3-Cylinder Oscillating Paddle Engine

This engine was designed for use in a small paddle boat. The idea was to produce something fairly simple, quick to make and that would be self starting and reversing.

To me, simplicity means a single acting oscillator, and to get self starting at least 3 cylinders. Oscillators usually involve spring loading the valve faces together – I'm not at all keen on this as there is quite a lot of unnecessary friction involved.

The design presented here seems to fit my requirements fairly well. The valve faces are held together by steam pressure rather than springs, this also means that higher pressures than the usual maximum of around 30 p.s.i. can be used. Admittedly the ports are small, but this is a paddle engine and not required to run very fast.

Although particular materials are specified on the drawings, you don't really have to stick to them. If I remember, I'll suggest alternatives as we go along.

1 – End Plate Two of these required from 1/8" or 3mm thick material. Shown as light alloy, but anything you fancy really. The only important dimension is the 2.75" between the holes for the valve shaft and the crankshaft. The central cut out is obviously not compulsory – do whatever you fancy. Clamp both plates together when drilling all the holes so they will assemble nice and square. Put a slight chamfer on the outside of the main bearing holes. Don't forget the tiny tapped hole at the bottom for the grub screw that locks the valve shaft into position.

2 – Main Bearings From bronze or brass, an easy turning job. If you are confident of your abilities, make them a press fit in the end plates, otherwise, allow one or two thou clearance on the ¼" diameter, assemble the frames and spacers, push a piece of the 1/8" as used for the crankshaft through the bearings and then loctite them into the end plates. You may need to reduce the .185 dimension a little so the crankshaft has a few thou endways movement.

3 – Spacers Again, material is not important. Better to make them a few thou too long than short. The main thing is to make them all the same length – say ± .001" and ensure they are faced off nice and square

4 – Crankshaft Probably the most awkward of all the parts. This was my third method of making it. The first involved silver soldering the main shaft, the big end journals and four steel discs together. It proved to me for the umpteenth time that I am incapable of silver soldering more than two pieces of steel together at any one time without making a hideous mess. The second attempt was to machine from solid – now I have made several multi-throw cranks this way, but this time things were just too flimsy. While pondering just how to make the darn thing, I suddenly realised that there was no need for each web to pass the centreline – all I needed was a series of return cranks. As you can see from the drawing, all the parts are really simple to make, and it is just the assembly that needs some care.

Now is the time to decide just what you want to use the engine for. If it is just to demonstrate gently under compressed air, loctiting the crank together should be OK. But if you intend loading it to any extent, it will probably be best to pin all the joints as well. The series of photos should demonstrate the assembly procedure. To set the two long links at 60º apart, a strip of packing 3/16" thick is wanted. On one face mark a line at right angles to one edge, and on the opposite face, draw a few lines at 30º to the same edge. Both links are fed onto the crank pin, one clamped in line with the "right angle" line and the other parallel with the 30º lines. The photos show what I mean. A drop of loctite 290 is applied to each joint. Loctite 290 has a very low viscosity and will wick into the joint, at the moment it is named "Screw Lock", but I seem to remember that it used to be known as "Penetrating Loctite". In all cases, I slightly roughened the mating areas of the shaft and crank pins with some course emery paper to give a better bond.

If you are going to pin the joints you will need something very small. Known as "Universal clock pins", I bought mine from a clockmakers suppliers. A bag of about 100 taper pins, 0.70mm at the small end, 1.8mm at the large end and 25mm long are available in brass and steel, they aren't at all expensive. Here in the UK the bag of brass pins is about £4.00 and £3.50 for the steel.

The problem of how to make the matching tapered hole now arises. I assume that high speed steel cutters are available, but I guess that they would cost an arm and a leg. So I made a "D" bit from one of the steel pins and it worked a treat!

5 – Cylinder Heads (make parts 6 first) I find it easiest to start off with the heads in a strip rather than cutting them up first. A length of 3/8" square brass is gripped in the milling vice and one end milled off square. You will notice that I have a small recess milled in the top of the replaceable jaws of the milling vice. This makes holding strips of material truly horizontal nice and easy. The first hole is drilled and reamed 1/4" dia, 3/16" from that end, the next 0.700" further along, and the next a further 0.700" along. A shallow slot was then milled across the bar with a 1/16" end mill at 0.400" along from the centre of each of the 1/4" holes. This is to leave a witness for machining the cylinder end to length. They were then sawn apart (in that 1/16" slot). Using a split collet, which you will have to make, they were faced to length, turned to fit inside part No.6, and drilled No.56.

6 – Cylinder Preferably use thin wall brass tube. Anything up to 3/8" dia will do, but note that if you do use 3/8" tube, you will have to put a small flat on adjacent sides to give a little clearance between them. After drilling the vent hole, make sure that all inside burrs are removed.

7 – Cylinder outer ends A simple turning job, but make sure the piston rod is an easy fit – say two to three thou larger than the rod.

8 – Pistons A simple turning job, but you must decide what sort of packing you want to use. If the engine is to be used only for demonstration with compressed air, probably plain pistons with no packing will be OK. Alternatives for use with steam or compressed air could be a soft packing of graphited yarn, silicone 'O' rings or shop made PTFE rings.

9 – Piston Rod Shown on the drawing as stainless steel, they could be nickel silver or even hard brass, and diameter doesn't matter too much – up to 3/32 should be OK.

10 - Big end These are made from ¼ x 3/16 material – not always readily available – I had to machine mine from ¼ square. The photos show how I machined the slots in the ends. You will have to position the work directly under the centre of the mill spindle. I always use an edge finder to do this. If you have a Digital Read Out (DRO), advance the edge finder and locate one side and zero the DRO. Now locate the opposite face and note the reading. Half that reading and advance the work until the DRO reads the same at which point the work should be centred under the spindle. Zero the DRO. You will notice that you don't have to know the material width or the edge finder diameter. If you don't have DRO, you'll have to use the hand wheel dial readings not forgetting to make an allowance for backlash.

The slots are then milled into the ends, and the small slots machined across the bar for the same reason as those on the cylinder heads – a witness when machining to length.

The cross holes for the retaining screws are located in a similar way as for the slots. Each big end is then sawn off the bar. Now, gripped in the vice as shown, they are milled to length. Using the same method as that used for centering the bar, repeat for the other axis. Now the spindle should be directly over the centre of the work. Drill and tap for the piston rod.

Face, drill and tap a bit of brass rod (same thread as the piston rod), screw a short length of studding into the end and the big end onto that so the chamfer can be machined – see the photo.

11 – Valve Shaft The simplest way to drill the deep holes in the valve shaft is to grip it in the three jaw chuck with some packing under one jaw. The get the required 1/16" offset, the packing should be 0.081" thick. Unless you have a long drill, you will have to drill short distances, backing off to clear the swarf each time. Follow up with a 3/32 drill for 3/16 depth. Now rotate the shaft as near to 180 degrees as you can judge. (Great accuracy is not needed here). Drill the second hole.

To machine the ports, grip the shaft in the milling vice with the two longitudinal holes horizontal - see the photo. A couple of pieces of 3/32 rod in the holes with a cross piece balanced or clamped on them allows the shaft to set up correctly. Centre it under the spindle and mill and drill as shown in the drawing. Use a slot drill rather than a mill.

12 – Mounting Plates I've shown a couple of brass angles for these items, but use whatever material and design you like.

13 – Spacers (valve shaft) A simple turning job. You may need to adjust the thickness on assembly so there is a few thou clearance for the cylinder to pivot on the valve shaft

Reverser / Regulator I've shown two designs for this item, one a bit simpler than the other. They are both a bit small and fiddly to make, so increase the size if you want – it will make no difference to their performance.

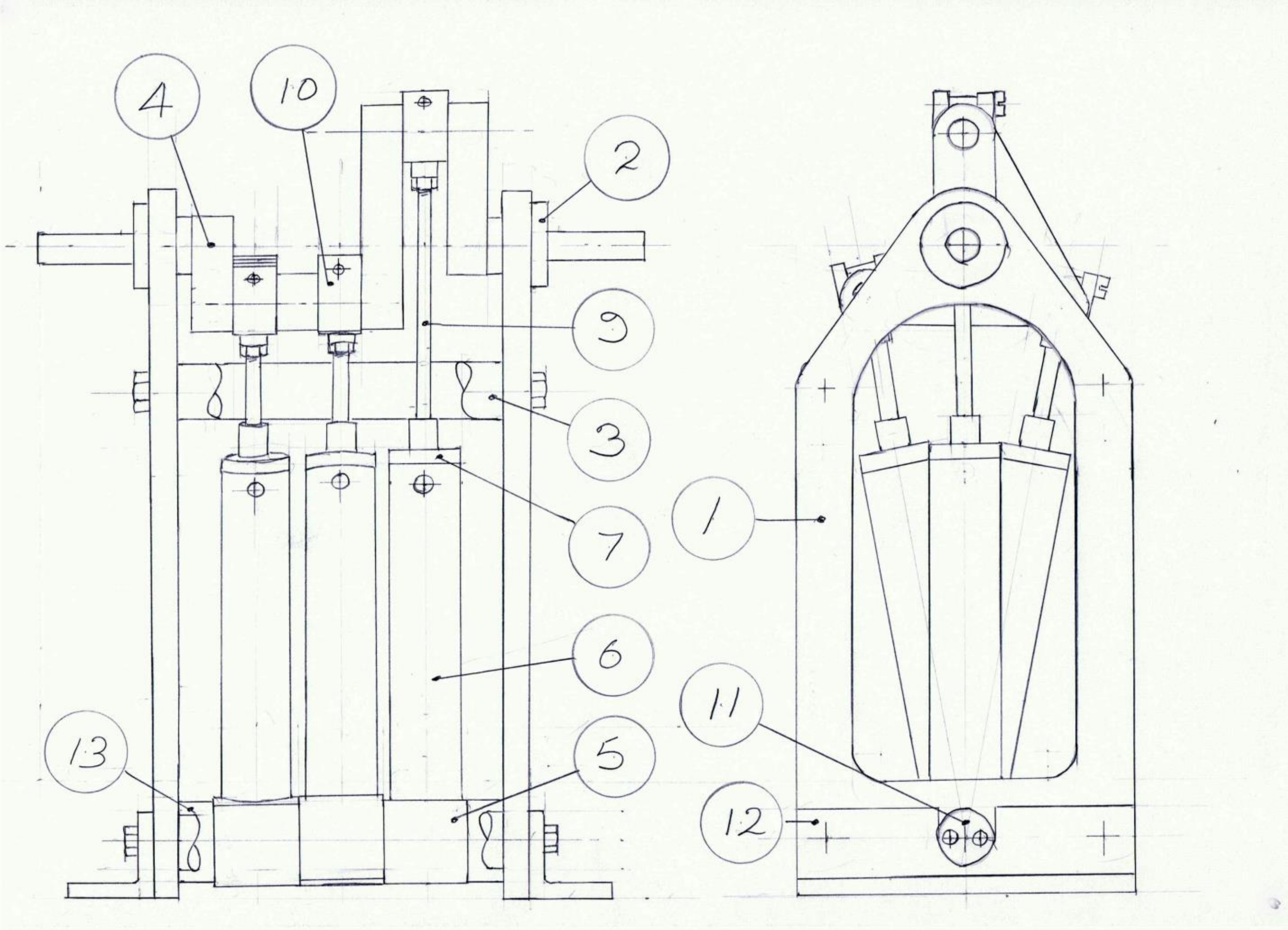
Assembly First thing to do is fit the reverser to the valve shaft. The two pipes from the base are soft soldered into the holes in the end of the shaft. It's up to you how long you want them, but use as little solder as possible – we don't want to block any holes.

The cylinders are soft soldered onto the heads being careful not to get any solder inside the bore where the piston will reach. The piston rods screwed into the pistons and whatever packing you have decided to use fitted on the pistons. Push the pistons into the cylinders – they should slide in and out with only slight resistance – rather difficult to describe – but definitely not tight. Feed the cylinder outer ends over the piston rods and secure them into the cylinders with just a touch of loctite. Screw a locknut onto the ends of the piston rods followed by the big ends, making sure that the thread doesn't protrude into the bearing surface.

Bolt the four spacers onto one of the end plates remembering that the main bearing flange should be on the outside. Feed the valve shaft through the hole for it in the end plate and slip on a small spacer followed by the three cylinder assemblies then the other small spacer. They must face upwards towards the crankshaft. Slide the crankshaft through its bearing. Now fit the other endplate – there are only the crankshaft and valve shaft to line up – and bolt it to the four spacers. Check that there is some endplay in the crankshaft and that the cylinders can move and are not clamped tight.

The big ends can now be fitted to the crankshaft journals and the locknuts tightened. If any of the pistons touch at either end of their stroke, the big ends can be adjusted a small amount by screwing in or out.

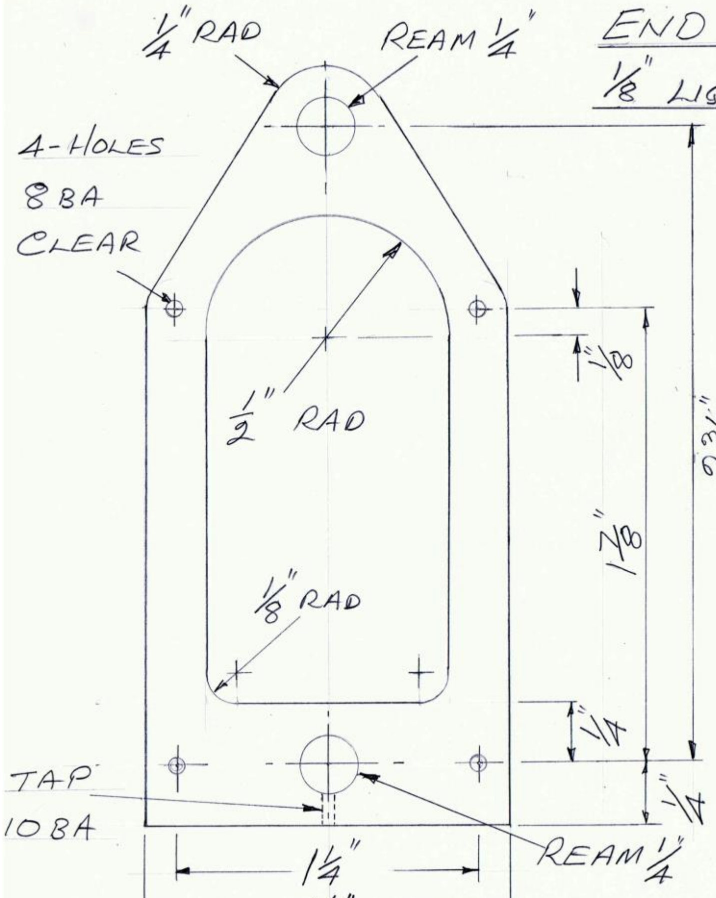
For initial running, a flywheel can be fitted – about 1 ½ diameter and ½ thick should do. The positioning of the valve shaft is critical. With air pressure on, rotate the valve shaft gently and the engine should run. To get it running equally well in either direction, some fine tuning of the valve shaft position will probably be needed. When satisfied, tighten the grub screws to lock it in place.

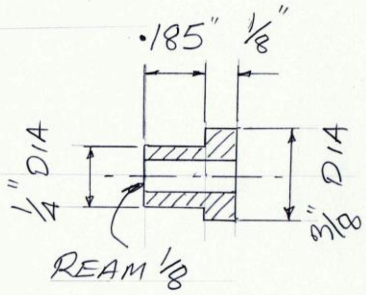


END PLATES 2-OFF

1/8" LIGHT ALLOY

1

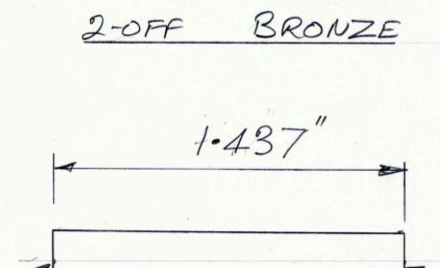




2

MAIN BEARINGS

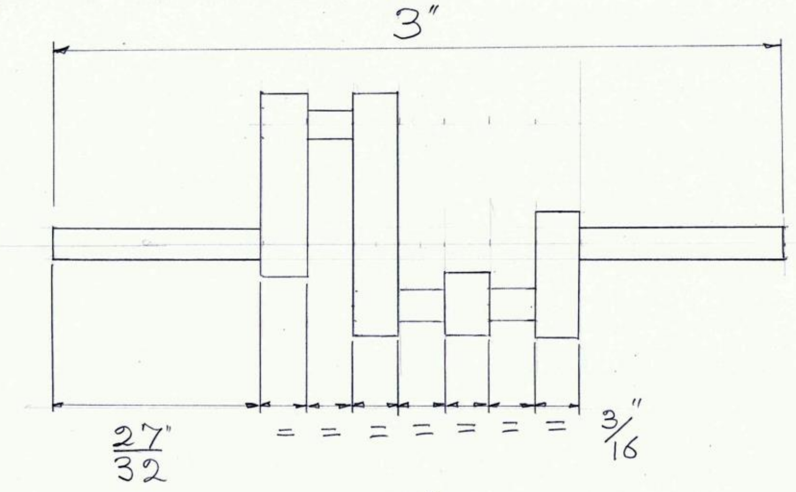
2-OFF BRONZE



3

SPACER 4-OFF

1/4" DIA BRASS OR L.A.



ALL JOURNALS 1/8" DIA MILD STEEL

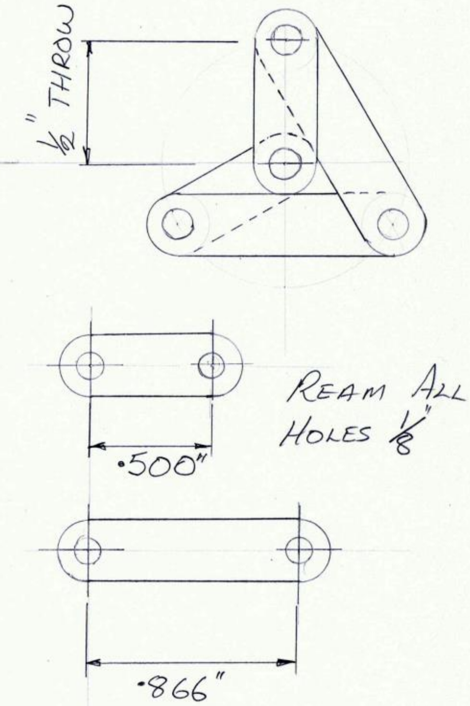
CRANKSHAFT (4)

ASSEMBLE WITH MAIN SHAFT IN ONE PIECE

CLAMP UP WITH 3/16" PACKING PIECES

APPLY PENETRATING LOCTITE (260)

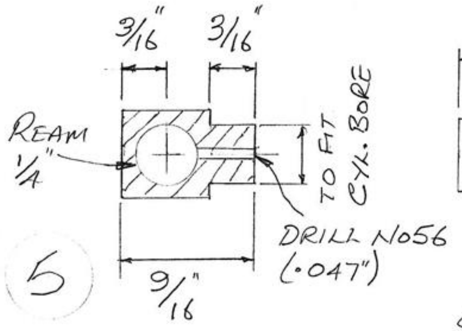
TO JOINTS THEN PIN EACH JOINT



REAM ALL HOLES 1/8"

CRANK LINKS 2-OFF EACH

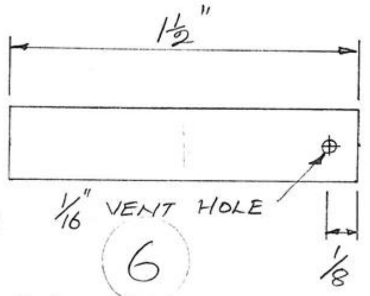
1/4" X 3/16" MILD STEEL



5

CYLINDER HEAD 3-OFF

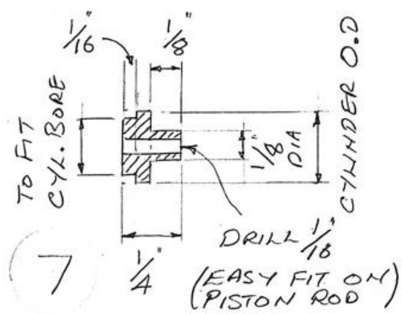
3/8" SQ. BRASS



6

CYLINDER 3-OFF

BRASS TUBE UP TO 3/8" O.D.



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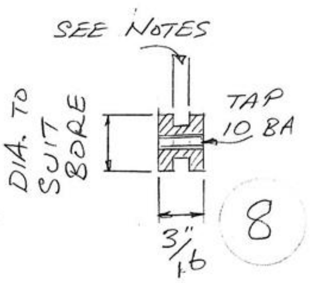
CYL. OUTER END

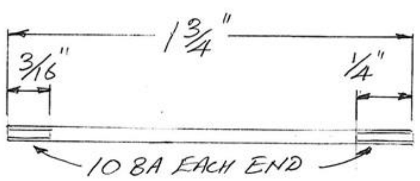
3-OFF BRASS



8

PISTON 3-OFF

BRASS OR BRONZE

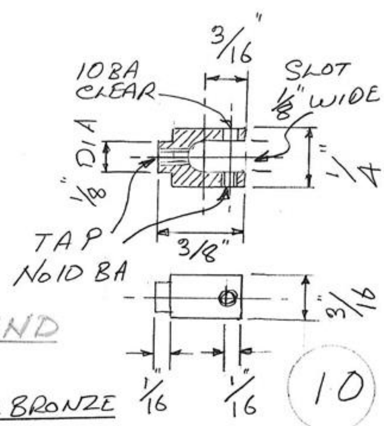


PISTON ROD

3-OFF

1/16" STAINLESS STEEL

9

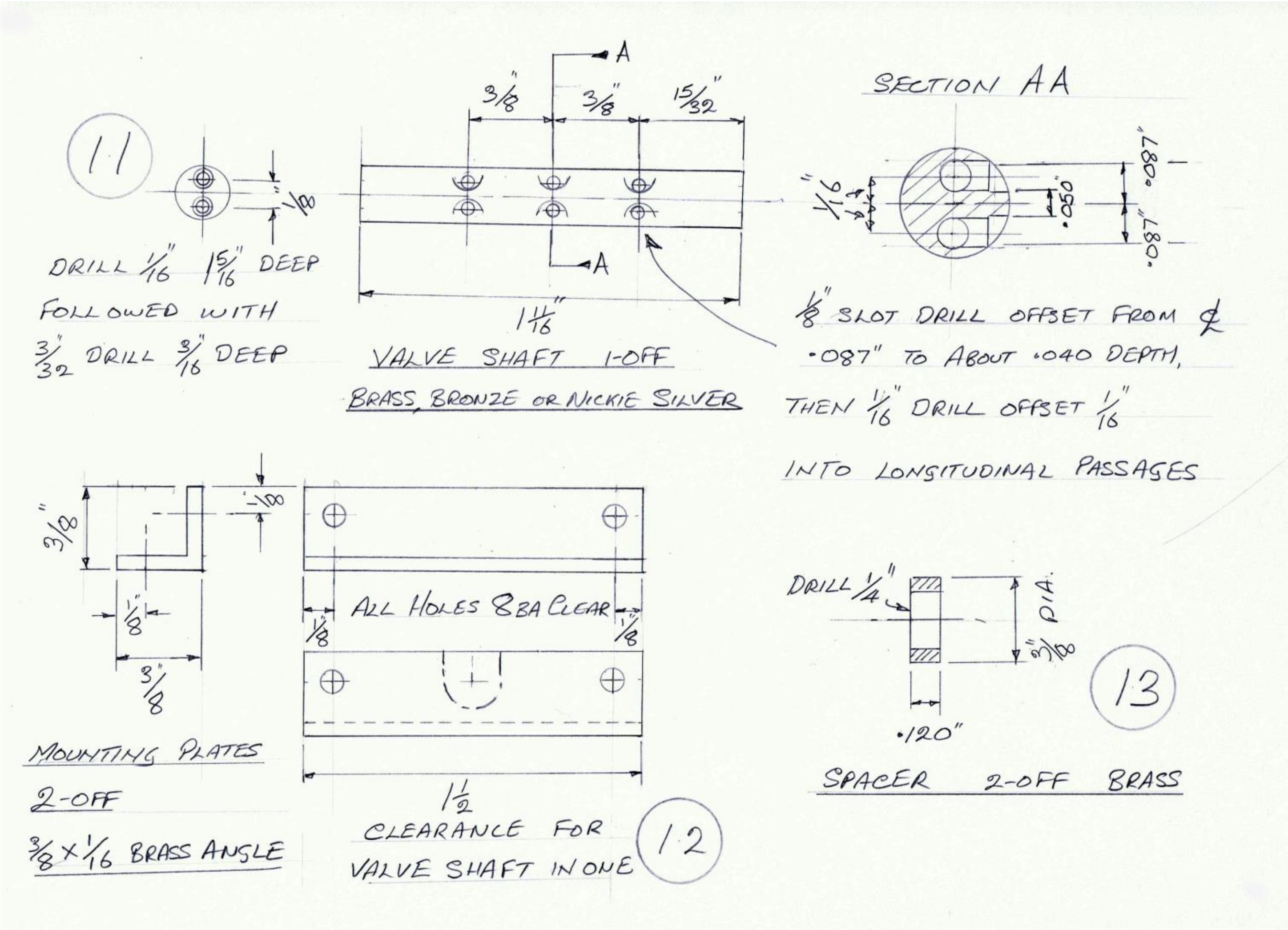


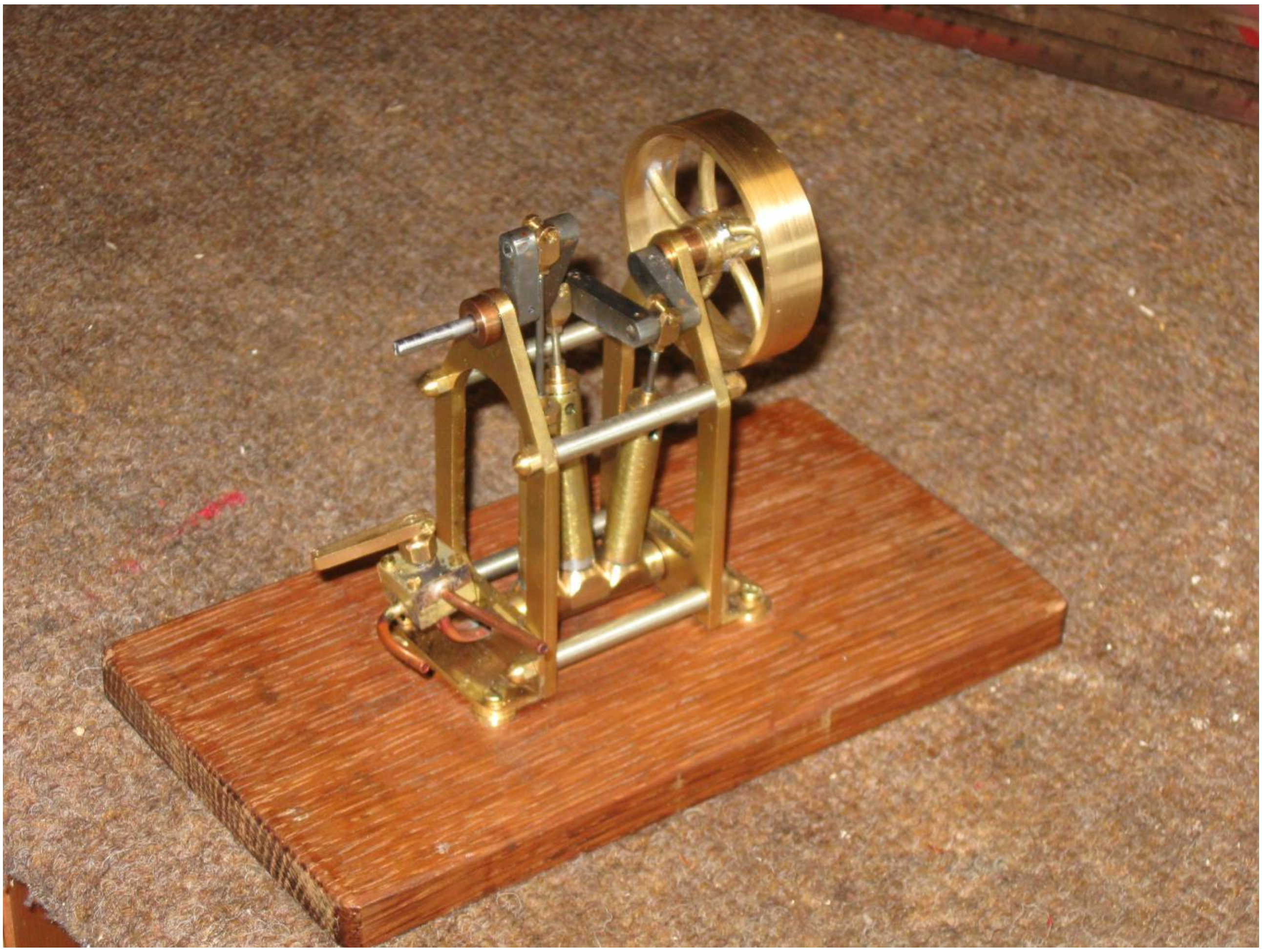
BIG END

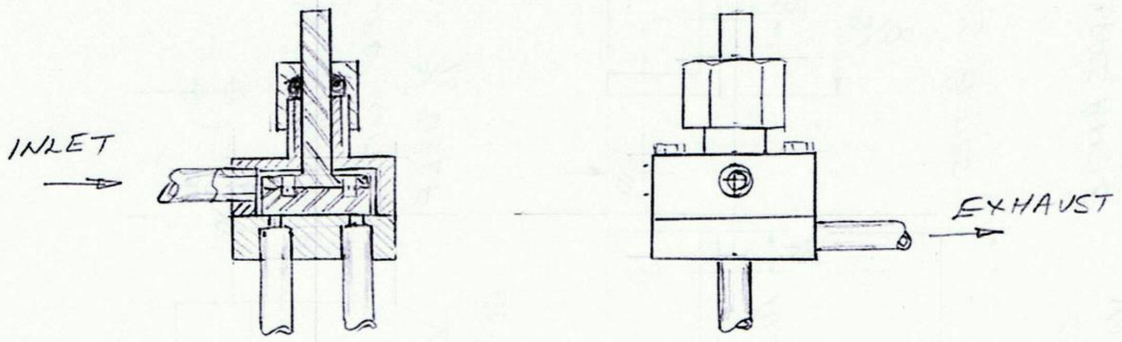
3-OFF

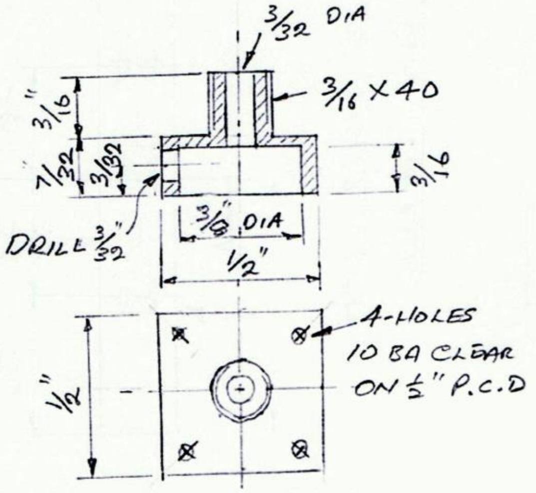
BRASS OR BRONZE

10

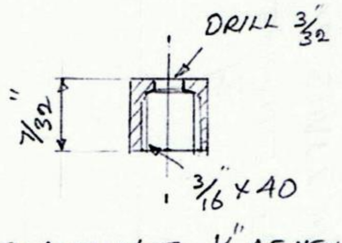

11
1/8
DRILL 1/16" 1 5/16" DEEP
FOLLOWED WITH
3/32 DRILL 3/16" DEEP
A
3/8" 3/8" 15/32"
1 1/16"
VALVE SHAFT 1-OFF
BRASS, BRONZE OR NICKIE SILVER
SECTION AA
1/16"
.050"
.087"
.087"
1/8" SLOT DRILL OFFSET FROM ℄
.087" TO ABOUT .040 DEPTH,
THEN 1/16" DRILL OFFSET 1/16"
INTO LONGITUDINAL PASSAGES
3/8"
1/8"
1/16
3/8"
MOUNTING PLATES
2-OFF
3/8 x 1/16 BRASS ANGLE
ALL HOLES 8BA CLEAR
1/8" 1/8"
1 1/2
CLEARANCE FOR
VALVE SHAFT IN ONE
12
DRILL 1/4"
3/16" DIA.
.120"
13
SPACER 2-OFF BRASS



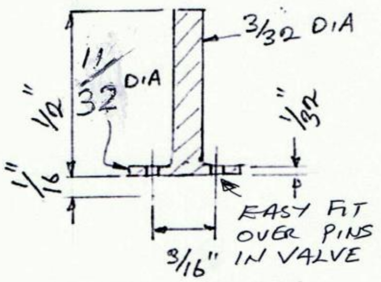




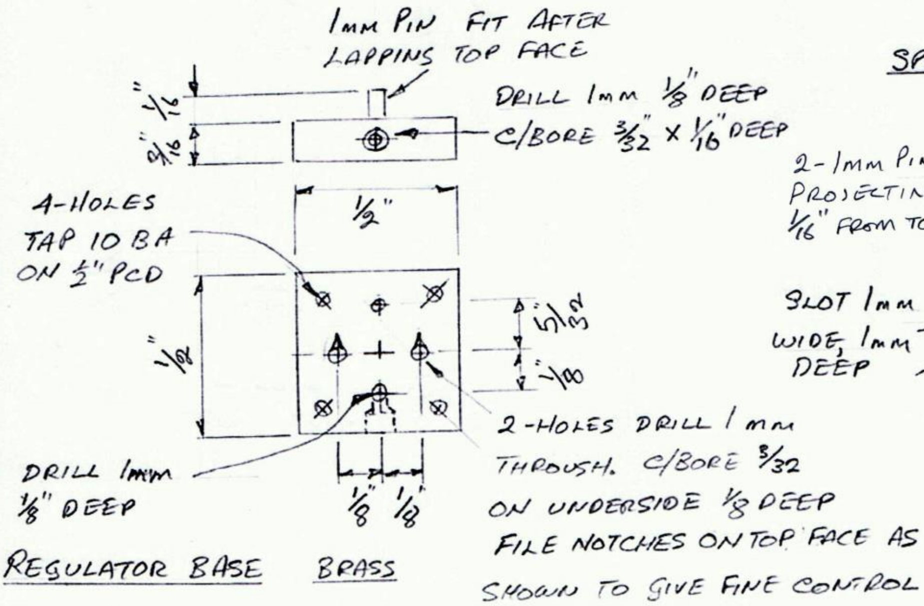
REGULATOR TOP BRASS



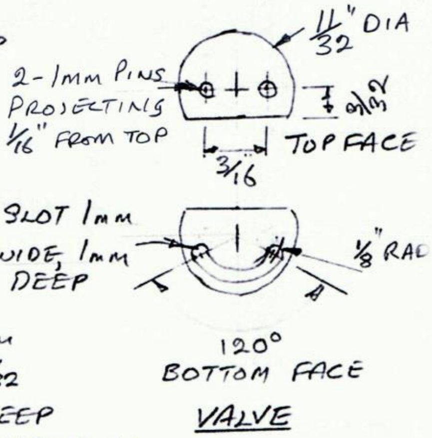
GLAND NUT 1/2" AF HEX



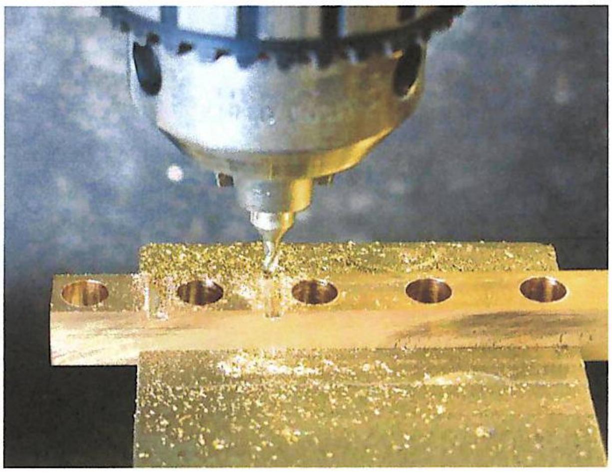
SPINDLE BRASS

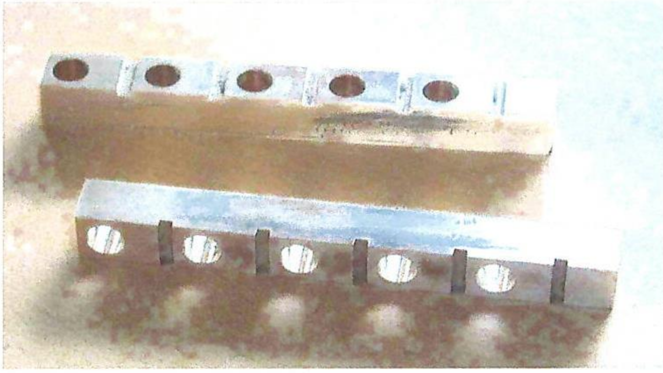


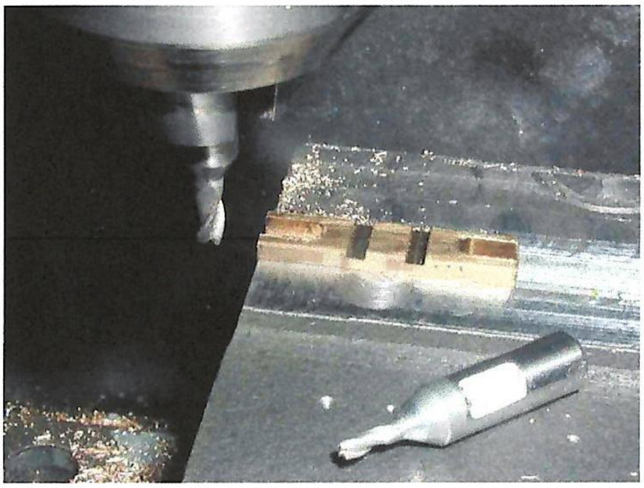
REGULATOR BASE BRASS



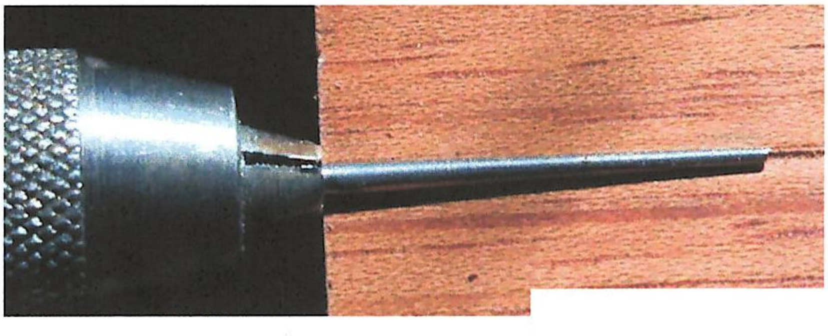
VALVE 1/8" THICK BRASS







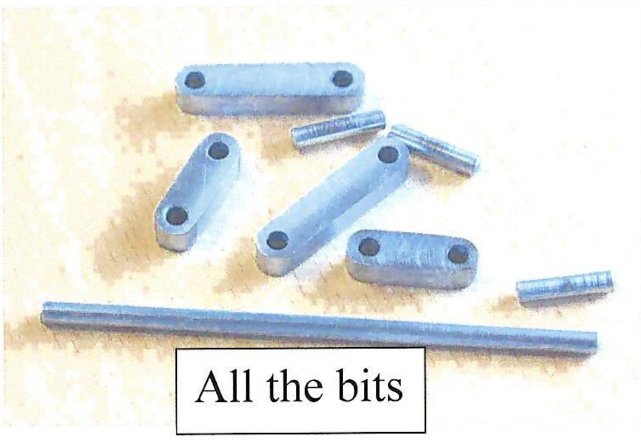
Taper pin being made into a D bit



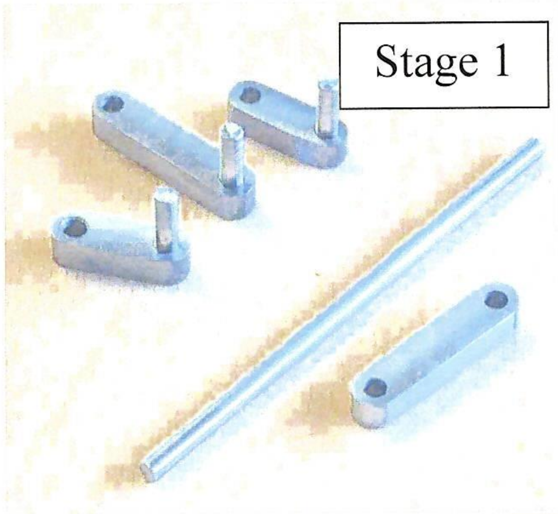
Holding the taper pin (1/8" of large end turned parallel) ready for filing to ½ diameter

Taper pin case hardened and ready for use

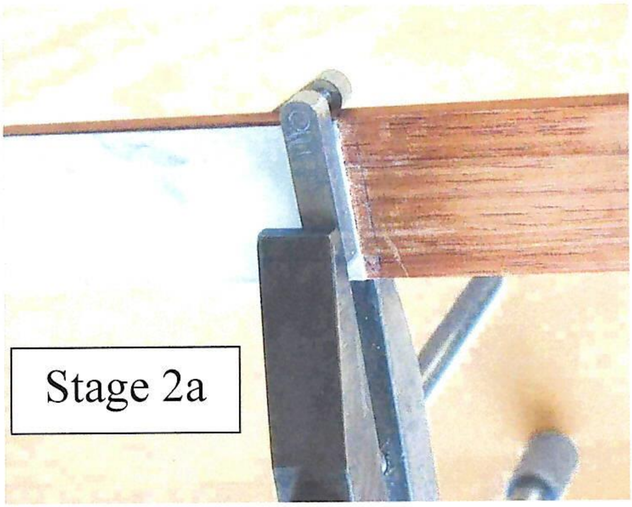
Crankshaft construction sequence



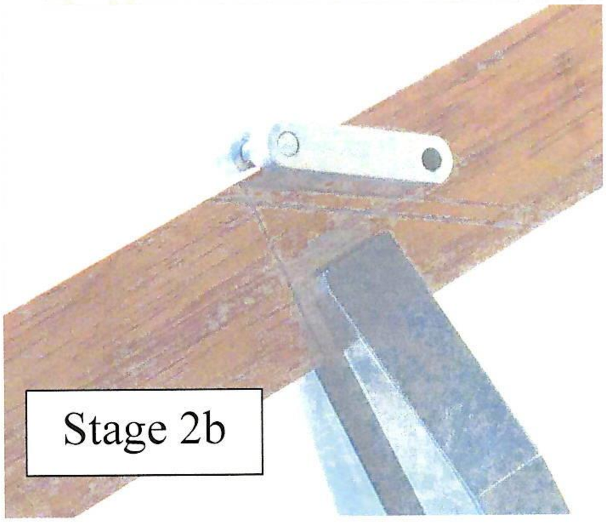
All the bits



Stage 1

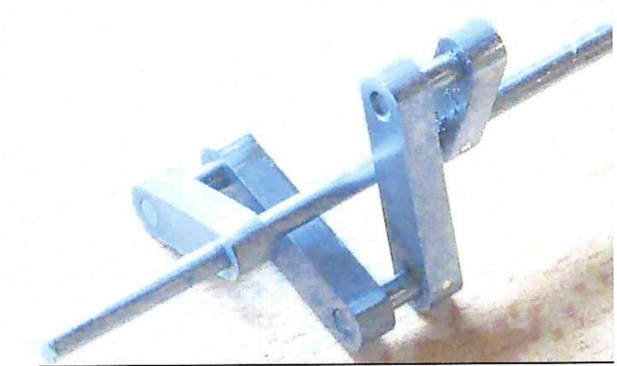


Stage 2a



Stage 2b

Stage 3



Stage 4 Central portion of main shaft to be cut out and joints pinned if required

Lining up the valve shaft to machine the ports