

pump in the tunnel. This pump was fixed in the side of the tunnel, near the face, and from it wrought-iron piping, with a flexible end-piece, carried the high-pressure water to the receiver on the shield, and a similar arrangement of pipes returned the exhaust water to a small tank below the pump. The whole mechanism was most compact, tank and pump occupying a space of less than 8 x 2 x 4 ft.

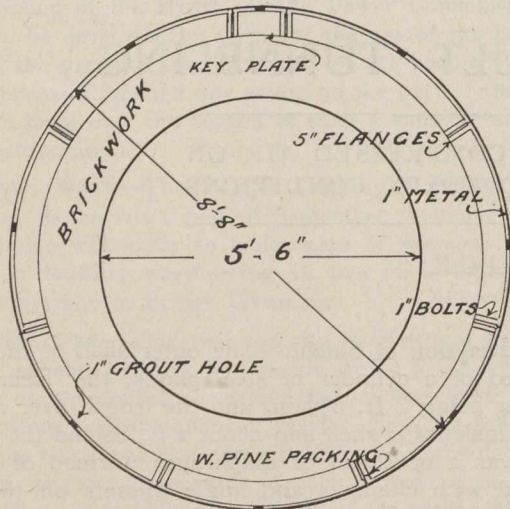


Fig. 1—Section of Sewer.

Erection of Shield.—As the use of a shield had not been contemplated in the original layout, the erection of this shield was carried out, not in a shaft as is usual, but in a specially excavated chamber in the tunnel, which was enlarged for a short distance to a diameter of 11 ft. This shield chamber might have been excavated ahead of the iron had it not been that the face was already very near to the wall; but in any case, it was probably safer to excavate around the outside of the iron—from which temporary propping could be erected—rather than to open up new ground.

In the last length of eight rings, seven were taken out, the eighth being left as a rib to support the longitudinal bars used in poling back. Two plates were broken to obtain an opening in the lining, and the key-plates of the unbroken rings were taken out first, the upper plates being supported by struts from the invert. A crown bar was put in through the lag-space and carried on short props from the leading and ninth rings. The upper plates were next taken out, those along one side at a time, and the ground poled back on bars similarly supported. Below springer the excavation was taken down and timbered outside the rings as far as possible before the removal of the plates.

All this temporary timbering had cement grout under pressure forced into the ground behind it. The bars were then sheeted inside, and the space was pressure-grouted. By this means the top was made practically air-tight, and a fairly good pressure maintained while the bottom was being excavated and poled with 3-in. sheeting.

The shell was taken into the tunnel in pieces and erected round the framework of the bulkhead. The taps fixing the cover-plates to the shell were cut and hammered flush with the inside face to allow the tunnel segments to fit closely. The body segments were also attached to the shell by means of screw taps. Bolts with counter-sunk heads held the angle-stiffeners to the shell and the bulkhead; thus the only variation from a smooth outside surface was the longitudinal cover-plates. A cradle of half-timbers supported the shield at its proper level, and on the completion of erection, the space be-

tween shell and walls of chamber was packed with dry brick and grouted with cement under pressure. There was now a set of crown bars held by the shield, forming cantilevers in support of the ground above the leading ring, which was taken down and the shield driven hard to the old face polings. These were bored out in small parts and clay put into pockets excavated ahead around the cutting edge of the shield, new face-boards being put in horizontally to form a circular shutter of timber about 2 ft. less in diameter than the cutting edge, as shown in Fig. 2.

Method of Excavating.—As a rule, the shield was driven forward until the diaphragm was within about 10 in. of the horizontal face poling-boards, these boards being supported during the period of movement by two raking struts off a cross-piece on the second last ring, and butting against two vertical soldiers running across the boards. Fig. 3 shows the shield ready to move ahead, and Fig. 4 shows excavation in progress. When the shield came to rest each poling-board was strutted off the diaphragm with short blocks and wedges. With the face thus supported the rakers and soldiers were taken down and excavation proceeded with by withdrawing the top poling and pulling out the sand with hand-tools.

A pocket or groove was cut out a little beyond and above the cutting edge, and clay rammed in, after which the first poling-board was carried forward and re-erected against the new face with long struts off the diaphragm. In this way each board in turn was carried forward and the face kept continually poled up. Below the lowest board the sand was roughly excavated down almost to the cutting edge, and, after erecting the rakers and soldiers, the struts were removed, leaving the shield again in position to travel ahead. The excavated sand was thrown upon a staging at the level of the sill of the openings, from which it was shovelled into wagons and taken through the air-locks to the shaft.

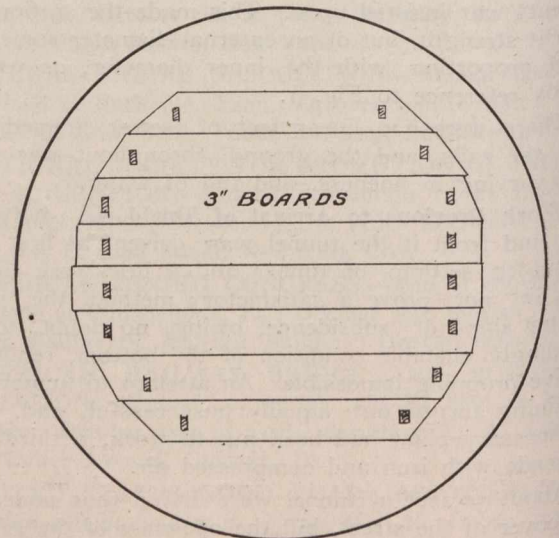


Fig. 2—Poling of Face.

In this ground the shield showed a decided tendency to go downward while in movement, but it was kept to proper level by using the 3 lower rams only during the first part of the movement. After the cutting edge was fairly buried the two upper side rams were brought into action as the first three did not give a force sufficient to drive the shield ahead. During the first period, with three 4-in. diameter rams working under a pressure of 1,500 to 1,600 lbs. per sq. in., the total effort was about