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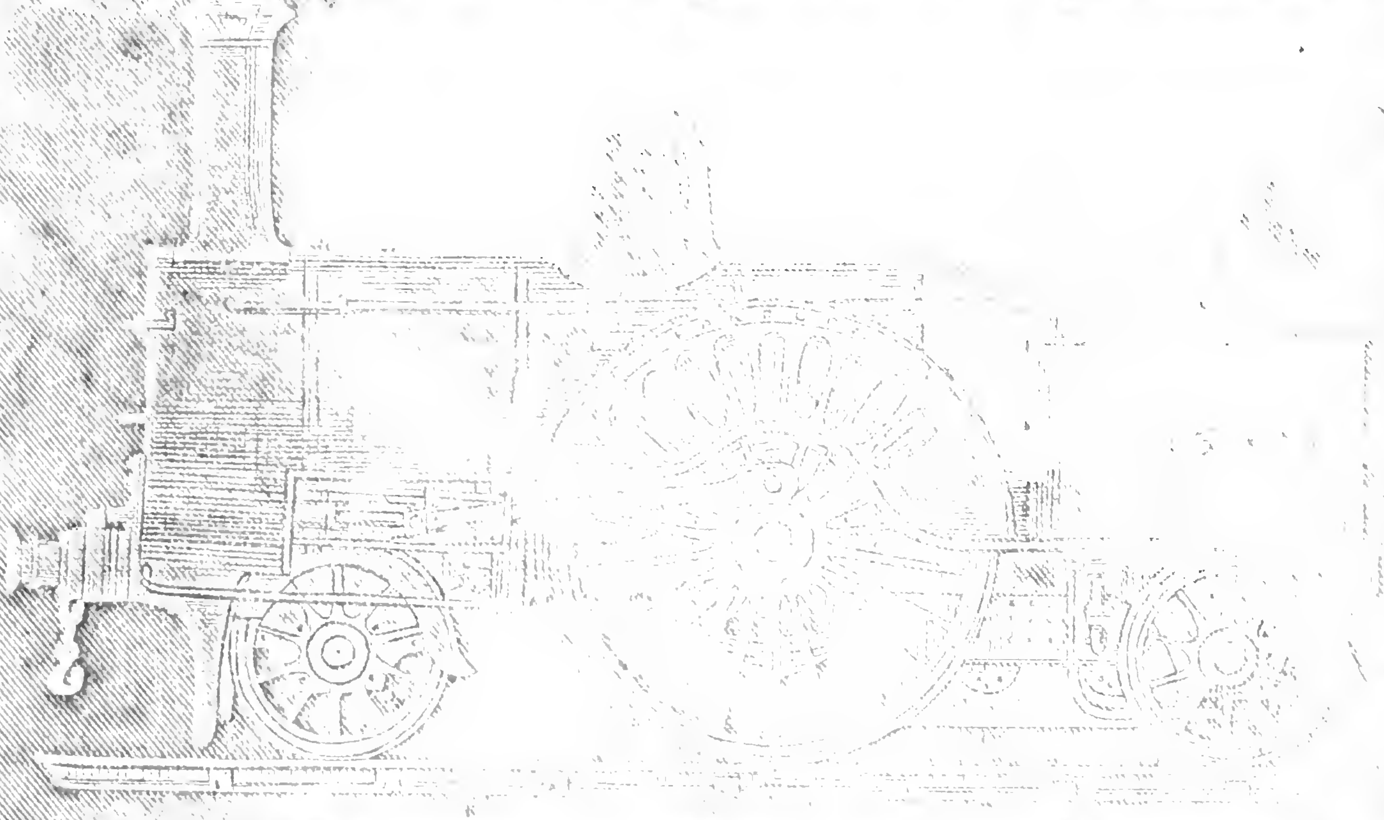

MICHAEL REYNOLDS

Yours faithfully
Michael Reynolds.

London: Crosby Lockwood & Co. Stationers' Hall Court

LOCOMOTIVE ENGINE DRIVING

A PRACTICAL MANUAL

FOR ENGINEERS IN CHARGE OF LOCOMOTIVE ENGINES

By MICHAEL REYNOLDS
MEMBER OF THE SOCIETY OF ENGINEERS,
FORMERLY LOCOMOTIVE INSPECTOR LONDON, BRIGHTON, AND SOUTH COAST RAILWAY

EIGHTH EDITION

COMPRISING, BESIDES OTHER ADDITIONAL MATTER

A KEY TO THE LOCOMOTIVE ENGINE

With numerous Illustrations

LONDON
CROSBY LOCKWOOD AND SON
7, STATIONERS' HALL COURT, LUDGATE HILL
1888

TO

THE ENGINEMEN AND FIREMEN

OF

LOCOMOTIVE ENGINES

THROUGHOUT THE UNITED KINGDOM

THIS WORK

IS

Dedicated

AS A TRIBUTE OF REGARD AND RESPECT

BY THEIR SERVANT

THE AUTHOR

PREFACE.

I am ambitious to extend and improve the social condition of locomotive drivers by placing within their reach a standard test of capacity that will be unaffected by local or temporary prejudices, fancies, fashions, or accidental connections.

It appears to me that our enginemen of to-day will be to those of the next century what "Puffing Billy" in 1825 is to the "Monarch of Speed" in 1877. I hold a very strong opinion that our enginemen may be stripped of old habits and customs by self-help and self-reliance, and developed into a high state of efficiency. In carrying out such a measure of progress, difficulties, no doubt, which usually attend the work of reformation, will crop up; and many disappointments await the pioneer. The engine is ahead of the engineman—all the hard scheming, comparatively speaking, is done; but the engineman remains where he was in George Stephenson's time, and his stationary condition jars with his surroundings.

I propose to introduce certificates for locomotive drivers, which will in my opinion be an efficacious method of celebrating and crowning the great and mighty work of Stephenson, who particularly watched over the craft (enginemen), and was, I am informed, in his element when he was with them. One can easily understand this, for he was himself originally an engine-driver.

By means of certificates of proficiency I hope to see the vocation of engine-driver brought up to the standard of what, I think, Stephenson would have worked it to, had he lived longer. He would have made every possible provision for the recognition of ability, and for giving enginemen a fair opportunity of advancing with the engine and with the times. By such means each man would develop the brightest tints of his nature ; and I see no reason why such anticipations should not come to maturity in the region of fact.

The life of engine-driving has in recent years undergone great changes for the better. In the improvements of engines and in personal comforts, introduced even during the last twenty years, locomotive enginemen may find much upon which to congratulate themselves. But—to summarise their experience—it has consisted of labour and bustle without progress. This unsatisfactory condition of things may, it is anticipated, be amended by the institution of certificates, with the encouragement of corresponding degrees of rank and of special uniforms. Certificates of examination afford a useful means of gauging a man's capacity, when one might otherwise be deceived by appearances.

My object in writing this work has been to communicate that species of knowledge which it is necessary for an engine-driver to possess who aspires to take high rank on the foot-plate, and to win a certificate of the first class. In the first part the elements of the locomotive are described, the general working conditions are specified, the principles and methods of inspection are elaborately set forth, and the causes of failure are analyzed and exposed. Moreover, the various duties of an engine-driver, from the moment that he enters the running-shed until he returns to it, are completely but concisely explained ; whilst the duties and the training of a fireman are described with much detail, and the principles of the management of the fire—not an easy problem—are very fully investigated.

With a brief notice of the arithmetical problems which most usually come within the range of an engine-driver's practice, the scientific principles of expansion, combustion, &c., involved in his practice, are explained.

Finally, the groundwork of examination for first-class, second-class, and third-class certificates of proficiency is succinctly set forth; to which is added a carefully compiled collection of regulations for enginemen and firemen.

Extracts from the General Acts of Parliament for the Regulation of Railways are added in an Appendix.

MICHAEL REYNOLDS.

BRIGHTON: *August*, 1877.

NOTE.

I have had much pleasure in revising the text of this work, the production of Mr. Reynolds. It contains a body of original matter, in a fresh field of literature, which carries with it the charm of novelty, as well as the more lasting attraction of solid utility. Many engineers will perceive in its pages the reflection of their own experience; and it may be questioned whether the business of a locomotive-engine driver could have been better presented, by a practical man, for the instruction of the engineers and firemen of the United Kingdom.

D. K. CLARK.

PREFACE TO THE THIRD EDITION.

IT is my high privilege to thank most sincerely locomotive engineers and firemen, the press and the public, for their help and patronage in making "Locomotive Driving" a practical success.

Short of eight months since, the first edition was issued, to take its chance—to rise or fall. I sometimes fancied it would live and thrive; at other seasons I thought it would die by the "Gorgon visage of neglect," for in its manuscript form it was unheeded by some, and set aside by others; and it had no friends. It was harshly judged, and wearily I wrapped it in brown paper, and laid it on a shelf, where it remained for a considerable length of time. But, when a lad, I had read of Columbus strolling as far as the gate cf the Convent Juan Perez de Marchena to talk with the Prior about the vast continent beyond the Atlantic, of the spherical form of the earth, of the construction of maps, and of other subjects, and I remembered how the Prior "shut him up," and how it turned out in the end that the Prior was wrong—very much wrong—and Columbus was right. I never forgot the story. So I flung aside uncharitable thoughts, and fetched the manuscript down off the shelf, hoped for the best, and found a discriminating and active publisher. Result: Success. I have been blamed for writing a book:—Found guilty of scattering light where there was no light. However, "Locomotive Driving," as is evident from the great demand for the work, and from the large number of letters I have received from all parts of the globe—supplied a want, proved of assistance to many; and this is my great reward.

This, the third edition, like its predecessors, has been revised by Mr. D. K. Clark, the eminent author of "Railway Machinery," and other works.

Much additional information is contained in this edition, more especially in the "Key to the Locomotive Engine," which will, I hope, be of assistance to every person whose avocation necessitates a thorough knowledge of a locomotive engine. I hope also that the other extra matter supplied will prove acceptable to the young engineer. It will, I believe, materially assist him in mastering the technical language employed in the profession.

MICHAEL REYNOLDS.

BRIGHTON: *May*, 1878.

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LOCOMOTIVE-ENGINE DRIVING.

INTRODUCTORY CHAPTER.

"I LOVE," says Elihu Burritt, writing about the locomotive engine, "to see one of those huge creatures, with sinews of brass and muscles of iron, strut forth from his stable and, saluting the train of cars with a dozen sonorous puffs from his iron nostrils, fall back gently into his harness.

"There he stands champering and foaming upon the iron track, his great heart a furnace of glowing coals, his lymphatic blood boiling within his veins, the strength of a thousand horses is nerving his sinews, he pants to be gone. He would drag St. Peter's across the desert of Sahara if he could be hitched on."

This is a fortunate hour for locomotive drivers, for, on all the great lines of railways, most of the engines attached to swift and important trains are, in design and workmanship, the best that have been placed upon the metals.

The grand aims and achievements of locomotive superintendents, are, without controversy, in the interests of the driver and fireman, not only in respect to the magnificent engines entrusted to their charge, but also with regard to matters appertaining to the engine-shed. Whether inside or outside, the progress that has been made is conducive to their comfort, health, and cleanliness.

The general introduction of the "cab" in locomotives is in itself a great boon; but, excellent as it is, it is surpassed, and is lost in the background, when we glance at the great improvements which have been made during the last few years in the construction of engines which are thorough masters of their loads.

An engine may be equipped with every imaginable modern improvement, but if unprovided with a good margin of power for extra traffic in its tubes and fire-box—that is in its heating surface—it is sure, whatever else there may be good about it, to reflect somewhat upon the abilities of its designer.

There is, however, no more pleasant fact to contemplate in connection with the practice of modern locomotive builders than this: they have unanimously endeavoured to combine, in one machine, a fine boiler with ample heating surface, direct connection between the cylinders and crank-axle, and a simplicity of arrangement that borders upon art. What is equally commendable, they have made the boiler quite independent of the frame, and free from the strain of the tractive power—conditions which are most conducive to the duration of the boiler and also to that of the engine.

Such splendid engines as are seen nowadays with all the "crack" trains—master-steeds "champering" and foaming about the iron track, having over a thousand square feet of heating surface, easily managed under cover of the cab, and fitted with steam brakes—are facts about which engine-drivers may safely talk, and upon which they may congratulate each other, making their calling to-day pleasanter than it has ever been since 1825.

Very well, such are facts; but it is seen, recognised, and commented upon, by those whose authority to speak from experience in such matters none can dispute, that the progress of the locomotive is ahead of that of the engineman. Think you, if to-day a separation were made, on every line, of the drivers who could set their engines for testing the valves and pistons from those who could not do so, would the numbers be equal? How many could explain the benefits of lap and lead? Could ten out of a hundred give an explanation why the slide-block rubs against the top slide-bar when the engine goes first, and not on the bottom bar? and why the slide-block rubs on the bottom bar going tender first? And what of the action of the blast and of the injector? What of the laws that govern the combustion of coal in the fire-box?

The above, and many other questions of equal importance, a knowledge of which is calculated to send a man along the path of progress, are awaiting solution by young drivers; for they ought to possess this knowledge at the onset of their career, and they should not be left to discover it for themselves, at hazard, only through unforeseen or accidental circumstances, spread over long periods of time.

Reticence on the part of the older drivers has always been a difficulty in the path of the younger ones. "I had to find it out through fines"—gold and silver probably—"you must do the same," said an old engineman to another, in answer to a question; and what experience had taught the elder one he very devoutly consecrated to the god *self*. Is not this a common feature, and a fact of every-day occurrence?

It is not an unusual occurrence that a fireman presents himself before his superintendent to pass for the position of driver who is totally in the dark respecting the manner of testing the pistons, or how the difference between the leaking of a piston and that of a valve is distinguished; notwithstanding that he may have been for several years upon the foot-plate, and may have fired for "tip-top" enginemen on "crack" locomotives, attached to important trains.

Such is the case, and the deficiency of knowledge awaits a speedy and effectual remedy in this age of keen investigation. Without inquiry and investigation, which lead up to distinction, men are even in this, as in many other departments of life, left out in the cold. There is, happily, an inquisitive spirit abroad on railways, and there are signs of improvement everywhere. The tide, which has brooded over whole acres of intellectual worth, is now on the ebb; marks of progress are visible, and there is hope for the future.

Upon all railroads there is plenty of genuine, solid, old Teutonic pluck; there are men as persevering and as fearless of toil and struggle as ever broke bread, who, in thousands of instances, have made hair-breadth escapes in order to reach the driver's handle—the only object of their earthly ambition. For this—and be it remembered it is sometimes taken from them by the hand of sudden death almost directly after it is attained—they pull hard and long, through winters and summers, in wind and in rain, in the stillness of night, in lightnings and thunder; at all times, while on duty, surrounded by hidden dangers, inseparable from life on the foot-plate. Such are a few of the vicissitudes in the lives of our locomotive drivers, calling forth no inferior quality of pluck, endurance, and courage.

No one can be a locomotive driver, whatever he may imagine, on any other terms than fearless toil. There is no "royal road" to the lever. Promotion is really and of necessity a matter of so many hundred thousand miles running with a moderate amount of *nous*. Though the way to the lever cannot be learned from books, still it must be acknowledged that a deal may be told which probably may assist, at the least, in preserving industry from being misapplied. The atmosphere of the foot-plate is a strong solution of books, and nothing whatever is learned there without close observation.

Dr. Smollett, in prefacing his translation of M. Le Sage's incomparable "Gil Blas," entertains his readers with a story that illustrates the nature of the philosophy which supplies the key to unlock and to obtain possession of locomotive knowledge.

Two scholars were travelling from Pannafiel to Salamanca, and, being fatigued and thirsty, they sat down by the side of a spring. After resting awhile, and having quenched their thirst, one of them perceived some letters engraved on a stone. After washing it they both read these words in the Castillian tongue, "Aqui esta encerrada el alma del Licentiate Pedro Garcias."

The elder of the two no sooner read the inscription, —which is, in English, "Here is interred the soul of the Licentiate Pedro Garcias"—than he cried out, "A good joke, i' faith! Here is interred a soul! A soul interred! Who on earth could be the author of such an epitaph?" and he arose and went on his journey. His companion, although younger, was blessed with a greater share of penetration, and stayed behind, resolved to discover the meaning of the strange writing. With his knife he digged around the stone, and succeeded so well that he got it up and found beneath it a leathern purse containing 100 ducats, and a card on which was written, "Whosoever thou art that hath wit enough to discover the meaning of the inscription, inherit my money." The lad replaced the stone, and walked home with the "soul" of the Licentiate Pedro Garcias in his pocket.

If we look into the character of those railway men who, by force of muscle and brain, have raised themselves, from either the vice or the footplate, into positions of honour, we shall find that each individual resembles the younger of the two scholars. Possessing his inquiring spirit and painstaking attention, they let nothing escape them—not a little bit; if there was something new to be seen or heard they saw it and their ears were open; were it something to be read, marked, or learned, there was nothing wanting on their part. True it is, that the more we know of such men, the more certain we are that each and all of their actions are evolved from one common but comprehensive principle, converging towards one ultimate achievement.

Before dealing closely with matter in keeping with the title of this work, referring to locomotive engines under steam, it will first be our duty to notice, as briefly as the nature of the subject will allow, with *what* and *how* the engine is erected, and the manner of putting it together—in a word, to walk round it. To play well upon an instrument it is necessary to know the notes; for, though music played by ear is listened to, the performer's field of usefulness is a limited one, moving in a small circle, like a white mouse in an Italian boy's cage; but music played from notes has an everlasting charm subject to no vagaries.

To play well upon a locomotive engine, in the sense of wielding over it a kind of sovereignty, it is essential that the performer be acquainted with it anatomically and physiologically, and that he should have a thorough knowledge of the principle of the generation and application of steam. Without such knowledge no man can become a locomotive engineer.

It is a fact that no two locomotive builders put their engines together precisely with the same quality of materials, or in the same way, any more than they follow one particular class or pattern; for the simple reason that the engine is not strictly a product of mathematical inquiry, but it is the outcome of many observations made by many men of taste and experience. It is therefore unnecessary, while noticing the various parts of a locomotive for the information of young drivers, to advocate any particular design or class of engine; the object is simply to explain some of its principal constructive features and cardinal lines.

PART I.

DESCRIPTION AND MANAGEMENT OF THE LOCOMOTIVE.

CHAPTER I.

GENERAL DESCRIPTION OF THE LOCOMOTIVE.

Classification of Locomotives.—According to the position of the cylinders, there are two kinds of locomotives, namely, inside-cylinder and outside-cylinder engines —the former having their cylinders between the frame-plates, and the latter having the cylinders outside the frame-plates. Locomotives are also distinguished as *Single* or *Coupled,* independently of their kind or class. When the driving-wheels are free to act by themselves, the engine is said to be a single engine. When the driving and leading wheels are connected by coupling-rods, the engine is said to be coupled in front; and when the driving and trailing wheels, under the foot-plate, are connected, the engine is said to be coupled behind. These are known as 4-wheel coupled engines to distinguish them from goods-engines, which have 6 wheels coupled. Tender-engines are such as have tenders attached to them for carrying supplies of fuel and water. Tank-engines are such as carry their supplies of fuel and water on their own frames or on the boiler—on the top, at the sides, or underneath the boiler. Locomotives which are carried upon a 4-wheeled truck or bogie, either before or behind, are known as bogie-engines. By means of the bogie, an engine with a long wheel-base can be made to run very safely and steadily, at high speed. With the assistance of the bogie also, an engine may traverse a sharp curve nicely and without excessive friction.

The Boiler.—The boiler consists generally of six parts, namely, the barrel, fire-box shell, fire-box, tubes, smoke-box, and chimney.

Barrel.—The barrel is made of three rings of plates, frequently arranged telescopically, so that the barrel in such cases is largest in diameter near the fire-box. One object of this arrangement is to maintain plenty of water over the fire-box when the engine is suddenly stopped. When the longitudinal seams are made with butt-joints, that is when the planed edges of the plates come together flush, a strip of iron, called a butt-strap, is riveted to the plates to connect them. The circular seams are generally made with lap-joints. All rivet-holes are drilled. The barrel is secured to the smoke-box tube-plate by means of a solid angle-iron ring; and the tube-plate is formed with a flange turned to a small radius, to which the smoke-box is secured.

Fire-box Shell.—The outside fire-box, or shell, is of the same brand as the barrel; the sides and top of this shell are sometimes formed of one plate, extending from the foundation-ring on one side over to the foundation-ring on the other side; the front plate is united to the barrel without the intervention of angle-iron, which formerly was extensively employed; and the back plate, in which the fire doorway is formed, is flanged and riveted to the inner surface of the large plate forming the sides and top.

The bottom of the shell, just described, is formed either horizontal or sloping at the bottom, according to design.

Fire-box.—The inside fire-box, in this country, is generally made of the very best copper, with the maker's name stamped on the plates; the side and top, like the outer shell, are very often in one plate ; the tube-plate is thicker than any other part of the fire-box, for it has more pressure to resist, or rather more work to do, being the support of about 200 tubes, carrying half their weight. The back plate is usually dished at the fire-door. The fire-box is put together with iron rivets, and placed inside the outer shell, to which it is fastened by means of a wrought-iron ring at the bottom and another at the fire-hole. These rings, the former of which is known as the foundation-ring, are of the very best iron, and are carefully fitted between the fire-box and the shell, so that after these are riveted together they are perfectly steam-tight.

The walls of the fire-box are further secured to the shell by rows of copper stay-bolts. The top or crown of the box is also secured and strengthened, either by stay-bolts or by wrought-iron ribs placed fore and aft of the box. The ribs, when employed, have sling-stays attached to them, riveted to the shell ; so that, whenever a fire-box happens to be burnt, and so weakened, the crown of the box is prevented from being driven in by the pressure of the steam. The tendency of the top of the box to fail by overheating is very commonly shown, and it proves that the nature of the copper has been injured.

Tubes.—The tubes are, in most engines, made of brass of No. 10, 11, or 12 B. W. G. (which means Birmingham wire-gauge). They are expanded and made fast by a tube-expander, and ferules are afterwards driven in at the fire-box end. Sometimes the ferule is made slightly larger than the bore of the tube, but is reduced and made to fit the bore by being cut through with a saw. The circumference of the ferule is reduced by as much as the thickness of the saw, and, when the ferule is pressed together, it enters the tube; then, by its elasticity, it binds the tube tightly into its place in the copper. It is found in practice that when tubes 1⅞ inch external diameter are employed, and placed about ¾ inch apart, they give good proportions for making steam.

Smoke-box.—The sides and top of the smoke-box are generally of Staffordshire brand. The smoke-box is secured to the boiler by means of the flanged tube-plate, and the front-plate is joined to the frame-plates by angle-irons. The smoke-box door is dished, and fitted with a pinching-screw and cross-bar; the carriers for the latter are riveted inside the smoke-box, and they can generally be removed for the purpose of making examination or of repairing inside.

Chimney.—The chimney is by some locomotive builders made slightly larger at the bottom than at the top, in order to obtain an even vacuum and to compensate for the condensation of the exhaust steam as it ascends the chimney. The cap on the top is not ornamental only; it is intended also to turn aside the wind, so as to facilitate the escape of the exhaust steam and the smoke. When the chimney is worn into holes near the top, the wear is, as a rule, a sign that the blast strikes it there, because of the blast-pipe not directing the current clear of the chimney.

The smoke-box and the chimney are two very important members of a locomotive; they to a certain extent control the size of the orifice of the blast-pipe.

Boiler-mountings.—Boiler-mountings include the various plugs, whistle, gauge for the water, clack-boxes, safety-valves, &c.

The safety-valves and seatings are invariably made of gun-metal. When spring-balances are used, it is a mere matter of choice with the builder what size of valve he adopts; it does not follow that because a valve is large it will ease the pressure within the boiler more promptly than a smaller valve. A small valve can be made to discharge in a given time as much steam as another, even 3 or 4 inches larger, by attaching to it a suitable spring-balance and lever, such as to allow the valve to rise through a greater distance than a larger one. Mr. Ramsbottom's safety-valve consists, in fact, of a pair of valves fitted into two brass pillars, pressed down by a cross-bar with a spiral spring attached to the centre of the bar between the two valves—an arrangement that cannot be locked. The valve is prompt in discharging any quantity of steam of excessive pressure. When the end of the lever is pressed upwards by the driver, it eases the valve nearest to him; and when pulled downwards, it eases the other valve.

Regulators are of several kinds, and they are sometimes fixed in a dome over the fire-box, or over the back of the centre ring of the barrel; but in many cases they are placed at the junction of the boiler and the smoke-box, as when there is no dome. The pipes for conveying steam to the cylinders are of copper, excepting the elbow-pipe placed on the outside of the tube-plate in the smoke-box, which is of cast iron, and forms the connection between the copper steam-pipes in the boiler and those in the smoke-box which lead to the cylinders.

It is scarcely necessary now to occupy any more space with the boiler, except to remark that, after it is fitted up complete, it is, before being fixed permanently in the frame, tested by steam and by hydraulic pressure.

From the foregoing remarks, it is clear that the boiler is quite independent of the frame and the machinery. The boiler is placed in the frame by means of a hydraulic lift. It is supported on the frame by expansion angle-irons riveted to the sides of the fire-box, and by the front tube-plate which rests on the back ends of the cylinders.

Recent practice does not approve of running the motion-plate up to the bottom of the boiler.

The smoke-box is now riveted to the frame, and thus forms a permanent attachment between the boiler and the frame.

Framing.—The framing consists principally either of two or of four slabs or plates of iron. If the framing have only two slabs, the engine is known as a "single-frame engine;" and if the frame be made up of four plates, or two slabs at each side, the engine is known as a "double-frame engine." But whether double or single, the frames have very important work to do. At the places where the cylinders and the axle-box guides are fastened, the depth of the frames is increased. As a rule, they extend from the front buffer-beam, alongside the fire-box, to the end of the foot-plate.

In the earlier locomotive engines, the frames stopped short at the fire-box shell. Some fire-box shells had a fearful lot of hard straining to resist, for the framing was rigidly bolted to them, so also were the drag-plates, and the angle-iron which supported the foot-plate. Fortunately it is not so now.

Machinery.—Cylinders.—The cylinders are formed of cast-iron of the first quality. In inside-cylinder engines they are bolted between the frame-plates—by turned bolts with counter-sunk heads. The holes are carefully drilled, to be perfectly round, and the bolts are made to fit the holes with a great degree of exactness. The frame-plates are further braced by the motion-plate, by transverse plates before and behind the fire-box, by the foot-plates, and by the wrought-iron buffer-plates fore and aft of the engine. A few minutes' inspection of an engine will prove that many of these parts are joined to the frames by angle-iron.

It is essentially requisite that the centre-lines of the cylinders, after these have been fixed in the frames, should run parallel throughout their entire length. There are other things also to look out for:—The centre-lines of everything else connected with or affected by the action of the steam must be, in accordance with the nature of the work, either parallel or exactly at right angles. For instance, the slide-bars must be parallel with the cylinder, and all the axles must be exactly at right angles to the lines of the cylinders, valve-faces, &c. In a word, the engine has to be built square, and not like a Bridgenorth election, all on one side.

Horn-blocks.—The horn-blocks are got up true on their faces, and fitted with axle-boxes, when all the centres for the axles can be marked off. Meanwhile the fitter may be engaged in erecting the slide-bars, pistons, and motion or gear.

Guide-bars.—Mr. Stroudley uses cast-iron for slide-bars, with good results. The piston generally in use consists of a body of brass, with two cast-iron rings—one of Mr. Wakefield's good ideas.

Bessemer steel is largely employed for guide-bars, piston-rods, connecting-rods, and coupling-rods. The gear is not unfrequently selected from the very best Yorkshire scrap tyres, case-hardened at all the working parts, and finished bright.

Crank-axle.—The crank-axle is either of steel or iron; the latter is very much admired for the purpose by some builders, as steel knows no compromise or surrender. The throws are forged and slotted out at right angles to each other, so that when one big-end is on one of the dead centres, the other big-end is under the full pressure of the steam, being exactly either on the top or the bottom centre.

Eccentrics.—The crank-shaft is fitted with four eccentric-sheaves, two for working the engine in fore-gear, and two for back-gear. The positions of these sheaves, in relation to the crank, are due to the movements of the valve being in advance of those of the crank. As the slide-valve is about half stroke when the big-end is at the end of its stroke, a little consideration will show that the sheave is fixed at about right angles, or a little in advance of that position, to the crank. The exact position for the sheave may be found thus:—When the crank is placed on one of the dead centres, a line is drawn to show the centre-line of the web or crank-cheek; a circle is then described around the centre of the axle, equal in diameter to the travel of the slide-valve; from the centre of the circle at the side opposed to the crank-arm, a distance is marked off equal to the sum of the lap and the lead. Suppose, for instance, that the lap is 1 inch and the lead $\frac{1}{8}$ inch, making together $1\frac{1}{8}$ inch. At this distance from the centre a perpendicular line is drawn, intersecting the circle above and below the centre-line of the crank-web. The two points of intersection show where the centre-line of the eccentric must fall, for forward and for backward motion.

Expansion-links.—The expansion-links, to which the eccentric-rods are attached, are frequently formed to a radius equal to the length of the eccentric-rod. The box-link is formed to a radius equal in length to the valve connecting-rod. Allan's link is straight.

The kind of expansion-link which is generally adopted by English locomotive builders is the curved open link, furnished with carriers for the lifting-links on the weigh-bar shaft—varying the periods of admission of steam by shifting the link on the block.

The horizontal motion of the link is communicated by the joint action of the eccentrics. At the centre of the length of the link it is a minimum, when it is equal to twice the linear advance of the eccentric, and it increases towards each end of the link. The movement is conveyed directly through the block to the slide-valve, and the valve receives its maximum travel when the eccentric-rod occupies a position in a straight line with the valve-spindle. A jaw, on the front end of the valve-spindle, is made to clip the expansion-link and "block;" and the valve-spindle is supported by a guide, either cast with or bolted to the motion-plate. To the back ends of the spindles are attached the slide-valves for regulating the distribution of the steam to the cylinders.

Steam-pipe and Blast-pipe.—In first-class workmanship, the joints of the steam-pipe and the blast-pipe are made with a scraping-tool, without cement. The blast-pipe is fixed truly concentric with the chimney, that the exhaust steam may be discharged straight up, without unduly impinging on the sides. The nature of the action of the blast is worth investigating; it is identical with that of the injector.

The exhaust steam, discharged up the chimney, has the effect of inducing the air out of the smoke-box, and thus creating a partial vacuum. The vacuum is filled by gases from the tubes, which in their turn are supplied from the fire-box, whilst the fire-box is supplied with air from the ash-pan. Hence it is that a smoke-box, which draws air by leakage through the door, deprives the fire of a portion of its draft, in so far as the vacuum in the smoke-box is supplied from the wrong end of the engine. The better to counteract the unbalanced external pressure which results from the vacuum in the smoke-box, the door of the smoke-box is dished or buckled—a process by which its power of resistance is greatly increased.

Feed-pumps.—There are two kinds of feed-pumps, long-stroke and short-stroke. The body of the pump is of gun-metal. The ram of the long-stroke is generally fastened at one end to the crosshead, or, as in the case of the "Terriers," it is screwed into the end of the slide-block. In the short-stroke pump the plunger—not ram—is most usually of brass, and it is worked either from an eccentric on the crank-axle or from a pin in the driving-wheel. Very few short-stroke pumps are now put into new stock.

There are three and sometimes more valves adapted to a locomotive pump. There is one on the side of the boiler, near the smoke-box, known as the "top-clack." This position is selected so that the boiler may be fed at the coolest place. Top-clacks must not be examined while the steam is up—a necessity which some men understand pretty well from experience, by having been severely scalded. The middle-clack is situated just above the pump and ram, and prevents the water returning to the pump-barrel after having been expelled by the ram or the plunger. The bottom-clack is fixed below the pump, and as the ram commences to enter the barrel the clack closes on its seat, and thus prevents the water in the pump from returning to the tender, out of the way of the advancing ram. The water occupying the pump is consequently shot up through the middle clack, and flows into the boiler. If there be air in the pump, it does not work, for want of water. In consequence of a tight gland a pump has stopped working, owing to the accumulation of air in the pipes, which is separated from the water by the churning action to which it is subjected by the ram or the plunger.

The Injector.—Steam is admitted into the injector (Fig. 1) through a cock on the top or the side of the boiler, to obtain steam free from water. When this cock is open, steam can enter the injector through A, and occupy the space B surrounding the spindle C. The spindle is finished conically at its lower end, and forms a steam-tight valve at D, controlling the egress of the steam into the lower portion of the injector. When the wheel E, on the end of spindle C, is moved to raise the spindle, steam rushes through D, past the mouth of the inlet-pipe X leading from the water in the tank

The current of steam, by the suctional action, induces or draws the air out of the pipe X—relieving the water in the pipe of the atmospheric pressure, and thereby forming a vacuum into which the water rises, by virtue of the atmospheric pressure above the water in the tank.

When the water comes in contact with the steam, whose velocity is very high—1,700 feet per second, or 1,157 miles per hour — the water is instantly carried along by the steam through the nozzle F, and beyond the valve G, on the pipe leading to the boiler. The water, on coming in contact with the steam, condenses

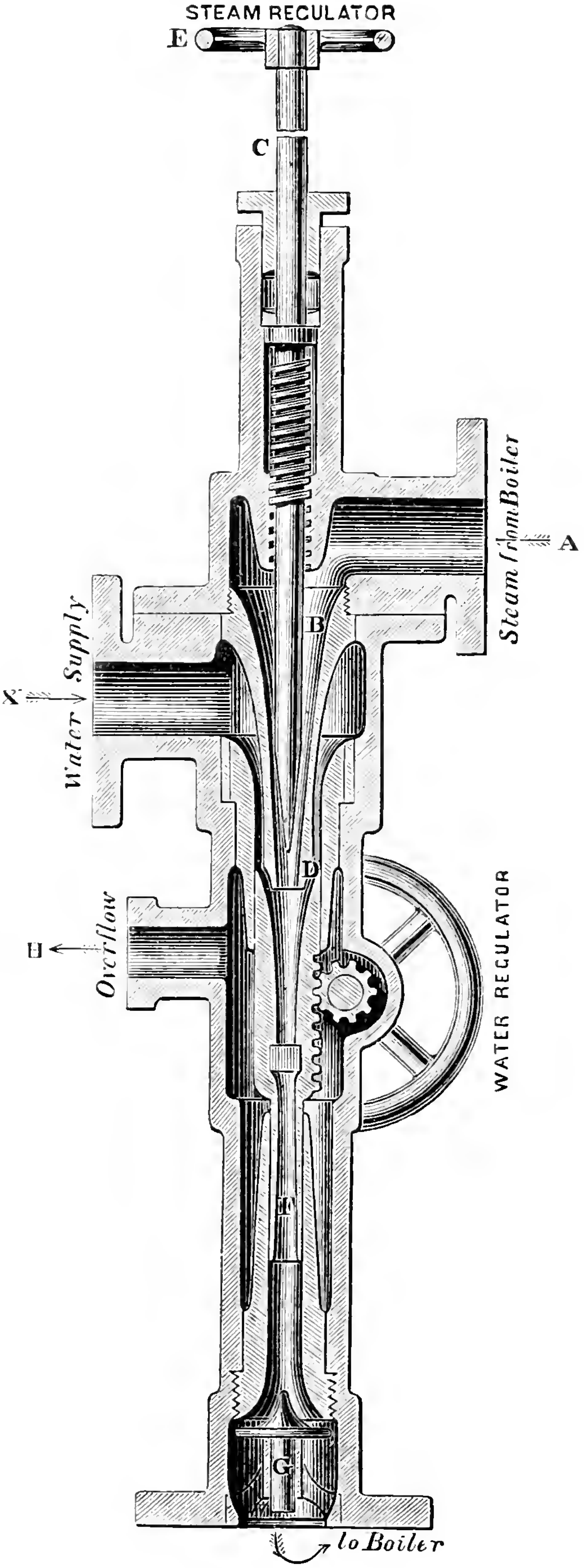

Fig. 1.—Injector.

it considerably, but not before the steam has imparted to the water a velocity equal to about 90 miles per hour. The motion of the water at that speed, is sufficient to force it into the boiler against the pressure of the steam and water inside the boiler. H is the overflow-pipe, through which the water escapes when the injector is turned off, either by the spindle C being screwed down, or when the momentum of the combined jet is not sufficient to lift the top-clack against the pressure within the boiler. This deficiency may be caused by the jet of steam from the boiler being insufficient in volume, when its velocity is wholly absorbed by the water. In this case, the steam-pipe requires to be made larger or to be cleaned out, or the volume of water must be reduced.

Slide-valves.—There is no subject about a locomotive engine that young drivers delight to talk about more than valves. It is their favourite topic, though there is no other subject about which they have so much misgiving and conscious uncertainty. Is not this a fact? Valves are Latin, Algebra, and Greek. Many of our young enginemen, when they know their engines are "blowing through"—not knowing what it is exactly, or where it is—report such matters as "valves and pistons want examining." This covers the whole box of tricks, and helps them over their difficulty. Let us hope that such reports, made under such circumstances, will soon become things of the past.

It will, then, after the above remarks, be well if valves, ancient and modern, form our next subject. A driver may be able to work his engine with creditable economy, keep time, and all that kind of thing; but so long as he is a comparative stranger to the action of the valves, he feels within himself that one thing is needful. Such thoughts frequently occupy the minds of young enginemen.

The annexed Fig. 2 illustrates the old slide-valve, now out of use. It is shown here, because it will aid in explaining the meaning and functions of lap and lead. The position of the excentric, in relation to the crank, for working the valve is also shown, for convenience, above the crank, on the right. A is the valve, B the cylinder, C the back port, D the front port, and E the exhaust port; F the cavity of the valve. The valve is shown in the position which it occupies when the piston is at the termination of the front stroke, whilst the crank is on the back dead-centre, near the fire-box casing, and the centre of the excentric is vertically over the centre of the axles, or at right angles to the crank.

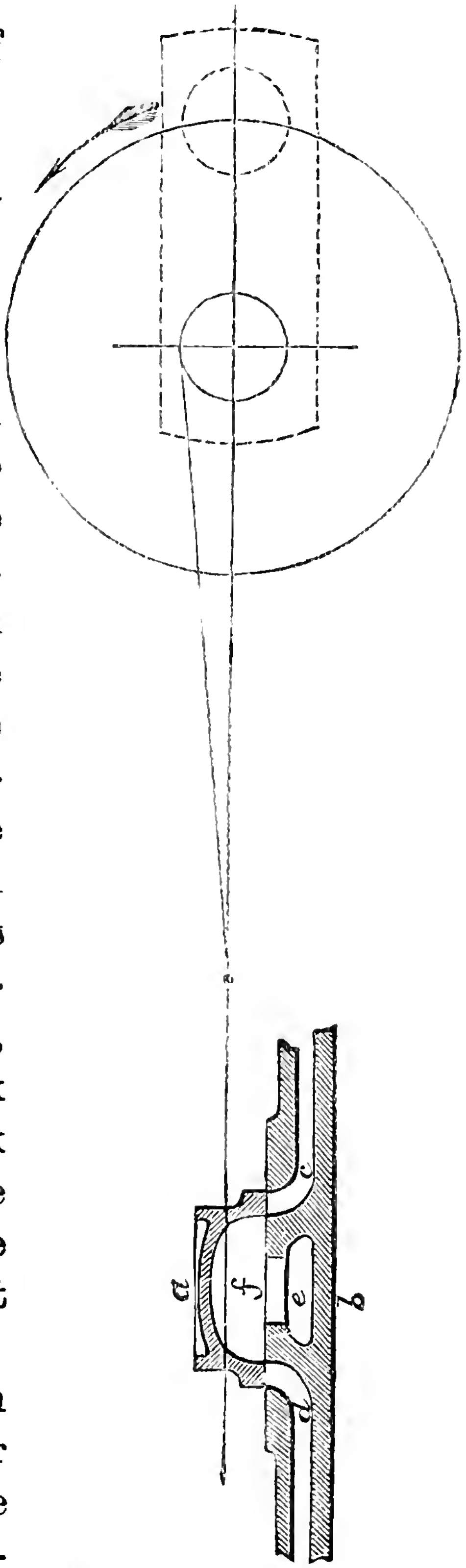

Fig. 2.—Old Slide-valve.

The excentric, as shown in the sketch, would work or move round the centre of the crank-axle, ahead or in advance of the crank, in the direction of the arrow, to let steam into the cylinder. The piston also moves, commencing its back stroke, and at the same time the steam-passage, communicating with the cylinder at the other end, is uncovered to the exhaust. There are two defects about both these movements of the valve, which are now remedied in modern practice, illustrated by the diagram, Fig. 3. First, the steam is now admitted *slightly before* the piston commences the stroke, and the steam thus acts as a cushion for the piston, assisting in stopping it, and reversing its movement—with a fine effect at high speed. Secondly, the steam is released from the cylinder before the piston terminates the stroke; and by this timely exhaust excessive back pressure on the piston is prevented during the return stroke.

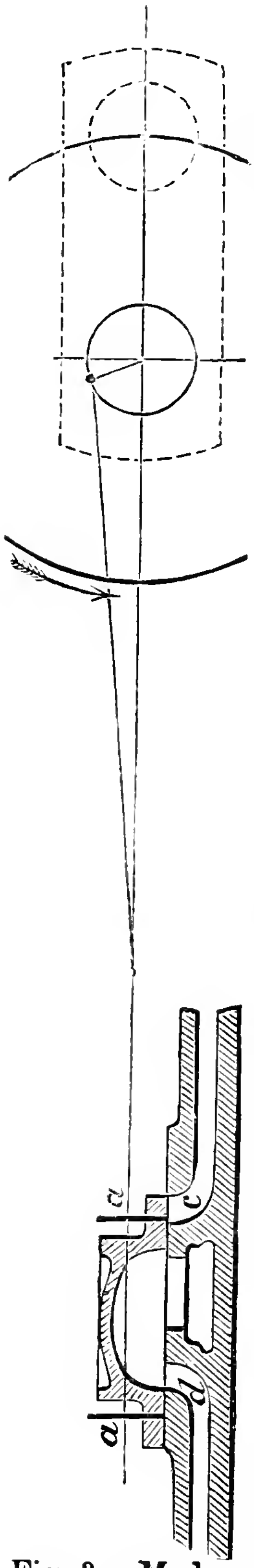

Fig. 3.—Modern Slide-valve.

When the improved valve, Fig. 3, was first tried, it was the means of reducing the coal-bill twenty-five per cent.—a result which, it may be imagined, caused extraordinary surprise. The difference between this valve and the old valve consists in the addition of lap at each end of the valve, with lead to the eccentric. The valve may be described as the same valve as in Fig. 2, except that it is lengthened at each end; and, instead of just covering the outer edges of the front and back steam-ports, C and D, it overlaps them both. A A is the lap on this valve; and if a driver states that his engine has valves with $\frac{7}{8}$ of an inch of lap, he means us to understand that when the valves stand in the position of half-stroke they overlap the steam-port by that much at each end, back and front.

Looking at Fig. 3, it will be observed that, in the modern valve, while the crank is on the back dead-centre, as shown for the old valve, Fig. 2, the centre of the excentric for the new valve is shifted farther ahead of the crank. The amount of this additional advance varies with the lap, for it is necessary to bring the edge of the lap-valve over the edge of the steam-port, when the piston is on the centre, into such a position as to open the port to the extent of $\frac{1}{8}$ inch or $\frac{1}{4}$ inch.

With regard to lead, suppose that the engine is perfectly at rest, with the big-end straight out on the back dead-centre, and the edge of the valve right over the edge of the steam-port. If the centre of the excentric-sheave be moved $\frac{1}{8}$ inch further from the crank, the valve is also moved an $\frac{1}{8}$, and opens the port that much, before the piston commences the stroke. This is lead. When a driver states that his engine has valves with an $\frac{1}{8}$ of an inch of lead, he intends us to understand that the valve opens the steam-port $\frac{1}{8}$ inch just as the piston has finished its stroke.

The general principles of lead and lap may be briefly summed up thus:—

Lead.—The lead of a valve is the amount of opening which the valve permits to the steam-port when the piston is at the end of its stroke, the opening being given to enable the steam to fill up the steam-port and clearance, and to act as a cushion upon the piston, so causing it to reverse its motion easily and without noise.

Lap.—Lap is the amount by which the valve exceeds the extreme width over the cylinder-ports; providing means for cutting off, and also for expanding, the steam during the stroke. After the steam is cut off by the valve, it is shut into the cylinder until the valve has travelled onwards, by the amount of its lap, when the inner edge of the valve opens the steam-port on the exhaust side, and the steam instantly leaves the cylinder and ascends the blast-pipe. The determination of the amount of the lead and the lap rests with the engine-builder; generally, for a high speed of piston, 1 inch lap and $\frac{1}{8}$ inch lead are adopted. Outside lap is a great friend to the locomotive; it enables an engine-man, by altering the travel of the slide by means of the link-motion, to cut the steam off before the piston has performed one quarter of its stroke. Inside lap is given for the purpose of preventing the locked-up steam from escaping too early. By deferring the release of the steam, the expansive working is prolonged; but if inside lap is carried too far, it may reduce injuriously the time of release for the steam from the cylinder, and so give rise to back pressure.

Inside Lead.—Inside lead, or clearance, has the opposite effect to that of inside lap, by causing an earlier and freer escape of the steam from the cylinder; but as the steam is not confined in the cylinder so long, as a matter of course, it shortens the period of the expansion.

Compression.—There is one more element of the working of the slide-valve, and that is compression, which is due to the exhaust steam not being all cleared out of the cylinder when the valve shuts the exhaust-port. The valve is then going one way and the piston in the opposite direction. The action of the piston-head on such locked-in steam is to push it into the port and the space termed the clearance, where it is compressed until the valve, which, while travelling the amount of the lap, was the cause of compression, lets the steam into the cylinder again. Finally, for each stroke of the piston, there are four periods of the distribution of the steam effected by the slide-valve: 1st, the Admission, when steam is admitted into the cylinder; 2nd, Expansion, after steam is cut off; 3rd, Release, when steam is liberated and goes up the chimney; 4th, Compression, when the remnant of exhaust steam is shut into the cylinder and compressed by the advancing piston.

Axle-boxes.—The axle-boxes are carefully fitted into the slides, or, as they are sometimes termed, horn-blocks. The brass-bearing is cast with a recess in the crown for the reception of white metal, to reduce the friction, and to facilitate the flow of oil to the journal. A keep of cast-iron or brass is placed below the axle, having a recess into which a sponge is sometimes introduced, for taking up the oil brought over from the top by the revolving axle. By this means no oil is wasted, and if, occasionally, the driver should forget to oil the bearing, the lubrication is continued by the sponge itself for some little time.

The causes of hot bearings are various; the following are a few of them. The keep binding against the journal is one, too much weight is another, and a fast-box is a third. The cotton may be too nicely fitted in the syphon-pipe; the cotton may be too far from the oil; the oil may contain glutinous matter, such as india-rubber or resin; the cotton may be in so great quantity as to fill the oil-chamber, leaving room for but a small quantity of oil; the cotton may be wet; the cotton may be too slack, allowing the oil to syphon too fast for the supply; the cotton may be choked with tallow and dirt; the cotton may be right to-day but wrong to-morrow, as there is a fixed period after which it fails through ordinary wear. Sponge, cotton, and similar materials are porous; and oil, water, and other liquids will rise in them. If the end of a towel happen to be left in a basin of water, it will, by what is called capillary attraction, probably empty the basin. On such a principle of action axles are generally lubricated.

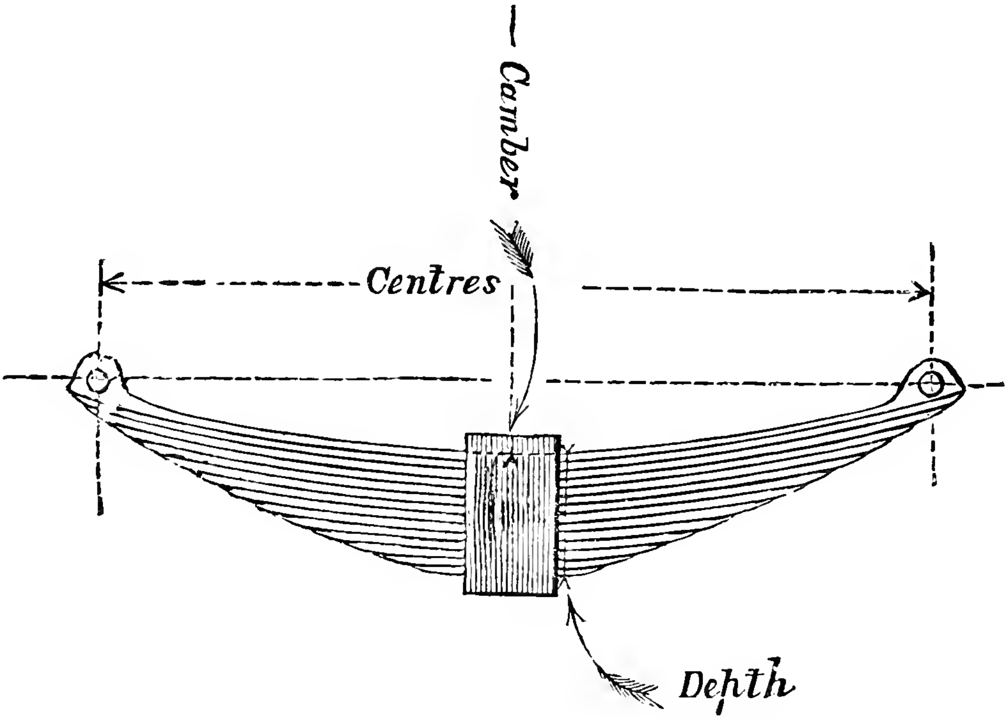

Fig. 4.—Laminated Bearing-spring.

Springs.—The springs carry the engine. The leaves of a spring, made generally of mild steel, are kept together by a buckle; the thrust-pin, between the buckle and the axle-box, transmits the irregularities of the permanent way, through the wheels and axle-boxes, to the springs. Underhung springs, below the axle, have a lip or eye forged upon the buckle, by means of which it is fastened by a pin to the axle-box. Such springs are frequently fitted with neat spring-links, or socket-pieces, by which they are connected to the frames, and by means of which the weight of the engine is equally distributed. The leading dimensions of an *elliptic* spring are those of the length, the camber, the number of plates, and the thickness of each plate. (See Figs. 4, 5.)

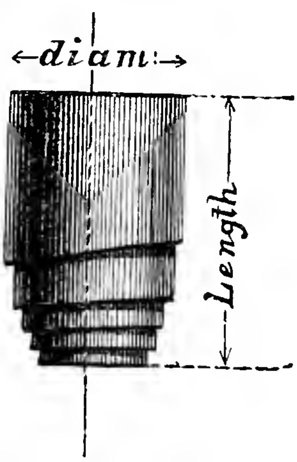

Fig. 5.—Conical Bearing-spring.

Wheels.—The wheels are generally of best selected scrap-iron, forged solid. The spokes are forged with T heads, and the boss of the wheel is formed by welding up the ends of the spokes, previously shaped to form a perfect fit before being welded, with a washer on each side the rim, for the tyre is afterwards made solid. The wheels are said to be crank-bossed, when crank-pins are fitted into the wheels. The wheels are forced upon the axles by hydraulic pressure; they are in many cases perfectly firm without the aid of keys. The tyres are heated for the purpose of being enlarged by expansion, and are then placed on the rim of the wheel and cooled. The tyres contract in cooling, and they are bound by the shrinkage firmly to the wheel; after which they are turned in the lathe.

Coupling-rods.—The connecting-rod and the outside coupling-rods are generally forged, each from one solid piece of iron. Welds are thus avoided. The small end of the connecting-rod is sometimes fitted with a steel bush. When it is not fitted too tight, and is properly attended to, it is an excellent job; but when allowed to seize it may make a nice mess. It has been known to pull down all the motion, and to send the connecting-rod into the fire-box.

Brick Arch.—The brick arch in the fire-box is designed to assist in the proper combustion of the fuel. It is generally formed to a versed sine or rise of 5 or 6 inches.

Fire-bars.—The fire-bar bearers support the bars and the fuel. The fire-bars are of wrought iron, and, when cut, proper allowance is made for them to expand, without binding at each end against the fire-box. If this provision for expansion is disregarded, the bars will be liable to bend, and close together at some places, and ultimately to burn and drop into the ash-pan. Fire-bars should not be pulled up; the clinkers should be removed from them by means of the splice or clinker shovel. Many first-class drivers run for weeks together without making sufficient clinker to interfere with the steam. They break the clinker up, after which it will not set to the bar again; and they spread it about the box to protect the fire-bars during the next trip, or they get it into the corners, where it is very serviceable in preventing cold air from rising and getting into the tubes.

Ash-pan.—The ash-pan is a very important member of a locomotive engine. When it is kept sound and clean it is capable of doing much for the driver. By its instrumentality tons of fuel may be prevented from being wasted. The door or damper should be capable of shutting quite close.

Blower.—The blower is, according to the best arrangement, fitted round the top of the blast-pipe. Bricks or cement is applied in the smoke-box to protect the cylinders and the joints from rust. For this reason the joints are, as a rule, situated above the reach of moisture.

Sand-box—Sand-boxes are now most commonly made for dry sand, which is made to pass through disc-valves or ordinary cocks by means of a light lever under the control of the engineman. The handle of this lever is fitted in a sector-plate, which, with the reversing lever and damper-handles, is placed by the side of the driver. The remainder of the foot-plate furniture consists of the whistle-handle, the handles of the blower and cylinder lubricator, gauge-cock fittings, fire-door, and regulator. Turning to the tender, there are the feed-handles for regulating the supply of water to the boiler. These handles are connected to spindles, which are connected to the valves in the tender. These valves require to be fixed so that they may not be interfered with by pieces of wood, waste, or other matter floating about.

Cab.—The cab, which is a boon to engine-drivers, is furnished with plate-glass windows, set in polished brass frames, which, on some railways, are arranged so that they may be opened if required.

Tools, &c., required for an Engine.—Before an engine joins a train, the following tools and articles are required to go with it.

A complete set of fireman's tools :—

1.—Splice for getting clinkers out of the fire-box, and for drawing back the coals from under the brick arch in the case of a choked fire.

2.—Pricker for pulling up bars in cases of emergency.

3.—Rake for cleaning out the ash-pan, and for raking the brick arch down, when it can be done.

4.—Long chisel-bar for lifting and breaking a clinker.

5.—Pinch-bar for rapping fire-bars and other purposes.

6.—Shovel, coal-pick, and bucket.

A complete set of driver's tools:—

1.—Set of spanners to suit every size of nut and of plug in the engine.

2.—Screw-jack, with ratchet or bar, in good working order.

3.—Several plugs for the tubes, and a rod to suit them.

4.—Quarter, hand, and lead hammers.

5.—Two cold chisels, and a few punches for knocking pins out of the motion, &c.

6.—Large lamps (3), gauge-lamp, and motion-lamp, the latter fixed over the spindle-glands.

7.—Two oil-feeders, two oil-bottles—one feeder for the driver and the other for the fireman; one oil-bottle for general use and one to keep store oil, so as to have an extra quantity of oil on the engine in case of axles &c., running hot.

8.—A quantity of flax, spun yarn, and tar band.

9.—Half-a-dozen fog signals.

10.—A few split pins and cotters of various sizes for eccentric-bolts, &c.

11.—A few gauge-glasses.

12.—Some copper wire.

13.—Some worsted.

14.—A copy of the Company's rules.

15.—Service time-book for the current month.

16.—A foot-plate motto—A place for everything and everything in its place.

Some of the above articles may be dispensed with on short-train service.

Tool-box.—It is well for every driver to provide himself with a small tool-box, which is easily carried about, and is useful, either for putting in a gauge-glass or for fitting in a fresh split-pin in the motion or the brake-irons. It will be found a valuable aid when time presses; when a glass, or a split-pin, or worsted, or wire, or other small store is wanted. When all these little friends are mixed up with spanners, coats, &c., much time may be lost in finding them; but when they are kept together in a little box by themselves, no matter how dark the night may be or how much steam there is about, they can always be found; and that is more than can be said in many instances when a gauge-glass goes off "bang." The box should be long enough to take in gauge-glasses, and should be fitted with a till to hold them, about 6 inches wide by 4 inches deep, furnished with a lock and key.

Gauge-glasses.—A few glasses should be cut to the exact length required for the engine, with india-rubber washers or flax in readiness for immediate use.

It is not a wise plan to cut every glass in the engine to suit any one particular engine, because some one may want a glass unusually long, and the opportunity of showing another driver what a fine thing it is to be prepared with such things would be lost, to say nothing about the value of a glass to a man who has more than a hundred miles yet to run. The proper length to which a glass should be cut is such that it may not interfere in the least, either at top or bottom, with the passage into the boiler. It is cut by inserting a small round file, or a piece of one, within the bore or hole, to the point where it requires to be cut, and then scratching it all round with the point of the file. This place thus becomes the weakest place in the glass. With the file still in the hole, break the waste piece off, exactly as a notched stick is broken through.

CHAPTER II.

DETAILED DESCRIPTION OF THE LOCOMOTIVE, WITH KEY.

The locomotive engine selected for detailed illustration in Figs. 6 to 6 *d* is the "Grosvenor," an express locomotive, one of a very powerful class, specially designed and constructed by Mr. Wm. Stroudley, for the service of the London, Brighton, and South Coast Railway. It is a single engine, on six wheels, which are well distributed, with a large boiler of abundant steam-generating power, with cylinders of great capacity, and driving-wheels of moderate diameter. This locomotive was constructed with extreme care, and the workmanship is as nearly perfect as possible. It is accompanied by a tender on six wheels, capable of holding a supply of 2,520 gallons of water, and 40 cwt. of coals. Notwithstanding its great capacity, this tender is so low that a tall man may stand on the coals without the risk of being knocked down by any of the bridges on the line. There are upwards of 47 tons of metal in the locomotive and its tender together, and when they are in full working the gross weight with fuel and water amounts to 59 tons. Notwithstanding the largeness of the quantity of metal consumed in their construction, the engine and the tender are remarkable for their shapeliness and for the lightness of their movements. They are painted with a uniform coat of a mixture of gamboge yellow and dark claret, picked out in black and vermilion.

The "Grosvenor" ran the first through train between London and Portsmouth—a distance of 87 miles—in 1 hour 50 minutes.

Frame.—The engine is constructed with inside longitudinal frame-plates, giving inside bearings for the axles. The plates are securely bound together transversely, by several connections: two wrought-iron buffer-plates, one at each end of the engine, the motion-plate, and two transverse plates, before and behind the firebox and the cylinders; and also by the running boards, which are each in one continuous piece from end to end of the engine.

Boiler.—The plates for the barrel of the boiler are bent to a true circle, and the joints are butted, with straps both outside and inside. The rivet-holes in the inside and outside straps are countersunk nearly through the thickness, so as to shorten the parallel portion of the rivet, and to secure a good fit. The rivets are driven in by flogging hammers, and are brought much more closely home than they could be by ordinary hand or steam rivet-work. The front tube-plate is secured by an angle-iron ring to the boiler, where they are brought close together. There is also an inner angle-iron of the same section as the ring, at the upper portion of the inside circumference, to further support the plates and do away with longitudinal stays. The sides and top of firebox-shell are one plate, extending from the foundation-ring on one side over to the foundation-ring on the other side.

All the seams are double-riveted, except the circular seams of the barrel and the vertical seams of the firebox, for which the lap of plates is $2\frac{1}{2}$ inches, with $\frac{3}{4}$-inch rivets, at a pitch of $1\frac{7}{8}$ inches.

The angle-iron ring forming the man-hole has a butt-strap welded to its flange, so that the ring becomes very much stronger than those generally adopted by locomotive makers. It is of such a thickness as to bring up the sectional area of metal across the man-hole to an amount slightly in excess of the sectional area of the portion of the solid plate that is cut away, so that this man-hole is absolutely the strongest place in the boiler.

The process of applying the stays to the roof of the firebox is commenced by placing an iron frame or mould round the firebox in the exact position to be taken by the shell of the boiler. Notches are made in one edge of this frame, to hold the end of a mandril which has a small tail-piece projecting from the end, to pass into the hole to be afterwards occupied by a stay. A smaller mandril, having a hole in its centre, is held on the inside of the firebox, being guided by the tail-piece of the outer one to a right line. These mandrils are then struck with a hammer, when they readily set the plate, one edge inwards and the other edge outwards, so that after they are tapped the collar on the stay and its nut on the inside take a fair bearing.

This operation is easily performed, and not one stay done in this way has been known to leak, notwithstanding that several fireboxes have been run so short of water as to melt the lead-plug. The crown of the firebox is lower at the back than at the front, next the tubes. Thus the roof-plate is covered by a greater depth of water where the flame impinges with the greatest force. The sides of the box also slope inwards, and offer a very good form for the escape of the steam formed upon the plates. The tube-plate is made wider than the back-plate of the firebox, in order to permit the full complement of tubes. To receive these, a part of the side-plate at each side is dished into the side water-space, to admit of the feruling of the tubes at the sides; but the other portions of the side-plates are left plain, having a very wide water-space. The back end of the boiler is supported above the firebox by palm-stays, which are securely riveted to the outer shell, and also riveted by countersunk holes to the back-plate.

Regulator.—The regulator is made upon a plan used by Messrs. Sharp, Stewart, & Co. for many years. It differs from this only in having a much larger central pivot, by means of which a much more even wear on the surface is produced, as the difference of surface between the inner and the outer rings is so slight that the wear is practically equal. In practice, these valves remain almost absolutely tight. They are relieved by a small cast-iron valve at the back, having an opening of 4 square inches of area. The large valve has an area of 10 square inches.

There is a peculiarity in the arrangement of the stuffing-box and drivers' handle. The stuffing-box is made of brass, and is projected into the boiler. It is fitted with a spindle, also of brass, having a socket cast upon the end which is inside the boiler. This socket has a square hole to take on the end of the regulator-rod, and a collar to fit against the end of the stuffing-box, where it works like a valve, being held up to the surface of the stuffing-box by the steam-pressure, and being left free to adapt itself to the stuffing-box by the square socket, which is made an easy fit upon the regulator-rod, and acts as a universal joint. This stuffing-box gives no trouble; the packing remains steam-tight for a year or two at a time.

The stoppers for arresting the motion of the valve, when closed and opened wide, are cast upon the head of the regulator: superseding the ordinary ugly quadrant on the back of the firebox.

Safety-valves.—The safety-valves (Adams's patent) are 2½ inches in diameter, with a lever of 18 inches, and a distance of 3¾ inches from the fulcrum to the valve.

These valves act with great certainty, and they are sufficient to release the surplus steam under any circumstances. It is found, in practice, that a short lever with a long spring acts better with even a smaller valve, than the old-fashioned combination of a long lever, large valve, and short spring-balance.

Gauge-glasses.—The boiler is fitted with duplicate gauge-glasses, which are not only valuable as a check upon each other, and on the level water in the boiler; but one of them continues serviceable should the other happen to be broken.

Cylinders and Valves.—The steam cylinders are 17 inches in diameter, with a stroke of 24 inches. They are placed at a distance of 2 feet 2 inches between centre and centre; and the valve-faces, which are vertical, are 4½ inches apart. It has always been a delicate matter to make room for large cylinders in the narrow space between the wheels of inside-framed engines, with due consideration to the length of axle·

bearings and other details. When the cylinders are brought close together for the purpose of affording wide bearings for the axles, the exhaust-way is restricted; whilst any arrangement for placing the valves in other than a vertical position between the cylinders, with a view to the provision of free exhaust-passages, has always involved more or less complexity in the gear.

It will be seen that the steam-ports and exhaust-ports are divided into two sets, the upper and the lower; whilst the valves extend from the top to the bottom of the valve-chest, and cover both sets of ports. The steam escaping from the lower ports passes through a belt round the cylinder, and joins the exhaust from the upper ports at a point near the base of the blast-pipe.

A portion of the exhaust is conducted by a pipe into the tender for the purpose of heating the feed water.

The steam supply-pipes are in duplicate, one of them leading into the back of the valve-chest on the one side, and the other into the front of the valve-chest on the other side, thus obviating the employment of complicated passages, which are sometimes required for the purpose of connecting the ends of the valve-chest together; seeing that the middle region of the valve-chest is almost entirely monopolized by the valves. The slide-valves have $\frac{7}{8}$-inch lap outside, and $\frac{1}{8}$-inch lap inside, and they are set with $\frac{1}{8}$-inch of lead. They are provided with flanges on their lower edges, by which they slide upon the raised surfaces planed for them on the floor of the valve-chest, in order to prevent their wearing downwards and letting the edges of the ports out of line: a kind of wear which takes place with valves of the old construction. The cylinders are cast with the inside covers, brackets for motion-bars, and stuffing-boxes, all solid—that is in one piece—doing away with a considerable amount of fitting and jointing.

Instead of bolts for holding the cylinders together, a wrought-iron hoop, carefully slotted and finished, is shrunk on at the junction of the valve-spindle stuffing-boxes: making a very efficient union.

In order to supply equal volumes of steam to the two ends of each cylinder for the front and the back strokes, compensation is provided for the inequality of the periods of admission caused by the oblique action of the connecting-rod, by placing the group of steam-ports in each face, in advance of the central position, to the extent of 1¾ inches, towards the front end of the cylinder. The length of the back steam-port is thus made to exceed that of the front port, to the extent of 3½ inches, and the cubic capacity of the back port, which is of course filled with steam from the boiler for each stroke, is greater than that of the front port, by the amount which is required to balance the excess volume of steam nominally cut-off in the front end of the cylinder, over and above the volume cut-off in the back end. By means of such adjustment, which is specially adapted for the ordinary working position of the valve-gear, the crank is subjected to a more nearly uniform stress than that which would obtain with steam-ports of equal length. It is to be observed that the equalisation of the work of the steam on the piston is effected during the expansive period of the steam's action, after it is cut off, and before it is exhausted.

The flanges by which the cylinders are united are planed with a tongue which is left on the one cylinder, and a corresponding groove in the other, at the bottom of the steam-chest. The parallelism of the cylinders is thus permanently secured; besides which a good joint is made.

Slide-bars.—The slide-bars are cast-iron of L section. They are bolted by their fore ends to projections on the cylinders, and near their back ends to the motion-plate, through which the back ends are passed and overhung about 6 inches. Support is thus given to them near the centre of their length, where the greatest strain is thrown upon them by reason of the angularity of the connecting-rod. Besides, by the very forward position of the motion-plate, there is liberal clearance for the valve-motion, and long rods may be employed.

Cylinder-covers.—The cylinder-covers are double-faced, with a recess in the centre round the line of the studs. The face is finished by a scraping-tool, and it makes a perfectly steam-tight joint.

The cylinder-covers and the valve-chest-covers are cast hollow, having air-spaces to prevent the escape of heat; the outsides of the covers are cased in sheet-iron suitably formed, by which the nuts and other projecting pieces are covered and kept clean.

Pistons and Piston-rods.—The steel piston-rods have cross-heads formed solid with them. The pistons, which are of gun-metal, are taken off the rod for the renewal of the two packing-rings, or for examination. The piston is readily removed by unscrewing the brass nut by which it is held whilst the piston is warm, when it easily leaves its steep conical seat on the piston-rod.

The piston-rods are made of special gun-steel, manufactured by Vickers & Co., of such a quality that they can be extended 25 per cent. in length, and can be doubled up close, while cold, without fracture. The ultimate tensile strength of the steel is from 28 to 30 tons per square inch.

Connecting-rod. — The connecting-rod is 6 feet 6 inches long, and it is specially so designed that it may be finished by machinery; the greater portion of the work being done in the lathe and the drilling-machine.

The little-end is held by a single cotter, which takes the whole of the work, and a bolt, which holds the ends of the strap firmly down to the rod, but which does not take any part of the longitudinal stress.

The big-end brasses are bored and turned as simple concentric rings, and they are prevented from moving out of their places by the two main bolts. These brasses being, together with the whole of the rods, made to gauge, can be prepared in quantities to be kept in reserve for future use. When required they can be put into their places without the use of a file. Holes are drilled in the principal bolts to reduce the sectional area approximately to an equality with that at the bottom of the thread, and thus to render them uniformly elastic. No check-nuts are used.

Valve-gear.—The whole of the valve-gear is worked out with geometrical accuracy, and it is arranged in a simple and plain manner. The pins and wearing joints are large, and there is almost an entire absence of split-pins and loose washers, which so often bring locomotive-engines to grief. The centre lines are so struck that, when the gear is in the best working position, all the levers oscillate equally on each side of their several centres, thus producing the smallest possible amount of distorted action.

The expansion and lifting links are forged from the best Yorkshire tyres, and are thoroughly casehardened at all the working parts.

Excentrics.—Each pair of excentrics is cast together, in halves united by screws. They are not keyed on the axle, but they are driven by a projecting claw, which takes over the edge of the crank-arm. Special value is attributed to the avoidance of key-seats and notches in a crank-shaft.

The manner of driving the excentrics by the crank-arm insures their always being accurately placed in position. The holes or recesses left for the screw-heads are, after fixing, run up with patent metal, which prevents the screws working loose, and facilitates the lubrication of the excentric-straps.

The excentric-straps are of cast-iron, and are made sufficiently strong to retain their circular form when the strain of the valve is upon them. The bolts are placed as closely as possible to the excentric, and are made very long and elastic. The points of the strap at the joints are projected outwards, so as to form cantilevers, and thus to assist in stiffening still further the strap against distortion. The effect of this arrangement is, that the wear of the excentric-straps is incredibly small. The surface between the strap and the excentric-sheaves is so large, in proportion to the load placed upon them, as to admit of a film of oil remaining between the two metals, and holding them entirely apart.

Reversing-handle.—The reversing-handle and rod are of wrought-iron, finished bright and casehardened.

Crank-axle.—The crank-axle is of Vickers's steel, carefully annealed after the webs have been slotted out.

Wheels.—The wheels are forged solid, of the best scrap-iron. The spokes are brought together in the centre, and the bosses are made by washers welded on the spokes. The ends of the spokes are made solid with the rim of the wheels. The wheels are keyed on the axles before the tyres are shrunk on. The tyres are of Krupp steel, made with a projecting lip fitted to the side of the rim of the wheel, and secured by screws. The counterweight is forged solid with the wheel.

Axle-boxes.—The flanges of the axle-boxes are continued upwards, so as to entirely close the side of the horn-block, and thus prevent dirt and foreign matter from finding its way to the working surfaces, and also to keep the axle-boxes perfectly upright. The axle-brasses are made of a square form on the outside, and they project downwards for a considerable distance below the centre of the axle, so that they may be supported by the keeper, which fits up between the points of the brass, and so prevented from clinging to the journals.

The brass is made to rest upon the journal by a narrow edge at the centre only about 1 inch wide, and it is free to follow the inclination of the axle when it is thrown off the level by irregularities in the road. The brasses so constructed are found to work very well.

Springs.—The springs are constructed of mild steel, so soft that they will not break.

Feed-pumps.—The engine is fitted with two pumps, worked direct from the cross-head. These pumps are specially designed to pump hot water at high speed, and they have been very successful. One of the principal features of the feed-pump consists in the large clack-area in proportion to the ram, giving a large area of escape, with a small lift, and requiring a very small pressure to lift the bottom clack and fill the pump with water. When ball-clacks are used for pumps the weight of the valve is so great, in proportion to the area exposed for the feed-water to act upon, that the pump does not get a sufficient supply, and hence the difficulty of pumping hot water at high speed; for, of course, the vacuum formed by the ram is but very slight.

The clacks have spiral wings, or guides, thus turning partially round by the action of the water at every stroke, wearing the flat seats very evenly, and keeping perfectly tight. The beaters are formed with a very large area of surface, for the purpose of preventing the clack from striking the beater too hard. With the proportion given in these pumps, the two metals never come into absolute contact, the force required to drive out the volume of water between the two surfaces being sufficient to arrest the motion of the valves. This has been proved to be the case; for there are many instances of pumps that had been working upwards of two years, in which the head of the clack was found to be discoloured, and had the marks of the turning-tool remaining.

The air-vessel forming part of the pump, and in immediate connection with the clack, also operates to prevent percussion.

The delivery-pipe to the boiler is made of small diameter, and it is found to be amply large enough for the purpose. There is a small snifting clack on the suction-pipe of these pumps, to admit air, so that whilst the pump is supplied with as much water as is found necessary for the boiler, the remainder of the working barrel is filled with air, which is forced along with the water into the boiler, and still further tends to take off percussion.

The pump-rams are of steel, secured direct into the slide-block; they are found to work in this position with very little wear. One pump is in practice capable of supplying more water than is required for the boiler, although two pumps are provided.

Lubrication.—The manner of oiling has been well considered. All the axle-boxes and the horn-plates are supplied with oil through pipes, from oil-cups fixed to the inner side of the wheel-splashers, to secure at all times a plenteous supply of oil to the working surfaces. The swabs on the glands of the piston-rods and the valve-spindles are likewise, and in a similar way, constantly furnished with sufficient oil to lubricate the piston-rods and valve-spindles throughout the trip.

Steam-brake.—It is necessary with fast trains to keep time by running at a high speed. This, however, can only be safely done when the engine is provided with a very powerful brake that will act promptly when required, so that the train may be stopped at any point where the driver may be called upon to do so. This engine is provided with a brake consisting of one large brake-block placed in front of each of the driving and trailing wheels, connected by transverse rods at the bottom, to the end of which, outside the wheels, are attached two continuous rods with other short transverse rods at the back end, extending to two short levers on the weigh-shaft placed across the engine, behind the firebox.

On this weigh-shaft are fixed two levers, one of which is connected with a screw for the hand-brake, having slotted links to permit the motion of the lever independently of the screw if necessary ; the other one is attached to the piston of the steam-cylinder, which is bolted directly under the footplate in a vertical position. This cylinder is 9½ inches in diameter and has a stroke of 6 inches. The weight of its piston is sufficient, when the steam is taken off, to force the brake-blocks away from the wheels. The piston is controlled by a 3-way valve placed upon the front of the boiler, having a lever very conveniently arranged for the driver to operate. By turning the lever in one direction, steam is admitted below the piston ; and by turning the lever in the other direction, the steam is allowed to escape from below the piston, into the tender. By a judicious movement of the handle, the action of the brake may be modified in its intensity, varying from a slight touch of the wheels up to a pressure of two tons on each brake-block. This pressure is found to be nearly sufficient, but not quite so, to skid the wheels. The bottom of the cylinder is also provided with an inverted valve about ½-inch diameter, which falls open by its own gravity, and remains open, allowing water to escape entirely from the cylinder, being placed a little lower than the bottom of the cylinder.

Speed-indicator.—A speed-indicator, patented by Mr. Stroudley, is fitted to the engine. It consists of a small fan with straight arms, revolving in a brass casing full of water. The water is, by the centrifugal force of the fan, maintained in a vertical copper tube, terminated by a glass tube like that of a water-gauge. By the height at which the water stands in the tube, which is suitably graduated, the speed is continuously indicated. The fan is driven by a leather belt from the crank-shaft, as will be seen from the illustration.

The Cab and its Fittings.—The cab, or covering for the engine-driver and the stoker, is erected over the foot-plate. It is furnished with sundry fittings, with a view to make everything exceedingly convenient for the engine-driver. Fixed by the side of him are handles for working the front and the back dampers, dry-sand boxes, and the waste-water cock at the bottom of the steam-chest. In front of him are the handles for the pet-cock of the pump, the blower, and the lubricator fixed on the smoke-box for the cylinders.

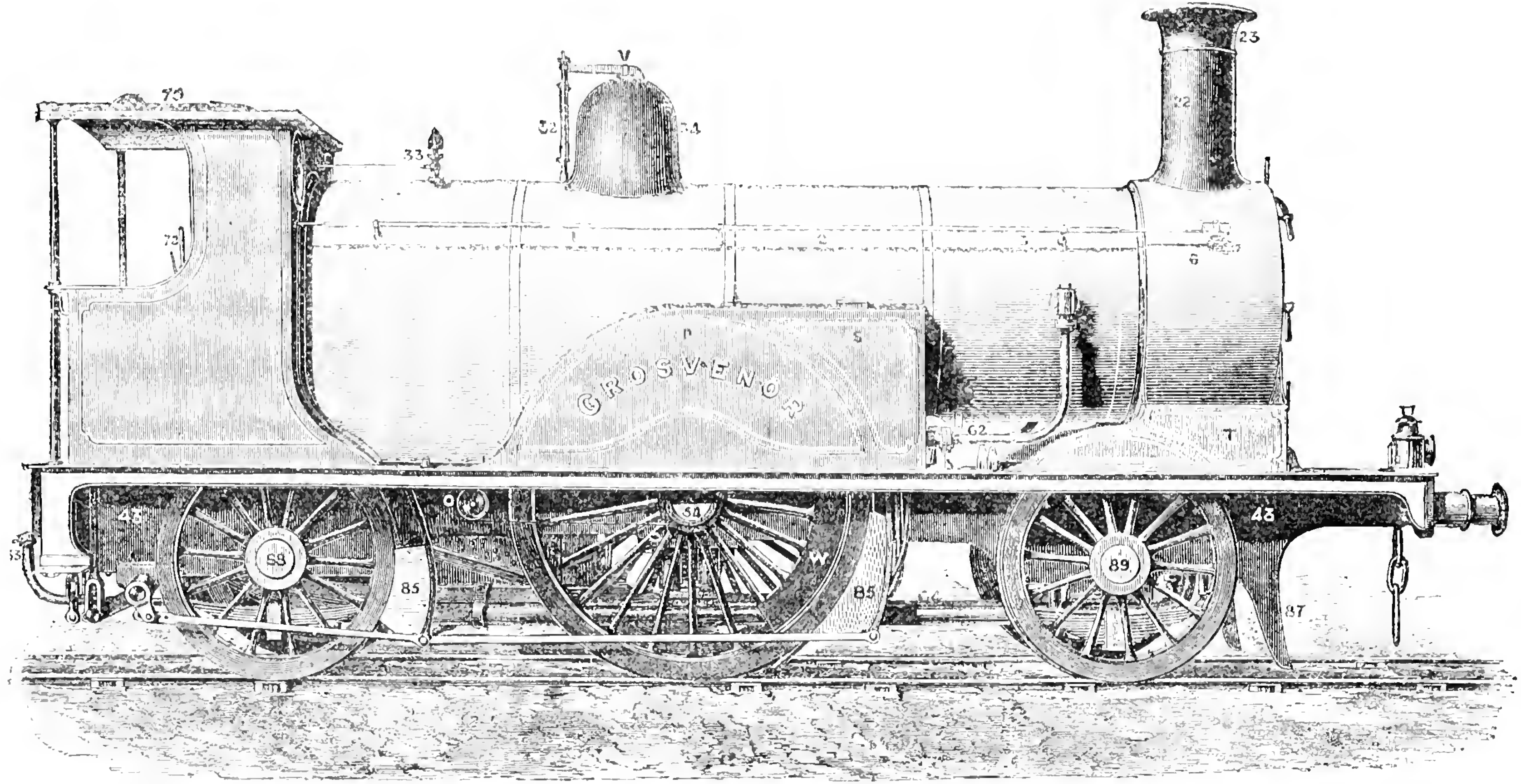

Fig. 6.—Mr. William Stroudley's Locomotive "Grosvenor," London, Brighton, and South Coast Railway. Longitudinal Elevation.

LONGITUDINAL ELEVATION.

Fig. 6.

1.
2. Barrel of boiler
3.
6. Smoke-box
22. Chimney
32. Spring balance
33. Whistle
34. Dome
64. Exhaust-pipe
70. Cab
85. Brake-blocks
87. Life-guards
88. Trailing-axle and wheel
89. Leading ditto
(54. Driving-axle)
O. Speed-indicator
P. Splasher
S. Sand-box
T. Tool ditto
V. Safety-valve
W. Balance in driving-wheel

LONGITUDINAL SECTION.

Fig. 6 *a*.

1.
2. Rings arranged telescopically, forming barrel of boiler
3.
4. Solid angle-iron ring
5. Tube-plate
6. Smoke-box
7. Shell, or covering-plate
8. Foundation-ring
9. Throat-plate
10. Back-plate
11. Fire-door
12. Covering-plate of inside fire-box
13. Tube-plate
14. Back-plate
15. Stays
16. Mouthpiece
17. Stays from inside firebox to shell-plate
18. Palm-stays
19. Tubes
20. Smoke-box door
21. Pinching-screw
22. Chimney
23. Chimney-cap
24. Blast-pipe
25. Top of blast-pipe
26. Balance-weight
27. Wheel-spokes
28. Front buffer
29. Mud-plug
30. Safety-valve
31. Ditto lever
32. Spring balance
33. Whistle
34. Dome
35. Regulator
36. Steam-pipes
37. Elbow-pipe
38. Brick arch
39. Fire-bars
40. Ash-pan
41. Front damper
42. Back ditto
43. Frame-plate
44. Iron buffer-beam (front)
45. Ditto ditto (back)
46. See plan (cylinder)
47. Cylinder, ports, valve
48. Valve-chest
49. Steel motion-plate
50. Horn blocks
51. Axle-boxes
52. Slide-bars
53. Connecting-rod
54. Crank-shaft
55. Big end
56. Arm of ditto
57. Expansion-link
58. Weigh-bar shaft
59. Valve-spindle
60. Ditto rod-guide (see plan)
61. Pump
62. Delivery-pipe
63. Feed ditto
64. Exhaust ditto
65. Volute spring
66. Draw-bar hook
67. Lamp-iron
68. Oil-cup
69. Ditto pipes
70. Cab
71. Regulator handle
72. Reversing-lever

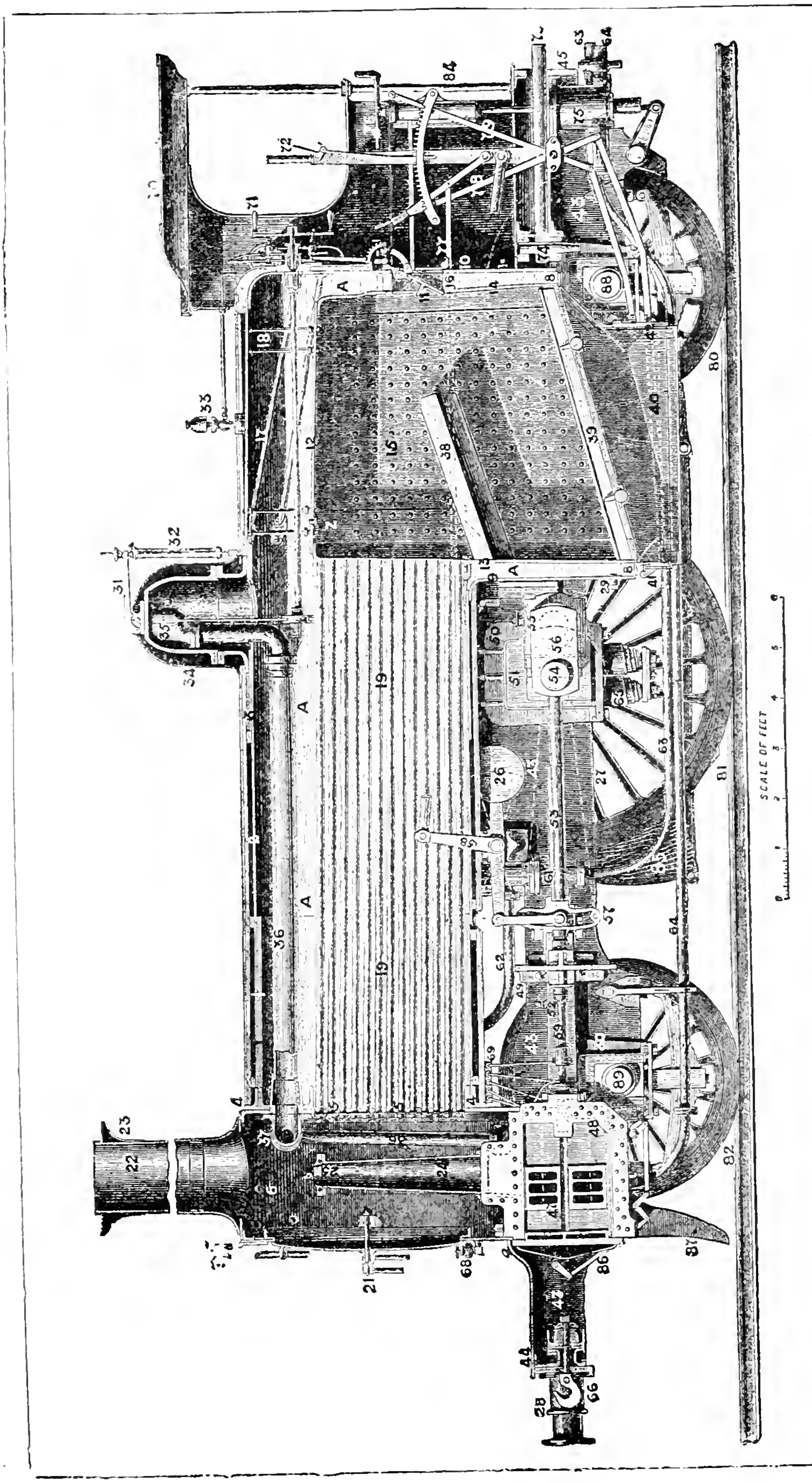

Fig. 6 *a.*—The "Grosvenor." Longitudinal Section.

73. Draw-bar
74. Ditto pin
75. Steam-brake cylinder
76. Hand-brake
77. Sand-rod
78. Front damper
79. Back ditto
80. Trailing-wheel
81. Driving ditto
82. Leading-wheel
83. Spring
84. Hand-rail
85. Brake-blocks
86. Waste water-cocks
87. Life-guard
88. Trailing-axle
89. Leading ditto
Z. Lead-plug

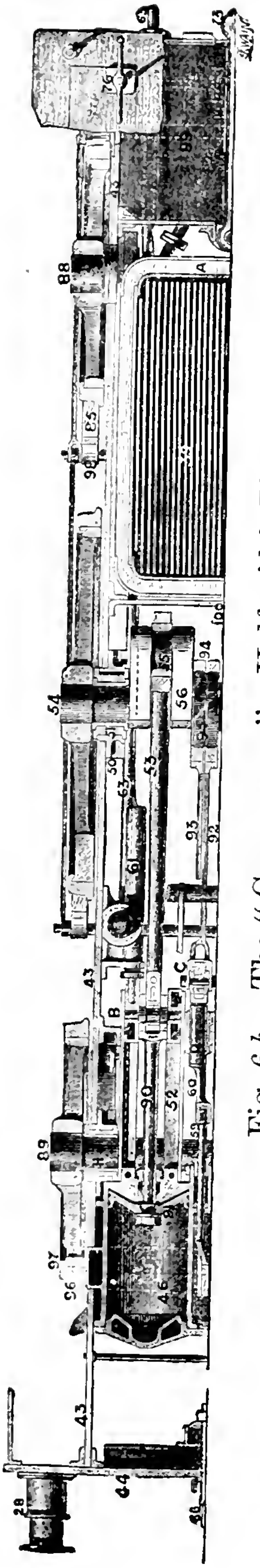

Fig. 6 *b*.—The "Grosvenor." Half-width Plan.

HALF-SECTIONAL PLAN.

Fig. 6 *b*.

43. Frame-plate from end to end of engine
44. Iron buffer-beam
46. Cylinders
50. Horn block, to carry axle-box and brass
51. Axle-box and brass
52. Slide bars
53. Connecting-rod
54. Driving-axle
55. Big end
56. Arm of ditto
59. Valve-spindle
60. Valve-rod guide
61. Pump
76. Hand-brake
85. Brake-blocks
88. Trailing-axle
89. Leading-axle
90. Piston-rod
91. Ditto head, held on the rod by a brass nut
92. Back-way ecc-rod
93. Front ditto
94. Ecc-strap
95. Ecc-sheaves
96. Tyre
97. Lip on tyre
98. Brake-irons
99. Foot-plating
100. Transverse-stay
A. Water-space between inside and outside fire-boxes
B. Slide-block, with end of pump-ram screwed into the end
C. Link-motion (see 57 long. sec.)
D. Slide-valve-rod working-guide
H. Inside journal, showing the axle is supported inside of frame-plates
I. Cross-head, solid, with piston-rod

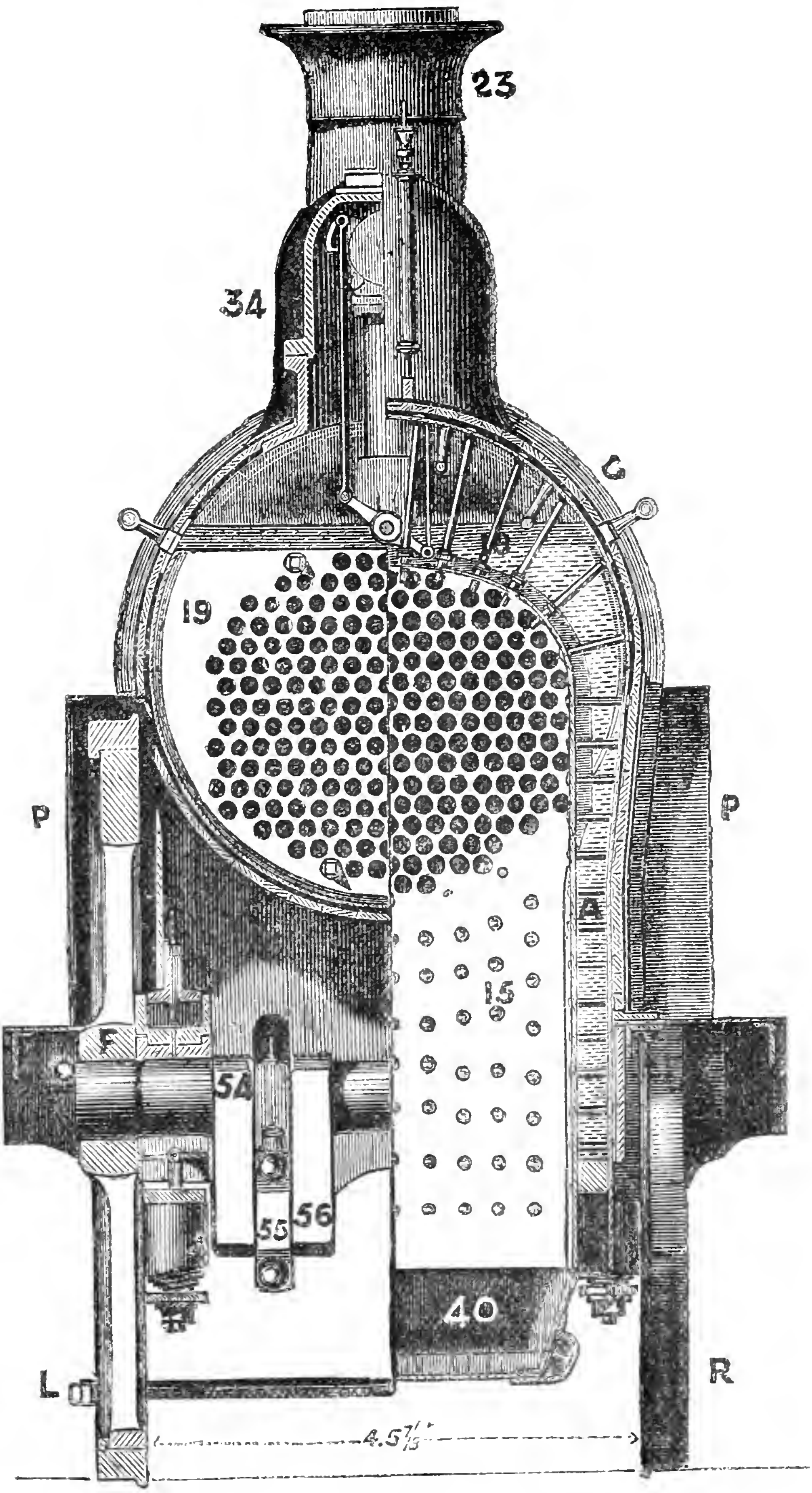

Fig. 6 *c*.—The " GROSVENOR." Cross Sections.

15. Stays in walls of fireboxes. 18. Ditto from crown-plate to covering-plate. 19. Tubes. 23. Chimney-cap. 40. Ash-pan. 54. Crank-shaft. 55. Big end. 56. Arm of big end. 34. Dome. A. Water space. F. Nave of wheel. P. P. Splashers over driving-wheels. R. Right side of engine. L. Left ditto.

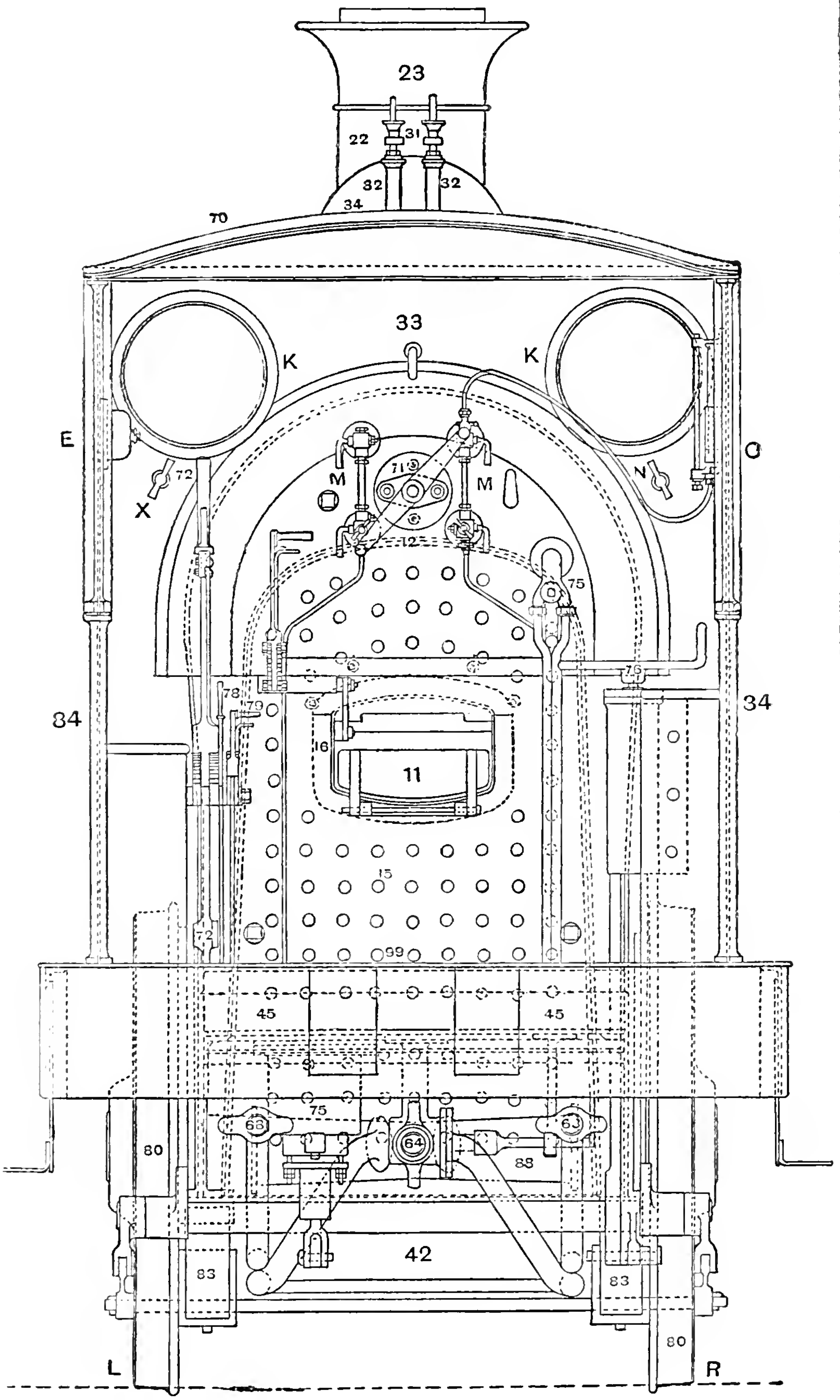

Fig. 6 *d*.—The "Grosvenor." End View.

75. Steam-brake handle. 33. Whistle-handle. 23. Chimney-cap. K. K. Weather-glasses. O Speed-indicator. E. Guard's bell. N. Oil for cylinder. X. Blower-handle. R. Right side of engine. L. Left ditto. M. M. Gauge-glasses.

PRINCIPAL DIMENSIONS OF THE "GROSVENOR."

With references to the Illustrations, Figs. 6 to 6 *d.*

BOILER.

		ft.	in.	
Nos. 1, 2, 3. *Barrel*—				
	Length	10	5	Long. Section.
	Diameter outside	4	5	„
	Thickness of plates	0	$0\frac{1}{2}$	„
	Ditto tube-plate	0	$0\frac{3}{4}$	„
Nos. 7, 9, 10. *Outside Firebox*—				
	Length outside	6	$2\frac{1}{4}$	„
	Breadth ditto	4	1	„
	Thickness of covering plate	0	$0\frac{9}{16}$	„
Nos. 9, 10.	Thickness of front and back plates	0	$0\frac{5}{8}$	„

Nos. 12, 13, 14. *Inside Firebox* (Longl. Section)—

		ft.	in.
	Length inside at bottom	5	6
	Ditto ditto top	5	2
	Breadth ditto bottom	3	$4\frac{7}{8}$
	Ditto ditto top	3	$2\frac{7}{8}$
	Height—bars to crown—front	5	11
	Ditto ditto ditto back	4	$4\frac{1}{2}$
	Thickness of plates.	0	$0\frac{1}{2}$
	Ditto tube-plate	0	$0\frac{7}{8}$
	Water space, front at bottom	0	3
	Ditto ditto top	0	6
	Ditto sides at top	0	6
	Ditto ditto bottom	0	3
Nos. 7, 12.	Distance between crown of inside firebox and outside firebox, front	1	$3\frac{1}{4}$
Nos. 7, 12.	Distance between crown of inside firebox and outside firebox, back	1	$4\frac{1}{4}$
No. 17.	Number of crown stays . . 110		
	Centre to centre of ditto, in copper-plate	4 in. by	$4\frac{7}{8}$
	Diameter of ditto	0	$0\frac{7}{8}$
No. 15.	Centres of firebox copper-stays	0	4
	Diameter of ditto	0	$0\frac{7}{8}$
	Pitch of thread on ditto	0	$\frac{1}{12}$
No. 39.	Area of fire-grate, square feet . 19·3		
	Surface of firebox, ditto . 110·0		
No. 19. *Tubes*—			
	Length	10	10
	Diameter outside	0	$1\frac{3}{4}$
	Thickness, B.W.G.	10 and 11	
	Number . 206		
	Outside heating surface, sq. ft. . 1022		
	Total heating ditto ditto . 1132		

			ft.	in.
No. 6.	*Smoke-box*—			
	Length outside		2	$7\frac{1}{8}$
	Breadth ditto		4	$11\frac{1}{4}$
No. 20.	Diameter of door		3	9
	Thickness of plates		0	$0\frac{3}{8}$
No. 22.	*Chimney*—			
	Height from the rail		13	2
	Diameter at bottom		1	5
	Ditto at top		1	4
No. 24.	*Blast-pipe*—			
No. 25.	Diameter at top		0	$4\frac{3}{4}$
	Area at bottom	90 sq. in.		
	Height from centre of boiler		1	$0\frac{1}{4}$
No. 61 plan.	*Pump*—			
	Number	2		
	Diameter of ram		0	2
	Stroke		2	0
No. 62 long. sec.	Diameter of delivery		0	2
No. 63.	Ditto of water supply		0	2
No. 30.	*Safety-valves*—			
	Diameter		0	$2\frac{1}{2}$
No. 31.	Total length of lever		1	6
	Centre of valve to fulcrum		0	$3\frac{3}{4}$
	Effective load of lever, valve, and spring per square inch	140 lb.		
	Number of valves	2		
No. 46 plan.	*Cylinder* (Horizontal)—			
	Diameter of cylinders		1	5
	Length of stroke		2	0
	Centre to centre		2	2
No. 36 long. sec.	Diameter of steam-pipe (two)		0	3
No. 90 plan.	Ditto piston-rod		0	$2\frac{3}{4}$
	Centres of valve-spindles		0	$5\frac{1}{2}$
No. 48*a*.	Diameter of valve-spindles		0	$1\frac{3}{4}$
No. 47 long. sec.	*Ports*—			
	Length		1	3
a and *b*.	Breadth of steam		0	$1\frac{1}{2}$
c.	Ditto exhaust		0	2
Fig. 3.	*Slide-valve*—			
	Travel		0	4
	Lead		0	$0\frac{1}{8}$
	Lap outside		0	$0\frac{7}{8}$
	Throw of excentric	$5\frac{1}{2}$ by $2\frac{3}{4}$ in.		
	Breadth of excentric		0	$2\frac{1}{8}$
	Length of excentric-rods		4	10
No. 53 long. sec.	*Connecting-rods*—			
	Length		6	6
	Diameter at small-end		0	$2\frac{15}{16}$
	Ditto big-end		0	$3\frac{1}{2}$

		ft.	in.
	Ditto of bolts at big-end	0	2⅛
	Ditto of cross-head gudgeon	0	3
D plan.	Length of slide-block	0	11
	Wheels—		
No. 82 long. sec.	Diameter of leading-wheels	4	6
81 „	Ditto of driving ditto	6	9
80 „	Ditto of trailing ditto	4	6
E	Centres leading to driving	8	0
E	Ditto driving to trailing	7	9
E	Total wheel-base	15	9
	Between backs of tyres, leading	4	5½
	Ditto ditto driving	4	5⅞
	Ditto ditto trailing	4	5½
No. 54 long. sec.	*Crank-axle—*		
	Diameter at centre	0	7½
F plan.	Ditto in nave of wheel	0	8¼
No. 55 long. sec.	Ditto of crank-pin	0	8
No. 56.	Crank-arm	11 by 4⅝ in.	
H plan.	Diameter of inside bearings	0	8
H	Length of ditto	0	8
H	Centres of ditto	3	11¼
F	Depth through nave of wheel	0	7⅛
F	Diameter of nave ditto	1	4½
Nos. 89, 88.	*Leading and Trailing Axles—*		
	Diameter at centre	0	6½
	Ditto in nave of wheel	0	8¼
	Ditto of bearings	0	7
	Length ditto	0	8¾
	Centres ditto	3	11¼
	Depth through nave of wheel	0	7⅛
	Diameter of ditto	1	2½
No. 43.	*Inside Frames—*		
	Distance apart inside	4	1½
	Least depth	1	3
	Thickness	0	1
No. 65 long. sec.	*Driving Springs—*		
	Volute (2) 11¾ long, diam.	0	$7\frac{3}{16}$
No. 83 long. sec.	*Leading and Trailing Springs—*		
	Length	3	6
	Breadth	0	5
	Depth	0	6½
	Camber, loaded	0	3½
	Centre of boiler from rail	7	3½
	Foot-plate from rail	4	0
	Width of platform	7	2

	tons	cwt.
Weight on leading wheels	10	8
Ditto driving ditto	14	0
Ditto trailing ditto	8	12
Total weight of engine empty	33	0

CHAPTER III.

CHARACTERISTICS OF GOOD-WORKING ENGINES PERFORMING LONG RUNS.

THE "PANDORA" EXPRESS LOCOMOTIVE, BY MR. JOHN RAMSBOTTOM.

THE "Pandora" is an express passenger locomotive of the class of the "Lady of the Lake," designed and constructed by Mr. John Ramsbottom for working the Limited Mail and the Irish Mail trains on the London and North-Western Railway. The chief features of interest in the engines of this class (Fig. 6 *e*), from the engine-driver's point of view, are that they steam well and run well. It is a sight worth seeing, and not easily forgotten, to view these engines steaming away across the Trent Valley—worthy of the descriptive pen of Elihu Burritt:

> "A tale like 'Waverley' we yet may scan;
> But shall we read a lay like 'Marmion.'"

The steam-generating properties of these engines have been found by experience to be remarkably good. They will take a moderate load at express speed with a consumption of 22 lbs. of Welsh coal per mile.

The barrel of the boiler is formed of three rings of plates $\frac{7}{16}$-inch thick, arranged telescopically. The covering plate of the firebox is made to form a straight-

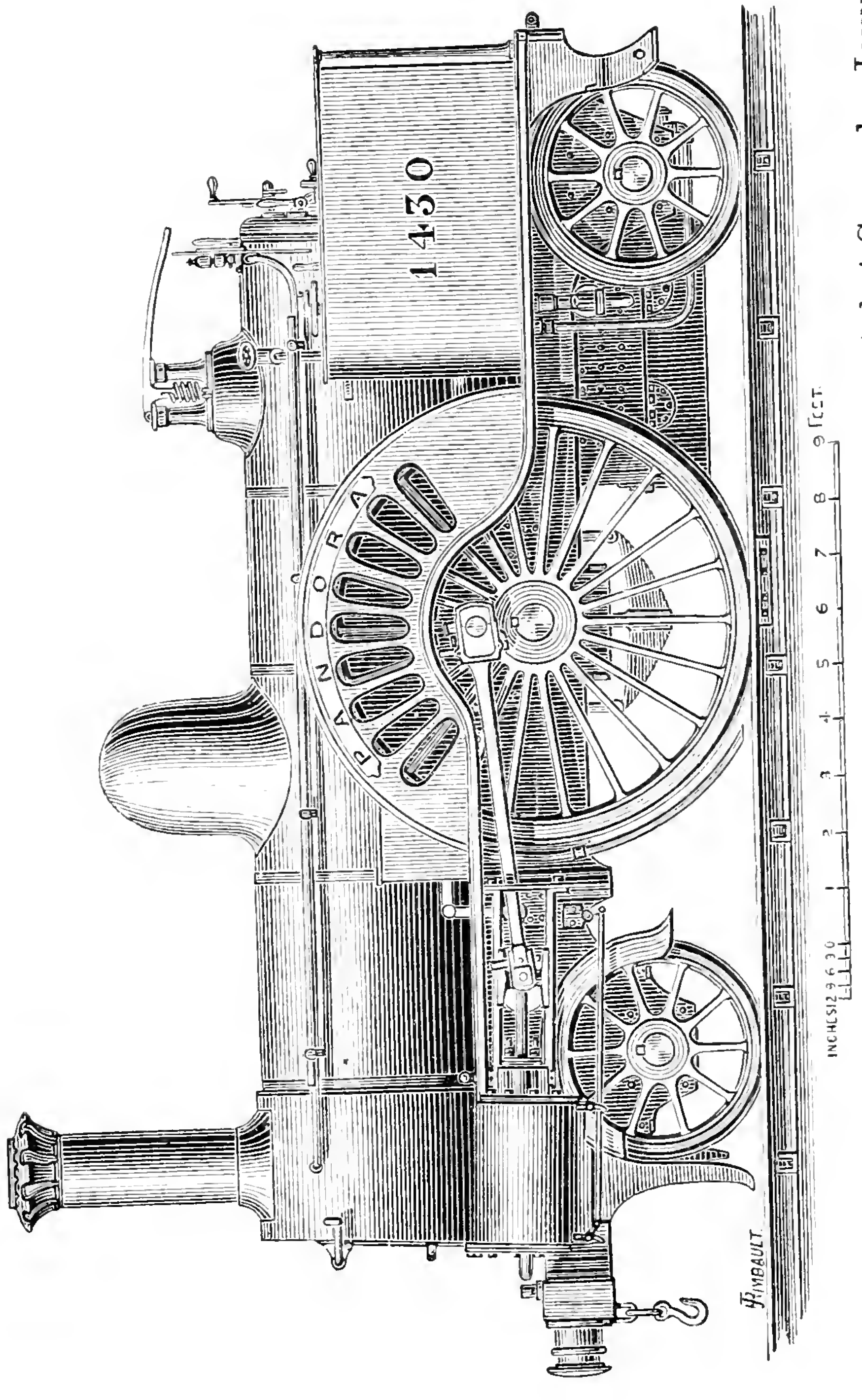

Fig. 6*e*.—"PANDORA," an Express Engine, designed and constructed at Crewe, by JOHN RAMSBOTTOM, Esq., late Locomotive Superintendent L. & N. W. Railway.

backed boiler, the centre of which is 6 feet 6$\frac{5}{8}$ inches above the rails, and the mean internal diameter of the barrel is 3 feet 10$\frac{3}{4}$ inches.

The copper firebox is 4 feet 1$\frac{1}{2}$ inches long, 3 feet 6 inches wide, and 5 feet 4$\frac{1}{2}$ inches high.

The copper stay-bolts uniting the shell to the copper firebox are 4 inches apart, centre to centre, vertically and lengthwise.

The boiler is fitted with 192 tubes of brass 1$\frac{7}{8}$ inches in external diameter, and they are placed $\frac{3}{4}$-inch apart.

From the above dimensions we obtain for the tubes 1,013 square feet of heating surface for the firebox, and 85 square feet of heating surface, and 14.9 square feet of grate.

It therefore appears that the boiler is somewhat smaller than what is now generally made for heavy passenger traffic; and it is necessary to explain that the "Pandora" class was designed and built by Mr. Ramsbottom many years ago, and when the traffic was much lighter; but as the engines were models and favourites, it was thought desirable and worthy to give them a place in this volume. Subsequently, Mr. Ramsbottom designed other engines that steamed and ran admirably, of the 4-wheel coupled class, to meet the demands of the traffic requirements on the heavier portions of the line; but the drivers never took to these engines as they did to the "Pandora" class. This is like Englishmen; they like to see big things—big ships, big bells—Big Ben—big wheels. Go to King's Cross station, Great Northern Railway, when one of Mr. Stirling's engines stands there, "champering and foaming," waiting for the signal; and then go to St. Pancras when one of Mr. Johnson's magnificent bogie-engines is going away; and, although both engines are superb and designed for special work, the 8-feet driving-wheel acts as a kind of magic and "brings down the house."

Turning again to dimensions:—

The driving-wheels of the "Pandora" class are 7 feet 7½ inches, cylinders 17 inches by 24 in.

The piston, Mr. Ramsbottom's patent, has three grooves in it to receive three steel rings, each ¼-inch square, which keeps the piston steam-tight. These steel rings are sprung over the piston into the grooves.

The safety-valves, "Ramsbottom's patent," consist of two 3-inch valves fitted into two brass pillars pressed down by a cross-bar with a spiral spring attached to the centre of the bar between the two valves—an arrangement that cannot be locked. The valve is prompt in discharging any quantity of steam of excessive pressure.

When the end of the lever is pressed upwards by the driver, it eases the valve nearest to him, and when pulled downwards, it eases the other valve.

The steam-pipe in the boiler is 5½ inches, and in the smoke-box 3¾ inches in diameter.

The slide-valves are moved by excentrics having 2½ inches radius, or 5 inches total throw, and connected by rods 3 feet 10 inches long, to a link of 3 feet 10 inches radius. The valves have ⅞-inch lap at each end, and $\frac{1}{32}$-inch inside lap, with ¼-inch lead.

The orifice of the blast-pipe is 4¼ inches in diameter. The chimney is cylindrical, 15½ inches in diameter; the top is 13 feet 1 inch from the rail.

The connecting-rod is 6 feet 2 inches long, centre to centre; the crank-pin, fitted into the crank-bossed driving-wheel, is 4½ inches in diameter, and the cross-head pin 2¼ inches in diameter—half the diameter of crank-pin.

The axles are all of wrought-iron case-hardened.

DIMENSIONS OF AXLES.

	Journals.	Body.	Ends in wheel
Leading . .	6″ × 10″	5½″ dia.	7½″ × 6½″
Driving . .	7″ × 7″	6½″ ,,	6½″ × 8½″
Trailing . .	6″ × 10″	5½″ ,,	7½″ × 6½″

Wheel base	14 ft. 9 in.
Weight	27 tons.

EXPRESS LOCOMOTIVE, BY MR. PATRICK STIRLING.

The engine illustrated by Fig. 6*f* may be accepted, by reason of its dimensions and the work it performs, as ably representing a good type of an English single engine. The cylinders are 18 inches by 28 inches, and the driving-wheel is 8 feet in diameter. Engines of this class run from London to Grantham, with the steam on, a distance of 105 miles, and, as Mr. John Hollingshead says in one of his "Odd Journeys," drag us "out of the sunlight into the mist, again out of the mist into the sunlight, past undulating parks rich with the red-brown tints of autumn; past quiet pools and churches in among the hills; past solitary signalmen and side stations, where weary engines rest from their labours; past hurrying trains, with a crash and a whirl, and away." The above is the longest daily run without a stop, made in England; performed day after day with complete success, much to the satisfaction of the "gods" who are in a constant state of migration between the Tweed and the Thames,

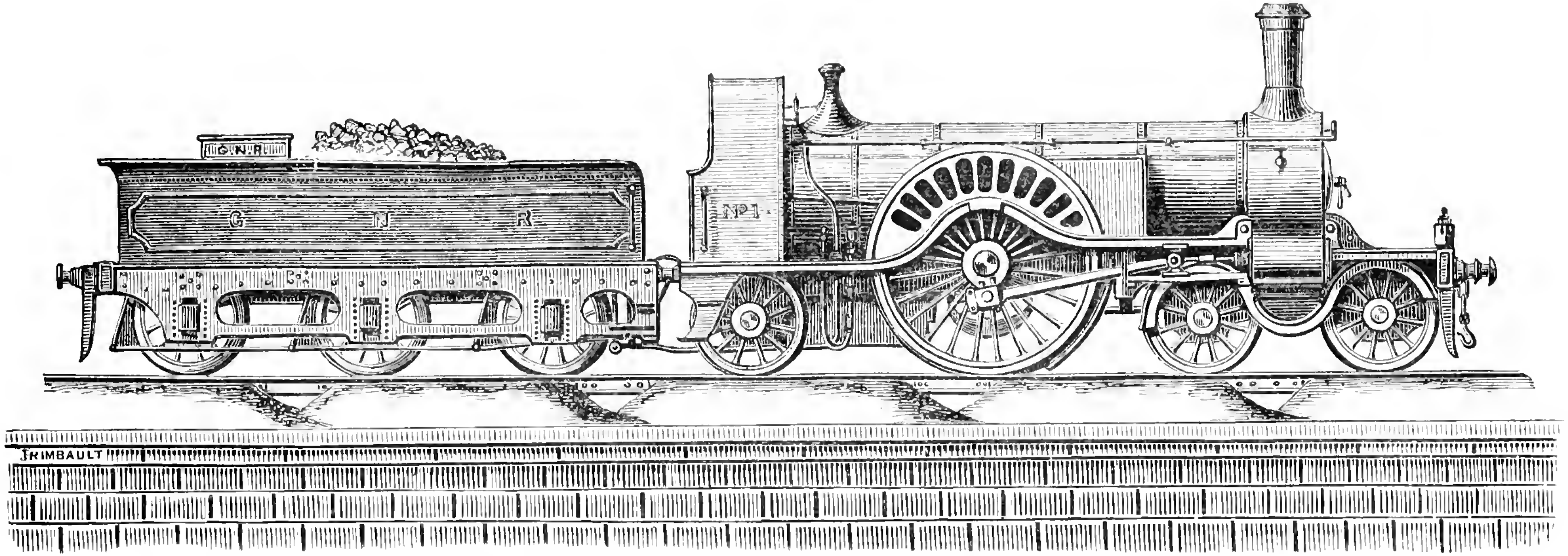

Fig. 6*f*.—Express Locomotive, by Mr. Patrick Stirling, Locomotive Superintendent, Great Northern Railway, Doncaster.

and who enjoy a bold bit of enginemanship. The service done by these engines is well done, and the trains they work are very popular.

The impression made by one of these beautiful mechanical constructions upon any observer is one of admiration. Few indeed could withhold from it the praise due to a piece of work which is considered by well-qualified judges and by people of taste and authority to be a masterpiece. It has marks of the "go" about it, and is really a fine engine.

DIMENSIONS AND PARTICULARS OF THE 8-FEET PASSENGER ENGINES OF THE GREAT NORTHERN RAILWAY.

Outside Cylinders—	ft.	in.
Diameter	0	18
Stroke	2	4
Diameter of driving-wheels	8	0
Wheel base—		
Bogie-wheels, centres	6	6
From centre of bogie-pin to driving-wheel	10	9
From driving-wheel to trailing-wheel	8	8
From trailing-wheel to centre of bogie-pin	19	5
Extreme wheel base	22	11

Heating surface in tubes	1043	square feet,	external.
,, ,, firebox	122	,,	,,
Total	1165		

Weight on Wheels—	tons	cwts.	qrs.
Bogie leading	7	0	0
,, trailing	8	0	0
Driving	16	0	0
Trailing	9	10	0
Total	40	10	0

Capacity of tender for water	2,700 gallons
,, ,, coal	3½ tons.
Average consumption per train-mile of Yorkshire steam-coal	26 lbs.

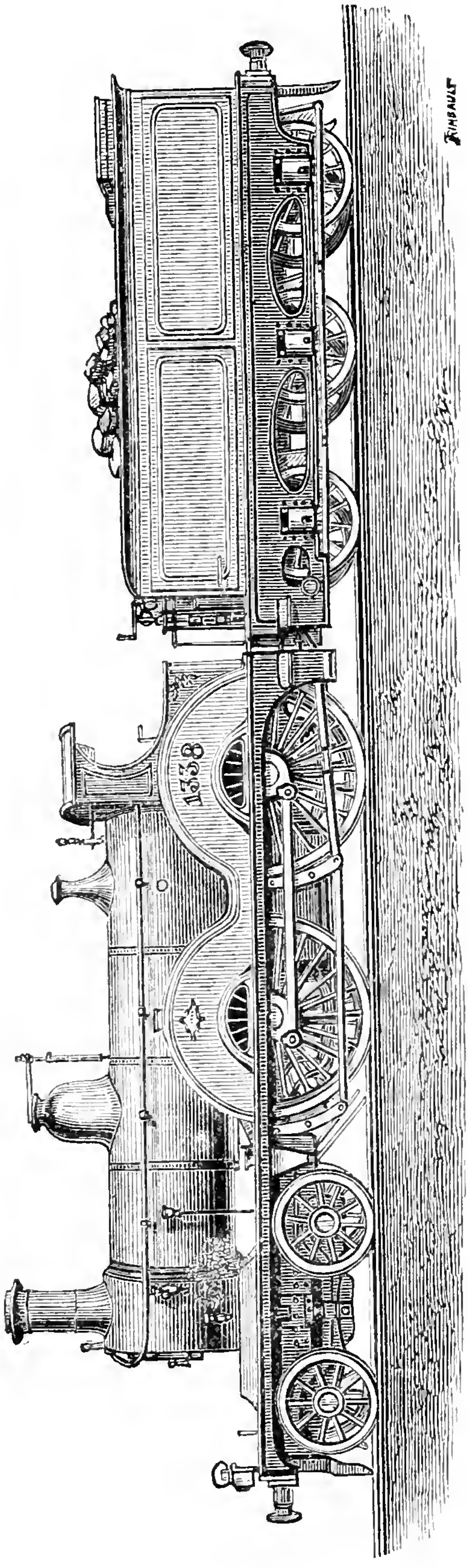

Fig. 6*g*.—An Express Bogie-Engine, designed and constructed by Mr. S. W. Johnson, Locomotive Superintendent, Midland Railway Company, Derby.

Express Bogie-Engine, by Mr. S. W. Johnson.

This very handsome express engine may be accepted as a model of its class. It is specially well proportioned. The greatest degree of attention has been given to the perfecting of the design of the engine, even to the most minute details; and the result of such well-directed study has been a beautiful form, commanding admiration as a mechanical achievement of the highest order.

The class of engines here represented run very steadily at high speed, either on curves or on straight lines. They can draw 14 carriages at a speed of 50 miles per hour from London to Leicester, a distance of 100 miles, without stopping intermediately. The line is constructed with gradients averaging 1 in 300. The fuel consumed on this work is 28 lb. of ordinary Derbyshire coal per mile. The boiler is fed by two of Gresham's non-adjustable single cone injectors, one of No. 7 size and one of No. 8. The No. 7 size injector is fitted on the left side of the boiler, and for ordinary work will, when continually in action, keep the boiler supplied with water. The No. 8 injector is turned on during heavy-working and in very rough weather; or in case of the failure of No. 7. This arrangement of injector is generally adopted, providing a continuous supply and preventing the waste of water necessitated otherwise by frequent starting and stopping of the injector.

The bogie of this engine is arranged on Adams's system. The tender is capable of holding 2,900 gallons of water, and carries about 4 tons of coal.

Some of these engines are fitted with steam-brake on both the engine and the tender. The chief dimensions of these engines are as under—

	ft.	in.
Diameter of cylinder	1	6
Stroke of piston	2	2
Diameter of wheel (coupled)	7	0
Ditto ditto (bogie)	3	6
Wheel base—centre of bogie to centre of tracting axle	18	6

Heating Surface—

Tubes	1,150 sq. ft.
Firebox	110 „
	1,260 „
Grate-area	17½ „

Differences of Sister Engines.—It is an old saying on railways that no two sister engines were ever built that would steam and race alike. This is true. The difference cannot, of course, be attributed to the drawings or the templates from which the engines were made. It is, for the most part, due to the putting of the parts of the engines together; for no two engines ever were put together geometrically alike; and even when they are very nearly identical in the erection, they may be, and have been, made very unlike by so simple a matter as the construction of the brick arch by the "brickie" in the firebox. Arches may be too long, too short, too high, or too low. They may also be rendered unlike by following slightly different lines in cementing the smoke-box—probably the most sensitive member about a locomotive engine. There are many other ways of explaining why a difference should exist between sister engines. It may be in the castings of the cylinders, in the copper of the firebox, in the valves, or in the chimney. But, whatever it may be, an engineer may, by close observation, be enabled soon to detect its true locality and its cause.

Free Running.—To secure a free-running engine, the crank-axle, when in its position, must be exactly at right angles to the centre-line of the cylinders, and absolutely parallel to all the other axles; for when these important parts are not in line with each other, the want of parallelism occasions a host of calamities too numerous to be mentioned. It causes a sinuous motion. Want of parallelism excites a constant tendency to roll the engine in a curved path, always toward the same side, so causing the flange of one wheel to wear away rapidly, while the other wheel on the same axle may have its flange in good form.

Steadiness and Safety.—To secure a steady and safe engine, the oblique action of the connecting-rod, which produces pitching and rolling, by lifting the engine up when steam is on the piston, and dropping it again when it is exhausted, must be neutralized to a greater or less degree by suitable springs. Again, the fore-and-aft movement of the engine which would arise from the reciprocation of the piston and its appendages—a movement independent of any unsteadiness by the pressure of the steam—is neutralized by the counterweights which are placed between the spokes of the wheels. The leading wheels, which guide the engine laterally, are placed well forward, and to get the wheels so placed the cylinders, in some engines, are inclined. In other engines, bogies are used, with horizontal cylinders, as, for instance, in the express engines built at Doncaster by Mr. Patrick Stirling (Fig. 6*f*), and those made by Mr. Johnson at Derby (Fig. 6*g*).

The driving-wheels, or rather the crank-axle, is placed well backward toward the firebox, which places the centre of gravity, and consequently a preponderance of the weight of the engine, in advance of the axle. By this arrangement the disturbing influence of the connecting-rod is subdued; and, besides, a longer connecting-rod than can be got otherwise is admitted, which also contributes to reduce the pitching and rolling movements.

The trailing-axle is placed well backward, and checks any pitching movement better than if it be placed more forward. The springs, at least for the leading and trailing axles, are placed well apart; and they are of sufficient strength promptly to absorb the rolling motion.

The height of the centre of the boiler from the rails, within reasonable limits, is not an element which affects materially the stability of the engine when running at high speed. There is no doubt, in fact, that the safest engines running are high-pitched.

The distance from the centre of the trailing-axle to the centre of the leading-axle is the measure of the wheel-base of the engine.

CHAPTER IV.

TO SET THE SLIDE-VALVES.

THE slide-valves are set thus:—First, the valve is placed in the steam-chest, with the spindle attached, so that one edge of either the front or the back steam-port is just uncovered; and the position of the spindle is marked outside of the gland, and also upon the stuffing-box. The distance between these marks corresponds to the distance between the two points of a trammel used by the valve-setter. The valve is shifted, and the spindle again marked, with the steam-port a little open, at the opposite end of the cylinder; the punch mark on the stuffing-box used in the first instance serves again; and therefore, in this case, all that is required is to place the leg of the trammel into it and mark the spindle with the point of the other leg.

This operation is also performed with the other valve; and, all things being ready, the steam-chest cover may then be put on. After the valve-spindles are connected to the links and the eccentric-rods in their places, the next step is to try the engine over, with the reversing lever in the best working position, which is that in which most engines beat the best, and do the most work.

The engine is moved by pinch-bars, until one cross-head is nearly at the end of the stroke, when it is stopped. A perpendicular line is made by a steel scriber on the side of the slide-block and slide-bar, so that the engine may be put exactly into the same position again. Before the engine is moved another mark is made on the frame-plate, and also upon the face of the tyre of the driving-wheel, to be used, like the marks made elsewhere, to obtain relative points. In the centre pop in the frame one leg of a trammel is placed while the other is extended to the face of the tyre and marks it; here another pop is made. The engine is again moved until it has passed the dead-centre, and the slide-block has reached the same position it occupied when it was before marked. This position is determined by the scribe marks on the slide-block and slide-bar. When this position is attained, the leg of the trammel is placed in the same centre mark in the frame and the other point of the trammel marks the face of the wheel at another place, which is fixed by a centre pop.

Two relative points are thus obtained upon the face of the wheel, the distance between which is bisected with a pair of compasses, and a third point is made midway between them. The engine is then moved back until one point of the trammel, with the other in the frame-mark, drops into the third or middle point of the three. On a little reflection, it will clearly appear that, when the above conditions are obtained, the engine is exactly on one dead-centre, with the connecting-rod and the crank in a horizontal line. Now, it is already known when the valve is open a little, from the valve-trammel and the marks upon the stuffing-box and the valve-spindle ; and, therefore, the valve-setter may ascertain exactly, by means of the trammel, whether the valve is open or not, when the engine is on the dead-centre; or, further, he can ascertain exactly, to a hair-breadth, the position of the valve in relation to the piston at any point of the stroke.

The centres are all found in the same way; and, when there is any difference in the leads, the eccentric-rods are either shortened or lengthened until the motion is "square."

There is, however, another method of setting valves, when the dead-centres are found as above. Four wedges are provided and marked R.F., R.B., L.F., L.B. The first one, right front, is, when the steam-chest cover is off, inserted into the port as far as it will go, assuming that the engine stands on the right front dead-centre. The wedge is run up and down by hand in the opening, that it may be marked or scribed by the edges of the port and the valve. It is then withdrawn, and the amount of opening, gauged by the marks, by which the valve uncovers the port for steam, when the piston is in the above-named position, is clearly seen and may be measured. The piston is moved to the other centres, and the respective amounts of opening are obtained in the same manner. The wedges are then compared, and, being lettered, any difference in the leads is discovered, and is rectified.

When the valves are to be finally set the boiler should be warmed, and should have about two inches of water in the gauge-glass; the motion also should be at a working temperature. Thus all uncertainty respecting the expansive working of the steam is excluded. Moreover the engine may, in this condition, be moved freely by pinch-bars.

CHAPTER V.

HOW TO BECOME A MODEL ENGINE-DRIVER.

THE most important questions that can be asked by an aspirant of the foot-plate is, How can I best be taught? and, How can I best learn locomotive driving?

To learn anything well, a great philosopher hath laid down three things most essential, namely, models, rules, and practice.

The foot-plate of a locomotive engine is the only place where experience can be acquired of the ways in which it is possible for an engineman or an engine to go wrong.

During the time that an engine is under steam with a train, everything seen, heard, felt, and smelt is capable of affording a lesson. On the engine foot-plate the eye is trained to distinguish different colours at considerable distances. The ear learns to detect the slightest variation in the "beats" and knocks about the machinery, it learns to distinguish the difference between the knock of an axle-box and the knock of a journal. The human frame learns to distinguish the shocks, oscillations, &c., which are due to a defective road from those which are due to a defective engine. The olfactory nerves become from experience very sensitive, so as to detect the generation of heat from friction before any mischief is done.

It is only whilst an engine is in steam and going at good speed that the rocks, coral-reefs, and sand-banks on railways can be seen and learned; and the value of, and rank acquired by, an engineman, are proportionate to the pains that he takes to find them out, and to mark their dangerous position upon his chart. Just by so much as there is of this inquiring spirit within a man will he achieve success.

It is very natural for those who are unacquainted with locomotive driving to admire the life of an engineman, and to imagine how very pleasant it must be to travel on the engine. But they do not think of the gradations by which alone the higher positions are reached; they see only, on the express engine, the picturesque side of the result of many years of patient observation and toil. Among the masters of the iron horse we shall find models; but they are not all models on the express engines.

The Model Engine-driver.—A model driver is distinguished for the fulness of his knowledge of the engine. He is possessed by a master-passion—a passion for the monarch of speed; and whatever contributes to enlarge his stock of information concerning it, contributes to his happiness. Thomas Telford, who designed and erected the Menai Bridge, Conway, North Wales, used to say to his friends, when they endeavoured to introduce political topics into their conversation, "I know nothing about politics; talk about *lime*." What then? Why, he was in his element. A model driver is just as much at home about engines as Thomas Telford was about "lime." Pointing to any particular class of engine, or part of an engine, he can inform his friends that such an engine was built by Timothy Hackworth.

Further, he can tell them what railway engines everywhere owe to that engineer. He can single out a Sharp's, a Wilson's, or a Slaughter's engine. "Look here," says he, "that big-end was in use when I was a boy: it went out of date, and now Mr. So-and-So has adopted it. This piston was brought into use by an eminent engineer, now retired, namely, Mr. Ramsbottom, late Locomotive Superintendent of the London and North-Western Railway. That radial axle-box is Mr. Bridges Adams's patent; this carriage-wheel is Mr. Mansel's; that is the straight-link invented by Mr. Allan; and that is the box-link." He is able and pleased to begin at "Puffing Billy," 1825 (Fig. 7), and to trace the historical progress of the locomotive to the present time.

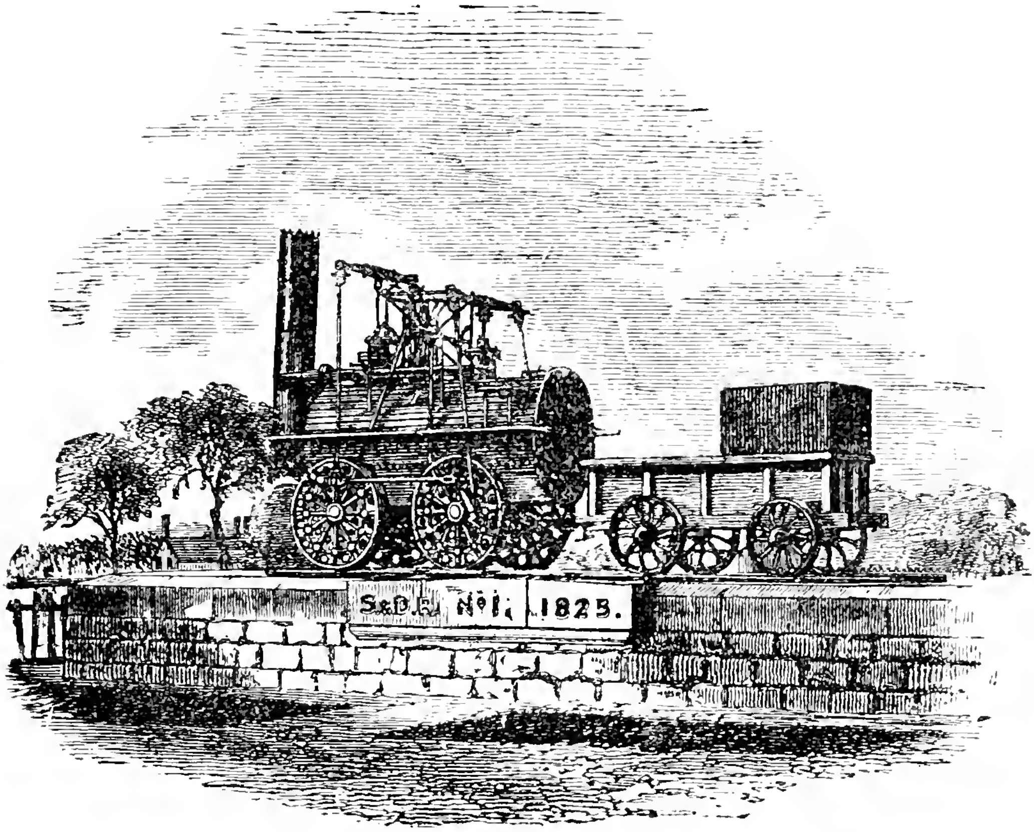

Fig. 7.—Puffing Billy, 1825.

The model driver is a good fireman. A man may be a first-rate mechanic; he may have worked at the best class of machinery; he may have built engines, and have read all the published books on locomotive engines; and yet, if he be not a good shovel-man, he must be classed with the men who, as Shakespeare says, are "of no mark or likelihood," for he will never be a first-rate driver; his firing must be first-rate who possesses the like quality of driving, for the power of first-rate firing is a qualification indispensably necessary for, and inseparable from, first-rate driving. For such reasons it is that, as a rule, mechanics make but indifferent enginemen. A good fireman knows *when* to put the coals on, *how*, and *where*, and the right quantity required at each firing.

A model driver is *clean*, and, depend upon it, his engine is clean also. The man costs the company less than other men in paper, and his engine costs the least for repair. Ask all the locomotive superintendents in Europe if this is not a fact. Cleanliness is said to be next to godliness. Upon a railway, it may with truth be said, that cleanliness is next *below* the highest talent, and next *above* length of service. A clean driver frequently scales the ladder of progress much faster than a dirty driver, although the latter may have experience in his favour. There is something so very degrading about dirt, that even a poor beast highly appreciates clean straw. Cleanliness hath a charm that hideth a multitude of faults, and it is not difficult to trace a connection between habitual cleanliness and respect for property, for general order, for punctuality, for truthfulness, for all placed in authority. It is for ever associated with a kindly feeling towards poor dumb animals.

If we glance at those men who have raised themselves into the position of first-class inspectors, drivers, and firemen, we shall find each individual blessed with some special qualification, but the predominating one will be found to be cleanliness. Did we ever see an engineman get on who wore dirty, greasy cap, coat, vest, and trowsers, shining like velvet. And, on the contrary, did it ever occur to us that the greatest torments upon a railway, both to themselves and to others, are those who are habitually dirty, who carry the prime marks of their inner man outside. A model driver runs the most important trains, makes the longest run without a stop, makes the longest run with fewest stops, and he runs every trip with undeviating success, day after day.

The "Limited" and the "Irish" mails are two very important trains; and the engine attached to the latter train ran for years, until recently, the longest distance daily between two stopping stations without an intermediate stoppage—Holyhead and Chester, ninety-seven miles.

Both of the above trains are run with marked punctuality. Moreover, some of the Crewe "engineers" run from Crewe to London and back in ten hours, a distance of three hundred and thirty miles, including a stoppage of three minutes at Rugby each way. It should be mentioned that they remain about two hours in London before starting on the "down" trip. This is superior running; and, what is more, it taught others what was possible to be performed day after day, and all the year round, without any time being lost by the engines, or delays booked to "loco."

How Successful Driving is attained.—A philosopher has written "a frequent similar effect argueth a constant cause." What is then the cause of constant successful locomotive driving? Not length of service, for it would be easy to give cases in which young drivers have eclipsed older drivers. Not because a man has served so many years upon the goods train, and been promoted, by order of seniority, to driving the passenger trains, for the best drivers upon all railways are those who have been promoted over the heads of others because of their *brightness.* "Promotion according to merit in this establishment," is a notice that should be posted in some conspicuous place in every running-shed in England. Chance never built an engine, and it can have nothing to do with the driving of an engine. Yet, when driver A retires, or dies a natural death, or is killed, driver B is promoted; he may be as dull as ditch-water, and driver Y as bright as silver; but on the chance death of A, nevertheless, B is promoted. Driving, to be good, must be based upon rules and principles. He who strictly observes them, wins; he who does not, loses. With the latter class all is uncertainty, the hand trembles upon the regulator, the eyes watch with painful anxiety the needle of the pressure gauge, and gaze into the fire to find out its deficiencies, and are sometimes stricken with blindness in the attempt. Nothing unpleasant of this kind occurs to an engineman who has a reason for every act performed, either by himself or his mate, upon the foot-plate. He works to rules and principles that have proved themselves, a thousand times over, safe, practical, and certain in their results. Sound rules and principles are absolutely sure in the effects of their application ; not right to-day and wrong to-morrow ; not right on a short trip and all astray on a long trip ; not right with one particular engine and wanting with a different engine ; not right the first part of the trip and found wanting at the end ; not right with one class of coal and wrong with another. Under the guidance of sound rules and principles, the mind of the driver is free ; and he is enabled, under all circumstances, to handle the regulator with confidence, to travel with a boiler full of steam, and to finish with success. In a word, there are rules and principles which lead up to, and command the attainment of, successful locomotive-driving.

CHAPTER VI.

DUTIES OF AN ENGINE-DRIVER.

Rules and Principles.—The Notice-Board.—Before going to his engine, every engineman should, for his own safety, as well as that of the public, visit the special and the general notice-board. By the non-observance of this simple rule, on one occasion, a driver lost his life, and so also did his fireman. By incessant rain a river had become so swollen that, by the rush of water, the buttresses of a wooden railway bridge became shifted. The bridge was inspected, and one side of it was pronounced to be dangerous. Arrangements were made to work the traffic "single road," and "notice" of such arrangements was posted in the running-shed. The driver neglected to read the notice; he ran his train past the man appointed to pilot him over, and got off the metals down an embankment. The regular fireman came late on duty, and was sent home again, "*until wanted;*" an extra fireman was sent to do his work, and while the poor fellow, no doubt, was striving to do his best, and probably rejoicing to think that he had come down to the shed in good time to secure a trip, he was suddenly summoned into another world.

After a driver has read the special notices, and made himself fully acquainted with them, and has also looked at the weekly lighting-list AGAIN, he proceeds to his engine. An inspection of the weekly lighting-list is important. Two drivers have been known to go off the same shed, chattering with each other, and when they got to the station, they found, in some strange way, that they both wanted to hook on to the same train.

Inspection of the Engine from the Foot-plate.—When on the foot-plate, the *first thing* that requires the driver's attention is the level of the water in the gauge-glass. He should ascertain whether the level, as it appears, shows correctly the height of the water within the boiler, by opening the lower cock in the usual manner. On being satisfied that the boiler is safe, he at once takes upon himself the responsibility of looking after it; and should anything prove to be wrong afterwards, he alone can be called to account for it. He should also observe what pressure of steam there is in the boiler, what is the condition of the fire, how much coal there is in the tender, and its quality; and, lastly, he should make sure that the tender is properly filled with water.

When a driver sees that his fame and his prospect as a first-class locomotive driver rests with himself, and on the condition in which he ventures to take his engine to a train, there is very little doubt that he will discover that his success depends in no small degree upon *the way* in which he examines his engine. In a word, he will feel that his reward is dependent upon his own industry, and that his case is no exception to the proverb, "Whatsoever a man soweth, that shall he also reap."

It may appear sufficient to some drivers to sow anyhow—by halves, roughly, or unsystematically; but such sowers generally reap pains and penalties, to their sorrow.

A model driver, however, knows from experience and reflection, that the only means by which he acquires and maintains his sovereignty over his engine consists in habitual, thorough, and systematic inspection; for in no other way is a man to become a model driver.

Inspection of the Engine, over a Pit, in Shed.—It is a good and safe rule to examine an engine over a pit before leaving the shed; and, whenever it is done properly and regularly, the habit is unmistakably the mark of a thorough driver. Whoever, on the contrary, thinks that such painstaking is unnecessary, does not yet, certainly, comprehend the secret of success in every calling of life.

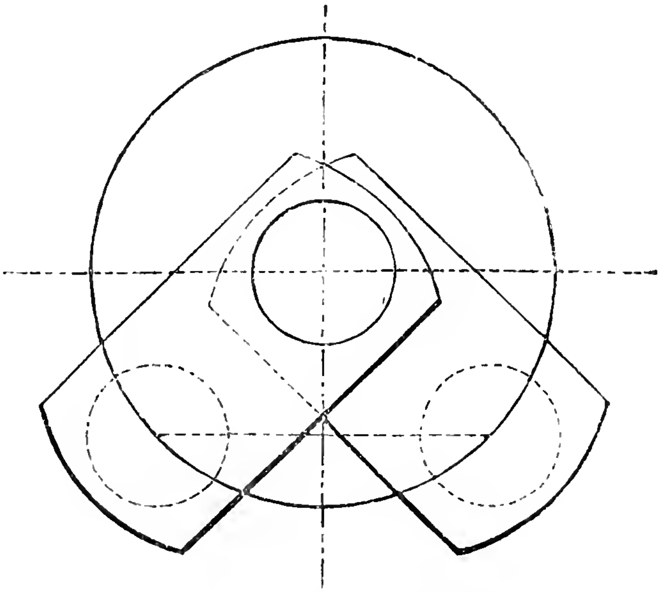

Fig. 8.—Position of the Cranks for the Inspection of an Engine.

That an engine may be properly examined over a pit, it is necessary that it should be placed in such a position that every part of it may be seen and inspected without having the machinery moved. The annexed figure (8) is intended to show in what position the cranks should be placed to secure this advantage. The brake should be screwed hard-on, the cylinder-cocks should be open, and the reversing-lever should be out of gear. Many excellent drivers have lost an arm by neglecting to place the engine under the above-named conditions before going underneath to make their examinations.

The examination, to be complete, should be commenced at one specified point, and conducted systematically all round the engine, until the driver returns to the place where he began. In general, the only tools which he requires to carry with him are two gland spanners and one set-pin spanner. The two former should be alike, having one end made to fit the piston-gland nuts and the other for the spindle-gland nuts, for by this arrangement means are provided for locking the nuts. The other spanner should have one end made to fit the set-pins, which hold the keys in the big-ends and the little-ends, and the other end to fit the nuts on the big-end cotters.

The inspection should commence at the trailing engine-axle, on the driver's side; and the best rule is to examine everything, not forgetting the fact that more engines break down and detach themselves from their trains in consequence of bolts and split-pins working out than from any other cause. After the driver's side has been properly scrutinized, the under side of the engine next claims attention. The driver should begin at the crank-shaft, taking his stand, where it is possible to do so, between the shaft and the fire-box whilst he is testing the bolts and nuts connected with it.

Big-ends.—Big-ends require to be fitted brass-and-brass to work well, and to be well cottered or bolted up, but with a sufficient slackness on the crank-bearing to allow of their being easily moved sideways by hand, so that a little room may be left for the expansion of the journal by heat. Before a brass of any kind is tightened up, it is advisable to mark the cotter—on the underside, generally—that it may show, when it is driven down, how much it descends at each blow. In performing this operation a lead hammer should in every instance be used. It looks like mischief to see anything else used on work got up nicely.

Big-end brasses do best, wear longest, and knock least, when tightened up a little at a time and often, instead of being allowed to run until they thump alarmingly. With proper attention they seldom run hot.

Big-ends require plug-trimmings made of copper wire and worsted. The wire should be from four to six inches long, doubled and plaited in the middle several times, and, in fact, very nearly the whole length; leaving a bow at one end which requires to be cut at the middle, and to have the cut ends opened out. The worsted is then wound over and over the two ends until the proper thickness is obtained. When fixed in the syphon pipe, the trimming should just clear the journal at one end, whilst the other end should be $\frac{3}{8}$ inch or $\frac{1}{2}$ inch *below the top of the syphon-pipe,* so as to form a very small reservoir for oil in the pipe, above the worsted or trimming. These plugs require to be adjusted to pass about four drops of oil per minute. Trimmings of the same kind are also required for the eccentrics and the outside-rods; but everywhere else tail-trimmings are needed. These are extremely simple; the worsted is placed on the middle of a straight piece of copper wire, which is then doubled and plaited several times, to bind the worsted just sufficiently to hold it. It is placed within the syphon-pipe, and pushed down to a position just clear of the axle, whilst the ends of the worsted lie in the oil. This trimming will supply lubrication as long as there is oil in the well. When possible, whilst the engine is standing or is placed in the shed, such trimming should be pulled out of the syphon-pipe, and placed on one side in the cup or the axle-box, until the engine is about to be worked again. Before replacing them, it is advisable to pour a little oil down the pipe, to allow time for the trimming to commence working. The adoption of this precaution assists, in many instances, in preventing the axle from cutting—a contingency which may arise from the sluggishness of the oil in the oil-chamber, caused sometimes by frost, or by the presence of glutinous matter. For such a reason it may be some little time before the oil begins to circulate, especially when the trimming is partially choked; and it is for this reason that, frequently, trimmings suddenly refuse to lubricate, and are wound up in a flare. Worsted is much cheaper than the lifting of an engine, and some thousands of hot axles would be prevented if drivers would only change a dirty trimming for a clean one a little more frequently, or see that it is done. When the spring-pin rests upon the axle-box-top, and the trimming is difficult of access, it is even then a matter of only a few *minutes* to place a screw-jack under the buffer-beam, and take the weight off, to admit of the renewal of the worsted.

Little-ends.—Little-ends fitted with steel bushes require scarcely any supervision, excepting what is required with the oil-feeder: those which are fitted with brasses held with gibs and cotters require the same attention that has been recommended to be given to big-ends.

Eccentrics.—When the eccentrics are being examined, particular attention should be bestowed upon the bolts, nuts, safety-cotters, and the set-pins and keys which hold them in their proper position, well to their work. The bolts that hold the two halves of each eccentric-strap together should always nip tightly, for not only do they help to maintain the lead of the valve, but any slackness, on the contrary, which they may have detracts very much from the efficiency of the engine. The eccentric-straps should be let up as often as may be required, and should not be allowed to work with a knock.

Inside-springs and Axle-boxes.—Inside-springs and axle-boxes require their full share of inspection, especially the interior of the latter, if it be left to the fireman to oil them; for whatever he oils the driver alone is responsible. The top of the axle-boxes and the bottom of the boiler should be free from dirt.

Gearing.—When the engine stands in mid-gear, the examination of the "links" can be done *under the eye.* That part of the machinery known as the motion is held together by pins, and not by nuts or keys, which require to be well looked after. It is astonishing what numbers of times these tiny split pins have brought the "iron monarch" and his guide to grief—a fact which we all know, more or less; and therefore it is well to remember that where many have failed caution is most necessary.

Glands.—The first thing to be done respecting glands is to see whether they stand fair with the rods—this is an important point. When they are quite square, one spanner should be held in the left hand, on the gland stud-nut nearest to the gland, and the other spanner should be held with the right hand upon the lock-nut, which should be screwed close up to the first nut.

Every gland should be done in the same way each time that the engine leaves the shed ; and drivers running long trips should repeat the examination before they attach the engine to the train for the return trip.

Piston-rod, &c.—The piston-rod crosshead-cotter, the valve-spindle crosshead-cotter, and the pump-ram crosshead-cotter, when they have split pins underneath, require to be attended to *every time* the engine goes out of the shed.

In some kinds of engines, the leading axle-boxes are sometimes full of water after the boiler has been washed out. When such is the case, the water should be mopped out with a piece of waste or with the end of a cloth.

Ash-pan.—When the examination of machinery has been finished underneath, the fireman should open the ash-pan door, or damper, so that the driver can have a good view inside the ash-pan. It should be nicely raked out, especially in the corners, where most firemen neglect it ; and a first-class driver will see that his mate performs at least this part of his duties to his satisfaction. It is not unfrequently the case that, in consequence of the ash-pan having been imperfectly raked out, the hot cinders roll out of it when the engine is at work, and, after coming in contact with the ballast, rebound into the wood work about the boiler, and set on fire the lagging. Further, the driver will also see that each fire-bar is well down on the cross-bearers, and that the fire is bright and free from clinkers. The presence of clinker can be detected by observing that the fire looks black or dull. A clean ash-pan, with grate-bars well down on the cross-bearers, makes a driver feel, when called upon to give his engine the "stick," in consequence of a strong side-wind or of extra traffic, that the source to which he must look for deliverance from the "lost time list" is perfectly sound and trustworthy.

Smoke-box.—When the driver has finished his inspection underneath, his first business, when standing at the fireman's side of the engine, is to see that the chimney-end, or, more properly speaking, the smoke-box door, is securely fastened. Sometimes, after the cross-bar has been taken out to get at the wash-out plug, or the tubes, it has been put in again wrong side outwards; and although the handles of the door may have been screwed up tight, *still the door was not tight.* But the driver, when he examines the door, and the position of the *hands on the screw,* can see at a glance how matters stand. The door should be made air-tight, in order that plenty of steam may be made. The fireman's side of the engine requires the same careful overhauling as should be given to the driver's side: springs, spring-hangers, hornstay-bolts, splasher-bolts, sand-pipe, feed-pipes, and everything that can possibly come to pieces, should never escape inspection.

Brake.—The brake-screw demands special notice, for the constant duty discharged by it, especially upon engines working into terminal stations. When it is neglected and allowed to get into bad working order, it is just as liable to strip the thread when entering a terminal station as it is at some country place, where no risk or damage need follow from its inefficiency. The way to test the brake is to turn it on so that it fetches the brake-blocks just up to the tyres of the wheels, and then observe, as it is taken off, the distance traversed by the handle of the brake before the screw begins to slack the blocks from the tyres. The driver will then have no difficulty in forming an opinion respecting its condition, especially if he thinks about the matter—a new screw and nut would move the blocks instantly when the handle, or hand-wheel, is turned either "on" or "off." Many failures have occurred in consequence of the working out of the split-pins in the brake-irons. But it is impossible for them to work out if they are properly opened and looked after. Beware of split-pins.

Screw-shackle.—The screw-shackle at the back of the tender must be examined every time the engine is to go out. To do this, and to see that its connections under the tender are in proper working order, the driver should stand in the pit. After having satisfied himself that his engine will stick to the train, barring unforeseen accidents, he should proceed as far as the trailing engine-axle, under the foot-plate, and examine it, with the draw-pin and its cotter, the feed-pipes, side-chains, and everything else that he can see that might possibly become uncoupled. All that now remains for inspection is the driver's side of the tender, beginning at the trailing-end and concluding this minute but absolutely essential examination at the leading left-hand tender-axle.

To put a gauge-glass in quickly, after it is put into its place, a driver should keep by him, in the little box, a small round piece of wood, which should be put on the *top* of the glass and the nut then screwed down on the top of the wood one or two turns: this will be found to keep the glass in its right place during the operation of packing, and it will do away with the troublesome tendency of the glass to lift up, when the packing in the top is being screwed up steam-tight.

Examination of the special notice-board, and of the engine both over and off the pit, coupled with a well-selected and properly arranged set of tools for the use and convenience of the fireman and the driver, have everything in them calculated to ensure the engine against a mishap ; but there is one more point that claims special attention, and which must be perfection before a start is made, and that is the *fire :* it must be right !

Condition of the Fire in the Shed.—There is nothing on which a driver's good name, success, and future prospects depend so much as on the condition of the fire at the beginning of the day's work. The old saying, that a good beginning makes a good ending, is very true of locomotive driving. If the fire is not well burned through at the start, however good the abilities of the driver may be, the consequence of its defects will be felt not only throughout the trip, but its influence will extend to the consumption list, and affect the driver's position on the face of it, to be seen and read by all men.

It is a habit with some firemen to arrive late on duty. They never think of coming on duty an hour or so before their booked time, even for the sake of having an excellent fire to begin the day's work with. Such individuals will of course in time be made drivers, but they never do anything sufficiently good to induce their foreman to push them on to the best running engines or express trains.

On the other hand, if a fireman allows himself abundance of time to get his engine ready, works with heart and soul, works as though the engine would stop, fail, and get short of steam if it was not for his exertions, depend upon it such an one is destined to make his mark on the foot-plate, on the coal-list, on the minute-list, and on those placed in authority over him.

Examination after arriving in Shed.—On arriving at the shed the engine requires to be thoroughly examined. The valves and the piston-rings should be tested. This is very important; although many a man has been made a driver without his foreman having taken the trouble to show him how to test them. Yet the driver has, in some instances, had a good blowing-up for booking complaints against pistons when the valves were amiss: this is a great hardship very common upon some railways.

To test the valves and the pistons without moving the engine, and to test them separately, both of the little-ends must stand opposite each other and as near to the motion-plate as it is possible to get them; when one crank will be above the axle and one below it, whilst they will be both at the same distance from the back of the fire-box, as in Fig. 8*a*. If, in this position, the left crank be above the axle, the engine leads by the left-hand crank; if the right crank be above the axle, the engine leads by the right-hand crank. Suppose the engine is a right-hand crank engine, in the above described position, if steam be turned on whilst the

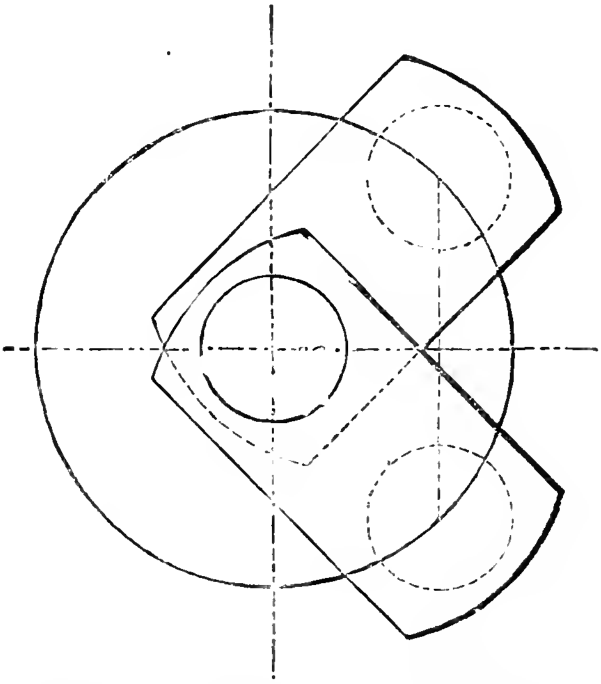

Fig. 8*a*.—Position of the Cranks for testing the Valves and Pistons.

reversing-lever is in full forward gear, it will test the right-hand piston from the back.

If steam is put on with the reversing-lever in full back gear, it will test the left-hand piston from the back.

If steam is put on with the reversing-lever in the centre out of gear, that will test the valves. If the engine is a left-hand crank engine, the left-hand piston is tested first, with the lever full over in forward gear; and the right-hand piston is tested with the lever in full gear backward. For the valves, the lever is at the centre, the same for either crank. It may be observed that by this method the piston-rings are tested at the back only. To test them from the front the little-ends require to be placed opposite each other, above and below, as near as possible to the *cylinders;* the *leading crank* will be below the shaft, and its piston will be the first to be tested with the reversing-lever in full gear forward.

Sometimes a blow is heard at one end of a cylinder and not at the other end. This is frequently caused by a crack or air-hole in the steam-port, leading into the exhaust, and allowing the steam to blow through it into the chimney.

If a piston fitted with two rings have one of them broken or worn slack, a driver can, after a little practice, decide, on the foot-plate, whether the broken ring is the front or the back ring.

The smoke-box door should be opened, steam turned on, and all the joints and pipes certified to be in proper working order. The blower should be put on and tested, the tallow-pipe examined, and the ashes and the tubes examined. As the engine gets out of order, the ashes increase in size and quantity, even whilst the load remains about the same.

CHAPTER VII.

DUTIES AND TRAINING OF A FIREMAN.

Before a fireman is placed with a driver on passenger work, he should have served some time on shunting engines, and been employed for a few years on the goods traffic; and before being placed second man in charge of an express engine, he should have done at least 100,000 miles on slower trains, and have been passed by the superintendent for a driver, so as to be fully capable of taking charge of the engine in case of accident to the driver. It has been mooted even by some foremen that very young hands should be taught by the oldest of the drivers; but such a course would be highly dangerous, and when it is, fortunately, not attended with disastrous consequences, the least that can be said of it is, that it exhibits, on the part of the person who sends green hands on express engines, a want of practical experience on the foot-plate. An express driver has quite sufficient to do to attend to the signals and the working of the engines in his charge, and his fireman should be quite capable of working the fire and feeding the boiler with water, independent of any instructions from the driver.

Before taking his place on an express engine, a clever fireman—and he should be the cleanest and sharpest to be found—has generally furnished his mind with various foot-plate information. He has never allowed any of his former mates to look, touch, say, or do anything without asking the question, "Why do you do that, mate?" so as, when possible, to discover the principle which prompts each action. He has never seen the cylinder cover, the steam-chest cover, or the dome off, but he hastened to satisfy his anxious inquiring mind. When the fitter has been working at his mate's engine, taking big-ends down or what not, he has willingly stopped and assisted; and by these means he has learned how to uncouple an engine, learned the position of the valves at various points of the stroke, learned to test both them and the piston-rings, learned how to make a joint, and in fact exercised his mind and his talent, as well as worked his shovel.

In the case of young men who have served their apprenticeship in the shops, less time in firing on goods trains will, in some instances, suffice before they join express drivers. But before mechanics can be trusted with an engine, or even before they can trust themselves with one, the following are the principal things they require to know thoroughly:—

1.—How to make up a proper fire in a locomotive fire-box.

2.—How to handle the shovel when the engine is running.

3.—How to learn "*roads*" and signals.

4.—How to calculate the effect of the weather on the rails.

5.—How to manage an engine and train on varying gradients.

6.—How to have full control of an engine and train at full speed.

7.—How to work the steam expansively and yet keep time.

8.—How to "brake" a train up in the least possible time.

On long trips it is essential that the best firemen should be employed, as they are supposed to arrive before the driver, and to make up the starting fire in his absence; but before any fireman is allowed to do this, the driver should give him, when he is first appointed with him, certain instructions as to the quantity and the manner in which the coals should be put on and left to burn until starting time.

Training Firemen.—Some drivers have no instructions to give, and therefore it is not a matter to be so very much wondered at if the fireman, when "trying his hand," should choke a few fires, stop a few trains, and put his hands into the driver's pockets a few times, not to mention the waste of fuel, before there appears any sign of a fireman about him.

With some drivers, however, the reverse of the above is their practice. A first-class man will show a strange mate what he requires, how to do it, and when to do it, and insist, under all circumstances, upon having everything done properly and in the most efficient manner. If we take notice of such drivers, we shall see that, with them, an awkward fireman very soon changes his habits and his appearance—he gets the knots dressed off him. Has he been taught to come on duty dirty and late, and to neglect the foot-plate front? He is sharply untaught, and very properly too. Does he throw the fire-irons anywhere after using them? He is told there is a place for everything on *that* engine. Is he dirty about his work? He is shown how to handle the shovel, oil-feeder, and everything else without blackening himself to such a degree that a boy in the street mistakes him for a chimney-sweep. Thanks to such drivers, who deserve much praise for keeping their firemen in proper training; for, just as they *are* trained, so they will turn out as enginemen.

When the fireman arrives, there is, as a rule, but little steam, and about three inches of fire on the bars. On the foot-plate he should test the water in the boiler by opening the waste-water cock, and letting out the water and shutting the cock again; and by looking at the pressure-gauge he should see what pressure of steam there is in the boiler. The first performance is necessary to insure the safety of the boiler, and the latter to form some idea of the condition of the fire. If the steam is low, the fireman should at once, before doing anything else, attend to the fire, either by spreading what is already on the bars, or, should he think necessary, by putting some more coal on, and by opening the damper, if not already opened. His next duty is to rake out the ash-pan, provided that he can get the engine over a pit used for that special purpose outside the shed. This is not absolutely necessary, because it can be done as the engine is moved out of the shed by the driver; but when the fireman finds that there is every appearance of the engine being late in getting up steam, in consequence of the ash-pan being choked with ashes, he should use every means to clear them out as early as possible. In well-regulated running-sheds the ashes are all raked out before the engine is put away on its return from duty.

Before raking out, if there are no water-cocks or pipes for wetting the ashes connected with the feed-pipes by the side of the ash-pan, the fireman should throw a few buckets of water into the ash-pan to lay the dust, which otherwise would fly all over the motion, framing, and wheels, and completely spoil the honest work of the cleaner; and really such want of appreciation by the fireman of the work of the cleaner, which is oftentimes done in the night while the fireman is snoring, is extremely disheartening to the cleaner.

Where the working boiler-pressure is 140 lbs. per square inch, and the trip about to be run is something about 160 miles, with only a stop of three minutes, the fireman, before making up his starting fire, should see that there is not less than 100 lbs. pressure of steam in the boiler; because, when it is less than this pressure, and a thick fire is put on, it often requires some time in burning through *upwards;* consequently, train-time drawing near, the blower is required to be put on and the damper to be opened wide; and in nine cases out of ten, although the engine is blowing off "mad" when backing into the train, the fire is simply, properly speaking, artificially burning on the top. This fact many a driver has found out by getting short of steam soon after starting. A blown-up fire is the worst of fires.

To see an engine blowing off furiously at the commencement of its trip, and afterwards to hear of its being stuck for want of steam, is not by any means an uncommon occurrence. But to see an engine back into a train with not the slightest sign of any steam about the safety-valves, and afterwards to know that the engine kept exact time, speaks volumes for its driver, and is a matter of sufficient importance for all firemen to aim at achieving.

When the fireman has satisfied himself that there is plenty of water and steam in the boiler, with sufficient fire in the box to cover the bars a few inches, he should obtain some old fire-bricks and break them up to the size of a tea-cup, and then sprinkle them with the shovel over the grate-bars, particularly at the corners. By the adoption of this expedient the bars will be prevented from burning by exposure to the heat; it will help to keep the fire open, to keep down the cold air at the four corners, and to prevent the fire from falling through. When the fire-bars are too short, a few shovelfuls of broken bricks placed along the front or back of the box will greatly assist in remedying the deficiency. When old bricks (arch-bricks) cannot be found, chalk may be used, which answers just as well; and when neither are at hand, sand will preserve the bars from burning.

Making-up the Fire.—The fire should be made up by the hands when Welsh coal is used, and with the damper open, which admits of a free circulation of air to spread among the coals whilst they are being put on. The best coals upon the tender should be used first; that is lumps, and with "Welsh" they cannot be too large, provided that they are put on one and a half or two hours before train-time. The lumps should be placed side by side, *all round the box against the walls.* If the box is large it may probably require *a second row within the first row; but in every instance there should be left sufficient space in the centre for the coals to occupy when they are expanded by the heat.*

Of good Welsh, about half the quantity the box contains when fully charged, with the train, is enough for a starting fire. A large lump dropped into each of the back corners at last will, when burned up, give to the fire a greater depth under the door than what it will have under the arch. This is how it should be, unless the box is very shallow indeed, and then the fire should be straight and thin. In boxes inclined towards the front, the fire is always deepest under the tube-plate.

The best Welsh coal swells very much if it is allowed time to burn gently through, and under the influence of heat it assumes an appearance which reminds one of a cauliflower plant. The quality of Welsh coal may be known, even before it is exposed to the fire, by breaking it with the hammer. If it is good it will return the blow with a blinding cloud of fine dust. Upon some railways accordingly it is called "Blynd" coal on account of its dusty nature. If it will blind, it will make steam; if not, its character is uncertain, and some of it only fit for malt-house purposes.

Hard coals should be broken up into lumps about the size of a brick, and *watered*, and put on with the shovel all round the box exactly like Welsh, as already explained. With an extra shovelful in each back corner, hard coal, like the soft (Welsh), can be put on one and a half or two hours before train-time, with good dampers; indeed, some first-class drivers always do so, and they find that it pays them. Hard-coal fires have been drawn, after standing in "bank" engines for several hours, having the appearance and all the hardness of coke. In consequence of hard coal making much smoke, particularly when the dampers and doors do not fit very closely, it is best *not* to put much of it in the fire until starting time. Still, where it can be done, the first-mentioned practice should have the preference, because the fire is then known to be good at the bottom, hard, and partly coked, well burned through *upwards*—resembling capital to start with.

A good beginning makes a good ending.

Oiling the Machinery.—The oiling generally is done partly by the driver and partly by the fireman; the former does the outside, and the latter goes below. The engine should be fixed so as to get at both of the big-ends nicely; this is attained by placing both big-ends *below* the crank-shaft; in fact, the most suitable position is exactly the same as was recommended for making an examination of the engine.

It is the fireman's duty to be as frugal with the oil as possible without incurring any risk of heating. No doubt can be left in the mind of any one who understands oiling and trimming, after looking underneath at the motion and the boiler of the engines of *some* drivers, that the waste of oil is enormous. The waste should not exist, for it can be safely avoided by care.

The oiling of big-ends, eccentrics, straps, and outside-rods, need not be done with any regard for the distance about to be run, since, with plug-trimming, the oil only drops when the engine is in motion; but the syphons should never be filled so full as to waste the oil over the side, for what is wasted in this way would, in some instances, serve for the *motion*. Four drops of oil will take a big-end one mile. The oiling of the slide-bars, glands, motion, and axle-boxes, should be the last thing to be done, and as near train-time as circumstances will admit of. A little oil, however, before coming off the shed, is necessary to moisten the trimming, and to prevent anything cutting, but on no consideration should they be filled up so long as half an hour or an hour before starting. There are many ways and means to economize oil, and a driver may, by circumspection, soon find out if his trimmings allow the oil to "fly;" the boiler-bottom will show it, and the machinery and wheels will be coated all over. Trimmings require to be well looked after and adjusted, until they are the exact "ticket." When an engine is fresh out of the shops the trimmings are slack; and, as the motion wears, they require to be tightened by adding strand after strand. It is really astonishing to observe on what a small quantity of oil an engine may be made to run without heating.

Some drivers make use of tallow in the big-ends and outside-rods, because they have not yet learned how to make a proper trimming. Of course such practice is confined to ballast-men. Sometimes even the better class of drivers use tallow in the tender axle-boxes with oil; but it is frequently the cause of an axle running hot when the tallow chokes the worsted. The more a driver can do without tallow, the better his engine will run; if he uses it, let him mix it with oil over the fire before putting it into the boxes. Even then it requires but a small amount of judgment to perceive that the trimming which is suitable for pure oil must be unsuitable for a mixture.

The oiling should be performed systematically, that is, if the driver does the whole of the oiling, it should be commenced at the trailing-axle of the engine on the driver's side, then the outside of the driving-axle, then the motion and the leading-axle, followed by the crank shaft and inside-bearings. Next, the fireman's side of the engine and tender, concluding by crossing to the driver's side of the tender, not forgetting the screw-coupling.

On long trips of, say, 160 miles, with only three minutes' stoppage for oiling on the way, the fireman should drop off on his own side and commence at the trailing tender-axle; and after oiling his side of the engine, he should oil the crank-shaft, then the driver's side to the trailing tender-axle, and *the motion afterwards*, as this can be done after the engine is started, from off the framing.

CHAPTER VIII.

DUTIES OF AN ENGINE-DRIVER WITH A TRAIN.

Number of Vehicles in the Train.—After the engine is attached to the train, the oiling of the slide-bars, &c., should be finished; and, before starting, the driver should ask his guard what number of vehicles are in the train, so that he may know how to work his engine with economy, and also that he may know the state of things when descending inclines and entering stations on the road. This is very important.

It is well known that some drivers have pulled out of a station without their trains, and have not found their mistake until they overshot the next station-platform a tender's length, and actually then whistled for the guard to put on his brake. Others have lost eight carriages out of twelve, and observed no difference in the working of the engine.

But there are drivers who habitually work their engines according to the load; and such drivers can tell, after knowing the number of coaches they have, when a guard's brake has been inadvertently left "on." An express engineman one day, as soon as his train stopped at Brighton, jumped off his engine, and said to the guard, "Guard, thy brake's been on, I'll swear." "No it has not," said the guard. "Then thy mate's has," replied Ben; and when the wheels of the rear van were examined, they were found to be black-hot, with a flat place worn on the tyre.

Management of the Engine with a Train.—Starting.—In starting, the regulator should be opened gently, especially with a full boiler. This is absolutely necessary in some cases, where the tender will just carry the engine through the trip. Much of the inconvenience arising from priming, when getting away, may be prevented by blowing the water out of the steam-pipes and cylinders before joining the train—as the engine is moving tender first—so that the "blacks" and waste water may fall quite clear of the engine and boiler. If the engine has to wait some time for a train, the steam-pipes and cylinders may be kept warm and free from water of condensation by opening the regulator a very little, with the brake screwed on hard.

Care is necessary, in moving "off," to keep the cylinders and valves clear of water. Half a pint of hot water will wash the grease off dirty plates and dishes, and it will just as effectually wash the faces of the cylinders and valves, and when this is fully effected at the start it is a great misfortune. In numerous instances, it simply arises through the sand-valves not being opened in good time. Slip or no slip, it is better to expend a quantity of sand than to incur the risk of slipping, when the rails are inclined to be slippery.

As the engine comes to feel the load, so the regulator may be opened more, until the engineman and lookers-on can hear what it is likely to do with the train. A few clear sonorous puffs at the start do good; they rouse the fire into action at once—there is no hesitation in the matter. They also clear the tubes of loose cinders or soot left in them after being swept out. It is cruel, wicked, not to give the noble iron steed a little grace at the start, so as to give him an opportunity of shaking the cold and stiffness out of his iron limbs; and, moreover, it is a loss of time to commence reining in, by extra cutting off the steam, before he is half a dozen yards away. "Loose him, let him go."

The exact time and distance when to notch an engine up depends upon the load, and the time allowed for running the train; but, however much circumstances may alter cases, there is one thing that will remain unalterable, and that is, after the engine has got the train into a pretty good speed, the *lever* should always be pulled up *a notch or two at a time,* and not pulled almost out of gear at once. This point is very important, and worth following out in practice.

The steam should not be entirely shut "off" in order to pull the lever back when about to work the steam expansively; and in fact, when it is possible, the lever should not be touched; for the practice of shutting the regulator *first* cannot be allowed in first-class enginemanship, and for this reason: it is unproductive of any good effect, and is, on the contrary, liable to do a vast amount of damage, especially to engines having a *worn* motion. Some thousands of cases have occurred in which engines have broke down just after starting; and, in a certain district, where some drivers habitually shut "off" before pulling the lever up, they scarcely ever give up their train without its being possible to trace the cause to the practice now condemned.

Nothing looks so bad to "engineers" as to see the driver suddenly close the regulator, pull the lever very nearly out of gear, and "smack" the steam on again. The force with which the steam may strike the piston-head under such circumstances is very great indeed; and it is sufficient, with a loose piston or cross-head cotter, to do some damage, not to mention the sudden snatch among the couplings and draw-bars.

To an attentive engineman the starting away is full of interest; for, although he may have made a careful and thorough inspection of his engine before joining his train, still he cannot feel satisfied that all is right until the full pressure of the steam is on the piston and the engine feels the load.

Has he had the pistons examined?—it is at the start he listens for improved effects. Have the valves been changed, or faced-up, or re-set?—it is at the start that he satisfies himself if they are tight, true, or not true, as the case may be.

By a little attention and watching of the outside-crank or crank-pin, it is possible for the driver, while he stands upon the foot-plate, and the engine is moving, to discover the slightest defect in the piston or the valve, and, without leaving the foot-plate, to trace it home to either piston. Thus:—

Steam-blowing.—Suppose a "blow" is heard at each turn, and *only* when the outside-crank is nearly in a straight line with the piston-rod, looking from the left-hand side of the foot-plate, and with the outside cranks on the same centre line, and on the same side of the axle as the inside crank; it would be discovered that a piston is "blowing," owing to the sound being intermittent, for the blowing through of a valve would be a continuous leaking. Further, it would be known that the defect was not in the left-hand cylinder, there being no steam in it, when the cranks are in the position above described, and therefore we should have to look to the right-hand cylinder, where the full pressure of the steam must be on the piston.

Beats of the Engine.—There are four beats for one revolution of the driving-wheel, or the crank-axle.

In a coupled engine, fitted with the right-hand crank leading, as in Fig. 9, in which the right-hand big-end is straight up against the bottom of the boiler, when the left-hand big-end is straight out against the fire-box, observe the motion of the outside crank, as above, from the left-hand side. We shall hear the beats in the following order :—

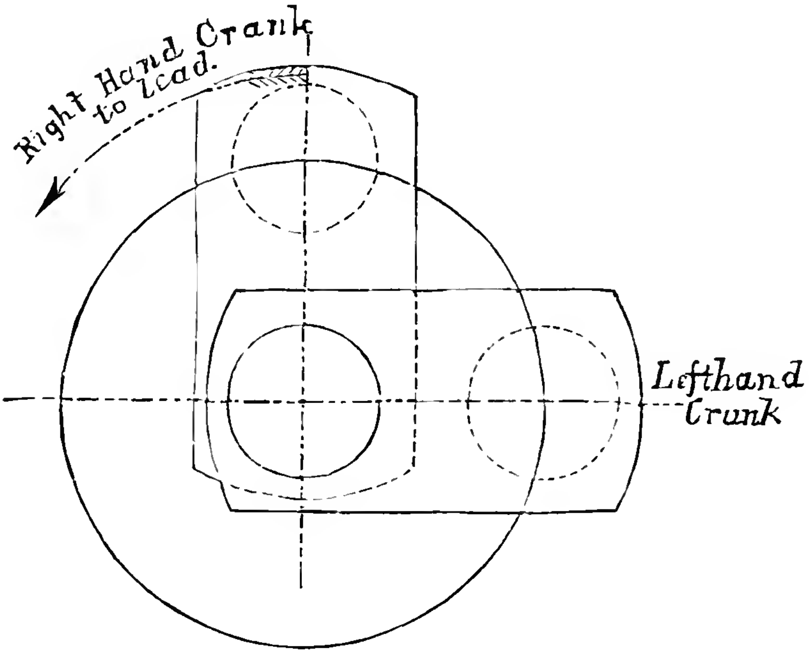

Fig. 9.—Right-hand Engine.

R. H. cylinder, back beat, about A, Fig. 10.
L. H. ,, ,, ,, ,, B, ,,
R. H. ,, front ,, ,, C, ,,
L. H. ,, ,, ,, D, ,,

By giving attention to the outside-crank, an engineman can easily detect the growing weakness in either

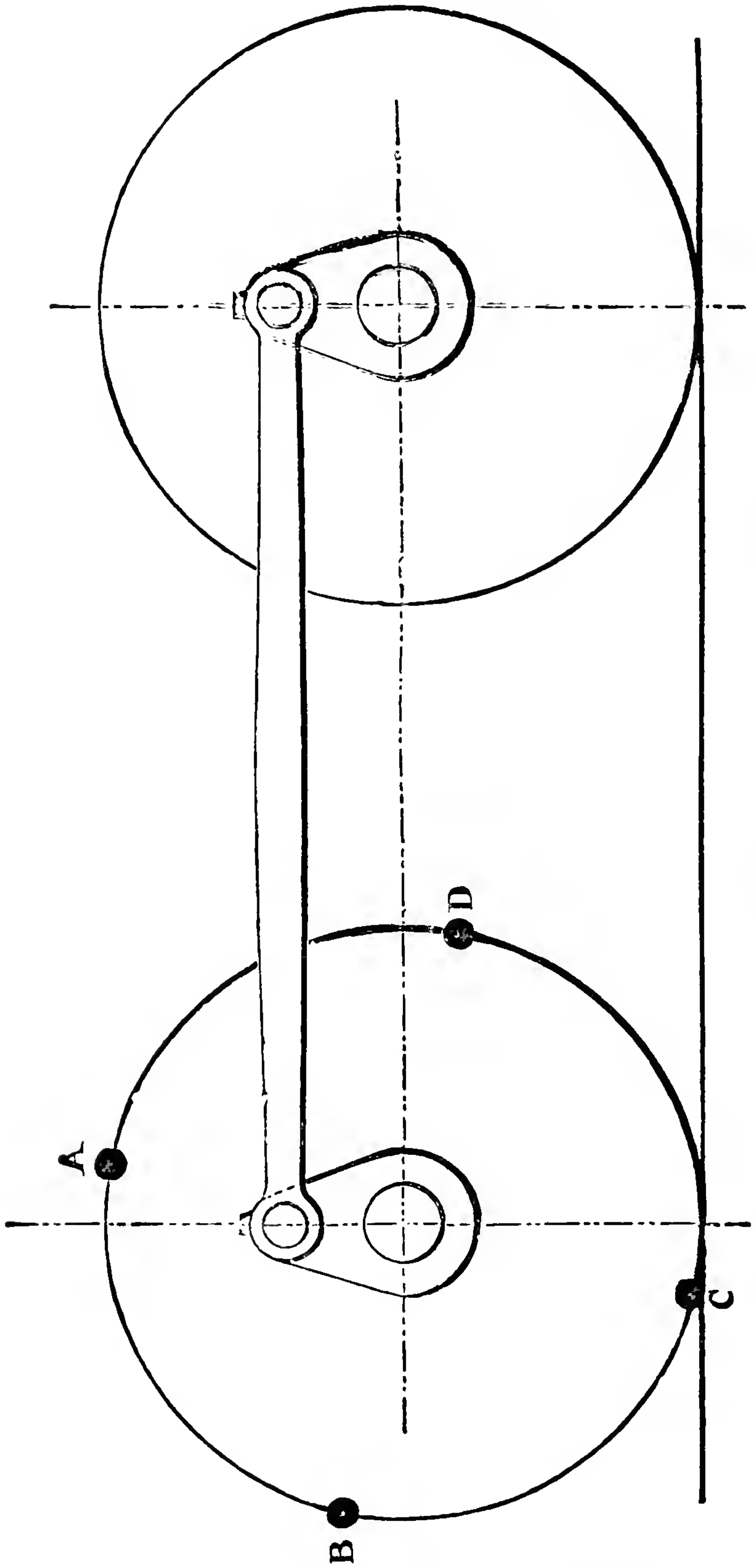

Fig. 10.—To Mark the Beats of an Engine.

of the beats, and at once give an opinion on the matter. If the rings in the right-hand cylinder be slack, and if he know what part of the circle the outside-crank is traversing when the steam is full on that piston, by a very little practice he will be enabled to detect the slightest wear, and to watch daily the gradual deterioration of the rings in that piston. By the same rule, any ring that blows may be watched, and notes taken from the ashes in the smoke-box of the necessity of having it renewed or tightened.

Pressure on the Slide-bars.—Most drivers have observed that, when the engine is running chimney first, the bottom slide-bars require scarcely any attention with regard to lubrication; and that, at the same time, nearly all the rub is against the top bars, necessitating every care to keep them from cutting

On the other hand, they will have noticed that, when the motion of the engine is reversed, and it is run tender first, the rub of the slide-block is against the bottom bars, and is least against the top bars.

The pressure of the slide-block is constantly upwards in forward motion, and constantly downwards in backward motion. It is not, as might be supposed, alternately up and down, according as the crank and the connecting-rod change from the top to the bottom centre.

This is to be explained. When the crank is standing on the top-centre, near the bottom of the boiler, the piston-rod must *pull* to move it towards the cylinder in forward motion; and, as the pull is oblique, the little-end and slide-block are forced *upwards*, when the top slide-bar acts as a fulcrum to the piston to pull the crank over. When the crank, connecting-rod, and piston-rod are all in a line, the pressure of the slide-block is then slightly on the bottom bar, and is that due simply to the weight of half the connecting-rod, &c. When the crank has passed the dead-centre and gone below, the piston-rod must *push,* and, as the resistance is below the piston-rod, the slide-block is forced *upwards* against the top bar, which again acts as a fulcrum to the piston to push the crank under.

So that, in forward motion, whether the crank is above or below the centre of the crank-axle, the cross-head, both in pulling and in pushing, rubs against the top bar.

Going Tender first.—When the crank is standing on the top-centre, against the bottom of the boiler, the piston-rod must *push* to move it toward the fire-box for back-way motion, and as the push is oblique, the cross-head is forced *downward,* the point of resistance being *above* the horizontal line of the piston-rod. When the crank is gone below the back dead-centre, the piston-rod must *pull;* and then again, as the pull is in an oblique direction, and the focus of resistance is below the centre line of the cylinder, the cross-head is pulled down upon the bottom bars by pulling the crank up, which opposes with a force equal to the resistance of engine and train.

Keeping-up Steam.—By the time that the engine has got the train up to speed, steam should have commenced to be just issuing from the safety-valves. When it does not do so, the advantage of starting with a boiler full of steam is lost; and the fireman has somewhat to learn in making up a starting fire that shall be ready for action as the engine is getting over the first mile. Short-train drivers, of course, would scarcely feel the force of such circumstances, for they can almost run from station to station without using the feed until the steam is shut off; but matters are very different on long runs. If the engines are not instantly up to the mark at the start, and if the feeds must be held "off" to allow the fire and the engine a chance of recovery, the consequences are that the water in the boiler gets lower and less, and the uncertainty of ever getting the water up again becomes greater every minute, especially with a heavy train and against a strong side wind.

Management of the Fire.—A skilful fireman seldom misses this important element of good management. The engine no sooner discharges a few vigorous puffs than, with a well-managed fire, there are signs of everything being right, the steam is seen blowing off at the safety-valves, though very slightly.

Sometimes Welsh coal, probably from being too much wetted, hangs together in the fire-box, and prevents the engine from steaming nicely, causing the fire to burn hollow, and to draw air. An engine-fire will sometimes run for miles without any variation of pressure in the boiler of ½ lb. per square inch either way, unless the feed happens to be put on. The first thing required to be done with such a stupid fire is to get a shovelful of small coals and scatter them pell-mell over the top of the fire, but chiefly along the sides and front of the box; the effect will be that some of the small coals put on in this way will fall into the very hole or holes through which the engine is drawing air. Tobacco-smokers sometimes do this kind of thing to get their pipes to burn; they slightly move the tobacco with their finger on the top, and that knocks a morsel of weed into the air-hole, and the pipe afterwards burns charmingly. When this plan is of no effect—and this can be soon ascertained by watching if the needle of the pressure-gauge begins to rise—the dart should be thrust into the centre of the fire, and the fire gently raised so as to open it if close, or to close it together when it has burned hollow. Provided that a driver can see his way with such a fire, it is, in point of economy, best to leave it undisturbed, for sooner or later the action of the blast and the vibration of the road will bring it round; but, of course, on fast and important trains, action is required to be taken at once, and either of the two mentioned remedies will seldom fail to move the needle.

When the fire is right at the start, a few good puffs, with the damper slightly open, will set the incandescent coals into a fierce flame, and the steam will be seen just at the point of blowing off. This is the signal to commence firing. On short trips, such as those of fifty miles or less, one fire made up before starting is sufficient, in some instances, to carry an engine through; but for a run of 160 miles, with one intermediate stop only, the first fire is not sufficient, and the question is, What is the best thing to be done?

The driver of such a train is very particular about keeping time, as such running is generally performed by "crack" men, on "crack" trains, in "crack" time, and the only possible way to do that is to start with the pressure-needle indicating a full boiler of "gas," and to keep it at the same point until the *Home* signal is sighted. To do this, a fireman must not only give his heart and soul to his work, but he must not depend upon *any* particular mode of firing for success; for whatever is to be wrought with absolute certainty—

to be repeated again and again, week after week, and from one year's end to another—must be done upon some principle; and, if it is not, his reputation as a fireman will be crumbled into dust by the first difficulty he meets with. If, however, a fireman works upon a principle, he can keep the boiler full of steam as well to-morrow as he can to-day; as well with No. 1 as with No. 2 engine; as well with driver A as with driver B. It makes no difference to him whether the season be summer or winter, whether it be light or dark, or whether twelve or twenty carriages are behind him. He works both his mind and his shovel; and he is sufficiently inquisitive to ask: "Why do I fire this way? Is it the best way? Will my way stand the test of a four hours' run? Can I build upon it as upon a rock? Is it safe, sound, lasting?"

These are questions of great importance, and their solution can alone give rest and satisfaction to an aspirant after the very best possible practice in locomotive firing.

In the coke-firing days the fire did not require such an amount of attention and skill as is now necessary with a coal fire. Smoke is a "nuisance," and it will not be consumed by a slip-slop way of firing; besides, a coal-fire, to be efficient, is *worked* on account of its adhesive nature.

Haycock-fire.—The coal fire of haycock shape, eminently associated with failures through want of steam, is made by shovelling the coals into the middle of the fire-box—a practice about as far behind the times, comparatively speaking, as the use of the flint and the tinder-box would be in the year 1877.

The characteristics of such a fire are—uncertainty as regards making steam, and certainty as regards destruction to fire-boxes and tubes. It generally draws air at the walls of the box, and, in consequence, the fire-irons are always in the fire, knocking it about and wasting the fuel. As such fires are formed on the centre of the grate, they weigh down the fire-bars in the middle, and may even cause them to drop off their bearers or supports. But there are greater evil consequences even than these: the cold air being admitted into the fire-box up the sides, instead of in the middle, comes into direct contact with the heated plates and stays, doing them a deal of damage by causing intermittent expansion and contraction.

It would be an easy task to pick out certain engines, known to be fired on the haycock system, and to show that, although the boiler work is superb, they are always subject to sudden leakage either in the joints of the plates or in the stays, the tubes, or the foundation-ring—in a word, that they are continually in for repairs of the boiler.

In no small degree, the value and the life of a locomotive boiler depend upon the system on which it is fired.

Concave-fire.—That the fire in a locomotive fire-box should maintain steam under all circumstances of load and weather, should consume its own smoke, should burn up every particle of good matter in the coal, and in fine should be worked to the highest point of economy, it requires to be made in the beginning, and maintained, to a form almost resembling the inside of a tea-saucer—shallow and concave—where the thinnest part of the fire is in the centre.

A fire of this form makes steam when other fires do not, being built upon a principle that never yet misled either the driver or the fireman. It has obtained a man a good name many a time.

How to fire? This is a very important question.

How to Fire properly.—To fire properly, the fireman is required to stand in such a position as to command the coals in the tender, and to work the shovel without shifting his feet, except when he turns slightly on his heels, first toward the coals, and then towards the fire-hole. If a fireman, when he is in the act of firing, lifts either of his feet off the foot-plate, he will roll about, and the firing will be imperfectly done, in consequence of the coals being knocked off the shovel by the latter catching against the fire-hole ring or the deflection-plate.

To fire properly, the shovel should enter the fire-box as little as possible. It should be stopped dead at the fire-hole ring; and the impetus given to the coals should be sufficient to discharge them, like shot, right into their intended destination, close to the copper.

It is, however, a common practice to pick up with the shovel as much coal as it is possible to heap upon it, pushing the shovel into the coal with the knees. There is no necessity for doing so. The foot-plate of a locomotive is not a mixen. A few lumps of coal, such as will lie nicely on the body of the shovel, are all that is required; and the shovel should be worked by the muscles of the arm.

The first shovelful of coal should find a billet in the left-hand front corner; the second shovelful in the right-hand front corner; the third shovelful in the right-hand back corner; the fourth shovelful in the left-hand back corner; the fifth shovelful under the brick arch close to the tube-plate; the sixth, and last, shovelful under the door. To land this one properly the shovel must enter into the fire-box, and should be turned over sharp to prevent the coals falling into the centre of the grate or the fire.

It will at once be seen that this fire is made close against the walls of the fire-box, and in actual contact with the heating surface, also that the principal mass of the coals lies over the bearers which carry the fire-bars. The centre of this kind of fire is self-feeding, for by the action of the blast and the shaking of the engine the lumps in the corners are caused to roll or fall towards the centre. On this system the centre is the thinnest part of the fire—quite open and free from dirt. The dirt falls down by the sides of the copper-plates, and assists in preventing the cold air from touching the plates. With a fire of this description the air or oxygen can only get into the fire-box and into the neighbourhood of the tubes through the centre—through fire—and, mingling with the flame, it becomes instantly heated to a very high temperature before entering the tubes, which are thereby assisted in maintaining an even pressure in the boiler.

Coals of the same description have been delivered to two different drivers, having engines of the same class, working on the same day, running the trains over the same ground, with equal average loads; and the result has been that while one driver could do anything with the coals, the other man was "afraid" of them. The former put his coals against the "walls" of the fire-box, and the latter put them in the centre of the grate.

When to Fire.—Next to the question, How to fire? follows one of equal importance: When to fire? To fire properly, with the greatest effect in saving fuel, it should be done as soon as the steam begins to lift the valves ; when, by opening the fire-door and putting a small quantity of fresh coals on, the steam is slightly and sufficiently checked to prevent its being wasted by blowing off. There is an idea abroad that, unless the steam blows off "mad," there can be no very great demonstration of skilled enginemanship. There cannot be a much greater mistake. When steam, water, and fuel are being thrown away through the safety-valves, it is a positive proof of the existence of either one or both of the following evils: either the engine is too small for its work, or the engine is too great for its man, and the engine or the man would do better on short-train work; the former until it was convenient to place it under the steam-hammer, and the latter until he had learned how to bottle his noise, or anyhow until, for the sake of the engine, he could enable her to obtain a fair position on the coal-premium list.

Intervals of Firing.—The interval between the rounds of firing, which should consist of six shovelfuls *only*, each time the door is opened, is in every case regulated by the weight of the train or load, the state of the weather, and the time allowed for running the trip, together with the quality of the coals.

Hard coals burn away much more quickly than soft or Welsh ; but, whatever there may be to vary the circumstances under which each trip is performed, one thing remains constant and certain, and that is, if the fire is to retain its proper shape throughout the trip, the coals must be *put* into the very places already mentioned, and never into the middle ; this will look after itself.

The aim in first-rate locomotive firing is to maintain the fire in a state of efficiency; and to do this the services of a willing and persevering fireman are required, for the shovel may never be out of his hands after he has commenced to fire, on "crack" runs, until he finds that he has sufficient fire in the box with which to finish the trip.

Bad Firing.—Without doubt, the greatest mistake made upon the foot-plate by some firemen is to put too much coal on at each firing. The result is, the fire is partially choked; that is, the oxygen is shut out at the grate-bars. Clinkers then commence to be formed, by the dross in the coals reaching the bars without coming in contact with sufficient oxygen to consume it; the temperature of the boiler is reduced; stays, tubes, &c., start leaking by unequal contraction of the plates, some being thicker than others; the smoke-box door gets hot; the engine loses time; and the driver loses caste.

A driver, who had been a source of trouble, both to himself and to his engine, arrived one day at H station with his blower turned full on, and the boiler containing 130 lbs. steam. The fireman, as soon as the train stopped, took up, in all, seven large lumps of coal, and, placing each lump successively on the fire-hole ring, allowed them to drop or roll anywhere in the box. Upon these he afterwards discharged fourteen shovelfuls of coals.

The train was signalled to start, and as the engine got on her way the pressure of steam gradually fell, and as it did so the fireman set to with the dart and knocked the fire all to pieces. When there was only 60 lbs. steam, the driver put his ear to the door, and in a moment exclaimed, "There, mate! she is going to serve us a trick again ; don't you hear them tubes leaking like billyho ?" There were also serious complaints against some patches that had given out before, but which were not very great trangressors. The dampers were wide open, and the blower going for the remainder of the trip.

The cause of the leakage was explained to the driver, and the advantage to be gained by firing frequently, a little at a time, instead of fourteen or twenty shovelfuls at one time. From that time the driver, not above being taught, has never been seriously short of steam ; and, instead of his driving being a burden to him, he rolls from station to station with pleasure.

The Secret of Good Firing.—The secret of first-rate firing is to fire frequently, a little at a time. It requires perseverance, but it is *the only* way to accomplish four hours of hard running with anything like success. Numerous plans have been resorted to for the perfect combustion of smoke, and for making steam well in a locomotive engine; but the best plan is the employment of intelligent firemen, who understand and work to principles affecting combustion, and the expansion and contraction of metals.

Firing with the Steam on.—Locomotive firing should be performed whilst the steam is "on." It is an unsightly thing to see an engine, especially a passenger engine, entering a station with the blower hissing loudly, the driver at the brake, and the fireman "puddling" at the fire, or putting on coals—trying, in fact, to make smoke. When the firing is done with steam on, the foot-plate is kept clean, and the bright work on the front is not tarnished by smoke; and, further, the sulphur from the coal is not troublesome, as it is carried off to the chimney by the action of the blast. When the firing is done with steam on, the force of the blast at the grate-bars remains efficient, and the coals put on are prevented from choking up the bars through which the iron steed draws his breath, and whose motto is—

"Upon the four elements I feed,
Which life and power supply,
To run my race of boundless speed;
Take one away—I die."

Take any two enginemen known to work in opposite ways. One fires with the regulator open, and the other fires with the steam off, and generally about a station. The result will be greatly in favour of the one who always contrives to have his firing done with the steam on; he makes no smoke about a station, and he makes no clinker worth notice. But the other one is all smoke and clinker.

In firing with the steam on, the driver can give his attention for a moment to the fireman's actions. Casting his eye downwards each time the shovel approaches the fire-door, he can see whether the stoker puts the coals against the walls of the box. Such a degree of supervision on the part of the driver does not in the slightest degree interfere with his other duties.

When the firing is done with steam on, each man upon the engine, when the train enters the station, is free to attend to his respective duties, the one at the brake and the other at the regulator; and these undoubtedly are the proper things to see to. There can be no great objection, when circumstances warrant it, to the firing being done occasionally as the engine leaves a station; but preference should be given to some spot at some distance from a stopping station; say, two or three miles before the point where the regulator is to be closed. As soon as fresh fuel is shovelled into the box, its gases almost immediately combine with the oxygen, and form flame or gas heavily laden with carbon, owing to imperfect combustion, which rolls off the top of the chimney in black clouds. If sufficient time is allowed for the oxygen to deprive the black flame of its carbon before the regulator is closed, there is very little attention required afterwards to prevent smoking in a station. When firing on long runs, the most favourable spots on the line for working the shovel should be selected and habitually used for that purpose; but on no consideration should any stoking business be in hand when the engine approaches junctions, signals, or stations. It should be done after passing them. The grand aim of first-rate stoking is to keep the steam at one pressure; that is to say, the needle of the pressure-gauge should, as nearly as possible, point to a full boiler pressure, up hill and down dale. To accomplish this—and it is done on the crack engines every day—firing must be studied. Engines are not alike. Some are robust, others very delicate, but the generality of engines require the exercise of trained skill to jockey them. Some engines steam best with a low fire, and others may carry fuel up to the fire-hole. Nearly all engines are affected by cross winds. The firing should be done when the steam is just on the point of blowing off—a condition which generally happens while the engine is on a rising gradient, for the fierce blast causes a maximum supply of oxygen to pass through the fire and the tubes, which generates great heat and much steam. Even on a partially level line a "crack" fireman chooses certain places for firing, so that the opening of the fire-door will not be necessary for checking the production of steam when the reversing-lever is pulled up, whilst, at the same time, the pressure-gauge is not an ounce behind the maximum working pressure.

Economy by Good Firing.—It is really astonishing what can be accomplished by some enginemen and firemen in economizing fuel. A case occurred a short time ago that will just illustrate the point. Driver A had for a long period been a heavy consumer of coal, compared with other drivers working the same trains. His engine was equal to theirs in condition, and there was no distinction between them in any one point, or in the coals, the loads, or in keeping time. But he always consumed two or three pounds per mile more than other men in his "link." Driver B, on the other hand, stood at the top of the premium list month after month. It was decided by the locomotive superintendent to change the firemen of the two drivers who were so wide apart in consumption. This was done for three months. After working a month the change was striking. Both men had felt the electric shock, and figured on the coal-premium list both together in the centre of eighteen other drivers; but driver B was still first by fourpence. The next month both men "went in for it," and it was in every sense of the word a struggle. Their coal was weighed, and everything they required to be done to their engines was done at once. Well! the long looked-for coal-premium list came out for the second month, and, as was fully anticipated by those who knew anything of the firemen, the formerly heavy consumer beat the man who had so long been top coal-man by 8*s.* 6*d.* The secret of this change rested with driver B's fireman, who studied economy with a vengeance from every point of view. He did what many others did not care about doing, namely, he fired little at a time and often, he studied the road, and kept the shovel and the fire-irons out of the fire-box.

It is expedient for all firemen who wish to attain perfection to do as driver B's fireman did, who took advantage of every possible contingency to work the engine fully up to the mark with a shovelful of coal less to-day than yesterday.

When the wind blows hard sideways, advantage is required to be taken, for firing, of the "cuttings" and places where the line is protected by trees; for the opening of the fire-door in such winds is a matter of consideration. Engines, as a rule, make steam very indifferently in such winds, a result which is attributable to the wind, when blowing hard at right angles to the line of motion, causing a partial vacuum in the ash-pan.

To examine the Fire.—To examine the interior of the fire-box—to see if the fire is straight—the shovel is required to be placed on the fire-hole ring; and by holding the shovel on its side, with the handle in a straight line with the corner or place deemed necessary to be inspected, a clear view of it will be obtained through the air which enters by the shovel and passes forward as a flameless current. Should the fire burn down more in one corner than another, it should be filled up by placing an extra shovelful of coals in it.

The two back corners should, under all circumstances, be kept well up to the door with coals, and in nine cases out of ten, if these are properly looked after, any engine will make steam freely. It is possible to put too much coal under the brick arch and choke the fire, but this can scarcely be said of the back of the box.

The best advice that can be given for avoiding a choked fire has already been given; fire a little at a time, and often.

Working the Damper.—Some engines are fitted with a back damper as well as a front damper—an arrangement intended for such engines as run to and fro without being turned. But some enginemen, when running engines so fitted, with the smoke-box first, close the front damper and only open the back damper. This is done when the engine steams well, but it has the effect of burning the coals away at the front; and, as the secret of coal-saving consists in mixing as much air as possible with the coals in actual contact with the grate, it is better to work the front damper when the engine runs funnel first, and the back damper when going tender first. The damper should be made to work with a wheel and screw, so that the driver may adjust the position of it according to the load.

Management of the Feed.—The maintenance of steam frequently depends to a considerable extent upon the manner in which the boiler is fed with water. The aim should be, as far as possible, to regulate the supply to the demand—just sufficient to keep the water at one level in the glass. Thus an even temperature may be maintained in the plates of the boiler, the tubes, and the fire-box; and such regularity of temperature has much to do with the service of an engine. A locomotive, like a man, should have *a chance* to do well; but some drivers habitually work the feed exactly in the way to spoil an engine. So soon as the boiler is full of steam—blowing off—they turn on the pump full, and keep it on until the steam is 30 lbs., 40 lbs., and even 50 lbs. below the maximum pressure, before turning it off. Under such treatment the temperature and the pressure are allowed to rise to the utmost degree, only to be knocked down again by a barbarous, wicked, and wretched system. There are times, of course, when the feed must be withheld for a brief interval; but, for economical working, coal-saving, premium-getting on the road, and first-rate enginemanship, there is nothing to beat a *constant moderate* supply of water to the boiler.

It has often been remarked that an engine consumes more water when the water-level is an inch off the bottom of the gauge-glass, than it does when it is an inch off the top of the glass. The remark is not altogether based on fancy, for when an engine is working hard the water may be allowed to sink in the glass to the lower level in consequence of a scarcity of steam, that is to say, a reduction of pressure. Therefore, as a result, the water, relieved from the pressure of the steam, has a tendency to prime; and although the priming may not show itself at the top of the chimney, yet large quantities of water do, under such circumstances, escape with the steam through the cylinders in the form of fine spray, which, with a full boiler and a good pressure of steam, would not have been primed over at all.

Some drivers, of course, can recollect that when they have had to run with a tender which, with a heavy train, would only hold just sufficient water to carry them, with the greatest economy, from one water-station to another, the only possible way to do it, without being driven to straits for water, was to maintain the boiler full of water, and keep the steam just on the point of blowing off.

Further, probably, some drivers can recollect when they could not maintain the full pressure, and were compelled to check the water-supply in order to keep up the speed ; that they had barely sufficient water to keep the boiler safe, having to close the damper, and even to damp the fire, before they arrived at the water-crane.

Injectors.—When injectors are used, with such nice running, one of them should be screwed down so that it may act moderately, like a pump ; this will save the water which is usually lost in turning an injector *on* and *off*. What is best to be done on a run of 160 miles, with one stop only, is also, from an economical point of view, the best for all kinds of running.

Priming.—Priming is an indication of at least one of three things : it is the result of dirty water, low steam, or careless slovenly driving ; and all three causes may exist at the same time.

Composition of Feed-water.—Water is composed of two elementary bodies, oxygen and hydrogen, in the following proportions approximately :—

	By Weight.	By Volume
Oxygen	8	1
Hydrogen	1	2

Water, when pure, is transparent, colourless, tasteless, and inodorous. But it is capable of dissolving saline and other earthy matter in passing through rocks, soils, &c. In this way, the water supplied at one station may be acidulous, chalybeate at another, sulphurous at a third, and saline at a fourth—partaking, in fact, in no small degree, of the nature of the soil which it traverses. At Brighton, for instance, it is chalky, like the soil.

After a large quantity of water has been evaporated from a boiler, be it ever so pure, a certain quantity of deposit is accumulated upon the surface of the tubes, the bottom of the barrel, and the fire-box. A boiler in such a state is rendered rather ticklish to work, even if there be no effort to economize water and coal. Under such circumstances, the only advice that can be given is to exercise increased care in keeping the boiler and the steam at an even temperature, and the water-level as high as it is possible to carry it. Instructions for washing out a boiler will be given when we get a shed-day.

But when the boiler is clean, and also the water in it, and when, nevertheless, the outside of the boiler is covered with marks of priming, there is evidence generally of carelessness or want of attention to the indications of the gauge-glass. It should be borne in mind, before a driver is judged respecting the management of his engine, that marks of priming may result from a leak in the steam-pipe, or they may be the result of the condensation of the exhaust steam in striking the chimney at the top, round which the condensed steam hangs in drops, to be blown off by the wind upon the boiler.

Gauging the Boiler for Water.—It is an excellent plan for every driver, who has an engine to himself, to take the first opportunity, when the manhole-joint is broken, of examining exactly how the boiler is gauged for water—whether high or dangerously low. This examination may be made, after the boiler has been partially emptied, by filling it up gently until the water is visible in the glass, and then, with a gauge of some kind, measuring the depth of water over the crown, or highest part, of the fire-box. Information obtained in this manner will set aside all uncertainty, and will prevent a driver from speculating: he then knows exactly the level of the fire-line.

On the Foot-plate.—While the engine is under steam with a train, the driver should stand in his proper place upon the foot-plate, so as to be able to command the regulator and the reversing-lever in an instant. The observance of this regulation is especially requisite at night, when it is imperatively necessary that the driver's attention should be continuously directed to the engine, listening constantly to the sound of the *beat*, to detect any irregularity that may arise from some defect in the machinery or from priming, frequently casting his eye on the pressure-gauge and on the level of the water in the gauge-glass. As the fireman puts on the coals, the driver should occasionally see that he is placing them next the walls of the fire-box, and not in a heap in the middle. When the rails are slippery, great care is required to prevent the engine from slipping, by closing the regulator in time. By unceasing attention to the action of the engine a man will soon be enabled to check her in the act of slipping, and to prevent her from flying round at the rate of 800 or 1,000 revolutions per minute. Just before entering a tunnel, there is no doubt that the sand-valves should be opened, and the sand should be allowed to flow until the train emerges from the tunnel; for, as was said before, sand is cheaper than steam.

Knowledge of the Signals.—But evidently a great part of every driver's time on the foot-plate must be employed in looking out for signals, and until he is thoroughly familiar with them he may approach them involuntarily. The great master drivers, who travel the road at express speed, manage to secure a few seconds in reserve before reaching a busy junction station, so as to reduce speed. This, of course, is required only at exceptional places, where the view of the signals is defective, and where a great traffic is going on, or where the road is not exactly straight. It must never be taken for granted that, because the "distant" signal and all the other signals are "off," the line is clear. This is a very important point.

Every driver should, as far as possible, not only see that each signal is "off," but he should also cast his eyes over the road in front of him to see whether it *should* be "off." At night the circumstances are different, and a man can only protect his engine buffer-plank by proceeding with caution, that is, by keeping a good look-out. Most drivers have found that such special carefulness has been the means of preventing many collisions. Though a second or so be lost over it, the engineman has derived the solid satisfaction of knowing, what is testified by thousands, that vigilance at all points of the line seldom remains long in activity without making some discovery which naturally supplies an interpretation of the real character of the discoverer, showing up the actor and his acting, the thinker and his thoughts, the judge and the judgment, and speaking eloquently for faith and hearty good service, which, like bread cast upon the waters, is, in some instances, apparently lost. Yet, with humility and patience, duty is, sooner or later, sure to reap its true reward.

Knowledge of the Road.—Next in importance to a knowledge of signals, and how to act upon them, we must place the knowledge of the road. It should ever be remembered that, in order to run swift trains with safety, the driver should not only be acquainted with the line itself, but should also possess a thorough knowledge of the gradients. It will not suffice to know that the line runs down-hill from the Four-Ashes to the Spread-Eagle station, but the steepness of gradient must be known, as well as the length of it. Young drivers should lose no time in obtaining possession of such information. When a driver has combined his knowledge of the signals and their positions with his knowledge of the road and its varying gradients, he may run with confidence. Should he be running down an incline of 1 in 100, and should he have to look out for a signal nearly at the bottom, he knows exactly where to shut off steam ; and therefore, until he reaches that spot, he can maintain the speed by keeping on the steam without the least fear of overlooking the signal should it stand at " danger."

Some signals are very badly situated, and cannot be sighted nicely until the engine is close to them. In other instances they can best be seen afar off, *across the country ;* and as the train approaches them they become hid from view by intervening objects. By keeping a good look-out, one man will sight a signal from a point whence another man never thought of looking for it ; and in this way, while one is running cautiously for fear that the signal may be turned on at " danger," another having sighted it several miles off is prepared to shut off steam or to run past the signal with full steam on, just as the case may be.

Moreover, while the sun shines, the signals, junctions, landmarks, and gradient-posts are clearly visible, and the track is easily followed; but when the sun has set, and all is covered with darkness—mountains, streams, bridges, and stations alike—a driver finds he is left without anything to guide him except his personal acquaintance with the road.

There is nothing in our calling that excites the astonishment of the public more than seeing some fast express train rush past them in the midst of darkness at fifty miles per hour. The noble iron steed, as it approaches them, has the appearance of some monster broken loose from Vulcan's forge. Here a spark and there a spark, a flash here and a flash there, the fire flying about the heels of the monster as though some mighty giant was, by a powerful arm, pulling it down upon its haunches. Instead of all this, it is in charge of two men who are as self-possessed as though they were on the box of a family chaise. Experience is everything.

Knowledge of the Traffic.—Knowledge of locomotive machinery and of the line in all particulars are acquisitions worthy of every driver's ambition, but it would never do to rest there. First-rate running, to be done with ease and safety, is inseparably dependent upon a thorough acquaintance with the traffic, and with what is going on " up " and " down " the line.

A circumstance that took place a few years ago in respect to an important train will somewhat explain this point. A goods train, having two engines attached, was proceeding south at midnight, and after it had passed a fast express train a thought struck the driver of the express that, for two engines, it was a *very short* goods train. He stepped over to the fireman's side of the foot-plate for the purpose of seeing whether there were any tail lights on the last vehicle, but, owing to a curve in the line, he could not ascertain that point. He, however, shut off steam, and gave instructions to his mate to have the brake in readiness, " for," said he, " it strikes me very forcibly, mate, all the train is not there." When they had run about two miles, and were thinking of getting up the speed again, a red light was seen ahead surging violently from right to left. They pulled up at once to it, when a goods guard informed them, as he held his bull's-eye light into their faces, that a waggon-axle had broken in *his* train, and had caused twelve trucks to leave the rails, and that they were across the down-road right in the way of the express. The guard got up on the step of the engine, when they pulled gently down to the scene of the accident, where a sight presented itself which told them that something else besides being able to drive an engine was required to make a man a good railwayman.

Presence of Mind.—Railway service demands heads that think and eyes that roll, ready at a moment to detect the slightest intimation of anything wrong in the working of trains.

Driver Standiford, in charge of an up midnight mail, running to time, expected to pass driver Coven at or very near the Harrow Junction—Coven being also in charge of a mail going down. But as they did not pass each other near the usual spot, driver Standiford became very anxious about the whereabouts of Coven, and he looked with the greatest anxiety at every signal he approached to see whether the latter was signalled.

Disappointed, he said to his mate, "Coven not signalled yet; something is surely wrong; stand handy to thy brake."

Such a thing as losing time with the down mails was very rare; so that, when they were late, the first idea about the matter was that a pitch-in had happened, and nine times out of ten this thought was the correct one. "Ten minutes late," said Standiford, as he crossed over to the fireman's side of the engine to get a better view of the line in going round a curve, at the same time telling his mate to let the fire alone awhile until they knew or saw something of the down mail. During those anxious moments Standiford never lifted his hand off the regulator-handle. For aught he knew, his life and those of others were threatened, and he expected at every chain to be suddenly summoned to shut the regulator and stop quick. With the assistance of the gauge-lamp Standiford once more looked at his watch; the mail was now seventeen minutes overdue. As he returned his watch to his pocket he also stepped over to his own side of the engine foot-plate, and he had scarcely been there fifteen seconds when something was struck by the buffer-beam or guard-iron of the engine. It was neither timber nor stone, but was something much softer. Standiford heard something grating under the ash-pan; he shut off steam, and ordered his mate to stop the train. A spot of oil, as he thought, had settled on his face; but on wiping it off with the back of his hand he observed it was blood! Forty thoughts sped through his brain. A man killed—fogman, signalman, Coven, front guard, or fireman—and on this he urged his fireman to put his brake on tighter if possible; but he had no sooner done so when, to his astonishment, he heard the mail coming at a tremendous speed; he instantly seized the gauge-lamp with his right hand, and with his left opened the whistle freely to attract the down mail engineman's attention. Coven, as he came round the corner, saw the danger light and shut off steam, put on the brakes, and pulled up as quickly as possible. When he had stopped he jumped down, and discovered, a few yards in the front of his engine, in the four-foot, two dead steers and ten living ones wandering about the track. Meanwhile Standiford had stopped also; but after examining his engine, and on being satisfied that it was a beast he had run over, he put on steam again and pursued his way south.

Now, how soon *Standiford* would have pulled up at a red light, after *Coven* with the down mail was overdue to pass him, we can readily understand; but for his thoughts, expectations, intentions, and plans to be suddenly sent to the "right about," and yet to be capable of quick action, promptitude, and self-possession, we cannot so easily conceive. We must admire the coolness of the man. Standiford is what may be termed a good railway man as well as a good driver.

In view of the perils of locomotive driving, and the nature of locomotive machinery, it is necessary at all times to be ready to act with judgment and decision.

Whatever a driver knows about an engine he may, unexpectedly, be called on to bring forward, and put to a practical test; and who can say under what circumstances this will take place? A crank-axle may break, a train may part in the dark, and events similar to those above described may form this day a portion of the experience of a man who has for years past been gliding onward like a pleasure-boat on a piece of fresh water.

Suddenly, with a fearful summons, he is called upon to pull himself together, and prepare to perform some simple act of duty which, when performed at the right time and in the right way, may not unfrequently excite admiration. But, too often, the performance is left to blind chance, on the spur of the moment, and in belief in one's luck. When the unexpected sharp sound of the whistle denoting extreme danger is heard, or when the crash comes, the mind is thrown into a state of confusion, vacillation, or hopeless distraction, and actions are abrupt and changeable, the driver not having already anticipated the occurrence of such circumstances, stored the memory with facts and incidents bearing upon every possible mishap that can overtake an engine-driver, and through these acting with judgment and exercising sovereignty over the machinery.

Making Notes.—It is possible, at all times, under every condition of employment, whether of cleaner, fireman, or driver, to make notes and to lay in a store of valuable information, gathered from the circumstances of explosions, collisions, hair-breadth escapes, and temporary failures, sufficient to qualify even the youngest driver to grapple with railway difficulties.

It is related of one of the great generals of antiquity, that whenever in his walks he met with a place which appeared to his mind to possess all the points that make a place either difficult to storm or to defend, he would ask his friends how, in case of war, a place like that was to be dealt with. He would draw with his stick a plan upon the ground, showing the positions in which he would place his soldiers, where to deposit the baggage and erect the tents; and, if he had to make a retreat, he would explain the best possible way in his judgment to do so neatly, and with the least possible loss to his army. Consequently, nothing ever happened to him, as it is recorded, but what he had already planned in his mind years before. The ancient general was a fine instance of a mind that loves its profession; and he afforded a bright example of what contributes to greatness of character—"nothing ever happened but what he had already planned." It is this kind of forethought which we require upon the foot-plate—a disposition to look in the face every possible difficulty that can befall a railway driver "years before."

What to do when an Engine breaks down.—Every driver should ask himself such questions as he knows others have had to answer, in a practical fashion, rather more promptly than pleasantly. This night, for example, your crank-shaft shall break, and who can say that it shall not? Therefore be prepared with material to pack it up. But the most needful thing is to know how to do it, and the quickest and safest way of doing it. It is the young driver's privilege, whenever an opportunity offers of seeing an engine a cripple, packed up, of going underneath and seeing how the packing is fixed underneath the axle-boxes in the case of a broken crank-shaft, so that the flanges of the wheels are raised several inches above the rails. In the running-shed, in a word, a great variety of breakdowns daily invite inspection—broken crank-shafts, broken eccentric-rods, eccentric-straps and sheaves, broken motion, and broken springs.

It is well known that, though an engine may have one thing broken, it is not always of sufficient importance to disable the engine from working its train home after the mishap is discovered. This is a very important consideration. Some drivers scarcely know when they are beaten—a fact which opens up a wide discussion. Everybody upon the railways has heard of "Hell-fire Jack," and his daring flight over the Dee Bridge at Chester, after one side had fallen into the river below. Thousands of deeds quite as daring as this are successfully accomplished every year, and at this moment there are "Hell-fire Jacks" upon every railway.

The most important question is, Having broken down, what is the first thing to be done? On the right solution of this question railway heroism not unfrequently depends. It is, therefore, advisable to go now and again to the side of an engine, and, looking at the machinery, ask ourselves questions. Suppose that that right-hand back-gear eccentric-rod breaks, what then? Could I get along in forward gear, after having dismounted the rod and the strap? The answer is, Yes. And it should be prompt, as all such answers should be, with such an amount of readiness as really makes of breakdowns of this kind a matter of a few minutes.

Supposing it is a fore-gear eccentric-rod that breaks; then, of course, one side of the engine would require to be disconnected altogether,—piston, &c.; but, if such an accident occurred near a turn-table, on which the disabled engine could be placed by another engine, and turned, then the eccentric-rod and strap only need come down.

Supposing that a right or left hand spindle was to be doubled up, so as to prevent the valve from being so adjusted as to close, say, the front port. First, the valve-spindle should be uncoupled from the valve connecting-rod, and the latter taken down or tied up. To take it down, the pin which goes through the link must be withdrawn; secondly, the big-end on the side nearest the broken valve-spindle is to be uncoupled; then the little-end; thirdly, draw the piston to the back end of the cylinder, next the slide-bars, and insert a piece of wood between the cross-head and the cylinder-cover or the stuffing-box, taking care to make the wood safe with tar-band or spun-yarn run round the slide-bar. By this operation the piston-head is brought over the back steam-port, so that the steam, although it may be admitted into the cylinder through the front port, cannot move the piston; for after the steam has filled the cylinder it simply remains full, and becomes, in fact, a *steam-chest* for the opposite cylinder.

Supposing that a connecting-rod broke; after uncoupling it from the crank-shaft and the cross-head, the piston should be drawn to the back end of the cylinder and secured exactly as already described in the previous case. Provided that the piston-head is quite close against the cylinder-cover, the valve need not for a *short distance* be disconnected, because the steam cannot enter the back of the cylinder, since the piston-head is right over the port, and the steam which enters at the front end can have no effect whatever on the piston, and leaves the cylinder when the exhaust is open to the chimney exactly as though the piston was working.

When the valve is disconnected from the " link " by which it is worked, it requires to be placed centrally over the steam-ports, so as to prevent any steam from entering the cylinder, either at the front or the back. This can be done by observing, on the spindle, the limits of the travel of the valve, and setting the spindle to the middle point; or, the measurement can sometimes be better made off the valve connecting-rod when it works in a guide fastened to the slide-bars or motion-plate; or, after opening the cylinder-taps, when there are one or more to each cylinder, and opening the regulator a little so that the steam blows through, and then the valve may be gently moved towards the cock from which steam issues, until the steam ceases to blow, or, in other words, until the valve closes the port.

If a reversing-lever breaks, the engine should be worked by the regulator until another engine can be obtained.

If a regulator should become uncoupled, or a steam-pipe should break, so that the steam to the cylinder cannot be controlled by the regulator, the engine should be worked by the reversing-lever, putting it in the centre knotch, out of gear, when about to stop.

If an outside coupling-rod breaks, the coupling-rod on the opposite side must also be taken off before the engine is moved again.

If a brake-screw strips the nut, the fact is to be communicated to the guards, who will "brake" the train up to the station themselves.

Tools should be at Hand.—It is highly necessary that the engine-driver should ask himself—What tools have I upon the engine? What could I do with them? Uncouple? Could I lay hands upon any one particular thing, such as a pin-punch or gauge-glass, in the dark, or in the midst of a cloud of escaping steam. If my engine left the rails, in what condition is the screw-jack? Will it work properly? Have I a ratchet or bar to work it? Such self-interrogation may be extended to every object: to the signals, for instance, the sights, the road, and the casualties which daily befall engine, train, engineman, or fireman.

The press—newspapers—supply material for thousands of questions which are suggested by reading the reports. For this object the papers should be read every day.

It is impossible to say under what circumstances a driver may have to decide at a moment's notice or to act with great firmness. But one thing is certain, he would be an extraordinary railway man who would never make a slip; who would not meet with any misfortune through the neglect of others; who never has a broken crank-shaft, a bent valve-spindle, an outside-rod broken, or bent, broken connecting-rods or pistons, or choked fires; who retains five fingers on each hand and five toes in each boot, with his ribs intact. Such an one *is very unfortunate.* Railway enginemen glory in relating their hair-breadth escapes, and, ever and anon, lay special emphasis on the first personal pronoun when narrating the circumstances surrounding a good pitch-in between two goods-trains. The influence of such honest pride no one can sum up. On the iron track, in charge of the iron steed, George's troubles will come. The speed and the power are great, and danger lies even in the worm that burrows into the sleeper; but the more extensive our acquaintance is with the unfortunate accidents in which our comrades have been killed, maimed for life, or bruised, the more extensive will be our power to steer clear, if possible, of every ill.

Managing the Fire towards the End of the Journey.—The principal point in the management of the engine with a train which remains to be noticed, is the finish.

With respect to economization of coal, it is, at this part of the trip, where one engine-driver may be distinguished from another; for difference of management can decide the fate of several hundredweights of coal.

From the start to that point of the trip where it is considered that there is sufficient fuel in the fire-box with which to finish the trip, the fire has been kept well up to the door by frequent firing; when, by experience and judgment, it is decided that there is sufficient in the box to run the remainder of the trip. A gentleman obtained an engine-pass: he was very anxious to see some locomotive firing; but he happened to join the engine when it was only 58 miles from where it would have to be detached from the train. As the train proceeded on its passage, our friend, not seeing any firing going on, expressed his astonishment. Mile after mile was left behind and still no firing nor application of fire-irons was needed. As the fire burned down it naturally became fiercer, and the fireman was solely occupied in attending to the pump, and getting as much water into the boiler as it would carry, checking the steam, and enabling the engine to run for the last few miles without requiring any farther supply of feed water.

The pressure-gauge was watched very narrowly, and when it was inclined to fall off the pump was shut-off; if the needle attempted to rise again the feed was introduced to check it. After having run some 45 miles, it became evident that the pressure was inclined to fall, and the fireman gently, with a fire-iron, levelled the fire, and raised the damper one more knotch. To this the engine replied, and the needle again began to look up surprisingly, more water was introduced, and the boiler was filled up. The fire having become very low, the pump was shut off, and the water already in the boiler, being in excess of the ordinary quantity, supplied steam for some miles and until the regulator was shut, when the pump was put on again with one inch of water in the glass, to run in some more water, the pressure of steam still admitting of an additional supply of water; which is not always the case at the finish. When the train arrived at the platform, the visitor particularly wished to see inside the box, where there was but a mere handful of fire, and, having looked about it, he said he was greatly disappointed, and "should certainly go on some engine where there was less pumping and more firing."

It is not possible to make a fire last, like the one just described, to the end of every trip; but, when the attempt succeeds, a very large saving of coal is effected, and the average consumption is considerably modified—sufficiently so, if habitually practised, to make a decided impression upon any coal-list. One or two hundredweights of coals are scarcely observed in a large box, but two hundredweights saved at the conclusion of each day's trip is equal to about two tons per month. Now, it is not an unfrequent occurrence to find engines in charge of drivers who are very good in all other respects, who think nothing of a fine finish, and who take no pains to compete with others for economizing of fuel. They keep excellent time, and all that kind of thing, but they dislike to be troubled with the necessary effort of working the fire, water, and steam to the utmost limit of economy at the finish. Generally such men, however, look well to the steam when on the road, and they work their engine with almost incredible economy of water.

Upon a particular railway, certain express trains had a run of 80 miles between two stopping points, and it was only by first-rate enginemanship that the train could be run without making an additional stop for water. Some drivers could do it—do it every time; others failed to do it—failed at heart when they were not actually out of water. These men regarded it as a risk, having no doubt done it once, and, having found it close work, they never attempted it again. Those who did it, calculated, measured, and economized the water; to them there was no risk, for they knew exactly how far 20 gallons of water would take them. But then there were other drivers whose tenders could not carry sufficient water to take them through.

Driver A, an old experienced engineman who can remember, when 90 lbs. was the maximum pressure of boilers, that the engines then ran quite as fast as they do now. Although his present maximum pressure is 140 lbs., yet 100 lbs. is about what the finger on the pressure-gauge on his engine points to, taken on the average. This man works with the regulator full open, and he maintains the speed, against the resistance of the atmosphere and the load, by means of the reversing-lever, which is generally in the third notch from the centre. There is an injector and a pump on his engine. He makes use of the former occasionally, but he works the pump as a rule. This man cannot get over that bit of 80 miles run without making an extra stop for water.

Driver B is also a man of some experience. He likes to see 140 lbs. pressure on the gauge, but is not disposed to rouse his fireman over a paltry difference of 20 lbs. This man works the regulator to maintain the speed, with the reversing-lever in No. 2 notch. He has an injector and a pump, and he works the latter as the boiler requires it. This man also cannot get across the 80 miles without stopping for water.

Driver C goes in for 140 lbs. from the start to the finish, not a pound less; works with the regulator full open, and with the reversing-lever in No. 1 notch (next to the centre of the sector), expanding the steam until it can scarcely rise over the chimney top, when it swoops down on the boiler, and in the face of the driver. No steam is allowed to blow off, and having, like A and B, an injector and a pump, he works the injector, screwing it down in the barrel until it supplies the boiler with exactly the same amount of water that it parts with as steam. Thus no water is wasted by turning it on and off, and the waste of water at the pump-gland is avoided by not using the pump. This man can run the 80 miles, and even then he has water in the well of his tender—a reserve which is no doubt due, in a great measure, to his using steam of a very high pressure, and expanding it to the smallest convenient pressure, just sufficient to keep a moderate blast on the fire. It is, in this case, absolutely necessary to fire often, with about six shovelfuls of coal at one firing.

We return to the finishing advantages to be gained by a trip with a fire that has gradually burned down to the bars. Suppose that, at 50 miles from home, the fire has received the finishing touch. By the time the engine has traversed 20 miles of this length nearly every appearance of smoke, or carbon, will have disappeared, the gaseous elements of the fuel having been consumed by oxygen, or atmospheric air. The fire commences about the same time to make steam rapidly, and the rapid production will continue even until the fire may be only a few inches thick, making more steam than when the box was full of coal. The explanation is, that after all the smoke in the coals has been consumed, carbon is no longer deposited in the tubes, whilst the carbon particles which have already been deposited as a coating of soot on the tubes and the tube-plate, assisted by vapour given off from the fuel, are violently attacked by the oxygen and literally consumed. The fiercer the fire, the farther along the tube is the cleaning-out action extended.

The increase of steam is therefore due to the absence of smoke; to increased cubical capacity in the fire-box for oxygen; to the increased transmission of heat due to the clearing out of the soot. If a kettle coated with soot is placed by the side of a smokeless fire, the heat will fetch off the soot in scales.

The author remembers having an engine, in place of the regular engine, that refused to steam nicely, and was only made to keep time by working a thin fire by stratagem. The tubes were, at the termination of the trip, put through a scorching process similar to that described above, and the effect was incredible; for the engine steamed wonderfully well on the return-trip, which, very much unlike the up-trip, was performed with pleasure.

A clean fire, in the sense of being free from smoke, when worked at the end of the trip, is a most effectual cleaner of tubes and destroyer of clinker. But if there be not quite sufficient fire in the box to run the engine and train home, it is better to add a little more coal to it before the fire gets too low; and in doing so care should be taken to see if there are hollow places anywhere—about the corners, for instance—that want filling up, so that the fire may burn down quite evenly; and, provided that the fire is level, and that there are several inches of fuel on the bars, and more fuel is required, it is advisable to use the chisel dart, routing the clinker off the bars before putting any more coals on. This will be found necessary to secure a good draft and rapid combustion. For this purpose the coal should be small; and it is a good opportunity to work off small coal. The brick arch should, when possible, be cleared by the rake when the trip is being finished, so that the fine coal lodging on it and raked off on to the grate may contribute a little towards getting the engine home. This should be done when there is a good hot fire.

In inclined fire-boxes the fire requires to be raked back, so that the bars near the door may be covered. In running in, the pump and the blower are generally employed—the former to fill the boiler for the next day's trip, and the latter to get as much steam as is possible out of the dying embers, if only to blow it back into the tender to warm the water for the next day.

Use of the Blower.—In all cases, before shutting "off" steam, the blower should be put on, and the fire-door opened a little, if there be smoke in the fire-box, or if the pressure in the boiler is at its maximum, so that the flame and sulphurous smoke may be discharged up the chimney instead of darting out by the doorway as soon as the regulator is closed.

Lubrication of the Cylinders and Valves.—The cylinders and the valves should be properly lubricated, as often as there is an opportunity of doing so, on long trips—when checked by signals, or when reducing speed for a junction; and they should always be lubricated just on running in from a trip, so that the engine may be able to move without a groan when leaving the shed for the next journey.

Approaching a Terminus.—In approaching a terminal station, the train should be well under control, so that the engine may be able to stop, *by signal*, at any part of the platform. If a driver is not thoroughly acquainted with a place, it is ten thousand times better to have to put on steam again to get the train into the station than to go into the buffers with the engine reversed, whilst the fireman perspires in his efforts to twist off the handle of the brake, after the wheels of the tender have all been locked.

When on the station, whilst the engine is waiting to pull out the carriages, the driver should look round his engine, and ascertain if all the axles are running cool. Sometimes when the engine is long detained in the station, all the axles, if hot before, may have become cool when the engine arrives over the shed pit; and no defect by hot axles can be discovered until after the engine gets some distance on the road the next day, when an axle is found hot that probably might have been previously restored to good order had the driver examined his engine when he arrived in the station on the previous trip.

Where there are pits the engine can also be examined underneath with the same object—to detect anything hot before it has cooled down. And here, it may be remarked, there is a great want of engine-pits at most of the great terminal stations. They would, if built there, not only confer a great boon on the enginemen, but would save the companies the cost of many a vexatious failure; not to mention the damages which generally follow upon the failure of an engine in the form of compensation for loss of time, cab fares, &c.

CHAPTER IX.

CAUSES OF FAILURES.

To learn what have been the causes of failures in locomotive engines is a most instructive practice; and whoever reads the fine-sheets and the newspapers carefully cannot but learn how many, even the most of them, are brought about. It may be advisable now to note *how* and *where*, in their machinery, some engines have failed.

In consequence of not properly examining his engine, the driver lost the nuts off the studs of the piston-gland, by which the gland was allowed to work out of the stuffing-box. When it thus became free, the gland accompanied the piston-rod outwards, and on returning homewards it failed to enter the stuffing-box. The consequence was that it received a tremendous blow from the cross-head on the return stroke; and, by the concussion, the piston-rod was snapped asunder. While the driver was uncoupling he thought of the water in the boiler, and jumped up on to the foot-plate just in time to draw his fire and save the boiler. This accident caused a delay of one hour.

By the driver's negligence, the fire-bars of his engine melted, or ran together, the ashes not having been raked clear out of the ash-pan. When the ashes are piled up to the bars, these are placed, practically, between two fires. It is a very common thing to neglect clearing the *corners* of the ash-pans, which is not only a disadvantage to an engine for steaming, but the accumulation being wet, from various causes, it corrodes the ash-pan and makes holes in it, so that when the engine is standing full of steam, the steam blows off, and it is impossible to keep it quiet. This entails extra consumption of fuel and waste of steam; and, further, when the engine is running with the damper open, the air which enters at the opening rushes out through the holes, instead of rushing into the fire.

In consequence of the driver not examining his engine properly before joining the train, he gave it up a few hundred yards from where he hooked on to it, the cross-head cotter being loose.

In consequence of the driver not seeing that the tender was full of water before starting, he had to make an extra stop with a first-class train, thereby losing *caste* as an express man.

In consequence of the driver not examining the set-pin in the little-end cotter, the latter worked out, and delayed an important express train forty minutes.

In consequence of the fireman not ascertaining what pressure of steam there was in the boiler before making up the fire, his engine could not take its train.

In consequence of the fireman being left to do *all* the oiling, the little-end (of steel) seized, causing the engine to fail; the fireman forgot to oil it.

In consequence of the sand-pipes not being properly tested before the engine joined the train, they would not work when required, causing the engine to lose forty-five minutes, where, being on an easy gradient, it should not have lost a second.

In consequence of the driver not making sure that there was a split-cotter in the draw-bar pin, the pin worked out, and the engine was separated from the tender and train.

The driver did not inspect his engine before leaving the running-shed, and he lost the pin that connected the eccentric-rod to the "link," thereby giving up his train and causing delay.

The split-pins in the motion should be carefully examined with the fingers. It is usual for some drivers to give them a gentle tap with a hammer; but the tap often fails to detect if the pin is broken in the eye of the connection.

By trusting to chance or luck, a driver was obliged to give up his train, through an eccentric-bolt working out. The bolt and nut were found, but not the safety-cotter, which had no doubt been lost some time previously. The bolts, nuts, and cotters about the eccentrics require daily inspection, not only to prevent a failure, but also to assist in keeping the motion compact and square. When an unusual amount of slackness is allowed between the eccentric-strap and the sheave, the valve is permitted to slugger, and in consequence the timing of the valve is affected, with the distribution of the steam and the "beat." In some instances it causes the bolts to break. When the bolts have worn slack the fitter should let them up early.

By not looking round his engine properly, the driver started with the smoke-box door insufficiently screwed up. It was not air-tight, and he lost half an hour with an express. The washing-out men had taken out the cross-bar to get access to the smoke-box, and had replaced it with the wrong side outwards. They then, without taking any notice, screwed the handles on the smoke-box door tight up against the collar on the spindle. This kind of mistake has happened several times.

In consequence of the driver not inspecting the trimming in a big-end, after a fitter had put in fresh metal, he was obliged to give up his train. In this case the trimming was too tight. It is very important that every driver, who knows what quantity of oil his big-ends take, should put in the trimming himself. Some engines require more oil than others, although made from the same drawings, owing to their being more out of line than others—not built square.

In consequence of the driver not looking after his engine, he lost the syphon-top off the eccentric-strap, by which the oil was allowed to escape, when the strap seized the sheave, and got broken, delaying the train. The same kind of accident has occurred to big-ends, causing the breaking of the connecting-rod and sending a piece of it into the boiler.

In consequence of the driver's negligence in not seeing that the pump-ram of his engine was all right, it worked off the gudgeon, damaging the engine and delaying his train. The set-pin head was hid in grease and dirt, showing that it had been neglected daily both by the driver and the cleaner.

In consequence of the driver not seeing that the valve spindle-gland was screwed up "fair," it heated the spindle, and consequently weakened it, so that it bent. Care is required both with piston-rods and valve-rods, so that they may stand in the centre of their respective glands; nothing is so irritating to them as a gland which interferes with their operations, either by the gland being out of centre or by its working loose on the studs. In packing a gland, it is a great mistake to suppose, as is often done, that the quantity of flax put in represents the efficiency of the job. It is often the case that the flax has been packed so tight and so hard as to be incapable of receiving any moisture from the oil or tallow in the gland; consequently the flax is charred and becomes hard in a very short time. The best way to make a gland stand well is, first, to clean out the stuffing-box and tallow it a little; then to put in some moderately tallowed flax, of the same thickness throughout, not too tight, with the joint at the top. After having packed the gland once, take particular note of the exact length of it required to fill the stuffing-box, so that the two ends, if the body was removed, would make a butt joint. The glands should not be screwed up tight, but should be well secured with lock-nuts. If there is a recess in the gland for oil or tallow it should be carefully trimmed, not too tightly, and it should be liberally, but not wastefully, supplied with lubrication. The duration of the packing depends principally upon the attention given to the swabs, or oil-cups, for feeding the flax in the stuffing-box. If they are neglected the flax will soon burn and perish. With proper attention, a freshly packed gland will last for weeks by adding a little flax now and then, and by keeping it very moist with oil or tallow.

In consequence of the driver fitting an air-tight cork in the syphon-top of the big-end, the lining metal melted out. When corks are used they should be pierced through the centre, and a couple or more strands of worsted pulled through the hole; this will permit the air to enter the cup, and prevent the oil from flying out.

In consequence of the driver not examining his engine, he failed, owing to a fitter having forgotten to replace a pump-ram which he had taken down.

In consequence of the driver's neglect, the cross-head cotter worked out, and left the piston-rod to drive out the cylinder-end.

Superior locomotive drivers, upon all railways, follow no false illusions respecting luck; they habitually examine their engines before joining a train.

It is a very uncomfortable feeling to be working an engine which one fears may give out every minute, and unless it is properly examined how can a driver know but what, before he has finished his day's work, the connecting-rod may drive right through the fire-box, owing to a broken cotter or gib, or by a set-pin slacking back. Such things have taken place, and simply await like conditions to occur again. However, when the engine is properly examined, the driver derives from the practice a wonderful amount of confidence in his charge; and without this no man can be a great driver.

It is a good *rule* to examine the engine off the pit. As the engine leaves the shed both pumps should be turned on and well tested, and the dry-sand boxes opened so as to ascertain that they are workable. Should the engine have been under slight repairs, these particular jobs should be thoroughly tested or examined before the engine leaves the running-shed yard. Fitters, like the rest of mankind, are liable to make mistakes; consequently, all their work freshly done should never be accepted as perfect until it has undergone a proper test. Callipers have been left in the feed-pipes; pump-rams left down; rings left out of the piston; files left in the valve-chest; cylinder-cover joints and valve-chest joints not screwed up tight; big-ends fitted up too tight; water let out of the tender, and no intimation of the incident given to the driver; feed-pipes uncoupled. One individual, who had to do some work in a smoke-box after the fire was lighted, put a large sheet of thin iron between the blast-pipe and the tubes to keep the smoke off, and when he had done his work left it there, and fastened up the door. The consequence was that the driver, after having done everything he could think of to get on the road, put into a siding with an important express, when he found out what was the matter. Such a case would lead one to consider whether it is not necessary regularly to examine the smoke-box as well as everything else. Many things have been found wrong whilst the engine has been leaving the shed which were not discovered over the pit—things that would have amounted to a vexatious *little big failure.* That is, the causes would have been small, but the effects on an express sufficient to have made London Bridge echo again. It is by far the best way to find out in the shed that we have only part of an engine, than to join the train and find it out there.

In conclusion, the science of locomotive driving is based upon close observation, and by just so much as there is of this faculty in a young driver will he succeed.

By closely watching what is going on in the engine upon a railway, it is possible, with patience, to become able to detect little irregularities taking place in the machinery of the engine, in the traffic, and in the signals, the discovery of which, made in good time, enables the driver to avert many failures and collisions.

The eye of a skilled physician no sooner meets that of his patient than he at once diagnoses the complaint, and prescribes the remedy; and it cannot be doubted that the same skill and precision of judgment are necessary, and may be acquired, on the part of an engine-driver in respect to an engine.

The iron horse, like its master, is liable to serious indisposition, subject to strains and ruptures, and is sometimes nearly choked. Now and again, therefore, it is not very lively, and consequently requires extra supervision. It is undeniable that break-downs and failures of every possible description, like everything else, have their cause or their origin within reach of investigation.

Every failure of an engine is one of three things: it is either a deviation from what the builder intended, a deviation from perfect enginemanship, or a deviation from sound genuine locomotive properties. It is clear we cannot tell what the deviation, the something wrong, is, unless we know what the thing deviated from, the prior something right, was, which can only be ascertained by observation and experience.

Observation in a shed may appear, to some persons, to be very tame and unphilosophical; but by it alone some worthy individuals have discovered the cause of certain effects which others have deemed unknown or unassignable.

He who resolves never to investigate the cause of any other failure than his own, must remain all his life unfit to govern a powerful engine coupled to an express train.

There can be no doubt that he who has made the most of his time, and made the most investigations, is best qualified to take charge of the most important trains. The excellences of our calling are not arrived at by chance, but a man must begin with the conviction that he is in his proper sphere, a sphere suitable to his abilities. With both hands and a bouyant will he must buckle to, resolved to know all about the engine; all about the laws of combustion, the fire, water, and steam; all about failures, choked fires, priming, and the quality of coal.

Every object exhibited to view upon the line may furnish matter for investigation. Even when standing by a water-crane, the position of some portion of the engine in relation to the column or dip of the crane can be taken; for ever after the information gained may be really valuable. The same thing may be said of the turn-table; and such notes, although seemingly trifles in themselves, very often enable a man to exhibit tact and skill sufficient to warrant his superior in recommending him for promotion.

But whilst diligence is strongly recommended to the young driver, who frequently has no other means of gleaning facts—for few men will make him as wise as themselves—yet there are certain things which take place about an engine that require years for their solution. No doubt some persons are trying to solve them now, and have been trying for years. They may have obtained the solution of a few problems, which are to them "chance pearls which diligence loveth to gather and hang around the neck of memory"

To such persons be it known that self-reliance is a grand element of character; it has won Olympic crowns and Isthmian laurels; it confers kinship with men who have vindicated their divine right to be held in the world's memory.

Let the master passion of the soul evoke undaunted energy in pursuit of the attainment of one end, aiming at the highest in the spirit of the lowest, prompted by the burning thought of reward, which sooner or later will come, for earnestness and foresight are steeds which never fail. This is a beautiful Persian proverb: "A stone that is fit for the wall shall not be left in the way." If you are fit for the wall, heed not. Only, be fit, squared, polished. Learn such knowledge as is necessary and falls within your sphere, and it is certain your turn will come. The builders will find you, the wall will require your services to fill up a place quite as much as you need a place to fill.

CHAPTER X.

SHED-DAY.

Washing out the Boiler.—Previously to washing out the boiler, and before the engine is taken into the shed, the smoke-box requires to be cleaned and perfectly cleared of ashes with the shovel and the hand-brush, so that the wash-out plugs can be easily taken out and that there may not be any ashes to be washed into the tubes.

To cool a boiler down quickly, and without injuring the plates, after all the steam is blown out of it, let out the hot water, and allow the boiler to stand for several hours, when the whole of it gradually cools down. Two persons are required to wash out a boiler properly. The washing-out rods should be of copper, that the plug-hole threads may not be damaged by the rods. The hose should be placed first over the top of the fire-box, next in the chimney-end, and afterwards in each mud-hole or plug-hole around the bottom of the fire-box. After the boiler has become perfectly clean, which may be known by the colour of the water running out of it, it should be thoroughly examined with a small spirit-lamp, on the end of a piece of copper wire, by the foreman boiler-maker or the running-shed foreman. In any case, it should not be left to the driver's judgment. Some one else should share the responsibility, and be able to testify as to the manner in which the boiler is cleansed every shed-day. The most particular parts for examination are the stays around the fire-box, upon which the dirt sometimes lodges, and is accumulated until the copper is damaged, causing it to bulge inside of the box, and thereby throwing a very severe strain on the stays near it. Many fire-boxes have been completely ruined by dirt.

After the boiler is perfectly washed out, the plugs before they are put in require to be greased, to prevent their sticking, and so requiring extra power to get them out again, after having been exposed for a time to the action of the water and steam.

The driver or the leading hand of the washers-out should always restore the plugs to their places. Inexperienced men have occasionally put them in across thread—a mishap which has in many instances led to serious delay, in consequence of the steam blowing through the opening made by the plug in its oblique position, and the necessity for letting off the water to get the plug properly replaced.

When the boiler is cold and the plug is out, the latter does not require to be screwed in so frightfully tight, because when the boiler is warmed up it expands and closes on the plug; and therefore a plug put in tight when the boiler is cold becomes still tighter when the boiler is hot; and this is invariably the condition of the boiler when plugs are withdrawn.

Filling the Boiler.—Whilst the boiler is being filled with water, or being emptied, the regulator should be opened; the reason of which will be explained in the chapter on Pneumatics.

For raising steam in a tight boiler, it is sufficient to fill it for about two-thirds of its capacity; for water expands when heated. After the boiler is filled the regulator should be shut.

Examination of the Fire-box.—On shed-days the driver should get inside the fire-box and thoroughly examine with a light everything in it, down to the fire-bars. By such an examination he acquires some knowledge of the construction of the box, and he acquires confidence.

When the copper plate round the stay-heads is bulged, the bulging is generally a sign of the presence of dirt at the back of the plate, which requires to be at once removed. The brick arch, when it begins to get shaky in the middle, requires to be attended to. It is generally formed to a versed sine of six inches.

The Mounting.—On shed-day, or, as it is sometimes described, shady day, all the gauge-cocks, safety-cocks, and other cocks are generally examined. When the plug of a cock requires to be ground in, it should not be treated with emery, but with silver sand. Sometimes the plug of a cock causes a leak, in consequence of its bearing hard at one end; then with a fine file it is reduced a little. A very little reduction is often sufficient to enable the plug to touch the shell all the way through. The grinding is generally done with water and sand, and as the plug is lifted up and down during the process of grinding, the hand at the same time sets the plug down in the shell at a different place each time, to avoid making the shell oval.

When the shell requires grinding, a leaden plug is used, cast in sand from the proper plug, making allowance for increased size by rapping the pattern plug in the mould. The lead plug should be provided with a handle at one end.

When the lead plug is fitted, by grinding with sand and water, to the shell, should the shell not touch the proper brass plug in the centre, the lead plug is reduced in the middle by a file, so that it bears only at the ends on the shell. Being thus eased in the centre, the lead plug will rub down the shell at both ends until it has worn and restored the interior of the shell to the form of a true cone.

The plug and the shell require to be perfectly freed from sand before they are put in working trim. They should also be tallowed. Every plug about the boiler should be properly attended to, and made perfectly steam-tight. The taps of the gauge-cock require extra care; and, whilst being perfectly tight, they should be workable at all times by the thumb and forefinger only. The screw-plug, which is in a direct line with the water-way into the boiler, should be taken out and the water-way cleaned.

It is a sure indication of a third-rate engineman when we hear of a gauge-glass breaking and giving people a wetting; but several men have made very serious mistakes by neglecting the cocks. In one instance, when the glass broke while the driver was trying with the *shovel* to shut off the steam and the water, he lost all thought of W— distant signal, which was against him, and he ran into a horse-box standing at the station.

A very promising young driver, who had just relieved another driver, lost his life entirely through the bad condition in which the gauge-taps were left by the first driver. The glass broke, and the relieving-driver, finding that he could not shut the cocks, proceeded towards the back of the tender to obtain a monkey-spanner, which he constantly carried with him. In the excitement of the moment, the steam and the water blowing about, he forgot to look out for bridges, and was unfortunately knocked off the tender and killed.

On shed-day, every little job should be attended to by the driver, or the fireman, or a fitter. To do so thoroughly a little foresight is needed, and especially where the appliances of the running-shed are limited. It is therefore desirable that it should be pretty well known, in advance, by the foreman and the fitter, what is required to be done to an engine on the shed-day, when it comes round.

It has happened, in consequence of the driver's speculating on everything necessary being found in the stores, that several days' running has been lost to the company by engines which might have been at work, had the driver given timely notice of what was required to be done. Some pumps fail gradually, working with a harder knock every day. The foreman receives no notice of the failure, until driver A reports that the engine-pumps have given out. The result may be that the repairs are such that the engine must be stopped between its shed-days, and the other engines which have their regular shed-days are neglected in order to attend to that engine. Hence a host of risks may be encountered through the dilatoriness of one man in reporting defects as soon as they are discovered.

When engines fail by the want of timely reporting, the failure is, properly speaking, that of the man, not of the engine. He fails in carrying out his obligation to his superintendent, who, though he is not always on the engine, is nevertheless accountable to his directors for the proper performance of the engine.

Cleaning the Tubes.—On shed-days the tubes require to be cleaned and cleared of ashes. There is scarcely a tube but has about five square feet of heating surface in it, and one might enter many a shed and find engines having, say, six tubes totally choked with ashes. These tubes contain, say, thirty square feet of heating surface. Now to form a proper and permanent idea of what six stopped-up tubes signify, let a young engineman mark thirty square feet of surface upon the ground, and the importance of thirty square feet of heating surface will be impressed upon his mind. Where there are a sufficient number of engines, it is economical to employ men specially to sweep the tubes, or to see that the fireman makes every tube perfectly clear by examining them.

On the first shed-day in each month the tender should be washed out and examined inside.

Packing the Glands.—On shed-day all the glands require to be attended to—re-packed, and furnished with nice clean trimmings or swabs.

When patent packing is employed to keep the gland tight, with break-joints, it should not be screwed too tight, for thus the material would be pinched to such an extent that the lubrication could not penetrate the packing, and its value would be lost.

On shed-day the tool-boxes, &c., should be overhauled, and superfluities thrown away. There should be a place for everything, everything should be in its place, and there should be a use for everything which occupies a place.

Re-metalling a Brass.—The following is the method generally adopted for re-metalling a brass, though it is not often that an engineman is required to do this :—The brass is first held over a fire, to melt out any metal remaining in it, and to free it of all foreign matter, as grease and dirt. If the tin is melted or destroyed, the recess in the brass will require to be washed with spirits of salts and re-tinned before the white metal will hold. To tin the brass, it is heated until it will melt block-tin, with which those parts intended for white metal should be thinly coated. The brass is then allowed to cool, but should yet be quite hot when the metal is poured into the recess.

Brasses require to fit easily on the journal; they should be tight nowhere. The horizontal channel in the crown must be clear, to secure a body of lubrication near the axle. The keep underneath must not touch the journal.

Big-end brasses should be brass-and-brass when put together; and, when the axle is cold, a little play should be allowed between the brass and the journal, for the latter to fill when expanded by heat, whether the heat be derived from the fire-box or generated by the work on the journal. The heat from the fire-box, however, has been known to make a big-end too tight, which, when put together, was considered a superb fit.

PART II.

SCIENTIFIC PRINCIPLES.

CHAPTER I.

THE INDICATOR.

By means of the indicator, an instrument originally invented by James Watt, and improved by others, diagrams are traced with a lead pencil on a small piece of paper, representing the action of steam in the cylinder.

Very accurate information respecting the character of the distribution of steam to the cylinders by the slide-valves may thus be obtained, together with particulars of the pressure, and its variations, at all points of the stroke. It is by means of this instrument alone that it has been discovered that the pressure in the cylinder is several pounds per square inch below that in the boiler—a fact which is due to the radiation of heat, the resistance of bends in the pipes, and wire-drawing of steam.

The indicator is to the engine-builder exactly of the same importance as the pressure-gauge is to the engine-driver. By the former, the state of the valves and the motion is ascertained; and by the latter, the state of the fire and the temperature of water in the boiler are ascertained.

Fig. 11 is a representation of a normal diagram, taken by the indicator at a low speed; when the pace is increased the tracing is more irregular, but still, to an experienced judge, the nature of the distribution—too soon or too late, &c.—is clearly defined.

The indicator consists of a miniature cylinder and piston, fitted with a spiral spring to resist the pressure of the steam. It is connected to the cylinder-cover, or covers, of the engine; and when the communicating cock is opened the steam from the engine-cylinder acts upon the indicator-piston and compresses the spring, which resumes its normal position at the line of atmospheric pressure when the pressure is with-

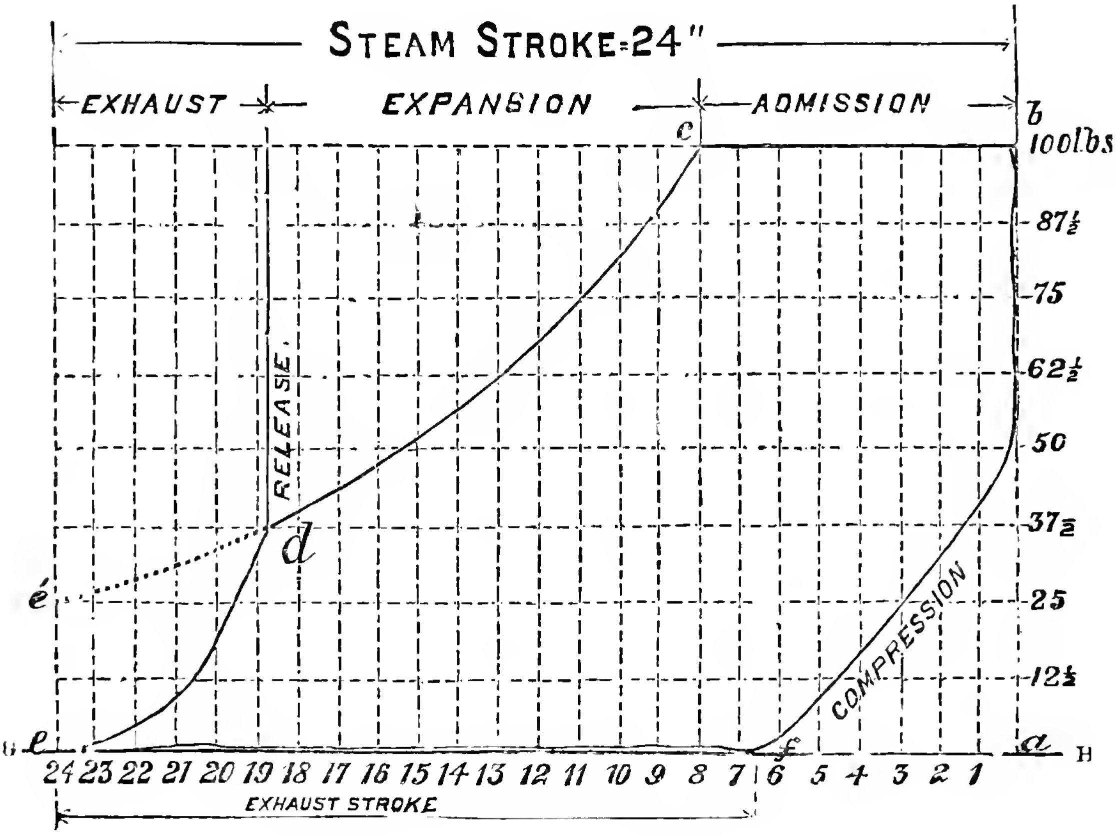

Fig. 11.—Normal Indicator Diagram.

drawn by the exhaust of the steam. The piston-rod of the indicator is so fitted as to govern the movements of a small lever, which carries a lead pencil that is brought in contact with a piece of white paper coiled round a barrel, fixed on a bracket in a vertical position by the side of the cylinder. The barrel turns on a vertical pivot, on which it receives a reciprocating movement from the cross-head of the engine, representing the stroke of the engine, and quite independent of the movements of the indicator-piston, which are vertical, capable only of marking a vertical line, which would represent the minimum and maximum pressure, without the variations, during one stroke of the engine—neither would the line teach anything respecting the valves.

Timing the steam at all points of the stroke, the

Point of admission,
Period of ditto,
Point of suppression,
Period of ditto,
Point of release,
Period of ditto,
Point of compression,
Period of ditto,

are to be obtained and traced through the medium of the barrel, which it is now necessary to describe more particularly. On its face is fixed a graduated scale, say from 10 to 150, which is intended, with a suitable spring in the cylinder, to register, by means of the pencil attached to the indicator piston-rod, the pressure of the steam in the engine-cylinder. Within the barrel is fixed a kind of watch-spring, but very much stronger than a watch-spring; and at the foot, outside, a pulley is fitted, having a groove in it. At the bottom of the groove the end of a cord is made fast, and wound round once or twice; this cord is also, at the opposite end, fastened to the cross-head of the engine, which, when in motion, pulls the barrel round *once* at each stroke, and the force of the spring returns it to the original position.

But it must be observed that while the engine-piston moves, say, 2 feet, the motion of the barrel can be reduced, by a system of levers very simply arranged, to the length of the required diagram, viz. 4 or 5 inches.

From what has now been stated, when the steam is put on and the engine begins to make a move, provided all things are ready—pencil in contact with the paper, and the cross-head of the engine connected to the card-barrel by a cord—we obtain two different motions, which are absolutely necessary to know exactly what the steam is doing. The motion of the indicator-pencil is vertical, and that of the barrel horizontal. Instantaneously the steam drives up the pencil and scores the pressure in the cylinder, making the line *a b*; when the pencil gets to *b* it remains still, the pressure underneath the spring being continuous; but the barrel still moves round, and the pencil therefore marks the line in the direction of *c* from *b*. At *c* we find a change, that is produced not by the barrel but by the indicator-cylinder, which marks a reduction of pressure. Owing to the valve having closed the steam-port, the pressure becomes gradually less from *c* to *d*, which is the period of expansion; at *d* there is a second decrease of pressure, owing to the exhaust-port being opened, and the steam being released from behind the piston, and the pencil consequently falls to the eduction corner, *e*. The line *e f* is marked by the pencil during the return stroke of the piston, and whilst the spring in the barrel is returning the latter to its normal position. The line G H is called the atmospheric line, and it is made by the indicator, before steam is admitted to its cylinder, by moving the barrel round; its object is of the utmost importance, as it enables the engineer to measure the amount of back pressure, as shown in the diagram. In a locomotive diagram the return-stroke line never crosses the atmospheric line, but in a condensing engine it does, with a good vacuum, produced by the condenser and air-pump.

Once more, it should be observed on the diagram that just before the pencil arrives at the admission corner it leaves the back-pressure line, and cuts the corner off, to join the line *a b* again. This requires some slight notice, because the circumstance may be produced by two widely different causes, viz. by cushioning and by pre-admission. Cushioning is produced, and increases as the admission is reduced, by steam remaining in the cylinder after the exhaust-port is closed; there being no way of escape, it is compressed between the piston-head and cover, and hence the cause of the pressure in the cylinder, increasing and driving the pencil up before reaching the corner, *a*. This corner, *a*, is also cut off by the pencil under the influence of pre-admission, or, more plainly speaking, by the lead given to the valve in advance of the piston. We have now traced the diagram through a complete revolution of the wheel, and, before concluding this subject, it will be profitable to notice some changes that appear on a diagram taken from an engine labouring under slight defects.

For instance, if, instead of a straight line, *a b*, we get one slanting to the left, towards *c*, the valve is without lead, and the eccentric requires to be shifted a little more in advance of the crank, or the valve-spindle is too long. If the lead corner is cut off too much, the valve has too much lead, and the eccentric requires to be shifted a little more towards the crank.

If the expansion corner, *c*, slopes too much towards the eduction corner, *d*, instead of presenting a tolerable good round corner, it shows the steam is wire-drawn, that is, a certain amount of elasticity is taken out of the steam, either by the regulator being partially open, instead of wide open, or through the steam-pipes and steam-ports not being properly proportioned and thereby causing the steam to condense in forcing its way to the cylinder. This imperfection also affects the full steam line, *b c*, causing it to dip before reaching *c*, instead of maintaining a horizontal line. If the eduction corner, *d*, is rounded off too much, and the back pressure line remains too far from the atmospheric line, with excessive cushioning at the admission corner, it shows the engine has too much inside lap and cannot clear herself of steam.

CHAPTER II.

HYDROSTATICS—HYDRAULICS—PNEUMATICS.

HYDROSTATICS.

The Science of the Gravitation of Fluids.—From the experiments which have been made in this branch of natural philosophy, we are taught that fluids press perpendicularly, vertically, laterally, and in every direction equally.

The vertical or downward pressure of fluids is in common with that of solids. The pressure of water vertically is illustrated in the case of the gauge-glass. The pressure of fluids laterally or sideways is demonstrated by seeing water flow out of the *side* of the fire-box. It is an important principle in hydrostatics that the surfaces of all waters in free communication with each other are in one level. By the property of the gravitation of water inducing the tendency to find a common level, hydraulic engineers are enabled to supply our principal towns and city with water from reservoirs, situated on an elevated spot, and sometimes several miles off the dwellings of the inhabitants.

HYDRAULICS.

The Science of Fluids in Motion.—Under this branch of natural philosophy we find the locomotive pump, out of which water is forced into the boiler. When the feed is opened on the tender, the water in many instances falls into the pump-barrel, and, when the ram is drawn outwards, fills it—the water running through the bottom clack, which is purposely constructed to open into the pump-chamber only. On the inward motion of ram commencing, the water, being pressed by the ram, closes the bottom clack and lifts the middle one, which is constructed to open so as to allow the water to escape into the delivery-pipe. As soon as the ram reverses its motion, to leave the pump, the middle clacks close, through the water already in the delivery-pipe attempting to drop back into the pump-barrel, and at the same instant the bottom clack opens and, as the ram proceeds, charges the pump with water again. Assuming that the delivery-pipe and pump are filled with water when the ram returns into the barrel, it is evident, owing to the bottom clack preventing the water from running to the feed-pipe and tender again, by great pressure the water must move to somewhere to make room for the ram, for water is incompressible, and therefore the top and middle clacks are designed to meet the case—opening towards the boiler, and thereby allowing the ram, when entering the pump, to force a stream of water corresponding to its length and diameter into the boiler at each alternate stroke.

There are a variety of small deficiencies which, either wholly or partially, prevent pumps from working.

In practice the bottom clack has a little more lift than the others to insure a good supply of water; but notwithstanding this arrangement some pumps do not work efficiently. The want of efficiency may arise from several causes. Sometimes the feed-pipe gets partially made up with dirt, waste, and lime; the lime is the result of blowing the steam back through the feed-pipe to the tender. These obstructives prevent the pump from filling properly with water, in time for the plunger to force it into the delivery-pipe, when entering the barrel. Sometimes the bottom clack fails to work properly by not closing promptly, allowing some water to return past it towards the tender. To prevent this reverse movement ball-valves are generally employed. Sometimes, with a tight gland, the barrel is charged with air, which is separated from the water by the churning action of the ram, and air being, unlike water, compressible, it is not forced into the boiler, but remains in the pump, its pressure being sufficient to prevent the bottom clack from acting. Sometimes the water-way into the boiler is nearly closed up, and therefore cannot pass the water as fast as the pump delivers it, when the top-clack joint is broken.*

Pneumatics.

The Science of the Air.—It was discovered by Torricelli, in the seventeenth century, that air was a material substance, having weight, elasticity, and compressibility.

The weight of the atmosphere is found to be equal to a pressure of about 15 lbs. per square inch of surface. Suppose a vessel capable of resisting a pressure of 15 lbs. per square inch only, with both ends made up, and the whole perfectly air-tight; on extracting the air from the interior by means of an air-pump, the vessel would collapse, for the external atmospheric air would make it

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* The object of the holes in the feed-pipes is to let out the air: this takes the knock off the pump.

as flat as a pancake. There is nothing like fixing the fact in the mind that air is a real body, and, although we cannot grasp it by stretching out the hand, yet there are many little incidents which occur about a locomotive, proving that it is a substance just as much as water is, or a piece of iron. Let us take the presence of air in the pump for one illustration, and almost every fireman is sufficiently informed, superficially, to know that the pump will not act when the feed-water is put on *until* the pet-cock is opened.

Why it would not act is not quite so clear to him until he has learned pneumatics, and satisfied himself that air is a real substance, and that, while it occupies the space in the pump, water could not enter. Two bodies cannot occupy the same space.

But how comes it that, when the pet-pipe is opened, the air rushes out very cold sometimes, colder than the water in the tender, colder than the pump or the ram, and colder than the atmospheric air through which the engine is running? To illustrate the pressure of the air, we cannot find anything better than a mud-hole in the bottom of the outside fire-box or shell. When a plug is withdrawn, with the regulator tight or shut, the water refuses to leave the boiler; sometimes it will run for a few seconds, and then stop entirely.

This interesting phenomenon is caused by the pressure of the atmosphere on the surface of the water at the mud-hole, which is more than sufficient to balance the weight of water around and above the mud-hole.

As soon as the regulator or the whistle is opened, making a communication with the external atmosphere, the air rushes into the boiler, and balances by its pressure on the surface of the water the external pressure at the mud-hole; when the water, under hydrostatic pressure, at once rushes out at the mud-hole. Once more: when the steam in a locomotive boiler, with a tight regulator and whistle, is dropped—converted again to water—there is a vacuum formed above the water, that is, a space with nothing in it; and if the feed-pipes are opened the water from the tender will actually run into the boiler and fill it. This is caused by the atmospheric pressure of 15 lbs. per square inch acting on the surface of the water in the tender, against the non-resisting vacuum in the boiler. The axiom that "Nature abhors a vacuum" is here fully illustrated.

The elasticity of air is proved by its rushing out of the pet-pipe, or by its rushing into the boiler when the regulator is open.

Again, when a boiler has been filled up with water, and the regulator and the whistle have been closed, if the whistle be opened shortly after the fire is lighted in the fire-box, the air, hitherto confined, rushes out, and, if the pressure be sufficient, sounds the whistle. That it is not steam may be proved by placing the hand near it; it will be sometimes very cold, although the chill is off the water. How is this? When the boiler is partly full of cold water, and the regulator, &c., shut tight, the heat that is communicated to the water is partly transmitted to and raises the temperature of the air, at the same time that the water, by its expansion, compresses the air into a smaller volume. The result is that the pressure of the air is raised above atmospheric pressure. This is a proof of the compressibility as well as the elasticity of air. Or it may be proved thus: Shut the regulator of an empty boiler full of air, and run water into it through the feed-pipe. The air will be compressed until it balances the pressure of the water in the main, if filled from the waterworks, and the exact pressure may be found on the pressure-gauge. Again, if we place one finger on the upper end of a gauge-glass to make it air-tight, and then dip the open end into water, the level of the water in the glass will be slightly higher than that outside of it, which proves that the air in the glass is compressed.

CHAPTER III.

PRINCIPLES OF COMBUSTION.

COAL contains carbon, hydrogen, nitrogen, and oxygen in about the following proportions:—

75¼	per cent. of	Carbon
4¼	„	Hydrogen
16	„	Nitrogen
4⅛	„	Oxygen

The percentage of each element varies with different coals. The proportion of carbon, which is the chief source of heating power, is subject to the greatest extent of variation. The more carbon there is, the more water will be evaporated per pound of coal. Combustion is a chemical combination, resulting in heat and light, and when coal burns in the fire-box of a locomotive engine, this chemical combination is sustained by means of oxygen (the supporting element of atmospheric air) introduced into the box in proportion to the amount of fuel the box contains. The admission of too much air or oxygen does injury, by cooling the plates of the fire-box and reducing the temperature of the water in the boiler. By a want of sufficient air, on the contrary, the combustible gases are not all ignited—they escape wasted from the chimney. In some cases they take fire on coming in contact with the atmosphere at the top of the chimney—a fact which may be seen as a railway train passes on a dark night.

Perfect combustion is attended by intense heat, and is only effected in the engine by practice and close observation. It is controlled by the most simple laws, which, when recognised, are capable of not only annihilating a clinker, but, as is well known, burning and melting the fire-bars.

Combustion cannot take place without the assistance of oxygen. By excluding this agent of nature a fire can be put out. Oxygen is then clearly necessary, and it *governs* combustion entirely. It is capable of being controlled, both in quantity and in the direction of its action, and by paying strict attention to the condition on which its action is dependent, an engineman can safely work his engine fire without being afraid of running short of steam. Let us assume, for a moment, that we are looking into a locomotive fire-box at a smouldering fire without a gleam of light about it—all smoke. The gases that are escaping are hydrogen, hydruret of carbon, bihydruret of carbon, bicarburetted hydrogen, carbonic oxide, and *carbon vapour*, which are all inflammables, capable of generating intense heat; but their calorific value is lost, owing to the supporters of combustion—oxygen and atmospheric air—being stinted in supply.

We will now suppose that a better supply of air is introduced below and above the fire. So soon as the oxygen comes in contact with the incandescent fuel they combine, and the gases instantly take fire. The inflammables are changed, and the fire-box above the fire presents quite a cheering appearance, owing to the combustion being perfect, producing nitrogen, carbonic acid, sulphurous acid, and aqueous vapour. The more the oxygen, within proper limits, the greater the heat, the whiter the fire. The quantity of atmospheric air absolutely necessary for the combustion of a pound of fuel is 13½ lbs., but in practice twice this amount is required to be admitted to the fire-box to support perfect combustion, owing to the blast drawing the air through the tubes before it can render the best service in the furnace.

To consume the smoke in a locomotive fire-box—and it can be consumed—requires a fire not too deep for the load or the blast. It is a great mistake to burn the carbonic oxide in the tubes instead of on the grate, which is sometimes done by drivers who work their engine with the dampers shut. Having a large area of grate, they place a large fire on it, which enables them to get plenty of steam—with closed dampers; but the consequence is that the tubes frequently require sweeping out. If he opened the front damper, the carbonic oxide would be burned over the grate, and the tubes would be maintained perfectly clear of carbon or soot. If we analyse the contents of some chimney-ends we find the steam-pipes, the blast-pipe, and the walls of the smoke-box deeply coated with carbon that has escaped through the tubes—the result of imperfect combustion in the box, where every particle of smoke should be divested of vapoury gas which adheres to the tube-ends, and coats the interior of the tubes until the poor engine is absolutely choked. There is, without doubt, great need for inspectors to go round to farmyards, where threshing and traction engines are employed, to instruct the enginemen how to burn their engine smoke

It is unnecessary to point out that what is deemed best to do on a locomotive to burn the smoke, is in every respect applicable to portable and traction-engines.

CHAPTER IV.

STEAM AND THE PRINCIPLE OF ITS EXPANSION.

Steam proper is wholly invisible, and therefore cannot be seen above the water in the gauge-glass; it is also elastic and dry, but as soon as it comes in contact with the atmosphere it loses those properties and becomes vapour, and is visible and moist.

The pressure of steam is measured by atmospheres. Steam of 15 lbs. per square inch is steam of one atmosphere. Its pressure, and consequently its elasticity, is, in a locomotive boiler, sometimes increased to upwards of 9 atmospheres, or 140 lbs. per square inch, effective pressure. The repulsive power of steam may be compared to that of a compressed vertical spring, ready to expand on the resistance being withdrawn, wholly or partially. High-pressure steam, on entering the cylinder of an engine, is opposed by the cylinder-cover and the piston. On the former, the pressure of the steam makes no impression. But upon the latter, whose resistance is only equal to the friction of the engine and vehicles attached to it, and also the resistance of the atmosphere, the pressure of the steam acts as a motive power, overcoming those resistances. When the steam-pressure applied to the piston materially exceeds the amount of the resistances, the redundant pressure goes to increase the speed of the engine, and so long as the pressure of the steam is greater than the counteracting friction of the engine and vehicles, the motion of the train must be accelerated or increased. But, beside the friction of axles, &c., a train in motion is opposed by the atmosphere, and as the speed increases the resistance of the atmosphere also increases, in the ratio of the square of the speed; that is, for example, if the speed is doubled, the resistance of the atmosphere is increased four times, since a greater volume of air is to be cut and run through in less time. When the work of friction and resistance is exactly equal to the power applied to the piston in the cylinder, the engine and train attain a uniform motion, which is called the greatest or maximum speed.

The expansive working of steam is effected in the following manner. The steam is not allowed to follow the piston for the whole length of the stroke. The supply from the boiler to the cylinder is, on the contrary, cut off by means of the valve-gear, when the piston has only travelled a portion of the stroke; and the steam thus shut into the cylinder expands like a compressed steel spring against the piston for the remainder of the stroke. The pressure of the steam is reduced nearly in proportion as it expands in volume. For the purpose of calculating power and work done, it may be assumed that the pressure is reduced just as the volume is increased.

Let a steam-cylinder, 18 inches in diameter, and having a stroke of 24 inches, be represented by the annexed diagram.

Let the steam be admitted to the cylinder during a fourth of the stroke, at the pressure in the boiler of

PRESSURE OF STEAM WORKED EXPANSIVELY IN A CYLINDER.

inches					per cent. of stroke.
1	Total pressures	120 lbs.,	effective pressure	105 lbs.	
2		120	,, ,,	105	
3		120	,, ,,	105	
4		120	,, ,,	105	
5		120	,, ,,	105	
6		120	,, ,,	105	25
7	$\frac{120 \times 6}{7}$	= 102·85	,, ,,	88·85	
8	$\frac{120 \times 6}{8}$	= 90	,, ,,	75	
9	$\frac{120 \times 6}{9}$	= 80	,, ,,	65	
10	$\frac{120 \times 6}{10}$	= 72	,, ,,	57	
11	$\frac{120 \times 6}{11}$	= 65·45	,, ,,	50·45	
12	$\frac{120 \times 6}{12}$	= 60	,, ,,	45	50
13	$\frac{120 \times 6}{13}$	= 55·38	,, ,,	40·38	
14	$\frac{120 \times 6}{14}$	= 51·42	,, ,,	36·42	
15	$\frac{120 \times 6}{15}$	= 48	,, ,,	33	
16	$\frac{120 \times 6}{16}$	= 45	,, ,,	30	
17	$\frac{120 \times 6}{17}$	= 42·31	,, ,,	27·31	
18	$\frac{120 \times 6}{18}$	= 40	,, ,,	25	75
19					
20					
21					
22					
23					
24					100

$$\frac{1472{\cdot}41}{18} = 81{\cdot}80 \text{ lbs.} \qquad \frac{1202{\cdot}41}{18} = 66{\cdot}8 \text{ lbs.}$$

say, 105 lbs. effective pressure per square inch, or, adding the pressure of the atmosphere, 120 lbs. total pressure per square inch; and let the steam, after having been expanded until the piston has described three-fourths of the stroke, be exhausted into the atmosphere. The whole pressure in the boiler, 120 lbs., is marked in the figure, as following up the piston for 6 inches of the stroke, when it is cut off, and the total pressure is reduced at the end of the 7th inch, inversely in the proportion of 6 to 7 (120 lbs. $\times \frac{6}{7} =$) 102·85 lbs. per square inch. The pressures at the ends of successive inches of the stroke are calculated in the same way, until, when 12 inches of the stroke are completed and the volume is doubled, the pressure falls to half the initial pressure, or to (120 lbs. $\times \frac{6}{12} =$) 60 lbs. per square inch. When the piston has completed 18 inches of the stroke, or $\frac{3}{4}$ths, the valve opens the port to the exhaust, and the expanded steam, reduced to (120 lbs. $\times \frac{6}{18} =$) 40 lbs. total pressure, or 25 lbs. effective pressure, leaves the cylinder.

A second column of pressures is added on the diagram, showing the net or effective pressures above the atmospheric pressure, which is taken at 15 lbs. per square inch.

From these data, it is seen that the average total pressure during the 18 inches of the stroke is approximately 81·8 lbs. per square inch, and that the average effective pressure is 66·8 lbs. per square inch.

The influence of the clearance at each end of the cylinder, on the variation of the pressure, has not here been taken into account. The greater the volume of clearance, the less rapidly does the pressure fall.

Calculation of the Effective Average Pressure.—In practice, though the exhaust is opened to the steam before the piston has completed the stroke, the pressure during the remainder of the stroke is not instantly reduced to atmospheric pressure. On the contrary, the pressure falls so slowly that at working speeds the reduction of pressure to the end of the stroke may be assumed to be simply that due to the enlargement of volume. It was seen even in the indicator-diagram (page 134), taken at a very slow speed, that the fall of pressure from the opening of the exhaust at *d*, did not reduce the pressure to atmospheric pressure until the piston reached the end of the stroke. At ordinary working speeds the curve of exhaust would nearly follow the regular expansion line, *d e*. It may therefore be assumed, for the sake of simplicity, that the steam is regularly expanded to the end of the stroke. Again, the back pressure, partly of exhaust and partly of compression, is to be deducted from the positive pressure to give the effective average pressure on the piston. The following formula is given by Mr. D. K. Clark* for the average effective pressure in the cylinder:—

$$(p - p') = \frac{\mathrm{P}\,[l'\,(1 + \text{hyp. log. R}') - c]}{\mathrm{L}} - p',$$

in which p and p' are the average positive pressure and the average back pressure, in lbs. per square inch, on the piston, including atmospheric pressure, and $(p—p')$ is the average effective pressure; P is the total initial pressure; l' is the period of admission plus the clearance; c is the clearance measured in parts of the

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* "Manual of Rules, Tables, and Data," p. 830.

stroke; R′ is the actual ratio of expansion, being equal to the stroke plus the clearance, divided by the period of admission plus the clearance; and L is the length of the stroke. The lineal dimensions are all in feet or all in inches.

The foregoing formula may be expressed by the following rule:—

Rule.—*To find the Average Effective Pressure on the Piston.*—To the hyperbolic logarithm of the actual ratio of expansion add 1, and multiply the sum by the period of admission plus the clearance. From the product deduct the clearance, and multiply the remainder by the total initial pressure of the steam admitted to the cylinder. Divide the product by the length of the stroke, and from the quotient deduct the total average back pressure. The remainder is the average effective pressure on the piston.

For example, taking the data already given, and assuming an amount of clearance equivalent to 5 per cent. of the stroke, or 1·2 inches; $P=120$, $l'=6+1{\cdot}2$ $=7{\cdot}2$ inches, $R'=\frac{24+1{\cdot}2}{7{\cdot}2}=3{\cdot}5$, $L=24$, $p'=$ say 20 lbs. (or 15 lbs. atmospheric + 5 lbs.). Then the hyperbolic logarithm of 3·5 is 1·25276, and

$$p-p'=\frac{120\,[7{\cdot}2\,(1+1{\cdot}25276)-1{\cdot}2]}{24}-20;$$

$$=\frac{120\,[16{\cdot}2-1{\cdot}2]}{24}-20=75-20=55 \text{ lbs.},$$

the average effective pressure on the piston for the whole of the stroke.

TABLE OF HYPERBOLIC LOGARITHMS.

No.	Log.	No.	Log.	No.	Log.
1¼	·22314	3¼	1·17865	5¼	1·65823
1½	·40547	3½	1·25276	5½	1·70447
1¾	·55962	3¾	1·32176	5¾	1·74920
2	·69315	4	1·38626	6	1·79176
2¼	·81093	4¼	1·44692	6¼	1·83258
2½	·91629	4½	1·50408	6½	1·87180
2¾	1·01160	4¾	1·55814	6¾	1·90954
3	1·09861	5	1·60944	7	1·94591

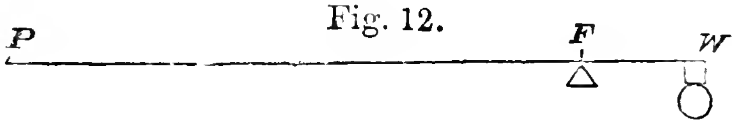
CHAPTER V.

PRINCIPLE OF THE SAFETY-VALVE LEVER.

If the distance between P and F is five times the distance between F and W, a mechanical advantage is gained, because a small weight is made to balance a large one; for instance, 1 lb. weight at P will balance 5 lbs. at W, or 4 lbs. at P will balance 20 at W.

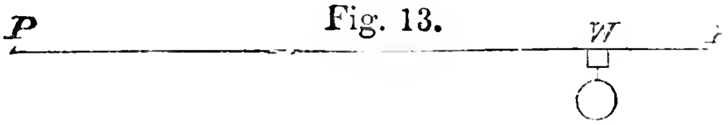
In the safety-valve lever, the weight is between the fulcrum and the power, thus—

Fig. 12.



Observe, it is the distance from the power to the fulcrum, F, divided by the distance of the weight from the fulcrum, that gives the leverage or mechanical advantage. Thus, if P and F are 17½ inches apart, and W and F are 3½ inches apart, then 17½″ ÷ 3½″ = 5, the leverage. And 1 lb. weight at P will balance a weight of 5 times 1, or 5 lbs., at W.

Fig. 13.



The weight, or rather the power, on the end of the safety-valve lever of a locomotive engine, is generally applied through the elastic action of a helical spring properly graduated to indicate any required intervals of pressure. The power on the end of the lever, as just explained, is multiplied in the ratio of the leverage, which immediately results from the principle of equality of moments.

Different engine-makers choose different lengths of lever, but the area of the valve on the steam side must coincide with the number which expresses the leverage, to indicate on the balance so much per square inch.

Thus—

Safety-valve . 2½ inch diameter = 5 square inches area nearly.

Distance from fulcrum to valve .	3½ inches	leverage 5.
Lever	17½ „	

A weight placed on the end of the lever would have an advantage of 5 on the valve, and therefore would act as if the valve, though actually of 5 square inches area, were reduced to 1 square inch area; the virtue of which coincidence is that when steam is just blowing off, the balance indicates the pressure in the boiler per square inch.

PART III.

CERTIFICATES FOR DRIVERS AND FIREMEN.

CHAPTER I.

CERTIFICATES FOR LOCOMOTIVE DRIVERS.

THE proposal to establish a system of certificates for locomotive drivers has been ventilated in the columns of *The Engineer*, and their universal adoption has been strongly recommended by the editor.

Enginemen would not only be improved by certificates, exciting a just and honest pride, but certificates would, as symbols of service and of competency, give much satisfaction.

The Engineer is of opinion that, "In the first place, certificates would enable locomotive superintendents to form an excellent opinion as to the capacity, which is a different thing from the capabilities, of a man presenting himself for a berth; and in the second place, they would tend to elevate the position of, on the whole, an honest, trustworthy, and hardworking body of men. Certificates would supply the men with a stimulus to exertion; for they would enable the best men to come to the front and take the position which they desired;

and the elevation of the type could scarcely fail to prove serviceable not only to the public but to railway companies."

The author is of opinion that every driver, before he is permitted to take charge of the regulator, should serve as a fireman on goods and passenger trains not less than 150,000 miles, after which he may offer to pass an examination, and obtain, if possible, a third-class certificate, and hold himself in readiness for an engine. This certificate might read as follows:—

"*Third-class Locomotive Driver's Certificate.*

"This is to certify that J. Stubbs has served as a fireman on goods and passenger engines 150,000 miles or upwards, that he has passed a third-class examination, and is a competent person to take charge of a locomotive engine working goods trains."

The subjects on which examination should be made, to obtain this certificate, should embrace reading, writing, signals, examination of engines before joining the trains, firing, trimming of syphons, oiling, testing of valves and pistons, and the various modes of uncoupling engines when they fail with a train. After having run 100,000 miles as a driver, and gained confidence and experience, a third-class engineman should be at liberty to apply for a second-class certificate, which might read thus:—

"*Second-class Locomotive Driver's Certificate.*

"This is to certify that N. Forster has served as a driver 100,000 miles on goods and passenger trains that he has passed a second-class examination, and is a competent person to take charge of a locomotive engine working passenger trains."

The subjects to be questioned upon for this certificate might be printed on a form, so that they could be obtained at any time; and they should embrace the steam-engine and boiler described generally, combustion considered practically, steam, and the principle of its expansion. After having run with this certificate 50,000 miles, a driver might be entitled to apply for a first-class certificate, which might read:—

"*First-class Locomotive Engineer's Certificate.*

"This is to certify that E. Sparrow has served as a driver 150,000 miles, that he has passed a third-class, second-class, and first-class examination, and is a competent driver to take charge of a locomotive engine working express trains."

The subjects to be questioned on to obtain this certificate should be printed on forms and marked, "Subject 1," "Subject 2," &c., &c., which should embrace—1st, diagram of the applicant's engine-running; 2nd, drawing of elementary forms; 3rd, working drawing, with dimensions of any part of a locomotive engine; 4th, arithmetic, decimals, mensuration of superficies and solids; 5th, natural science, mechanics to explain the safety-valve lever, hydraulics to explain the pump, hydrostatics to explain the water in the gauge-glass, pneumatics to explain the pet-cock;

6th, chemistry, caloric to explain heat and expansion, oxygen to explain combustion, composition of coal to give the percentage of carbon, hydrogen, oxygen, nitrogen, sulphur, and ash, composition of water to give the percentage of oxygen and hydrogen.

The subjects above specified embrace nearly all that a locomotive driver need be expected to know to obtain a certificate; and, as the author is of opinion that the time is at hand when such tokens of capacity will be in vogue everywhere, he has noticed each subject, and given some examples in arithmetic, &c., &c., with rules for the benefit of those whose early education was *nil*, but who are ambitious to reach a locomotive driver's certificate.

Some such evidence should be produced by every locomotive foreman. The foremen should also hold certificates of competency as well as the men.

CHAPTER II.

SUBJECTS OF EXAMINATION FOR CERTIFICATES.

Proposition I.

Conditions on which a Third-class Certificate might be issued, and the Mode of Examination.

Reading.—To read the rules applicable to drivers and firemen.

Writing.—To write 12 rules from the Section, "Engine Drivers and Firemen."

Signals.—To describe the use and observance of all signals :—

Semaphores	Day.
Flags	
Personal	
Lamps (lights)	Night.
Percussion	

Engines.—To describe generally the locomotive engine

with inside cylinders,
,, outside cylinders,
,, double frame,
,, single ,,

To state the difference in the construction of the driving-axle when inside or outside cylinders are employed.

To describe the link-motion, and the position of the eccentrics in relation to their respective cranks.

To give an explanation of lap and lead, and to point out their advantages.

To describe the means used for preventing a piston from leaking or a valve from blowing.

To state in what position the big and little ends must be placed to test the tightness of both pistons and valves, without having to move the engine.

To give some reasons for examining an engine both over and off the pit. How should such inspection be performed? Give the method to ensure its being done efficiently.

To explain generally the nature of the material used in forming the barrel and fire-box shell and fire-box.

To mention the reasons which induce engine-builders to strengthen the top of the inside fire-box, and to connect it with the outside shell.

To explain the use of the lead-plug.

To give a description of the foundation-ring, mouthpiece, and the method adopted to connect the barrel of the boiler to the front tube-plate, and how the latter is formed to receive the smoke-box.

To explain the method of securing the tubes in the tube-plate. What are tubes made of generally?

To explain the arrangements for carrying the boiler on the frame. How is the expansion of the boiler provided for?

To explain the effects of expansion and contraction on the boiler generally.

To observe that whatever is done again and again with certainty must be done upon some principle. If it is not, it cannot be repeated.

To describe the principle advocated in this volume for examination of engines over and off the pit before joining the train.

To explain why an engine should be notched up with the steam *on*.

To explain wire-drawing as applied to steam.

To explain how water is economized in working the regulator and reversing-lever.

To explain why it is necessary to know the number of vehicles in the train before starting.

Why is 140 lbs. steam better than 120 lbs. steam?

To explain, if possible, why the pressure of the slide-block is constant in one direction instead of pressing first against the top slide-bar and then against the bottom one, as the crank moves from the top to the bottom centre.

Trimming.—To explain capillary attraction and to show how a film of oil is capable of preventing two bodies from coming in contact with each other.

To state the principal causes that operate in getting an axle hot, viz.—

A brass may fit too tight end-ways.
,, ,, have no groove in the crown.
,, ,, have too much bearing.

An axle may be irritated by the keep binding against it underneath.

The principle of capillary attraction may be nullified—

By the cotton or worsted being too thick.
,, ,, ,, damp.
,, ,, ,, dirty.
,, oil being too thick.
,, ,, ,, wet.
,, ,, ,, dirty.

To go through the operation of making plug-trimming, and to give an opinion as to what should be fitted with it and what with tail-trimming. How long should a trimming be allowed to work before being renewed?

Oiling.—To point out that the operation of oiling, to be safe and perfect, must be done systematically.

To understand that 4 drops of oil per minute will keep a big-end cool.

To observe that a tight syphon button or cork, which excludes air, will cause the oil to stop in the syphon-cup by virtue of unbalanced atmospheric pressure.

To make a note that most oils contain glutinous matter—sometimes dissolved india-rubber — and that the action of syphoning in process of time chokes the tubes of the cotton or worsted with refuse matter.

Firing.—To describe the general construction of the fire-grate and the use of the brick arch.

To point out the advantages to be obtained by using broken bricks, sand, or chalk on the fire-bars before making up the fire.

To explain how a fire requires to be made to be in accordance with the method set forth in this work.

To point out the importance of firing round the box and placing the fuel against the heating surface.

To show the defects of a fire made and maintained in the centre of the grate.

To state the particular mode of firing essential to support a high pressure of steam. How many shovelfuls is enough at one firing?

To explain why a fire will not clinker in the centre when allowed to feed itself from the fuel when put on the sides or against the walls of the box.

To state where to fire and how to give the maximum quantity of coal in shovelfuls that should be put on at one firing.

Locomotive Ailments.—To describe what provisions are necessary to be able to surmount any slight break-down—spanners, packing, &c.—and the quickest way to dismember an engine.

To observe that one of the best precautions against ailments is to keep everything well cottered up, to the total exclusion of knock.

To describe how to pack up a broken spring.

To state why the bottom centre is the best position in which an engine should be placed to uncouple.

To give a description of various modes of uncoupling, of blocking the piston against the back cylinder-cover, closing the ports with the valve, or pulling the valve back like the piston.

To state what must be done in the case of the regulator losing all control over the steam to the cylinders.

Proposition II.

Conditions on which a Second-class Certificate might be granted, and the Subjects of Examination.

A candidate for this certificate should, in addition to the possession of the qualifications required for a third-class engineer, have run the stipulated number of miles as a goods and passenger driver.

The examination for this certificate might be partly *vivâ voce* and partly by examination papers.

The candidate should possess some knowledge of the locomotive from the time of Stephenson, and also give a general description of one or two engines on which he has been employed.

He should be able to describe, in keeping with his personal experience, some modern improvements introduced into locomotive practice.

He should be able to state the general advantages of cushioning, clearance, lap, and lead.

He should be able to give a general explanation of the methods adopted for regulating and maintaining in efficiency such advantageous elements as lap and lead. How is the lead and lap diminished, and what effect does it produce as compared with an engine having its due amount of lead and lead intact?

He should be able to state the general principle of combustion. What is oxygen?

How is the combustion of coal in a locomotive firebox rendered completely successful? What is carbon?

He should be able to give an opinion as to the value of different kinds of coal which have come under his notice, and distinguish them as bituminous, slightly bituminous, non-bituminous or anthracite, and prepared to give some idea of the value of each for making steam economically.

He should be able to calculate the result of certain tests with a view to form a correct opinion as to which was good coal, by registering the weight of water evaporated by each pound of coal.

He should be able to explain that steam, as a gas, is subject to the common laws of gaseous fluids.

He should be conversant with the expansive working of steam in the cylinder.

He should be able to show the pressure of steam in the cylinder at any part of the stroke when worked expansively, and also give the approximate and effective pressure.

PROPOSITION III.

Conditions on which a First-class Certificate might be granted, and the Subjects of Examination.

A candidate for this certificate should, in addition to the conditions required for a third and second class engineer, have run the stipulated number of miles as a goods and passenger driver.

He should be in a position to give satisfactory proof of his capacity by giving a complete answer to each of the questions proposed on page 192.

This certificate might be granted by examination, partly *vivâ voce* and partly by examination paper.

Rank and Uniform.

It is proposed by the author that engine-drivers in possession of certificates shall be called "engineers," for they are, with such a symbol of capacity at their command, as much entitled to such rank as engineers at sea.

It is further proposed that a suitable uniform be designed to distinguish the grade of "engineers." The advantage of this change would be to elevate the position of a body of men whose influence on the safe working of all railways is no small factor in the public confidence.

With such symbols of competency there would certainly be universal expressions of pleasure and satisfaction.

PART IV.

EXAMINATION MATTER.

ARITHMETIC.

SIGNIFICATION OF SIGNS USED IN CALCULATION

$=$	signifies	Equality	as 3 added to 2 $=$	5
$+$	,,	Addition	,, $4 + 2$	$= 6$
$-$	,,	Subtraction	,, $7 - 2$	$= 5$
$\times$	,,	Multiplication	,, 6×2	$= 12$
$\div$	,,	Division	,, $12 \div 2$	$= 6$
$: \; :: \; :$	,,	Proportion	,, 2 is to 3 as 4 is to 6	
$\sqrt{}$	,,	Square root	,, $\sqrt{16}$	$= 4$
$\sqrt[3]{}$	,,	Cube root	,, $\sqrt[3]{64}$	$= 4$
3^2	,,	3 is to be squared	,, 3^2	$= 9$
3^3	,,	3 is to be cubed	,, 3^3	$= 27$

$\overline{2 + 5} \times 4$,, that 2 and 5 = 7, and four times 7 = 28

$\sqrt{5^2 - 3^2} = 4$. This reads, 3 squared taken from 5 squared, and the square root extracted = 4

$\sqrt[3]{\frac{10 \times 6}{15}} = 1{\cdot}587$, reads 10 multiplied by 6 and divided by 15; the cube root of the quotient . . = 1·587

mph signifies miles per hour.

An engine-driver should understand Simple Proportion, Decimals, &c., &c.

SIMPLE PROPORTION.

When we have three numbers given, this rule teaches how to find a fourth number, which may have the same proportion to the third number that the second has to the first.

Thus, if the three given numbers be 3, 9, 4, it is required to find a fourth number which will have the same proportion to 4 that 9 has to 3; now the 9 is 3 times the 3, therefore the required number must be **3** times the 4, that is 12.

To express proportions the numbers are put down thus 3 : 9 : : 4 : 12, and reads thus 3 is to 9 as 4 is to 12.

Rule with Example.—Place them thus 3 : 9 : : 4 and multiply the second and third numbers together, and divide by the first.

$$\begin{array}{r} 3 : 9 : : 4 \\ 4 \\ \hline 3)\,36 \\ \hline 12 \text{ Ans.} \end{array}$$

To	3. 6. 12	find a fourth proportional.	Answer,	24.
,,	6. 12. 4	,, ,,	,,	8.
,,	10. 150. 68	,, ,,	,,	1020.
,,	68. 1020. 10	,, ,,	,,	150.

If 4 lbs. of tallow cost 20 pence, what will 16 lbs. cost?

Rule with Example.—In this question there are two things mentioned, tallow and money; the answer required is the price, money,

Put down the money—20 pence—for the third term. This is always so, that is, the third term is of the same kind as the answer required, and is worth remembering. If the *answer* is to be greater than the third term the greater is placed second, and if it is to be less it is placed first and the less of course second. The question before us requires an answer greater than the third term, and is worked out thus—

4 lbs. : 16 lbs. :: 20 pence
20
4) 320
80 pence = 6s. 8d. Ans.

If 6s. 8d. will purchase 16 lbs. of tallow, how many pounds will 1s. 8d. buy? Here the answer is to be less than the third term, and it is pounds of tallow and not money; therefore observe,

pence. pence. lbs.
80 : 20 :: 16
16
120
20
80) 320
4 lbs. Ans.

If a locomotive engine takes 150 minutes to perform 100 miles, what is the speed or miles per hour?

NOTE.—The answer is miles, and there are 60 minutes in an hour; then—

Min. Min. Miles.
150 : 60 :: 100
100
150)6000
40 miles per hour.

At 40 miles per hour, what mile-post will an engine reach in 150 minutes?

NOTE.—The answer is to be greater than the third term.

Min. Min. Miles.
60 : 150 :: 40
40
60)6000
100th mile post.

If the above engine departed from Euston Station at 12 o'clock, what will be the exact time on its passing the 75th mile-post, speed 40 miles per hour?

Miles. Miles. Min.
100 : 75 :: 150
150
3750
75
100) 11250 (112·5 = 1 hour $52\frac{1}{2}$ min., or
100 $7\frac{1}{2}$ min. to 2 o'clock.
125
100
250
200
500
500

DECIMALS.

By decimals are meant tenths. Decimal arithmetic is the simplest possible method of working calculations, and a few examples are sufficient to enable any driver or fireman to become, for the remainder of his term, a decimal arithmetician.

It is worthy of special attention that, in decimals, the dot performs a very important part: separating integers from cyphers, or the fractional parts from a whole. Decimals, contrary to vulgar fractions, are written in one line like integers; and they are, in all respects, worked out in a plane-sailing way.

Decimals fractionals are written thus, . . .	·25 :	·5 :	·75 :
Their equivalents in vulgar fractions are written .	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$

The value of a decimal is altered by placing ciphers to the left, but not by placing ciphers to the right.

Thus ·05 = $\frac{5}{100}$; and, by placing a cipher to the left, the decimal becomes ·005, or $\frac{5}{1000}$, which is ten times less than $\frac{5}{100}$.

ADDITION OF DECIMALS.

Add 4·15; ·002; ·3 :—

$$\begin{array}{r@{}l} 4 & ·15 \\ & ·002 \\ & ·3 \\ \hline 4 & ·452 \end{array}$$

Observe the position of the dot.

SUBTRACTION OF DECIMALS.

Rule.—If the number of decimal places be not the same in all the fractions, annex so many ciphers to the right hand as will render it so. We do not alter the value of the fractions so supplied, but they are reduced to the same denominator.

Subtract 106·125 from 125·5.

$$\begin{array}{r} 125·500 \\ 106·125 \\ \hline 19·375 \\ \hline \end{array} \qquad \text{Ans. } 19\tfrac{3}{8}$$

MULTIPLICATION OF DECIMALS.

Rule.—Arrange the numbers as if they were integers.

Multiply 148·74 by 2·67.

148·74 } Observe 4 decimal
2·67 } figures used.

104118
89244
29748

397·1358 (Four decimals cut off.)

Note.—Count the number of decimals in both the multiplicand and the multiplier, and point off as many figures from the right hand of the product.

Multiply ·02 by ·045.

·02
·045

·00090

In counting the number of decimals in the multiplicand and multiplier to point off in the product, if there are not sufficient figures in the product, place ciphers to the left, and prefix the dot as above.

DIVISION OF DECIMALS.

Rule.—Divide as in whole numbers, and mark off in the quotient as many decimal places as the dividend has more than the divisor.

Divide 72·125 by 6·25.

Dvsr. Dividnd. Quot.
6·25)72·125$\hat{0}$(11·54
62 5

9 62
6 25

3 375
3 125

2500
2500

....

The cipher in the dividend is brought in and shown above as making the number of decimals in the dividend equal to the number in the divisor and quotient together.

REDUCTION.

To reduce a Vulgar Fraction to a Decimal.

Rule.—Divide the numerator by the denominator, annexing as many ciphers to the numerator as may be necessary. Point off as many decimal places in the quotient as there are ciphers annexed to the numerator.

Reduce $\frac{1}{4}$ to a decimal.

$4)1\hat{0}\hat{0}$ Observe 2 ciphers added.

$\cdot 25$ Ans. „ 2 decimals cut off.

Reduce $\frac{3}{4}$ to a decimal.

$4)3\hat{0}\hat{0}$

$\cdot 75$ Ans.

Reduce $\frac{7}{8}$ to a decimal.

$8)7\hat{0}\hat{0}\hat{0}$

$\cdot 875$

The annexed table, of decimal equivalents of the fractional parts of an inch, is calculated as above.

Vulgar Fraction.	Decimal Equivalent.	Vulgar Fraction.	Decimal Equivalent.
$\frac{1}{32}$	·03125	$\frac{1}{2}$ $\frac{1}{32}$	·53125
$\frac{1}{16}$	·0625	$\frac{1}{2}$ $\frac{1}{16}$	·5625
$\frac{3}{32}$	·09375	$\frac{1}{2}$ $\frac{3}{32}$	·59375
$\frac{1}{8}$	·125	$\frac{5}{8}$	·625
$\frac{1}{8}$ $\frac{1}{32}$	·15625	$\frac{5}{8}$ $\frac{1}{32}$	·65625
$\frac{3}{16}$	·1875	$\frac{3}{8}$ $\frac{1}{16}$	·6875
$\frac{1}{8}$ $\frac{3}{32}$	·21875	$\frac{5}{8}$ $\frac{3}{32}$	·71875
$\frac{1}{4}$	·25	$\frac{3}{4}$	·75
$\frac{1}{4}$ $\frac{1}{32}$	·28125	$\frac{3}{4}$ $\frac{1}{32}$	·7812
$\frac{1}{4}$ $\frac{1}{16}$	·3125	$\frac{3}{4}$ $\frac{1}{16}$	·8125
$\frac{1}{4}$ $\frac{3}{32}$	·34375	$\frac{3}{4}$ $\frac{3}{32}$	·84375
$\frac{3}{8}$	·375	$\frac{7}{8}$	·875
$\frac{3}{8}$ $\frac{1}{32}$	·40625	$\frac{7}{8}$ $\frac{1}{32}$	·90625
$\frac{3}{8}$ $\frac{1}{16}$	·4375	$\frac{7}{8}$ $\frac{1}{16}$	·9375
$\frac{3}{8}$ $\frac{3}{32}$	·46875	$\frac{7}{8}$ $\frac{3}{32}$	·96875*
$\frac{1}{2}$	·5	1	1·000

* Reads—Decimal nine six eight seven five.

To reduce Money, &c.

RULE.—Divide by as many of the lower denomination as make one of the higher, annexing ciphers at will. If there be several denominations, proceed in the same manner with each, beginning with the lowest denominator.

Reduce 12*s.* $8\frac{1}{4}$*d.* to the decimal of a pound sterling.

(4 farthings = 1 penny $4)\overline{10\hat{0}}$

(12 pence = 1 shilling $12)\overline{8{\cdot}25\hat{0}\hat{0}}$

(20 shillings = £1 $20)\overline{12{\cdot}6875\hat{0}}$

·634375 = decimal value of 12*s.* $8\frac{1}{4}$*d.*

To re-value this decimal, multiply it by the various fractional denominations of the whole number, cutting off from the right hand of each product, for decimals, a number of figures equal to the number of decimals given, then multiply the remainder by the next lower denomination, and proceed until the lowest is reached.

·634375   6 decimals.
20

12·687500   6 decimals cut off.
12

8·250000   „   „
4

1·000000   „   „

Ans. 12*s.* $8\frac{1}{4}$*d.*

To find the Value of a Decimal.

RULE.—Multiply the decimal by the number of the next lower denomination which is equal to one of its present denomination. Cut off as many places as there are places in the multiplicand.

Find the value of ·75 foot.

·75
12

9·00 Ans. 9 inches

Find the value of ·3875 of a £.

·3875
20

7·7500
12

9·0000 Ans. 7s. 9d.

Find the value of ·375 ton.

·375
20

7·500
4

2·000 Ans. 7 cwt. 2 qrs

INVOLUTION.

When a number is multiplied by itself, the product is called a power, and the number multiplied is called the root.

Thus $2 \times 2 = 4$. Here 4 is the square or second power of the root 2. Again, $2 \times 2 \times 2 = 8$. Here 8 is the third power of 2.

EVOLUTION.

Evolution is the method of finding the root of a number.

To extract the square root of any given number is to find a number which, when multiplied by itself, will produce the given number.

Extract the square root of 55225.

Rule with Example.—Divide the given number into periods, that is, set a dot over the unit and right-hand figure, and then over every alternate figure towards the left. Find the square root (2) of the first period (5), and place it in the quotient. Subtract the square of it (4) from the first period (5), and to the remainder annex the next period (52) for a dividend. Double 2, the root already found for a divisor, and place it (4) to the left of the dividend, looking upon it as 40 and not 4. After finding that this divisor (40) will go 3 times in the dividend (152), place the figure representing the number of times in the quotient, and also in the divisor, making the latter 43; then multiply the 43 by 3, and subtract the product. Bring down another period (25).

In forming the second divisor, 465, double the last figure (3) in the first divisor, and look upon it as 460. After finding that this divisor (460) will go 5 times in the dividend, place the 5 in the quotient and divisor, making the latter 465; then multiply the 465 by the 5 just placed in the quotient, and subtract the product, which leaves nothing; 235 being the answer.

$$
\begin{array}{rl}
 & \dot{5}5\dot{2}2\dot{5}(235 \\
 & 4 \\ \cline{2-2}
43) & 152 \\
 & 129 \\ \cline{2-2}
465) & \;\;2325 \\
 & \;\;2325 \\ \cline{2-2}
\end{array}
$$

What is the square root of 177241?

```
      177241(421
      16
     ------
 82)  172
      164
     ------
841)   841
       841
     ------
       ...
       ===
```

EXTRACTION OF THE THIRD OR CUBE ROOT.

To extract the cube root of any given number is to find a number which, when multiplied twice by itself, will produce the given number.

RULE AND EXAMPLE.—Make a dot over every third figure, beginning at the unit or right-hand figure point to the left with whole numbers and towards the right in decimals.

What is the cube root of $88\dot{4}73\dot{6}$? Place the root (9) of the first period (884) in the quotient, on the right, and its cube (729) under the first period (884). Subtract, and to the remainder (155) bring down the next period of three figures (736). Multiply the square of the quotient (9 × 9 = 81) by 300 for a divisor. Find how often it is contained in the dividend, and put the number (6) in the quotient. Multiply the divisor (24300) by this number (6). Add to the product the amount of all the figures in the quotient (9), multiplied by 30 —except the last (6)—and the product by the square of the last.

To these figures add the cube of the last figure in the quotient, and subtract the sum of the whole from the dividend: thus,—

$\sqrt[3]{88\dot{4}73\dot{6}}$ (96 Ans.
729

9 × 9 × 300 = 24300)155736*
~~145800~~
145800 = divisor × 6
9720 = 9 × 30 × 6^2
216 cube of 6

155736* see figs. in dividend above.

Another way:—
What is the cube root of 10648?

$\sqrt[3]{1\dot{0}64\dot{8}}$(22
8

2 × 2 × 3 = 12)26~~48~~

Here, after squaring the root of the first period, we multiply it by 3 = 12, and, rejecting the units and tens, we find the divisor is contained twice in the dividend, which is put in the quotient, making 22, the cube root of 10648.

Proof
22
22

44
44

484 square of 22
22

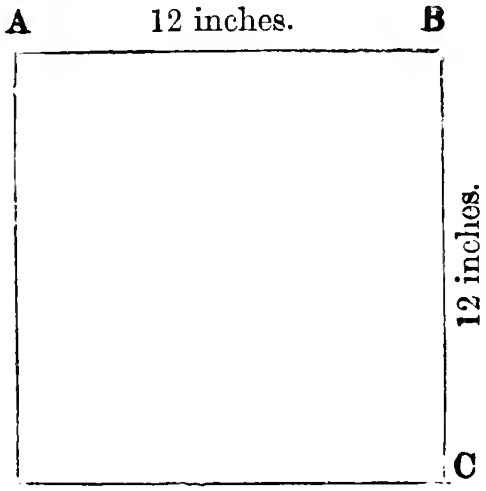
968
968

10648 cube of 22

MENSURATION OF SUPERFICIES.

This teaches how to find the area of any plane figure—that is, the surface without any regard to thickness.

To find the area of a square, multiply the side by itself, A B by B C. For example, the length of each side is 12 inches; then,—



12
12

144 square inches.

To find the area of a rectangle, multiply the length by the breadth. Required the area of a locomotive fire-grate 5 feet 6 inches long and 3 feet 6 inches wide.

By Decimals.

5·5
3·5

275
165

19·25 Ans. 19¼ square feet

To find the area of a triangle, multiply the base by the perpendicular height, and half the product is the area. Required the area of a triangle, of which the base is 15·4 inches, and the perpendicular 7·8 inches :—

15·4
7·8

1232
1078

2)12012

60·06 Ans. 60·06 square inches.

What is the circumference of a 7-feet driving-wheel?

Multiply 3·1416 by 84, or by 7 and by 12 for feet and inches.

```
   3·1416
        7
 --------
  29·9912 feet
       12
 --------
 263·8944 inches
```

What is the diameter of a driving-wheel of which the circumference is 263·8944 inches?

Multiply the circumference by ·31831.

```
       263·8944
         ·31831
   ------------
        2638944
       7916832
     21111552
     2638944
   7916832
   ------------
   84·000226464 inches.
```

The Lady of the Lake, North-Western Railway, has 192 tubes, each 10 feet 9 inches long, $1\frac{7}{8}$ inches external diameter; required their total heating surface in square feet.

```
       1·875 diameter of each tube.
      3·1416
   ---------
       11250
       1875
      7500
     1875
    5625
   ---------
   5·8905~~000~~ circum. of each tube in inches.
```

5·8905
129 length in inches.

530145
117810
58905

sq. inches in 1 sq. foot 144) 759·8745 (5·2769 sq. feet in each tube
720

398
288

1107
1008

994
864

1305
1296

. . . 9

5·2769 square feet in each tube.
192 total number of tubes.

105538
474921
52769

1013.1648

Total heating surface of the tubes, 1,013 square feet.

What is the area of an 18-inch piston-head?

Multiply the diameter in inches by itself and by ·7854.

18
18

144
18

324
·7854

1296
1620
2592
2268

254,4696 area. Ans. $254\frac{7}{16}$ square inches.

Or thus—

$$18 \times 18 \times \cdot 7854 = 254 \cdot 469.$$

Or thus—

$$18^2 \times \cdot 7854 = 254 \cdot 469.$$

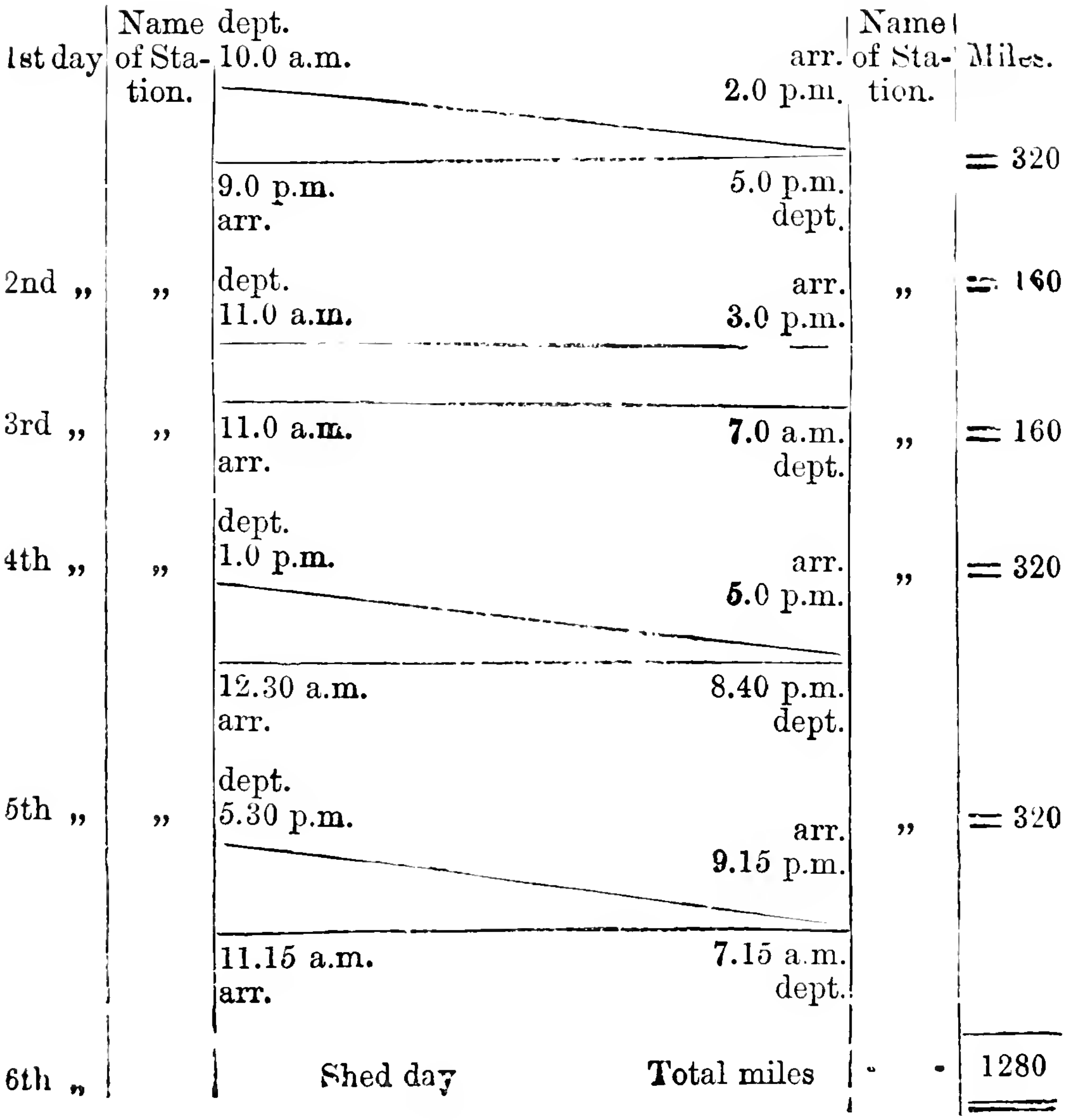
The circumference of a 7-feet driving-wheel being 263·8944 inches, find the diameter.

$$
\begin{array}{r@{}l}
3 \cdot 1416) & 263 \cdot 8944(84 \text{ inches.} \quad \text{Ans.} \\
 & 251328 \\
\hline
 & 125664 \\
 & 125664 \\
\hline
 & \cdots\cdots \\
\hline
\end{array}
$$

Find the area of a circle whose diameter is 17 inches say, a steam-cylinder.

$$
\begin{array}{r}
17 \\
17 \\
\hline
119 \\
17 \\
\hline
289 \\
\cdot 7854 \\
\hline
1156 \\
1445 \\
2312 \\
2023 \\
\hline
226 \cdot 9806 \text{ area.}
\end{array}
\quad \text{Ans. } 226 \cdot 98 \text{ square inches.}
$$

DIAGRAM OF ENGINE-RUNNING.



1st day	Name of Station.	dept. 10.0 a.m.	arr. 2.0 p.m.	Name of Station.	Miles.
		9.0 p.m. arr.	5.0 p.m. dept.		= 320
2nd „	„	dept. 11.0 a.m.	arr. 3.0 p.m.	„	= 160
3rd „	„	11.0 a.m. arr.	7.0 a.m. dept.	„	= 160
4th „	„	dept. 1.0 p.m.	arr. 5.0 p.m.	„	= 320
		12.30 a.m. arr.	8.40 p.m. dept.		
5th „	„	dept. 5.30 p.m.	arr. 9.15 p.m.	„	= 320
		11.15 a.m. arr.	7.15 a.m. dept.		
6th „		Shed day	Total miles	- -	1280

Required the coal consumption per mile as per annexed Driver's Monthly Stores Account.

1876.	Coal.	Miles.	Truck No.	1876.	Coal.	Miles.	Truck No.
Aug. 1	60 cwt.	320	1020	Aug. 18	35 cwt.	150	1460
,, 2	65 ,,	330	830	,, 19	60 ,,	290	1521
,, 4	65 ,,	320	646	,, 21	60 ,,	320	426
,, 6	40 ,,	180	1124	,, 22	50 ,,	202	1121
,, 8	70 ,,	302	758	,, 23	65 ,,	303	896
,, 10	40 ,,	195	250	,, 25	60 ,,	320	520
,, 11	65 ,,	320	84	,, 26	65 ,,	320	1143
,, 13	35 ,,	168	1014	,, 29	65 ,,	320	94
,, 15	70 ,,	320	962	,, 30	40 ,,	168	862
,, 17	65 ,,	280	652	,, 31	25 ,,	100	1002

```
                  1100  cwts of coal.
                   112
                 -----
                  2200
                 1100
                1100
Miles.          ------
5228)123200(23·565
         10456
         -----
          18640
          15684
          -----
           29560
           26140
           -----
            34200
            31368
            -----
             28320
             26140
             -----
              2180
              ====
```

Ans. 23·565 lbs. per mile.

If a locomotive engineman is allowed 14 lbs. per mile for his engine, and 1½ lbs. per mile for each vehicle, with 18 vehicles and engine, for 50 miles; required the total consumption.

14 lbs. per mile for Engine.
50 miles

700 lbs. of coal for 50 miles, Engine.

13 × 1½ = 27 lbs. per mile for Train.
50 miles

1350 lbs. of coal for 50 miles, Train.

700 Engine.
1350 Train.

2050 lbs. of coal for 50 miles, Engine and Train.

```
      Lbs.
112)2050· (18· 3035
    112           4
    ----       ----
    ·930     1·2140
     896     ======
     ---
     ·340
      336
      ---
     ··400
       336
       ---
       ·640
        560
        ---
        ·80
        ===
```

Ans 18¼ cwt.

If an engine, in a run of 50 miles, consumes 12 cwt of coal, and evaporates 1,250 gallons of water, required the weight of water evaporated per lb. of coal.

A gallon of water equals 10 lbs.

1250 gallons of water.
10 weight of one gallon.
12500 total weight of water in lbs.

12 cwt. of coal.
112 lbs. in one cwt. of coal.
24
12
12
1344 lbs. of coal in 12 cwt.

Lbs. of Coal.	Weight of Water.
1344)	12500(9·300
	12096
	..4040
	4032
	800

Ans. $9\frac{3}{10}$ lbs. of water evaporated by 1 lb. of coal.

What number of turns will a 7-feet driving-wheel make in a mile?

Rule.—Divide 1,680 by the diameter.

7)1680
240 Ans.

What number of turns or revolutions will a 7-feet driving-wheel make per minute, at 40 miles per hour ?

Rule.—Multiply the speed in miles per hour by 28, and divide by the diameter of the driving-wheel.

```
          40
          28
         ———
         320
         80
        ————
7 feet)1120
        ————
         160 revolutions per minute.
```

REVOLUTIONS OF DRIVING-WHEELS PER MILE.

Diameter of Wheel. Inches.	Revolutions Mile.
42	480·4
43	469
46	439
48	420
50	403·5
54	373·5
55	367
60	336
62	325·4
63	320
66	306
72	280
78	254·6
81	249
84	240

What is the speed of the piston of an engine having 24 inches of stroke, and 7-feet drivers, at a speed of 40 miles per hour ?

Rule.—Multiply the speed in miles per hour by 28, divide by the diameter of the driving-wheel, and multiply the product by 4.

40
28
320
80
7)1120(160 rev. per minute.
... 4 ft. of piston for 1 rev. of driv. wheel.
640 ft. speed of piston per minute.

Or thus—40 × 28 ÷ 7 = 160 × 4 = 640.

The speed of a train is 60 miles per hour, what is the speed in feet per second?

Rule.—Multiply the speed by 22 and divide by 15, thus:—

60
22
120
120
15)1320(88 feet per second.—Ans.
120
120
120
...

Or thus— $\frac{60 \times 22}{15} = 88$ feet.

The cylinders of a locomotive are 17 inches in diameter, and 24 inches in stroke; pistons making 150 strokes per minute, effective mean pressure 100 lbs. per square inch. What is the horse-power?

17
17

119
17

289
·7854

1156
1445
2312
2023

226·9806 area of 1 cylinder
2

453·9612 „ 2 cylinders
100 pressure

45396·1200
4 ft. = 2 complete strokes

181584·4800
150

90792240000
1815844800

33000)27237672·0000(825·384
264000

83767
66000

177672
165000

126720
99000

277200
264000

132000
132000 Ans. 825 horse-power.

Find the horse-power of a locomotive engine to draw a train of 100 tons up an incline of 1 in 80, at the rate of 20 miles per hour, allowing 8 lbs. per ton for friction.

Distance train moves per minute . $= \frac{20 \times 5280}{60} = 1760$ feet.
Resistance due to friction . . $= 100 \times 8 = 800$ lbs.
Work of friction per minute. . $= 1760 \times 800 = 1408000$ ft. lbs.
„ „ „ hour . . $= 1760 \times 800 \times 60 = 84480000$
Rise of incline in a mile . . $= \frac{5280}{80} = 66$ feet.
Work due to gravity in a mile . $= 100 \times 2240 \times 66 = 14790600$
„ „ 20 miles . $14790600 \times 20 = 295812000$

Total work of gravity and friction in an hour.
Gravity 295812000
Friction 84480000
380292000

Horse-power per hour $= 33000 \times 60 = 1980000$ foot pounds.
1980000)380292000(192 horse-power.
1980000
18229200
17820000
··4092000
3960000
·32000

To find the Heating Surface of a Fire-box.

Rule.—Length multiplied by the breadth; added to twice the breadth, multiplied by the height; added to twice the length, multiplied by the height; from which subtract the sectional area of the tubes and the inside surface of the fire-hole door.

What is the heating surface of a fire-box 4 feet 9 inches high, 4 feet long, and 3 feet 3 inches broad? With an oval fire-hole 2 feet by 1. The boiler contains 180 tubes, 2 inches in diameter.

ft. in. ft. in. ft. in. ft. in. ft. in. ft. in.
(4 0 × 3 3 + 2(4 0 × 4 9) + 2 (3 3 × 4 9)

sq. ft. 13 0 + sq. ft. 36 0 + sq. ft. in. 30 126 = sq. ft. in. 79 126

sq. ft.	in.			sq. ft.	in.
1	82 (fire-hole door)				
3	132) section area of tubes)	. . . .	=	5	70
	Heating surface of fire-box	. . . .		74	56

What is the area of a safety-valve $2\frac{1}{2}$ inches diameter?

$2·5^2 \times ·7854 = 4·9$

2·5
2·5

125
50

625
·7854

2500
3125
5000
4375

4·9 —say 4·9 square inches.

4·9087
60

74·59)294·5220(3·9485
223 77

70752
67131

36210
29836

63740
59672

40680
37295

3395

Ans. Distance from end of lever nearly 4 inches.

Required, the weight to be placed on the end of a safety-valve lever 17½ inches long, 3½ inches from fulcrum to valve; valve 2½ inches diameter, pressure in the boiler required 80 lbs. per square inch, weight of valve and lever 20¼ lbs.

17½ ÷ 3½ = 5, leverage.

25
25

125
50

625
·7854

2500
3125
5000
4375

4·908750 area of valve.
80 pressure.

392,7~~00000~~
20·25 weight of lever and valve.

Leverage 5)372·45

74·59

Ans. 74½ lbs.

Particulars as in last case: required, the distance from the end of the lever to which the weight must be moved to effect a pressure of 60 lbs. per square inch.

What is the leverage of a safety-valve lever 17½ inches total length, with a distance of 3½ inches from fulcrum to valve?

3·5)17·5(5 leverage
175

· · ·

Required, the direct weight to be placed on the top of a safety-valve $2\frac{1}{2}$ inches diameter, to allow steam to escape at 80 lbs. per square inch.

$$2·5^2 \times ·7854 = 4·9087 \times 80 = 392·7000$$

2·5
2·5

125
50

625
.7854

2500
3125
5000
4375

4·908750
80

112)392,700000(3·5062 cwts.

336	4
·567	2·0248 qrs.
560	4 × 7 = 28
·700	·0992
672	7
·280	0·6944 lb.
224	8 × 2 = 16
·56	5·5552
	2
	11·1104 oz.

Ans. 3 cwt. 2 qrs. 0 lbs. 11 ozs., including the weight of valve.

The Consumption of Fuel in lbs. per Mile for a

MILES.	Fuel in Cwts.	Lbs. per Mile.	Fuel in Cwts.	Lbs. per Mile.	Fuel in Cwts.	Lbs. per Mile.	Fuel in Cwts.	Lbs. per Mile.	Fuel in Cwts.	Lbs. per Mile.	Fuel in Cwts.	Lbs. per Mile.	Fuel in Cwts.	Lbs. per Mile.	Fuel in Cwts.	Lbs. per Mile.	Fuel in Cwts.	Lbs. per Mile.	Fuel in Cwts.	Lbs. per Mile.
30	5	18½	10	37	15	56	20	74½												
35	5	16	10	32	15	48	20	64	25	80										
40	5	13	10	28	15	42	20	56	25	70										
45	10	25	15	37	20	42¾	25	62	30	74¾										
50	10	22½	15	33½	20	45	25	56	30	67	35	78								
55	10	20¼	15	30½	20	40¾	25	51	30	61	35	71¼								
60	10	18½	15	28	20	37	25	46½	30	56	35	65	40	74¾						
65	10	17	15	26	20	34½	25	43	30	52	35	60¼	40	69	45	77½				
70	10	16	15	24	20	32	25	40	30	48	35	56	40	64	45	72				
75	10	15	15	22½	20	30	25	37½	30	45	35	52½	40	60	45	67½	50	75		
80	10	14	15	21	20	28	25	35	30	42	35	49	40	56	45	63	50	70		
85	15	12¾	20	26½	25	33	30	39¼	35	46	40	52¾	45	59¼	50	66	55	72½		
90	15	18¾	20	25	25	31	30	37	35	43½	40	49½	45	56	50	62	55	68½	60	74⅓
95	15	17¾	20	23¾	25	29½	30	35½	35	41¼	40	47	45	53	50	59	55	65	60	71
100	15	16¾	20	22½	25	28	30	33¾	35	29	40	45	45	50	50	56	55	61¾	60	67
105	15	16	20	21¼	25	26¾	30	32	35	37¼	40	42¾	45	48	50	53¼	55	58¾	60	64
110	15	15¼	20	20¼	25	25½	30	30¾	35	35¾	40	40¾	45	45¾	50	51	55	56	60	61
115	15	14¾	20	19¼	25	24	30	29¼	35	34½	40	38½	45	43¼	50	48½	55	53½	60	58½
120	20	11¾	25	23¼	30	28	35	32¾	40	37¼	45	42	50	46¾	55	51¼	60	56	65	60¾
125	20	18	25	22½	30	27	35	31½	40	36	45	40½	50	45	55	49½	60	54	65	58½
130	20	17¼	25	21½	30	26	35	30	40	34½	45	39	50	43	55	47¼	60	51½	65	56
135	20	16½	25	20½	30	24¾	35	29	40	33	45	37¼	50	41½	55	45½	60	49¾	65	53¾
140	20	16	25	20	30	24	35	28	40	32	45	36	50	40	55	44	60	48	65	52
145	20	15½	25	19¼	30	23	35	27	40	30¾	45	34¾	50	38½	55	42¼	60	46¼	65	50
150	25	18¾	30	22½	35	26	40	29¾	45	33½	50	37½	55	41	60	45	65	48¾	70	52½
155	25	18	30	21¾	35	25¼	40	28¾	45	32½	50	36¼	55	39¾	60	43½	65	47	70	50¾
160	25	17½	30	21	35	24½	40	23	45	31½	50	35	55	38½	60	42	65	45½	70	49
165	25	17	30	20	35	23¾	40	27	45	30½	50	34	55	37½	60	40¾	65	44	70	47½
170	25	16½	30	20	35	23	40	26¼	45	29½	50	33	55	36¼	60	39½	65	43	70	46
175	25	16	30	19	35	22½	40	25½	45	28¾	50	32	55	35½	60	38½	65	41½	70	44¾
180	30	18¾	35	21¾	40	25	45	28	50	31	55	34¼	60	37¼	65	40½	70	43½	75	46½
185	30	13	35	21	40	24¼	45	27¼	50	30¼	55	33¼	60	36¼	65	39¼	70	42¼	75	45½
190	30	17½	35	20½	40	23½	45	26½	50	29½	55	32½	60	35½	65	38½	70	41¼	75	44¼
195	30	17	35	20	40	23	45	25¾	50	28¾	55	31½	60	34½	65	37½	70	40¼	75	43
200	30	16¾	35	19½	40	22½	45	25¼	50	28	55	30¾	60	33½	65	36¼	70	39	75	42

given number of cwts. consumed in a given distance.

Fuel in Cwts.	Lbs. per Mile.	Fuel in Cwts.	Lbs. per Mile.	Fuel in Cwts.	Lbs. per Mile.	Fuel in Cwts.	Lbs. per Mile.	Fuel in Cwts.	Lbs. per Mile.	Fuel in Cwts.	Lbs. per Mile.	Fuel in Cwts.	Lbs. per Mile.	Fuel in Cwts.	Lbs. per Mile.	Fuel in Cwts.	Lbs. per Mile.	Fuel in Cwts.	Lbs. per Mile.	Fuel in Cwts.	Lbs. per Mile.
65	72¾																				
65	69¼	70	74½																		
65	66	70	71¼																		
65	63¾	70	68	75	73																
70	65¼	75	70	80	74¾																
70	63	75	67½	80	71½	85	76¼														
70	60¼	75	64½	80	69	85	73¼														
70	58	75	62¼	80	66¼	85	70½	90	74½												
70	56	75	60	80	64	85	68	90	72												
70	54	75	57¼	80	61¾	85	65½	90	69½	95	73¼										
75	56	80	59¾	85	63½	90	67½	95	71	100	74½										
75	54¼	80	57¾	85	61½	90	65	95	68½	100	72¼										
75	52½	80	56	85	59½	90	63	95	66½	100	70	105	73½								
75	51	80	54½	85	57¾	90	61	95	64½	100	67	105	71	110	74½						
75	49½	80	52¾	85	56	90	59½	95	62½	100	66¾	105	69¼	110	72½						
75	48	80	51¼	85	54½	90	57½	95	60¾	100	64	105	67¼	110	70½	115	73½				
80	49½	85	52¾	90	56	95	59	100	62	105	65¼	110	68½	115	71½	120	74½				
80	48¼	85	51½	90	54½	95	57½	100	60½	105	63½	110	66½	115	69½	120	72½	125	75½		
80	47	85	50	90	53	95	56	100	59	105	62	110	64¾	115	67¾	120	70¾	125	74	130	76½
80	46	85	49	90	51½	95	54½	100	57½	105	60½	110	63	115	66	120	69	125	71¾	130	74½
80	45	85	47¾	90	50½	95	53¼	100	56	105	58¾	110	61½	115	64¼	120	67	125	70	130	72¾

TO TEST THE QUALITY OF IRON

If the fracture gives long silky fibres, of leaden-grey hue, fibres cohering and twisting together before breaking, the iron may be considered a tough, soft iron.

A medium even grain, mixed with fibres—a good sign.

A short blackish fibre indicates badly refined iron.

A very fine grain denotes a hard steely iron, apt to be cold-short, hard to work with a file. Coarse grain, with brilliant crystallized fracture, yellow or brown spots, denotes a brittle iron, cold-short, working easily; when heated, welds easily.

Cracks on the edges of bars, sign of hot-short iron.

Good iron is readily heated, soft under the hammer, throws out but few sparks.

Iron, with heating, if exposed to air, will oxidize; when at white heat, if in contact with coal, will carbonize, or become steely.

To restore burnt iron—give a smart heat, protected from the air, if injured by cold hammering; anneal slowly and moderately, if hard or steely; give one or more smart heats to extract the carbon.

FORCE OF THE WIND.

Miles per Hour.	Feet per Minute.	Feet per Second.	Force in lbs. per Square Foot.	Description.
1	88	1·47	·005	Hardly perceptible.
2	176	2·93	·020	Just perceptible.
3	264	4·4	·044	
4	352	5·87	·079	Gentle breeze.
5	440	7·33	0·123	
10	880	14·67	0·492	Pleasant breeze.
15	1·320	22	1·107	
20	1·760	29·3	1·970	Brisk gale.
25	2·200	36·6	3·067	
30	2·640	44·	4·429	High wind.
35	3·080	51·3	6 027	
40	3·520	58·6	7·870	Very high wind.
45	3·960	66·	9·900	
50	4·400	73·3	12·304	Storm.
60	5·280	88·0	17·733	Great storm.
70	6·160	102 7	24·153	
80	7·040	117·3	31·490	Hurricane.
100	8·800	146·6	49·200	

KNOTS.

A Common Bend.—It is formed by passing the end of a rope through the bight of another rope, then round both parts of a rope and down through its own bight.

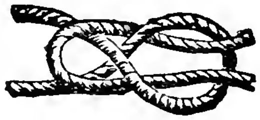


Fig. 14.—A Common Bend.

Figure of Eight Knot.—Take the end of the rope round the standing part, under its own part and through the lower bight.

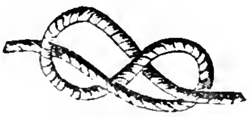


Fig. 15.—Figure of Eight Knot

Timber Hitch.—It is made by taking the end of a rope round a spar, passing it under and over the standing part, and then passing several turns round its own part.

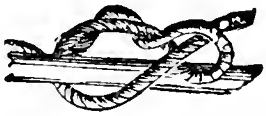


Fig. 16.—Timber Hitch.

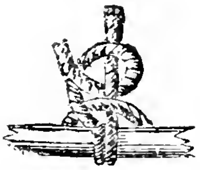


Fig. 17.—A Fisherman's Bend.

Fisherman's Bend.—With the end of a rope take two turns round, then form a half hitch round the standing part, and under the turns, and another half hitch round the sanding part.

Fig. 18.—Two Half-Hitches.

To make Two Half-Hitches.—Pass the end of the rope round the standing part, and bring it up through the bight—this is one half-hitch ; two of these, one above the other, constitute two half-hitches.

Fig. 19.—Overhand Knot.

Overhand Knot.—This is made by passing the end of the rope over the standing part and through the bight.

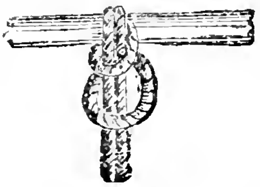


Fig. 20.—Rolling Bend.

Rolling Bend.—It is something similar to a fisherman's bend. It is two round turns round a spar, two half-hitches around the standing part, and the ends stopped back.

To make a Bowline Knot.—Take the end of the rope in your right hand, and the standing part in your left; lay the end over the standing part, then with your left hand turn the bight of the standing part over the end part; then lead the end through the standing part above, and stick it down through the cuckold's neck formed on the standing part, and it will appear as the sketch.

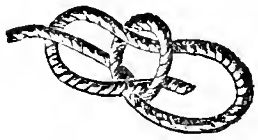


Fig. 21.—A Bowline Knot.

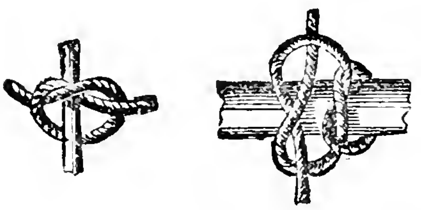


Fig. 22.—Square or Reef Knot.

A Reef Knot.—First make an overhanded knot, supposing it to be round a yard; then bring the end being to you over the left hand, and through the bight haul both ends taut. This knot is used chiefly for joining the ends of ropes or lines together.

A Short Splice.—A short splice is made by unlaying the ends of two ropes, or the two ends of one rope, to a sufficient length, then crutch them together as per adjoining sketch; draw them close and push the strands of one under the strands of the other, the same as the eye-splice. This splice is used for block-straps, slings, &c. If the ends are to be served over, they are but once stuck through; if not, they are stuck twice and cross-whipped across the strands, so as to make them more secure. When the ends are to be served, take a few of the underneath yarns, enough to fill up the lay of the rope for worming, then scrape or trim the outside ends, and marl them down ready for serving.

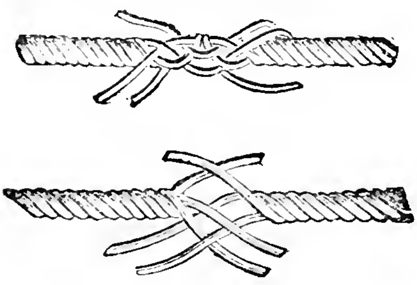


Fig. 23.—Short Splice.

PART V.

REGULATIONS FOR ENGINEMEN AND FIREMEN.

CODE OF SIGNALS.

As the *Public Safety* is the first care of every officer and servant of a Railway Company, and is chiefly dependent upon the proper use and observance of the *Signals, all persons* employed are particularly *required* to make themselves *familiar with this code.*

The Signals in regular use are—

SEMAPHORES............	*by Day.*
FLAGS	
LAMPS	*by Night.*

Also, PERCUSSION and PERSONAL SIGNALS.

Flags and Lamps are distinguished by Colours, as follows :—

RED is a Signal of *Danger—Stop.*
GREEN—Caution—Proceed Slowly
WHITE—All right—Go on.

HAND SIGNALS.

Men required to give Hand Signals are provided with Red, Green, and White Flags, and a Signal Lamp, with Red, Green, and White Glasses, and with Fog Signals; but in any emergency, when not provided with those means of signalling, the following are adopted, namely,—

The All Right Signal is shown by extending the arm horizontally, so as to be distinctly seen by the Engine-driver, thus—(Fig. 24).

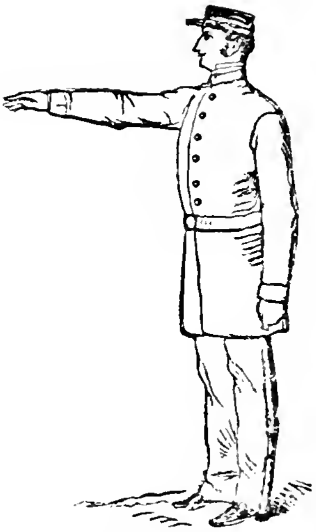


Fig. 24.

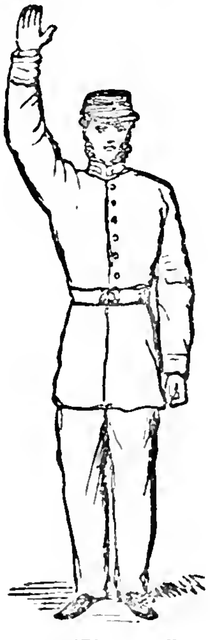


Fig. 25.

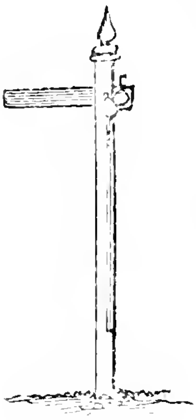
The Caution Signal, to Proceed Slowly, is shown by one arm held straight up, thus—(Fig. 25).

The Stop Signal is shown by holding both arms straight up, thus, or by waving any object with violence—(Fig. 26).

Fig. 26.

STATIONARY (SEMAPHORE) SIGNALS.

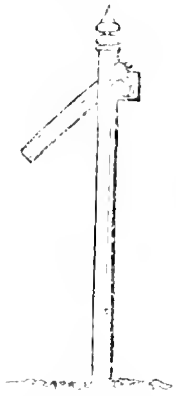
Semaphore Signals are constructed with Arms for day Signals, and Coloured Lamps for night and foggy weather.



The "Danger Signal" is shown, in the day time, by the arm on the left-hand side of the post being raised to the horizontal position, thus:—(Fig. 27).

Fig. 27.

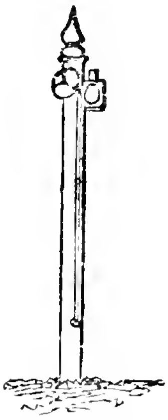
and by the exhibition of a *red* light at night.



The "Caution Signal" is shown, in the day time, by the arm on the left-hand side of the post being placed half-way to the horizontal position, thus:—(Fig. 28).

Fig. 28.

and by the exhibition of a *green* light by night.



The "All Right Signal" is shown, in the day time, by the left-hand side of the post being clear, thus:—(Fig. 29).

Fig. 29.

and by a *white* light by night.

PERCUSSION OR FOG SIGNALS.

The *Percussion Signal* is used in addition to the ordinary Day and Night Signals in *foggy weather*, and when *unforeseen obstructions* have occurred which render it necessary to *stop* approaching trains.

It is fixed upon the rail (label upwards) by bending down the leaden clips attached to it for that purpose, and upon being run over by an engine or train *explodes* with a loud report.

The Signal, *Caution—Proceed slowly*, after bringing the train to a stand, is to be given by the *explosion* of *one* Fog Signal.

The Signal, *Danger—Stop*, is to be given by the *explosion* of *two* or *more* Fog Signals in near succession.

HAND SIGNALS BY NIGHT.

To *prevent* ordinary *Hand Lamps* being *mistaken for Signals*, men must avoid waving them when moving about, unless when absolutely necessary, taking care in all cases to hold the *dark side* as much as possible towards the *Engine-driver*. In the exhibition of *Hand Signals*, men on duty should select positions *conspicuous* to the Enginemen and Guards of Trains.

To provide for the proper guidance of the movement of trains *taking on* or *putting off* Wagons or Carriages upon some railways at *Stations*, the following Signals are used :—

When the Train at a Station is wanted to be moved *forward* to the points of a Connection or Siding, the *Guard, when on the ground*, signals to the Engineman for this by moving his *Green Light up and down*, and continues to do so until the tail of the train is far enough forward, when he gives a *Signal to Stop*, by showing a *Red Light.*

When the train has to be *backed* through a Connection or into a Siding, the Guard moves his *Green Light from side to side* across his body, and continues to do so until the train is far enough through, when he stops the train by exhibiting a *Red Light.*

Again, when the train has to *return* to the Main Line, the Guard signals with his *White Light* by moving it *from side to side* across his body, continuing to do so until the Train arrives on the Main Line. When he takes his place on the Train he signals to the Engineman to proceed on his journey by simply showing a *White Light.*

During these movements all parties are required to see that a *proper look-out* is kept, to prevent collisions with other Trains coming up, and each, in his department, to take the necessary precautions.

BEFORE STARTING.

The enginemen and firemen should appear on duty as clean as circumstances will allow ; and they should be with their engines at such time previous to starting as their foreman may require, in order to see that the engines are in proper order to go out.

Every engineman, before starting on his day's work, is in all cases to *inspect the notices* affixed to the notice-boards in the steam-sheds, in order to ascertain if there is anything requiring his special attention on parts of the line over which he is going to work, as he is responsible for any accident that may take place owing to his neglecting to read the notices posted in the sheds.

The duty of each engine-driver is determined by the locomotive superintendent; and no turn of duty should be altered, and no over-work should be undertaken, by any man, on any account, without the sanction of the locomotive superintendent, or his foreman, except on sudden emergencies, and it must then be reported by the engine-driver in his daily return.

It is the duty of *drivers, before starting,* to see that their engines are in proper working order, have the necessary *supply* of *coal* and *water*, that the *fog-signals* are in a fit *state for use,* and that all the necessary *tools* and *stores* are on the tender, and in efficient order.

Enginemen should always see before starting that their lights are in proper order, and that they have the proper distinguishing light for the train they are drawing.

Under no pretence are enginemen allowed to meddle with safety-valves, to obtain higher steam pressure.

Snow brooms must not be used on the engine guard-irons except snow is actually on the ground, lest they should remove fog signals placed on the rails.

Enginemen when leaving the shed should test the pumps or injectors and sand-valves, to see they work properly; particular attention must also be given to those parts recently renewed, and should any irregularities be felt or heard, the engine must be stopped and examined.

No person, except the proper engineman and fireman, is allowed to ride on the engine or tender without the special permission of the directors, or one of the chief officers of the company; and no fireman must move an engine except when instructed by the driver, and unless he has also an order from the superintendent.

WHILST RUNNING.

Engine-drivers are strictly enjoined to start and stop their trains slowly and without a jerk, so as to avoid the risk of snapping the couplings; and, except in case of danger, they must be careful not to shut off steam suddenly, and thereby cause unnecessary concussion of carriages or waggons. On starting, the fireman must look out behind to see that all the carriages are attached and all right.

When two engines are employed in drawing the same train, the engineman of the second engine must watch for and take his signals from the engineman of the leading engine, and great caution must be used in starting such a train to prevent the breaking of the couplings.

Every engine-driver is provided with a time-table, showing the exact time in which each journey is to be performed, excepting for special and ballast trains, the speed of which must be regulated by circumstances. He must endeavour to run the engine at a uniform speed, from which he should vary as little as possible. He must on no account run before the time specified in the time-table: and he will do well to consult the following table frequently, to enable him to judge with certainty the rate at which he is travelling, or should travel, to arrive at a given station at a certain time:—

TABLE showing the speed of an Engine, when the time of performing a Quarter, Half, or One Mile is given.

Speed per hour.	Time of performing ¼ mile.	Time of performing ½ mile.	Time of performing 1 mile.	Speed per hour.	Time of performing ¼ mile.	Time ot performing ½ mile,	Time of performing 1 mile.
miles.	m. s.	m. s.	m. s.	miles.	m. s.	m. s.	m. s.
5	3 0	6 0	12 0	33	0 27	0 54	1 49
6	2 30	5 0	10 0	34	0 26	0 53	1 46
7	2 8	4 17	8 34	35	0 25	0 51	1 43
8	1 52	3 45	7 30	36	0 25	0 50	1 40
9	1 40	3 20	6 40	37	0 24	0 48	1 37
10	1 30	3 0	6 0	38	0 23	0 47	1 34
11	1 21	2 43	5 27	39	0 23	0 46	1 32
12	1 15	2 30	5 0	40	0 22	0 45	1 30
13	1 9	2 18	4 37	41	0 21	0 43	1 27
14	1 4	2 8	4 17	42	0 21	0 42	1 25
15	1 0	2 0	4 0	43	0 20	0 41	1 23
16	0 56	1 52	3 45	44	0 20	0 40	1 21
17	0 53	1 46	3 31	45	0 20	0 40	1 20
18	0 50	1 40	3 20	46	0 19	0 39	1 18
19	0 47	1 34	3 9	47	0 19	0 38	1 16
20	0 45	1 30	3 0	48	0 18	0 37	1 15
21	0 42	1 25	2 51	49	0 18	0 36	1 13
22	0 40	1 21	2 43	50	0 18	0 36	1 12
23	0 39	1 18	2 36	51	0 17	0 35	1 10
24	0 37	1 15	2 30	52	0 17	0 34	1 9
25	0 36	1 12	2 24	53	0 17	0 34	1 7
26	0 34	1 9	2 18	54	0 16	0 33	1 6
27	0 33	1 6	2 13	55	0 16	0 32	1 5
28	0 32	1 4	2 8	56	0 16	0 32	1 4
29	0 31	1 2	2 4	57	0 15	0 31	1 3
30	0 30	1 0	2 0	58	0 15	0 31	1 2
31	0 29	0 58	1 56	59	0 15	0 30	1 1
32	0 28	0 56	1 52	60	0 15	0 30	1 0

When an engine is in motion, the *driver* must stand where he can keep a *good look-out* ahead.

The *fireman* must also keep a sharp *look-out*, when not otherwise engaged, and especially for any *signals from the guard*, which he will immediately communicate to the engineman.

Firemen must always *obey the orders* of enginemen.

Enginemen should before starting ascertain the number of vehicles in their trains, in order to work their engines accordingly.

Enginemen should not close the regulator to cut the steam off with the reversing-gear, and they should allow their engines to get away smart, with a few vigorous beats, before pulling the lever up, which should be done by degrees as the speed increases.

Enginemen must pay *implicit attention* to the *orders and signals of guards* in all matters relating to the stopping or starting of trains.

Enginemen must on no account place any reliance on the belief that their train is signalled by telegraph; as the fact of a train being so signalled should not in any way diminish the vigilance of their "look-out." The fixed station, junction, and distant signals, with the hand and detonating signals, must alone be regarded and depended on by the enginemen.

Enginemen and *firemen* must pay *immediate attention to all signals*, whether the *cause* of their being given is *known* to them *or not.*

On approaching junctions, enginemen are to sound the whistle, to give the pointsmen notice of their approach. Enginemen are, as far as practicable, to have their firemen disengaged when passing a station, or on approaching or passing a junction, so that they may assist to keep a good look-out for signals.

When an engineman finds a distant signal exhibiting the danger signal, he must immediately turn off steam, and reduce the speed of his train, *so as to be able to stop at the distant signal;* but if he sees that the way is clear he must proceed slowly and cautiously within the distant signal, having such control of his train as to be able to *stop it at any moment,* and bring his engine or train to a stand as near the station or junction as the circumstances will allow.

Whenever a distant or other signal appears in any intermediate position to the proper distances at which it works, it is to be treated as if indicating "Stop," the presumption being that the machinery of the signal is out of order.

The absence of a signal at a place where a signal is ordinarily shown, or a signal imperfectly exhibited, is to be considered as a danger signal, and treated accordingly.

Whenever an engineman *perceives a red flag, or other symbol,* which he understands to be a signal *to stop,* he must bring his engine to a *complete stand close to the signal,* and must on no account pass it.

An unlighted signal after dark must be considered a stop signal.

There may be cases requiring a train to stop, either from a signal or from the personal observation of the engine-driver, when the most prompt judgment and skill will be required to decide whether to stop quickly or merely to shut off the steam, and let the train stop of itself; this must be left to the judgment of the driver. As a general rule, it may be considered that, if anything is the matter with the engine requiring to stop, the quicker it can be done the better; but if any intermediate parts of the train are off the rails, allowing the carriages to stop of themselves has, in some cases, kept up a disabled carriage, when it is probable, if the brake had been applied in front, the carriages behind would have forced themselves over the disabled one. If, however, the disabled carriage should be the last, or nearly the last, in the train, the brake in front may be applied with advantage; but if towards the middle or the front of the train, it is better to let the carriages stop gradually, as, by keeping up a gentle pull, the disabled carriage is kept more out of the way of those behind until the force of the latter is exhausted. In all cases the application of brakes behind the disabled carriages will be attended with the greatest advantage and safety.

The engine whistle must not be used more than is absolutely necessary, the sound being calculated to alarm and disturb passengers, and the public residing in the vicinity of the railway, and to frighten horses.

When two engines are with a train, the signals are to be made by the leading engine.

As a general rule, enginemen are at all times to exercise the greatest watchfulness; they are to be ever on the alert, and, while on duty, to keep their minds entirely fixed on that which is required to be done.

If an engineman should observe anything wrong on the line of rails opposite to that on which his train is running, or should he meet an engine or train too closely following any preceding engine or train, he must exhibit a caution or danger signal, as occasion may require, to the engineman of such following engine or train.

When the road is obscured by steam or smoke (owing to a burst tube or any other cause), no approaching engine is allowed to *pass through the steam* until the engineman shall have ascertained that the road is clear; and if any engineman perceive a train stopping, from accident or other cause, on the road, he is immediately to *slacken his speed*, so that he may pass such train slowly, and stop altogether if necessary, in order to ascertain the cause of the stoppage, and report it at the next station.

Where there is an accident on the opposite line to that on which he is moving, he is to stop all the trains between the spot and the next station, and caution the respective enginemen; and he is, further, to render every assistance in his power in all cases of difficulty.

Engine-drivers must report, immediately on arrival at the first station, any obstruction upon the line from slips or other causes.

When meeting another engine, the drivers should stand on the right-hand side, so as to be near each other in passing, ready to give or receive a signal whether the line which they have passed is clear, whether a train is a-head, or any cause of danger exists.

Enginemen, in bringing up their trains, are to pay particular attention to the state of the weather and the condition of the rails as well as to the length of the train; and these circumstances must have due weight in determining when to shut off the steam. Stations must not be entered so rapidly as to require a violent application of the breaks.

In going down inclined planes, enginemen must take care that they have complete control over the trains, by applying their breaks; and they must on no account attempt to make up lost time in going down inclined planes.

No train with two engines attached is to be allowed to descend any inclined plane without the steam being shut off the second engine.

Due regard must be paid to the caution boards passed at various parts of the line, and the drivers are strictly forbidden to exceed the speed marked thereon where it is specified.

Enginemen must carefully approach all stations at which their trains are required to stop, and must not overrun the platform.

In no case is the engine-driver to put back when he has run past a station until he receives a signal from the station-master or guard; and he must be careful to avoid any delay from overrunning or stopping short of stations.

Enginemen are warned against improperly cottering up any joint or brass, and thereby causing the journals to become hot, or allowing any slide, block, or journal to cut or tear for want of oil or grease.

The fireman is to look back at starting from a station to see that the stop signal is not subsequently given, and that all the train is attached, and frequently when on the journey, and more particularly in passing all points where a signalman is stationed, to observe if he or the guard continues the "all right" signal after the train has passed, or turns on the "stop" signal to indicate that something is wrong, and to *satisfy himself* the engine is *on the right line.*

In case a train, when in motion, should become disconnected into two or more parts, care must be taken not to stop the front part of the train before the detached portions have either stopped or come gently up.

Should *fire* be discovered in a train, the steam must be instantly shut off, the brakes applied, and the train brought to a stand; the proper signals must then be made for the protection of the line, and the burning vehicle or vehicles be detached with as little delay as possible, and the best means adopted to extinguish the fire.

Whenever an engine passes over a detonating signal, or a hand signal to stop is seen, the driver must *immediately shut off steam,* and proceed with *great caution* until he has ascertained that the line is *quite clear,* or until a *second signal* is passed, when the train must be *stopped immediatety.*

Should an accident occasion the stoppage of both lines of railway, the engineman must send the fireman in advance of the train to signal trains travelling on the opposite line of rail to that upon which his train was running.

The following is the mode of applying the detonating signals. In case of obstruction, where it is necessary to stop any engine or train following on the same line, one of the signals is to be placed by the person engaged in the duty, at the end of *every* 250 yards, for a distance of not less than 1,000 yards from the place of obstruction (on levels, but farther on descending gradients, or, if a curve, to continue it until the red signal can be seen round the curve; and should the distance end in a tunnel, then the signal is to be exhibited at the end of the tunnel furthest from the obstruction), in the proper direction, and *two* must be fixed *ten yards apart* at the point where the signalman stands at the moment a following train comes in sight, or, on arriving at the end of the distance named, between him and the approaching train: *five* signals will thus be required to protect the train. The *stop flag signal,* or *lamp at night,* must at the same time be exhibited as conspicuously as possible, and *every exertion* made to stop any approaching engine or train.

AT STATIONS AND STOPPING PLACES.

On stopping at a station, the engine-driver should examine and oil the engine, and if any of the journals or working parts are hot, they must have more oil, and, if necessary, be eased.

Whenever an engine is standing, the spare steam must be turned into the tender, so as to allow as little as possible to escape by the safety-valves.

In all cases when an engine is standing, however short the time, the tender-brake is to be screwed on tight until the signal is given for starting.

Enginemen and firemen must not go away from their engines during their hours of duty, unless authorised by the locomotive foreman, and must never leave an engine in steam without shutting the regulator, putting the engine out of gear, and fixing down the tender-brake.

Whenever an engine-driver is required by a station-master to do anything which may appear in excess of the driver's duty or unreasonable, he is not to refuse to do it unless inconsistent with safety; but the matter is to be referred to the locomotive superintendent.

Enginemen are not allowed (except in case of accident or sudden illness) to change their engines on the journey, nor to leave their respective stations without the permission of their superior officers.

It is very important that engine-drivers use the utmost caution when shunting waggons into sidings, so as to avoid injuring the waggons or other property of the Company.

Engine-drivers should avoid, as much as possible, blowing off steam or opening the feed-pipes at stations, or in passing trains or men, or anywhere where the steam might occasion danger by obstructing the sight.

Enginemen and firemen must not interfere with points connected with the main line except in cases of extreme urgency, and when there is no pointsman who can attend to them.

Every engine-driver is to afford all assistance with his engine that may be required for the arrangement and despatch of the trains; and if running an engine alone or with goods, he must not refuse loaded or empty waggons, if he has power to pull them, unless he has special orders on the subject.

If a train, or a portion of it, is drawn into a station or a siding with a tow-rope, care must be taken to stretch the rope gradually by a gentle advance of the engine; and great attention must be paid to the signals given by the man conducting the operation.

When trains are shunted for other trains to pass, the tail lamps must be removed, or so disposed as not to exhibit the red light to the following train.

AT THE END OF A JOURNEY.

The engine-driver after every trip should carefully examine his engine, test the valves and pistons, and make immediate report to the locomotive superintendent or foreman of any accident to it or to the train; as also of any obstruction or defect in the line, neglect of signals, or other irregularity observed during the journey.

Every engineman, at the conclusion of the day's work, must put his engine in the place appointed for it after the fireman has dropped the fire and raked the ash-pan clean out over the pit appropriated for that purpose ; and he must see that the regulator is left properly shut, the engine out of gear, tender-brake on, and the boiler properly filled with water.

Every engineman, at the *end of his journey*, must *report* in the driver's report-book provided for that purpose—*first*, as to the *state of his engine* and tender ; *second*, as to any *defect* in the road ; *third*, as to any defect in the working of signals, as to any irregularity in the working of his trains, such as time lost by engine and traffic causes, hot axles, &c.

The engine-driver is to keep an account of the duty performed by his engine, and make a daily return of the same to the foreman.

APPENDIX.

EXTRACTS FROM THE GENERAL ACTS OF PARLIAMENT FOR THE REGULATION OF RAILWAYS.

5 & 6 Victoria, cap. 55, sec. 17.

Railway Servants guilty of Misconduct. Punishment of Persons employed on Railways guilty of Misconduct.

Sec. 17.—And whereas by the said recited Act for regulating railways provision is made for the punishment of servants of railway companies guilty of misconduct, and it is expedient to extend such provision; be it enacted, That it shall be lawful for any officer or agent of any railway company, or for any special constable duly appointed, and all such persons as they may call to their assistance, to seize and detain any engine-driver, wagon-driver, guard, porter, servant, or other person employed by the said or by any other railway company, or by any other company or person in conducting traffic upon the railway belonging to the said company, or in repairing and maintaining the works of the said railway, who shall be found drunk while so employed upon the said railway, who shall commit any offence against any of the bye-laws, rules, or regulations of the said company, or who shall wilfully, maliciously, or negligently do or omit to do any act, whereby the life or limb of any person passing along or being upon such railway or the works thereof respectively shall be or might be injured or endangered, or whereby the passage of any engines, carriages, or trains shall be or might be obstructed or impeded; and to convey such engine-driver, guard, porter, servant, or other person so offending, or any person counselling, aiding, or assisting in such offence, with all convenient despatch before some Justice of the Peace for the place within which such offence shall be committed, without any other warrant or authority than this Act; and every such person so offending, and every person counselling, aiding, or assisting therein as aforesaid, shall, when convicted before such Justice as aforesaid (who is hereby authorised and required upon complaint to him made upon oath, without information in writing, to take cognizance thereof, and to act summarily in the premises), in the discretion of such justice be imprisoned, with or without hard labour, for any term not exceeding two calendar months, or, in the like discretion of such Justice, shall for every such offence forfeit to her Majesty any sum not exceeding £10; and in default of payment thereof shall be imprisoned, with or without hard labour as aforesaid, for such period, not exceeding two calendar months, as such Justice shall appoint; such commitment to be determined on payment of the amount of the penalty; and every such penalty shall be returned to the next ensuing court of quarter-sessions in the usual manner.

3 & 4 Victoria, cap. 97.

Justice may send any case to be tried at the Quarter Sessions.

Sec. 14.—Provided always, and be it enacted, That (if upon the hearing of any such complaint he shall think fit) it shall be lawful for such Justice, instead of deciding upon the matter of complaint summarily, to commit the person or persons charged with such offence for trial for the same at the quarter sessions for the county or place wherein such offence shall have been committed, and to order that any such person so committed shall be imprisoned and detained in any of her Majesty's gaols or houses of correction in the said county or place in the meantime, or to take bail for his appearance, with or without sureties, in his discretion; and every such person so offending and convicted before such court of quarter sessions as aforesaid (which said court is hereby required to take cognizance of, and hear and determine such complaint), shall be liable in the discretion of such court to be imprisoned, with or without hard labour, for any term not exceeding two years.

8 & 9 Victoria, cap. 16.

Bye-Laws—Company may make Bye-Laws for regulating the conduct of their Officers and Servants.—Copies to be given to Officers.

Sec. 124.—It shall be lawful for the company from time to time to make such bye-laws as they think fit, for the purpose of regulating the conduct of the officers and servants of the company, and for providing for the due management of the affairs of the company in all respects whatsoever, and from time to time to alter or repeal any such bye-laws, and make others, provided such bye-laws be not repugnant to the laws of that part of the United Kingdom where the same are to have effect, or to the provisions of this or the special act; and such bye-laws shall be reduced into writing, and shall have affixed thereto the common seal of the company; and a copy of such bye-laws shall be given to every officer and servant of the company affected thereby.

Fines may be imposed for Breach of such Bye-Laws.

Sec. 125.—It shall be lawful for the company, by such bye-laws, to impose such reasonable penalties upon all persons, being officers or servants of the company, offending against such bye-laws, as the company think fit, not exceeding five pounds for any one offence.

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