



**STIRLING
CRYOGENICS**

The 2-Stage Stirling Cycle

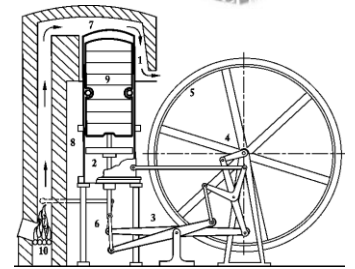
The ultimate way to generate 20-60 K cooling power

History

The Stirling cycle is a thermodynamic closed cycle invented in 1816 by the 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 steam boilers were prone to life-threatening explosions. The counterpart of the Stirling engine, the refrigerator, was first recognized in 1832.



Both machines experienced highs and lows 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 Stirling engine attracted their attention.

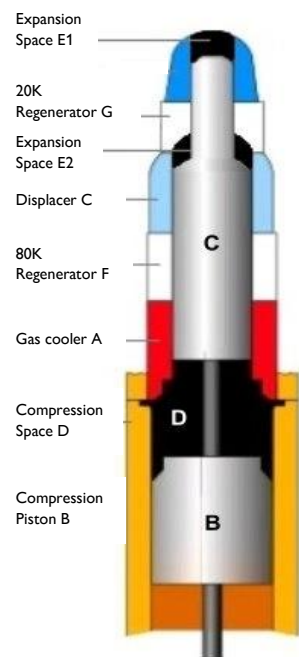
In 1946 Philips started optimizing the Stirling cycle to be used for cryogenic cooling. The result was the development of the world conquering Stirling Cryogenerator, marking the start of significant cryogenic activities at Philips. Though the Stirling engine itself never became a commercial success,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

Today

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

Stirling Cryogenics is the only company in the world that successfully produces two-stage Stirling cycle-based Cryogenerators with cooling powers of 50 – 500 Watt per unit in the 20-30 K temperature range.

Thanks to continuous innovations and considerable investment in R&D, the Stirling Cryogenerator is now used in a wide range of applications, such as using a flow of 20 - 60 K helium gas to cool research applications and industrial processes, as well as the production of liquid gases such as LH₂ and LNe.



The two-stage Stirling Cycle Stirling Cryogenerator

Stirling efficiency

The 2-Stage Stirling Cryogenerator is extremely efficient compared to other cryogenic cooling cycles. Carnot efficiency is 30%, resulting in a high practical over-all efficiency defined as Watts of cooling power available to the application divided by kW of electric input power. Depending the application's temperature, the over-all efficiency of the Stirling Cryogenerator is 4% for LH₂ liquefaction.

The central element in all equipment of Stirling Cryogenics is the Stirling Cycle Cryogenerator. The Stirling Cycle is remarkable because it is a closed cycle in which the Cryogenerators internal working gas (He) never comes into contact with the fluid to be cooled; they connect only by flow of heat through the heat-exchanger wall. This concept eliminates contamination of the customers process as well as of the Stirling Cycle working gas, resulting in long continuous operating periods and longevity.

The 2-Stage Stirling Cycle

The Stirling Cycle alternately compresses and expands a fixed quantity of helium 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 cryogenic temperature required by the application.

For the purpose of explanation, the process may be split up into four distinct piston positions illustrated in Figure 1. In position 1, all helium is at room temperature in the compression space D. Going to position 2, this gas is compressed by the piston B increasing the gas temperature to about 80°C, refer to Figure 2, column 1. When the displacer C moves down from position 2 to 3, the compressed helium gas is displaced from the compression space to the expansion spaces E1 and E2 above the displacer, forcing it first through the gas cooler A. Here the compression heat is dissipated into the cooling water, reducing the gas temperature to about 15°C (column 2). Next, the helium flows first through the 80K regenerator F. Using the cold which was stored in the regenerator by the previous cycle, the helium gas is cooled to about 80K. Part of the helium collects in expansion space E1, the rest passes through the 20K regenerator G where it is cooled to almost the final working temperature when arriving in expansion space E2 (column 3). The final and main action is the displacer and piston moving down to position 4, expanding the helium gas in both expansion spaces. This creates the actual cooling power in the cold head (column 4), cooling the customers process at both temperature levels.

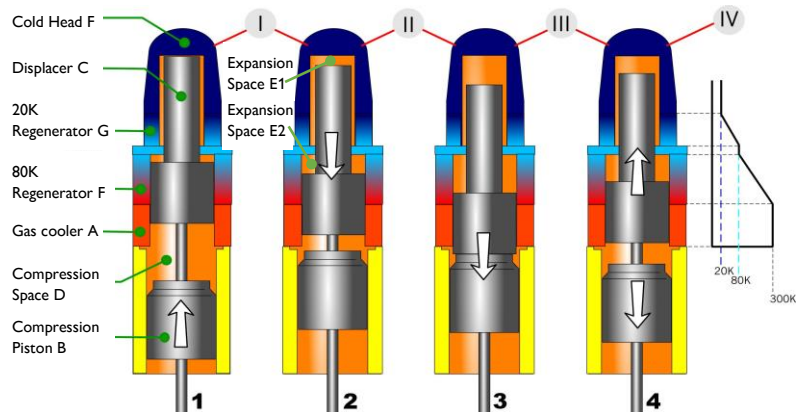


Figure 1: The Four stages of the 2-Stage Stirling cooling cycle

For a new cycle to begin, the displacer moves up to position 1, displacing the helium to the compression space again. The regenerators are cooled by the passing helium (column 3), storing cold to be used in the next cycle. The helium is re-heated to nearly room temperature so the initial situation of the cycle has now been restored for the cycle to repeat. This cycle is typically repeated at 25 Hz, providing a continuous extraction of heat.

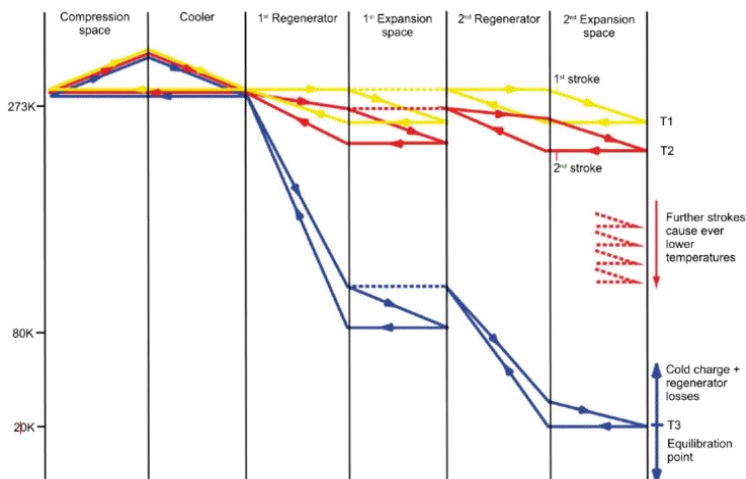


Figure 2: Temperature gradient in a single stage cycle

When starting warm, the Cryogenerator will initially first cool down itself, building up a cold buffer in the regenerator (column 3). This cool-down requires about 10 minutes only, allowing a fast start-up of the total process.

Process integration

Integration of the Stirling Cryogenerator into the process is straight-forward. Next to the utilities of power and cooling water, the in and outlet lines of the process shall be connected, through which the flow of cryogen passes to be cooled or be liquefied.