A

PROJECT REPORT

ON

"FABRICATION OF STIRLING ENGINE"

Submitted to

CHHATTISGARH SWAMI VIVEKANAND TECHNICAL UNIVERSITY

BHILAI

In partial fulfillment of requirement for the award of degree

Of

BACHELOR OF ENGINEERING

in

MECHANICAL ENGINEERING

By

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DEPARTMENT OF MECHANICAL ENGINEERING

BHILAI INSTITUTE OF TECHNOLOGY

BHILAI HOUSE, DURG, 491001

SESSION:2014-2015

D E C L A R A T I O N

We undersigned solemnly declare that the report of the project work entitled “FABRICATION OF STIRLING ENGINE”, is based on my work carried during our study under the supervision of Ms. S. N. SIDDIQUE (FACULTY OF MECH. ENGG. DEPT.)

I assert that the statement made, and conclusions drawn are an outcome of the project work. I further declare that to the best of my knowledge and belief that the report does not contain any part of any work which has submitted for the award of any other degree/diploma certificate in this University.

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C E R T I F I C A T E

This is to certify that the report of the project submitted is an outcome of the project work entitled “FABRICATION OF STIRLING ENGINE” carried out by

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Carried out under my guidance and supervision for the award of degree in Bachelor of Engineering in Mechanical Engineering of Chhattisgarh Swami Vivekanand Technical University, Bhilai (C.G.), India.

To the best of my knowledge the report

i) Embodies the wok of the candidate him/herself,
ii) Has duly been completed,
iii) Fulfils the requirement of ordinance relating to the BE degree of the University. and is up to the desired standard for the purpose of which is submitted.

Ms. S. N. SIDDIQUE
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The project work as mentioned above is hereby being recommended and forwarded for examination and evaluation.

(Signature of Head of the department with seal)

CERTIFICATE BY THE EXAMINERS

This is to certify that the project work entitled

"FABRICATION OF STIRLING ENGINE"

Submitted by

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It has been examined by the undersigned as a part of the examination for the award of bachelor of engineering degree in Mechanical Engineering of C.S.V.T.U. Bhilai.

Internal Examiner   External Examiner

Date: Date:

ACKNOWLEDGEMENT

I have taken efforts in this project. However, it would not have been possible without the kind support and help of many individuals. I would like to extend my sincere thanks to them.

I would like to thank our principle Dr. Arun Arora for never ending support and helping nature towards the students.

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I would like to thank our project guide Ms. S. N. Siddique (Associate Prof., Mech. Engg. Dept.) for his guidance and help to accomplish our objective. This list is never ending, so we give thanks to all the persons who have directly or indirectly helped us to achieve success for our future endeavor. Finally, we would like to thank our parents for their moral enlistment of cooperation.

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ABSTRACT

The aim of this project was to get a detailed study and understanding of the Stirling Engine based on the Stirling Cycle. Several theories and designs were studied and analyzed. The design proposed by Robert Stirling was studied and found out to be one of the most efficient design till date. Problems and difficulties faced in running the prevailing Stirling engines were also studied. Group discussion was carried out among the group members to carry out a detailed discussion about the engine. Different scopes of the engine were discussed, and future fields of applications were considered.

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Chapter-1

INTRODUCTION

1.1 Stirling engine

A Stirling engine is a heat engine operating by cyclic compression and expansion of air at different temperature levels such that there is a net conversion of heat energy to mechanical work.

Like the steam engine, the Stirling engine is traditionally classified as an external combustion engine, as all heat transfers to and from the working fluid take place through the engine wall. This contrasts with an internal combustion engine where heat input is by combustion of a fuel within the body of the working fluid. Unlike a steam engine's (or more generally a Rankine cycle engine's) usage of a working fluid in both of its liquid and gaseous phases, the Stirling engine encloses a fixed quantity of air.

As is the case with other heat engines, the general cycle consists of compressing cool gas, heating the gas, expanding the hot gas, and finally cooling the gas before repeating the cycle. The efficiency of the process is narrowly restricted by the efficiency of the Carnot cycle, which depends on the temperature between the hot and cold reservoir.

The Stirling engine is exceptional for of its high efficiency compared to steam engines, quiet in operation and the ease with which it can use almost any heat source. This is especially significant as the prices of conventional fuel prices rise in a more "green cautious" world.

1.2 Competition from Internal combustion

The invention of the internal combustion engine in the 1900's put the nail on the coffin for the Stirling type of engine because it generated more power and proved to be more practical in the automobile industry.

Due to the rigorous solar energy exploration taking place in the developed economies, this old technology is being given a newer and fresher approach.

In the Indian scenario, the Stirling engine hopes to offer energy to rural and marginalized areas where the most common sources of energy include:

- Biomass fuel –from burning of charcoal, firewood, rice husks, coal, maize cobs among others
- Biogas- which has become of great use in the rural areas for both cooking and lighting
- Solar heating- which has made its debut in the rural areas as an alternative means of cooking energy through use of solar concentrators.

1.3 A brief History of the Stirling engine

1.3.1 Reverend Robert Stirling

On September 27, 1816, Church of Scotland minister Robert Stirling applied for a patent for his economizer in Edinburgh, Scotland. The device was in the form of an inverted heat engine, and incorporated the characteristic phase shift between the displacer and piston that we see in all Stirling Engines today. [1]

The engine also featured the cyclic heating and cooling of the internal gas by means of an external heat source, but the device was not yet known as a Stirling Engine. That name was coined nearly one hundred years later by Dutch engineer Rolf Meijer to describe all types of closed cycle regenerative gas engines.

Stirling originally regarded his engine as a perpetual motion machine of the second kind (i.e. all heat supplied would be converted into work even though his original hot air engine did not include a cooling system.

Due to the invention of the more powerful internal combustion engine at the middle of the 19th century, the Stirling technology was abandoned. But even so, the Stirling engine had an extra advantage over the steam engine due to its low operating cost. Also, the steam engine was prone to major failures like explosions. The only major problem with the Stirling engine was its tendency to fail when the cylinder being heated became too hot.
Although improvements were made to curb up the problem, stiff competition from the internal combustion engine forced the hot air engine out of the commercial scene.

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[1]*http://www.kontax.co.uk/docs/history*

Over the years, researchers have continued on Stirling engines, working out many of the design solutions that are used today in low temperature differential Stirling engines.

1.3.2 Designing a Stirling Engine

In the country's Vision 2030, the government committed itself to provide affordable universal electricity to its citizens.[2]To achieve this goal, the academia and investors should work closely and come up with a sustainable solution. To this end, for our final year project, we took the challenge upon ourselves to design and fabricate a small subsistent power generator.

This project aims to provide affordable electricity to the people in the marginalized parts of our country. Places in focus include central India, and the remote northeast. These marginalized parts of the country present the biggest challenge to supply affordable power. Compounding the complexity of this challenge, these places do not have economic significance for the national power distribution company, NTPC to invest in power transmission lines.

With this conspicuous power vacuum in sight, we set out to design an alternative source of power. To achieve this, we intended to use the locally available sources of energy, such as charcoal, firewood and biomass fuel, to generate subsistence power for domestic consumption. Thus, we sought to find a transducer that could convert the low calorific sources of energy available, while having economic sense at the back of our minds.

The Stirling engine was the perfect solution.

Our idea was to model a special Stirling engine that could generate power from both an open fire, such as a firewood stove, and have the potential to generate power on a sunny day using a solar concentrator. This ingenious idea would take advantage of both the available energy while taking a "green" turn and utilizing solar heat to supplement the power generated. Thus, the HYBRID CONCEPT.

In addition to taking advantage of the local energy sources, the simplicity in fabrication of a Stirling engine meant that the overall cost of a unit would be within reach for many.

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[2]*Kenya Vision 2030, Harnessing strategic natural resources: "The potential for Kenya to develop bio-resources for medicinal, industrial and other products is recognized*"

In the preliminary design, we hoped to achieve about 300rpm from the engine arrangement, and a potential of about 100watts. This in our view would be enough power to light a couple of energy saving bulbs, while at the same time powering a small FM tuner, and charging a mobile phone for the family.

This subsistence and sustainable source of power would have far reaching benefits to the marginalized communities. For instance, with this power source, a local green grocer would have electricity to extend trading hours, while children would have light to extend study hours.

All these benefits would have positive compounding benefits to India and aid the government in attaining the ambitious Vision 2030.

1.3.3 Scope of design

The hybrid Stirling engine we designed and fabricated was in two pieces: a normal Stirling engine that could be heated externally using an open flame and a detachable solar concentrator that could be placed in front of the Stirling engine to take advantage of solar heat.

A gamma configuration of the engine was chosen, whose working shall be explained further in this report.

The solar concentrating unit consisted of a solar reflector, like the ones being used in solar cookers in the most rural areas. Its design was simple and with the right focal length in the curved mirror, the heating of the displacer head would be most efficient.

The aim of choosing this design was to make the manufacturing cost of this engine low and keep it simple. The design and fabrication of the engine are also documented in this report.

1.3.4 Stirling Engine's place in a 'renewable energy' world

Countries such as India have made investments in simple renewable energy solutions that have been able to make rural electrification possible to the poor. Companies such as Husk power systems[3] in India, generate electricity by burning rice husks in CNG[4] engines to produce electricity.

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[3]http://www.huskpowersystems.com
[4] CNG Engine- Compressed Natural Gas Engine

In the US, use of Stirling engines as a source of renewable energy is being explored. Companies such as Stirling Engine Systems plan to invest in large solar Stirling engines that generate power more than 500MW.

By 2030, the Indian government hopes get all Indians to be dependent on clean and efficient renewable sources of energy.

We view that the Stirling engine would also be an idea worth looking into. By investing into the research of this technology, with time, better and more compact & affordable models can be built for commercialized purposes and thus the goal of achieving close to 100% rural electrification will not seem like a pipe dream.

Thus, early investment in this technology by the government would be a boost for the country’s Energy Grid in future.

Chapter-2

LITERATURE REVIEW

2.1 "Design Analysis methods for stirling engines", paper presentation by H Snyman, T M Harms and J H Strauss:

Worldwide attempts are being made to increase the use of our renewable energy sources as well as to use our current fossil fuel energy sources more efficiently. Waste heat recovery forms a substantial part of the latter and is the focus of this project. Stirling technology finds application in both the renewable energy sector and in waste heat recovery.

Investigating the applicability of Stirling engines in the above-mentioned fields is relevant to develop more efficient external combustion units as well as to utilize our renewable energy sources. Developing a design analysis and synthesis tool capable of optimizing Stirling powered units forms the main objective of this project. The methodology followed to achieve this, involved the application of three different methods of analysis, namely the method of Schmidt, the adiabatic analysis and the simple analysis based on a five-volume approach. The Schmidt analysis is used to obtain the internal engine pressure which is a required input for the adiabatic analysis while the simple analysis introduces pumping losses and regenerator inefficiencies.

Stirling engines are combusted externally, and modern versions of this engine have a closed internal gas cycle. The 'hot-air' engine, first so referred to by the Rev. Robert Stirling, was renamed after its inventor in the early parts of the twentieth century, since it was found that gasses with lighter molecular weight such as helium and hydrogen were superior to air, and the title Stirling engine was therefore considered to be a more appropriate description than 'hot-air'.

In a beta configuration like the engine used in this study, two pistons are present, namely the displacer and the power piston as shown in Figure. Although not shown in Figure, these two pistons are driven by a drive mechanism. Two variable volumes, namely the expansion and compression spaces and three fixes volumes, namely the hot side heat exchanger (Heater), the cold side heat exchanger (Cooler) and the regenerator constitutes the rest of the engine.

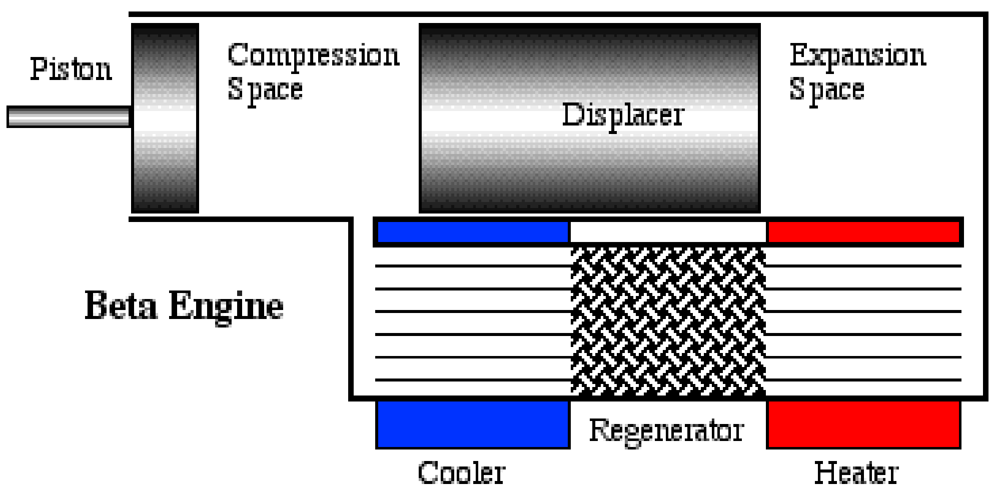


Figure 2.1: Simplified image of a Beta type Stirling

2.2. R Stirling, Improvements for diminishing the consumption of fuel and in particular, an engine capable of being applied to the moving of machinery on a principle entirely new. British Patent 5456 (1817)

From this paper we studied how to reduce the consumption of fuel. Some key points being:

i. The oil in the power cylinder seemed to dry off at a faster rate than we could anticipate. We realized that this was due to a design flaw in that we hadn't included a means on oiling the chamber when necessary. It was therefore noted that an oil nipple should be introduced on the power cylinder so as to make lubrication of the chamber easier when needed.

ii. There was a lot of “out of balance” movement from the fly wheel which might have caused a lot of vibrations if the engine were running. It is therefore necessary to carry out a kinematic assessment to be able to do a mass balance on the flywheel.

iii. To tap generated power from the engine we propose the attachment of a dynamo to the flywheel and a battery to store the energy realized.

2.3 “Using supercritical heat recovery process in Stirling Engines for high thermal efficiency”, paper presentation by ZhaolinGu, Haruki Sato & Xiao Feng:

Stirling engine, using a composite working fluid, such as two-component fluid; gaseous carrier and phase change components and single multi-phase fluid as the working fluid is studied to get high thermal efficiency. In Stirling engine with a composite fluid, a thermodynamic supercritical heat recovery and heating process is proposed and demonstrated to improve the heat transfer of the heat regenerator and cooler of common gaseous stirling engine.

Considering constant supercritical pressure, the specific volume of the liquid, illustrated by Fig, will expand with the increase of temperature. The continuous phase change from liquid to vapour with no evaporation at point *l* takes place if temperature of liquid rises to the temperature of point *l* when heated. The vapour will then reach the superheated state when its temperature is raised higher than the temperature at point *l*.

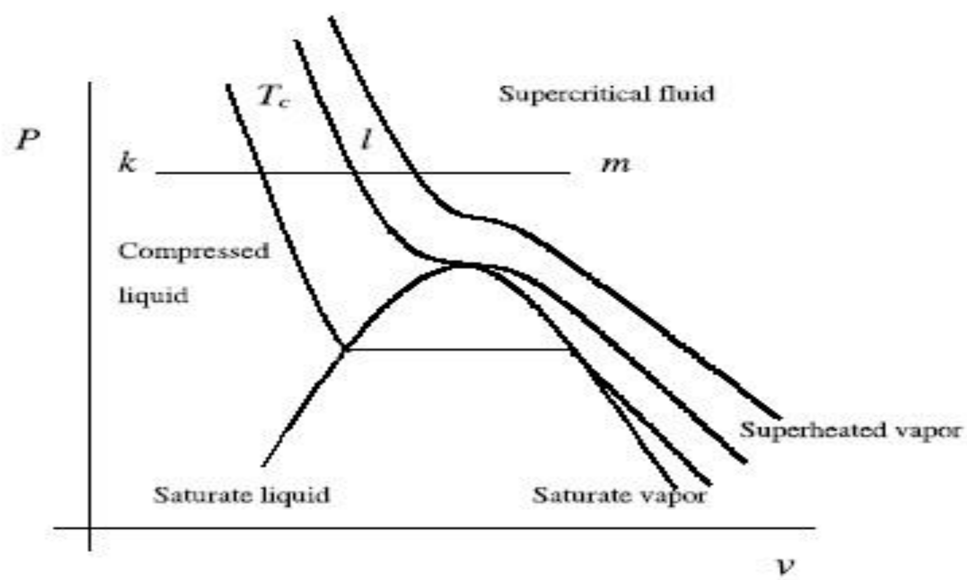


Figure 2.2: Heating of supercritical fluid

Chapter-3

PROBLEM IDENTIFICATION

3.1 General Problems faced in using Stirling Engine

Before seeing the current and past applications, before studying the future possible applications, it seems necessary to list the disadvantages of the Stirling engine.

3.1.1 The Price:

Its cost is probably the most important problem, it is not yet competitive with other means well established. A generalization of its employment should solve this problem inherent in any novelty.

3.1.2 Unawareness:

The ignorance of this type of engine by the general public. Only a few fans know it exists. It is therefore necessary to promote it.

3.1.3 Lack of Standardization:

The variety of models prevents standardization and, consequently, lower prices.

3.1.4 Sealing:

The problems of sealing are difficult to solve as soon as one wishes to have high pressures of operation. The choice of “ideal” gas would be hydrogen for its lightness and its capacity to absorb the calories, but its ability to diffuse through materials is a great disadvantage.

3.1.5 Paraphernalia:

Heat transfers with a gas are delicate and often require bulky apparatuses.

3.1.6 The Lack of Flexibility:

The fast and effective variations of power are difficult to obtain with a Stirling engine.

This one is more qualified to run with a constant nominal output. This point is a great handicap for an utilization in car industry.

3.1.7 Size and cost issues

Stirling engine designs require heat exchangers for heat input and for heat output, and these must contain the pressure of the working fluid, where the pressure is proportional to the engine power output. In addition, the expansion-side heat exchanger is often at very high temperature, so the materials must resist the corrosive effects of the heat source, and have low creep. Typically, these material requirements substantially increase the cost of the engine. The materials and assembly costs for a high temperature heat exchanger typically accounts for 40% of the total engine cost.

3.1.8 Power and torque issues

Stirling engines, especially those that run on small temperature differentials, are quite large for the amount of power that they produce (i.e., they have low specific power). This is primarily due to the heat transfer coefficient of gaseous convection, which limits the heat flux that can be attained in a typical cold heat exchanger to about 500 W/(m^2·K), and in a hot heat exchanger to about 500–5000 W/(m^2·K).[56] Compared with internal combustion engines, this makes it more challenging for the engine designer to transfer heat into and out of the working gas. Because of the thermal efficiency the required heat transfer grows with lower temperature difference, and the heat exchanger surface (and cost) for 1 kW output grows with second power of 1/deltaT. Therefore, the specific cost of very low temperature difference engines is very high. Increasing the temperature differential and/or pressure allows Stirling engines to produce more power, assuming the heat exchangers are designed for the increased heat load and can deliver the convected heat flux necessary.

Chapter-4

METHODOLOGY

4.1 Introduction

The Stirling engine has over the years evolved. The most common configurations include the Alpha, Beta and Gamma. These vary in the arrangement of the different parts including the displacer, piston and flywheel.

The Stirling engine operates on the Stirling cycle that has a theoretical efficiency close to the Carnot efficiency. In the theory developed later, it is noted that addition of a regenerator in the configuration improves the overall performance and increases the output power of the system.

4.1.1 Basic Components

A Stirling engine consists of a number of basic components, which may vary in design depending on the type and configuration. The most basic are outlined as follows:

- Power Piston and Cylinder

This consists of a piston head and connecting rod that slides in an air tight cylinder. The power piston is responsible for transmission of power from the working gas to the flywheel. In addition, the power piston compresses the working fluid on its return stroke, before the heating cycle. Due to the perfect air tight requirement, it is the most critical part in design and fabrication.

- Displacer Piston and Cylinder

The displacer is a special purpose piston, used to move the working gas back and forth between the hot and cold heat exchangers. Depending on the type of engine design, the displacer may or may not be sealed to the cylinder, i.e. it is a loose fit within the cylinder and allows the working gas to pass around it as it moves to occupy the part of the cylinder beyond.

- Source of Heat

The source of heat may be provided by the combustion of fuel, and since combustion products do not mix with the working fluid, the Stirling engine can run on an assortment of fuels. In addition, other sources such as solar dishes, geothermal energy, and waste heat may be used. Solar powered Stirling engines are becoming increasingly popular as they are a very environmentally friendly option for power production.

- Flywheel

The flywheel is connected to the output power of the power piston, and is used to store energy, and provide momentum for smooth running of the engine. It is made of heavy material such as steel, for optimum energy storage.

- Regenerator

It is an internal heat exchanger and temporary heat store placed between the hot and cold spaces such that the working fluid passes through it first in one direction then in the other. Its function within the system is to retain heat which would otherwise be exchanged with the environment. It thus enables the thermal efficiency of the cycle to approach the limiting Carnot efficiency.

On the flip side, the presence of regenerator (usually a matrix of fine steel wool), increases the “dead space” (unswept volume). This leads to power loss and reduces efficiency gains from the regeneration.

- Heat Sink

The heat sink is typically the environment at ambient temperature. For small heat engines, finned heat exchangers in the ambient air suffice as a heat sink. In the case of medium to high power engines, a radiator may be required to transfer heat from the engine.

4.1.2 Operation and Configuration

Since the Stirling engine is a closed cycle, it contains a fixed mass of gas called the "working fluid", most commonly air, hydrogen or helium. In normal operation, the engine is sealed and no gas enters or leaves the engine. No valves are required, unlike other types of piston engines. The Stirling engine, like most heat engines, cycles through four main processes: cooling, compression, heating and expansion. This is accomplished by moving the gas back and forth between hot and cold heat exchangers, often with a regenerator between the heater and cooler. The hot heat exchanger is in thermal contact with an external heat source, such as a fuel burner, and the cold heat exchanger being in thermal contact with an external heat sink, such as air fins. A change in gas temperature will cause a corresponding change in gas pressure, while the motion of the piston causes the gas to be alternately expanded and compressed.

When the gas is heated, because it is in a sealed chamber, the pressure rises, and this then acts on the power piston to produce a power stroke. When the gas is cooled the pressure drops and this means that less work needs to be done by the piston to compress the gas on the return stroke, thus yielding a net power output.

In summary, the Stirling engine uses the temperature difference between its hot end and cold end to establish a cycle of a fixed mass of gas, heated and expanded, and cooled and compressed, thus converting thermal energy into mechanical energy. The greater the temperature differences between the hot and cold sources, the greater the thermal efficiency. The maximum theoretical efficiency is equivalent to the Carnot cycle; however, the efficiency of real engines is less than this value due to friction and other losses.

The specific operation of Stirling engines differs from one configuration type to another. These are distinguished by the way they move air between the hot and cold sides of the cylinder. There are three most common basic configurations:

- **Gamma type:** This design also uses a mechanical displacer to push the working gas between the hot and cold sides of the cylinder, but the displacer is housed in a separate cylinder for easier mechanical fabrication.

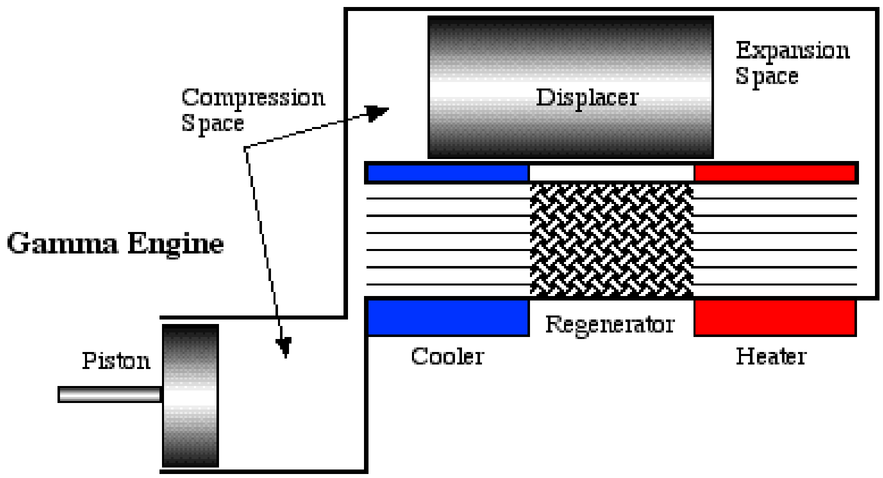


Figure 4.1: Simplified version of a Gamma type

- **Alpha type:** This design has independent cylinders and a gas driven between the hot and cold spaces.

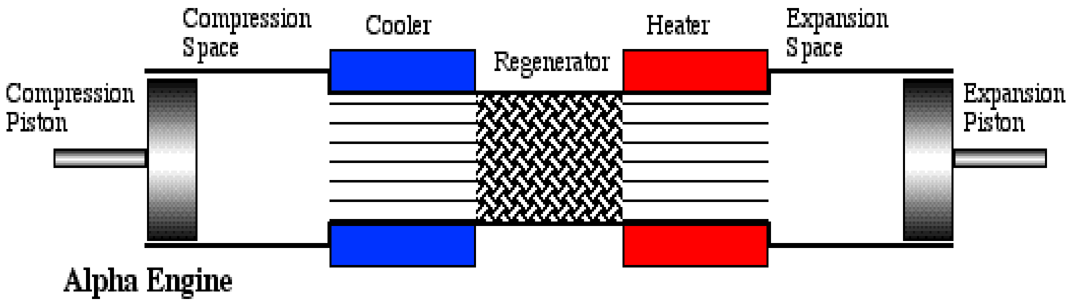


Figure 4.2: Simplified version of an Alpha type Stirling engine

- **Beta type:** This design uses an insulated mechanical displacer to push the working gas between the hot and cold sides of the cylinder. The displacer piston runs though the power piston, for less "dead space".

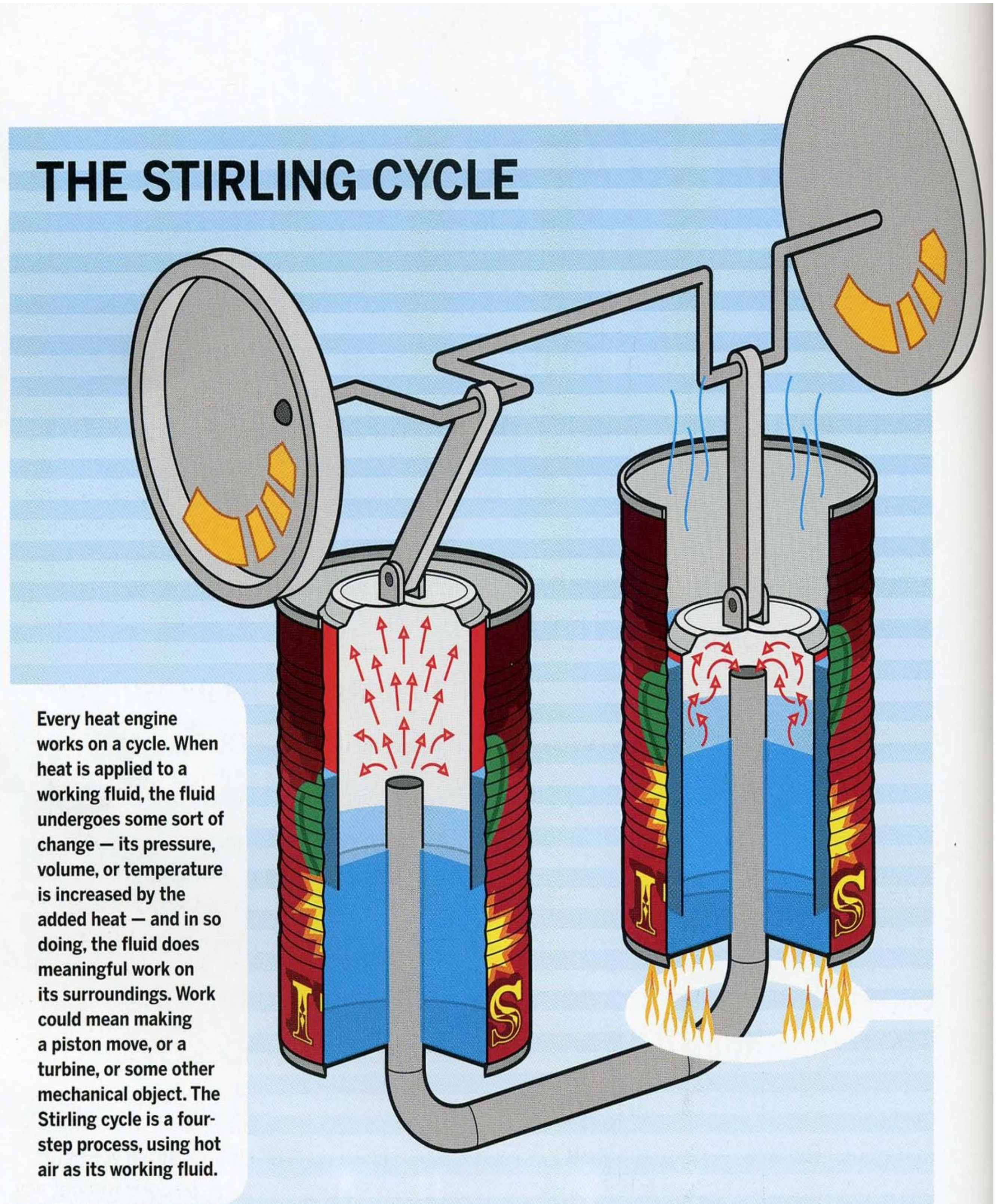
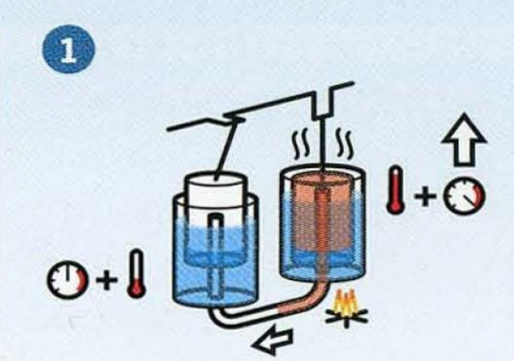
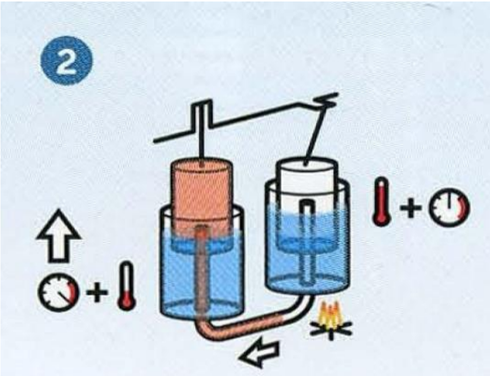


Figure 4.3: Animated model of Stirling Engine

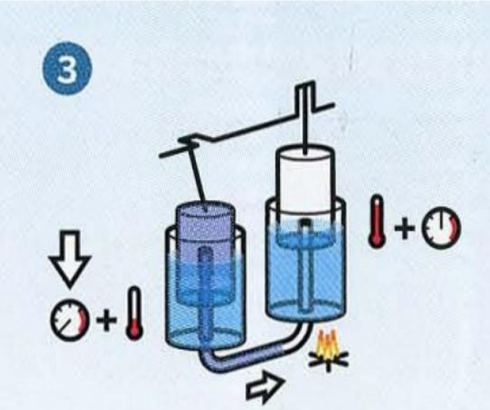
FOUR STEPS OF STIRLING ENGINE



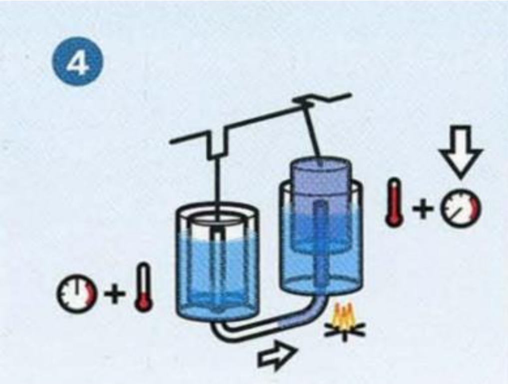
COOLING
Cold piston (left) moves upward by flywheel inertia, drawing hot air over to cold side.



EXPANSION
Hot air is forced to the left cylinder, forcing the cold piston up. This is the power cycle.



COMPRESSION
As air in the cold water contracts, the cold piston moves down.



HEATING
With the cold piston fully down, most air is on hot side and getting reheated.

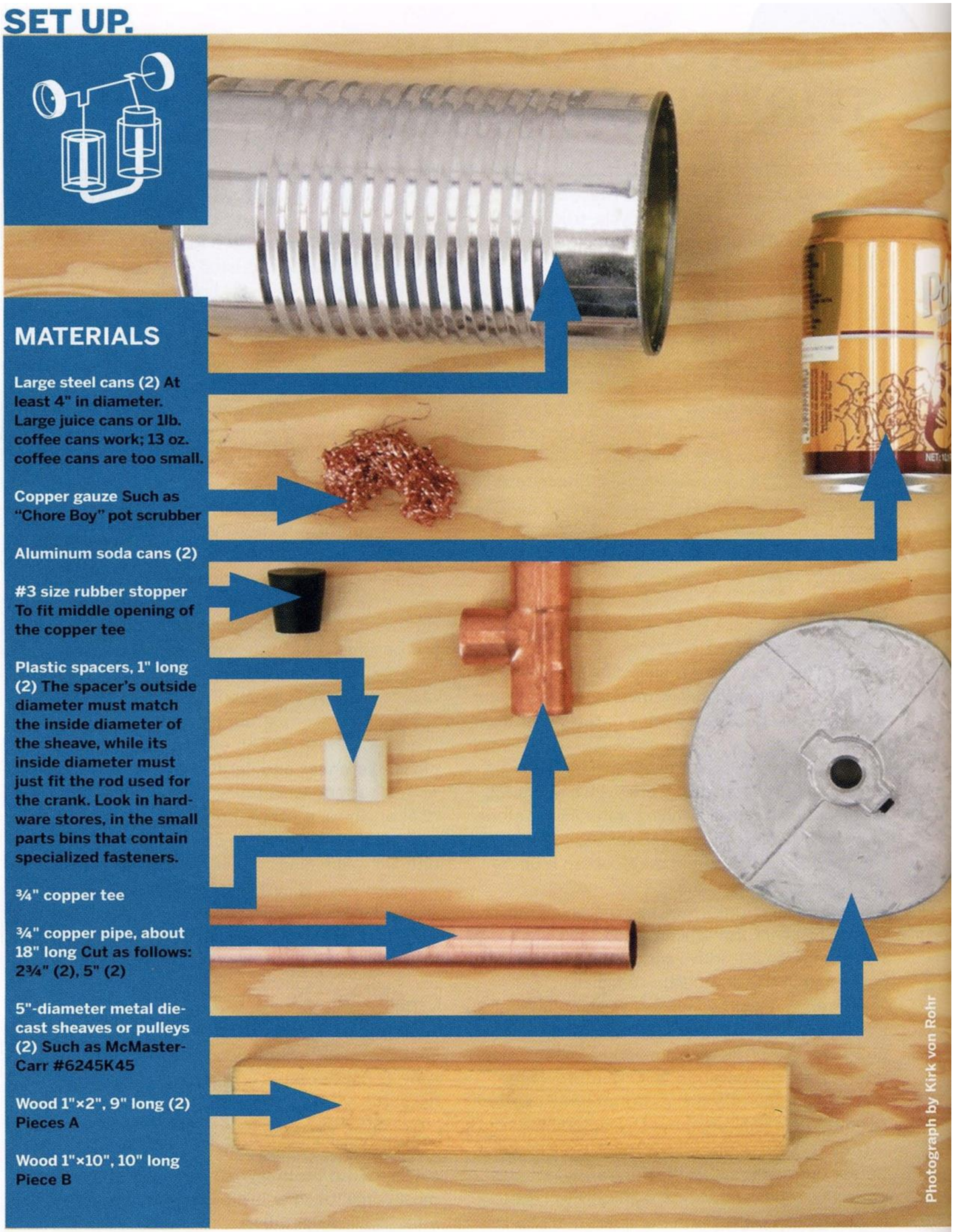
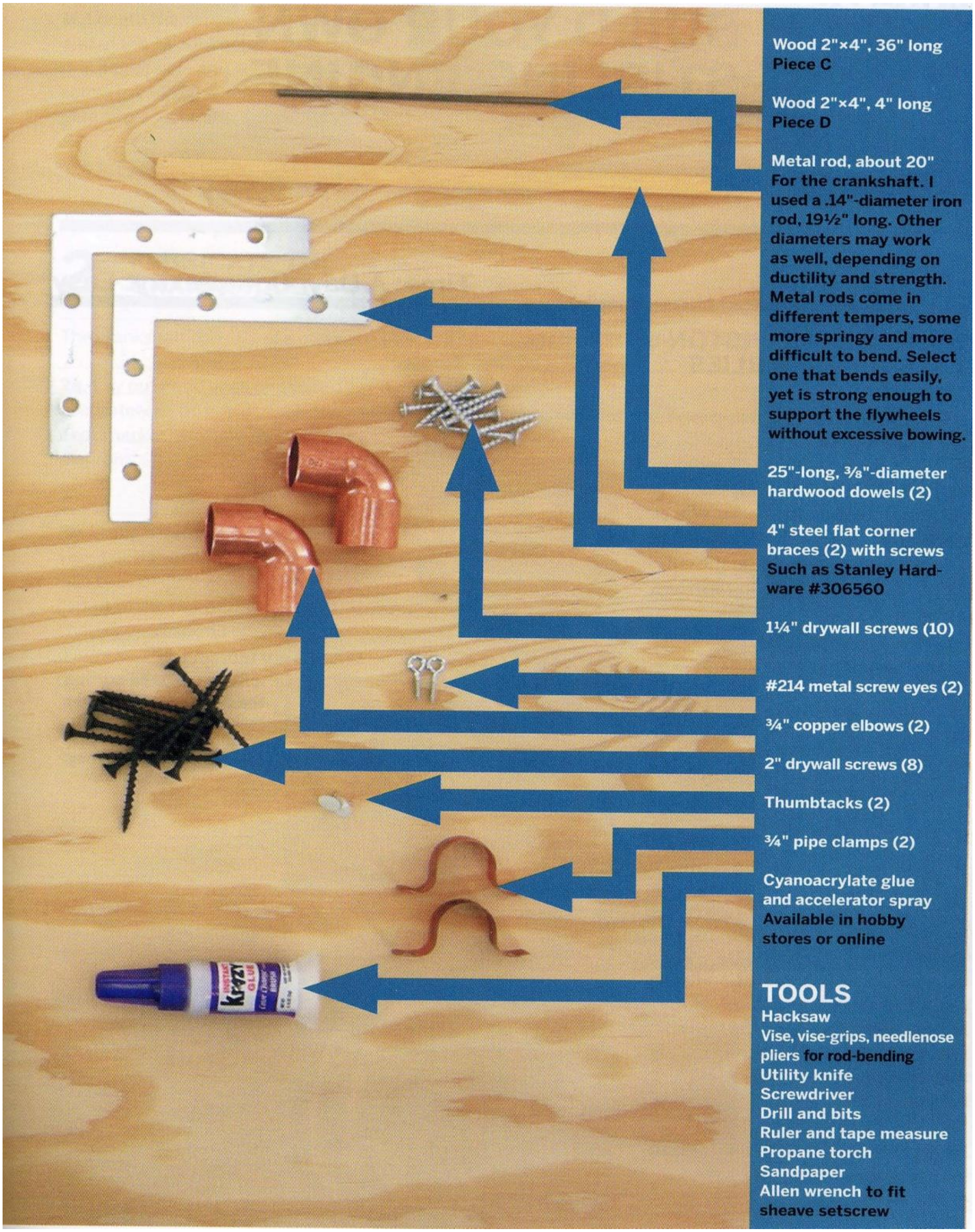


Figure 4.4: Materials used


Wood 2"×4", 36" long
Piece C
Wood 2"×4", 4" long
Piece D
Metal rod, about 20"
For the crankshaft. I used a .14"-diameter iron rod, 19½" long. Other diameters may work as well, depending on ductility and strength. Metal rods come in different tempers, some more springy and more difficult to bend. Select one that bends easily, yet is strong enough to support the flywheels without excessive bowing.
25"-long, ⅜"-diameter hardwood dowels (2)
4" steel flat corner braces (2) with screws
Such as Stanley Hardware #306560
1¼" drywall screws (10)
#214 metal screw eyes (2)
¾" copper elbows (2)
2" drywall screws (8)
Thumbtacks (2)
¾" pipe clamps (2)
Cyanoacrylate glue and accelerator spray
Available in hobby stores or online
TOOLS
Hacksaw
Vise, vise-grips, needlenose pliers for rod-bending
Utility knife
Screwdriver
Drill and bits
Ruler and tape measure
Propane torch
Sandpaper
Allen wrench to fit sheave setscrew

4.2 Make the Piston Subassemblies

There are two pistons in this engine, one for the hot side and one for the cold side.

4.2.1 With a hacksaw, carefully remove the top end of each soda can. Cut the can at the point where the flat side of the can curves to meet the top, resulting in a 4” long piston. Sand the cut edge to remove burrs, the wash and dry the interior.

Figure 4.5: Slicing of can top

4.2.2 Locate the centre of the can bottom as accurately as possible. Push the thumbtack through the can bottom at that point. Remove the thumbtack.

4.2.3 From the interior of the can, re-insert the thumbtack through the hole you just made.

Figure 4.6: Locating can center with thumb pin

4.2.4 Locate the center on the end of the 3/8”-diameter dowel and push the thumbtack into the wood. Carefully remove the thumbtack and coat the bottom of the dowel and the tack with super glue.

4.2.5 Test the can for water tightness. If it leaks, apply more glue.

Figure 4.7:Insert wooden dowel to pin

4.2.6 Locate the centre of the opposite end of the 3/8”-diameter dowel, and drill a pilot hole and screw the screw eye into the centre. Apply super glue.

Figure 4.8:Screw in opposite end of dowel

4.3 Fabricate the Crankshaft

The crankshaft consists of a metal rod bent in a precise way that holds the piston connecting rods in alignment.

4.3.1 Lay out bend lines on the rod as accurately as possible using a permanent marker, as shown on the bend diagram.

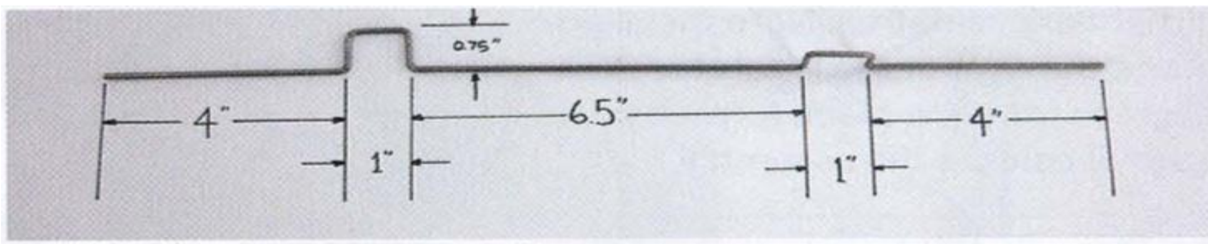


Figure 4.9:Shaft dimensioning

4.3.2 Using a hammer, vise-grips, and vise, bend the metal rod as shown. Use special care when bending the rod to make the bend sizes and shapes correspond closely to the diagram. The bends must be offset by exactly 90 degrees, and the distance from the end of the crank to the centerline of the crank shaft must be ¾".

Figure 4.10:Crank Shaft making

4.3.3 Insert the plastic spacers into the sheaves. Tighten the setscrew inside the collar of the sheave to lock the plastic spacer in place. Do not put flywheels on the crankshaft yet.

Figure 4.11:Flywheel on crank shaft

4.4 Assemble the Air Cylinder

4.4.1 Before soldering or gluing, cut down the 2 $^{3}/_{4}$ " pipes if necessary, so that the overall distance of the finished assembly will be 7 $^{1}/_{2}$", center-to-center.

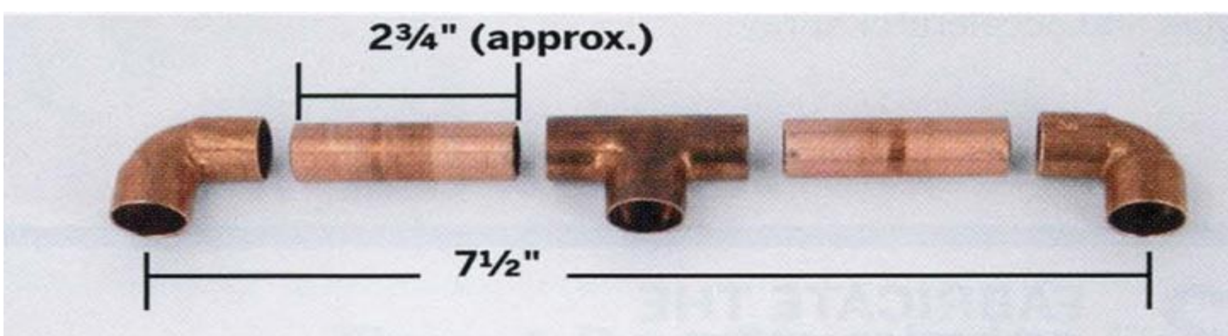


Figure 4.12 : Assembling pipes

4.4.2 Solder or epoxy the copper pipes and fittings together as shown, making certain the connections are airtight and leak free. Note the alignment; the copper tee is rotated 90 degrees from the plane formed by the other 2 holes in the assembly.

4.4. 3 Place the rubber stopper into the middle hole, in the tee. This is the system's water drain.

Figure 4.13 : Stopper in the middle T-shaped pipe

4.5 Assemble the Water Reservoirs

4.5.1 Remove the top from each steel can, leaving the bottom intact. Sand edges smooth.

4.5.2 Mark a $^{3}/_{4}$" diameter circle in the center of the bottom of each can.

Figure 4.14 : Marking pipes circumference in the bigger can end

4.5.3 With utility knife, carefully make 8 to 12 radial slits on the bottom of the can, but within the $^{3}/_{4}$"circle. The slits should form a star shape, radiating out from the center.

Figure 4.15 : Radial splits in marked region

4.5.4 Push the 5" copper pipe into the can's bottom, through the hole formed by the slits. Slide the pipe until just 1" of pipe still extends out the bottom.

Figure 4.16 : Pushing pipe into the can

4.5.5 With the pipe concentric and parallel to the slides of the can, solder the pipe in place.

Figure 4.17 : Soldered the mating parts

4.6 Make the Frame

4.6.1 Using deck screws or nails, assemble wooden pieces A-D to form a frame, as shown.

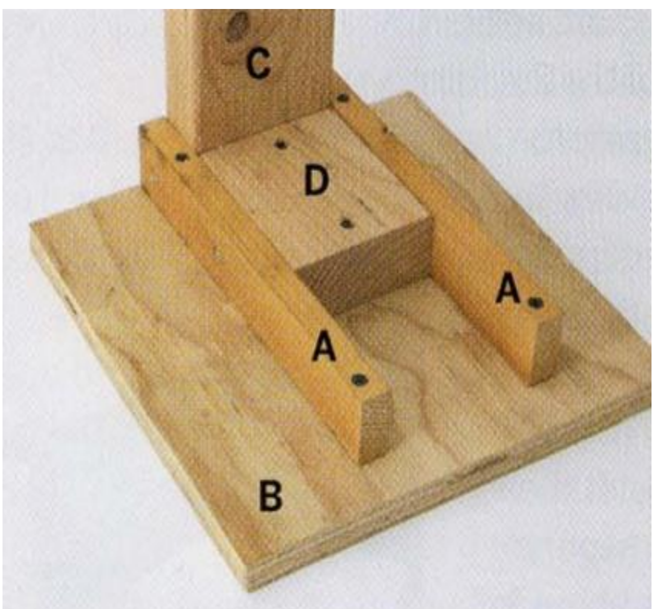


Figure 4.18 :

4.7 Assemble the Stirling Engine

4.7.1 Insert the water reservoir assemblies into the air cylinder assembly. Fill the reservoir cans with water and check for leaks. Repair leaks with epoxy and let dry.

Figure 4.19 :Water reservoir assemblies into the air cylinder assembly

4.7.2 Measure and then mark a spot on each 1”x 2” fame pieces. $3^{3}/_{4}$” from the back edge of the frame. Place the combined water reservoir and air cylinder assembly on the 1”x 2” frame pieces at the marked spots. Now place the $^{3}/_{4}$” copper pipe clamps over the assembly. Screw the pipe clamps into the 1”x 2” pieces. The clamps must hold the combined assembly firmly in plac

Figure 4.20 :Clamping pipes to the base frame

4.7.3 Slide the screw eyes on the connecting rods onto the crankshaft, so that 1 screw eye is on each of the 2 cranks. Place the soda- can pistons inside each of the water reservoirs so that each soda can rests on copper pipe. Turn the crankshaft so that one of the cranks is pointing downwards.

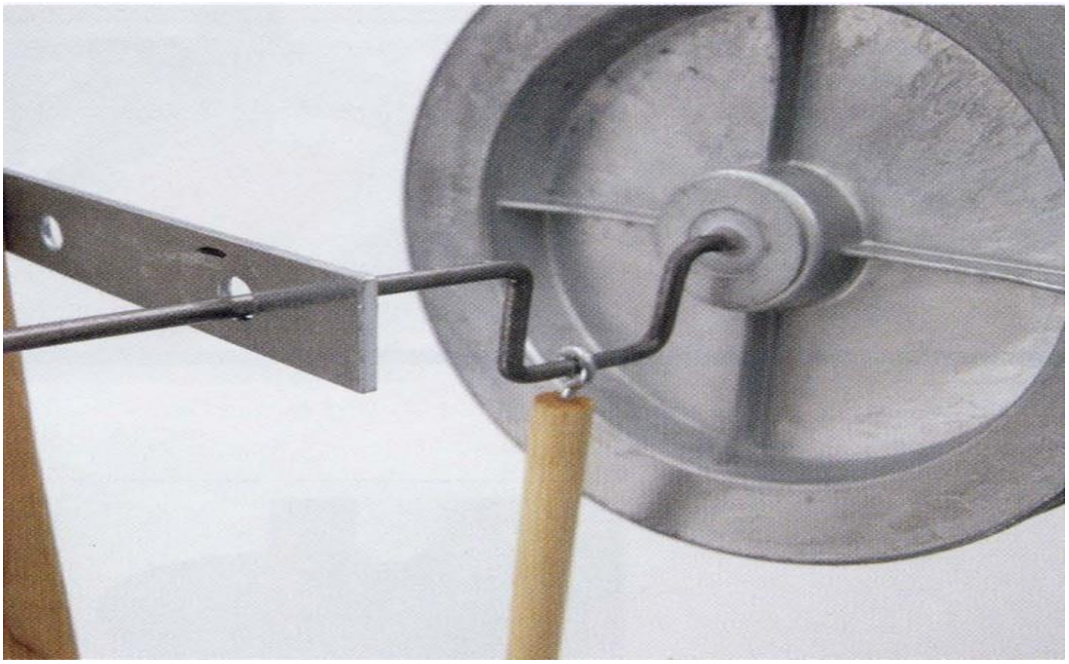


Figure 4.21 :Water reservoir assemblies into the air cylinder assembly

Holding the crankshaft level, lift the crankshaft until the can corresponding to the bottomed crank is about $^1/_2$" above the top of the copper pipe. This is the desired height for the crankshaft. Mark this height on the upright 2"x 4" and attach the angle bracket at this point, making sure that the hole through which the crankshaft will pass is located $3^3/_4$" from the back of the 2"x 4".

4.7.4 Slide one flywheel onto each end of the crankshaft. Position the flywheels so that they are as far inboard as possible without interfering with the cranks or piston rods. Glue the flywheels onto the crankshaft using super glue and accelerator spray.

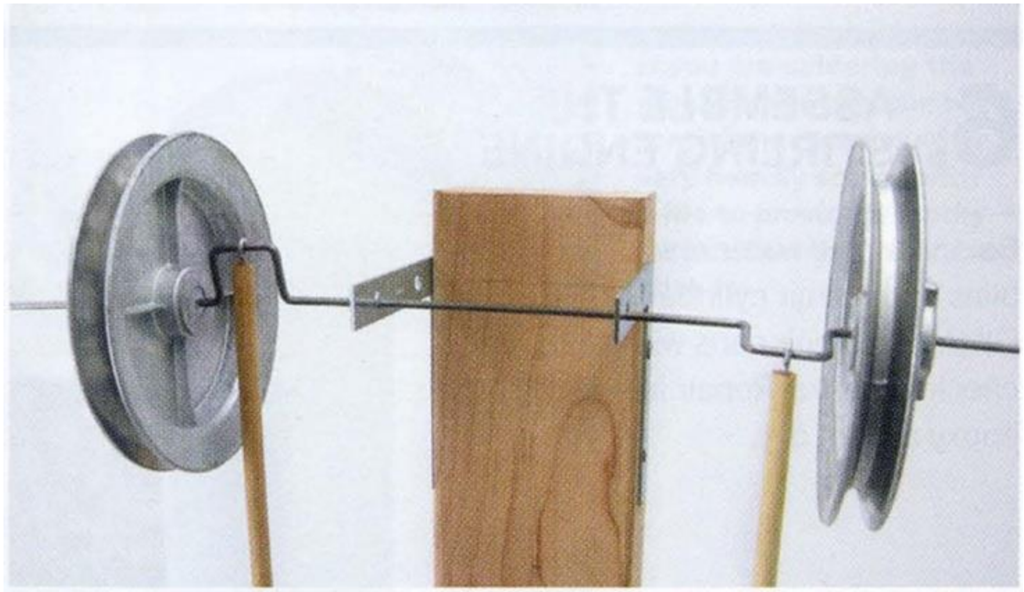


Figure 4.22: Final assembly of flywheel and crankshaft

Chapter-5

EXPECTED RESULTS AND DISCUSSIONS

The project was carried out with an objective to explore the possibility of tapping power for subsistence use from a Stirling engine. This was done with the view of aiding the research field find alternative sources of energy to for the rural electrification.

To achieve this, a thermal powered Stirling engine was envisaged as a possible route to explore alternative energy. This concept was chosen to take advantage of locally available biomass source of energy as well as the hot and sunny weather experienced in some of the marginalized parts of India.

With this vision, sketches were made that gave a graphical representation of what was anticipated during and after fabrication.

After designs approval and acquisition for funds and materials, fabrication was carried out in a span of about 8 weeks and a prototype came to being.

Tests were carried out with a view of estimating actual efficiency and calculating power output from the engine. The engine was put through a series of tests that were not conclusive due to air loss. The intension to measure the power output was therefore not feasible. The theoretical efficiency was then used to estimate the net power output using the Baele equation (eqn. below) as 45 watts. With this power estimate, the engine efficiency was calculated as 7.7%. This efficiency, compared to the theoretical Stirling engine efficiency of 63%, was found to be more reasonable and practical.

$$\boldsymbol{Power(W) = N_b \times Mean\ effective\ Pressure\ in\ MPa \times Swept\ volume(cm^3) \times Rotation\ in\ Hz}$$

Where Nb is the Baele number = 0.1112

Some of the losses of power, as reflected from the efficiency, were attributed to friction in the engine. In spite of the thorough lubrication that was done, friction was inevitable. From the assessment carried out, the greatest source of friction was in the flywheel assembly. This was because the flywheel assembly constituted several mating pieces, which rubbed on each other during operation. In addition, there was a lot of friction in contact between the piston and power cylinder arrangement.

Further, the engine experienced power loss due to out-of-balance masses in the assembly. It is noted that the attachment of the crank shaft to the flywheel introduced an out of balance mass that contributed to the power loss. To rectify this, a re-examination of the parts in the assembly was recommend, in addition to a kinematic assessment of the engine to ensure all parts were balanced.

In carrying out the project, many challenges were encountered. Top on the list of these was lack of funds to actualize desired results. This was a major problem that saw us not have enough money to get a new power cylinder to further test the engine. Most of the money consuming parts were the high precision ones that required outsourcing services in town.

Another challenge was lack of materials from the Mechanical Engineering workshop store. This further aggravated the lean working budget. Lastly, time constrain was another factor of challenge. This saw us spend long hours in the workshop, and even more time in Indra market Road and Supela, with the burning ambition to actualize the project idea. In spite of all these challenges, we were able to fabricate a prototype that pointed us to the right direction and took the project a step closer to actualization.

Chapter-6

CONCLUSION

The project was undertaken to explore the practicality of power production from a Stirling engine. This included design and fabrication.

The fabricated model was then tested, and it was noted that some air leaks existed in the power cylinder. The power cylinder was constrained by monetary resources; discussions were carried out and the project was wrapped up.

On the overall, the project was successful on several accounts. First, a successful research led to a design. In addition, the prototype was fabricated and pointed the project exploration in the right direction. The setbacks encountered were discussed and some ways were pointed out for project improvement. A theoretical energy assessment showed that with an open flame of sufficient temperature, the designed Stirling engine would generate enough power.

In conclusion therefore, the project successfully explored the practicality of generating power from a Stirling engine.

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