

blasts were first fired in mines, it is certain that blasting had become fairly common in 1650, for powder is mentioned as having been purchased for the Harz mines as early as 1634, drill holes are reported at Dullen which bear the date of 1637, and blasting is known to have been introduced into the Freiberg district in 1643.

The use of gunpowder gave a new impetus to mining and a large number of men became skillful in overcoming the difficulties of underground drifting, so that it is not surprising to note that an increased number of tunnels for other purposes were begun soon after. The chief of these purposes was transportation, and in the eighteenth and early part of the nineteenth centuries many tunnels were driven for canals which, aside from wagon roads, were the only highways at that time. Later the development of steam railroads and the desirability of maintaining level gradients led to the building of a still greater number of tunnels. A brief summary of the features of the more important transportation tunnels constructed abroad and at home follows.

Canal Tunnels.

The first modern tunnel constructed for commercial transportation was the Malpas tunnel on the Langue-doe Canal in France. It was 515 ft. long, 22 ft. wide and 27 ft. high, and was built between 1679 and 1681, by Riquet, a French engineer. Although it showed that canals could be constructed through country before thought impassable, no more canal tunnels were driven in France until nearly a hundred years later, the Rive de Gier Tunnel (1,656 ft. long) being constructed on the Givors canal in 1770, and the Torcy tunnel (3,970 ft. long) on the Centre canal in 1787. The Tronquoy and the Riqueval Tunnels on the St. Quentin canal were started in 1803, and the Noireu tunnel (approximately 39,400 ft. in length) on the same canal was begun in 1822. On the Bourgoyne canal, the St. Aignan tunnel was started in 1824, so that by the middle of the nineteenth century nearly 20 canal tunnels, with a total length of nearly 93,500 ft., had been constructed in France.

The earliest transportation tunnel in England was the Harecastle, on the Grand Trunk canal, which was begun in 1766 and opened for traffic in 1777. This tunnel was 8,640 ft. in length, 9 ft. wide and 12 ft. high. There were originally four other shorter tunnels on this canal. The Harecastle tunnel was found to be too small to accommodate traffic, and was replaced in 1824 by a parallel tunnel which was 16 ft. high and 14 ft. wide, 4 ft. 9 in. of the width being used for a towpath. The Sapperton tunnel on the Thames-Medway canal was started in 1783. It was approximately 12,500 ft. long and its construction took six years. The next large canal tunnel in England was the Blisworth (9,250 ft. long), on the Grand Junction canal. It was started in 1798 and required seven years for its completion. In 1856 there were over 45 tunnels on the various English canals, aggregating some 220,000 ft. in length.

The first canal tunnel in the United States was the Auburn tunnel at the Orwisburg landing on the Schuylkill Navigation canal. The tunnel (which was 450 ft. long, 20 ft. wide and 18 ft. high) was begun in 1818 and opened for traffic in 1821. The hill it pierced is composed of red shale, and the highest point was only 40 ft. above the top of the tunnel. The tunnel was shortened in 1834-37 and again in 1845-46, and was finally made an open cut in 1855-56. The "Summit Level," or Lebanon tunnel, on the Union canal, begun in 1824 and finished in 1826, was the second canal tunnel

in this country. It was originally 720 ft. long, 18 ft. wide and 15 ft. high, being driven through argillaceous slate at a total cost of \$30,464. It was followed by the "Cone-maugh" and "Grants Hill" tunnels, on the western division of the Pennsylvania canal (1827-30); the Pawpaw tunnel, on the Chesapeake and Ohio canal (1836); and two tunnels on the Sandy and Beaver canal, Ohio (1836-38).

Railway Tunnels.

The first railroad tunnel of which the authors have record was the Terre-noire tunnel, near St. Etienne, France, on the Roanne-Andrezieux horse railroad. This tunnel, which was begun in 1826, was 4,920 ft. long, 9.8 ft. wide and 16.4 ft. high. Some 14 other tunnels were built on the road from St. Etienne to Lyons between 1826 and 1833. The first tunnels on a railroad using steam locomotives were those on the Liverpool and Manchester Railway, constructed between 1826 and 1830. It was on this road that the famous trial between the "Rocket," "Novelty" and "Sans Pareil" locomotives took place in 1829. The following summary of early railroad tunnel building in Europe is quoted from Drinker's work on tunneling:

Tunnels, of course, multiplied rapidly in England with the extension of railways, and during the 12 or 15 years following the construction of the Liverpool and Manchester line there were a large number of tunnels built throughout the Kingdom, among them being the famous Kilsby, Box and Woodhead tunnels. The first tunnels on a steam railway in France were those built on the St. Germain line in 1837. Subsequently the ones on the Versailles, the Gard, and the Rouen lines raised the total length of tunnels in France in 1845 to 12,833 meters (42,105 ft.). The report of the Corps des Ponts et Chaussees on tunnels for 1856 shows at that date a total on French railroads of 126 tunnels, of a total length of 65,106 meters. Among the noted early French tunnels may be cited the Nerthe, Arschwiller, Rilly, La Motte, Lormont and Alouette. In Belgium the Cump-tieh tunnel, built in 1835, on the Chemin de l'Etat, seems to have been the earliest. In Germany (Prussia and other States) the earlier lines were so located as to not require much tunnel work; and the Oberau tunnel (1839), on the Leipzig-Dresden line, in Saxony, was the first. In Austria Rziha gives the Gumpoldskirch tunnel as the first. A tunnel at Eriebitz (perhaps the same), on the North line, is mentioned in the Ponts et Chaussees report (above cited) as an early Austrian one. In 1856 there were some 50 tunnels in Austria, of a total length of 13,522 meters. In Italy the Naples-Castelamare line, opened in 1840, had several tunnels. In 1856 the total Italian tunnels amounted to 10,181 meters. The Boloina-Pistoja line is especially remarkable for its semisubterranean character. Among the early Swiss tunnels especially to be noted is the Hauenstein, commenced in 1853 and finished in 1858.

The first railway tunnel in the United States was constructed between 1831 and 1833 on the Allegheny Portage Railroad in Pennsylvania. The tunnel (which was driven through slate) was 901 ft. long, 25 ft. wide by 21 ft. high, and was lined throughout with masonry 18 in. thick. It was followed by the Black Rock tunnel (1835-37) on the Philadelphia and Reading Railroad and the Elizabethtown tunnel (1835-38) on what is now the Pennsylvania Railroad. After this time railroad tunnel construction became so general that by 1850 as many as 48 tunnels had been completed on American railways.

Mine Tunnels.

Among the early European mining tunnels driven with gunpowder and hand drilling mention should be