Building Rudy Kouhoupt's Walking-Beam Engine

Some time ago I came across a copy of Rudy Kouhoupt's article: "Build this Walking-Beam Engine" (Popular Mechanics August 1969), and decided to try and make the engine. Since I am used to working with metric dimensions I made some metric drawings, and I didn't follow his directions to the letter. I didn't start with the *Bedplate*, but with the *Cylinder*, and made the cylinder from a piece of Cast Iron. I have used mainly mild steel for most of the parts, except for the *Cylinder* – Cast Iron – and the *Parallel Links* – Brass (as instructed in the Popular Mechanics article). Several other parts were made differently, either because I used materials I had at hand or the materials at hand were of a different size. Rudy used a long ¼" bolt to clamp the *Column* to the *Bedplate*, I did that in a different way.

Many thanks to Graham Meek for valuable advice during the build.

Materials

I made the *Bedplate* from 6mm thick Aluminium, the *Column* was fabricated from a 22mm dia. steel tube and some pieces of 10mm thick mild steel. The *Beam* and *Spring Beam* were made from 1mm thick mild steel sheet, and as said the *Cylinder* from a piece of Cast Iron I had lying around.

Cylinder

I started with the *Cylinder*, and used a piece of Cast Iron I already had instead of brass. The work was first squared in the milling machine and milled to 25 x 25mm and a length of just over 46mm. This is a bit larger than the ¾" brass square Rudy used, this just meant I had to adjust the size of the *Piston* and *Cylinder Covers*, and I could bore the cylinder to 16mm (instead of ½"). There was also enough material at the rear so where Rudy used a piece of Brass for the *Port Face*, I could incorporate the *Port Face* in the *Cylinder* block.

The work was transferred from the milling machine to the lathe and mounted in the 4-jaw and the centre of the cylinder bore marked out.

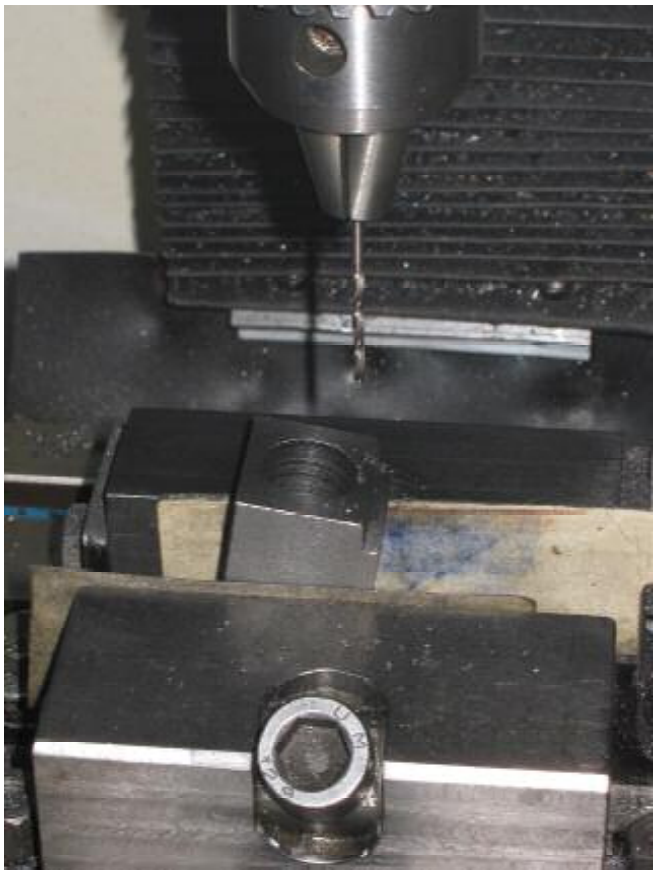
First I drilled a pilot hole and then opened that out to 15mm before using a boring bar to bring the cylinder to 16mm. The front face of the *Cylinder* was given a light cut just to clean up the length to 46mm. I marked which end was machined at the same setting as the bore. This will be the face where the *Top Cover* goes.

I rotated the work in the 4-jaw so that the *Port Face* was facing outwards and small curves were turned at the top and bottom just to make the Port Face stand out a bit.

The work was transferred back to the milling machine and the *Valve Pivot Screw* and the four port openings were marked out on the *Port Face* at a PCD of 15mm. I used a 2mm drill for the ports and drilled them to a depth of just over 3mm.

Rudy drilled the steam passages parallel to the cylinder bore, I placed the *Cylinder* at a slight angle and drilled from the outer edge of the cylinder so that the steam passage meet up with the upper and lower port holes just drilled – see photo. Before I started drilling I milled a small flat and then used a Centre Drill.

The holes for the *Cylinder Covers* will be drilled when the covers are made. The covers can be used to spot the holes in the cylinder ends.



Beams

I decided to make the beams next, and the *Column* and *Stretcher* (Spacer).

I had some 1mm thick mild steel sheet, and used that to make the beams. This is thicker than the dimension given by Rudy, but I used what I had at hand.

The outline and the holes of one *Spring Beam* were marked on the sheet metal and I used a hacksaw to cut out the rough shape. I drilled a couple of the holes and used them as a jig to drill corresponding holes in the second piece. The two pieces were bolted together using two small screws and then the other holes could be drilled through both pieces, as advised by Rudy. I used a file to file the parts to final dimensions.

The *Main Beams* were made the same way as the Spring Beams.

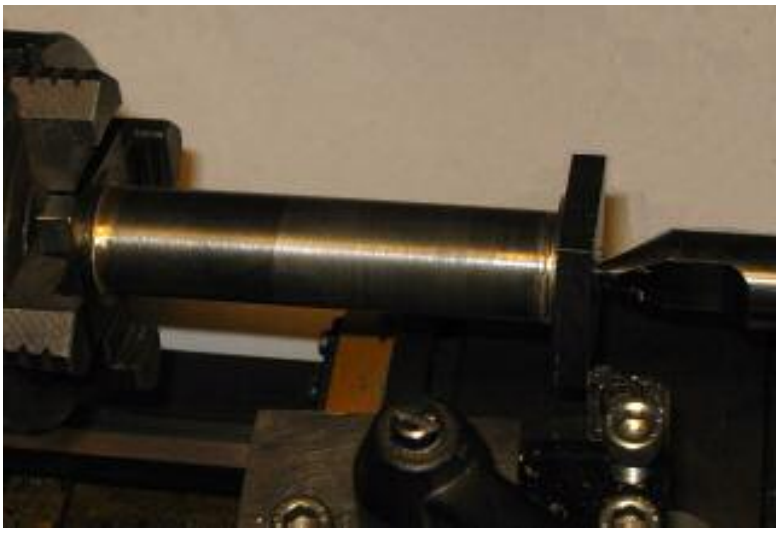
The *Spring Beams* are attached to the *Entablature* on top of the *Column* at one end and there is a *Stretcher* (spacer) at the opposite end. I made this spacer from a piece of 8mm square mild steel. A 2.5mm hole was drilled centrally at each end and tapped M3. The corresponding holes in the *Spring Beams* were opened up to 3mm.

Column

I used a piece of 22mm diameter mild steel tube for the column, and some 10mm thick pieces of black mild steel for the *Entablature*. The three pieces will be silver soldered together. I decided to make two *Entablatures*, and drill holes through the *Bedplate* and into the bottom Entablature to clamp the *Column* to the *Bedplate*. Using countersunk screws will make the bottom of the *Bedplate* flat. This differs from the procedure given by Rudy.

The pieces for the *Entablature* were milled square and to the 32 x 32mm dimension in the milling machine, and the transferred to the lathe so I could turn a 3mm deep hole with a

diameter just over the diameter of the tube I used for the column. I also drilled a 2mm hole through the centre of each piece; it is necessary with at least one through hole when silver soldering the last piece to the tube. I also used the holes (I used a centre drill first) to support the column when facing each end of the *Column* after soldering – see photo.



Then the pieces were degreased and fluxed and silver soldered together. After pickling in a citric acid bath the work was dipped in a solution of sodium bicarbonate to neutralise the acid. Then the work was mounted in the lathe and the ends faced. I also turned the inner part of the *Entablature* to get a nicer transition towards the column.

I used the holes in the *Spring Beams* to spot the corresponding holes in the Entablature and drill 2.5mm and tap M3. The matching holes in the *Spring Beams* were opened up to 3mm.

Parallel Links

The *Parallel Links* were made from 1/8" i.d. (5/32" o.d.) brass tube and 3/32" brass rod, as advised by Rudy. However, I silver (hard) soldered the pieces together, so I had to make my soldering jig from a piece of mild steel from my scrap box.

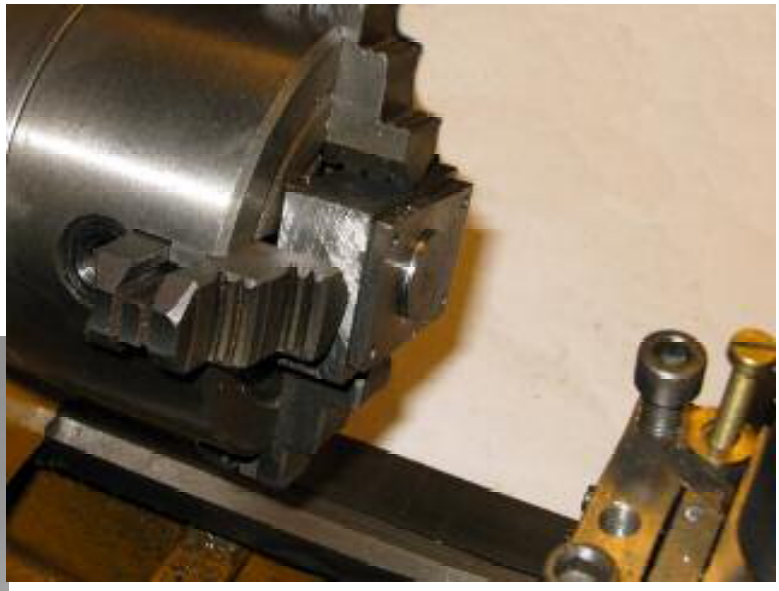
I used the feed-screw on the milling table to space two holes 32mm apart on the soldering jig. The holes were drilled 2.5mm and tapped M3. Then I milled away material on the inner half of the 2.5mm holes to a depth of just over 1mm, I also milled lengthways except for a 2mm wide section in the middle. I hoped this would prevent the brass tube from being soldered to the jig. I cut the brass tube over length (and filed them to length after soldering) so the solder should not flow over the top of the brass tube and solder it to the stainless steel M3 screw used to hold the tube bits. The brass rod was cut slightly over length and a small round file used to file the ends to a close fit on the tubes. Each end was fluxed and I bent a small length of solder to a crescent and placed one over each end of the brass rod. Then I silver soldered, and pickled in a citric acid solution. The rods of silver solder I had at hand was a bit thick – 1mm – so I believe a 0.5mm rod would have given better results.

Bottom Cylinder Cover

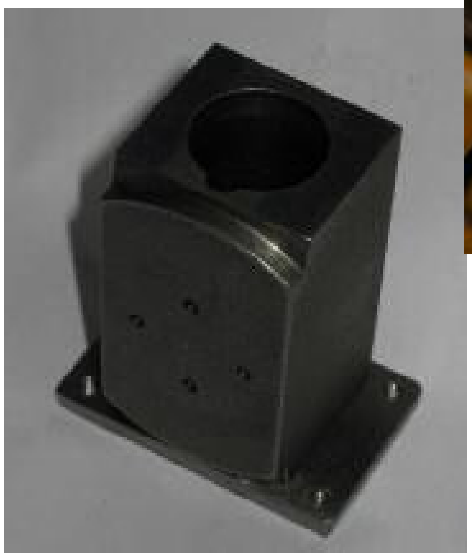
I found a suitable piece of 4mm thick mild steel I could use for the *Bottom Cylinder Cover*, and decided to make that. I wondered how to hold such a thin piece when turning the 1mm spigot protruding into the cylinder, and decided to make a simple jig. The jig was just a rectangular piece of 15mm thick steel that I faced on both sides, to make them parallel.

I milled the *Bottom Cylinder Cover* to dimension, marked out the four holes that I will use to clamp the *Bottom Cover* to the *Bedplate*, and drilled 2.5mm and tapped them M3. I then used the *Bottom Cover* to spot through to the jig and drilled four 3mm holes in the jig. The 3mm

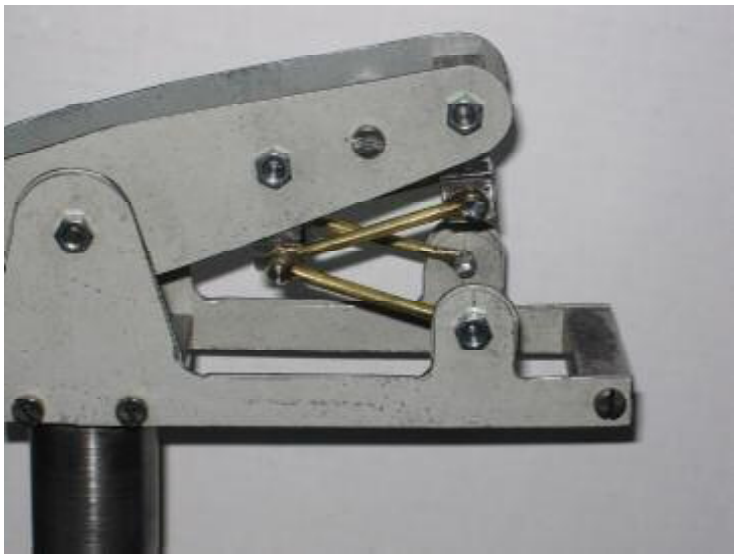
holes were counter bored on the side of the jig that will be facing the 4-jaw chuck. I could now use four M3 screws to hold the Bottom Cover and clamp the whole in the 4-jaw – see photo.



The spigot on the *Bottom Cover* was turned, and then transferred to the milling machine and four 3mm holes drilled 90 deg. apart. These holes were used to spot the corresponding holes in the bottom of the cylinder, so they could be drilled 2.5mm and tapped M3. The 3mm holes in the *Bottom Cover* were countersunk on the side facing the *Bedplate*.



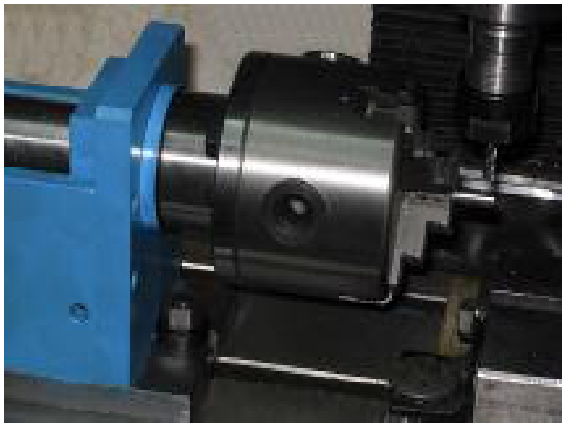
The photo to the left shows the *Cylinder* and *Bottom Cover*.



Links and Beam Spacers

I made the centre *Beam Spacer* and the *Main Link* and *Back Link* from pieces of Cast Iron I had left from making the Cylinder. The gudgeon pins were made from mild steel rod and I think they will run well in Cast Iron.

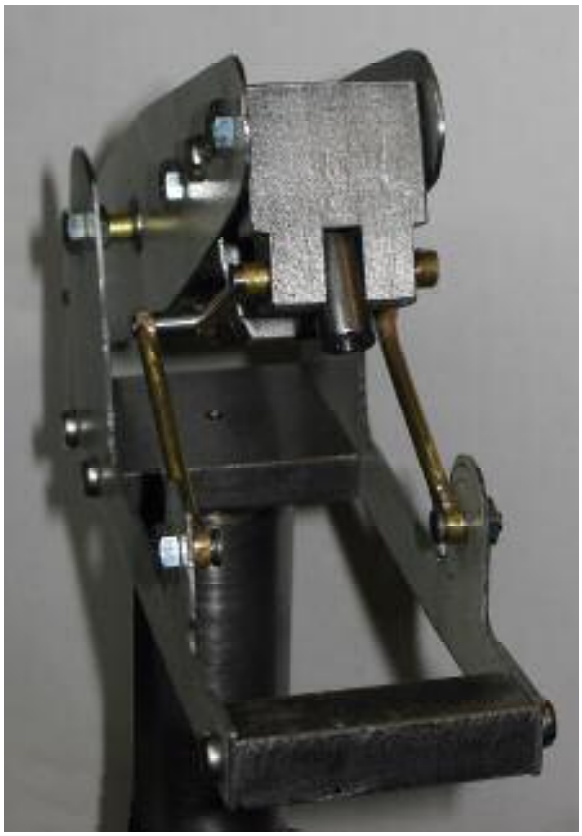
The *Centre Beam Spacer* was made from a piece of steel rod that cleaned up to a diameter of 11mm, each end was turned down to 7mm for a length of about 1.2mm, and a 4mm hole was drilled and a piece of brass tube Loctited in, for the gudgeon to run in. The width of the 11mm dia. part was about 0.2mm wider than the inside space between the two Main Beam members. This way the centre spacer will not rotate in the 7mm holes I drilled in the Main Beams.



The *Main Link* and *Back Link* was milled to dimension in the milling machine and the holes for the gudgeon pins drilled 15.8mm apart using the handwheel dial on the milling machine table to get the distance correct.

The *Piston Rod Eye* was made from a piece of

6mm dia. mild steel rod. The (over length) work was held in the 3-jaw on my indexing head and one side milled down 1mm for a length of just over 8mm. Then rotated 180 deg. and milled the same way. Then over to the lathe and the work was parted off to just over finished length, faced and centre drilled and drilled 2.5mm and tapped M3 for the *Piston Rod*. Then a 1.6mm hole was drilled from the front and into the hole for the gudgeon, and tapped M2.



The only part left on the Beam is the *Connecting Rod Little (*or *Small) End*, which was made from a piece of steel from my scrap box. The width of the work was milled to just under 19mm and a 4mm hole drilled near one end. Just like the Centre Beam Spacer I used a piece of brass tube Loctited into the 4mm hole as a bearing for the gudgeon. At the other end and at 90 deg. to the 4mm hole I drilled 2.5mm and tapped M3 for the *Connecting Rod*.

Top Cylinder Cover

The *Top Cylinder Cover* was fabricated from a piece of 4mm thick mild steel and a piece of 10mm dia. brass rod. The mild steel part was milled square and to dimension in the milling machine and the centre marked, and a 9.5mm hole drilled through. The brass rod was turned down for a length of 4mm, to a sliding fit in the 9.5mm hole. The brass rod was parted off to give a total length of 13mm. The parts were fluxed and silver (hard) soldered together, pickled in citric acid and neutralised in a sodium bicarbonate solution. The work could now be transferred to the lathe and held in the 3-jaw by the brass rod and the spigot that will enter the Cylinder could be turned. I used a centre drill to mark the start of the hole for the Piston Rod and drilled through. I then used a D-bit to finish the hole. I drilled four 3mm holes 90 deg. apart in the Top Cover and used the Top Cover to spot the corresponding holes in the Cylinder top face. The four holes in the Cylinder were drilled 2.5mm and tapped M3.

Piston and Piston Rod

The *Piston* was made from a piece of Cast Iron. It was turned slightly oversize and a 2.5mm hole drilled through. The hole was opened up to the diameter of the *Piston Rod* for a length of half the width of the piston, the 2.5mm part was threaded M3. I used a parting off tool to cut the packing groove. The *Piston* was parted off and the

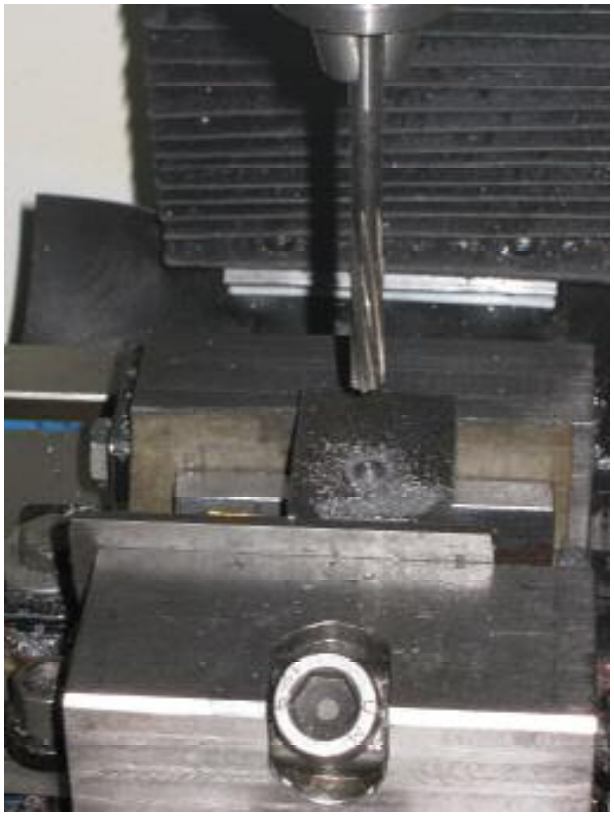
parted off side faced. The *Piston* with *Piston Rod* was then turned to a nice fit in the *Cylinder*. The *Piston Rod* was made from a piece of 1/8" free-cutting stainless steel, the M3 thread on the end was cut in the lathe.

Crank and Crankshaft

The *Crank* was made from a piece of 8mm thick mild steel from my scrap box. I used a hacksaw to cut it roughly to shape, and then a file. The centres were marked and the *Crank* was mounted in the milling vice and I used the table dials to space the two holes 12.5mm apart. This will give a throw of 25mm, somewhat less than Rudy's. The hole for the *Crankshaft* was drilled slightly undersize so it was a press fit in the *Crank*. The hole for the *Crankpin* was drilled 3.3mm and tapped M4. Before pressing the *Crankshaft* in a drop of anaerobic glue was placed in the hole.

Crankshaft Bearing Blocks

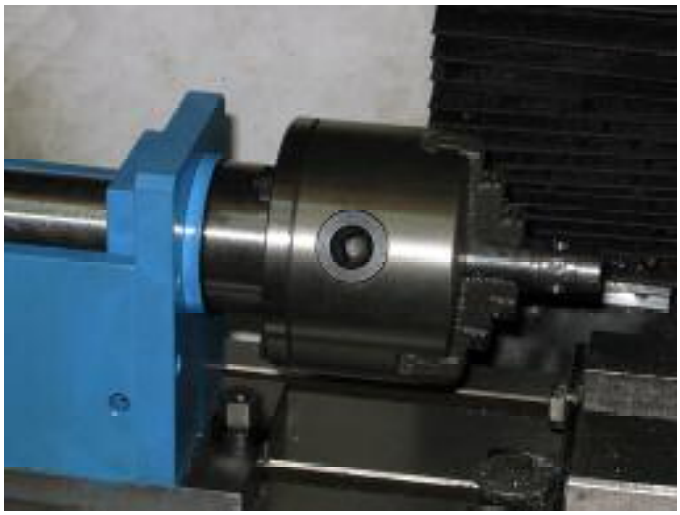
The *Bearing Blocks* were made from 10mm thick black mild steel, I first used a hacksaw to cut the work roughly to shape, then ver to the milling machine to mill them. They ended up 29mm wide and 33mm high, not exactly as the drawing, but the most important part is to get the hole for the *Crankshaft Bearing Bushes* to correct height. I assumed that the centre height of the *Crankshaft* should be the same has the height from the *Bedplate* to the centre of the *Valve Pivot Screw* on the *Cylinder*. I mounted both *Bearing Blocks* together in the milling vice and milled them to the same height in one operation. They were then turned lying on two parallels and a pilot hole drilled through both blocks at the marked centre. The drilled hole was opened up to 10mm and a couple of Cast Iron bushes with slightly undersize holes, pressed into the bearing Blocks. I added a drop of Loctite before pressing the bushes in, a relatively light press fit. After the Loctite had cured the blocks were mounted together again in the milling vice and the holes reamed to 6mm in one operation.



Here are the *Bearing Blocks* with the *Crankshaft* sitting on the piece of alloy that will become the *Bedplate*.
Later I used a 1.5mm drill and drilled a hole from the top centre of each *Bearing Block*, and down into the hole in the Cast Iron bush. The 1.5mm hole was opened up to 4mm to a depth about 1mm over the CI bush, this will act as a small oil reservoir and lubricate the *Crankshaft*.

Flywheel

Rudy used an old gear wheel as a flywheel on his engine; I didn't have anything suitable so I decoded to fabricate a spoked *Flywheel*. In my scrap box I had a short piece of thick-walled steel tube just over 80mm diameter and a piece of thin-walled steel tube that I was just able to press into the thick-walled one. I made a hub from a piece of 16mm dia. mild steel rod, I drilled a 5.9mm hole through the centre and reamed it 6mm. I then used my Indexer to drill six 4.3mm holes spaced 60 deg. and took care the holes didn't break into the 6mm hole. The 4.3mm holes were tapped M5 – right photo.



I did the same with the thin-walled steel tube, except I drilled the holes 5mm and I didn't tap them.

The spokes were made from a piece of 5mm bright mild steel rod, they were parted off a few millimetres over length. One end was faced and chamfered and a few M5 threads cut so the spoke would just enter the threaded hole in the hub. I made a soldering jig (right photo) from a piece of steel from my scrap box. Four arms would have made adjustments easier but I managed to centre the steel tube fairly well. The spokes were screwed firmly into the hub and the joint between the steel tube and the spokes fluxed before silver (hard) soldering.

After silver soldering and pickling, the protruding parts of the spokes were sawn off and then filed flush with the rim. After using emery paper on the outer part of the rim and inner part of the thick-walled tube I mixed some epoxy that I applied between the two parts and pressed the part with the spokes into the tyre. I let it rest on a flat surface with some polyethylene plastic underneath so it wouldn't stick to the flat surface.

After the epoxy had cured I drilled three 2.5mm holes through tyre and rim and tapped M3 for three short pieces of M3 threaded rod. After the Loctite I used to secure the threaded rod had cured the ends were filed flush and the flywheel

was mounted on a tapered mandrel between centres and the outer diameter and sides finish turned to remove some wobble, well most of it. The thick-walled tube used for the outer ring should have been a bit wider, but I used what I had at hand.

Eccentric

I made my eccentric different from what Rudy described in his PM article. I used a piece of Cast Iron while Rudy used brass. He just turned a groove in the brass, I turned a narrow collar at one end and used a piece of sheet steel on the other end to locate the *Eccentric Strap*. I drilled and reamed the 6mm hole after turning the collar to 25mm and the rest to 19mm. The work was then transferred to the milling vice and I drilled a 3.3mm hole and tapped M4 through the thick part of the *Eccentric* – see photo.

I made the *Eccentric Strap* from a piece of steel tube, 22mm o.d. The tube was clamped in the 3-jaw and the i.d. turned to 19mm with a smooth finish. The end was given a facing cut and a length of 5mm was parted off. To the short piece of steel tube I silver soldered a small piece of mild steel, a 2.5mm hole was drilled in this small piece and tapped M3 for the *Eccentric Rod*. Since I didn't follow Rudy's drawings when I made the *Eccentric*, I had to make a small bend on the 3mm rod I used to make the *Eccentric Rod* so It aligned with the *Valve*. The Little End of the rod is just a small pice of Cast iron with a 3mm through hole near one end and a 2.5mm hole threaded M3 and at 90 deg. to the 3mm, in the other end.

Here is a photo of the *Flywheel*, *Bearing Blocks* and *Eccentric* mounted on the *Crankshaft*. I just put a long M3 screw in the *Eccentric Strap* so it wouldn't rotate when I turned the *Flywheel*.

Valve

The *Valve* was made from a scrap piece of Cast Iron. I mounted a small home made vice on the Rotary Table. I centred the table under the milling spindle using centres, and marked out the pivot centre on the work. The small vice was then adjusted on the Rotary Table until the centre coincided with the pivot centre.

I used an end mill to mill most of the outer profile and a 2mm slot drill (the smallest I have) to mill the semi-circular steam channels – see photo.

The hand-wheel dials on the milling table was used to place the cutter 7.5mm from the centre of the 4mm pivot hole when milling the steam channels, and the 17.5mm distance to the 2.5mm hole that will be tapped M3 for a screw to hold the Little End of the *Eccentric Rod*.

Bedplate

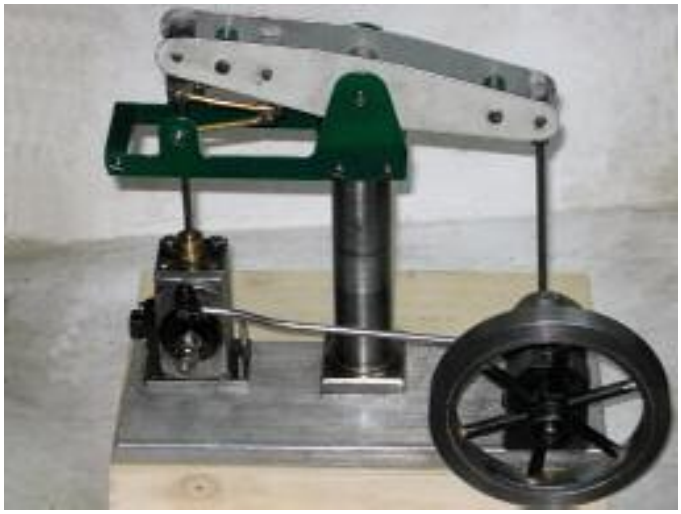
I used a piece of 6mm thick and 65mm wide alloy for the *Bedplate*. I used a hacksaw to cut it slightly over length. It was then mounted on the milling table and I used a DTI to align the long side parallel to the table longitudinal travel. Then I could mill each end square using an endmill. The edges were then rounded using a corner rounding cutter.

I marked out the position of the *Column* on the *Bedplate* and drilled four countersunk 3mm holes through the *Bedplate* so they would end up at each corner of the square bottom plate on the *Column*. These holes were then used to spot the corresponding holes in the Column. The holes in the *Column* were drilled 2.5mm taking care not to break through. The 2.5mm holes were then tapped M3 and I used four M3 screws with countersunk heads to mount the *Column* to the *Bedplate*.

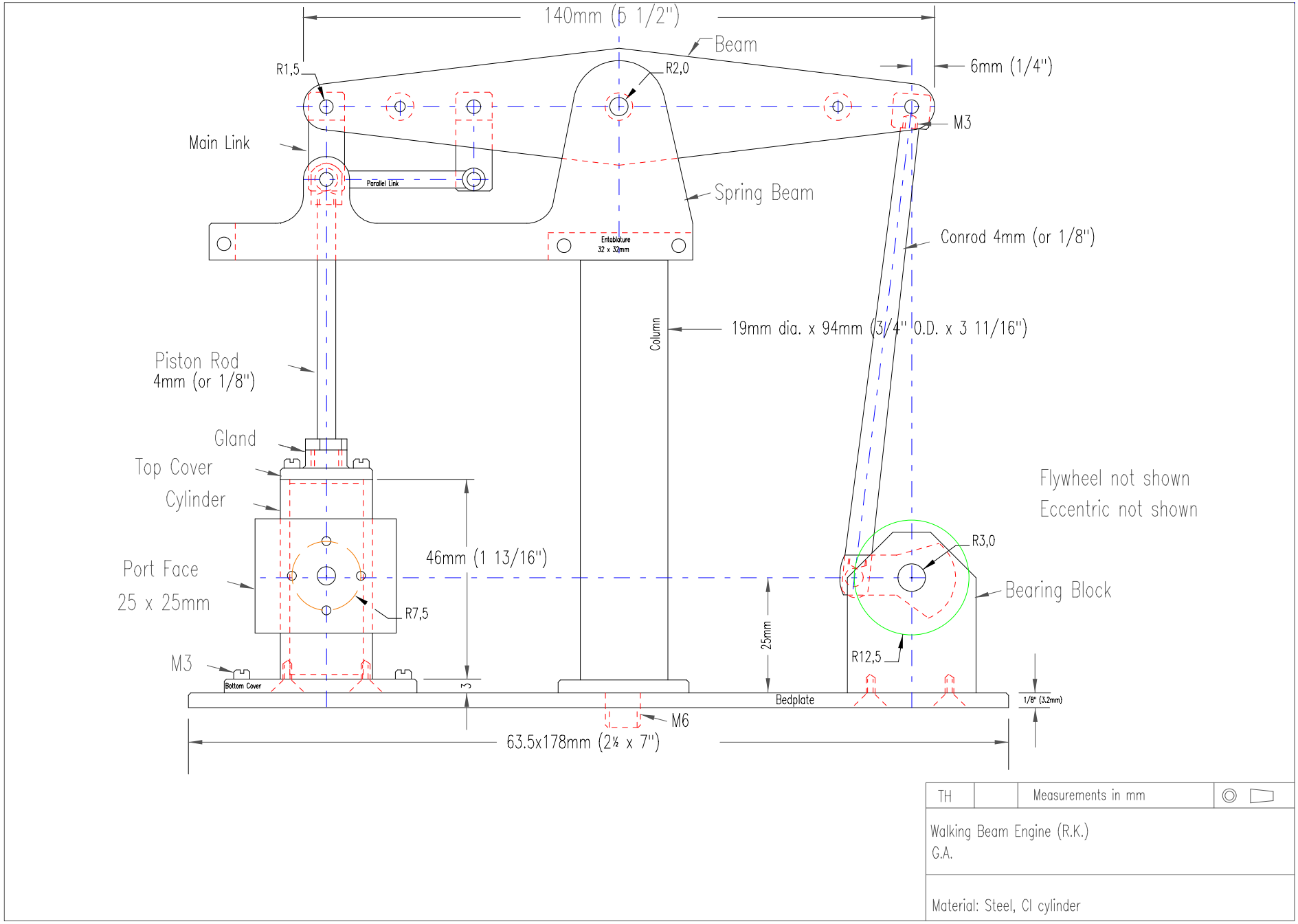
More or less the same procedure was used to mark the position of the *Bearing Blocks*, and they too were screwed to the *Bedplate* using cheese head screws in counter-bored holes.

The *Cylinder* with *Bottom Cylinder Cover* were placed on the *Bedplate* and the *Piston Rod* screwed into both the *Piston* and the *Piston Rod Eye* in the *Main Link* with the *Piston* in the *Cylinder* so the correct position for the cylinder assembly could be marked out on the *Bedplate*, using the four holes in the *Bottom Cover* to spot the holes.

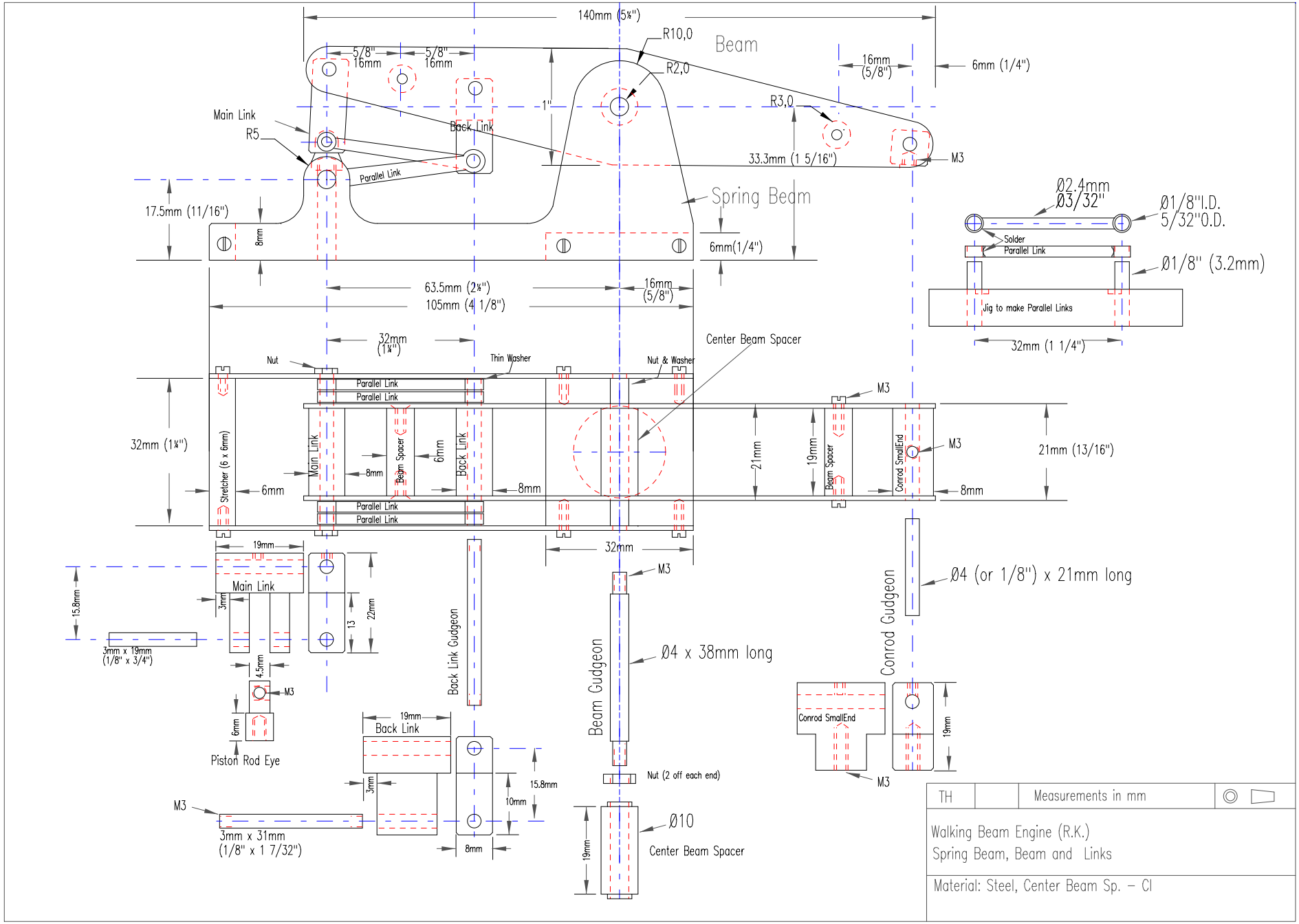
Final assembly

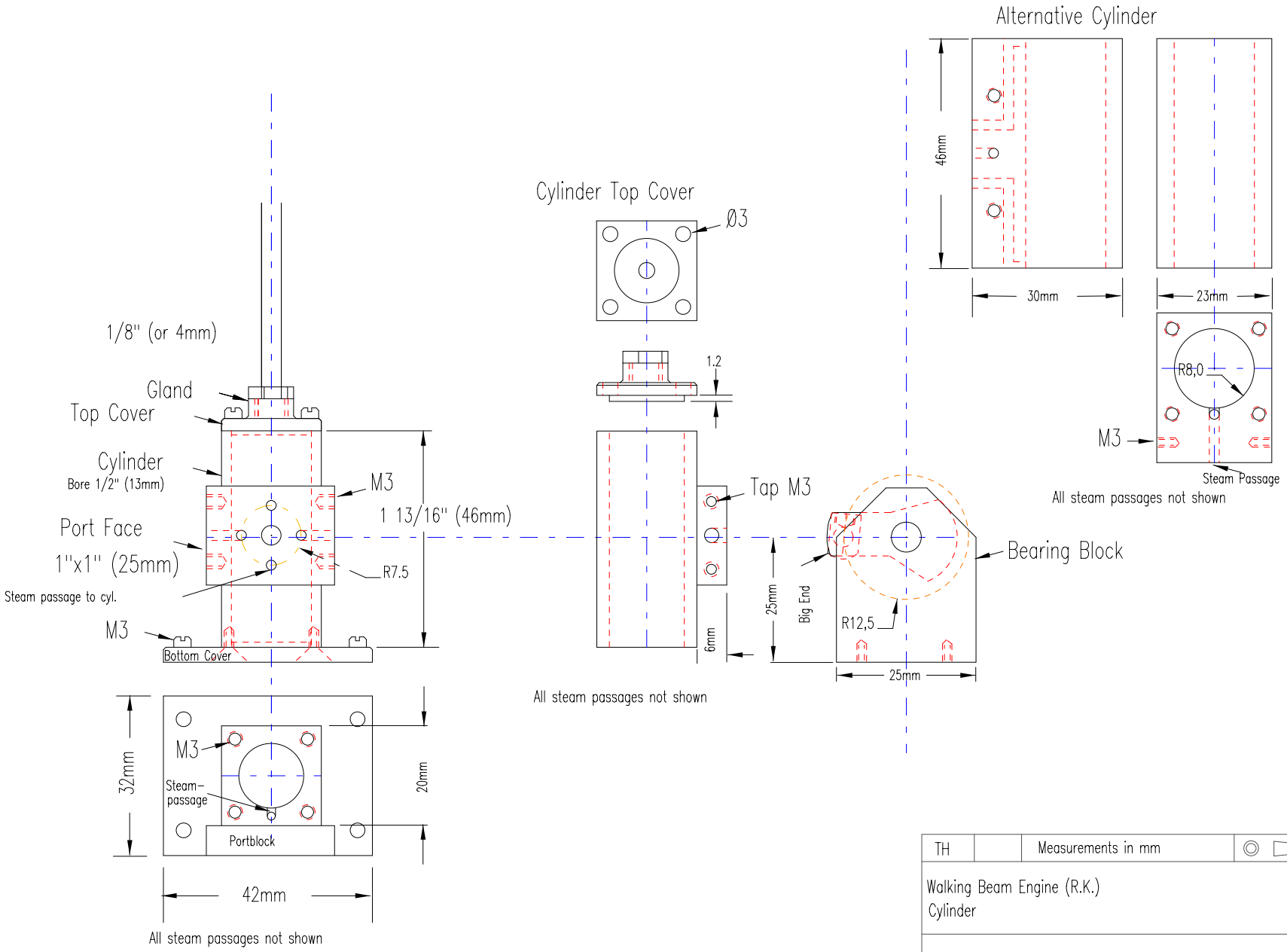


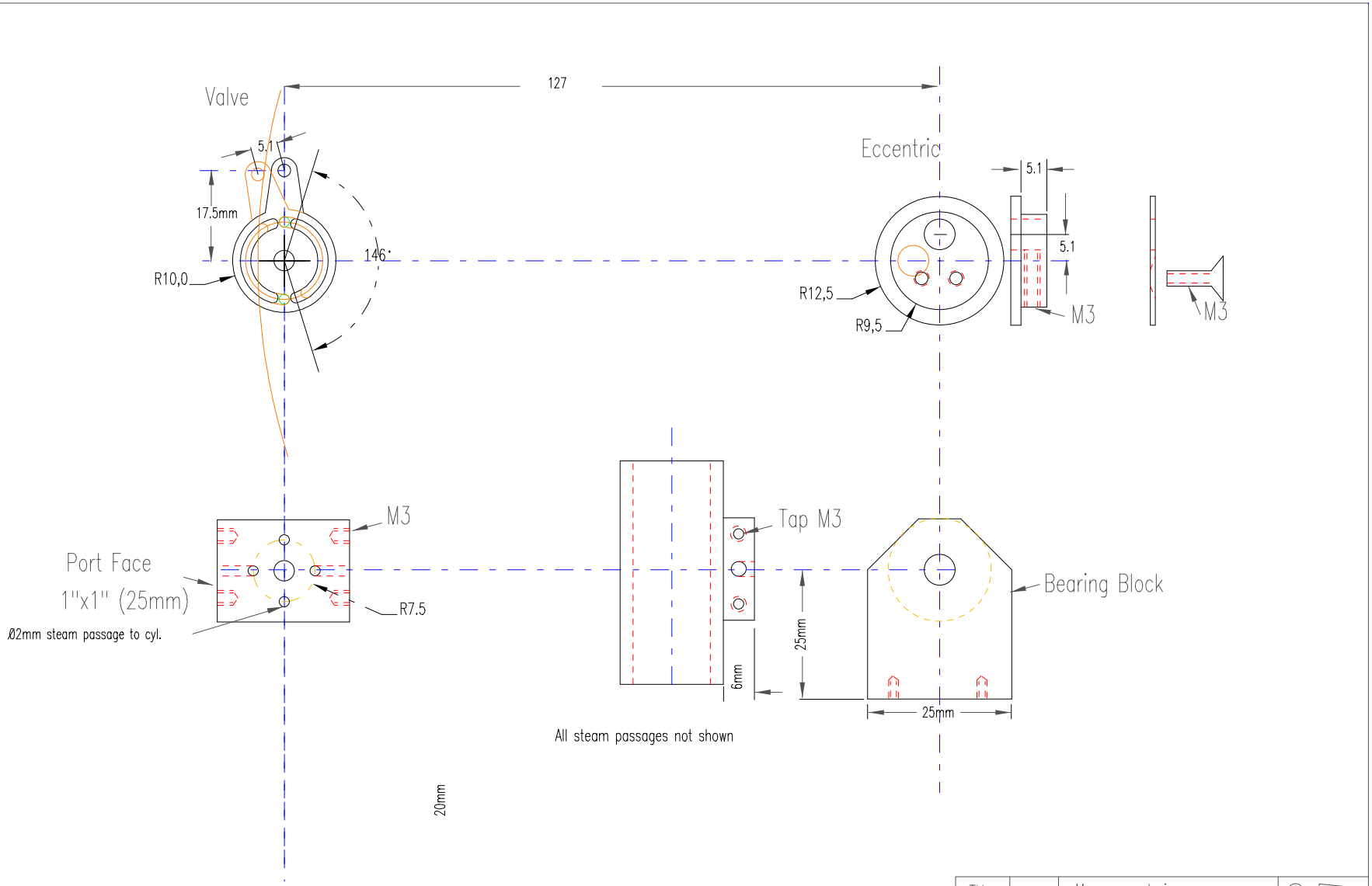
The various parts were assembled and the *Eccentric* adjusted so when the *Piston* was at TDC the *Valve* was in mid-position blocking the steam passages from the *Port Face* to the *Cylinder*. I had made the *Eccentric Rod* slightly over length so I had to shorten it a bit to get the Eccentric to move the Valve correctly. The air hose from the compressor was attached to the steam in port and after rotating the *Flywheel* a few times the engine started running, even if there was no packing in the piston groove and no gland packing. I must just find time to finish the paintwork.



TH		Measurements in mm	
Walking Beam Engine (R.K.) G.A.			
Material: Steel, CI cylinder			


140mm (5½")
R10,0
Beam
5/8"
16mm
5/8"
16mm
R2,0
16mm
(5/8")
6mm (1/4")
R3,0
1"
Main Link
R5
Back Link
Parallel Link
33.3mm (1 5/16")
M3
Spring Beam
17.5mm (11/16")
8mm
6mm(1/4")
Ø2.4mm
Ø3/32"
Ø1/8"I.D.
5/32"O.D.
Solder
Parallel Link
Ø1/8" (3.2mm)
Jig to make Parallel Links
32mm (1 1/4")
63.5mm (2½")
105mm (4 1/8")
16mm
(5/8")
32mm
(1¼")
Nut
Thin Washer
Nut & Washer
Center Beam Spacer
Parallel Link
Parallel Link
32mm (1¼")
Stretcher (6 x 6mm)
6mm
Main Link
8mm
Beam Spacer
6mm
Back Link
8mm
21mm
19mm
Beam Spacer
M3
Conrod SmallEnd
M3
8mm
21mm (13/16")
Parallel Link
Parallel Link
19mm
Main Link
3mm
13
22mm
15.8mm
3mm x 19mm
(1/8" x 3/4")
4.5mm
M3
6mm
Piston Rod Eye
32mm
M3
Beam Gudgeon
Ø4 x 38mm long
Nut (2 off each end)
Back Link Gudgeon
Conrod Gudgeon
Ø4 (or 1/8") x 21mm long
Conrod SmallEnd
19mm
M3
19mm
Back Link
3mm
15.8mm
10mm
M3
3mm x 31mm
(1/8" x 1 7/32")
8mm
19mm
Ø10
Center Beam Spacer
TH
Measurements in mm
Walking Beam Engine (R.K.)
Spring Beam, Beam and Links
Material: Steel, Center Beam Sp. – CI


1/8" (or 4mm)
Gland
Top Cover
Cylinder
Bore 1/2" (13mm)
Port Face
1"x1" (25mm)
Steam passage to cyl.
M3
1 13/16" (46mm)
R7.5
M3
Bottom Cover
32mm
M3
Steam-
passage
Portblock
20mm
42mm
All steam passages not shown
Cylinder Top Cover
Ø3
1.2
Tap M3
6mm
25mm
Big End
R12,5
Bearing Block
25mm
All steam passages not shown
Alternative Cylinder
46mm
30mm
23mm
R8,0
M3
Steam Passage
All steam passages not shown
TH
Measurements in mm
Walking Beam Engine (R.K.)
Cylinder
Material: CI cylinder


Valve
127
5.1
17.5mm
146°
R10,0
Eccentric
5.1
5.1
R12,5
R9,5
M3
M3
M3
Port Face
1"x1" (25mm)
Ø2mm steam passage to cyl.
R7.5
Tap M3
6mm
25mm
Bearing Block
25mm
All steam passages not shown
20mm
TH
Measurements in mm
Walking Beam Engine (R.K.)
Valve & Eccentric
Material: CI eccentric, Valve brass