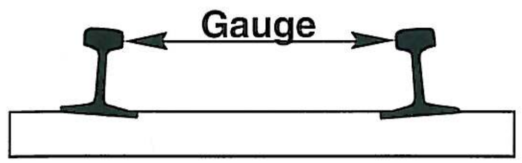
PART 1

EARLY RAILWAY HISTORY

Railways and Railway Gauges

PART 1 - CHAPTER 1



RAILWAY GANGERS measure the gauge of their track between the inside vertical face of the head of one rail to the inside vertical face of the other (see diagram) and normally keep it constant within a range 10mm either side of the nominal dimension. Standard gauge throughout the world is generally regarded as 4ft 8½ in or 1,435mm and other gauges (there are about 36 in common use) are called either broad gauge or narrow gauge depending on whether they measure more or less than 4ft 8½in. Note though, that in the early days in Britain 4ft 8½in gauge was often referred to as "narrow gauge" because 7ft 0in was "broad gauge". In South Africa, "standard" gauge is 3ft 6in.

ANCIENT TIMES

Some writers maintain that the use of a gauge of 4ft 8½in between wheels can be traced as far back as 2000 B.C. at which time the ancient Egyptians and Assyrians spaced the wheels on their horse-drawn chariots to roughly this dimension. They found this to be a suitable spacing for the wheels so they would avoid catching the heels of horses. Over time, the wheels wore ruts in the surface of the stone roadways and it was found that progress was made easier by using these ruts to guide the wheels of wagons. This led to deliberately cut ruts, which have been found by archaeologists in the Middle East, especially in the urbanised areas of Mesopotamia (now Iraq).

Opposite: *Richard Trevithick, the first man to build a steam locomotive to run on rails.* [SCML]

Later, the Greeks developed "rutways" laying their roads with rows of stones (to reduce friction) but with two ruts either carved or worn in them to keep wheels running on the stones. Their horse-drawn carts ran on these or on ordinary roads with equal facility, but so they could run in the rutways, cart makers were obliged to make the cartwheels of a uniform gauge. The oldest known example of a continuous rutway is the Corinth Diolkos in Greece, which, however, had a broader gauge of 5ft 6in and was five miles long. Sections of this early example of a rutway, which was in use from about 600 B.C. until 67 A.D., are still in existence to this day. A further example exists in Malta, dating from about the same time, which had a gravity marshalling yard and sidings.

Archaeological excavations at Pompei - preserved by volcanic ash from 79 A.D. until more recent times - found rutways used by the Romans and according to measurements taken at the time, these rutways had a "gauge" very close to what we consider to be standard gauge. Indeed, from surviving measurements of a Roman chariot wheel, the distance between the inside edges of the wheels was 4ft 7.9in and the wheels were roughly 1½in wide on the tread.

The so-called "gauge" of these early rutways demonstrates that where a horse was used as motive power, it was practical for the wheels to be spaced well apart. Thus, the horse could trot between the ruts without its hooves being fouled by the wheels and would not be disadvantaged by the ruts in the rutway. This set an inner limit to the gauge. The need on occasion to attach additional horses outside the thills ('thill' = shaft of cart or carriage esp. one of a pair. *Oxford Dict.*) set the outer limit since these horses would also want to avoid running in the ruts or having their hooves fouled by the wheels. Thus it became the custom for any horse-drawn vehicle, particularly running in ruts or on rails, to have wheels spaced 4 to 5 feet apart.

MODERN TIMES

The technology surrounding the early rutways seems to have died with the fall of the Roman Empire in the 5th century A.D. It was nearly one thousand years before anything like these early examples of what we might call "railways" re-emerged. Although a stained glass window in the German cathedral at Freiburg-im-Breisgau dating from about 1350 is believed to contain the earliest surviving illustration of a railway vehicle, the evidence is not irrefutable. The first irrefutable evidence of railways occurred in the 16th century.

The first railway definitely on record was a narrow gauge railway in the mines at Leberthal, Alsace, illustrated in *Cosmographie universalis* by Sebastian Munster in 1550. Another example is to be found in a 1556 book on the medieval mining industry entitled *De Re Metallica* by Georgius Agricola. This shows wagons and tracks using an iron pin running in the gap between the "rails".

Miners from the Tyrol migrated to England in 1564 and may have brought this technology with them but to date no hard evidence has been uncovered suggesting that they used any such railway in England. Contemporary inventories show small trucks were in use but it is not clear whether these ran on the ground or on rails.

Up until the 16th century, no "railway" had been built that could be called a "true" railway in the way that we know it. The true railway consists of two "rails" spaced apart by the "gauge", which support the rolling wheels, the latter being guided either by upturned flanges on the rails or down-turned flanges on the wheels. The first of these railways appeared in Britain and gave rise to Britain claiming to be the "birthplace of railways".

Unlike the rest of Europe, Britain was blessed with huge reserves of coal, which it mined and conveyed across the country for both domestic and industrial use and for export. Transport over the shocking roads of the time was expensive and it was in the search for a more efficient and economical movement of coal that railways came into prominence. In the meantime, canal systems, which grew from about 1760 had a brief period of glory but were slow and inconvenient.

The oldest available evidence of a surface wooden railway - a "true" railway - in England is revealed at some coal pits, near Nottingham, formerly owned by Sir Philip Strelley. About two miles long, this railway was the work of Huntingdon Beaumont who came from a Midlands coal owning family and who had leased the Strelley pit. The railway was laid between October 1603 and October 1604.

Beaumont needed to run his track across land owned by Sir Percival Willoughby and was granted a lease, which in part read, "to carry coals through Wollaton alonge the passage now laide with Railes, and with suche or the lyke Carriages as are now in use for that purpose".

Beaumont fell out with his mentor (Sir Percival Willoughby) and although the wagonway proved vastly superior to conventional road carts, the colliery was unprofitable and eventually closed. It is likely the wagonway lasted fifteen years at the most, as Beaumont's lease ran out by 1618. In the meantime as early as 1605, Beaumont had moved in on the Northumberland coalfield and apparently built three wagonways from collieries down to the River Blyth, hoping thereby to circumvent the established Newcastle sea-coal trade. But he was no more successful in this new venture and as W. Gray, Newcastle's first historian, wrote:

> "Master Beaumont a Gentleman of great ingenuity, adventured into our Mines with thirty thousand pounds. He brought with him many rare engines, not then known in these parts. For example, boring with Iron Rods to test the depth and thickness of the Coals: engines to draw water out of the pits: wagons with one horse to carry down coal from the pits, to the staiths and the river. Within a few years he consumed all his money, and rode home upon his light horse".

The size of his losses may have been exaggerated, but the railways built by Beaumont were the first of what eventually became the hundreds of lines serving the heavily industrialised north-east of England. Embittered and deeply in debt, Beaumont, perhaps the true 'father of railways', died in Nottingham Gaol in 1624.

The "Newcastle Road" so called soon spread far and wide - to Scotland, Cumberland, Leeds, South Yorkshire, Somerset and Ulster. Parallel with these developments was the growth of wooden wagonways in the Severn coalfield of Shropshire. This is where the terms *railway* (first recorded in 1681 at Pensnett) and *railroad* (first recorded in 1702 at Broseley) were first used.

The wooden railways, particularly those in the northeast, in their final development anticipated later railway construction in many ways. Following

excavation and preparation of the roadbed, the track was laid on a bed of ballast. This received its name from the ships' ballast (from the Dutch *bar* 'bare, waste' and *last*, 'load') used by returning coastal coal vessels, which liberally piled the stuff on the banks, and even the bed, of the Tyne. Even in those early times the vital part played by ballast was understood - to carry the weight of the traffic, drain away water from the wood and protect the wood somewhat from the elements. The wooden rails (usually of oak) were laid on cross sleepers to a gauge anywhere between 4ft and 4ft 6in and pinned with trenails usually of young oak. ['trenail' - or 'treenail' a wooden peg used to join timbers, which swells with moisture - *Websters Dict.*], Track workers packed the ballast firmly under the rails so that the load was as evenly distributed as possible.

During the latter half of the 18th century, a second layer of rails (of beech) was fixed to the top of the first creating the so-called double-way. This increased their life as the top rail could be worn down completely and then easily replaced. Soon it became the practice to add strips of iron to the first rails, which gave an even better wearing surface.

THE IRON RAILWAY

The early years of the 19th century witnessed the ongoing Napoleonic Wars, which surprisingly turned out to be of quite strategic importance to the development of railways.

Due to both the Royal Navy and merchant shipping companies increasing the size of their fleets and monopolising supplies of oak timber there was a continual loss of timber supplies. During this same period, trees were also used for making charcoal upon which the iron industry was completely dependent. As a result, suitable timber for railway lines increased in scarcity and price.

Also, all transport, except for coastal and river sailing vessels, was dependent on horses, the demand for which was forever increasing. Harvests and the ongoing war with Napoleon affected their availability and cost.

With the arrival of the iron railway, both problems were soon alleviated. The iron railway utilised a material increasingly available at an economic price and due to reduced friction required fewer horses to handle a given task.

John Curr was undoubtedly responsible for advancing the iron railway. Believed to have been a native of County Durham, Curr spent the material part of his working life in Sheffield and at one time worked at the Sheffield Colliery, owned by the Duke of Norfolk. A wooden 'Newcastle Road' had been laid to the colliery before Curr arrived but his invention of flanged iron rails was at first only used underground. He illustrated in a book various arrangements of pre-fabricated track (including straights, curves, points and passing loops) and drawings for tubs to carry the coals. His flanged rails allowed the use of ordinary wheels on the tubs so they could run off the rails if necessary.

A contemporary source states that whereas previously a horse could only draw two loads of coal, on his underground plateway one horse could pull between ten and fourteen. The plateway was soon also adopted as a surface railway system, first being used to link with the Chesterfield Canal south of Chesterfield.

Two canal builders, William Jessop Snr. and Benjamin Outram, together built and spread the concept of the plateway or tramroad and as partners (among others) in the Butterley Iron Company in Derbyshire were able to supply suitable plate-rails to any of the new tramroads.

Stone block sleepers sunk into the earth supported the plate rails, usually between three and four feet long. The blocks also carried the rail joints. Earth was built up to rail level between the plates to give a firm path for horses. Growing industry, making profits, needed more transport and industrialists had the money to invest, hence in the 1790s came the 'Canal Mania' coinciding nicely with the availability of the new plate-ways as feeders to the canals. Wooden wagonways had often been built to connect with earlier canals but in the Canal Mania they became part of the companies' Bills as presented to Parliament. They were also used as temporary links whilst larger engineering works were undertaken (a flight of locks, for example) but as investment dried up it became clear that the cheaper tram-roads could be used *instead* of canals.

William Jessop suggested such an option for the whole of a proposed canal between Croydon and the Thames at Wandsworth. The scheme, the Surrey Iron Railway, which received the Royal Assent (i.e. an Act of Parliament) on 21 May 1801, was the very first independent public railway in the world and also the first Railway Company; it was opened throughout on 26 July 1803. The number of such *public* railways increased steadily especially in South Wales, and in 1807 the Oystermouth

Railway between Swansea and Mumbles, became the first public railway to carry fare-paying passengers.

It is noteworthy that during this period, no distinct universal gauge had been adopted. In 1789, Jessop made a cast iron edge rail, which required the flange to be incorporated into the wheel. The first railway of this type using Jessop's rails was constructed at Loughborough with fish bellied cast iron rails from three to four feet long resting on stone blocks rather than sleepers. The rails were laid so that the distance over the outside of the rails was exactly 5 feet; the head of the rails being 1¾in wide this made the gauge between the rails 4ft 8½in. There was, however no continuity of development between this isolated use and later adoption of 4ft 8½in as "standard" gauge, and the fact is quoted to show how easy it is to be mislead by such a co-incidence. Jessop's rails had cast iron feet at each end, which frequently broke off. Hence there was a call for detached feet and so we find the birth of the chair made of cast iron and first used in 1797 near Newcastle-on-Tyne.

Railway builders used many different gauges in the 18th century. It is difficult to imagine the countryside covered by so many of these lines all owned and used by different mines and all of various gauges to suit the wagons in use by the respective owners. By 1800, more than 150 miles of lines were laid around the Newcastle area alone in County Durham. Gauges varied from 3ft 10in to 5ft 0in. And they were busy, too. By 1727, 930 wagons a day were being conveyed over the Tanfield line at just 45 second intervals.

The first public railway in the world - as mentioned earlier - the Surrey Iron Railway used rails that were cast iron, angular in shape, 37in long with 4in treads and a flange standing 2½in high on the inside with another 1in flange projecting downwards on the outside edge of the plate. They were fastened to stone sleepers 15in square and 8in thick. Horses hauled the wagons, each horse being harnessed to a train of four trucks and travelling on average 174 miles per week. The gauge between the flanges was 4ft 2in. The Wylam wagonway - the home of *Puffing Billy* - was 5ft 0in gauge.

It is to be noted that from the birth of railways in the 16th century until the coming of the steam locomotive in the 19th century the almost universal method of haulage was by horse.

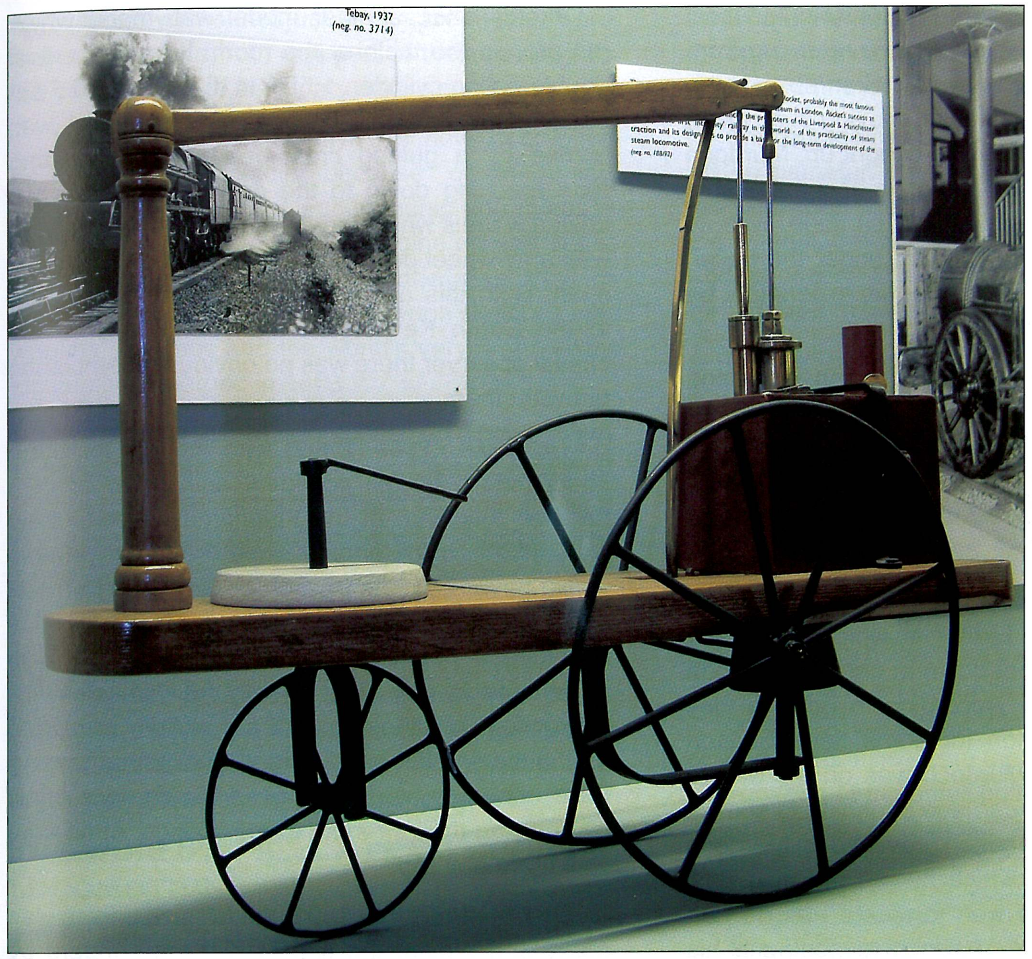
Above: *William Murdoch.* [SCML]

In 1797, William Murdoch (see picture) lived in a house in Cross Street while, next door to him at Moreton House lived Richard Trevithick (see page 10). In 1799, after eighteen years as engineer to Boulton and Watt's Cornwall plant, Murdoch was moved to superintend their works in Soho. These two men were business competitors. Murdoch was engaged in erecting Watt's engines and looking after Watt's interests. "Captain Dick" Trevithick on the other hand was the most prominent of the Cornishmen who were using every means to evade or improve on Watt's patents.

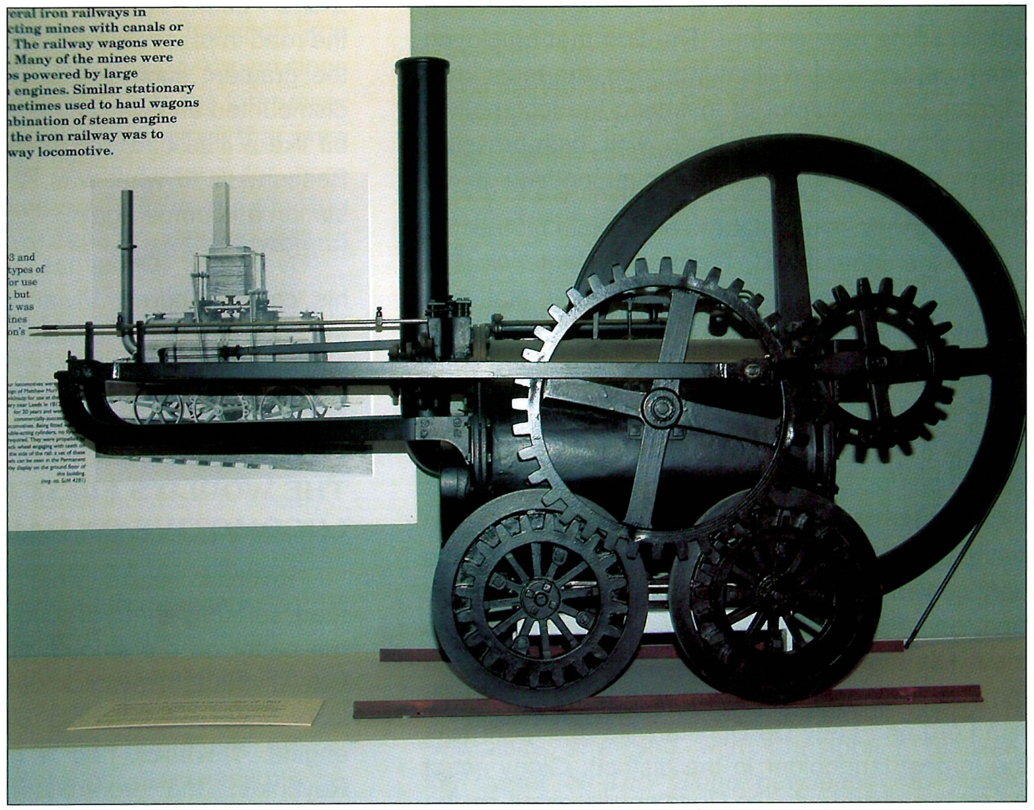
THE STEAM LOCOMOTIVE

In 1789, James Watt was helped by one of his men to invent a locomotive, so he included the use of steam for land transport in his patents. "Locomotive" in this context refers to the use of steam propulsion for road vehicles. Oddly enough, Watt was not particularly interested in developing a road locomotive and discouraged any experiments by his staff in this direction. But Murdoch at Redruth had a freer hand and took up the challenge of developing a wheeled carriage that would move itself.

As one story goes, one evening, wishing to put a model he had built to the test, Murdoch headed down the path to the Redruth church. This was a narrow way bounded on each side by a high hedge. It was dark and he was alone. Lighting the burner under the boiler he got up steam and off went the little locomotive with the inventor in hot pursuit. It soon outpaced him, leaving him to



Left: *A replica of the experimental model steam road vehicle built by William Murdoch in 1797. Approximately 1 in 8 scale, the replica is held at the Science Museum in London.* [SCML]



Right: *A model of Trevithick's 2nd 0-4-0 Penydarren locomotive. The prototype was built in 1804; the model was built in 1970 and is held at the Science Museum, London.* [SCML] chase after it. According to the daughter of the local parson, her father and mother were returning from town when they were somewhat taken aback by a fizzing sound and saw this thing moving in a zigzag manner on the road. When he caught up, Murdoch found the local clergyman in a state of considerable distress for he had mistaken the carriage, with its billowing smoke and fire burning under the boiler, for the devil. Murdoch asked that his experiment be kept secret for the time being.

It would appear that Murdoch probably made at least two models. One had a stroke of 1½in while another had a stroke of 2⅛in. But after this, Murdoch appears to have lost interest in his work on the steam locomotive and the reason may be explained as follows.

One day, when Boulton was going to Cornwall, he met a coach near Exeter in which he caught sight of Murdoch. He got down at once whereupon Murdoch also alighted. According to Boulton they engaged in conversation for some time. Boulton soon discovered that Murdoch was on his way to London with his steam carriage intending to show it and take out a patent. Boulton prevailed on Murdoch to return to Cornwall, which he did the next day. Boulton considered he was fortunate that he had been able to persuade Murdoch to postpone his interest in the steam carriage. In short, Boulton and Watt had enough on their plate without launching out on some new venture. The firm that employed him thus deprived William Murdoch, the most loyal of men, of the honour of inventing the locomotive. Murdoch's venture had been with high-pressure steam and the Soho firm wanted nothing to do with it.

On the other hand, Richard Trevithick was a high-pressure man through and through. Naturally inventive, he was intent on inventing a locomotive. From the newspapers he probably learned of what others were doing, or he was probably told by Murdoch himself, of the latter's little caper on the church path.

In 1797, he had his own model developed and ready to go. At the age of twenty-six he had married and settled the family home at Moreton House. And, here, only a few weeks later, the model was tried. His friend, Davies Giddy, later President of the Royal Society was there and he brought with him Lord and Lady De Dunstanville (the latter was the largest landholder in the district). Giddy acted as stoker while Lady De Dunstanville acted as the engine driver.

Shortly after, another model was made which ran around the table or the room. It had a vertical double-acting cylinder, 1.55in in diameter and 3.6in stroke sunk into the boiler. The piston rod was carried by a guided cross-head, the connecting rods reaching down to the crank-pins in the two driving wheels which measured 4in diameter. There was a fly-wheel driven by a spur gear on the crank shaft. Both this and Murdoch's model finished up in the South Kensington Museum where to the casual observer there was no obvious resemblance between them.

Trevithick experimented with models for three years before he felt confident enough to erect a full size machine. In the meantime he conducted experiments to determine whether smooth wheels would have sufficient traction on any road to move their load. He did this with the help of his friend Giddy by hiring a post-chaise ('post-chaise', a carriage once used in travelling, usually four wheeled, for two or four passengers with a postilion, who rode on the leading left hand horse). After unharnessing the horses, the two men moved the carriage uphill by applying their strength to the spokes. At no time was there any slip.

On Christmas Eve 1801, the full size engine was ready and moved the first load of passengers by steam on what was known in the district as "Captain Dick's Puffer." The rain was coming down heavily, the road in places was rough with loose stones and the gradient such that a wise cyclist would have dismounted and walked his machine. But "she went off like a little bird" for three-quarters of a mile up Beacon Hill to what was later Cambourne railway station and home again.

Over their Christmas dinner, Trevithick and his cousin Andrew Vivian became partners and they were soon in London armed with letters of introduction from Giddy to Humphry Davy, who introduced them to a certain Mr. Rumford, both of whom helped them in securing their patent.

THE WORLD'S FIRST STEAM LOCOMOTIVE ON RAILS

Trevithick learnt from running on different road surfaces that his locomotive would probably run better on the smooth surface of an iron road. Late in 1802, Trevithick decided to build another locomotive, which could be run as a 'tramway' engine. Trevithick had a good friend in William Reynolds, the Ironmaster in charge of the Coalbrookdale Company. This Company, which

had various works (not just at Coalbrookdale) were manufacturers in iron, and part of their output was the construction of stationary steam engines.

Trevithick wanted to have his new locomotive built at Coalbrookdale because of their fine reputation for quality of workmanship and it was a place where he could test the engine on one of the 3ft 0in gauge iron plateways in the area. William Reynolds converted Trevithick's rough sketches into working drawings and the world's very first railway locomotive emerged in 1803.

This pioneer steam locomotive had a boiler 4 feet in diameter with walls 1¼in thick, raised steam at 45 lb per square inch pressure and was driven with a single horizontal cylinder 7in diameter by 3ft stroke. It had a grate area of 4 square feet but because of the layout, the firebox could not be fed while the engine was in motion.

While this first steam locomotive was but a prototype and was not perfect (as one would expect), it inspired Trevithick to build the locomotive with which the railway era is often said to have begun.

THE WORLD'S FIRST STEAM GOODS LOCOMOTIVE

In October, Trevithick was at the Penydarren Ironworks near Merthyr Tydfil, at the invitation of Samuel Homfray who encouraged him to build a high-pressure steam locomotive to transport iron on the Merthyr Tramroad. This engine, known since as the "Penydarren locomotive," was the forerunner of the many thousands of goods engines that were to haul the freight traffic of the railways for more than 150 years. It worked on the tram-road for the first time on 13 February 1804. Trevithick wrote to Giddy:

> "It worked very well and ran up hill and down hill with great ease and was very manageable. We had plenty of steam and power."

On the following Monday, he wrote,

> "The engine, with water included, is about five tons. It runs up the tramroad of two inches in a yard - forty strokes per minute with the empty wagons. The engine moves forward nine feet at every stroke. The steam that is discharged from the engine is turned up the chimney about 3 feet above the fire. When the engine works at forty strokes per minute, 4ft 6in stroke, 8¼in diameter of cylinder, not the smallest particle of steam appears out of the top of the chimney, though it is but 8 feet above where the steam is delivered into it. The fire burns much brighter when the steam goes up the chimney than when the engine is idle."

This engine had a cast iron boiler 6ft 0in long by 4ft 3in diameter. It is interesting to note that because the tram-road used plate rails with a flange to guide the wheels, the wheels on this locomotive were flat and the locomotive could also run on the road. The Penydarren railway had a gauge of 4ft 4in.

On the Tuesday, another run took place:

> "Yesterday," wrote Trevithick to Giddy, "we proceeded on our journey with the engine; we carried 10 tons of iron, five wagons and seventy men riding on them the whole of the journey. It is just over nine miles, which we performed in 4 hours 5 minutes. The engine while working went nearly five miles per hour; no water was put into the boiler from the time we started until we arrived at our journey's end. The coal consumed was 2 cwt. On our return home, about four miles from the shipping place of the iron, one of the small bolts that fastened the axle to the boiler broke, and all the water ran out of the boiler, which prevented the return of the engine until this evening."

The engine continued working and 10 days later was tried with 25 tons of iron.

> "We were more than a match for that weight," wrote Trevithick to Giddy; and continued, "the steam is delivered into the chimney above the damper; when the damper is shut the steam makes its appearance at the top of the chimney but when open none can be seen. It makes the draught much stronger by going up the chimney."

The little engine was kept busy for some time after this, but was eventually taken to work the rolling mill. Unfortunately for Trevithick, the ironmasters of Merthyr Tydfil had invested heavily in the Glamorganshire Canal and they were against any improvement to the tramway, which would take away revenue from the canal. What with the criticism heaped on him from this opposition and the damage his locomotive caused to the fragile plates of the "plateway," Trevithick returned to the north of England to further develop his steam locomotive.

In September 1805, Trevithick was at Newcastle arranging with Christopher Blackett, the owner of *The Globe* newspaper, to supply him with a locomotive for the Wylam Colliery Waggonway, which was five miles long. This was erected at John Whinfield's foundry at Pipewellgate, Gateshead (Newcastle) and was completed in May 1805. Like the Penydarren locomotive on which she was an improvement, she had no bellows draught - Trevithick had abandoned it as soon as he found the steam blast was sufficient.

This Gateshead engine was the first with flanged wheels. On a temporary iron railway at Whinfield's yard, she had worked satisfactorily and became the first engine to work on an iron edge rail. Unfortunately, the Wylam track then had wooden rails, and so she was taken off and used as a stationary engine for some years. Three years later, the rails were replaced with cast-iron rails.

During the next ten years, Trevithick who was a man of many inventions built several other engines. In 1808, he distinguished himself further. Having built the world's first steam railway locomotive and the world's first goods locomotive, he now turned to building the world's first passenger railway locomotive.

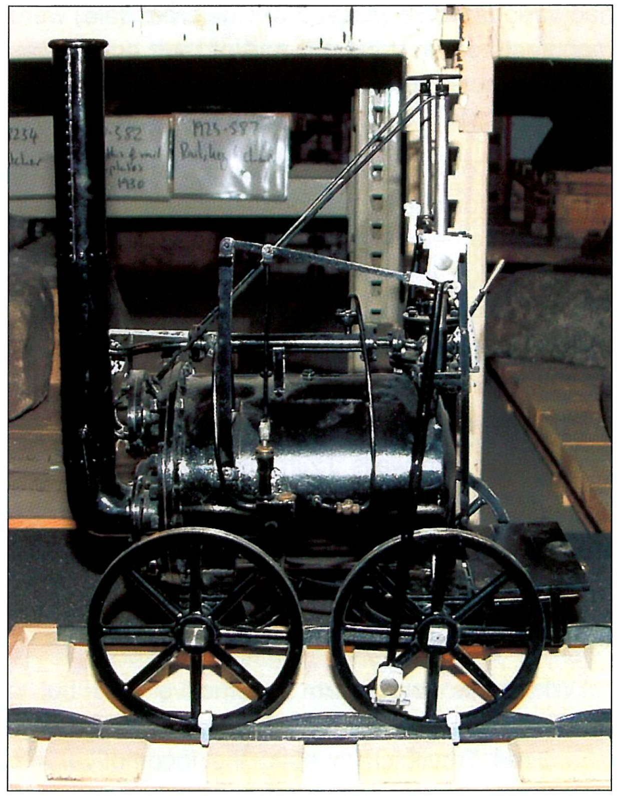
THE WORLD'S FIRST STEAM PASSENGER LOCOMOTIVE

In this year, he demonstrated his *Catch-me-who-can* on a circular iron road of no more than 100ft radius at a site, which later became Torrington Square in London. Passengers were carried at up to twelve miles per hour for a shilling a head.

To build *Catch-me-who-can*, Trevithick joined forces with John Urpeth Rastrick, the engineer of the Hazledine Foundry in Bridgnorth. Followers of the modern railway scene will know that Bridgnorth is the northern terminus of the famous Severn Valley Railway, one of England's premier preserved railways. It is most apt that the world's first passenger steam locomotive should have been born in such a locality.

Christopher Magner in his important work on early railways describes the locomotive as follows:

> "The locomotive was more 'refined' than the three earlier designs having a single vertical cylinder placed at the closed end of the boiler (the opposite end to the chimney and firedoor), a direct drive with connecting rods linked to the crank pins on the driving wheels and it weighed eight tons. Unlike his earlier locomotives it did not have the cumbersome horizontal slide bar arrangement and a large flywheel like the earlier 1802/3, 1804 and 1805 locomotives. The boiler is believed to have been the same type as the 1805 stationary engine built in Bridgnorth at the Hazledine Foundry, now in the Science Museum, and had similarities in design to the model engine at the Straffan Museum. *Catch-me-who-can's* name came from a suggestion by Davies Gilbert's sister, Mrs Guilmard. This was the first demonstration of a steam 'passenger' railway in the world."



Above: Catch-me-who-can. [SCML]

But at first, Trevithick's early locomotives were a liability owing to the frequent breakages of the cast iron plates upon which they ran and many finished up as stationary engines.

In October 1816, Trevithick went to South America where he made his fortune but in the War of Independence he was ruined and was lucky to escape with his life. When the boat he was using was upset at the mouth of the Magdalena, he was lassoed from drowning - and an alligator - by Bruce Hall, who took him to Robert Stephenson at Cartagena. "Is that Bobby?" asked Trevithick, "I have nursed him many a time!" And so he had. He and Robert Stephenson had left South America together. Trevithick died on 22 April 1833, aged 62. So was ended the life of the man who built the first steam locomotive to run on rails and who, like many another inventor, died in poverty, never making a fortune from his invention.

Above: *George Stephenson.* [SCML]

GEORGE STEPHENSON

Trevithick's locomotive for the Wylam Colliery marked the birth of locomotive construction on the Tyne and also acted as a spur to other locomotive builders such as Matthew Murray, John Blenkinsop, William Hedley and George Stephenson.

Stephenson has often been called the "Father of Railways" but he has been credited with more than his due, for in the days when opposition to railways was at its fiercest, promoters of railways found it necessary (for parliamentary and advertising purposes) to magnify Stephenson's reputation as an authority on every branch of railway engineering. He was not the "Father of the Railway Engine", that honour having fallen to Richard Trevithick; nor was he the inventor of the railway.

But his knowledge, derived from the machines and the men who made them, was immense and his organising powers were remarkable. Despite much opposition, he led the fight against the old order of things and he became the one conspicuous figure to whom the railwaymen looked up to for leadership. Around him the storm centred; and it is to him more than any other man that Britain owes so much of their railway systems. And although he neither invented railways nor steam locomotives he was responsible, in part, for setting the "standard gauge".

George Stephenson started his working life by herding cows for twopence per day and ten years had passed before he was appointed brakesman on the West Moor Pit at Killingworth, earning £2 a week.

In 1812, the owners of Killingworth High Pit appointed Stephenson to the position of engine-wright at a salary of £100 a year. In riding about inspecting the collieries belonging to his employers and those of other owners he became interested in the new railway between the Kenton and Coxlodge collieries and the River Tyne. This had the Blenkinsop rail and engines.

In 1811, John Blenkinsop had patented a rail with a "toothed rack or longitudinal piece of cast iron or other fit material having the teeth or protuberances or other parts of the nature of teeth standing either upwards, downwards or sideways." The teeth were at suitable intervals for "a wheel having teeth or protuberances" to engage, the latter being part of the driving mechanism of the engine. Thus he became the originator of the mountain climbing rack railways although it was only his intention to give greater power to locomotives on level track. He did not produce rolling stock and Matthew Murray erected his first "rack" locomotive.

William Hedley had found by experiment (confirming Trevithick's experience) that smooth wheels had sufficient adhesion on smooth rails to surmount the gradients on the Wylam Colliery track. The following year, at the suggestion of Christopher Blackett, he built *Puffing Billy*.

Puffing Billy was built with four wheels in 1813 for the Wylam Colliery, and at first ran on cast iron plates, each of which weighed 45lb and was three feet long. But these plates were broken to such an extent under the weight of the engine that it became necessary to carry half a dozen spare plates upon the engine to replace any that might break during the journey.

In 1815, to reduce the weight on individual axles, the engine was rebuilt as an eight wheeled locomotive, each group of four wheels being carried on a sort of bogie. In 1830, the line was relayed with cast iron edge rails, and then *Billy* again reverted to a four-wheeler. This engine from the first was a great improvement on the horses and was kept at work until 1862. A sister engine, *Wylam Dilly* worked until 1867.

Stephenson carefully watched the working of these engines on the railway that ran past the cottage where he was born in 1781. He came to the conclusion that he could improve on them as well as on the Coxlodge engines; and in 1814 he built *Blucher*, his first locomotive. To begin with, this was rather a failure, but as soon as he turned the waste steam into the funnel as Trevithick had done he doubled the power and made it a success. This led to his Killingworth engine of 1815. At first this had coupling rods connecting inside cranks on the axles, but owing to one of the axles getting bent he replaced the rods with the chain gearing familiar to us in the bicycle. The same chain coupling with the sprocket wheels was used in an engine he built in 1816.

But the engines were waiting for the development of roads strong enough to carry them. Although cast-iron rails continued to be used owing to their cheapness, for some years rails had been made here and there of wrought iron. When Timothy Hackworth went to the Walbottle Colliery as foreman of the smiths he found rails of malleable iron which had been laid as early as 1805; and in 1808 wrought iron rails were in use on the Tindale Fell line, merely a square bar spiked to stone blocks. Then in 1820 came John Birkinshaw with his mill to produce reliable malleable rails in quantity. To quote from Thomas Baker, the poet of the "Steam Engine":

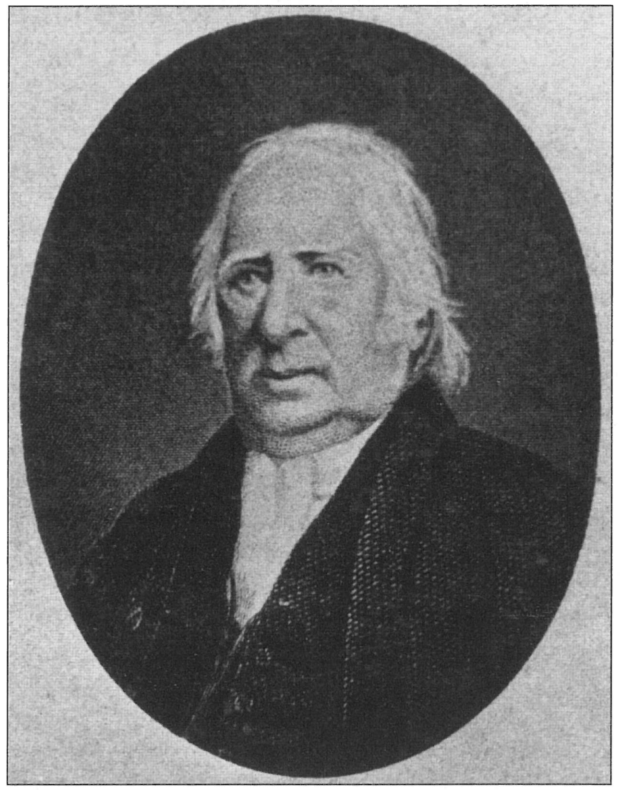
"By rolling mill he these tough rails produced,
And these, without improvement,
still are used,
No hammer-work, unseemly weld, or flaw
Was in the work of famous Birkinshaw!"

The weakness of early track is the reason why most early engines were tender engines and the proliferation of tank engines in later years had to wait until the track was strong enough to support locomotives that carried their own coal and water.

Stephenson had the backing of a wealthy group of miners who not only encouraged and assisted him to improve the steam locomotive but permitted him to try his engines on their wagonway at Killingworth Moor where the gauge was 4ft 8in.

THE STOCKTON AND DARLINGTON RAILWAY

The Stockton and Darlington Railway was built to overcome the difficulty of navigating the River Tees. Ships took as long to sail from Stockton to the mouth of the river as they did from the latter to the Thames. Surveys for a canal or alternatively a tram-road to avoid the long river journey were carried out as early as the year 1768. In 1810, the Tees Navigation Company dug a 220 yard cutting called the Mandale Cut, which cut off over two miles, but it was a drop in the ocean compared to the total distance up the river.



Above: *Edward Pease.* [SCML]

Meanwhile Edward Pease, owner of the woollen mills at Darlington - "Neddie Pease who started the Stockton and Darlington when he was already fifty years old," and lived till he was ninety-one - had become satisfied that the old plan for a railroad was "as good as a canal and cheaper." He called in John Rennie to carry out a second survey and report. The report appeared in 1815 and as a result, after three year's consideration, two rival parties emerged - the businessmen in Stockton who were anxious for a canal and those in Darlington who favoured a railroad.

Then Jonathon Backhouse, a Darlington banker, endeavoured to bring about peace between the rival factions by suggesting that the Tees should be made navigable up to Yarm and that the railroad should run from Yarm to Darlington and on to the collieries. In this proposal, Backhouse was joined by Thomas Meynell, the squire of Yarm. Stockton would have none of this, and so the project was put to the vote at

Darlington, when the majority was in favour of Pease's plan of a railway all the way. Having failed in their efforts at reconciliation, both Meynell and Backhouse joined with Pease. Residing in the neighbourhood was Thomas Richardson, Pease's cousin, a retired bill-broker whose financial abilities were renowned. He joined the triumvirate and it was really these four who brought about the Stockton and Darlington.

The first Bill introduced into Parliament in 1818 failed to pass; Rennie had taken the line too close to one of the Duke of Cleveland's fox-coverts. George Overton of Lanthetty (near Brecon), the engineer of several of the successful South Wales lines made a third survey. He submitted his plans on 20 October 1818. His estimated costs were £2,000 per mile, single track, £2,400 single track but formed for a double track and £2,800 a mile if laid with a double track.

The submission was unacceptable to the proponents. On 19 December 1818, Robert Louis Stevenson's father, Robert Stevenson of Edinburgh, was asked to make a fourth survey but even this was unacceptable. Nevertheless, Stevenson continued to be consulted up until July 1821, when as we shall see, George Stephenson succeeded him.

On 12 February 1820, at the George and Dragon public house in Yarm, the promoters of the railway held a further meeting. Thomas Meynell was in the chair. It was decided to submit a second Bill into the next session of Parliament. In preparation for that Bill a fifth survey was made this time again by Overton and on 19 April 1921, the Act was obtained.

Meynell laid the first rail with great ceremony near St John's Well, Stockton on 23 May 1922. Soon after, a boy with papers in his hand was shouting in Stockton Streets, "Speech of Mr T Meynell. One penny!" A man who bought one, found nothing but a sheet of blank paper. "Why, you little rascal, there's nought here!" "No, sir," replied the boy, "because he said nought!"

Shortly after securing the Act, Edward Pease was writing in his room when a servant announced that two strange men wished to speak to him. He was busy, and he sent them a message that he was too much occupied to see them. Hardly had he done so than he thought that perhaps he had been unkind and he rose from his chair and went downstairs. Going into the kitchen he found them and they gave their names as Nicholas Woods, viewer at Killingworth Colliery and George Stephenson, enginewright.

Pease sat down on the edge of the kitchen table to listen to what they had to say and Stephenson handed him a letter from Mr Lambert, the manager of Killingworth mine, recommending him to the notice of Pease as a man who understood the laying down of railways. Pease read the letter and took stock of "Old George". As he said afterwards, there was such an honest, sensible look about George Stephenson, and he seemed so modest and unpretentious speaking in the strong Northumberland dialect that - in short - he took to him at once. Here was a man after his own heart.

In the conversation that followed, Stephenson agreed that Pease had acted wisely in proposing an edge rail road not-with-standing that all the traffic must go on flanged wheels. But he asked for information as to what was meant by the vehicles being drawn "by men, horses or otherwise". This phrase had been adopted from the Act of the Oystermouth Railway at the suggestion of Overton, who knew what steam was doing in South Wales and the Forest of Dean. Stephenson learnt that all the calculations had been made on the basis of horse traction, though steam might be used later. It was that "or otherwise" that had brought him to Darlington and he thereupon told Pease that he would do much better in using locomotives to start with. "Come over to Killingworth and see what my Blucher can do; seeing is believing, sir."

The interview ended with Pease promising to support Stephenson's application for the position of engineer and agreeing to visit Killingworth to see what was going on. Stephenson was appointed, the edge rail was adopted instead of the flat rail and Stephenson expressed a desire to re-survey the route again as soon as possible. This, the sixth and final survey was at once begun by George Stephenson and John Dixon, assisted by George's son, Robert as chainman. "Esteemed friend, George Stephenson," wrote Edward Pease, when sending him his first instructions with regard to the Stockton and Darlington Railway, "in making thy survey, it must be borne in mind that this is for a great public way - its construction must be solid."

In the summer of 1822, Edward Pease and his cousin Richardson went over to Killingworth to see and believe. Further, in 1823 the company obtained an amending Act giving them power to definitely use locomotives and to haul and carry passengers as well as merchandise.

There were stationary engines at Brusselton and Etherley and it was from the "Permanent Steam Engine below Brusselton Tower" that the proprietors and their friends, after examining the extensive incline planes there, started the "first train" on the opening day, 27 September 1825. First came a man with a red flag. Then "The Company's Locomotive Engine" (*Locomotion No.1*); then "The Engine's Tender" (described as a water barrel on the top of a muck wagon); then six wagons loaded with coals and merchandise; then "The Committee and Other Proprietors in The Coach" (*The Experiment*) belonging to The Company. This was followed by six wagons for strangers and a string of other wagons. It was a great triumph, but the man to whom it was due was not there.

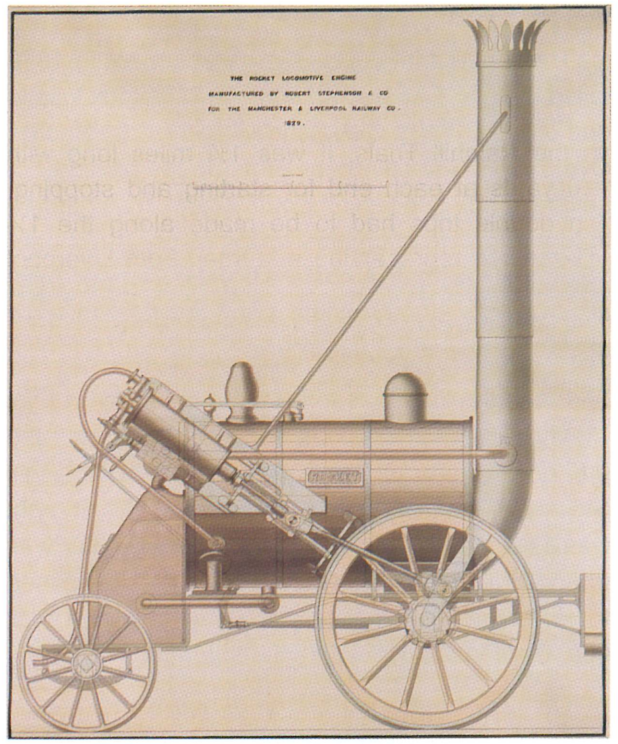
That day, Edward Pease's son Isaac had died and in the silent room he heard the distant cheers telling him in the hour of his bereavement that his work had been completed.

The line was single with a loop every quarter of a mile. With its four branches it was 36¼ miles long. It cost £9,000 per mile which is about four times as much as what Overton had estimated. Despite Stephenson holding a patent for cast iron rails he recommended using wrought iron rails manufactured under Birkinshaw's patent. "They" - the cast iron rails - "will not stand the weight and you will be at no end of expense for repairs and delays", he advised. So the rails used were of malleable iron, fish-bellied in pattern, 28lb per yard, 2¼in wide on the head, 2in deep at the ends and 3¼in in the middle, with a flange of ¾in. Some of them were laid on stone blocks and some on oak sleepers well bedded in the ballast. Stephenson laid the rails to the same gauge as he had used on the Killingworth colliery railway, i.e. 4ft 8in.

STEPHENSON'S WORKS

In August 1823, the first piece of land was bought in Newcastle for the Forth Street Works, destined to be known all over the world as Robert Stephenson and Company. On 13 December 1824, Michael Longridge, then manager, set out to buy adjoining land to add a foundry to the plant and on 30 December, an office was opened for engineering and railway surveying.

The first two locomotives built there were for the Hetton Colliery and then early in 1825, the third engine built was *Locomotion No.1* for the Stockton and Darlington Railway. The next three engines built there were Nos. 2, 3 and 4 also for the S&DR, which carried the names *Hope*, the *Black Diamond* and the *Diligence*. Wilson of Newcastle built No.5 (*Stockton*).



Above: *The* Rocket. [SCML]

THE "ROCKET"

There are a few misconceptions about the *Rocket*. Popular boy's books give the impression that George Stephenson built the *Rocket*, whereas it was Robert Stephenson and Company who must be so remembered, although old George would have been closely involved. Also it was by no means the first locomotive built by the company for they had been building locomotives since 1825.

The *Rocket* is associated with the Liverpool and Manchester Railway, which was opened to traffic in 1830. George Stephenson was the construction engineer for this line. In building this line, Stephenson used two of his own locomotives, the *Twin Sisters*, which had two boilers and two chimneys and the *Lancashire Witch*. These engines were used hauling material during the construction of the earth works and were probably the first "work train engines". Despite this demonstration of suitability and experience

with locomotives, some of the directors of the company were not convinced that steam locomotives could handle the traffic and held out in favour of rope traction using a number of stationary engines at strategic locations. In fact, rope traction was adopted for the Liverpool and Sutton inclines because of their severe gradients.

To settle this matter it was finally decided to hold a competition with a prize of £500 for the best locomotive to work the rest of the line. The test course was a level stretch on the Manchester side of Rainhill Bridge and the contests were known as the Rainhill Trials. It was 1¾ miles long with 220 yards at each end for starting and stopping. Ten double trips had to be made along the 1½ mile course representing a journey from Liverpool to Manchester. Water was then to be taken and another ten trips run to represent the return journey. The minimum speed was to average 10 miles per hour and the load was to be three times the weight of the engine. Maximum boiler pressure was to be 50 lb per square inch. Engines over 4.5 tons were to have three axles. Judges were John Urpeth Rastrick, who built Trevithick's *Catch-me-who-can* and most of the London - Brighton railway; Nicholas Wood who invented the railway carriage and John Kennedy who was involved with the cotton-spinning industry.

There were four entries. The only two worthwhile entries were Stephenson's *Rocket* and Timothy Hackworth's *Sanspareil*. Other entries were Braithwaite and Ericson's *Novelty* and Timothy Burstall's *Perseverence*. Thomas Shaw Brandreth a director of the company, who resigned before completion of the line, was allowed to demonstrate his *Cyclopede* in which the weight of a horse on a moving platform was able to carry itself at a rate of six miles per hour.

The *Perseverence* was a failure and Burstall gave up the contest as hopeless. The *Novelty* only did four trips before her boiler gave way and she had to be withdrawn. The interesting point about this engine is that it was driven by Charles Fox who later became well known in the Structural Engineering field. He built the Great Exhibition in 1851 and the Crystal Palace at Sydenham (see note page 32).

Timothy Hackworth built the *Sanspareil*, an 0-4-0 tender engine. He received his training under the Stephensons and was recommended by George to be the locomotive superintendent of the Stockton and Darlington Railway. Robert Stephenson's Works made the cylinders for the engine, as the SD&R's shops were not up to the task. The boiler was made by John Birkinshaw at Bedlington. The boiler was a cylindrical shell with one flat end and the other dished. It had an internal return flue projecting on the fire grate side and enclosed in a water jacket. It had two vertical 7in by 18in cylinders, which worked downwards on the two back wheels. These were coupled to the front wheels, both being 4ft 6in in diameter. The 3in blast pipe combined the exhaust from both cylinders and entered the chimney half way up. It had a grate area of 10 square feet and heating surface of 90 square feet. It weighed 4¾ tons, which was a quarter of a ton over weight for four wheels but the judges allowed it to compete. On one trip it went at 17½ miles per hour and it had actually run 27½ miles at an average speed of nearly 14 miles per hour when, unfortunately, it broke down. Just after starting, according to Hackworth one of the cylinders burst due to the casting being too thin on one side, which allowed the boiler to discharge straight to the atmosphere on every stroke of the engine.

Thus, the only survivor and the only engine to comply with all the conditions won the competition. On 8 October 1929, the *Rocket*, an 0-2-2 tender engine, ran the full distance out and home at an average speed of 13.8 miles per hour, the fastest journey being at 24.1 miles per hour. A description of this engine is as follows.

The boiler was cylindrical, 3ft 4in diameter by 6ft 0in long. The firebox was made of copper and was bolted on to the end of the boiler. At the top, back and sides it had a 2½in water space and at the front it had a firebrick lining. The hot gases from it passed through 25 copper tubes, 3in diameter placed in the bottom half of the boiler, which led into a chamber at the base of the chimney, which served as a smokebox. The heating surface was 138 square feet and the grate area was 6 square feet. Two 2½in pipes connected the water space of the firebox with that of the barrel and two similar pipes connected the top of the firebox with the steam space. The working pressure was 50 lb per square inch and beside two safety valves, there was a slender mercury gauge as tall as the chimney running up the left hand side of it indicating steam pressures of between 45 and 60 lb per square inch. Two pipes carried the exhaust from the two cylinders along the top of the boiler, entering on each side of the chimney and ending in a blast nozzle, 1½in diameter.

The cylinders at an angle of 37 degrees were 8in diameter by 17in stroke. The 4ft 8½in diameter driving wheels were of wood, with cast iron bosses and iron tyres; the cast iron trailing wheels were 2ft 10in diameter and the all up weight of the engine alone was 4 tons 5 cwt in working order while the tender weighed 3 tons 4 cwt (making a total of 7 tons 9 cwt). In the trials the tender was included as part of the load.

On the day of the contest, according to a reliable witness, it was painted yellow, lined with black and her chimney painted white.

The prize money was divided equally between Robert Stephenson, who designed the engine and Henry Booth, the company secretary, who suggested the use of copper tubes and incidentally also invented the screw coupling.

There was no more talk of ropes or horses and when the line opened on 15 September 1830, there were eight engines to take part in the ceremony, as follows:

Engine	Driven by
Northumbrian ‡	George Stephenson
Phoenix ‡	Robert Stephenson
North Star ‡	Robert Stephenson*
Rocket	Joseph Locke
Dart †	Thomas Gooch
Comet †	William Allcard
Arrow †	Frederick Swanwick
Meteor †	Anthony Harding

*(George's brother)

All the above engines had outside cylinders, those marked ‡ were built last and had 11in by 16in cylinders while those marked † had 10in by 16in cylinders. The first inside cylinder engine was *Planet*, put on the line soon after it opened.

THE STANDARD GAUGE

Locomotion, which was the first engine built by Stephenson's for the Stockton and Darlington Railway was built to a gauge of 4ft 8in. When the Stockton and Darlington Railway was extended to Middlesborough in 1828, the gauge was fixed by Parliament at 4ft 8in and it is notable that this was the first time that the gauge of a railway was provided for in its enabling Act.

The Liverpool and Manchester Railway was the first public railway (i.e. a common carrier of goods and passengers). It was constructed to a gauge of 4ft 8in at the Manchester end by platelayers from the Stockton and Darlington Railway who brought "their gauges with them as part of their stock of tools" and these gauges were used as a matter of course to lay the rails.

Above: *Robert Stephenson.* [SCML]

Rocket was made to a gauge of 4ft 8in according to the records of the Robert Stephenson and Company.

During the construction of the Liverpool and Manchester Railway, Mr. Thomas Gooch who was engaged to carry out the work (and was also George Stephenson's very excellent secretary) stated that discussions arose over the value of coning the tread of the railway wheels. On the curves, the wheels could move laterally so that the wheels on the outer rail would run on a slightly larger diameter than the wheels on the inner rail and balance out the stresses caused by the outer rail being longer than the inner rail. To enable the wheels to move across the gauge according to theory, some extra play was needed and consequently the gauge of the Liverpool and Manchester was widened to 4ft 8½in throughout.

Railways, which connected with the Liverpool and Manchester, such as the Grand Junction and the London and Birmingham, were then also built to the 4ft 8½in gauge to enable through running.

The 4ft 8in gauge continued in use on the Stockton and Darlington because the old cauldron wagons were able to run on this gauge. In 1840, the main North line between York and Darlington was opened to a gauge of 4ft 8½in and it was decided to widen the gauge of the S&DR to allow

through running. Even so, it was only widened to 4ft 8¼in at first; the track was laid on stone blocks which tended to spread the gauge anyway, so it may be surmised that this was recognition of an existing situation. The gauge was further widened to 4ft 8½in when the line was relayed with new rail. It is notable that in 1839, the Chairman of the S&DR, Joseph Pease stated before a Parliamentary Committee "that the width inside the rails was 4ft 8in," but added, "in practice 4ft 8½in." This seems to be the first occasion on which this gauge was placed on public record. (Note that Pease was careful to state that the gauge was nominally in accordance with the enabling Act and hence "legal.")

After Stephenson surveyed the new Liverpool and Manchester Railway, he devoted his time wholly to constructing new railways. When the plans for another of the earliest lines - the Leicester and Swannington - were under discussion, someone suggested that 3ft 0in might be a better gauge than 4ft 8½in. "This won't do", George Stephenson is reported to have exclaimed. "I tell you the Stockton and Darlington, the Liverpool and Manchester, the Canterbury and Whitstable and the Leicester and Swannington must all be 4ft 8½in. Make them of the same width; though they may be a long way apart now, depend upon it, they will be joined together one day."

Thereafter, wherever Stephenson built railways he continued to use the gauge, which had been derived from the Killingworth colliery railway. He was responsible for spreading it through Europe where he was consultant for many Continental countries, and where, for their railways, his son's workshops at Newcastle supplied their first locomotives. His son, Robert, continued to manufacture engines and advocated the use of 4ft 8½in gauge to all who sought locomotives from him as his machinery was set up to manufacture engines for this gauge the most economically.

Also some railways were built to a gauge, which was not quite 4ft 8½in. For example the following railways adopted the 4ft 9in gauge when built:

York and North Midland (1839)
Birmingham and Derby (1839)
Chester and Crewe (1840)
Manchester and Birmingham (1840)
Manchester and Leeds (1840)

Modern railways can tolerate wide gauge up to at least ½in (13mm) without fear of derailment

Above: *Great Western Railway broad gauge 4-2-2 locomotive and passenger train at Castle Hill (Ealing Down) station, London, c. 1890.* [SCML]

and "tight" gauge of about the same. The French high-speed railways (TGV) use a gauge of 4ft 8¼in (1432mm) as their track is laid to very strict tolerances and their curves are of very large radius.

BRUNEL'S "BROAD GAUGE"

In England, Parliament enacted a law to make 4ft 8½in gauge mandatory until it was withdrawn at the request of the Great Western Railway in 1836. Few railways were built after 1836 to other than "standard" gauge, apart that is from the Great Western with its 7ft gauge and the Great Eastern with 5ft gauge.

Because he was a much more scientific engineer than Stephenson, Brunel adopted for the Great Western Railway a much broader gauge - 7ft. (Due to an oversight, Brunel's first locomotives were built to a gauge of exactly 7ft 0in and as it was found that these were too tight in a track gauge of 7ft 0in, Brunel was obliged to increase his track gauge to 7ft 0¼in). He believed that the wider gauge was necessary to obtain the low centre of gravity in his engines, which, together with large driving wheels, was essential for safety and smoothness in fast running. With the wheels so far apart, the Great Western was able to lower their larger boilers down between the wheels. Modern practice, however, has shown that engines with a high centre of gravity can run safely and smoothly.

The problem facing Brunel was that the introduction of his broad gauge meant there were two gauges in Britain with all the humbug of transfer for both goods and passengers at break of gauge stations. Advocates of the two gauges were those who supported Stephenson or those who supported Brunel. Both parties were keen to extend their systems in to each others' territory thus initiating a "gauge war" between them.

THE BRITISH GAUGE COMMISSION

Finally, on 25 June 1845, Richard Cobden of the British Parliament moved in the Commons for a Royal Commission to be set up to investigate the practicability of ensuring that all future railways in Britain were built to the one gauge and the practicability of converting existing railways to the common gauge. More to the point was deciding what that common gauge should be.

The motion was passed and the Royal Commission set up with the following Commissioners:

Sir Frederick Smith, R.E.,
(late Inspector-General of Railways);
George Airy, the Astronomer-Royal;
Peter Barlow, Professor of Mathematics at
Woolwich Military Academy.

Both sides presented their arguments before the Commission, but at the suggestion of Brunel, test runs were carried out on the two gauges to settle which gauge was the better. The Stephenson team ran their test between Darlington and York, but the engine swayed and wobbled so much that it derailed at about 53 miles per hour. On the other hand, the Brunel team ran their test between Paddington and Didcot and, in complete smoothness, attained a speed of 60 miles per hour.

To be perfectly fair, it has to be mentioned that the Stephenson engine was the North Midland Railway's *No.54 Stephenson*, a "long boiler" with inside cylinders and a central driving wheel, and such a high centre of gravity that Daniel Gooch (who was observing for the GWR) wondered how it kept on the rails at all. The long boiler engines were already known to be apt to pitch alarmingly at speed, so it was inevitable that near Thirsk, the engine jumped the rails and came to rest on its side with the carriages on top. No-one was killed and injuries were minor and all concerned considered themselves lucky that the derailment did not occur on an embankment or a bridge. With another engine, the outcome could easily have been more favourable to the "narrow" gauge.

Now, while it was clear that the broad gauge certainly gave the best results, the Commissioners decided that the smooth ride on the broad gauge owed much to the fine permanent way laid by Brunel together with the design of Gooch's locomotive and that with the same design of permanent way and locomotive similar results could be attained on 4ft 8½in gauge. They also took into account that at that time in Britain there were 1,901 miles of the Stephenson gauge as opposed to only 274 miles of Brunel's gauge. Many have found since that it is easier to convert broad to standard gauge than vice versa.

The Commissioners submitted the results of their inquiry as a Minute to the Board of Trade on the 6th of June 1846. As a result, during June and July 1846, the recommendations were debated hotly in both Houses of the British Parliament.

It was agreed that there was no difference of opinion as to the great inconvenience "which a want of uniformity of gauge in all the railroads throughout Great Britain occasioned; or that wherever a break of gauge occurred, there, an interruption of the communication took place; and the effect was to detract from that convenience which the public derived from the rapid and cheap communication they now had by means of railroads." But it was argued that as the Parliament had sanctioned two different gauges in the first place it would be unfair to throw the cost of conversion to one gauge back on the private companies concerned (estimated to cost £1,000,000 sterling). On the other hand the Legislature was not willing to pay it out of the public purse.

The Commissioners favoured the narrow gauge in their Minute. So it seemed that if their recommendation for a uniform gauge was to be adopted, the broad gauge would be the one eventually phased out. On the one hand, the House was disposed to resolve that no new lines should be built on the broad gauge, but on the other hand, realised that this would extend the very inconvenience, which they wanted to remove, particularly in those cases where new lines were extensions of existing broad gauge lines. It is easy to see the logic of this when considering in South Australia the lines from Cutana to Radium Hill and Kowulka to Kevin, which were built to the 3ft 6in gauge long after a decision had been made to construct all new railways in Australia to the 4ft 8½in gauge.

Although logic favoured eventually converting all railways to the Stephenson gauge there were a number of speakers who had misgivings. Some considered that Brunel's 7ft gauge was far superior with regards to rapid travel, comfort and safety and regretted that the 4ft 8½in gauge was established purely due to an accident of history. Some felt that if they were starting all over again that a wider gauge would have been used.

The visionary Lord Redesdale declared that the 4ft 8½in gauge was the worst possible choice and boldly advocated making all future railways in Great Britain of a gauge of six feet and when, in due course, there was a majority of such railways the others would have to convert to the six feet gauge or become isolated. At the beginning of 1845 there were 250 Bills for new lines awaiting consent before Parliament and it appeared that if even only half of them were built, soon new ones would swamp the existing railways.

Redesdale went on to say he regretted the resolution of the Gauge Commissioners, which precluded hope of Great Britain in the foreseeable future having a uniformity of gauge. As he said:

> ".....of those who advocated that, regardless of cost, a system of uniform gauge was essential, it would be, in fact, the only thing creditable to this Empire, which had distinguished itself by the first introduction of this system; but if not adopted, he feared that England which had originated railway communication, would present nothing to future ages but a bungling and complicated system, when it ought to have been more perfect than that of any other country."

If only Lord Redesdale had been around to express such sentiments to the Australians a few years later!

The upshot of all the hot air and opinions expressed in the Commons and the Lords was the Railway Regulation (Gauge) Act, 1846, which was passed and became law on 18 August 1846. This Act specified that:

- Future railways would be built to a gauge of four feet eight and a half inches in Great Britain and five feet three inches in Ireland, with some obvious exceptions i.e. where extension in that gauge would create a further break of gauge.
- Without the consent of the Legislature, no railway company shall alter the gauge of their railway, but existing broad gauge lines were to be converted to standard gauge as opportunity permitted.
- Severe penalties were laid down for non-compliance with the provisions of the Act.

The Great Western was allowed to continue with its broad gauge but was obliged to fall into line with the standard gauge in due course. This conversion was not completed until 46 years later in 1892, but thereafter the whole of England, Wales and Scotland was on the standard (or Stephenson) gauge except for a few small narrow gauge railways.

IRELAND

The 1846 Act prescribed 5ft 3in gauge for Ireland and the origin of this gauge, which was closer to Lord Redesdale's "ideal gauge" of six feet, was brought about in an interesting way.

In 1836 the Irish Railway Commissioners had set the track gauge for Irish railways at 6ft 2in and subsequently the Ulster Railway was at first built to the aforesaid gauge. The Dublin and Kingstown Railway, opened in 1834, had a gauge of 4ft 8½in, while the engineer of the proposed Dublin and Drogheda Railway, ignoring the commissioners, fixed on a gauge of 5ft 2in. In 1843, the Board of Trade appointed its chief inspector of railways, Maj.-Gen. Pasley, to sort things out. General Pasley wrote a circular letter to locomotive builders and railway engineers of the day asking them what gauge they would recommend if no railways yet existed. He deliberately did not consult Brunel, nor, at first, the Stephensons, considering them to be too firmly committed to their existing systems.

All the parties consulted said they considered 5ft to be the narrowest and 5ft 6in the widest gauges preferable, so Pasley split the difference and recommended 5ft 3in for the Dublin and Drogheda and for all future Irish railways. His report was accepted.

AMERICA

The first railway in America - the Baltimore and Ohio - imported Stephenson locomotives and since these were of 4ft 8½in gauge, the "standard" gauge gained a foothold in America, not only on the B. and O., but on several other New England railroads as well as the Pennsylvania Railroad. Not all American railroads were built to standard gauge. The Erie had quite an extensive system with 6ft gauge (perhaps they had been listening to Lord Redesdale!); the Missouri Pacific was built to 5ft 6in gauge; the Jersey and Ohio to 4ft 10in and the Delaware and Hudson was originally built to 4ft 3in gauge. But by far the greatest lengths of non-standard lines were those of the many southern railways built to 5ft gauge.

At the end of the American Civil War, barely 50% of the US rail network was on the 4ft 8½in standard gauge but by 1881, due to some piecemeal conversion, some uniformity had already been achieved. A conference of railroad managers in 1885 agreed that one common gauge was essential for commercial viability and the obvious choice was 4ft 8½in. On 1 June 1886, the remaining southern lines were converted to standard gauge in one massive change; all lines not complying were converted in two days! A minority of narrow gauge lines never were converted.

AUSTRALIA

The first railway of any kind in Australia was at a coal mine in New South Wales. The Australian Agricultural Company operated two short inclined tramways from their "A" and "B" pits for the haulage of coal to the loading staiths in Newcastle Harbour. The "A" pit line was opened as a funicular railway in 1831 and is understood to have operated on the self-acting incline principle. In about 1841 the "B" pit line was opened using partly gravitation and partly horse traction, the horse riding behind the loaded skips on a "dandy truck" and then hauling the empties back to the mine. Although the gauge of the original line is not clear, by 1854 the system, which was now quite large, had been strengthened with heavier rails to take locomotives. The gauge was 4ft 8½in.

In 1836, a five mile railway was opened on the Tasman Peninsula, Van Dieman's Land (Tasmania) in connection with the Port Arthur convict settlement. The line used convicts for motive power and was constructed using timber sleepers and wooden rails. About 16 rail carriages were in use; these were of rather crude construction using cast iron wheels. Three convicts were assigned to each carriage. Eight of the carriages were for carrying freight and the other eight were for passengers with seating for four passengers on each carriage. In a limited way this was a public railway because a charge was made for the carriage of civilian passengers.

In May 1854, a horse-drawn railway using iron rails was opened between Goolwa and Port Elliot in South Australia, being in due course extended to Victor Harbor and connected to Adelaide. At the turn of the 21st century the greater part of this line was still in use as a tourist line and consequently this is now the oldest railway in Australia still in use.

The first railway in Australia to use a steam locomotive was the Melbourne and Hobson's Bay Railway Company's line from Melbourne to Sandridge opened in September 1854.

GAUGE CONVERSION

Although there were many different gauges perpetuated around the world (see Appendix 1), countries originally embracing a number of different gauges usually took the step of converting to a common gauge to ensure that their railways were a convenient form of transport. This has only been partially true of Australia and, in 2007 South Australia still had three different gauges in commercial use.

Conversion to a universal 4ft 8½in gauge took place in America in 1886 and England in 1892. Sir Felix Pole of the Great Western Railway wrote in 1900 the following very interesting description of converting the last remnants of 7ft 0in gauge of the GWR to the 4ft 8½in gauge in use by the rest of England:

THE CONVERSION OF THE GAUGE OF THE GREAT WESTERN RAILWAY MAIN LINE

By Felix J C Pole

(Originally published in the early 1900s)

"It is proposed to convert the whole of the main line and branches west of Exeter from broad to narrow gauge in the month of May 1892, when it is intended that the alteration shall be carried out between a Friday night and the following Monday, the running of broad gauge vehicles on the line between Paddington and Exeter being thereupon discontinued."

So ran the official announcement by the Great Western Railway that the entire abolition of the broad gauge had been decided upon, and that the work of conversion was to be undertaken with such expedition as to create for all time an engineering feat of the first magnitude, not on account of the difficult character of the work in itself, but from the perfection of engineering and railway organisation necessary to accomplish it in the time allotted.

In 1869, the first conversion of Great Western lines was undertaken, and thence forward, partly by "mixing" the gauge, that is, adding a third rail to accommodate both broad and narrow gauge vehicles, and by conversions, the narrow lines were extended throughout the country, until in 1892, the broad gauge was confined to some 423 miles of main and branch line between Paddington and Penzance, of which the portions not provided with a third rail were between Exeter and Truro

Above: *Obsolete Great Western Railway broad gauge carriages at Swindon, about 1895, awaiting demolition.* [SCML]

and certain branches, having an aggregate length of many miles.

Compared to previous conversions that had been undertaken, those on the lines in Devon and Cornwall were the most exacting, for the reason that they consisted chiefly of single track, precluding the adoption of the plan followed in the case of the South Wales Railway, for instance, which was to close one of a pair while altering its gauge. The conversion contemplated in the west of England therefore necessitated the entire closing to traffic of a long length of railway, and the problem was how to alter in two days the gauge of lines that had taken as many decades to construct.

The success of the project was essentially one of perfect organisation, and the officials of the Great Western Railway resolved to leave no detail to chance. The main features were:

- to move all broad gauge rolling stock from the lines to be converted;
- to subdivide the work and provide sufficient men to carry out the alteration of gauge in the time allowed; and
- to equip the line with narrow gauge engines and rolling stock for future traffic.

Picture some 200 miles of railway in full working order suddenly denuded of all engines, carriages, and wagons, and some idea will be obtained of the appearance of the lines between Exeter and Truro on the morning of Saturday, 21 May 1892. Every siding and yard was devoid of vehicles; not a single shunting engine remained. This in itself was by no means the least noteworthy feature of the conversion. During the last few days that the broad gauge lines were in use, every vehicle that could possibly be spared was moved to Swindon and placed in the miles of sidings specially provided there, to await conversion to suit the narrow gauge; a work so well arranged that upwards of a dozen coaches were altered in a single morning, or consigned to the scrap heap.

Many special trains of engines and vehicles travelled to Swindon - "the broad gauge mortuary", as it was termed - forming a motley procession of old-world stock of all shapes, sizes, designs, and origins, relics of early railway times and once independent lines. Concurrently with the withdrawal of broad gauge equipment, a supply of narrow gauge engines and vehicles was being concentrated at Exeter and Plymouth, the latter place being reached over the metals of the London and South-Western Railway. Indeed, a few narrow gauge vehicles were even conveyed on broad gauge trucks to remote parts of West Cornwall, in readiness for the recommencement of traffic.

In due course the last day of broad gauge working arrived, and amid many sighs of regret from the crowds that assembled along the route, the *Cornishman*, the 10.15am from Paddington, made the last broad gauge movement to Penzance. It was drawn by the famous single [driving] wheel engine *Great Britain*, and at hundreds of points on the line men, women, and children placed coins of the realm on the railway metals, the flattened discs being preserved as mementos of the broad gauge. At one station in Devonshire the last through trains in each direction met, and the curious spectacle was witnessed of passengers joining hands to the accompaniment of the strains of *Auld Lang Syne*.

The last broad gauge train to pass between Exeter and Plymouth left the former city at 10.25pm, and as this section was largely double track, it was arranged to hand over the "down" line at once for conversion. To effect this, officials travelled with the train, their duty being to deliver to each stationmaster a certificate that it was the last train to pass westward. In turn, the station officials gave written permission to representatives of the engineering department that the work of altering the "down" line might be commenced. The final "up" train left Penzance at 9.10pm. It consisted of the vehicles forming the "down" *Cornishman*, and called at all stations to Exeter, reaching that place at 4.00am on 21 May. Its passing was the signal that the line was no longer needed for traffic purposes, and it will be of historic interest to quote the official regulation regarding it. From a copy still preserved we extract this passage: "Inspector Scantlebury must travel by this train, and he must ascertain from each stationmaster that all broad gauge stock has been worked away, and he must also satisfy himself that the whole of the trains timed to leave the respective junctions in advance have departed. Having done this, he must issue a notice in the following printed form to every stationmaster between Penzance and Exeter. 'This is the last broad gauge train to travel over the line between Penzance and Exeter.' [Note that Pole does not explain how the stock of the last "down" movement, the 10.25pm from Exeter, got back to Exeter.]

> "On receipt of this notice the stationmasters at the stations between Penzance and Exeter must give a printed notice to the representative of the engineering department, in the following form, that he, can take possession of the line: 'This is to certify that the last broad gauge train from Penzance has left this station, and the engineering department can now take possession of the line from the station in the rear up to this station for the purpose of converting the gauge.'"

It is easier to imagine than to describe the feelings of regret with which these "death warrants" were delivered by men, most of whom had grown grey in association with the broad gauge, and who, like many of the local inhabitants, resolutely declined to place faith in the utilitarian narrow track. However, the certificates were given, and between 3.30am and 4.00am on Saturday morning, 21 May, some 5,000 men commenced the task of abolishing the broad gauge.

Before describing the operations, it is necessary to digress for a moment in order to relate how this army of labour had been gathered and was organised. All day long on the previous Thursday special trains crowded with workmen were converging on Devon and Cornwall from all parts of the Great Western system. At hundreds of stations these trains embarked about 3,500 workmen (1,500 others were indigenous to Devon and Cornwall), with their permanent way implements. Even the embarkation was arranged in the most methodical manner. One compartment in four was reserved for tools, while labels on the carriage windows indicated the accommodation for each batch of men. The men thus conveyed to the scene of operations were dropped in gangs of sixty all along the track to be converted, and the broad gauge trains in which they had travelled were then hurried away to Swindon. They bivouacked in station waiting rooms, goods sheds, and tents pitched alongside the railway, these latter being the object of much local attention. Each man provided his own food, but the railway company supplied many tons of oatmeal, which, in the form of thin gruel, oatmeal, water, and sugar, was the staple beverage.

To carry out the work, the men were divided into gangs of twenty, each under a ganger. An inspector or foreman was in charge of every three gangs, while controlling the entire work were the chief engineer of the Great Western Railway, two divisional engineers, and their technical assistants. Each gang was responsible for converting about 11 miles of line.

The permanent way on the Great Western line was as distinctive in character as the gauge. Brunel had so designed his road as to secure a

maximum of support under each rail, and instead of the now universal (in the British Isles) cross-sleeper and chair method, he adopted what was known as the "longitudinal" track. This consisted of large timber baulks placed under and running in the same direction as the rails, connected at intervals by cross-timbers termed transoms, and firmly secured with tie-bolts.

To alter this type of permanent way involved cutting the transoms, slewing one of the sleepers and the rail upon it to the 4 feet 8½ inches gauge, inserting new tie-bolts and re-ballasting the track. In order to reduce these operations to minimum proportions, the ballast had previously been partially removed to admit of one sleeper being brought in towards the other, and alternate transoms had been cut through, the intermediate ones being cut half through. One section of each gang completed the cutting, a second slewed the sleeper into position, and a third bolted together the timbers and picked up the ballast. A witness of the scene has recorded that usually three men cut off the ends of the transoms; then some ten or twelve others, armed with gigantic crowbars, stationed themselves along a length of rail and by a series of rhythmic lifts and heaves moved the longitudinal sleepers, with rails upon them, some 6 or 8 inches, continuing this to the end of their stretch of line. Afterwards they returned and repeated the operation, closing up the sleepers another few inches, and finally, with a third lift and heave, placed the two at the proper narrow gauge distance apart.

This was naturally quite a simple expedient in straight stretches of line. Indeed, by midday on the Saturday long lengths were ready for the tie-rods that were to keep the rails true to gauge, and for the final packing of the ballast. But where track was curved the alteration was a more difficult matter. The outer or inner rail, as the case might be, in a curved broad gauge line was longer or shorter than would be the case on a narrow gauge, as the two gauges gave arcs of circles described at different radii hence much cutting, exact fitting, and testing were necessary. This work was a feature of a great part of the job, as the railway through South Devon and Cornwall is notorious for its many curves. The men, therefore, were constantly cutting a piece from one rail, or substituting a longer length for another. Now, cutting a rail in a workshop with every facility for doing so is simple enough, but on the stretch of line undergoing conversion the work had to be done with cold chisel and sledge-hammer, a very different matter. To cut a single rail occupied several men for half an hour or longer - quite a considerable period, having regard to the time in which the entire work had to be done - and unless the measurement had been most carefully made, the task of cutting might be completed only to find that an extra inch must be removed.

In one or two places, where the line had been relayed previously, cross-sleepers had been introduced, chairs being provided at the narrow width. On these lengths the rail had merely to be transferred from one set of chairs to another and the sleeper end cut off; but at stations, particularly large ones, the work was of a most exacting character, owing to the number of lines and the complicated blocks to be laid in. At Plymouth and some other large centres the broad gauge lines, were entirely swept away, and crossings inserted; but whichever expedient was adopted, the work proceeded apace, and by Saturday night the gauge was narrowed practically throughout and the sleepers tied, all that remained to be done on the following day being to complete the laying in of some of the fittings, and to finally ballast, test, and adjust the line. For testing and consolidating the track a number of narrow gauge engines were employed to pass to and fro over the several sections, which, one by one, were certified complete and ready for the passage of traffic.

The entire work was finished well within the appointed time, thanks to the fine weather that prevailed and the completeness of the arrangements; and the Sunday night mail train from Paddington to Penzance, after traversing the London and South-Western Railway from Exeter to Plymouth, continued its journey to Penzance over the newly altered track. On Monday, 23 May, the usual service of trains was in operation, the conversion having been carried out in about thirty hours, without any accident whatever, and with a minimum of inconvenience to the travelling public - even the mails being conveyed by the Great Western steamers between Plymouth, Fowey, and Falmouth, and distributed thence by special road vehicles.

The cost of alteration of lines, rolling stock, and other incidental improvements exceeded £1,000,000, but a barrier to free transportation had been removed, and the way was paved for doubling the line and enhancing the *Cornish Riviera Express* and other services, for which the Great Western line has since become famous. Gauge standardisation in South Australia has yielded similar results.

Above: *After the demise of the 7ft 0¼in gauge on the Great Western Railway, the broad gauge locomotives were cut up - except for a few built for conversion to standard gauge. The photograph shows long rakes of locomotives on specially constructed sidings at Swindon awaiting their fate.* [SCML]

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Note to page 23: As a matter of interest, Fox established the firm of Sir Charles Fox and Son in 1857, which was the founding firm of Hyder Consulting. Hyder celebrated their 150th anniversary in 2007. Projects carried out by the firm include: the Tower Bridge in London; Victoria Falls Bridge in Zambia; Sydney Harbour Bridge; the Mulberry Harbours defence system in World War 2; the (first) Severn Crossing in the UK; the Hong Kong Mass Transit system; the Greater Cairo Wastewater Project in Egypt; the first and second Bosphorus Bridges in Turkey; Abu Dhabi Tourist Tower in the UAE; AMP Tower in Sydney; Humber Bridge in the UK; Emirates Tower in the UAE; Taiwan High Speed Rail Project; Ski Dubai in the UAE and Burj Dubai Tower in the UAE.

Left: *The National Railway Museum (York, England) replica of the Liverpool and Manchester Railway (L&MR.) steam locomotive 0-2-2 "Rocket". The working replica of this famous locomotive was built in 1979 and is seen in steam at the NRM in 1982.*

Below: *A working replica of the Great Western Railway broad gauge "Iron Duke".* [both NRMY]

chase after it. According to the daughter of the local parson, her father and mother were returning from town when they were somewhat taken aback by a fizzing sound and saw this thing moving in a zigzag manner on the road. When he caught up, Murdoch found the local clergyman in a state of considerable distress for he had mistaken the carriage, with its billowing smoke and fire burning under the boiler, for the devil. Murdoch asked that his experiment be kept secret for the time being.

It would appear that Murdoch probably made at least two models. One had a stroke of 1½in while another had a stroke of $2\frac{7}{8}$in. But after this, Murdoch appears to have lost interest in his work on the steam locomotive and the reason may be explained as follows.

One day, when Boulton was going to Cornwall, he met a coach near Exeter in which he caught sight of Murdoch. He got down at once whereupon Murdoch also alighted. According to Boulton they engaged in conversation for some time. Boulton soon discovered that Murdoch was on his way to London with his steam carriage intending to show it and take out a patent. Boulton prevailed on Murdoch to return to Cornwall, which he did the next day. Boulton considered he was fortunate that he had been able to persuade Murdoch to postpone his interest in the steam carriage. In short, Boulton and Watt had enough on their plate without launching out on some new venture. The firm that employed him thus deprived William Murdoch, the most loyal of men, of the honour of inventing the locomotive. Murdoch's venture had been with high-pressure steam and the Soho firm wanted nothing to do with it.

On the other hand, Richard Trevithick was a high-pressure man through and through. Naturally inventive, he was intent on inventing a locomotive. From the newspapers he probably learned of what others were doing, or he was probably told by Murdoch himself, of the latter's little caper on the church path.

In 1797, he had his own model developed and ready to go. At the age of twenty-six he had married and settled the family home at Moreton House. And, here, only a few weeks later, the model was tried. His friend, Davies Giddy, later President of the Royal Society was there and he brought with him Lord and Lady De Dunstanville (the latter was the largest landholder in the district). Giddy acted as stoker while Lady De Dunstanville acted as the engine driver.

Shortly after, another model was made which ran around the table or the room. It had a vertical double-acting cylinder, 1.55in in diameter and 3.6in stroke sunk into the boiler. The piston rod was carried by a guided cross-head, the connecting rods reaching down to the crank-pins in the two driving wheels which measured 4in diameter. There was a fly-wheel driven by a spur gear on the crank shaft. Both this and Murdoch's model finished up in the South Kensington Museum where to the casual observer there was no obvious resemblance between them.

Trevithick experimented with models for three years before he felt confident enough to erect a full size machine. In the meantime he conducted experiments to determine whether smooth wheels would have sufficient traction on any road to move their load. He did this with the help of his friend Giddy by hiring a post-chaise ('post-chaise', a carriage once used in travelling, usually four wheeled, for two or four passengers with a postilion, who rode on the leading left hand horse). After unharnessing the horses, the two men moved the carriage uphill by applying their strength to the spokes. At no time was there any slip.

On Christmas Eve 1801, the full size engine was ready and moved the first load of passengers by steam on what was known in the district as "Captain Dick's Puffer." The rain was coming down heavily, the road in places was rough with loose stones and the gradient such that a wise cyclist would have dismounted and walked his machine. But "she went off like a little bird" for three-quarters of a mile up Beacon Hill to what was later Cambourne railway station and home again.

Over their Christmas dinner, Trevithick and his cousin Andrew Vivian became partners and they were soon in London armed with letters of introduction from Giddy to Humphry Davy, who introduced them to a certain Mr. Rumford, both of whom helped them in securing their patent.

THE WORLD'S FIRST STEAM LOCOMOTIVE ON RAILS

Trevithick learnt from running on different road surfaces that his locomotive would probably run better on the smooth surface of an iron road. Late in 1802, Trevithick decided to build another locomotive, which could be run as a 'tramway' engine. Trevithick had a good friend in William Reynolds, the Ironmaster in charge of the Coalbrookdale Company. This Company, which

had various works (not just at Coalbrookdale) were manufacturers in iron, and part of their output was the construction of stationary steam engines.

Trevithick wanted to have his new locomotive built at Coalbrookdale because of their fine reputation for quality of workmanship and it was a place where he could test the engine on one of the 3ft 0in gauge iron plateways in the area. William Reynolds converted Trevithick's rough sketches into working drawings and the world's very first railway locomotive emerged in 1803.

This pioneer steam locomotive had a boiler 4 feet in diameter with walls 1¼in thick, raised steam at 45 lb per square inch pressure and was driven with a single horizontal cylinder 7in diameter by 3ft stroke. It had a grate area of 4 square feet but because of the layout, the firebox could not be fed while the engine was in motion.

While this first steam locomotive was but a prototype and was not perfect (as one would expect), it inspired Trevithick to build the locomotive with which the railway era is often said to have begun.

THE WORLD'S FIRST STEAM GOODS LOCOMOTIVE

In October, Trevithick was at the Penydarren Ironworks near Merthyr Tydfil, at the invitation of Samuel Homfray who encouraged him to build a high-pressure steam locomotive to transport iron on the Merthyr Tramroad. This engine, known since as the "Penydarren locomotive," was the forerunner of the many thousands of goods engines that were to haul the freight traffic of the railways for more than 150 years. It worked on the tram-road for the first time on 13 February 1804. Trevithick wrote to Giddy:

> "It worked very well and ran up hill and down hill with great ease and was very manageable. We had plenty of steam and power."

On the following Monday, he wrote,

> "The engine, with water included, is about five tons. It runs up the tramroad of two inches in a yard - forty strokes per minute with the empty wagons. The engine moves forward nine feet at every stroke. The steam that is discharged from the engine is turned up the chimney about 3 feet above the fire. When the engine works at forty strokes per minute, 4ft 6in stroke, 8¼in diameter of cylinder, not the smallest particle of steam appears out of the top of the chimney, though it is but 8 feet above where the steam is delivered into it. The fire burns much brighter when the steam goes up the chimney than when the engine is idle."

This engine had a cast iron boiler 6ft 0in long by 4ft 3in diameter. It is interesting to note that because the tram-road used plate rails with a flange to guide the wheels, the wheels on this locomotive were flat and the locomotive could also run on the road. The Penydarren railway had a gauge of 4ft 4in.

On the Tuesday, another run took place:

> "Yesterday," wrote Trevithick to Giddy, "we proceeded on our journey with the engine; we carried 10 tons of iron, five wagons and seventy men riding on them the whole of the journey. It is just over nine miles, which we performed in 4 hours 5 minutes. The engine while working went nearly five miles per hour; no water was put into the boiler from the time we started until we arrived at our journey's end. The coal consumed was 2 cwt. On our return home, about four miles from the shipping place of the iron, one of the small bolts that fastened the axle to the boiler broke, and all the water ran out of the boiler, which prevented the return of the engine until this evening."

The engine continued working and 10 days later was tried with 25 tons of iron.

> "We were more than a match for that weight," wrote Trevithick to Giddy; and continued, "the steam is delivered into the chimney above the damper; when the damper is shut the steam makes its appearance at the top of the chimney but when open none can be seen. It makes the draught much stronger by going up the chimney."

The little engine was kept busy for some time after this, but was eventually taken to work the rolling mill. Unfortunately for Trevithick, the ironmasters of Merthyr Tydfil had invested heavily in the Glamorganshire Canal and they were against any improvement to the tramway, which would take away revenue from the canal. What with the criticism heaped on him from this opposition and the damage his locomotive caused to the fragile plates of the "plateway," Trevithick returned to the north of England to further develop his steam locomotive.

In September 1805, Trevithick was at Newcastle arranging with Christopher Blackett, the owner of *The Globe* newspaper, to supply him with a locomotive for the Wylam Colliery Waggonway, which was five miles long. This was erected at John Whinfield's foundry at Pipewellgate, Gateshead (Newcastle) and was completed in May 1805. Like the Penydarren locomotive on which she was an improvement, she had no bellows draught - Trevithick had abandoned it as soon as he found the steam blast was sufficient.

This Gateshead engine was the first with flanged wheels. On a temporary iron railway at Whinfield's yard, she had worked satisfactorily and became the first engine to work on an iron edge rail. Unfortunately, the Wylam track then had wooden rails, and so she was taken off and used as a stationary engine for some years. Three years later, the rails were replaced with cast-iron rails.

During the next ten years, Trevithick who was a man of many inventions built several other engines. In 1808, he distinguished himself further. Having built the world's first steam railway locomotive and the world's first goods locomotive, he now turned to building the world's first passenger railway locomotive.

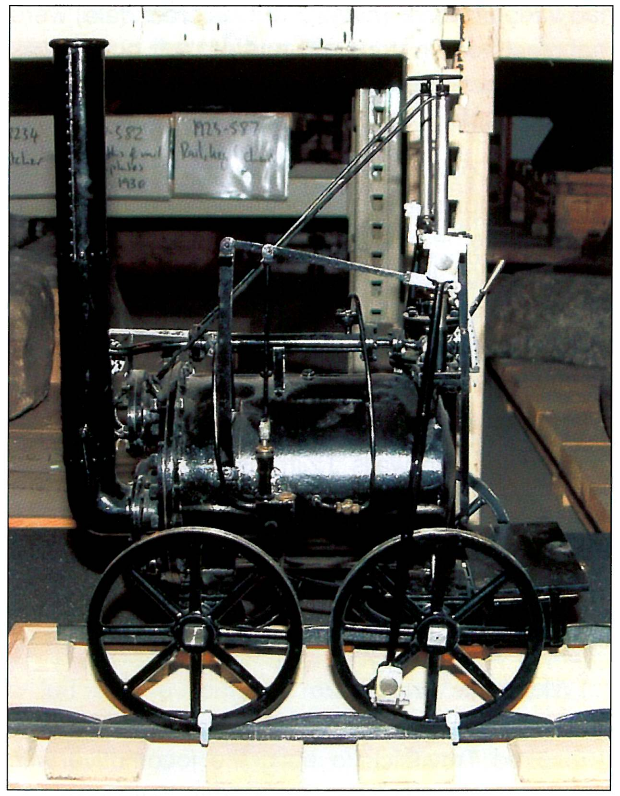
THE WORLD'S FIRST STEAM PASSENGER LOCOMOTIVE

In this year, he demonstrated his *Catch-me-who-can* on a circular iron road of no more than 100ft radius at a site, which later became Torrington Square in London. Passengers were carried at up to twelve miles per hour for a shilling a head.

To build *Catch-me-who-can*, Trevithick joined forces with John Urpeth Rastrick, the engineer of the Hazledine Foundry in Bridgnorth. Followers of the modern railway scene will know that Bridgnorth is the northern terminus of the famous Severn Valley Railway, one of England's premier preserved railways. It is most apt that the world's first passenger steam locomotive should have been born in such a locality.

Christopher Magner in his important work on early railways describes the locomotive as follows:

> "The locomotive was more 'refined' than the three earlier designs having a single vertical cylinder placed at the closed end of the boiler (the opposite end to the chimney and firedoor), a direct drive with connecting rods linked to the crank pins on the driving wheels and it weighed eight tons. Unlike his earlier locomotives it did not have the cumbersome horizontal slide bar arrangement and a large flywheel like the earlier 1802/3, 1804 and 1805 locomotives. The boiler is believed to have been the same type as the 1805 stationary engine built in Bridgnorth at the Hazledine Foundry, now in the Science Museum, and had similarities in design to the model engine at the Straffan Museum. *Catch-me-who-can's* name came from a suggestion by Davies Gilbert's sister, Mrs Guilmard. This was the first demonstration of a steam 'passenger' railway in the world."



Above: Catch-me-who-can. [SCML]

But at first, Trevithick's early locomotives were a liability owing to the frequent breakages of the cast iron plates upon which they ran and many finished up as stationary engines.

In October 1816, Trevithick went to South America where he made his fortune but in the War of Independence he was ruined and was lucky to escape with his life. When the boat he was using was upset at the mouth of the Magdalena, he was lassoed from drowning - and an alligator - by Bruce Hall, who took him to Robert Stephenson at Cartagena. "Is that Bobby?" asked Trevithick, "I have nursed him many a time!" And so he had. He and Robert Stephenson had left South America together. Trevithick died on 22 April 1833, aged 62. So was ended the life of the man who built the first steam locomotive to run on rails and who, like many another inventor, died in poverty, never making a fortune from his invention.

Above: *George Stephenson.* [SCML]

GEORGE STEPHENSON

Trevithick's locomotive for the Wylam Colliery marked the birth of locomotive construction on the Tyne and also acted as a spur to other locomotive builders such as Matthew Murray, John Blenkinsop, William Hedley and George Stephenson.

Stephenson has often been called the "Father of Railways" but he has been credited with more than his due, for in the days when opposition to railways was at its fiercest, promoters of railways found it necessary (for parliamentary and advertising purposes) to magnify Stephenson's reputation as an authority on every branch of railway engineering. He was not the "Father of the Railway Engine", that honour having fallen to Richard Trevithick; nor was he the inventor of the railway.

But his knowledge, derived from the machines and the men who made them, was immense and his organising powers were remarkable. Despite much opposition, he led the fight against the old order of things and he became the one conspicuous figure to whom the railwaymen looked up to for leadership. Around him the storm centred; and it is to him more than any other man that Britain owes so much of their railway systems. And although he neither invented railways nor steam locomotives he was responsible, in part, for setting the "standard gauge".

George Stephenson started his working life by herding cows for twopence per day and ten years had passed before he was appointed brakesman on the West Moor Pit at Killingworth, earning £2 a week.

In 1812, the owners of Killingworth High Pit appointed Stephenson to the position of engine-wright at a salary of £100 a year. In riding about inspecting the collieries belonging to his employers and those of other owners he became interested in the new railway between the Kenton and Coxlodge collieries and the River Tyne. This had the Blenkinsop rail and engines.

In 1811, John Blenkinsop had patented a rail with a "toothed rack or longitudinal piece of cast iron or other fit material having the teeth or protuberances or other parts of the nature of teeth standing either upwards, downwards or sideways." The teeth were at suitable intervals for "a wheel having teeth or protuberances" to engage, the latter being part of the driving mechanism of the engine. Thus he became the originator of the mountain climbing rack railways although it was only his intention to give greater power to locomotives on level track. He did not produce rolling stock and Matthew Murray erected his first "rack" locomotive.

William Hedley had found by experiment (confirming Trevithick's experience) that smooth wheels had sufficient adhesion on smooth rails to surmount the gradients on the Wylam Colliery track. The following year, at the suggestion of Christopher Blackett, he built *Puffing Billy*.

Puffing Billy was built with four wheels in 1813 for the Wylam Colliery, and at first ran on cast iron plates, each of which weighed 45lb and was three feet long. But these plates were broken to such an extent under the weight of the engine that it became necessary to carry half a dozen spare plates upon the engine to replace any that might break during the journey.

In 1815, to reduce the weight on individual axles, the engine was rebuilt as an eight wheeled locomotive, each group of four wheels being carried on a sort of bogie. In 1830, the line was relayed with cast iron edge rails, and then *Billy* again reverted to a four-wheeler. This engine from the first was a great improvement on the horses and was kept at work until 1862. A sister engine, *Wylam Dilly* worked until 1867.

Stephenson carefully watched the working of these engines on the railway that ran past the cottage where he was born in 1781. He came to the conclusion that he could improve on them as well as on the Coxlodge engines; and in 1814 he built *Blucher*, his first locomotive. To begin with, this was rather a failure, but as soon as he turned the waste steam into the funnel as Trevithick had done he doubled the power and made it a success. This led to his Killingworth engine of 1815. At first this had coupling rods connecting inside cranks on the axles, but owing to one of the axles getting bent he replaced the rods with the chain gearing familiar to us in the bicycle. The same chain coupling with the sprocket wheels was used in an engine he built in 1816.

But the engines were waiting for the development of roads strong enough to carry them. Although cast-iron rails continued to be used owing to their cheapness, for some years rails had been made here and there of wrought iron. When Timothy Hackworth went to the Walbottle Colliery as foreman of the smiths he found rails of malleable iron which had been laid as early as 1805; and in 1808 wrought iron rails were in use on the Tindale Fell line, merely a square bar spiked to stone blocks. Then in 1820 came John Birkinshaw with his mill to produce reliable malleable rails in quantity. To quote from Thomas Baker, the poet of the "Steam Engine":

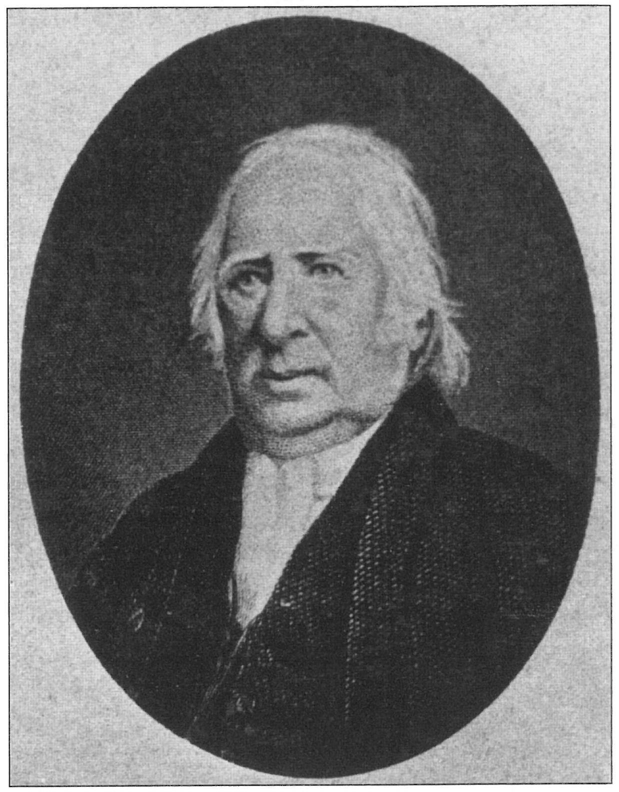
"By rolling mill he these tough rails produced,
And these, without improvement,
still are used,
No hammer-work, unseemly weld, or flaw
Was in the work of famous Birkinshaw!"

The weakness of early track is the reason why most early engines were tender engines and the proliferation of tank engines in later years had to wait until the track was strong enough to support locomotives that carried their own coal and water.

Stephenson had the backing of a wealthy group of miners who not only encouraged and assisted him to improve the steam locomotive but permitted him to try his engines on their wagonway at Killingworth Moor where the gauge was 4ft 8in.

THE STOCKTON AND DARLINGTON RAILWAY

The Stockton and Darlington Railway was built to overcome the difficulty of navigating the River Tees. Ships took as long to sail from Stockton to the mouth of the river as they did from the latter to the Thames. Surveys for a canal or alternatively a tram-road to avoid the long river journey were carried out as early as the year 1768. In 1810, the Tees Navigation Company dug a 220 yard cutting called the Mandale Cut, which cut off over two miles, but it was a drop in the ocean compared to the total distance up the river.



Above: *Edward Pease.* [SCML]

Meanwhile Edward Pease, owner of the woollen mills at Darlington - "Neddie Pease who started the Stockton and Darlington when he was already fifty years old," and lived till he was ninety-one - had become satisfied that the old plan for a railroad was "as good as a canal and cheaper." He called in John Rennie to carry out a second survey and report. The report appeared in 1815 and as a result, after three year's consideration, two rival parties emerged - the businessmen in Stockton who were anxious for a canal and those in Darlington who favoured a railroad.

Then Jonathon Backhouse, a Darlington banker, endeavoured to bring about peace between the rival factions by suggesting that the Tees should be made navigable up to Yarm and that the railroad should run from Yarm to Darlington and on to the collieries. In this proposal, Backhouse was joined by Thomas Meynell, the squire of Yarm. Stockton would have none of this, and so the project was put to the vote at

Darlington, when the majority was in favour of Pease's plan of a railway all the way. Having failed in their efforts at reconciliation, both Meynell and Backhouse joined with Pease. Residing in the neighbourhood was Thomas Richardson, Pease's cousin, a retired bill-broker whose financial abilities were renowned. He joined the triumvirate and it was really these four who brought about the Stockton and Darlington.

The first Bill introduced into Parliament in 1818 failed to pass; Rennie had taken the line too close to one of the Duke of Cleveland's fox-coverts. George Overton of Lanthetty (near Brecon), the engineer of several of the successful South Wales lines made a third survey. He submitted his plans on 20 October 1818. His estimated costs were £2,000 per mile, single track, £2,400 single track but formed for a double track and £2,800 a mile if laid with a double track.

The submission was unacceptable to the proponents. On 19 December 1818, Robert Louis Stevenson's father, Robert Stevenson of Edinburgh, was asked to make a fourth survey but even this was unacceptable. Nevertheless, Stevenson continued to be consulted up until July 1821, when as we shall see, George Stephenson succeeded him.

On 12 February 1820, at the George and Dragon public house in Yarm, the promoters of the railway held a further meeting. Thomas Meynell was in the chair. It was decided to submit a second Bill into the next session of Parliament. In preparation for that Bill a fifth survey was made this time again by Overton and on 19 April 1921, the Act was obtained.

Meynell laid the first rail with great ceremony near St John's Well, Stockton on 23 May 1922. Soon after, a boy with papers in his hand was shouting in Stockton Streets, "Speech of Mr T Meynell. One penny!" A man who bought one, found nothing but a sheet of blank paper. "Why, you little rascal, there's nought here!" "No, sir," replied the boy, "because he said nought!"

Shortly after securing the Act, Edward Pease was writing in his room when a servant announced that two strange men wished to speak to him. He was busy, and he sent them a message that he was too much occupied to see them. Hardly had he done so than he thought that perhaps he had been unkind and he rose from his chair and went downstairs. Going into the kitchen he found them and they gave their names as Nicholas Woods, viewer at Killingworth Colliery and George Stephenson, enginewright.

Pease sat down on the edge of the kitchen table to listen to what they had to say and Stephenson handed him a letter from Mr Lambert, the manager of Killingworth mine, recommending him to the notice of Pease as a man who understood the laying down of railways. Pease read the letter and took stock of "Old George". As he said afterwards, there was such an honest, sensible look about George Stephenson, and he seemed so modest and unpretentious speaking in the strong Northumberland dialect that - in short - he took to him at once. Here was a man after his own heart.

In the conversation that followed, Stephenson agreed that Pease had acted wisely in proposing an edge rail road not-with-standing that all the traffic must go on flanged wheels. But he asked for information as to what was meant by the vehicles being drawn "by men, horses or otherwise". This phrase had been adopted from the Act of the Oystermouth Railway at the suggestion of Overton, who knew what steam was doing in South Wales and the Forest of Dean. Stephenson learnt that all the calculations had been made on the basis of horse traction, though steam might be used later. It was that "or otherwise" that had brought him to Darlington and he thereupon told Pease that he would do much better in using locomotives to start with. "Come over to Killingworth and see what my Blucher can do; seeing is believing, sir."

The interview ended with Pease promising to support Stephenson's application for the position of engineer and agreeing to visit Killingworth to see what was going on. Stephenson was appointed, the edge rail was adopted instead of the flat rail and Stephenson expressed a desire to re-survey the route again as soon as possible. This, the sixth and final survey was at once begun by George Stephenson and John Dixon, assisted by George's son, Robert as chainman. "Esteemed friend, George Stephenson," wrote Edward Pease, when sending him his first instructions with regard to the Stockton and Darlington Railway, "in making thy survey, it must be borne in mind that this is for a great public way - its construction must be solid."

In the summer of 1822, Edward Pease and his cousin Richardson went over to Killingworth to see and believe. Further, in 1823 the company obtained an amending Act giving them power to definitely use locomotives and to haul and carry passengers as well as merchandise.

There were stationary engines at Brusselton and Etherley and it was from the "Permanent Steam Engine below Brusselton Tower" that the proprietors and their friends, after examining the extensive incline planes there, started the "first train" on the opening day, 27 September 1825. First came a man with a red flag. Then "The Company's Locomotive Engine" (*Locomotion No.1*); then "The Engine's Tender" (described as a water barrel on the top of a muck wagon); then six wagons loaded with coals and merchandise; then "The Committee and Other Proprietors in The Coach" (*The Experiment*) belonging to The Company. This was followed by six wagons for strangers and a string of other wagons. It was a great triumph, but the man to whom it was due was not there.

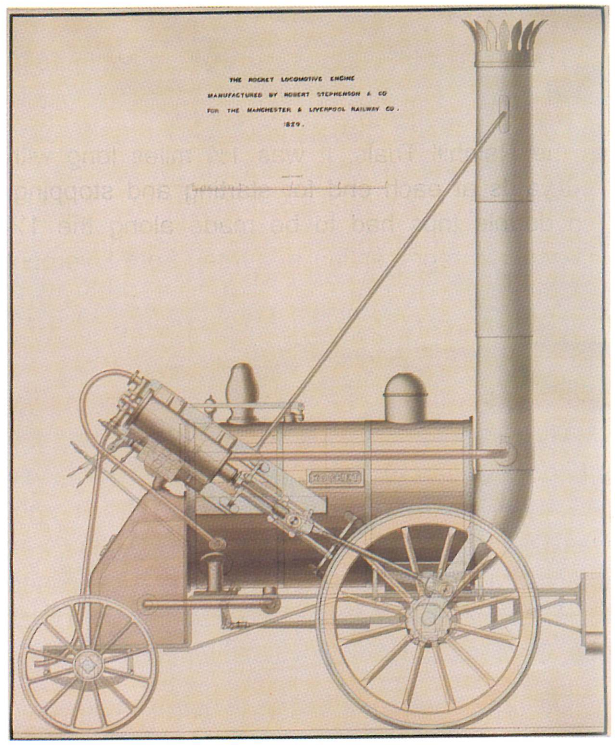
That day, Edward Pease's son Isaac had died and in the silent room he heard the distant cheers telling him in the hour of his bereavement that his work had been completed.

The line was single with a loop every quarter of a mile. With its four branches it was 36¼ miles long. It cost £9,000 per mile which is about four times as much as what Overton had estimated. Despite Stephenson holding a patent for cast iron rails he recommended using wrought iron rails manufactured under Birkinshaw's patent. "They" - the cast iron rails - "will not stand the weight and you will be at no end of expense for repairs and delays", he advised. So the rails used were of malleable iron, fish-bellied in pattern, 28lb per yard, 2¼in wide on the head, 2in deep at the ends and 3¼in in the middle, with a flange of ¾in. Some of them were laid on stone blocks and some on oak sleepers well bedded in the ballast. Stephenson laid the rails to the same gauge as he had used on the Killingworth colliery railway, i.e. 4ft 8in.

STEPHENSON'S WORKS

In August 1823, the first piece of land was bought in Newcastle for the Forth Street Works, destined to be known all over the world as Robert Stephenson and Company. On 13 December 1824, Michael Longridge, then manager, set out to buy adjoining land to add a foundry to the plant and on 30 December, an office was opened for engineering and railway surveying.

The first two locomotives built there were for the Hetton Colliery and then early in 1825, the third engine built was *Locomotion No.1* for the Stockton and Darlington Railway. The next three engines built there were Nos. 2, 3 and 4 also for the S&DR, which carried the names *Hope*, the *Black Diamond* and the *Diligence*. Wilson of Newcastle built No.5 (*Stockton*).



Above: *The* Rocket. [SCML]

THE "ROCKET"

There are a few misconceptions about the *Rocket*. Popular boy's books give the impression that George Stephenson built the *Rocket*, whereas it was Robert Stephenson and Company who must be so remembered, although old George would have been closely involved. Also it was by no means the first locomotive built by the company for they had been building locomotives since 1825.

The *Rocket* is associated with the Liverpool and Manchester Railway, which was opened to traffic in 1830. George Stephenson was the construction engineer for this line. In building this line, Stephenson used two of his own locomotives, the *Twin Sisters*, which had two boilers and two chimneys and the *Lancashire Witch*. These engines were used hauling material during the construction of the earth works and were probably the first "work train engines". Despite this demonstration of suitability and experience

with locomotives, some of the directors of the company were not convinced that steam locomotives could handle the traffic and held out in favour of rope traction using a number of stationary engines at strategic locations. In fact, rope traction was adopted for the Liverpool and Sutton inclines because of their severe gradients.

To settle this matter it was finally decided to hold a competition with a prize of £500 for the best locomotive to work the rest of the line. The test course was a level stretch on the Manchester side of Rainhill Bridge and the contests were known as the Rainhill Trials. It was 1¾ miles long with 220 yards at each end for starting and stopping. Ten double trips had to be made along the 1½ mile course representing a journey from Liverpool to Manchester. Water was then to be taken and another ten trips run to represent the return journey. The minimum speed was to average 10 miles per hour and the load was to be three times the weight of the engine. Maximum boiler pressure was to be 50 lb per square inch. Engines over 4.5 tons were to have three axles. Judges were John Urpeth Rastrick, who built Trevithick's *Catch-me-who-can* and most of the London - Brighton railway; Nicholas Wood who invented the railway carriage and John Kennedy who was involved with the cotton-spinning industry.

There were four entries. The only two worthwhile entries were Stephenson's *Rocket* and Timothy Hackworth's *Sanspareil*. Other entries were Braithwaite and Ericson's *Novelty* and Timothy Burstall's *Perseverence*. Thomas Shaw Brandreth a director of the company, who resigned before completion of the line, was allowed to demonstrate his *Cyclopede* in which the weight of a horse on a moving platform was able to carry itself at a rate of six miles per hour.

The *Perseverence* was a failure and Burstall gave up the contest as hopeless. The *Novelty* only did four trips before her boiler gave way and she had to be withdrawn. The interesting point about this engine is that it was driven by Charles Fox who later became well known in the Structural Engineering field. He built the Great Exhibition in 1851 and the Crystal Palace at Sydenham (see note page 32).

Timothy Hackworth built the *Sanspareil*, an 0-4-0 tender engine. He received his training under the Stephensons and was recommended by George to be the locomotive superintendent of the Stockton and Darlington Railway. Robert Stephenson's Works made the cylinders for the engine, as the SD&R's shops were not up to the task. The boiler was made by John Birkinshaw at Bedlington. The boiler was a cylindrical shell with one flat end and the other dished. It had an internal return flue projecting on the fire grate side and enclosed in a water jacket. It had two vertical 7in by 18in cylinders, which worked downwards on the two back wheels. These were coupled to the front wheels, both being 4ft 6in in diameter. The 3in blast pipe combined the exhaust from both cylinders and entered the chimney half way up. It had a grate area of 10 square feet and heating surface of 90 square feet. It weighed 4¾ tons, which was a quarter of a ton over weight for four wheels but the judges allowed it to compete. On one trip it went at 17½ miles per hour and it had actually run 27½ miles at an average speed of nearly 14 miles per hour when, unfortunately, it broke down. Just after starting, according to Hackworth one of the cylinders burst due to the casting being too thin on one side, which allowed the boiler to discharge straight to the atmosphere on every stroke of the engine.

Thus, the only survivor and the only engine to comply with all the conditions won the competition. On 8 October 1929, the *Rocket*, an 0-2-2 tender engine, ran the full distance out and home at an average speed of 13.8 miles per hour, the fastest journey being at 24.1 miles per hour. A description of this engine is as follows.

The boiler was cylindrical, 3ft 4in diameter by 6ft 0in long. The firebox was made of copper and was bolted on to the end of the boiler. At the top, back and sides it had a 2½in water space and at the front it had a firebrick lining. The hot gases from it passed through 25 copper tubes, 3in diameter placed in the bottom half of the boiler, which led into a chamber at the base of the chimney, which served as a smokebox. The heating surface was 138 square feet and the grate area was 6 square feet. Two 2½in pipes connected the water space of the firebox with that of the barrel and two similar pipes connected the top of the firebox with the steam space. The working pressure was 50 lb per square inch and beside two safety valves, there was a slender mercury gauge as tall as the chimney running up the left hand side of it indicating steam pressures of between 45 and 60 lb per square inch. Two pipes carried the exhaust from the two cylinders along the top of the boiler, entering on each side of the chimney and ending in a blast nozzle, 1½in diameter.

The cylinders at an angle of 37 degrees were 8in diameter by 17in stroke. The 4ft 8½in diameter driving wheels were of wood, with cast iron bosses and iron tyres; the cast iron trailing wheels were 2ft 10in diameter and the all up weight of the engine alone was 4 tons 5 cwt in working order while the tender weighed 3 tons 4 cwt (making a total of 7 tons 9 cwt). In the trials the tender was included as part of the load.

On the day of the contest, according to a reliable witness, it was painted yellow, lined with black and her chimney painted white.

The prize money was divided equally between Robert Stephenson, who designed the engine and Henry Booth, the company secretary, who suggested the use of copper tubes and incidentally also invented the screw coupling.

There was no more talk of ropes or horses and when the line opened on 15 September 1830, there were eight engines to take part in the ceremony, as follows:

Engine	Driven by
Northumbrian ‡	George Stephenson
Phoenix ‡	Robert Stephenson
North Star ‡	Robert Stephenson*
Rocket	Joseph Locke
Dart †	Thomas Gooch
Comet †	William Allcard
Arrow †	Frederick Swanwick
Meteor †	Anthony Harding

*(George's brother)

All the above engines had outside cylinders, those marked ‡ were built last and had 11in by 16in cylinders while those marked † had 10in by 16in cylinders. The first inside cylinder engine was *Planet*, put on the line soon after it opened.

THE STANDARD GAUGE

Locomotion, which was the first engine built by Stephenson's for the Stockton and Darlington Railway was built to a gauge of 4ft 8in. When the Stockton and Darlington Railway was extended to Middlesborough in 1828, the gauge was fixed by Parliament at 4ft 8in and it is notable that this was the first time that the gauge of a railway was provided for in its enabling Act.

The Liverpool and Manchester Railway was the first public railway (i.e. a common carrier of goods and passengers). It was constructed to a gauge of 4ft 8in at the Manchester end by platelayers from the Stockton and Darlington Railway who brought "their gauges with them as part of their stock of tools" and these gauges were used as a matter of course to lay the rails.

Above: *Robert Stephenson.* [SCML]

Rocket was made to a gauge of 4ft 8in according to the records of the Robert Stephenson and Company.

During the construction of the Liverpool and Manchester Railway, Mr. Thomas Gooch who was engaged to carry out the work (and was also George Stephenson's very excellent secretary) stated that discussions arose over the value of coning the tread of the railway wheels. On the curves, the wheels could move laterally so that the wheels on the outer rail would run on a slightly larger diameter than the wheels on the inner rail and balance out the stresses caused by the outer rail being longer than the inner rail. To enable the wheels to move across the gauge according to theory, some extra play was needed and consequently the gauge of the Liverpool and Manchester was widened to 4ft 8½in throughout.

Railways, which connected with the Liverpool and Manchester, such as the Grand Junction and the London and Birmingham, were then also built to the 4ft 8½in gauge to enable through running.

The 4ft 8in gauge continued in use on the Stockton and Darlington because the old cauldron wagons were able to run on this gauge. In 1840, the main North line between York and Darlington was opened to a gauge of 4ft 8½in and it was decided to widen the gauge of the S&DR to allow through running. Even so, it was only widened to 4ft 8¼in at first; the track was laid on stone blocks which tended to spread the gauge anyway, so it may be surmised that this was recognition of an existing situation. The gauge was further widened to 4ft 8½in when the line was relayed with new rail. It is notable that in 1839, the Chairman of the S&DR, Joseph Pease stated before a Parliamentary Committee "that the width inside the rails was 4ft 8in," but added, "in practice 4ft 8½in." This seems to be the first occasion on which this gauge was placed on public record. (Note that Pease was careful to state that the gauge was nominally in accordance with the enabling Act and hence "legal.")

After Stephenson surveyed the new Liverpool and Manchester Railway, he devoted his time wholly to constructing new railways. When the plans for another of the earliest lines - the Leicester and Swannington - were under discussion, someone suggested that 3ft 0in might be a better gauge than 4ft 8½in. "This won't do", George Stephenson is reported to have exclaimed. "I tell you the Stockton and Darlington, the Liverpool and Manchester, the Canterbury and Whitstable and the Leicester and Swannington must all be 4ft 8½in. Make them of the same width; though they may be a long way apart now, depend upon it, they will be joined together one day."

Thereafter, wherever Stephenson built railways he continued to use the gauge, which had been derived from the Killingworth colliery railway. He was responsible for spreading it through Europe where he was consultant for many Continental countries, and where, for their railways, his son's workshops at Newcastle supplied their first locomotives. His son, Robert, continued to manufacture engines and advocated the use of 4ft 8½in gauge to all who sought locomotives from him as his machinery was set up to manufacture engines for this gauge the most economically.

Also some railways were built to a gauge, which was not quite 4ft 8½in. For example the following railways adopted the 4ft 9in gauge when built:

- York and North Midland (1839)
- Birmingham and Derby (1839)
- Chester and Crewe (1840)
- Manchester and Birmingham (1840)
- Manchester and Leeds (1840)

Modern railways can tolerate wide gauge up to at least ½in (13mm) without fear of derailment

Above: *Great Western Railway broad gauge 4-2-2 locomotive and passenger train at Castle Hill (Ealing Down) station, London, c. 1890.* [SCML]

and "tight" gauge of about the same. The French high-speed railways (TGV) use a gauge of 4ft 8¼in (1432mm) as their track is laid to very strict tolerances and their curves are of very large radius.

BRUNEL'S "BROAD GAUGE"

In England, Parliament enacted a law to make 4ft 8½in gauge mandatory until it was withdrawn at the request of the Great Western Railway in 1836. Few railways were built after 1836 to other than "standard" gauge, apart that is from the Great Western with its 7ft gauge and the Great Eastern with 5ft gauge.

Because he was a much more scientific engineer than Stephenson, Brunel adopted for the Great Western Railway a much broader gauge - 7ft. (Due to an oversight, Brunel's first locomotives were built to a gauge of exactly 7ft 0in and as it was found that these were too tight in a track gauge of 7ft 0in, Brunel was obliged to increase his track gauge to 7ft 0¼in). He believed that the wider gauge was necessary to obtain the low centre of gravity in his engines, which, together with large driving wheels, was essential for safety and smoothness in fast running. With the wheels so far apart, the Great Western was able to lower their larger boilers down between the wheels. Modern practice, however, has shown that engines with a high centre of gravity can run safely and smoothly.

The problem facing Brunel was that the introduction of his broad gauge meant there were two gauges in Britain with all the humbug of transfer for both goods and passengers at break of gauge stations. Advocates of the two gauges were those who supported Stephenson or those who supported Brunel. Both parties were keen to extend their systems in to each others' territory thus initiating a "gauge war" between them.

THE BRITISH GAUGE COMMISSION

Finally, on 25 June 1845, Richard Cobden of the British Parliament moved in the Commons for a Royal Commission to be set up to investigate the practicability of ensuring that all future railways in Britain were built to the one gauge and the practicability of converting existing railways to the common gauge. More to the point was deciding what that common gauge should be.

The motion was passed and the Royal Commission set up with the following Commissioners:

Sir Frederick Smith, R.E.,
(late Inspector-General of Railways);
George Airy, the Astronomer-Royal;
Peter Barlow, Professor of Mathematics at
Woolwich Military Academy.

Both sides presented their arguments before the Commission, but at the suggestion of Brunel, test runs were carried out on the two gauges to settle which gauge was the better. The Stephenson team ran their test between Darlington and York, but the engine swayed and wobbled so much that it derailed at about 53 miles per hour. On the other hand, the Brunel team ran their test between Paddington and Didcot and, in complete smoothness, attained a speed of 60 miles per hour.

To be perfectly fair, it has to be mentioned that the Stephenson engine was the North Midland Railway's *No.54 Stephenson*, a "long boiler" with inside cylinders and a central driving wheel, and such a high centre of gravity that Daniel Gooch (who was observing for the GWR) wondered how it kept on the rails at all. The long boiler engines were already known to be apt to pitch alarmingly at speed, so it was inevitable that near Thirsk, the engine jumped the rails and came to rest on its side with the carriages on top. No-one was killed and injuries were minor and all concerned considered themselves lucky that the derailment did not occur on an embankment or a bridge. With another engine, the outcome could easily have been more favourable to the "narrow" gauge.

Now, while it was clear that the broad gauge certainly gave the best results, the Commissioners decided that the smooth ride on the broad gauge owed much to the fine permanent way laid by Brunel together with the design of Gooch's locomotive and that with the same design of permanent way and locomotive similar results could be attained on 4ft 8½in gauge. They also took into account that at that time in Britain there were 1,901 miles of the Stephenson gauge as opposed to only 274 miles of Brunel's gauge. Many have found since that it is easier to convert broad to standard gauge than vice versa.

The Commissioners submitted the results of their inquiry as a Minute to the Board of Trade on the 6th of June 1846. As a result, during June and July 1846, the recommendations were debated hotly in both Houses of the British Parliament.

It was agreed that there was no difference of opinion as to the great inconvenience "which a want of uniformity of gauge in all the railroads throughout Great Britain occasioned; or that wherever a break of gauge occurred, there, an interruption of the communication took place; and the effect was to detract from that convenience which the public derived from the rapid and cheap communication they now had by means of railroads." But it was argued that as the Parliament had sanctioned two different gauges in the first place it would be unfair to throw the cost of conversion to one gauge back on the private companies concerned (estimated to cost £1,000,000 sterling). On the other hand the Legislature was not willing to pay it out of the public purse.

The Commissioners favoured the narrow gauge in their Minute. So it seemed that if their recommendation for a uniform gauge was to be adopted, the broad gauge would be the one eventually phased out. On the one hand, the House was disposed to resolve that no new lines should be built on the broad gauge, but on the other hand, realised that this would extend the very inconvenience, which they wanted to remove, particularly in those cases where new lines were extensions of existing broad gauge lines. It is easy to see the logic of this when considering in South Australia the lines from Cutana to Radium Hill and Kowulka to Kevin, which were built to the 3ft 6in gauge long after a decision had been made to construct all new railways in Australia to the 4ft 8½in gauge.

Although logic favoured eventually converting all railways to the Stephenson gauge there were a number of speakers who had misgivings. Some considered that Brunel's 7ft gauge was far superior with regards to rapid travel, comfort and safety and regretted that the 4ft 8½in gauge was established purely due to an accident of history. Some felt that if they were starting all over again that a wider gauge would have been used.

The visionary Lord Redesdale declared that the 4ft 8½in gauge was the worst possible choice and boldly advocated making all future railways in Great Britain of a gauge of six feet and when, in due course, there was a majority of such railways the others would have to convert to the six feet gauge or become isolated. At the beginning of 1845 there were 250 Bills for new lines awaiting consent before Parliament and it appeared that if even only half of them were built, soon new ones would swamp the existing railways.

Redesdale went on to say he regretted the resolution of the Gauge Commissioners, which precluded hope of Great Britain in the foreseeable future having a uniformity of gauge. As he said:

> ".....of those who advocated that, regardless of cost, a system of uniform gauge was essential, it would be, in fact, the only thing creditable to this Empire, which had distinguished itself by the first introduction of this system; but if not adopted, he feared that England which had originated railway communication, would present nothing to future ages but a bungling and complicated system, when it ought to have been more perfect than that of any other country."

If only Lord Redesdale had been around to express such sentiments to the Australians a few years later!

The upshot of all the hot air and opinions expressed in the Commons and the Lords was the Railway Regulation (Gauge) Act, 1846, which was passed and became law on 18 August 1846. This Act specified that:

- Future railways would be built to a gauge of four feet eight and a half inches in Great Britain and five feet three inches in Ireland, with some obvious exceptions i.e. where extension in that gauge would create a further break of gauge.
- Without the consent of the Legislature, no railway company shall alter the gauge of their railway, but existing broad gauge lines were to be converted to standard gauge as opportunity permitted.
- Severe penalties were laid down for non-compliance with the provisions of the Act.

The Great Western was allowed to continue with its broad gauge but was obliged to fall into line with the standard gauge in due course. This conversion was not completed until 46 years later in 1892, but thereafter the whole of England, Wales and Scotland was on the standard (or Stephenson) gauge except for a few small narrow gauge railways.

IRELAND

The 1846 Act prescribed 5ft 3in gauge for Ireland and the origin of this gauge, which was closer to Lord Redesdale's "ideal gauge" of six feet, was brought about in an interesting way.

In 1836 the Irish Railway Commissioners had set the track gauge for Irish railways at 6ft 2in and subsequently the Ulster Railway was at first built to the aforesaid gauge. The Dublin and Kingstown Railway, opened in 1834, had a gauge of 4ft 8½in, while the engineer of the proposed Dublin and Drogheda Railway, ignoring the commissioners, fixed on a gauge of 5ft 2in. In 1843, the Board of Trade appointed its chief inspector of railways, Maj.-Gen. Pasley, to sort things out. General Pasley wrote a circular letter to locomotive builders and railway engineers of the day asking them what gauge they would recommend if no railways yet existed. He deliberately did not consult Brunel, nor, at first, the Stephensons, considering them to be too firmly committed to their existing systems.

All the parties consulted said they considered 5ft to be the narrowest and 5ft 6in the widest gauges preferable, so Pasley split the difference and recommended 5ft 3in for the Dublin and Drogheda and for all future Irish railways. His report was accepted.

AMERICA

The first railway in America - the Baltimore and Ohio - imported Stephenson locomotives and since these were of 4ft 8½in gauge, the "standard" gauge gained a foothold in America, not only on the B. and O., but on several other New England railroads as well as the Pennsylvania Railroad. Not all American railroads were built to standard gauge. The Erie had quite an extensive system with 6ft gauge (perhaps they had been listening to Lord Redesdale!); the Missouri Pacific was built to 5ft 6in gauge; the Jersey and Ohio to 4ft 10in and the Delaware and Hudson was originally built to 4ft 3in gauge. But by far the greatest lengths of non-standard lines were those of the many southern railways built to 5ft gauge.

At the end of the American Civil War, barely 50% of the US rail network was on the 4ft 8½in standard gauge but by 1881, due to some piecemeal conversion, some uniformity had already been achieved. A conference of railroad managers in 1885 agreed that one common gauge was essential for commercial viability and the obvious choice was 4ft 8½in. On 1 June 1886, the remaining southern lines were converted to standard gauge in one massive change; all lines not complying were converted in two days! A minority of narrow gauge lines never were converted.

AUSTRALIA

The first railway of any kind in Australia was at a coal mine in New South Wales. The Australian Agricultural Company operated two short inclined tramways from their "A" and "B" pits for the haulage of coal to the loading staiths in Newcastle Harbour. The "A" pit line was opened as a funicular railway in 1831 and is understood to have operated on the self-acting incline principle. In about 1841 the "B" pit line was opened using partly gravitation and partly horse traction, the horse riding behind the loaded skips on a "dandy truck" and then hauling the empties back to the mine. Although the gauge of the original line is not clear, by 1854 the system, which was now quite large, had been strengthened with heavier rails to take locomotives. The gauge was 4ft 8½in.

In 1836, a five mile railway was opened on the Tasman Peninsula, Van Dieman's Land (Tasmania) in connection with the Port Arthur convict settlement. The line used convicts for motive power and was constructed using timber sleepers and wooden rails. About 16 rail carriages were in use; these were of rather crude construction using cast iron wheels. Three convicts were assigned to each carriage. Eight of the carriages were for carrying freight and the other eight were for passengers with seating for four passengers on each carriage. In a limited way this was a public railway because a charge was made for the carriage of civilian passengers.

In May 1854, a horse-drawn railway using iron rails was opened between Goolwa and Port Elliot in South Australia, being in due course extended to Victor Harbor and connected to Adelaide. At the turn of the 21st century the greater part of this line was still in use as a tourist line and consequently this is now the oldest railway in Australia still in use.

The first railway in Australia to use a steam locomotive was the Melbourne and Hobson's Bay Railway Company's line from Melbourne to Sandridge opened in September 1854.

GAUGE CONVERSION

Although there were many different gauges perpetuated around the world (see Appendix 1), countries originally embracing a number of different gauges usually took the step of converting to a common gauge to ensure that their railways were a convenient form of transport. This has only been partially true of Australia and, in 2007 South Australia still had three different gauges in commercial use.

Conversion to a universal 4ft 8½in gauge took place in America in 1886 and England in 1892. Sir Felix Pole of the Great Western Railway wrote in 1900 the following very interesting description of converting the last remnants of 7ft 0in gauge of the GWR to the 4ft 8½in gauge in use by the rest of England:

THE CONVERSION OF THE GAUGE OF THE GREAT WESTERN RAILWAY MAIN LINE

By Felix J C Pole

(Originally published in the early 1900s)

"It is proposed to convert the whole of the main line and branches west of Exeter from broad to narrow gauge in the month of May 1892, when it is intended that the alteration shall be carried out between a Friday night and the following Monday, the running of broad gauge vehicles on the line between Paddington and Exeter being thereupon discontinued."

So ran the official announcement by the Great Western Railway that the entire abolition of the broad gauge had been decided upon, and that the work of conversion was to be undertaken with such expedition as to create for all time an engineering feat of the first magnitude, not on account of the difficult character of the work in itself, but from the perfection of engineering and railway organisation necessary to accomplish it in the time allotted.

In 1869, the first conversion of Great Western lines was undertaken, and thence forward, partly by "mixing" the gauge, that is, adding a third rail to accommodate both broad and narrow gauge vehicles, and by conversions, the narrow lines were extended throughout the country, until in 1892, the broad gauge was confined to some 423 miles of main and branch line between Paddington and Penzance, of which the portions not provided with a third rail were between Exeter and Truro

Above: *Obsolete Great Western Railway broad gauge carriages at Swindon, about 1895, awaiting demolition.* [SCML]

and certain branches, having an aggregate length of many miles.

Compared to previous conversions that had been undertaken, those on the lines in Devon and Cornwall were the most exacting, for the reason that they consisted chiefly of single track, precluding the adoption of the plan followed in the case of the South Wales Railway, for instance, which was to close one of a pair while altering its gauge. The conversion contemplated in the west of England therefore necessitated the entire closing to traffic of a long length of railway, and the problem was how to alter in two days the gauge of lines that had taken as many decades to construct.

The success of the project was essentially one of perfect organisation, and the officials of the Great Western Railway resolved to leave no detail to chance. The main features were:

- to move all broad gauge rolling stock from the lines to be converted;
- to subdivide the work and provide sufficient men to carry out the alteration of gauge in the time allowed; and
- to equip the line with narrow gauge engines and rolling stock for future traffic.

Picture some 200 miles of railway in full working order suddenly denuded of all engines, carriages, and wagons, and some idea will be obtained of the appearance of the lines between Exeter and Truro on the morning of Saturday, 21 May 1892. Every siding and yard was devoid of vehicles; not a single shunting engine remained. This in itself was by no means the least noteworthy feature of the conversion. During the last few days that the broad gauge lines were in use, every vehicle that could possibly be spared was moved to Swindon and placed in the miles of sidings specially provided there, to await conversion to suit the narrow gauge; a work so well arranged that upwards of a dozen coaches were altered in a single morning, or consigned to the scrap heap.

Many special trains of engines and vehicles travelled to Swindon - "the broad gauge mortuary", as it was termed - forming a motley procession of old-world stock of all shapes, sizes, designs, and origins, relics of early railway times and once independent lines. Concurrently with the withdrawal of broad gauge equipment, a supply of narrow gauge engines and vehicles was being concentrated at Exeter and Plymouth, the latter place being reached over the metals of the London and South-Western Railway. Indeed, a few narrow gauge vehicles were even conveyed on broad gauge trucks to remote parts of West Cornwall, in readiness for the recommencement of traffic.

In due course the last day of broad gauge working arrived, and amid many sighs of regret from the crowds that assembled along the route, the *Cornishman*, the 10.15am from Paddington, made the last broad gauge movement to Penzance. It was drawn by the famous single [driving] wheel engine *Great Britain*, and at hundreds of points on the line men, women, and children placed coins of the realm on the railway metals, the flattened discs being preserved as mementos of the broad gauge. At one station in Devonshire the last through trains in each direction met, and the curious spectacle was witnessed of passengers joining hands to the accompaniment of the strains of *Auld Lang Syne*.

The last broad gauge train to pass between Exeter and Plymouth left the former city at 10.25pm, and as this section was largely double track, it was arranged to hand over the "down" line at once for conversion. To effect this, officials travelled with the train, their duty being to deliver to each stationmaster a certificate that it was the last train to pass westward. In turn, the station officials gave written permission to representatives of the engineering department that the work of altering the "down" line might be commenced. The final "up" train left Penzance at 9.10pm. It consisted of the vehicles forming the "down" *Cornishman*, and called at all stations to Exeter, reaching that place at 4.00am on 21 May. Its passing was the signal that the line was no longer needed for traffic purposes, and it will be of historic interest to quote the official regulation regarding it. From a copy still preserved we extract this passage: "Inspector Scantlebury must travel by this train, and he must ascertain from each stationmaster that all broad gauge stock has been worked away, and he must also satisfy himself that the whole of the trains timed to leave the respective junctions in advance have departed. Having done this, he must issue a notice in the following printed form to every stationmaster between Penzance and Exeter. 'This is the last broad gauge train to travel over the line between Penzance and Exeter.' [Note that Pole does not explain how the stock of the last "down" movement, the 10.25pm from Exeter, got back to Exeter.]

> "On receipt of this notice the stationmasters at the stations between Penzance and Exeter must give a printed notice to the representative of the engineering department, in the following form, that he, can take possession of the line: 'This is to certify that the last broad gauge train from Penzance has left this station, and the engineering department can now take possession of the line from the station in the rear up to this station for the purpose of converting the gauge.'"

It is easier to imagine than to describe the feelings of regret with which these "death warrants" were delivered by men, most of whom had grown grey in association with the broad gauge, and who, like many of the local inhabitants, resolutely declined to place faith in the utilitarian narrow track. However, the certificates were given, and between 3.30am and 4.00am on Saturday morning, 21 May, some 5,000 men commenced the task of abolishing the broad gauge.

Before describing the operations, it is necessary to digress for a moment in order to relate how this army of labour had been gathered and was organised. All day long on the previous Thursday special trains crowded with workmen were converging on Devon and Cornwall from all parts of the Great Western system. At hundreds of stations these trains embarked about 3,500 workmen (1,500 others were indigenous to Devon and Cornwall), with their permanent way implements. Even the embarkation was arranged in the most methodical manner. One compartment in four was reserved for tools, while labels on the carriage windows indicated the accommodation for each batch of men. The men thus conveyed to the scene of operations were dropped in gangs of sixty all along the track to be converted, and the broad gauge trains in which they had travelled were then hurried away to Swindon. They bivouacked in station waiting rooms, goods sheds, and tents pitched alongside the railway, these latter being the object of much local attention. Each man provided his own food, but the railway company supplied many tons of oatmeal, which, in the form of thin gruel, oatmeal, water, and sugar, was the staple beverage.

To carry out the work, the men were divided into gangs of twenty, each under a ganger. An inspector or foreman was in charge of every three gangs, while controlling the entire work were the chief engineer of the Great Western Railway, two divisional engineers, and their technical assistants. Each gang was responsible for converting about 11 miles of line.

The permanent way on the Great Western line was as distinctive in character as the gauge. Brunel had so designed his road as to secure a

maximum of support under each rail, and instead of the now universal (in the British Isles) cross-sleeper and chair method, he adopted what was known as the "longitudinal" track. This consisted of large timber baulks placed under and running in the same direction as the rails, connected at intervals by cross-timbers termed transoms, and firmly secured with tie-bolts.

To alter this type of permanent way involved cutting the transoms, slewing one of the sleepers and the rail upon it to the 4 feet 8½ inches gauge, inserting new tie-bolts and re-ballasting the track. In order to reduce these operations to minimum proportions, the ballast had previously been partially removed to admit of one sleeper being brought in towards the other, and alternate transoms had been cut through, the intermediate ones being cut half through. One section of each gang completed the cutting, a second slewed the sleeper into position, and a third bolted together the timbers and picked up the ballast. A witness of the scene has recorded that usually three men cut off the ends of the transoms; then some ten or twelve others, armed with gigantic crowbars, stationed themselves along a length of rail and by a series of rhythmic lifts and heaves moved the longitudinal sleepers, with rails upon them, some 6 or 8 inches, continuing this to the end of their stretch of line. Afterwards they returned and repeated the operation, closing up the sleepers another few inches, and finally, with a third lift and heave, placed the two at the proper narrow gauge distance apart.

This was naturally quite a simple expedient in straight stretches of line. Indeed, by midday on the Saturday long lengths were ready for the tie-rods that were to keep the rails true to gauge, and for the final packing of the ballast. But where track was curved the alteration was a more difficult matter. The outer or inner rail, as the case might be, in a curved broad gauge line was longer or shorter than would be the case on a narrow gauge, as the two gauges gave arcs of circles described at different radii hence much cutting, exact fitting, and testing were necessary. This work was a feature of a great part of the job, as the railway through South Devon and Cornwall is notorious for its many curves. The men, therefore, were constantly cutting a piece from one rail, or substituting a longer length for another. Now, cutting a rail in a workshop with every facility for doing so is simple enough, but on the stretch of line undergoing conversion the work had to be done with cold chisel and sledge-hammer, a very different matter. To cut a single rail occupied several men for half an hour or longer - quite a considerable period, having regard to the time in which the entire work had to be done - and unless the measurement had been most carefully made, the task of cutting might be completed only to find that an extra inch must be removed.

In one or two places, where the line had been relayed previously, cross-sleepers had been introduced, chairs being provided at the narrow width. On these lengths the rail had merely to be transferred from one set of chairs to another and the sleeper end cut off; but at stations, particularly large ones, the work was of a most exacting character, owing to the number of lines and the complicated blocks to be laid in. At Plymouth and some other large centres the broad gauge lines, were entirely swept away, and crossings inserted; but whichever expedient was adopted, the work proceeded apace, and by Saturday night the gauge was narrowed practically throughout and the sleepers tied, all that remained to be done on the following day being to complete the laying in of some of the fittings, and to finally ballast, test, and adjust the line. For testing and consolidating the track a number of narrow gauge engines were employed to pass to and fro over the several sections, which, one by one, were certified complete and ready for the passage of traffic.

The entire work was finished well within the appointed time, thanks to the fine weather that prevailed and the completeness of the arrangements; and the Sunday night mail train from Paddington to Penzance, after traversing the London and South-Western Railway from Exeter to Plymouth, continued its journey to Penzance over the newly altered track. On Monday, 23 May, the usual service of trains was in operation, the conversion having been carried out in about thirty hours, without any accident whatever, and with a minimum of inconvenience to the travelling public - even the mails being conveyed by the Great Western steamers between Plymouth, Fowey, and Falmouth, and distributed thence by special road vehicles.

The cost of alteration of lines, rolling stock, and other incidental improvements exceeded £1,000,000, but a barrier to free transportation had been removed, and the way was paved for doubling the line and enhancing the *Cornish Riviera Express* and other services, for which the Great Western line has since become famous. Gauge standardisation in South Australia has yielded similar results.

Above: *After the demise of the 7ft 0¼in gauge on the Great Western Railway, the broad gauge locomotives were cut up - except for a few built for conversion to standard gauge. The photograph shows long rakes of locomotives on specially constructed sidings at Swindon awaiting their fate.* [SCML]

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Note to page 23: As a matter of interest, Fox established the firm of Sir Charles Fox and Son in 1857, which was the founding firm of Hyder Consulting. Hyder celebrated their 150th anniversary in 2007. Projects carried out by the firm include: the Tower Bridge in London; Victoria Falls Bridge in Zambia; Sydney Harbour Bridge; the Mulberry Harbours defence system in World War 2; the (first) Severn Crossing in the UK; the Hong Kong Mass Transit system; the Greater Cairo Wastewater Project in Egypt; the first and second Bosphorus Bridges in Turkey; Abu Dhabi Tourist Tower in the UAE; AMP Tower in Sydney; Humber Bridge in the UK; Emirates Tower in the UAE; Taiwan High Speed Rail Project; Ski Dubai in the UAE and Burj Dubai Tower in the UAE.

Left: *The National Railway Museum (York, England) replica of the Liverpool and Manchester Railway (L&MR.) steam locomotive 0-2-2 "Rocket". The working replica of this famous locomotive was built in 1979 and is seen in steam at the NRM in 1982.*

Below: *A working replica of the Great Western Railway broad gauge "Iron Duke".* [both NRMY]