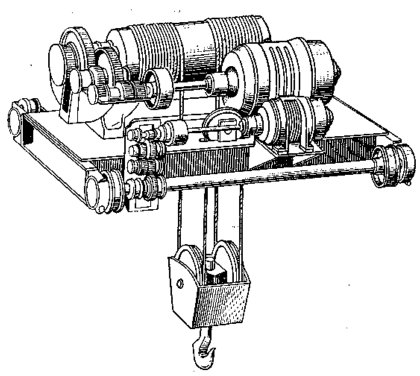


Fig. 8.5.7. Crane trolley

Control of all the movements (hoisting, cross travel of hoisting devices and long travel of the bridge) of an electric overhead travelling (abbreviated as EOT) crane can be through pendant from floor, or may be remote operated through radio or other devices. Many of these cranes are provided with a cab fixed to the bridge, from which an operator controls the crane. Electrical power is fed to the crane by means of festooning cable or from bare conductors running along the runway through collectors connected with the bridge structure.

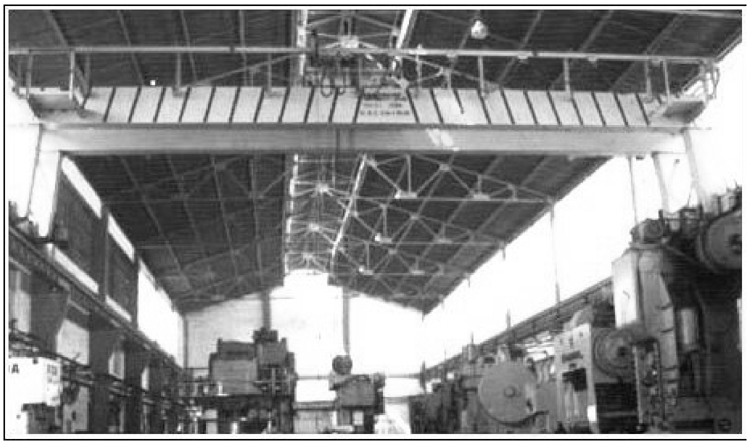


Fig. 8.5.8. View of an overhead travelling crane

Characteristics and uses

The major advantage of overhead travelling bridge crane is that it does not interfere with work on floor. It can move materials over the working zone. Other characteristics are:

(*i*) It can reach the entire rectangular area bounded by the bridge length and runway length.

(*ii*) Runways can extend beyond the building, supported by columns erected suitably.

(*iii*) Capacities may vary from small value (1 ton) to up to 1000 tons.

(*iv*) Bridge cranes are designed and built as per requirement by specialist companies.

(*v*) Requires heavy frame work and are expensive.

(*vi*) Requires trained operators.

These cranes are mainly used in heavy machine shops, foundries, steel plants, assembly and repair shops, warehouses and yard storages. With appropriate hoisting attachments like slings, grabs, grab buckets, magnets etc. these crane can handle an extremely wide range of large, heavy and awkward unit loads as well as bulk load.

Types of bridge crane

Bridge cranes are classified according to the load capacity as follows:

(*a*) Light duty—up to 5 tons. May be hand propelled.

(*b*) Medium duty—5 to 20 tons, used in factories and warehouses.

(*c*) Heavy duty—20 to 50 tons, used in foundries, heavy shops.

(*d*) Extra heavy duty—over 50 tons, used in steel plants, docks etc.

The medium and heavy duty crane bridges are essentially electrically driven.

Design wise the traveling bridge crane may be classified as.

(*a*) **Top running** or (*b*) **Bottom running** (under slung).

The bridge girders of a top running crane are carried on top of the end trolleys (Fig. 8.5.9). The girders of the bottom running crane are suspended from the end Trolleys. The hoisting device is also top running or bottom running in corresponding designs. Bottom running bridge crane are generally limited to 10 tons capacity.

Major specifications of a bridge crane are :

(*i*) Lifting capacity, (*ii*) Span of the crane, (*iii*) Hook lift, (*iv*) Hoisting speed, (*v*) Hoist travel speed and (*vi*) Long travel speed of bridge.

The specifications are generally limited to 1000 ton lifting capacity, 40 m span, 10 to 20 mpm hoisting speed, up to 30 mpm hoist travel speed, and 60 to 150 mpm bridge travel speed. Two speeds of hoisting are provided in many cranes as demanded by the application.

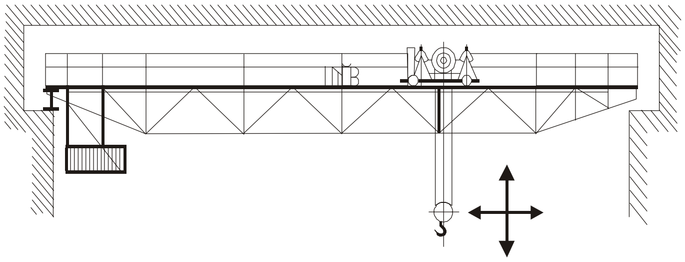


Fig. 8.5.9. Double girder top running bridge crane

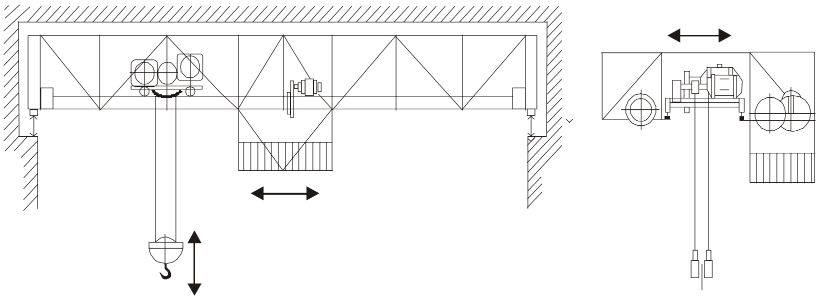


Fig. 8.5.10. Top running bridge crane with bottom running crab

8.5.3 Gantry Cranes

Definition, Characteristics and Uses

Gantry cranes have a girder or bridge, on which the hoisting device/s operate, similar to an overhead travelling crane, except that the bridge is rigidly supported on two or more legs with wheels which run on fixed rails or runways at the level of the floor. The movement of the gantry crane may be done manually or through motor.

The characteristics of a gantry crane are :

(*i*) Can be used indoors or outdoors.

(*ii*) Relatively easy to change its location.

(*iii*) Simple operation.

(*iv*) Long life and low maintenance.

These crane are used for loading and unloading carriers, outdoor storage operations, for handling unit or even bulk materials where movement is short. These cranes serve purpose of a bridge crane and are used where installation of a bridge crane is not possible. Limitation of these cranes are their limited movement and capacities up to a maximum of 300 te.

Types of gantry crane

A few types of gantry cranes are possible based mainly on the design of the legs:

(*i*) **Fixed gantry crane** whose both legs are fixed on floor

(*ii*) **Portable gantry crane** in which both legs are fitted with small wheels which can travel on plain floor. These are generally of small capacity up to 3 te.

Fig. 8.5.11. Portable gantry crane

(*iii*) **Semi-gantry** or **single leg gantry crane** is a gantry crane with one end of the bridge is rigidly supported on one or more movable legs supported on fixed rail or runway, the other end of the bridge being supported by a truck running on an elevated rail or runway.

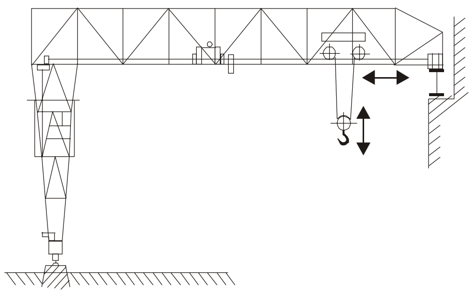


Fig. 8.5.12. Semi-gantry crane

(*iv*) **Cantilever gantry crane** in which the bridge girder is extended beyond the crane runway on one or both sides. Its runway may be either on the ground or elevated.

Fig. 8.5.13 shows photograph of a large capacity outdoor gantry crane.

Fig. 8.5.13. 40 te gantry crane

8.5.4 Wharf Cranes

Wharf cranes are versatile machines which are extensively used in shipyard and port for unloading and loading of ships to and from jetty and can handle a variety of cargo. These cranes essentially consist of a long boom which is mounted on a 3600 rotating frame which is supported on the sub-structure fixed on foundation or travelling on rails along the jetty. The boom can be luffed up and down thus moving the load towards or away from the crane. A sheave is provided at the tip of the boom and ropes with a hook or grab bucket, depending on the type of load to be handled, is suspended from the sheave. The load is moved up or down by pulling the rope. The luffing motion in the boom is often **level luffing** type, which is explained later.

Courtesy : TRF Limited, Calcutta

Fig. 8.5.14. 10 te capacity shipyard wharf crane

Depending on the design of the sub-structure, wharf cranes are grouped into following types:

(*a*) **High pedestal wharf crane.**

(*b*) **Portal crane** in which the sub-structure is a gantry structure. The gantry may be fixed in foundation or on wheels which can run on fixed rails or runways.

(*c*) **Semi-portal crane** which uses a semi-gantry sub structure.

Fig. 8.5.14 shows photograph of a wharf crane.

Level luffing system

In an ordinary design, when the boom is luffing up to bring the load closer to the crane, the load also moves vertically up, which requires considerable power for operating the luffing mechanism. In level luffing mechanism, it is possible to keep the load in the same horizontal plane during its movement by boom luffing. Compensation for the dead weight of the boom is achieved by using movable boom counterweight. This reduces the luffing effort and power substantially, and level luffing may be done easily through rope reeving, by mechanical linkage or by screw and nut. The later allows very accurate positioning of the load, required during lowering.

Level luffing may be achieved by using one of the following methods:

(*i*) **Toplis mechanism** is shown in Fig. 8.5.15. In this mechanism the guide pulley, fixed on the separate A-frame, is in such a disposition with respect to the top pulley at the end of the boom that when the boom is luffed upward, the distance between the two pulleys shortens and allows corresponding length of rope to be delivered out from top pulley. This allows the load to remain at the same height.

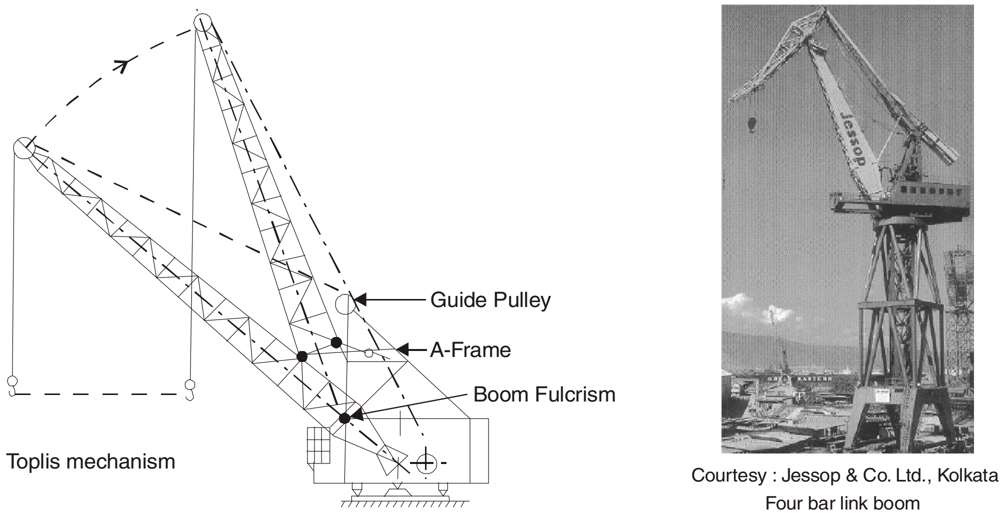


Fig. 8.5.15. Level luffing cranes

(*ii*) **Swing lever type level luffing mechanism.** In this design, the guide pulley is connected with a particular point of the boom through a link in such a way that when boom is luffed, the relative positions of the top and guide pulley go on changing in a manner that some length of rope will be delivered out or taken in such that the load remains at the same height.

(*iii*) Using a **four bar link** type boom. In this design, the front portion of the boom known as **jib lever**, gets folded with respect to the rest part of the boom, which form a four bar link, when the boom is moved up or down. This allows the top pulley fixed at the end of the front portion of the boom, to remain at the same horizontal level and achieve level luffing.

Courtesey : TRF Limited, Kolkata

Fig. 8.5.16. 26 te level luffing kangaroo type portal crane in luff out and luff in positions

Technical specifications of wharf crane

The capacity of dock side wharf cranes generally varies from 3 tons to 20 tons and an outrich of 30 m maximum to 6m minimum. The inclination of the boom with horizontal, at the maximum out reach condition is kept about 34°. Typical specifications of high pedestal balanced level luffing wharf cranes, as per ''Electric Crane'' by H.H. Broughton are shown in Table 8.5.1.

Table 8.5.1. Important Specifications of Wharf Cranes

Working load, tons	3	5	6	10	20
Maximum out-reach, m	26	20	20	26	23
Minimum out-reach, m	8.5	6.7	6.7	9	10.6
Height of lift, m	26	21	23	29	22
Boom length, m	29	22	22	28.6	–
Height of boom fulcrum from ground, m	21	18	18.5	21	–
Hoist drum diameter, m	–	–	0.9	0.9	1.2
Rope size 6/37 construction, mm	24	32	32	38	–
Hoist speed, m/min	61	42.7	42.7	15	8
Slewing rpm	1.25	1.5	1.5	0.75	0.5
Luffing speed, m/min`	36	36	36	30	4
Traveling speed, m/min	15	15	15	15	18
HP of hoist motor	55	70	70	55	50
HP of slewing motor	10	15	15	15	20
HP of luffing motor	8	12.5	12.5	15	10

Stability of wharf crane

The margin of stability of a wharf crane is defined to be the percentage additional load required to bring the crane to the point of tipping, while handling any load at any radius from the centre of the crane and the boom is at right angles to the direction of the track on firm level ground.

IS:4594-1968, ''Code of Practice for Design of Portal and Semi-portal Wharf Cranes'' provides in clause 4, the condition of tipping and margin of stability of wharf crane under storm condition and under service condition. As per the above standard, the following stability requirements should be met.

(*a*) **Stability under storm condition:** The crane is subjected to a wind force of not less than 150 kg/mm^2 and a margin of stability of 25% of this wind force shall be met.

(*b*) **Stability under service condition:** (*i*) 50% of the safe working load at the operating radius without causing any undue stress on centre pin or the centre column; and (*ii*) 75% of the safe working load at the operating radius and subjected to a wind force of 25 kg/mm^2 acting at the same time, without any of the track wheels leaving the track.

8.5.5 Pillar Cranes

It is a stationary crane consisting of a vertical member (pillar) held fixed in position at the base to resist overturning with a constant radius revolving boom supported at the outer end by a tension member, and carrying an end pulley over which the lifting rope with hook is suspended.

8.5.6 Tower Cranes

A crane in which a horizontally swinging, usually non-luffing boom is mounted on a tall vertical mast or tower. A travelling hoist operates on the rails fixed to the boom, which is suitability counterloaded. A tower crane may be fixed standing on a tripod. It may also be mounted on rails, on a crawler or a truck, when it is called a **mobile tower crane**.

These cranes are used for construction of tall buildings and erection of technological structures, blast furnaces, chimneys, air turbines etc.

A crane erected upon and supported by a building or other structure, which may be raised or lowered to different floors or levels of the building or structure is called a **climber tower crane**.

Fig. 8.5.17 shows a tower crane in working position.

Fig. 8.5.17. Tower crane at construction site

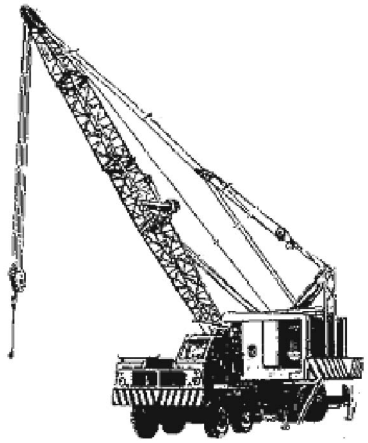
8.5.7 Truck and Wagon Cranes

This is one type of mobile crane in which a boom-type crane is mounted on a motor truck or wagon frame or rubber-tired chassis. It consists of a rotating superstructure (for slewing boom), operating mechanism, boom and the source of power for operation.

Capacities of such cranes vary from a fraction of a ton to about 50 te. Basic crane rating is the maximum allowable lift with the shortest boom at its minimum operating radius. Rated capacities are generally 85% of tipping load.

In a **full swing-turntable truck crane**, the revolving turntable provides 360° rotation in either direction. The luffing motion is obtained by spooling rope or by hydraulic cylinder, and hoisting motion is by spooling rope. Booms for small cranes may be of one-piece construction or telescoping for variable length. Large cranes may use long two-piece booms. Long booms may require use of a boom support. During operation, the truck is supported on outriggers to avoid overturning or rolling of the truck. Power source is generally I.C. engine.

Figure 8.5.18 shows two different designs of truck mounted cranes:



Full swing turntable luffing boom

Non-swing hydraulic cylinder luffing boom

Fig. 8.5.18. Truck mounted cranes

These cranes are used for interplant and intra-plant heavy load movement as well as in various civic service needs.

8.5.8 Crawler Cranes

Cranes consisting of superstructure with power plant, operating machinery and boom, mounted on a base equipped with crawler treads for travel.

Crawler cranes are slow in speed but can work outdoors on field. Capacities vary from about 1 ton to 100 tons. Rated capacities are generally 75% of tipping load. The booms may be full-swing turntable type, part-swing type (270° arc) or even nonswing type. Crawler cranes are widely used in outdoor mechanical constructional jobs. Many of these are adaptable for use as **shovels**, **backhoes** and **draglines** for handling bulk materials. Fig. 8.5.19 shows a typical crawler crane.

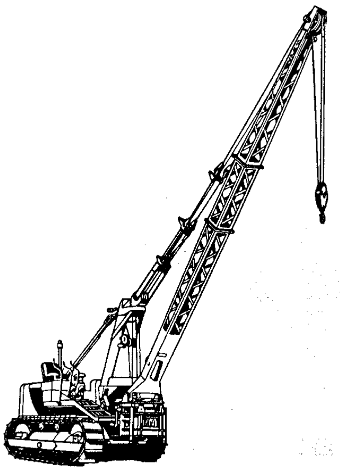


Fig. 8.5.19. A typical crawler crane

8.5.9 Railroad / Locomotive Cranes

A **railroad crane** is a single-flange wheel, rail mounted travelling crane. The **locomotive** crane is a boom-type mobile crane consisting of a self-propelled locomotive car operating on a railroad track, upon which is mounted a rotating body supporting the power-operated mechanism, together with a boom capable of being raised or lowered at its head end from which is led the wire rope with hook, connected with the hoisting mechanism.

8.5.10 Floating Cranes

Cranes fitted on a floating body like ship, barge, boat, etc. are called floating cranes. These are used for handling material on, around and from the water. They are specifically used for salvage work, harbour clearing, dredging, excavating, pipe-laying, alongshore, and off-shore construction, ship servicing, ship repair and bulk-cargo loading or discharging. Capacities may vary from small to as large as 800 te.

8.6 DERRICKS

Derrick is an apparatus consisting of one or two masts or fabricated strut members supported at the bottom by a pivoting arrangement and held at the top by guys or braces, with or without a boom, for use with a hoisting mechanism and operating rope, for lifting and lowering a load and moving it horizontally.

Derricks are principally used in construction work for erection of technological structures and heavy components to a height. Advantages of derricks are: (*i*) inexpensive, (*ii*) very easy to erect and dismantle, (*iii*) simple in design and may be fabricated easily at the working site, (*iv*) a number of derricks may be used together for manipulation of a large and/or weighty component.

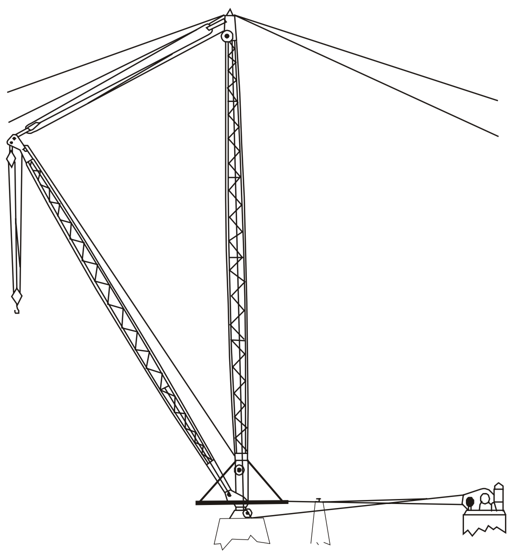


Fig. 8.5.20. Guyed derrick

Derricks may be of different types. Some of the common types of derricks have been described below:

(*a*) **Guy Derrick:** A fixed derrick consisting of a mast mounted on a turntable and capable of being rotated, supported in a vertical position by guys, and a boom whose bottom end is hinged or pivoted to move in a vertical plane with a reeved rope between the head of the mast and the boom point for raising and lowering the boom, and a reeved rope from the boom point for raising and lowering the load.

(*b*) **Gin Pole Derrick:** A derrick without a boom. Its guys are so arranged from its top to permit leaning the mast in any direction. The load is raised and lowered by ropes reeved through sheaves or blocks at the top of the mast.

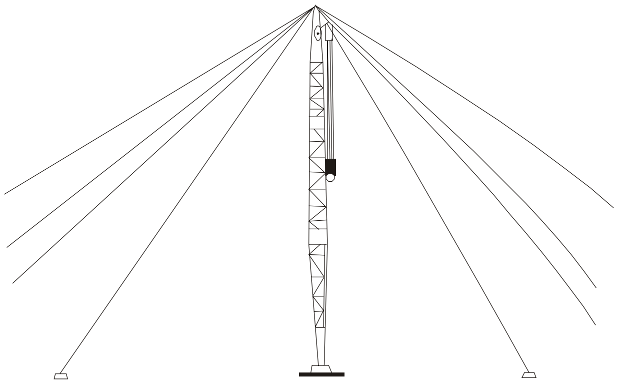


Fig. 8.5.21. Gin Pole derrick

(*c*) **A-frame Derrick:** A derrick in which the boom is hinged from a cross member between the bottom ends of two upright members spread apart at the lower ends and joined at the top; the boom point secured to the junction of the side members, and the side members are braced or guyed from this junction point.

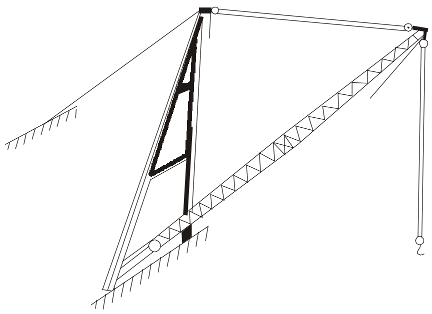


Fig. 8.5.22. A-frame derrick

(*d*) **Stiffleg Derrick:** A derrick similar to a guy derrick except that the mast is supported or held in place by two or more stiff members, called stifflegs, which are capable of resisting either tensile or compressive forces. Sills are generally provided to connect the lower ends of the stifflegs to the foot of the mast.

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CHAPTER

9.0 Bulk Handling Equipment and Systems

The term ''bulk handling'' means handling and storage of very large quantities of materials amounting to lakhs of tonnes. Handling and storage of such large quantities involves careful study of the choice of materials handling equipment as well as storage method.

Bulk handling is generally involved in certain areas of operation like (*i*) open cast mining, (*ii*) ports and dockyards, (*iii*) stockpiling (storage) area of large process plants (*e.g*. steel plants, power plants etc), (*iv*) railroad terminals and others.

In this chapter, the different storage systems and some of the specialised equipment used for bulk handling have been discussed briefly. The discussion has been limited to bulk solids, though bulk storage and handling of liquid is also quite common in different chemical and petro-chemical industries. Storage and handling of unit load, involved in railroad and marine terminals, have also been excluded from limited space of present discussion.

9.1 STORAGE OF BULK SOLIDS

Different methods are employed for storing different bulk materials. The factors which determine the selection of storage are nature of material, quantity of materials to be stored, charging and discharging rate and frequency etc. Depending on storage methods and above factors, suitable charging and discharging equipment have to be selected. Some of the common storage means and methods are briefed under.

9.1.1 Bins

A bin is a large container of cylindrical or rectangular shape made from sheet metal supported on legs. Filling of bins is from the open or covered top and discharge is from the bottom opening. Inside agitators or outside vibrators are used for facilitating flow of materials from the discharge opening. Generally conveyors, bucket elevators, pneumatic conveyors are used for delivery of materials into the bin. Discharge of materials at desired rate into suitable materials handling equipment is ensured by using different types of feeders.

9.1.2 Bunkers

A bunker is essentially a large bin, used for storage of materials like coal in a power station. These may be a few hundred meters in length. Belt conveyors, with automatic trippers, dumpers etc. are used for filling of the bunkers.

9.1.3 Stockhouse Bins

These are actually a number of conventional bins, grouped in an elevated structure for batch delivery of materials to the process. A blast furnace generally has such stockhouse bins. The bins may be filled by railroad cars or transfer cars or belt conveyors. The discharge is through mechanical bin gates to equipment like skip hoist.

9.1.4 Silos

Silo is a tall cylindrical structure unusually made of reinforced concrete. These are used for storage of materials like grain, cement, sand, crushed stone, coal coke, salt, clay, gypsum etc.

9.1.5 Sheds

Many materials which need to be stored under a cover for one reason or other, but are difficult to be stored in a bin or silo, are generally stored in a shed. Sheds may be upto 100mtrs in width and several hundred meters in length. Sheds are covered at top by G.I sheets/asbestos sheets supported on full width strusses. Materials are generally brought in by belt conveyor and distributed in the shed by a distributing conveyor with self-propelled tripper or by a shuttle conveyor.

Discharge is generally through reclaiming conveyors working below floor levels. Equipment like bull-dozers, power hoe, or a drag scraper are used for moving materials towards feeding pockets for the reclaiming conveyors.

Sheds are used for short to long duration storage of different materials, a few of them are like bauxite ore, gypsum, clay, salt, raw sugar, cement clinker etc.

9.1.6 Open Pile Storage

Some solids, in bulk are frequently stored in open storage piles. A number of different methods and types of equipment are employed for handling these plied materials. Materials which are not weathered easily and need to be stored and reclaimed at substantial hourly rate are kept in open pile storage. The piles can contain materials from 5000 tons to some million tons, while handling rate may vary from 100 to 2000 tonnes per hour. Such wide variation of pile size and handling rate influence selection of type and size of materials handling plant and equipment for the job.

9.2 BULK HANDLING EQUIPEMENT

Belt conveyor, crawler crane, gantry crane, rotary crane with grab bucket etc. are widely used as bulk handling equipment, which have already been discussed in earlier chapters.

Some of the other frequently used bulk handling equipment, for the following major areas of application have been briefly discussed below.

Open Cast Mining

Open cast mining (as opposed to underground mining) may be carried out either as a discontinuous operation, generally with **power shovels**, etc. or may be done as a continuous process. For continuous mining the following machines are employed either singly or in combination:

— Bucket Wheel Excavator

— Belt Wagon (also known as Mobile Transfer Conveyors)

— Spreader

9.2.1 Bucket Wheel Excavator

The Bucket Wheel Excavator is used to dig up the material with the help of a rotating wheel with a number of buckets on its periphery. The bucket wheel is mounted at the end of a boom which can be moved up and down (luffing) along the face of the area being excavated with the help a rope winch or hydraulic cylinders. The boom is supported from a horizontally rotating (slewing) frame mounted on the undercarriage which moves on the uneven mine surface on crawlers. The material discharged from the buckets is guided on to a belt conveyor running along the boom and, near the machine centre, is discharged on to a similar boom with a belt conveyor, called the discharge boom, which transfers the material for onward transportation. The discharge boom can also rotate independently of the main boom to facilitate convenient discharge.

Capacity of bucket wheel excavators may start at 150 m^3/hr and exceed 10,000 lm^3/hr.

Courtesy : Sandvik Asia Ltd., India

Fig. 9.2.1. Bucket wheel excavator, capacity 5000 lm^3/h

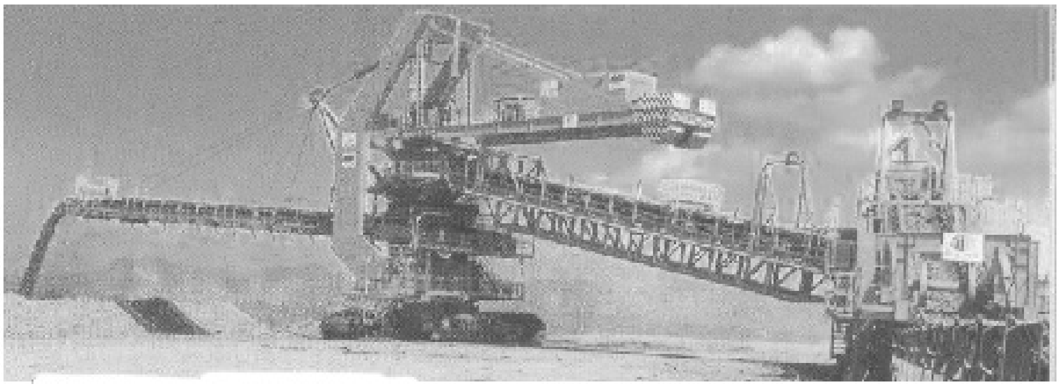
9.2.2 Belt Wagon/Mobile Transfer Conveyor

The Belt Wagon forms the link between the Bucket Wheel Excavator and the ground conveyor at the mine.

Like the bucket wheel excavator the belt wagon also has two independently slewable and luffable booms, each with a belt conveyor, mounted on and extending on either side of the undercarriage with crawlers. One of the booms receives the materials discharged from the bucket wheel excavator and transfers it to the other discharge boom which transports the material to the ground conveyor. Capacity of belt wagon has to be matched with that of bucket wheel excavator to provide a matched system.

9.2.3 Spreader

In any mining operation a substantial amount of unusable material has to be removed prior to getting access to the actual material to be mined. These materials, called overburden, are normally dumped at a distance from a mine with the help of spreaders. The material discharged from the excavator is transported to the spreader on a ground conveyor. The spreader operates in conjunction with a **tripper car** which discharges the incoming material on the ground conveyor to the belt conveyor on the receiving boom of the spreader. The conveyor transfers the materials to another conveyor supported on a long discharge boom which discharges into a pile. The boom is capable of being luffed up and down and also slewed on the supporting undercarriage running on crawlers. The stockpiling of material is required for temporary storage between the time it is received and the time it is used or moved to the next stage. The material is received and also discharged on belt conveyors at ground level. There is a large range of spreaders for different applications and capacities. The equipment may range from 30 m to more than 350 m in length, and discharge capacity up to 12,000 lm^3/h.



Courtesy : Sandvik Asia Ltd., India

Fig. 9.2.2. Spreader, theoretical capacity 11,700 lm^3/h

(B)Stock Piling System

The stockpiling of material is required for temporary storage between the time it is received and the time it is used or moved to the next stage. The material is received and also discharged on belt conveyors at ground level.

9.2.4 Stacker

The stacker is used for preparing the stockpile with the incoming material.

The machine travels on rails with the material fed to it through the yard conveyor between the rails. It is provided with a boom with a belt conveyor which is moved up and down with the help of wire ropes or hydraulic system. Depending on the application, the entire boom system may also be slewed on the substructure which travels on wheels running on the rails.

The material coming on the yard conveyor is raised by a tripper attached to the stacker and discharged into the boom conveyor which carries the material up to its end and allows it to fall to form a stock-pile.

The machine travels continuously to and fro so that the pile is built up layer by layer.

Courtesy : Sandvik Asia Ltd., India

(a)

Courtesy : TRF Ltd., Kolkata

(*b*)

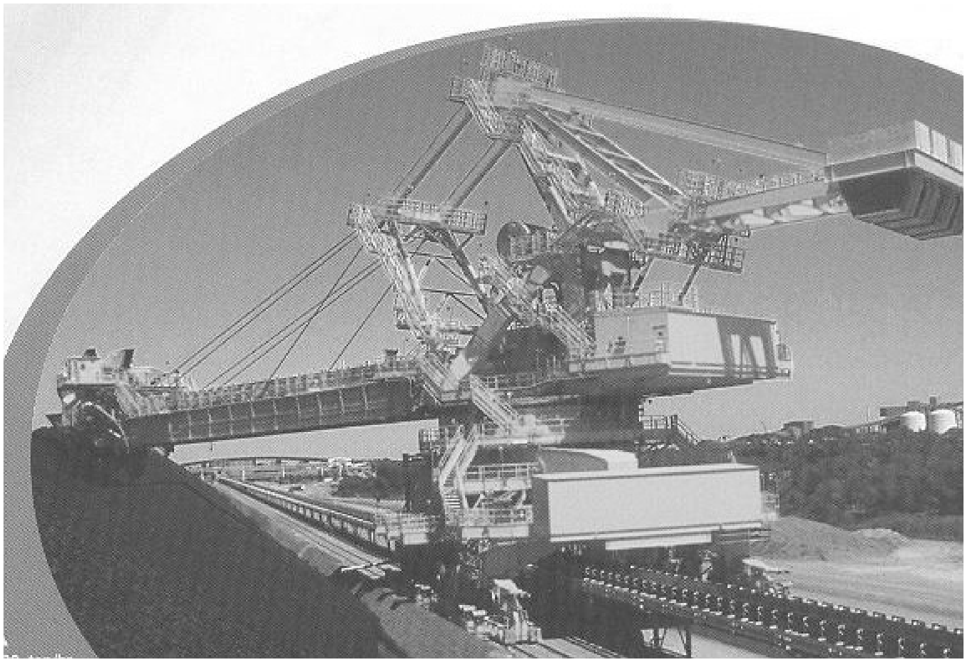
Fig. 9.2.3. Stacker, (*a*) single boom, (*b*) twin boom

9.2.5 Bucket Wheel Reclaimer

The reclaimer is used to pick up the material from the stockpile for onward dispatch. A rotating wheel with a number of buckets around the circumference is mounted at the end of a long luffing and slewing boom and cuts into the pile with to and fro rotary movements of the boom across the pile. The material picked up by the buckets is discharged on to a conveyor running along the boom.

The boom is mounted on a rotating frame supported on the undercarriage which travels on wheels on rails running along the track. The boom conveyor discharge the material at the centre of the machine from where it moves down to the ground conveyor which runs between the travel rails.

Capacities of bucket wheel reclaimers can vary widely from 150 te/hr to 10,000 te/hr, boom length can vary from 20 m to 60 m.



Courtesy: Sandvik Asia Ltd., India

Fig. 9.2.4 Bucket wheel reclaimer

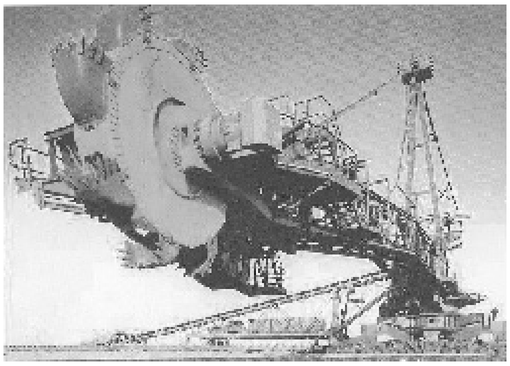
9.2.6 Scraper Reclaimer

As the name suggests the material is picked up from the stockpile by a scraping action. A large number of scraper blades are attached to a pair of endless moving chains for scraping the material from the pile. The material is brought to one side of the pile and finally loaded on to the conveyor running along side the stockpile.

Depending on the layout of the stockyard, various designs of the scraper reclaimer are employed. In some designs the material is moved down from the pile by using rakes and then picked up by the scraper blades.

9.2.7 Stacker-cum-Reclaimer

This combination machine does the functions of both a Stacker and a Bucket Wheel Reclaimer. It is basically similar to the bucket wheel reclaimer, but with the boom conveyor as a reversible one for stacking operations, and also has a tripper attached to it for feeding as in the case of the stacker. This machine is an economical solution for stockyards where stacking and reclaiming is not required simultaneously.



Courtesy : Sandvik Asia Ltd., India

(a)

Courtesy : TRF Ltd., Kolkata

(*b*)

Fig. 9.2.5. Stacker-cum-reclaimer,
(*a*) shows reclaimer bucket wheel in details, capacity 2000 t/h, (*b*) capacity 1500 t/h for coal

(C) Port Handling Equipment

The principal purpose of the port handling equipment is to load and unload ships or barges in a fast and efficient manner.

9.2.8 Shiploader

For continuous loading of dry bulk cargo into ships at a high rate, shiploaders are employed. The material arrives through a conveyor running along the jetty which is raised by a tripper attached to the machine and discharged on to a belt conveyor on the machine. The conveyor is carried on the boom structure and discharges at its end into the ships' hold.

The loaders generally run on rails laid along the jetty. Various designs of loaders are used depending on the application. Generally, in all loaders the boom can be luffed up and down and, depending on the design, it can have telescopic section at the front and also rotate horizontally.

Courtesy: Sandvik Asia Ltd., India

Fig. 9.2.6. Ship loading a ship, theoretical capacity 11,000 t/h

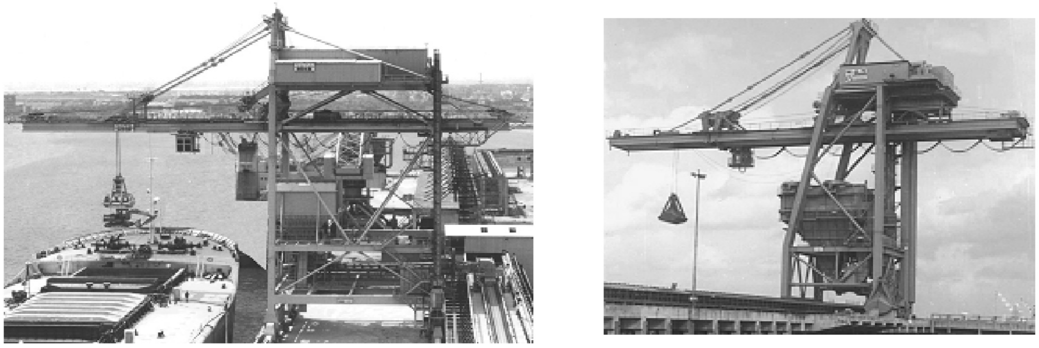
9.2.9 Ship Unloader

The ship unloader travels on rails laid along the jetty and is designed to transfer bulk solid cargoes from a ship's hold to a conveyor on the jetty. The cargo is unloaded by digging into it and picking up with a mechanical grab bucket.

The grab bucket, operated by wire ropes for opening/closing and raising/lowering, is suspended from a trolley which moves along the boom of the machine projecting out over the ship.

The material is emptied from the grab into a hopper that is mounted on the frame between the supporting legs of the unloader. From the hopper, a feeding system transfers the material to the jetty conveyor.

When not in operation, the boom is raised to allow ships to pass.



(a) (b)

Courtesy : TRF Ltd., Kolkata

Fig. 9.2.7 Ship unloader, (*a*) 33 te lifting and (*b*) 1500 t/h unloading capacity.

9.2.10 Container Handling Crane

This crane is similar to a ship unloader. Instead of grab bucket, a special grab is suspended from the crane trolley to handle the standard containers.

Courtesy: Jessop & Co.Ltd. , Kolkata

Fig. 9.2.8. Container handling crane

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   (*i*) M/s Sandvik Asia Limited, India
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   (*iii*) Jessop & Co. Ltd., Kolkata

CHAPTER

10.0

Robotic Handling

10.1 MATERIALS HANDLING AT THE WORKPLACE

Feeding of parts and components into a machine for their processing and taking them out is an important activity in any discrete mass manufacturing process. This is known as **materials handling at the workplace.**

Materials handling at the workplace may be defined as the handling of materials after it has been delivered for use at the workplace and before it is again picked up by some conventional handling process and equipment, to be removed to the next operation.

Materials handling at the workplace has long been neglected, possibly because they appeared to be a minor part of the overall system and does not always involve large or expensive materials handling equipment. However, studies have proved beyond any doubt that in most of the manufacturing operations, the handling of individual jobs take more time than that for processing the jobs.

The various activities at the workplace may be grouped under following different phases:

(*a*) **Preparatory:** Handling of materials adjacent to the workplace consists of

- (*i*) bringing materials closer to or onto the workplace or machine.
- (*ii*) unwrapping, unpacking, untangling, cleaning materials.
- (*iii*) sorting or separating materials, re-arranging, restacking etc.

(*b*) **Feeding :** Placing or directing materials closer to work place or point of-use.

(*c*) **Positioning:** Orienting materials in exact location, placing into fixture, jig or machine.

(*d*) **Manipulating:** Handling of materials during actual manufacturing operation.

(*e*) **Removing:** Taking material out of workplace consisting of—

- (*i*) taking out of jig, fixture etc.
- (*ii*) keeping it at a position for moving to next workplace.

(*f*) **Transporting:** Moving materials out of the workplace to the next workplace. This is generally traditional/conventional materials handling.

The materials handling at workplace is not only monotonous, fatiguing but involves personal safety of the operators. Moreover, time that can be saved from this handling time, directly increases productivity of the manufacturing process. It is in this context **industrial robots** have been increasingly used in materials handling at the workplace.

10.2 ROBOTS AND THEIR CLASSIFICATION

Robotic Institute of America (RIA) has defined a robot as:

‘‘A robot is a reprogrammable, multifunctional **manipulator** designed to move material, parts, tools, or specialised devices through variable programmed motions for the performance of a variety of tasks’’.

Out of the many possible industrial tasks like (*i*) spot welding, (*ii*) arc welding, (*iii*) materials handling, (*iv*) spray painting, (*v*) assembly of parts and (*vi*) other tasks, materials handling is one of major jobs in which industrial robots are being used.

There is no scope here to go into much details about robots. This chapter will briefly discuss some of the features which make robot a smart material handling equipment, and some of their specific applications.

10.2.1 Major Components of a Robot

Four common components of a robot are:

(a) **The manipulator:** The manipulator is the body of a robot, made of a collection of mechanical linkages connected at joints to form an open-loop kinematic chain. The manipulator is capable of movement in various directions and does the work of the robot. It can conveniently be compared with the arm of a human. At the joint, the individual link can either rotate (revolute joint) or make translatory motion (prismatic joint) by means of electric motors (servo or stepper) and hydraulic or pneumatic cylinders. Through a combination of motions of the joint, the manipulator can achieve different desired positioning and orientation. A manipulator can have many joints up to 8, and a robot manipulator with six joints (six degrees of freedom) is considered quite versatile for most the robot tasks. A manipulator generally has three structural elements: the **arm**, the **wrist** and the **hand (end effector).** The end effector is individually designed to grip individual tools or jobs, and simulates palm of a human arm.

(*b*) **Sensory devices:** These elements inform the robot controller about status of the manipulator. These sensors may be (*i*) non visual or (*ii*) visual.

Nonvisual sensors provide information about position, velocity, force etc. Connected with manipulator motion. The visual sensors are used for tracking an object, its recognition and grasping. These are comparable to senses like kinesis, touch, vision etc.

(*c*) **The controller**: Robot controllers generally perform three function which are:

(*i*) Initiation and termination of motion of different joints at desired sequence and specific points.

(*ii*) Storage of positional and sequence data in memory.

(*iii*) Interfacing the robot with outside world through the sensors.

Generally a microcomputer or minicomputer acts as the robot controller, and acts as the brain of the robot.

(*d*) **The power conversion unit:** This component provides necessary power for movement of the manipulator for doing work. It can be electrical power source with amplifiers to feed servo motors or compressor or hydraulic power pack.

With proper programming of the robot controller, the manipulator can be made to undergo a desired sequence of motions of linkages of the manipulator, repeatedly and accurately and thus make the robot to perform its desired task. Another advantage of a robot is that by changing the programme, the manipulator can instantly change from one set of task to another, thus making it a flexible and versatile equipment.

10.2.2 Classification of Robotic Manipulators

Manipulators are generally classified in two ways, one based on **mechanical configuration** and the other based on **method of controlling individual joints.**

Classification by configuration (coordinate system)

(*a*) **Cylindrical coordinate robots:** When a horizontal arm (boom) is mounted on a vertical column which is mounted on a rotating base. The projected length of arm is adjustable. The workspace of the arm tip is a hollow cylindrical space as shown in Fig. 10.2.1(a).

(*b*) **Spherical coordinate robots:** A manipulator resembling a tank turret, is called a spherical coordinate device. The workspace is frustrum of a hollow sphere. The configuration is shown in Fig. 10.2.1 (b).

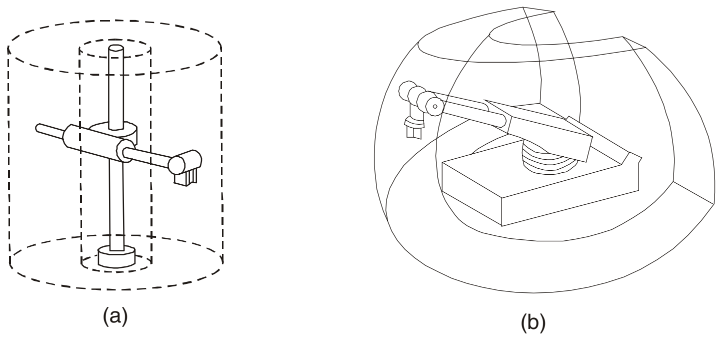


Fig. 10.2.1. Robots with their workspaces, (*a*) cylindrical, (*b*) spherical

(*c*) **Cartesian coordinate robots:** This is a robot which can have independent translatory motion in three cartesian coordinates. The wrist and end-effector may have additional rotational motions. This robot may be a cantilevered type or a gantry style. Fig.10.2.1(c) shows a cantilevered one.

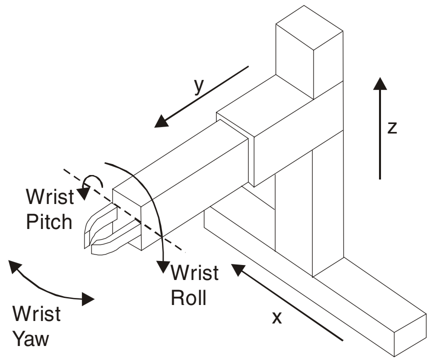


Fig. 10.2.1. (*c*) Cantilevered cartesian coordinate robot

(*d*) **Jointed arm** (also called **articulated**) **robots:** There are three distinct types of jointed arm robots: (*i*) **pure spherical**, (*ii*) **parallelogram jointed** and (*iii*) **jointed cylindrical**.

(*i*) **Pure spherical:** This is the most common of the jointed configuration. All the links are pivoted and hence can move in a rotary manner. It consists of a jointed arm consisting of upper portion and lower portion (forearm). Forearm is connected to a base. The base can also rotate. The major advantage of this design is that it is possible to reach close to the base of the robot over any obstacle within its workspace. The workspace (or work envelope) is approximately spherical. Puma (made by Unimation, Inc.), Cincinnati Milacron T^3, Fanuc Japan are having this configuration.

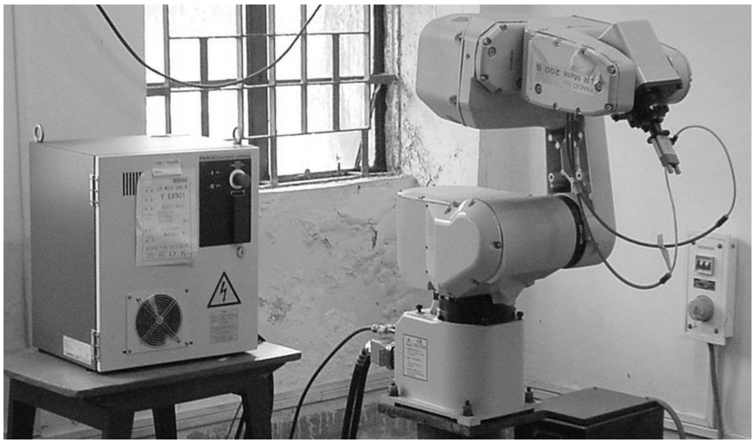


Fig. 10.2.2. Pure spherical robot

Fanuc six axis robot with controller at Mechanical Engineering Department, NITTTR, Kolkata

(*ii*) **Parallelogram jointed:** Here the single rigid upper arm is replaced by a multiple closed-linkage paralellagram arrangement, actuated by a hydraulic cylinder. This robot can carry larger load than a pure spherical one, but has limited workspace. Robots of this type are made by ASEA, Hitachi, Cincinnati Milacron, Toshiba etc.

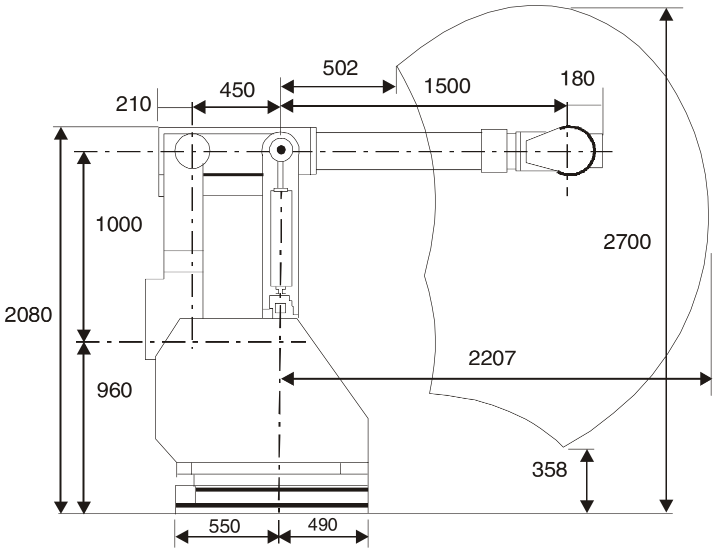


Fig. 10.2.3. Parallelogram jointed robot and its workspace (dimensions in mm, not to scale)

(*iii*) **Jointed cylindrical:** In this configuration, the single arm of a cylindrical coordinate robot is replaced by an articulated open kinematic chain. These robots are precise and fast working but have a limited vertical reach. This configuration robots are made by Hirata, Reis, GCA and United States Robots.

10.3 ROBOTIC HANDLING APPLICATIONS

Materials handling by robots are of two categories:

(*i*) Material transfer.

(*ii*) Machine loading and unloading.

Both these two categories are applicable to the different phases of workplace handling like feeding, positioning, manipulating and removing.

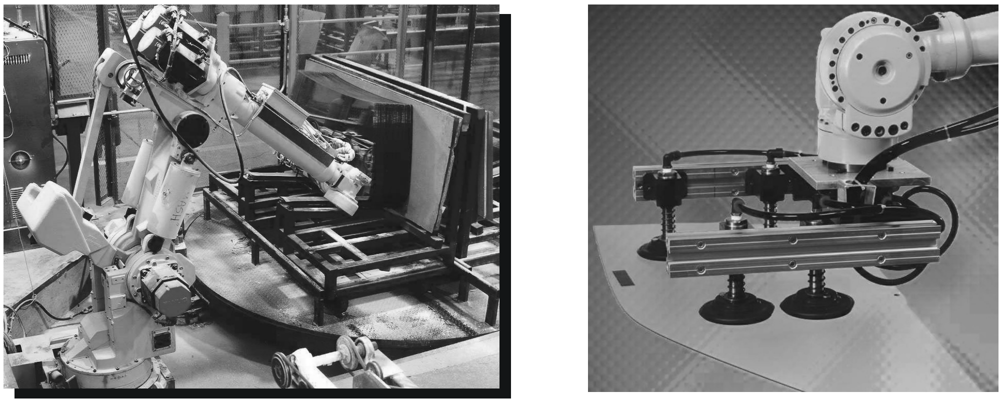
Material transfer: The task of moving a part from one location to another within the workplace is one of the common applications for robots (**pick-and-place** operations). A slightly more complex operation of the same category is **palletisation or depalletisation**. Robot deposits to or takes from a new position and height of the pallet in each subsequent operation. After the pallet/box is filled up or emptied, the same may be moved by the same or by a larger robot.

Machine loading and/or unloading: Robot centred machine cell is most common example of this category of application. The workcell consists of one or more production machines, the robot and some material handling system for delivering parts into or out of the workcell. A mobile robot may also be employed for this operation, though less common.

Some of the processes in which robotic loading/unloading is often used are:

- Die-casting—unloading of parts and dipping them in water bath for cooling.
- Plastic moulding—unloading of injection moulded parts.
- Machining—loading raw blank and unloading finished product. The end effector should be designed to handle sizes and shapes of both raw material and finished product.
- Forging—loading raw stock to furnace, unload hot material from furnace and transfer to forging press and hold and manipulate during forging.
- Pressworking—loading individual blanks into press. However, when coiled strip is fed, no robot is needed in the continuous pressing operation.
- Heat treatment—loading and unloading of parts from a furnace.

Fig. 10.3.1. Robot feeding component to CNC machine



(a) (b)

Fig. 10.3.2. Robots in action, (*a*) stacking, (*b*) transferring glass sheet

Depending on handling and processing time, one robot may be used for handling materials to and from more than one machine.

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CHAPTER

11.0 Auxiliary Equipment

By definition, any materials handling equipment (or machine) is involved in some sort of movement of materials like transportation, conveyance, transferance etc. However, there are many other equipment or gadgets which are used in the field of materials handling but are not directly or independently used for movement of materials, and hence cannot be termed as materials handling equipment. But these very large group of items are used in conjunction in with conventional materials handling equipment to make them function better, more efficient, more versatile. Without some of these, certain functions of the handling equipment would not be possible at all. These equipment or gadgets are called **auxiliary materials handling equipment**. The various attachment of fork lift truck (discussed in section 5.3.4) or different crane attachment like hook, grabs, tongs, grab buckets etc. (discussed in section 8.1.5) are examples of auxiliary equipment.

There exist innumerable number of auxiliary equipment. Many of these auxiliary equipment are of standard design and specifications and built by specialist manufacturers. There are also many auxiliary equipment which are application specific, and developed by the user organisations.

Use and working principle of some of the common auxiliary equipment have been briefly discussed below. The attachments for forklift truck & cranes and some of the packaging equipment have already been discussed earlier and hence not included in this chapter.

11.1 GATES

Gates are used in conjunction with various bulk materials storage hoppers (bins, silos etc.) to close or open the outlet and adjust discharge of materials in batches from the hoppers. According to the principle of operation, gates are divided into three main groups (*i*) **slide gates**, (*ii*) **trough gates** and (*iii*) **pivoted gates**.

11.1.1 Slide Gate is a flat plate valve which slide in guides, and is actuated by hand operated rack-pinion or lever mechanism. The design is simple but under material load, it may be difficult to move gate, the slideways may be blocked and lumps of material has a tendency to wedge in when gate is closed. These gates are, therefore, generally used with small lumped, free flowing materials and where gate operation is infrequent.

11.1.2 Trough Gate consists of a trough hinged at the hopper outlet. When trough is in raised position, it keeps the outlet closed, but when lowered, it allows flow of material using the trough as a chute. Trough gates exclude jamming and allow control of flow. Its large height projecting below hopper outlet and the force required for closing are the disadvantages.

11.1.3 Pivoted Gate is a part of cylindrical plate pivoted about its horizontal axis, which can be pivoted easily up and down to close or open the hopper outlet. The gate may be made of one or two sectors. This type of gate can be operated with less effort but not good for controlling material flow rate.

Figure 11.1.1 shows the schematic diagrams of these gates.

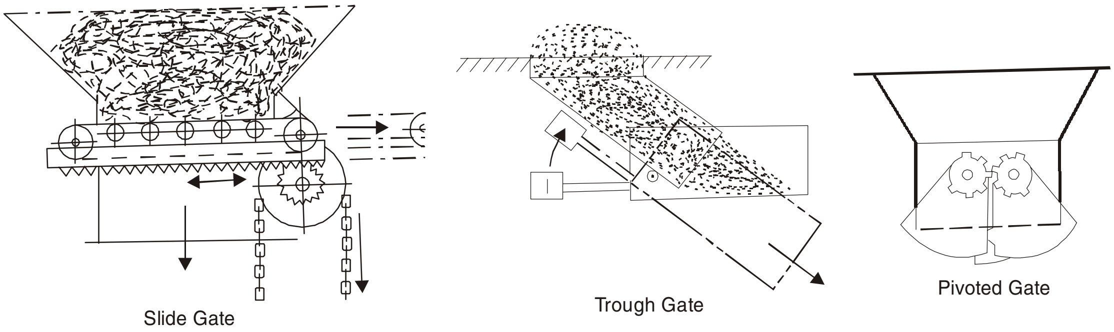


Fig. 11.1.1. Schematic diagrams of gates

11.2 FEEDERS

Powered feeders are used for continuous and controlled flow of bulk materials from a storage to a MH equipment or to a processing equipment.

Bulk material feeders are generally installed near the outlet of a material hopper and serve to unload the hopper in a controlled rate. Desired flow is achieved by varying infinitely the rate of operation of the loading element.

Different types of feeders are used primarily depending on the properties of the materials, like lump size, flowability, specific weight, and also on flow rate, hopper shape etc. The major types are (*i*) **belt feeders** (*ii*) **apron feeders**, (*iii*) **screw feeders** (*iv*) **oscillating feeders**, (*v*) **vibrating feeders** and (*vi*) **rotary disk feeders.**

Another type of feeders are used for feeding components one by one, from a large quantity of small components, into the workplace or the processing machine. These are called **bowl feeders.**

Some of these bulk material feeders and component feeders have been briefly described below:

11.2.1 Belt Feeders are small length flat belt conveyor, the working side of belt being supported by closely spaced idle rollers, and no support for the return belt. The conveyor is provided with stationary skirt boards. Belt speed is low. Belt feeder is put just below the outlet of a hopper with a flow control valve which regulates flow. Belt feeders are used for granular, small sized and less often for medium lumped materials. Fig. 11.2.1 shows the basic scheme of a belt feeder.

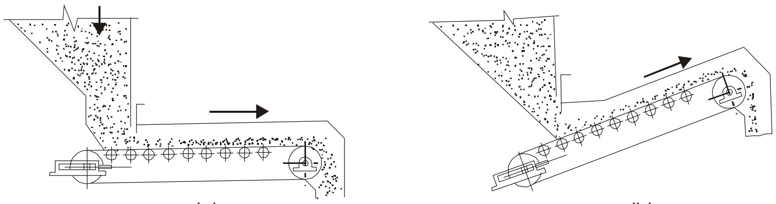


Fig. 11.2.1 Belt feeder, (*a*) horizontal, (*b*) inclined

11.2.2 Apron Feeders are similar to belt feeders, may be installed horizontal or inclined, where the belt conveyor is replaced by an apron conveyor. An apron feeder is directly placed under the outlet of a hopper without any valve. The speed of the feeder is infinitely variable from 0.05 to 0.25 m/sec to control discharge flow rate. This type of feeder is generally used for heavy, medium to large sized materials. Fig.11.2.2 shows the schematic diagram of an apron feeder.

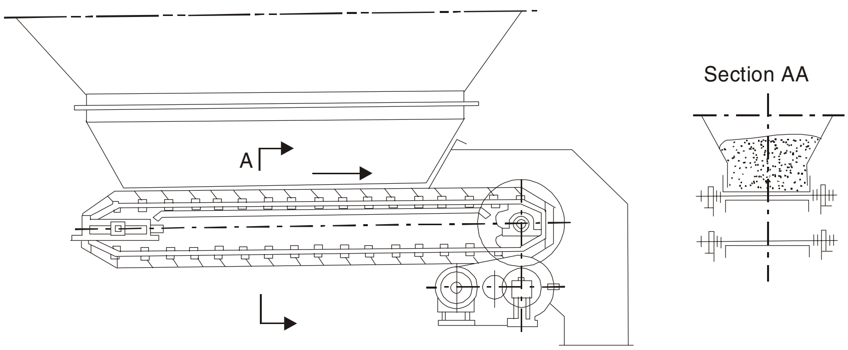


Fig. 11.2.2. Apron feeder

11.2.3 Screw Feeders are used for materials which do not deteriorate on crushing. These are essentially small length screw conveyors. A special type of these feeders have been described in chapter 8 while discussing pneumatic conveyors.

11.2.4 Oscillating Feeders consist of a horizontal or slightly declined table with side boards, placed below the hopper outlet. The table is given a reciprocating motion (50 mm to 175 mm) at a frequency of ranging from 20 to 60 strokes per minute. In the forward motion it carries some material forward, but during return stroke the material cannot go back due to dam of material from the hopper, and, therefore, spills over the front edge of the table.

11.2.5 Vibrating Feeders. A vibrating feeder consists of a trough or tube mounted on a stiff base frame with springs inbetween to convey bulk material through vibration. Inclination and stiffness of springs determine the vibrating angle and position of resonance. The feeding of material takes place on the micro-throw principle.

Vibratory feeders are classified based on the source of vibration exciters which are either (*i*) electromagnets or (*ii*) mechanical exciter.

In **electromagnetic vibrating feeders,** the frequency of vibration is 50 Hz, and the feeding rate is controlled by vibration amplitude by controlling voltage across magnet through thyristor controller.

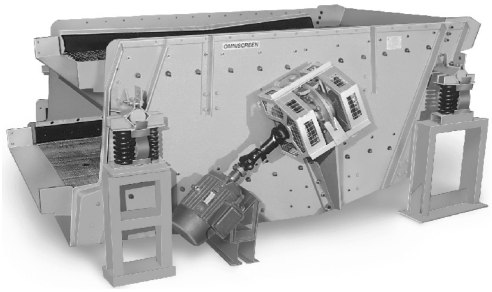
In **mechanical vibrating feeder,** either **direct force exciters** or **unbalanced motor exciters** are used. Direct force exciter comprises of two shafts fitted with unbalance masses, rotated in opposite direction through a set of gears and generate linear motion. In the later system, two unbalanced motors are used for each feeder for generating linear motion. In both the systems, both amplitude and frequency is varied simultaneously by varying the speed of the exciter motors. The sizes and shapes (rectangular or trapezoidal section) of vibrating feeders and recommended frequencies with corresponding range of amplitudes are specified in BIS standard IS:8723-1978.

Vibro feeders are available for either base mounting or suspension mounting arrangement. These feeders handle all types of bulk solids from very large lumps to fine grains, wet or dry, hot sinter, etc.

Fields of application for electromagnetic feeders include controlled feedings from bins to scales, mills, filling devices, crushers, process equipment, dryers, coolers etc. Application of mechanical vibro feeders include sinter and palletising plant, deep bunker discharge, blast furnace burden plant, for dust feeding under electro filter, feeding rotary kilns, sand feeding in foundry, knock-out stations in foundry, sand and gravel industry, cement, lime and gypsum plant, mining industry (coal, ore), chemical industry, food processing etc.

Courtesy : International Combustion (India) Limited, Kolkata

Fig. 11.2.3 Electromagnetic vibrating feeders



Courtesy : International Combustion (India) Limited, Kolkata

Fig. 11.2.4. Mechanical feeder with direct force exciter

11.2.6 Disk Feeder consists of a motor driven disk shaped table, a telescopic spout fitted with the outlet of the hopper above, and a scraper blade which can be radially fed in or out on the disk. The table is rotated slowly, telescopic spout is adjusted to keep desired gap between spout and table and then the blade is adjusted in position to allow a definite amount of the material formed below spout mouth, to be scarped and fed below. (Fig 11.2.5).

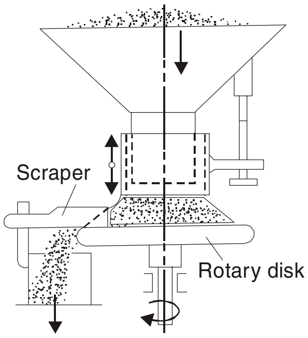


Fig. 11.2.5. Disk feeder

11.2.7 Bowl Feeders: Rotary or vibrating bowl feeders are used for feeding small components into high speed processing equipment. Various designs of feeding bowls are used to suit different sized and shaped components. A few schematic diagrams are shown below:

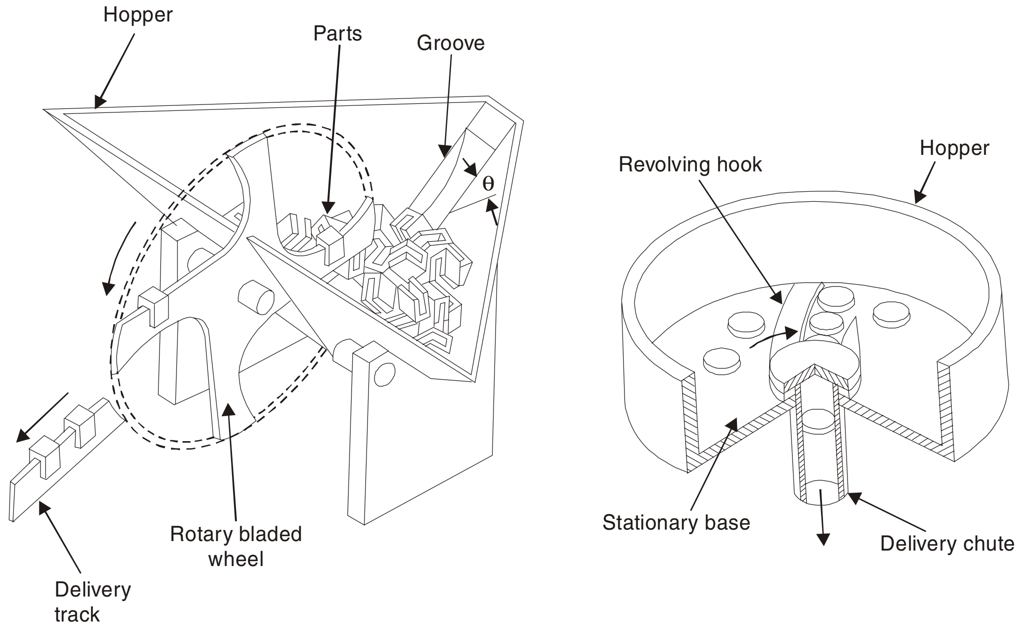


Fig. 11.2.6. Bowl feeders for feeding components

11.3 CHUTES

Chutes are inclined connections between two systems of materials handling equipment or production equipment, in the form of troughs of definite geometrical cross section or pipes, which convey unit or bulk load by gravity. A chute may connect two conveying mechanisms, two process equipment or may be installed between one materials handling equipment and one processing equipment.

Depending on the load to be handled, chutes are made of various size, shape and material:

11.3.1 Troughs: For bulk materials, rectangular or round shaped **troughs** are used. These may be lined by cast iron or hard plates or glass tiles for abrasive materials. Bowl feeders to processing equipment are always connected by trough like chutes to deliver the components in correct orientation to the exact location. Suitable change in cross section or cut-out left on the chute can correctly orient the components and/or discard the defective or wrongly oriented component.

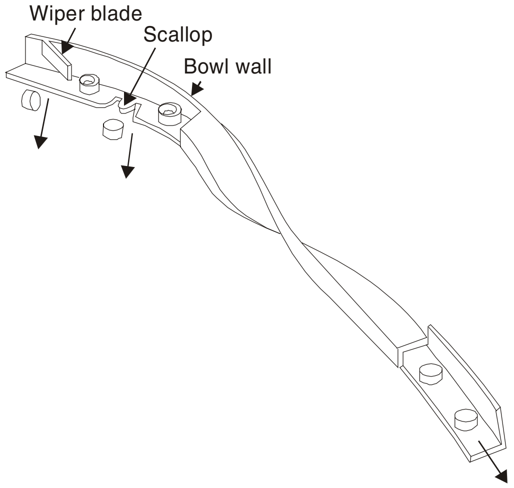


Fig. 11.3.1. Trough chute to feed bottle caps in correct orientation

11.3.2 Pipes are used for dusty or liquidous materials. **Swinging pipe** is used to distribute the material along a circular path.

11.3.3 Ladders and Spiral Chutes: These are used to lower loads vertically. They retard velocity of descend and prevent landing of load with impact. (See Fig. 11.3.2).

11.3.4 Transfer Slides: These are used to roll unit loads of round shape down an incline by gravity. They generally comprises of two rigid guides made of round or profiled steel, mounted on a framework. The loads roll over and are also guided by the two guides.

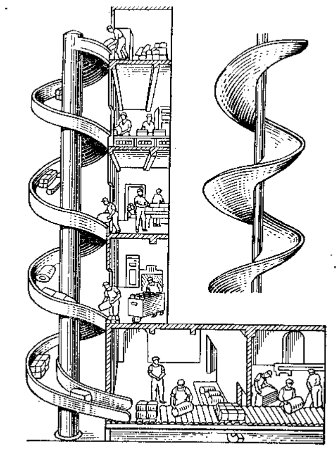


Fig. 11.3.2. Spiral chute

11.4 POSITIONERS

Positioning is defined to be the task of orienting materials into the workplace or at point of use. It is a component of **material handling at the workplace** (refer section 10.1). Positioning is conventionally a manual operation performed by the operator at the processing equipment. The purpose of a **positioner** is to perform the positioning operation independent of the operator, as well as better, and thus achieve increased production, higher safety, less fatigue of the operator and less rejection.

Depending on the product and processing needs, various manufacturers design and fabricate the desired positioners in-house. Most of the **fixtures** used in workplace also act as positioners for the jobs. However, some of the standard positioning equipment, which are classified under different heads, are mentioned below:

11.4.1 Positioning Holding Fixtures

(*i*) **Universal vise** which can be tilted horizontally and vertically, or may be positioned at any orientation through ball-and-socket joint.

(*ii*) **Welding positioner** are made as standard equipment for large and small jobs and consist of simple to complex mechanism.

(*iii*) **Turning-roll positioner** for positioning large cylindrical jobs during welding.

(*iv*) **Magnetic bench positioner.**

(*v*) **Elevating platform** can also act as a positioner for a tall job where manual work like welding, cabling, fitting etc. has to be done.

11.4.2 Manipulators and Chargers

Forging manipulators, furnace chargers, cake pushers in coke ovens, roller table deflectors and manipulators (refer section 6.6.2) are examples of above type of positioners.

11.4.3 Tables, Lifts, Bridges and Ramps

(*i*) **Positioning tables** are essentially tables whose height can be adjusted to hold job at the level at which it can be manipulated easily. Examples are sheet feeding table, die-handling table, spring operated tray positioners etc.

(*ii*) **Hydraulic lifts** are common positioning devices for lifting and lowering a heavy object. The operator can easily control this. These are used in any process and manufacturing plants, departmental stores, vehicle service centre etc.

(*iii*) **Bridges** are specially designed platform to bridge the gap or height difference between the dock edge or surface to the carrier floor, and allow use of hand trolleys or powered trucks to load or unload materials between dock and carriers. Examples are **dock board** to bridge gap, **dock leveler** to bridge height, **portable dock** etc.

(*iv*) **Ramp** is a portable device for placing at the door of a carrier or building to bridge the vertical distance to the ground by a sloping runway.

11.5 BALL TABLE

A ball table consists of a group of **ball transfers** over which any flat surfaced object may be moved or manipulated easily in any direction. Ball transfer is a device in which a larger steel ball is mounted and retained on a hemispherical seat lined with smaller steel balls. A **castor table** also serves the same objective, in which ball transfers are substituted with castors (skate- like wheels). Ball tables are often used as a section in roller, belt or similar conveyors, for changing direction of objects.

11.6 WEIGHING AND CONTROL EQUIPMENT

In any materials handling system, the quantity of materials handled is one of the most important factors. The quantity may be measured in terms of weight, volume or number of loads being handled.

Weighing scales and weigh bridges are used for off line weighing of materials. However, on-line weighing of bulk materials during conveyance is possible by **automatic weighing scales**. Volume of bulk materials are measured by **batchers**. **Counters** count unit loads.

11.6.1 **Conveyor Scale** is a section of belt conveyor with its own drive arrangement, load sensing devices (generally load cells) and electronic instruments for indicating, recording and integrating the weight of material passing through the conveyor scale. This is generally installed in the horizontal section of a belt conveyor. The equipment may be used to keep record of total weight of materials conveyed, or may be used as a controller to control speed of main conveyor such that the rate of materials delivery is kept at the desired level.

11.6.2 Batchers may be of different designs like rotating cell drums, plunger devices, alternately filled and emptied calibrated containers. Last mentioned batchers are most popular, and operating principle of one of these is shown in Fig.11.6.1. The shaped container is placed at the outlet of a hopper, and kept at that position by a pneumatic cylinder. When the container is filled to desired extent, the weight tilts the vessel against the pneumatic force and discharges the material. At the tilted position the container closes the hopper outlet.

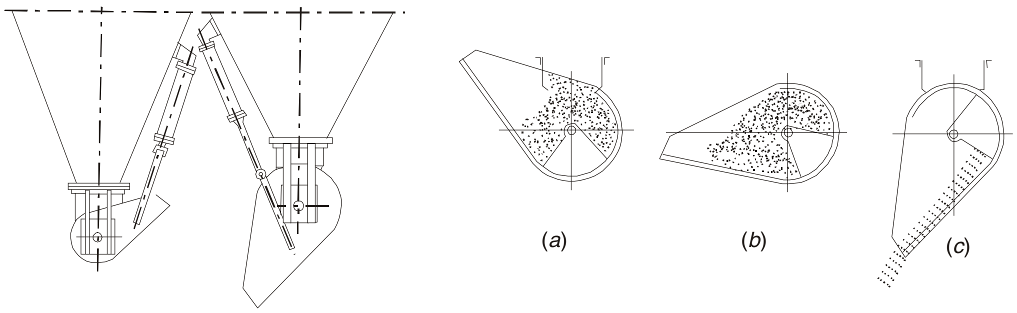


Fig. 11.6.1. Pneumatic batcher. (*a*), (*b*) and (*c*) are three positions during discharge

11.6.3 Weigh Hopper is a hopper which is mounted on its supporting frame through load cells. As material is accumulated in the hopper, the material gets weighed. At the predetermined level of weight, further filling may be stopped and the weighed amount of materials is taken out from the hopper.

11.6.4 Level Control is measurement of level of materials in large hoppers, bins or silors through bulk solid level measurement devices. These give measurement of volume of materials in the hopper. There are many types and designs of such level measurement instruments like (*i*) mechanical diaphragm type, (*ii*) mechanical pendent type.

11.7 PALLET LOADERS AND UNLOADERS

A **pallet loader**, also called **palletiser** is an automatic or semi-automatic (requiring assistance of an operator) machine to receive cartons, crates, bags etc. from an incoming conveyor, through its own synchronized conveyor, which are automatically arranged into a pallet pattern, and pushed onto a pallet held in the bed of machine. After filling of one layer, the pallet is taken down by the height of one layer, and the process continues till the entire pallet loading is complete. The pallet is then discharged, to be removed by a lift truck or conveyor. The **pallet unloader** or **depalletiser** performs the opposite function and unloads the unit loads from a pallet and feed them out in a single file into a conveyor.

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CHAPTER

Organisation, Maintenance and Safety

12.0

Importance of materials handling has already been stressed. It has also been pointed out that, correct choice of materials handling system may be the sole reason for success or failure of an industry. Use of different types of materials handling equipment have also been discussed in some details.

Having understood the importance of choosing the appropriate type of handling system and then maintaining them for continuous and safe operation of the same, one can naturally expect a proper organisation to exist within a company for managing the materials handling activities. Organisation, maintenance and safety aspects of materials handling activities are briefly discussed below.

12.1 ORGANISATION

The type of organisation responsible for materials handling activities often depends on various other operating characteristics of a company. The size of the organisation and extent of specialisation involved often determines its character and position in the company.

12.1.1 Factors Determining Importance of Materials Handling

Following are the factors, which generally determine the importance of materials handling activity in an organisation:

(*i*) *Value of materials:* In many operations, the weight or bulk of the materials being handled to its value is a high ratio, and the cost of handling is often the one largest component of the total cost of operation. Rock quarries, mining, processing of a large number of basic raw materials, etc. are examples of such operations where materials handling is the major component of processing as well as cost.

(*ii*) *Weight and size of product:* As the weight and size of the product increases, and the shape of the product gets complicated, the need for specialised handling method and equipment becomes greater. Therefore, the amount of planning, operation and maintenance of these equipment become proportionately more important.

In large foundries, heavy machine shops, metal rolling plants, process industries, shipyards etc., the products are almost exclusively handled by specialised materials handling equipment.

(*iii*) *Nature of the process:* In many processes, the raw material is carried by means of one or a number of coordinated materials handling systems through various processes and finished product is unloaded at the output of the line. An automobile assembly line or a cement production plant etc. are examples of such process lines, where materials handling operation is of great importance for continuous operation of the processing line.

(*iv*) *Mass production industry:* Mass production of various products like automobiles, house hold appliances, televisions etc. at an economic price for use by masses, is made in automated mass production lines, where materials handling between processes plays a vital role.

12.1.2 Functions involved in Materials Handling

The various functions involved in designing and operating materials handling systems have been discussed below. The functions of a materials handling organisation of a company should be the same. However, depending on the size of the organisation and relative importance of the materials handling functions, the nature of the Materials Handling organisation and forming of a separate departmental set-up for this is determined.

The different functions involved in any materials handling system vis-à-vis the scope of the materials handling organisation is as follows:

(*i*) *Planning and Designing:* The degree of planning and designing for the optimum materials handling system depends on the processes and quantum of materials handling involved. This is basically a methods engineering function.

In an existing plant of medium to large size, identification of need for additional materials handling systems, their planning and determination of the exact equipment is generally done by the materials handling engineer placed in the industrial engineering department or in the engineering department. In a smaller organisation, this may become the responsibility of the production department itself.

When a new plant involving speicalised materials handling system is set up, the design of materials handling system for the new set of plant and equipment are suggested by the respective equipment designers. The interfacing materials handling systems between individual plants or equipment is generally the responsibility of the technical consultant engaged for the entire plant. Consultant does the functions like survey, analysis, feasibility study, drawing up the technical specifications. These functions are often done in consultation with equipment suppliers and process consultants.

(*ii*) *Engineering Drawings:* For proprietary materials handling equipment, the detailed drawings always remain with the equipment manufacturers. However, they provide the Layout and General Arrangement drawings with necessary foundation drawings with load data necessary for installation of such equipment. They also provide the operation and maintenance manuals of such equipment.

In an existing plant, the engineering drawings and data necessary for setting up of a new system or modification of some existing system is made by the materials handling engineer. A consulting firm may be involved depending on the value and specialisation involved.

(*iii*) *Installation:* In most plants, this is the function of the project department, if existing, or of the plant engineer. Specialised installation and commissioning services are often provided by the respective equipment manufacturer.

(*iv*) *Operation:* Operation of different materials handling equipment and systems is necessarily considered to be the responsibility of the plant operation or production department.

(*v*) *Maintenance:* Materials handling equipment are often considered as a part of regular operating plant and their maintenance becomes the responsibility of plant maintenance department.

However, in certain plants, the maintenance of the materials handling equipment is entrusted to the materials handling section right from the beginning. In many cases, when the materials handling plants require specialised maintenance skill, the need for setting up of a separate materials handling section/department often arises out of such a need.

Maintenance, of highly specialised equipment are often subcontracted to the equipment manufacturers.

12.1.3 Materials Handling Department/Division

From the functional standpoint materials handling really belongs to the methods engineering which itself is a part of industrial engineering department. However, in a large plant or where materials handling activity is very critical for the operation of the plant, a separate materials handling department may be created to emphasise its importance and independent accomplishment of their plans and programmes.

As an independent entity, the scope and activities of a materials handling department may include some or all of the following:

(*i*) To determine the most efficient and economic means of moving, handling and movement of all raw materials, semiprocessed parts and finished products/assemblies from storage areas through production processes to shipping.

(*ii*) To establish procedures for receipt, storage and movement of all raw materials, semiprocessed parts and finished products/assemblies from storage areas through production processes to shipping.

(*iii*) Packaging, packing or crating of finished product for shipping.

(*iv*) Inter-plant movement of semiprocessed parts and assemblies.

(*v*) Analysis and design of new materials handling systems or for modification of existing systems.

(*vi*) Procurement installation and commissioning of materials handling equipment

(*vii*) Evaluation and testing of new/modified installations.

(*viii*) Maintenance of materials handling equipment.

(*ix*) Conduct training programme for operation and maintenance personnel, which includes the safety aspect of materials handling as well.

12.2 MAINTENANCE

In most of the organisations, maintenance of materials handling equipment is taken care of by the plant maintenance group. At best, it is considered to be a specialised part of general maintenance of plant and equipment. Hence, all the considerations for general maintenance work also apply to the maintenance of these equipment.

Only in case of large plants with many materials handling equipment, or in plants where materials handling equipment plays a very important role for the plant, a separate maintenance group may be involved for maintenance of the materials handling equipment. In such case, it is likely that a separate materials handling department exists and the maintenance crew is part of this department.

Apart from the general maintenance programmes like regular lubrication and inspection of the working parts, which is applicable to all types of machinery and equipment, certain specialised maintenance routines have been found to be useful for certain group of materials handling equipment. Most manufacturers of equipment provide complete instructions in the form of maintenance manual for proper care and maintenance of their products. It provides the period of greasing and lubrication of different parts and components along with the location of oiling/greasing points. These maintenance manuals are also important for repair or replacement of parts of the equipment.

However, some typical observations for a few specific group of equipment are given below, which may act as starting point in developing the maintenance plan and schedule for such materials handling equipment.

12.2.1 Industrial Trucks

Maintenance of an industrial truck is largely similar to that required for commercial vehicles/ cars, and therefore they can be maintained in a well-equipped auto garage. Regular inspection of the following systems/parts should be made for keeping them in good condition:

Battery and battery charging system; Brakes; Transmission, Clutch and shift linkages; Wheels; Steering; Fuel and hydraulic system leakage etc.

12.2.2 Conveyors

Maintenance of conveyors fall into two parts : (*i*) motive-power devices i.e. electric motor, gear box and drive system and (*ii*) track and rolling facilities. The condition of trolley wheels, chain & sprocket, belt, wire rope & sheaves, brakes etc. should be inspected at stated intervals. The wheels, tracks, chain & sprocket etc. should be kept properly lubricated to avoid excessive wear. If possible automatic and/or centralised lubrication system should be employed.

12.2.3 Cranes and Hoists

All bearings should be lubricated regularly and to be inspected periodically. Wire ropes/chains and load handling attachments must be inspected regularly. Any excessive wear or breakage of even a single wire of the wire rope calls for immediate rectification of the situation and replacement of the wire rope. Arresting gears and brakes deserve special attention so that they are in good operating condition all the times.

12.3 SAFETY IN MATERIALS HANDLING

Safety principle of materials handling, as stated in chapter 2 of this book, demands that the "handling methods and handling equipment use must be safe". A safe materials handling means the activity is free from recognized hazards that can cause or likely to cause physical harm including death to employees or public and damage to materials. Materials should always be handled such that injuries or damages are brought to the minimum, if cannot be eliminated altogether.

In order to achieve a safe materials handling operation, it is essential to follow a **safety policy** in the plant or workplace. This safety policy provides guidelines for elimination or reduction of accidents causing injuries and damage due to both manual and equipment assisted materials handling. The safety policy generally include training provisions, guidelines for manual and equipment assisted materials handling, materials storage and also provides guidelines on housekeeping, securing load on vehicles, fire-fighting, requirements for guarding, illumination, labels, signs, makings etc. The safety policy may also specify the responsibility towards safety procedures of various personnel and departments of an organisation.

Different countries have developed and adopted their National Health and Safety Standards and proper administrative bodies to overview whether industry and other areas of employment are adhering to such standards. In USA, the Occupational Safety and Health Administration (OSHA) is such a body, who issues different laws on occupational health and safety. Subpart N of their laws deals with Materials Handling and Storage, and paragraph SP #1910.176 is specifically on Materials Handling. Similarly, part 14 of Canada Occupational and Safety Regulations is devoted on Materials Handling.

In India, Safety and Health regulations and rules are dispersed over various different Acts and Rules. Some of the important ones are:

- Indian Factories Act 1948, amended at various stages. Some of the states have incorporated additional regulations applicable to their states.
- Dock workers Health and Welfare Act, 1986
- Indian Mines Act & Rules, 1952
- Indian Explosive Act, 1984
- Static and Mobile Pressure Vessel Act, 1981
- Underground Storage Tank Act, 1990
- Indian Boiler Regulation, 1949
- Motor Vehicles Act, 1988
- Indian Electricity Rules, 1965
- Indian Fire Act, 1990
- Air Pollution Act, 1980
- Water Pollution Act, 1982

There are many other acts, rules and regulations involving Nuclear and other Radiation Hazards, Food Adulteration, Medicines and Drugs etc.

So specific comprehensive safety and health regulations involving all areas are in existence. However, a central controlling authority called National Health and Safety Council has been formed recently for integrating all relevant existing rules and regulations.

General provisions of the safety guidelines make good sense from the standpoint of practical and safe materials handling. These safety provisions/guidelines on some aspects of materials handling are briefly discussed below:

12.3.1 Training

Training is required for each employee who manually handles or moves materials and for employees who move items using materials handling equipment. This training shall be provided to employees prior to them performing any job requiring manual handling or equipment assisted handling tasks. This initial training should be based on the discretion of the supervisor and supplemented with refresher training. Training will include instruction in:

- Proper lifting techniques for manual materials handling
- Available equipment types for equipment assisted materials handling
- Equipment operations for applicable materials handling equipment
- Any special rules or guidelines that may cover specific types of materials handling equipment.

12.3.2 Manual Materials Handling

Manual materials handling involves the handling, moving, lifting, and carrying of materials without the use of mechanical equipment. Minimizing injuries from materials handling requires knowledge and training about these tasks. Some basic safe practices for manual material handling include:

- Inspecting materials for slivers, jagged edges, burrs, rough or slippery surfaces.
- Getting a firm grip on the object.
- Keeping fingers away from pinch points, especially when setting down materials.
- Keeping hands away from ends of lumber, pipe, or other long objects, to prevent them from being pinched.
- Wiping off greasy, wet, slippery, or dirty objects before trying to handling them.
- Keeping hands free from oil and grease.

In most cases, gloves, hand leathers, or other hand protectors must be used to prevent hand injuries. Employees should be physically fit to perform jobs requiring heavy and / or frequent lifting. If a load is thought to be more than what one person can handle, two employees should be assigned to the operation, or materials handling equipment should be provided.

All employees who lift materials will be trained in proper methods to use to pick up and put down heavy, bulky or long objects for reducing the probability of back injuries due to improper lifting. Every attempt should be made to reduce manual lifting through the use of mechanical equipment or by rearranging the storage pattern of the materials.

12.3.3 Materials Handling with Equipment

When materials over 20 kgs to be handled, then additional tools and equipment should be used for materials handling. A variety of tools and equipment are available to assist in the handling of materials. Theses tools and equipment fall into the following categories.

- Manual Materials Handling Equipment
- Powered Industrial Trucks (rider-operated and walker-operated)
- Hoists
- Rigging

Manual materials handling equipment is used for a wide variety of tasks. Each of these items should be used only for its designed task and kept in good condition. The common manual materials handling equipment are those described in section 5.1.

Guidelines on the safe use of some of these manual materials handling equipment are given below:

Manual Handling Equipment Guidelines

Dollies : Load materials evenly on dollies to prevent tipping and view obstruction. Push rather than pull dollies, unless specially designed to be pulled.

Jacks : Use a jack properly rated for the load. Place the jack on a level, stable, and clean surface. Avoid metal-to-metal contact (jack to surface being lifted) by using wooden shims. Block the load after the jack lift.

Two wheel trucks : Select trucks with widely spaced wheels to prevent overloading. Use knuckle guards to protect hands from contact. Make sure that hand trucks are parked in a vertical position when not in use.

Powered industrial trucks comes in two general classifications:

- Rider-operated (mostly forklifts)
- Walker-operated (motorized handtrucks)

Powered industrial trucks are versatile and efficient materials handling equipment, which have eliminated many high risk manual handling tasks. However, inherent in their physical and operational design are potential hazards which can lead to accidents. Occupational injuries involving forklifts or lift trucks are commonplace. Major reasons for forklift accidents include:

- Improper ventilation and battery charging
- Instability caused by shift in the centre of gravity
- Limited visibility
- Poor communication among employees in the work area
- Inadequate vehicle maintenance
- Using trucks for unsuited tasks.

Following list presents a checklist to help prevent forklift accidents.

Checklist Forklift (Lift Truck) Accident Prevention

System Evaluation

Operators Trained?

Production speed evaluated?

Trucks properly maintained?

Drivers' skill/trucks matched?

Truck tools/attachements/accessories available?

Age/Condition of trucks considered?

Operational Requirements

Operating speed controlled?

Proper loading practices followed?

Alerting workers of trucks' presence?

Proper backing/turning?

Proper lifting practices followed?

Prohibiting unauthorized operators/riders?

Communication with co-workers while performing shared tasks?

General attentive operation?

Servicing of trucks?

Blocking wheels on semi trailers/railroad cars?

General prohibition of unsafe behavior?

Parking of trucks?

Worksite Characteristics

Sufficient width of aisles/travel lanes?

Travel lanes unclusttered?

Visibility/warnings at intersections/doors?

Environmental conditions considered (noise, gases, dusts, lighting)?

Restriction of personnel in travel lanes?

Traffic patterns controlled?

Driving path is on level/nonslippery surfaces?

Load Characteristics

Proper palleting?

Weight of loads?

Condition of pallets and skids?

Stable loads/good visibility?

Truck Condition

Are the following items in good repairs, and/or in good condition, and have good design characteristics:

Brakes?

Transmission, clutch and shift linkage?

Mirror with unobstructed vision?

Operating controls?

Steering?

Minimal leaks (hydraulic, gas, oil, transmission, brakes)?

Operation of safety features (Turn signals, backup alarm)?

Acceptable emission levels from truck?

Hoists are used to raise, lower, and transport heavy loads for short distances. They usually range from 250 kg to 2 tonnes in capacity. Major factors affecting the safe use of hoists are design and operating conditions, operator skills and knowledge, and proper rigging practices. Accidents generally associated with hoists are:

- Failure of attachment devices during a lift, resulting in dropped loads
- Collision with persons or objects as a consequence of uncontrolled movement of the hoist or load.
- Contacts to personnel in the work area while loads are being attached.
- Failure of structural or mechanical parts of hoists during the lifting or moving of loads.
- Lift loads greater than the rated capacity of hoists.

Following list presents suggestions for design and operator conditions and operator control to minimize accidents and injuries on hoists.

Recommendation for Safe use of Hoist

Design and Operating Conditions

- Supply hoists specially designed to handle the maximum anticipated loads. Require the posting of safe load capacity charts and safe operating procedure on each hoist.
- Confirm that all hoists are properly installed and tested prior to initial use. Make certain that supports have an adequate design factor for the maximum loads to be imposed (including the weight of hoists and rigging).
- Place hoists in a reasonably unobstructed area and away from personnel traffic areas. Do not allow workers under loads during any lift or movement.
- Perform regular inspection, testing, maintenance and needed repair.
- Authorize only trained and experienced personnel to operate hoists, to conduct hitching (rigging), and to give load lift and movement signals.

Operator Control

- Inspect and test hoist operating systems, including transport, controls, limit switch, hoist ropes and chains, and brake functions.
- Determine the weight of the load to be lifted keeping within structural and stability limitations.
- Make sure that the hoist and load hitch are centered above the load.
- Ensure that load attachments are secure and within capacity prior to the lift.
- Select in advance the load travel path, paying particular attention to personnel and fixed obstacles.
- Check to be certain that rigging and signaling personnel and others are away from the load when it is being lifted or moved.
- Make smooth lifts and movements of load; avoid abrupt movements, which may cause a load to fall.
- Report all equipment, structural, or functional problems.
- Have regular inspections, testing, lubrication, maintenance, and repairs performed.

12.3.4 Storage

Planning for materials storage reduces the handling required to move materials and articles for processing, use, or shipment. Material movement is facilitated by adequate storage space at receiving, processing and shipping areas. Long and short-term storage should be considered to reduce hazards and to facilitate the placement and removal of materials. Storage equipment (racks, bins, pallets, etc.) should match the materials to be temporarily held or stocked. Bags, bundles, and other containers should be properly stacked, blocked, interlocked, and limited in height. For open pits, tanks, vats, etc., covers and guardrails must be provided to reduce contact and fall hazards. Special precautions are required for the storage of hazardous and flammable materials. The level of precaution should match the potential for injury posed by particular substances. Materials storage guidelines for the following mode of storage or type of materials have been discussed below:

Materials Storage Guidelines

Warehouse Storage: When planning materials storage, make sure materials do not obstruct fire alarm boxes, sprinkler system controls, sprinkler heads, fire extinguishers, first-aid equipment, lights, and electric switches. All exits and aisles must be kept clear at all times and shall be appropriately marked. "No Smoking" signs must be posted where necessary throughout the warehouses. Maximum safe load limits of floor within buildings and structures shall be conspicuously posted in all storage areas, except for floors or slabs on grade. Maximum safe loads shall not be exceeded.

Open Yard Storage: Plan open yard storage to have driveways between and around combustible storage piles at least 5 meters wide and maintained free from accumulation of rubbish, equipment, or other materials. Driveways should be spaced so that a maximum grid system unit of about 16 meters is produced. Combustible materials must be piled with due regard to the stability of piles and no higher than 6 meters.

Bagged Material: Bagged material must be cross-tied with the mouths of the bags toward the inside of the pile. When the pile is 1.6 meters high, it must be stepped back one row for each additional 1meter. of height. A pile of sacks must never be disturbed by the removal of sacks from lower rows.

Pipes and Bar Stock: Pipes and bar stock must be stored on specially designed skills or racks and shall be safely blocked to prevent rolling or spreading. When moving these materials, employees should work from the end of the pile as much as possible. Employees must be instructed never to attempt to stop rolling or sliding pipes or bar stock.

Sheet Metal: Sheet metal must be handled with hand leathers, leather gloves or gloves with metal inserts. All bundles must be separated by strips of wood to facilitate handling when the material is needed for production and to lessen chances of shifting or sliding of the piles of material.

12.3.5 Housekeeping

Storage areas will be free from excess materials that create hazards that result in fire, explosion, slips, trips, or infestation by insects or rodents. Weeds and other vegetation must be controlled by cutting or using herbicides when necessary.

12.3.6 Aisles and Passageways

Where mechanical handling equipment is used, sufficient safe clearances shall be allowed for aisles, at loading docks, through doorways and wherever turns or passage must be made. Aisles and passageways shall be kept clear, unobstructed and in good repair, with no obstruction across or along aisles that could create a hazard. Permanent aisles and passageways shall be appropriately marked. Additionally, clearance signs and warning of clearance limits shall be posted. Equipment working in aisles will be marked indicating the working load it will safely support.

REFERENCES AND BIBLIOGRAPHY

1. Immer, J.R., “Materials Handling”, McGraw Hills.
2. Allegri, T.H. “Materials Handling: Principles and Practice”, CBS Publishers & Distributors, New Delhi.
3. Occupational Safety and Health Administration (OSHA), USA, subpart N, paragraph # 1910.176
4. North Carolina Department of Environment and Natural Resources (NCDENR), “Safety Policy: Materials Handling SP# 1910.176
5. Canada Occupational Health and Safety Regulations Part 14—Materials Handling.

Appendix

List of Materials Handling Equipment Manufacturers

A large number of companies throughout India, big and small, are engaged in manufacturing different kinds of standard as well as custom-built materials handling equipment.

The following list contains names of a few of such companies with their addresses and products/ services. The list is not a comprehensive one and omission of names is not intentional. The below mentioned websites may be used for searching many more Indian materials handling equipment manufacturers and their range of products:

(1) www.indiamart.com (.) (2) www.mosaicindia.com (.) (3) www.indianindustry.com (.) (4) www.easy2source.com (.) (5) www.seekandsource.com (.) (6) www.infobanc.com (.) (7) www.pr.com (.) (8) www.surfindia.com (.) 9)www.product.jimtrade.com (.) 10)www.indiayellowpages.com (.) (11) www.gidoline.com (.)

Sl. No.	Name & Address of Manufacturers	Products
1.	ACME Cranes, Mumbai	EOT Cranes
2.	Advance Equipment Company Mumbai- 400604 Maharashtra	Conveyor Belts, Roller Conveyors, Belt Conveyors, Screw Conveyors, Slat Conveyors, Chain Conveyors
3.	Appolo Cranes (P) Ltd C-225/5, Mayapuri Industrial Area, Phase-II, New Delhi - 110 064, India Phone: +(91)-(11)-28111222/28111333 Fax: +(91)-(11)-28111444	Hydraulic mobile cranes, Hydraulic crawler cranes, Mobile grove cranes, Hydraulic grove cranes, Grove carry cranes, Pick up cranes
4.	Armatic Engineering Private Limited 8, SIST Industrial Area, 27th Cross, Banashankari II State, Bangalore - 560 070, India Phone: +(91)-(80)-26717078/26711733 Fax: +(91)-(80)-26713138	Material handling equipment for handling coils, Slabs, Ingots, Truck mounted hydraulic cranes, Down shop lead (DSL) system, Plate clamps for plate handling, Festooning cable system.

Sl. No.	Name & Address of Manufacturers	Products
5.	Ashton Green & Co. No. 118, Sir Vithaldas Chambers 16, Mumbai Samachar Marg Horniman Circle Mumbai-400023 (91)-22-22044375/2209, 22880526	Belt Conveyors, Chain Conveyors, Bucket Elevators, Wire Mesh Conveyors, Roller Conveyors, All Type of Conveyor Chains
6.	Avon Cranes Private Limited 395, Udyog Vihar, Gurgaon-122016, India (91)-(124)-341934/2341935/2341026 (91)-(124)-2347251/2341197	Cranes, EOT cranes, Goliath cranes, elevators, Pinion elevators, Jib cranes, Piston elevators, Rack elevators
7.	BHEL, Delhi BHEL House, Siri Fort, New Delhi-110 049 (011)2600-1010	Materials Handling Plants
8.	Braithwaite & Company Limited, 5, Hide Road, Kolkata - 700 043, (91)-(33)-4397415/4397413/4394414 (91)-(33)-4395607/4397632	All kinds of cranes
9.	Competent Conveyor Systems (P) Ltd. C-117, Sector -65, Distt. Gautam Budh Nagar, Noida- 201 301, India	Bucket elevators, Belts conveyor, Chain conveyors, Overhead conveyors, Screw conveyors, Slat conveyors, Roller conveyors
10.	Conveytech Engg., T. T. C. Industrial Area, No. W-386, M.I.D.C.Industrial Area, Rabale, Mumbai Navi Pin code-400701 (91)-22-2769 3247/2769/9634	Screw Conveyors, Slat Conveyors, Wire Mesh Belt Conveyors, Roller Conveyors

Sl.No.	Name & Address of Manufacturers	Products
11.	Consolidated Hoists Pvt. Ltd. No. 29-30 Industrial Estate, Gultekadi Pune-411037 (91)20-24271428	Elevators
12.	Desol Associated Engineers SRA-21B, Shipra Rivera Indrapuram, Ghaziabad - 201 012, India	EOT cranes, HOT cranes, Jib cranes, Single grinder cranes, Double grinder cranes, Hydraulic lift cranes, Hydraulic stackers, Hand Pallet Trucks, Roller conveyors, Belt conveyors.
13.	Devcon Systems and Projects Private Limited, 18, Flat No. 102, Prince Anwar Shah Road, Kolkata - 700 033, India	Belt conveyors, Screw conveyors, Steep angle bucket conveyor, Idler and pulleys for conveyors, Bucket elevator, Vibrating screen, Vibrating Feeder
14.	Doosan Heavy Industries & Construction Co. Ltd. Marubeni Office, (2nd Floor), 25, Mittal Chambers, Nariman Point Mumbai-400 02 (022)5633-2076 cminuk@doosanheavy.com	Containers Cranes, Stacker Reclaimers, Ship Loaders/Unloaders, Materials Handling Plants
15.	Elecon Engineering Co. India Limited, P.O. Box No. 6, Anand-Sojitara Rd. Vallabh Vidyanagar, Gujarat-388 120 (0)2692-230017 (0) 2692 230017 email:infogear@elecon.com www.elecon.com	Stacker Reclaimers, Wagon Loaders/ Unloaders, Conveyors Components, Materials Handling Plants
16.	Electromech Engineers 16/3, F2 Block, M.I.D.C, Pimpri, Pune-18 Pune, Maharashtra, INDIA PIN-411 018 (020)-7474616,(020)-7473666 www.electromechengineers.com	Electric Hoist, E.O.T. Cranes, Goliath Cranes, Stacker Cranes, Winches

Sl.No.	Name & Address of Manufacturers	Products
17.	Elite Steels (P) Ltd. Plot No. 13, Sector-25, Faridabad-121004, Haryana, India http://www.pushpak.co.in	EOT cranes & electric hoists for hot metal handling & engg.,
18.	Emtici Engineering Limited Appejay House 1st Floor DinshawVachha Road Churchgate Reclamation Mumbai-400 020 (022)2282-1315 a_bablad@bomemtici.ele.con.com	Reach Stackers
19.	Engineering Projects India Limited Core-3, SCOPE Complex 7, Institutional Area, Lodhi Road New Delhi-110 003 (011)236-1666(E-2212) epind@nde.vsnl.net.in www.engineeringprojects.com	Materials Handling Plants
20.	Equipment Engineers Pvt. Ltd. 428, Lake Gardens, Kolkata-700 045, West Bengal, India (0) 33 2417 0661 (0) 33 2417 0661	Screw Conveyors, Chain Conveyors, Belt Conveyors, Skip hoist, Trolleys.
21.	Ernst Komrowaski & Co. R-71, Greater Kailash 1 New Delhi-110 048 (011)2646-7387	Stacker Reclaimers, Wagon Loaders/ Unloaders, Ship Loaders/Unloaders, EOT Cranes, Conveyors, Materials Handling Plants
22.	Eskorts Ltd., Faridabad, Haryana	Tractors

Sl. No.	Name & Address of Manufacturers	Products
23.	Essar Industries #4, Byrappa Lane, 100 Feet Road, Jalahalli Cross, Bangalore-560057, Karnataka, India http://www.elitecranes.com	Bulk & Coil Handling Systems
24.	Furnace and Foundery Equipment Co., Plot No. 4, Chandivoli Farm, Off Saki-Vihar Road, Mumbai-400072	EOT Cranes, Skip Hoists, Grab Buckets
25.	Fenner India Limited Mktg_mhd@fennermail.com	Conveyors, Conveyor Belts
26.	FFE Minerals India Private Limited, Chennai, FFE Towers 53, G.N. Chetty Road Chennai-600017 (044)5218-712 HYPERLINK gmaitra@ffegroup.co.in	Stacker Reclaimers, Wagon Loaders/ Unloaders, Conveyor Components, Conveyor Belts, Pipe Conveyors
27.	Garden Reach Ship Builders & Engineers Limited, P-70, Karl Marx Sarani Kolkata-700 043 (033) 2469-8100	Material Handling Plants, Conveyors
28.	GEA Energy System (I) Ltd. New Delhi (011)2693-2473 geadelhi@vsnl.net	Material Handling Plants

Sl. No.	Name & Address of Manufacturers	Products
29.	Godrej & Boyce Mfg. Co. Ltd., Pirojshanagar, Vikroli, Mumabi-400 079 (0) 22 55964652 (0) 22 55964652 mhemktg@godrej.com www.godrej.com	EOT Cranes, Fork Lift Trucks, Hand Trucks
30.	HIC International Co. D-136, Shankar Road, New Delhi - 110060, India http://www.rubber-steel-industrial- products.com	Belt Conveyor
31.	Him Cableways 57, Industrial Area, Phase-2, Chandigarh-160002,India (91)-(1722)-656749 (91)-(1722)-637791	Aerial ropeways, Cable cranes, other material handling equipment
32.	Hitech Enterprises J3/191, IInd Floor, Rajouri Garden, New Delhi- 110 027, India net/conveyor-belts.html" \t "_top" http://www.hitechenterprises.net/conveyor- belts.html	Belt conveyor, Cleated belt conveyors, Truck loaders, Rotary air lock,Elevators
33.	Hi-Tek Engineers & Techno Services, Bangalore 45 & 46, Sri Lakshmi Venkateshwara Industrial Estate, 2nd Cross, 8th Main Road, Peenya 2nd Stage, Bangalore - 560 058, India +(91)-(80)-28362593 +(91)-(80)-28360275	EOT cranes, Gantry cranes, Jib cranes, Electric hoists, Good lifts Electric winches

Sl. No.	Name & Address of Manufacturers	Products
34.	Hi-Tech Material Handing Engineers Limited, 604 A, Shivalaya, 179, Ethiraj Salai Egmore, Chennai - 600 008, India +(91)-(44)-28252990/26811204/55688755	Hydraulic floor cranes, Scissor lift Stackers battery operated fork lift, Electric wire rope hoists, Shrouded conductor.
35.	Hyderabad Industries Limited 307/308, Om Rachana CHS, Sector-17, Vashi, Navi Mumbai - 400 703, India +(91)-(22)-39581787 +(91)-(22)-27895792	Crawler cranes, Hydraulic excavators
36.	International Combustion India Limited, Kolkata,107/1, Park Street, 4th Floor, Kolkata- 700 016	Vibratory Conveyors and feeders, Conveyors, Material Handling Plants
37.	Ishar Hoist & Cranes (P) Ltd. Mumbai Navi - 400705 Maharashtra	Cranes
38.	Jaypee Engineering and Hydraulic Equipment Limited G/106, Block F, New Alipore, Kolkata-700053, India	Hydraulic cranes, Hydraulic scissors lift, Hydraulic truck unloader, Hydraulic grabs, Hydraulic mobile cranes, Stationery cranes
39.	Jessop & Co.Ltd., 1, Rawdan Street, Subham Building, 6th Floor, Kolkata-700 016	Level Luff Cranes, EOT Cranes, Material Handling Plants
40.	Josts Engineering Company Limited Road 12, Wagle Ind Estate, Thane-400604, India 25821727/25821746/25821748/ 25823478/25823478	Material handling equipment
41	Jindal Steel and Power Limited Jindal Centre, 12, Bhikaji Cama Place, New Delhi - 110 066, India http://www.jindalsteelpower.com	Cranes

Sl. No.	Name & Address of Manufacturers	Products
42.	JMC Engineers 25-26/8, Nilsin Mill Factory Compound, Phase I, GIDC Vatva, Ahmedabad-382445, India http://www.jmcmachines.com	Deep bucket conveyors, Vertical bucket conveyor, Vertical bucket elevators, Vertical pneumatic conveyors
43.	K M Engineering Co. Ansa Industrial Estate, Saki Vihar Road, Mumbai, Maharashtra, INDIA PIN-400072 (022)-28522626	Goliath Cranes, Grabbing Cranes JIB-Cranes, Wire Rope Hoists
44.	Larsen & Toubro Limited, Chennai 303, Mount Poonamalee Road, P.B. 979, Manapakkam, Chennai - 600 089, India +(91)-(44)-22492747/22493318 +(91)-(44)-22493317	Level Luff Cranes, Wagon Trippers Stacker Reclaimers, Wagon Loaders/ Unloaders, Ship Loaders/Unloaders, EOT Cranes, Fork Lift Trucks, Conveyor, Material Handling Plants
45.	Macmet India Limited 27-B, Camac Street, Kolkata-700020,India +(91)-(33)-22479694/247819/24117365 +(91)-(33)-22479694/247819	Bulk material handling equipment
46.	Mannesman Dematic (India) Pvt. Ltd. 1, Sarojini Naidu Sarani, Kolkata - 700 017 (0) 11 25525200 (0) 11 25542455 dccin.delhi@demagcranes.co.in www.demagcranes.co.in	EOT cane, Hoists, Mobile cranes, Storage & Retrieval systems.
47.	Max Industries 27-28, G.I.D.C., Modasa Road, Kapadvanj - 387 620 (2691)-262682/263436	Hoists, canes, Materials handling Equipment, Chain pulley block, Trolley conveyor, Jib crane, EOT cranes, Monorail.

Sl. No.	Name & Address of Manufacturers	Products
48.	McNally Bharat Engg. Co. Ltd. Park Street, Kolkata- 700 016	Container canes, Level Luff Cranes, EOT canes, Conveyors, Material handling plant.
49.	Moktali Engineering Company 94-A, Chhani Road, Opp. Octroi Naka, Vadodara-390002 265-2775601 www.moktaliengg.com	Vibrating Screens, Belt Conveyors, Screw Conveyors, Bucket Elevators, Feeders, Mixers
50.	Mukand Limited, Mumbai	Level Luff Cranes, EOT Cranes Grabs
51.	Otis Elevators Co. (India) Limited, Magnus Towers, 9th Floor, Mindspace, Link Road, Malad (West) Mumbai- 400 064 (91-22)28449700/56795151 www.otis.com	Elevators
52.	Phoenix Yule Limited, 40, Strand Road, 3rd Floor, Kolkata- 700 001 (22432-2795)	Conveyors Belts
53.	Pilco Storage Systems Private Limited B-51, Derawal Nagar, First Floor, Opp. Model Town, New Delhi - 110 009, India http://www.pilcoonline.com	Material handling products like plastic pallets, pallet racks
54.	Promac Engineering Industries Limited Alahalli Anjanapura Post Bangalore-560 062 (080)2632-0372 promac@vsnl.com promacindia.com	EOT Cranes

Sl.No.	Name & Address of Manufacturers	Products
55.	Raman Engg. Co. Pvt. Ltd. Ahmedabad-382445 Gujarat	Materials Handling Plants
56.	Robotic Equipments 115, Diamond Centre, L.B.S. Marg, Vikhroli (West), Mumbai-400083, India +(91)-(22)-25780666 +(91)-(22)-25781815 http://www.indiamart.com/ roboticequipments	Elevating truck, Scissors lift platforms, IPC lifter, Floor crane hydraulic pallet trucks, Skid jack, Semi live skid pallets, Pallet stackers, Floor crane and dock leveler
57.	Rotomechanical Equipments Plot No. 327, IInd Cross Street, Nehru Nagar, Old Mahabalipuram Road, Kottivakkam, Chennai - 600 096, India +(91)-(44)-24927127 +(91)-(44)-24926872 http://www.indiamart.com/ rotomechanicalequipments	Belt conveyor, Roller conveyor, Slat conveyor, Overhead conveyor Apron conveyor, Wire mesh conveyor, Bucket & chain elevators, Trolleys, Jib crane, Gantry crane.
58.	Safex Equipments Pvt. Ltd. No. 517, G.I.D.C. Industrial Estate Phase IV, Vatva Ahmedabad-382445 (91)-79-25842836 www.safexcrane.com	Electric overhead travelling cranes, Gantry cranes, Electric hoists
59.	Sandvik Asia Limited Mumbai-Pune Road Dapodi Pune-411 012 (020)710-4831 Anantha.ks@sandvik.com	Stacker Recliamers, Wagon loaders/ Unloaders, Ship loaders/unloaders, Conveyors, Material handling plants

Sl.No.	Name & Address of Manufacturers	Products
60.	Santec Hydrofluid Engineers GD-96, 'Santec' House, Vishakha Enclave, Pitampura, New Delhi - 110 034, India http://www.santecindia.com/ material-handling-equipment.html	Pallet trucks, Stackers, Lifts, Lifting tables, Conveyors
61.	Saroj International Plot No. B-7, Industrial Estate, Delhi Road, Partapur, Meerut- 250103, India	Pallet trucks, High lift pallet trucks, Hand lift scissor platform, Stackers, Mobile platform, Mobile floor jib crane, Mini pallet stacker
62.	Sarada & Company, Chennai C-7, Ground Floor, Marina Square, 26/27, Santhome High Road, Mylapore, Chennai - 600 004, India +(91)-(44)-25361609/24934933 +(91)-(44)-24642458	Tyre mounted cranes, Crawler cranes
63.	S Crane Engineering Works Pirani Compound, No. 39, Ambawadi, Dahisar (E), Mumbai-400068 (091)-22-28951230 www.scranes.net	Cranes products, EOT Cranes
64.	Sicco Engineering Works Shed No. 454, Sidco Industrial Estate, Ambattur, Chennai-600 098, India	Gravity roller conveyors, Chain driven roller conveyors, Lifting table Turn table, Slat conveyors, Flat belt conveyors
65.	Sureka Engineering Industries, 19, Pollock Street, Kolkata-700 001 2235-1792/6453/3385	EOT cranes, Goliath cranes, Gantry cranes, Electric winches
66.	Sri Sahib Enterprises S-221/144-A, Street No. 4, Vishnu Garden, New Delhi - 110 018, India "http://www.indiamart.com/	High reach stacker, Pallet trucks Traction battery, Traction charger

Sl. No.	Name & Address of Manufacturers	Products
67.	Techno Industries Address: PLot No. 613, Phase IV, GIDC, Vatva, Ahmedabad-382445, India +(91)-(79)-5830742 +(91)-(79)-5831839	Electric chain pulley block, Jib Cranes, EOT cranes—double girder & single girder, Under slung cranes
68.	Telco Construction Equipment Company Ltd., Jubillee Building 45, Museum Road Bangalore-560 025 (080) 2558-3345 dipak@teslon.co.in	Grabs, Mobile Cranes, Fork Lift Trucks
69.	Technocraft Cranes Pvt. Ltd. Mumbai- 400083 Maharashtra	Cranes
70.	TIL Limited, Kolkata 1, Taratolla Road Kolkata-700 024 (33)2469-3739 sb@tilindia.com	Container cranes, Reach stackers Level luff cranes, Wagon loaders/unloaders, Ship loaders/unloaders, Grabs, Mobile cranes
71.	TRF Limited, Kolkata Tata Centre, 6th Floor, 43, Chowringhee Road Kolkata- 700 071	Level luff cranes, Wagon tipplers, Stacker reclaimers, Wagon loaders/Unloaders, Ship loaders/Unloaders, EOT cranes, Grabs conveyors, Material handling plants, Pipe conveyor
72.	Usha Hydraulics Arya Center, Opposite Color Chem. Ltd., Balkum, Thane - 400 608, India	Hydraulic dock levelers, Scissor tables, Pallet trucks, Stackers Fork trucks, Transfer trolleys
73.	Vinar Systems Ltd., 5A, Lord Sinha Road, Kolkata-700 071 (033) 2282 5424/3661 infor@vinar.com	Power & free conveyors, Monrails, Roller conveyors, Belt conveyors, Screw conveyors

Sl. No.	Name & Address of Manufacturers	Products
74.	Vishwa Industrial Company Private Limited 62-A, Hazra Road, Kolkata-700019, India (91)-(33)-24759901	Conveyors haulage equipment
75.	Voltas Limited, Bombay Voltas House, Dr. Babasaheb Ambedkar Road, Chinchpokli, Mumbai-400 033	Reach stacker, EOT cranes, Fork lift trucks, Hand trucks, Mobile cranes, Material handling plants
76.	WMI Cranes Ltd., Pune	Level Luff Cranes, EOT Cranes, Conveyors

INDEX