No. 149].

G.W.R. Mechanics' Institute.

SWINDON ENGINEERING SOCIETY.

TRANSACTIONS, 1925-26.

ORDINARY MEETING—October 13th, 1925.

Chairman—Mr. W. A. Stanier, M.I.Mech.E.

"THE EVOLUTION OF THE LOCOMOTIVE."

BY

Mr. J. G. H. WARREN, M.I.Mech.E., M.I.Loco.E.

After the success of the Liverpool and Manchester Railway, George Stephenson was acclaimed by his fellow countrymen as the inventor of locomotives and railways. This was not the case. Several men had been concerned with experiments in the construction and design of locomotives before Stephenson's first successful attempt, and some, naturally enough, protested against Stephenson being called the ''Father of the Locomotive.'' To a great extent these protests were justified, but some went further, in particular the son of one of these early engineers tried to claim for his father the principal, indeed the only, part in the successful development of the locomotive.

He also endeavoured to discredit everything done by the Stephensons, particularly George Stephenson, and openly stated that the first locomotives on the Stockton and Darlington Railway were complete failures, and that it was only on account of the success of Timothy Hackworth's later engine that the Directors had continued the use of the locomotive in preference to horse traction. It was not the intention of the lecturer to belittle the work of such a distinguished engineer as Hackworth, but he was of opinion that Hackworth himself would not have claimed some of the things which had been claimed for him by his descendants, and which have subsequently been disproved by official documents. When they had just celebrated the Centenary of the successful opening of the Stockton and Darlington Railway by steam power, stories of this kind must either be proved and accepted, or disproved and rejected, and they would be left to the judgment of the audience after photographic slides of original contemporary documents and letters had been shown, some of which are preserved in the Science Museum, South Kensington.

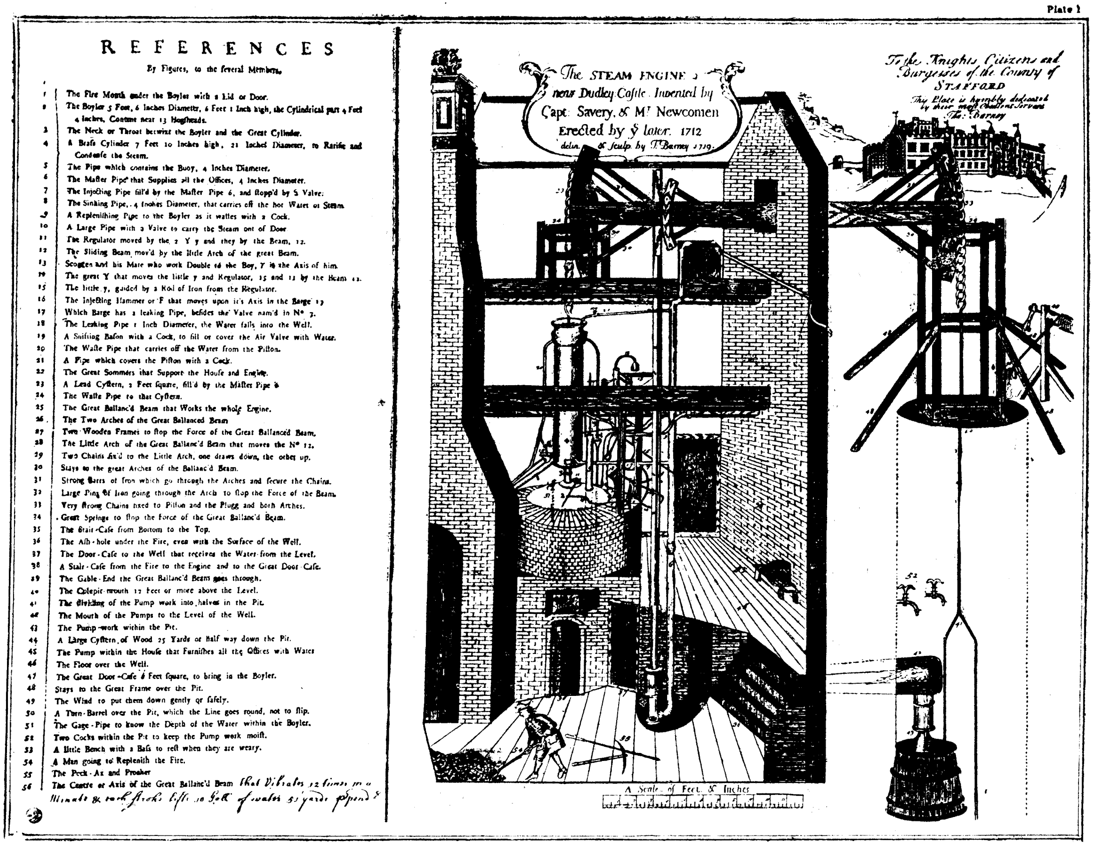


FIG. 1.—Savery and Newcomen Atmospheric Steam Engine, 1712.

After this evidence had been seen, no doubt they would agree that the Stephensons certainly did play an important part in improving and stabilising the design of the locomotive.

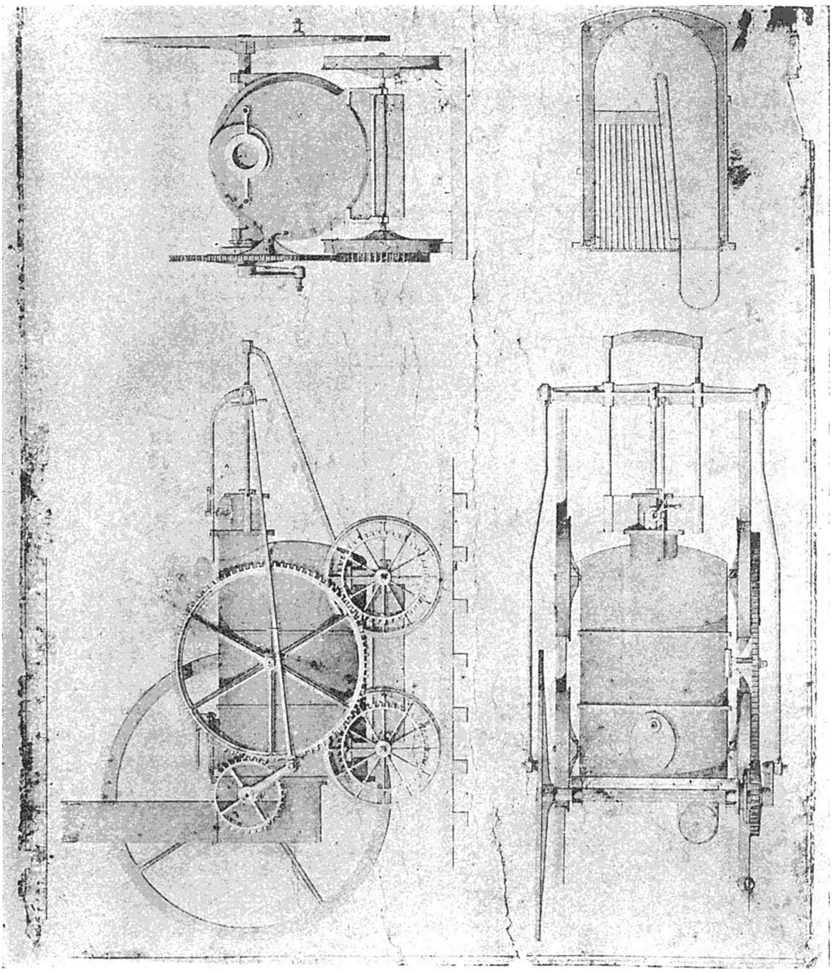


FIG. 2.—Trevithick's Locomotive, 1804.

The problem which confronted the early designers of the locomotive was to make the existing stationary steam engine "loco-motive." Fig. 1 shows the type in use at the time, a Savery and Newcomen engine for pumping mines. The essential features to notice were the large upright boiler and cylinder, the piston of which actuated the beam which operated the pump.

Trevithick realised that with a boiler working at atmospheric pressure, this problem could not be solved and he boldly advo-

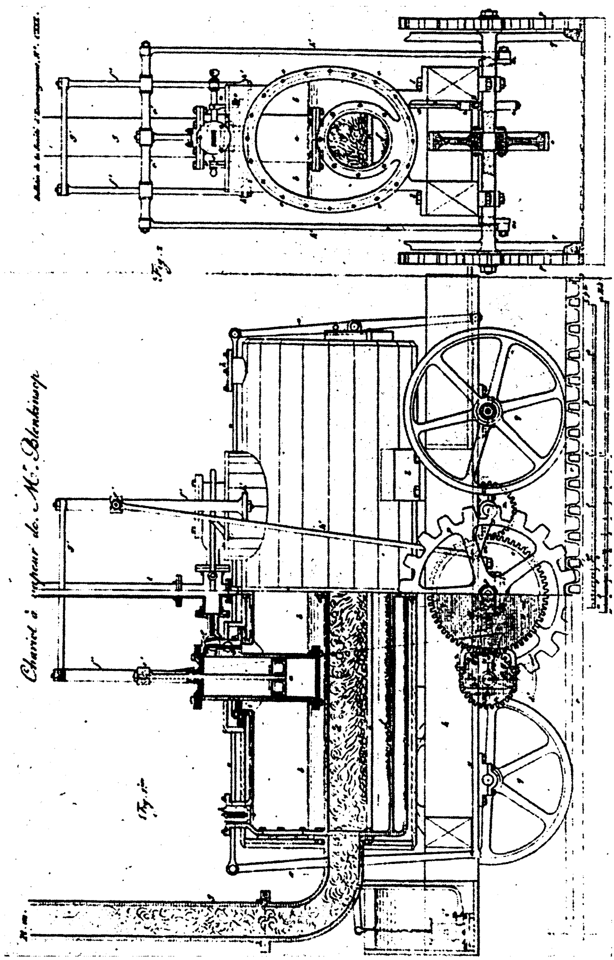


FIG. 3.—Murray and Blenkinsop's Rack Rail Locomotive, 1812.

cated a working pressure of 50 lbs. per sq. inch. A good deal about his first locomotive in South Wales is wrapped in mystery, but his Gateshead tram locomotive (1804) is shown by fig. 2. The boiler was cylindrical and it had one horizontal cylinder. The fire door and chimney were at the same end, and by means of a return flue he obtained practically double the heating surface possible with a single straight flue. Motion was obtained through a fly wheel which drove through toothed wheels on to the driving wheels. The exhaust steam in Trevithick's first engine was turned into the chimney as a convenient method of getting rid of it, probably not originally with the intention of increasing the draught, though Trevithick noted its beneficial effect. After 1804 he discontinued work on the locomotive, and the next one of note was by Murray, to work on Blenkinsop's Rack Railway near Leeds, shown by fig. 3, from a contemporary French drawing. The boiler was cylindrical, with a single flue which, turned up in front, formed the chimney.

In Murray's locomotive, though based on Trevithick's patents, the steam was not turned into the chimney, but straight into the air. The engine had two vertical cylinders, and motion was obtained by means of crossheads working through connecting rods to gear wheels, which again operated a central toothed wheel which engaged in the rack rail on one side, not on two sides as shown by the drawing.

It was a common belief at the time that there was not enough adhesion between smooth wheels and rails to make the locomotive a success.

The next commercially successful locomotive was by Hedley at Wylam, built with the assistance of Hackworth. An engine of this type is now in the Edinburgh Museum. The two cylinders were at the sides of the boiler, the machinery following the lines of a stationary beam engine. The cylinders were made of wrought iron plates. The piston drive was on to a central shaft which was connected by means of gears to both axles. The wheels were smooth, the engine relying on adhesion for motion. George Stephenson observed this engine at work and being unfavourably impressed by the complicated method or transmitting motion to the wheels, determined to built something of simpler design. He used two cylinders, following the Murray Blenkinsop engine, and depended on adhesion, but drove through gears. This locomotive was not a great success. In his next the wheels were coupled by rods and pins, or alternatively, by means of a chain. The engine shown by fig. 4 shows a great simplification of drive, but it still has vertical cylinders.

Stephenson now introduced for the first time steam cushions (through pistons and rods bearing on the axle brasses) to ensure contact of all four wheels with the road at all times. These steam ''springs'' worked more or less successfully until it became possible to make suitable steel springs, but the vertical cylinder probably made the use of a sensitive spring impossible. For the

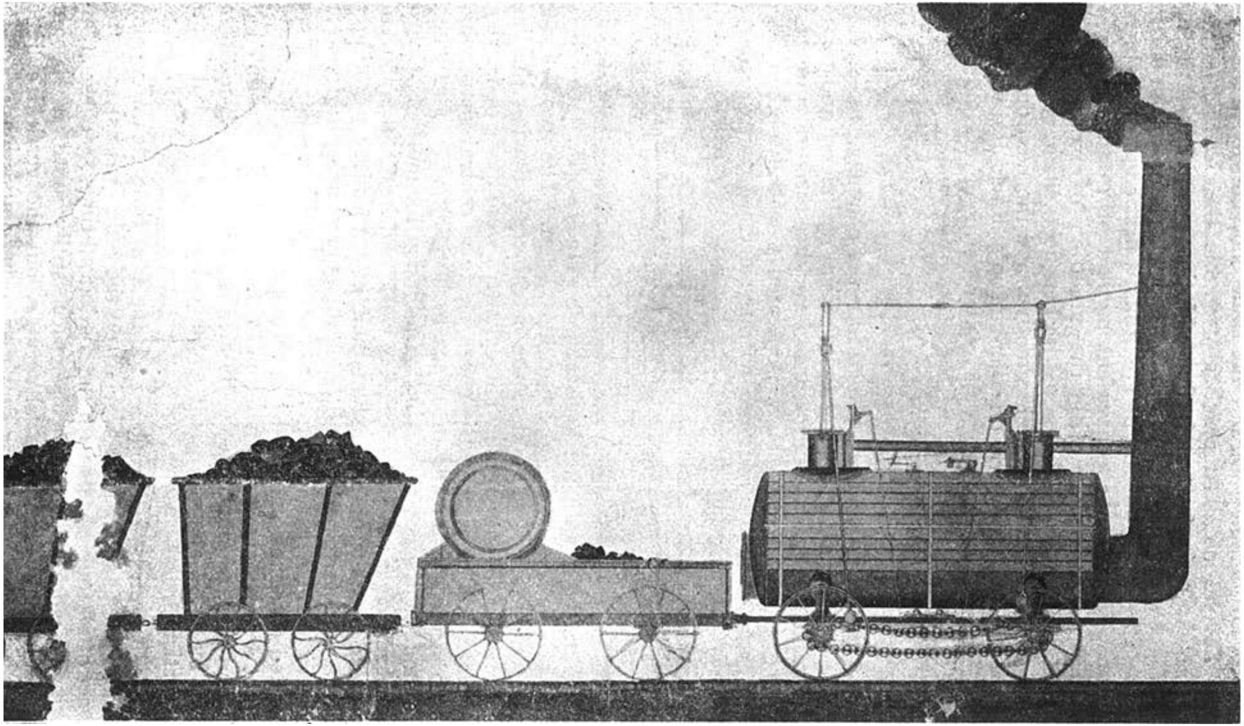


FIG. 4.—George Stephenson's Locomotive, 1815.

boiler, Stephenson abandoned the return flue for a single straight flue, thus reducing the nominal heating surface.

In the meantime experiments had been going on to improve the draught of locomotives, and it was realised again by 1825 that turning exhaust steam into a chimney did accelerate the velocity of the current, although this method was said to cause a disagreeable ''trumpet-like'' noise and a good deal of fuel was drawn up the chimney; but economy in fuel consumption was not the object of the locomotive engineer of 1825. Stephenson was aware that this method improved combustion, and Trevithick had observed the same thing.

Fig. 5 shows one of the earliest Stockton and Darlington engines. It has been often stated, and lately repeated, that these engines were complete failures and were actually more expensive than horse power, but an entry in the Stockton and Darlington Railway Company's Minute Book of 1827 states, as the result of ''a strict scrutiny,'' that there was a saving of nearly 30% when compared with horse power.

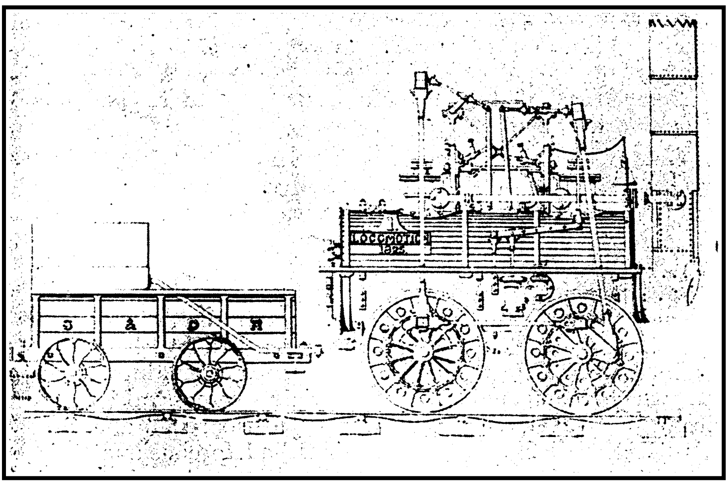


FIG. 5.—Stockton and Darlington Locomotive, 1825-7.

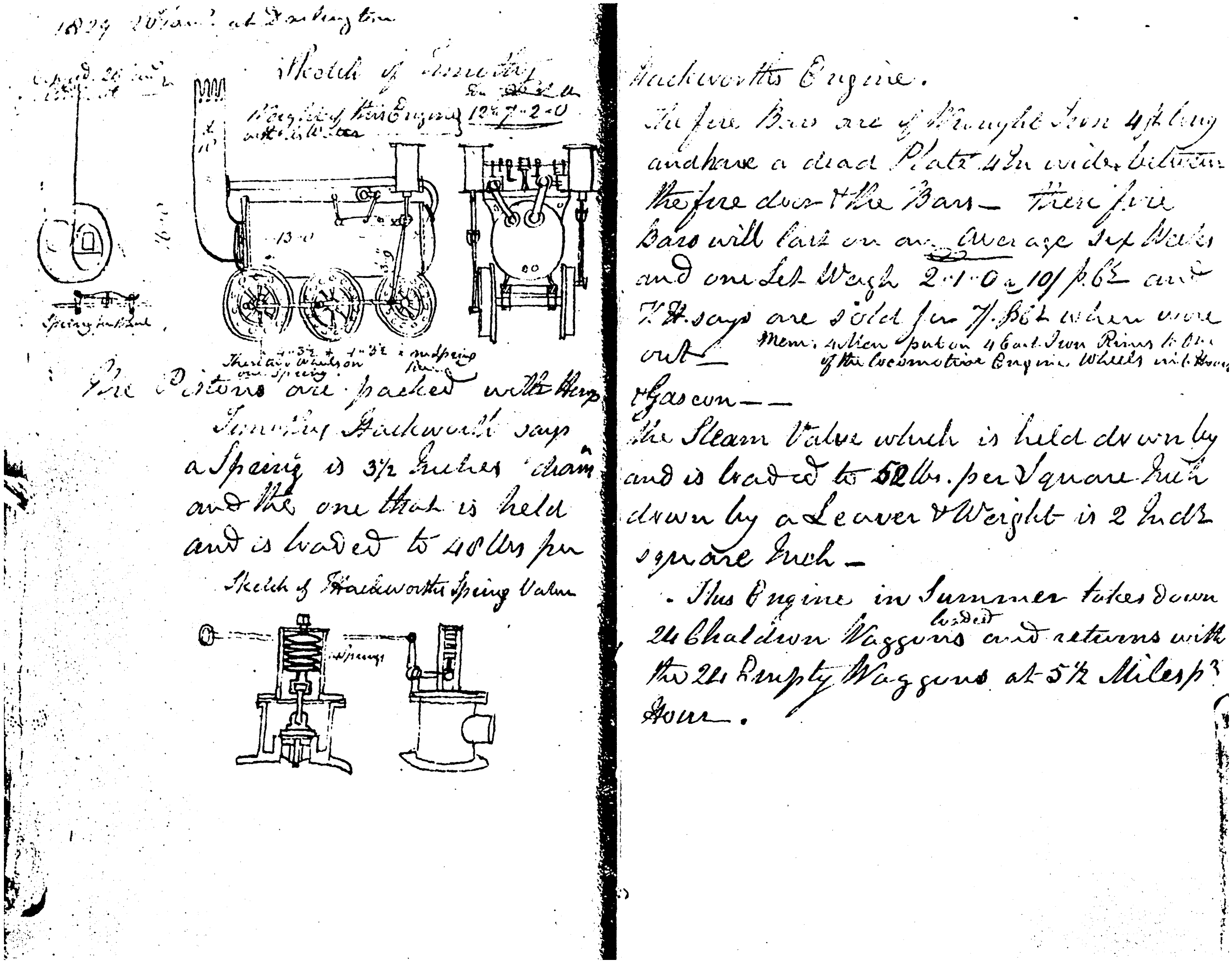
In 1826/7 Stephenson built a remarkable engine, afterwards called ''Experiment,'' in which the drive from two cylinders was, for the first time, combined in one axle. Prussian engineers, who visited England in 1827, reporting on this engine, have left almost sufficient data to enable us to reconstruct it and a later sketch has been discovered showing many remarkable features, including horizontal cylinders, feed heating and water-tube firebars, but as a type this engine did not survive. In 1827, Hackworth built the "Royal George" (fig. 6) which was really an experimental engine built with the boiler of a previous engine. The boiler was 13′ long with a return flue and the chimney was formed by the extended flue turned upwards. The exhaust steam was turned into the chimney and the pistons drove direct on to the crank pins of the rear pair of wheels, a most important improvement, but the cylinders were vertical and springs impossible for the driving wheels.

By 1828 the requirements of the Liverpool and Manchester Railway for passenger services at a comparatively high rate of speed caused the two Stephensons to consider further improvements in locomotive design, and from this time forward, Robert Stephenson contributed more to the improvement of the locomotive than his father. Cylinders took an inclined position—a step nearer the horizontal—making springs practicable. The straight flue became general, although in some engines it was split and ran through the boiler as two tubes, thus increasing the heating surface.

Stephenson's "Lancashire Witch," shown by fig. 7 from a French publication, was built in 1828, and is noteworthy as the prototype of the "Rocket." French engineers who saw it at work considered that it was the most up-to-date and efficient locomotive they had seen.

One of the provisions of the Liverpool and Manchester Railway Act was that coke instead of coal was to be used as fuel, to avoid the smoke nuisance which was becoming increasingly apparent. The Stephensons experimented in burning coke, and no doubt it was soon proved that the circular flue, with shallow fire was inefficient. Subsequent developments show quite clearly how they appreciated the need for greater depth in the firebox. This stage of development had been reached by the eve of the Rainhill Trials of October, 1829. The three engines of importance which competed in these trials were Braithwaite and Ericsson's "Novelty," Hackworth's "Sanspareil," and Stephenson's "Rocket," fig. 8. The engines had to consume their own smoke, to weigh not more than six tons, and to have a boiler pressure of not more than 50 lbs. per sq. inch. The course was about 1½ miles in length, and the engines had to make forty runs over the course, in all about sixty miles, or approximately equal to the distance between Liverpool and Manchester and back.

Stephenson's "Rocket" embodied a very important feature of locomotive design. The boiler was multitubular, containing 25 tubes of 3″ diameter, in addition to a separate and deep firebox. The idea of a multitubular boiler was not new; it had been



1827 20 Jan^y at Darlington

Sketch of Timothy

Weight of this Engine 12 - 7 - 2 - 0 with its Water

The Pistons are packed with Hemp

Timothy Hackworth says
a Spring is 3½ Inches diam
and the one that is held
and is loaded to 40 lbs per

Sketch of Hackworths Spring Valve

Hackworths Engine.

The fire Bars are of Wrought Iron 4 ft long
and have a dead Plate 4 In wide between
the fire door & the Bars — these fire
Bars will last on an Average Six Weeks
and one Set Weigh 2-1-0 a 10/ p C^t and
T.H. says are sold for 7/ p C^t when worn
out — Mem. when put on 4 Cast Iron Rims to one of the Locomotive Engine Wheels
& Gascon —
The Steam Valve which is held down by
and is loaded to 52 lbs. per Square Inch
down by a Leaver & Weight is 2 Inch
square Inch —
. This Engine in Summer takes down
24 Chaldron Waggons loaded and returns with
the 24 Empty Waggons at 5½ Miles p^r
Hour.

Fig. 6.—Hackworth's "Royal George," 1827.

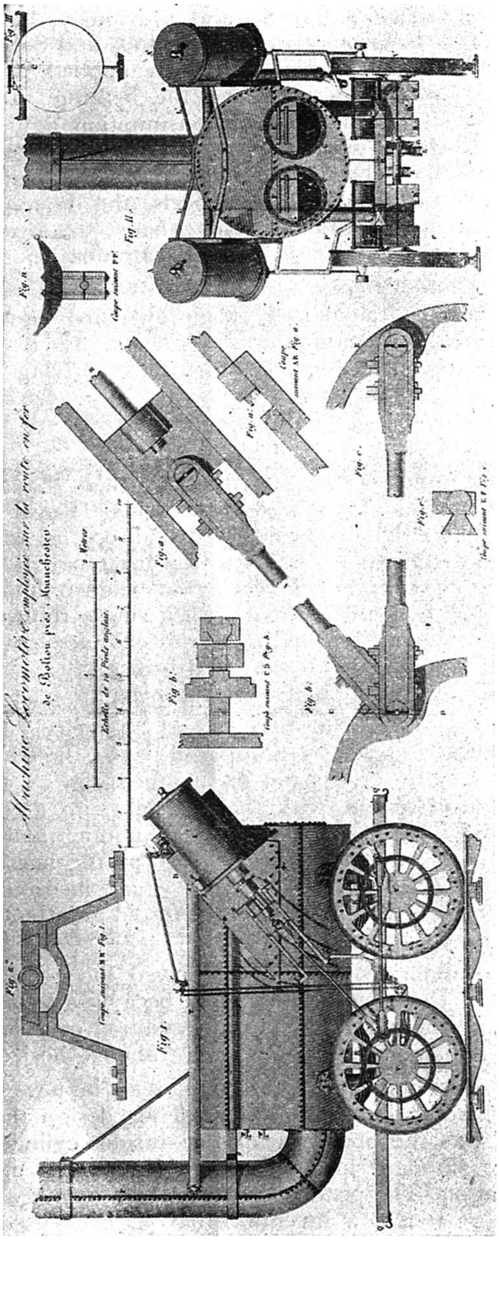


Fig. 7.—Stephenson's "Lancashire Witch," 1828.

patented by a Frenchman (M. Seguin) previously, but this was its first application to locomotives in England, and Seguin's own locomotive had the principle differently applied. The use of small tubes enormously increased the heating surface and at the same time reduced the fuel consumption figure. In its engine the ''Rocket'' was the logical development of the ''Lancashire Witch.'' The cylinders were inclined and drove on to crank pins on the front pair of wheels, the other pair being placed to the rear of the firebox. The exhaust steam was turned into the chimney at first through two separate nozzles.

Braithwaite and Ericsson's ''Novelty'' was of a particularly neat design, built on the lines of their own fire engines. The boiler was vertical and motion was obtained by two vertical pistons, which were placed inside the frames, driving on to the axle through bell cranks. The fire was fed from the top of the boiler, like a slow combustion stove, and there were bellows to create a forced draught in the ashpan.

The third engine to compete—Hackworth's ''Sanspareil''—followed on a smaller scale the design of his ''Royal George,'' *i.e.*, with vertical cylinders which drove direct on to the rear pair of wheels, which were coupled to the front pair by rods and pins. The use of vertical cylinders again made it impossible to use springs. The boiler was fitted with a single return flue and the exhaust steam was injected into the chimney as a blast, through a single nozzle with contracted orifice.

As a result of the Rainhill Trials, the £500 prize was awarded to Stephenson, both the ''Sanspareil'' and ''Novelty'' developing defects during the tests, the ''Sanspareil,'' too, failed to satisfy other conditions as to weight and the use of springs. After this, the ''Rocket'' was rebuilt with the cylinders in a practically horizontal position. Fig. 9 shows the rebuilding and how she stands to-day at the Science Museum, except for missing parts. The chimney and exhaust pipes now on her are incorrect restorations made before she was sent the Museum, in an attempt to give her the original appearance.

The ''Northumbrian,'' fig. 10, followed the general design of the ''Rocket'' except that the firebox became an integral part of the boiler and there is the important addition of a smoke box. The cylinders remained outside and were almost horizontal.

The next development in design is seen in fig. 11, which shows the ''Planet,'' built in 1830. This design had inside cylinders and was the prototype of the inside cylinder engine which was the standard locomotive in this country until about twenty years ago. The pistons drove on to a crank axle. The crank axle was not a new invention, having been used as early as 1815, but for coupling the axles. Another feature of the

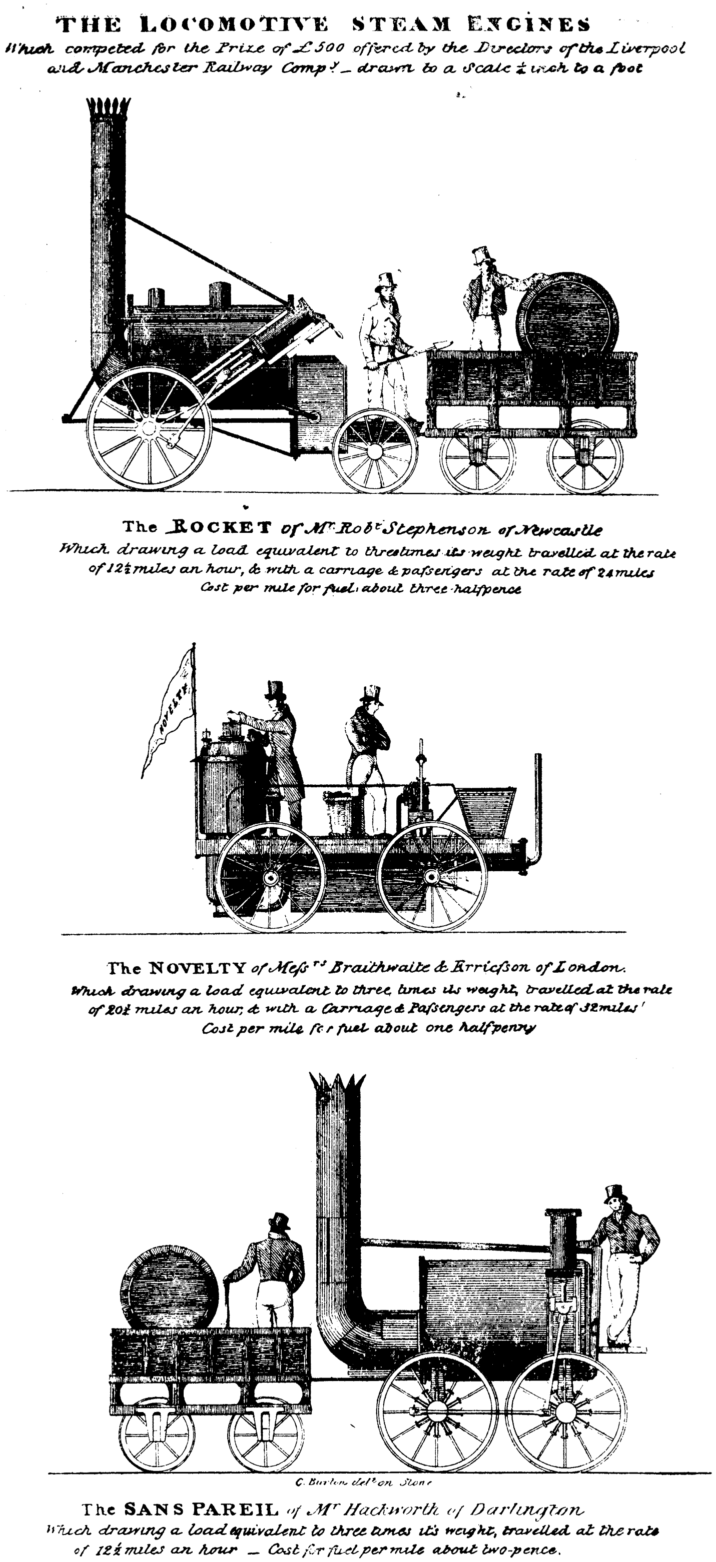


FIG. 8.—Locomotives at the Rainhill Trials, 1829.

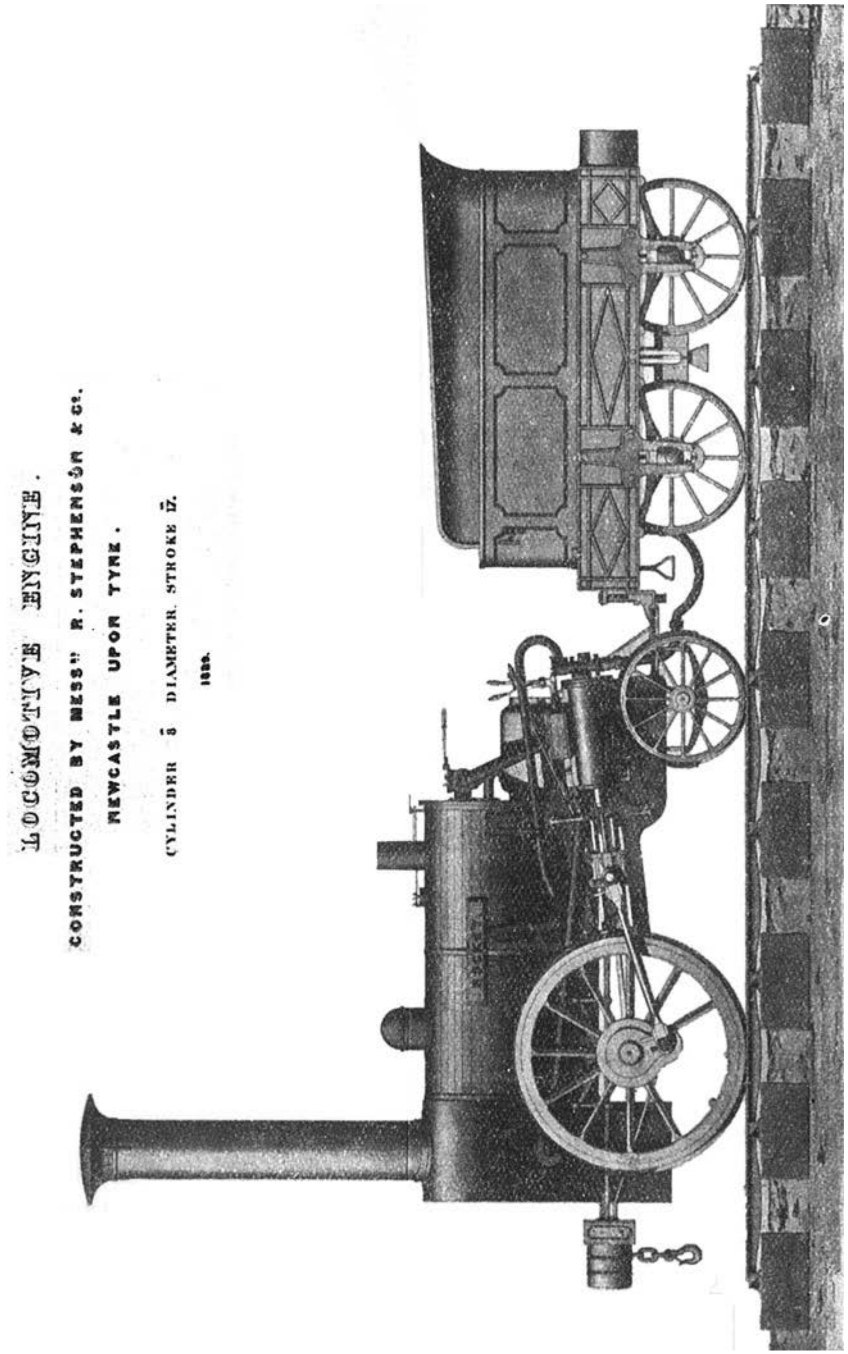


FIG. 9.—The "Rocket" as rebuilt after 1829.

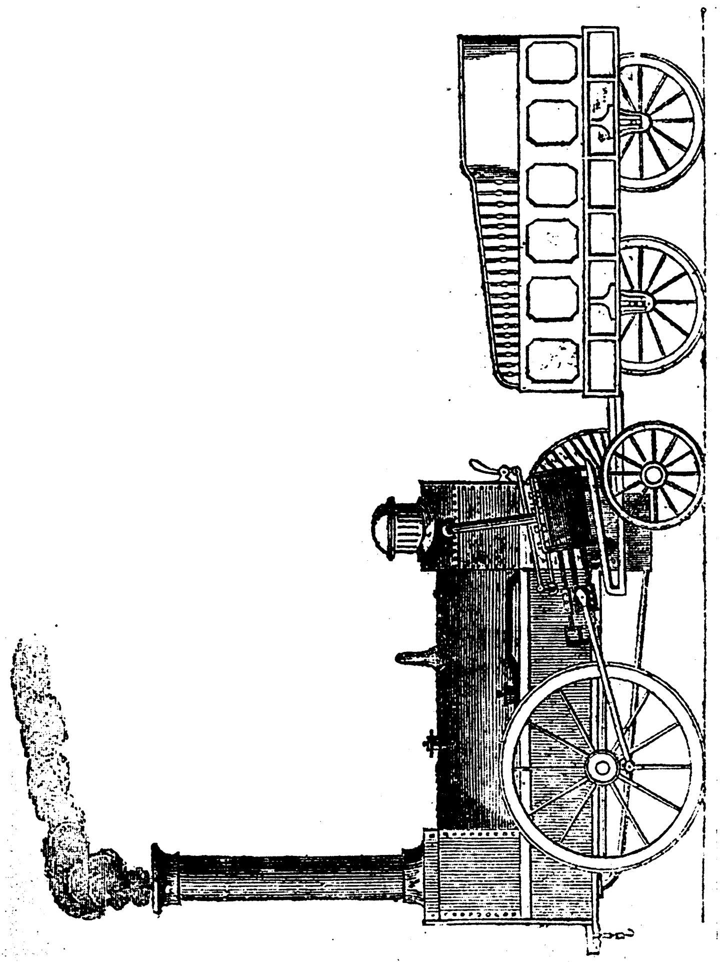


FIG. 10.—Stephenson's "Northumbrian," 1830.

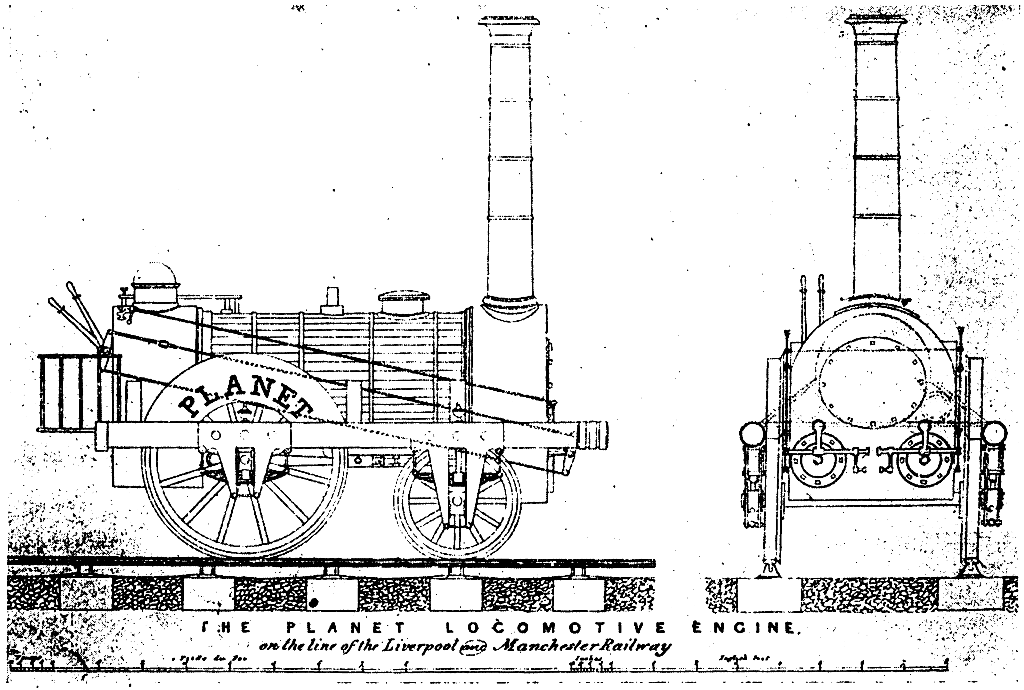


Fig. 11.—Robert Stephenson's "Planet," 1830.

''Planet'' was the casing of the cylinders by the smoke box, which greatly reduced loss of heat by radiation. This engine could haul a load of between 80 and 90 tons on the level at a rate of about 15 miles per hour, but the locomotive builders found that the more they improved their engines, the, more was expected of them, and the tendency was for boilers to increase in size, eventually necessitating a trailing axle.

The ''Goliath,'' fig. 12, a four-wheel coupled goods engine which was used for working the heavy inclines on the Liverpool and Manchester Railway, marked an important stage in locomotive design. This engine was built in 1830—within five years of the opening of the Darlington line. It had four frames made of wood, the outside frames to take the weight and the inside to take the longitudinal thrust from the cylinders.

Between 1825 and 1830, constructional development lay mainly in attempts to obtain greater heating surface, first by means of the return and double flue arrangements, then by multitubular boilers and separate fireboxes (as in the case of the ''Rocket''), later with the firebox integral with the boiler (as in the case of the ''Northumbrian''). The weight of locomotives increased in this period from 5 to 10 tons, the horse power from 7 to 50, the heating surface from 41 sq. ft. to 450 sq. ft. The ''Planet'' became the standard type of the Liverpool and Manchester Railway, and locomotive builders were requested to follow its design when supplying engines for that company, but some contractors stuck to the vertical cylinder engine with indirect crank drive. George Stephenson, as the Company's engineer, was asked to report on the position of the cylinders, and replied strongly in favour of the horizontal. Another locomotive builder, Bury, constructed an inside cylinder locomotive with four wheels of much the same size as the ''Planet,'' but he advocated single inside frames, and a heated discussion took place as to the relative advantages of inside and outside frames. The principal claim for Stephenson's double frame was greater safety in case of crank axle breakage, at that time a common occurrence. Bury also advocated the D-shaped firebox instead of Stephenson's square box, and on this point again the two men clashed. The question was ultimately submitted to arbitration, when the square box as designed by Stephenson was recommended. Stephenson's own report on the advantages of the square box contains his recommendation of the 4″ pitch for side stays which remained standard for so many years.

For the time being, however, Bury's engines proved quite satisfactory, but he tenaciously held to the idea that four-wheeled engines were sufficiently powerful for the traffic demands of the time, in spite of the fact that by 1835 other makers were building six-wheeled engines. He supplied all the first locomotives for the London and Birmingham Railway, but carried his four-wheel policy too far, for it is stated that no less than seven engines were required to work a train on one occasion. The effect of such expensive working led the Directors eventually to order six-wheeled engines of Stephenson's later long-boiler design.

An interesting sidelight is thrown on the manufacturing problems of that time by fig. 13, which shows a page from the sketch book of a smith (John Nuttall) giving the details of a crank axle made by him in 1840, and the bar frame of a Bury design.

Hackworth's engine of this period is shown by fig. 14. These engines were suitable for coal trains, but not for fast passenger trains.

Engines of the four-wheel single and coupled ''Planet'' type were sent to America and France, where they remained the standard locomotives for some years. In America, however, an additional pair of wheels was soon added in front to guide the engine on roads which were much worse than those in England. Generally, however, the Americans adopted a four-wheeled bogie, which quickly developed to meet local requirements.

An American engine working up the Lickey Incline hauling a train of coal is shown by fig. 15. This incline had a gradient of 1 in 37, one of the worst in the country at that time. It was considered by both Stephenson and Brunel that such gradients could not be worked economically by the locomotive; whether the English makers, as has been stated, refused to build for this line seems open to doubt.*

Fig. 16 shows a stage in the development of the double frames of the Stephenson locomotive. Originally they were made entirely of wood as in the ''Planet,'' the frames of which are illustrated, but later they were made of wrought iron inside and wood and iron outside. Bury adhered to inside frames only, of iron, in bar form.

So early as 1832 double slide valves were in use, giving short ports, and an original letter from Robert Stephenson recently discovered shows that trouble was being experienced with friction and that balanced valves were considered. Fig. 17 shows the double slide valve of 1832 which was abandoned soon afterwards for the single valve. No lap was provided beyond a small

---

*The author has since found that they declined to supply engines of the American type, in spite of the sensational reports of performances in America which led to their importation.

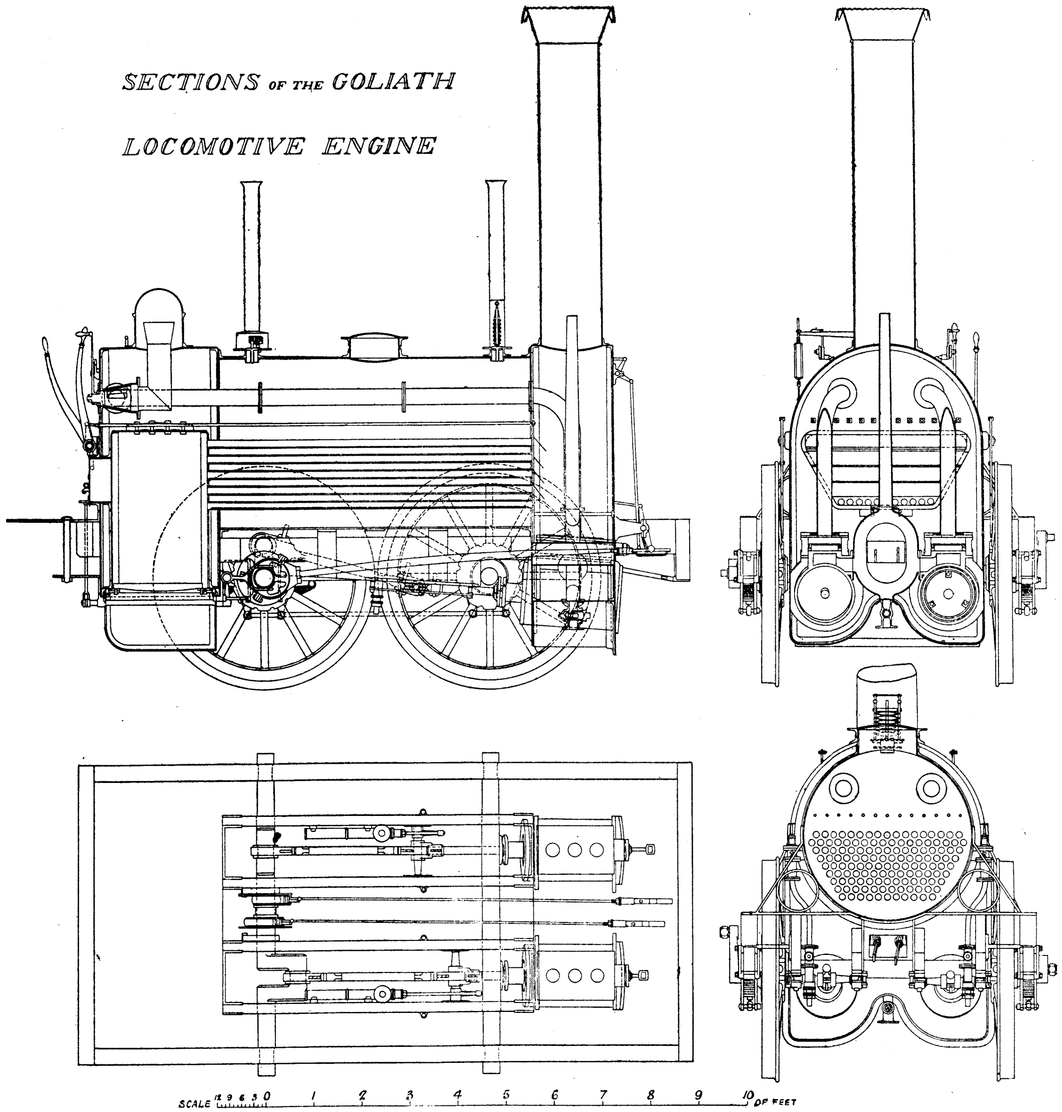


FIG. 12.—Stephenson's "Goliath," 1830.

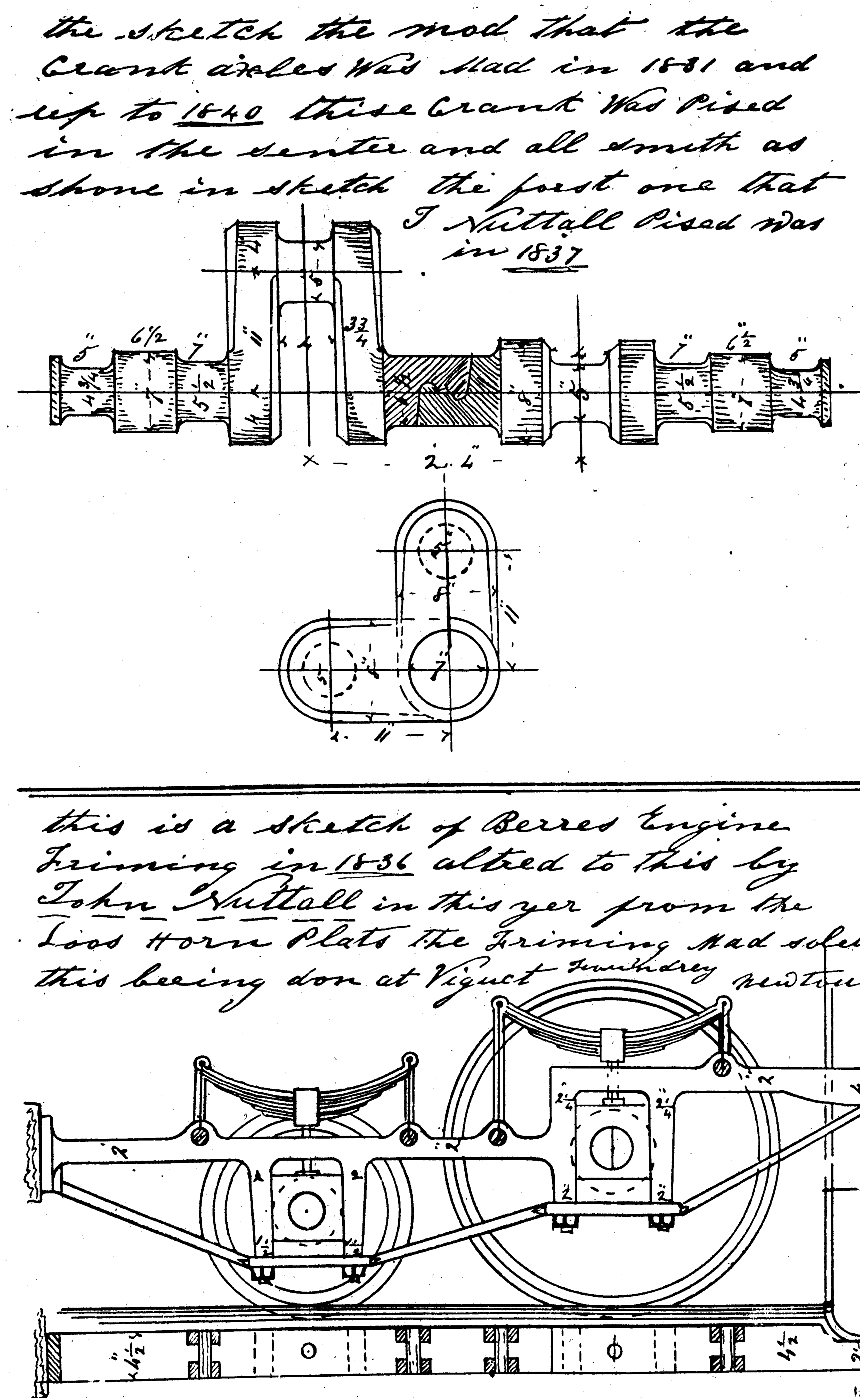


FIG. 13.—Crank Axle and Bar Frame, 1837. (*By courtesy of Mr. E. Colclough*).

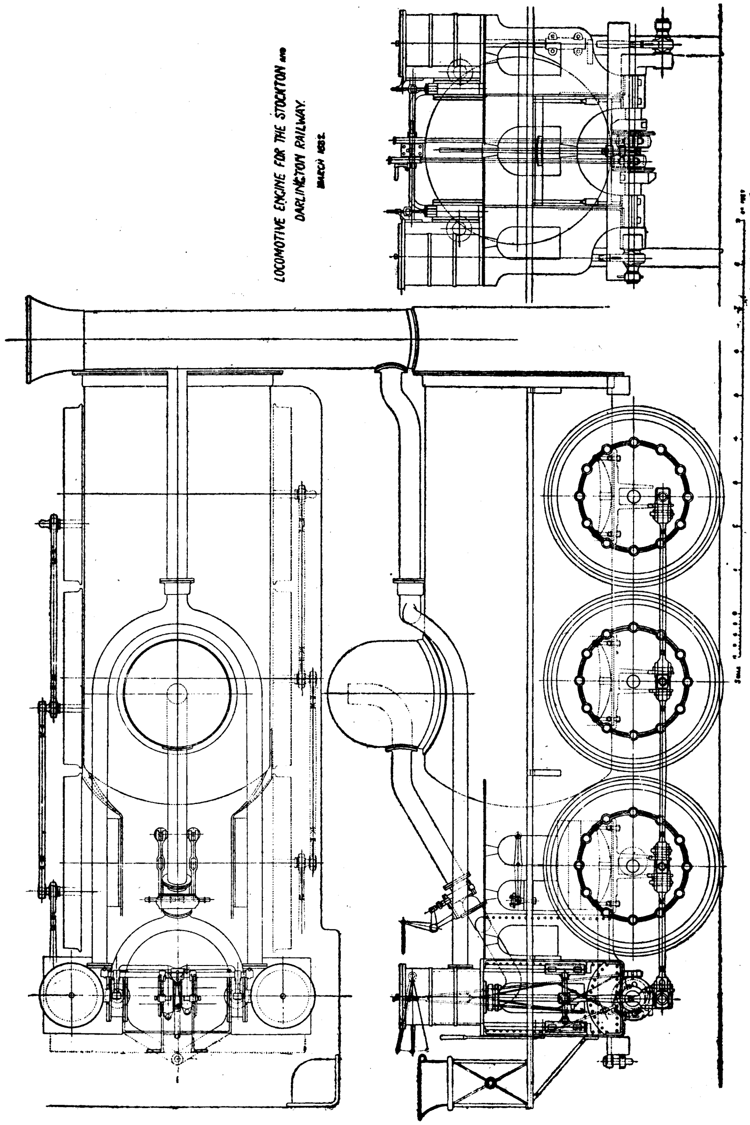


Fig. 14.—Hackworth's Coal Engine, 1832.

amount to allow for expansion or errors in fitting which might have allowed steam to enter both ends at the same time.* A piston valve, shown by fig. 18, also appeared at this time and was tried.

The next important feature in general locomotive design was the addition in 1833 of a trailing axle behind the driving wheel (fig. 19). The "North Star," shown by fig. 20, made its appearance in 1837. This represents generally Stephenson's standard engine of the period, though it had a frame outline which remained peculiar to the Great Western Railway. An important new feature of the "North Star" was the single reversing gear, in which reversing was effected by one lever, instead of the four levers shown by fig. 19.

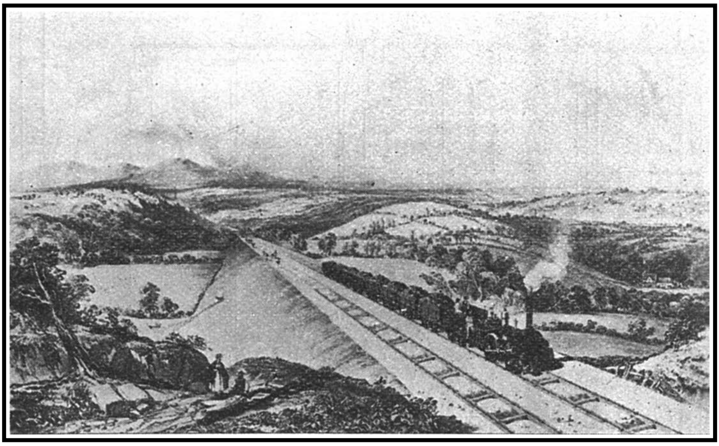


FIG. 15.—American Bogie Locomotive on the Lickey Incline, 1840.

Fig. 21 shows Stephenson's standard boiler of 1840, with raised firebox giving a large steam space. It is interesting to follow the development of the multitubular boiler. The "Rocket" had tubes 3″ diameter outside, but it was found that better results could be obtained by having more tubes of less diameter and by 1830 that diameter had fallen to 1 5-8″ outside. By 1840, tubes of 2″ diameter were in use, which appears large for the short boiler barrel of that time. The length of the boiler barrel had

* The further development of "lap," first to permit of pre-exhaust, is described in the articles on the re-constructed "North Star." See "The Locomotive," p. 90, March 1926.

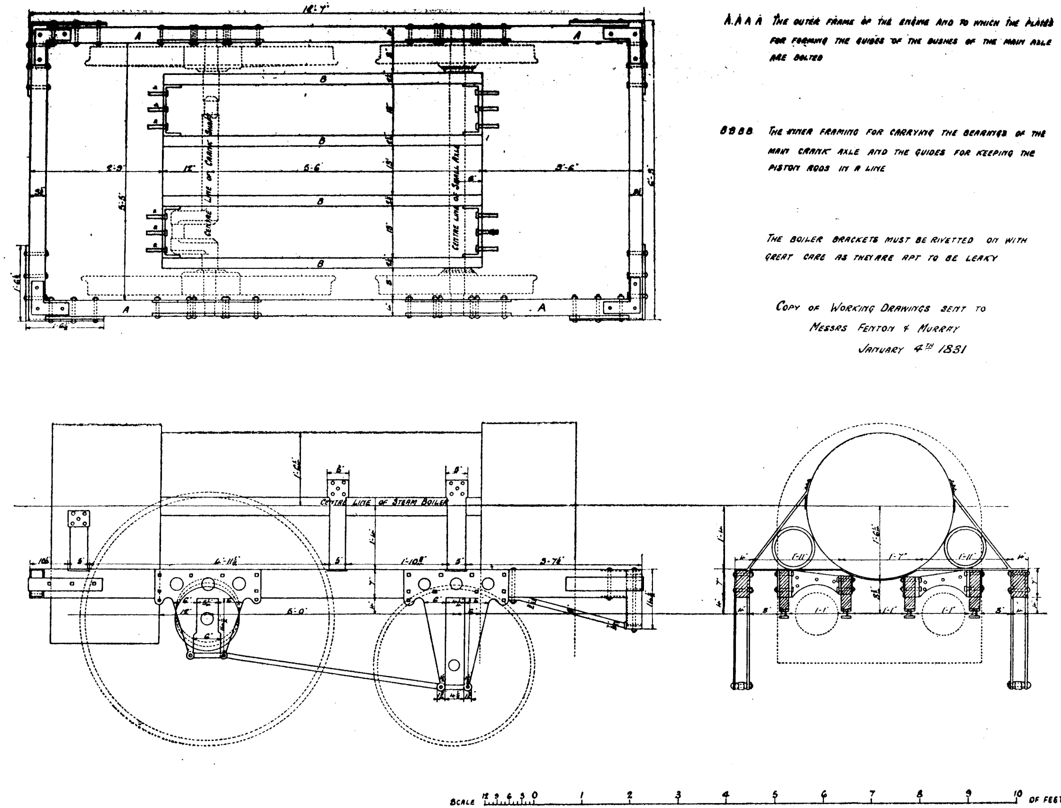


Fig. 16.—Frame of Stephenson's "Planet" Type.

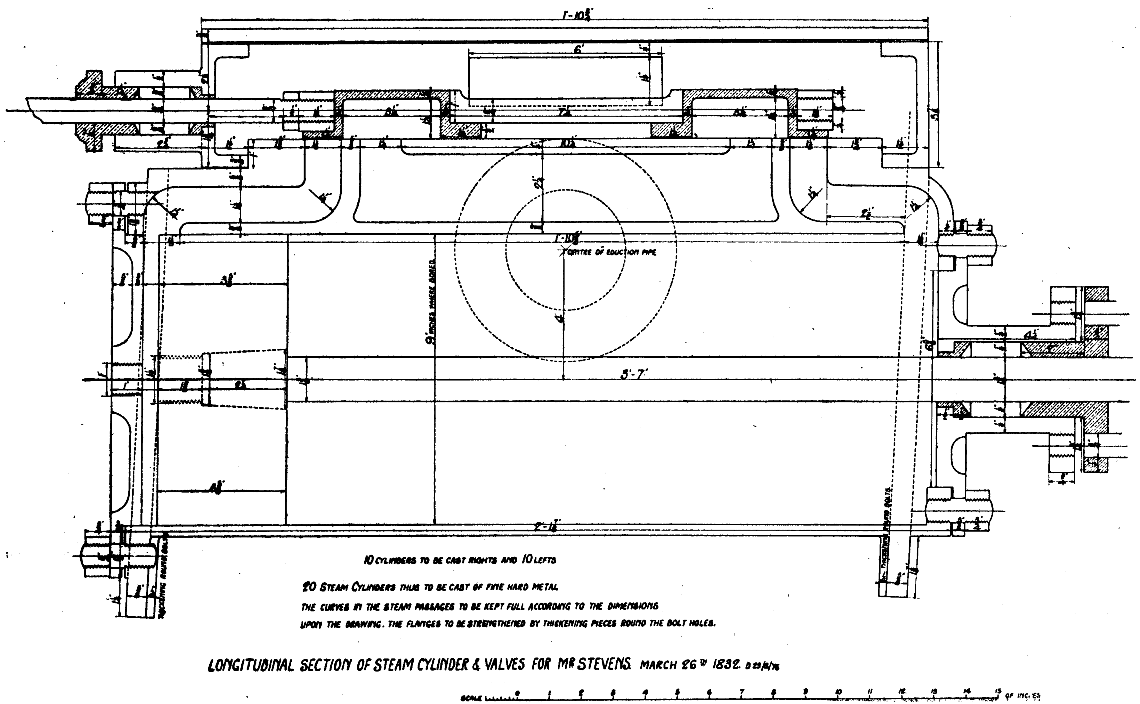


FIG. 17.—Double Slide Valve, 1832.

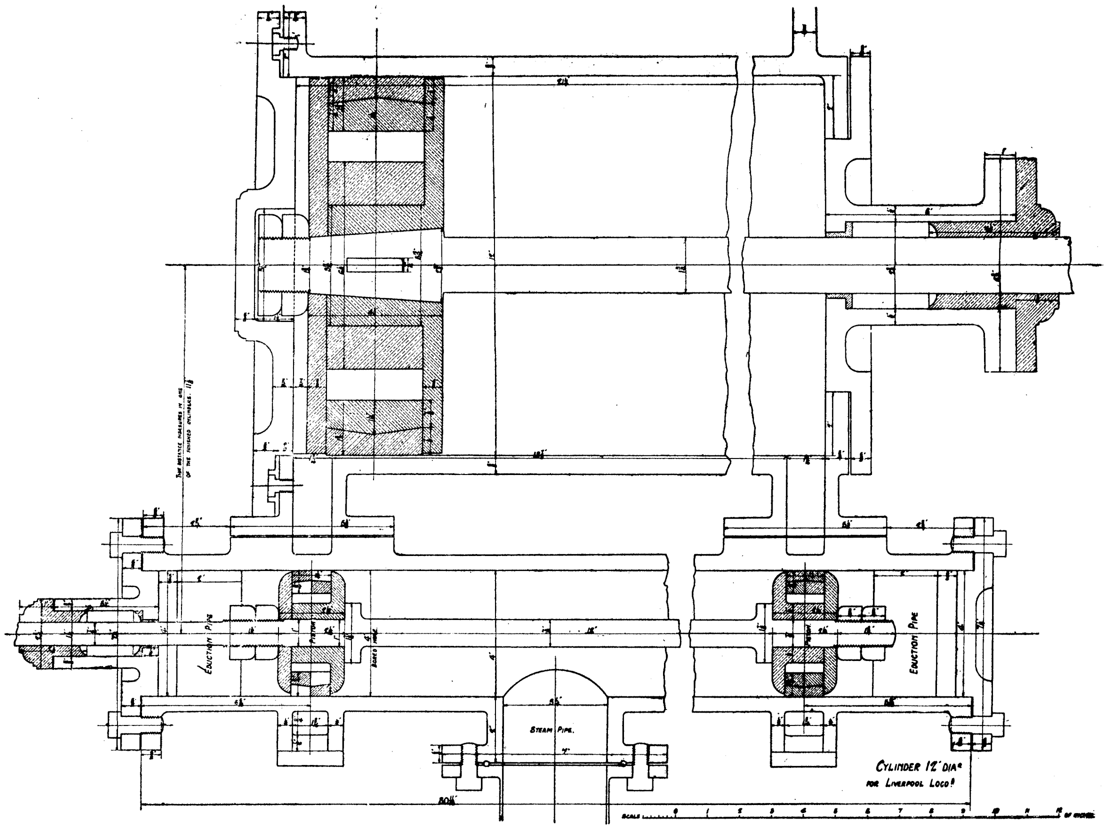


FIG. 18.—Stephenson's Piston Valve, 1832.

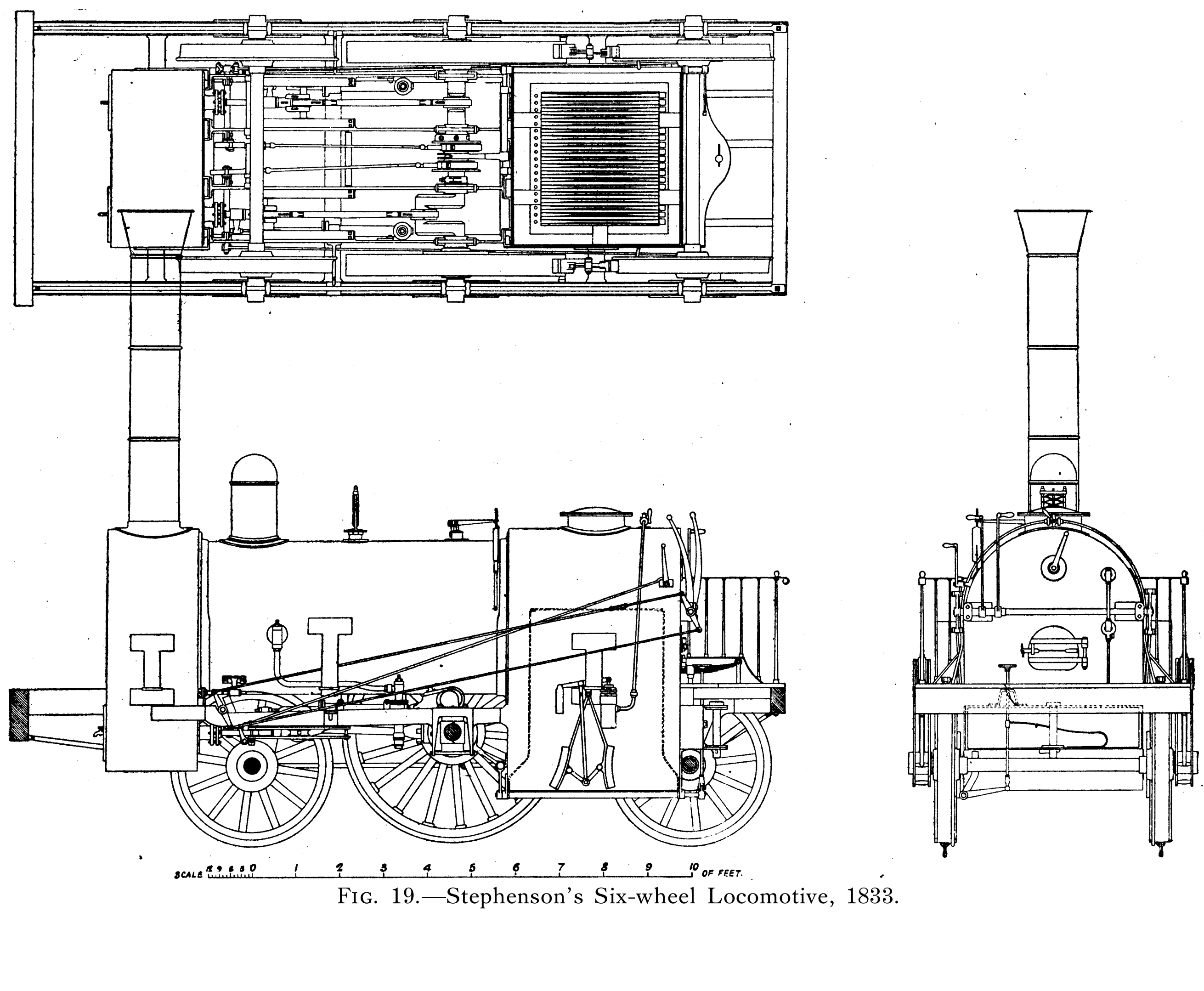


FIG. 19.—Stephenson's Six-wheel Locomotive, 1833.

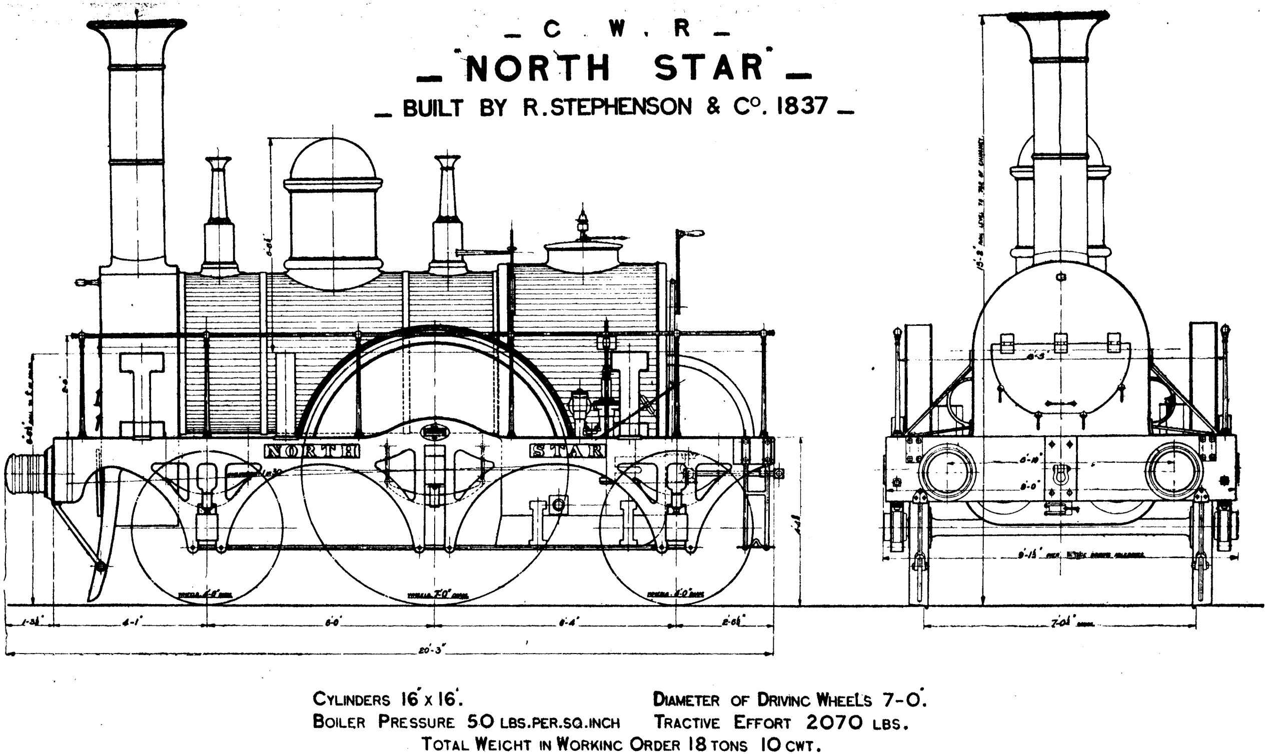


Fig. 20.—Showing the re-construction at Swindon, 1925.

remained practically constant and this meant high smokebox temperatures. Locomotive development being restricted then, as now, by the length of turntables as well as the condition of the permanent way, it followed that to accommodate a longer barrel without increase of wheel base the firebox had to overhang the rear axle, and this method of construction was adopted by Robert Stephenson (fig. 22a). A natural development of this is seen in his six-coupled ''long boiler'' engine (fig. 22b), which was for some time largely used at home on the narrow gauge lines and became the standard goods engine of the Continent till the end of the 19th century. Its short wheel base made it useful for working goods yards, and the length of the barrel reduced smokebox temperatures and effected an economy in the consumption of fuel.

In his first ''long boiler'' engine Stephenson also introduced inside plate frames. He put the steam chest between the cylinders, and the valves of these engines were operated by an improved ''gab'' gear, with eccentric rods driving direct on to the valve spindles. By 1842 the link invented by Williams and improved by Howe was introduced, and at once removed difficulties which had for years caused trouble in the reversing of the fork motion; it also enabled steam to be cut off in varying degrees. The link motion was quickly adopted by other home locomotive builders but more slowly in America.

At this time, Stephenson built some long boiler engines for the Marseilles and Avignon Railway, shown by the model at Paris of a similar engine, fig. 23, but in these he made what he afterwards admitted was a mistake. Crank axles could not then be made satisfactorily in France, and to get over this difficulty he adopted a straight driving axle and outside cylinders. But engines were not balanced for reciprocating weights in those days, and, while suitable for low speeds, long boiler engines of this outside cylinder type were very unsteady at higher speeds. The limits of the long boiler engine with short wheel base were therefore reached in Stephenson's engine ''The White Horse of Kent,'' of the type shown by fig. 23. The boiler was about 22′ long overall, while the wheel base was only about 10′ long. Gooch reported on this engine before the Gauge Commission and stated that owing to the overhang at both ends the engine was extremely unsteady, and was, he considered, quite unfitted for the high speeds which were being attempted by 1845 as the result of Brunel's challenge to the narrow gauge lines.

In order to get over the difficulty caused by the long boiler on a short wheel base and with driving wheels in the middle, Stephenson placed the drivers at the back (fig. 24), and this next stage of locomotive evolution is also seen in engines designed by

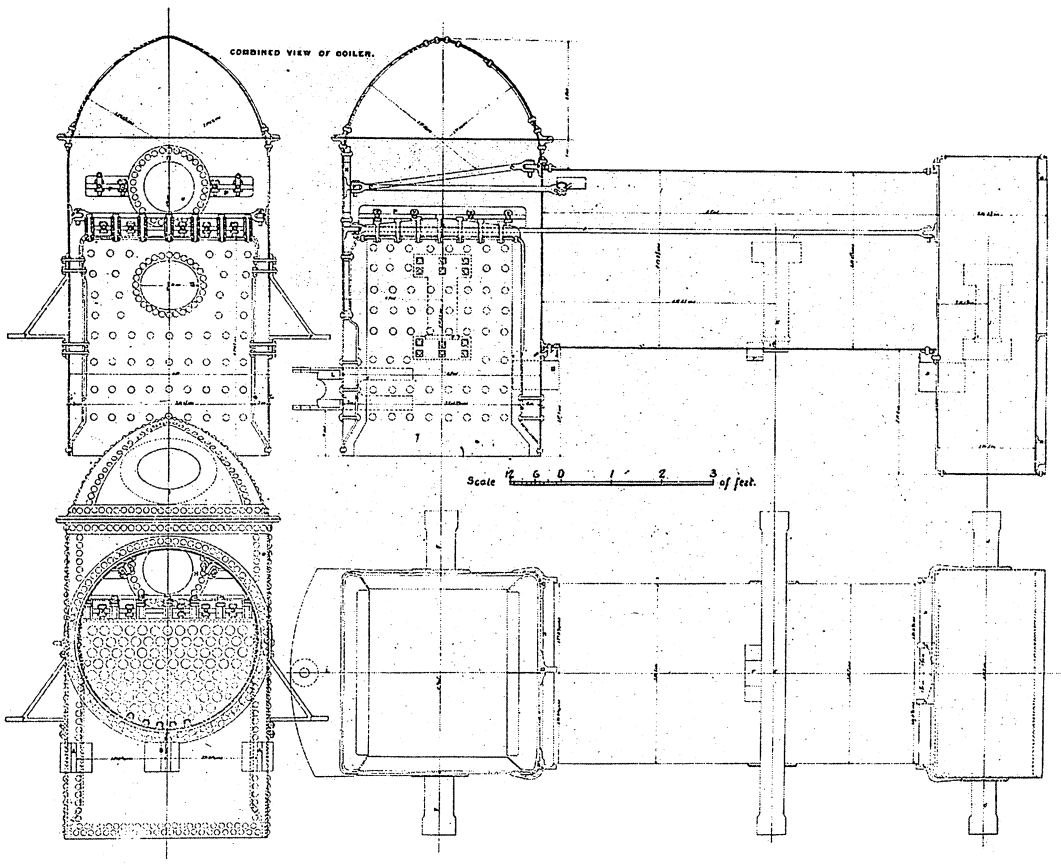


FIG. 21.—Stephenson's Standard Boiler, 1840.

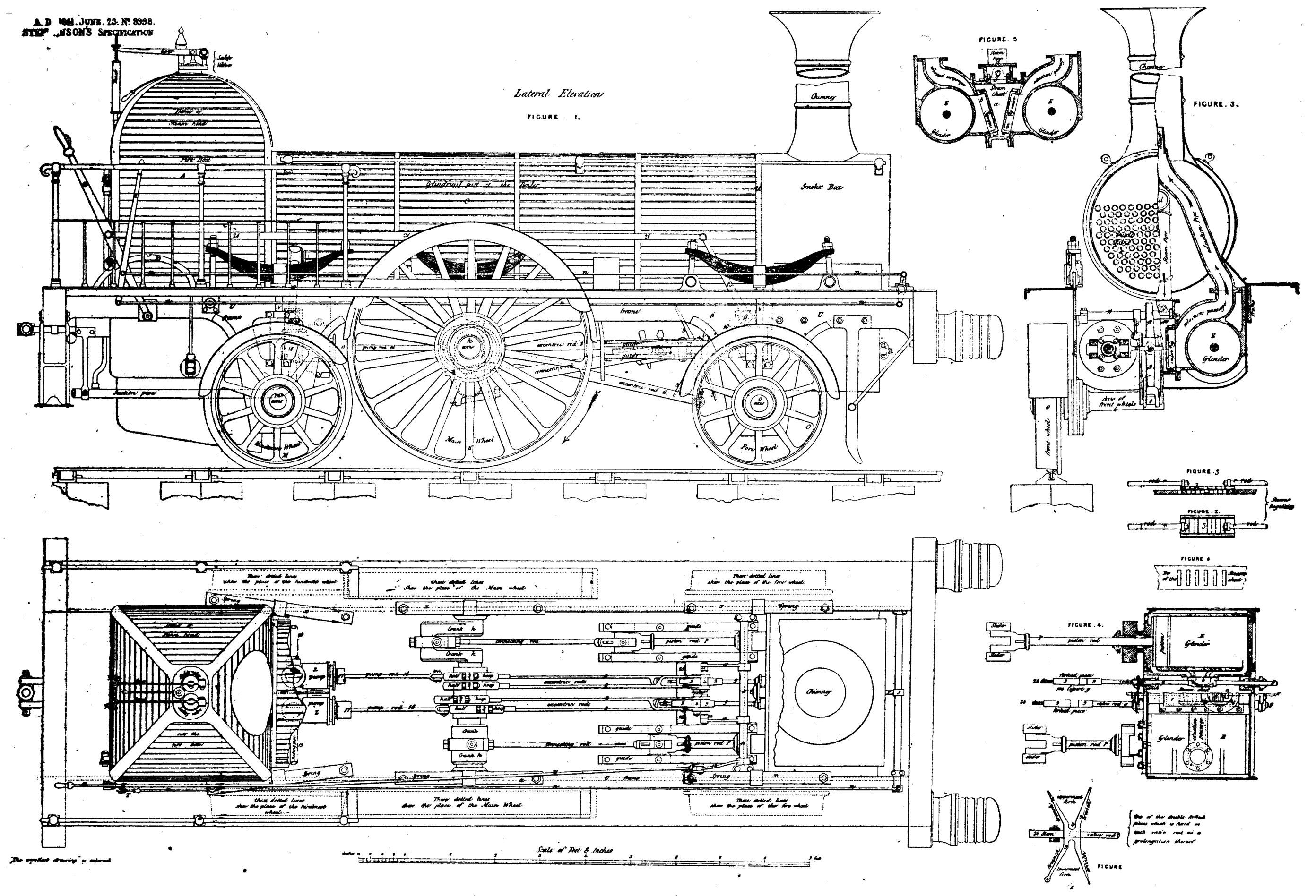


FIG. 22A.—Stephenson's Long Boiler Passenger Locomotive, 1841.

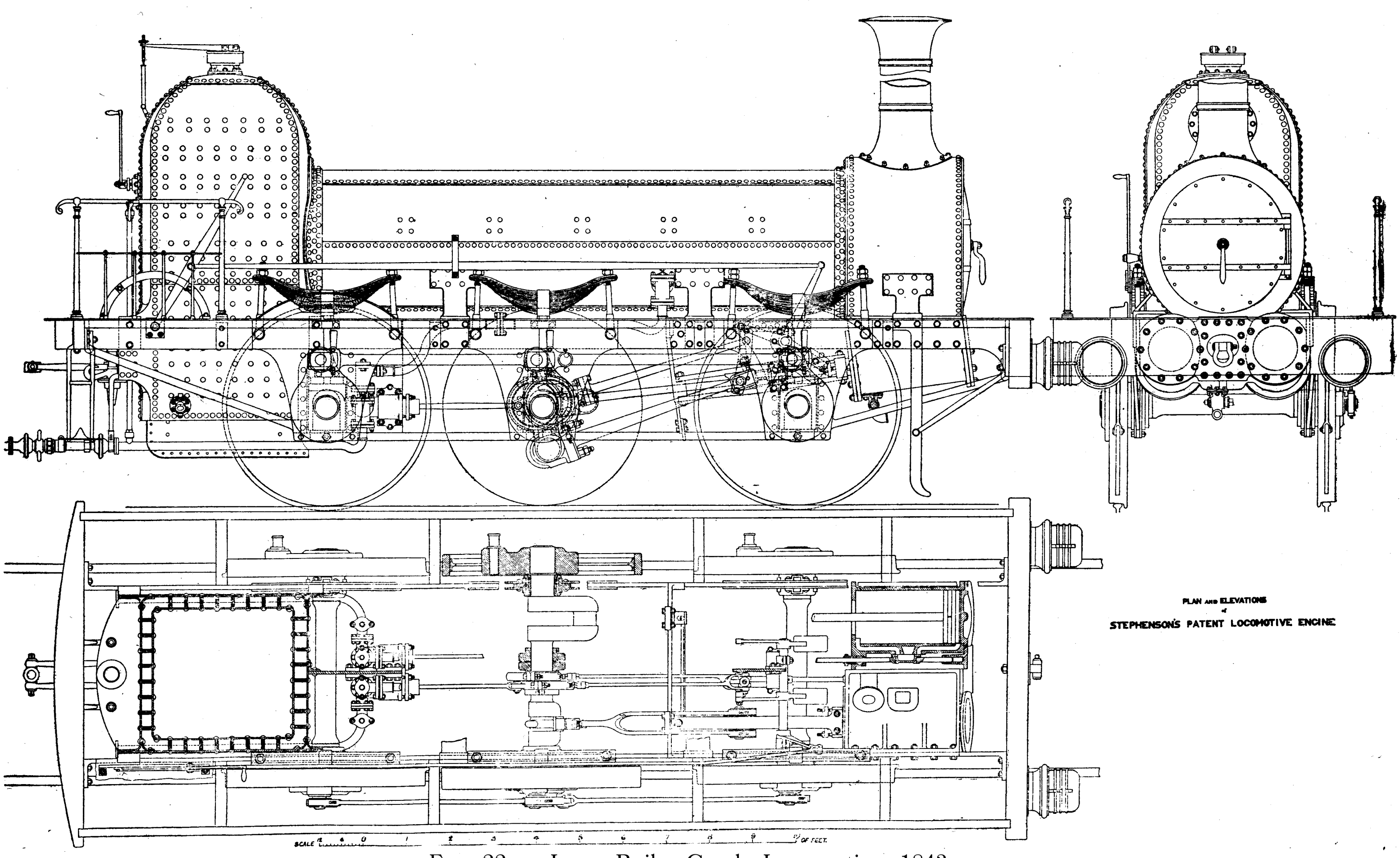


FIG. 22B.—Long Boiler Goods Locomotive, 1843.

Crampton (fig. 25a). He, however, placed his driving wheel behind the firebox, and his cylinders, as in Stephenson's new engine, to the rear of the leading wheels. By this means both designers obtained a much steadier engine.

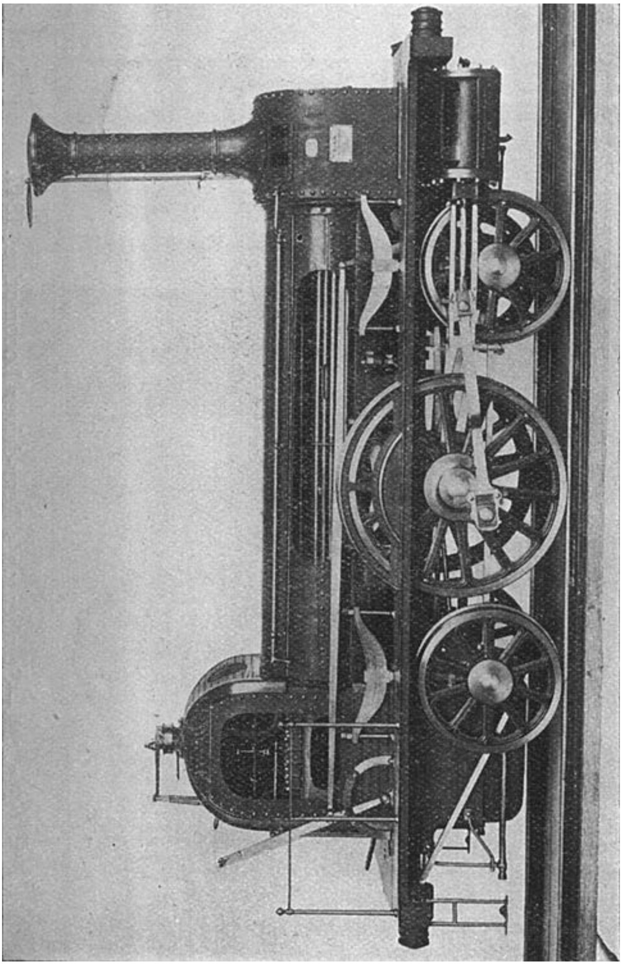


FIG. 23.—Long Boiler, Outside Cylinder Locomotive, 1843.

It was a common belief at this time that for steady running the boiler must be kept down on the axles to lower the centre of gravity, and all contemporary locomotive designs of the period embody this feature, particularly those by Crampton. Engines built to both these designs were exported to France, and continental locomotive design was influenced by them to a marked degree, particularly by the construction of Crampton's engines. Engines of this type were at work in France up to 1914, and one

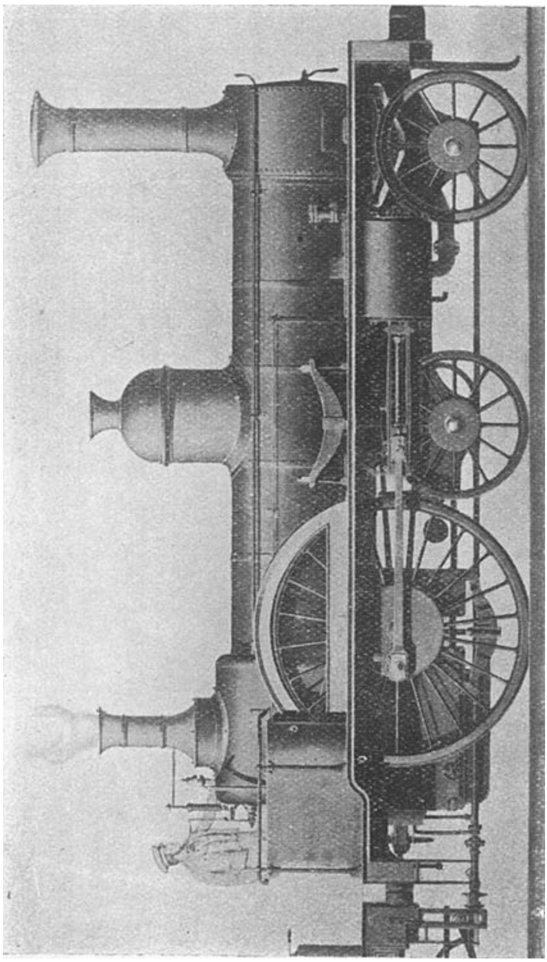


FIG. 24.—Stephenson's Rear-driver Locomotive, 1847.

of them has been preserved by the Est Railway Company. In England they did not have any great or lasting use.

Fig. 25b shows Crampton's enlarged engine, the "Liverpool," built in 1848. This engine had four leading wheels and two intermediate; the driving wheels were situated behind the firebox, with cylinders well to the rear of the leading group of wheels. The heating surface was over 2,000 sq. ft., and while in many respects it was a remarkable engine, it was both ahead of its time, and unsuitable for the permanent way, which was not fit to carry an engine weighing 37 tons with a long rigid wheel base. The engine was soon discarded.

The development in locomotive design from 1833 to 1848 may be summarised in the six-wheeled single-driver engine of the "North Star" type for passenger work; a similar engine with

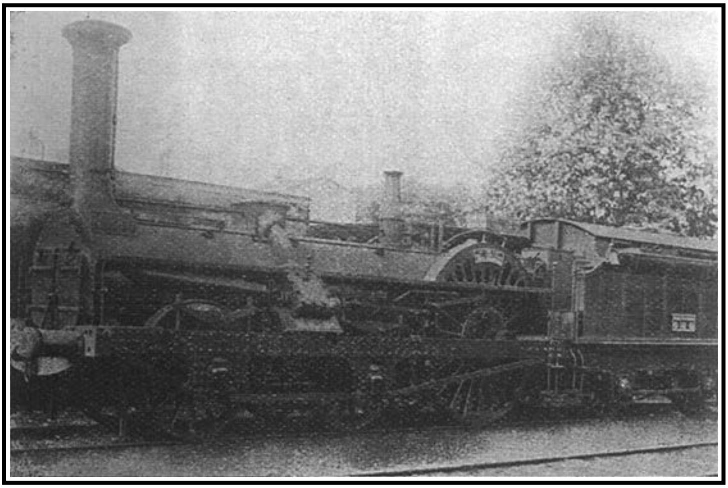


FIG. 25A.—Crampton Locomotive, France.
(*Now preserved on the Chemin de Fer de l'Est. Photo by M. A. Henry, Paris. By permission*).

four coupled leading and driving wheels of smaller diameter, and six wheel coupled engine for goods work; followed by Stephenson's long boiler short wheel base engines, and Crampton's rear driving engine with the cylinders abaft the leading wheels.

The lengthening of turntables and improvement of the permanent way enabled a return to earlier practice in wheel arrangement, from 1850 to 1890, though on some lines to a much later date long boiler engines were used in this country for goods work, and with some modifications and alterations for passenger services.

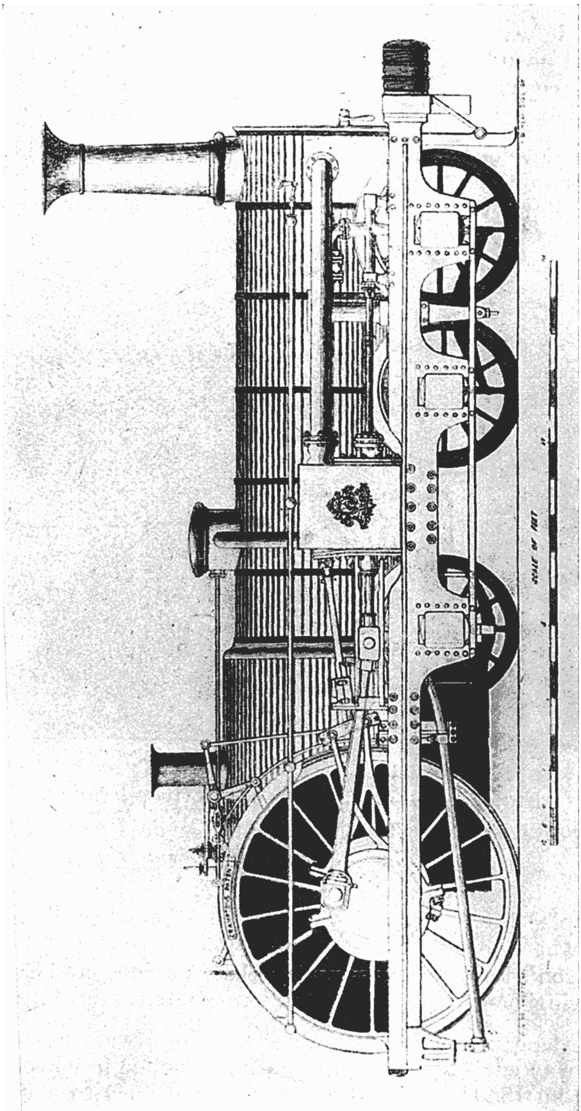


FIG. 25B.—Crampton's "Liverpool," L. & N.W.R., 1848.

In America locomotive development followed the lines of Bury's first engines, exported to that country, including the bar frame, but the four-wheeled bogie quickly became general. Fig. 26 shows an American locomotive of 1845 which in some of its constructional detail appears to be much behind contemporary British practice, still showing traces of the primitive English designs first sent to America.

The development of the British four coupled passenger engine with the leading bogie which was not adopted till about 1860 is shown by Fig. 27.

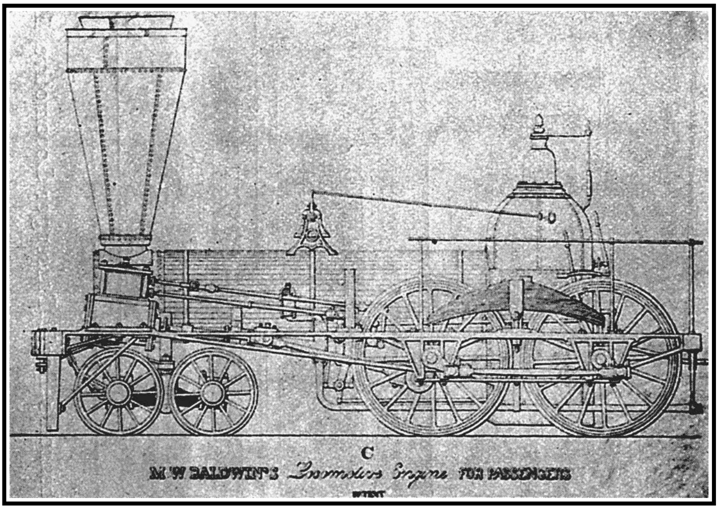


FIG. 26.—American Passenger Locomotive, 1845.

Locomotive development during the period under review, *i.e.*, from the Murray-Blenkinsop engine until the introduction of the eight-wheel engine may be summarised (Fig. 28) in :—

The early colliery type with simple single or return flue, *vertical cylinders,* first with indirect beam, and then with direct drive, with first gear, then chain and finally rod coupling of wheels ;

Stephenson's engine ''Experiment'' with *horizontal cylinders,* indirect lever drive, but *drive combined on one axle ;*

Hackworth's ''Royal George,'' first *driving direct on to crank pins in wheels of one axle,* but with vertical cylinders ;

The ''Lancashire Witch,'' with direct combined drive but with *inclined cylinders ;*

The "Rocket," embodying these advantages and with the *multitubular boiler* and *separate deep firebox;*

The "Planet" with *inside horizontal cylinders;* driving on to a crank axle;

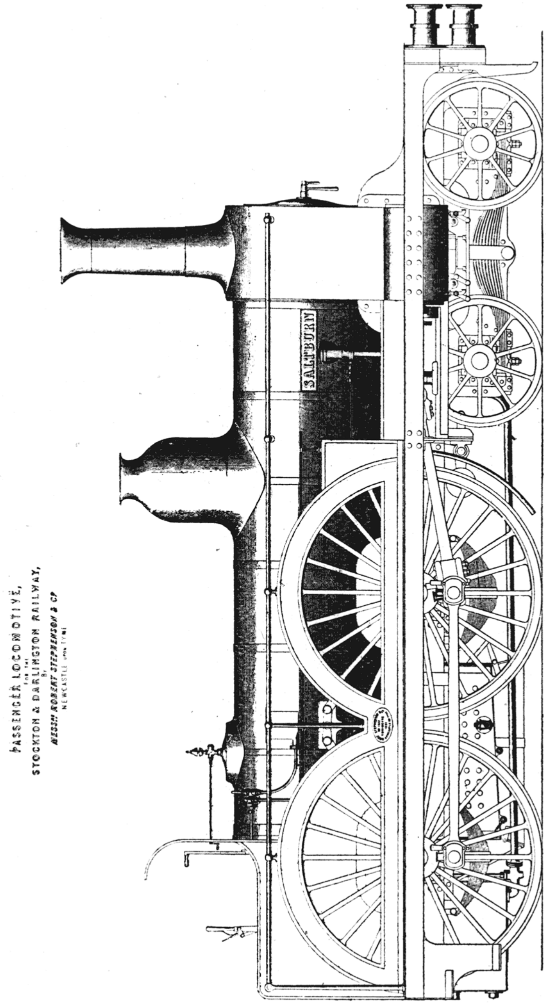


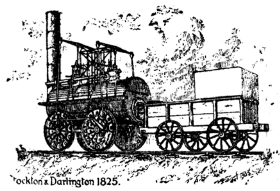
FIG. 27.—Stephenson's Bogie Passenger Locomotive, 1860.

The four and six-wheel coupled goods engines, enlargements of the "Planet"; leading up to—

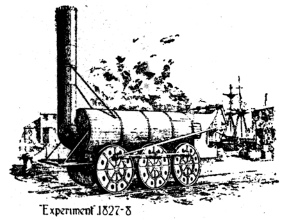
The "North Star" of the Great Western Railway in 1837.

1823—1923

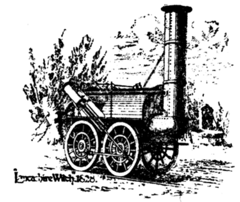
1822
CHAIN COUPLING—SINGLE FLUE



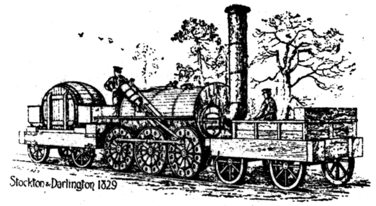
1825
ROE COUPLING—SINGLE FLUE



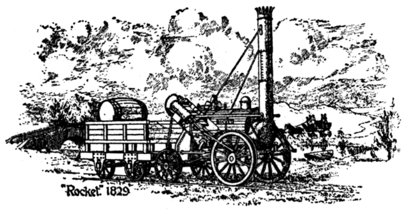
1827–8
HORIZONTAL CYLINDERS—LEVER DRIVE



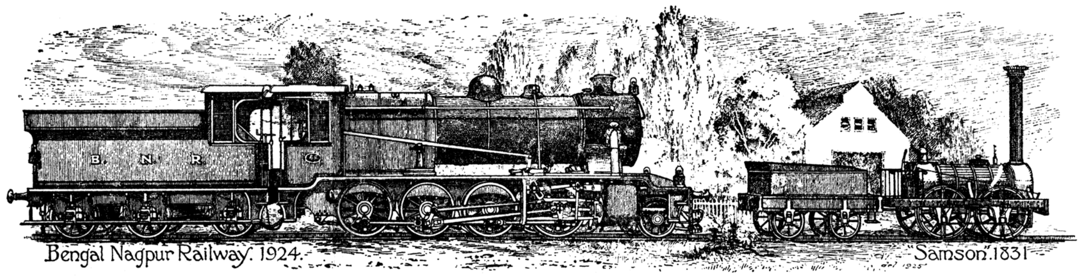
1828
INCLINED DRIVE—TWIN FLUES



1829
INCLINED DRIVE—RETURNED FLUE

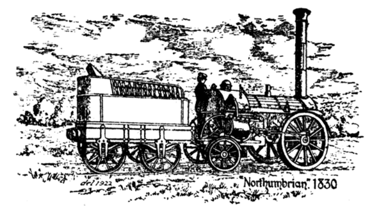


1829
MULTI-TUBULAR BOILER—SEPARATE FIREBOX
THE " ROCKET "

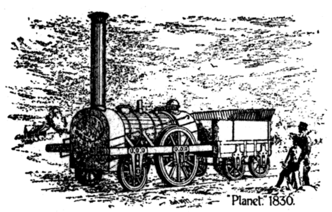


1924
HEAVY GOODS ENGINE
BENGAL NAGPUR RAILWAY

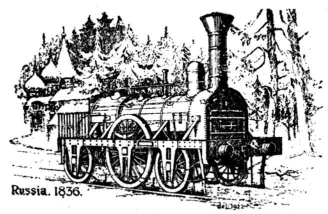
1831
BANKING ENGINE
LIVERPOOL AND MANCHESTER RAILWAY



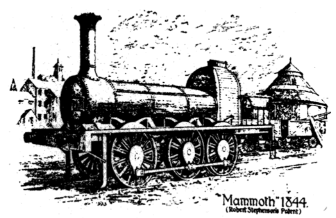
1830
HORIZONTAL DRIVE—BOILER & FIREBOX COMBINED
THE " NORTHUMBRIAN "



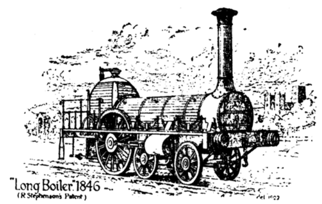
1830
INSIDE HORIZONTAL CYLINDERS—CRANK AXLE



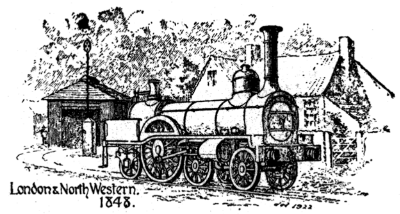
1836
DRIVING WHEELS WITHOUT FLANGES



1844
LONG BOILER—PLATE FRAMES



1846
LONG BOILER—REAR DRIVING WHEELS



1848
LONG BOILER—TRAILING CARRYING WHEELS

A CENTURY OF LOCOMOTIVE BUILDING.

ILLUSTRATED BY TYPICAL ENGINES SHOWING THE DEVELOPMENT OF THE STEAM LOCOMOTIVE

BY

GEORGE and ROBERT STEPHENSON

FIG. 28.

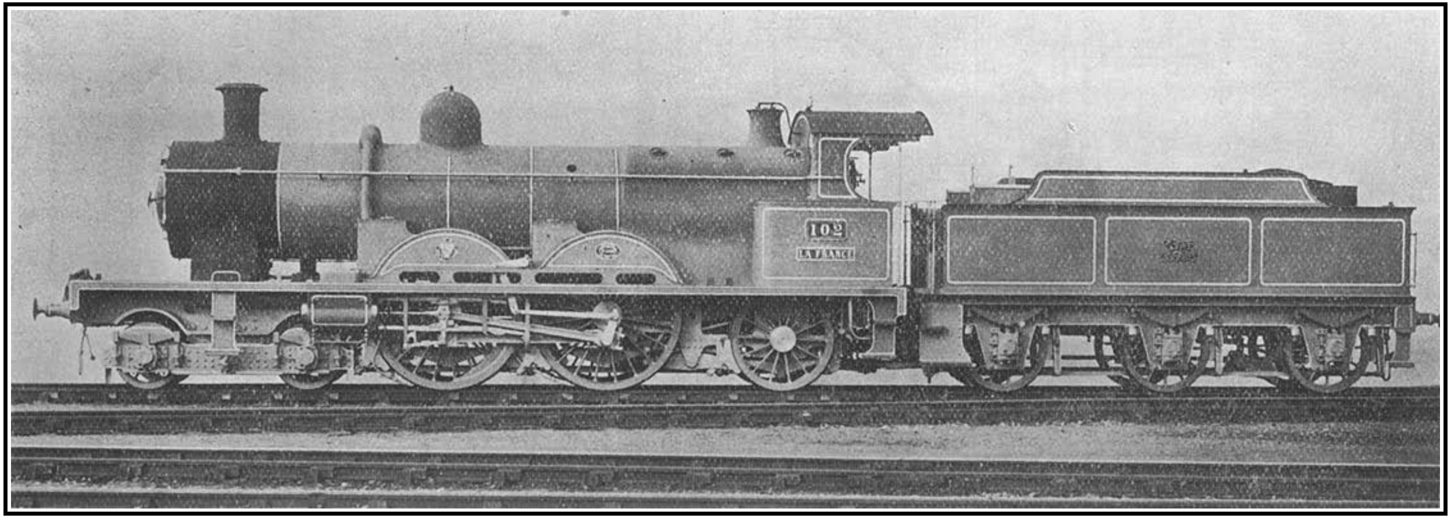


FIG. 29.—"La France," De Glehn Compound Locomotive, G.W.R.

There is then a break away from ''normal'' British practice in Stephenson's long boiler engines and Crampton's rear driver engines, but all the principal elements have been determined and the logical processes of development through which the modern heavy passenger and goods engine have been derived.

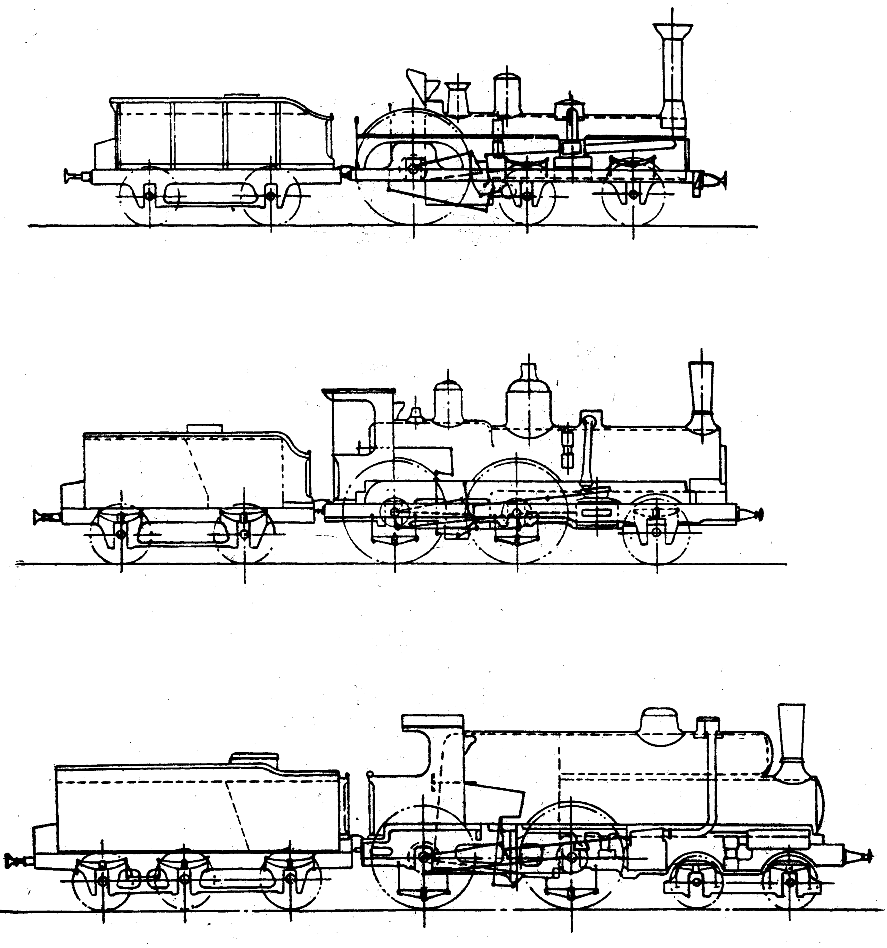


FIG. 30.—Development from the Crampton type on the Chemin de fer de l'est.

The arrangement of the outside cylinders behind the leading group of wheels, generally abandoned in this country after 1850, was reintroduced when the Great Western Railway bought their first French Compound. The essential principles of Crampton's rear driver engines are perpetuated. The cylinders are to the rear of the bogie, the pistons drive on to the rear wheel, but in the case of the ''La France'' (Fig. 29) an additional wheel has been coupled.

It is important to visualise the relative sizes of a locomotive and stationary steam engine plant of the same powers. Amateurs and articles in the daily Press at the present time were criticising the locomotive designers of to-day, saying that they have not progressed very much from the days of Stephenson. Relatively, the stationary engine is still thermally more efficient than the locomotive, but as Robert Stephenson pointed out in reply to similar criticism in 1830, something must be sacrificed for *mobility* and the problem which confronts the locomotive engineers of the present time and those of the future is much the same as that which faced the early men. It is simply this: ''What is the best way of making the relatively efficient, though much larger, stationary engine, loco-motive?"

DISCUSSION.

Mr. W. A. Stanier, the Chairman, in opening the discussion, said he felt they would all agree that the lecture had been most interesting and illuminating, showing the development of the locomotive in a very clear way, and they would all appreciate Mr. Warren's coming to speak to them.

He would like to mention one or two points which had impressed him. The first was that the ''Planet'' was really the start of present day locomotive design, from which the modern engine had not altered very much in principle. Secondly, it was very extraordinary that the Great Western engines of 1850 were so much ahead of the time, and were more efficient than those on the Continent and in America.

Mr. J. C. Jones said he would like to know if any particular difficulty was found in the use of engines fitted with long boilers, because, looking at the photographs and illustrations, he thought that the ratio of the total evaporative surface to the fire box surface was about 20 to 1, whereas modern practice showed that a ratio of about 12 to 1 gave the best performance.

The lecturer replied that this point had been raised by Daniel Gooch before the Gauge Commission in 1845. He had regarded fire box heating surface as the measure of the power of the locomotive. Up to a point, Robert Stephenson had agreed with him but the question seemed to the lecturer one which cannot be answered definitely. The ratio increased tremendously in the case of the long boiler engine, in fact it went too high and it was found that greater draught was required to pull the gases through the tubes. The difficulty was that, as to-day, the length of the tubes was often largely determined by the wheel arrangement, and while this was restricted by the length of turn-tables and the condition of the permanent way, the tube length remained more or less constant in the standard type of 1835-40 with its firebox between the second and third axles, while the tendency was for the fire box to increase in size, and consequently the waste temperature increased also. For this the long boiler offered a remedy. Moreover the problem differed from ours at the present day in that coke was burnt instead of coal, coke being the standard fuel till after 1850, and with coke a smaller fire box was required for economical burning. Economy in fuel consumption and rapidity in raising steam are important points to consider, and it is difficult to say where the two meet. Modern practice tends to favour Gooch's shorter tubes and larger ratio of firebox to tube heating surface. No doubt the Stephenson long boiler became too long in the latest types, and a compromise was reached with the return to the previous wheel arrangement with the firebox between the driving and trailing, or coupled axles.

Mr. A. W. J. Dymond said Mr. Warren had emphasised the effect that the long boiler engine had had on continental design, particularly in regard to the wheel and cylinder arrangement. This system was reintroduced into this country when the Great Western Company purchased the De Glehn Compound engine ''La France.'' Up to the time of this purchase, the G.W.R. had been staunch supporters of the earlier Stephenson tradition, exemplified by and originally transmitted to the G.W.R. in the ''North Star'' and her prototypes. This design remained predominant on the G.W.R. long after the Stephensons had abandoned it and had gone in for the ''long boiler'' design, which represented a vastly different school of thought. The relative merits of the two designs were the subject of much contemporary controversy. Later, further developments resulted in the ''long boiler'' type being naturally abandoned in this country, although it was continued very strongly on the continent. The ''North Star'' type, however, remained pre-eminent on the G.W.R. right up to the purchase of ''La France.'' Thus it appeared that after the lapse of a considerable time, the ''long boiler'' was reintroduced into this country by the very people who had so strenuously upheld the rival claims of the ''North Star'' type in earlier controversies, which struck one as a very interesting fact.

He would, however, like to ask if the present arrangement of wheels and cylinders on the ''Castle'' class which was largely influenced by the De Glehn engines was due, not so much to the ''long boiler'' tradition, as to the satisfactory valve gear and divided drive which were made possible in such an arrangement.

The lecturer replied that the ''long boiler'' type, particularly that with outside cylinders at the front and overhanging firebox (Fig. 23), as pointed out, was found to be unsteady at high speeds.

There was also the difficulty even with the first type ''long boiler'' having inside cylinders (Fig 22a) that when the driving springs were unduly loaded the engines become more or less a rocking horse, and the little weight left on the leading wheels was probably a frequent cause of derailment. Engines at this time were also very light, and it is perhaps a wonder that derailments were not more common from this cause, considering that they were running at speeds up to 45 miles an hour. In order to obtain a steadier engine, Stephenson, in his last ''long boiler'' type, had put the cylinders behind the leading wheels and the driving wheels more to the rear of the engine. A similar arrangement was adopted by Crampton and was introduced to the continent in both types. There it has persisted, first in simple two-cylinder types, and later, generally in compound locomotives, derived from them. Both the De Glehn and ''Caerphilly Castle'' types, no doubt, derived the advantage of greater steadiness, which had been appreciated in the earlier engines. They also have the advantage of the divided drive.

It was not correct to say that the ''long boiler'' itself came back to England in the ''La France''; only the outside cylinders and driving wheel relation had returned. But there is an interesting historical irony in the fact that this arrangement had been first adopted by Robert Stephenson for an engine which took part in the Gauge experiments on the narrow gauge in rivalry with Gooch's standard engine on the broad gauge, and Gooch, in very strong language, had expressed his contempt of the narrow gauge design, and the efforts of its designers to ensure steadiness by various means. (Fig. 30, showing the development from Crampton's engine has been added.)

Mr. H. F. Bannister said that Stephenson recognised the need for higher boiler pressures and used a pressure of 50 lbs. to the square inch. He would like to know what has been the trend of boiler pressures up to the present day.

In replying, Mr. Warren said that it was rather Trevithick who first recognised the need for a comparatively high pressure, and in the days of atmospheric engines boldly went for 50 lbs. to the square inch, this pressure remaining general for locomotives until about 1840. By the time of Gooch, it had nearly doubled that figure. The general increase in boiler pressure might be summarised as from 50 to 80 lbs. per square inch between the years 1804 and 1840; and from 80 to 160 between 1840 and 1890.

Mr. G. S. Taitt asked if particulars could be given in regard to cone and Belpaire boilers, and whether wind catchers had been placed on engines with the idea of increasing the blast.

Mr. Warren regretted that he could not answer the first part of the question definitely, but it was probable that the cone boiler was first introduced in America in the 'forties as a development of the dome firebox boiler, while the Belpaire boiler was first introduced in Belgium, he thought, in the 'eighties. With regard to the second part of the question, as early as 1815 a cowl was placed on the chimney (as may be seen in Fig. 4), but there is no evidence to prove that it was with the object of increasing the draught. All sorts of devices were tried, such as bellows, but it was known from a printed statement that in 1825 Stephenson turned the exhaust from the cylinders into the chimney for this purpose. Hackworth found later that with a long boiler, such as that on the "Royal George," something more was required to increase the draught, and introduced a contracted nozzle which came to be called the "blast pipe." For the Rainhill trials, the "Sanspareil" was fitted with a similar device, and it then gave some remarkable exhibitions of power (due to the blast), but at the expense of much unburnt fuel.

Mr. H. E. Lister said he would like to know the ratios between the bore and stroke of the early engines.

The Author replied that the Stephenson early engines of the Colliery lines had cylinders 9″ x 24″ stroke; the "Rocket" 8″ x 17″; the "Planet" 11″ x 16″. By 1840 the standard passenger engine had a stroke of 14″ x 18″. The "North Star" of the Great Western Railway had an unusual ratio of 16″ x 16″.*

---

*Between 1835 and 1840 some engineers held that high piston speeds were undesirable, but it is clear that by 1841 Robert Stephenson began to aim consistently at longer strokes; the cylinders of his first "long boiler" type with inside cylinders (Fig. 22a) were 14″ x 20″, and in the third type with outside cylinders (Fig. 23) he reduced the bore to 13″ and increased the stroke to 24″, giving a very high ratio of stroke to piston area. After 1848 the English locomotive reverted to the earlier proportions. Cylinders increased from 16″ x 20″ to 18″ x 24″, the ratio deteriorating according to modern ideas. In the Gauge experiments, 1845, the G.W.R. engine had cylinders 15″ x 18″; Stephenson's engine (type Fig. 24) had 15″ x 24″ cylinders. To-day G.W.R. practice follows Stephenson rather than Gooch.—J.G.H.W., 1927.

Mr. W. H. Pearce raised the question of lubrication of the engines of early times, and in reply, Mr. Warren said they relied generally on wet steam. The difficulties of efficient lubrication delayed the use of superheated steam, the principle and advantage of which were known by 1825.

Mr. Stanier pointed out that one of the most serious impediments to the use of high-pressure steam was the unsatisfactory packing of the pistons and glands. It was not until Mr. Ramsbottom of the L. and N.W. Railway invented his ring that it became practicable to introduce high-pressure steam, and with this opinion Mr. Warren agreed.

Mr. K. J. Cook observed that very early in American practice the pony truck made its appearance, and asked if it were quite as scientific in the way of equalising the loading as it appeared from the illustration.

Mr. Warren replied that the pony truck shown in the slide to which he referred, effected no equalisation, it was really a makeshift, and may have been due to two reasons: that it was found useful to accommodate the additional weight of the cow-catcher, but originally because of the defects of the American roads, to which a good deal of damage was done by the use of rigid wheelbase engines of the "Planet" type.

Mr. C. K. Dumas asked when the American cab first came into use, and desired details of cab development to be given.

Mr. Warren regretted that he could not give the lines of general development, but cabs certainly came into use in America earlier than in this country, and for many years were more roomy and convenient.

Another member asked if particulars of steam brake experiments could be given.

The Lecturer replied that a steam brake was fitted to Stephenson's 6-wheeled engine of 1833 (Fig. 19), but did not come into general use, and for some years the only brake was a hand brake on the tender. Speaking generally, he thought that brakes in this country had been behind the times.

Mr. J. F. Cuss said he would like to know when compound engines first appeared.

The Lecturer replied that he did not remember when the first practical attempt at compounding the locomotive had been made, but it was many years before 1883 when Webb began to compound with some success on a large scale. (It is, however, interesting to know that the arrangement of the cylinders in Webb's compound was derived directly from that of a patent three cylinder simple locomotive built by Stephenson in 1846. This engine had two outside cylinders, having both cranks in a plane at right angles to a single inside cylinder of double the capacity; the object being to eliminate the alternative pressures on the sliding bar causing a rolling motion. The engine was of the ''long boiler'' rear driver type having the cylinders behind the leading wheels and this arrangement was followed by Webb for his outside cylinders with the expressed intention of dividing the drive.)

Mr. Cook, in proposing a vote of thanks to the lecturer, said it had been a great pleasure to listen to Mr. Warren's lecture. It had shown the difficulties the pioneers were up against at the times their experiments were being carried out, and gave an insight into the ideals which inspired them. He would have liked to have seen again the slide exhibited at a previous lecture given by the author in which there appeared an extract from a smith's notebook, against a sketch of a valve gear detail stating that he was ''in his 'glore''' (glory) in making such things. Such was the spirit of the early men, and they must not lose sight of that.

Mr. T. C. Davison, in seconding the vote of thanks, said he was convinced that the evidence put before them all went to prove the fact that the prominence given to the Stephensons was in every way due to them. The lecture was especially interesting to him in that he could claim some association with the Stephensons. His father came from their parish, and his grandmother said that she had often seen the younger Stephenson going from Newburn to Newcastle to school.

Mr. Warren thanked both Mr. Cook and Mr. Davison for their vote of thanks. He said it was interesting to meet a link with the Stephensons in Mr. Davison, and from those who had actually known ''Old George'' and his son, he gathered, they must have been as loveable as they were remarkable.

Certain claims to which he had referred at the beginning of his lecture had divided writers on the locomotive into two distinct schools, but (although he had, in the past, been connected for many years with the firm of Robert Stephenson and Co.), he had endeavoured to approach the subject with an open mind. He had gone carefully through a great amount of original and hitherto unpublished material, and after much study had come to the conclusion that Robert Stephenson did more for locomotive design than was usually realised, and that the Stephensons together did certainly stabilise the design of the locomotive on sound lines at a very critical period.

He was sorry he had not been able to answer more definitely some of the questions put to him in regard to engines of later construction, but he had intended his lecture to cover the period from about 1800 to 1850 or 1860, and he was very grateful for the interest they had shown and the welcome accorded to him.

In closing, he said he was glad to see that the Great Western had still a very definite link with the past. The engine of the 3211 type, which had brought him to Swindon recently, showed, in reality, the frame of the ''North Star'' still running. A remarkable link with the days of Brunel and Robert Stephenson, which, he hoped, would be preserved.

The Society desires to place on record its appreciation for the loan of blocks for illustrations to Messrs. Robert Stephenson and Co., Ltd., the Institution of Locomotive Engineers, and the Locomotive Publishing Company.