

sylvania Lines East of Pittsburgh, including the through lines between New York and Pittsburgh. Underneath the walkway is a continuous refuge niche, except at splicing chambers, where trackmen may sit on the duct bench at the bottom of the dividing wall and be absolutely protected from passing trains.

Excavation.

The method of excavation adopted is perhaps more European than American, although a close analysis would show it to be the resultant of several systems. In modern tunnel practice, lines of demarcation and sectionalism that were quite distinct only a comparatively few years ago are gradually becoming lost, so that an engineer is apt to select a combination of several systems which he considers wisest for his ground and structure. The things that stand out most sharply in all tunnels where great progress has been made and which are principally European in origin are: First, the opening heading is always comparatively small and usually in the bottom of the section; second, a horizontal bar is used to support the drills instead of columns; and, third, short rounds are drilled and shots are fired often. Every little economy in time is practised, and all delays, no matter how trifling, are analyzed and corrected, when possible. Workmen are given a bonus for extra progress above the specified minimum, and machinery, such as drill carriages, is used where it is found advantageous.

European engineers, like our Western miners, like to get under the muck, so that much of it falls into the cars by gravity instead of having to be lifted in. Sometimes this is accomplished by stopping, and sometimes by driving a top heading directly above the bottom heading. The one important point is to

rock, for by this method the heading can be driven on rapidly and the timbering work and full sized section developed with care and without hurry in many places simultaneously along the line.

A great many mechanical drilling, ex-

centre heading with break ups at intervals where the full sized tunnel section is developed. The heading is driven by the horizontal bar method. In one heading, where very hard rock is encountered, requiring extra heavy drills, a drill car-



Mount Royal Tunnel—West Portal, Crushing Plant and Tipple.

excavating and mucking apparatus have been devised, and in some cases they were found to work advantageously, but where the space is confined and delays serious, the laborer, with his pick and shovel, is usually employed. One man

is used with a mechanical muck carrier for loading the cars. In this drill carriage the drill bar is supported on a beam which can be extended 20 ft. ahead of the carriage over the muck pile and has also a vertical and lateral movement to accommodate the heading.

On the city end outside conditions are very disadvantageous. The city of Montreal has never had any previous experience in underground excavation, so that blasting that would be hardly noticeable in New York, for instance, is considered quite serious. For this reason under the city proper, where the cover was light, no blasting was allowed between 11 p.m. and 7 a.m.; the holes in the heading were reduced to 36 and 42 in. in depth, including the cut, and the powder was reduced to a mere "trace."

The effect of all this on heading progress was not so serious as might have been expected. While the holes were short, the rounds were fired so often that an average progress of about 17 ft. a day was maintained. In approaching the mountain, where 5 ft. cut holes could be used, the average progress was about 20 ft. per day.

Record Tunnel Progress.

During the month of May, just ended at this writing, as the rock cover had very much increased, shooting was allowed at night, which very much improved the heading progress. In this way, a total of 810 ft. of 8 x 12 ft. heading were driven in the 31 working days immediately following May 1. This, the writer believes, is the best tunneling record yet made in a hard rock heading.

A greater record than the above was made in the Loetschberg tunnel in Switzerland, where 1,013 ft. of 6.5 x 10 ft. heading were driven in one month through soft triassic limestone. An excellent record was also made last year in Arizona, where 799 ft. of 8 x 8 ft. heading were driven in 31 working days through granite porphyry sufficiently hard to drill well and in general stand without timbering. Neither of these



Mount Royal Tunnel—Heading. Observe Drills on Horizontal Bar and Water Attachment to Drills.

keep the bottom heading open for traffic at all times, so that the heading progress is never materially affected. The full size excavation can be carried on over jumbo timbers at as many places as necessary to keep up with the heading.

A bottom heading in bad ground, if possible, is even more desirable than in

can handle a good deal of muck in his shift, shoveling off slick sheets into low cars. At present muckers in the Mount Royal tunnel heading are handling 15 cu. yd. of muck per man per eight hour shift.

Bottom Heading Method.

The method of excavation adopted in the Mount Royal tunnel is a bottom