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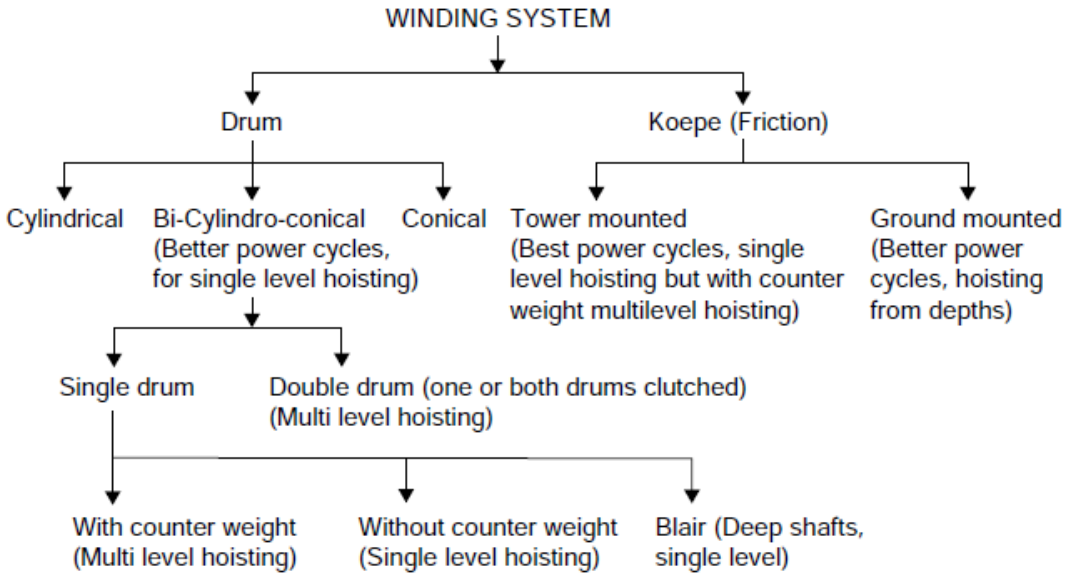
MINING MACHINERY

CLASSIFICATION OF HOISTING SYSTEM



COMPARISON OF HOISTING SYSTEMS

Drum and **friction hoists** are the two types of hoists that are in operation in the mines. Their main features have been compared in following table, and their sub-classification has been presented by way of a line diagram shown in following figure.

Features	Drum hoists	Friction sheaves hoist	Multi rope friction drum hoist
Relation w.r.t. rope	It stores rope	Rope not stored but extends in the shaft	Use multiple ropes extends in the shaft but extends in the shaft
Important features	Single rope; Multi level; Medium depth; Widely used	Multi rope; Single level; Limited depth; High output; Efficient	Used for great depths
Max. skip capacity	25 tons.	75 tons.	50 tons.
Max. output tons./hr.	800	2500	1600
Optimum depth	< 1800	< 900	>1800
Mounting	Head frame	Tower	Head frame

THE DRUM HOISTING SYSTEM

It is the only practical system for all mine shafts- inclined, compound, and vertical. It had served the mining industry since its inception with great success until it came to be challenged by the friction (Koepe) hoist in the 1950s. Great depths in metal mines especially in gold mines had resulted in the design and installation of conical and cylindroconical hoists before World War II but the high installation costs, high moment of inertia of the drums which had reached massive properties of 10.7 m in diameter, the doubtful overall saving in power costs, and the development of multi-layer coiling on drums have ruled out their use as mine hoists. Today, the conventional **parallel cylindrical drum hoist** is the only type which is still used both above and below ground.

Parallel Cylindrical Drum Hoists

The parallel cylindrical drum hoists may be classified depending on:

Number of drums used

- Single-drum hoists, and
- Double-drum hoists (i) with one drum clutched, and (ii) with two drums clutched.

Number of ropes used

- Single-rope drum hoists, and
- Blair multi-rope hoists.

Methods of drive

- Geared-drum hoists, and
- Direct-driven drum hoists.

Single-drum hoists

These are used in smaller shafts as service or production hoist for single or two-compartment hoisting with or without balance rope. In single-compartment hoisting, either a single unbalanced cage may be used or a cage/skip in counterbalance with a counterweight while in two-compartment hoisting, two cages/skips are used in counterbalance.

A single-drum unbalanced hoist is suitable for small installations often used for sinking shafts. The drive motor draws considerable energy from the supply when hoisting the loaded conveyance and returns some of it when lowering the empty conveyance. It may be used as a small service hoist when the cost of additional shaft section and guides required for a counterweight or second conveyance cannot be justified. A good proportion of the cost of the

drive is in the control equipment. By means of a two-speed gearbox, the hoisting speed can be reduced to 1 m/s for man-riding.

As service or production hoist with cage/skip in counterbalance with a counterweight, a single-drum hoist can efficiently serve one or more levels, since the location of the counterweight at any time is not important. As a production hoist with cages/skips in counterbalance, the single-drum hoist is best used for single-level hoisting. By designing the counterweight as a service skeleton cage, service facilities can be provided at no extra cost. The peak power required is less than that required for an equivalent unbalanced hoist.

Double-drum hoists

These are normally designed with either *one or two clutched drums*.

The double-drum hoist with one drum clutched and a cage in counterbalance with a counterweight can be used as a service hoist for serving several levels efficiently as quick adjustment of rope can be facilitated. It can be used as a production hoist with two cages/skips in balance for one level or multi-level operation.

The main *advantages* claimed for double-drum hoists with both the drums clutched are that, if something happens in one of the two compartments, the hoist can operate in the other compartment to raise or lower men and supplies, and also that they facilitate rope changing. This hoist is particularly favoured in metal mines.

With continual two-compartment hoisting from more than one level, the use of balance rope is useless as operation from levels other than for which designed is only possible with an out-of-balance hoist. Also, the use of the balance rope would prevent clutching to the different levels as the dividers between the compartments would foul the loop of the balance rope. The other *disadvantages* of a balance rope are: increase in tension of main (head) rope due to vibrations of balance rope; oscillation of the loop during acceleration and deceleration; difficulty of changing the ropes; increase in the weight of the conveyance as well as conveyance suspension gear; and necessity of a guided tail sheave to compensate for variation in effective diameter in a multilayer-coiled drum for deep shafts. In the gold mines of South Africa, a few double-drum hoists with balance ropes had been installed in the past because of the restriction imposed by the power peak demands.

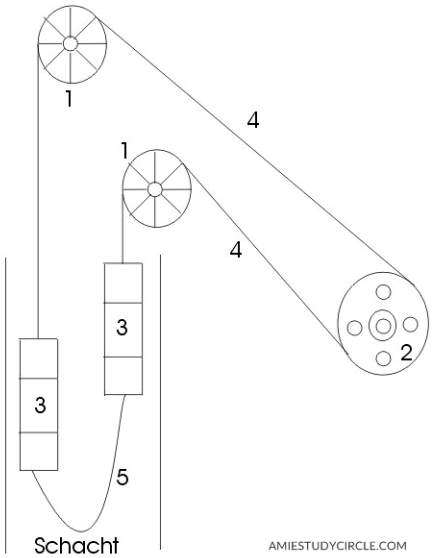
THE KOEPE (FRICTION) HOISTING SYSTEM

In earlier times the machines had huge cylinders on which the ropes were winded up. This was connected with the disadvantage that - with heavy loads in the pit cages and especially in the inner windings - a great strain was effecting the ropes, because they were winded up very tight. That caused a heavy wear and tear of the rope. That is the reason why a clever man named

Koepe had the idea that this effect could be avoided by not winding the rope up, but leading it around a driving wheel and then back to the winding tower and into the shaft.

The principle works in the following way: The rope coming out of the shaft is lead around the wheels at the winding tower's top and by this to the winding machine in the corresponding building. Then the rope is driven by the driving wheel and after this it is sent back vertically into the shaft after passing another wheel at the winding tower. So there are two pit cages fixed at each rope - one moving upwards and the other moving downwards the shaft at the same time.

After that one of the pit cages arrived at the onset of a certain level and the other one arrived at the pit bank, there is a strong difference concerning the sharing of the loads: At the first side of the driving wheel just a few metres of rope and the pit cage are pulling and at the other side there are up to 1.500 metres of rope and the pit cage, so that another rope is used for levelling out these differences: It is fixed under the pit cages and connects their floors. In this way the load of both sides is levelled out, so that the machine just has to bring up the power to move what has been put into the pit cages, for example the miners, the mine cars or the coal. The rope connecting the bottom ends of the two pit cages is in most cases a flat one. If you imagine the rope at the top, the both pit cages and the rope connecting them at the bottom, you can nearly see a circle. That is why this kind of hoisting is called "endless rope hoisting".



In given figure

1. Upper head sheave
2. Friction pulley
3. Skips
4. Ropes
5. Tail ropes

In Koepe hoisting system, a friction hoist is used that uses the principle of friction to drive the hoisting rope. The driving force of the motor is transmitted to the rope by static friction between the rope and the tread of the Koepe sheave. As long as the frictional force available is greater than the driving force of the motor and greater than the difference in rope tensions between the heavier and lighter loaded ropes at the drive sheave (see figure), the rope will not slip under any condition of operation.



The limiting condition occurs when

$$\frac{F_1}{F_2} = e^{\mu\alpha}$$

where

F_1 = the rope pull or tension in the heavier loaded rope;

F_2 = the rope pull or tension in the lighter loaded rope;

α = the angle of contact (180° - 205°); and

μ = the coefficient of friction between rope and rope tread, which for design purposes, is taken as equal to either 0.20 for locked-coil or 0.25 for stranded ropes.

A balance or tail rope must be used with Koepe friction hoists to maintain an adequate value of F_2 in order that the rope does not slip.

The Koepe hoists may be classified depending on:

Method of mounting

- Ground-mounted hoists, and
- Tower-mounted hoists.

Number of ropes used

- Single-rope friction hoists, and
- Multi-rope friction hoists.

Method of drive

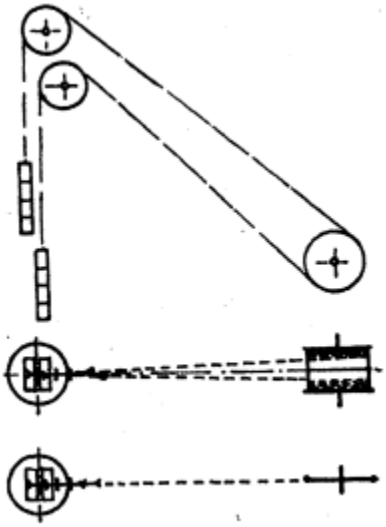
- Direct-driven D.C. hoists, and
- Geared A.C. hoists.

Single-rope and multi-rope hoists may be used as production hoists for single-level hoisting with two conveyances in balance, or with a conveyance and a counterweight for single or multi-level hoisting. They can also be efficient as service hoists with conveyance and counterweight for single- or multi-level hoisting.

Advantages of Koepe Hoisting

Compared with the drum hoisting system, the Koepe hoisting system has the following advantages:

- The Koepe system is most suitable for heavy-duty hoisting from great depths. With drumhoisting, large drums are required for hoisting large payloads from great depths and multi-layer coiling results in reduced rope life on account of crushing and heavy wear.
- When it is required to hoist from a greater depth with an existing hoisting plant, the drum hoist cannot take the greater length of rope. In such a case, it is possible to replace the drum by a friction sheave and use the existing plant to raise the load form the deeper loading level. If the existing hoisting plant is a friction hoist, it can easily be adapted to hoisting from greater depth by fitting a longer rope and altering the depth indicators and the signalling and controlling devices.
- The Koepe hoist is simpler, more compact, and lighter than the drum hoist. Less costly engine house foundations are required. The carrying capacity and the span of crane required will also be less. The capital cost with Koepe hoisting will, therefore, be lower than with drumhoisting for similar duty, the saving in cost increasing with depth.
- With Koepe hoisting, the inertia of rotating parts is less than with drumhoisting, This is, however, partly offset by the greater inertia of the ropes and conveyances. The smaller inertia and the balance rope lower the peak h.p. demands. For the same duty, the r.m.s. motor power can be as low as two-thirds of that required by an equivalent drum hoist. There is an appreciable saving in the overall consumption of electrical energy.
- With ground-mounted hoists, the headsheaves can be arranged so that the underlay and overlay ropes do not deviate at the headsheaves as well as at the friction sheave rope tread. In this way, the fleet angle becomes zero. With drumhoisting, on the other hand, the ropes deviate at the headgear sheaves and also fleet across the drum.



Fleet Angles with Vertical Arrangement of Heads heaves with Drum and Friction Hoists.

- The wear of rope tread does not affect the decking of cages. With drumhoisting, owing to non-uniform wear of the wooden grooving where used on the drums, difficulty is experienced with cage decking.
- The Koepe system is ideally suited for multi-rope hoisting. The use of multiple ropes means that, for a given payload, smaller diameter ropes can be used with consequent reduction in the size of the friction drum and tower and saving in capital cost. As a tower-mounted hoist, it is directly mounted over the shaft which is not possible with a drum hoist. The tower-type mounted hoist is most suitable for sub-vertical and internal shafts as the amount of excavation required for its installation will be much less than for a drum hoist for the same hoisting capacity.
- In the case of ground-mounted hoists, there is flexibility in the choice of location of the hoist with respect to the shaft. The distance of the hoist from the shaft can be considerably reduced to render stresses in the headframe as nearly vertical as possible and to save on space requirement.
- A smaller length of main rope is required compared to drum hoisting using a balance rope.
- Koepe ropes are much less severely treated than multi-layer drum hoist ropes.
- Operating costs are less due to the smaller rated output of the electric motor, the smaller electrical and mechanical losses, and less mechanical maintenance required because of fewer moving parts.
- Koepe hoists are commonly designated for push-bottom operation.
- A high measure of standardization in Koepe hoist design is practicable since the unloaded hoisting system is in static balance for all shaft depths.

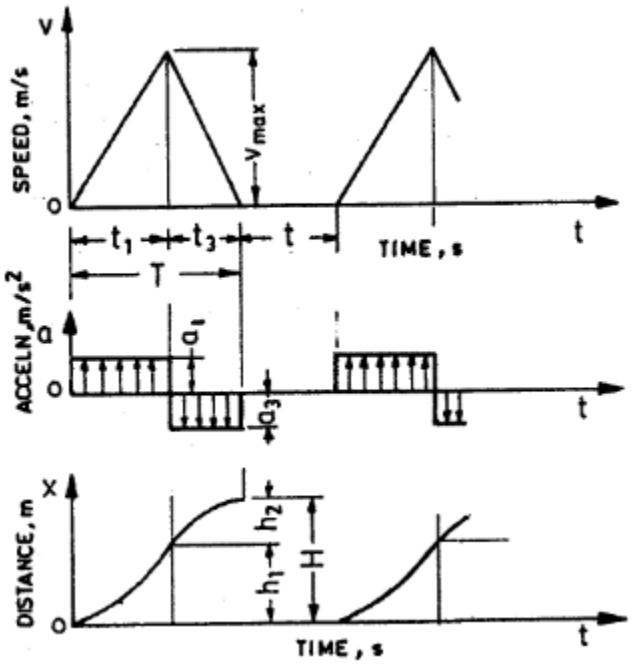
FACTOR OF SAFETY

The factor of safety of a hoist rope is the ratio between the minimum breaking load of the rope and the maximum static safe working load (or static permissible working load). It is in effect a load factor. It may be based on the actual breaking load, rated breaking load, aggregate breaking load, or load bearing capacity of the rope.

HOISTING SPEED TIME DIAGRAM

The motion of cage/skip during a hoisting cycle is governed by the hoisting speed-time diagram chosen. The selection of the most suitable speed-time diagram for economic hoisting depends on the hoisting distance, the type of cage or skip used, and the type of drive selected. Generally speaking, for a payload to be hoisted which should be as large as possible, the maximum hoisting speed and the acceleration should be taken low to keep the r.m.s. power and peak power of the hoist motor down.

2-peroiod speed-time triangular diagram with linear change of speed during the accelerating and decelerating periods but without maximum speed (or full speed) period is shown below.



Two-Period Speed-Time, Acceleration-Time and Distance-Time Diagrams

Let

v_{max} - maximum hoisting speed, m/s;

t_1 = accelerating period, s;

t_3 = decelerating period, s;

T = running time, s;

t - rest time (or idle time), s;

H = hoisting distance, m;

a_1 - acceleration, m/s^2;

a_3 = deceleration, m/s^2.

Accelerating period

$$t_1 = \frac{v_{max}}{a_1}$$

Distance travelled by conveyance

During accelerating period

$$h_1 = \frac{v_{max}}{2}.t_1$$

Decelerating period

$$t_3 = \frac{v_{max}}{a_3}$$

Distance travelled by conveyance

During decelerating period

$$h_3 = \frac{v_{max}}{2}.t_3$$

Running time

$$T = t_1 + t_3 = v_{max}\left(\frac{1}{a_1} + \frac{1}{a_3}\right)$$

Hosting distance (= area of triangular)

$$H = \frac{v_{max}}{2}t_1 + \frac{v_{max}}{2}.t_3 = \frac{v_{max}T}{2}$$

$$v_{max} = 2\frac{H}{T} = 2.v_{avg}$$

where v_{avg} = average speed = H/T

When acceleration is equal to deceleration, the triangle becomes an isosceles triangle, and

$$v_{max} = \sqrt{aH}$$

where $a = a_1 = a_3$

$$T = \frac{2H}{v_{max}} = 2\sqrt{\frac{H}{a}}$$

Now $v_{max} = TC = 2v_{avg}$

It is obvious that greater the value of the maximum speed, less will be the running time of the shaft conveyance and larger the hoist motor power required. Furthermore, as the motor does not work under constant load, such hoists are **used only for very small hoisting distances of 15 to 20 m.**

MULTI-ROPE FRICTION HOISTS

As mine shafts grow deeper in coal- and ore-mining industries and the hoisting distance increases, the mass of the suspended hoisting rope will increase. Since the prescribed factor of safety for the rope is to be maintained, an increase in the mass of the hoisting rope can only take place at the expense of payload. Consequently, the rope diameter will increase affecting the size of hoisting equipment. For a reasonable size of rope diameter and hoisting equipment, the operating or working load must be uniformly divided between two or more smaller but equal diameter ropes. For the same total static rope pull or tension on the heavier side, the diameter of rope of a multi-rope friction hoist, d_n will be $1/\sqrt{n}$ of the diameter, d, of an equivalent single-rope hoist.

$$d_n = \frac{d}{\sqrt{d_n}}$$

The diameter of rope of a 4-rope hoist will, therefore, be half of the diameter of rope of an equivalent single-rope hoist.

The diameters of ropes employed in multi-rope hoists vary between 16 and 65 mm. Payloads up to 60 t can be hoisted from depths of 600 to 1500 m with reasonable rope diameters using multi-rope hoists. Hoisting speeds vary between 4 and 18 m/s.

Multi-rope hoists are now being widely used in all new installations in both coal and metal mines using 2 to a maximum of 10 ropes and the older installations are being converted to multi-rope hoists.

DRUM HOISTS

Drums

The drum must have adequate strength to withstand crushing and distortion due to rope pull and to transmit the torque produced by the drive motor. It must also possess great rigidity to prevent movement between the separate component parts resulting from the periodic reversals

of drum rotation and changes in the magnitude of the rope pull. Its moment of inertia must be as low as possible.

Drums may be of cast iron, cast steel, or completely fabricated steel construction, drums made of cast iron have diameters less than 1.35 m and consist of a barrel or shell, a plane flange, and a flange with a brake path, all cast separately from high quality cast iron and bolted together.

Steel drums, either cast or fabricated, are preferred to cast iron drums and are extensively used due to the extremely good service given by them. In larger sizes (drum diameter greater than 2.3 m), they can be fabricated in halves for ease of transportation and assembly. For light- and medium-duty hoists, cast iron flanges with integral brake paths may be used as it is generally recognized that grey cast iron is probably the best material for brake paths.

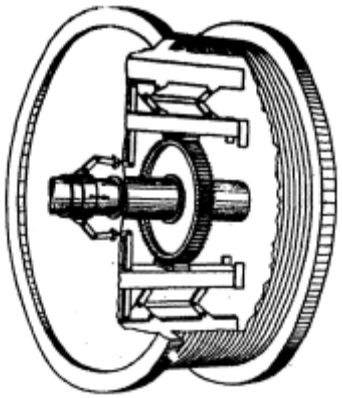
Drum diameters are usually not less than 100x rope diameter or 1200x the largest wire diameter in the rope. Width is governed by the hoisting distance, number of layers permitted, and the fleet angle.

On most of the smaller hoists, less than 2.0 m drum diameter, the drums are plain in order to accommodate various sizes of ropes.

On larger hoists, the drums are provided with rope grooves machined either directly on the drum shell or on replaceable sleeves to facilitate correct coiling of the hoists rope(s).

Clutches

All double-drum hoists are normally designed with either one or two clutched drums. A clutch transfers the motor torque on the drum. On small drum hoists, friction-type clutches or external gear clutches are used but on larger hoists positive internal clutches must be used. The clutch designs commonly used are the internal expanding jaw and sliding gear constructions. The internal expanding jaw clutch, two opposed to toothed jaws are moved radially to engage with a large internally toothed ring gear secured to the drum. A toggle mechanism locks the clutch in the engaged position. Such clutch can also be used as an external clutch on small drums. In the sliding gear clutch, an externally toothed wheel or a clutch spider having toothed arms (2, 3 or 4) sliding on the drum shaft is hydraulically shifted to engage with an internally toothed gear fixed to the drum (see figure).



Sliding gear clutch assembly

In all cases, clutches and brakes are usually interlocked both electrically and mechanically so that a clutch cannot be disengaged unless the brake on the corresponding drum is set.

Today, double-drum hoists can be built without mechanical clutches as the drums can be electrically coupled requiring no mechanical drum clutches.

Main Shafts

The drum shafts are forged from high-grade steel and machined all over and heat treated during manufacture.

Drive Arrangements

A drum hoist may be driven by one or two direct-coupled low-speed electric motor(s) or a geared high-speed electric motor.

Bearings

Both plain bearings with spherically-seated sleeves (sleeve bearings) and anti-friction spherical roller bearings have been successfully used.

Sleeve bearings should be of generous design with an average bearing pressure not exceeding 1750 N/m^2. The sleeves are of split construction to facilitate their inspection and replacement. A high-tin babbit (85% tin, 10% antimony, 5% copper) is recommended. They are lubricated by means of oil rings dipping into an oil reservoir or by a motor-driven pump which is the preferred method. The clutched drums of a double-drum hoist are supported by bronze bushes installed and fixed from inside the drum.

The spherical roller bearings results in smaller overall length and smaller diameter shaft. They adapt themselves to shaft deflection automatically and ensure uniform load distribution over the bearing area.

Generally, the roller-bearings are used for low speeds and sleeve bearings for high speeds.

FRICTION HOISTS

Single-rope friction hoists are available from 1000 to 8000 mm diameter drive sheave size while multi-rope hoists are available from 850 to 6000 mm diameter drum size. All mechanical parts of the hoists are designed for infinite fatigue life.

Friction Sheave/Friction Drum

All friction sheaves/drums are of welded steel plate construction with integral brake paths. The inertia of the sheave/drum is kept as low as possible.

The renewable rope tread comprises circumferential segments of a suitable tread material inserted in hard wood or aluminium blocks grooved to provide path(s) for rope(s). The blocks are clamped or slotted into the sheave/drum periphery.

The tread materials used in practice are: timber (elm, beech, poplar, and oak), bonded chrome and brown leather, rubber, high-density polyurethane, and other proprietary materials.

Two types of friction sheave/friction drum may be used with single- or multi-rope systems; the magazine and the non-magazine types.

Main Shaft

The main shaft should be very rigid construction. Shafts must be designed to resist this unbalanced pull as well as bending and torsional forces. Stiffness is usually the limiting factor.

Drive Arrangements

Like drum hoists, a friction hoist may be either direct coupled or geared to the driving motor(s).

The design of the drive arrangement has an important bearing on the layout and support of the hoist. The simplest arrangement from the support point of view is the drive coupled to a single motor or twin motors with overhung armature. Such a hoist would occupy less room and reduce the cost of the tower when it is tower-mounted.

Reduction Gears

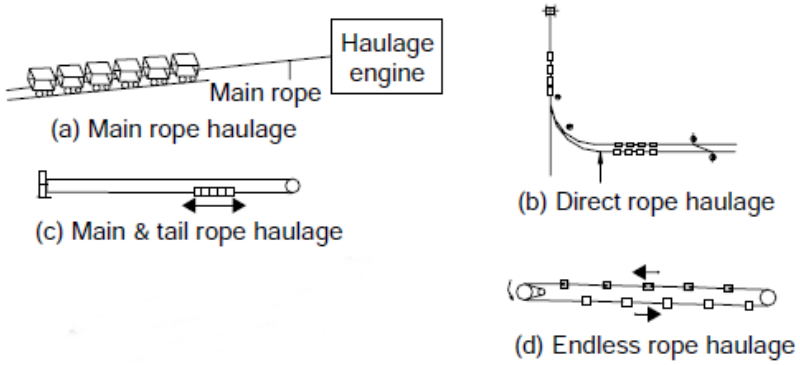
In geared drive arrangement, single-, double-, or triple-reduction gears are used. Double-reduction gears can be supplied up to a ratio of 25:1 and triple-reduction gears to over 100:1.

ROPE HAULAGE SYSTEMS

This system is simple in construction and maintenance. It can suit any gradient and curvature of roadways. Even gravity can assist it to the extent that in hilly terrain it could be installed. This type of arrangement, when installed in an incline, it is known as self-acting-incline.

Main drawbacks of rope haulage are large amount of manual work required at the terminals; absence of complete mechanization and automation of all operations, less reliability and complicated work involved in negotiating branches and junctions. This makes the system inadequate for modern mines and tunnels. This system could be used for low capacity mines having low degree of mechanization. It finds its application as a auxiliary haulage for material transport in some mines. However, on steep gradients, where belt conveyors cannot be deployed, its use is almost mandatory; and it is used in conjunction with cage and skip hoisting operations in shafts and inclines.

Direct (fig. a, b), main and tail (fig. c) and endless (fig. d) are the principal designs of the rope haulage that are used.



Direct Rope Haulage

Single Drums Direct Rope Haulage

This is simplest system of rope haulage. It consists of one track, one rope & one drum which are connected to a motor through gears. One end of the rope is connected with the train of tubs on the track & another end of the rope is connected to the drum. When the drum rotates situated at the top of the incline, the loaded tubs moves upwards. But for the downward journey of the empty tubs it does not require any power because a tub moves downward due to their own weight. The system can be on inclines steeper than 1 in 12 & the speed of the haulage is 8 – 12 kmph.

Double Drum Direct Rope Haulage

It consists of two drums, two ropes & two tracks but only one driving motor. One end of each rope is connected with two drums & another end of rope is connected with the set of tubs. In such a way that when one set of tub is at incline top, the other set is at incline bottom. The two drums are connected with each other. When drum rotates, the rope coils on one drum & uncoils from another drum. It can be used if inclination is more than 1 in 12. The speed of the system is 8 to 12 kmph.

Main & Tail Rope Haulage

In this system the haulage engine provided with two separate drums, one for main rope which hauls the loaded tubs up the gradient & one for tail rope which hauls the empty tubs down the gradient. When one drum is in gear, the other drum revolves freely but controlled. The main rope is approximately equal to the length of the incline & tail rope is twice this length. The system can be used if the gradient is unsuitable for the use of direct rope haulage. Its speed is 15 – 18 kmph.

Endless Rope Haulage

This system consists of double track, one driving pulley & one return pulley. An endless rope passes from the driving pulley which is situated at the inby end & back again to the driving pulley. One track is used for loaded tubs & another track is used for empty tubs. Rope moves in one direction only with the speed of 3-7 kmph. Only one train of tubs is attached to the rope at a time but some times a set of tubs can be attached to the rope. The system is used where the gradient is less, generally less than 1:12 or where the ground is undulating. A squirrel cage motor is commonly employed.

Under Rope Endless Rope Haulage

If the rope passes below the tubs, it is known as under rope endless rope haulage. In this system there is more wear & tear to this rope but also there is an advantage that there is more direct pull on the tubs.

Over Rope Endless Rope Haulage

If the rope passes over the tubs, it is known as over rope endless rope haulage. In this system rope is unaffected by wet floor & liable to wear & tear. The rope is at better working height & a system is generally used for undulating roadways.

Gravity Rope Haulage

This is haulage without motor or any external source of power. It is used when load is to be transported from up hill to down the gradient. It consists of brake path on one side & is way pulley. It is located at the top of the incline roadway. The one end of the single rope is attached to the loaded tub & the other end is attached to the empty tubs while passing over the jib pulley. When the loaded tubs moves down the gradient at sometimes empty tubs moves up the gradient. The brake strap is provided with brake path & is connected to a lever. When the lever is depressed the braking effect on the jib pulley is produced.

Rope Haulage Calculations

Drawbar pull The pull or force required to overcome the resistance to motion is known as Drawbar Pull. The resistance to motion is equivalent to the frictional resistance (+/-) the gradient resistance.

Frictional Resistance

$F = \mu W$, on a horizontal plane

$= \mu W \cos\theta$ on an inclined plane having inclination θ with horizontal.

But for all practical purposes, highest value $F = \mu W$ is considered.

Gradient Resistance

Gradient resistance $= W\sin\theta$, but for all practical purposes $\sin\theta = \tan\theta$

$\therefore$ Gradient resistance $= W\tan\theta = Wi$ where $i = 1/n$, n is gradient value.

Tractive effort

Tractive effort = Drawbar pull $= \mu W + Wi$

Direct rope haulage system

Tractive Effort = Drawbar Pull = Pull required to draw loaded mine cars + Pull required to draw rope

$= (F + G) + (f_1 + g_1) = (\mu W + Wi) + (\mu_1 w_1 + w_1 i)$

where F – Frictional resistance of loaded cars;

G – Gradient resistance of loaded cars;

f – frictional resistance of empty cars;

g – gradient resistance of empty cars;

W – weight of loaded cars;

w – weight of empty cars;

w_1 – weight of rope;

i –gradient of road;

μ– coefficient of friction between mine car's wheel and track;

μ_1 – coefficient of friction between rope and rollers;

g_1 – gradient resistance of rope;

f_1 – frictional resistance of rope.

Endless rope haulage system

Tractive Effort = Drawbar Pull = Pull required to draw loaded mine cars + Pull required to draw empty cars + pull required to draw rope

$= (F + G) + (f - g) + [(f_1 + g_1) + (f_1 - g_1)]$

$= F + f + 2f_1 + G - g = (\mu W + \mu w + 2\mu_1 w_1 + Wi - wi)$

IHP = (Tractive effort in kg x Haulage speed in m/sec)/75

BHP = IHP/η

where IHP = Indicated horse power

BHP = IHP/η

η = overall efficiency

Example

135 ton of coal is to be hauled by direct rope haulage in a shift of 6 hours hauling time where the length of haul is 1100 m. The average speed of rope is 6 km/hr. Set changing time is 1 min and tub capacity is 1.5 ton. Calculate the number of tubs per set?

Solution

Explanation: In one cycle tub will cover=1100+1100 - 2200 m = 2.2 km

Time taken in one cycle - 2.2/6 = 0.37 hr = 22 min

Total time taken in one cycle including set changing time = 22 + 1 + 1 = 24 min

In 6 hours i.e. 6 x 60 min number of cycles = 360/24 = 15

Let there be N number of tubes

So15 x N x 1.5=135

∴ N = 6 tubs

Example

For a direct rope haulage installation in a mine drift if the total rope tension is 115 kN, the moment of inertia of the 3 m diameter drum is 9000 kg/m^2, and the speed of. the rope is 12 m/s, the total torque of the drum in kNm is ____.

Solution

Torque = F x R

= 115 x (3/2) = 172.5 kNm

Example

The r.m.s torque of a 3.8 m diameter winder is 109 kNm. If the rope speed is 7.6 m/s, motor power required to run the winder is ____

Solution

R = 3.8/2 = 1.9 m

T = 109 kNm

v = 7.6 m/s

P = ?

T = FR

109 = F x 1.9

∴ F = 57.37 kN

Now, P = Fv

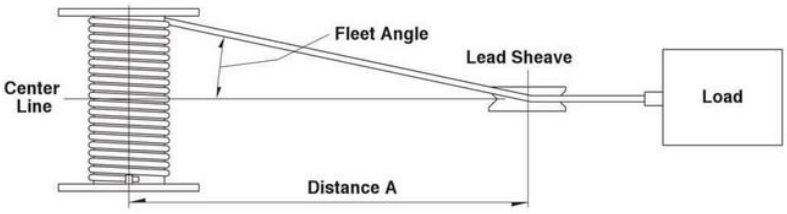
∴ P = 57.37 x 7.6 = 436 kW

Example

The centre lines of winding drum and winding pulley are parallel and 0.6 m apart. When one cage is at pit bottom, its winding rope is positioned at 1.8 m from the drum centre. The plan distance between the winding drum and the winding pulley axes is 60 m. The fleet angle of installation is ____

Solution

See figure.



Distance of wire rope from drum centre = 1.8 - 0.6 = 1.2 m

Distance A = 60 m

Fleet angle $\theta = \tan^{-1}(1.2/60) = 1.15^0$

ROPES

Steel wire ropes used in mining and general engineering industries consist of many individual wires laid into a number of strands which are in turn laid around a center core (Fig. 2.1). They

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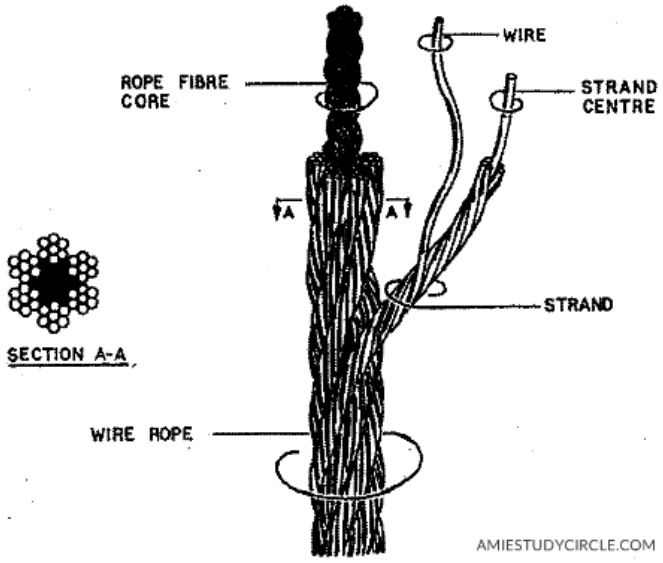
may be broadly grouped under the two heads: round ropes and flat ropes. In mine shafts they are used as main or head ropes and balance or tail ropes.



MAIN HOIST ROPES

Whereas round ropes are used with drum and friction hoists in mine shafts, flat ropes are used exclusively with reel hoists.

Round ropes may be further divided into: *stranded ropes and non-stranded locked- coil ropes*.

Round-stranded hoisting ropes are manufactured in size from 19 to 80 mm using wire sizes ranging from 1.4 to 3.0 mm. Ropes larger than 80 mm can be manufactured without any serious difficulties but problem arise in their transport, installation, examination, rope changing and shortening, and making rope attachment. Furthermore, they are subjected to greater wear due to large twist and larger diameter of driving drum/friction sheave and pulleys will be required resulting in larger size of the hoist. When the calculated diameter of rope of a single-rope hoist exceeds 50 mm, multi-rope friction hoists may be considered.

Full-locked coil ropes are manufactured up to a maximum diameter of 65 mm.

Flat ropes for reel winders are usually made of six parallel alternating right- and left- lay ropes sewn together by ‘single stitching’ utilizing a number of wires, or ‘ordinary stitching’ utilizing a strand instead of single wires.

STRANDED ROUND ROPES

There are five basic elements of rope design each of which influences the characteristics of the stranded ropes. The design objective is to provide a rope with characteristics balanced to withstand the demands of a particular service.

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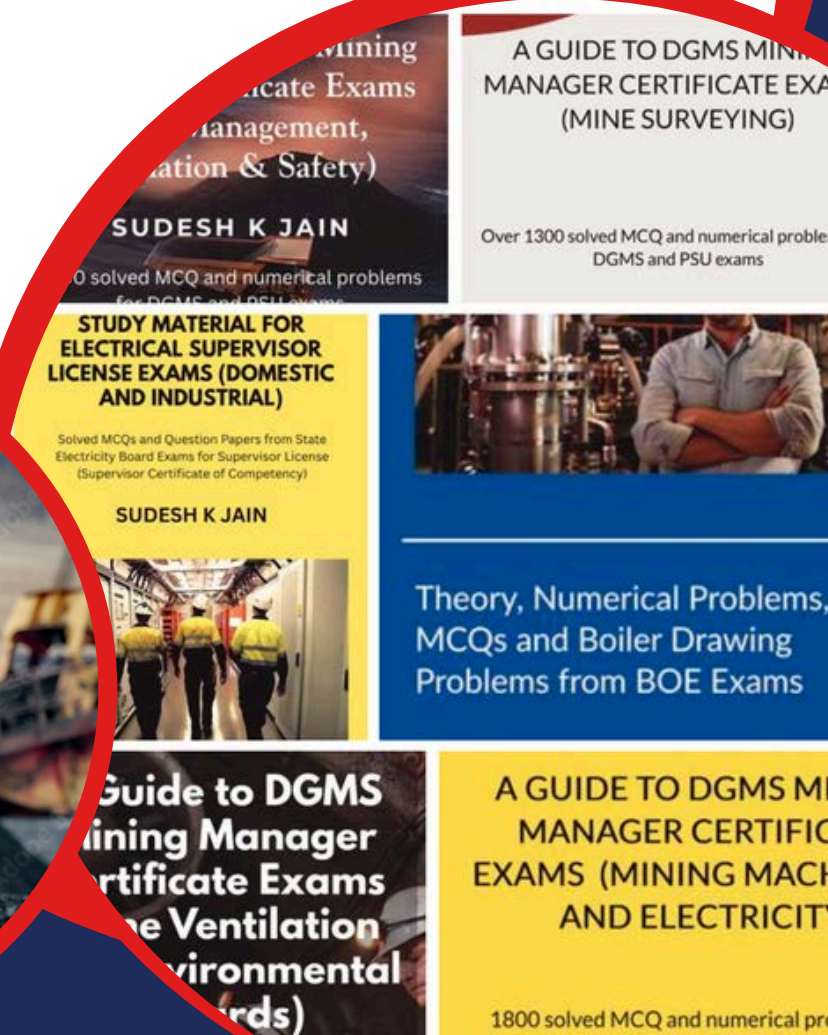


These are:

- Grade of wire and wire finish;
- Rope construction (number of strands per rope strand constructions);
- Type of lay;
- Performing; and
- Type of core.

Stranded wire ropes are characterized by their strand shape (see figure) as follows:

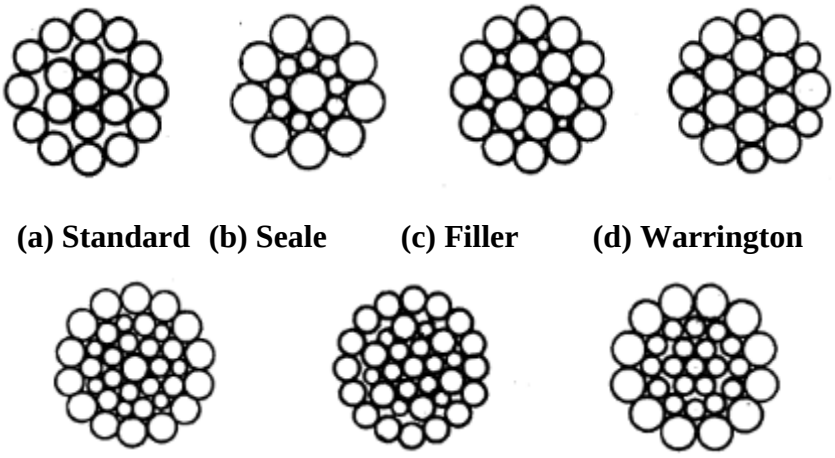
- Round-strand ropes;
- Triangular (Flattened)-strand ropes; and
- Oval (Flat)-strand ropes.



Round **Triangular** **Oval**

To obtain ropes possessing varying degrees of resistance to bending fatigue and abrasion, the ordinary strand construction is modified by using wires of varying sizes and number and arranging them in certain geometric patterns called ’constructions’.

There are three basic types of parallel-laid construction; Seale, Warrington, and Filler Wire. Combination of rope classification and strand constructions are used to build large-diameter ropes with varying degrees of resistance to bending fatigue and abrasion and flexibility characteristics (see figure).



(a) Standard **(b) Seale** **(c) Filler** **(d) Warrington**

(e) Warrington-Seale

(f) Warrington covered Compound – Laid

(g) Seale compound laid

Type of Lay

The term '**lay'** signifies the *direction of rotation of wires* in the strands and of the strands in the rope about their respective cores. Rotation may be either to the right, clockwise (Right Lay) or to the left, counter-clockwise (Left Lay). Right lay is the standard. The lay of the rope affects its flexibility and resistance to wear.

Strands may be laid in a hoist rope in two ways: **Regular Lay and Lang Lay**. In the Regular Lay rope, the wires in the strands have a lay opposite to that of the strands in the rope.

The outer wires run approximately parallel to the longitudinal axis of the rope and are bent on a relatively short are at the wearing surface.

In the Lang Lay rope , the wires in the strands and the strands in the rope have the same direction of lay. The outer wires run diagonally to the longitudinal axis of the rope and are on a longer arc so that greater lengths of individual wires are exposed to wear. The Lang Lay ropes must be secured at both ends to prevent untwisting.

Regular Lay ropes offer greater resistance to distortion and crushing on drums than Lang Lay ropes which, however, possess greater resistance to abrasion and bending fatigue and are more flexible.

Types of Core

The wire rope core forms the *heart* of the rope. It provides a support to the main rope strands laid around it in their relative positions throughout the rope life.

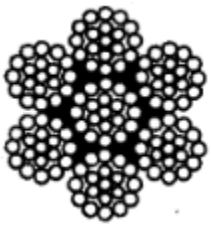
There are two main types of cores: **fibre core and wire cores**.

A natural fibre core is the standard core for most hoist rope constructions. It gives adequate support to the strands and makes the rope resilient. The core must be free from water-soluble acids and be treated with water- and rust-repelling solutions before it is impregnated with a compatible lubricant. They may also be manufactured from man-made fibres such as polypropylene or nylon. Fibre-core ropes should not be used when multi-layer coiling is used since they are susceptible to crushing.

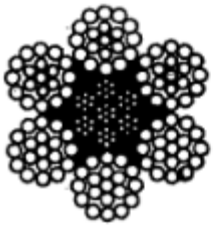
Following figure shows the different types of wire rope cores.



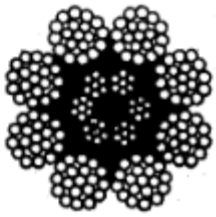
(a) Fibre core



(b) Wire string core



(c) Independent wire rope core



(d) Independent wire rope core with fibre wrapped strands

The symbolic cores such as nylon and polypropylene thermoplastics have uniform quality, repel water, are resistant to many acids and rotting, and are less susceptible to compacting.

COMPARISON OF ROPE HAULAGE SYSTEM

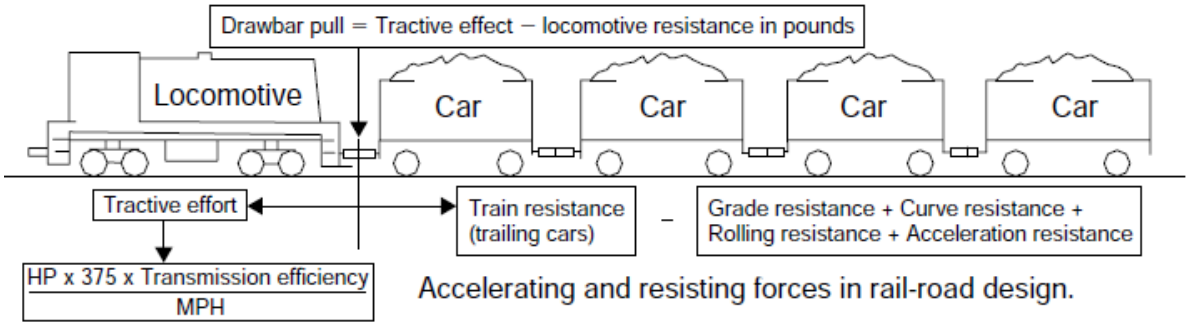
Parameters	Direct	Endless Rope Haulage	Main & Tail
System	Loaded tubs are hauled up the gradient using power, whereas empty tubs are hauled down the gradient using gravity. Bad track may cause derailment.	System consists of an endless rope running or two tracks. On one side of rope loaded mine cars and on the other empty cars run. Rope moves with a speed of 0.4 to 1 m/sec in one direction only. Rope tensioning devices required.	System consists of double drums for two ropes (which may be of different dia.); one is attached at the leading end of a train of cars and the other at its tail end. The tram runs on a single track and loaded cars are hauled up the gradient.
Haulage road required	Uniformly graded (not below 5-6°), straight single tracked road.	Straight roads laid with double track. Gradient below 1 in 10.	Roads may be undulating single tracked.

Applications, output & mode	For low output in u/g mines usually at the development districts. Batch system.	Low but continuous output, installed at the main haulage levels in u/g mines.	Low output from the main haulage roads those are undulating and rough in u/g mines.

LOCOMOTIVE HAULAGE

In case of rope haulage the power to move the load is available from external fixed motor to the haulage. While in case of locomotive haulage the driving unit i.e. locomotive is coupled to a train due to which more safety can be attained. The locomotives are very flexible in nature & they can be used for men transport also.

The rail transport finds its application as gathering and main haulage in the underground mines and tunnels. The rope haulage system works on track and so is the locomotive haulage. The locomotive haulage (see figure) is best suited as a long distance haulage with a gradient in the range of 1 in 200 to 300.



Locomotive haulage

However, gradient up to 1 in 30 for a short distance can also be negotiated by this system. The system is flexible comparing to rope and belt conveyor systems.

Calculations

Tractive effort

It is the total force delivered by the motive power of locomotive, through the gearing, at wheel treads. When this force is greater than the product of locomotive weight and the coefficient of adhesion between the wheels and rails, the wheels will slip i.e. it will roll. This can be numerically expressed as:

Total or maximum tractive effort

$$T_E = W_L C$$

Whereas: C is the coefficient of adhesion whose value depends upon the condition of track, and whether it is sanded or not.

Drawbar pull

This is the force exerted on the coupled load by a locomotive through its drawbar, or coupling, and is the sum of the tractive resistance of the coupled load. The drawbar pull that a locomotive is capable of developing is determined by subtracting the tractive effort, from the sum of the tractive resistance of the locomotive. This resistance is offered by the several sources: rolling resistance, which the entire train offers is equal to weight of train in tons. (i.e. weight of locomotive + weight of mine cars with pay load) multiplied by a frictional coefficient μ which could be 10-15 kg/ton.; Curve resistance which can be ignored gradient resistance and the force required to provide acceleration to the motion (as given in the formulae specified below).

Drawbar pull

$$= R_0 W_T$$

Running resistance/t

$$R_0 = \mu +/- \{(1/n) \times 1000)\} +/- (a/g)$$

Total tractive effort

$$T_E = R_0 (W_L + W_T)$$

Also, total tractive effort

$$T_E = T_0 W_L$$

Equating these two equations

$$T_0 W_L = R_0 (W_L + W_T)$$

$\therefore$ Drawbar pull

$$R_0 W_T = T_0 W_L - R_0 W_L$$

$$= W_L (T_0 - R_0)$$

or trailing load (or weight of train which can be hauled)

$$W_T = \{W_L (T_0 - R_0)/(R_0)\}$$

BHP will be

$$= (\text{tractive effort in kg} \times \text{speed of locomotive in m/sec})/(75 \times \eta)$$

$$= (T_E \times v)/(75 \times \eta)$$

Whereas:

T_0 - Tractive effort/t in kg.

T_e - Total tractive effort in kg.

R_0 - Running resistance/t in kg.

W_L - Weight of locomotive in tons.

W_T - Weight of trailing load i.e. weight of train in tons. T

η - Efficiency of the system

μ - Frictional resistance/ton in kg.

n - Denominator value of gradient i.e. 1/n. use sign + for up; - for down gradient.

a - acceleration of train in m/sec^2; Use (+) for acceleration and (-) for retardation

g - acceleration due to gravity in m/sec^2 = 9.81

v - Locomotive speed in m/sec.

Example

An 8 t locomotive has a coefficient of adhesion 0.18 and a coefficient of rolling resistance 100 N/te mass. The maximum tractive force available to haul the trailing load in kN along a straight track is ____

Solution

W = mg = (8 x 1000) x 9.8 N = 78400 N

Total roller resistance = 8 x 0.18 = 800 N

Draw bar pull (DBP) = Tractive effort - pull required to move the loco

= μW - pull = 0.18 x 78400 - 800

= 13312 N = 13.3 kN

Example

A 10,000 kg locomotive runs at a speed of 3 m/s along a level track. The coefficient of adhesion at the track is 0.23, and the rolling resistance of the locomotive is 90 N per 1000 kg. The maximum power available for hauling the train in kW is ____

Solution

W = mg = 10,000 x 9.8 = 98000 N

V = 3 m/s

μ = 0.23

Rolling resistance = 90 N/1000 kg

Hence, Rolling resistance for 10,000 kg locomotive = 90 x 10 = 900 N

Tractive effort (TE) = μW

= 0.23 x 98000 = 22540 N

Drawbar pull (DBP) = TE - pull (or rolling resistance)

= 22540 - 900 = 21640 N

Now, Power = DBP x V

= 21640 x 3 = 64920 W

≈ 65 kW

SLURRY TRANSPORTATION SYSTEM

Stages in a slurry transportation

A slurry transportation system usually comprises five separate stages:

- Material preparation;
- Slurry preparation and storage;
- Slurry transportation;
- Storage and dewatering of slurry at the pipeline terminal; and
- Processing for utilization.

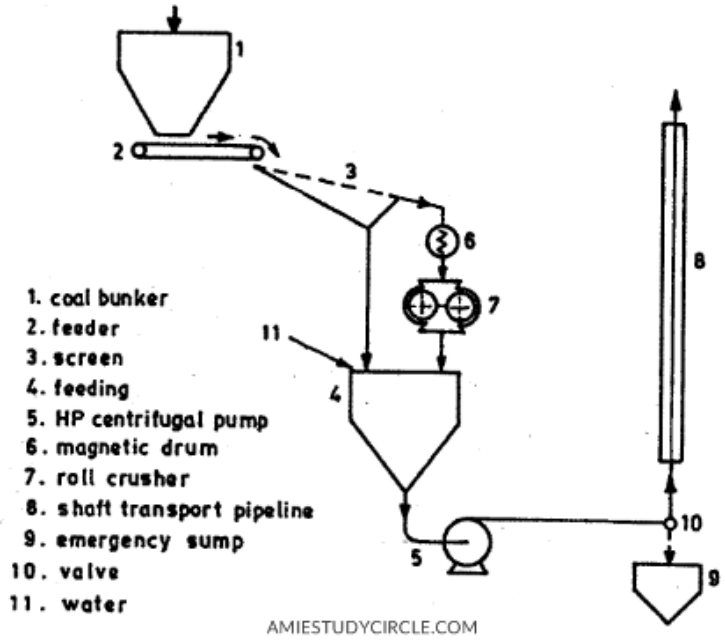
Hydraulic Hoisting Methods

These are following

- Airlift method
- pumping method
- feeder method
- combined hydraulic and mechanical hoisting method

PUMPING METHOD

Hydraulic hoisting by direct pumping using high-pressure centrifugal pumps is limited to a head of 200 m by operating two pumps in series and horizontal distances up to 2 km. High-pressure centrifugal pumps can handle solid particles of maximum size up to 150 mm compared to -2 mm with positive displacement pumps. The hoisting plant (hydro hoist) may consist of a bunker, a screening and crushing plant, and a pumping plant (see figure).



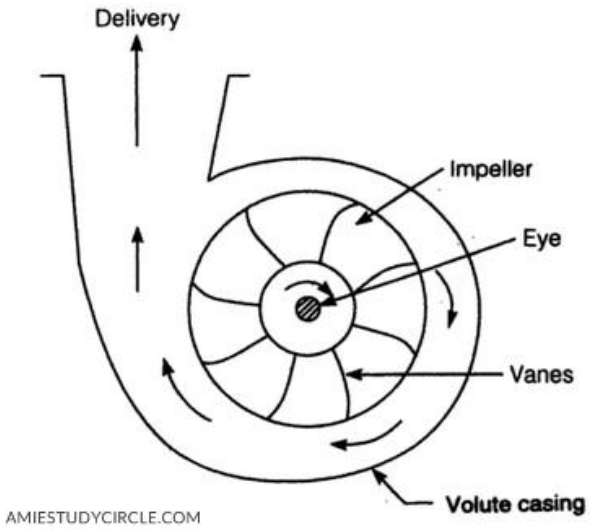
The solid-water ratios lie between 1:2 and 1:5 with slurry velocities of 2-4 m/s depending on the type of material and size of particles used. Coal slurry pumps usually have a capacity of 900 m^3/h for coals up to 100 mm size.

CENTRIFUGAL (ROTODYNAMIC) PUMP

These are specially designed for transportation of homogeneous, heterogeneous, and complex slurries. They, the "work horse" of in-plant commercial slurry transportation systems, serve as booster pumps for providing suction pressure required for mainline positive displacement pumps. They are designed for large flow rates at moderately high pressures and their application is generally restricted to short distances because of their limited head capacity, lower allowable casing pressure, and lower efficiencies. They are selected for discharge pressure under 45 bar, which is the limit set by the casing pressure capacity. Solids may be handled with a size up to one-half the smallest impeller channel width.

The efficiency of centrifugal slurry pumps is low because of the presence of solids, robust nature of the impeller design, and the relatively wide throat impeller clearance. Efficiencies of 65 per cent are common, compared to 85-90 per cent with positive displacement pumps. Power consumption increases proportionally with the specific gravity of the slurry.

The main components of centrifugal pumps are (1) the impeller, (2) the casing and (3) the drive shaft with gland and packing.



The liquid enters the eye of the impeller axially due to the suction created by the impeller motion. The impeller blades guide the fluid and impart momentum to the fluid, which increases the total head (or pressure) of the fluid, causing the fluid to flow out. The fluid comes out at a high velocity which is not directly usable. The casing can be of simple volute type or a diffuser can be used as desired. The volute is a spiral casing of gradually increasing cross section. A part of the kinetic energy in the fluid is converted to pressure in the casing.

Rotodynamic pumps, also known as centrifugal pumps, can be broadly classified into three categories, namely radial, axial and mixed.

PNEUMATIC HOISTING SYSTEMS

Pneumatic conveying of materials has been practiced successfully for many years in various engineering industries throughout the world. Pneumatic conveying sometimes solves problems which could not be solved by any mechanical systems. Its flexibility, relative low capital cost, increasing labour costs, environmental factors, and other reasons have tended to rapidly increase its application in mining and construct inn industries.

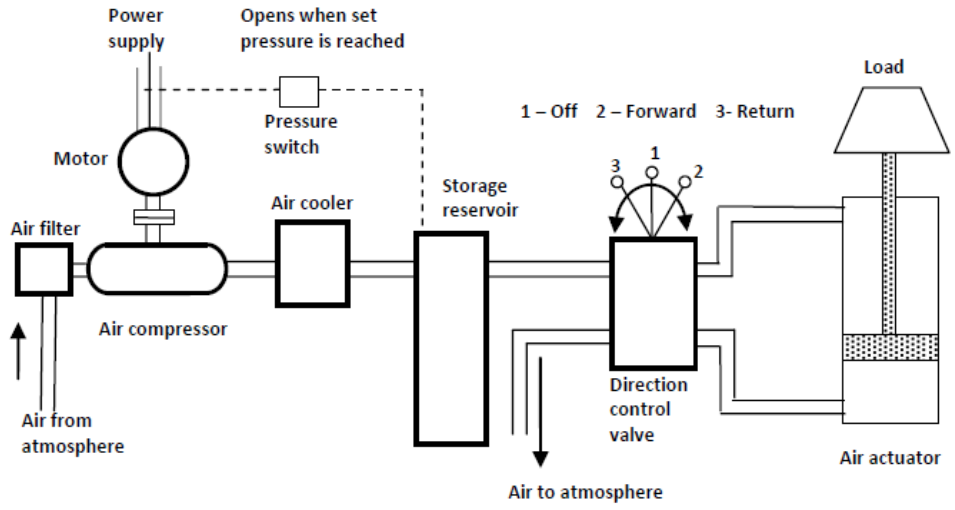
Pneumatic transportation of relatively large particles of abrasive materials in pipelines has been used for many years in the mining industry in different pm In of the world. Its main application has been in the back-filling of mined-out areas, muck removal from boring machines, building compact gateside packs for immediate disposal of waste rock from rippings and dintings, muck disposal from tunnelling machines, and hoisting minerals to surface.

The **main problem** with pneumatic transportation is that different materials behave totally different from one another, being considerably influenced by the type of the material being conveyed, operational velocity range, phase density, and conveying distance.

Phase density is the ratio of the mass flow rate of the material being conveyed to the mass flow rate of the air used. The terms dilute or lean, medium, and dense phase are often used in pneumatic conveying. A flow is usually considered to be in dilute or lean phase if the phase density is below about 8, in dense phase if the phase density i s above 40, and in medium phase if the phase density lies between the two limits.

Basic Components of a Pneumatic System

A pneumatic system carries power by employing compressed gas, generally air, as a fluid for transmitting energy from an energy-generating source to an energy-using point to accomplish useful work. Following figure shows a simple circuit of a pneumatic system with basic components.



Components of a pneumatic system

The functions of various components are as follows:

- The pneumatic actuator converts the fluid power into mechanical power to perform useful work.
- The compressor is used to compress the fresh air drawn from the atmosphere.
- The storage reservoir is used to store a given volume of compressed air.
- The valves are used to control the direction, flow rate and pressure of compressed air.
- External power supply (motor) is used to drive the compressor.
- The piping system carries the pressurized air from one location to another.

Air is drawn from the atmosphere through an air filter and raised to required pressure by an air compressor. As the pressure rises, the temperature also rises; hence, an air cooler is provided to cool the air with some preliminary treatment to remove the moisture. The treated pressurized air then needs to get stored to maintain the pressure. With the storage reservoir, a pressure

switch is fitted to start and stop the electric motor when pressure falls and reaches the required level, respectively.

COMPARISON BETWEEN HYDRAULIC AND PNEUMATIC SYSTEMS

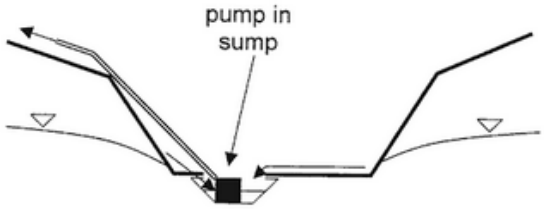
Usually hydraulic and pneumatic systems and equipment do not compete. They are so dissimilar that there are few problems in selecting any of them that cannot be readily resolved. Certainly, availability is one of the important factors of selection but this may be outweighed by other factors. In numerous instances, for example, air is preferred to meet certain unalterable conditions, that is, in "hot spots" where there is an open furnace or other potential ignition hazard or in operations where motion is required at extremely high speeds. It is often found more efficient to use a combined circuit in which oil is used in one part and air in another on the same machine or process. Table 1.2 shows a brief comparison of hydraulic and pneumatic systems.

Hydraulic System	Pneumatic System
It employs a pressurized liquid as a fluid	It employs a compressed gas, usually air, as a fluid
An oil hydraulic system operates at pressures up to 700 bar	A pneumatic system usually operates at 5–10 bar
Generally designed as closed system	Usually designed as open system
The system slows down when leakage occurs	Leakage does not affect the system much
Valve operations are difficult	Valve operations are easy
Heavier in weight	Lighter in weight
Pumps are used to provide pressurized liquids	Compressors are used to provide compressed gases
The system is unsafe to fire hazards	The system is free from fire hazards
Automatic lubrication is provided	Special arrangements for lubrication are needed

SUMP PUMP AND SUMP DEWATERING

Virtually all deep and surface mines which work below the water table will require some form of dewatering.

Sump dewatering involves the creation of basins in the floors of workings, to which all water is diverted, and from which it is all pumped out of the mine (see figure).

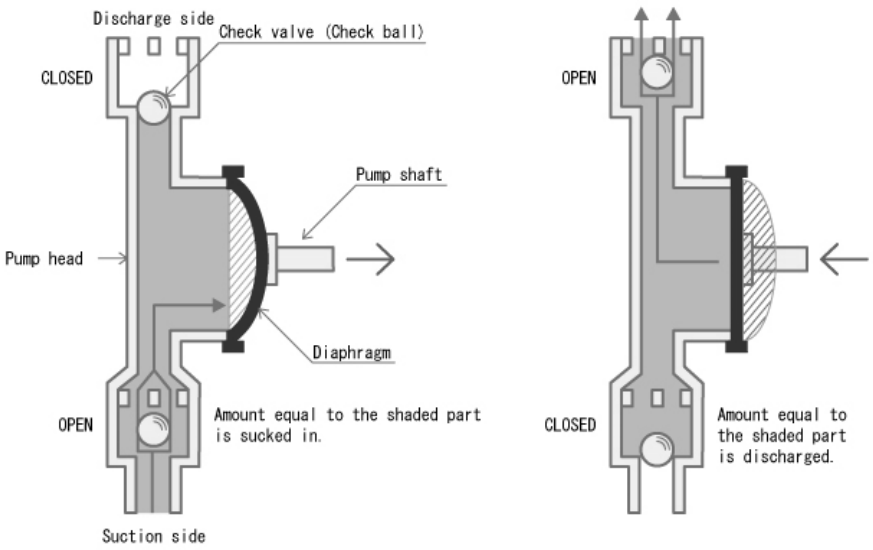


Sump dewatering is the most widespread dewatering method in both surface and deep mines world-wide Indeed, even where other dewatering methods are employed to handle the bulk of the water make, there will nearly always be some need to support these with some localised sump dewatering.

The plant employed includes a diaphragm or a self priming centrifugal pump, a suction line and a discharge line. The pipes may be rigid or flexible, the suction line being equipped with a strainer at the intake end to prevent clogging.

Diaphragm sump pump

Diaphragm pumps are known as *positive displacement pumps* as the diaphragm plays the role of the limited displacement piston. When the diaphragm is forced into reciprocating motion using the mechanical linkage, compressed air or any fluid from the external source the pumps starts functioning. There is no contact between the liquid that is pumped and the source of energy so the possibility of leakage is not there. As no leakage is possible such pumps are very useful in handling toxic or any other expensive liquid. There are certain cons of using these pumps. These pumps have limited head and capacity range. The check valves are necessary In the suction and discharge nozzles of these pumps.



Diaphragm sump pump

When the volume of a chamber of either type of pump is increased (the diaphragm moving up), the pressure decreases, and fluid is drawn into the chamber. When the chamber pressure later increases from decreased volume (the diaphragm moving down), the fluid previously drawn in is forced out. Finally, the diaphragm moving up once again draws fluid into the chamber, completing the cycle. This action is similar to that of the cylinder in an internal combustion engine. Diaphragm Pumps deliver a hermetic seal between the drive mechanism and the compression chamber, allowing the pump to transfer, compress, and evacuate the medium without a lubricant.

Example

The approximate head generated by a single-stage centrifugal pump of 250 mm diameter impeller running at 1440 rev/min with manometric efficiency of 0.7 is ____

Solution:

$v = \pi DN/60$

$= 3.14 \times 0.25 \times 1440/60$

$= 18.84$ m/s

$H = v^2/2g = 18.84^2/2 \times 9.8$

$= 18.11$ m

Now Manometric head (the head to which pump has to work)

$= H/\eta = 18.11/0.7 = 25.87$ m

Example

If a pump develops 10 bars of pressure and has a flow rate of 1500 l/min, what will be the pump motor power at 90 % efficiency?

Solution

Pressure = 10 bars

$= 10 \times 10^5$ Pa $= 10^6$ Pa

$= 10^6$ N/m^2

$Q = 1500$ l/min $= 1500 \times 10^{-3}$ m^3/60 s

Now $Q = AV = (\text{Force/Pressure}) \times V$

= Power/Pressure

$\therefore$ Power = Q x Pressure

$= (1500 \times 10^{-3}/60) \times 10^6$ W

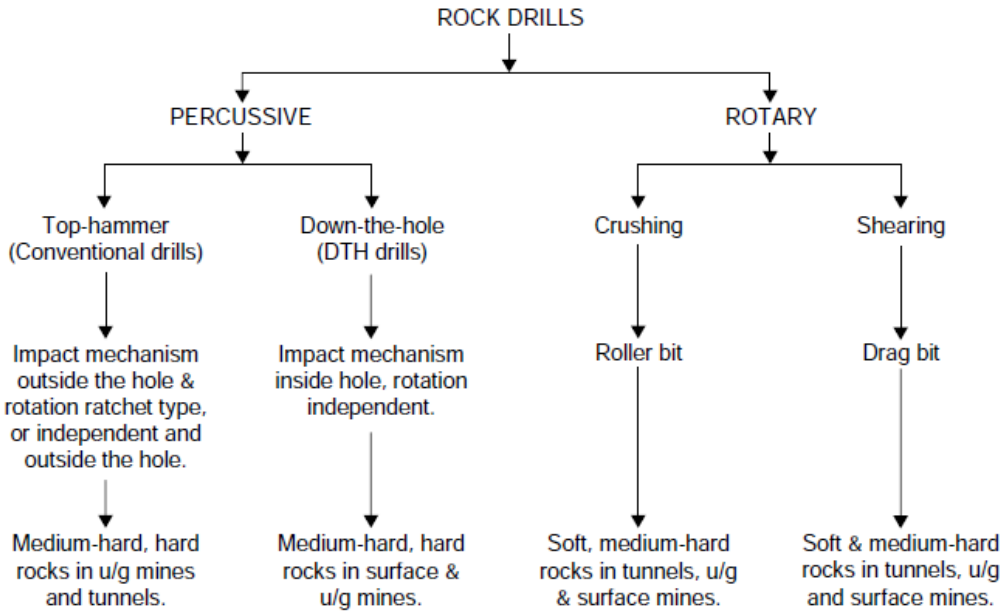
= 25000 W = 25 kW

Power needed at 90% efficiency

= 25/0.9 = 27.7 kW

DRILLING

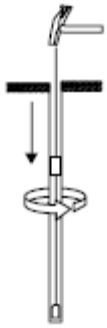
Using the drills the rock is attacked mechanically, either by percussive or rotary actions. Combinations (roller bit, rotary-percussion) of these two methods are also used. The resulting action of the bit in each case is almost similar i.e. crushing and chipping; what differs mainly is that the crushing action predominates in percussion drilling and chipping action in the rotary drilling, and a hybrid action in the combination of the two systems. Based on this logic the drills are manufactured as percussive, rotary-percussive and rotary. Classification based on this logic is presented in following figure.



Percussive Drills

Top Hammer Drilling

In this system the top-hammer's piston hits the shank adapter and creates a shock wave, which is transmitted through the drill string to the bit (see figure).

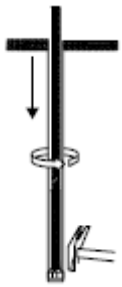


Top hammer drilling

The energy is discharged against the bottom of the hole and the surface of the rock is crushed into drill cuttings. These cuttings are in turn transported up the hole by means of flushing air that is supplied through the flushing hole in the drill string. As the drill is rotated the whole bottom area is worked upon. The rock drill and drill string are arranged on feeding device. The feed force keeps the drill constantly in contact with the rock surface in order to utilize the impact power to the maximum. In good drilling conditions use of these drills, is an obvious choice due to low energy consumption and investments on drill-strings.

Down the Hole (DTH) Drilling

In this system the down-the-hole hammer and its impact mechanism operate down the hole. The piston strikes directly on the bit, and no energy is lost through joints in the drill string (see following figure).



DTH Drilling

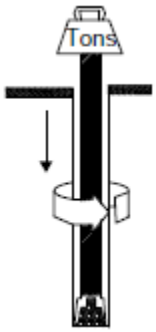
The drill tubes (rods, steels) convey compressed air to the impact mechanism and transmit rotation torque and feed force. The exhaust air blows the holes and cleans it and carries the cuttings up the hole. The drills, which are known by the various trade names such as ‘down-the-hole drill’, ‘in-the-hole-drill’ have been, referred here as DTH drills.

DTH drills differ from the conventional drills by virtue of placement of the drill in the drill string. The DTH drill follows immediately behind the bit into the hole, rather than remaining on the feed as with the ordinary drifters and jackhammers. Thus, no energy is dissipated through the steel or couplings, and the penetration rate is nearly constant, regardless the depth

of the hole. Since the drill must operate on compressed air and tolerates only small amounts of water, cuttings are flushed either by air with water-mist injection, or by standard mine air with a dust collector. This is very simple method for the operators for deep and straight hole drilling.

Rotary Drilling

Rotary crushing is a drilling method, which was originally used for drilling oil wells, but it is now days also employed for the blast hole drilling in large open pits and hard species of rocks. It is used for a rock having the compressive strength upto 5000 bar. In rotary drilling energy is transmitted via drill rod, which rotates at the same time as the drill bit is forced down by high feed force (see figure).



Rotary drilling

All rotary drilling requires high feed pressure and slow rotation. The relationship between these two parameters varies with the type of rock. In soft formations low pressure and higher rotation rate and vice versa, are the logics usually followed.

The rotary drills can be operated using either compressed air or electrical power.

When drilling is done by rotary crushing method, the energy is transmitted to the drill via a pipe which is rotated, and presses the bit against the rock.

Electric Drills

These are used for the rotary drilling of the shot holes. These can be hand and column mounted. Handhold drills are suitable for drilling in soft rocks having weight: 15 - 25 kg; motor rating 1–1.5 kW; and rotation speed 300–900 rpm. Column mounted drills can be used for the blast-hole drilling and for the core drilling, e.g. diamond drills for exploration and prospecting purposes.

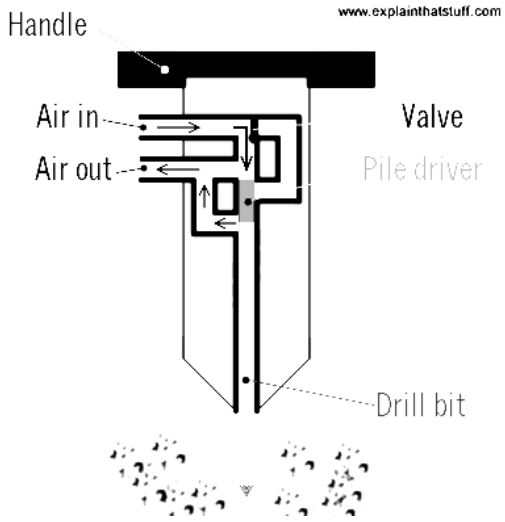
Pneumatic Drills

These are the most commonly used drills in metal and non-metal mines, and tunnels. These are low cost, simple in design and suitable for rough handling and use. These drills suffer from the disadvantage of its low efficiency in terms of its input compressed air power. Also these drills

are noisy and their exhausts generate mist and fog. They are suitable for any degree of toughness of the rock.

Jack Hammer Drill

It is a *compressed air operated drill* to which air is supplied from external compressors through hose pipes at a pressure of about 6 kgf/cm^2. The drill weighs 15 to 25 kgf and drills holes of dia. 30 mm to 38 mm (rarely upto 50 mm) upto 3 m depth.



Jack hammer

The drill rod is hexagonal in cross-section, suitably shaped at one end to form the shank and the other end is so shaped as to form a non-detachable single chisel bit with a tungsten carbide insert. Drill rods may also be equipped with detachable X type tungsten carbide (kill bits. In a shift of 8 hrs, two workers who hold the drill can drill 60 holes, each 1.2 to 1.5 m deep in sand stone, laterite, etc. When hand-held, the machine drills vertically downward holes only but if mounted on air legs, it may be used for drilling inclined holes. An oil bottle placed between the drill sad the air receiver, and connected by hose pipes to both, provides lubrication to the drill when working. For dust suppression a jack hammer can be adapted to wet drilling by some modifications so that the drill cuttings mixed with water come out of the hole in the form of a sludge. The air consumption is generally 2-2.5 m^3 of free air/min.

Hydraulic Drills

Introduction of hydraulic drills in underground mines and tunnels is recent. Presently more than dozen-reputed manufacturers are in arena giving considerable different designs. Initially rotary hydraulic drills came up and later on the rotary percussive drills.

The hydraulic drills operate by the intermittent application of high-pressure hydraulic oil to a double acting piston; the frequency oil application is controlled by the movement of piston or

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by the action of sliding or rotating valve or by a combination of both. Both may operate by the oil pressure, or by the piston or the valve. These drills have separate rotation motors giving adjustable rotation speeds maximum of 30 rpm. Some of the models are also fitted with reversible rotation mechanisms.

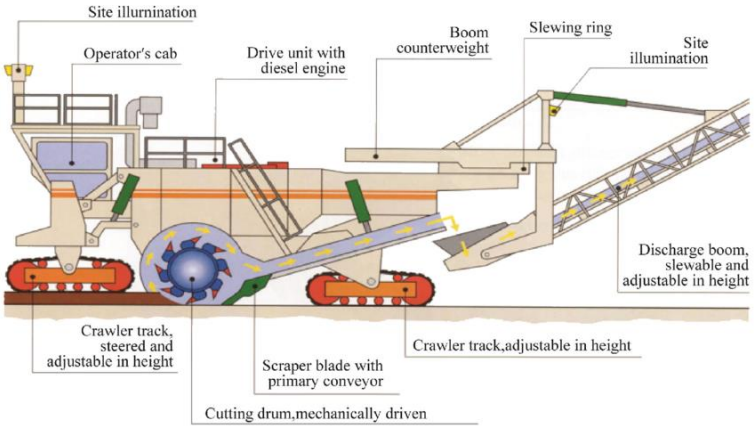
One to four boom jumbos are available for their use in civil tunnels, and development and stoping operations in underground mines.

SURFACE MINER

Relatively new to use in surface mining excavation, surface miners can be used to excavate material where drilling and blasting is prohibited (such as in some quarry applications) or where selective mining is required or where materials have a relatively lower compressive strength. Surface miners can be used in either a discontinuous system (where the surface miner cuts the material and loads it into a haul truck) or in a continuous system (where the material is wind-rowed behind or to the side of the machine for later loading (usually by a front-end loader into a haul truck). Combinations of a surface miner with a conveyor system can also be achieved.

Surface miner is a continuous mining machine shown below. It is used in open pit mining of coal, lignite, gypsum etc.

The framework of the opencast miner is of rigid, welded box design with integrated tanks of hydraulic oil, diesel and water. The total length without conveyor is approximately 11 m. The machine runs on three (3000 SM) crawler or four (3800 SM) crawler units. Following figure shows the operational parts of the surface miner.



Due to the central position of the milling drum the rear crawlers travel at a level lower than the front crawlers which is equal to the cutting depth. The milling drum of 3000 mm or 3800 mm width are the actual mining units of the machine.

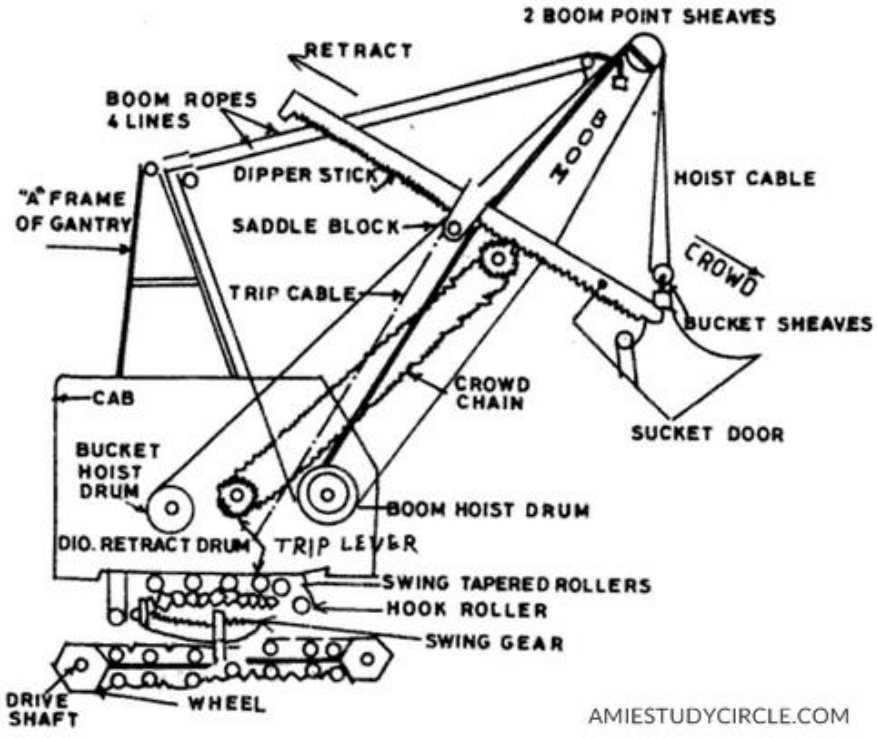
The conical picks with tungsten carbide inserts presently used on 3000 SM rotate in tool-holders.

The required milling (mining) depth can be adjusted via 2 hydraulic cylinders which are connected to the drum. The surface slope can be regulated within certain limits by laterally tilting the drum to a maximum of 7° (only 3000 SM). With 3800 SM. the entire machine is tilted.

The material loosened by the almost circular motion of the picks is similarly to the operation of a spiral feeder transported in the drum scroll to the drum centre, because the drum is of twin-helix design. Thereafter the material moves over a slopping scraper blade on to the rigidly installed primary conveyor. It is then fed on to the 12 m discharge conveyor, which can be slewed through an angle of 180° and adjusted to a maximum height of 7.70 m.

SHOVELS

The field of application of power shovels (see figure) extends from the removal of shallow overburden prior to opencast mining, to stripping and mining deposits of large area and tonnages which are fairly uniform in character, and shovelling material broken down by explosives.



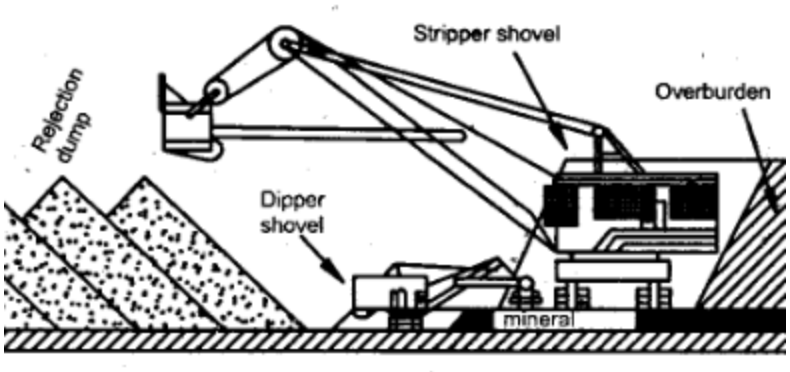
Power shovel

Crawler mounted face shovel is the machine most capable of handling hard, heavy, blasted ground by virtue of its positive crowd action and high break-out force. It can accurately spot for loading dump trucks, rail wagons, etc.. the larger units are used for direct casting. The shovels dig the material above the base level and have little ability to dig below base level. For the operation of the shovels a competent floor is required to allow positive traction by crawlers, without the possibility of damage or 'bogging down' and the surface area of the crawler must provide a bearing pressure to match that can be accepted by the ground. The level width must be sufficient so as to preferably allow trucks to pull it either side of the shovel to minimise track spotting delays.

Shovels may be powered electrically or by diesel engine. The power consumption is approximately 0.26 to 0.6 KWh per bank m^3.

Shovels may be broadly put in two classes:

- **Stripping shovel** The stripping shovels are used for the removal of overburden. They can handle all types of material including large blocky material. However, it is restricted to rigid operating conditions and has a limited ability to spoil. The shovel digs material from its operating base upwards.



Stripping and dipper shovels

- **Face-loading shovels** It is similar to stripper shovel but smaller in size. The shorter boom of the loading shovel is equipped with cither a bottom-dump or a rigidly attached side-dump bucket. The loading shovel is widely used for coal loading in surface mines, but it is not very mobile. It is being replaced at many mines with front-end loaders which can perform better than shovels especially in contour mining. The loading shovel can load above the grade and over the end of the truck; can handle coarser material than the front-end loader; has a large life and better availability; and can load selectively under various mine conditions.

BULLDOZER

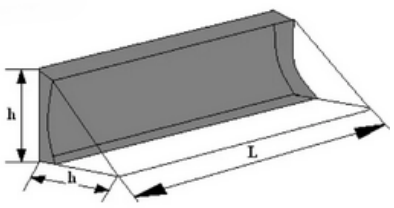
A bulldozer is often referred to simply as a dozer. It is a tractor with a pusher blades attached to the front portion. The tractor is the diesel-operated power unit equipped with either crawler chains or rubber tyred wheels for lifting. The pusher blade can be raised or lowered or tilted through small angles horizontally by rams operated through hydraulic pressure or by ropes. The dozer blade is used for pushing loose material or for digging in earth, sand and soft weathered rock. The machine is also engaged for levelling or spreading earth, for levelling of rock spoil in the dumping yard, grading and compacting temporary roads, pushing mineral into sub-ground level bunkers through grizzly, for towing dumpers, etc.

It also serves the purpose of pushing boulders, pulling down trees, and is an essential equipment to push scrapers. A dozer equipped with a fork like attachment is known as ripper and operates like a plough to loosen moderately hard rock. The loosened rock may be loaded by a scraper. A dozer can dig 1.2 m to 1.5 m below ground in earth or weathered rock.

Example

Dozer blade has the dimension of 4500 mm x 2000 mm operates on level ground. The output capacity of the dozer is____ (DGMS FMC 2015)

Solution: Consider following figure.



Solution

The output of the dozer blade = (1/2) x h^2 x L

= 0.5 x 2 x 2 x 4.5 = 9.0 m^3

Consider a 20% bulging of the material in front of the blade.

The output of the dozer blade = 9 x 1.2 = 10.8 m^3

SHEARER

Shearers are one of the *most popular* cutter loaders for use in the longwall faces. The cutting unit consists of one or two rotating drums, faced with cutting tools which may be fixed or mounted on ranging arms.

Longwall shearers cut away the face of a coal seam in longwall mining operations by mounting over an armoured face conveyor (AFC). They are equipped with cutting drums positioned against the coal seam by ranging arms powered by hydraulic rams. They can weigh more than 100 tons, travel at speeds up to 30 m/min, and cut away slices of coal seams up to 100 cm thick. They can also be called shearer loaders.

Longwall shearers consist of large cutting drums mounted to a slim body. The cutting drums are used to cut a predetermined height of coal across the face of the coal seam on each pass. The shearer loader can be divided into three basic types.

- **Double-ended ranging drum shearers (DERS)** are the largest and most efficient type of shearer loader. The double-ended machine includes two cutting drums mounted on ranging arms that can be positioned to accommodate a range of seam thicknesses.
- **Single-ended ranging drum shearers (SERS)** consist of a single cutting drum mounted to a single raging arm. Typically two SERS are used simultaneously to cut away the face of a coal seam.
- **Single-ended fixed drum shearer (SEFS)** like SERS are also typically used in pairs, but lack a ranging arm and are used to extract thin coal seams approximately 48 inches thick.

The machine may be mounted on armoured face conveyor or it may be floor mounted and is hauled up and down the face by rope, chain or by a system of chainless haulages. Anderson Strathclyde AM 500 Double Ended Ranging Drum Shearer (DERDS) is operated by a 375 or 300 kW electric motor at 550 or 1,100 volt supply. It can cut a coal seam up to 4.8 m thick and can work on gradients up to 35°.

Shearers in conjunction with Armoured face conveyors and powered supports have regularly given a production of over 2,000 tonnes per day and in some cases up to 5,000 or even 10,000 tonnes per day.

COAL PLOUGH

The ploughs are operated remotely from one end of the face unlike the shearer in which case the operator moves with the machine.

Reisshaken plough

This plough is designed to work in seams up to 3 m thick and on gradients up to 54°. In this plough the haulage chain travels along the goaf side of the conveyor.

The new. standardized "S" type Reisshaken Ploughs are arranged on either a three part or a five-part base. Intermediate and top portions are available to extend the working range of the ploughs. A special Panzer box guide has been developed for the Reisshaken Plough suitable for all types of Panzer conveyors. With this assembly, plough chains of 30 x 108 mm nominal thickness may be used.

The "S" type ploughs require only a 200 mm wide track so that friction and conveyor float are sharply reduced. As a result, a maximum proportion of the power installed is available for ploughing. The bottom bits are mounted on swivel segments which are vertically adjustable in several stages.

Gleithobel Plough

Gleithobel Plough System operates without a base plate, its guidance and stability being provided by ramp plates attached to the face side of the conveyor. These plates not only serve to guide the plough but also to trap both the pulling and return chains. Since the plough does not run on the floor and there is no base plate under the conveyor, friction with the result that most of the pulling force is available as effective cutting force.

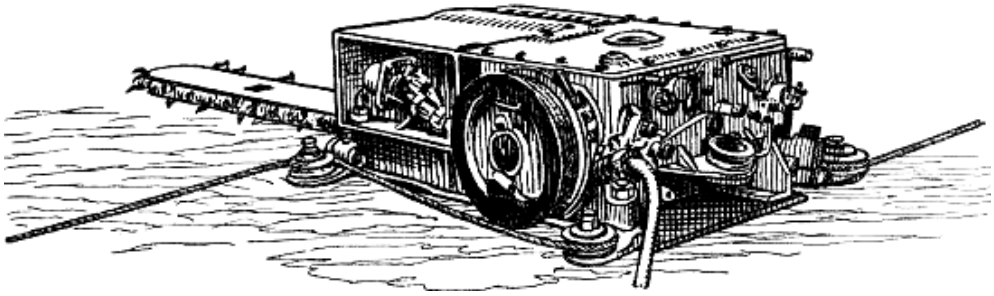
Two types of Gleithobel ploughs are available: the standard 7-26 type and heavy-duty 8-30 type. In most details the systems are identical except that the chains used are different in thickness and the guides, different in height. The 7-26 plough is equipped with a 26 x 92 mm chain and the 8-30 plough, with a 30 x 108 mm chain. The plough body is assembled from two portions which are hinge-connected. This design allows the plough to adapt to any undulation in the floor.

LONGWALL CHAIN TYPE COAL CUTTER

A longwall chain machine consists of three parts, namely, *the gear-head, the motor, and the haulage.* These units are joined together by spigot and faucet registers which are held together by high tensile steel bolts and studs. All the working parts are as far as practicable enclosed within casings so as to prevent them from dust, etc., and in the electrically operated machines the motor is enclosed within a F.L.P. cover. All parts are made of cast steel.

A longwall-type coal cutting machine can be used in bord and pillar workings also.

Following figure shows Anderson coal cutter with gum slower for undercutting a longwall face.



The machine is driven by 60 kW radiation cooled or 93 kW water cooled interchangeable electric motors.

SHORTWALL COAL CUTTER

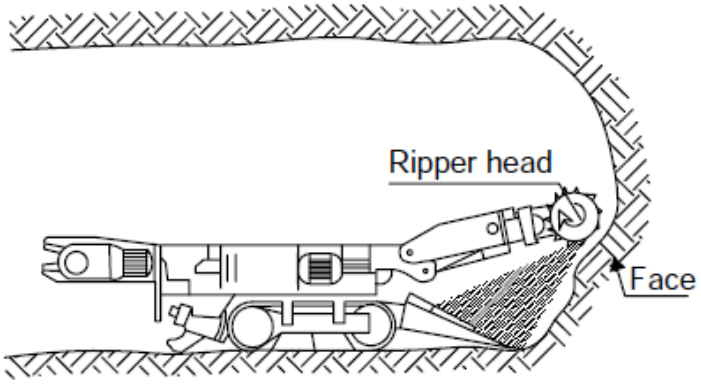
In the shortwall coal cutter, the jib is permanently fixed in line with the body of the machine and extends underneath and to the rear of the machine casing. It has two sections: (i) the driving motor and switch housed in the front of the section, and (ii) the gears in the rear portion of the machine for driving the cutter chain and haulage drums. Two rope drums are provided, of which one, is the feed drum and the other is the hauling drum so as to control the angle of the jib when the machine is cutting across the face of a heading. The machine cuts across from right to left and with a 2.28 m jib gives a cut of 2.13 m. The chain has about 40 pick boxes.

Shortwall coal cutting machines cannot be used for longwall faces. The other types of coal cutting machines especially designed for bord and pillar workings are: (i) Arc-Shearing (Arcwall-and-shearing) coal cutters, and (ii) Arcwall coal cutters.

HEAVY-DUTY ROADHEADERS

These normally weigh 60 tonnes and due to improved weight to power ratio, are able both to withstand machine-frame stresses and to increase the cutting forces applied to the face of the drivage.

Following figure shows a heavy-duty roadheader.



It has a total installed power of 300 h.p. and is designed for tunnel drivage in stone. The machine is designed on the unit construction principle. It is crawler mounted and a gathering arm loading system feeds a heavy-duty conveyor passing through the centre of the machine. A 112 kW (150 h.p.) air cooled electric motor powers the two-speed telescopic cutting boom through a reduction gearbox. An identical electric motor drives the hydraulic power pack through a splitter gearbox. With the exception of the cutting head all the machine functions are hydrostatically powered and controlled.

SHOVELS

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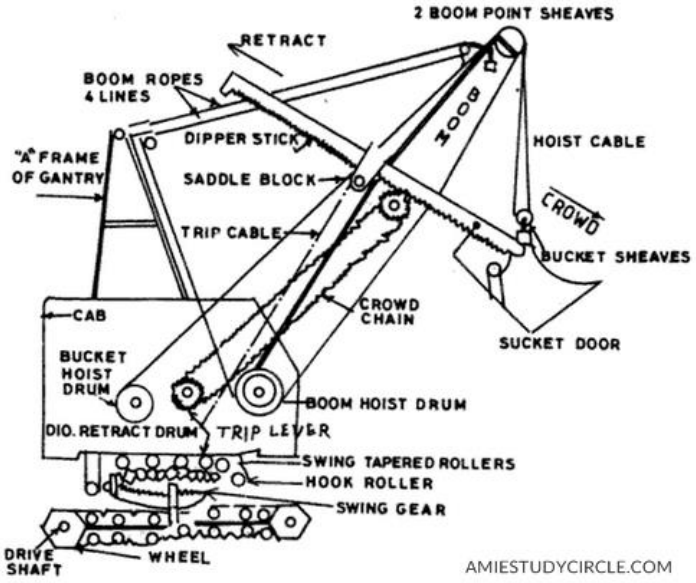

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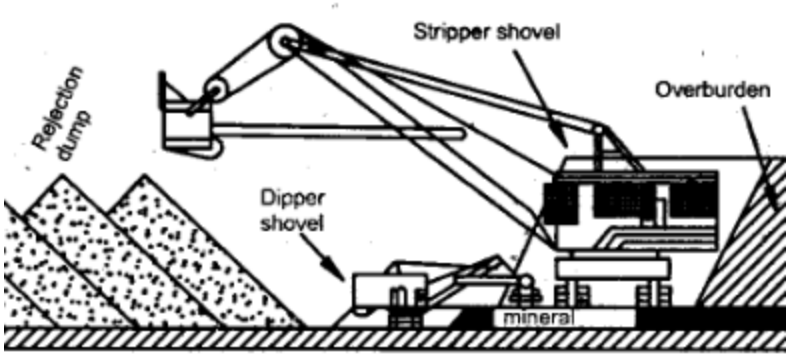

Stripping and dipper shovels

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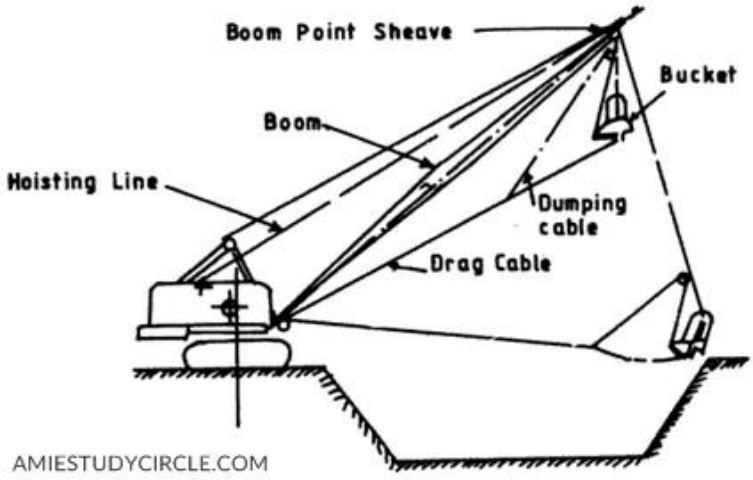
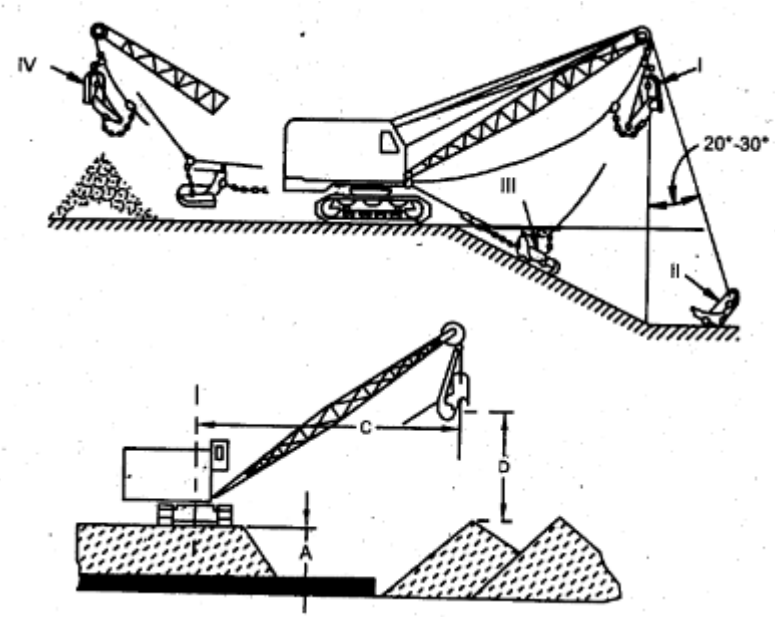
DRAGLINE

A drag line is a machine used for excavating earth, sand or soft rock and consists essentially of a revolving deck, a long light boom, crawler chains, and a special type of bucket held in position and controlled by cables (see following figures).



(a) Parts of dragline



(b) Ranges of dragline

The bucket, when it has to be loaded, is lowered in the earth or loose rock by manipulation of the cables and is dragged by them. As it is dragged it gets loaded. Hence the name dragline. A dragline is operated by diesel engine or a motor which is supplied power at high voltage from external source through a trailing cable. The depth to which a dragline digs is limited by the capacity of the drums to hold the hoist cable. When digging, the bucket, after it is loaded, is hoisted up, the boom given a swing through 90° and the contents then unloaded by manipulation of the cable.

A dragline is suitable for digging alluvium, sandy soil, unconsolidated rock or blasted coal/rock. It digs below the level, at which it stands and from position can dig over a wide

working place and cast the earth over a wide area within the reach of the boom. It is generally not employed to load dumpers as the accurate positioning of the dragline bucket over a limited area of the dumper delays the cycle of operation and the common application is for dumping overburden. It is suitable for working a quarry with watery conditions as the dragline works from a higher and, therefore, dry position.

A drag line may be crawler mounted or of waling type.

SIDE DISCHARGE LOADERS

The design and manufacture of a mining vehicle called Side Discharge Loader (SDL) and its successful use in Indian under ground Coal mines took several years passing through various stages of development.

Use of this machine is prevalent in India for extracting coal by *Board & Pillar method*, which is a semi-mechanised method, compared to fully mechanised Long Wall mining technology. The machine is used to collect coal from the blasted face and deliver side-wisely from its bucket on to a chain conveyor without tilting the bucket. All functions of the machine are hydraulically operated from an in-built hydraulic power pack run by a flame proof electric motor.

CONVEYORS

Mechanical conveyors are used for transporting most bulk solids (sand, ash, grains etc.) handling.

They are used not only in transportation of bulk solids from one location to another location but also for feeding, discharging, metering and proportioning such materials to and from bulk solids storage silos and other solids handling and processing equipments.

Conveyor is a device which is used for continuous transportation.

Conventional Belt Conveyors

Belt conveyors are most versatile and widely used mechanical conveyors. They are used for transportation, feeding, discharging bulk solid material. This conveyor is suitable to almost dry type of material free flowing solid to met stocky and lumpy powders. Normal belt may be conveyed at angle of inclination of upto 22°. The bulk material on the belt conveyor is discharged over the drive pulley of other conveyors.

The capacity of belt conveyor depends on speed, shape and width of belt, method of feeding and solid properties. Belt conveyor are the most common form of material handling system used in manufacturing and mining industries thermal plants and in construction projects.

Heavy industries like steel, fertilizer, chemical and cement etc. cannot function without the belt conveyors. In construction project the belt conveyors are used for handling. The material in asphalt plant, crushing and screening plants, aggregates mixing plants etc. In coal mining and other mining industries these are used for handling coal or other raw material. The belt conveyors are capable of conveying large quantities of material continuously over considerably long distances at a fast speed.

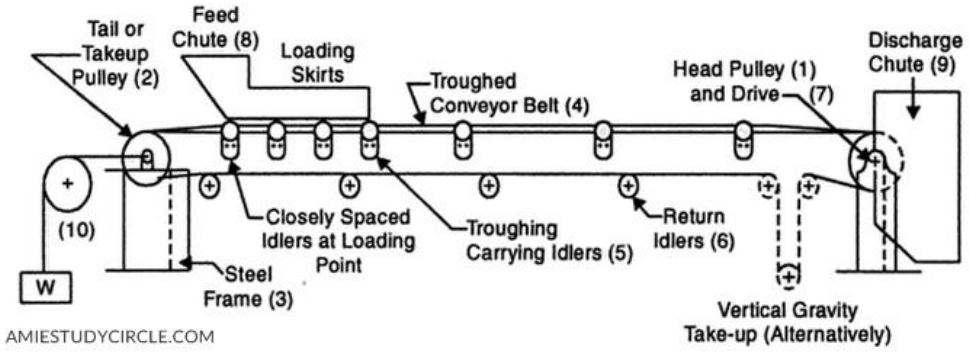
For transporting the material for short distances conveyors may be a portable or a fixed unit. When a belt conveyor system is to be used to transport for a considerable distance upto several kilometres in such cases, the system consists of a number of **flights**. Each flight is a complete conveyor unit discharging its load on the tail end of the successive unit. Belt used in the system are costly and hence needed to be carefully maintained. The belts are generally made of rubber cover cotton or rayon laid up in the plies. The strength of the rubber belt depends on number of plies, canvas plies. Wooden wire mesh and steel belts are also used depending upon the strength required for the conveyor to conveying various types of materials, their quantity to be transported etc. Belts are specified by width, number of plies and weight of each layer of ply.

These include conveyors using fabric-ply belting and conveyors using fabric free steel cord belting.

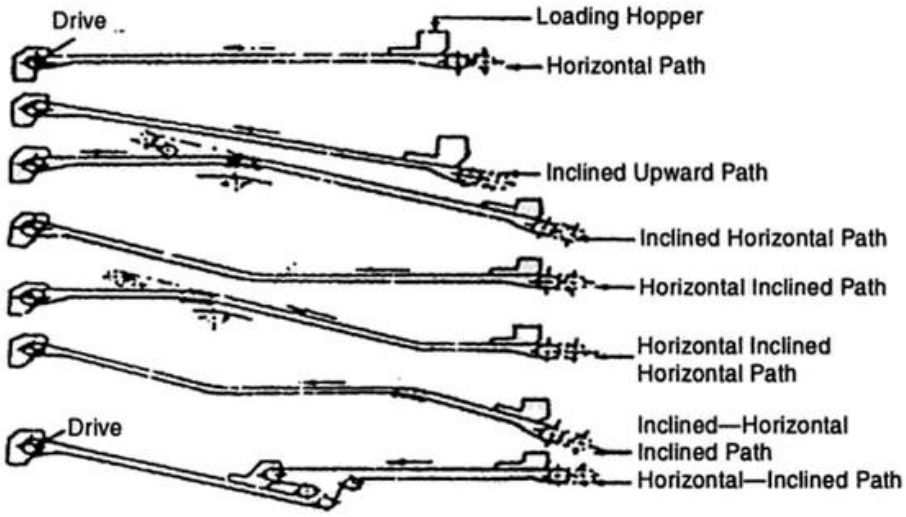
Components of conveyor

Following are conveyor components:

- The **belt** which carries the material and transmits the tension or pull.
- The **idlers** which support the carrying and return strands or runs of the belt.
- The **pulleys** which support and move the belt and control its tension as well change its directions.
- The **drive** which transmits the motive power to one or more pulleys to move the belt and its carrying load.
- The **structure** which supports and maintains the alignment of idlers and pulleys.



Following figure shows typical layouts of conveyors. Belt conveyors can be designed for practically any desired path of travel.

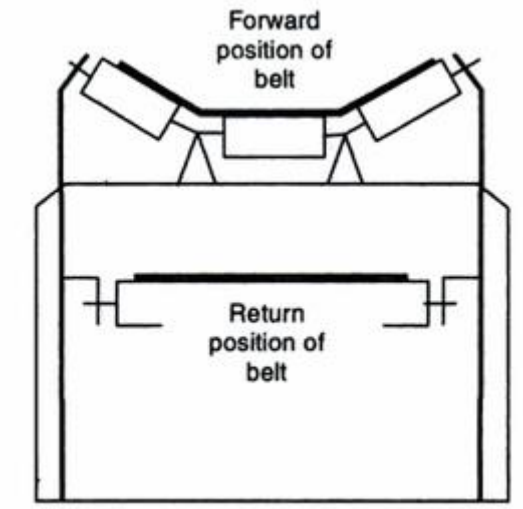


Flat Belt Conveyor

- These types of conveyors are simple in design are simple uses flat belts supported on a single idlers.
- The width and thickness of belt depends on the material to be conveyed generally used for shorter distance.
- Major problem is a spillage of material from a belt surface at higher speeds.
- Upper rollers have low pitch as lower rollers have high pitch.
- These can be of various types such as shown in figure 8.3 a, b, c.

Trough Belt Conveyors

Though Belt Conveyors are designed to leverage the open frame and trough effect of the Rubber Belt Conveyors to fully contain the load of materials. Trough belt conveyors are the most widely used and efficient means of moving bulk materials Trough conveyors for light to medium capacity systems. These conveyors are used in areas of cement, coal packing, food industry, sand & gravel and package handling.



The trough belt conveyor

Trough belt conveyor is that in which the belt forms a trough on the carrying side while running over idler rollers which are either in set of 5 rolls, 3 rolls or 2 rolls. The troughing angle adopted are: 15°, 20° , 25° , 30° , 35° , 40° , 45° . Return Idlers are usually straight roller type.

Trough belt conveyors are used for higher capacity, higher speed requirement, and for handling bulk material of large lump size. It suitable for inclined or declined type conveyors.

Transition distance is defined as the distance from the center line of the first fully troughed idler roll to the center line of either the head or tail pulley. The distance from the pulley to the top of the wing idler is certainly greater than the distance from the pulley to the center roll of the troughing set. If the transition distance is too short, the edge of the belt can be over stretched. This will adversely affect the load support and belt life.

Aspects of Belt Conveyor Design

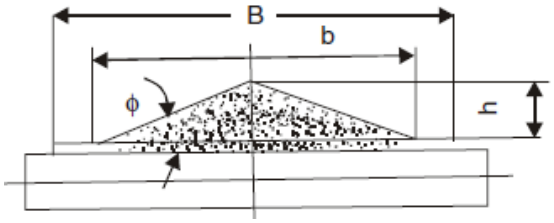
The major points in selection and design of a belt conveyor are:

- Checking/determining capacity of a conveyor.
- Calculating maximum belt tension required to convey the load and selection of belt.
- Selection of driving pulley.
- Determining motor power.
- Selection of idlers and its spacing.

Above points have been discussed below in respect of flat as well as troughed belt conveyor.

Checking/Determining Conveyor Capacity

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



The cross sectional area of the load on a flat belt is

$$F_1 = \frac{bh}{2} = \frac{1}{2}(0.8B\,x\,0.4B\tan\varphi) = 0.16B^2\tan(0.35\varphi)$$

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

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

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

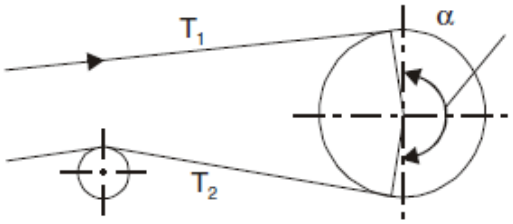
V = velocity of belt in m/sec

B = belt width in metres.

Belt Speed Recommended belt speed depends on the width of the belt as well as lump size factor of the bulk material, its air borne factor and also its abrasiveness factor. IS: 11592:2000 gives the maximum recommended belt speeds for different sizes of belts based on ‘‘speed factor’’ (speed factor = lump size factor + air borne factor + abrasiveness factor).

Belt Tension

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



$$\frac{T_1}{T_2} = e^{\mu\alpha}$$

where T_1 = belt tension at tighter side

T_2 = belt tension at slack side

α = wrap angle in radian

μ = coefficient of friction between pulley and belt

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

$$T_e = T_1 - T_2 = T_2(e^{\mu\alpha} - 1)$$

Selection of Driving and Other Pulleys

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

Diameter of pulley is selected based on the construction (number of plies which is proportional to carcass thickness) of the belt used. As a thumb rule, diameter 'D' can be approximated from the relation, $D \geq ki$, where i = number of plies of belt, and k = 125 to 150 for i between 2 to 6, and k = 150 for i between 8 to 12. Calculated 'D' is rounded off to the larger standard sizes of 250, 315, 400, 500, 630, 800,1000,1250,1400,1600, 1800 and 2000 mm.

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

The drive pulley may be covered (lagged) with a layer of suitable material like rubber, polyurethane, ceramics etc, whenever necessary, to increase the coefficient of friction between the pulley and belt.

The thickness of such lagging may vary between 6 to 12 mm.

Motor Power

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

$$P_d = \frac{T_e V}{1000} kW$$

where T_e = effective tension = $(T_1 - T_2)$ in Newton

V = belt speed, m/sec

P_d = driving power, kW

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

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

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

R_{bd} = driving pulley bearing resistance.

Selection of Idlers

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

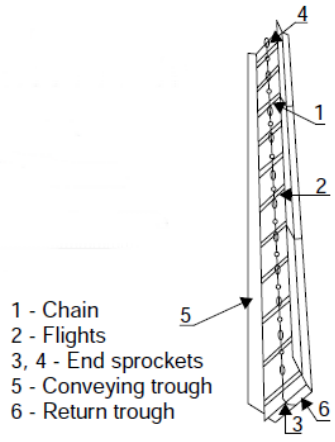
The range of idler diameters to be selected depends on belt width, maximum belt speed and type of materials to be conveyed.

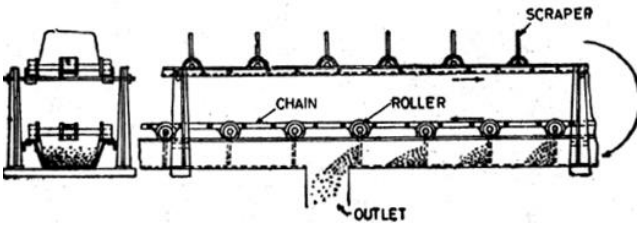
Spacing for carrying and return idlers also depends on belt width, and bulk density of the material to be conveyed.

Scraper Chain Conveyors

These types of conveyors have been designed to withstand rigorous mining conditions particularly at a working face, which is always advanced ahead. These conveyors can negotiate gradient of more than 18° i.e. more than the belt conveyors usually negotiate.

These conveyors are easily extendible without their dismantling but their length is limited and usually not more than 200 m. A scraper chain conveyor consists of the following parts (see figure): Troughs; Endless chain/chains (which may be one or two depending upon the design); Sprocket wheel; Drive head having motors, gears, tensioning devices and other parts.





Scraper conveyor

Example

Find the power transmitted by a belt running over a pulley of 600 mm diameter at 200 r.p.m. The coefficient of friction between the belt and the pulley is 0.25, angle of lap 160° and maximum tension in the belt is 2500 N.

Solution

Given :

d = 600 mm = 0.6 m ;

N = 200 r.p.m. ;

$\mu = 0.25$;

$\theta = 160° = 160 \times \pi / 180 = 2.793$ rad ;

$T_1 = 2500$ N

We know that velocity of the belt,

$$v = \frac{\pi DN}{60} = \frac{\pi(0.6)(200)}{60} = 6.284\, m/s$$

Let T_2 = Tension in the slack side of the belt

We know

$$\frac{T_1}{T_2} = e^{\mu\theta} = e^{0.25(2.793)} = 2.01$$

and $$T_2 = \frac{T_1}{2.01} = \frac{2500}{2.01} = 1244N$$

Power transmitted by belt will be

$$P = (T_1 - T_2)v = (2500 - 1244) \times 6.284 = 7890 \text{ W}$$

Example

An AFC of length 114 m runs at a speed of 0.535 m/s. The mass of chains and flights is 54 kg/m, and the coefficient of friction between the chain and trough is 0.33. What is the power needed to drive the empty conveyor?

Solution

W = mg = 54 x 9.8 = 529.2 N

F = μW = 0.33 x 529.2 = 174.64 N

Power = FV = 174.64 x 0.535 = 93.43 Watt

Total power to drive the conveyor

= Power per m x total length

= 93.43 x 114

= 1065 Watt = 10.65 kW

Example

A conveyor transported the coal at the rate of 220 te/hr is 600 m long moving up a gradient of 1 in 60. If the belt width (W) is 0.75 m, and cross-sectional area of the material is 0.1 W^2, determine the belt speed. The bulk density of coal 0.8 te/m^3.

Solution

T = 220 t/hr = 0.061 t/s

W = 0.75 m

a = $0.1W^2$ = 0.1 x 0.75^2 = 0.056 m^2

b = 0.8 t/m^3

T = abV

Hence, 0.061 = 0.056 x 0.8 x V

From this, V = 1.36 m/s

Example

For a 150 m long chain conveyor, the component of power required to move coal against gravity along an inclination 15° is 5 kW. Hourly capacity of the chain conveyor will be

Solution

P = 5000 Watt

L = 150 m

Angle = 15^0

Force, F = mg sinθ

P = Fv = F x (distance/time)

For 1 sec

P = F x distance

= mg sinθ x distance

∴ 5000 = m x 9.8 x $\sin 15^0$ x 150

Giving m = 13.14 kg in one second.

Hourly capacity/hr = Mass handled/hr

= 13.14 x 3600 = 47310 kg

= 47.3 te

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