mately true and useful. He applied his investigation to the then important question of the relative strength and stiffness of different sections of rails.

Like all Baker's papers, these articles contained many experimental observations carefully and accurately made.

The first great work on which Baker was engaged in a position of responsibility was the construction of the London Underground Railways, and his connection with this work continued till the completion, in 1871, of the sections from Moorgate Street to the Mansion House, a length of 13 miles. He described the works, which were of a specially novel, difficult, and expensive character, in a paper in the 'Proc. Inst. Civil Engineers,' vol. 81, 1884—85, and discussed generally the problem of Urban Railways in some important papers in 'Engineering' in 1874. He pointed out in these articles that at the time of the inception of the system of underground urban railways, none of the engineers concerned, either as promoters or opponents, evinced the dimmest intuition of the fact that the traffic over an urban line might be the heaviest in the world, and of a character to test the capabilities of a locomotive engine to the uttermost. It was even proposed at first to work the trains with locomotives carrying a charge of hot water, and an engine of this type was built, with unsatisfactory results. It was this intention which led to an insufficient provision for ventilation, which afterwards gave much trouble. In portions of the line constructed later, the stations were in open cutting, and a length of open cutting was introduced between the stations. Baker pointed out the great expenditure of power in acceleration required with stations half a mile apart and suggested that an ideal urban railway should undulate, the stations being placed at the summit of the undulations. By this means gravity would assist the engine in starting and supplement the brakes in stopping. He was able to carry out this arrangement subsequently in the construction of the Central London Tube Railway. He indicated the necessity for great tractive force to ensure a reasonable mean speed and the need of powerful brakes, because the time occupied in accelerating and reducing speed is a large fraction of the whole time of transit when the stations are not far apart. He showed that the laws governing urban traffic were widely different from those obtaining on ordinary railways, and that with weak engines and inefficient brakes the horse-power would vary as the cube of the speed. He calculated that with a level line and moderate speed about 60 per cent. of the energy of the engine is expended in the mischievous work of grinding the brake blocks, and that of 36 lbs. of fuel used per train mile only 15 lbs. would be usefully employed. He checked his calculations by observations on the Metropolitan Railway, where, with the powerful engines used, the mean speed was only 12 miles an hour. He showed that with an undulating railway with the stations at the summits, 50 per cent. more speed could be obtained with the same fuel consumption as on the existing railway.

The building of shallow underground railways through the heart of a great city involved a host of new and unexpected problems in construction and

difficulties in dealing with the pipes, sewers, and other obstructions below the street surface, and in supporting, with as little damage as possible, the heavy buildings above the railway.

Baker was largely concerned in the introduction of electrically worked tube railways in London. He was Consulting Engineer to the South London, the first tube railway, and the still more important Central London Railway was constructed under his superintendence. This railway, of 6½ miles in length, consists of two tunnels of circular section, built with a casing of cast-iron segments, 11 feet 6 inches in diameter. At the stations the cylinders are 21 feet 6 inches in diameter. The railway is generally about 60 feet below the street level, and few difficulties or obstructions were met with. In this railway the stations are at the summit of undulations, the gradients falling each way so that the arrangement suggested in the early papers on urban railways was for the first time carried out. The railway was commenced in 1896 and opened by the late King, then Prince of Wales, in 1900.

From the year 1869, Mr. Fowler was much engaged in Egypt in advising the Khedive Ismail Pasha in regard to various engineering projects for developing the resources of the country, and Baker made more than one visit to Egypt to assist his partner, and later became Consulting Engineer to the Egyptian Government. One result of studies then undertaken was the project for the Soudan Railway between Wady Halfa and Shendy near Khartoum and a ship incline at Assuan. By means of a railway 3 kiloms. in length, over which boats, floated in a cradle, could be dragged by hydraulic machinery of 400 h.p., the obstacle to navigation at the first cataract was to be overcome, and continuous navigation without change of boat established between Wady Halfa and Lower Egypt. From Wady Halfa a railway of 550 miles length and of 3 feet 6 inches gauge was to be constructed at a cost of £4,000,000, to tap the rich southern provinces; about 60 miles were constructed and then the financial difficulties of Egypt compelled the interruption of the work.

Another great project in Egypt in which Fowler and Baker were concerned, in 1875, was a Ship and Irrigation Canal (an alternative Suez Canal) *via* Cairo and Alexandria. The project embraced a sweet water ship canal, 118 miles in length, from Alexandria to Cairo, and another from Cairo to Suez, a distance of 122 miles. At Cairo, low water is 39 feet above sea level, so that there would be a current down the canals to the Mediterranean and Red Sea. The rate of the current would be manageable and would depend on the amount of water abstracted for irrigation. Locks were to be provided on both stretches of the canal. For crossing the Nile at Cairo a railway bridge was to be provided, connecting the lines on the two sides of the river, and serving to support a traversing mooring to which ships could be attached when crossing the river. It was estimated that the payments for irrigation water would give a handsome return on the expenditure, independent of ship dues. In 1883, when the question of doubling the Suez Canal was mooted, Baker and Fowler, in an article in the 'Nineteenth Century Magazine,' recalled attention