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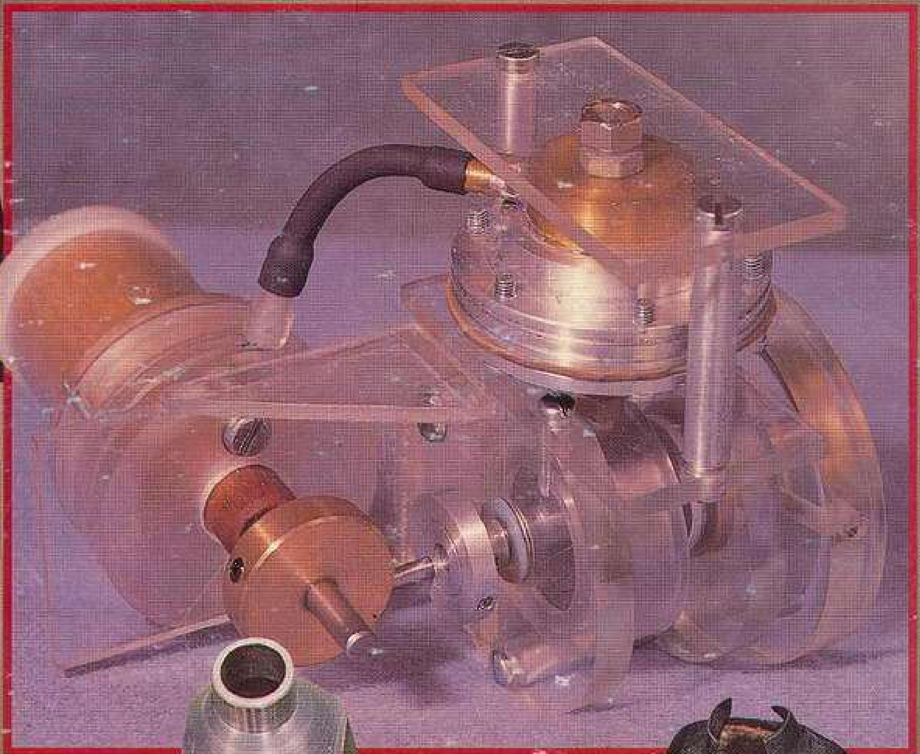
FREE PULL-OUT SUPPLEMENT
NANO 0.1cc C.I. ENGINE FULL DETAILS



HOT AIR MATTERS

Development and Experimental engines

MORE XMAS GIFT IDEAS

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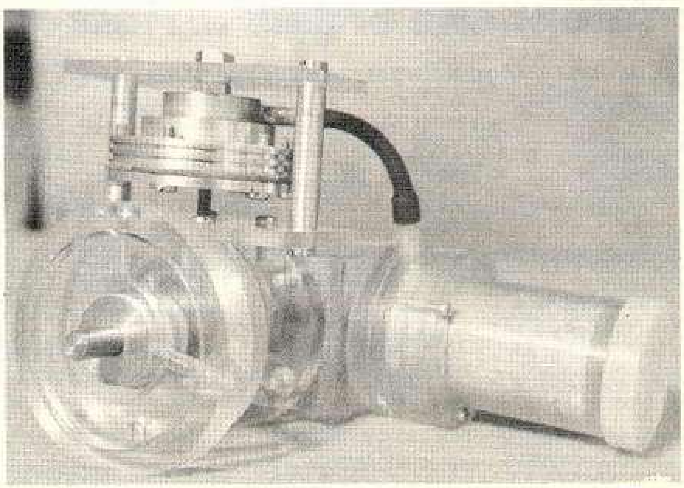
On the cover...

● *A group of hot air engines made by Geoff Bartlett of Birmingham. The transparent engine was made to demonstrate the principles involved - it proved almost impossible to make an understandable drawing. Story starts page 567. (Photos. John Jolliffe).*

Trying to move the job over in this four jaw chuck will result in expensive crunching noises, and this type of persuasion will get you thrown out of the small lathe users league! Learn the correct method on page 558.

It will not run, but this transparent model demonstrates the construction superbly. It is a novel hot air engine, and the story behind it starts on page 567.



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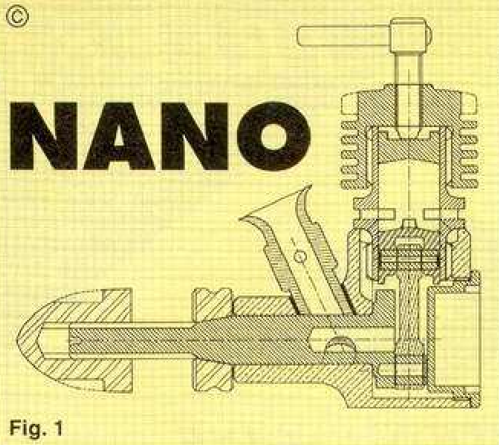
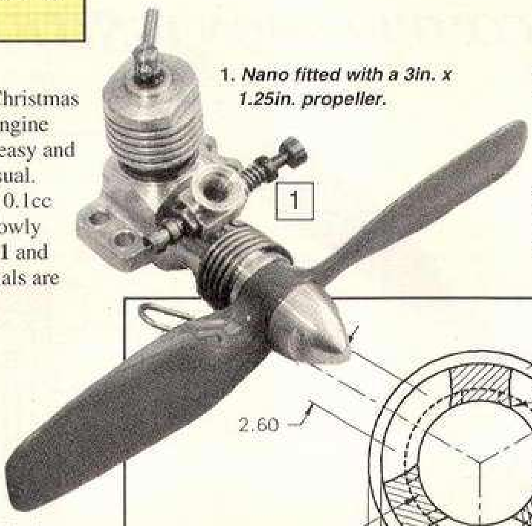


Fig. 1

A 0.1cc Compression Ignition Engine



1. *Nano fitted with a 3in. x 1.25in. propeller.*

As boredom set in over Christmas I decided to design an engine which would be small, easy and cheap to make and slightly unusual. With these objectives in mind a 0.1cc two stroke aero diesel engine slowly came to life as shown in **Photo 1** and **Fig.1.** Specifications and materials are listed below:

Specifications

Bore	5mm dia
Stroke	5mm
Capacity	0.1cc
Total Height	32mm
Total Length	38mm
Max Speed	40,000RPM
Fuel	Model Diesel Engine Fuel (20% castor oil, 80% fuel containing Ether) Model Technics D1000, D2000 or equivalent.

Materials

Cylinder	EN8 (or Equivalent)
Piston	Cast Iron
Crankcase	Aluminium Alloy
Connecting Rod	Duraluminium
Crankshaft	EN8

Manufacture was carried out exclusively on a 5in. Boxford lathe with only a small range of tools and materials came mostly from the scrap metal box. So pleased with the engine when it burst into life, I thought readers of *Model Engineer* may be interested in the design and manufacture of this neat little engine. It should be suitable for the IC engine novice who already has basic machining skills.

Construction

Designed to be easily made, all that is needed is a screw cutting lathe, preferably metric, with a compound slide and adjustable tool post (or vertical slide). Three simple, easily made jigs are required.

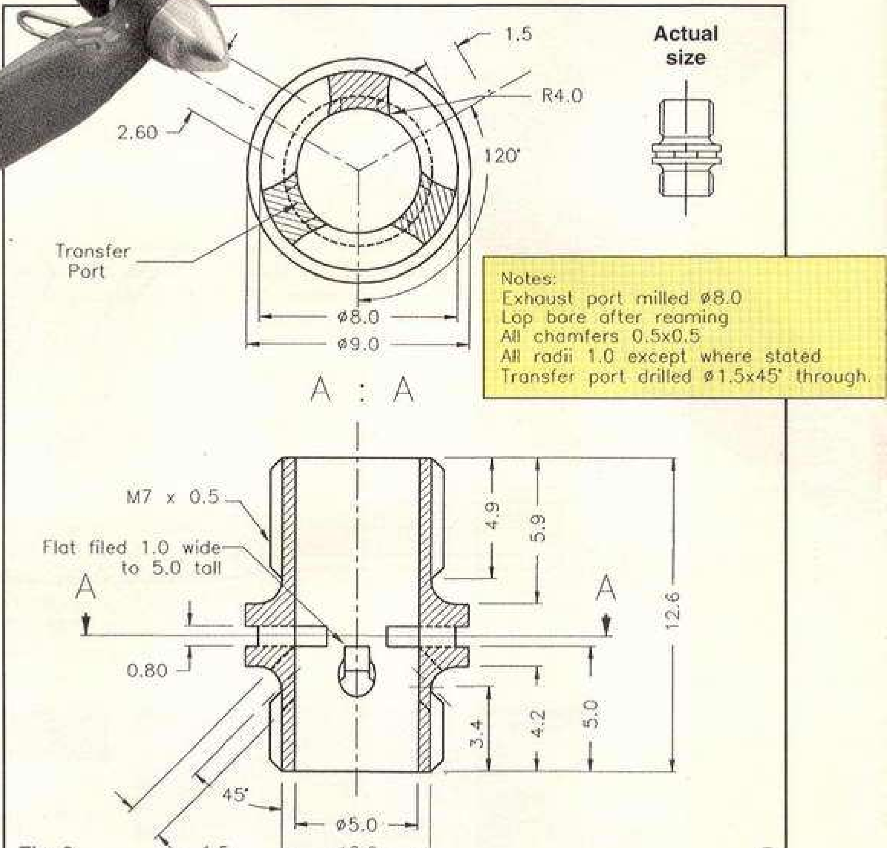
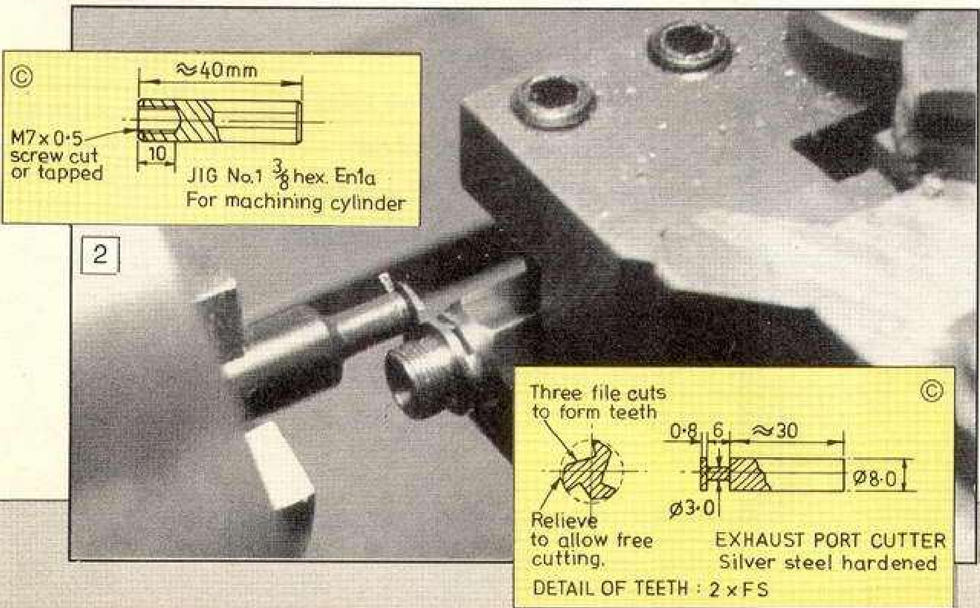


Fig. 2

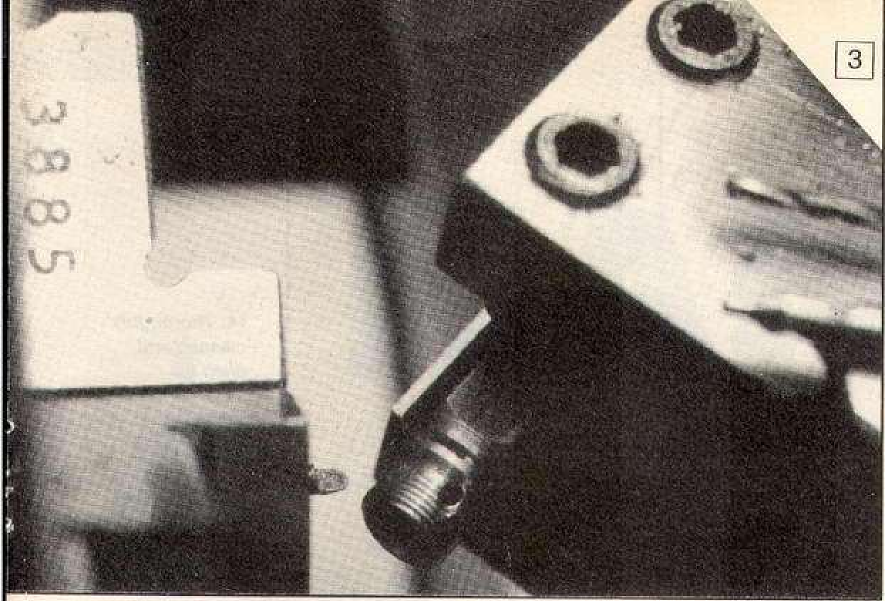


2. *Milling the exhaust ports using a home-made cutter with the cylinder mounted in Jig 1.*

Cylinder

The best place to start is with the cylinder (**Fig.2**). A length of ⅜in. dia. EN8 steel is chucked and turned as shown in the drawing and is drilled and reamed 5mm dia. With the compound slide set to 29 deg. the threads are cut at 0.5mm pitch or 0.02in. pitch if you have an Imperial lead screw. This will require a narrow, sharp cutting tool to clear the shoulder when cutting the thread on the left hand side of the cylinder. Now part off and re-check all dimensions.

It is now time to make jig No.1, shown in **Photo 2** and the drawing. It is simply a piece of ⅜in. hex. mild steel bar about 40mm long, bored and screw cut to accept the cylinder just turned.



3. ***Machining the transfer ports.***

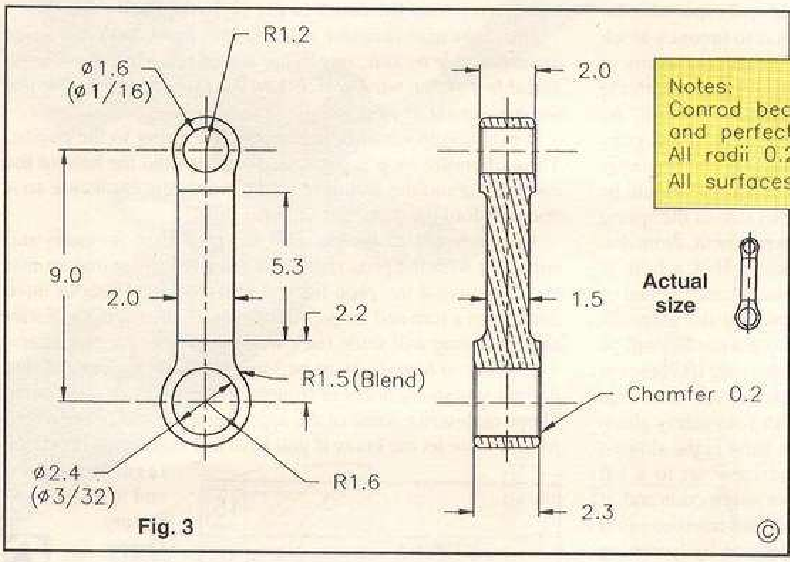


Fig. 3

To mill the exhaust ports a cutter of 8mm dia. with a shaft of 3mm dia. and a width of 0.8mm is needed. This was turned from silver steel, three teeth filed out and suitably relieved and hardened.

Screw the cylinder tightly into the jig (a *small* flat on the shoulder will help) and mount in the tool post parallel to the lathe axis at centre height. The cutter is then placed in the lathe chuck and the cylinder aligned so the cutter locates into the 0.8mm wide recess in the cylinder. Zero the cross slide dial with the cutter just touching the base of the recess, set the lathe to top speed and feed the cylinder 2.0mm to form the exhaust port. Rotate the jig 120 deg. and repeat the operation (**Photo 2**).

A similar technique is used to machine the transfer ports but the compound slide is set over to 45 deg. Place an accurate pointer in the 3 jaw chuck, align the point with the end of the cylinder at the 6mm dia. chamfer and zero the compound slide. Lock the cross slide and move the cylinder away with the saddle. Now move the compound slide 3.4mm towards the chuck. Check if the position looks correct against the pointer and when satisfied you are ready to start machining but first clamp a block behind the cylinder jig to allow it to be replaced in the same position when it is rotated for the other ports. Start the hole with a small centre drill and follow with a 2.5mm dia. ball-nose endmill or D bit fed in just enough to make a 1.5mm dia. ring which is flat relative to the chuck. This should ensure that the 1.5mm dia. drill will locate accurately (**Photo 3**). Rotate the jig through 120 deg. and repeat for the other ports.

Using the jig once again, address the top of the transfer ports with a square needle file until they align with the bottom of the exhaust port, as shown in the drawing (**Fig.2**). The cylinder can now be lapped. I used a length of 5mm dia. free cutting steel but you may prefer to make an expanding copper lap. Start with a fine valve grinding paste and try to keep the cylinder moving and parallel to the lap to avoid bell mouthing the bore. Surprisingly quickly the bore will be smooth and nicely cross hatched. Finish off with a fine crocus paste to remove any high spots.

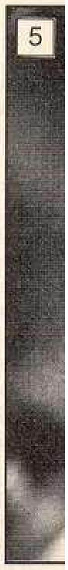
To reduce friction it is common practice to increase the bore diameter just below the exhaust port where a good seal is not required. This can be done by placing the cylinder and jig the lathe, holding some very smooth 'wet and dry' paper wrapped around a small drill and touching the bore, but only up to the exhaust port. The cylinder should now be scrubbed clean, oiled and put safely aside.

Connecting rod

Photo 4 shows the start of work on the connecting rod (**Fig.3**). A piece of 16 to 20mm dia. aluminium alloy (dural) about 40mm long is clamped in the tool post and centred by the parting-off pip. The cross slide is then moved 4.5mm, locked and the dial zeroed. The dural is then centre drilled, drilled 2.3mm dia. and reamed 3⁄32in. dia. The cross slide is then moved exactly 9mm and the dural centre drilled and drilled 1⁄16in. dia. Transfer the dural to the 3 jaw chuck and, using a parting tool, part half way through to leave the con rod blank 2.3mm thick but still joined to the rod. This allows the shape of the rod to be filed or milled more easily. Part off and finish to shape; don't forget to lightly chamfer both sides of both bores.

Crankshaft

Simple turning and screw cutting quickly produces the crank shaft blank (**Fig.4**). Take care with the taper and polish the journal to a very good finish. Part off from



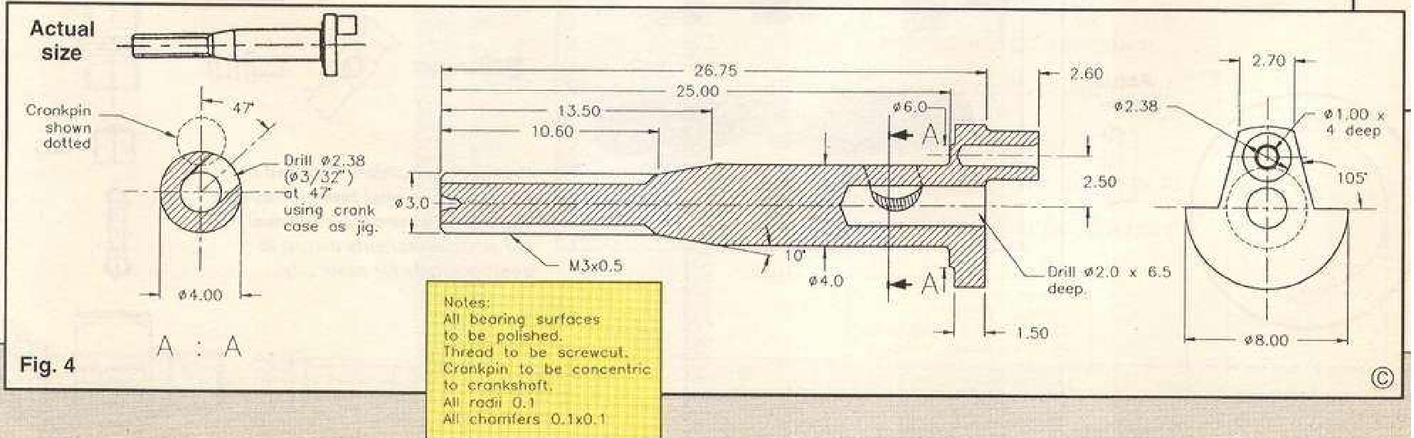
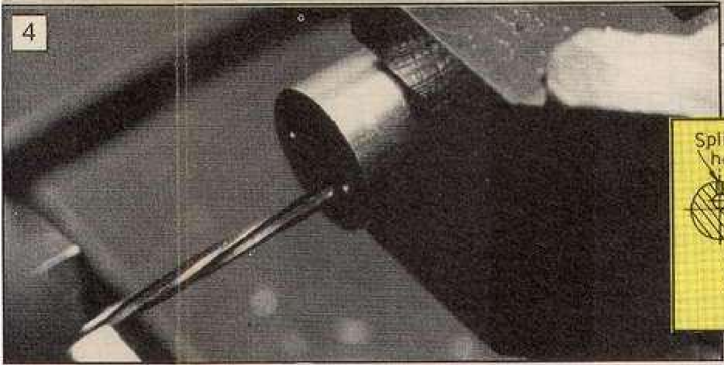
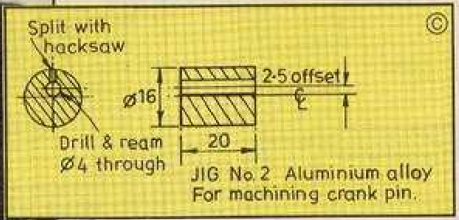
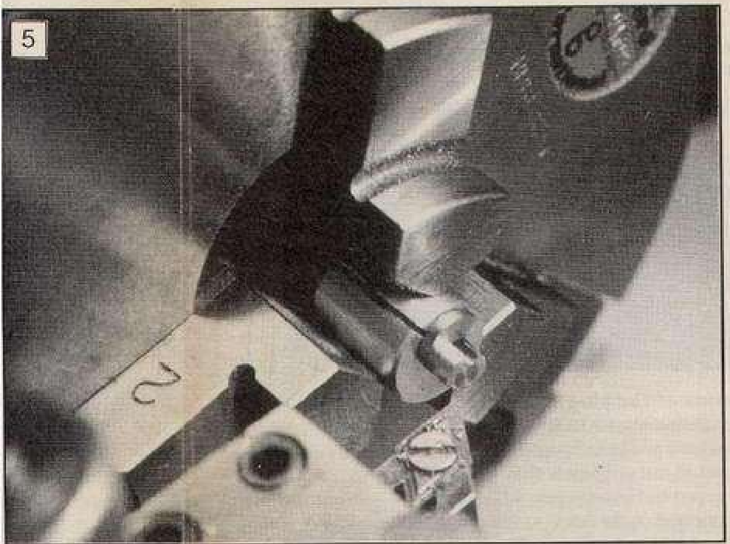


Fig. 4

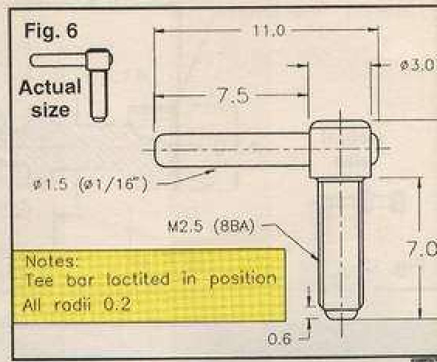






4. Reaming the connecting rod bearings.

5. Using Jig 2 for finishing the crankpin.



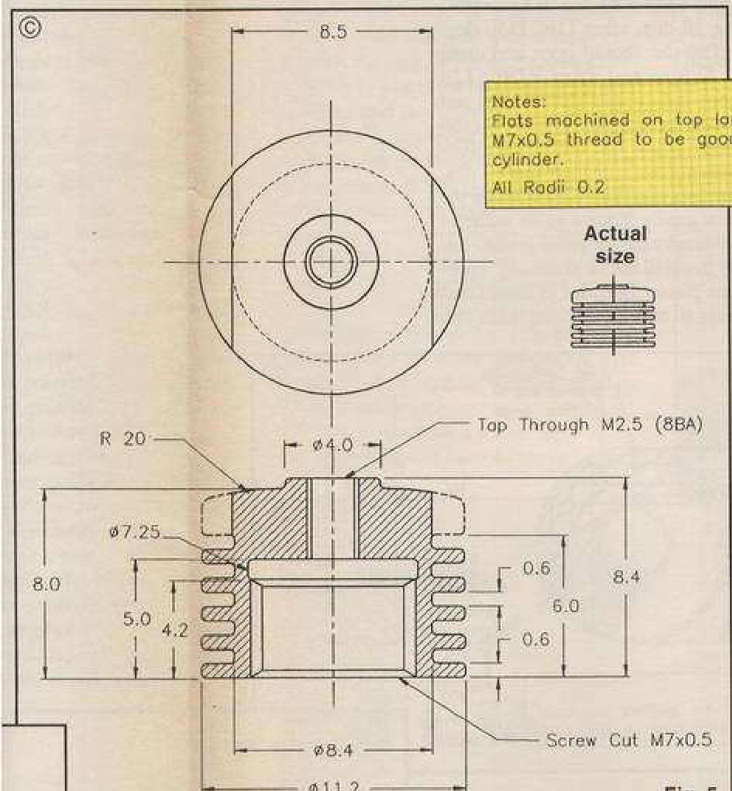


Fig. 5

the 3/8in. dia. EN8 rod leaving the exact length of 8mm dia. to form the web and crank pin. Turn this round in the chuck gripping by the 8mm dia. section and drill the intake hole 2mm dia. 9.1mm deep (from the tip of the pin). A second jig is now required, as shown in the drawing, to turn the crank pin (**Photo 5**). Turn a piece of aluminium to 16mm dia. and lightly centre drill before parting off 20mm long. Place this in the tool post and centre it accurately using a point in the chuck and zero the cross slide dial. Place a small centre drill in the lathe chuck, move the cross slide exactly 2.5mm and centre drill the jig. This can now be set up and centred in the 4 jaw to be drilled through 3.9mm and reamed 4mm dia. Split with a hacksaw and carefully deburr. Pop the crank into the jig, set in the 3 jaw and turn the crank pin, carefully polishing to a running fit in the con rod. Next drill the lightening hole.

The jig can next be used to mark out and cut the webs shown on the drawing. With the engine running up to 40,000RPM I thought it wise to try and balance the engine. The web and the lightening hole come close to balancing it completely. It is critical that you do not try to drill the final intake hole at this stage; this will be much easier later using the crankcase as a jig.

Cylinder Head

The cylinder head, (**Fig.5**), can be tackled next. Drill and bore the head 6.4mm dia., not forgetting the 7.25mm dia. undercut. Using the cylinder as a gauge internally screw cut the head to a good fit on the cylinder. The fins can be turned with a 0.6mm wide rounded parting tool using the compound slide to get them equally spaced. The radius can be produced by careful manipulation of the controls but tap through M2.5 or 8BA first.

Compression Adjust Screw

The compression adjust screw (**Fig.6**), can quickly be turned up with the tee bar either Loctited or pressed in place.

Piston

The piston, (**Fig.7**), is best made from centrifugally cast cast iron; this may prove expensive because it seems that 1in. dia. is the smallest available stock so look for some off-cuts first! Turn a rod to 10mm dia. 40mm long and carefully turn a length of 10mm to 5.02mm dia. With a thin parting tool machine a groove at 4.6mm length to mark the end of the piston and with some fine 'wet and dry' paper fixed to a flat piece of metal gently lap the piston to just fit into the bottom of the cylinder but ***clean everything before trying for a fit.*** When satisfied drill the 3/32in. dia. hole 3.8mm deep and bore the 4mm dia. recess. Leaving the piston on the rod set it accurately in the tool post exactly at right

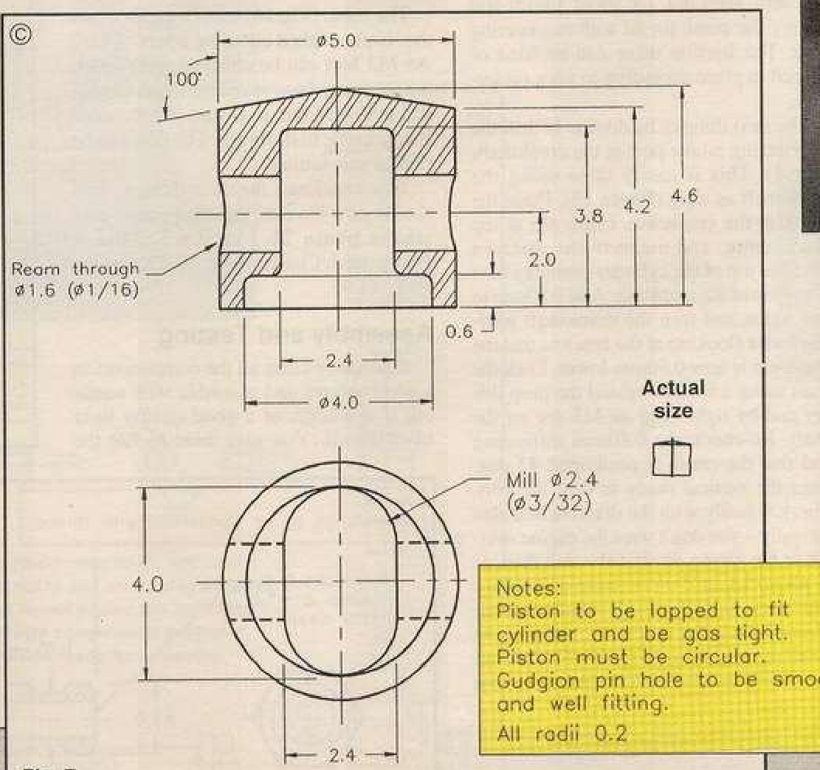
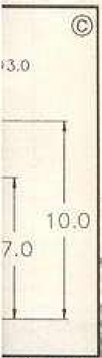
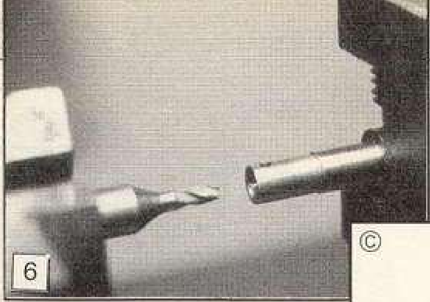
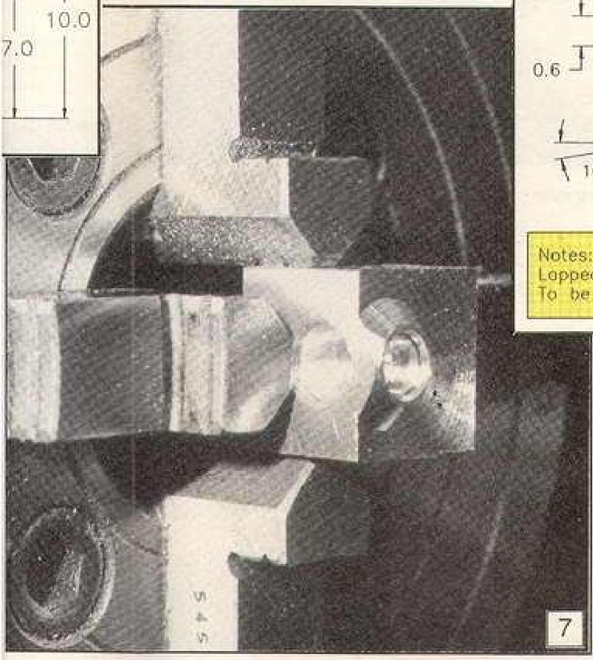


Fig. 7







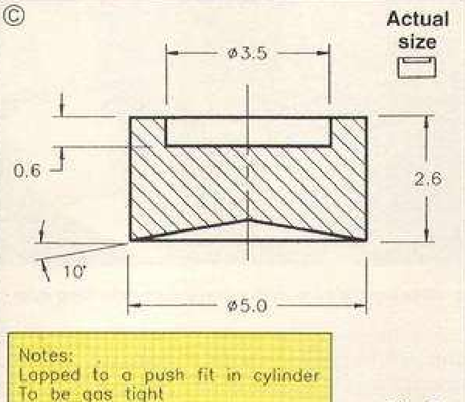
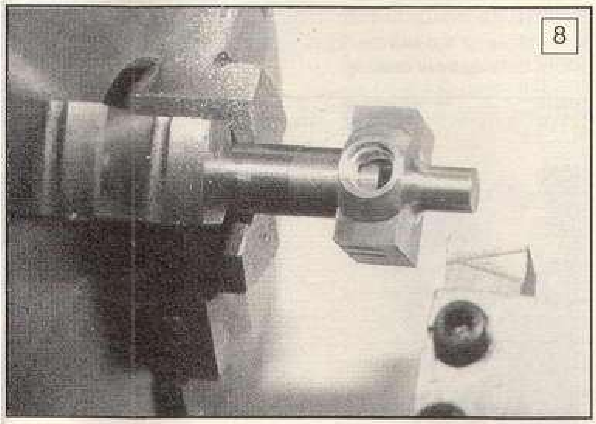


Fig. 8

6. *Milling the connecting rod recess into the piston.*

7. *Turning the crankcase cylinder mounting face.*

8. *Using Jig 3 for turning the crankshaft bearing.*



angles to the lathe axis. This can be checked with a DTI mounted in the lathe chuck. Centre drill and drill through 1/16in. dia. for the gudgeon pin. Turn the piston rod 90 deg. in the tool post and arrange its axis to be parallel with the chuck axis. Machine the con rod recess with a 3/32in. dia. cutter (**Photo 6**). Return the rod to the 3 jaw, set the compound slide to 10 deg. and part off to leave the piston sides 4.2mm long with a total length of 4.6mm.

Contra Piston

Next, with the rod still in the 3 jaw chuck, the contra piston (**Fig.8**) can be formed. It must be a tight fit in the top of the cylinder so bear this in mind whilst lapping it as you did the piston. Bore and part off at 10 deg. as shown in **Fig.7.**

Finally clean and dry the piston, contra piston and cylinder, lightly oil them and try the fits. At this stage the piston should just pass up to the exhaust ports but if worked slowly back and forth the high spots will soon be worn down and it will easily pass up the bore with a perfect fit. The contra piston should be tight but capable of being moved by the compression adjust screw. Time spent in perfecting the fit of these components is time well spent, especially in these small sizes.

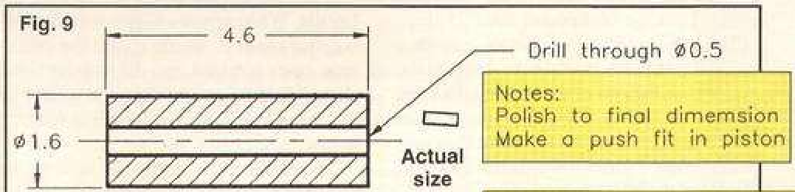
Gudgeon Pin

The gudgeon pin, (**Fig.9**), (piston pin) is turned from 3/32in. dia. silver steel and is made a running fit in the connecting rod but with one end a push fit in the piston so that the pin stays in place and does not scratch the bore. It is more common practice to make the pin a floating fit and to use soft pads in each end to protect the bore but due to the small sizes involved and the risk of such a pad jamming in a port the pressed in method was chosen. I have not hardened the pin and have as yet noticed no undue wear.

Crank Case

The crank case, (**Fig.10**), is rather complex but taken slowly and methodically should present few difficulties. Start by accurately face milling a cube about 21mm square to produce datum surfaces for later operations. Mark a line 11mm from one face, which will be the top face of the cylinder, mark it so, turn the block 90 deg. and mark a central line which will be between the mounting faces so identify these as well. The crankshaft centre is located where the lines intersect. Set this point to run true in the 4 jaw chuck and ensure it is centred between the two mounting faces using a DTI. Bore and thread as shown in the drawing, **Fig.10**, ►

Fig. 9



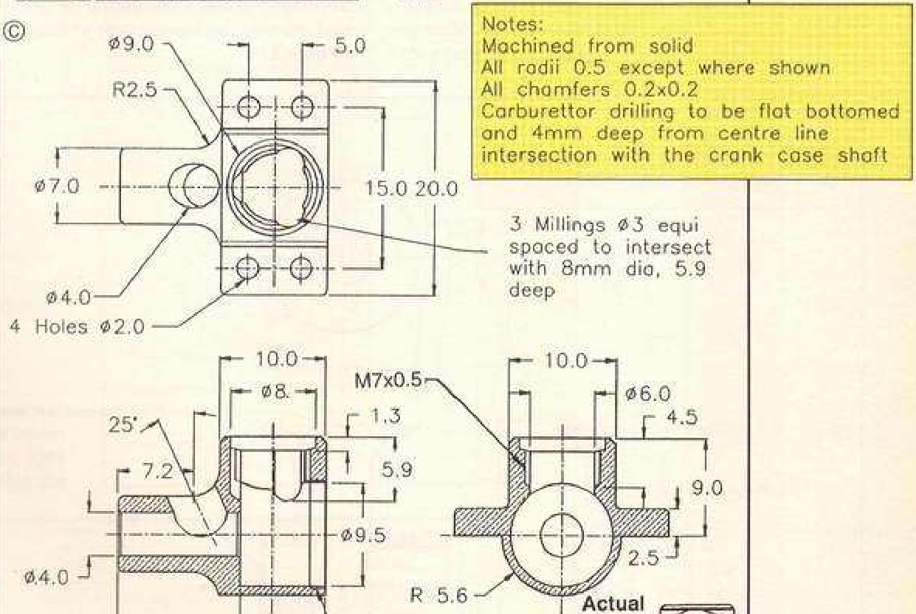


Fig. 10

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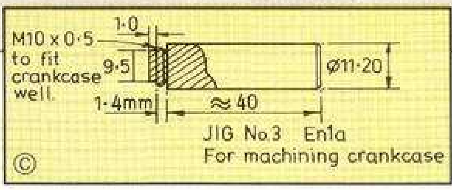
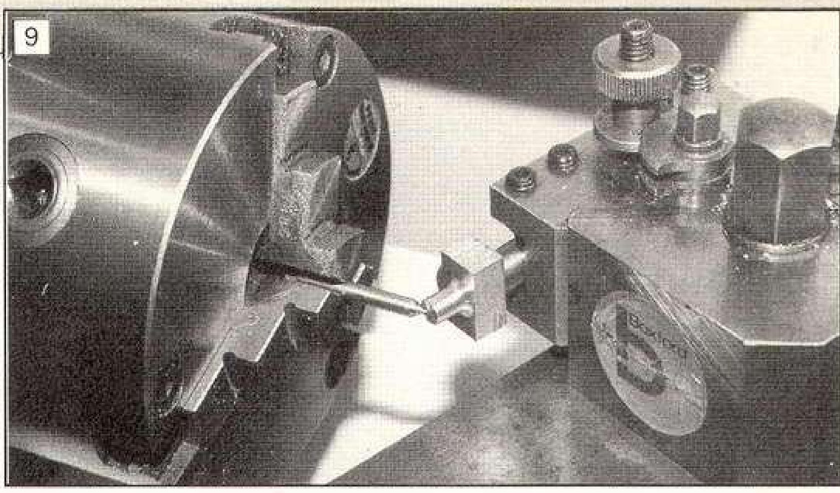


but do not drill the crankshaft bore yet. Lightly face the block as well. Now mark a line on the top face 5mm from the rear edge just machined to indicate the cylinder mounting hole. Measure from the top face to the inside of the 9.5mm dia. bore to determine how much must be removed from the top face to obtain the 9.00mm crank centre line dimension. This finished depth should be 4.25mm. Set up in the 4 jaw chuck, centring once more with the DTI and ensure that the block is square in the chuck. Drill, bore and thread as indicated using the cylinder again as a gauge. Face the top by the amount previously calculated. Turn the 45 deg. taper (from the 9mm dia. clamping face) to a depth of about 2.5mm from the top (**Photo 7**).

We now require jig no. 3. This is a piece of mild steel 11.2mm dia. 40mm long threaded to accept the crankcase rear thread. Before removing it from the chuck mark the position of jaw 1 to allow it to be replaced accurately. Screw on the crankcase and turn the front bearing slowing the lathe speed as you reach the radius but still ***do not*** drill the bearing hole.

Next the carburettor mounting hole must be drilled. Use the good old tool post again for this. Set the jig, with the crank case still firmly attached, so that the cylinder clamping face is perpendicular to the lathe bed (using a square) and also perpendicular to the lathe chuck (using a DTI). Turn the compound slide 25 deg., (**Photo 9**), and centre the case with a pointer in the chuck. Place the point on the top edge at the end of the bearing, lock the cross slide and zero the compound slide. Move the saddle to the right and the compound slide 7.2mm towards the chuck as shown in the drawing to position the crank case for the carburettor drilling. When you are certain of the positioning, start with a centre drill using the saddle to feed the drill in. Then drill 2.5mm dia. 5mm deep from the top of the bearing and complete the operation to 5mm depth with a 4mm dia. slot drill.



9. Aligning the carburettor crankcase mounting hole.

Carburettor

Now the carburettor, (**Fig.11**), must be made. It is Loctited into the crankcase after which the bearing can be drilled and reamed.

The carburettor is a fairly easy bit of 4 jaw work once the shape has been roughed out of the alloy plate. Make sure the tapped holes are aligned with the bore axis and concentric with each other but at this stage only drill the bore half-way through. **Photo 10** shows the Venturi being bored but a form tool such as a D bit could be made. The 4mm dia. stub should be turned 0.01mm under-size to allow room for the Loctite. When you are happy with the carburettor clean it, secure it into the crankcase - taps screwed into the tapping holes should help to ensure that it is square in the case - and leave it aside for at least 24 hours.

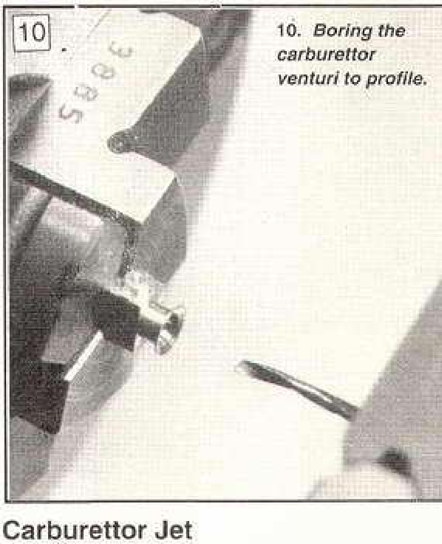
The crankcase and jig can now be set accurately in the 3 jaw chuck for drilling and reaming the bearing hole to 4mm dia. (**Photo 11**).

Photo 12 shows the set up used for milling the transfer passages, this arrangement was also used to mill the sides and the base but make quite sure that the crankcase is tightly screwed to the jig or it will undo, as I found out! By adjusting the tool post down gradually each cut is made with an end mill held in the chuck. Alternatively, you could use a vertical slide.

Because the jig is 11.2mm dia. it can now be used as a filing rest to form the crankcase shape. It can also be used as support when drilling the mounting holes 8BA clearance.

Carburation Needle

For a bit of fine turning you can now have a go at the carburation needle, (**Fig.12**). Make the taper smooth, try to make the thread a good fit in the carburettor body and don't forget to harden it. Find or make a small spring and a washer to fit between the needle and the carburettor body to keep the needle from moving whilst the engine is running.



10. Boring the carburettor venturi to profile.

Carburettor Jet

For the jet, (**Fig.13**), you will need a 0.3mm dia. drill. I made one from 1/16in. dia. silver steel in the form of a D bit about 0.6mm long. If treated gently, I found it worked quite well. Turn the jet, drill the 0.3mm dia. hole, thread 8BA and part off. Drill and tap 8BA the bar still in the chuck, screw the jet into this and drill the remaining holes which should intercept with the jet drilling.

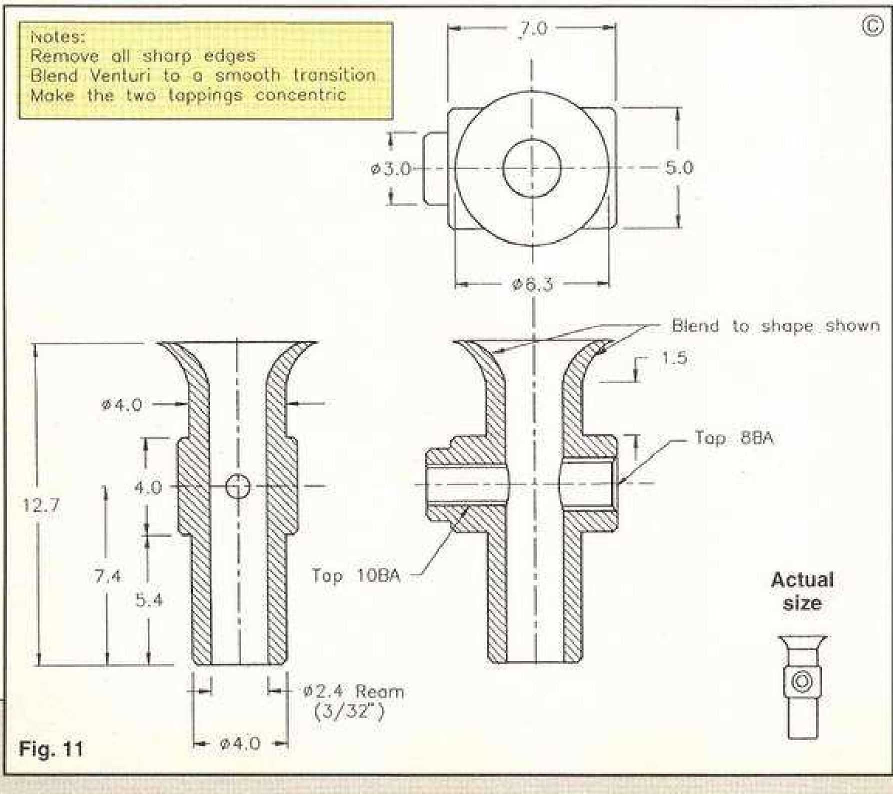


Fig. 11

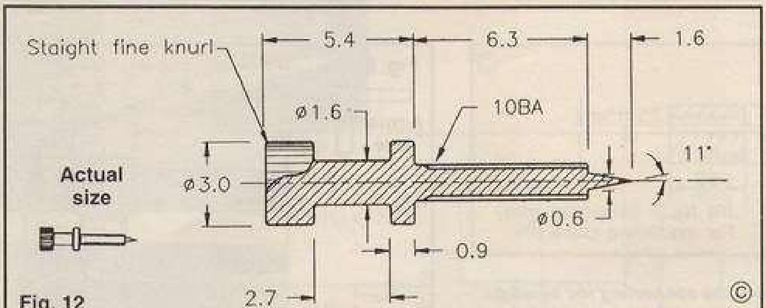


Fig. 12

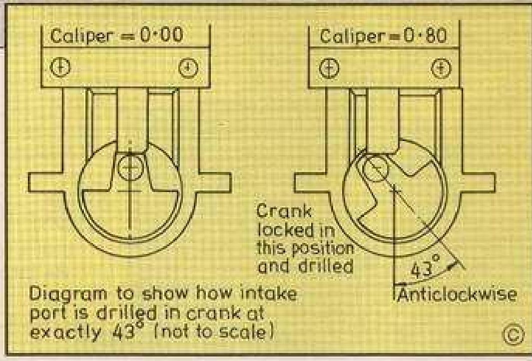
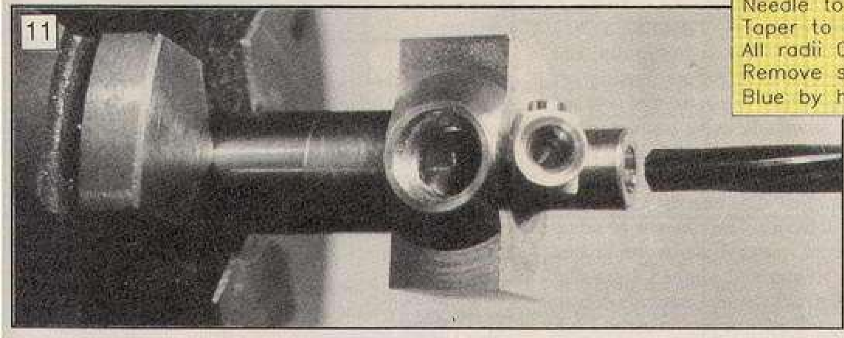
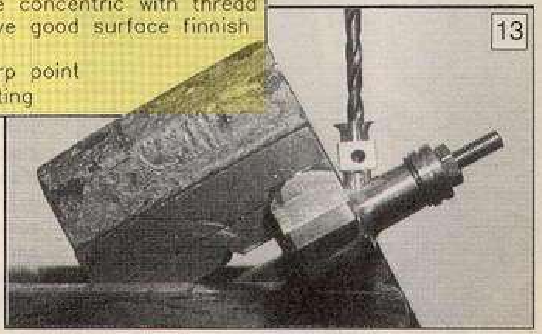


Fig. 16

Notes:
Needle to be concentric with thread
Taper to have good surface finnish
All radii 0.2
Remove sharp point
Blue by heating

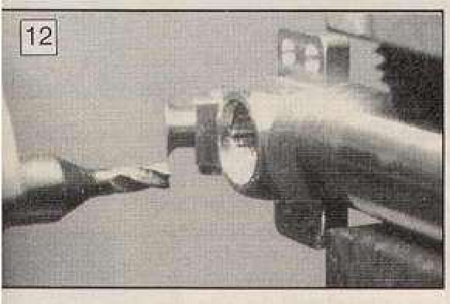




11. *Reaming the crankshaft bearing.*

12. *Milling the crankcase transfer passages.*

13. *Drilling the intake port.*



Propeller Driver

The prop driver taper, (**Fig 14**), should be machined to suit your crankshaft; if you drill 3mm dia. for about 14mm you can try the crank for fit with engineering blue. The friction drive can be filed or shaped in place according to your preference.

The next thing to be done is to drill the intersecting intake port in the crankshaft, (**Fig.4**). This is easily done using the crankshaft as a jig (**Photo 13**). Place the crank in the crankcase, crank pin at top dead centre, and measure the distance from the top of the cylinder clamping face to the top of the crank pin. Add 0.80mm to this value and turn the crankshaft ***anti-clockwise*** (looking at the case) so that the crank pin is now 0.80mm lower. Lock the shaft using a washer behind the prop driver and by tightening an M3 nut on the shaft. Re-check the 0.80mm difference and that the crank is positioned 43 deg. from the vertical ready to drill the port. Check visually with the drawing and also mentally – you don't want the engine starting in the wrong direction! – and then, as in **photo 13**, drill through the carburettor and one side of the crank to intercept the central hole being specially careful not to go all the way through the crank! This can be ensured by using a tube placed around the drill leaving the correct length of drill protruding. Clean up the intersection of the two holes using a dental burr in an electric drill, try to make it as smooth as possible but steer clear of the sharp edges on the journal face.

Crankcase End Plug

All that remains is the crankcase end plug, (**Fig.15**), which should be a good fit in the case, and the cone. The plug is most easily bored out and threaded at the same setting but this means you cannot try the thread for fit. The two short grooves can be milled in the tool post before it is parted from the rod. By the way, the plastic top from a Smarties tube works well as a tool to do up the plug without damaging it.

Cone

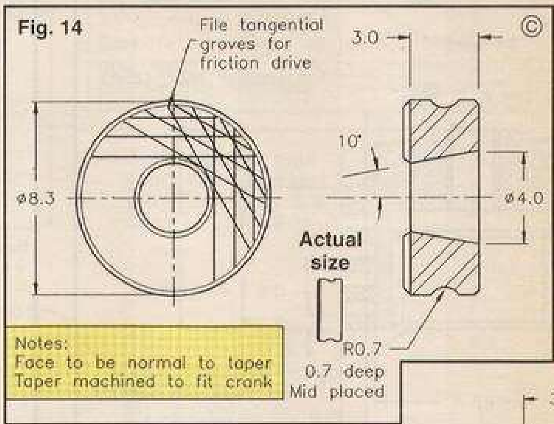
The cone, (**Fig.16**), can be tapered and the shape roughed out using a parting tool. An M3 bolt can be chucked onto which the cone may be screwed for finish turning and polishing but do ensure that the cone is concentric to its thread. The flats can be filed at this setting.

That concludes the construction. You should now have all the components present in **photo 14.** I used a 3in. dia. x 1.25in. pitch Cox propeller which cost me about £1.95.

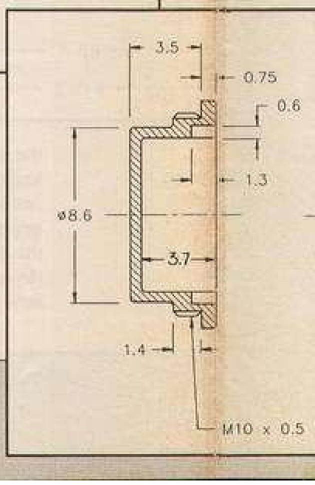
Assembly and Testing

Rigorously clean all the components in a good solvent and assemble with castor oil, if available, or a good quality light machine oil. You may need to file the intersection of the plug and cylinder threads in the crankcase to allow the connecting rod and piston to fit onto the crank pin – it should just go! Screw the cylinder onto the piston and into the case with plenty of oil smeared on the bore. At this point it is worth checking the timing. The intake port should open 120 deg. before TDC and close 30 deg. after TDC (150 deg. period). Transfer should open and close 60 deg. before and after BDC (120 deg.period) and exhaust should open and close 75 deg. before and after BDC (150 deg. period). If you find any of the cylinder timings out by more than about 3 deg. then either fit a thin shim washer under the cylinder or gently remove some material from the crankcase as appropriate, but hopefully this will not be necessary. Press the contra piston into the cylinder and check that it can be moved with the

Fig. 14



Notes:
Face to be normal to taper
Taper machined to fit crank



Notes:
All drillings to be concentric with thread

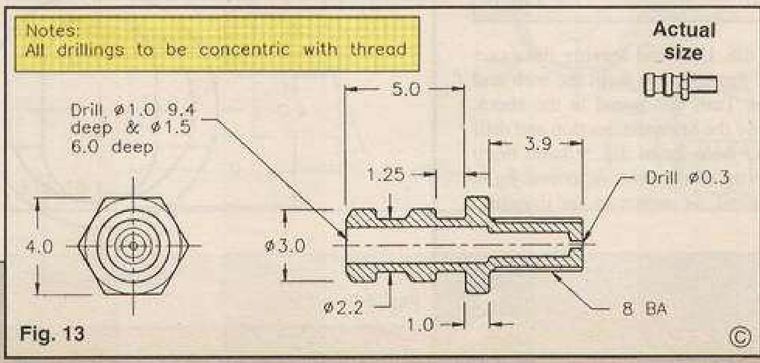


Fig. 13

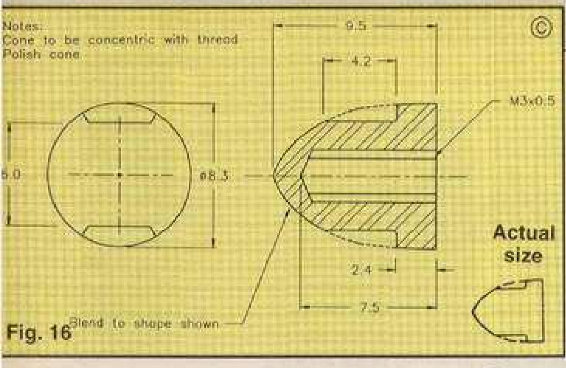


Fig. 16

adjustment screw. With all the components fitted the engine should turn freely up to compression where resistance should be felt for at least a few seconds.

Make a simple hard wood test bed, secure the engine with 8BA screws as shown in **photo 15** and arrange a fuel tank with the top of the fuel level with the needle valve of the engine. If this is not so the engine ***will not*** start. If transparent fuel tubing is used you will be able to see whether the engine is drawing fuel.

The moment has now arrived to test your creation (and your patience!). These small engines are not very easy to start first time but much can be done to ease this situation;

1. Set the prop vertically with the piston on compression
2. Set the fuel to the jet level
3. Open the needle valve 1.5 to 2 turns
4. Place a finger over the Venturi and crank the engine anti-clockwise to draw fuel into the engine - about three turns
5. Flick the prop near the root to achieve maximum cranking speed
6. Adjust the compression ⅛ of a turn until it starts to feel like firing and/or perhaps runs in short bursts
7. If nothing happens prime the engine once again as in 4
8. Repeat 5 and 6 until it runs continuously.

When the engine starts adjust the compression and the needle valve until it runs without misfiring but do not set it to run too fast before it is run in. This may take up to half an hour. If resistance is felt when turning it is probably flooded so move the piston down, blow through the exhaust ports and reduce the compression ⅛ of a turn.

The fuel I used was Model Technics D1000 model diesel engine fuel.

Strip the engine after its first run and inspect for any undue wear. All being well the engine should last for many hours to come! When fully run in the engine should achieve 36 to 40,000 RPM under load and your neighbour may ask if you have built a gas turbine – it certainly sounds like one!

Starter Spring

Probably the best accessory for any small engine, a starter spring removes the risk of cutting your fingers and spraining your wrist to turn the engine quickly enough to start it. I strongly recommend that you make this simple aid.

The spring is best wound on the lathe from pre-tempered carbon steel wire using the leadscrew to form evenly spaced coils. A good way to do this is to mount a block of wood, with a saw cut three-quarters of the way through, in the tool post with the spring wire passing through the cut. As the tool post is tightened the wood grips the wire and so forces it to wrap cleanly around a mandrel. The mandrel should be smaller than the internal size of the spring and is best found be experiment; 8mm dia. is a good starting point. If if a hole is drilled through the mandrel and the end of the wire poked into the hole the wire will be pulled around. The pitch needed will be about the diameter of the wire (0.75mm or 34 TPI). This will give a little clearance between the coils. With your safety glasses firmly in place, the lathe in the slowest backgear and the leadscrew set to a left hand thread, turn about seven coils and, if satisfied with the result, cut the wire (after slowly relieving the tension by loosening the tool post grip) to leave enough to make the prop catcher loop shown on the drawing (**Fig.17**). Clip the wire just where it enters the hole in the mandrel and remove the spring. With two pairs of smooth jawed long nose pliers bend the prop loop to shape, the required amount of wire being unwound from the spring to bend up the carburettor loop.

If you do not have a screw cutting lathe you will have to move the lathe carriage by hand as the wire coils up but remember to move away from the chuck to get a left hand coil.

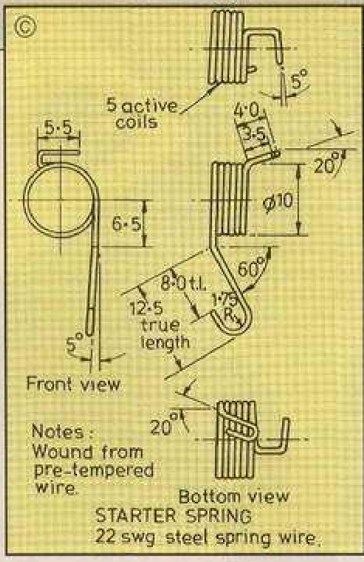
(You may also consider winding the spring with two wires arranged side by side, one being the spring wire, the other a suitable copper wire which can be removed to leave the required spacing – Ed.)

It is a simple job to fit the completed spring to the engine. The carburettor loop is persuaded to fit around the base of the carburettor and the spring moved towards the crankcase so it does not foul the propeller driver.

Its use is just as simple. Pull the prop loop forwards and engage it with the prop (hence all the angles required on that bit). Now wind the prop backwards (clockwise) about three quarters of a turn and let go. All being well the engine will start and the spring will settle back well away from the propeller.

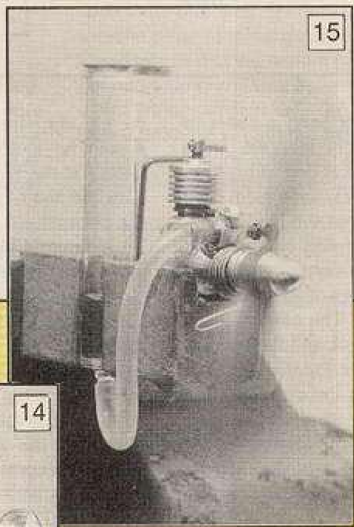
I hope you have enjoyed building this little engine and that it gives you many hours of trouble-free service. In due course I hope to describe some of the applications which I have found for it. Please let me know if you have any comments or advice regarding Nano and its manufacture.

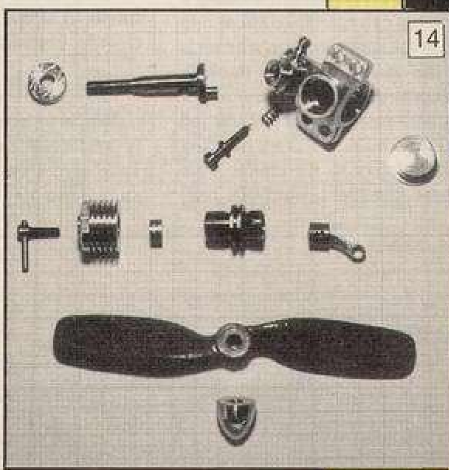
Happy running.

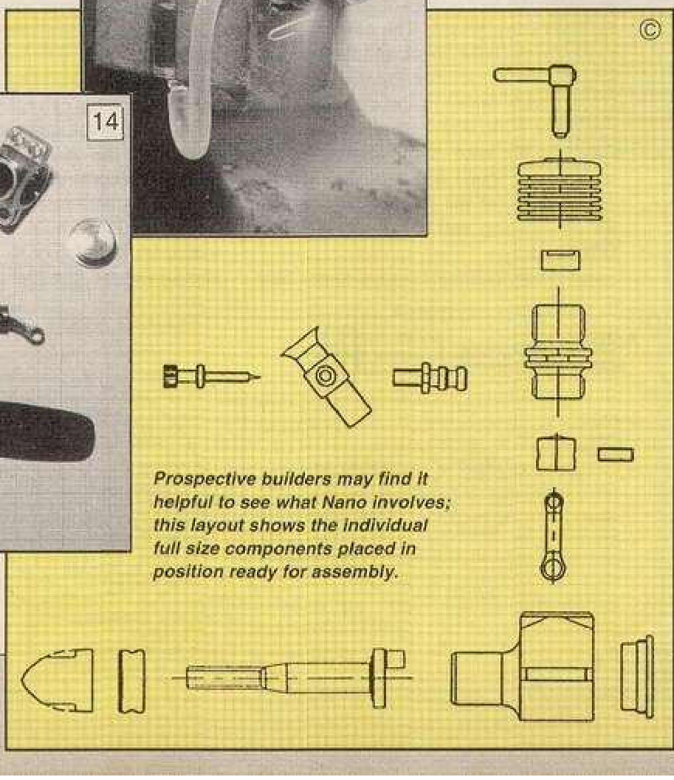


14. *Thoroughly cleaned and oiled for assembly, the components of Nano are shown here arranged on a 5mm grid.*

15. *Nano springs into life.*







Prospective builders may find it helpful to see what Nano involves; this layout shows the individual full size components placed in position ready for assembly.

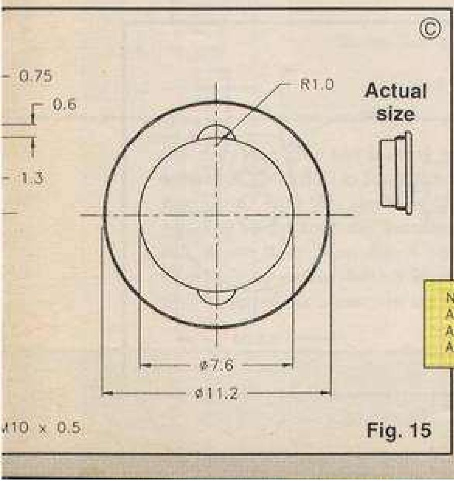


Fig. 15

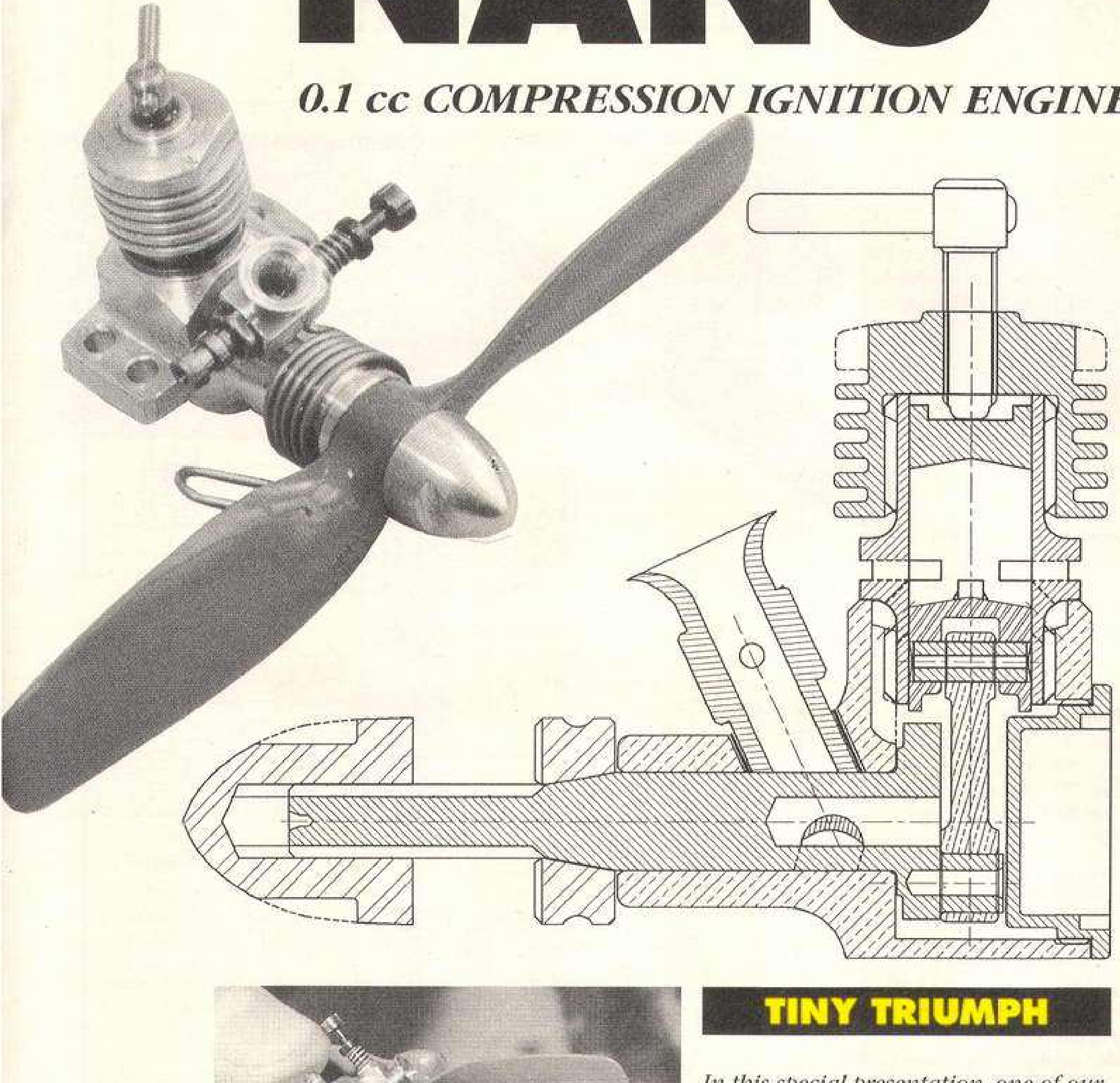
Notes:
All Radii 0.2
All machinings concentric
All sharp edges removed

FREE 8-page pull-out

WITH MODEL ENGINEER

NANO

0.1 cc COMPRESSION IGNITION ENGINE



TINY TRIUMPH

In this special presentation, one of our younger contributors, RICHARD GORDON, describes how to machine, assemble and test a tiny IC engine.

He produced the components using a 5in. Boxford lathe, prepared the drawings using AutoCAD® and then composed the words so that you could follow his example.

The future of our hobby would seem to be secure with young men like Richard about.