CHAPTER XII.

MANUFACTURE AND MANAGEMENT OF STEAM ENGINES.

CONSTRUCTION OF ENGINES.

700. *Q.*—What are the qualities which should be possessed by the iron of which the cylinder of steam engines are made?

A.—The general ambition in making cylinders is to make them sound and hard; but it is expedient also to make them tough, so as to approach as nearly as possible to the state of malleable iron. This may be done by mixing in the furnace as many different kinds of iron as possible; and it may be set down as a general rule in iron founding, that the greater the number of the kinds of metal entering into the composition of any casting, the denser and tougher it will be. The constituent atoms of the different kinds of iron appear to be of different sizes, and the mixture of different kinds maintains the toughness, while it adds to the density and cohesive power. Hot blast iron was at one time generally believed to be weaker than cold blast iron, but it is now questioned whether it is not the stronger of the two. The cohesive strength of unmixed iron is not in proportion to its specific gravity, and its elasticity and power to resist shocks appear to become greater as the specific gravity becomes less. Nos. 3 and 4 are the strongest irons. In most cases, iron melted in a cupola is not so strong as when remelted in an air furnace, and when run into green sand it is not reckoned so strong as when run into dry sand, or loam. The quality of the fuel, and even the state of the weather, exerts an influence on the quality of the iron: smelting furnaces, on the cold blast principle, have long been known to yield better iron in winter than in summer, probably from the existence of less moisture in the air; and it would probably be found to accomplish an improvement in the quality of the iron if the blast were made to pass through a vessel containing muriate of lime, by which the moisture of the air would be extracted. The expense of such a preparation would not be considerable, as, by subsequent evaporation, the salt might be used over and over again for the same purpose.

701. *Q.*—Will you explain the process of casting cylinders?

A.—The mould into which the metal is poured is built up of bricks and loam, the loam being clay and sand ground together in a mill, with the addition of a little horse-dung to give it a fibrous structure and prevent cracks. The loam board, by which the circle of the cylinder is to be swept, is attached to an upright iron bar, at the distance of the radius of the cylinder, and a cylindrical shell of brick is built up, which is plastered on the inside with loam, and made quite smooth by traversing the perpendicular loam board round it. A core is then formed in a similar manner, but so much smaller as to leave a space between the shell and the core equal to the thickness of the cylinder, and into this space the melted metal is poured. Whatever nozzles or projections are required upon the cylinder, must be formed by means of wooden patterns, which are built into the shell, and subsequently withdrawn; but where a number of cylinders of the same kind are required, it is advisable to make these patterns of iron, which will not be liable to warp or twist while the loam is being dried. Before the iron is cast into the mould, the interior of the mould must be covered with finely powdered charcoal—or blackening, as it is technically termed; and the secret of making finely skinned castings lies in using plenty of blackening. In loam and dry sand castings the charcoal should be mixed with thick clay water, and applied until it is an eighth of an inch thick, or more; the surface should be then very carefully smoothed or sleeked, and if the metal has been judiciously mixed, and the mould thoroughly dried, the casting is sure to be a fine one. Dry sand and loam castings should be, as much as possible, made in boxes; the moulds may thereby be more rapidly and more effectually dried, and better castings will be got with a less expense.

702. *Q.*—Will you explain the next operation which a cylinder undergoes?

A.—The next stage is the boring; and in boring cylinders of 74 inches diameter, the boring bar must move so as to make one revolution in about 4½ minutes, at which speed the cutters will move at the rate of about 5 feet per minute. In boring brass, the speed must be slower; the common rate at which the tool moves in boring brass air pumps is about 3 feet per minute. If this speed be materially exceeded the tool will be spoiled, and the pump made taper. The speed proper for boring a cylinder will answer for boring the brass air pump of the same engine. A brass air pump of 36½ inches diameter requires the bar to make one turn in about three minutes, which is also the speed proper for a cylinder 60 inches in diameter. To bore a brass air pump 36½ inches in diameter requires a week, an iron one requires 48 hours, and a copper one 24 hours. In turning a malleable iron shaft 12¾ inches in diameter, the shaft should make about five turns per minute, which is equivalent to a speed in the tool of about 16 feet per minute; but this speed may be exceeded if soap and water be plentifully run on the point of the tool. A boring mill, of which the speed may be varied from one turn in six minutes to twenty-five turns in one minute, will be suitable for all ordinary wants that can occur in practice.

703. *Q.*—Are there any precautions necessary to be observed in order that the boring may be truly effected?

A.—In fixing a cylinder into the boring mill, great care must be taken that it is not screwed down unequally; and indeed it will be impossible to bore a large cylinder in a horizontal mill without being oval, unless the cylinder be carefully gauged when standing on end, and be set up by screws when laid in the mill until it again assumes its original form. A large cylinder will inevitably become oval if laid upon its side; and if while under the tension due to its own weight it be bored round, it will become oval again when set upon end. If the bottom be cast in, the cylinder will be probably found to be round at one end and oval at the other, unless a vertical boring mill be employed, or the precautions here suggested be adopted.

704. *Q.*—Does the boring tool make the cylinder sufficiently smooth for the reception of the piston?

A.—Many engine makers give no other finish to their cylinders; but Messrs. Penn grind their cylinders after they are bored, by laying them on their side, and rubbing a piece of lead, with a cross iron handle like that of a rolling stone, and smeared with emery and oil, backward and forward—the cylinder being gradually turned round so as to subject every part successively to the operation. The lead by which this grinding is accomplished is cast in the cylinder, whereby it is formed of the right curve; but the part of the cylinder in which it is cast should be previously heated by a hot iron, else the metal may be cracked by the sudden heat.

705. *Q.*—How are the parts of a piston fitted together so as to be perfectly steam tight?

A.—The old practice was to depend chiefly upon grinding as the means of making the rings tight upon the piston or upon one another; but scraping is now chiefly relied on. Some makers, however, finish their steam surfaces by grinding them with powdered Turkey stone and oil. A slight grinding, or polishing, with powdered Turkey stone and oil, appears to be expedient in ordinary cases, and may be conveniently accomplished by setting the piston on a revolving table, and holding the ring stationary by a cross piece of wood while the table turns round. Pieces of wood may be interposed between the ring and the body of the piston, to keep the ring nearly in its right position; but these pieces of wood should be fitted so loosely as to give some side play, else the disposition would arise to wear the flange of the piston into a groove.

706. *Q.*—What kind of tool is used for finishing surfaces by scraping?

A.—A flat file bent, and sharpened at the end, makes an eligible scraper for the first stages; or a flat file sharpened at the end and used like a chisel for wood. A three-cornered file, sharpened at all the corners, is the best instrument for finishing the operation. The scraping tool should be of the best steel, and should be carefully sharpened at short intervals on a Turkey stone, so as to maintain a fine edge.

707. *Q.*—Will you explain the method of fitting together the valve and cylinder faces?

A.—Both faces must first be planed, then filed according to the indications of a metallic straight edge, and subsequently of a thick metallic face plate, and finally scraped very carefully until the face plate bears equally all over the surface. In planing any surface, the catches which retain the surface on the planing machine should be relaxed previously to the last cut, to obviate distortion from springing. To ascertain whether the face plate bears equally, smear it over with a little red ochre and oil, and move the face plate slightly, which will fix the color upon the prominent points. This operation is to be repeated frequently; and as the work advances, the quantity of coloring matter is to be diminished, until finally it is spread over the face plate in a thin film, which only dims the brightness of the plate. The surfaces at this stage must be rubbed firmly together to make the points of contact visible, and the higher points will become slightly clouded, while the other parts are left more or less in shade. If too small a quantity of coloring matter be used at first, it will be difficult to form a just conception of the general state of the surface, as the prominent points will alone be indicated, whereas the use of a large quantity of coloring matter in the latter stages would destroy the delicacy of the test the face plate affords. The number of bearing points which it is desirable to establish on the surface of the work, depends on the use to which the surface is to be applied; but whether it is to be finished with great elaboration, or otherwise, the bearing points should be distributed equally over the surface. Face plates, or planometers, as they are sometimes termed, are supplied by most of the makers of engineering tools. Every factory should be abundantly supplied with them, and also with steel straight edges; and there should be a master face plate, and a master straight edge, for the sole purpose of testing, from time to time, the accuracy of those in use.

708. *Q.*—Is the operation of surfacing, which you have described, necessary in the case of all slide valves?

A.—Yes; and in fitting the faces of a D valve, great care must, in addition, be taken that the valve is not made conical; for unless the back be exactly parallel with the face, it will be impossible to keep the packing from being rapidly cut away. When the valve is laid upon the face plate, the back must be made quite fair along the whole length, by draw filing, according to the indications of a straight edge; and the distance from the face to the extreme height of the back must be made identical at each extremity.

709. *Q.*—When you described the operation of boring the cylinder, you stated that the cylinder, when laid upon its side, became oval; will not this change of figure distort the cylinder face?

A.—It is not only in the boring of the cylinder that it is necessary to be careful that there is no change of figure, for it will be impossible to face the valves truly in the case of large cylinders, unless the cylinder be placed on end, or internal props be introduced to prevent the collapse due to the cylinder's weight. It may be added, that the change of figure is not instantaneous, but becomes greater after some continuance of the strain than it was at first, so that in gauging a cylinder to ascertain the difference of diameter when it is placed on its side, it should have lain some days upon its side to ensure the accuracy of the operation.

710. *Q.*—How is any flaw in the valve or cylinder face remedied?

A.—Should a hole occur either in the valve, in the cylinder, or any other part where the surface requires to be smooth, it may be plugged up with a piece of cast iron, as nearly as possible of the same texture. Bore out the faulty part, and afterward widen the hole with an eccentric drill, so that it will be of the least diameter at the mouth. The hole may go more than half through the iron: fit then a plug of cast iron roughly by filing, and hammer it into the hole, whereby the plug will become riveted in it, and its surface may then be filed smooth. Square pieces may be let in after the same fashion, the hole being made dovetailed, and the pieces thus fitted will never come out.

711. *Q.*—When cylinders are faced with brass, how is the face attached to the cylinder?

A.—Brass faces are put upon valves or cylinders by means of small brass screws tapped into the iron, with conical necks for the retention of the brass: they are screwed by means of a square head, which, when the screw is in its place, is cut off and filed smooth. In some cases the face is made of extra thickness, and a rim not so thick runs round it, forming a step or recess for the reception of brass rivets, the heads of which are clear of the face.

712. *Q.*—What is the best material for valve faces?

A.—Much trouble is experienced with every modification of valve face; but cast iron working upon cast iron is, perhaps, the best combination yet introduced. A usual practice is to pin brass faces on the cylinder, allowing the valve to retain its cast iron face. Some makers employ brass valves, and others pin brass on the valves, leaving the cylinder with a cast iron face. If brass valves are used, it is advisable to plane out two grooves across the face, and to fill them up with hard cast iron to prevent rutting. Speculum metal and steel have been tried for the cylinder faces, but only with moderate success. In some cases the brass gets into ruts; but the most prevalent affection is a degradation of the iron, owing to the action of the steam, and the face assuming a granular appearance, something like loaf sugar. This action shows itself only at particular spots, and chiefly about the angles of the port or valve face. At first the action is slow; but when once the steam has worked a passage for itself, the cutting away becomes very rapid, and, in a short time, it will be impossible to prevent the engine from heating when stopped, owing to the leakage of steam through the valve into the condenser. Copper steam pipes seem to have some galvanic action on valve faces, and malleable iron pipes have sometimes been substituted; but they are speedily worn out by oxidation, and the scales of rust which are carried on by the steam scratch the valves and cylinders, so that the use of copper pipes is the least evil.

713. *Q.*—Will you explain in what manner the joints of an engine are made?

A.—Rust joints are not now much used in engines of any kind, yet it is necessary that the engineer should be acquainted with the manner of their formation. One ounce of sal-ammoniac in powder is mingled with 18 ounces or a pound of borings of cast iron, and a sufficiency of water is added to wet the mixture thoroughly, which should be done some hours before it is wanted for use. Some persons add about half an ounce of flowers of brimstone to the above proportions, and a little sludge from the grindstone trough. This cement is caulked into the joints with a caulking iron, about three quarters of an inch wide and one quarter of an inch thick, and after the caulking is finished the bolts of the joints may be tried to see if they cannot be further tightened. The skin of the iron must, in all cases, be broken where a rust joint is to be made; and, if the place be greasy, the surface must be well rubbed over with nitric acid, and then washed with water, till no grease remains. The oil about engines has a tendency to damage rust joints by recovering the oxide. Coppersmiths staunch the edges of their plates and rivets by means of a cement formed of pounded quicklime, with serum of blood, or white of egg; and in copper boilers such a substance may be useful in stopping the impalpable leaks which sometimes occur, though Roman cement appears to be nearly as effectual.

714. *Q.*—Will you explain the method of case hardening the parts of engines?

A.—The most common plan for case hardening consists in the insertion of the articles to be operated upon among horn or leather cuttings, bone dust, or animal charcoal, in an iron box provided with a tight lid, which is then put into a furnace for a period answerable to the depth of steel required. In some cases the plan pursued by the gunsmiths may be employed with convenience. The article is inserted in a sheet iron case amid bone dust, often not burned; the lid of the box is tied on with wire, and the joint luted with clay; the box is heated to redness as quickly as possible and kept half an hour at a uniform heat: its contents are then suddenly immersed in cold water. The more unwieldy portions of an engine may be case hardened by prussiate of potash—a salt made from animal substances, composed of two atoms of carbon and one of nitrogen, and which operates on the same principle as the charcoal. The iron is heated in the fire to a dull red heat, and the salt is either sprinkled upon it or rubbed on in a lump, or the iron is rubbed in the salt in powder. The iron is then returned to the fire for a few minutes, and finally immersed in water. By some persons the salt is supposed to act unequally, as if there were greasy spots upon the iron which the salt refused to touch, and the effect under any circumstances is exceedingly superficial; nevertheless, upon all parts not exposed to wear, a sufficient coating of steel may be obtained by this process.

715. *Q.*—What kind of iron is most suitable for the working parts of an engine?

A.—In the malleable iron work of engines scrap iron has long been used, and considered preferable to other kinds; but if the parts are to be case hardened, as is now the usual practice, the use of scrap iron is to be reprehended, as it is almost sure to make the parts twist in the case hardening process. In case hardening, iron absorbs carbon, which causes it to swell; and as some kinds of iron have a greater capacity for carbon than other kinds, in case hardening they will swell more, and any such unequal enlargement in the constituent portions of a piece of iron will cause it to change its figure. In some cases, case hardening has caused such a twisting of the parts of an engine, that they could not afterward be fitted together; it is preferable, therefore, to make such parts as are to be case hardened to any considerable depth of Lowmoor, Bowling, or Indian iron, which being homogeneous will absorb carbon equally, and will not twist.

716. *Q.*—What is the composition of the brass used for engine bearings?

A.—The brass bearings of an engine are composed principally of copper and tin. A very good brass for steam engine bearings consists of old copper 112 lbs., tin 12½ lbs., zinc 2 or 3 oz.; and if new tile copper be used, there should be 13 lbs. of tin instead of 12½ lbs. A tough brass for engine work consists of 1½ lb. tin, 1½ lb. zinc, and 10 lbs. copper; a brass for heavy bearings, 2½ oz. tin, ½ oz. zinc, and 1 lb. copper. There is a great difference in the length of time brasses wear, as made by different manufacturers; but the difference arises as much from a different quantity of surface, as from a varying composition of the metal. Brasses should always be made strong and thick, as when thin they collapse upon the bearing and increase the friction and the wear.

717. *Q.*—How is Babbitt's metal for lining the bushes of machinery compounded?

A.—Babbitt's patent lining metal for bushes has been largely employed in the bushes of locomotive axles and other machinery: it is composed of 1 lb. of copper, 1 lb. regulus of antimony, and 10 lbs. of tin, or other similar proportions, the presence of tin being the only material condition. The copper is first melted, then the antimony is added, with a small proportion of tin—charcoal being strewed over the surface of the metal in the crucible to prevent oxidation. The bush or article to be lined, having been cast with a recess for the soft metal, is to be fitted to an iron mould, formed of the shape and size of the bearing or journal, allowing a little in size for the shrinkage. Drill a hole for the reception of the soft metal, say ½ to ¾ inch diameter, wash the parts not to be tinned with a clay wash to prevent the adhesion of the tin, wet the part to be tinned with alcohol, and sprinkle fine sal-ammoniac upon it; heat the article until fumes arise from the ammonia, and immerse it in a kettle of Banca tin, care being taken to prevent oxidation. When sufficiently tinned, the bush should be soaked in water, to take off any particles of ammonia that may remain upon it, as the ammonia would cause the metal to blow. Wash with pipe clay, and dry; then heat the bush to the melting point of tin, wipe it clean, and pour in the metal, giving it sufficient head as it cools; the bush should then be scoured with fine sand, to take off any dirt that may remain upon it, and it is then fit for use. This metal wears for a longer time than ordinary gun metal, and its use is attended with very little friction. If the bearing heats, however, from the stopping of the oil hole or otherwise, the metal will be melted out. A metallic grease, containing particles of tin in the state of an impalpable powder, would probably be preferable to the lining of metal just described.

718. *Q.*—Can you state the composition of any other alloys that are used in engine work?

A.—The ordinary range of good yellow brass that files and turns well, is about $4\frac{1}{2}$ to 9 ounces of zinc to the pound of copper. Flanges to stand brazing may be made of copper 1 lb., zinc $\frac{1}{2}$ oz., lead $\frac{3}{8}$ oz. Brazing solders when stated in the order of their hardness are:—three parts copper and one part zinc (very hard), eight parts brass and one part zinc (hard), six parts brass, one part tin, and one part zinc (soft); a very common solder for iron, copper, and brass, consists of nearly equal parts of copper and zinc. Muntz's metal consists of forty parts zinc and sixty of copper; any proportions between the extremes of fifty parts of zinc and fifty parts copper, and thirty-seven zinc and sixty-three copper, will roll and work at a red heat, but forty zinc to sixty copper are the proportions preferred. Bell metal, such as is used for large bells, consists of $4\frac{1}{2}$ ounces to 5 ounces of tin to the pound of copper; speculum metal consists of from $7\frac{1}{2}$ ounces to $8\frac{1}{2}$ ounces of tin to the pound of copper.

ERECTION OF ENGINES.

719. *Q.*—Will you explain the operation of erecting a pair of side lever engines in the workshop?

A.—In beginning the erection of side lever marine engines in the workshop, the first step is to level the bed plate lengthways and across, and strike a line up the centre, as near as possible in the middle, which indent with a chisel in various places, so that it may at any time be easily found again. Strike another line at right angles with this, either at the cylinder or crank centre, by drawing a perpendicular in the usual manner. Lay the other sole plate alongside at the right distance, and strike a line at the cylinder or crank centre of it also, shifting either sole plate a little endways until these two transverse lines come into the same line, which may be ascertained by applying a straight edge across the two sole plates. Strike the rest of the centres across, and drive a pin into each corner of each sole plate, which file down level, so as to serve for points of reference at any future stage; next, try the cylinder, or plumb it on the inside roughly, and see how it is for height, in order to ascertain whether much will be required to be chipped off the bottom, or whether more requires to be chipped off the one side than the other. Chip the cylinder bottom fair; set it in its place, plumb the cylinder very carefully with a straight edge and silk thread, and scribe it so as to bring the cylinder mouth to the right height, then chip the sole plate to suit that height. The cylinder must then be tried on again, and the parts filed wherever they bear hard, until the whole surface is well fitted. Next, chip the place for the framing; set up the framing, and scribe the horizontal part of the jaw with the scriber used for the bottom of the cylinder, the upright part being set to suit the shaft centres, and the angular flange of cylinder, where the stay is attached, having been previously chipped plumb and level. The stake wedges with which the framing is set up preparatorily to the operation of scribing, must be set so as to support equally the superincumbent weight, else the framing will spring from resting unequally, and it will be altogether impossible to fit it well. These directions obviously refer exclusively to the old description of side lever engine with cast iron framing; but there is more art in erecting an engine of that kind with accuracy, than in erecting one of the direct action engines, where it is chiefly turned or bored surfaces that have to be dealt with.

720. *Q.*—How do you lay out the positions of the centres of a side lever engine?

A.—In fixing the positions of the centres in side lever engines, it appears to be the most convenient way to begin with the main centre. The height of the centre of the cross head at half stroke above the plane of the main centre is fixed by the drawing of the engine, which gives the distance from the centre of cross head at half stroke to the flange of the cylinder; and from thence it is easy to find the perpendicular distance from the cylinder flange to the plane of the main centre, merely by putting a straight edge along level, from the position of the main centre to the cylinder, and measuring from the cylinder flange down to it, raising or lowering the straight edge until it rests at the proper measurement. The main centre is in that plane, and the fore and aft position is to be found by plumbing up from the centre line on the sole plate. To find the paddle shaft centre, plumb up from the centre line marked on the edge of the sole plate, and on this line lay off from the plane of the main centre the length of the connecting rod, if that length be already fixed, or otherwise the height fixed in the drawing of the paddle shaft above the main centre. To fix the centre for the parallel motion shaft, when the parallel bars are connected with the cross head, lay off from the plane of main centre the length of the parallel bar from the centre of the cylinder, deduct the length of the radius crank, and plumb up the central line of motion shaft; lay off on this line, measuring from the plane of main centre, the length of the side rod; this gives the centre of parallel motion shaft when the radius bars join the cross head, as is the preferable practice where parallel motions are used. The length of the connecting rod is the distance from the centre of the beam when level, or the plane of the main centre, to the centre of the paddle shaft. The length of the side rods is the distance from the centre line of the beam when level, to the centre of the cross head when the piston is at half stroke. The length of the radius rods of the parallel motion is the distance from the point of attachment on the cross head or side rod, when the piston is at half stroke, to the extremity of the radius crank when the crank is horizontal; or in engines with the parallel motion attached to the cross head, it is the distance from the centre of the pin of the radius crank when horizontal to the centre of the cylinder. Having fixed the centre of the parallel motion shaft in the manner just described, it only remains to put the parts together when the motion is attached to the cross head; but when the motion is attached to the side rod, the end of the parallel bar must not move in a perpendicular line, but in an arc, the versed sine of which bears the same ratio to that of the side lever, that the distance from the top of the side rod to the point of attachment bears to the total length of the side rod.

721. *Q.*—How do you ascertain the accuracy of the parallel motion?

A.—The parallel motion when put in its place should be tested by raising and lowering the piston by means of the crane. First, set the beams level, and shift in or out the motion shaft plummer blocks or bearings, until the piston rod is upright. Then move the piston to the two extremes of its motion. If at both ends the cross head is thrown too much out, the stud in the beam to which the motion side rod is attached is too far out, and must be shifted nearer to the main centre; if at the extremities the cross head is thrown too far in, the stud in the beam is not out far enough. If the cross head be thrown in at the one end, and out equally at the other, the fault is in the motion side rod, which must be lengthened or shortened to remedy the defect.

722. *Q.*—Will you describe the method pursued in erecting oscillating engines?

A.—The columns here are of wrought iron, and in the case of small engines there is a template made of wood and sheet iron, in which the holes are set in the proper positions, by which the upper and lower frames are adjusted; but in the case of large engines, the holes are set off by means of trammels. The holes for the reception of the columns are cast in the frames, and are recessed out internally: the bosses encircling the holes are made quite level across, and made very true with a face plate, and the pillars which have been turned to a gauge are then inserted. The top frame is next put on, and must bear upon the collars of the columns so evenly, that one of the columns will not be bound by it harder than another. If this point be not attained, the surfaces must be further scraped, until a perfect fit is established. The whole of the bearings in the best oscillating engines are fitted by means of scraping, and on no other mode of fitting can the same reliance be placed for exactitude.

723. *Q.*—How do you set out the trunnions of oscillating engines, so that they shall be at right angles with the interior of the cylinder?

A.—Having bored the cylinder, faced the flange, and bored out the hole through which the boring bar passes, put a piece of wood across the mouth of the cylinder, and jam it in, and put a similar piece in the hole through the bottom of the cylinder. Mark the centre of the cylinder upon each of these pieces, and put into the bore of each trunnion an iron plate, with a small indentation in the middle to receive the centre of a lathe, and adjusting screws to bring the centre into any required position. The cylinder must then be set in a lathe, and hung by the centres of the trunnions, and a straight edge must be put across the cylinder mouth and levelled, so as to pass through the line in which the centre of the cylinder lies. Another similar straight edge, and similarly levelled, must be similarly placed across the cylinder bottom, so as to pass through the central line of the cylinder; and the cylinder is then to be turned round in the trunnion centres—the straight edges remaining stationary, which will at once show whether the trunnions are in the same horizontal plane as the centre of the cylinder, and if not, the screws of the plates in the trunnions must be adjusted until the central point of the cylinder just comes to the straight edge, whichever end of the cylinder is presented. To ascertain whether the trunnions stand in a transverse plane, parallel to the cylinder flange, it is only necessary to measure down from the flange to each trunnion centre; and if both these conditions are satisfied, the position of the centres may be supposed to be right. The trunnion bearings are then turned, and are fitted into blocks of wood, in which they run while the packing space is being turned out. Where many oscillating engines are made, a lathe with four centres is used, which makes the use of straight edges in setting out the trunnions superfluous.

724. *Q.*—Will you explain how the slide valve of a marine engine is set?

A.—Place the crank in the position corresponding to the end of the stroke, which can easily be done in the shop with a level, or plumb line; but in a steam vessel another method becomes necessary. Draw the transverse centre line, answering to the centre line of the crank shaft, on the sole plate of the engine, or on the cylinder mouth if the engine be of the direct action kind; describe a circle of the diameter of the crank pin upon the large eye of the crank, and mark off on either side of the transverse centre line a distance equal to the semi-diameter of the crank pin. From the point thus found, stretch a line to the edge of the circle described on the large eye of the crank, and bring round the crank shaft till the crank pin touches the stretched line; the crank may thus be set at either end of its stroke. When the crank is thus placed at the end of the stroke, the valve must be adjusted so as to have the amount of lead, or opening on the steam side, which it is intended to give at the beginning of the stroke; the eccentric must then be turned round upon the shaft until the notch in the eccentric rod comes opposite the pin on the valve lever, and falls into gear: mark upon the shaft the situation of the eccentric, and put on the catches in the usual way. The same process must be repeated for going astern, shifting round the eccentric to the opposite side of the shaft, until the rod again falls into gear. In setting valves, regard must of course be had to the kind of engine, the arrangements of the levers, and the kind of valve employed; and in any general instructions it is impossible to specify every modification in the procedure that circumstances may render advisable.

725. *Q.*—Is a similar method of setting the valve adopted when the link motion is employed.

A.—Each end of the link of the link motion has the kind of motion communicated to it that is due to the action of the particular eccentric with which that end is in connection. In that form of the link motion in which the link itself is moved up or down, there is a different amount of lead for each different position of the link, since to raise or lower the link is tantamount to turning the eccentric round on the shaft. In that form of the link motion in which the link itself is not raised or lowered, but is susceptible of a motion round a centre in the manner of a double ended lever, the lead continues uniform. In both forms of the link motion, as the stroke of the valve may be varied to any required extent while the lap is a constant quantity, the proportion of the lap relatively to the stroke of the valve may also be varied to any required extent, and the amount of the lap relatively with the stroke of the valve determines the amount of the expansion. In setting the valve when fitted with the link motion, the mode of procedure is much the same as when it is moved by a simple eccentric. The first thing is to determine if the eccentric rods are of the proper length, and this is done by setting the valve at half stroke and turning round the eccentric, marking each extremity of the travel of the end of the rod. The valve attachment should be midway between these extremes; and if it is not so, it must be made so by lengthening or shortening the rod. The forward and backward eccentric rods are to be adjusted in this way, and this being done, the engine is to be put to the end of the stroke, and the eccentric is to be turned round until the amount of lead has been given that is desired. The valve must be tried by turning the engine round to see that it is right at both centres, for going ahead and also for going astern. In some examples of the link motion, one of the eccentric rods is made a little longer than the other, and the position of the point of suspension or point of support powerfully influences the action of the link in certain cases, especially if the link and this point are not in the same vertical line. To reconcile all the conditions proper to the satisfactory operation of the valve in the construction of the link motion, is a problem requiring a good deal of attention and care for its satisfactory solution; and to make sure that this result is attained, the engine must be turned round a sufficient number of times to enable us to ascertain if the valve occupies the desired position, both at the top and bottom centres, whether the engine is going ahead or astern. This should also be tried with the starting handle in the different notches, or, in other words, with the sliding block in the slot or opening of the link in different positions.

MANAGEMENT OF MARINE BOILERS.

726. *Q.*—You have already stated that the formation of salt or scale in marine boilers is to be prevented by blowing out into the sea at frequent intervals a portion of the concentrated water. Will you now explain how the proper quantity of water to be blown out is determined?

A.—By means of the salinometer, which is an instrument for determining the density of the water, constructed on the principle of the hydrometer for telling the strength of spirits. Some of the water is drawn off from the boiler from time to time, and the salinometer is immersed in it after it has been cooled. By the graduations of the salinometer the saltness of this water is at once discovered; and if the saltness exceeds 8 ounces of salt in the gallon, more water should be blown out of the boiler to be replenished with fresher water from the sea, until the prescribed limit of freshness is attained. Should the salinometer be accidentally broken, a temporary one may be constructed of a phial weighted with a few grains of shot or other convenient weight. The weighted phial is first to be floated in fresh water, and its line of floatation marked; then to be floated in salt water, and its line of floatation marked; and another mark of an equal height above the salt water mark will be the blow off point.

727. *Q.*—How often should boilers be blown off in order to keep them free from incrustation?

A.—Flue boilers generally require to be blown off about twice every watch, or about twice in the four hours; but tubular boilers may require to be blown off once every twenty minutes, and such an amount of blowing off should in every case be adopted, as will effectually prevent any injurious amount of incrustation.

728. *Q.*—In the event of scale accumulating on the flues of a boiler, what is the best way of removing it?

A.—If the boilers require to be scaled, the best method of performing the operation appears to be the following:—Lay a train of shavings along the flues, open the safety valve to prevent the existence of any pressure within the boiler, and light the train of shavings, which, by expanding rapidly the metal of the flues, while the scale, from its imperfect conducting power, can only expand slowly, will crack off the scale; by washing down the flues with a hose, the scale will be carried to the bottom of the boiler, or issue, with the water, from the mud-hole doors. This method of scaling must be practised only by the engineer himself, and must not be intrusted to the firemen who, in their ignorance, might damage the boiler by overheating the plates. It is only where the incrustation upon the flues is considerable that this method of removing it need be practised; in partial cases the scale may be chipped off by a hatched-faced hammer, and the flues may then be washed down with the hose in the manner before described.

729. *Q.*—Should the steam be let out of the boiler, after it has blown out the water, when the engine is stopped?

A.—No; it is better to retain the steam in the boiler, as the heat and moisture it occasions soften any scale adhering to the boiler, and cause it to peel off. Care must, however, be taken not to form a vacuum in the boiler; and the gauge cocks, if opened, will prevent this.

730. *Q.*—Are tubular boilers liable to the formation of scale in certain places, though generally free from it?

A.—In tubular boilers a good deal of care is required to prevent the ends of the tubes next the furnace from becoming coated with scale. Even when the boiler is tolerably clean in other places the scale will collect here; and in many cases where the amount of blowing off previously found to suffice for flue boilers has been adopted, an incrustation five eighths of an inch in thickness has formed in twelve months round the furnace ends of the tubes, and the stony husks enveloping them have actually grown together in some parts so as totally to exclude the water.

731. *Q.*—When a tubular boiler gets incrusted in the manner you have described, what is the best course to be adopted for the removal of the scale?

A.—When a boiler gets into this state the whole of the tubes must be pulled out, which may be done by a Spanish windlass combined with a pair of blocks; and three men, when thus provided, will be able to draw out from 50 to 70 tubes per day,— those tubes with the thickest and firmest incrustations being, of course, the most difficult to remove. The act of drawing out the tubes removes the incrustation; but the tubes should afterward be scraped by drawing them backward and forward between the old files, fixed in a vice, in the form of the letter V. The ends of the tube should then be heated and dressed with the hammer, and plunged while at a blood heat into a bed of sawdust to make them cool soft, so that they may be riveted again with facility. A few of the tubes will be so far damaged at the ends by the act of drawing them out, as to be too short for reinsertion: this result might be to a considerable extent obviated by setting the tube plates at different angles, so that the several horizontal rows of tubes would not be originally of the same length, and the damaged tubes of the long rows would serve to replace the short ones; but the practice would be attended with other inconveniences.

732. *Q.*—Is there no other means of keeping boilers free from scale than by blowing off?

A.—Muriatic acid, or muriate of ammonia, commonly called sal-ammoniac, introduced into a boiler, prevents scale to a great extent; but it is liable to corrode the boiler internally, and also to damage the engine, by being carried over with the steam; and the use of such intermixtures does not appear to be necessary, if blowing off from the surface of the water is largely practised. In old boilers, however, already incrusted with scale, the use of muriate of ammonia may sometimes be advantageous.

733. *Q.*—Are not the tubes of tubular boilers liable to be choked up by deposits of soot?

A.—The soot which collects in the inside of the tubes of tubular boilers is removed by means of a brush, like a large bottle brush; and the carbonaceous scale, which remains adhering to the interior of the tubes, is removed by a circular scraper. Ferules in the tubes interfere with the action of this scraper, and in the case of iron tubes ferules are now generally discarded; but it will sometimes be necessary to use ferules for iron tubes, where the tubes have been drawn and reinserted, as it may be difficult to refix the tubes without such an auxiliary. Tubes one tenth of an inch in thickness are too thin: one eighth of an inch is a better thickness, and such tubes will better dispense with the use of ferules, and will not so soon wear into holes.

734. *Q.*—If the furnace or flue of a boiler be injured, how do you proceed to repair it?

A.—If from any imperfection in the roof of a furnace or flue a patch requires to be put upon it, it will be better to let the patch be applied upon the upper, rather than upon the lower, surface of the plate; as if applied within the furnace a recess will be formed for the lodgment of deposit, which will prevent the rapid transmission of the heat in that part; and the iron will be very liable to be again burned away. A crack in a plate may be closed by boring holes in the direction of the crack, and inserting rivets with large heads, so as to cover up the imperfection. If the top of the furnace be bent down, from the boiler having been accidentally allowed to get short of water, it may be set up again by a screw jack,—a fire of wood having been previously made beneath the injured plate; but it will in general be nearly as expeditious a course to remove the plate and introduce a new one, and the result will be more satisfactory.

735. *Q.*—In the case of the chimney being carried away by shot or otherwise, what course would you pursue?

A.—In some cases of collision, the funnel is carried away and lost overboard, and such cases are among the most difficult for which a remedy can be sought. If flame come out of the chimney when the funnel is knocked away, so as to incur the risk of setting the ship on fire, the uptake of the boiler must be covered over with an iron plate, or be sufficiently covered to prevent such injury. A temporary chimney must then be made of such materials as are on board the ship. If there are bricks and clay or lime on board, a square chimney may be built with them, or, if there be sheet iron plates on board, a square chimney may be constructed of them. In the absence of such materials, the awning stanchions may be set up round the chimney, and chain rove in through among them in the manner of wicker work, so as to make an iron wicker chimney, which may then be plastered outside with wet ashes mixed with clay, flour, or any other material that will give the ashes cohesion. War steamers should carry short spare funnels, which may easily be set up should the original funnel be shot away; and if a jet of steam be let into the chimney, a very short and small funnel will suffice for the purpose of draught.

MANAGEMENT OF MARINE ENGINES.

736. *Q.*—What are the most important of the points which suggest themselves to you in connection with the management of marine engines?

A.—The attendants upon engines should prepare themselves for any casualty that may arise, by considering possible cases of derangement, and deciding in what way they would act should certain accidents occur. The course to be pursued must have reference to particular engines, and no general rules can therefore be given; but every marine engineer shoud be prepared with the measures to be pursued in the emergencies in which he may be called upon to act, and where everything may depend upon his energy and decision.

737. *Q.*—What is the first point of a marine engineer's duty?

A.—The safe custody of the boiler. He must see that the feed is maintained, being neither too high nor too low, and that blowing out the supersalted water is practised sufficiently. The saltness of the water at every half hour should be entered in the log book, together with the pressure of steam, number of revolutions of the engine, and any other particulars which have to be recorded. The economical use of the fuel is another matter which should receive particular attention. If the coal is very small, it should be wetted before being put on the fire. Next to the safety of the boiler, the bearings of the engine are the most important consideration. These points, indeed, constitute the main parts of the duty of an engineer, supposing no accident to the machinery to have taken place.

738. *Q.*—If the eccentric catches or hoops were disabled, how would you work the valve?

A.—If the eccentric catches or hoops break or come off, and the damage cannot readily be repaired, the valve may be worked by attaching the end of the starting handle to any convenient part of the other engine, or to some part in connection with the connecting rod of the same engine. In side lever engines, with the starting bar hanging from the top of the diagonal stay, as is a very common arrangement, the valve might be wrought by leading a rope from the side lever of the other engine through blocks so as to give a horizontal pull to the hanging starting bar, and the bar could be brought back by a weight. Another plan would be, to lash a piece of wood to the cross tail butt of the damaged engine, so as to obtain a sufficient throw for working the valve, and then to lead a piece of wood or iron, from a suitable point in the piece of wood attached to the cross tail, to the starting handle, whereby the valve would receive its proper motion. In oscillating engines it is easy to give the required motion to the valve, by deriving it from the oscillation of the cylinder.

739. *Q.*—What would you do if a crank pin broke?

A.—If the crank pin breaks in a paddle vessel with two engines, the other engine must be made to work one wheel. In a screw vessel the same course may be pursued, provided the broken crank is not the one through which the force of the other engine is communicated to the screw. In such a case the vessel will be as much disabled as if she broke the screw shaft or screw.

740. *Q.*—Will the unbroken engine, in the case of disarrangement of one of the two engines of a screw or paddle vessel, be able of itself to turn the centre ?

A.—It will sometimes happen, when there is much lead upon the slide valve, that the single engine, on being started, cannot be got to turn the centre if there be a strong opposing wind and sea; the piston going up to near the end of the stroke, and then coming down again without the crank being able to turn the centre. In such cases, it will be necessary to turn the vessel's head sufficiently from the wind to enable some sail to be set; and if once there is weigh got upon the vessel the engine will begin to work properly, and will continue to do so though the vessel be put head to wind as before.

741. *Q.*—What should be done if a crack shows itself in any of the shafts or cranks ?

A.—If the shafts or cranks crack, the engine may nevertheless be worked with moderate pressure to bring the vessel into port; but if the crack be very bad, it will be expedient to fit strong blocks of wood under the ends of the side levers, or other suitable part, to prevent the cylinder bottom or cover from being knocked out, should the damaged part give way. The same remark is applicable when flaws are discovered in any of the main parts of the engine, whether they be malleable or cast iron; but they must be carefully watched, so that the engines may be stopped if the crack is extending further. Should fracture occur, the first thing obviously to be done is to throw the engines out of gear; and should there be much weigh on the vessel, the steam should at once be thrown on the reverse side of the piston, so as to counteract the pressure of the paddle wheel.

742. *Q.*—Have you any information to offer relative to the lubrication of engine bearings ?

A.—A very useful species of oil cup is now employed in a number of steam vessels, and which, it is said, accomplishes a considerable saving of oil, at the same time that it more effectually lubricates the bearings. A ratchet wheel is fixed upon a little shaft which passes through the side of the oil cup, and is put into slow revolution by a pendulum attached to its outside, and in revolving it lifts up little buckets of oil and empties them down a funnel upon the centre of the bearing. Instead of buckets a few short pieces of wire are sometimes hung on the internal revolving wheel, the drops of oil which adhere on rising from the liquid being deposited upon a high part set upon the funnel, and which, in their revolution, the hanging wires touch. By this plan, however, the oil is not well supplied at slow speeds, as the drops fall before the wires are in proper position for feeding the journal. Another lubricator consists of a cock or plug inserted in the neck of the oil cup, and set in revolution by a pendulum and ratchet wheel, or any other means. There is a small cavity in one side of the plug, which is filled with oil when that side is uppermost, and delivers the oil through the bottom pipe when it comes opposite to it.

743. *Q.*—What are the prevailing causes of the heating of bearings?

A.—Bad fitting, deficient surface, and too tight screwing down. Sometimes the oil hole will choke, or the syphon wick for conducting the oil from the oil cup into the central pipe leading to the bearing will become clogged with mucilage from the oil. In some cases bearings heat from the existence of a cruciform groove on the top brass for the distribution of the oil, the effect of which is to leave the top of the bearings dry. In the case of revolving journals the plan for cutting a cruciform channel for the distribution of the oil does not do much damage; but in other cases, as in beam journals, for instance, it is most injurious, and the brasses cannot wear well wherever the plan is pursued. The right way is to make a horizontal groove along the brass where it meets the upper surface of the bearing, so that the oil may be all deposited on the highest point of the journal, leaving the force of gravity to send it downward. This channel should, of course, stop short a small distance from each flange of the brass, otherwise the oil would run out at the ends.

744. *Q.*—If a bearing heats, what is to be done?

A.—The first thing is to relax the screws, slow or stop the engine, and cool the bearing with water, and if it is very hot, then hot water may be first employed to cool it, and then cold. Oil with sulphur intermingled is then to be administered, and as the parts cool down, the screws may be again cautiously tightened, so as to take any jump off the engine from the bearing being too slack. The bearings of direct acting screw engines require constant watching, as, if there be any disposition to heat manifested by them, they will probably heat with great rapidity from the high velocity at which the engines work. Every bearing of a direct acting screw engine should have a cock of water laid on to it, which may be immediately opened wide should heating occur; and it is advisable to work the engine constantly, partly with water, and partly with oil applied to the bearings. The water and oil are mixed by the friction into a species of soap which both cools and lubricates, and less oil moreover is used than if water were not employed. It is proper to turn off the water some time before the engine is stopped, so as to prevent the rusting of the bearings.

MANAGEMENT OF LOCOMOTIVES.

745. *Q.*—What are the chief duties of the engine driver of a locomotive?

A.—His first duties are those which concern the safety of the train; his next those which concern the safety and right management of the engine and boiler. The engine driver's first solicitude should be relative to the observation and right interpretation of the signals; and it is only after these demands upon his attention have been satisfied, that he can look to the state of his engine.

746. *Q.*—As regards the engine and boiler, what should his main duties be?

A.—The engineer of a locomotive should constantly be upon the foot board of the engine, so that the regulator, the whistle, or the reversing handle may be used instantly, if necessary; he must see that the level of the water in the boiler is duly maintained, and that the steam is kept at a uniform pressure. In feeding the boilers with water, and the furnaces with fuel, a good deal of care and some tact are necessary, as irregularity in the production of steam will often occasion priming, even though the water be maintained at a uniform level; and an excess of water will of itself occasion priming, while a deficiency is a source of obvious danger. The engine is generally furnished with three gauge cocks, and water should always come out of the second gauge cock, and steam out of the top one when the engine is running: but when the engine is at rest, the water in the boiler is lower than when in motion, so that when the engine is at rest, the water will be high enough if it just reaches to the middle gauge cock. In all boilers which generate steam rapidly, the volume of the water is increased by the mingled steam, and in feeding with cold water the level at first falls; but it rises on opening the safety valve, which causes the steam in the water to swell to a larger volume. In locomotive boilers, the rise of the water level due to the rapid generation of steam is termed "false water." To economize fuel, the variable expansion gear, if the engine has one, should be adjusted to the load, and the blast pipe should be worked with the least possible contraction; and at stations the damper should be closed to prevent the dissipation of heat.

747. *Q.*—In starting from a station, what precautions should be observed with respect to the feed?

A.—In starting from a station, and also in ascending inclined planes, the feed water is generally shut off; and therefore before stopping or ascending inclined planes, the boiler should be well filled up with water. In descending inclined planes an extra supply of water may be introduced into the boiler, and the fire may be fed, as there is at such times a superfluity of steam. In descending inclined planes the regulator must be partially closed, and it should be entirely closed if the plane be very steep. The same precaution should be observed in the case of curves, or rough places on the line, and in passing over points or crossings.

748. *Q.*—In approaching a station, how should the supply of water and fuel be regulated?

A.—The boiler should be well filled with water on approaching a station, as there is then steam to spare, and additional water cannot be conveniently supplied when the engine is stationary. The furnace should be fed with small quantities of fuel at a time, and the feed should be turned off just before a fresh supply of fuel is introduced. The regulator may, at the same time, be partially closed; and if the blast pipe be a variable one, it will be expedient to open it widely while the fuel is being introduced, to check the rush of air in through the furnace door, and then to contract it very much so soon as the furnace door is closed, in order to recover the fire quickly. The proper thickness of coke upon the grate depends upon the intensity of the draught; but in heavily loaded engines it is usually kept up to the bottom of the fire door. Care, however, must be taken that the coke does not reach up to the bottom row of tubes so as to choke them up. The fuel is usually disposed on the grate like a vault; and if the fire box be a square one, it is heaped high in the corners, the better to maintain the combustion.

749. *Q.*—How can you tell whether the feed pumps are operating properly?

A.—To ascertain whether the pumps are acting well, the pet cock must be turned, and if any of the valves stick they will sometimes be induced to act again by working with the pet cock open, or alternately open and shut. Should the defect arise from a leakage of steam into the pump, which prevents the pump from drawing, the pet cock remedies the evil by permitting the steam to escape.

750. *Q.*—What precautions should be taken against priming in locomotives?

A.—Should priming occur from the water in the boiler being dirty, a portion of it may be blown out; and should there be much boiling down through the glass gauge tube, the stop cock may be partially closed. The water should be wholly blown out of locomotive boilers three times a week, and at those times two mud-hole doors at opposite corners of the boiler should be opened, and the boiler be washed internally by means of a hose. If the boiler be habitually fed with dirty water, the priming will be a constant source of trouble.

751. *Q.*—What measures should the locomotive engineer take, to check the velocity of the train, on approaching a station where he has to stop?

A.—On approaching a station the regulator should be gradually closed, and it should be completely shut about half a mile from the station if the train be a very heavy one: the train may then be brought to rest by means of the breaks. Too much reliance, however, must not be put upon the breaks, as they sometimes give way, and in frosty weather are nearly inoperative. In cases of urgency the steam may be thrown upon the reverse side of the piston, but it is desirable to obviate this necessity as far as possible. At terminal stations the steam should be shut off earlier than at roadside stations, as a collision will take place at terminal stations if the train overshoots the place where it ought to stop. There should always be a good supply of water when the engine stops, but the fire may be suffered gradually to burn low toward the conclusion of the journey.

752. *Q.*—What is the duty of an engine man on arriving at the end of his journey?

A.—So soon as the engine stops it should be wiped down, and be then carefully examined: the brasses should be tried, to see whether they are slack or have been heating; and, by the application of a gauge, it should be ascertained occasionally whether the wheels are square on their axles, and whether the axles have end play, which should be prevented. The stuffing boxes must be tightened, and the valve gear examined, and the eccentrics be occasionally looked at to see that they have not shifted on their axles, though this defect will be generally intimated by the irregular beating of the engines. The tubes should also be examined and cleaned out, and the ashes emptied out of the smoke box through the small ash door at the end. If the engine be a six-wheeled one, with the driving wheels in the middle, it will be liable to pitch and oscillate if too much weight be thrown upon the driving wheels; and where such faults are found to exist, the weight upon the drivings wheels should be diminished. The practice of blowing off the boiler by the steam, as is always done in marine boilers, should not be permitted as a general rule in locomotive boilers, when the tubes are of brass and the fire box of copper; but when the tubes and fire boxes are of iron, there will not be an equal risk of injury. Before starting on a journey, the engine man should take a summary glance beneath the engine—but before doing so he ought to assure himself that no other engine is coming up at the time. The regulator, when the engine is standing, should be closed and locked, and the eccentric rod be fixed out of gear, and the tender break screwed down; the cocks of the oil vessels should at the same time be shut, but should all be opened a short time before the train starts.

753. *Q.*—What should be done if a tube bursts in the boiler?

A.—When a tube bursts, a wooden or iron plug must be driven into each end of it, and if the water or steam be rushing out so fiercely that the exact position of the imperfection cannot be discovered, it will be advisable to diminish the pressure by increasing the supply of feed water. Should the leak be so great that the level of the water in the boiler cannot be maintained, it will be expedient to drop the bars and quench the fire, so as to preserve the tubes and fire box from injury.

754. *Q.*—If any of the working parts of a locomotive break or become deranged, what should be done?

A.—Should the piston rod or connecting rod break, or the cutters fall out or be clipped off—as sometimes happens to the piston cutter when the engine is suddenly reversed upon a heavy train—the parts should be disconnected, if the connection cannot be restored, so as to enable one engine to work; and of course the valve of the faulty engine must be kept closed. If one engine has not power enough to enable the train to proceed with the blast pipe full open, the engine may perhaps be able to take on a part of the carriages, or it may run on by itself to fetch assistance. The same course must be pursued if any of the valve gearing becomes deranged, and the defects cannot be rectified upon the spot.

755. *Q.*—What are the most usual causes of railway collisions?

A.—Probably fogs and inexactness in the time kept by the trains. Collisions have sometimes occurred from carriages having been blown from a siding on to the rails by a high wind; and the slippery state of the rails, or the fracture of a break, has sometimes occasioned collisions at terminal stations. Collision has also repeatedly taken place from one engine having overtaken another, from the failure of a tube in the first engine, or from some other slight disarrangement; and collision has also taken place from the switches having been accidentally so left as to direct the train into a siding, instead of continuing it on the main line. Every train now carries fog signals, which are detonating packets, which are fixed upon the rails in advance or in the rear of a train which, whether from getting off the rails or otherwise, is stopped upon the line, and which are exploded by the wheels of any approaching train.

756. *Q.*—What other duties of an engine-driver are there deserving attention?

A.—They are too various to be all enumerated here, and they also vary somewhat with the nature of the service. One rule, however, of universal application, is for the driver to look after matters himself, and not delegate to the stoker the duties which the person in charge of the engine should properly perform. Before leaving a station, the engine-driver should assure himself that he has the requisite supply of coke and water. Besides the firing tools and rakes for clearing the tubes, he should have with him in the tender a set of signal lamps and torches, for tunnels and for night, detonating signals, screw keys, a small tank of oil, a small cask of tallow, and a small box of waste, a coal hammer, a chipping hammer, some wooden and iron plugs for the tubes, and an iron tube holder for inserting them, one or two buckets, a screw jack, wooden and iron wedges, split wire for pins, spare cutters, some chisels and files, a pinch bar, oil cans and an oil syringe, a chain, some spare bolts, and some cord, spun yarn, and rope.