X.—ON HORSE POWER.

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"Results of the application of Horse Power to raising Water from the working shafts at Saltwood Tunnel, on the South-Eastern Railway, in 1842. By Frederick William Simms, M. Inst. C. E.*

This tunnel is driven in the middle bed of the lower green sand, between which and the surface of the ground is interposed only the upper bed of the same stratum; but in sinking the eleven shafts for the work, it was found that at the level of the top of the tunnel the ground assumed the character of a quick sand, saturated with water, in such quantity that it could not be reduced by manual labour. Under these circumstances horse gins were erected for drawing the water by barrels, containing 100 gallons each, weighing when full about 1310 lbs.

The engineer's intention was to drive simultaneously from these shafts, in the direction of the tunnel, an adit or heading, to carry off the water; but the earth, which was sand mixed with fine particles of blue clay, was so filled with water as to become a mass of semi-fluid mud—great exertions were therefore necessary to overcome the water, without erecting pumps. At first this was accomplished by making each horse work for 12 hours, and then for 8 hours per day, allowing one hour for food and rest; as the water increased it became necessary to work night and day, and the time of each horse's working was reduced generally to 6 hours, and sometimes to 3 hours. As all the horses were hired at the rate of 7*s.* per day, the author, who had the direction of the works, ordered a daily register to be kept of the actual work done by each horse, for the double purpose of ascertaining whether they all performed their duty, and also hoping to collect a body of facts relative to horse power, which might be useful hereafter. This detailed register, which was kept by Mr P. N. Brockedon, is appended to the communication.

The author gives as a proposition, "That the proper estimate of horse power, would be that which measures the weight that a horse would draw up out of a well; the animal acting by a horizontal line of traction turned into the vertical direction by a simple pulley, whose friction should be reduced as much as possible." He states that the manner in which the work was performed necessarily approached very nearly to these conditions; and after giving the principal dimensions of the horse gins, he analyzes each set of experiments, and by taking the mean of those against which no objections could be urged, he arrives at the following results:—

The power of a horse working for 8 hours	=	23,412 lb.	raised 1 ft. high in one minute.
Ditto . .	6 "	= 24,360 "	ditto.
Ditto . .	4½ "	= 27,056 "	ditto.
Ditto . .	3 "	= 32,243 "	ditto.

Of these results he thinks the experiments for 6 hours and for

* From the minutes of the transactions of the Institution of Civil Engineers.

Mr Field remarked that in all estimates of horse power, the speed was considered to be at an average of 2½ miles per hour, and all experiments were reduced to that standard.

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Mr Hawkins said, that some years since he had made numerous inquiries respecting the work done by horses in drawing upon common turnpike roads, and found, that four good horses could draw an ordinary stage coach, with its complement of passengers, 8 miles a-day at the rate of 10 miles an hour; that if they ran stages of 10 miles in the hour, the horses must rest one day in each week: that good horses, so worked, would last only five years, each horse drawing about half a ton; he had been informed by waggoners, that good horses would walk, at the rate of 2½ miles per hour, for twelve hours out of the twenty-four, making 30 miles a-day, and that they would continue to do such work, day by day, each horse drawing one ton, for many years, provided they had been worked hard when young.

Mr Gravatt observed, that although there might exist some hesitation in receiving these results of work actually performed, as a general measure of horse's power, yet as engineers frequently required to know what could be performed by horses,

* The horses were supplied by Mr Richard Lewis, Folkestone, Kent.

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which employed for short periods, in works of haste or difficulty, he thought that the experiments were useful, and would form good data for reference. He was sorry to observe that in too many cases, an idea was prevalent, that it was cheaper to work a small stock of horses to death, than to keep a large number and to work them fairly; the results which he had been enabled to arrive at were perhaps not a fair value of a horse's work, continued for any length of time, at the best rate of economy for both the contractor and employer.

The President believed that however, in cases of emergency, which he allowed did occur in engineering works, the forced system of labour mentioned by Mr Gravatt might be tolerated, he was convinced that it was not the most economical; but on the contrary, humanity and economy would be found to go hand in hand. It would be desirable to know the average speed at which the different rates of work had been performed; this was essential in order to found any calculation upon the results given. Coach proprietors calculated that, at a speed of 10 miles per hour, a horse was required for every mile going and returning, so that one horse was kept for every mile of road. Now supposing a four-horse coach, with an average load, to weigh 2 tons, the load for each horse was 10 cwt.; whereas in the case of a horse drawing a cart, the gross load frequently amounted to 2 tons, but the speed was reduced to 2½ miles per hour, at which pace he conceived that 16 miles per day might be considered a fair day's work; this therefore was double the distance with four times the load, or eight times the coach-work, but with a heavier horse. The law that the quantity of work done, was as the square root of the velocity, or, as the cube root of the velocity, in equal times, was confined to work upon canals, or bodies moving through water.

Mr Rennie had tried some experiments on the force of traction of the boats on the Grand Junction Canal. The towing rope was attached to a dynamometer which had previously been tested by weights. The horse, although urged at first starting, was afterwards allowed to fall into his natural speed, which was 2½ miles per hour on the average of 20 miles. The maximum speed was 4 miles, and the minimum 2 miles per hour. The dynamometer indicated an average of 180 lb., which was capable of overcoming the resistance of the loaded barge of 25 tons, being in the ratio of 1·500. The weight of the horse was about 11 cwt. He had also tried many experiments upon a fast boat lent to him in 1833 by the late Colonel Page. These experiments were principally made in order to ascertain the comparative resistance of vessels moving through water at different velocities, and the Grand Junction Canal afforded a convenient opportunity of undertaking them. The boat was 70 feet in length, 4 feet in breadth, and drew 9 inches of water. The traction indicated by the dynamometer the following resistance:—

Miles per hour.		lb.	Miles per hour.		lb.
At 2½	the resistance was	20	At 6	the resistance was	97 to 214
3	"	27	7	"	250
3½	"	30	8	"	336
4	"	50	9·69	"	411
4½	"	60	10	"	375
5	"	70 to 75	11¼	"	392
			Average . .		336

One horse was employed in these experiments. Two horses were employed in these experiments.

Stakes were fixed near the margin of the canal, so as to ascertain the rise and fall of the wave caused by the boat in passing; and it was observed that when the boat passed with a velocity of from 4 to 6 miles per hour, the rise of the wave was 5 inches, and the fall 5 inches, making a wave of 10 inches in depth; and when the velocity was 11¼ miles, the rise was reduced to 2½ inches, and the fall to 2½ inches. Great difference existed in the power of horses, their weights, and structure; and the large dray horses used by Messrs. Barclay, Perkins, & Co., did a full average duty as assumed by Boulton and Watt; but considering the average power of strong and of weak animals, he had adopted 22,000 lb. raised 1 foot high as the standard; much however depended on the nature of the work performed.

Mr Charles Wood remarked that although, on an emergency, it might be necessary to work horses to the extent which had been mentioned, it had always been found more economical to feed them well, and not unduly to force the speed, the weight drawn, or the hours of labour. By the recorded experiments on

3 hours alone should be adopted as practical guides, all the others being in some degree objectionable.

As a means of comparison, the following table of estimates of horse power is given:—

Name.	Pounds raised 1 foot high in a minute.	Hours of Work.	Authority.
Boulton and Watt	33,000	8	Robison's Mec. Phil. vol. ii. p. 145.
Tredgold - -	27,500	8	Tredgold on Railroads, p. 69.
Desaguliers - - -	44,000	8	Dr Gregory's Mathematics for Practical Men, p. 183.
Ditto - - -	27,500	Not stated.	
Sauveur	34,020	8	
Moore, f. Society of Arts	21,120	Not stated.	
Smeaton - -	22,000	Not stated.	

These are much higher results than the average of his experiments, and would more nearly accord with the extremes obtained by him; but under such excessive fatigue the horses were speedily exhausted, and died rapidly. Nearly one hundred horses were employed,* they were of good quality, their average height was 15 hands ¼ inch, and their weight about 10½ cwt., and they cost from £20 to £40 each. They had as much corn as they could eat, and were well attended to.

The total quantity of work done by the horses, and its cost, was as under:—

Registered quantity of water drawn 104 feet, the average height, 28,220,800 gallons	=	128,505 tons.
Ditto, earth 3,500 yards, 1 ton 6 cwt. per yard .	=	4,550
Total weight drawn to the surface		133,955
Total cost of horse labour, including a boy to drive each horse		£1,585 15 3
Or, 2·85 pence per ton, the average height of 104 feet.		

As soon as the adit was driven, all the water was carried off by it, and the works are stated to be perfectly dry.

Remarks.—Mr Palmer said, it should be understood, that in stating 33,000 lb. raised one foot high in a minute, as the measure of the power of a horse, Boulton and Watt had not intended to fix that as the average work which horses were capable of performing; they had taken the highest results of duty performed by powerful horses, in order to convince the purchasers of their steam-engines that they received all that had been contracted for. He had made some experiments on the amount of work performed by horses tracking boats on canals: on the upper end of the mast of the boat a pulley was hung; over this the towing rope was passed, with the means of suspending to its extremity given weights, so as exactly to balance the power exerted by the horse. The results arrived at by these means were so various, that he could not deduce any average conclusions; as the power exerted varied between 30 lb. and 120 lb.—the power diminishing as the speed was increased—he thought that 2½ miles was too high an average estimate, and that it should not exceed 2 miles per hour.