LONDON AND NORTH-WESTERN LOCOMOTIVE WORKS AT CREWE.

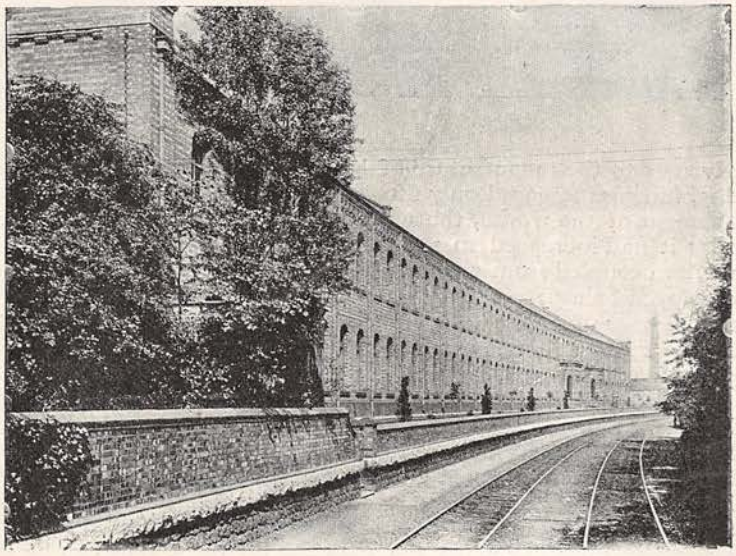
By C. J. BOWEN COOKE,

[Assistant Running Superintendent, Locomotive Department.]

Illustrated from Official Photographs.

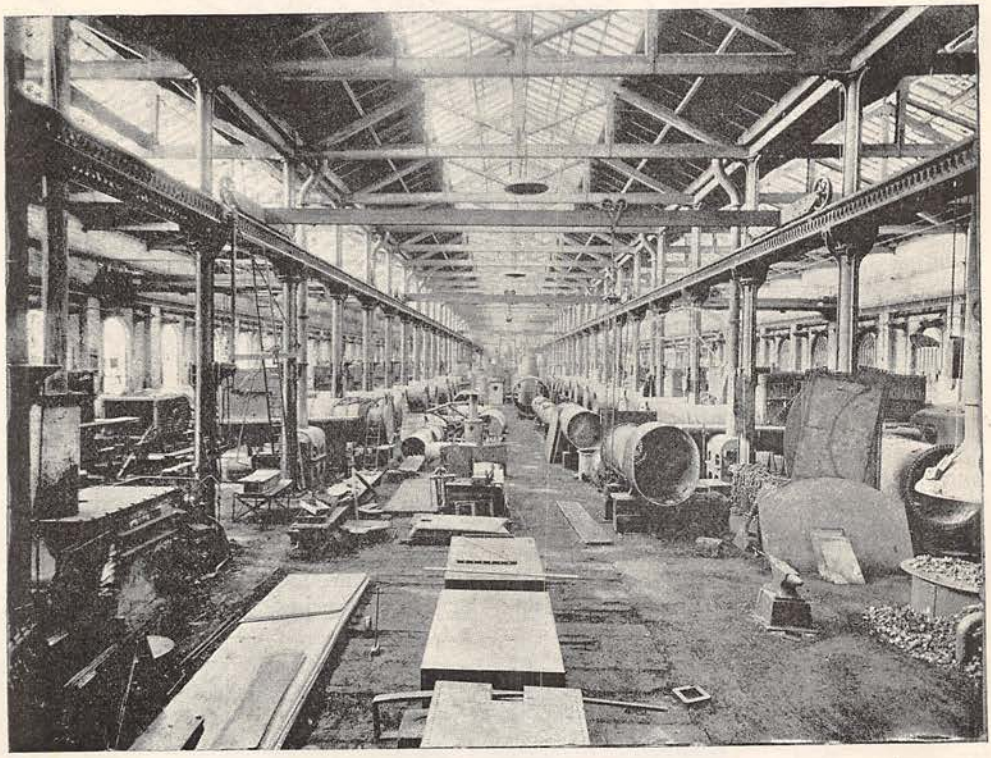
THERE is no busier railway station in the country than Crewe, the principal junction of the London and North-Western system. Through it more than six hundred passenger and goods trains run every twenty-four hours. The locomotive works which extend for a mile and a half in length are situated in the fork of land between the Liverpool and Chester and Holyhead lines, close by the side of the latter, but before describing what may be seen inside these works, I will say a few words about the town in which they are situated.

Crewe has no architectural pretensions, but consists principally of small red brick houses, inhabited by working men all in the service of the Company. Its rise and progress are contemporaneous with the development of the London and North-Western Railway Company. Sixty years ago on its present site it contained a population of one hundred and forty-eight souls. On July 4th, 1837, the first train passed through this small village on, what was then called, the Grand Junction Railway. An amalgamation was in that year effected between the Manchester and Liverpool, the Manchester and Birming-



OFFICES OF THE LOCOMOTIVE DEPARTMENT.

ham, the London and Birmingham, and other lines. The new Company was called the London and North-Western, and in August, 1842, the complete line, so far as it had been constructed, was opened to the public. The authorities connected with this great undertaking were not slow to perceive the central situation of Crewe. It was apparent that several lines must converge there, and that it would thus become a great meeting place for railways. It was seen, too, that the place would be an admirable site for the construction of locomotive engines, carriages, and wagons, the result being that in 1843 the Grand Junction Works, which had previously been situated at Edge Hill, Liverpool, were transferred to Crewe, and from that time the development of the town began. In 1853 however the wagon department was removed to Earlestown, and in 1861 the carriage department was transferred to Wolverton, and so the Crewe Works are now entirely

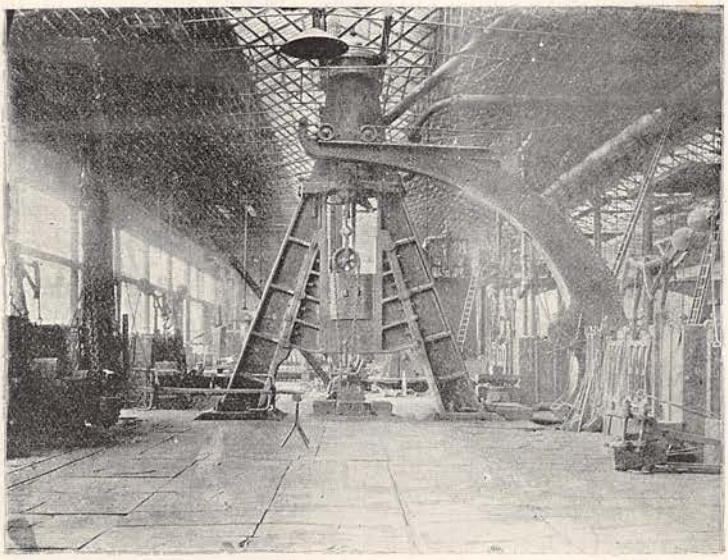


BOILER SHOP.

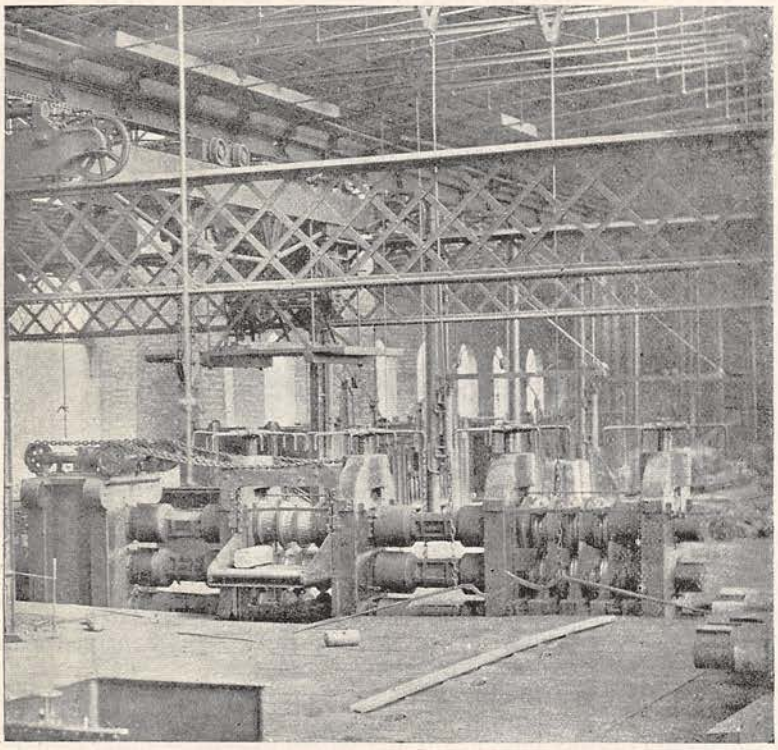
given up to the manufacture of locomotives. In 1841, the population of Crewe was 203, having increased only fifty-five in ten years. In 1851, eight years after the establishment of the works, the population had risen to 4,571; in 1861 it was 8,159; in 1871 it had increased to 17,810; and at the present time it is 30,000. In 1843 the works occupied from two-and-a-half to three acres of ground, the number of men employed being 161 They now occupy 116 acres, thirty-six of which are covered; the number of men employed being upwards of 7,000. In May, 1876, the completion of the 2,000th engine was signalized by public rejoicing. On July 4th, 1887, the 3,000th engine was completed.

Crewe possesses a Mechanics' Institute, built and supported by the Company. Excellent Science and Art classes are connected with the Institute, and its students have won more Whitworth Scholarships than any other place in the country. It has also a well stocked library and good reading room. There is a Volunteer Engineer Corps, 600 strong, composed entirely of men employed in the works. A well-trained Works Fire Brigade has its depot close to the offices, and in case of a fire breaking out while the men are off duty, they can be instantly summoned by means of electrical communication which is established between the "Time Offices"

at the works and the house of each member of the brigade. With the exception of two sewing factories employingfemale labour, there is no other source of employment whatever in Crewe, except that afforded by the Railway Company. The Parliamentary Division is named after the town, which comprises more than half theelectorate. In 1848 the Queen, Prince Albert, the Prince of Wales, and other members of the Royal Family, paid an unexpected visit to the town and stayed the night at the Crewe Arms Hotel, on their route to London from Scotland. The Royal Family had set sail from Aberdeen for Portsmouth, but meeting with very stormy weather, The Queen decided to return to Aberdeen and proceed overland. The whole party feeling fatigued, Her Majesty sent word shortly in advance of the train's approach to Crewe that she would stop at the hotel there for the night, which she accordingly did, proceeding on her journey the next morning. There is probably no other place without a history which has been visited by more distinguished and learned people than the great locomotive workshops of the London and North-Western Railway Company.



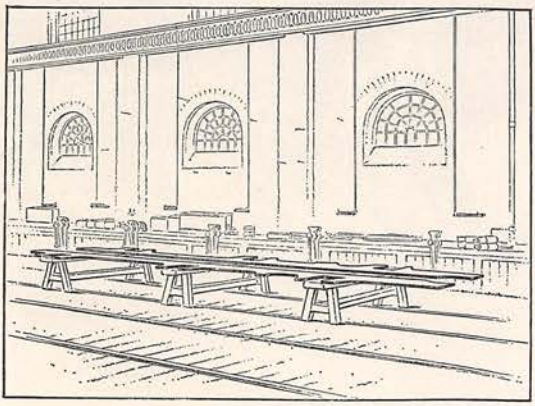
EIGHT TON STEAM HAMMER.



RAIL MILL, CREWE WORKS.

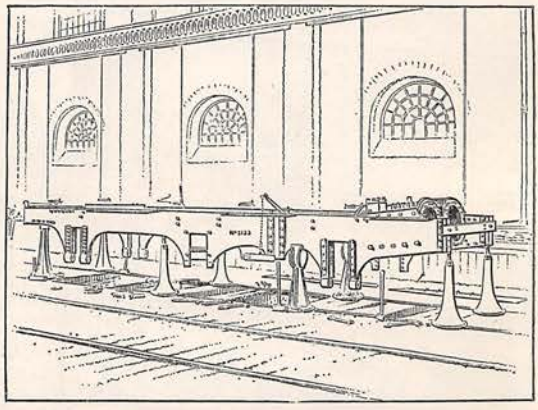
Mr. F. Trevithick was the first Locomotive Superintendent at Crewe. He was the son of the great Trevithick who in 1805 exhibited his wonderful "steam coach" on the site now occupied by the London and North-

Western Railway Terminus at Euston. At this time, however, the Company had only seventy-five engines in stock. He was succeeded in 1857 by Mr. Ramsbottom, who effected many important improvements; and in 1871 he was followed by Mr. Francis William Webb, the present Chief Mechanical Engineer and Locomotive Superintendent. Mr. Webb served his apprenticeship at Crewe Works, and has been connected with them for thirty-five years, acting as manager during Mr. Ramsbottom's superintendence, and it is owing to his ingenuity that the North-Western Railway possess upwards of fifty patents for improvements connected with railway plant, ranging from a foot-warmer to a locomotive.



ENGINE ERECTED IN TWENTY-FIVE HOURS AND A HALF. FIRST STAGE AT SIX A.M. MONDAY, FEB. 4TH.

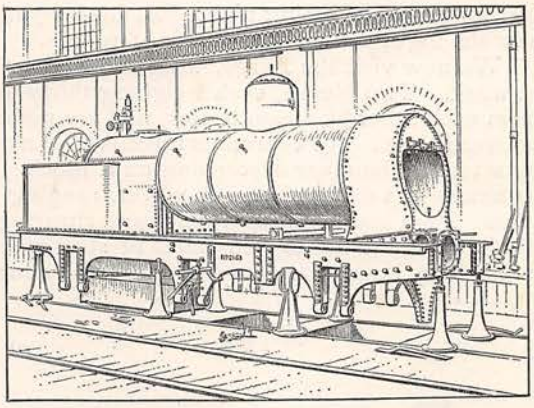
We will now suppose ourselves to have arrived at Crewe Station, armed with a letter of introduction to enable us to see the works; for be it strictly noted that without this "open sesame" the doors are closed to visitors. We have then to make our way through the town to the "General Offices," which form the starting point for detouring over the works. These offices are situate in the centre of the town, and also of the works. Having signed our names in the "Visitors' Book" we are placed in the care of a guide and begin our journey of inspection. We pass out of the offices through a spacious doorway on the works side, and are agreeably surprised to see the verdant freshness which meets the eye all around, instead of the grimy appearance which might naturally be expected. The offices, which are lighted throughout by electricity, extend several hundred yards in length and face some lines of rails connecting the old and new works. A well-kept border of grass several yards in width and studded with evergreens runs along the whole length of the building, and ivy climbs its walls. The residence of Mr. Webb is close to the end of the offices, and notwithstanding the immense amount of fuel burned in the works, such is the purity of the atmosphere, owing to the use of gas furnaces and smoke-consuming appliances, that luxuriant vegetation and beds of flowers surround the house. The Drawing, Stores, Accountants', Running and Signal Offices, Photographic Studio and Laboratory, together with the private offices of the Superintendent and heads of departments are concentrated here. Many hundreds of clerks are engaged in them who record every pound of coal burned, every mile run, every item of expenditure in any shape connected with the building, repairs, or working of each individual locomotive.



ENGINE ERECTED IN TWENTY-FIVE HOURS AND A HALF. SECOND STAGE AT ONE P.M. MONDAY, FEB. 4TH.

Upon emerging from the offices we find waiting for us a vehicle called by Crewe works people a "cab," which is a low kind of covered truck attached to a locomotive, several of which are run on the railway lines about the works to convey either men or material from one part to the other. We step into it, and are at once conveyed to the Steel Works, which is usually the first place to which visitors are taken. Here we see the manufacturing of steel by the Bessemer process. This is the first step towards the making of a locomotive, viz., making the steel which is so largely used in its compo-

sition. About five tons of pig-iron, previously melted in a cupola, are run into a "converter," which is a large egg-shaped vessel with a gigantic kind of spout. This vessel is then revolved on its own axis until the spout points upwards, and then a strong blast of air is turned into the metal from below, which acting upon the molten mass keeps up a fierce combustion, and ejects all the impurities from the iron. This "blowing" is kept up for some fifteen or twenty minutes. Showers of glittering sparks and a fierce roar of flame shoot out of the upturned orifice, and at night light up the whole place in a weird fantastic way. When the "blowing" has ceased the "converter" is again turned down, and a quantity of "spiegeleisen," an iron highly charged with carbon, which has been previously melted in a furnace, is poured into it. This chemically combines with the molten iron, and the result is Bessemer steel. The mixture is then emptied into a huge ladle suspended at the end of a crane, from whence it is poured into the various moulds standing ready, and is cast into ingots, to be used for making rails, tyres, axles, plates, or any other purpose required. We glance at the splendid horizontal engines supplying the converters with air, and passing by the furnaces (of which there are seven) for making steel by the Siemens'-Martin process, we go on to the Rail Mills.



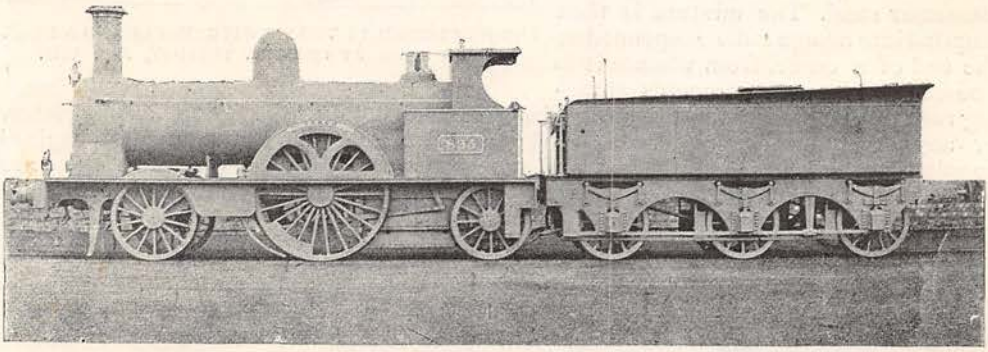
ENGINE ERECTED IN TWENTY-FIVE HOURS AND A HALF. THIRD STAGE AT ONE P.M. TUESDAY, FEB. 5TH.

ENGINE ERECTED IN TWENTY-FIVE HOURS AND A HALF. COMPLETED ONE P.M. WEDNESDAY, FEB. 6TH: AND WORKMEN.

The North-Western is the only English railway that rolls its own rails. The plant has a capacity for turning out 45,000 tons of rails annually, the actual output being 25,000 tons. The mill is driven by a magnificent 700 horse-power engine of the Corliss pattern. An ingot similar to one we have just seen cast is taken out of a furnace to the mouth of the largest of the swiftly revolving rollers of the mill. This ingot is about 3 feet long by 10½ inches square The rollers may be compared to a large

mangle, and the ingot in passing to and fro between these is first transformed into a thick bar of steel ; with each squeeze it becomes longer and thinner, the last few times the top and bottom of the bar flatten out, and the middle becomes thinner until it emerges from the last pair of rollers. It is then carried on small rollers to a circular saw close by, the ends are cut off square, and we behold a perfectly finished rail thirty feet long, and weighing ninety lbs. to the yard, in about a minute from the time we saw the ingot enter the first pair of rollers.

We now visit the Forge, where we see a thirty-ton Ramsbottom duplex hammer at work. Two blocks, each weighing thirty tons, are being driven horizontally to and from each other by steam power, and are pounding away at a mass of white hot metal between them. An enormous force is here made use of without the vibration caused by a vertical hammer descending on a block. We see at work eight of these latter hammers of various size and power, ranging from sixteen hundredweight to eight tons. Here are also plate rolling and shearing machines ; the former transforms huge blocks of hot metal to thin plates of steel or iron with the same ease and dexterity as the busy housewife converts a lump of dough into a thin pie-crust, and the latter



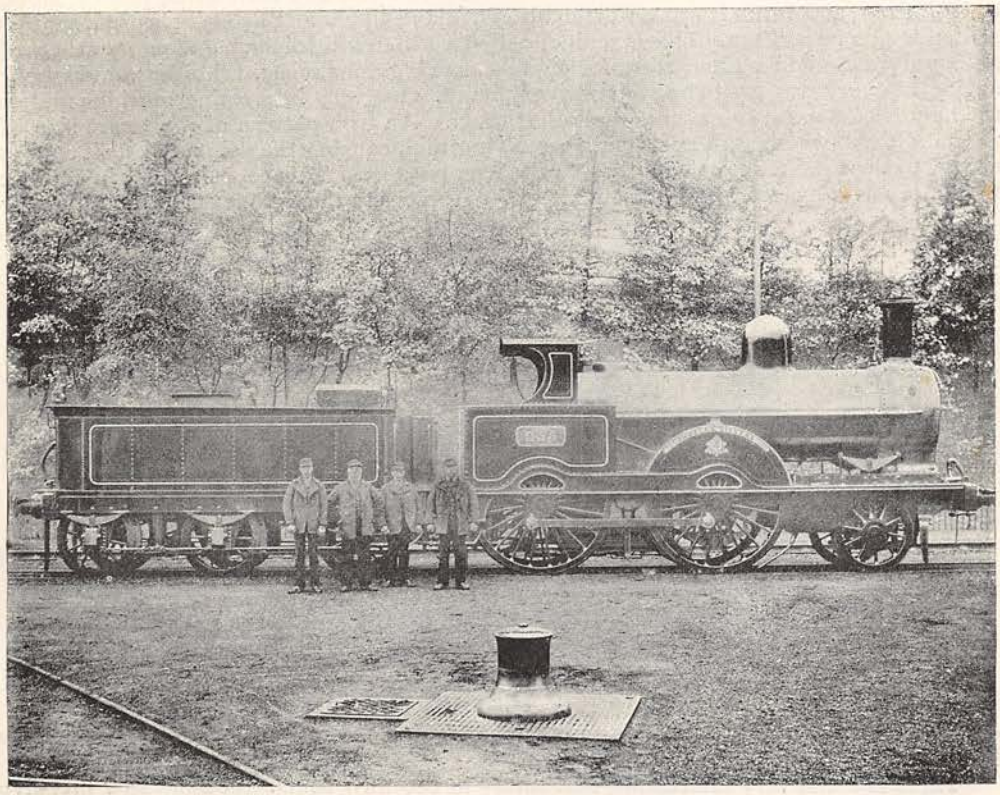
WOLVERTON BLOOMER ENGINE, "TORCH."

emulates the same individual plying her scissors, for it snips and cuts up great pieces of cold iron and steel with equal facility. The plate rolling machines perform the important part of making all the plates from which the engine boilers and frames are constructed. Here also Mr. Webb's patent steel sleeper is rolled, over 100,000 of which are laid down in the present permanent way of the Company. A large circular saw, seven feet in diameter, driven at a speed of 13,000 feet per minute, demonstrates its power by cutting through an iron axle nine inches in diameter in thirty seconds. The metal which has to be treated is all heated in gas furnaces, of which there are thirty-seven, the gas being generated in forty-nine gas producers, and conveyed to the furnaces in underground pipes.

Our next visit is to the Boiler Shop, where we see engine boilers in every stage of construction. The barrel-shaped part of a locomotive boiler has in it upwards of 200 tubes extending from the "fire box" to the chimney end. These tubes when the engine is "in steam" are surrounded by water, and the flames pass from the furnace to the chimney through them, the greater the number of tubes, the greater the "heating surface" acted upon by the fire to generate steam. The fire-box is the most costly part of an engine, being made entirely of copper, the tubes are usually brass and the rest of the boiler steel ; more than a million tubes are used annually for new boilers and repairs. These tubes and the copper plates for the fire-boxes are the only things imported into Crewe Works in a manufactured state. The noise of hundreds of men closing rivets up is deafening, and we leave this place with a sense of relief.

At the extreme end of the works near the Boiler Shop there is a large brick-making plant ; the yearly output from a circular kiln being over five millions. Passing through the Flanging Shop, where the fire-box and tube plates

are flanged in a powerful hydraulic press, we go to the Engine Repairing Shops, which are a counterpart of those we shall see at the Old Works, and on to the Tender Shop, where tenders are in all stages of manufacture and repair. The London and North-Western Company's tenders are fitted with an ingenious apparatus—the invention of Mr. Ramsbottom—for picking up water while travelling. A pipe called a scoop, with a bend at the end, is let down into a water trough between the rails while the engine is passing over it, and the rapid motion of the train forces the water up the scoop into the tank on the tender. This system enables the tenders to be constructed of a lighter



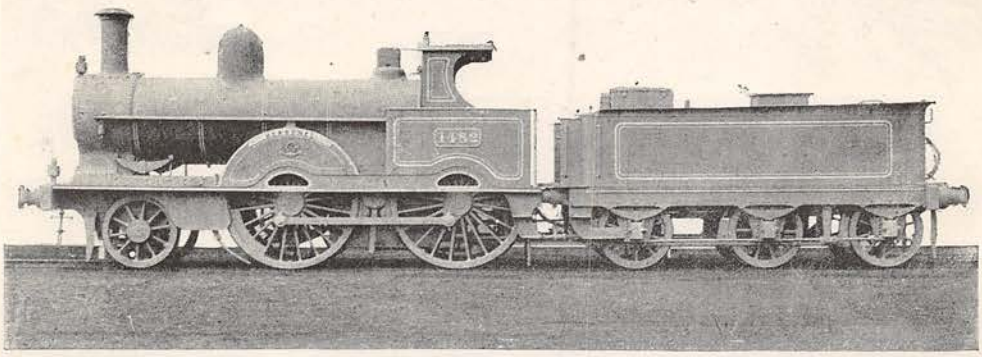
"CHARLES DICKENS," AND DRIVERS AND FIREMEN.

pattern, and avoids the necessity of carrying a large supply of water; thus reducing weight and consequently working expenses.

Our next visit is to the Iron Foundry, where moulders are making, with wood and metal patterns, the shapes in the sand into which liquid iron is afterwards poured, and which subsequently come out in the form of cylinders, wheels, and all parts of locomotives, signal gearing and other machinery for which cast iron is used.

We next pass the Brass Foundry, where all sorts of brass castings are made, and enter the Signal Shop, where all the signal apparatus is fitted. The signal frames are all put up temporarily in this shop before being conveyed to the signal boxes wherever they may be required along the line. This is a department which has made very rapid strides since the first introduction of railway signalling. The old-fashioned "policeman"—still bearing that name on many parts of the line—with his long-tailed coat and stove-pipe hat, whose only duty was to wave a flag by day or a lamp by night, has long been superseded by the highly trained "signalman," who has to pass a strict examination in all the complicated details of block working, which requires intelligence and constant attention upon the telegraph instruments and signal levers. In this shop the Webb-Thompson electric staff apparatus, now being largely adopted in single line working, and which ensures the safe and economical transit of trains over such lines, is pointed out to us.

Passing the large Paint Shop on the left, where the engines receive their final treatment before leaving the works, we begin to retrace our steps towards the Old Works lying in the direction of Crewe Station. We first enter the "Deviation Works,"—so called owing to the Chester line being here deviated to run outside the works, it having formerly run within at that point. At this place carpentry, joinery, pattern-making, and wood-working of all descriptions is carried on. Here are some very wonderful machines, perhaps of even a more interesting character to the non-scientific mind than many of the metal work machines. A machine, controlled by one man, seizes hold of a log of wood and then saws, planes, slots, drills, adzes, and turns it out a finished buffer plank in almost as short a time as this sentence can be written. This machine, called a "General Joiner," and many others of an equally astonishing character, for planing, sawing, morticing, rabbiting, and labour saving in every way are to be seen on every hand. One very interesting machine makes the handles of axes, hammers, and other tools. An iron pattern of the exact size of the handle to be made guides a rapidly revolving tool, causing the point of it, as it travels along, to describe a shape exactly like the iron pattern. This tool brought in contact with a revolving piece of wood, cuts it out to precisely the required shape in a few



"HERSCHEL," FOUR-WHEEL COUPLED PASSENGER ENGINE. SIX FEET SIX INCH DRIVING WHEELS.

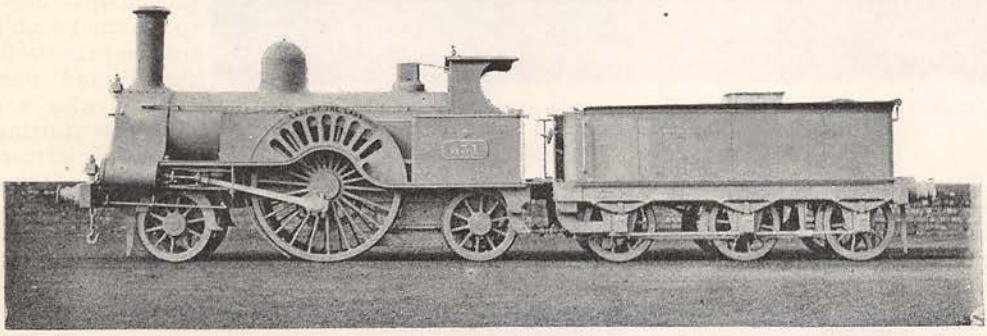
minutes. Another machine performs the astonishing feat of drilling a clean cut *square* hole.

There is some very interesting machinery in the Saw Mills. A band saw fifty-five feet in length of great power has lately been added. This saw is about four inches wide, and is capable of cutting through a block of wood six feet thick in an incredibly short time. The machinery in the Joiners' Shop and Saw Mills is all driven from shafting fixed in the cellars below. This has rather a curious effect, as ordinarily in a shop full of machines there is a bewildering maze of belts and innumerable pulleys, whereas here the motive power is completely hidden. Underneath the Saw Mills is to be seen some of the finest belt driving machinery in the world. The transmission of about ninety horse-power from one part of the building to another is effected by an arrangement of large pulleys and belts, these working with the least possible friction and doing away with the wear and tear of bevelled cog wheels and other expensive machinery.

We now pass on to the Pattern-Makers' Shop, where men are engaged making patterns for castings. These have to be made with the greatest accuracy, and are put together in sections to enable the moulder to draw them out of the sand without injuring the shape of their imprint. The size of the pattern has to be so calculated as to insure the casting to be of the right dimensions after the metal has shrunk in cooling. There is an immense number of patterns stored away in this shop ready for use at any time whenever a casting may be required from any one of them. In the adjoining Millwrights' Shop we observe mechanical engineering work in almost every conceivable branch going on : cranes, warehouse machinery, stationary engines, electrical, hydraulic, marine, and all kinds of machinery are in course of construction or under

repair. Close by is the Testing and Chain-Making Shop, where all kinds of chains, samples of steel made in the works, pieces of each boiler plate that is to be used, and other material, are subjected to severe tests by hydraulic and other machinery to see whether they can satisfactorily stand the stress of work which will be put upon them in the particular service for which they are intended.

Again mounting the friendly "cab," we are whisked off to the "Old Works," which are entirely devoted to the manufacture and repair of locomotives. We are first shown a novel machine, called an "electric welder." By its means pieces of metal are joined by fusion together through the heat which is generated at the points of contact by an electric current. This enables welds to be made in parts which could not otherwise be got at without taking the object to pieces; in fact, many things which are welded by it could not be done by any other means; and as it does its work expeditiously, it is an excellent labour-saving machine. Having watched the process, we enter the Smithy, in which there are 120 smiths' hearths, at each of which men are busily engaged. Each fire is connected by a tube to a pipe in which a strong current of air is compressed by a fan, and in order to obtain a draught to his fire, all the smith



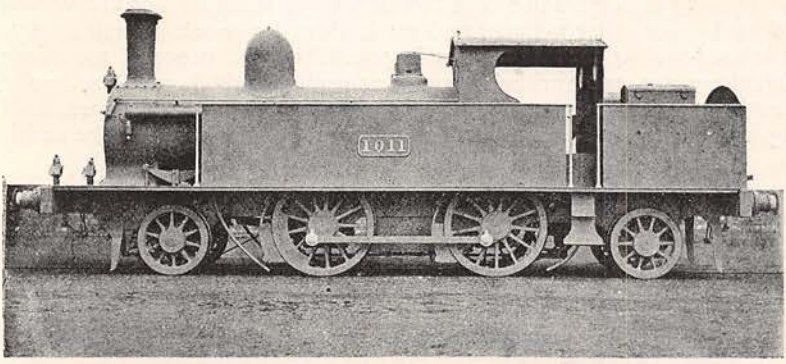
"LADY OF THE LAKE." EXPRESS ENGINE. SEVEN FEET SIX INCH DRIVING WHEELS.

has to do is to move a handle which turns on the blast of air from the pipe. Here various, principally the smaller, parts of engines are forged. When the Shah of Persia visited the works he witnessed in this shop a large forging operation under a steam hammer, and the cascade of sparks sent forth by the first blow from the ponderous machine falling among the group of spectators so worked upon the feelings of his Majesty that he beat a hasty retreat, preferring the request that spectacles of a less alarming character should be brought under his notice.

We now proceed to the Erecting Shop, where engines are in all stages of construction. The different parts which have been manufactured in other shops all ultimately find their way here, and are put together piece by piece until the whole machine is completed. First the frame plates (which are made at the plate mills at the steel works) are fixed by temporary cross bars into exactly the same position they will occupy when the engine is completed. This is the ground work from which the engine is built up. The cylinders and foot-plate are then fixed in position, and other work done to complete the skeleton. The boiler, which has already been completed and tested at the boiler shop, is then put on, being lifted into position by an overhead crane; after this has been fitted the engine is again lifted by the cranes, and the wheels, which are made at the steel works and are usually cast steel, and to which the axles and axle-boxes have already been fitted, are run under and the engine lowered down on to them. The internal working parts, such as connecting rods and intricacies of the valve motion, are then fitted in their proper places, and all the internal and external fittings completed. Between the steel boiler plates and the outside casing, which is made of plates of thin sheet iron, there is a layer of thick felt, which prevents the loss of heat that would take place if the boiler plates were exposed to the atmosphere. The engine being finished, it is lifted bodily up clear of all obstruc-

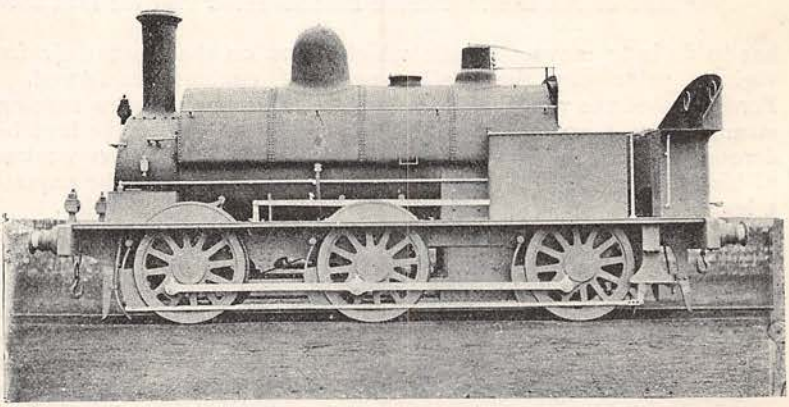
tions and carried by the two powerful overhead travelling cranes to the central gangway, where it is run out on a pair of rails, got in steam, and sent for a trial trip before going to the Paint Shop, from which latter it is sent forth ready to take up its duties on the line. The usual time taken in constructing an engine is four weeks; but, as an experiment, one was once built in twenty-five and a half working hours.

In the Repairing Shops, adjoining the "new work" Erecting Shop, are veteran heroes of the road, minus wheels, boilers, and internal fittings, stripped so as to be very much in the same state as some of the new engines we have seen in the most embryo condition, but which in time will be turned out renovated and improved up to date, so as to be able to compete with their brand new sisters who are only just starting upon their career.



EIGHT-WHEELED SIDE TANK ENGINE. FOUR-WHEEL COUPLED FOUR FEET SIX INCHES, CYLINDERS SEVENTEEN BY TWENTY INCHES.

These shops are divided into a number of sections, in each of which three engines are in course of construction, or under repairs. Each of these sections is called a "pit," and is under one man, called a "leading hand," who has a certain number of men under him, and is responsible for the workmanship of the engines erected or repaired under his supervision. Over 2,000 engines are repaired annually. In the adjoining Wheel Shop the wheels and axles are turned; and here is some of the most powerful machinery to be seen in the works. Some of the wheel lathes are splendid pieces of mechanism, capable of turning wheels nearly nine feet in diameter. One machine called a "roughing lathe" has seven tools all employed at once in taking a rough cut off the crank axle, tearing the steel away in huge bites, and making the axle ready for the finishing tool. A "nibbling machine," with 160 cutting tools, eats its way into the solid forging of a crank, and cuts out the "throw" or inner bend of the crank.

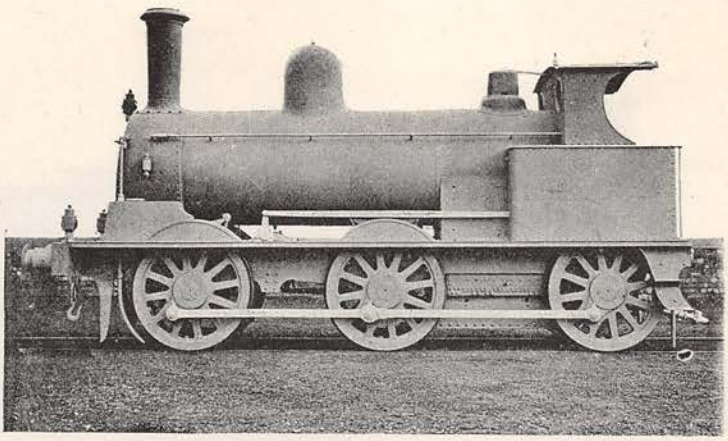


SPECIAL TANK ENGINE. SIX COUPLED WHEELS FOUR FEET THREE INCHES. CYLINDERS SEVENTEEN BY TWENTY-FOUR INCHES.

We are next shown the Fitting Shops, which are perhaps kept by our conductor as a *chef d'œuvre* to finish the round of wonderful sights. To the visitor this is perhaps the most marvellous place in Crewe Works. A perfect maze of pulleys, straps,

shafting, revolving wheels, and machinery of every description presents to the bewildered spectator a scene which he is never likely to forget. The space permitted by this article is too limited to admit of any detailed description being given of it, suffice it to say that machines and appliances of every kind devised by human ingenuity crowd upon the eye in all directions. Lathes, emery wheels, grindstones ; planing, shaping, slotting, boring and drilling machines are busily working upon all the different parts used in making a locomotive. Cylinders, pistons, valves, connecting rods, axle boxes, air pumps, slide bars, lubricators, and the numerous pieces of which an engine is constructed are here perfected and made ready to be fixed in their proper places in the Erecting and Repairing Shops. A very clever machine for cutting in a brass plate the name of the engine on which it is to be fixed may be alluded to. The required letter sunk in a die is traversed round by a guide, which causes a tool to work in exactly the same lines in a brass plate, cutting out the letter in an incredibly short time with the greatest ease to the operator.

One great principle with regard to engine fittings at Crewe is having them all made to a "standard." For instance, one pattern of "connecting rod" is interchangeable with about two thousand engines. The enormous saving in this system can be seen at a glance. All such fittings are made "piece work," the men becoming very expert at the particular job they are engaged upon. The different articles are thus made in the most expeditious manner possible, and are ready to put up in their places without any further fitting. Should any particular part of an engine fail at an out-station, a wire to Crewe giving the number and letter by which the part is designated, brings a finished article direct from the stores by the next train, and the engine can be got to work again with only a few hours' delay.

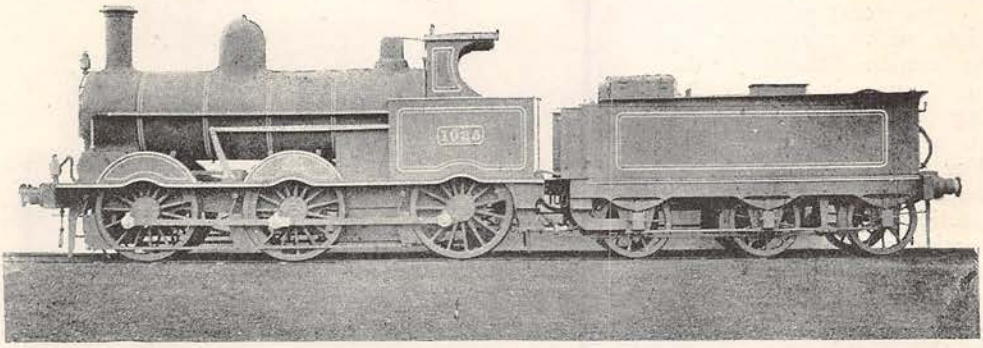


COAL ENGINE. SIX COUPLED WHEELS FOUR FEET THREE INCHES. CYLINDERS SEVENTEEN BY TWENTY-FOUR INCHES.

We have now reached the end of our tour of inspection, which has of necessity been very cursory, and as we stand by the building in which the works' stores of materials are kept we see across the labyrinth of rails to the right the "steam shed," in which one hundred and forty engines are stabled. There an army of "cleaners" are constantly, night and day, engaged in cleaning iron horses coming in after performing their journeys, and preparing them for fresh ones. Before us is a bridge stretching across the lines from the works to the platform of the station, a distance of several hundred yards ; along the bridge and winding in and out of the works, covering a distance of five miles, is a narrow gauge line eighteen inches in width on which little engines with appropriate names, as "Tiny," "Midget," &c., run, conveying goods wherever they may be wanted.

This review of Crewe Works would be incomplete if I failed to give some particulars of the various classes of engines made in them. I will therefore describe them as briefly as I can. The first illustration of a locomotive is one of the type called "Bloomer," an express passenger engine built by Mr. McConnell about the year 1847, at the time when the southern section of the line had its head-quarters and separate locomotive works at Wolverton. The illustration shows the engine as rebuilt at Crewe. This engine did excellent work in its day, but the pattern is now

obsolete, having had to give place to modern improvements with the advance of engineering development. In bygone years the performances of these engines stood second to none. The "Lady of the Lake," an engine with single driving wheels, is perhaps one of the prettiest engines that was ever built The details of its design were worked out by Mr. Webb when in the Crewe Drawing Office under Mr. Ramsbottom. It is capable of running at a very high speed, although not heavy enough, and the single driving wheels not having a sufficient grip on the rails, to work an ordinary express train of the present day. It is nevertheless very useful for light trains, and ran the 10 A.M. Edinburgh express between London and Crewe, which consisted of only four coaches, at the time of the race to Scotland in the summer of 1888. On one of these runs the speed maintained from Tring to Bletchley was between seventy-five and eighty miles an hour. North of Crewe, however, the train was worked by one of Mr. Webb's coupled engines with 6ft. 6in. driving wheels, of the "Charles Dickens" class. These engines have until recently been the standard express engines in use. The "Charles Dickens" is now a famous engine, and well known to every habitual traveller between Manchester and London. Since February, 1882, this



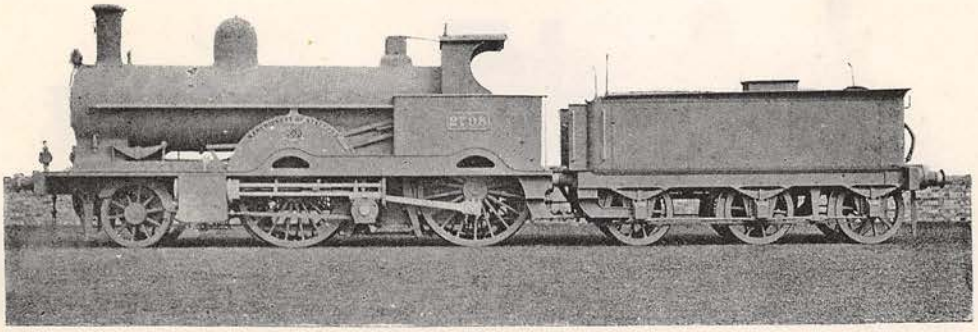
SIX-WHEELED COUPLED EXPRESS GOODS ENGINE. FIVE FEET DRIVING WHEELS. CYLINDERS EIGHTEEN BY TWENTY-FOUR INCHES.

engine has run daily a double trip between these points, except when, of necessity, stopped for repairs, and on the 12th September, 1891, it completed its 2,651st trip, having accomplished the extraordinary feat of running 1,000,000 miles in nine years, 219 days. During this time, in addition to the Manchester and London trips, ninety-two other journeys were made ; the total amount of coal consumed by it during the period being 12,515 tons.

The ever-increasing weight of trains, caused by improved carriages, &c., and greater speed desired by the public, caused the frequent use of "pilot" engines —a term used to describe the assistant engine when there are two attached to a train. This led Mr. Webb to consider the question of designing more powerful engines. He determined upon trying the experiment of applying the "compound" principle to an express passenger locomotive, with the idea that such an engine, properly constructed, would possess many advantages, and prove economical in working, in addition to attaining the desired result as regards increased power. The principle of a compound engine is this: the exhaust steam from the high pressure cylinder instead of passing away direct through the chimney (as is the case with an ordinary simple high pressure engine) is conveyed from one cylinder at a high pressure into another of larger diameter, where at a lower pressure it is again expanded and acts upon the piston and crank of a second pair of driving wheels, and made use of to the greatest possible extent before being discharged into the atmosphere, thus doing a maximum amount of work at a minimum cost. Mr. Webb's system is an arrangement of three cylinders, two high pressure, acting on the rear, or "trailing" wheels, and one low pressure inside cylinder (into which the steam passes from the two outside cylinders) driving the middle wheels.

The first compound engine built was named "Experiment," and the results obtained from it, and others of the same pattern, were so satisfactory, that this type of engine, enlarged and improved in many details, is now recognized as the standard London and North-Western express passenger engine.

The "Marchioness of Stafford," a splendid specimen of this class of engine, with 6ft. driving wheels, was exhibited at the Inventions Exhibition ; it was awarded a gold medal, and was an object of much interest. The "Jeannie Deans," which was exhibited at the last Edinburgh Exhibition, is an engine with 7ft. driving wheels, and represents the latest batch of compounds turned out of the works. This class of engine is—with the one exception I shall mention directly—the most powerful that has been made at Crewe, and the increased size of the driving wheels renders it capable of attaining a higher speed than the others. The "Jeannie Deans" at the present time may be seen any day on the 2 P.M. Scotch express from Euston. This is one of the heaviest and fastest trains on the line. It consists frequently of from eighteen to twenty vehicles, among which are the heavy dining cars. But the driver, although not disdaining a pull up the one in seventy gradient to Camden Town, to obtain a good



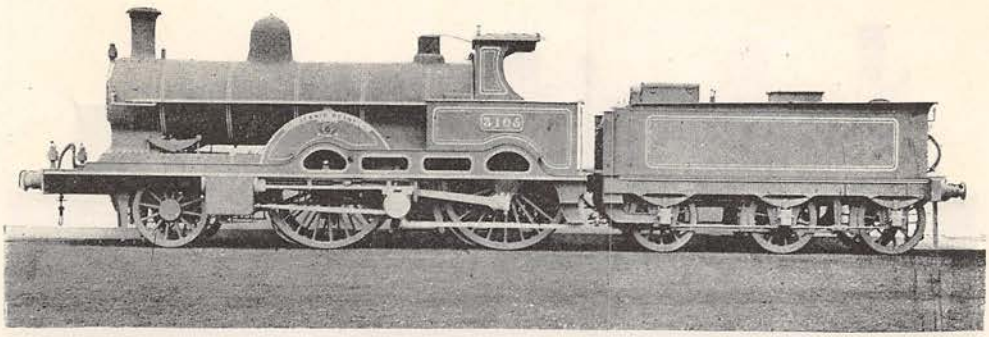
COMPOUND EXPRESS PASSENGER ENGINE, "MARCHIONESS OF STAFFORD." SIX FEET DRIVING WHEELS. SHOWN AT INVENTIONS EXHIBITION.

start, would scorn the idea of "Jeanie Deans" taking a "pilot," and he rattles his big load away down the country as easily as the "Lady of the Lake" took her four carriages with the Scotch racing train.

Mr. Webb's most recent achievement in compounds is the engine "Greater Britain," which, at this time of writing, has only been out of the shops a fortnight, but has already had the honour of conveying Her Majesty from Carlisle to Wolverhampton, *en route* from Scotland to Windsor last November. This is perhaps the most powerful engine that has ever been built. Although heavier than any other that has been made at Crewe, it is so constructed that there is no more than the usual weight on any one pair of wheels, and there is therefore no extra strain on the permanent way or bridges. This is brought about by the two pairs of driving wheels being placed in front of the fire-box, and an additional pair of small wheels, behind the fire-box and underneath the foot-plate, having half an inch of side play. The wheels under the front, or leading end, are fitted with Mr. Webb's patent radial axle-box, so that, although of great length, the engine can travel over curves with complete safety. One of the chief features is the combustion chamber inside the barrel of the boiler, which has the effect of arresting the gases from the fire-box on their way to the chimney, causing all the heat developed by them to be made the utmost use of for generating steam. This engine has attracted great attention in the engineering world. The London and North-Western engines collectively consume 3,095 tons of coal per day ; and seeing that compound engines have been proved in actual working to consume about six pounds of coal per mile less than other engines on the same work, and that they are daily taking loads without assistance, which any other type of engine would require two engines to work, it is evident that their invention and adoption has been of material advantage to the London and North-Western Railway Company.

The illustration of the "Herschel" represents a class of engine originally built by Mr. Ramsbottom, which for many years was the most powerful express engine owned by the Company. Increased weight and speed of trains, however, rendered it not up to modern requirements, and most of the "6 feet 6 inch Ramsbottoms," as they were called, have been rebuilt by Mr. Webb, and have now cylinders and boilers the same size as the "Charles Dickens" pattern.

The goods engine with six coupled wheels five feet in diameter was designed by Mr. Webb. It has cylinders 18 inches in diameter, and is used for running the more important through express goods trains. A coal engine, by the same designer, is the standard pattern of engine used for working the heavy coal and mineral traffic. This engine is capable of working trains on the main line, consisting of forty-five loaded coal wagons, the total weight of such a train amounting to over 600 tons. The standard type of shunting engine is called a "Special Tank." This engine carries the water for feeding the boiler in a semi-circular tank fitted round the top of the boiler. It is capable of shifting heavy loads, and can be started and stopped very quickly—an important qualification with shunting engines. The eight-wheel side tank



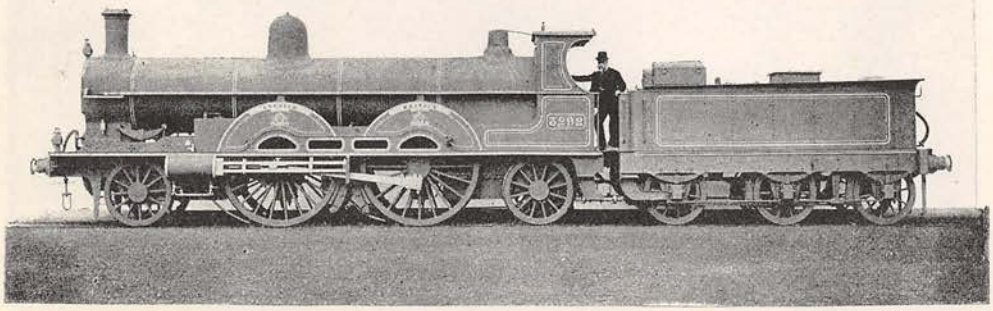
"JEANIE DEANS" (COMPOUND EXPRESS PASSENGER ENGINE). SEVEN FEET ONE INCH DRIVING WHEELS. SHOWN AT EDINBURGH EXHIBITION.

passenger engine is used for working local passenger trains. It is a very handy engine, and can run, with equal facility, in either direction when working trains. It is so constructed as to be able to carry a sufficient supply of coal and water for a long day's work. There are two models at Crewe which link the present and the past in locomotive building. One is an exact fac-simile of the "Rocket" as it appeared at the Rainhill contest (the "Rocket" now in South Kensington Museum is altered from its original state), the other is a working model of the compound engine "Dreadnought." The latter, at present in the Victorian Exhibition, has appeared at many previous exhibitions, and hundreds of pounds have been realized from pennies dropped in the slot, which set it in motion. The money collected in this way is always distributed to charities. Whether finality has been reached in locomotive development or not is a question time must decide, but judging from the leading record which the London and North-Western can show in railway history, it may be justly presumed that Crewe Works will still keep in advance of the motto "Never Behind" of the town by being always a step in front of every other Railway Company.

The following items of information show at a glance the great magnitude of this commercial undertaking. Capital, £101,000,000. Revenue per annum, £11,580,000. Expenditure per annum, £6,229,000. Number of persons employed by Company, 60,000. Number of persons employed in locomotive department, 18,000. Miles operated on, 2,700; engines owned, 2,620; carriages owned, 6,000; wagons owned, 57,000; carts, 3,500; horses, 3,500; steam ships, 20. Passengers carried annually, 63,000,000; weight of tickets issued annually, 50 tons; tons of goods and minerals carried annually, 37,500,000. Number of stations, 800; signal cabins, 1,500; signal levers in use, 32,000; signal lamps lighted every night, 17,000. Value of

work done at Crewe for various departments, £650,000; mileage per annum, 61,417,483; fuel consumed, 1,129,612 tons; water used 8,416,000 tons; number of special trains run—passengers, 56,000; goods, 155,000.

Crewe provides for the whole line. All the 18,000 men in the locomotive department are under the locomotive superintendent; of these about 10,000 are drivers, firemen, cleaners, and mechanics, at the various steam sheds on the line. These are divided between the southern and northern divisions, Crewe being the dividing line. Mr. A. L. Mumford is the head of the "running" department for the southern, and Mr. G. Whale



"GREATER BRITAIN." EIGHT-WHEELED COMPOUND (EXPRESS PASSENGER) ENGINE, 1891. DRIVING WHEELS SEVEN FEET ONE INCH.

for the northern division; they are responsible for everything connected with the working of trains so far as the locomotive department is concerned, and with Mr Earl, the manager of the works, Mr. Thompson, the signal superintendent, and Mr. Adamson, the outdoor superintendent of stationary engines, hydraulic, and water works, are the principal assistants to Mr. Webb. There are thirty-five "steam sheds" on various parts of the lines in which the locomotives are stabled, and all their many requirements while in active service attended to. There are also repairing shops at Longsight, Carlisle, Rugby, and Willesden; these all receive the material they use from Crewe Works. The iron work for the carriages made at Wolverton, and the wagons made at Earlstown, is also made at Crewe.

A LOOK ROUND SWINDON WORKS.[1]

By A. H. MALAN.

With Illustrations from Photographs by the Writer.

THE ordinary individual, with little more than a smattering of mechanical knowledge, who should essay to "do" any large railway works, and expect to come away with the construction of engines or carriages at his fingers' ends, would be likely to be more or less mistaken. For what between the heated forges, thumping steam hammers, whirring lathes, and deafening riveting sheds, a casual visitor is lucky to escape with only a slight headache, and may consider himself fortunate if he carries away an intelligent perception of the working of some few of the more interesting machines. So it is with Swindon, the nursery and hospital of the Great Western rolling stock.

But as one wanders round from shop to shop, bewildered and inquisitive, two points at least seem to impress themselves upon the mind :

(1) The economy of mechanical power, through duplication of work ; and

(2) The giant forces, invisible and unsuspected, literally beneath the feet, only requiring the touch of a handle to exert tremendous power in divers ways and methods.

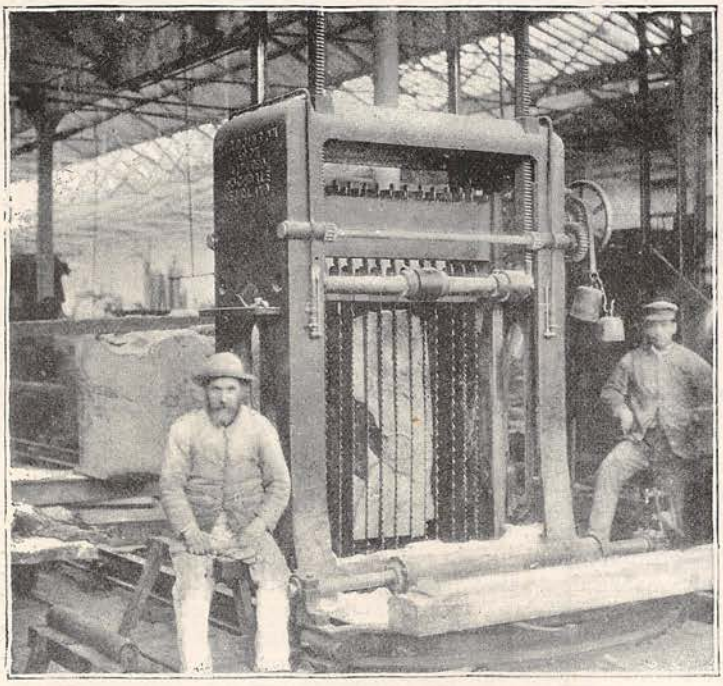
This duplication of work is seen, for example, in the cutting out of iron plates, in the boring therein of rivet holes, in the sawing of timber, and I know not what else besides. Just as a pair of scissors can cut a dozen folds of paper as easily as a single sheet, so a colossal machine here cuts through a pile of frame plates (each plate ranging from three-quarters to one inch thick) at one operation, thereby saving both time and mechanical wear and tear, and producing plates absolutely identical ; while other machines subsequently bore all the holes needed, with their multiple drills. Great trunks of oak and teak are also operated upon in a similarly wholesale fashion ; large saws, fastened side by side so as to be actuated simultaneously, converting a balk quickly into so many planks of any required thickness.

Perhaps the wood-working department,—a veritable variety shop of industries,—is the most captivating part of the whole works ; and none the less so on account of the resinous, turpentiny smell, which is deliciously fragrant and refreshing, as compared with the oily atmosphere of most of the other buildings. Here is one man turning elliptical pick handles ; another cutting out, by means of a band-saw, ovals and rounded parallelograms, for the moulded decoration of the carriage-interiors ;

[1] My thanks are due to Mr. William Dean, and other gentlemen belonging to the Great Western Railway staff at Swindon, for the assistance they have rendered me in preparing this paper.—A. H. M.

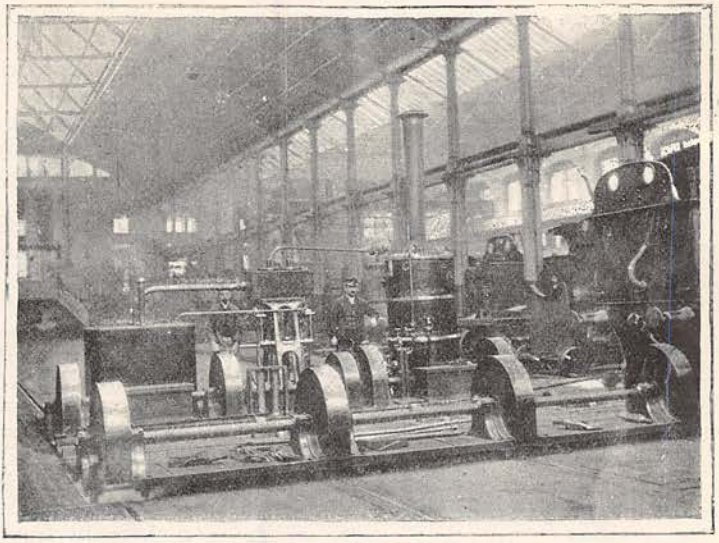
while a third attends to the machine which does the moulding in the pieces of board previously perforated.

And what a wonderful machine that is! Imagine an iron table with nothing upon it but one solitary steel spindle, standing up like a ninepin. The piece to be moulded is laid flat on the table, its edge pressed and pushed along against the ninepin, and behold, from the shavings and saw-dust flying round in a whirlwind, it transpires that the innocent-looking spindle is really a most formidable tool, revolving at incredible speed, its cutter being the exact counterpart of the mould to be produced. Whether it works *with* the grain or *against* the grain, makes no difference to this machine, the resulting mould proving to be, throughout all its parts, equally true, smooth, and uniform.



LOG FRAME SAWING MACHINE.

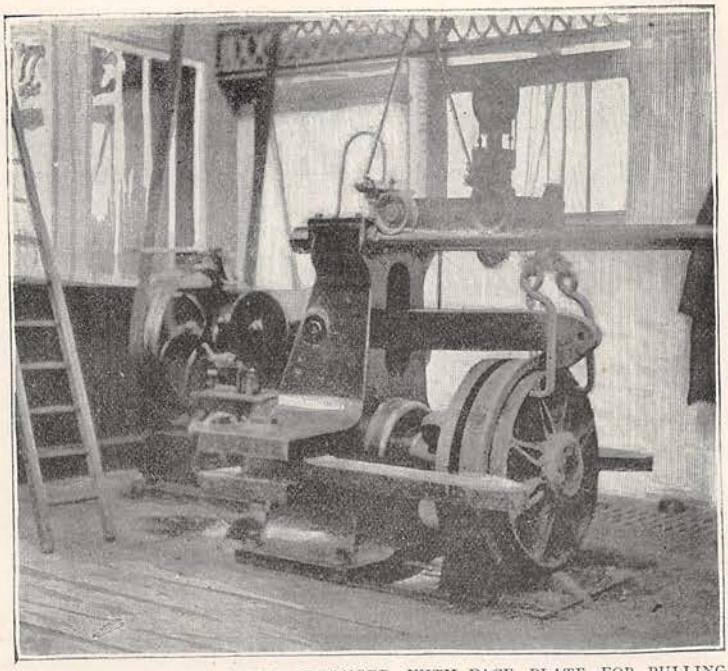
That this moulded work is of mahogany is not surprising, considering that it is intended for ornamentation; but what is rather surprising is that some of the other wood-work, which is not moulded, and which in its finished state will be covered with paint, is made of mahogany also. So lavish seems to be the use of this material, that even the outside panels of the carriages below the windows are made of it: inferior wood appears to be nothing accounted of, even as in the days of Solomon.



ENGINE TRAVERSING TABLE.

On passing from this department, the gates of a long building opposite happened to swing open, and there emerged into the light of day the queerest locomotive that ever was built! This proved to be an engine-traversing table, the function of which is to receive upon its platform a disabled engine (run on to it, as on to a turntable), and transfer it broadside within the repairing shed, ridding itself of its burden at one of the many rails running at right angles to the

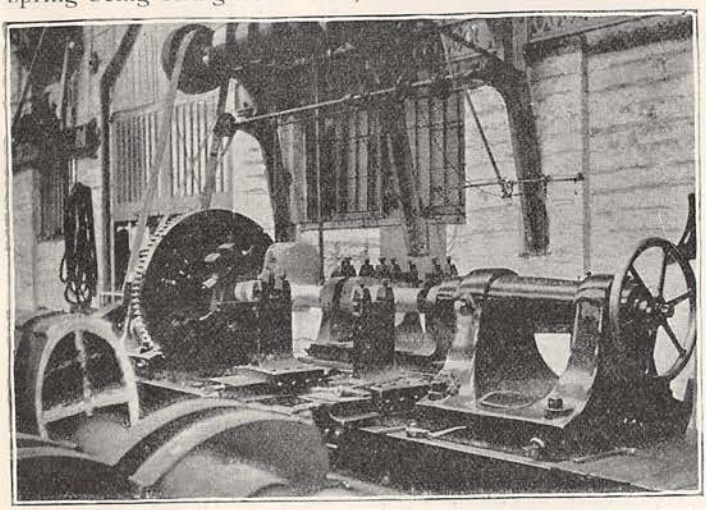
central lines on which it travels; or, again, to pick up, from a batch of cripples, some convalescent engine, and bring it once more into communication with the permanent way. In the right hand of the print the tail-end of an engine is seen, ready to be placed on the table.



HYDRAULIC WHEEL PRESS ARRANGED WITH FACE PLATE FOR PULLING TYRES OFF WHEELS.

In the carriage works much care is seen to be exercised over the safety and comfort of the public. Here, for instance, is a machine for testing spiral springs. If a spring were to snap, when a train was running at speed, a carriage might be derailed. Every precaution is taken that this shall not occur. In goes a spring to be tested, down comes an hydraulic ram, pressing down the spiral coil at one thrust, and recording on its gauge the pressure exerted—in other words, the weight and strain which the spring, if called upon, might sustain without detriment.

In another machine laminated springs are tested in the same way; the bow of a spring being straightened out, allowed to resume its normal shape, and straightened out again, as though it was fashioned of laths of willow.[1]

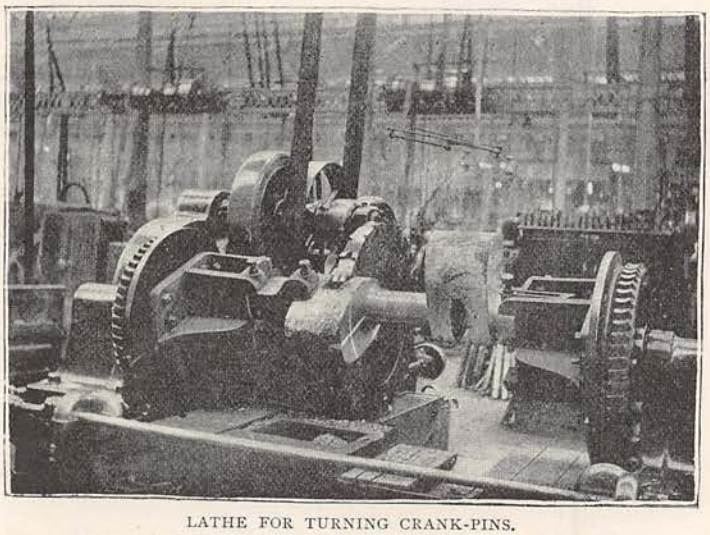


LATHE FOR TURNING LOCOMOTIVE CRANK AXLES. BED TWENTY-FIVE FEET LONG, HEAD STOCKS TWO FEET SIX AND A HALF INCHES. SIX TOOLS.

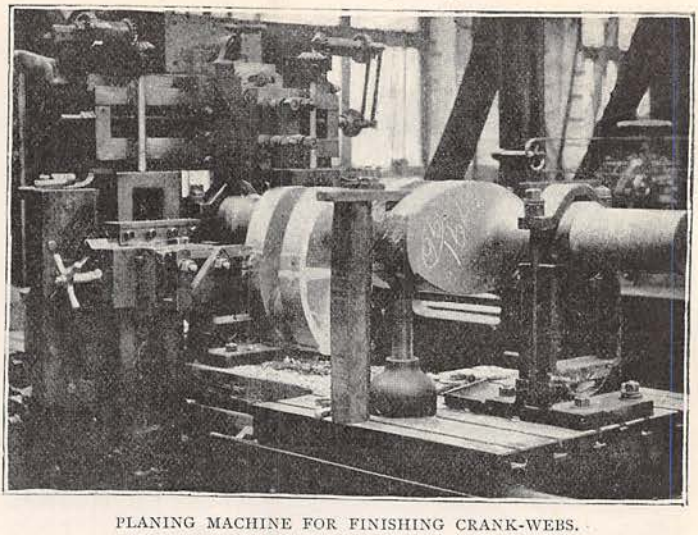
Then, again, those buffer-guides, which appear to be simply of cast iron as one looks at them attached to the carriage-ends, are by experience found to be more reliable and durable when constructed of wrought iron, and accordingly of wrought iron they are made. Thus: three pieces of iron plate are punched out to form the top, bottom, and middle part, and these, when brought to a welding heat, are placed in their relative positions in hydraulic press doing the duties both of hammer and mould, and after one or two operations the finished article is turned out, without any trace of join-

[1] The power required to straighten the larger laminated springs for waggons and carriages is about seven tons; that for compressing spiral springs about five tons.

ing, and apparently a single forging. To see these made, we resort to the forges; and while we are in that direction a far more elaborate example of welding and building up is met with in the case of engine and truck wheels. These, in their earlier stages, consist of several sections which are stamped out in dies under the steam hammer. One section forms a segment of the rim and outer part of the spoke; another, which is stamped in duplicate and sawn by a circular saw, gives the inner half of the spoke and segment of the centre. The two sections being then welded together, are ready to be framed for receiving the washers which form the boss. They are temporarily held together by an iron hoop, and after being brought to a white heat at the centre, are placed under the bossing hammer; a white-hot washer is then placed on the centre, which, with one mighty thump, the hammer securely fixes in position; another washer is welded on the other side and the boss is complete. The spaces left in the wheel rim are filled up, and welded, while at white heat, by a hydraulic press technically known as a "Veeing" machine. The whole operation presents a most picturesque appearance. The men standing round the hammer, with one dazzling spot in their midst, their outlines thrown into highest relief by the strong glare from the neighbouring forges, pose themselves naturally, and produce an excellent Rembrandtesque effect. Indeed the forge-light is so bright that, with the addition of a good flash-lamp for burning magnesium powder (which the writer should have had), a satisfactory photograph of the scene would be perfectly possible, with but a moderate exposure.



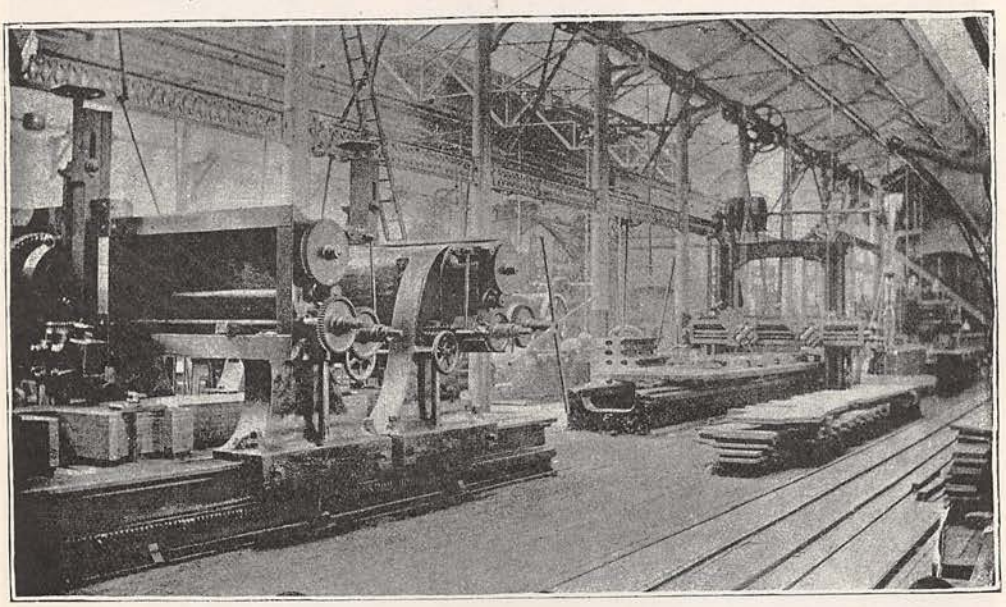
LATHE FOR TURNING CRANK-PINS.



PLANING MACHINE FOR FINISHING CRANK-WEBS.

The carriage wheels, too, are constructed especially with a view to minimum of noise and dust, and maximum of smoothness of motion; and these desirable features in railway travelling are partly secured by the portion of the wheels, where the spokes would otherwise be, being a solid disc of teak, built up of triangular blocks around a cast-iron centre, with the tyres bolted thereto. The way these wheels are secured on their axles is both simple and ingenious. First, the ends of the axle-shaft are turned perfectly true and parallel, the portions where the wheels will be fixed being slightly larger in diameter than the bore in the centre of the wheels;—and to ensure this

being done as accurately as possible, the callipers which serve as a gauge are themselves tested once a week. Then, two wheels having been passed over the ends of the shaft (previously smeared with oil and white lead), the pistons of two hydraulic presses are applied, which pistons, working towards each other, press the wheels towards the centre of the shaft. And usually when the wheels are found to be at exactly the correct interval apart for the metals of the permanent way, the needles on the gauges indicate a pressure of seventy tons. Near by is a similar kind of press adapted for breaking off *riveted* tyres from truck-wheels that have served their time, or need repairs. In this case the wheel is fixed in such a position as to have the tyre grasped by four projecting arms attached to the body of the press, and then a ram, capable of working up to four hundred tons, is set to work noiselessly and at first imperceptibly; in a few seconds, however, a loud report is followed by the wheel falling down, the



FRAME-PLATE SLOTTING MACHINE, WITH THREE MOVABLE HEADS, WILL CUT THROUGH TWELVE PLATES EACH THREE-QUARTERS TO ONE INCH THICK.

MACHINE FOR PLANING FACES OF PLATES.

tyre remaining suspended, the rivets having been sheared in half between the inside of the tyre and the outside of the wheel-rim.[1]

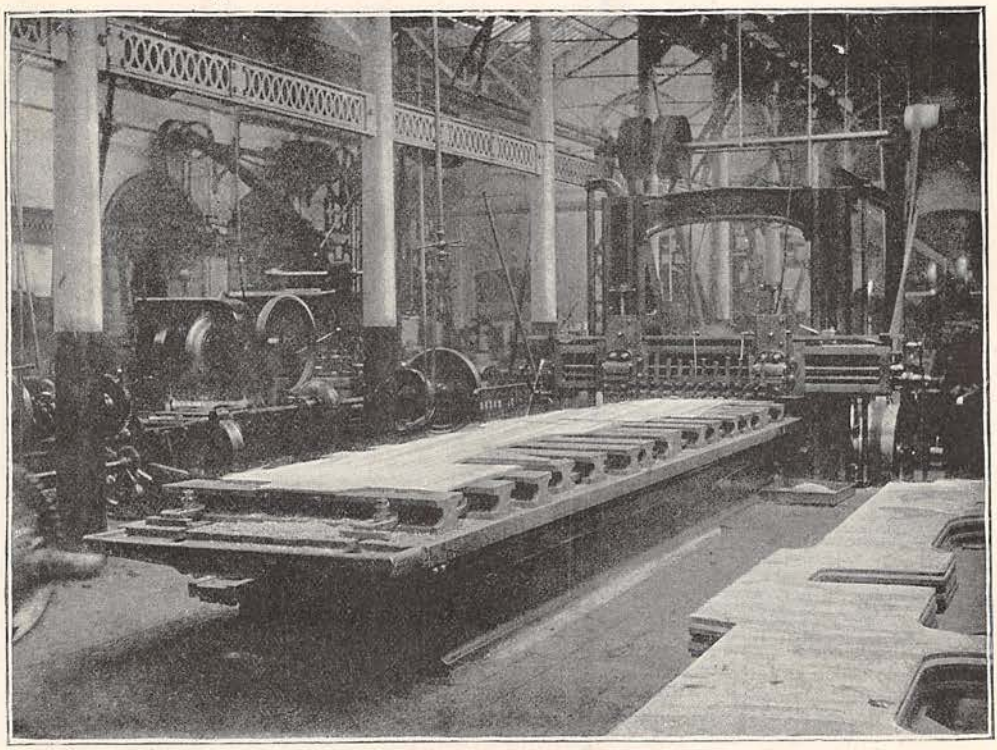
To see these and the thousand and one other operations, the sum total of which result in the construction, or repair, or demolition of rolling stock, we are taken here and there, through gloomy un-roomy forges, and vast well-lighted buildings (some of them seven hundred feet long), endeavouring, as we proceed, to absorb some few grains of knowledge from the full measure of information supplied by our cicerone; replying to the instructive description of the varied and various machinery with a kind of dumb show, since no small degree of caution is required by a stranger wishing to steer clear of the red-hot sparks, revolving wheels, and ubiquitous oscillating arms; and the air is too full of many noises to admit of intelligible conversation.

Noise, indeed, there is more or less everywhere throughout this busy hive; but the finest effects of genuine ear-splitting clatter are naturally met with in the riveting shops. Hydraulic riveters—so nicely balanced, and easily moved, that a little child might guide them—do all the work within their reach; and very prettily they do it, just giving one noiseless "squelch" with their great crab-like callipers upon the red-hot iron, and leaving a neatly shaped head where the long exposed end of the rivet previously protruded. But where these silent workers cannot operate, for lack of space or other reason, there *human* riveters are in all their glory; showing their appreciation of the pandemonium they create, by performing merry rataplans with

[1] Usually when the tyres burst their bonds the needle shows a pressure of sixty or seventy tons; but in some cases it reaches as high as one hundred and fifty tons.

their hammers at every moment of waiting. It is sad to think these men seem all doomed to be deaf; but on the whole this appears certainly a more merciful dispensation than if they were doomed to retain the faculty of hearing, unimpaired.

It would be a truly Herculean task to count all the lathes scattered over Works which employ upwards of nine thousand men. But the bulk of the lathes being congregated in the great fitting and turning shop (know as the R shop), by resorting thither we can get a general idea of the class of work done by these machines. It being the dinner hour when we entered, every wheel was at rest, and the grip of many vices relaxed. But scanning from the foreman's office window the area below, with evidences of the highest mechanical ingenuity spread before the eyes, it seemed plain



FRAME-PLATE PLANING MACHINE.

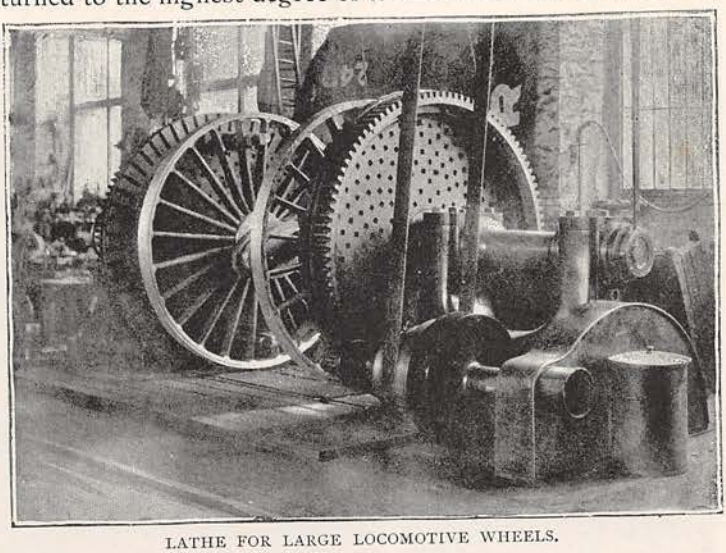
enough that those who pass their time in such pursuits as these have many tangible advantages over Hodge the labourer and cousin Jacky the miner.

Here "the pale mechanic" by no means pores over his lathe, with bent shoulders, contracted chest, and anxious gaze absorbed in the tool-point. He simply sets the machine at which he is posted upon a piece of work, sees that the cutter or borer or planing tool is doing its duty, and then leaves it to work its own sweet will till the task is completed, when he proceeds to provide it with fresh material.

There may be monotony in this, as in most forms of labour; but at least such an artisan is constantly knocking against other men engaged in other departments; the work going on around him is calculated to make him *think;* and if he sees fit to improve his mind or learn drawing, there are books in plenty in the Institute, and science and art classes well within his reach. Possibly he may not after all prove to be such a good all-round man, or such a desirable engineer for a steamer, as a fitter who has served in a smaller foundry, and practically gone the round of *all* the shops; but while railways continue, and machines to turn out the different items in their construction need men to tend them, his wages are sure, and he can always count upon a free Sunday as well as a weekly half-holiday.

Many objects attract attention in this exhibition of mechanics, but space only permits reference to one or two. Near the foreman's office, for instance, there catches the eye a compact machine apparently in the act of smoothing the crowns and

sewing on the ribbons of four white straw hats, symmetrically arranged on a little rest at each corner. These hats are bosses for wood wheels, and are manipulated by one cutter working on the outside, while another accurately finishes the rough-boring of the hole for the axle. A little way off are a series of lathes for equipping engine-cranks. The first of this series turns a crank at all parts of its length except where the crank-pins are to be. In this case the crank-shaft revolves, and the tools, six in number, are stationary. The next is for cutting out and shaping the crank-pins themselves, which are to be embraced by the brasses of the big ends of the connecting rods, and require to be turned to the highest degree of trueness and smoothness. In this case the crank-shaft being stationary, the work is performed by cutters fixed in a revolving disc. The space, which is observed already removed in the right-hand crank, is cut to a sufficient depth by the disc advancing while it rotates. After this operation is completed, the crank is caused to revolve slowly on the axis indicated by the intersection of the chalk lines (clearly shown on the left-hand crank), while the cutters, revolving at the same time, cut out a cylindrical crank-pin. To finish the pins, the crank is transferred to another machine, in which a cutter, revolving round the pin, imparts thereto a perfectly true and smooth surface. But even so the cranks are not finished, for the crank-webs have to be cut to the requisite curve This is done by yet another machine, the ingenious tool of which, while moving to and fro, and cutting both in its forward and backward path, follows the slotted curve seen at the left of the print, and thus effects the required shape in the crank-web.



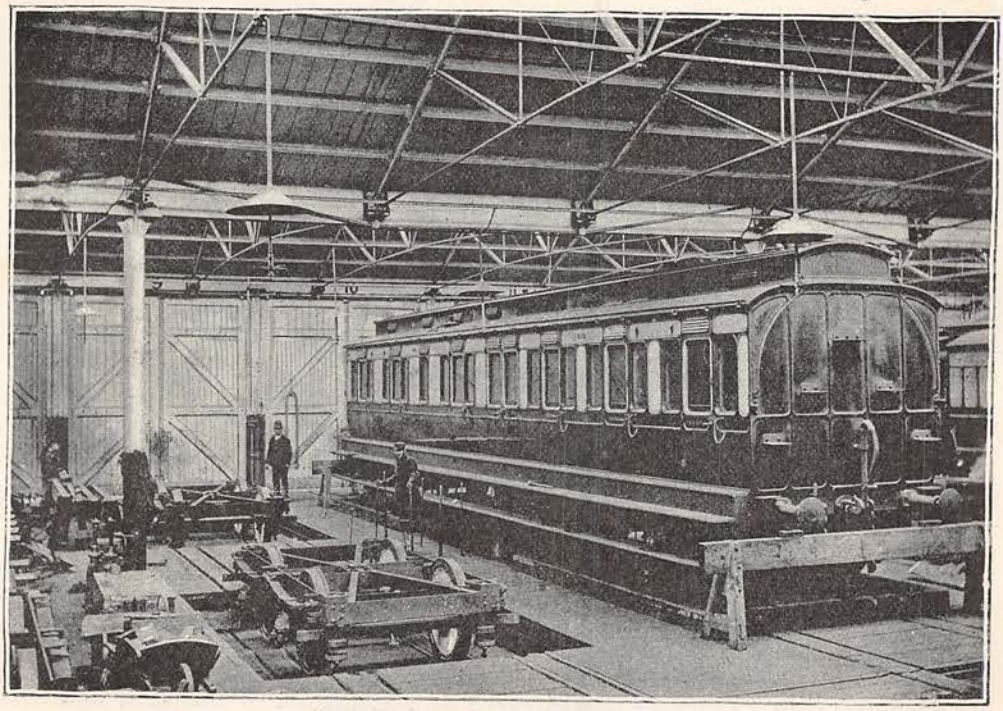
LATHE FOR LARGE LOCOMOTIVE WHEELS.

Here, too, new cylinders were being bored out—in pairs, side by side, like gun-barrels ; affording a fair illustration of that cramped arrangement of machinery, simply unavoidable in narrow-gauge engines with inside cylinders, which is of course obviated in the broad-gauge. If a new gauge were to be instituted throughout the country now, that gauge might not be seven feet, but it is fairly certain it would not be four feet eight and a half inches. Let a broad-gauge "eight-foot single," and a modern narrow-gauge engine be viewed from opposite their driving wheels, and both appear equally imposing objects ; but let a front view be taken of them from between the rails, and then the one stands up, well proportioned to the base of support, and rests with all stability upon the seven foot way, while the other seems to protest, top-heavily, at being squeezed in between the hard and fast limits of a *too*-narrow gauge.

Were we to make an arbitrary classification of the large machines, it would perhaps be into those which are remarkable for the cleverness of their action, and those which strike one with their smoothness of motion. Of the former division an excellent illustration is met with in the curvilinear wheel-slotting machine. Obviously the inside surface of a wheel-rim cannot be turned, as one would turn a solid disc (*i.e.* by revolving the whole wheel), because the spokes would be in the way ; hence the need of some other arrangement. But the almost human sagacity with which the tool in this machine does its work must be seen to be appreciated ; raising the fore part of its body upwards, and nibbling its way downwards, and repeating the same tactics in measured cadence, absurdly like some great hawk-moth caterpillar intently engaged upon a leaf. Among the latter division might well be placed the great plate-planing machine in V shop, where the whole frame-plate travels on its bed so evenly, that

throughout its length of thirty feet every inequality on its surface is uniformly removed. Also the big lathes for turning the rims of the engine wheels, and boring the inside of their tyres. A lathe that will tackle an eight-foot driving wheel, and turn its rim perfectly true, or bore its tyre by shaving off shreds of metal no thicker than paper—not, be it observed, while the wheel, or the tyre is spinning round, but only making, say, two revolutions per minute—can assuredly neither "wobble" much, nor be in any way loose in any of its parts.

In anticipation of the change of gauge on May 20—a day to be marked with the blackest charcoal by all good friends of the broad gauge—arrangements are



IN THE CARRIAGE BUILDING SHEDS.

already perfected for changing carriages from broad to narrow gauge within the space of *half-an-hour!* The bodies and frames of many of the carriages, at present running on broad-gauge rails, being already of narrow-gauge dimensions, it will suffice to substitute narrow-gauge bogies for those now in use. This will be effected as follows:—The carriages will be run into the changing shed in batches of about half-a-dozen; the floor of the shed, at the parts where the wheels rest, being capable of rising and falling. Arrived at their proper position, the bodies of the carriages will be raised clear of their bogie-frames by hydraulic power, and propped up so as to stand upon the supports when the wheels are removed, and then the platforms, bearing the broad-gauge bogies, having been lowered beneath the level of the floor, the bogies will be run underground to the contiguous pair of rails, elevated to the line-level, and run out of the shed. Pairs of narrow-gauge bogies will be then brought in on to the platforms, which will again sink under the floor, and pass up under the carriages; the whole being performed by hydraulic power.

This arrangement, the clever invention of some of the heads at Swindon, well illustrates the wide range of use within the capability of that water-pressure, which appears to be here utilized nearly to the same extent as steam; and serves also to show the ability of the staff to grapple with great undertakings.

THE MIDLAND RAILWAY LOCOMOTIVE WORKS AT DERBY.

By CHARLES HENRY JONES,
Assistant Locomotive Superintendent of the Midland Railway (Southern Division).

With Illustrations from photographs taken by Mr. SCOTTON, the Company's official photographer.

N 1844 the Midland Counties from Derby to Nottingham and Rugby, and the North Midland from Leeds to Derby amalgamated with the Birmingham and Derby, and became the Midland Railway. By the construction of new lines and the absorption of others the Midland has since spread out in every direction. Its main arteries connect Carlisle, Liverpool, and Manchester with London, York with Bristol and Bournemouth, and Swansea with Lynn, while its branches place it in communication with most of the important towns in the kingdom.

The Company's headquarters are at Derby, where all the principal workshops and offices are concentrated. Adjoining the station are large blocks of offices occupied by the General Manager, Secretary, Accountant, Superintendent of the Line, Goods Manager, Mineral Manager, and the Engineer. The directors, too, have their board-room at Derby, and the shareholders assemble there every half-year to hear their Chairman give an account of his stewardship. There is also the Midland Railway Literary Institute with its library and reading-room. Near the station are the Locomotive and Carriage Works, and the shops connected with the Telegraph and Signal Departments. The Company cannot, it is true, boast of steel works and rail mills like its big neighbour the London and North-Western, but its Locomotive and Carriage Factories are very extensive. Nothing can better illustrate the growth of the line than the following figures :—

1844.	Ground Area. Acres.	Covered Area. Acres.
Locomotive and Carriage Works	8½	2½

1891.	Ground Area. Acres.	Covered Area. Acres.
Locomotive Works	80	12½
Carriage „	86	24
Total	166	36½

Some idea, too, may be formed of the amount of work carried out in these two establishments by remembering that in them is built and repaired the great bulk of the rolling stock owned by the Company, which comprises 2,150 engines, 4,389 carriages, 104,908 wagons. If these were marshalled in a continuous line close coupled, they would form a passenger train thirty-four miles long with six miles of engines, and a goods train 370 miles long with thirteen miles of engines, or altogether one train 404 miles long, including nineteen miles of engines, which would reach from London to Edinburgh.

The Locomotive Department is presided over by Mr. Samuel Waite Johnson, who is in command of an army of 12,500 men. About 8,500 of these are drivers, firemen, cleaners, and mechanics stationed at eighty locomotive engine sheds at different places on the line, many of which have large workshops attached. Mr. Johnson has under his control 2,150 locomotives, 258 stationary engines, 235 stationary boilers, 787 hydraulic machines, 393 cranes of every kind, and all the turntables, water columns, pumping plant and other mechanical appliances throughout the system. He also superintends the manufacture and distribution of gas, the fire brigades and the maintenance of weighing machines. It will be seen that the office of Locomotive Superintendent is no sinecure. He is aided in the administration of his department by a Works Manager, two Assistant Superintendents (one over the Southern and the other over the Northern Division), thirty-three District Superintendents, a Secretary, Gas Engineer, and other officers. Nearly 4,000 men are employed in his department at Derby. Twenty-two stationary engines, total 2,400 horse-power, drive the machinery in the workshops. On the average forty new engines are built in the works every year, 120 rebuilt with new boilers, and from 750 to 800 undergo heavy repairs. An engine will

ENTRANCE TO THE MIDLAND WORKS, DERBY.

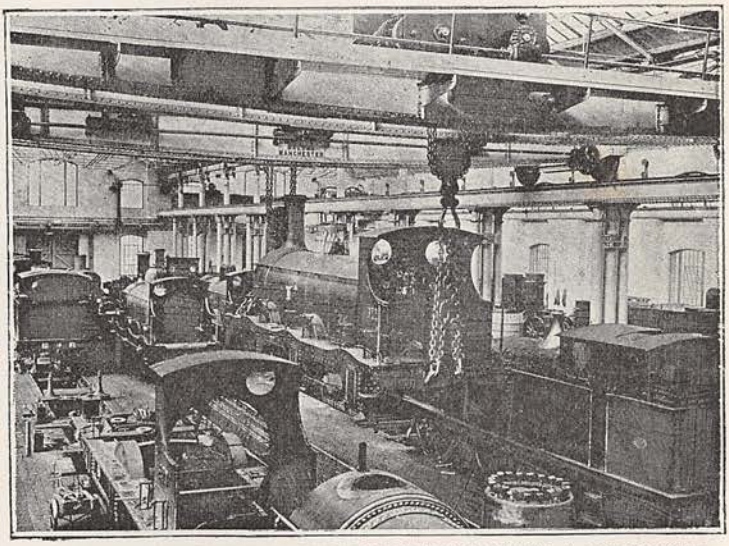
run eighteen months or two years with slight repair; the boiler, which is the most costly item, lasts on an average fifteen years, or it would probably be worn out after the engine has run from 350,000 to 500,000 miles.

The works are entered through the chief offices of the Locomotive Department, which are represented in the engraving. One hundred and twenty clerks are busy conducting the general correspondence, adding up wages, making innumerable returns of the miles run, fuel and stores consumed by the locomotives, and keeping records of all materials used and repairs done. Twenty draughtsmen are engaged in preparing plans, designing machinery, and making drawings and tracings for the workmen in the factory. A chemist and two assistants are constantly employed in testing metals, analyzing water, and conducting a variety of experiments to ascertain that the stores purchased by the Company are of the quality specified in the tenders. In another room samples of metal cut from boiler plates, wheels, tyres, axles, copper-plates, brass tubes, &c., are subjected to severe mechanical tests to gauge their quality. The machinery used for the purpose will exert a power of 100 tons per square inch, and the result, whether it be tension, compression, torsion or bending can be measured to one ten thousandth part of an inch. The samples after testing are carefully arranged and classified in glass cases, with their fractures exposed to view; a complete record is kept of all, so that the character of material supplied by the different manufacturers is always known. In the photographic studio, which is now an indispensable adjunct to large works, three artists are regularly employed photographing engines, machinery, tracings, and drawings, and taking views of the scenery and places of interest on the Midland route for the adornment of the carriages. Near the offices is the fire brigade

station, where a "Merryweather" steamer, which will throw 600 gallons per minute, is always in readiness to be despatched on a specially constructed truck to any place where a fire may break out upon the Company's premises. In a siding hard by is the breakdown train fully equipped with lifting tackle and all the necessary appliances to cope with a railway accident. Similar provision against fire and accident is made at other principal stations on the line.

Three large mess-rooms are provided for men who cannot go home for their meals. One, where smoking is allowed, will seat 700 men; another, in which it is forbidden, 500; the third, where religious services are held during breakfast, will accommodate 300. Each room has its own cooking apparatus, and the cooks always appear in clean white caps and aprons. It is often a matter of surprise to visitors to learn that the men seldom have any trouble in claiming their provisions, which they bring from home; the difficulty is easily got over by each man adopting some particular device by which he is able to recognize his own dish.

The Forge is seen to best advantage after dark. Smiths with their characteristic fisher caps and leather aprons are grouped round fifty glowing fires, while strikers, with sleeves tucked up, are swinging heavy hammers, which they bring down with unerring precision on the heated iron as the smith turns it about on the anvil. Down the centre of the shop are several steam hammers, the largest of which is capable of striking a blow of seven tons or cracking a nut without injuring the kernel. Scrap iron collected in the factory is worked up under this hammer. It is cut cold by huge shears into small pieces, which are cleaned by being rubbed against each other in revolving cylinders, then piled up on square boards in heaps of about 180 lbs. weight, laid in the furnace and heated into "blooms." These are pounded under the big hammer into "uses" or rough forgings of connecting and coupling rods, eccentric rod feet, cross heads, &c. About eleven tons weekly of finished forgings are made by the hammer. The shears which cut the scrap will snip a piece of cold iron three inches thick and five inches wide as readily as one might cut an apple with a pocket knife. The other steam hammers are largely used in stamping, out of wrought iron, spanners, draw bar hooks, and numerous other articles which were formerly forged by hand. A few blows squeeze them into shape between steel dies on the hammer and anvil blocks.



TWO 20-TON OVERHEAD TRAVELLING CRANES LIFTING A LOCOMOTIVE.

In the Spring Shop skilled men are at work bending and tempering steel plates, and setting them up into springs fastened together with wrought iron hoops. The importance of having springs carefully made, tested, and adjusted will be understood when it is borne in mind that upon them depends the smooth running of engines and tenders, which together weigh from seventy to eighty tons. The springs must be sufficiently elastic to counteract all the irregularities of the road, aggravated, it may be, by a speed of sixty or seventy miles per hour. The hoops or buckles expanded by heat are shrunk on to the springs by rapid cooling until they grip with a grasp of many tons. It used to take repeated blows of heavy hammers to remove buckles when springs were pulled to pieces for repairs; by the aid of hydraulic power they are now drawn off as easily as a lady takes off her glove, thus saving a vast amount of hard manual labour without injuring the plates and buckles. Four hundred engine and tender springs are repaired weekly exclusive of new work.

The Iron Foundry is served by four cupolas, two of which are constantly in use. To inspect the charging of one we step on the hydraulic lift and ascend to a stage twenty feet above the shop floor, where coke, pig and scrap iron are being tumbled into the mouth of the furnace. Under the influence of a strong blast of air all this is soon reduced to a seething mass of molten liquid. The pure metal falls to the bottom to be drawn off as required for use in the foundry, impurities rise to the surface and are run out from time to time. A fully-charged cupola holds about five tons of iron, ten cwts. of coke, and a small quantity of limestone.

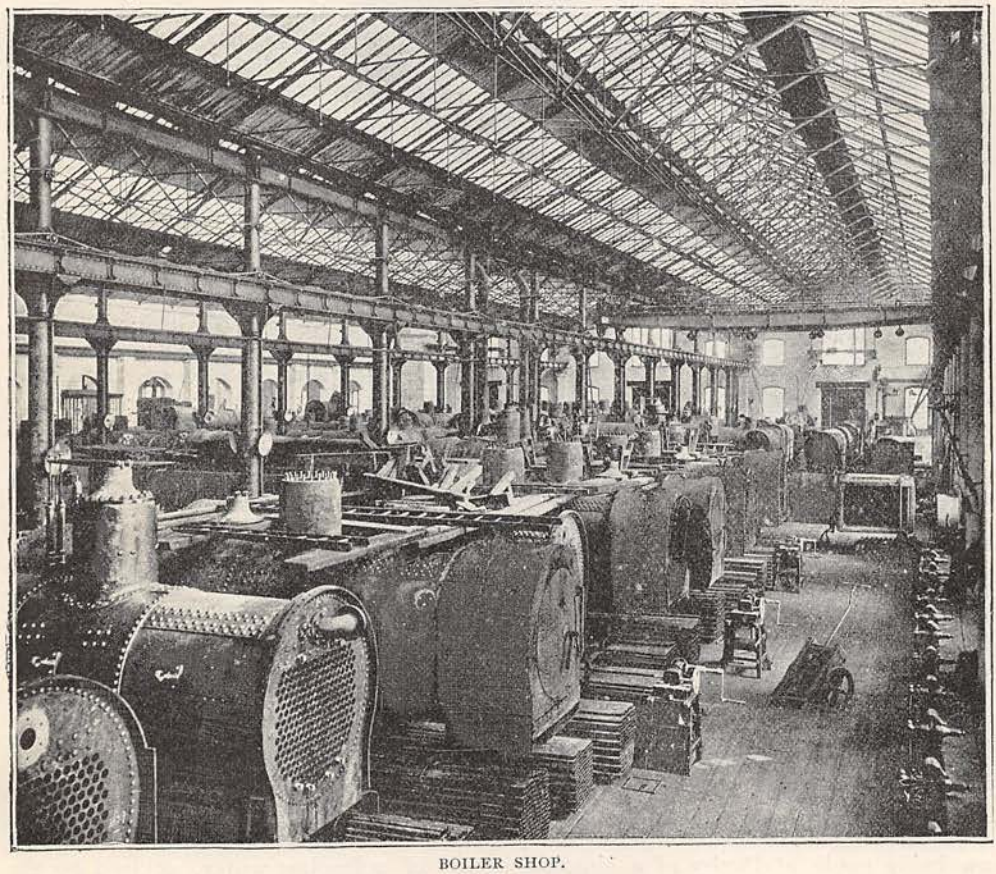
In the Foundry are a twenty-ton overhead travelling crane and three hydraulic five-ton cranes, which swing huge ladles of red-hot metal from the furnace to the

THE IRON FOUNDRY.

different moulds. The whole shop floor is covered with loose black sand. Red-hot metal castings, wooden patterns and moulding boxes lie in all directions. The steam and noise is somewhat bewildering to a stranger, but, notwithstanding the apparent confusion, every man knows his own particular duty. Let us stop and examine more minutely what is being done. Kneeling on the floor is a man with an iron box in front of him. He partly fills the box with sand from the floor, and inside lays a wooden pattern of an eccentric strap; adding more sand, he presses it tightly round the pattern until the box is quite full, then gently withdrawing the model, it leaves its impression in the sand. The lid is filled in like manner, fixed on the top of the box, and a hole is scooped out to admit the metal; soon two men make their appearance carrying a ladle of molten iron which they pour into the mould. When the iron has set the box is opened, the sand falls away, leaving a casting of the exact form of the wooden model. In this way are produced cylinders, water-pipes, lamp-posts, weighing machines, signal fittings, wheel splashers, engine chimneys, and every conceivable form of iron casting used on a railway. The castings vary in weight from sixteen tons to a few ounces. The weekly output averages 100 tons. Engine firebars and brake blocks are in constant demand, and are made in special

machines at considerably less cost than by hand. The firebars are cast with their faces downwards on a chilled plate, to insure that when in use the purest and strongest iron will be in contact with the fire. In the foundry is a machine for moulding toothed wheels without the use of wooden models. It is a most accommodating tool, dealing with bevel, spur, mitre, worm or helical teeth with equal facility, varying to any extent the size of teeth or wheels.

The Brass Foundry is a smaller building. It contains twenty-four furnaces below the level of the floor. The articles produced, such as water gauges, axle brasses, lubricators, brake fittings, steam whistles, &c., being of light weight, no heavy lifting tackle is required. The crucibles in which brass is melted hold 120 lbs. each ; they are

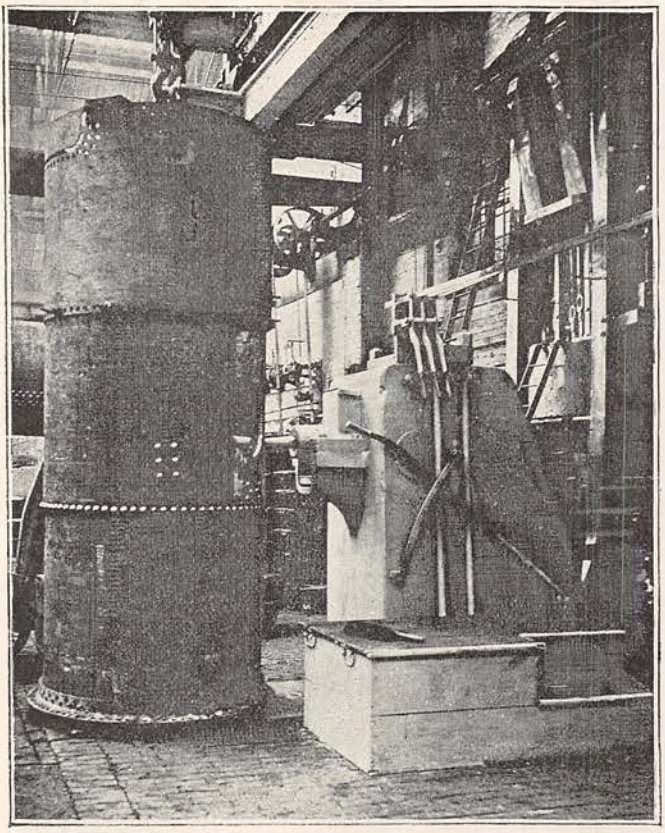


BOILER SHOP.

readily lifted out of the furnaces and carried to the moulds by hand. Some of the brass axle-bearings are coated in this shop with a more durable white metal. A useful and interesting little machine is at work here. At the bottom of a long wooden box revolves a spindle with magnets fixed spirally round it ; sweepings from the floors of the turning and fitting shops are poured through a hopper into the box, the bits of iron and steel are picked out by the magnets, and revolving brushes sweep them off into a separate tray, leaving the brass, which is of considerable value, to run out at a side aperture for re-use. Sixty men work in this shop, and twelve tons of castings are turned out weekly. The Coppersmiths, Tin and Pattern Shops are all interesting, but space will not admit of any description of them.

In the Boiler Shop 460 men are employed. The barrel of a large new pattern boiler contains 246 copper tubes 10 ft. 6 in. long and $1\frac{3}{4}$ in. in diameter. A strong blast created by the exhaust steam from the cylinders draws the flames and hot gases from the furnace through these tubes into the chimney. When the engine is in steam all the tubes and hot copper plates of the inner fire-box are covered with water, and they together give such a large heating surface that steam is rapidly generated. When

the boiler shop door is opened the din of the riveting which greets the ear is deafening. About eighty boilers and tender tanks are in various stages of construction. On one side is a long row of smiths' fires at which is done all the forging and welding in connection with the boiler work. Here are ponderous machines for shearing, punching, drilling, and flanging iron plates and planing their edges. There are, besides, rolls through which plates are repeatedly passed until they assume a cylindrical form. Looking upwards one sees a boiler barrel 4 ft. in diameter and 10 ft. 6 in. long suspended vertically from a travelling crane, which carries it across the shop to the steam riveter, as shown in the illustration. The line of holes at the junction of two plates of the barrel is brought between the steam plunger and the anvil; as red-hot rivets are inserted by one attendant another opens the valve and causes the plunger to dart forward to clench the rivet with a thud. One blow on each rivet is sufficient to hold the plates so tightly together that when steam is got up in the boiler at a pressure of 140 to 160 lbs. per square inch, a leakage in the joint will rarely be found. Boilers and fireboxes are built up, the tubes put in, and all gauges, taps, and other mountings fixed; in fact they are finished in every respect and tested before leaving this shop. New boilers are tested with hydraulic pressure to 220 lbs. per square inch, also with steam to 160 lbs. After the locomotive gets into traffic the boiler is periodically examined and tested. Boilers using hard water soon get incrusted with a coat of lime necessitating frequent repairs. To prevent this a trial on a large scale is now being made at Derby of a simple process of softening water, devised by the Company's chemist and by one of the engineers in the works.

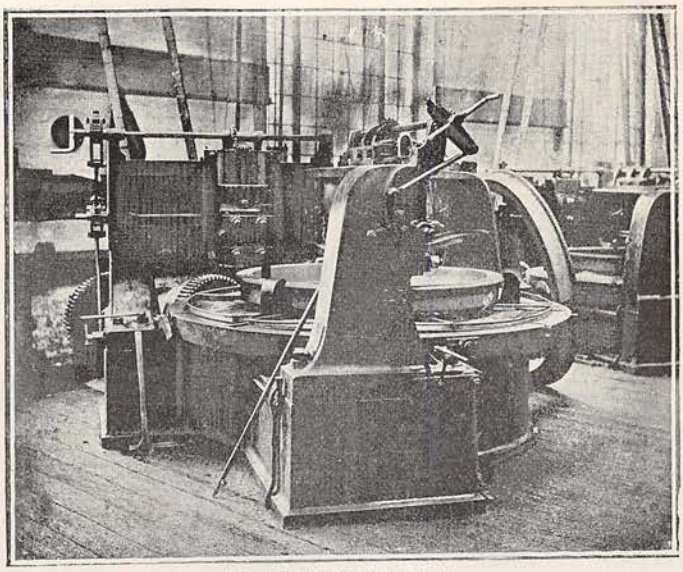


STEAM RIVETER.

In the Turning and Press Shops, wheels, tyres, and axles, received from the makers in the rough, are finished and put together by some of the most powerful machines in the works. A rough forging of a steel crank axle weighing 1 ton 8 cwts. revolves slowly in a big lathe, while seven tools pare down and round its surface. It has to be slotted, planed, drilled, and turned again before it is finished; its weight will then have been reduced by half-a-ton. Passing several other machines for centring and turning axles, cutting key-ways in axles, and turning, facing, and boring wheels and tyres, also numerous lathes and slotting machines, we come to the mill for boring wheel tyres (see illustration). A tyre is laid on a round iron table; by turning a screw three cramps, working in radial grooves, close simultaneously, grip the tyre, and fix it exactly in a central position on the table. The mill is then set in motion; as the table revolves, three tools in slide-rests turn the inside of the tyre to the standard dimensions and cut the "lip" which helps to secure it to the wheel.

In an adjoining shop is performed the operation of shrinking tyres on wheels. The furnace door is lifted, and a hot tyre 7 ft. 6 in. in diameter is dragged out of the flames to a "bosh" or circular iron trough let into the floor; a pair of wheels, com-

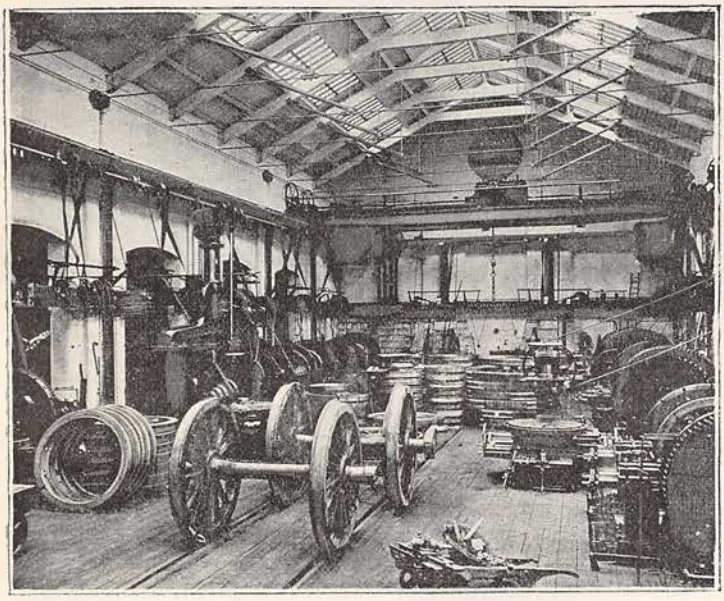
plete except the tyre, and fixed on an axle, is suspended from an overhead crane one wheel over the other; and lowered until the bottom wheel drops inside the heated tyre, which is then slightly cooled by water. Before heating the tyre is a shade smaller than the rim of the wheel, but the heat expands it sufficiently to admit the wheel, and the contraction whilst cooling shrinks it tightly on. Some very unpretending hydraulic machines in this shop are quietly pressing wheels on and off their axles, each exerting a force of 500 tons.



TYRE-BORING MACHINE.

The Machine, Erecting, Paint, and Millwrights' Shops are all under one roof; the whole building is 450 feet square, and is one of the recent additions to the works.

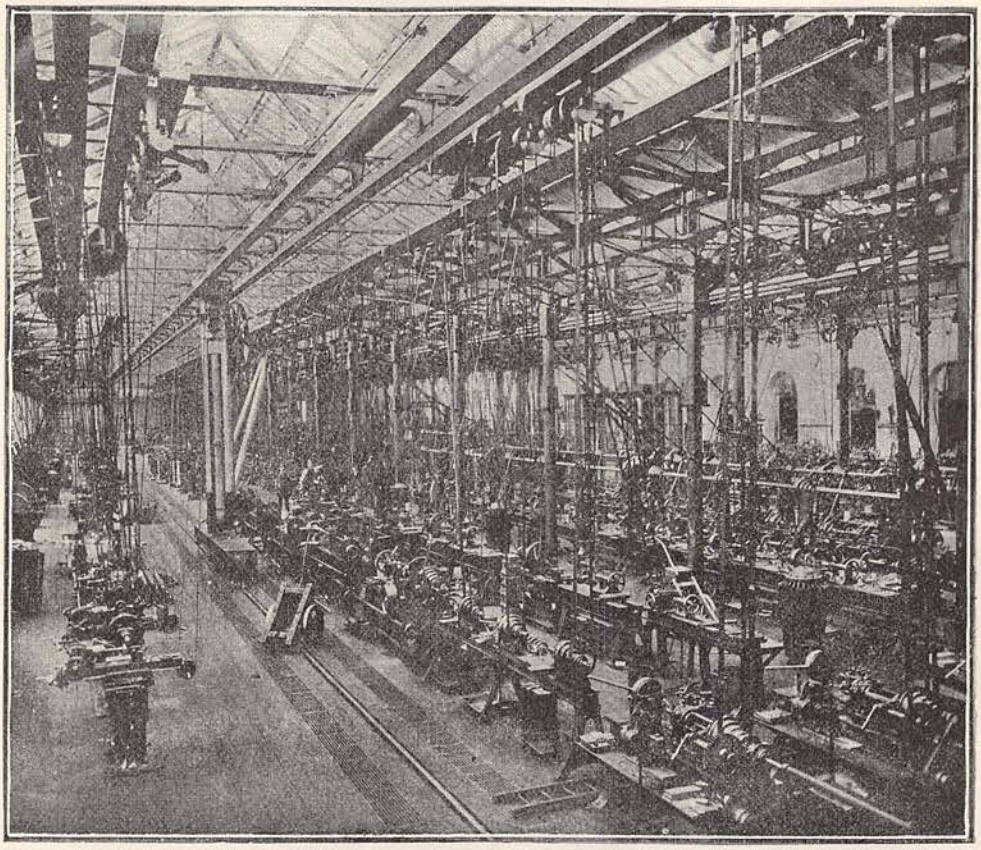
In the Machine Shop are over 400 machines capable of accomplishing almost everything which human ingenuity has devised in the way of cutting and shaping metals. Boring tools slowly worm their way through locomotive cylinders, eighteen inches in diameter, and skim the inner surface as smooth as writing paper. Steel plates, twenty to twenty-five feet long, three feet wide, and one inch thick, lie, seven deep, on the tables of slotting and drilling machines, while several tools, operating together, shape them into engine frames and pierce them with hundreds of bolt holes. Walking cranes promenade the shop, stopping here and there to pick up rough castings and forgings, some three tons weight, and place them gently on the machines, or remove the finished articles. The "sand blast" is at work here, sharpening blunted cutting edges of fitters' files at the rate of six or seven dozen per day. To ensure accuracy and uniformity of workmanship hundreds of steel gauges which will measure to the ten-thousandth part of an inch are provided for the fitters and machinists.



WHEEL SHOP.

In the Erecting Shop are nine lines of rails running throughout the 450 feet length; on each line is standing room for twelve engines, so that the building accommodates 108 locomotives. Cranes, capable of carrying an engine bodily to any part

of the shop, run on gantrys overhead. The method of driving the cranes is a remarkable example of the conversion of speed into power; a rope only one inch thick running at 2,000 feet per minute lifts a weight of twenty-five tons. All the component parts of an engine, which we have seen in process of manufacture, are brought to the erecting shop to be built up into the complete locomotive. Frames, cylinders and cross-stays are bolted together and the accuracy of their adjustment tested by careful measurements. The finished boiler is then lowered into position between the frames, the foot-plates and weather screens fixed, the valve motion put up, and the wheels rolled under the frame. All that is then required is to fix the outside lagging and paint the engine, after which it is ready for traffic. Usually a gang of



MACHINE SHOP, SHOWING TRAVELLING CRANE.

four men and two boys work together at each engine; it takes about three weeks to erect it. All labour is paid for by piece-work. The leading hand of each gang contracts to build the engine (labour only) at a given price. During the progress of the work he and his assistants receive stated weekly wages; when finished, the balance is equitably divided.

In the Paint Shop thirty or forty locomotives are being made spick and span with four coats of paint and three of varnish ready to appear in public. Formerly green was the distinctive colour of Midland engines, but now they are reddish-brown to match the carriages. They require repainting every three or four years, and between 600 and 700 annually undergo that process.

In the Millwrights' Shop an endless variety of work is done. Scattered over the floor are electric light and hydraulic engines, travelling cranes, sewing machines for waggon sheets, chaff cutters, warehouse cranes, capstans, turntables, water tanks, &c., &c., all in course of construction or under repairs. The millwrights execute all repairs to the machinery and shafting throughout the line.

Some years ago the Midland Company acquired the original Derby Gas Works,

adjacent to the station, from which, in 1891, 105,460,000 cubic feet of gas were supplied to the Company's works, station, offices, sidings, and all the signals in the neighbourhood.

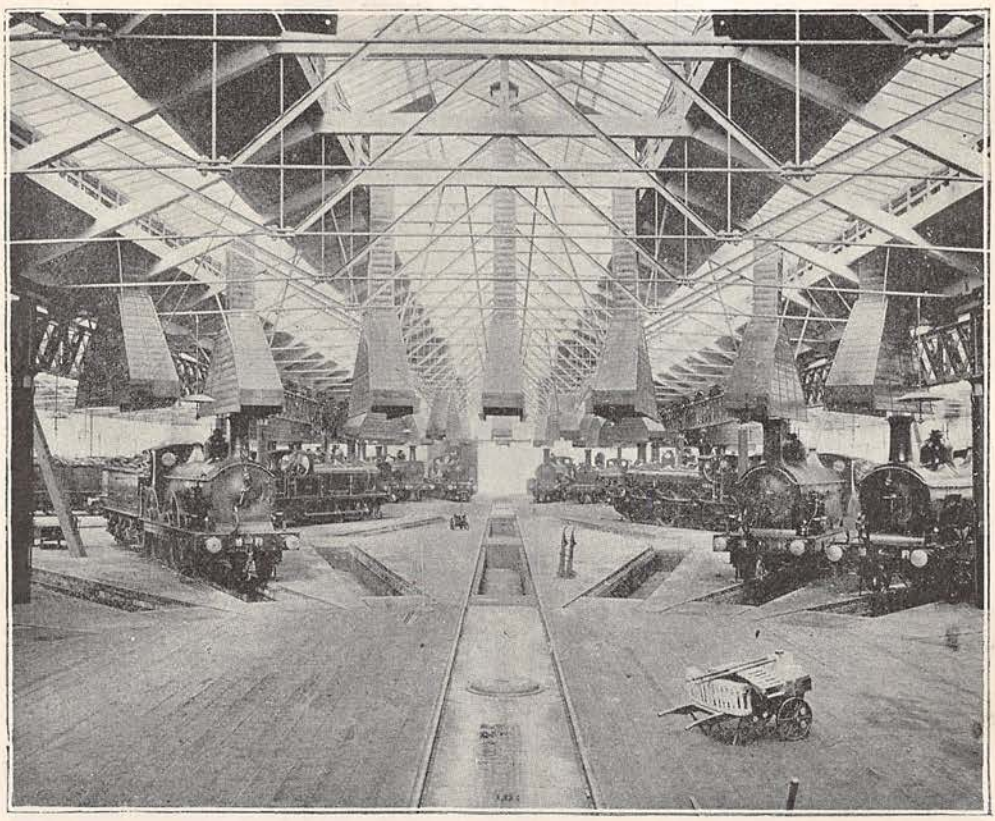
There are four Running Sheds at Derby, and 150 locomotives are stabled in them. The one which is the subject of our illustration holds forty-eight engines; there are two turntables in it, and around each radiate twenty-four pits over which the engines stand on rails whilst they are cleaned and steam is got up. Drivers and firemen are coming to or leaving their work at every hour during the day and night. After signing on duty they take in coal and water, oil their engines and then join their trains. When booking off duty the driver enters on his "sheet" the quantity of coal, oil, and

ERECTING SHOP.

waste with which he was supplied, and the miles he has run. He also reports repairs required to his engine, and any unusual circumstance that may have happened on the journey. There are 2,833 locomotive drivers, 2,557 firemen, and 1,340 cleaners on the line, exclusive of numerous steam-risers, boiler-washers, gland-packers, bar-boys, and labourers connected with the running sheds.

The types of locomotives on any line should be as few as possible, and the parts interchangeable, as in case of the failure of an engine at any place, the defective fittings require to be renewed from headquarters without delay. Besides, engines are constructed more cheaply and expeditiously, when the same drawings and models are used, and when the workmen are constantly engaged repeating the same articles and putting them together without special fitting. The standard types on the Midland are shown in the illustrations. The express passenger engine No. 1,853 was exhibited in the Paris Exhibition, 1889, and its designer, Mr. Johnson, obtained the Grand Prix. This engine has a single pair of driving-wheels and a bogie in front; it was specially constructed for the express service between London, Nottingham, and Leeds, booked at fifty-three and a half miles per hour, with loads of from nine to thirteen coaches. Engines of this class have been performing the work for several years with an average

consumption of twenty to twenty-three lbs. of Derbyshire coal per mile ; they have frequently taken from thirteen to sixteen coaches. In their design economy of fuel, steadiness and facility of working have been considered of most importance, so that the attention of drivers and firemen may be distracted as little as possible from the performance of their duties. The engines are fitted with automatic steam and vacuum brakes, also with steam-sanding apparatus, which in a great measure overcomes the tendency sometimes found with "single" engines to slip on a greasy rail. They are provided with an automatic sight feed lubricator, which enables the driver to see what quantity of oil is being used, as it rises through a glass tube drop by drop



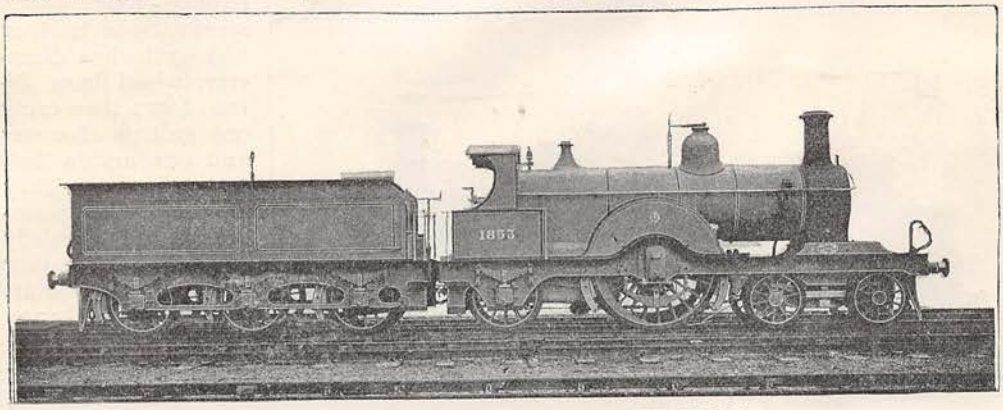
ENGINE STABLE OR RUNNING SHED.

on its way to lubricate the valves and cylinders. The following are the leading dimensions of the engine :—

Diameter of cylinders	18½ in.
Length of stroke	26 ,,
Diameter of driving wheels	7 ft. 6 ,,
Total length over buffers	52 ,, 0 ,,
Working pressure of steam	160 lbs. per sq. in.
Tubes	242 ea. 1⅝ ins. diameter.
Heating surface, tubes	1,123 sq. ft.
,, ,, fire-box	117 ,,
Total	1,240 ,,
Grate area	19½ sq ft.
Weight in working order, engine	43 tons.
,, ,, ,, tender	35 ,,
Total	78 ,,

Weight on driving-wheels	17½ tons.
Water capacity of tender	3,250 galls.
Coal ,, ,,	3½ tons.

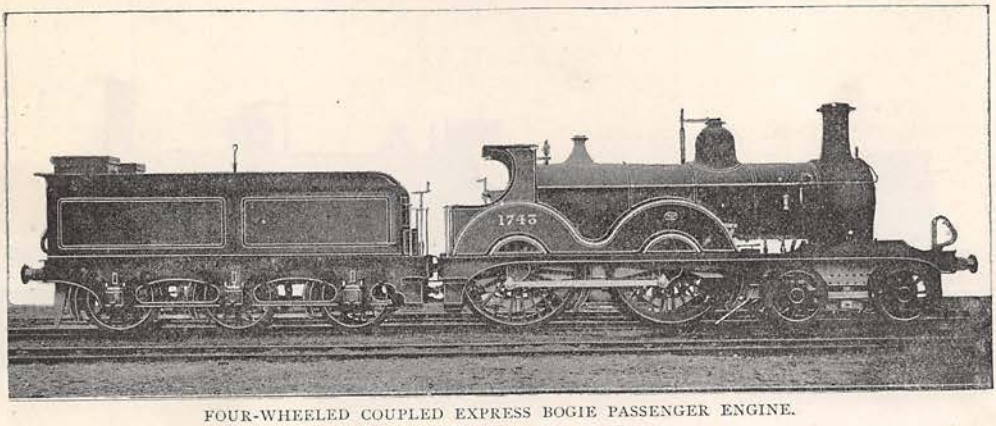
The four-wheel coupled bogie tender engine No. 1,743 has eighteen-inch cylinders, twenty-six inch stroke, driving and trailing wheels seven feet diameter, boiler pressure 160 lbs. per square inch, the tender carries 3,250 gallons of water and three and a half tons of coal. It is a representative of the type of engines which do the heaviest



SINGLE-WHEEL EXPRESS BOGIE PASSENGER ENGINE.

passenger work on the main line. They are daily running between London, Leicester, and Leeds, with from twelve to twenty vehicles, at a booked speed of fifty miles per hour. An engine of this class obtained for Mr. Johnson the gold medal at Saltaire in 1887. It has the honour of being called after Princess Beatrice, who opened the exhibition, and is the only engine on the line which is distinguished by a name ; the rest are known by their numbers. The "Beatrice" took Her Majesty from Derby on her way to Scotland in May 1891.

The four-wheel coupled bogie passenger tank engines, of which No. 1,636 is an



FOUR-WHEELED COUPLED EXPRESS BOGIE PASSENGER ENGINE.

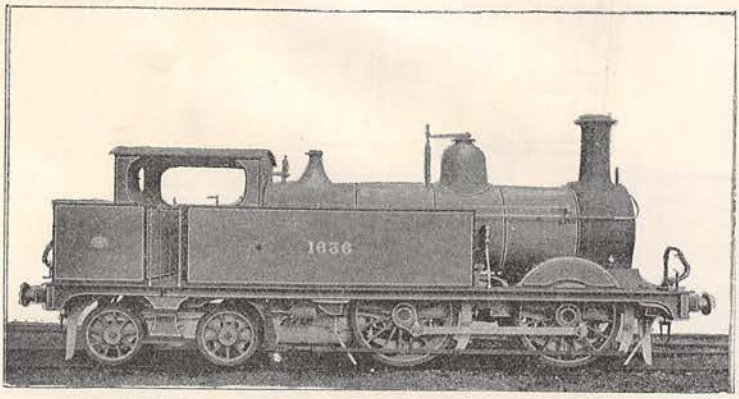
example, have eighteen-inch cylinders, twenty-four inch stroke, leading and driving-wheels five feet three inches in diameter ; they carry 950 gallons of water and one and a half tons of coal. They work "shuttle" trains on branch lines where the runs are short and frequent, and there is not time for turning at the terminal stations. Similar engines fitted with apparatus for condensing exhaust steam in the tunnels work the Midland trains over the Metropolitan line.

The six-wheel coupled tender engines of No. 1,700 class have eighteen inch cylinders, twenty-six inch stroke, wheels four feet ten inches in diameter. Their tenders hold 2,950 gallons of water and four and a half tons of coal. They are built for mineral traffic, and are capable of hauling forty-five loaded coal wagons (600 tons)

on a moderately level road at a speed of twenty miles per hour. The standard goods engines are of the same construction, excepting that their wheels are five feet two and a half inches diameter.

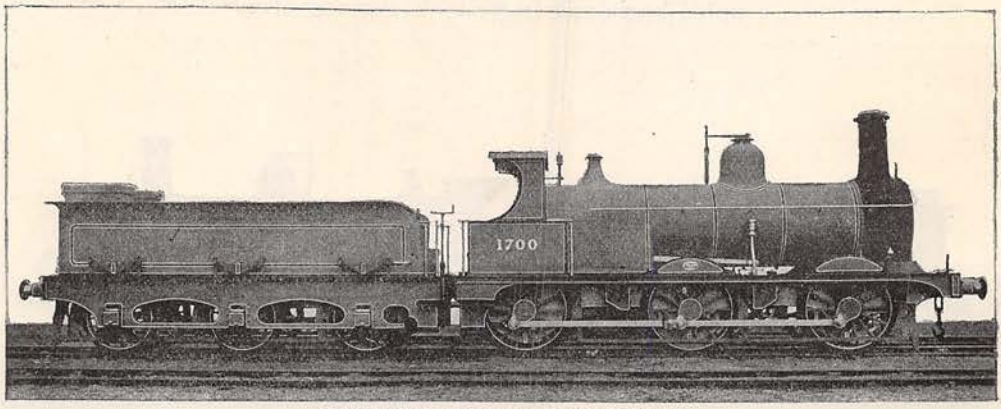
Both goods and mineral engines are fitted with the steam-brake applied to all the wheels of the engine and tender ; some of the goods engines have also the vacuum brake, as they are frequently required in the summer time to work heavy excursion trains.

The six-wheel coupled tank engines like No. 218 have seventeen inch cylinders, twenty - four inch stroke, wheels four feet six inches diameter, wheel base fifteen feet ; they carry 900 gallons of water and one and a half tons of coal. They are fitted with steam-brakes, and are chiefly used for shunting purposes ; they start and stop quickly and move heavy loads, essential qualifications for sorting traffic with despatch. These engines also work goods and mineral traffic over branch lines which have exceptionally steep gradients.



FOUR-WHEELED COUPLED BOGIE PASSENGER TANK ENGINE.

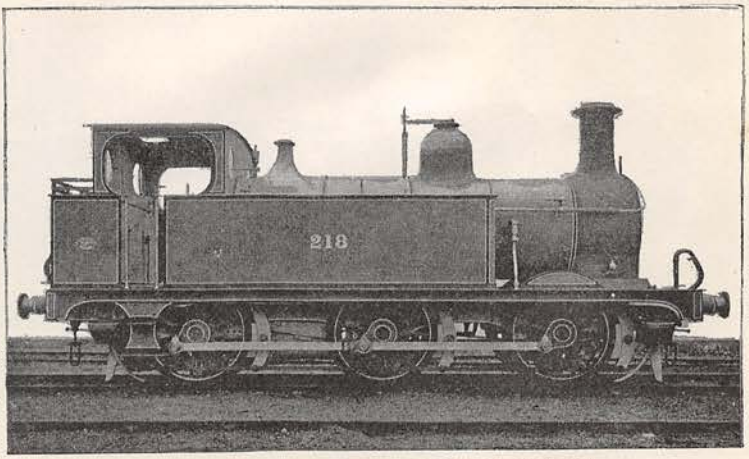
The four-wheel tank engines of No. 1,322 class, fitted with a steam-brake, have thirteen inch cylinders, twenty inch stroke, leading and driving wheel three feet nine inches diameter, carry 400 gallons of water and eight cwts. of coal. They are useful in dock and brewery yards, as the wheel base (seventeen feet) is so short that they will travel round any curve over which a wagon will pass.



SIX-WHEELED COUPLED GOODS ENGINE.

The composite carriage No. 916 on two six-wheeled bogie trucks, was exhibited with engine No. 1,853 at the Paris Exhibition, 1889. It is one of the ordinary type, containing three first class, three third class, lavatory, and guard's compartments. It is fitted with automatic vacuum continuous brake and electric light. The carriage is fifty-six feet long over the body, eight feet wide, seven feet high, weighs twenty-four tons thirteen cwts., and will accommodate sixteen first class and twenty-eight third class passengers. The first class compartments in this carriage are samples of different styles adopted for the Midland Company's stock. That for ladies is upholstered in brown plush, the non-smoker's in blue woollen carriage-cloth, the smoker's in crimson morocco ; the third class compartments have crimson and black linings as in the ordinary Midland carriages. In the guard's compartment is a hand-

brake, a valve for applying the continuous brake, a switch for controlling the electric light, and appliances for communicating by cord with the driver. The under-frame is of oak, the floor, partitions, roof, and inside casing red deal, the outside panelling and mouldings Honduras mahogany. Bogie trucks are chiefly wrought iron, tyres and axles Bessemer steel, wheel discs of teak wood segments, the bosses cast iron. The axle-boxes are so arranged that the brass bearings can be taken out and replaced without lifting the carriage.



SIX-WHEELED COUPLED GOODS TANK ENGINE.

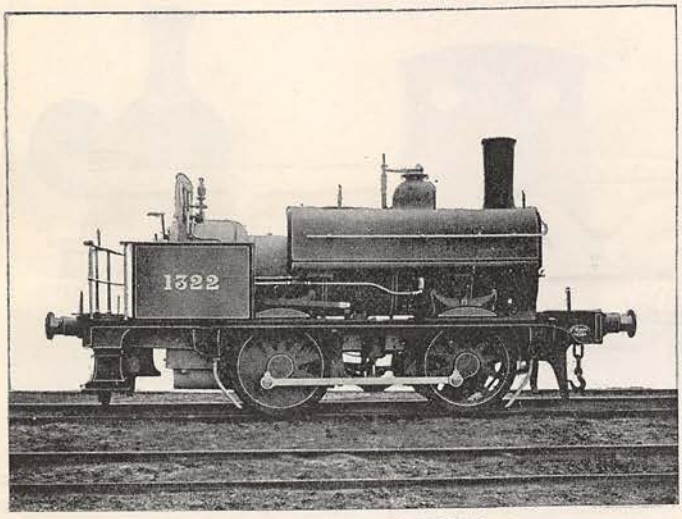
The Midland is frequently spoken of as the "Pioneer" Company, a title fairly earned by the beneficial changes in railway practice which it has initiated.

In 1872 the Midland decided to allow third class passengers to travel by all trains at the rate of a penny a mile; this change, inseparably connected with the name of Sir James Allport, is a great boon, especially to the working classes.

In 1874 came the abolition of second class carriages in order to reduce the weight of the trains, which had become abnormally heavy through the great increase in third class passengers. A comparison of the number of passengers carried in 1874 and 1891 is striking:—

	1st Class.	2nd Class.	3rd Class.	Total.
1874	1,204,377	2,703,420	20,316,346	24,224,143
1891	1,290,696	—	36,772,294	38,062,990

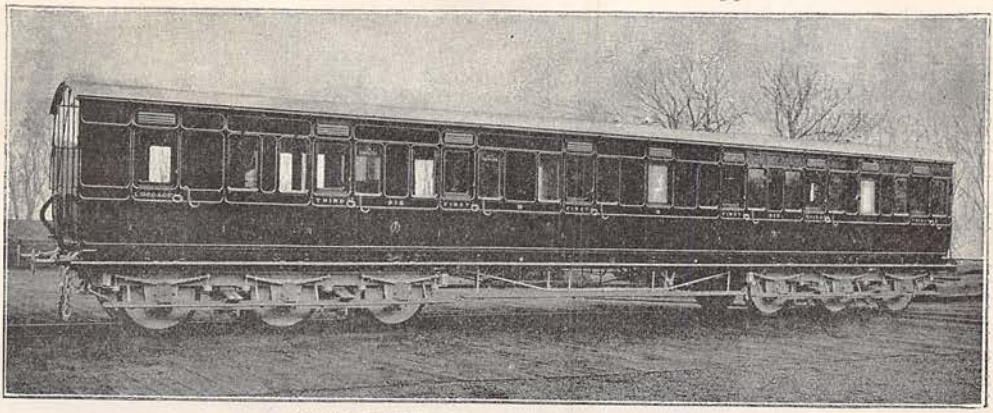
In 1881 another very important change was resolved upon by the Midland Board, viz., the purchase by the Company of private owners' wagons. So long as nearly all the large traders possessed their own wagons they were of course exclusively used by them. For example, a truck loaded with coal from Derbyshire to London had to be returned empty to the colliery, but when it became the property of the Midland Company it could be loaded in a contrary direction or sent elsewhere. Formerly an immense amount of shunting was required to sort out the right wagons for the different collieries, &c., whereas when all traders are served from one common stock that is avoided. Another consideration which had great weight with the directors was that when wagons were under the control and supervision of the Company's own officers, they could rely upon their being kept in a more efficient state of repair. The wisdom of the course adopted has been made manifest by a marked reduction in the working expenses, and a singular immunity



SMALL GOODS TANK ENGINE.

from accidents through the breaking down of trucks in transit since the change was made.

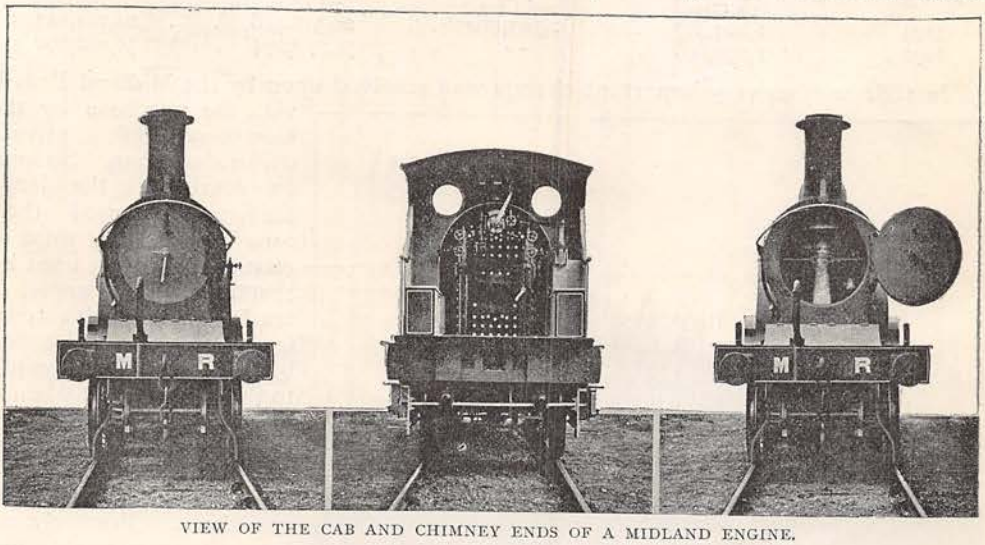
In 1875 a trial of competitive railway brakes was made by the Royal Commissioners on Railway Accidents on the Midland line near Newark. The result was a death-blow to hand-brakes. It was shown that a train travelling on a level road at forty-five miles per hour could not with the ordinary hand-brakes be stopped in less than 800 or



TWELVE-WHEELED COMPOSITE CARRIAGE.

1,000 yards, whilst any good continuous brake would stop it in one-third that distance. Since that time the whole of the Midland passenger stock has been fitted with the continuous brake. The system adopted is a steam-brake on the engine and tender, combined with the automatic vacuum on the carriages. One movement of the handle on the engine or in the guard's van applies both brakes simultaneously.

Dining-Room and Sleeping Cars and Lavatory Carriages have been introduced;



VIEW OF THE CAB AND CHIMNEY ENDS OF A MIDLAND ENGINE.

many of the trains are lighted with gas or electricity, and in the hope of increasing the comfort of the passengers the Locomotive and Carriage Superintendents are now experimenting with a new contrivance for warming the carriages in cold weather with hot water from the engine boiler. Two pipes, with suitable couplings between the vehicles, run throughout the train; the driver charges them by opening a special valve on the engine, which allows the hot water to flow down one pipe and return to the tender tank through the other. After a few minutes he slightly closes the valve, thereby reducing the supply of hot water to an exceedingly small quantity, but sufficient to keep up the circulation. No water is wasted, as, after passing into the

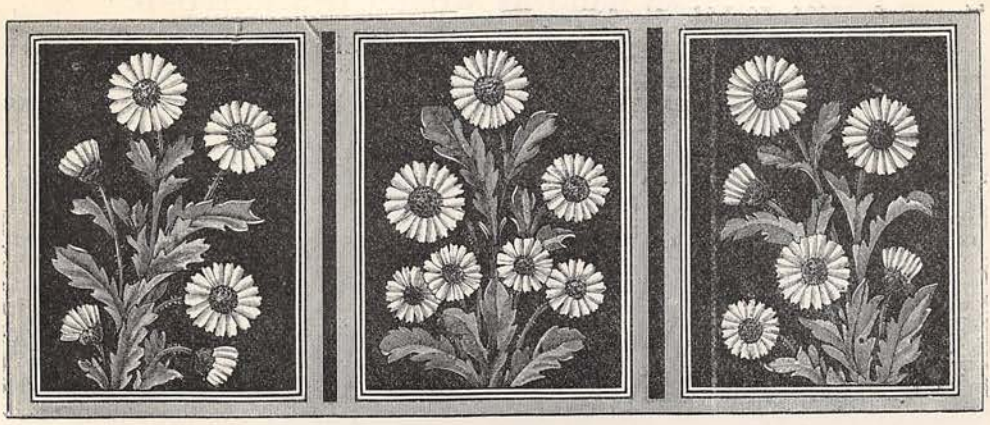
tender, it is injected into the boiler again. Very little steam is required to maintain an even temperature throughout the train. By a simple arrangement the pipes are always emptied when the vehicles are uncoupled, so there is no chance of the water freezing in winter. Two trains fitted with this warming apparatus have been running for some time between London and Bradford; so far the result has been satisfactory. It is to be hoped that foot-warmers will soon be relics of the past.

The following statistics will give some idea of the magnitude of the Midland Company :—

Capital	£95,032,250
Revenue per annum	£9,121,756
Expenditure „	£5,011,413
Miles operated on	1,942
Train mileage per annum	40,902,305
Engine „ „ „ (including shunting)	55,290,560
Coal consumed (tons)	1,056,793
Number of persons employed by the Company, including 12,538 in Locomotive Department, and 5,914 in Carriage and Wagon Department	52,000
Engines owned	2,150
Carriages „	4,389
Wagons „	104,908
Carts „	4,052
Horses „	4,462
Passengers carried annually	38,062,990
Season ticket holders	47,643
Tons of goods and minerals carried annually	31,341,019
Number of stations, exclusive of those owned jointly with other Companies	550
Number of signal cabins	1,459
„ signal levers in use	16,725
Weighing machines, ranging from the 80-ton machine which registers the weight on each pair of wheels of a locomotive, to chemists' scales which weigh to the fraction of a grain	3,200

The Midland Company is quite abreast of the times with regard to the use of electricity. About 60,000 batteries and 14,000 instruments (including nearly 1,000 telephones) are used on the line for transmitting messages, working the block telegraph, and indicating whether signals which cannot be seen by the signalmen are "on" or "off," or whether the lights are burning in them. In 1891, over 12,000,000 messages passed over the Company's wires. Eight trains fitted with the electric light are running daily, three passenger stations, five large goods depôts and three hotels are already lighted by electricity, and it has been decided to light the chief offices at Derby by it also. In the Midland Grand Hotel, London, are 1,100 incandescent lamps. The Adelphi Hotel, which the Company has recently acquired in Liverpool, has been fitted throughout with telephones, 210 being in use. Each room is arranged on an inter-communication system, so that conversation can be carried on between one room and another. A telephone attendant is located on the ground floor, and has the necessary switch-boards and numbers under his complete control. In establishing this system thirty-three miles of wire were laid in the house.

The Midland Company is not unmindful of the welfare of its employés. It subscribes liberally to the Superannuation and Friendly Societies, exclusively established for them; last year its contribution to the Friendly Society was over £11,000. The drivers, firemen, signalmen, and many of the clerks receive at stated periods handsome bonuses for good conduct or economical working. The servants of the Company and their families have the privilege of travelling as often as they please when off duty at a quarter the ordinary return fare, and once a year they may claim a free pass for any journey they may select on the system. The Company, too, has given encouragement to the St. John Ambulance movement; and between two and three thousand men have qualified themselves to administer first aid in cases of accident.



GREAT EASTERN RAILWAY WORKS AT STRATFORD.

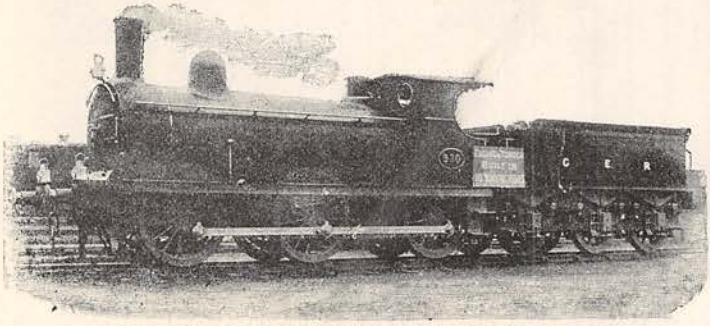
By ALEX. P. PARKER, Secretary to the Locomotive Superintendent.

With Illustrations from Official Photographs.

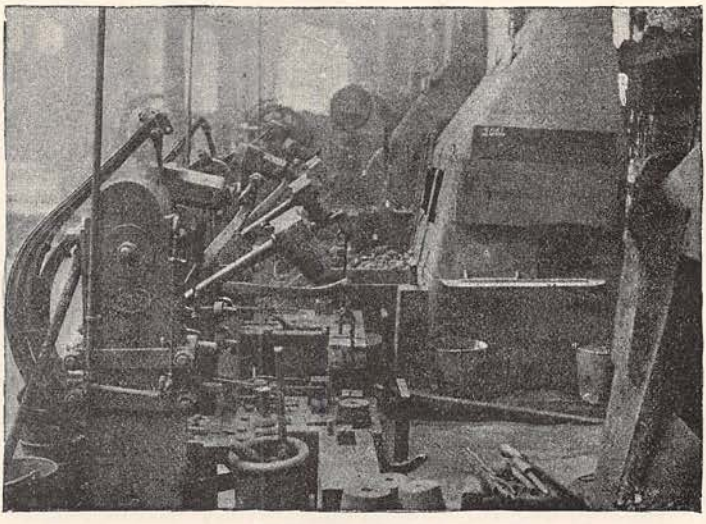
THE Eastern Counties Railway, the forerunner of the present Great Eastern, was incorporated on July 4th, 1836, and as scheduled was the longest line which had yet obtained the sanction of Parliament. It was constructed to a five-feet gauge, and commenced its career as a public carrier on June 20th, 1839, when it opened from Mile End to Romford, at which latter station the first repairing shops were built. It is a matter of history that the anticipations of the first Chairman, who held out to an exceptionally sanguine proprietary "a prospect of one of the proudest triumphs of the march of science," were not fulfilled, and we will lower the veil over its misfortunes and misdeeds. Suffice it to say that in 1862 it was considered expedient to consolidate the wisdom of some eighty Acts of Parliament by an amalgamation scheme under a new nomenclature. But the "Great Eastern" phœnix which arose from the ashes of the Eastern Counties was not at first more successful than its progenitor, and in 1867 the locomotives were seized at the instance of creditors, and loaned to the Company. In order to get out of this difficulty, and to put the line and rolling-stock into better condition, it was deemed necessary to apply for power to raise £1,500,000 extra capital; but the application although made under the auspices of the present Marquis of Salisbury, who was Chairman at the time, was refused; so, as Mr. Acworth amusingly puts it, "the Company amended their Bill, asked for £3,000,000, and got it." Gradually an improvement became manifest, and under the guidance of Mr. C. H. Parkes, who assumed control in 1872, has continued, until the Great Eastern Railway now holds the premier position for punctuality of all lines running into London.

The Stratford Works were built by the Eastern Counties in 1847, during "King" Hudson's reign, at a cost of £100,000—a mere trifle to a concern claimed to rest "on the broad and stable basis of national utility," and therefore dismissed in the Directors' report with a few remarks about "the shops at Stratford being in progress." Comprehensive as they were for the requirements of the day, they have been in progress ever since; but the Great Eastern being still the reverse of a rich Company, and the original works being hemmed in on one arc of a circle by Stratford New Town, formerly known as "Hudson's Town," and on the other by a network of main lines and sidings, considerable ingenuity has had to be exercised in covering in here, or building an extra story there, and so making the most of the available space. Human ingenuity however has its limit, and we shall see that on the further side of the main line, away among the marshes, more modern buildings have had to be erected to provide for the largely increased rolling-stock.

Let us begin by a walk through the Steam Hammer Shop, keeping in mind that we are in the "Hudson" Works. There are here five steam hammers thumping away night and day, fed by four coal and three gas furnaces, the glare from which when a door is momentarily raised is almost blinding to a novice. The head forgeman is a certificated member of the St. John Ambulance Association, which has a strong corps in Stratford Works, and first conducts us to one of the well-appointed Ambulance cupboards with which every shop is provided. But this, although of considerable importance when we bear in mind the risks of personal injury with which mechanics have to contend, is hardly what we want on this occasion. "Well, come and look at these butterflies." Then we remember he has a penchant for entomology, but are relieved on finding that his "butterfly" is a forging, and very interesting it is to see how the grain of the iron is worked at different angles, to ensure that in the spring clip which is the finished form of the "butterfly" the greatest possible strength shall be in the directions where it is most needed. On the way we notice men packing "piles" of wrought-iron scrap, such as old drawbars, couplings, and the waste from stampings, on boards about fourteen inches square. Each pile is brought to a welding heat in the furnace, and is then hammered into a "bloom," which after reheating is in some instances stamped under the hammer between suitably shaped dies, and in others simply pounded into shape by the heavy blows which, metaphorically speaking, rain upon it, the forgemen's deft manipulation of the glowing mass as they turn and twist it between each blow, and their weird appearance as the fiery flashes illumine their dusky faces, creating an impression on the mind which is not easily forgotten. We make arrangements for a photograph showing the processes from pile to finish of a quadrant link and spring clip, and then walk into the adjoining Smithy, where we see some 280 men busily engaged on the smaller forgings appertaining to a locomotive, the clang of the hand-wielded hammers forming a striking contrast to the ponderous thud of their steam-fed neighbours. On one side of this shop we notice a row of curious-looking machines for making bolts, ferrules, and other small details. These are known as "Olivers," and have a forty-pound hammer poised in the air ready to descend at any moment by foot pressure on a treadle fixed in a trough on the floor; thus, instead of allocating a whole man to the striking as at an ordinary anvil, one leg suffices, and the hands are free to ply the tongs, and give the finishing touches to the work with an ordinary hammer.

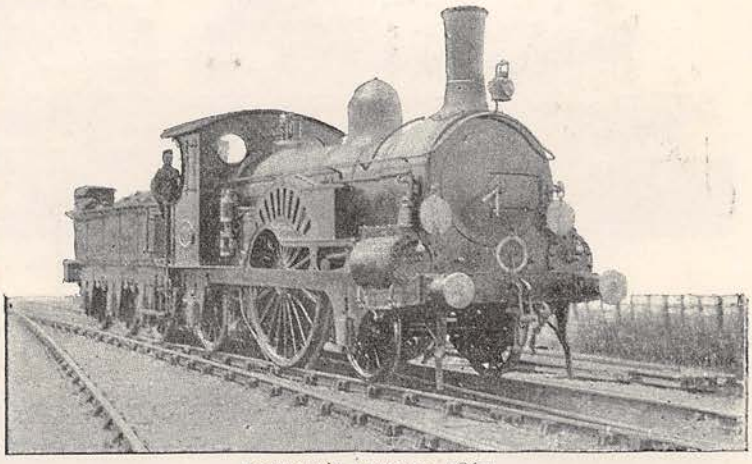


ENGINE BUILT AND IN STEAM IN TEN WORKING HOURS.

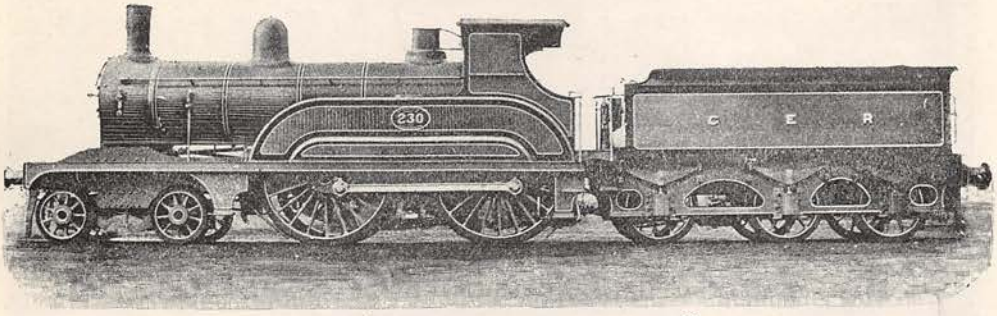


GROUP OF OLIVERS.

Passing again through the Steam Hammer Shop we enter the Boiler Shop, and are shown a vertical rolling-machine, not unlike a huge domestic mangle, standing on its side, between the rolls of which great plates of steel, which have previously had the rough edges planed and the rivet holes drilled or punched, are passed and bent barrel-shaped. The barrel is then bolted together with its rings and straps, and conveyed by overhead travelling cranes, of which there are six, with a lifting capacity of ten tons each, to an "iron man" actuated by hydraulic force, whose jaws measure six feet long, and who with a pressure of forty-one tons "closes up" the red-hot rivets as they are placed in position by the workmen. The riveting of less accessible parts is performed by portable machines, also hydraulic, in appearance like the gripping claws of a crab, and their silent though determined clench when brought into position makes one wish that hand-riveting with its incessant clattering could be abolished altogether. Punching, shearing, and planing machines attract attention by the apparent ease with which they treat cold steel, but so great is the force employed that the mere act of punching out a piece $1\frac{1}{2}$ inches in diameter, and $1\frac{1}{8}$ inches thick, raises its temperature about 70° Fahrenheit in less than a second. We ask how many



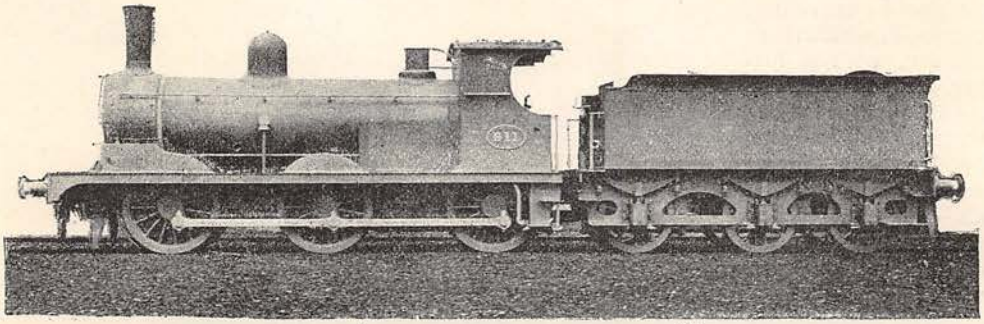
SINCLAIR'S EXPRESS, 1862.



WORDSELL'S TWO-CYLINDER COMPOUND, 1884.

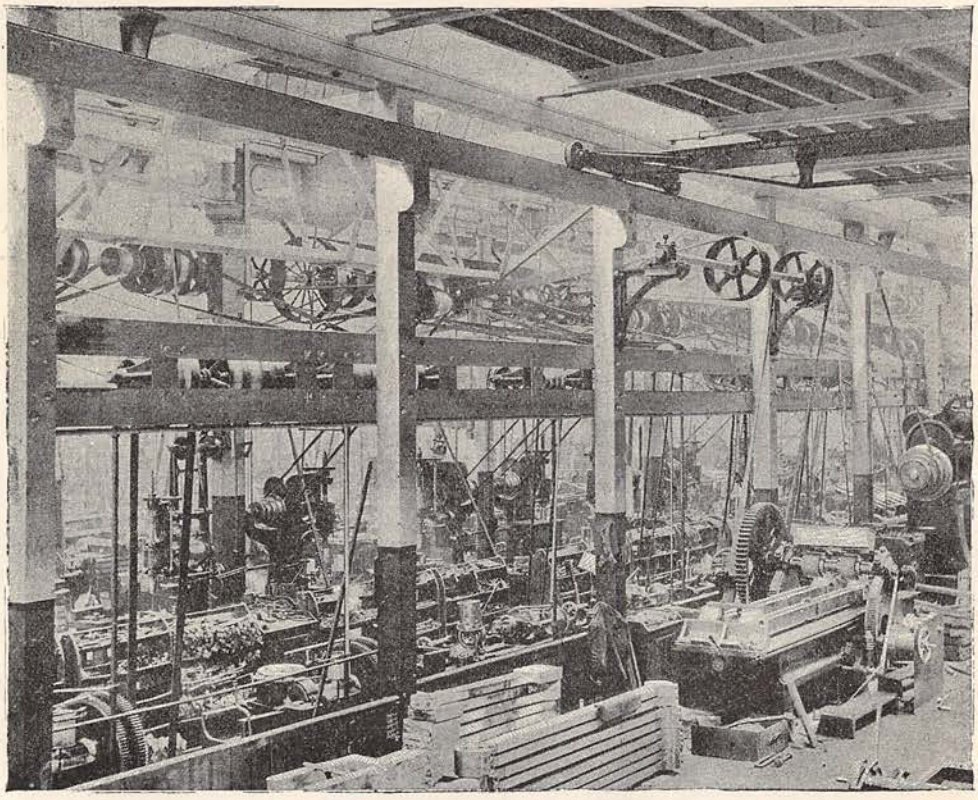
holes are punched in a year, and are told that at four of the machines close by the records of nine men show an aggregate of over seven millions, the weight of the punchings alone amounting to nearly 250 tons. Outside the Boiler Shop are gas furnaces for plate heating, and two hydraulic flanging presses, the power for which comes from a drum-shaped accumulator containing about forty-three tons of ballast, the accumulator being poised on a cushion of water forced through a central column by a pair of vertical pumps. This apparatus certainly has the charm of simplicity: a red-hot plate is brought from the furnace and secured between two iron slabs smaller than the plate itself; a valve is then opened in a pipe connecting the column with the press, and the weight of the accumulator forces the water against a twenty-inch ram, which in its rise presses a suitably shaped die against the exposed parts of the plate and

turns up the edges all round. In less time than it takes to describe it, we see a flange turned up to a height of three inches, and so silently that one could almost hear a



WORDSELL'S SIX-COUPLED GOODS ENGINE, 1883.

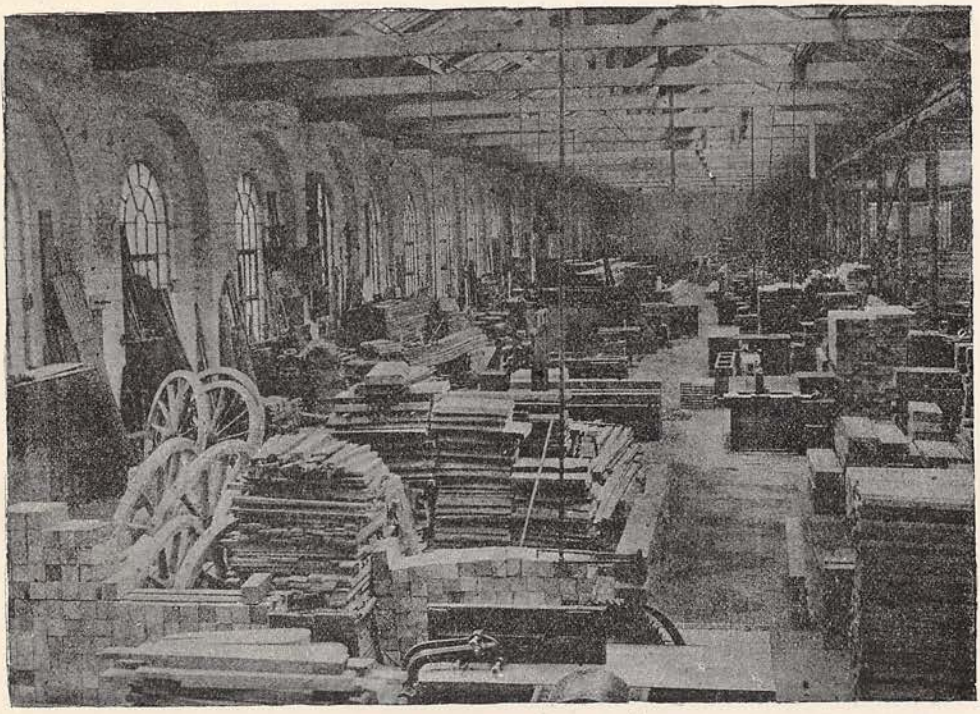
pin fall during the operation. The number of rivets in a locomotive side tank has, by the substitution of flanged plates for angle irons, been reduced from 700 to 350, thus not only effecting an important economy but ensuring additional strength.



MACHINE SHOP.

Looking in at the Iron and Brass Foundries and the Coppersmiths' Shop, we pass to the Machine Shop, where the twelve thousand feet of leather belting whirling round innumerable pulleys are apt to create a sense of bewilderment, but where in reality everything is of a most orderly description. In the tool store we at once notice a

number of gleaming circular tools, varying from half an inch to twelve inches diameter, the latter built up in forty-two segments. These are milling cutters, and for an idea of their working one may imagine a coin revolving either vertically or horizontally on its own axis, each tooth of the milled edge being sharpened and set to a particular cutting angle. It thus bites its way into the article operated upon, and we are shown as an example a beautifully finished fluting, three-quarters of an inch deep by two and three quarter inches wide and six feet six inches long, cut in a cold iron coupling rod at one operation. Another ingenious application of the milling cutter is a tool which at one operation cuts two grooves and machines three sides in a brass index plate. These cutters are also used in the manufacture of "twist" drills, so named through having two spiral grooves in their length something like that in an

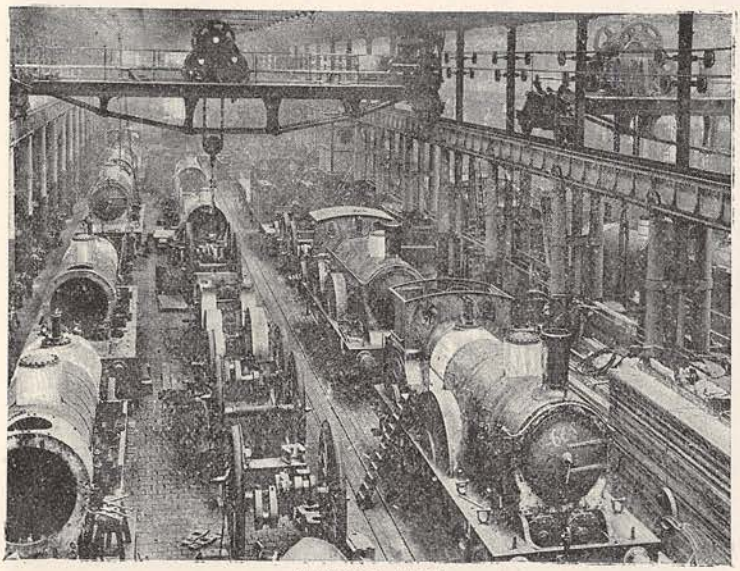


THE SAW MILLS CARRIAGE DEPÔT.

ordinary auger. The drill "blank" is given a longitudinal and circular motion in a machine, corresponding to the spiral in a metal pattern, a milling tool fixed in the head-stock cutting the spiral as the blank travels under it. Other features are sharpening machines with emery wheels revolving at great speed, and sending out showers of tiny sparks as they grind away at cutting tools of various kinds; slotting, shaping, screwing, and tapping machines; bolt and nut lathes; and a little smithy which this shop has entirely to itself. It is in the machine shop that embryo engineers gain their first experience, after which they enter the Fitting and Erecting Shop. This building, which measures 350 feet by 150, has six rows of "pits" running lengthwise through the two centre bays for engine construction and repairs, the two side bays being occupied with fitters' benches and heavy machinery. So complete is the organization, so efficient the machinery, and so skilful and willing are the workmen, that in December last a six-wheels-coupled goods engine, weighing with its tender over sixty-seven tons, was erected, painted lead colour, and in steam in the almost incredible space of ten working hours, and after running the usual trial trip was immediately put to work on the London and Peterborough coal service, at which it has since been continuously engaged. With the exception that a greater number of hands were employed, and that special care was taken to lay down the details in order of sequence, the method of construction was the same as that of all engines built at Stratford, and we are given a short description of how an engine is erected. The engine frame plates, originally of

rectangular form, come here from the boiler shop punched roughly to the required shape, and are now, so to say, "pared" accurately to dimensions, ten at a time, on a triple-headed shaping machine, after which the necessary holes are drilled, and then the "horn blocks" or axle-guards and the spring brackets attached by the fitters; the cylinders, which come as rough castings from the iron foundry close by, are bored, planed, and the attachment parts drilled, and are then tested by steam pressure; the boiler is brought in, and at one end of the shop, given over specially to such work, has its mountings—water-gauges, safety-valves, regulator, &c.—fitted, and is then tested, first by water and then by steam; the many items of the working gear, technically known as the "motion," come from the machine shop, and are carefully fitted up at the benches to ensure accurate working; and the wheels, which have been forced on the axles with a pressure of eighty tons, are brought in and conveniently placed.

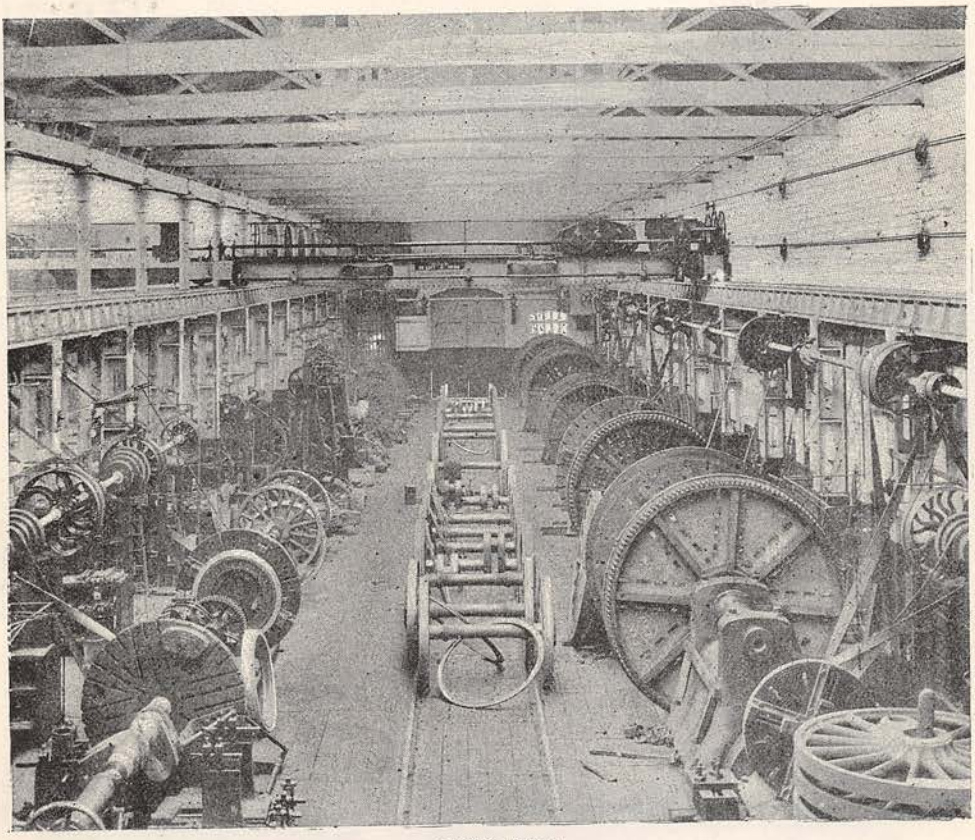
We will now watch the process of erection, noticing first that for the lifting of the heavy parts there are four overhead cranes, each of thirty tons capacity, which traverse the length and breadth of the shop, and are driven by an endless or "flying" cotton rope running at a speed of about half a mile a minute, the cranes being actuated by the bite of the rope on the grooved surface of the pulleys. The engine frames are brought into position one at each side of the pit, and are stayed together by temporary bolts; the frame stays and cylinders are then put in and bolted together, the rivet holes, which have been drilled below the standard size, being reamed out with standard rosebits actuated by an ingenious arrangement known as a Stow shaft, consisting of wires twisted spirally in a leather casing, thus forming a flexible line, which transmits rotary motion from the main shafting as easily as an india-rubber tube will convey gas or water. The work so far as it has gone is then "squared"; the motion put up; the boiler, which has meanwhile been clothed with wood strips to prevent loss of heat by radiation, is lifted into position on the frames; the cab, smoke-box, and chimney added; the wheels, which have had the axle-boxes fitted to them, put under; the eccentric and connecting rods coupled up; and then comes the setting of the valves which regulate the admission and exhaust of steam through the cylinder ports. Assuming the 9438 parts contained in a Great Eastern standard goods engine to be now in position, she—for an engine like a ship is generally spoken of in the feminine gender—goes to the weigh-bridge where the weight on each wheel is adjusted. Then with the tender, which has had its 7504 parts put together in a shop on the other side of the line, she receives a coat of lead paint, and is despatched on her trial trip, the leading hand of the pit upon which she was built accompanying her, to take note of any little defects that might show themselves. Should all be satisfactory, as is almost invariably the case, she now returns to the shops for painting, preparatory to turning out in the world for a living.



ERECTING SHOP.

But not only is the engine stock kept in repair at Stratford, and a new engine turned out every thirty-two working hours, there are also the carriages and wagons to be maintained, and new carriages built at the rate of one every eight working hours, and wagons at the rate of one every three and three-quarter hours. Let us walk through

the Spring Shop to the Carriage Department, making our first call at the Stores. Here, on a duly authorized requisition, can be obtained almost anything employed in railway carriage building, from tinned tacks or tenpenny nails to those beautiful photographs which are now substituted for the old-fashioned, and we regret to say almost unheeded, admonitory notices which were the delight of all travellers with an eye for the artistic. Proceeding on our tour, we come to the Saw Mill, where the usual sweet smell of freshly sawn timber is quite overcome by the peculiar and unpleasant odour of teak wood, the material of which the panelling of a Great Eastern carriage is constructed. Wood-working machines of all kinds are humming and buzzing, and some shrieking with a faint imitation of a syren, but they are only visible

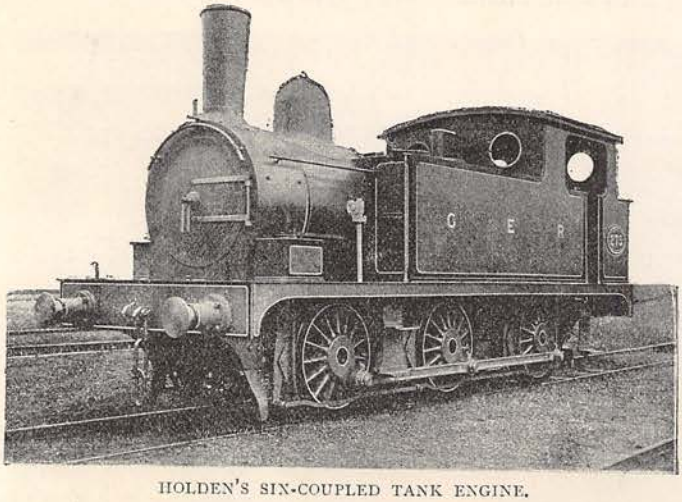


WHEEL SHOP.

by close inspection, the shafting being below the floor, and the machines almost hidden by the stacks of timber dotted about. We see a matchboarding machine plane two sides of a board at the rate of thirty-five feet per minute, and at the same time form a tongue and a groove; a wood scraper, the fixed cutter of which takes a continuous shaving two feet wide off a panel board; and a machine in which a square-section stick passed through revolving cutters emerges as a round-section curtain rod; and then we go to the timber grounds, where we see hundreds of oak logs from the Galician forests, and from Michigan or Ohio, waiting their turn for conversion into plank. Further on, in sheds from which the sun's rays are excluded, but through which the air is allowed free circulation, are teak and mahogany panels, planks, and scantlings, oak, ash, elm, hornbeam, and other woods, methodically stacked for drying by process of nature.

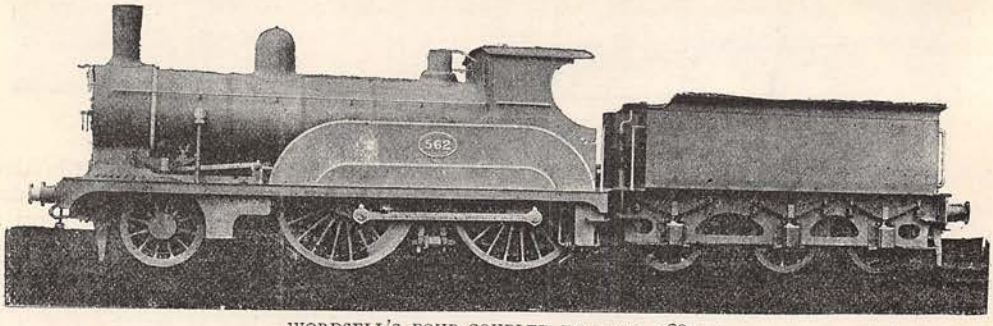
Returning we pass through a carriage hospital, containing passenger train vehicles in all stages of repair, and come upon a steam traverser. This is situated in an opening between the Repairs Shop and the Body Shop where new stock is built, and is a necessary convenience for enabling carriages to be moved quickly

from one set of rails to another on completion or in an emergency. Entering the Body Shop we are reminded that a peculiarity of wood workers is that each man has his own tools and chest, bought with his own money or made in his own time. These clean-looking men in their white aprons form a strong contrast to the men we have left working among the oil and rust on the locomotive side. No description of carriage work comes amiss to them, a horse-box or a train of dining cars, a carriage truck or a royal saloon. Walking on, our voices are involuntarily hushed as we draw near a vehicle, which at a few hours' notice was draped with purple velvet and converted into a mortuary car for conveying the remains of the late Duke of Clarence to Windsor, and now stands, in the sad irony of fate, next an elegant saloon, the completion of which had been originally timed for that royal wedding which was destined never to be.



HOLDEN'S SIX-COUPLED TANK ENGINE.

Our course now takes us through a spacious machine shop, in which a machine for testing india-rubber buffing and draw-springs calls attention to the unceasing care bestowed on every item in this vast establishment in order that neither the lives nor the comfort of the travelling public shall be jeopardized. Then we proceed to an upper story, where trimmers are at work with knife, scissors, needle,

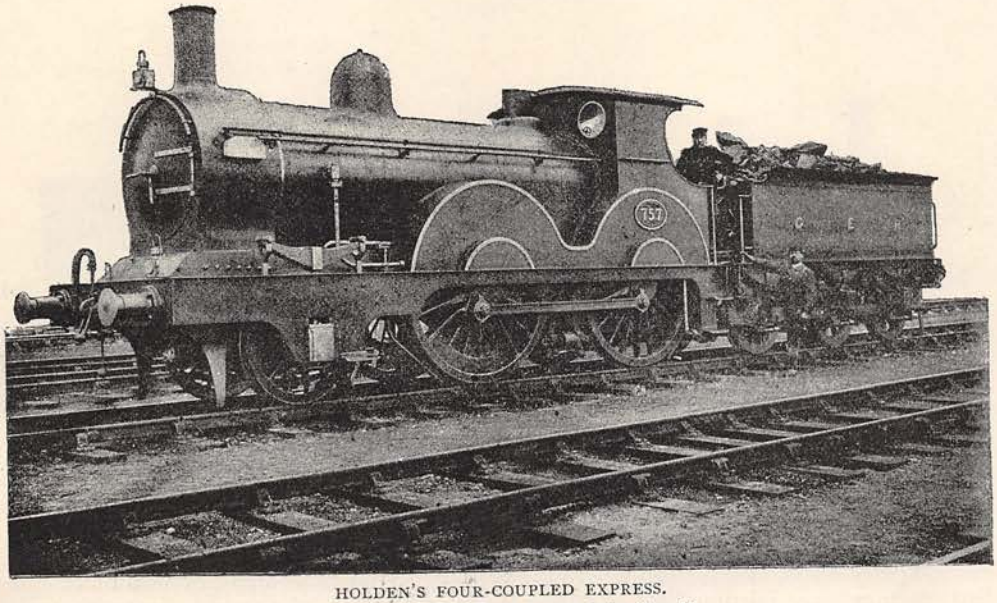


WORDSELL'S FOUR-COUPLED EXPRESS, 1882.

and hammer, cutting, stitching, and tacking carriage upholstery. Very varied are the materials shown us: buffalo hides, morocco goat-skins, horse-hair seatings, velvet, woollen, and merino goods, and a roll of material some two thousand feet long waiting conversion into carriage rugs. Near at hand there is a shop where the Company's road stock is repaired, but we omit visiting it, and wend our way to the Coach Painters' Shop. The under frame of a new carriage is painted, but the body is varnished only, so as to bring out the natural grain of the wood. As a rule the first varnishing lasts about two years, when the carriage again undergoes similar treatment, the second varnishing

lasting about another three years, but in time the sulphur-laden atmosphere of the great metropolis so discolours the wood as to render further varnishing ineffective, and the grain then hides itself for ever under a coat of brown paint. It may here be remarked, that on December 31st, 1891, the average age of the whole of the Company's engines was 6·37 years, and of the carriages, 9·6.

We have now completed our tour of the Hudson Works, with the exception of the Laboratory, which we will notice on our return, and passing for safety's sake through a subway instead of crossing the lines, we emerge close to an oil-gas works which supplies light for some 1,200 carriages. The special feature of gas made from oil is that it possesses a very high illuminating power, and compared with coal-gas loses very little of it by compression, so that a cylinder six feet long by twenty inches diameter will carry a thirty-six hours' supply. It is stored in stationary holders at a pressure

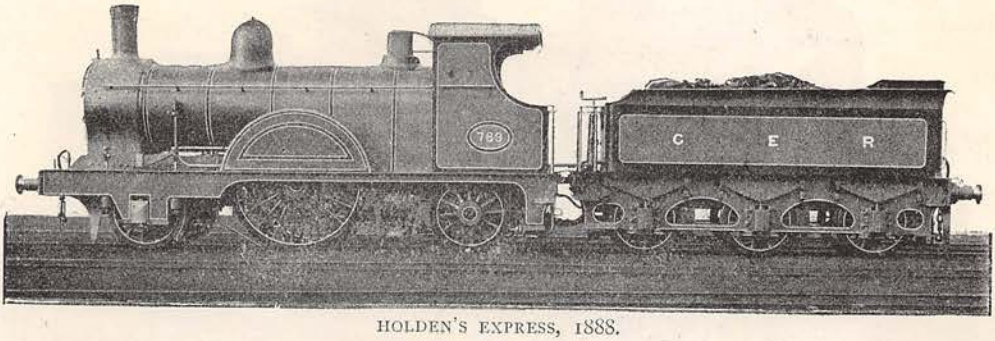


HOLDEN'S FOUR-COUPLED EXPRESS.
(From a photograph by W. M. Spooner & Co., Strand.)

of twelve atmospheres, and is conveyed thence through underground pipes to the sidings, and delivered to the carriage cylinders by means of stand-pipes erected at convenient distances. Travelling holders convey the gas to such trains as can only be filled at out stations. Of course there are by-products from oil-gas making as from coal, and thereby hangs a tale. One of these by-products is a tar for which there was neither sale nor use, and it was consequently allowed to run to waste. Finding its way into the waters of the Channelsea and the Lea, its iridescent appearance and pungent aroma attracted the attention of the sanitary authorities, who, not appreciating its disinfecting qualities, considered it a nuisance calling for abatement. What to do with it now became a serious question, until, at the suggestion of the Chairman, the present Locomotive Superintendent, Mr. Holden, utilized it for fuel. Never was there a better exemplification of the saying that "Necessity is the mother of invention." The liquid fuel injector, designed originally with the sole object of using up this refuse, is now a feature of considerable interest in the engineering world. At Stratford it is applied to various uses, and we shall speak further of it when among the locomotives. We have now reached the new Wheel Shop, and watch the manufacture of carriage wheels. As a rule, these wheels have no spokes, but are built up solid of teak wood segments, care being taken to place segments of equal weight opposite each other, in order that the wheel may be properly balanced. When

the tyres and axles have been forced on, the wheels are tested on a balancing machine, and any excess of weight in one part adjusted by an iron strip bolted on opposite. There is more in this than one might imagine, a pound or so too much or too little in any part of the wheel being enough to convert an otherwise comfortable carriage into a veritable "sea on land."

In the Wagon Department we get a good idea of the varieties of traffic for which the Company has to cater. For farm produce and general merchandise the ordinary goods wagons suffice, but these are totally unsuitable for heavy machinery, or, on the other hand, for eggs and light but bulky articles which come in large quantities from the Continent by the Parkeston route. Special wagons also are required for yeast, and for fruit, and for the American lard which comes by the Great Eastern route from Liverpool to London. As one particular traffic grows or another diminishes, modifications become necessary in the designs for new vehicles, but wherever practicable these are confined to the body, the under frame, which is now generally made of steel instead of wood, being kept to standard dimensions. The wagon department has its own saw-mills, smithy, and machine shop. We are shown a combination machine which will cross-cut a wood solebar to length, cut the tenons



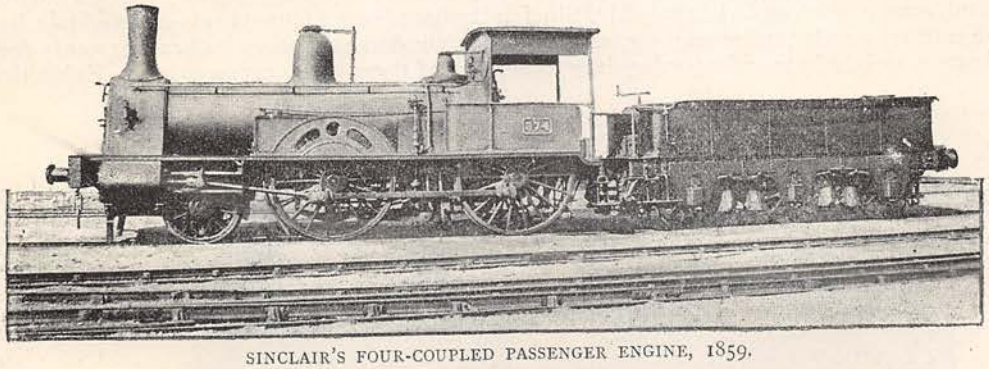
HOLDEN'S EXPRESS, 1888.

at either end, bore all necessary holes, and bore and chisel out the mortices. This is so ingenious and interesting that it seems a pity it will have to be disestablished and disendowed ere long by the all-conquering steel.

There are several shops close by the wagon department, including a tinsmiths', an engine paint shop, and a shop where the tender for the record engine was built, but a little further there is something that breaks the monotony of a round of manufacturing processes, and thither we hie. We refer to the Engine Stables. Here, if we may use the similitude, we see the heavy cart-horse, the more active cab-hack, and the well-groomed and carefully tended racing-steed, their life-blood swelling within them; and from the readiness with which they respond to the touch of command, as proud, apparently, of their drivers as their drivers of them. And this is saying a good deal, for the love of an engineman for his locomotive is next to that of an affectionate man for his wife and family. It must not be imagined from this that most enginemen are celibates; on the contrary; and when we enter the smoking-room attached to the Dormitory, and remark that the occupants seem very comfortable, one of them lays down his paper and declaims vigorously against his enforced absence from home, due to the revised working and shortened hours adopted in consequence of the pressure put upon the companies by Parliament and the press since the publication of the return called for by Lord Delawarr in 1887.

The Dormitory buildings consist of a kitchen, bath-room and lavatory, dining room, smoking and reading room, and a dormitory chamber containing thirty-eight separate cubicles. Each cubicle has a well-covered and comfortable bed, over the head of which there is an electric glow lamp regulable by the occupant. Within arm's length is a shelf on which there stands a water-bottle and a Bible. The whole of these buildings are lit by electricity, and although plainly furnished are as clean and comfortable as could be wished. Underneath are the cleaners' rooms and a suite of

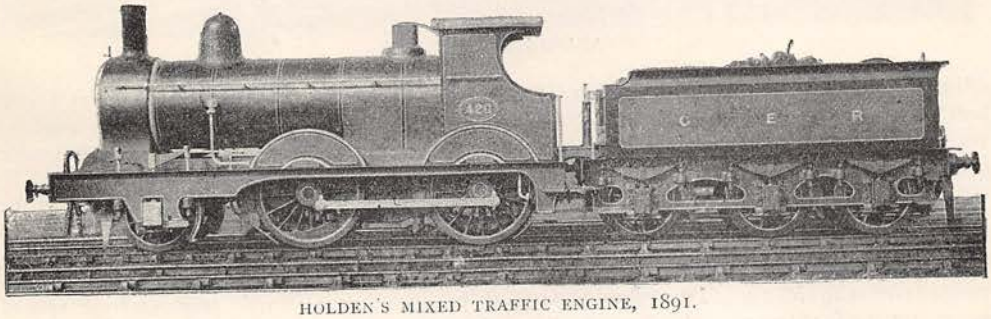
offices ; and to gain an idea of how much the engineman of to-day differs from his prototype of 1840—when the Eastern Counties Directors recorded that "the duties of engine-drivers are so simple that unwearied vigilance and watchfulness are almost the only qualities required,"—it is only necessary to walk into the room where the duty list is exhibited, and after careful study of the many notices and diagrams of working, enter for an examination as to their contents. These diagrams have been aptly described as "mysterious-looking sheets, covered with figures and with lines which



SINCLAIR'S FOUR-COUPLED PASSENGER ENGINE, 1859.

zigzag all over their pages, requiring a special training to arrange them, and another special training to understand what they mean."

Leaving the offices we notice several huge stacks of coal, and asking how long the ten thousand tons they contain would last, are answered that the annual consumption throughout the line, if measured at forty cubic feet to the ton, would equal a column one hundred feet square, and three and a half times as high as St. Paul's Cathedral ; whilst the water puffed into the atmosphere as steam would equal a river ten feet

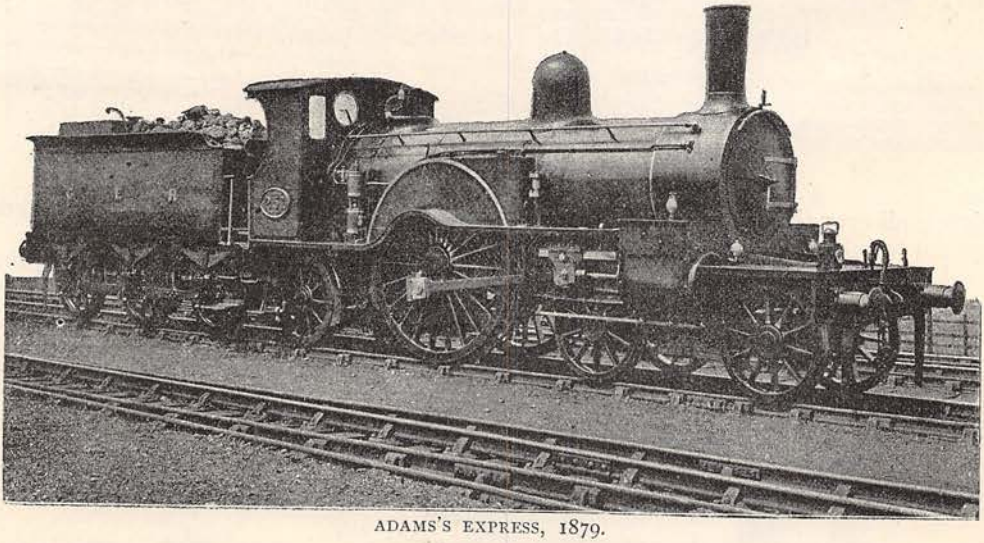


HOLDEN'S MIXED TRAFFIC ENGINE, 1891.

deep, twenty-five feet wide, and nearly eighty miles long. We are now conducted to the stages from which the engines are coaled, and witness the operation of putting some three tons of coal in a tender in less than five minutes. As the trucks arrive from the collieries, they are taken up an incline between two platforms, and at once attacked by a set of grimy-looking men, who shovel the coal into iron trolleys, each of which holds ten hundredweight, and as fast as a truck is emptied it is run out of the way down an incline at the opposite end. The platform level is a little higher than the top of a tender, and when an engine comes up on one of the two outside roads, the trolleys are run on to an overhanging table which falls with the weight, and the door of the trolley opening automatically, the contents are shot into the tender. A careful record is kept of the coal consumed per mile by each engine, and premiums are

awarded monthly to the driver and fireman of the most economical and best kept engine in their district.

A chat with the chief foreman of the Running Department leads to a mention of the various engines of which he has had control at one time or another, and gives an opportunity of jotting down a few particulars relating to some of them. The first engines built in Stratford Works were designed by the Locomotive Superintendent, Mr. J. V. Gooch (brother of the late Chairman of the Great Western Railway), in 1850. They were passenger tank engines, and had single driving-wheels six feet six inches diameter, and outside cylinders twelve inches by twenty-two inches, and weighed in working order twenty-three tons. These engines were employed for express trains, and the water capacity being limited was in some instances supplemented by tanks carried under the brake vans. In 1859, Mr. Sinclair designed some four-wheels-coupled (six feet diameter) goods tender engines, with outside cylinders seventeen inches by twenty-four inches, weight in working order sixty tons ; one of these (No. 327) was in the Exhibition

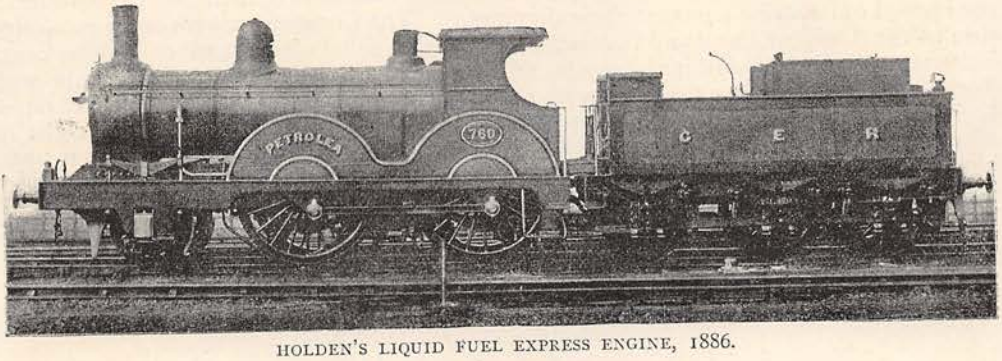


ADAMS'S EXPRESS, 1879.

of 1862. About the same time Mr. Sinclair also designed some single wheel (seven feet diameter), outside cylinder sixteen inches by twenty-four inches, passenger engines, weight in working order fifty-seven tons, somewhat similar to Gooch's, but with tenders in lieu of tanks. These engines, one of which (No. 284) was specially decorated for conveying the Prince and Princess of Wales to their new home at Sandringham whilst the wedding bells were gaily ringing, continued to work the chief expresses until about ten years ago, and six of them are still in running. As the suburban service grew, another class of engine became necessary, and Mr. Johnson, now Locomotive Superintendent of the Midland Railway, designed in 1873, some tank engines four wheels coupled (five feet four inches diameter), inside cylinders seventeen inches by twenty-four inches, weight in working order forty-five tons ; these are still in running, and one of them (No. 193) burns liquid fuel. In 1878, Mr. Adams (now Locomotive Superintendent of the London and South Western Railway) designed the single wheel (seven feet six inches), outside cylinder eighteen inches by twenty-four inches, passenger express engines, the weight of which in working order is seventy-six tons. All the foregoing engines, with the exception of Gooch's tanks, were purchased outside ; but on the advent of Mr. T. W. Worsdell in 1882, this practice was discontinued, and every new engine since has been built at Stratford. Mr. Worsdell began with a four-wheels-coupled (seven feet diameter,) inside cylinder eighteen inches by twenty-four inches passenger express engine, page 768, weight in working order seventy-seven tons, and then came his six-wheels-coupled (four feet ten inches diameter), inside cylinder

seventeen and a half inches by twenty-four inches goods tender engine, weight in working order sixty-eight tons. These were followed by a two-cylinder compound bogie express, four-wheels coupled (seven feet diameter), one cylinder eighteen inches by twenty-four inches, and the other twenty-six inches by twenty-four inches, weight in working order seventy-seven tons. It is worthy of note that the first compound locomotive of which there is any record was originated and tried on this line. It was a two-cylinder goods engine, compounded about the year 1848 from the ideas of a fitter named John Nicholson, employed at the Company's works ; but although this engine was in running for some years, and experiments made with other engines also, little is known of their performances.

In 1886, Mr. J. Holden, the present Locomotive Superintendent, built some six-wheels-coupled (four feet diameter), inside cylinders sixteen and a-half inches by twenty-two inches, tank engines, page 768, weight in working order forty tons, for suburban passenger and local goods trains, and followed on with some four-wheels-coupled (seven feet diameter) express tender engines, given below, cylinders eighteen inches by twenty-four inches, weight in working order sixty-five tons. A special feature of these engines is that the cylinders are cast in one, with the slide valves working below, so as to ensure better lubrication. One of these, "Petrolea," is fitted to burn liquid fuel, but beyond the addition of an oil tank on the



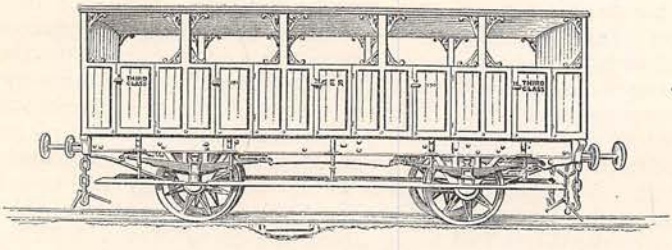
HOLDEN'S LIQUID FUEL EXPRESS ENGINE, 1886.

tender, and a few pipes leading to the injectors below the fire-hole door, there is nothing in its outward appearance to distinguish it from a coal-burning locomotive, to which indeed it can be converted at any moment, there being no alteration in the construction of the fire-box. A special feature of the injector is an outer ring through which jets of steam pass, these jets impinging at the nozzle on the liquid fuel induced through a central cone, and breaking the fuel up into a very finely divided spray which ignites immediately. There is a passage in the injector through which air also is induced, and as the emission of steam, liquid, and air can be adjusted independently of each other, combustion is regulated to a nicety, and the slightest suspicion of smoke avoided. The fire is lit up with coal in the usual way, and a bed of incandescent fuel and chalk or broken bricks kept up, the weight of coal used in conjunction with the liquid fuel being about one-third of the total fuel consumed. It can be readily imagined what a saving of labour this is to the fireman, whilst the incandescent base enables the engine to lie practically inert for hours if required, yet ready to start into action directly the injector is worked. "Petrolea" is engaged regularly on heavy express trains, and having a striking appearance is an object to much interest to the crowds of people swarming Liverpool Street Station—the busiest terminus in the world. Another of Mr. Holden's engines is No. 789, shown on page 770. There are at present eleven to this design, which is similar to the 760 class, but with single instead of coupled wheels. They have been specially built for long journey fast trains, and are engaged chiefly on the London and Doncaster service. Still another variation of the 760 class is the 420 class, page 771, four wheels coupled (five

feet eight inches diameter), cylinders seventeen and a-half inches by twenty-four inches, weight in working order seventy-one tons, designed for use either as passenger or goods engines. Almost all details of these three classes are interchangeable, a point of much greater importance than the general reader would suppose, and a very different state of affairs to that existing a quarter of a century back when, we are told, there were in the repairing shop on one occasion forty engines, of which hardly a single part of one was interchangeable with another !

Returning to the works, we are shown a hydraulic testing machine registering from twenty pounds to fifty tons, and are then conducted to the Laboratory, which consists of an office and consulting rooms, a balance room, the laboratory proper, and an operating room, containing metallurgical appliances and a stock of commercial chemicals. Many, we learn, are the duties a railway chemist is called upon to perform : testing milk for the hotel department, or new explosives which the goods department is called upon to carry ; reporting upon samples of water suggested for drinking at different points on the line ; whilst in connection with the locomotive department the percentage of carbon in a steel plate or arsenic in a copper plate has to be ascertained, the calorific value of fuels determined, and doubtful stores to be analyzed for suspected adulterations.

As regards the social aspects, there is an Accident Fund, to which each of the 5,260 workmen subscribes, a Pension Fund and a Savings Bank, optional, and a Contagious Diseases Fund. The institution of the three former is due to the present well-beloved Chairman ; the latter is a workmen's movement entirely, and an excellent one, not only preventing the deprivation of the members' means of support when most needed, but by removing the risk involved in coming to work when disease is in their homes preventing the spread of infection amongst their shopmates. The Company covers every subscription to the Accident Fund and Pension Fund with an equal amount, gives four per cent. interest on Savings Bank investments, and supports a Science and Art Institute and Technical School situate near the works, which has a library of nearly 7,000 volumes. Last, but by no means least, every person in the Company's employ has the right to travel once a week, with any members of his family residing with and dependent upon him, to any point on the system at a fare of a farthing a mile.



OLD THIRD CLASS CARRIAGE.