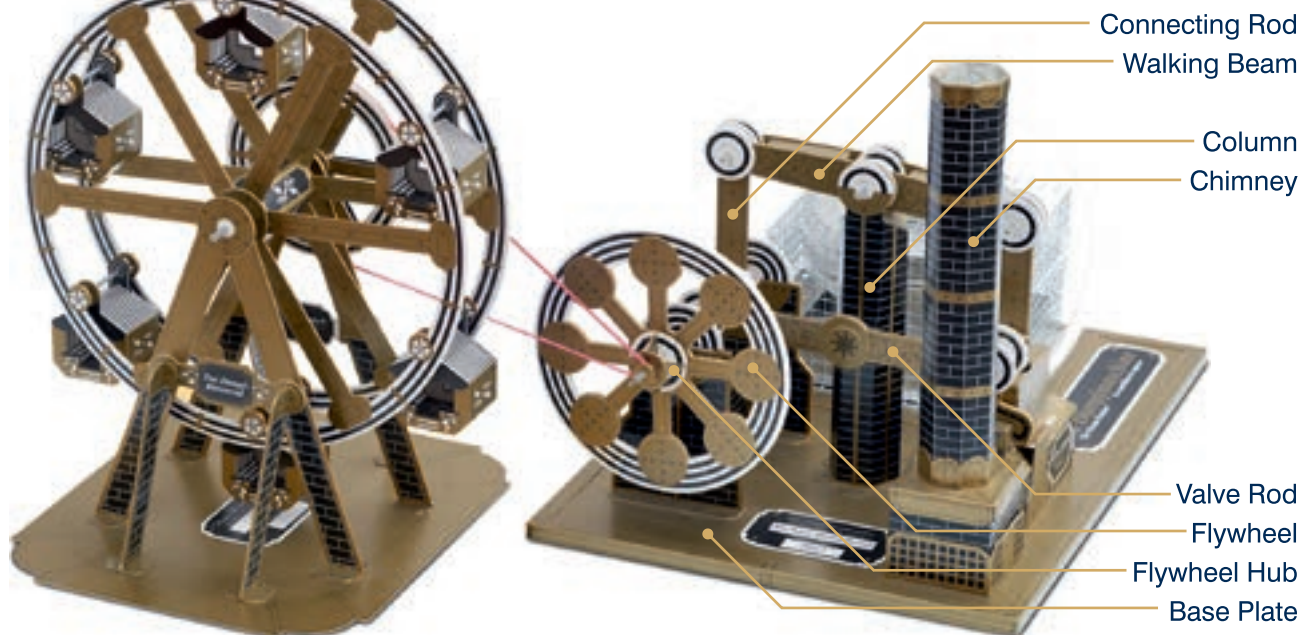
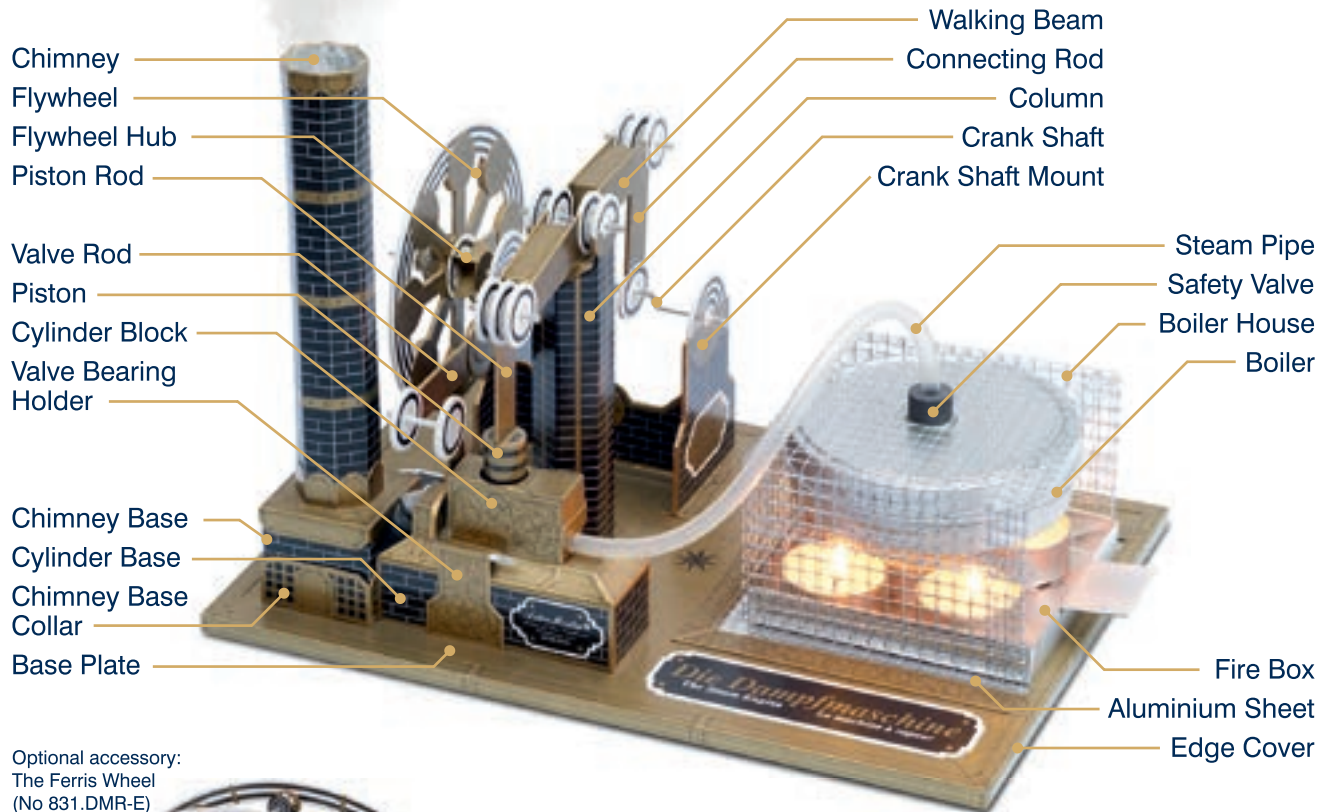


The Steam Engine



AstroMedia

Hands-on Science

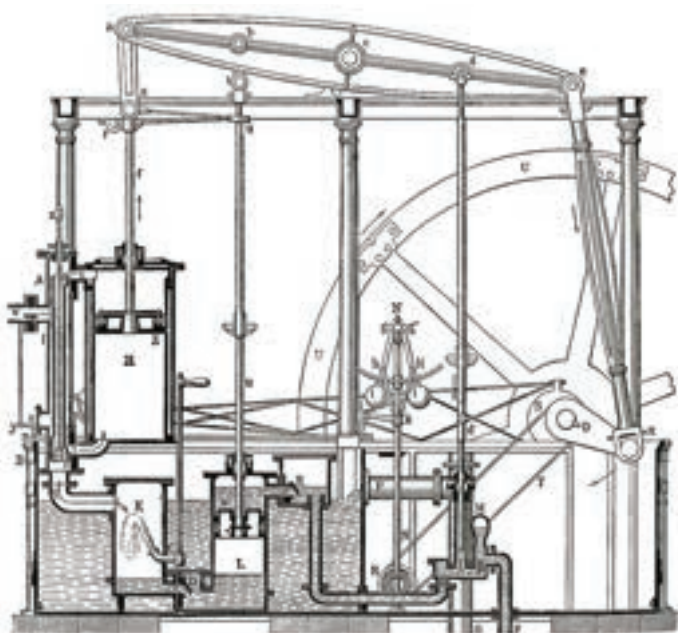
Steam Engines

Most people think that the steam engine was invented by the Scotsman James Watt (1736 - 1819), who received a patent for it in 1769. He indeed invented the crucial improvements that led the steam engine to victory and powered the industrial revolution. But the first useful and fully functional steam engine was invented in 1712 by the Englishman Thomas Newcomen; and even he had predecessors, although their constructions were not successful: his fellow countryman Thomas Savery (1698) who also invented the "horse power", the Frenchman Denis Papin (1690), the Spaniard Blasco de Garay (1543), and of course the Greek Hero of Alexandria (10-70 AD) whose steam powered ball gyro was the model for the AstroMedia Steam Gyro.

The principle of a steam engine is easily explained: steam uses up 1673 times as much volume as the water it was produced from. Therefore a high pressure is built up inside a boiler in which water is brought to the boil. This pressure is used by the steam engine: the steam is channeled into a cylinder with a mobile piston that yields to the pressure and starts moving. This movement is transferred to a flywheel by a connecting rod and can then be used to power all kinds of machinery.

Now you might ask of course whether a steam engine made from cardboard parts is at all possible, considering the known incompatibilities of paper, water, and fire. The answer is this kit: it is possible, providing some heat and water resistant parts are used at critical points of the construction, e.g. the aluminium boiler and firebox, or the steam pipe made from silicone. These parts make sure that the steam, from its production to its release into the air, never comes in contact with the cardboard. A separate, protected firebox, low steam pressure, and a reliable safety valve eliminate possible risks, but keep in mind that steam has a temperature of 100°C and that therefore this steam engine is not a toy for unsupervised children.

Get ready for a very special engineering project... we wish you lots of fun!



Contents:

2 pre-punched sheets of construction cardboard 0.5mm
4 pre-punched sheets of construction cardboard 0.4mm
2 printed but not punched sheets of cardboard
1 sheet aluminium 0.18mm
1 aluminium tin with screw-on lid
1 wire mesh, 220x330mm, welded and galvanised
5 parts made from 1.5mm spring steel:
 1 crank shaft with two cranks, 1 valve bracket
 1 axle 40mm, 2 axles 27mm
15 discs d1.5 x D15mm made from 1mm PVC
3 cotton buds
1 silicone tube d0.8 x D2.8 x 110mm
1 silicone tube d5 x D7 x 275mm
1 plastic glove
1 ring magnet d6 x D16 x H10mm
1 galvanised washer, d8.4 x D16mm
2 x 2 O-rings D6.5mm and D8.5mm
1 hard board plate 6 x 210 x 297mm
1 foam seal 2.5cm
2 syringes 2ml and 10ml
1 template sheet for the wire mesh
1 template sheet for the aluminium sheet
8 One Euro Cent coins

You will also need for assembly:

- * Standard solvent based all purpose glue, e.g. UHU, Evo-Stik Impact, B&Q All Purpose Glue. **Do not use water-based glue:** it softens and warps the cardboard, and doesn't stick properly to the printed surfaces. Solvent based glues also dry much faster.
- * Two-component glue, e.g. UHU Plus Schnellfest or another epoxy based glue, for the boiler, the washer, and the valve bearing.
- * Some sticky tape
- * A sharp knife with a fine point (thin carpet knife, craft knife, scalpel), to cut the thin holding tabs of the pre-punched parts, the cotton buds, and the silicone tube.
- * Strong, but not too large scissors to cut the aluminium sheet.
- * A ruler and a tool suitable to groove the aluminium sheet, e.g. an old biro or a thin screwdriver.
- * A cutting board or mat, made from hardboard, plastic, or wood. Self healing cutting mats are ideal as the material recloses after each cut.
- * A pair of tweezers or small needle-nosed pliers to fit the spacers made from cotton bud tube.
- * A medium sized nail or similar tool to punch a hole into the aluminium tin. Some simple tools to widen this hole (screwdriver, closed scissors, etc).
- * About 50cm of aluminium foil (kitchen foil) to line the chimney as a steam barrier and a broom stick (or something similar) to form a tube from the foil.
- * Some strong twine or a piece of wire to secure the silicone tube on the large syringe.
- * 5 tea lights in aluminium holders (not plastic).
- * One empty aluminium tea light holder to catch the condensate.
- * A lighter to melt the sharp edges of the waste steam tube.
- * For perfectionists: black and golden pens to paint the white edges of the cardboard parts.

Tips for successful construction

Please read before commencing!

1. In order to ensure good results and for straightforward construction, the building instructions have been broken down into **chapters A to V**, which are broken down further into smaller steps. Do not be worried by the long text - it is simpler and faster than it appears and helps avoiding mistakes. Read each step from the beginning to the end before commencing and allow yourself 10-20 hours for the construction (depending on experience). The more care you take, the better the steam engine will work.
2. Every part has its **name** and/or **part number** printed on front or back. The part number consists of a letter and a number: the letter denotes the chapter it belongs to, the numbers denote the order of construction. The part number can be recognized by its rectangular frame, e.g. **G2**. Only remove the parts as you need them.
3. Places needing glue are marked in **grey**. On each of these grey areas you will find a part number followed by an arrow in a square: K2 →
This number denotes the part (or tab of the part) that will be glued in this place. On some grey areas you will find the symbol . This means that the part will be glued to itself on this area. Please keep in mind that the glueing areas are slightly smaller than the parts that will be glued to them. This ensures that grey areas will be completely covered.
4. The cardboard parts that have to be covered with a steam barrier of **aluminium foil** are printed with a pattern of **grey dots**.
5. We recommend that you do not tear the parts out of the cardboard sheet, but cut through the thin **connecting tabs** to make sure that the edges stay smooth.
6. All **folding lines** are pre-grooved, or prepared by short cuts. If they are to be bent "**forwards**", you have to fold them towards you when looking at the printed side of the part. If they are to be bent "**backwards**", you need to fold them away from you. You get a straighter fold if you position the folding line over a sharp edge.
7. **IMPORTANT: Please read the safety instructions in Chapter V before operating the steam engine!**

Building Instructions

Chapter A

The Base Plate

The base plate has a hardboard core that is lined by the two covers [A1] and [A2], and the edge covers [A3] to [A8]. To protect the hardboard plate from the heat of the firebox, the cardboard is replaced by a piece of aluminium in that area.

Step 1: Cut out the white square area including the grey areas for the edge covers from the upper base plate cover [A1, Bogen 7] and put it to the side. The two name plates [A9 and A10] will be cut out and glued on the two grey areas with the same shapes at the very end. Now glue the plate cover onto the hardboard plate, let dry, and cut off any protruding cardboard edges.

Step 2: Glue the bottom base plate cover [A2, Bogen 8] onto the other side of the hardboard plate, let dry, and cut off any protruding cardboard edges.

Step 3: Cut out the template for the boiler house bottom plate from the aluminium template sheet. Fix the template on the aluminium sheet with sticky tape so that one corner of the square lies over one corner of the aluminium sheet. Cut out the bottom plate using scissors.

IMPORTANT: the edges of the aluminium are sharp, so be very careful when handling the aluminium parts!

Tip: you can also use the cut out cardboard piece from the upper cover as template if the cuts are nice and accurate.

Make sure that the aluminium bottom plate fits nicely into the cut out on the upper cover and glue it in place. It should not protrude over the edge of the hardboard plate. Thin gaps between the aluminium and the cardboard do not matter, they will be covered later.

Step 4: Sharply fold back all grooves of the four corner covers [A3 to A6, Bogen 3 + 4]. Then glue them on all four corners of the base plate. The short sides of the base plate are covered completely by the corner covers, on the long sides there is still space for the middle edge covers.

Step 5: The measurements of the hardboard plate can vary slightly. Therefore the middle edge covers [A7 and A8, Bogen 5] are deliberately longer than needed. Sharply fold back all grooves, fit the covers into the gaps by cutting off the same length on both sides, and glue them in place.

Chapter B

The Column

The column stands between the cylinder base and the crank shaft mount and carries the walking beam. In its centre and at the bottom it is reinforced by inner hexagons, at the top it has two fittings for round bearing discs. These will later house the axle of the walking beam.

Step 6: Remove part 1 and 2 of the column [B1 + B2, Bogen 3 + 4] from the sheets, also remove the small discs from the bearing holders, and fold the three long grooves on both parts backwards. Do the same with the two small triangular tabs next to the bearing housing and fold the three small tabs at the foot of the column forwards. Then glue the two parts together along one of the long tabs and after drying along the other one to form a hexagonal column.

Step 7: Fold the six tabs of the inner hexagon [B3, Bogen 3] backwards and, without applying any glue, push it from the bottom into the column, roughly to the middle. For this you can use a pencil or, even better, something thicker, that just fits inside the column. The inner hexagon should not be tilted but should sit at right angles to the wall of the column. Fix it in place by letting some glue drip on its tabs from the bottom of the column.

Step 8: Fold the six tabs of the column bottom [B4, Bogen 4] backwards and glue it, tabs first, into the lower end of the column. The bottom should be flush with the end of the column when stood upright, with the foot tabs spread outwards.

Step 9: Remove the round cardboard discs from the bearing housings 1 and 2 [B5 + B6, Bogen 1] and glue the two housings exactly back to back. Do the same with the bearing housings 3 and 4 [B7 + B8, Bogen 2]. Now the bearing housings have exactly the same thickness and diameter as the PVC bearing discs. Place the housings on your work space and press one of the bearing discs into each of the housings.

Make sure that the discs are completely flush with the cardboard on both sides. You might have to push them in a little with a hard object, e.g. a spoon.

Step 10: Glue the two bearing housings with the fitted bearing discs flush onto the inside of the bearing holders at the top of the column.

Step 11: The top cover [B9, Bogen 5] closes the opening at the top of the column. Fold the grooves at the two triangles backwards and the other two grooves forwards. Try to fit the cover first without applying any glue to check that it fits properly. The two round bits are parts of the bearing housings and cover the bearing discs, apart from an 8mm large opening in the middle. The triangles of the cover fit exactly onto the small triangular tabs of the column. Now glue the cover into this position.

Do not glue the column onto the base plate yet!



Fig 1: Cross section of the walking beam connecting piece

Step 15: Glue the two connecting pieces with their sides onto the glue markings of one of the beam parts, taking care to leave at least 2mm distance to the bearing covers at the ends of the beam. Then glue the other beam part on top, making sure that they are exactly on top of each other by pushing their edges against your worktop before the glue sets. Important: the holes in the bearings have to be exactly opposite each other, so the axles will be at right angles.

Step 16: Take off the head of one of the cotton buds and cut off six pieces of 4mm length from the plastic tube. Two of these are used as spacers for the beam axle, the other ones will be used later for the axles of the piston rod and connecting rod. Also cut off six pieces of 6mm length from the thin silicone tube as axle end stops. These will be used to secure the axles in their bearings. The end stops have an inner diameter of only 0.8mm and will therefore hold nicely on the axles, but will still be movable. Again we only need two of them now, so save the other ones for later.

In the next step the walking beam will be fitted to the bearings at the top of the column using the 40mm long axle made from 1.5mm spring steel. Important: one edge of the walking beam is straight, the other one forms a narrow triangle. This edge has to be at the top, the straight one at the bottom. The bearings at the ends of the beam will then be slightly lower than the ones in the middle (see front picture). Fig 2 shows how the walking beam, the spacers, and the end stops are arranged.

Step 17: First push one of the end stops on the 40mm axle until it is flush with the end. Hold the axle at this end and push it from the outside through one of the column bearings. Fit a spacer on the axle before pushing it through the two middle bearings of the walking beam. With the help of tweezers or needle-nosed pliers fit another spacer between the walking beam and the other column bearing, push the axle through and secure it with a second end stop. Check that the beam moves freely without friction on the axle. It also needs to be able to move a little bit sideways.

Tip: If you have problems fitting the second spacer you can carefully bend the column bearing to the side until you can reach in between and slip it over the axle.

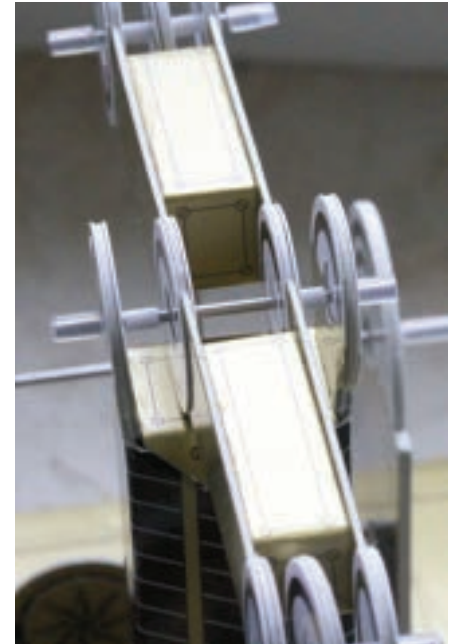


Fig 2: Mounting of the walking beam on the column

Chapter C

The Walking Beam

The walking beam is the central power transmitting element of the steam engine. On its one end it receives the push of the steam on the piston through the piston rod. On the other end it passes this power through the connecting rod on to the crank shaft. Its bearing on the top of the central column has extremely low friction, as is the case with all other bearings in this kit.

Step 12: Remove and discard the discs from the holes in the beam parts 1 and 2 [C1 + C2, Bogen 1] and glue them accurately back to back. Then glue three bearing covers [C5 to C7, Bogen 3] on one side of the beam and press three bearing discs into the openings from the other side, again making sure that the PVC discs are flush with the cardboard. Then glue three more bearing covers [C8 to C10, Bogen 4] onto the bearings to enclose the PVC discs apart from the 8mm openings on both sides.

Step 13: Repeat step 12 with the beam parts 3 and 4 [C3 + C4, Bogen 2] and the bearing covers [C11 to C16, Bogen 6].

Step 14: Fold all grooves of the two beam connecting pieces [C17 + C18, Bogen 5] backwards. Glue them each into a four-cornered trapezoid by winding them in a spiral as shown in Fig 1. The edges have to be completely flush.

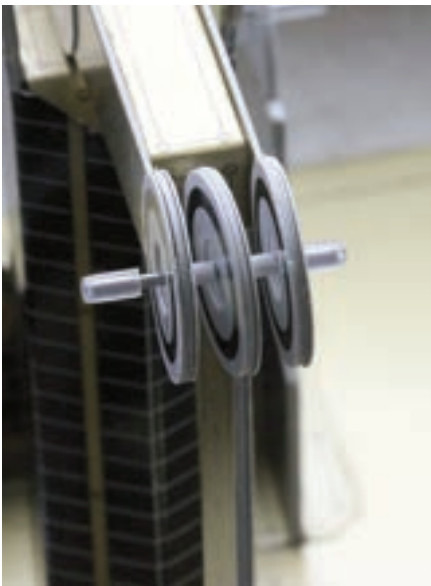


Fig 3: Mounting of connecting rod and piston rod on the walking beam

Chapter D

The Connecting Rod

The connecting rod transfers the power from the walking beam to the crank shaft. Its upper end is pushed down by the walking beam each time the piston is pushed upwards by the steam. The lower end of the connecting rod is fitted to one of the cranks of the crank shaft and so converts the linear downward movement into rotation.

Step 18: Glue the two inner parts of the connecting rod [D1 + D2, Bogen 1 + 2] back to back and push a bearing disc into each of two holes.

Step 19: Glue the outer parts of the connecting rod [D3 + D4, Bogen 6] on both sides.

Step 20: Take one of the two 27mm axles and fit one of the end stops to it. Push the axle through one of the bearings at the end of the walking beam, and then through a spacer made from the cotton bud tube. Now push the axle through one of the connecting rod bearings, add another spacer, push it through the other walking beam bearing and fit a second end stop. Check the bearing for frictionless function, the connecting rod is fitted correctly when it shows a bit of play and can also be slightly twisted sideways (Fig 3).

Chapter E

The Piston and Piston Rod

The piston is made from cardboard and should therefore not come into direct contact with the steam. The steam is piped through the steam bellows on which the piston sits loosely. The steam bellows is inflated periodically and pushes the piston upwards each time.

Step 21: Glue the inner parts of the piston rod [E1 + E2, Bogen 1 + 2] back to back and push a bearing disk into the hole.

Step 22: Glue the outer parts of the piston rod [E3 + E4, Bogen 6] onto the sides. The slits at the bottom of the piston rod should be completely flush.

Step 23: Glue the two inner parts of the piston mount [E5 + E6, Bogen 1 + 2] back to back and then the two outer parts [E7 + E8, Bogen 6] onto the sides. Again make sure that the slits are completely flush.

Step 24: Slide the piston mount into the slit of the piston rod and glue it in place. The cross section of mount and rod now forms a cross and they should be



flush at the bottom.

Fig 4: Piston rod and piston

Step 25: Bend the piston [E9, Bogen 6] into a round tube. You can either carefully pull the part over an edge, or wind it tightly around a pen. Then glue the connecting piece [E10, Bogen 6] halfway behind one edge of the piston

and after the glue has set, also behind the other edge to form a closed round tube. Let the piston dry thoroughly and then slide it about halfway onto the mount at the end of the piston rod. The piston should stick nicely without any glue; if it is too loose, you can try bending it a bit to make the fit slightly tighter.

Important: The piston should not be glued on yet because you need to be able to adjust its height for optimal function. If at all, it will only be glued into place at the very end of construction.

Step 26: Glue the piston bottom [E11, Bogen 6] on the bottom of the piston to close it on this side. The two parts of the piston top [E12 + E13, Bogen 6] will only be glued on at the very end, when the position of the piston is adjusted properly.

Step 27: Fit the piston rod to the other end of the walking beam, the same way you fitted the connecting rod.

Don't glue the column into its place just yet. First we need to construct the cylinder.

Chapter F

The Cylinder Base

The cylinder base forms a stable basis for the cylinder, raising it high enough to make sure the condensate can drain properly. Its side facing the boiler is closed, the opposite side, facing the chimney, is open. It is reinforced by two internal walls [F2 to F5, Bogen 3 + 4].

Step 28: Fold all grooves of the cylinder base [F1, Bogen 5] sharply backwards and glue the tabs of the end wall onto the inside. Now the cylinder base has the same cross section as the internal walls.

Step 29: Glue the internal wall parts 1 and 2 [F2 + F3, Bogen 3] back to back, do the same with the parts 3 and 4 [F4 + F5, Bogen 4]. Then glue the two walls into the base, roughly at the positions indicated by the glue markings, making sure they are fitted at right angles. Also take care that their upper edge is glued in properly.

Step 30: Now glue the cylinder base as

Chapter G

The Cylinder Block

*The cylinder block contains the steam bellows which is pumped up and de-
flated rhythmically and in this way turns the thermal energy of the steam into kinetic energy. On the outside of the cylinder block is the bearing for the valve that opens and closes the bellows and therefore governs the bellows' movement. The cylinder block consists of two parts: an internal part, that is built and glued into its place on the cylinder base first, and an external part, which forms an outer shell. On its upper side is the hole for the piston and the cylinder lid that can be opened to gain access to the internal parts.*

Step 31: Remove the small round disk from the cylinder block [G1, Bogen 6] and fold all grooves backwards. You can already see that the inside is grey.

Step 32: On the inside of the cylinder there is a rectangular, grey curled area for the valve abutment made from a piece of foam draft excluder. Cut off a sufficiently large piece, remove the plastic strip from the double sided sticky tape, and glue the foam into place.

Step 33: Glue the two parts of the inner rails 1 and 3 [G2 + G4, Bogen 1] back to back, do the same with the inner rails 4 and 6 [G5 + G7, Bogen 2], and also with the dividing wall [G8 + G9, Bogen 3 + 4]. Put these parts to the side for a moment.

Step 34: The front side of the inner cylinder block, recognisable by the 7mm hole for the steam pipe, has a glue tab on each side. Glue the inner rails [G3 + G6, Bogen 1 + 2, not the double ones you just made] on the backs of these tabs. Then glue the tabs onto the grey marked glue areas on the inside of the cylinder block. On the opposite side of the cylinder block, glue the gold printed bracket and the grey holder for the waste steam pipe in their respective places. You will now have a narrow, long box with an open top, dark grey on the inside.

Now the double inner rails from step 33 will be fitted. The slit that is formed will later hold the dividing wall which holds the steam pipe in place.

Step 35: Next to the glued-in tabs of the front side of the cylinder are the glue marks for the double thickness inner rails [G2+4] and [G5+7] from step 33. The small gap denotes the slit for the dividing wall [G4+9]. Glue the two inner rail in place and check that the slit is just wide enough for fitting and removing the dividing wall. The wall

should not be glued in place, it needs to be removed later to fit the steam pipe. Leave it in place for the moment.

Step 36: Glue the inner cylinder block onto the cylinder base. The gold printed front side with the 7mm hole for the steam pipe should face the aluminium sheet. The other side with the holder for the waste steam pipe should be exactly flush with the edge of the cylinder base.

Now the outer cylinder block [G10, Bogen 6] will be fitted like an outer shell. On its top it has a hole in which the piston can move up and down and next to it the cylinder lid, a flap with a strap that allows access to the cylinder.

Step 37: Remove the outer cylinder block [G10, Bogen 6] from the cardboard sheet, remove the round disc, and put it in front of you the way it was oriented in Bogen 6: the gold printed side on top, the hole for the cylinder in the middle closer to you, and the grey area with the glueing instructions for part G11 (the valve bearing holder) pointing to the right. Fold the following parts forwards along the grooves: the big flap with the angled corners on the left, the similar but shorter flap on the right hand side, as well as the part below which, next to a further groove, holds the grey valve bearing holder. Also folded forwards is the groove above the round piston hole. All other grooves are folded backwards.

Step 38: Without any glue, put the outer cylinder block in its position over the

inner cylinder block. The correct position is given by the grey glue markings on the cylinder base. The grey lug that will receive the valve bearing holder in the next step, forms a short gold and grey horizontal platform, with the edge of the lug resting on the base plate. On the left the inner and outer cylinder block are completely flush, on the right the cylinder lid is constructed. It allows access to the dividing wall and its angled flap can be stuck under a narrow strap. Now you can glue the outer cylinder block in place. Pull the strap around the front side and glue it in place with enough space to be able to stick the flap of the cylinder lid behind it.

Step 39: Glue the valve bearing holder [G11, Bogen 6] onto the grey lug. It is slightly higher than the platform, so the valve bearing can be glued into the so formed corner.

Step 40: Fold the two inner grooves of the waste steam pipe holder [G12, Bogen 6] backwards, the two outer ones forwards, and glue the part on the grey bracket of the inner cylinder block.

Step 41: Now you can glue the column on its grey glue markings on the base plate. The walking beam must be exactly parallel to the short sides of the base plate. The piston enters the hole in the cylinder block, the connecting rod faces the side of the crank shaft mount.



Fig 5: Inner cylinder block

Chapter H

The Valve

The function of the valve is to rhythmically close and open the steam bellows. It consists of a piece of steel wire that is bent threefold at right angles and is covered with cardboard. The valve bearing, a piece of cotton bud tube, needs to be glued in place by 2-component glue, since normal glue doesn't adhere to this kind of plastic. To save having to mix the glue twice, the construction of the boiler will be done at the same time.

Step 42: Glue the two inner parts of the valve [H1 to H4, Bogen 6] exactly on top of each other, making sure that the slits are exactly flush. Then glue this block onto the back of the outer valve part [H5, Bogen 6], thereby forming a groove on the underside of the valve.

Step 43: Take a closer look at the threefold bent steel wire. The three bends divide the wire into four parts: two middle parts and two end parts. The two end parts point into opposite directions, and one of them is quite a bit shorter than the other one. Stick this shorter end from the back through the small hole in the round part of the other outer valve part [H6, Bogen 6]. Then, first without glue, place this part onto the the part from the last step. The two middle parts of the wire should sit nicely in the slit and the groove. Now glue the parts together in this position.



Fig 6: The valve

Step 44: Cut off a 20mm long piece of cotton bud tube and place it in the corner between the valve bearing holder and the cylinder block.

In the next steps the boiler is prepared for glueing with the 2-component glue. For this you need to drill a hole into the lid, which is easily possible without special tools because of the soft aluminium it is made of.

Step 45: Make sure to take any paper or Put the lid of the aluminium tin, from which the boiler will be made, with the opening downwards on your work surface and, using a ruler, find the centre of the lid as accurately as possible. Now drill or push a hole into the lid in this position. You can use a drill, a bodkin, or a medium sized nail, etc to make this hole. Then widen the hole to a diameter of at least 9mm, using a suitable implement, e.g. closed scissors or a screw driver. Of course you can drill the hole with an electric drill as well.

Important: To check the size of the hole put the washer over the hole: the hole in the lid should be slightly bigger than the hole in the washer.

Step 46: Put the lid on your worktop with the opening facing upwards. Mix a sufficient amount of 2-component glue and cover the inside of the lid thread with the glue. Then glue the tin together, to make sure that the glue is distributed evenly between lid and bottom of the tin.

Step 47: Turn the tin around, cover one side of the washer with glue and glue it over the hole. If necessary, slightly roughen the bonding surfaces with sandpaper. If the washer is slightly concave, glue it on with the rounded side upwards. The upper side of the washer should not receive any glue, otherwise the magnetic safety valve will not seal properly.

Tip: After the glue has set you should check whether the boiler is airtight. Press your lips on the tin and blow into the hole. Top and bottom of the tin should bulge slightly outwards, but no air should escape through the thread. If you want to test the safety valve, put the ring magnet on the washer first.

Step 48: Finally put some 2-component glue on the 20mm cotton bud tube to secure it in the corner of the valve bearing holder and the cylinder block. It has to touch the valve bearing holder on its whole length and should not stand out on either end. Take care that no glue reaches the openings of the tube. Let the glue set properly before carrying on.

Step 49: Push the 29mm long axle of the valve through the valve bearing and make sure that it can move freely. Cut off a 2mm long spacer from the cotton bud tube and push it over the end of the axle. Secure it with a 6mm long end stop made from silicone tube.

Chapter J

The Valve Rod

The valve rod is the central controlling element of the steam engine. It is

moved back and forth by the crank shaft and has to shut and open the valve at the right moments. If it is too short, the valve will seize, if it is too long, the valve will not properly close the steam bellows. Therefore the valve rod can be adjusted in length. It consists of two parts that can be pushed into each other: a tongue and a pocket part. With these you can find the length of the rod with which the engine runs best. If at all, these two parts are only glued together when the steam engine is fully adjusted.

Step 50: Glue the two inner parts of the valve rod tongue [J1 + J2, Bogen 1 + 2] exactly on top of each other and push a bearing disc into the hole after the glue has set. Then glue the two outer parts [J3 + J4, Bogen 6] on the sides.

Step 51: Remove the two inner parts of the valve rod pocket [J5 + J6, Bogen 1 + 2] from the sheet of cardboard and put the two small cover discs [J11 + J12] on the side for later. Glue these two delicate parts on top of each other, making sure that no glue seeps into the pocket. Push a bearing disc into the hole and glue the two outer parts [J7 + J8, Bogen 6] on top of both sides. Again make sure that no glue seeps into the pocket. Let dry properly and then test that the tongue fits nicely into the pocket and can be moved back and forth. You might have to pinch the tip of the tongue slightly so it is easier to fit. The tongue can be a bit tight, but should not seize completely.

Tip: If the tongue moves too easily you can cover one side thinly with glue to make it slightly thicker. Of course the glue has to set fully before you push it back into the pocket.

Step 52: Pull the tongue back out and glue the two cardboard discs [J9 + J10, Bogen 1 + 2] on the round parts at the end of the pocket, so that the holes come to lie over the opening of the pocket and you can look right through them. Again, no glue should seep into the inside. The holes make it possible to apply glue on the tongue once the correct length is found. If the tongue sits tight enough inside the pocket you don't have to glue it in, of course. The holes are covered by the cover discs [J11 + J12] at the very end of the construction.

The valve rod will be adjusted and connected to the valve after crank shaft and flywheel are mounted.

Chapter K

The Crank Shaft Mounts

The two crank shaft mounts are connected by a middle part that gives the necessary support and ensures the accuracy of the distance between them. The mounts carry the crank shaft bearings, which have tongues sticking out from the underside. These tongues fit into pockets inside the top of the mounts. This way it is easy to dismantle the crank shaft for adjusting or maintenance.

Step 53: Glue the two inner parts of the crank shaft mount [K1 + K2, Bogen 1] back to back. Take care that no glue seeps into the pockets for the bearings.

Step 54: Fold the foot tabs of the outer parts of the crank shaft mount [K3 + K4, Bogen 3] outwards and glue them flush onto the inner part.

Important: Take care that no glue seeps into the pockets for the bearings.

Step 55: Repeat the last two steps with the other crank shaft mount [K5 + K6, Bogen 2, and K7 + K8, Bogen 4].

Step 56: Fold all tabs of the two middle parts [K9, Bogen 3, and K10, Bogen 4] forwards and glue the parts back to back.

Step 57: Push one crank shaft mount with splayed foot tabs firmly on your worktop. On one side the foot tabs are separated and form a gap. Put the middle part down as well and push it into this gap so that its glue tabs cover the grey gluing areas on the mount. Glue the middle part in this position and then do the same with the other crank shaft mount.

Step 58: Now glue the complete crank shaft mount in its position on the base plate indicated by the grey glueing marks.

Step 59: Remove the two small discs with the star logo [K11 + K12, Bogen 1 + 2] from the flywheel parts and glue them on their markings on the middle part of the mount.

Chapter L

The Crank Shaft Bearings

Step 60: Glue the inner parts of the crank shaft bearing [L1 + L2, Bogen 1] back to back and push a bearing disc into the hole. Then glue the outer parts [L3 + L4, Bogen 3] on both sides. The crank shaft bearing now looks like a half circle with two tongues sticking out from the straight side.

Step 61: Construct the other bearing the same way from its inner and outer parts [L5 + L6, Bogen 2, and L7 + L8, Bogen 4].

Step 62: Let the bearings dry thoroughly and then try fitting them to the crank shaft mount. They should not sit too loosely, otherwise they might be pulled from their pockets by the moving walking beam. On the other hand they should not fit too tightly either, or they might get bent when fitted.

Tip: When the tongues are too loose, you can also thicken them slightly by applying some glue to their surface.

Chapter M

The Flywheel

The flywheel is needed to bridge the phases without power that last approximately half a turn. When the piston is pushed upwards by the steam pressure it gains rotational energy, part of which is then used to push the piston back down for the next stroke. To increase the usable rotational energy, the flywheel houses 8 metal weights (e.g. coins) because the cardboard doesn't provide enough mass on its own. Ideally use 1 Euro Cent coins, but of course other coins, washers, etc can be used as well, as long as their weight is comparable. By-the-way, it is not illegal to use legal tender for this: you are not destroying the coins, you are just hiding them in a safe place!

Step 63: Remove the two inner parts of the flywheel [M1 + M2, Bogen 1] from the cardboard sheet and discard the empty discs and bits of cardboard between the spokes, as well as the tiny bit from the hole in the middle. Retain the hub cover 1 [N9] for later use.

Step 64: Remove the superfluous bits from the outer flywheel parts [M3 + M4, Bogen 2], retaining the hub cover 2 [N10] for later use. Glue the outer parts flush on the inner part from the last step.

Step 65: Glue the cover plates 1 to 8 [M5 to M12, Bogen 3] over the holes of one side of the flywheel. The edges of the covers should be flush with the curved parts of the spokes.

Step 66: Put the flywheel on your worktop with the open holes facing upwards. Glue one coin into each of the holes and cover them with the cover plates 9 to 16 [M13 to M20, Bogen 4].

Chapter N

The Flywheel Hub and Fitting of the Crank Shaft

If you fitted the flywheel to the crank shaft as it is, it would slip and wobble because the connection between the flywheel and the thin wire of the shaft is not strong enough. To remedy this, the flywheel is fitted with two external hubs, one on each side, and is then secured to the crank shaft by two tightly fitting end stops. Each of the eight hub parts has two white and two golden segments. Each of the golden segments of one part is glued to the back of one golden segment of another part, so that four parts together form a cross. The white parts are then glued to the flywheel.

Step 67: Fold all grooves of the hub parts 1-4 [N1 to N4, Bogen 3] forwards. Glue the back of one golden segment to the back of one golden segment of another part. You don't have to follow the numbers on the back of the parts, since they are all identical.

Step 68: In the same way glue the backs of one golden segment of each of the remaining parts together and then the two half hubs together to form the complete hub. You should now have a hub with a cross-like cross section as shown in Fig 7.



Fig 7: The flywheel hub

Step 69: Take the Flywheel and stick the long end of the crank shaft through the small hole in the middle and further on from the back through the hub by carefully pushing the wire through the middle of the cross. First without glue, push the hub against the Flywheel to see that the white segments sit nicely on the grey glue markings. Glue the hub into this position and make sure that the Flywheel is kept at right angles to the axle until the glue has set. Remove the axle.

Step 70: Fold the hub parts 5 to 8 [N5 to N8, Bogen 4] and glue them together in the same way as the ones before and afterwards glue the hub onto the other side of the Flywheel. This time push the axle from the side with the already glued-on hub through and again make sure that the Flywheel stays at right angles until the glue has set. Remove the axle afterwards.

Step 71: Glue the hub covers 1 and 2 [N9 + N10] on top of the hubs, again with the axle in place to check the alignment.

In the next steps the connecting rod, the valve rod, and the Flywheel will be mounted on the crank shaft and its bearings will be fitted. The crank shaft has two "cranks", one for the connecting rod and the other one for the valve rod. Their bearing discs will be held in place the same way: on both sides with a 5mm end stop and a 2mm spacer between these and the bearing disc. The longer end of the crank shaft carries the Flywheel, the shorter end points in the direction of the aluminium sheet on the base plate.

Step 72: First check that the ends of the crank shaft are properly aligned and carefully bend it if that is not the case. Cut off six spacers of 2mm length from the cotton bud tube; that means they are slightly shorter than their diameter. Cut off four end stops of 5mm and three end stops of 7mm length from the

thin silicone tube. There's only a small amount of the tube left now, but we will not need any more.

Step 73: First slide a 5mm end stop from the short end of the shaft to the end of the first crank, then a 2mm spacer, followed by the bearing disc of the connecting rod, another 2mm spacer and finally another 5mm end stop (see Fig 8, left). Check that the bearing disk has a little play and adjust the end stops if needed.

Step 74: Slide a 5mm end stop from the long end of the shaft to the end of the other crank, then a spacer, one of the bearing discs of the valve rod, another spacer and finally the last 5mm end stop (see Fig 8, middle).

Step 75: Pull the two crank shaft bearings from their mounts, put them on the ends of the crank shaft and re-fit them with the crank shaft in place. On the Flywheel side the crank shaft ends roughly above the edge of the base plate, on the boiler house side it sticks out by only 10cm. On this short end fit a 2mm spacer and secure it in place with a 7mm end stop. Then do the same on the long end of the shaft. Push the two end stops in only so far that the shaft still has a little sideways play.

Step 76: Push the Flywheel onto the long end of the crank shaft until it touches the end stop, then fit the last 7mm end stop and push it against the outer hub of the Flywheel to lock it in place. Make sure that it can't slip on the shaft, if necessary push the end stop against it a bit harder, while taking care that the inner end stop is not pushed against the crank shaft bearing. The crank shaft needs to be able to rotate without any tangible friction. The crank shaft now sticks out by about 4mm, which allows for the possibility of mounting a small drive wheel (see Chapter "Questions and Answers").

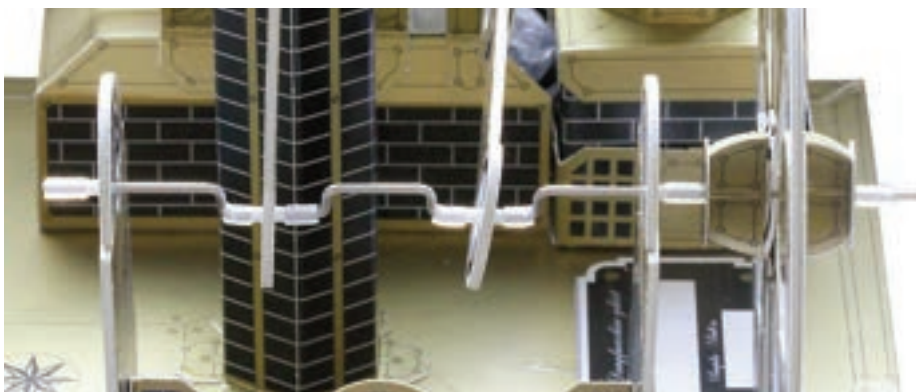


Fig 8: The crank shaft

Chapter O

The Chimney Base Frame

The chimney and the base frame, into which the chimney is loosely fitted, do not come into direct contact with the steam. Nevertheless they will be lined with kitchen foil to protect them against mistakes and accidental spills. The bottom of the base frame is lined as well and will hold the condensate reservoir, an empty metal tea light cup for the condensate.

Step 77: Glue kitchen foil (aluminium foil) onto the back of part 1 and 2 of the chimney base frame [O1 and O2, Bogen 3 + 4], cut off any overlap, and fold all grooves backwards. Take care that the kitchen foil doesn't tear.

Step 78: Connect the two parts with the connecting pieces 1 and 2 [O3 and O4, Bogen 6] to form a quadratic frame. The two parts should touch behind the connecting pieces and be flush with them at the top.

Step 79: Glue the base frame on its glue marks on the base plate, right next to the cylinder base. The cross section of the frame is exactly square and at its bottom is a round depression to hold the condensate reservoir.

Step 80: Cut out a fitting square piece of kitchen foil to cover the bottom of the base frame including the glue tabs and glue it in place.

Tip: Completely remove any excess glue. Although the glue is hard when set, it might soften again when heated by the steam and then adhere to the chimney when it sits in the base frame.

Chapter P

The Chimney

The chimney conducts the waste steam from the waste steam cone upwards to remove it from the sensitive parts of the cardboard construction. The chimney and its base will also be lined with kitchen foil. In addition, the chimney is fitted with an aluminium tube made from kitchen foil in which the steam partly condenses.

Step 81: Glue kitchen foil onto the grey dotted area on the back of the chimney [O5, Bogen 5], but not yet onto the 8 small foot tabs. Fold all long grooves backwards and the short ones at the foot tabs forwards. Then glue the long tab onto the glue mark on the opposite side to form an eight-sided tube.

Step 82: Remove the octagon from the upper part of the chimney base [O6, Bogen 6], push the chimney in from below and glue in the foot tabs.

Step 83: Cut out a 44mm x 44mm square of kitchen foil, cover it with glue and stick it on the inside of the chimney base, covering the opening of the chimney. Then, using a pointed knife, cut the foil covering the chimney opening, from each chimney corner towards the middle, into eight narrow triangles. Push these into the chimney and glue them in place.

Step 84: Fold all grooves of the chimney base [O7, Bogen 5] backwards. It forms a box, open at top and bottom, with a large cutout on one side. Line the back with kitchen foil, include the glue tab, but leave the glue area free. Then glue the base together.

Step 85: Put the chimney with the upper base part on top of the base. The round cutout should be located above the cutout in the base. Glue the parts together in this position.

Step 86: Fold all grooves of the upper and lower chimney collar [O8 and O9, Bogen 5] backwards and glue them onto their glue markings on the chimney.

Step 87: Cut off a 20cm wide and at least 30cm long piece of kitchen foil, take a broom stick or similar round piece of wood with a diameter of 24 to 25mm, and wind the foil around it to form a 20cm long tube. Pull the tube off the broom stick and trim off the ends so the tube is exactly 18cm long. To cut off the ends you can temporarily push the tube flat and then form it into a proper tube again afterwards.

Step 88: Put the tube into the chimney until it is flush with the top and stands out about 1cm at the bottom. In this position it will be glued into the chimney. Since the diameter of the tube is slightly smaller than the one of chimney, you have to make about 8 cuts of 2cm length into the upper end of the tube. With the emerging tabs you can glue the tube in at the top of the chimney.

As a check, place an empty tea light cup as condensate reservoir into the chimney base frame and fit the chimney base over it. The sticking out aluminium tube should be right above the reservoir. The smaller diameter of the tube makes sure that all condensing water will drip into the reservoir.

Tip: If you bend the walls and corners of the chimney base slightly inwards, it is easier to fit into the frame.

The Boiler House

The boiler house consists of a welded wire mesh that is bent into a rectangular enclosure, open on one side, with sticking out mounting tabs at the bottom. It provides a secure retainer for the boiler and the fire box, containing five tea lights. The two side walls of the boiler house are folded into two protruding rails that will carry the boiler. Underneath is enough space to hold the firebox. The boiler house stands on the aluminium sheet that is glued onto the base plate, its mounting tabs will be fixed with strips of cardboard, holding it securely in place.

The wires of the mesh are quite soft and thin, and can be cut with strong scissors or small wire-cutting pliers. They can be bent easily and accurately by hand. It is easier if you use a sharp edge (a book, board, ruler, etc) for bending the mesh. The mesh is slightly larger than A4, so it is folded in half for packaging reasons. It is cut and bent according to the enclosed cutting template.

Step 89: Fold out the wire mesh and push it completely flat on your worktop.

Step 90: Take the cutting template and straighten the crease in the middle. The template has a background of squares, whose size is the same as the mesh loops. Put the wire mesh on top of the template, with the loops right over the squares and the red boundaries inside the mesh. Then fix the mesh to the template, using three or four strips of sticky tape on each side.

Step 91: First cut out the mesh along the red edge lines. Important: As soon as you have cut off one edge, the template will be loose on that edge. Glue it back in place straight away by applying some more strips of sticky tape. Next cut along the lines indicated by a red arrow. Also cut out the square in the middle of the mesh. This opening will be in the middle of the roof of the boiler house and permits the fitting of the magnetic safety valve on the opening of the boiler. All wire ends sticking out into this opening should therefore be cut off right next to the welding points.

Step 92: Put the mesh in front of you so that the letters are right side up. Fold the right lower wing of the mesh upwards along the green line marked A until it is upright at right angles. The paper is folded together with the mesh. If you are unsure if the green line is underneath the correct row of loops, you can check the number of loops between any two points on the template by the numbers given. When folding, place a ruler in the corner and

push the mesh upwards from the other side. The fold should be a nice rectangular bend, but can have a small radius instead of a sharp corner (see Fig 9).

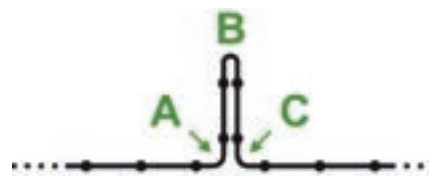
Fig 9

Step 93: Now fold the mesh along line



sharply back down by 180° and forwards again at line C by 90°. The emerging shape should look like the one in Fig 10. This is one of the rails for the boiler.

Fig 10



Step 94: Repeat the last steps with the folding lines D, E, and F to form a rail in the left, lower wing (see Fig 11).

Fig 11



Step 95: Fold both wings forwards by 90° along the lines G and H. These are the two side walls of the boiler house. Fold the two foot tabs outwards along the lines J and K. Now you can already recognise the form of the boiler house, although it is still upside down. Its cross section now looks like Fig 12:



Fig 12

Step 96: Fold the front tab completely into the inside of the boiler house along the line L. This way the sharp wire ends are out of the way. Remove the paper from the finished parts, but keep in mind the position of the lines Q, R, S, and T.

Step 97: Fold the back wall of the boiler house upwards along the line M and then its foot tab outwards along the line N.

Step 98: The two supporting wings on the back wall are folded along the lines O and P onto the outside of the side walls. Now remove the rest of the paper and sticky tape, and secure the supporting wings by folding the front tabs fully backwards along the lines Q, R, S, and T.

Step 99: Turn the boiler house over and stand it on its foot tabs. If necessary, bend it into shape to form a nice rectangular box. Now put it on the aluminium sheet on the base plate and check that it fits nicely into its space, the foot tabs flat against the aluminium, the edges just short of the cardboard sides. Also check that the boiler fits into its drawer and make sure it sits there nicely. If you need do make any corrections of the shape of the boiler house, you should make them now.

In the next steps the boiler house will be fitted on the base plate by securing it in place on three sides by glueing in the edging strips. These strips consist of two layers of which the upper one reaches 6mm over the aluminium sheet. The gap in between will hold the foot tabs of the boiler house. Due to technical requirements the edging strips for the side walls are mitred on both sides, although this is only needed at the back of the boiler house. Therefore the front mitre will be cut off.

Step 100: Glue the lower back edging strip [P3, Bogen 5] on its glue mark on the base plate close to the column. Its shorter edge has to be flush with the edge of the base plate cardboard.

Step 101: Put the lower left edging strip [P1, Bogen 3] in its position on the base plate, so that the angled edge is flush with the one of the back edging strip.

Mark the part that is sticking out over the edging of the base plate and cut it off so it fits nicely into the gap between the back edging strip and the edging of the base plate. Now glue it in this position and do the same with the other lower edging strip [P2, Bogen 4].

Step 102: Glue the back upper edging strip on the top of the lower one, so that the rear edges and corners are flush. Between this strip and the aluminium sheet you now have a 6mm deep gap. Let the glue set properly.

Step 103: Push the rear foot tab of the boiler house so far into this gap that the front of the house is flush with the visible edge of the aluminium sheet. If necessary you have to shorten the rear foot tab slightly so you can push the house further back. Also check again that the side foot tabs lie flat against the aluminium sheet and fit in between the edging strips. If necessary shorten these as well.

Step 104: Put the left upper edging strip [P4, Bogen 3] on top of the lower one, again aligning the rear mitre with the boiler house in place and mark the front edge at the base plate edging. Cut off the excess and glue the strip in place. Do the same with the right upper edging strip [P5, Bogen 4].

Apart from the piston covers, the valve rod covers and the name plates, all cardboard parts of the steam engine are now dried.

Chapter R

The Firebox

The ☐rebox houses ☐ve tea lights. It is cut from the aluminium sheet with strong scissors. Important: The cut edges are sharp, so be very careful when handling the aluminium! The sheet is easy to bend by hand, but you can also use a ruler to help getting the edges nice and straight. The ☐rebox is of square shape with low walls and a small handle. It doesn't get hot, even after a long time, so it doesn't need any insulation.

Step 105: Cut out the template for the **Crebox** from the template sheet for the aluminium parts along the edge of the white area (not along the red line). Also cut out the square in the middle.

Important: this square is only needed to glue the paper to the aluminium, it is NOT cut out from the aluminium!

Stick the inner and outer edges of the template to the aluminium sheet using sticky tape. Make sure that enough aluminium is left for the waste steam cone.

Step 106: Groove the aluminium along the green dashed line using an old biro, a small screw driver, or a similar tool. For the grooves to be better visible, place the sheet on a slightly flexible support, e.g. several layers of newspaper. You should be able to clearly see the grooves in the aluminium.

Step 107: Cut out the sheet along the red lines, also make the two cuts along the red lines between handle and front wall. Although the sides of the template are now loose, it is still held in place by the sticky tape in the centre square.

Step 108: Fold the rear wall sharply upwards along the groove A by 90° and then the two side flaps along the lines B and C forwards by 90°. They are now roughly parallel with the lines L and N.

Step 109: In the same way bend the front wall upwards along the line D and its flaps backwards along the lines E and F.

Step 110: Bend the handle downwards by 90° along the line G, so it is parallel to the bottom of the **Box**. Remove the paper from the area of the handle. Then fold its two **Flaps** down and back along the lines H and J until they lie **Flat** against the underside of the handle to reinforce it. Now fold the front **Flap** of the handle down and back along the line K against the underside of the handle.

Tip: The handle is practical, but you don't really need it. In case you manage to break it off you can still hold the **Rebox** by its corners.

Step 111: Fold the left side wall along the groove line L upwards at right angles so that it touches the flaps of the front and rear wall. Now fold the upper half of the side wall along the line M fully inside and down so that the flaps are enclosed by the double side wall. This gives the walls of the box their stability. If necessary, remove the paper before folding the aluminium.

Step 112: Repeat the last step with the right side wall and the groove lines N and O. Remove all paper and sticky tape bits that are left.

Now the firebox is finished. It is just big enough to hold five tea lights.

Chapter S

The Steam System

The steam pipe consists of heat resistant silicone. On one end is the magnetic safety valve that connects the pipe to the boiler. The other end is fitted to the steam bellows, which in turn is connected to the waste steam pipe. In the first step we prepare the proportioning pump that is needed to fill the boiler with the correct amount of water.

Step 113: Cut off exactly 2cm from the steam pipe and fit it to the nozzle of the 10ml syringe. Secure the pipe by tightly winding several rounds of strong twine around it. Fasten the twine with a knot and a bit of glue. The piece of pipe will hold even better if you roughen the nozzle beforehand with some sand paper. The proper use of the pump will be explained later.

Step 114: Take the glove made from extra-thin PE film and cut off the middle finger right at the base. This finger is going to be made into the steam bellows. Cut off a small bit from the finger tip to make a hole just large enough for the steam pipe. Push the pipe from the large opening through the finger and the small hole and pull it through until only 10mm of the pipe remain inside the finger. In this position the bellows should be fixed on the pipe. For this take the two small O-rings with an internal diameter of 6.5mm (that is 0.5mm less than the diameter of the steam pipe). Thread one O-ring on the bellows and push it forwards to the end of the steam pipe, and then further on until it sits on the steam pipe holding the bellows securely in place.



Fig 13: The steam system

Tip: If you have problems threading the O-ring onto the bellows, you can try

folding and holding its end together. This way the O-ring should slide on easily.

Then slide the second O-ring next to the first one, leaving a distance of about 1cm. On the other side of the O-rings the bellows should stick out a bit to make sure the connection is completely airtight.

Tip: Check the connection by holding the other side of the bellows shut and gently blowing into the steam pipe (don't blow too hard or you might rupture the bellows). If there is a leak, check the O-ring connection first. If the bellows itself is leaking, you can replace it by another finger from the glove.

Step 115: Take the small syringe and remove the plunger. With a sharp knife cut off both the bottom with the nozzle, and the top to obtain a tube of 35mm length, the waste steam pipe. To make sure that the sharp ends don't cut into the bellows, hold them for a few seconds over the flame of a lighter. This way the sharp ends are molten round.

Step 116: Push the two larger O-rings onto the bellows and push the waste steam pipe about 10mm into the open end of the bellows. Then push the two O-rings over the pipe, clamping the bellows in place. Then adjust the rings until the free length of the bellows between the ends of the steam pipe and the waste steam pipe is 65mm. Again check that the steam system is airtight.

Fitting of the Steam System and the Waste Steam Cone

The steam system, consisting of steam pipe, steam bellows, and waste steam pipe, is fitted in a way that it can easily be taken out for maintenance and repair. The small, but important aluminium waste steam cone stands in the condensate reservoir above the end of the waste steam pipe, and channels the steam directly into the aluminium tube in the chimney. This way practically no water condenses inside the chimney base. This only happens inside the tube in the chimney, from which it drips straight into the condensate reservoir.

Step 117: Open the valve fully, open the cylinder lid, and remove the dividing wall from the cylinder block. Push the steam pipe with its open end first, from the chimney side, through the waste steam pipe bracket, through the cylinder block, and through the small hole in the front side of the cylinder. Pull the steam pipe through the small hole until the two small O-rings securing the bellows on the steam pipe are just on the inside of the cylinder wall. Then push the dividing wall back in to hold the steam pipe in place. The two O-rings are now located between the dividing wall and the front wall of the cylinder. The steam bellows is now nearly completely inside the cylinder block, the waste steam pipe ends inside the chimney base frame. Put the condensate reservoir into the base frame under the waste steam pipe. Push the valve back up, it can now close the steam bellows by pushing it into the foam of the valve abutment. Close the cylinder lid.

Step 118: Push the open end of the steam pipe through the ring magnet, the important safety valve. Fold the end of the tube into a narrow tip, so you can easily push it through the magnet until it sticks out by 1-2mm. Since the tube is slightly thicker than the inner diameter of the magnet, it sticks tightly inside and makes the connection airtight. Now put the safety valve on the hole in the boiler. It will click shut on the washer, but will open automatically if the pressure in the boiler gets too high. Also, the valve is easy to take off for filling the boiler with water.

Step 119: Cut out the template for the waste steam cone along the edge of the white area and stick it on the aluminium sheet, using sticky tape. Groove the two short green dotted lines across the small tabs and cut out the part.

Step 120: Bend the part into a cone, with a big opening at the bottom, a small one at the top, and a large, rounded cut-out at one side. It is easy to do this with your fingers. You can also use a pencil to help with forming the shape. Bend the small tabs inwards, stick them through the slits on the opposite side, and then bend them fully back, see Fig 14.



Fig 14: The waste steam cone

Tip: If you squeeze the tabs tight with needle-nosed pliers, the connection is going to be much more stable.

Now place the waste steam cone into the condensate reservoir with the waste steam pipe sticking through the opening on the side of the cone.

Chapter U

Adjustment of Piston Rod and Valve Rod

Now we are going to do a first adjustment of the piston rod and the valve rod, and with a little luck the steam engine will work at the first attempt.

Step 121: Pull the piston and piston rod, which are not glued together, as far as possible apart, so that the walking beam stands as high as possible and the piston is pushing the steam bellows flat against the bottom of the cylinder. Then, whilst holding the piston in place, push the piston rod back into the piston until the other side of the walking beam stands as high as possible.

Important: Make sure that the pull on the crank shaft does not get too large. Otherwise it might pull the crank shaft bearings from their mounts.

Now the piston is adjusted so that on its downward stroke it will push the steam bellows flat and nearly touches the bottom of the cylinder. By turning the fly-

wheel check that the piston can move freely. If it collides with the bottom of the cylinder, the piston rod has to be pushed in a bit further.

Tip: Check that the end of the steam pipe doesn't stick too far into the cylinder and that the piston doesn't touch it.

Step 122: Cut off one 2mm and one 8mm long spacer from a cotton bud tube and a 7mm end stop from the thin silicone tube. Fit the 8mm long spacer on the axle sticking out sideways from the top of the valve. Now push the bearing disc of the valve rod onto the axle, followed by the 2mm spacer and the end stop. The bearing should have enough play to move freely without friction.

Step 123: Carefully turn the flywheel and observe the movement of the valve. If the valve jams because it pushes into the bottom of the cylinder, you have to make the valve rod slightly longer. The valve should push the steam bellows only so far into the foam abutment that it just closes the bellows completely and the flywheel is braked only very slightly. If the valve doesn't close far enough, the steam will just blow through without building up enough pressure to move the piston. In that case the valve rod needs to be slightly shortened.

Now your steam engine is ready for the first test run.

Chapter V

The First Test Run

Please always observe the following safety instructions:

- * Never let the steam engine run unattended.
- * Never heat the boiler when it is empty. It could be damaged beyond repair.
- * Be cautious with open flames and hot steam: burn hazard!
- * Supervise children at all times.
- * Check the condensate level regularly and empty the reservoir in due time.
- * Empty the condensate reservoir after use, check the water out of the chimney, and let it dry thoroughly.

Fill the boiler only with clean water. If your tap water is very hard, it is better to use distilled water or rain water, to avoid build up of limescale inside the boiler. The boiler should not be filled more than halfway, otherwise water is

splashed into the steam pipe. The correct water level can be adjusted with the proportioning pump made from the large syringe and the 2cm piece of silicone tube.

Step 124: Repeatedly pull water into

the pump and fill it into the boiler. Each time push the nozzle of the pump fully into the hole and try pulling water back out of the boiler. As long as you only draw air, you can still add more water. As soon as you start drawing water back out of the boiler, it has reached its maximum filling level.

Step 125: Put five tea lights into the firebox, light them, and put them into the boiler house underneath the boiler. Don't put the chimney into its base frame just yet.

Step 126: When, after a few minutes, steam escapes from the waste steam pipe, you can try starting the flywheel. It can only turn anti-clockwise. If the steam engine doesn't run straight away, you need to remove the firebox, extinguish the lights instantly, and investigate the problem. Check and try to improve the adjustments of the piston and valve rods, as well as the air tightness of the steam system. Don't forget to check the boiler and the safety valve. When the engine runs reliably, you can stand the chimney carefully into the base frame. Take care that the end of the aluminium tube in the chimney doesn't get pinched. The steam from the waste steam cone needs to raise freely into this tube, otherwise you will get condensation inside the walls of the chimney base, and possibly damage the cardboard parts.

Step 127: When the engine runs well, you can glue on the two halves of the piston top [E12 + E13, Bogen 6], the valve rod cover plates [J11 + J12, Bogen 1 + 2], and the name plates [A9 + A10, Bogen 7].

Congratulations! You have successfully built a steam engine and got it running. If you have any comments or suggestions, please write us an email: AstroMediaShop@gmail.com or info@astromedia.de

Questions and Answers

Can I drive anything with my steam engine?

- * In principle yes. You can clamp a narrow drive wheel between the Flywheel and the outer end stop. Since the power you can take off the crank shaft is rather small, your driven object has to run extremely smoothly. Tell us about your experiments! We would love to receive your photos, videos, and letters.

How can I increase the power of my steam engine?

- * The largest increase of power can be achieved by pinching the steam pipe slightly (but NEVER completely!), for example with a paper clip. This increases boiler pressure, steam temperature, and energy content of the steam.
- * Try minimising friction, by making sure the bearings have enough play, and maybe apply tiny drops of oil to the bearings.
- * Put a drop of oil between the magnet and the washer. The oil acts as additional seal.
- * Try out minimal changes in the length of piston rod and valve rod until you have found the optimum.
- * Avoid drafts. Moving air reduces the temperature under the boiler.
- * Use new tea lights.
- * Try lifting the Firebox a few millimetres by laying something (heat-resistant) underneath. This way the Flames are closer to the boiler.
- * If necessary remove the soot from the bottom of the boiler.
- * Experiment with different Filling levels of the boiler. But be careful: if the water level is too high, water might be splashed into the steam pipe. If the level is too low, the risk is that the boiler is heated empty and is destroyed.

How do I know if my steam engine is optimally adjusted?

- * Check if it runs with less than Five tea lights. It should at least run with four, although slightly slower. If it runs on three tea lights it is very well adjusted. The current record is two tea lights, but that needs a lot of tweaking.

If you have found more answers to these questions, or have completely different questions, please get in contact with us. We would love hearing from you and put your ideas on our website.

List of part numbers and part names

No	Bogen / Sheet	German Name	English Name
A1	7	Grundplatte, Abdeckung oben	Upper base plate cover
A2	8	Grundplatte, Abdeckung unten	Bottom base plate cover
A3-6	3,4	Grundplatte, Kantenverkleidung Eckteil 1-4	Corner edge cover 1-4
A7+8	5	Grundplatte, Kantenverkleidung Mittelteil 1+2	Middle edge cover 1+2
A9+10	7	Typenschild	Name plate
B1+2	3,4	Säule, Teil 1+2	Column part 1+2
B3	3	Säule, Innenversteifung	Column inner hexagon
B4	4	Säule, Boden	Column bottom
B5-8	1,2	Säule, Lagerhalterung 1-4	Column bearing housing 1-4
B9	5	Säule, Abdeckung	Column top cover
C1-4	1,2	Balancier, Teil 1-4	Walking beam parts 1-4
C5-16	3,4,6	Balancier, Lagerkappe 1-12	Walking beam bearing cover 1-12
C17+18	5	Balancier, Verbindungsstück 1+2	Walking beam connecting piece 1+2
D1+2	1,2	Pleuelstange innen 1+2	Connecting rod inner part 1+2
D3+4	6	Pleuelstange außen 1+2	Connecting rod outer part 1+2
E1+2	1,2	Kolbenstange innen 1+2	Piston rod inner part 1+2
E3+4	6	Kolbenstange außen 1+2	Piston rod outer part 1+2
E5+6	1,2	Kolbenhalterung innen 1+2	Piston mount inner part 1+2
E7+8	6	Kolbenhalterung außen 1+2	Piston mount outer part 1+2

E9	6	Kolbenmantel	Piston
E10	6	Kolbenmantel, Verbindungsstück	Piston connecting piece
E11	6	Kolbenboden	Piston bottom
E12+13	6	Kolbendecke 1+2	Piston top 1+2
F1	6	Zylindersockel	Cylinder base
F2-5	3,4	Zylindersockel, Innenversteifung 1-4	Cylinder base inner wall part 1-4
G1	6	Zylinderblock innen	Cylinder block
G2-7	1,2	Zylindertrennwand, Schiene 1-6	Cylinder block inner rails 1-6
G8+9	3,4	Zylindertrennwand 1+2	Cylinder block dividing wall
G10	6	Zylinderblock außen	Outer cylinder block
G11	6	Ventillager-Halterung	Valve bearing holder
G12	6	Bügel für Abdampfrohr	Waste steam pipe holder
H1-4	6	Ventil innen 1-4	Valve inner part 1-4
H5+6	6	Ventil außen 1+2	Valve outer part 1+2
J1+2	1,2	Ventilstange, Zunge innen 1+2	Valve rod tongue inner part 1+2
J3+4	6	Ventilstange, Zunge außen 1+2	Valve rod tongue outer part 1+2
J5+6	1,2	Ventilstange, Tasche innen 1+2	Valve rod pocket inner part 1+2
J7-10	6,1,2	Ventilstange, Tasche außen 1-4	Valve rod pocket outer part 1+2, cardboard disk 1+2
J11+12	1,2	Ventilstange, Abdeckung 1+2	Valve rod cover disc 1+2
K1+2	1	Kurbelwellenständer 1, Innenteil 1+2	Crank shaft mount 1 inner part 1+2
K3+4	3	Kurbelwellenständer 1, Außenteil 1+2	Crank shaft mount 1 outer part 1+2
K5+6	2	Kurbelwellenständer 2, Innenteil 1+2	Crank shaft mount 2 inner part 1+2
K7+8	4	Kurbelwellenständer 2, Außenteil 1+2	Crank shaft mount 2 outer part 1+2
K9+10	3,4	Kurbelwellenständer, Mittelteil 1+2	Crank shaft mount middle part 1+2
K11+12	1,2	Kurbelwellenständer, Sternlogo	Crank shaft mount star logo
L1+2	1	Kurbelwellenlager 1, Innenteil 1+2	Crank shaft bearing 1 inner part 1+2
L3+4	3	Kurbelwellenlager 1, Außenteil 1+2	Crank shaft bearing 1 outer part 1+2
L5+6	2	Kurbelwellenlager 2, Innenteil 1+2	Crank shaft bearing 2 inner part 1+2
L7+8	4	Kurbelwellenlager 2, Außenteil 1+2	Crank shaft bearing 2 outer part 1+2
M1+2	1	Schwungrad innen 1+2	Flywheel inner part 1+2
M3+4	2	Schwungrad außen 1+2	Flywheel outer part 1+2
M5-20	3,4	Schwungrad Deckkappe 1-16	Flywheel cover plate 1-16
N1-8	3,4	Schwungradnabe 1-8	Flywheel hub part 1-8
N9+10	1,2	Schwungrad Nabenabdeckung 1+2	Flywheel hub cover 1+2
O1+2	3,4	Kamin, Sockelfassung 1+2	Chimney base frame 1+2
O3+4	6	Kamin, Sockelfassung Verbindung 1+2	Chimney base frame connecting piece 1+2
O5	5	Kamin	Chimney
O6	6	Kaminsockel, Oberteil	Chimney base upper part
O7	5	Kaminsockel	Chimney base
O8	6	Kamin, Manschette unten	Upper chimney collar
O9	6	Kamin, Manschette oben	Lower chimney collar
P1	3	Kesselhaus-Einfassung links, unten	Lower left boiler house edging strip
P2	4	Kesselhaus-Einfassung rechts, unten	Lower right boiler house edging strip
P3	5	Kesselhaus-Einfassung hinten, unten	Lower back boiler house edging strip
P4	3	Kesselhaus-Einfassung links, oben	Upper left boiler house edging strip
P5	4	Kesselhaus-Einfassung rechts, oben	Upper right boiler house edging strip
P6	5	Kesselhaus-Einfassung hinten, oben	Upper back boiler house edging strip

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