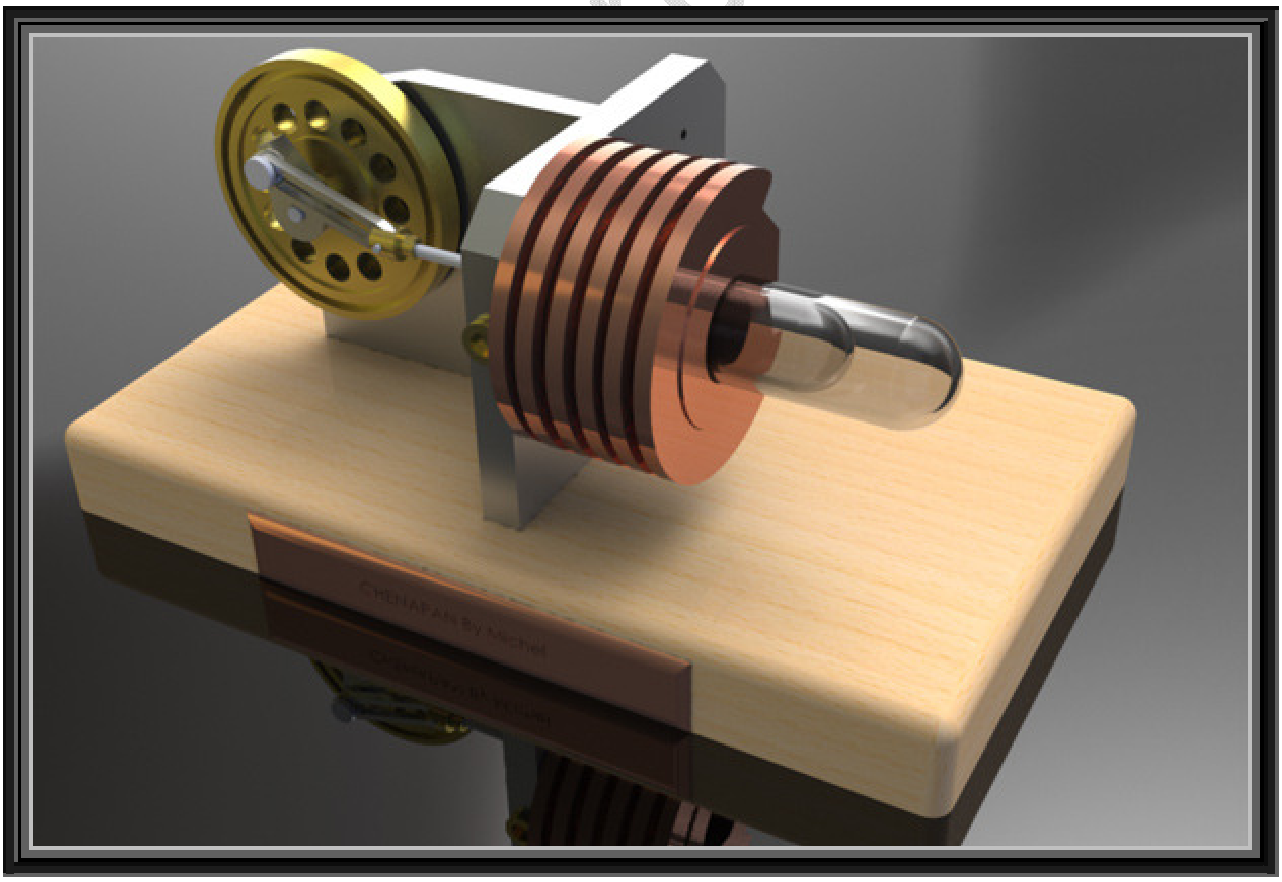
A project report

on

BATTERY CHARGER WITH STIRLING ENGINE



In rural area electricity problem, but its cost effective to supply electricity. Thus in project we make simple stirling engine by that we can generate electricity here we demonstrate it for simple battery charger. Stirling engine when heated, there will mechanical motion in engine. From that by rotating motor we generate 12V for battery charging or another application.

This report consists of back ground about project and the first chapter covers the introduction about heating and our project. Second chapter covers the over view, applications of solar hater and benefits of solar garage heater. The third chapter consists with literature review and description of heater. The forth chapter is written on materials and methods and fifth chapter gives cost estimation for the heater. Sixth chapter covers conclusions and recommendations and final chapter consist with references. This project report gives a great guideline about designing of low cost garage heater compare with the other competitive industrial heater technique.

INDEX

LIST OF FIGURE

CHEPTER - 1

INTRODUCTION

Invented in 1816 by the Reverend Robert Stirling, the Stirling engine is a heat engine, which means it produces power from heat. It was originally known as a hot air engine, but nowadays other gases such as helium are used for increased performance. Unlike other engines, such as a petrol or diesel car engine, the Stirling engine gets its heat from outside the engine rather than inside the engine. This is one of the major advantages of the Stirling engine, as it can run on just about any fuel source to provide heat, from salad oil or hydrogen to solar or geothermal energy, whereas internal combustion engines are more selective in the fuel they use to generate power. The use of an external heat sources means the Stirling engine is a more basic engine than other types, as it does not require valves for inlet and outlet of the fuel. The simplicity of the engine means it is also remarkably quite in its operation, which gives it another major advantage over other heat engines.

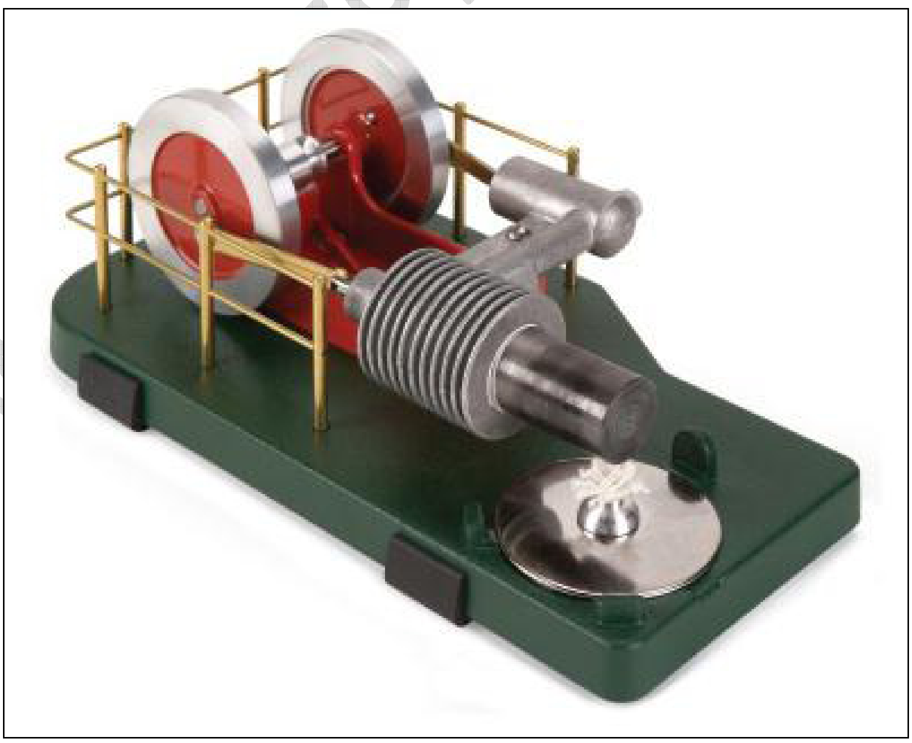


Fig 1.0 Stirling Engine

The Stirling engine operates continuously on a cycle by repeatedly heating and cooling a gas sealed inside the engine. When the gas is heated it expands to push out a piston. When cooled it contracts to pull in the same piston. Once the piston is completely pulled back in, the heating of the gas starts all over again. Thus the piston continuously moves back and forth. The movement of the piston usually rotates a flywheel by means of a linkage mechanism connecting both components, a rotating flywheel is the power produced as a result of heating and cooling the gas.

The Stirling hot air engine was originally developed to pump water in mines as a safer alternative to the steam engine. Development led to small compact Stirling engines being extensively used to pump water from household wells. Nowadays, the Stirling engine is used to generate power from renewable sources of energy such as solar power; it is used in submarines as a backup to its primary diesel-electric engines when a silent approach is required. Increasingly it is used to provide complementary heat and power in houses. The conventional central heating boiler is being replaced by a Stirling engine which heats the home but also generates 1kW of electricity.

CHEPTER - 2

HISTORY OF THE STIRLING ENGINE

In 1816, the Reverend Robert Stirling, a Scottish clergyman, invented a hot-air engine at the age of 26, which later became known as the Stirling engine. The hot-air engine did not become known as the Stirling engine until the mid-1900s.

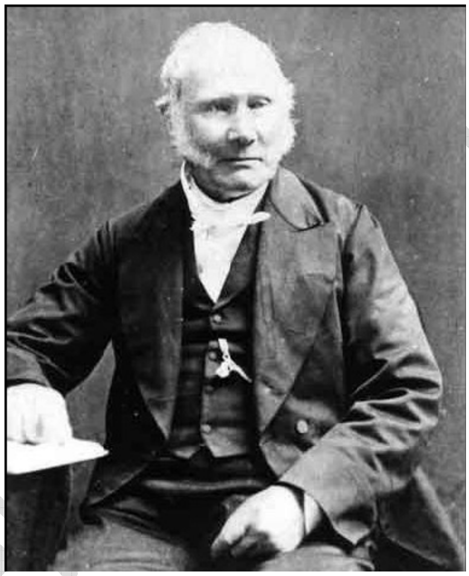


Figure 2.1
Reverend Robert Stirling, 1790 – 1878

At the time of Stirling's invention, steam engines were the driving force of the Industrial Revolution; however, very little was understood about the steam engine as the first study to understand the characteristics of the steam engine was not published until 1824, eight years after the invention of Stirling's hot-air engine. Steam engines at this time were very problematic, with reports of boilers regularly exploding, often with fatal consequences for the steam engine operators and bystanders. These reports were of great concern to Robert Stirling as steam engines were in operation in his locality.

Robert Stirling’s original hot-air engine was proposed as a safer alternative to the steam engine for the purpose of pumping water in a local quarry.

While the idea of a hot-air engine was not a new one, Stirling’s invention was unique as it was the first closed cycle hot-air engine. This means the Stirling engine uses a fixed amount of air all of the time, it doesn’t take in more air to continue working. Stirling also introduced the idea of a regenerator, which Stirling referred to as an economizer in his patent. The regenerator is a heat exchanger; it allows heat to be reused which would otherwise have been wasted as part of the engine’s cycle; this greatly improved the efficiency of the heat engine**. Figure 2.2** shows a replica of the model engine built by Stirling in 1816 to prove or demonstrate the principle of his invention.

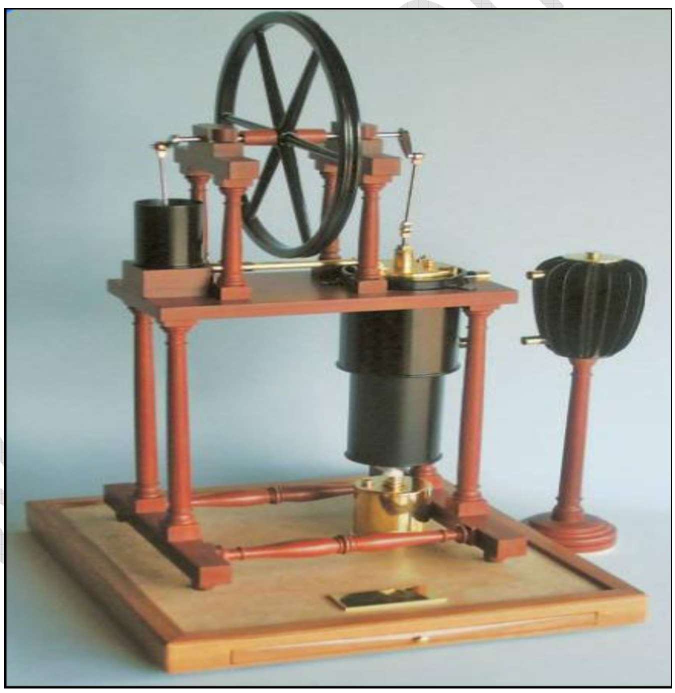


Figure 2.2
Model of hot-air engine built by Robert Stirling in 1816 to prove his idea

A full-size version of the model shown in **Figure 2.2** was constructed to pump water from a nearby quarry. It ran continuously for two years with an estimated output of two horse-powers (1.5 kW). This proved that Stirling's engine worked; however, the power produced by the hot-air engine was certainly not enough to compete with the best steam engines of the day. Also, as with most steam engines of the day, the hot-air engine suffered problems due to the poor quality of metal and materials available at the time, such as cast and wrought iron. These metals were unable to withstand the continuous high temperatures which the hot parts of a Stirling engine must be maintained at for operation. Stirling later commented that had Bessemer's steel been available when he was working on his engines, the engine would have been more successful.

CHEPTER – 3

STIRLING ENGINE PRINCIPLE OF OPERATION

When a gas, such as air, is heated it expands.

If the same gas is sealed inside the cylinder of an engine when heated, meaning the gas no longer allowed to escape, the expansion due to heat will be seen as a pressure increase in the gas.

Also, if the same air was cooled it would cause the air to contract; this contraction would cause the pressure in the engine cylinder to drop. This pressure increase and decrease, due to heating and cooling, can be used to move a piston back and forth, as shown in **Figure 3.2**. It is also important to note that the pressure and temperature are proportional to each other, meaning if the pressure decreases, the temperature will decrease in equal measure.

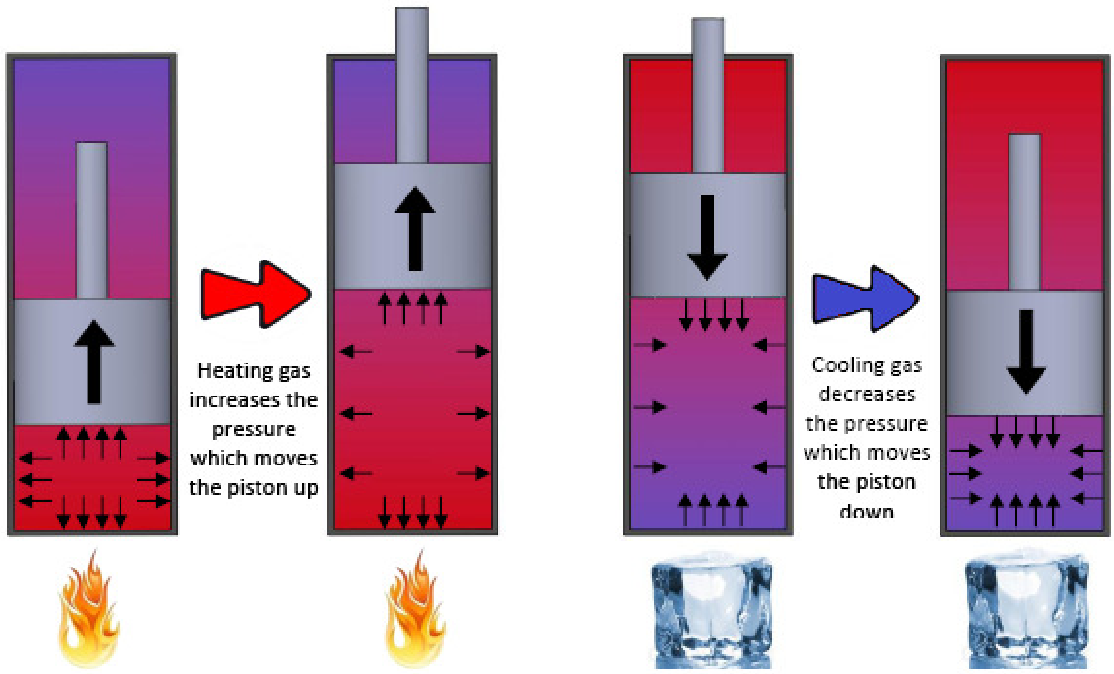


Figure 3.1

Heating and cooling of a gas changes pressure which moves a piston

If the piston shown in **Figure 3.2** is linked to a circular disc, known as a flywheel, then the heating and cooling which caused linear movement of the piston will rotate the flywheel. The rotating flywheel is mechanical energy, which the Stirling engine has converted from the temperature difference due to heating and cooling of the gas.

This process of heating air to raise its pressure in order to turn a flywheel is the basis of how a heat engine operates; hence the Stirling engine is a type of heat engine. The term heat engine is applied to any engine that produces mechanical work from heat energy, as shown in **Figure 3.2**.

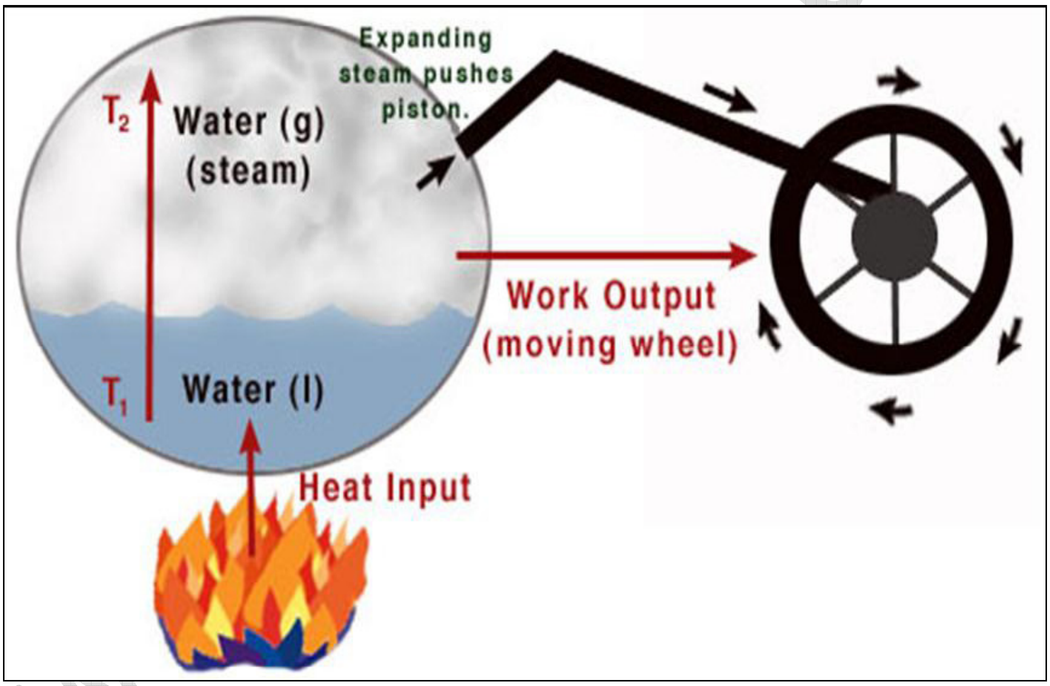


Figure 3.2

Principle Of a Heat Engine

The Stirling engine operates continuously on a cycle by heating and cooling air, or other gases, within the engine over and over again to produce useful power that can drive a machine. The air is sealed inside the engine being moved back and forth as heating and cooling occurs, so it is known as a closed cycle heat engine. This gives the

Stirling engine the advantage of being a much simpler engine, as it does not require inlet and outlet valves used in diesel and petrol engines.

In order to maintain continuous operation, the Stirling engine needs a flywheel. The flywheel, usually a circular disc made from steel, stores energy. The Stirling engine only produces power for a portion of the cycle when the gas is expanding; it requires an input of energy during the compression of the gas. The flywheels momentum, gained from expansion of the gas, is partly used to overcome the compression of the gas and maintain the smooth running of the engine.

The Stirling engine is an external combustion engine meaning the engine obtains heat from outside rather than inside the working cylinder, unlike internal combustion engines such as the diesel or petrol engine. Internal combustion engines are sensitive to its fuel type, which gives the Stirling engine the advantage of being able to generate power from any source of heat, so long as the temperature is high enough.

3.1 The parts of the Stirling engine

There are a great many different Stirling engine designs available, however there are three components common to all Stirling engines, without these components, it is not a Stirling engine:

- The **power piston** – this is connected to a flywheel via a crankshaft to provide the output power of the engine
- The **displacer** – unique to a Stirling engine, the function of the displacer is to move the air from one end of the cylinder to the other.
- The **regenerator**, also known as a heat exchanger – unique to a Stirling engine, it reduces the amount of waste heat in the engine cycle to improve the efficiency of the engine.

This section will describe the function of all three components. There are hundreds of Stirling engine designs available today, however, there are only three basic layouts for Stirling engines; Alpha, Beta and Gamma engine layouts, as shown in **Figure 3.3**, which also illustrates the main components of the Stirling engine. The gamma (The first

Stirling design) and beta engines were associated with Robert Stirling, the Alpha engine design followed after Stirling's work ended.

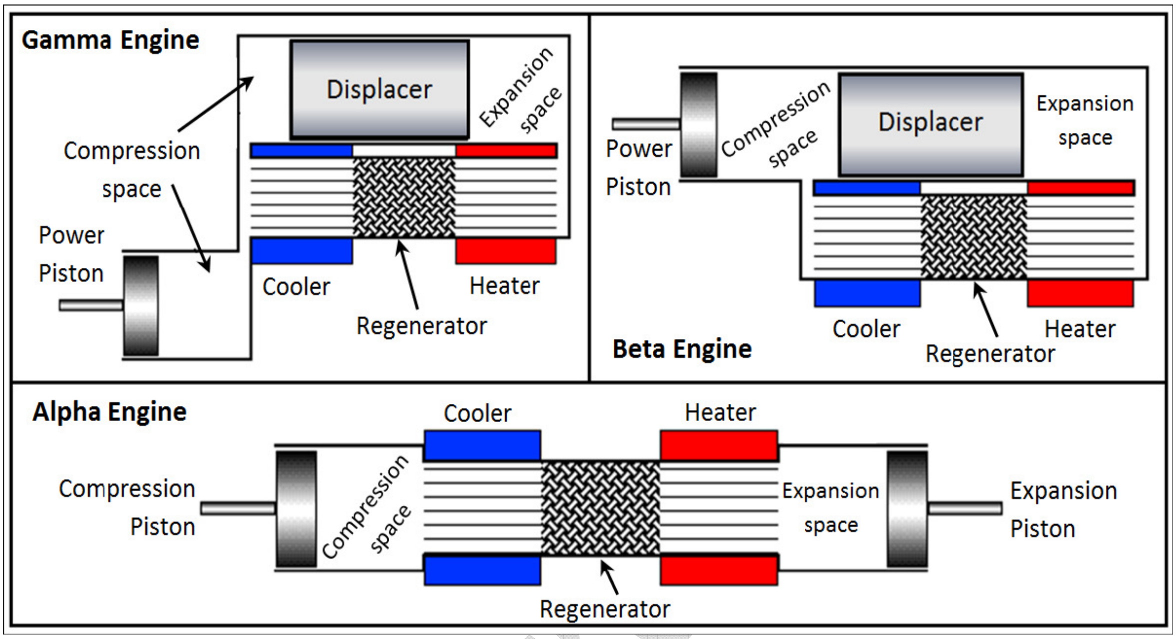


Figure 3.3

Three Basic Mechanical Configurations For Stirling Engines

3.2 The displacer and power pistons

Two cylinders, one containing a displacer and the other a power piston, make up the enclosed space of the Stirling engine, which is completely sealed; ideally no gas can enter or leave.

The displacer is unique to Stirling engine design. Heat is applied to one end of the displacer cylinder and extracted at the opposite end. The function of the displacer is to move air from the heated place to the cool place. The displacer is a cylinder inside a cylinder which acts like a plunger, it is not a piston as it does not affect the pressure, but controls the position of the gas. The displacer is loose fitting of 60-70% of the length of its cylinder which is moved by a rod connected to the crankshaft through a linkage mechanism; the displacer rod always emerges from the cold end. When the displacer moves from one end of the cylinder to the other, the air has to move round the displacer to get to the other end of the cylinder, as illustrated in **Figure 3.4**.

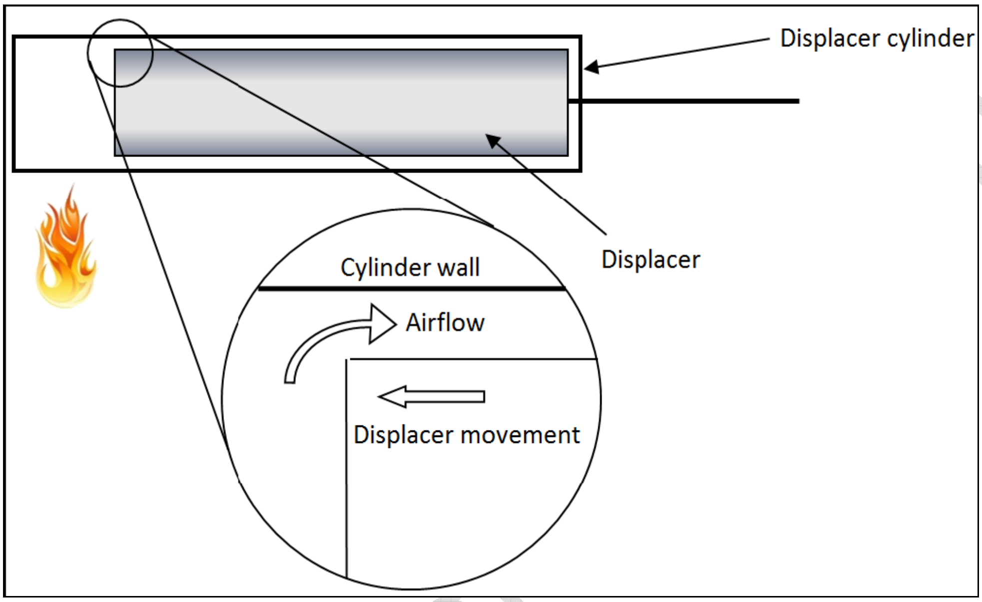


Figure 3.4
Displacer Principle

When the displacer is at the cold end , the gas is at the hot end increasing in temperature and pressure, this increase in pressure will push the power piston forward. As the displacer is moved from the cold end to the hot end, the pressurized gas is forced to the cold end, pushing the power piston to expand forward, as indicated in **Figure 3.5**.

On the other hand, when the displacer is at the hot end, the air is forced to the cold end. As a result the air contracts and pulls the piston back, also illustrated in **Figure 3.5**.

For the Stirling engine to work the displacer must first move the air, the air then heats up before expanding to move the power piston. The displacer moves first, the piston stroke follows, so both the displacer and the power piston are said to be "**out of phase**". As both are connected to the same flywheel a phase difference is required, usually 90 degrees is sufficient. A linkage system is designed so that the piston and displacer move together but have a 90° phase difference, for example, the displacer is at the end of its cylinder when the power piston is midway along its cylinder.

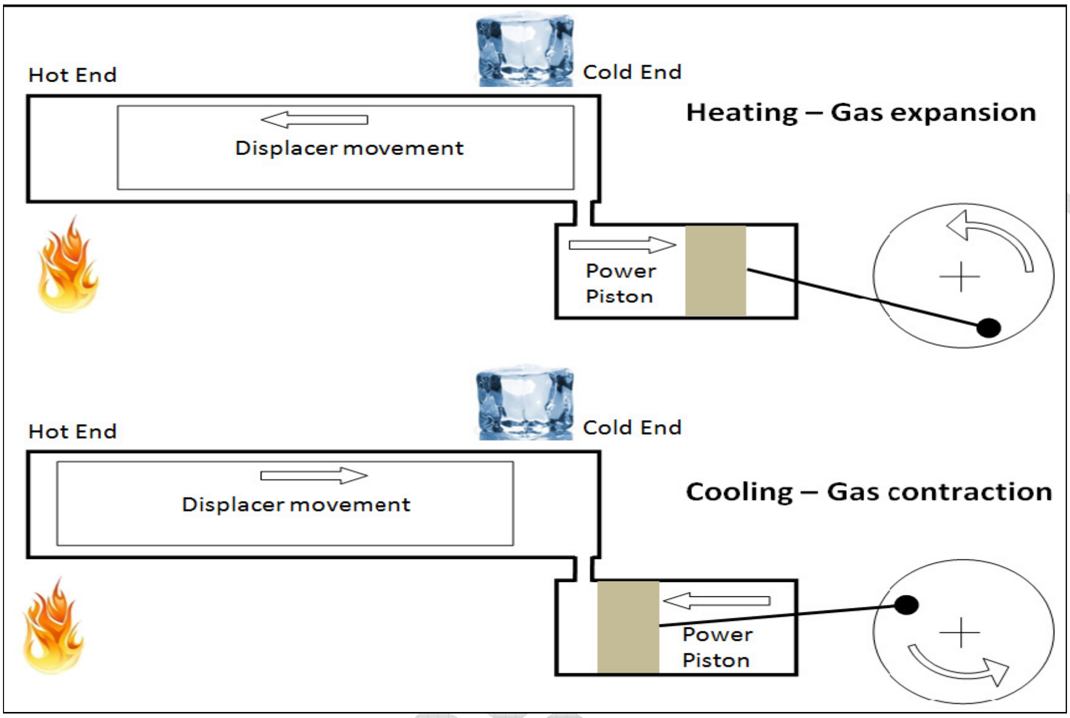


Figure 3.5

Displacer And Power Piston Position During Heating And Cooling

3.3 The regenerator

When first looking at the Stirling engine, it may appear that the purpose of the hot end of the displacer cylinder is to add heat which will be lost to the cold end and that the cold end absorbs heat added by the hot cap, but this is not the case. The main unique feature of Robert Stirling's patent in 1816 was the inclusion of a thermal store, known as a regenerator, in the air passageway between the hot and cold ends of the displacer cylinder. The purpose of the regenerator is to remove heat from the gas as it moves from the hot end to the cold; the regenerator stores the heat, and returns it to the gas as it moves from the cold end to the hot end, as illustrated in **Figure 3.6** and also shown previously in **Figure 3.3**. The regenerator usually consists of wire mesh, as the wire mesh can absorb heat easily but also allows free passage of the air. Usually the gap between the displacer and its cylinder is increased to accommodate. The benefit of the regenerator is the reduction of waste heat through cooling fins, which reduces the demand on the fuel needed. Also less cooling and heating is required for the same power output, so the engine is more efficient.

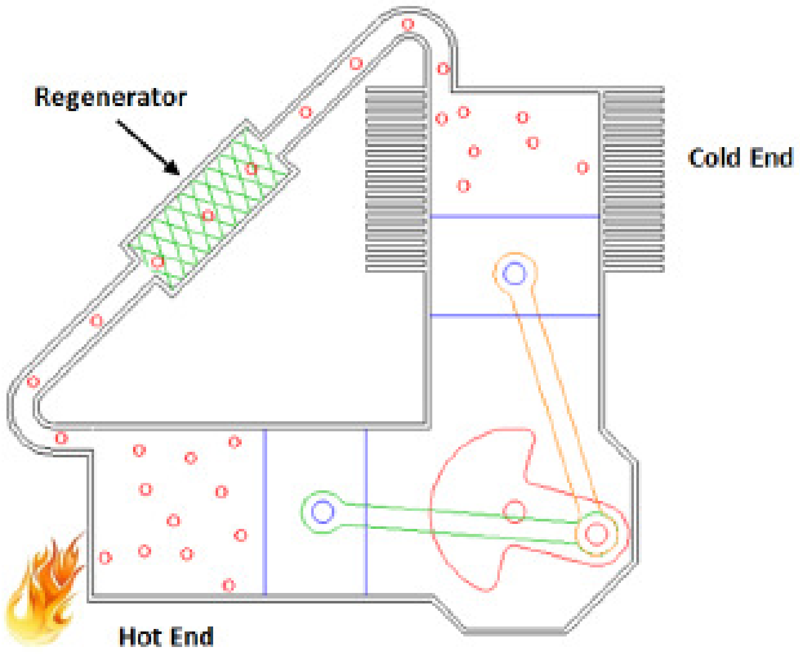


Figure3.6
Alpha Type Stirling Engine With Regenerator

3.4 The Gamma Stirling Engine Cycle

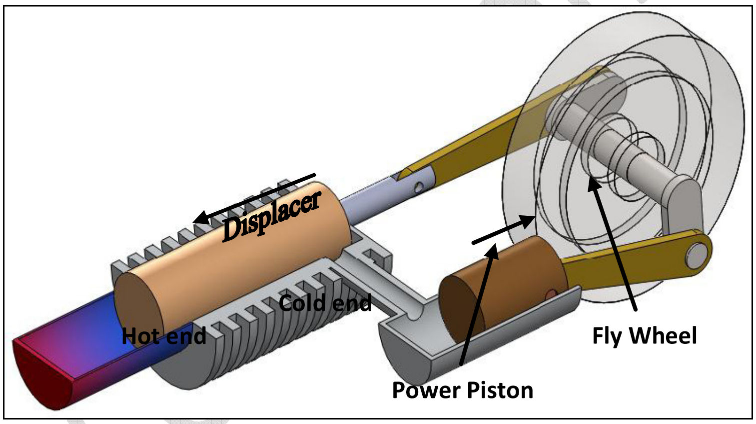
The following illustrations show the complete cycle of a gamma type Stirling engine in four stages. Power in the form of a rotating flywheel is only produced in part of the cycle; the flywheel's momentum completes the cycle. The flywheel is transparent to show the 90° phase difference between displacer and piston.

Stage 1 – Expansion (Heating)

Displacer is at cold end. Power piston is mid position.

Gas in the displacer cylinder is at hot end, so it heats up and expands due to pressure increase. Pressure increase drives the power piston forward to the end of its stroke, this rotates the flywheel.

This is the power producing phase cycle.

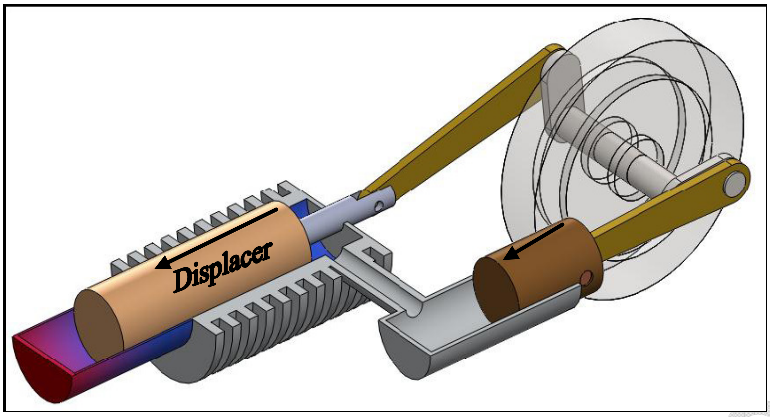


Note: arrows indicate movement of components from stage 1 to 2

Stage 2 – Transfer

Displacer is mid position. Power piston is bottom of stroke.

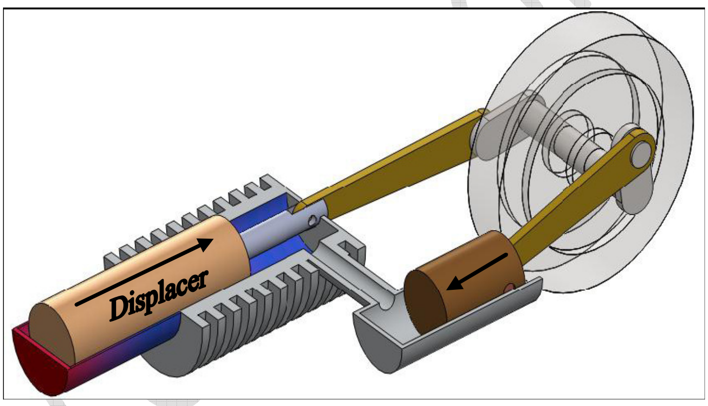
The gas has now expanded; most of the gas is still in the hot end of the cylinder. The flywheel's momentum will carry the crankshaft the next quarter turn. The gas is moved around the displacer to the cold end of the cylinder.



Note: arrows indicate movement of components from stage 2 to 3

Stage 3 – Contraction (Cooling)

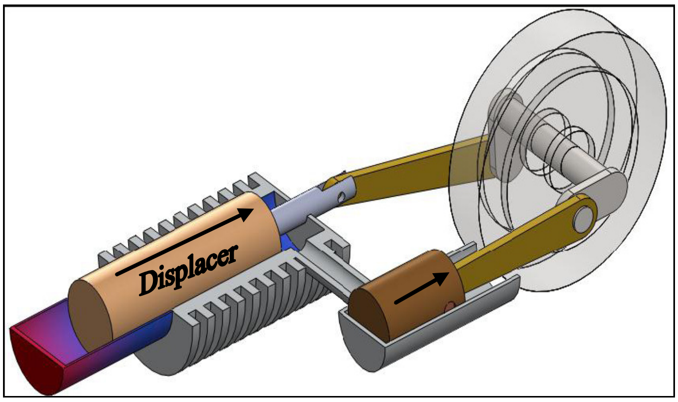
Displacer is at the hot end. Power piston is mid position. The majority of the expanded gas has moved to the cold end. The gas cools and contracts, allowing the piston inward.



Note: arrows indicate movement of components from stage 3 to 4

Stage 4 – Transfer

Displacer is mid position. Power piston is top of its stroke, ready to start the power output stroke. The contracted gas is still located near the cool end of the cylinder. Flywheel momentum carries the crank another quarter turn, moving the displacer and transferring the gas back to the hot end of the cylinder.



Note: arrows indicate movement of components from stage 4 to 1

Figure 3.7

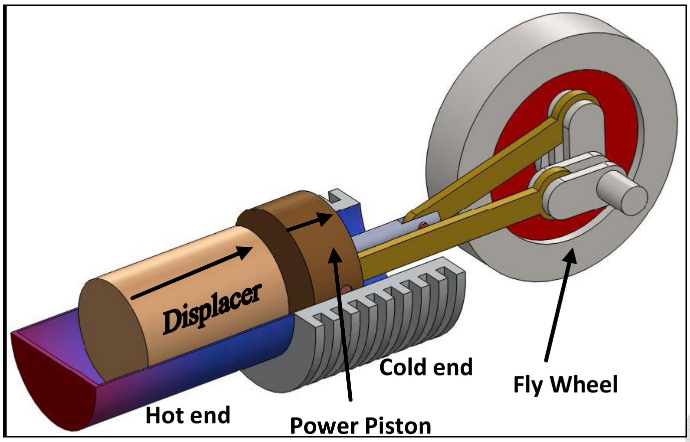
Gamma type Stirling engine cycle

3.5 The Beta Stirling engine cycle

The following illustrations show the complete cycle of a beta type Stirling engine in four stages. The beta engine differs to the gamma in that both the displacer and power pistons are in the same cylinder. Power in the form of a rotating flywheel is only produced in part of the cycle , the flywheel's momentum completes the cycle. The 90° phase difference between displacer and piston is also illustrated.

Stage 1 – Expansion (Heating)

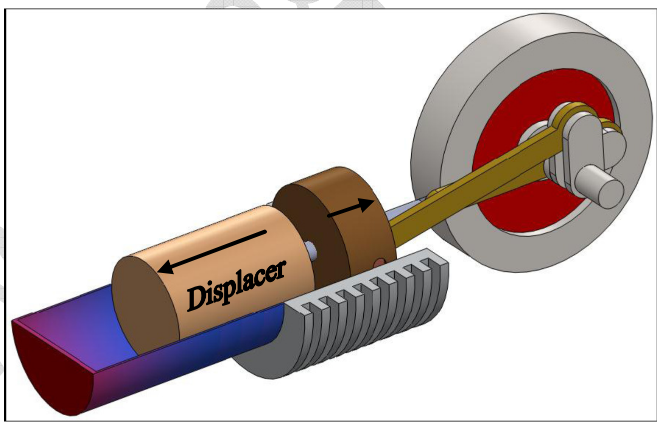
Displacer is mid position. Power piston is top of its stroke. Most of the air in the system has just been driven to the hot end of the cylinder. The air heats and expands, driving the piston outward. This is the start of power producing phase of the cycle.



Note: arrows indicate movement of components from stage 1 to 2

Stage 2 – Transfer

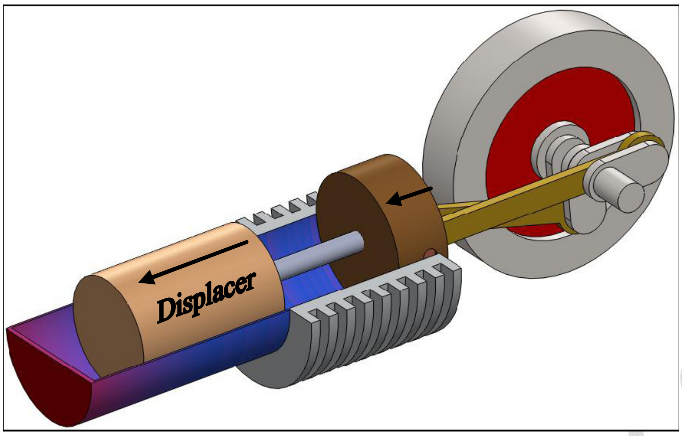
Displacer is at cold end. Power piston is mid position. The air has expanded. Most of the air is still located in the hot end of the cylinder. Flywheel momentum carries the crankshaft the next quarter turn. The most of the air is moved around the displacer to the cool end of the cylinder.



Note: arrows indicate movement of components from stage 2 to 3

Stage 3 – Contraction (Cooling)

Displacer is mid position. Power piston is bottom of stroke. The majority of the expanded air has moved to the cold end. The air cools and contracts, pulling the piston inward.



Note: arrows indicate movement of components from stage 3 to 4

Stage 4 – Transfer

Displacer is at the hot end. Power piston is mid position. The air is fully cooled at the cold end of the cylinder. Flywheel momentum carries the crank another quarter turn, moving the displacer and transferring the air back to the hot end of the cylinder to begin the cycle again.

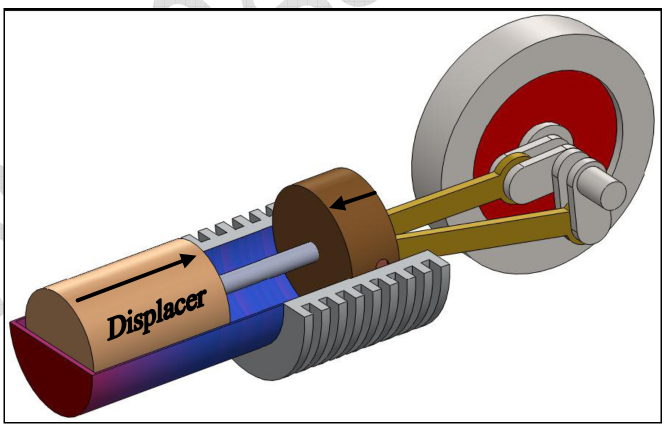


Figure 3.8
Beta type Stirling engine cycle

Note: arrows indicate movement of components from stage 4 to 1

CHEPTER – 4

STIRLING ENGINE PERFORMANCE

The Stirling engine cycles described in the previous two sections can be plotted on a graph to illustrate the power output of the engine. In **Figure 4.1**, the four lines show the four stages of the cycles previously discussed: Heating, Expansion, Cooling and Contraction. The area enclosed by the four lines measures the power output of the Stirling engine.

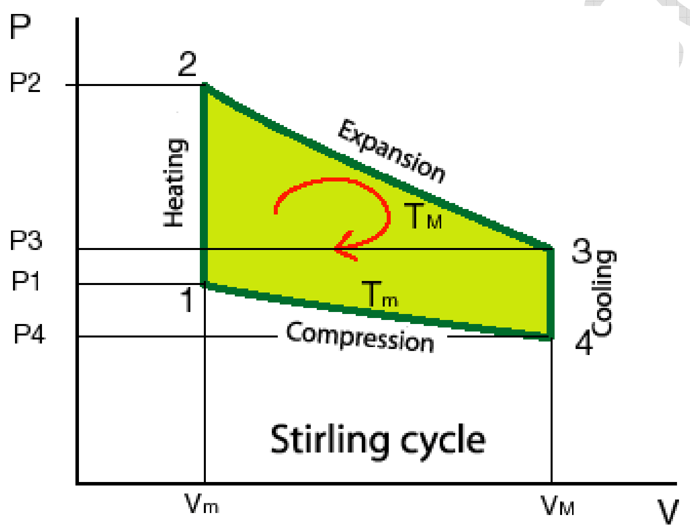


Figure 4.1

Pressure - volume diagram indicating the power output of a Stirling engine

The volume in the diagram is the volume of gas in the power piston cylinder. It can be calculated based on the diameter of the piston and the position of the piston.

$$Volume\ of\ a\ cylinder = (\pi \times r^2) \times height$$

The change in volume during the expansion process can be calculated as:

$$Change\ in\ volume = (\pi \times r^2) \times distance\ moved\ by\ the\ power\ piston$$

The pressure can be determined from the temperature of the gas; they are directly related to each other. If the temperature is doubled, the pressure doubles.

Note: The temperature must be in Kelvin. Kelvin = Degree Celsius + 273

The performance of any heat engine is defined by its efficiency. The performance, or efficiency, is expressed as a ratio of the output of the engine divided by the input required for the engine:

$$\text{Stirling engine efficiency} = \frac{\text{Desired output of the engine}}{\text{Required input of the engine}} \times \frac{100}{1}$$

However, a theoretical maximum efficiency for the Stirling engine can be calculated based on the temperatures of the hot end (T_{hot}) and cold end (T_{cold}). The previous formula can be written as:

$$\text{Stirling engine maximum efficiency} = \frac{T^{hot} - T^{cold}}{T^{hot}} \times \frac{100}{1}$$

Example:

If the room temperature in which the Stirling engine is operating is 20℃.

$T_{cold} = 20 + 273 = 293K$

Butane is to be used as the fuel source. If the temperature of a butane flame is 600℃.

$T_{hot} = 600 + 273 = 873K$

$$\text{The maximum efficiency of the Stirling engine} = \frac{873 - 293}{873} \times \frac{100}{1} = 66.4\%$$

Based on this formula, increasing the hot end temperature or decreasing the cold end temperature will improve the efficiency. The higher the efficiency, the greater the power output from the engine. Increasing the pressure in the engine also increases the power output.

This ideal efficiency for a Stirling engine is the highest possible efficiency of any heat engine. The car engine is approx. 25% efficient, less than half the possible efficiency of the Stirling engine.

4.1 Advantages of the Stirling Engine

- Stirling engines can run from **any available heat source**.
    - o Engine can be used to harness solar energy.
- The engine works on a **closed cycle** so the gas is unpolluted.
    - o Increases the life of the engine as there is very little corrosion or associated problems.
- **Simple engine design**.
    - o Only two cylinders needed and the gas is sealed inside the engine so no inlet and outlet valves are needed.
- **Silent in operation**.
    - o Due to no valves being required to exhaust gases.
- Operates at **lower pressures**.
  o Engine can be a lighter construction than other types, more portable.
- **No phase changes** take place in the engine, making it a much safer engine.
    - o Steam engine must alternate between liquid and vapour during the cycle.
- Significantly **lower emission** as the combustion is continuous rather than intermittent.
    - o Most smoke comes when a fire starts, intermittent combustion generates more smoke
- Engine can be manufactured to very **small sizes**, not possible with an internal combustion engine.
    - o Applications in miniature cooling/power producing systems.
- Greater **flexibility of applications**.
    - o The engine can either be used to produce power or when power is supplied it can either be used as a cooler or a heater.
- Continuous combustion means the potential **efficiency of the Stirling engine is higher** than any other engine.

4.2 Disadvantages of the Stirling Engine

- Stirling engines have **low power to weight ratio**
  - Lower power output compared to internal combustion engine of same size. This is the reason it will not be used in automobiles
- Stirling engines are **more expensive** than internal combustion engines with same power output.
  - The design of effective heat exchangers also increases the cost. The cost is more critical than the simplicity of the construction without valves for manufacturers.
- Stirling engines are **not self-starting**.
- Stirling engines **require a longer warm up time** than other engine types.
- The **efficiency of the Stirling engine drops** if the temperature difference between the hot and cold ends decreases.
  - As the engine heats up, heat from the hot region may move to the cold region, this would see the efficiency of the engine decrease.
- It is **difficult to vary the power output** of Stirling engines.
  - Usual methods include varying the displacement of the engine. But the response time to change in temperature is quite long and hence not preferred.
- **Sealing of Stirling engines is an extremely difficult** job.
  - Unlike internal combustion engines in which the working fluid is exhausted in every cycle, Stirling engines use the same working fluid their entire life.

CHEPTER– 5

APPLICATION OF THE STIRLING ENGINE

Originally developed as a means to pump water in mines, the Stirling engine was developed into small domestic units widely used to pump water from household wells. Another early use was the driving of church organs where using steam engines would have drowned out the sound.

- **Solar Power Generation**

Stirling engines can operate using heat from the sun, providing a renewable form of energy to power homes. The solar power is generated using a dome (parabolic) shaped mirror and a Stirling engine positioned at the focus of the mirror. The sunlight is focused on the hot side of the engine; this heats and expands a gas to drive a piston and crankshaft. An alternator converts the power generated by the engine into electricity. In 2010, 60 Stirling solar units capable of generating 25kW of electricity each were installed near Phoenix Arizona, generating a total 1.5 MW of electricity. There are several larger scale solar Stirling projects currently in development.

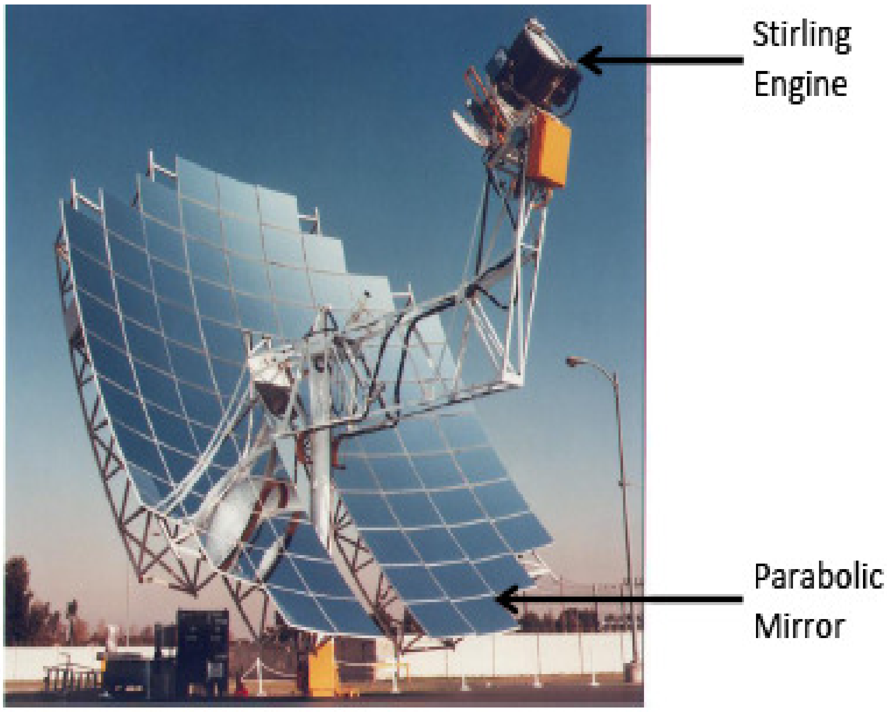


Figure 5.1
Solar Power Stirling engines

- **Automobiles using Stirling engines**

The 1970s oil crisis caused an increase in fuel prices due to a fuel shortage. This led companies such as General Motors and Ford to invest millions of dollars to develop Stirling engines to replace the internal combustion engine. **Figure 5.2** shows an experimental car powered by a Stirling engine. It was not a success, and when fuel prices fell in 1980s, the interest in the area declined.

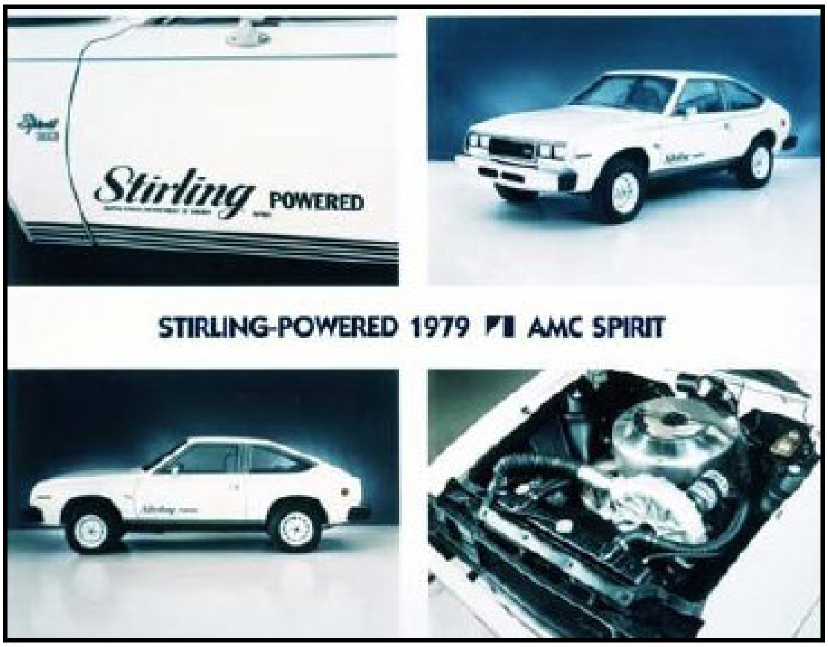


Figure 5.2
Stirling Engine Powered Automobile

Despite being the most efficient engine possible, the main issue with the Stirling engine was the time needed to warm up, you had to wait 20 seconds after you turned on the ignition key before the car moved . There was also difficulty in changing the engines speed, which limited the flexibility of driving and the cost of the engine was very high. Currently most of the research is focused on building hybrid engines incorporating Stirling engines.

- **Computer chip cooling**

Recently, computer motherboard manufacturer Micro-Star International Co., Ltd (MSI), Taiwan, developed a very clever miniature Stirling engine to function as a cooling system for personal computer chips. This Stirling engine takes heat from the processor to power the engine which then drives a fan to cool the processor; the processor cools itself! MSI claim the engine is 70 per cent efficient, as it can convert 70 per cent of the heat from the chip into power for the fan, and it uses no electricity to drive the fan. It is also self-regulating, as the more heat generated by the chip, the more power output from the Stirling engine to cool the processor.

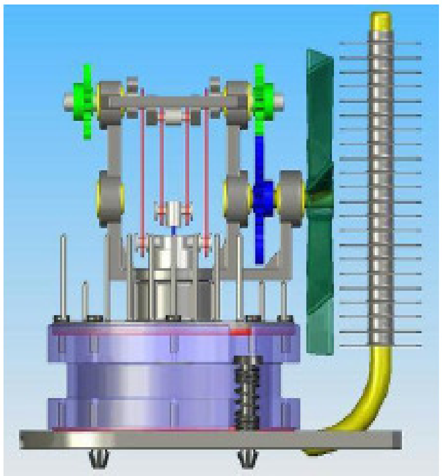



Figure 5.3
Stirling engine powered computer chip cooling

This is a great example of the innovative ways in which this technology can be used in the future.

- ## Stirling engine powered submarines

One of the advantages that the Stirling engine has over other engines is that it is remarkably quite. As a result Stirling engines have been developed for use in military submarines as a backup to its primary modern diesel-electric engines when a silent approach is required. The Swedish navy is pioneering this technology, which has allowed them to extend their time underwater from a few days to a few weeks. Once the submarine is submerged using the diesel engines, the Stirling engines are used to power a 75kW generator for either propulsion or charging batteries.

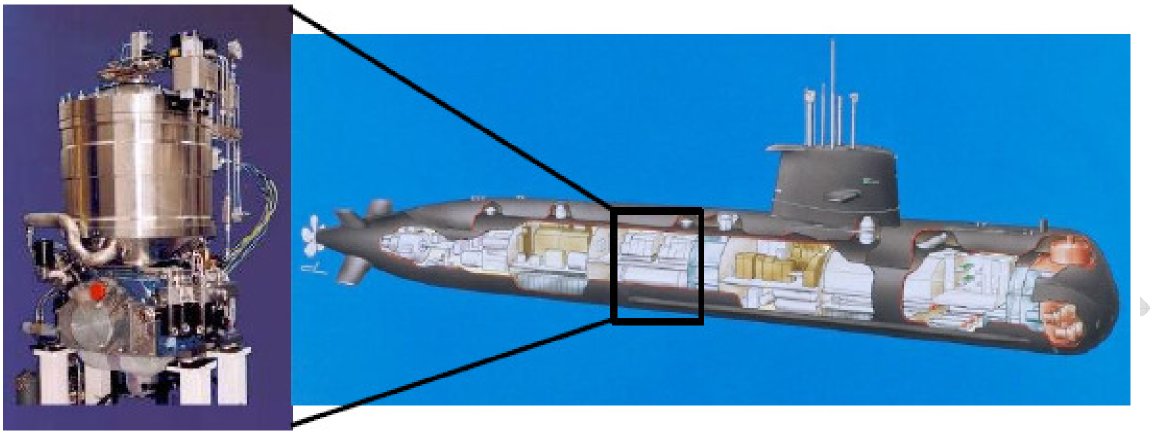


Figure 5.4
Stirling engine power submarines

Domestic heat and power

Currently, the most significant development of the Stirling engine technology is in the area of micro combined heat and power **(CHP).** In micro CHP systems, the Stirling heat engine is used to generate both heat and electricity for the home. In a Stirling CHP unit fuel is used to drive the Stirling engine to generate mechanical power which is used to produce electricity. However, the waste heat from the engine is used to provide heating for the home instead of being dumped.

Micro CHP Stirling Engine units are capable of generating up to 5 kilowatts of heat and 1 kilowatt of electricity by driving a displacer and magnetic piston up and down between a generator Other applications include reversing the Stirling engine to operate as a refrigeration system. At normal refrigeration temperatures (as low as -20℃) the Stirling coolers are not as efficient as other refrigeration units. However, below -40℃ the Stirling cooler is competitive with other coolers. Stirling coolers that operate at temperatures as low as -200℃ are known as cry coolers. coil, as shown in **Figure 5.5.**

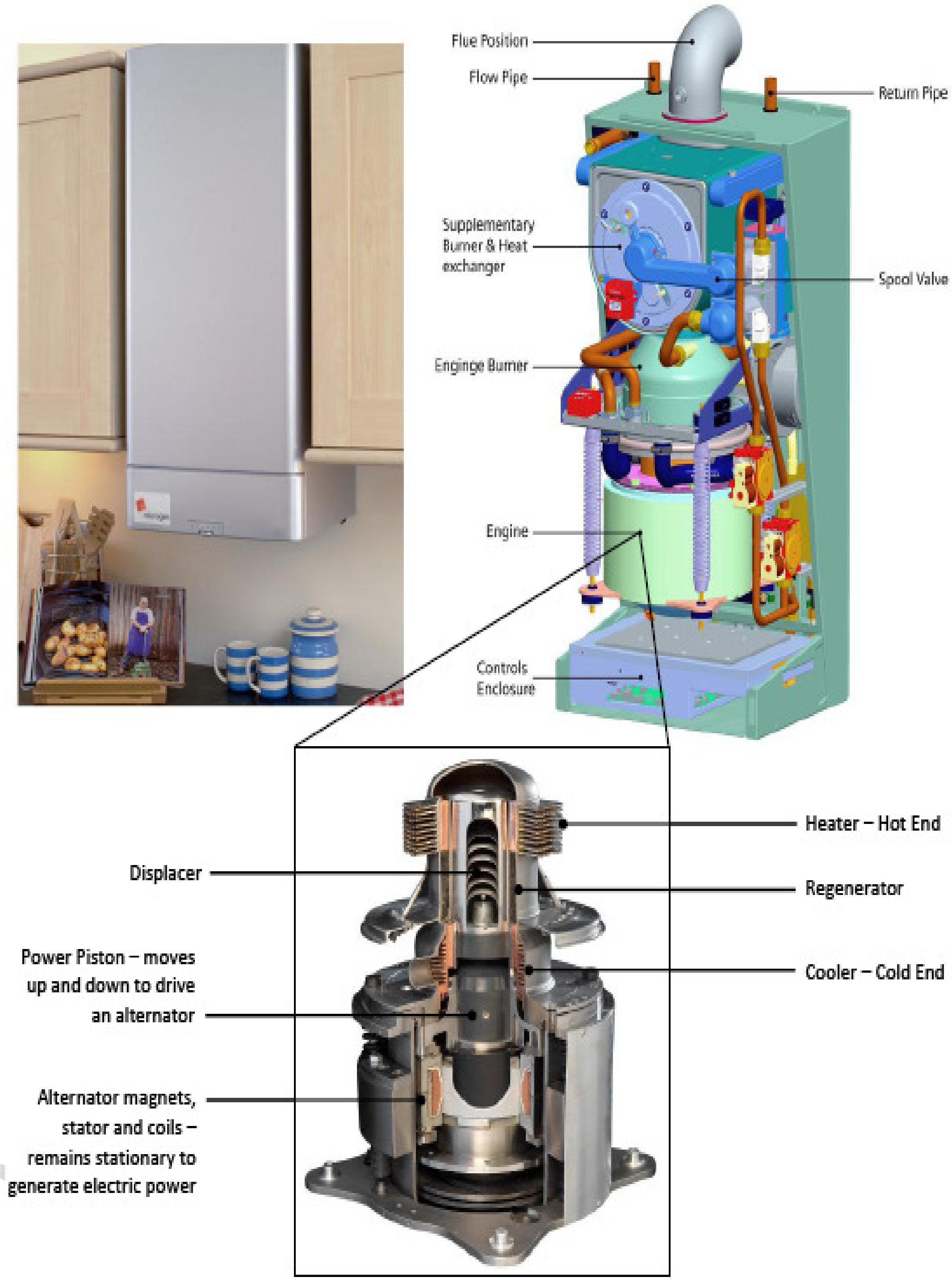


Figure 5.5

Micro CHP unit with Stirling engine

CHEPTER – 6

CONCLUSION

We successfully accomplished the following task.

- Battery charger with help of stirling engine. Stirling engine required first throust to start. When it start make crank shaft to rotate and thus we get current to charge battery.
- Its economical and simple to use in rural area for electricity purpose.
- we can also say that the genius of Robert Stirling is not only in having imagined Stirling cycle , but rather in the invention of the regenerator (or economizer) which improves significantly the performance of engines.

- In order to be more efficient, it requires metals with very high thermal conductivity, which can be expensive.

- Rotation is not always smooth – the fluid sometimes heats up faster than it cools off.

REFERENCES

- **Stirling and Hot Air Engines**
  Roy Darlington and Keith Strong, 2005, The Cordwood Press Ltd., ISBN 1 86126 688 X
- **Stirling Cycle Engines**
  Andy Ross, 1997, 3rd Ed., Solar Engines
- **Engineers**
  Adam Hart-Davis, 2012, DK Publishing,
- **An Introduction to Stirling Engines**
  James R. Senft, 1993, Moriya Press,
- **An Introduction to Low Temperature Differential Stirling Engines**
  James R. Senft, 1993, Moriya Press,

WEB SITES :-

- http://www.stirlingengines.org
- http://www.robertstirlingengine.com
- http://www.wikipedia.com