March 9, 1869.

CHARLES HUTTON GREGORY, President,
in the Chair.

BEFORE commencing the ordinary business, the President referred to the recent decease of one of the oldest Members, Mr. James Simpson, Past President of The Institution of Civil Engineers. The President observed that Mr. Simpson had left a name which would long be remembered with honour;—by the world as a man of the most upright character, and a distinguished hydraulic Engineer;—by The Institution of Civil Engineers as one who, for many years, was a most regular and valued attendant at the meetings;—and by those who enjoyed his intimacy as a faithful and devoted friend.

No. 1,230.—"American Locomotives and Rolling Stock." By ZERAH COLBURN, M. Inst. C.E.

IN construction and working the American railways represent little more than a modified application of English practice.

When the systems of the railway machinery of the two countries are compared, many of the differences which first strike the eye are found to be external rather than fundamental; and so, too, many of the peculiarities of construction now retained in America will be found to be due to the initiative of English engineers. But for the necessities of a new country, and the comparative scarcity of capital, American railways and their rolling stock would have doubtless been constructed, as in other countries, upon English models, and worked, in most respects, upon English principles of management. The first two locomotives worked in America were made in England, in 1828, one by Mr. George Stephenson, the other by Mr. J. U. Rastrick, then of Stourbridge, for a short line owned by the Delaware and Hudson Canal Company. They were both of the early Stockton and Darlington pattern, with single-flue boilers, and they were thus deficient in steam power for working the gradients of the line, while they were also much too heavy for its primitive permanent way. In 1828 also the engineers of the Baltimore and Ohio Railroad (not then begun) visited England; and the late Mr. Robert Stephenson once informed the Author, that he suggested to them, what is now the chief distinguishing feature of all American railway rolling stock, viz., the bogie, to be applied to the engines intended to work round curves of 6 chains radius, at that time proposed to be adopted. The bogie, which had grown out of William Chapman's invention of 1812, was then, Mr. Stephenson stated, in regular use upon the quays of Newcastle. With few exceptions, the railways then contemplated and afterwards constructed in the States were surface lines, with frequent and often comparatively steep gradients, sharp curves, and a cheap and weak permanent way, if indeed the latter term can be properly applied at all. It was essential that the locomotives for such lines should be both light and cheap, and the first engines made in the States, between 1830 and 1832, weighed but from $3\frac{1}{2}$ tons to 4 tons. Some of the English built engines imported at about the same time had their leading wheels removed, and a swivelling bogie substituted. The bogie was not, however, exclusively employed. Considerable numbers of engines made by Messrs. Stephenson and Co., Messrs. Bury, Curtis, and Kennedy, Messrs. George Forrester and Co., and Messrs. Braithwaite and Co., were afterwards imported and worked as originally constructed; and in 1834 the Locks and Canals Company of Lowell, Massachusetts, commenced, and for several years continued upon an extensive scale, the construction of locomotives of the type fixed by Messrs. Stephenson and Co. for the Liverpool and Manchester engines. At least one hundred locomotives of English construction, or made almost exactly upon Messrs. Stephenson's plans, could have been counted at work in the States as late as 1855; and there may be some, here and there, at work still. For many years wood only was employed as fuel, and as it produced great quantities of sparks, as annoying to passengers as they were dangerous to goods, much ingenuity was directed to the problem of separating and withholding them from the escaping smoke and steam; and the voluminous and toppling erections, under the name of 'spark arresters,' of nearly every shape between that of a mill-hopper and a balloon, which bestride the smoke-boxes of American engines, are very successful in this respect, while they also give an unmistakable individuality to the engines themselves. Nor was it long before the rigours of the American winters compelled the adoption of some kind of shelter for the enginemen and firemen. The bulky, and often extravagantly painted and decorated 'cabs' which distinguish the American locomotives at once strike the eye, and impart a novel and foreign appearance to the whole design; yet it need hardly be said, that they in no way affect the principles, or economical conditions of working, of the engine itself.

As already observed, the bogie or swivelling truck is the chief distinguishing feature of American locomotives and railway rolling stock. It permits of almost any length of wheel-base upon sharply curved lines, and it thus secures an amount of steadiness in the engines and rolling stock to which it is applied quite unattainable with the disposition of wheels more ordinarily adopted in England. As made in the States, the bogies are not only singularly cheap in first cost, but are durable and inexpensive in maintenance, and it will be shown in the course of the present Paper that they work with a very low tractive resistance.

Keeping in mind the distinguishing merits of the bogie, the other differences between English and American locomotives are differences more of costume and of toilette than of vital principles of construction. The earlier engines had each a single pair of driving-wheels, but these bore a good proportion of weight for adhesion, partly because the centre of the bogie was 2 feet or 3 feet forward of the position occupied by the leading wheels in Stephenson's engines, and partly because a portion of the weight of the tender was made to bear upon the foot-plate. The last-named mode of increasing the adhesion was followed for years, more as a neat trick, however, than as an acknowledged expedient, yet it was duly patented in 1835; and it is a question even now, whether it would not be better to adopt it, rather than to load the foot-plates of so many goods engines with heavy cast-iron dead weights to increase the adhesion.

As high speeds were but seldom attempted upon the early American lines, the greatest steam tractive power was sought and obtained, both by working high-pressure steam and by employing driving-wheels of small diameter. Thus, although, in 1835, the English-built engines, and those copied from them, were worked at 50 lbs. pressure, and had only 5 feet driving-wheels, it was not long before American practice settled upon 90 lbs. to 100 lbs. pressure and 4 feet or even 3 feet 8 inch driving-wheels. It was soon found, however, that the adhesion weight upon a single pair of wheels, necessary to work up this increased steam tractive force, was too great for the strength of the way, and coupling was then resorted to; and in 1839 the eight-wheeled engine, with four coupled wheels and a bogie, came into extensive use. Mr. Joseph Harrison supplied a simple yet most valuable improvement, that of the compensating levers, whereby the weight was not only equalized between the coupled wheels, but the effect of a jolt upon one pair of wheels was divided and distributed, through the springs and levers, upon the other pair. It is for the latter reason, and hardly for any other, that compensating levers are now employed on all American engines, and those who have once witnessed their action upon rough lines cannot understand why they are not more used in English practice. It has now been usual for some years to make the outer ends of the springs of the coupled wheels bear upon india-rubber blocks; and even the compensating levers have been made of long steel springs; but without the last-named refinement, the subdivision of the shocks, occasioned by low joints or depressions in the rail, is most complete and effective.

The comparatively weak and imperfect permanent way of American railways required a greater subdivision of the rolling weights than in England, and, with the exception of a few light tank engines, worked on branch lines, there is not probably an engine in the States having single or uncoupled driving-wheels. It may be said that a weight of 4 tons has been the maximum per wheel for many years, while 3 tons was the more usual average. Ten-wheel engines, having six coupled wheels and a bogie, weighed less than 3 tons upon each of their coupled wheels, and the eight-wheel coupled engines, long worked on the Baltimore and Ohio and Reading Railroads had but 3 tons on a wheel, although they had cylinders of the large diameter of 19 inches, with 22-inch stroke, and 3-feet-7-inch coupled driving-wheels. The tons quoted are English tons, the ton more generally understood in the States being the New York ton of 2,000 lbs.

While the subdivision of weight referred to involved the coupling of a greater number of wheels, their size was so moderate, indeed in many cases so very small, that they could almost always be grouped together over a wheel base of moderate length. The base of the eight-wheel coupled engines, to which allusion has just been made, was only 11 feet 3 inches, the 3-feet-7-inch wheels being placed but 3 feet 9 inches apart from centre to centre, while only the leading and the trailing wheels had flanges. The subdivision of weight has been carried to the extent of ten, twelve, and fourteen-wheel engines, and of these some have six, some eight, others ten, and one twelve wheels coupled and worked by a single pair of cylinders. These are in all cases goods or bank engines intended to work at slow speeds, although a twelve-wheel engine made in 1855 by Mr. Ross Winans was intended for working passenger trains over the long inclines of 1 in 45½ of the Baltimore and Ohio Railroad. This engine had 22-inch cylinders, 22-inch stroke, eight coupled wheels, 3 feet 7 inches in diameter, and a bogie. The weight per wheel averaged but 3 tons, and the extreme wheel base was under 17 feet. On the Reading Railroad are a moderate number of engines with ten coupled wheels and a bogie, the average weight being under 3 tons per wheel. There is also a ten-wheel coupled engine weighing 50 tons, and having 5 tons on a wheel, employed to work the incline of 1 in 16½, and 1¼ mile long, at the Madison Terminus of the Madison and Indianapolis Railroad. This engine has twelve coupled wheels 3 feet 11 inches in diameter, and loaded to 3¾ tons to a wheel, the total weight being 44¾ tons. It has 20-inch cylinders, and 26-inch stroke, and is employed to assist coal trains, of a gross weight of 850 tons, up a bank of 1 in 155, and 1½ mile long. The line being moderately straight, no difficulty is experienced from the considerable length of wheel base, which is 19 feet 7 inches. Compared with English practice, in which six-wheeled coupled engines have from 5 tons to 6 tons on a wheel, and the eight-wheeled coupled engines, weighing 56 tons, (of which two are employed at the London end of the Great Northern line,) have 7 tons on a wheel, it will be seen that the subdivision of weight in American engines is carried about half as far again, or, in other words, that they average only about two-thirds as much weight per wheel, and that they thus require, for a given total weight, half as many more wheels. Except with smaller wheels, this could not be done upon any practicable length of wheel base; but none of the American goods and bank engines, of which the particulars have been given, have wheels larger than 3 feet 11 inches in diameter. There are objections also, of much weight, to coupling a large number of wheels from a single pair of cylinders. It is more or less difficult, if not impossible, to preserve an exact equality in the diameters of the wheels, an exact parallelism of the axles, and an exact equality in length of the coupling rods. The extent to which coupling has been carried in American goods engines has been due, in a great measure, to the following expedients:—The coupled wheels were as equally loaded as possible; their tires, in a majority of cases, were of chilled cast iron, since replaced by steel; and the former were cast, and the latter turned, nearly or quite to a cylindrical form, or with but little or no cone. The driving-wheels were the middle pair, or, in the case of an even number of pairs, one of the pairs nearest to the mid length of the wheel-base; compensating levers were employed, and adjusting wedges have for some years been applied to the axle-boxes. The coupling rods, in many cases, were made without brasses, round steel bushings being fitted to circular eyes formed at the exact required distance apart in the ends of the rods. With the exception of the leading and trailing wheels, the coupled wheels were more generally fitted with plain cylindrical tires having no flanges. Outside coupling cranks, necessary with outside frames, have rarely been employed, and are now wholly abandoned. The coupling rods are counter-weighted within the wheels themselves, no attempt being made, in inside cylinder engines, to set off their weight against that of the cranks and attached parts. In other words, the coupling pins of the driving-wheels are coincident, on each side of the engine, with the position of the crank in inside cylinder engines, and, of course, necessarily so in outside cylinder engines. The experience of American locomotive engineers has been to the effect that with this arrangement, which is the opposite of English practice, the axle boxes wear more uniformly, and that there is less 'knocking,' where a little play in the horn plates has once begun. And lastly, the length of the crank being one-half the radius of the small coupled wheels employed, any inequality in the length of the coupling rods is attended with less slipping and binding than where, with larger wheels, the crank is but about one-third the radius of the wheel. These various expedients and facts, taken in connection with the very moderate weight upon each wheel, and the moderate speed maintained, have enabled coupling to be more extensively, if not more successfully, carried out in the States than in England. It appears to be well settled also that coupled engines work more 'sweetly' when fitted with a bogie than when not so fitted, and the bogie, especially Bissell's, permits of a much longer wheel base than is safe when the leading axle is set permanently square across the engine.

Although a great variety, and often extraordinary types, of engines have existed in the States, but one general form of passenger engine is now retained. It has in most cases outside cylinders,—indeed inside cylinder engines have not been built for many years,—and it invariably has four coupled driving-wheels, and a four-wheeled bogie. As a general representation of all the passenger engines now built, it may suffice to describe one constructed at the workshops of the Chicago and North Western Railroad; and although having driving-wheels but 5 feet 8 inches in diameter, it has run a special train, probably of no great weight, 91 miles in 95 minutes, of which run 51 miles were made in 49 minutes, as certified by Mr. Cushing, Locomotive Superintendent of the line. High speeds are not, however, maintained on American lines, and no express train is timed to more than 32 miles in an hour, nor to more than 27 miles an hour in a run of 300 miles, although in this case the stops are longer and more frequent than on English lines. The speeds of passenger, and even so-called express trains, are more generally from 20 to 25 miles an hour, while average speeds of from 14 to 18 miles an hour are scheduled in the time-tables of many local lines in the Western and Southern States. Nor does the American Bradshaw (Appleton's Guide) show a single instance of a continuous run without stopping of more than 40 miles, and those of even 32 to 36 miles are unfrequent, most of the so-called expresses stopping at more frequent intervals, often at distances of from 10 to 15 miles. For such service an adhesive weight of from 14 to 16 tons, moderate-sized driving-wheels and cylinders, and the means of working full steam pressure for nearly the whole stroke in starting, are all that is required. The leading dimensions of the representative type of passenger engines are:—cylinders from 15 inches to 17 inches in diameter, with a length of stroke of from 22 inches to 24 inches, and coupled driving-wheels of from 5 feet to 5 feet 8 inches in diameter. Such engines will exert a tractive force of $3\frac{1}{2}$ tons to 4 tons in starting, for which their adhesive weight, assisted sometimes by sand, is sufficient; and thus they can get quickly away from stations even with trains of a gross weight of 200 tons or more. Economy of fuel has not been studied to the same extent in American as in English locomotives: the blast pipes of the former are smaller, the draught more forced, the back pressure greater, and less expansion is attempted in the cylinders, the link motion being generally arranged to cut off at one-third stroke as a minimum, and nine-tenths or more as a maximum. It is thus that boilers of moderate size are made to supply steam for work equal to 300 indicated H.P., or the exertion of upwards of 2 tons of draught upon a passenger train at a mean speed of 25 miles an hour; but there is nothing remarkable in the consumption of from 50 lbs. to 60 lbs. of coal per mile in such work.

As relating to the consumption of fuel the Pennsylvania Central Railroad may be instanced. Its main line is 356 miles long, the eastern and western portions having gradients of 1 in 100, while its middle division has but very moderate ascents; for a few miles, however, on the western division, there are gradients of 1 in 55, up which the goods trains are assisted by pushing engines. Of four hundred and nine engines on the line in October, 1868, two hundred and forty had six coupled, and three had eight coupled wheels of from 3 feet 8 inches, to 4 feet 6 inches in diameter, the larger number having 18-inch cylinders with 22-inch stroke. The standard pattern of passenger engines had 17-inch cylinders, 24-inch stroke, and four coupled wheels 5 feet to 5 feet 6 inches in diameter, and of this class there were upwards of one hundred. The mean speed of fast passenger trains is about 25 miles an hour, and of other passenger trains about 23 miles an hour, yet the consumption of coal for both goods and passenger engines averaged respectively, on the eastern, middle and western divisions 52·7 lbs., $66\frac{3}{4}$ lbs., and $70\frac{3}{8}$ lbs. per engine mile, corresponding to a general average of about 70 lbs. per train mile, the goods mileage being about three and a half times the passenger mileage. The coal is of excellent steaming quality, and is found so near at hand, and in such abundance, that its cost is after all but about $3\frac{1}{2}$*d.* in currency, or $2\frac{1}{2}$*d.* in coin, per train mile. At this rate a difference in consumption of 24 lbs. of coal per mile would only cause a variation of a penny per mile in the cost of fuel, and it has been argued that such a waste is better than the alternative of employing an engine 4 tons or 5 tons heavier, to work with a less rapid rate of combustion, a slower piston speed, and more expansively. It is to be remembered that for every pound of coal burnt, from 6 lbs. to 7 lbs. or 8 lbs. of water require to be provided, and an additional weight of at least half as much in the structure of the tender itself is necessary to carry it. Thus if an engine burn 67 lbs. of coal, and consume seven times the weight, or 469 lbs. of water per mile, and stops every $33\frac{1}{2}$ miles, it will require to start with at least a ton of coal and 7 tons of water, the average weight of both, progressively consumed over the whole distance, being 4 tons. If the coal could be economized one-fourth, the average weight of coal and water would still be 3 tons; and it appears better, therefore, where fuel is so cheap, to waste a portion of it, perhaps a considerable portion, than to economize it by adding 4 tons or 5 tons of weight to the engine, to obtain a larger boiler, and working gear admitting of a slower piston speed and a higher grade of expansion. The question turns upon the cost per ton per mile of moving a passenger engine and tender, but much more upon the length of run without stopping; upon whether the water may be picked up along the line or taken only at stations; and upon the original cost and the interest on it, the repairs, and the depreciation of the engine. Every locomotive engineer can easily examine the question in the light of these circumstances, as applying to his own line; and it might be found in some cases that it would be absolutely cheaper to employ engines burning 40 lbs. of coal per mile than heavier and costlier engines burning but 30 lbs.

Much of what has just been observed of the passenger engines applies with even greater force to the goods engines. Of but moderate total weight, they have large cylinders and small wheels, and they draw heavy trains at a fair speed with a consumption of coal often amounting to 100 lbs. or more per mile. One instance, taken from the regular working of the standard type of goods engine on the Pennsylvania Central railroad, will suffice. This class of engines has ten wheels, of which six, each 4 feet 6 inches in diameter, are coupled. The whole weight of the engine is only $31\frac{1}{8}$ tons, and of this but $23\frac{1}{2}$ tons rest on the coupled wheels, available for adhesion. The cylinders are 18 inches in diameter, with a length of stroke of 22 inches. With 60 lbs. mean effective pressure per square inch upon the pistons, these engines would exert a tractive force, less their own internal resistances, of rather more than $3\frac{1}{2}$ tons, or about one-seventh of their adhesion weight, although in starting a train, or in ascending a gradient, with 100 lbs. pressure on the pistons, the steam tractive force would be 6 tons, equal to more than one-fourth of the adhesion weight, the efficiency of which would then be assisted when necessary by sand. There are thirty of this class of engines, besides many others of nearly the same weight and dimensions, on the middle division alone of the Pennsylvania Central line; this division being 132 miles long, and gently descending for nearly its whole length to the eastward, the only exceptions worth noticing being 300 yards up 1 in 293, and 400 yards up 1 in 352. The regulation load going eastward, in which direction only the wagons are nearly or fully loaded, is forty-five eight-wheel wagons, each weighing $7\frac{1}{2}$ tons empty, and $16\frac{1}{2}$ tons loaded, making a total load of 743 tons. The total fall in the 132 miles is 851 feet, equivalent to an average descent of 1 in 808 for the whole distance. Yet in October last, 1868, the average consumption of the best bituminous coal by these engines was 100 lbs. per mile, in addition to the wood employed for lighting, and the average for all engines, passenger and goods, one hundred and fourteen in number, was $66\frac{3}{4}$ lbs. per mile. On the same division, two engines, having six wheels coupled and a two-wheel bogie, the whole weight being $31\frac{3}{4}$ tons, of which all but $2\frac{1}{4}$ tons were available for adhesion, were loaded to heavier work. They had 19-inch cylinders, 24-inch stroke, and 4 feet coupled wheels, and with 60 lbs. mean effective cylinder pressure would exert a tractive force, less their own internal resistances, of 4·83 tons, equal to about $\frac{1}{6}$th of the adhesion weight. The distance run by these engines averaged 100 miles a day each, with a consumption of coal respectively of $127\frac{1}{2}$ lbs. and 104 lbs. per mile. Their regulation load going eastward was sixty eight-wheeled wagons, weighing, when fully loaded, 990 tons. It is not probable, however, that they were always fully loaded, nor even if they were, can an accurate estimate of the resistances be formed. Yet if the latter be taken, after allowing for gravity in favour of the eastward trip, at $8\frac{5}{8}$ lbs. only per ton, for a train, engine and tender included, of 1,040 tons weight, the total resistance would be 4 tons, and thus the work done on each mile would be equal to 24 H.P. exerted for one hour. For

$$\frac{5{,}280 \text{ feet per mile} \times 8{,}960 \text{ lbs. (4 tons)}}{1{,}980{,}000 \text{ foot lbs. per H.P.}} = 24 \text{ H.P. per hour}$$

nearly; so that, could these estimates be trusted, the consumption of coal per H.P. per hour would not after all exceed $4\frac{1}{4}$ to $5\frac{1}{4}$ lbs. The speed would not probably exceed 15 miles an hour, corresponding to 360 H.P. Exact data are unfortunately wanting to determine the dynamical effect of these engines, and it is not pretended that the general assumptions just made have any claim to exactness, although the Author is convinced, from a somewhat lengthy acquaintance with engines of the same general type, that the estimates above given are not very far wide of the mark.

The policy of American railway managers with respect to goods traffic, as it is also the policy of the managers of most of the French lines, is maximum loads at slow speeds, involving a minimum resistance per ton, and correspondingly a minimum working expenditure per ton. No experiments upon the dynamical efficiency of American engines have been made, so far as the

Author is aware, beyond general observations as to the load drawn and the consumption of fuel, the essential element of speed being too often omitted, while the evidence afforded by the indicator has almost invariably been wholly wanting. Yet experiments of some magnitude, which the Author conducted, appear by their results to show, that the resistance of bogie rolling stock, even under disadvantages, is less than that of English rolling stock as ascertained by the best authorities, and also that the ratio of adhesion to weight averages considerably more in the States than in England. With respect to adhesion, as the surfaces in contact are identical with those on English railways—indeed, the rails and tires in general use in the States are commonly of English manufacture—any difference in this respect must be attributed partly to the influences of climate and partly to a better application of sand, when necessary to increase the bite upon the rails. In the States, the rails are seldom in the condition known as 'greasy;' they are usually either quite dry or quite wet. Clean, sharp, dry sand is provided for use when wanted, and it is dropped equally upon both rails of the line, not by being poured in intermittent handfuls down a pipe on but one side of the engine, but by means of the hand gear and regulating valve adopted for the engines on the North London Railway.

In the autumn of 1855, the Author, at the request of Mr., now General, M'Callum, the Manager of the Erie railroad, took charge of an experimental train which he ran over the whole length of the line and back, a total distance of nearly 900 miles. The same engine was employed throughout the run, occupying in all nearly three weeks, making an average for each week-day of about 50 miles. The line is divided into four divisions, varying considerably in respect of gradients, and the utmost load the engine could draw was taken in both directions over each division. The maximum inclinations were 1 in 88. The results of the experiments were so voluminous, that it will be sufficient to detail the particulars of what may be termed crucial tests of adhesion and resistance to traction.

The engine had four coupled wheels and a bogie, the total weight in working trim being $29\frac{1}{2}$ tons, of which $17\frac{7}{8}$ tons rested on the coupled wheels available for adhesion. The coupled wheels were 5 feet in diameter; the outside cylinders were 17 inches in diameter, and the stroke 24 inches. The safety valves were set to blow off at 130 lbs., and the steam, as observed by a Bourdon gauge, was seldom allowed to exceed that limit. No indicator diagrams were taken, nor was any measure taken of the wood burnt, all that could be consumed by the engine, in maintaining the requisite steam, being supplied. The tender, loaded, weighed $18\frac{1}{2}$ tons. The train drawn consisted of eight-wheel wagons fully loaded with deals. The average weight of each wagon empty was 5 tons 8 cwt. 3 qrs., and of each wagon with its load 15 tons 5 cwt. 3 qrs. nearly. The wagons had cast-iron chilled wheels, each 2 feet 6 inches in diameter, with inside journals $3\frac{7}{8}$ inches in diameter, and 8 inches long. All the wagons had been put in complete order, and the journals, fitted with oil-tight boxes, were kept well oiled. The gauge of the line was 6 feet. The weather was most favourable, clear and dry, with the exception of a single day of heavy rain.

Upon about 100 miles of the line, forming a portion of the Susquehanna division, a train of one hundred wagons, weighing with engine and tender 1572 tons was taken. The train was a few feet more than half a mile in length.

At one point it was stopped where the line commenced an ascent of 24 feet in 4 miles, averaging 1 in 880 up for the whole distance. There were also long and easy curves upon this portion. The train was taken up and purposely stopped on the second mile, to be sure of starting again with no aid from momentum. The average speed up was 5 miles an hour, and neither was the pressure of steam increased nor sand used except in starting from the stops purposely made. The engine, even were its full boiler pressure of 130 lbs. maintained as effective pressure upon the pistons throughout the whole length of their stroke, could not have exerted a tractive force greater than $\frac{17^2 \times 130 \text{ lbs.} \times 2 \text{ ft.}}{5 \text{ ft.}} = 15{,}028$ lbs.; nor is it at all probable that the effective cylinder pressure could have approached this limit by from 10 lbs. to 15 lbs. per square inch. Supposing however, for the sake of a *reductio ad absurdum*, that the full boiler pressure had been maintained upon the pistons for the whole length of their strokes, the adhesion of the coupled driving-wheels, not deducting the internal resistances of the engine, would have been $\frac{15028}{40050} = \frac{3}{8}$ of the weight upon them. In any case there was a resistance of 4011 lbs. due to gravity, and if even 120 lbs. mean effective cylinder pressure be assumed, corresponding to a total tractive force of 13,872 lbs., the quotient representing the rolling and other resistances, exclusive of gravity, would be but 6·27 lbs. per ton of the entire train; a resistance including all the internal resistances of the engine, the resistance of the curves, easy although they were, and the loss in accelerating and retarding the train in starting and stopping. This estimate of resistance would correspond, at the observed speed of 5 miles an hour (upwards of three-quarters of an hour having been consumed on the 4 miles), to 185 indicated H.P., which with the driving-wheels making but twenty eight revolutions per minute, would be the utmost that an engine with but 1,038 square feet of heating surface could be expected to exert. This was the highest result observed during the three weeks' trial, but one or two others are worthy of mention. On the Delaware division of the same line, the train, of 1,572 tons' weight, was run over 5 consecutive miles of absolutely level line, at a mean rate of 9·23 miles an hour, and, during the same day, over 5 other consecutive miles of level at a mean rate of 9·7 miles per hour. On both levels there were 14½ chain curves of good length, and the speed, from 9 to 12 miles an hour, at which the train entered the respective levels, was not quite regularly maintained throughout the half-hour expended in running over them. But if even 7 lbs. per ton of the total weight be taken as the resistance at these speeds, the tractive force will be 11,004 lbs., which is more than one-fourth the adhesion weight of 40,050 lbs. On the next day, the same engine drew thirty wagons weighing 466½ tons, or, including engine and tender, 514 tons nearly, up a gradient of 1 in 117½, three miles long, at a mean speed of 10¼ miles an hour. The resistance due to gravity was 9,814 lbs., and supposing the other resistances to traction to amount to no more than 7 lbs. per ton, the total resistance would be 13,412 lbs., corresponding to a mean effective cylinder pressure of 117 lbs. per square inch, and to a coefficient of adhesion of almost exactly one-third.

It is needless to repeat instances of much the same kind, as occurring during the experiment referred to. The Author is bound to say that they were, no doubt, influenced by the favourable circumstances of weather, and something is to be allowed also for the great length of train drawn, very long trains having a less tractive resistance per ton on a level than short ones, and something, possibly more than is commonly supposed, may have been due to the use of oil-tight axle-boxes, the saponaceous compound known as 'Railway Grease' being nowhere in use on railways in the States. It could not possibly be used, except in a congealed form, in the severe American winters; and Messrs. Guebhard and Dieudonné's experiments,[1] made in 1867, on the Eastern Railway of France, showed a very considerable diminution in the resistance of oil-boxed rolling stock as compared with that fitted with grease-boxes. But, weighed upon the other hand, are the facts, first, that the line was of 6 feet gauge, and, *pro tanto*, so much the worse for traction; secondly, that the wheels were comparatively small, and the inside journals of comparatively large diameter, the ratio of the former to the latter being as 7¾ to 1, instead of 12 to 1 as on English lines. It is difficult to believe that the length and steadiness of the double bogie goods wagons, scarcely liable as they are to lateral vibrations, had not something

[1] *Vide* "De la résistance des trains et de la puissance des machines," 8vo. Paris, 1868, p. 36.

to do with the result, which is in some respects unique in the history of railway traction. The result, although not absolutely showing the real resistance to traction, nor the real adhesion of the engine, presents this alternative, viz., that the resistance must have been unusually small, or the adhesion unusually large.

Of the mechanical details of American locomotives, considered apart from those already touched upon, much might be said. There are differences, and they are numerous, but they involve no important principles. The chilled cast-iron wheel, however, for engine and tender bogies, and especially for carriages and wagons, deserves special mention. No wrought-iron wheels, so far as the Author can learn, are now employed in the States, unless in a few cases for engine-driving wheels; and wrought-iron wheels, at first exclusively adopted, have been wholly abandoned by the engineers and managers of the Grand Trunk and the Great Western Railways of Canada. The cast-iron wheels are not only much cheaper, but they are more durable, and, if not safer, are at least equally safe. The wheels employed for passenger carriages are 2 feet 9 inches in diameter, and weigh 5 cwt. The bogie wheels of engines, tenders, and goods wagons are generally 2 feet 6 inches in diameter, and vary in weight from 4 cwt. to 4½ cwt. They are cast of special mixtures of the best qualities of iron, the requisite conditions being great absolute strength to resist both sudden and progressive strains, and the property of taking a deep and uniform chill. But little of the cast iron employed for wheels has a tensile strength of less than 15 tons per square inch, and it breaks with a fracture, almost suggestive of fibre, and of a dark-grey colour, but when chilled, of a silvery whiteness; the chill, at a depth of ½ inch, blending by almost imperceptible changes through another ½ inch, with the unchanged and softer iron beyond it. To break off the flange of the wheel at any point by the heaviest blows of a 28 lb. sledge, wielded by a strong man, is a long and laborious task, and to break up the wheel altogether is, *à fortiori*, still more difficult. The chilled wheels run from two to six and even seven years, according to the traffic, before becoming so much worn as to require removal. During all this service of from 80,000 miles to 200,000 miles, they do not require, or rather they do not admit of, turning down, and when at last condemned, they are worth generally about half their original cost as old iron. The present cost reduced from currency into gold, and into English money, is, for the 5 cwt. wheels, for passenger carriages, from £3. 6*s*. to £3. 10*s*. each, or from £13. 4*s*. to £14 per ton; while wheels 2 feet 6 inches in diameter, and weighing 4 cwt., are sold at the rate of about £11. 8*s*. per ton. These prices represent an originally high price of iron, dear labour, and excessive government taxation. In the last-named respect, the ingenuity, not to say genius, of the framers of the protective system, surpasses anything that can be said of a corresponding nature of the American railway system. Besides taxing the incomes of the owners of the minerals requisite for making the iron, and those of the manufacturers through whose hands it subsequently passes, there is a special tax upon the iron, as such, a further tax upon it as a wheel, and a still further tax upon it as a component part of a railway carriage.

It should be mentioned, that engine driving wheels of from 4 feet to 5 feet in diameter, have been cast with chilled faces, thus requiring no tires, and chilled tires, from 4 feet to 6 feet in diameter, and $3\frac{1}{2}$ inches thick, have been extensively and successfully employed at fair rates of speed, say 28 miles an hour. At one time the Baltimore and Ohio Railroad Company had not a single wrought-iron or steel tire on their whole stock of engines, then numbering about two hundred and twenty-five.

Wood was almost exclusively employed as fuel, except upon two or three important lines in the coal districts, until within the last ten or twelve years. Iron fire-boxes and copper tubes were generally adopted; and for both the fire-boxes and the barrels of boilers, from $3\frac{1}{2}$ feet to 4 feet in diameter, and worked at from 100 lbs. to 130 lbs. pressure, iron of but $\frac{5}{16}$ inch thickness was generally used, and in many cases the thickness was but $\frac{1}{4}$ inch. At the present time coal is burnt wherever it can be obtained at a less cost than wood. A 'cord' of wood (the 'cord' being an old English measure now obsolete here) is a pile of billets cut in 4 feet lengths, and piled 8 feet long and 4 feet high, thus forming a bulk of 128 cubic feet. Its cost, according to locality and quality, ranges from 10*s.* to 30*s.*, yet its heating value is equal to that of but from 10 cwt. to 15 cwt. of coal, varying according to quality. The cost of wood fuel, on the railway system of the State of New York, averaged $7\frac{1}{2}$*d.* per train mile as long ago as 1855, and on some of the leading lines it was as high as 15*d.* In the case of goods engines burning 100 lbs. of coal per mile, a rate of which examples have been given, a cord of wood would last but from 11 miles to 16 miles, and at the higher price just given, would cost from 1*s.* 11*d.* to 2*s.* 9*d.* per mile, the last-named sum being greater than the total working expenses of English lines.

For burning coal, steel fire-boxes and iron tubes are now adopted. Of upwards of four hundred steel fire-boxes in the engines of the Pennsylvania Central Railroad, some have been in use six years or more. The tubes are set without ferrules, and very little trouble, as the Author is informed by the General Manager of the line, is experienced either from leaking or cracking.

The boiler-work of American engines falls short of the standard in respect of strength and finish, maintained by English locomotive engineers; and boiler explosions, although not conspicuously numerous, are certainly much more numerous in the States, even after allowing for the fact that fifteen thousand locomotives are working on their railway system of 42,000 miles, as against ten thousand locomotives on 15,000 miles of line in the United Kingdom. But it is worthy of observation that the evil of 'furrowing,' by no means uncommon in this country, is unknown in the States, and no other explanation appears available, than that the thinner iron employed there permits of a certain elasticity in the structure of the boiler, sufficient to prevent the localisation or accumulation of bending or other strains at particular points, or rather upon particular *lines* of resistance.

Apart from all æsthetic considerations, and regarded only from its commercial aspect, the preternaturally gaudy exterior of the American engines involves neither great original cost nor much cost for maintenance. Indeed it is believed in the States that a showily-decorated and coloured engine—and the Author grieves to state that even the diagrams do but scant justice to the lavish expenditure of sheet brass and polychromatic pigments which ornament, or otherwise, the locomotives at work there—is, after all, the cheapest in maintenance. The locomotive engine shown in the American department of the Paris Exhibition was overdone, even to an American eye, but its German-silver boiler casing and chimney casing were not so very far in excess of what almost any locomotive maker in the States is ready to turn out, or any of his customers prepared to pay for. The planished Russian iron, ordinarily employed for covering boilers, is not dear; it is very durable, and it only requires the daily application of a handful of greasy cotton waste to preserve its deep-sea, or lustrous indigo brilliancy. The painted work must stand upon the merits of its own varnish. The ornamental brass-work is quickly got over, and a pennyworth of rotten stone goes a long way with it. The engine-driver or engine-man, known to American minds as the 'Engineer,' fettles and grooms his engine for the love he bears to it; and his fireman, who looks forward to early promotion, is always ready to do his full share of work of this kind, *con amore*. It cannot be imagined that the gaudy decoration of locomotives, with such objects in view, would lead to the slightest advantage if attempted on English lines. In other respects, American locomotives present, in their external finish, more bright work polished upon a grinding stone than English engines. In their structure, too, there is a much more extensive use of cast iron,- as in the driving and bogie wheels, the cross heads, the eccentric hoops, &c. But it is to be mentioned here, as the result of an intimate acquaintance with both the design and working of rolling stock in the States, that, for the especial purposes named, cast iron is preferred as much for its strength, and, when not subjected to great friction, for its good wearing qualities, if not even more than for its original cheapness.

What are now understood as steep, or exceptionally steep, gradients, are rare in the States. The engineers of that country were perhaps the first to adopt long inclines of from 1 in 45 to 1 in 90, but from considerations of cheapness of construction only. Indeed, so long ago as 1838, a short line, the Hudson and Berkshire, was opened with an incline 1,232 yards long, and rising at the rate of 1 in 28·7 or 184 feet per mile, and this has been regularly worked ever since by engines of ordinary construction. This and the incline of 1 in $16\frac{1}{2}$ at Madison, Indiana, are the steepest, it is believed, now worked by locomotive power in the States. The last-named incline, $1\frac{1}{4}$ mile long, was worked for nearly twenty years by four-cylinder engines gearing into a rack rail, as in the early plan of Blenkinsop. A tank engine weighing 50 tons, and having ten coupled wheels, each 3 feet 8 inches in diameter, supporting the whole weight, is now employed. It has 20-inch cylinders and 24-inch stroke, and with 145 lbs. boiler pressure has drawn up twice its own weight behind it at a speed of 5 miles an hour. On an incline of this pitch, $\frac{2}{33}$rds of the weight of the engine are lost for adhesion, a weight of 50 tons pressing upon the rails with a force of but 47 tons. The ordinary load is a little less than the weight of the engine. The working of temporary inclines of 1 in 10 on the Baltimore and Ohio Railway, and of 1 in 18 on Mr. Ellet's Mountain-top Track, has been fully described to the Institution in Mr. Isaacs' Paper, read in 1859.[1] Mr. George Escol Sellers, of Cincinnati, constructed five engines, prior to 1853, for the Panama Railway, on which it was proposed to lay down the mid rail. These engines had four cylinders each, two of them driving a single pair of horizontal gripping wheels by means of bevil gearing. The Panama Railway has no gradients, however, exceeding 1 in 88, and such engines were wholly unnecessary and consequently they were never put to work. This was the case, also, with two much heavier engines made by the same maker in 1856, for a mineral line in Pennsylvania, having inclines of 1 in 27. Mr. Sellers' engine is more or less known to English engineers by his patent of 1847, granted in the name of his patent agent, Mr. Newton.

It may be mentioned, that in July, 1836, one of Norris's engines weighing 6 tons $8\frac{1}{2}$ cwt., and drawing behind it, including tender, a load of 8 tons $11\frac{1}{2}$ cwt., ascended an incline near Philadelphia of 1 in 14, and 933 yards long, at an average speed of $15\frac{3}{4}$ miles an hour. The nominal weight on the driving-wheels was $3\frac{1}{2}$ tons, but it is believed that a portion of the weight of the

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xviii. p. 55.

tender was made to bear upon the foot plate, thus increasing the adhesion.

In attempting any comparison of the cost of maintaining locomotives in this country and in the States, a great variety of considerations must be weighed. The reported cost in America is given in a paper currency of fluctuating value, and must be first reduced to a specie standard. Even then the cost of labour and of iron, copper, &c., indeed of nearly all materials (excepting wood), which enter into repairs, is much greater than in Great Britain. The average cost of engine repairs in the States, exclusive of those renewals which amount to building a new engine, may be taken as a maximum at 10 cents currency, per train mile, equal to $3\frac{3}{4}d.$ in coin. Of this, the absolute difference in the cost of labour and materials would account for nearly or quite $1d.$, leaving $2\frac{3}{4}d.$ to $3d.$ as the cost at English prices. But the elements of comparison are still unequal. It is impossible to say what in each country are the relative proportions of the whole cost of repairs as due to accidents and as due to ordinary wear and tear. It is certain also that the rigours of the American winters tell more heavily in repairs than in this comparatively mild climate. Again, engine repairs are conducted, upon American railways, in a manner which, regarded from an English view of railway economy, shows great want of system and organisation. While every short line of 100 miles or so has its repair shop for its twenty or thirty engines, the great lines, with from two hundred to five hundred engines, have three, four, or more principal shops, wholly independent of each other, each having its separate managing and clerical staff, responsible only to the locomotive or general superintendent. The engines are not designed by the company's engineers, but are of widely different patterns by competing makers, who conform only to certain general dimensions. Nor are the repair shops—at least they were not when the Author was last in the States—fitted with some of the appliances considered essential to English engine shops. Overhead travellers were hardly thought of, nor were double headstock lathes for turning both tires of a pair of wheels at once. Hardly any machinery whatever is used in boiler making, and the smithy plant would not compare with that in English shops. Stamped forgings appear to be almost or quite unknown. Vice work is largely employed where machine work would be substituted in this country. The system of piece-work is not carried out to so great an extent; nor is the management so efficient, the men being left to a great extent to work upon their own responsibility, and but seldom with the aid of exact drawings, or, indeed, drawings of any kind. The variety of patterns, the want of templates, and the high interest upon capital, often prevent a proper assortment of duplicates being kept in stock, and thus, and in other ways, repairs are conducted at a disadvantage. Again, a larger proportion than is the case here of the whole traffic is goods traffic, carried on in long and heavy trains, and, as has been shown, at an expenditure of from 75 lbs. to 125 lbs. of coal per train mile, an expenditure no doubt more or less wasteful, yet indicative of hard work. Even when the extreme subdivision of weight of American engines is considered, and the consequently lessened wear on the tires is allowed for, it is to be borne in mind that there are so many more tires to wear and to be turned down; and that a 31-ton engine with ten cast-iron wheels under it, with their axles, axle-boxes, counterweights, coupling pins and coupling rods, has a greater proportion of its whole weight below the springs, and unrelieved by them, than an ordinary six-wheeled goods engine, weighing 35 tons.

Whatever economy in repairs may attach to the American engines is due, after allowing for the moderate working-speed, to three causes only, viz.:—First, the use of the bogie; Secondly, the use of chilled cast-iron bogie wheels, which can be renewed at a cost of from £2 to £2. 10*s*. each, after allowing for the value of the wheel taken out as old iron; and Thirdly, the use of steel or iron fire-boxes and iron tubes. It may be added, that there is no 'furrowing' of the thin iron employed for the boilers. The great number of wheels and coupling rods represent only a watchful care for the permanent way. As for the engine itself, the great multiplication of wheels, axles, journals, springs, compensating levers, and coupling rods, is anything but conducive to economy in repairs. Did English goods traffic admit of being worked at slower speeds permitting of heavier trains, could the prejudices against chilled wheels be overcome, and had English experience with steel fire-boxes proved more encouraging, a further considerable reduction in working expenses could be effected. There are other tests of locomotive economy than those already suggested. It is now the great aim of locomotive superintendents to keep their engines on the road and out of the shops as long as possible. From twelve to fifteen years ago the average mileage of American engines, taking the full stock of the leading lines, was not above 15,000 miles yearly—now it is probably not far short of 20,000 miles, and on some lines it may be even more. Of the four hundred and nine engines on the Pennsylvania Central Railroad in October, 1868, three-fourths of them being heavy goods engines, the average mileage for the month was 1,960, the average for September, with four hundred and two engines, having been 1,906. A large number of the goods engines averaged from 100 miles to 132 miles daily, while several of the passenger engines averaged 150 miles or more. In September forty-four engines, and in October forty-eight, did no work, having come in for repairs; while in September forty-one, and in October forty-four, other engines received repairs in the month to an amount of £100 or more currency. The engine stock was of all ages between a month and eighteen years, one half of the number being less than ten years old. The engine-men have no 'shed days,' but must keep the road until their engines need repairs, and they must then take another, and the engine-report sheets of the line just named show that this may happen twice, thrice, and even four times a month. It is only a question whether the newer engines have really better constitutions than the older class. If not, they cannot under more constant work have the same expectation of life, in the sense understood by actuaries. The London and North Western Railway Report for the last half-year shows, for fifteen hundred and twenty-seven engines, besides one hundred and seventy-seven out of work and condemned, a mileage of 11,461,870, nearly equally divided between passengers and goods, and giving an average of 15,012 miles yearly.

There now remains the consideration of the carriage and wagon stock, with reference to its mechanical peculiarities and its commercial relation to traffic. The earlier American carriages were made upon the English model, but it was found, not only that a short wheel base was required for curves of 6 chains and 9 chains radius, but also that side buffers aggravated the difficulty. The bogie, already in use on the engines, was, therefore, adopted for the carriages, and it was soon discovered that the length of body could be considerably increased, and that the longer it was the steadier it became. But the long bodies precluded the use of side buffers, and so the central buffer with a loose coupling took their place. End doors afforded an obvious means of economy in the structure of the carriage, and left the whole depth of the body below the window-sills available for any combination of trussing, most effective for carrying a comparatively long span. It is an objection to long bodies with side doors, like those in use on the Metropolitan Railway, that having no vertical stiffness in their sides, they require unduly heavy under-framing. The end doors, with a continuous passage throughout the carriage, afforded obvious facilities for communication; and although partitions might be made across the carriage, it was soon found that passengers, with the easier habits of intercourse which prevail in America, preferred to share the whole carriage together. The central passage required an additional width of carriage, and from 9 feet to 9 feet 6 inches is a common outside width; while, in some cases, even on the narrow gauge, a width of more than 10 feet has been adopted. These widths allow seats for four passengers, as well as for the longitudinal passage dividing the seats. The seats have reversible backs, so that the passenger may face either way, the carriages running in either direction without turning, the same as English carriages. It might be urged as an objection, that whereas, in English carriages, there is but one intermediate space between the seats of every compartment, or, in other words, that the seats occupy two-thirds of the floor area, the American carriages require a total amount of intermediate space equal to the total widths of the seats themselves. Taking the English compartments as 6 feet wide, then there are—less the space lost in partitions and upholstery—two seats, 2 feet each in depth and a space between them 2 feet wide. In the American carriages the seats along the whole length of the vehicle are spaced 3 feet from centre to centre, sometimes less. This division gives 18 inches width of seat and 18 inches intervening space, but as no space is lost in partitions, and but 2 inches or 3 inches in the padding of seat backs, and as each passenger has plenty of room to stretch his legs under the seat in front of him, the accommodation is by no means so contracted as it might appear to be. It is undeniable, however, that the seating is not so roomy and comfortable as in an English first-class carriage, and that, as compared with a second-class carriage, there is a certain loss of space. It is equally undeniable that such carriages could never answer for short traffic lines, where forty, fifty, or more passengers are to leave, and as many more to enter in a minute or a minute and a half. But without pursuing the question, it may be said, that the long body, with end doors and platforms, possesses obvious mechanical advantages. Its length gives steadiness, and the depth below the window-sills affords ample opportunity for providing vertical stiffness without undue increase of weight. There are no cross partitions; there are but two doors where English carriages would require, for the same number of seats, according to class, from twelve to twenty-six; there is much less sash and glazing required, while there is at the same time much more light; there is an important saving in respect of draw-springs, buffers, buffer-rods, and screw couplings, and there is every facility for applying breaks, as is always done in the States, to every wheel in the train, either from the platforms of the carriages or from the engine. It is an advantage of the long body, with its corresponding weight and number of wheels, that the application of the breaks, however suddenly, does not produce the jolting of which passengers complain so much when the same thing is attempted upon English carriages.

Passenger carriages upon the double bogie plan are made of various lengths, from 45 feet to 60 feet, exclusive of the additional 2 feet 6 inches at each end for platform and covering porch. They accommodate from sixty to eighty-four passengers, and weigh, empty, 12 tons and upwards, or from 16 tons to 22 tons loaded. Here, again, the subdivision of weight is carried far beyond what is common in English practice. It is usual to provide six-wheel bogies or twelve wheels in all; and for the heavy sleeping cars, eight-wheel bogies, or sixteen wheels in all, are employed. The sleeping carriages known as Pullman's, are often 60 feet in length, and weigh 22 tons to 25 tons empty, but the weight is kept well below 2 tons per wheel. The first example of a so-called 'Palace Car,' upon the American plan, was made in 1855, by Messrs. Winans, of the Nicolai Railway, St. Petersburg, for the Emperor of Russia. It is 85 feet long and 10 feet 6 inches wide.

The eight-wheel bogie has been more or less employed in the States since 1849. In its original form, as embodied in a state saloon carriage, made in 1859, at Springfield, Massachusetts, for the late Viceroy of Egypt, each eight-wheel bogie was formed of two separate four-wheel bogies, connected by framing, the latter having a central socket for the pivot under the end of the main body of the carriage. The weight is sometimes taken, as far as this can be controlled, upon the centre of the bogie, side stops or bearings, with a slight allowance for vertical play, being introduced to preserve the equilibrium of the carriage. It should have been mentioned, that in the case of engine bogies, the whole weight resting upon them is received upon the flat bottom of a shallow central socket 10 inches in diameter, any tendency to roll being restrained by the support upon the driving and trailing axles, or rather the fastenings of the springs. In the case of tenders the forward bogie has no side stops to prevent rolling, the weight on the hind bogie being however supported equally upon the two sides. This form of support is known as that of the 'three-legged kettle,' and it is obvious, that it best secures the distribution of jolts to the whole frame of the vehicle, instead of at one or two points. In the case of the sixteen-wheel carriages, the motion, at high speeds, and over comparatively rough lines, is more like sailing than rolling.

The greatest improvement, unless it be Bissell's, made in the bogie, since its first introduction, is that of the 'swing beam,' introduced about twenty-five years ago, and for the last twenty years exclusively employed under all American passenger carriages, and for the last eight or nine years more or less extensively adopted for engine bogies. Instead of the weight being taken directly upon the bogie frame, it rests upon a series of springs, steel or india rubber, placed upon a transverse beam which is suspended by links from the cross timbers of the bogie frame—passenger carriage bogies being always made with timber frames. The transverse beam is thus free to swing endwise, or across the line, to an extent limited by stops, and which varies from ½ inch to 1 inch each way. The main framing of the bogie has also its own springs over the axles, the same as if no swing beam was employed. The double system of springs thus introduced, and the regulated allowance for swinging right and left, secures an ease of motion for which those who have not experienced it would hardly be prepared. It may be asserted, broadly, that these long double bogie carriages, thus supported, yet having neither screw couplings nor side buffers—having, too, small wheels, and but a limited range of play in the springs, and drawn over lines which are often in anything but first-class condition,—are, nevertheless, the easiest railway carriages to be found.

The oil-tight axle-box has now been in use for upwards of twenty years, and it has recently been adopted on the North London Railway. A leather collar surrounds the axle just inside the journal, while the outer end of the axle is enclosed by a closely-fitting cover, screwed to the face of the box. This cover is capable of ready removal when the box requires filling with oil, or when the brass wants renewal. By lifting the box, by means of a jack-screw, to the extent of $\frac{1}{2}$-inch or so, a distance piece or packing piece over the brass may be withdrawn, when the latter can be taken out and replaced without difficulty. The bottom of the box is filled with woollen waste, the requisite quantity of oil poured in, the box tightly closed, the number of the vehicle and the date noted; and, if a passenger carriage, it is not again oiled or examined for a month, nor, if a goods wagon, for two months. It is evident that the lubricating material is thus greatly economised, no attendance to the boxes during a journey is requisite, and a hot journal is almost unknown. It is considered beyond doubt, and Messrs. Guebhard and Dieudonné's experiments, already referred to, confirm the belief, that oil lubrication, with the perfect exclusion of dust, materially diminishes the tractive resistances, more especially in cold weather. It is a fact, however, that oil, tallow, and waste, cost, on an average, and when reduced to coin, a penny a train mile on most of the American lines. Of this comparatively high cost, however, much is accounted for by the high price and large consumption of tallow by the engines, especially in descending gradients without steam. On the more undulating portions of the Pennsylvania Central Railroad, a quart of oil, or its equivalent in melted tallow, serves only for about 13 or 14 miles' run of an engine; while, in the case of the heavier goods engines, but from 8 to 10 miles are made for the same quantity. Two gallons for a day's work are thought nothing remarkable, judging from the engine-report sheets, printed every month.

Another feature of American railway rolling stock is the use of breaks upon every wheel of every train, the engine wheels only excepted. Since 1855 a system of continuous breaks, known as Loughridge's, has been more or less extensively employed on American lines. It is similar to that known in this country as Clark's, employed on the North London and other lines, with the exception that the friction wheel, instead of being pressed against the face of one of the wheels of the guard's van, is pressed against the flange of one of the trailing wheels of the engine. Another system of continuous breaks is that known as Creamer's, as applied, in 1863, to one of the trains of the South Eastern Railway. The breaks are put on, either in the ordinary manner by hand, from the end platforms of the carriages; or instantaneously, by the force given out by a stout coiled spring of sheet brass, previously wound up, and released by a pull at the bell rope or signal cord which runs through all American passenger trains. The force thus applied is only a little less than sufficient to lock the wheels, and taking the friction of the latter upon the rails as so little as one-eighth, it is possible to stop a train moving at 40 miles an hour, or $58\frac{2}{3}$ feet per second on a level, in a distance of 142 yards. Taking the friction of the wheels upon the rails at one-fifth, the stop would be made in rather less than 90 yards, and this or very nearly this quickness of stopping has been attained with Creamer's breaks, a result confirming Mr. Fairbairn's experiments made some years since on Fay's continuous break.

In comparing the cost of maintenance of American carriage and wagon stock with that on English lines, many considerations are to be regarded. To say that the cost, in 1867, on the 1,612 miles of railway in the State of Massachusetts, for a train mileage of nearly ten million miles, was 6·55 cents, currency, or about $2\frac{1}{2}d.$ coin, per train mile, does not permit of any accurate deductions. The American passenger trains are made up of carriages of but a single class; there are no through carriages from branch lines; the average number of passengers continuously carried over the whole distance made by a train is generally one half greater than in England, although the proportion of dead weight to live load is probably nearly as high as in this country; the speed is less, and there remains the fact that labour and nearly all materials are much dearer. On the other hand, there is a considerable saving in the use of chilled cast-iron wheels, such a thing as a wheel turning lathe for carriage or wagon stock being unknown in the States; the maintenance of buffer and draw springs costs much less; the maintenance of the carriage bodies is cheaper from their greater strength and simplicity of structure, and from the fact that there are no side doors to slam, and to this cause alone much of the repairs of English carriage stock is due. It may be added, also, that the cutting of seats, and the breaking or even scratching of carriage windows has not become a habit in the States, and even from abuses like these the cost of carriage repairs is considerably swelled on English lines.

In closing this lengthy Paper, the Author finds his greatest difficulty in drawing from it conclusions of value to English engineers. Much that is peculiar to American practice is only externally so. Much that is essentially distinctive is, from circumstances of traffic, and from national habits, inadmissible, or inapplicable here. The extreme subdivision of the rolling weights, with the consequent multiplication of wheels, is not required on the heavier and smoother permanent way of English lines. For passenger engines the bogie is already largely employed here. For goods engines, however, working under the conditions of English climate, the adhesion due to the whole weight is generally requisite, and to throw any portion of that weight upon a bogie unconnected with the driving or working power, is to lessen, *pro tanto*, the effective duty of the engine. In all that has been said of the adhesion of American engines, it has been the object to show, that the maximum adhesion may be greater than is commonly admitted; but it is not the less intended to acknowledge the fact that adhesion is, from many causes, very variable. Instances of maximum adhesion can be found, of course, in one country as well as another, and the experience of many engineers of English lines will confirm a maximum adhesion of one-fourth the total weight.

While it is the wish of the Author not merely to disclaim, but sedulously to guard against professional preferences founded upon anything like national feeling, he cannot help repeating that the safety and economy of chilled cast-iron wheels entitle them to the best consideration of English engineers. One objection to these wheels, not referred to in the earlier portion of the Paper, is that, being almost necessarily of the disc form, their weight increases in a ratio nearly as the square of the diameter, and thus the largest railway carriage wheels yet employed in the States were but 3 feet, and this size was long ago discontinued in preference for 2 feet 9 inches. In the case of cast-iron spoked wheels, the chill is less hard opposite the ends of the spokes than elsewhere, and they thus soon show flat spots.

The success of steel fire-boxes and iron tubes, in American engines, gives new interest to the question of the further introduction of steel here.

The bogie tender, with the tank carried on three supports, that is, on the centre of the front bogie, and on the sides of the hind bogie, would be found much easier on the line than the ordinary six-wheel type. Sir Edward Watkin, when in Canada, in the winter of 1861-62, as Controller of the Grand Trunk Railway, had all the six-wheel tenders changed to double bogies, and to this change he attributed a great diminution in the breaking of rails during that unusually severe period. There is no difficulty or danger, as is sometimes supposed, in applying breaks to the bogie tenders, even on the steepest inclines ever resorted to in practice.

As for carriage stock in which side doors are requisite, and where, therefore, the side framing between the windows and the sole plates has no strength of itself, there seems to be little advantage in long double-bogie carriages, beyond the facts that they offer less tractive resistance than ordinary carriages on curved lines, and that the longer they are the steadier they are.

If English engineers can anywhere introduce all the peculiarities of American practice, it appears to the Author that it must be on colonial and foreign lines, especially those in comparatively new districts. At home, a few only would probably be found both economical and acceptable to the general wants and habits of the public. It may be said, in conclusion, that if American railway practice be in any or in many respects more daring than that which prevails in England, failure, if not too often repeated, is regarded in the cousin country as a misfortune, where in this, unless it proceed from causes absolutely beyond prevision, it is rightly judged as a fault, a misdemeanour, or even a crime.

The communication is illustrated by a series of highly-coloured diagrams, executed by Mr. T. J. Ellis, Stud. Inst. C.E.

[Mr. Colburn