UNIT I

CONVEYING EQUIPMENTS

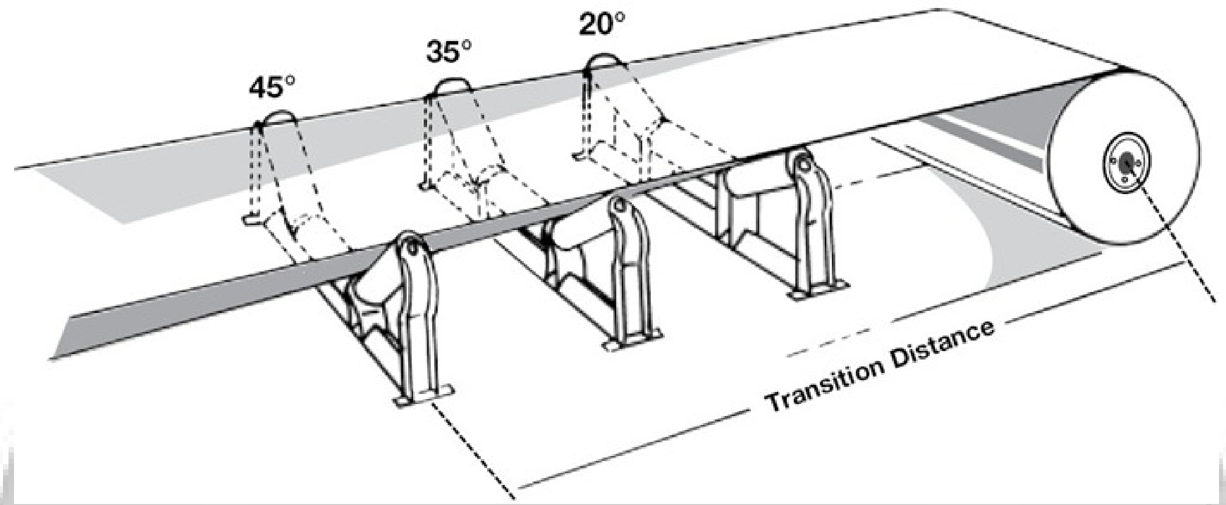
- A **conveyor system** is a common piece of mechanical handling equipment that moves materials from one location to another. Conveyors are especially useful in applications involving the transportation of heavy or bulky materials. Conveyor systems allow quick and efficient transportation for a wide variety of materials, which make them very popular in the material handling and packaging industries
- Transporting material from one place to another over a stationary structure.
- Caries material in continuous stream with its distinct feature such as endless chain or belt.
- Can be done horizontally, vertically or inclined.
- When the equipment does horizontal conveying, it is known as conveyor and when it does vertical, it is known as elevator.
- Conveying are mainly used in mining, construction and in some of the industries.
- In construction industry, conveyors are mainly used for concreting purpose.

Utility

The Advantage of using conveyors are as follows:-

- It increases the output.
- It facilitates continuity in operation.
- It results in time saving.
- There are no waiting periods.

1. **Belt conveyor**
    - Used when large quantities of materials have to be conveyed over long distances at fast speed.
    - It consists of a belt running over a pair of end drums or pulleys and supported at regular intervals by a series of rollers called idlers.
    - These idlers are supported on a conveyor frame.
    - The middle sag provided in the belt prevents the spilling of material.
    - Generally, rubber is most commonly used as conveyor belt.

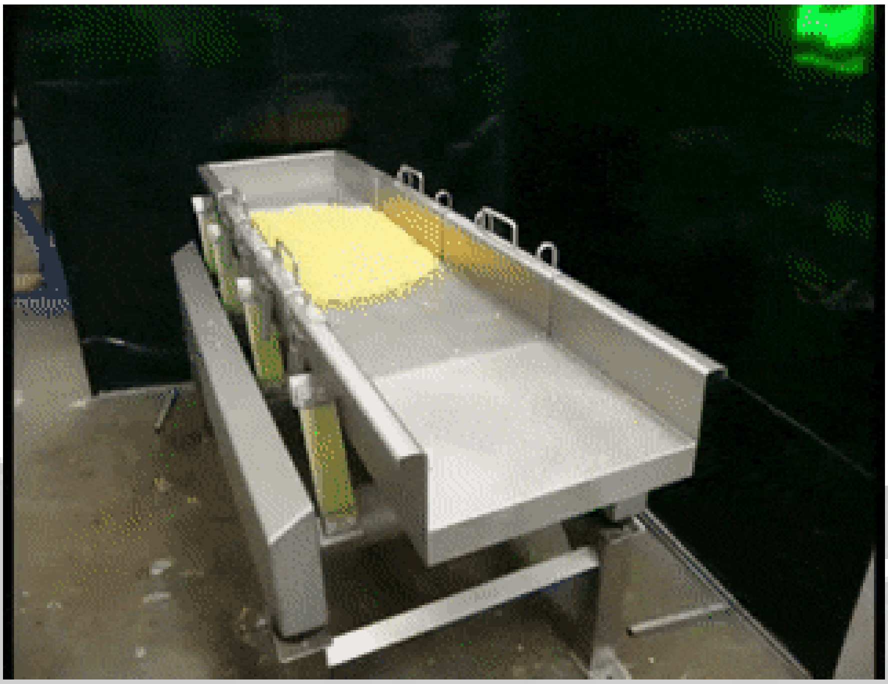


The advantages of using belt conveyor are as follows:-

1. It can handle light as well as heavy materials, dry or wet, fine or coarse etc.
2. It can and for distances to convey several thousand tons of material per hour and for distances of distances of several kilometers.
3. It can carry material horizontally or inclined.
4. It is lighter in weight then other conveyors.
5. It gives controlled discharge of material and discharge can be controlled by the speed of the belt.

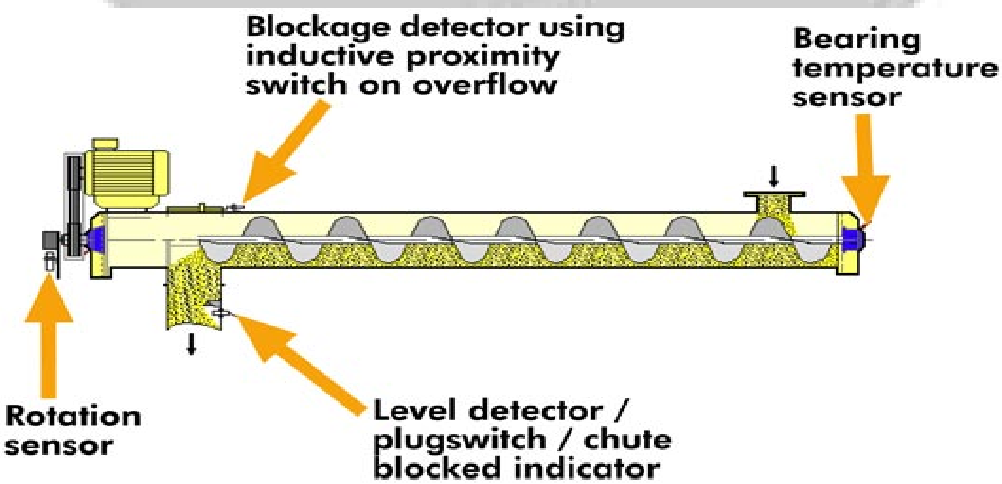
2. Vibratory Conveyer

- A vibratory feeder is an instrument that uses vibration to "feed" material to a process or machine. Vibratory feeders use both vibration and gravity to move material. Gravity is used to determine the direction, either down, or down and to a side, and then vibration is used to move the material. They are mainly used to transport a large number of smaller objects.
- A belt weighed are used only to measure the material flow rate but weigh feeder can measure the flow material and also control or regulate the flow rate by varying the belt conveyor speed.



3. <u>Screw conveyor</u>

- Widely used for handling granular or pulverized material.
- The quantity of material conveyed is less compared to the conveyor, but at the same time the cost is also less.
- A screw conveyor consists of a helix mounted on a bearing at the ends and at intermediate points and is driven by a motor from one end.
- The material enters the through at one end is carried to the other end by screwing action of helix.
- The length of the conveyor is about 65m. with an inclination up to a maximum of 350.



4. **Bucket conveyor**

- It has buckets in the shape of 'V' which are open at the top.
- They may be feeder loaded or may drag in a vertical movement or along an incline.
- The length of these type of conveyors are generally limited to 25 m. (due to weight of the conveyor and strength of the chains.)
- This type of conveyer is mainly used in coal handling where bucket elevators carry the material vertically.

5. **Aerial transport**

- Aerial transportation through cableways, rope-ways and tram ways
- Often used with advantage for transportation of material in hilly regions.
- Reducing the distance of transportation as well as cost of transportation
- The load being passed over intermediate towers or stations for long distances.

HOISTING EQUIPMENTS

- Hoisting is the lifting a weight from one location and moving it to another location which is at a reasonable distance.
- These equipments are used for lifting the loads, holding them in suspension during transfer from one place to other and placing them at designated location.
- Big projects such as, construction of dams, industrial buildings etc. require hoisting equipment.

- Hoisting equipment includes jacks, winches, chain hoists and cranes.
- Crane is the only single machine which, as a single piece, is capable of providing three-dimensional movement of a weight.
- It constitutes a group of equipment which are employed mainly for lifting or lowering of unit load and other.

Forklifts

- A **forklift truck** (also called a **lift truck**, a **fork truck**, a **forklift**, or a **tow-motor**) is a powered industrial truck used to lift and transport materials.
- Forklift trucks are available in many variations and load capacities. In a typical warehouse setting most forklifts used have load capacities between one to five tons. Larger machines, up to 50 tons lift capacity are used for lifting heavier loads.

HOISTS

- A **hoist** is a device used for lifting or lowering a load by means of a drum or lift-wheel around which rope or chain wraps. It may be manually operated, electrically or pneumatically driven and may use chain, fiber or wire rope as its lifting medium. The load is attached to the hoist by means of a lifting hook
- Also known as a Man-Lift, Buck hoist, temporary elevator, builder hoist, passenger hoist or construction elevator, this type of hoist is commonly used on large scale construction projects, such as high-rise buildings or major hospitals. There are many other uses for the construction elevator.
- Many other industries use the buckhoist for full time operations. The purpose is being to carry personnel, materials, and equipment quickly between the ground and higher floors, or between floors in the middle of a structure.

a. <u>Boom Hoist</u>

- Boom hoists are used to lift weights on the hooks that are attached to the special metal ropes designed to bear maximum loads.
- Boom hoist is mostly used as industrial machine where it loads the weight on containers.

b. **Chain Hoist**

- Chain hoists are quite common example of hoist system and it can be seen at most of the construction and industrial purposes. Basically, chain hoist consists of chain rope and pulley that is used to move the load from up to down.

c. **Electric Hoist**

- Electric hoist is modernized form of chain and boom hoist mostly used in the industries for fast working.
- It is very much popular in material handling industries because it saves labor costs by handling maximum loads at a time with no damage threats.
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- It is very much popular in material handling industries because it saves labor costs by handling maximum loads at a time with no damage threats.

d. Tractor Hoist

- Tractor hoist consist of a boom that is attached with base of tractor and a hook with rope is installed on this boom that can operated through driver controls.

CRANES

- A crane is a type of machine, generally equipped with a hoist, wire ropes or chains, and sheaves, that can be used both to lift and lower materials and to move them horizontally. It is mainly used for lifting heavy things and transporting them to other places.
- It uses one or more simple machines to create mechanical advantage and thus move loads beyond the normal capability of a man. Cranes are commonly employed in the transport industry for the loading and unloading of freight, in the construction industry for the movement of materials and in the manufacturing industry for the assembling of heavy equipment.
- Cranes are considered to be one of the most important equipment used in construction due to their key role in performing lifting tasks all over the construction site.
- Plenty of crane models are available in different shapes and sizes.

SELECTION OF CRANES

Factors affecting the selection of cranes are—

1. Building Design
   - Building Height
   - Project Duration
2. Capability
   - Power Supply
   - Load lifting frequency
   - Operators Visibility
3. Safety
   - Initial Planning and Engineering

1. Derrick cranes-

- Derrick cranes consist of a mast, a boom and a bull wheel on which the boom rotates about a vertical axis and guys or supporting members.
- Preferable for high-rise and apartment buildings.
- Can be used for both long term and short term projects.
- Cheaper than mobile and tower cranes. Not considered to be safe.

- Used when clearance is inadequate for the other units and sufficient space is unavailable for the erection of a tower foundation.
- Electrically operated, diesel operated or diesel-electrically operated.
- The boom can revolve through 360º. This crane is used for heavy loads upto 200 tons.

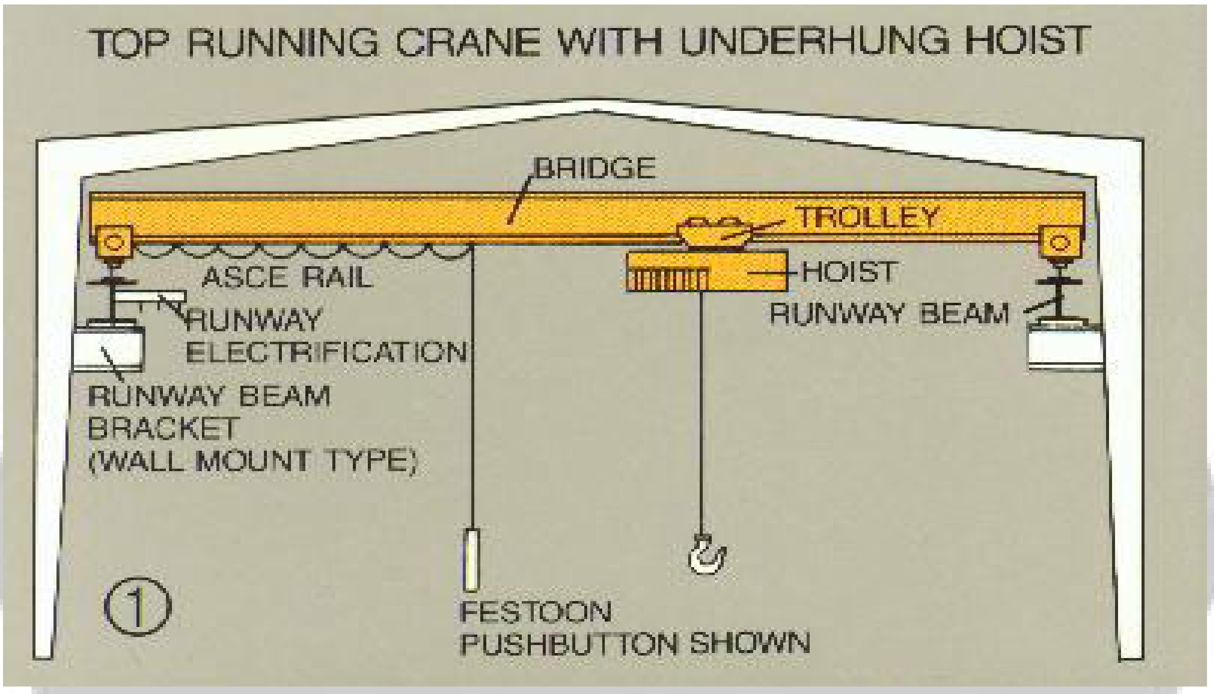
2. **Mobile cranes-**

- These cranes are mounted on mobile units which is either crawler type or wheel type
- Truck cranes have high mobility while the crawler mounted cranes move slowly.
- Crawler mounted cranes are capable of moving on rough terrain.
- Adequate for all types of structures (up to 107 m)
- Used for shorter projects duration (less than 4 months).
- Not considered to be very safe due to lack of safety devices or limited switches to prevent overloading.
- Can operate in muddy terrain but requires good ground conditions.
- Needs adequate operating clearance

.

3. **<u>Overhead or gantry cranes-</u>**

- large service area,
- freedom from floor obstructions
- and three-way mobility,
- Widely used in erection, foundry, steel plants, storage yards and different types of industrial works.
- These type of cranes consist of two main parts i.e., the bridge and the crab.
- The bridge consists of two main girders fixed at their end to end and capable of moving on gantry rails.
- The crab consists of the hoisting gear mounted on a frame.
- The frame itself is mounted on another set of wheels and capable of travelling across the main girder.



4. **<u>Traveler cranes</u>**

- Travelling or bridge cranes have their crabs moving on girders which are supported on legs instead of on overhead gantry track as used in overhead cranes.
- The legs are capable of moving on tracks laid on the floor.

5. **<u>Tower cranes</u>**

- Tower cranes are actually a derrick crane mounted on a steel tower.
- Tower cranes are usually used for industrial and residential high-rise buildings.
- These are commonly used for assembly of industrial plants with steel structures.
- The main parts of tower crane are under carriage, slewing platform, tower with operator's cabin and jibs.
- The tower has a truss structure welded from steel bars and channels.
- Preferable for high-rise (over 107 m).
- Used for longer project duration.
- Considered to be very safe due to the presence of limit switches.
- Can operate where ground conditions are poor.
- Does not need adequate operating clearance.

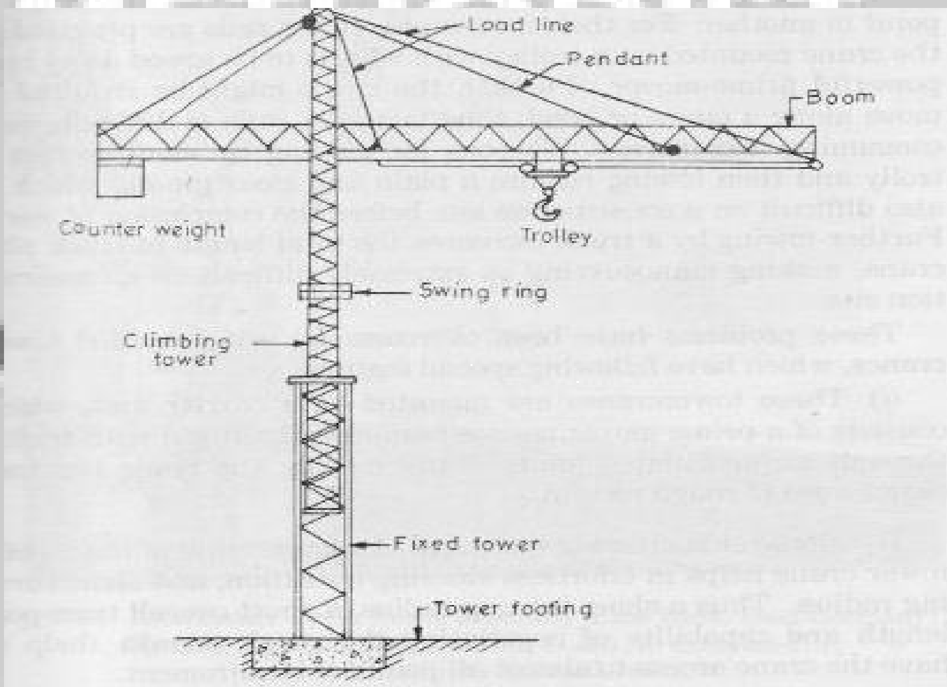


Fig. 2.20. Tower Crane

UNIT II

Hydraulic and Pneumatic Systems Conveying Systems

- Use fluids as working media
- Convert electrical/mechanical energy into potential energy of fluids (pump, compressor)
- Transmit power through distribution lines (pipes, air hoses)
- Convert potential energy of fluids/compressed gas into mechanical energy that turns linear/rotary actuators

Hydraulic conveying System:

- Move large loads by controlling high-pressure fluid in distribution lines and pistons with mechanical or electromechanical valves
- 1000psi – 3000psi
- Closed systems, always re-circulating same fluid

Advantage:

- Able to generate extremely large forces from compact actuators
- Easy to control speed
- Easy to implement linear motion

Disadvantage:

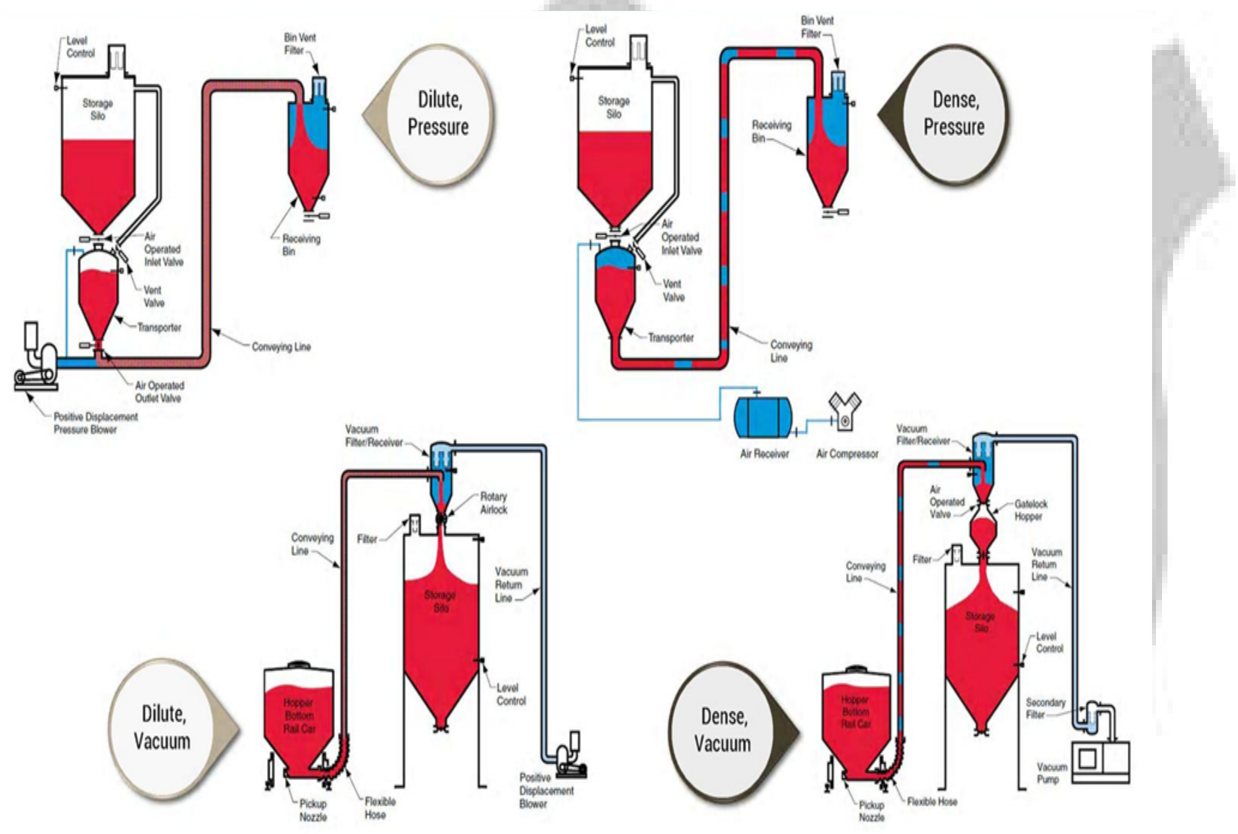
- Large infrastructure (high-pressure pump, tank, distribution lines)
- Potential fluid leaks
- Noisy operation
- Vibration
- Maintenance requirements, expensive
- Characteristics of working fluids change with temperature and moisture

Pneumatic systems:

Every pneumatic system, makes use of pipes or ducts called transportation lines that carry mixture of materials and a stream of air . These materials can be transported conveniently to various destinations by means of a stream of high velocity air through pipe lines. Products are moved through various tubes via air pressure, allowing for extra vertical versatility.

Pneumatic conveying is routinely used to move solids of all sizes within process plants. On account of the compressibility of the conveying gas, the pneumatic conveying of solids is quite different from the pumping of liquids or slurries The selection of many of the components that comprise a conveying system such as rotary valves, feed chutes, conveying pipe, and air movers is examined, especially as it relates to reliable operation of a conveying system.

Energy is also required to move material through a pneumatic conveying system, but in this case the energy is supplied by pressure differential (in pounds per square inch) and airflow(in cubic feet per minute).



In a pneumatic conveying system, the air pressure in the conveying line is changed by the system's air mover, which generates pressure or vacuum. Where the air mover is located in the system determines whether it generates one or the other. When located at the system's start, the air mover pushes air through the system and the system operates under pressure.

When located at the system's end, the air mover pulls air through the system and the system runs under vacuum. By controlling the pressure or vacuum and airflow inside the system, the system can successfully transfer materials.

A conventional mechanical conveying system runs in a straight line, with minimal directional changes, and each directional change typically requires its own motor and drive. The mechanical conveying system may be open rather than enclosed, potentially generating dust. It also has a relatively large number of moving parts, which usually require frequent maintenance. The system also tends to take up a lot of valuable real estate in a plant.

On the other hand, a pneumatic conveying system uses a simple, small-diameter pipeline to transfer material. The pipeline can be arranged with bends to fit around existing equipment, giving the system more layout flexibility, and the system also has a relatively small footprint. The system is totally enclosed and typically has few moving parts as it is electronically managed.

Basic Components

Major pneumatic system components include:
1. Pressure blowers and vacuum pumps with integral sound enclosures
2. Rotary airlock valves
3. Transfer line including piping, elbows; divert valves (flex-tube diverters, wye-diverters, plug diverters and other line diverter configurations).
4. Filter receivers
5. Cyclone separators
6. Gain-in-weight and loss of- weight batching systems
7. Dust collectors and bin vents
8. Controls and electrical equipment
9. Silos, day bins and other storage vessels

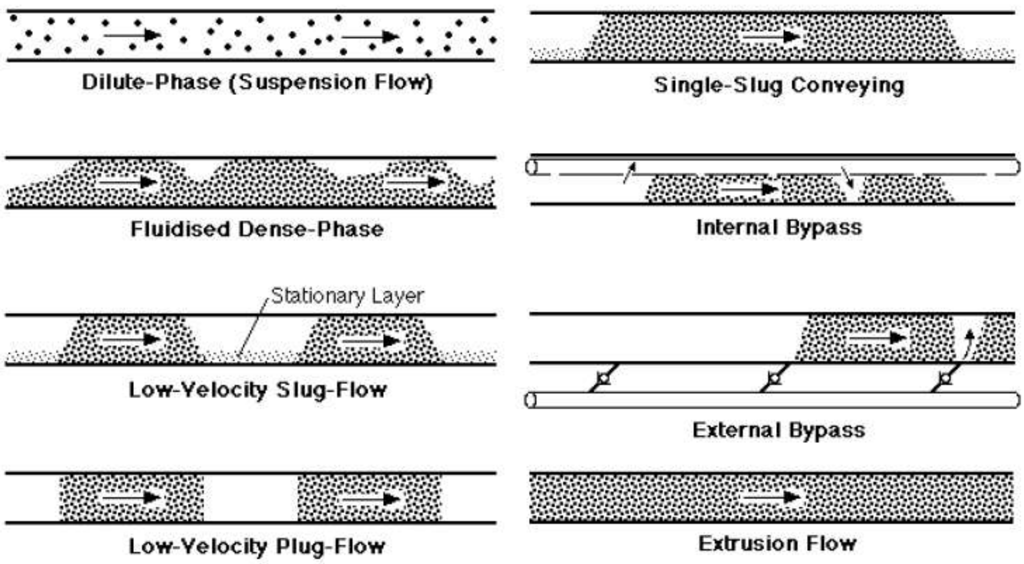
Types of Pneumatic Systems

Three basic systems that are used to generate high velocity air stream:

•**Suction or vacuum systems,** utilizing a vacuum created in the pipeline to draw the material with the surrounding air . The system operated at a low pressure, which is practically 0.4–0.5 atm below atmosphere, and is utilized mainly in conveying light free flowing materials.

•**Pressure-type systems,** in which a positive pressure is used to push material from one point to the next. The system is ideal for conveying material from one loading point to a number of unloading points. It operates at a pressure of 6 atm and upwards.

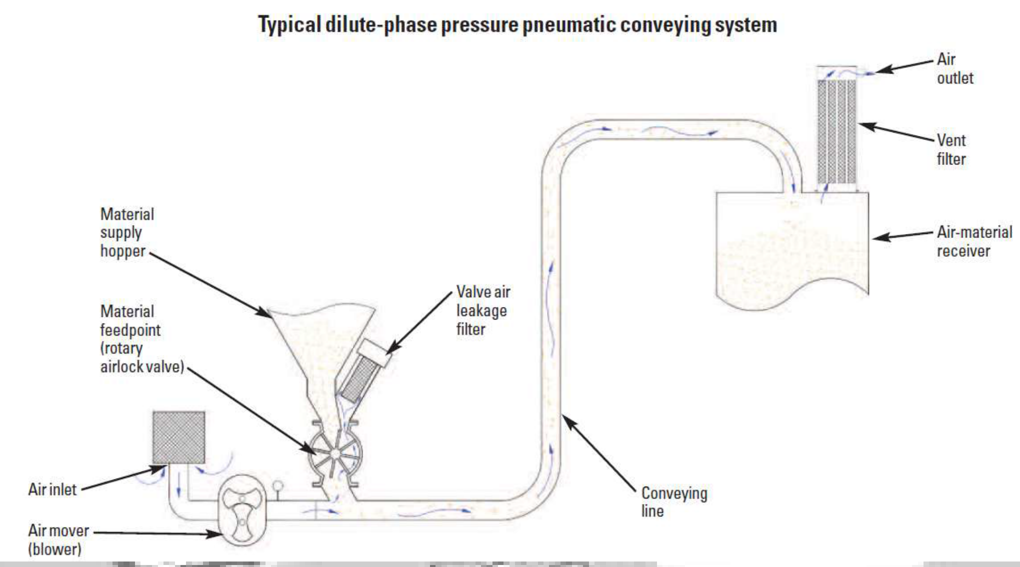
•**Combination systems**, in which a suction system is used to convey material from a number of loading points and a pressure system is employed to deliver it to a number of unloading points.



Modes of Pneumatic Conveying

Dilute Phase Introduction

•The dilute-phase conveying system relies on the airstream's velocity to pick up and entrain each particle , keeping the particles in suspension throughout the conveying line.
•It operates at a relatively high velocity at a relatively low pressure differential.
•The pickup velocity at the system's start (that is, the airstream velocity at which material is picked up and entrained at the material feed point) is generally considered the system's most critical area, because the air is at its lowest speed in the entire system at this point. Because the material is dropping from a static state into the airstream below it , the material must immediately become entrained. The air speed required to pick up the material depends on each particle's size and density, but can rangefrom3,000 to 8,000 fpm.
• The air mover must also be able to overcome the flow resistance caused by the frictional loss of the air and material against the conveying line's inside wall.

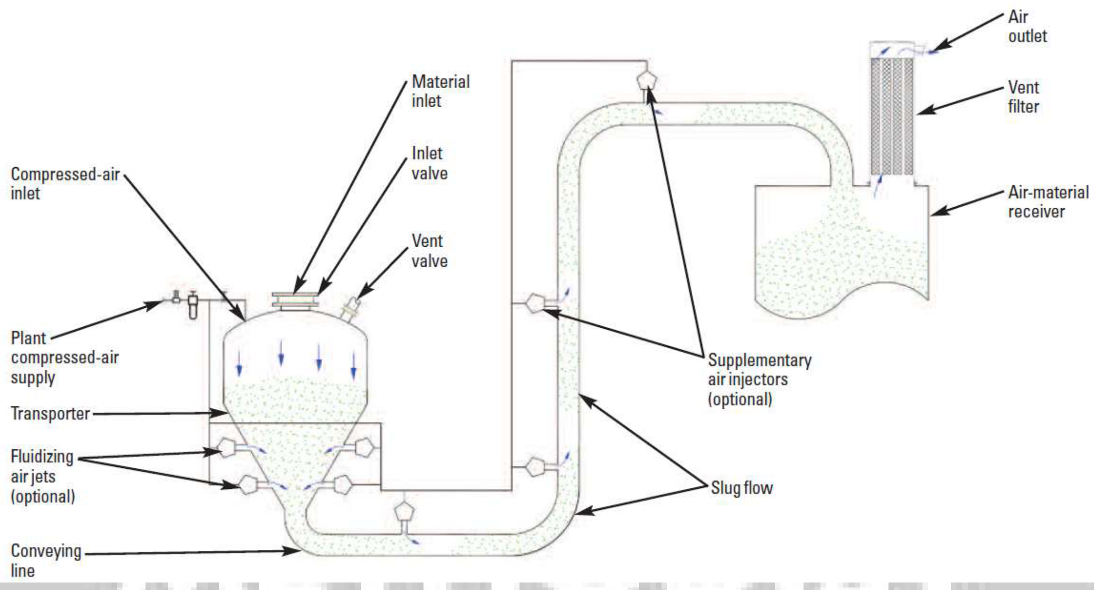


Dense Phase Introduction:

An ideal dense-phase conveying system would extrude material with enough pressure to transfer it in one long, continuous piece through the pipeline's entire length, just like a continuous length of ground meat inside a sausage casing. But with dry bulk materials like powders and granules, this usually isn't possible because of the material's high frictional resistance against the conveying line's inside wall. Instead, air and material flows through the line in any of several patterns (including various forms of two-phase flow and slug flow).

While various dense-phase conveying system types are available, all uses are relatively high pressure differential with a relatively low air velocity. The most common dense phase system type, provides batch transfer using a transporter (also called a blow tank or pressure tank). In this system ,material from a storage vessel is loaded by gravity into the transporter. After the transporter is full, its material inlet valve and vent valve are closed and compressed air is metered into the transporter. The compressed air extrudes the material from the transporter into the conveying line and to the destination . Once the transporter and conveying line are empty, the compressed air is turned off and the transporter is reloaded .This cycle continues until all the material required for the process has been transferred.

Typical dense-phase pressure pneumatic conveying system



Advantage:

- Constant force
- Clean (food industry)
- No return lines needed
- Adaptable infrastructure
- Possible light, mobile pneumatic systems
- Fast system response

Disadvantage:

- Difficult to achieve position control (compressible air)
- Noisy

Fans and Blowers

- Any device that produces a current of air by the movement of broad surfaces can be called a fan.
- Fans fall under the general classification of turbo machinery and have a rotating impeller at least partially encased in a stationary housing.
- Fans are similar in many respects to pumps. Both are turbo machines that transfer energy to a flowing fluid. It is easy to distinguish between fans and pumps: pumps handle liquids; fans handle gasses.
- Broadly speaking, the function of a fan is to propel, displace, or move air or gas.

Fans, blowers and compressors are differentiated by the method used to move the air, and by the system pressure they must operate against.

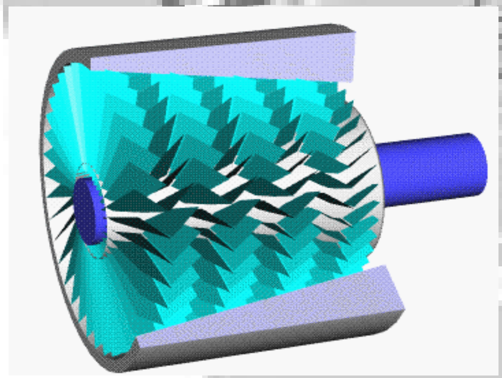
Difference Between Fans, Blower and Compressors	
Equipment	**Specific Ratio**
Fans	Up to 1.11
Blowers	1.11 to 1.20
Compressors	More than 1.20

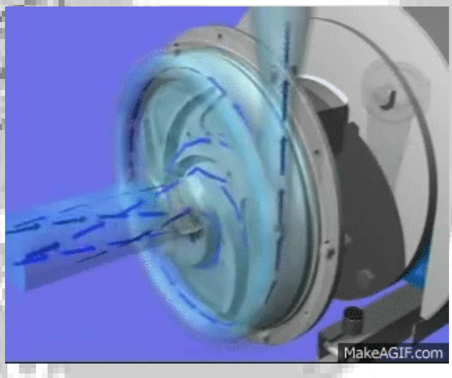
As per American Society of Mechanical Engineers (ASME) the specific ratio is the ratio of the discharge pressure to the suction pressure and is used for defining the fans and blowers

Fan Types:

Fans are classified according to the direction of flow through the impeller:

- **Axial Flow:** Air flows through the impeller parallel to, and at a constant distance from the axis. The pressure rise is provided by the direct action of the blades
- **Centrifugal or radial flow:** Air enters parallel to the axis of the fan and turns through 90^0 and is discharged radially through the blades. The blade force is tangential causing the air to spin with the blades and the main pressure is attributed to this centrifugal force





Compressors:

Compressors are mechanical devices that compresses gases. It is widely used in industries and has various applications

Difference between pump and compressor

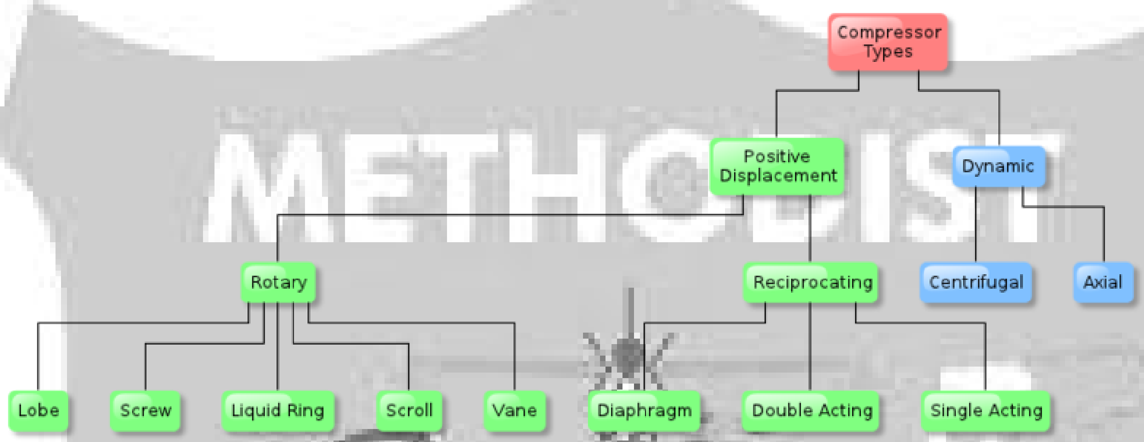
- Major difference is that compressors handles the gases and pumps handles the liquids.
- As gases are compressible, the compressor also reduces the volume of gas.
- Liquids are relatively incompressible; while some can be compressed

Applications:

Compressors have many everyday uses, such as in :

- Air conditioners, (car, home)
- Home and industrial refrigeration
- Hydraulic compressors for industrial machines
- Air compressors for industrial manufacturing

Types of compressors:



The **dynamic compressor** is continuous flow compressor is characterized by rotating impeller to add velocity and thus pressure to fluid.

It is widely used in chemical and petroleum refinery industry for specific services.

There are two types of dynamic compressors

- Centrifugal Compressor
- Axial Flow Compressor

Positive displacement compressors causes movement by trapping a fixed amount of air then forcing (displacing) that trapped volume into the discharge pipe.

It can be further classified according to the mechanism used to move air.

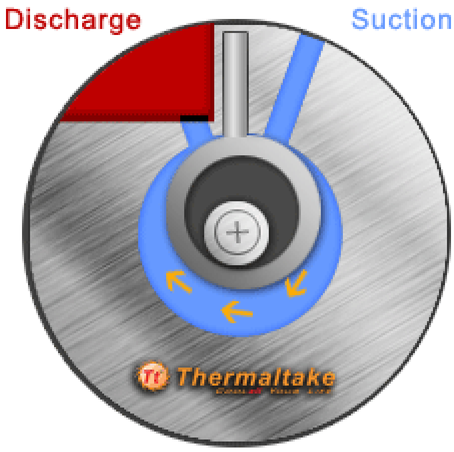
- Rotary Compressor
- Screw Compressor
- Reciprocating compressor

Rotary Compressor:

- The gas is compressed by the rotating action of a roller inside a cylinder.
- The roller rotates off-centre around a shaft so that part of the roller is always in contact with the cylinder.

➢ Volume of the gas occupies is reduced and the refrigerant is compressed.

➢ High efficient as sucking and compressing refrigerant occur simultaneously.



Screw Compressor:

- A rotary-screw compressor is a type of gas compressor, such as an air compressor, that uses a rotary-type positive-displacement mechanism.
- They are commonly used to replace piston compressors where large volumes of high-pressure air are needed, either for large industrial applications or to operate high-power air tools such as jackhammers and impact wrenches.

Reciprocating compressor:

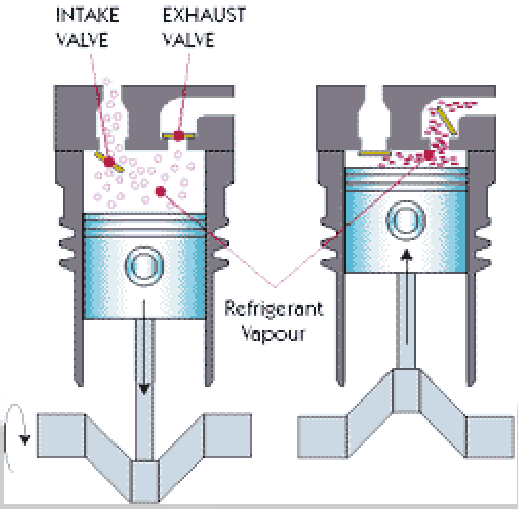
It is a positive-displacement compressor that

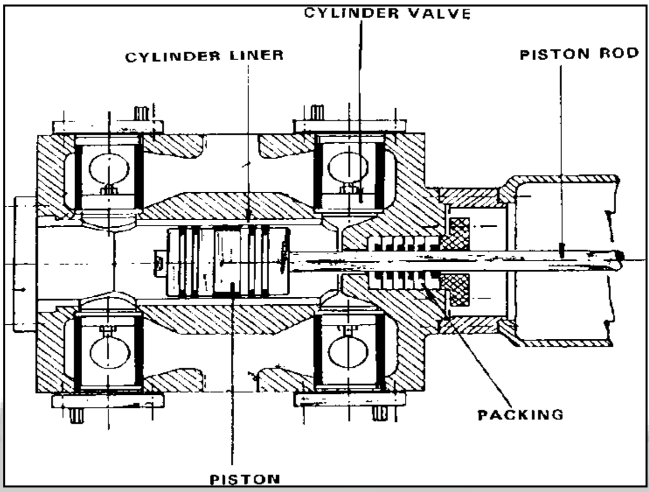
➢ Uses pistons driven by a crankshaft to deliver gases at high pressure.

➢ The intake gas enters the suction manifold, then flows into the compression cylinder

➢ It gets compressed by a piston driven in a reciprocating motion via a crankshaft,

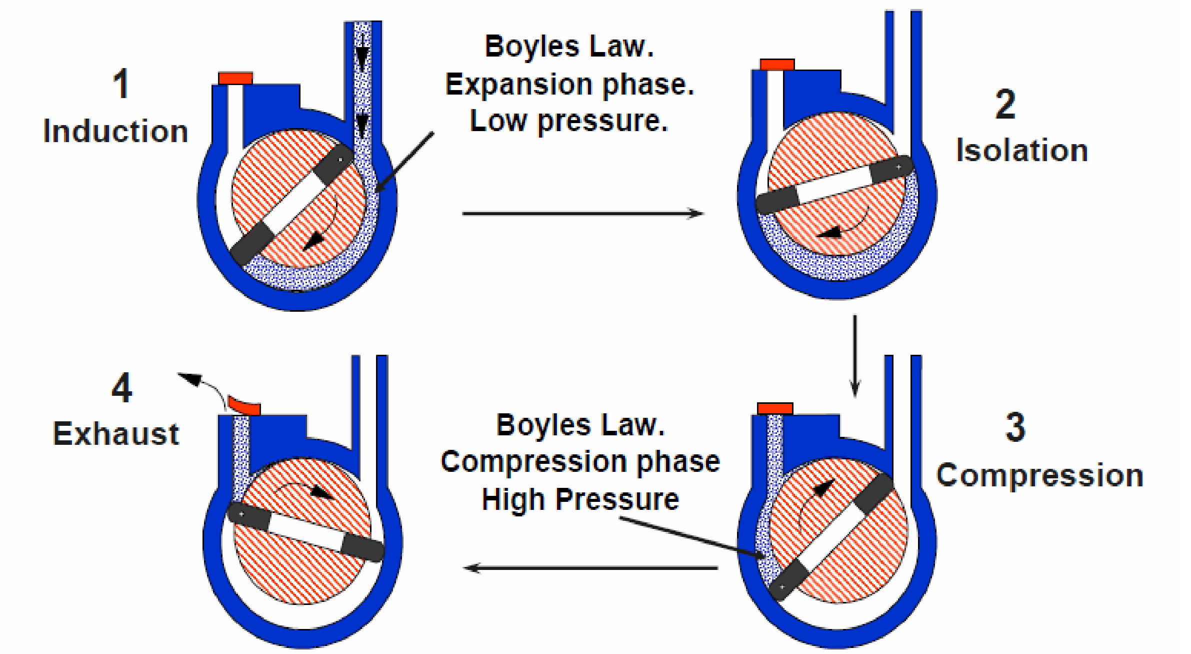
➢ Discharged at higher pressure





Vaccum Pump:

A *vacuum pump* is a device that removes gas molecules from a sealed volume in order to leave behind a partial *vacuum*.



Rotary vane vacuum pump

Unit III

BULK SOLIDS HANDLING

- Bulk solids handling is the science of storing and transporting bulk solids.
- The particular nature of bulk solids becomes most apparent in the design of storage containers
- The scope of bulk solids handling is very wide, although it “only” deals with shifting bulk solids through space and time. The latter is usually called “storage”, the former “transportation”.

Particle:

- Particle is a very small entity of matter.
- Particles together will form powder.
- Powders can be regarded as being either two- (solid–liquid) or three-phasic (solid–liquid–gas) systems which, at times, can be treated as a single continuum.
- Because there is a great variety in the bulk powder, there is a need to understand the mechanico-physical properties of discrete solid particles.

Properties of bulk solids:

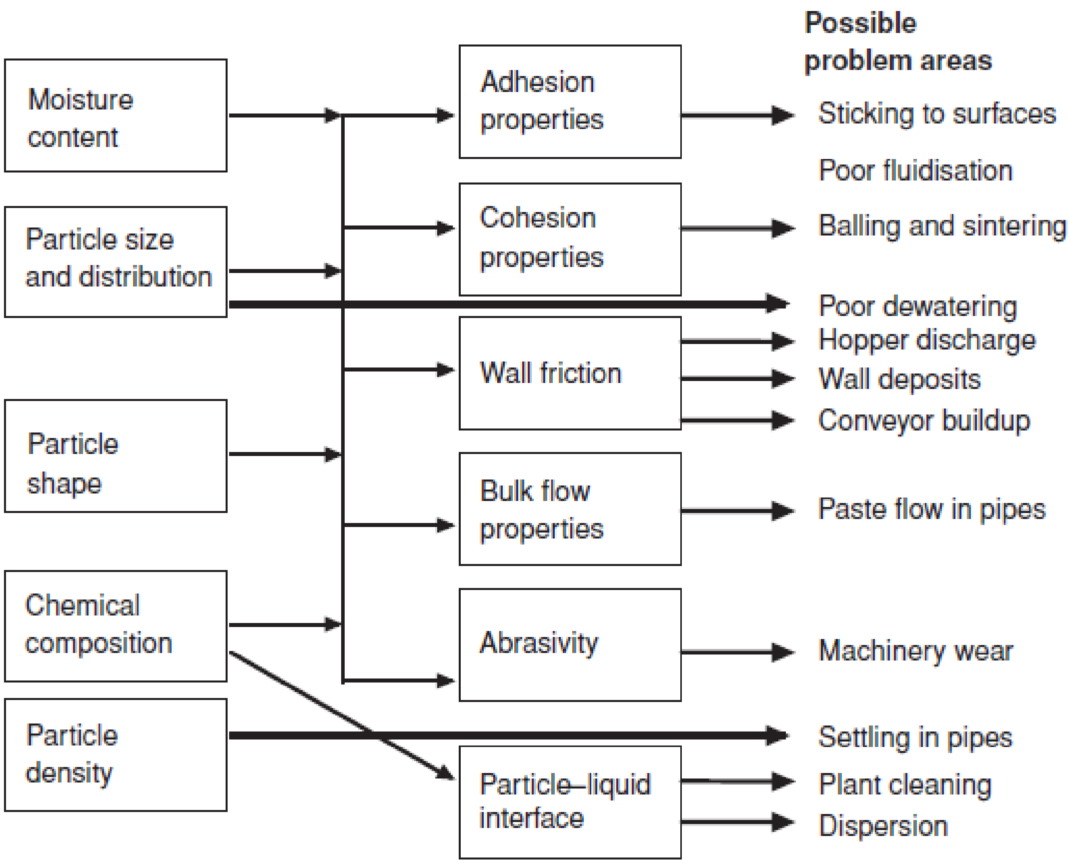
The properties and phenomena associated with an assembly of particles and powder behaviour in processing are due to the combination of many individual particle and powder

Properties, some of which are listed below:

- Particle size distribution and specific surface area
- Particle shape distribution
- Packing property (bulk density, voidage)
- Rate and compressibility of packing
- Flowability
- Failure properties and angle of internal friction
- Cohesion, strength and adhesion
- **Flowability** is the ability of a powder to flow
- Attraction between molecules of the same type are called **cohesion**
- Attraction between molecules of different types are called **adhesion**

- The amount of moisture present in the powder is termed as the **moisture content** of the powder

BULK SOLIDS HANDLING



Gravity flow of bulk solids:

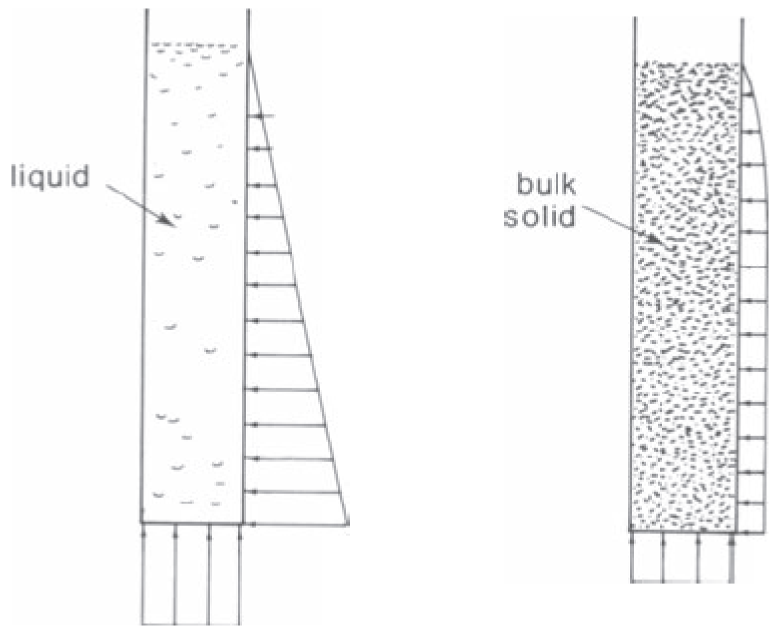
- A good understanding of the nature of bulk solids flow is an essential prerequisite to the design of virtually any system involving the storage or handling of such materials
- Observation of a bulk material discharging from a hopper or flowing under gravity along a steeply inclined channel will immediately suggest similarities to the behaviour of liquids.
- There are certainly some similarities between the flow characteristics of bulk solids and liquids, the analogy is one that it is unwise to pursue.
- In general it is more appropriate to model a bulk solid as a plastic solid than as a fluid continuum.

The main features of liquids which are not shared by bulk solids are as follows:

- At rest, liquids cannot sustain shearing stresses. This is most clearly demonstrated by the fact that bulk solids can be formed into a stable heap whereas liquids at rest always have a horizontal free surface.
- Changes of pressure in a liquid at rest are transmitted uniformly to all other points in the liquid.
- Shear stresses that occur in a flowing liquid are dependent upon the rate of shear and independent of the mean pressure of the liquid.

Pressure Distribution:

BULK SOLIDS HANDLING

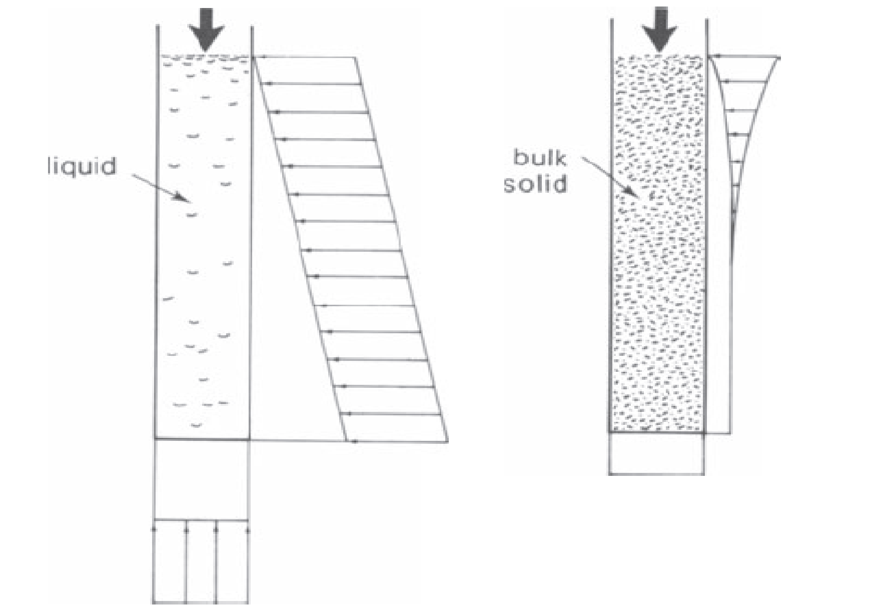


(a) Pressure distributions due to weight alone

- These distinctive features of liquids and bulk solids can be illustrated and compared by considering the distributions of pressure on the internal surfaces of two identical cylindrical containers; one filled with a bulk solid, the other filled with a liquid having the same (bulk) density.
- In Figure *a the pressure* distributions due to the bulk solid and the liquid are shown and the much greater stresses that exist in the liquid near the bottom of the container are immediately apparent.
- The reason for this difference lies in the fact that there is no shearing stress at the walls of the liquid container, and therefore the whole weight of the liquid is taken on the horizontal

base, whereas a significant proportion of the weight of the bulk solid is carried on the vertical walls.

Free Surface Loading:

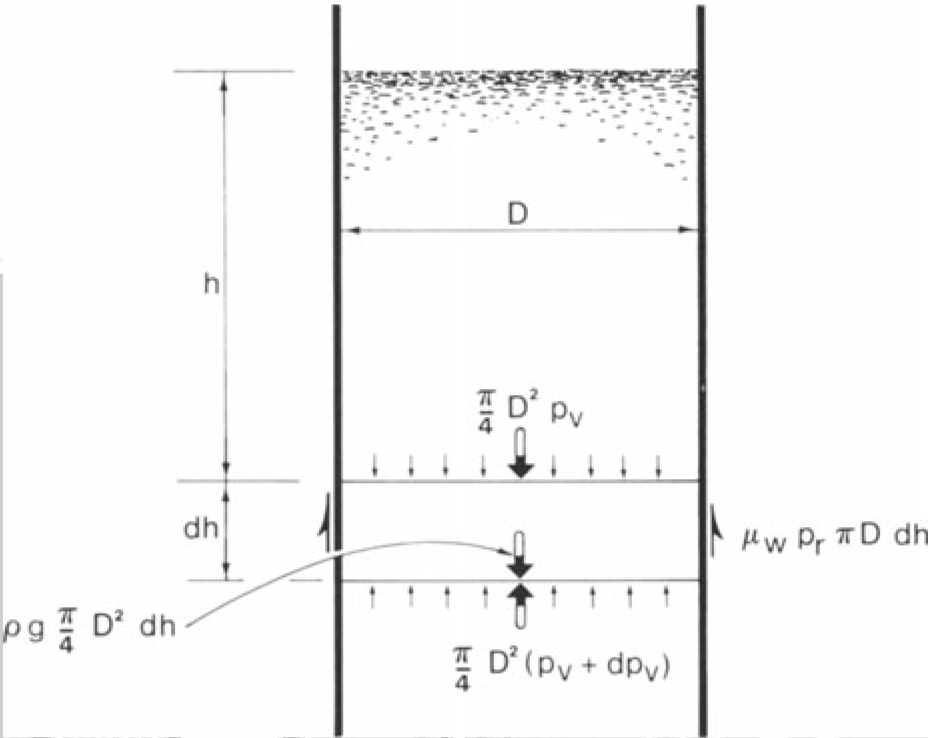


(b) Excess pressures due to additional free surface loading

- The manner in which internal stresses are transmitted through the bulk solid and the liquid are illustrated in Figure *b in which the effect of* increasing the loading on the free surfaces of each are shown.
- In the case of the liquid, the excess load is transmitted uniformly throughout, so that all of this excess load is, in fact, actually carried on the base of the container.
- However, at the base of the bulk solid container there is no change as a result of the additional loading on the free surface.
- The pressure distribution that would exist within a quantity of bulk solid contained in a hopper or bin is of interest when designing the container for strength, but does not have a direct influence on the pattern of flow from the container.
- Nevertheless, a good understanding of the pressure distribution under storage and flow can prove to be a valuable aid when assessing the likelihood of obstructions to flow occurring.
- At distance *h below the free surface of the bulk solid, the lateral pressure is Pr* and the vertical pressure, due to the overlying head of material, is P_v'

- ***In*** general, for particulate materials, the ratio of P_r *to Pv is found to be* appr. constant, so that $p_r = kp_v$

where *k is a constant less than unity.*



- Now for the elemental slice of material, of diameter *D and thickness dh,* the vertical forces acting are those resulting from

$$\text{pressure (difference)} = \frac{\pi}{4} D^2 \mathrm{d}p_v$$

$$\text{gravity} = \rho_b g \frac{\pi}{4} D^2 \mathrm{d}h$$

$$\text{wall friction} = \mu_w p_r \pi D \mathrm{d}h$$

where ρ_b is the bulk density of the particulate material and μ_w is the coefficient of friction at the walls.

Then for equilibrium of this element

$$\rho_b g \frac{\pi}{4} D^2 \mathrm{d}h - \frac{\pi}{4} D^2 \mathrm{d}p_v - \mu_w p_r \pi D \mathrm{d}h = 0$$

$$\rho_b g \mathrm{d}h - \mathrm{d}p_v - \frac{4\mu_w p_r}{D} \mathrm{d}h = 0$$

$$\left(\rho_b g - \frac{4\mu_w k p_v}{D} \right) \mathrm{d}h - \mathrm{d}p_v = 0$$

from which

$$\frac{\mathrm{d}p_v}{\rho_b g - \dfrac{4\mu_w k p_v}{D}} = \mathrm{d}h$$

Integration then gives

$$-\frac{D}{4\mu_w k} \ln \left(\rho_b g - \frac{4\mu_w k p_v}{D} \right) = h + C$$

where C is a constant of integration.

Now $p_v = 0$ for $h = 0$, so that

$$C = -\frac{D}{4\mu_w k} \ln \rho_b g$$

and

$$-\frac{D}{4\mu_w k} \ln \left(1 - \frac{4\mu_w k p_v}{\rho_b g D} \right) = h$$

from which

$$1 - \frac{4\mu_w k p_v}{\rho_b g D} = \exp\left(-\frac{4\mu_w k h}{D} \right)$$

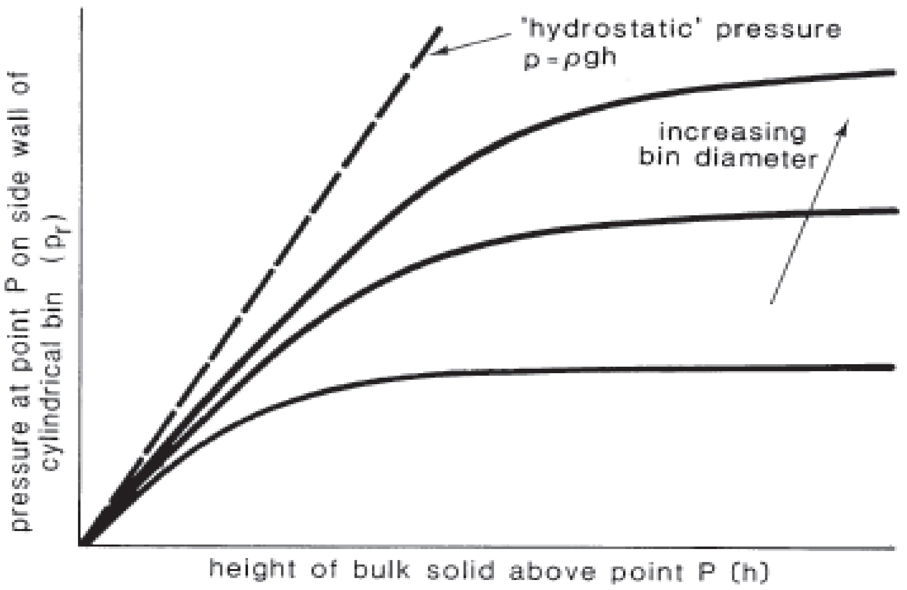
Rearranging this to give an expression for p_r leads to

$$p_r = \frac{\rho_b g D}{4\mu_w} \left(1 - \exp\left(-\frac{4\mu_w k h}{D} \right) \right)$$

This is one form of the well-known Janssen formula for radial pressure on the vertical wall of a cylindrical bin containing a bulk solid.

It may be noted that for tall bins *h is large compared with D, so that*

$$p_r \max = \frac{\rho_b g D}{4\mu_w}$$ and $$p_v \max = \frac{\rho_b g D}{4\mu_w k}$$



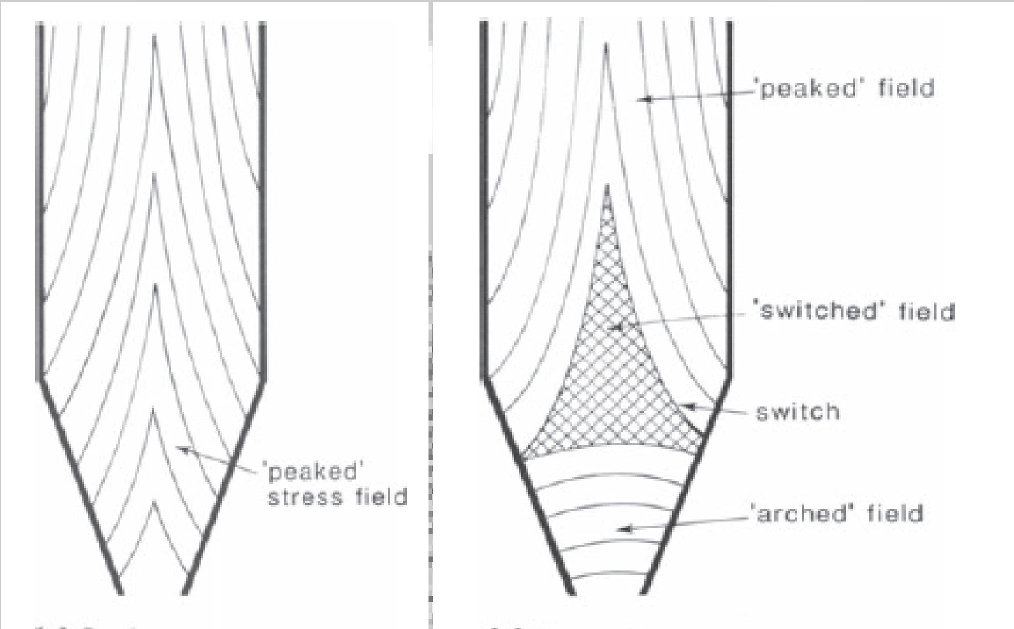
Relationship between the pressure at a point on the wall of a cylindrical bin and the height of material above that point, from equation

Static and dynamic stress fields in a bulk solid contained in a storage bin:

- There are many records of serious mechanical damage occurring to bulk solids
- storage vessels, notably grain silos, as a result of an apparent physical weakness of the vertical walls. Investigations subsequently showed that the problem was basically due to the failure of the designer to appreciate that during discharge of the material from the bin or silo the lateral pressures developed could be considerably greater than existed with the material at rest.
- Tests on models have suggested that the so-called 'overpressure' on the side wall may be as much as three or four times the static pressures.
- The maximum possible lateral pressure during flow is a function of the height of the bulk solid in the bin, being given simply by $P_{rmax} = P_b\, gh$,

where P_b is the bulk density of the material.

- The transient pressures occurring on the sloping and vertical sides of storage vessels during emptying are a complex phenomenon and it is only in relatively recent years that progress has been made towards a satisfactory explanation.
- The following description of the varying pressure distribution within a bulk solid discharging from a storage vessel is attributable to Jenike and J0hanson.
- During the filling of a bin an active state of pressure exists, as the material tends to settle and thus contract vertically under the increasing load.
- The lines of principal stress are almost vertical and form a 'peaked' or 'static' stress field as shown in Figure *a,*



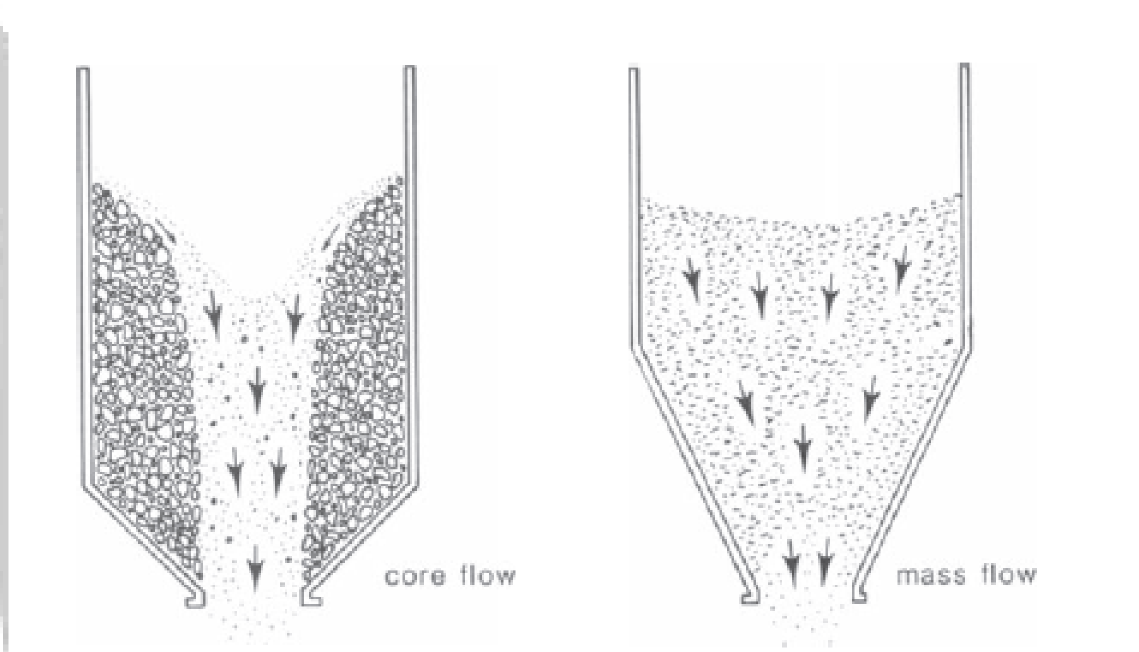
(a) Static (b) Dynamic

- When the bin outlet is opened and flow begins, the material expands in the vertical direction, but it must contract laterally in order for flow to continue through the converging hopper section,
- The principal stresses now tend to align themselves with the lateral contractions of the bulk material, becoming almost horizontal across the outlet of the hopper and forming an 'arched' or 'dynamic' stress field in this region,
- The change from a static to a dynamic stress field occurs quite rapidly, the effect travelling upwards through the bulk solid as a shock disturbance or 'switch' which may appear on the side wall as a narrow band of higher pressure (Figure *b).*
- This 'overpressure' is necessary to maintain equilibrium, since the dynamic pressures existing below the level of the switch are less than the static pressures that existed initially.
- The switch, with its associated band of higher pressure, travels upwards at least to the transition where the conical and cylindrical sections of the bin intersect, reaching a higher level in a free-flowing material than it will in a cohesive one.

- Where there is a considerable height of bulk material in a bin, the peak pressure occurring at the transition can be very large.
- Above the level of the switch the material is undisturbed and a static stress field still exists.

Modes of flow

- Mass Flow
- Funnel flow or core flow



Mass Flow:

- The most important single distinguishing characteristic of so-called 'mass flow' is that every particle of the bulk material in the hopper begins to move when the outlet is opened (Figure).
- A hopper designed for mass flow would generally be recognized by the steep wall slopes of the converging section, the absence of sharp transitions and the relatively large outlet to the feeder or flow control valve.
- For most purposes mass flow is regarded as the ideal, or at least the preferable, flow pattern

The beneficial properties of mass flow may be listed as follows:

- Channeling, hang-ups, surging and flooding are absent
- Flow is uniform, and steady flow (independent of the head of material in the bin) can be closely approached

- The bulk density of the drawn solid is constant, and practically independent of the head of material in the bin
- Pressures are relatively uniform across any horizontal section of the bin
- There are no dead regions within the bin
- A first-in first-out flow pattern can be obtained
- Segregation of the bulk solid is kept to a minimum.

Core flow or Funnel flow:

- In core flow from a bin, the discharge of the bulk solid is essentially irregular, with material sloughing off the free surface and falling through a vertical channel which forms within the bin (Figure).
- The material around this central channel is stationary.
- Core flow bins tend to be relatively short with rather more shallow wall slopes than would usually be associated with mass flow.
- Such bins are sometimes deliberately designed for situations where the headroom is severely limited, but often they are the result of ignorance about the advantages of mass flow.
- Nevertheless, core flow may be acceptable in situations where segregation is unimportant, deterioration of stored material is not likely to be a problem and the outlet is sufficiently large to ensure flow without the help of a discharge aid

The main characteristics of core flow, most of which are generally regarded as undesirable, may be listed as follows:

- First-in, last-out sequence of flow
- If the bulk solid has a tendency to spoil, cake or degrade with time, this will
- happen in the non-flowing region
- For materials which segregate on charging, there is no re-mixing in the hopper
- Flow rate tends to be erratic with a widely varying density of the feed
- The erratic flow rate may cause fine powders to become aerated and 'flood'
- 'Rat-holing' will occur if the non-flowing material consolidates sufficiently to remain stable after the flow channel has emptied out.

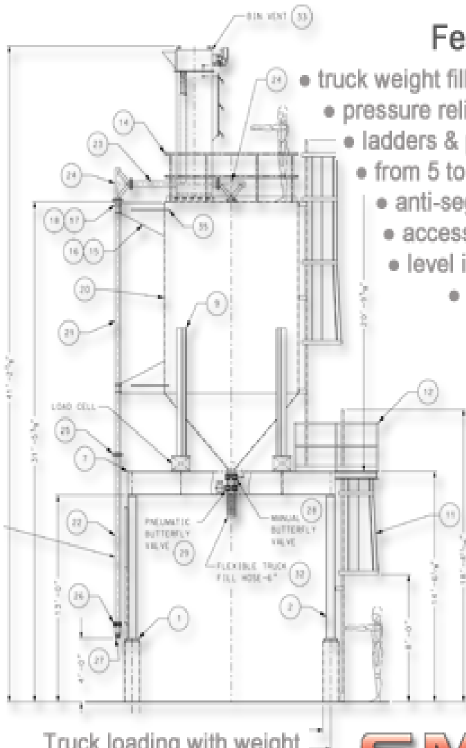
Silos and Hoppers:

Silos and Hoppers

custom designed skirted or legged

New silo for housing thermally reclaimed sand. This skirted silo houses a pneumatic transporter, includes sand fill pipe and bin vent.

Re-purposed slio installed for thermal reclamation system.



Features:

- truck weight fill systems
- pressure relief valves
- ladders & platforms
- from 5 to 300 tons
- anti-segregation
- access hatches
- level indicators
- bin vents

Truck loading with weight based system.

Bulk Bins & Hoppers


Magnum F

UNIT IV

INTRODUCTION

AUTOMATED GUIDED VEHICLE

An automated guided vehicle or automatic guided vehicle (AGV) is a mobile robot that follows markers or wires in the floor, or uses vision or lasers. They are most often used in industrial applications to move materials around a manufacturing facility or a warehouse

Automated guided vehicles increase efficiency and reduce costs by helping to automate a manufacturing facility or warehouse. The AGV can tow objects behind them in trailers to which they can autonomously attach. The trailers can be used to move raw materials or finished product. The AGV can also store objects on a bed. The objects can be placed on a set of conveyor and then pushed off by reversing them. Some AGVs use forklifts to lift objects for storage. AGVs are employed in nearly every industry, including, pulp, paper, metals, newspaper, and general manufacturing. Transporting materials such as food, linen or medicine in hospitals is also done.

An AGV can also be called a laser guided vehicle (LGV) or self-guided vehicle (SGV). Lower cost versions of AGVs are often called Automated Guided Carts (AGCs) and are usually guided by specific lines magnetic tape. AGCs are available in a variety of models and can be used to move products on an assembly line, transport goods throughout a plant or warehouse, and deliver loads to and from stretch wrappers and roller conveyors.AGV applications are seemingly endless as capacities can range from just a few kgs to hundreds of tons. The Aim of the project is to design and fabricate such a AGV

There are many definitions of AGVs, different according to points of view.

Wikipedia, the free encyclopedia, defines AGVs as:

"A robot that been used highly in industrial applications to move materials from point to point"

The American Society of Safety Engineers (ASSE) defined AGVs as:

a. Machines without drivers that can move along pre-programmed routes, or use sensory and navigation devices to find their own way around.

b. Vehicles that are equipped with automatic guidance systems and are capable of following prescribed paths. Or Driverless vehicles that are programmed to follow guide path.

BACKGROUND

The creations of Automated Guided Vehicle (AGV) have been around since the 1950's and the technology was first developed by Barret Electronics from Grand Rapids, Michigan. It was then developed by the Europeans in the 1970's and nowadays AGVs can be found in any countries. One of the first AGVs was a towing vehicle that pulled a series of trailers between two points, and today's there are many task given to AGVs and they also have their own name and potentials.

Considering the full potentials and advantages of the Automated Guided Vehicle (AGV) in our livings, it is valuable to do this project, as it also will be the first step towards the creation of more intelligent technology or system. The simplest AGV model may use just a sensor to provide its navigation and can be the complex one with more sensors and advance systems to do the task. They can work or do the task everywhere needed but the safety for the AGV as well as the people and environment surround it must be provided.

The AGVs is just the same as mobile robot, which can moves from one place to another to do their task, but mostly the mobile robot is used for difficult task with dangerous environment such as bomb defusing. Furthermore, the mobile robot can be categorized into wheeled, tracked, or legged robot. Although the AGVs may not be glamorous of robots, but their work, which usually menial, are often be essential to the smooth running of factories, offices, hospitals, and even houses. They can work without any complaint around many workplaces all over the world.

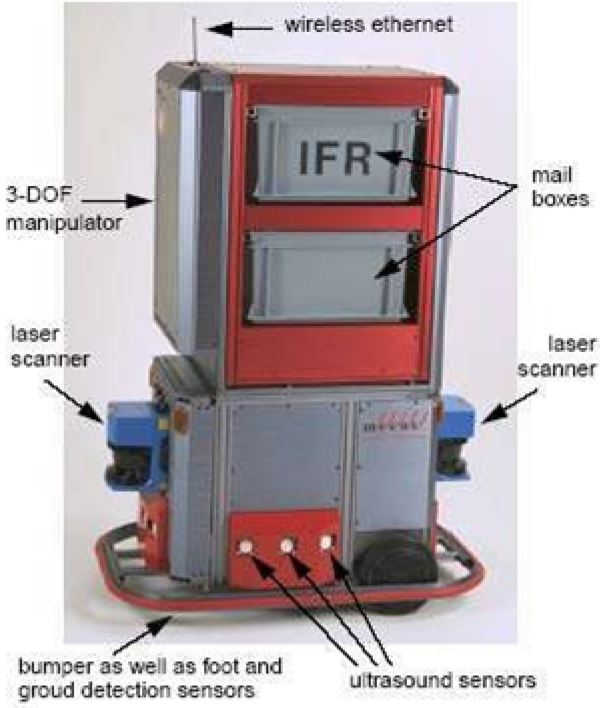
AUTOMATED GUIDED VEHICLE BUILT WORLDWIDE

Some of the Automated Guided Vehicles (AGVs) that are well known are discussed in brief.

MOBILE POST DISTRIBUTION SYSTEM (MOPS)

MoPS or Mobile Post Distribution System (Tschichold, Vestli, Schweitzer, 1999) is a research AGV developed at the Institute of Robotics in Zurich, Switzerland. It is used to transport mail around the Swiss Federal Institute of Technology in Zurich. MoPS is powered up by rechargeable batteries which give it a 4-hour active life, weighs around 90kg and can carry up to 50 kg of postal payload. It is also capable of hot-swapping its own batteries pack, thus ensuring 24h availability.

The MOPS provide services of picking up boxes with incoming mail at the ground floor of the five floor building, which is sorted by human first, delivering them to the secretaries' offices, subsequently bringing back the outgoing mail to the ground floor station.



It is also capable of switching floors by sending an infrared signal to the building's lifts. As the building is open to the public, protection against theft of the mail is provided by motorized blinds over the pigeon-hole mail points, which can be opened by the robot and by authorized staff.

PARKSHUTTLE AGVS OF AMSTERDAM'S SCHIPHOL AIRPORT

The ParkShuttle (FROG Navigation Systems) is an automatic navigating vehicle which provides transportation for passengers. It is a people mover system. There is no driver onboard, instead a computer and an electronic navigation system do the driving. This ParkShuttle has a safety system of sensitive and intelligent sensors. The sensors scan the area in front of the vehicle and will decelerate or stop the vehicle when an unknown obstacle is detected.

An additional safety feature is provided by the bumper system that brings the vehicle to an immediate halt when it is impressed. In addition, the vehicle has emergency stop buttons (both inside and outside) that can be operated by the passengers. The speed is limited to 40 km/h obtain a good ride quality. 8 The ParkShuttle vehicle runs on four rubber tires. Traction is provided by an electric motor powered by a rechargeable battery. Up to 100 km can be covered on one battery-load. It has a capacity of 10 passengers, 6 seated and 4 standees. It is easy to get into and out of the vehicle (wheelchair accessible) and provides good all-round visibility. Inside the vehicle is a console on which the passengers can indicate their destination.

Each vehicle is also fitted with an information display that announces the stop at which the vehicle has arrived. The maximum load is 800 kg. The maximum vehicle weight is monitored by means of weight sensor.

LINE FOLLOWING ROBOT

Line following robot is generally a wheeled mobile robot. The method of line following varied depending on the number of sensors available and the type of line to be followed. There are four methods identified including edge following, line search, line trap, and cross-over. These four methods are different in number of sensors that used and also the results that will be obtained are different. With only one light sensor, the robot will have to know where the line is, or spends time searching to find it. Whereas with two light sensors, the robot is possible to remember which direction the line went. With more sensors, the result that will be obtained would be more excellent and the robot will be more intelligent.

Table 1 *Line Following Method*

Method	Characteristics
Edge following	Stay on the edge of the line
Line search	Stay on the line
Line trap	Keep the line between the sensors
Cross over	Move back and forth over the line

KERWIN'S LINE FOLLOWING ROBOT

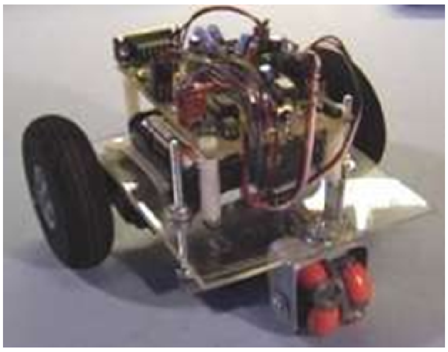


Fig The *Kerwin's line following robot using three matched IR transmit/receive pairs*

The Kerwin's line following robot (ranchbots) is a design with Futaba S-148 servo motors mounted to the bottom of the plexiglass. It has three wheels with the front wheel is the omni-directional wheel. The sensor system consists of an array of three matched IR transmit/receive pairs mounted on a circuit board that can be raised or lowered to fine tune the sensitivity. It uses the Atmel microcontroller as the controller part. The microcontroller takes input from sensor array and drives the servo motors in response.

COMPONENTS SELECTION & DESCRIPTION

DESIGN OBJECTIVES

In nowadays AGV has a greater influence in the production field. Why we prefer this system is mainly because of its accuracy to transport goods, avoiding accidents at industrial zone, decreasing production overall cost etc.

In our project the important factor is that, we give an additional functions to AGV, i.e. we provide a lifting mechanism to take loads from station to station. The lift will actuate at those particular stations using sensors. Also we provide a sensor which detects the objects in the paths to avoid collision with those objects, by stopping the vehicle and moves after the when object leaves the path.

DESIGN CONSIDERATIONS

In design problems many decision variables arise. The impact of decisions on mutual interactions and performance might be difficult to predict. It might be hard to decide on one thing without considering other decision variables. At least the following tactical and operational issues have to be addressed in designing an AGV system

- Flow path layout
- Traffic management: prediction and avoidance of collisions and deadlocks
- Number and location of pick-up and delivery points
- Vehicle requirements
- Vehicle routing
- Vehicle scheduling
- Battery management

A flow path layout compromises the fixed guided paths on which vehicles can travel to the various pick-up and delivery points of loads. Traffic management is required to avoid collisions and deadlock situations in which two or more vehicles are blocked completely. To ensure that loads are transported in time, sufficient vehicles should be available and the right vehicle should be dispatched to the right load.

This layout is usually represented by a directed network in which aisles intersections and pickup and delivery locations can be considered as nodes. The arcs represent the guide path the AGVs can travel on. Directed arcs indicate the direction of travel of vehicles in the system. The layout of this flow path directly influences the performance of the system. In our project we just mark two stations only. One loading and one unloading station. The carrier moves in the loop which connects these two stations.

In controlling and designing AGV systems the problem of prevention of AGV collisions and deadlocks should be addressed. By attaching sensors on AGVs, physical collisions can be avoided. An AGV should have the ability to avoid obstacles and the ability to return to its original path without any collisions. We had fabricated only one AGV. So the traffic management has only less important in our case. But while using more than one carrier we should take care about them.

To determine an optimal AGV's system, capable of meeting all requirements, many factors have to be taken into account. Several of these factors are:

- Number of units to be transported
- Points in time at which units can be or need to be transported
- Capacity of the vehicle
- Speed of the vehicle
- Costs of the system
- Layout of the system and guide path
- Traffic congestion
- Vehicle dispatching strategies
- Number and location of pick-up and delivery points

If AGVs use batteries, frequent battery changing might be required. McHaney (1995) presents an overview of AGV battery technology. The time required for replacing or charging batteries can impact the number of vehicles required. Simulation results from McHaney (1995) indicate a significant increase in the number of AGVs required while incorporating battery management issues in the simulation study compared to neglecting these issues in the studies. Furthermore, the time required for charging batteries impacts throughput, congestion and costs.

COMPONENTS OF AGV

1. MECHANICAL PARTS

The Mechanical components includes,

1. Chassis
2. Steering system
3. Lift mechanism

Chassis

Act as a frame for attaching other components

Carry the load of other components and the payload.

Act as sacrificial component to prevent damage of expensive payload in case of accidents

Steering System

Steering system is for steering the AGV. The two individual motors are directly attached with the wheel for steering

Lifting Mechanism

Lifting mechanism is one of the main part of AGV, the lifting surface moves upward and downward at specified stations. And carry the load during load transfer.

2. ELECTRICAL COMPONENTS

Electrical components include the motor and the power supply unit for the motor, sensoring unit

3. ELECTRONIC COMPONENTS

Electronic components provide sensing, logical decision and control of the vehicle. It includes microcontroller, which is the brain of the vehicle for the decision logic, the motor driver as both sensing and control of motor, regulator ICs, LCD Display unit, sensors for sensing the path, position of loading and unloading stations, detect object in the path etc.

4. SOFTWARE COMPONENTS

Computer is used for making and implementing program for the microcontroller, using embedded computer programming language. For this project we use Arduino Uno microcontroller board based on the ATmega328 .The Arduino Uno can be programmed with the Arduino software.

MECHANICAL PART

CHASSIS

The chassis is fabricated from Acrylic sheet. This is done for ease of fabrication, and to reduce the overall weight. It was designed in Catia; part of fabrication was outsourced due to unavailability of precision cutting tools. The chassis was designed to take a static load of 3kg.

The Top part of chassis has lots of drilled holes which serves as holes for bolting other parts and reduce the weight of the chassis. The Holes are arranged in a zigzag linear arrangement so that the decrease in strength of chassis is not considerable.

The flange which holds the motor was designed using Aluminium and is bolted to the chassis. So that the driving motors can easily accommodate below the chassis. The chassis incorporates hole for attaching front globe wheel, and also for attaching the lift structure

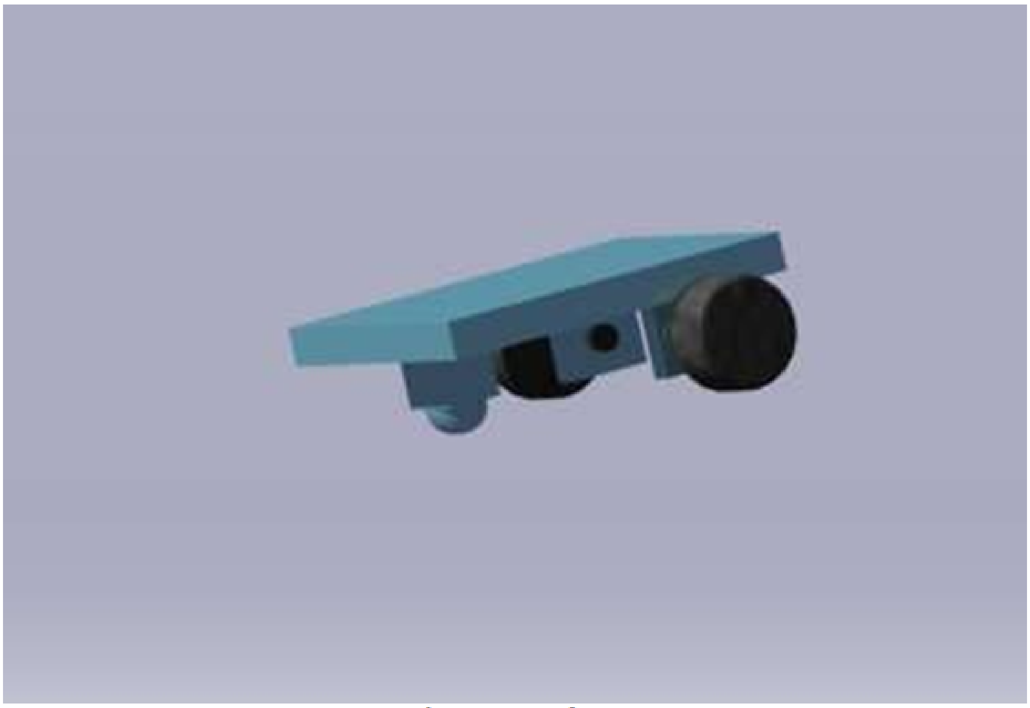


Fig: *Chassis of AGV*

Table : Technical Data of Chassis

Features	Data
Length	300mm
Breadth	160mm
Height	62mm
Material	Colored Acrylic sheet, Aluminum
Maximum load	
Mounting Holes	14×3mm ø Holes for general mounts 2×8mm ø Holes for motor 1×10mm ø Hole for switch

STEERING SYSTEM

The steering system used in the model is of differential type. A differential wheeled vehicle is a vehicle whose movement is based on two separately driven wheels placed on either side of the body. It can thus change its direction by varying the relative rate of rotation of its wheels and hence does not require an additional steering motion. It allows the turning center to be on the vehicle body thus the ability to rotate on the point

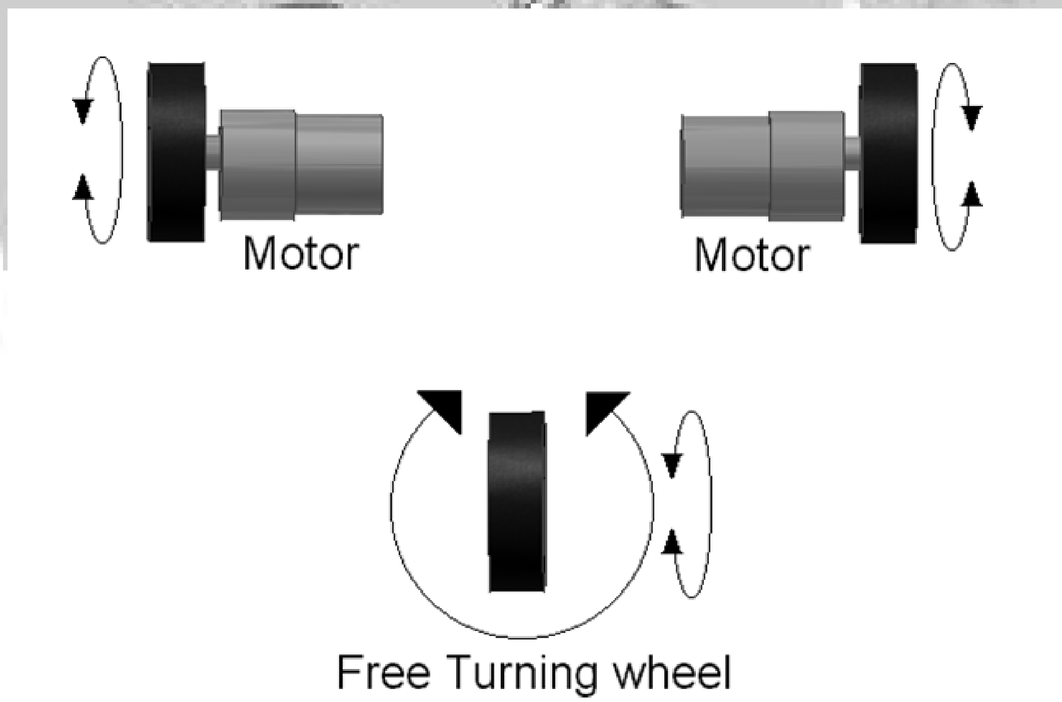


Fig: *Differential Steering*

If both wheels rotate at the same speed and in the same direction, the robot will move in a straight line.

Table 3.2 *Steering Specifications*

Feature	Data
Wheel Base	180mm
Wheel Diameter	70mm
Track Distance	170mm
Material	Rubber and plastic
Turning radius	190mm

LIFTING MECHANISM

The lift is the main component of this AGV. The lift takes and gives loads at specific stations. The vehicle under stands the stations using sensors. Lift is attached in the front portion of the chassis. The power for lift is transmitted from a motor using a threaded shaft.

The lift consists of mainly two plates. One is centrally drilled and tapped. Second plate is attached with the lower one, using bolts, at a distance. The shaft of the motor drilled axially and made internal threads using tap. Both the plates moves in between two guide ways. The threaded shaft is passed through the centrally tapped hole of lower plate.

During the rotation of shaft the lower plate moves up or down. And the upper plate moves according to it. The time for the rotation is limited for few seconds. It can be adjusted by making changes in the microcontroller program. A magnet is attached above the upper plate, which helps to hold the items to be lift, which have magnetic behavior.

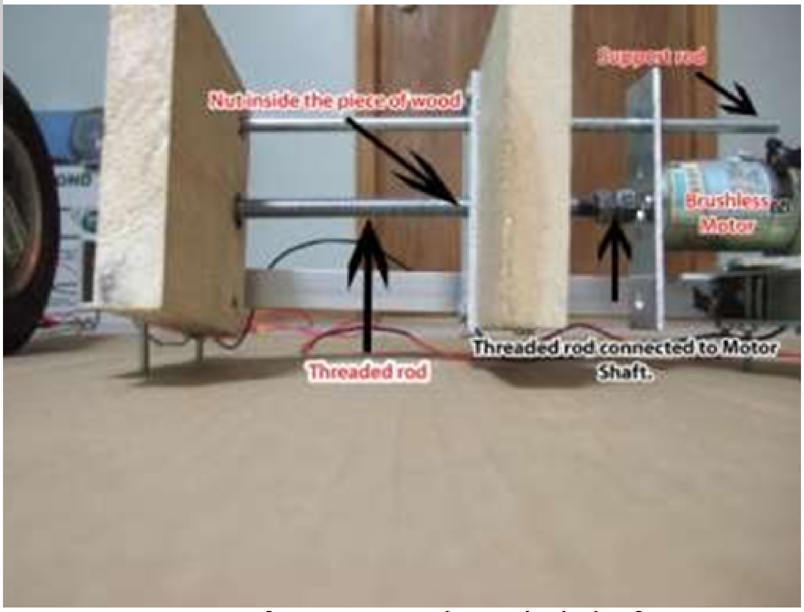


Fig: *Lifting using threaded shaft*

In order to reduce the overall cost and weight of the AGV, we used acrylic sheets for the manufacturing of lifting surfaces, Aluminum C channels for the guide ways in between the plates moves are used for the fabrication

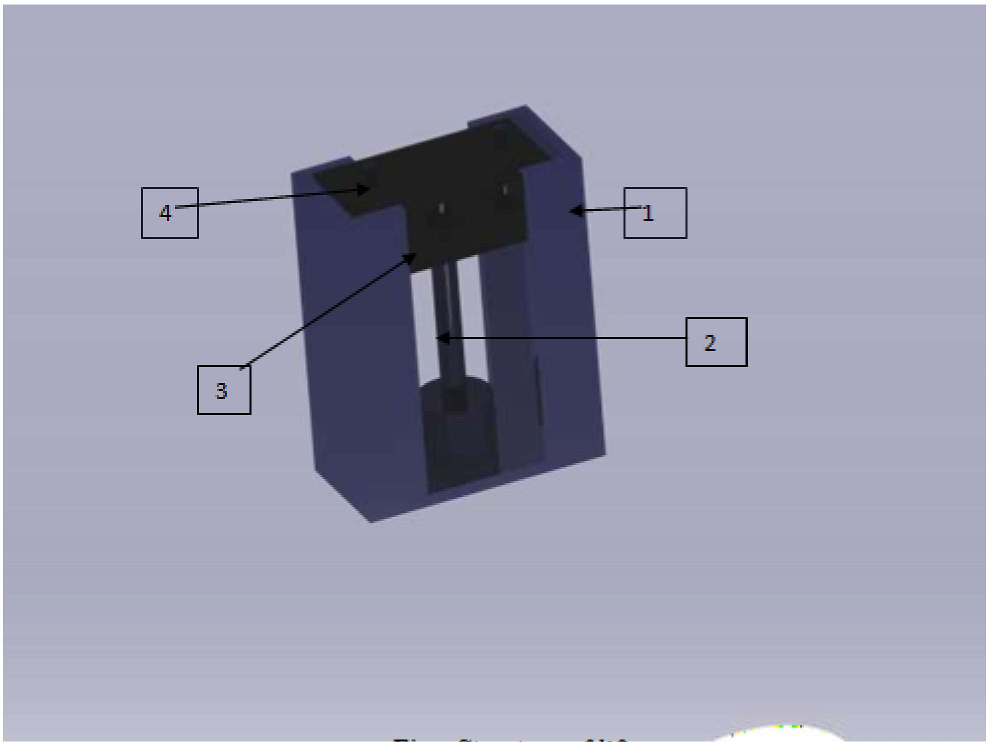


Fig : *Structure of lift*

1. Guide ways
2. Threaded shaft
3. Lower plate
4. Upper plate

Sensors used in AGV

INFRARED SENSORS

IR Sensor is one of the important parts. Path detection and obstrucle detection is done with the help of IR Sensors. There are five IR Sensors are in our AGV. Out of them four are used for the path detection and rest of one is used for obstrucle detection.
IR sensor have a transmitter and a receiver port.

The strength of signal reached at the receiver port after the reflection of light is used to detect the path. Path is marked in the black background by white lines. Sensor detect the white line by the strength of IR wave. The reflected wave from white line has high strength than that of from black. TSOP1730 are used in the design.

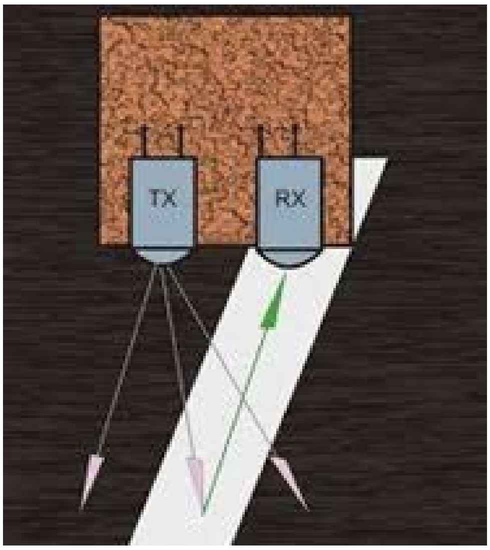


Fig : *IR for Path Detection*

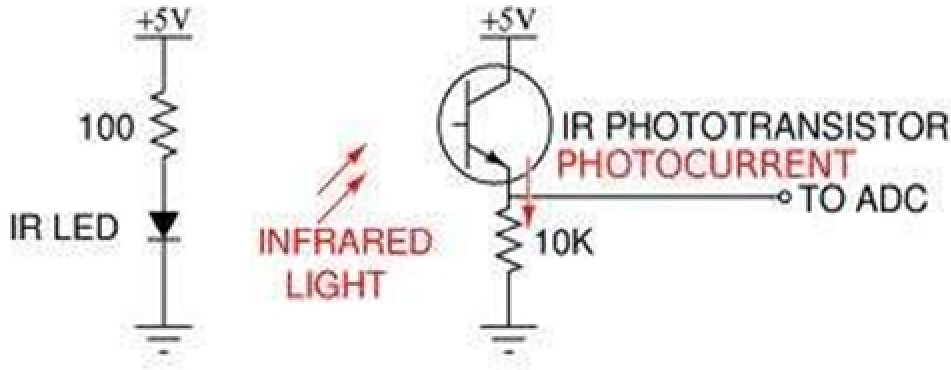


Fig : *IR pair Circuit*

The main features of this IR pair are:

- Photo detector and preamplifier in one package Internal filter for PCM frequency
- Improved shielding against electrical field disturbance TTL and CMOS compatibility
- Output active low
- Low power consumption
- High immunity against ambient light
- Continuous data transmission possible (up to 2400 bps) Suitable burst length 10 cycles/burst

MAGNETIC SENSOR

Magnetic sensors or magnetic switches are electronic switches that close under the magnetic field. In this AGV there are two magnetic sensors. XEN-1210 is the sensor used in this design.

The XEN-1210is a CMOS linear magnetic field sensor with a very low offset. It uses Xensor's patented high performance spinning-current Hall-plate technology, a precision amplifier and a sigma delta AD converter, and offers full digital control and communication through a SPI serial bus. The device does not need calibration and in contrast to low-offset

AMR sensors does not use a set/reset method. It has no hysteresis and is indestructible by high magnetic fields. It does not need any external components and is truly a one-chip solution.

These sensors are used for the purpose of position detection. It is used for detect the loading and unloading station. The sensor is attached with the vehicle at two different positions. Magnets are placed in such a way that one sensor close when the vehicle comes to the loading station. And when that switch close lift operates and moves up. After loading the vehicle moves along the path. When it reach the unloading station the next sensor close and lift operates to move down.

The main features of this sensor are

- Single axis magnetic measurement One chip solution
- 15nT resolution
- Wide magnetic field range (±63mT) No magnetic hysteresis
- Low voltage operation (2.5V to 3.3V) Single supply
- -40°C to 125°C Temperature Range

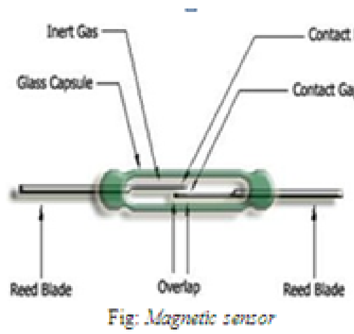


Fig: *Magnetic sensor*

Automated Storage and Retrieval System:

An automated storage and retrieval system (ASRS or AS/RS) consists of a variety of computer-controlled systems for automatically placing and retrieving loads from defined storage locations. Automated storage and retrieval systems (AS/RS) are typically used in applications where:

- There is a very high volume of loads being moved into and out of storage
- Storage density is important because of space constraints
- No value is added in this process (no processing, only storage and transport)
- Accuracy is critical because of potential expensive damages to the load

An AS/RS can be used with standard loads as well as nonstandard loads, meaning that each standard load can fit in a uniformly-sized volume; for example the film canisters in the image of the Defense Visual Information Center are each stored as part of the contents of the uniformly sized metal boxes, which are shown in the image. Standard loads simplify the handling of a request of an item. In addition, audits of the accuracy of the inventory of contents can be restricted to the contents of an individual metal box, rather than undergoing a top-to-bottom search of the entire facility, for a single item.

AS/RS systems are designed for automated storage and retrieval of parts and items in manufacturing, distribution, retail, wholesale and institutions. They first originated in the 1960s, initially focusing on heavy pallet loads but with the evolution of the technology the handled loads have become smaller. The systems operate under computerized control, maintaining an inventory of stored items. Retrieval of items is accomplished by specifying the item type and quantity to be retrieved. The computer determines where in the storage area the item can be retrieved from and schedules the retrieval. It directs the proper automated storage and retrieval machine (SRM) to the location where the item is stored and directs the machine to deposit the item at a location where it is to be picked up. A system of conveyors and or automated guided vehicles is sometimes part of the AS/RS system. These take loads into and out of the storage area and move them to the manufacturing floor or loading docks. To store items, the pallet or tray is placed at an input station for the system, the information for inventory is entered into a computer terminal and the AS/RS system moves the load to the storage area, determines a suitable location for the item, and stores the load. As items are stored into or retrieved from the racks, the computer updates its inventory accordingly.

The benefits of an AS/RS system include reduced labor for transporting items into and out of inventory, reduced inventory levels, more accurate tracking of inventory, and space savings. Items are often stored more densely than in systems where items are stored and retrieved manually.

Within the storage, items can be placed on trays or hang from bars, which are attached to chains/drives in order to move up and down. The equipment required for an AS/RS include a storage & retrieval machine (SRM) that is used for rapid storage and retrieval of material. SRMs are used to move loads vertically or horizontally, and can also move laterally to place objects in the correct storage location.

The trend towards Just In Time production often requires sub-pallet level availability of production inputs, and AS/RS is a much faster way of organizing the storage of smaller items next to production lines.

Material Handling Institute of America (MHIA), the non-profit trade association for the material handling world, and its members have broken AS/RS into two primary segments: Fixed Aisle and Carousels/Vertical Lift Modules (VLMs). Both sets of technologies provide automated storage and retrieval for parts and items, but use different technologies. Each technology has its unique set of benefits and disadvantages. Fixed Aisle systems are characteristically larger systems whereas carousels and Vertical Lift Modules are used individually or grouped, but in small to medium-sized applications.

A fixed-aisle AS/R machine (stacker crane) is one of two main designs: single-masted or double masted. Most are supported on a track and ceiling guided at the top by guide rails or channels to ensure accurate vertical alignment, although some are suspended from the ceiling. The 'shuttles' that make up the system travel between fixed storage shelves to deposit or retrieve a requested load (ranging from a single book in a library system to a several ton pallet of goods in a warehouse system). The entire unit moves horizontally within an aisle, while the shuttles are able to elevate up to the necessary height to reach the load, and can extend and retract to store or retrieve loads that are several positions deep in the shelving. A semi-automated system can be achieved by utilizing only specialized shuttles within an existing rack system.

Another AS/RS technology is known as shuttle technology. In this technology the horizontal movement is made by independent shuttles each operating on one level of the rack while a lift at a fixed position within the rack is responsible for the vertical movement. By using two separate machines for these two axes the shuttle technology is able to provide higher throughput rates than stacker cranes.

Storage and Retrieval Machines pick up or drop off loads to the rest of the supporting transportation system at specific stations, where inbound and outbound loads are precisely positioned for proper handling.

In addition, there are several types of Automated Storage & Retrieval Systems (AS/RS) devices called Unit-load AS/RS, Mini-load AS/RS, Mid-Load AS/RS, Vertical Lift Modules (VLMs), Horizontal Carousels and Vertical Carousels. These systems are used either as stand-alone units or in integrated workstations called pods or systems. These units are usually integrated with various types of pick to light systems and use either a microprocessor controller for basic usage or inventory management software. These systems are ideal for increasing space utilization up to 90%, productivity levels by 90%, accuracy to 99.9%+ levels and throughput up to 750 lines per hour/per operator or more depending on the configuration of the system.

Advantages

An effective automated storage and retrieval system provides several benefits for supply chain management:

- An efficient AS/RS system helps companies cut expenses by minimizing the amount of unnecessary parts and products in storage, and improving organization of the contents of a warehouse. Due to automated processes, it also allows for more storage space due to high-density storage, narrower aisles, etc.
- Automation reduces labor costs while lowering workforce requirements and increasing safety.
- Modeling and managing the logical representation of the physical storage facilities (e.g. racking, etc.). For example, if certain products are often sold together or are more popular than others, those products can be grouped together or placed near the delivery area to speed up the process of picking, packing and shipping to customers.
- Enabling a seamless link to order processing and logistics management in order to pick, pack, and ship product out of the facility.
- Tracking where products are stocked, which suppliers they come from, and the length of time they are stored. By analyzing such data, companies can control inventory levels and maximize the use of warehouse space. Furthermore, firms are more prepared for the demands and supplies of the market, especially during special circumstances such as a peak season on a particular month. Through the reports generated by an AS/RS system, firms are also able to gather important data that may be put in a model for it to be analyzed.

Vertical lift module

VLMs can be built quite high to match the available overhead space in a facility. Multiple units can be places in 'pods' whereby an operator can retrieve items from one unit while the other units are moving. Variants include width, height, load, speed and a control system.

The VLM is a board controlled automated vertical lift module. Inventory within the VLM is stored on front and rear tray locations or rails. When a tray is requested, either by entering a tray number in the built-in control pad or by requesting a part through software, an extractor travels vertically between the two columns of trays and pulls the requested tray from its location and brings it to an access point. The operator then picks or replenishes stock and the tray is returned to its home upon confirmation.

VLM systems are sold in numerous configurations, which could be applied in different industries, logistics, as well as office settings. The VLM systems could be customized to fully utilize the height of the facility, even through multiple floors. With the capability of multiple access openings on different floors, the VLM system is able to provide an innovative storage and retrieval solution. The rapid movement of the extractor, as well as inventory management software, can dramatically increase the efficiency of the picking process. This occurs by simultaneously retrieving and storing trays in multiple units. Unlike large AS/RS systems, which require a complete overhaul of the warehouse or production line, the vertical lift modules are modularized, which can be easily integrated into the existing system, or to be rolled out in gradually over different phases.

Most common applications include: MRO, order picking, consolidation, kitting, parts handling, buffering, inventory storage, WIP, buffer storage, and many more.

VLMs provide floor space savings, increased labor productivity and picking accuracy, improved worker ergonomics, and controlled process.

Most VLMs offer dynamic space storage which measures the tray every time it is returned to the unit to optimize space, safety features and some offer tilt tray delivery for increased ergonomic accessibility, and laser pointers which indicate the exact item to be picked on each tray.

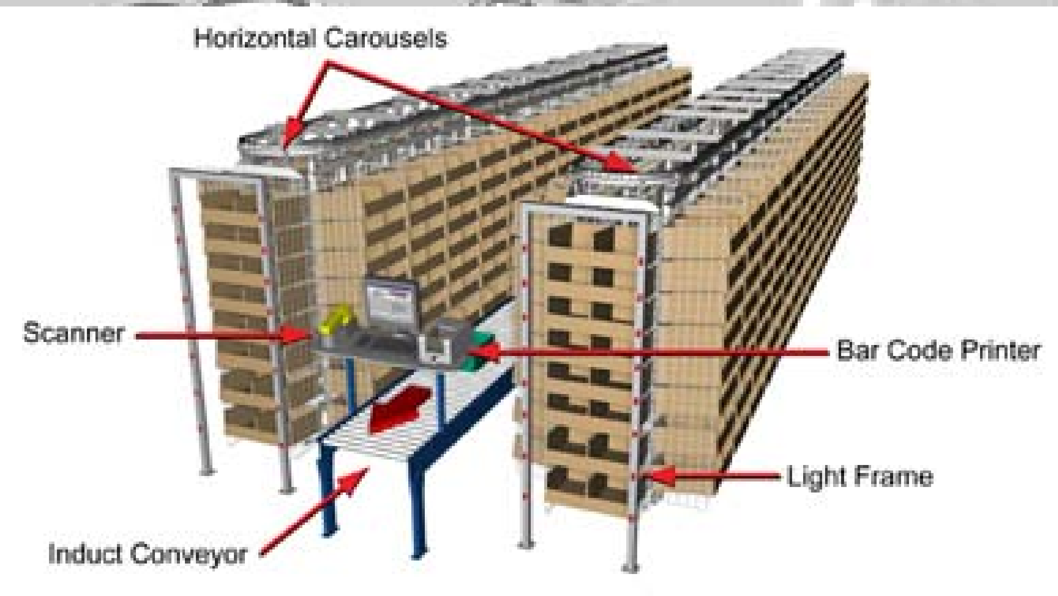
Horizontal carousels:

A horizontal carousel is a series of bins which revolve on an oval track. Every bin has shelves which are adjustable to .75" and can be configured for a myriad of standard and special applications. An operator simply inputs a bin number, part number or cell location and the carousel will rotate via the shortest path. Multiple horizontal carousels integrated with pick to light technology and inventory management software (a pod of carousels) are used for order fulfillment.

A wave of orders are sent to the pod. A group of orders are selected to create a batch. The operator simply follows the lights and pick round robin from the carousels and place items in a batch station behind them. Each carousel pre-positions and rotates when picked. By applying the "product to person" principle, operators do not have to move from their position to prepare the order.

When the batch is complete, a new batch is inducted and the process repeated until the wave is complete. Horizontal carousels can save up to 75% of floorspace, increase productivity by 2/3, accuracy levels to 99.9%+ levels and throughput up to 750 lines per hour/operator.

Horizontal carousel systems generally outperform robotic systems for a fraction of the cost. Horizontal carousels are the most cost effective AS/RS system available.



Robotic Inserter/Extractor devices can also be used for horizontal carousels. The robotic device is positioned in the front or rear of up to three horizontal carousels tiered high. The robot grabs the tote required in the order and often replenishes at the same time to speed up throughput. The tote(s) are then delivered to conveyor which routes it to a work station for picking or replenishing. Up to eight transactions per minute per unit can be done. Totes or containers up to 36" x 36" x 36" can be used in a system.

On a simplistic level, horizontal carousels are also often used as "rotating shelving." 'With simple "fetch" command items are brought to the operator and otherwise wasted space is eliminated. AS/RS Applications: Most applications of AS/RS technology have been associated with warehousing and distribution operations. An AS/RS can also be used to store raw materials and work in process in manufacturing.

Three application areas can be distinguished for AS/RS:

(1) Unit load storage and handling,

(2) Order picking, and

(3) Work in process storage.

Unit load storage and retrieval applications are represented by unit load AS/RS and deep-lane storage systems. These kinds of applications are commonly found in warehousing for finishing goods in a distribution centre, rarely in manufacturing. Deep-lane systems are used in the food industry. As described above, order picking involves retrieving materials in less than full unit load quantities. Minilpass, man-on board, and items retrieval systems are used for this second application area.

Work in process storage is a more recent application of automated storage technology. While it is desirable to minimize the amount of work in process, WIP is unavoidable and must be effectively managed. Automated storage systems, either automated storage/retrieval systems or carousel systems, represent an efficient way to store materials between processing steps, particularly in batch and job shop production. In high production, work in process is often carried between operations by conveyor system, which this serves both storage and transport functions.

Unit V

Design & calculation of MH Systems

A common approach to the design of MH systems (MHSs) is to consider MH as a cost to be minimized. This approach may be the most appropriate in many situations because, while MH can add real value to a product, it is usually difficult to identify and quantify the benefits associated with MH; it is much easier to identify and quantify the costs of MH (e.g., the cost of MH equipment, the cost of indirect MH labor, etc.). Once the design of a production process (exclusive of MH considerations) is completed, alternate MHS designs are generated, each of which satisfies the MH requirements of the production process. The least cost MHS design is then selected.

The appropriateness of the use of MHS cost as the sole criterion to select a MHS design depends on the degree to which the other aspects of the production process are able to be changed. If a completely new facility and production process is being designed, then the total cost of production is the most appropriate criterion to use in selecting a MHS—the lowest cost MHS may not result in the lowest total cost of production. If it is too costly to even consider changing the basic layout of a facility and the production process, then MHS cost is the only criterion that need be considered. In practice, it is difficult to consider all of the components of total production cost simultaneously, even if a new facility and production process is being designed. Aspects of the design that have the largest impact on total cost are at some point fixed and become constraints with respect to the remaining aspects of the design.

Principles of Material Handling

Although there are no definite "rules" that can be followed when designing an effective MHS, the following "Ten Principles of Material Handling,"3 as compiled by the College-Industry Council on Material Handling Education (CIC-MHE) in cooperation with the Material Handling Institute (MHI), represent the distillation of many years of accumulated experience and knowledge of many practitioners and students of material handling:

1. Planning Principle.

All MH should be the result of a deliberate plan where the needs, performance objectives, and functional specification of the proposed methods are completely defined at the outset.

2. Standardization Principle.

MH methods, equipment, controls and software should be standardized within the limits of achieving overall performance objectives and without sacrificing needed flexibility, modularity, and throughput.

3. Work Principle.

MH work (defined as material flow multiplied by the distance moved) should be minimized without sacrificing productivity or the level of service required of the operation.

4. Ergonomic Principle.

Human capabilities and limitations must be recognized and respected in the design of MH tasks and equipment to ensure safe and effective operations.

5. Unit Load Principle.

Unit loads shall be appropriately sized and configured in a way that achieves the material flow and inventory objectives at each stage in the supply chain.3

6. Space Utilization Principle.

Effective and efficient use must be made of all available (cubic) space.

7. System Principle.

Material movement and storage activities should be fully integrated to form a coordinated, operational system which spans receiving, inspection, storage, production, assembly, packaging, unitizing, order selection, shipping, and transportation, and the handling of returns.

8. Automation Principle.

MH operations should be mechanized and/or automated where feasible to improve operational efficiency, increase responsiveness, improve consistency and predictability, decrease operating costs, and to eliminate repetitive or potentially unsafe manual labor.

9. Environmental Principle.

Environmental impact and energy consumption should be considered as criteria when designing or selecting alternative equipment and MHS.

10. Life Cycle Cost Principle.

A thorough economic analysis should account for the entire lifecycle of all MHE and resulting systems.

Characteristics of Materials

The characteristics of materials affecting handling include the following: size (width, depth, height); weight (weight per item, or per unit volume); shape (round, square, long, rectangular, irregular); and other (slippery, fragile, sticky, explosive, frozen).

Table 1. Material Categories

	Physical State		
Material Category	Solid	Liquid	Gas
Individual units	Part, subassembly	—	—
Containerized items	Carton, bag, tote, box, pallet, bin	Barrel	Cylinder
Bulk materials	Sand, cement, coal, granular products	Liquid chemicals, solvents, gasoline	Oxygen, nitrogen, carbon dioxide

The impact of the material category listed in Table 1 on the type of MH equipment is as follows: • Individual units and containerized items ⇒ discrete material flow ⇒ unit loads ⇒ unit handling equipment

• Bulk materials ⇒ continuous material flow ⇒ bulk handling equipment

Figure 1 shows an example of alternate ways of handling a dry bulk material: as containerized (bagged) items on pallets handled using unit handling equipment (boxcar, pallet, fork truck), or as bulk material handled using bulk handling equipment (hopper car, pneumatic conveyor, bulk storage bin).

The Unit Load Concept

A unit load is either a single unit of an item, or multiple units so arranged or restricted that they can be handled as a single unit and maintain their integrity. Advantages of unit loads: 1. More items can be handled at the same time, thereby reducing the number of trips required and, potentially, reducing handling costs, loading and unloading times, and product damage. 2. Enables the use of standardized material handling equipment

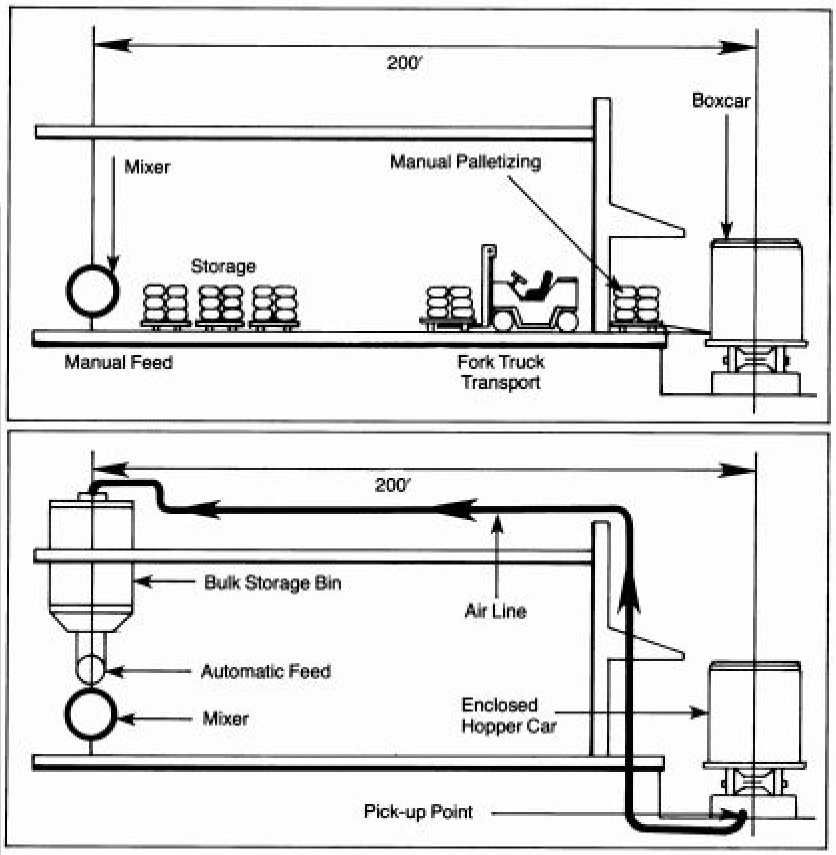


Figure 1. Unit vs. bulk handling of material.

Disadvantages of unit loads:

1. Time spent forming and breaking down the unit load.
2. Cost of containers/pallets and other load restraining materials used in the unit load
3. Empty containers/pallets may need to be returned to their point of origin.

Basic ways of restraining a unit load:

- Self-restraining—one or more units that can maintain their integrity when handled as a single item (e.g., a single part or interlocking parts)
- Platforms—pallets (paper, wood, plastic, metal), skids (metal, plastic)
- Sheets—slip sheets (plastic, cardboard, plywood)
- Reusable containers—tote pans, pallet boxes, skid boxes, bins, baskets, bulk containers (e.g., barrels), inter modal containers
- Disposable containers—cartons, bags, crates
- Racks—racks
- Load stabilization—strapping, shrink-wrapping, stretch-wrapping, glue, tape, wire, rubber bands

Basic ways of moving a unit load:

• Use of a lifting device under the mass of the load (e.g., a pallet and fork truck)
• Inserting a lifting element into the body of the load (e.g., a coil of steel)
• Squeezing the load between two lifting surfaces (e.g., lifting a light carton between your hands, or the use of carton clamps on a lift truck)
• Suspending the load (e.g., hoist and crane)

Unit Load Design

Unit loads can be used both for in-process handling and for distribution (receiving, storing, and shipping).

Unit load design involves determining the:

1. Type, size, weight, and configuration of the load
2. Equipment and method used to handle the load
3. Methods of forming (or building) and breaking down the load.

Selecting unit load size for in-process handling:

• Unit loads should not be larger than the production batch size of parts in process—if the unit load size is larger, then a delay would occur if the load is forced to wait until the next batch of the part is scheduled to start production (which might be days or weeks) before it can be transported.
• Large production batches (used to increase the utilization of bottleneck operations) can be split into smaller transfer batches for handling purposes, where each transfer batches contains one or more unit loads, and small unit loads can be combined into a larger transfer batch to allow more efficient transport (e.g., several cartons at a time can be transported on a hand truck, although each carton is itself a unit load and could be transported separately); thus:
Single part ≤ Unit load size ≤ Transfer batch size ≤ Production batch size
• When parts are transferred between adjacent operations, the unit load may be a single part.
• When operations are not adjacent, short distance moves ⇒ smaller unit load sizes, and long distance moves ⇒ larger unit load sizes.
• The practical size of a unit load (cf. the Unit Load Principle) may be limited by the equipment and aisle space available and the need for safe material handling (in accord with the Safety Principle). Selecting unit load size for distribution (see Figure 2):
• Containers/pallets are usually available only in standard sizes and configurations.
• Truck trailers, rail boxcars, and airplane cargo bays are limited in width, length, and height.
• The existing warehouse layout and storage rack configuration may limit the number of feasible container/pallet sizes for a load.
• Customer package/carton sizes and retail store shelf restrictions can limit the number of feasible container/pallet sizes for a load.

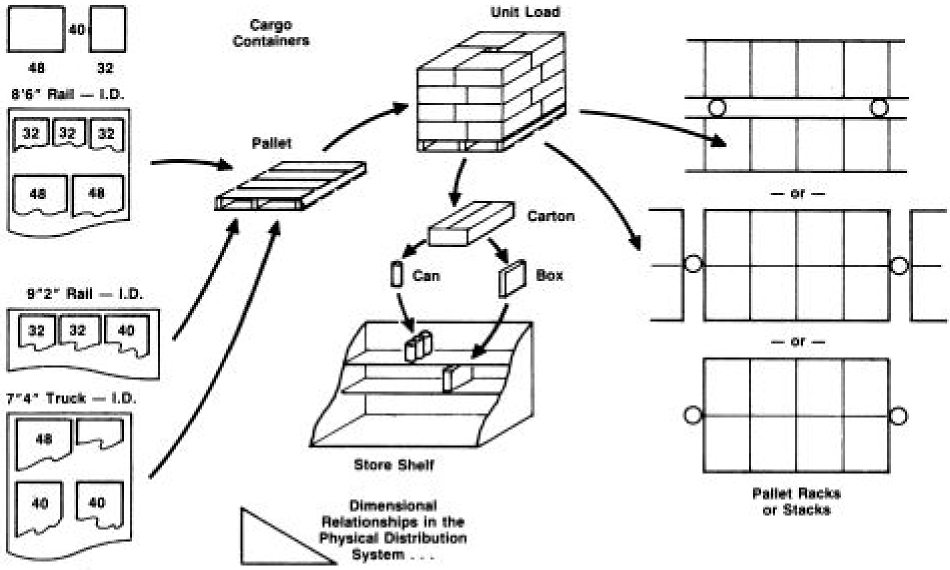


Figure 2. Unit load size for distribution.[5]

Major Equipment Categories

The different types of MH equipment listed in Table 2 can be classified into the following five major categories.

I. Transport Equipment.

Equipment used to move material from one location to another (e.g., between workplaces, between a loading dock and a storage area, etc.). The major subcategories of transport equipment are conveyors, cranes, and industrial trucks. Material can also be transported manually using no equipment.

II. Positioning Equipment.

Equipment used to handle material at a single location (e.g., to feed and/or manipulate materials so that are in the correct position for subsequent handling, machining, transport, or storage). Unlike transport equipment, positioning equipment is usually used for handling at a single workplace. Material can also be positioned manually using no equipment.

III. Unit Load Formation Equipment.

Equipment used to restrict materials so that they maintain their integrity when handled a single load during transport and for storage. If materials are self-restraining (e.g., a single part or interlocking parts), then they can be formed into a unit load with no equipment.

IV. Storage Equipment.

Equipment used for holding or buffering materials over a period of time. Some storage equipment may include the transport of materials (e.g., the S/R machines of an AS/RS, or storage carousels). If materials are block stacked directly on the floor, then no storage equipment is required.

V. Identification and Control Equipment.

Equipment used to collect and communicate the information that is used to coordinate the flow of materials within a facility and between a facility and its suppliers and customers. The identification of materials and associated control can be performed manually with no specialized equipment.

Table 2. Material Handling Equipment

I. Transport Equipment			
A. Conveyors	B. Cranes	C. Industrial Trucks	D. No Equipment
1. Chute conveyor	1. Jib crane	1. Hand truck	1. Manual
2. Wheel conveyor	2. Bridge crane	2. Pallet jack	
3. Roller conveyor	3. Gantry crane	3. Walkie stacker	
4. Chain conveyor	4. Stacker crane	4. Pallet truck	
5. Slat conveyor		5. Platform truck	
6. Flat belt conveyor		6. Counterbalanced lift truck	
7. Magnetic belt conveyor		7. Narrow-aisle straddle truck	
8. Troughed belt conveyor		8. Narrow-aisle reach truck	
9. Bucket conveyor		9. Turret truck	
10. Vibrating conveyor		10. Order picker	
11. Screw conveyor		11. Sideloader	
12. Pneumatic conveyor		12. Tractor-trailer	
13. Vertical conveyor		13. Personnel and burden carrier	
14. Cart-on-track conveyor		14. Automatic guided vehicle	
15. Tow conveyor			
16. Trolley conveyor			
17. Power-and-free conveyor			
18. Monorail			
19. Sortation conveyor			

II. Positioning Equipment	III. Unit Load Formation Equipment	IV. Storage Equipment	V. Identification and Control Equipment
1. Manual (no equipment)	1. Self-restraining (no equipment)	1. Block stacking (no equipment)	1. Manual (no equipment)
2. Lift/tilt/turn table	2. Pallets	2. Selective pallet rack	2. Bar codes
3. Dock leveler	3. Skids	3. Drive-in rack	3. Radio frequency identification tags
4. Ball transfer table	4. Slipsheets	4. Drive-through rack	4. Voice recognition
5. Rotary index table	5. Tote pans	5. Push-back rack	5. Magnetic stripes
6. Parts feeder	6. Pallet/skid boxes	6. Flow-through rack	6. Machine vision
7. Air film device	7. Bins/baskets/racks	7. Sliding rack	7. Portable data terminals
8. Hoist	8. Cartons	8. Cantilever rack	
9. Balancer	9. Bags	9. Stacking frame	
10. Manipulator	10. Bulk load containers	10. Bin shelving	
11. Industrial robot	11. Crates	11. Storage drawers	
	12. Intermodal containers	12. Storage carousel	
	13. Strapping/tape/glue	13. Vertical lift module	
	14. Shrink-wrap/ stretch-wrap	14. A-frame	
	15. Palletizers	15. Automatic storage/ retrieval system	

Transport equipment (see Table 2) is used to move material from one location to another, while positioning equipment is used to manipulate material at a single location. The major subcategories of transport equipment are conveyors, cranes, and industrial trucks. Material can also be transported manually using no equipment.

The following general equipment characteristics can be used to describe the functional differences between conveyors, cranes, and industrial trucks (see Table 3):

Path: Fixed—move between two specific points

Variable—move between a large variety of points

Area: Restricted—move restricted to a limited area
Unrestricted—unlimited area of movement

Move frequency: Low—low number of moves per period, or intermittent moves
High—high number of moves per period

Adjacent move: Yes—move is between adjacent activities
No—move is between activities that are not adjacent

Table 3. Transport Equipment Characteristics

Path	Fixed			Variable		
Area	Restricted			Restricted		Unrestricted
Frequency	High	Low		High	Low	—
Adjacent	—	Yes	No	—	—	—
Equipment Category	*Conveyor*	*Conveyor*	*Industrial Truck/Crane*	*Industrial Truck*	*Crane*	*Industrial Truck*

Storage Space

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.

Estimation based on no. of 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.

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 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.

Spare part management of few vehicles:

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.

1 Industrial Truck

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.

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.

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.

Material handling system cost

Material handling system costs may be comprised of variable and fixed costs. Variable costs are generally the operating costs of the material handling system. These costs can include the cost of power, lubricants, and maintenance. The variable costs may also include the routing or travel expenses, which are proportional to the distance travelled. Costs associated with idle or waiting vehicles may also be included in the variable costs. Fixed costs include such costs as the construction and purchase of equipment and hardware. Total cost is used as a performance measure by considering Cost ratio (C) as a performance measure. This cost ratio (C) is defined as:

$$C$$

where

C_{in} : moving cost of one unit load and one unit distance within a department,

C_{out} : moving cost of one unit load and one unit distance between departments.