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TIMBERING OF METAL MINES

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PREFACE.

This manual on methods of timbering in underground metal mines is intended chiefly for the practical miner or small operator who desires to acquaint himself with the general principles of mine timbering. No attempt is made to cover the entire field of metal-mine timbering, but brief descriptions are given of one or more reliable ways for each of the timbering operations employed in the development and working of the smaller metal mines; steel, concrete, and other types of support common in larger mines are not discussed. Effort has been made to use terms that will be understood readily by men without technical training, but it is hoped that mine superintendents and engineers who are already familiar with much of the information presented will find the book useful for convenient reference.

A number of books deal with mine timbering or contain chapters on the subject, and from time to time excellent articles regarding the methods employed to solve particular problems of timbering at some one mine have appeared in the technical press, but no single publication answers the many questions on mine timbering that continually present themselves to the practical miner, such as:

1. Under what conditions is timbering necessary in mining?
2. What are the principles governing its use?
3. Which kinds of timber are best suited for mine use?
4. What are the best methods of timbering the various mine openings?
5. What determines the different methods of framing?
6. Should preservatives be used on mine timbers?

The data presented have been gathered mostly from personal notes and experiences of several Bureau of Mines engineers in timbering metal mines, but are supplemented by information from the literature. Books and articles in technical journals that deal with mine timbering have been drawn on freely for both text and illustrations, especially the publications of the American Institute of Mining Engineers, Engineering and Mining Journal, Mining and Scientific Press, W. H. Storms's "Timbering and Mining," and the Coal and Metal Miners' Handbook. The outline of the manual was prepared by E. A. Holbrook and Richard V. Ageton, and additions and revisions have been contributed by H. E. Tufft, Dan Harrington, and R. R. Hornor. Acknowledgments are also due T. T. Read, of the Bureau of Mines, and Dean Francis A. Thomson, of the University of Idaho.

George S. Rice,
Chief Mining Engineer.

TIMBERING OF METAL MINES.

By E. A. Holbrook, Richard V. Ageton, and Harry E. Tufft.

NECESSITY FOR TIMBER IN MINING.

When an underground excavation is made, the rock surrounding the sides and top of the opening is deprived of its natural support and tends to fall. Whenever caving takes place, the time and extent of the caving depend on the character and condition of the rock. In strong homogenous rock, such as solid granite, even a large chamber may stand indefinitely, whereas a soft material, such as clay or a loose material like unconsolidated sand, falls immediately if not supported. Weaknesses in the rocks induced by structural features, such as joints, fissures, bedding and cleavage planes, and fractures produced by blasting, will cause the falling of insecure blocks or slabs unless means are provided to support these in place.

In an unsupported mine opening, as a tunnel, the first slight settling or adjusting movement of the rocks (the "initial creep" or "set") is caused by the great weight of overlying material pressing down the rock masses above and around the roof and sides of the opening until they key together in roughly the form of an arch. The rock, after it has adjusted itself to this shape, becomes self-supporting.

Timbering is necessary in all mining only to support, therefore, those comparatively small blocks or pieces of rock which tend to loosen from the top and sides of the opening during or after the formation of the natural rock arch, and which lie between this natural rock arch and the opening. This statement, of course, has its limitations. For example, a layer of strong rock, like limestone, may act as a beam; then only the material under the limestone will need support. Timbering is not, as is commonly supposed by the layman, used to support the huge mass of rock between the back (roof) of an underground opening and the surface. It would be impossible to place enough timbers in any underground opening to support such a mass. This fact is not perceived by all miners. Tunnels have been observed with roofs that were practically self-supporting and needed almost no timber, but in these tunnels complicated and expensive systems of timbering were used, evidently with the thought that it was necessary to support the full weight of rock extending to the surface.

Timbers have another advantage in mining, because under a load they split and crack before breaking, and thus warn the miner before an actual fall of rock takes place.

PRINCIPLES OF MINE TIMBERING.

A fundamental principle always to be kept in mind is that timbering should afford adequate support at least expense. Enough timber should be used to insure safety to the workings and to the men, but as timbering is often one of the chief items of cost in mining, the excessive use of timber is an economic waste.

Timbering serves primarily, by the prevention of caving and spalling, to keep the workings open for such time as is necessary for extracting the ore, or for purposes of transportation and ventilation. When the workings are abandoned, the timber therein has fulfilled its purpose and is so much waste material, although some of it may perhaps be recovered for reuse in other parts of the mine.

Because timber suitable for use in mines is becoming increasingly scarcer in nearly all mining districts, and at many places must be shipped in, and because of the labor cost involved and the further fact that most mine timber can not be recovered, there is greater and greater need for exercising good judgment in utilizing timber to the best advantage.

In determining the proper amount of timber to use, experience is the best guide. Calculations on the crushing strength of different woods and the pressure on different types of rock at various depths are useful to some extent in mine engineering, but in general the load that is to be expected can not be determined even approximately. Thus the best and usually the only practical way is by trial and by previous experience. Familiarity with the ground and experience gained in other parts of the mine or in near-by mines are of especial importance in timbering. After timber is in place it should be carefully observed for signs of weakness or crushing as the weight of the rock comes on it.

The most important principle of mine timbering is to timber in time; that is, immediately after excavation and before the rock inside the natural rock arch becomes broken and begins to settle. If this principle is followed it will save time, money, and many lives.

Other principles of mine timbering are mechanical and have to do with the structure of the wood and the methods of preparing and using the individual timbers so that every advantage can be taken of the strength of the wood.

STRUCTURE OF WOOD.

Observation of a lengthwise section of a piece of wood through a microscope (Pl. I, *A*) shows that it is made up of a series of cigar-shaped cells, side by side and running lengthwise of the timber. Plate I, *B* is a cross section of the same piece of wood and shows that the cells are four and six sided. Their thickness is from one-fourth to one-tenth of their length. As is true of tubes of any material, these fibers or cells resist pressure best when the weight comes upon them lengthwise or with the grain of the wood. Therefore mine timbers should be so placed that they may resist pressure with the grain.

BEHAVIOR OF WOOD UNDER PRESSURE.

A piece of wood when put under pressure resists pressure from different directions as follows:

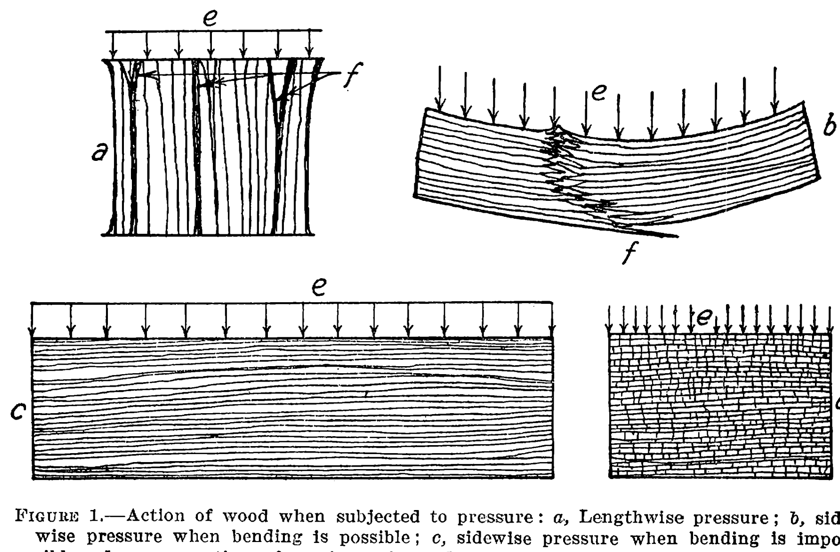


FIGURE 1.—Action of wood when subjected to pressure: *a*, Lengthwise pressure; *b*, sidewise pressure when bending is possible; *c*, sidewise pressure when bending is impossible; *d*, cross section of a piece of wood that could not bend when subjected to sidewise pressure; *e*, pressure; *f*, splits or cracks due to pressure.

LENGTHWISE PRESSURE.

When pressure comes upon a piece of wood lengthwise (fig. 1, *a*) the fibers bend and tend to tear apart from one another, and under heavier pressure the piece splits and fails gradually. The so-called full strength of the wood to resist pressure is obtained when a timber is placed in this manner.

SIDEWISE PRESSURE WHEN WOOD CAN BEND.

When pressure comes upon a piece of wood sidewise, and the piece can bend (fig. 1, *b*) it breaks quickly, especially if unsupported beneath the point where the pressure is applied. Therefore mine timbers so placed that the rock pressure comes against the side of the timber are of little use for resisting pressure.

SIDEWISE PRESSURE WHEN WOOD CAN NOT BEND.

When pressure comes upon a piece of timber sidewise and the piece can not bend (fig. 1, *c*), the walls of the fibers flatten and squeeze together (fig. 1, *d*). A piece of mine timber 12 inches square in cross section resisting pressure in this manner has been reduced to a thickness of 4 inches. This squeezing of the individual fibers offers strong resistance to the pressure, therefore timber resists pressure well when used under these conditions.

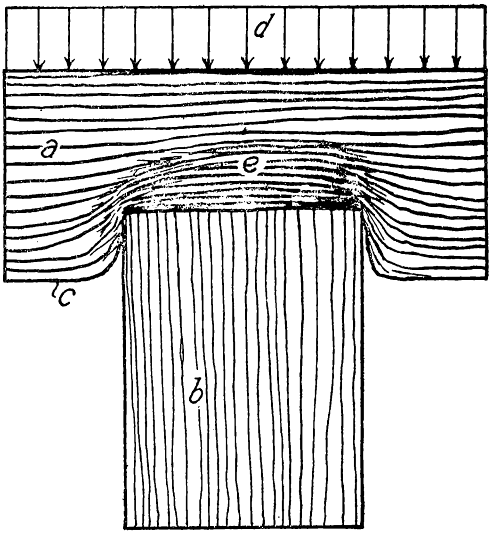
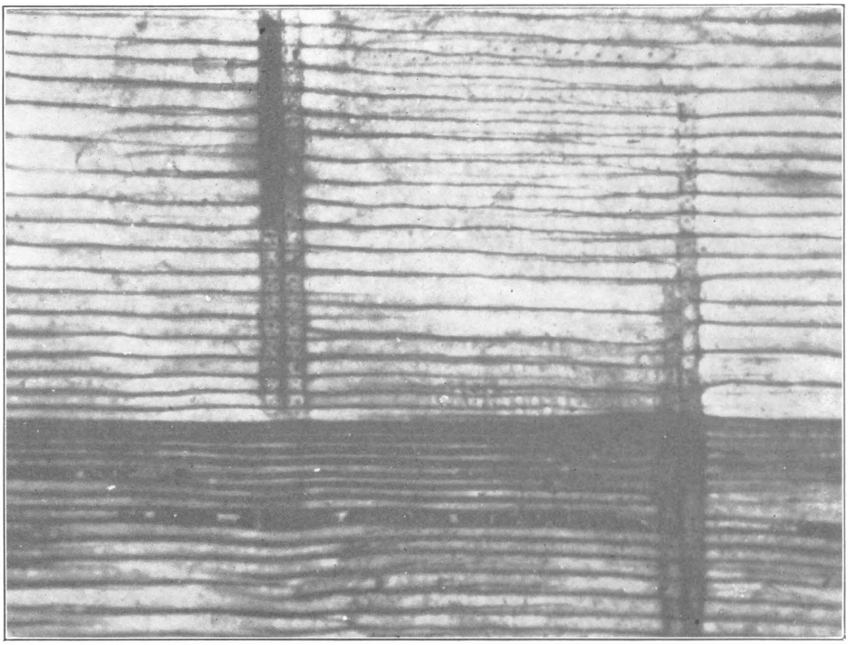


FIGURE 2.—*a*, Piece of wood under sidewise pressure; part of piece supported by the end section of another piece; *b*, piece under lengthwise pressure when protected by another piece subjected to sidewise pressure; *c*, protective ring of uncrushed fibers; *d*, pressure; *e*, crushed cells or fibers.

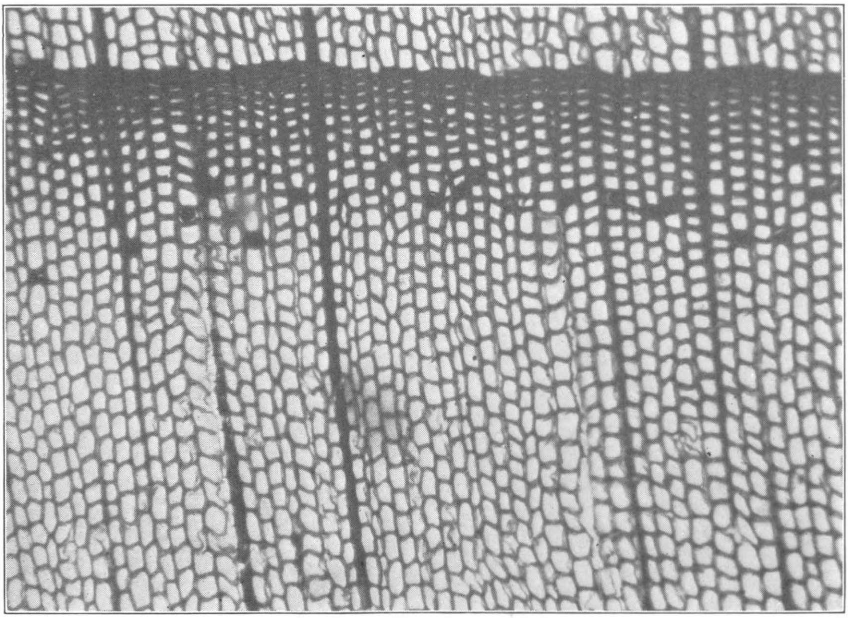
HORIZONTAL PIECE OF TIMBER SUPPORTED BY THE END SECTION OF A VERTICAL PIECE OF TIMBER.

When the pressure acts sidewise upon a piece of timber (fig. 2, *a*), a part of which is supported by the end section of another piece (fig. 2, *b*), two actions may take place. First, the fibers of the wood, in the supported part of the piece *a* flatten and come together as just explained, and absorb or take up a part of the pressure. Second, the unsupported part of the piece is forced down by the pressure and forms a protective ring of strong uncrushed fibers *c* around the end of the supporting piece *b*. This ring keeps the individual fibers of the supporting piece from splitting apart and gives the timber additional strength. When two pieces are placed in this manner the supporting piece lasts much longer than if it rested directly against the hard rock.

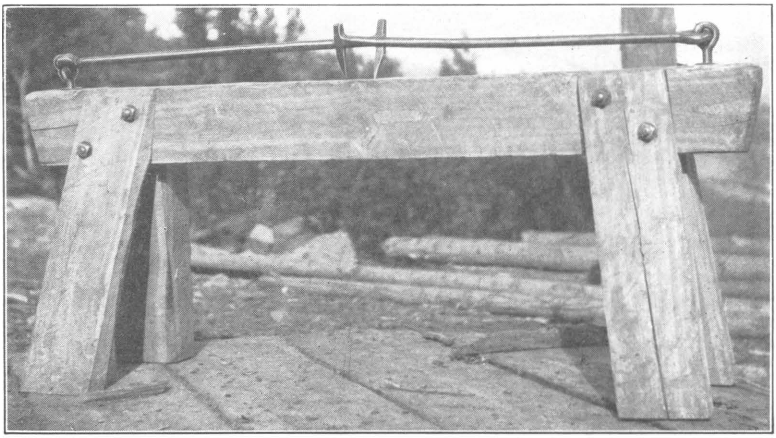
Therefore, in order to obtain the best results with the individual timbers employed in mining, they should be so placed that the end section of the main timber (fig. 1, *a*), is directed against the pressure, and the side section of a smaller piece of wood (fig. 1, *c*) is placed



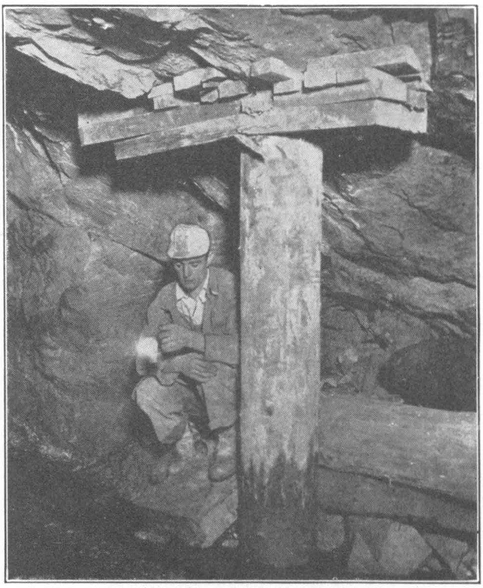
A. LENGTHWISE SECTION OF A PIECE OF PINE WOOD (×100). NOTE THE TUBULAR SHAPE OF THE CELLS.



B. CROSS SECTION OF A PIECE OF PINE WOOD (×100). NOTE THE SHAPE OF THE CELLS. THE BLACK RING AT THE TOP IS AN ANNULAR RING.



A. SAWBUCK USED IN MARKING AND CUTTING THE TIMBERS FOR FRAMING.



B. SINGLE POST USED TO SUPPORT THE BACK OR ROOF—SHOWS GOOD PRACTICE EXCEPT THAT HEADBOARDS ARE COMPARATIVELY LONG AND WEDGING EXTENDS BEYOND SUPPORTED PARTS.

between the main timber and the rocks it supports, or as shown in figure 2.

KINDS OF TIMBER EMPLOYED IN MINING.

The kinds of timber used in mining operations are as varied as the localities in which the mines occur. In most districts local woods are used, even if of an inferior quality. In some districts in which there is a scarcity of good timber, such as in the Southwest, the prospector and small mine operator use the dwarf varieties usually found in these arid regions, such as mesquite, sage brush, juniper, cottonwood, pinon, etc.

Long-grained timbers such as pine, fir, spruce, oak, and chestnut are preferred because they will crack and split when pressure comes on them, and thus give warning long before they break. Although timbers should be long-grained, strong, and elastic, they should not be too heavy. Oak and chestnut and other long-grained hardwoods are strong, but many hardwoods are heavy to handle. Short-grained woods are often unreliable as an indicator of dangerous pressure because they may break without warning.

The use of such flexible woods as hickory, eucalyptus, and willow should be avoided if possible, as they bend easily under pressure and do not offer, in proportion to their size, much resistance to the movement of the rock. The willow especially lacks both strength and durability.

Those timbers of the Pacific coast that are best adapted to mining uses are Douglas fir, California fir (white fir), Sitka and white spruce, yellow pine (bull pine), but western hemlock, cedar, and redwood, also oak, maple, chestnut, and other hard woods are used where most easily available. Sometimes the scorched timbers of burned-over districts are used. When the heart of the timber is sound these have proved acceptable; they are cheaper than unscorched timber and are practically as strong.

In Alaska there have been many objections given to the use of native spruce and native hemlock for mine timber. Some mining companies have preferred to ship in Douglas fir from Washington and Oregon instead of using the native woods. At present the amounts of Alaskan timber being used in the mines there are much larger than formerly. Experiments by the Forest Products Laboratory, Madison, Wis., on Sitka spruce and Alaska hemlock indicate that the better grades of these woods compare favorably with lodgepole pine and Douglas fir. When men are opening a mine in a new district, it is advisable for them to write the United States Forest

Service for such data as it may have on the timbers of that particular district before they discard any of the local timber as unsuitable.

FRAMING TIMBERS.

One should always remember that the cheapest, quickest, and easiest way to cut and frame mine timbers is at the surface. Sometimes it may be necessary to frame timbers underground but, in general, all measurements should be made and the place to which they are to be delivered plainly marked on paper, then the timbers should be framed on the surface and delivered underground when needed.

The larger mines commonly have a timber-framing machine; prospectors and the operators of small mines can not afford to use one; consequently at small mines the framing is done by hand. As an aid in framing timbers by hand, the saw-buck shown in Plate II is suggested. The only tools necessary are a cross-cut saw, a ripsaw, an ax, an adze, a level, a carpenter's square, and two or three peaveys. The iron dogs (the iron pieces bolted to the sawbuck) are made of either round or square iron three-quarters of an inch thick. Such iron can be obtained and made up at any blacksmith shop; drill steel may be used if no cheaper material is available. In framing the timbers, first place two sawbucks about 5 feet apart, then lay the timber to be framed on them and drive the iron dogs into it to keep it from slipping. With the timber held securely on the sawbucks, it becomes a simple matter to mark and cut the framing of any commonly used mine timber.

Where there is a small sawmill in the neighborhood, or where timbers have to be shipped in a considerable distance, it is sometimes advantageous to buy the timber already squared (and sometimes already framed) from the mill.

A point that the mine operator should insist on when he purchases timber from sawmills is that all square timbers should be cut parallel with the grain of the wood (Pl. I, *A*); otherwise they break more easily, and the cost of renewing timbers is always high.

METHODS OF TIMBERING.

In metal mines are to be found every conceivable variation in dip of vein, character of wall rocks, and nature of ore. The dip ranges from horizontal to the vertical. The rocks encountered, both in the ore and the walls of the deposits, range from the extremely hard volcanic rocks found in some gold mines to the soft clayey material encountered in the oxidized zones of some lead mines. Thus in any mine there must be used a type of timbering that will best meet local conditions, or as it is generally called, the "character of the ground."

With respect to the need of timbering, three classes of "ground" are recognized, as follows:

1. Hard ground, requiring little or no support.
2. Medium ground, requiring a fair amount of support. This condition is the most common.
3. Soft or heavy ground, requiring a great deal of support.

In the development of a mine all exploring for ore bodies should be done in the quickest, surest, and least expensive way; consequently the first timbering in a mine is in adits (tunnels), drifts, or crosscuts, or in vertical or inclined shafts. Later, the winzes, raises, stopes,

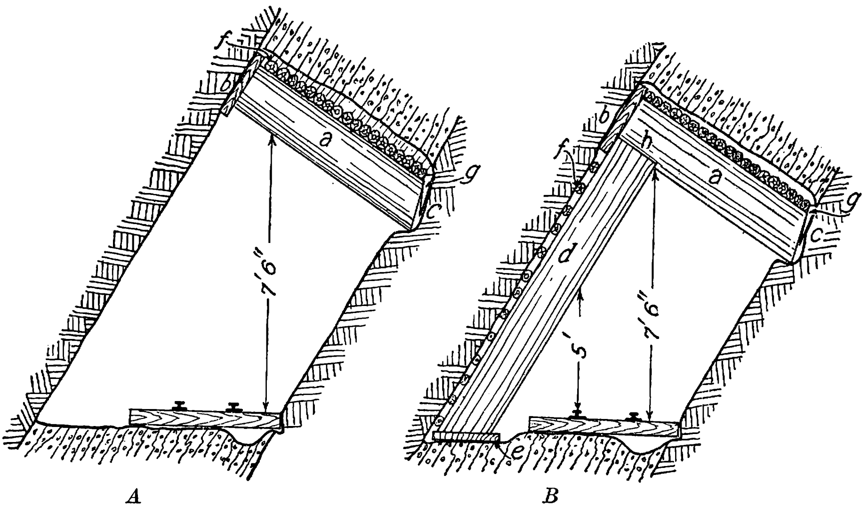


FIGURE 3.—One and two-piece drift sets used in metal mining: *A*, One-piece drift set; *B*, two-piece drift set; *a*, stull; *b*, hanging-wall head block; *c*, foot-wall hitch; *d*, angle post; *e*, footboard for post; *f*, pole lagging; *g*, wedge; *h*, dap or seat for post.

chutes and other openings must be timbered. The different methods of timbering used in these openings under each condition of the ground are outlined on succeeding pages.

TIMBERING TUNNELS, DRIFTS, AND CROSSCUTS.

The simplest forms of timbering employed in metal mining are found in adits, drifts and crosscuts, and are usually referred to as one, two, three, or four piece sets, according to the number of timbers used to make up the set. Hexagonal and octagonal (six and eight pieces) sets are occasionally used under special conditions.

ONE AND TWO PIECE SETS.

The simplest form of roof or back support is a single piece of timber. When the piece is placed vertically (Pl. II, *b*), it is called a **post**, and when placed horizontally, or approaching the horizontal (fig. 3, *a*) it is called a stull. These two classes of supports are used where the ground is firm and when there is only a small piece of loose rock to be supported.

When a post is needed to support a loose rock in the back of the drift or crosscut, a shallow hole is first dug in the floor of the drift, and the bottom of this hole leveled up to provide a firm even footing for the post. Where the ground is soft, a footboard may be placed in the hole as at *e* (fig. 3, *B*), to provide a firm bearing. Then the post is placed in the hole and one or more headboards are placed on the top of the post and wedged in place as shown in Plate II, *B*. The headboard serves to distribute the load uniformly on the upper end of the post, and under heavy pressure forms a protective ring (fig. 2, *c*) of uncrushed fibers around the post, which helps to prevent it from splitting (fig. 1, *f*). The wedges are used to fill up any space between the boards and the rock, and in this way distribute the pressure evenly over the headboard; they also hold the post and the headboard in position until the rock pressure comes upon them. Wedges should always be cut with the grain of the wood, as they are less liable to split in driving, and on compression they take up some of the pressure coming on the headboard and post.

In veins of steep dip where the rock stands well, stulls (*a* in fig. 3, *A*) are placed across the drift to support loose rocks in the back or top and on the sides. Stulls are commonly used in drifts that do not require much support. Stulls are also employed in stopes, and their use there is described in the chapter on stope timbering. The method of placing the stull is the same in both cases. First a hitch is cut in the footwall *c*, to support one end of the stull, high enough to permit a man to pass beneath it when standing erect. In order to cut the stull correctly, the distance between the hitch in the footwall *c* and the place where the stull is to be blocked on the hanging wall *b*, also the bevel, or the angle upon which the ends of the stull is to be cut, should be measured quickly, easily, and accurately. The slide staff shown in figure 4 is employed for this purpose.

To use this staff, first loosen the wing nuts *a* and *a′* on both the bands and the end pieces and extend the slide staff across the drift from the hitch *c* (fig. 3) to the place on the hanging wall *b* where the stull is to rest, allowing 6 or 8 inches for the headblock. Next adjust the end pieces *b* (fig. 4) so that their angle will correspond to the angle of the walls, then clamp all the wing nuts and take down the slide staff. Now lay the slide staff on the timber to be used as the stull and cut along the lines of the end pieces. After the stull has been cut, place one end of it in the footwall hitch *c* (fig. 3); between the other end and the hanging wall place a headblock *b*. The stull should never be placed at exactly right angles to the dip of the vein, because in such a position it would be readily dislodged by a slight movement of the wall, a falling rock, or by the weight of ore or men coming on it. In practice the stull is cut slightly longer than the shortest distance between the walls of the drift, consequently it sets up a little at its upper end and will not fall out before the pressure of the walls comes on it; also, any downward movement of the hanging wall at the point *b* (fig. 3) will tend to seat the stull more securely in the hitch *c* on the footwall. Wedges are then placed at the upper end of the stull and the stull is wedged securely in place. Sometimes a wedge is placed between the footwall *c* and the lower end, as shown at *g*.

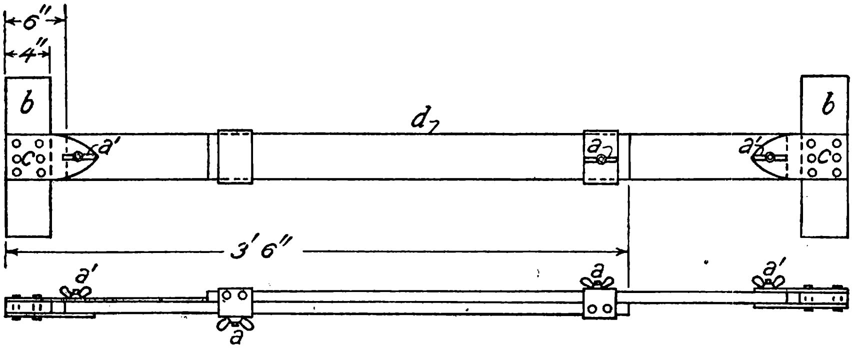


FIGURE 4.—Slide staff used to measure stulls: *a*, *a'*, wing nuts; *b*, end pieces; *c*, rivets; *d*, 1 by 4 inch dressed band.

TWO-PIECE SET.

In veins of moderately steep dip, 45° or thereabouts, if the hanging wall needs support, or if the back of the drift needs more support than is afforded by the one-piece set, the two-piece set (fig. 3, *B*) is used; it consists of a stull *a* and a post *d*. The method of placing the stull has been described. The post is placed in the same manner as the single post, except that a dap *h*, about one-half inch deep, is cut in the bottom of the stull to keep the post from falling inward before the pressure comes on it. In soft ground a footboard *e* should always be used at the bottom of the post to give a firm bearing.

When a considerable length of drift is to be supported and the walls are weak, pole lagging *f* (fig. 3), which are small pieces of round timber 2, 3, or 4 inches in diameter and about 5 feet long, or 2-inch plank are laid on top of the stulls or behind the posts to prevent small loose rocks from falling. Under pressure the lagging crushes and permits a slight movement of the rock; in this way it absorbs part of the pressure and relieves the main timbers of some of their load.

THREE AND FOUR PIECE SETS.

In medium ground that needs more support than the one-piece or two-piece set affords, three-piece sets (fig. 5) or four-piece sets (Fig. 7, p. 14) are employed. The former consists of two posts and a cap, and the latter of two posts, a cap, and a sill, respectively, with distance pieces or girts between each pair of sets. Some advantages of the use of three and four piece sets are:

1. The weight or pressure is distributed over a number of timbers.
2. The timbers are securely supported in all three directions and are not easily loosened and dislodged.

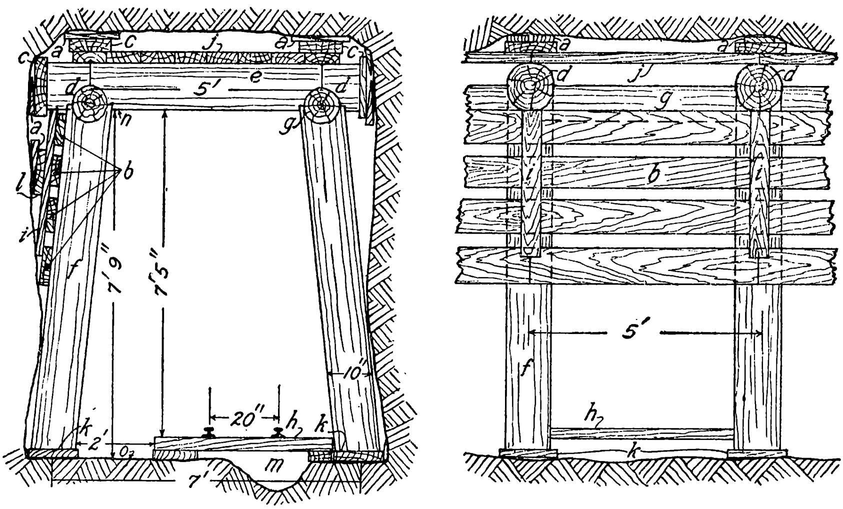


FIGURE 5.—Three-piece set for timbering a drift: *A*, Front view of set; *B*, side view of set; *a*, wedge; *b*, lagging; *c*, headblock; *d*, butt cap; *e*, cap, round; *f*, post, round; *g*, girt; *h*, tie; *i*, bridge piece; *j*, top lagging; *k*, footboard; *l*, block; *m*, ditch; *n*. bottom of cap; *o*, bottom of drift.

3. Lagging can be placed against the sides and top if necessary, thus lessening the chances of injury to men and animals from falling rocks, and keeping the passageway clear.
4. They provide a uniform opening of convenient shape and size, and provide support for air and ventilating pipes and electric wires.

In framing or cutting the posts and cap of these sets one should remember that properly made joints in mine timbering are fully as important as the correct placing of the timbers. No matter how well the timber is placed, if it has not been joined correctly it may fail under comparatively slight pressures or rock movements.

The pressure on a timber joint may come in one or more of three directions—that is, down (vertically) and sidewise (horizontally), either across or lengthwise of the opening. Therefore the joint must have three members so placed that the set will be able to take pressure from any or all of these three directions. In narrow vertical mine openings the pressure is chiefly at right angles to the walls and the main timbers are placed horizontally. In a wide, flat opening the heaviest pressure is from above, so the strongest timbers are the posts. In drifts and tunnels the pressure may be in either direction, therefore the vertical member or post *f* (fig. 5) and the main-horizontal member or cap *e* are usually made approximately the same size. The minor horizontal member *g*, called variously the girt, collar brace, studdle, stretcher, or distance piece, does not need to be as strong as the other two; sometimes it is used only to keep the sets in place until they are blocked tight. However, where girts were not used, accidents have happened from several sets collapsing lengthwise at the same time like a pack of cards on end. Also, without girts, there is more likelihood of sets near the face being dislodged by blasting. The tendency has been to make the girts stronger and stronger in order to care for any possible pressure lengthwise in the

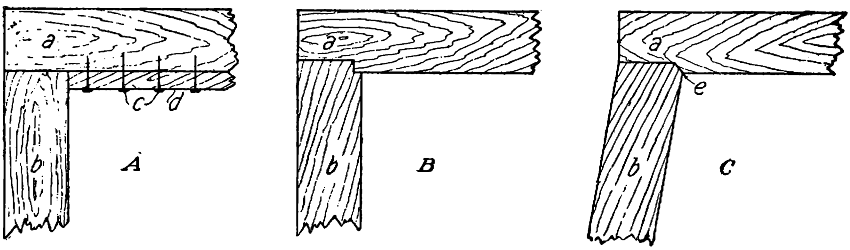


FIGURE 6.—Simple joints used in drift timbering: *A*, Simple correct method of joining cap and post; *B*, incorrect method of joining cap and post; *C*, correct method of joining cap and post on a bevel; *a*, 10-inch cap; *b*, 10-inch post; *c*, nails; *d*, spreader; *e*, bevel joint.

drift, and now they are generally made of timbers about two-thirds the size of the caps.

For single-track tunnels (adits), drifts, and crosscuts the posts *f* are usually made 7 feet 6 inches long and the caps *e* 5 feet long. The individual sets are generally placed 5 feet apart from center to center; thus the girts are about 4 feet long. Figure 6 shows three methods of joining the posts and caps in drift timbering. The joint *A* on the left is a simple, efficient method for square timbers; it can be placed by inexperienced labor, and has the added advantage that neither the post nor the cap is weakened by framing. A spreader, which is a piece of 2-inch board cut to fit snugly between the posts and nailed to the bottom of the cap, keeps the posts from falling into the drift until the vertical pressure comes upon them.

The method in *B* (fig. 6) is much used but is not recommended. The small recess is cut in the post to provide a shoulder for the lower edge of the cap to rest on and thus prevent the cap splitting along its lower side, but this advantage, if any, is offset by the weakening of the post; also, experienced timbermen are needed to frame and place these timbers properly, for both the cap and the post must be cut for a proper fit. If a square dap is desired, the joint is better made without this recess.

To join round timbers properly, it is necessary that the timbers be dressed, thus insuring a smooth fit and a good bearing surface. Placing the round end of a cap on the flat end of a post, or hollowing the end of the post to conform to a round cap, is sure to result in an early failure of the post by splitting.

The joint shown in *C* (fig. 6) is the mitered or beveled joint and is applicable either to square or round timbers. This joint is widely used and is exceptionally good in heavy ground. The dap, or the seat of the post, is cut in the cap and on a one-to-one bevel, 1 inch deep and 1 inch wide; and the post is beveled to fit. Such a dap is more difficult to cut than a simple square dap, but more easily cut than the one shown at *B*. The bevel serves the same purpose as cutting a recess in the post, but does not weaken the post as much.

In any method of joining it is recommended that the posts be cut so that they can be placed at an angle or bevel to the caps *C* (fig.6), because a shorter cap that will resist pressure better can be used; more room is provided at the bottom of the drift for track, ditch, piping, etc., and less excavation is required than with straight posts. Posts so placed will withstand a heavier side pressure than vertical posts. The amount of bevel commonly used on drift posts is one-half inch to the foot; that is, if the post is 7 feet long, the posts will be 7 inches farther apart at the bottom than on top.

To place the three-piece drift set, shallow holes are dug in the bottom of the drift 5 feet from the last set, and, if the ground is soft, footboards are placed in the hole; then the posts *f* (fig. 5) are stood on the footboards *k*, and the cap *e* is placed on top of the posts. Next the girts *g* are placed between the set being erected and the last set, and blocks are fitted snugly between the regular cap *e* and the wall. If the distance between the end of the cap and the wall is more than can be easily filled with a block, a butt cap *d* may be used. This is a short timber that is placed endwise; that is, with one end against the end of the cap and the other against the wall. Next from the front of the set the wedges *a* are placed between the block *c*, or end of the butt cap, and the side of the drift. The set is tightened up by slightly driving in wedges *a*. Next the top lagging *j* is placed on top of caps *d* and *e*, the head blocks *c* on top of the lagging, over the part of the caps *e* resting on the post. The head blocks are then secured in position by wedges *a*. Next all joints are examined and all blocks and wedges tightened carefully so that there will be no danger of the set moving before the pressure comes upon it. If necessary, the side lagging *b* can be placed in position and held there by the bridge piece *i*, which is another piece of lagging, held in place by the block *l* and the wedge *a*.

The blocking *c* and *l* (fig. 5), or any blocking used on mine timber sets, braces the joint of the set against movement. The blocking crushes under the weight or pressure that is being transmitted through it to the timbers, and in this way absorbs part of the initial creep of the ground and relieves the timbers of some of their burden.

When timbers have to be blocked at the side *l*, or at any point away from a joint, the blocking should always be placed so that the pressure will come on it across the grain. Then the blocking will crush under the pressure, absorbing some of it, and not transmit it all along the grain of the wood to the timber being blocked, as it would if placed so that the pressure came lengthwise. Another reason for placing blocking in this way is that when it becomes necessary to take out the blocking in order to place a new timber for one which has to be renewed the blocking can be split out of its place instead of having to be chopped out.

Lagging, *b* and *j*, most commonly used is 2-inch plank 8 or 10 inches wide, or else round sticks called pole lagging. They extend from the center of one set to the center of another set, and are placed so that the pressure comes upon them sidewise. For stope floors in square-set work or where heavy pressure is expected 3-inch plank are widely used for lagging. For especially heavy duty 4-inch or 6-inch lagging is sometimes employed, but both 4-inch and 6-inch are too heavy for convenient handling.

In lagging a stope floor upon which to blast the rock, it is customary to use two thicknesses, one crosswise on top of the other, of 2-inch or 3-inch planks to make the floor strong enough to withstand the shock of blasting.

FOUR-PIECE SETS.

The four-piece drift set shown in figure 7 is employed when the ground is heavy or the bottom soft. The addition of the sill piece *c* to the three-piece set makes it a four-piece set. (For fig. 7, see p. 14.)

The first step in placing this four-piece set is to dig out for the sill *c* (fig. 7) a trench 5 feet from the last set in place. When this trench has been dug deep enough so that the sill will be approximately on a level with those in place, the sill is placed in the trench and if necessary is leveled up by placing thin strips or wedges under it. Next the posts *b* are erected on the sill in the same manner described for the three-piece set. The sill girts *e* are then placed between the sills, which have been dapped to hold the

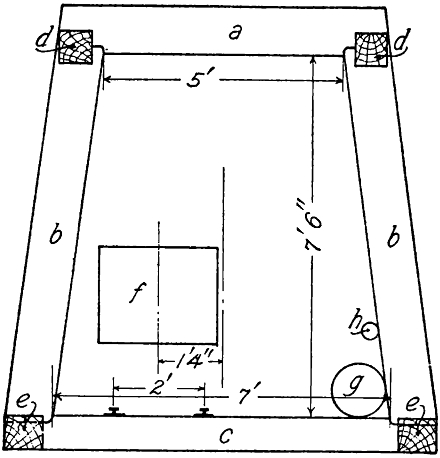


FIGURE 7.—Four-piece drift timber set: *a*, 12 by 12 inch cap; *b*, posts; *c*, 8 by 12 inch sill piece; *d*, 8 by 8 inch cap girts; *e*, 8 by 10 inch sill girts; *f*, car; *g*, ventilation pipe; *h*, air pipe.

sill girts in place, in the same way as the caps *a* are dapped for the cap girts *d*. After the sills and the sill girts are in place, the rest of the set is erected in the same manner as the three-piece sets.

SIX-PIECE SET.

The six-piece set shown in Figure 8, known as the arch set, is only used in main haulage ways and in exceptionally heavy ground. The method of placing six-piece sets is as described for four-piece sets, except that the arch caps *a* and main cap are placed on top of the posts as shown in the figure and are held in position by the girts *d*, which are placed at the junctions of arch caps with the main cap, as well as at the junction of the arch caps with the posts.

METHOD OF REPLACING BROKEN DRIFT POSTS.

Sometimes it is necessary to remove a broken post in a drift set and put in a new one. The cap must be supported while the post is changed, also the correct bevel must be cut on the new post. The cap *e* (fig. 5) can be supported temporarily by placing a false post, cut the right length to extend from the bottom of the drift at *o* to the bottom of the cap at *n* (fig. 5), and wedging it securely. After the old post has been chopped out, one end of the slide staff (fig. 4) is placed on the bottom of the drift at *k* (fig. 5), and the staff

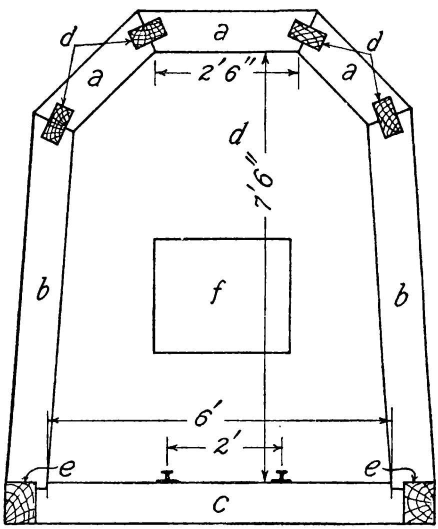


FIGURE 8.—Hexagonal, or six-piece drift set: *a*, Arch cap-pieces, top piece 8 by 8 inches; *b*, posts; *c*, 6 by 8 inch still pieces; *d*, 4 by 6 inch cap girts; *e*, 6 by 6 inch sill girts; *f*, car.

extended until its upper end reaches the cap at *n* (fig. 5). Then the foot pieces on the slide staff are adjusted and the wing nuts tightened. Next the slide staff is laid on the timber to be used as the new post, and the post is cut along the lines given by the foot pieces of the slide staff. Then the post is placed in position, blocked and wedged in the manner described under "Placing of drift sets," and the temporary support is knocked out.

If the cap has sagged from place and it must be forced back, wedges may be driven from both sides between the cap and the top of the false post, or a jackscrew may be used.

CUTTING BEVEL ON CROOKED POSTS.

In tunnel or other mine timbering it is sometimes necessary to use crooked posts. The correct method of cutting these crooked posts on a bevel is shown in figure 9. Stick a knife in the center of the post near one end, *a*, and measure the length desired (say 7 feet) plus one-half the amount of batter, to the nearest side of the post at point *b*. If the batter of the post is to be one-half inch to the foot

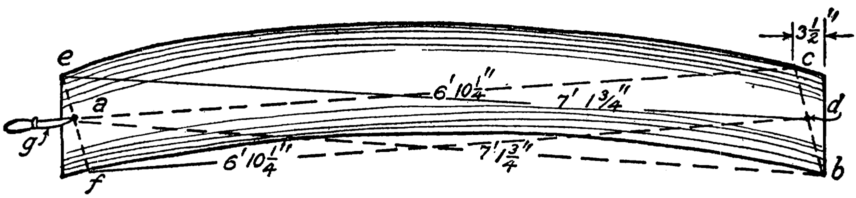


FIGURE 9.—Method of cutting crooked posts on a bevel: *a*, Middle of end of post; *b–c*, first cut; *d*, middle of other end of post, or first cut; *e–f*, second cut; *g*, knife.

or 3½ inches in all, then the distance from *a* to *b* will be 7 feet 1¾ inches. The other side must be cut 1¾ inches less than 7 feet. Measure 7 feet minus 1¾ inches or 6 feet 10¼ inches from the point *a*, and cut off the other end of the post along the line *b* to *c*. Then place the knife in the other end of the post at *d*, and measure in reverse order and cut the post at the opposite end along the line *e* to *f*.

SPILING, OR FOREPOLING IN LOOSE, RUNNING GROUND.

Timbering loose running ground which is sometimes encountered in tunnels, drifts, or crosscuts in gravel, shear zones, or other unconsolidated material presents many difficulties. One of the best and simplest methods of timbering under these conditions is called the spiling, or forepoling method, illustrated in figure 10. The breast boards *k* indicated are not often required, but they are shown in order to explain their use.

First the top spiling *a*, having been sharpened, are driven forward a short distance over the top of the regularly placed drift set with a sledge, or if the ground is very bad, with a jack screw. Next the side spiling is driven ahead practically the same distance. Then the breast boards *k*, which are held in place by sprags or sometimes by special jacks, are moved ahead, one at a time, starting at the top of the drift and working downward until the whole face of the drift has been carried forward to the end of the top spiling. Next the

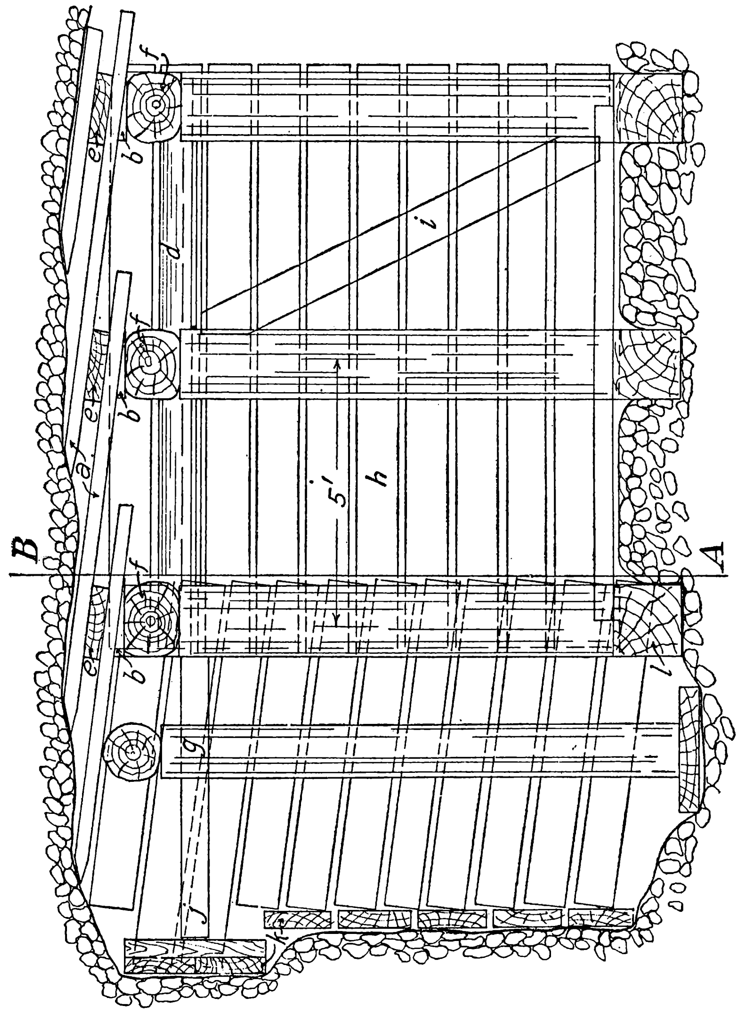
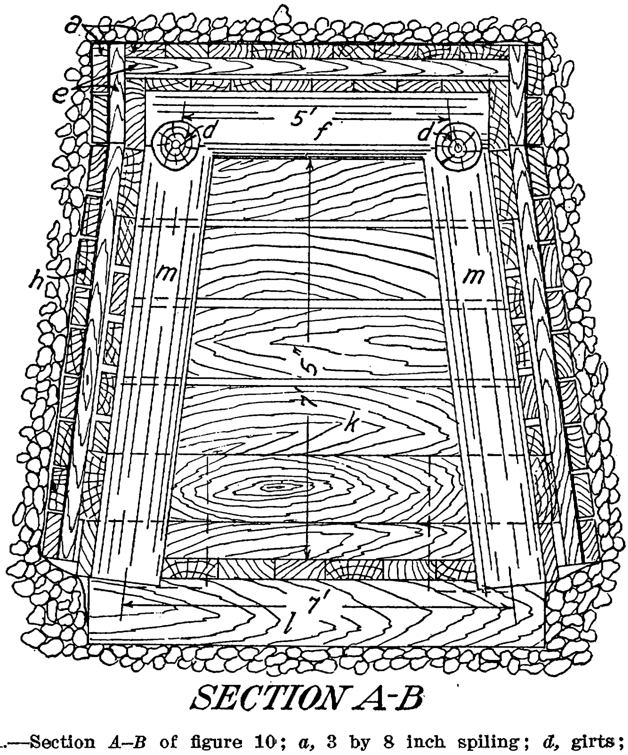


FIGURE 10.—Spiling, or forepoling, in loose running ground; *a*, 3 by 8 inch top spiling; *b*, wedge; *d*, girts; *e*, bridge; *f*, cap; *g*, false set; *h*, side spiling; *i*, sway brace; *j*, sprag; *k*, breast boards; *l*, sill.

false set *g* is put in to support the top spiling *a*, and if the pressure makes it necessary, false pieces can be placed across the drift to aid in supporting the side spiling *h*. After these false sets are placed the operation is continued as before until enough advance has been made to place the regular set. The top and side spiling are then blocked out from the timbers by the bridges shown in section *A–B*.

Then the false set is removed and the operation just described is repeated until the end of the soft ground is reached. Special care is necessary to brace each set securely by sprags, *j*, or even by sway braces or angle braces, *i*, to the preceding set, in order that the pressure from the soft ground at the face does not collapse the sets backward. Forepoling is tedious work, requiring great care and experienced workmen; and the daily advance is very slow.



SECTION A-B

FIGURE 10A.—Section *A–B* of figure 10; *a*, 3 by 8 inch spiling; *d*, girts; *e*, bridge; *f*, cap; *h*, side spiling; *k*, breast boards; *l*, sill; *m*, posts.

DRIFT TIMBERING IN HEAVY, BLOCKY GROUND.

In driving a drift or cross-cut in ground that "breaks high" (where large slabs of rock may loosen and fall out of the back) it is necessary to carry the timber close to the face of the drift, and the space between the top of the set and the back or roof must be completely filled with blocking. If this extra blocking is not placed, a large rock may work loose, drop through the lagging, and injure the men working in the drift.

Where timbering is carried close to the face, it is an excellent precaution to reinforce with sprags and angle braces the sets nearest the face, in order to lessen the chance of these sets being dislodged in blasting.

TIMBERING IN SWELLING GROUND.

Swelling or creeping ground is due generally to exposure of certain kinds of rock to the air, whereby they undergo a change and increase in volume; so that the excavation not only closes in from the top and sides, but may heave or swell from the bottom. Heavy pressures on a soft bottom will also cause heaving or creeping ground. The octagonal or eight-piece set shown in figure 11 has been used in adits (tunnels) or main haulage ways where the ground swells in this manner. If the 12 by 12 inch timbers shown can not resist the pressure when set at the usual distance of 5 feet between sets, it is customary to place them close enough to withstand the pressure; placing them skin to skin, or tight against one another, is sometimes necessary. The method of placing these sets is essentially the same as that described for the six-piece drift set.

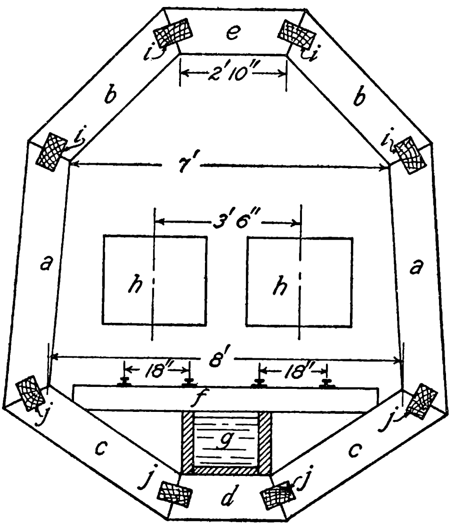


FIGURE 11.—Octagonal or eight-piece set used in swelling ground: *a*, 12 by 12 inch posts; *b*, top arch-pieces; *c*, bottom arch-pieces; *d*, sill key-piece; *e*, 5-foot by 10-inch cap key-piece; *f*, 6-foot by 10-inch tie; *g*, drain; *h*, car; *i*, top girt-pieces; *j*, bottom girt-pieces.

However, whenever ground requiring such unusually strong construction is encountered, it is becoming common practice to use concrete construction in main opening. In drifts, a common method of timbering in swelling ground is to place drift sets consisting of an especially large cap and post, with the posts spread at a wider angle than ordinarily is used. A sill may or may not be used, depending on the nature of the floor. If the swelling ground is very soft, as it often is, wedges are sometimes used as bridge blocks and the lagging is spaced 4 to 6 inches apart. The ground is permitted to swell out from between the lagging, and from time to time is taken out with a pick; in this manner much of the pressure on the timbers may be relieved. Experience has shown that it is usually better to provide for relieving rather than for resisting pressure. Where the floor heaves, it must be taken up, from time to time, and the track ties relaid on grade.

In connection with the four-piece drift sets shown in figure 7, coating the walls with "gunite" (cement mortar) has also been tried in some mines and found satisfactory. As the swelling of the ground is often caused by the action of the air on the rock, the cement coating protecting the rock from the air prevents this action. Plate XVII, *A* (p. 65) shows this application of gunite to drift sets in swelling ground.

GRADE AND ALIGNMENT OF DRIFT TIMBERS.

While most adits (tunnels), drifts, and crosscuts are driven on a grade which has been decided beforehand, yet a proper grade for the finished opening can only be obtained by placing correctly the individual sets of timber. These openings should always be driven on a slight upgrade from the mouth, in order to drain the water from the workings and aid in tramming out the loaded cars.

The factors that decide the choice of grade, such as the problem of drainage, method of haulage used, type of rolling stock, and accuracy with which the track is laid, will not be discussed here as they are related to engineering rather than to timbering methods.

The timberman who must maintain the grade selected will find the "level stick" or the "grade stick" detailed in figure 12 a very

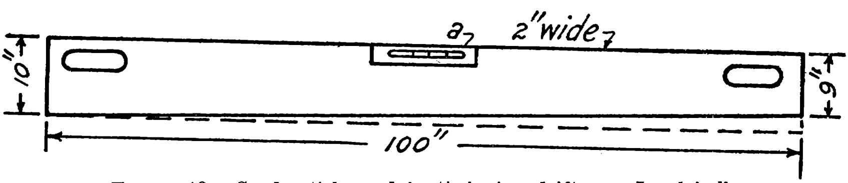


FIGURE 12.—Grade stick used in timbering drifts: *a*, Level bulb.

useful tool. This grade stick is 100 inches (8 feet, 4 inches) long and will cover three track ties spaced 2½ feet apart. It is 10 inches high at one end and 9 inches at the other; these dimensions will give a grade of 1 per cent, which is usually enough. The 10-inch end of the grade stick is placed on a sill piece or on the tie in place, and the 9-inch end on the tie to be placed on grade. This tie is raised or lowered until the level bulb is between the hair lines, and then the tie is blocked into position. Several sets can be placed with a grade stick in this way with enough accuracy for track in drifts and headings, but for longer distances or in main haulageways grade points should be established at 50 or 100 foot intervals by means of a transit or a surveyor's level.

The common method of aligning a tunnel or crosscut, on the line on which it is to be driven, is to establish the line with a transit and place center points by fixing pegs in the roof or back, or in the caps of timber sets, but preferably in the roof, as a slight movement of the timbers might cause a serious deflection in the alignment.

In a drift which is being driven on line the alignment of the sets can usually be obtained with sufficient accuracy by placing two plumb bobs in the center of two caps which are some distance apart and which are properly aligned; then marking the center of the cap that is to be placed next. One man holds a light at this center point, and moves this last cap until the light and the plumb bob strings are in line. The set is blocked and wedged securely in place. If maintaining an accurate alignment in the drift is necessary, this method should be checked occasionally with a transit.

Another method of aligning drift sets, where the heading is far enough in advance of the timber to permit this, is to establish a center point some distance ahead of the last set of timber in place, and then stretch a line between this point and the nearest center point back of the timbering.

TIMBERING INCLINED SHAFTS AND WINZES.

The timbering employed in inclined shafts or winzes may, for the purpose of this discussion, be divided into two classes: Where the inclination is less than 30°, and where the inclination is greater than 30°. This division is more or less arbitrary, and may be varied to suit conditions.

In general, the more nearly the shaft approaches the vertical the more timbering is required. Moreover, an ordinary mine car will not hold a full load when the inclination of the shaft is more than 20°, consequently a skip, bucket, or some other hoisting arrangement must be used. Therefore, the design of the shaft timbering, as well as the design of the shaft station is different.

SHAFTS INCLINED LESS THAN 30°.

When the inclination of the shaft is less than 30° and the ground is moderately hard, the ordinary four-piece drift set shown in figure 7 may be used. The sets are placed 5 feet apart, center to center, as in drift timbering, and the track, if possible, is placed at one side of the shaft. Sometimes when the ground stands well, the cap may be dispensed with and only ties and posts used.

It is much better for the purpose of ventilation, as well as for safety, to have at least two compartments in all shafts or winzes. The drift set shown in figure 7 (p. 14) can be changed into a set for a two-compartment shaft by lengthening the cap and placing another post in the center of the cap (Pl. III, *A*). This will divide the shaft into two compartments, a haulageway, and a manway. Lagging the dividing posts between the two compartments will permit better circulation of air, keep men from stumbling over into the haulage side of the shaft, and prevent injury to the men from rocks falling from the loaded cars into the manway.

SHAFTS INCLINED MORE THAN 30°.

When the ground needs more support than is afforded by the simple cap-and-post set, or when the inclination of the shaft is more than 30° and less than 45°, the method of timbering detailed in figure 13 is sometimes employed. This illustration shows a three-compartment shaft, consisting of two haulage compartments and one manway; but for small operations the number of compartments can be reduced. The manway is shown in the lower left-hand corner; in it are placed a ladder and sometimes a small car track for lowering supplies. The top and sides of these shafts, when the ground requires it, should be covered with lagging, *f*, to keep pieces of rocks from falling. The method of procedure in placing these timbers is the same as that described before, with the exception that hanging bolts *e* are used to tie the sets together until such time as the weight of the ground wedges the set securely in position, and to support the sets as the work of sinking the shaft progresses. The posts *c* are used to keep the sets properly spaced, and the hanging bolts keep the wall plates *a* and the end plates *b* tight against the posts. These hanging bolts are generally three-fourths inch round iron and made in two sections, with hooks at one end and nuts and washers on the other. In inserting the hanging bolts it is best to use large washers about 4 inches in diameter against the wood, as the weight on the bolts is sometimes very great. Hanging bolts are not always left in permanently, but may often be removed after a considerable portion of the shaft has been completed and the timbers have taken up the weight of the ground.

The details of the joints used in this method of shaft timbering, which are different from the joints used in the ordinary drift set, are shown in the upper left-hand and lower right-hand corners of figure 13. The posts *c* fit into the framing on the wall plates *a* in the manner shown. The method of framing the divider *d* and the wall plate *a* at their junction in the center of the shaft will also be clear from a study of the drawing.

SHAFTS INCLINED MORE THAN 45°.

When the dip of the shaft is greater than 45°, no matter if the ground is moderately hard, it is the practice to use the vertical shaft method of timbering, shown in figure 14. If the opening is for exploration, this same method of timbering should be used. The sets are usually placed 5 feet apart, center to center, and made 5 or more feet high.

The framing of the ends of the plates *f* (fig. 14), the wall plates *e*, and the posts *h*, at their junction in the corner of the shaft, is the so-called square-cut method and is shown in detail in figure 15.

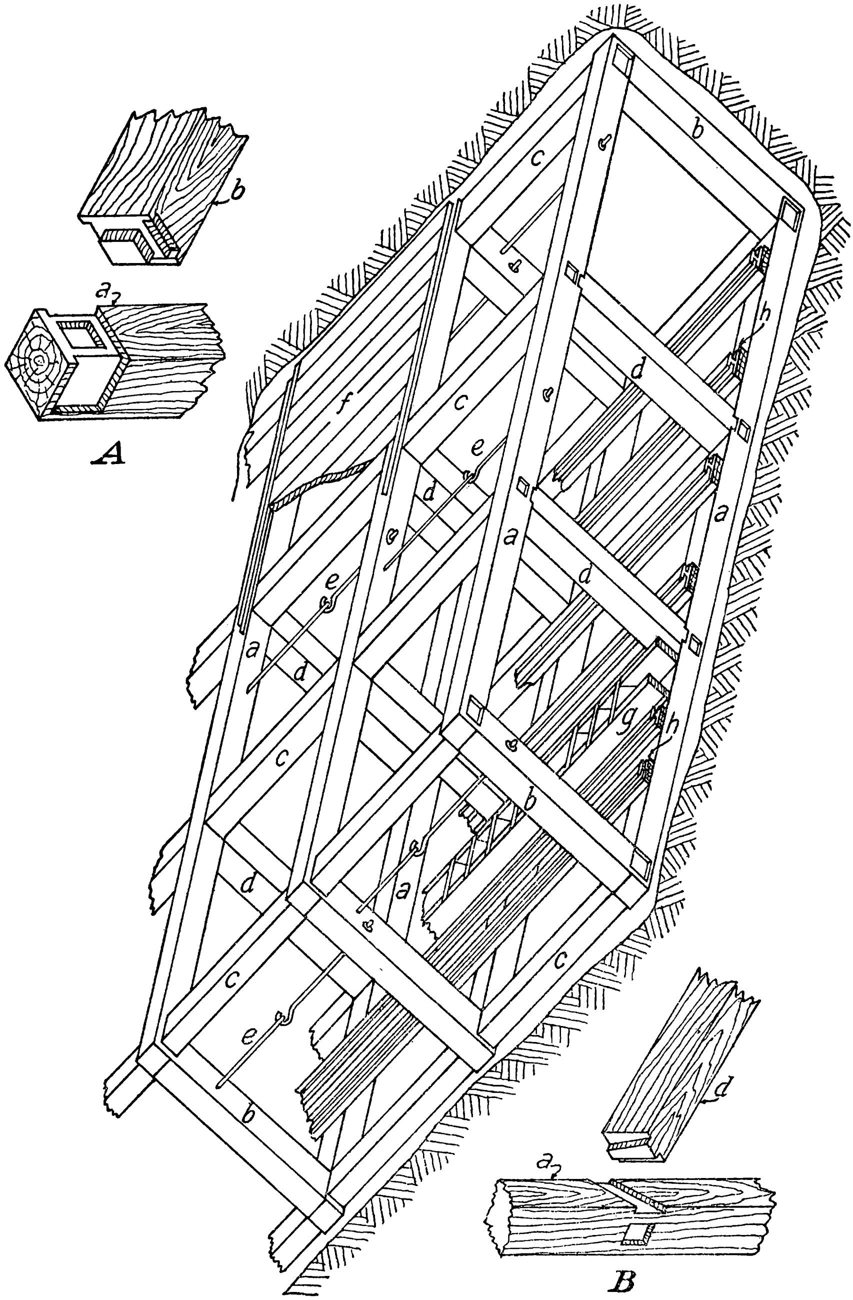


FIGURE 13.—Details of timbering used in inclines of less than 45°. One manway and two hoisting compartments: *A*, Detail of corner joints; *B*, detail of center joints; *a*, wall plate, 9 by 9 inches; *b*, end plate, 8 by 8 inches; *c*, posts; *d*, dividers, 9 by 6 inches; *e*, hanging bolts; *f*, lagging; *g*, ladder; *h*, rails.

These methods of framing are the ones commonly used, but in exceptionally heavy ground the mitered or beveled joint (fig. 6, *C*) is employed. The timbers as shown are of 8 by 8 inch material; but the method of framing other sizes is the same. When the beveled

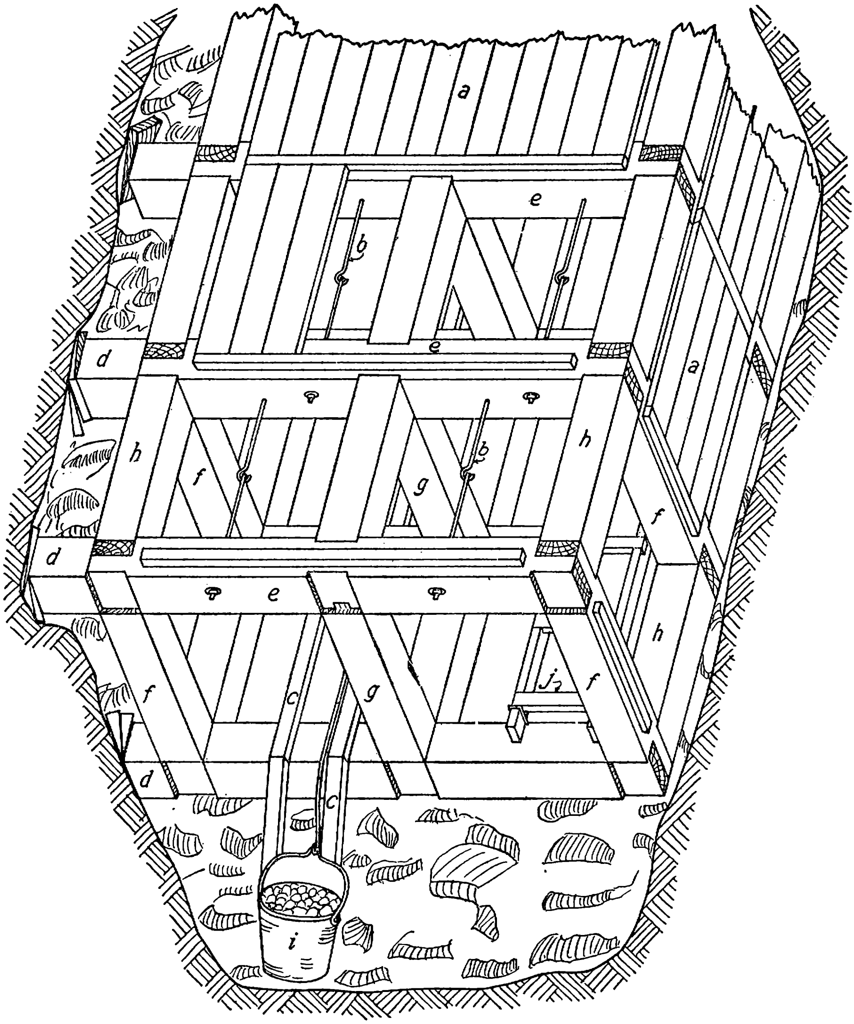


FIGURE 14.—Timbering in inclines of over 45° inclination: *a*, 3-inch lagging; *b*, hanging bolts; *c*, 5-foot slide skids; *d*, blocks; *e*, wall plate; *f*, end plate; *g*, divider; *h*, posts; *i*, bucket; *j*, ladder.

joint is used, the horn of both the wall plate *c* and the end plate *a* (fig. 15) is made 7 inches wide instead of 8 inches; and a 1 to 1 bevel is cut on these timbers where they come together to form the corner of the shaft.

The square-cut method of framing, howev[illegible] recommended in all but the heaviest ground because it is [illegible]r, easier, and cheaper to frame, and does not need an expe[illegible] carpenter to make the square joint. Moreover, with the mite[illegible] joint sand and gravel may get into the bevel, and it is difficult to make the timbers fit snugly.

At some mines the practice is to make the horn of the wall plate *e* (fig. 14) one-half inch shorter than the width of the end plate *f*. When the blocking *d* is placed at the corner of the set, the pressure

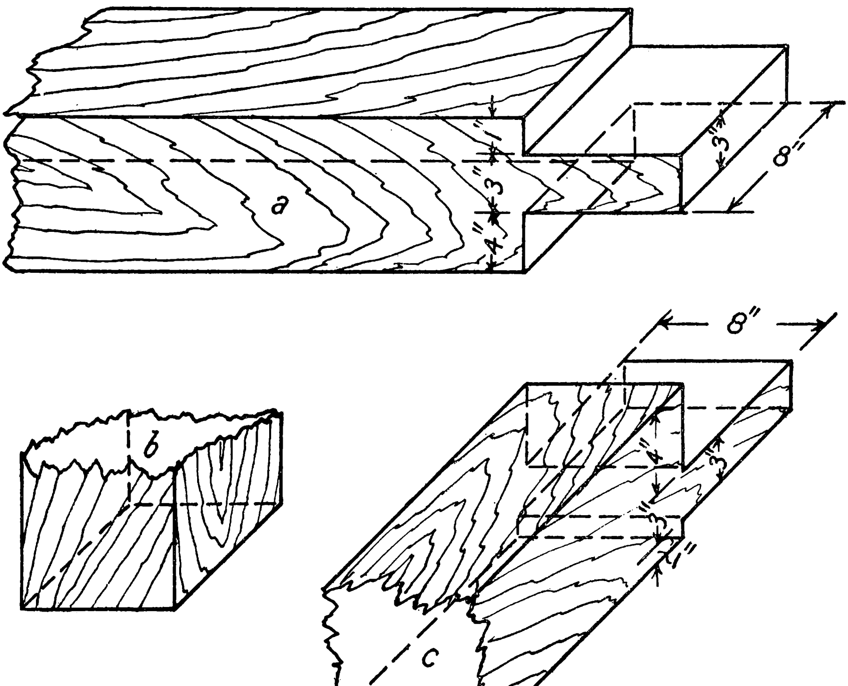
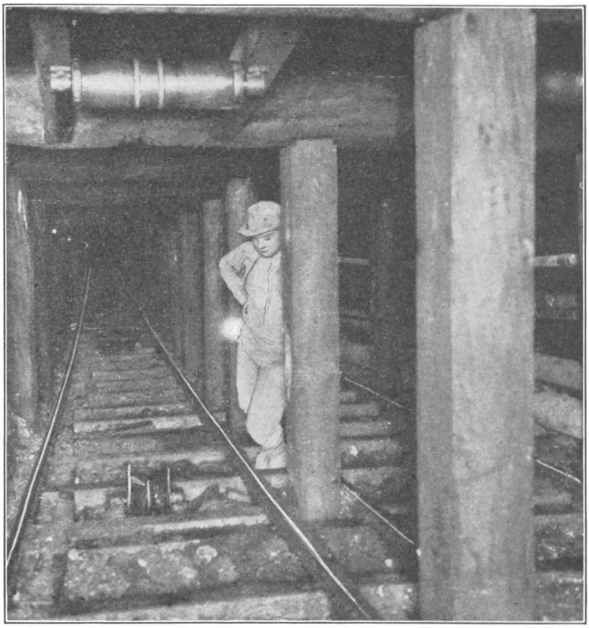


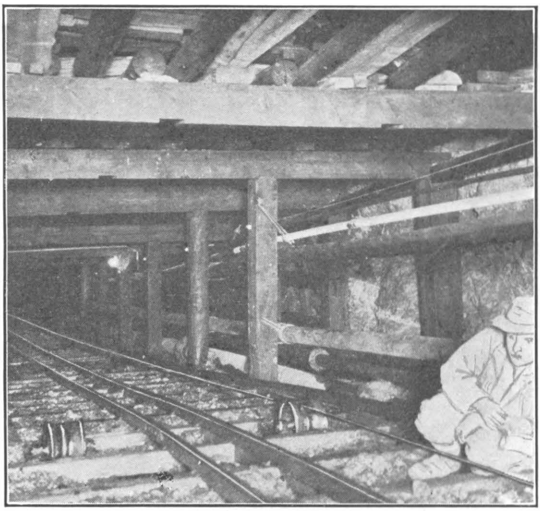
FIGURE 15.—Framing of post, wall plate, and end plate, used in vertical shafts: *a*, 8 by 8 inch end plate; *b*, 8 by 8 inch post; *c*, 8 by 8 inch wall plate.

comes upon the blocking, then upon the side of the end plate, which crushes slowly and thus prevents the full pressure coming on the end of the wall plate, making the joint more solid. Again, both the wall plates *e* and the end plates *f* may be cut with their horns 1 inch short. The joint thus obtained is said to be nearly as strong as the mitered joint, and requires much less framing.

The framing of the end of the divider *g* (fig. 14) and the wall plate *e* at their junction in the center of the shaft, is shown in detail in figure 16. While this method of framing is complicated, the divider *g* (fig. 14) does not need support from below prior to the

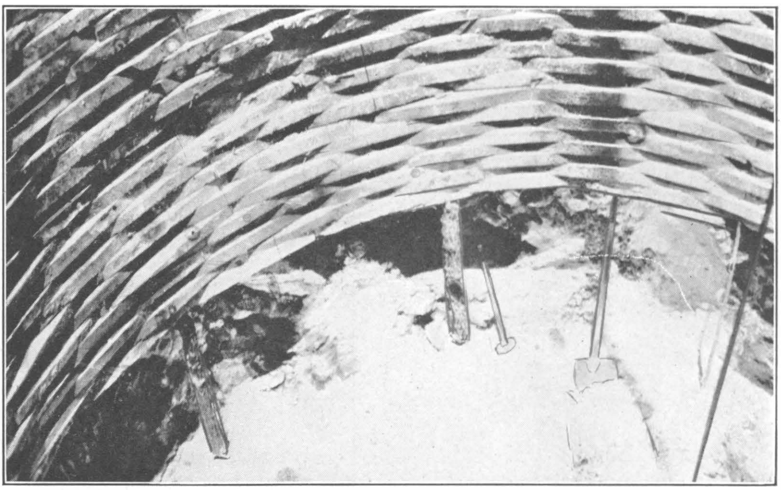


A. VIEW OF THE TIMBERING EMPLOYED IN SHAFTS INCLINED LESS THAN 30°. NOTE THE ROLLER AT THE TOP OF THE SHAFT AND THE DIVIDING POSTS BETWEEN THE TWO COMPARTMENTS.

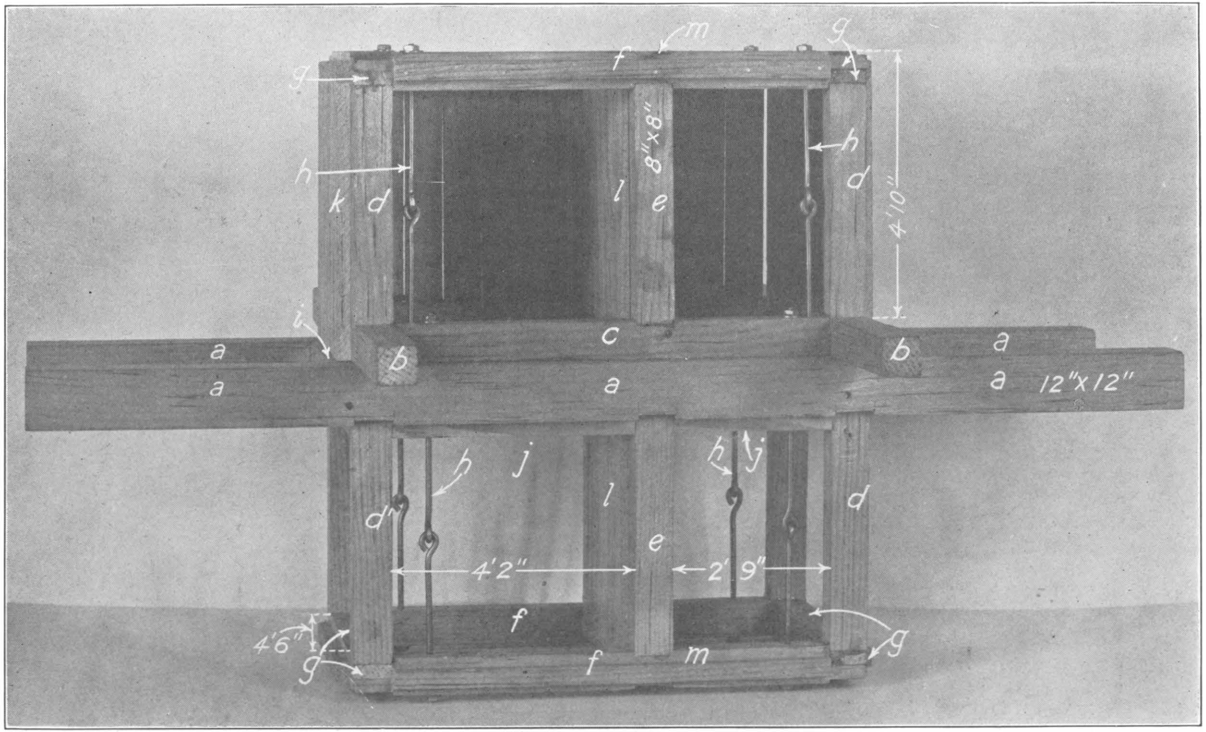


B. VIEW OF HAULAGE WAY AND PIPE COMPARTMENT IN SHAFT INCLINED LESS THAN 30°.

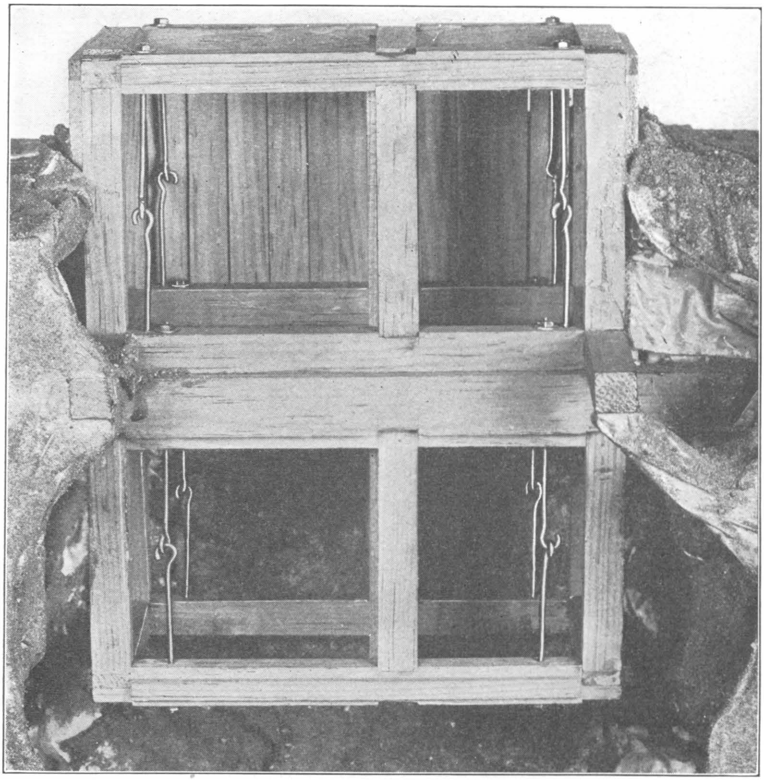
A. TIMBERING AT THE COLLAR OF A CIRCULAR SHAFT.



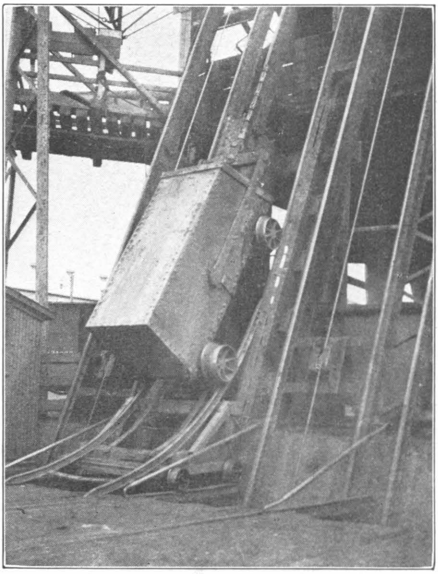
B. TIMBERING AT THE BOTTOM OF A CIRCULAR SHAFT.



MODEL OF TIMBERING USED AT THE COLLAR OF A VERTICAL SHAFT: *a*, STRINGERS; *b*, CROSS BEARERS; *c*, CROSS-BEARER WALL PLATES; *d*, POSTS; *e*, DIVIDER POSTS; *f*, WALL PLATES; *g*, REGULAR END PLATES; *h*, HANGING BOLTS; *i*, SHORT END PLATES; *j*, CLEATS; *k*, LAGGING 2" OR 3"; *l*, DIVIDER BOARDS 1" OR 2"; *m*, DIVIDERS.



A. MODEL OF THE TIMBERING USED AT THE COLLAR OF A VERTICAL SHAFT, SHOWING HOW THE TIMBERS ARE PLACED IN THE GROUND.



B. METHOD OF LOWERING SKIP FROM SHAFT TO LANDING PLATFORM, USED IN INCLINED SHAFTS.

placing of the next set, as the dovetail framing will keep it in place; and any pressure on the wall plates *e*, when posts *h* are placed both above and below it, tends to seat the divider more securely and makes the joint stronger.

Where it is necessary to carry the timbering near the bottom of the shaft, the divider *g* (fig. 14) is sometimes left out, in order to obtain more room for shoveling, and placed in position after the bottom of the shaft has been cleaned. When this is done the post *b* (fig. 16) is cut out 2 inches so that the divider can be slipped into position.

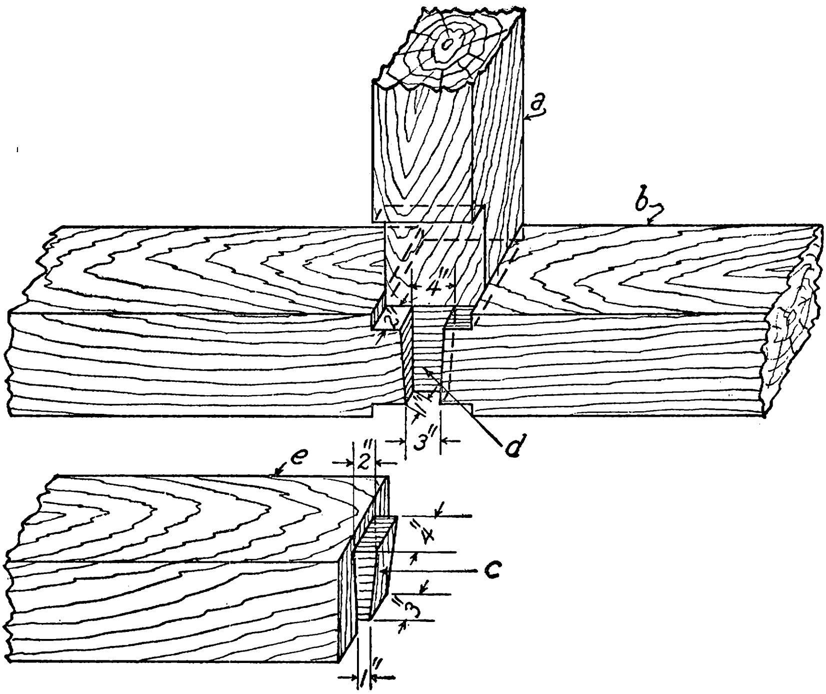


FIGURE 16.—Framing of divider, divider post, and center of wall plate, used in vertical shafts: *a*, 8 by 8 inch divider post; *b*, 8 by 8 inch wall plate; *c*, divider horn; *d*, divider-horn seat; *e*, 8 by 8 inch divider.

After the divider *g* (fig. 14) has been set in place, the gap in the post is filled with 2-inch blocking in order to hold the divider securely in place.

MAINTAINING GRADE AND ALIGNMENT.

The method of timbering these inclines is practically the same as that explained for timbering drifts on page 19, with the exception that more care must be taken in maintaining an even grade and proper alignment.

The template is a convenient device for aligning sets in short shallow shafts, where the mine surveying instruments commonly used in shaft work are not available, or as an auxiliary to such instruments. For this purpose a template similar to the one detailed in figure 17 is commonly used; the template illustrated is for a 45° shaft, but the construction is the same for any other angle. It is so constructed that the bottom piece, or the piece resting on the straightedge, is on the same angle to the horizontal piece that the shaft is to the horizontal. In using this template, first place the

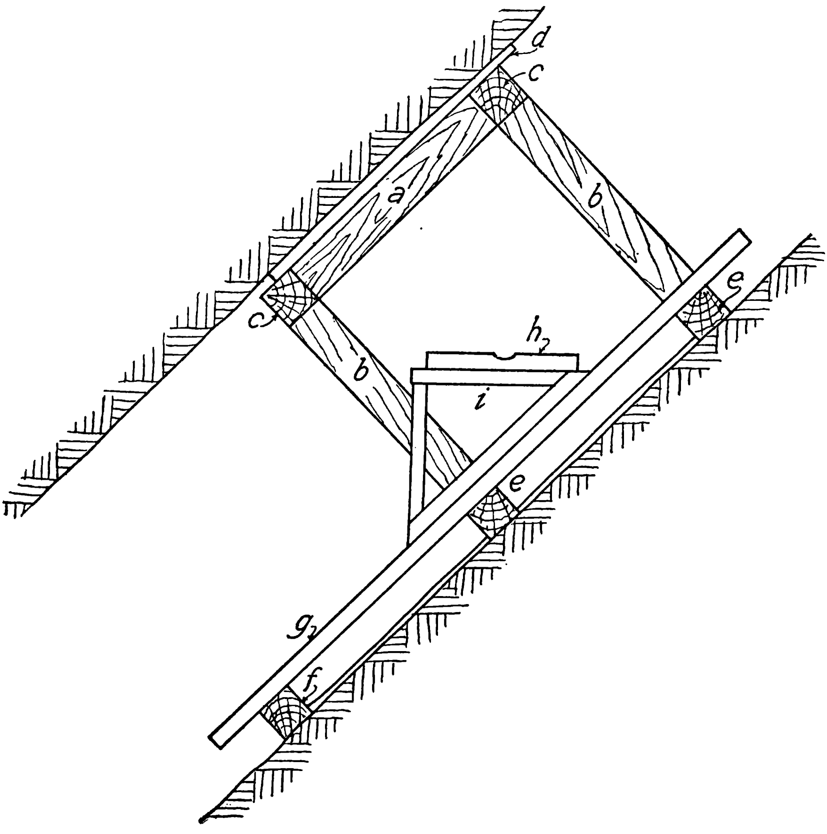


FIGURE 17.—Template used in maintaining grade in incline shafts: *a*, Girt; *b*, posts; *c*, caps; *d*, lagging; *e*, old sill pieces; *f*, new sill pieces; *g*, straightedge; *h*, level; *i*, horizontal piece.

bottom piece of the set, then place the template on the straightedge between the sills to be placed on grade. Next block up the new sill piece until all three are on the same level. This will be determined by glancing at the level occasionally; and, when the level bulb is in the center of the level, the three sills are all on an even grade.

The method of placing the individual sets in alignment is the same as that explained for drifts and crosscuts on pages 19 and 20.

TIMBERING VERTICAL SHAFTS.

There are three general types of vertical shafts used in metal mining—rectangular shafts, square or box shafts, and round or circular shafts. All other shafts are a variation of one or more of these types.

The timbering methods used in lining round shafts are entirely different from those used in square and rectangular shafts. Two views of a method of timbering round shafts are shown in Plate IV. It is obvious that this method of timbering is too complicated, and hence too costly for the average mine operator. Where a round shaft is used, it is usually lined with brick, concrete, or even, under special conditions, with iron.

While the timbering employed in square shafts is the same as that used in rectangular shafts (fig. 14), the rectangular shape is better suited to utilizing the full area of the opening and in shafts of more than one compartment it is a much stronger shape. Thus the square shaft is not commonly used.

Methods for timbering rectangular vertical shafts and methods for framing the individual members of the sets have already been explained for inclined shafts (figs. 14, 15, and 16). These sets and the framing of the members of the sets are the same for vertical rectangular shafts, and the only difference is in the practice of placing the timbers. For small, shallow prospect shafts some form of cribbing is often used. While it is not difficult to frame and place in a shallow shaft, cribbing becomes too expensive for deeper shafts.

PLACING TIMBER SETS FOR DEEPER SHAFTS.

Most vertical shafts at metal mines are sunk from some point on the surface where the shaft will intersect the vein or ore deposit, and usually pass, first, through loose soil, then through decomposed rock, and finally through solid rock. This necessitates supporting by suitable means the collar or first sets of the shaft from the surface downward.

In prospecting, either a one or two compartment shaft is commonly used. It is recommended, however, that a two-compartment shaft (Pl. VI, *A*) be used whenever possible, as there is less interruption to hoisting of ore, repairs can be more conveniently made, ventilation is less affected, and there is less chance of accident to the men. The size of the compartments varies greatly, but they are frequently 4 feet 6 inches by 4 feet 2 inches in the clear. In beginning a new shaft, first sink a hole about 10 feet deep, unless solid rock is encountered sooner, or unless the ground must be supported immediately, and at the same time frame the timbers for the collar or first set (Pl. V). The methods of framing the end plates *g*, the wall plates *f*, the posts *d*, the divider posts *e*, and the dividers *m* are shown in figures 14, 15, and 16. The method of framing the stringers *a*, the cross-bearers *b*, the short wall plates *c*, the short end plates *i* are shown in figure 18.

After a sufficient number of the various timbers have been framed, and the shaft excavated for a depth of about 10 feet, dig on the surface at the ends of the shaft opening two trenches 12 or 16 inches

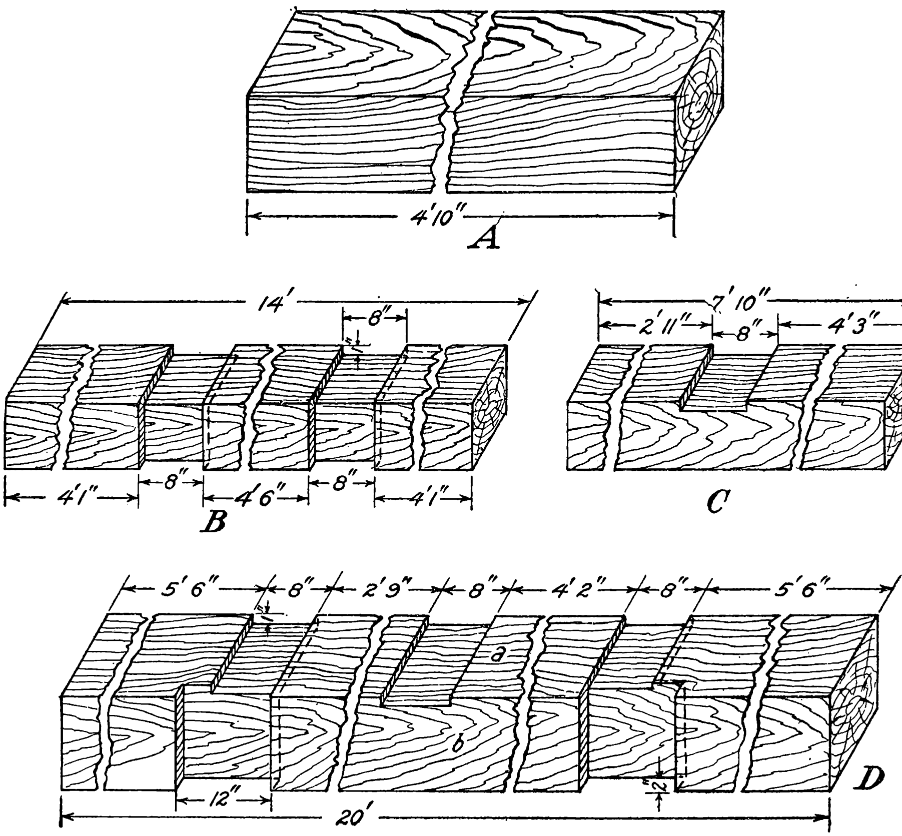


FIGURE 18.—Framing of timbers used at collar of vertical shaft: *A*, 12 by 12 inch short end-plate; *B*, 8 by 8 inch cross bearer; *C*, 8 by 8 inch short wall-plate; *D*, 12 by 12 inch stringer; *a*, bottom; *b*, inside.

wide, 2 to 5 feet deep, and 4 feet 6 inches apart. Now place the two stringers *a* (Pl. V), in these trenches and between them place the two short end plates *i*. Next fasten these four pieces together securely with 1-inch bolts. Place the two cross-bearers *b* crosswise of the stringers *a* on top of the two short end plates *i* and then put the two short wall plates *c* on top of the two stringers *a*, between the two cross-bearers *b*. With a carpenter's square true the joints of the cross-bearers *b* and the short wall plates *c* until they are at exactly right angles and flush with the inside of the stringers *a*, and nail these pieces securely to the stringers. Then place the lower half of the hanging bolts *h* in their proper holes in the stringers *a*, and erect the end posts *d* and the divider posts *e* at their proper places at the corners and the center of the short wall plate *c*. Next place the end plates *g* on top of the posts *d* and put the wall plates *f* on top of them. Put the upper half of the hanging bolts *h* in their proper holes in the wall plates *f*, and connect the two halves of the hanging bolts. Now tighten up on the hanging bolts until the joints of the posts *d* and the end plates *g* and the wall plates *f* are snug and secure. After this slip the divider *m* into its proper position.

The next step is to place the set of timbers immediately below the stringers *a*. Having lowered the individual timbers to the bottom of the shaft, place the upper half of the hanging bolts *h* (Pl. V) in their proper position in the stringers *a* and the lower half in the wall plates *f*. Raise the wall plates *f* until the two halves of the hanging bolts *h* can be connected together as described before, and place the end plates *g* on top of the wall plates *f* in their proper seats at the ends of the wall plates. Next put the end posts *d* upright in their positions at the junction of the wall and end plates and fit them into the hitches cut for them in the stringers *a*; place the divider posts *e* in position and tighten up on the hanging bolts *h* until all joints are snug and secure, using a carpenter's square at the corner of the shaft to be certain the end and wall plates are joined to each other at exactly right angles.

The next step is to place the lagging *k* (Pl. V) around the outside the set above the stringers *a*. In shaft sinking 2-inch to 3-inch lagging are ordinarily used. Place the lagging in position between the cleat *n* and the short end plate *i* and nail them securely to the end plate *g*. Finish lagging on both ends, then on the two sides in the same manner, and then pack in with dirt. Plate VI *A* shows a finished collar set, placed in position in the ground. The final step is to block, wedge, and lag the set below the stringers *a* (Pl. V). This work is the same as will be indicated for a regular set. Before the shaft is deepened, dirt or concrete should be placed around the top set and the whole area leveled off.

PLACING REGULAR SETS IN MEDIUM GROUND.

After the collar sets have been placed the new sets are placed below, one by one, as the shaft deepens. For the first few sets this work is usually done from the top of the pile of broken rock in the bottom of the shaft; that is, after the rock has been blasted it is removed down to about 10 feet below the last set. The timbermen standing on this rock pile put the set in place as described before.

In hard rock, as the shaft is deepened, the bottom of the shaft is usually 20 to 50 feet in advance of the timbering, and the timbermen work from a platform resting on stulls supported by hitches cut in the solid rock. This prevents the timbers being dislodged or damaged by flying rock caused by blasting, and permits timbering to proceed without interrupting the drilling and shoveling. Another method of supporting the platform is from timbers held by long hanging bolts or chains attached to the set above.

After a set has been placed the next step is to align the timbers and so block the set that it will not be forced out of alignment unless the whole shaft moves. First two blocks, *e* (fig. 19), fifteen-sixteenths of an inch thick are placed in diagonal corners of a shaft set (*A*), which has been placed in alignment—for example, the top collar set. Then a 1-pound plumb bob is tied to a one-eighth-inch line *d* and lowered down the shaft over the blocks *e*. These blocks hold the plumb bob line *d* out from the corner of the shaft at a point 1 inch from both the end plates *c* and the wall plates *b*. While the timber is being framed on the surface the mine carpenter marks a line *j* 1 inch from the inside of the horn of both the end plates *c* and the wall plates *b*. When the sets are properly aligned the lines *j* and the plumb bob line *d* will be exactly in line with each other. Now place the blocks *h* at the four corners of the shaft timbers in the order shown by the numbers 1, 2, 3, 4, etc., and put wedges between these blocks *h* and the ground until the lines *j* and the plumb bob line *d* correspond; tighten the blocking by driving the wedges until all joints are firm and tight and the set of timber is solidly held. Finally stretch a line from the centers of the end plates *c* and mark the center of the divider *a*. Then place the blocks 9 and 10 and by the use of wedges move the center of the set until the center *b* of the divider *a* is directly beneath the line stretched from the center of end plate *c*.

About every 50 feet as the shaft is deepened the plumb-bob lines *d* have to be lowered to a new set. The new set is selected and measurements taken each way from the plumb-bob line *d* (fig. 19) in order to determine how far the wall plates *b* and the end plates *c* are out of line. If the timbers are nearly in line the blocks *e* are nailed in the corners of the set, any slight error being corrected by shaving the blocks *e* with a pocket knife. When sure that the new blocks are perfectly in line with the old ones, the plumb-bob line *d* is fastened to the new set *A* and the alignment of the shaft below is carried on from this set. It is better to place the first blocks and plumb-bob lines in the collar set with the aid of a transit, especially if the shaft is larger than two compartments. An additional check is to measure across the diagonal of the shaft between the plumb-bob lines *d* every few sets to be certain that this distance does not change. A slight error can be corrected by the use of wedges and blocking.

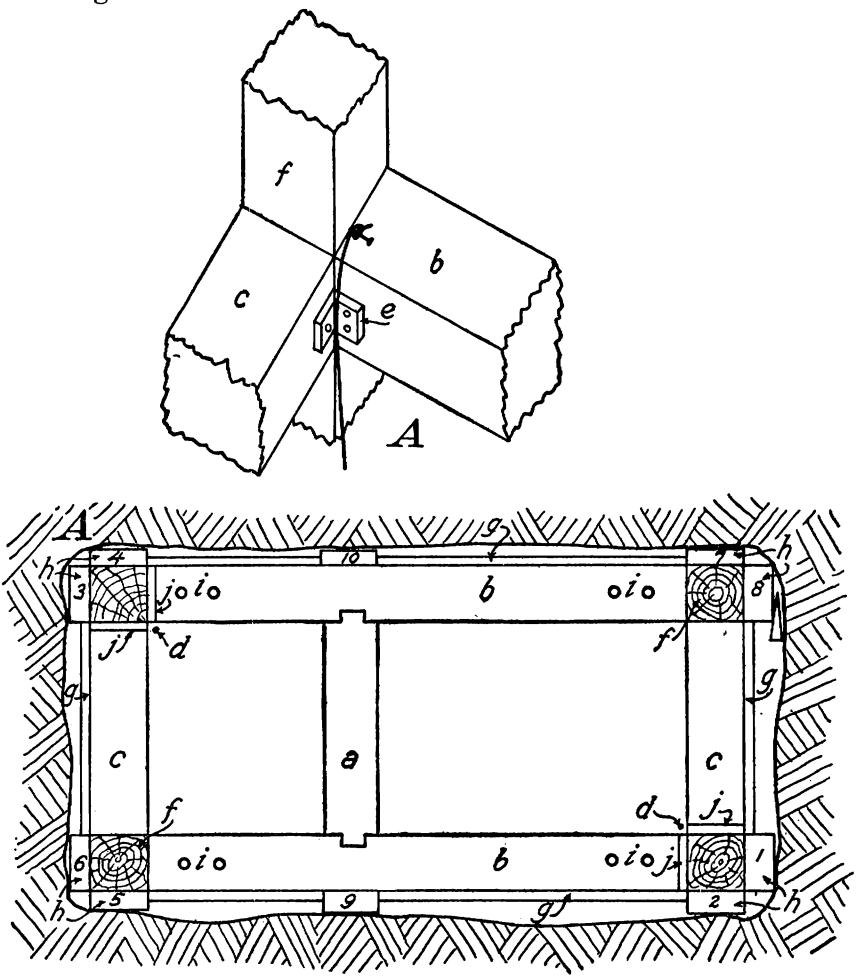


FIGURE 19.—Method of aligning vertical shafts: *A*, Diagonal corners of shaft set; *a*, dividers; *b*, wall plate; *c*, end plate; *d*, one-eighth-inch plumb-bob line; *e*, fifteen-sixteenths-inch plumb-bob block; *f*, post; *g*, cleat; *h*, block; *i*, holes for hanging bolts; *j*, scratch line used in checking alignment.

Ordinarily the next step in timbering a shaft, after the alignment of the timbers, is to place the lagging on the outside of the end plates *c* and the wall plates *b*. However, when the timber is carried close to the bottom, or when the ground is very hard and requires a heavy charge of explosive to break it, the end plates and wall plates in the lowest set may, unless they are protected, become badly damaged from the pieces of flying rock. In this case, the lagging is not placed in position in the two bottom sets, but "blasting timbers," *a* (fig. 20) are placed on the bottom of the shaft set to protect the regular timbers. These blasting timbers are usually old pieces of 12 by 12 inch timbers, cut with square ends and fastened to the regular sets, either by the short hanging bolts *e* or by the chain *i* and wedges *h*. The blasting timbers are placed on the

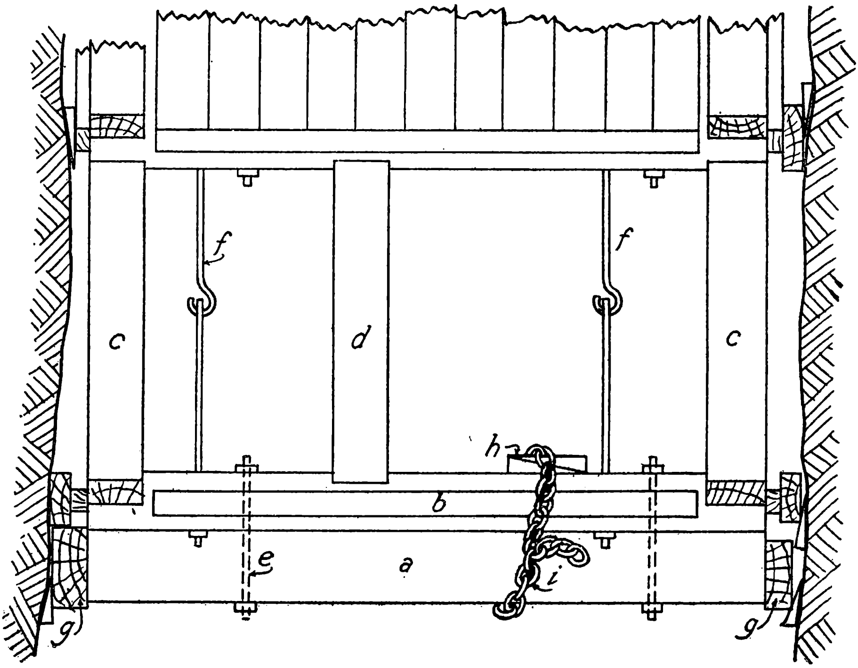


FIGURE 20.—"Blasting timbers" used in vertical shafts: *a*, Blasting timbers; *b*, wall plate; *c*, shaft post; *d*, divider post; *e*, blasting-timber hanging bolts; *f*, regular hanging bolts; *g*, block; *h*, wedges; *i*, chain.

bottom of the regular sets before the rest of the round is shoveled out, and are held out from the sides of the opening by the blocks *g* and wedges.

LAGGING TIMBERS IN VERTICAL SHAFTS.

Figure 21 shows the method of blocking the lagging *h* on the end plates *b* of the shaft timbers. The method of placing the lagging on the wall plates *a* is the same as when they are placed on the end plates; 2-inch or 3-inch planks 8 inches wide are generally used for shaft lagging.

In placing the lagging, first the pieces No. 1 and No. 2 (fig. 21) are put in position between the cleats *f*. These cleats are 2-inch

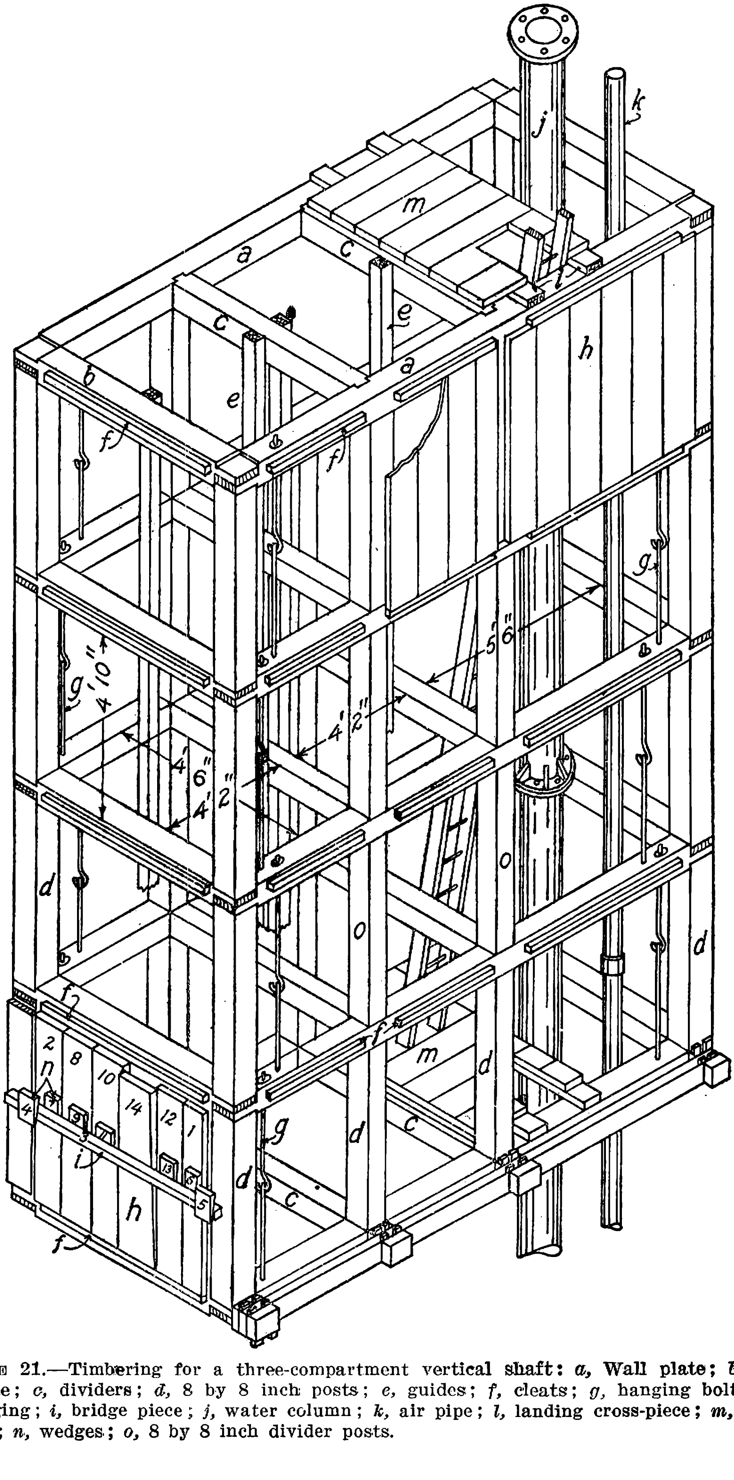


FIGURE 21.—Timbering for a three-compartment vertical shaft: *a*, Wall plate; *b*, end plate; *c*, dividers; *d*, 8 by 8 inch posts; *e*, guides; *f*, cleats; *g*, hanging bolts; *h*, lagging; *i*, bridge piece; *j*, water column; *k*, air pipe; *l*, landing cross-piece; *m*, landing; *n*, wedges; *o*, 8 by 8 inch divider posts.

by 2-inch pieces and are usually nailed to the sides of the end-plates and wall plates before they are lowered into the shaft. Then the bridge piece *i* is placed between the lagging strips (1 and 2) and the rock. Next the wedges (4 and 5) are put in between the wall rock and the bridge piece *i* to hold it snugly against the lagging (1 and 2), and wedges (6 and 7) are placed between laggings (1 and 2) and the bridge piece *i*. The rest of the lagging and the wedges with them are then placed in position in the order shown in the drawing, 8, 9, 10, etc., until 14 is reached. Lagging 14 is not blocked from the inside of the set; but sometimes, when the set below has been placed in position, a wedge is slipped in from below between the rock and this lagging (14) to hold it in place.

When the distance between the shaft timbers and the wall rock is more than 8 or 10 inches, the large blocks and stringers shown at the bottom of the drawing may be used to keep the sets from moving. The stringers are only blocked at the joints of the shaft timbers and not at the center or unsupported portion of the timber; also, long blocks properly wedged can be used, and the stringers omitted.

Figure 21 is a drawing of a three-compartment shaft used in metal mining and shows the methods of placing the water column *j*, the air pipe *k*, the ladders and ladder landings *m*, and the guides *e*.

In most shafts having two or more compartments 1 or 2 inch boards are placed on the dividers between the compartments. This not only keeps rocks which fall from the cars or skip in the hoisting compartment from bounding over into the manway but also aids materially in ventilation.

GUIDES.

Guides (fig. 21) are placed in vertical shafts in order to guide the cage or skip through the shaft as the rails do in inclined shafts. Two methods of joining the guides to the shaft timbers are shown in figure 22. The method on the left, while used frequently, is not recommended, as there is danger of the shoes of the cage cutting into this joint and tearing the guide loose from its fastening; also, if the pressure on the shaft timbers forces the guides into the shaft they will be more liable to break loose and project into the shaft and cause an accident. The fastening shown on the right is recommended and is the one in most general use. Heads of lag screws should be countersunk at least one-half inch in the guide timber. Metal plates having four holes at the corners (or sides) and turned up on two corners (or sides) are also used. Two of these plates are bolted onto the divider, one above and one beneath it, and the upturned corners or sides are bolted to the guide.

The sizes of guides vary greatly, but the 4-inch by 6-inch guide is common. Guides are usually made from fir or longleaf yellow pine. Occasionally hemlock and oak guides are used but are not recommended, as they split more easily than fir.

CROSS BEARERS.

Firm blocking and wedging, supplemented by the pressure that comes on the timbers, are the principal means relied on for holding the shaft sets securely in place. As a further provision, however, bearers should be inserted at intervals. The bearers are heavy timbers, placed crosswise of the shaft, beneath the end plates (see *k*, fig. 29), and are supported in hitches cut in the wall rock. The ends of the wall plates and divider rest on the bearers, which are dapped on the upper side to receive the wall plates and divider, and on the under side for the posts of the next set below.

The purpose of the bearer is to take up any unsupported weight of the shaft sets above it and prevent uneven settling of the sets. Any movement of some of the sets, through blocking or wedges coming loose on account of shrinkage through downward pressure of the shaft walls or other causes, might be transmitted downward from set to set unless checked by bearers.

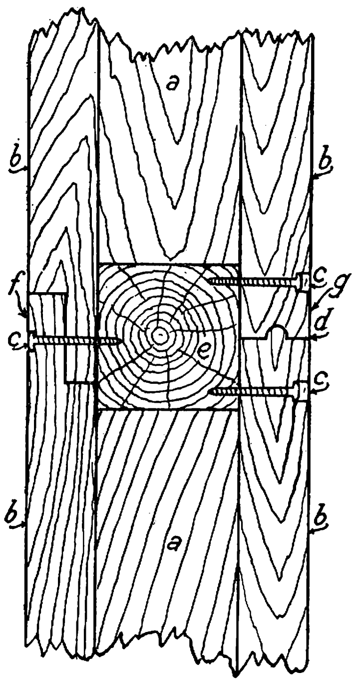


FIGURE 22.—Two methods of fastening the guides to the shaft timbers: *a*, Post; *b*, guides; *c*, lag screws; *d*, tongue and groove framing; *e*, divider; *f*, wrong way; *g*, right way.

The spacing and depth of footing vary with the character of the ground; in heavy ground bearers may be required at 30-foot intervals, in medium ground the distance may be 50 by 100 feet, and in hard rock 150 feet or even more. Correspondingly, the depths of hitches or bearing length range from 3 to 4 feet in heavy ground to 6 inches to 1 foot in solid rock.

TIMBERING IN SOFT GROUND.

JACKET SETS.

In timbering or repairing vertical shafts in soft, moving, or swelling ground, where the ground stands well enough to permit timbering the shaft, but later the pressure on the shaft timbers is so great that it breaks and crushes them, it may be necessary to place so-called "jacket sets" around the regular timber sets in order to save the shaft and relieve the pressure. The method of framing the individual members of this jacket set is shown in figure 23; each part of the jacket set being a small complete set of timbers. This method of framing provides an opening around the outside of the regular shaft timbers in which the men can work while the shaft is in operation; and also it is not necessary to have a large untimbered opening in any one place, which in loose ground would be dangerous.

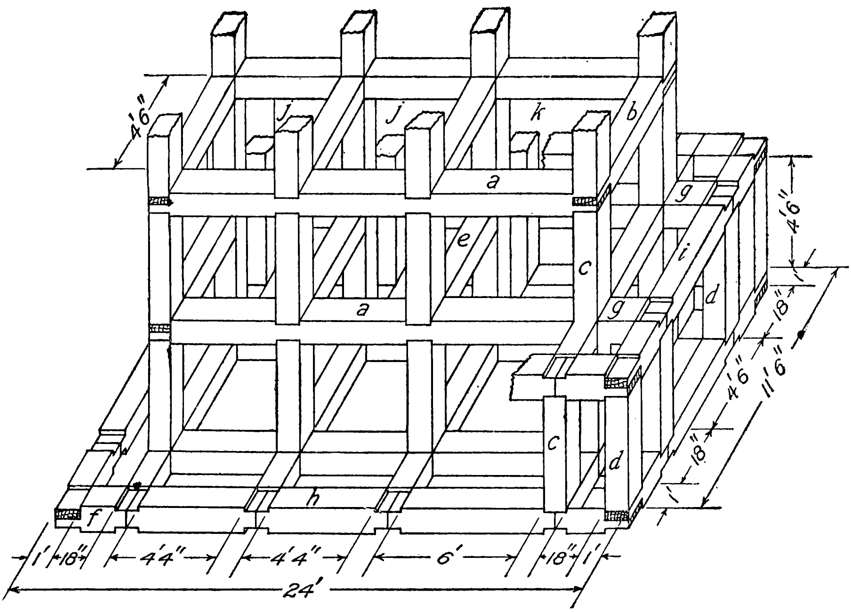


FIGURE 23.—Jacket sets for lining vertical shafts in loose, running ground: *a*, Wall plate; *b*, end plate; *c*, posts; *d*, jacket-set posts; *e*, dividers; *f*, joint used in jacket-set wall plates; *g*, jacket-set blocks; *h*, jacket-set wall plates; *i*, jacket-set end plates; *j*, hoisting compartment; *k*, manway and pipe compartment.

Ordinarily the place where the ground is the heaviest is selected as the starting point for the jacket-set timbering. This is usually at some level or station. The material, which ordinarily is soft, is picked out from around the shaft sets, and, as fast as room is made for one section of the jacket set it is placed and blocked in position. A complete set of jacket timbers is placed in position before the rock is excavated in the set above. The first step in placing these timbers is to install the bottom wall plates *h* (fig. 23) of the jacket set, then the jacket-set posts *d* are placed on them as in drift timbering, the top wall plates of the jacket set are placed on top of the posts, the blocks *g* between the jacket sets and the regular timbers, before the jacket set is blocked. Care must be taken that not more than one joint of the regular shaft timbers is unblocked at a time, which will be a simple matter if the jacket sets are framed as shown in this drawing. The corners of the jacket sets are usually boarded up to make chutes, and any material that is removed in placing the jacket set is shoveled into these chutes and is taken out at the station below.

Occasionally, as a precaution in heavy ground, these jacket sets are placed at the same time as the regular sets. When this is done, the jacket-set wall plates are cut into two pieces, instead of into three or four pieces, as is done when the jacket sets are placed after the regular shaft timbering is in place. Figure 24 shows this method of framing the spliced wall plates and dividers when it is desired to cut the wall plates into two sections only. This method of framing the joint is good, as the divider extends over and becomes a part of the joint.

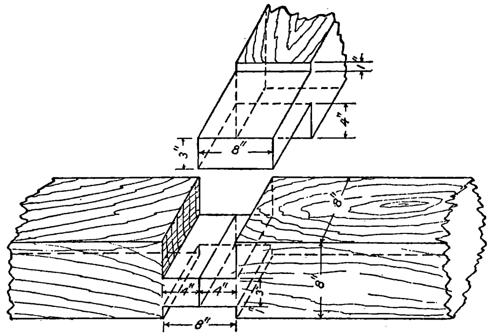


FIGURE 24.—Method of framing spliced wall plates and dividers for jacket sets.

Where the ground in the shaft is difficult to hold with timbering, forms are put in flat with the inside of the shaft timbers and concrete is poured outside of the regular sets so that the jacket sets are incased in it. This adds considerably to the strength of the shaft, and forms a fire wall to protect the timbers either above or below it, and is an anchor for the sets below and a foundation for the sets above.

SPILING IN VERTICAL SHAFTS.

Where the ground is so soft that it will not stand long enough after excavation to permit placing the regular sets, or where the shaft must pass through loose gravel, the method of spiling shown in figure 25 can be employed. The methods of placing the spiling in vertical shafts are the same as explained for drifts and crosscuts (fig. 10, p. 16) and, if it is necessary, false sets can be used. If the bottom of the shaft is soft, bottom boards corresponding to the head boards (fig. 10) used in forepoling a drift can be employed. The individual spiling used in shaft timbering is usually heavier and thicker than that used in drift timbering. Planks 4 inches thick, 8 or 10 inches wide, and 6 feet long are generally used. One end of the spile is sharpened as in drift spiling, and if the ground is difficult to penetrate, iron caps are placed on the driving end of the spile so that the blows of the hammer or the small air drill, which is sometimes used, will not batter and split them.

CRIBBING.

Cribbing (fig. 26) is sometimes used for timbering vertical shafts in soft ground, but this is a slow method and is not resorted to unless all other methods have failed. In cribbing a shaft enough ground is excavated to permit placing a wall plate, then room is

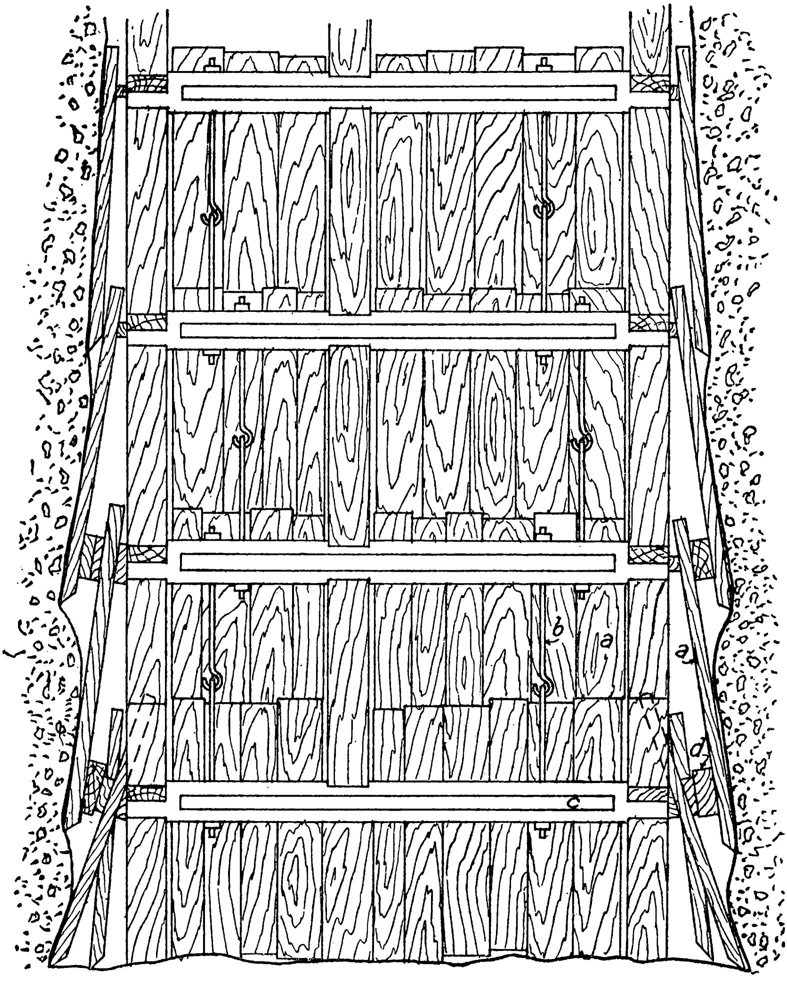


FIGURE 25.—Spiling in vertical shaft timbering: *a*, Spiling; *b*, hanging bolts; *c*, cleat; *d*, bridge.

made on the end of the shaft for an end plate, and the two are joined together. The first crib timbers are joined to the regular shaft timbers by short hanging bolts, but the rest usually are held in position by long lag screws. The wall plates and end plates of the next set are then excavated for and placed one by one, until five or six sets are in position in the bottom of the shaft. The center of the shaft, which has been left undisturbed until a number of these cribs have been placed, is then shoveled out and the dividers, if it is a two-compartment shaft, placed in position. These operations are continued until the bottom of the soft stratum is reached. The method of framing the dividers placed in the center of the two-compartment shafts is the same as that illustrated in figure 16 (p. 25).

In recent years reinforced concrete is being used more and more in shaft sinking, for holding soft or loose ground, and especially for water-bearing strata, and its use is often preferable to a difficult timbering job.

COMBINATION OF VERTICAL AND INCLINED SHAFTS.

In many places it is necessary to sink a vertical shaft to reach veins that lie at a comparatively low angle or do not outcrop within the boundaries of the property, and then it may be expedient to follow the vein with an inclined shaft.

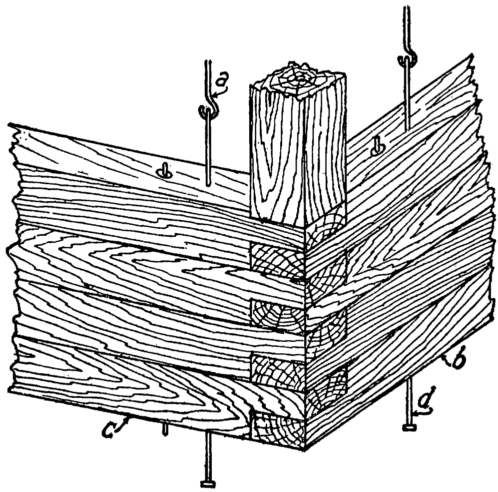


FIGURE 26.—Cribbing used in vertical shafts: *a*, Hanging bolt; *b*, 12 by 12 inch end plate; *c*, 12 by 12 inch wall plate; *d*, lag screws.

The work of laying out and timbering the junction of a vertical with an inclined shaft requires careful engineering. Since such work is done only under the direction of experienced engineers, the method will not be described here. Those interested will find the timbering methods employed described in W. H. Storm's book on "Timbering and Mining" and other books on mine engineering.

TIMBERING STATIONS IN VERTICAL AND INCLINED SHAFTS.

In prospecting or in developing a mine, levels with their accompanying stations often are placed at some point in the shaft where there is a particularly good showing of ore, no attention being paid to the distance between levels. Also the interval between levels will depend more or less on the character of the ore body, closer spacing (50 to 100 feet) of levels being necessary where the ore is of uncertain extent, or occurs in shoots and stringers, than for ore that is continuous. It has been found from experience that levels, with their stations, ordinarily should not be placed less than 100 feet apart. When the distance is less, the cost of installation and maintenance is greatly increased, and in addition there is a possibility that if from movements of the ground or from some other cause the weight of the station timbers is transmitted to the shaft timbers, they in turn may transmit the weight to the station below and cause its failure. Also stations should not be placed farther apart than 300 feet, as it is difficult to support a stope with timbering when it is too far between

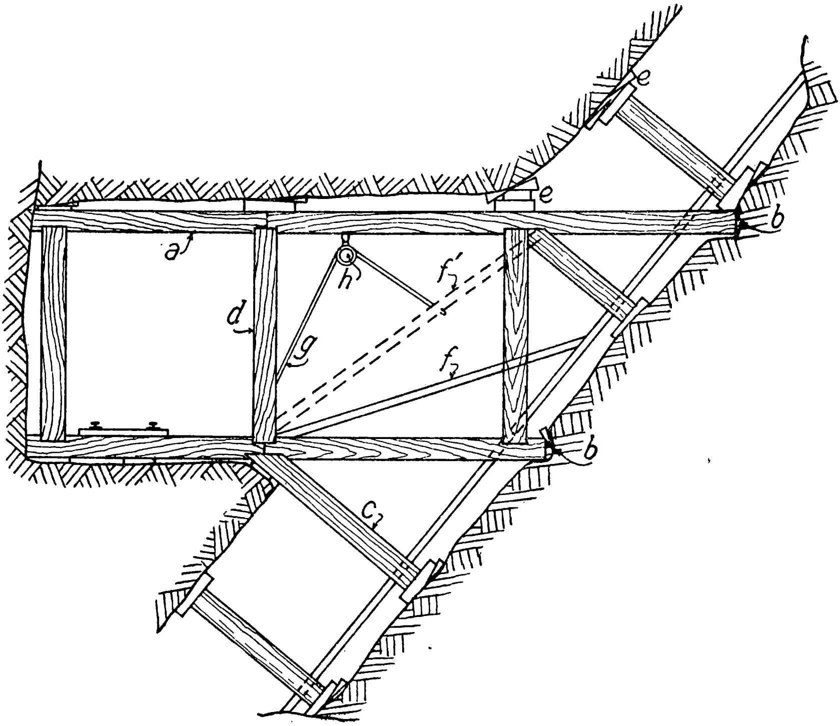


FIGURE 27.—Stull method of timbering shaft station: *a*, Long top sprag; *b*, hitch in foot wall; *c*, long bottom sprag; *d*, first drift set post; *e*, blocks and wedges; *f*, rails in position to lower car; f^1, rails pulled up to clear the shaft; *g*, cable or rope used to hold rails when clear of shaft; *h*, block.

levels, and to get men and material into the stopes. The distance between levels in western metal mines is often 200 feet.

The method of timbering shaft stations where room is made only for cars, timbers, supplies, and other materials differs in some respects from the timbering of those stations where additional room is required for a hoisting engine or ore bin.

INCLINED SHAFTS.

The stull or sprag method of timbering level stations is applicable in inclined shafts ranging up to 30° inclination or even somewhat steeper than 30°. The framing of the individual timbers used in this method of station timbering are shown in detail in figure 27. In this type of shaft it is necessary to run the mine cars from the shaft out upon the station and thence to the different mine workings. The rails *f*, when not in use are raised into the position *f'*, and held there by the cable. Another method of making and placing these rails is shown in Plate VI, *B*. In this photograph their application is shown at the collar of a nearly vertical shaft for lowering the skip to the landing platform, but the same method is sometimes used at stations underground for running mine cars upon the station platform.

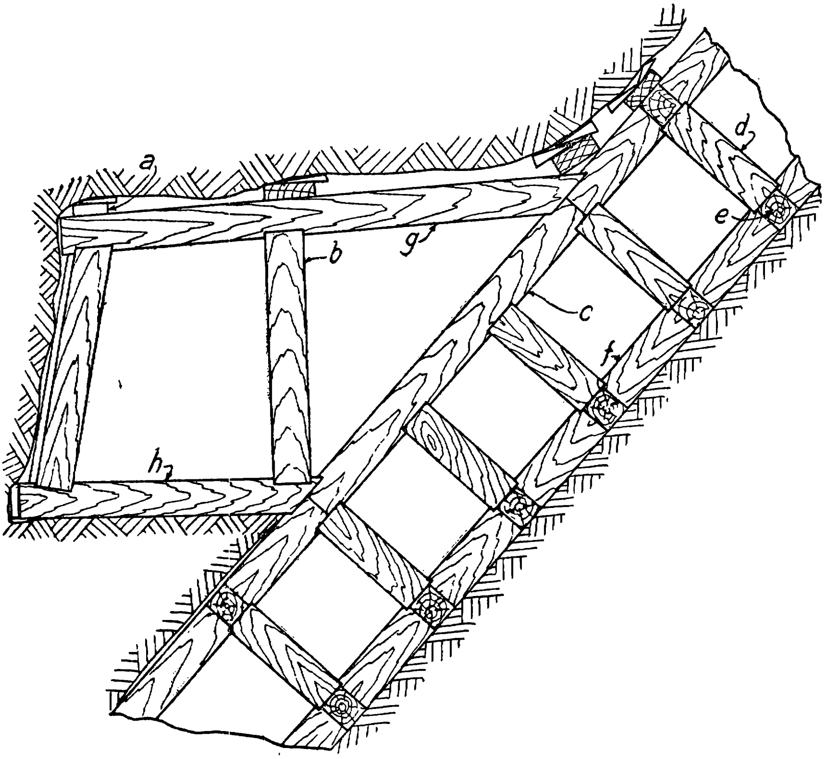


FIGURE 28.—Station timbering for shafts of more than 30° inclination: *a*, 3-inch lagging; *b*, 12 by 12 inch post; *c*, 8 by 8 inch long post; *d*, 8 by 8 inch end plate; *e*, wall plate; *f*, 8 by 8 inch post; *g*, 12 by 12 inch sprag; *h*, 12 by 12 inch sills.

The station timbering shown in figure 28 is applicable to shafts of more than 30° inclination and involves no new method of timber framing or setting. This landing is designed so that the mine cars dump directly into the skips instead of into an ore pocket below the station, and then into the skips. It is not necessary for the small mine operator to construct skip pockets or ore pockets in the shaft, since the tonnage to be handled does not justify it. Even in many mines producing 800 or 1,000 tons daily, all the ore is handled directly by cans or by cars and cages instead of skip pockets.

VERTICAL SHAFTS.

Station timbering in vertical shafts is more complicated than in inclined shafts or winzes, because of the difference in timbering in the two kinds of shafts. For timbering stations in vertical shafts,

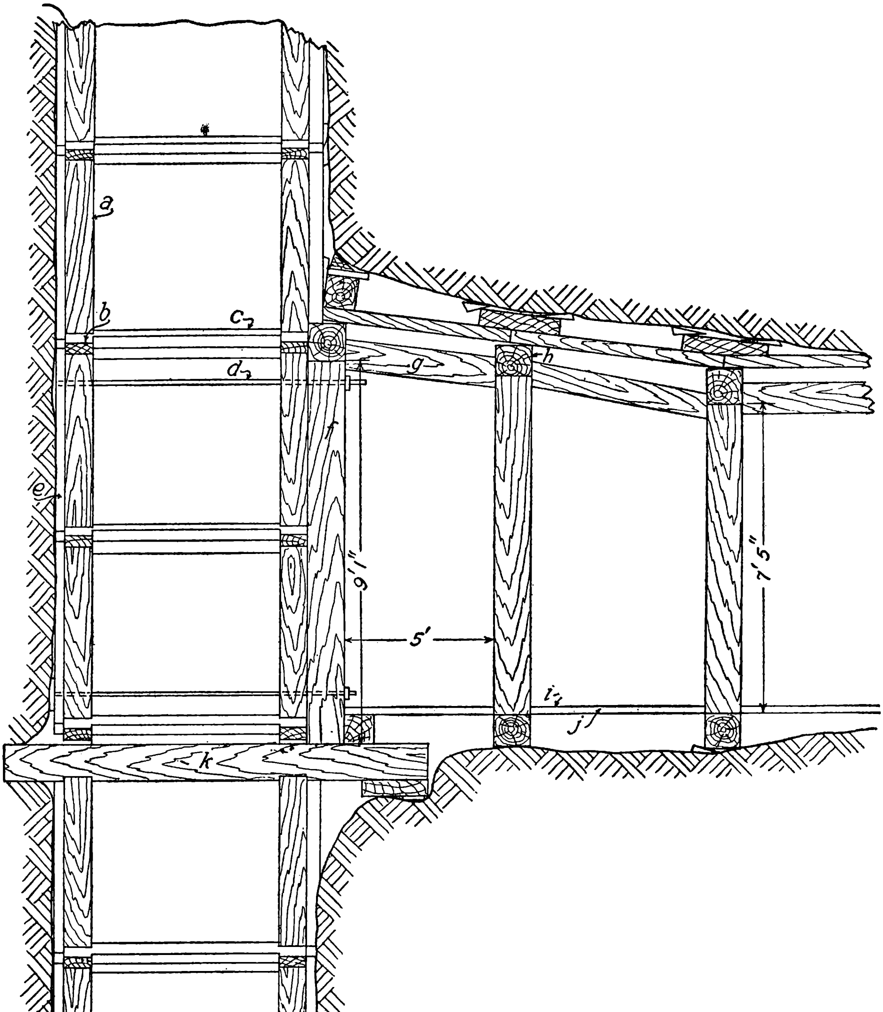


FIGURE 29.—Timbering of stations in vertical shafts: *a*, 8 by 8 inch posts; *b*, end of wall plate; *c*, end plate; *d*, 1-inch round iron bolt; *e*, 4-inch lagging; *f*, station-set post; *g*, 8 by 10 inch girt; *h*, 10 by 10 inch cap of six-piece drift set; *i*, ¼-inch sheet iron; *j*, 3-inch lagging; *k*, 10 by 10 inch cross bearer.

two methods are generally employed, one (fig. 29) which resembles the four-piece drift set, and the other (Pl. VII) which is like the hexagonal or six-piece drift set.

This first method (fig. 29) is applicable to ground that is moderately hard and which can be timbered, except for the difference in the size of the timbers, in the same manner as the four-piece drift set. A staging is built after the posts are placed (Pl. VIII, *A*), and from this staging the caps, girts, lagging, etc., are placed as in drift timbering. No switches are shown at this station, because it has become almost universal practice to use turn sheets on the floor of vertical shaft stations in order to transfer the cars more easily from one compartment to another; and because cars of ore, cars of waste, and empty cars, can be placed on the station floor at the same time without requiring a number of tracks and switches.

The second method of station timbering (Pl. VII) is known as the arch method and is applicable to soft or heavy ground. The station timbers are placed in the same manner as the six-piece drift set.

The procedure in timbering the shaft at the station is the same for either of these methods, but it differs slightly from the regular shaft timbering as follows:

Ordinarily as soon as the shaft reaches the point where it is desired to place the station, the shaft timbers are brought down to within three sets of the station level or the bottom of the shaft, and the bottom is widened out sufficiently to make room for the first set of station timbers (fig. 29). A transit or other means is employed to align the shaft, and to determine whether there is any difference in elevation between the end plates of the last set.

The next step is to place the cross-bearers *k* (fig. 29) crosswise of the shaft in hitches cut for that purpose, in such position that they are in line with the side plates of the last shaft set, which is, of course, some distance above. The cross-bearers are leveled, and the correct alignment of the corners determined. When it is found that there is a difference in elevation between the end plates of the last regular set, a "leveling-up" set is placed between the cross bearers and this last set. The only difference between this leveling-up set and an ordinary shaft set is in the length of the posts. These posts (Pl. VII, *A*) are made about three sets long; the exact length of the individual posts is determined by measuring between the cross-bearers and the last regular set. When the posts have been cut to their proper lengths they are placed in position between the cross-bearers and the last shaft set, and the timbers are blocked and wedged as described before.

Next the first station set (fig. 29) is placed "skin to skin" against the leveling-up set and bolted there with 1-inch round iron bolts. When this work has been completed it is possible to continue the shaft sinking as before, and at the same time start timbering the level station.

The cross-bearers in the arch set (Pl. VII) are shown at the top of the station timbers. This method of placing the cross-bearers, while it is still in use in a few places, is not recommended, since a part of the weight of the shaft timbering, both above and below the station timbering, comes on these cross-bearers, with the result that the cross-bearers may transmit some of this weight to the station timbers, and overload them. Moreover, in soft ground it is necessary to use long cross-bearers placed below the station timbers to give them a firmer foundation for the weight of the sets above, and make a more solid anchor for the shaft timbering below. Besides, when cross-bearers are placed above the station timbers, it means unnecessary widening of the shaft in two places and the use of two leveling-up sets.

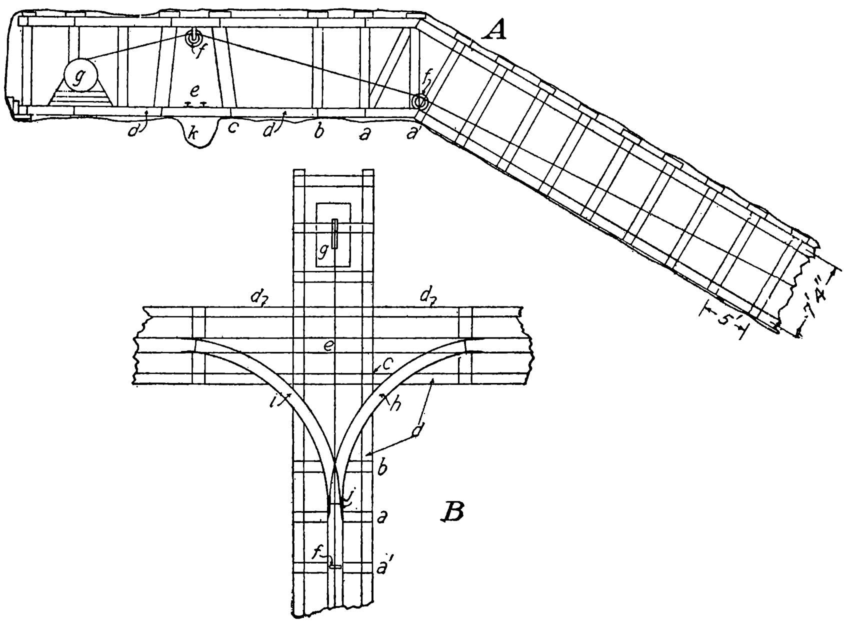


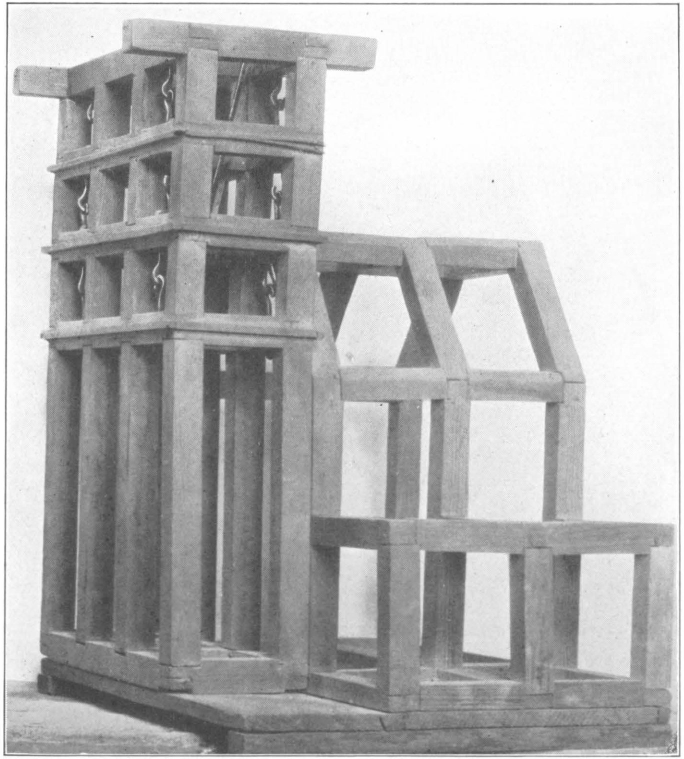
FIGURE 30.—Timbering for a footwall hoisting station: *A*, Elevation; *B*, plan; *a*, last set of drift; *a'*, top set of incline winze; *b*, station set; *c*, drift set; *d*, long sill sprag; *e*, main line; *f*, pulley; *g*, hoist; *h*, loads; *i*, empties; *j*, latch switch; *k*, ditch.

TIMBERING HOISTING STATIONS IN INCLINED SHAFTS, OR WINZES.

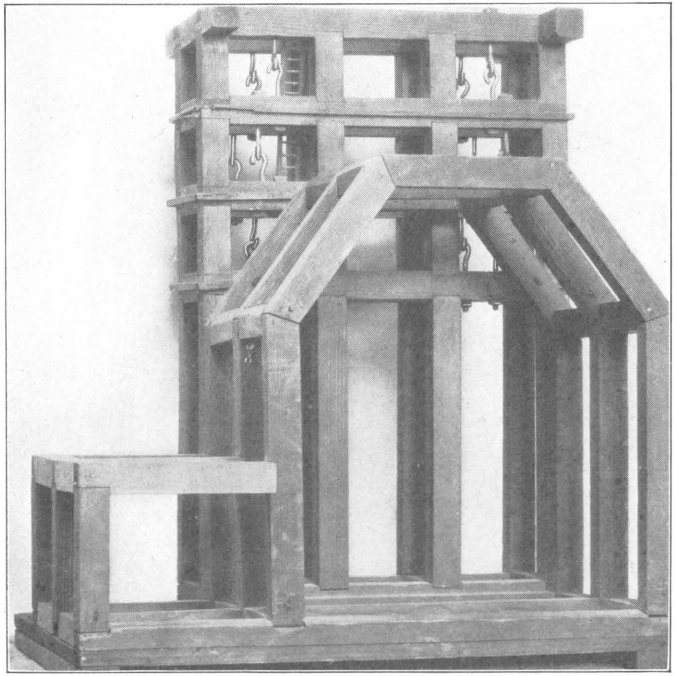
When a shaft or a winze is being sunk and drifted from at the same time, a station must be made and timbered that will accommodate the loaded and empty cars at that level, and will allow room for the installation of an auxiliary hoist. The station may be in either the footwall or in the hanging-wall side of the vein.

FOOTWALL HOISTING-STATIONS.

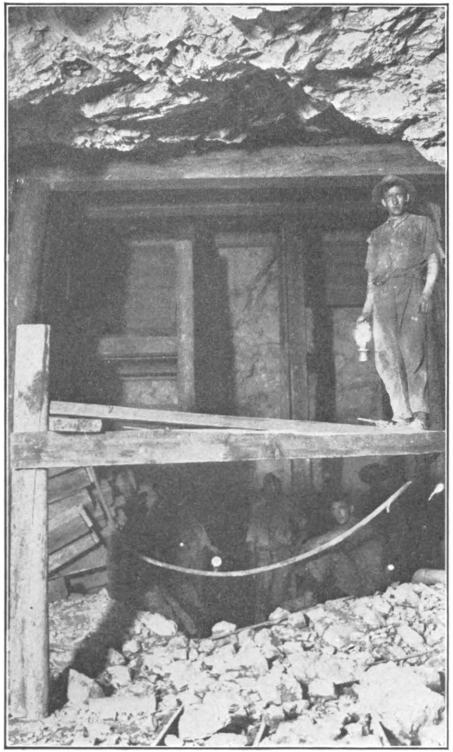
The footwall hoisting-station timbering shown in figure 30 is suitable for use with shafts or winzes of less than 30° inclination.



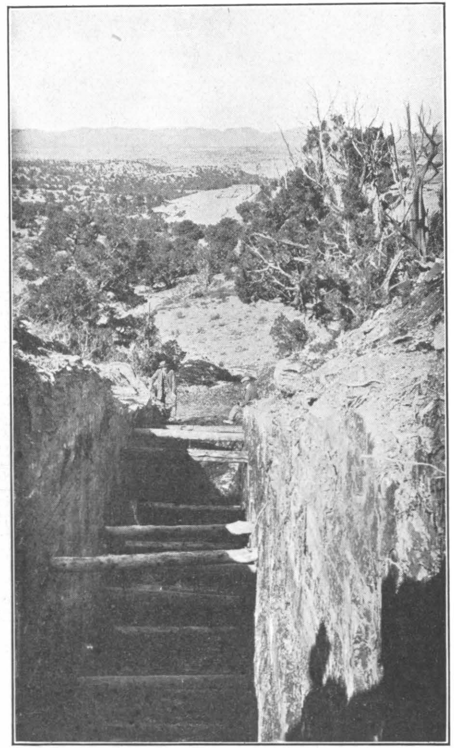
A. SIDE VIEW OF A MODEL OF THE ARCH-SET METHOD OF TIMBERING LEVEL STATIONS IN VERTICAL SHAFTS.



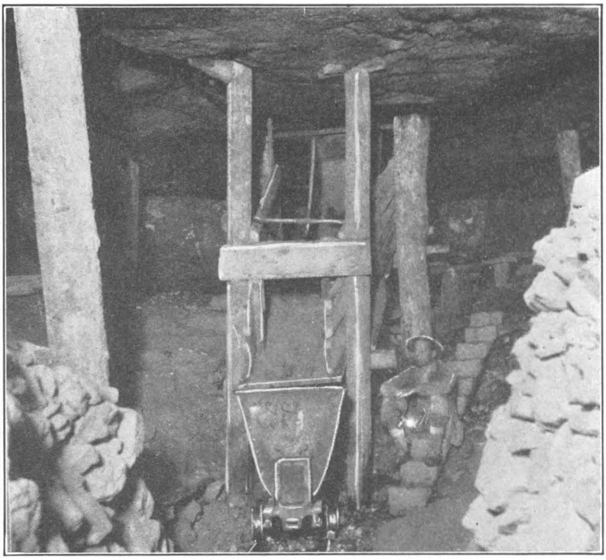
B. FRONT VIEW OF A MODEL OF THE ARCH-SET METHOD OF TIMBERING LEVEL STATIONS IN VERTICAL SHAFTS.



A. STAGING USED IN PLACING THE CAPS IN STATION TIMBERING.



B STULL METHOD OF STOPE TIMBERING; STOPE WORKED THROUGH TO THE SURFACE.



A. CHUTE AND CAR USED IN THE STULL METHOD OF STOPE TIMBERING.

B. LOOSE CRIBBING USED AT THE BOTTOM OF A STULL STOPE TO HOLD WASTE.

This arrangement has the following advantages: (1) There is a separate track for both the loaded and the empty cars; (2) there is less danger of pulling a loaded car into the hoist than if a single track and turn sheet are used; (3) only a small amount of ground is excavated, consequently the timbering can be simple.

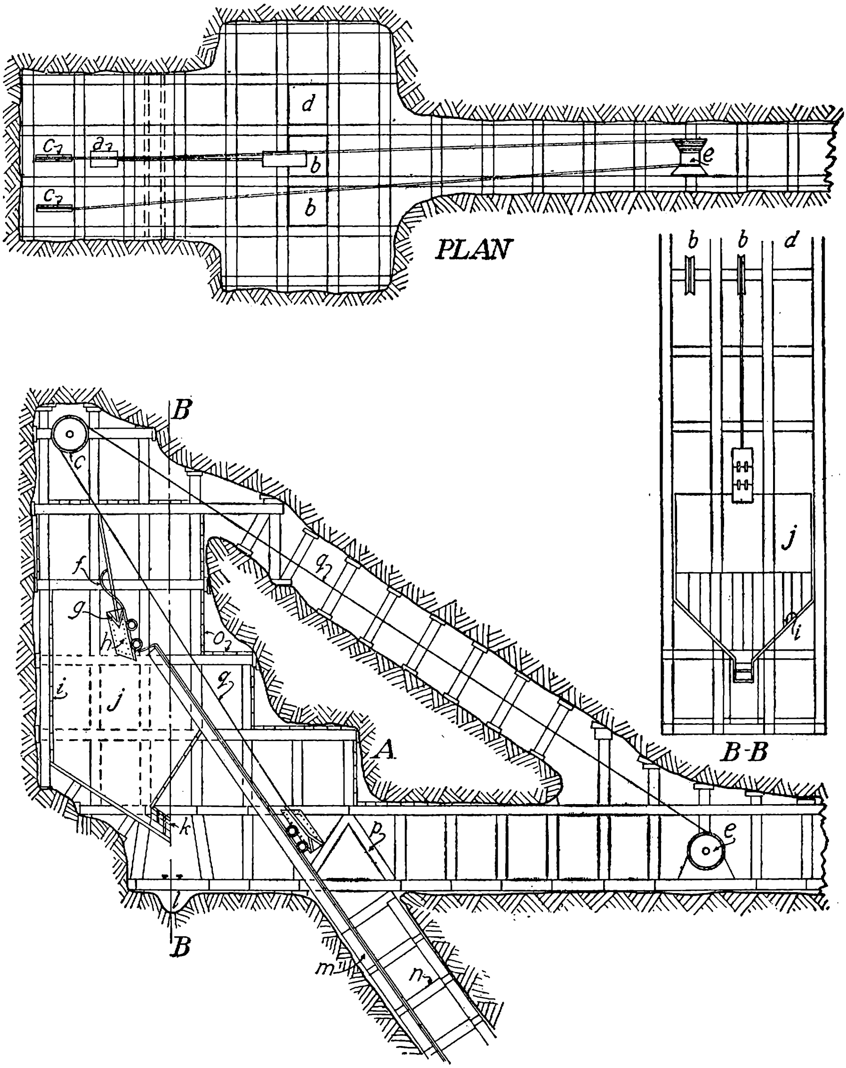


FIGURE 31.—Timbering for a hanging-wall hoisting station: *A*, joint of shaft and station timbers; *B–B*, cross section through bin; *a*, skip; *b*, hoisting compartments; *c*, sheave; *d*, manway and pipe compartment; *e*, hoist; *f*, dumping rail; *g*, skip bridle; *h*, skip in position for dumping; *i*, one-fourth-inch sheet iron; *j*, ore bin; *k*, chute mouth; *l*, ditch; *m*, stringers for ties and rails; *n*, shaft timbers; *o*, lagging; *p*, bridge truss set; *q*, cable.

The particular station shown in the figure is designed for use with a single-compartment shaft, but it can be enlarged for a two or three compartment shaft. The method of framing and placing the timbering is the same as for the four-piece drift set. The sill sprags *d* (stretchers or distance pieces) are merely long double-length sill sprags and are placed in the same manner as the regular sprags. The method of connecting the shaft timbers and the station timbers is shown in detail in the drawing.

HANGING-WALL HOISTING STATION.

The hanging-wall hoisting station (fig. 31) is suitable either for steeply inclined vertical shafts or winzes. In timbering hoisting stations of this type, unless cars are used, some method of dumping the skip must be employed and extra room for this dumping arrangement must be made and timbered.

The particular hanging-wall station shown in figure 31 has the advantages that the skip is dumped automatically, the hoist is placed on one side of the shaft timbering and the ore bin on the other (consequently there is not a single large opening on either side) and the timbering employed is simple.

In timbering stations of this type either the stull-and-post method or the square-set method (p. 53) of stope timbering can be employed.

The method of joining the shaft timbers with the station timbers is shown at *A*. It is especially important that this junction should be lagged tightly so that no rock will fall down the shaft.

STOPE TIMBERING.

After the ore body has been opened by means of an adit or shaft, and drifts or levels—that is, development work—the next step is the mining of the ore thus exposed. The removal of the ore from the deposit in underground mining is called stoping. Either overhand or underhand stoping or a combination of the two is employed. Overhand stoping consists of removing the ore by a series of steps, working from the back of a drift upward, until the next higher level is reached. Underhand stoping is the reverse of overhand stoping, and the ore is removed from the deposit by a series of downward steps, starting at the bottom of the drift and working downward until the next lower level is reached. This latter method is little used except in narrow rich veins, when it is desired to obtain a small amount of rich ore without the expense of further development. In most metal mines with either method of stoping some form of timbering is necessary.

There are three general methods of timbering overhand stopes, the stull, the stull and post, or the cap and post, and the square-set methods. All other methods are variations or extensions of one or more of these (such as the equilateral triangle, or diamond method), and are not so commonly used.

STULL METHOD.

In working veins of any dip up to 15 feet in width, in which the wall rocks and the ore are hard, the stull method (Pl. VIII, *B*) of stope timbering can be employed.

The stull *h* (fig. 32) is usually a piece of round timber placed between the walls of the deposit to hold the wall rocks in place until such time as the ore has been removed. This is the simplest form of stope timbering.

The diameter of the stulls used depends upon the character of the walls, on the distance between the walls of the vein, and on the amount of ore or waste to be piled on the stulls. In very hard narrow veins, stulls 6 inches in diameter can be used; in veins 15 feet wide, stulls 30 inches in diameter have been used.

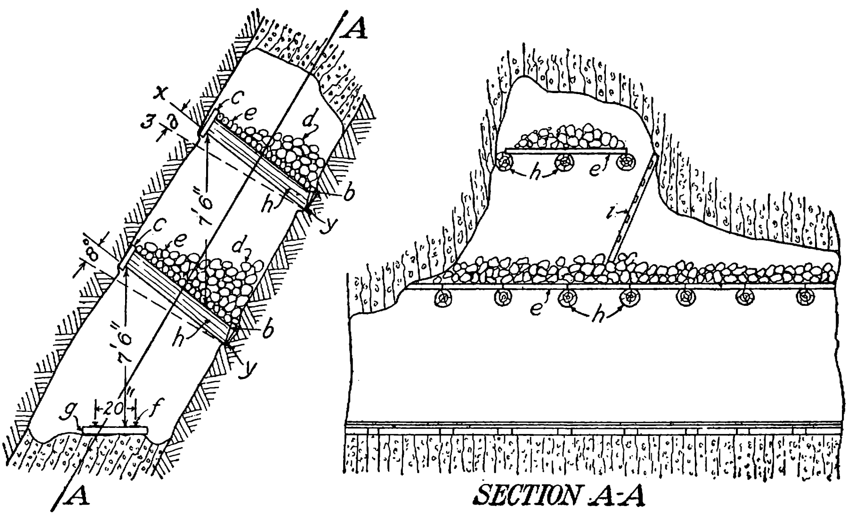


FIGURE 32.—Stull method of stope timbering: *A–A*, Cross section of stope; *a*, angle of underlie; *b*, foot wall hitch; *c*, hanging wall block; *d*, broken ore; *e*, pole lagging; *f*, rails; *g*, ties; *h*, stulls; *i*, ladder; *x–y*, bottom line of the stull; *y–z*, perpendicular line to hanging wall; *x–y–z*, proper angles of underlie.

The method of placing the individual stulls in drifts, tunnels, and crosscuts, has been described (p. 7). They are placed in stopes in the same way with the exception that greater care must be taken to see that the stulls are not placed at exactly right angles to the walls of the deposits.

ANGLE OF UNDERLIE OF STULLS.

The angle between the bottom line of the stull (see line *x–y* in fig. 32) and a line drawn perpendicular to the hanging wall (line *y–z*) is called the proper offset or the angle or underlie of the stull (angle *x–y–z*). This angle varies from one-tenth to one-quarter of the dip of the vein. For example, if the dip of the vein is 30°

then the angle of underlie of the stulls placed in this vein should be $7\frac{1}{2}°$. Most authorities agree that the angle of underlie should never be less than 5° in nearly flat veins, nor more than 15° in steeply dipping veins.

The dip of the vein and the angle of underlie corresponding to it are given in the following table:

Dip of the vein.	Angle of underlie of the stull.
Degrees.	*Degrees.*
20	5
30	7½
40	10
50	12½
60	15
90	0

In actual mining this table is not always followed literally but it is offered as a guide, which, if followed roughly, will improve the timbering and add to the life of the individual stulls.

Where the ore and wall rocks are hard enough, the stulls *h* (fig. 32) are placed about 7 feet apart vertically and 5 feet apart horizontally. Pole lagging *e* are laid horizontally on the stulls to make a floor on which the miners may stand while working out the rest of the stope to the next higher level or to the surface (Pl. VIII, *B*). The pole lagging are taken up and placed on the next higher stulls (see fig. 32) as the stope is mined upward.

The ore as fast as it is mined from the back is allowed to fall down to the bottom of the stope, where it is loaded into cars by means of chutes (Pl. IX, *A*) and taken out of the mine.

Where the ground is not hard enough to allow the stope to be carried through from one level to another in the regular way, a part of the wall rock is broken to make a filling for the stope (Pl. XII, *B*), or a part of the broken ore is left in the stopes. In the first case the waste placed in the stopes is permitted to remain there, and is kept from coming out into the drift by means of loose cribbing (Pl. IX, *B*). In the latter case the miners work from the top of the broken ore; only enough ore is drawn off from below to keep the top of the broken ore about 7 feet below the back of the stope. The ore remaining in the stope, after it has been worked through to the next higher level, is drawn out through the chute (Pl. IX, *A*) and the stope abandoned.

STULL AND POST METHOD.

The so-called stull and post method, with the use of girts, for timbering stopes is an extension of the method of using single stulls either with or without posts, and involves the principles of the square

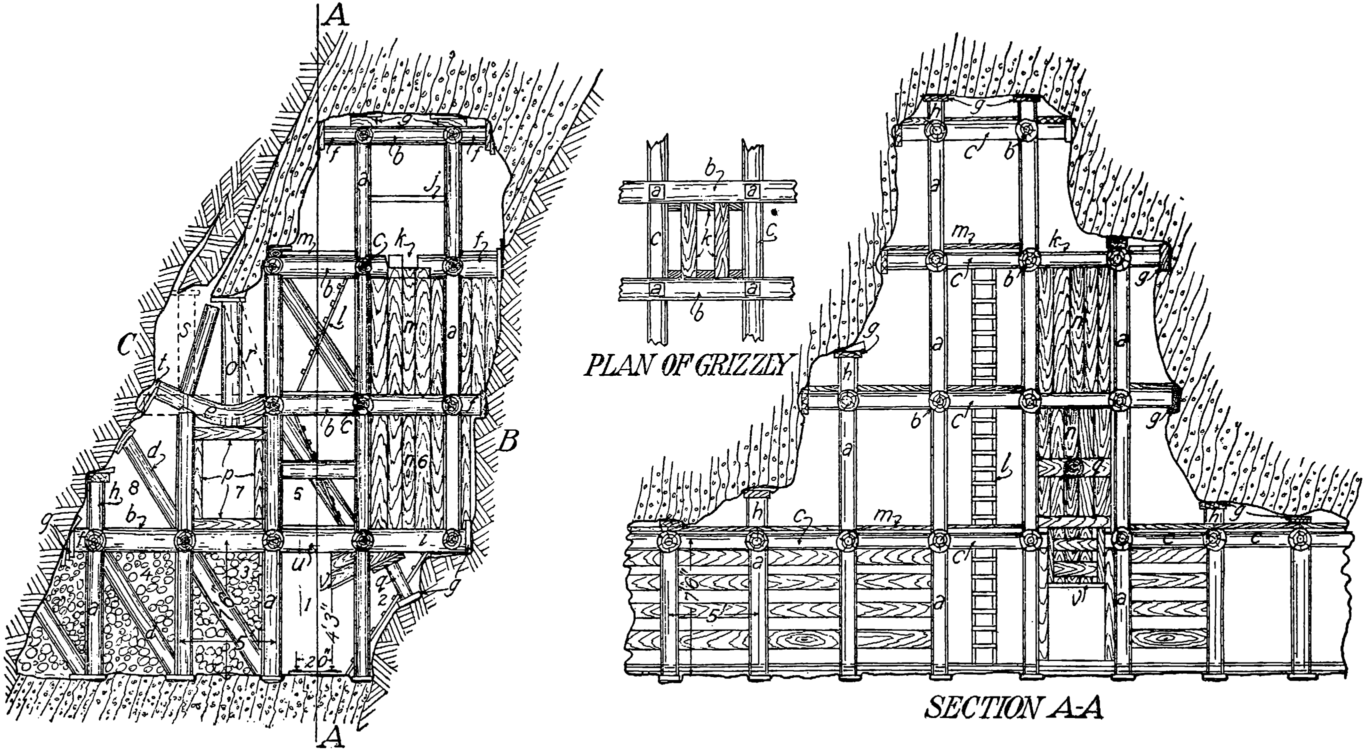


FIGURE 33.—Stull and post method of stope timbering, showing cross section and lengthwise section of the stope: *A–A*, Cross section of drift; *B*, foot wall; *C*, hanging wall; *a*, posts; *b*, stulls; *c*, girts; *d*, angle braces; *e*, broken cap or girt; *f*, butt caps; *g*, head blocks; *h*, short posts; *i*, cap sills; *j*, guard rail; *k*, grizzly; *l*, ladder; *m*, stope lagging; *n*, chute lagging; *o*, post, wrongly placed; *p*, doubling-up set; *q*, chute brace; *r*, angle brace; *s*, proper position for post; *t*, hanging wall left unsupported by breaking of cap; *u*, drift cap; *v*, chute.

set, which in turn is an extension of the stull and post method. The method is ordinarily applied to deposits which do not exceed 25 or 30 feet in width, and with wall rocks and ore that are moderately hard. The timbers employed (fig. 33) are: Long stulls, *b*, reaching from one wall of the vein to the other; posts, *a*, placed under the stulls at regular intervals of 5 feet; and girts or collar braces, *c*, placed at the junction of the stulls and the posts.

Stulls 20 feet long and 30 inches in diameter are sometimes used, but they are not recommended. The placing of these large stulls requires the aid of nearly all the men in the stope, and furthermore the weight of such large stulls may break the posts before much pressure of ground comes upon the timbering. When the vein is over 15 feet wide, it is better to cut the stull into two parts (fig. 34) and join them over a post.

The posts *a* (fig. 33) are usually round sticks of timber $7\frac{1}{2}$ feet long cut with square tops and bottoms (fig. 34) and fit into a dap cut at regular intervals of 5 feet in the upper and lower sides of the stulls. The girts *c* (fig. 33) are usually round timbers 4 feet long placed at the junction of the stulls and posts; sometimes 3-inch or 4-inch lagging will answer the purpose. The girts are used as in drift timbering to keep the sets from collapsing lengthwise of the stope and to take up a part of the pressure.

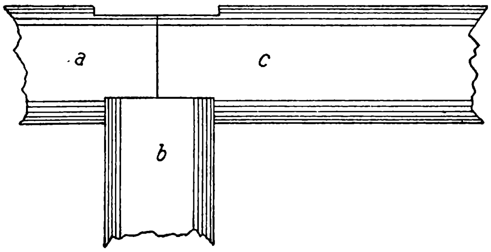


FIGURE 34.—Method of joining stulls and posts in the stull and post method of stope timbering: *a*, Butt cap ; b, post ; *c*, stull, 15 inches in diameter.

In timbering stull-and-post stopes (fig. 33) the first operation is to timber a drift (section *A–A*) driven 8 or 10 sets along the vein, in the same manner as the three-piece drift set. Then the drift is widened until the ore has been removed for its entire width between the foot wall *B* and the hanging wall *C*, and one set high and one set along the strike of the vein. The cap sill *i* is then placed from the end of the drift cap *u* to a hitch in the footwall *B* and blocked as shown. Next the stull *b* of this set is so placed that it extends from the other end of the drift cap *u* to the hanging wall *C* with posts, *a*, placed under the stull *b* at the regular 5-foot intervals. Afterwards the girts *c* are placed between the two sets in their regular position at the junction of the posts and the stulls, and the sets wedged and blocked securely in place. This operation is continued until the whole bottom floor of the stope, or the sill floor, as it is generally called, is exposed. After the sill floor has been excavated and timbered, for the entire width of the vein, and for 8 or 10 sets along its length, a raise (a more or less vertical opening driven up to connect two levels) is made and timbered, between this level and the next higher one.

Raises, like shafts, are made with two or more compartments, usually one for a manway, and one, called a chute, for the ore (section *A–A*), fig. 33). Generally, they are driven before the actual stoping begins in order to determine the extent and value of the ore shoot, to provide for better ventilation in the stope, and to furnish some means of transferring waste and supplies into the stope.

The point selected for starting a raise is generally on the footwall *B* side of the vein in a sill set. The back lagging is removed from the top of this sill set and the ore above it taken out. When sufficient room has been made above the sill for a set of timbers, the first raise set is placed. Short stulls or caps are generally used in raising, so framed that they can later be connected with the stope stulls. In this way, the raise timbering becomes a part of the stope timbering. Before stoping, however, these caps are connected with butt caps (fig. 34) on top of the posts, so that the raise timbers can be securely blocked in position. The method of placing the raise sets is the same as that of placing the four-piece drift set (p. 13) with the exception that the cap or stull in the set below takes the place of the sill used in the drift set.

Sometimes in this method, in order to obtain a large amount of ore quickly, stoping is carried on at the same time as raising. In this event, a series of stope floors or working platforms are opened up in the same manner as described for the first-floor set of the raise. From this first-floor set, the first stope floor is mined toward each end of the stope in the same manner as the sill floor; when there is sufficient room for the men to work in both ends of the first floor, the second floor in turn is opened up. This method of stoping will give a series of upward steps as shown in section *A* to *A* (fig. 33), which extend across the vein and permit three or four floors to be worked at the same time. Chutes are placed at various distances along the stope as they are required, usually about five or six sets apart.

It is difficult to make the men understand that, due to heavy and unexpected pressures often encountered in mining wide veins with this method of timbering, the posts should be placed directly over each other and not placed like post *o*, which supports a loose piece of rock and is blocked down to the center of the stull *e*. When a post is placed in this way, the stull usually breaks, and two or three such misplaced posts may cause failure of the whole timber structure.

One of the writers once worked in a large stope of this kind, where no attention was paid to placing the posts correctly. One day the stope, which was about 100 feet long, 70 feet high, and 30 feet wide, caved completely.

It is often necessary to support a piece of loose rock which is directly over the center of a stull. In this case, it is much better to use an angle brace, *r*, for the purpose than to use the post *o;* since with the angle brace *r* the weight of the rock is transferred to a joint, and from there to the end sections of the timbers instead of having the pressure come upon the center of an individual stull, *e*.

Angle braces, *d* (fig. 33), offer strong resistance to any lateral movement, and should be placed in position before there is any tendency of the sets to sway. If placed after the swaying movement has started, angle braces are useless. Moreover, if angle braces are used in a stope, they must be used throughout or not at all. The pressure along each angle brace has a lifting effect upon the end of the stull opposite to the end on which the angle brace is seated, and tends to unseat the stull from the post below it unless this end is correspondingly braced.

Another method of blocking loose rock in the walls in this method of timbering is by cap sills, *i* (fig. 33), short posts, *h*, and by short caps or butt caps, *f*. Cap sills, *i*, are used to anchor the timbering to the footwall *B*. If the distance between the last post and the footwall is not quite 5 feet, it is advisable to cut a small hitch in the footwall and lay a 5-foot cap sill, *i*, in this hitch. A post can be fitted into the cap on top of the cap sill, and the regular timbering carried on above that point. Short posts, *h*, and butt caps, *f*, should always be used on the hanging wall when it is not possible to place the regular posts *a* and stulls *b* in their full length.

If a timber set starts to sway after it is in position, the movement may be stopped by "doubling-up" or "helper" sets, *p* (fig. 33), or by using cribbing (Pl. X). Doubling-up sets are smaller sets placed inside the regular sets so that they will aid in keeping the sets perpendicular. They are usually made of square timber and are placed in the manner shown in the drawing. The cribbing may be of the "loose" or open type (Pl. X, *B*), that is, timbers piled pair on pair in alternate layers, or "tight" or close cribbing (Pl. X, *A*) where the timbers are carefully laid with close-fitting joints and are spaced more closely together, to insure a stronger and more rigid construction.

Whether loose or tight the crib should be at least two sets square, and should be carried from the sill floor to the roof or back of the stope. Sometimes cribs are started on the second or third floor of the stope; this should not be permitted unless the stope has been filled with waste to this floor, else when the pressure of the ground is transmitted through the cribbing to the unsupported stope timbering, a serious cave may result.

When the log cabin, or open cribbing is used, it will be stronger if filled with waste. In close cribbing the material employed may be old posts, green timber, or any odds and ends that will hold together, but the crib must be tight and rigid in order that it will not give under pressure.

SQUARE-SET METHOD.

The square-set method of stope timbering (Pl. XI) has been frequently described in the technical journals and publications on mining; consequently only a brief review of its history and the more recent modifications will be given. This method is an extension of the stull and post or cap and post method just described, in which the same principles are employed and which differs mainly in the length and framing of the individual timbers.

The square-set method has been applied to all classes of ground, but is chiefly employed in medium to soft ground that can not be held by simpler methods of timbering. The great amount of timber required makes the method an expensive one, hence it is employed only when necessary. In hard ground, either the stull and post, or the stull method are preferable, as they are simpler and cheaper, both as to framing and placing the individual timbers.

The square-set method is said to have been first used by Phillip Deidesheimer, at the Ophir mine, Virginia City, Nev., in 1860. As originally designed it was intended for the wide soft deposits of the Comstock, in which the main weight on the timber structure came from the back, or roof, of the deposit. Consequently, Deidesheimer designed his individual timbers so that the posts were butted together, the caps and girts being held in place on the posts by framing. Such a method in which the individual timber sets could be extended out to fill openings of large size and give equal strength in all directions, had long been needed by the mining operators. Therefore the square-set method was adopted quickly in practically all of the western camps. At various camps different local underground conditions caused the development of modifications of Deidesheimer's original methods, the principal ones being called the Burlingame, the Eureka, the Richmond, and the Anaconda. The principal point in these modifications is the variation in the framing of the individual members of the spuare set. In the Deidesheimer and the Burlingame methods the timbers were so framed that the posts were butted together (Pl. XI, *A*). In the Eureka, the Richmond, and later in the Anaconda, the timbers were framed so that the caps, or major horizontal members, were butted together (Pl. XI, *B*).

For a long time after the Eureka method was introduced it was common to frame the individual timbers so that the posts were butted when the main pressure was vertical, and so that the caps butted when the pressure was largely horizontal. However, so much trouble was experienced in renewing the timbers and so many caves occurred when the posts were butted, especially in stopes where the progress was slow and where a great deal of blasting was necessary, that it was decided by some of the larger mining companies to use the butted-cap method (Pl. XI, *B*) of framing the individual timbers in all places.

The three main reasons for discarding the use of the butted post method of framing are:

1. The horn or the extreme end section of the post (Pl. XI, *A*) must be made long and narrow in order to permit room for the caps and girts to rest on the posts, and consequently it is not strong.

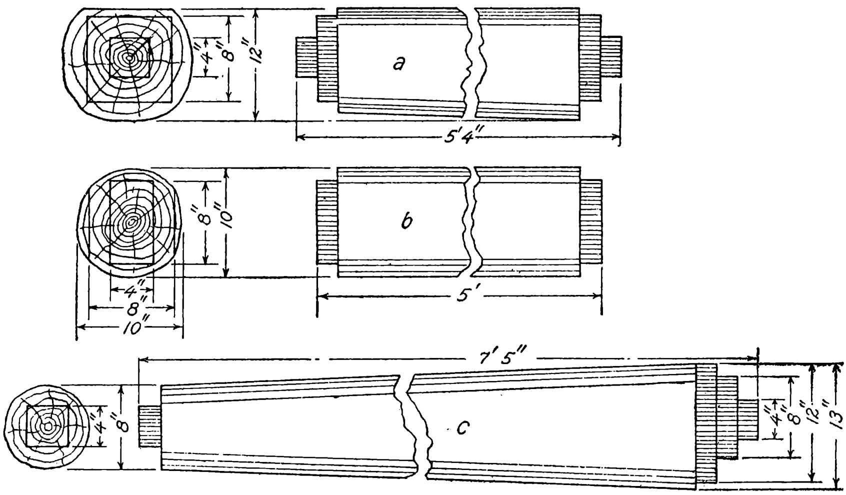
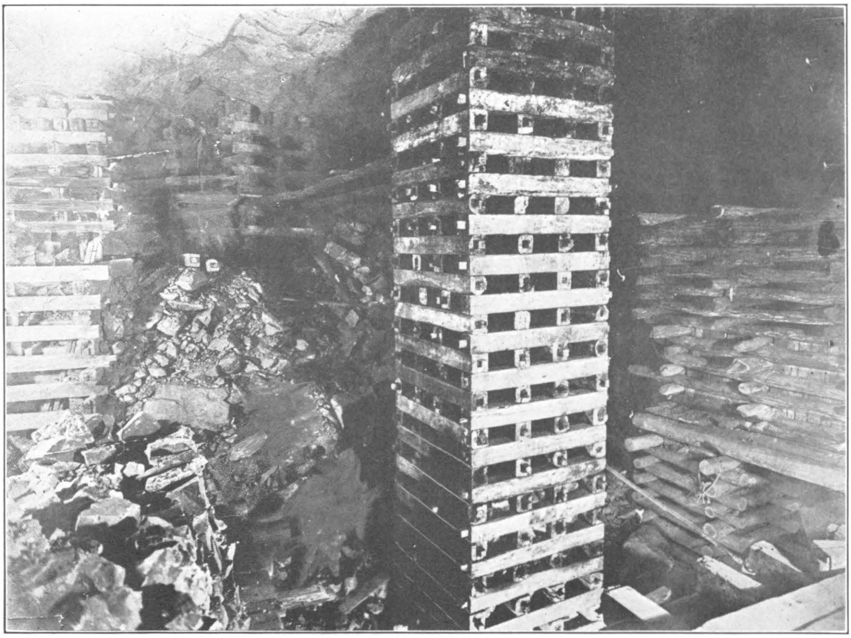


FIGURE 35.—Details of Rocker method of framing square set timbers: *a*, Cap; *b*, girt; *c*, post.

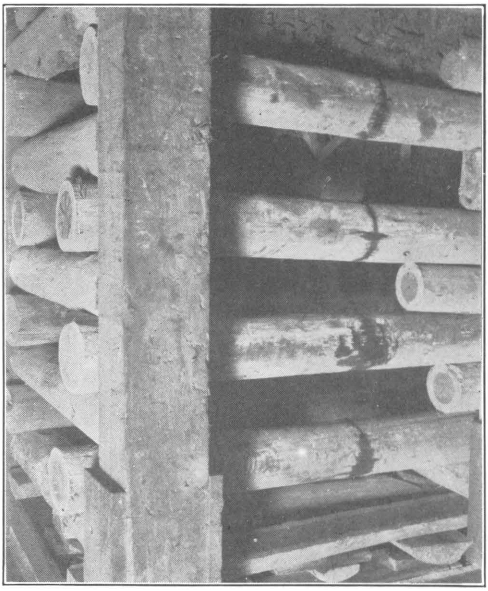
2. When the pressure comes upon the posts vertically, these long narrow horns take up the pressure, lengthwise of the grain, and the wood fibers in the horns split and tear apart one from the other (fig. 1, *a*), and in spreading force the caps and girts from their seat on the post.

3. When the pressure comes upon the post horizontally, or capwise, the wood fibers in the long narrow horns crush and flatten (fig. 1, *d*), and later when any sudden pressure is exerted upon them, such as a heavy blasting shock, these crushed horns break and the whole timber structure fails.

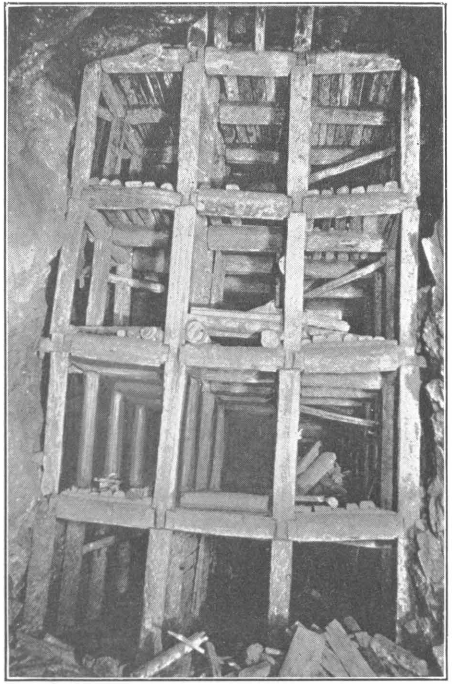
The use of the butted cap method of framing square set timbers will do away with many caves which occur in the stopes as a result of using the butted post method.



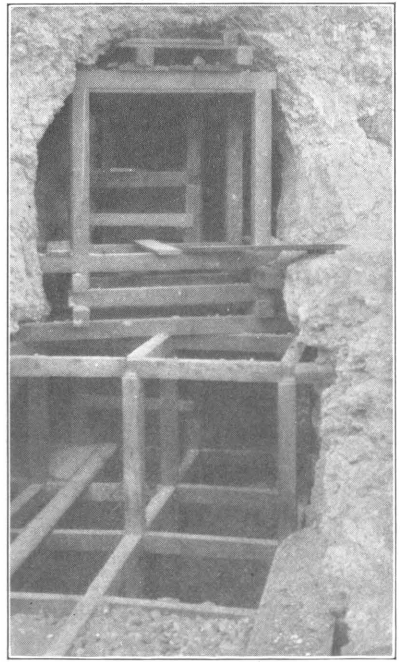
A. TIGHT CRIBBING USED TO SUPPORT CAVING ROOF IN STOPES.



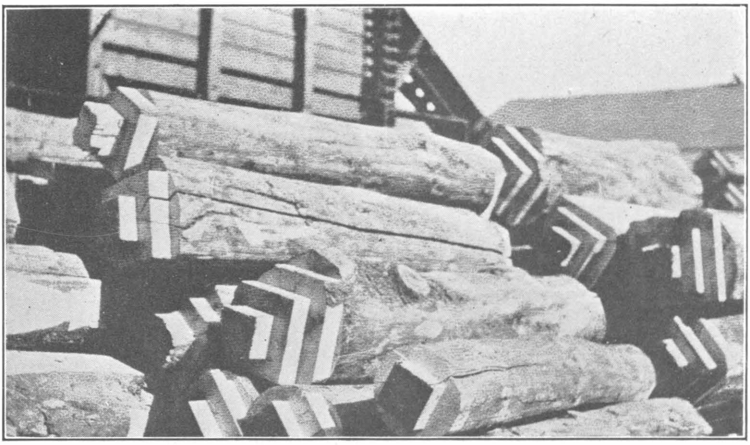
B. LOOSE CRIBBING USED IN TIMBERING STOPES.



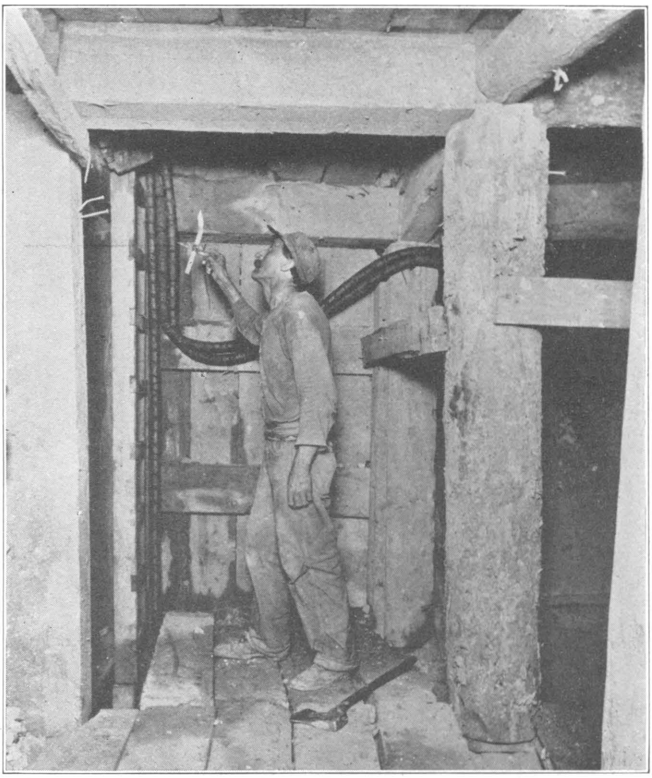
A. BUTTED-POST METHOD OF FRAMING SQUARE SETS. NOTE ABSENCE OF BLOCKING BETWEEN THE ENDS OF THE TIMBERS AND THE WALLS.



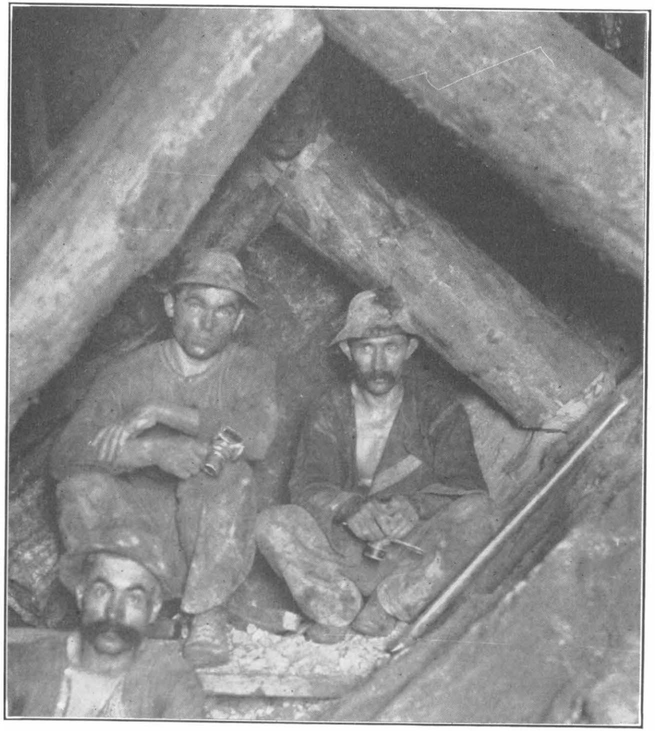
B. BUTTED-CAP METHOD OF FRAMING SQUARE-SET TIMBERS. NOTE HOW THE LONG STRINGERS ARE PLACED OVER THE JOINT OF THE TIMBER SET.



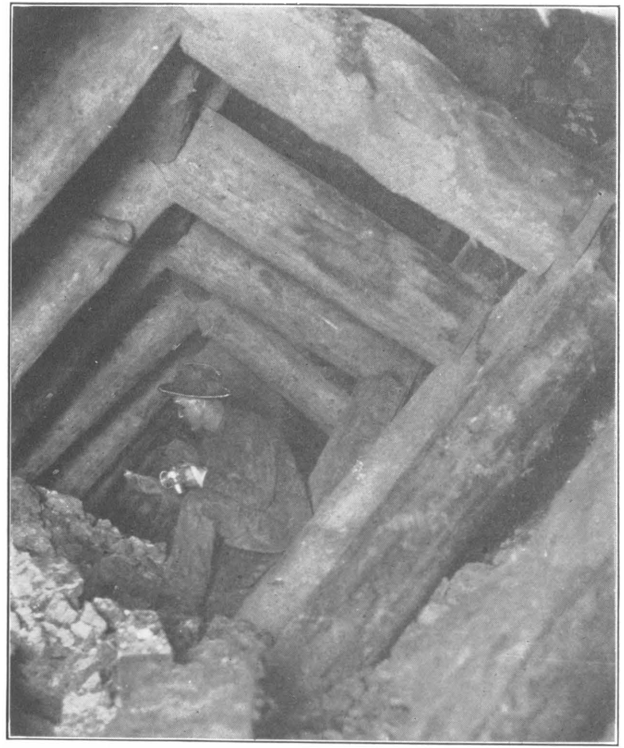
A. SQUARE-SET TIMBERS FRAMED BY STEP-DOWN OR ROCKER METHOD.



B SQUARE AND ROUND TIMBERS FRAMED INTO SQUARE SETS BY STEP-DOWN OR ROCKER METHOD.



A. THREE-PIECE SET ROCKER FRAMING IN NARROW VEIN.



B. FOUR-PIECE SET ROCKER FRAMING IN NARROW INCLINED VEIN.

When the caps are butted together, the horn of the post can be made short and thick and thus will not break off easily. The horns of the caps are also made short and thick, and when square timbers are used the girts are not framed at all.

When the pressure comes upon such a joint vertically, or postwise, the posts bear down on and compress the fibers in the cap pieces until the wood is compressed enough to transmit the pressure to the post below. The joint then acts as an individual piece, and the pressure is transmitted through the entire end section of the post, instead of through a long narrow horn.

When the weight comes on the timbers horizontally, or capwise, the posts are compressed over their entire section, as are the caps when the pressure is vertical and the posts transmit the pressure to the opposite caps through their entire section.

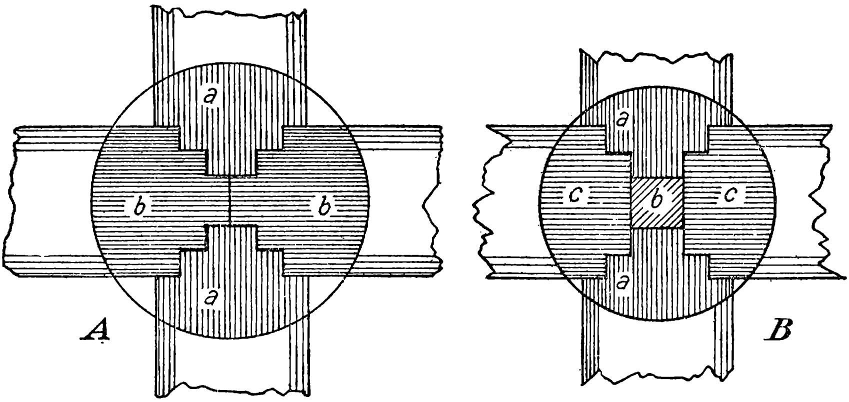


FIGURE 36.—Vertical sections of the joint in the Rocker method of framing square set timbers: *a*, Post; *b*, cap; *c*, girt.

A step in the development of framing square-set timbers was to use small regularly framed round timbers instead of large square pieces. The operators felt that small timbers would cost less, would be easier to handle underground; and, if a method of framing could be devised which could be applied equally well to round and to square timbers, many timbers could be used which are too small to be squared without abandoning the use of square timbers. Many devices, such as bevel joints, square joints (fig. 34), and the cutting of timbers to one dimension, say 12 by 12 inches, and allowing the timbermen to fit the joints together underground, were tried with but very little success. In the copper mines at Butte, Mont., there has been developed a method of framing timbers, called the "step-down," or "Rocker" method (Pl. XII, *A* and *B*) which can be applied equally well to either round or to square timbers.

In this method (figs. 35 and 36) the post starts with a horn 4 inches square, then a step down of 2 inches, and another horn of 8 inches. If the post is large enough, there is another step down of 2 inches and a horn of 12 inches square.

The caps (figs. 35 and 36) are framed exactly as the posts with the exceptions that the top side is slabbed off 5 inches from the center of the cap in order to permit placing lagging in the floor of the stopes. The caps are only 5 feet 4 inches long, while the posts are 7 feet 6 inches. The girts start with a horn 4 inches by 8 inches, then a step down of 2 inches, and another horn of 6 by 12 inches. The girt seldom reaches a diameter of over 10 inches (fig. 35) and is 5 feet long. When these individual members of the set (Pl. XII, *B*) are joined together in the stope, it will give a set which is 5 feet 4 inches square horizontally, and 7 feet 6 inches high.

The Rocker method of framing square set timbers has many important advantages as follows:

1. It can be applied to either round or square timbers (Pl. XII, *B*).
2. Each step-down of the individual members of the set rests directly on a similar step-down of one of the other members (fig. 36).
3. Due to the step-down method of framing, the horn of each member is the whole end section of the timber instead of one long narrow horn (fig. 36).
4. The caps butt together instead of the posts (see diagram *B* in fig. 36).
5. Each member of the set is different from the other members, and as both ends of each member are the same, the timbers can be placed by inexperienced men.
6. It is a simple matter to substitute a new member for a broken one.
7. The cap is squared off on top (fig. 35) so that it is possible to lay a tight level floor in the stope.

Practically the only disadvantage of the Rocker method of framing is that it is almost impossible to frame the timbers by hand with the sawhorse. However, when it is evident that square setting must be resorted to, a small framing machine, preferably one which will frame both ends of the timber at the same time, can be purchased from any mining machinery company. With the framing machine all joints can be made exactly the same size and consequently will fit.

The square-set method of timbering is ordinarily confined to stopes which are less than 100 feet wide and not over 200 feet high; commonly, intermediate levels are run every 100 feet and the ore transferred from these intermediate levels to haulage levels which are 200 or 300 feet apart. It is difficult to keep stopes over 100 feet high open, when the square-set method of timbering is used, as the weight of the timbers above the sill floor will often crush out the sill and first-floor timbers before the next higher level is reached.

The methods of working and placing timber in square-set stopes is essentially the same as that described for the stull and post method, with the exception that instead of working out the sill floor for the entire width of the vein at one time, only space for one set at a time is mined.

Sometimes the square-set method of timbering is applied to stopes in inclined veins (Pl. XIII, *B*). However, there is one dangerous feature in this practice. At the junction of the first stope floor set with the drift timbers (fig. 37), unless the posts are made either flat bottomed or with an angled framing that will set down into the framing on the caps and girts, the posts will kick out of the joints when heavy pressure comes on them. Butt blocks similar to those shown at *d* can be employed on either side just above this junction, and they, with a sprag placed between the posts, will overcome part of this tendency. When the ground is hard enough it will be cheaper and easier to use some form of the stull and post method.

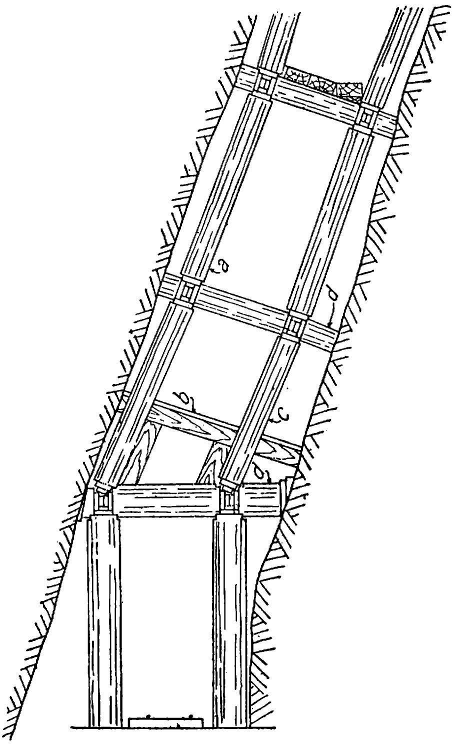


FIGURE 37.—Danger point in using square-set timbers in inclined veins: *a*, Post of usual length; *b*, 2-inch plank; *c*, short post; *d*, butt cap.

MISCELLANEOUS METHODS OF TIMBERING.

CHUTES, SLIDE CHUTES, AND GRIZZLIES.

The chute (fig. 38) is necessary in both the stull and post and the square-set methods of timbering stopes and can be placed in any set of timbers, either girtwise or capwise. To build a chute, take out the cap (fig. 38) and place the chute standards *e* and the chute standard cap *h* between the posts and block out from the regular posts with the chute blocks *f*. Next, place the crotch pieces *j* and the crotch-piece cap *o* between the chute standards *e* and at the bottom of the crotch pieces place the spreader *i*. Now lay the chute bottom-brace *m* at the centers of the girts and place the doubling-up posts *l* at both ends of the bottom brace *m*, upon which place the wedge piece *n* and fasten securely.

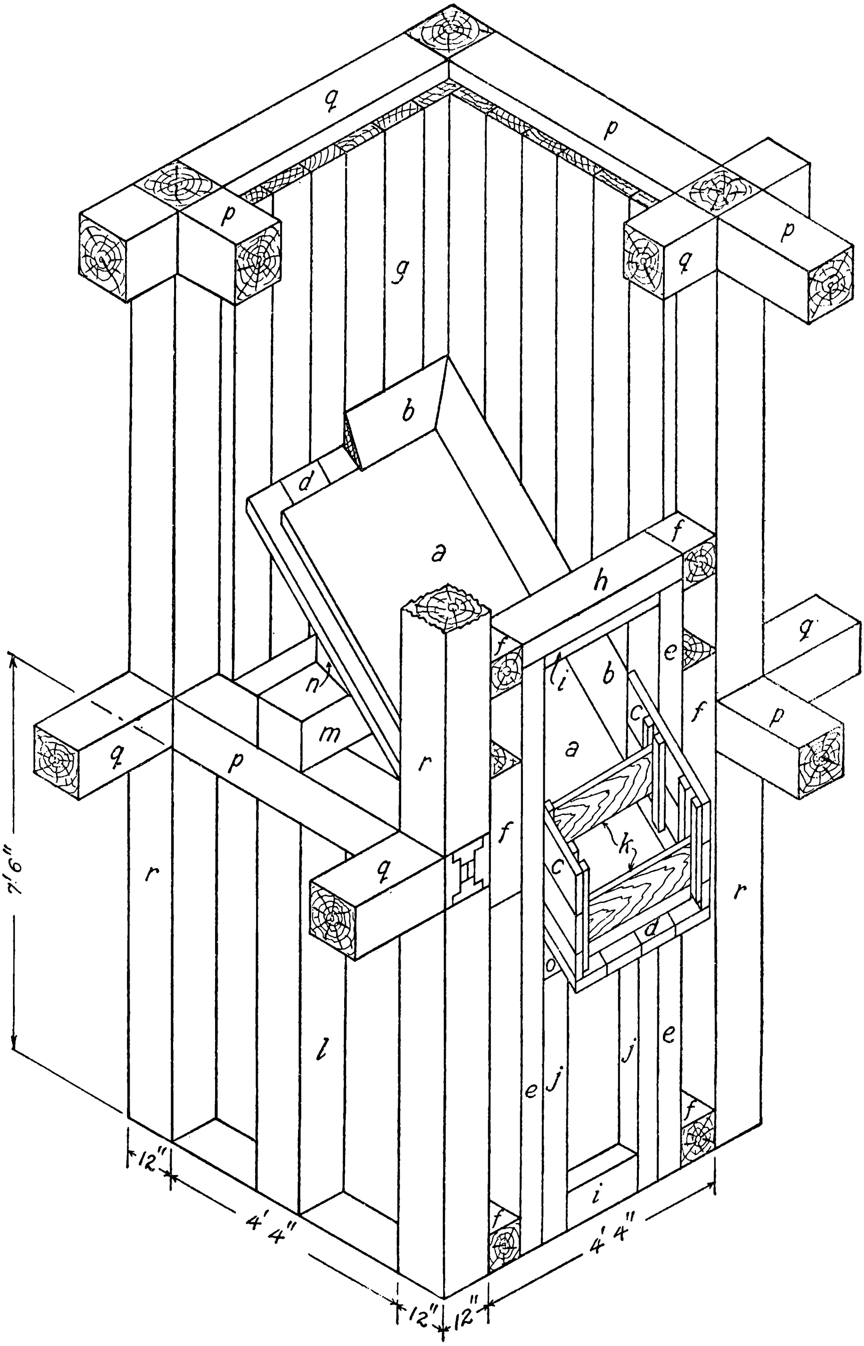


FIGURE 38.—Design of chutes used in square-set method and stull and post method of stope timbering: *a*, Sheet iron chute floor; *b*, bottom angle piece; *c*, chute jaw; *d*, chute bottom; *e*, chute standard; *f*, block; *g*, 3-inch chute lagging; *h*, chute standard cap; *i*, spreader; *j*, crotch pieces; *k*, stop board; *l*, "doubling up" post; *m*, chute bottom brace; *n*, wedge; *o*, crotch piece cap; *p*, girt; *q*, cap; *r*, post.

Next place the 3-inch chute laggings *g* at the back and on both sides of the chute set, leaving the front of the chute open until later. Afterwards place the chute-bottom laggings *d* in their position at the bottom of the chute and nail them securely to the wedge piece *n*, the crotch-piece cap *o*, and the chute laggings *g*. Now cut two pieces of one-fourth-inch sheet iron, *a*, for the bottom of the chute, one piece, 30 by 36 inches, to be placed between the chute jaws *c* and the other piece, 3 feet by 5 feet 6 inches, to be placed on the bottom of the chute underneath the bottom angle pieces *b*. After this has been completed place the bottom angle *b* in position and make and cut the chute jaws *c* and the stop boards *k* and place them in their proper positions. Now lag up the front of the set between the cap in the set above the sill and the chute standard cap *h*, and the bottom chute set is complete.

In many mines the caps and girts used in all chute raises are made from squared timbers (see Pl. XII, *B*), so that the chute lining can be easily attached to them. Ordinarily 3-inch or 4-inch lagging is used for this chute lining. When there is considerable pressure on the timbers, or when the chute is to be used to transfer ore or waste after the stope has been worked out, the chute is cribbed up tight with short blocks placed between the caps and girts in one set and the caps and girts in the next higher set so that their end section extends into the chute. This makes a strong rugged chute.

Plate XII, *B* (p. 54), shows a raise used in the square-set method of stope timbering. On the right of the man is the ore chute; the plate shows the chute lining and the square caps.

When the chutes and raises are placed on the footwall side of the vein and the vein is more than 20 feet wide, a slide chute (Pl. XIV, *A*) is used to transport the ore from the hanging-wall side of the vein to the main chute. The slide chute is merely four or five 3-inch lagging, 12 or 15 feet long, so placed that one end rests on the cap underneath the set upon which the ore is to be blasted and the other end is at the top of the regular chute. After the ore has been blasted on the stope floor one or more of the lagging are cut and the ore slides down this slide chute into the regular chute. These slide chutes will do away with a large amount of shoveling otherwise necessary to get the ore from the working face to the car. When filling is not used in connection with stoping, these slide chutes can be extended upward and along the vein for four or five floors, making it easier to handle the ore and also making possible less frequent raising of the main chute.

Grizzlies (Pl. XIV, *B*) are large timbers (frequently 10 inches by 10 inches) placed capwise of the set (see fig. 33, p. 49) and held in place by blocks and wedges. They are used in most mines at the tops of both the regular chutes and the slide chutes to prevent too large rock from entering the chute. They are easy to place in position and easy to remove and replace on the next higher set, when it becomes necessary. Grizzlies also prevent men from accidently falling down the chute. and for this purpose the grizzly

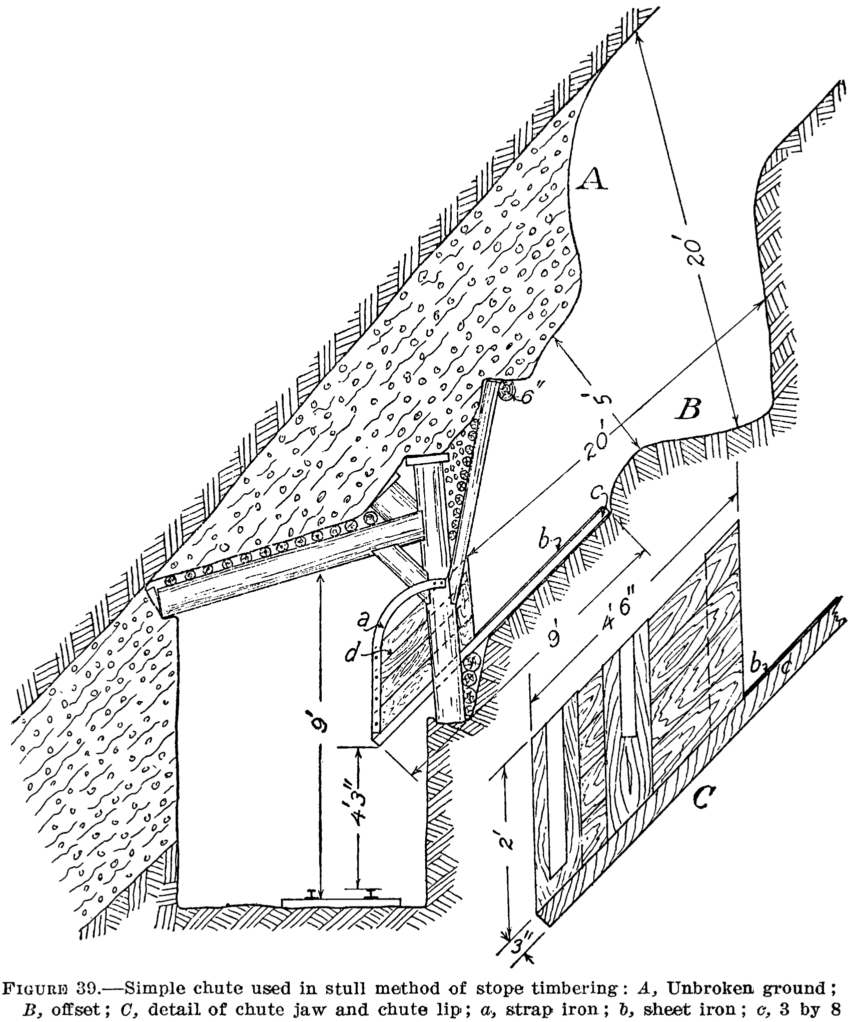


FIGURE 39.—Simple chute used in stull method of stope timbering: *A*, Unbroken ground; *B*, offset; *C*, detail of chute jaw and chute lip; *a*, strap iron; *b*, sheet iron; *c*, 3 by 8 inch board; *d*, chute jaw, 2 by 8 inch.

timbers should be spaced not more than 10 inches apart, as men have fallen through grizzlies with timbers 12 inches apart.

Guard rails *j* (fig. 33) should be placed around every opening in the floor of the stope or drift (Pl. XV, *A*) whether it is a slide chute, a regular chute, or merely a hole down into the "waste corral."

They can be made of split lagging, round lagging, or any material that is fairly strong, and should not be placed more than 3 feet above the floor (fig. 33) or, if the hole is fairly large, two of them should be used (Pl. XV, *A*).

The chute (fig. 39) used in the stull method of stope timbering is of much simpler construction than the one employed in the square-set or the stull and post methods. The individual pieces of the chute are placed similarly to those of the square-set chute (p. 58), except that the offset, *B* (fig. 39), is driven before the chute mouth is placed in position. It is recommended that such offsets be used in every case so that the ore falling down the raise will strike the ground *A* and not the chute itself, else the chute will soon be broken.

The chute raises are made with two compartments, so there will be a passageway for the men, timbers, and supplies, as well as one for the ore. The partition between these compartments is made of 3-inch plank or pole lagging, but should be tight enough to prevent ore falling into the manway and the men falling into the chute. Stulls are placed at 7-foot intervals vertically in the chute raise (p. 48), and the lagging are nailed to them and thus form the partition. In some cases where the stope is filled with waste, or where a part of the broken ore is left in the stope, cribbing similar to that shown in figure 26 (p. 39) is used to line the chute. The details of the chute jaw and chute, which are placed as in the square-set chute, are shown in the lower right hand corner of figure 39. Stop boards are fitted into the slots to keep the ore from falling out of the chute.

TIMBERING THE CONNECTION OF DRIFTS AND RAISES.

When holing through a raise into the drift on the next higher level, it is necessary to support the drift timbers (fig. 40) until such time as they can be connected with the raise timbers.

The point where the raise is to be holed through, is determined (*A*, fig. 40) and a 15-foot stringer is placed underneath the three drift caps directly over the raise, the end of the stringer being placed directly over the place (*A*, fig. 40), where the raise is to break through. This stringer is supported by means of a false post (section *B–B*) placed at its center, the stringer then acting as a lever to support the two caps on the ends of it. Next the posts in the set directly over the place where the raise is to break through (section *A–A*) are spragged back against the walls (*i*) and held in place by blocks and wedges. When this has been completed the blasting holes (section *A–A*) are shot and after the ore is removed the drift timbers and the raise timbers are connected directly or as shown in Plate XI, *B* (p. 55).

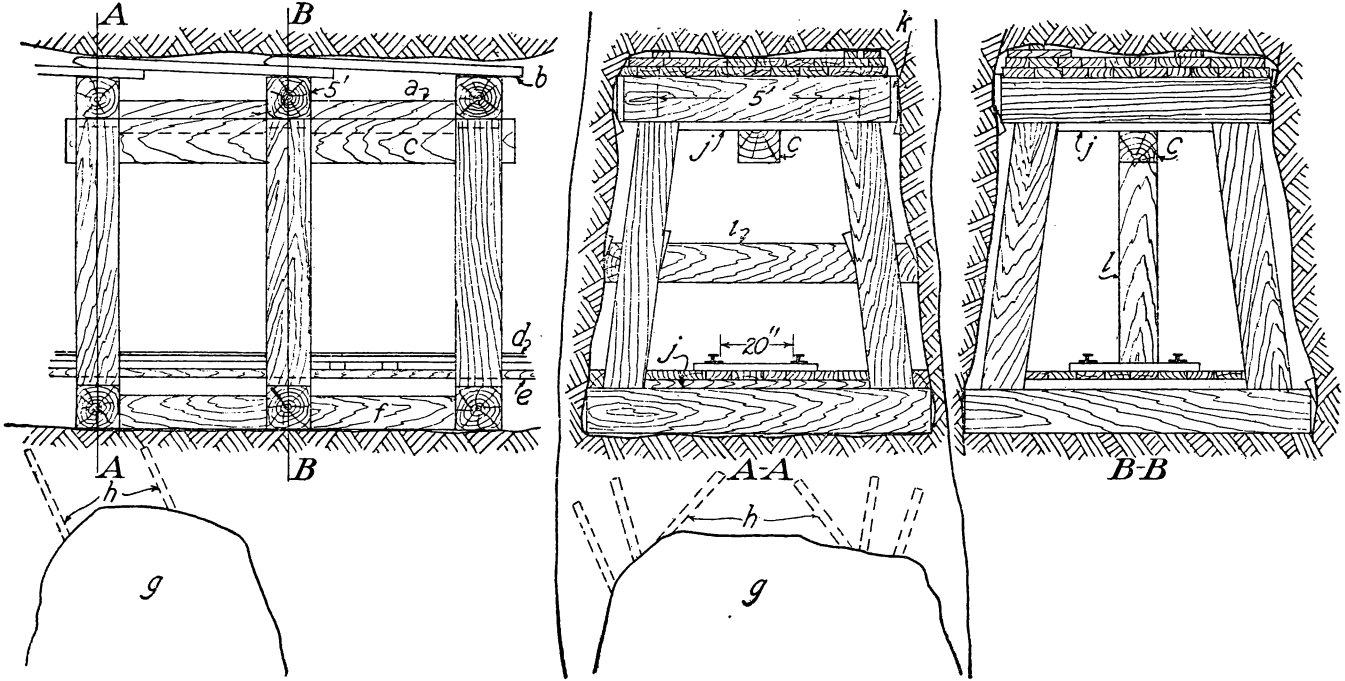
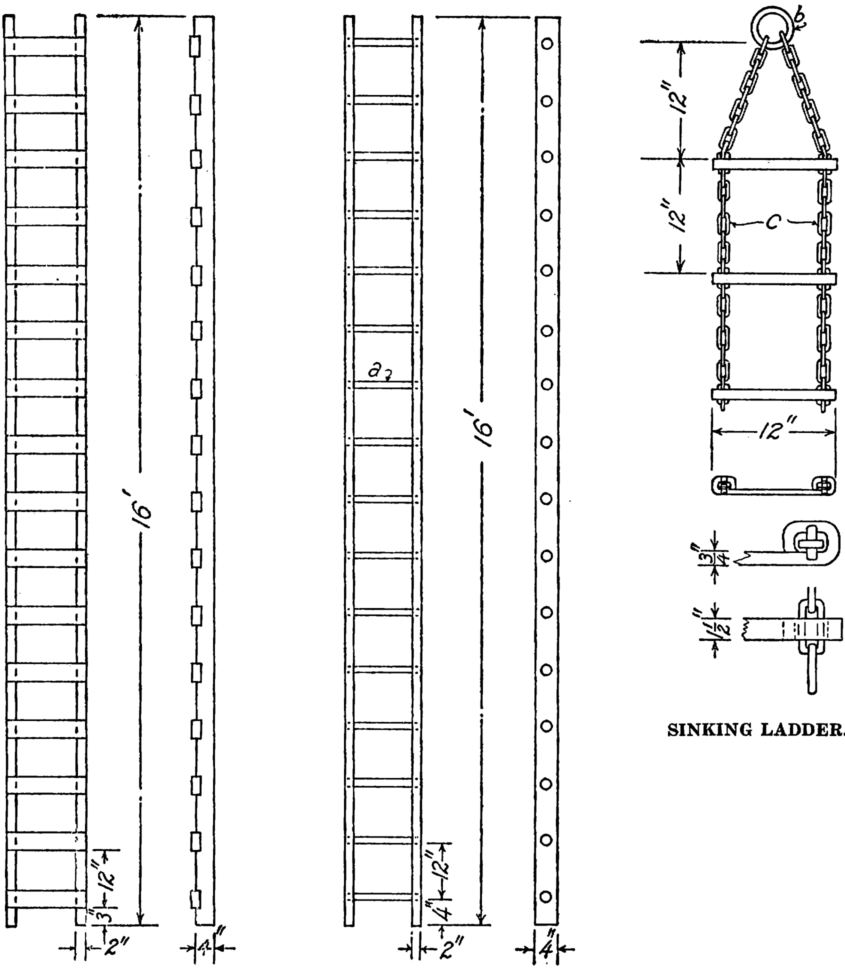


FIGURE 40.—Method of supporting drift timbers when holing through from a raise: *A–A*, section through point of break-through; *B–B*, section through false post; *a*, girt; *b*, *e*, lagging; *c*, 12 by 12 inch stringer; *d*, rail; *f*, sill sprag; *g*, rail; *h*, holes for blasting; *i*, 10 by 10 inch sprag; *j*, spreader; *k*, head block; *l*, false post.

In connecting drift and raise timbers the sets should never be so blocked that the ground above the drift will bear down on the center or unsupported part of the raise timbers. Also, short posts, cap sills, or short caps should be used so that regular joints can be made between the drift and raise timbers.



SINKING LADDER.

STOPE AND RAISE LADDER. IRON-PIPE LADDER.

FIGURE 41.—Three types of ladders used in metal mining: *a*, 1½-inch iron pipe; *b*, 1-inch round iron; *c*, five-eighths-inch chain.

Sometimes, especially in soft ground, instead of using one stringer with a false post at its center, so that the raise is holed through at one end of the stringer (fig. 40), two stringers are placed one on each side of the drift with false posts under each end of them, and the raise is holed through at their center.

CHUTE COVERS.

After the raises are connected with the next higher level some means of keeping men and animals from falling into them must be employed. If the raises are not to be used as a manway, transfer chute, or timber slide, lagging nailed across the raise timbers (Pl. XV, *A*) will be sufficient; but if they are to be used for any of these purposes, a cover or door (Pl. XV, *B*) should always be provided. The top of the set is lagged up tight and the doors (Pl. XV, *B*) are placed in one corner of the set directly over the chute or manway. While it takes a little longer to dump each car when the top of the chute is covered in this way, there is little danger of a man or an animal falling into the chute.

LADDERS USED IN MINE TIMBERING.

Three types of ladders used in metal mining are shown in figure 41. The ladder with wooden rungs on the left is used both in shafts and in stopes, whereas the ladder in the center with iron pipe rungs is commonly used in shafts. In sinking vertical shafts the ladder on the right, usually 15 or 20 feet long and made of iron chain, is hung from the last set of shaft timbers and extends to the bottom of the shaft. Sometimes in prospect shafts a rope ladder may be used, but the iron chain ladder, while heavier than the rope ladder, will last much longer and is safer, as it is not so easily damaged by blasting.

SAFETY IN MINE TIMBERING.

Promoting safety in mine timbering offers difficulty even under the most favorable circumstances. Of all the accidents that happen in metal mining, 36 per cent are traceable to faulty timbering; therefore it is decidedly to the personal interest of the individual miner, be he shoveler or general superintendent, to see that so far as his mine or stope is concerned every precaution is taken to place and keep the timbering in a safe condition.

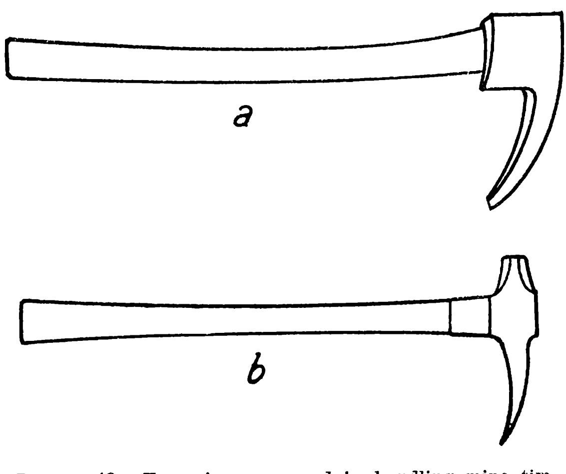
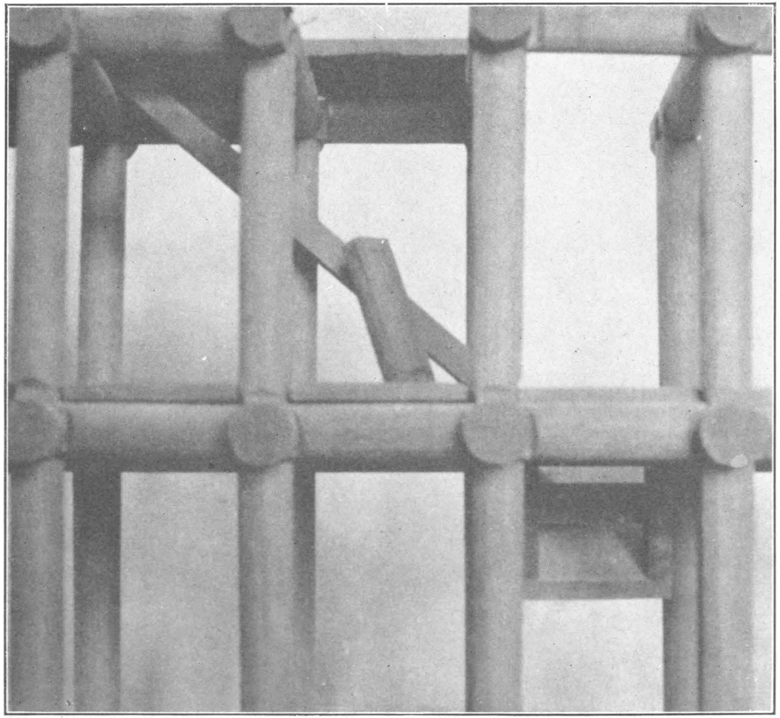
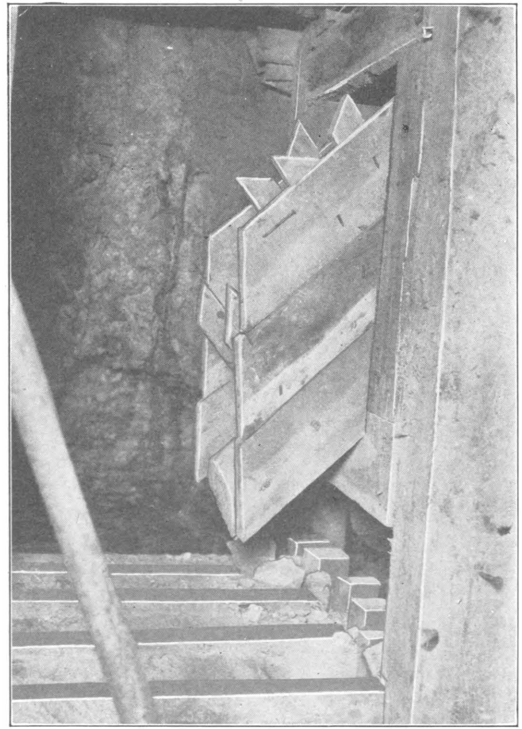


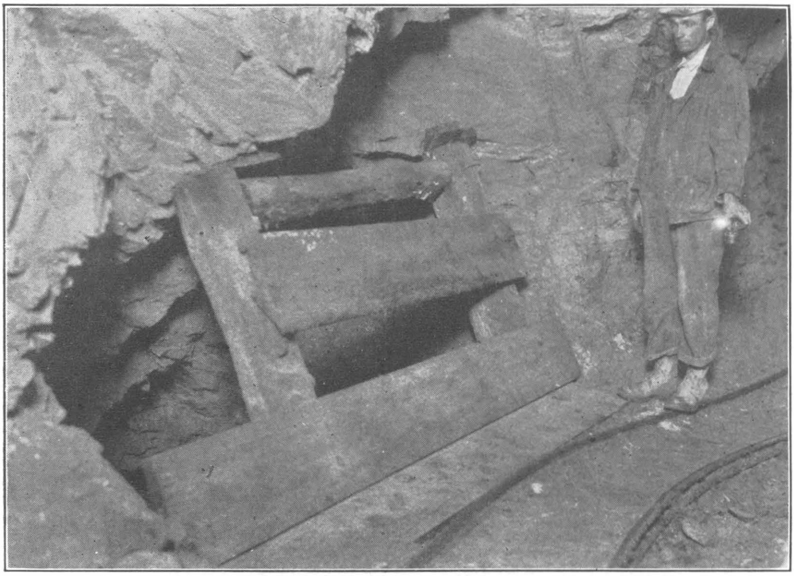
FIGURE 42.—Two picaroons used in handling mine timbers: *a*, No. 5 poleax picaroon; *b*, pick picaroon.



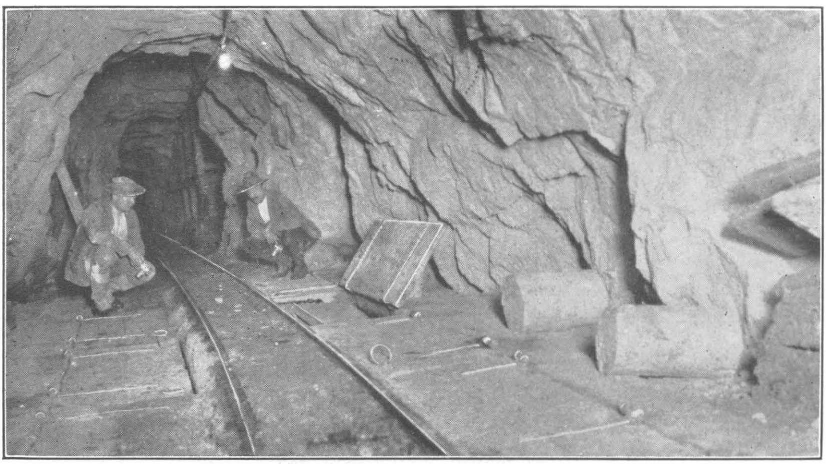
A. MODEL OF THE SLIDE AND MOUTH OF A CHUTE, USED IN METAL MINING.



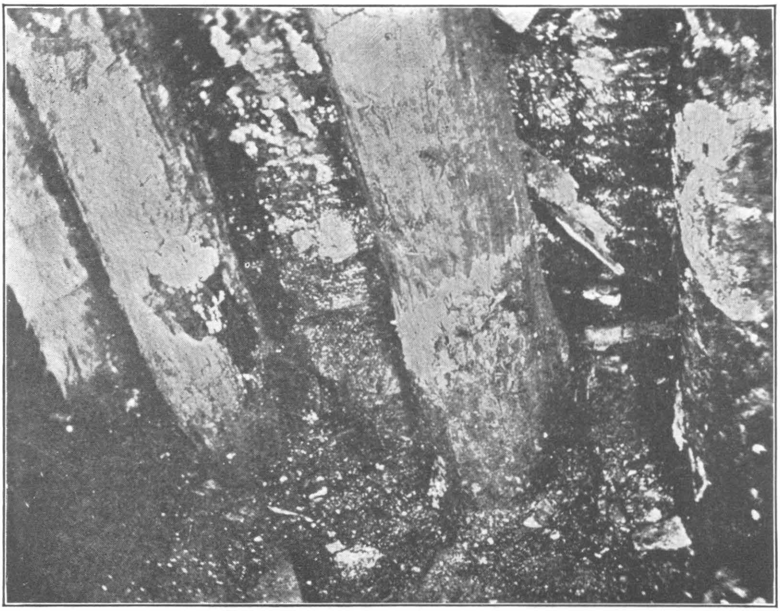
B. METHOD OF PLACING GRIZZLIES USED IN METAL MINING.



A. METHOD OF BLOCKING OFF THE TOP OF A RAISE.

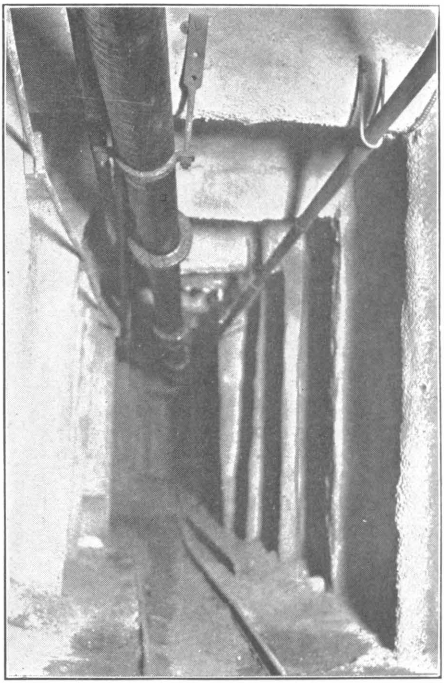


B. CHUTE COVERS USED AT THE TOP OF A RAISE.

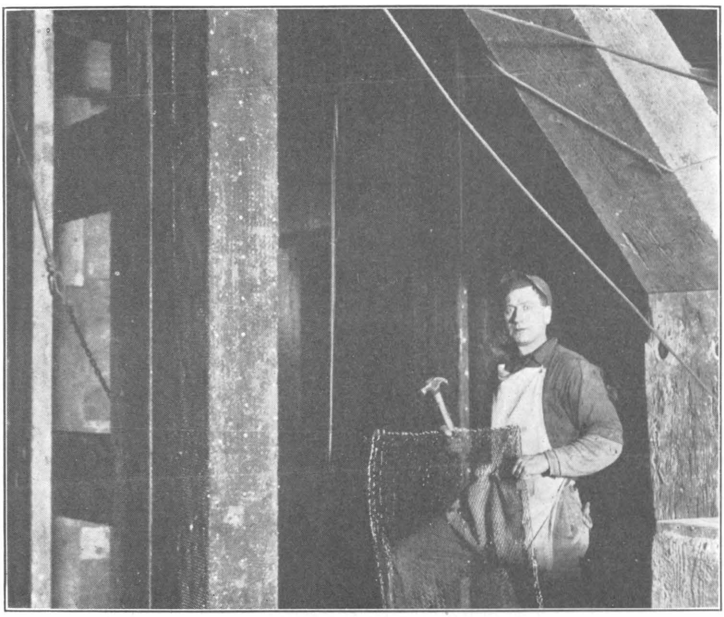


A. FUNGOUS GROWTHS ON MINE TIMBERS. THE UPPER PART OF THE CENTER TIMBER WAS TREATED WITH CREOSOTE; THE LOWER PART WAS UNTREATED. AFTER U. S. FOREST SERVICE.

B. FAILURE OF AN UNTREATED LOBLOLLY PINE POST BY DECAY. DIRECTLY TO THE LEFT OF THE BROKEN POST IS A POST PLACED AT THE SAME TIME AND TREATED WITH ZINC CHLORIDE. AFTER U. S FOREST SERVICE.



A. GUNITE PLACED ON BOTH TIMBERS AND SIDES OF OPENING IN THIS DRIFT HAS KEPT IT IN REPAIR FOR OVER A YEAR. PRIOR TO USE OF GUNITE TWO MEN HAD TO BE CONSTANTLY EMPLOYED REPLACING DRIFT TIMBERS.



B. METHOD OF PLACING METAL LATHING ON SHAFT TIMBERS BEFORE APPLYING GUNITE.

HANDLING TIMBERS.

More than in any other way, accidents in timbering are caused by the careless handling of timbers. Men should be instructed always to use picaroons to handle timbers with, so that their hands

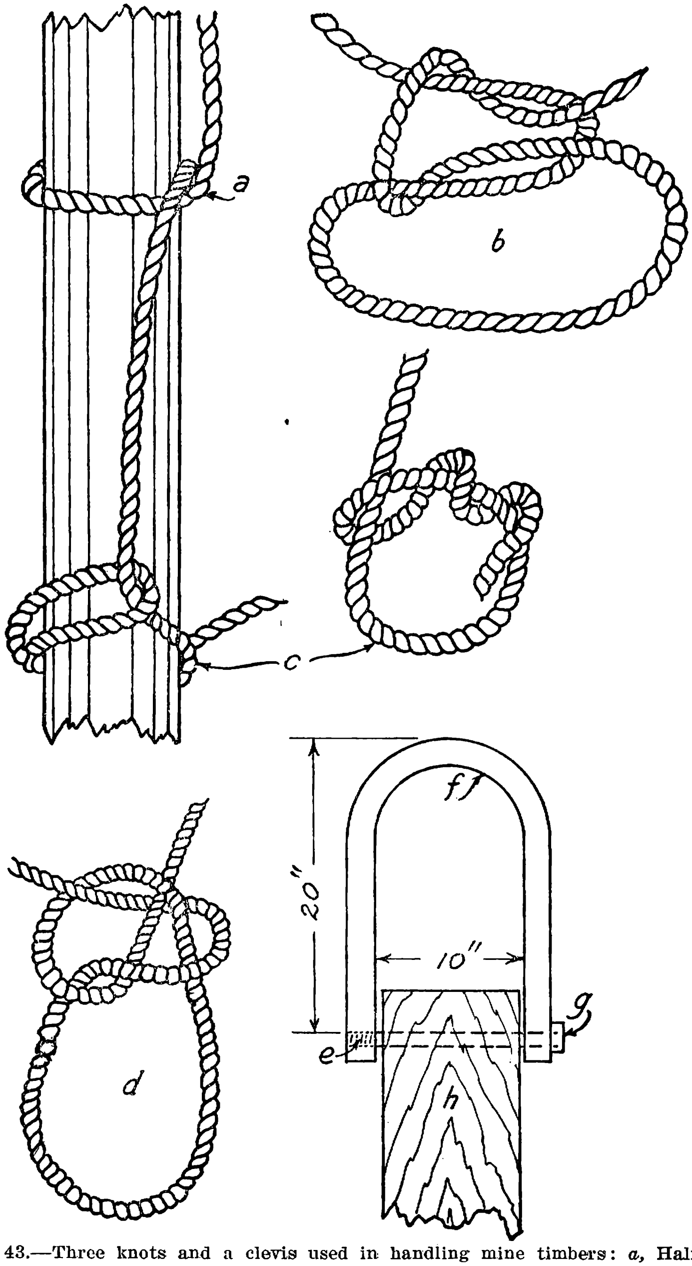


FIGURE 43.—Three knots and a clevis used in handling mine timbers: *a*, Half hitch; *b*, figure eight or square knot; *c*, timber hitch; *d*, bowline or loose knot; *e*, *f*, *g*, and *h*, clevis; *e*, threaded end of strap iron; *f*, ½ by 2 inch strap iron; *g*, 1-inch bolt; *h*, timber.

will not be subject to injury. A picaroon can be made from an old ax or from an old pick. The upper picaroon (fig. 42) shows one made from an old ax. The blacksmith cuts the bit of the ax as shown in the drawing, and points and sharpens it with little difficulty. The other picaroon is made from an old pick; one end of the pick is cut off and the other end curved and sharpened.

ROPE KNOTS USED IN HANDLING MINE TIMBERS.

Three rope knots recommended for handling mine timbers and the methods of tying them are shown in Figure 43. They are all familiar to the average miner, but oftentimes are called by other names. For example, some miners call the bowline a "loose knot." At one time a discussion came up underground as to how a bowline was tied. Finally one miner tied what he called a "loose knot," which was, in fact, the bowline. No matter what name these knots are known by, they all will be found satisfactory in handling timbers, because they will not slip. Whatever knot is used, always throw a half hitch around the top of the timber being hoisted or lowered, so that it will be kept in line and not sway. The half hitch also adds to the security of the rope's hold on the timber.

A shackle or clevis should always be used for handling heavy timbers in vertical shaft timbering. There are several designs of clevices in use, one of which is shown in figure 43. In inclined or vertical shafts and winzes, the timbers must be placed in the cage or skip for lowering, and should always be securely tied to the sides; otherwise they may work loose and cause damage. Men should never be allowed to ride on the cages when timber is being lowered.

SOME PRECAUTIONS.

Timber in time, before the rock arch becomes broken and begins to settle.

Place timbers properly to utilize their greatest natural strength.

Lay stope floors absolutely tight.

Landings must be made in every shaft, raise, or winze, or wherever ladders are used as a travel way.

Put in grizzlies at the tops of all chutes and slide chutes.

Guard rails should be placed around every opening in the drift, crosscut, shaft, raise, or stope as a necessary precaution.

Joints in timber sets should be properly blocked, otherwise the joint will work loose and fail.

Tighten all loose blocking.

In lowering timbers down an inclined or vertical shaft, tie them securely in the skip or cage. For large timbers in a vertical shaft use a shackle or clevis.

It is much safer not to ride on a skip or cage that is partly loaded with timber.

DON'T take a chance where your own or another's safety is concerned.

EFFECT OF VENTILATION ON TIMBERING.

The ventilation of a mine has considerable effect on the life of the timber. Damp stagnant air will cause mold and fungus growth (Pl. XVI, *A*), which will be followed by decay or rot. All timbered active places in mines should be well ventilated, and special provision should be made for the removal of the damp, hot air which is commonly found underground in pumping stations and around steam lines.

PRESERVATION OF MINE TIMBERS.

Timbers used in mines are subject to destruction from decay and insect attack, breakage, mechanical wear and fire. It is estimated that under average conditions 50 per cent of the total timber used is destroyed by decay and insect attack, and the remainder by other causes.[1]

Decay and its accompanying evil, boring by insects, the most destructive agencies acting on underground timber, can be retarded by peeling and seasoning the timbers before use, and by treatment with a suitable preservative.

PEELING AND SEASONING.

While it may not always be feasible for the small mine operator to use preservatives, peeling and seasoning timbers is always possible. Bark, when left on the timber, retards the evaporation of moisture, leaving the timber more easily attacked by fungus growths (Pl. XVI, *A*), and various wood-boring insects.

The average life of green, unpeeled, and untreated timber used in a mine is from one to three years; but by peeling alone, the life of timber when used in dry mine workings may be increased 10 to 15 per cent. Timbers should always be cut in the fall or winter and peeled and seasoned for three to six months in the forest when practicable. This peeling and seasoning will lessen the weight 15 to 35 per cent and thus reduce the cost of shipping and handling.

To obtain the best results in seasoning, timbers should be piled on skids so that air can circulate throughout the pile, and should be

[1] Peters, E. W., The Preservation of Mine Timbers: U. S. Dept. of Agric., Forest Service Bull. 107, 1912, p. 6.

left piled for 8 to 10 weeks. Too rapid seasoning results in checks, which weaken the timber. Too long seasoning, especially of timber cut in summer, may cause decay.

Unless the cut timbers are properly piled, they may be quickly damaged by fungus or insects, and thus the benefit ordinarily obtained by seasoning will be offset.

PRESERVATIVES USED.

Timbers which will be covered shortly with waste, those which are subjected to severe crushing, or those used in temporary openings should not be treated. Where the opening is of a more permanent character, as in a shaft or a main haulage way, it may be economical to treat the timbers with some preservative. There are several kinds of wood preservatives which have been used successfully on mine timbers—creosote (Pl. XVI, *A*), zinc chloride (Pl. XVI, *B*), and sodium fluoride are the ones most commonly used. The bark should always be removed from the timbers before treatment.

CREOSOTE.

Creosote has three distinct advantages as a preservative of mine timbers: (1) If properly applied, it fills the pores of the wood and prevents saturation by water; (2) it retards decay, as it destroys the organic life—the fungi (Pl. XVI, *A*) ; (3) it is not easily soluble in water, and hence can be used on timbers to be placed in wet or in dry places.

ZINC CHLORIDE.

Zinc chloride will retard decay and the boring of insects but, on account of its ready solubility in water, it is not recommended for treating timbers to be placed in wet shafts and drifts. However, if the timbers are to be placed in comparatively dry drifts, it will be found effective.

SODIUM FLUORIDE.

Sodium fluoride is a water soluble salt which has been used extensively in Europe as a wood preservative and found quite satisfactory. In this country it has not found so wide an application as either creosote or zinc chloride, but is gaining in favor. It is less soluble than zinc chloride, but is more expensive.

SODIUM CHLORIDE.

Sodium chloride (common salt) was at one time in extensive use in Europe, but has never been widely used in this country.

Timber treated with salt was found to be fairly satisfactory in dry places, but as salt is easily soluble in water, it is of no value in wet places.

COPPER SULPHATE.

Copper sulphate is also soluble in water, and for this reason is not used to any extent. However, in mines which make a great deal of water that contains copper salts, it has become the practice to dam a drift enough to hold a small reservoir of sulphate water and then throw the timbers into the water and allow them to remain for two to four weeks. After they have been removed and permitted to dry for a short time, they are ready to be placed in the dry drift or crosscut.

GUNITE.

Another method which is now widely used to protect timber from fire is covering with gunite, a cement mortar blown by compressed air against the timber or the surface to be protected. This method is especially suited for shafts and for permanent drifts or crosscuts, and is being used by a number of large metal mines.

Plate XVII, *A* and *B*, shows timbers coated with gunite.

METHODS OF APPLYING PRESERVATIVE.

The liquid preservative is applied to mine timbers by brushing or spraying, by open tank, and by pressure methods.

BRUSHING OR SPRAYING.

Brushing or spraying timbers with creosote can always be resorted to by the small-mine operator. All that is necessary is a large brush or a hand sprayer and a pail of creosote. Brush or spray the timber with two coats of boiling creosote and allow it to dry for two or three days. Treatment with creosote in this way will add one to three years to the life of mine timber. If the timber is cut after it has been treated, the cut must be brushed with creosote, for fungus or insects will attack any exposed portion of the untreated timber and cause its failure.

A set of timber consisting of 24 pieces (2 posts, 2 girts, 1 cap, 1 sill, and 18 lagging) were treated by brushing with two coats of creosote during 1914 at an expense of 28 to 94 cents per set, the creosote costing about 8 to 15 cents per gallon, and approximately 1½ gallons being required for a set. The main cost of treating the timbers by brushing or spraying is for labor, and this may be reduced as the men become familiar with the work.

OPEN-TANK TREATMENT.

When the amount of timber to be treated warrants it, a small open tank can be used. A tank could be bought and erected during 1916 for $1,500 to $2,000 which would treat about 100,000 cubic feet of timber in a year. The tank must be so constructed that a fire can be built under it, or if steam is available, so that steam coils can be placed in it in order to heat the preservative to the boiling point. The timbers are submerged in the hot bath and allowed to remain there for three to eight hours, or longer, depending upon the variety and condition of the timbers. They are then removed and placed in a cold bath of the same preservative for two to five hours. When only one tank is available, the timbers can be given the hot treatment and then the heat withdrawn and the timbers and solution permitted to cool together. In the cold bath the cooling of the air and moisture in the wood creates a partial vacuum in the wood cells, thus drawing the preservative into the cells. This method has the advantage of inexpensive equipment and simplicity of treatment as compared with the pressure method.

PRESSURE METHOD.

The pressure method is the most effective method for treating wood. The timbers are placed in a closed cylinder; the hot preservative at temperatures up to 220° F is forced into the timber by means of pressure. The most common preservative solution used in the pressure method is creosote, but zinc chloride and sodium fluoride are also used; however, any preservative solution that has a corrosive effect on iron can not be used. Plants using pressure are efficient, but in 1915 cost from $10,000 to $15,000, and therefore are not within the reach of operators of small mines.

The United States Forest Service has published numerous books on the preservative treatment of woods, including mine timbers.

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