The LTD Stirling engine always impresses first time viewers with its simplicity and the apparent lack of a fuel source. This particular engine is made almost entirely out of recycled materials, so it's easy to build. You can get most of the parts for free, it needn't cost a lot to build.

**How does it work?**

The Stirling engine contains a sealed volume of air (this can be other gasses like helium!) that is repeatedly heated and cooled, causing it to expand and contract. When the air expands or contract this moves the diaphragm. Inside of the displacer cylinder there is a piston called the displacer, this moves air between the top and bottom of the coke can which are hot and cold, this allows the engine to continue turning rather than the air expanding and staying like that a long as heat is applied. This particular engine uses a polystyrene displacer.
Materials

- 2 Tuna tins
- 1.59mm (1/16”) brass rod (K&S Metals recommended)
- 2.38mm (3/32”) brass tube (K&S Metals recommended)
- 5 minute epoxy
- 1.2mm steel wire
- Balloon
- Plastic bottle cap
- Sellotape
- Polystyrene
- 2 litre plastic bottle
- 4 Steel washers about an inch in diameter
- 2 5 Electrical terminal connector blocks
- M5 Bolt around 40mm long and matching nut
- Cable ties

Tools

- Pliers (2 pairs handy)
- Tin Snips
- Drill and 2mm bit
- Needle nose pliers
- Scissors
- Marker Pen
- Hot wire cutter (or make one)
- Drawing pin
- Can opener

Safety first! Always wear proper protective safety gear when handling sharp/hot dangerous materials. Tin cans can be very sharp so be careful at all times
Step 1: Cut the top and bottom from the plastic bottle

The plastic bottle will form the sides of the displacer cylinder, so that you can see the displacer moving. Cut the top and bottom curved parts off, and cut down the side of it.
**Step 2 : Cut the side to size**

I made a template, so that I could cut the plastic bottle to size. The dimensions are 263mm x 40mm. The length of the template depends on the size of the tuna cans that you use, measure the diameter and times that by 3.141 (Pi) to get the correct size.

![Template drawing.](image)

Tape to the plastic then cut around the template to get the plastic to size. Remove the template when you're done. You'll also need to cut a small piece of plastic to about 40mm by 10mm, so that you can join the seams together.

![Template taped to the plastic](image)
STEP 3: Epoxy the plastic back together.

You need to tape the two edges of the plastic together, so that they won't pull apart whilst the glue dries. Stick the tape to the inside of the plastic ring. We're going to use the little piece of plastic to join the two edges together.

*Tape is on the inside edge*
Apply some epoxy to the edges, ready for the little plastic joining piece. Use plenty of epoxy as the seam needs to be airtight. When you fit the joining piece, tape over it to hold it in place while the epoxy dries.

Epoxy to join the edges together

Seam with joining piece glued on
STEP 4: Make the displacer cylinder top and bottom.

The displacer cylinder top and bottom parts are made from the bottoms of tuna cans. You can mark a nice curvy line, or just cut them about 5 mm up from the bottom. Remove the top rim using a can opener to make it easier to cut the shape using tin snips. Before you cut anything, mark the centre point on one of the cans using a caliper or a compass set to half of the diameter. Draw three arcs, this should point to the centre, though it isn't always perfect, but it should be enough.
Now you can mark the line to cut, about 5mm up from the bottom of the can.

*Marking the lines*

*Cut out displacer cylinder end. You need two of these.*
Step 5: Cut the displacer bushing

For the displacer bushing, you'll need a 10mm long piece of tubing. To cut the tube, roll a sharp knife over it applying gentle pressure. When you've cut the tube, you'll need to remove the burrs from the ends of the tube, so that they don't catch the 1/16” rod. Test that the 1/16” rod slides smoothly through the piece of cut tube, if it doesn't there's probably still some burrs remaining.
Step 6: Drill the hole for the displacer bushing.

In one of the lids that you marked the centre of, you'll need to drill a hole for the displacer bushing to fit into. I used a 2mm drill bit and just gently widened the hole by running the drill through it, so that it is big enough for the 2.38mm (3/32”) tubing.
Step 7: Epoxying the brass tub in place

The brass tube is epoxied in place, so that most of it's length is above the bottom of the tuna can. Stick a piece of tape loosely over the inside of the can so that there is around 1mm of tube showing on the inside of the tuna can. To get the tub straight, firstly epoxy it where ever it falls naturally, then wait for the epoxy to begin hardening. As the epoxy is hardening, remove the tape and insert a piece of 1/16” rod through the bushing so that you can hold the tube straight by eye.
Step 8: Cut an air hole for the diaphragm

To allow air to flow into the diaphragm, you need to cut a small hole about 5mm, you can either drill this or cut it with a knife, I cut mine with a knife. The hole sits around 20mm away from the edge of the tin can.

*Air hole cut*
Step 9: Cut a bottle cap for the diaphragm and epoxy it in place

The diaphragm is fitted around a plastic bottle cap. The bottle cap needs a hole in the bottom to allow the air into it. Cut the bottom of the bottle cap out with a sharp knife. Now you can epoxy the bottle cap in place over the air hole. Make sure that you use plenty epoxy all around the bottle cap to ensure that it is airtight.
Step 10: Cut the displacer

The displacer is made from polystyrene, the kind used to protect fragile items during shipping. To cut the polystyrene you'll need a hot wire cutter. You can either make one yourself using resistance (ni-chrome wire) or buy one. The one I made was made from resistance wire out of an old electric heater which I stretched between two screw. This was connected to a 12V power supply to heat the wire. **DO NOT ATTEMPT TO WIRE THIS UNLESS YOU ARE COMPETENT IN WIRING ELECTRICAL SUPPLIES!** If you buy a wire cutter, make sure that it's capable of cutting the size of polystyrene you have, as some of the commercially available cutters are quite small.

The size of the squares you need to cut are around 90mm x 90mm x 12mm, just a little a bigger than the tuna cans. You need two of these. We're going to make a cookie cutter next to cut the circle shape next. It's a good idea to cut a few spare in case the next step goes wrong.

Polystyrene square cut out
To cut the exact circle shape for the displacer I used a tuna can like a cookie cutter, the difference is that this cookie cutter is going to be hot! Insert a large screw or bolt in the centre of the tuna can to use a handle. Wear gloves though, as it'll still get very hot! With your special cookie cutter made, you can heat it up on a heat source such as an electric hob. Beware, this will make a fair amount of pungent toxic smoke, so either do this outside or make sure that the room is very well ventilated.

Trim the edges neat with tin snips

Magic cookie cutter
Once the cutter is hot, you can press it into the polystyrene you cut earlier. You should have two perfectly round displacer pieces now. They might have a taper on them, this is normal and acceptable.
Step 11: Assemble the displacer

Now you can fit the displacer together and epoxy in it's brass rod Start by epoxying the two polystyrene circles together
Next fit the plastic ring to the top tin can and put the polystyrene displacer inside of it. Making sure that the displacer is centred in it's cylinder, push a length of 1.59mm brass rod through the displacer bushing and through the polystyrene displacer. You can trim the brass rod to around 40mm above the bushing at this stage. Check that the displacer moves freely, it should fall under it's own weight.

To keep the brass rod from sliding out of the polystyrene, it is epoxied to the bottom of the displacer. Carve a little recess for the epoxy to sit in. With the displacer upside down, fill this recess with epoxy around the brass rod.
Step 12: [OPTIONAL] Paint the parts

You can paint the parts a colour of your choosing at this stage, or just leave their original colours. Make sure that you cover the ends of the displacer bushing with some tape, as any paint getting in there will prevent the engine from running.

*Parts painted black*
Step 12: Assemble and seal the displacer cylinder.

The displacer cylinder needs to be airtight, so bear that in mind when sealing the engine. Fit the top and bottom tuna cap into the displacer cylinder, with the displacer in between. Check the displacer still moves freely.

If the displacer is moving freely, you can begin sealing the cylinder with epoxy. Seal all around the top first. Let that dry, and then turn it over and seal the bottom. Make sure you fill all of the gaps, as any air leak will stop the engine running.
Step 13: Make the diaphragm

The diaphragm is made from a balloon, with two washers either side of a bolt that is threaded through the balloon. This is so that you can attach the diaphragm to the cranks. First you need to make the two plastic washers, start by drilling a hole in the centre of the bottle caps (you need two of these washers).

*Image: Bottle cap drilled*

Then cut all around the outside of the bottle cap.

*Image: Cutting the bottle cap*
Keep cutting until you have two small washers they should be around 5mm smaller than the inside of the bottle cap

![Finished washers](image1)

Take your balloon and cut the neck off, discard the neck.

![Cut balloon](image2)
Stretch the balloon over a spare bottle cap so that it is taught. Then pierce a hole roughly in centre. It appears in the photo that I have made a large hole, but it's deceptive because the balloon is very stretchy and resists the knife quite well.

Put one of the washers onto the bolt.
Now thread the bolt through the hole you made in the balloon earlier.

![Bolt threaded through](image)

Now you need to stretch the balloon out again as you did earlier.

![Stretched balloon and bolt](image)
Add the second washer and tighten the nut. It's finished now.

**Step 14: Fit the diaphragm**

The diaphragm is simply fitted loosely over the bottle cap that you epoxied to the tin can lid. Tie an elastic band around it to seal the diaphragm.
**Step 15: Make the cranks**

The crankshaft is made from 1.59mm brass rod. It has two parts that are bent outwards to connect the displacer and the diaphragm. The two parts are rotated 90 degrees away from each other, the reason for this is so that the engine can never reach equilibrium, it will keep rotating as the displacer that controls the pressure in the engine is always ahead of the diaphragm position.

To find the correct length for the displacer part of the cranks, lower the displacer to its lowest position, and place a mark on the rod at the top of the bushing. Then, raise the displacer to the highest position it will go. Measure the space between the mark and the top of the bushing. This will be the total stroke needed for the displacer. In this case, it was around 10mm. The cranks should be bent out about half of the total stroke. It's almost impossible to bend the cranks by hand to an exact size, so you should make the cranks stroke a little smaller than is needed, in this case I made them 4mm (8mm total stroke).
Finished cranks

Diagram showing cranks dimensions

12mm 5mm 12mm

90 degrees rotation between displacer and diaphragm

Displacer Crank

Diaphragm crank

125mm

See text
Step 16: Cut the bearing sides

The crankshaft sit on two cut out from a large tin can (the same diameter as the tuna cans. Remove both ends from the can using a can opener:

![Can ends have been removed](image1.jpg)

Then cut about 35mm of the can off using tin snips. The exact size isn't important, we just want it to be a bit smaller.
Can cut down to size
Now cut two pieces about 75mm long each, you can cut a curve to make them look nice or, just leave them straight:

Side cut outs

Line the two pieces up exactly, and pierce a hole around 5mm from the top and in the centre:

Piercing a hole for the bearings
You will need to make the holes bigger using a piece of 1.59mm brass rod:

*Enlarge the holes with a piece of brass rod*

You can spray these a colour of your choice at this stage, if you wish.

*Painted parts*
Step 17: Make the flywheel

The flywheel is made from the end of a tin can. Cut the end off by using a can opener around the side of the can. Mark the centre, and drill a 2mm hole in the centre.

Flywheel

Dismantle two electrical terminal blocks so that you just have the metal parts. Discard the plastic.

Screw one terminal block on a piece of 1.59mm brass rod:
First terminal block

Then slide the flywheel on and secure it with another terminal block. Push the two terminal blocks together, so that the flywheel runs true.

Securing terminal block

Secured flywheel
Now you can epoxy one of the terminal blocks to the flywheel. Mix some extra epoxy up and glue the four washers to the flywheel. This is to give it a bit of extra weight. When the epoxy has dried, you can remove the flywheel from the brass rod. You only need one terminal block epoxied to this.

Washers and terminal blocks epoxied on.

Like all of the other parts, you can paint the flywheel too:
Step 18: Epoxy the power piston push rod on

To connect the diaphragm to the cranks, use a piece of 1.2mm steel wire. Wrap it around the bolt and epoxy it in place. You want to leave about 60mm long, the other end will be formed later.

Step 19: Epoxy the sides on

The two sides are epoxied to the displacer cylinder. Whilst the epoxy dries, you'll need to use a cable tie to hold them in place. I actually had to use two cable ties locked together, so check whether one will fit before you proceed.
Preparation of the parts to be epoxied together

Apply epoxy to one of the sides:

*Epoxy applied to the side*

The side piece is epoxied on about with about 5mm touching the side of the displacer cylinder. Use your cable ties to hold it in place whilst the epoxy dries:
The side cable tied in place, while the epoxy dries

Once the epoxy is dry, you can do the same on the other side. You need to thread the crankshaft through when you epoxy the side through. Make sure you get the cranks the right way around as the displacer side is bigger than the diaphragm side.

The other side epoxied in place and the cranks fitted

Step 20: Make the displacer connecting rod

To connect the displacer rod to the crankshaft we'll use some 1.2mm wire formed in a zig-sag. The zig-zag pattern allows easy adjustment of the length of the rod. Begin by wrapping some wire around a piece of 1.59mm brass rod several times, this will make the bearing that contacts the displacer rod. When you've done this, you can form a zig zag about 2" tall
The first bearing point

The displacer rod has a 90 degree bend just above the bushing, this is to allow the connecting rod to pivot. Attach the bearing that you just made to this.

Bend the displacer rod like this

You can now line it up with the crankshaft and form the other bearing point in the same way:
In the end, my connecting rod ended up slightly distorted, for it to be in the correct position. This isn't a problem.

**Step 21: Connect the power piston**

The power piston is connected in the same way as the displacer connecting rod, except that it only has one or two turns on the bearing.
Step 22: Attach the fly wheel

The flywheel is simply screwed onto the crankshaft.

It's finished now!

The engine is powered by the heat from a cup of hot water. Oil all of the bearings before you run the engine, Hopefully the engine should run first time without and problems. I hope you enjoyed building it as much as I did.

Do not try to hear this engine with any heat source other than hot water, and do not submerge the engine in boiling water. The materials the engine is made from can only withstand low temperatures.

If it doesn't work, here are some tips to help diagnose the problem:

The first thing to check for is air leaks, if you suspect an air leak, submerge the engine in a bath of warm water and any air leaks should be obvious. Dry the engine quickly to prevent any water getting into the engine through the leak.

The other thing that could prevent this engine from working is too much friction. The engine should be very easy to turn, if it isn't you need to find whatever is causing too much friction.