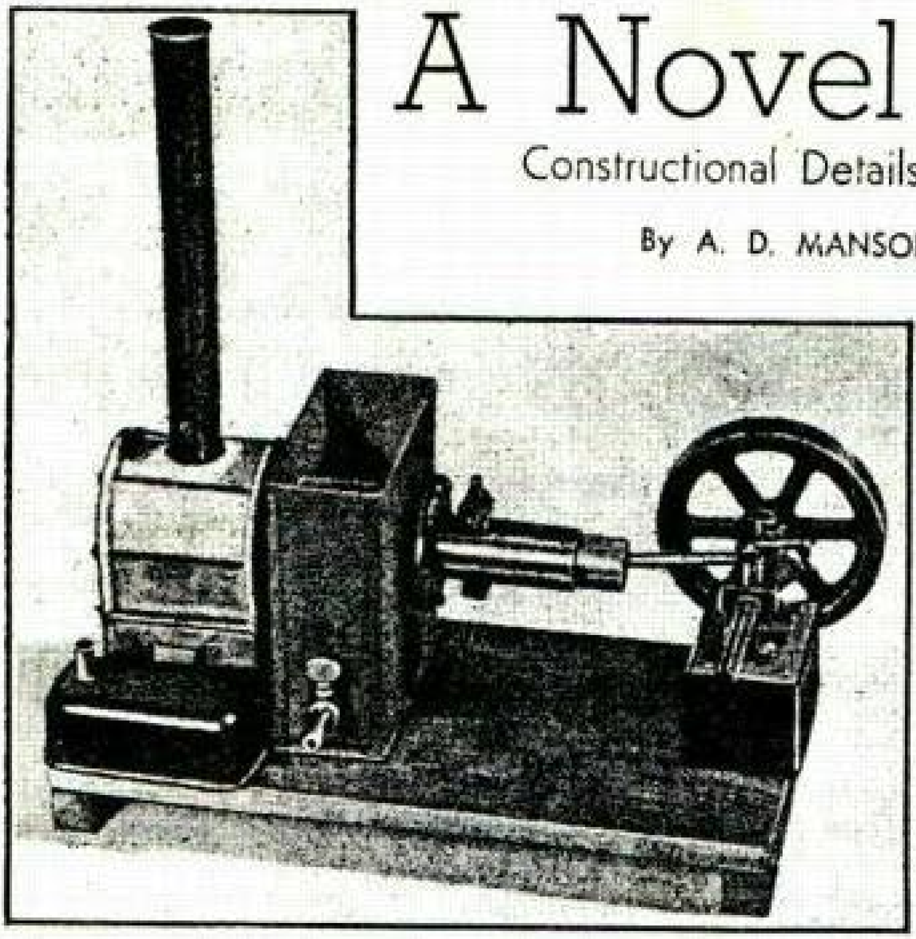
A Novel Hot-air Engine

Constructional Details of an Experimental Double-acting Model

By A. D. MANSON   From Newnes Practical Mechanics 1952



The completed experimental hot-air engine.

THE hot-air engine here described works on a new principle devised by the writer. As will be seen by the sketch (Fig. 1) it is simple and, therefore, should not be difficult for the average mechanic to construct.

The illustration shows the piston, which is tubular, to be directly connected to the displacer so that they move together as one piece.

The working cycle is as follows: starting on the out stroke. As the piston moves out the cold air contained in the cold portion of the displacer chamber A is displaced to the hot end and the pressure gradually rises, so driving the piston. At the end of the out stroke the piston comes to a position where the two ports X register, and therefore all the air above atmospheric pressure escapes from the hot end. On the return stroke the small quantity of hot-air remaining in the hot end of the displacer chamber is displaced to the cold end and cooled, therefore, a partial vacuum is formed, which increases as the stroke continues and the piston is thus forced in by the pressure of the atmosphere until near the end of the stroke, when the air-inlet port registers with that of the working cylinder. Air now rushes in to fill the vacuum and the cycle of operations is thus completed.

The following are the advantages for this type of hot-air engine: the heated air during the out stroke remains in the hot end till the end of the stroke and it is discharged directly from the hot end to the atmosphere and thus heating of the cold end is avoided to some extent. The incoming air is always at atmospheric temperature and pressure.

The engine is double-acting and can be reversed. There are few moving parts, no additional mechanism being required to drive the displacer.

Constructional Details

Starting with the displacer chamber, this is made from a piece of mild steel tube, or it can be constructed from sheet metal not more than 1/32in. thick. One end is closed by a piece which is cut a little larger than the diameter of the chamber. It is then beaten out hollow or dished, as in Fig. 1, and fitted in the end of the tube, being secured air tight by brazing or welding.

A ring made from ¼in. square iron rod, or cut from plate, is fitted on the outside of the other end. It can be brazed on or soft soldered. The chamber should then be placed in the lathe and the ring trued up, as it has to carry the working cylinder.

Working Cylinder

This cylinder is made from a piece of mild steel pipe, the finished size being 1⅜in. bore by 3⅝in. long. The outside should be turned bright, and the step to receive the flange should be cut for a distance of 3/16in. at one end. Before smoothing out the bore the air-inlet ports and the exhaust port should be drilled, care being taken to ensure their correct positions.

The cylinder flange is made from a piece of mild steel plate 3/16in. thick. It should be turned, and a spigot of 1/32in. deep made on the inside to fit the mouth of the displacer chamber. A light groove should be cut in the other side to mark the pitch circle of the eight fixing screws, the holes for which should now be drilled. The flange can now be used as a jig to drill the tapping holes in the chamber flange ring. The flange can now be pressed or lightly driven on to the cylinder and solder should afterwards be applied all round the joint. A thick paper gasket rubbed with oil and graphite will make an air-tight joint when the cylinder and chamber are finally united together.

The Displacer

The displacer can be made from a piece of tube or from sheet metal about 1/32in. thick. The outside diameter should be 1/16in. less than the inside diameter of the chamber. One end is dished like that of the chamber, while the other is about ⅛in. thick and flat. All joints on this part should be brazed or welded and air tight. A hole should be drilled in each end at its centre to take the ¼in. bore exhaust pipe, C.

The Piston

The piston, which is in the form of a tube, can be brass or other anti-friction metal. It should be 4½in. long by 1⅜in. outside diameter and a fairly tight fit in the cylinder. A flange 3/16in. thick, having four equally pitched countersunk holes for the ⅛in. screws that unite it to the displacer, is fitted at one end. It can be brazed or soldered to the piston and afterwards this part should be trued in the lathe and the outside diameter of the flange made equal to that of the displacer.

There is also a disc soldered in the piston tube flush with the flange at this end. It is about ⅛in. thick and is bored at its centre to take that part of the exhaust pipe which is fitted inside the piston. The air-inlet pipe should then be made and fitted; care is necessary to fit them in their correct positions. (See Fig. 1.)

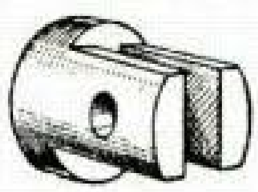


Fig. 2.—Fitting for taking the small end of connecting rod.

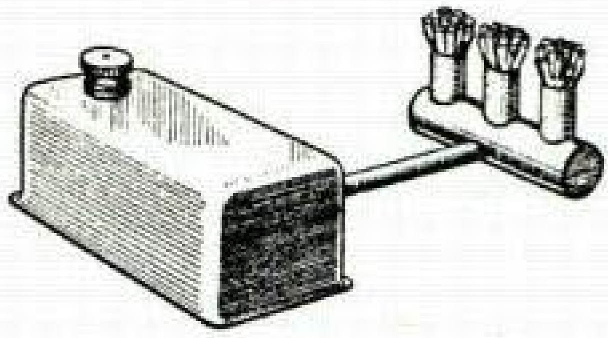


Fig. 4.—The methylated spirit lamp.

A short piece of brass rod (Fig. 2) having a slot to take the small end of the connecting rod has also to be fitted and soldered inside the piston. The hole for the gudgeon pin is then drilled square through the piston tube and the piece of brass, which thus forms the bearing for the gudgeon pin.

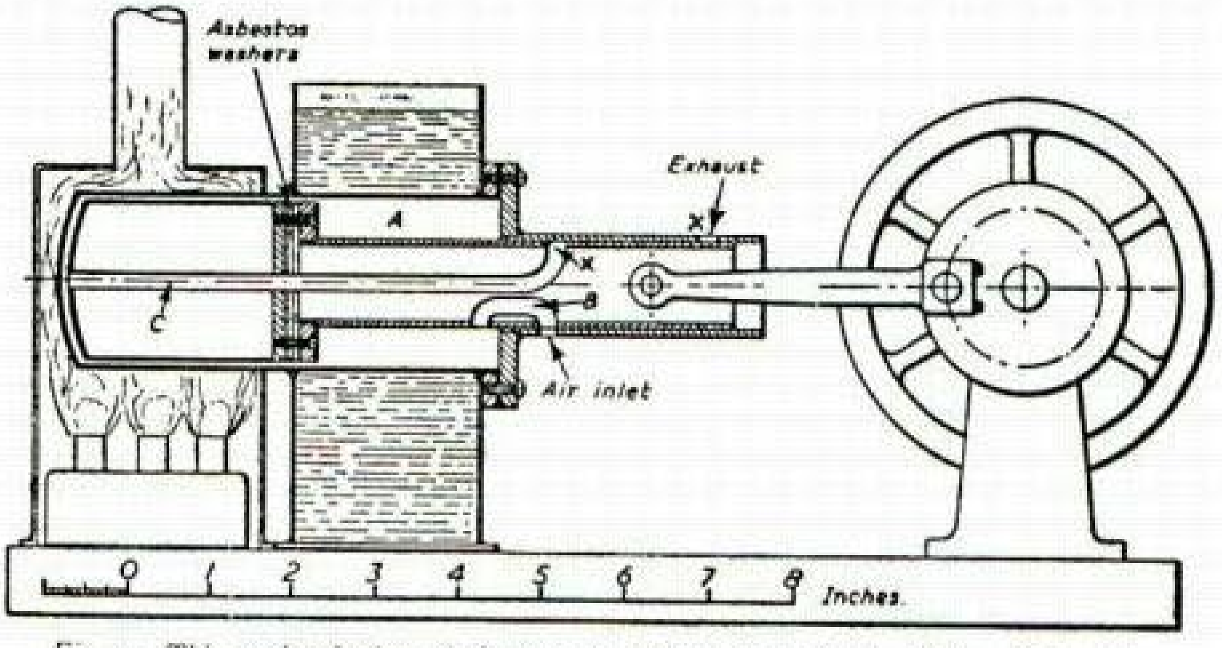


Fig. 1.—This sectional view of the hot-air engine shows the simplicity of the design.

The gudgeon pin is held in position by a short screw passing through the upper side of the top end of the connecting rod and for a short distance into the pin itself. A hole in the piston tube allows the screw to be fitted.

Having got the piston to this stage it should now be made a good sliding fit inside the cylinder by lapping, using metal polish as a grinding medium.

Two or three asbestos washers are fitted between the piston flange and the displacer to prevent, as far as possible, heat getting to the cold end. By varying the number of the above-mentioned washers the length of the displacer can be finally adjusted.

When assembled the piston should move freely the full stroke of the engine, and allowing 1/16in. for clearance; the displacer should not rub on the inside of the displacer chamber.

The exhaust should be on top and the air-inlet port on the underside of the cylinder. The connecting rod does not need to be heavy. A disc or a double-web crank can be used. The crankshaft may be 5/16in. diameter and the flywheel about 5in. diameter.

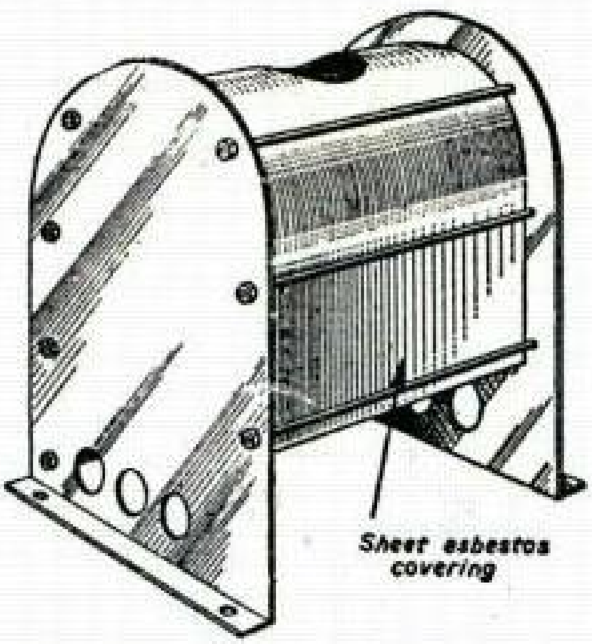


Fig. 3.—Perspective view of the fire-box.

Cooling Water Tank

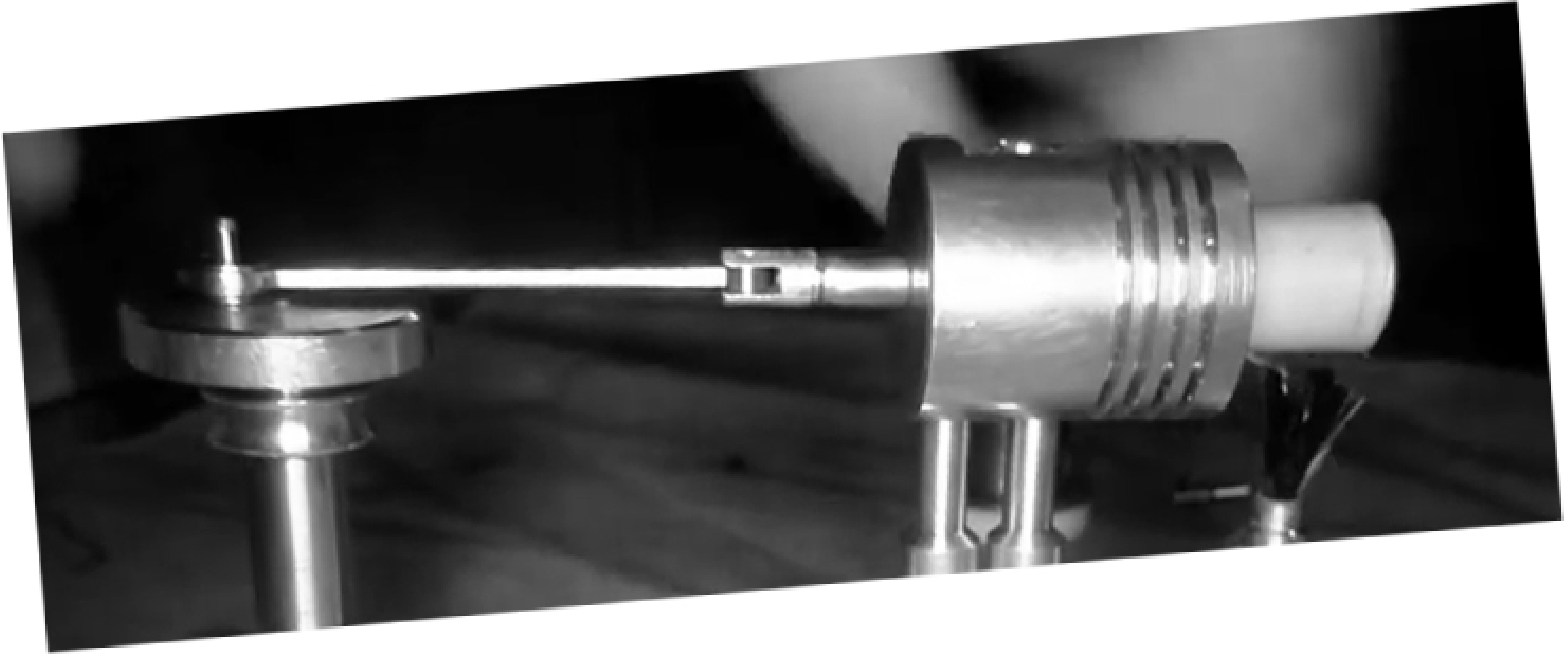
This tank can be constructed of galvanised iron. It will have to be soldered to the displacer chamber, and the bottom, which should be 1/16in. thick, will have to project ½in. at each side to take the holding-down screws, as the thrust and pull of the piston is taken on this part.

The fire-box (Fig. 3) is made of 1/32in. galvanised iron. Long studs pass through the ends and hold the centre part, which carries the funnel, in place. It can be lined inside the ends and the centre part covered with asbestos sheet to conserve the heat.

Three air holes, ½in. diameter, are drilled on each side at the bottom of the ends of the fire-box. A small fire door is fitted at one side to allow the lamp to be removed and to prevent too much cold air entering here.

The lamp for burning methylated spirit is provided with a rectangular reservoir, having a short length of ¼in. tubing soldered at the bottom, on the other end of which is another piece of tubing fitted with three ⅜in. diameter burners (Fig. 4).

The wicks are made of asbestos cord twisted together. The lamp should be placed centrally under the hot end of the displacer chamber. The base-board may be of oak or other hardwood ½in. or ⅝in. thick. It should have two endpieces screwed on to prevent warping, as shown in the photograph of the completed model.




Engine stops when air

The Operation of the Manson Cycle Engine.

The Manson cycle is an open cycle hot-air engine cycle. It has a suction stroke and an expansion stroke. Both strokes produce power which may be coupled to a crankshaft via a con-rod and crank-pin, or the reciprocation motion of the power piston may be used directly to drive a linear alternator if electrical power output is required rather than rotary motion. This paper introduces the Manson cycle starting with a basic engine configuration and then shows ways in which the design may be improved to raise the efficiency and the specific power output.

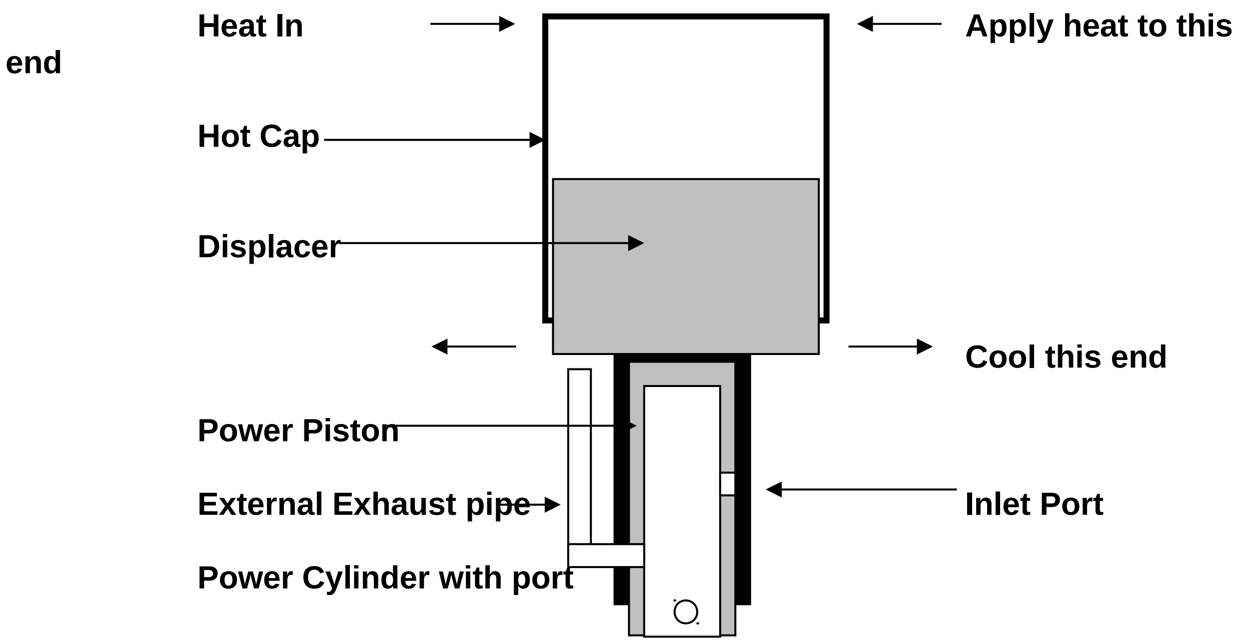


Fig. 1. Simple Manson Engine

Fig. 1. Shows a simple embodiment of the Manson cycle engine. Many other variations are possible.

In this example a power piston with an inlet port aperture cut in the side wall, runs in a power cylinder. A can like displacer is attached to the crown of the power piston and this runs inside an upper cylinder which forms the expansion cylinder. This expansion cylinder is heated in its upper section and cooled at its lower end. It may be assumed that the power piston is connected by a conventional con-rod to a crankshaft and flywheel (not shown).

When the piston is at top dead centre TDC, the port vents the upper chamber via the hollow centre of the piston to the atmosphere.

The piston is shown at bottom dead centre and the skirt of the piston has uncovered a pipe which leads into the upper chamber. Thus the chamber is vented to atmosphere at BDC. At all other times in the cycle the upper chamber is effectively sealed from the atmosphere.

Basic Operation.

Suction Stroke.

In the above example with the piston at BDC all the gas is contained in the hot space and has completed its expansion. The port opens and any internal pressure is vented to the atmosphere. The piston begins to rise under flywheel momentum, closing the port and the displacer transfers the heated gas back to the cold space of the engine. The gas cools and contracts as it loses heat energy and the internal pressure falls below atmospheric causing the piston to be pushed upwards by atmospheric pressure.

Expansion Stroke

When the piston reaches top dead centre, the piston port is uncovered and air rushes in to equalise the internal pressure. This air is chilled as it passes through the cooler section. The piston is carried by the flywheel past TDC and begins to descend closing the port. The chilled air is transferred via the annular gap between the displacer and the hot cap into the hot space. All along the route the air is progressively warming by picking up heat from the hot cap. Its thermal energy rises causing it to expand and increase the internal pressure of the engine. This internal pressure exceeds atmospheric pressure and accelerates the power piston downwards causing more rapid transfer of air from cold space to hot. At BDC the lower piston port opens and releases the expanded air, through the centre of the piston into the crankcase area.

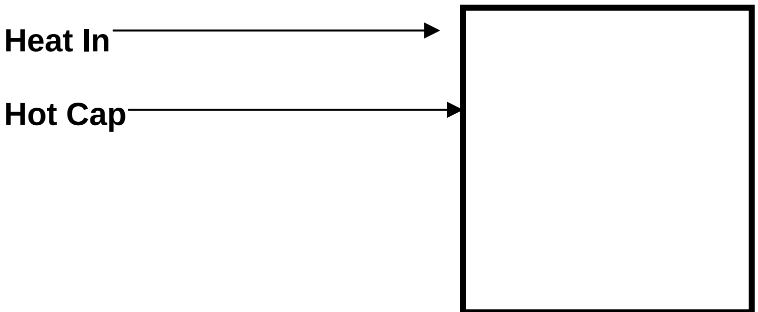
The crankcase should be made of fairly large internal volume - say 10 times the displacement of the engine, so that it can act as a buffer space. Too small a volume will result in excessive crankcase pumping losses. The flip side of this is however is that on a linear reciprocating version of this engine the crankcase volume can be used advantageously to act as a gas spring, and store energy from the downward stroke of the engine, then release it on the upstroke.

Improving the Efficiency.

The efficiency of the Manson cycle engine may be increased by using a working fluid at higher pressure for the expansion stroke, and venting the suction stroke to a lower than atmospheric pressure. This is common practice with steam engines to use a high pressure steam input, and then exhaust to the condenser which is maintained at a partial vacuum. External heat-exchangers may be used to generate these pressures, and they may be made as large as necessary, because they are effectively isolated from the working cylinder of the engine by the piston sleeve valve arrangement.

Improvements to the Basic design.

The Manson engine may be improved by incorporating a transferator instead of the conventional displacer. The advantage of this is the transferator can be made in the form of a lightweight open cup as it does not have to withstand a pressure differential. This also gives the advantage of packing the power piston and cooler *inside* the hollow transferator.



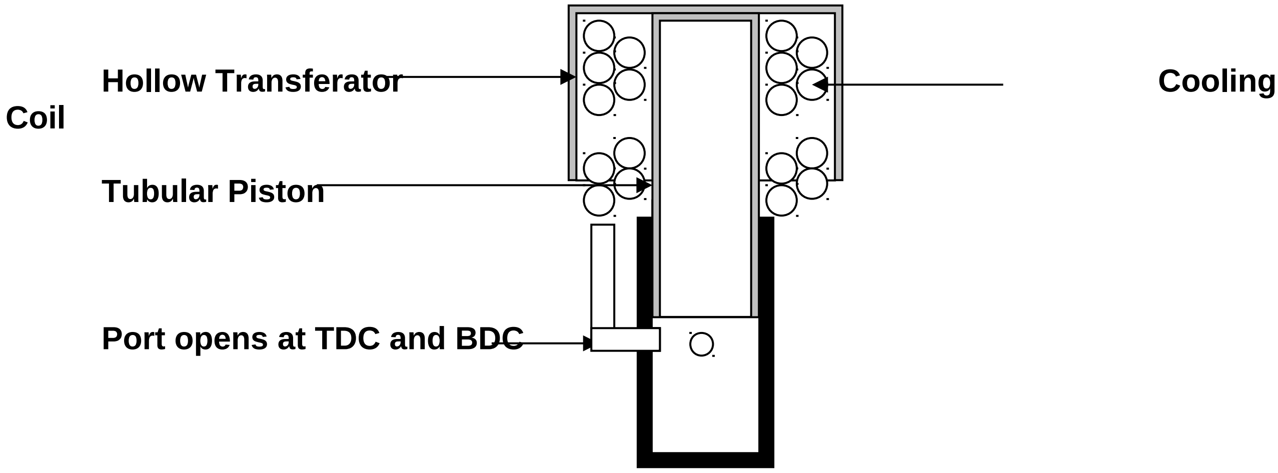


Figure 2 Basic Transferator Configuration.

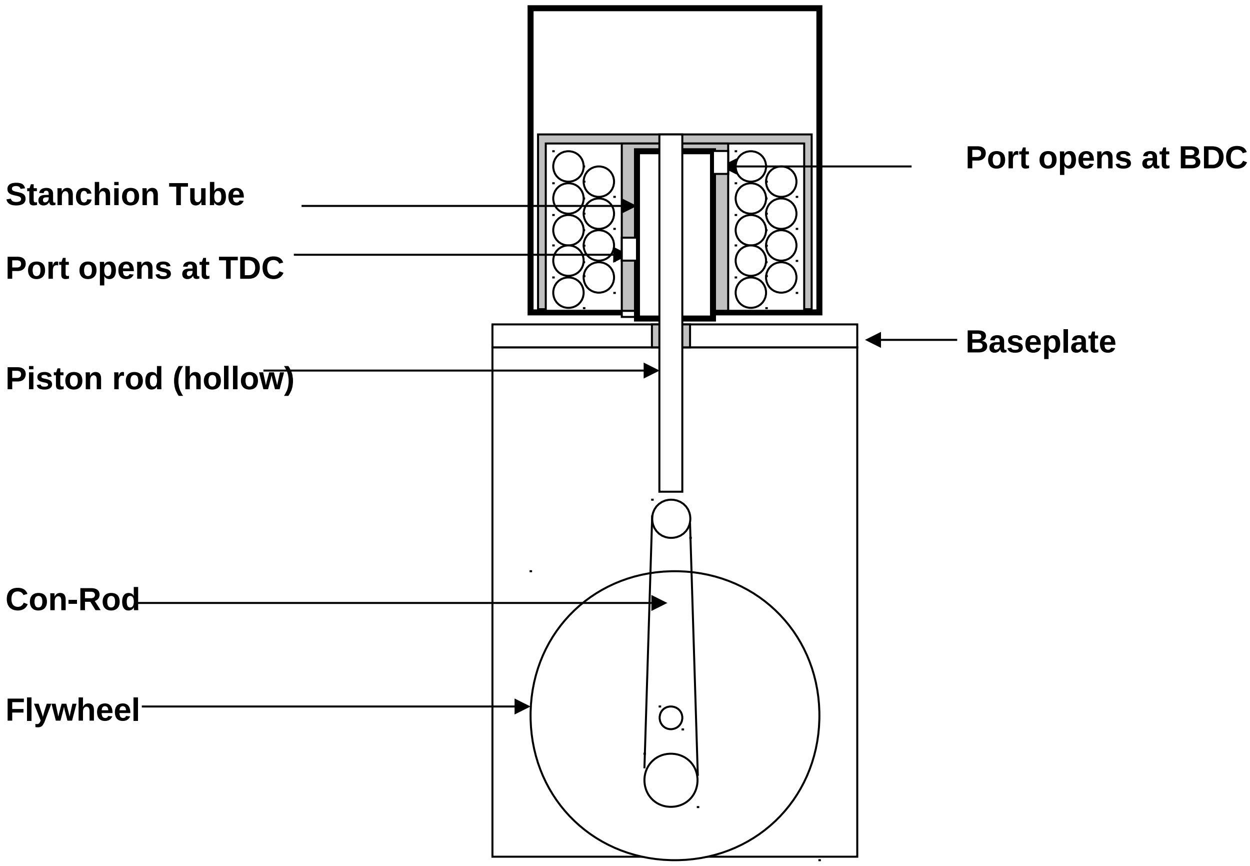


Fig. 3. Transferator Engine design with sleeve type" external piston"

This configuration uses a lightweight aluminium tube to form and external sleeve type piston. This results in low reciprocating mass and as the engine warms up the aluminium expands more than the steel stanchion tube and so will not bind.

The stanchion tube is sealed at the top, but does allow the hollow piston rod to pass through. The stanchion tube is stationary and could be made from a solid bored with the port passages and retain a couple of oilite bushes at either end for guiding the piston rod. A baseplate is shown which holds the lower piston rod bush, and forms a convenient bulkhead between the thermal side of the engine and the mechanical side. The fittings to accept the ends of the water cooling coil can be fitted through this bulkhead.

Work in Progress.

A simple transferator Manson is now in construction based on the design in figure 3. The sleeve piston is aluminium tube nominal 2.5" OD x 2.0" ID. The Stroke is 1.5". The heater cap is a deep drawn stainless steel container 4.25" in diameter, and the transferator is a 4" diameter stainless steel container sourced from a cookware shop.

The crankcase is made from fabricated aluminium extrusions and the flywheel is 6" in diameter keyed onto a 0.5" diameter crankshaft running in twin ball races.

The cooling coil is a double layer coil of 3/16" copper brake tubing wound on a 3" mandrel. The total length of the coil is 16.5'.

The complete engine stands approximately 20" high on an 8" x 8" footprint.

Novel Features.

The Manson engine has only one reciprocating assembly and is thus extremely simple in design.

The Manson-Transferator assembly could be added to the top of an old 2-stroke lawnmower engine so that it can be run on firewood – as an example application.

The cup shaped transferator has no pressure differential across it and can be made lightweight.

Packaging the cooling coil within the transferator shortens the overall height of the engine.

The expansion piston is an external tube of aluminium running on a stanchion tube. As it heats up, it expands at a greater rate than the stanchion tube and therefore will not seize up or bind.

All heat-exchanger components are mounted onto a simple aluminium baseplate. Below this plate the crankshaft components can be conventional or may be replaced with a linear reciprocating drive mounted on springs.

The engine contains very few components of high tolerance and can be constructed using a basic lathe and drilling machine using readily available materials. This makes it suitable for amateur or Developing World construction.

25 YEARS OF TRANSFERATORS

from : John Bourne, Southhampton, U.K.

New or rediscovered types of air engine seem to be in vogue lately, so here is another one you may not have heard of, I call it a transferator.

The original idea first occurred to me over 25 years ago, I have since heard of something similar, that was used in a rather different way in a toy engine of the 1920's. It was an electrical toy, which I find surprising. To get back to the transferator, the term refers in my case to a component that takes the place of a displacer in a beta engine. The layout of the engine has to be changed to accommodate this so we have a unique form of Stirling referred to again as a "transferator". This is the story of how it came about and later developed.

During the 1970's I built a stern-wheel paddleboat about four feet long with a Stirling engine. This boat convinced me that for my models a Stirling engine had advantages over the more usual steam plant. No boiler to make and test, it could not run out of water, had no high pressures to contain. There loomed the prospect of a silent, simple engine capable of long unattended running times.

The first boat engine was not very elegant, being all rods, cylinders and pipes, also it was too large. But, some good runs made at an appropriately sedate speed. If only the size of the engine could be reduced and a more compact layout devised, it would be ideal. I hoped to achieve a large capacity with no need to pressurise. I pondered the problem and was struck by the large amount of unused space within the displacer. Could this space be used somewhere or an alternative to the displacer be found? Eventually I had an idea! Suppose you put two plastic coffee cups together, pull them apart—air rushes in, push them together and you pump the air out again. Now assume that the inside cup is replaced by a power cylinder (and piston) surrounded by a water jacket or other form of cooler. The outer cup is replaced by a metal open ended can (½ a coke or beer can, say) that just fits over the cylinder and cooler, put the lot inside a hot cylinder like any other beta engine and the outer can becomes a "transferator"

A combined transfer piston and regenerator, that will do the job of a displacer. This very compact concentric arrangement was the thing I was after. But, it is one thing thinking up something and another to make it work, a trial engine was built. Rather to my surprise the thing was determined to go! It revved up and vibrated about all over the bench, until the cooler ruptured, filling the engine with water. No matter, it ran and I was feeling pretty pleased about it. An article describing it was published in Model Engineer 6th to 19th May 1977.

After many design changes, tests and experiments I decided that a more elegant engine of the original simple design was the best. A single cylinder engine with a scotch crank to drive the transferator and twin piston rods arranged one either side for the power piston, was put together and a 36 inch model tug built for it to drive. Cooling was by ram effect and thermo-syphon, pond water being circulated from pipes facing forward (inlet) and aft (outlet). The boat, also was described in Model Engineer as a Stirling tug, 21st and 31st March 1980.

Many trouble free runs of up to two hours duration were made in all sorts of weather and I must admit some less than successful runs as well. The cooling system was my boats Achilles heel, mud and weed blocked it, filters were added, coolers split (they were soft solder in 15 thou brass) filters blocked in a short time. The hot cylinder made from a tin can was never up to the job and would only tolerate being red for a few runs before replacement became due but at the time I could find nothing better. All these problems have now been overcome and a reliable engine with a good low speed torque is the result.

After the tug I made a German “E” boat, a long narrow boat with a displacement (or round bilge), hull 49 inches long with twin engines, similar to the tug’s but even more compact. It went really well, a speed of 3 to 4 mph (a good walking pace) for 2 hours on a can of ‘camping gaz’ but with the same drawbacks as the tug engine—so near and yet so far! Now we had twin engines going wrong instead of one!

Much thought and experimentation eventually enabled the tug to be made very satisfactory, even the radio control seems now to be trustworthy. Some of the solutions to my problems will seem obvious. Yes hindsight is a wonderful thing! I see it all now. Instead of soldering 15 thou brass together to make a cooler, I wind as much as 3/16 o.d copper tubing as possible around the cylinder and pump the water around this with a very small electric pump running on 4 rechargeable A.A cells—it goes for hours and there is now no fragile water jacket to worry about. After passing through the cooler the water goes along a piece of the same tubing alongside the boats keel (outside the hull). Only about 2 feet of tubing in the water will adequately cool the engine. The via the header tank, the water returns to the pump, a simple closed circuit and no more pond water blocking the pipes. this is even more important if running on sea water as I often do, as this no longer runs through the engine.. The engine in its present form uses less gas than before the new type of cooler devised, it is much more efficient than an equivalent steam plant.

Many types of transferator have been made and it appears that a simple ‘can’ of aluminium such as the lower 2½ inches or so of a coke or beer can is as good as anything and very light. The old idea of using a tin can (baked beans) as a hot cylinder has been superseded by stainless steel sugar shaker, I think this last forever.

Now we all know how a transferator engine is put together, would you care to reflect on why they seem to work so well? I think it is largely to do with the effect of the transferator causing very turbulent air flow over the cooler and the hot surfaces within the engine. As the air flows from hot to cold it must perform a 180° turn around the skirt of the transferator, as it goes over and between the coil of copper tubing it will be very effectively cooled. When the air returns from cold to hot it is again swirling over the all the hot surfaces with less static boundary layer air to prevent the heat transfer than in more lamina flow conditions that obtain in a displacer engine. Quite large clearances between the transferator and the hot cylinder walls seem to have no ill effects. The is a large surface area to act as a regenerator on the transferator, bear in mind that the air travels over the inner surface not just the outer (as in the case of a displacer). Aluminium will give good transfer. A transferator can be made much lighter than a displacer as it has no pressure differences to resist. In fact the 5/32 dia steel rod used to drive my transferator when weighed was far heavier than the 2½ inches of aluminium can! Tubing will save weight, in this case I have only been able to get 5/32 inch diameter tubing so for the moment will give it a try as it is about half the weight of steel rod, low weight of reciprocating parts is important. As a guide to size, my engines have power cylinder bore if around 1·125 inches with a stroke for both power piston and transferator of 2 inches. The overall size of the engine can be around 10 inches by 3 inches by 3 inches, excluding the gas container.

The actual design of engine finally arrived at is: horizontal cylinder, overhung crank, flywheel running horizontally (like a record player) 90 degree geared drive to prop shaft, with propeller running 2½ times engine speed.

The cooler can be improved with a second layer of tubing wound back over the first. This will fill the dead space seen at the top of the diagram. No doubt another slight performance improvements would result. I should point out that this sort of internal cooler encircling the cold power cylinder causes less heat conduction from the hot end of the hot-cylinder. Conventional engines having a cooler encircling the cold end of the displacer cylinder suffer considerable loss of efficiency from this cause.

The next requirement is obviously some from of speed control and reverse. This will probably have to come from the transmission rather than the engine itself. I have no doubt that the engine in its present form is far from fully developed, but it is practical, compact and simple, and I think you will agree it is different.