Building Your Own Toy Steam Engine

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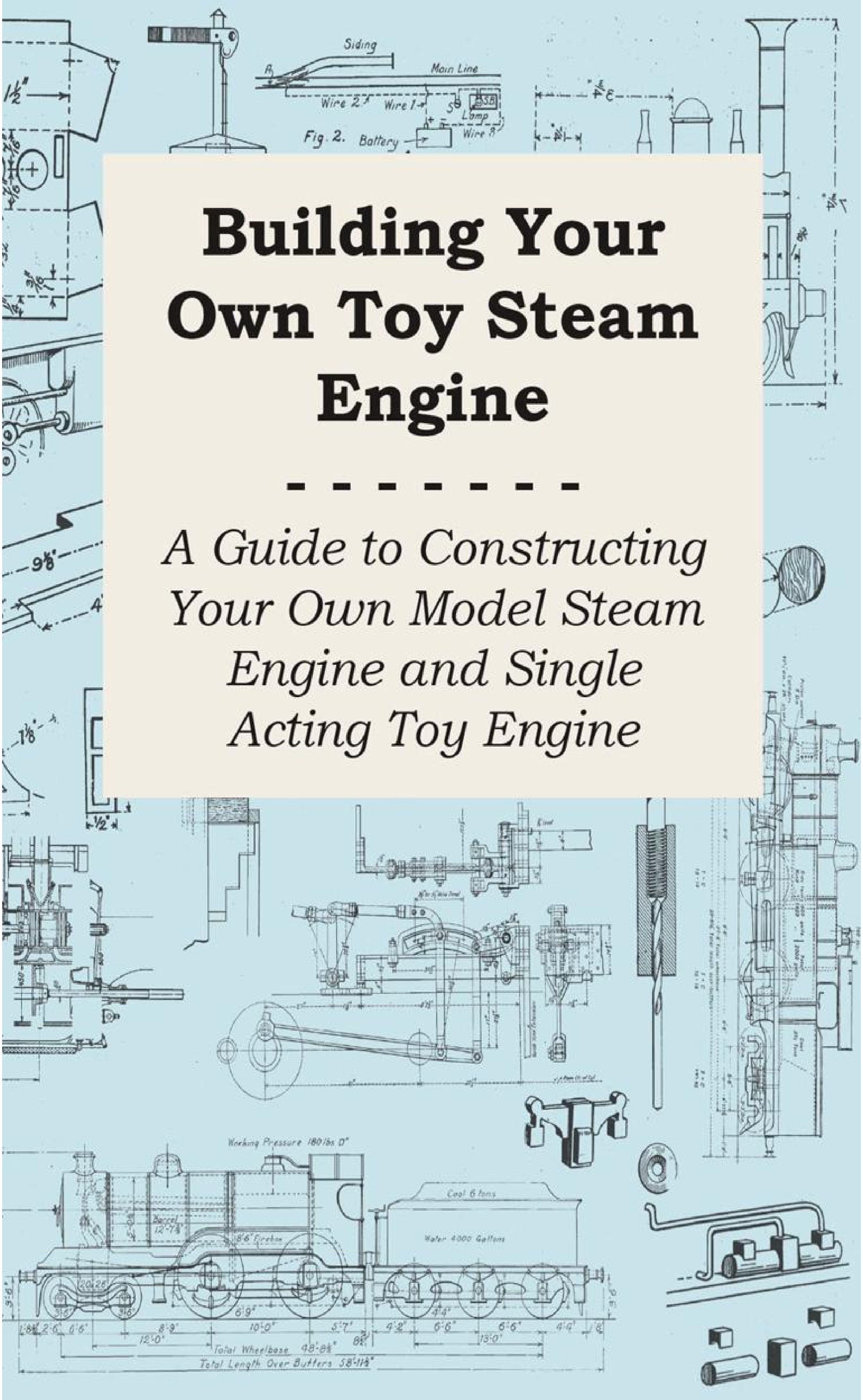
A Guide to Constructing Your Own Model Steam Engine and Single Acting Toy Engine



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Model Building

Model building as a hobby involves the creation of models either from kits, or from materials and components acquired by the builder. The most common form of modelling is the 'scale model', produced with varying degrees of accuracy, dependent on the interests and intentions of the creator. This is most generally a physical representation of an object, which maintains accurate relationships between all important aspects of the model, although absolute values of the original properties need not be preserved. Scale models are used in many fields including engineering, architecture, film making, military command, salesmanship and most widely, for fun with hobby model building. While each field may use a scale model for a different purpose, all scale models are based on the same principles and must meet the same general requirements to be functional.

Perhaps the most common form of model building is model cars, or toy cars. This category can often include other miniature motor vehicles, such as trucks, buses, or even ATVs as well. Because many miniature vehicles were originally aimed as children as playthings, there is no precise difference between a model car and a toy car, yet the word 'model' implies either assembly required or some attempt at accurate rendering of an actual vehicle at smaller scale. Regarding the former, the kit building hobby became popular through the 1950s, while the collecting of miniatures by adults started to pick up steam around 1970. Precision detailed miniatures made specifically for adults are a significant part of the market since perhaps the mid-1980s

Miniature models of automobiles first appeared about the time real automobiles did - first in Europe and then, shortly after, in the United States. These were initially duplicates made of lead and brass, and later in the twentieth century, made of slush cast plaster or iron. Tin and pressed steel cars, trucks, and military vehicles, like those made by Bing of Germany followed in the 1920s through the 1940s, but models rarely copied actual vehicles - it is unclear why, but likely had to do with the crudeness of early casting and metal shaping techniques which prevented precision rendering of an actual car's shape and detail. Casting vehicles in various alloys, usually zinc (called zamac or mazac), also started during these decades and came on stronger in the late 1930s, prominent particularly after World War II. Today, China, and other countries of Southeast Asia are the main producers of metal miniature vehicles from European, American, and Japanese companies. For the most part, only specialty models for collectors are still made in the Europe or the United States.

Another incredibly popular form of modelling is aircraft; be they models of existing or imaginary aeroplanes. Such models vary enormously in complexity, and can be flying or non-flying (static), and may or may not be an accurate scale model of a full-size design. Flying models range from simple toy gliders made of card stock or foam polystyrene to powered scale models made from materials such as balsa wood or fibreglass. Some can be very large, especially when used to research the flight properties of a proposed real design. The models intended for static display are usually made as highly accurate reproductions, requiring, in some cases hundreds, or even thousands of hours of work. Simpler models, for the amateur modeller are available in kit form however, typically made of injection-moulded polystyrene.

Most of the world's airlines allow their fleet aircraft to be modelled as a form of publicity, and in the early days of air travel, airlines would order large models of their aircraft and supply them to travel agencies as a promotional item. In a very similar way, the shipping industry was one of the first promoters of model ships; model building is a craft as old as shipbuilding itself, stretching back to ancient times when water transport was first developed. Some of the oldest surviving European ship models have been those of early craft such as galleys, galleons, and possibly carracks, dating from the twelfth through to the fifteenth centuries and found occasionally mounted in churches, where they were used in ceremonies to bless ships and those who sailed in them, or as votive offerings for successful voyages or surviving peril at sea, a practice which remained common in Catholic countries until the nineteenth century.

A consequence of Britain's naval supremacy in the eighteenth and nineteenth centuries was wide public interest in ships and ship models. Numerous fairly crude models were built as children's toys leading to the creation of functional, as opposed to decorative, ship models. Britain also led the world in model ship sailing clubs - in 1838 the *Serpentine Sailing Society* was started in Hyde Park, followed by the first *London Model Yacht Club* in 1845. By the 1880s there were three model sailing clubs sharing the Kensington Gardens Round Pond alone. Perhaps one of the most popular forms of model ships however, was (and is) the ‘ship in a bottle.' The simplest way of constructing this seemingly impossible feat is to rig the masts of the ship and raise it up when the ship is inside the bottle. Masts, spars, and sails are built separately and then attached to the hull of the ship with strings and hinges so the masts can lie flat against the deck. The ship is then placed inside the bottle and the masts are pulled up using the strings attached to the masts. Make sure the hull of the ship still fits through the opening though! Alternatively, with specialized long-handled tools, it is possible to build the ship inside the bottle.

Last but not least, in this brief tour of modern and historical modelling, railway models are an incredibly popular sub-genre; worthy of an entire introduction on their own. The scale models include locomotives, rolling stock, streetcars, tracks, signalling, roads, buildings, vehicles, model figures, lights, and features such as streams, hills and canyons. The earliest model railways were the 'carpet railways' in the 1840s. Electric trains appeared around the start of the twentieth century, but these were crude likenesses compared with the model trains of today. Now, modellers (hobbyists and professionals) create modern railway and road layouts, often recreating real locations and periods in history.

Involvement ranges from possession of a train set, to spending hours and large sums on an enormous and exacting model of a railroad and the scenery through which it passes, called a 'layout'. These range in size, with some large enough to ride. For many people who build railway models, the eventual goal is to eventually run the layout as if it were a real railroad (if the layout is based on the fancy of the builder) or as the real railroad did (if the layout is based on a prototype). If modellers choose to model a prototype, they may reproduce track-by-track reproductions of the real railroad in miniature, often using prototype track diagrams and historic maps. Probably the largest model landscape in the UK is in the Pendon Museum in Oxfordshire, UK, where a 1:76.2 scale model of the Vale of White Horse in the 1930s is under construction. The museum also houses one of the earliest scenic models - the Madder Valley layout built by John Ahern. The largest live steam layout, with 25 miles (40 km) of track is *Train Mountain* in Chiloquin, Oregon, U.S.

Contents

How to Make a Steam Engine

I now propose to assist the young mechanic in special work, instead of continuing general directions. This will enable me to explain to him various lathe appliances, and other details of mechanical work hitherto passed by.

Of all models which boys (and very big boys too) are desirous to construct, the steam-engine holds the chief place, and deservedly so; for every boy calling himself mechanical, ought to know how this made, and the general principles of its construction as well. However, I am aware, from experience, that many a youngster, who is even in possession of a model engine, is utterly ignorant of the cause of its motion; although it is a great delight to them to see the steam puffing out, and the wheel revolving "nineteen to the dozen," as schoolboys say. Now, an engine is a very simple affair, and can be easily explained; and, as I wish my readers to work rationally, I shall show them what they have to do before I tell them how to do it.

A, Fig. represents a cubical vessel of tin of any other substance. By cubical, I mean that all its side are squares, and all exactly equal; each side in the present case is to be 1 inch wide and long, or a square inch. B is a similar vessel, 1 foot cube. It contains, therefore, 1728 cubic inches, or is 1728 times as large in capacity as the first. Now, if I were to fill the little vessel with water and tip it into the second, and put a lamp under it, the water would all soon boil away, as it is called. It would be converted into steam; and the quantity of steam it would produce would exactly fill the larger vessel, without exciting any particular pressure upon its sides.

Steam, thus allowed plenty of elbow room, is like a lazy boy; it will play and curl about very prettily, but will do no work. We must put some sort of pressure, therefore, upon it—confine it, and we shall soon see that, by struggling to escape, it will serve our purpose, and become a most obedient workman. We have, therefore, only to put double the quantity of water into our larger vessel, that is, two cubic inches. We will put on a cover tightly, adding a pipe through which to pour in the water. Soon we shall have the steam formed as before; but it has no longer room enough, and out it comes fizzing and roaring, very savage at having been shut up in so small a cage. And we can make it work too, for if we set up a little fan-wheel of tin right in its way, we shall see it spin round merrily enough; or if we cork the tube lightly, we shall find this cork soon come out with a bang. We have, in fact, already constructed a steam-engine and a steam-gun on a small scale. The pressure in this case is, indeed, not great, but what it is I must now try to explain.

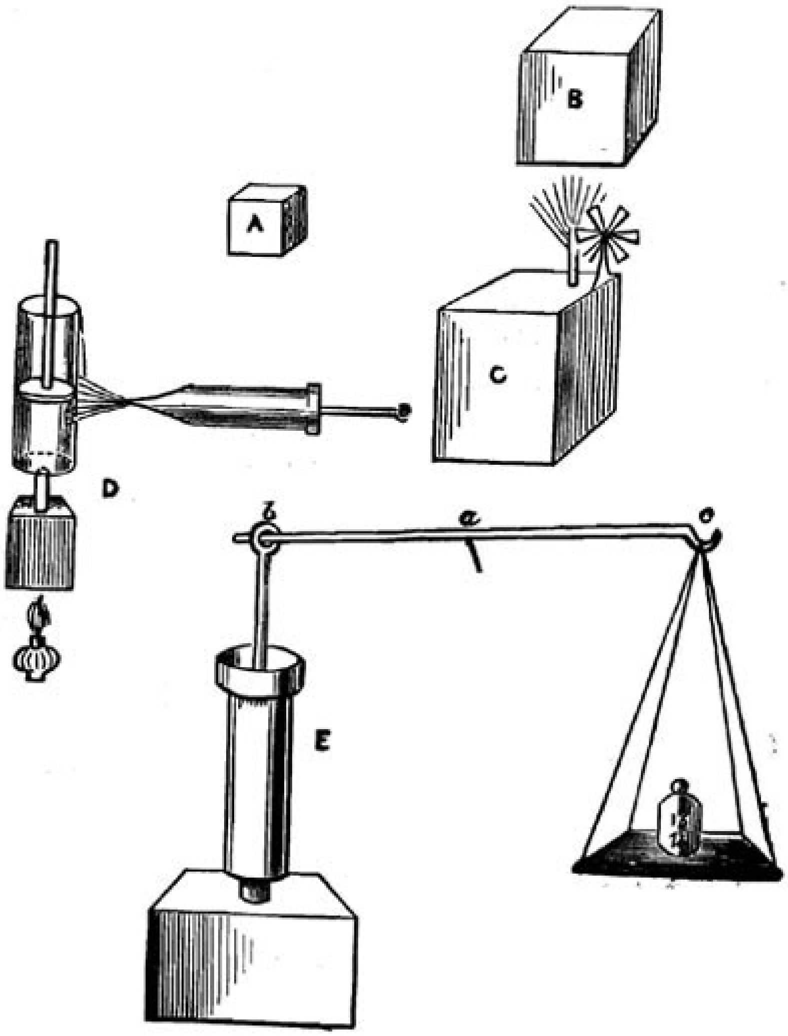


Fig 56.

The air or atmosphere, which surrounds us on all sides, exercises a pressure upon everything of 15 lbs. on every square inch of surface. If our little cubical inch box of tin had no air inside it, and no steam, but was absolutely empty, each side, and top, and bottom would have 15 lbs. pressure upon it; which would be evident if it were not very strong, for it would sink in on all sides directly, just as much as if you were to add a weight of 15 lbs. when it was full of air, as it would ordinarily be.

When I spoke of the larger box being exactly filled with steam from the evaporation of the cubic inch of water poured from the smaller box, I supposed it empty of air. The steam from that quantity of water, occupying the place of the air, would also be of the same pressure, 15 lbs. per square inch of surface; and as this only balances the pressure of the atmosphere, which would be, in such a case, pressing in on all sides, the steam would not show any pressure; just as, if you put equal weights into each scale of a balance, the beam of it would remain horizontal, neither scale showing to the outward senses that it had any pressure upon it. But in the second case, we have doubled the quantity of steam, but compelled it to occupy the same space; therefore we have now real, visible pressure of 15 lbs. upon each square inch; and if were again halve the space which the steam has to occupy, or double the quantity of water, we shall obtain a pressure of 30 lbs, beyond the pressure of the atmosphere.

Let us now disregard atmospheric pressure, and fit up such an apparatus as Fig. D. Here we have first our small box, closed on all sides, and from it a small tube rising and entering into the bottom of a larger one, which is very smooth in the inside; in this is a round plate or disc, called a piston, which fits the tube nicely, but not so tight as to prevent it from moving up and down easily; and let a weight of 15 lbs. be laid upon it. Let us suppose this large tube or cylinder to be 1700 times larger than the cubic inch box, into which water is to be poured till full. Now we heat it as before, and when 212 degrees of heat are attained by the water (which is its boiling-point) when it begins to be converted into steam, the piston will be seen to rise, and will gradually ascend, until quite at the top of the tube, because the steam required exactly that amount of room.

Now we have arrived at the same conclusion which we came to before; for you see that not only has the cubic inch of water become a cubic foot of steam (about 1700 to 1728 of its former volume), but it is supporting 15 lbs. weight, which represents that of the atmosphere, and if we could get rid of the latter, a solid weight of 15 lbs. would be thus supported. Now, still neglecting the atmospheric pressure, suppose instead of 15 lbs. we add another 15 lbs., making the weight 30 lbs., down goes our piston again, and stands at about half the height it did before. We have thus, as we had previously, a cubic foot of steam made to occupy half a cubic foot of space, giving a pressure (which is the same as supporting a weight) of 30 lbs.

I ought, perhaps, to add in this place, however, that under 30 lbs. pressure, or atmospheric weight and 15 lbs. additional, the water would not become steam at a temperature of 212 degrees, but it would have to made much hotter, until a thermometer placed in it would show 252 degrees.

So far we have seen what a cubic inch of water will do when heated to a certain degree, and at first sight it may not seem a great deal. Far from being light work, however, this is actually equal to the work of raising weight of 1 ton a foot high. Let us prove the fact. Suppose the tube or cylinder to be square instead of round, and that its surface is exactly 1 square inch, how can we give 1700 times the room which is occupied by the water? It is plain that the piston must rise 1700 inches in the 1-inch cylinder or tube, carrying with it, as before, its weight of 15 lbs.—that is, it has raised 15 lbs. 1700 inches, or about 142 feet. But this is the same as 15 times 142 feet raised 1 foot, which is 2130 lbs. raised 1 foot, very nearly a ton, the latter being 2240 lbs. So, after all, you see that our little cubic inch of water is a very good labourer (sic), doing a great deal of work if we supply him with sufficient warmth.

Now this is exactly the principle of the ordinary steam engine: we have a cylinder in which a piston is very nicely fitted, and we put this cylinder in connection with a boiler, the steam from which drives the piston from one end of the cylinder to the other. In the first engine that was made, the cylinder actually occupied the very position it does in our sketch; it was made to stand upon the top of the boiler, a tap being added in the short pipe below the cylinder, so that the steam could be admitted or shut off at pleasure. But it is plain that although or little engine has done some work, it has stopped at a certain point; there is the piston at the top, and it cannot go any farther; we must get it down again before it can repeat its labour.

How would you do this, boys? Push it down, eh? If you did, you would find it spring up again when you removed your hand, just as if there were underneath it a coiled steel spring; by which, however, you would learn practically what is meant by the elasticity of steam. Besides this, if you push it down, you become the workman, and the engine is only the passive recipient of your own labour. Try another plan; remove the lamp, and see the results—gradually, very gradually, the piston begins to descend.

Take a squirt or syringe, and squirt cold water against the apparatus. Presto! down it goes, now very quickly indeed, and is soon at the bottom of the cylinder. But we may as well try to get useful work done by the descent of the piston as well as by its ascent.

Set it up like Fig. E. Here is a rod or beam, b a c , the middle of which is supported like that of a pair of scales. From one end we hang a scale, and place in it 15 lbs., and as the piston sinks the weight is raised, and exactly the same work is done as before. Thus was the first engine constructed; but instead of the scale-pan and weight, a pump-rod was attached, and as the piston descended in the cylinder this rod was raised, and the water drawn from the well. This, however, was not called a steam engine, because the work is not really the effect of steam, which is only used to produce what is called a vacuum (i.e., and empty space, devoid of air) under the piston. In fact, the up-stroke of the piston was only partly caused by steam, and the rod of the pump was weighted, which helped to draw it up.

I must get you to understand this clearly, so that the principle may become plain——"clear as mud," as Paddy would say. I told you that the air pressed on every square inch of surface with a force of about 15 lbs. We do not feel it, because we are equally pressed on all sides—from within as well as from without—so that atmospheric pressure is balanced. Sometimes this is a very good thing. We should, I think, hardly like to carry about the huge weight pressing upon our shoulders, if something did not counteract it for us, so that we cannot feel it. Indeed, if it were otherwise, we should become flat as pancakes in no time—"totally chawed up."

But sometimes we should prefer to get rid of the air altogether —and I can tell you it is not easy to do so, unless we put something into its place; and we want perhaps simply to get rid of it, and make use of the room it occupied. We require to do this in the present instance, and in fact we have just done it. If the whole space below the piston, when we begin to work, is filled with water, it is plain there can be no air below it; and when the steam has raised it, there is still no air below it, but only steam. We then apply cold to the cylinder by removing the lamp and squirting cold water against it, which has the effect of reducing the steam to water again, which will occupy 1 inch of space only. We, therefore, now have a space of 1600 cubic inches with neither air nor water in it; and so, if the piston is 1 inch in size, there will be the 15 lb. pressure of the atmosphere upon it, and nothing below to balance it, for we have formed a vacuum below it, and of course this 15 lb. weight will press it rapidly down. It did so; and we therefore were enabled to raise 15 lb. in the scale-pan. You will know, therefore, henceforth, exactly what I mean by a vacuum and atmospheric pressure. It is, you see, the atter which does the work when a vacuum is formed as above; but you can easily understand that it might be possible to use both the atmospheric pressure and the pressure of steam as well, which is done in the condensing steam-engine.

In the earliest engine, called the Atmospheric for the reason above stated, the top of the cylinder was left entirely open, as in our sketch; but the condensing water was not applied outside the cylinder, but descended from a cistern above, and formed a little jet or fountain in the bottom of the cylinder at the very moment that the piston reached its highest point. Down it, therefore, came drawing up the pump-rod. When at the bottom the jet of water ceased. Steam was again formed below the piston, which raised it as before; and the process being repeated, the required work was done. A boy, to turn a couple taps, to let on or off the water or steam, was all the attendance required.

For some time the atmospheric engine, the invention of Newcomen, was the only one in general use; and even this was, in those days (1705-1720), so difficult to construct that its great power was comparatively seldom resorted to, even for pumping, for which it was nevertheless admirably suited. The huge cylinder required to be accurately bored, while there were no adequate means of doing such work; and although the piston was "packed," by being wound round with hemp, it was difficult to keep it sufficiently tight, yet at the same time to give it adequate "play." Then another drawback appeared, which, though of less importance in some districts, absolutely prevented the introduction of this engine into many parts of the country. The consumption of coal was enormous in proportion to the power gained. We can easily understand the reason of this, when we consider the means used for producing a vacuum in the cylinder below the piston. The water introduced for the purpose, chilled, not only the steam, but cylinder and piston also; and therefore, before a second stroke could be made, these had to be again heated to the temperature of boiling water. The coal required for the latter purpose was therefore wasted, causing a dead loss to the proprietor.

So matters continued for some time, until a mathematical instrument-maker of Glasgow, named Watt, about the year 1760, began to turn his attention to the subject; and having to repair a model of Newcomen's engine belonging to the University of Glasgow, the idea seems to have first struck him of condensing the steam in a separate vessel, so as to avoid cooling the cylinder after each upward stroke of the piston. This was the grand secret which gave the first impetus to the use of steam-engines; and from that day to this these mighty workmen, whose muscles and sinews never become weary, have been gradually attaining perfection. Yet it may be fairly stated that the most modern form of condensing engine in use is but an improvement upon Watt's in details of construction and accuracy of workmanship. For Watt did not stand still in his work; but after having devised a separate condenser, he further suggested the idea of closing the top of the cylinder, which had hitherto been left open to the influence of the atmosphere; and rejecting the latter as the means of giving motion to the piston, he made use of the expansive power of steam on each side of the piston alternately, while a vacuum was also alternately produced on either side of it by the condensation of the steam.

The atmospheric engine was thus wholly displaced. The saving of fuel in the working of the machine was so great, that the stipulation of the inventor, that one-third of the money so saved should be his, raised him from comparative poverty to affluence in a very short time. Watt, however, had still to contend with great difficulties in the actual construction of his engines. He was in the same "fix" as some of my young readers, who are very desirous to make some small model, but have little else than a pocket-knife and gimblet to do it with. For there were no large steam-lathes, slide-rests, planing and boring machines, procurable in those days, and even the heaviest work had to be done by hand, if indeed those can be called hand-tools which had frequently to be sat upon to keep them up to cut. It was therefore impossible for Watt to carry out his designs with anything like accuracy of workmanship, else it is probable that he would have advanced the steam-engine even further towards perfection that he did. In spite of these drawbacks, however, this great inventor lived to see his merits universally acknowledged, and to witness the actual working of very many of these wonderful and useful machines.

The first necessity which occurred from closing the cylinder at both ends was the devising some means to allow the piston-rod to pass and repass through one end without permitting the steam to escape. This was effected by a stuffing-box, which is represented in Fig. A, B,—the first being a sectional drawing, which you must learn to understand, as it is the only way to show the working details of any piece of machinery. We have here a cylinder cover, a, which bolts firmly to the top of the cylinder, there being a similar on (generally without any stuffing-box) at the other end or bottom of the same. On the top of this you will observe another piece, which is marked b, and which is indeed part of the first and cast in one piece with it. Through the cylinder cover, a, is bored a hole of the exact size of the rod attached to the piston, which has to pass through it, but which hole, however well made, would allow the steam to leak considerably during the working of the piston-rod.

To obviate this, the part b is bored out larger, and has a cup-shaped cavity formed in it, as you will see by inspecting the drawings. Into this cavity fits the gland, c, which also has a hole in it, to allow of the passage of the piston-rod. This gland is made to fit into the cavity in b as accurately as possible; and it can be held by bolts as in the fig. A, or be screwed on the surface as shown at B, in which latter case the greater part of the interior of b is screwed with a similar thread. The piston-rod being in place, hemp is wound round it (or india-rubber packing rings are fitted over it), and the gland is then fitted in upon it, and screwed down, thus squeezing the hemp or rubber tightly, and compelling it to embrace the piston-rod so closely, that leakage of steam, is wholly prevented. Whenever you have, therefore, to prevent steam or water escaping round a similar moving-rod in modelling pumps or engines, you will have to effect it in this way. The piston was also packed with hemp or tow, either loosely plaited or simply wound round the metal in a groove formed for the purpose. In Fig. C and D, I have added drawing of a piston, so made, partly for the purpose of again explaining the nature of sectional drawings. In this one, C, you are shown the end of the piston-rod passing through the piston, and fastened by a screwed nut below, a shoulder preventing the rod from being drawn through by the action of this nut. The hemp packing is also shown in section, but in the drawing D the groove is left for the sake of clearness.

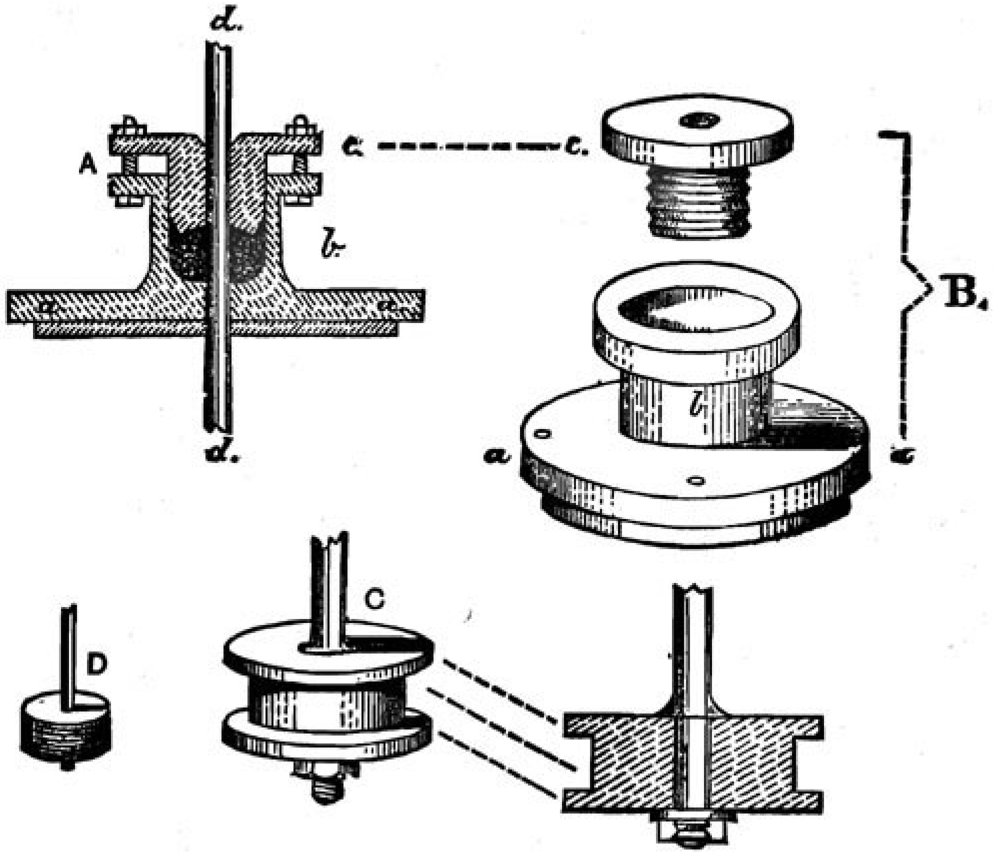


Fig. 57.

In all your smaller models you will have to pack your piston in this way, except in those where you entirely give up all idea of power. The little engines, for example, sold at $1 and upwards, with oscillating cylinders, have neither packed pistons nor stuffing-boxes; the friction of those would stop them, and escape of steam is of no great consequence. It will, however, be found advantageous to turn a few shallow groves round these unpacked pistons after they have been made to fit their cylinders as accurately as possible, like fig. C. These fill with water from the condensation of steam, which always occurs at first until the engine gets hot; and thus a kind of packing is made which is fairly effectual.

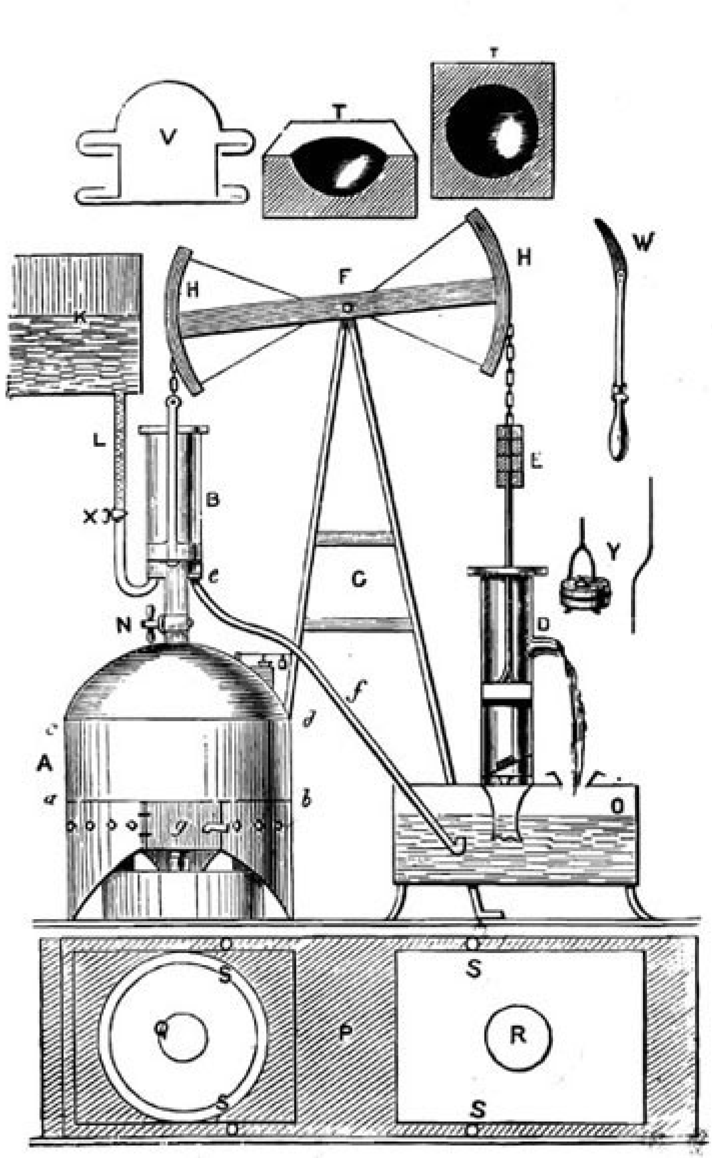
In Fig. 58 I have given a drawing of Newcomen's engine, in case you would like to make a model of one; but I do not think it will repay you as well for your labour as some others. There is the difficulty of the cistern of cold water and the waste-well; and the condensation of the steam is a troublesome affair in a small model, so that, on the whole, I should not recommend you to begin your attempts at model-making with the construction of one of these. I shall, however, add a few directions for this work, because what I have to say about boring, screwing, and so forth, will apply to all other models you may desire to construct.

The cylinder, in this case, will be more easily made by obtaining a piece of brass tubing, which can be had of any size, from 3 to 4 inches diameter to the size of a small quill. The first you will often use for boilers, the latter for steam or water pipes. You can also obtain at the model makers—Bateman, for instance, of High Holborn—small taps and screws, and cocks for the admission of water and steam, and all kinds of little requisites which you would find great difficulty in making, and which would cost you more in spoiling and muddling than you would spend in buying them ready made.

The drawing is given on purpose to show the best and easiest arrangement for a model. It had all parts, therefore, arranged with a view to simplicity. A is the boiler made of a piece of 3-inch brass tubing, as far as a, b, c, d, the bottom being either of brass or copper at the level of a, b; the upper domed part may be made by hammering a piece of sheet brass, copper, or even tin, with around ended boxwood mallet upon a hollowed boxwood block, of which T, T is a section. You should make one of these if it is you intention to make models your hobby, as it will enable you to do several jobs of the same kind as the present. Probably you will not be able to make the dome semi-circular, or rather hemispherical; but at all events, make it as deeply cupped as you can—after which, turn down the extreme edge one-sixteenth of an inch all round to fit the cupped part exactly. This requires a good deal of care and some skill. If you find that you cannot manage it, make your boiler with a flat top instead. Whichever way you make it, a very good joint to connect the parts is that shown in section at V. The edge of the lower part is turned outwards all round; that of the upper part is also turned outwards, first of all to double the width of the other, and is then bent over again, first with a pair of pliers and afterwards with a hammer, a block or support being placed underneath it. All this is done by the manufacturer with a stamping machine on purpose, and would be completed by the Birmingham brass-workers before I could write the description. It can, however, be done without any more tools than shown.

You will often need a tinman's boxwood mallet with one rounded end and one flat one, which, of course, you can now turn for yourself, as it is an easy bit of work. With the rounded end you can cup any round piece of tin; but it requires gentle work; do it gradually by hammering the centre more that the edges. I will show you presently how to do similar work by spinning in the lathe, which is a curious but tolerably easy method of making hollow articles of many kinds from round discs of metal without any seam.

After you have hammered the joint of the upper and middle parts together, you must solder them all round with tinman's solder. For this purpose you require a soldering-iron represented at W. This is a rod of iron, flattened and split at the end, holding between the forked part a piece of copper, which is secured to the iron by rivets. I should not recommend a heavy one, not so heavy nearly as what you may see at any blacksmith's or tinman's shop, because your work will be generally light, and such irons are all top heavy to use. The end, which may be curved over as shown, will require to be tinned, for without this it will not work at all well. File the end bright, and heat it in the fire nearly red hot. Get a common brick, and with an old knife or anything else, make a hollow place in it—a kind of long-cupped recess like a mussel shell, if you know what that is, and put a little rosin into it. Take your iron from the fire, and holding it down close to the brick, touch it with a strip of solder, which will melt and run into the cavity. Now rub the iron well in the solder and rosin, rub it pretty hard upon the brick, and presently you will see it covered with bright solder, from which wipe what remains in drops with a piece of tow. The iron is now fit for immediate use; but remember, the first time you heat it red-hot, you will burn off the tinning, and you must file it bright again, and repeat the process. So when you want to solder, heat the iron in a clean fire, until, when you hold it a foot from your nose, you find it pretty warm; and avoid red heat. You will now find that when the soldering-iron is hot, it will not only melt but pick up the drop of solder; and as you draw it slowly along joint (previously sprinkled with powdered rosin, or wetted with chloride of zinc, or with Baker's soldering fluid), the solder will gradually leave the iron, and attach itself to the work in a thinly-spread, even coat.



The secret of soldering is to have the iron well-heated and wiped clean with a bit of tow, and to apply it along the joint so slowly and steadily that the tin or other metal will become hot enough just to melt solder. Try to solder, for instance, a thick lump of brass; file it bright if at all tarnished—for this must invariably be done with all metals. You will be unable to do it at first, for the moment the solder touches it, it will be chilled, and rest in lumps, which you can knock off directly when cold. Now place the brass on the fire for a few seconds until hot, and try again; the solder will flow readily as the iron passes along it, for it is kept up to the melting-point until it has fairly adhered. This is why in heavy work a large iron is required; it retains heat longer, and imparts more of it to the metal to be soldered. But you will find it often better to use a light soldering-iron, and to place the brass-casting upon the bar of the grate for a short time. You may, indeed, often work without any soldering-iron as follows:—

Heat the pieces to be soldered (suppose them castings and not thin sheets of metal) until they will melt solder. Take a stick of the latter, and just dip it in one of the soldering solutions names, and rub it upon the work previously brightened. The solder will adhere to both such pieces. Now, while still hot, put them together and screw in a vice, or keep them pinched in any way for a few minutes, and you will find them perfectly secured. In making chucks for the lathe, and in forming many parts of your models, you will find it advantageous to work in this way; but, notwithstanding, you will often require a light soldering iron, and sometimes also a blowpipe, which I shall likewise teach you to use, as also how to make a neat little fire-place or furnace to stand on your bench by which to heat the iron.

I must now suppose that you have carefully soldered the dome to the middle of your boiler; and as the solder will be underneath, the joint will be concealed even if (as is likely) you should not have made a very neat piece of work. Before you put on the bottom of the boiler, you will have to make two holes in the top-one for the steam-pipe three-eights of an inch in diameter, the other for the safety-valve also three-eights-because this will require a plug of brass to be soldered in, which plug will have a hole drilled through it of a quarter of an inch diameter. These may be punched through from the inside, or drilled; they are easily made, but should be as round and even as possible.

Take a piece of three-eighths-inch tubing, with a stopcock soldered into the middle of it. I shall suppose you have bought this. It need not be over an inch in length altogether; and you must put it through the hole in the top of the boiler, and solder it round on the inside of the same. The nearer you can get the stop-cock to the bottom of the cylinder the better the engine will work, because the steam will have to rise through whatever water is left in this pipe from the jet used to cool the steam. You will see that it cannot run off by the pipe C into the pump well, like that which collects in the cylinder itself. In a real engine the steam-tap was a flat plate which slid to and fro sideways, level with the bottom of the cylinder; but this you would not make easily at present.

The plug for the safety-valve you must turn out of a little lump of brass. It must be about three-eighths of an inch long; and you must drill a quarter-inch hole through it, and countersink one end of the hole (that is, make it wider and conical by turning a rose-bit or larger drill round in it a few times), to make a nice seat, as it is called, for the valve itself, which need not be now attended to. Remember you can buy at Bateman's, or any model-maker's in London, beautiful safety-valves ready-made, as well as any part of a model engine that you cannot make yourself; and indeed it is so far a good plan at first that it saves you from becoming tired and disgusted with our work, owing to repeated failures. If you buy them, therefore, you must do so before you make the holes above alluded to, but in some respects it will be more to your advantage to try and make all the details for yourself. I cannot call it making an engine, if, like many, you buy all the parts and have little left to do but screw them, or solder them, together. Don't do this, or you will never become a modeller.

Your boiler from c to a is, in height, maybe 2 inches, the dome 1-1/2 or thereabout. This will slip inside the part that you see in the drawing, and which I here sketch again separately. A is the boiler lifted out of B, the outer case or stand, which you can make out of tin, and paint to imitate bricks. It is almost a pity to waste sheet-brass upon it, because it is not very important, its object being only to carry the boiler. It is like D before being folded round and fastened (not with solder, which would soon melt, but) by a double fold of the joint, similar to that which you made round the boiler itself, but turned over once more and hammered down. The holes are punched with any round or square punch with a flat end, and are intended to give more air to the lamp C, which should have three wicks, or two at the least, to keep up a good supply of steam. I have shown the flat piece of tin with three legs only, which is as well as if it were made with four; but you can please yourself in this matter.

The lamp I need hardly tell you how to make, for it is easier than the boiler, being merely a round tin box, in the top of which are soldered three little bits of brass tube for the wicks, and a fourth for the oil to be poured in-the latter being stopped with a cork.

You should remember that no soldered work, like the inside of the boiler, must come in contact with the heat of the lamp, unless it has water about it, because if the water should at any time entirely boil away, the boiler will leak and be spoiled. A little care in this respect will insure the preservation of a model engine for a long time; but boys generally destroy them quickly by careless treatment.

Let us now turn our attention to the cylinder. Cut off a piece of three-quarter-inch brass tube, 2-1/2 inches in length—you can do this with a three-square file—mount it in the lathe by making a chuck like Fig. E, of wood, the flange of which is just able to go tightly into one end of the tube. The other end will probably centre upon the conical point of the back poppit, over which it will go for only a certain distance. If your back centre will not answer on account of its small size, you must make a similar flange to go into the other end; but take care that when the back centre is placed against it, it runs truly. If the chuck is well made, it will do so. You can now with any pointed tool turn off the ends of the tube quite squarely to the side; but you should only waste one-quarter of an inch altogether, leaving it 2-1/4 inches long. When that is done, take it out of the lathe, and in place of it, mount a disc of brass rather more than one-eighth of an inch thick, or if you have none at hand, take an old half-penny or penny piece, which is of copper, and lay it upon the flat face of a wooden chuck, driving four nails round its edge to hold it, and with a point-tool cut out neatly the centre, of a size to fit inside your tube. You will scarcely, however, effect this perfectly without further turning; so take care to cut it too large; but before you cut it completely through, make the hole for the tube which you soldered into the top of the boiler, which is three-eighths diameter. This you can do beautifully in the lathe with a pointed tool, or with a drill, centred against the point of the back poppit, as I showed you before.

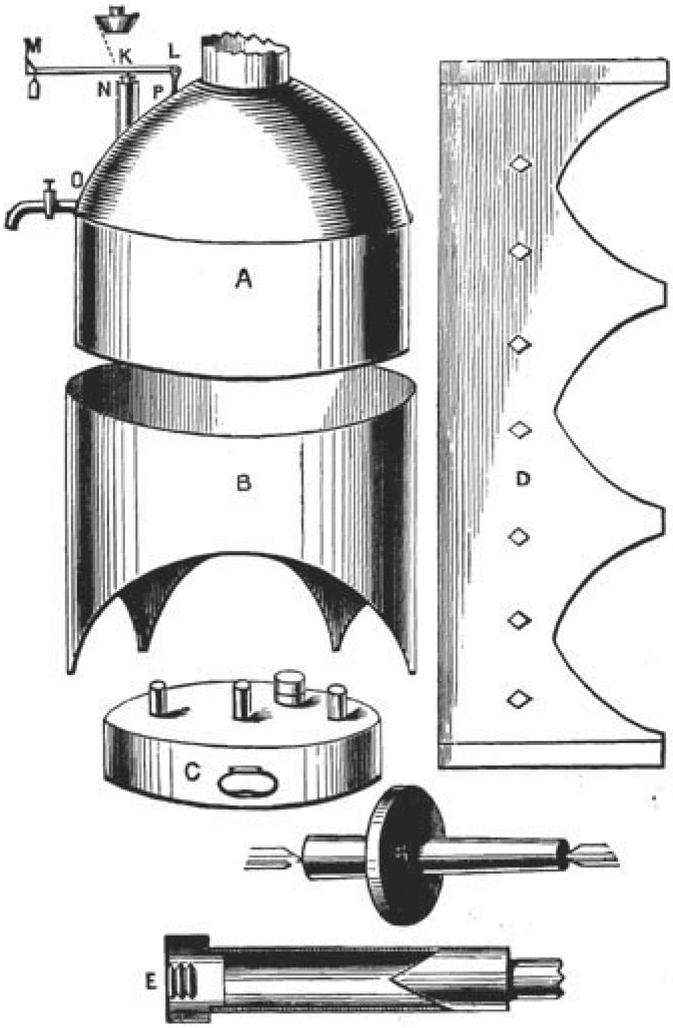


Fig. 59.

Cut the disc quite out (too large, mind) and then turn a spindle like G, mount the disc upon it as shown, by its central hole, and turn the edge with a graver of flat tool, such as is used for brass, until it will exactly fit the brass tube. You can cut out round discs of one-eighth or one-fourth sheet-brass by mounting any square pieces on a wooden face chuck, keeping it down by four nails or screws, and then with a point-tool cutting a circle in it until the disc falls out. You will often save time by so doing. You now have a disc of brass or copper with a hole three-eighths of an inch wide in it; and as the disc is three-fourths of an inch in diameter (i.e., six-eighths), you will have three-eighths of an inch remaining, or three-sixteenths, each way on the diameter between the edge of the hole and that of the disc. This will just give room for the two small holes required, on each side of the central one, for the pipes from the cold-water cistern and to the well below the pump. These must both be of brass; and the first should be turned up and end in a jet, like a blowpipe, so as to make the water rise in a spray under the piston; the other should be as long as can be conveniently arranged.

The bottom of the cold-water cistern is drawn a little above the top of the cylinder, which is 2-1/4 inches high. A jet would theoretically rise in the cylinder to nearly the height of the level of water in the cistern; but with a small pipe, and other drawbacks inseparable from a mode, you must not reckon on more than about half that height, which should be sufficient to condense the steam. The piston had better be nicely fitted, but not packed. You cut a disc of brass as before, drill the hole for the piston, make a spindle, which is the best plan, and then with a flat brass tool turn the piston accurately to fit the tube. Or, if you think it is easier, or wish to fasten the piston with a nut, as drawn, you can, if you like, turn it on a separate spindle; and thirdly, you may tap the hole in the piston, and screw the end of the piston-rod. The great thing to attend to is, to turn the edge of the piston square to the sides.

For the piston-rod, a steel knitting needle or piece of straight iron wire will do very well; but it will have to be flattened at the upper end, or screwed into a little piece of brass, which must be sawn across to make a fork by which the chain can be attached which goes over the beam. Do not solder the cistern pipes in just yet, but go on to other parts.

The cistern itself can be made out of any tin box. A scidlitz-powder box will answer well, or you can make one about that size, say 4 inches long, 2-1/2 wide, and 2 deep. The cistern for the pump will, of course, require to be the same size or a little larger; it may stand on legs or be fastened to the bed-plate direct.

This bed-plate is shown below the picture of the engine. It is merely an oblong plate of iron one-sixteenth inch thick, or in this particular engine may be of tin neatly fastened to a half-inch mahogany board, which will keep all firm. The white places show the position of the boiler and of the pump cistern, the inner rounds indicating the lamp, and pump, and cylinder. The square is merely made to show a boiler of that shape, which some prefer;—it is not so good as a cylindrical one.

Whenever you have to make an engine, you should draw upon the bed-plate the position of each part, as I have done here, because it will serve you as a guide for measurement of the several pieces. The four small circles at S S show the positions of the legs of the support C, which carries the beam. In the drawing only two are given, but there would be a similar triangular frame upon this side. This may be made very well of stout brass wire, but in a bought engine it would be a casting of brass, painted or filed bright.

The beam itself should be of mahogany, 6 inches long, half an inch wide (on the side), and a quarter of an inch thick. The curved pieces you will turn as a ring 3 inches diameter with a square groove cut in the edge for the chain. You can then saw into four, and use two of these, mortising the strip of mahogany neatly into them. Then finish with four brass wires, as shown, which will keep the curved ends stiff and give a finished appearance. The pin in the centre should be also of brass, as a few bright bars and studs of this metal upon the mahogany give a handsome look to the engine.

The pump will be of brass tube, made like the cylinder, but the bucket may be of boxwood, and so may the lower valve, each being merely a disc with a hole in it, and a leather flap to rise upwards. The bucket, however, should have a groove turned in its edge, to receive a ring of india-rubber, or a light packing of tow. The end of the pumprod must be split to make a fork like Y, to allow the valve to rise. You can get just such a fork ready to hand out of an umbrella, if you can find an old one; if not, and you cannot split the wire, make the rod rather stouter, and bend it, as shown, so as to form only one side of a fork, which will probably answer the same purpose in so light a pump.

The valve in both of these may be made of a flap of leather—bookbinder's calf, or something not too thick—and it may be fastened at one edge by any cement that will not be affected by water, or by a small pin, —cut off the head of a pin with half an inch of its shank, and point it up to form a small tack. If the valve-box is of boxwood, you must drill as hole;—you may make it, if preferred, of softer wood.

There is no support shown in drawing for the coldwater cistern; but you must stand it on four stout wires, or on a wooden (mahogany) frame, which can be attached to the bed-plate. As this last is always of some importance, I shall add it again in this place (Fig.60), to a scale of three-quarters of an inch to the foot, showing the position of each part.

Always begin with a centre line and take each measure from it, and draw another across for the same purpose, at right angles to the first. You will quickly see the use of this. We draw two lines as described A, B, C, D, crossing in o. The longest is the centre line of beam, cylinder, and pump. The beam is to be 6 inches long to the outside of the middle of each arc, whence the chain is to hang. We, therefore, from the centre point, set off 3 inches each way. At the exact 3 inches will be the centres of the cylinder and pump;—set these off, therefore, on the plan. The end of the tank we must have near the cylinder, because we have to bring a pipe from it into the bottom of the cylinder. Set off, therefore, the end of the tank 2-1/2 inches—i.e, 1-1/4 on each side of the central line, and draw it 4 inches in length. N shows the position of the pipe close to the end and on the line. The centre of the boiler is the same as that of the cylinder, so we draw a circle round it with aradius of 1-1/2 inches, which gives us the 3-inch circles of the boiler. Then we may set off equal distances, N, N, for the extremities of the legs of the frame which is to support the bean, and we complete our plan. M is the waste pipe, and K is the opening for the water to flow into the tank. We now find, therefore, that the bed-plate must be 13 inches long and 6 inches wide to take the engine of the proposed size, and we may, of course, extend this a little, if thought desirable. Mark off on the bed all the lines of the plan as here given, and always start any measurement from one of the two foundation lines, or else, if you make one false measure, you will carry it on, probably increasing the amount of error at every fresh measurement. Let this be with you a rule without exception. It is plain that if you work all parts of your engine to size, you can set it up on the marked bed-plate with perfect accuracy.

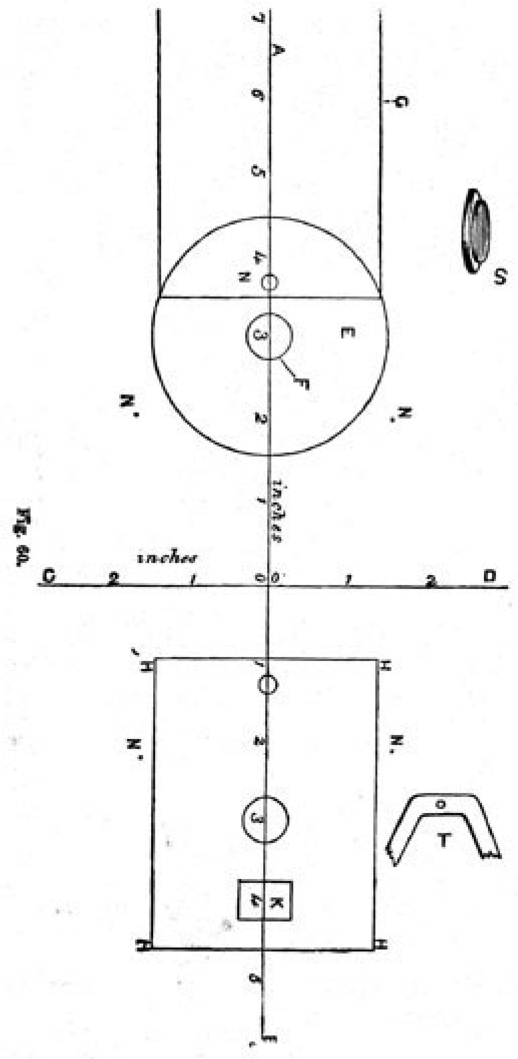


Fig. 60.

The description I have given will not only enable you to make a Newcomen engine with very little difficulty, but will give you an insight generally into this kind of work; and you will learn, too, a practical lesson in soldering, turning, and fitting. I must, nevertheless, help you a little in putting your work together.

You had better begin by soldering into the bottom of the cylinder the end of the steam-pipe, which you have already fixed upright in the middle of the dome of the boiler, taking care that it stands squarely across the pipe, or your cylinder will not be upright. Then place the boiler in position, and you may fix it by turning out slightly the ends of the legs, and putting a tack through, or screwing, if the bed-plate is of iron,—or with the help of Baker's fluid you can solder; but this is hardly safe work, and you had better have a wooden plate, covered with tin, and tack down the legs. I have drawn you a circular lamp, and given three and four legs to the boiler-stand; but take care that you so arrange size of lamp and openings of the stand as to enable you to withdraw the former for trimming and filling. Now fit in the two small pipes, previously bent as required. To bend them, if hard soldered or brazed, fill with melted lead, and then bend; after which melt out the lead again. If soft soldered, you must fill with a more fusible metal. There is a composition called "fusible metal," very convenient for this work, and well worth making, because you will often need to bend small pipes into various forms. Melt zinc, 1 oz.; bismuth and lead, of each the same quantitiy—this will melt in hot water; 8 parts bismuth, 5 lead, and 3 tin, will melt in boiling water. You can buy these at any operative chemist's, either mixed, ready for use, or separately. Rosin and sand are also used for bending tin pipes, the sole object being so to fill them that they will become like a solid strip of metal, and thus bend slowly and equally, with rounded and not sharp angles.

Pass the two pipes through from beneath the bottom of the cylinder, and soder them on the upper side of it, so that when the cylinder itself is added those two joints will not be visible.

Then set up the cold-water cistern; block it up with anything you like so as to keep in position, and, inserting the pipe from below, solder this also from above, i.e., on the inside of the cistern. Now, arrange the frame that is to support it, either stout wire or wood, and set it up so as finally to sucure it in its place. Now, you had better set up the pump cistern, so as to sucure the other small pipe in position, and prevent it from becoming displaced by any accidental blow. Fix this cistern therefore also, but leave the cover off for the present, that you may be able to solder the small pipe inside it.

You will now, at all events, have secured the position of the most important parts, and you may drop the cylinder into place, and solder this also round the bottom. This would be facilitated by turning a slight rebate, Fig. S, round the disc which forms the bottom of the cylinder, so that the smaller part of it will just fit inside it; but you will be able to manage it without. Let the cylinder project a very little beyond the bottom, just to allow a kind of corner for the solder to run in; it will not show when all is fixed. Do this as quickly as you can, so as not to melt off the soder round the small pipes. Now, make the pair of A-shaped supports for the beam. Measure the height of your cylinder top, above the bed-plate, and allow about another inch, and you will get the perpendicular height to the axis of the beam. Allow 3 inches more for each side, that is, in all for each side, 3 inches longer than if it was to be perpendicular instead of spreading. Take enough brass wire, about as thick as a small quill, to make two such legs. Bend it in the middle, like T, Fig. and flatten the bent part by hammering, so as to allow you to drill a hole to take the pivot on which the beam is to oscillate. If you like to flatten all of it, and then touch it up with a file, so as to get quite straight edges, it will look much more handsome. Make two such pieces exactly alike, and, at distances alike in each, put cross-bars. File a little way into each, making square, flat notches, which will just take two flattened bars of the same wire; heat them, and solder very neatly, so that no solder appears on the outside; file all flat and true. In this way you can make almost as neat supports as if they were of cast brass, and you are saved all the trouble of making patterns. By and by, nevertheless, you must do better.

As I have directed you in this instance to put a wooden bed-plate to your engine, you may point the ends of the wires, and, making holes sloping at the smae angle in the wooden stand, drive the wires into them. You have an advantage here, inasmuch as you can raise or lower your stand until the position of the beam comes exactly right, and you find the ends drop over the centre of the cylinder and pump-barrel as it ought to do. When this is the case, you can cut off any wire that projects below the stand and file it level, for it will not be likely to need more secure fixing. The pump may now be soldered into the cover of the cistern (before the cover itself is fastened on), and a hole must be then cut to receive the water that will flow from this spout, and then the cover can be fitted on. There is no need to solder it, if it is made to fit overtightly; and you may wish, perhaps, to get at the lower valve of the pump now and then.

The only thing left to do is to arrange the safety-valve of the boiler, which is in many cases the place through which the water is poured to charge it. In this engine it is, however, plain that you can fill the boiler by turning both the taps at the same time. A little will run off by the waste-pipe, but not enough to signify, because the tube below the cylinder is so much the larger of the two. The safety-valve is a little bit of brass turned conical to fit the "seat," made by counter-sinking the hole. It is shown at K, N being the seat, O P the dome of the boiler, and close to O is the guage-tap for ascertaining the height of water in the boiler. L M is a lever of flattened wire, pivoted to turn on a pin at L,—L O being an upright wire soldered to the boiler. A notch is filed across the top of the valve, on which the lever, L M, rests. The weight is at M. One, as large as a big pea, hung at the end of a lever 2 inches long, the valve at half an inch from the other end, will probably suffice for this engine.

Watt's Engine

I have already told you that Watt suggested the use of steam alternately on each side of the piston; and carried it out by closing the top of the cylinder, and allowing the rod of the piston to pass through a stuffing-box or gland. I now have to explain to you how this alternate admission of the steam may be effected.

You evidently require first an opening at the top and bottom of the cylinder, communicating with the boiler, one only being open at a time; but in this case, where is the steam to escape that was on one side of the piston when the opposite side was being acted upon? It must go somewhere, but evidently must not return to the boiler. Hence, some method has to be contrived by which, when one end of the cylinder is open to the boiler, the other may be open to the air or to the condenser (in which the steam is cooled under Watt's plan). Fig. 61 will, I think, render clear one or two of these arrangements.

The first is the four-way cock, a very simple contrivance, easily and frequently used in models. You must first understand how a common water or beer tap is made. Fig. A, represents one in section, turned so as to open the passage along the pipe to which it is attached; C is the pipe in which is the tap, a conical tube of brass set upright, and with a hole right and left made through it, fixed into a short horizontal tube (generally cast with it in one piece). Into this fits very exactly the conical plug B, also with a hole through it sideways. When this is put into place, no water or other liquid can pass, unless the hole in the plug is in the same direction with the hollow tube forming an open passage. If a key is put on the square part of the plug, and it is turned half round, the passage through the pipe will be closed. A steam tap would be made in a similar manner, if its only office were to open and close a passage in a tube. But we now want two passages closed and two opened, and then the alternate pair closed and two opened. This is cleverly effected by a fourway cock.

At D is shown a section of the steam cylinder and piston, with the staffing-box and all complete. A pipe enters this at the top and bottom, and another crosses it in the middle, making four passages. Shaded black is the four-way cock, the white places showing the open channels through the plug. When this plug stands as at D, steam can pass from the boiler to the top of the cylinder only, above the piston, which it drives downward; the steam below the piston escapes through the other open-curved channel into the air, or to the condenser. Just as the piston reaches the bottom of the cylinder, the tap is turned, and the passage stands as seen at E. Steam now passes to the bottom below the piston, driving it upward, and the steam above it, which has done its work, passes outward through the other open channel of the tap.

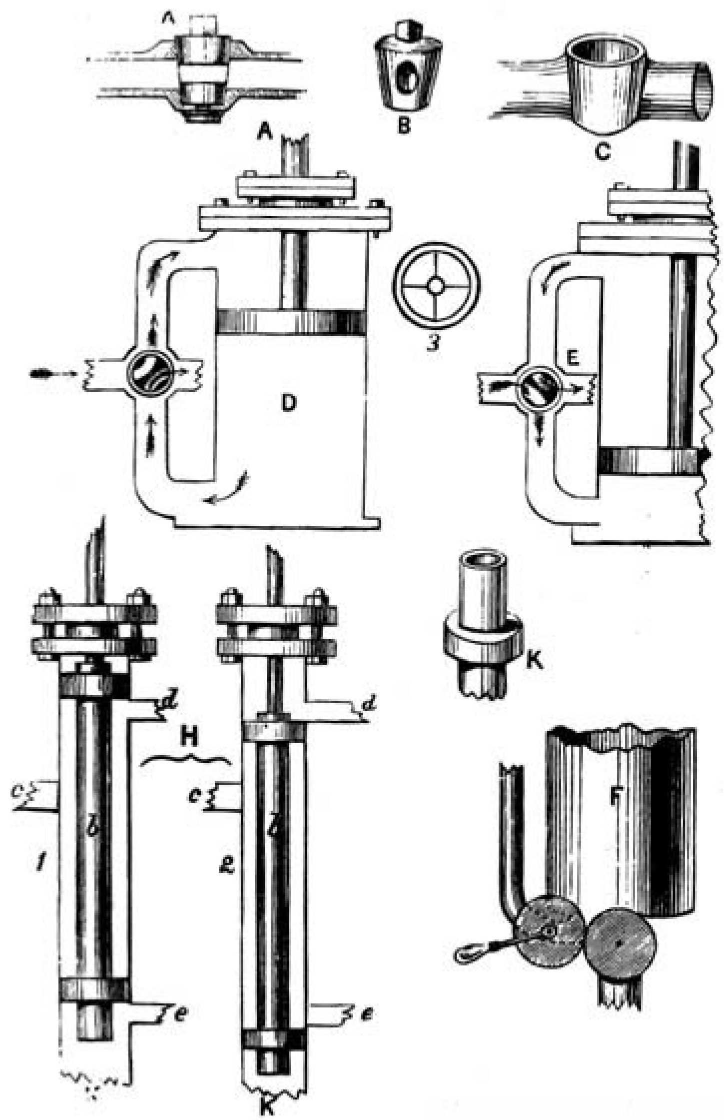


Fig 61

You must understand that when Newcomen first set up his engine, a man had to turn the taps at the proper moments; and it is said that one Humphrey Potter, a boy, being left in charge, and getting tired of this work, first devised a means to make the engine itself do this, by connecting strings tied to the handles of the taps to the beam that moved up and down above his head. Beighton and other improved on this, and very soon it became unnecessary for the attendant to do anything but keep up a good fire, and attend to the quantity of water in the boiler, and the pressure of the steam.

In the model I gave you of Newcomen's engine, I purposely left the taps to be moved by hand; but F of the present figure shows how, by bringing them near together, and adding cogged wheels or pulleys, you would make one handle answer for both; and I shall leave you to devise and easy method of making the engine work this one handle for itself. When Watt made his first engine, therefore, this work had been already done, and he only had to improve upon it, and to make it work accurately to suit the engine designed by himself.

If you should chance to pay a visit to the Museum at South Kensington, you may see, I believe, Watt's original engine, if not Newcomen's. The cylinders are so large and cubrous, that the wonder is they were ever bored by the inefficient means then in use; and the beam is a most unwieldy mass of timber and iron, that looks as if no power of steam could ever have made it oscillate. Yet it was in its day a successful engine, the wonder of the age; and did good work for its inventor and purchaser. I strongly advise my readers to try and visit Kensington, for there are many interesting models there, besides engines and appliances of older days. They will thus learn what rapid progress has been made since the days of Savery, Newcomen, and Watt; not only in the improvement of the arrangement of the parts, but in the workmanship, which last is mainly due to the invention of the side-rest and planing-machine.

We must now return to the double-acting or real steam engine, and consider a second means whereby the steam can be alternately admitted and exhausted.

The four-way cock, already explained, was found to wear very considerably in practice, and hence work loose, and a new contrivance, called the slide-valve, soon took its place. Of this there are two patterns, the long D-valve and the short one, which latter is used for locomotives. There is also a form called a tappet-valve, often used for large stationary engines, but which is noisy and subject to rapid wear. I shall describe the long D first, in the form in which it would be most easily made for a model engine.

The two ports by which steam passes to the cylinder are shown at d, e, of H, Fig. C is the passage to the boiler, K is that to the condenser. These are openings in a tube smoothly bored within, and having at the top a stuffing-box like that on the cylinder. Within this tube works an inner one, b, having rings or projections at the ends fitting perfectly, and which are packed with india-rubber, hemp (or, in modern days, with metal), to make a close fit. In a model, two bosses of brass, K, soldered on the tube and then turned, make the best packing. These packed portions of the inner tube form the stoppers to the steam ports, ee, alternately, at the top and bottom. The upper part of the inner tube has a cross arm, 3, affixed, from the centre of which rises the valve-rod by which it is moved up and down. In the position 1, the steam can pass from c round the tube to d, and thence to the top of the cylinder to which d is attached. The exhaust steam passes from e below the piston by k to the condenser. In the second position, 2, the steam is evidently shut off from d, but can passout at ee below the cylinder, while the communication is still open to the condenser from d, through the middle of the tube to K. This is a very good form of valve, because the exhaust is always open, and the motion is smooth and equal.

There are many modifications of the long D-valve, but the principle of all is the same; I shall therefore describe the short slide-valve which is nearly always used in the models which are purchased at the shops. This, too, is the usual form of valve in locomotives, traction-engines, and the majority of those in use for agricultural and similar purposes. A, Fig. is the cylinder as before in section with piston. A thick piece is cast with the cylinder, on one side of it, having steam ports also cast in it, which are here left white. The two as before go to the top and bottom of the cylinder, and have no communication with the central one, which is bored straight into the boss, and generally is turned at right angles and connected with the condenser, or with a pipe opening into the chimney of the engine to increase the draught by means of the jets of steam, as is the case always in locomotives, or into the air, which is less usual. Seen from behind, these ports are like B, being cast and cut rectangular; and the face, B, is planed quite level, which is absolutely necessary to the proper action of the slide-valve which has to work upon it. This valve is a box of iron, C, with a wide flange or rim, this flange being of sufficient width to close either port. If this valve is placed as it stands when the engine is at rest, b covers the upper steam port, and a the lower; while the exhaust or middle port is open to the hollow part of the box. Now, if we slide the valve downwards until the upper port is open, the other two will be in communication, being united by being both together in the inside of this box or valve. Suppose the valve then cased in, and that steam is admitted from the boiler into the case, it is evident that such steam could freely pass to the top of the cylinder above the piston to force it downwards, while that which was below would escape by the lower port into the box, and thence pass to the condenser. If, instead of pushing down the valve, we had drawn it upwards, the lower port would have been brought into communication inside the valve, and the contrary effect would have been produced upon the piston.

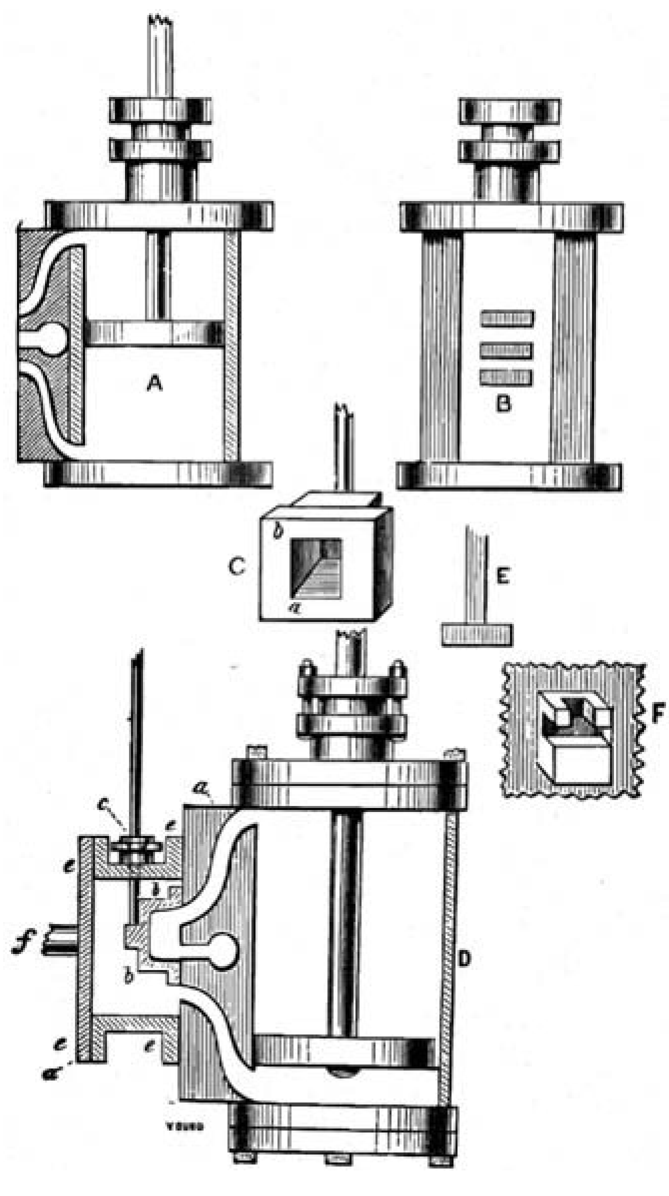


Fig 62.

This is the arrangement adopted, and which will be clearly understood from the following sectional drawing, D. a,a, is the thick casting upon the cylinder, with the upper and lower steam ports, which end towards the middle of the cylinder, with the third port lying between; then b is a section of the valve, in such a position that the flange of it no longer covers the lower steam port, while the other two are open together on the inside of the valve. The latter is cased in by the valve-box, ee, in the back of which is the steam pipe f coming from the boiler. The valve-rod, which is moved by the engine, passes at c through a stuffing-box. It is evidently necessary that this slide-valve should fit, and work very smoothly and correctly against the face of the ports, so as not to allow any escape of the steam. It is not, however, packed in any way at the back (although springs have been sometimes added), because, as the back is subjected to the full pressure of the steam from the boiler, this keeps it quite close to its seat. The rod, however, by which it is worked, might prevent this close contact of the two surfaces if it was screwed into the valve; it is therefore made with a cross, e, at the end, which falls into a notch in a boss cast upon the back of the valve as seen at F. This allows a certain degree of play in one direction, and permits the steam to press it close even after it has become worn by use.

You will, I think, now clearly understand how steam can be admitted alternately to the top and bottom of a cylinder, and how the exhausted steam that has done its work escapes. I must therefore now tell you how the rod of the slide-valve is moved up and down by the engine, but to do this, I must draw such engine complete.

The cylinder, A, is screwed down on its side upon the bed-plate, RR, out of which are cut two holes, one for the fly-wheel, P, of which part only appears for want of space, the other for the crank, L, on the end of the axle, MM, running through bearings, NN. The slide-valve-box is at B, C, being the steam-pipe from the boiler. The piston-rod has necessarily to move only in a straight line in the direction of its length, but the crank which it has to work to turn the fly-wheel must needs move round in a circle. Hence, a poker-and-tongs joint, F O F, is arranged. The connecting-rod, H, which is attached to the crank by brasses at K, divided or is attached to a forked piece, at the lower end of which are a pair of bearings or brasses, FF. The piston-rod carries the piece O, the cross-bar of which is turned, being, in fact, the pin which passes into these bearings at FF. This forms, therefore, a hinge-joint at this place, so that although the piston-rod cannot leave the right line, and can only slide in the guide, E, the rod, H, has an up-and-down motion upon this hinge, allowing the revolution of the crank-pin to take place. D is the valve-rod, in which is a hinge at S, which suffices for the slight movement required in the rod, as it rises and fills by the action of the eccentric, T, the motion and effect of which I now have to explain.

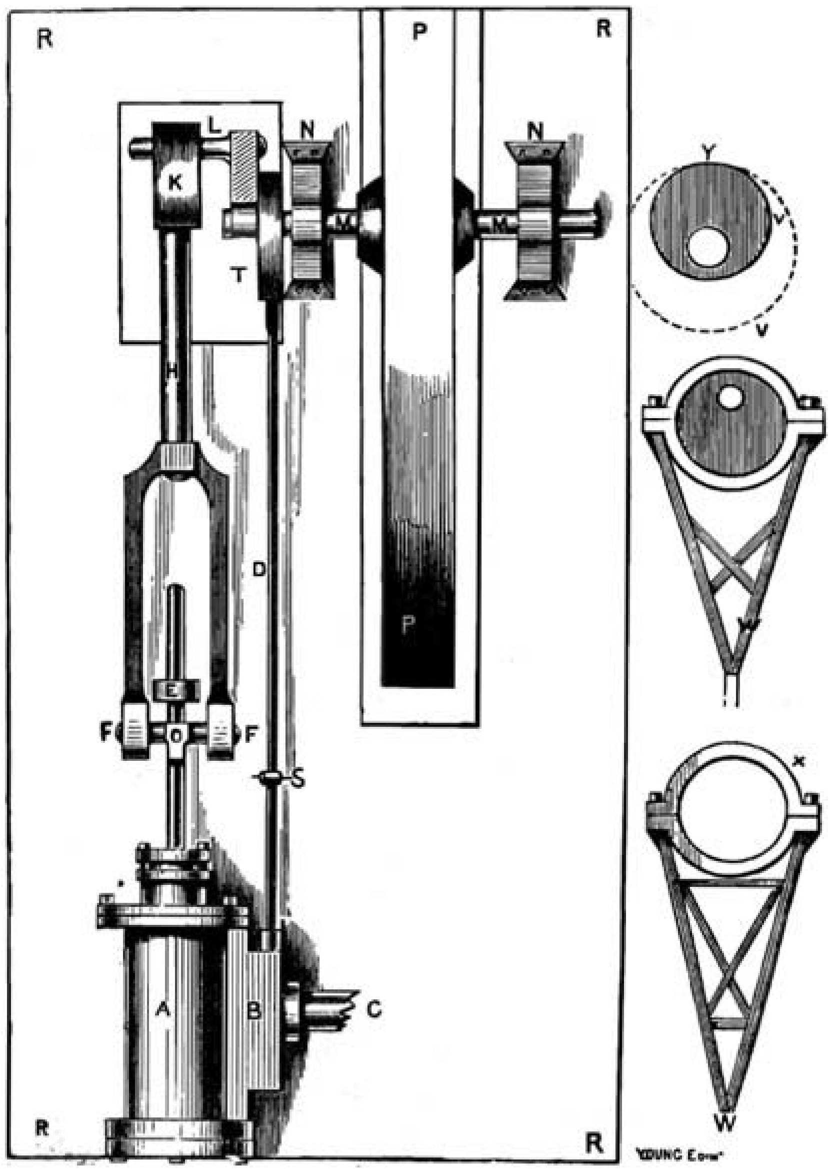


Fig. 63.

V is a round disc of metal with a recess on its edge, so that it is like and ordinary pulley, but large in proportion to its thickness. A hole for the main crank axle, to which it has to be firmly keyed, is made through it, but not in its centre (hence its name, eccentric—out of the centre). As the axle revolves, it is evident that this disc revolving with it will carry any point, Y, of its surface round in a circle; the centre of which is on the central line or axis of the crank-shaft. I have drawn such circle as described by the point Y, farthest from the axis; but any and all points describe larger or lesser circles round the same centre. The point Y may, therefore, be considered as the centre of a crank-pin; and the eccentric might, so far as its effects are concerned, be replaced by a crank. Now, if you turn the fly-wheel of your lathe by hand, the crank will revolve, but the treadle will rise and fall only in a straight line; and you will presently see how the eccentric, in its revolution, gives just such a to-and-fro motion to the rod D, and consequently also to the slide-valve, which it has to move.

Round the disc V, closely encircling it, is a flat ring, shown separately at X, with a rod, W, attached to and part of it. This ring is generally made in separate halves, united by bolts passing through projecting lungs or ears. The ring also fits into the groove turned on the edge of the disc V, so that it cannot slip off sideways. This outer ring is turned quite smooth and true on the inside, so that the eccentric disc can revolve within it. In doing so, it is plain that the whole ring will rise and fall, and that the rod W will move up and down, or to and fro, like the treadle of the lathe, thereby giving motion to the valve-rod, which is a continuation of the rod W. As the upper end, however, of this rod has an oscillating, or up-and-down motion, this is imparted, in a certain degree, to its other end, at the farthest distance from the eccentric; and hence the necessity for a hinged joint as S, to prevent the valve-rod from partaking of this movement. It is, however, very slight, so that the rod of the valve is not often made to pass through guides like the piston. The whole movement of the valve-rod is very limited, its traverse only being required to be sufficient to shift the valve the width of one of its ports at each stroke. The length of stroke or traverse which can be obtained by the eccentric is always equal to twice the distance between its real centre, and that on which it turns, which will always be a guide to you in making an engine.

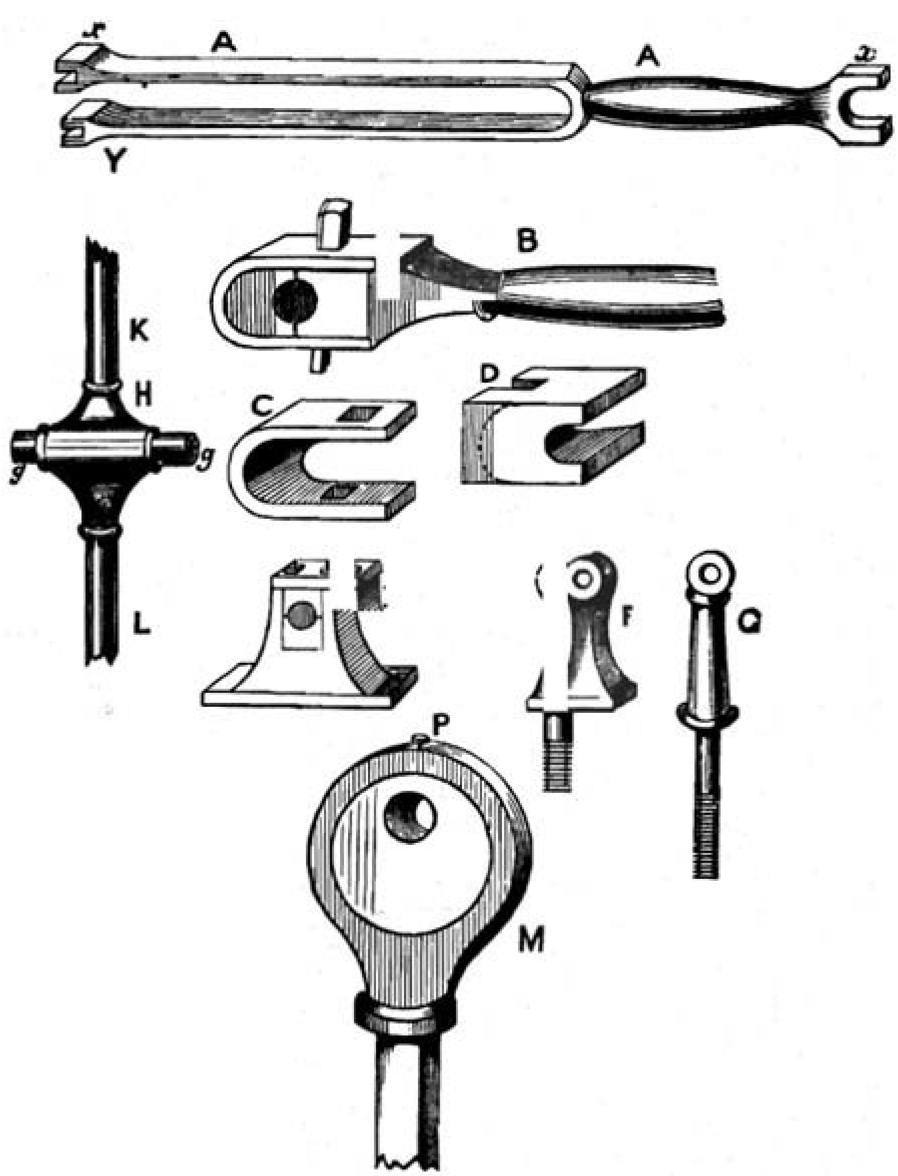


Fig. 64.

The drawing here described is a plan, i.e., a drawing viewed directly from above; therefore I cannot show you the perspective view of the parts, which are, indeed, in many cases only suggested by the shading. I have, therefore, added a second drawing of the several details. This engine is, in construction, the simplest that can be devised with a slide-valve, there being no additions beyond what are absolutely necessary to make it work; the exhaust-port is below, opposite to the letter B on the valve-box. A, Fig. is the forked connecting-rod, marked H in the previous drawing. This is cast with forked ends, x, and x Y (the latter being F F of Fig. These ends receive brasses in the following way, the end x being represented on a larger scale at B, with such brasses in place; of these there are two shaped like D. One of these lies in the fork of the connecting-rod end. A second similar one lies in the strap of iron C, which reaches beyond the first. A cotter or key, which is, in fact, a wedge of iron, is then passes through a slot in the strap, and a similar one in the rod; and being driven home, draws the two brasses tightly together, causing them to embrace the crank-pin, L, Fig. or any similar bearing. All shafts that revolve in bearings are made to pass through brasses, and whenever these occur at the end of a rod, they are fitted as here described. E is another bearing of cast-iron, also fitted with brasses; but in a case like this, a plate lies on the upper one, and is screwed down by bolts and nuts as required. This bearing would do very well at E, Fig. as a guide for the piston-rod; but in models such guide is commonly made without brasses, like F or G of the present drawing.

At H, I have shown the part F O F of the drawing 63. The middle is of brass or iron; if of the former, g g must be separate, as these gudgeons would not be substantial enough, unless of iron or steel. It is essential that K L, the piston-rod, should be in one right line; but, if this is attended to, they need not necessarily be one piece; and frequently the piston-rod, L, is fixed into one end of the central casting, and another rod, K, is screwed into the other. In a model, the piston-rod should pass quite through, and g g should be two separate gudgeons screwed in, and then turned together in the lathe, to insure their being exactly in one line. These go into the brasses in the forked ends of the connecting-rod, to form a hinge at that part, as will be understood by a reference to Fig.

At M, I have shown another simple eccentric and rod, which is less trouble to make in a model than the other. In this the ring is made in one piece, with a round rod screwing into it. The disc has a slight groove turned in its edge, and a small screw, P, passes through the ring from falling off sideways, and of course is not screwed down so tight as to prevent the disc from revolving. This is a very easy way to fit the eccentric, and is generally followed in small engines. The lattice eccentric rod is nearly always used in large beam engines.

I do not think the reader will now have any difficulty in understanding the precise arrangement of the various parts in the simple horizontal engine of which I have given a sketch. It is a neat and convenient form, easily arranged as a mode, and I shall proceed at once to the practical work of constructing this, and engines in general, presupposing a knowledge of the use of the lathe, and of the few tools required.

How to Make an Engine

The very first mechanical work of difficulty, but of pre-eminent importance, in making an engine, is boring the cylinder, that is, if the same is a casting, and not a piece of tube ready made and smooth on the inside. This is, properly speaking, lathe work, yet may be done in a different way. Suppose you have bought your entire set of castings, which is the best way, and that the cylinder is half an inch diameter inside, which is a manageable size to work upon. Get a half-inch rosebit, which is very like the countersinks sold with the carpenter's brace and bits. Mount it in the lathe in a chuck, A, Fig. Unscrew the point of the back poppit, and slip over the spindle a boring-flange, B, which is merely a flat plate like a surface chuck, only the socket is not screwed but bored out, generally large enough to slip over the spindle. Sometimes there is, however, a screw at the back, to screw into the spindle, the same as the points or centres. On the face of this lay piece of board of equal thickness, but it is as well if not planed, as its object is partly to prevent the cylinder from slopping about during the operation, as it is sometimes inclined to do upon the smooth metal flange, and partly to prevent the borer or rosebit from coming in contact with the flange when it has passed through the cylinder. Grasp the latter in the left hand, and you can easily prevent it from revolving with the drill, which will go through rapidly, and leave the hole beautifully finished and quite true from end to end,—indeed, I have bored iron also, rapidly and with great ease, with this tool.

It is absolutely necessary, remember, that this hole bored in the cylinder should be at right angles to the ends of the same, and to secure this you must now make use of it to mount the cylinder in the lathe to turn these ends or flanges. I will show you a simple and easy way to do this. C is a bar of iron or steel, preferably of the latter, about 6 inches long, and three-eighths diameter, filed into six sides. It is a good plan to have three or four sizes of such bars, with centre holes drilled carefully into each end, so that you can mount them with a carrier-chuck, as you would if you were going to turn them. Taking one of about the size names, mount upon it a piece of wood, and turn this down until your cylinder will just go tightly upon it. Being a six-sided bar, it is easy to mount the wood upon it by boring the latter with gimlet and then driving the bar into it. It will hold tightly, and not turn round upon the metal. The cylinder being fixed in this way, you must turn the two flanges with a graver if the cylinder is of iron, but with a flat tool or the four-sided brass tool if of the latter metal; and also turn the edges of the flanges. The rest of the cylinder will be left in the rough, and may be painted green or black. I should advise you always to bore the cylinder first when possible, and then to mount it as described and turn it on the ends, which are thus sure to be correctly at right angles to the bore. Some cylinders, however, especially short ones, may be squared up first, and then mounted on a face-plate and bored. Unless, however, you have either a grip-chuck, which is self-centring, or some clamps properly constructed for this particular work, you will find the first method the easiest, especially for small light work.

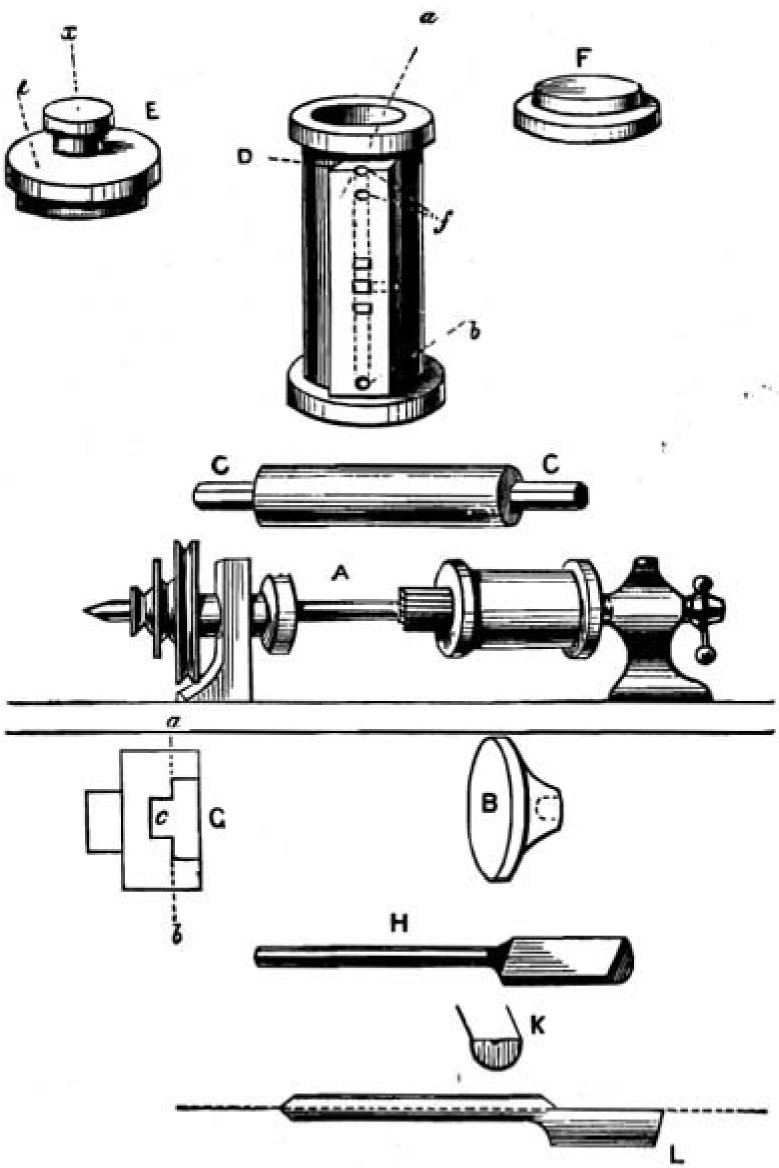


Fig. 65.

You should now make the ports for steam and exhaust. Mark them upon the flat part of the casting, after you have filed this as level as you can, and do not mark them so long as not to leave you room beyond the ends of the ports for the steam-box or case which has to be placed here. The upper and lower ports are to be the same size, but the middle one may be a trifle larger with advantage. In larger engines these are cast in the metal, and have only to be trimmed and faced; but in the small models you have to drill them out in the boss cast on the cylinder. Drill down from the top, as shown at D by the dotted lines, but take great care not to go farther than the outer ports, which are to be therefore first made, so that you can tell when the drill has gone far enough. If you pierce the middle port from either end, the cylinder is spoiled. To cut the middle one, you merely drill a hole straight in towards the cylinder, and meet it by another drilled from the side, into which the pipe for the exhaust is to be screwed. You also drill straight through into the cylinder at a b, and you then plug the end off, and that at the other end of the cylinder. Your port faces, however, are generally oblong, and not round. Make a row of holes with the drill, and then, with a little narrow channels with squared sides by thus drilling two or more holes, and throwing them into one with a file; but in reality, for these small engines, it is very little matter whether the ports are round in section or square.

The bottom and top of the cylinder demand our next attention. E and F show these. They are easily and instantly mounted in a self-centring chuck, but can be held very well in one of wood carefully bored with a recess of the right size and depth. You must here, nevertheless, be very particular, else you will get your work untrue at this point, and then you piston-rod will stand awry, and all your subsequent fitting will be badly done. I therefore give you at G a section of the chuck bored to take the cover truly.

Recess the part down to the line a b, to fit the cover exactly, taking care to level very carefully the bottom of the recess. Below this cut a deeper hole, to allow the flange in which the stuffing-box will be to go into it. It need not, however, fit the flange. The rough casting will hold very well in a chuck like this, even if it is of iron. You now carefully face the bottom of the cover, and turn the slight flange exactly to fit into the cylinder; then reverse it in the chuck, so as to get the stuffing-box outside; and in doing so, take the greatest care that it beds flat upon the bottom of the chuck. Turn off level the top of the flange first at x of fig. E, and then place a drill with its point against the middle of this, and its other end (with a little hole punched in it to keep it steady) against the back poppit centre, and carefully drill a hole down to the level of c, large enough to admit the gland of the stuffing-box or nearly so; but remember that you must not go too far, because the rest of the hole must only just allow the piston-rod to go through it. Therefore, after you have drilled about three-fourths of the distance, replace this drill by a smaller one, and with it bore quite through. The advantage of beginning in this way is, that you can now bring up the back centre of your lathe to steady the cylinder cover while you finish turning it; and as you will have to make a chuck only to take hold of the flange b, while you turn the edge, you will need probably some extra support of this kind. I have nevertheless, turned an iron cylinder cover 2-1/2 inches diameter without any such support; the actual strain not being very severe, provided you understand how a tool should be made and held.

The above directions apply equally to the cylinder bottom, the great secret in this and all similar work being to take care to bed the work well and truly against the bottom of the recess, turned in the chuck; this being neglected, will result in the two faces not being parallel, which will terribly throw out of truth the rest of your work. Indeed, in all fitting of this kind, it is absolutely necessary to be exact in the squaring and truing of each several pieces that has to be turned or filed; otherwise no planning or clumsy arrangement will make your mechanism work as it ought to do. Take a week, if necessary, over any part, and don't be content until it is well done.

Your cylinder ought now to have a finished appearance when the cover and bottom are placed in position, but the latter have to be permanently attached by small screws, and these I strongly advise you to buy. They cost about 50 cents a dozen, including a tap with which to make a thread in the holes made to receive them; or, if you prefer it, you can buy miniature bolts and nuts at almost as cheap a rate, which would cost you much time and trouble to make for yourself, if, indeed, you succeeded at all. You will want four of these for the top, and the same for the bottom, the holes for which you will make with a small archimedean or other drill.

The mention I have made of this reminds me that I am gradually adding considerably to your list of tools, and it is necessary to do so if you take up model-making. Set down, at any rate, the following:—

Archimedean Drill-Stock and 6 Drills

Table Vice

Hand Vice or Pin Vice

Small Brass-Back Saws for Metal

Pair of Small Pliers

And for use in the lathe, either two or three sizes of rosebits, or engineer's half-round boring bits, of which I shall have to speak presently; and, unless you buy all screws and nuts, you will want screw-plate and taps, or small stock dies. Files of square, round, and oblong section are matter of course. Remember, too, that after a file has been used on iron and steel, it is useless for brass; so use new ones on the latter metal first, and after such use they will answer for cast iron and then for wrought iron. You will find the cost of files rather heavy unless you attend to this. Have neat handles to all your smaller files, with ferules to prevent splitting.

When you purchase the castings of the engine, you will find a valve-box to enclose the slide and become a steamchest, as explained. It is like a box with neither top nor bottom, but with a flange, or turned-out edge all round, for the screws by which it is to be attached to the valve-tracings of the cylinder. This box must have its flanges filed up bright on their flat sides and edges—the rest may be painted. It will exercise your skill to get the two faces flat and true, to fit upon the cylinder; and at last you will find it expedient to put a brown paper rim or washer between the surfaces, or a bit of very thin sheet lead, to make a steam-tight joint. Do not solder it, if it is possible to use screws, because this is nearly certain to get melted off; and, if not, it is not nearly so neat and workmanlike a way of uniting the parts. You should, indeed, in all models, put them together in such a way as to be able at any time to separate the different pieces again, either for the purpose of cleaning or repair; and, if you solder, you cannot easily do this.

The valve-casing and its back are generally put on together; four screws at the corners passing through the back and both flanges into the flat side of the cylinder. This depends, however, upon the exact shape of these different pieces; and I can give you no special directions for a particular case unless I could see the castings which you have to fit together. The stuffing-box you will make quite separate, both its outer and inner part, and screw or solder the former into place. It is seldom cast upon the valve-casting, because of the difficulty of chucking a cubical object safely so as to turn any part of it.

You are not to screw or solder the valve-box to the cylinder until you have carefully filed up the valve itself to slide upon the port face, without the possibility of any escape of steam taking place. This needs the greatest possible care; and probably, after doing what you can with a flat file, you will have to put a little emery and oil between the surfaces, and grind them to a perfect fit, by rubbing them together. This grinding with emery is an operation mandrels are fitted in this way into the collars; the cylinder is also ground into the back poppit-head. It is not a very long or difficult operation, but whenever you have had to use it, take care to wipe off the emery, or it will keep on grinding. It is indeed very difficult to do this perfectly; and for very fine work, such as fitting the mandrel of a screw-cutting lathe(i.e., a traversing mandrel), oil-stone powder and crocus are used, in place of emery. These, however, cut very slowly, making the operation of grinding exceedingly tedious; and in the present instance, emery will answer quite well enough. In very small engines, a stroke or two of a file is all that is needed to fit the valve, which is so small as hardly to be worthy of the name; but in an engine with cylinder of 1 or 2-inch bore, it will be impossible to do with file alone, as well as you can with grinding.

The piston and piston-rod should be turned at the same time, as already suggested in treating of the atmospheric engine of Newcomen. By this, you will avoid getting the piston "out of square" with its rod, as if you had bored the hole for the latter askew—a not unusual occurrence.

I do not mean to say that it is absolutely necessary for you to turn the piston-rod at all, for, in models, it is generally of round iron or steel-wire, which is as cylindrical as you can possibly make it. Knitting-needles are in general use for this, as being well finished and equalised from end to end. But these are rather hard, being tempered only to about the degree of steel-springs; therefore you must never attempt to cut a screw on them until you have first heated the end to be screwed red-hot, and allowed it to cool again very slowly. If you do this, a screw-plate will put a sufficiently good thread to allow you to attach either the piston, or the small piece of brass necessary to form the hinge, upon the other end of the rod—that is to say, the piece marked H in Fig. Leave this for the present, however, not attempting at present to cut either the piston-rod or valve-rod to its intended length. You cannot do this until you have laid down the exact plan of the engine, and marked on the bed-plate the position of all the parts.

I shall now suppose that you have finished the cylinder, with its slide-valve, casing, stuffing-boxes, and piston, so that you have these in exactly the state in which you might buy them at Bateman's and elsewhere, if you preferred, to spare yourself the trouble of boring the cylinder and fitting it. You can buy them just in this condition, with the rest of the castings in the rough; but I rather hope you may prefer to try and do for yourself the not very heavy or difficult work which I have described.

I suppose you, indeed, to have bought the forked connecting-rod, either arranged for brasses, or with holes drilled (or to be drilled) in the ends, which would probably be the case for a model of the size named, and also the various bearings, guides, and some filed, but which ought now to present little difficulty to our young mechanic.

Try to keep sharp edges to all your files work, unless evidently intending to round them; for surfaces pretending to be flat, but partaking of a curved sectional form, characterize the workman as undeniably a bad hand with the file, and not worth his wages. Still I may tell you at once that nothing is so difficult as to use a file well. It has a knack of rounding off edges, which always get more than their proper share of its work. But this being the case, you will know what to try and avoid. Therefore, always endeavor in filing a flat surface to make it slightly hollow in the middle, which it is scarcely possible, however, for you to do; but the endeavor to effect this by filing the middle more than the edges will help you wonderfully in keeping the latter sharp. Those, for instance, on the fork of the connecting-rod, especially the inside ones, should be as straight and sharp as possible; and if you round the outside edge, take care to do it so that it shall be evident you intended it; and so with all edges, whether turned or filed.

The disc of the eccentric can only be turned by letting it into a chuck to something less than half its thickness, and levelling one side and half the edge, and then reversing it; unless you prefer to drill and mount it on a spindle upon its centre. If you do this, you will of course eventually have two holes in it; because this first one is not that by which it will be mounted when in place. This second hole is not, however, of the least importance, and may be left without plugging, and, if preferred, may become in part ornamented by drilling additional holes, and filing them into some pattern; or if it is desired to conceal the one it was turned upon, this can be plugged and faced off, and will then not be the least apparent. If the outer ring, or strap, as it is called, is to be made in two pieces, with projecting lugs, it is evident the outside edge cannot well be turned; and, unless you have that most useful addition to the lathe, a grip or jaw-chuck, you will have some little difficulty in letting the ring into a wooden chuck, so as to turn the inside. The solid ring is, therefore, preferable (if you use the first, however, you turn it up as a single ring, and then saw it across through the lugs), which can be let into a common chuck, with a place chiselled out to allow the boss to project, into which the eccentric rod has to be screwed. This boss also has to be drilled and turned on the outside. There are several modes of chucking it which can be applied, but the simplest is to use the carrier-chuck, and to let the ring become its own carrier by coming against the pin, as shown in Fig. A.

When the ring is very small, I should first drill the hole for the wire rod, and then screw and mount it upon a little wire spindle, as in fig. B, aiding this, if necessary, by the back centre. But the smallest models require to be put into a watch-maker's lathe or throw, and, except as curiosities, are scarcely worth making.

I have already told you never to undertake engine-making without first laying down a full-sized plan on paper, with centre lines through the principal pats, from which to take all measurements, and to mark these upon the baseplate, as a guide to the perfect adjustment of the various parts. Some of these are capable of a little extra adjustment after being put in place: the eccentric rod, for instance, can be lengthened or shortened by screwing into or out of the eccentric ring; and the piston-rod, too, may be similarly lengthened or shortened slightly; but try to work as near as you can to precise measure without such adjustment.

To turn the fly-wheel, which is the last operation (including the crank-axle), it is better carefully to drill the boss, if not already done, marking the centre on each side, and working half through from each, so as to insure the squareness of the hole with the side of the wheel, which is very important. Then mount it at once upon its axle, previously turned slightly conical, where the wheel is to be placed, and run both together in the lathe. This will insure the wheel running true when the engine is put together.

In the horizontal engine which I have sketched, the crank is quite separate from the axle; and this is the easiest way to make it. The crank itself is filed up, like C of Fig. and drilled for the axle and the pin upon which the brasses on the connecting-rod work. Turn down the end of the crank-shaft very slightly conical, until the crank will almost go over it. Then heat the crank, which will expand it and enable you to slop it on the shaft. Dip it in cold water, and it will be as firm as if made in one piece with the axle. This is called shrinking it on, and the operation will often stand you in good stead, and save the trouble of filing key-ways and making the small wedges called keys. The pin D can in this case be turned up separately, and screwed in, which will complete the work.

The eccentric must evidently be placed in position before the crank is added, and this, too, might be shrunk on, were it not that it cannot easily be fixed in a model until the engine is set up. The best way, therefore, is, in this case, to turn the eccentric with a little projecting boss to take a set screw, E, Fig.

Where the axle has to pass through bearings, it must be turned down at these parts, so that the whole will be like F. First on the right is the journal, e, then the place for the fly-wheel, d, very slightly conical—the smallest part being towards e—then the second journal, and then another slightly conical part, the smallest end towards a, to take the eccentric and crank. The fly-wheel you will key on shaft, thus:—G represents the boss or centre of the wheel bored for the axle, and a key-way or slot filed on one side at a. There is a flat place filed on the axle, and the wheel is turned round to bring this opposite to the keyway. A wedge or key, b, is then driven in, which keeps the wheel secure, and prevents it from turning round or working loose on the axle. If inconvenient to turn a boss and add a set-screw to the eccentric, this also may be keyed in its place after its position has been found; but, for the latter purpose, it should fit rather tightly on the axle, so that it can be moved round with the finger stiffly until its position with respect to the crank is ascertained.

This position I shall now endeavor to explain, using a diagram from an American work, in which this generally supposed difficult point is thus ably and satisfactorily explained. First, put your engine together as if for work, and having cut the eccentric rod to about the length you seem to require, judging from your plan drawn upon the bed-plate, turn round the eccentric, with your fingers upon the crank-shaft, and, having removed the cover of the valve-box, so that you can see the action on the valve watch the motion of the latter. Doubtless, the result will be that one of the steam-ports will be opened clear to the exhaust-port, while the other is nearly or entirely shut. The rod is then too long or too short. If in a horizontal engine the port nearest to the crank is wide open and the other shut, the rod is too long, and must be shortened half the difference only (you will do this by screwing it farther into the eccentric hoop). When the valve "runs square," or opens and shuts the ports correctly, set the eccentric as in the diagram, H, in respect to the crank, i.e., with its widest part at right angles to it. By running square is meant that when the eccentric is turned round as described, the valve opens the ports equally, and does not affect one more than the other. The line a of the diagram shows that the position of the eccentric may advantageously be a little beyond the right angle to the crank, to give what is called “lead,” i.e., to open the valve a little before the piston commences its return-stroke.

The boilers of model engines are made of tin, sheet-brass, or copper; seldom of the latter, which is, nevertheless, by far the best material, and one that you can braze, rivet, or solder satisfactorily, or bend into any shape with a hammer or wooden mallet. When polished, too, its rich red colour is very handsome. Brass is chiefly used from the facility of obtaining tubes of it ready brazed or soldered, from which any desired length can be cut. A brazed copper boiler will stand a great deal of pressure; will tear, and not fly into pieces when it bursts; and may be heated after the water has boiled away without suffering any injury. It would certainly not be worth while to make one for a model engine with a half-inch cylinder, but for one of 1 inch diameter and 2-1/2 stroke; and for larger sizes, it will amply repay the trouble; and I will show you how to make one, with a tube or flue inside to add to the heating surface.

I shall endeavor presently to give the proper dimensions of boilers to work cylinders of given diameters, but the general directions here subjoined apply to all boilers of models, whether large or small. The main body of the boiler is generally cylindrical, and is, in fact, a tube of sheet-metal, with riveted, brazed, or soldered seams, the last greatly predominating in the toy engines; the result of which is, that the first time the water gets too low, out drops the bottom, or, at the least, divers leaky places appear, and the boiler is obliged to go to the tinman’s for repair, it’s beauty being ever after a thing of the past. It is difficult to braze in an ordinary fire; because even if, by blowing it with a pair of bellows, you get sufficient heat, you cannot always manage to apply your work in a good position, as you can over the hot coals of a forge fire, where there are no bars, hobs, or other parts of the grate standing in the way. Moreover, you often want both hands free just as the solder commences to "run," and forge-bellows will keep up the blast for a few seconds after your hand is taken from the staff or handle of them. Still, if you have no forge, which is probable, you should make a fire of cinders or coke (the latter if possible); and if you can contrive a grate by putting together a few bricks in some out-house, with a bar or two of hoop-iron below for the coke to rest upon, you will have a far more convenient fire to work at than can possibly be obtained in any ordinary household grate or stove. You will require a pair of light tongs, which ought to be something like A, Fig. but it is quite possible to do without these if you can hold your work in any other way; as, for instance, with a loop of iron wire twisted round it and left long enough to form a handle.

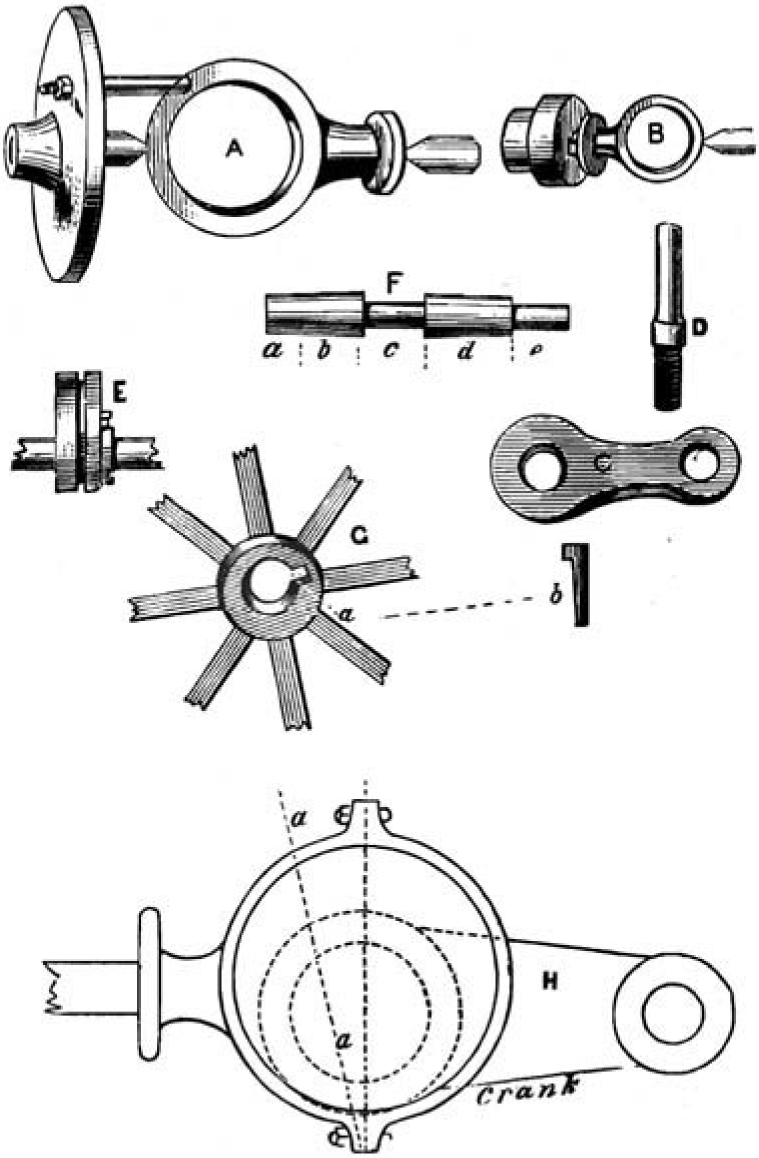


Fig. 66.

The first thing to do is to cut a strip of copper large enough to make the required tube. A piece 6 inches wide will roll up into a cylinder of about 2 inches diameter (the circumference of a circle being nearly equal in all cases to three times its diameter, or measure through the centre). If, therefore, you want one 6 inches across, which is the smallest size that can be advantageously fitted with a flue or internal tube, you must cut it out 18 inches wide, and if it is 8 in length to the bottom of the steam dome, it will be a large and serviceable boiler, fit to work an engine with a cylinder of 1-1/2 bore by 2-1/2 or 3 inch stroke, which would drive a small lathe. But observe that if you really have luck and skill enough to try your hand upon an engine that will give your real power, you must take care to remember that "strength of anything is the strength of its weakest part." So don't make the very common mistake of having a good boiler and ample cylinder, and then fit the engine with piston-rod, valve-rod, and such like, too small to bear the strain which you propose to put upon the engine. Remember that every screw and nut and pin upon which strain is liable to fall, must be of sufficient size and strength to bear it safely: if not, your engine will not only come to grief in the heavy trial, but it is quite possible that you also may become subjected to a bad scald or other disagreeable consequence of your error.

Whatever sized strips of copper you use for a boiler, the edges have to come together to form what is called a butt-joint; i.e., they do not overlap like the ordinary joints you see made in tin. Before you coil up the strip into a tubular shape, you have to cut out holes for any boiler fittings you may wish to add, such as safety-valve, steam-dome, and gauges to ascertain the level of the water. These, however, do not all come into the cylindrical part of our present boiler; the gauge-taps and glass water-gauge alone having to be provided for. The man-hole, too, which is added to all large boilers, may be dispensed with, its object being to enable one to get at the inside, which will scarcely be necessary if our work is well done at first. A boiler of the proposed size should be heated with charcoal, as it would require a very large lamp;

but where gas can be obtained, it may be preferably used, a ring gas-burner being paced below within the furnace. The object of a steam-dome, which, in a horizontal boiler, would have to be placed somewhere on the tube itself, is to prevent what is called priming, i.e., the carrying into the cylinder water as well as steam, which arises from the spurting caused by the violent boiling of the water. The dome merely provides a chamber for dry steam above the general level of the boiler, the steam-pipe passing from it direct to the cylinders. Our present boiler will be vertical like the last, but with a flue up the middle, and a grate fitted below. It is shown complete in Fig. B, with all the fittings usually attached.

Having coiled up the tube by hammering it over a cylinder of wood turned for the purpose, a little smaller than the intended size of the boiler (the edges having been previously filed up bright, and a width of a quarter of an inch of the upper being similarly cleaned on the inside all along the seam), a few loops of iron wire are tied round it, at intervals of 1 inch or 1-1/2 inches; there being a short piece put round, and twisted together at the ends by a pair of pliers. The object of these is to prevent the seam from opening on the application of heat, which it is otherwise certain to do by the expansion of the metal. Some borax, pounded in a mortar, and heated to drive off the water of crystallization, is next mixed with a little water to form a creamy paste, and smeared along the inside of the tube, upon the brightened part, the full length of the seam. It is generally better to heat this salt first sufficiently to dry it (or rather fuse it), because it swells prodigiously by the first application of heat, and if the spelter is laid on it, it often carries it off; after once fusing, it only melts quietly.

Before applying the little lumps of spelter, turn over the tube to heat the part opposite to the seam, so as to equalize the expansion. Then hold it in a pair of light tongs, lay the spelter along upon the borax, and expose it without actually touching the coals to the heat of the fire, urged by a strong blast. Continue this until a blue flame arises, which shows that the spelter has melted; this blue flame being, in fact, that caused by the burning of the zinc in the solder—spelter being copper and zinc fused together, or, if required softer, brass, tin, and zinc. The former is generally used, however, on copper. When the blue flame arises, the solder runs into the joint, and the work is done. With the hardest of these spelters, a red heat will not seriously affect the joint, and, therefore, if at any time the water should get below the line of this seam, so that it becomes exposed to the heat, no harm will be done. Nevertheless, this ought never to occur, as a gauge should be attached to every boiler to show the exact position of the water at any given time.

The inside tube of this boiler will be seen, from the section, to be conical up to the level of the lower part of the chimney. This is of copper, brazed like the cylindrical part, and is 2 inches wide below, and 1 inch above; consequently, the strips to make it must be 6 inches wide at one end, and taper to 3 inches at the other. If the dome rises 2 inches from the level of the top of the cylinder, it will be sufficient; and as this is a difficult piece of work for a boy to manage, a coppersmith should be asked to hammer the dome into the required form, as he will know from experience the best size of circular disc to use for the purpose. This part is so far removed from the action of the fire that it may safely be soldered, but it is, nevertheless, as well to rivet it, turning out both the edge of the cylinder and that of the dome. Use copper rivets, and make the holes half an inch apart. If you find any leakage, you can run a little solder into the joint on the inside. The bottom of the boiler may be quite flat and brazed, a few rivets being first put in to hold the parts accurately together. The same may be said of the tube which passes through both this and the dome. There is nothing equal to riveting and brazing for this kind of work.

I may as well state however here, that as such a boiler as I have now described is worth very good work, it would be a great pity to spoil it; and it will be better to content yourself with smaller boilers and engines soldered, where necessary, until you have had some practice in brazing. This indeed is not difficult in reality, but, as the same time, requires great care, because sometimes the solder and the work melt at so nearly the same temperature, that, like a bad tinker, you will sometimes make two holes instead of mending one. The brass, for instance, use for beer-taps is very soft, and contains lead, and to a certainty would itself melt before ordinary spelter, and could not therefore be brazed; but the best Bristol brass, or yellow metal, will braze easily. A blacksmith, brazing a key or other iron article, will braze it in a different way, using brass wire, with which he will envelop the parts thickly which are to be united, after position with iron binding-wire. He then sprinkles with borax, and heats the work until the wire runs into the joint; after which he files and cleans off levels. This makes a very good medium.

I have spoken of riveting in this place. There is no difficulty in this work. You can buy copper rivets of all sizes, and have only to punch holes, put a rivet in place, and hammer it so as to spread the metal to form a second head. If the rivets are heated before being applied, they will draw the parts closer together, because they shrink in cooling. All large boilers are made in this way, but smaller ones of iron are often welded, where such a mode of junction is possible. When you can rivet boilers water and steam tight, you will find no difficulty in construction them, for you can make riveted joints where brazing would be difficult or impossible.

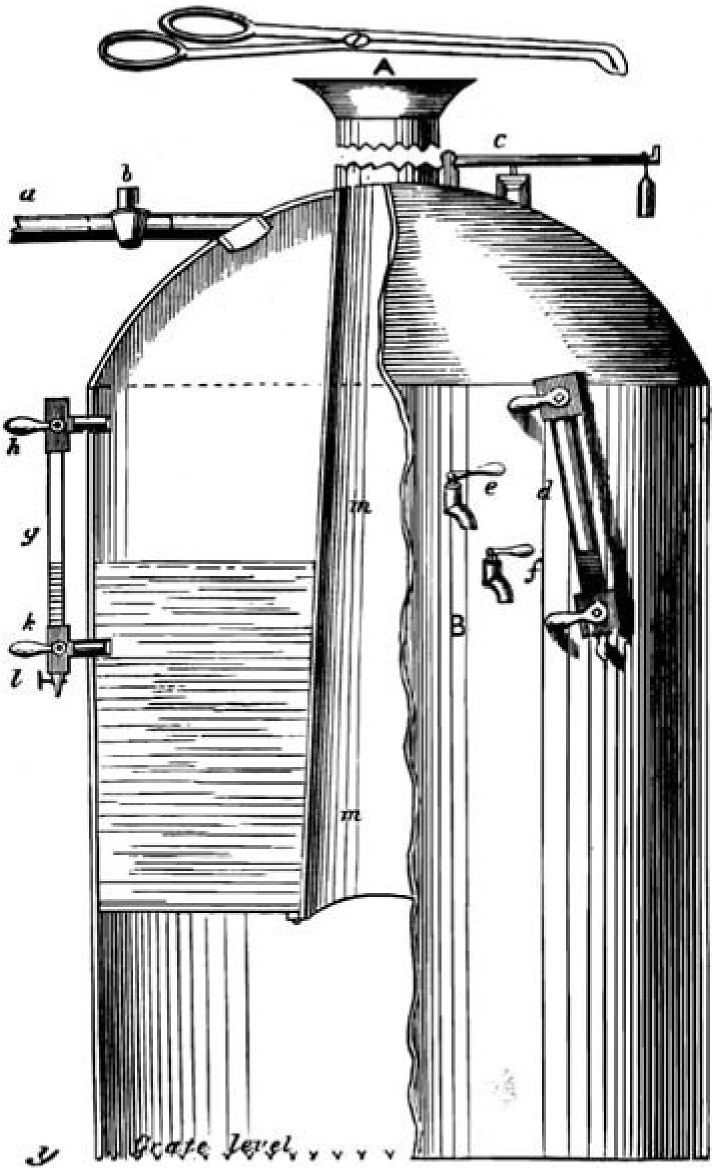


Fig. 67.

Fig. B, is a half-section of such a boiler as I have just described. Fig. A, is the lower part, which is separate, and forms the furnace in which the boiler stands, fitting it closely. This is drawn to scale, and is half the real size. a is the steam-pipe, fitted high up in the dome, the tap, b, serving to turn on or off the supply of steam for the cylinder; c is the safety-valve shown in section, and care must be always taken to make the conical part short and of a large angle, or it may stick fast, and cause an explosion; d is the glass gauge, to show the exact height of the water in the boiler. Its construction will be understood from the other which is attached, where the boiler is seen in section. There is no need to have two, and this is added solely to explain the nature of glass-gauges. The top and bottom are of brass, being tubes screwing into the boiler, or fastened by a nut inside; a tube, g, of thick glass, connects these two, so as to form a continuous tube, one end of which opens into that part of the boiler which is full of steam, the other opening below the water-level. Thus the tube forms practically part of the boiler, and the level of the water is clearly seen. The lower tap issued for blowing off water, to insure the communication being kept open, as it might get stopped up with sediment.

Gauge-cocks, e, f, are generally added, even where the glass water-gauge is used. One of these should always give steam, the other water, —the level of the latter being between the two. If the upper one gives water, the boiler is too full; if both give steam, the boiler needs to have water added. With these fittings, even a soldered boiler ought never to get burnt, and will last a long time with care.

The lower part, Fig.67, is made like that before described, except that, being intended for charcoal, a circular grate is used, which simply rests upon little brackets fixed by rivets for this purpose. The flame and heat play upon the bottom of the boiler, and also pass up the central tube—the latter adding greatly to the quantity of steam produced.

This furnace, when lighted, may be fed with bits of coke as well as charcoal, about the size of filberts, and will give plenty of heat. If the draught, however, is deficient, turn the waste steam into the tube, so as to form a jet at each stroke, and it will greatly increase it. It is in this way that the locomotive engines are always fitted, George Stephenson having first suggested the arrangement. Previously to this a fan had been fitted below the grate, which was put in rapid motion by the engine, and thus a sufficient draught was obtained.

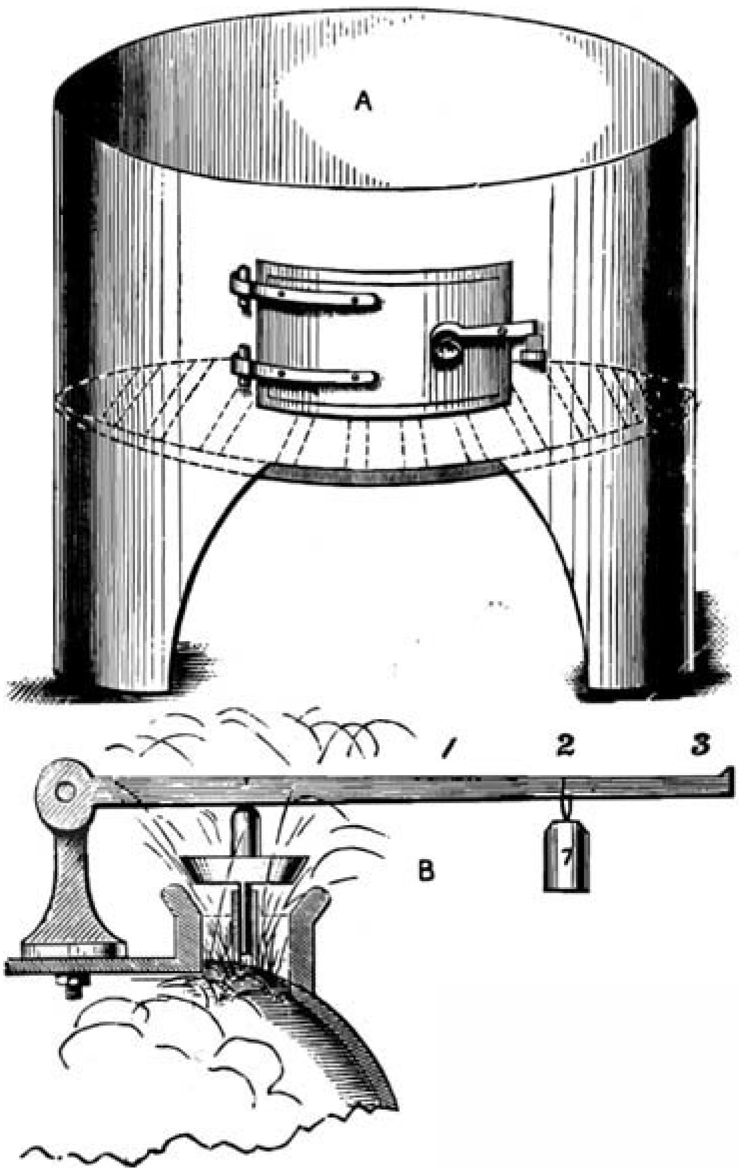


Fig. 68.

To find out what pressure is exerted by the safety-valve it must be clearly understood upon what principle it acts. I have in a previous chapter told you that the atmospheric pressure equals 15 lbs. on each square inch, so that if the surface of the valve which is exposed to the air is 1 inch in area or surface, it is pressed down with a force of 15 lbs. The steam, therefore, inside the boiler will not raise it until its elasticity exceeds this atmospheric pressure. If, therefore, we desire to have only just 15 lbs. per square inch pressing against the inside of the boiler (i.e., a pressure of "one atmosphere", as it is called), we have only to load the valve so that, inclusive of its own weight, it shall equal 15 lbs. But it is plain that we must not load it at all in reality; for a flat plate, 1 inch square, of no weight, is all that is needed, the atmosphere itself being the load. Suppose, then, that we do load it with 15 lbs. in addition to the 15 lbs. with which nature has loaded it, we shall not find the steam escape until it presses with a force of 30 lbs., on the square inch, or two atmospheres (which, however, is not 30 lbs. of useful pressure upon one side of the piston, if the cylinder is open at in an atmospheric engine, but only 15 lbs.) This is not the strain which the boiler has to stand, because the atmosphere is pressing upon it and counteracting it up to the 15 lbs., so that this strain tending to burst it is but 15 lbs. The number of pounds, therefore, which is straining the boiler can readily be seen; being always that with which the safety-valve is loaded, and this is also the useful pressure for doing any required work. Unfortunately, however, even in the best constructed engines, a pressure of 15 lbs. upon the boiler by no means represents that in the cylinder. Now it would be inconvenient to place weights upon the safety-valve itself, and therefore a lever is added, as seen in the sketch, with a weight hung at one end of it. This is shown at B, Fig. where a section of the valve is given with its stem passing through a guide to insure the correct motion of the valve. The lever is hinged at one end; and the rule of the pressure or weight which is brought to bear upon the valve is, that it is multiplied by the distance at which the weight hangs from the valve, compared with its distance from the hinge or fulcrum. If a weight of 7 lbs. is hung at 1, i.e., at a distance as far on that side of the valve as the fulcrum is on the other side of it, 7 lbs. will be the actual power exerted; at 2, where it is twice the distance, it will be doubled, and, as shown in the drawing, a pressure of 14 lbs. will be brought to bear upon the valve; while, if the weight is hung at 3, it will exercise a force of 21 lbs. This is very easy to understand and to remember. Sometimes (always in locomotives) the weight is removed and a spring balance is attached at the long end. Upon this is marked the actual pressure exerted; there being a nut to screw down, and thus bring any desired strain upon the spring. Mind, however, in case you should try this in any of your models, that the scale marked on the balance when you buy it must be multiplied, as before, according to the length of your lever. Thus, attach such a balance at 3 of the drawing, a real weight of 5 lbs. shown by the balance will be 3 x 5, or 15 lbs. upon the valve, and a balance made for such engine would be marked 15 lbs., to prevent the possibility of dangerous error.

ENGINES WITHOUT SLIDE-VALVES EASY TO MAKE

Having been led on from the atmospheric engine to that of Watt's, and to slide-valve engines generally, I am now going backward a little to a class easier to make, because they have no slide-valves, nor even four-way cocks; and then I shall have done with engines. But I dare say some of my readers will wonder why I have said so little about condensers and condensing engines. I am sure they will wonder at it if they understood what I explained of the advantage of a vacuum under the piston; so that 15 lbs. pressure upon the piston means 15 lbs. of useful work, instead of 30 lbs. being required for that purpose. But condensing engines are utterly beyond a boy's power. They require not only a vessel into which the steam in injected at each stroke, but there must be a pump to raise and inject cold water to condense the steam, and a pump to extract from the vessel again this water, after it has been use, and a cistern, and cold and hot wells; and all this is difficult to make so as to act; and I am sure no boy cares for a steam engine that will not work. Moreover, I have given you difficult as it is—work that many of my readers will no doubt be afraid to try—yet I did it on purpose; because if small boys are unequal to some of it, their big brother are not, or ought not to be; and mechanical boys must look at difficulties as a trained hunter looks at a hedge—viz., with a strong desire to go over it, or through it, or any how and some how to get to the other side of it. Indeed, you must ride your mechanical hobby very boldly and with great pluck, or you won't half enjoy the ride. However, I am quite aware that I have led you into several difficulties, and therefore now I propose to set before you some easy work as a king of holiday task which will send you with fresh vigor to what is not so easy.

The engines without slide-valves have also no eccentrics and no connecting-rods. There is just a boiler, a cylinder, piston, piston-rod, and crank, and you have the sum total, save and except the fly-wheel. These are direct-action engines, the cylinders of which oscillate like a pendulum, and the piston-rod itself is connected to the crank, doing away with the necessity for guides.

Fig. A, shows one of these engines, and you see that the cylinder leans to the left when the crank is turned to that side; and if you turn the wheel to the right, the crank will presently cause it to lean the other way; and thus, as it turns on a pin, or "trunnion," as it is called, it keeps on swinging from side to side as the wheel goes round.

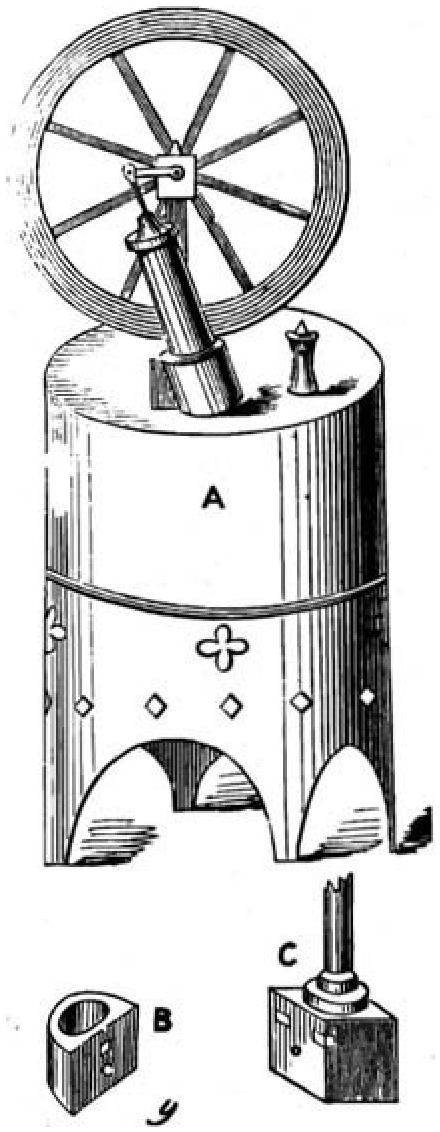


Fig. 69.

Now, when it is in its first position, the piston is at the bottom of the cylinder, and it then needs to have the steam admitted below it to drive up the piston; but when this has passed its highest position, and the cylinder is turned a little to the right, the piston must be allowed to descent, and, therefore, we must let out the steam below it. We ought, at the same time, to admit steam above the piston to force it down; but, in the simplest models, which are called single-action engines, this is not done. The flywheel, having been set in motion, keeps on revolving, and, by its impetus, sends down the piston quite powerfully enough to overcome the slight resistance which is offered by the friction of the parts.

Now, you can, I daresay, easily understand that it is possible to make this to-and-fro motion of the oscillating cylinder open first a steam-port to let it blow off into the air. This is exactly what is done in practice, and it is managed in the following manner:—

B, of Fig. shows the bottom of the cylinder, which is a solid piece of brass filed quite flat on one side, and turned out to receive the end of the brass tube, which, generally speaking, is screwed into it to form the cylinder, this being the easiest way to make it. In the middle of the upper part of the flat side you see a white steam-port, and below it a round white spot, which is the position of the pin, or trunnion, on which it oscillates. Fig. is a similar piece of brass, which is fixed to the top of the boiler. In this, on the left of the upper part, is also a port, which is connected with the boiler by a hole drilled below it to admit steam. On the right is also a port, which is merely cut like a notch, or it may go a little way into the boss, and then be met by a hole drilled to meet it, so as to form the escape or exhaust port. Between and below these is the hole for the trunnion.

Now, you can, I think, see that if the cylinder stands upright against this block, as it does when the crank is vertical (or upright) and on its dead points, the port at the bottom of the cylinder would fall between the two on this block of brass, and, as they are both flat and fit closely, no steam from the boiler can enter the cylinder. Nor do we want it to do so, because, if the crank is on a dead point, no amount of steam can make the piston rise so as to move it. But now, if we move the cylinder to the left, which we can do by turning the wheel, we shall presently get the crank at right angles to its former position, and, also, we shall bring the steam-ports in the cylinder and block together, so that steam will enter below the piston. But, practically to get as long a stroke as possible, steam is not allowed to enter fully until the crank is further on than in a horizontal position, that is, approaching its lower dead point; and this is the position in which to put it to start the engine. By altering the shape or the position of the port a little, we can so arrange matters as to let steam enter at any required moment

Steam having entered, the piston will rise rapidly, forcing up the piston, and presently, by the consequent revolution of the fly-wheel, the cylinder will be found leaning to the left, and at this moment the piston must evidently begin to descend. At this very time the steam-ports will have ceased to correspond, but the port in the cylinder will come opposite the exhaust-port in the brass block, and this port is made of such size and shape that the two shall continue to be together all the time the piston is descending; but, the moment it has reached the end of its downward stroke, they cease to correspond in position, and the steam-port begins again to admit a fresh supply of steam.

The pillar attached to the brass boss has nothing to do with it, but is one of the supports of the axle of the flywheel, as you will understand by inspection of A of this same drawing.

Such is the single-action model engine, of no power, but a very interesting toy and real steam engine.

The double-action engine is very superior to the foregoing, which, I may remark, has no stuffing-box, and of which the piston is never packed. I may also add, that the crank is formed generally by merely bending the wire that forms the axle of the wheel, and putting the bent end throught the hole of a little boss or knob of brass, screwed to the end of the piston-rod. Here you have no boring of cylinders to accomplish, but the cylinder cover, piston, and wheel (often of lead or tin) require the lathe to make them neatly. Many an engine, however, has been made without a lathe and I have seen one with a bit of gun-barrel for a cylinder, and a four-way cock of very rough construction, that was used to turn a coffee-mill, and did its work very well too.

But I must go at once to the double-action oscillating cylinder, in which, although a similar mode af admitting steam is used, it is arranged to admit it alternately above and below the piston, the exhaust also acting in a similar manner.

After the explanation I have given you, however, of the single-action engine, you will, some of you, I think jump at a conclusion almost directly, and perhaps be able to plan for yourselves a very easy arrangement to accomplish the desired end. All boys, however, are not “wax to receive, and adamant to retain” an impression; for I have known some who need an idea to be dirven into their brains with a good deal of hard hammering. Stupid?—No. Dull?—No, only slow in getting hold, and none the worse for that generally, if the master willbut have a little patience; for when they do get hold, they are very like bulldogs, they won't let go in a hurry, but store up in most retentive minds what they learned with such deliberation.

The cylinder of the double-action engine is of necessity made with ports very similar to those of the horizontal engine already described. There is a solid piece attached to the cylinder as before, which is drilled down to the upper and lower part respectively of a central boss, turned very flat upon the face, and which has to work against a similar flat surface as in the last engine. But the ports in the latter are four instead of two, and in an engine with upright cylinder would be cut as follows, as as shown in Fig. C.

Those on the right marked s t are steam-ports, which, being drilled into one behind, are connected with the boiler. The other two marked ex, are similarly exhaust-ports opening into the air. The spaces between a b and c d of fig. C must be wide enough to close the steam-ports in the cylinder, when the latter is perpendicular and the engine at rest. When the cylinder leans to the left, oscillating on the central pin between the ports in the middle of the circle, the lower port of it will evidently be in connection with the steam-port in C, while the upper port of the cylinder will be opposite to the exhaust. As the cylinder is carried over towards the right, the upper steam-ports will come into action in a similar way, while the lower exhaust-port is also carrying off in turn the waste steam. The impetus, therefore, of the fly-wheel has here only to carry the ports over the spaces a b, c d, and to prevent the crank stopping on the two dead points. This, therefore, is a genuine double-action engine, and will answer, even on a large scale, very satisfactorily. If you do not quite understand the action of these ports, cut out two pieces of card, E F. Let E represent the cylinder. Draw circles, and cut two ports. Cut another piece of card to represent the brass block, with ports, c d; pin them together through the centres of the circles and they will easily turn on the pin. Mark the ports, so that you will see at a glance which are steam and which exhaust. Now cut out the ports with a penknife, and as you work the two cards together, swaying that which represents the cylinder to and fro upon the other, you will see when the ports in each card agree with one another, and which are opposite to which. This will teach you far better than any further written explanation. You will also see that, instead of making the steam and exhaust ports respectively with a division between, the two steam-ports may be in one curve united, and likewise the two exhausts; but take care not to unite the exhaust with the steam-ports. There is no way so easy as this of reversing the action of the steam; it is, in fact, a circular slide-valve, but wonderfully easy to make, because you have no steam-case to make, nor any attachments whatever.

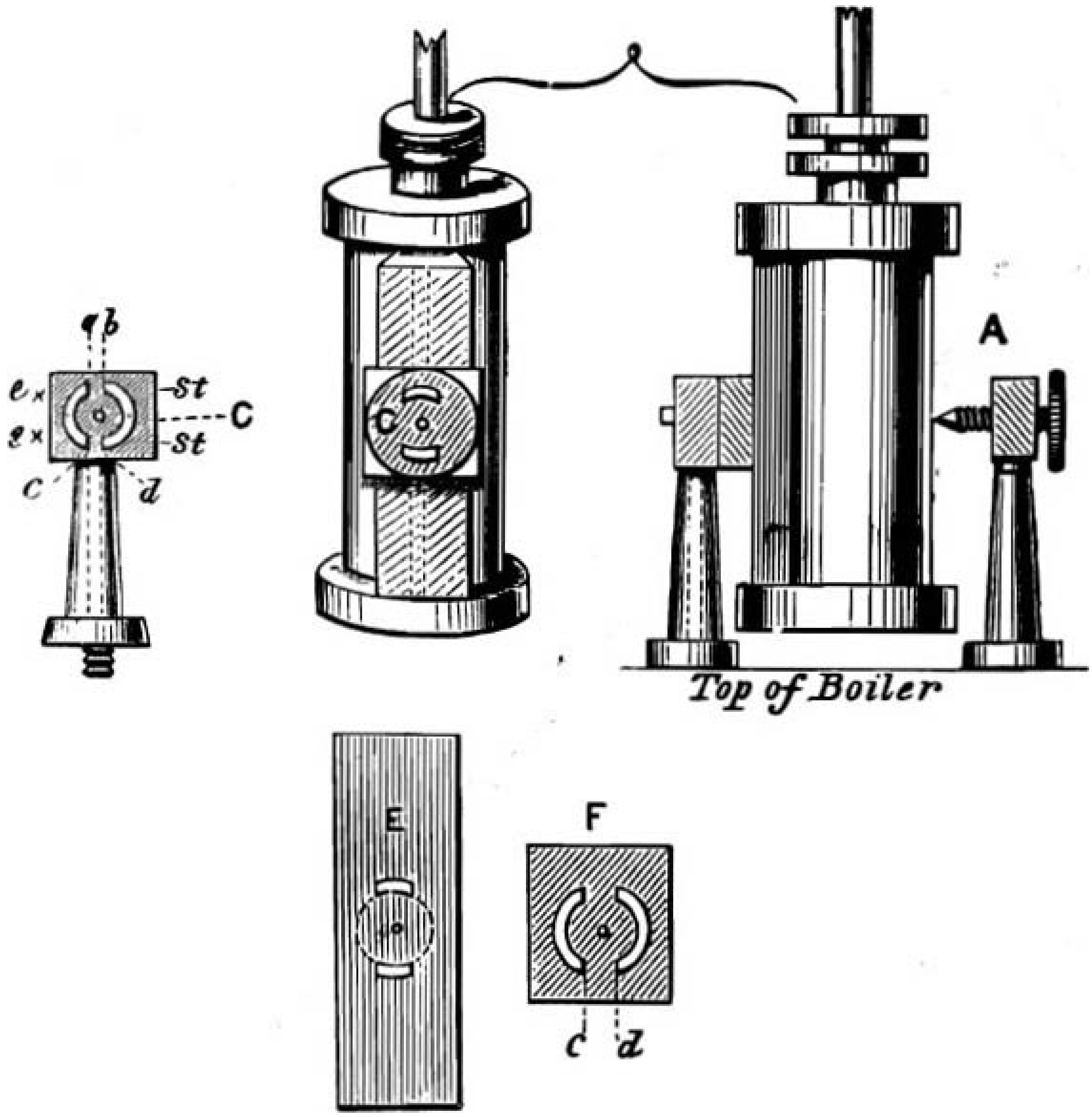


Fig. 70.

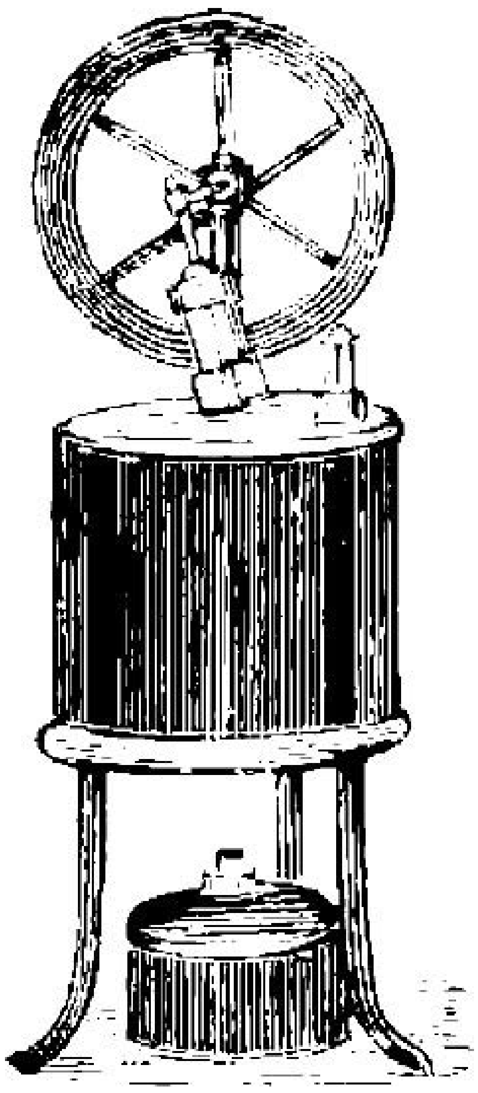
The faces of the valve are kept in close contact in one of two ways—either the centre-pin is fixed into the cylinder face, and after passing through the brass boss with the ports, is screwed up with a nut at the back; or else there is fixed a small pillar or upright on the opposite side of the cylinder, and a little pointed screw passing through this presses against the cylinder, and makes a point of resistance, against which it centres, and on which it turns. This is shown at fig. A. A small indentation is made where the point comes in contact with the cylinder.

In a locomotive engine there are two such cylinders, working against opposite faces of the same brass block containing the ports. The cranks are also two, on the shaft of the driving-wheels, and are at right angles to each other; so that when one piston is at the middle of its stroke, the other is nearly or quite at the end of it. Thus, between the two there is always some force being exerted by the steam; and the dead points of one crank agree with the greatest leverage of the other. In locomotives, too, the cylinders generally are made as in the present drawing, vix., to oscillate on a point at the middle of their length; but it is just as easy to have the two ports meet at the bottom instead, so that the point of oscillation may be low down, like the single-acting cylinders of the last sketch, and this is generally done when the cylinder is to stand upright.

There is no occasion for me to draw an engine with double-acting oscillating cylinders, because in appearance it would be like the single-acting one; but whereas the latter is of absolutely no use, seeing that the greater part of its motion depends on the impetus of the fly-wheel, the former can be made to do real work, and is the form to be used for marine and locomotive engines. For the former, oscillating cylinders with slide-valves are used in practice; but for real locomotives fixed cylinders are always used. Of course either will answer in models, and it will be good practice to try both.

I have now given sufficient explanation of how engines work, and how they may be made, to enable my young mechanic to try his hand at such work. The double-action oscillating engines especially are well worthy of his attention, as he may with these fit up working models of steamboats and railway trains, which are far more difficult to construct with fixed cylinders and slide-valves. I shall therefore close this part of my work with a description of one or two useful appliances to help him in the manipulative portion of his labour,——for here, as in most other matters, head and hand and heart must work together. The heart desires, the head plans the hands execute. I think, indeed, I might without irreverence bring forward a quotation, written a very long time ago by a very clever and scientific man, in a very Holy Book: "Whatsoever thy hand findeth to do, do it with all thy might." Depend upon it success in life depends mainly upon carrying into practice this excellent advice. If you take up one piece of work, and carelessly and listlessly play at doing it, and then lay it down to being with equal indifference something else, you will never become either a good mechanic or a useful man. If you read of those who have been great men—lights in their generation—you will find generally that they became such simply by their observance of that ancient precept of the wise man. They were not so marvelously clever—they seldom had any unusual worldly advantages; but they worked "with all their might," and success crowned their efforts, as it will crown yours if you do the same.

THIS handybook is intended to supply the information most generally useful to a maker of model engines. It is assumed that some knowledge of mechanical manipulation has been acquired by the reader. He should be able to use the lathe with tolerable certainty of result; in short, the handy-books which I have already produced in this series all form useful guides for the tyro maker of model engines.



Most Inexpensive form of Engine.

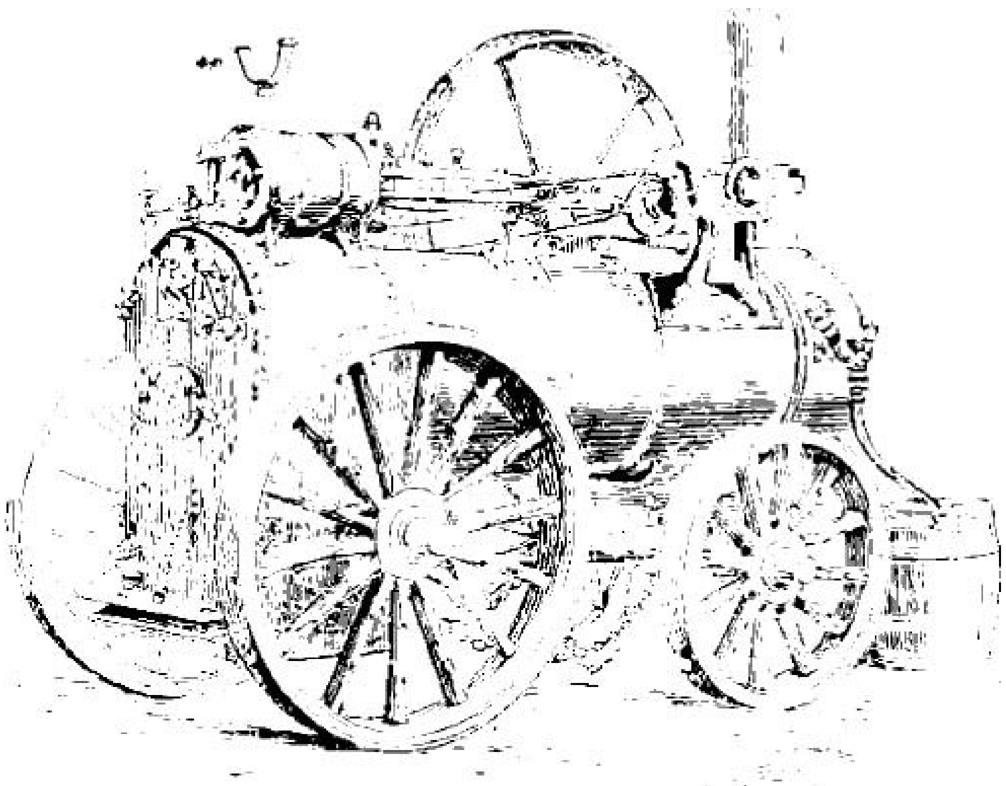
In order to give familiar illustrations of those types of engines commonly forming the stock-in-trade of the usual dealers, the blocks in this chapter have been borrowed from their catalogues. The most inexpensive type of working model is shown at Fig. and is more fully described in a later chapter. A similar engine, but slightly improved in its design, is shown at Fig. 2 on the opposite page.

Engines shown in the later chapters, and all the fittings belonging to them, are mostly original, illustrated from model engines that have been made specially, and which are not commonly to be purchased, either complete or in parts, from the usual trade supplies. Those readers who have acquired some manual dexterity in the use of tools will find little difficulty in making the engines illustrated, if the instructions given are carefully followed. In each case details of each process incidental to our engineering work will be carefully described, so that those even but slightly acquainted with the mechanical arts will be able to comprehend the method of procedure.

One of probably the tiniest working models in the world is in the possession of Messrs. Penn (of Greenwich), the eminent makers of the great engines of which it is the reduced counterpart. It will stand on a silver threepenny-piece; but it really covers less space, for its base-plate measures only 1/8 of an inch by about 3/10. The engines are of the trunk form introduced by Penn. They are fitted with reversing gear, and are generally similar in design to the great engines with which ships are equipped. The cylinders measure 1/8 of an inch in diameter, and the trunk 1/20. The length of stroke is 3/40 of an inch. From the extreme smallness of this model, a few of the most minute details have necessarily been omitted; some of the parts are so small that a powerful magnifying-glass is required to show their form. The bolts which hold the engine together are only 1/80 of an inch in diameter, and these are all duly furnished with hexagonal nuts, which can be loosened and tightened by a Liliputian spanner. The weight of the whole model is less than a threepenny-piece.

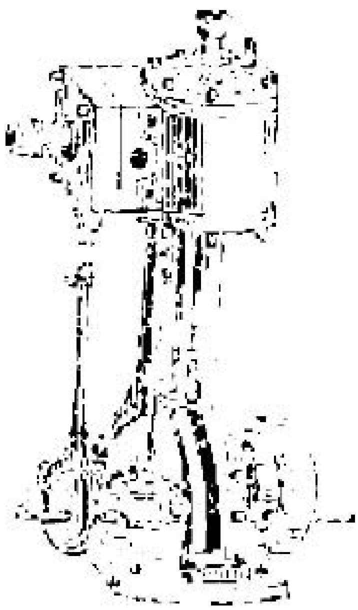
2.
Toy Engine with Oscillating Cylinder.

Another tiny working model is that of the famous *Great Britain* steamship, made to a scale of 1/40 of an inch to the foot. The length of the model is about eight inches, and the breadth about 1 1/4 inch. It is full-rigged, with six masts and their accompanying spars, and has all the hatchways and deck fittings. The deck of this tiny vessel is lifted off and, by the aid of a powerful magnifier, an accurate model of the original engines with which the *Great Britain* was fitted may be critically examined. This model is so small that it stands upon less space than the area of a shilling. The ship may be launched in an annular trough of water, and, when a tap is turned, off goes the tiny ship to circumnavigate its little sea. The total weight of the boat, with deck and rigging, engines, boiler, all complete, is less than an ounce! The weight of the actual working part of the engines—that is, all excepting the boiler—is just that of a sovereign.

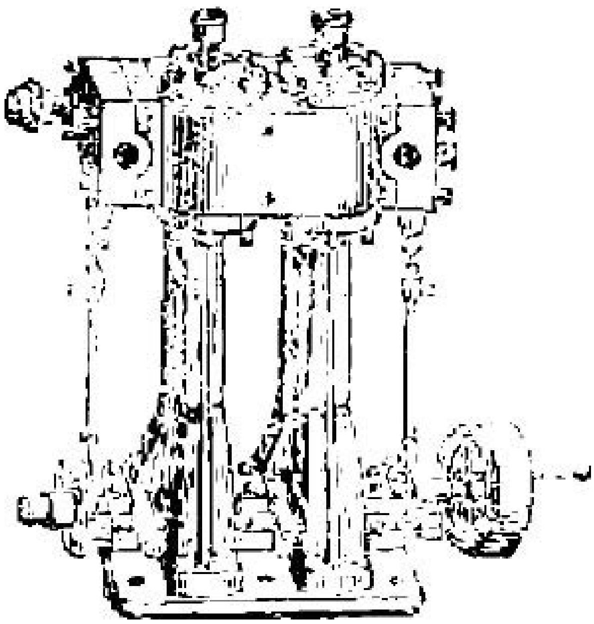


3.
Portable Engine for Agricultural Work.

The varieties of model engines are in many cases indicated by their names, but they may be classed into two principal divisions—those in which the cylinder is fixed, and the admission of the steam is regulated by means of a sliding-valve moving parallel with the piston, and actuated by an eccentric on the crank shaft; and those engines which have the cylinder pivoted at right angles to its bore, so that the rotary motion of the crank, coupled direct with the piston-rod, imparts an oscillatory movement to the cylinder. In this class the steam ports of the cylinder are alternately brought immediately over a hole, through which issues the steam from the boiler, and an exhaust hole, through which the steam escapes from the cylinder. The former are called slide-valve engines, and the latter oscillating engines. There are many varieties of each class, but the difference pointed out is so obviously discernable that it affords a ready means of distinction.



4.
Vertical Launch Engine.



5.
Double Cylinder Vertical Engine.

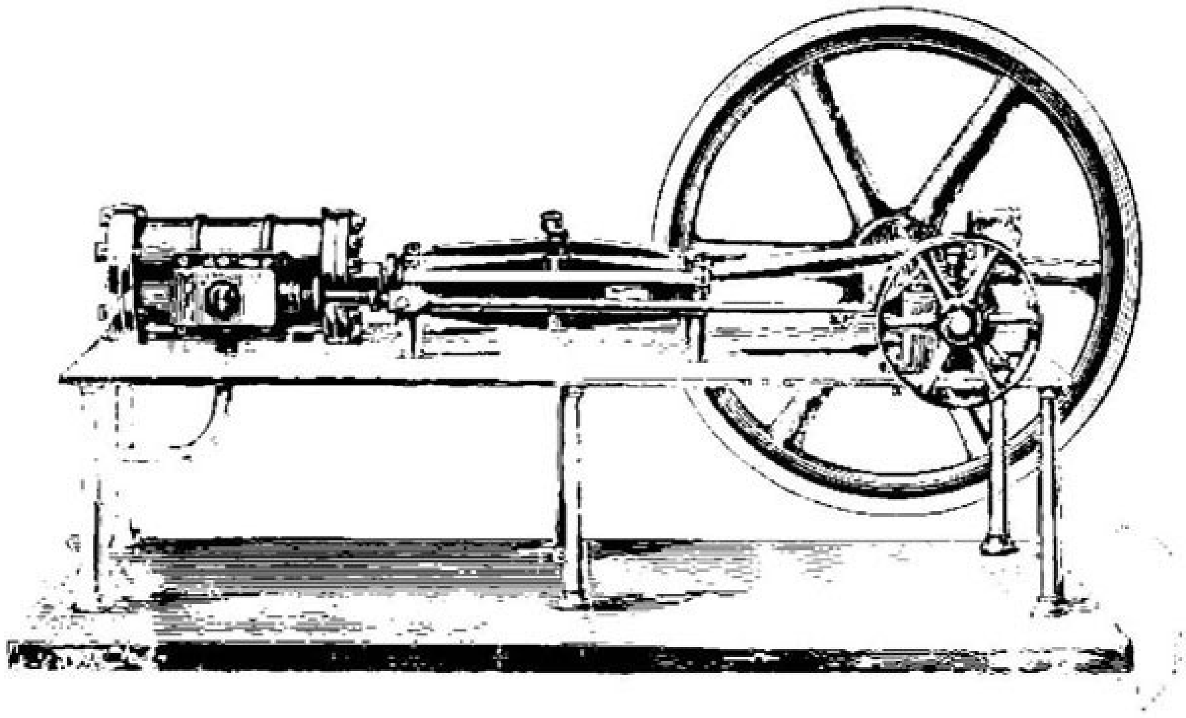
Stationary engines are intended to be fixed, as are those used for driving machinery. Portable engines are so that they may be moved from place to place, and put to temporary work. They are often used for agricultural purposes, such as for driving steam ploughs, thrashing machines, &c. The illustration, Fig. on page 12, shows an engine of this type. It is mounted on wheels, so that it may be drawn by horses along the highway roads.

Locomotives are those which are intended to travel by steam, and are self-moving. Marine engines are those used to propel ships. Figs. 4 and 5 are types. Of these classes we shall, for the present, exclude locomotives, which are much more complicated in their construction and consequently are more difficult to make.

Horizontal engines are those having the cylinder lying with its axis in a horizontal position.

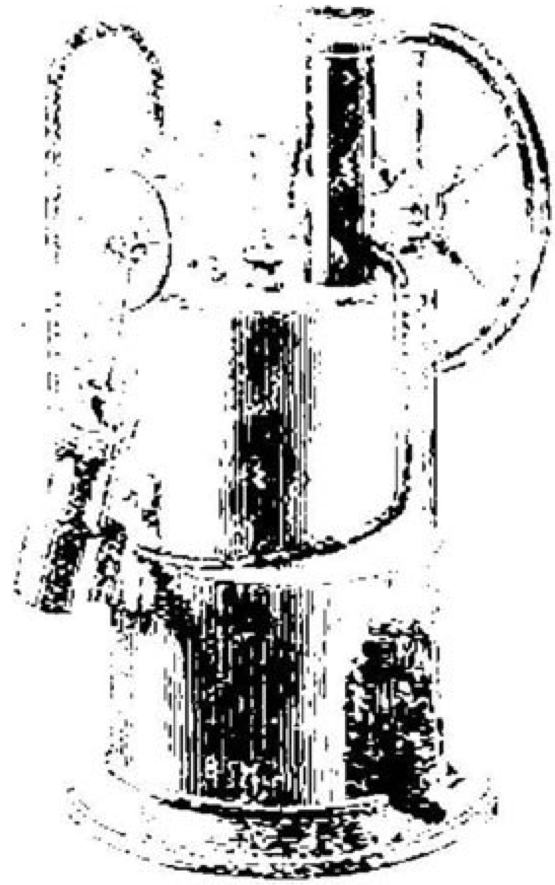
There are many modifications in the designs, but the essential characteristic is that the cylinder be placed with its bore lying horizontally. The illustration on the next page, Fig. shows a horizontal engine of a usual type. The bed-plate is sheet metal, mounted on six pillars, and cut away to allow the crank-arm and cross-head to pass. The six pillars often have their lower ends screwed into a wooden board slightly larger than the metal bed-plate. The crank-shaft carries the fly-wheel at one end, and the belt pulley at the other.

Vertical engines have the cylinder upright; sometimes they are designated by the latter adjective. Beam engines have an oscillating beam, as shown at Fig. p. 19; one end is connected to the piston, and the other to a rod which drives the crank. Cylinders are single-acting when the steam is admitted only at one end, and consequently with these the crank is propelled only during half of its rotation. Double-acting cylinders are provided with valves which admit the steam at each end of the cylinder alternately. Oscillating cylinders are fitted to oscillate with the motion of the crank, see Figs. 43 to 46, and the steam-valves are usually contrived to act by this oscillating motion. Slide-valve cylinders have a sliding valve worked by a rod connected to an eccentric on the crankshaft, which opens the steam poris to alternately admit live steam and exhaust at both ends of the cylinder. Slide-valve cylinders are invariably double-acting.

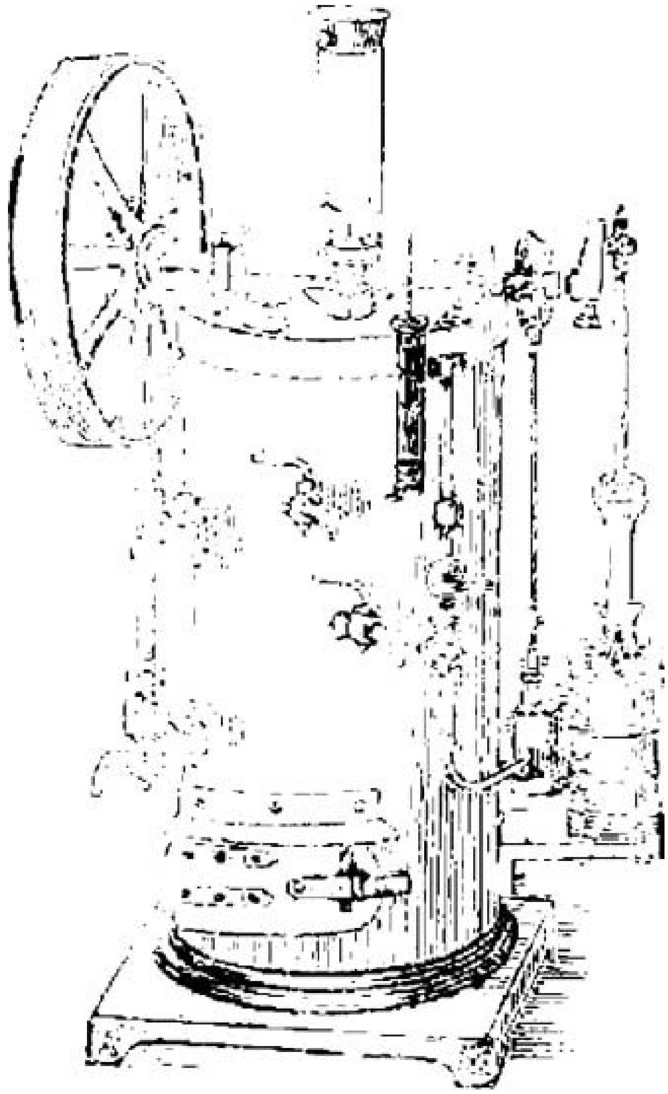


6.
Horizontal Engine.

A semi-portable engine, with oscillating cylinder, is shown at Fig. This is self-contained, and may be moved about, but is not mounted on wheels. A slide-valve cylinder engine of similar design is shown at Fig.



7.
Semi-portable Oscillating Engine.



8.
Semi-portable Slide-Valve Engine.

Small model engines are composed mainly of brass castings, and of steel which requires no special forging for the purpose. The screws or bolts used to unite the parts are usually purchased in a finished state. Makers of these employ machinery, which acts almost automatically, and the screws are sold at a very cheap rate. Large models require special forgings for the crank-shaft, and the castings employed are of iron, which is considerably cheaper than brass.

The castings are made from patterns which are counterparts of the object required. These are imbedded in sand, and leave a matrix, into which molten metal is poured, producing, on solidifying, a facsimile of the pattern. The operation is always carried out in a foundry where the necessary furnaces and moulding appliances are at hand. The founders charge for the rough castings by weight, and the price is reckoned to cover the cost of labour over the value of the metal. It is, however, necessary to supply the requisite patterns before a founder can proceed to do his part of the work.

THE may be consulted in this connection with advantage.

All vendors of castings have patterns from which their castings are moulded, and of course they charge, in addition to the cost of labour and a profit on the cost of the metal, something for the use of the patterns. The patterns for a founder's use require certain modifications, which it is unnecessary to explain in detail. Some are made in two or more parts, with pins to hold them together. Some have projections affixed to them; these make prints in the mould to receive cores, which form holes in the casting. Those patterns which enter deeply into the moulding sand are made tapering, to draw out easily. In all cases they must be made sufficiently large to allow for shrinkage in the metal. Ordinary iron castings shrink about one-eighth of an inch to the foot; brass about half as much again. Pattern-makers use a "contraction-rule" to work by; this is made longer than the standard measurement and patterns made according to it are the correct size to allow for shrinkage. All these details are fully explained in the Handybook above mentioned.

Models are often made with the boilers and engines forming but one machine. Fig. 9 shows an ordinary type of this kind. It is very like the horizontal engine shown on page Fig. but has an oscillating cylinder. A plain cylindrical boiler placed horizontally is let partially through the bed-plate, and the heat is applied by a spirit lamp beneath.

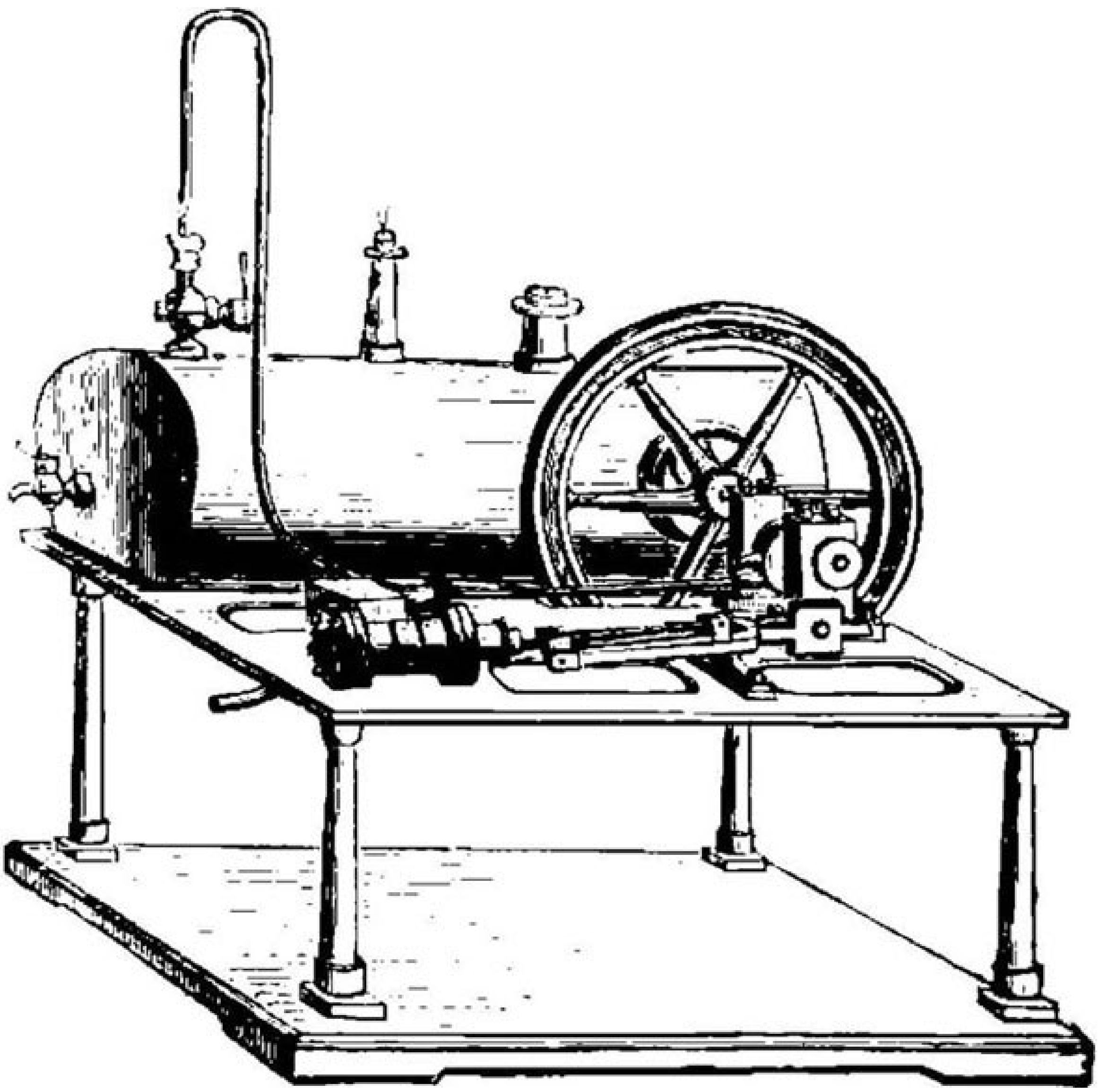
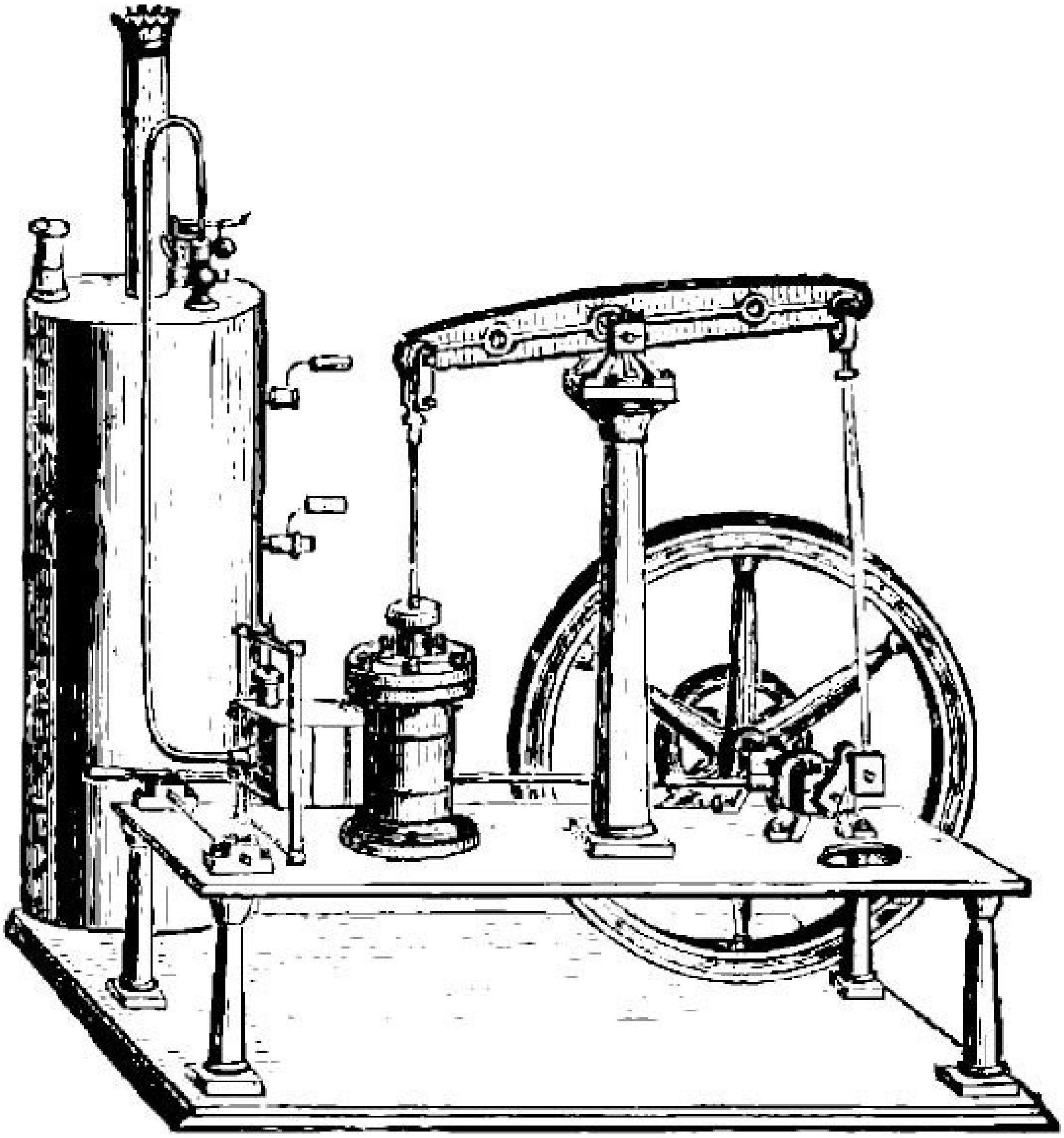


FIG. 9.
Horizontal Engine with Boiler.

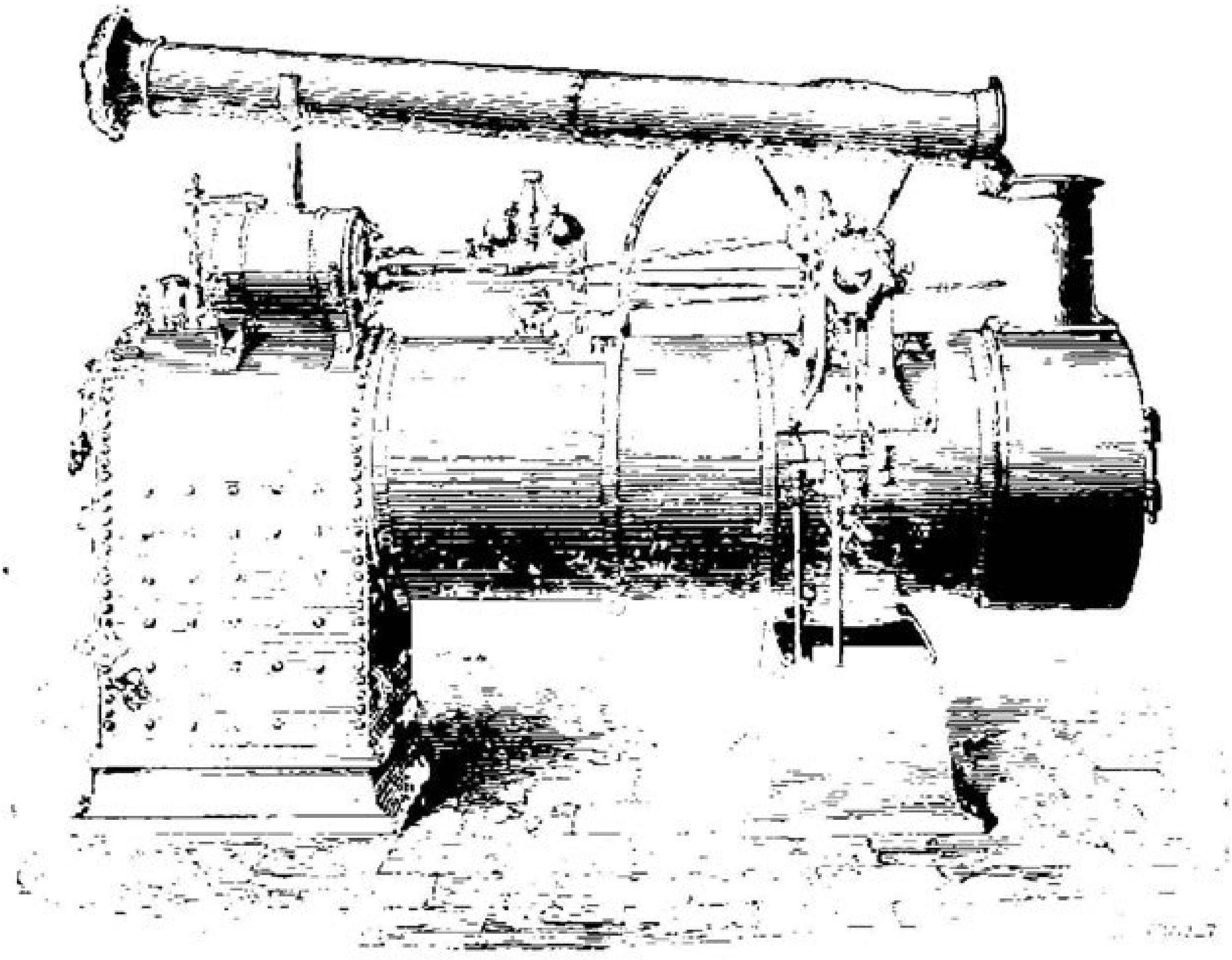
A complete beam engine is shown at Fig. and needs no special description. The boiler of this engine is placed vertically.

From what has been said it will be readily understood that vendors of castings charge various prices for their goods. Not in every case is the quality in accordance with the price, and it is difficult to give even approximate sums that should be paid for good castings. Speaking generally, the price is regulated by the weight, and the rate per pound is decided by the seller. In the catalogues issued by various firms will be found the prices charged. As an example of the difference, a certain size of bolts made by one wholesale firm, are retailed by shopkeepers at rates varying from 33 to 200 per cent. profit; the same rule probably holds good in all other items.



10.
Beam Engine with Vertical Boiler.

Another form of engine, differing from those previously illustrated, is shown at Fig. This type is well suited for model work. The engraving illustrates a semi-portable Robey engine; the smoke-stack is jointed and lowered for travelling. The boiler forms the foundation on which are fixed the cylinder, the crank-shaft bearings, and other parts of the engine.



11. Semi-portable Engine and Boiler.

Those readers who are not possessed of a lathe will not have the means of finishing the cylinders and some other parts which have to be turned. These can, however, be bought in various stages of completion, and the beginner, armed with only a screw-driver, may now purchase the component parts, and, having screwed his engine together, he may claim some merit for his share in the erecting department.

Sets of castings quite finished and ready to be screwed together are now sold. These are generally of the cheaper class, and, tacked on cards, may be seen in the windows of opticians. The prices for the complete engine, with boiler, lamp and all other parts, range from about five shillings upwards.

A few words on the better type of partially finished parts. These castings are more expensive than those quite rough, but they afford an opportunity of displaying considerable skill and judgment in completing them.

Boring the cylinders is the operation most likely to baffle the tyro. This is done by vendors of castings for various prices, according to size, and this charge usually includes turning the flanges ready to receive the covers, and also boring the steam-ways and cutting the port-holes. When all this has been done it will be necessary to use a lathe to turn the covers for the cylinder, and also for making the piston.

The cylinder may be purchased complete with the covers screwed on and the slide-valve fitted. Similarly every piece of an engine may be bought separately in a finished state, so that they only require putting together, and when the young engineer has not the tools required for doing the work, his best plan will be to purchase the finished parts.

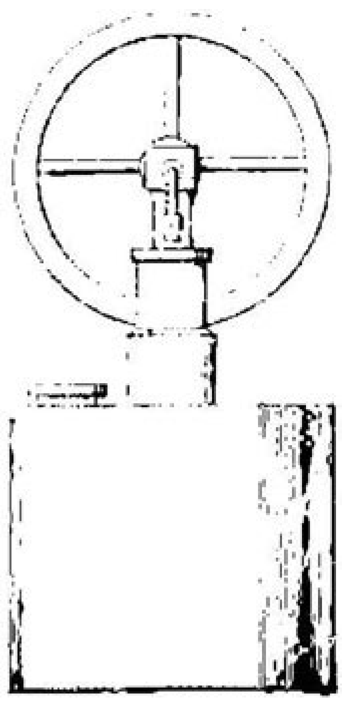
An examination of a finished engine will show that nearly every part of it has been fashioned on a lathe. This machine is indispensable for all kinds of engineering work, but, being somewhat costly, tyros are frequently compelled to forego its ownership, and in this case get the necessary turning executed by a professional latheman. Those who are happily possessed of this king of machines—the father of mechanism as it has been aptly called—will have the advantage of being themselves able to execute the work throughout For want of space we cannot discuss the lathe best suited for the work treated upon in this handbook. There are now many useful lathes manufactured in large numbers, and which may be purchased at a moderate cost. The fitting up of a lathe oneself is not an altogether impossible task, though there is some really very high-class work necessary to produce a good lathe suited for model engine making.

The young beginner should not choose a very small lathe; it is a mistake to suppose that better or finer work can be done on miniature lathes. Three inch centres—that is, a lathe which swings six inches—is the smallest useful size, though one about four and a-half inch centres would be better adapted for model engine making, and a larger lathe is necessary for some of this work. A slide-rest is an almost indispensable adjunct to a lathe required for turning parallel cylinders in metal. By means of a slide-rest, steam cylinders of any diameter of bore, within the capacity of the lathe, can be bored true, but without it a special boring bar is necessary for each size.

THE which is a companion volume to this, contains illustrations and descriptions of many lathes and their appurtenances suited for model engine making. Various chucks and tools employed in this and similar work are also shown in that book.

A few particulars of the different kinds of engines which a beginner may make will assist him in deciding as to the form and size best suited to his requirements. An idea of the general forms and peculiarities of engines may be gleaned from the illustrations already given and from what has been said in this chapter. It is entirely at the discretion of the maker whether he will build a vertical or a horizontal engine —whether it shall have oscillating or slide-valve cylinders, and whether it shall be of microscopic dimensions or a powerful model. All these points are for the consideration of the constructor, though some hints will be of service to and assist him in arriving at the desired result—that is the production of a working model.

THE most simple form of toy-engine is that illustrated below, and fully described in detail in this chapter. It consists of a tin boiler, a single-action oscillating cylinder, and a fly-wheel. These parts are sold, ready for putting together, at a very low price, and a complete engine may be bought for a couple of shillings, though one usually described as of "superior make" at twice that sum is by far a preferable investment.



12.

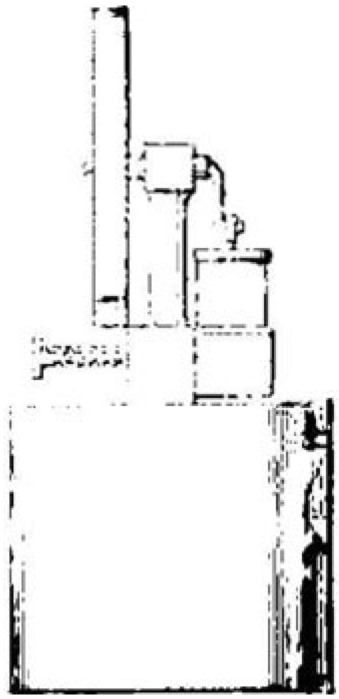
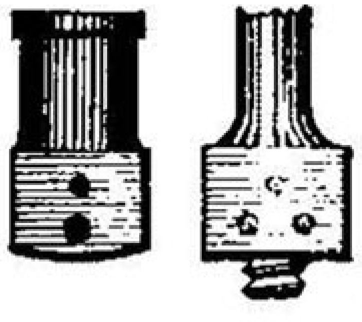


FIG. 13.

Two Views of Toy Oscillating Engine.

The drawings represent the most simple way of constructing a steam-engine, and, if the workmanship is fairly good, a working model will be produced. First is the boiler; a tin box 1 3/4 in. deep and 2 in. in diameter will serve for this. The joint at the side should be made by folding the edges of metal one over the other, and then soldering. The top and bottom are both soldered steam-tight on their respective places. The top of the boiler must be provided with small bosses of metal, soldered on the inner side, into which the pillar and the safety-valve are screwed.



14.
Cylinder and pillar, showing Steam Ports.

The tin plate is not sufficiently thick to afford a hold for the threads on the pillar and on the valve. A disc of brass, say the size of a sixpence, and 1/8 in. thick, is soldered on the under side of the lid, and the holes, which are tapped to receive the pillar and valve, are bored and threaded before the lid is fixed. By this means a strong hold is secured for the fittings. The screw plug in Fig. 12 is similarly provided for. When each piece is screwed into its place, a little hemp or cotton, placed between the shoulder of the "fitting" and the surface of the tin plate, will assist to ensure a steam-tight joint.

The standard, or pillar, is brass, about 2 in. long from end to end. Any form may be given to it, according to fancy, the one shown in Fig. 14 being perhaps as good as any. The lower part is circular, 1/2 in. in diameter, and it has a flat face on one side, against which the valve-face of the cylinder works. Fig. 14 shows this. The centre of the pillar is bored up in the middle of the screwed part to meet *one* of the two lower holes, it is immaterial which. The other hole is bored right through the pillar to the opposite side, and forms the exhaust port, the one communicating with the central hole in the pillar being the steam port. For the sake of distinction we will suppose the hole to the left is bored into the central hole, and that to the right is bored through the pillar; then when the pillar is screwed on to the boiler and steam is generated, it issues from the porthole on the left.

The upper end of the pillar is bored through at right angles to the flat at the bottom (see Fig. Through the top a piece of brass tubing about 5/8 in. long is fixed, generally by soldering; this is the bearing for the crank-shaft. The crank-shaft itself is a piece of steel wire bent to the form required. The fly-wheel is fixed to one end, and prevents the shaft coming out of the bearing, the bend of the arm serving the same purpose at the other end.

The cylinder itself is shown at Fig. and also in Figs. 13 and 13. The piston, piston-rod, and piston-head which fits the crank-pin are shown in Fig. It will be evident that the dimensions of this engine are microscopic. The bore of the cylinder is 5/10 in., and the barrel itself is often made of triblet-drawn brass tube. The enlarged part at the bottom is a casting with a flat face on one side, as shown in Fig. Some makers use a casting for the entire cylinder, but the tube is perhaps the cheaper method of making. A piece of good tube is sufficiently accurate in the bore for use as bought, so that the trouble of boring the cylinder is dispensed with. The base, for the tube to fit in, is bored to the external diameter, and the tube fixed with solder. The lid or cover is fixed only by being snapped on. Its object is only to guide the piston-rod.

Cylinders may be easily bored by the aid of a slide rest, if such an attachment forms part of the lathe available. Failing that, it is advisable to have the cylinder bored by someone having the requisite tools, or to purchase a cylinder casting already bored. A makeshift way of doing the job is to make a bit of the required size and broach out the cylinder. The bit is made of a flat bar of steel made true on the edges, and properly tempered; a bar 1/4 in. thick would do. Pieces of wood are put on both sides of the bar to keep it central and prevent either edge digging in and so spoiling the bore. It is improbable that a satisfactory job would be made by means of this latter arrangement, and one of the methods previously mentioned would be far preferable. Another makeshift would be to solder a piece of triblet-drawn brass tube inside the brass casting.

A reference to Fig. 14 will show the working of the oscillating valve. The face of the pillar is shown on the right. On this, to the left, is the hole from which the live steam issues, and to the right is the exhaust hole through which the dead steam escapes. These holes are technically called ports. The upper hole is bored through the pillar, and takes the trunnion or pin on which the cylinder oscillates. Fig. 13 shows this trunnion pin prolonged and having a nut on the end. A spiral spring around the trunnion, between the nut and the pillar, keeps the valve-face in close contact with the pillar-face. Now, turning to Fig. on the left is the cylinder, with two holes—the upper, into which the trunnion is screwed, and the lower, the steam-way. When the cylinder is in the position shown in Figs. 12 and 13, the port-hole of the cylinder is over the solid metal between the holes in the pillar. On turning the fly-wheel the crank draws the piston-rod out and inclines the cylinder sideways, bringing the port-hole to the left. The live steam from the boiler at once enters and forces the piston upwards, and on the crank reaching the highest point the cylinder is again vertical, and the hole in it is midway between port and exhaust. The momentum of the fly-wheel carries the crank round and brings the hole opposite the exhaust, allowing the steam to escape. The only force that keeps the engine going during this part of the time is the momentum of the fly-wheel. When the cylinder again inclines to the opposite side, the hole comes over the steam-port, and force—in the form of live steam—is again applied under the piston. This series of actions will keep the engine going.

The single-action oscillating cylinder, being supplied with steam at one end only, exerts power only during half the revolution of the crank. The return stroke is dependent entirely on the momentum of the fly-wheel, which also has to drive the dead steam out of the cylinder. Steam acts only in the lower part of the cylinder, and as there is no power tending to force off the cover it may be snapped on like the lid of a pill-box.

The piston has for its head a disc of brass, with a V-shaped groove in its edge. This is packed with hemp or lamp-cotton, to make it fit the cylinder steam-tight. The piston-rod is a steel wire, about 1/16 in. diameter. It is fixed in the piston-head by riveting, to save the trouble of screwing. The end of the rod has a small piece of brass fixed on it, which forms the cross-head, and fits on the crank-pin.

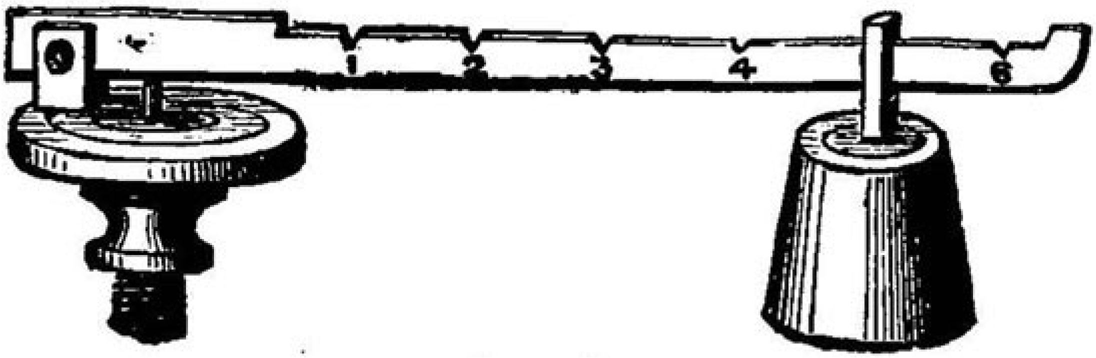
15. Piston.

The crank is itself all in one piece. A straight length forms the shaft. It is bent at right angles to form the throw, and a piece bent from this parallel to the shaft forms the pin. This is the most simple way of making a crank, and when large quantities are made the wire is bent upon a template.

A better type of crank is made by using a steel rod for the shaft, with a brass arm riveted to it, and a steel pin riveted into that. In Chapter IV., on the construction of the horizontal engine, will be found a more complete description of such a crank, and an illustration of it is shown at Fig. 32.

The safety-valve is very important as a safeguard in working. Though sometimes omitted from model engines, yet safety-valves are essential for security. They are intended to allow steam to escape freely from the boiler when the pressure exceeds a certain amount, and thus a dangerous explosion is provided against.

The types of safety-valve are shown in the accompanying figures. The weighted lever is most simple, and best when there is no chance of it becoming useless through, motion. For locomotives and ships a spring safety-valve as shown at Fig. 18 is used, and for models the small spring-valve is used.



16.

Weighted Lever Safety-Valve.

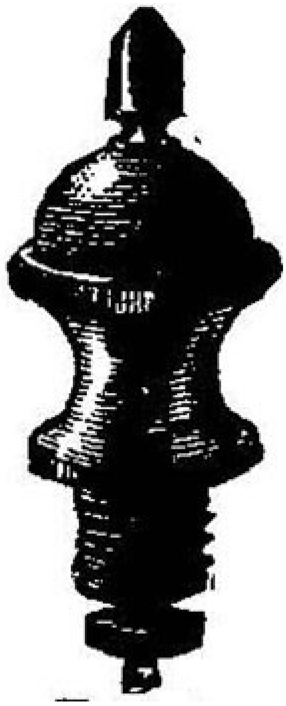
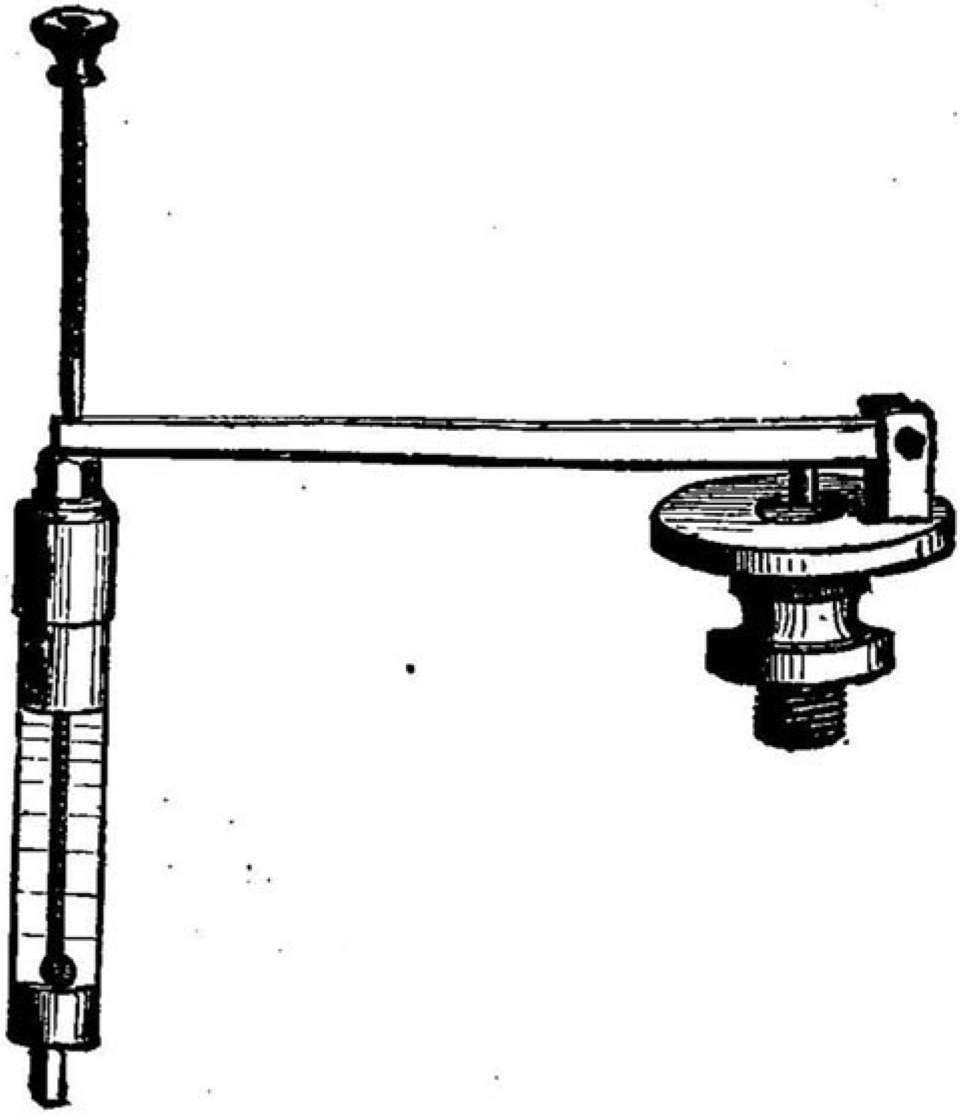


FIG. 17.

Spring Safety-Valve.



18.
Spring Lever Safety-Valve.

The valve used for the toy-engine now being described is illustrated at Fig. It has a spiral spring to keep the valve on its seat. This is effective when the power of the spring has been definably gauged; but when the valves are put together haphazard, no dependence can be placed upon the pressure at which the valve will blow off.

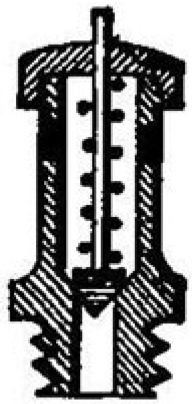


FIG. 19.
Section of Safety-Valve.

The body of the valve is shown in section. The valve is fitted on the rod; it rests on the conical seat of the body, and is pressed down by the spiral spring within the barrel. The body is screwed into the top part of the boiler by the thread at the bottom, and steam, coming up the hole, presses the under side of the valve. When the pressure of the steam is sufficient to overcome the pressure of the spiral spring, the valve is lifted, and the steam escapes through the holes shown at the top of the barrel.

The cover is screwed on the body-part, and confines the spring. It has a hole through its centre, to allow the valve-rod to pass. Especial attention should always be given to the safety-valve at the time heat is applied to the boiler. See that the valve is not fixed to its seat, nor in any way confined, as an explosion may follow if these precautions are neglected.

The engine shown by the illustration is usually mounted on a three-legged stand, which raises it from two to three inches. A wire stand may be made according to fancy, or perhaps some contrivance may be improvised to support the boiler at a convenient height for applying heat beneath. A glance at the illustrations on pages 10 and 11 will show this.

A small lamp, burning methylated spirit—that is, spirits of wine—will supply the requisite heat. It should have a clean and dry wick of lamp cotton. The size of the flame may be regulated to a certain extent by the quantity of wick that is drawn out. The lamp must not be quite filled with spirit: about two-thirds full is ample, and then the spirit will not be liable to overflow when warmed.

When charging the boiler, it is best to use boiling water from a kettle. This will save lots of time that would be lost in heating cold water with the spirit-lamp. The water is poured into the boiler through the water plug-hole The boiler should be only about half filled with water. The plug is replaced, and the lighted lamp put under the boiler, when steam will be generated in due course; and if the flywheel is turned in the right direction by hand for a few turns, the engine will presently work of its own accord.

It is scarcely necessary to repeat that the engine just described is of the most simple description, and every detail not strictly necessary is omitted.