CHAPTER 5

# OPENCAST MINING

Opencast mining or quarrying of minerals is easier than mining by underground methods. During quarrying the alluvium and rocks below which the mineral lies, are removed and dumped, in the initial stages, in a place which is not required in future for quarrying, residential or other purposes. The mineral exposed is completely extracted. Opencast mining is also known as open-pit mining, open-cut mining, surface mining and also as ***strip mining***, the latter term being commonly used in the U.S.A. for opencast mining of coal. The overburden and the mineral, coal, are excavated in long strips of a few metres thickness and hence the operations are termed *strip mining.* The operation of removing overburden and extracting mineral is done by one of the following methods.

**(1)** ***Manual quarrying***: In this case manual labour is employed. Small drilling machines, drilling 1.2 m to 1.8 m deep holes, 37 mm diameter, are used and the holes are blasted with gun-powder or other explosives. The overburden and mineral are manually loaded into tubs which are hauled by rope haulages or locomotives. Tipping trucks are also sometimes employed and manually loaded.

**(2)** ***Mechanised opencast working****:* In this method heavy earth moving machinery like draglines, power shovels, rear-dumping trucks (common type being Haulpaks), well-hole drills etc. are used. The blast holes are 6 m to 18 m deep, and 125 mm to 250 mm diameter. The rock is blasted by liquid oxygen, open cast gelignite or other high explosives. Mineral and overburden are transported by locomotives, belt conveyors or large trucks known as dumpers. Bucket wheel excavators are used in some mines for soft rocks e.g. at Neyveli lignite project.

A method of surface mining known as *placer mining* involves mining and washing together of generally unconsolidated or semi-consolidated rock near the ground surface and the method is normally not treated as opencast mining but a variation of it.

*Glory hole mining* is a method where the mineral is excavated in small open pits but is transported to the surface through underground excavations and transport system.

Nearly 70% of the mineral production in the world comes by opencast mining and in India this method of mining accounts for nearly 75% **of our mineral output.**

## Quarriable limit

The cost of removing overburden to extract mineral lying below it goes up as the quarrying operations extend to the dip side of the property and the thickness of overburden increases. The stripping ratio, thickness of overburden: thickness of mineral deposit therefore decides the economic working limit of quarrying, i.e. the quarriable limit. The softer the rock, the less is the expense of overburden removal and higher is the stripping ratio. The wages of labour, the selling price of mineral and the margin of profit are the major considerations in deciding the limiting ratio which is as follows in coal mines;

i. Manual quarrying 1.5 : 1
ii. Semi-mechanised quarrying 2 : 1
iii. Mechanised quarrying:
    a. With dipper-shovel, dumper combination; 4 to 5 : 1
    b. With draglines: 8 to 10 : 1
    c. With bucket wheel excavators: 3 to 4 : 1

The maximum depth from the surface in existing mines in our country is 120 m but future mines are planned to reach a depth of nearly 480 m.

## Advantages of quarrying

There is no problem of roof control or ventilation. Full extraction of mineral is possible. No mineral is blocked in shaft pillars, support of main roadways, etc. as in underground mining. Quick return on capital and early extraction are possible without the need to wait for a long period of development work or unproductive work like shaft sinking, etc. Large output is available from a small area and supervision is easy owing to concentrated work. Artificial lights are necessary only after dark.

Dangers and hazards are less as compared to underground mining. There is no risk of gas explosion. Very few stringent mining regulations are applicable to quarries. For example, compared to underground mining less number of competent persons are to be appointed and less number of statutory inspections are necessary.

Better sanitary conditions can be maintained.

High efficiency of mine workers; ease in loading the tubs in unconfmed space and natural light gives high O.M.S. (output per manshift).

Female labour can be employed. All the members of a family are often employed and the accommodation problem is simplified.

Once the mineral is exposed, output can be easily varied to meet wagon supplies, or consumer demand.

Training of operatives is easier.

Large scale mechanisation is possible as there is no restriction on the dimensions of machines to be used. Unlike in underground mines, machinery working at high voltage can be employed.

**Disadvantages.**

Among the disadvantages of quarrying are:

Work is affected by weather. During winter nights, and summer mid-days efficiency of workers is very low. During rainy season unless effective steps are taken to dewater the mine mineral which is at the lower levels, cannot be worked and mining comes practically to a standstill.

Surface land is destroyed and is rendered unfit for agriculture and residential purposes.

Mining lease gives only underground rights; surface rights have to be acquired for quarrying.

The method is uneconomic for working mineral beds at depth.

Where quarrying aims at quick return on capital, outcrop mineral is also mined. As it is inferior in quality due to weathering .and percolation of water, the overall quality available to the consumers is affected in earlier phases of mining.

The quarried area and the OB heaps present an unpleasant sight. In some foreign countries the mining law requires that the quarried area should be filled up with overburden and restored to the pre-quarry state fit for agriculture. Marshy land, after extraction of underlying mineral and restoration of surface has, in a few cases, resulted in a good agricultural area. Such law requiring surface restoration to pre-quarry stage does not exist in India.

The overall O.M.S. is low due to a large labour force engaged in OB removal in manual quarrying.

A property with extensive area on the strike and containing a thick mineral bed moderately inclined, lying at shallow depth, is ideal for quarrying. In India coal seams with inclination as steep as I in 3 have been worked by mechanised opencast mining methods in Karanpura field. Seams at shallow depths which are actively gassy, liable to spontaneous heating or with bad roof should preferably be extracted by quarrying as the mining legislation for underground working of such seams is stringent.

Before the quarrying operations are undertaken it is necessary to vacate buildings and divert electric overhead lines, aerial ropeways, water mains, telephone lines, roads, railway lines, streams, etc. from the area which has to be quarried. The trees have to be cut. Sufficient space for dumping of overburden, not far from the quarry, has to be considered. Where mechanised opencast mining is to be adopted, plans should be prepared to show the contour lines and the thickness of coal and overburden at various points. An extensive area for dumping of overburden and good roads without steep inclinations and sharp curves should receive attention. Dumping yard for OB should be so selected that wind does not carry the dust to residential colony. By dumping of OB if the ponds, paddy fields, mango/coconut groves, not under the ownership of the mine owner, are likely to be affected, the compensation payable should not be ignored.

If heavy explosive charges have to be blasted as in mechanised quarries, the quarry site has to be far away from residential area (beyond 300 m.) Such heavy blasting may cause cracks in old buildings resulting in demand for compensation.

On the surface reference lines have to be marked on a square pattern, every 30 m apart, for monthly measurement of the excavation and they should extend 50 m beyond the limits of the proposed quarry. Junctions of the squares should be marked by permanent pegs in brick pillars.

**Formation of benches:**

The overburden and mineral deposit can be extracted by formation of benches or by keeping the surface sloped so that the angle of slope does not exceed 45° from the horizontal. A bench has two elements, the floor and the face (high wall). The width of the floor should not be less than the height of the face (high wall) and the heights of benches are as follows:—

1. *Loose material:* In alluvium, morrum, loose earth, etc. which is likely to slide the bench height should not exceed 1.5 m. During the rainy season, there is possibility of land slide of the loose debris and it is desirable to keep the width of the floor much larger than the height of the bench.
2. *Coal:* The height of coal bench, i.e. the coal face, should not exceed 3 metres.
3. *Sand stone and hard rock:* Benches in sand stone and hard rocks are rarely vertical but generally sloping at a small angle with the vertical. The mining regulations do not stipulate definite bench heights in hard rocks except that the bench width has to be more than the bench height. In manual quarry the bench height is usually 3 metres to 4.5. metres and in mechanised quarries, more than 5.5 metres and depends upon the height of the boom of shovel above the bench floor. Suitable bench height for a 2 $m^3$ shovel is 6 to 8 m and for a 3.5 $m^3$ shovel, about 12m. The slope of the high wall is usually 20° off vertical and depends upon the travel of the bucket during loading. The width of bench floors in mechanised quarries is usually 15 metres and preferably more for movement of dumpers, tractor loaders and other equipment.

Gradients of roads in quarries for tyred vehicular traffic should not exceed 1 in 10.

**Manual opencast working in coal**

The quarriable area is divided into sections along the strike so that overburden extraction takes place in some sections arid coal extraction in others which have the coal already exposed after 'overburden removal. Small pillars of the rocks excavated are left for measurement. These are called *witnesses* or 'Sakhi' in Hindi. They are removed after measurement' of excavated area, usually once a week, is over. The height of such 'sakhi' should not exceed 2.5 m and where the height of such pillar exceeds 1.25 m its base should not be less than 1.5 m in diameter.

**Removal of overburden:**

The soft material like earth and weathered rock is cut by earth cutting picks. A team of workers consists of 3 or 4 members, one cutting and two loading. As female workers are allowed in quarries, a team of 3 workers usually includes one or two female members who are normally permitted to work only between 5 a.m. and 7 p.m. under the Mines Act. Each team is allowed a small plot usually 4.5 m x 4.5 m. The average output per worker in soft rock or earth is about 2.8 $m^3$ (in situ) per day.

In the hard rocks which need blasting holes are drilled

(a) manually with the help of hexagonal steel rod with chisel end or

(b) by compressed air hammer drill (jack hammer).

Method (a) is used in a small quarry where the output is only 50 to 100 te of coal per day, electricity or compressed air is not available and labour is cheap. A hole is 1.2 m to 1.5 m deep and one man can dri-11 5 to 8 holes, each 1.2 m deep in a shift (8 hrs.) Method (b) is now-a-days commonly employed. Compressed air is supplied by steel pipes 50 to 100 mm dia, up to central places and branch pipes supply air to drills through hose pipes. Two workers (one driller-and one helper) drill 40 to 50 holes, each 1.5 m deep, in one shift. The holes one placed 1.2 to 1.5 m apart and are blasted with gun powder or other suitable explosives. Blasting is done during the rest interval of the workers to prevent frequent interruption of work.

The overburden is loaded into tipping tubs (0.73 $m^3$ capacity) which are hauled by direct or endless haulages. In seams of mild gradients locomotives may be used. The haulage track is taken to each bench or alternate benches. Blasted overburden of higher bench is sometimes dropped on the lower bench for loading into tubs.

Overburden is dumped at the rise of the outcrop or beyond **the** quarriable limit but as the coal extraction proceeds, the overburden may be dumped in the area from which coal is extracted— an operation known as **back filling.** The overburden should be so dumped that it does not roll down at the coal benches when it assumes its angle of repose, nor should it choke water courses of damage paddy fields, other agricultural area or water reservoirs.

**Extraction of Coal:**

The coal which is exposed after removal of overburden is blasted after drilling holes. The same drills which are used for stone may be utilised for coal also but if the compressor has a limited capacity electrically operated drills are used for coal due to their relative lightness and better performance. The spacing of holes in coal is 1.5 m to 2.2 m, the depth varying from 1,2 m to 2 m. The coal available per kg of high explosive like special gelatine (60 to 80%) is generally 10-12 tonnes. With blasted coal, the average loading performance per loader is nearly 4 tubs (1.1 $m^3$ capacity).

Fig. 5.1 shows the layout of a large manual quarry, after it has advanced some distance along the dip. The entrance to the working places is by steps and inclined roads. The permanent installations like haulages, compressors, power transmission lines, etc. are installed in such places that their frequent shifting is not necessary when the stone benches or coal benches advance.

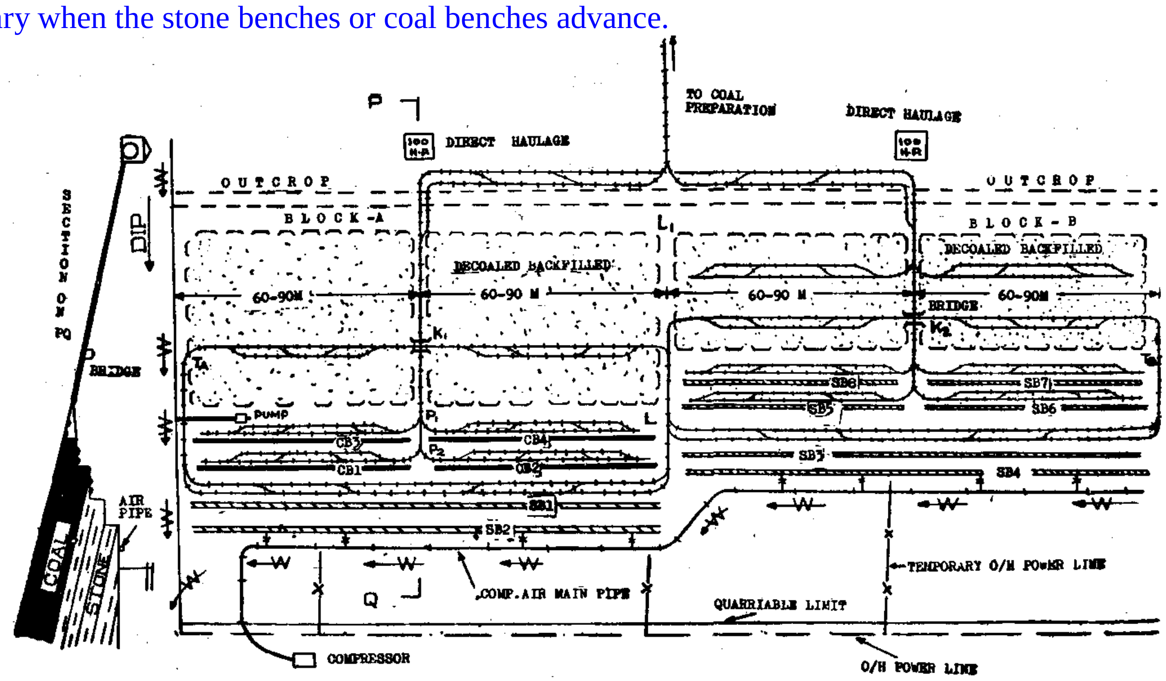



**Fig. 5.1. Layout of a manual quarry (coal). W with arrow indicates water drains.**

On a level track hand pushing of empty tubs having pedestal bearings is not uncommon for a distance of 100 m. If the same track is used for loads as well as empties, the gradient of the track should be nearly 1 in 80 in favour of loads. These factors limit the length of benches.

The property is divided into blocks, each 120 to 180 m long along the strike. Each block has a direct or endless haulage in the middle and the benches are formed along the strike on either side of the haulage. Block A which is shown more advanced than Block B, raises coal from the coal benches CBl, CB2, CB3, CB4. Each bench is 3 m high and has a haulage track on its floor. From the clipping point PI to the junction P2 the haulage track is either level or slightly rising inbye at 1 in 80 or so. The stone benches SB1, SB2, are ahead of the coal benches so that the exposed coal lasts for 2—4 weeks. Stone from the higher bench SB2, is dropped on the lower bench SB1 which has haulage tracks on its floor. The stone is taken in tipping tubs along a level track TA by hand pushing for dumping in the de-coaled area. The track TA is along the barrier. The tubs cross the direct haulage track over a bridge K, to fully utilise the decoaled area for dumping. As the stone benches advance the position of the bridge $K_t$ has to be shifted to the dip side. Another level haulage track is taken from the stone bench SB, to the decoaled area over a ledge LL. This ledge is 3m wide at the top and is a solid barrier of coal and stone left between blocks A and B. The coal of the ledge is not recoverable.

In block B, there is emphasis on removal of overburden. The direct haulage track is along the floor of the coal seam and more stone benches than in block A are provided for employment of a large number of workers on overburden removal. The stone benches $SB_5$ $SB_6$ $SB_7$ $SB_8$ are served by the central direct haulage. Stone benches $SB_3$ and $SB_4$ are worked by a level track $T_B$ and another level track passing over the ledge $LL_1$, Stone is taken over these tracks in tipping tubs for dumping in the decoaled area in the same manner as described for block A. The bridge $K_2$ serves the same purpose as bridge K, in block A, and is advanced towards the dip at intervals.

During rainy season coal raising may be suspended in block A which is on the dip side, and only overburden removal may take place from the higher stone benches which are free from water. From block B, only coal raising may take place during monsoon and the block can be kept free from water by making a through connection 1.8 m high in the ledge $LL_1$ for the water to gravitate to block A.

Drains for water, as shown in the figure, called garland drains are cut to minimise inflow of surface water into the quarry. Pumps are installed at possible places of heavy accumulation of water. The installation of compressed air pipes and the overhead power lines is as shown in the figure.

## MECHANISED OPENCAST MINING

Opencast mining is the oldest method of excavating minerals but the mining operations have been mechanised by the use of heavy earth moving machinery during the last 50 years resulting in excavations on a scale which was unthinkable half a century ago.

Some of the coal mines planned for large production (million tonnes per year) are: Kusmunda - 6.0, Mukunda -15.1, Gevra -14.0, Nighai-12, Rajmahal - 10.5, Jayant/Dhudhichuva/Khadia -10.0 each, Dipka expansion/Anant - 8.0

For mechanised quarries, employing heavy earth moving machinery the DGMS makes byelaws covering bench sizes, roads etc. These have to be studied before planning a mechanised quarry. Mechanised opencast mining is preferred when there is a thick mineral bed of mild inclination, practically continuous and not in pockets, at a low depth and the reserves are plentiful. For coal, a seam of less than 6 m thickness and with less than one million tonnes of quarriable reserves will not justify the heavy capital expenditure, large amount of interest on il and the depreciation charges.

The overburden may be removed by a combination of dozers and scrapers if the rocks are soft. If they are hard, blast holes arc drilled by wagon drills or well hole drills and blasted with explosives. The blasted rock is loaded into dumpers by dipper shovels or tractor shovels. Draglines are also used where the overburden is alluvium, sand or soft rock, but if it consists of hard rock it is loosened by sparse blasting for loading.

The equipment commonly used in a mechanised quarry for drilling, loading and transporting is briefly described below.

### Crawler chain vs. pneumatic tyred equipment

The machines employed in a mechanised quarry are mounted on pneumatic tyred wheels if they have to be towed from one place to another e.g. compressors, wagon drills, etc. Self propelling units having their own engines (like tractors, dozers, shovels, cranes, etc.) may however be mounted on pneumatic tyres or crawler chains. Table 1 shows the approximate rolling resistance of various road surfaces to pneumatic tyres and crawlers.

TABLE 1

**Rolling resistance**

| Type of surface | Pull in kgf per 1,000 kgf of gross weight | |
|---|---|---|
| | Low pressure tyres | Crawler chains |
| Smooth concrete | 18 | 28 |
| Good macadem | 30 | 35 |
| Earth roads, dry, dusty | 40 | 43 |
| Unploughed earth | 60 | 55 |
| Earth road, rutted, uneven | 90 | 70 |
| Loose sand and gravel | 110 | 85 |
| Construction haul roads or roads in loose soil | 145 | 112 |

A resistance of 9 kgf per 1,000 kgf is roughly equivalent to that offered by an up gradient of l% i.e. a road rising 1 m vertical through 100 m horizontal.

It will be seen that the advantage of pneumatic tyres recedes rapidly as the ground conditions worsen and for rough roads a crawler unit is at an advantage. Machines using crawler chains are not allowed to cross public roads which are damaged by the cleats of grouser plates and the latter should be replaced by plain plates preferably with rubber soles, 'for such crossing. Speed of crawler chains is slower than that of tyres. Where public roads have to be crossed often, or where the flitting is frequent, it is an advantage to use pneumatic tyred equipment. In the Held crawler mounted equipment scores over the tyred one for climbing steep gradients and has better traction on rough roads and better gripping capacity on bench floor when the machine has to dig hard, e.g. when extracting toe. Crawlers can negotiate sharp turns, a big advantage in a quarry of limited size. The quantity of mineral and rock that remains frozen in the roadways of a quarry where tyre mounted dozers and tractor shovels are used is much larger compared to that when similar equipment on crawlers is deployed.

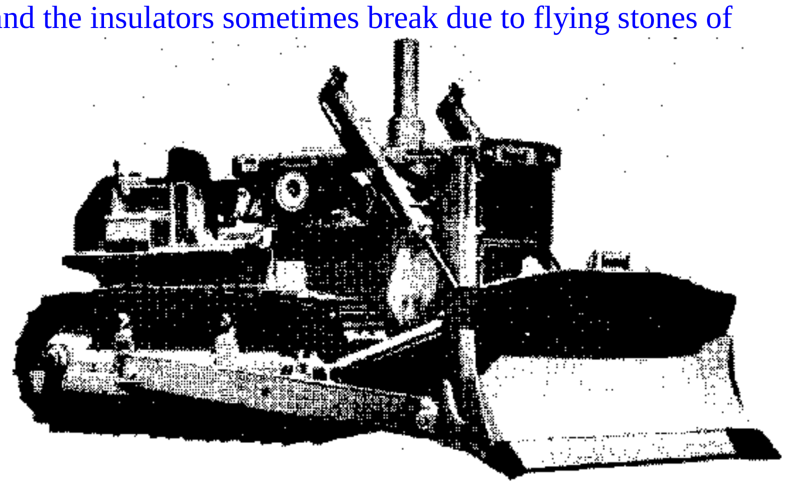
### Diesel-driven vs. electrical equipment

The equipment used in quarries may be diesel operated or electrically operated. Machines which have to move frequently from place to place are operated by diesel engines e.g. bulldozers, scrapers, graders, dumpers, tractors dozers. But the equipment which has to 'work from one site over long periods in a shift may be electrically operated or diesel operated e.g. dipper shovels, draglines, compressors, well hole drills, bucket wheel excavators. Permanent or semi-permanent machines are always powered electrically e.g. large centrally located compressors, pumps, etc.

An electric shovel avoids fuelling problem, is comparatively quiet, simple and maintenance cost is cheaper than for the diesel one. In electric shovel motors can be placed so as to eliminate complex gear trains and chain drives, and controls are esay to operate. Initial cost of electric shovel is however higher than for a diesel unit. Ward-Leonard system is the standard method of drive and control on large H.P. shovels and draglines. Dipper shovels of smaller size (upto 3.5 $m^3$) are usually diesel driven, but electric drive is preferred for larger machines. The electric shovel, due to limited length of the trailing cable, operates only within a restricted area and. the trailing cable being heavy needs men to handle it during movement from one place to another. Some shovels are diesel-electric. In this type of drive a diesel engine mounted on the shovel itself drives a generator that supplies electricity to motors which do the heavy work of the machine and the various controls on the shovel. Such drive is found in medium large shovels.

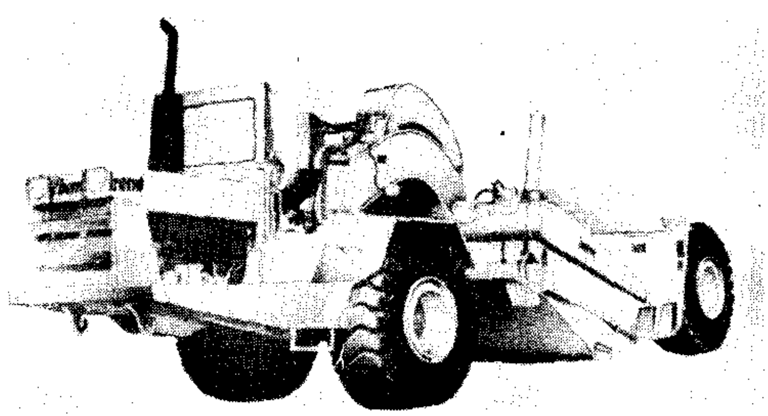
The voltage of small machines is usually medium, 400 or 500, though H.T. voltage (3300-6600) is often essential for large machines like dipper shovels which have to move very little during a shift. The bucket wheel excavators at Neyveli are supplied power at 11 kV through T.R.S. cables and transformers in the machine step down the -voltage to 3.3 kV for some motors and to 400 V for some other motors. Overhead power transmission lines bring the power to a convenient point near the quarry and from there the pliable armoured cables which are sufficiently flexible carry it to the machines. In mechanised quarries it is difficult to construct the power lines entirely outside the blasting zone as trailing cable lengths are restricted by the Electricity Rules and such overhead lines and the insulators sometimes break due to flying stones of blasting.

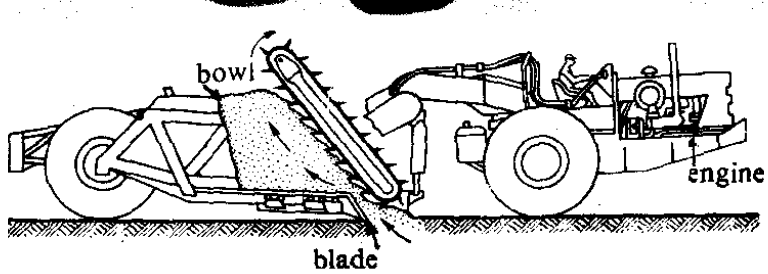
### Bulldozer



A bulldozer is often referred to simply as a **dozer.** It is a tractor with a pusher blade attached 10 the front portion. The tractor is the diesel-operated power unit equipped with either crawler chains or rubber tyred wheels for flitting. 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. (Fig 5.2)

### Scraper






This machine is diesel-operated with pneumatic tyred wheels and has at the centre a bow! fitted with a cutting blade at bottom.

The blade is reversible and can be replaced when blunt. Its working may be compared to that of a lawn mower. As a scraper is pushed forward by a dozer, its blade cuts a thin slice of earth usually between 75 mm and 225 mm thick over a distance of nearly 30 m. The earth is automatically collected in a central bowl whose capacity ranges from 3 $m^3$ to 22 $m^3$ and it takes nearly one minute for loading. When the scraper is fully loaded its bottom opening is closed by the operator through manipulation of a cable (rope) and the loaded scraper, with the bowl lifted, travels to the dumping yard on its own power. At the dumping yard, as the scraper moves, the bottom opening of the bowl is opened and the contents are unloaded in a layer 150 mm to 250 mm thick, over a distance of 30 to 70 m. The bowl is always bottom discharging. Scrapers are unsuitable in soils with stumps, large boulders and hard rocks. When the ground is hard, it is necessary to rip the surface with the help of a ripper before loading by a scraper. Sandy soil is best for a scraper which has to be stopped during rains, if engaged in alluvium. (Fig. 5.3).

Scrapers are used in coal mines for cutting and transporting weathered sandstone as well as coal. The coal excavated by it is however smaller in size.

A Scraper may take 5 to 6 minutes for a complete cycle of loading and unloading if the total up-and-down distance of a trip is nearly 300 m. One-way traffic of loaded and empty scrapers is desirable for good results. One dozer is normally sufficient for every two scrapers used.

The scraper manufactured by BEML has the following **main** specifications.

Flywheel H.P. of engine 332 at 2100 rpm;

Capacity: payload 23000 kg; struck 11.5 $m^3$, heaped 16 m

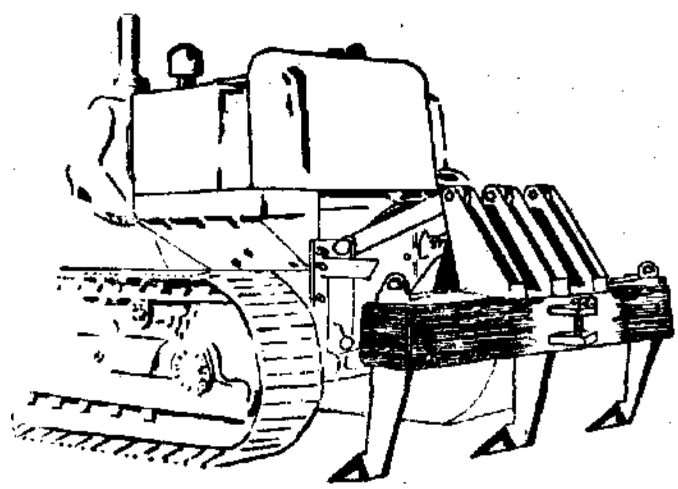
Max. Travel speed (forward) 44 km/hr

Overall dimensions mm: length 12600; width 3470; height 3890.

Net weight (no load): 26584 kg.

## Ripper

A ripper is a machine which cuts, as it travels, 0.6 to 1 m deep furrows in the ground and it can be well compared with the farmer's plough. The ripper is essentially a crawler mounted heavy duty diesel tractor with a ripper attachment as shown in Fig. 5.4. Like a farmer's plough, the ripper with the ripping tool thrust into the ground by hydraulic pressure, travels along close parallels paths, 1.2 to 1.5 m apart and during the travel rips open the ground. The broken ground or rock can be dozed to form a stockpile for convenience of loading or, can be loaded by a scraper. If the overburden or mineral is suitable for ripping its breaking is possible with the help of a ripper and the process of drilling and blasting can be dispensed with. Soft rocks and medium hard rocks, below hardness 5 on Moh's scale, which are laminated and stratified, provide suitable material for ripping. The alluvial surface deposits, weathered sandstones and shales underlying them in the coalfields can be easily ripped and the relative rippability of the rocks can be known with the help of an instrument known as *Refraction Seismograph*



The Refraction Seismograph operates on the principle that "Sound waves travel through subsurface material at different velocities, depending upon the degree of consolidation of the material". It is believed that the same factors that affect consolidation also affect rippability. Thus poorly consolidated material with low seismic wave velocities could be ripped easily, while highly consolidated material with high velocities would be difficult to rip.

Equipment needed for seismic analysis includes a source of a sound or shock wave, a receiver, an electric counter, and a set of cables. The main items are:

1. *Refraction Seismograph:* An electronic counter that determines the time interval between the strike of the hammer and the arrival of the seismic wave at the geophone.
2. *Geophone:* Receiver of sound waves. A *geophone* is a velocity gauge suitable for defecting frequencies in the range of 1-100Hz. The geophone converts the mechanical vibrations into its electrical analogue. This electrical signal is then amplified and transmitted to the monitoring station.
3. *Sledge Hammer* and *Impact Plate:* Source of sound wave transmits sound through earth and also through an impact switch having direct connection with seismograph, through a connecting wire.
4. *A 30 m Tape:* For measuring distances between the geophone and various impact points (wave sources).

The seismic wave is produced by a-sledge hammer striking a steel plate at various distances from a geophone receiver. Immediately upon impact, a wave "front" composed of innumerable seismic waves travels in all directions away from the point of impact, or source. Some of the waves are refracted into the layers of subsurface materials and the angle of refraction is determined by Shell's law which gives the following relationships.

$$\frac{\text{Sine of angle of incidence}}{\text{Wave velocity in upper layer}} = \frac{\text{Sine of angle of refraction}}{\text{Wave velocity in lower layer}}$$

The geophone receiver is sensitive only to the first seismic wave that reaches it. Thus, either the wave which travels the shortest distance, or one which travels a longer path but which includes a high velocity segment, arrives first at the geophone.

In addition to determining the degree of consolidation or rippability of each layer, it is also possible to determine the depth of each layer.

In iron ore areas of Goa the practical results obtained with seismograph were as follows: Seismic velocity in overburden (practically laterite) was 600 to 1,200 m per second. In iron ore it was 1,050 to 1,500 m per second, but in some cases velocities as high as 1,800 to 2,100 m per second were also recorded.

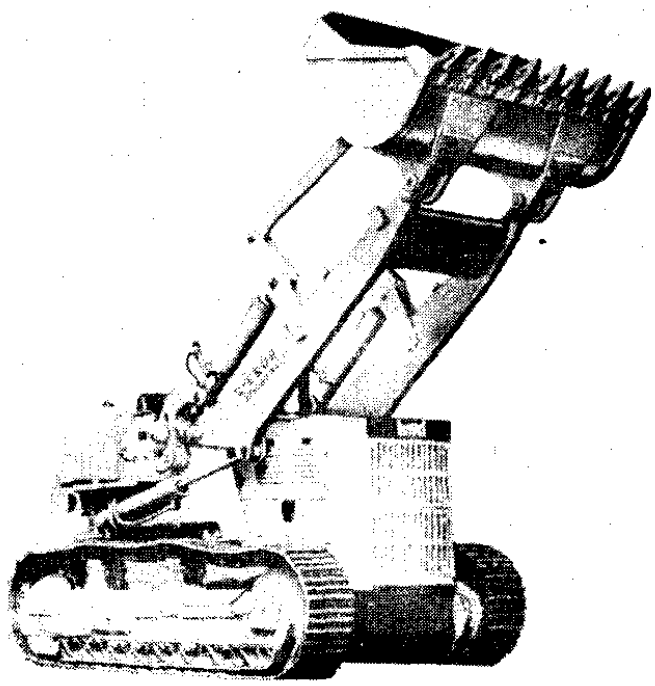
When selecting a tractor for ripping purposes, it is necessary to consider (1) the down pressure on the tooth to determine whether penetration can be accomplished, (2) the tractor H.P. which should be capable of advancing the tooth through the rock and break it, (3) tractor weight which provides traction for full use of the **H.P.** in advancing the tooth.

The tractor speed is 0.8 to 2.5 km/hr during ripping. If the rock is soft it is advisable not to increase the speed but to add one or more ripping teeth. The distance between adjacent furrows during ripping may be 1 to 2 m and the harder the rock, the c-loser are the furrows.

In some rock formations ripping is possible after sparse blasting of widely spaced charges

**Tractor shovel**

It is essentially a diesel operated tractor with a bucket as the front attachment and is called a front-end loader or pay loader. It may be on pneumatic tyres or crawler chains. The tractor shovel attachments consist of a push frame and a bucket that can be raised, lowered and dumped hydraulically or mechanically. The shovel usually has a pusher fan so that the dirt falling from the bucket will not be sucked back towards the operator and engine air intake (fig. 5.5.)



For digging, the complete tractor shovel has to move forward towards the bench and for unloading the contents of the bucket the entire unit has to come back and position itself conveniently to empty the bucket on to a dumper. Its rate of digging and loading cannot, therefore, be as fast as with a revolving shovel,-described later.

Main specifications of two wheel-loaders (B.E.M.L)

| | **WA 200-1** | **Model-3035** |
|---|---|---|
| Bucket capacity $m^3$ | 1.5 | 3.3 |
| Heaped 2:1 (SAE) $m^3$ | 1.7 | 3.8 |
| Flywheel H.P, | 108 at 2,400 RPM | 300 at 2,100 RPM |
| Max. Travel Speed Forward, km/hr | 37 | 31.6 |
| Dumping Reach, mm | 1,025 | 1,300 |
| Turning Radius, mm | 5,620 | 6,300 |
| Overall Height, mm | 3,190 | 4,075 |
| Length, bucket on ground, mm | 6,715 | 9,200 |

Tractor shovels have been employed in some mines to load the stacked mineral at the siding into railway wagons or to push it into ground-level bunkers. Capacities of the buckets are from 0. 57 $m^3$ upwards. Heavy rock buckets for handling blasted rock carry teeth as standard equipment, though the buckets used for coal handling need not be so equipped.

An excavator, technically speaking, is any machine which excavates the rock or earth and swings or transports it, within narrow limits, to an adjacent place or dumps it on to a receptacle like a dumper or railway wagon. In this sense, a tractor shovel which cuts or digs to some extent below the floor on which it stands, may well be considered an excavator—the name *traxcavator* for the tractor shovel manufactured by one company aptly conveys the meaning—but, in earthmoving terminology the term *excavator* covers machines of the following type:—

1) Power shovels like dipper shovels, stripper shovels and back-hoes or pull shovels.
2) Draglines
3) Bucket wheel excavators.

A power shovel is a shovel using electric or diesel motive power for its operation, as distinct from a hand-operated shovel. The functions of power shovels are very simple. Basically, these machines lift fragmented rock, and swing it to a different location such as dumpers or spoil heaps.

The main components are:

1) Propelling arrangements consisting of either crawler chains or pneumatic tyres.
2) A deck or cab mounted on a turn table and housing the prime mover, all the controls for operation, cable (wire rope) drums and the operator's seat. The deck or cab can swing through 360" independently of the propelling crawler chains or tyres.
3) Deck swinging mechanism. When the deck swings, all the equipment mounted on it, including the boom and the bucket, also swings.

A shovel is made in three structural divisions. Anatomically, the top or revolving unit is the head and torso, the mounting or travel unit is the legs, and the various attachments are the arms and hands. A revolving and a travel unit together make up a basic shovel which may be fitted with any of the five front attachments shown in fig. 5.6. The machine may thus become any one of the following: a crane, a clam shell, a dipper shovel, a drag line, a pull shovel or a back-hoe.

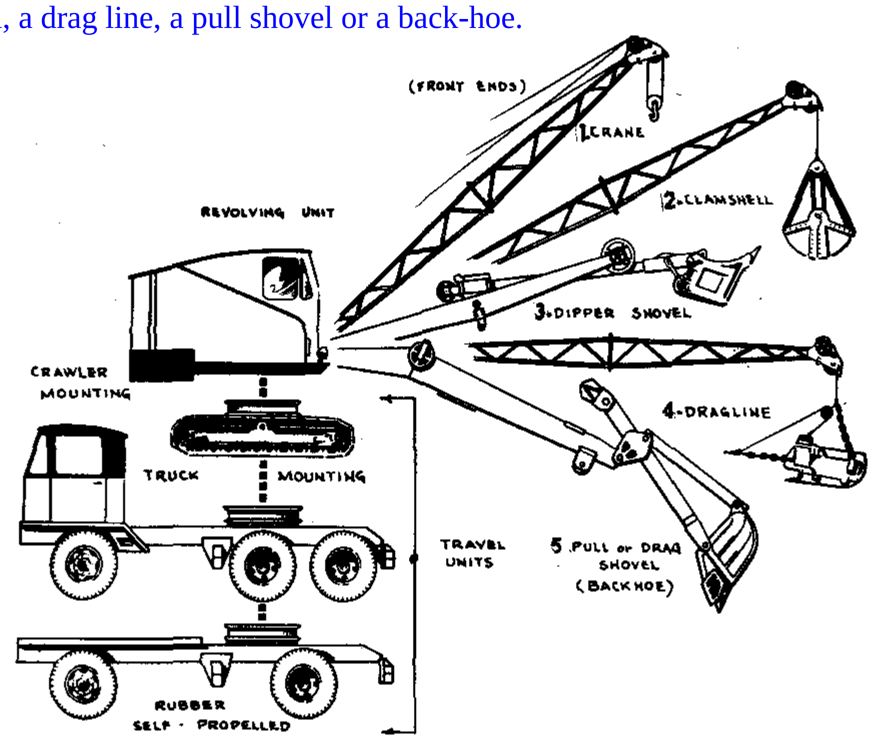



**Fig. 5.6** Various front attachments possible on a basic shovel.

## Dipper shovel

This is a machine employed for excavating soft rock or loading fragmented rock from a bench and is very commonly used in mines. It is usually mounted on crawler chains. Fig 5.7 B shows the principal parts and controls. The cab carries the power unit which may be an electrical motor at 3300JV, supplied with power from an external source through a flexible electric cable, or a diesel engine. The bucket (also called dipper) commonly used may be of 1 $m^3$ to 4.5 $m^3$ capacity. It is used for loading dumpers and for this purpose it has to stand on the floor of the bench. Watery conditions in the quarry are not suitable for efficient operation of this machine, as dumpers have to move inside the quarry. During operation, the crawlers are stationary within 3 to 5 m of the toe of the bench. To load the bucket, the operator crowds it into the fragmented rock with the dipper stick and hoists it. As it moves through an arc in the rock pile, it gets loaded fig. 5.6 A)- It is then retracted and the cab, along with all the machine mounted on it, the boom and the bucket, is swung horizontally through nearly 90° to position the bucket over the dumper. The bucket is bottom-discharging and its door is opened by the trip cable. Normally five buckets are required to load a dumper. The teeth of the bucket wear out fast and when worn out, have to be built up to size by welding. The trip cable lasts for nearly 35 hours and the hoist cable, for nearly 100 hours. In one shift a shovel loads 450 to 500 buckets. Where the dumping yard is away from the quarry a dipper shovel loading into dumpers is advantageous.

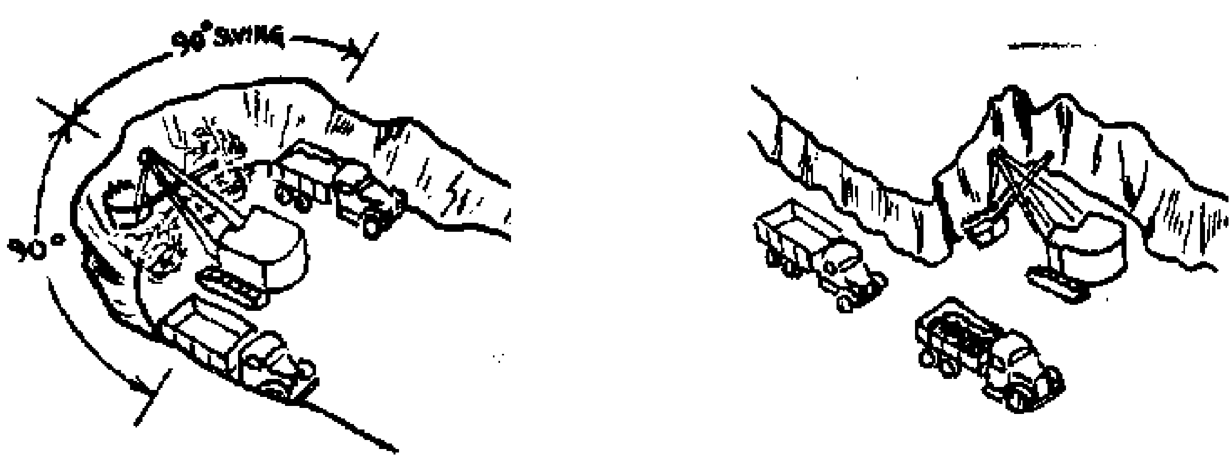



Fig 5.6 A Dipper shovel in operation

Hydraulic shovels which eliminate use of wire ropes (cables) have become popular in recent years. The electric motor or diesel engine mounted on the shovel drives the hydraulic pump and the pressure developed is utilised for various operations of the shovel. Hydraulic motors are of low speed, high torque with hydrostatic braking. One example of such hydraulic excavator is Poclain shovel of Larsen Toubro Ltd.

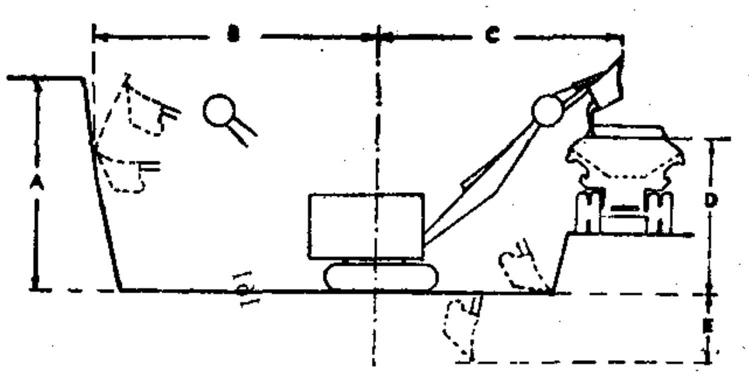



Fig. 5.7 A. Working ranges of a dipper shovel (maximum). Figures in brackets show the working ranges in m of Tata dipper shovel, model 1055 B, at a boom angle of 50°. Boom length is 8.53 m.

A—Cutting height. (10.83 ) B—Cutting radius. (11.96) C—Dumping radius. ( 9.51)

D—Dumping height. (7.25) E—Cutting depth below crawler level. ( 2.51)

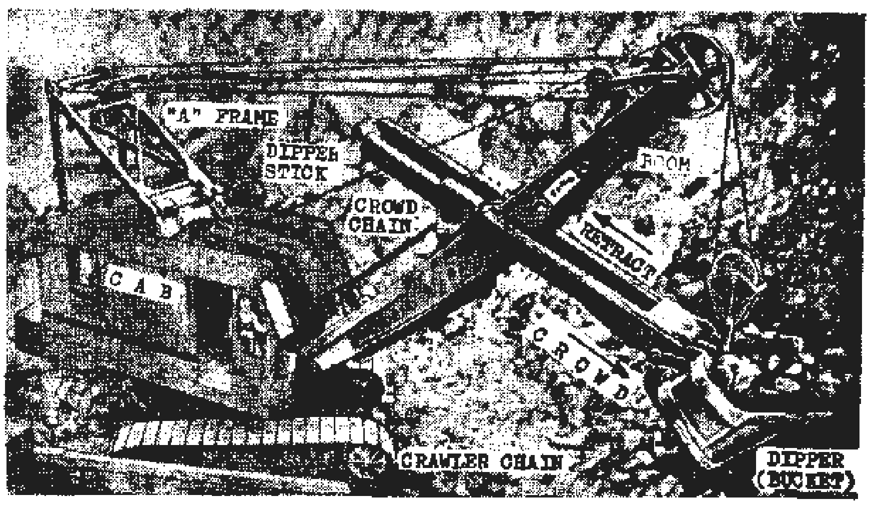



**Fig. 5.7, B. A dipper shovel, model TATA 1055 B**

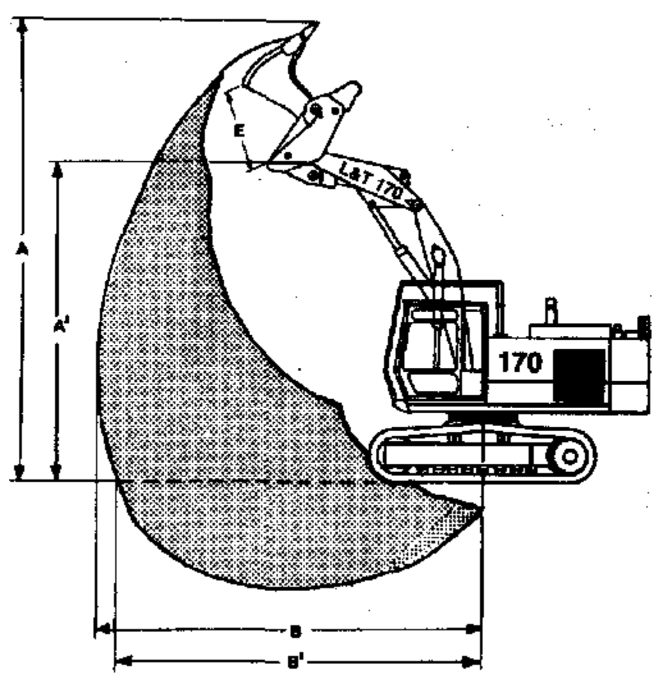



**Fig. 5.8.** Working ranges of L & T 170 **CK-II** bottom dumping shovel

A-8.67 m, A'-5 63 m, B-7.45, B'-7.06 (mm) Hydraulic excavator. Gross power 240 HP.

Dipper shovels commonly employed in Our mines are of 2 m$^3$ - 4.6 m-$^1$ bucket capacities. Only a few mines employ shovels of or 10 m$^3$ capacity, e.g. Matanjkhand Copper Project employs 10 m$^3$ dipper shovels.

Under conditions existing in India the loading capacity of 2 ni$^3$ shovel in good condition and well fragmented rock is as follows:

| | |
|---|---|
| Per hour | 80 passes of bucket. |
| Per shift (8-hours) | 500 passes. |
| Per day (2-shifts) | 950 passes or 190 dumper loads or 1070m$^3$ solid. |
| Per week | 5,800 m$^3$ |
| Per month, dry | 23,000 m$^3$ |
| Per year | 2,53,000 m$^3$ |

Loading capacities or performance of other shovels may be considered as follows:

| | |
|---|---|
| 3.5 m$^3$ capacity | 400,000 m$^3$ per year |
| 4.5 m$^3$ | 550,000 m$^3$ per year. |

**Main specifications of some shovels of B.E.M.L.**

| | Pull shovel (Backhoe) PC 220-3 | Loading shovel PC 650-3 (diesel) | Dipper shovel 182 M-HR-17 (Elec.) |
|---|---|---|---|
| Bucket capacity SAE-Heaped, m3 | 1.0 | 3.8 | 10 |
| Operating Weighing | 22,000 | 67,000 | 3,27,500 |
| Flywheel | | | |
| Horsepower (H.P.) | 148 at 2,100 RPM | 404 at 1,800 RPM | 600 |
| Boom Length,mm | 5,850 | 8,400 | 12,240 |
| Arm Length, mm | 3,045 | 3580 | 8230 |
| Max. Travel Speed km/hr | 3.4 | 4.1 | 1.61 |
| Operating Data Max. digging/ cutting height, m | 9.18 | 10.68 | 12.70 |
| Max. dumping height, m | 6.36 | 7.71 | 7.65 |
| Max. digging depth, m | 6.70 | 3.43 | - |
| Max. digging reach, m | 10.18 | 10.00 | 17.42 |
| Overall length, mm | 10,000 | 9540 | N.A. |

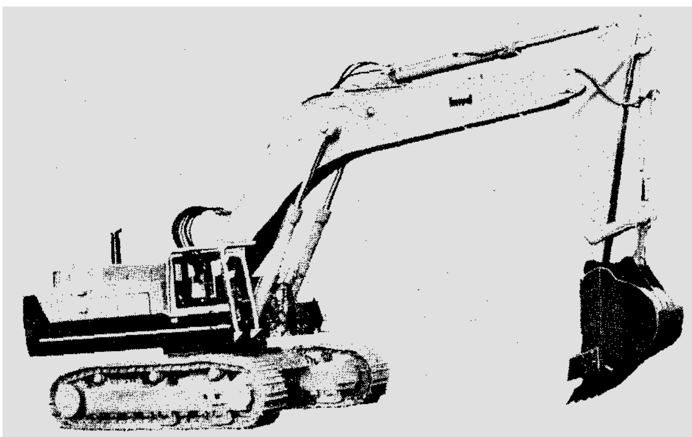


**Fig. 5. 9. A pull shovel or** back hoe.

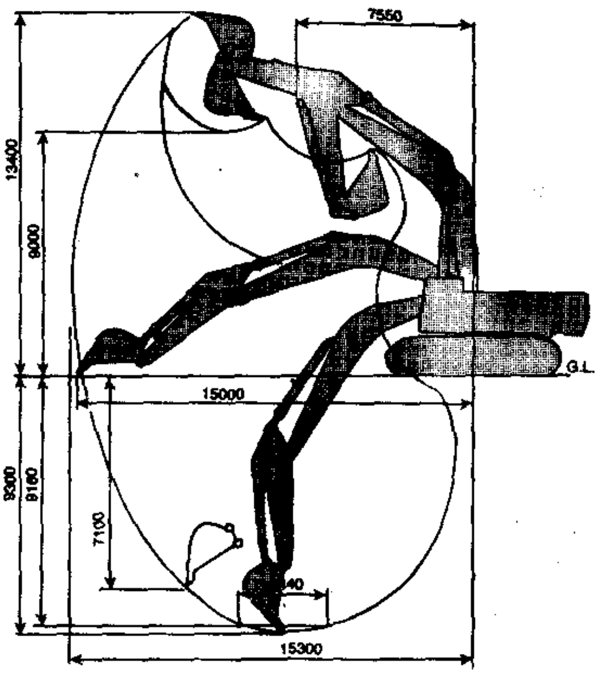



**Fig. 5.10** Above. Pull shovel (Backhoe) Model PCM000-1 of Bharat Earth Movers Ltd. Hydraulic. Wt. 95,000 kgf, 405 kW, bucket capacity 4.3 cubic metres. Working ranges of the **same** backhoe.

**Stripper shovel**

A stripper shovel is only a modification of dipper shovel with a long boom and is used for casting fragmented rock or earth into a dump of overburden. It is mostly deployed for overburden.

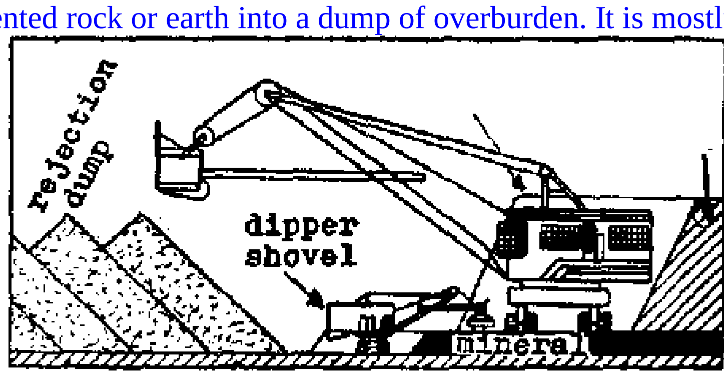



**Fig. 5.10.** -Quarry working with stripper and dipper shovels.

**Pull shovel or hoe**

Fig. 5 .9 show a pull shovel, which is also known as a hoe, back hoe, drag shovel, or ditching shovel. It is used for loading dumpers and its best application is for digging below the level on which it stands. The shovel and the dumpers can stand al a higher level free from water and mud of the quarry floor. As the attachments to the bucket are by dipper stick and not by cables, the bucket is under positive control of the operator and therefore suitable for hard digging.

The shovel is used for stripping top soil, and making shallow cuts and trenches upto a depth of 3.5 to 6 m. Compared to dipper shovel, the hoe is slower in digging and less efficient for loading trucks.

In deep digging, the face should be kept fairly straight and the shovel should be as far back from the edge as possible, otherwise there may be danger of caving of the edge.

**Dumpers or tippers**

These are heavy duty trucks with a container-body of steel open at the top for receiving material loaded mechanically by tractor shovel, dipper shovel, dragline, etc. All dumpers/tippers are provided with arrangements to lift the loaded body by utilising hydraulic-pressure to force a ram out. The body swings from its horizontal position round a fulcrum through nearly 70° to dump its load and the hydraulic system also functions to pull the body back on its seat i.e. the chassis. Fig. 5.11. shows a typical hydraulic system layout for the tipping gear of a dumper. From an oil tank oil flows by gravity to hydraulic pump. When the driver engages the power take off (P.T.O) control lever, power from the engine is transmitted from the transmission countershaft to the power take off which drives the pump. The oil under high pressure from the pump goes to the control valve whose lever can be manipulated for 4 different positions.

*(a) Raise position:* High pressure oil goes through the hose pipes to the bottom of the hoist cylinder and the ram is then forced out. Oil at the top of the hoist travels back to the control valve through the hose connected to the piston rod.

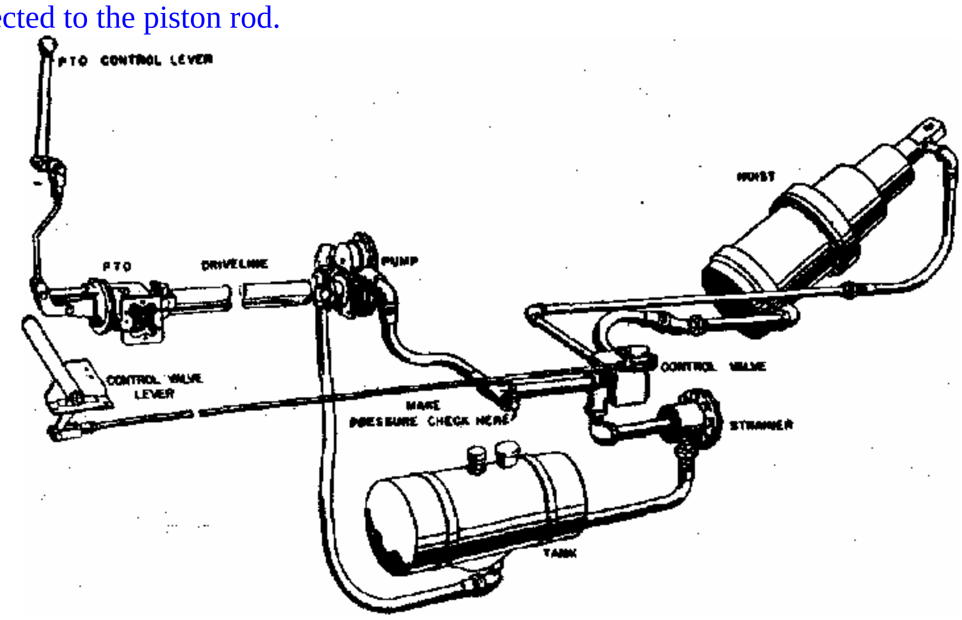



Fig.5.11 The tipping gear for dumpers

*(b) Hold position:* Both the passages between the control valve and hoist arc closed so that oil at the bottom and top of the hoist is at a stand still and the latter is unable to move in either direction.

*(c) Float position:* Both hose passages between the control valve and hoist are open so that oil at either end of the hoist can flow either way. The hoist can then travel in either direction depending upon the direction in which the force is applied.

*(d) Lower position:* High pressure oil goes to the top of the hoist which then telescopes itself by the oil pressure and the oil at the bottom of the hoist travels back to the tank via the control valve. The body is thereby lowered on to the chassis.

Steering on all the heavy duty dumpers is mechanical but assisted by hydraulic power, generated by the engine. The dumper operator's exertion is thereby considerably reduced.

Mechanical transmission from the engine to the rear wheels is the standard practice now-a-days, though for some years the rear wheels were driven by individual electric motors controlled from operator's cabin. Medium sized mechanised quarries employ dumpers of 25-50 te carrying capacity. 50-60 te coal haulers are on the manufacturing line of B.E.M.L. and Hindusthan Motors. Future planning of large projects is for employment of 100-150 te dumpers which will be fed by shovel of 8-10 $m^3$ capacity. Bottom discharging coal haulers of 55 te payload, 43 $m^3$ struck capacity (model GB 60C) are manufactured by BEML

Brakes on dumpers are operated *by* compressed air (Fig. 5.12). Some dumpers are equipped with *hydraulic retarder* (hydrotarder). This is a device used on some trucks and dumpers to prevent the speed from exceeding certain limits when travelling a steep down-slope and also to produce a braking action on the vehicle. In a way, it acts as a governor. It uses the hydraulic friction to produce the braking action. Unlike the regular brakes, the hydrotarder will not completely stop the vehicle but will slow it down preparatory to stopping with the familiar friction brakes, operated by compressed air or hydraulic pressure.

The retarder essentially consists of a vane type rotor turned by the drive shaft, a fixed casing or stator fitted with vanes and an oil circulation system.

The machines deployed in the opencast mines, at the crushing and ore preparation plant have to be of matching capacities. At **Kudremukh** Iron Ore Project, one of the largest opencast mines in India, the capacities of some of the machines are: shovels 10.7 $m^3$, production trucks 108 te, front end loaders 10$m^3$, electric drills for 310 mm dia. blast holes, gyratory crushers 4000 te/hr.

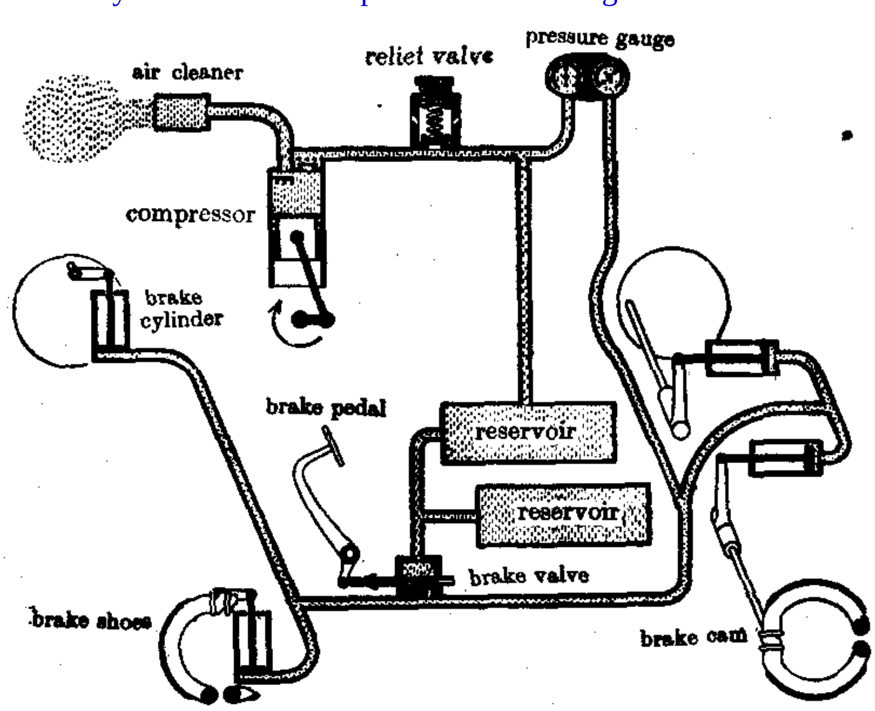
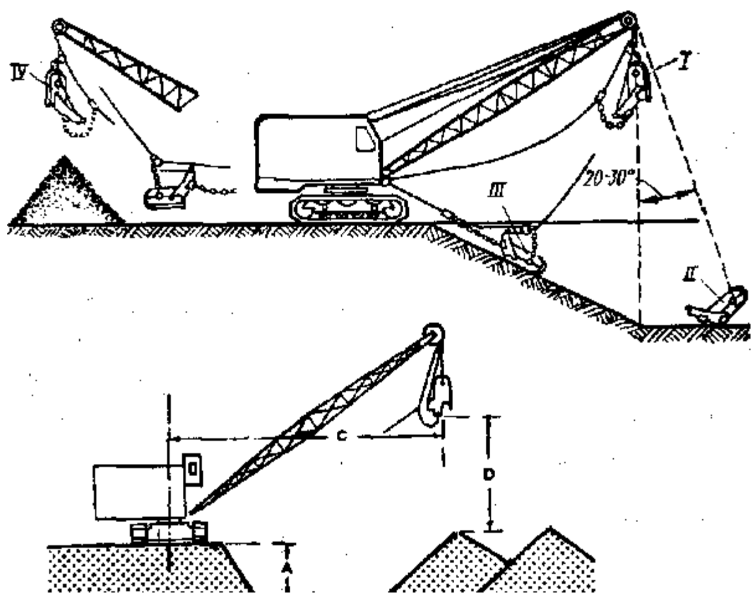



Fig. 5.12. Schematic arrangement of compressed air brake

## Drag line

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 (Fig. 5.13). 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 nearly 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 one 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 the limited area of the dumper delays the cycle of operations 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.




**Working ranges of a dragline**

A—Digging depth. C—Dumping and digging radii, D—Dumping height

**Fig. 5.13**

(Above) **A dragline** showing the bucket in various stages

1-Bucket empty, II-Bucket starts digging, Ill-Bucket being dragged and getting loaded, IV-After a swing of the boom bucket unloaded on 9 spoil heap.

### *Loading capacity of a dragline*

A dragline is capable of dealing with the following quantities of rock/earth (solid) in a year (12 to 14 hours work daily)

| **Bucket size** | **Million m$^3$** |
|---|---|
| 4.5 to 7.5 m$^3$ (6 to 10 cyd) | 0.25 to 0.75 |
| 11.5 to 15 m$^3$ (15 to 20 cyd) | 1.5 to 1.7 |
| 23 to 30 m$^3$ (30 to 40 cyd) | 3 to 4.5. |

A drag line may be crawler mounted or of walking type. Crawler mounted machines have travelling speeds of 0.25 to 5 km/hr. A walking dragline has a travelling speed of 0.18 to 0.6 km/hr.

## Road grader

This is a machine for levelling the road surface by smoothening out the ups and downs and for casting aside the boulders on the road. It is always pneumatic lyre mounted with only rear wheel drive and the front wheels are small. The grading blade is attached to a circle that is hung from the overhead frame and pulled by a drawbar fastened to the front of the frame. The blade is usually 3.5 to 4 m long having replaceable edges on the sides and bottom. Steering is direct-connecting mechanical by a hand wheel though a hydraulic booster is fitted on some models (Fig. 5.14)

Fig. 5.14. Road grader.

The motor grader (Model GD 605 R-2) of B.E.M.L. has the following main specifications: Engine flywheel HP 145 at 1800 RPM; operating weight 12,650 kg; Max. Drawbar pull 7,280 kg; Max. speed Forward-43.6 kmph; steering— full hydraulic; overall length-8415 mm; width 2375 mm; height-3200 mm, minimum turning radius 10.4 m.

## Rock drills

Rock drill is the term applied to all machines using air for drilling holes into rock by combined percussive and rotary action. The hole diameter is normally upto 100mm.

The rock drills are classified mainly as follows:

(1) Jack hammers (also called *Sinkers)*

(2) Drifters.

(3) Stopers.

(4) Wagon drills.

A jack hammer, so familiar to mine workers, is a hand-held and unmounted drill used for vertically downward drilling. It weighs from 15 to 25 kgf and is used for drilling upto a depth of 2 m (rarely 3 m); hole dia. is generally 30 to 37 mm and rarely 50 mm. In a few cases a jack hammer may be mounted on an air leg. Though ordinarily used for dry drilling, it can be adapted for wet drilling as well.

A drifter is a mounted drill, generally designed for horizontal drilling; It is heavier than the Jack hammer and is used in quarries and for tunnel driving. The widely used mounting is the column and arm and the drill may be used for wet as well as dry drilling. Its working is like a jack hammer.

A stoper is a drill for drilling upward and derives its name from its widespread use in mine slopes. It is used normally for wet drilling.

A wagon drill- is essentially a drifter type drill capable of movement up and down a vertical guide and mounted on a portable frame fitted with wheels. The hole dia. is from 50 to 100 mm and the depth drilled ranges from 3 to 15 m.,

Compressed air was the motive power for wagon drills till recently but now-a-days some wagon drills are operated by hydraulic power, as hydraulic power is more efficient than compressed air power.

## 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 to38 mm (rarely upto 50 mm) up to 3 m depth. 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 drill 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 and 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. (See Vol. *3* for more description).

## Wagon drill

A compressed air operated drifter mounted on a mobile frame and capable of travel up and down a mast is known as Wagon drill. The frame is usually tyred wheel mounted though crawler chain mounting is provided in a few models. Tyred wheel mounted wagon drills can be pulled by the operator and his helper to the hole sites on a level ground. A wagon drill, as stated earlier, is used to drill holes of dia. varying from 50.mm to 100mm for depth of 3m to 15 m. The mast for the drifter is usually 3 m long providing for nearly, 3 m vertical travel of the latter. This travel is possible with the help of a comp. air driven feed motor through chain (known as chain feed). The drifter provides the rotary motion as well as the percussive action to the drill rods, and in turn, to the drill bit. The drill bit is detachable X type with tungsten carbide insert. Compressed air fed through the hollow drill rods blows away the cuttings to the surface. Total meterage drilled in an 8-hour shift is 60-70 m in rocks like

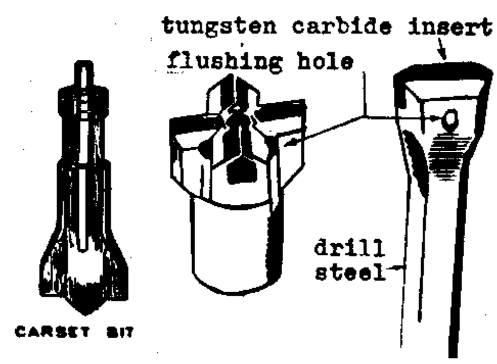



Fig. 5.15
Common types of drill bits

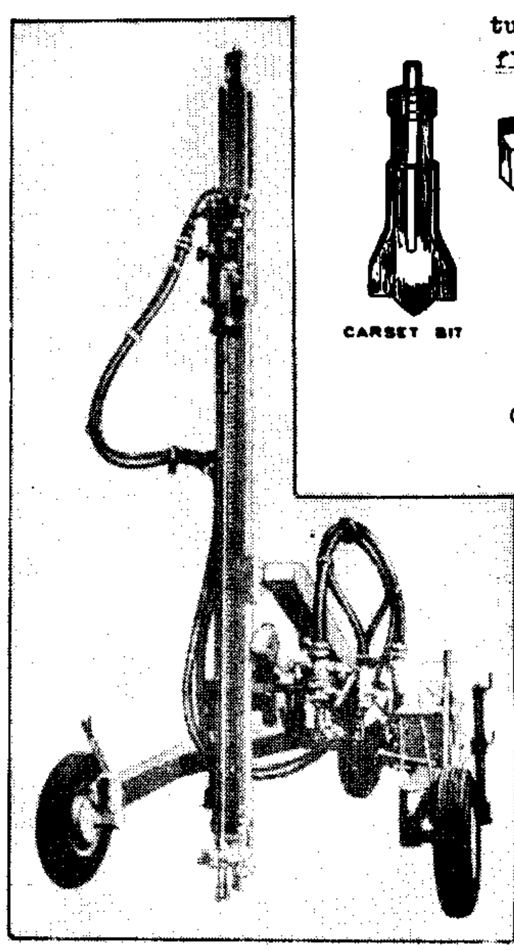


Fig. 5.16
Wagon drill Model BVB 25 of Atlas Copco suitable for drilling holes of dia. 50 to 115 mm. It may be fitted with a heavy duty rock drill (drifter) or with a down-the-hole-hammer.

sandstone, coal, etc. including the time spent on shifting the drill from hole to hole. The mast is capable of swivelling from vertical to a horizontal position and it can be kept fixed at any angle between the horizontal and the vertical, thereby facilitating vertical, horizontal or inclined drilling upto40°. The drill is not self propelling, and receives air from external compressor (Fig. 5.16).

The maximum air consumption is 8 to 19 $m^3$/min. of free air at 6 kgf/$cm^2$ including air blowing for drill bit of 60-75 mm dia.

Though a detachable X-bit is the drill bit on most of the wagon drills, some wagon drills used for 100 mm dia. holes use down-the hole hammers. Such down-the-hole hammers are used for larger dia. holes also and are described a little later.

## Down-the-hole hammers

In a large size wagon drill using a drifter a considerable portion of the drifter's energy is utilised in overcoming the inertia of the drill string making up the column of the drill rods and in rotating them. Such loss of the drill energy increases with depth. .This waste of energy is considerably reduced by the use of the down-the-hole hammer. The drill bit used may be a carset bit (a X-bit with little modification) or a button bit which is fitted in the hammer. The comp. air going down the hollow drill rods forces the piston which directly hammers the drill bit without any drill rod in-between. The number of blows is from 500 to 2400 per min. When using down-the hole hammer the drifter is replaced by a rotary head placed at the top of the drill string and driven by a built-in piston type air motor. The rotational speed of the drill rods is nearly 15-25 r.p.m. The rotary head is also used to tighten and loosen threaded joints on rods. The-up and down travel of the drill rods is by a chain feed. Fig. 5.17 shows down-the-hole hammer, type 100 ASS used on HALCO drills for holes of 100 mm to 125 mm dia. Its specifications: Outside dia. 89 mm, length without bit 94 cms; weight without bit 31 kg.

Air consumption at 7 kgf/$cm^2$ is 5.5 $m^3$/min.

(The **largest well hole drills** in India are at Kudremukh iron ore project — electric rotary drills for 310 mm dia. blast holes The matching equipment at Kudrcmukh has the capacities; electric shovels, 10.7 $m^3$; production trucks, 108 te; front end loaders, 10 $m^3$)

## Hydraulic wagon drill

Some of the heavy duty wagon drills are powered by hydraulic pressure system. Fig. 5.18 shows a hydraulic wagon drill, model ROC 810 H manufactured by Atlas Copco (India) Ltd. It is equipped with a rock drill model COP 1038 HB manufactured by the same company. In the drill, compressed air is replaced by hydraulic pressure and the prime mover for the hydraulic power pack is an air cooled diesel engine. The absence of exhaust air results in a much lower noise level when compared with air-powered rock drill. It can drill holes of dia. 65 mm to 327 mm and can therefore be used as a well hole drill for 127 mm dia. holes for depth upto about 12 m. The hole is flushed with compressed air at 10 kgf/$cm^2$. The rate of penetration in hard rock is generally 1 m/min using 90 mm dia bit. The rock drill 1038 HB is equipped with a hydraulically powered rotation motor whose speed can be varied from 0 to 200 r.p.m. and easily adapted to prevailing rock condition. The hydraulic system incorporates indicators which point out any fault or malfunction in the system, The boom system is operated by hydraulic pressure.

Automatic disc brakes contribute towards increased safety for the operation when travelling along steep inclines.

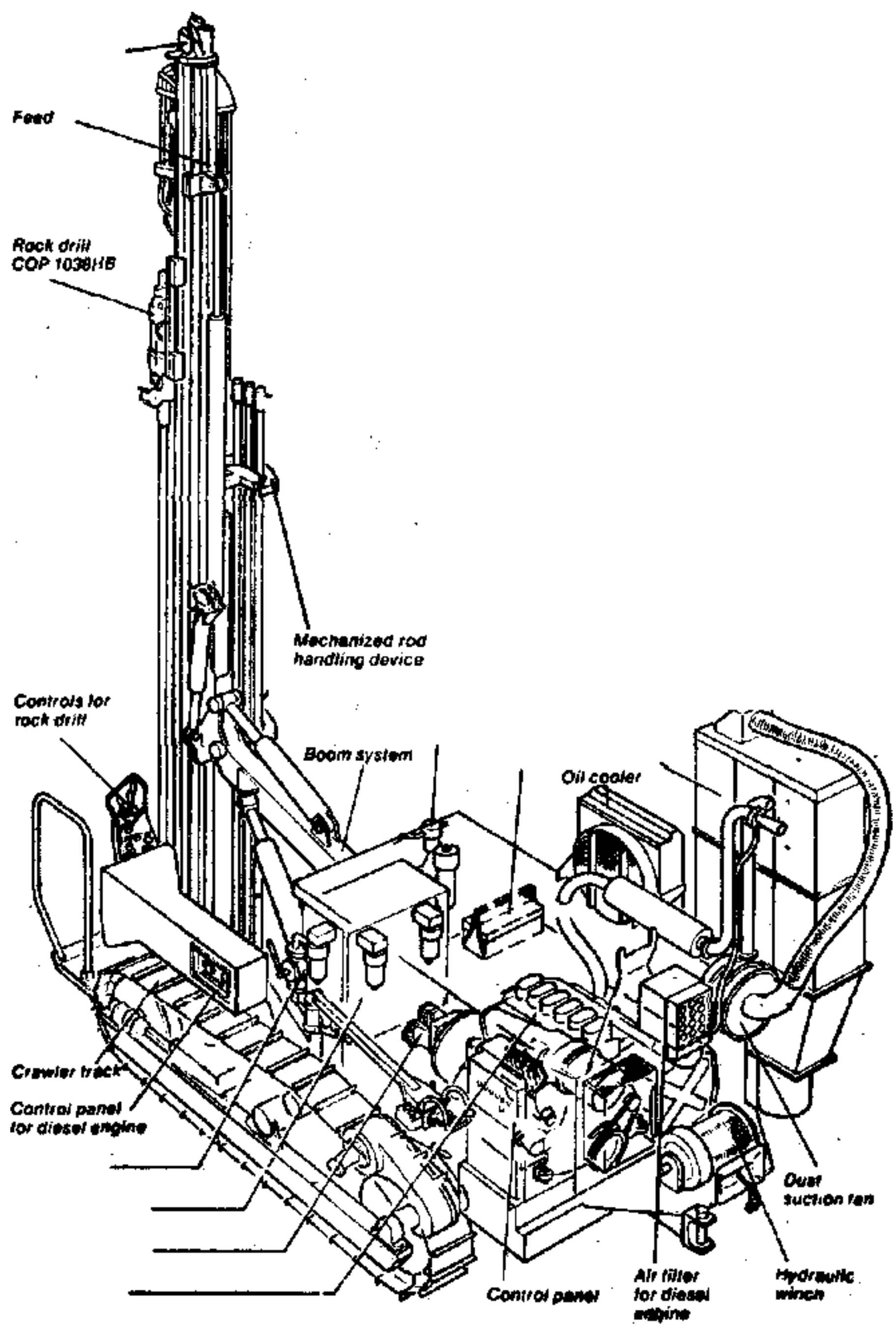



Fig. 5.18. Hydraulically operated wagon drill; model ROC 810 H *Courtesy of Atlas Copco (India) Ltd,*

## Well hole drill

This is usually a crawler mounted drill operated by a diesel engine or by an electric motor which is supplied power from an-external source through a trailing cable. It drills holes of 125 mm to 300 mm diameter, depth varying from 6 m to 18 m. It has a long mast, 3 m to 6 m, to accommodate the length of the drill rod. The mast is collapsible and the drill should not be moved over an, appreciable distance with the mast raised. The drills are of percussive as well as rotary type but the latter is common in coalmining areas. The drilling tool of rotary drill is a tricone bit on most of the drills but on the machines which are known as "down-the-hole percussive drills" (sometimes called "down-the-hole hammer drill"), the drilling tool is a cross bit (carset bit), or a button bit. In down-the-hole hammer drill the assembly of the drill bit and its short length pipe is called *down-the-hole hammer* (see fig. 5.17).

In the rotary drill the drill string is rotated by the prime mover through suitable gearing. The tricone bit attached at the end of the drill string is thus rotated and it is kept pressed against the rock by hydraulic or pneumatic pressure.

In down-the-hole percussive drill the rotation of the hollow drill rods is provided by a rotary head placed at-the top of the drill String and driven by a built—in air motor. The air motor is also used to tighten and loosen threaded joints on rods and bits. The up or down travel of the drill rods is by a chain, operated by a reversible piston type air motor (Chain Feed). A compressor mounted on a well hole drill helps to clean the hole as it is drilled. During drilling, the machine is levelled with the help of 3 hydraulic jacks. Normally twenty holes, each 9 m deep, can be drilled in one shift in sand stone, shale and coal. Only vertically downward drilling is possible on most models though holes 20° off vertical can be drilled by a few machines. On some machines the drill-rods and the tool are at one end and on others, in the middle of the machine. The latter arrangement is permissible where the burden of blast hole is large and the ground at the quarry edge strong enough to support the weight of the machine; but where this is not practicable drill rigs with the drill rods and tool at one end have to be used.

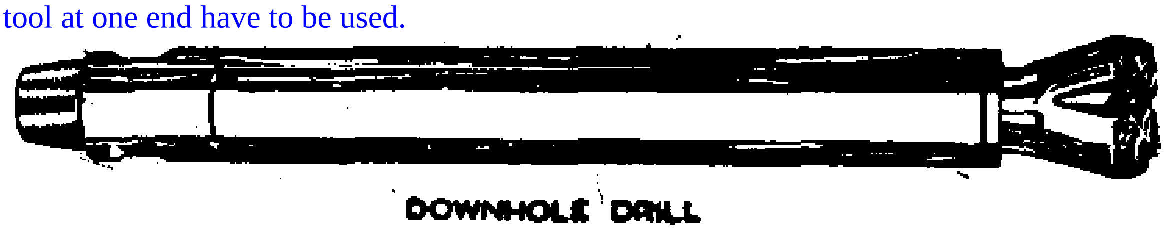



**Fig.** 5.17. Down-the-hole-hammer.

A Well hole drill appears like a wagon drill suitable for large diam. holes, e.g. the wagon drill shown in fig. 5.18.

A rotary well hole drill can drill in a shift of 8 hours nearly 20^ holes, 200 mm dia. each 9 m deep, in sandstones, coal, shale and similar rocks.

## Inclined drilling

Where the overburden consists of soft rock which can be conveniently removed by ripper and scraper-dozer combination an alternative to ripper is the method of drilling nearly horizontal blast_ holes and blasting them. Vertical (or nearly-vertical) blast holes have to be drilled where the overburden consists of hard rock like sandstone, laterite, etc.

30° off vertical may be considered to be the limit for inclined drilling of nearly-vertical holes on a bench. Larger angle increases the length of the hole, difficulties in charging it with explosives of fixed-shaped cartridges, proportion of stemmed section of the hole and gives face inclination unsuitable for travel of the shovel bucket.

The toe of a bench can be removed by extra drilling of short length horizontal holes only in the toe and blasting them, or by resort to inclined drilling of the main (nearly vertical) blast holes. In vertical as well as inclined blast holes for the face, it is always essential to extend the hole slightly beyond the level of bench floor to secure proper fragmentation of toe if the hole-is terminating in hard rock.

## Layout of a mechanised quarry

The layout of a quarry depends primarily on

(1) shape, size and dip of the deposit.
(2) proposed depth upto which mining activity is planned to extend,
(3) thickness of the overburden,
(4) surface topography,
(5) desired production,
(6) transport system for mineral and OB,
(7) arrangement for disposal of debris,
(8) type of mechanisation and finance available for it.

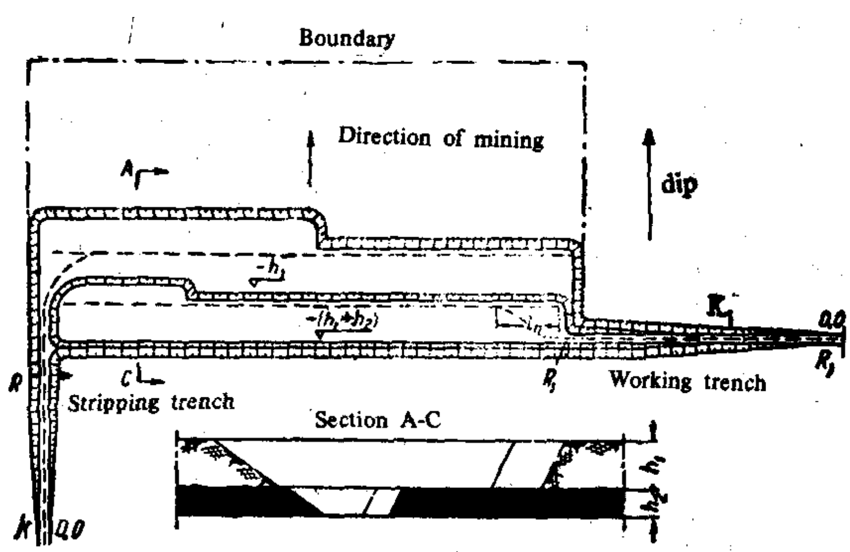



Fig. 5.19. Layout of a mechanised quarry with separate trenches

The layout of a quarry should depict the following:-

(1) Position of OB benches and mineral benches.
(2) Access to the benches and exit roads for the dumpers.
(3) Position of back filling area.
(4) Location of machinery which operates from one site over a long period such as a shovel, dragline, bucket wheel excavator, in relation to the benches.

Fig. 5.19 shows the layout of a mechanised quarry using dipper shovels, dumpers and well hole drills, the common equipment 'in most of our mines. The property is divided into areas along the strike, each area being nearly 100 to 300 m long. In the initial stages a box cut (trench) RK is made with the help of scraper, dozers or small capacity (2 $m^3$) shovels to suit the depth of the trench. Such trench is essential for a shovel which stands on the floor of the quarry and operates on benches. Some amount of blasting may be necessary in making a trench in hard rocks. In the advanced stage of the quarry two Trenches RK and R|K] are in use, one for the OB and the other for the mineral which goes to the crushing plant. The OB bench and the mineral bench are usually parallel to each other and advance towards the quarriable limit of the mine.

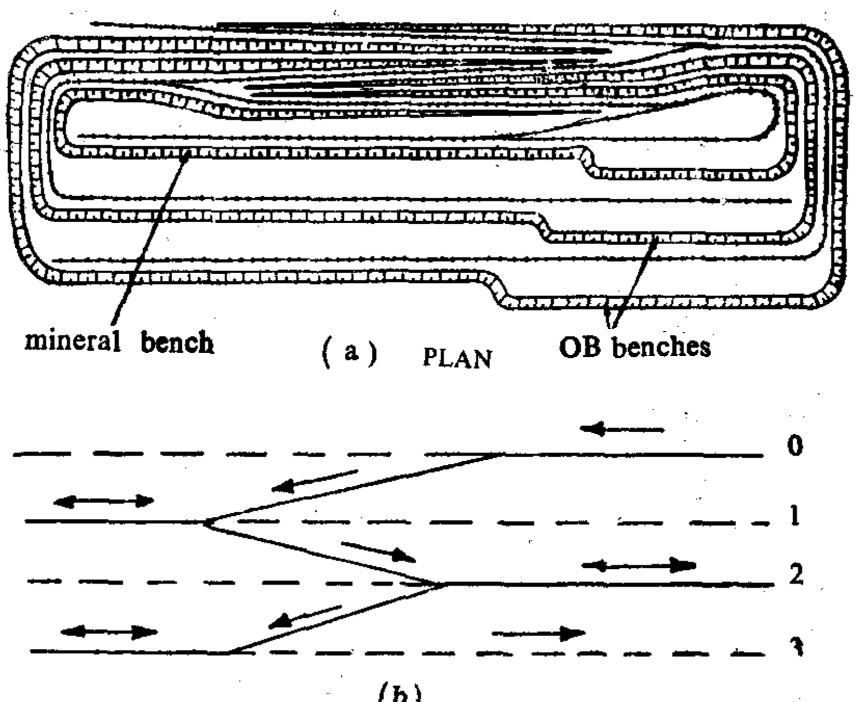
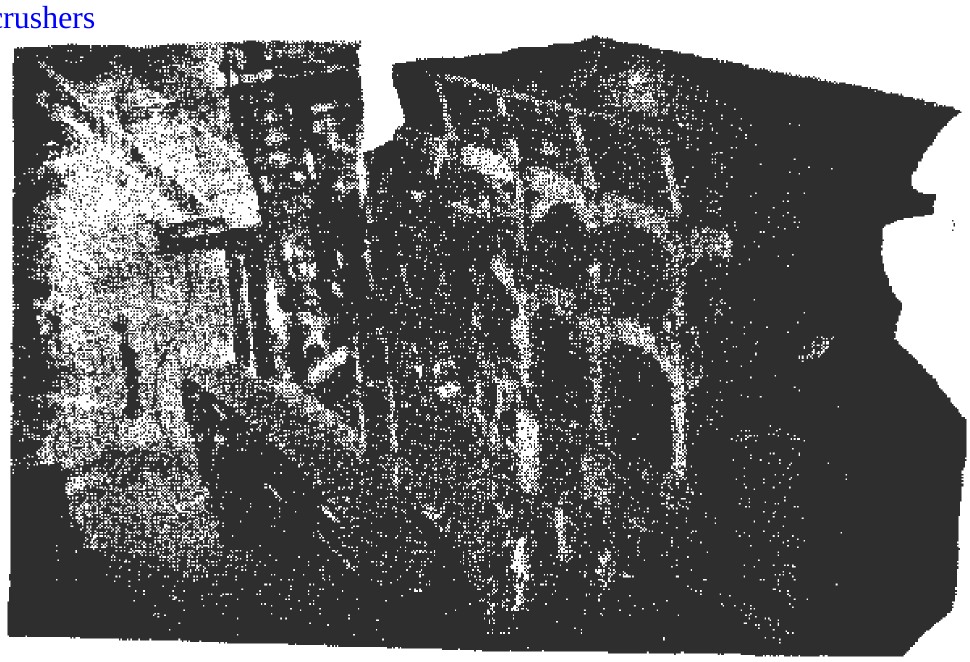


Fig. 5.20. Switch back layout (Vertical section exaggerated).

(b) Fig. 5.20. Switch back layout (Vertical section exaggerated).

In the figure, hi and hi are OB bench and mineral bench respectively. If the OB and mineral are of considerable thickness,, there may be two or more benchs for OB as well as for the mineral. In such cases ramps have to be provided between adjacent benches. Provision of two trenches, one for OB and the other for mineral, avoids congestion of dumpers on the haul roads. This layout can be modified to have a crusher and outgoing belt conveyor on the lower end of mineral trench. In-pit crusher with feeder breaker is the trend_ in open cast mines these days. Mineral is then transported by conveyor belts to coal handling plant or mineral processing plant. Some of the ntschanised opencast mines in South Eastern Coalfields Ltd., are now having in-pit crushers



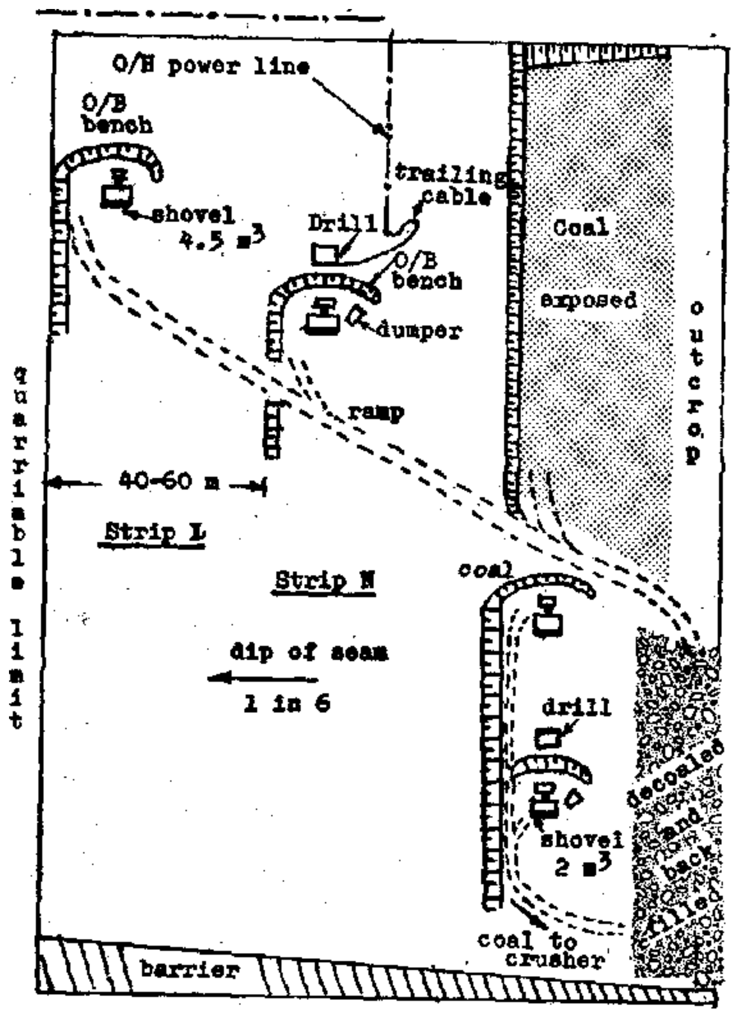
**A mobile crusher in a** mechanised quarry receiving **finishing touches** in the manufacturing shop.

*Courtesy of Simplex **Engg.** & Foundry Works Ltd., **Bhilai.***

Such layout of two trenches is not suitable it tne mineral is at much depth as formation of trenches would involve removal of large volume of earth and rock. Layout of one trench for both mineral and OB may then be adopted.

For deeper quarries switchback system of track layout is advantageous. Fig, 5.20b shows the tracks as they would appear in a vertical projection (exaggerated) for a locomotive-mine car combination of transport system. Numbers 0, 1, 2, 3, mark the levels of the floors. Thus to get from level 0 to working floor 3 a train must follow the route marked by the arrows. Switchbacks entail a big loss of time for shunting operations. Each switchback should be sufficiently long to hold a train and railway switches, or else to allow enough room for mine cars to turn round.

Fig. 5.21 shows a modified layout depicting the position of various coal and OB benches in a quarry (Shovel-Dumper Combination) at an advanced stage if OB is backfilled in the decoaled area. The seam is considered to be 18m thick dipping at 1 in 5.



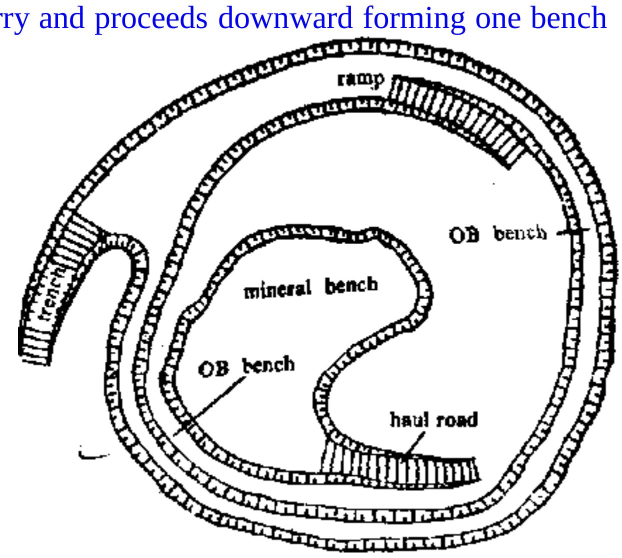

The benches formed are sometimes designated as Bench No. 1, Bench No. 2, etc. or by the reduced level of the floor of the bench e.g. 500 metre bench, 510 metre bench, 520 metre bench, etc.

Pumps are installed in the quarry which has to be kept nearly dry for operation of shovel and dumpers. The usual arrangement is to have two or three pumps as a semi permanent installation fed by small portable pumps.

The area may be divided into strips of 45 to 60 m width along dip rise. A width of 45 to 60 m permits easy movement of dumpers, the minimum width required being 18 metres. Each strip provides a bench, which is equipped with *a* shovel and a well *hole drill Daily* progress of shovel in the strips L, N, is along dip rise direction, but the advance of the bench is along the strike when considered over a quarter or half year. The quarry excavation of course advances towards the dip to the quarriable limit.

The shovels S1 and S3 work on stone benches and the others (2 m$^3$; work on coal benches. The overburden may be taken to dumping yard away from the quarry, or dumped in the decoaled area. Suitably graded roads, not steeper than I in 10, with rumps between the strips, are provided as shown in the figure. Shortage of shovels and ancillary equipment may require the management to work only a few benches at a time and not as many as shown in the figure.

Fig. 5.22 shows a spiral layout for dumper transport. As the haul road runs along the periphery of the quarry, excavation commences from the boundary of the quarry and proceeds downward forming one bench at a time. Such layout is an advantage in hill-top deposit which may be worked in horizontal slices.




## LIGNITE MINING AT NEYVELI & BUCKET WHEEL EXCAVATORS

In India lignite is excavated on a large scale at Neyveli Lignite Project by mechanised opencast mining employing bucket wheel excavators and other heavy duty matching equipment. India is among the four countries after West and East Germany and Australia to engage in lignite mining on a large scale and Neyvcli mines are the largest lignite mines in Asia 'forked by Neyveli Lignite Corporation

The Neyveli Lignite Project is located at Neyveli in South Arcot District of Tamil Nadu. Situated in far South, having no coal mines, the project fulfils to a great extent, the requirements of solid mineral, fuel in that region and has, therefore, a special significance. Lignite based two pit-head thermal power stations, one of 600 MW and the other of 1470 MW capacity contribute nearly 40% of electricity consumption of Tamilnadu.

Lignite is a low calorific fossil fuel with a gross calorific value of 2600 to 3000 kcl/kg (as received samples) with the following proximate analysis:

Moisture 45-60%; ash 3-6% (in some cases even less than 3%; V.M. 22-26%; F.C. 20-26% (in a few cases even less than 18%; grindability index 108 to 127.

The average bulk density (in-situ) is 1.15 gm/cc or 1.15 te/m$^3$. Total sulphur content is less than 1%

The Neyvcli Lignite Complex consists of the following units, all based on lignite (in 1995)

(1) Opencast mining project, No. 1 Mine, to extract 6.5 million tonnes/year of lignite proposed to be expanded lo 8.5 MTe/yr in the second expansion scheme. Ultimate planned capacity 10 Mte/yr.

(2) No. 2 Mine Project. It has an instated capacity for producing 10.5 million tonnes/yr lignite. This mine caters to the requirements of thermal power station If which has been expanded from initial installed capacity of 3 x 210 MW to 8 x 210 MW.

(3) Two thermal power stations, one of 600 MW and the other of 1470 MW capacity, as stated above.

(4) Fertiliser plant lo manufacture urea; capacity 1,30,000 te/yr.

(5) Briquetting and L.T. carbonisation plant producing carbonised briquettes called LECO for domestic use. Capacity 2,62,000 te/yr. Certain carbo-chemicals are produced as byproducts.

(6) Clay washing plant, capacity 6000 te/yr of washed clay.

Reserves of lignite at and around Neyveli spread over 400 $km^2$ are estimated to be around 3300 million te. Out of these, mineable reserves within the parameters of not less than 8 m lignite thickness and not more than 110 m overburden thickness work out to be 1500 million te.

No. 1 mine is spread over an area of about 15 $km^2$ with deposits of 230 million te of lignite. Average thickness of lignite seam is about 15 m at a depth of 70 m and the lignite bed dips at 1 in 100. The overburden thickness increases from 50 to 100 m at the rate of 1 in 100 towards south-south west direction of the mine field. The lignite thickness ranges from 11 to 25 m. No 1 mine is planned to produce ultimately 10 M te of lignite per year.

The ratio of overburden to lignite is nearly 5:1 and quite favourable for extraction by bucket wheel excavators which remove, without blasting, the overburden as it consists mostly of soft rocks. Lignite being soft needs no blasting and it also is excavated by bucket wheel excavators.

The project is situated near the sea and control of artesian water under high pressure below lignite is a serious problem. The artesian water exerts an upward thrust of nearly 6-8 $kgf/cm^2$ on the base of lignite and there is risk or water bursting through the lignite seam on removal of overburden. Nearly 1,35,000 lit/min of water is pumped out with the help of nearly 50 bore hole pumps, most of them located around the area being worked out, to maintain pressure of water below the lignite at a safe level. Water table is kept below the lignite floor by such peripheral bore hole pumping and 15-20 te of water has to be pumped out for each te of lignite mined.

The second mine is planned for an initial capacity of 4.7 million te/yr of lignite ($1^{st}$ phase) and the final capacity in $2^{nd}$ phase will be 10.5 million te/yr, This second mine will extract lignite from 26 km- area south of the first mine and the deposits of extractable lignite are 390 million te.

**Excavation and Transportation:** Presently (10.5 Mte/year stage) the overburden is removed in 4 benches (Surface, Top, Middle & Bottom). The Top two benches (Surface and Top) arc equipped with two 1400 litres bucket wheel excavators (BWE), a system of 2400 mm width conveyors and a spreader of 20,000 TPH capacities each. The third bench (Middle Bench) comprises one 1400 litres BWE, a system of 2000 mm width conveyors and a spreader of 11,000 TPH capacity. The fourth bench (Bottom Bench) is equipped with two 700 litres BWEs, a system of 2000 mm width conveyors and a spreader of 11,000 TPH capacity. The lignite bench has three 700 litre BWEs and a system of 2000 mm width conveyors. The excavated lignite is transported to a storage bunker on the surface of the mine. From there, lignite is reclaimed to the Thermal Power Station II by two Reclaimers of 2000 TPH capacity each and a system of 1800 mm width belt conveyors.

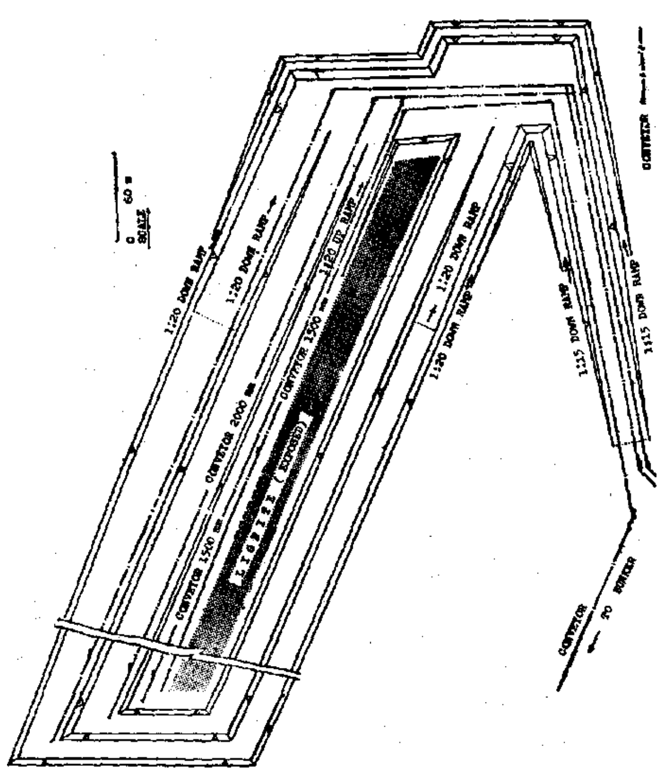


Fig 5.23 Plan of second mine cut at Neyveli Lignite Corporation Lid.

**Dewatering Arrangements**:

The principle of controlling the ground water is depressurisation by dewatering with large scale continuous pumping from a series of pump wells situated at hydro logically calculated distances around the mine. The pumpage of ground water is presently at the rate of about 150 Cu.m/minute from about 35 to 40 pump wells in the Second Mine. By the large scale pumping operation all that is achieved is keeping the pressure under control locally below lignite.

**Storm Water Control**:

Neyveli, being close to the eastern coastal area and being in the cyclonic belt, has a normal annual rainfall of 1200 mm to 2000 mm. The rain water during the monsoon months (October to December) poses many problems in the operation of the mine. This storm water is coursed to the deepest point of the mine by a pattern of toe and cross drains, where pumps mounted on pontoons are deployed in these sumps and the pontoon pumps are shifting accoring to the configuration of the lignite floor. Storm water from the sumps can be pumped directly to the surface with high head pumps mounted on pontoons.

**Drilling and Blasting**:

**The** overburden in the Northern half of the mine consists of hard Cuddalorc Sandstone which needs blasting before excavation. Presently about 30% of the total overburden is to be blasted in the Surface and Top benches.

**Communication:**

Due to enormous size and multifarious activities special communication facilities are provided through wireless between various machines, conveyors, drive head/tail end stations and service yards to the Control Room for smooth co-ordination of all activities in the mines. Separate frequencies/channels have been provided so that there exists no interference in communications amongst various machines and yards. Paging system is also planned to be introduced for quicker contacts.

Exploration work is going on for the third mine of proposed 10 million te/yr capacity. The third mine, area 25 $km^3$, will be located to south of the second mine.

**Bucket wheel excavator**

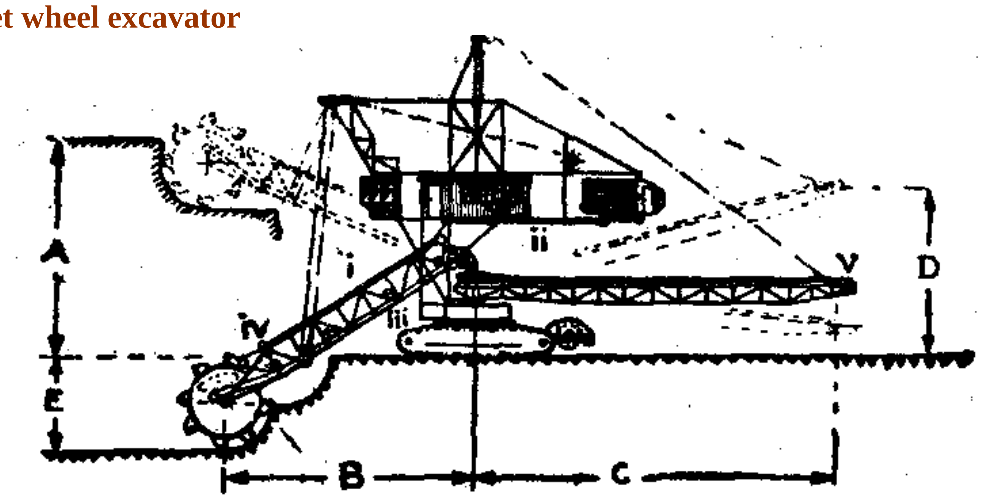



*Fig. 5,2$. General arrangement ol a bucket wheel excavator*

*(i) Boom which can be raised and lowered (ii) Superstructure with machinery houses, ballast and winches (iii) Under-carriage with crawler travel gear- control equipment, cabins for switch gear, workshops and crew (iv) Operation cabin (v) Discharge end.*

*Working Ranges (Figures in bracket relate to 700 lit. B. W.E. at Neyveli A - Cutting height (20 m.)*
*B - Cutting radius C - Dumping radius D - Dumping height E - Cutting depth (3m),*

Neyveli lignite project is the only mining field in India where bucket wheel excavators are used.

A bucket wheel excavator is perhaps the most spectacular of all the excavating machines. It is used for the excavation and removal of soft or unconsolidated overburden, eoal and soft ores in benches of upto 90 metres.

The bucket wheel excavator essentially consists of 3 units:-

(1) the bucket wheel,
(2) The connecting belt to the main crawler mounted carriage, and
(3) the loading belt which disposers pn the excavated material continuously into rail wagons or conveyor belts through hopper cars.

The bucket wheel may be compared with the Persian wheel used in the past on large wells and is a large wheel known as bucket wheel with 6 to 12 buckets. The bucket has a lip with manganese steel teeth for cutting the rock and these are faced with tungsten carbide for hard rocks. The maximum life of teeth with t.c. inserts is 250hours in soft sandstone at Neyveli. The wheel is mounted at the end of the boom which can be (a) pushed out or pulled back (b) lowered or raised, (c) swung through 90° in a horizontal plane depending upon design. The dumps/min by the buckets vary from 70 in small models to 27 in large models, The hourly capacity of an excavator is equal to the total volume of all buckets x wheel speed per hour. The hourly capacities of small models is only 100 $m^3$, but in large models, it is nearly 4000 $m^3$ (3720 $m^3$ solid for 1400 lit. bucket capacity B.W.E.) hr. TK: excavators are crawler mounted. Fig. 5.25 shows relative positions of the various units of a bucket wheel excavator.

The excavated rock is transported by a system of belt conveyors mounted on the machine to hopper cars, belt conveyors or rail wagons.

Power is supplied to bucket wheel excavators at A.C. voltage upto 25 kV though motors operate at 3300 V and 500 V. At Neyveli the B.W. Excavators are supplied electric power at 11 kV through T.R.S. cables and transformers in the machine step down the voltage to 3.3 kV for some motors and to 400 V for some others.

## Methods of working with a bucket wheel excavator

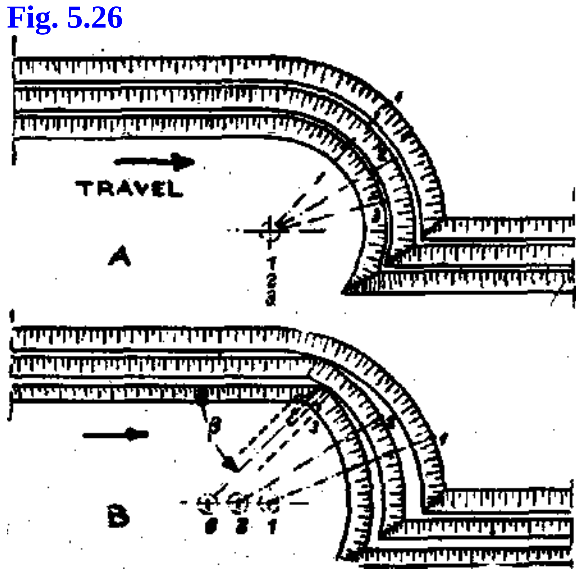
A bucket wheel excavator is employed to operate on 1) full block method, or 2) the lateral block method.

### *Full Block Method*

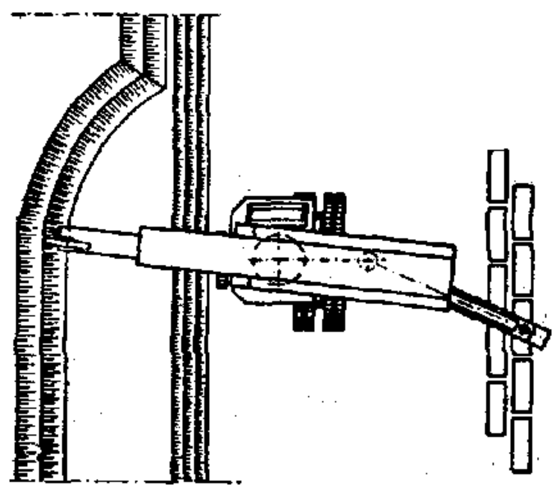
This is commonly adopted and is shown in fig. 5.26. The position of the excavator is shown by the numerals 1,2,3. Fig. 5.26A shows the full block method as practised with a bucket wheel excavator having a boom that can be pushed out and pulled back, i.e., capable of thrust forward. Fig. 5.26B shows the full block method as practised with an excavator having a bucket wheel boom that can be lifted and lowered but has no thrust movement.

Where selective winning of minerals is not necessary, full block method is employed so that the bucket wheel cuts in full blocks and in parallel operation with "cuts which are made as wide as possible. The blocks removed by giant bucket wheel excavators have a width of 45 m to 100 m. This large width of cut which can be maintained along the whole face, not only reduces the travel way for the crawlers, and consequently, the time required for this displacement, but also the shifting work required for the transport system used to dispose of the mineral. The method is therefore simple and economical.

**Fig. 5.26**




**Full block method.**



**Method of cutting lateral blocks**

During cutting, the excavator cuts its own ramp of 1:20 into the new block and finally excavates the ramp also.

### *Lateral Block Method*

In order to remove continuously waste partings or mineral seams of minor thickness selectively, the excavator adopts the method of cutting lateral blocks. Both bucket wheel excavators with thrust or without thrust — can dig the necessary lateral slopes. The width of the block depends, however, always on the length of bucket wheel boom (Fig, 5.26). Bucket wheel excavators with a short bucket-wheel boom are not suitable for cutting lateral blocks. Should the level of the selected seam lie high above the travel-way of the machine, and taking into account the necessary slope angle, a "super" bucket wheel would be required, i.e., with a diameter larger than that which would actually be needed for the output required.

In any case, the amount of crawler travel increases with decreasing width of blocks. The travel-way is reduced if an excavator with thrust is employed.

The excavated rock is transported by a system of belt conveyors mounted on the machine to hopper cars and thence to belt conveyors or rail wagons. The loading belt of the machine is also mounted on a boom.

## Reclamation

Reclamation is the act of restoring the quarried area to the pre-quarry state and renders it useful for different purposes. In USA and other foreign countries, the mining laws require that the quarried area is restored to the pre-quarry state. As already stated, such law does not exist in our country and the abandoned quarries present unsightly appearances of hillocks of overburden and vast ponds of stagnant water. Only in Neyveli Lignite Complex the quarried area has been-reclaimed and turned into pleasant parks, mini-forests, zoos and recreational centres, In fact, with a little foresight and planning, the quarried area can be rendered more useful and valuable than in the original pre-quarry state. Thus waste marshland, after the underlying mineral is excavated, can be turned into a profitable agricultural land.

When starting the quarrying activity in an area, if reclamation is one of the final objects, the top soil is removed by rippers and scrapers and collected at a suitable place where it will not be carried away by wind and will not prove a nuisance to nearby localities and dwellings. In suitable cases such soil can be sold away, thus doing away the need to stack it over a long period of the life of the quarry. Small grass is allowed to grow over it so that it is not raised and carried away by the wind.

After the mineral is excavated and the quarried area backfilled, it is compacted by rollers. Tamping or *sheepsfoot rollers* are the standard tools for compacting fills. They consist of steel drums fitted with projecting "feet" and towed by means of box frames. The portions earmarked for roads and houses are further compacted, but the areas reserved for agriculture, farm land or plantation of trees are covered with 1-1.5 m of soil transported from other places. Such soil is often mixed with appropriate type of manure to suit the agriculture or vegetation planned.

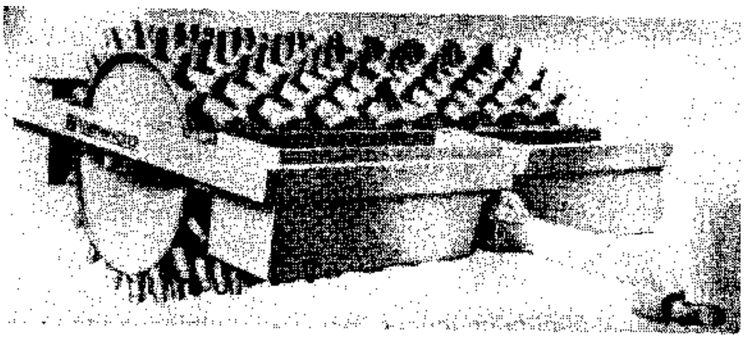


Fig. 5.27. Asheepfoot roller for compaction.

Drains are provided all around the reclaimed area. In the areas earmarked for houses, and roads compaction by rollers is carried out for 2 or 3 seasons after the rains with a view to consolidate the back filled debris nearly as compact as in the pre-quarry state.

*QUESTIONS*

1. What is the scope and what are the limitations of working a seam by opencast mining ? What is quarriable limit?

2. What is the common type of equipment used in a mechanised quarry ? State the purpose for which it is used.

3. Under what conditions will the following equipment be used ?

(a) A dipper shovel

(b) A scraper

(c) A dragline

(d) A wagon drill

4. What is the reasonable performance of a $2m^3$ shovel in (a) an 8-hour shift (b) a week (c) an year.

** Information on Lignite mining is based partly on an article by T. K. Moihilal, General Manager, Neyveli Lignite Corporation, Lid.*