(*Paper No. 2273.*)

"The Sinking of two Pits at Gneisenau Colliery, near Dortmund."[1]

By H. Tomson.

(Abstracted by Hilary Bauerman, Assoc. M. Inst. C.E.).

The strata above the coal at this place include 52 feet of drift sand and clay and about 700 feet of marls, which are close at the top, but fissured and water-bearing below. There are also two beds of green marl 3·28 and 5 feet thick respectively, and about 36 feet of greensand at the bottom, which is generally plastic and stops the downward percolation of water from the upper measures, but in the locality in question this plasticity is not well developed. In 1873 the Company, then proprietors of the mine, commenced a shaft at this spot. After a somewhat difficult sinking through the upper alluvial beds, the ground was secured by cast-iron tubbing wedged with wood, and the upper marls were traversed without special difficulty to a depth of 570 feet, when fissured ground was reached, yielding from 5,500 to 6,600 gallons of water per minute. The sinking was then abandoned and the bottom was plugged with a layer of concrete 45 to 50 feet thick, with the intention of resuming the work at a later period. Nothing was, however, done until 1882, when a new company was formed, who decided to complete the shaft by boring down to the Coal Measures, and to put down a second one in the immediate vicinity by the same method.

On the 1st of July, 1882, the operations were commenced by drawing the water with a bucket, and when this was done all timbers and other materials built into the shaft were removed to give free play to the boring-tools. On the 20th of December the boring by Messrs. Kind and Chaudron's method was commenced, of a diameter of 5 feet and reached the Coal Measures at 788 feet in June 1883, and the first coal seam at 807 feet. On the 1st of July, 1883, work was begun with the large borer of 14·26 feet

[1] This is an abstract of an account furnished by Mr. Tomson, director of the Gneisenau Colliery, contained in a memoir on "Novelties and Progress in Sinking in Loose Ground," by Mr. H. Lueg, of Dortmund, published in the Zeitschrift für das Berg-, Hütten- und Salinen-Wesen, vol. xxxv. Abhandlungen, p. 1.

diameter, and considerable difficulty was experienced in boring through the original concrete stopping, which included large quantities of extraneous substances, such as oak timbers, steel tools, and iron ladders, which had to be cut to pieces by the borer before the marl below was reached. Other difficulties of a similar kind were experienced from imbedded flints and hard beds which occur irregularly on the lower marl strata. In February 1885, the level proposed for the moss-box was reached at 792 feet, or 4·6 feet within the sandstones of the Coal Measures. As the water-bearing bed is only encountered at a considerable depth below the surface, Mr. Chaudron considered that the shaft might be rendered perfectly safe by tubbing it through the fissured ground only, and stopping the water by a lining of concrete between the tubbing and the rock, instead of building a column of cast-iron rings up to the natural water-level in the shaft, as had been done in all previous cases. As this proposition seemed likely to effect a large saving in the cost of the sinking, the proprietors determined to try it; but as no data were available for forming an opinion as to the resistance of concrete to the pressure likely to be encountered at such a depth, it was resolved to apply the new method only in putting down the second pit, while the first was finished on the old system, in so far modified that provision was made for pulling out so much of the column of tubbing as could be spared, when a water-tight joint had been made above the fissured marly ground. The rings so recovered would then be available for use in the second sinking.

The building of the tubbing was commenced on March 4th, 1885, and although some delay was experienced, owing to defective flange joints which had to be replaced before they could be made water-tight, the moss-box was lowered into its place by the 13th of April. The building then went on continuously, electric light being used at night, and as many as twelve rings (13 feet 1½ inch diameter inside and 5 feet high) having been put together in twenty-four hours. The total weight of the tubbing which was made by Messrs. Haniel and Lueg, of Düsseldorf, was about 1,500 tons. The compression of the moss-box went on regularly, the depth of the layer of moss being reduced from 3 feet to about 10 inches. The concreting, which was done with four ladles suspended by wire ropes that were used alternately, was begun on the 19th of April, and finished up to the level of 512 feet on the 27th. In order to ascertain the most advantageous composition for the concrete backing, which had to resist pressures varying from 15 to 24 atmospheres, numerous experiments were made with mixtures of

cement and sand in varying proportions, which were cast in tubes, and, after being allowed to set, were subjected to considerable pressure. The best results as regards impermeability were obtained with pure cement, which, however, was too costly to be employed for the whole length of the column (279 feet). The details of the mixtures adopted are given in the account of the second sinking.

The concrete was left to harden until May 17th, when the lifting of the water out of the shaft was commenced. On June 4th, the false bottom of the tubbing was removed, and the moss-box having been found to be watertight, the sinking was resumed in the Coal Measures. On June 18th, a bearing crib was laid at 798 feet, upon which a series of closing rings were built up to finish the joint up to the moss-box, which was done on the 25th of June. It now remained to draw the water out of the circular space above the concrete, and to remove the upper part of the sinking column of tubbing. The first operation was effected by means of very long and narrow kibbles. When the level was lowered a certain distance, a flow of about 26 gallons of water per minute, due to a broken segment of the old tubbing near the surface, was discovered; but after this was repaired, the drainage went on regularly until the concrete joint was dried. The upper tubbings were then taken out in a very few days, as the shaft was entirely free from all fixed obstacles. The space behind the uppermost permanent ring was then concreted with pure cement, and a closing curb, made up of two rings built together in ten segments, was laid at the level of 516 feet. The bottom ring is united to the top ring of the tubbing by ninety bolts of 1½ inch diameter, the joint being packed with lead. A conical ring of masonry built upon the closing curb forms the footing of the wall lining the shaft through the impermeable part of the wall above. In order to stop water coming from above, a screen of six light iron tubbing-rings is carried to a height of 30 feet within the walled part of the shaft, and as the space behind is not filled with concrete, lodgment is afforded for about 6,000 gallons of water.

The subsequent sinking in the Coal Measures was carried on without any particular difficulty in the ordinary way to a depth of 1,295 feet.

Pit No. II, which is 115 feet from No. I, was begun on January 9th, 1883, a brick cylinder of 28 feet internal diameter, 4 feet thick below, 3 feet 8 inches at the top, and weighing about 1,200 tons, was used in the upper alluvial ground, the excavation being effected partly by buckets, and partly by a Körting mud-

elevator. The wall continued to sink until the first-bed of gravel and flints was reached, when it remained fast; the sinking was then continued by hand, and on March 16th the marl bed was reached at 54 feet, when the influx of water suddenly increased from 44 gallons to 570 gallons per minute. At 80 feet a segmental tubbing of cast-iron wedged with iron, was commenced, and on May 11th it was completed. The water then diminished to 275 gallons, and was kept down by a pulsometer.

For the deep sinking a pair of direct-acting winding-engines with cylinders 20 inches in diameter, and of 48 inches stroke, with a conical drum 3 feet 4 inches in diameter, and a powerful steam-capstan with 10-inch cylinders, 16-inch stroke, working a drum of 3 feet 4 inches diameter by a double train of spur-gearing, were used. The larger engine was devoted to raising and lowering *débris* and materials, while the steam-capstan carried the working platform for the masons by a steel wire-rope 2 inches in diameter. The sinking-tubs were guided by wire-ropes 1 inch in diameter, made fast to a cross-bar below, bearing against sockets in the shaft-wall, while their upper ends were passed round the drum of a windlass. By simply slacking the strain on the rope, the cross-bar was released, and the whole could be brought to the surface.

A continuous ladder-way was provided down the centre of the pit, as a means of escape for the sinkers, in the event of any great outburst of water. The ladders, made in $16\frac{1}{2}$-feet lengths, were connected by fish-joints, and suspended from a strong cross-timber at the surface. A flat iron bar ran parallel to the ladder on either side at a distance of 24 inches, and was connected with it by iron rings, which were cased with wooden lattice-work. Resting and changing platforms, $15\frac{3}{4}$ inches wide, were placed at $16\frac{1}{2}$ feet intervals. The total weight of this arrangement was 33 lbs. per foot, and it was so arranged, that when the shaft became inaccessible, the whole could be pulled up and taken to pieces in lengths by unscrewing the fish-bolts. The pulsometers were hung by wire-ropes from hand-windlasses; the rising pipe, 12 inches in diameter, was of galvanized sheet-iron, and the steam-pipe was a drawn tube of $3\frac{1}{2}$ inches in diameter. The latter was connected at the surface with a horizontal steam-pipe 40 feet distant, which allowed the depth of the pulsometer to be altered 13 feet without lengthening the steam-pipe.

The working platform for the masons was made of wrought-iron, with four projecting horns for fixing it in position during the building of the shaft-wall. The whole of these arrangements

were found to answer admirably, and are recommended in all cases where there is a possibility of having to substitute boring for hand work at the lower part of a deep sinking.

The sinking through the marl was resumed on June 18th, with the following succession of events:—The first set of wedged tubbings was finished on the 30th July, and a second at 160 feet on September 5th, when the water diminished from 106 gallons to 9 gallons per minute. A third set at 200 feet was completed on October 22nd, when the influx was further diminished to 3 gallons, so that the pulsometers were no longer required, and the drainage was thenceforth effected by buckets.

The first length of walling was commenced upon a cast-iron crib at 308 feet, and was finished December 28th, 1883; the second from 416 feet on February 26th, 1884; and the third from 519 feet on May 3rd. The flow of water was then 5 gallons per minute. At 522 feet, the diameter of the pit was diminished to 14 feet 9 inches, and as the water-bearing bed was approached, the distance below the footings of the lengths of walling was diminished. To prevent the rise of water between the rock and the walls, a narrow space was left behind the latter, which was filled up with pure cement. The first notable influx of water occurred on August 22nd, 1884, at 656 feet, at which date the shaft was completely walled down to 650 feet. The whole of the sinking plant and appliances were then pulled up, and on August 31st the pit was cleared for boring under water. The advanced bore of 6 feet 6 inches diameter was begun on October 15th, reached the Coal Measures at 795 feet on February 25th, 1885, and was continued to 826 feet, when it was contracted to 4 feet 9 inches in diameter down to 846 feet. The object of the contraction was to form a bearing for the sludge-collector, which was left at the bottom during the subsequent boring out to the full size.

The time occupied by the small boring was as follows:—

	Total Working.	Boring.	Repairing.
	Days.	Days.	Days.
October, 1884 . . .	17	15½	1½
November „ . . .	30	28	2
December „ . . .	30	22½	7½
January, 1885 . . .	31	21½	9½
February „ . . .	28	25¼	2¾
March „ . . .	19	17¼	1¾
	155	130	25

The full-sized boring (15 feet) was commenced in May, 1885, and completed to the seat of the moss-box at 720 feet on the 3rd of October.

	Working.	Boring.	Repairing.	Reboring with Small Borer.
	Days.	Days.	Days.	Days.
May, 1885 . . .	28	25½	2½	..
June „ . . .	30	26	4	..
July „ . . .	29	26¼	2¾	..
August „ . . .	31	22	1	8
September „ . . .	30	20¼	3¼	6½
October „ . . .	3	2¾	¼	..
	151	122¾	13¾	14½

The tubbing was built with a false bottom, the rings being bolted together with lead packing at the joints. When a number of rings equivalent to the depth of the fissured ground had been put together, a cover was added, similar in form to the false bottom with a valve which was kept shut by the water above it, but could be opened by a lever or a chain worked from the surface. Water was then admitted in such quantity that the weight of the closed tubbing somewhat exceeded that of the water to be displaced below, so that by careful manipulation either by rods or ropes, the whole mass could be lowered as easily as one of only a few cwt. In order to expel the water below the false bottom a central rising pipe is attached to the latter passing through a packed joint in the top cover. For the final compression of the moss-box the tubbing is loaded with water by filling it through the valve on the cover. The tubbing is kept centred during the sinking by four cast-iron guides bearing on the wall of the shaft.

The building of the tubbing up to 240 feet was finished on November 3, when the cover was fitted, and the lowering commenced on November 6. On the evening of the 8th, the moss-box reached the shaft-bottom, when the top valve was opened, and the compression of the moss packing went on regularly. No accident of any kind occurred during the operation, whose success fully justified Mr. Chaudron's bold innovation upon the original practice.

The concreting was begun on November 15th, 1885, and finished on the 19th. Eight wire-ropes of 0·39 inch diameter, attached to the second ring (from the bottom) of the tubbing, and paid out as the latter sank, formed guides for the four concreting ladles. The mixtures used, which were the same as in Pit No. I, were as follow:—

Pure cement	up to	787 feet.
1 part „ 1 part sand	„	755 „
2 parts „ 1 „	„	670 „
Pure cement	„	649 „
1 part „ 2 parts sand . . .	„	610 „
2 parts „ 1 „	„	603 „
Pure cement	„	599 „

The concrete was left to harden until the 28th of December, when the drawing out of the water began. On the 3rd of January, 1886, the top cover of the tubbing was reached at 561 feet, and the concrete was found to be perfectly tight. The cover was then removed, as well as four rings of the tubbing next below. The joint was finished with an iron ring and cement packing in the same way as in Pit No. I. The subsequent sinking of No. II pit has been suspended until the completion of the permanent pumping-engine in No. I, when a communication will be made between them. This is due to the fact that a small feeder of water has been struck in a sandstone bed near the top of the coal-measure.

Cost of Sinking No. II Pit.—The following condensed account of the cost of the works shows very clearly the advantage to be gained by the adoption of the method of boring over that of hand sinking when there is any notable influx of water.

	£.	£.
1. Sinking through alluvium and upper marls down to 82 feet, including 52½ feet of brick walling and 29½ feet of cast-iron tubbing :—		
a. Winding clay and sand, carriage, sinking in marl to 82 feet, drainage, supervision, and technical charges	909	
b. Materials for walling and tubbing and cost of building and erection	1,769	
		2,678
2. Sinking through fissured marl with cast-iron tubbing, 82 to 200 feet :—		
a. Sinking cost (items as above)	1,485	
b. Tubbing, inclusive of erection	2,227	
		3,712
3. Sinking and walling in compact marl 200 feet to 656 feet	4,488	
Total cost down to 656 feet		£10,878

	£.	£.
Brought forward		10,878
4. Boring from 656 to 800 feet and tubbing 587 feet to 800 feet:—		
a. Preliminary to boring		255
	£.	
b. 6½ feet bore, 656 to 803 feet	815	
c. 14¾ feet bore, 656 to 800 feet	1,368	
d. Tubbing—	£.	
Various materials	348	
Tubbing rings	3,665	
Moss-box	274	
Bolts and screws	211	
Wages	465	
	4,964	
Closing curb	48	
e. Supervision and technical remuneration	1,149	
f. Concreting—		
Materials	440	
Wages	98	
	538	
		8,882
5. Depreciation of temporary appliances, boring-machinery, tools, &c.—		
Boring-frame and foundations	525	
Engine and boiler	248	
Various tools	2,065	
		2,838
Total for the bored portion of the shaft		11,975
Total for the entire sinking		£22,845

The cost, therefore, from the surface to the foot of the tubbing was £28 10*s.* per foot; but if the old plan of tubbing up to the top had been followed, the cost would have been about £7,500 more, or about £39 per foot.

Comparison of Cost of Boring with that of Sinking and Pumping.— On the assumption that the footing of the tubbing could have been put in at 764 feet depth, that the influx of water between 656 and 764 feet would not have exceeded 3,300 gallons] per minute, and that the sinking tubbing could have been carried on at the rate of 16 feet per month, and that no interruption of importance were encountered, the cost may be estimated as follows:—

	£.	£.
a. Pumping-machinery—		
2 direct-acting engines of 600 HP. each (effective), with pumps capable of lifting 4,400 gallons of water from a depth of 771 feet per minute . . .		25,000
20 boilers of 1,000 square feet heating surface, with feed arrangements and chimney		12,500
Steam capstan		500
		£38,000
b. Pumping cost per day—	£. s.	
100 tons of coal at 5*s.*	25 0	
Other stores	2 10	
Wages and supervision	3 15	
Interest on cost	4 10	
	35 15	
or per metre (3·28 feet) of shaft . . .		214
c. Depreciation of the pumping-engines—		
Assuming one engine and ten boilers to be retained for permanent use, the second engine with the remaining boiler would be depreciated one half on resale, leaving £9,887 10*s.* to be provided, or per metre, between 200 and 233 metres		300
Or a cost per metre for pumping of		514
	£.	
The cost of sinking per metre is	75	
„ „ tubbing „ „	75	
	—	150
Total cost per metre of hand sinking . .		664
The sinking and tubbing between 200 and 233 metres at the above rate would cost		21,915
And from 233 to 243·9 metres about		300
		22,215
The actual cost of boring and tubbing under water .		11,975
Or a saving of		£10,240

The boring between 656 and 800 feet, and the tubbing up to 587 feet, was finished in about a year. If pumping had been adopted, the building of the engines would have occupied about $5\frac{1}{2}$ months, and the actual sinking operations about $7\frac{1}{2}$ months, or about the same time.