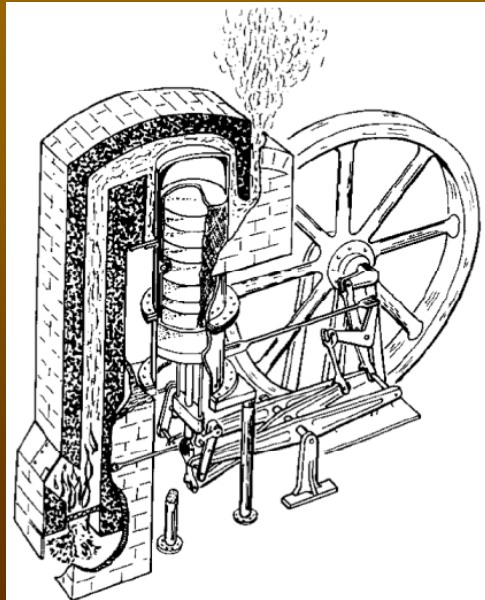




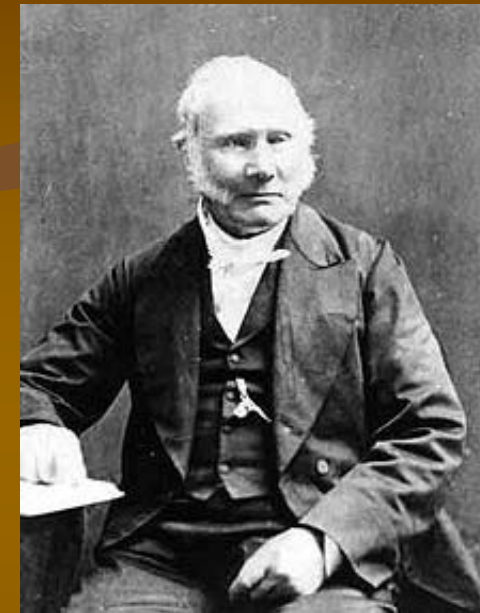
Wood gas suitability for stirling engine

History

Engine type, invented by a Scottish minister Robert Stirling in 1816. He received a patent invention in 1817. In the first hot-air engine was a vertical cylinder with a diameter of 60 cm. The engine produced 1.5 kW of power. The machine worked two years before the hot cylinder head burned out. Wear and sealing of the cylinder was a problem.



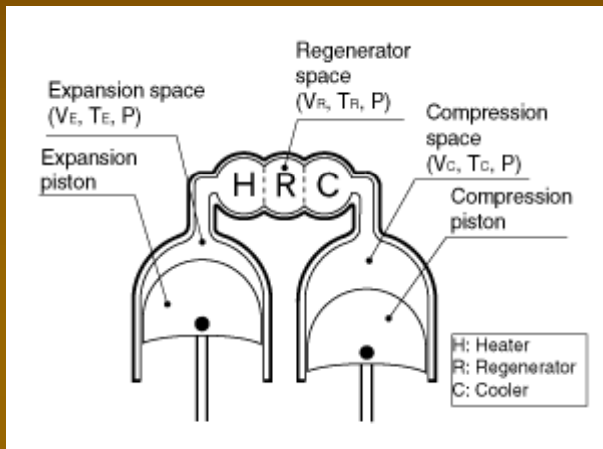
Hot air engine



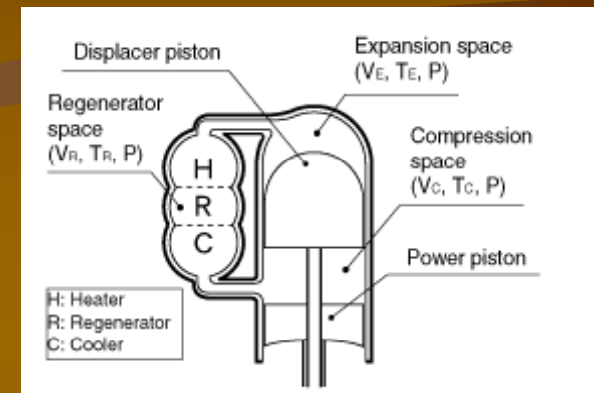
Robert Stirling
1790-1878



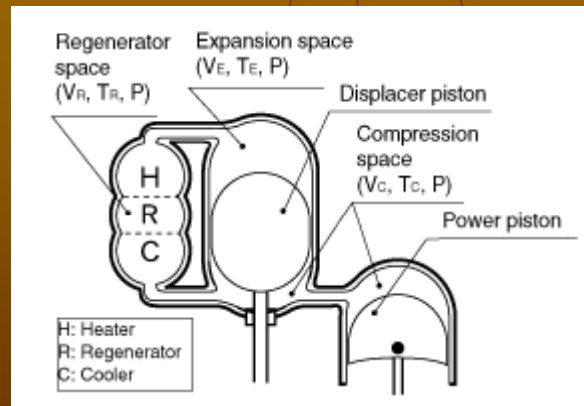
Wood gas suitability for stirling engine



Alpha-type Stirling Engine



Beta-type Stirling Engine



Gamma-type Stirling Engine



Wood gas suitability for stirling engine

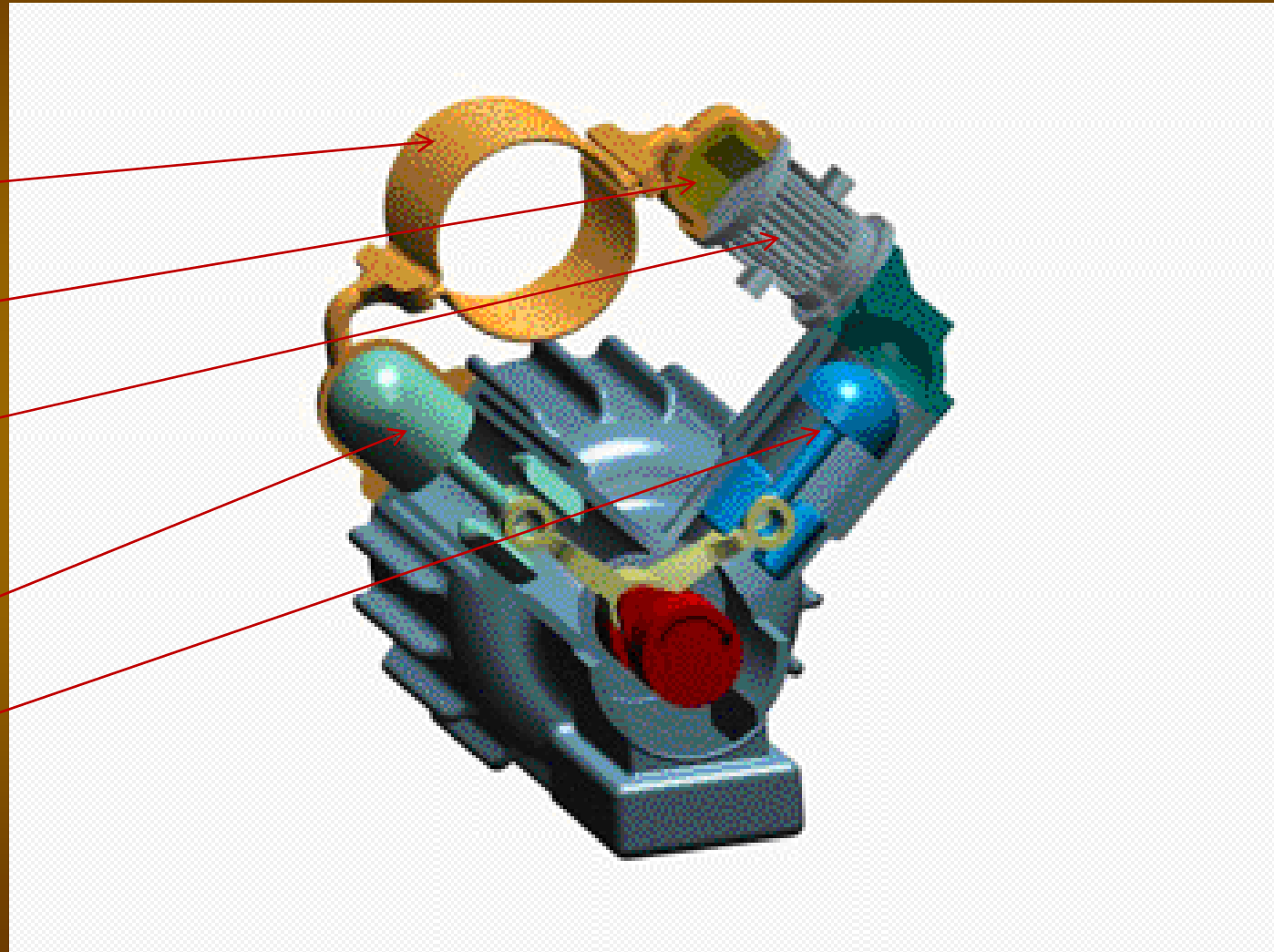
"Crown"

Regenerator

Cooler (heat exchanger)

Expansion piston

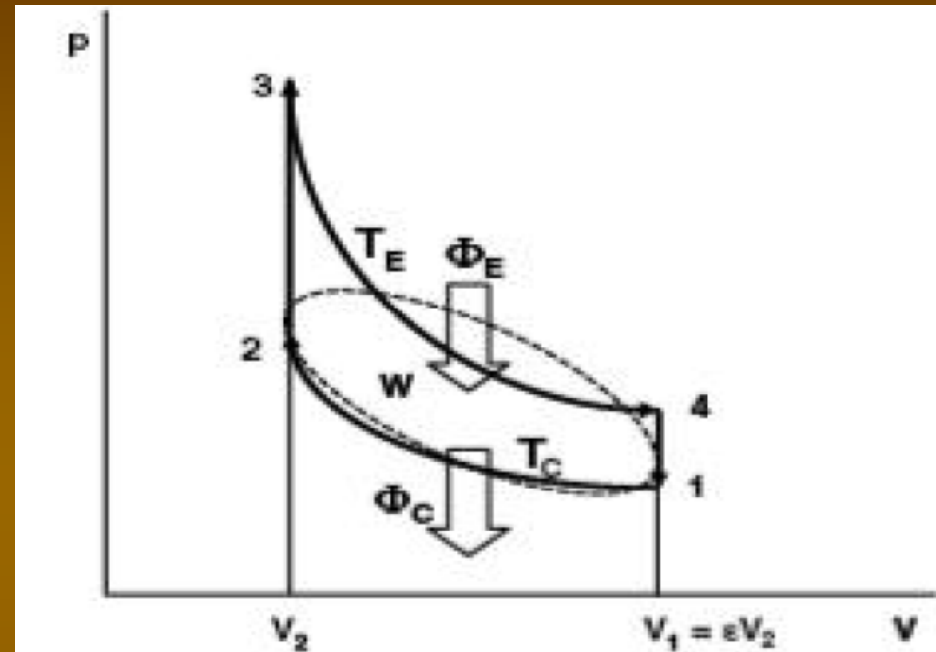
Compression piston





Wood gas suitability for stirling engine

PV process of
an ideal Stirling-cycle



1- 2	gas compressed to higher pressure at a constant temperature
2- 3	gas heated to higher temperature at a constant volume
3- 4	gas expands at a constant temperature
4- 1	gas cooled to lower temperature at a constant volume



Wood gas suitability for stirling engine

CENTRIA`s modificaton

Heat exchanger

Stirling engine

Gas burner
Bentone BG 300

Pipe of wood gas



Yrjö

Kauko

Mauri



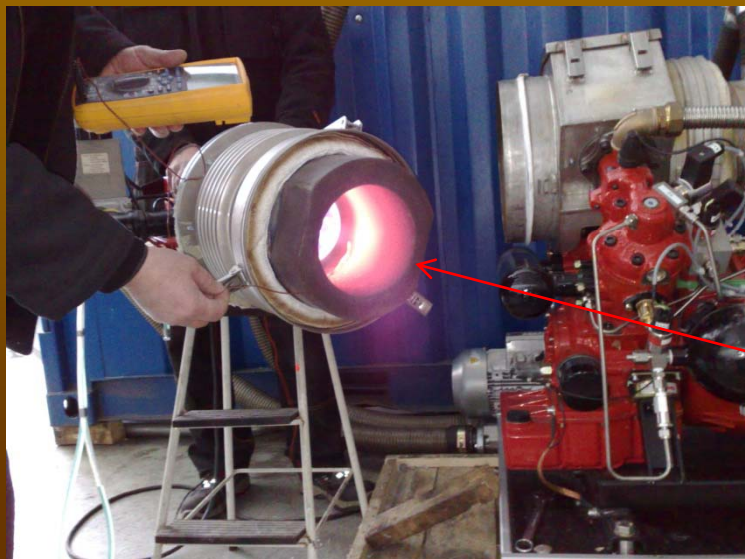
Wood gas suitability for stirling engine

CENTRIA`s modifacaton

"Crown"

Blower

Gas burner
Benton

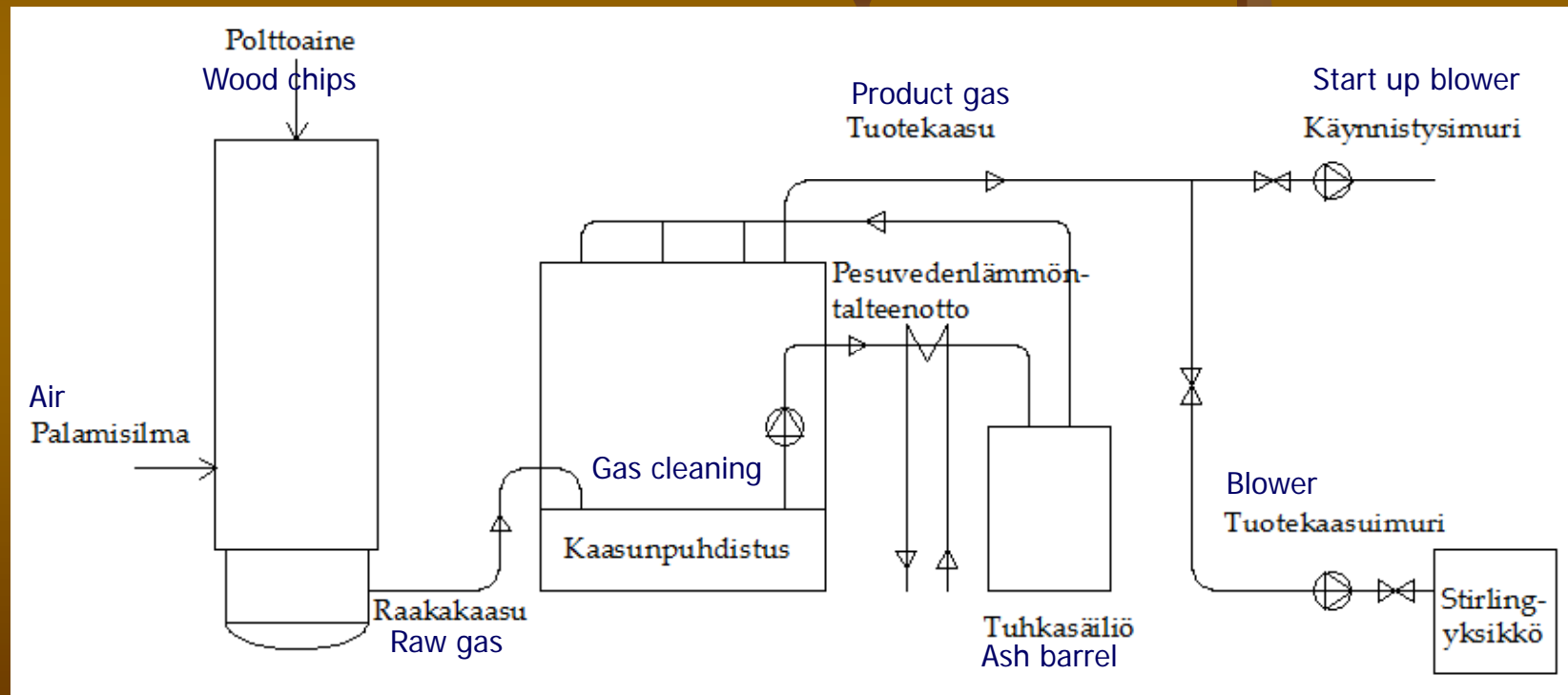


Flame 1000°C



Wood gas suitability for stirling engine

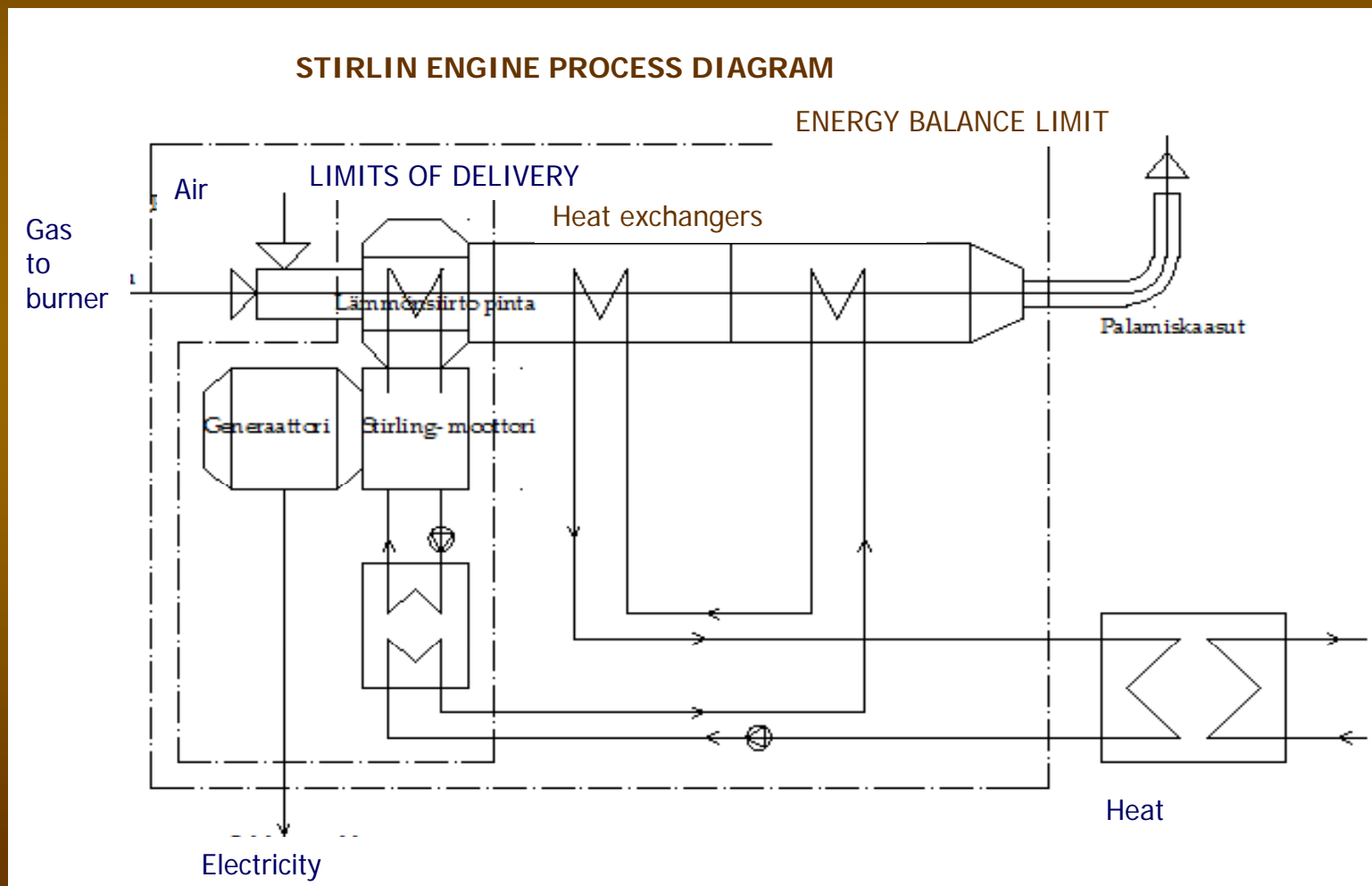
CENTRIA`s modifacaton





Wood gas suitability for stirling engine

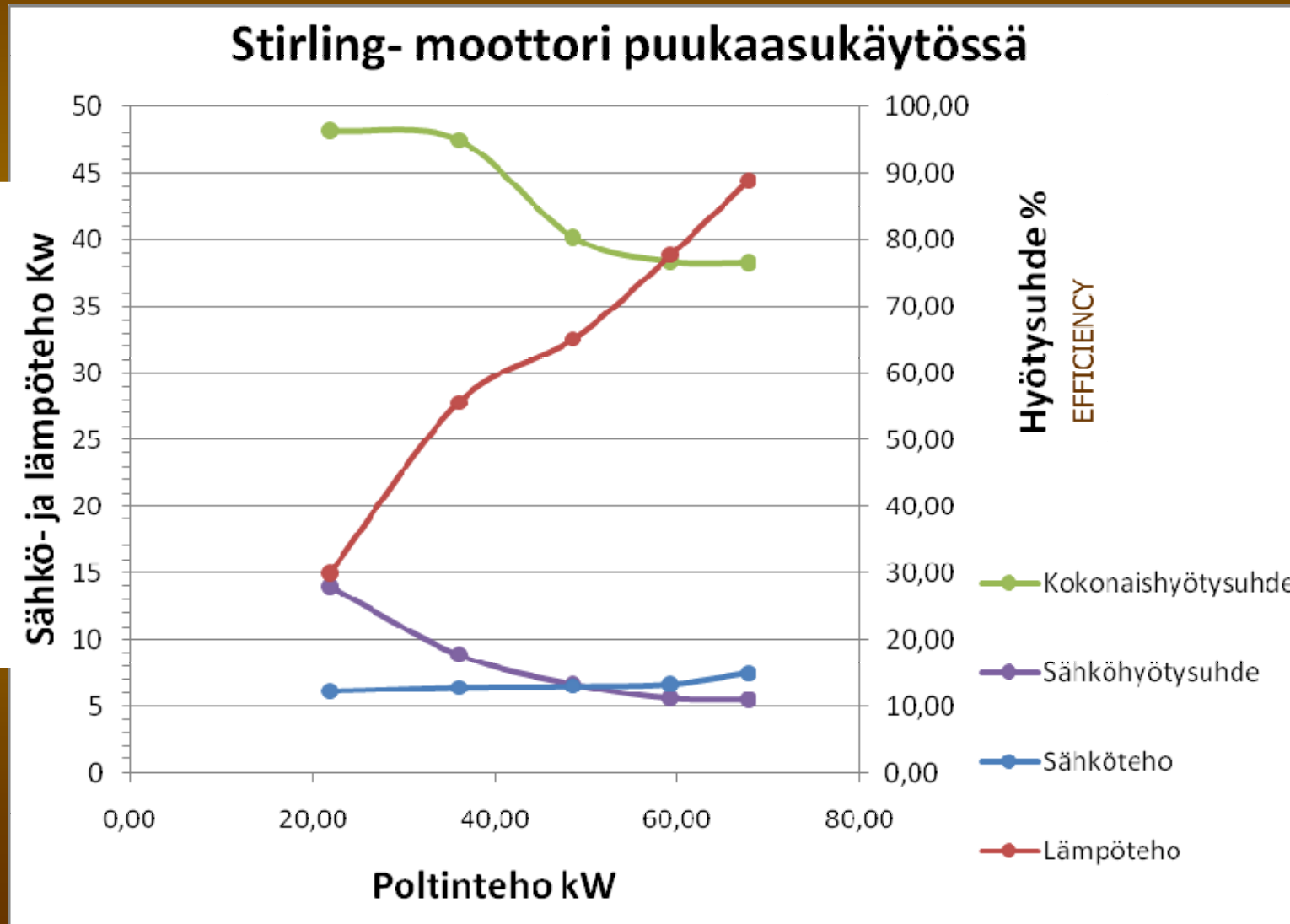
CENTRIA`s modificaton





Wood gas suitability for stirling engine

MEASUREMENTS and RESULTS



ELECTRICAL AND THERMAL POWER

Sähkö- ja lämpöteho Kw

Poltinteho kW

Hyötysuhde %
EFFICIENCY

- Kokonaishyötysuhde
- Sähköhyötysuhde
- Sähköteho
- Lämpöteho



Wood gas suitability for stirling engine

GASEOUS EMISSIONS

Input: Wood gas

Gas:		%
Nitrogen	N ₂	57,99
Hydrogen	H ₂	14,20
Carbon monoxide	CO	11,19
Methane	CH ₄	1,33

Burner -> Stirling -> Electricity + Heat


Output: Exhaust

H ₂ O	9,1 til%
CO ₂	9,0 til%
CO	0,0 ppm
N ₂ O	4,0 ppm
NO	23,2 ppm
NO ₂	0,7 ppm
SO ₂	7,6 ppm



Wood gas suitability for stirling engine

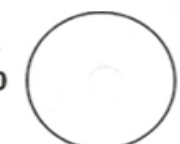
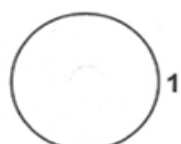








DUST EMISSIONS acc. ASTM: D2156-80 / DIN 51402



Sample is sucked ten times with the pump through a filter paper, filtering point color compared to the reference value

Samples one and two correspond to the value zero or one.

Smoke Gauge
Russezahl-Vergleichsskala
Echelle

0			1
2			3
4			5
6			7
8			9



Wood gas suitability for stirling engine

Combustion of wood gas is very clean

Contamination of the crown has been an obstacle to the use of biofuels.

Upper picture shows the situation before use.

Lower picture is after forty hours test period.





Wood gas suitability for stirling engine

Thank you for your interest!

yrjo.muilu@centria.fi

kari.pieniniemi@centria.fi

kauko.jarva@cou.fi

mauri.niskanen@cou.fi

Source: Thesis KPAMK 2011. Kauko Jarva, Mauri Niskanen.
STIRLING-MOOTTORI PUUKAASUKÄYTTÖSSÄ