MODERN PRACTICE IN MINING

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VOL. III

METHODS OF WORKING COAL

BY

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WITH ONE FOLDING PLAN AND OTHER ILLUSTRATIONS

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PREFACE

THE conditions under which coal seams occur are so different, and, consequently, the methods of working them so varied, that it is impossible in a work of the size of the present volume to do more than introduce the subject, indicate the main features, and describe some characteristic examples. It is hoped, however, that this little book may prove of some assistance to young mining engineers and others interested in the working of coal mines at home and abroad, and incite them to prosecute further the study of so interesting and important a branch of mining.

Many of the figures have been specially drawn for illustrating the text; for permission to make use of the others, the author desires to thank the several gentlemen and H.M. Stationery Office from whom they have been borrowed.

Grateful acknowledgment is also made to Mr. R. Nelson, H.M. Electrical Inspector of Mines, for the trouble he has taken in reading the proof sheets.

R. A. S. REDMAYNE.

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MODERN PRACTICE IN MINING

INTRODUCTION

THE IMPORTANCE OF THE SUBJECT—COST—COMPLETENESS OF EXTRACTION—SAFETY

In determining the system of working and the plan on which he should lay out and carry on his mine, the mining engineer will be guided by three most important factors, viz. the cost of working the mineral, the completeness with which the mineral can be extracted, and the safety of the persons employed in the mine—three factors which are largely interdependent. His object will be to make the margin of profit as wide as possible—that is to say, he will aim at making the difference between the selling price f.o.r. (free on rail), or at the pit mouth, as the case may be, and the cost of producing and delivering the mineral at either of those points as great as possible. He is able to exercise but little if any control over the selling price—that will be governed largely by the laws of supply and demand—but he can direct his energies towards keeping down the cost of production of the mineral. Eliminating for the moment the question of wages, the chief determining factor in respect of cheapness of production is the selection of the best method of working the mineral—in other words, the adoption of that method which will allow of the greatest possible output of mineral *per diem* during the life of the mine, consistent with good condition of the mineral produced and the safety of the persons employed.

A system of laying out the mine and of working the mineral might be pursued which would produce for a time a large output, but might result in the long run in the ruin of the mine. Then, coal mines, or portions of coal mines, have frequently in the past been lost through "creep" owing to a wrong system of working having been pursued. Again, the drowning out of a mine, or of part of a mine, has been brought about by projecting the workings to the "dip," when, by a judicious system of working, they would either have been advanced to the rise, or some system of "fore-draining" arranged had it been necessary to work to the dip, and in either event adequate "standage" room with an under level drift would have been provided. The questions of haulage (see Vol. V.) and ventilation (see Vol. IV.), also, will be governed, in greater or less degree, by the system of working pursued. The quantity in which the mineral is gotten and its nature are important features, so that the "squeeze" or weight of the superincumbent strata may be properly regulated, with a view of preventing crush as in the case of a tender coal, or of obtaining fullest advantage of the "weighting" as in the case of a hard coal.

Completeness of extraction has an important bearing on the problem, some methods of working giving much better results than others: thus in the case of stratified deposits—notably in respect of coal—the "long-wall" method of working secures a fuller extraction of the seam than other methods, other things being equal. If a coal seam is of the same value throughout, or if it is of sale-able quality throughout, even though it may vary in value through its section, some bands or sections being of higher quality than others, the manager of the colliery will undoubtedly aim at completeness of extraction for purely economic reasons; but sometimes there is a band of coal in the seam or seams immediately above or below that being worked which it does not pay to work or bring to the surface, and the coal either remains unworked, or if its working is necessary to secure coal of greater value, is cast back into the "waste." In some cases, owing to the peculiar nature of the coal—in all probability its physical structure as well as its chemical composition—the leaving of the coal in the mine is fraught with danger of creating "gob" fires, as the spontaneous combustion of coal in the mine is called. The owner of the minerals (lessor) naturally desires, when letting a mineral "taking" or "royalty" to the colliery owner (lessee), that there should be as little waste in the getting of the mineral as possible, and therefore that the method of working pursued by the latter should be such as will allow of the highest percentage of recovery practicable. With this object in view, as well as that of seeing that the colliery owner renders a full and true account of the mineral worked, the lessor appoints an independent mining engineer as his mineral agent, sometimes known by the name of "check viewer," to watch over and safeguard his interests. This mineral agent will from time to time observe the development of the mine as evidenced by the working plans, the accuracy of which he will occasionally check, as well as the correctness of the methods pursued by the management, by occasional underground inspections. In this way he will determine whether or not the terms of the lease are being observed by the lessee.

The safety and health of the persons employed is, or should be, the first consideration in the mind of the manager of the mine, and the method of working adopted, as well as the manner in which it is carried out, have important bearings in this direction. When it is considered that about half of the fatalities due to accidents in mines are caused by falls of ground, it will be realised how great is the need for unceasing vigilance in respect of the support of the roof and sides of the mine. Further, as is shown in Vol. IV., the scheme of ventilation, as well as its effectiveness, are intimately connected with the system of working.

CHAPTER I

OPENING OUT—SHAFT PILLARS—THE SHAFT SIDINGS —THE PERMANENT SUPPORT OF SHAFT SIDINGS— UNDERGROUND ENGINE HOUSES AND STABLES

Opening-out Operations.—The shafts having been sunk to the seam which it is intended to work, and having been equipped for the raising of coal, the management will have to determine the number and direction of the main roads to be driven for the most economical exploitation of the tract of coal to be worked. There will have to be considered at the same time the extent of the support which will have to be left for the maintenance of the shafts, and of the mine buildings on the surface in their neighbourhood.

Shaft Pillars.—It has been customary, when mining stratified deposits, to leave a certain amount of the coal in the neighbourhood of the shafts unworked, so as to support the shafts and the buildings in their immediate vicinity on the surface, and only to recover this when all the rest of the mineral tract has been worked out. It has recently been suggested, however, that a seam could be satisfactorily opened out without leaving shaft pillars,[1] and it is evident that certain advantages would result, for—

(*a*) The coal otherwise left in shaft pillars until the exhaustion of the mine would be worked in the first in-

[1] At Dunsyston, near Airdrie, in 1865 an ironstone mine was opened out without shaft pillars. The depth was 290 feet and the thickness of the seam between 2 and 3 feet out. The woodwork of the shaft was damaged by the working.—*Trans. Inst. M.E.*, vol. xliii. p. 428.

stance, and, being close to the shaft, would be cheaply got, whereas if left until the exhaustion of the mine it would not be possible to exhaust it in its entirety, and it would be obtained in a more or less weathered or crushed condition.

(*b*) The cost of driving "narrow roads" would be obviated, a face being at once opened out.

(*c*) The danger of spontaneous combustion in a most likely place—the edge of the shaft pillars—in the case of those collieries the coal of which is liable to spontaneous ignition (North and South Staffordshire, Warwickshire, South Yorkshire), would be eliminated.

It is more than doubtful whether the gains specified above would not be far outweighed by the effects of the complete extraction of the coal in the neighbourhood of the shaft unless certain precautions of a costly nature were adopted. In some Silesian collieries, however, the coal is entirely extracted in the neighbourhood of the shafts, and the space left stowed with sand or debris by the flushing process. Subsidence in these circumstances is not entirely eliminated but it is much reduced and rendered of a more gradual nature, resulting in bending but not fracture of the superincumbent strata. But, however carefully the packing of the excavated area may have been carried out, and even though one seam only may have been worked, subsidence will usually make itself felt in the shaft; and this, in the case of a shaft the sinking of which had been of a difficult and dangerous nature owing to the presence of large quantities of water or running sand, might mean disaster to the undertaking; especially if, in each successive seam, the same practice is followed. The presence of a fault in the neighbourhood of the shafts would be almost certain to accentuate the danger.

If the coal of the excavated area were replaced with solid masonry, doubtless the amount of subsidence would be so small as to be negligible, but the cost of the masonry would probably outweigh any advantage from working the coal.

The Size of Shaft Pillars.—Authorities differ as to what should be the size of the shaft pillars, and no rule can be laid down which is applicable to all conditions. The question is really determined by what we know of subsidence, and the governing factors are:

(*a*) The inclination of the seam.
(*b*) The thickness of the seam.
(*c*) The depth of the seam from the surface.
(*d*) The nature of the superincumbent strata.
(*e*) The occurrence or absence of faults or dykes in the neighbourhood of the shafts.

(*a*) The fracture of strata by subsidence, except in abnormal circumstances (*e.g.* sand, gravel, the occurrence of faults or intrusive dykes), does not take place along vertical lines, but somewhere between the vertical and perpendicular to the planes of bedding: the effect of this in respect of the size of the shaft pillars is shown by Fig. 1, the fractures following the curved lines.

(*b*) The thicker the seam the greater will be the amount of subsidence, and though the extent of the *draw*—the distance between *a* and *a′* in Fig. 1 is the extent of the draw in that instance—is not directly affected by the thickness of the seam, yet it is indirectly so affected as the thicker the seam the greater the amount of wasting of the coal and consequent gradual diminution of the area left for support—unless it is protected by, say, masonry.

(*c*) The greater the depth the greater the pressure exerted on the coal left for support, and, consequently, if pillars are left too small, the coal becomes crushed and constitutes an unreliable support. In considering the extent of the pressure which may be exerted on pillars of coal in mines the writer has stated elsewhere[1] that the load or statical pressure is sometimes asserted to increase directly as the depth of the seam from the surface, and to be the product of depth into

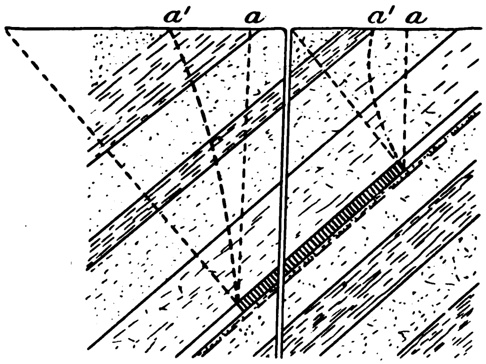


FIG. 1.—Shaft Pillar in an Inclined Seam and the Lines of Fracture due to Subsidence.

the average density of the overlying beds. A cubic foot of sandstone weighs roughly 150 lbs., of shale 160 lbs., of coal 82 lbs., and if the strata of the North of England coal-field be taken as representative of average conditions, sandstone, shale, and coal occur in the proportion of 20 sandstone, 12 shale to 1 coal, and the average weight may be taken at 144 lbs. per cubic foot, or at the value of 1 lb. per square inch for each foot in depth from the surface. The crushing stress of coal has been roughly estimated as between 2000 and 4000 lbs. per square inch. Therefore at depths of 2000 to 4000 feet

[1] *Colliery Working and Management*, by H. F. Bulman and R. A. S. Redmayne. 3rd edition, p. 160.

(according to the strength of the coal), the statical pressure on a coal seam is equal to its cohesive strength. But it is very doubtful if the pressure on a seam is directly proportional to its depth from the surface. It would be more in accordance with practical experience to say that the pressure is greater and that this greater pressure bears some rough and varying relation to the depth.

(*d*) The bearing that the nature of the superincumbent strata has on the problem has, to some extent, been indicated, but it should be mentioned that the rule laid down in (*a*) as to the line of fracture due to subsidence is subject to variation if beds of incohesive material, such as gravel or sand, intervene.

(*e*) The presence of "lines of weakness," such as faults or intrusive dykes, might render necessary an increase in the area of solid coal left for the support of the shaft. Thus, in Fig. 2, supposing *a b* to be the diameter of a circular area of coal left to support the shaft and mine buildings, in the case of a flat seam, and *d e* the line or hade of a fault, the subsidence would take place along the latter and not along the line *a c*. It would be necessary, therefore, to extend the shaft pillar on the fault side of the shaft well beyond the line of the fault, say to *f*.

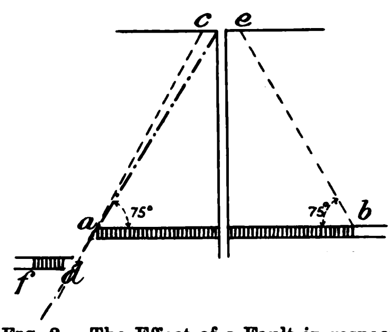


FIG. 2.—The Effect of a Fault in respect of the Size of a Shaft Pillar.

In level seams, or seams nearly level, the following rule is sometimes used for determining the size of shaft pillars when the seam to be worked does not exceed a depth of 400 yards from the surface. A minimum size of 40 yards is taken for 120 yards depth, and for every

40 yards beyond this depth 10 yards are added. Another rule is to lay out the pillars so that the size is equal in yards square to one quarter of the depth of the shafts in yards.

Taking two instances of modern collieries as a guide, one in Yorkshire and the other in South Wales, I find that the areas left are as follows:

Yorkshire colliery: depth from surface, 750 yards; diameter of shaft support, 600 yards.

South Wales colliery: depth from surface, 433 yards; diameter of shaft support, 200 yards.

Continental Practice.—The subject of subsidence in connection with mining has been closely studied by Continental mining engineers, and a case recently came before the writer's attention of a mine in Silesia in which a coal seam of 15 feet thickness was worked at a depth of 1200 feet from the surface and where the subsidence ("draw") extended 2400 feet beyond the advancing face, that is to say, for a distance equal to twice the depth of the shaft—a fact which would render nugatory the bases given above for determining the size of shaft pillars, were they applicable to all cases; but one of the most important factors in the case would appear to be the character of the superincumbent strata.

The practice until lately at many collieries in Silesia was so to determine the size of the shaft pillar that the angle contained by two lines drawn one from the shaft bottom to the edge of the pillar and the other from the edge of the pillar to the top of the shaft was 78°. But in the case of very deep mines a lesser angle is now being adopted.

Precautions to be taken in respect of Shaft Pillars.—So far as the strength of the support for the shaft is concerned, the fewer the number of roads driven through the coal the better; and in respect of collieries the coal of which is liable to spontaneous combustion, it is not only important to have as few roads as possible, but such roads as are necessary should be as far apart as possible, to guard against the formation of fissures or "breaks" in the coal and the consequent leakage of air through the coal—a fruitful source of spontaneous combustion.

Probably the best way is to make no roads in the proximity of the shafts in the seam at all, but to drive them in some soft stratum either above or below the coal seam, and, at some distance away, to dip down or rise up into the seam. Bad as it is to have fires in the workings, they are very much more difficult and dangerous to deal with if in the neighbourhood of the shafts.

If the roads are driven in the coal in collieries liable to spontaneous combustion, the packing—presuming the seam to be worked by "long-wall"—against the coal forming the shaft pillars should be as solid and tight as possible. Indeed, unless the packing has been done by the hydraulic method of stowage, it will probably save a good deal of trouble later on if solid masonry several yards in thickness is built along the edges of the shaft pillars, in order to prevent, as far as possible, the access of air to the coal.

Formation of the "Pit's Eye" or Shaft Inset.—The main roadways having advanced some distance beyond the shaft pillars, the formation of the pit's eye and shaft sidings will occupy the thoughts of the management.

Care must be taken in driving such of the roads from the shaft as are to be used for haulage roads to see that their "centre lines" are in proper line with the shaft, *i.e.* midway between the cages.

The formation of the "pit's eye" or "inset" necessitates, in nearly all cases, a considerable enlargement of the main haulage road or roads in the vicinity of the shaft and the protection of the roof and sides thereof with arching or some other form of permanent support. Indeed whatever form of support is used for the shaft sidings, the support of the actual "pit's eye," viz. the point where the main road joins the shaft, will in nearly all cases take the form of an arch groined into the shaft

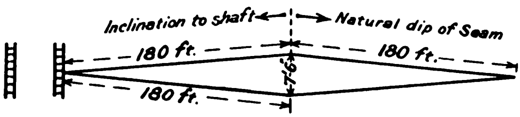


FIG. 3.—Longitudinal Section of "Kip and Dish."

walling: the proper construction of this is a matter of great importance, and one that requires considerable care. The net or finished size of the shaft siding or sidings will be governed by the size of the tub (gauge of the track) and number of tracks, and the sidings will be so graded as to allow of the inclination being in favour of the full tubs, *i.e.* towards the shaft. If, however, the "main-and-tail rope" system of haulage is adopted, in which long "sets" (journeys or trains) of tubs are hauled at one time—and in which, consequently, the haulage is spasmodic and rapid, as opposed to the "endless rope" system, where the haulage is continuous and slow—the grading of the siding will have to be arranged in the "kip and dish" style, that is to say, the full track will have to be raised above the empty track in order to allow of the full set being hauled on to an incline or "kip," whereas the empty track or "dish" will have to be so arranged that empty tubs can run back from the shaft and be formed up into a "set" to be sent in-bye (see Figs. 3 and 4).

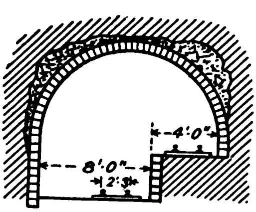


FIG. 4.—Cross-section of "Kip and Dish."

Methods adopted of Supporting Roof and Sides at Shaft Insets.—Various methods of supporting the roof and sides at the pit's eye or shaft inset are adopted. The simplest is of course by ordinary timbering, but in deep mines or where the shaft sidings

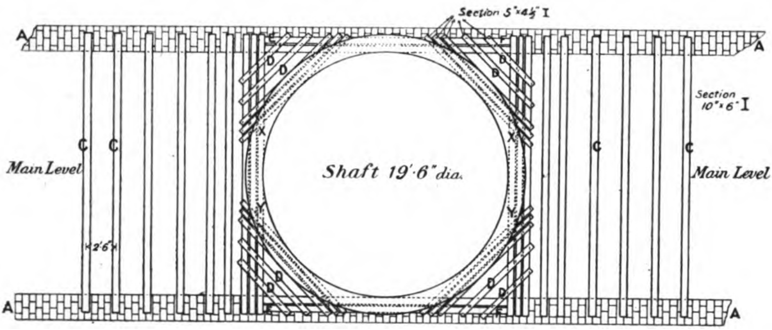


FIG. 5.

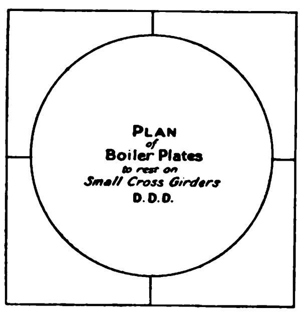


FIG. 6.

FIGS. 5 and 6.—A Method of Supporting the Roof and Sides of a Shaft Inset. Fig. 5 shows in Plan the Side Walls, Steel Girders, and Cross-girders. Fig. 6 is a Plan showing the manner of Arranging the Steel or Iron Plates.

are wide, or the strata forming the roof and sides of a friable character, this will not suffice. If the roof is of rock, and not liable to close fracturing, it can be supported by steel or iron girders carried on side walls of masonry—stone or brick—the masonry constituting an admirable support for the sides.

An arrangement of this sort is shown in Fig. 5. The manner of placing the girders in the vicinity of the shaft should be noted; in this instance boiler plating was placed above the girders, which made the roof support still more efficient, and precluded any fragments of stone falling away. In Fig. 5, AA are the wing-walls upon which rest the girders CCCC. Boiler plates are laid upon these, forming a complete covering. DD are cross-girders of small section, which are held in position by clamps or knees on the girders EF. Boiler plates (see plan, Fig. 6) are fastened on top of the girders DD. In the space occupied by the girders EF, brickwork can

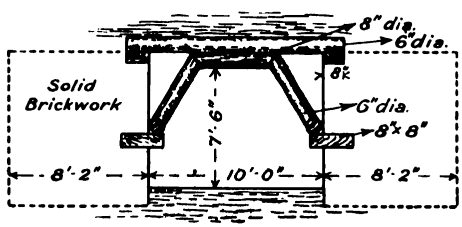


FIG. 7.—Arrangement of Supports for Roof and Sides of Shaft Inset at a Belgian Colliery of great depth.

be substituted for the girders, and the boiler plates put on this. The space XY is filled up with brickwork to the level of the short cross-girders DD. Where, however, the pressure is great, this form of support would be insufficient, and ordinary arching (and, if the bottom is liable to heave, barrel arching) will have to be resorted to (see p. 76).

At a Belgian colliery visited some years ago by the writer, where the seam at the shaft was 3772 feet from the surface, the pressure was so great that arching would not stand, and the method illustrated in Fig. 7 was adopted. Masonry, 8 feet 2 inches thick, and about 7 feet 6 inches high, was inserted, carrying a wooden balk 6 inches in diameter, wooden lids being inserted between the balk and the masonry. Central support was afforded to the wooden lid by means of timbering erected in the manner shown in the figure. But even with this method of support the shaft siding required to be renewed every six months.

Reinforced concrete has of late years been used in some shaft sidings. A notable instance of this is at Baggeridge Colliery, where this mode of support was recently carried out on a gigantic scale by Mr. H. W.

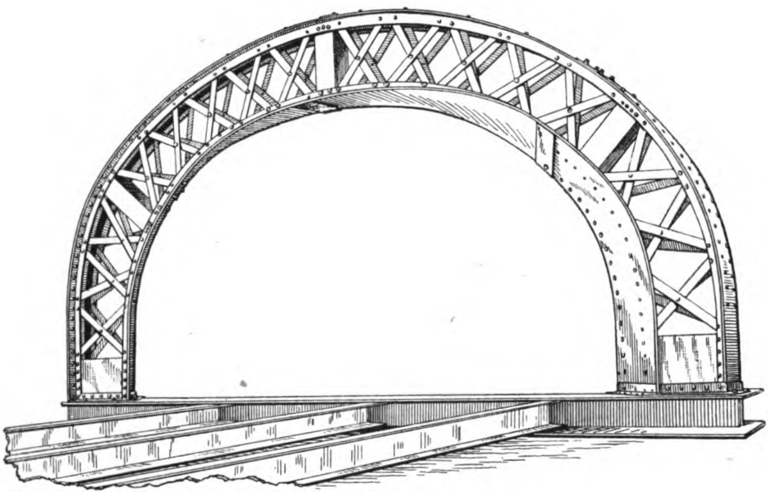


FIG. 8.—Steel Frame and Cross-struts for Underground Arch of Reinforced Concrete.

Hughes, the mining engineer in charge of the operations. The "thick" or "ten-yard" coal[1] and its associated seams exists here at a depth of approximately 900 feet from the surface, and the shaft inset at the thick coal level is 54 feet high inside the lining, which consists principally of reinforced concrete strengthened by steel frames and cross-struts. Fig. 8 is a view taken at the surface of the steel strut and cross-struts which were put in in the underground arch.

[1] The "thick coal" of South Staffordshire is formed by the coming together of several seams, and has a thickness ranging from 15 to 32 feet.

Another satisfactory method with which the writer is acquainted of supporting a large shaft inset where the crush is great, is by means of slightly tapered wooden (oak) blocks, built in the form of an arch. Owing to the compressability of the wood this results in a very satisfactory structure.

It will in all probability be found most convenient to carry on the work of enlarging the road in the neighbourhood of the shaft for the purposes of constructing the shaft sidings during the night-time, as the day will be occupied in driving out the main roadways and sending out coal and stone to the shaft.

The Laying Out of Shaft Sidings.—There are six ways of laying out shaft "kips" or landings, the proper lay-out being determined by the method of haulage adopted on the shaft landings. The different methods are:

1. The tubs are hauled to and from the "onsetters"[1] by horses.

2. The full tubs are lowered to the shaft by means of a "kip," with a "dish" for the empties.

3. Duplicate "kips" are used, so that each deck of a double-decked cage may be loaded simultaneously.

4. All full tubs are brought to the pit bottom on the level and dropped down to the several floors of the cage by balanced drop cages or lifts worked by hydraulic power.

5. The shaft landing haulage is worked by an endless rope.

6. The coals are brought at different levels to the cage landing-place and any of the preceding methods for the removal of the "empties" is adopted.

The old system of horse haulage is objectionable, as it is unsafe, slow, and costly. A horse requires a large

[1] The "onsetters" are the workmen who load and unload the cages.

amount of space in which to turn, and the liability to accident is considerable, yet the system is still in use for bringing tubs to and from the "onsetters" at some collieries of outputs up to 500 tons a day.

Perhaps the most costly arrangement is that in which "kips" are constructed. The single self-acting "kip" is still largely used in collieries worked by the main-and-tail rope system of underground haulage, the "kip" being variously constructed. With a seam dipping in the direction of the proposed "kip" it is a matter of considerable cost to arrange for a gradient of sufficient fall towards the shaft on which the full tubs can be hauled, so as to allow the number of tubs required to keep the shaft fully employed. With sets of 80 tubs, allowing 5 feet per tub, $80 \times 5 = 400$ feet, and allowing 90 feet for spare tubs, we have a length of "kip" of 490 feet.

Allowing $\frac{3}{8}$ of an inch per yard of gradient for full tubs, we have 163 yards at $\frac{3}{8}$ of an inch per yard = 5 feet 1 inch; and assuming the same gradient for the empty tubs, the height at 163 yards from the shaft will be 10 feet 2 inches.

To construct the "kip" would necessitate (assuming the seam to be 5 feet high) about 712 cubic yards of top stone to be taken down, and assuming that this would cost 6s. per cubic yard:

712 cubic yards at 6s.	£213	0	0.

In addition to the above, a retaining wall would be required of an average thickness of 2 feet, the cost of which would be as follows:

Bricks, 92,000 at 25s. per thousand . . .	£115	0	0
To labour on the above	25	0	0
Sundries, including timber, rails, &c. . .	350	0	0
Total cost	£490	0	0

Fig. 9, however, indicates an arrangement which obviates the necessity of such a costly construction. In an instance where this method was adopted the seam dipped at the rate of 1 in 36 inbye in the direction of the engine-plane, and the connecting road between shaft and engine-plane was at right angles to the latter, the engine-house being about 300 feet behind the shaft, the tubs being hauled beyond the shaft and above the switches AA. There were two full roads which were emptied alternately, the load being lowered down to the onsetters by putting the hauling-engine drums out of

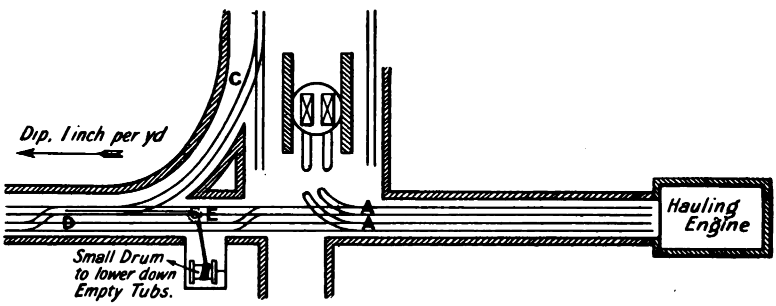


FIG. 9.—An Arrangement of Shaft Sidings for Main-and-Tail Rope Haulage.

gear and checking them with the brake. The empties were taken out at the opposite side of the shaft, put on to the road C, which had a fall of about $\frac{3}{8}$ of an inch per yard from the shaft, and lowered down to the point D. On the first tub arriving at this point it was connected with a chain lying in the centre of the track, on the end of which there was a detaching hook. The chain was then passed round the sheave and round the small drum six or eight times. The drum was provided with a powerful brake and lever, conveniently placed within reach of a boy at the point E, and as the empty tubs continued to accumulate and were coupled at that point, they were lowered by the drum and lever as required.

When connected up to form a set, they were lowered to their proper position, and the tubs constituting one of the full sets being probably by that time all drawn to the surface, the main rope was hauled down from the point A by a pony and connected to the empty load. The set was then allowed to tighten gently on the main rope, thereby preventing the possibility of the set being sent away with any tubs uncoupled. On ascertaining that all the coupling chains were right the chain was disconnected from the first tub, the opposite end being now ready for the next set, and the set was despatched.

With the duplicate "kips" the road has to be of great width. In one case of which the writer is aware, where this arrangement had been adopted, the road had to be spanned by an arch 24 feet wide, 24 feet high, and 2 feet thick, the arching at the shaft being made of sufficient height to allow of loading three decks of the cage at once, over 100 tons an hour being drawn.

Simultaneous decking of cages conduces to a considerable increase in the output. By a system of simultaneous decking applied to surface and underground at a colliery with which the writer was at one time connected the output was increased by fully 10 per cent. The adoption of this method will not, however, affect the dimensions of the road.

It is questionable whether the practice sometimes adopted of bringing coal from several seams to one drawing-shaft is advisable, as the traffic is apt to become congested in the vicinity of the shaft and confusion results. Fig. 10 shows an arrangement at a colliery where three seams were being extensively worked. The coal from the upper seams was lowered to the level of the middle seam and wound at the upcast shaft together with the coal from the middle seam; the coal from the lowest or third seam being wound at another shaft. The labour

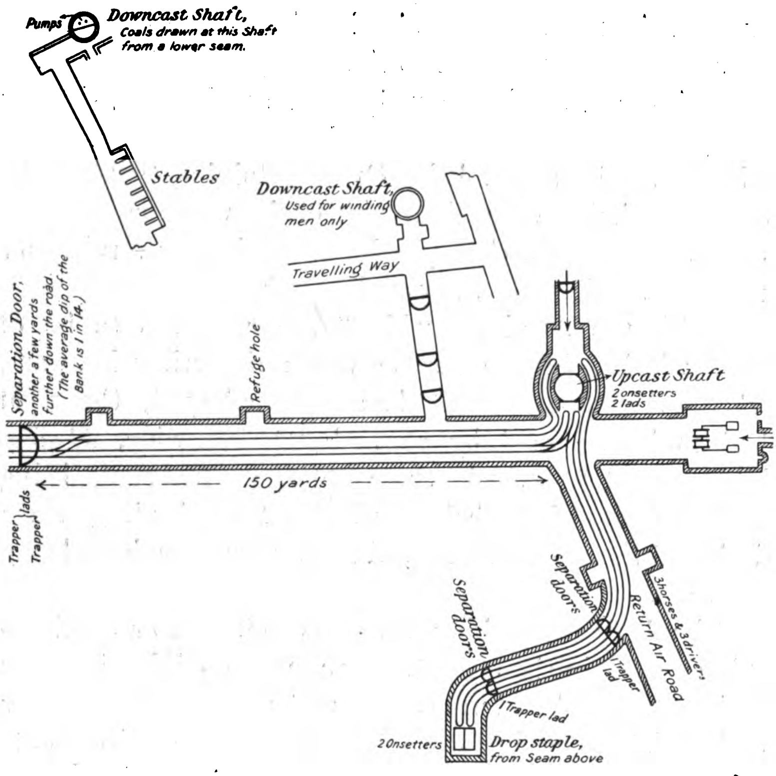


FIG. 10.—An arrangement of Shaft Sidings in the Middle Seam of a Colliery working Three Seams, the Coal from the Upper and Lower Seams being brought to the Middle Seam Level and wound therefrom at the Upcast Shaft.

employed in working the haulage in the neighbourhood of the drawing-shaft at the middle pit level is indicated in figure.

Figs. 11, 12, and 13 show characteristic ways of arranging the full and empty tracks, so as to allow of the conveyance of the empty tubs round each side of the shaft and past the full tubs.[1]

In Fig. 11 the shaft bottom is bell-mouthed, whereas in Figs. 12 and 13 two narrow back roads are driven into the shaft pillar for the empty tubs.

If the strata at the pit's eye are sufficiently stable to allow of bell-mouthing, this method of arranging the tracks is the less costly of the two, but if the strata are friable or greatly "cleaved" or liable to movement, the second plan is the safer to adopt, and possibly, in such circumstances, the cheaper.

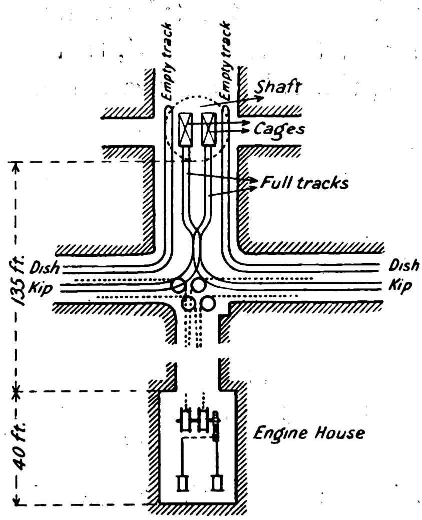


FIG. 11.—Arrangement of Sidings in the case of a Bell-mouthed Shaft Bottom.

The *length* of the shaft landing or siding will be governed by the system of haulage. If the "main-and-tail" rope system is adopted, a greater length of landing is required than if the "endless rope" is the system selected, as in the former case room will be required to stand a whole set of, say, from thirty to seventy tubs; the haulage, as already explained, being intermittent, whereas in the case of endless rope it is continuous.

The *width* will be determined by:

(*a*) The thickness of the side supports.
(*b*) The space to be left between the tracks of rails.
(*c*) The space between the sides of the tubs and the wall.

[1] Other names used for a tub in different parts of the country are corf (corves), waggon, train, hutch, box.

By the Coal Mines Act, 1911 (see Section 43 (3)) there must be a clear space of at least 2 feet on either side, between the tubs and the wall sides, or at least 3 feet in the middle of the road between the tubs standing on the tracks. If, therefore, the tubs measure 2 feet 6 inches across the top, we have the following width of road (Fig. 11):

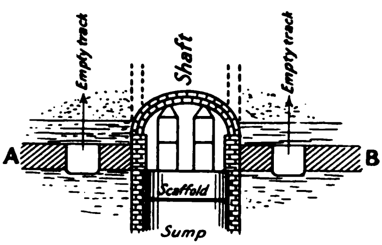


FIG. 12.—Plan.

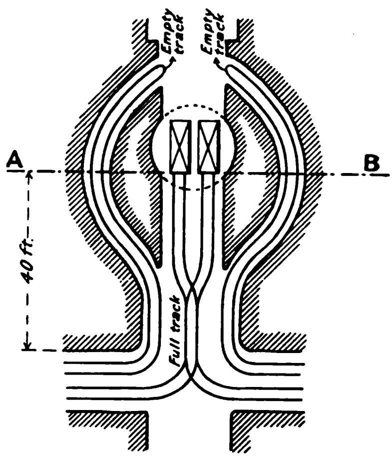


Fig 13.—Section along line AB.

FIGS. 12 and 13.—Shaft Sidings showing Narrow Roads formed round the Shaft for Empty Tub Ways.

	Ft.	In.
Side space, say	2	2
Width of tub	2	6
Space between the tubs	0	3
Width of tub	2	6
Central space, say	1	6
Width of tub	2	6
Space between tubs	0	3
Width of tub	2	6
Side space, say	2	2
	16	4

In Fig. 12 it is evident that less width would be required.

Hauling Engine-House and Stables.—When the shaft sidings have been completed, or it may be whilst work thereon is still in progress, the space for the engine-house—if the hauling engine is to be placed underground—and for the stables will be made.

The position of the hauling engine-house if placed below ground depends on the arrangement of the haulage.

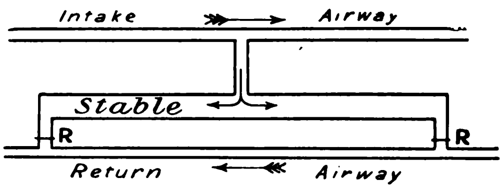


FIG. 14.—Plan showing Position of Stables in respect of Intake and Return Airways.

Its position in a characteristic example is indicated by Figs. 10 and 11. It will be necessary to so arrange its position that a scale of fresh air can be carried through the engine-house, and this can be most satisfactorily effected by having a connection with the return airway

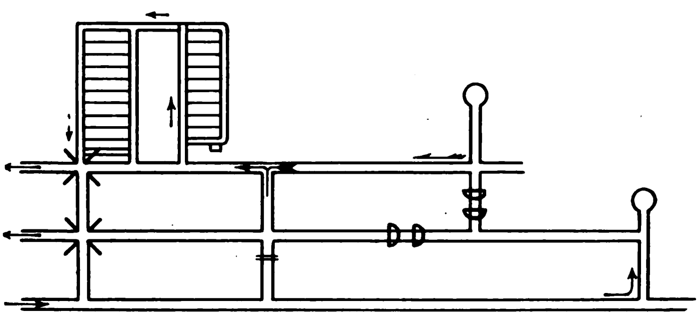


FIG. 15.—Plan showing Position of Stables in respect of the Shafts.

at the back of the "house," with a regulator inserted therein. As to its size, this will depend on the size of the engine, and this again is governed by whether it is a steam (or compressed air) engine, or whether it is an electric motor, and on the horse-power required. It will have to be borne in mind that the engine-house must be provided with at least two proper means of egress (Coal Mines Act, 1911, sec. 59).

As to the stables, it is the practice of some collieries to have the stables "in-bye," but the more usual and better way is to have them near to the shaft. No loss of

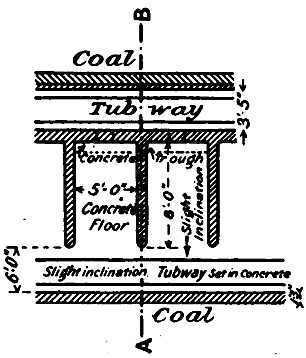


FIG. 16.

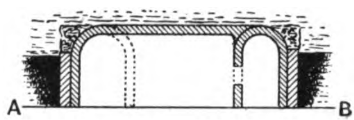


FIG. 17.

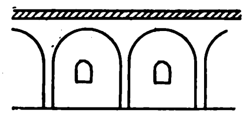


FIG. 18.

FIGS. 16, 17, and 18.—Illustrating the Construction of Underground Stables.
FIG. 16.—Plan of two Stalls.
" 17.—Section along line AB in Fig. 16.
" 18.—Front Elevation.

work is occasioned by placing them "out-bye," and the supervision of the horses is likely to be more thorough and effective than if the stables are "in-bye." No useful object is served by making the horse-keepers travel a long distance to and from the stables.

Figs. 14 and 15 show how the stables may be placed in order to secure satisfactory ventilation and accessibility.

It should be remembered that the Coal Mines Act of 1911 (Rule 3 of Third Schedule) provides that all stables shall be thoroughly ventilated with intake air—it will not therefore be possible to place them in the return airways, as used sometimes to be done.

Figs. 16, 17, 18, 19 are rough sketches of two of the stalls of an extensive underground stable at a colliery at which the writer was employed a number of years ago, a form of stable which he found to be very satisfactory. It will be observed that no woodwork is employed in the construction of these stables, even the troughs being made of concrete. Frequently both flooring, partitions, and troughs are of wood, but this is a most undesirable arrangement, as woodwork tends to decay and conduces to the harbouring of vermin. It is much more sanitary to use

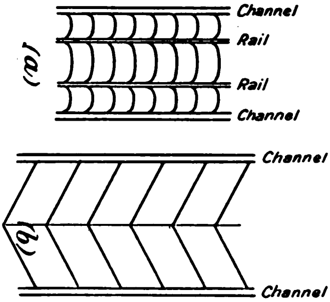


FIG. 19.—Showing Plan of Concrete Floor of Stables; (a) with Rails and Curved Cross Channels; (b) with Straight Channels.

such material as brick, concrete, or iron. It is, however, inadvisable to use the first for penning out the floor, as cracks and crevices are apt, after a time, to be formed in the joints and so render difficult the adequate cleansing of the stables.

The following are the details in respect of cost of

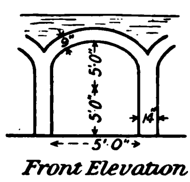


FIG. 20.

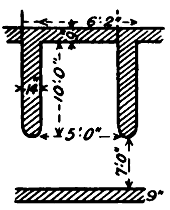


FIG. 21.

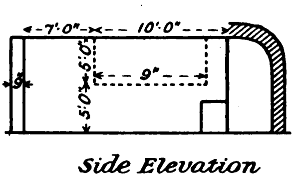


FIG. 22.

FIGS. 20, 21, and 22.—Front Elevation, Plan, and Side Elevation of a Stable Stall.

labour of building with brickwork an underground stable for fifty ponies at a colliery in Northumberland in the year 1900 (see Figs. 20, 21, and 22).

Cost per Stall for Fifty Ordinary Stalls.

	£	s.	d.
Back wall—6 ft. 2 in. × 9 in. × 8 ft. = 5½ sq. yds. super. at 1s.	£0	5	6
Side wall—10 ft. × 1 ft. 2 in. × 5 ft. = 5½ sq. yds. super. at 1s. 4d.	0	7	4
Arch—diam. 5 ft. $\frac{5 \times 3}{2}$ } 7 ft. 6 in. × 9 in. × 9 ft. $5^2 \times \cdot 7854 \times 10 = 196 \div 2 = 98$ sq. ft. = 11 sq. yds. at 1s.	0	11	0
Front wall—6 ft. 2 in. × 9 in. × 8 ft. = 5½ sq. yds. super. at 1s.	0	5	6
	£1	9	4

Penning—6 ft. × 10 ft. = 60 sq. ft., say 6 sq. yds. at 4d. per sq. yd. = 2s. per stall.

	£	s.	d.
Say building cribs and penning, per stall	£0	7	6
Stalls	1	9	4
	£1	16	10

And allowing 5s. 6d. for the work of building the walling of road in front of the head of the stall, the estimated price was £2. 1s. 4d. per stall, the contract price being £2. 5s. 6d. per stall. At this time masons' wages were 4s. 7d. per shift and labourers 3s. 7d.

The complete cost for labour of the stables when finished was:

	£	s.	d.
50 small (ordinary) stalls at £2. 5s. 6d. per stall	£113	15	0
13½ large stalls at £2. 8s. 6d. per stall	32	14	9
9 large extra walls at 10s.	4	10	0
Washpond and opening, &c.	1	17	0
22 yards paving and grating	0	11	0
Extra walls to loose box, 18 ft. do. at 1s.	0	18	0
4 feet arch at low end	0	4	0
1 drinking trough, single	1	0	0
2 double troughs, £1. 15s. each	3	10	0
	£158	19	9

CHAPTER II

THE MAIN ROADS—GOVERNING FACTORS IN THE DETERMINATION OF THEIR NUMBER AND POSITION —SUPPORT OF MAIN ROADS

As the main roads, or arteries of the mine,[1] will have to act as the travelling, ventilation, or haulage roads during the greater part of its life, much thought should be devoted to the determination of their number and their relative positions. A number of things will have to be considered before a conclusion is arrived at—*e.g.*, the system under which the seam is to be worked, the inclination of the seam, the position and magnitude of the faults traversing the mining tract, the situation of the different royalties, if the tract to be exploited comprises more than one, so as to allow of as few "instrokes" as possible. These points having secured due consideration, it may be laid down that the main roads, other things being equal, should :

(*a*) Be central in respect of the mining tract.

(*b*) Drain water from as large a proportion of the tract as possible.

(*c*) Have the gradient in favour of the full load coming out to the shaft.

(*d*) Pass through as few different properties as possible.

(*e*) Encounter as few faults as possible.

(*f*) Be driven as cheaply as possible.

[1] "Mine" means coal mine throughout the succeeding pages of this book.

The Main Roads in very Highly Inclined Seams.—Very highly-inclined seams are sometimes termed "rearers" (North Staffordshire). If the inclination of the seam is 45° or over, and so simulating the vein or lode in a metalliferous mine, the shafts are sometimes, but rarely, sunk in the seam. Where they are not sunk in the seam (see p. 10, Vol. II.) the bottoms of the shafts will be some distance from the coal seam, so that it will be necessary to make the connection by means of "cross-measure" or "stone" drifts ("cruts" in North Staffordshire); that is to say, a drift will be driven from the downcast shaft and another from the upcast, the one somewhat below the other, in order to allow of the main roads in the seam, when reached, being separated by pillars of adequate size. These cross-measure drifts may be extended to connect up other seams with the shafts (see Figs. 106 and 107). The main roads driven in the coal will be turned away right and left, as shown in Fig. 108, and the district laid out to the full rise. The method of laying out and working out the districts by this—the so-called "rearer" system—is described in some detail later on (see p. 122).

At Gelsenkirchen, in Westphalia, where the seams are very steep and much contorted, no less than fifteen seams are passed through by the shafts. Fig. 23 represents the arrangement of cross-measure drifts and subsidiary drifts connecting the seams to the shaft, and a section of one of the subsidiary drifts is shown in Fig. 24.

The Main Roads in Seams of Lesser Inclination.—If the shafts have been sunk at the deep end of the property to be worked, and the inclination of the seam is such as would allow of a satisfactory system of self-acting haulage, probably the best method will be to drive the main roads to the full rise, laying out the

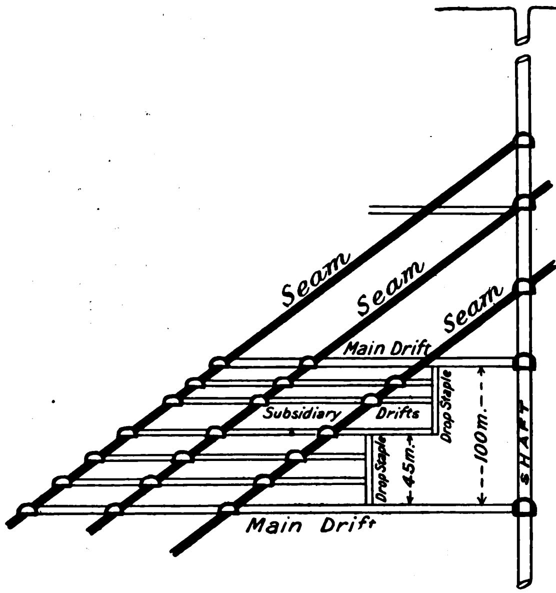


FIG. 23.—Section at Gelsenkirchen Colliery, Westphalia, showing an arrangement of Cross-measure Drifts and Subsidiary Drifts connecting the Workings in the Highly Inclined Seams with the Shafts.

districts right and left on the level. This is a satisfactory arrangement from the point of view of haulage and

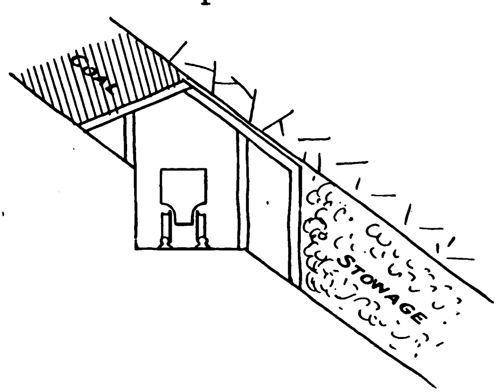


FIG. 24.—Section of a Subsidiary Drift at Gelsenkirchen Colliery.

drainage; but it is not so satisfactory in respect of ventilation, for if the seam gives off much firedamp the tendency will be for the gas to hang about the faces, that is, the part of the mine where most of the daily work is proceeding.

The ideal method would be to drive the main roads to the dip until they reach the boundary of the mineral tract and work the coal back on a retreating system of "long-wall," the only drawback to this scheme being the length of time the mine would have to remain unremunerative. If, however, the coal is one subject to spontaneous combustion, this course, if adopted, would probably ultimately result in a considerable saving in expenditure, as troubles of this nature would be left behind.

The Main Roads in Flat Seams.—In a large modern colliery, the winding power of which is considerable, one great object is to keep the shaft constantly fed with coal during the daily coal-winding period, and in order to make more certain of this result, there is frequently more than one haulage road delivering coal at the shaft, so that if through accident, or a shortage of hewn coal, there is a cessation of supply from one part of the mine, delivery may be continued from one or more of the other parts.

Fig. 25 shows characteristic arrangements of roadways at and near to the shafts of a mine worked on either the "bord-and-pillar" system of working, or it may be on the long-wall system if the main roads are maintained in coal, as they sometimes are, instead of being, as is commonly the case, maintained through the goaf or waste. Thus in Fig. 26 is reproduced a portion of a plan of a seam worked by long-wall with the main roads protected by pillars of coal, and the branch roads maintained through the goaf or waste.

As to the number of such roadways, two is the minimum, an intake and a return airway, the intake

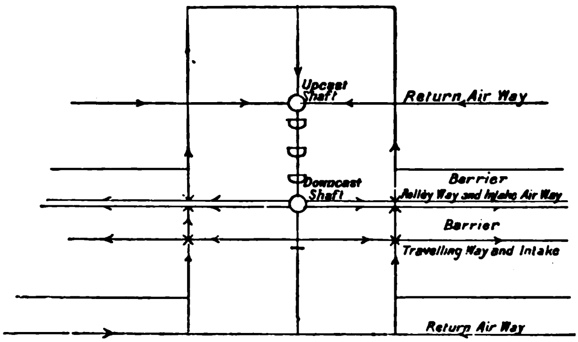


FIG. 25.—Plan of Shaft Pillars and Main Roads in Neighbourhood of the Shafts. (From Bulman and Redmayne's *Colliery Working and Management.*)

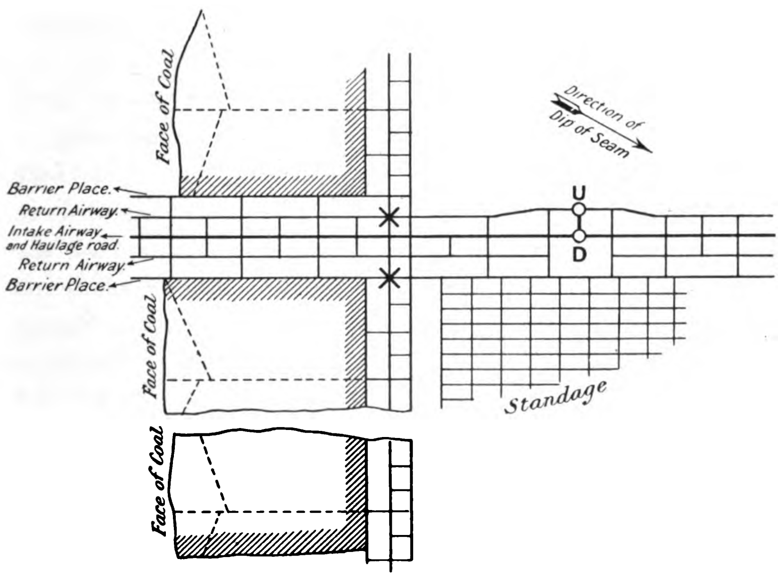


FIG. 26.—Portion of a Plan of a Seam worked by Long-wall, the Main Roads protected by Pillars of Coal.

being usually and preferably the haulage road; but the better practice is to have three roads, the intake being skirted on either side by return airways (see p. 189 of

Vol. IV. on Ventilation), and the best possible practice is to make four roads, two intakes and two returns, one of the intakes to act as a haulage road, the other as a travelling road for persons and animals. It is, however, in some cases, where the strata are subject to much movement, or where the roof is difficult to maintain, impossible on account of the cost to maintain so many roadways.

In the case of a seam liable to spontaneous combustion, if the pressure on the coal is considerable and the coal consequently liable to fracture, probably the roads would have to be made in the waste; but this would not be practicable in the case of a seam too thick to allow of its being worked by long-wall, when it might be necessary to maintain as few roads as possible. This question, however, is one on which mining engineers are not agreed. The better plan in such a case would be to drive all or some of the main roads in a thin seam or stratum of soft rock either above or below the seam which it is intended to work, and to connect them at intervals with the workings. From the point of view also of ventilation, if the main intakes are in one seam and the return airways at another level, loss by leakage of air between the shafts and the working face is reduced to a negligible quantity and a vastly better face ventilation is secured.

The Coal Mines Act of 1911 requires that in all mines opened after the commencement of the Act there shall be two main intakes of such size and maintained in such condition as to afford a ready means of ingress to and egress from the workings, only one of which roads is to be used for the haulage of coal. Certain circumstances and conditions, defined by General Regulations under the Act, allow of the exemption of some mines from this requirement. These conditions are given by the following extract from the General Regulations:

"*Exemptions from the Provision requiring Two Main Intake Airways.* [*Section* 42 (1) *of the Coal Mines Act*, 1911.]

(89) The provision in Section 42, sub-section (1), of the Act requiring two main intake airways shall not apply:

(*a*) To any seam the coal of which is so liable to spontaneous combustion that the provision of a second main intake airway in such seam would increase the risk of fire.

(*b*) To any seam where, owing to the character of the strata or the nature of the pressure, the cost of making or maintaining two main intake airways in that seam might be so great as to prevent the seam being worked at a profit.

(*c*) To any part of a seam where the mineral field leased or owned is not of sufficient width to allow the distances required by the regulations of the mine to be maintained between the roads in such part.

(*d*) To mines of stratified ironstone in the Cleveland District, to mincs of oil shale, or to mines in any other district as respects which the Secretary of State is satisfied that similar conditions prevail.

(*e*) To any mine in which the number of persons employed below ground does not at any one time exceed one hundred.

(*f*) To any seam which is naturally wet throughout.

If any question arises as to whether any of the foregoing exemptions applies to a mine or seam, that question shall be determined in the manner provided by the Act for settling disputes.

(90) The distance from the downcast shaft within which the two main intake airways shall not be required to be provided shall be the distance between the shaft and the edge of the shaft pillars. In the case of an inclined shaft or level entrance not driven in the coal seam the distance shall be the distance between the point where the shaft or entrance strikes the seam and the edge of the pillar left to support the shaft or entrance. In the case of an inclined shaft or level entrance driven in the coal seam, the distance shall be two hundred yards from the mouth of the shaft or entrance."

And the requirements in respect to the construction of stoppings between main intake and main return airways are as given by the following extract from the same regulations:

"*Construction of Stoppings.* [*Section* 42 (3).]

General Regulation.—(91) (*a*) All stoppings between main intake and main return airways shall either:

(i.) Be constructed of tight stone, dirt, sand, or rubbish packing at least 5 yards thick; or

(ii.) Be constructed of tight stone, dirt, sand, or rubbish packing at least 3 yards thick, and have the end of the packing nearest the intake airway faced with a wall of masonry, brick-work, or concrete not less than 9 inches thick, the face of which shall be covered with a coating of mortar so as to prevent leakage of air.

(*b*) The space between the face of the stopping and the roadway shall be kept clear.

(*c*) This regulation shall apply only to mines in which coal is worked, and shall not apply to any mine in South Staffordshire which is liable to spontaneous combustion in the unworked coal."

The Making of Main Roads.—The general plan on which the mine is to be laid out having been projected, the main roads will be turned away, and if they are being driven in the coal, as is usually the case, and the coal is left to support them, they will be driven probably 9 feet to 12 feet wide, and made of such a height as to allow of the easy passage of workmen, tubs and ponies. The cross connections between a pair of roads (variously known as thirls, thirlings, stentons, holings) will be made at stated intervals for the purpose of ventilation and haulage, but the further apart they are—that is, the greater the length of the pillars—the better in respect of the ultimate ventilation of the mine, as the more holings there are the greater the number of stoppings and therefore the greater the liability to leakage. The distance between the respective roads, that is the width of the pillars separating the roads, will be largely determined by the strength and thickness of the seam and its depth from the surface, and may be anything between 20 yards and 80 yards.

If the method of working is by long-wall, and the roads are through the waste, it may be difficult to have parallel intakes and return airways near together, owing to the slow settling of the strata and the open nature of the waste (goaf, gob). An instance of this kind is illustrated in Fig. 100, Vol. IV., in which the intake passes through the middle of the district and there is a return along each side of the district.

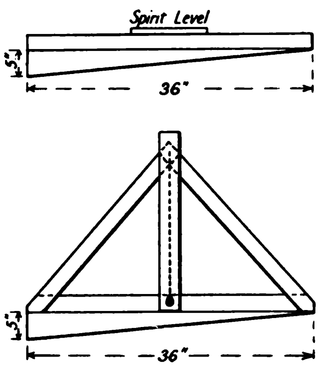
Gradient.—It is not practicable to make the road in one operation, that is to say, when driving the winning places, as unforeseen undulations and faults often occur in the seam, and it is very necessary that the question of gradient should be carefully studied. It is, therefore, usual to make the road suitable, in the first instance, for horse haulage only, and when well advanced to straighten off any irregularities of side, and to make the road of regular gradient by cutting into the roof or floor (brushing, ripping). A preliminary "brushing" will probably have been carried in if the seam is a thin one when driving the place; but, especially if the method of working is the long-wall and the roads are made through the waste, a second, and in some cases a third, "brushing" is necessary in order to maintain the proper height, owing to the squeeze or subsidence following the advance of the workings. No rule can be laid down, but it will usually be found to be a safe practice to take up bottom instead of taking down top stone when driving the place; for if, when making (straightening and grading) the permanent road, it is found necessary ultimately to raise the level, this can easily be done without ill effect, but if it is necessary to lower the level, and the brushing has been carried out in the top, the effect is to make the place unduly high and difficult to support.

Other things being equal, the less the variation in the gradient of the haulage roads the better. If the road is to be worked by horse or mechanical power, the best possible gradient will be such that the amount of work performed in pulling the full load out is equal to that expended in drawing the empty load in. If the co-efficient of friction of coal tubs (trains, hutches, boxes, waggons, corves) on the rails be taken at one-tenth, this will be a gradient (fall) of about 1 in 120 to the shaft.

Or where G = the gradient (*e.g.* when the gradient is 1 in 10, G = 10).
F = the coefficient of friction.
L = full load.
E = weight of empty tubs.

$$G = \frac{L - E}{L + E} \times F.$$

Accuracy of gradient is maintained by constant checking by means of the spirit-level or the T-bob. If, for the sake of example, the seam has, say, an average inclination of 1 in 7·2, *i.e.* 5 inches to the yard, and it has been determined to drive the roads to the full rise and work the haulage by self-acting inclines, the spirit-level (Fig. 27) or T-bob (Fig. 28), being 1 yard in length, will have fixed to the bottom a piece of wood 5 inches thick at one end, tapering out gradually to nothing, and the instrument will be constantly applied to the rail to check the gradient.

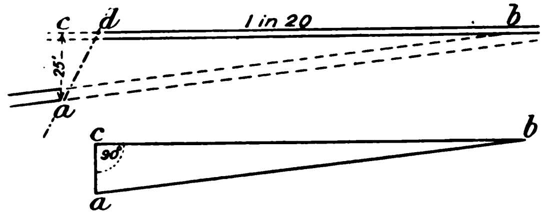


FIGS. 27 and 28.—Spirit Level and T-bob.

If a fault is encountered of some magnitude, it may be necessary to connect the faulted seam by means of a steeply-inclined drift or by a staple pit; it is advisable, however, to drive some distance in the recovered seam before properly and finally grading the connecting road. It may even be necessary to drive a long stone drift for this purpose. Two examples may be given :

(1) When driving to the dip on a seam (*a*) (Fig. 29) a rise fault (*ad*) is encountered, the amount of "throw"

of the fault being, say, 25 feet. A temporary connection is made between the dislocated portions of the seam by means of an inclined road cut along the "leader" of the fault, and driving in the upper or recovered portion of



FIGS. 29 and 30.—Illustrating Drifting to recover Lost Seam in the case of a Dipping Seam and Up-throw Fault.

the seam. Having driven some distance in the recovered seam without discovering any further irregularities, a permanent connecting road may be made by driving a level stone drift (ab).

The amount of the dip of the seam and the throw of the fault being known, it is a simple matter to calculate the length of this drift.

Thus (Fig. 30):

$$ac = 25 \text{ feet}$$
$$bc = 25 \times 20 = 500$$
$$ab^2 = ac^2 + bc^2.$$

(2) In like manner if a down-throw fault is encountered when driving on a level seam, and the throw

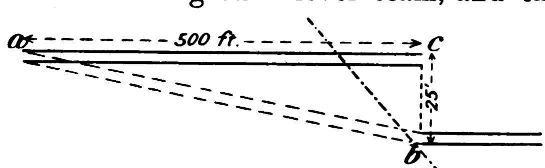


FIG. 31.—Drifting to recover Lost Portion of a Seam in the case of a Level Seam and a Down-throw Fault.

of the fault is 25 feet (Fig. 31), the length and gradient of the drift (ab) can be determined thus:

$$\text{The length } ab = \sqrt{ac^2 + bc^2}$$

and $\frac{500}{25} = 20$. 1 in 20 is the gradient.

(3) It is sometimes desirable to drive a cross-measure drift to connect up parallel seams (Fig. 32). Assuming the drift to be level and the dip of the seams and the

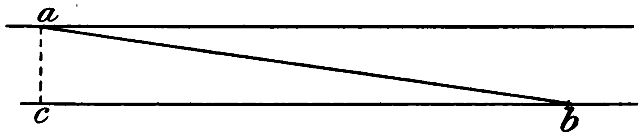


FIG. 32.—Drifting to connect two Parallel Seams.

distance between them to be known, the length of the drift can be calculated on the same principle, viz.:

Thus, if ab be the connecting drift, ac the perpendicular distance between the seams, then $ab = \sqrt{ac^2 + bc^2}$.

Direction.—It is of great importance that the roads should not be allowed to deviate from their predetermined course. A centre line should be kept on the roof and periodically advanced, and by means of plumb lines hung therefrom a chalk mark made at or near to the face every working day to guide the coal hewer.

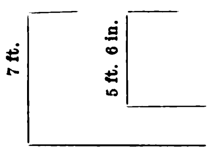
The Use of Mechanical Power in Driving Main Roads.—In those cases where any considerable portion of a main road is driven through hard rock, the advisability of utilising power-drills for making the blasting-holes should be considered. Mechanical power has been successfully applied also for the purpose of driving winnings in the coal. Thus at the Nuneaton New Colliery in Warwickshire the main headings and levels were rapidly and cheaply driven by the Stanley Coal Heading Machine; these roads being driven to the boundary and the coal worked on the retreating system of long-wall.

Mr. F. C. Swallow, the author of an interesting paper on this method of driving main roads,[1] describes the

[1] "Notes on the Opening Out of Coal Royalties by Machinery," by F. C. Swallow. *The Journal of the British Society of Mining Students*, vol. xxiii. p. 57.

application of the Stanley Cutter in cutting the main roads in a seam giving a section of 10 feet 5 inches of workable coal. The shape of the road cut by the machine is circular, two sizes of machine being used, one 5 feet 6 inches, the other 7 feet in diameter. The section of the seam was as follows:

Roof—Stone.



	Ft.	In.	Ft.	In.
Good coal . .	2	1		
Ell coal . .	1	0		
Good coal . .	2	11		
Fire-clay . .			0	1
Good coal . .	4	5		
Fire-clay . .			0	6
	10	5	0	7

Floor—Strong fire-clay.

The main roadways were cut by the 5 feet 6 inch diameter machine, and the back winnings, out of which the long-wall face was opened, by the 7 feet diameter machine.

Mr. Swallow gives the cost of driving roads by this means in 1900 as amounting to 2s. 5·86d. per ton of coal cut by the machine (inclusive of loading the coal into tubs and delivering it 100 yards back from the face), and the average rate of progress at 6·1 yards per day of 24 hours.

The Law respecting the Supporting of Main Roads.—The Coal Mines Act of 1911 requires that the roof and sides of every travelling road and working place shall be made secure.

That in *all parts* of a roadway in which sets or trains consisting of three or more tubs are coupled or uncoupled (rest landings, &c.), the roof and sides shall be *systematically* and adequately supported, and in such parts and in all *other parts* of the roadway, if props and bars are used for supports, they shall be set at regular intervals, and in accordance with a notice in which the manager shall specify the system of supporting (sec. 50, Coal Mines Act, 1911).

The Manner of Supporting Main Roadways.—It has been mentioned that main roads are driven to serve different purposes respectively, viz. haulage, travelling, ventilation, &c., but the conditions obtaining in them are not the same. The main haulage road may be—usually is—the main intake, but sometimes it is a return airway. The travelling road may be the main return, but in the majority of cases the workmen travel to and from their work on a main intake, sometimes a road distinct and separate from the haulage road.

The main haulage road should be a well-graded and roomy airway; the same necessity for attention in respect to the gradient of the return airway if not used for haulage does not arise, so that falls of roof or side are frequently not completely removed but roughly levelled down and the supports where necessary set on the fallen ground. A habit exists, too, of building up such falls as side pack, so gradually diminishing the original size of the return airway; when properly the return airway should (unless duplicated) have a cross sectional area exceeding that of the intake in order to allow of the increase in air-volume due to expansion caused by the higher temperature.

The support of main roads may be considered under the following heads:

(1) When driven in flat or moderately inclined thin seams or seams of medium thickness;

(2) When in similar seams but highly inclined;

(3) When driven in thick seams which are flat or moderately or highly inclined;

(4) {When driven through loose ground; or
When the roads are subject to great pressure.

1. *The support of Roads Driven in Thin Seams or Seams of Medium Thickness when Flat or Moderately Inclined*

The greater number of seams and the greater part of the coal-winning area of the United Kingdom are included under this heading.

After the 1st January 1914, no person (other than an official or a person employed on the road in connection with the haulage or the performance of repairing work which requires to be carried out forthwith) will be allowed to travel on foot on haulage roads when the haulage is worked by gravity or mechanical power except in respect of mines opened before the commencement of the Coal Mines Act of 1911, and in mines in which the character of the strata makes it unreasonable to require the clear space of 2 feet to be provided between the track and the side of the road, where there is a side travelling road at least 3 feet wide, and the rate of haulage is not more than 10 miles per hour, or alternatively, where the rate of haulage is not more than 3 miles per hour and the gradient does not exceed 1 in 12.

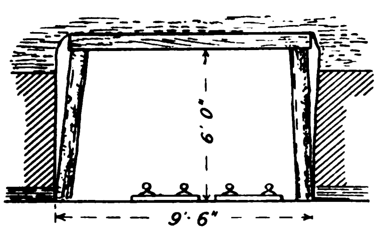


FIG. 33.—Timbering on a Haulage Road.

A few characteristic examples may be given illustrative of different practices to meet different conditions in respect of supporting roadways in mines.

EXAMPLE 1.—Fig. 33 represents a method of timbering a haulage road—the system of haulage being endless rope — where the roof, composed of what is known as "bluestone with post girdles," is fairly strong, and where there is no side pressure and the vertical pressure is not excessive. The height of the seam of coal is 4 feet. This arrangement of timber is variously known as a pair of gears (Northumberland and Durham), prop and bar

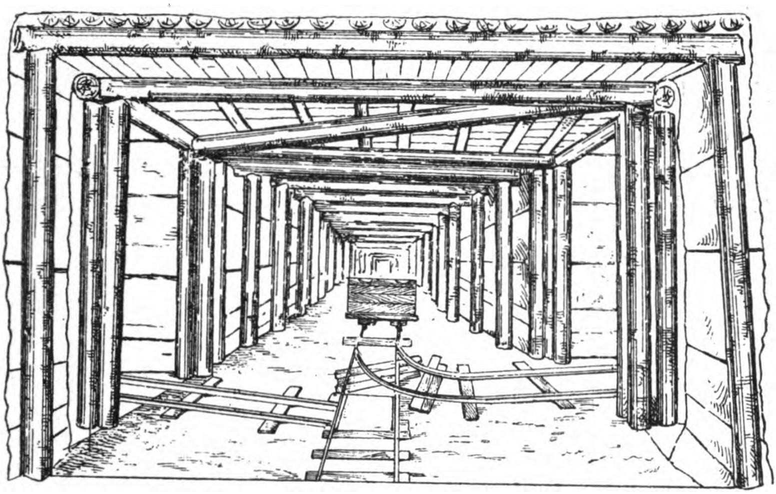


Fig. 34.—A Mode of Roof Support at "Way Ends" by means of a Diagonal Bar.

(Yorkshire), trees and bars (Staffordshire), and post and collar (South Wales).

Steel girders, either let into the sides or supported on wooden props, are frequently used instead of the balks of timber.

Example 2.—A somewhat similar method of support is shown in Fig. 34; but the special feature in this instance is the manner in which the roof at the "way ends" of branch roads is supported by means of a diagonal balk (crown-tree, plank, bar) which is not under or over the other balks but is separately set, thereby occasioning less loss of height and facilitating the setting of covering timber.

EXAMPLE 3.—Attention may be drawn to the use of side packs where the coal sides are liable to waste owing to roof pressure. The seam in question (Fig. 35) is 4 feet 11 inches in thickness, 8 inches of which is a band of fire-clay, and lies at a depth of 700 yards from the surface. The roof is a stratum of sandstone 120 feet in thickness. The bord and pillar system of working, originally practised, had to be discontinued, owing to the pressure, in favour of the long-wall system.

For the support of the roads, where such is necessary—the bed of sandstone being so thick usually requires little

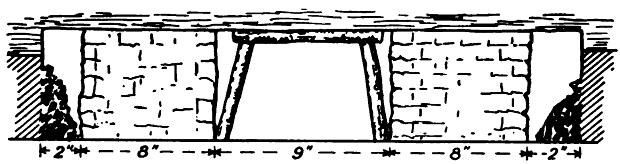


FIG. 35.—Support of a Haulage Road, showing Side Packs and Wastage Spaces.

support—balks and girders resting on props are used. The main haulage road is in parts supported by pillars of coal, and in parts it passes through the waste. It was found that where the road passed through it, the coal, owing to the crush, flaked off, falling on to the road, which, besides leading to haulage accidents and making travelling on the road difficult, conduced to the formation of great quantities of coal dust. To prevent this, the road was inclined to the extent of 10 feet on either side and side packs built, a space of 2 feet being left between the packs and coal side, which gradually filled up with crushed coal and acted as a sort of buffer. It was found that if this space was not left the packs would not stand, the crushed coal knocking the packing out.

EXAMPLE 4.—Steel girders are now much used as supports in main roadways and, to some extent, at the working face also. Sometimes the girders are used as "bars" (crowns, crown-trees, collars), and supported by steel girders, or by wooden props or let into the sides of the road, or the sides are walled by brick or stone masonry and the girders supported by the walling, the latter method being under some conditions of strata a satisfactory substitute for arching.

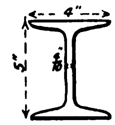
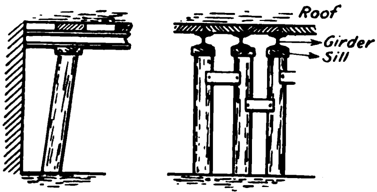


FIG. 36.—Steel Girder used for support of Roof.

Fig. 36 represents a type of steel girder 70 lbs. to the yard, which is held in position usually by wooden or steel



FIGS. 37 and 38.—Showing Steel Girders as used to support the Roof on Roadways.

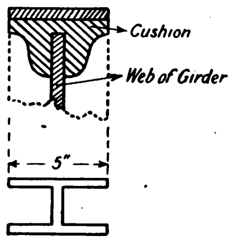


FIG. 39.—Arrangement at end of Steel Prop.

props (legs, trees, posts, arms, &c.). Wooden sills or caps are placed between the props and the bar to act as a cushion (Figs. 37 and 38).

When a steel girder was used to form a prop, a steel pad or cushion was fitted at the web of the girder before the ends of the girder were bent over (see Fig. 39), it being found that this arrangement tended to prevention of breakage of the bent portion.

Sometimes distance pieces or lateral wooden struts or stays are used as is shown in Fig. 40.

These are useful in resisting lateral thrust, and help to keep the steel bars in position.

EXAMPLE 5.—In some districts the roadways, even though of long standing, are subject to considerable and constant pressure owing to the peculiar geological and physical conditions of the field. In Great Britain this is peculiarly the case; in South Wales not only do the sides press in but the floor heaves as a result of the downward pressure, a pressure which is probably slanting in direction somewhere between the vertical and horizontal. The roof, sides, and bottom are therefore bad, and consequently the roadways are difficult and costly to maintain.

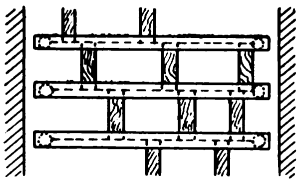


FIG. 40.—Showing application of Distance Pieces to keep Steel Girders in Position.

Fig. 41 represents the manner usually adopted of supporting the roof and sides of a main haulage road in a

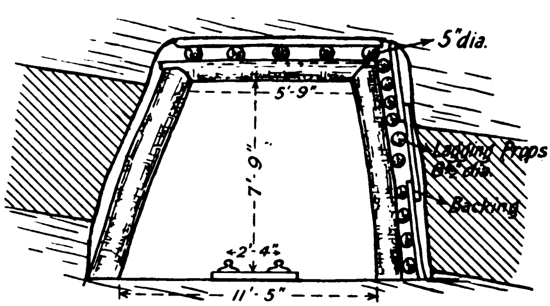


FIG. 41.—Manner of Timbering a Roadway in a Colliery in South Wales.

steam coal colliery of South Wales. In this particular instance the seam lay at about 900 feet from the surface. The coal was about 4 feet 6 inches thick, and was overlaid by 2 feet 3 inches of unstable bands of shale and clay ("clod" and "dirt"), above which was the roof proper of stronger shale ("rock clift" or "blue metal") of from 3 feet to 10 feet in thickness. The immediate floor was of dirt (" rashings ") and coal.

It will be observed that the "arms" (props), which are 10 inches to 12 inches in diameter, are considerably inclined to support the side, the vertical or nearly vertical timbering practised in the northern and several of the other coalfields of the United Kingdom having been found not to answer in South Wales owing to the side pressure. For the same reason the ends of the "collars" are notched and those of the arms shaped to fit the notch. The shaping of the ends of the collars and arms

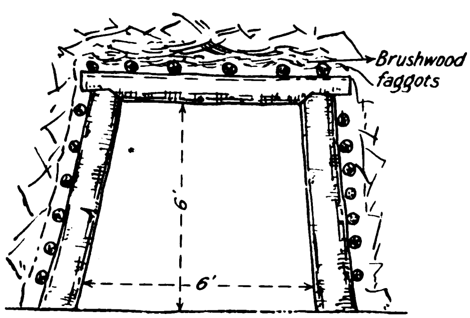


FIG. 42.—Manner of supporting the Roof and Sides of a Cross-Measure Drift in a Belgian Colliery.

has to be so performed as to allow of the latter pressing against the collar without cutting it.

This method of timbering main roads is also widely practised in French and German collieries where the pressure is considerable.

If the roof is of a very "short" or broken character, brushwood made up into faggots is sometimes used in continental collieries, these being placed above the collars as in Fig. 42, which shows the manner of supporting the roof and sides of a cross-measure drift in a Belgian colliery. The depth from the surface is 1000 metres (3280 feet).

2. *The Support of Roads Driven in Thin Seams or Seams of Medium Thickness which are Highly Inclined*

The method of timbering the main roads driven on the strike of the seam, *i.e.* horizontally, does not differ greatly from the methods practised in respect of flat seams, except in so far as the angle at which the timbers are set is concerned.

EXAMPLE 1.—Thus, in a Scotch colliery, where the seam lay at a depth of 1422 feet from the surface, averaged about 7 feet in thickness, and had a dip of 1 in 2 (26°), the roads were timbered as shown in Fig. 43. But the roof, of blaes (shale), though it had a strong appearance, is in reality a soft stone, constituting an indifferent roof. So much so that when the roof settles, which is not until the lapse of many weeks after the road has been driven, and when—to use the local phrase—the road "has got a seat," the roof or floor is re-brushed (re-ripped) and the timber crowns replaced by steel girders supported on wooden props. Frequently the roads are re-brushed twice before the permanent supports are put in.

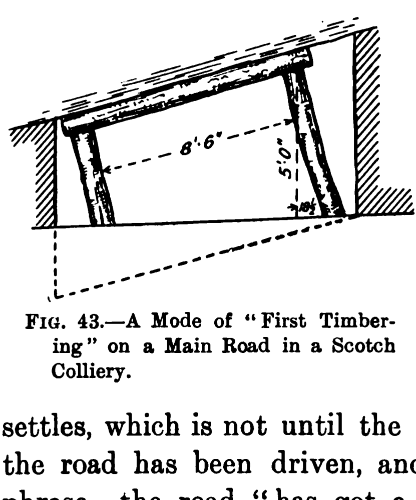


FIG. 43.—A Mode of "First Timbering" on a Main Road in a Scotch Colliery.

EXAMPLE 2.—At another Scotch colliery where the section of the seams varied from 2 feet 4 inches to 7 feet in thickness, with an inclination varying from a minimum of 35° to a maximum of 70°, the seams were worked by levels driven out at stated intervals from an inclined shaft sunk in a seam, and formed the main haulage roads, the other seams being connected by "cross cuts" (cross-measure drifts). The timbering of these roads was carried out in the manner shown below (Fig. 44).

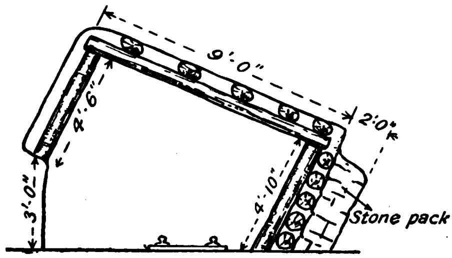


FIG. 44.—Cross-Section of a Level driven in a Highly Inclined Seam in a Scotch Colliery.

EXAMPLE 3.—At another Scotch colliery, the seam worked has a section of 8 feet, the immediate roof being 4 feet 6 inches thick, of shaly rock known as blaes (2 feet 6 inches) and darkbands (2 feet), above which is

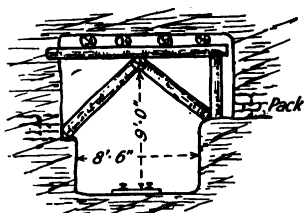


FIG. 45.

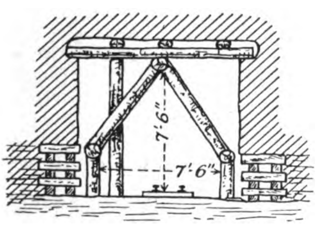


FIG. 46.

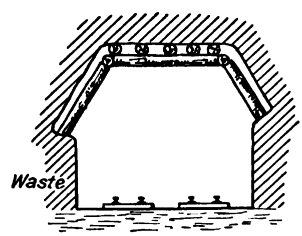


FIG. 47.

FIGS. 45, 46, and 47.—Three Methods of supporting the Roof and Sides of Main Roads in a Scotch Colliery.

sandstone rock, and the inclination is 1 in 4 and 1 in 3 (9° to 18°). The roof is a very bad one, and *three* methods, shown above, of supporting the main roads are resorted to.

The method shown in Fig. 45 is used where the roof is bad and the floor (pavement) fairly firm.

The method shown in Fig. 46 is used where the roof is bad and the floor soft.

The method shown in Fig. 47 is used where the road is wide, owing to the existence of a double haulage track.

The form of timbering shown in these figures is sometimes described as "herring bone," and in Scotland as "double timbering." It is more frequently adopted in the temporary roads than in the main or permanent roadways of the mine, and is usually resorted to when the *side* pressure is considerable. The "chocks" shown in Fig. 46 are placed continuously along both sides of the road. They become much crushed and are never withdrawn. The method shown in the third figure is not regarded as so effective as that illustrated in the other two figures, and it is only used when the roadways (observe the double track) are too wide to admit of the adoption of the other systems.

3. *Methods of Supporting Main Roadways when Driven in Thick Seams which are Flat, Moderately Inclined, or Highly Inclined*

Where the seam is very thick and the top coal will stand, the roads are usually driven in the bottom section of the seam, as there is no object in making the roadways higher than is necessary for the passage of the haulage and the comfort of the workmen and horses. Generally speaking, coal, if a natural parting is not broken through, constitutes an excellent roof. The method of timbering the roadways where the coal stands well, therefore, does not present any peculiar feature. If, however, the coal does not stand but breaks away, or if it flakes off the side owing to the "thrust," support of the roof and sides may become a difficult and costly matter.

EXAMPLE 1.—Fig. 48 illustrates the methods adopted of supporting the main roadways driven in a seam 26 feet 3 inches thick lying at a depth of 642 feet from the surface. Immediately above the seam are layers of black shale and dirt (clod), then comes the roof proper of strong sandstone rock. Though the roads are driven in the bottom layers of coal, in many parts the top coal would not remain up, and in the places where it broke away the roadway was spanned by steel girders carried on props, wood cogging (lofting) being built above the girders and carried up to the roof. Timber placed horizontally behind the props supported the sides.

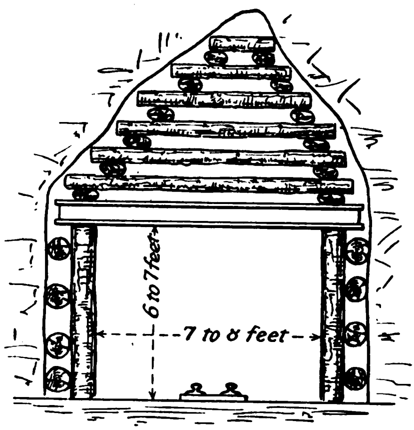


FIG. 48.—A Mode of supporting the Roof and Sides of a Thick Seam in South Staffordshire.

EXAMPLE 2.—In some cases, generally those in which the coal sides are prone to break away and where the floor is soft, *e.g.* composed of a true fireclay, it is found advantageous to either drive the road wide in the first instance or drive it narrow, and, later on widen it out by taking off the side coal, and insert side packs, which, allowing of compression, take up the "thrust," wooden chocks being placed at equal distances along each side of the road (Fig. 49).

In the case of highly-inclined thick seams, the main roads will invariably be driven on the strike of the seam, and the mode of supporting them does not differ materially from that adopted in main roads in thick

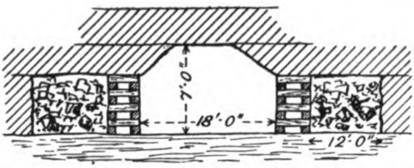


FIG. 49.—Application of Sidepacks and Chocks for the Support of a Main Road driven in a Thick Seam.

seams which are flat. The road will be cut entirely out of the coal; that is to say, the roof, floor, and sides will be of coal.

4. *The Support of Roads when Driven through very Loose Ground or when the Roads are subject to Great Pressure*

Mining ground is termed "loose" or "heavy" when the stratum to be penetrated has little or no cohesion. Thus sand, gravel, and alluvial generally constitute loose ground, but some rocks may warrant the application of the term though not coming within the category of either sand, gravel, or clay. A very broken argillaceous shale, for instance, sometimes forms the roof of coal seams, but more commonly in French and Belgian collieries than in those of the United Kingdom.

When roads are driven through ground of this character very close timbering or arching is necessary for their support; and, if the pressure also is great, the support of the roads is a matter of considerable difficulty and great cost.

Where the ground, though very loose, is not wet, or not very wet, and the pressure is not excessive, the road may be supported either by placing running planks or corrugated iron behind the props and above the crown-trees (or bars or balks), or by setting the props and crown-trees "cheek by cheek." The former method is that commonly adopted when working the hæmatite ore in North Lancashire and Cumberland, with the addition of running planks on the floor also.

The use of brushwood in continental collieries has already been explained as a means of preventing the small stones in a greatly broken stratum falling between the main supports on to the road and acting also as a sort of buffer between the rock and the main supports. The writer has never seen brushwood similarly used in mines in the United Kingdom, but in very few instances can the roofs be regarded as being of the same character.

EXAMPLE 1.—Mr. H. W. Hughes has described a good method of timbering through very heavy ground,[1] the timbering being subjected to severe side and top pressure. Ordinary frame timbering having quite failed to meet the requirements of the case, a method of support was resorted to, in which the outside sets of timber were put in side by side touching each other, and about every 12 feet two steel H girders 6 ins. × $4\frac{1}{2}$ ins. × $\frac{1}{2}$ in. were placed below the bars in the corners of the frame and parallel with the roadway, being supported by props (see Fig. 50) set every 4 feet,

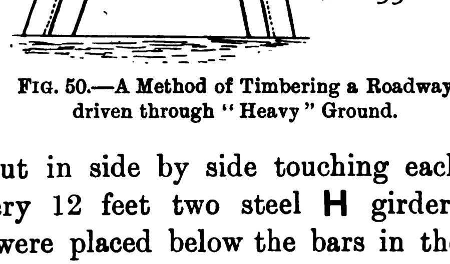


FIG. 50.—A Method of Timbering a Roadway driven through "Heavy" Ground.

[1] *Journal of the British Society of Mining Students*, vol. xxiii. p. 161.

and stretchers were placed between the girders also at intervals of 4 feet.

The timber used throughout was 9 inches diameter.

EXAMPLE 2.—The method adopted of supporting a water-level drift in the county of Durham,[1] nearly 600 yards of which was driven through alluvial, from 200 to 300 yards of which was running sand, is shown in Figs. 51 and 52. Fig. 51 shows the manner of support of that

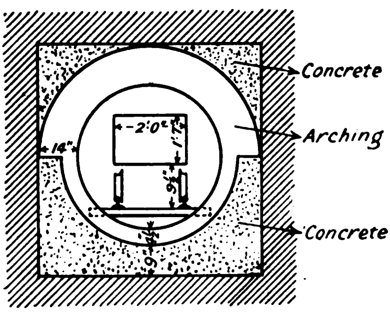


FIG. 51.—Cross-Section of an Under-level Drift driven through Running Sand, showing Method of Arching.

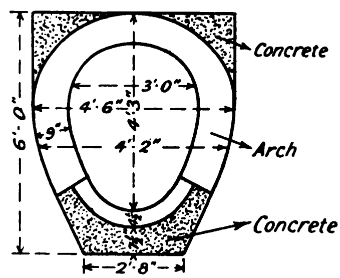


FIG. 52.—Cross-Section of an Under-level Drift, showing Arching under more favourable conditions than those in Fig. 51.

portion of the level which passed through the running sand, and Fig. 52 illustrates the method adopted where the ground was of a more favourable character. In the former case the invert arch was of concrete, and the two top corners were packed with the same material.

The Use of Reinforced Concrete

Reinforced concrete has come very largely into use of late years for supporting roads subject to great pressure. It has also other advantages. Concrete better resists the effects of weathering than masonry, it offers less resistance to the air current inasmuch as it presents a

[1] *Journal of the British Society of Mining Students*, vol. xviii. p. 126.

smoother surface, and, for the same reason, prevents the accumulation of dust. It can also be easily swept or watered. And, finally, a roadway can be more rapidly lined with concrete than with masonry.

To quote some instances. In the mines of the Reading Coal Company in Pennsylvania reinforced concrete has been tried as a substitute for the usual timber supports, and at the North Franklin Colliery a plant is in operation for the manufacture of concrete props for use at the various mines worked by the Company, the object, the writer understands, being to secure a less perishable material than wood. Reinforced concrete has also been tried in some German coal mines.

Three typical instances of continental practice may be given, viz. Béthune Collieries in the Pas-de-Calais Coalfield, Marihaye Collieries in Belgium, and Machienne Colliery, Belgium. The particulars respecting the first and the last arrangements are from notes taken by the writer on the occasion of a visit to the mines in question; the particulars of the application of reinforced concrete at Marihaye Collieries are taken from an account by Mr. A. Renier.

EXAMPLE 1—*Béthune Colliery.*[1]—Lining of the main roads of the mines of the Compagnie des Mines de Béthune with reinforced concrete was resorted to about nine years ago by the management when, owing to the scarcity of masons, it was found impossible to complete the support of the roadways with masonry quickly enough, the original mode of supporting the roadways being by means of side walls and steel girder bars. The side walls were 20 inches thick, whereas the thickness

[1] See also *Note sur le Revêtment en Béton Armé des Bowettes et des Bures aux Mines de Béthune*, contributed by M. J. Lombois, Ingénieur Principal des Travaux du Fond des Mines de Béthune, to the *Société de l'industrie Mineral* in 1907.

of the reinforced concrete was only 6 inches. Another advantage was that whereas the erection of the side walls of masonry required for the execution of the work the employment of masons, the reinforced concrete could be

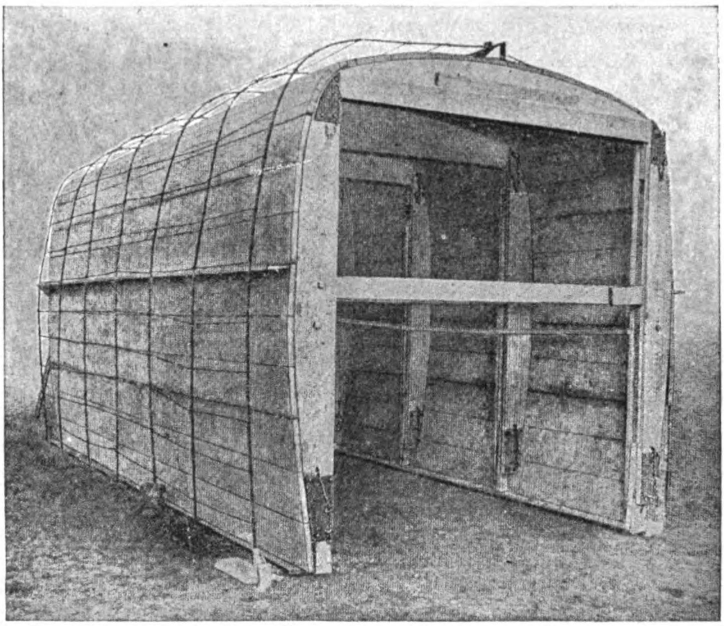


FIG. 53.—General View of the Arrangement of Wooden Framing and Reinforcing Bars used in the Concrete Lining of Underground Roads in Béthune Colliery.

inserted by ordinary labourers working under the supervision of an experienced foreman mason.

Figs. 53, 54, 55, 56, 57, 58, and 59 illustrate the manner in which the concreting was carried out. The lining was executed in 5-metre (16 feet 4 inches) lengths by means of timber moulds. M and N (Fig. 56) are the boards supported by the frames D spaced 1·25 metres (4 feet 1 inch) apart centre to centre, each frame being supported by the uprights DD separated by distance pieces on crossbars E, or alternately by two struts P and a crossbar C surmounted by centering H. F and Q are making-up pieces, pierced with holes in which are mounted pins.

The making-up pieces slide between cheeks of the

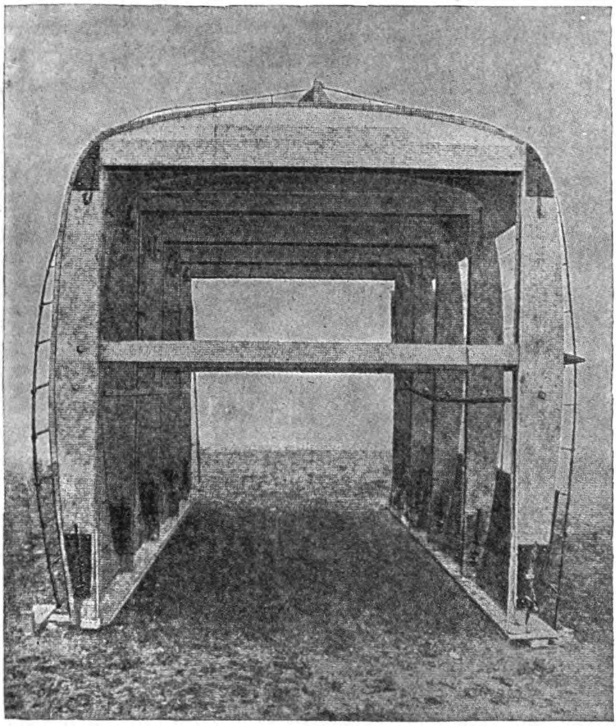


Fig. 54.—End View of Wooden Framing and Reinforcing Bars at Béthune Colliery.

uprights D, and so allow of the adjustment of the centering, whatever be the irregularity of the section.

When a section of reinforced concrete is to be put in, the four frames are erected and spaced by means of templates (straps of steel, L), reinforcing bars 10 mm. (3·93 inches) square being bent to the form of the cross section and placed 75 mm. (29·52 inches) behind the frames. The bars were spaced 80 cm. (31·49 inches) apart centre to centre and connected by bolts passing through eyeholes at the termination of the curves, being laterally connected by horizontal rods 5 mm. (0·196 inches) in diameter spaced 23 cm. (9 inches) apart centre to centre. O are strips of wood, four in number, attached to the up-

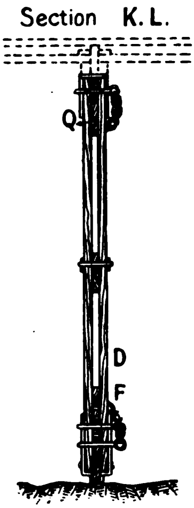


FIG. 55.

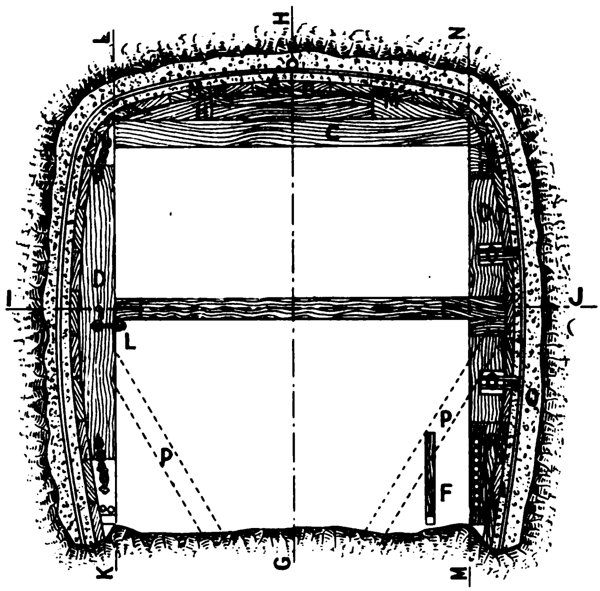


FIG. 56.

FIGS. 55 and 56.—Béthune Colliery. Details as to Material employed for Lining the Main Roads with Reinforced Concrete.

rights, the object of which is to secure the proper position of the reinforcing bars, grooves 10 mm. (3·93 inches) wide being cut, at the required distances apart, in the inner surface of the timber for the reception of the bars.

The frames being placed, the reinforcing bars and the two panels of shuttering at the base being in position, the concreting is commenced, the concrete being thrown behind the panels, the piers and part of the arched roof being built up by moving the shuttering

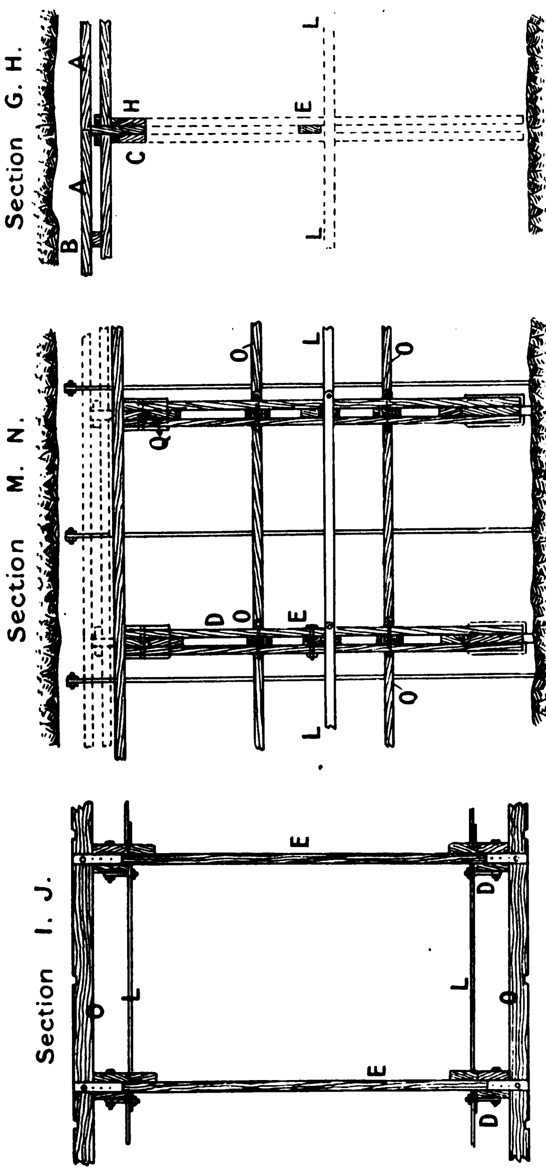


FIG. 59.

FIG. 58.

FIG. 57.

FIGS. 57, 58, and 59.—Béthune Collieries. Details as to Material employed for Lining the Main Roads with Reinforced Concrete.

upward upon the frames, after the concrete below has hardened. It is necessary to ram the concrete in order to render it homogeneous and expel the excess of water.

In order to complete the central portion of the arched roof, the two frames at one end are connected, close to the part where the lining has been so far completed, by a rectangular frame supporting in its centre a curved piece B. Half the space between the two main frames is then filled with concrete and the centering placed half upon the end frame and half upon the rib B. The remaining half of the space is filled in a similar manner, and the roof completed by depositing concrete between the remaining frames of the centering, each space being filled in two operations as before. If, when the concreting is complete, it does not form a sufficiently tight lining, greater closeness can be secured by forcing in grout or liquid cement behind the lining by means of compressed air. The concrete was composed as follows:

For side walls.—Equal parts of mortar (one-third limestone, two-thirds boiler ashes) and red earth (burnt shale from pits) broken up and mixed.

For arch above side walls.—There was added to the above 100 to 150 kilogrammes (220·46 to 330·69 lb.), according to the nature of the ground, of Portland cement per running metre.

The total cost for this work per running metre (3·281 feet) was:

	fr.	c.		s.	d.
Surface labour	3	55	=	2	10¾
Concrete	6	93	=	5	5¾
Metal skeleton	2	54	=	2	0
Cement	4	20	=	3	4
Underground labour	8	42	=	6	8
	25	64	=	20	3½

The framing was made of white wood and iron; the material, it was said, would last for two years, and could be used sixty times; the cost for one section of 5 metres (16 feet 5 inches) was:

	fr.	c.		s.	d.
Wood	114	83	=	90	11
Iron	30	75	=	24	4
Labour	32	25	=	25	6
	177	83	=	140	9

The difference of cost as compared with masonry was 40 per cent. in favour of the reinforced concrete.

EXAMPLE 2—*Marihaye Collieries.*—At some places in these collieries where concreting is adopted the thrust is intense. The Béthune method was first tried, but afterwards a somewhat simpler method was followed. The side walls, instead of being somewhat curved, were made straight; the roof support being slightly arched. The usual sections are 5 feet by 6 feet with a 6 inch rise, and 7 feet by 7 feet with an 8 inch rise.

In cross-measure drifts the concreting follows the advancing face at from 16½ feet to double that distance.

The reinforcement is arranged thus. The lower ends of the vertical wires are fastened to a wire stretched horizontally or to an old rail; and longitudinal wires are so arranged as to make a mesh of 3 feet, 2 feet, or even 1 foot, according to the character of the strata. Two unskilled hands can form 16½ feet of side wall in a day. After 6 days the coffering is taken down and re-erected further on. The space between the wall and rock is filled with dry stones.

In forming the arched roof, stringing planks inside the walls rest on tubular metal props, and carry the timber centering, but only 2 feet 8 inches long, in order to facilitate the horizontal ramming. The arch, which is 7 inches, 9 inches, or 12 inches thick, is reinforced transversely and longitudinally against the side walls, and the space behind is filled with dry stones. A length of 5 feet to 7 feet is accomplished by two men in a day.

The cost for an average thickness (side walls and arch) of 9 inches is 21s. per yard, including concrete and labour, but not the power and labour for making the concrete, nor carriage, nor the materials for the coffering, nor the reinforcement, for which purpose old wire ropes annealed and untwisted are used.

The concrete consists of 5 parts of granulated slag, 1 of quartzose sand, and 2 of slag cement, triturated with water for half an hour in a mortar-mill; and costs slightly over 6s. per cubic yard. The resistance to crushing is 2645 to 2987 lbs. per square inch.

EXAMPLE 3—*Machienne Colliery, No.* 18 *Pit.*—This coal mine is the deepest but one in the world, being about 3900 feet to the sump (*i.e.* the lowest point in the shaft). The roadways are driven on the strike of the seam and are subject to very great pressure, so that they are excessively difficult to maintain by ordinary methods of support. Experience has shown that the pressure does not become evident on a length of roadway until about twenty-four hours after the road has been driven. At the time of the writer's visit, the procedure which the management intended to follow was not to make use of temporary supports, but to follow with the concreting hard behind the advancing face. The outer lining to consist of ordinary concrete, to be succeeded by an outside ring of steel, the lateral reinforcement to be formed of steel tubes and steel lattice work, as shown in Figs. 60 and 61.

The roads which it was intended to concrete in this manner were the main intake and main return airways.

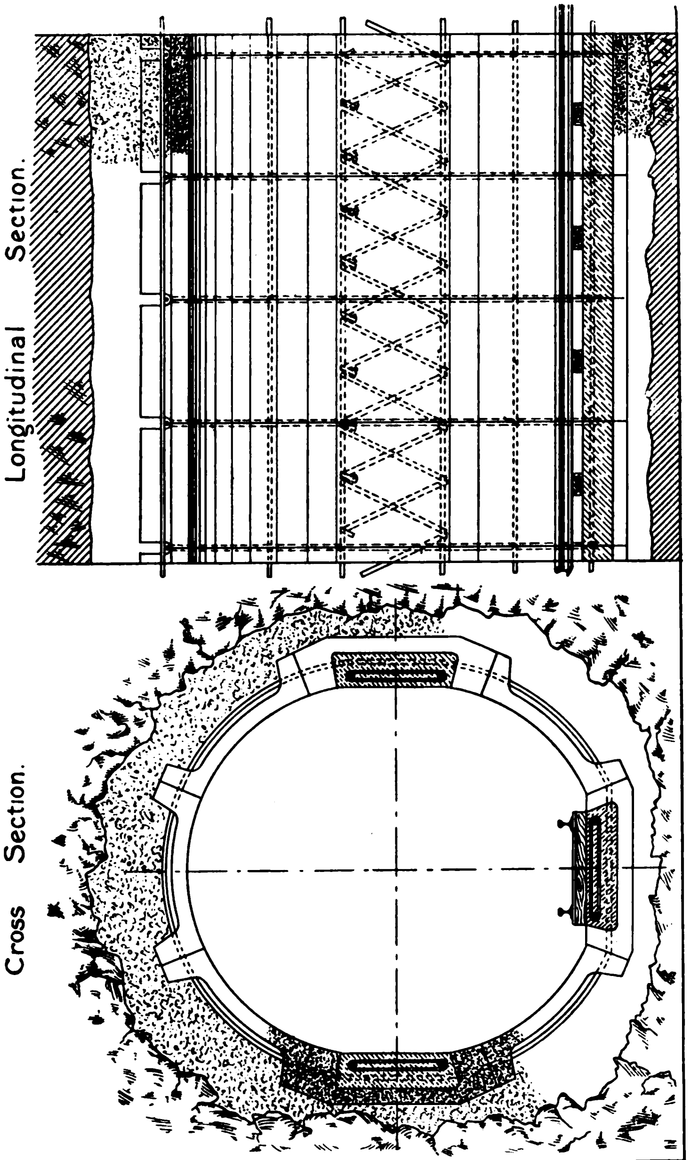


FIG. 61.

FIG. 60.

FIGS. 60 and 61.—A Proposed Method of Reinforced Concrete Lining for Galleries at Machienne Colliery, Belgium.

The length which, if it proved a successful mode of support, would be lined in this manner would be 5120 feet in each road.

EXAMPLE 4.—In the deep pits of the Zwickau and Lugau-Oelsnitz district, where the roof and side pressure is very great, various elaborate methods of supporting the roads have been resorted to. Some of these methods are shown in Figs. 62, 63, 64, and 65. In Figs. 62 and 63 an arrangement of wood and concrete is shown—a recess is cut in roof and floor and cogging

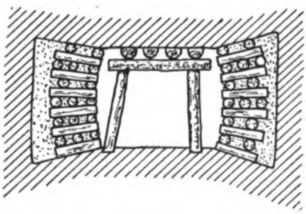


FIG. 62.

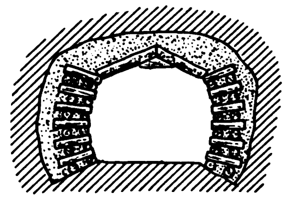


FIG. 63.

FIGS. 62 and 63.—A Combination of Wood and Concrete for the Support of Roadways in the Zwickau and Lugau-Oelsnitz Districts.

arranged as shown, the space between the cogs, and the cogs and the rock sides, being rammed with concrete.

Sometimes the road is so cut that the cross section is completely circular, when the cogging is arranged radially and affords great strength. Sometimes the form adopted is octagonal or dodecagonal.

The concrete employed consists of cement and flints, the admixture of clay, with the object of ensuring better contact with the timber and so preventing dry rot, not having proved a success.

With a view to preventing the cracking and chipping of the unprotected concrete, it was found desirable in some cases to place iron rings about 40 inches apart holding lining boards in position. Figs. 64 and 65 illustrate this arrangement in a roadway of circular cross-section.

EXAMPLE 5.—Fig. 66 illustrates a method of supporting the level cross-measure drifts and main levels which the writer observed on the occasion of a visit to a Belgian mine where the pressure—top and side—was great.

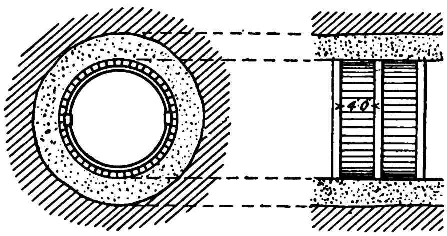


FIG. 64. Cross-Section. FIG. 65. Side View.

FIGS. 64 and 65.—An Arrangement of Concrete Lining, protected by Wood, in a Circular Roadway.

The inclination of the seams worked was 15°, or 1 in 3·73; and occasionally *inclined* roads were driven to connect one seam with another, the mode of supporting the roof and sides of such inclined roads being as shown in Fig. 67.

Synopsis of Continental Practice.—As summing up the practice in vogue in different parts of the Continent, reference may be made to the *Report of the Prussian Commission on Falls of Stone and Coal* (reported 1903). Towards the close of their Report the Commission makes some general observations on timbering in the different countries visited by it. In respect of the galleries or main roads, it found that "wood is mainly used for lining, iron being seldom used except for capping. In Saxony the caps are made of one or two iron rails, according to the roof pressure; and in the north of France H girders are used for the same purpose, sometimes with iron

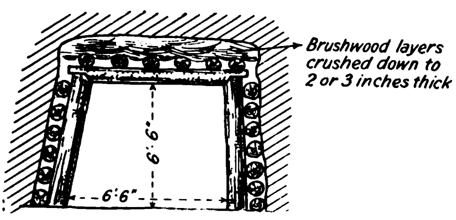


FIG. 66.—A Method of Supporting Levels in a Belgian Colliery in order to resist Great Pressure.

bars inserted between the caps and the roof. Stress is everywhere laid on a careful protection of the roof and walls. In Belgium the door-post timbers are often set in brushwood where the pressure is heavy; under similar conditions in other places, cogs of rock, timber, or concrete are employed for keeping the roads open. In the South of France, where the roads are generally exposed to heavy pressure, it is a common practice to set the upright timbers side by side; and at the crossings the capping timbers are supported by diagonals. In the North of France the mouths of the roads are protected by special means. In certain of the Saxon mines good results have followed placing the timbers a little distance from the walls, and providing a lining in the rear of the uprights, an arrangement facilitating the release of the timbers when the rock shifts."[1]

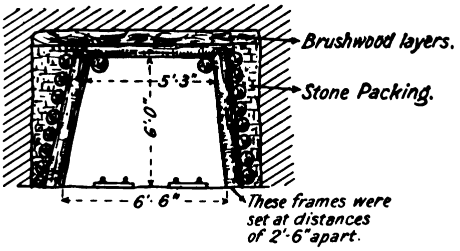


FIG. 67.—A Method of Supporting the Roof and Sides of Inclined Roads in a Belgian Colliery.

Cost of making Main Roadways.—After the roads have been driven in the coal or formed through the goaf, a good deal of work requires to be done on them before they are suitable for mechanical haulage and the effective drainage of water, and in order to prevent undue friction to the passage of the ventilating current. Or it may be that, owing to the presence of geological disturbances, parts of the roads may actually have to be made in the solid rock. The formation of the air-crossings, which may properly be regarded as incident to the work

[1] *Abstract of the Report of the Prussian Commission on Falls of Stone and Coal*, published by the Mining Association of Great Britain, p. 90.

of making the main roadways, frequently necessitates the performance of a good deal of stone work. The following notes may be of some service to the young mining student in helping him to determine the cost of the stone work incident to the underground development of the mine, more especially in respect of the making of the main roads.

The payment for stonework in a coal mine is frequently a matter of bargain, and in the determination of the price many factors enter into consideration which, to be adequately discussed, would require far more space than is afforded by the scope of the present work. But for the purposes of estimating the cost of driving stone drifts, taking up or down thickness (caunches) of stone or coal (brushing or ripping), the writer has drawn up a scale of *basis* prices to meet the requirements of most cases likely to arrive for settlement.

For Stone Drifts ("cross-measure" drifts, "cruts").—Where the mode of calculation is so much per cubic foot, the prices in each case vary chiefly as the width of the drift, for the wider it is the easier it is to blast the stone:

Sandstone ("Post," "Rock").—10s. to 11s. 6d. per cubic yard in a stone drift 6 × 8 feet or 5 × 8 feet or thereabouts. If under 8 feet, the price would be 10s. per cubic yard.

Bluestone ("Clunch," "Clift").—6s. to 7s. Dimensions as above.

"*Caunches*" (or Canches).—Where the mode of calculation adopted is so much per inch in height of stone to be taken down or up, for a standard width of 6 feet the prices would be approximately as follows:

Top coal	1¼d. per inch.
Top stone, blue (soft)	1½d. ,,
Top stone, blue (fairly soft)	1¾d. ,,
Top stone, blue (fairly strong)	2d. ,,
Bottom stone (soft)	1½d. ,,
Bottom stone, blue	2d. to 2½d. per inch.
Top stone (post)	2½d. to 3d. ,,
Bottom stone (post)	2½d. per inch.

All these prices are dependent on the condition that explosives are used in working the stone.

Air-Crossings.—Other expenses incidental to most main roads are the formation of air-crossings, or overcasts as they are sometimes called, *e.g.* for the conveyance of the return ventilating current over the intake or fresh-air current.

The manner of estimating the cost of the excavation necessary for making an air-crossing may be illustrated by the following example:

Dimensions for the calculation of the extent of the excavation in the stonework:

	Ft.	In.
Allowance for thickness of arching	1	0
Height of return airway above the arch	6	0
Height of intake airway beneath the arch	6	6
Total height	13	6
Deduct height of the coal seam . . .	3	6
Thickness of sandstone	10	0

The dimensions of the excavation were as shown in the following sketch (Fig. 68):

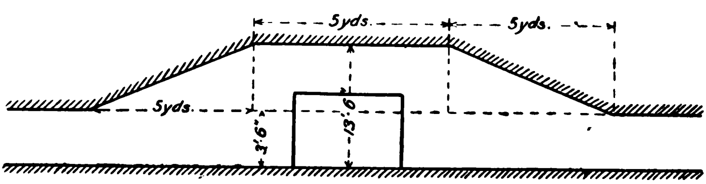


FIG. 68.—Diagram showing manner of determining the Amount of Excavation Work necessary to form an Air-Crossing.

Amount of stone to be taken down:

$$10 \times 8 \times 30 \text{ feet} = 2400 \text{ cubic feet}$$
$$= 88{\cdot}9 \text{ cubic yards,}$$

which at 6s. 9d. per cubic yard = £30.

The manner of arriving at the price per cubic yard was as follows:

	d.
The first 2 feet thickness to be shot down at 3d. per inch per 6 feet in width	72
The second 2 feet thickness to be shot down at 3½d. per inch per 6 feet in width	84
The third 2 feet thickness to be shot down at 4d. per inch per 6 feet in width	96
The fourth 2 feet thickness to be shot down at 4½d. per inch per 6 feet in width	108
The fifth 2 feet thickness to be shot down at 5d. per inch per 6 feet in width	120
	480

The place when finished to be 9 feet wide:

Then as 6 : 9 : : 480 : 720, and 720*d.* = £3.
£3 × 10 yards = £30, ÷ 88·9 = 6s. 9d. per cubic yard.

The form of agreement which the writer used to adopt when contracting to let the driving of a stone drift—and a similar form is suitable in respect of most kinds of stonework—was as shown below:

—— Colliery.
—— Stone Drift —— Pit.

An AGREEMENT between —— on behalf of the —— Coal Company, Limited, the one party, and —— the other party, relative to the driving of the above-named stone drift.

First Part.—The contractors agree to drive the stone drift in a straight and uniform manner. It is to be finished —— feet high by —— feet wide, and to rise at the rate of —— inches per yard. The stones to be filled into tubs and "put" to the siding. The contractors to set all timber necessary for their safety and in accordance with the regulations of the mine, and erect the brattice for the ventilation of the drift; and to keep the drift in a safe and workable condition to the satisfaction of the —— (inserting here the designation of the official—manager or master-shifter).

Second Part.—The owners agree to provide the explosives and blasting materials. Also to provide and sharpen all necessary gear. The timber and brattice to be taken to the end of the drift at the owners' expense.

The rate of payment to the contractors to be at the rate of —— per lineal yard.

Coal or whinstone of 6 inches in thickness to break the bargain.

The contract to be for —— yards, but the manager reserves to himself the right to stop the drift before the distance for which it has been let is completed should he deem it advisable to do so.

Signed on behalf of the Owners,

____________ *Manager.*

Signed on behalf of the Contractors,

____
____________ } *Contractors.*
____

Witnesses to the above signatures,

____
____

Strength of Supports.—The figures given by the ordinary formulæ for calculating the breaking strength of supports should only be used as approximate guides in determining the dimensions of roof and side supports in mines. The conditions of application vary greatly, and the pressure which each support has to resist is generally unknown and often indeterminate. The effective support of roof and sides is almost always a matter of experience, based upon repeated applications of the principle of "trial and error." This applies as well to masonry (retaining walls and arches) as to timber and girder supports.

The Breaking Stress of Wooden Beams.—The strength of every beam varies directly as the square of its depth multiplied by its breadth. On this fact is founded all the formulæ for determining the strength of beams, and it follows therefrom that a beam, say, 8 inches × 4 inches laid on its flat side will only support one half the weight it would support if placed on its edge. For whereas $4^2 \times 8 = 128$, $8^2 \times 4 = 256$, and $\frac{128}{256} = \frac{1}{2}$.

If an oak beam of good quality be supported at both ends and loaded at the middle it will break under a load in cwts. equal to about five times the value of the fraction $\frac{BD^2}{L}$, where B is the breadth of the beam in inches, D its depth in inches, and L its length in feet. The general form of the formula for transverse breaking load is:

$$W = C\frac{BD^2}{L},$$

where C is the weight in cwts. required to fracture a bar 1 inch square and 1 foot long loaded in the middle and supported at each end.

Values of C are as follows:

Cast Steel	40·0	Pine	4·8
Wrought Iron	22·0	Larch	3·5
Ash	6·0	Oak	5·0
Beech	4·5	Yellow Pine	4·0
Fir	3·6	Pitch Pine	5·0
Greenheart	8·0	Teak	5·0

In the case of a beam supported at one end and *fixed* at the other, $C = \frac{5}{4}$ of value given above.

In the case of a beam fixed at both ends, $C = \frac{3}{2}$ of value given above.

If the beam takes the form of a cantilever fixed at one end and loaded at the other, $C = \frac{1}{4}$ of the value given above.

Beams in all cases will support an evenly *distributed* load equal to twice that which can be placed in the middle.

The factor of safety for timber should be taken as not less than 5 for a stationary load, and not less than 7 for a live load. For steel girder supports a factor of safety as low as 3½ or 4 may be taken.

The Strength of Struts and Columns.—There is an important difference between material under compression and the same material under tension. If the distribution of compressive stress is for any reason not uniform, the yielding of the piece tends to increase the inequality instead of reducing it. A want of perfect straightness in a strut or column, or unsymmetrically shaped ends which make the loading not perfectly axial, are factors which introduce bending, so that it is impossible to apply the crushing strength of the material to any but the shortest struts or columns. Hence no formula can be found that does more than approximate very roughly to the results of investigation and practice. The following may, however, be useful:

In the case of rectangular timber props,

$$W = \frac{C}{\left(\frac{L^2}{B^2} \times \cdot 004\right) + 1} \times BD,$$

where

W = Breaking stress in lbs. per square inch.
L = Length of prop in inches.
B = Width of prop in inches.
D = Depth of prop in inches.

The constant for various woods may be taken as follows:

Wood.	Crushing Load in Lbs. per Square Inch.
Ash	6800
Beech	7000
Birch	8000
Oak	7000
Pine (white)	5400
Pine (pitch)	5000
Spruce (black)	5700
Spruce (white)	4500

The safe working load should be taken as not more than one-third of the crushing load.

For "green" timber use *half* the value of the above constants.

If the prop is *cylindrical*, the mode of procedure is to find the square prop, the ends of which are of the same area as those of the cylindrical prop, and then calculate as above.

Crushing Load of Short Masonry Columns.—The following formula is commonly used for determining the crushing load of short columns or pillars of masonry. If:

A = Area of pillar in square inches.
W = Crushing load in tons.
K = Coefficient depending upon material.

Then

$$W = KA,$$

or

$$A = \frac{W}{K}.$$

The value of K for	ordinary brick is	.	0·38
„ „	firebrick is	.	0·75
„ „	sandstone is	.	1 to 3
„ „	granite is	.	3 to 5·7.

Cost of Supporting the Roof with Steel Girders as compared with Timber.—Mr. Ellison,[1]

[1] *British Society of Mining Students*, vol. xvi. pp. 102–111.

describing the use of steel girders as supports, gives some interesting figures respecting cost, of which the following is a synopsis.

In one instance, steel girders of the section shown in Fig. 69 were used, and the manner in which the

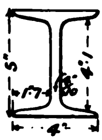


FIG. 69.—Section of Steel Girder.

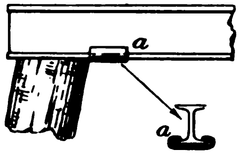


FIG. 70.—Manner of supporting Steel Girder.

girders were "set," or supported by wooden props, is shown in Fig. 70.

a is a "lug" or "chair" shrunk on to the girder, the object of which is to prevent the prop from being pushed out by side pressure, the chair having the same effect as notching the timber.

Taking a fir beam 9 inches by 9 inches by 10 feet, as equivalent to a steel bar 4 inches by 5 inches by 10 feet, and 50 lb. per yard, the comparative cost per set of supports is:

Steel

	s.	d.
One 10-feet bar at £5, 10s. per ton; and two 7-feet legs or props	19	8

Timber

	s.	d.
One 10-feet fir bar at 9d. per cubic foot . .	4	3
Two 7-feet legs at 1s. 6½d. each	3	1
Cost of set . .	7	4

Or, in respect of first cost, the steel is 2·45 times the cost of timber; but, taking a road in which the "weight" has settled, steel supports may be regarded as having a life of ten years, and timber as requiring to be renewed every two years, and, calculating over a decennial period, the cost would be:

For steel	£1 7 8
For timber	3 9 2

and for supporting a road 1000 yards long in the one case with steel and the other with timber, the cost would be:

For steel	£1998
For timber	4800

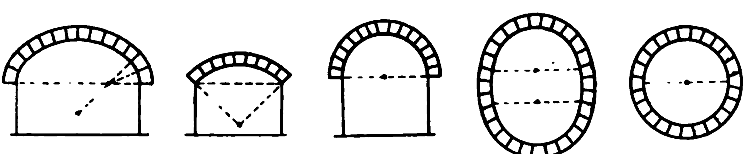
or per annum:

Timber	£480	
Steel	199	
	£281	in favour of steel.

Of course it is not under all conditions of roof and side that steel girders can be profitably used. If the pressure is such in direction and intensity as would soon bend the girders, leading to frequent straightening, and consequent weakening and breakage, the cost would exceed that of timber supports. The conditions favourable to the use of steel supports as compared with timber are an evenly-applied roof weight, little side pressure, and damp roads.

Arching.—Arching built of brick or stone—commonly the former—and mortar is very largely adopted for the support of main roads of which the roof or sides, or both, are difficult to maintain, more especially if the road is to remain in use for many years; and though the first cost is heavy the maintenance is nil. Four or five shapes of arching are commonly used in mines, viz. the elliptical, segmental, circular, and barrel or invert arch (see Figs. 71, 72, 73, 74, and 75), the form of arch used being usually determined by the circumstances of the road in point of height and breadth, and the character of the roof and sides or floor in respect of stability. Thus, if it was inadvisable to cut into the roof, and it was unnecessary to restrict the width of the road in question, probably the elliptical or segmental type of arch would be adopted, especially if the top pressure was not excessive. Otherwise the circular—the form in most common use—would be selected.

If, in addition to the roof, and perhaps the sides, being difficult to maintain with timbering or girders,



Elliptical FIG. 71. *Segmental.* FIG. 72. *Circular.* FIG. 73. *Barrel.* FIG. 74. *Complete Circle* FIG. 75.

FIGS. 71, 72, 73, 74, and 75.—Shapes of Arches used to support Underground Roadways in Mines.

the bottom of the road is subject to "heaving" (creeping), it may be found necessary to arch the road completely (Figs. 74 and 75). The *pointed* form of arching is seldom, if ever, used in mines.

The following are the names of the various parts of an arch. The outer surface is termed the *back* of the arch; the inner, or concave surface, the *soffit;* the joints of all arches should be perpendicular to the surface of the soffits; the stones or bricks constituting the arch are known as the *arch stones*, the first course on each side being called the *springers*, which rest on the *abutments*. In the case of a segmental arch, the courses beneath the springers are called the *skewbacks*. The extreme width between the springers is the *span*, the versed sine of the curve of the soffit being the *rise* of the arch.

All arches should be well sustained by backing on the *haunches*. The line of intersection of arches cutting across each other transversely is called a *groin*, and the arches themselves *groined arches*.

Arching is not often used for the support of highly-inclined roads, for the reason that it is not so well able to withstand the stresses due to the inclination of the road, these being other than those on flat roads.

The common practice in the United Kingdom is to build brick arching either 9 inches or 15 inches thick, 9 inches being the length of a brick, and 15 inches the length of one brick plus the width of another.

A good basis price for the *labour* (masons) of building an arch underground is 9d. per square yard for 9-inch work, and 1s. per square yard for 15-inch work, the masons stowing (packing) the spaces behind the arch level and above the crown of the arch free of extra payment, but receiving extra payment for any stowing work above this at, say, the rate of 1d. to 2d. per inch. The masons pay their own labourers. The centres should not be removed before the stowing above each length of arching is completed. For building pillars above the arching the masons would be paid, usually, at the rate of about 1s. 6d. per cubic yard.

The following is an actual example (see Fig. 76):

Dimensions

	Ft.	In.
Height of side walls	3	6
Width of road within arch	12	0
Height on this arch	8	6
Spring of arch	5	0
Thickness of arching	0	9 = two rings.

The price per running yard in the contract for building this arch (material not included) was 11s.,

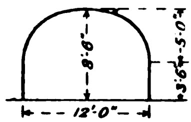


FIG. 76.—Section of an Arched Roadway.

masons paying their own labourers. Two masons and one labourer were employed per shift, and an average of 2 yards per shift was accomplished.

CHAPTER III

METHODS OF WORKING COAL—THE BORD AND PILLAR SYSTEM

The Methods to be adopted in Working the Seams.—In all probability, before any work whatever in the seam is begun, the system in which it is to be developed and worked will have been projected by the management, based on data gleaned from practical experience of the seam in neighbouring collieries. There are, however, but two principal systems, all methods of working coal being modifications of these two systems.

Different Systems of Working Coal briefly Described and Compared.—The bord[1] and pillar system may at the moment be briefly described as that system by which the coal is removed so that the mine is divided up into districts or panels of pillars, each district being separated from the adjoining one by barriers of solid coal, this being termed the first working or "working in the whole," the operation of removing the barriers and pillars being known as the second or "broken" working. The bord and pillar is the system chiefly practised in Durham, parts of Northumberland, Cumberland and Lancashire, and in Scotland. The modification known as "double" or "single" stall is most commonly followed in the anthracite district and some other parts of the South Wales coal-field, and the widest modification, namely that termed "wide" or "square" work, is restricted to the thick coal of South Staffordshire. The long-wall system,

[1] Bord is a Saxon word meaning a road.

which used to be known as the "Shropshire" method, owing to its first having been practised in that coal-field, consists in entirely removing the coal in one working, and either completely or partially packing the vacancy with stone, the haulage, travelling roads, and ventilating roads being maintained through the waste ("goaf" or "gob") unless the "retreating" (in contradistinction to advancing or ordinary long-wall) system be adopted, in which case the roads are driven out to the boundary, and the coal worked "home" towards the shafts—the best method from the point of view of safety, but necessitating a considerable loss of time before a return can be received on the capital expended.

The long-wall system of working is that chiefly in vogue in Lancashire, the Midlands, South Wales, and Northumberland, but during the last half century it has come more and more into use in all the coal-fields of the United Kingdom.

The principal conditions which are favourable to the bord and pillar system of working coal, or some modification of that system, are as below:

(1) Where the seam is a thick one.

(2) Where the roof contains water, or where a seam is being worked beneath old workings which are water-logged, and the maintenance of the roof is necessary either entirely or for a long period of time.

(3) Where there are many important buildings or reservoirs on the surface.

(4) Where the workings are beneath the sea, and there is no intervening bed of plastic clay between the sea bed and the coal seam, and the thickness of intervening strata is not great.

(5) Where there is difficulty in obtaining sufficient material to pack the goaf.

(6) Where there are many faults, prohibiting the maintenance of a proper line of long-wall.

On the other hand, the conditions favourable to the adoption of the long-wall system of working, and some modifications of the same, may be stated thus:

(1) Where the seam is thin and the top or bottom has to be taken down to make height.

(2) Where a bed of fireclay, ironstone, or limestone is worked contemporaneously with the coal seam.

(3) Where interstratified with the seam is a layer or bed of stone.

(4) Where a seam has a suitable roof which does not break easily at or close to the coal face.

(5) Where the mining area is comparatively free from faults.

(6) Where the coal is hard and difficult to hew.

With long-wall, other things being equal, there is less waste of coal, less consumption of timber, and greater safety. Where the coal lies at great depths the long-wall system is preferable, as the pressure of the superincumbent strata is thrown on to the goaf, whereas, if the bord and pillar system were followed, it would crush the pillars of coal and break the roof.

At many mines a system of modified long-wall working has been adopted. It consists of breaking into the coal opposite the gate end with a place about 3 yards in width, and, when sufficient coal has been extracted, in taking slices off the face, in some cases both to the right and to the left, 4 or 5 yards wide, at right angles to the gateway or "bord" or cleat in the coal. The gateways are usually 40 yards apart. The juds or slices sometimes meet in the middle, and when this is the case the intervening coal is much crushed and the roof broken down.

Such briefly are the main characteristics of the different systems of mining. We shall presently, however, have to enter into greater detail of each system, the various modifications of each system, and their applicability under various natural conditions, such as thickness and inclination of seam, depth from the surface, character of the coal, adjacent strata, and so forth.

Early Manner of Working Coal—the Bord and Pillar Method.—In the early days of coal mining the flat or moderately inclined seams were first attacked as presenting least difficulty in the way of drainage and working. Only those seams which outcropped to the surface or lay at shallow depths were attacked at all, the depth to which it was possible to work being chiefly governed by the level at which a free outlet for water could be obtained through adits or drifts.

The invention of the Atmospheric Engine by Thomas Newcomen in 1710, however, changed the aspect of affairs. About this time 180 feet was about the maximum depth of shafts of mines where free drainage was not obtainable, and the area of coal worked was seldom more than 200 yards radius round the shaft.

The earliest method of working coal at shallow depths was to sink a shaft and entirely extract the coal for as extensive an area round the shaft as possible; the mine being abandoned when it was impossible, on account of the danger from subsidence, to proceed further. A fresh shaft was then sunk and a new mine opened out a little distance away.

But as mining operations became more extended, the method of working the coal which most naturally suggested itself, was to get all the coal possible, leaving only as much unworked as was necessary to keep up the roof and prevent the closing of the mine. This manner of working became crystallised into the bord and pillar (bord and wall, pillar and stall, stoop and room, &c.) method of working.

In the earliest stages, when working by the bord and pillar system, it was customary to leave pillars (stoops) as small as possible, and to make the roads—the bords—as wide as possible, in order that as large a percentage of the coal seam as possible might be obtained in winning out the pillars, which usually were then abandoned. The bord, it should be explained, is the road which was usually driven at right angles to the main cleavage (see p. 54, Vol. I.) of the coal, on account of the coal being thereby obtained more easily and in larger masses. The walls are the roads connecting the bords, and, driven usually in the direction of the main "cleat" or cleavage ("on end," as it is usually termed), are made as narrow as convenient for travelling and haulage. In the old days the sizes of the pillars varied, and the bords being turned away narrow out of the walls (say 2 yards to 3 yards wide), were gradually widened out so that the pillars were frequently holed through in the middle. It will be seen that an enormous amount of the coal in a mine worked on this principle was sacrificed, in fact in few instances would more than 65 per cent. of the available area be recovered. At the beginning of the last century, according to Mr. John Buddle, under no mode of working then known could more than 45½ per cent. of the contents of a fiery seam be obtained, the pillars being made 6 yards by 22 yards.[1]

[1] Mr. Buddle on *Mining Records*, 1838.

When the working away of the pillars was first practised is not known, but Mr. Nicholas Wood was of the opinion that there must have been at some mines in the North of England an extensive system of taking away pillars at quite an early date, certainly before 1740.[1]

The evidence as to the date when working off the pillars was first adopted is very contradictory. In all probability it was practised at some collieries which presented peculiarly favourable conditions for the extraction of the pillars some time in the first half of the eighteenth century, but it did not come into general practice until early in the nineteenth century.

This question has been treated at some length in *Colliery Working and Management*,[2] and the writers of that work conclude that "the documentary evidence cited goes to show that, previous to 1708, the general practice was to leave small pillars of coal standing for the support of the roof; thirty years later pillars were being partially, sometimes entirely, removed; and during the remainder of that century, in mines free from gas, a second working of the pillars was frequently carried out. In the deeper and fiery collieries, which began to be developed about the middle of the eighteenth century, the risk of creep as well as of gas explosions prevented the removal of the pillars. The invention of the safety lamp, improvements in ventilation, and the formation of much larger pillars in the first working . . . were introduced during the first thirty or forty years of the present (nineteenth) century . . . which enabled the pillars to be removed in a second working."

[1] *Colliery Working and Management*, by H. F. Bulman and R. A. S. Redmayne, 2nd edition, pp. 10–11.

[2] *Ibid.* p. 14.

There was danger, when the pillars were left too small or were irregularly worked off, of producing a "creep" or "thrust"; that is to say, when the floor was soft (say a fine clay), the pillars were forced downwards and the floor rose up, filling the roads (creep), or if the floor was hard (hard shale or sandstone—the latter rock rarely occurs immediately below a seam) the coal in the pillars became crushed (thrust), in either case the area affected was usually lost.

"Creep" and "thrust" were far more frequent accompaniments of the methods of working coal, as practised in the old days, than at the present day; in fact if the bord and pillar system is properly worked neither creep nor thrust should take place. It came to be realised that for the effective extraction of the pillars, that is, both for completeness of extraction and the production of the coal in the best condition for sale, the size and the shape of the pillars were factors of great importance.

With a view to the prevention of creep—and later as a means of improving the ventilation—Mr. Buddle in 1809 introduced what is known as the panel system, that is to say, he worked the coal in districts, leaving barriers of solid coal round each district, "so that," says Mr. Mathias Dunn, in his work on the *Winning and Working of Collieries*[1] (1852), "even if a creep or other casualty shall take place in one portion of the colliery it cannot extend beyond the allotted limits," a statement true as regards creeps but not, alas, in respect of colliery explosions.

The Long-Wall Method of Working.—The long-wall, long-way, or, as it is sometimes termed, the

[1] *The Winning and Working of Collieries*, by Mathias Dunn, 2nd edition, p. 92.

Shropshire method of working, from its having been early practised in that coalfield, consists in extracting all the available coal in one working; the roads being maintained through the waste (goaf or gob), or sometimes the *main* roads are supported by pillars of coal.

Besides Shropshire and parts of Staffordshire, this method was extensively followed both near Edinburgh and in the West of Scotland many years before it came into extensive use elsewhere. Mr. M. Dunn mentions it in his book on the *Working of Collieries*,[1] as having "prevailed extensively in all parts of Scotland."

The Panel System of Working Bord and Pillar.—Allusion has been made to the "panel" system of laying out and working by the bord and pillar method, and the bord and pillar method of working as now practised is always on the panel system. This system consists in dividing the seam into districts of varying area—say 30 acres or more—each district or panel being separated from the adjoining panel by a barrier of solid coal, generally from 30 to 60 yards wide, which, when the district has reached its boundary, is worked off at the same time that the pillars are being worked, or "brought back in broken" as the technical expression runs.

Fig. 77 illustrates an actual example of the bord and pillar working at a mine in the county of Durham at which the writer was employed; two panels are shown, both of which are in course of being brought back in the broken, and a portion of a third panel is shown which is advancing "in the whole."

[1] *The Winning and Working of Collieries*, by Mathias Dunn, 2nd edition, p. 83.

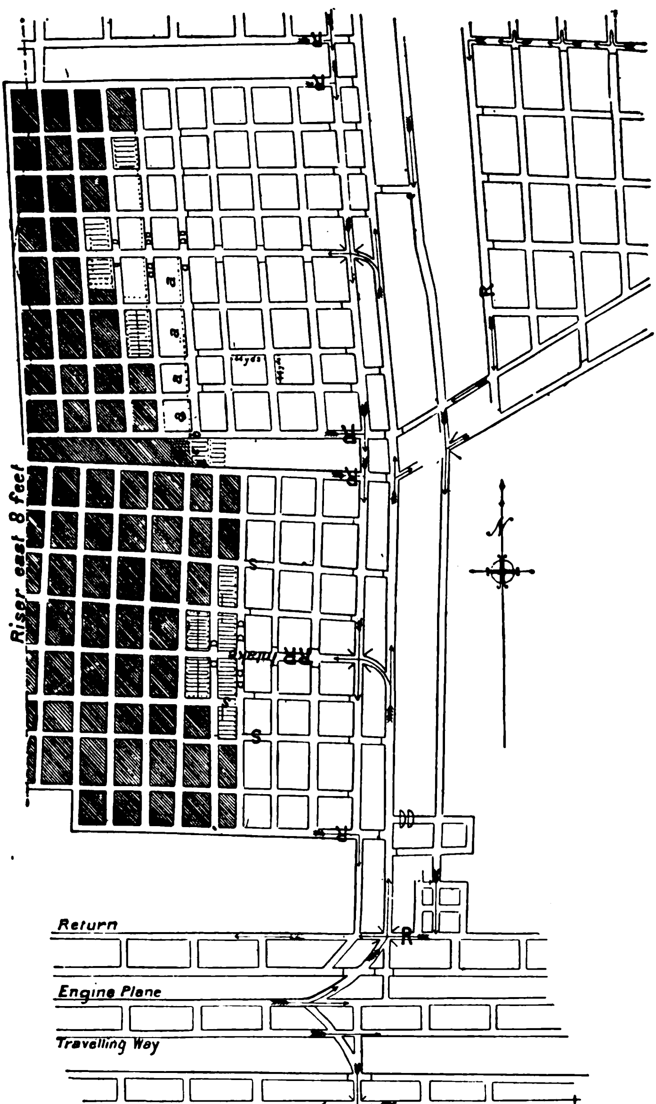


FIG. 77.—Plan of Panel Workings, Bord and Pillar System

Reference.—Shaded part, Goaf; Air-crossings shown thus, × ; Regulators, R ; Doors, D ; Stoppings—Air Scales, S ; Arrows denote Direction of Air-currents.

(From Bulman and Redmayne's *Colliery Working and Management.*)

The section and character of the coal is as follows:

Roof: Inferior sandstone.

	Ft.	In.	
Top coal . . .	1	6	Unworked.
Good coal . .	3	6	Worked. Running through the middle of the coal is a band of "grey" and inferior coal 5 inches thick, and with it a band of black shale 1 inch thick, both of which are picked out and cast back.
"Slippy" Band .	0	1	The "holing" or "kirving" (under-cutting) is made in this band, which is as far as possible picked out of the small coal or kirvings and cast back.
Good coal . .	0	6	Taken up after the middle portion of the seam has been wrought or recovered.
Bottom coal (steam coal) . . .	1	0	
	6	7	

The floor is sandstone.

The top coal is left unworked and constitutes a good roof. The seam, which at the shafts lies at a depth of 882 feet from the surface, has a dip of 1 in 18.

The character of the seam whilst being worked in the "whole" is decidedly strong. The walls were driven 3 yards in width, the bords being made 5 yards wide. The pillars in two of the panels were left 44 yards by 44 yards centre to centre; in the third panel the pillars were somewhat larger. The proportions of coal worked by the first and second workings were therefore, by the first working 17·4 per cent., and by the second working 82·6 per cent. This may be seen by reference to Fig. 78.

The dimensions of a pillar of coal are there shown to be:

$$41 \times 39 = 1599 \text{ square yards.}$$

Taking this area from the full area (44 × 44), viz. 1936 square yards, there remain 337 square yards, which is the area excavated by the first working—that is to say, 17½ per cent. of the workable section of the seam is obtained by the first working.

In this calculation it will be observed that no allowance has been made for the small portion of coal left on the pillar due to the bord being turned away out of the wall and driven narrow (2 or 3 yards wide) for a distance of 2 yards; a common practice, the object of which is to leave as much support as practicable at the cross roads.

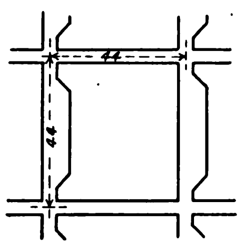


FIG. 78.—Sketch illustrating the Proportion of Coal got in the First and Second Workings by the Bord and Pillar System.

When driving the roads forming the pillars, the ventilating air-current was carried into the face by means of wooden bratticing nailed to a row of props, canvas doors being hung at the outbye end of the bratticing to prevent the current short-circuiting. Frequently a rough kind of canvas soaked in creosote is used for this purpose, but often pipes constructed of thin sheet iron or wooden boxes are substituted for bratticing.

Removal of the Pillars.—When a panel has reached the prescribed distance, the removal of the pillars ("broken workings") is commenced, the pillars at the two extremities of the panel being first attacked and a diagonal line adhered to in the removal of the pillars, in order that no pillar, or portion of a pillar, is left with "goaf" ("gob," "waste") on either side. If this matter of line of retreat in working pillars were not well attended to much coal would be irretrievably lost.

When the roof is strong and will stand without much support, it may pay to keep the bords and walls open in order that these roads may be made of use when the pillars are being removed, but often it is cheaper to let them fall and drive fresh roads in the pillars themselves.

In the case which has just under review, all the bords and walls had fallen, and roads (skirtings, *a*, *a*, *a*, Fig. 77) were driven along the bottom end of a row of pillars so as to constitute what is locally termed a "going headways," and each pillar was worked off in successive order by taking off slices (juds)—roads 6 yards in width driven to the rise and the full breadth of the pillar, the last "jud" being shortened by a "lift" driven so far along the top end of the pillar. Or a road (jenkin) was driven up one side of the pillar, the pillar skirted along the top side, and juds were driven half way down, the other half of the pillar being taken off by judding from the bottom end.

If the roof stone is of a short, shaly character—and consequently apt to fall away however well timbered—and the coal has been removed by "judding" across the breadth of the pillar, with the exception of the width of the last jud, it is not unusual (especially when the pillar happens to be next to the main haulage road of the panel) to take off this last 6 yards—the width of a jud—by a series of "headways lifts" driven from the haulage road, for, if it is attempted to "jud" it off, the jud is very liable to close, and the coal in that event would probably be lost.

When a jud falls, the method adopted of reaching the face is seldom that of "ridding out" (clearing) the fallen jud, as the cost of so doing would far exceed the value of the timber and rails recovered thereby, but a narrow place is turned away and driven in the coal alongside the fallen jud, "loose" at one side, until the termination of the jud is reached, when a "siding over" is driven across the face of the jud and the jud continued.

The timbering of the juds was carried out as shown in Fig. 79, that is to say, the tub way, which was carried along the fast side, was spanned by props and bars (*i.e.* props supporting a split prop, the flat side of the latter being against the roof), and next the "loose" side was a row of chocks built of oak logs 22 × 4 inches. The chocks, which were placed about 5 feet apart, were about 7 feet from the "fast" side, the space between the chocks and the goaf being allowed to fall. The face of the jud was timbered with rows of props and bars, which were drawn out and advanced as the extraction of the coal proceeded. When the jud holed, *i.e.* when it had reached the extremity of the pillar, the chocks were, as far as possible, extracted.

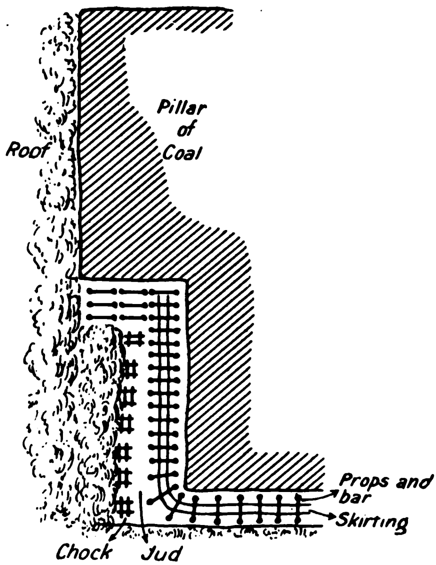


FIG. 79.—A Method of Timbering a Jud (or Lift) when working off a Pillar of Coal.

The barrier is worked off in a manner similar to that adopted in removing the pillars.

Following up the "Whole" with the "Broken."—Following up the "whole" with the "broken" is frequently resorted to (see Fig. 80), that is, the back pillars are worked off at the same time that the panel is advancing in the whole. The advantages of this method are: (1) the existing roads can be utilised, resulting in a saving of coal, for when skirting has to be resorted to, a certain amount of coal is lost by ribs having frequently to be left to support the loose side, and the cost of relaying rails and resetting timber for

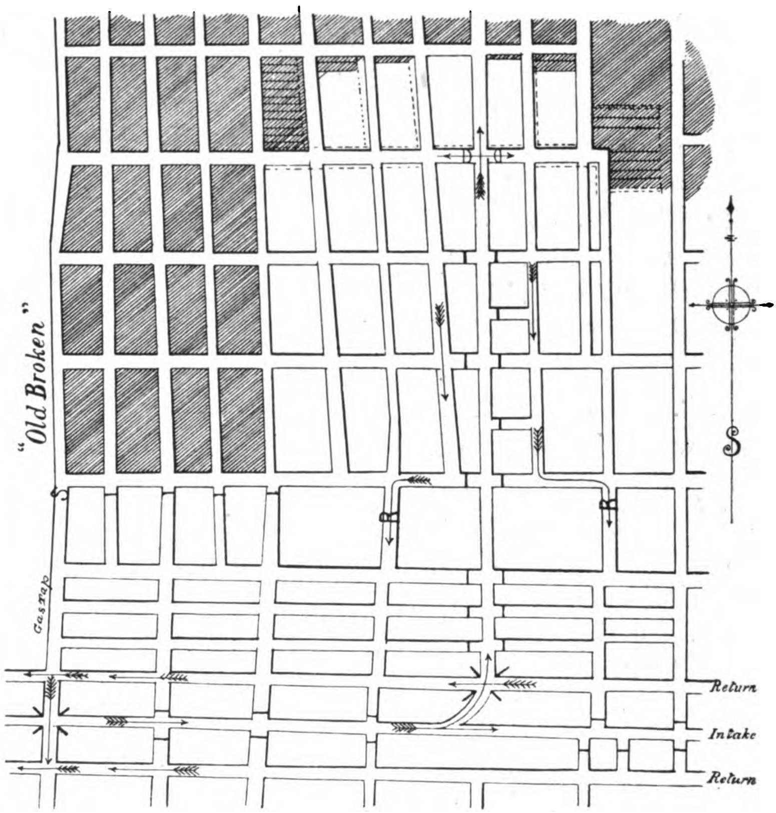


FIG. 80.—Illustrating a District in which a Special Method of removing the Pillars had to be adopted.

these roads is also saved; (2) it allows of the early and rapid extraction of the pillars, a matter of importance in a district subject to "creep" or "thrust," where it is desirable to work out the pillars as soon as possible, otherwise they are liable to become crushed or they may be difficult of extraction later on.

A Method adopted of working off Large Pillars in a Gassy Seam and under a Bad Roof.—Another example in pillar working may be given as showing the manner of removing pillars under peculiarly difficult conditions. It may be mentioned that owing to the nature of the roof and the quantity of firedamp evolved from the waste—the latter fact rendering necessary the complicated system of ventilation which was pursued—no other method of working off the pillars could have been adopted.

In this case the seam, which at the shafts was at a depth of 1038 feet from the surface, was of the following section:

	Ft.	In.
Good coal	3	0
Bottom coal	0	3
Splint coal	0	3

The roof was a bed 4 feet thick of shale, locally termed "blue metal," above which was a thick bed of strong white sandstone. From this it might be supposed that the roof was a strong one, but the reverse was the case. In the part of the mine under consideration, even when working in the whole, it was exceedingly difficult to support—so difficult, indeed, that when the bords and walls holed the timber was drawn out as soon as possible and the roof allowed to fall, and when the walls were well fallen and the pressure relieved, a fresh wall 2 yards wide was driven "fast" to the top, leaving a 6 feet rib of coal next to the drawn-out wall (see Figs. 80 and 81).

The floor consisted of a bed of fireclay about 1 foot 9 inches thick. The seam had an inclination of 1 in 20.

Some of the pillars had been removed by "following up the whole with the broken," but we are now concerned with the working of the pillars (which it had not been possible to remove at that time, as they had to be left to support the intake and return airways as the panel was advancing "in the whole") and with the barrier between the panels.

The pillars were 66 yards by 33 yards centre to centre.

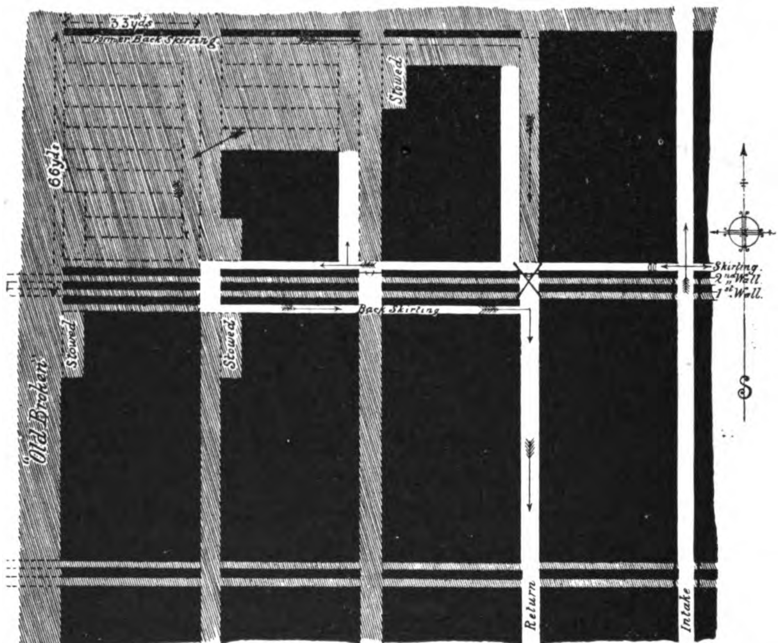


FIG. 81.—Showing in Detail the Method practised of working off Pillars under difficult Conditions in respect of Pressure and existence of Firedamp in the Goaf.

The direction of the bords was north and south, the walls east and west. The bords were 5 yards wide and the first wall 3 yards wide.

A "skirting" was turned away out of the wagon-way, as the haulage road of the panel or district is locally termed, and driven "fast" alongside the old walls of the row of pillars—four in number—to be removed.

The width of the skirting was 2 yards, and a rib of coal about 6 feet wide was left between it and the old walls. "Jenkins," 5 yards in width, were turned away out of the skirting and driven up the side of the old bords, and the pillars were judded off to the west (see Figs. 80 and 81).

In order to secure the proper ventilation of the workings it was necessary to drive a "back" skirting, also 2 yards wide, communications being made between the two skirtings. As the bottom stone had to be taken up to make height when driving the roads, "stowbords" were made out of the skirting.

Occasionally, owing to the broken character of the roof, it was found advisable to "draw out" the first jenkin, allow the roof to fall, and so relieve the roof-pressure, and then to drive a second jenkin.

The juds were about 27 yards long, the last three juds being shortened by means of a "headways lift" driven up the west side of the pillar. All "lifts" and "juds" were driven 5 yards wide, and no "stooks" (*i.e.* small blocks of coal at the commencement of a jud left to support the roof until the jud holes, when they are worked off) were left, owing to the difficulty in working them off when the jud was drawn out.

As regards the ventilation of the "broken" workings, two examples may be given, the one to show the manner in which the air-current was conducted before the completion of the driving of the "back" skirting, and the other to indicate the course of the current after this skirting had been driven.

Supposing, then, that the intake skirting had not holed into the "old broken," but had only reached the length of three and a half pillars, and that several juds had been taken off the north end of the first pillar, *i.e.* the pillar next to the "old broken," and that the back skirting had also not holed into the goaf; the air would in such case pass along the intake skirting up the jenkins, to ventilate the juds, and thence pass into the goaf, travelling along the *last* or old back skirting which had not yet tightly fallen, and then down the return bord, over the intake skirting—at which place a temporary wooden air-crossing was built—and so into the return airway of the district. If, on the other hand, the skirtings had been holed into the "old broken," the air would pass along the intake skirting, up the jenkins, to ventilate the juds, thence along the edge of the goaf, down by the side of the "old broken," into the back skirting, and finally into the return airway of the district.

As already explained, there was opposite each jenkin a communication between the two skirtings, through which the air-current is prevented by wooden stoppings from short circuiting. In these stoppings were manholes covered with canvas flaps, these communications forming in succession, as the workings retreat, air roads to the back skirting.

A somewhat similar method was practised in removing the barrier between the two districts (see Fig. 82).

A fast skirting was driven from the tramway towards that portion of the barrier which it was desired to work off. On reaching the barrier, a fast jenkin was driven north and south for a distance of about 30 yards in each direction. From the north end of the jenkin a fast skirting was driven east to the edge of the barrier goaf, *i.e.* that portion of the barrier already worked off. From the south end of the jenkin another "place" was similarly driven through the barrier, and from the far end of both of these places a lift was driven at a width of 5 yards. When these two places holed, the excavation constituted a road for the air. As soon as they holed the timber was drawn out. The portion of the barrier thus blocked out was judded off, as shown

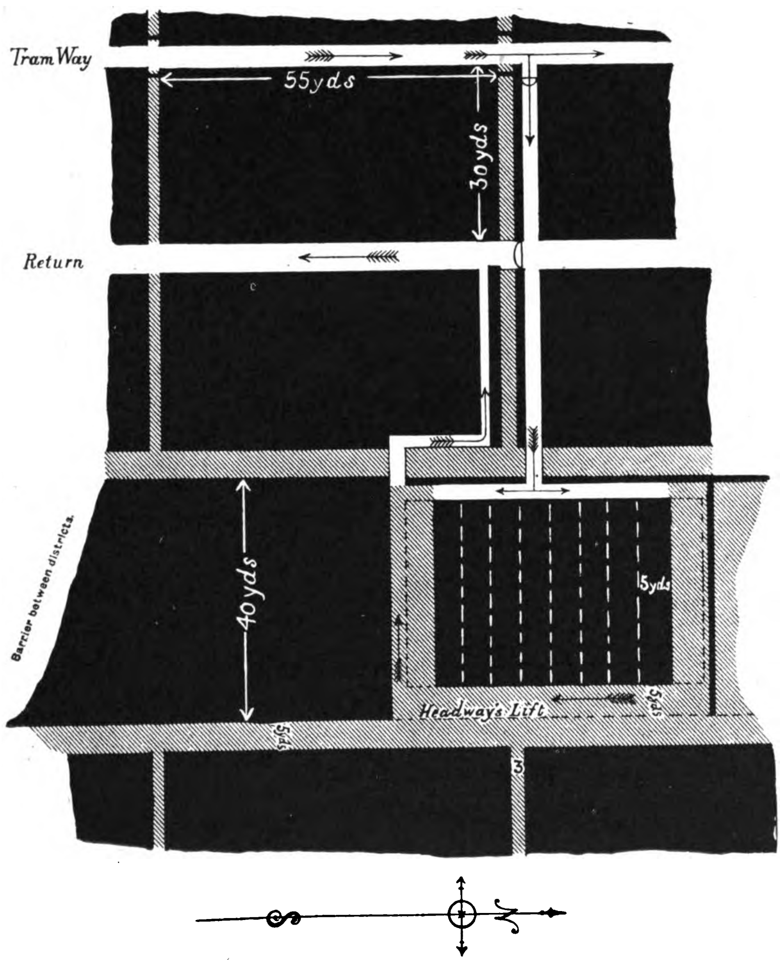


FIG. 82.—Manner of Working off a Barrier between two Panels in Fig. 80.

in the figure. It will be observed also that there is a "back" skirting, the object of which has already been stated, leading to the return airway of the district.

Extraction of Large Pillars.—Fig. 83 represents in detail a method adopted in working off some large pillars, 71 yards by 47 yards centre to centre, or 66 yards by 44 yards of coal, the section of the seam being as follows:

	Ft.	In.	
Top coal (unworked)	1	6	
Good coal	4	4	worked
Bottom coal	0	9	worked
	6	7	

The depth from the surface was about 900 feet.

The roof was not good, and did not allow of long juds being driven. The arrows denote the direction in which the juds were driven. The pillars were skirted along the bottom end and the pillar to be worked jenkined up its full length and a skirting driven along its top end, the pillar being judded from this skirting for a distance of about 22 yards, the two last juds of the row being driven up instead of down, a narrow place being set into the solid for a distance of about 10 yards for this purpose. A skirting was then driven (loose) alongside the bottom end of the fallen juds, and the same course of operations followed until the pillar was entirely removed. All jenkins and skirtings were driven narrow, viz. 2 yards in width.

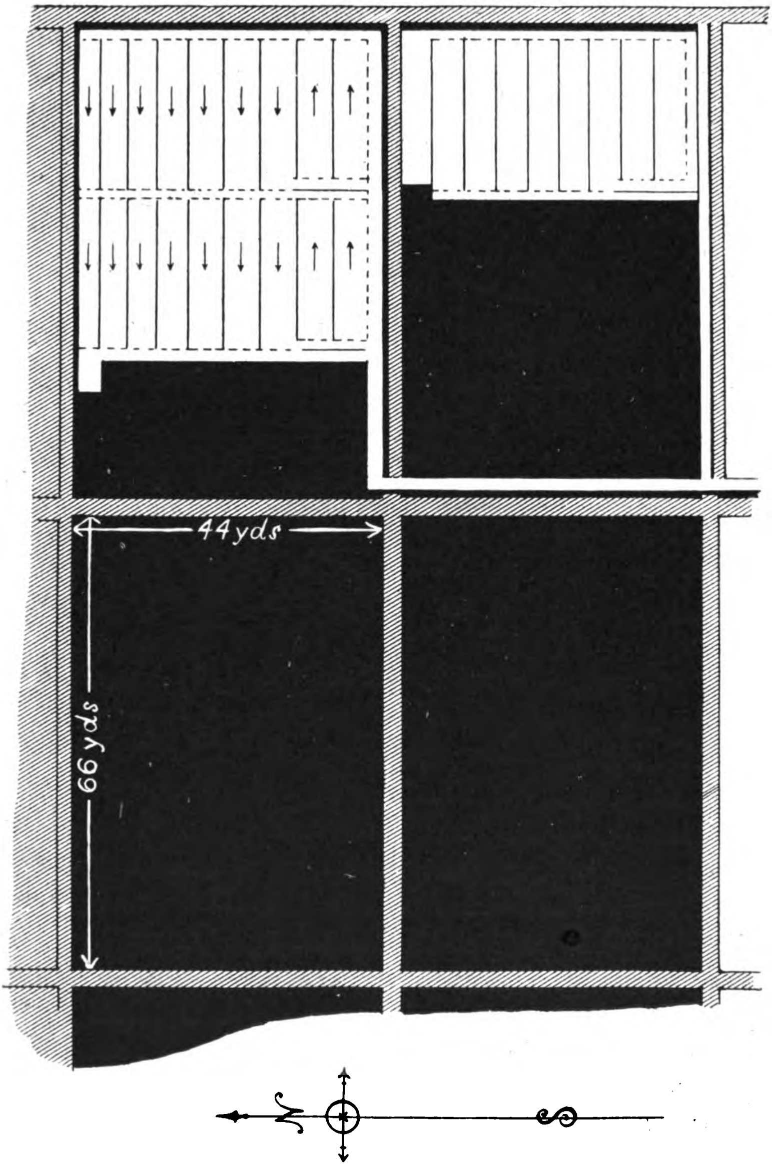


FIG. 83.—A Method of Working off Large Pillars.

CHAPTER IV

MODIFICATIONS OF THE BORD AND PILLAR SYSTEM —SINGLE AND DOUBLE STALL; WIDE OR SQUARE WORK; THE METHOD OF WORKING "REARERS"

Various Modifications.—The modifications which may now be considered of the bord and pillar system of working coal are:

The single and double stall, by which thin seams and seams of moderate thickness, whether flat or inclined, are worked.

The systems adopted in the United States of America and elsewhere of working thick seams which are highly inclined.

The square or wide work system of working thick, flat seams.

The modification known as the "Rearer" system of working highly-inclined seams of moderate thickness.

There are other modifications of the bord and pillar system of working, but as those mentioned are the most characteristic and bring out the most important variations, they are perhaps the best examples to take.

The Single and Double Stall Method of Working.—In the British coalfields the single and double stall methods of working are chiefly practised in South Wales, but these methods have of late years largely given place to the long-wall system. There are, however, peculiar advantages belonging to the former methods which under certain conditions render their adoption more suitable than other methods, as will be seen presently.

The Single Stall Method.—The following is the manner in which the single stall method was applied in working a seam of coal in South Wales:

	Ft.	In.		
Roof—Shale clod . .	1	3	thick with rock top above.	
Coal . . .	2	0		
Parting . .	0	4	Ft.	In.
Coal . . .	1	0	3	4

Floor—Underclay.
Inclination of the seam—30°.

Main galleries or levels were 9 to 12 feet wide, driven partly in the coal and partly in the floor (see

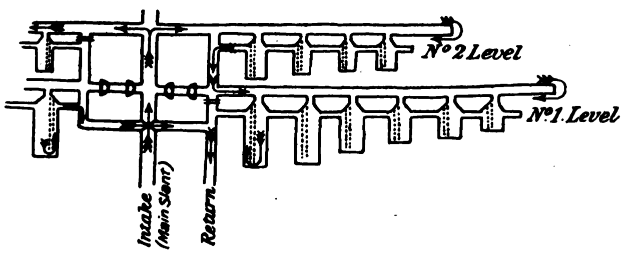


FIG. 84.—Single Stall Workings in a South Wales Mine.

Figs. 84 and 85) on the strike of the seam, the distance between the galleries being from 20 to 30 yards, according to the nature of the roof. Out of these, and at intervals of 15 yards, stalls were turned away and gradually widened out to 5 or 6 yards and driven on the full rise of the seam, and when the levels had attained their limit the pillars of coal between the stalls were worked off, commencing at the extremity of the gallery and working homewards. The direction of the ventilating current is shown in Fig. 85, the current was carried up the stalls by means of brattice, against which rubbish was packed.

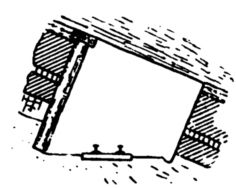


FIG. 85.—Section of a Level in a Single Stall District.

A method of working bord and pillar practised in some mining districts of the United States of America is shown in Fig. 86. It is known as the "double entry" method of working the "room and pillar" system. The main roads or "gangways" are driven in pairs, the coal being worked out in panels or "blocks," as they are sometimes called. The entries are driven on end, or, as the local term is, on the "butt" of the seam ("headways way," as it would be expressed in the North of England), the "rooms" (bords), which are usually 6 to 7 yards in width, being turned away every

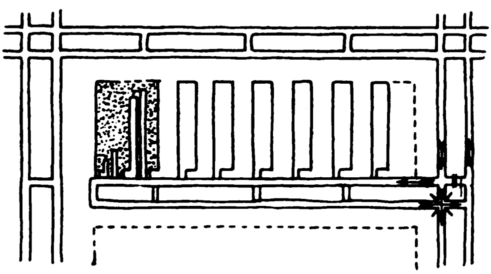


FIG. 86.—The Double Entry System of Working in an American Mine.

12 yards from one side only of the "butts" and driven a distance of 133 to 166 yards, the limit of the "lift" or range, and the ribs, or "room pillars," are then taken out. The manner of working off the ribs consists in splitting them longitudinally and working back the coal on both sides. The writer is informed that this method of working is suitable for flat seams with a soft floor and tender roof lying at considerable depths from the surface. Sometimes the "butts" are driven to the limit of the block and not until then are the "rooms" turned away, commencing at the far end, and working off the ribs as soon as the room has reached its full distance. It is claimed that by so doing less

timber is used, and there is less chance of gob fires breaking out if this retreating system is adopted. Under this system the length of the "butt entries," distance apart, width of ribs, width of the rooms, and the length to which they are driven, vary according to circumstances.

The Double Stall Method.—Two examples of this method of working as practised at collieries in the North of England, at which the writer was at one time employed, may be given.

The first was in working a portion of a seam which lay at a depth of 308 yards from the surface, and of which the following is a characteristic section:

	Ft. In.	Ft. In.	
Top coal	...	0 11	not worked.
Stone	...	1 8	
Coal	1 7	...	
Foul coal	...	0 3	
Coal	0 11½	...	
Splint	...	0 3	
Coal	2 3	...	
Stone band	...	0 6	
Bottom coal	1 0	...	
	5 9½	3 7	

Total height of seam, 9 ft. 4½ in.

The seam dips at the rate of about 1 in 14½. The stone between the seam proper and the top coal is of a soft, shaly character, and constitutes a very bad roof. When the seam was worked on the bord and pillar system proper, bore holes were put through this stone and into the top coal every 5 yards in order to release the "gas" contained in these beds and so relieve the pressure. This acted beneficially to some extent.

The floor ("thill"), which is composed of fireclay, was subject to lifting in the roadways, a fact which acted injuriously on the timbering of the roads and workings, and necessitated occasional bottom cutting, which rendered it very desirable to keep open as few roads as possible; and this fact was one of the reasons for adopting the double stall method of working in preference to the ordinary bord and pillar system.

The work was carried out in the following manner. A pair of narrow places, 8 yards apart, were turned away out of the headways course and driven bordways (at right angles to the main cleavage), or "on face," for a distance of 10 yards, then connected by means of a narrow holing or "wall" driven parallel to the headways course, and so forming a small pillar or "stork" of coal 8 yards by 10 yards. The whole width of the face, 12 yards, was then carried forward bordways in the form of a wide "jud" or "stall" and driven for a distance of about 44 yards, a rib of coal 12 yards wide separating each stall. No timber was allowed to stand in the middle portion of the stall, but the roof was allowed to fall; two roads being kept, 2 yards wide, on either side of the fallen stone, so that each road had a "fast" and a "loose" side. The roof of these roads was supported by wooden chocks built every yard apart along the loose side of the road. Not less than three sets of timber ("pairs of gears," each consisting of a "plank" or "crown-tree" set horizontally and supported by a prop at each end) were kept across the face to protect the coal hewers, these being daily advanced. The whole length of face was holed ("kirved" or undercut) above the lowest stone band by the hewers and nicked up one side, the coal, top and bottom, being got by driving in steel wedges. No explosives were used.

The stalls having attained the specified distance, the working back of the ribs is commenced, 6 yards being worked off each rib out of each stall.

When the double stall method was first applied to working the seam, it was the custom to work off the ribs from the extreme "inbye" end of the stall back *towards* the headways course, but after a trial of some months it was found that owing to the very broken character of the roof a great saving of "back" timber could be effected if the ribs were worked off in the same direction as that in which the stalls were driven; for by the first method the rib was worked off by a series of short juds, seldom extending beyond 6 yards, and then drawn out, a fresh one being set away in front of the drawn out portion, so that a place 6 yards wide plus the width of the stall road, 2 yards, or 8 yards in all, had to be timbered; whereas by the second way, the timber in one-half of the road alongside the rib about to be removed was drawn completely out and the roof allowed to fall, a place having been driven into the coal half of the rib was worked off for half its length (see Fig. 87).

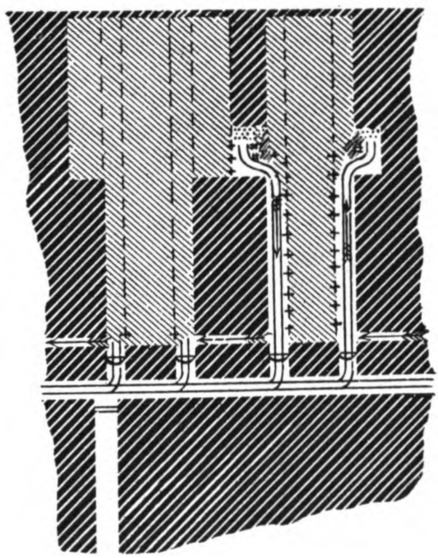


FIG. 87.—Double Stall Working, showing Method of Removing the Ribs.

The ventilation is simple; the air passes up the first stall, down the second stall, up the third, and so on. The proper ventilation, it will be observed, is dependent, in a great measure, on a large number of canvas doors placed in the headways course, which is also the haulage road, where the heavy traffic tends to interfere with the regular flow of the current. In order to obviate this, holings were made through the ribs from stall to stall, the doors being placed in the stalls, where the traffic is less than on the headways course. The distance which the air current has to travel is also lessened by this means.

The other case in which the double stall was adopted instead of the ordinary bord and pillar method of working was at a neighbouring colliery where the seam lay at a depth of 240 yards from the surface, and the section of the seam was as follows:

	Ft.	In.	
Good coal	3	6	Very hard.
Splint coal	0	4	Thrown back.
Height of seam	3	10	

The seam was nearly flat. The roof of the seam was a good one, being composed of sandstone rock and a hard floor of shale.

The mode of working was practically the same as that described in the last example. The stalls, however, were driven for a greater distance, in one instance for a length of 130 yards, before the working off of the ribs was commenced. On account of the strength of the roof allowing of it, the ribs were worked back *towards* the headways course.

As regards the double stall method in the South Wales Coal-field, the late Mr. T. F. Brown, writing in 1874,[1] stated that "in South Wales there are three principal systems of getting the coal, namely: first, single road stall; second, double road stall; and third, long-wall. . . . The seams of the upper and lower Pennant series, and the

[1] "The South Wales Coal-field," by Thomas Forster Brown. *Transactions of North of England Institute of Mining and Mechanical Engineers*, vol. xxiii. p. 220.

9-feet seam of the White Ash series, are generally worked by the first or second systems, or a modification, and the seams of the White Ash series are chiefly worked upon the long-wall system;" and he adds, "the last-named system was generally substituted a few years ago for No. 1 system in working the steam coals of the Rhondda and Aberdare Valleys, and the result has been to increase the produce of large coal, simplify the ventilation, and reduce the labour of the workmen." However, as has been previously remarked, there are conditions, and in South Wales too, which are more favourable to the adoption of the stall system of working than even long-wall, more particularly, perhaps, in the anthracite region, where the veins, as the seams are called, frequently highly inclined, are variable in dip.

The double stall system used to be practised in the Black Vein of the Celynen Colliery, but the long-wall system has of late years been adopted in preference. The seam varies from 5 feet 6 inches to 9 feet in thickness, the average thickness being about 6 feet, and it is of slight inclination. The coal is what is locally termed "kind"; that is, being full of breaks and slips, the collier can, by putting his bar into the breaks, pull down large blocks of coal. There was practically no hewing to be done, and 70 per cent. of round coal was obtained.

Fig. 88 is a plan of a portion of the double stall workings at this colliery. Where stone was lacking, the middle of the stalls was filled with small coal packed as tightly as possible against the roof. The cogs (chocks) were set along the "loose" side of the roads at distances of 4 or 6 feet, the spaces between the cogs being built up with stones, or, when these were not available, cogged with small sticks 4 or 6 feet long, according to the distance between the main cogs.

The distance to which the stalls were usually driven was 50 yards.

The Advantages and Disadvantages of the Stall Method as compared with true Bord and Pillar.—One is enabled by the stall method to concentrate

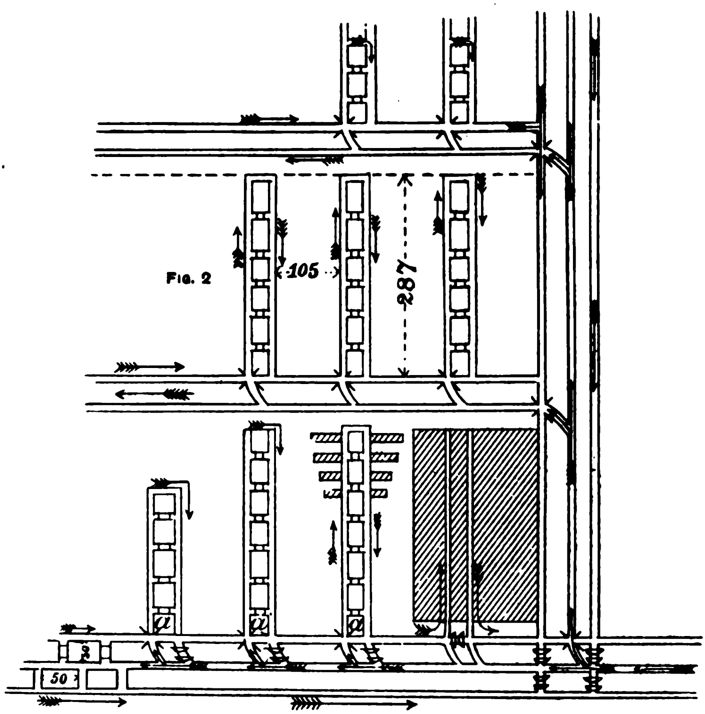


FIG. 88.—Portion of a Plan showing Double Stall Workings.

a larger number of hewers in a limited area than in the bord and pillar method, and for a given output to maintain a less length of roadway—an important item in those cases where roadways are costly of upkeep. The coal is more quickly extracted from a given area, and loss from crush, which in respect of the pillars in bord and pillar working is sometimes considerable, is greatly diminished. A higher percentage of extraction and a higher proportion of "round" (large) coal is obtainable.

The disadvantages are increased cost in respect of timber, and the dependence of effective ventilation on a large number of canvas doors.

Working a very Thick and Highly Inclined Seam by the Double Stall Method.—The thickest seam of coal in the anthracite region of the Pennsylvania coal-field is the "Mammoth" seam, which in some districts averages 60 feet in thickness and reaches 100 feet. Owing to folding there is in some places, however, a mass of coal several hundred feet thick.

The usual method of working this bed is to drive level tunnels across the measures to cut the coal, and when this is reached, to drive slopes, usually about 28 feet wide and 15 feet high, on the full dip of the seam, turning away level horse roads out of the slope at every 100 yards thereof, and working the coal to the rise by means of stalls or "breasts."

The level or gangway is driven on the strike and in the top of the seam (see *a*, Figs. 89 and 90), and an airway (*b*) above it, and from the gangway two "chutes" (*cc*), about 9 feet wide and 6 feet high, are driven across the full width of the seam, at an angle which will allow of the easy control of the broken coal. On reaching the floor of the seam the chutes are widened out to the full width, the face of the coal being cut up to the top of the seam (see cross-section, Fig. 91) and the breast advanced, the distance between the chutes being usually 30 feet. Manways (*d*) are driven through the pillar separating the stalls, and branches (*ee*) are driven right and left, connecting with two of the manways, which are kept up on either side of the stalls by inclined timber supports, or "jugglers," as they are termed locally (see Fig. 91). It will be seen that the broken coal is drawn from the side of the breasts, and the resultant movement to the body of loose coal in the stall sometimes causes breakage and stoppage in the manways. This difficulty is surmounted if the breasts are arranged with

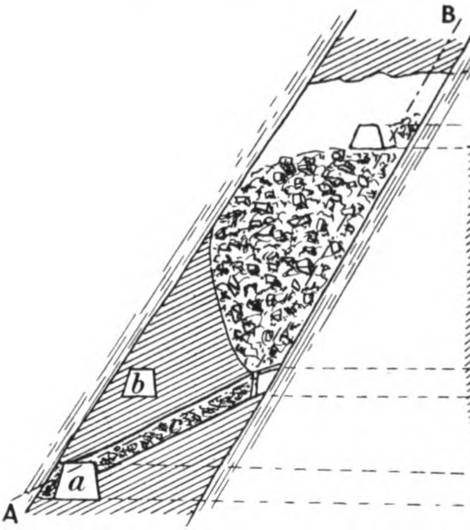


FIG. 89.—Section along Line AB in Fig. 90.

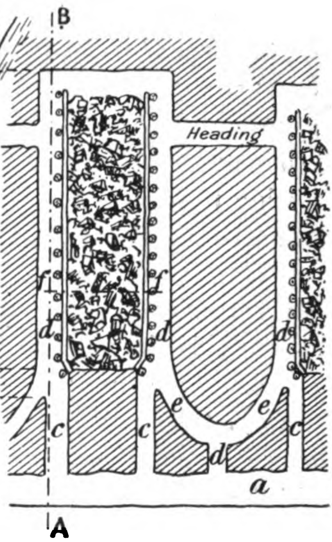


FIG. 90.—Plan along Line AB in Fig. 89.

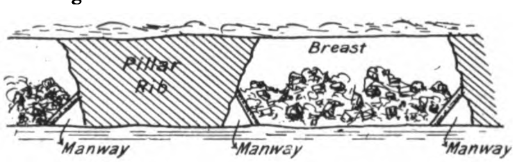


FIG. 91.—Cross-Section of Stall and Rib.

FIGS. 89, 90, and 91.—Method of working Highly Inclined Thick Seams of Coal by means of Stalls with Double Chutes.

one chute in the centre, as shown in Figs. 92 and 93. Here (*a*) is the level or gangway, (*d*) being a manway driven in the middle of the pillar for a few yards, when the branches (*ee*) are turned off, so connecting the adjacent stalls as before by means of the manways (*ff*), the filling of the coal being restricted to the central chute.

There is a small airway connecting the airway (*b*) with the manway (*f*), but these small airways are not in common use. Should, however, the ventilation be blocked by the accidental closing of the manway (*f*), the air-current can be conveyed by way of these airways on the removal of the stoppings.

This method is also adopted in working the thick and

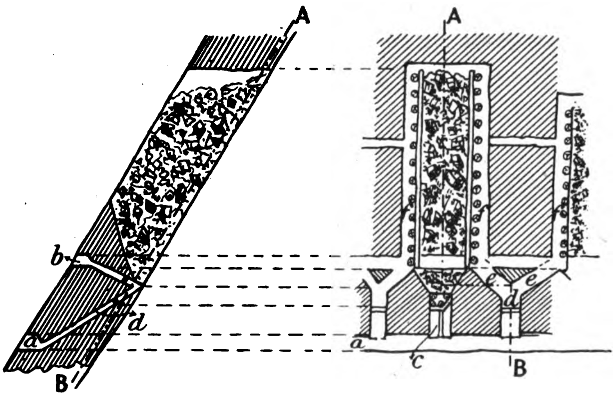


FIG. 92.—Section along Line AB in Fig. 93.

FIG. 93.—Plan along Line AB in Fig. 92.

FIGS. 92 and 93.—Method of working Highly Inclined Thick Seams of Coal by means of Stalls with Single Chutes.

highly-inclined seams of soft coal in the United States of America.

The "Wide" or "Square Work" Method of Working Coal.—*General.*—The method known as "wide" or "square work" is perhaps one of the most satisfactory methods so far devised of working very thick seams which are flat or have only a slight inclination, though it cannot be said to fulfil all the requirements of coal mining, seeing that it is perhaps the most wasteful of all the methods described in this book. Such seams occur in Great Britain only in South Staffordshire, East Worcestershire (the South Staffordshire coal-field), Warwickshire, and Fifeshire. The method has been practised for very many years in South Staffordshire in working the so-called "ten-yard" or "thick" coal (the thickest coal seam in the United Kingdom). This seam, which varies from 5 to 12 yards in thickness, is divided into a series of layers by thin "partings," and is in reality an agglomeration of a number of coal seams which further north exist separately, being divided by a considerable thickness of intervening strata, and are worked separately.

The method has undergone modifications in the process of time, but under modern conditions would be carried out somewhat on the following lines. The shafts having been sunk to the coal, main roads would be driven out to the boundary and branch roads turned away to the right and left and also driven to the boundary. More than one pair of main roads may be necessary, the determining factors being, of course, the shape of the "royalty" and the positions of the shafts. The reason for driving the roads to the boundary is that, on account of the liability of the seam to spontaneous combustion and crushing, it is desirable, as far as possible, to practise a retreating system of working, and thus have the waste, in which the fires chiefly occur, in the rear of the workings.

The main roads are driven on the strike of the seam, and act as the main haulage, ventilation, and travelling roads. They are usually from 33 to 45 yards apart. These, as well as the branch roads, if made in the coal, are driven in the bottom portion of the seam. But it is now considered advisable, owing to the liability to spontaneous combustion taking place actually in the solid coal itself, to make the main roads, at any rate in the vicinity of the shafts, in some thin seam above or below the thick coal, or to drive them in the rock as inclined drifts.

The coal opened out by the branch roads is worked by dividing it into a number of large chambers termed "sides of work" (see Fig. 94); these "sides of work," when completed, are in the form of a parallelogram, 50 yards or more in "the side," each parallelogram being divided from the adjoining one by barriers of solid coal from 8 to 10 yards wide, known as "fire ribs," through which two openings only are left for the purpose of ventilation and travelling. When the parallelogram is formed,

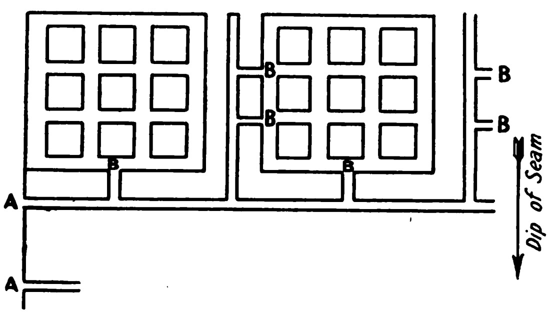


FIG. 94.—Sides of Work.
A, Gate Roads; B, Bolt Holes.

the roof coal is cut down in beds according to the partings in the seam, small pillars being left to support the roof. When a side of work is abandoned, the roads known as "bolt holes" are dammed off.

The ventilation is simple; the return air from each side of work is conducted directly into the main return of the district, so that the fumes from any fire which may exist may not pass from one set of workmen on to another.

Detailed Description of Method of Laying out a Side of Work.—In the case under consideration the seam is 24 feet thick and lies at a depth of

418 yards from the surface. The roof immediately above the seam consists of "binds," totalling 10 to 12 feet thick, above which is a bed of hard sandstone rock about 50 feet in thickness.

The main and branch roads having been driven out to the boundary, the process of opening out sides of

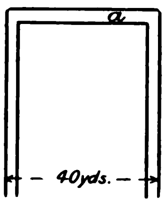


FIG. 95.

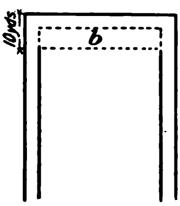


FIG. 96.

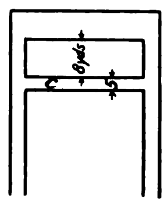


FIG. 97.

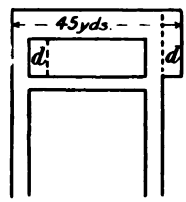


FIG. 98.

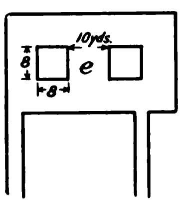


FIG. 99.

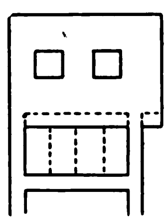


FIG. 100.

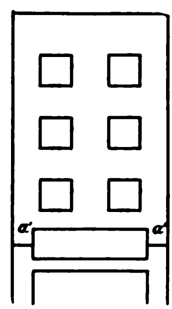


FIG. 101.

FIGS. 95, 96, 97, 98, 99, 100 and 101.—Illustrating the Stages in the Development of a Side of Work.

work is commenced, the chambers in this case being from 36 to 46 yards wide. The *modus operandi* is as follows. The gate roads, having reached the boundary, are holed across (*a*, Fig. 95). The holing is then widened out to 10 yards, the widening-out process being termed "side-laning" (*b*, Fig. 96). While this is being done a second holing (*c*, Fig. 97), 8 yards back from the first, and about 5 yards in width, is made between the two gate roads, so forming a block of coal 8 yards wide. The side gates are then "side-laned" off to a width of 10 yards (*dd*, Fig. 98), and a stall (*e*, Fig. 99) driven through the 8 yards wide block of coal. All this work has so far been carried on in the lower layer of coal, that is, to a height of, say, 6 or 7 feet, forming a kind of simple bord and pillar work. In the furthest in opening (*b*), however, the coal above will now be

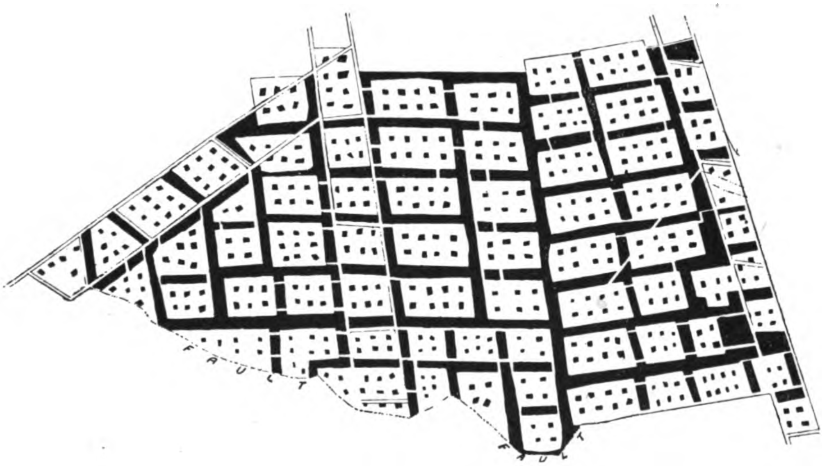


FIG. 102.—Plan of a Portion of a Mine worked by Wide-Work.

taken down layer by layer, a niche or groove being cut vertically along the side of that section intended to be removed, and "spurns" (divisions of coal 18 inches to 2 feet at the face, and tapering out at the top when holed through) left in the niche (or nicking), which are cut through in the upper part, afterwards further cut away, and finally entirely removed by knocking at them with an instrument very similar in design to a boat-hook (see Fig. 103) called a "pricker." Whilst the work of taking down or preparing to take down the coal in this holing is proceeding, a third holing (Fig. 100) is made between the gates at a distance of 13 yards back from holing (*c*), and (*c*) is widened out to 10 yards, and the course of operations already described repeated until the side of work is complete, as shown in Fig. 101. Fire-

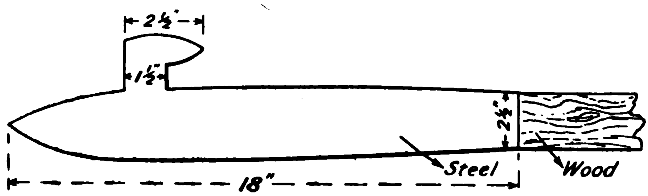


FIG. 103.—Pricker used for removing "Spurns" in a Side of Work.

dams are then built in the bolt-holes at *aa*, and a new side of work started.

A plan of a portion of a mine worked on the wide-work method is shown in Fig. 102.

For supporting the roof, "trees" are set about 6 feet apart in every direction. These trees are from 5 inches to 6 inches at the tops and they are set with both "roof" and "foot lids." When setting long trees, *i.e.* when the layers have been removed, the process is extremely difficult, and a man has to mount a ladder held up by another worker. For drawing the timber an instrument called a "bunter" (Fig. 104) is used.

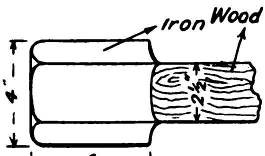


FIG. 104.—"Bunter" for knocking out Props.

Usually about sixteen workmen occupy a side of work, consisting of stallmen, pikemen, loaders, and fillers; and a side of work will be let to a superior stallman or contractor.

Only from 40 to 50 per cent. of the available coal is recovered in the process described above, but the larger portion of the coal left is ultimately recovered by second or even third workings carried out after the lapse of some years, so that ultimately the loss in working may not exceed 10 per cent. of the available coal; but the coal recovered in these later workings is frequently much crushed.[1] The cost, too, of supporting the roof in the second working is heavier than in the first, and in the third working the roads have to be made through the waste, and very close timbering is necessary. As to the depth from the surface at which it is possible to recover the ribs and pillars left in the first working, what the writer has written elsewhere may be repeated here.[2] "In depths of less than 300 yards, the ribs and pillars should be recovered by second and third workings to greater or less extent, such amount being in inverse proportion to the depth. No second or third workings have, so far, been found possible in depths greater than 300 yards, hence down to 300 yards (to which depth second workings may be carried on) it is better to make the pillars and ribs larger than smaller, and below that as small as possible, *i.e.* to extract as much coal as possible in the one working."

Mr. F. G. Meachem drew up and submitted to the last Royal Commission on Coal Supplies (which reported 1903, 1904, and 1905) a valuable table, based on actual working plans of South Staffordshire collieries, and giving the amount of coal lost in working the "thick" coal by the wide-work system, which is reproduced on the next page.

Another method of working the thick coal in South Staffordshire, which came under the observation of the

[1] Mr. F. G. Meachem says that from 40 to 50 per cent. of the available coal is recovered in the first working, 30 per cent. in the second working, and 20 per cent. lost, "other than places 20 to 30 yards deep, when 15 per cent. of the remainder is gotten." (Mr. Meachem's evidence before the Royal Commission on Local Supplies.)

[2] *Colliery Working and Management*, 2nd edition, p. 246.

Table giving the Amount of Coal Lost in working the "Thick" Coal of South Staffordshire at various Depths, by F. G. Meachem.

Numbers.	Depth in Feet from Surface.	Thickness of Seam in Feet.	Got in First Working.	Left.	Mea-urements left in		Total Worked.	Area of Sides of Work.	Pillars per Side.	Yield per Working.			Total Yield per Acre.	Percentage.		Theoretical Contents of Seam at 1·274 S.G.=79·8 Lbs. per Foot reduced to 1,400 Tons per Acre for Sale, &c.	Actual Yield per Foot per Acre.	Loss per Foot per Acre.	Loss per Acre.
					Ribs.	Pillars.				First.	Second.	Third.		Coal.	Slack.				
			Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Acres.		Tons.	Tons.	Tons.		Per Cent.	Per Cent.	Tons.	Tons.	Tons.	Tons.
1[1]	300	24–30	55–65	10·00	...	...	85–90	1½	...	16,000	12,000	2,000	30,000	60	40	33,600	1,250	125	3,600
2	450	24·0	69·39	32·61	20·61	12·00	80·0	1¼	14	,,	10,000	...	26,000	,,	,,	,,	1,083	266	7,600
3	600	,,	66·40	33·60	25·20	8·40	70·0	1⅛	13	15,000	8,000	...	23,000	,,	,,	,,	965	241	10,600
4[2]	600	,,	57·22	42·78	33·46	9·32	84·0	1¼	...	18,000	10,000	...	28,000	55	45	,,	1,161	239	5,000
5	900	,,	60·00	40·00	25·00	...	89·0	1⅛	12	,,	8,000	...	26,000	52	48	,,	1,083	317	7,600
6[3]	1,200	,,	62·00	38·00	,,	13·00	62·0	1⅛	10	16,000	...	...	16,000	50	50	,,	666	733	17,600
7[3]	1,500	17·6	60·09	39·01	30·91	9·00	60·0	1¼	7	13,000	...	...	13,000	45	65	23,600	742	616	10,800
8[3]	1,800	20·0	57·00	43·00	36·00	7·00	57·0	¾	4	,,	...	...	,,	40	60	28,000	650	750	15,000
9[3]	2,100	14·0	54·25	46·75	37·47	9·28	54·25	¾ or less	5 or less	to 9,000	...	...	to 9,000	35	65	19,600	642	755	10,600

[1] Fine unsaleable slack was left under foot, but is included in measurements as we are now considering system of work. Had the slack been of any use it would have been drawn out.
[2] There is a great discrepancy in weights owing to the various weights and parcels sold.
[3] No second working yet tried to my knowledge.

writer some years ago, is, in the opinion of some local mining engineers, an improvement on the wide-work method described above.

The seam at the colliery under consideration is 214 yards from the surface, and presents the following section :

Roof : Strong white rock of considerable thickness.

	Ft. In.	Ft. In.
White clod	2 0	
Black bat	3 0	
Coal—Top slipper and rooves	...	3 0
Jags	...	1 6
Lambs	...	2 0
Tow coal	...	3 0
Brazils	...	2 0
Foot coal	...	2 3
Grey clay and shale	3 0	...
Hard stone	1 0	...
Stow coal (worthless)	0 10	...
Coal—Patchells	...	1 6
Sawyer	...	4 6
Henches	...	1 6
	4 10	21 3

Floor : Black bat (pouncill).

The above represents the maximum thickness of each *division* of the seam at the colliery. The average thickness of the coal (only) does not exceed 18 feet.

The method of working is somewhat different from that usually pursued in thick-coal collieries in South Staffordshire, and consists (see Fig. 105) in forming off a pillar of coal about 45 yards broad by 50 yards long, and driving three places, *a*, *b*, and *c*, 15 yards apart through its entire length. In the top stall (A) the coal is taken out for a width of 10 yards, sometimes in one working and sometimes by a process of thinning off the pillars, the method adopted depending on the condition

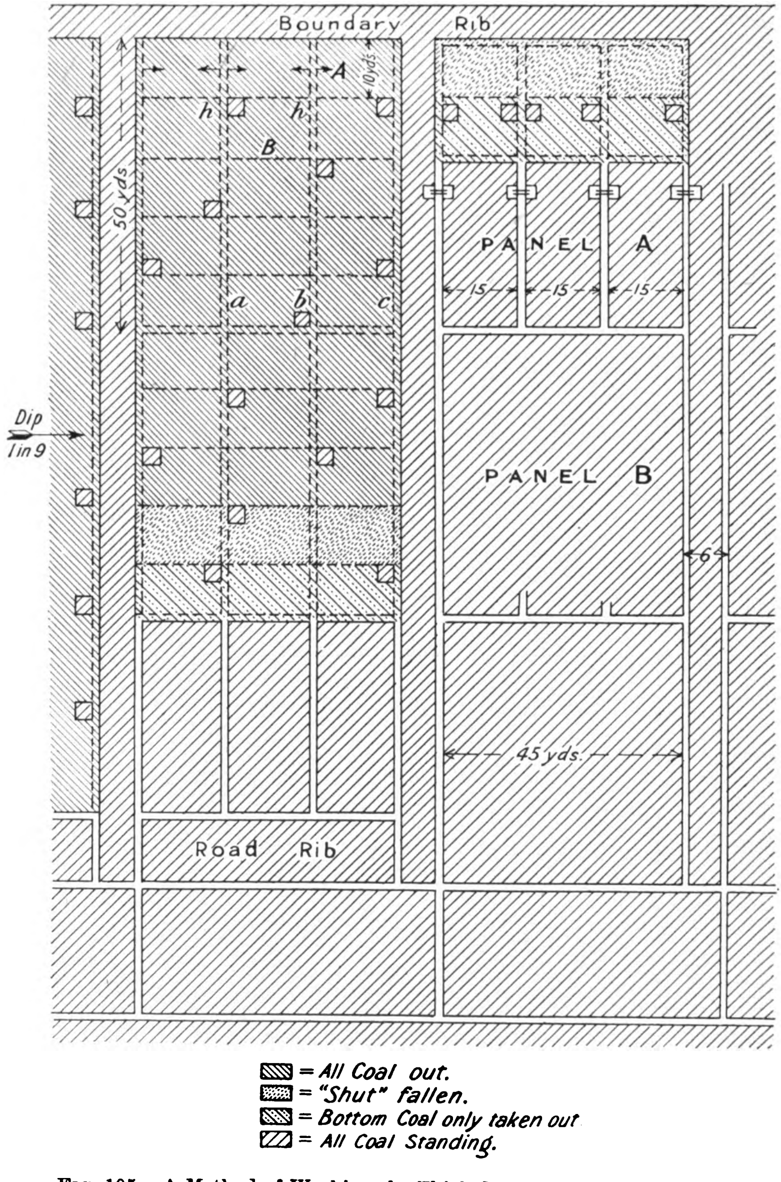


FIG. 105.—A Method of Working the Thick Coal of South Staffordshire.

of the coal. Then 10 yards further back a place (B) 7 feet by 7 feet 6 inches wide is driven across the pillar, all this work being carried out in the bottom coal. Whilst the road (B) is being driven the dirt band is "dropped" in the stall (A) by withdrawing the timber supports, and partially drawn out by the bolt-holes (*hh*), so enabling the workmen to get into the stall, where they level down the remaining dirt and take down the upper layer of coal section by section.

The timbering during this process is done by setting trees on large sills placed on the levelled and beaten-down dirt with a lid on top of each tree, thus securing an efficient support on loose material and preventing roof movement. Successive operations on these lines are carried out until the whole block has been cut up into five rows of pillars and the greater part of these have been removed; but with the exception of that worked by the top stall it is not possible to remove entirely the coal—and sometimes not even in the case of the top stall. Small pillars or "nobs," as they are locally termed, are left —not in parallel lines or in accordance with any preconceived plan—where necessary for the support of the roof.

A point worthy of special notice in this method of working is the taking down of the upper layer of coal in the innermost stall before attacking it in the next succeeding stall further outbye, so that should the "shut" (dirt) bend on the roof and cause trouble, the innermost stall can be abandoned and closed off from the outbye workings. If, also, there is trouble from spontaneous combustion, so frequent in the thick-coal collieries, the inner stall can be dammed off and a fire-rib left and work carried on in the next stall in succeeding order.

When working the upper coals, the "top slippers," "rooves," and "jags" are timbered up to, and when all the coal below this horizon has been excavated the timbering is gradually withdrawn outwards. The upper coal is then allowed to fall. Experience has shown that if the roof is "worked up to" it will not stand, but that if the coal is allowed to fall in the manner mentioned ("fretting") not only is more coal got, but the roof stands better.

When driving out the stalls the timber is set in advance of the loading point, and though there is no specified rule as to timbering, the trees are usually set 6 feet apart in pairs, though sometimes they are set alternately.

When taking down the upper layers of coal "trees" are set where possible, it having been found impracticable to set trees on the loose coals, unless they are levelled and beaten down in the same manner as in the case of the dirt ("shut"), but this is not done. Eventually the timbering is carried up to the "jags," and, when "coming back," is drawn out, a few trees at a time, until all the long timber is got out and the coal has fallen. The process of getting out the fallen coal is hurried as much as possible, for if the roof becomes unsafe the coal has to be abandoned.

The "Rearer" Method of Working Inclined Seams.—In a portion of the North Staffordshire coalfield the seams are very highly inclined: they commence at an easy gradient and steadily rise until they attain a very steep inclination, at some places reaching the vertical. At others the contortion is so complete as to cause the seams to double back. The seams when steeply inclined are locally termed "rearers," and the modification of the bord and pillar system which is usually adopted is termed the "rearer" method of working. It has been found that this method of working gives better results with rearers than the long-wall system, which has been tried from time to time.

The thicknesses of the seams worked (and there are about eight of them) vary from 2 feet 6 inches to 8 feet in section, and the depth from the surface at which they are worked from about 160 to 170 yards.

Mr. J. R. L. Allott, who is a recognised authority on the working of the rearer seams of North Staffordshire, has kindly allowed me to reproduce two illustrations pre-

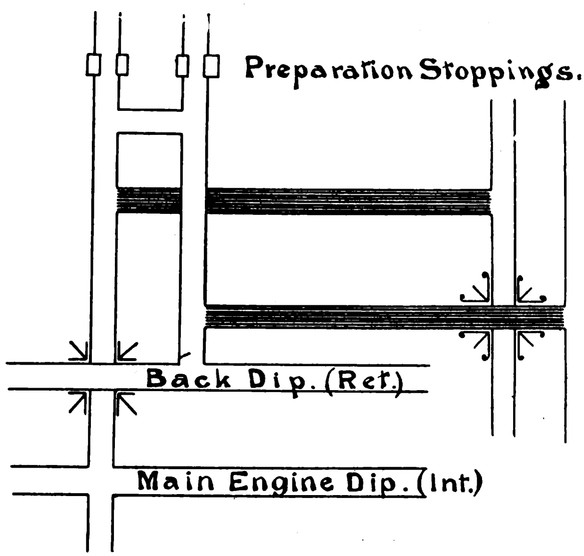


FIG. 106.—Plan showing "Engine Dips," "Cruts," and Levels in Rearer Workings.

pared by him, descriptive of the method of working as actually practised at a colliery in the management of which he is concerned (see Figs. 106, 107, 108, 109, and 110). Mr. Allott strongly advocates this method of working for highly-inclined seams having similar characteristics.

The rearer method of working is practised where the inclination of the seam is anything between 45° and the vertical. The seams are recovered by a pair of "cruts" or cross-measure drifts, driven the one at a higher level than the other, but not vertically above each other, from the shaft to strike the seam or seams; the lower crut serving as the haulage road and the upper as the return airway, so that the air-crossings are what are known as "natural" crossings, that is to say, they are not built, but the two roads are divided by the solid stone or coal as the case may be (see Figs. 106 and 107).

When the seam is reached it is opened out and "recovered" in the following manner. The royalty is divided into working breadths by driving pairs of levels

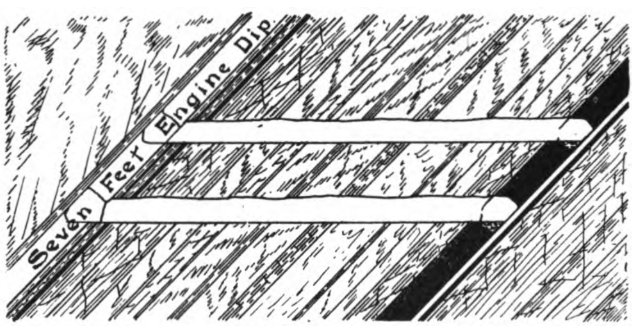
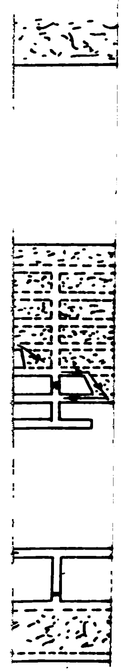


FIG. 107.—Section showing "Engine Dip," "Cruts," and Levels in Rearer Workings.

from the point where the coal is reached to the boundary, the distance between the pairs of levels being usually 230 yards. From these levels pairs of "dips" (or sometimes in sets of three) are, at intervals of about 120 yards, driven for 150 yards to the full rise of the seam, from which to the right and left for 60 yards on either side and about 10 yards between them levels are driven, and, by means of holings between the levels, the area to be worked is divided up into a panel of inclined pillars, the pillars being worked off from the rise downwards. The removal of the pillars is carried out in the following manner. If ABCD (Fig. 109) represent a pillar of coal,



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a "shoulder" (*a*), 5 feet in breadth, is taken off at the bottom end. A second shoulder (*b*) is commenced, and the two gradually worked upwards, (*a*) leading, until the top of the pillar is reached, the coal falling into the level BC, where it is loaded up and conveyed to the cage dip, down which it is lowered on a kind of self-acting inclined plane to the main level, along which it is hauled to the shaft. When "entering up," as this process of starting to work off a pillar is locally termed, the miners are careful to maintain the face of the pillar at an angle of about 45° from the line of full dip, as this is found to give the best results in respect both of safety and convenience. If there is no goaf or gob above the pillar, a scaffolding has to be maintained for the purpose of protection from falls of ground and in order to enable the miners to work at the coal face. If, however, the pillar is one which is below the gob, the breaking through the coal into the gob is a matter requiring a special mode of procedure. When the working of the pillar has proceeded up to the point at which the first break through is to be made, a heavy shot is put (as at S in Fig. 110), so as to set the gob moving down. The gob sliding down fills the excavated space, acting as both support against falls and foundation for the colliers to stand to work.

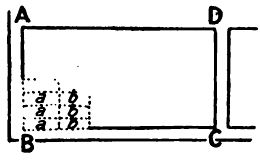

Fig. 109.—Manner of "entering up" or working off a Pillar in the Rearer System of Working.

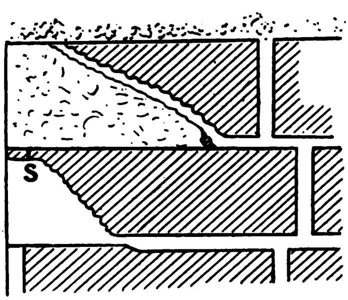

Fig. 110.—Manner of breaking through to the Goaf above when working off Pillars in the Rearer System.

Care is taken to maintain the line of retreating face at an angle of about 50° from the line of full dip, so as to reduce crush and loss of coal to the greatest possible extent, secure good ventilation, and prevent a dangerous condition of the superincumbent gob.

The haulage is done in the cage dips, the road being laid with double tracks of rails, one track for the cage which carries the tub, the other for the "dummy"—the dummy track being narrower than that for the cage—which pulls up the empty cage.

Barriers of a width varying from 80 to 150 yards are left between a panel and the one above it, the recovery of these barriers not being commenced until the deepest district has been worked out, when they are removed, commencing with the lowest and working upwards.

The loss of coal in this method of working is heavy, only about 60 per cent. of the available coal being sent to the surface; crushed pillars, other sources of loss in working off the pillars, and portions of barriers impossible of recovery, account for the loss.

The seams, generally, in this part of North Staffordshire are very liable to spontaneous combustion, and Mr. Allott has laid down eight conditions which should be observed with a view to the prevention of gob-fires or minimising the risks arising therefrom should they occur. These are:

1. The districts should be as small as possible, and worked out quickly.

2. Only sufficient ventilation should be passed through the districts to keep the faces and goaf edges clear of gas and properly ventilated.

3. Intermediate goaves as between the intake and the working faces should be avoided.

4. As few openings as practicable should be made to

each district, and preparations made so that stoppings can be rapidly erected.

5. The coal should be worked out as far as possible, especially in the neighbourhood of faults.

6. The face should be maintained as level as possible.

7. The stoppings should not be built close up to a main roadway, but kept back a few yards, so that they can be constantly examined for leakages.

8. All districts should be sealed off when finished, whether there has been trouble from gob heats or not.

The author does not necessarily subscribe to these conditions,[1] they are given as the outcome of the thought and experience of a mining engineer who has had great experience in this mode of working. It should be mentioned that Mr. Allott does not mean by the second condition that the conditions in respect of ventilation laid down in the Coal Mines Act, 1911 (sec. 29), need not be observed, but that the ventilation should be "under control." He would direct the air-current into the working and travelling places, and keep it from circulating in the goaves above. As to whether this would be a wise practice or not, there may be a difference of opinion. The manner in which the preparation is made in advance for stopping off a district in the event of a fire occurring therein is shown by Fig. 111, for which also the author is indebted to Mr. Allott.

One of the disadvantages of this mode of working is the limited daily output that it is possible to obtain from one seam. The maximum has been stated to be 350 tons. Against this, however, should be placed the fact that in North Staffordshire there are a number of seams which can be worked from the same cruts, and Mr. Ernest

[1] A Departmental Committee is at present inquiring into the cause and prevention of spontaneous combustion in mines.

Craig has stated[1] that "out of one pit working nothing but rearers, but having four seams in operation, there is

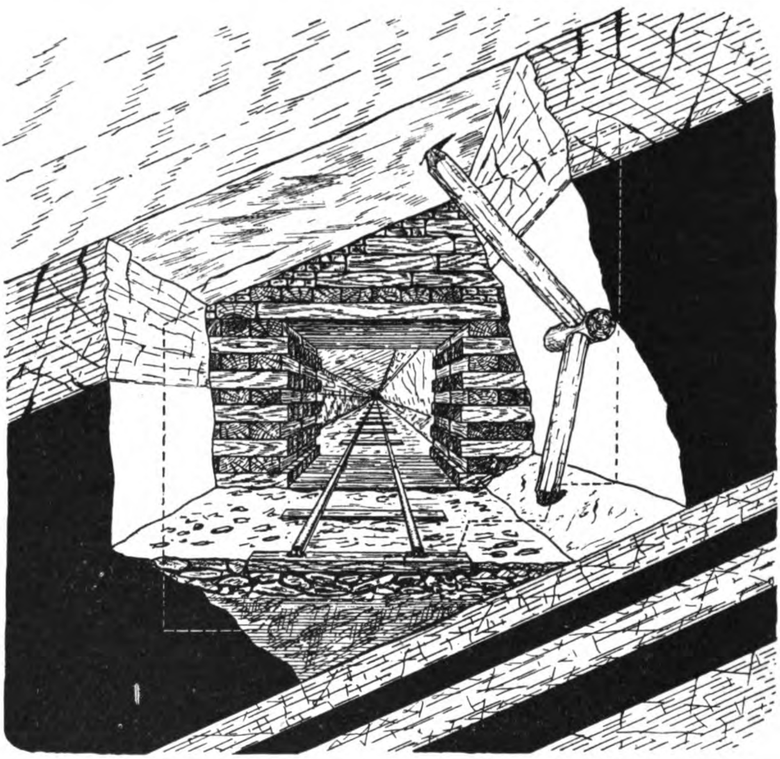

FIG. 111.—Advance Preparation for stopping off a District in the Rearer System of Working.

no difficulty in producing 1000 tons per day from a depth of 400 yards."

[1] *Transactions of the Institute of Mining Engineers*, vol. iv. p. 52.

CHAPTER V

THE LONG-WALL SYSTEM OF WORKING COAL—THE LONG-WALL SYSTEM AND ITS MODIFICATIONS AS APPLIED TO WORKING SEAMS OF MODERATE INCLINATION AND THICKNESS

The Long-wall System of Working Coal.—The long-wall system, as practised in one or other of the examples to be given under this heading, is probably the system of working most extensively in operation throughout the world for working coal. And yet, as has been shown, its wider application has been a matter of comparatively recent growth. In the earlier half of the last century nearly all coal mines were being worked on the bord and pillar system or some modification thereof, and in some districts of the United Kingdom this system still predominates, *e.g.* Northumberland and Durham, a district "which justly claims to be the 'cradle' of the coal trade and the *alma mater* of coal mine engineering." As has been remarked elsewhere,[1] a *single* fact seldom determines the manner of working, and factors other than what may be called the natural and geological conditions exercise considerable influence in arriving at a conclusion; much depends on the custom of the district, the *genius loci*, and the adaptability of labour.

Synopsis of the Most Important Considerations in Working by Long-wall.—The vital points in respect of working by the long-wall method—some of

[1] *Colliery Working and Management*, by H. F. Bulman and R. A. S. Redmayne, 2nd edition, p. 139.

which have been mentioned above—have elsewhere[1] been concisely summed up as follows:

"(i.) The direction in which the face should be worked, whether 'on face' (bordways) or 'on end' (headways) or 'half-end and bord' (cross-cut). This varies in different mines, and depends on the vertical 'slips' or 'balks' or 'partings' in the seam itself and on the roofstone (and, as has been added above, on the inclination of the seam). The advancing line of face should usually (other things being equal) form an angle with the direction of these 'slips.' The support of the roof at the working face, and the getting of the coal in good condition, are largely dependent on this. (ii.) Whether the face should be kept in one continuous line or stepped; this, too, greatly affects the maintenance of the roof and size of the coal got. Experience has proved that an alteration in this respect may sometimes be most beneficial. (iii.) The rate of advance of the face: sometimes it pays to let the coal stand for a little while on the timber sprags or cochers after holing, so that the pressure of the superincumbent strata may act upon it; and, on the other hand, sometimes the faster the face can be moved forward the better. (iv.) The building of the pack walls and the stowing of the goaf. The packs should be built as strongly as possible, and carried close against the roof and kept well up to the face; care should be taken to leave no timber in the goaf. Attention to these points will often make the difference between a profitable working of a seam and the reverse."

The subject of working stratified deposits by the long-wall method divides itself for consideration under the following heads:

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[1] *Colliery Working and Management*, by H. F. Bulman and R. A. S. Redmayne, 2nd edition, p. 220.

1. As applied to the working of seams of moderate thickness and inclination;

2. As applied to the working of seams of moderate thickness and of high inclination; and

3. As applied to the working of thick seams.

Under these heads will also be considered modification of the system.

We have seen from the examples given in the preceding pages that it is either impracticable or less profitable to work seams under *all* conditions by the long-wall method; but it may be regarded as a general rule that where it is practicable to work a seam by this system, it can usually be more profitably adopted than any other system.

I. As Applied to the Working of Seams of Moderate Thickness and Inclination

Before giving examples illustrative of some of the long-wall methods usually adopted in working seams of moderate thickness and inclination, there are some points affecting the subject generally which may with advantage be considered.

The Long-wall Method of Working. Various Considerations.—The conditions chiefly favourable to long-wall working have been set out in brief on p. 81. It is sometimes stated that a hard roof and floor are among these conditions, but in this connection it is interesting to reproduce the conclusion of so eminent an authority as the late Mr. J. Forster Brown, as expressed in his well-known paper on the South Wales Coal-field, read before a meeting of the North of England Institute of Mining and Mechanical Engineers in the year 1874.[1] He says, under the heading "Long-wall": "This system is adopted when the roof is sufficiently strong to remain up with only the aid of a few props, but more generally when it is sufficiently friable to settle down permanently behind the working face. *On account of the friable roofs and the great pressure, it would be almost impracticable to work some of the steam coal seams in the deeper pits otherwise than long-wall;*[2] and so pernicious an effect have stumps or pillars upon the roof, that it has become the general practice to work the whole of the coal away with the exception of the large pillars at the shaft bottom. *It is important in this system that the working face should be kept moving on, so as not to give the roof time to break at the face;*[2] regard, too, must be had to the quantity of rubbish available for packing. The ventilation is more simple in this system than in stall and pillar working, and the percentage of large coal is higher."

Having formed the shaft pillars, long-wall faces are opened out and advanced in various directions towards the boundary of the tract to be exploited. The more common method is to divide up the area into separate districts, the face of one district being unconnected with the face of an adjoining district, and each district having its own intake and return airways. In a gassy mine, a mine subject to blowers of gas or to spontaneous combustion, this for obvious reasons is undoubtedly the best mode to adopt. Another method, which may be adopted when there is comparative freedom from inflammable gas and entire freedom from spontaneous combustion, is to open out a continuous face around the pillars

[1] *Transactions of the North of England Institute of Mining and Mechanical Engineers*, vol. xxiii. pp. 197–256.

[2] The italics are the present writer's.

and advance the same in a roughly circular form towards the boundary. It will be inadvisable, however, when this face has advanced to some extent and the mine has become fairly developed, to ventilate it with one continuous air-current. Not only would the resistance from friction be considerable, but there would be liability to occasional more or less complete obstruction, due to falls of coal or stone blocking the air-course; and there would be difficulty in maintaining the standard of purity and adequacy of ventilation required for safety, for the coal face is that part of the mine most liable to falls of ground.

Usually when opening out a mine by the long-wall method the main roads are made in the gob or goaf, but sometimes these roads are driven in the coal, and the long-wall face opened out from a barrier place. Where this practice is adopted, it is usually due to the fact that the gob or goaf does not settle down quickly, but is what is known as an "open" goaf, and consequently were the roads formed in the goaf, the leakage of air would be very considerable. A disadvantage presented by this method is the crush to which the pillars and barriers of coal are subjected. This crush, when the pillars come to be worked off, results in the production of much "small" coal. The writer is also of the opinion that there is more danger from falls of roof when working off these pillars than there is at the advancing long-wall face, as there is a dead weight of superincumbent strata lying on the pillars which their working off will release.

It may be laid down as a general principle that it is better to work the face "to the rise" than "to the dip," as there is then less tendency for the roof pressure or "squeeze" to crush the coal at the face—this is of more importance in the case of tender than of hard coal. The reasons of efficiency in respect of haulage and drainage of course also obtain. Generally speaking, in "tender" seams with a crushing roof, the wall face should be advanced at right angles to the main "cleat" or cleavage of the coal, and in the case of "strong" seams, parallel thereto. But the proper line of face is dependent more upon the inclination of the seam than on the nature of the "cleat" of the coal; and in respect of this, the following guiding rules may be noted.

If the inclination of the seam is moderate, the wall face should be advanced in a direction at right angles to the line of dip, in which case the roads are more easy of maintenance, and the face is level.

If the dip of the seam is considerable, it is advisable to advance the face parallel to the line of dip, and make the principal haulage roads in a "cross-cut" direction, viz. at a gradient half-way between the dip and strike of the seam, these being worked as self-acting inclines, the "stalls" or gates being of short breadth.

In the case of very great inclination, the wall face should probably be advanced in a cross-cut direction.

Should an early return on the capital invested in a colliery be not essential, there can be no doubt that the best and safest manner in which to work coal seams in the majority of cases, especially when the seams are flat or only moderately inclined, would be by *retreating* long-wall, that is, to drive out the main roads to the boundary and advance the face homewards towards the shaft. It may in some instances be found also to be the most profitable method of working, *e.g.* where the seam is liable to spontaneous combustion, or where the roads are very difficult and costly to maintain, but the inclination of the seam has an important bearing on the point.

EXAMPLE 1. An example may be given of long-wall working in the North of England. The average section of the seam gives 2 feet 7 inches of clean coal. There are no bands of interstratified "dirt" or stone. The roof consists of sandstone and sometimes of strong strata, and the floor of fireclay. The inclination of the seam is at the rate of 1 in 18, and its depth from the surface at the shaft is 300 feet.

As will be seen from Figs. 26 and 112, the seam was developed by driving out two, and sometimes three, winning places; one place, that which ultimately constituted the main haulage road, being driven 12 feet wide and made 6 feet high; the other place (or places, as the case might be) being 9 feet wide and 6 feet high, though it was sometimes found convenient to drive these places 12 to 18 feet wide, so as to afford stowage room for the stone shot down to make height (brushing or ripping). Connections (stentons, thirlings, or holings) were made between the roads every 44 yards, the width of the pillars of coal separating the winning places being 15 yards. Barriers of coal 35 yards in width were left on each side of the winning places in order to protect them from the crush, and, as far as possible, to prevent leakage of air (see Fig. 112). When within 200 or 300 yards of the boundary neither pillars nor barriers were left, the "fore" and "back" places being formed in the goaf, somewhat in the manner shown in Fig. 113, though this figure is illustrative of another example. The manner in which the long-wall face commenced was as follows: the "barrier place" was driven about 10 yards wide, and a stone pillaring 5 yards wide was built up against the side nearest to the winning place, and every 11 yards gateways were turned away, that is to say, the distance between the gateways "centre to centre" was 11 yards. This 11 yards of coal face, 5½ yards on either side of the centre of the gateway, was allotted to two coal hewers per shift. In order to make height for men and for the putters (boys who "put" the coal, *i.e.* drive the ponies drawing the coal tubs) and ponies, a top "caunch" was shot down (ripped or brushed) for a width of from 3 to 4 yards to each 11 yards of coal face, and a pillar 6 feet thick was built on either side of the tramway, so forming the gateways along which the putters conveyed the coal to the main haulage road of the district. Any stone left over after the pack walls were built was stowed in the waste between the packs. The width of the finished gateway was 6 feet. The roof at the face was supported by props and head-trees, and occasionally it was found necessary to set pairs of gears (props supporting a cross-bar or "crowntree").

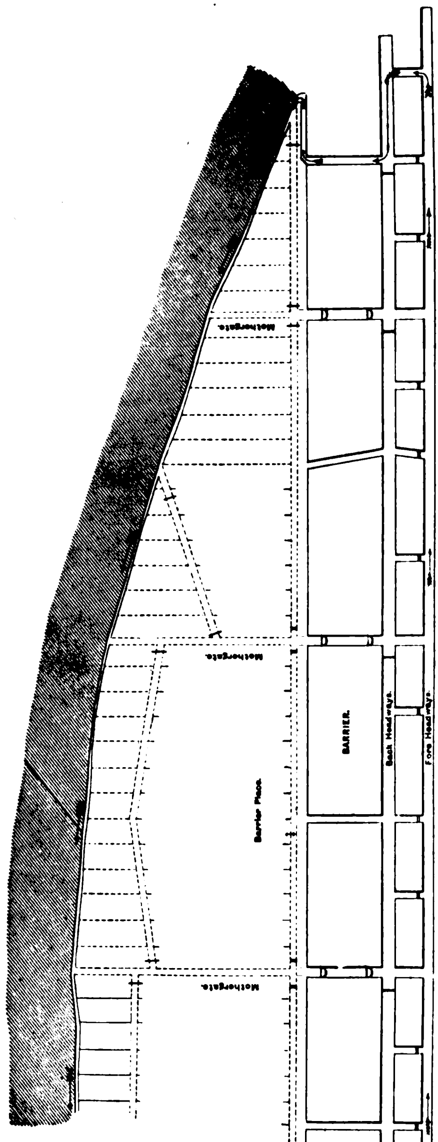

FIG. 112.—Long-wall as practised in a Thin Seam, the Main Roads being protected by Pillars and Barriers of Coal.

Under the Coal Mines Act of 1911, these are required to be set at stated regular intervals (systematic timbering), not at irregular intervals.

Usually thirteen gateways constituted a "flat" or

FIG. 113.—Long-wall Workings in a Thin Seam, the Roadways being maintained through the Goaf.

deputy's (fireman's) district, the central gateway being known as the "mothergate," all the coals from the other gateways being brought along the cross-headings to the mothergate and thence to the main haulage road. The gateways were about 80 yards in length and were cut off by the cross-heading, so as to allow of the advancement of the mechanical haulage and so as to ensure the "putting" and driving distance (with horses) being kept within reasonable limits. One method of forming a cross-heading is illustrated by the sketch on this page (Fig. 114).

The gateways and cross-headings which are so cut off are used as stowboards into which are stowed superfluous stone and dirt, except when such roads are required for return airways or travelling roads.

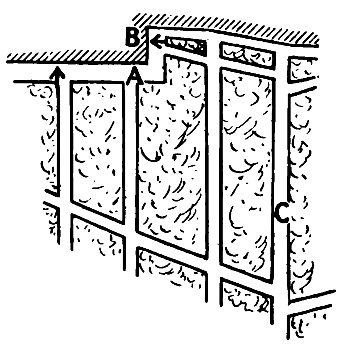

FIG. 114.—A Manner of forming a Cross-heading.

Arrows indicate the direction of the places being driven. A. This gateway is stopped 10 yards short of its full distance of 80 yards, as the remaining 10 yards of coal is worked off in the formation of the cross-heading B. C is the "mothergate."

The thinness of the seam precluding a tub-way being made along the coal face unless the roof or floor had been ripped—which would have entailed far too great an expense—the distance between the gates or stalls was not allowed to exceed 11 yards, this distance being selected for convenience in respect of carting the coals, for before the advent of face-conveyors for carrying the coal to the tubs in the gateways this was an important factor in determining the width of the stalls, *i.e.* the distance between the gateways. The use of

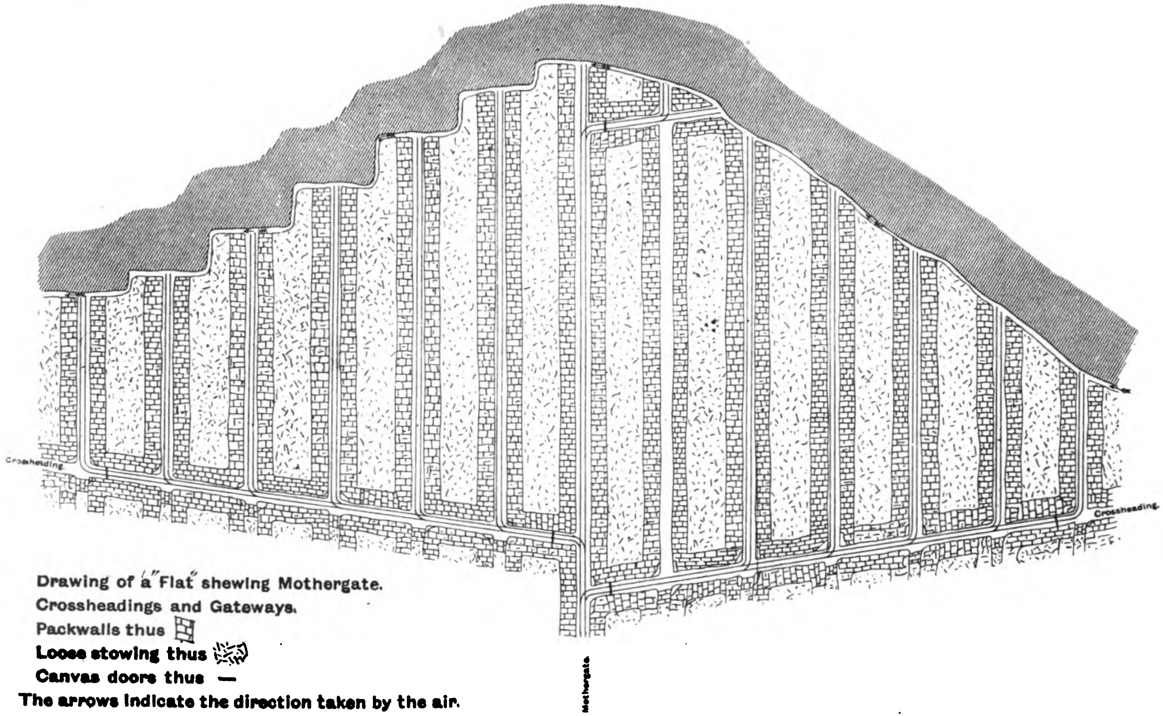

FIG. 115.—Long-wall Working in a Thin Seam, the Face being advanced in the same Direction as the Main Cleavage of the Coal.

mechanical conveyors at the face allows, of course, of a considerable distance between gateways, and a consequent saving in the cost of stonework.

The character of the superincumbent strata and the method of working were such that one of the chief considerations in connection with the long-wall system of working was achieved. The roof did not break along the line of face, but drooped gradually on to the pillaring, compressing it finally to about two-thirds of its original height; the "squeeze," as it is called, necessitating the occasional reheightening of the mothergates by carrying through top "caunches" of stone (back rippings); but when the degree of compression mentioned was attained, the roads, as a rule, did not require further attention in this respect.

Fig. 115 shows another method adopted in working the same seam, no pillars or barriers being left.

EXAMPLE 2.—The following is a description, taken from a colliery in Northumberland, of a notable example of the long-wall method of working where the coal is mechanically cut and conveyed along the face, and where an admirable system of supporting the roof is in operation.

The seam worked is the same as that referred to in the last example, but at a different colliery. Its depth from the surface at the shafts is 104 yards, its inclination nearly level, and its average thickness about 3 feet. The roof, which is composed of "blue metal" with "post-guilles" (*i.e.* shale with bands of sandstone), is a fairly strong one. The floor is also composed of blue metal, but between the coal and the roof proper there is a band of what is locally termed "following stone," that is, soft stone which either naturally falls away as the face advances or is so broken and unstable that it has to be taken down forthwith. The thickness of this stone is from 10 inches to 12 inches, and it contains many slips and breaks.

The faces are arranged as shown in Fig. 116, the "mothergates" being driven 4 yards wide into the solid coal in advance of the faces so as to provide space for the tubs. The height of the "mothergates" is from 8 feet to 9 feet, the height being made by taking up bottom, so as to allow of the top of the tubs coming just beneath the jib of the conveyor. In the "barrier gates," the height of the roads is 6 feet, for, as the conveyors do not deliver

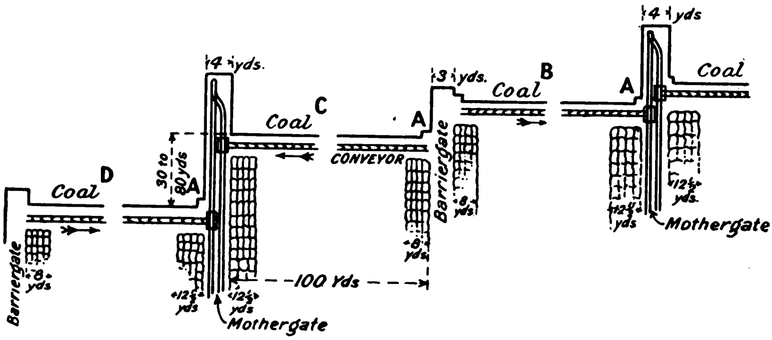

FIG. 116.—An Arrangement of Long-wall Faces for Mechanical Coal-cutting and Conveying of Coal.

into these roads, the greater height is not required and the height is made by taking down *top* stone.

The distance between the gateways is from 90 yards to 100 yards, the use of conveyors allowing of this greater distance as compared with the last example. An advantage, from a safety and economic point of view, resulting from this arrangement, is that the total length of roadways to be supported is lessened owing to the fewer gateways. The coal is undercut with disc (Diamond) mechanical coal-cutters, one cutter cutting from gateway to gateway and serving each 90 yards or 100 yards of face, as the case may be. After the forward "cut" has been broken down and then removed by the conveyor, the backward is commenced. The type of conveyor in use is the "Blackett." It is made up of iron troughs each about 6 feet in length, along which scraper links are drawn, either by electrical or compressed air power, to the gateway, where they pass over a jib, the coals which are loaded on to the convéyor being shot into tubs under the jib. After the cutter has commenced, the conveyor at that end is moved up to within 9 inches of the coal

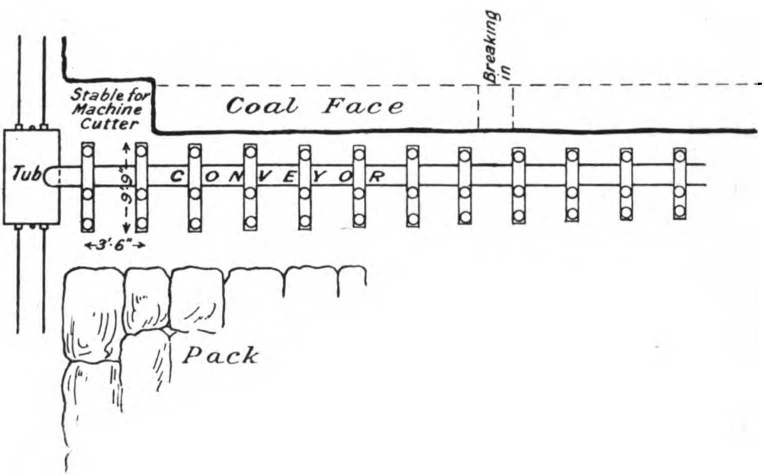

Fig. 117.—Position of Timber Supports at Face in Fig. 116 after the Machine has cut across the Face.

face, and breaking down and filling operations can be commenced in rear of the advancing cutter. It is customary, however, to first cut right across the whole 90 yards or 100 yards and then advance the conveyor and timbering. When the cutter has passed along the width of face allotted to it, it is stabled in a place specially arranged for the purpose (see AAA, Fig. 116) until the web of coal which it has cut has been broken down and filled away, when it makes the return cut. The cutter having completed its journey across the face, and the conveyor and timbering having been advanced, a shift of shot-firers enters the mine and shot-holes at various points along the face are drilled, charged, and fired; the shot-firers being succeeded by fillers, who fill the coal into the conveyors.

Fig. 117 is explanatory of the mode of timbering at the face; the illustration representing the position of the supports after the machine has cut across it, the conveyor advanced, and the breaking-down shots fired. As the coal is filled away, it will be seen that a row of crowns (bars) supported by props is set in advance of the last row (Fig. 118). When the conveyor is again advanced, which, as has been stated, is done section by section, a middle prop is set under the advanced row of crowns, the prop nearest the conveyor being knocked out to allow of the advancement of the conveyor section. When the advancement has been accomplished, the crown is again "ended" and the middle prop removed.

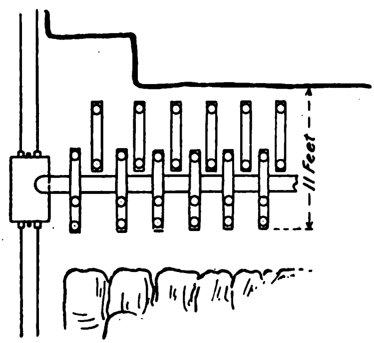

FIG. 118.—Descriptive of the Mode adopted of advancing the Supports in Fig. 117.

The height of the cut is 5 inches, and its depth 4 feet 3 inches. Wedges are placed in the cut every 5 feet apart to hold the coal up in case of weakness. As many as ten complete cuts have been made across a face in a fortnight (*i.e.* in eleven working days), or, say, a rate of face advancement of 20 feet per week.

The packs are built of the stone taken up to make the requisite height of roadway. They are 12½ yards thick on either side of the "mothergates," and 8 yards on either side of the barrier gateways.

The stall faces are stepped in the manner shown for the purpose of delivery of the coals. Obviously it would not be satisfactory from a safety and from other points of view to have the conveyors so arranged as to deliver directly opposite each other; as contributing to congestion and to difficulties in the service of the tubs, and as requiring too great a space. As it is the roof pressure on the "mothergates" at these points is considerable, and to support it, balks are set with a steel girder between, with running battens held up by three props as in Fig. 119.

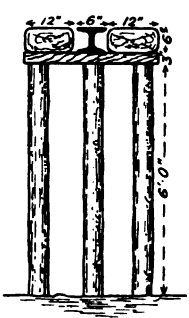

FIG. 119.—Mode of supporting the Roof at the Delivery End of a Conveyor.

EXAMPLE 3. *Yorkshire.*—In this case the seam worked is 4 feet 3 inches thick, with a band of fireclay averaging 8 inches in thickness. Above the seam is a bed of sandstone 40 yards in thickness. The depth from the surface at the shafts is about 700 yards. The seam was originally worked by the bord and pillar method; but, owing to the pillars being crushed by the great weight coming on them and the consequent difficulty in maintaining the roadways, the long-wall method was introduced. The gateways are 33 yards apart, with side packs 6 feet wide on each side and a waste pack between. The cross headings are turned away from the "mothergates" every 110 yards, and are also supported on either side by packs 6 feet wide; the pack walls on either side of the "mothergates" being 9 feet wide. The holing (bannocking) is done in the fireclay band. The "face-ripping" to make height and obtain stones for packing is about 3 feet thick. It is made in the roof and kept at a distance of about 7 feet

6 inches back from the face. Owing to the subsidence which takes place as the face advances, it is necessary to carry through a second or back ripping, as it is usually termed; this is done by shooting down the roof stone to the extent of 2 feet in thickness.

The "face weight" is not great, as the roof bends down in the goaf and settles evenly on the packs.

The roof is supported at the face by three rows of props, 5 feet long and 5 inches in diameter at the small end, capped with small lids, and set in the order shown in Fig. 120.

EXAMPLE 4. *Yorkshire.*—The particulars of this

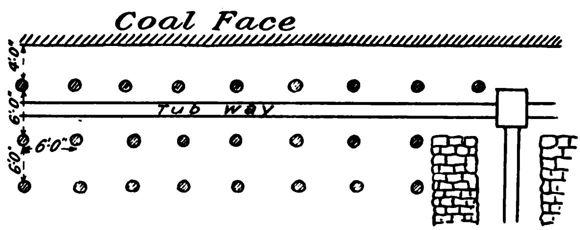

FIG. 120.—Timbering at a Long-wall Face in a Yorkshire Colliery.

most interesting example were provided by Sir W. E. Garforth, the eminent mining engineer.

The seam is practically level and the strata is very slightly faulted. The depth from the surface at the shafts is 520 yards. The seam, which is 3 feet 3 inches thick of coal, has a very good roof, the stratum immediately overlying the seam being a bed of blue bind (blue stone—strong shale), 30 feet in thickness, a thickness of 4 feet of which is taken down in the ripping.

The floor is a bed of fireclay, 7 inches thick, in which the mechanical coal-cutters "hole" or undercut the coal to a depth of 5 feet to 5 feet 6 inches, the height of the "cut" being 5 inches.

A *straight* face is advanced "on end"; the distance between the gateways is 33 yards centre to centre, and these are cut off every 176 yards (8 chains) by "slants," as the cross-headings are locally termed, which are made at an angle of about 35° to the "mothergates."

The gateway pack walls are made 5 yards in width, the middle waste packs being 3 yards thick, there being intervals of space (waste) between side and waste packs of 8 yards. The fireclay cuttings are cast into the waste.

A remarkable feature in connection with this instance of long-wall working is the rigid straightness of the face, the whole line of advance being at right angles to the direction of the gate roads; and, seeing that the coal is cut mechanically, it is easier to maintain regularity in this respect than if the face were hand holed. It follows that a *regular* line of roof breaks is *induced*, so that the position of the breaks is known, and the supports can be placed accordingly at regular intervals, and with greater certainty of securing safety than if the breaks in the roof were irregular and their position uncertain. As Sir W. E. Garforth has said:[1] "After an excavation has been made in or under the seam to induce the upper part of the seam to fall, the roof, or overlying stratum, is thrown upon the remaining portion of the coal face. As the width of the excavation increases, the immediately overlying stratum settles down on the coal face and pack, and a species of 'arching over' takes place in the overlying stratum, something like a girder, supported respectively by the coal face and dirt pack. As the space increases, additional weight is thrown upon the coal face and pack walls, with the result that the former is crushed, which is detrimental,

[1] "The Application of Coal-cutting Machines to Deep Mining," by W. E. Garforth. *Transactions of the Institute of Mining Engineers*, vol. xxiii. pp. 312–344.

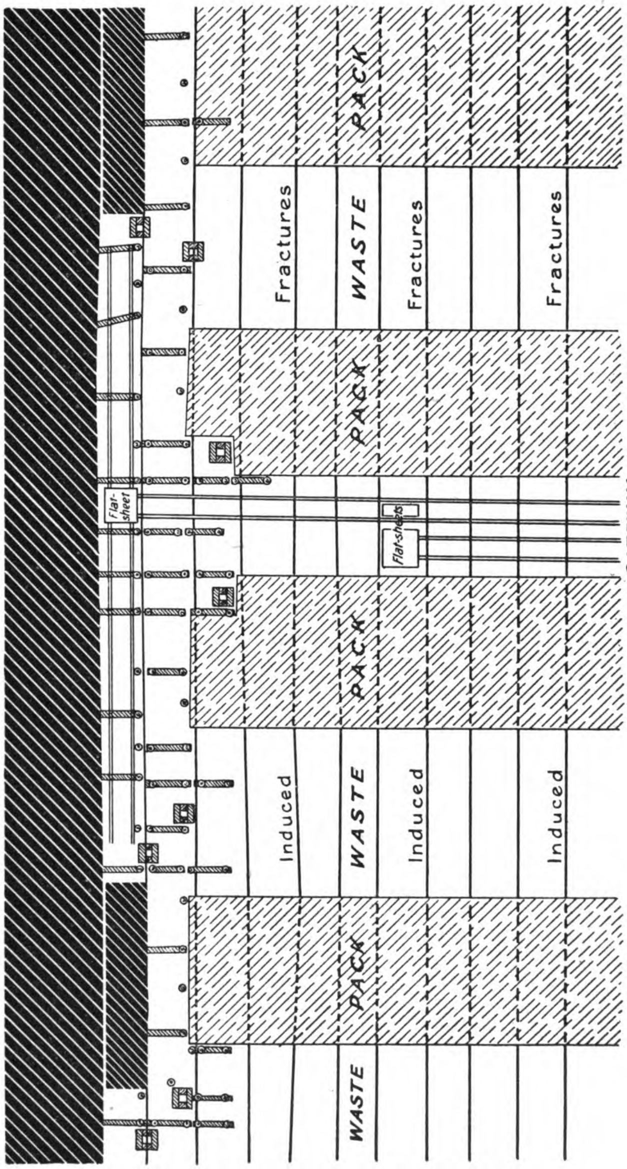

FIG. 121.—An ideal Method of Long-wall with Straight Faces as practised in a Yorkshire Colliery.

and the latter consolidated, which is desirable for many reasons connected with safety as well as profit. The longer the time to which the face is subjected to such weight, especially if its line is irregular with projecting pieces of coal, the greater will be the production of low-priced coal; and the quicker a straight fracture is induced, by which the maximum superincumbent weight is thrown on the pack, the larger will be the yield of high-priced coal. If, in addition to such a face-break, other fractures and settlements can be frequently induced, the coal is not only relieved, but the strata immediately above the pack and extending for some distance into the goaf become disintegrated, with a greater tendency to settle down quickly and vertically upon the pack walls than when the cohesive strength of the overlying strata is maintained and the weight is thrown forward on the coal face."

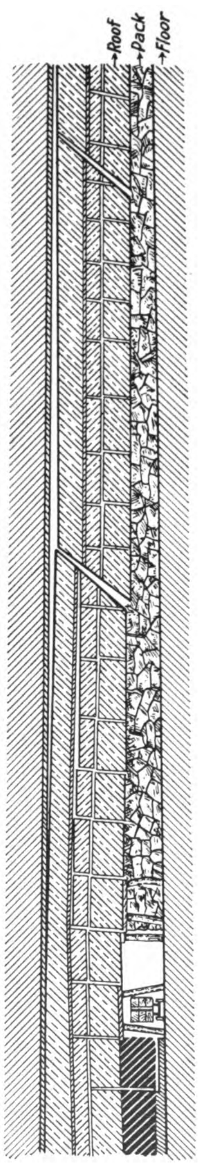

FIG. 122.—Section showing regularity of induced Fractures secured by an ideal System of Long-wall with Straight Faces.

Fig. 121 shows the position of the pack walls and face timber, whilst Fig. 122 illustrates in section the effect on the roof of preserving a straight line of face. The chocks, which are of oak, elm, or poplar, are 22 inches by 5 inches square. They are set in position and advanced alternately, as shown in Fig. 121.

The props are from 3 feet 3 inches to 4 feet 8 inches high. Usually they have 5-inch tops tapered at the bottom to prevent splitting, a practice largely adopted in many mining districts in the United Kingdom. Top lids are used with the props, which are frequently set with foot lids also. The coal when cut settles down regularly on the sprags, which are slipped into the cut at intervals of 5 feet, and side stays in the manner shown in Fig. 123 are also used to keep up the holed coal.

The rate of advance of the face is about 7 feet a week, as three cuts of about 5 feet are made across the face in a fortnight.

The shifts are arranged in the following succession: coal-cutting and filling, ripping, filling.

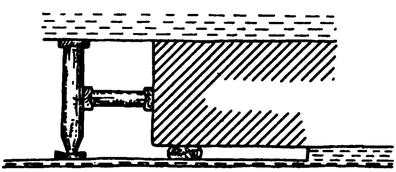

Fig. 123.—Manner of supporting the "holed" Coal in a Yorkshire Colliery.

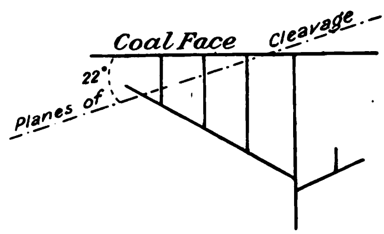

Fig. 124.—Sketch Plan of a Portion of a District worked by Long-wall in a Nottingham Colliery.

Example 5. *Nottingham.*—The depth from the surface of the seam in this case is 220 yards at the shafts, and in the deepest place in the workings, 300 yards. The section of the seam is as follows:

Roof: Bind.

	Ft.	In.	
Coal	0	9	
Dirt	0	6	
Coal	1	1	
Dirt	1	6	
Coal	5	0	worked.

Floor: Fireclay.

The roof is not a strong one, and, if allowed to stand unsupported even for a very short time, shows signs of breaking.

The distance between the gateways is 50 yards, centre to centre, and the cross-headings are slanted in the manner shown in Fig. 124. The coal is hand-holed, and is kept in as straight a line as a hand-holed face can be kept. The rate of advancement is between 7 and 8 feet per week. The first, or face ripping, which is 2 feet thick, advances from 4 to 5 yards in rear of the face; the second, or back ripping, which is 3 feet thick, is from 40 to 50 yards back from the face ripping. The coal is worked in a "cross-cut" direction, the line of face forming an angle of about 22° with the plane of cleavage.

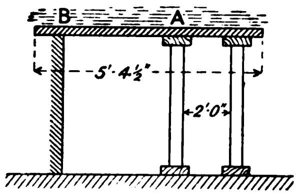

FIG. 125.—Use of Steel Supports at a Long-wall Face.

The manner of supporting the face is of special interest. For this purpose rolled steel bars are used, 5 feet 4½ inches long by 5 inches wide, by 1⅛ inch thick, weighing 50 lb. to the yard; these are held up by steel props (H section), 4 feet 3 inches long by 5 inches by 4 inches.

The distance between the end of the pack walls (4 to 5 yards wide) and the face is about 10 feet. Two rows of supports are always maintained at the face. The supports in the waste and roads are not withdrawn until the packs are "topped." The following is the manner in which the supports are advanced: one end of the steel bar is "stamped" into the coal face (B, Fig. 125), the other end being supported by a steel prop, and the steel bar is "middle set" (A, Fig. 125) when the face is sufficiently advanced to allow of it; the middle prop being finally advanced to the further end of the bar. The lateral distance between the supports is 3 feet 6 inches, and two rows are always maintained (see Fig. 126), no supports being taken out until the face props and bars have been set up. All supports are withdrawn by means of a "ringer and chain," "dog and chain," or a "Sylvester" prop withdrawer.

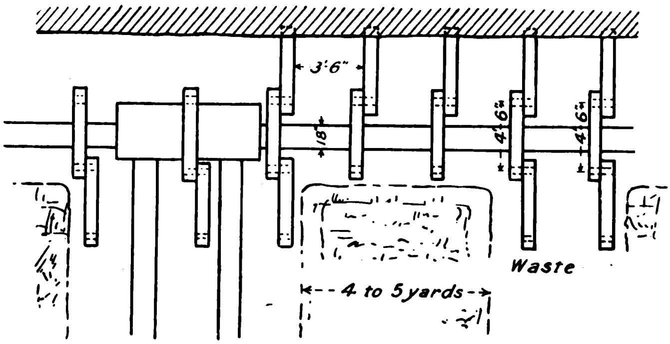

Fig. 126.—Plan showing Steel Supports at a Long-wall Face of a Nottingham Colliery.

Example 6. *South Wales.*—The seams worked have the following section:

The Five Feet Seam.—Roof clift with 3 to 8 inches of "bat"; below it, seam coal, 4 feet 1 inch.

The Nine Feet Seam.—

		Ft.	In.	
Roof	Rock	7	3	
	Clift	15	5	
	Clod	1 to 7 inches.		
Seam	Coal	3	2	
	Clod			1 to 5 inches
	Coal	2	1	
		5	3	

Floor: Fireclay.

The dip of the seam is at the rate of 1 in 24, and its depth from the surface considerable.

The seams are in both cases worked by the system of long-wall, common to South Wales and Northumberland, the stalls being 13 yards wide centre to centre,

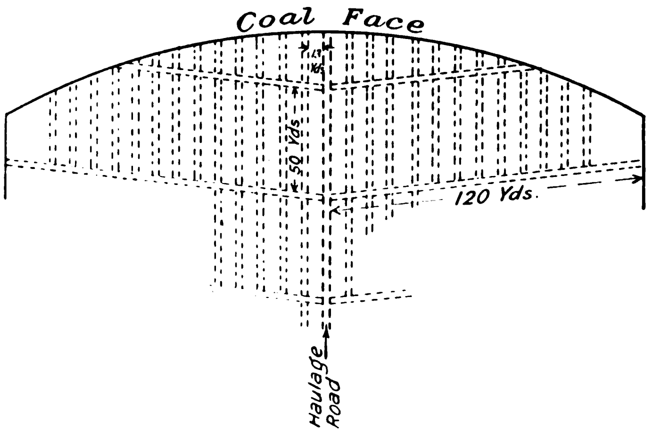

FIG. 127.—Plan of Long-wall Workings in a Welsh Colliery.

the cross-headings cutting them off at distances of 50 yards at an angle somewhat less than 90° (see Fig. 127).

The packs are built as shown in Fig. 128, the side

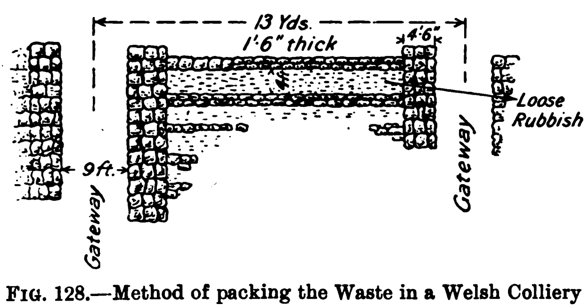

FIG. 128.—Method of packing the Waste in a Welsh Colliery worked by Long-wall.

or gateway packs being 4 feet 6 inches thick. Cross-packs which are put in, 1 foot 6 inches in width, every 4 feet, are usually built of a single stone, loose rubbish being thrown in between them.

The rate of advance of the face is, in the 5-feet seam, 105 yards, and in the 9-feet seam 75 yards, per annum.

The timbering at the face consists of posts (props) and lids, the latter being made by the colliers out of old wood. Posts and "flats" (bars) are set close up to the ripping; and, under the lip of the ripping, as ordered by the fireman, cogs (chocks), 4 feet square, are set at both sides of the end of the stall road (gateway); about 4 or 5 feet from them, smaller cogs, 2 feet 6 inches square, are set. The maximum distance between all timber supports is (9-feet seam) 5 feet 6 inches.

The colliers set the face supports, and those at the ripping in the roads, and build the packs; besides which, they do the first ripping also, though there is not much to do. Very little timber is drawn out of the waste.

A feature peculiar to the steam coal seams, in particular in South Wales, is the number of slips in the coal. These usually are inclined from the vertical and pass into the roof, and are a source of much danger; they may be either "back" or face slips. Very little coal-hewing, as understood in the North of England and Midlands, is carried out in these seams, the coal being got mostly by *pulling* it off the face. Mechanical coal-cutting is not therefore necessary, nor is it often practicable owing to the character of the roof and the coal seams.

By working "on end," the danger resulting from the slips (falls of ground) is lessened.

Modified Long-wall as applied to Working a Seam of Moderate Thickness and Inclination. —There is a modification of long-wall working which is sometimes practised, chiefly in the North of England, and perhaps to a greater extent in the past than at the present time (the writer has had experience of it in Durham), which consists in taking a series of slices or lifts off the solid coal. The gateway is advanced 6, 7, or 8 yards into the solid coal, and a lift turned away at right angles is driven half-way across to the

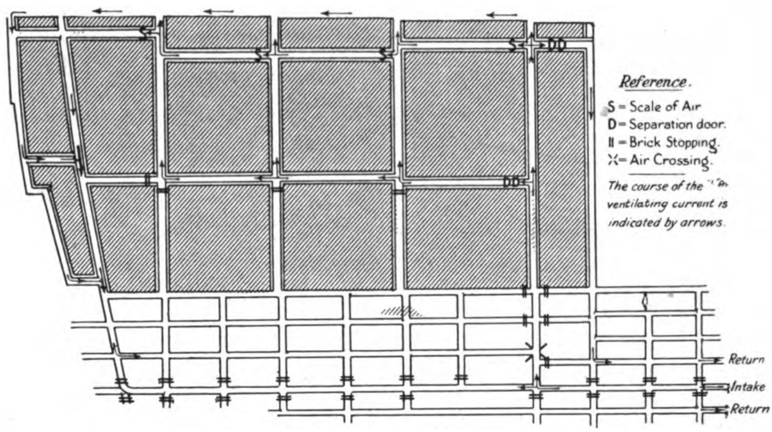

FIG. 129.—A Method of modified Long-wall as practised in a Durham Colliery.

next gate road, that is, for a distance of say 60 yards, the gateways being 120 yards apart. Fig. 129 represents the plan of a district worked by this method at a

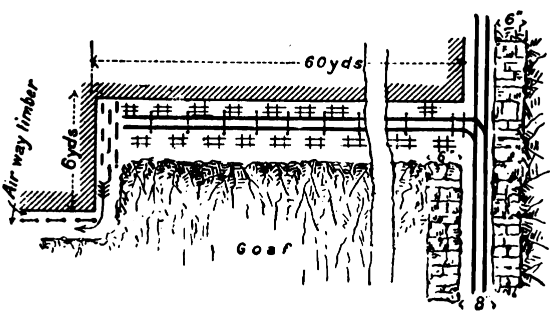

FIG. 130.—Detailed Sketch of a "Lift" in modified Long-wall as practised in a Durham Colliery (from Bulman and Redmayne's *Colliery Working and Management*).

colliery in the county of Durham, and Fig. 130 is a plan showing the details of one of the lifts or juds (the slices being termed "lifts" if driven headways, and "juds" if driven bordways). The width of the jud in this case was 6 yards, and that of the gateways between the packs 8 feet, the packs—only side-packs were built—being 6 feet wide. Cross-gates were made at intervals as shown.

For the successful working of this method a good roof is a necessity, as otherwise the ventilation is impeded. The method allows of greater concentration of the workmen and the driving of less narrow places as compared with bord and pillar. It also utilises the top pressure in assisting to get the coal. The method has been adopted chiefly at collieries where it

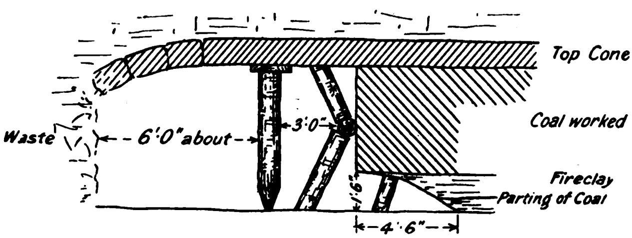

FIG. 131.—Manner of supporting Coal when undercut.

has been customary in the past to work by the bord and pillar system, but in which that system has been abandoned owing to the hardness of the coal. It has the advantage, as compared with ordinary long-wall, that less stonework is necessary under like conditions in respect of height of seam, &c., as the gate-roads are so much fewer, area for area.

Examples of Timbering at the Face.—Various modes of supporting the coal and roof at the face have been indicated in the foregoing examples; others are illustrated below.

Fig. 131 shows an arrangement for supporting the coal by means of "cocker sprags," set 6 feet apart, and upright or holing sprags set at the same distance, the roof being supported by means of lids supported by props, the former being placed at right angles to the line of face so as to cross the line of fissure. The distance between the props is 5 feet.

Figs. 132 and 133 show an arrangement in which the bars or a short inclined stays are notched in the coal.

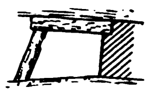

FIG. 132.

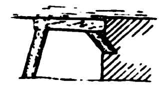

FIG. 133.

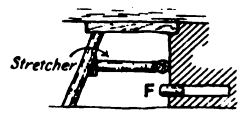

FIG. 134.

FIGS. 132, 133, and 134.—Various Arrangements of Face Supports in a North Staffordshire Colliery.

Another arrangement, also adopted at a colliery in North Staffordshire, is illustrated in Fig. 134. Before the coal-cutting machine is allowed to cut the coal, each of the gob side "posts" (props), set under every drift-bar, has a "stretcher" set between it and the face, and the man in charge of the mechanical coal-cutter has to see that sprags are put into the "cut" every 5 feet.

Corrugated iron bars have been adopted of late years for supporting the roof at gate ends at the inbye side of the ripping. Four of these are supplied to each gate, and the bars are supported in the manner shown in Fig. 135 at a maximum distance of 5 feet apart, the last one being advanced as the face advances, so that three such supports are always set, the object being the better support of a part of the face where much work is done in respect of turning of tubs, &c., namely, the flat sheets. The thickness of one seam where this mode of support is carried out is 7 feet 2 inches.

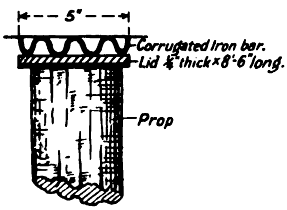

FIG. 135.—Corrugated Iron Bar used for Roof Support at the Inbye Side of the Ripping.

CHAPTER VI

THE LONG-WALL SYSTEM AND ITS MODIFICATIONS AS APPLIED TO WORKING INCLINED SEAMS AND TO THE WORKING OF THICK SEAMS

The Long-wall System as Applied to Seams of Moderate Thickness but Highly Inclined

IF steeply inclined seams are worked by long-wall, it is usually in a modified form. For instance, it is seldom, if ever, found practicable to have long unstepped faces in the case of very highly inclined seams; indeed, when the seams have so steep a gradient as to simulate in this respect a metalliferous lode, the method of working is practically the same as that adopted in working metalliferous veins, viz. by cross-cutting from the shaft and driving a succession of levels in the seam or seams and working the coal between the levels by overhand stoping. At lower inclinations, between 20° and 50°, a stepped face will usually be advanced to the full rise of the seam, the wrought coal being lowered down the gateways, which are self-acting inclines, to the level below. With flatter seams, say at inclinations below 15°, it is sometimes found convenient to work a continuous unstepped face. The following examples illustrate some typical cases:

EXAMPLE 1.—In this example, which is illustrated by Figs. 136 and 137, and which may be taken as representative of the common mode of working a seam of considerable though not very great inclination, the seam, which is 5 feet 6 inches thick, has an inclination of 1 in 4 (14°). It will be observed that the main roads are made on the strike of the seam, whilst the face is advanced at a slight angle with the full rise, so as to obtain a satisfactory gradient for "jigging" the coals down the gateways on to the levels. The pack-walls are built 5 yards wide, the waste spaces between packings being 7 yards wide. Owing to the inclination of the seam being high, it is found necessary to place wooden chocks in the gateway packs at regular intervals as shown. The height of the "ripping" is 4 feet. Notice the angle of the line of the roof fracture shown in Fig. 137. The mode of timbering the roads is illustrated in the cross-section, and is that known as herring-bone timbering.

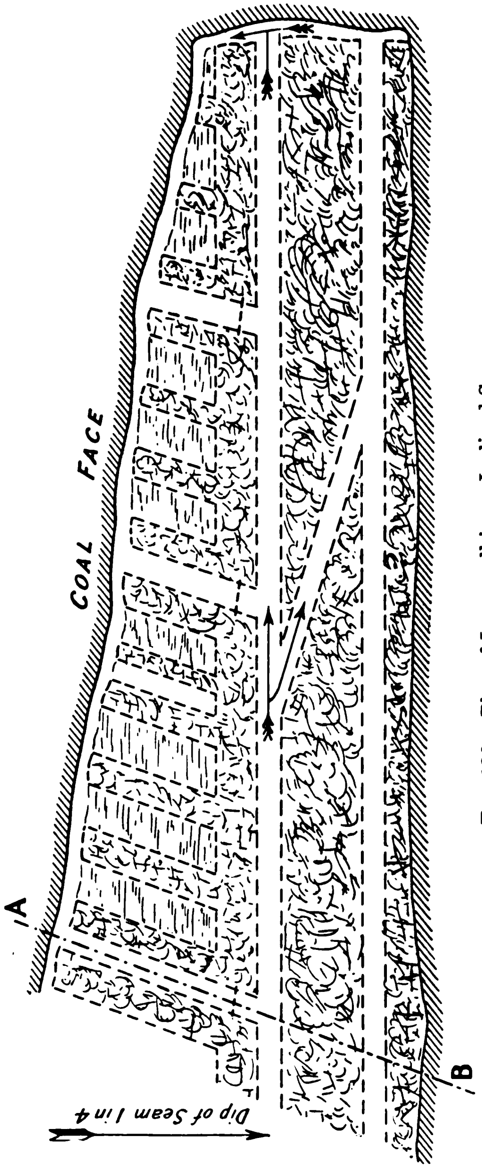

FIG. 136.—Plan of Long-wall in an Inclined Seam.

EXAMPLE 2. *Bristol Coalfield.*—In the Bristol coalfield the seams worked are from 12 inches to 2 feet 6 inches thick, and their inclination varies between 20° and 30°. The system of long-wall adopted is that of stepped long-wall advanced to the full rise (see Fig. 138), the width of the separate faces or stalls being about 100 feet—that is to say, the stall or gate roads are 100 feet apart. In the case illustrated, the seam is 2 feet 6 inches thick, and has an inclination of 20°. A 3-feet thickness of ripping is taken down in the headings to make height necessary for the passage of horses and tubs. The stall roads are made 6 feet high and 9 feet wide, and are cut off every 300 feet by a fresh level.

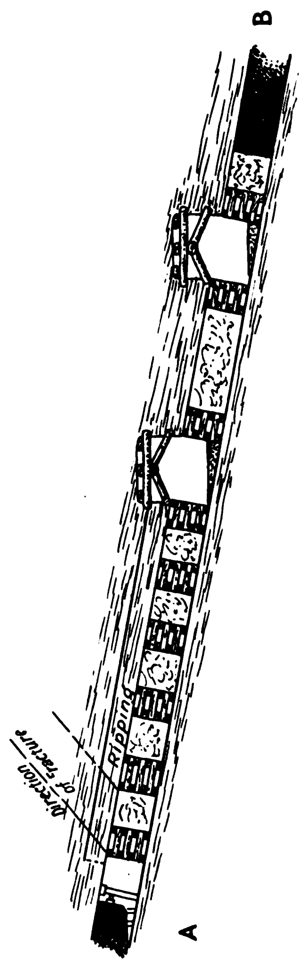

FIG. 137.—Section along Line AB in Fig. 136.

EXAMPLE 3. *Scotland.*—The seam is 2 feet 4 inches thick, the roof being composed of shale of the kind termed "blaes" in Scotland, the floor consists of a thickness of 2 feet 4 inches fireclay with hard sandstone below. The depth from the surface at the point where the seam was struck by the level at which the writer inspected the workings was 620 yards vertical; at this point the inclination of the seam was 70° from the horizontal.

The seams are won by vertical and inclined shafts, and by driving out cross-measure drifts to intersect the seams, in which levels are driven at intervals of about

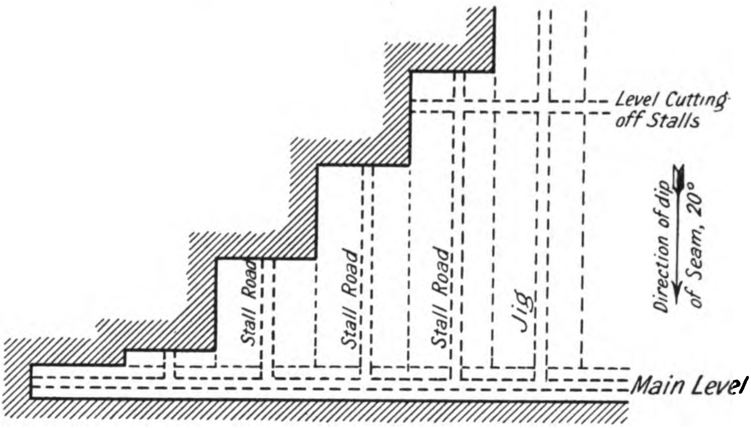

FIG. 138.—Plan of Long-wall Working as practised in a Highly Inclined Seam in the Bristol Coal-field.

30 yards. The seam worked off the side, as in overhand stoping in metalliferous mining, until the level above is reached, the coal being shot down into the level

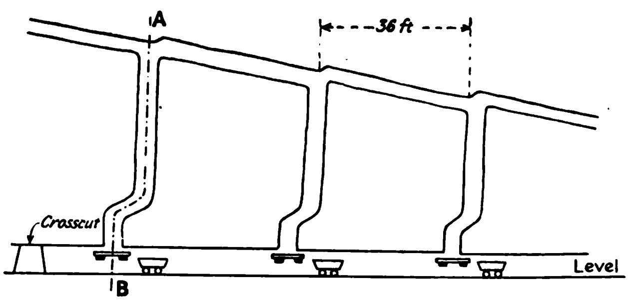

FIG. 139.—Plan of Working of very Highly Inclined Seams in a Scotch Colliery.

below (see Fig. 139). The shoots, which are 3 feet to 3 feet 6 inches square, are made on the full rise of the seam with a "blind chock," as shown in the figure, put in about 9 feet above the loading stage, so as to check the fall of the coal. The distance between the shoots is 12 yards. The sides of the shoots are supported by dry-walling and timber chocks, the wastes being filled in with timber and rubbish, which forms the floor on which the coal-getters stand when working at the face. The face timbering is done by means of stretchers (see Fig. 140) set 3 feet 9 inches apart, lids being used. Whenever breaks and slips are suspected or occur,[1] the packs, timber, &c., above the levels are carried on strut pieces set from the roof to the floor of the seam. They become so compressed as hardly ever to give way.

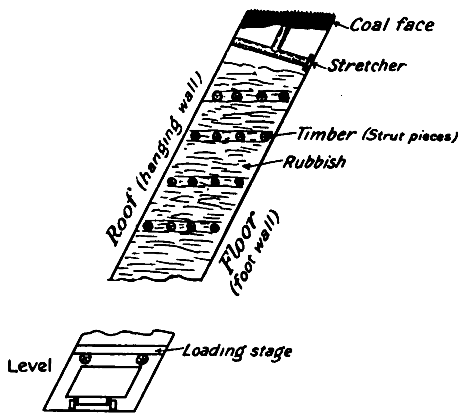

FIG. 140.—Section along Line AB in Fig. 139.

The men travel up and down the shoots and pull up the timber by means of ropes: these "roads" are also used for the ventilation of the face.

A fact worthy of notice in respect to the working of this and, I believe, other highly inclined seams, is that when the crush comes on, the roof (which is really the "hanging wall") is not affected as in the case of seams lying at an angle nearer the horizontal.

EXAMPLE 4.[2] *Belgium and France: (a) When the Angle of Inclination approximates to the Vertical.*—The

[1] Since the coming into force of the Coal Mines Act, 1911, lids will require to be used universally at the mine.

[2] See also "Notes upon Coal and Coal Mining in Belgium," by W. S. Gresley, in the *Journal of the British Society of Mining Students*, vol. x.

coal seams of the Belgium coal-fields, though very numerous, are in most instances very thin, greatly contorted, and very difficult to work. The seams are won by cross-measure drifts (*étages*) 10 feet wide and 9 feet high, driven out from the shafts, 55 to 60 metres (169 to 197 feet) apart. When a seam is struck, roads are turned away right and left and driven in the seam on the level course, a place being put up to the level above for the purpose of ventilation.

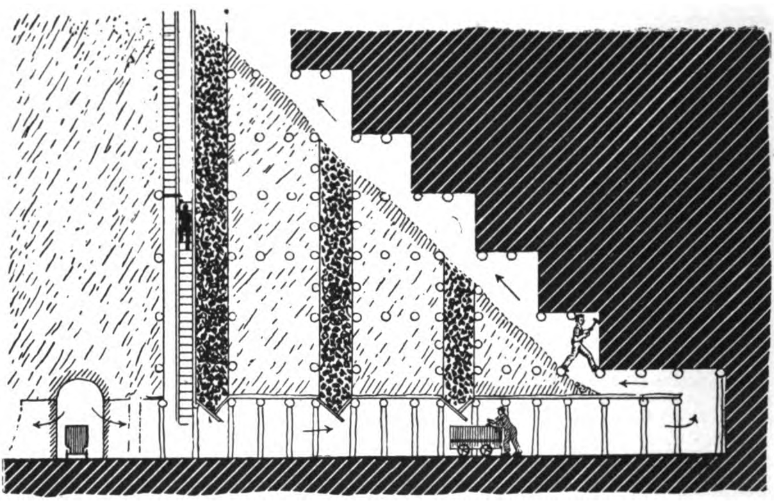

FIG. 141.—Elevation showing a Mode of working Thin and Vertical Seams in a Belgian Colliery (Liége Coal-basin).

Considering the case of seams which are nearly vertical (known as *dressants*), the faces (*maintenages*), which are worked much in the manner of overhand stoping, advance in a series of steps, each of a height of about 6 feet, and so inclined that the lower workmen are in advance of the upper, there being a step of 10 to 12 yards of solid coal protecting each miner from anything falling from above (see Fig. 141). The miner cuts up the *sides* of the seam and wedges down the coal. There is frequently insufficient stone to pack the waste, so sticks and brushwood are also used for the purpose. The worked coal is passed down shoots to the level below and then conveyed by trams to the main levels.

A *tranche* is the extent of a seam measured along the slope of the seam and comprised between the *étages*. In some cases where the number of steps in each *tranche* is large, inclined roadways are made in the waste (*remblai*), the sides being formed of packwalls, and

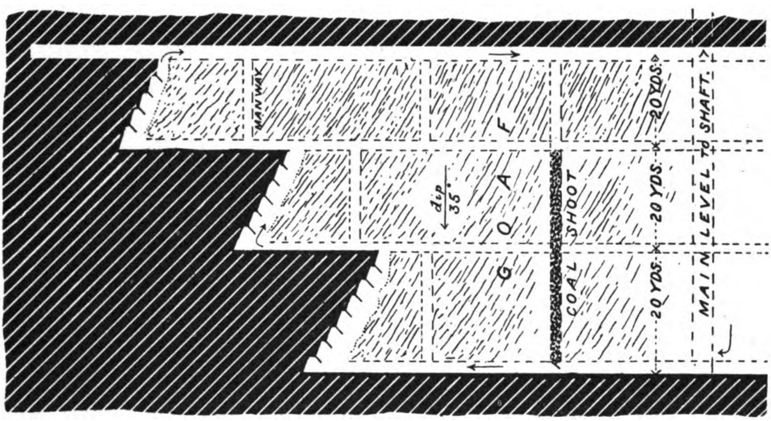

FIG. 142.—The System known as *Tailles Chassantes* in a Colliery near Liége. Seams dipping from 30° to 40°.

boards are laid on the floor in the form of a channel to allow of the passage of the coals.

(*b*) *When the Inclination of the Seam is about* 35° *to* 40°.—When the seams are thin, *i.e.* under 2 feet 6 inches in thickness, the system known as *tailles chassantes*, or long-wall worked on the level, in contradistinction to *tailles montantes*, or long-wall worked to the rise, is adopted, the latter system being practised in cases where the inclination is comparatively low, say 10°. The latter is merely stepped long-wall as we know it in our own country.

In the *tailles chassantes* (see Figs. 142 and 143) system, the distance between each *étage*, or main level, is about 60 yards, and this distance is divided by levels 20 yards apart. There are, therefore, three steps to each *étage* of 20 yards each. The coal worked by the hewers (four to each stall) slides down the face behind the men, who are

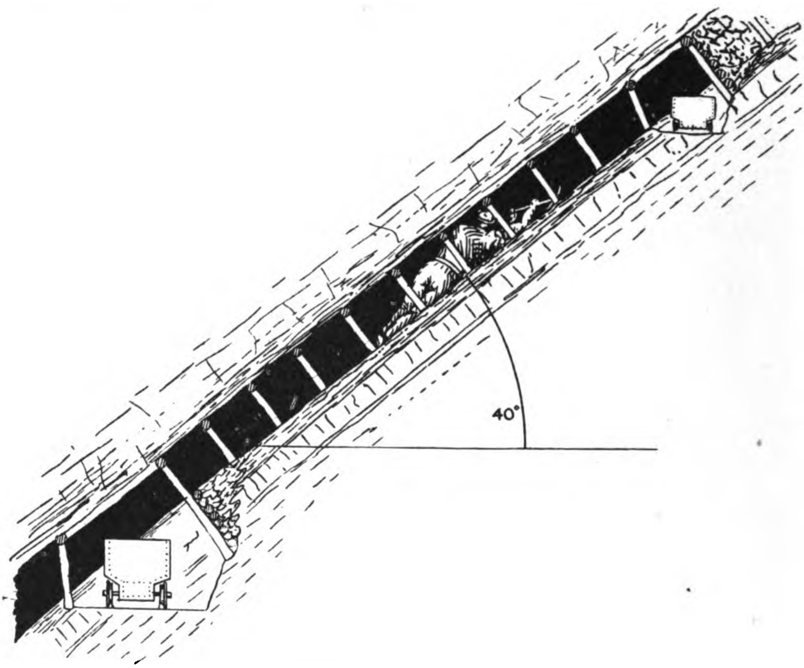

FIG. 143.—Transverse Section through a Stall or One Division of a *Tranche* in System *Tailles Chassantes* of Fig. 142.

protected by slanting boards (see Fig. 142), and is filled into trams and pulled along the levels to shoots, where it is shot down into the main levels. The higher stalls, it will be seen, are kept in advance of those to the dip.

In the case of thicker seams, the practice is to drive out parallel levels to the boundaries and form pillars by holings (thirlings, stentons, cross-cuts, &c.), and work these off towards the shafts, one stall in advance of the other, in a series of steps. This system is called *epilage* in Belgium, and in the Pas-de-Calais (Northern France) *tailles chassantes prises en rabattant*, *i.e.* long-wall advancing on the level and working home. At one colliery on the Pas-de-Calais, where the writer studied this system, the length of the face was 45 to 65 metres (50 to 70 yards), and the number of men in one face fifteen, with an output of 75 tons per nine hours.

Long-wall as applied to Working Inclined Seams of moderate Thickness in the Pas-de-Calais.—Allusion has been made above to the method of working by stepped long-wall in Belgium and in the Pas-de-Calais, and some further particulars may be given of the methods practised in the latter field.

EXAMPLE 1. *Courrières Collieries.*—The inclination of the seams at the Courrières Collieries—which furnish an excellent example of the system characteristic of the field —is usually from 10° to 20° from the horizontal, but whereas parts of the seams are nearly flat, in other places they are completely overturned, and here the dip is often as much as 50° to 60° (see p. 175).

The seam in one case inspected is 5 feet 10 inches thick and 1161 feet from the surface at the shafts. The coal is very tender.

In one case inspected by the writer the roof is composed of loose shale, and might properly be described as a *bad* but not a *heavy* roof.

The method of working adopted was that of faces advancing on the level course (*tailles chassantes*), although in the Pas-de-Calais field the other method, viz. faces advancing to the full rise (*tailles montantes*) is also practised. Each step was from 39 to 46 feet long, and stepped to the extent of from 32 to 39 feet, there being a gate road to each step, four men working in each stall or face. The upper section of the seam, 2 feet 7 inches thick, is worked slightly in advance of the lower section.

Figs. 144, 145, 146, 147, and 148 illustrate in detail the system of support in vogue at the Courrières Collieries. The method of supporting the roof is a double one, viz. the temporary support followed up by close, systematic timbering. The temporary support is carried out by means of flat-pointed, wrought-iron bars, termed

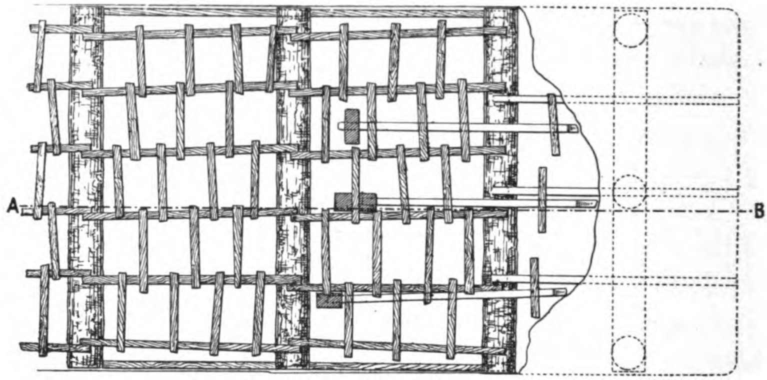

FIG. 144.—Plan showing Timbering in a Gallery.

allanges, 4 feet 6 inches long and $1\frac{5}{8}$ inches square, which are driven over "bars" or crowns (*rallanges*) and into the coal, the distance between the crown and the face never exceeding one metre (3 feet 3 inches). The four inspectors of mines who visited Courrières collieries towards the close of 1900 thus describe the method of supporting the roof at the working face: "Between the last 'bar' (*rallange*) and the actual working face the roof is supported temporarily by iron bars . . . the leading ends of which are flattened to a chisel edge. These are pushed forward till they almost touch the working face. When an advance of more than 3 feet has been accomplished under this provisional means of support light poles are put in, one end being supported by the last 'bar' and the other by a light temporary prop close to the coal, and the iron bars (*allanges*) are withdrawn. As soon as room enough in the working face has been excavated for taking the full length of a fresh bar (*rallange*), no time is lost in putting it in under the forward ends of the poles and supporting it by the usual props; the temporary props used as provisional supports

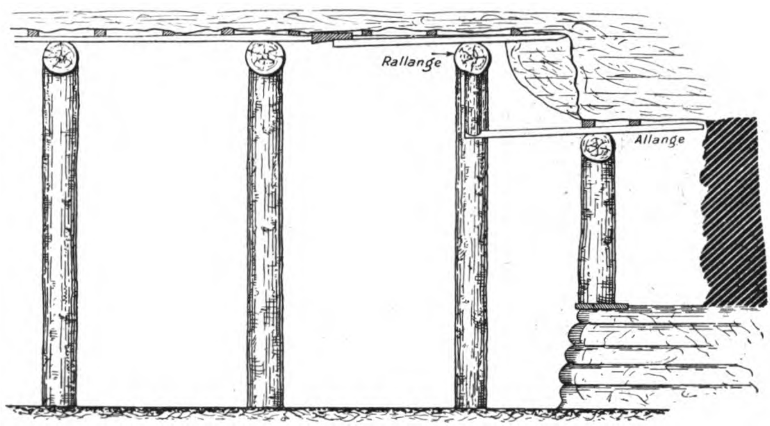

Fig. 145.—Section along Line AB in Fig. 144.

for the light poles are then taken out. The result is, that as the men work them face forward, there is no space of roof unsupported exceeding 3 feet 3 inches by 20 inches." The manner of the secondary or following-up supports is illustrated in the figures. Rows of crowns or bars (*rallanges*) are set parallel to the face and supported by props, and across the bars are laid small pieces of timber called *queues*, and across these again shorter pieces, termed *esclimbes*, when necessary (see Fig. 146).

There is a feature which may be mentioned in respect of the stowing of the goaf, namely that the material for the purpose is brought in from other seams. At that part of the workings inspected by the writer, the goaf

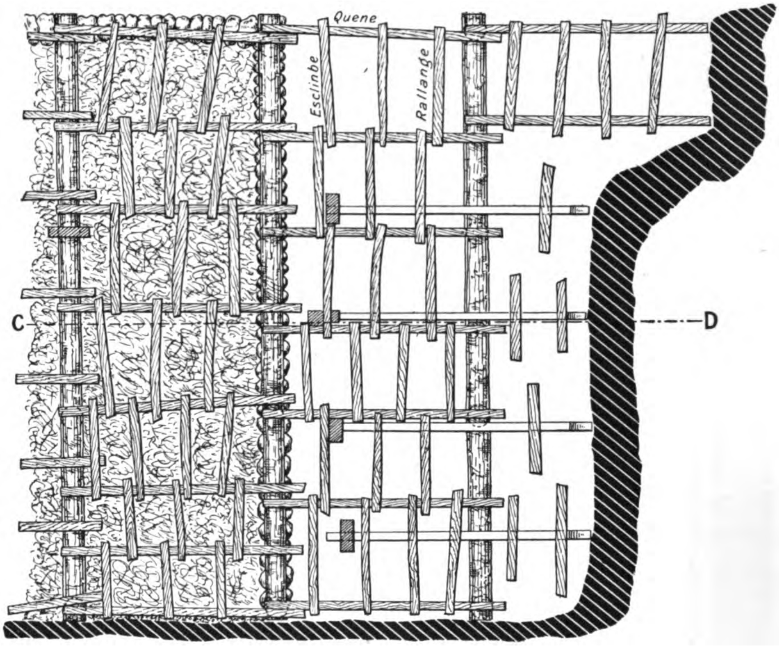

FIG. 146.—Plan showing Timbering at Long-wall (Modified) Face.

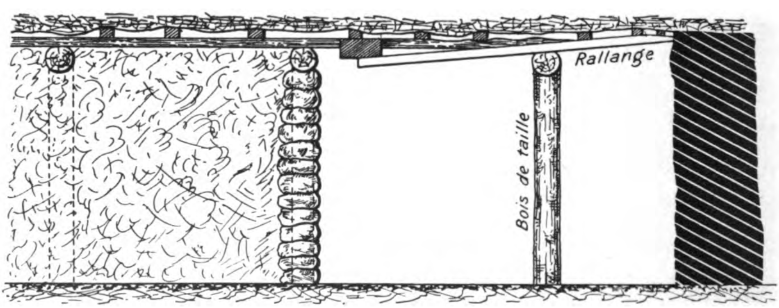

FIG. 147.—Section along Line CD in Fig. 146.

was being closely packed, though usually, he was informed, two-thirds only of it is so packed, and one-third, in the middle, left unpacked. But in no case is any timber withdrawn, except, of course, that which is advanced at the face on top of the bottom coal, and the *allanges* or iron bars. Even in other seams where the roof is good, no timber is recovered from the goaf, although the management agreed that when originally back timber had been drawn, the roof at the face, and for several metres back, was improved thereby. The reason for not drawing the timber out is the close

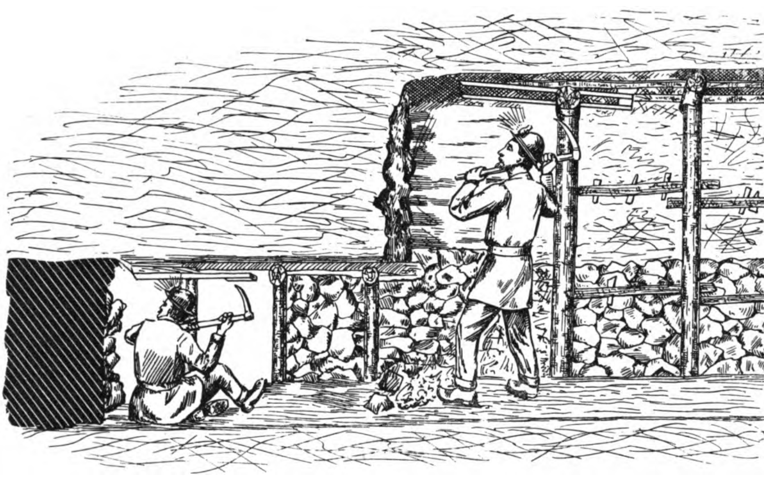

FIG. 148.—Section of a Stall showing the Arrangement of Supports at a Long-wall Face of a Thin Seam and at the "Ripping."

proximity of the seams of coal—on the average the distance apart being only 25 metres (82 feet)—so that were the timber drawn it would adversely affect the gate and other roads to such an extent as to outweigh advantages in point of saving timber, &c.

The packs are built by a special class of men in the afternoon, after the coal-getting shift has gone out of the mine.

EXAMPLE 2. *Hydraulic Stowage.*—The method employed in working at another mine in the Pas-de-Calais is interesting, on account of the fact of the utilisation of the hydraulic or flushing system for the stowage of the goaf.

The seam was 1·10 metres (3 feet 7 inches) thick, and the depth from the surface at the shafts 334 metres (1095 feet).

The method of working was that known as *tailles chassantes prises en rabattant*, i.e. long-wall retreating from the boundaries and worked on the level (see p. 165).

Owing to subsidence of the surface, due to insufficient stowage, it had been decided to experiment with the flushing process, and it was proved that with a pressure of 75 kilos[1] per cubic metre,[2] when the stowing substance was composed of:

10 per cent. sand, there was a compression of 3 per cent.

20 per cent. sand, there was a compression of 6½ per cent.

From 200 to 300 cubic metres of stowage is done per diem. The manner of carrying out the operation is as follows:

The shale or spoil is conveyed to the pit in trucks, which are raised by hydraulic power, and their contents tipped into a hopper or storage hole A (see Fig. 149), from whence two elevators B convey the debris to a shoot C, delivering into a basin D, into which water is played in vertical and horizontal jets, which washes the spoil down the pipe F, the large fragments being prevented from passing down the pipes, and so possibly choking them, by the interposition of a screen or grating E. The spout (*glassiere*) holds 5 cwt. of material, which is sufficient for the good working of the arrangement. The basin D should be small, so as to allow of obstruction being easily removed by the man in charge

[1] A kilogramme = 2·2046 lbs. [2] A cubic metre = 1·308 cubic yards.

at that spot. Experience has shown that the rubbish should be of such a nature that it can pass through an aperture of 40 mm.[1] The external diameter of the pipes conveying the stowage is 170 mm., and the internal diameter 152 mm., but the end of the pipe column is of somewhat smaller dimensions in order to allow of increased velocity of discharge. The pipes are of steel, and cost 14·50 francs[2] per metre.[3]

After the last of the supply of rubbish has been

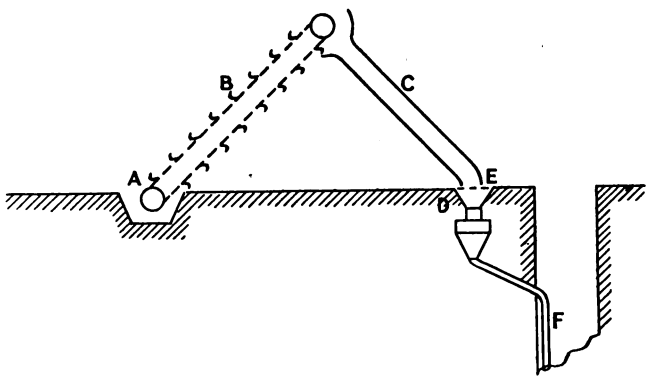

FIG. 149.—Sketch showing Surface Arrangements for Conveyance of "Stowage" Material to the Shaft.

carried down the pipes, the flow of water is continued for five minutes so as to wash the pipes clean.

After about 50,000 cubic metres of spoil have been passed through the pipes they are reversed in order that the lower may become the upper end of the column, as the lower the pipes the greater the wear and tear due to increased pressure. It has been found that for every 100 metres in depth of shaft the material can be forced along a horizontal distance of 600 metres. At this colliery the material is forced a distance of 1400 metres, and at other collieries the stowing stuff is being forced

[1] A millimetre = ·03937 inch. [2] A franc (100 centimes) = 9·513d.
[3] A metre = 1·094 yards.

a distance of 2 kilometres[1] in pipes of 15 cm.[2] diameter at the surface, and 10 cm. at the terminus.

The volume of water used with the rubbish was at the rate of 800 to 1150 litres[3] per cubic metre of rubbish. The pipes are carried right to the rise end of a face, and delivered into a trough and spout, which passes down to the lowest end of the goaf (the seam has an inclination of 17 degrees), and is gradually drawn up as the stowing proceeds. Telephones and electric signals are so arranged that the working of the elevator at the surface can be regulated to meet the underground requirements. The length of the faces was from 45 to 65 metres, and the number of men employed in a face was 15. The roof is fairly good. Frequently as large an area as 250 square metres[4] of waste is awaiting stowage.

The system of timbering at the face and stowage of the goaf is as follows:

Rows of crowns or *rallanges*, each *rallange* being 2·5 metres in length, and set parallel to the face, are supported by props; across these are set small pieces of timber or *queues*, and across these, again, still smaller timbers when necessary. The space between two parallel rows of *rallanges* (1 metre thick) is known as a *havée*. Five *havées* are formed before stowing is commenced, and they are stowed three deep at a time—that is to say, two *havées* are left unstowed, and stowage is not commenced until the face has further advanced by 3 metres.

When a *havée* is to be stowed a brattice of jute is carried on props, as shown in Figs. 150 and 151, planks 1¼ inch thick being placed between the props and the jute for the support of the latter; at the roof the jute is fastened by a wrought-iron channel girder. The props

[1] A kilometre = 3,281 feet.
[2] A centimetre = 0·3937 inch.
[3] A litre = 0·22 gallon.
[4] A square metre = 10·764 square feet.

are set in under the channel girder as shown in Fig. 152, and between the girder and the roof is a stuffing of straw. This erection forms a barrier for retaining the stowage, and is not removed until more space is ready for stowage, but the stowage sets so well that it is probable that the same system might with advantage be adopted for stowing wastes in level seams. Props, boards, and girders are drawn out after the stowage has set, and used over again, but the jute is sent to the surface, dried, and used for other purposes. The latter costs about 40 centimes[1] per

FIG. 150. FIG. 152.

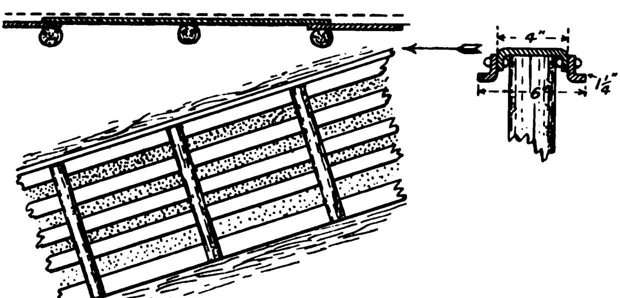

FIG. 151.

FIG. 150, Plan. FIG. 151, Elevation showing Arrangement of Brattice for Purposes of Hydraulic Stowage. FIG. 152, Arrangement of Props.

square metre, and 5000 square metres of it are used per annum at the collieries under consideration.

Alongside the level at the low end of the face the ripping from the gate road is built up as a pillar, 1 metre in thickness, so forming a wall for the hydraulic stowage to lie against.

At this colliery use is made of the *Queues d'Oburon*, so called from the name of the inventor of this kind of support, in supporting the roof and sides of inclined roads. *Queues d'Oburon* are small rods of wrought iron,

[1] About 3¾d.

¾ inch square and 2 feet to 2 feet 9 inches long, shaped and set thus (see Fig. 153). They have the effect of making a more or less rigid structure of the supports.

The system is perhaps the most perfect of all means of stowage of goaves, inasmuch as it allows of closer packing of the goaf than by any other method.

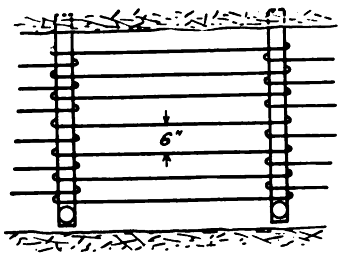

FIG. 153.—Plan of an Inclined Roadway showing the use of the *Queues d'Oburon*.

The chief advantages derived by hydraulic stowage are:

1. Less subsidence of the surface.

2. Saving of timber.

3. The keeping of a longer length of face, hence less damage to and cost of upkeep of roadways.

4. The securing of a larger percentage of round coal, the increase being estimated, in this instance, as amounting to 10 per cent.

5. Prevention of gob fires.

The Application of the Long-wall System to the Working of Thick Seams

Very thick seams cannot, as a rule, be profitably worked on the long-wall system, but there are conditions under which this method can be profitably employed in a modified form. For instance, in those parts of the Pas-de-Calais where, owing to the contorted character of the strata, an abnormal thickening of the coal is occasioned by the seam bending back, the coal is worked by a modification of long-wall.

These overlappings or foldings of a seam are termed *couchons*, and the method of working them is as follows:

At distances of 100 metres (328 feet) inclines such as AB are driven (Fig. 154) on the dip of the seam to meet

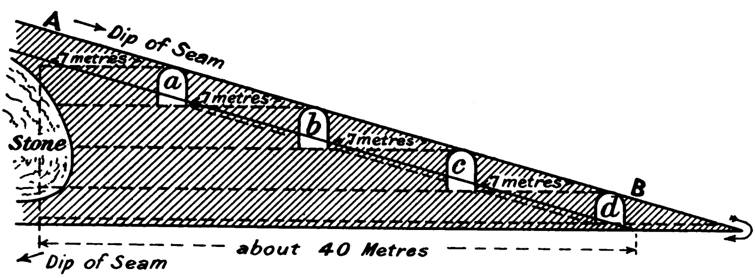

FIG. 154.—Transverse Section of Working of Folding of a Seam in the Pas-de-Calais Coal-field.

the level "D," which has been driven in advance, and afterwards the levels "*a*," "*b*," and "*c*" are driven. When the level "D" is reached, a strip of coal 4 metres (13 feet) in width is taken off parallel with the incline (see Figs. 154, 155, 156, and 157); 2 metres of this is packed, and another two, and so on until a face is formed which can be advanced, by side slicing in the manner described, in a direction at right angles to the direction of the incline and from both sides of it.

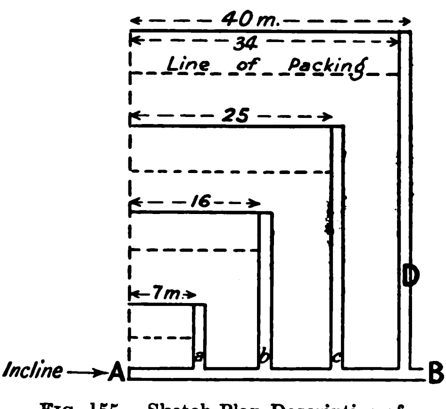

FIG. 155.—Sketch Plan Descriptive of Mode of working *Couchons*.

Operations are then commenced in the coal above, so that eventually the workings present a stepped appearance (see Fig. 157).

Supposing "1" (Fig. 157) to be the uppermost face, its width (at right angles to the plane of the paper) is 7 metres (23 feet); and if "4" represent the lowest face, it has a width of about 40 metres (131 feet) (at right angles to the plane of the paper); in other words, the faces are advanced by what in South Staffordshire would be termed "side-laning," in the direction of the *width* of the fold, that is, at right angles to the plane of the drawing.

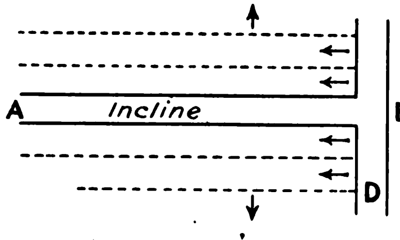

FIG. 156.—Plan of Incline and Lateral Strips in working *Couchons*.

The goaf is filled by debris passed down shoots from level to level, which serve also as means for ventilation. This method of working largely depends for its success on the closeness of the stowing of the waste.

It is possible that this method might be adapted to the successful working of thick horizontal seams.

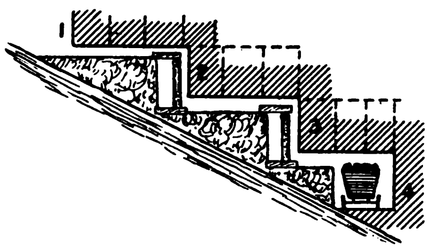

FIG. 157.—Section showing Stepped Appearance of Workings and Stowing in Removal of *Couchons*.

Another Method of Working a Thick Seam by Long-wall.—Fig. 158 is a plan showing a method of working a thick horizontal seam of coal in Central France. From the description given below, it will be seen that the method differs little from that described on p. 182, viz. of a method of working seams near together. AB and CD are winning roads driven in the bottom portion of the seam and about 150 to 180 yards apart; *ab*, *cd*, and *ef* are holings made between the winnings in the bottom, middle, and upper sections respectively. It will be seen that the distance between the faces of the respective sections is about 100 yards. When the stalls in the upper section attain the 100 yards limit, the other two "panels" in the lower sections of the seam will also have attained their 100 yards limit; the

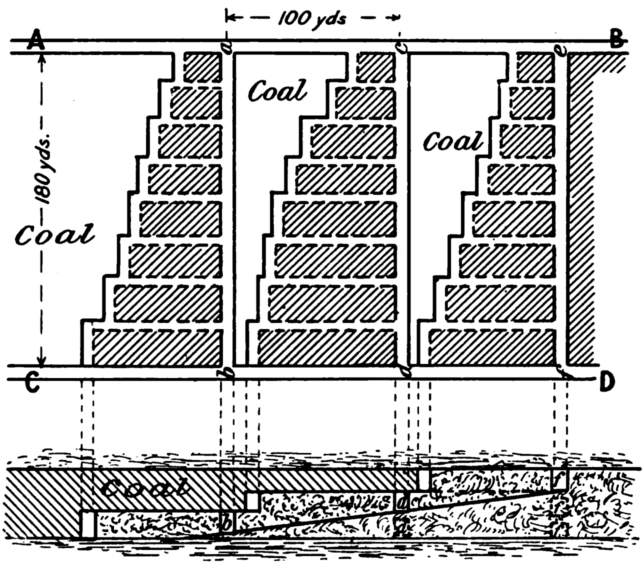

FIG. 158.—Plan and Section explanatory of a Method of working a Thick Seam by Long-wall in Central France.

cross cuts *ab*, *cd*, and *ef* will therefore be stoned up, and fresh cross cuts formed, *i.e.* on top of *cd* will be formed new *ef*, and on top of *ab* will be formed new *cd*. The three cross cuts *ab*, *cd*, and *ef* open on to the inclines *ace* and *bdf*, which are formed on the packing, and which are reconstructed each time the panels are cut off.

Working Very Thick Seams by Modified Long-wall in South Staffordshire.—In South Staffordshire, where the modified long-wall method of working is practised, if the seam is 15 feet or under in thickness, it is worked out in one getting. If, however, it is thicker than 15 feet, it is won in two gettings, that is to say, the upper half is worked first and the lower half several years subsequently.

Large pillars are formed and worked back by long-wall, "fire-ribs" of coal, varying from 6 to 8 yards in breadth, being left round the goaf of the extracted area; the area they enclose being much greater than is the

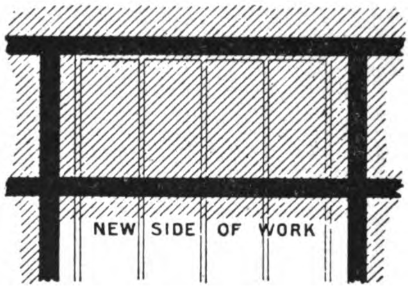

FIG. 159.—A Method of Working a thick Seam in One Division. Fire-ribs distant. Scale, 6 chains to an inch.

case where the square or wide-work method is practised. Mr. F. G. Meachem is of the opinion that the yield in tons per acre is greater when the square-work method is practised in depths down to 300 yards and when the seam is "in one," but that at greater depths, and where the seam is divided by thick bands, a better yield will be obtained by working by the modified long-wall method.

Figs. 159 and 160 illustrate two applications of modified long-wall as applied to working the thick coal in South Staffordshire. In the case of Fig. 159, the seam is "in one," the "fire-ribs" are far apart, the pillars are cut off, "undergone" and cogged, the cogs being built between the pillars to keep up the roof while the pillars are being taken out. Fig. 160 shows the fire-ribs "close set," the method shown being adopted when the seam is less than 15 feet in thickness, or is in two divisions with dividing spoil (bands) of more than 3 feet thickness. The width is often increased and the pillars cut off when

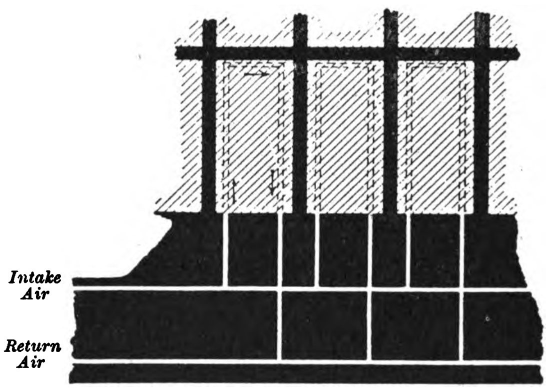

FIG. 160.—A Method of working a thick Seam either in One Division, if the Seam is not more than 15 feet thick, or in Two Divisions if more than 15 feet thick. Fire-ribs close set. Scale, 6 chains to an inch.

wood cogs are built in the space between and the pillars then removed.

Working Highly Inclined and Very Thick Seams.—In the St. Étienne coal-field there are seams of various thickness and inclination, one—the Grande Couche—being extremely thick. In some places the Grande Couche is as thick as 82 feet, and its inclination varies between 30° and 90° to the horizontal. The very thick and highly inclined seams in the field are won by cross-measure drifts from vertical shafts, and worked by one of the following methods or modifications of them. Levels are driven along the strike of the seam, one above the other, connected by inclines, and the coal between the levels worked off either by (*a*) horizontal slices or "lifts," or (*b*) inclined slices or lifts.

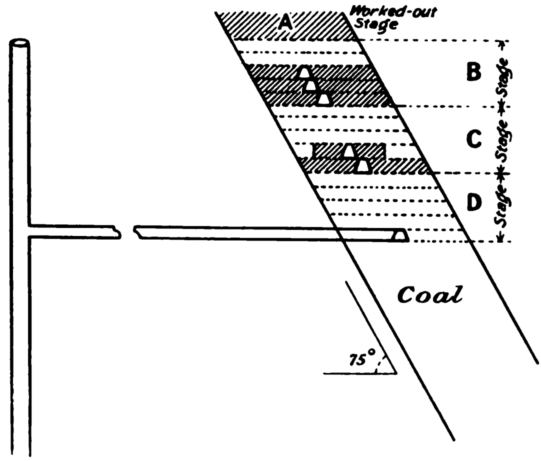

FIG. 161.—Section showing a Method of working a Highly Inclined and very Thick Seam.

(*a*) In the first method (see Fig. 161) the vertical distance between the levels is from 36 to 40 feet, and it is divided into, say, five sub-stages, 7 to 8 feet high. It will be seen from Figs. 161 and 162 that the levels are driven in about the middle of the seam, and, at stated distances along the levels in each sub-stage (*a*, *b*, in plan, Fig. 162), level holings or cross-cuts are driven to the hanging and foot-walls respectively, out of which the horizontal juds or lifts are turned, and so the coal is worked off. As the working-off in one sub-stage progresses, the excavated portion is tightly packed with

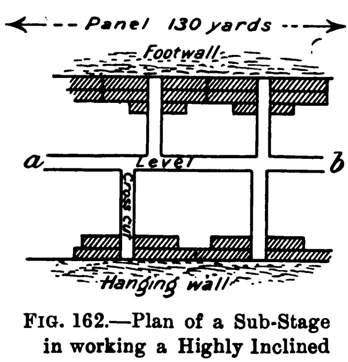

FIG. 162.—Plan of a Sub-Stage in working a Highly Inclined and very Thick Seam.

stone, usually sent down from the surface, and the workings of the sub-stage above rest on the stoned-up sub-stage below. The sub-stages are worked in ascending order, the stages in descending order. For example, in Fig. 161, Stage A is exhausted, Stage B nearly so; the working of Stage C is not far advanced, and Stage D is just commencing. The next stage will be opened immediately below D.

The concession or royalty is divided into panels, a width of 130 yards going to form a panel. An inclined

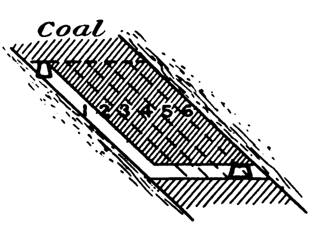

FIG. 163.

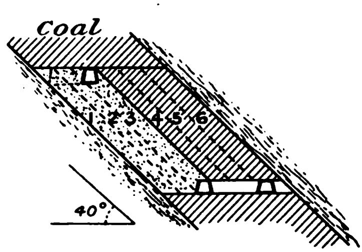

FIG. 164.

FIGS. 163 and 164.—Working a Highly Inclined and very Thick Seam by means of Inclined Lifts or Slices.

plane is made in the middle of the panel, and one on either side of the panel from the bottom main level to the bottom of the first or top stage, the level in each sub-stage being turned away out of the middle incline and holed into the side or airway inclines, so that proper ventilation is secured. The position of the inclines is not shown in the figures. A holing is frequently put through from slice to slice, down which the coals pass on to No. 1 level, and also by means of which the second and succeeding slices are ventilated. The arrangement, it will be seen, is really an extension of the "rearer" system, as practised in North Staffordshire when working thin seams, to the working of thick seams.

(*b*) *Inclined Lifts.*—When the coal is firm, is not so thick, nor so highly inclined—say, where the dip does not exceed 45°—it may be worked by inclined lifts in the manner shown in Figs. 163 and 164. In this method the roads, about 7 to 8 yards apart, are driven to the footwall and connected by inclines at distances of about 43 yards. The coal is worked off by successive parallel slices of about 7½ feet thick at the same inclination as the seam, commencing at the footwall, slice by slice, towards the hanging wall; the excavated portion being close packed, the debris for the packing being brought in by the higher level, and the coal passing out along the lower level. Fig. 164 shows two slices to have been taken out and the third in process of completion.

Working Two Seams when Near Together.—A difficult set of conditions is created when the thickness of strata intervening between two seams of coal, which it is desired to work, is small. If the bed of intervening stone is very thin—little more than a band—the two seams can be worked as one and the interstratified stone used for the purpose of packing; but this is not possible where it exceeds a few feet in thickness. The question then arises, which seam should be worked first, the upper or the lower? On this point opinions differ. But the determining factor would seem to be the character, in respect to thickness and strength, of the stratum or strata intervening between the two seams, and that forming the roof of the upper seam. If, say, the roof of the upper seam is a bad one and the stone between the two seams either thin or "broken," the probability is that it will be advisable to work out the lower seam first, though there must be put against this the fact that in all probability this proceeding will make the working of the upper seam difficult, dangerous, and costly. As has been said elsewhere,[1] "The truth seems to be that in most cases, and especially when the intervening stone is firm and cohesive, it is certainly best to work the top seam first, allow the roof to settle, and then work the lower seam; but sometimes, when the stone is loose and friable, the bottom portion should be first attacked, or otherwise it may be found impossible to work it at all." The late Sir George Elliot, a well-known mining engineer and coal-owner in the North of England, has given it as his experience that in deep coal-mines it will prove advantageous to work the upper seam first, "and so improve the lower beds in hardness."[2]

Working of Several Seams when Near Together.—The following method of working several seams when close together, which the writer has seen practised, is capable also of being applied to the working out of very thick seams of coal, provided the seam has an inclination of 1 in 7, and packing material is available. There were five seams of coal, but only three of them were worked, viz. those which are indicated by the numbers 1, 3, and 5. The section of the seams at the shafts was as follows:

	Ft. In.	Ft. In.	
No. 5 seam	6 2	...	
Fire-clay parting	...	0 1	
No. 4 seam	2 3	...	(not worked)
No. 3 seam	6 3	...	
Batt	...	0 1	
No. 2 seam	3 3	...	(not worked)
Fire-clay parting	...	0 2	
No. 1 seam	6 0	...	
Total thickness of coal	23 11	0 4	(stone)
Thickness of coal worked	18 5		

[1] *Colliery Working and Management*, by H. F. Bulman and R. A. S. Redmayne 2nd edition, p. 237.

[2] "The Effect produced upon Beds of Coal by working away the Over or Underlying Seams." *Transactions of the North of England Institute of Mining Engineers*, vol. iv.

The roof in the workings is composed of what is locally termed "binds," *i.e.* shale, and constitutes a good roof.

The depth of the upper seam from the surface is 1500 feet, and it is worth recording that the diameter of the area of the coal left for the support of the shafts is 500 yards.

The method of working is that known as the "hill"

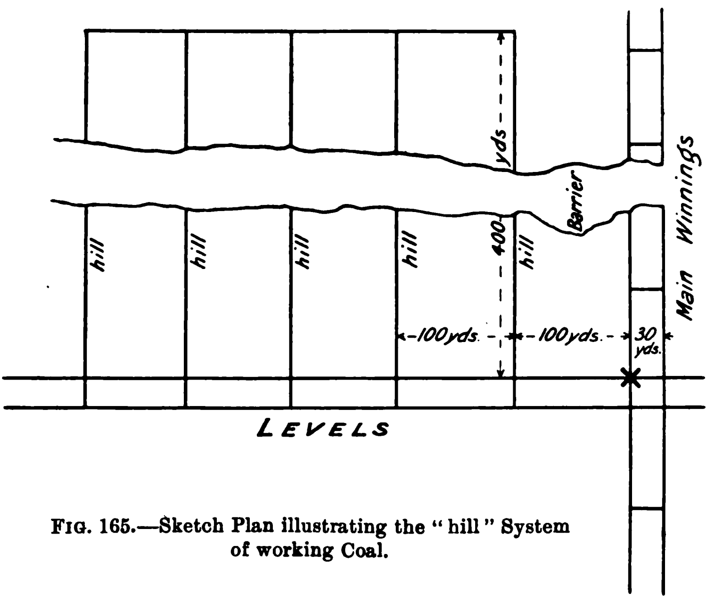

FIG. 165.—Sketch Plan illustrating the "hill" System of working Coal.

system, so called from the fact than an important feature in this method consists in forming pillars to the dip and working them off by long-wall to the rise.

A pair of main winnings are driven, 30 yards apart, to the full dip, and district winnings are driven from them at right angles, and therefore on the level course, and likewise with 30 yards of coal between the levels. A district is comprised of several very large pillars formed to the dip 400 yards long and 100 yards wide. All the roads are driven in the bottom or No. 1 seam. When the "hills," as dip roads are termed, have reached the limit determined upon—in the present case, 400 yards from the level—a holing is made between them, and the seam worked back for a few yards and the excavated portion packed. What is called a "congate," a road passing through the various seams, is then formed, being on the packs in the lower seam and ripped through the other seams. When the "congate" is completed, holings are made between the "congates" in the seams to be worked, and these seams are carried forward by long-wall working.

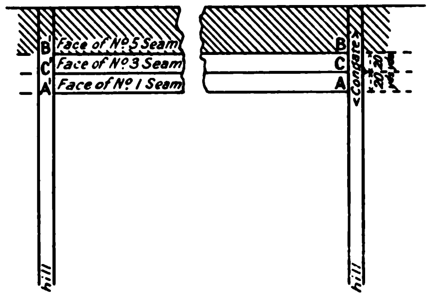

FIG. 166.—Sketch Plan showing "Congates" and Relative Position of Faces when working Three Seams of Coal near together.

A reference to Figs. 165, 166, and 167 will make the method of working more intelligible. The three long-wall faces follow 20 yards the one behind the other. The gradient of the "congate," which retreats as the face retreats, being made on the packs, is not so inclined as shown in the figure. The gradient is indeed very little off the horizontal, as the roof and coal "sags" (bends down) considerably.

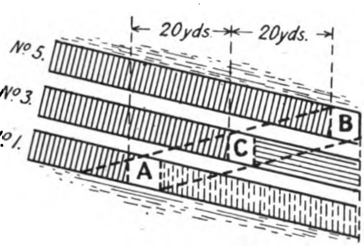

FIG. 167.—Section along Line of "Congate" showing Position of Faces when working Three Seams near together.

The gob is packed with the holings and the unmerchantable coal, there being little or no stone available for this purpose. The packs are built 2 yards wide, and there are 5 yards waste spaces between them. Gob fires are very prevalent in the waste. They are extinguished by filling sand into the gob, and, if this does not suffice, by walling off, with sand packing behind the walling.

The obvious advantage of this system is that troubles arising from gob fires are more easily dealt with than if working to the dip were practised, and water can be allowed to rise in the waste. The obvious disadvantage is the heavy haulage, due to pulling the sets up the inclines. This work is performed by 10 horse-power electric haulage sets situated at the top of each hill.

CHAPTER VII

COMPARISON OF VARIOUS METHODS OF SUPPORT AT THE WORKING FACE; AND ACCIDENTS FROM FALLS OF GROUND.

Comparison of different Methods of Supporting the Workings, with special reference to the question of the Withdrawal of Timber.

The Committee of the Prussian Commission on Falls of Stone and Coal, which was deputed to report on that part of the Commission's inquiry which dealt with timbering in collieries in the United Kingdom, arrived at some interesting conclusions as to the relative merits of the methods of support in the different mining districts, a *résumé* of which will be of value as showing how the different methods impressed highly-trained continental mining engineers who were engaged in a special inquiry into the matter.

As characteristic examples of the methods of working in the North of England, the Midlands, Staffordshire, and South Wales have been described in the preceding pages, the reader will be the better able to follow and realise the force of the summing up of the Commission. The Commission said: [1] "With regard to the applicability and efficiency of long-wall methods in relation to falls of roof and coal, they (the committee deputed to report on British methods) express the opinion that the system in

[1] Page 72 of the "Abstract of the Report of the Prussian Commission on Falls of Stone and Coal," published by the Mining Association of Great Britain.

vogue in the Midlands and northern districts affords protection against falls only when the roof is good, and there is consequently but little risk of accident from this cause. In South Wales, the generally bad state of the roof would render long-wall working impossible,[1] if the goaf were not thoroughly well packed; and such packing forms the best and most reliable means of preventing falls. Special mention is made of the circumstance that the robbing (recoverying) of timbers from the goaf, in the North and Midlands, results, when the roof is bad, in continual dislocation, which frequently extends to the coal face. Not only does the roof collapse close behind the last row of standing timbers, but a second line of fracture is often found close up against the coal face; and the loosened rock, being supported by the timber alone, is a source of great danger to the miners. Whilst admitting that the method of robbing (recoverying) the goaf timbers combines great economy with safety, the committee were of the opinion that, except in the case of the excellent roof found in some Scottish pits, full packing is preferable, since it would prevent the above-mentioned dislocation of the roof. Under these conditions, the recovery of the goaf timber would lose some of its importance, thus diminishing the risk attaching to the work, especially when performed by the usual method of rings and chains. It is considered advisable to advance the face at a more rapid rate than is generally practised in the North and Midlands, since men are safer when working under a freshly uncovered roof than under one that has been exposed for some time."

These conclusions, as the considered opinions of mining engineers of eminence, are worthy of serious

[1] Compare also with the remarks of the late Mr. T. Forster Brown, p. 131.

attention; but a marked difference of opinion exists in the minds of most British mining engineers, and must remain. For instance, the expert committee appointed by the Royal Commission on Mines to report on accidents from falls of ground, reported: "We are of the opinion that in all those cases where the systematic withdrawal of timber from the waste is in operation, it conduces greatly to safety, inasmuch as the pressure is relieved as regards the coal face; whereas, when timber is left upstanding, the weight is thrown on the face."

As to the advisability in point of safety of a rapid advance of the face, there can be no difference of opinion. But the rate of advancement in the North of England and the Midlands is, on the average, greater than in South Wales, for in the North of England (*i.e.* Northumberland and Durham), and in many Midland collieries, two—and in many Northumbrian and Durham cases three—shifts of coal-hewers are employed *per diem*, and the use of mechanical coal-cutters is common; whereas in South Wales the custom is to employ one shift only of coal-getters in the day of twenty-four hours, and the use of mechanical coal-cutters is very rare owing to the peculiar character of the breaks in the coal, which render it liable to fall on the cutter.

The Prussian Commission stated further: "In connection with pillar working, it is pointed out that the usual English practice, of robbing the goaf timbers when the roof is sound, differs from that current in the Ruhr coalfield. Provided, however, that the roof is carefully timbered in front of the working face, and the subsidence is regular, there seems no objection to this course; but, if this is not the case, the firmest and most compact roof is frequently a source of danger, inasmuch as it is liable to come down suddenly and in large quantity close against the face, and thereby produce disastrous accidents."

Heavy falls such as these are well known when the roof consists of a thick bed of strong sandstone. Probably in such cases it would be well to build substantial stone or wooden "chocks" in the goaf before withdrawing the timber. The writer doubts whether, even if the timber, in the form of ordinary props and lids, were left in the goaf, it would on the formation of a large area of goaf suffice to withstand a sudden oncome of pressure and prevent the results the Commission alludes to.

Conclusions by the Committee appointed by the Royal Commission on Mines as to the Modes of Supporting Roof and Sides.

The following are some of the conclusions arrived at by the Committee appointed by the Royal Commission on Mines to inquire into and report to the Commission on accidents from falls of ground. It will be seen that they differ in some respects from those arrived at by the committee appointed by the Prussian Commission.

Face Timbering and Supports in the case of Thin Seams and Seams of Medium Thickness Lying Flat or having a Moderate Inclination.

Two methods of applying mechanical coal-cutting to long-wall faces were given in the report, one an example from Northumberland, the other from Yorkshire.

The latter example was a case of long face cutting in one direction, whilst the former was a case of short face and back and forward cutting, this being the more modern development. The feature which is of particular importance in properly worked mechanically cut coal faces is that by the maintenance of a straight line of regular advance with the same depth of cut the fractures induced in the roof are a regular and known quantity, and can be met by a definite width and systematic advance of supports, whereas with hand holing an uneven line of face is maintained, resulting in irregularity of roof fractures, so that possible falls of roof cannot be so well guarded against.

It should be stated that although undoubtedly the physical conditions in these examples were very favourable to the economical and safe application of mechanical coal-cutting, the Committee thought the conditions had been further improved by careful management.

Cleavage, so characteristic of most coal seams, is not limited to the coal itself, but is a feature of many roof stones, especially of marlstone (bluestone) of a shaly nature. In Fig. 122 are shown the induced fractures corresponding to the depth of the cut, and the secondary fracture due to subsidence of the stone on the packs. During the inspection by the Committee these were clearly noted as occurring in the manner indicated.

In systematic timbering the right distance that should exist between supports can only properly be determined from an intimate study and knowledge of the local conditions prevalent in each case, and these can only be obtained by experience and experiment.

There are some districts in which the application of mechanical coal-cutting with the appliances at present at our disposal must be very limited. In South Wales, for instance, owing to the number of slips in the coal, not only is mechanical coal-cutting unnecessary in a great many collieries—the coal is mostly "got" by *pulling*, it off the face—but it is rendered impossible, as, during the process of under-cutting a long-wall face, blocks of coal would break away and bury the machine. The coal would not in some cases stand for cutting, and the roof conditions, too, are often against its application. In the thick coal of South Staffordshire, again, the mechanical cutting of the coal is impracticable.

Very little timber is drawn in South Wales and in many of the Scotch collieries. The reason advanced by the colliery managers and others with whom the Committee discussed the subject in South Wales was that each prop is generally set under a loose stone, so that if it is withdrawn, a fall larger than that of the individual stone results, or may result. One manager, whose experience until recently had largely been gained in Durham, Yorkshire, and Lancashire, where the practice is to recover all the timber possible, maintained (1) that were the timber drawn there would be no stowage room for the amount of debris which is made at his colliery (in the Rhondda Valley) owing to the falls of roof which follow immediately on the withdrawal of any posts (as it is, no less than 300 tons of debris were being sent to the surface every night); and (2) goaves would become gasometers for the accumulation of inflammable gases generated in the mine. Hence they stowed the goaf tight in the manner described above. He quoted a case where he had actually to stow goaves in a part of the mine where the late manager had allowed the roof to fall and so close the waste. The timber adjacent to the road packs is never drawn. The faces in South Wales generally travel very slowly, much more so than in the other coalfields of the United Kingdom, owing to a less number of men being employed in a given length of face, this being the effect of local custom.

In respect of South Wales, several important matters suggested themselves for consideration:

1. The irregularity of the line of the face and its slow rate of advancement are features which make for danger. The unevenness of line of face must affect the regularity of roof-pressure, and the slow rate of advancement leads to greater breakage and insecurity.

2. The packs might be increased in width, to allow in some degree of the withdrawal of more timber. The packs are not in many instances as well built as they might be, and more debris might be stowed if they were better built. Again, in Leicestershire, for instance, where the seams are as thick as those in South Wales, and where heavy timber is used, it is all recovered. If the goaves were packed tighter and the timber withdrawn, the settlement of the strata would be more even, and "gasometers" would not be formed; the face conditions would be improved, and accidents in consequence reduced.

3. The gateways are usually 11 to 14 yards apart, centre to centre, as, owing to the bad condition of the roof, difficulty is experienced in bringing the tubs along the face; but where it is possible to space them further apart, considerable benefits result. Where the seams are too thin to allow of the tubs being brought along the face, the employment of conveyors answers the same end, the distance between the gateways being increased to about 40 yards, more men being employed at the face, and a more rapid advance obtained, a feature conducive to improvement of roof conditions. Boys should not be employed in getting and filling coal at the face; they

are of little use as coal-getters, and inexperience often leads them to run risk of accident.

Accidents from Falls of "Ground" in Thick Seams.—The Committee attributed the high death-rate from accidents in the thick coal to three main causes:

(1) The inherent difficulties and dangers due to prevalent physical conditions, viz. bumps, slips, and great height;

(2) The system of working; and

(3) The "charter-master" or contractor system of payment of underground workmen.[1]

In respect to the system of working, the dangers of taking down coal from a great height are evident, and the Committee devoted much thought to the possibility of other methods being adopted to working thick seams which might be conducive to greater safety. The Committee drew attention to the method adopted at Courrières Colliery, which has been described on p. 175, which they thought should meet with the serious consideration of those engaged in the management of thick-coal collieries.

Some general Recommendations of the Committee for securing Safety Conditions at the Face and the immediate Vicinity.

1. The working of long-wall faces in straight lines and at an angle with the "cleat" should be practised

[1] The Coal Mines Act, 1911, passed since the Royal Commission (who appointed the Committee) reported, requires (under Section 27 (1)) that the materials required for the support of the roof and sides shall be provided by and at the cost of the owner of the mine, and that the firemen, examiners, or deputies, and all other officials of the mine shall be appointed and their wages paid by the owner, notwithstanding that the mine or any part thereof is worked, or any part of the operations therein is carried on, by a contractor. And no such contractor, nor any person employed by him, shall be appointed to be manager, under-manager, or fireman, &c., of the mine.

wherever possible as making for safety. The quicker the advancement of the face and the sooner the newly-exposed roof is supported, the less liability there is to falls of ground.

2. The use of mechanical coal-cutters is conducive to production of the desirable conditions mentioned above. The use of conveyors also, which renders it possible to work the face with a less number of gate roads, makes for safety.

3. The point chiefly aimed at in laying out and conducting all long-wall workings, in so far as safety conditions are concerned, should be the even and regular settlement of the roof "weight," or "squeeze," as it is generally termed, on the packs. And there can be no doubt that the building of well-constructed packs at regular intervals, *i.e.* the regular spacing of the gate roads, greatly conduces to the fulfilment of this desirable object. The closer and better built the packs and the closer the stowing of the goaf the safer the face conditions.

4. The necessity of setting temporary supports under dangerous cover in cases of emergency, even if the foothold for the prop is not a very secure one, strongly impressed the Committee.

5. Special timbering rules[1] had been established at

[1] The Coal Mines Act, 1911, requires by Section 50.—(1) That where props or props and bars or chocks are used to support the roof at the working face, the roof under which any work of getting coal or filling tubs is carried on shall be systematically and adequately supported, and the props or chocks shall be set at such regular intervals and in such manner as may be specified in the notice hereinafter mentioned.

(2) Holing props or sprags shall be set as soon as practicable, and shall be set at such regular intervals and in such manner as may be specified in the notice hereinafter mentioned, and shall not be removed until the coal is about to be taken down and before the roof supports (if any) have been advanced in the manner specified in the notice.

(3) In all parts of a roadway in which sets or trains consisting of three or more tubs are coupled or uncoupled, the roof and sides shall be systematically

most of the mines in the United Kingdom at the time the Committee reported—South Staffordshire being the only exception investigated by them—and it had frequently been stated that the establishment of such rules

and adequately supported, and in such parts and in all other parts of the roadway the roof or sides of which require to be supported, if props or bars are used as supports, such supports shall be set at such regular intervals and in such manner as may be specified in the notice hereinafter mentioned.

(4) The manager shall, by notice, specify the manner in which the supports are to be set and advanced, and the maximum intervals to be observed on roadways between the supports, and at the face—

(*a*) between each row of props;
(*b*) between adjacent props in the same row;
(*c*) between the front row of props and the face;
(*d*) between the holing props or sprags;
(*e*) between chocks:

Provided that the interval between holing props or sprags shall in no case exceed six feet.

(5) If the inspector of the division considers that the system of supporting the roof and sides adopted in any part of a mine is unsatisfactory, either by reason of the distances fixed or any of them being excessive or otherwise, he may require the manager to fix some less distance or otherwise modify the system, and the manager shall comply with the requisition unless he disputes the reasonableness thereof, in which case the dispute shall be settled in manner provided by this Act for settling disputes.

(6) This section shall not apply to the mines of stratified ironstone in the Cleveland district or of thick coal in the South Staffordshire district or to mines in any other district as respects which the Secretary of State is satisfied that similar conditions prevail.

(7) Nothing in this section shall prevent a workman from setting supports in his working place at more frequent intervals than those specified in the notice aforesaid, where necessary for safety.

And by Section 51.—That where the work of erecting the supports of the roof and sides of working places is done by the workmen employed therein, a sufficient supply of timber or other materials suitable for supports shall be kept at or within ten yards of every working place where, in pursuance of the Act, supports are required to be erected, and also at the pass-bye, siding, or other similar place in the mine convenient to the workmen; and it shall be the duty of the firemen, examiners, or deputies to see that such sufficient supply is so kept, and any working place in which such a sufficient supply is not kept shall not be deemed to be safe for the purpose of the provisions of the Act. Sufficient timber or other materials as aforesaid, to enable the firemen, examiners, or deputies to see that the provisions of this section are complied with, shall be constantly provided.

And by Section 52.—(1) That in any part of a mine where any work is being carried out which necessitates the removal of roof supports, temporary supports shall, in all cases, be set so as to secure the safety of the persons employed.

(2) Props shall not be withdrawn from the waste or goaf or from under a

had not been warranted, in that the results expected from the adoption of systematic timbering had not been achieved. The Committee thought that the reasons for this were not far to seek: viz. that (*a*) the rules were not always fully understood, or (*b*) were imperfectly carried out. In some cases the management had adopted such a maximum width between props as would not, under systematic timbering, necessitate a further use of supports than was in existence before the adoption of the rules. They therefore were of opinion that the specified distance at which roof supports should be set should be reasonable, and such as is carried out in actual practice.

The Committee were of opinion that the following requirements should be considered in framing any special rules for timbering in coal mines:

(*a*) The word "face" should be clearly interpreted as they found that this term is differently defined in different mining districts. It appeared to the Committee that some specified distance back from the *coal* face in the gate roads should be used in this respect, seeing that much of the face work (filling of tubs, &c.) is performed on the outbye side of the ripping, and at present only the roof inbye side of that point is usually included in the term "face."

(*b*) When timber set for the support of the face of the roof is set in rows, the rows should be parallel to the line of face.

(*c*) Wherever possible, a plan should be made to illustrate the system of timbering to be adopted.

roof which appears to a fireman, examiner, or deputy to be insecure otherwise than by means of a safety contrivance, and it shall be the duty of the firemen, examiners, and deputies to examine all roofs from under which props are about to be withdrawn with a view to determining whether the props ought to be withdrawn by means of a safety contrivance.

(*d*) A printed copy of the code of rules, with the plan, if any, should be posted at the pit-head of the colliery, and copies of the rules and plan should be supplied free of cost to the workmen on application.

(*e*) Every prop not set under a bar (or crown) should be capped with a lid, the minimum length, thickness, and breadth of the lid being specified, the dimensions to be sufficient to meet the requirements of the seam in question; such lids being so fixed that, in so far as is possible, all the natural joints and breaks in the roof are crossed at right angles.

(*f*) Holing sprags should be set as soon as there is room for them, and the distance between them should be specified in the rules; where the holing exceeds 5 feet in depth a further row of sprags should be set, and where the seam is more than 5 feet in height and is overhanging, "cocker," or long sprags, should be set.

(*g*) Pack-walls should be carefully built, should be of sufficient width, and should as soon as possible be well pinned up against the roof, and not left in a half-built state.

(*h*) In the majority of cases the roof within 4 feet of the face, under which the colliers and other persons work, was not supported. This appeared to the Committee to account for a large number of accidents, and it was thought, in order to prevent these, it would be necessary to adopt some method that would require supports being set to the roof within a stipulated distance of where the men work.

The Committee was much impressed by the fact that at mines where the system of timbering had been carefully thought out and rigidly enforced the death-rate from falls of roof and side was very low. At these mines provision was made for temporarily supporting the roof as soon as the coal was extracted and was being filled into tubs. It seemed to the Committee desirable, where possible, to adopt a similar system, modified in details to suit exceptional conditions.

(*i*) As trammers (putters, &c.) are constantly passing under the brow or lip of the ripping, it was desirable that the roof at this point should always be supported, especially as it was a point of frequent accident due to falls of stone from the ripping.

6. The Committee considered that there was need for more thorough and frequent inspection of working places. It was found that in many instances all the separate gateways or other roads about the face were not included in the inspection, though such was clearly required by General Rule 4 of the Coal Mines Regulation Act of 1887.[1]

[1] The Coal Mines Act, 1911, requires by Section 14.—(1) That for every mine there shall be appointed by the manager in writing one or more competent persons (hereinafter referred to as firemen, examiners, or deputies) to make such inspections and carry out such other duties as to the presence of gas, ventilation, state of roof and sides, and general safety (including the checking and recording of the number of persons under his charge) as are required by this Act and the regulations of the mine.

(2) A fireman, examiner, or deputy shall be required to devote his whole time to such duties as aforesaid (hereinafter referred to as his statutory duties), but this provision shall not apply in the case of a fireman, examiner, or deputy in—

(*a*) any mine in which the total number of persons employed below ground at one time does not exceed thirty; or

(*b*) any mine in the counties of Durham or Northumberland; or

(*c*) any mine exempted by the inspector of the division on the ground of the special circumstances of the mine;

and nothing in this provision shall prevent any fireman, examiner, or deputy in any mine being employed in measuring the work done by persons in his district, or in firing shots in his district:

Provided that any duties assigned to or undertaken by any fireman, examiner, or deputy in addition to his statutory duties shall not be such as to

In addition to the statutory inspection during the shift, at many collieries there was a second inspection, but in only a few districts was the inspection during the shift recorded.

prevent him carrying out his statutory duties in a thorough manner; and, if any question arises whether any additional duties are such as to prevent him carrying out his statutory duties in a thorough manner, that question shall be decided by the inspector of the division, whose decision shall be final.

(3) The district of a mine assigned to a fireman, examiner, or deputy shall not be of such a size as would prevent him from carrying out in a thorough manner all his statutory duties.

(4) A mine in which there is a contravention of this section shall be deemed not to be managed in conformity with this Act.

By Section 15.—(1) That a person shall not, after the first day of January nineteen hundred and thirteen, be qualified to be appointed or to be a fireman, examiner, or deputy, unless he—

(*a*) is the holder of a first or second-class certificate of competency under this Act or is twenty-five years of age or upwards and has had at least five years' practical experience underground in a mine, of which not less than two years have been at the face of the workings of a mine; and

(*b*) has obtained a certificate in the prescribed form from a mining school or other institution or authority approved by the Secretary of State as to his ability to make accurate tests (so far as practicable with a safety lamp) for inflammable gas, and to measure the quantity of air in an air current, and that his hearing is such as to enable him to carry out his duties efficiently; and

(*c*) has, within the preceding five years, obtained from such approved school, institution, or authority as aforesaid, or from a duly qualified medical practitioner, a certificate in the prescribed form to the effect that his eyesight is such as to enable him to make accurate tests for inflammable gas and that his hearing is such as to enable him to carry out his duties efficiently, the expense of obtaining which shall, in the case of a person employed at the time as fireman, examiner, or deputy, be borne by the owner of the mine:

Provided that a person shall not be required to have obtained a certificate as to ability to make tests for inflammable gas or as to eyesight, if he is employed in a mine in which inflammable gas is unknown.

(2) The certificate as to the eyesight and hearing of a fireman, examiner, or deputy employed in a mine shall, whilst he is so employed, be kept at the office at the mine, and, whenever a requisition in that behalf is made by an inspector, produced for his inspection.

By Section 63.—That for the purpose of the inspections before the commencement of work in a shift hereinafter mentioned, one or more stations shall be appointed at the entrance to the mine or to different parts of the mine, as the case may require, and no workman shall pass beyond any such station until the

The Committee thought that there should be two inspections during a shift, one of which should be recorded, and that the first should be made within not more than two hours of the men commencing work.[1]

7. A considerable number of accidents occur at the face when packs are in the process of being built, owing to roof supports being withdrawn to make room for the pack without precautions being taken temporarily to support the roof. Before this timber is withdrawn the roof should be supported by a new length of pack or by temporary timber to uphold the roof and to enable any timber that may be retarding the building of the pack being withdrawn, without the persons employed on the work running undue risk.

part of the mine beyond that station has been examined and reported to be safe in manner hereinafter mentioned.

By Section 64.—(1) That the firemen, examiners, or deputies of a mine shall, within such time not exceeding two hours immediately before the commencement of work in a shift as may be fixed by the regulations of the mine, inspect every part of the mine situated beyond the station or each of the stations, and in which workmen are to work or pass during that shift, and all working places in which work is temporarily stopped within any ventilating district in which the men have to work, and shall ascertain the condition thereof so far as the presence of gas, ventilation, roof and sides, and general safety are concerned.

(2) Except in the case of a mine in which inflammable gas is unknown, the inspection shall be made with a locked safety lamp, and no other light shall be used during the inspection.

(3) A full and accurate report specifying whether or not, and where, if any, noxious or inflammable gas was found, and whether or not any, and, if any, what defects in roof or sides and other sources of danger were observed, shall be recorded without delay in a book to be kept at the mine for the purpose, and accessible to the workmen, and such report shall be signed by, and, so far as the same does not consist of printed matter, shall be in the handwriting of, the person who made the inspection.

(4) For the purpose of the foregoing provisions of this section, two or more shifts succeeding one another so that work is carried on without any interval are to be deemed to be one shift.

[1] And by Section 65.—That a similar inspection shall be made twice at least in the course of each shift of all parts of the mine situated beyond the station or each of the stations aforesaid and in which workmen are to work or pass during that shift, but it shall not be necessary to record a report of the first of such inspections in a book: Provided that, in the case of a mine worked by a succession of shifts, no place shall remain uninspected for an interval of more than five hours.

8. The Committee thought that the face of the ripping in long-wall gateways, except in very thin seams, where it cannot well be avoided, should not be taken nearer than, say, 5 yards to the coal face, and that good packs should be kept at least 2 yards in advance of the ripping face, the Committee's reason for this being that if the ripping is taken close up to the face, as was often done, two "loose ends" were created in the stone forming the roof at each gate end, making the roof difficult to support, and in those cases where coal shots are fired the stone is much shaken and may be rendered dangerous. In the case of very thin seams where the ripping is carried up to the coal face, the roof should be well and systematically supported.

9. The Committee was of opinion that in all those cases where the systematic withdrawal of timber from the waste was in operation it conduced greatly to safety, inasmuch as the pressure was relieved as regards the coal face, whereas when timber is left upstanding the weight is thrown on to the face.

10. The Committee thought that a greater use might be made of light face bars; in many cases two props set with lids were found, when two props supporting a light bar might have been substituted.

11. In Derbyshire, Nottinghamshire, Leicestershire, and Warwickshire it was necessary, under the special rules there in force, that all timber from any waste or under any heavy roof should be withdrawn by means of a ringer-and-chain, and it was a breach of these rules to attempt to do so in any other way. In Leicestershire, props 9 feet in length and 8½ inches in diameter were being satisfactorily withdrawn by this means.

The Committee thought that this should be required at all mines, and also that it should be done between shifts when there is less noise in the vicinity of the place where the timber is being withdrawn. Instead, however, of stipulating that the appliances shall be a ringer-and-chain, they suggested that the wording of the rule should allow the use of a ringer-and-chain, Sylvester, or other similar appliance. To confine the use to any particular tool would, they thought, tend to prevent the introduction of improved types.[1]

The Committee was impressed by the advantages that have resulted from using tapered props at some collieries, and was surprised that the use was not more general, as not only are the safety conditions enhanced in that snapping of props is lessened, but a saving in consumption of timber results from the adoption of the practice.

12. Respecting the system of timbering in operation at the face at Courrières and other collieries in the Pas-de-Calais, the Committee was of the opinion that a similar method of fore-setting and the lattice work system of supporting the roof might be adopted with advantage in some collieries in Great Britain where the roof conditions are the same, for the roof conditions at Courrières are not worse than, nor very different from, those at some collieries in the United Kingdom.

13. As to the general systems of labour in operation in respect to the setting of timber at the face, namely, that in which the collier (coal-hewer) sets the timber himself, and that in which the greater part of the timbering is done by "deputies" (or special timber-setters), the Committee made no recommendations, as any alteration, disturbing as it would the practice honoured by generations of application, might, it was thought, at any rate in its initiation, be attended with an increase rather than a diminution of accidents.

[1] See footnote to pages 196 and 197.

14. Where seams are worked in close proximity to each other the whole of the intervening strata are in a state of movement, which is conducive to the occurrence of falls of ground. The Committee thought it advisable, therefore, to allow a considerable period to elapse after working one seam before exploiting another removed from the worked-out one by no great thickness of intervening strata

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