

caught up by a pair of jaws (A), which are locked by a wedge. The wedge being withdrawn by means of a large disk of wood (b), at the commencement of the return stroke, permits the Trepan to fall nearly 2 feet without being detached from the rods. This apparatus was attached to the small Trepan in boring the No. 2 small pit between the depths of 234 feet and 334 feet. A disk, 5 feet 2½ inches in diameter, gave most satisfaction, the diameter of the small pit being 6 feet 6½ inches.

After the boring has been continued about three hours, in moderately hard rock, the Trepan is withdrawn, and the Sludger (p. 237, Figs. 6 and 7), with a capacity of four cubic yards, or 10 tons, is lowered. The Sludger is sometimes attached to the Lever, and worked up and down by the rods, and at other times by the rope only. The *débris* rises into it through the valves in the bottom, it is then withdrawn and emptied. The emptying of the Sludger, and the unshipping of the Lever, to allow of the rods being removed, are effected by ingenious and time saving arrangements, which must be seen to be understood.

After the centre boring is advanced 30 or 40 feet, the large Trepan (p. 236, Fig. 3), 16 tons in weight, is put in, and the large pit is similarly bored, the *débris* falling into the small pit, which requires to be frequently cleared out. This was the process in the first instance adopted at Marsden, but it was afterwards modified. In every new sinking by this system slight variations are found in the character of the rock, which entail modifications in its application. At Marsden the rock proved to be harder than in any locality where the system had been previously in operation.

During the boring out of No. 1 small pit no difficulty was found in raising the *débris* with the ordinary Sludger; but in boring the large pit it would not rise into the sludger, and became solidified at the bottom of the small pit. This was probably due to the particles being larger than those produced in the boring of the small pit. To remedy this, at first clay was thrown down the pit, and the small Trepan was again introduced to loosen the *débris*, and mix it with the clay, which could then be withdrawn by the ordinary Sludger. But the process was a long one, the re-boring taking quite as much time as the original boring. It was therefore determined to lower the Sludger into the small pit, release the rods, and leave it there to catch the *débris* as it fell. Accordingly the Sludger was lowered to the bottom of the small pit, and left there, as shown in Plate 4, Fig. 1. On attempting to withdraw it, however, it was found that the mud which had settled in the water at the bottom of the pit, or which had passed the sides of the Sludger, imbedded it so far that great violence had to be used to extract it, which would have certainly, sooner or later, resulted in serious accidents. Arrangements were then made to suspend the Sludger on the edge of the small pit at the top by Claws (p. 240, Fig. 2), and the two inner of the interior teeth of the large Trepan were removed to avoid striking these claws. This plan succeeded imperfectly, and on several occasions when the Claws were struck the Sludger fell down the small shaft, and was only extracted with difficulty, and with a liability to accidents.

A successful attempt was then made to form a ledge within the smaller pit, by taking out all the teeth but the two outer, and the Sludger was thus suspended about 1 foot from the top of the small pit. This operation, however, entailed so many changes of the teeth, etc., that it was attended with great loss of time. But having found the correct principles on which to proceed, it was not difficult to devise a plan for leaving a suitable ledge within the smaller pit. To effect this, the outside tooth of the small Trepan on each side was enlarged 3 inches, the tool was again introduced, and the small pit bored to a diameter 6 inches wider than previously, leaving a ledge of 3 inches all round (p. 240, Fig. 3), on which the Sludger was suspended by an angle-iron ring.

In No. 2 pit a third Trepan was used, having a diameter of 6 feet 6 inches. By this Trepan the small shaft was bored to a depth of 383 feet, not only through the Limestone, but 50 feet into the Coal Measures, and 6 feet 6 inches below where it was intended to place the Moss-box of the Tubbing, and therefore below, and entirely clear of, all future operations with the large Trepan.

The smallest Trepan was then introduced, and the boring continued 32 feet 9 inches further, leaving a ledge of stone 9½ inches in width all round, on this ledge a cast-iron ring was deposited, to form a permanent bed for the Hanging Sludger to rest on. This arrangement acted perfectly, never having

been the cause of the slightest accident throughout the sinking of the second shaft.

The cast-iron ring was adopted in the second pit, because the weight of the Sludger soon wore away the ledge of stone by being suspended from it. At first the Hanging Sludger was lowered into its seat by the regular screw, which was left slightly slack, all the other screws of the rods, as they were lowered in, being tightly screwed home. When the Sludger was deposited on its bed, by turning the rods backwards, the slack joint yielded, and the rods were unscrewed at this point and drawn away. It did, however, happen occasionally that some of the other screws became detached, and then the remaining rods and sludger had to be fished up. A double hook (p. 237, Fig. 11) was next adopted for lowering the Hanging Sludger into place, it was simply fastened on to the bow of the Sludger, and when the latter was lowered and rested on its bed, the rods were let down a few inches further, and turned half round, so as to free the hook entirely from the bow, they were then drawn away, leaving the Sludger in place.

The Author has described this portion of the operations in detail, being the first instance in which the Hanging Sludger was used in the Kind-Chaudron process for shaft boring, although it had been used by Mr. Kind, on a somewhat similar design in boreholes.

SAFETY TOOLS.

No small part of the success of this process arises from the ingenious arrangements, and forms of tools, for picking up material at the bottom of the shafts, and for taking hold of broken spears, etc., which, from the character of the operations, must be of frequent occurrence. These are termed "safety tools," and consist of the following apparatus:—

1st. The Catching Hook (p. 237, Fig. 12), which, on being swept round the shaft below the top of the broken spear, guides the spear into the angle made by the hook and its rod, where a properly-shaped recess is formed, into which the ironwork of the spear falls, and can by this means be retained and withdrawn.

2nd. The Spear Catcher (p. 237, Fig. 13) is a fish-head, with a pair of serrated jaws, which on touching the top of the broken rod, and the wooden chock keeping the jaws open being forced out, the teeth press firmly against the ironwork of the Spears, enabling them to be withdrawn.

3rd. The Grappling Tongs (p. 237, Fig. 14) being a pair of large rakes which can be opened and shut by levers worked by ropes. By moving and working this across the bottom of the shaft, any pieces of material larger than 2 inches square, can be extracted with ease.

THE TUBBING.

The most important part of the process, and that attended with the greatest risk, is that of lowering into the shaft the metal Tubbing. At the Marsden Sinking, the dimensions of each ring or cylinder were as follows (p. 241, Figs. 6 and 7):—

	No. 1 Pit.	No. 2 Pit.
	Feet Inches.	Feet Inches.
Internal diameter	12 7½	13 8½
External "	12 9½	13 11½
Thickness of top cylinder	0 1	0 1½
" " bottom "	0 1½	0 1½
Height of each cylinder	5 0	5 0
Total height of Tubbing	250 0	255 5
	Tons cwt. qrs.	Tons cwt. qrs.
Weight of top cylinder	5 4 0	6 10 1
" " bottom "	7 0 0	8 19 2
Total weight including bolts and lead joints	400 0 0	450 0 0

The flanges of each top cylinder are 3½ inches wide by 2 inches in thickness; and between every ring is placed a plain lead wedge 4½ inches wide, by ½ inch thick, covered on each side with red lead. The cylinders are attached to each other by

1 The bottom of the rods where they are attached to the Sludger by a female screw is fitted with a small inverted funnel (Plate 4, Fig. 5), to guide the male screw which is attached to the Sludger, into the female screw at the end of the rods, as they are lowered; an arrangement successfully carried out through the whole of the boring of both pits, without failure or difficulty, even at a depth of nearly 400 feet.