ventilating engine, an air blower with a capacity of 10,000 cubic feet of air per minute, a hydraulic pump for operating the rams, a machine shop with machines for tunnel work, a water pump for the pit, and an electric light plant. The tunnel will be lighted by electricity. The electric plant is in Sarnia, where permanent brick boiler and engine rooms have been erected.

The great cuttings for the approaches were commenced New Year's, 1889. Each cutting was made about sixty feet deep at the portal. The Canadian cutting at its broadest portion is 260 feet wide, the American about 200 feet wide. Into each pit inclined tracks were laid for engines to haul out the dirt. On the banks derricks were erected for hoisting the soil. In September, 1890, steam shovels began work on the cuttings. On each side of the river two shovels were used, each attended by an engine and train of flat cars. Several hundred men were employed night and day, lime lights being used at night, and the soil was removed in layers. The work of these shovels was greatly hindered by rains, and numerous landslides occurred.

### THE HYDRAULIC MINING SHIELDS.

Because of water and quicksand the St. Clair tunnel could not have been constructed without the aid of hydraulic mining shields. Such shields have been used successfully in London, Chicago, Buffalo, Broadway tunnel, New York City, the Hudson River tunnel, and in other works. This shield is a cylinder, like a headless barrel. Its front end has sharpened edges to cut into the earth. The thin rear end is called the hood. The inside is braced with iron, both vertical and horizontal. Around the main walls are sets of hydraulic jacks. Each jack has a valve whereby it may be cut off at any time from the pump that supplies all the jacks. The masonry, or iron plates, of the tunnel, being built up within the thin hood of the shield, air is supplied to the jacks and the shield is forced ahead, usually the length of the pistons of the jacks, or about two feet. The shield having advanced, the men remove the soil from the front of the shield. Everything being in readiness the shield is again pushed forward, the tunnel walls built up, and the excavated soil removed.

Each of the St. Clair tunnel shields weighed eighty tons. They were made of steel, manufactured at Hamilton, and erected on a bank of a cutting. Each shield was circular, having an outside diameter of 21 feet and 6 inches, its length was 15 feet, and its thickness 1 inch. The shields were lighted by electricity. When erected the shields were rolled on wooden tracks into the cuttings. Each shield has two dozen hydraulic rams, operated by two men. The air pump might have exerted 3,000 tons pressure upon the shield, but the greatest pressure used was 1,700 pounds per square inch, 40 tons per ram and 960 tons on the shield. Each morning the direction of the shield was taken. By the pressure of the hydraulic rams the direction of the shields could be absolutely governed. How well is shown by the fact that when the shields met, after traveling 6,000 feet, they were exactly together.

The American shield was started July 11th, 1889, the Canadian September 21st, 1889, and they met at 11.30 p.m. August 30th, 1890. The shields' shells were left in the tunnel, and the tunnel walls laid up in them. The American had done the most work, and the easiest progress was towards Canada, the average being ten feet each day. The greatest advance in a day was 27 feet 10 inches. The time spent was less than in any similar tunnel construction. The American shield, in fourteen months, bored 3,313.85 feet; the Canadian, 2,686.10 feet. Sunday afternoon, August 24th, 1890, the two gangs of workmen talked and exchanged presents through the auger hole bored between the two shields. The first man through was Chief Engineer Hobson, followed by other officials, and then the whole working force. Three gangs of seventy-five men were employed in three shifts, each of eight hours.

At first long, thin spades were used to remove the clay. A workman whose trade was coopering took an old saw, bent it like a horseshoe, and made a knife with which he could do three men's work. His knife was then used as a model tool for cutting the clay. Two men, grasping the two handles, sliced out slabs of blue clay a yard long, and easily kept ahead of the layers of the tunnel lining. The clay was loaded upon flat cars by men. Mules or horses drew the clay-loaded cars out of the tunnel upon a tramway, on one of whose tracks the cars returned by their own gravity. The bed of this tramway was the blue clay, about two feet deep. When the tunnel was completed the removal of this clay bed consumed two months' time. At the tunnel entrance the clay cars were hoisted to the banks and dumped upon large railway flat cars, by which the soil was removed, and used in grading the new freight yards, where about twenty miles of side tracks were laid on each side of the river.

The tunnel walls are made of cast iron, suggested by Chief Engineer Hobson. In the circle are thirteen segments and a key. Each segment is 4 feet 10 inches long, 18 inches wide, and 2 inches thick, with flanges inside of $1\frac{3}{4}$ inches thick and 6 inches deep. In each segment were cast 32 holes, 4 in each end flange and 12 in each side flange. Through these holes passed steel bolts seven-eighths of an inch in diameter. In each section of the tunnel the circular joints required 157 bolts and the longitudinal joints required 56 bolts. The flanges took in a circle of 20 feet and 5 inches in diameter. The edges of the plates were planed in the machine shops near the tunnel entrances. Each plate was then heated and dipped in cold tar. This had been found better than to dip the cold iron into hot tar. Formerly the tar would not dry quick enough; later the tar was dried by the time the segments were cool. The segments were lifted to place by a circular crane revolving on a spindle in the center of the shield. This spindle had a vise at one end and a counterbalance weight at the other.

### EFFECTS OF COMPRESSED AIR.

When the bed of the river was reached, quicksand and water made great trouble. For some time it was thought the tunnel might have to be abandoned. Compressed air was found a sure remedy. At the river line on each side, brick and cement, air-tight bulkheads were built across the tunnel. Each bulkhead had two air chambers, one on each side, 7 feet in diameter and 17 feet long, with air-tight doors at each end. Through each air chamber passed a car track. Inside the tunnel, beyond the bulkhead, work was begun under air pressure of 10 pounds to the square inch. From time to time the air pressure was gradually increased, until the men worked under an artificial pressure of 22 pounds per square inch, a total atmospheric pressure of 37 pounds per square inch, or about $2\frac{1}{2}$ atmospheres. On the Canadian side the highest air pressure was used because of quicksand. On the American side compressed air was used from April 7th, 1890; on the Canadian, May 20th, 1890.

The compressed air was shut off October 7th, 1890. It kept back the quicksand and water. Horses could not stand it, and mules had to draw the cars. The men had to be examined by the company's physician, and were required to have strong constitutions. Several deaths resulted from using the compressed air. About five minutes were needed to in-