occasionally a small ventilating fan, and a timber derrick or head-frame over the shaft mouth, with appliances for dumping the buckets, handling the rock and safe-guarding the men in the shaft against falling objects. In some circumstances a portion of the permanent mine plant is erected for sinking. The choice between hand and machine drilling depends chiefly on the kind of rock and the size and depth of shaft. For very hard rock or when rapid work is desired, machine drilling is advisable, a compressor and additional boiler capacity being then required. Remarkable speeds, however, have been made by hand-sinking in some of the deep vertical shafts on the Rand, the world’s record being that of the Howard shaft, sunk by hand labour 203 ft. in one month. But such speeds are attainable only in dry, or nearly dry, ground, at a high cost per foot and by crowding as many men into the shaft as possible, both for drilling and loading away the blasted rock. The conditions being the same, inclined shafts closely approaching the vertical can be put down about as fast as vertical shafts; but for inclinations between say 75° and 30° to the horizontal, inclines are generally slower on account of the greater inconvenience of carrying on the work, both of excavation and timbering. Very flat shafts, on the other hand, can be sunk at speeds little less than for driving tunnels, unless there is much water. The highest speed on record for a very flat incline (10°) is 267 ft. in one month.

As a rule, the speed attained in sinking depends less on the drilling time per round of holes than on the time required to handle and hoist out the rock; hence the speed generally diminishes with increase of depth. Furthermore, omitting shafts of small area, the cost per foot of depth does not increase greatly with the cross-sectional dimensions. For the same rock the rate of advance in wet formations is always much slower than in dry and the cost greater.

The work of sinking in rock is carried on as follows. A round of holes is drilled, usually from 3 to 4 ft. deep if by hand, or from 5 to 8 or 9 ft. if by machine drilling (see Blasting). A common mode of arranging machine drill holes is shown in plan and section in fig. 1. The holes are charged with dynamite and fired by fuze or electricity— in deep shafts preferably by electricity, as the men may have to be hoisted a long distance to reach a place of safety. After the smoke has cleared away (which may be hastened by sprays or by turning on the compressed air if machine drills are used), the work of hoisting out the broken rock is begun and drilling resumed as soon as possible. For shafts not over 6 or 8 tt. wide, machine drills are usually mounted on horizontal bars stretching across from wall to wall, or, in wider or cylindrical shafts, on tripods or special sinking-frames. In shafts of small area, or deep shafts which are timbered during sinking, the hoisting buckets must be guided to prevent them from striking against the sides. Small quantities of water are bailed into the buckets; when the inflow is too great to be so disposed of, a sinking pump is employed (see Mining).

*Shaft Timbering.—*In sinking rectangular vertical shafts under normal conditions the excavation through the surface soil is com­monly lined with cribbing, inside of which a concrete curb is sometimes built to dam out the surface water. After reaching rock the lining is generally composed of horizontal sets of 8 by 8 in. to 12 by 12 in. squared timber wedged against the walls, with smaller pieces, or planking, called “ lagging,” placed behind them, to prevent portions of the walls from falling away. In firm rock lagging may be omitted. Each set consists of (fig. 2) two long timbers (wall-

plates) W, W, two shorter pieces (end plates) E,E, and usually one or more cross pieces (dividers or buntons) D,D, to form the compartments, strengthen the sets and support the cage guides, G,G. The sets are from 4 to 6 ft. apart, with vertical posts (studdles) S,S, between them. At intervals of say 80 to 120 ft., longer timbers

(“ bearers ”) are notched into the walls, under a set, to prevent dis­placement of the lining as a whole. A series of shaft sets, with their posts, are either built up from a bearing-set, or suspended from the latter by hanger-bolts. When the rock is firm, a considerable depth of shaft may be sunk and then timbered; generally, however, it is safer to put in a few sets at a time as sinking advances, the lowermost set being always far enough from the bottom to prevent it from being injured by the blasting. Inclined shafts in solid ground are often timbered as described above, though sometimes merely by setting longitudinal rows of posts, for supporting the roof and dividing the shaft into compartments.

*Lining for Cylindrical Shafts in Rock.—*Wooden linings are oc­casionally put in small shafts, or for temporary support, before the permanent lining is built, but a cylindrical shaft of any importance is lined with masonry or iron. Masonry linings are generally built in sections, as the sinking advances, each section being based on a walling-crib AB, CD. (fig. 3). Specially moulded tapered bricks are convenient, shaped to conform with the radius of the shaft. Concrete may be similarly moulded into

large blocks, often weighing 1200 to 1600 lb

each. The thickness of the walling depends

on the depth of shaft and pressure antici­

pated; it is usually from 13 in. to 2 ft., laid

in cement mortar. Such linings, while not

entirely water-tight, will shut out much of

the water present in the surrounding rock. Iron lining, or “ tubbing,” is employed

when the inflow of water is rather large. It

is usually composed of cast iron flanged

rings, each cast in a single piece for shafts

of small diameter, or in segments bolted

together for large diameters. To permit the

rings to adjust themselves to the pressure,

the horizontal joints are rarely bolted ; they

are packed with sheet-lead or thin strips of

dry pine, any leaks appearing subsequently

being stopped with wedges. Though preferably of cast iron, tubbing is occasionally

built of steel plate rings, stiffened by angles

or channels riveted to them. The irregular

annular space between the tubbing and rock-walls is afterwards filled with concrete or cement grouting. The lowermost tubbing ring is based upon a “ wedging-crib.” This is a heavy cast iron ring, composed of segments bolted together, and set on a projecting shelf of rock, carefully dressed down. The space behind the crib is driven full of wooden wedges, which expand on becoming water-soaked and thus make a tight joint at the bottom of the tubbing with the rock just above the mineral deposit. By this means most of the water may be permanently shut out of the shaft, and the cost of pumping materially reduced.

*Kind-Chaudron System of Sinking.—*This ingenious method, introduced in 1852, has thus far been confined to Europe. Up to 1904, 79 shafts had been sunk by its use, some of them to depths of 1000 ft. or more, without a single instance of failure. It is applicable only to firm rock and was devised to deal with cases where the quantity of water is too great to be pumped out while excavation is in pro­gress; that is, for inflows greater than 1000 or 1200 gallons per minute. In its after results the system is most successful when the water-bearing rocks rest on an impervious stratum, overlying the mineral deposit. The entire excavation is carried on under water ; then a lining of special design is lowered into place and the shaft unwatered. The shaft is sunk by boring on an immense scale, by apparatus resembling the rod and drop-drill (see Boring). Instead of ordinary drills,

massive tools

called “ trepans ”

are employed, con­sisting of a heavy

iron frame, in the

lower edge of

which are set a

number of separate cutters (fig.

4). Shafts not

exceeding 8 ft.

diameter are

bored in one

operation; for

larger diameters

an advance bore

is usually made

with a small

trepan and afterwards enlarged to full size. The advance bore may be completed to the required depth of shaft before beginning enlargement, or the small and large trepans used alternately, the advance being kept 30 to 6o ft. ahead of the enlargement. An 8 ft. trepan weighs about 12 tons, those of 14 or 15 ft. 25 to 30 tons. The trepan is attached to a heavy rod, suspended from a walking-beam operated by an engine on the surface, as in ordinary boring. A derrick is erected over the