Vertical Steam Engine from barstock

By Thor Hansen

After having built several small oscillating steam engines and Rudy Kouhoupt's Walking Beam engine I decided to have a go at a slide valve engine. My vertical steam engine was inspired by the Trojan steam engine that was described by Edgar T. Westbury in Model Engineer in Feb. – Mar. 1949. In Model Engineer June 1978 to Feb. 1979 J. P. Bertinat describes an improved version – Mk II. He replaces the cross-head guide with a trunk guide and larger diameter shafts and bearings. So I decided to adopt many of the ideas introduced by Bertinat although my engine is built from barstock and dimensions are metric. Also, I made mine with a 16mm bore and 20mm stroke. My engine differs from the Trojan in several other areas as well. Many thanks to Graham Meek for his advice and encouragement.

Materials

I had a piece of cast iron left over from another project that could be used to make the cylinder. I found some steel profiles in a skip that I used to fabricate the Bedplate. Mild steel rods were used for the Columns. I bought some brass for the Bottom Cylinder Cover and the Trunkguide. The rest was made from various parts of mild steel I found in my box of scrap.

Bedplate

While I was waiting for the brass to arrive I decided to start by fabricating the Bedplate. I had found some U shaped steel in a skip and after a bit off hacksawing I could weld the parts together. I also welded a couple of clamping lugs, one on each side of the Bedplate. After a bit of grinding with the angle grinder and a bit of filing I ended up with this:

I drilled a couple of holes in the top of the Bedplate – where the holes for eccentric and the crank will be. I filed the top so it would lie on the milling table without rocking. The Bedplate was then placed with the bottom up on the milling table and clamped with a couple of bolts so I could mill the bottom flat – right photo.

Then I could turn the work over and clamp by the

lugs and mill the top of the Bedplate flat.

Crank and Crankshaft

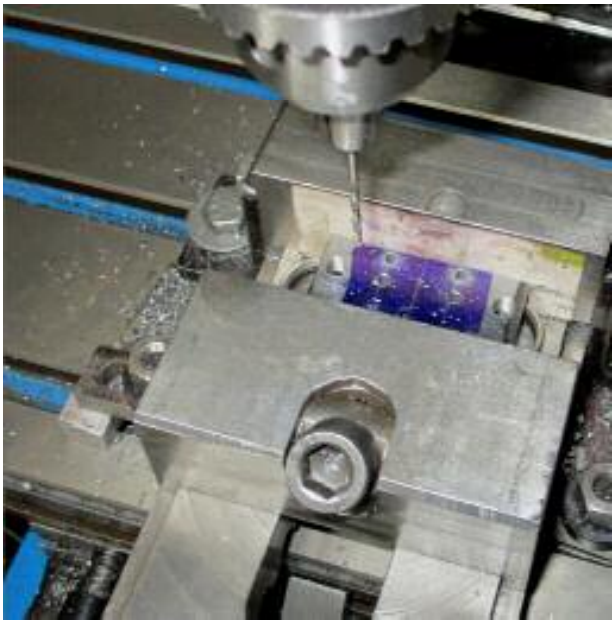
The Crankshaft was made from a piece of 8mm diameter bright mild steel and the Crank from a piece of mild steel from my box of scrap. The Crank piece was roughly sawn a bit oversize and I used the dials on the milling machine table to centre drill two holes 10mm apart to get the 20mm throw on the engine. The hole in the centre was drilled 7.8mm, the other will be drilled 5mm and tapped M6.

The ends of the Crankshaft were faced and one end turned down slightly for a length of 8mm, about 0.02 to 0.03mm oversize to give a press fit in the 7.8mm hole in the Crank. Before pressing the two parts together I put a drop of Loctite on the Crankshaft end.

The Crank and Crankshaft were clamped in a 3-jaw chuck on the Rotary Table and the Crank milled to final shape.

Bearing Blocks

The Bearing Blocks were made from a piece of 7mm thick mild steel, the pieces I had at hand were a bit taller than the dimension on the drawing so the centre of the Crankshaft ended up 16mm above the Bedplate (instead of 13mm). That means I could make the Flywheel with a slightly larger diameter, and the rods and Columns also needed to be longer. The Bearing Blocks were first cleaned up in the milling machine and the upper corners cut off.



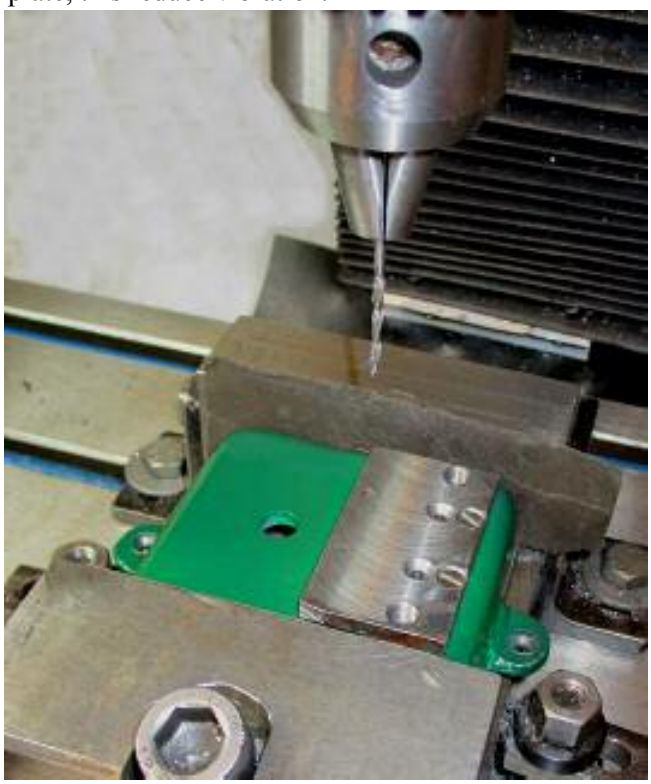
To be able to get the holes for the bearings at the same height I decided to make a drilling and boring jig. The jig will have holes drilled to match the position of the Bearing Blocks on the Bedplate and another set of holes that allows me to mount the two Bearing Blocks close together for drilling and boring the hole for the bearings. The jig is just a piece of 6mm thick steel milled top and bottom and square, the jig was then clamped in the vice and I used the milling machine dials to place the holes in the correct position. I started with a centre drill and then drilled through with a 3mm drill – right photo. The 3mm holes were countersunk on the underside of the jig.

I also drilled a couple of larger holes at each end so the jig could be clamped to an angel plate.

The jig was then used to spot the holes on the under side of the Bearing Blocks – right photo. In the photo the first Bearing Block has been drilled and the last hole in the second Bearing Block is about to be drilled (2.5mm).

After drilling and tapping (M3) the holes in the Bearing Blocks the blocks were clamped to the jig and the jig mounted on an angle plate on the lathe faceplate, and the hole for the Crankshaft bearing drilled and bored – left photo.

I clamped a piece of steel rod opposite to the angle plate, this reduce vibration.



The holes were bored slightly undersize for the bearings to give a light press fit. I used a piece of brass tube as bearings, gunmetal or bronze would have been better. But I used what material I had at hand, and I don't run my small engines for a long time. Later, on top of the bearings I drilled a 3.3mm hole almost down to the brass bearing, I then used a 1.5mm drill and drilled through, these holes will be used to lubricate the bearings.

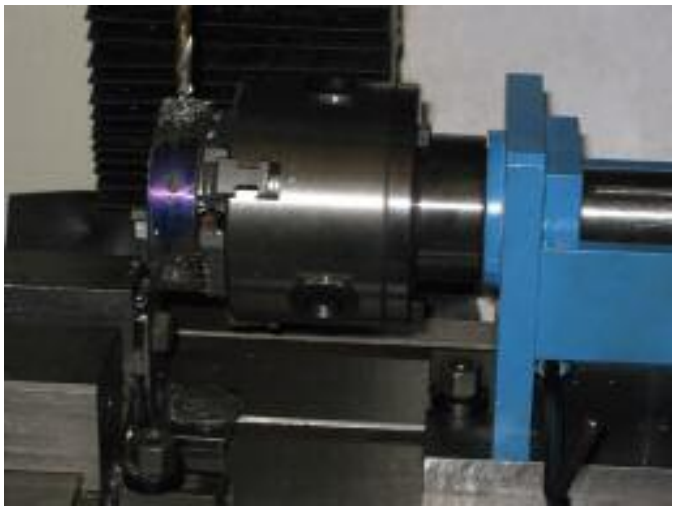
Then the Bearing Blocks were then removed from the jig and the jig was used to spot the corresponding holes in the Bedplate – right photo. After mounting the Bearing Blocks I put the 8mm reamer through, it barely made some swarf, the left photo show Bearing Blocks and Crankshaft in place. The Crankshaft turned easily in the bearings.

Flywheel

The next part I made was the Flywheel. I decided to fabricate the flywheel since I had a short piece of thick-walled steel tube approximately 62mm in diameter. When I fabricated the flywheel for the Walking Beam engine I made earlier, I used two tubes, one epoxied on the outside of the other. But this time I didn't have two pieces of tube so I couldn't epoxy a thin-walled tube on the outer rim.

I started by making the hub of the flywheel, the end f a 16mm mild steel rod was first turned and bored to 8mm, then mounted in my indexer so I could drill and tap six holes evenly spaced. I used a centre drill first, and then drilled 4.3mm before tapping M5 – see right photo.

Then I mounted the thick-walled tube in the indexer and drilled another six holes evenly spaced using a centre drill first and ten a 5mm drill – see right photo.



I cut off six 5mm mild steel rods slightly over length and threaded one end M5mm and mounted the parts – see left photo.

Then all joints were fluxed and I silver (hard) soldered the parts together. The flywheel was a bit wobbly after the soldering so I mounted it on a between centres mandrel so I could turn the outside and sides – see right photo.

To drive the wheel I just used a piece of steel wire around one of he spokes. I took light cuts and had no problems. Below is the result.

Steam Chest

I found a piece of steel in my box of scrap that was suitable for the Steam Chest. The work was first squared up a bit longer than the finished size, then I drilled a couple of holes in opposite corners and used a small hacksaw to saw away the central piece.

The work was then moved to the milling machine and the cavity milled to dimensions. The steam chest was left as this, while I made the Cylinder Top and Bottom Cover and the Trunk Guide.

Trunk Guide

The Trunk Guide was fabricated from a piece of brass tube with 16mm inner diameter and a piece of 3mm thick brass flat. I hacksawed off the corners of the brass and turned a small spigot so the brass tube just fitted over the spigot. I fluxed the pieces

and silver soldered them together – see right photo.

After pickling in citric acid the work was transferred to the milling machine and the sides of the brass tube milled with a 10mm end mill. An emery paper and a bit of elbow grease gave this.

Cylinder Bottom Cover

The Cylinder Bottom Cover was fabricated from a rectangular piece of 3mm thick brass flat, some pieces of 1mm thick brass sheet and a piece from a 10mm diameter brass rod. I drilled a 1.5mm hole through the centre of all the pieces and put a brass nail through the holes to keep the parts together while silver soldering, see above photo.

Next I marked out for the four holes for the Columns, and drilled 3.3mm and tapped M4. I intend to make the columns from 5mm diameter mild steel rod that will be threaded M4 for a length just longer than the thickness of the 3mm brass flat plus a M4 nut.

The corresponding holes in the Bedplate will be drilled 4mm and the other end of the Columns turned down to 4mm and the part that protrudes underneath will be threaded M4 so the Columns can be attached with Nyloc nuts from the underside.

I made a small jig for holding the Bottom Cover while turning the 16mm spigot that will enter the Cylinder. I drilled four clearance holes in the jig, spotted from the Bottom Cover and used four M4 screws to clamp the Bottom Cover to the jig. The jig was then clamped in the 4-jaw – right photo. The photo also shows the gage with a 16mm reamed hole that I used to get the correct size of the spigot.

Then I transferred the work to the rotary Table and drilled four 3mm holes around the spigot on a 23.5mm PCD, these holes will be used to attach the Bottom Cover to the Cylinder. I will also use the Bottom Cover to spot the 4 holes in the cylinder.

Cylinder

The cylinder was made from a piece of cast iron from my box of scrap. I milled the work to dimension except I made it a bit over length.

Then the centre of the bore was marked out and the work was transferred to the lathe and clamped in the

4-jaw independent and adjusted so the centre of the bore was on lathe centreline. A pilot hole was drilled first and then I used a 15mm drill to open up the cylinder bore. The hole was then bored to just less than 16mm before using a 16mm reamer.

Then I took a light facing cut to be sure that the bottom of the cylinder was square to the centre line of the bore.

To be able to turn the spigot on the underside of the Bottom Cover I first used the Bottom Cover to spot the holes on the bottom end of the cylinder (while still clamped in the 4-jaw) – left photo.

I could then use my Dremel clone and drill four blind holes with a 2.5mm drill and tap them M3. I then used some M3 cheese head screws to hold the Bottom Cover with bottom side away from the chuck and drill a small centre hole. I then replaced the cheese head screws with short pieces of M3 threaded rod and used a Centre in the tailstock to push the Bottom Cover against the Cylinder. This way I could turn the spigot on the bottom side of the Bottom Cylinder Cover and be sure it was concentric with the cylinder bore. The centre hole was opened and tapped for the gland.

The Bottom Cover was also used to spot the holes in the Trunk Guide.

Top Cylinder Cover

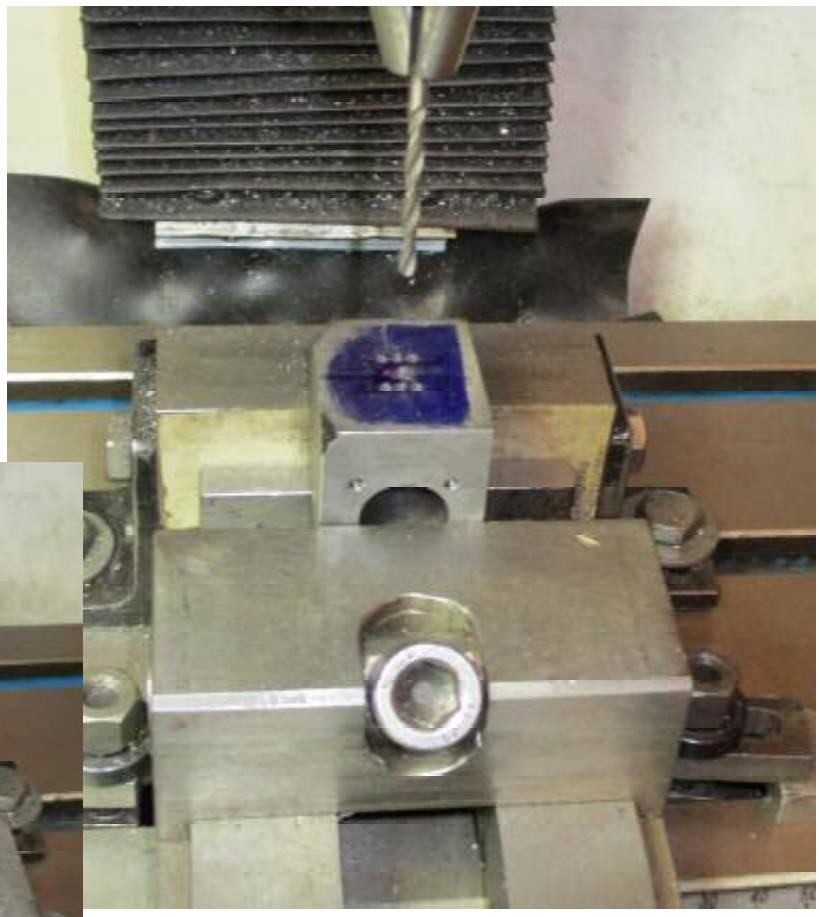
The Top Cover was made from a 3mm thick piece of mild steel. To be able to hold the thin work I made another jig from a piece of mild steel from my scrapbox. Four 3mm holes were drilled in the jig. I then drilled four 2.5mm holes in the Top Cover and tapped them M3. I could then use four long countersunk M3 screws to hold the work while turning the small spigot that enters the cylinder

bore. The work was then mounted with the other side out and the top of the cover faced. The 2.5mm holes were then opened up to 3mm. The Top Cover was then used to spot the 4 holes in the Cylinder, so they could be drilled 2.5mm and tapped M3.

Cylinder ports

With the covers finished the next job was to machine the steam ports and steam passages.

After marking out the positions I drilled 3 holes for each port to a depth of around 7 to 8mm. For the two narrow ports that will allow steam to each end of the Cylinder I used a 1.5mm drill, for the exhaust I used a 3mm drill.



I then used a 1/16" slot drill to mill the two narrow ports and a 3mm slot drill for the exhaust port. A 3mm hole was drilled from one side of the Cylinder into the exhaust.

To drill the steam passages I mounted the Cylinder at an angle in the vice and used a small slot drill to mill a flat before drilling the two steam passages. I started with a centre drill, then a 1.6mm drill. I had marked out the position of the

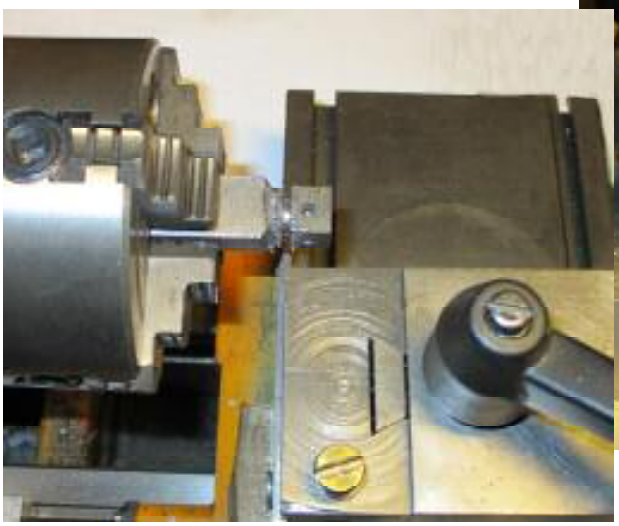
port cavity to make sure the drill just entered the steam port cavity and didn't drill through into the exhaust cavity. Here's a photo of the Cylinder, covers and Trunk guide.

Slide Valve

I used a piece of 13mm square mild steel and the work was clamped in my indexer and two 3mm holes drilled at 90 deg. – right photo. The work was milled to final dimensions.

The work was then transferred to my small lathe and given a light facing cut. I then used a slot drill to make a small cavity at the end – right photo.

The valve was then parted off – photo below.



The work was then transferred to the milling machine so I could mill the two 3mm wide slots at the top.

Then the work was mounted the other way so the cavity at the bottom of the valve could be milled to its final dimensions using a 2mm slot drill – right photo.

Connecting Rod

Bertinat made the Connecting Rod from one piece, I decided to fabricate it from two pieces of mild steel rod and a piece of cast iron from my scrap box. The cast iron part was used to make the "Big End".

I started with the fork-shaped part that will connect with the Crosshead. A piece of 20mm diameter mild steel was used and the work was turned down a bit at one end and clamped in my indexer and then milled roughly to shape with a slot drill – right photo.

A 3.3mm hole was drilled at through the "fork". One part was tapped M4, the other opened up to 4mm. I used a file to round some corners.

The work was then transferred to my small lathe and a 2mm pilot hole drilled – right photo. This hole will be opened up to 2.5mm by drilling from the other end (after parting off), and then tapped M3 for the Piston Rod.

Before parting off the work was mounted on a rotary table and the ends rounded – above photo. The finished part is shown to the right.

Since I didn't have any 4mm mild steel rod left I just used a piece of M4 threaded rod (readily available where I live) between the fork-shaped part and the "Big End" part.

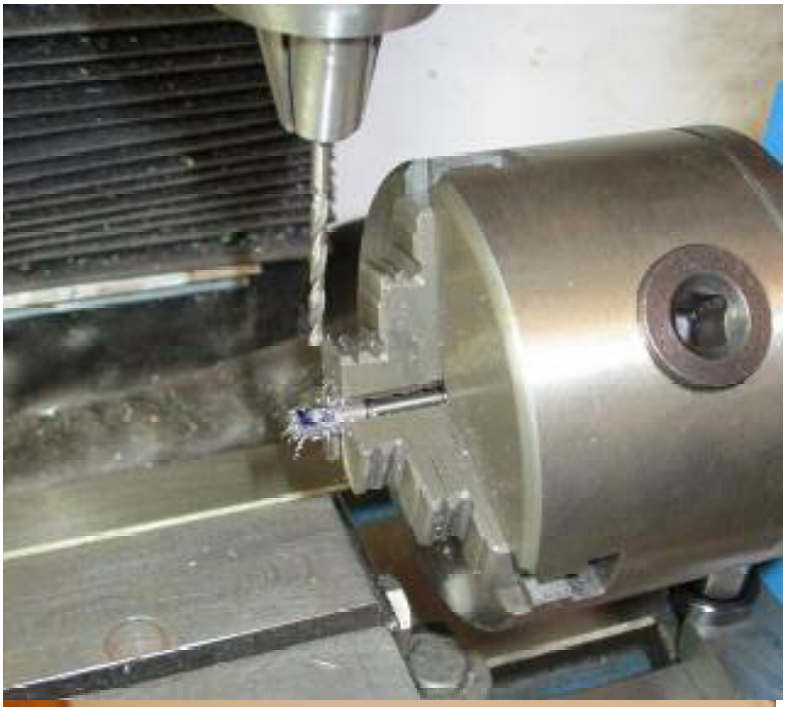
Eccentric

I used a piece of cast iron from my scrapbox for the Eccentric, it was slightly undersize but that will not influence the running of the engine. It was difficult to hold the short work so I centre drilled a piece of 16mm rod and used that to support the work – right photo.

Next the work was transferred to the milling machine. I used a SC 3-jaw chuck to hold the work and used a small centre drill to find the centre of the Eccentric. When I faced the Eccentric in the lathe I left a small pip protruding, and could use that to find the centre of the Eccentric. I had measured how much the Slide Valve would have to travel from fully exposing one steam inlet to fully exposing the other – almost 5mm. So after finding the centre I used the hand-wheel dials and moved the table between 2.4 and 2.5mm, and drilled a pilot hole. The hole was opened up to 7.8mm and reamed to 8mm.

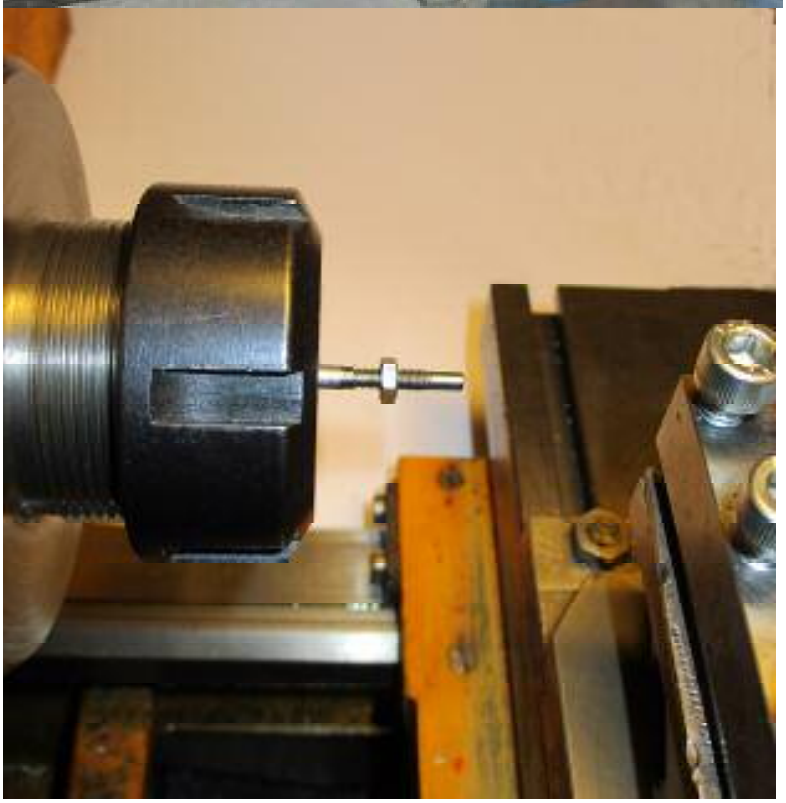
A 3.3mm hole was drilled radially from the outer rim into the 8mm hole and tapped M4, this will take a grub (set) screw to hold the Eccentric in position.

The Eccentric Strap was fabricated from a piece of steel tube with 18mm I.D. from my scrapbox. I silver soldered a piece of mild steel to the tube, and drilled a 2.5mm radial hole in the mild steel piece and tapped it M3 for the Eccentric Rod.



I used a piece of 5mm mild steel rod to make the small end part of the Eccentric Rod. The end of the rod was faced and a 2.5mm hole drilled to a depth of nearly 5mm, and then tapped M3. The work was then transferred to the indexer on the milling machine and the flats milled and the small hole for the Eccentric Rod Pin drilled – right photo.

The Valve Rod was made from a piece of 3mm mild steel rod. I mounted the rod in my ER-32 chuck with a short part protruding. This was turned down to just under 2.5mm for a length a bit over 5mm. This part will enter the 2.5mm hole in the brass bush at the upper end of the Steam Chest. The work was moved out a bit and I used the lathe to screwcut part of the rod M3. I did this in two operations moving the work further out in the ER chuck and managed to "pick up" the previous cut thread, so a M3 nut fit.



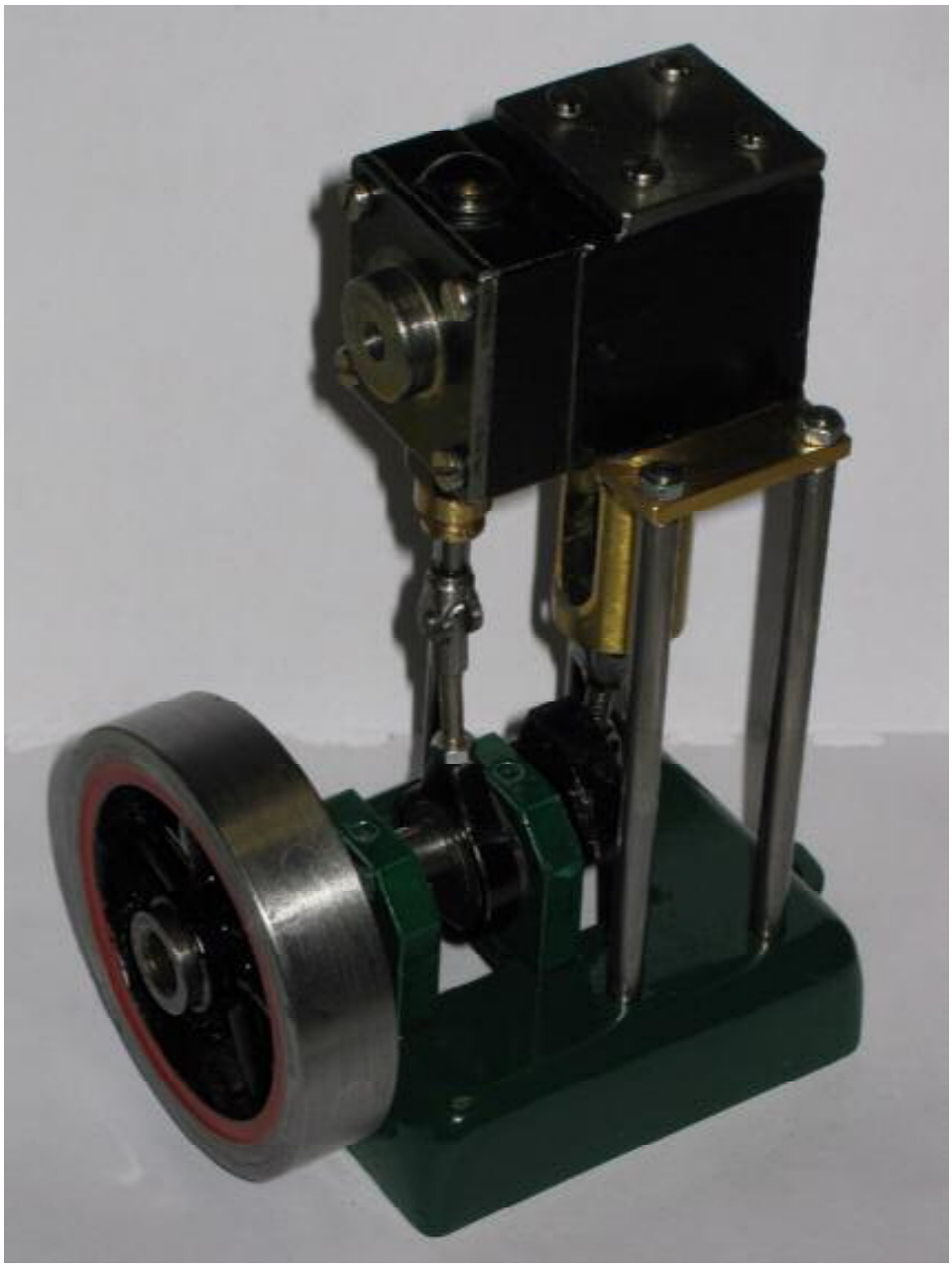
The fork shaped small end that attaches to the end of the Valve Rod (and connects with the small end of the Eccentric Rod) was made more or less in the same way as I made the fork shaped part of the Connecting Rod.

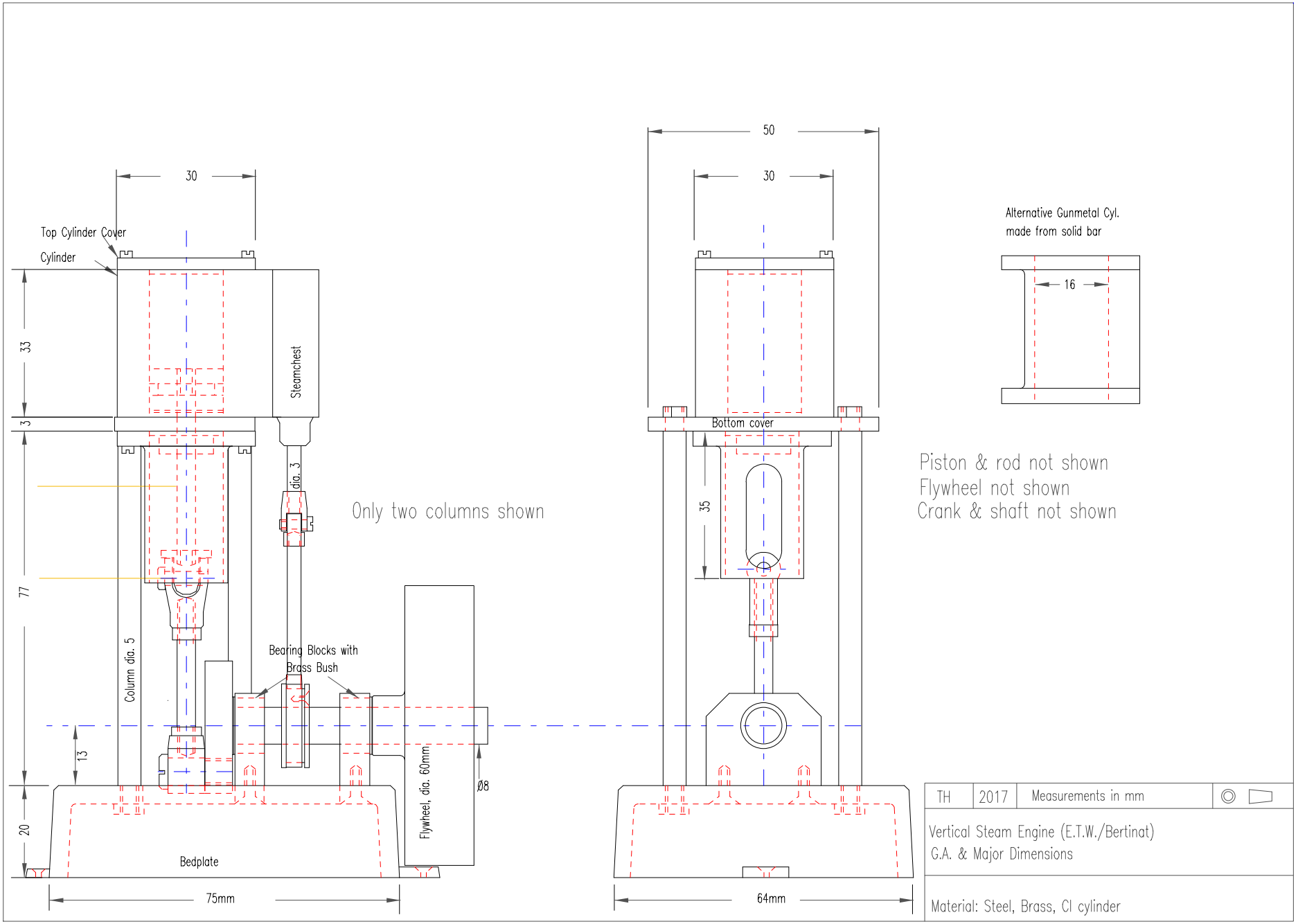
I painted the Cylinder and Steam Chest black and used the last part of my green paint on the Bearing Blocks. I haven't decided what to do with the Top Cylinder Cover and Steam Chest Cover.

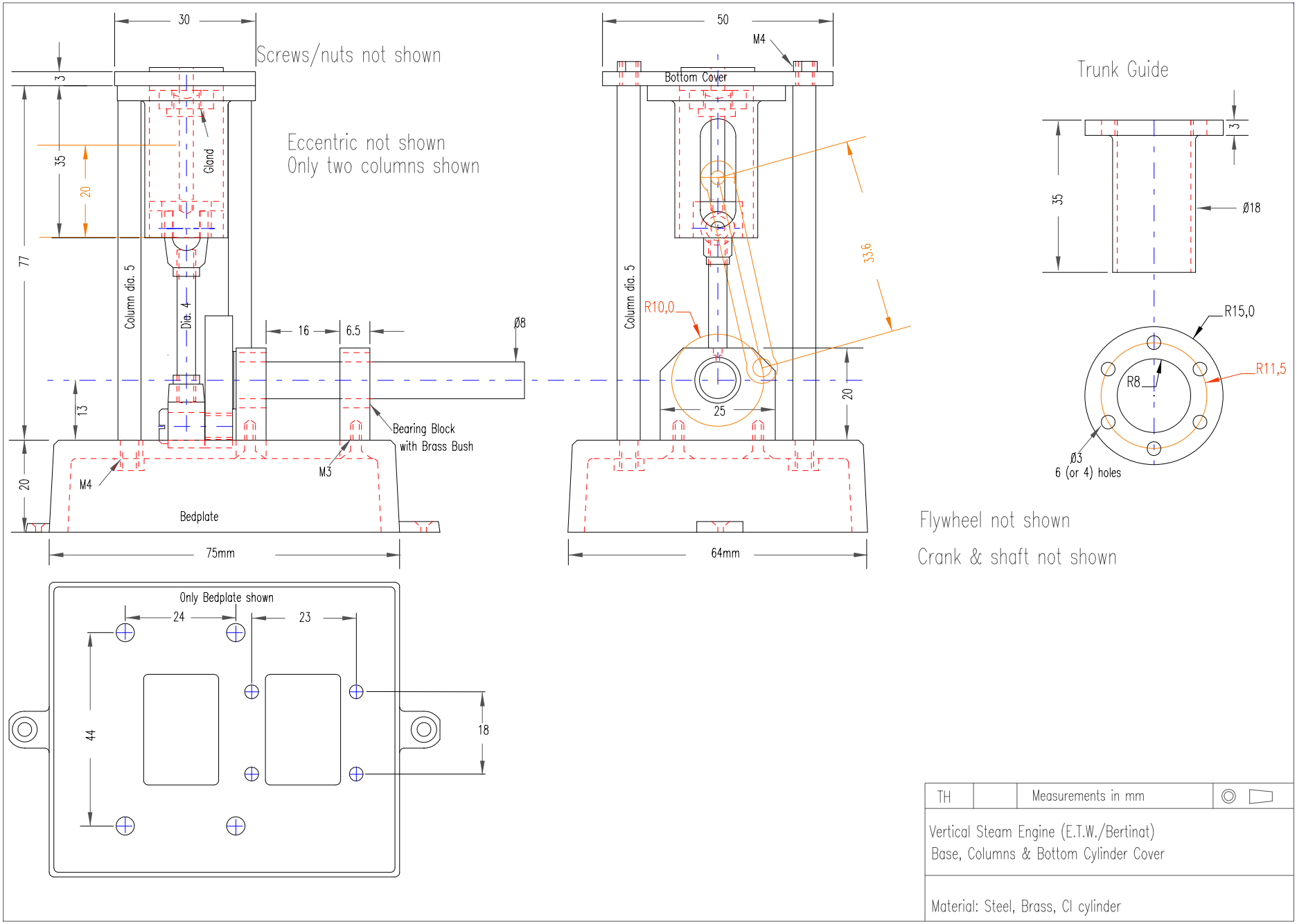
First run

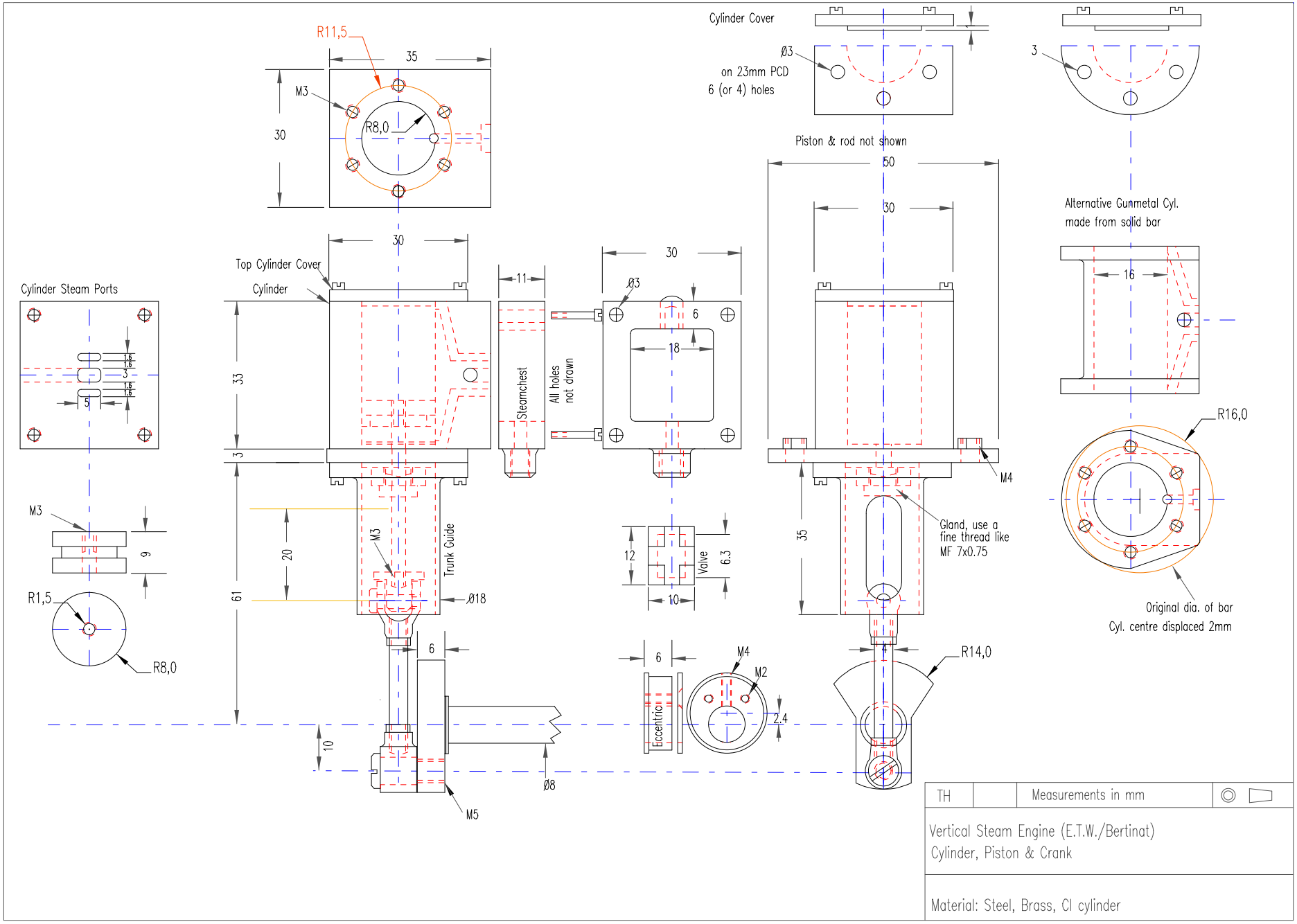
The parts of the engine were assembled and the Eccentric adjusted so the Slide Valve just started to open the steam in port when the Piston was at TDC. I oiled the various moving parts and connected the air hose from my small compressor to the Steam Chest and gave the flywheel a push and the engine started running.

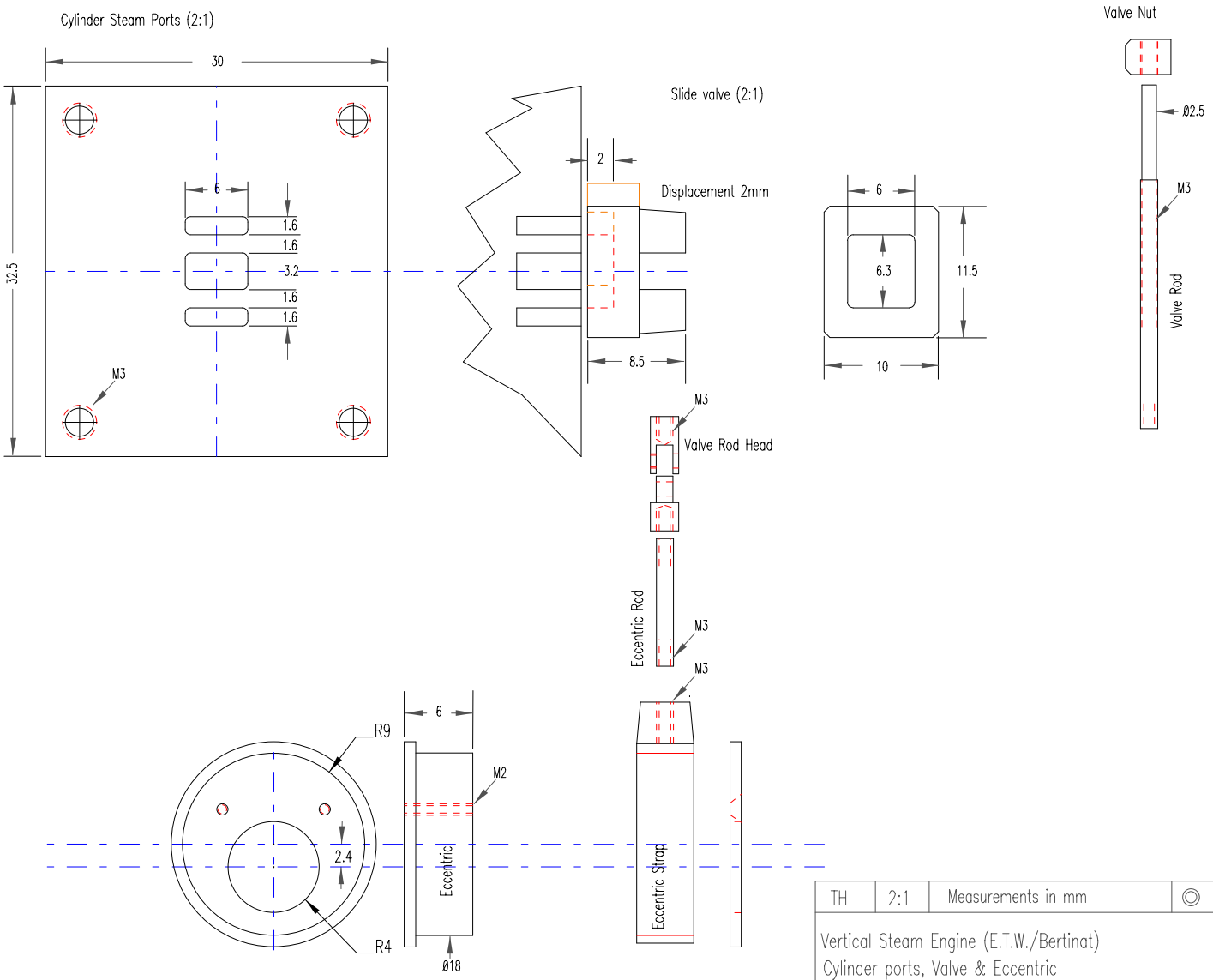
I later replaced the cheese head screws with studs – well M3 threaded rod – and M3 nuts.




30
Top Cylinder Cover
Cylinder
33
3
77
20
13
Steamchest
dia. 3
Column dia. 5
Bearing Blocks with
Brass Bush
Flywheel, dia. 60mm
Ø8
Bedplate
75mm
Only two columns shown
50
30
Bottom cover
35
64mm
Alternative Gunmetal Cyl.
made from solid bar
16
Piston & rod not shown
Flywheel not shown
Crank & shaft not shown
TH
2017
Measurements in mm
Vertical Steam Engine (E.T.W./Bertinat)
G.A. & Major Dimensions
Material: Steel, Brass, CI cylinder


30
Screws/nuts not shown
3
35
20
77
Gland
Column dia. 5
Dia. 4
16
6.5
Ø8
13
20
M4
M3
Bearing Block
with Brass Bush
Bedplate
75mm
Eccentric not shown
Only two columns shown
50
M4
Bottom Cover
Column dia. 5
R10,0
33.6
20
25
64mm
Trunk Guide
3
35
Ø18
R15,0
R11,5
R8
Ø3
6 (or 4) holes
Flywheel not shown
Crank & shaft not shown
Only Bedplate shown
24
23
44
18
TH
Measurements in mm
Vertical Steam Engine (E.T.W./Bertinat)
Base, Columns & Bottom Cylinder Cover
Material: Steel, Brass, CI cylinder


R11,5
35
M3
30
R8,0
Cylinder Cover
Ø3
on 23mm PCD
6 (or 4) holes
3
Piston & rod not shown
50
30
Alternative Gunmetal Cyl.
made from solid bar
16
R16,0
Original dia. of bar
Cyl. centre displaced 2mm
Top Cylinder Cover
Cylinder
Cylinder Steam Ports
11
Steamchest
All holes
not drawn
Ø3
6
18
33
3
61
20
M3
Trunk Guide
Ø18
12
Valve
6.3
10
35
M4
Gland, use a
fine thread like
MF 7x0.75
M3
9
R1,5
R8,0
6
M4
M2
Eccentric
2.4
R14,0
10
Ø8
M5
TH
Measurements in mm
Vertical Steam Engine (E.T.W./Bertinat)
Cylinder, Piston & Crank
Material: Steel, Brass, CI cylinder


Cylinder Steam Ports (2:1)
30
32.5
6
1.6
1.6
3.2
1.6
1.6
M3
Slide valve (2:1)
2
Displacement 2mm
8.5
6
6.3
11.5
10
Valve Nut
Ø2.5
M3
Valve Rod
M3
Valve Rod Head
Eccentric Rod
M3
M3
6
R9
M2
2.4
Eccentric
R4
Ø18
Eccentric Strap
TH
2:1
Measurements in mm
Vertical Steam Engine (E.T.W./Bertinat)
Cylinder ports, Valve & Eccentric
Material: Steel, Brass, CI cylinder