STIRLING
CRYOGENICS

The Stirling Cycle

The ultimate way to generate cooling power

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The history of the Stirling Cycle

The Stirling cycle is a thermodynamic closed cycle invented in 1816 by a Scottish minister Robert Stirling. It was used as an engine and was considered at the time to be capable of replacing the steam engine since boilers used in early steam engines were prone to life-threatening explosions.

The counterpart of the hot air motor, the refrigerator, was first recognized in 1832. Both machines experienced high and low points during the nineteenth century. The principle behind the machines was almost condemned to obscurity after the invention of the internal combustion engine (gas-, petrol-, and diesel motors) and compressor refrigerators with external evaporation.

In 1938 the famous Dutch Philips Research Laboratory was looking for a means to power electricity generators for short wave communication systems in remote areas without electricity supply. The practically-forgotten hot air motor attracted attention.

In 1946 Philips started optimizing the cooling techniques used in the Stirling cycle. The result was the development of the world conquering cryogenerator, marking the start of significant cryogenic activities at Philips. Though the Stirling hot air motor itself never became a commercial success, the Stirling cryogenerator has been selling by thousands worldwide and has been incorporated in equipment and projects used from Antarctica to the North Pole.

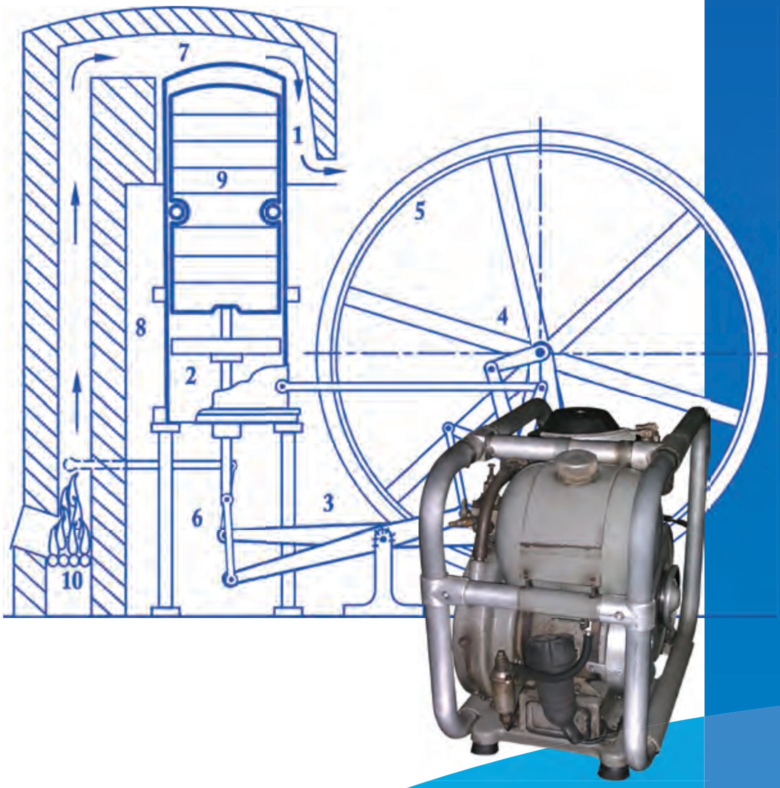
Stirling based cryogenerators are used in a wide range of applications, including the production of liquid gases and the cooling of gases, liquids and industrial processes.

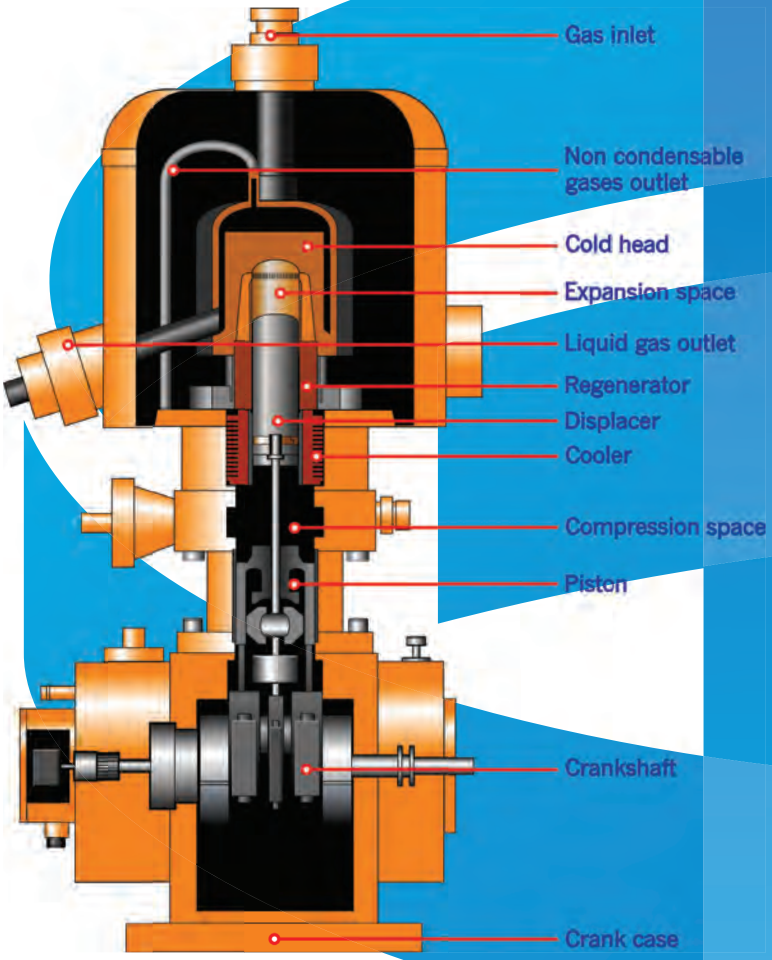
In the beginning of the 90's the Philips Cryogenic Division became independent and continued its worldwide activities under the name of Stirling Cryogenics BV.

Thanks to continuous innovation and considerable investment in R&D, the Stirling cryogenerator is now used in advanced technological machinery for cooling gases and liquids to very low temperatures (i.e. 200K to 20K).

The central element in all equipment made by Stirling Cryogenics BV (Stirling) is the Stirling cycle cryogenerator. The cycle is remarkable because it is a closed cycle in which the cryogenerator's working gas never comes into contact with the fluid to be cooled. This two-circuit approach eliminates contamination of the working gas resulting in long continuous operating periods and longevity.

The Stirling cryogenerator is extremely environmentally friendly: it does not cause ozone layer depletion in any way, does not contribute to the greenhouse effect and does not emit any harmful or toxic product. It is extremely efficient compared to other cryogenic cooling principles. Stirling is the only company in the world that successfully produces Stirling cycle-based cryogenerators with cooling powers of 1,000-4,000 watt (at 77K) per unit.





Ins and Outs

The Stirling cycle alternately compresses and expands a fixed quantity of a nearly perfect gas (also known as ideal gas) in a closed cycle. The compression takes place at room temperature to facilitate the discharge of heat caused by compression, whereas the expansion is performed at the required low temperature.

For the purpose of explanation, the process may be split up into four distinct phases illustrated in Figure 1 and each indicated by a number.

Cylinder **A** is closed by piston **B** and contains a certain amount of gas. The space inside the cylinder is divided into two sub-spaces, **D** and **E**, by a second piston **C**, called displacer,
An annular channel **F** connects spaces **D** and **E** and contains three heat exchangers: regenerator **G**, cooler **H** and freezer **J**.
In position I most of the gas is in space **D** and at room temperature. During phase **1** this gas is compressed by piston **B**. In phase **2** the gas is displaced by means of the displacer from space **D** to space **E**, which is already at a low temperature.
During this displacement the gas passes through the heat exchangers. The cooler dissipates the heat caused by compression through cooling water. The regenerator cools the gas almost to the temperature prevailing in space **E**. In Phase **3** the actual cold production takes place by allowing the precooled gas to expand through movement of the displacer and piston together. Finally, by moving the displacer (phase **4**), the gas is returned to space **D** for a new cycle to begin. While passing the freezer its cold is dissipated to the ambient environment, and in the regenerator it is reheated to nearly room temperature. The initial situation of the cycle has now been restored.

It is clear that a large temperature difference will occur between the compression space and the expansion space. The way in which this temperature difference is established and what influence the regenerator has in this is shown in the two graphs on the right.
The working gas in both the compression and expansion space is initially at ambient temperature. During the first working cycle the gas is successively cooled by the cooler and by the expansion to temperature T1.
When the expanded gas returns to the compression space, a temperature gradient is established in the regenerator. This means that, after the second compression stroke, the working gas is slightly pre-cooled in the regenerator before it is expanded in the expansion spaces to reach temperature T2.
After a number of strokes the temperature gradient in the regenerator reaches an equilibrium, which means that the working gas reaches its lowest temperature, T3 after expansion. It is obvious that the regenerator is the most important component in this cooling process.

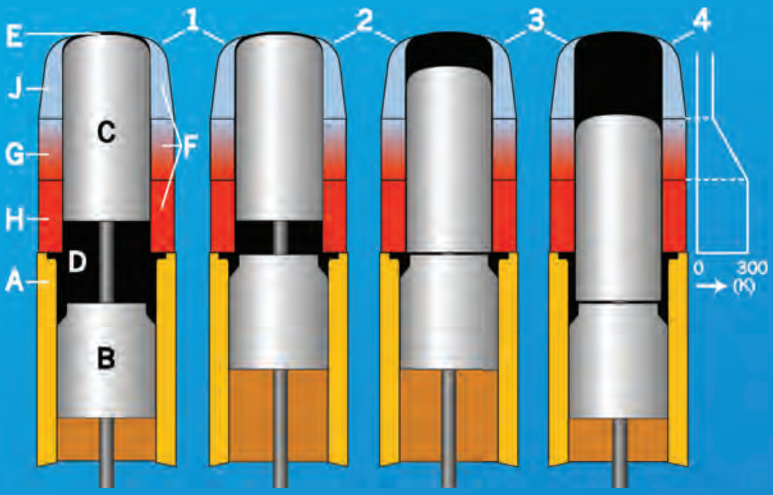


Figure 1: The four phases of the Stirling cooling cycle

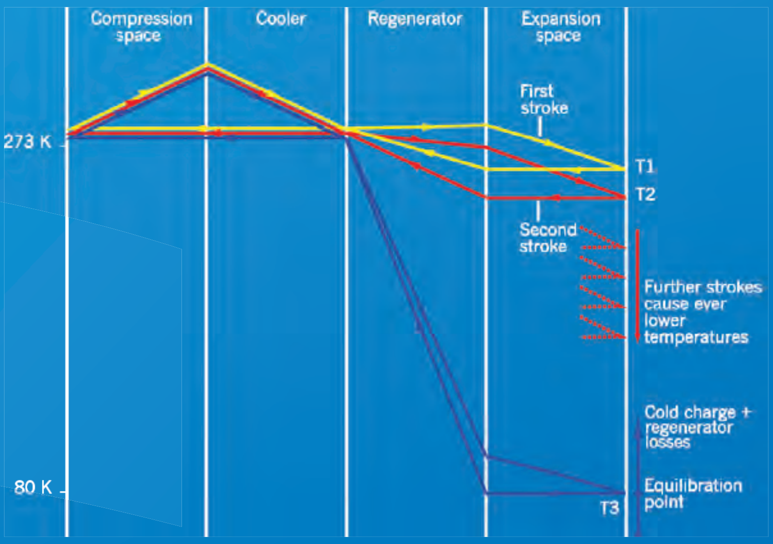


Figure 2: Temperature gradient in a one-stage cycle

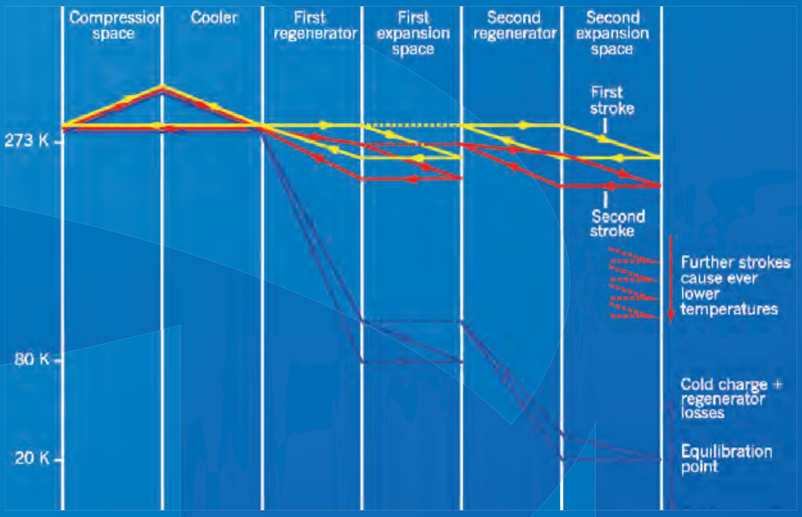


Figure 3: Temperature gradient in a two-stage cycle

STRONG BELOW ZERO

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