The sinking was commenced on the 23rd of December, 1874, and at a depth of 35 yards the *water-bearing stratum* was reached 2 feet below high-water mark of ordinary spring-tides. After sinking a few feet further, a large feeder, or spring of water was met with and the first set of pumps was put in. With these engines 3,200 gallons of water were pumped per minute; but it was soon found that the water could not be successfully kept under by these appliance. The engines having still a larger surplus of power, it was decided to procure extra and larger pumps, to endeavour to overcome the water by pumping in the ordinary way. The arrangements then carried out consisted of the following, viz.:—

No. 1 Pit.—Two 30-inch sinking sets, with 6 feet length of stroke, were attached to one end of a double-ended quadrant, and worked by the large engine (A). These lifted to two similar sets (in a staple) attached to the other end of the quadrant. One 20-inch sinking set, with 5 feet length of stroke, lifting to another, was attached to the second engine (B).

No. 2 Pit.—Two 20-inch sinking sets, with 5 feet length of stroke, lifting to the surface, were worked by the engine (C).

With the assistance of these pumps, the pits were sunk to a depth of 51 yards from the surface, or 16 yards below the level of saturation, when it was found *impossible to continue* the sinking further against the enormous quantity of water. By this time the water had become strongly saline, and it was clear that an influx had set in from the sea, through the open gullets in the limestone, and that sea-water was being pumped.

It was then decided to discontinue the sinking for a month, and endeavour to drain the district of the land waters by steady pumping. The engines were accordingly set to work at the following speeds:—

Engine.	Strokes per Minute.	Pumps.		Quantity of Water Pumped in Gallons per Minute.[1]
		Number of.	Diameter.	
			Inches.	
A	17	1	30	6,120
		1	30	
B	26	1	20	1,820
C	27	2	20	3,672
				11,612

This quantity of water was pumped for a month without accident; and indeed during the whole of the period of four months of pumping, no accident beyond the breaking of two Spears occurred. The above is probably the largest quantity of water ever pumped at one mine, and also the highest speed at which such large pumps have been worked.

This enormous drainage-power succeeded in overcoming the water sufficiently to enable the sinkers to resume operations in the pit; but the influx of water was so rapid that it was evident the cost of sinking in the ordinary way would be too great to be continued. The influx of water into the shaft when the pumping stopped was at the rate of 12 feet in height in the shaft in two minutes.

The arrangements of the various engines and crabs on the surface are shown in Page 229, Fig 5.

It was then decided to adopt the Kind-Chaudron process for the further prosecution of this undertaking, the Author having given considerable attention to this method prior to the sinking of the Silksworth Colliery. In that case, however, as the quantity of water met with in sinking through the Magnesian Limestone never exceeded 1,000 gallons per minute, it was overcome by a single 20-inch set of pumps; and therefore that sinking was more rapid and economically completed by the ordinary process.

Kind-Chaudron Process.

On the 2nd of May, 1877, steps were taken to remove the head-gear at No. 1 shaft (which had been erected and used for the ordinary sinking), as it was intended to utilise this shaft, so far as it was already sunk, and to continue the sinking of a somewhat smaller pit within by the Kind-Chaudron process. The diameter of 14 feet 3 inches was ultimately chosen for this shaft, on account of its having been the largest size hitherto sunk by this system on the Continent. The whole of the tools were purchased secondhand, and had been used and tested in previous sinkings. This not only considerably reduced the cost, but also eliminated the risk that attend the use of new tools.

[1] At one time the rate was somewhat faster, and a total quantity (by calculation) of more than 12,000 gallons per minute was pumped.

The first operation was the lowering of a wrought-iron tube, ½ inch thick, and *riveted with countersunk rivets* so as to form a smooth surface, 54 feet long and 14 feet 4 inches in internal diameter, from the top of the water to the bottom of the shaft, so as to ensure that no stones could fall from the sides during the boring. This was safely accomplished on the *16th of August, 1877, and the space* between the tube and the sides of the shaft were then filled in with concrete, and the boring commenced by the Kind Chaudron process at a depth of 155 feet, on the 24th of September, 1877

As this process of boring out pits has been fully described in Papers read before the North of England Institute of Mining and Mechanical Engineers,[1] in May, 1871, by Mr Warrington W. Smyth, and before this Institution, in March 1872, by Mr Emerson Bainbridge, Assoc. M. Inst. C.E.,[2] the Author will only very briefly allude to the tools employed, and give in greater details the particulars wherein the operations at Marsden differed from those previously described.

Description of Tools, &c.

A substantial Headgear was erected, strongly framed together with timbers (p. 232, Figs. 1 and 2). The whole of this is covered in with wood cleading, so that the workmen are always protected from the weather. At 37 feet from the ground, two rails are laid on stout balks A A of timber, which carry travelling carriages X X, on which the heavy tools are run backwards and forwards. At 52 feet from the ground similar rails, on longitudinal balks of timber B B, support *small carriages* (p. 237, Fig. 8) for carrying the boring-rods, this great height being necessary in order to obtain sufficient length of rods. It is this system of carrying and moving the tools on traversing carriages which enables the operations to be conducted with so *small an amount of manual labour.*

Description of the Process.

The Kind-Chaudron process consists of two distinct series of operations.

1st. *Those connected with the boring out of the shaft, on a* system closely resembling that first adopted by Mr. Kind many years ago for boring deep holes for artesian wells. 2nd. That of lowering down the shaft a water-lining or Tubbing.

The first process therefore at Marsden was the boring of a centre hole *in No 1 pit, 4 feet* 11 inches in diameter, by a small Trepan or chisel (p. 236, Fig. 1). This Trepan, 7 tons in weight, is attached to the massive wooden Lever (A, p. 236, Figs 2 and 3 by rods of the best pitch pine, 5 inches square (A, p. 236, Fig. 4), and 58 feet long, with iron terminations, having tapered screws. One end of each rod is fitted with a male screw (A, p. 236, Fig, 5), and the other with a female screw. The screws have coarse threads carefully cut, so that, after having entered, a few turns are sufficient to screw the joint quickly home.

The Lever is attached on the opposite end to a steam cylinder (C, p. 232-3, Figs. 2 and 3), 39 inches in diameter, actuated by a single valve only on the top side. The valve is worked by hand, the rods are lifted by the pressure of the steam on the top side of the piston, and they fall by their own weight when the valve is opened to the atmosphere. The length of stroke is regulated by *the machinist*, and varies from *6 to 18 inches* according to the hardness of the rock. An important adjunct to the Lever is the spring beam (B), against which the Lever strikes at the termination of each stroke. The number of strokes per minute varies from nine to eighteen. In very hard *rock comparatively few and light blows only can be given.* When the rods are suspended at the end of each stroke, they are turned through an angle of 2° to 4° by four workmen holding a crosshead lever, walking round the top of the pit, similarly to an ordinary boring.

An *essential* part of the boring tools is the Sliding Piece (p. 236, A, Figs. 1 and 3), by which the Trepan is connected to the rods through the medium of a slot 12 inches long. This permits the Trepan to strike the bottom without communicating a severe shock to the rods, which continue their descent until arrested by their buoyancy in the water, aided by the Spring Beam striking against the inner end of the Lever Except for the play thus allowed, it would be impossible to strike even a light blow without fracturing the rods.

An apparatus called the Freefall (p. 236, Fig 2) is sometimes also attached. On the descent of the rods the Trepan is

[1] Transactions, vol. xx., p. 187.

[2] Minutes of Proceeding Inst. C.E., vol. xxxiv., p. 43.