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Brevet Major C. E. I. McNalty^a

^a Army Service Corps.

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MECHANICALLY PROPELLED VEHICLES FOR MILITARY PURPOSES.

By Brevet Major C. E. I. McNALTY, Army Service Corps.

Wednesday, 6th July, 1904.

The Right Hon. GRAHAM MURRAY, M.P., Secretary for Scotland,
in the Chair.

BEFORE reading my paper, it may be said that the question of the use of mechanically propelled vehicles is one of to-day, and not one of the past; it is, therefore, with a view of ventilating the difficulties to be overcome, rather than their solution, that this paper is written. In the discussion of a subject in a state of rapid evolution, it is not easy to differentiate between the present, past, and future. We are liable to allow our minds to become prejudiced by the failures of the past without carefully examining into the cause, or to become enthusiastic with the dreams of the future without enquiring into their practicability, whilst the ever-changing present does away to-day with the defect of the day before, or raises some fresh problem to be solved.

The same principles govern transport and locomotion, whether civil or military, by land or sea, in each consecutive age.

In 1798 the military reinforcements and stores sent to Ireland had to travel along by roads and in wagons, taking many days to reach their destination. Nowadays we move troops, etc., by rail to Ireland, and the journey can be completed in one day.

To continue the analogy, up to recently, civilians, their luggage, and stores went by railway. Now we have come to another development, and the most modern science has brought us back to roads, roads which have always been a commanding factor in strategy. People now travel to a great extent by road, taking their luggage with them, and stores are also transported in this manner, so that it would not be in advance of the times to convey troops and military stores in a like manner.

The title of the subject for discussion to-day is somewhat comprehensive. To arrive at useful conclusions it is necessary to consider it under the following headings:—

1. Motor cars for the conveyance of general and staff officers, and for the transport of men for fighting and technical services.
2. Motor cyclists as messengers and for combatant purposes.
3. Mechanically propelled vehicles for transport of munitions of war, and haulage of the heavy field guns.

Of these headings, No. 3 has received the greatest attention up to the present, has been seriously adopted, and steps are being taken to render it as efficient as possible. The other sub-divisions of the subject, with the exception of motor cars for general and staff officers, have not yet had their utility tested. I therefore propose to mainly devote my paper to dealing with the employment of mechanical transport for the haulage of guns and stores, with a view to demonstrating how much more can be done by practically testing the possibilities and limitations of the machines in question by actually using them, instead of theorising about them on paper. We are all aware of the lengthy discussions that preceded the purchase of submarines for the Navy, and now they have advanced beyond the experimental stage by a few being actually put to use.

MOTOR CARS.

Passing to the first sub-head mentioned, we will now briefly consider the military use of the motor cars.

Although motor cars as at present used and constructed for military purposes cannot claim any financial saving, as the expense of upkeep is considerably more than the amount saved in travelling expenses, the car is a most valuable and almost indispensable adjunct to the means already at the disposal of a general officer and his staff at the present time for supervising the proper training of the troops in his command. In war time, of course, the question of expense must fall to the ground before that of efficiency.

Too much stress cannot be laid on the importance of general officers having the means to personally, at any moment, inspect and supervise the working of their commands instead of relying upon a prearranged periodical visit; it is only with the aid of motor cars that this can be done. Personal supervision is of more value than all the volumes of orders, regulations, and carefully prepared reports put together can ever be.

Troops at stations are now more scattered and field operations more extended, thus necessitating the supervision of the staff over a much larger area. With the ordinary means of transport, either proper and efficient personal supervision cannot be given at all, or, if given, is only possible at great expense of time, causing other important work to be left undone, and very often at considerable personal expense to the officers of the staff, and the premature exhaustion of their energies.

The cars which have been used experimentally by the Mechanical Transport Committee have been found of great value, but they have been in some cases considerably over-worked, insufficient time having been allowed for their proper and economical upkeep. The result of this overwork has been extensive, and costly repairs, that would probably have been avoided had small defects been rectified at once, have become necessary.

The peace establishment of motor cars is about three per army corps, but general, staff, and other officers have found their use to so considerably facilitate their work, that a number of private cars are being used for the execution of the public service, maintained at the personal expense of the officer concerned.

I will not speculate as to what might have happened had generals in wars of the past been able rapidly to proceed by motor cars to the various scenes of action of their armies; but it may be observed that more than one general in our own Army have earned their reputation and secured the success of our arms by their ubiquity, marvellous considering the means at their disposal.

Napoleon, in conducting his wars and campaigns, made many long journeys at considerable physical self-sacrifice in order to be present in the proper place at the psychological moment. How much greater might have been his successes had he had motor cars at his disposal for conveyance!

Motor cars, even as they are at present constructed, are capable of passing over country that animals would negotiate more slowly, with continual and irritating stoppages. (Note: Fentiman across the Alps in a 16-H.P. Peugeot, the recent ascent of Snowden, etc.) Though it is admitted there are many places at present that animals can traverse, impossible for machines, in the future we look for the movement of motor cars over all surfaces possible to the animal.

In addition to the motor cars used for staff work and a few for technical duties, the only organised body of motorists is the Motor Volunteer Corps. The present strength of the Motor Volunteers is 29 officers possessing motor cars and 1 officer with a motor cycle. The members of this corps have 76 cars and 40 motor cycles. At last year's manœuvres the motor cars were used for conveying staff officers, and the cyclists were used as messengers. It is somewhat disappointing that they were not used for combatant purposes; it is contemplated to use them in the latter capacity during manœuvres this year. The Motor Volunteers place their machines at the public service, and receive 30s. a day while employed. It is unnecessary to say the cost to the Government would have been doubled, if not trebled, if these cars had been hired from an ordinary commercial firm. In addition to military work some of the cars were used by the compensation staff, whose duty it was to inspect and adjudge the value of the damage done by the troops. By using motor cars they were able to immediately visit places where the troops had been, and settle forthwith with the owners of property which had been damaged. The effect of this immediate settlement was most satisfactory to both parties, and resulted in a very considerable reduction in the amount spent on compensation in previous years.

As I have already said, generals in every age have utilised the most rapid means at the time available for the transport of their men. Napoleon marched his infantry by carrying numbers of them in wagons and country carts on many occasions, notably in his march from Boulogne to the Rhine in 1805. This march was one of the most rapid of his age, enabling him to surprise Mack at Ulm on the Danube, where he compelled him to capitulate. Jackson, in his quick march through Virginia, to facilitate his movement put some of his men in railway wagons, and some marched along the road by the side of the railway, taking their turn in the train with the others when fatigued. Many instances may be quoted.

Railways have played a most important part in all recent wars, but as the trains cannot leave the permanent way they considerably hamper the general in his movements. With motor cars, properly constructed for carrying guns and men, it would do away with the

great encumbrance of being tied to railways, of which there must be relatively few compared to roads.

We are constantly told in text-books and by other authorities that owing to the great power of modern weapons, cavalry or mounted infantry can hold positions for a period and act as tactical detaining forces, impossible with the earlier instruments of war, as well as cover flanks and assail flanks in battle; but mounted infantry could not do half so well as men conveyed in motor cars—shall we call them motor infantry?—who could turn up with triple the celerity in the most unlikely places, and surprise and harass the enemy in most theatres of modern war. Moreover, timely reinforcements can save battles, protect retreats, or enfilade flanks; thus a brigade at the first battle of Bull's Run in 1861, coming out of a train, gave the victory to the Confederate general, Beauregard, and a few guns against the Federal right at the second battle of Bull's Run in 1862 facilitated Jackson's defence.

But the virtue of the motor does not rest in rapidly covering short distances. It is in its capacity to travel for long continuous periods and for great distances without having to stop for rest that its great military value lies.

For a force acting on the defensive in its own country, where every road is well known and free from obstruction, motor cars are invaluable. As the pace at which one proceeds increases, so, in proportion, does the difficulty in finding one's way become the more either by day or night, and one can quite imagine the sensations of a driver of a motor car belonging to an invading Army, who is not only unfamiliar with the roads, but who is also unaware of what obstacles may have been placed in his path.

I have mentioned that there is at present no financial saving in the use of motor cars as at present used, but their employment in lieu of cavalry to act as scouts or as a screen, would, I think, be far less costly, because the number required would be far less. As an example may be quoted the great screen of 20,000 German cavalry that covered the 3rd and 4th German Armies from Stenay, by Vitry and Vassy in August, 1870. This enormous cloud of horsemen only covered a frontage of about 60 miles, and then failed to locate MacMahon at Chalons, and it was not until he had received orders to relieve Metz that he was encountered by the Germans on their extreme right, when moving on that place, and the well-known battle of Sedan ensued. The work done on that occasion by the German cavalry would have been far more effectively carried out by motor infantry, and at a very much lower cost.

In speaking of defensive operations guerilla warfare cannot be neglected, and this method of warfare will be facilitated in every direction and phase by motor infantry. In an emergency time does not permit of men being trained to ride horses—as an example of this at the very beginning of the 1870 war it was necessary to spend time to train the Engineers to ride on horseback in order to enable them to proceed rapidly to blow up a bridge, Zweibrucken Viaduct—but they can always be placed in cars and proceed rapidly from one place to another. Raids against the invaders' communication could be carried on with surpassing facility, and there would be few difficulties as to repairs, mechanical aid, motive power, and similar details, because the motor industry is now, or will soon be, part of the daily life of a large number of shopkeepers and operatives in every large town.

What has been said with reference to the conveyance of men by motor cars equally applies to that of machine and light guns, and a motor carriage at the present moment is being constructed in America to carry two 6-pounders, and I believe an enterprising member of the Motor Volunteer Corps is willing to have a car constructed for the conveyance of a Maxim, should one be allotted to his corps.

For a Volunteer arm of the Service for the internal defence of the United Kingdom, I cannot imagine any more effective than one composed of motor infantry. Infantry thus conveyed can assemble immediately at any point, without having to wait to arrange for trains, with all the irritating delays which are likely to occur on such occasions. Of course, the railways would be placed at the disposal of the Government should an invasion threaten this country, but we must remember the sudden upheaval of the ordinary traffic arrangement will not conduce to expedite the working of the railway.

The invader is, moreover, as fully aware as ourselves as to where the bulk of our forces are situated, where they would mobilise in case of war, and also would possess a map of our railway system; he would naturally avoid attempting a landing where our forces could be rapidly concentrated by rail.

In dealing with the conditions a military motor car should fulfil, the following are the principal points to be considered:—

- a. It should be driven by an internal combustion engine capable of using a less volatile oil than petroleum spirit.
- b. All military motor cars should be of a standard type.
- c. Should be as silent and raising as little dust as possible.
- d. Tyres to be inexpensive and reliable.
- e. Reliability and capacity for hill climbing and for passing over difficult ground to be of first importance compared with high speed.
- f. Handy to control, and of as few wearing parts as possible.
- g. Easy of repair in the field.

Conditions *a* are open to discussion. There are many advocates of the steam car, but it is unnecessary for me to give an opinion in the face of the fact of the comparative number of manufacturers of steam and internal combustion cars and the comparative numbers on the road. Of course, the small radius of action of the electric car and many other reasons place it at present outside the pale of military consideration. With reference to the nature of oils to be used, there are three principal reasons why petroleum spirit is unsuitable, the first being that it is exceedingly volatile, thus rendering its handling, carriage, and storage one of difficulty, especially so in high temperatures, and in war time these difficulties would be only increased. We are all aware of the stringent regulations that exist with reference to its use in this country. The question that naturally arises is, is it easier to provide for the safe carriage, etc., of petroleum spirit or to construct engines using less volatile oil? It will be particularly interesting to hear opinions on this point. I am inclined to the opinion that the latter will be the best solution, and engines of this nature are being made. The second reason is that petroleum spirit is difficult to obtain in many places, and, thirdly, that it is more expensive than paraffin and other hydro-carbon oils.

Reference to the use of motor cars of technical services, I may mention that motor cars fitted with search-light apparatus are being used by the Royal Engineers. They were originally intended for the late South African War, but were not completed till after that campaign. They were used successfully, I believe, in last year's manœuvres. There are many other duties for which motor cars could be used, but it is for the officers carrying out those services to say to what degree they are likely to be of use.

MOTOR CYCLES.

We now come to the consideration of motor cycles. What has been said of the tactical advantage of motor cars may be said of motor cycles, but they differ in many ways. To the ordinary observer a motor cycle seems to be a somewhat complicated and unmanageable machine, but, as a matter of fact, it is a very simple one, and taking an individual who is equally ignorant of a horse and motor cycle, I am quite sure he would learn to ride and manage the latter in far less time than he would the former. The motor cycle can go wherever the car can go. In addition it can go through narrow lanes, along footpaths, through narrow gates, and can be lifted over obstacles such as stiles, etc., and it would require no great measure of ingenuity to have appliances fitted so that one cycle could assist another or be united in such a manner so as to carry a machine gun. The cycle does not raise so much dust, and can be quickly concealed. The fact of its simplicity renders its repair and supply of spare parts very easy. It burns less petrol than a car, and, of course, if the engine fails it can be pedalled. The cost of upkeep of tyres for a motor cycle is less than that of a motor car. The machine can be so constructed so that the engine can be easily removed, in order that in case of emergency where it might be desirable to use the bicycle as an ordinary pedalled machine, this could be done. But, as compared with the car, it has against it a tendency to side-slip, is noisy, and is a bad hill climber, and very difficult to start up a slope.

The horse, of course, has the advantage of being able to negotiate almost any country, but, as I have already said, the motor cycle can go in many places besides roads, and it has the following advantages:—Great rapidity, enormous radius of action, smaller cost for purchase and maintenance, requires little food, if I may so express it, and only then when working.

The fact that one can dismount and leave the cycle unattended is greatly in the favour of the cycle, when one remembers that 20 per cent. of mounted infantry are supposed to remain out of action in care of the horses. Further, in addition to being able to perform long continuous journeys, the rider arrives at his destination in a fitter state to perform whatever work he has to do than he would if he had been riding a horse.

Trimobiles, quadricycles, and such machines may be classed under the head of motor cycles, and whatever has already been said of the latter practically applies to the former.

With the exception of those in possession of the Motor Volunteer Corps, there are no motor cycles in the Army, though a number of privately-owned machines are constantly being used for military duties. During last year's manœuvres those belonging to the Motor Volunteers were placed at the disposal of the Umpire Staff. The weather and

roads were far from being good. At the beginning of the manœuvres it poured with rain. The roads were chalky and became very slippery. On the whole, the manœuvres demonstrated that an orderly mounted on a horse was preferable for short distances over difficult country, but for long distances, even if the cyclist had to dismount from his machine and walk for some little distance to reach the officer to whom the message was sent, the motor cycle remains unequalled.

It must be understood that the remarks I have made about the use of motor cars and cycles do not pretend by any means to completely deal with the subject, but only to open a field of discussion.

THE USE OF MECHANICALLY PROPELLED VEHICLES FOR THE TRANSPORT OF STORES AND THE HAULAGE OF HEAVY FIELD GUNS.

The question of transport of material of every description by mechanical means where animals are now used is one which for some years past has been the subject of much enquiry and experiment. The returns of large commercial companies, who were the first to adopt this means of transport as a practical undertaking, show that it is less costly than animal haulage, and this has entirely been borne out in its employment in the Army. Its employment in South Africa resulted in a saving of at least £50,000 over animal haulage, and this in spite of the very adverse circumstances under which it was employed. But the financial advantage accruing from the use of mechanical transport is liable to be entirely lost, if means are not provided for the efficient and immediate carrying out of repairs and the proper training of the *personnel*.

The advantages of mechanical transport of stores from a military point of view are many; the following are perhaps the most important:—

1. Greater loads and the absence of long teams of animals reduce the length of a convoy to a minimum, and consequently diminish the strength of the escort required.
2. If likely to be captured by the enemy, it takes but few minutes to render the engine useless; nor can the loaded trucks be removed without an engine.
3. It is absolutely free from the ravages of the diseases common to transport animals; it does not foul camping grounds, or strew the theatre of war with rotting carcasses.
4. The *personnel* required is very much smaller than that required for animal transport.
5. The bulk and cost of fuel is less than that of the food for animals, except those that exist by grazing, which, on the other hand, must do so at regular and often particular times of the day.
6. It is easier to move by rail or sea.
7. When the engines are fitted with a crane it can form its own loading party to a great extent.
8. Climatic influences do not affect its working, so long as the ground is suitable for its action.
9. Long and continuous journeys can be performed without fatigue.

Summed up, then, mechanical transport can be used with great advantage wherever the surface of the ground is suitable, thus setting free the animal transport for use in districts where it alone can work, and easing the railway of the carriage of stores, so as to allow of a passage of troops and guns.

The Royal Engineers have used traction engines, etc., to some extent for many years, but it was not until the spring of last year that mechanical transport was officially included in the organisation of the transport branch of the Army, *i.e.*, the Army Service Corps. Engines are also being used by the Artillery for their movable armaments, and it is proposed to use them still further, and provide a permanent establishment for the movement of heavy field guns.

The forms of machines at present and hitherto in use in the Army are of mainly two types, *viz.*: traction engines and lorries, both of which are more or less the commercial pattern. The traction engines at present in use by the mechanical transport vary in weight from 10 to 19 tons, and only differ from the commercial type in that they have been specially strengthened, the tyres of their wheels broadened, etc., to meet the rough work they have to perform in the Army. The engines are well designed and strongly constructed, keep steam easily, and are accessible as to their parts. Engines of this type performed yeoman service in South Africa when used in their proper sphere, and effected a saving of some £50,000. Their great H.P. and weight make them capable of hauling 25 tons of useful load, or a gross load of 45 tons on average roads. They have a winding drum and wire hawser by which they can wind themselves over difficult ground or up steep gradients, and then, having anchored themselves, proceed to wind their train truck by truck, or as a whole, after them. So long as they can get a bearing without sinking too deep they can work their way over most surfaces. The ability of these engines to haul heavy loads makes them exceedingly economical, in addition to which they are economical in their consumption of fuel and water. Oil, coal, or wood can be used as fuel, and in a country where wood is plentiful they resemble the animal that subsists by grazing, since they can collect their fuel as they proceed. Traction engines of a similar design but of lighter type, weighing from 8 to 10 tons, were used in South Africa, and the evidence of the officers under whom they were working shows that they worked more successfully over soft ground than the heavier type. The advantage of engines of being able to leave their trucks to be loaded or unloaded and to pass their train piecemeal over weak and temporary bridges, and of being used for other purposes; such as pumping, driving machinery, or lighting purposes, is obvious.

The other type of mechanically propelled vehicle at present in use in the Army for the carriage of stores is known as the lorry, and differs from the traction engine in that it carries its load on the same structure as the engine. This latter type of vehicle has been used principally for station work, where the roads are fairly good, and on the whole have given good results. The majority of those in use are fitted with smooth tyres, and this alone makes them quite unsuitable for work on such surfaces as soft camping ground, etc. As general service vehicles they are not suitable. The great disadvantage from which the lorries suffer is that of not being able to extricate themselves when in difficulties on bad ground, even when fitted with a wire hawser and winding drum. The useless moving weight and road pressure per

wheel is greater than that necessary with a traction engine. The firm of Messrs. Thornycroft & Co. have gone to considerable trouble and expense to make the lorry suitable for general service work in the Army, but for the reasons already stated the sphere of work is limited. In their favour it is to be noted that they are very handy machines, can quickly get up steam, move rapidly, have a smart appearance, and can be driven by one man.

HAULAGE OF HEAVY FIELD GUNS AND ARMAMENT.

The haulage of heavy field guns by mechanical means has been under consideration for some time, and I think what has been said about the conveyance of stores applies equally to the transport of guns, with this exception: that heavy field guns may have to occupy positions very difficult to reach, but such difficult ground would only be for comparatively short distances. It has been suggested that the engines should draw the guns as far as possible, accompanied by a team of horses to drag them over any bad ground. It will be said: what is the use of having two means of transport? But this, on second thought, answers itself. The horses will only be required to bring the guns into action in a position the approach to which is impossible to an engine. The engines are intended to relieve the horses of their most fatiguing, most wearing work, that of long continuous hours in the collar, and often without proper intervals for watering and feeding, leading to lameness, want of strength and weight, and eventually to the cruelty of death from overwork, and the using up of team after team of horses during a campaign. Every war that has taken place affords ample evidence of the enormous sacrifice of animals, and the overburdened taxpayer has a more acute realisation of the cruelty than ever he had in times of peace.

Traction engines were used extensively in the recent rearmament of Gibraltar. The guns, weighing 30 tons, with the "drug" being taken up 500 feet, the gradient being about 1 in 6 in some parts. The higher portion of the road being zig-zag and narrow, the guns had to be winched up—a very slow and laborious operation compared with the first part of the journey. I may say that for no part of the journey could animal haulage be used. Similar services were rendered in mounting the heavy guns in the forts around Pretoria during the South African war.

Artillerists suggest that the best equipment for a battery of 4·7-inch or 5-inch guns would appear to be as follows:—

For each sub-division of one gun, two engines, of which one to draw one wagon and the gun, and the other to draw two wagons.

The loads of these wagons to be as follows:—

	Tons.	Cwt.
Wagon with gun - - - - -	5	0
Water and fuel - - - - -	1	13
12 men - - - - -	0	18
10 rounds ammunition - - - - -	0	8
Stores - - - - -	0	6
Total - - - - -	8	5

1st Wagon of 2nd Engine	-	-	-	Tons.	Cwt.
Water and fuel	-	-	-	1	13
4 men	-	-	-	0	6
25 rounds ammunition	-	-	-	1	0
Stores	-	-	-	0	6
Total	-	-	-	3	5

2nd Wagon of 2nd Engine	-	-	-	Tons.	Cwt.
65 rounds ammunition	-	-	-	2	12
Stores, kits, etc.	-	-	-	0	15
Total	-	-	-	3	7

It is unnecessary for me to say any more on this point in view of the presence of artillery officers, who, I hope, will give us the benefit of their opinions.

PROBLEMS NOW BEING SOLVED WITH A VIEW TO INCREASING THE EFFICIENCY OF MECHANICAL TRANSPORT.

With a view to increasing the efficiency of mechanically propelled vehicles for military purposes, the three great problems to be solved are:—

1. A more extended radius of action than hitherto has been possible.
2. The possibility of negotiating greasy, soft, or broken ground, and steep gradients.
3. Absence of noise and smoke.

These are the problems which the Mechanical Transport Committee are working at, and, though very shortly stated here, are problems the solution of which will only be found after very careful investigations and by an intimate knowledge of the science of self-propelled vehicles and the problems of military transport.

The requirements of an efficient military vehicle of this nature differ from those in commercial life. Thus it is necessary that the trade should be led in this matter, and the more efficient machines that have been evolved is due to this leading and the hearty co-operation of the manufacturers, who have in some instances expended money as well as thought and time on the matter. Before entering on a description of the work that has been done (since the South African War) with a view to solving these problems, and before referring to recent inventions by civilians, some allusion is necessary to the altered conditions which have now caused the general adoption of mechanical road locomotion. As stated by Mr. Worby Beaumont in his valuable treatise on "Motor Cars," in the early days the railways absorbed all the attention and all the capital which the country could give to locomotive and transport questions, thus robbing the successes of early inventors of the support which was necessary to establish mechanical locomotion on common roads. Railways have now ceased to make material extensions either in length or as a means of distribution, and no longer offer the most attractive investments.

Secondly, the far-reaching influence and beneficial results of mechanical engineering have commanded attention in the House of

Commons, and the laws for the suppression of mechanical road transport have been repealed, fresh and more reasonable enactments have been passed, and to this the recent remarkable developments in road locomotion are greatly due. Thirdly, the improvements which have been made in machine tools now render accurate work not only possible but cheap, and from their general use has been derived the practical possibility of the modern high-speed engine, and now the engine which took up much valuable space in the road carriages of 1830 can be put in a small box on the fore-carriage, or slung out of sight on the frame.

Taking the problems I have mentioned in succession, the increase of radius of action was the first to be dealt with. To overcome this difficulty a traction engine was fitted with an air-cooled condenser. The engine constructed was of the heavy type. The condensation took place successfully, increasing the distance the engine could go up to 40 or 50 miles, instead of only 15, as is the case with an ordinary engine. But the condenser suffers severely from the jolting and jarring on the road, and its practical efficiency is liable to be lost. It is possible that in a smaller type of engine the condenser may be made sufficiently strong to stand the strain of road work, and enable an engine to travel about 50 miles, or even further, without requiring water. In addition to the increase of the distance, the engine could travel without taking in extra fuel and water; it was constructed with a view to, and obtained the following advantages:—

1. Silence in working.
2. High speed.
3. Absence of smoke and smell.
4. Ease in steering.
5. Motion dust-proof and out of sight.
6. Oil for lamp could be obtained in any town or village.

Having apparently arrived at the limit of radius of action which a steam engine can attain, it was thought that an internal combustion engine using a cheap, heavy oil would more effectively grapple with the problem. With this in view, a specification was issued, and a prize of £1,000 offered for an engine of this nature. One competitor only, however, came forward, prepared to build an engine of this class; this was the well-known firm of Messrs. Hornsby and Sons, of Grantham, makers of stationary oil engines.

The conditions of the competition were that the tractor was not to weigh more than 13 tons when loaded with fuel and water, and to be able to draw a load of 24 tons, including the weight of the wagons, for a minimum distance of 40 miles without requiring more fuel or water than that carried on the engine.

The engine Messrs. Hornsby built is not an older pattern converted or any patched-up arrangement, but is quite a new departure, and the amount of time, thought, and money expended by the firm in its construction is by no means compensated either by the gaining of the prize or the purchase of the engine.

This engine succeeded in obtaining a radius of action of 78 miles, and, with an additional tank of oil which can be fixed on the engine, can travel 100 miles. Of the total weight of the engine, over 10 tons are on the driving wheels, and under 3 on the front wheels, so that the maximum adhesion is obtained. The engine is of the ordinary Hornsby-Ackroyd type, having two cylinders one above the

other, the lower being horizontal and the upper one inclined so that its axis passes through the centre of the crank-shaft; the connecting rods of both are connected side by side to a common crank-pin. The cylinders are of the ordinary single acting gas engine type, each having its own vaporiser, oil pump, and valve motion, the timing of the latter being timed to give an explosion every revolution. The speed of the engine is governed by an ordinary bill-crank governor.

The cylinders are water-jacketed, and the water is circulated by a rotary pump through a cooler under the foot-plate.

The air for combustion is drawn from a silencing box in the upper part of the frame between the crank-shaft and cylinders, inside the box are arranged the ends of the air-pipes. The main exhaust silencer consists of a box in front of the frame, with which the exhaust pipes from the engine cylinders are lead. A chimney is placed on top of this box, and is constructed to form a second silencer.

The propelling gear is started, and stopped by a friction-clutch, and the train starts easily without a perceptible jerk.

There are four changes of speed and reverse.

The levers actuating the changes of speeds, oil pumps, etc., and all the lubricators are worked from the foot-plate. It takes about half-an-hour to start up when the engine is cold.

The engine, as fitted, is suitable for using refined Russian oil, and can be adjusted to use refined American, Scotch shale, crude Russian, Texas liquid fuel, and Burmah oils.

The second problem is that of negotiating difficult ground; this nature of ground is of two styles: *a.* Hard surfaces, such as metal roads, where the difficulty lies in steep gradients and the greasy condition to which they are liable. *b.* Soft ground, whether it be country roads or the soft soil of the country and sometimes water-logged. Naturally the difficulty is increased where there are steep gradients.

The problem in the first instance is only one of power and adhesion. The power can always be obtained by using a suitable engine; but how is the necessary adhesion obtained?

In tractors and lorries there are only two wheels—the driving wheels—which exert a tractive effort; the rest of the wheels in the train are idle in this capacity, and, with the exception of the steering or front wheels of the tractor or lorry, the less adhesion they have the better, so long as they have sufficient to prevent slipping sideways or down hill. The whole adhesion, then, necessary for the power of the engine being converted into work, or moving the train or lorry along the road, must be found by the driving wheels alone, and this is done in two ways, namely, by placing as much weight as possible on the driving wheels, and by placing in their road strips. By these means gradients practical to other forms of traffic are negotiated. When hard surfaces are slippery the only way to overcome the difficulty at present is by doing away with the cause of slip by placing something under the wheels, such as sacking, etc. The second class of ground offers more difficulties, as it includes one of flotation as well as adhesion and power.

As I have already said, adhesion can be obtained by weight, but there is a limit to their manner of obtaining it on soft ground. We

find that the big, heavy engines of great power only break through the upper crust of the ground, and grind themselves in, and it takes some time before they can rope themselves out, or have baulks of wood placed under their wheels to enable them to do so.

Spuds, which resemble short strips of angle iron, are placed on the tyres of the driving wheels and act as a sort of paddle, and over many natures of soft surfaces are successful. But they by no means improve the ground for other engines or transport that may have to pass over the same ground. It was thought that a very light traction engine might give better results. With this in view a small tractor weighing about 5 tons, and capable of drawing a gross load of 5 tons, built by Messrs. Tasker, of Andover, was tried in the vicinity of the old "Supply-Depôt," at Aldershot. The ground near the depôt was of a very variable nature:—

1. Rough road on incline of 1 in 8, surfaces of which were soft.
2. Low-lying swampy surface covered with water, mud and grass.
3. Slopes covered with coarse rank grasses, heather and gorse.

With a gross load of 2 tons, composed of an A.S.C. Bristol wagon and its load, the tractor pulled without difficulty over all the above ground. The load was then increased to three tons, and the tractor pulled successfully over the ground with the exception of the very short steep rise of 1 in 4, practically a bank, when the rod in the spring draw-bar broke, necessitating the load being roped up. The tractor was then tried over the low-lying swampy ground with a gross load of $4\frac{1}{2}$ tons in the traction engine trailer. It successfully pulled over this ground; but when ascending a slope with a very rough and sandy surface, thickly covered with gorse, had to rope its load. So, then, it successfully negotiated almost every nature of ground likely to be met with in camps. The most notable feature in the small tractor is its power on grassy land. For instance, a big 19-ton traction engine without any load at all endeavoured to cross such a surface, and immediately ground itself in, while a small tractor with a fair load behind it accomplished it without even requiring spuds. It would therefore seem that an engine sufficiently light not to break through the crust or upper surfaces of the ground and able to divide its load, will be able to work in places prohibitive to heavier types, or over which lorries carrying their own load cannot pass.

But the capacity for traversing surfaces over which other engines cannot pass is not the only advantage the light tractor has. In addition, it can be easily man-handled, conveyed by rail or sea, and can pass over military bridges, or be rafted across rivers. But it must be remembered that these light traction engines are not comparatively economical in their fuel consumption, and some difficulty is experienced in keeping up steam. It will therefore appear that the transport tractor of the future will be a light internal combustion engine, using cheap, heavy oil, and efforts are being made to obtain an engine of this nature.

At the Automobile Exhibition in Paris last December, Colonel Renard exhibited a new method of transmission of power for a train of vehicles, by which he endeavours to deal with these questions.

The governing principle of this invention lies in the disposition, or rather distribution, of the motive power. Instead of making the first car the tractor, and using it in the ordinary way to haul the rest of the train, Colonel Renard transmits the rotary motion obtained from the ordinary petrol engine on the front car to each of the others in succession by means of a bevel gear and Carden shafting, thus making each car automobile, though not itself creating the energy it absorbs.

Many advantages are claimed for this arrangement. Use is made of the whole gross weight of the train for adhesion instead of obtaining only that produced by weight on the driving wheels of the engine. The first car need not be any heavier than the others, since it exerts no tractive power, further than is required for its own propulsion; there is practically no slip in starting or stopping, since each car has its own propelling wheels. The same principle has been carried out electrically in the United States, where a train of this nature is used for hauling borax at the Death Valley in California—the hottest place in *this* world. Details of this train are not to hand, but I imagine this system will save that power which must be lost when a mechanical means of transmission be employed.

Another invention which has been designed to grapple with the problem of the mechanical traction is the Pedrail. The following is a brief summary of the interesting description of this machine given by Professor Hele Shaw at Liverpool last year:—

THE PEDRAIL.

Mr. Diplock, the inventor, has gone back to nature to seek for a solution of the problem of Mechanical Traction over all kinds of surfaces.

If one has studied the mechanical movement of a man, one will realise that when he walks he places his foot upon the ground as a support, and moves forward upon it by using the ankle as a pivot. The movement his body is thus able to make is strictly limited in amount; but nature has provided a means by which the movement can be made continuous. This is effected by means of another leg, which, being brought forward, enables the other foot to be placed in a position to carry on the movement of the body, whilst the foot which came down first is brought forward to the new position.

The plan upon which this is based consists essentially of a rolling movement, since rolling takes place by turning about some point.

If we now attempt to translate an animal mechanism into a mechanical device, it is easy to imitate the general principle of action by having a number of spokes radiating from the centre upon which the weight is carried. To make this movement mechanical and continuous, the simplest method is to carry the spokes round in a circle. Suppose we increase the number of spokes indefinitely, we get a circular disc, and substitute for a jerky and irregular movement the continuous motion of a rolling wheel. This simple explanation indicates the relation (from a mechanical point of view) between the action of walking and the rolling of a wheel, and it enables us to appreciate the relative advantages and disadvantages of both methods of locomotion. With the wheel, the whole surface to be moved over becomes in turn a point of support; and unless the surface is both hard and smooth, the

resistance which the wheel experiences is always appreciable, and may be very considerable.

The wheel can only act without appreciable resistance when it makes contact with the smallest possible amount of surface. When it moves on soft ground the motion is not one of true rolling at all, but an amount of slipping takes place, which bears a definite ratio to the depth of the rut left by the wheel, and may, in extreme cases, be so great as to render it impossible for the wheel to turn at all. A wheel on the road has an enormously greater resistance than a wheel on the railway, and, taking the average resistance given by various authorities, it may be said that on railways the resistance is, roughly, from 8 to 10 lbs. per ton, while on the ordinary turnpike road the resistance varies from 50 to 500 lbs. per ton.

Now, the Pedrail indicates by its name that it is a rail carried upon feet, and the principle of its action may be explained in a few words. It is simply this: Instead of having a permanent rail carried for the whole of its length on permanent feet, viz., sleepers, and the wheels running upon this rail, this process is inverted. The feet are (as in the case of the railway) placed upon the ground, but instead of the rails being carried upon the feet, these feet support wheels, and the wheels thus supported act as bearers for a short length of rail attached to the moving carriage.

The Pedrail invention, however, does more than this. The feet and wheel which they support are attached to the moving carriage itself, so that by an automatic process the feet are carried round after the rail is moved over them, and placed again in front of the machine, thus affording a continuous track of wheels upon which the supporting rails can be carried in any direction in which the engine is steered. It is scarcely possible to make this invention clear without being able to show the actual machine itself at work.

Briefly, the invention might be described as replacing the wheels of an ordinary traction engine by revolving frames, carrying sliding spokes, each spoke having at its end a circular foot, and on the spoke itself, at a little distance above the foot, a small wheel or roller. In connection with each series of revolving spokes a fixed frame is attached to the side of the traction engine. This fixed frame somewhat resembles in form an inverted heart. When the axis revolves, the spokes are carried round and place in turn upon the ground the feet. At the same time, the wheels which run round in contact with the heart-shaped frame when brought underneath it (that is, under what may be described as the broader portion of the heart) act in turn as supports for the heart-shaped frame to glide over. Hence the engine is itself supported in turn, through the wheels, by the spokes, which happen at the time to be resting with their feet upon the ground.

The Pedrail consists of two parts, one of which is a railway which is fastened to the axle-box and does not revolve, and the other part is a kind of circular box carrying sliding spokes, rollers, and feet in such a manner that the rollers and feet are placed in succession on the ground, and the rail runs over them.

From the above a general idea may be formed of the principle of the Pedrail; but it requires careful study of this somewhat complex machine to appreciate the ingenuity which has been shown.

Time does not permit of a detailed explanation of the systems of the springs and sliding joints by which the spokes obtain the necessary flexibility of movement, nor of a description of the system of lubrication, which is the result of a vast amount of thought and ingenuity, since through one oil-hole the complete lubrication of the whole structure is maintained; but it may be remarked that the feet themselves are lubricated by being filled with a mixture of tallow and blacklead, and upon opening one of them after 12 months' intermittent work it was found to be in as good condition as the day it was filled.

SECTION OF PEDRAIL WHEEL.

The latest developments of the Pedrail is to place such wheels on the small tractor, to serve as driving wheels. Mr. Diplock considers an engine so fitted will probably traverse all surfaces that a wagon and 6 horses can negotiate.

Whether this remarkable invention will stand the test of time, and prove itself to be within the sphere of practical utility, remains to be seen; but its future must be kept in view by all who are interested in mechanical transport.

LIGHT TRACTION ENGINE, WEIGHING 5 TONS, WITH PEDRAL WHEELS.

The CHAIRMAN (The Rt. Hon. Graham Murray, M.P., Secretary for Scotland) :—I shall only trouble you with a very few observations, because, although I was exceedingly glad to have the opportunity of coming here to-day and hearing the discussion on this subject, it would be idle for me to say that I have any knowledge or experience which would warrant me in pronouncing an opinion on some of the difficult problems we have heard discussed. I can claim no more than this: a certain amount of very practical experience of fighting with motors in both perfect and imperfect conditions. The interesting subject that we have had before us to-day is the use to which mechanical traction can be put in the operations of war. I think we may at once dismiss a subject which, indeed, was only incidentally mentioned by the lecturer—the use of the ordinary motor car for the purpose of manœuvres. When you come to war, it is quite evident that that problem is enormously complicated by the class of country with which you have to deal. It is impossible to compare the different countries in which a British force, at any rate, might have to operate, when you come to consider their practicability to motor transit. But I am bound to say that I am perhaps a little sceptical of the motor ever being used—I am not now talking of the transit of heavy goods, but the motor for the purpose of conveying troops—ever being found very useful except in what is more or less a civilised country, because the conditions with regard to a motor, when you come to a slippery and uneven surface, become so enormously difficult that it would be almost impossible, even if we had the more or less perfect machine that was outlined by the lecturer, to cope with the difficulties that might arise. With regard to his proposals for having a certain amount of motor infantry, I think it is evident that if you were dealing with a country like our own, or any country where roads are good, that it would be an enormous advantage over even the railways, wherever you come to the question of cross-country routes. Everyone of us knows that although the railway is still the quickest way of getting to London or any given point, especially that point which is far off, as soon as you come to a cross-country journey, no train can compete with a good motor. With regard to the lecturer's requisites for a car, I looked at them with great interest. I think there are people other than military men, who are searching for a car which has all the qualities which he asks for—in particular, an inexpensive and reliable tyre would be a source of gratification and joy to many besides the military expert. In looking at his list, I was very much reminded of an old picture of John Leech, of the "Horse Dealer," who, after going through all the various virtues of the horse, added that it was a moderate price; and then, when the customer said, "That is just what I want," he replied, "When I find it I will let you know!" With regard to the use of other spirit than petrol, I take it many persons are on that quest. It would be an enormous advantage, of course, not only to have a cheaper spirit, but a spirit which is more easily procurable in every place. I suppose it is really a question of carburation and of carburation alone; but that is easy to say, but not so easy to discover. Certainly, those who, like myself, have often, with the more volatile spirit, spent many a five minutes in that excellent occupation of turning a wheel, will have, at least at present, a certain doubt as to the efficacy of a less volatile spirit than petrol. The motor cycle was perhaps the part of the problem with which I, in one sense, have had most practical experience. There again, on country roads one could easily see that a body of troops provided with motor cycles would have a mobility which could not be touched by any other form of transit; but a motor cycle has its

troubles. The lecturer said it was now not at all a complicated machine. Well, it is a good deal better than it was, but I am not quite sure that its complications are all gone; and from my observations it is not a very uncommon sight to see a person on the roadside with a motor cycle who is in obvious temporary trouble! I also wondered to myself whether the lecturer had had the personal experience that I have had when he talked about the motor cycle being easily pedalled. The pedalling of a motor cycle is a thing that would very well do for military discipline, and indeed any form of discipline — I do not know of any harder form of work; but at the same time, I am rather inclined to agree with the conclusions that he arrived at, namely, that the motor cycle is such an easy form of transit that its use could not profitably be excluded in the military arrangements of the future. That brings us to what was really the chief part of his paper, and on which I do not feel that I am at all competent to speak. It is quite evident that mechanical traction for the transit of heavy stores and also, perhaps, to a certain extent, even of guns, has a great future. I thought one other suggestion made by the lecturer was excellent, namely, that in the case of guns, you might avail yourself of both forms of transit, and that while using the mechanical transit for the long hours of heavy labour where that was possible, you might at the same time with perfect ease reserve to yourself the greater advantages of the horse, which you could call to your aid in the last conditions of difficulty when you were in action, and when you might be at a place where motor transit would be practically unavailable. I should think it very far from my duty if I stood in the way of other people, especially as I am sure we should like to hear a few words from the author of the being of that hideous practical animal that we have just seen; it seems to get over one of the difficulties of surface which was a stumbling block in the way of the ordinary wheel. I will conclude by saying that I hope I am expressing the feelings of everybody when I say how interesting I have found the paper, and I hope it will give rise to a practical discussion by those who know something of the subject.

Captain J. N. C. KENNEDY, R.E. (Superintendent of Workshops, Chatham) :—I must congratulate Major McNulty on the amount of detail contained in his lecture, and in the interest shown by his audience. He has covered the ground very completely as regards transport requirements, but I would like to supplement a few remarks on the technical application of motors and motor vehicles to military engineering. The internal combustion engine, owing to its light weight for power developed, is well adapted for employment in the field. All the fuel carried is utilised, and the machine requires no water, which is the great difficulty where steam engines are used. This system of obtaining power and transport is now being employed for the field search-light and wireless telegraph service with satisfaction. The experience of South Africa and the last manoeuvres goes to show how useful portable light installations are. The lighting of temporary railway platforms and dépôts will enable work to be carried out which would otherwise be impracticable. For field workshops a better means of providing energy could not be devised, and for hospital work, charging accumulators for Röntgen Rays apparatus, driving fans, etc., small engines would be invaluable. The application of motors in war will in the future undoubtedly be large, but at present the utility of motor cars is being recognised in connection with staff work at home in preparing the Army for war during peace. For this purpose I think the

formation of the Volunteer motorists was a very practical movement. Our senior officers are being shown how very efficient motor cars can become when properly used in the hands of skilled drivers. The only charge that can be laid against Colonel Mark Mayhew, whom I see present, is that his men are too efficient and make too good a show altogether, so much so, that many of our generals have received the impression that the cars run by themselves without attention. The Volunteer movement should be extended and developed as regards cars, but more especially motor cycles. It is in this direction I feel certain that a great future lies before the motor vehicle in its tactical application. Personally, I cannot foresee that a car will ever be brought under fire with advantage, but there appears no reason why the cycles should not be used in the first line. I would suggest the following as a rough idea for a unit, which, I think, would be most valuable:—

20 Motor cycles	1 Rifles.
40 Ordinary cycles	!
2 Cars	 Repairing stores, ammunition.
1 Lorrie	 Transport.

This would be a self-contained body capable of operating wide on the flanks, making detours of more than 100 miles if necessary. The operations would be largely governed by the existence of roads; on the other hand, the mobility would more than compensate by affording great choice of route. On the march the motors would each tow two ordinary cyclists, who would assist by pedalling up steep gradients, and if a motor should break down the cyclist could render assistance. The cyclist would also be able to assist the motorist over hedges and across country if necessary. For line of communication and station work, while active operations were not in progress, the employment of this unit would effect an enormous saving of time and horseflesh. During the recent manœuvres I found motor cyclists absolutely invaluable in superintending transport when spread over a long length of road. The delay occasioned by the engines stopping to take in water at every public-house was minimised. There are many people both in and outside the Army who are waiting for the motor car to become more simplified before identifying themselves with the movement. It is very desirable that such persons should have plenty of spare time on their hands, as they may have a long time to wait. The tendency in all modern improved appliances is to make for efficiency, not simplicity. The present type of traction engine is twice as complicated as that of twenty years ago; at the same time, it is four times as efficient. Our best policy now would be to adopt the existing types of machines and train our men to drive them properly. We should not waste time in endeavouring to obtain something that can be "easily repaired in the field," but rather to make our drivers sufficiently skilled as not to break them down. It may be very satisfactory to effect a smart roadside repair, but it is better to avoid it altogether by good driving. The motor cars of to-day are as nearly perfect as they are ever likely to be, but we have not got the perfect driver by any means. In my experience, I should say that 90 per cent. of the "breakdowns" are due to the drivers, not the cars. I disagree with the lecturer as to the necessity of introducing a standard pattern car. It would be very convenient to have everything interchangeable and of a fixed pattern, but standardisation tends towards laziness and inefficiency, want of progress, and general stagnation. One might as well try to adopt a sealed pattern for a lady's hat as for a motor car. In a few years we would find the Ordnance Stores fuller than they now are of out-of-date appliances. Petrol offers

so many advantages as a fuel that it is bound to be adopted, and, as far as we can see, the supply is not likely to diminish during the next 50 years. The danger connected with it is largely imaginary, and the disastrous fires and explosions that were predicted on its introduction have not as yet taken place. Under certain circumstances, it is more safe than paraffin. It requires a flame to ignite it, a lighted cigar may be dropped into it with impunity. The sea carriage of petrol requires care, as does also its transport by rail, nevertheless, we see civilians engaged in peace time conveying it to all parts of the world, and why should not soldiers be willing to undertake the so-called risk in war? As regards "silence," a noisy car has the advantage that it does not come on you unawares, and as motor cars should have no business in the picquet line at night, it should not be debarred on that account. When you approach the enemy so close that he can hear the car it is time to stop the engine and get underneath. Half the troubles of motor cars arise from the rubber tyres, but of these quite 80 per cent. are due to pure ignorance or neglect. I have classified 53 common causes of failure in pneumatic tyres, of which 46 are easily avoidable, and with special care most of the remaining 7 need not be encountered. To my mind, solid tyres possess no virtue whatever, except in the case of very heavy vehicles, although they are not liable to punctures. I have in my charge three cars shod with the former description of tyres, which have been subjected to heavy work since last January without having experienced a puncture.¹

Colonel EUSTACE J. A. BALFOUR, A.D.C. (late 7th Middlesex V.R.C.):— I welcome this lecture very much indeed, because I myself have been, I may say for years, a voice crying in the wilderness trying to bring this very subject forward. Perhaps I may be allowed very shortly, not to controvert anything that the lecturer has said, but rather to try to supplement it from my own small experience. The first point I would like to raise is the one to which both the Chairman and the last speaker alluded, namely, the tactical employment of motor cars. I was Chief Staff Officer to Major-General Sir Frederick Maurice during the cycle manœuvres two years ago, and we came to the conclusion then that the combined use of cyclists and motor cars—I am referring now to ordinary cycles rather than to motor cycles—might, in certain circumstances, be extremely valuable. The essential use of cycles tactically is the employment of a force which is absolutely independent of base. You must be able to send them round any distance you like, and they must carry with them, in some form or another, all the stores they require, more especially the stores of ammunition. Suppose, for instance, that an army corps, or two army corps, were to land in this country, we should be at an enormous advantage if, by a turning movement of 100 miles, we could send a battalion of cyclists, supported by a certain number of motor cars, and hit their baggage train. The cyclists could scarcely do it themselves, because they would run short of ammunition rapidly, but, combined with motor cars, I believe they would be a most valuable force. To show what could be done in this way, I may mention that we had, on Saturday week, the ninth annual competition for what is called the Wolseley Cup. The competition consists of teams of cyclists riding 40 miles, at an average of 10 miles an hour, and then firing at figure targets, the object being to test the power of firing after a long ride. The four highest scores were all over 100, one being up to 115, out of a possible 160; it shows how valuable

¹ September—No punctures to date.—J.N.C.K.

they should be regarded. To come now to traction engines, in my battalion, during the last four or five route marches we had through Scotland, we always employed steam traction. One or two advantages struck me very much indeed in that experience. The first is the enormous simplicity of the traction engine wagon and the trailer, as compared with the cart when it comes to loading and unloading. We could get our camp pitched, when we were unloading a traction engine transport, in less than half the time we could when we were dealing with horse traction. When you come to think how very important every half hour's rest that the men get in each day is, that is a very valuable point. But we did find in certain cases that we could not use steam traction. The last march we had was from Aberdeen to Blairgowrie. That route goes over the highest pass in Scotland, one of General Wade's roads,¹ and the county road surveyor absolutely refused to give us leave. It was not so much the difficulty connected with the bridges and culverts, because that can always be got over, as you easily might with a party of engineers either by strengthening the bridges or giving a wide bearing; but the danger that you have, when you have a road like that on the side of a hill, is that the whole thing will slip down; and there is no possibility of getting over that difficulty. So when we came to a place like that we had to revert to horse traction, which, of course, would not be done in war. Another point which I think would be very well worthy of consideration is to make steam traction bullet-proof. Horse traction is probably one of the most vulnerable things it is possible to have, but if these wagons and locomotives are even partially bullet-proof, the baggage guard could be mounted, instead of having to march by their side, which would delay the speed of the engines and trains, and it would be practically invulnerable to anything but artillery.

Lieut.-Colonel R. M. F. KELLY, D.S.O., R.A. (Chief Instructor, School of Gunnery, Shoeburyness):—I am very glad I was able to be present this afternoon to hear the very interesting paper that Captain McNalty has read to us. A few months ago I had myself some experience with the old pattern engine, so I was very glad to hear the lines on which development is progressing, by which the difficulties which I have myself very often experienced, chiefly difficulties arising from slippery chalk roads, going up steep hills, and from the slipping or skidding of the engine on soft ground, may, I hope, be overcome. From what the lecturer said, the development appears to be going on two rather distinct lines, namely, in the Hornsby engine they appear to be going for a greater radius of action, silence, and absence of smoke. Those are three things which are of vital necessity for an engine that is to go into the fighting line in times of war. In the second case, the light engine—I did not catch the name of it—the development appears to be going on the lines of overcoming the tendency of skidding on soft ground. The heavy engine can, under certain circumstances, overcome the slipping on slippery steep roads, but it gives way on soft ground; and the heavier the engine the more it, as it were, digs a grave for itself in the ground, instead of hauling its load on. I did not gather from the lecture that these light engines also share the advantage of the Hornsby engine in having a very extended radius of action, nor share the advantage of

¹ Readers of Scott will recollect the Irishman's description of these roads—which were part of the great "Blockhouse System" after 1745: "If ye'd seen these roads before they were made, ye'd have held up your hands and blest General Wade."—F.J.A.B.

noiselessness and smokeless fuel. I think there is no doubt that the present attitude of artillery officers, or at least that portion who are at all concerned in thinking of the means of traction for heavy guns, is that the time certainly has not arrived in which you could safely entrust your first line, that is to say, your guns, and your first line of ammunition wagons to mechanical transport. It does not, however, for a moment follow from that, that we have no interest in the development of mechanical transport, or that we, as it were, despise it and think it is a thing that has no concern for us at all. I think that at the present moment mechanical transport could be used in three distinct ways, short of being used actually for bringing guns into position. I think it could be used, firstly, for the transport of the second line of wagons and for the ammunition column. I take it that each gun would be accompanied by at least two ammunition wagons besides the ammunition column. The first line of wagons, I think, should be horsed, or provided with animal transport, as also the guns. Secondly, I think mechanical transport might possibly be used as adjuncts to help at a critical point. I think one of the greatest advantages mechanical transport has over animal transport is the power of sending your engine right up a difficult place, or to circumvent a difficult place, and then, by means of haulage as a stationary engine, to utilise its enormous power in pulling the guns up. That is an advantage which you can never get from horses; there are no means of sending your horses on and getting them to turn windlasses that will pull your guns up. The third way in which they can be used would be to use them day by day for the coolie work—I think someone before me has mentioned this—of hauling your guns over the roads, and thus saving your teams of horses to be used for taking the guns from the road to their place of action, and, if necessary, taking them, not at a rapid pace, but perhaps at a quicker pace than the four miles an hour that you would expect to get out of your traction engine. That, of course, would be a rare luxury and a great advantage, but it would mean duplicating your haulage power, and necessarily increasing the expense. In that way it would have to be a question as to whether the money could not be more usefully spent on other things; but there is no doubt that if it were spent in that way it would tend to promote the life of your teams, which are most difficult to replace. I should very much like to know if the lecturer could give us a sort of rough comparison between the fuel that is consumed by an engine and the corresponding weight of food necessary for animal transport of a battery. Take a horse transport of eight horses to a gun and four to a wagon, you would want for one gun and one wagon about 240 lbs. of forage a day. Touching that point, I would also like a comparison between the case of replenishing or conveyance of the forage for the horses and the fuel for the engine. The other point on which I should very much like a few words would be the comparison of vulnerability of the two things. Take the effect of a certain amount of fire on an engine, how far it would be possible to repair the engine in the field. If the engine could not be repaired, you lose one gun and one wagon, whereas the same amount of fire might only put one horse out of action, and you can still get your gun on, even if two horses were put out of action, or, perhaps, for a short distance, even more. So that the thing to be thought of with regard to the traction engine is that you have rather got all your eggs in one basket, compared with a team of horses, in eight baskets. Those are the points on which I should very much like a few remarks from the lecturer.

Colonel R. E. B. CROMPTON, C.B., R.E. Vols. (Electrical Engineers): — I think the point that has now been raised by Colonel Kelly is the real crux of this matter. If our guns are to be taken into action by mechanical power, it is of first importance that we do not put all our eggs into one basket. We must have many hauling engines, and these must be small ones. By so dividing up our engine power we gain several of the advantages mentioned by the lecturer; first by using light instead of heavy engines we can work over more difficult ground, as much of the ground may be which must be traversed by artillery; although it may have a hard crust, this crust is easily cut through by the wheels of heavy engines, so that much of the power of the engine is expended in moving itself over such soft ground. With engines light enough not to cut through the crust this difficulty does not occur, at any rate, not to the same extent. As previous speakers have said, the problem of dealing with the fighting line is a far more difficult matter than that of supplying stores to the second line; but I think we ought not to say that we must abandon the idea of taking mechanical hauling engines into the fighting line. This matter is very parallel to the use of steam in our war-ships. I am old enough to remember the Crimean War, and recollect our sailing battle-ships being taken into action for the first bombardment of Sebastopol by steam frigates lashed alongside them. We then commenced to put engines as auxiliary power into our sailing war-ships. Gradually the steam power was increased, the sails became the auxiliaries, and now we see their use finally abandoned. I believe that mechanical means of haulage will follow on the same lines, and very wisely so. We have already applied it in the easier operations of supplying the second line, and it did yeoman service in South Africa, as everyone will testify. The lecturer has pointed out that what kills and strews the theatre of war with the carcases of the animals is the heavy slogging day-to-day work of dragging the loads to supply the second line, and this is the work we must tackle first, and even now are able to carry it out efficiently by mechanical transport. The requirements for this class of haulage are not difficult, although they vary for different countries. As one speaker has already said, there are two distinct requirements open to us, one being long radius of action or the power of moving great distances from the fuel and water base, and the other that of manœuvring with our engine in difficult ground. These two requirements are not incompatible, although of course, long radius of action is somewhat easier with larger and heavier engines, but small and handy engines with a sufficient range of action can now be designed. As regards manœuvring engines in difficult ground, a great deal depends on perfecting the winding gear. The use of the winding rope, which has a most important function to perform, has been very imperfectly developed up to the present time. It causes a serious delay to stop the engines and get the winding gear to work; this ought not to be the case. It can be so arranged that the driver can stop and change from direct haulage to winding his load in a few seconds of time. The next important feature is the perfecting of the driving wheels, for although we all admire the beautiful invention put before us by Mr. Diplock, and all wish him success, his invention appears to me to entail considerable complication and difficulties of repair in the field; but for the present I think we must look for great simplicity in the wheels. What we require are wheels of large diameter and considerable width of tread without the great increase of weight which has been always considered necessary in the wheels of the traction engines of commerce. Commercial engines cannot pay for refinements in these wheels, but I

believe that as we have now such very perfect materials at our command, such as oil-toughened nickel-steel, wheels of the traction engine type could be designed far lighter than they are at present, and this is a line of improvement which those responsible for the design of military hauling engines can safely follow. It is not too much to say that the chief difficulties met with by the driver of a military hauling engine are due to insufficient diameter or width of his driving wheels, and practically the same may be said of the modern motor car, which fails to be useful for transporting officers and men over heavy ground simply because the modern motor car has been designed with small wheels fitted with pneumatic tyres, which diminish the vibration on good roads, but which are useless to go across country where there are many ditches and depressions in the ground; these can be only satisfactorily crossed by wheels not less than 5 feet in diameter.

Sir J. THORNYCROFT, F.R.S.: — I do not know that I can enlighten the meeting very much on this subject, but I do feel it is one of great importance, and one in which, as Colonel Crompton said, we have to look forward, not only to the secondary work, but working right in the front. For myself, I have had a good deal of experience in engineering, and I have had considerable experience in motor-car driving, and when I compare my own legs with what I can do on a motor car, I feel that ordinary animal traction is not well adapted for getting over the ground if you want to do it rapidly. In war, the difficulties are great, and it has been stated that it will be in civilised countries only where mechanical traction may perhaps be used with much advantage. But I take it that it is in countries where there are roads that it is most important we should hold our own; we should be well prepared for countries well fitted with roads, and there is not the least doubt that where there are roads mechanical traction can beat any traction by animal power, no matter how good your horses may be. The question before us is one that has been solved in several ways. The earliest development of mechanical traction was by means of a steam engine. The steam engine has this disadvantage when compared with an internal combustion engine: In the steam engine you have a large system of pipes and vessels, all conveying material under high pressure, and any failure of any part of the machine subject to pressure may make it very difficult to repair that machine in a short time. The internal combustion engine has the advantage of using less fuel. It is also, in many of its simplest forms, only subject to internal pressure at the time the pressure is wanted and in that particular place in which it is required. The pressure is an instantaneous thing in the working cylinder, and that simplifies the matter enormously with regard to repairs, because the ducts that carry the fuel, gas and vapour are only subject to a very limited pressure. I remember with much pleasure the incident where a car broke down, and the tube conveying the gas from the carburettor to the cylinder was broken, but in the course of two or three minutes a pocket handkerchief was wrapped round the tube, and the car became workable again. That is a great contrast to the steam engine. With regard to the use of paraffin compared with a very volatile spirit, some people are of opinion that volatile spirit is much more dangerous, but there is one reason why it is not. Volatile spirit has the property of being dissipated through the air and being conveyed right away, so that if you get a leak in a place where there is a circulation of air no quantity of oil accumulates, whereas if you take ordinary paraffin, and there is anything of such a nature as will soak it up, you may get a large accumulation, which will

greatly increase until it becomes a source of very considerable danger. But I would not like to argue that paraffin is a more safe thing to carry. My firm has made experiments on the matter, in which we have been successfully working with ordinary paraffin. That certainly has an advantage. There is, of course, more difficulty in starting an engine where you use the ordinary paraffin; but I do not think it is insurmountable, and I trust that this problem will be solved. I do not think I will say more, except to thank the author for the paper which he has brought before us, and to say that I think the subject is of very great importance.

Captain J. H. DICKSON (Mechanical Transport Officer, Quetta District): — The difficulty with the steam engine that has been experienced in working at Quetta, which is the only place in India where we have used it, is, as Sir John Thornycroft says, in connection with the repairs. When you have to make a roadside repair, you very often have to let down steam before you can carry it out, which means a loss of some four or five hours, whereas in the internal combustion engine you have no steam to deal with, and you can set about your repair at once. I find wherever I go I have to make my own roads or greatly improve the existing tracks. It is not sufficient to say that where there are good roads mechanical transport can work; but they must be able to work over any country, and with this view I am inclined to suggest that we should have our traction engines supplied with sets of road roller wheels, so that when on service, roads for mechanical transport can be made, just as it is recognised has to be done for mule, camel, or cart transport. I think if this is done, and we get a certain number of pioneers, or sappers and miners, to assist us in making roads for our mechanical transport, we shall then, and not till then, work well and economically over countries that have no roads at present.

Major McNALTY, in reply, said:—A great many points have been raised in the course of the discussion, and I will try and reply to them in order. The Chairman says that an inexpensive and reliable tyre would be a source of gratification to many besides the military expert. In the private motor car of to-day, both these conditions are sacrificed to comfort and ease of running at high speeds, but in the military car the condition of reliability or freedom from delays due to tyre trouble, even with the best form of pneumatics, must be the primary one, and this condition, in conjunction with that of cheapness, both in first cost and upkeep, will doubtless be complied with by some form of wheel whose resiliency will be obtained by means other than that of placing between the rim and the road a cushion particularly susceptible, not only to wear and tear by friction, but to be rendered temporarily useless through puncture. At present everything points to solid or semi-solid tyres as being most suitable for military purposes; and were more attention paid to springing cars, and the legal limit of speed never exceeded, no doubt these would prove quite as comfortable as pneumatics. I said that a motor cycle could be pedalled should the engine fail, and this is, I consider, an advantage which the cycle has over a car, but I am not prepared to say it is easy work. In any case, a total breakdown may often be avoided by this means. With regard to the use of a heavier oil than petroleum spirit, the many advantages of the former are obvious, and I agree with Sir John Thornycroft in hoping that the problem will shortly be solved in a satisfactory manner. In reply to Colonel Balfour's question as to what extent traction engines

were bullet-proof, I have a slide which shows the effect of bullets fired from 400 yards range at a locomotive. It is an interesting one, and, I think, clearly demonstrates the invulnerability of a traction engine to rifle fire. Captain Kennedy said that petrol offers many advantages as a fuel, and in motor cars perhaps its cleanliness and the absence of any disagreeable smell may be advantages, but for the heavier types of machines ordinary commercial paraffin is cheaper, more easily obtained, more easily stored, and, if the carburation is suitably arranged, gives more power for equal bulk than petrol. I cannot agree with Captain Kennedy that the danger connected with the use of petrol is purely imaginary. I could instance numerous cases where disastrous fires have occurred, and these are rare where paraffin is employed. I said that machines must be easily repaired in the field, not meaning that efficiency should be sacrificed to simplicity, but that everything should be accessible and capable of removal with the minimum of labour. Many otherwise well-designed machines fail in this important respect, and in order to economise space parts are crowded together so as to render the removal of one, without the dismantling of the greater part of the machine, a matter of impossibility. Captain Kennedy also disagrees with me on the point of standardisation of cars. The object to be attained is efficiency as a whole, not that of individual cars, and this can only be done by standardising. Though the cars may not be of the latest pattern, the interchangeability of parts and the comparatively small quantity of spare parts which need be kept are obviously of paramount importance on active service, and it must be remembered that mechanical transport is for practical and not experimental work. Lieut.-Colonel Kelly asks for a comparison between the fuel consumed by an engine and the corresponding weight of food necessary for animal transport of a battery. One engine would be required to replace 12 horses for the transport of one gun and one wagon. Taking the greatest average distance that would be travelled per diem at 25 miles, the fuel required for an internal combustion engine would be 5 gallons of petroleum, weighing under 100 lbs. and being under two cubic feet in bulk. The forage required for 12 horses, using the most compact form of forage, would be 240 lbs. in weight and nearly 5 cubic feet in bulk. The attached table shows the comparison more clearly. Every day that the gun does not move makes the balance in favour of the engine greater.

Table Showing Comparative Weight, Bulk, and Cost of Fuel or Forage for Transport of one 4·7-inch Gun and one Wagon.

	Greatest average distance travelled per diem.	Fuel or Forage used.	Total weight Fuel or Forage used per diem.	Bulk of Fuel or Forage.	Cost of Fuel or Forage.
Internal Combustion Tractor	25 miles.	Paraffin	50 lbs.	1 cub. ft.	20 pence.
Horse Transport...	25 miles.	{ Compressed } forage.	240 lbs.	4·84 cub. ft.	234 pence.

Major-General UPRON PRIOR:—I would like to propose a vote of thanks to the Chairman for his kind attendance to-day. Parliament is very busy now, and the Ministry, and our Chairman happens to belong to both, and

I am sure we are most grateful to him for giving us the advantage of any of his spare time. I think the interesting lecture we have had to-day and the discussion which followed show the great importance that mechanical transport is to any Army. One can imagine the amount required by modern Armies if you consider the front occupied by the Japanese Army now—something like 150 miles, with three lines of communication going from the front to the rear, each some 70 or 100 miles long. I think they would be very glad of some of those little carts of which we saw photographs on the wall. It only shows that in any estimates submitted in future by the War Office to the Chancellor of the Exchequer, a large sum for motor transport must be included, and I think we are fortunate in knowing that any estimate like that will meet with the sympathy of our Chairman.