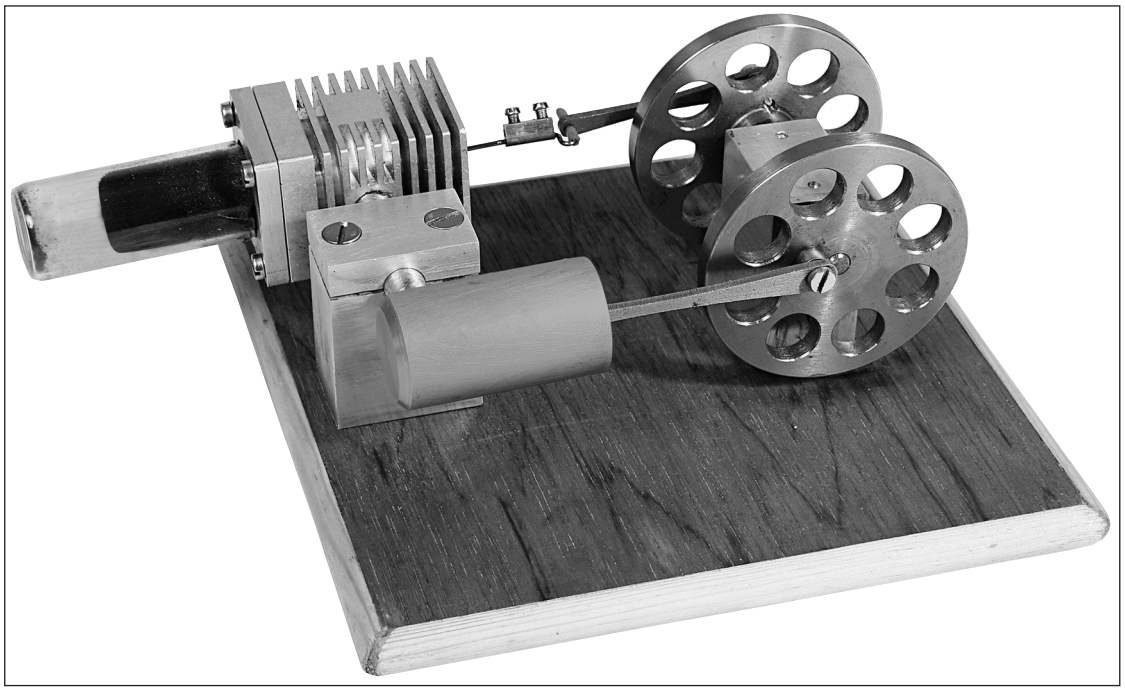
OPITEC

112.778

Hot air motor

Please Note

The OPITEC range of projects is not intended as play toys for young children.They are teaching aids for young people learning the skills of Craft, Design and Technology.These projects should only be undertaken and tested with the guidance of a fully qualified adult.
The finished projects are not suitable to give to children under 3 years old. Some parts can be swallowed. Danger of suffocation!



Contents

1. Product Information:

Article: metal construction pack for a functioning model

Use in Design Technology Key Stage 4 (age 14 upwards)

2. Material Information:

2.1 Material: Steel (iron)

Working: Sawing, filing, drilling, shaping

Joining: Screws, glue

Finish: Oil

2.2 Material: Pine wood (coniferous) softwood
Wood should be relatively dry before working

Working: Drilling, countersinking
Mark out according to the plan

Joining: Screws

Finish: Wax (liquid or solid)
Wood varnish
Staining (colour water soluable-finish with varnish)

2.3 Material: Aluminium (Non rusting; Light metal; Non magnetic)
Light and soft to work

Working: See steel

Joining: Screws, glue

Finish: Oil

2.4 Material: Brass (Alloy made from Copper and Zinc)
Hard, brittle

Working: Sawing, filing

Joining: Gluing, clinching

Finish: Oil

3. Tools:

Filing: Choose the correct grade of file, use a needle file for small notches / slots etc

Note! Files cut in the forward direction only

Sawing: Use a hacksaw for straight cuts

Note! The teeth on the blade should face forward
Hacksaws only cut on the forward stroke

Drilling: Use a pillar drill

Note! adhere to the safety precautions, tie all long hair back, remove all jewellery and rings, wear an apron and safety glasses

Finishing: Use a glasspaper and block for all flat surfaces.
Loose sheets for individual shapes.

4. Foreward:

The hot air motor is since 1827, after the steam engine, the second oldest development in heat driven machines. The beginning of this century saw Otto and Diesel motors taking their place, leaving the steam engine to become a museum piece. However the hot air motor (Stirling motor) is still being used on a developmental basis.

This is because it has some advantages over the petrol/ diesel motor.

The advantages are:

- Multi fuel function
Hot air driven machines can use gas, fluid and even solar energy to drive them.

- Higher working effiency
The working effciency is 40 percent.

- Closed system
As a working medium nearly all types of gasses can be used. (air, helium, hydrogen) when so powered the it is known as a “cold machine - that is it is free from CFCs. Also the burnt by products cannot damage the internal working components.

- Outer burner
Because of its outside burner the amount of dangerous emissions is very low.

- Steady running
Due to the outer burner system, continuous burning does not cause high pressures, ensuring that it reaches its highest rpm easily. The motor is also very quiet running.

- Low maintenance
A Stirling motor needs relatively few parts. Due to low vibration the inner parts can work nearly oil free and need little maintenance.

- Different working possibilties

Stirling motors are used for example as cold running machines and as:

Motors for third world countries - under development

Generator - under development

Ships motor - prototype

Car,lorry - prototype

In space - prototype

The dis-advantages of the Stirling motor are:

Too high a weight

High pressure

large cooler needed (heat exchanger)

Sealing problems

Needs good materials

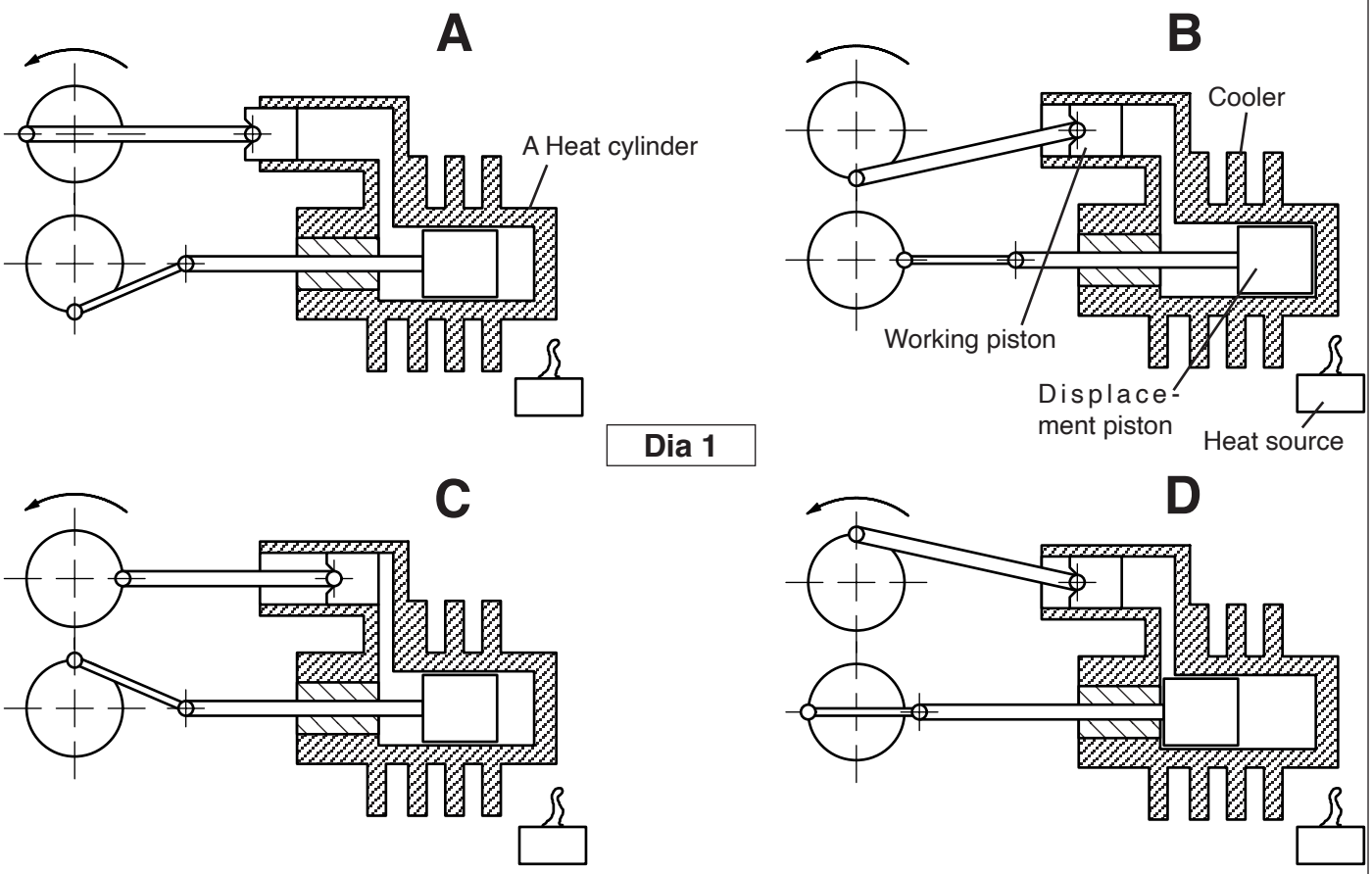
Not so well known
Until now they have no great economical advantages

In spite of all its disadvantages the Stirling motor still has a chance to be developed further. Machines that already use this principle are increasing in production. Being run as a cold motor it has an even larger market share.

5. Function of the Stirling Motor

The main function is shown in Diagram 1. The model consists of two parallel cylinders which are joined by a tube. The working piston is open at one end Between the pressure piston and the displacement cylinder is a small airway in which the air can move. Both of the pistons work at 90 degrees against each other from a single crankshaft. The hot air is made at the end of the displacement cylinder (combustion chamber).
A cooler ensures that the temperature falls to ensure a better working efficency.

The following diagrams explain the various stages



Dia 1

A: The air in the working cylinder has cooled down. A slightly lower pressure is formed and the working piston is drawn into the cylinder. The air volume is at its greatest. The displacement piston moves forward towards the heated end of the cylinder and pushes the air into the cooler area. Mechanical movement follows.

B: The Displacement piston is at the far end of its stroke. On the way it has pushed the the warm air into the working cylinder.The movement of the two flywheels push the working piston into its cylinder.

C: In diagram C the working piston pushes the cooled air into the heated displacement cylinder just as the piston is reaching the cooler end. Then the air is heated and expands pushing the working piston back again. Mechanical movement follows

D: In diagram D the displacement piston has reached its top dead centre and the working piston is about to be moved to the position in diagram A

6. Tools needed to make a working Stirling motor

- Bench with metal working vice and soft jaws	
- Pillar drill	
- Machine vice with soft jaws	365.107 (365.048, 365.059)
- Gas burner for silver soldering	
- Hacksaw	350.035
- Hammer (200gm)	343.055
- Vernier calliper	366.043
- Metal working try square	366.496
- Drawing pins	366.146
- Parallel scriber, adjustable	366.599
- Centre punch	342.061
- Centre drill 1.6mm	333.589
- Reamer (ø 2, ø 4 and ø 5 mm)	333.590; 302.168; 333.604
- Half round files (medium, also round file)	367.399; 367.403
- Needle files 2mm	367.211
- Tap holder and die stock	347.066; 347.125
- Taps M4/M3	347.022; 347.011
- Die M5	347.099
- Compass / Dividers(ø 15)	333.578
- Countersink	366.191
- HSS drills (dia 1,0:1,8,:2,5:3,0: 3,1:3,8:4,1:7,0: 8,0:11,0)	see main catalogue

Other materials

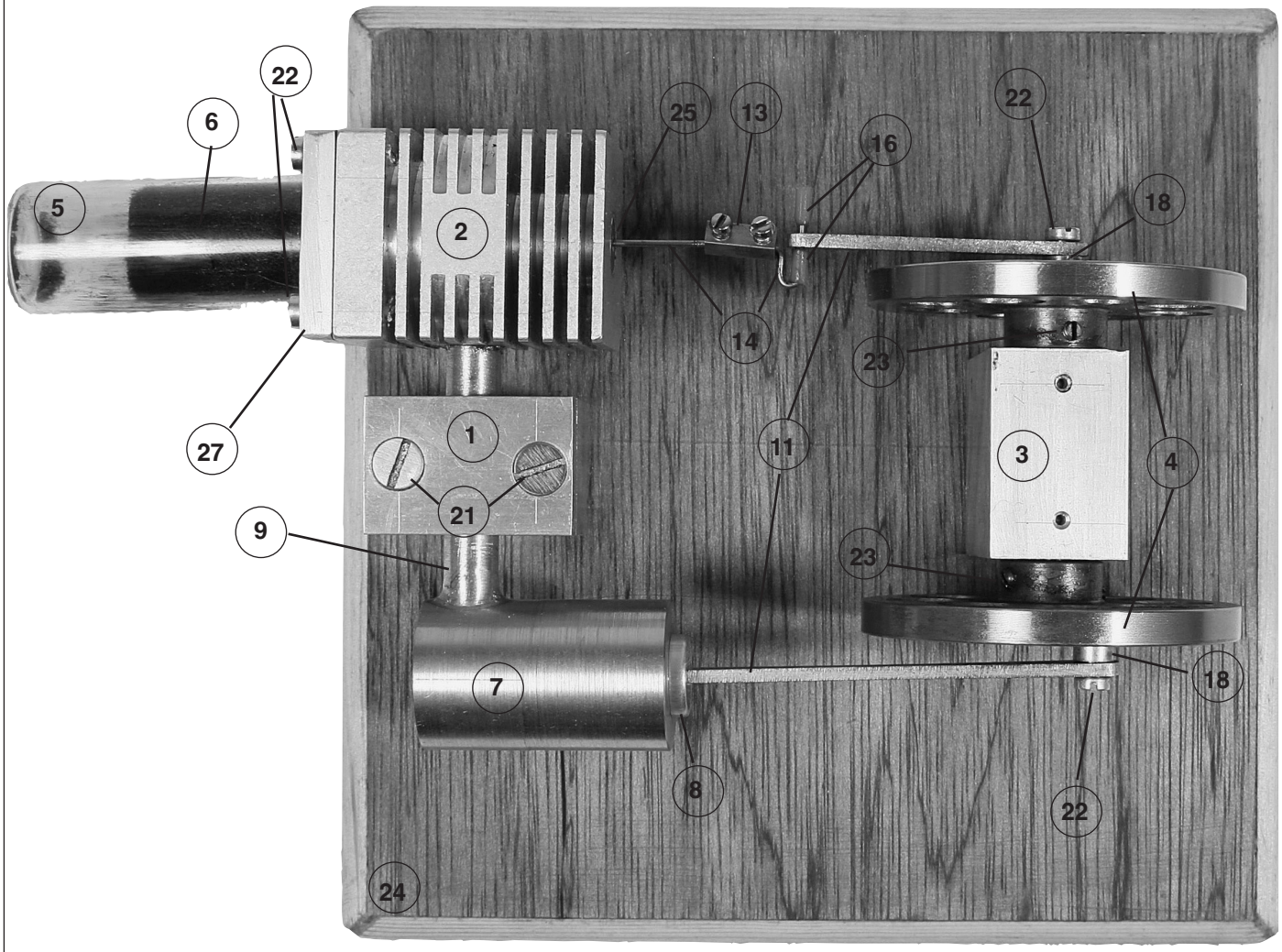
- 2 Component glue
-Spray oil
-Emery cloth
- Cutting paste

7. Material list

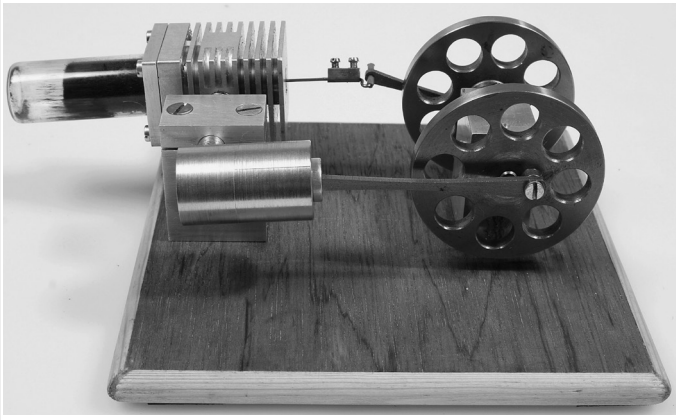
No.	Quantity	Description	Size in mm	Use
1	1	Aluminium section	20x30x40	Motor holder
2	1	Aluminium section, drilled	30x30x38	Cooler
3	1	Aluminium section	20x30x40	Bearing block
4	2	Flywheel in Steel	Ø55x5	Flywheel
5	1	Test tube	(Ø20x1,2)x55	Displacement cylinder
6	1	Verdränger sehr feine Stahlwolle	15x85x180	Verdrängerkolben (Regenera-tor)
7	1	Fine cast cylinder with hole	(22x5)x40	Working cylinder
8	1	Aluminium cylinder	(12x2,5)x16	Working piston
9	1	Brass tube	(8x2,5)x43,5	Joining tube
10	1	Steel rod	Ø5x100	Axle
11	1	Flat steel	(10x2)x120	Connecting rod 1/2
12	1	O-Ring	Ø20x2	Seal between cooler, Flange and cylinder
13	1	Connector and screws	5x4x10	Joiner between Connecting rod
14	2	Steel wire	Ø1x200	Joiner between- Connecting rod
15	2	Brass bush	(4x0,5)x6	Carrier bush on Flywheel
16	1	Silicon tube	Ø3x1x20 for 2 pieces (3mm and 7mm long)	Guide for connecting rod
17	2	Brass tubes	(7x1)x7,5	Bushes in bearing block
18	2	Brass tubes	(6x1)x3,5	Carrier bush in steel flywheel
19	1	Pin	2x12	Piston & rod
20	1	Cellular foam	ca. 90x95	Feet for base
21	6	Countersink machine screws	M4x16	Fixings
22	6	Cheesehead screws	M3x10	Fixings-
23	2	Grub screws	M3x6	Flywheel & axle
24	1	Base plate	140x140x10	For model
25	1	Brass bush	3 x1x18	Bearing in cooler block
26	2	Washers	Ø 18/6,4	Bearing block
27	1	Flange	(30x30) mit hole 20mm dia	Seal for cooler-

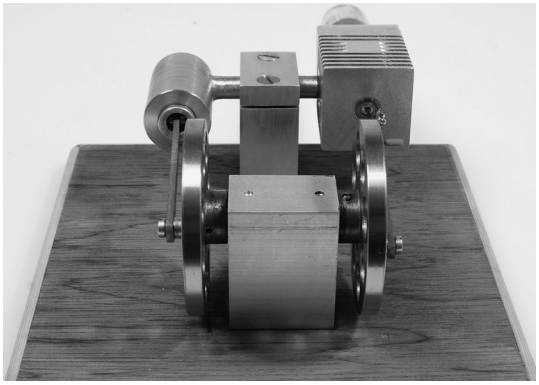
8. Manufacturing the parts

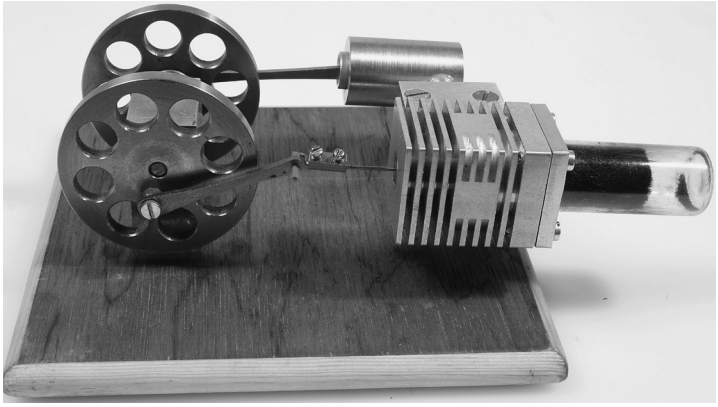
Plan view



Side view

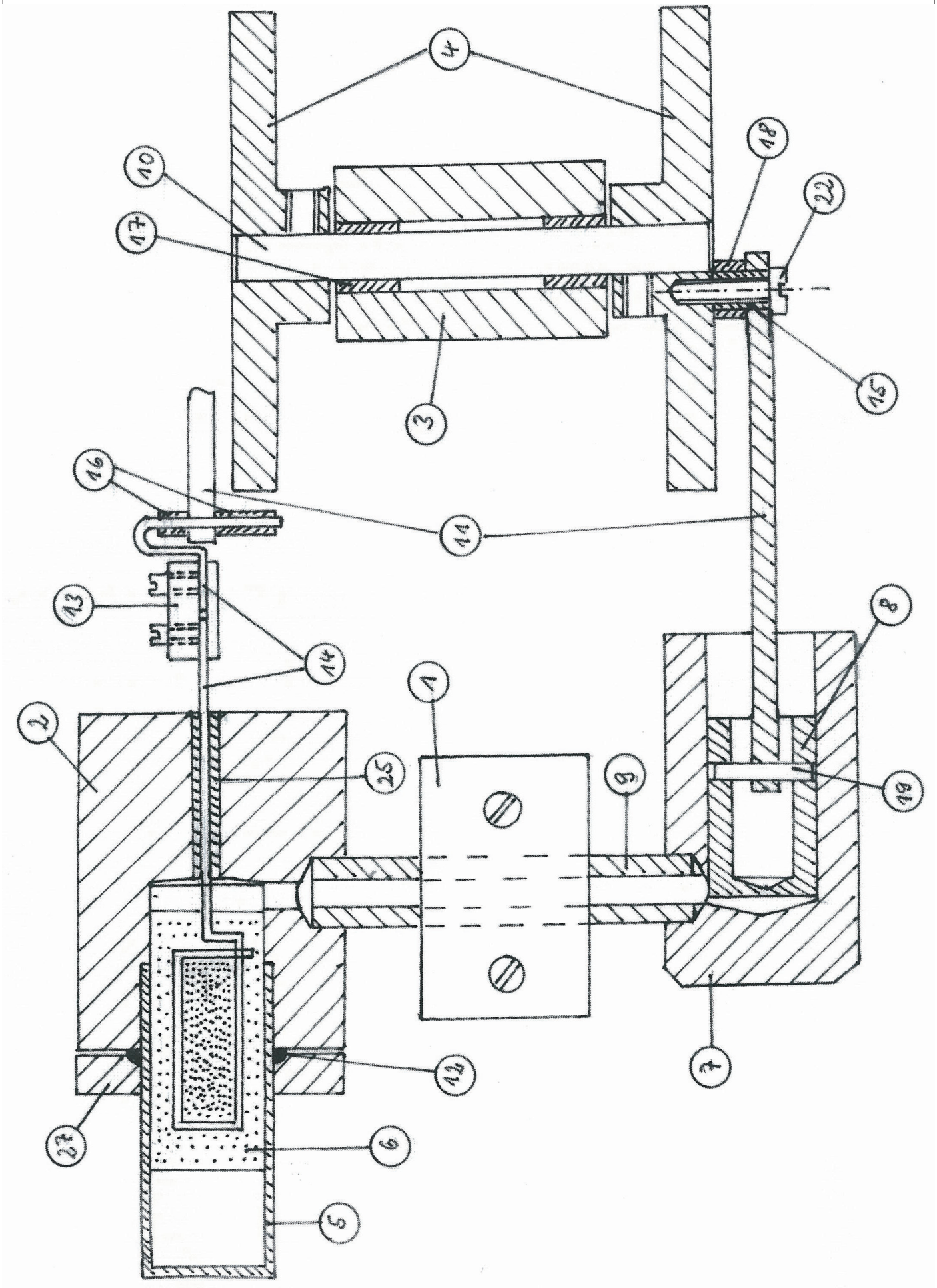






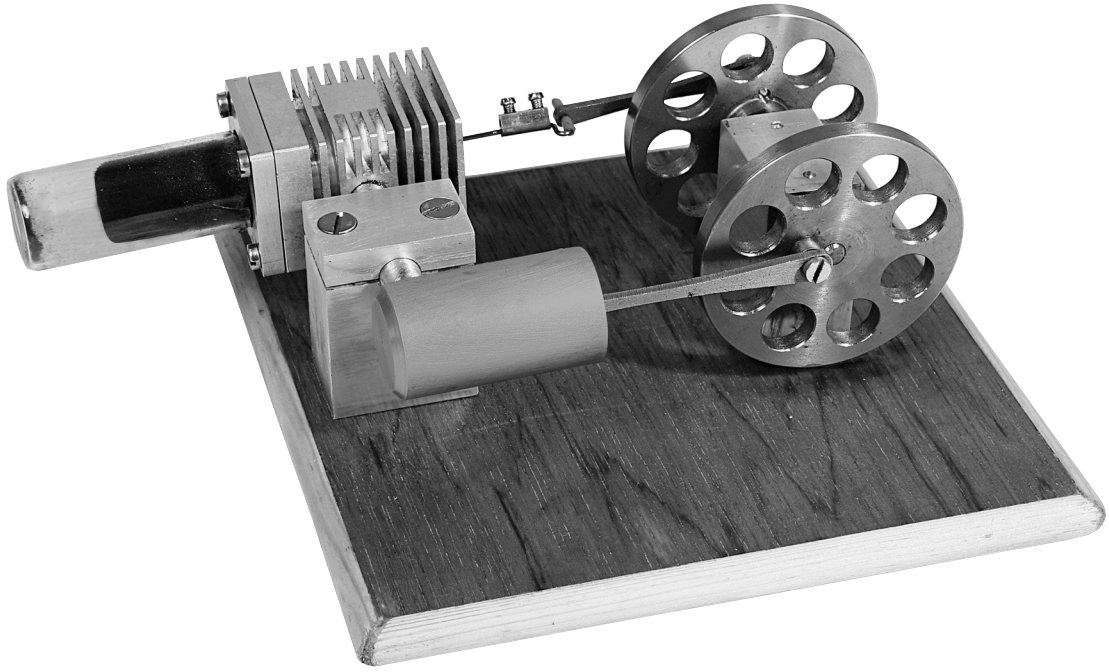
8. Manufacturing the parts

Section view



8. Manufacturing the parts

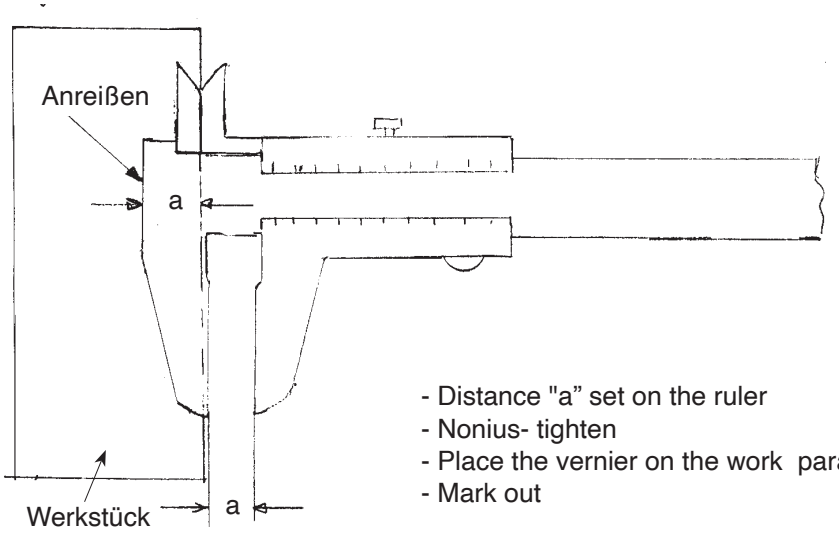
Three dimensional view



Technical data:

Working cylinder stroke:	ø 12 x 14 mm
Compression cylinder:	ø 18 x 18 mm
Revolutions without load:	ca. 1000 U/min

Some parts will need an exact measurent with a vernier ruler:

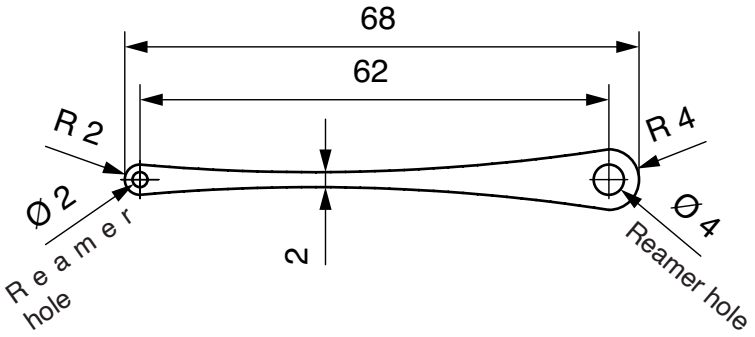


- Distance "a" set on the ruler
- Nonius- tighten
- Place the vernier on the work parallel in the stop (Back of the vernier)
- Mark out

8. Manufacturing the parts

8.1 Making the connecting rod 1 (Pos.11) for working cylinder:

Pos. 11



- Cut the flat strip (11) 10 x 2 x 120 to length
- File the end to 90 degrees
- Mark out
- Centre punch
- Remove burr
- Drill the holes (3,8 and 1,8mm diameter, open them out to 4 and 2mm diameter)

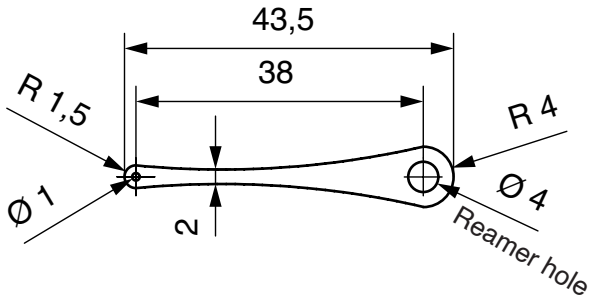
Note: hold the work vertically in a vice!!

- File to shape and then finish with emery cloth

8.2 Making the connecting rod 2 (Pos.11) for the "displacement" piston:

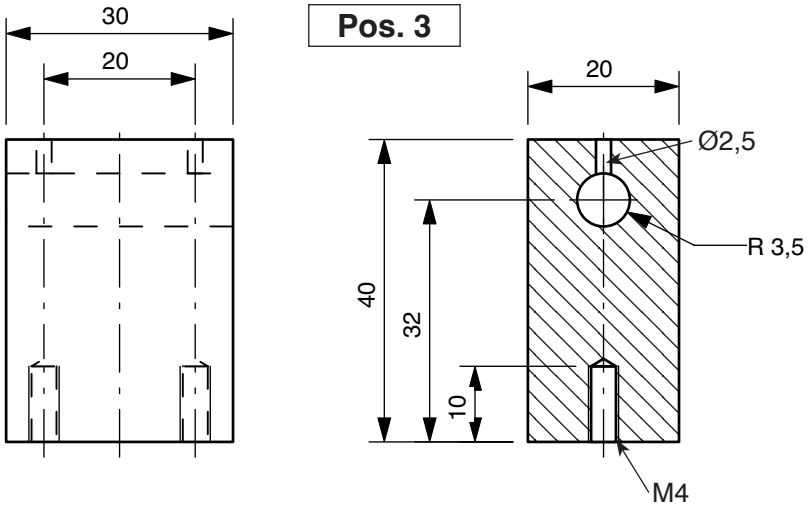
Working order as in step 8.1

Pos. 11



8.3 Making the bearing block (Pos. 3) according to plan:

Pos. 3



- Remove burr
- Mark out
- Drill the 7mm diameter holes (Drill the pilot hole 1.6mm diameter first !!!)

Note ! Place work vertically in a machine vice

- Internal thread. Tap the M4 internal thread –drill a 3,3 mm pilot hole first

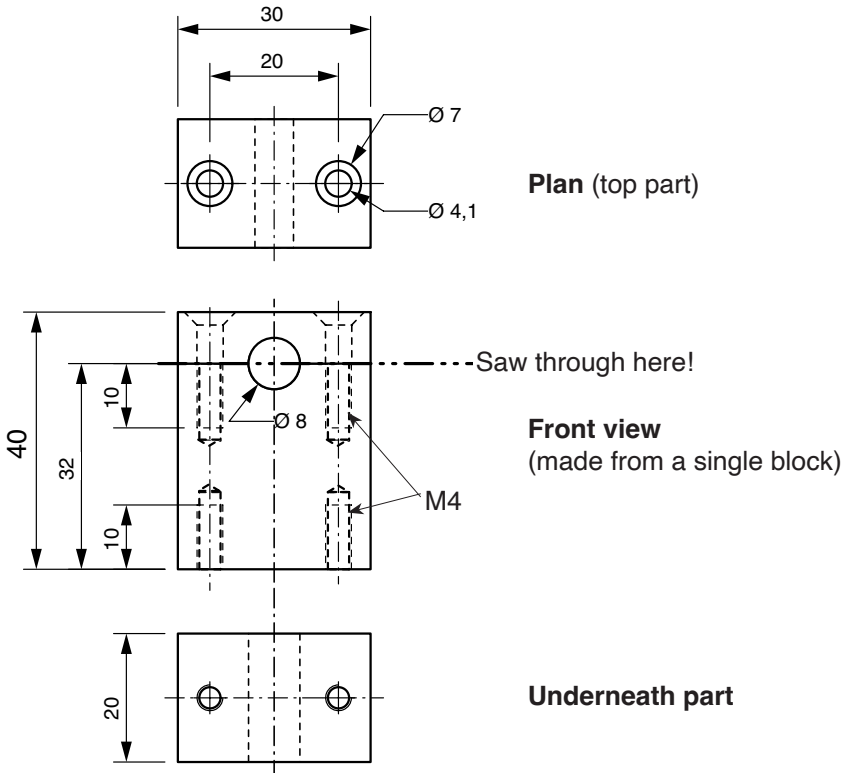
Note! Hold the work tight when making the thread by hand

- The oil way hole are drilled at a later stage

8. Manufacturing the parts

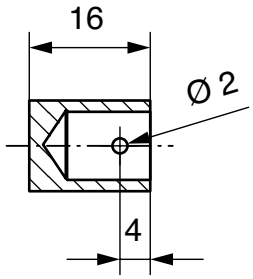
8.4 Making the motor holder (pos.1) according to the drawing:

Pos. 1



-Remove burr
- Mark out
- Centre punch for the holes
- Holes for the internal threads M4, 4x diameter 3.3 mm (top and bottom)
- Hole diameter 8mm for the joining galleries. Pre-drill using a centre drill 1,6mm
  Note: Hold the work piece in a vice!
- Saw off the top small piece, saw from all four sides
- Make the four internal threads
  Note! Hold the work in a vice and turn the tap by hand
- Drill both the holes
- Drill the holes in the upper part to 4.1 mm dia
- Countersink 15mm (Test with countersink machine screw)
- Remove burr and emery cloth surface
- Lightly chamfer corners if necessary

8.5 Working piston (Pos. 8)



Pos. 8

- Drilling for the hole dia 2mm

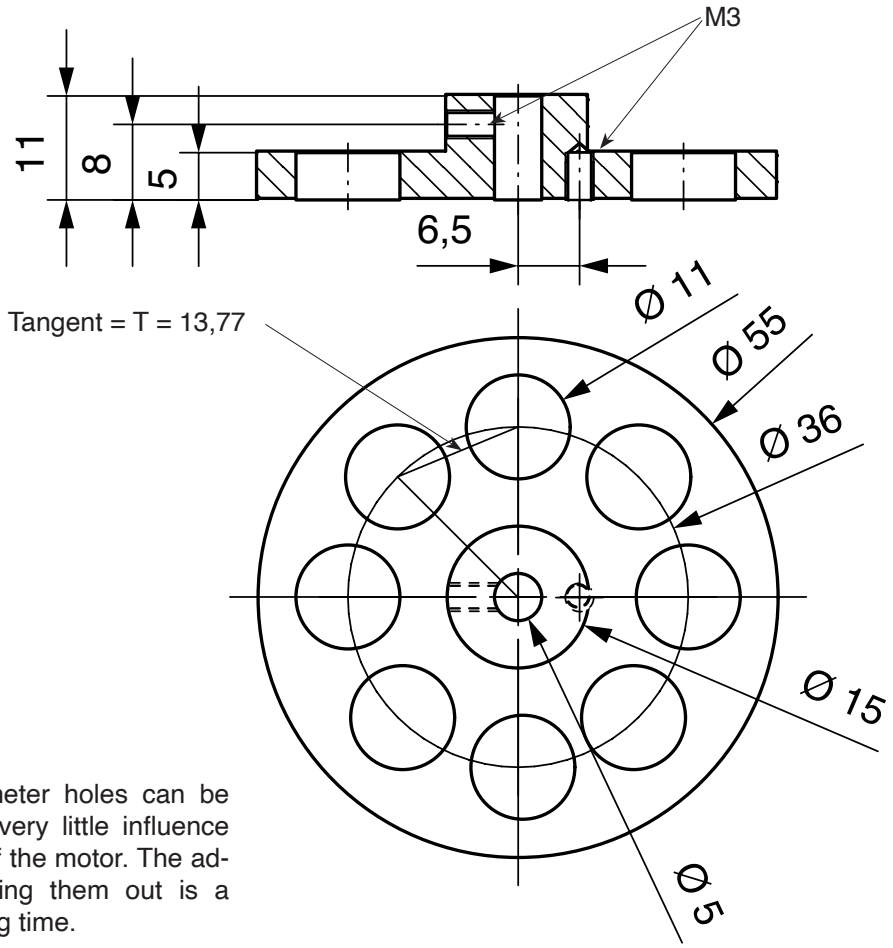
  Note : Hold tight in wood or plastic vice jaws, to protect surface
- Centre punch
- Pre drill 1.8 mm diameter

  Note: Hold the work upright in a machine vice- check !
- Use a reamer to widen the hole to 2 mm diameter
- Remove any burr

8. Manufacturing the parts

8.6 Making the flywheel for the working piston according to plan:

Pos. 4



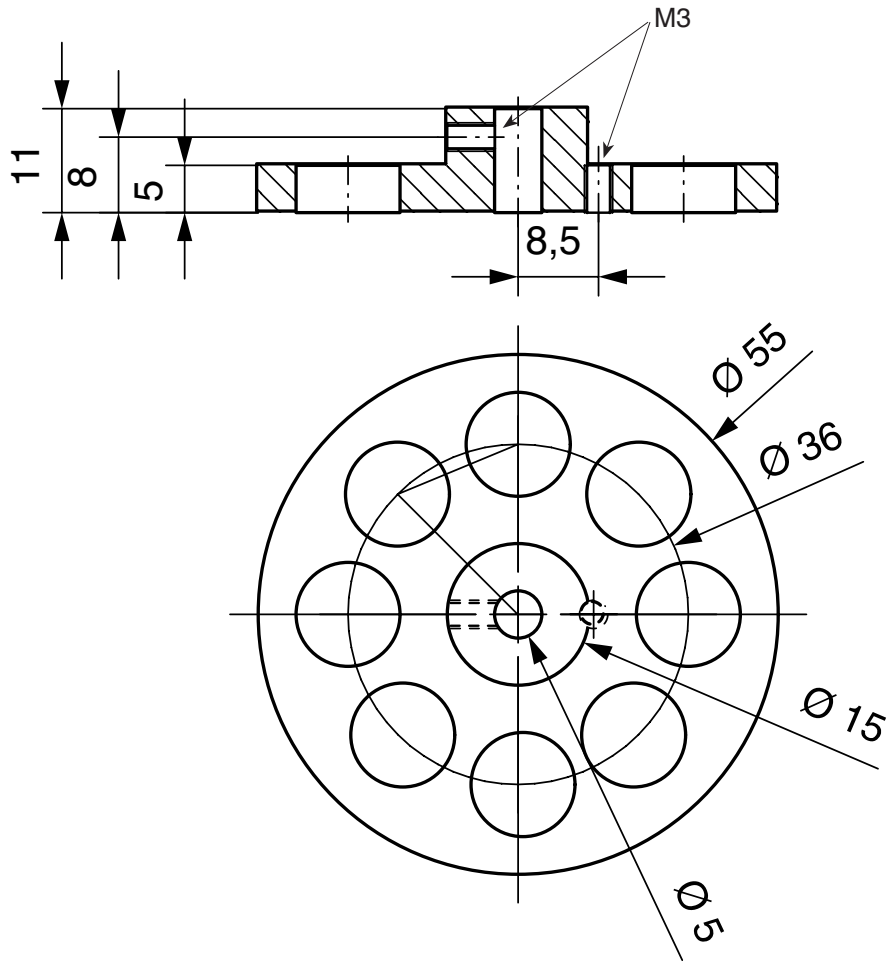
Tip!

The 11mm diameter holes can be left. They have very little influence on the running of the motor. The advantage of leaving them out is a shortened making time.

- Mark out both of the internal M3 holes
- Pilot drill with a 1.6mm diameter bit
- Drill out to 2.5mm dia
- Make the M3 thread
- Place the axle 5 in the 5mm diameter hole
- Mark ou the middle of the axle
- Scribe part circle R18
- Mark out the 8 holes in the flywheel using the Tangent T=13,77 (Adjust if necessary)
- Centre punch
- Pre drill with a 8mm pilot drill. (Carefully hold the work in a vice)
- Drill the 11mm diameter holes
- Remove the burr with a countersink bit

8. Manufacturing the parts

8.7 Finishing the flywheel (Pos. 4) for the displacement cylinder shown in the plan:

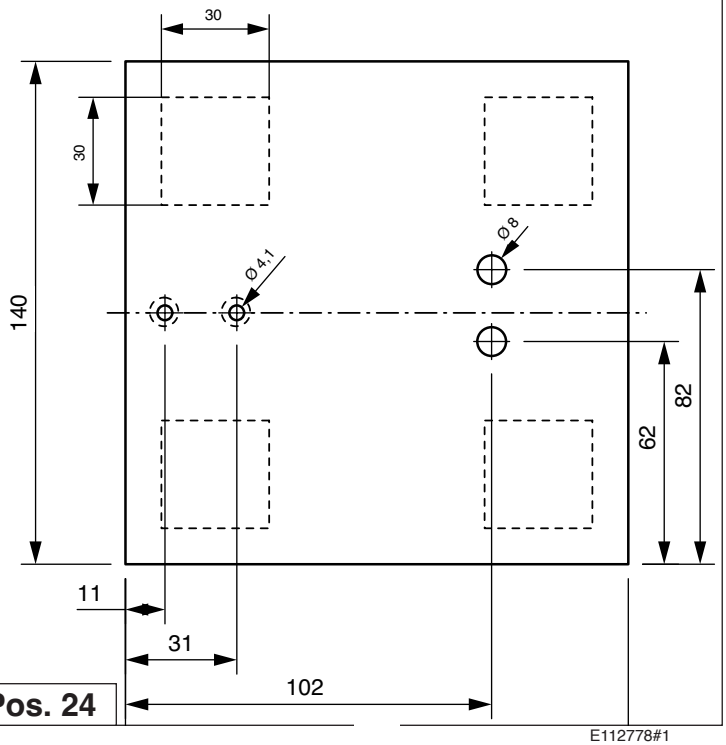


Pos. 4

Working stages the same as shown in steps 8.9

8.8 Manufacturing the base as shown in the plan (Pos.24):

- Mark out the shape
- Drill 2 holes 4.1 mm diameter
- Drill 2 holes 8mm diameter
- Use a countersink on the back of the base underneath (4.1 mm dia) Test with a screw M4)
- Let washer 18/6,6 mm diameter into the base with a countersink (Test with a M4 screw head)



Pos. 24

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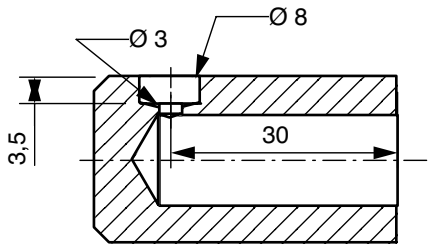
8. Manufacturing the parts

8.9 Working cylinder (Pos. 7; 3mm and 8mm holes)



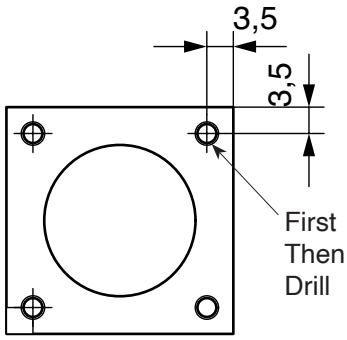
Pos. 7

Mark out the holes 3mm and 8mm diameter

- Centre punch
- Make 2 holes (3mm and 8mm)

Note! Make sure the centre is accurate – use centre drill 1.6mm and note the depth !

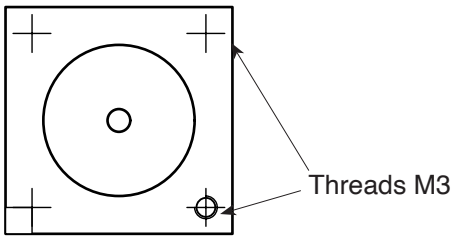
- Carefully remove burr



Pos. 27

8.10 Making the flange (Pos.27) according to the plan:

- Remove any burr
- Mark out, centre drill the holes
- Pilot drill 2.5mm diameter
- (Once the flange and the cooler fit with each other, finish the 4 holes with a 3.1 dia. drill



Pos. 2

8.11 Finishing the cooler (Pos. 2) according to the plan:

- Place the "O" (12) ring in the flange and insert the test tube (5) in the flange
- Lay the flange (With test tube + O ring) on the front of the cooler and push the test tube until it reaches a stop.
- Place the flange and cooler in a vice, making sure the test tube is upright to the cooler and flange.
- Mark out the 4 x 2.5mm, holes in the flange on to the cooler (Drill)
- Use a scriber on one side position to mark the position of the flange on the cooler
  Remove the flange with the test tube and drill through 2.5dia to the 1st cooler rib
- Cut the 4 M3 threads in the cooler
- Remove the cooler from the vice and add the brass bush (25) 3 x1 x18 press in the 3mm hole (If it has too much play use a little glue)
- Now drill out 4 holes 3, 1 diameter in the flange
- Remove all the burr

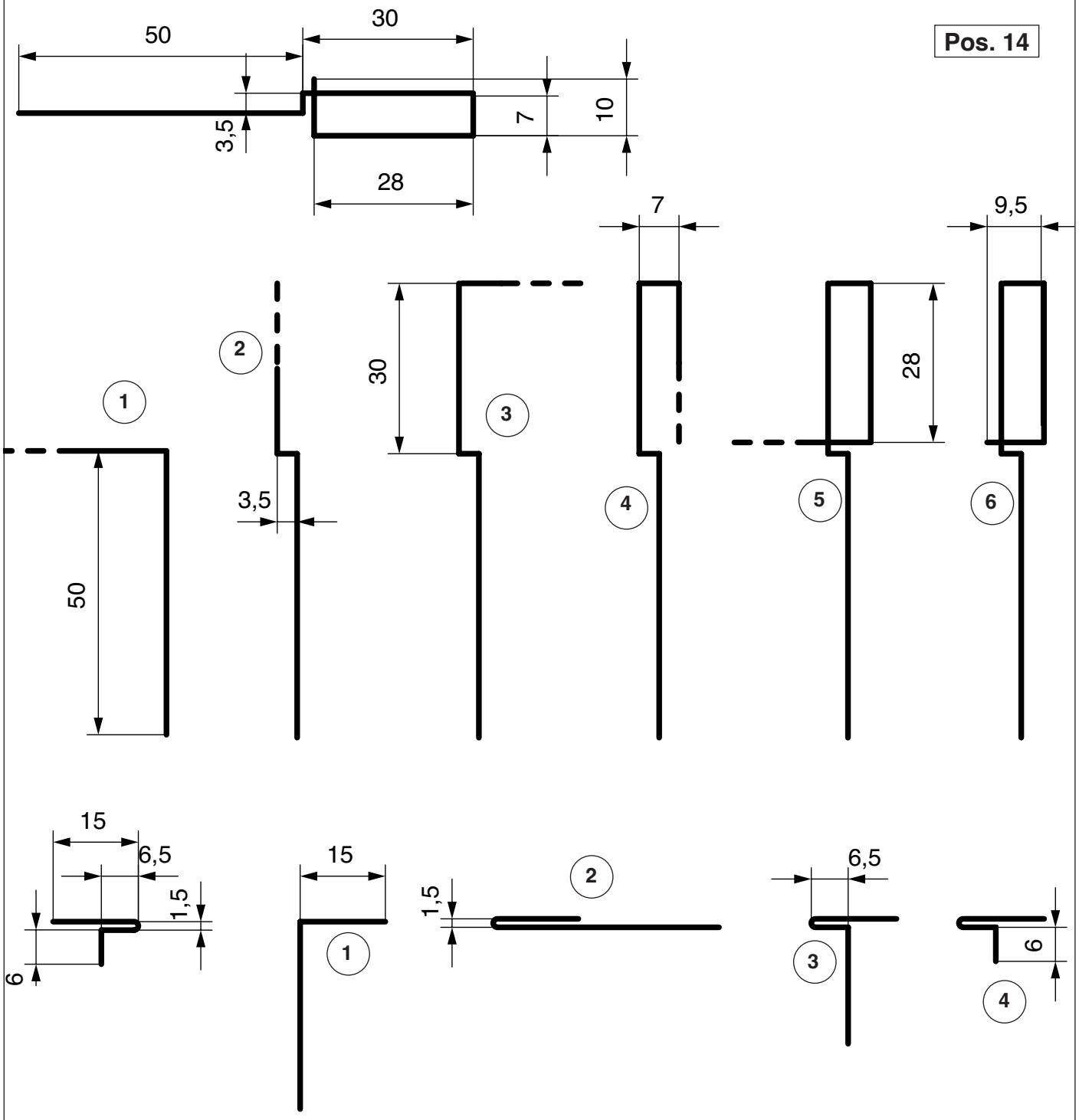
8. Manufacturing the parts

8.12 Making the push rod for the " Displacement" cylinder:

- Form the steel rods (14) as shown in the plans using a small pair of pliers

To take the displacement cylinder.

Note: The whole arrangement must be straight!

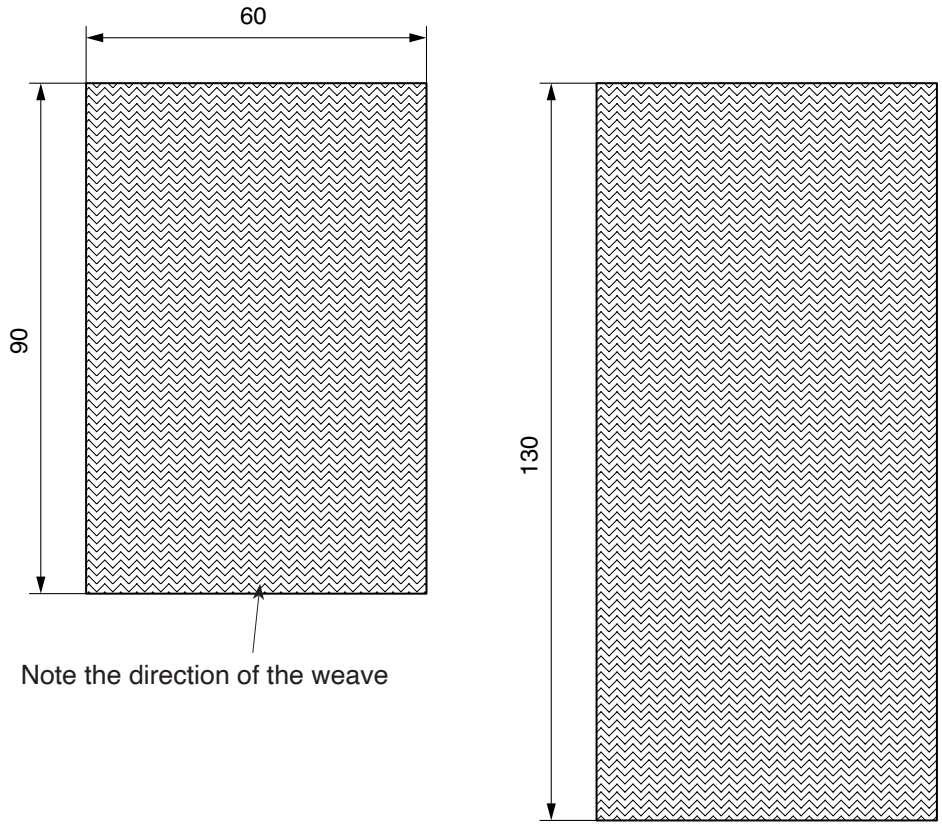


- Use the remainder of the metal (14) to bend the connecter rod

8. Manufacturing the parts

8.13 Making the displacer (Pos.6) as shown in the plan:

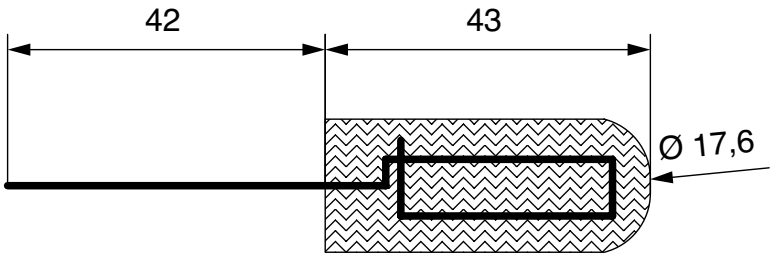
- - Cut a piece 60 x 90mm from the steel wool (6) (Note, the direction of the weave!)

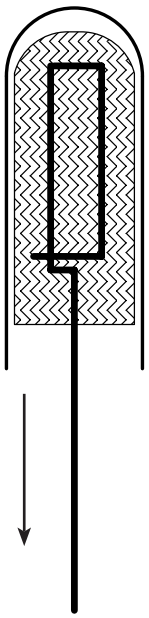


- Stretch the piece to size of ca. 130mm
- About 2/3 the strip (do not cut off !) is rolled to a thick cylinder (Core of the displacement piston. This is core then pressed into shape (7x 28mm)

  Now the rest of the material is wound loosely around the core and the shaped into a cylinder.

  At the end this is placed on a table and rolled with a piece of wood until a diameter of 17.6mm diameter is reached (It might be





some material must be removed !)

- Cut the finished length as shown in the drawing (43mm)
- Checking the displacer
- When is passes in the test tube and can be moved back and forth then its correct
- If its too tight some of the material must be removed !

9. Completion of the model

- Glue the working cylinder (7) the cooler (2) and the joiner (9) together with two component glue. The glue points must be airtight and the glue must not seep into the joiner. The distance between the cooler and the working cylinder is 36mm. Check the sizes once more before the glue sets –adjust if necessary. The axis of the cooler and the working cylinder must be lie parallel to one another

- Now the two bushes for the flywheels (17;dia 7 x 1 x 7,5) be inserted in the bearing block (3) and glued in place with 2 component glue. Finally drill the two oilways (Dia 2,5mm)

- Remove any burr in the bushes (17) with a reamer (5mm dia)

- Cut off axle to 52 mm, remove any burr and insert it into the bearing block. Emery cloth and oil so that it spins easily

- Shorten pin (19) to 11.7mm (Or shorter) so that it does not protrude over the working cylinder piston (12mm dia) and rub on the cylinder wall.
  Join together the connecting rod (11) the working piston (8) and the shortened pin (19)

  Now the mount it on the base (24) use the washers (26) countersink with a 8mm drill so that the screws (21) do not stand do not stand proud. Mount the bearing block (3) with flywheels (4) and motor holder (1) with washers (26) and the screws (21) on the base

  Finally join the connecting rods (11) with the cylinder head screws (22) and the carrier bushes (15/18) to the flywheels

  Cut for square feet 30mm from the cellular foam and glue them on the base (24)

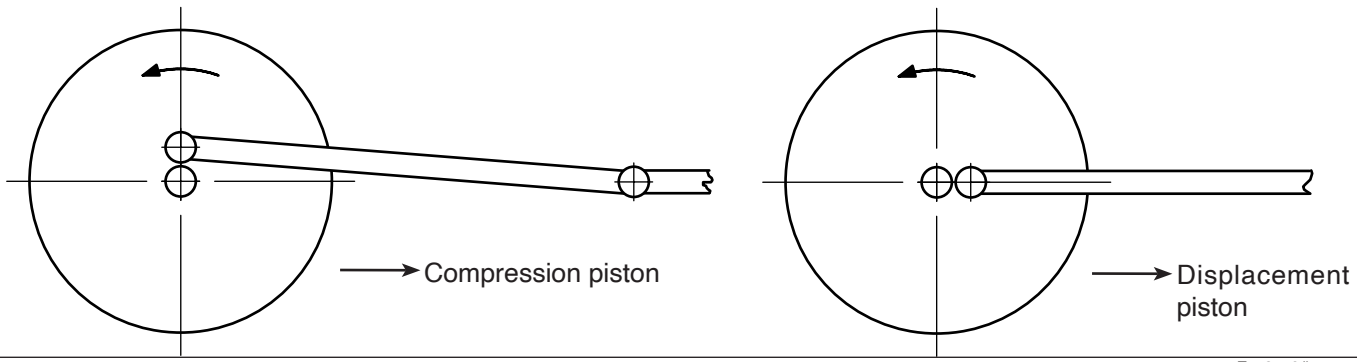
- Now take the displacement piston (6) in the cooler (2) until the stop (You may may have to reamer the bush (25) (1dia) Lay the O ring in flange and insert the test tube (5) into the flange. Insert the test tube in the cooler up to the stop and then fix the flange (22) with 4 machine screws (22) (test tube and cooler must be vertical with each other. The backward and forward movement of the diplacer must be free and easy

  Connecting rod (11) with the hooks (14) and then use the connector block to join them. Place the silicon tube (16/3 +7mm) on the hooks to control the movement of the connecting rods

  When adjusting the flywheels (4) on the axles (10) its necessary to see that the working piston and the displacement piston are not stopped . The two connecting rods must run parallel to each other (Correct by adjusting the bearing block –cooler with the working cylinder is possible)
  The " compressor" piston must not be stopped on the front or the back dead point

- Finally the 90 degree angle between the two connecting rods (11) and the flywheels (4) are set as shown in the sketches

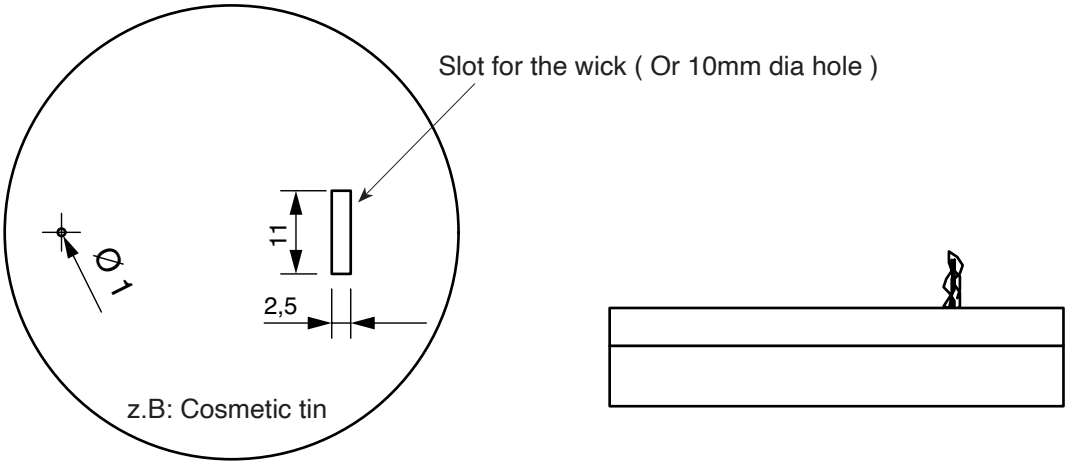
- Undo the grub screw (23) and adjusted and the retightened.



10. Working:

- All the moving parts should be lubricated with a thin oil (spray oil)
  (Working piston, connecting rods, joiner and oil holes !)

- As a heat source use a small spirit burner (Fondue or scented oil is not hot enough)
  If you do not have a burner you can make one yourself from an old tin



Fill the tin half full with methylated spirit
Place the flame at the front (10-15mm) under the front of the test tube.

Note:
- A home made burner does NOT fulfil any general safety regulations
- Using such a device is at your own risk !
- Take great care when using flammable materials

- By the first attempt it can be that the motor only starts up with difficulty

- This is mostly this is mostly due to friction problems with the working piston axles and bushes. When the friction level is lower is the revolutions should climb to 1000revs per minute.

Possible problems when the motor does not run:

- Check the 90 degrees angle (11) between the flywheels (4) is correct (if necessary
Set a smaller angle)

- Check the leaks between
  - displacement cylinder, cooler, flange,
  - Push rod and cooler,
  - Joiner and cooler with working cylinder.

Other faults

- Wrong lubricant used

- To much friction between the parts

- The displacement piston touches the front dead point in the cylinder

- The displacement piston touches the rear dead point in the cylinder

- The displacement piston rubs on the cylinder too much

- Heat not enough (Use meths)

- The displacement piston not properly wound.

The displacement cylinder (Steel wool) does not move with the push rod- not working properly

Spare parts list for the Hot air motor Article No 112.710

No.	Quantity	Description	Size in mm	Article No	€/ Price each	€/	Use
1	1	Aluminium section	30x20x40	809419	0,90		Motor holder
2	1	Aluminium section	30x30x38	802.004	2,75		Coole
3	1	Aluminium section	30x20x40	809.419	0,90		Bearing block
4	2	Flywheel	55dia x 5	819.243	2,75		Flywheel
5	1	Test tube	(15x 1)x36	425.491	1,10		Displacement cyl.
6	1	Steel woo	15 x85 x 180	509.136	2,45		Displacement piston
7	1	Cast cylinder					
		With hole	(22 x 5)x 40	802.510	2,10		Working cylinder
8	1	Aluminium cylinder					
		With hole	(12 x 2.5) x 16	802.521	2,50		Working piston
9	1	Brass tube	(8x2.5) x 43.5	814.520	1,45		Joining tube
10	1	Steel rod	5mm dia x 100	833.023	0,55		Axle
11	1	Flat stee	(10x2)x120	823.716	0,55		Connecting rod
12	1	O-Ring	Ø20 x 2	544.111	0,70		For displacement cyl.
13	1	Connector block					
		2 Screws	5x4x10	203855	0,95		Joiner
14	2	Steel wire	Ø1x200	822.053	1,50		Cap for heating cyl.
15	2	Brass bush	(4x0,5)x6	818.269	0,05		Carrier bush
16	2	Silicon tube	Ø3x1x20	842.310	0,10		Control for working cyl
17	2	Bass bush	(7x1)x7,5	818.236	0,12		Bushes in bearing block
18	2	Brass bush	(6x1)x3,5	818.247	0,10		Bush in flywheel
19	1	Steel pin	2x12	269.266	0,10		Con. rod to working piston
20	1	Steel pin	2x6	269.255	0,10		Con.rod to working piston
21	6	Counter Machine screw	M4x16	266.181	0,08		Holder for motor block
22	2	Machine screw	M3x10	265.050	1,15		Fixing bush and flywheel
23	2	Grub screw	M3x6	269.277	0,10		Join flywheel and axle
24	1	Wood base	140x140x10	715.186	0,65		Base
25	1	Brass bush	Ø 3x1x18	801.972	0,90		For con .rod
26	2	Washers	Ø 18/6,4	268.170	0,08		Bearing block
27	1	Flange	30x30 mit				Seal for cooler and
			With 20dia hole	802462	0,20		heat cylinder