THE GAS ENGINE.*

By DUGALD CLERK.

In earlier days of mechanics, before the work of the great Scottish engineer, James Watt, the crude steam engines of the time were known as "fire engines," not in the sense in which we now apply the term to machines for the extinguishing of fires, but as indicating the source from which the power was derived, motive power engines deriving their vitality and strength from fire. The modern name—steam engine—to some extent is a misleading one, distracting the mind from the source of power to the medium which conveys the power. Similarly the name "Gas Engine" masks the fact of the motors so called being really fire or heat engines.

The gas engine is more emphatically a "fire engine" than ever the steam engine has been. In it the fire is not tamed or diluted by indirect contact with water, but it is used direct; the fire, instead of being kept to the boiler room, is introduced direct into the motor cylinder of the engine. This at first sight looks very absurd and impracticable; difficulties at once become apparent of so overwhelming a nature that the problem seems almost an impossible one; yet this is what has been successfully accomplished in the gas engine. Engineers accustomed to the construction of steam engines would not many years ago have considered any one proposing such a thing as having taken leave of his senses.

The late Sir William Siemens worked for many years on combustion engines, some of his patents on this subject dating back to 1860. In the course of a conversation I had with him on the subject of his earlier patents, I asked him why he had entitled one of those patents "steam engine improvements" when it was wholly concerned with a gas engine using hydrogen and air in the motive cylinder, the combustion of the hydrogen taking place in the motive cylinder. He answered me that in 1860 he did not care to entitle his patent gas or combustion engine simply because engineers at that time would have thought him mad.

Notwithstanding this widespread incredulity among engineers, and the apparent novelty of the gas engine idea, fire or combustion engines have been proposed long, long ago. The first Newcomen steam engine ever set to work was used by a Mr. Back, of Wolverhampton, in the year 1711. Thirty-one years before this time, in Paris—year 1680—Huyghens presented a memoir to the Academy of Sciences describing a method of utilizing the expansive force of gunpowder. This engineer is notable as being the very first to propose the use of a cylinder and piston, as well as the first combustion engine of a practical kind.

The engine consists of a vertical open topped cylinder, in which works a piston; the piston is connected by a chain passing over a pulley above it to a heavy weight; the upstroke is accomplished by the descent of the weight, which pulls the piston to the top of the cylinder; gunpowder placed in a tray at the bottom of the cylinder is now ignited, and expels the air with which the cylinder is filled through a shifting valve, and, after the products of combustion have cooled, a partial vacuum takes place and the atmospheric pressure forces down the piston to the bottom of its stroke, during which work may be obtained.

On the board I have made a sketch of this engine. Some years previous to Huyghens' proposal, the Abbe Hautefeuille (1678) proposed a gunpowder engine without piston for pumping water. It is similar to Savery's steam engine, but using the pressure of the explosion instead of the pressure of steam. This engine, however, had no piston, and was only applicable as a pump. The Savery principle still survives in the action of the well-known pulsometer steam pump.

Denys Papin, the pupil and assistant of Huyghens, continued experimenting upon the production of motive power, and in 1690 published a description of his attempts at Leipzig, entitled "A New Method of Securing Cheaply Motive Power of Considerable Magnitude."

He mentions the gunpowder engine, and states that "until now all experiments have been unsuccessful; and after the combustion of the exploded powder there always remains in the cylinder one-fifth of its volume of air."

For the explosion of the gunpowder he substituted the generation and condensation of steam, heating the bottom of his cylinder by a fire; a small quantity of water contained in it was vaporized, and then on removing the fire the steam condensed and the piston was forced down. This was substantially the Newcomen steam engine, but without the separate boiler.

Papin died about the year 1710, a disappointed man, about the same time as Newcomen. Thomas Newcomen, ironmonger and blacksmith, of Dartmouth, England, had first succeeded in getting his engine to work. The hard fight to wrest from nature a manageable motive power and to harness fire for industrial use was continued by this clever blacksmith, and he succeeded when the more profound but less constructively skillful philosophers had failed.

The success of the steam method and the fight necessary to perfect it to the utmost absorbed the energy of most able engineers—Beighton, John Smeaton—accomplishing much in applying and perfecting it before the appearance of James Watt upon the scene.

It is interesting to note that in England alone over 2,000 horse power of Newcomen engines were at work before Watt commenced his series of magnificent inventions; he commenced experimenting on a Newcomen engine model in 1759 at Glasgow University, and in 1774 came to Birmingham, entered into partnership with Boulton, and 1781 we find his beautiful double acting beam condensing engine in successful work.

From that time until now the steam engine has steadily advanced, increasing in economy of fuel from 10 lb. of coal per horse power per hour to about 1½ lb. per horse power per hour, which is the best result of to-day's steam engine practice. This result, according to the highest authorities, is so near to the theoretical result possible from a steam engine that further improvement cannot now be looked for. Simultaneously with the development of the steam engine, inventors continued to struggle with the direct acting combus-

tion or gas engine, often without any definite understanding of why they should attempt such apparent impossibilities, but always by their experiments and repeated failures increasing knowledge, and forming a firm road upon which those following them traveled to success.

In 1791 John Barber obtained a patent for an engine producing inflammable gas, mixing it with air, igniting it, and allowing the current so produced to impinge upon a reaction wheel, producing motion similar to the well known Aelopile, which I have at work upon the table. About this time, Murdoch (Jas. Watt's assistant at Birmingham) was busy introducing coal gas into use for lighting; in 1792 Boulton and Watt's works were lighted up with coal gas. From this time many gas engines were proposed, and the more impracticable combustion of gunpowder received less attention.

In 1794 Thomas Mead obtained a patent for an engine using the internal combustion of gas; the description is not a clear one, his ideas seem confused.

In the same year Robert Street obtained a patent for an engine which is not unlike some now in use. The bottom of a cylinder, containing a piston, is heated by a fire, a few drops of spirits of turpentine are introduced and evaporated by the heat, the piston is drawn up, and air entering mixes with the inflammable vapor. A light is applied at a touch hole, and the explosion drives up the piston, which, working on a lever, forces down the piston of a pump for pumping water. Robt. Street adds to his description a note: "The quantity of spirits of tar or turpentine to be made use of is always proportional to the confined space, in general about 10 drops to a cubic foot." This engine is quite a workable one, although the arrangements described are very crude.

The first gas engine that was actually at work for some years, and was applied to a variety of purposes, was Samuel Buren's. His patent was granted in 1823, and in 1826 he built a locomotive carriage with which he made several experimental runs in London; he also propelled a vessel with it upon the Thames, and fitted up a large engine for pumping purposes. A company was formed to introduce his engine, but it proved too wasteful of fuel, and the company went into voluntary liquidation. Like almost all engines of this time, the combustion of gas and air was used to produce a vacuum, the piston being driven by atmospheric pressure.

Buren's locomotive carriage was thus in action three years before the great trial in 1829, from which George Stephenson emerged victorious with his wonderful engine "The Rocket." To those curious in the matter, I may mention that S. Buren's patents are dated 1823, No. 4,874, and 1826, No. 5,350.

From this time on, a continuous series of gas engine patents appear, 20 engines being patented between 1826 and 1860, which is the next date worthy of particular mention.

In this year, 1860, the famous "Lenoir" engine appeared. The use of high pressure steam engines had long been common, and Lenoir's engine was analogous to the high pressure engine, as Buren's was to the condensing engine. It created a very general interest, and many engines were constructed and used in France, England, and America; it resembled very much in external appearance an ordinary high pressure horizontal steam engine, and it was double acting.

During the following six years, other 20 British patents were granted, and the gas engine passed from the state of a troublesome toy to a practicable and widely useful machine.

From 1791 to the end of 1866, in all 46 British patents were granted for gas engines, and in these patents are to be found the principles upon which the gas engines of to-day are constructed, many years elapsing before experience enough was gained to turn the proposals of the older inventors to practical account.

The most important of these patents are:

	No. Year.	
Robert Street.....	1,983 1794	Direct-acting engine.
Samuel Buren.....	4,874 1823	Vacuum engine.
Samuel Buren.....	5,350 1826	Vacuum engine.
W. L. Wright.....	6,525 1833	Direct-acting engine.
Wm. Barnett.....	7,615 1838	Compression first proposed.
Barsante & Matteucci, 1854	072 1854	Rack & clutch engine.
Drake.....	562 1855	Direct-acting engine.
Lenoir.....	335 1860	D. I. engine, electric ignition.
C. W. Siemens.....	2,074 1860	Compression, constant pressure.
Hugon.....	2,902 1860	Platinum ignition.
Millein.....	1,840 1861	Compression, both constant vol. and pressure.
F. H. Wenham.....	1,873 1864	Free piston.
Hugon.....	986 1865	Flame ignition.
Otto and Langen...	434 1866	Rack and clutch, flame ignition.

Leaving for the present the history of the gas engine, which brings us to a stage comparable to the state of the steam engine during the Newcomen's time, it will be advisable to give some consideration to the principles concerned in the economical and efficient working of gas engines, in order to understand the more recent developments.

It has been seen that gunpowder was the explosive used to produce a vacuum in Huyghens' engine, and that it was abandoned in favor of gas by Buren in 1823. The reason of departure is very obvious: a gunpowder explosion and a gaseous explosion differ in very important practical points.

Gunpowder being a solid substance is capable of being packed into a very small space; the gas evolved by its decomposition is so great in volume that, even in the absence of any evolution of heat, a very high pressure would result. One cubic inch of gunpowder confined in a space of one cubic inch would cause a pressure by the gas it contains alone of 15,000 lb. per square inch; if the heating effect be allowed for, pressures of four times that amount, or 60,000 lb. per square inch, are easily accounted for. These pressures are far too high for use in any engine, and the bare possibility of getting such pressure by accident put gunpowder quite outside the purpose of the engineer, quite apart from any question of comparative cost. In a proper mixture of inflammable gas and air is found an exceedingly safe explosive, perfectly manageable and quite incapable of

producing pressures in any sense dangerous to a properly constructed engine.

The pressure produced by the explosion of any mixture of gas and air is strictly determined and limited, whereas the pressure produced by the explosion of gunpowder depends greatly upon the relation between the volume of the gunpowder and the space in which it is confined.

Engines of the "Lenoir" type are the simplest in idea and construction; in them a mixture of gas and air is made in the cylinder during the first half of the piston stroke, air being taken from the atmosphere and drawn into the cylinder by the forward movement of the piston. At the same time gas entering by a number of holes, and streaming into the air to form an explosive mixture, the movement of a valve cuts off the supply, and brings the igniting arrangement into action. The pressure produced by the explosion acting upon the piston makes it complete its stroke, when the exhaust valve opens exactly as in the steam engine. The Lenoir and Hugon engines, the earlier forms of this type, were double acting, receiving two impulses for every revolution of the crank, the impulse differing from that in a high pressure steam engine in commencing at half stroke.

The Lenoir igniting arrangement was complicated and troublesome. I have it upon the table; the mixture was ignited at the proper time by the electric spark produced from a primary battery and Ruhmkorff coil.

The Hugon engine was an advance in this respect, using a flame ignited, and securing greater certainty of action in a comparatively simple manner.

It is really a modification of Barnett's lighting cock described in his patent of 1838.

Other difficulties were found in using these engines; the pistons became exceedingly hot. In the case of the Lenoir larger engines, it sometimes became red hot, and caused complete ruin of the cylinder by scoring and cutting up. Hugon to prevent this injected some water.

In the all important question of economy, these engines were found grievously wanting, Lenoir consuming 95 cubic feet per I.H.P. per hour; Hugon consuming 85 cubic feet per I.H.P. per hour.

The surviving engines of this type are only used for very small powers, from one to four man power, or ½ to ¾ horse, the most widely known of this kind being the "Bischoff," which is very largely used; its consumption of gas is even greater than the Lenoir, being 110 cubic feet per horse power per hour, as tested with a half-horse engine at a late exhibition of gas apparatus at Stockport.

So large a consumption of gas prevented these engines coming into extended use for engines of moderate power, and led inventors to work to obtain better results. The force generated by the explosion of a mixture of gas and air is very short lived, and if it is to be fully utilized must be used quickly; a high pressure is produced, but it very quickly disappears.

The quicker the piston moves after the maximum pressure is reached, the less will be the loss of heat to the sides of the cylinder. The flame which fills the cylinder and causes the increase of pressure rapidly loses heat, and the pressure falls.

The idea of using a free piston was proposed as a remedy; it was thought that a piston connected to a crank in the ordinary manner could not move fast enough to utilize the pressure before it was lost. Many inventors proposed to perform work upon a piston free from any direct connection with the crank or shaft of the engine; the explosion after attaining its maximum pressure expends its force in giving velocity to a piston; the velocity so acquired carries it on against atmospheric pressure until the energy is all absorbed, and a vacuum or deficit of pressure exists in the cylinder instead of an excess of pressure. The return stroke is accomplished by the atmospheric pressure, and the work is now done upon the engine shaft on the return only. The method of connecting on the return stroke while leaving the piston free on the out stroke varies, but in many engines the principle was the same.

Barsante and Matteucci, year 1857, British patent No. 1,625, describe the first engine of this kind, but Messrs. Otto and Langen were the first to successfully overcome all difficulties and make a marketable engine of it. Their patent was dated 1866, No. 434. To distinguish it from Otto's later patents, it may be called the rack and clutch engine.

The economy obtained by this engine was a great advance upon the Lenoir. According to a test by Prof. Tresca, at the Paris Exhibition of 1867, the gas consumed was 44 cubic feet per indicated horse power per hour. According to tests I have made myself in Manchester with a two horse power engine, Otto and Langen's free piston engine consumes 40 cubic feet per I.H.P. per hour. This is less than one-half of the gas used by the Hugon engine for one horse power.

The igniting arrangement is a very good modification of Barnett's lighting cock, which I have explained already, but a slide valve is used instead of a cock.

Other engines carried out the same principle in a different manner, including Gilles' engine, but they were not commercially so successful as the Otto and Langen. Mr. F. H. Wenham's engine was of this type, and was working in England, Mr. Wenham informed me, in 1866, his patent being taken out in 1864.

The great objection to this kind of engine is the irregularity and great noise in working; this was so great as to prevent engines from being made larger than three horse power. The engine, however, did good work, and was largely used from 1866 until the end of 1876, when Mr. Otto produced his famous engine, now known as "The Otto Silent Gas Engine." In this engine great economy is attained without the objectionable free piston by a method proposed first by Burnett, 1838, and also by a Frenchman, Millein, in 1861; this method is compression before ignition. Other inventors also described very clearly the advantages to be expected from compression, but none were able to make it commercially successful till Mr. Otto. To him belongs the great credit of inventing a cycle of operations capable of realizing compression in a simple manner.

Starting from the same point as inventors did to produce the free piston engine—namely, that the more quickly the explosive force is utilized, the less will be the loss, and the greater the power produced from a quantity of burning gas—it is evident that if any method can be discovered to increase the pressure upon the piston without increasing the temperature of the flame causing this pressure, then a great gain will re-

* Lecture by Mr. Dugald Clerk, before the Literary and Philosophical Society, Oldham.

sult, and the engine will convert more of the heat given to it into work. This is exactly what is done by compression before ignition. Suppose we take a mixture of gas and air of such proportions as to cause when exploded, or rather ignited (because explosion is too strong a term), a pressure of 45 lb. above atmosphere, or 60 lb. per square inch absolute pressure. Then this mixture, if compressed to half volume before igniting and kept at constant temperature, would give, when ignited, a pressure of 120 lb. total, or 105 lb. above atmosphere, and this without any increase of the temperature of the flame.

The effect of compression is to make a small piston do the work of a large one, and convert more heat into work by lessening the loss of heat through the walls of the cylinder. In addition to this advantage, greater expansions are made possible, and therefore greatly increase economy.

The Otto engine must be so familiar in appearance to all of you, that I need hardly trouble you with details of its external appearance. I shall briefly describe its action. Its strong points and its weak points are alike caused by its cycle. One cylinder and piston suffices to carry out its whole action. Its cycle is: First outstroke, gas and air sucked into the cylinder; first instroke, gas and air compressed into space; second outstroke, impulse due to ignition; second instroke, discharge of exhausted gases. When working at full power, it gets one impulse for every two revolutions; this seems to be a retrograde movement, but, notwithstanding, the advantages obtained are very great. The igniting arrangement is in the main similar to that used on the rack and clutch engine. The engine has been exceedingly successful, and is very economical. The Otto compression engine consumes 21 cubic feet of gas per I. H. P. per hour, and runs with great smoothness.

In 1876 I commenced my work upon gas engines, and very soon concluded that the compression system was the true line to proceed upon. It took me two years to produce a workable engine. My efforts have always been directed toward producing an engine giving at least one impulse every revolution and, if possible, to start without hand labor, just as a steam engine does. My first gas engine was running in 1878, and patented and exhibited in 1879. It was first exhibited at the Kilburn Royal Agricultural Society's show.

This engine was self-starting, gave an ignition at every revolution, and ignited without external flame. It consisted of two cylinders, a motor, and a compressing pump, with a small intermediate reservoir. Suitable valves introduced the mixture of gas and air into the pump, and passed it when compressed from the reservoir to the motor cylinder. The igniting arrangement consisted of a platinum cage firmly fixed in a valve port; this cage was heated in the first instance by a flame of gas and air mixed; it became white hot in a few seconds, and then the engine was started by opening a valve.

The platinum was kept hot by the heat derived from the successive ignitions, and, the engine once started, no further external flame was required. I have here one of these platinum cages which has been in use. Finding this method not well suited for small engines, I produced the engine which is at present in the market under my name.

The cycle is different, and is designed for greater simplicity and the avoidance of back ignitions. It also consists of two cylinders, motor cylinder and the displacer or charging cylinder. There is no intermediate reservoir. The displacer crank leads the motor by a right angle, and takes into it the mixed charge of gas and air, in some cases taking air alone during the latter part of its stroke.

The motor on the outstroke crosses V-shaped parts about from one-sixth to one-seventh from the out end, the displacer charge now passing into the motor cylinder, displacing the exhaust gases by these ports and filling the cylinder and the space at the end of it with the explosive mixture. The introduction of some air in advance of the charge serves the double purpose of cooling down the exhaust gases and preventing direct contact of the inflammable mixture with flame which may linger in the cylinder from the previous stroke. The instroke of the motor compresses the charge into the conical space at the end of the cylinder, and, when fully compressed, ignition is effected by means of the slide I have upon the table.

This system of ignition has been found very reliable, and capable of acting as often as 400 times per minute, which the Otto ignites is quite incapable of doing. By this cycle the advantages of compression are gained and one step nearer to the steam engine is attained, that is, an impulse is given for every revolution of the engine.

As a consequence, I am able with my engine to give a greater amount of power for a comparatively small weight. In addition to this, I have introduced a method of self-starting; in this I believe I was the first—about 100 of my engines are now using self-starting.

The largest single engine I have yet made indicates 30 H. P. The consumption of gas in Glasgow is: Clerk engine consumes in Glasgow 18 cubic feet per I. H. P. per hour; Clerk engine consumes in Manchester 22 cubic feet per I. H. P. per hour. So far as I know, the Otto engine and my own are the only compression engines which have as yet made any success in the market. Other engines are being continually prepared, gas engine patents being taken out just now at the rate of 60 per annum, but none of them have been able as yet to get beyond the experimental stage. The reason is simply the great experience necessary to produce these machines, which seem so very simple; but to the inexperienced inventor the subject fairly bristles with pitfalls.

I have here sections of some of the earlier engines, including Dr. Siemens' and Messrs. Simon and Beechy. Although interesting and containing many good points, these have not been practically successful.

The Simon engine is an adaptation of the well-known American petroleum motor, the Brayton, the only difference consisting in the use of steam as well as flame.

Dr. Siemens worked for some twenty years on gas engines, but he aimed rather high at first to attain even moderate success. Had he lived, I doubt not but that he would have succeeded in introducing them for large powers. In 1882 he informed me that he had in hand a set of gas engines of some hundreds of horse power for use on board ship, to be supplied with gas

from one of his gas producers modified to suit the altered conditions.

Summarizing the ground over which we have passed, we find the origin of the gas engine in the minds of the same men as were first to propose the steam engine, Huyghens and Papin, 1680 and 1690. Greater mechanical difficulties and ignorance of the nature of explosives caused the abandonment of the internal combustion idea, and the mechanical difficulties with steam being less, the steam engine became successful, and triumphed over its rival. The knowledge and skill gained in the construction of steam engines made it possible once again to attack the more difficult problem, and simultaneously with the introduction and perfecting of the steam engine, the gas engine idea became more and more possible, the practicable stage commencing with Lenoir and continuing with Hugon, Milne, Otto and Langen, F. H. Wenham, then Otto and Clerk. In 1860, 95 cubic feet of gas produced one horse power for an hour; in 1867, 40 cubic feet accomplished the same thing; and now (1885) we can get one horse power for an hour for from 15 to 20 cubic feet of gas, depending on the size of the engine used.

Considered as a heat engine, the gas engine is now twice as efficient as the very best modern steam engine. It is true the fuel used at present is more expensive than coal, and for large powers the steam engine is the best because of this. But the way is clearing to change this. Gas engines as at present, if supplied with producer gas, produced direct from coal without leaving any coke, as is done in the Siemens, the Wilson, and the Dawson producers, will give power at one-half the cost of steam power. They will use $\frac{1}{2}$ of a pound of coal per horse power per hour, instead of $1\frac{1}{2}$ lb., as is done in the best steam engines. The only producer that makes gas for gas engines at present is the Dawson, and in it anthracite is used, because of the difficulty of getting rid of the tar coming from the Siemens and Wilson producers, using any ordinary slack.

When this difficulty has been overcome, and that it will be overcome there can be no manner of doubt, gas engines will rapidly displace the steam engine, because a gas engine with a gas producer, producing gas from any ordinary coal with the same ease as steam is produced from a boiler, will be much safer, and will use one-half the fuel of the very best steam engines for equal power. The first cost also will not be greater than that of steam. The engine itself will be more expensive than a steam engine of equal power, but the gas producer will be less expensive than the boiler at present. Perfect as the gas engine now is, considered as a machine for converting heat into work, the possibility of great development is not yet exhausted. Its economy may be increased two or even three fold; in this lies the brilliant future before it. The steam engine is nearly as perfect as it can be made; it approaches very nearly the possibility of its theory. Its defect does not lie in its mechanism, but in the very properties of water and steam itself. The loss of heat which takes place in converting liquid water into gaseous steam is so great that by far the greater portion of the heat given out by the fuel passes away either in the condenser or the exhaust of a steam engine; but a small proportion of the heat is converted into work.

The very best steam engines convert about 11 per cent. of the heat given them into useful work, the remaining 89 per cent. being wasted, principally in the exhaust of the engine.

Gas engines now convert 20 per cent. of the heat given to them into work, and very probably will, in a few years more, convert 60 per cent. into useful work.

The conclusion, then, is irresistible that, when engineers have gained greater experience with gas engines and gas producers, they will displace steam engines entirely for every use—mills, locomotives, and ships.

RAPID CONSTRUCTION OF THE CANADIAN PACIFIC RAILWAY.

By E. T. ABBOTT, Member of the Engineers' Club of Minnesota. Read December 12, 1884.

DURING the winter of 1881 and 1882, the contract was let to Messrs. Langdon, Sheppard & Co., of Minneapolis, to construct during the working season of the latter year, or prior to January 1, 1883, 500 miles of railroad on the western extension of the above company; the contract being for the grading, bridging, track-laying, and surfacing, also including the laying of the necessary depot sidings and their grading. The idea that any such amount of road could be built in that country in that time was looked upon by the writer hereof, as well as by railroad men generally, as a huge joke, perpetrated to gull the Canadians. At the time the contract was let, the Canadian Pacific Railway was in operation to Brandon, the crossing of the Assiniboine River, 132 miles west of Winnipeg. The track was laid, however, to a point about 50 miles west of this, and the grading done generally in an unfinished state for thirty miles further. This was the condition of things when the contract was entered into to build 500 miles—the east end of the 500-mile contract being at Station 4,660 (Station 0 being at Brandon) and extending west to a few miles beyond the Saskatchewan River.

The spring of 1882 opened in the most unpromising manner for railroad operations, being the wettest ever known in that country. Traffic over the St. Paul, Minneapolis & Manitoba Railroad, between St. Paul and Winnipeg, was entirely suspended from April 15 to the 28th, owing to the floods on the Red River at St. Vincent and Emerson, a serious blow to an early start, as on this single track depended the transportation of all supplies, men, timber, and contractors' plant, together with all track materials (except ties), all of these things having to come from or through St. Paul and Minneapolis. The writer hereof was appointed a division engineer, and reported at Winnipeg the 15th of April, getting through on the last train before the St. Vincent flood. No sooner was the line open from St. Paul to Winnipeg than the cotillon opened between Winnipeg and Brandon, with a succession of washouts that defied and defeated all efforts to get trains over, so it was not until the fifth day of May that I left Winnipeg to take charge of the second division of 30 miles.

By extremely "dizzy" speed I was landed at the end of the track, 180 miles from Winnipeg, on the evening of the 9th (4 days). My outfit consisted of three assistant engineers and the necessary paraphernalia for three complete camps, 30 days' provisions (which turned out to be about 20), 11 carts and ponies, the latter being

extremely poor after a winter's diet on buffalo grass and no grain. On the 18th day of May I had my division organized and camps in running order. The country was literally under water, dry ground being the exception, and I look upon the feat of getting across the country at all as the engineering triumph of my life.

On May 20 a genuine blizzard set in, lasting 24 hours, snowed five inches, and froze the sloughs over with half an inch of ice, a decidedly interesting event to the writer, as he was 18 miles from the nearest wood, therefore lay in his blankets and ate hard tack. I stabled my ponies in the cook tent, and after they had literally eaten of the sod inside the tent, I divided my floor with them.

On 28th day of May I saw the first contractor, who broke ground at station 7,150. On the 1st of June I was relieved from this division, and ordered to take the next, 50 miles west. On the 13th day of June ground was broken on this division, at station 8,070, or only about 62 miles west of the east end of the 500-mile contract. It looked at this time as though they might build 150 miles, but not more. But from this time on very rapid progress was made. On July 17 the track reached station 7,000, making however up to this time but about 50 miles of track-laying, including that laid on the old grade; but large forces were put on to surfacing, and the track already laid was put in excellent condition for getting material to the front. The weather from this until the freezing-up was all that could be desired. Work ceased about the 1st of January, 1883, for the season, and the final estimate for the work was as follows: 6,103,986 cubic yards earth excavation, 2,395,750 feet B. M. timber in bridges and the culverts, 85,708 lineal feet piling, 435 miles of track-laying. This work was all done in 182 working days, including stormy ones, when little, if anything, could be done, making a daily average of 33,548 yards excavation, 13,150 feet B. M. timber, 471 feet piling, 2.38 miles track-laying. We never had an accurate force report made of the whole line, but roughly there were employed 5,000 men and 1,700 teams.

The admirable organization of the contractors was something wonderful. The grading work was practically all done by sub-contractors, Messrs. Langdon, Sheppard & Co. confining themselves to putting in the supplies and doing the bridge work, surfacing, and track-laying. The grading forces were scattered along about 150 miles ahead of the track and supply stores, established about 50 miles apart, and in no case were sub-contractors expected to haul supplies over 100 miles. If I remember rightly, there were four trains of about forty wagons each, hauling supplies from the end of track to the stores.

As can be readily seen, the vital point of the whole work, and the problem to solve, was food for men and horses. 1,700 bushels of oats every day and 15,000 pounds of provisions, Sundays and all, for an entire season, which at the beginning of the work had to come about 170 miles by rail, and then be taken from 50 to 150 miles by teams across a wilderness, is on the face of it considerable of an undertaking, to say nothing about hauling the pile-drivers, piles, and bridge-timber there. To keep from delaying the track, sidings 1,500 feet long were graded, about 7 miles apart. A side-track crew, together with an engine, four flats, and caboose, were always in readiness; and as soon as a siding was reached, in five hours the switches would be in, and the next day it would be surfaced and all in working order, when the operating department would fill it with track material and supplies. From the head of the siding to the end of the track the ground was in hands of track-laying engine, never going back of the last siding for supplies or material, and my recollection is that there were but six hours' delay to the track from lack of material the whole season, at any rate up to some time in November. The track-laying crew was equal to 4 miles per day, and in the month of August 92 miles of track were laid.

The ties were cut on the line of the road about 100 miles east of Winnipeg, so the shortest distance any ties were hauled was 270 miles; the actual daily burden of the single track from Winnipeg west was 24 cars steel, 24 cars ties, aside from the transportation of grain and provisions, bridge material, and lumber for station houses. The station buildings were kept right up by the company itself, and a depot built with rooms for the agent every 15 miles, or at every second siding. The importance of keeping the buildings up with the track was impressed on the mind of the superintendent of this branch, and, as a satire, he telegraphed asking permission to haul his stuff ahead of the track by teams, he being on the track-layers' heels with his stations and tanks the whole season. The telegraph line was also built, and kept right up to the end of the track, three or four miles being the furthest they were at any time behind.

It might be supposed that work done so rapidly would not be well done, but it is the best built prairie road I know of on this continent. It is built almost entirely free from cuts, and the work is at least 20 per cent. heavier than would ordinarily be made across the same country in the States, on account of snow. 2,640 ties were laid to the mile, and the track ballasting kept well up with the laying; so well, in fact, and so well done, that as 100 mile sections were completed schedule trains were put on 20 miles an hour, and the operating department had nothing to do but make a time table; the road was built by the construction department before the operating department was asked to take it. The engineering was organized in divisions of 30 miles each, and as each was finished the parties moved ahead again to the front, the engineers usually finding men sitting on their shovels waiting for the work to be laid out for them. It was as much as the locating parties could do to keep out of the way of the construction. The road-bed was built 14 ft. wide in embankment and 20 in the very few cuts there were, there being no cuts of any moment except through the Coteaus and the Saskatchewan crossing, and these have since been widened out on account of snow, so that the road can be operated the year round and the bucking-snow account cut no figure in the operating expenses.

The country is a virgin desert. From Winnipeg to the Pacific Ocean there are a few places that might attain to the dignity of an oasis—at Brandon, Portage la Prairie, etc.—but it is generally what I should call worthless; 100 miles to wood and 100 feet to water was the general experience west of the Moose jaw, and the months of June, July, and August are the only three in the year that it is safe to bet you will not have sleighing. I burned wood and used stakes that were hauled