How to Build a Steam Engine

Introduction

Welcome to the ***How to Build a Steam Engine*** session… So you are all budding engineers? The word engineer is derived from the Latin words ingeniare ("to contrive, devise") and ingenium ("cleverness").

To be a proper engineer you need to know A LOT OF STUFF; how to put together machines but also how they work, how they are made and what they are made of. Hopefully today you will learn a bit of all four when building the steam engine.

My name is Simon. My hobby is making small stationary model steam engines like these…..
I do have an engineering degree but I have spent most of my career in computers starting long before smartphones and even the internet – although back then I worked with a lot of stuff that became an important part of modern tech.

What you are here to do today is using the set of parts in the box, build a working model of a steam engine – it would be nice to have a real big steam engine to build but that might take a bit more than an hour to put together. But the model has most of the same parts and works in the same way as the full size engines in the museum.

When you have built the engine you can then test it with the bike pump. Sorry "health and safety" will not let us use live steam for that, but it will show if you have put the engine together properly.

You have a few tools and a diagram and I will of course take you through each step. But listen because I will be giving you a little test at the end of the session to see what you have learned.

[NOTES: Included for information for workshop leader.]

Do's and Don'ts

Fire escapes, etc.

Be careful not to stab yourselves with the screw driver – if something is taking a lot of force you are doing something wrong.

If you are not sure about anything please ask.

Keep everything in the box until needed.

Don't wipe your dirty hands on your clothes – use a rag.

Wash your hands at the end.

A Brief History of Steam Engines

Have you all seen the Newcomen Engine near the entrance? That was a very early steam engine from 1712 and was used to pump water out of underground mines – solving a big problem at the time. This engine works using atmospheric pressure to push a piston.

This is different to later engines like the one you are building which use high pressure steam to push the piston.

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These are a lot more compact and powerful and were used in factories, on the farm, in ships and of course locomotives. Incidentally a lot of people confuse steam engines with locomotives that pull carriages and together form a train.

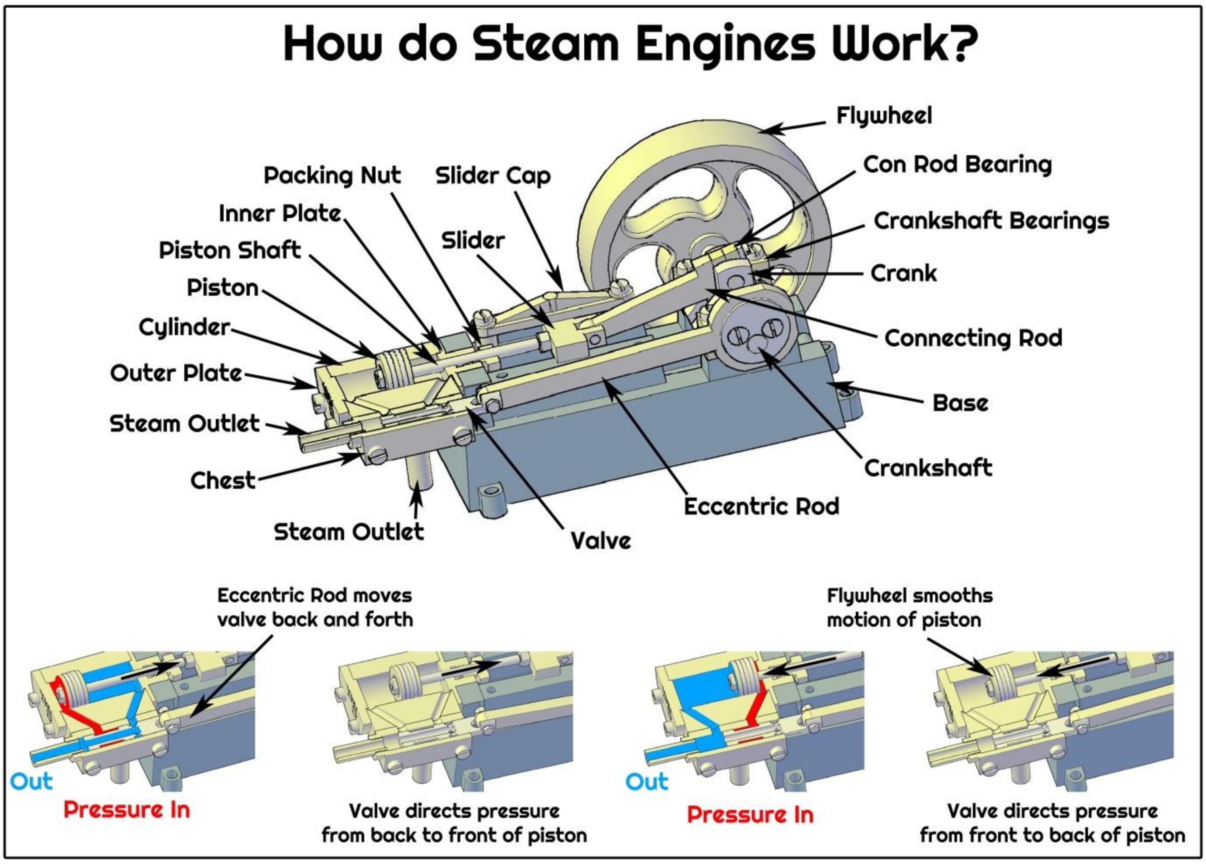
Steam engines of different forms continued to be used in large numbers right into the twentieth century when they were gradually replaced by internal combustion and turbine engines.

How the steam engine works

It all starts with water. Water, when heated, stores latent energy which is then released when it reaches boiling point and is hence converted into steam. If heated in an open container the water boils at 100degC and as water expands when it turns into steam, around half a litre of water turns into nearly 1000 litres of steam (1m cube). In the open this expansive force of steam just escapes freely to the atmosphere without doing any useful work. However, if steam is generated in an enclosed container, a boiler, from which it cannot easily escape, the expansion generates pressure. It is this pressure when the steam is released which is used to drive steam engines.

A pipe is used to connect the boiler to the engine along which the steam flows under pressure to the cylinder. The cylinder is a hollow metal tube inside which is a plunger called a piston.

The steam pressure from the boiler moves the piston, which in turn pushes or pulls a crank which in turn rotates a flywheel. A valve between the boiler and the engine is used to direct the steam alternatively to the front and back of the piston so that the flywheel continues to rotate. The angular momentum of the flywheel moves the piston at the end of its stroke when there is no steam pressure and provides smooth power output to whatever the engine is driving.



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Assembly Steps

NOTE: See document "Mill Single Cylinder Model Steam Engine Assembly Instructions v1.0" for details.

Familiarise yourselves with the parts as shown in the diagram and assembly drawing.

Do you all know how to use a screw driver…..?

- Make use the screw driver tip is engaged right into the screw head and the screw driver shaft is in-line with the screw shaft.
- Make use the screw is straight into its hole not at an angle as this will damage the thread.
- Gently turn the screw driver and "feel" the screw engaging in the hole and being pulled in smoothly.
- In building the engine today you do not need to do any screws up very tight – I'm getting old so if they are too tight I will not be able to undo them later for the next session.

Outline Steps:	***Supplementary Information:***
1. Connecting Rod to Crankshaft	***NOTE: Due to the size of the screws this step can be very fiddley - can be pre-assembled to save time in session.*** Make sure the "T" on the Slider is facing up and the long side of Crankshaft is on the right.
2. Crankshaft to Main (Crankshaft) Bearings on Base	Base – is made by casting, as this is the best way to make complex shapes, then machined for accuracy. The Base is made of steel which is of course very strong and should not wear out very quickly, but it can rust so needs painting. Bearings – cast and then machined. The bearings are made of an alloy called bronze as it has low-friction properties due to its high lead content (lead 6-8%, plus 20% tin, 73% copper), and is the resistance to corrosion. But it is expensive.
3. Piston Shaft to Piston (leave off locking nut)	Piston Shaft – machined. The Piston Shaft is made of stainless steel which is an alloy of steel and 13% chromium which makes is more resistant to corrosion, very important when using with water and steam, and strong for a small moving part.
4. Piston Shaft to Inner Cylinder Plate (leave off Packing Nut and locking nut)	Inner Cylinder Plate - machined. The plate, as other parts, is made of brass, which does not rust like steel. It is also easy to machine being softer than steel. Brass is an alloy made of a mixture of 65% copper and 35% zinc which makes it polish up nicely.
5. Inner Cylinder Plate to Base to Slider	Screw Piston Shaft into Slider through hole in end of Base – screw all the way in but not tight.
6. Cylinder and Outer Cylinder Plate to Base/Piston	Cylinder – cast and then machined in Brass. Look at the holes which supply the steam to each side of the piston as explained earlier.
7. Eccentric Rod to Valve	***NOTE: Due to the size of the screw this step can be very fiddley - can be pre-assembled to save time.*** Eccentric Rod – punched out of 4mm brass sheet and machined. Look how the Eccentric Wheel rotates. This is called a cam and makes the Valve move in and out as explained earlier – so turns rotational into longitudinal movement. Valve – also machined out of stainless steel. This is quite

		complicated as it has to control how steam enters and leaves the cylinder.
8.	Eccentric Rod to Crankshaft (short end)	A grub screw, a special type of screw, is used to secure the Eccentric Wheel to the Crankshaft and is tightened using a Hex or Allen Key (patented by William G. Allen in 1909)
9.	Chest to Valve to Cylinder	Slide the Chest onto the Valve and then screw Chest to Cylinder.
10.	Set Eccentric Rod angle	See assembly drawing. The angle determines when the steam enters the cylinder through the valve, so if it is wrong the engine will not work properly.
11.	Slider Caps and Spacers to Base	***NOTE: Engine will work without fitting the Slider Caps, so can be skipped if time is short.***
12.	Inlet and Outlet pipes to Chest	Stub pipes.
13.	Flywheel to Crankshaft (long end)	A grub screw is used to secure the Flywheel to the Crankshaft. The Flywheel has to be heavy to keep the engine moving smoothly.

Engine Testing

Check the engine rotates freely, adjust as needed and apply a little oil to bearings and slider.

Connect the rubber pipe from the bike pump to the engine inlet. Apply pressure to pump and rotate the flywheel to get it going, keeping pumping and watch fingers.

Final Quiz and Certificate

Questions, can anyone tell me:

1. What is good about steel? …and bad?
2. Why is the Piston Shaft made from stainless steel?
3. What is bronze good at making? What is bad about it?
4. What is good about Brass?
5. What is a good way to make complicated shapes in metal?
6. What can happen if you do not get a screw straight in its hole?
7. How do you tighten a grub screw?
8. What is a cam used to do?

…everyone gets awarded a Certificate.

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APPENDIX – Supporting Information

History of Steam Engines

Have you all seen the Newcomen Engine near the entrance? That was a very early steam engine from 1712 and was used to pump water out of underground mines – solving a big problem at the time. Works using atmospheric pressure to push a piston……

This is slightly different to later engines like the ones you are building which uses high pressure steam to push the piston….. Invented in 1800 by Richard Trevithick.

These are a lot more compact and powerful and were used in factories, on the farm, in ships and of course locomotives – a lot of people say steam engines pull trains but it is of course a locomotive that pulls carriages and together this is a train.

Steam engines of different forms continued to be used in large numbers right into the twentieth century when they were gradually replaced by internal combustion and turbine engines.

How the engine was designed

Design was the first stage and needed to the completed before anything was physically produced.

Based on research into how the engine would work and the necessary parts that would make up the engine, all information from the engineer who designed the parts to the workers who will make it, needed to be detailed. Traditionally this is done using a "technical drawing" which includes precise dimensions of the different parts.

Technical drawing is done using pen or pencil and paper on large drawing boards with rulers, set squares, etc. It is easy to make mistakes in a drawing so they should always be checked by other engineers before any expensive parts are made using the drawings.

Ultimately however the parts need to be made to ensure they fit together and work as envisaged. The initial parts made are called prototypes and are used to make changes or corrections to the drawings. Changes can also be to make it easier for the final production parts to be made. This traditional design process was very time consuming and error prone.

Computers have made a big difference to how designs are produced in particular how the different parts fit together. Parts can be modelled virtually in 3D (3 dimensions rather than the 2 of a paper drawing) and many problems or errors seem by the design engineer before any physical parts are made, hence speeding up the process. The design or CAD (Computer Aided Design) computers can also send information directly to the CAM (Computer Aided Manufacture) computers controlling the machines which make the parts. This also speeds up the process and reduces errors.

The design for the model steam engine used in the workshop, was produced on a computer using AutoCAD software and detailed information about the parts sent electronically to the manufacturer.

How the parts are made

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There are 60 parts in our stream engine, including all the screws, made of different types of metal. Looking at some examples:

- ***Base*** – cast (as this is the best way to make complex shapes), machined on a milling machine, holes drilled and tapped, filed then cleaned and eventually painted. The base is made of steel which is of course very strong and should not wear out very quickly.
- ***Cylinder*** - cast, machined in a milling machine, holes drilled and tapped, bore reamed to size, filed then cleaned and eventually painted. The cylinder is made of brass, which does not rust like steel especially useful when using water and steam. It is also easy to machine being softer than steel. Brass is what is called an alloy being made of a mixture of 65% copper and 35% zinc which makes it polish up nicely.
- ***Bearings*** - cast, machined in a milling machine, holes drilled and bore reamed size. The Crankshaft and Con Rod bearings are made of bronze as it has low-friction properties due to its high lead content (Lead — 6-8%, plus 20% tin, 73% copper). Bronze also has good resistance to corrosion.
- ***Valve and Piston Shaft*** – machined in a lathe and milling machine and holes drilled. The valve is made of stainless steel which is an alloy of steel and 13% chromium which makes is more resistant to corrosion and strong for a small moving part.
- ***Eccentric Rod*** – punched out of sheet, machined in a milling machine and holes drilled. The eccentric rod is made from brass and cut from 4mm sheets.

Casting

There are many different types, the one we used here is called lost wax or investment casting in which molten metal is poured into an expendable (used one) ceramic mould. It is a very old technique going back thousands of years up to today and can produce complex parts which are very accurate, including jet turbine engine blades.

If just one part is needed a copy or “pattern” of the part will be made. The pattern will be like the part we need but is made of wax not metal. Wax is easy to carve and form into the right shape. 3D printing using computers can also be used.

If large numbers of identical parts are needed, which I did, a mould called a “die” is made in low melting point alloy that will allow us to form a wax “pattern” of the part we want to make.

The pattern is surrounded, or "invested", into ceramic slurry that hardens into the mould which is used to form the metal part. Investment casting is often referred to as "lost-wax casting" because the wax pattern is then melted out of the mould leaving the void into which the molten metal is then poured.

Once the metal has cooled and become solid the ceramic mould is broken away to reveal the part. The part will then need to be finished by machining.

Milling Machine

A milling machine is used to very accurately cut metal forming flat surfaces either vertically or horizontally.

The part is fixed rigidly in place on the milling machine's table and a rotating cutter slices thin pieces of metal at a time off from the necessary places on the part. The cutter usually moves up and down as the metal is removed and the table, with the part fixed to it, moves back/forward and from side to side. The cutter may need to make lots of passes across the part removing a thin slice of metal each time, often hundredths of a millimetre, before the part is exactly the correct dimension.

Lathe

A lathe is used to very accurately make round metal parts or cut large holes.

A part is held in a "chuck" which rotates very quickly. A cutting tool which is fixed to the lathe bed is moved backwards and forwards across the part slicing off thin pieces of metal, again often hundredths of a millimetre at a time, until the part has exactly the correct dimension.

Drill

A drill rotates a drill bit which cuts a hole in the part when the bit is pushed onto the metal.

Sheet Punching or Cutting

Some parts can be initially formed by cutting them out of sheets of metal. The punch and die are made of hardened steel in the required shape. The punch is pressed through the metal sheet into the die. A huge amount of force is needed to do this and the press machines can be enormous.