is required; the powder actually amounting to less than one-quarter that required in heading work. The blasting in the break-ups is done with time fuses which are ignited electrically. Thus it will be seen that the break-up excavation requires but little labor and explosive, being both rapid and economical. With four break-ups and one heading working at the back of the mountain the average excavation was about 500 cubic yards of place measurement daily, all of which goes out through the west heading to the main crusher plant.

A very important advantage of this method of tunnel driving is that where bad ground is encountered no material delay is experienced. The bottom heading progresses on through the bad material, which is treated carefully at leisure later on. This saves much time in the ultimate completing, and much money and risk in the construction. Some bad ground in break-ups where heavy internal stresses developed in the roof, require considerable timbering. This will be all concreted in with a reinforced single arch before the steam shovel reaches it, so that neither time nor money will have been lost.

In connection with the physical risk involved by this method it is interesting to note that within 15 months since the tunnel headings were started and with nearly a mile and a half of break-ups completed there has been only one fatal tunnel accident.

Bench Excavation.—The side benches, below the level of the jumbo timbers, are taken out, after the break-up excavation has been completed, by a steam shovel operated by compressed air. By this method the benches may be drilled and blasted well in advance and by a special loading device the usual delay in spotting cars is avoided, and no time will be lost by the shovel, making this excavation very cheap and rapid.

At places where a steam shovel cannot be used because of timbering, special construction, or shield work, the benches will be handled by hand and a belt conveyer loading into the tunnel cars.

Shield Work.—At the city end where very soft heavy ground is encountered under most unfavorable conditions, a steel roof shield has been adopted. This avoids settlement of overlying material, reduces the drainage of the surrounding ground, and eliminates the very heavy and expensive timberwork that would otherwise be necessary.

This shield consists of a cutting edge, shaped to conform to the outline of the tunnel roof cross-section, which forms the front of a steel envelope extending over the platforms on which the men work and back far enough to lap over the last "ring" or section of tunnel lining erected. Steel poling boards, semi-attached to the shield will be used, especially in the boulder clay, thus producing a cutting edge that may be advanced in sections where desired.

The shield is supported on steel columns forming the centre wall and on side walls which rest on the solid rock. It is forced ahead by hydraulic jacks, under a pressure of about 5,000 pds. per sq. in. These jacks push against the tunnel lining as it is erected.

The procedure is as follows:—

After a shove, i.e., a move of the shield, 27 in. ahead, a ring of concrete blocks, 27 in. wide, along the axis of the tunnel, by 24 in. thick and about 5 ft. long circumferentially, are set up in place by means of a hydraulic erector. When this tier of blocks is in place, the jacks are put in motion, jamming the new blocks hard against the last tier erected and forcing the shield slowly ahead, as fast as the ground is excavated in front of it. The excavated material, like that in the break-ups, is dropped directly into cars in the heading below. As soon as this shield has made a shove of 27 in. the process is repeated.

Where boulders are encountered the shield will be retarded and the steel poling boards advanced along the rest of the shield face for the 27-in. shove, when the boulder will have been removed in part or wholly.

Where special rectangular sections are built, a steel structure will be erected and steel sheeting used over and around it. This steel sheeting will be advanced by jacks, the structural steel and enclosing concrete being placed under the sheeting as it advances.

By this method the roof is never exposed; the men are never endangered by falling material, and if water is encountered the face can be protected by poling and breast boards with small pneumatic guns, or jacks, so that very little water or ground can escape.

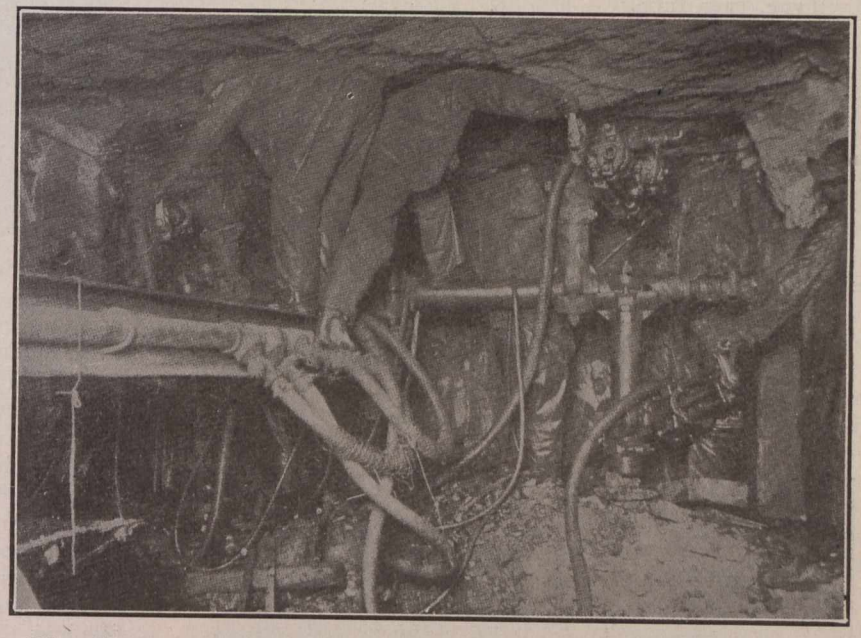

Fig. 3.—Heading Excavation Using Muck Handling Drill Carriage.

The blocks used are very massive and so designed that each block locks firmly into the two adjoining ones of the preceding ring, by oval shaped tenons. They are thus self-supporting and require no forms such as are usually necessary for concrete work. Since they are moulded many weeks in advance, before being brought into the tunnel, when they are erected under the shield they are sufficiently hard to withstand the thrusts of the jacks without injury. The blocks are also so designed that the extrados of the arch is continuous. but the joints in the intrados are about 1¼ inches wide. These joints are held to shape primarily by 3 part wedges or separators and later filled with mortar by means of a cement gun and grouting.

Crusher Plant.—All the rock excavated in the tunnel is being crushed for road materal and concrete stone. All that is not used by the company or railway is sold for local consumption about Montreal. The main crusher plant at the west portal consists of two No. 7 Kennedy gyratory crushers with Stephens-Adamson elevators, con-