September 27—No trouble; lowered Deane pumps; water 42 gallons per minute; sunk 4½ feet through 3 feet mucky clay and 1½ hard pan. Depth, 144½ feet.

September 28—Lowered Blake pump; broke lever; struck the large stream at 1.30 p.m.; running 500 gallons per minute; first rush brought about 10 barrels of sand; started the Deane pumps and kept the water down; water after rush 500 gallons per minute; sunk 2½ feet through sandy clay. Depth, 147 feet.

September 29—Lowered the west Deane; water now coming very clear; water 420 gallons per minute; sunk 2 feet through greenish clay. Depth, 149 feet.

September 30—Lowered both Deane pumps; the water all coming up as yet in the southwest corner and clear; water 350 gallons per minute; sunk 3 feet through clay with pockets of gravel. Depth, 152 feet.

October 1—Lowered east Deane and the Blake pumps; are now about the level of the water bed. water 350 gallons per minute; sunk 4 feet through sandy clay. Depth, 156 feet.

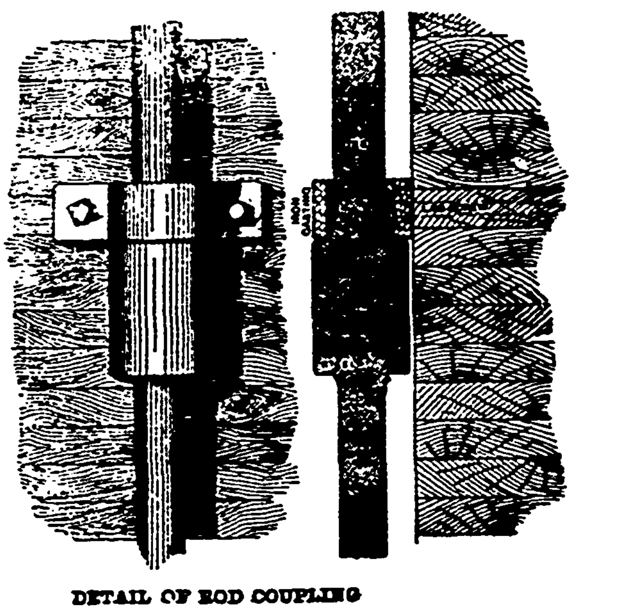
October 2—The discharge hose blew off the east Deane pump three times; at the same time the Blake pump played out, causing six hours delay; water clear and gravel not running; water 350 gallons per minute; sunk 3½ feet through gravel. Depth, 159½ feet.

October 3—The west Deane pump refuses to work, so we put in one more Blake pump; the water is coming in from all over; gravel has cement bands, sometimes running nearly across the whole bottom; water 350 gallons per minute; sunk 2½ feet through gravel. Depth, 162 feet.

October 4—The gravel being cemented together in cakes, it is very tough digging and jacking; the shaft is in good shape, no pulling; water 350 gallons per minute; sunk 3 feet through gravel. Depth, 165 feet.

October 5—Getting into the blue shale overlying the limestone; water 350 gallons per minute; sunk 3 feet through 2 feet of gravel and 1 foot of shale and gravel. Depth, 168 feet.

FIG. 5 FIG. 6



DETAIL OF ROD COUPLING

October 6—Got shoe on to rock; water cut off from under shoe; water 350 gallons per minute; sunk 2 feet through shale. Depth 170 feet.

October 7—Getting into rock, and some of compartments of shoe removed; pumps bothering; water 310 gallons per minute.

October 8—Getting more sump room in rock, and timbered down through shoe on to the rock; water 310 gallons per minute.

October 9—Got all the shoe braces out, and got farther down into rock; water 310 gallons per minute.

October 10—Got squared down through rock, and at 5.30 p.m. started inside cribbing and puddling from bottom; in this and the following shaft the inner cribbing was of 2 inch by 12 inch timber laid flat; the space between the outer and inner cribbing was 10 inches, which was filled with the puddling; water 310 gallons per minute; sunk during past four days 3 feet through limestone, practically finishing the difficult part of the shaft. Depth, 173 feet.

October 11 to 25—Occupied in building up inside cribbing and puddling between; water being allowed to fill up behind.

October 25—Tore down old top works and started permanent tower.

November 5—Started to pump the shaft out.

November 1—Got water out, but found puddling was not a success; the difficulty had been in getting it packed under running streams; caulking was now tried without effect, the shaft making 200 gallons of water per minute.

Nevertheless, sinking was resumed November 12th, and steadily progressed through the solid rock till coal was reached, except for two delays of a week each, when endeavors were make to shut out the water. Flooring was put on, but to no effect. Then the experiment was made of pumping in cement between the inner and outer cribbing, a method notably successful in the Croton aqueduct of New York city, to fill voids behind the brick lining; but here the conditions were such that it failed; the streams of water were too strong for the cement to set, and it washed out again.

After this no attempts were made to shut water out of the shaft, and except puddling, none in the later shafts. However, to keep the hoistways dry and also prevent the water from falling clear to the bottom of the shaft, water-rings were put in each shaft just below where the water enters, from which the water is piped to a pumping station on an upper seam. The water-rings are assisted in collecting the water by lining the shafts above them with flooring raised from the curbing by nailing on top of laths, thus keeping the water behind the flooring till it enters the ring.

Under the circumstances at Ladd, the writer believes this way is even better than if the shafts had been made water tight. The water has so materially lessened since the first shafts were sunk as to cause belief that the bulk of it was held in the ground like an underground lake, and that this has now been drained, so that what is coming now is the seepage from the surface water-shed. The total quantity from the present three shafts averages this year (1894) about 135 gallons per minute. As the water is of excellent quality, it is used in the boiler plant and the town water system. While largely in excess of present needs, it will no doubt all be wanted in the future. Moreover, had the shafts been made tight, there would be the constant menace of a large body of water liable to be let down on any rupture of the shaft, a thing unlikely and yet always feared. As it is, there is no pressure whatever from the water, the shafts draining freely the natural flow of the strata.

Before the shaft last described, now known as "A" shaft, had reached the coal the sixth attempt or "B" shaft, was started on November 14, 1889, 50 feet west of the third attempt, now known as the air shaft, but which was temporarily abandoned at 125 feet. The latter shaft was now kept pumped out, materially helping in the sinking of "B" shaft, which made much less water than the previous shafts. Even when "B" shaft got below the third attempt there was not nearly so much water, for the ground seemed already largely drained after a year and a half of steady pumping. Accordingly "B" shaft was sunk much more rapidly than its predecessors. This was not entirely due to less water but partly to the experience gained by the sinkers in meeting the peculiar difficulties of the field and partly to the improvements made in the appliances. Among the latter was the plan of suspending the curbing from solid wooden triangles instead of the open Howe truss, which could not be designed to meet immensely varying strains, and so on several occasions had been crushed. Another improvement was in the shoe in making the plate braces so they could be easily removed on reaching the solid. They were made heavier but fewer in number, forming 12 compartments, instead of 15, as in "A" shaft. This shoe was highly satisfactory in all respects (see Figs. 3 and 4).

The only serious difficulty that "B" shaft encountered was when, at a depth of 50 feet, a hole came to the surface along side of the shaft at the east end, causing it to swing 6 inches out of plumb. The hole was promptly filled up with clay, which stopped the running, and no further trouble ensued. On December 31, 1889, the shoe was down on the solid rock.

The speed of sinking the fourth, fifth and sixth shafts is as follows:—

Fourth Shaft.—Started January 8, 1889. Reached rock June 30, 1889, a period of 174 days. Of these, 96 days were lost in delays, 78 days only being spent in sinking. Depth of shaft to rock, 162 feet. Average progress per working day, composed of three 8-hour shifts, 2.1 feet. Maximum rate of pumping, 640 gallons per minute.

Fifth Shaft "A."—Started August 10, 1889. Reached rock October 6, 1889, 58 days total, of which 7 were lost in delays and 51 spent in sinking. Depth of shaft to rock, 170 feet. Average progress per working day, 3.3 feet. Maximum rate of pumping, 500 gallons per minute.

Sixth Shaft "B."—Started November 15, 1889. Reached rock December 31, 1889. Total, 47 days, of which but two were lost in delays; 45 were spent in sinking. Depth of shaft to rock, 160 feet. Average progress per working day, 3.6 feet. Maximum rate of pumping, 350 gallons per minute.

There was no detailed record kept of the third or air shaft, but after getting "B" shaft down, sinking was resumed from where it had stopped over a year before on account of the lightness of the shoe, and now that "B" shaft was draining the water there was no trouble in getting the air shaft down. Thus three of the original six attempts were finally successful; and all the shafts in which the shoe was used succeeded in reaching rock.

I will now give a description of the details of the shoe, method of hanging the curbing, etc., as finally developed and used in sinking "B" shaft.

Beginning at the top, there is first in order a platform of 2-inch plank laid on the surface about the shaft, and covering an area 30 by 46 feet; on top of these, running across them and parallel to the sides of the shaft are 60-pound steel rails. These form the foundation of the four solid wooden triangles which carry the weight of the curbing not sustained by the friction of the ground. Each triangle is made of 8 pieces of 12-inch by 12-inch timber, the bottom one 48 feet long, the next 4 feet shorter, and so on to the top one, which is 20 feet long. The triangles run across on top of the rails and the narrow way of the shaft. On them and across them rest two 16-inch by 16-inch timbers 20 feet long. These are nearly over the side walls of the shaft; through them pass the 8 rods which sustain the curbing, four to each side or timber, huge washers under each rod head distribute the strain over the timber, which in turn distributes it to the triangles. The whole forms an almost rigid structure, so that when subsidence comes, everything goes down at the same time. The hanging rods are steel, and made in 10-foot lengths, the ends upset or thickened so that screw-couplings are made without weakening. The upper lengths are 2½ inches in diameter, every three lengths down the size decreases ¼ of an inch, so that the bottom lengths are 1¾ inches in diameter. The support to the curbing is, as finally adopted, an iron lug placed under the screw-coupling piece at each joint and spiked to the cribbing.

The shoe as finally designed and used in "B" shaft was 12 feet 8 inches by 17 feet 6 inches inside measure, built of ¾-inch steel plate, the sides 4 feet deep, of which the upper 16 inches was the shield embracing the bottom of the curbing. The lower part of the shoe was divided into 12 compartments by three transverse braces of ¾-inch plate, doubled, 22 inches deep, and two longitudinal lines of braces, of ¾-inch plate, 16 inches deep. Around the inside of the shoe 12 inches from the bottom runs a shelf 9 inches wide of ¾-inch plate, braced below with brackets, and with a 2-inch ledge in front. This forms the press-plate on which are placed the jack-screws to force down the shoe; directly above is the shaft-cribbing against which the jack-screws bear. Although the shoe itself weighs 8 tons, the jacking was often very hard. The mode of operating is to apply the jack screws till the shoe has been forced down from 2 to 10 inches, depending on the ground, never more than 10 inches, which leaves but 6 inches of shield lapping the cribbing. Then the shoe is levelled carefully, the jack-screws removed, the 2-inch cribbing-plank put in place and spiked upward to the previous course. It is further tied, till the next hangers are put on, by boards nailed up and down the curbing. The cribbing is arranged with butting-joints, the planks alternately overlapping, a simple and a very strong way with plank laid flat. It is further strengthened by triangular corner-strips.

Two-inch planks are used for the cribbing instead of thicker timber, because more easily handled in the cramped space at the bottom of the shaft, and they are little less strong for the same thickness of wall. After as many courses of cribbing are in as the space allows for, frequently in bad ground only one, the jack-screws are replaced and the operation repeated. Separate plate-covers were provided for the compartments of the shaft "B" shoe, but it was found that the rushes of sand could be kept down if the excavation were not carried below the press-plates; and as the covers would hamper the work they were not used. They were kept at hand, however, the idea being, that when dangerous ground was expected, all the compartments except one or two would be closed.

Meantime the excavation and pumping goes on according to circumstances, and with the customary appliances.

To provide for supporting the shoes when a very soft spot is reached, chains, one in each corner, pass around the braces and hook to the hanging rods. An improved detail would be the insertion of a long turn-buckle at the lower end of each chain, fastened by clevis to a brace. At Ladd full weight was never thrown on the chains, the shoe always binding on some part; in soft ground, where there was danger of rushes, excavation was never advanced below the bottom of the shoe. There were usually three pumps hanging in the shaft, one in each compartment. The vertical Deane plunger pump with a 4-inch delivery was the favored type. The pumps were hung by hemp cables from capstans at the top, so as to be readily raised and lowered, the steam and water connections to the pipe lines being made with flexible hose.