Mr. VIGNOLES said, this subject was one to which he had paid great attention for many years, and he would make a few remarks, rather by way of explanation than of criticism, excepting that he would demur to the definition the Author had given in styling the 'Fauvelle' system a Chinese system. The Chinese system, with which he was familiar, and that of 'Fauvelle' were distinct. The principle in boring used by the Chinese, as appeared from records of 1,500 years ago, was simply that of percussion; the borer, having been drawn up to a certain height by a rope passing over a pulley, acted by its weight, and the rotary action of the rope enabled the tool to fall successively on different parts. To this system Fauvelle added the contrivance of introducing a stream of water to force up the debris and avoid the necessity of using the shell pump. On a small scale that contrivance had proved successful.

At the meeting of the British Association at Southampton in 1846,[1] he read a description of that system, and when he was at Perpignan, eighteen years ago, he saw it in operation, and in the strata which the apparatus had then to work in, it did well. He agreed with the Author, that in boring for water it was not always possible to get a supply to work the machine, but the quantity required was so small in comparison with the results, that he thought the Fauvelle system might be advantageously adopted.

With respect to the machinery introduced by M. Kind, the principle of it had been well known in Germany for many years. It was now between twenty-five years and thirty years since he examined into that principle, in the coal-fields near Zweibrucken, at which time holes of 18 inches diameter were being bored. Since that period it had been carried to such an extent, that in October last, in the Moselle coal-fields, on the eastern frontier of France, wells were bored at least 9 feet in diameter. The practice was, to make a beginning with an interior cutter of a smaller size, and immediately follow it by a larger concentric one, of the kind described in the Paper; and he believed a depth of 500 feet or 600 feet had been successfully reached through the rock. The average rate of working was half a mètre, or about 20 inches per day.

The system of boring in Paris, and elsewhere, might be divided into two parts—first, the method, and the precautions adopted in passing through the upper and softer strata, to prevent the falling of the material into the tubing; and then the application of the system of boring described in the Paper. He thought the two were distinct. The peculiar system introduced by the

[1] *Vide* "The Civil Engineer and Architect's Journal," vol. ix., p. 305.

authorities and the contractor for the well at Passy was applicable in hard soils; in the softer soils it was perhaps doubtful whether it could be so successfully applied.

The experience gained in France and Germany, particularly in sinking for minerals, was very great; for in those countries not merely the air shafts, but also the working shafts, were being sunk; and the precision, accuracy, and economy with which pits were sunk of that large diameter, on this principle, were remarkable. Therefore, he conceived, it might be applied to borings for Artesian wells on the moderate scale to which it was necessary to confine it in order to work it economically.

There was no doubt, however, that there was greater economy in working upon the larger scale, such as was required for coal pits, than upon the smaller scale for wells, inasmuch as many of the precautions and apparatus required upon a large scale were necessary on a small scale. That the general result would be the adoption of that system of boring, he had no doubt; for it was quite clear, from the knowledge acquired on the Continent, particularly in the case of coal-mines, and in the well at Passy, that, although there were difficulties in working by percussion, this system might be followed with great economy and propriety. But, while he admired the extreme ingenuity with which all the details of construction were carried out by foreign Engineers, he thought if this system were adopted by the English well-borers, their practical experience would enable them to carry it out with still greater economy. The adoption of timber rods, which, however, had long been used in Cornwall for pumping, he considered was an improvement, in respect of lightness and facility of working.

Mr. S. C. HOMERSHAM had given attention practically to this subject for many years. He had sunk several borings of 18 inches diameter by steam machinery, and he was now executing a boring 2 feet in diameter by the same means. On December 30th, 1861, he commenced boring at the bottom of a well 180 feet deep, in the red sandstone at Middlesborough, and for some time he proceeded at a rate varying from 13 feet to 15 feet per day, and in 532 working days he reached a further depth of 1,132 feet. This made as nearly as possible 2 feet 1½ inch for each working day, including all stoppages from whatever cause.

The system employed was something like that described by Mr. Vignoles. The boring head, which was about 18 inches in diameter, was hung by a rope passing over a pulley connected with the piston-rod of a steam cylinder. When the steam was let out of the cylinder, and the piston fell, the boring head, containing the boring tools, also descended upon the rocks by its own gravity, and the hardest blow was struck that the weight of the boring head and tools descending by their gravity could inflict. The

force of the blows was regulated by adjusting the escape of the waste steam from the cylinder. When the escape valve was closed at a certain point, a cushion of steam was formed between the piston and the cylinder cover, and a blow might thus be given either of extreme delicacy, or of the force of 20 cwt. falling upon the stratum from a height of 5 feet, or 6 feet. The machine employed was constructed by Messrs. Mather and Platt, of Manchester. The debris was cleared out by means of a shell pump, in a superior manner to anything he had hitherto seen. At the bottom of the shell was a valve of solid india-rubber, opening inwards; the piston, which quite filled the pump, was solid at the side, without packing, and had a valve opening outwards. When the shell was lowered to the bottom of the bore hole, the piston fell, and was then pulled suddenly up by the rope acted upon by the piston in the steam cylinder. A vacuum was thus created inside the shell pump, and the debris was carried by the current of water into the inside of it. By this means pieces of rock of considerable size and great weight, and even pieces of lead, were readily brought up from borings 1,100 feet or 1,200 feet deep, or from even a greater depth. This system had been tried successfully in many places and in different kinds of rock.

He had not seen the continental system in operation, but he considered the system of Messrs. Mather and Platt superior to the methods of boring described in the Paper, or, indeed to any other with which he was acquainted. In a dry stratum, however, Messrs. Mather and Platt's system could not be used. In Lancashire and Yorkshire it had been adopted extensively, and there was one well in the red sandstone at Manchester, yielding between three millions and four millions of gallons per day, which had been sunk on this system. When not interrupted by water, no doubt by far the better way was to sink wells or small shafts by manual labour, by which means the work was done cheaper, more expeditiously, and better, than could be done by any sort of machinery at present in use.

Mr. MATHER directed attention to specimens of rock, &c., which had been excavated with the machine which had just been described. This machine, since 1854-5, had bored sixteen or seventeen holes, making a total of 9,000 feet, from 15 inches in diameter, up to 2 feet in diameter; and a machine was now being made to bore a well 3 feet in diameter. The accounts as to the results were perfectly accurate, and coincided with the records of the borings already carried out. In one instance a boring had been carried to a depth of 1,100 feet. The first portion was 18 inches in diameter, but afterwards it was increased to 21 inches for the whole depth. A depth of 900 feet of boring was executed in four months. The advantages of this machine had been shown in

borings in the red sandstone, which had been executed at the rate of from 15 feet to 30 feet per week. A bore-hole in the Yorkshire stone, at Bradford, had just been completed, and a depth of 460 feet was attained, in seven months from the time of starting the work; and, from the specimens exhibited, it would be seen that the stone, being millstone grit, required very hard boring to bring it up. In the hardest rock at Bradford the progress was from 4 feet to 10 feet per week. The Middlesborough boring, for a depth of 500 feet, was executed at the rate of 50 feet per week; beyond that depth, the strata being harder, the speed decreased; but during the whole progress of the work, the rate was much greater than that shown by the records of Continental borings.

The system of M. Kind was no doubt ingenious. He had seen it in operation at Moscow, in an experiment as to whether a supply of water from an Artesian well was practicable there. The work, to the depth of 940 feet, was completed in two years. Comparing that rate of progress with the experience of similar works in England, it might fairly be said that an equal depth might be reached within twelve months. There appeared to be, under M. Kind's system, great loss of time in drawing out the rods, in removing the tool, and in clearing away the debris, which was avoided by the plan of boring with a flat rope; with this method, when the boring-head had descended, the striking cylinder was set in motion, and struck a number of blows on the rock. The rope, to which the boring-head was attached, passed over a pulley in the fork of the piston-rod of the striking cylinder; and as the piston-rod rose and fell, by admitting and exhausting the steam in the cylinder, the rope and head were drawn up and let fall, when the cutters in the latter struck the rock and broke it up into pieces, which the pump afterwards removed. As the boring-head struck, a slight twist was given to the rope, by a mechanical contrivance in the boring-head itself, so that when the strain came on again in lifting, the rope, in regaining its proper position, twisted the boring-head slightly round, and thus prevented the cutter from striking always in the same place. When a sufficient number of blows were given by the striking cylinder, the steam was shut off, and then the rope was drawn up and wound upon a large drum, by means of a separate engine, in the same way as in colliery shafts. The boring-head being removed, the pump was attached to the rope, and let down into the hole by the winding engine. When at the bottom, several rapid strokes were given, by winding the rope quickly up and letting it out again. In this way the cylinder of the pump was filled with the broken rocks, &c., and then brought to the surface to be emptied. This was repeated till the hole was found to be empty, and then the boring-head was put down again. The working of this machine required the attendance of only one

leading man and three labourers, for changing the head and clearing out the hole with the pump.

Mr. VIGNOLES said, that twenty-five years ago, on the Manchester and Sheffield Railway, he had used percussive action, by means of a tool at the end of the rope, as well as the shell pump for drawing up the debris, of the same description as that just alluded to, except that it was done by hand labour instead of by steam power. He had no doubt Messrs. Mather and Co. had introduced some improvements, of which the application of steam might be the chief; but in principle it was the same as the Chinese had used fifteen hundred years ago. He should be glad to be informed of the cost of the borings spoken of, because in early days, a boring of 6 inches or 8 inches in diameter was considered enormous; but at the present time borings of 18 inches or 2 feet in diameter were common in many parts of the Continent.

Mr. MATHER replied, that the cost would necessarily vary according to the nature of the strata to be bored through. At Stockport, a bore hole 18 inches diameter, and 420 feet deep, had been completed, and the total amount received for that was £240; but that could scarcely be taken as a datum of the cost of boring. Sometimes the expense would be 10*s*. per foot; at others it would be £5 or £6 per foot.

Mr. BEARDMORE inquired if he understood the Author to state, that the tool remained eight hours at work without being lifted from the hole.

Mr. BURNELL replied, that was so through an average of working.

May 31, 1864.

The Session was concluded by a Conversazione, at which the President received the Members of the Institution, and a numerous circle of distinguished visitors. The rooms were decorated with many choice works of art, and there was also exhibited a large and interesting collection of mechanical models.
