# EuroDish – Stirling

## *System Description*


**Schlaich Bergermann**
**und Partner GbR**

Structural Consulting Engineers

**Stuttgart; June, 2001**

# Content:




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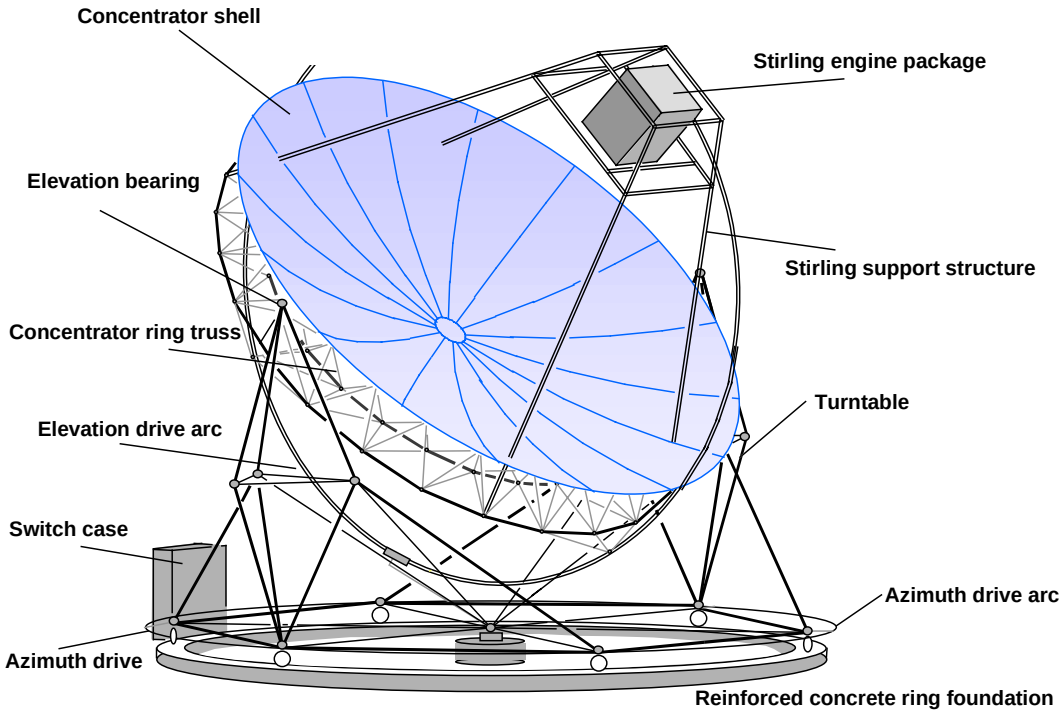
# 1. The Dish-Stirling System

Dish-Stirling Systems are small power generation sets which generate electricity by using direct solar radiation. The capacity of a single unit is typically between 5 and 25 (50) $kW_{el}$. This size and the modularity of the single units qualifies the Dish-Stirling system for very flexible applications. They are ideal for stand-alone or other decentralised applications. In clusters with a capacity of up to 10 MW, Dish-Stirling systems are even expected to meet moderate-scale grid-connected demands.



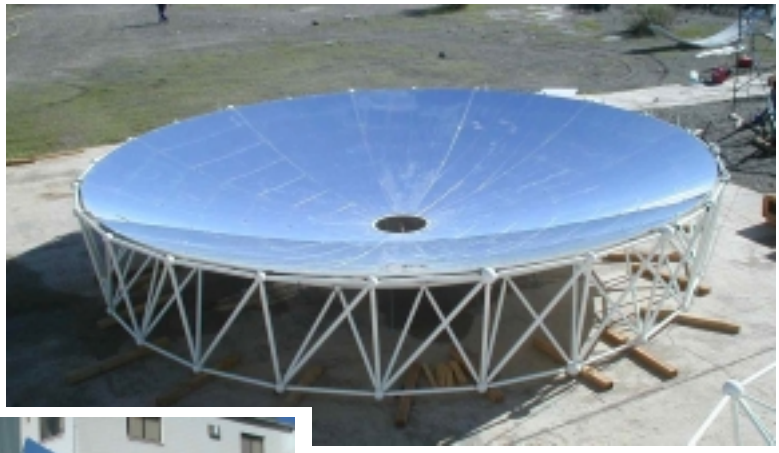

***Dish-Stirling Systems*** transfer concentrated solar radiation with high efficiencies into electrical energy. Essentially the system consists of the following components:

- Parabolic solar concentrator
- Tracking system
- Solar heat exchanger (Receiver)
- Stirling engine with generator

The parabolic concentrator reflects the incoming solar radiation onto a cavity receiver which is located at the concentrator's focal point. The solar radiation is absorbed by the heat exchanger (receiver) and thus heats the working gas (helium) of the Stirling engine to temperatures of about 650°C. This heat is converted into mechanical energy by the Stirling engine. An electrical generator, directly connected to the crankshaft of the engine, converts the mechanical energy into electricity (AC). To constantly keep the reflected radiation at the focal point during the day, a sun-tracking system rotates the solar concentrator continuously about two axes to follow the daily path of the sun.

The electrical output of the system is proportional to the size of the reflector, its optical losses and the efficiencies of the Stirling engine and the generator.

# 2. The Concentrator



Generally speaking ***the concentrator*** delivers the fuel for the Stirling engine. It reflects and concentrates the direct solar radiation in the so-called focal point. For the operation of the Stirling engine, temperatures as high as possible are desired. Therefore a large point-focus concentrator with an axial symmetrical shape is used for this system.

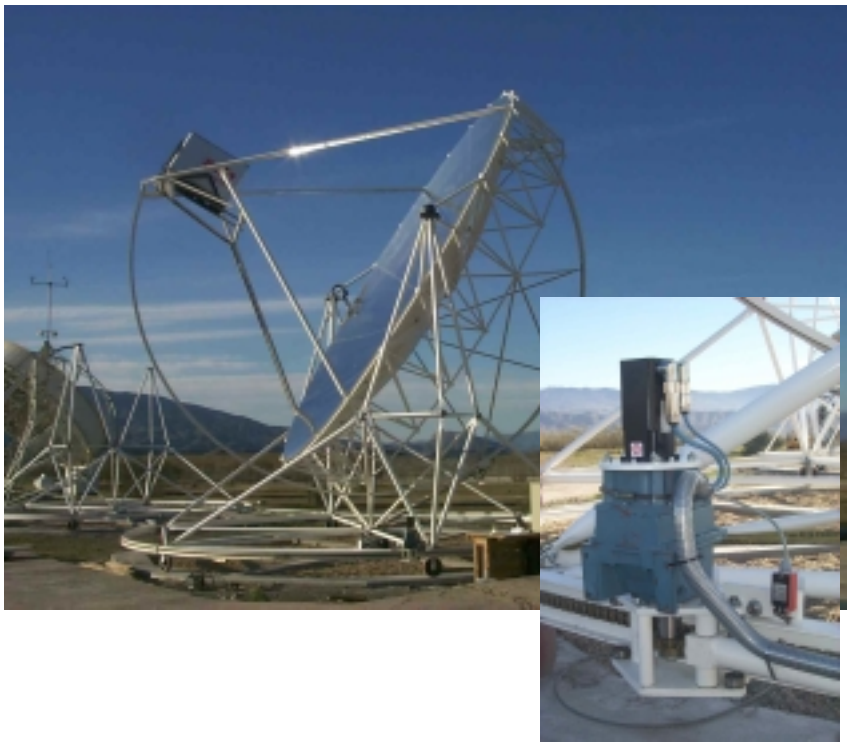
The concentrator consists out of 12 single segments made out of glass fibre resin. When mounted the segments form a nearly perfect parabolic shell. The rim of the shell is stiffened by a ring truss to which later on the bearings and the Stirling support structure are attached.

Thin glass mirrors, 0.8 mm thick, are glued onto the front side of the segments in order to obtain a durable high reflectivity of around 94%.

# 3. The Tracking System

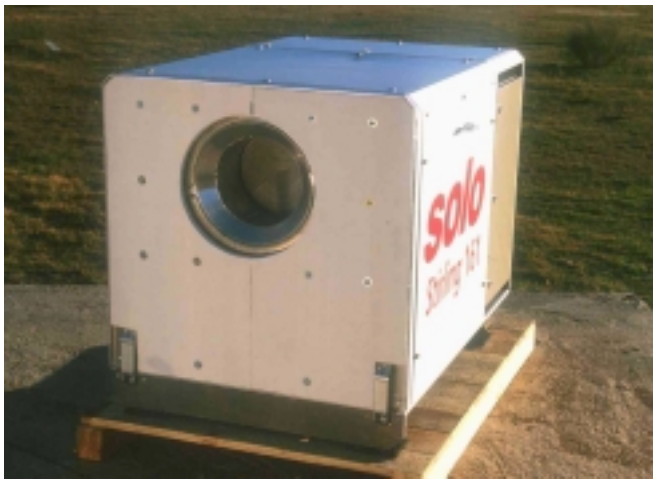
Since the concentrator always needs to be perfectly oriented towards the sun, it is mounted on a ***two-axial tracking*** system. Therefore a simple movable steel construction standing on six wheels has been developed. Both the horizontal and the vertical orientation of the concentrator is done by a small servomotor.

The orientation towards the sun is either determined by a sun tracking sensor, or by a special computer program which predicts the position of the sun.

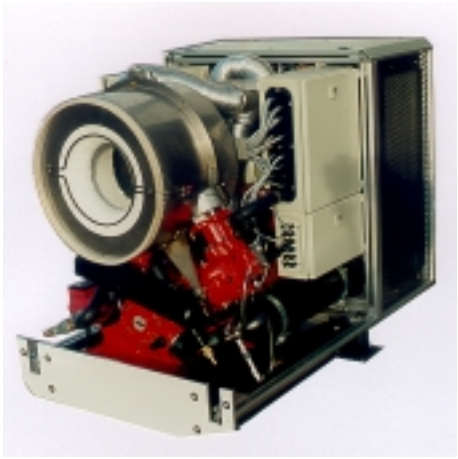


# 4. The Stirling - Engine

***The Stirling cycle*** is the most efficient thermodynamic cycle to transform heat into mechanical or electrical energy. As far back as in 1826 the Stirling engine was invented by the Scottish Rev. Robert Stirling. In the 19th century thousands of engines of this type had already been in use. The Stirling engine has some extraordinary properties:



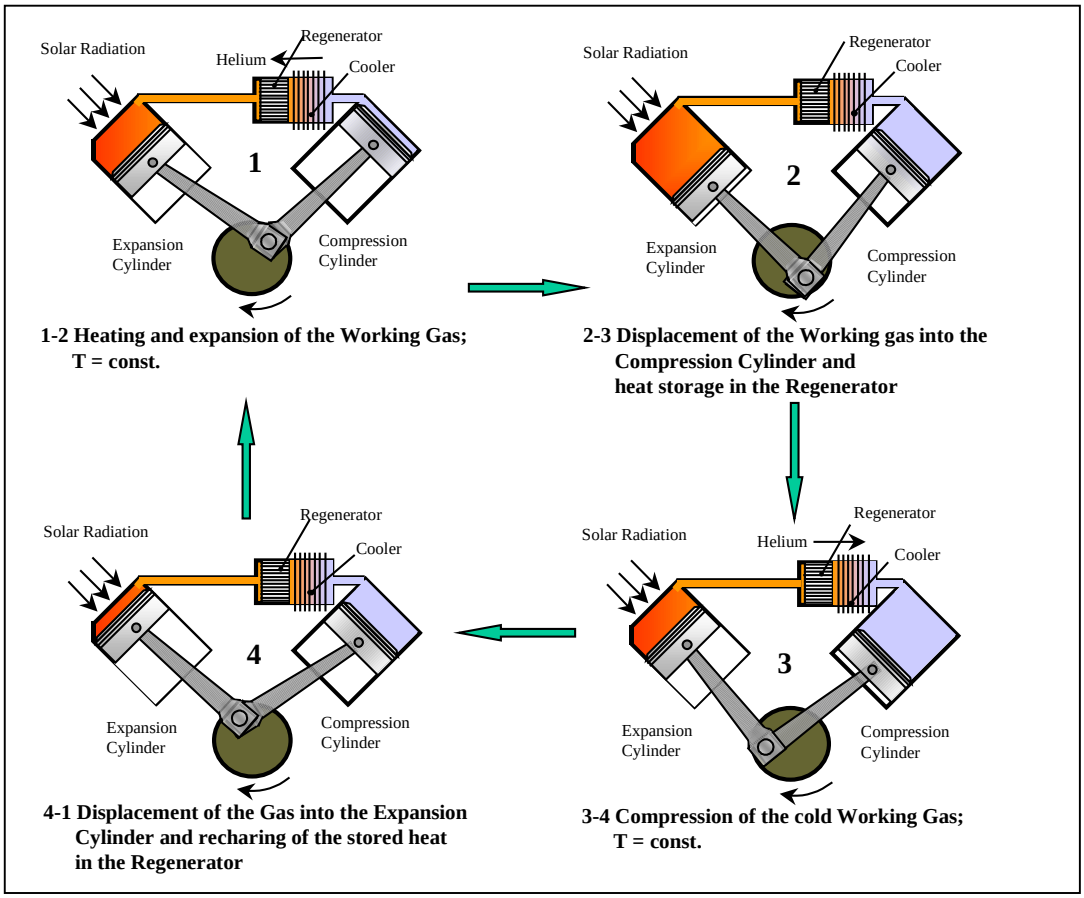

- Compared to an Otto or Diesel engine, which runs on internal combustion, the Stirling engine depends only on external heat supply, with no preference on how the heat is generated. Thus the Stirling engine is the ideal candidate to convert solar heat into mechanical energy.
- In the Stirling engine a constant amount of working gas (helium or hydrogen) is constantly heated and cooled. Due to expansion when heated and contraction when cooled, the working gas sets two pistons in motion, which both are connected to a crankshaft, and thus delivers energy.
- Since the efficiency of the Stirling engine increases with increasing upper process temperature, this engine is the ideal combination to produce energy with a solar collector.
- As there is no internal combustion, this engine produces almost no noise.
- The potential life-cycle of a Stirling engine is extraordinarily high since there is no internal pollution of pistons and bearings due to combustion of fuels.
- Due to the flexibility of the heat source, a Stirling engine can also be operated with a hybrid receiver. This means that with an additionally installed burner, the required heat can also be generated with fossil fuels (Bio-gas etc.).Thus the system is also available during cloudy periods and during night-time.



Schlaich Bergermann und Partner (SBP) together with SOLO developed the V160/V161 Stirling engine seen in the pictures. This is currently the most reliable and most advanced Stirling engine available (Picture with solar-only receiver).

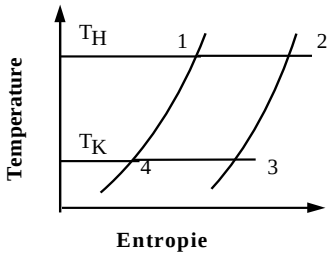
As a hybrid operated system, especially when using Bio-gas as additional energy source, the Dish-Stirling system fulfils all the requirements which can be demanded from a future oriented, environmentally friendly energy system.

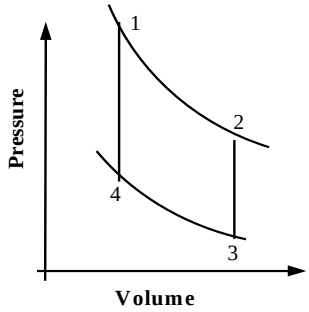
# 5. Function of the Stirling Engine




In the most simple version, a Stirling engine consists of a sealed system with two cylinders (expansion and compression cylinder) filled with a working gas (helium). The pistons of these cylinders are connected to one crankshaft. If now the working gas in the expansion cylinder (working cylinder) is heated (by the sun) it will expand due to the increasing temperature; pushes the piston down (1-2) and thus induces power. Part of this power is now used to push the hot working gas from the expansion cylinder into the compression cylinder (2-3): On its way the working gas passes through a regenerator where a major part of its heat is stored and also through a water cooled gas cooler, where it will be cooled further down. (2-3).Once completely in the compression cylinder, this piston will return due to the inertia of the crankshaft, and the working gas is compressed at low temperature (3-4). By reabsorbing the heat stored in the regenerator the gas is pushed back into the working cylinder. (4-1).

Overall the expansion of the hot gas in the working cylinder delivers more energy than is needed for the compression of the cold gas in the compression cylinder. This surplus of energy can be used to operate an electric generator which is directly hooked to the crankshaft of the engine.



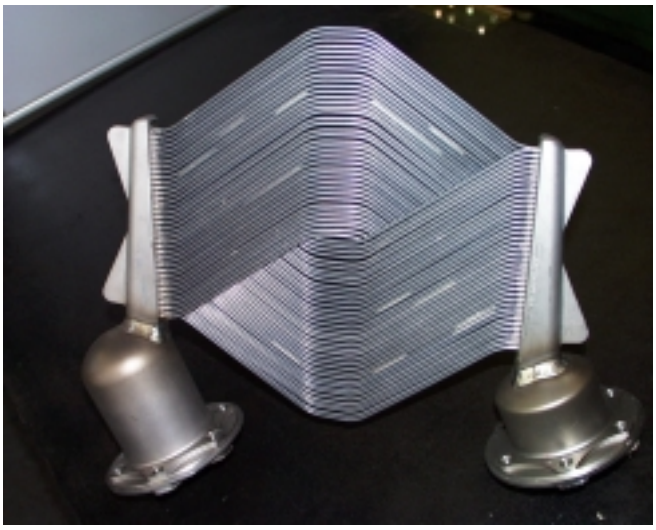



# 6. The Receiver: Link between Collector and Engine

The receiver is the link between the concentrator and the Stirling engine. It has essentially two tasks:

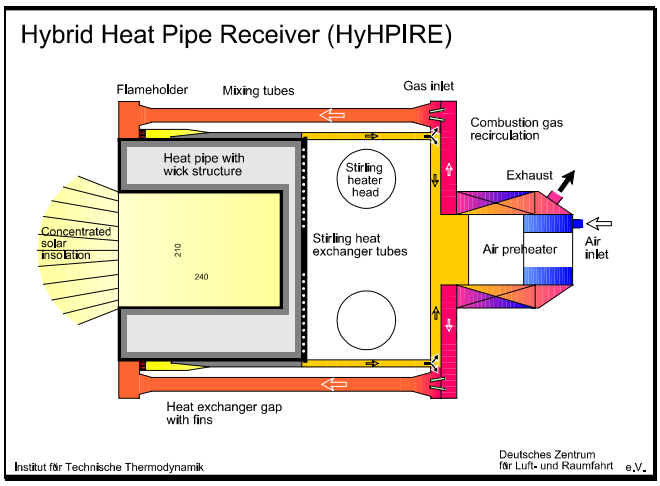
1. To absorb as much of the solar radiation reflected onto it from the concentrator as possible.
2. To pass on this absorbed energy to the Stirling engine in form of heat with the least possible losses.

In general there are two types of receivers. One type is a solar-only receiver which can only be operated during sunshine. The other type is a hybrid receiver which is additionally equipped with a gas burner and can be operated the whole day.



**Solar Receiver for the SBP/SOLO V-160/161 Stirling engine**

As solar-only receiver, a tube receiver was developed which is directly connected to the cylinder heads of the Stirling engine. The receiver consists of very thin tubes, approx. 3mm in diameter, which resist very high temperatures. They form an almost closed area which is the absorber surface. The concentrated solar radiation heats the working gas to approx. 650°C.




**Hybrid Receiver (DLR)**

In addition to the solar absorbing surface, the hybrid receiver is equipped with a gas burner. Thus the Stirling engine can be operated during times when the sun is covered with clouds or even in darkness. The hybrid Dish-Stirling system thus has the advantage of being available 24 hours a day. Therefore this system can be the ideal substitute for Diesel engines which are currently used to high numbers.

# 7. Technical Data

## Concentrator

| | |
|---|---|
| Diameter | 8.5 m |
| Projected area | 56.7 m² |
| Focal Length | 4.5 m |
| Average concentration factor | 2500 |
| Reflectivity | 94 % |

## Tracking and Control

| | |
|---|---|
| Suspension | azimuth |
| Stow position | face down |
| max. allowable wind velocity during operation | 65 km/h |
| Survival wind velocity in stow position | 160 km/h |
| Drive | servo motor |
| Drive velocity | 60 °/min. |
| Control system | PC, micro controller |
| Data transfer | InterBus-S |
| Remote control | telephone / WWW |

## Partners

Schlaich Bergermann und Partner; D
SOLO Kleinmotoren GmbH; D
Klein+Stekl GmbH; D
MERO-Raumstruktur GmbH&Co; D
DLR eV; D
Inabensa SA; ES
CIEMAT; ES

## Stirling engine

| | |
|---|---|
| Type | single acting, 90° V-engine |
| Swept volume | 160 cm³ |
| Gross power output | 9 kW |
| Net power output | 8.4 kW |
| Grid connection | 400 V, 50 Hz, 3 phase |
| Receiver gas temperature | 650 °C |
| Working gas | helium |
| Gas pressure | 20-150 bar |
| Power control | pressure control |

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| Partner in the co-operation | Contact person | Address |
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