# STIRLING CYCLE REFRIGERATION

## Description of Technology

The Stirling cycle cooler is a member of a family of closed-cycle regenerative thermal machines, including prime movers as well as heat pumps and refrigerators, known collectively as Stirling cycle machines. In any refrigeration cycle, including the reversed Stirling cycle, net work input is necessary in-line with the second law of thermodynamics. This is achieved by shuttling the gas in the system backwards and forwards between the hot end and cold end spaces so that the temperature of the system during compression is, on average, higher than during expansion. As a result the work done on the gas during compression is greater than the work done by the gas during expansion, Figure 1. Accordingly, the hot end and cold end gas spaces are also referred to as the compression space and the expansion space respectively. Furthermore, for operation as a refrigerator, heat must be rejected via a heat exchanger at the hot end, and heat must be absorbed from the space to be cooled via a heat exchanger at the cold end.

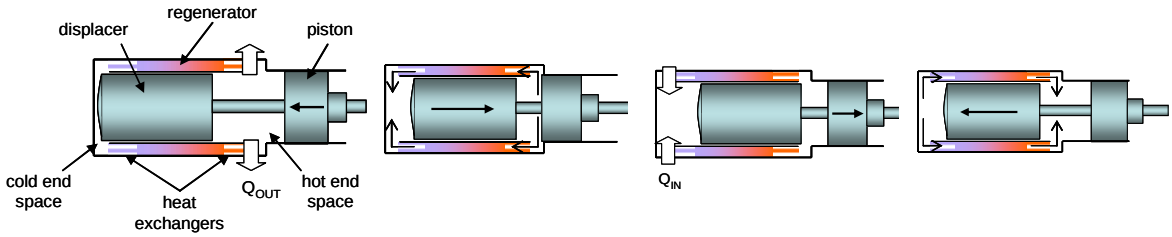


Figure 1 Piston and Displacer movements during Stirling refrigeration cycle

### State of Development

Free-piston machines (FPSC): This relatively recent development of free-piston technology, where the piston and displacer are not mechanically connected to a crankshaft, but supported by planar springs or gas springs and work transfer at the piston is achieved by employing a moving magnet linear motor, originated at Sunpower but is now led by Global Cooling. FPSCs are compact, helium filled (to 20-30 atm), hermetically sealed Stirling refrigeration machines. Heat exchangers must be attached to the cold and warm heads of the FPSC unit to facilitate heat absorption and heat rejection respectively. FPSC units with nominal maximum cooling capacities of 40 W and 100 W have been produced, with larger capacity units, up to 300 W, reported to be under development. FPSCs have been evaluated experimentally by Global Cooling and appliance manufacturers for application to domestic and portable refrigerators and freezers as well as a beverage can vending machine. FPSC based products, including freezer boxes and a system for the marine refrigeration market, have been developed by licensees. Coefficients of performance measured for FPSCs with warm head temperatures close to 30°C vary with the cold head temperature. Values of *COP* between 2 and 3 have been reported for cold head temperatures around 0°C, and values around 1 for cold head temperatures approaching -40°C.

## Applications in the food sector

FPSCs can operate down to cryogenic temperatures and hence can be used in many food refrigeration applications. Current limitations are the low cooling capacities, lower COP and higher cost compared to the vapour compression cycle. Market for FPSCs in the food sector is likely to be domestic and portable refrigerators and freezers as well as beverage can vending machines and other integral refrigerated display equipment

## Barriers to uptake of the technology

The main barriers to uptake of Sterling cycle refrigeration technology are:

- currently only small capacity units are available which in their present state of development cannot compete on price and efficiency with vapour compression systems.

- application of FPSC machines is tightly controlled by Global Cooling which determine the areas of application through licensing of the technology.

### Key drivers to encourage uptake

The main drivers to encourage uptake of the technology in the food sector are:

- legislation that significantly limits or prohibits the use of HFCs in small capacity, self contained refrigeration equipment.
- limits imposed on the amount of flammable refrigerant that can be used in self contained refrigerated cabinets

### Research and development needs

Wider application of FPSCs to the food sector will require higher cooling capacities and higher system COPs. Important areas of research are:

- development of higher efficiency linear motors and design to increase cooling capacity,
- improved heat exchange on the cold and hot sides and better system integration.