to ascend the grade of 533 ft. to the mile, upon which the first trial was made with the traction engine.

The day's work thus terminated and the party separated. The information which had been acquired respecting steam traction and the construction of metalled roads was most valuable, and it was considered by all that the day had been spent pleasantly and profitably.

RESUME.

Reviewing the experiments on the Aveling & Porter road locomotive and steam road-roller we may make a brief resume of the facts developed, thus:

1. A traction engine may be so constructed as to be capable of being easily and rapidly manouvered on the common road and in the midst of any ordinary obstructions.

2. Such an engine may be placed in the hands of the average mechanic, or even of an intelligent youth of 16, with confidence that he will quickly acquire, under instruction, the requisite knowledge and skill in its preservation and management.

3. An engine weighing rather more than 5 tons may be turned continuously in a circle of 18 ft. radius without difficulty and without slipping either driving wheel, even on rough ground, and may be turned in a roadway of a width, but slightly greater than the length of the locomotive, by proper manoeuvring.

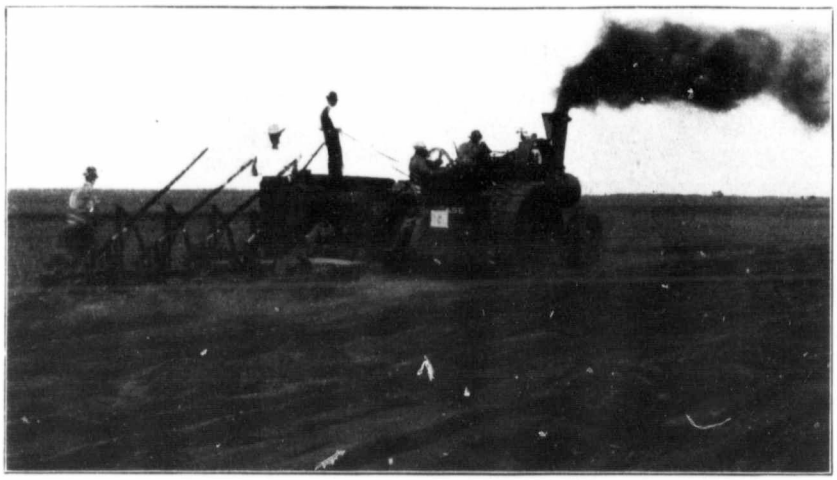
4. A road locomotive, weighing 5 tons 4 cwt., has been constructed, which is capable of drawing, on a good road, more than 23,000 lbs. up the almost unexampled grade of 533 ft. to the mile at the rate of four miles an hour.

5. Such a locomotive may be made, under similar conditions, to draw a load of more than 83,000 lbs. up a hill rising 225 ft. to the mile, at the rate of two miles per hour, doing the work of more than twenty horses.

6. The action of the traction engine upon the road is beneficial, even when exerting its maximum power, while, with horses, the injury to the road-bed is very noticeable.

7. The coefficient of traction is, with such heavily laden and roughly made wagons as were used at South Orange, and under the circumstances noted, not far from four per centum on a well made macadamized road.

8. The amount of fuel, of good quality, used may be reckoned at less than 500 lbs. per day, where the engine is a considerable portion of the time heavily loaded, and, during the remaining time running light. It may be considered, without probability of serious error, that, during the trials at South Orange, Engine No. 2 performed pretty nearly an average day's work.



The Case 12 h.p. Steam Tractor pulling a 4 bottom Cockshutt Engine Gang

DEDUCTIONS.

A number of interesting problems may be solved by reference to the facts learned here. A comparison of the efficiency of the road steam traction engine with that of horse-power in drawing heavy loads, is especially important, and we will now make such a comparison, basing it upon the most reliable data at hand.

Traction Force.—It has been already stated that Engine No. 2 developed a tractive force equal to that of twenty horses.

The actual tractive force may be determined as follows:—The coefficient of traction was, as has been shown, not far from 0.0427, which is also very nearly the maximum figure given by General Morin, as determined by his experiments with "draycarts" and "chariot-porte-corps d'artillerie," upon metalled roads and upon roads paved with sandstone. This coefficient is large, partly in consequence of the very slight breadth of the wheel tires and the small diameter of the wheels of the wagons used, and partly because the wagon bodies were not mounted on springs. To be absolutely certain that no error is committed by over-estimating in the following calculation, this coefficient will be taken at 0.03.

The actual tractive force required to overcome the rolling resistance was, then, $63,400 \times 0.03 = 1,902$ lbs. The force required to overcome that component of the force of gravity which directly resisted the motion of the load, in this case where the road lay at an angle with the horizontal, whose tangent was 0.0427, was W Sin θ = 2,700 lbs.; the total resistance was therefore 4,602 lbs.

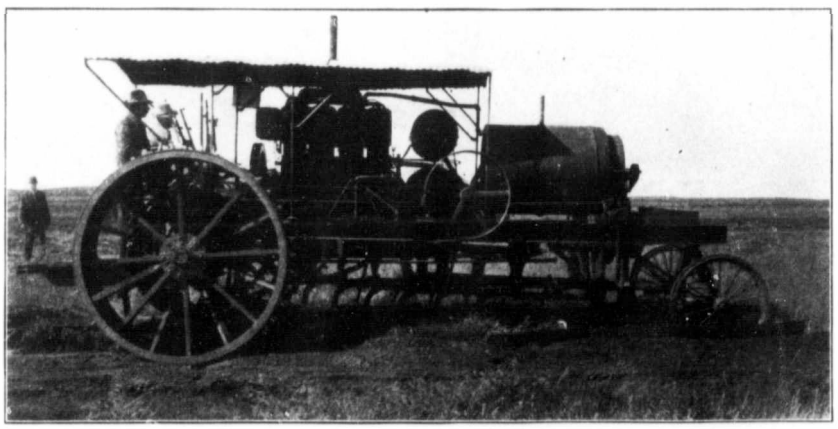
Including the weight of the traction engine itself, these figures become 2,251 and 3,002 lbs., giving a total of 5,253 lbs. direct resistance, and a coefficient of adherence of 5,253 : 18,348 = 0.28, which slightly exceeds that found on earlier trials of smooth wheels.

Experiments made by Capt. Robt. Merry, at the Jackson Iron Mine, Negaunee, Mich., and the observations and experiments of the writer, indicate the maximum direct tractive force of a good horse to be about 250 lbs. This corroborates the estimate already made, making the tractive power of this engine equal to that of twenty horses.

Deducting from the above the weight which could be drawn, on an equally excellent but level road, by this locomotive, the coefficient of traction being the same, we find it equal to $\frac{5253}{0.03} = 175,100$ lbs., or very nearly eighty gross tons, and, excluding the weight of the locomotive (163,452) 75 tons. With the machine, as with the animal, it would not be expected that in regular work, on ordinary roads, more than one-half of the maximum power would be exacted, although, with such a reserve, the machine possesses a decided advantage over the animal.

Working Time.—The working time of a horse is usually considered to be eight hours per day for dray horses, and less for carriage horses. The dray horse, which is kept in harness eight hours per day, is usually standing unworked a considerable proportion of this time while his load is handled, and also during one-half, usually, of the remaining time, his vehicle drawn unloaded. The horses of the Third Avenue street railroad, in New York city, are worked less than six hours per day, and are given one day in seven as a day of rest. This is about equal to the working time of horses and cattle crossing our Western plains with moderate loads.

The steam engine requires no such careful limitation of working time. It can work twenty-four hours uninterruptedly as readily as a single hour. Ten hours a day would be, in most cases, made the daily working time of a



The Birrell Motor opening up its first furrow, 6 Moline bottoms are being pulled