Stirling Cryocooler

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-Luis Gardetto
-John WIley
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Project Description

Design and build a benchtop demonstration device that utilizes a Free Piston Stirling Cryocooler (FPSC).

Experimental model will explore thermodynamic properties of Stirling Cycle with variable inputs, to be used within Experimental Methods Laboratory (ME 495)

Client: Dr. David Trevas

Technical advisement: David Willy

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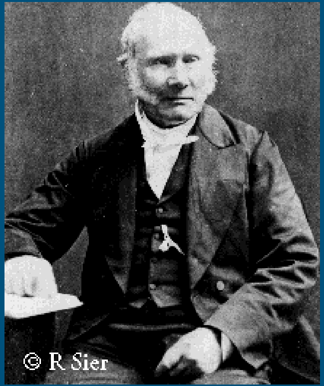
09 - 21 - 2018

Stirling Engines 101

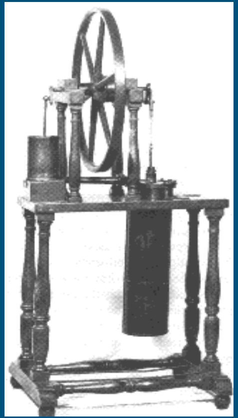
The Stirling Cycle engine creates work from a differential temperature provided by external combustion.

Parts include: power piston, displacer to shuttle air between hot and cold ends, regenerator material.

Rev Robert Stirling D.D, Robert Sier, Chelmsford, 1995 ISBN 0-9526417-0-4



Rev Dr Robert Stirling (1790-1878)



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Existing Design

Experimental Apparatus built by Global Cooling in operation at University of Ohio.

Basic Design Concept reverses Stirling Engine cycle by adding power via 120 VAC linear motor and removing heat at the “Cold Head”

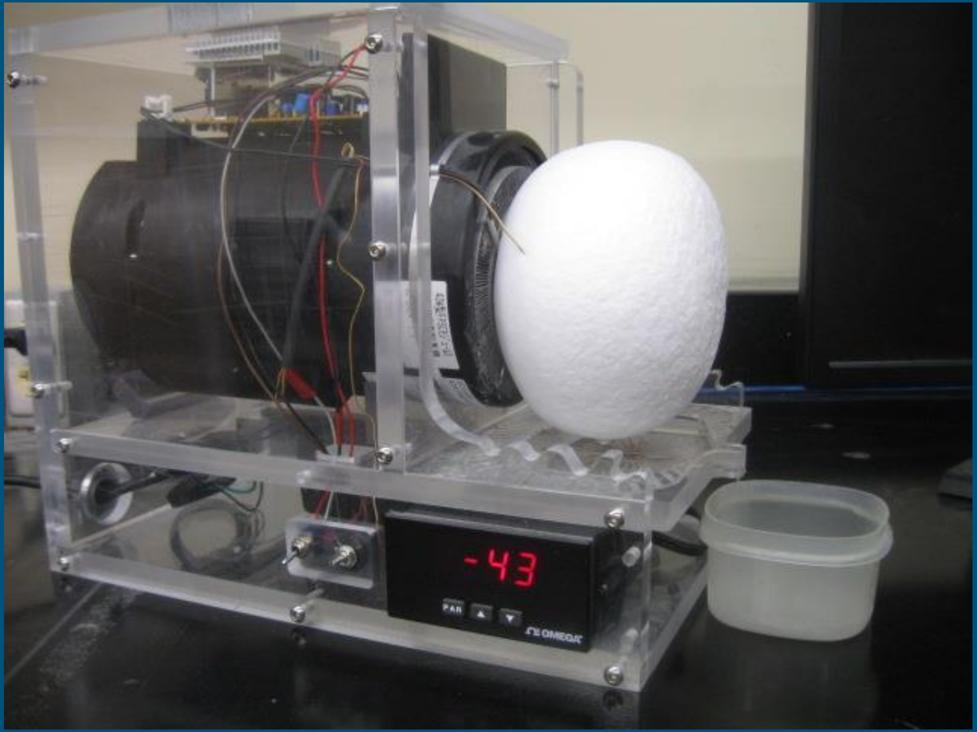
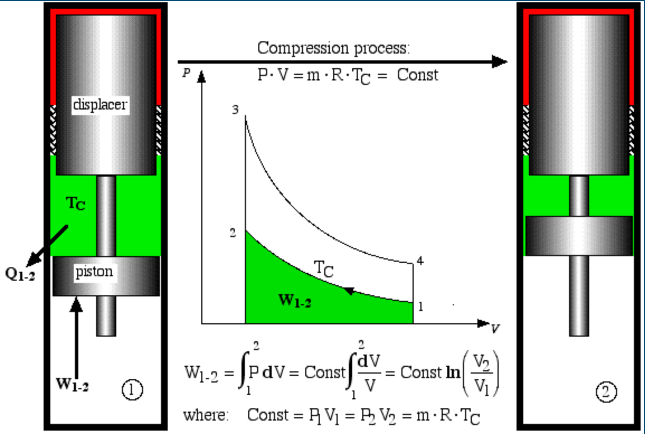
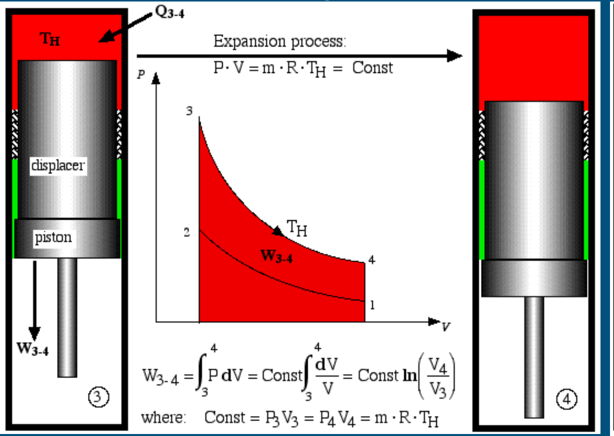
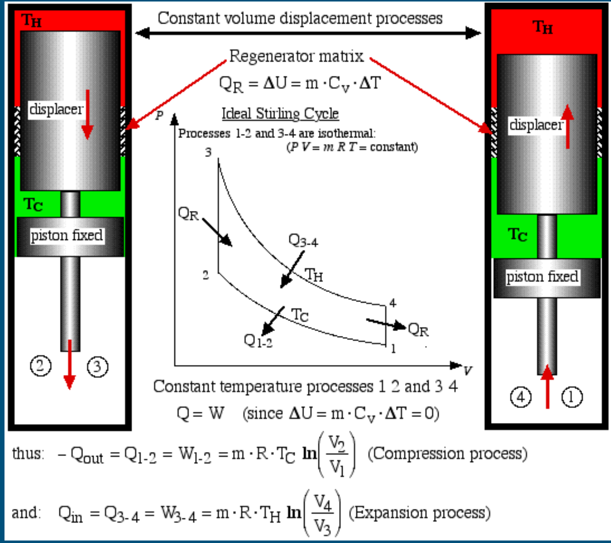


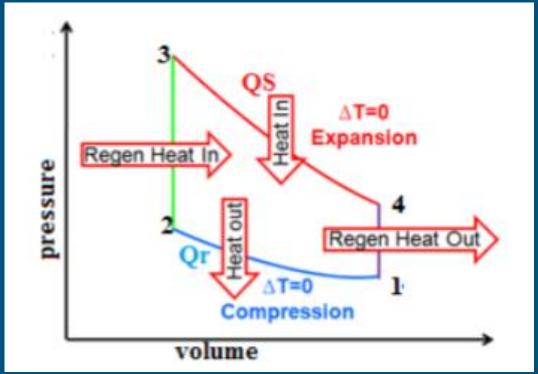
Photo courtesy of Global Cooling

Stirling Engine thermodynamic model









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Engineering Requirements

Engineering Requirement	Target Value
Vessel Pressure	$>$ 1 MPa
Power Input	~2 kW
Regenerator Porosity	$> 40; < 70$
Regenerator Specific Heat	$> 0.4 \frac{\mathrm{J}}{\mathrm{g} * \mathrm{K}}$
Regenerator Packing Factor	> 40
Insulation Material Specific Heat	$> .3 \frac{\mathrm{kJ}}{\mathrm{kg} * \mathrm{K}}$
Regenerator Material Conductivity	$> 14 \frac{\mathrm{W}}{\mathrm{m} * \mathrm{K}}$
Number of Seals	< 4
Frequency	$>$ 30 Hz; $<$ 100 Hz
System Volume	$< .1\ m^3$

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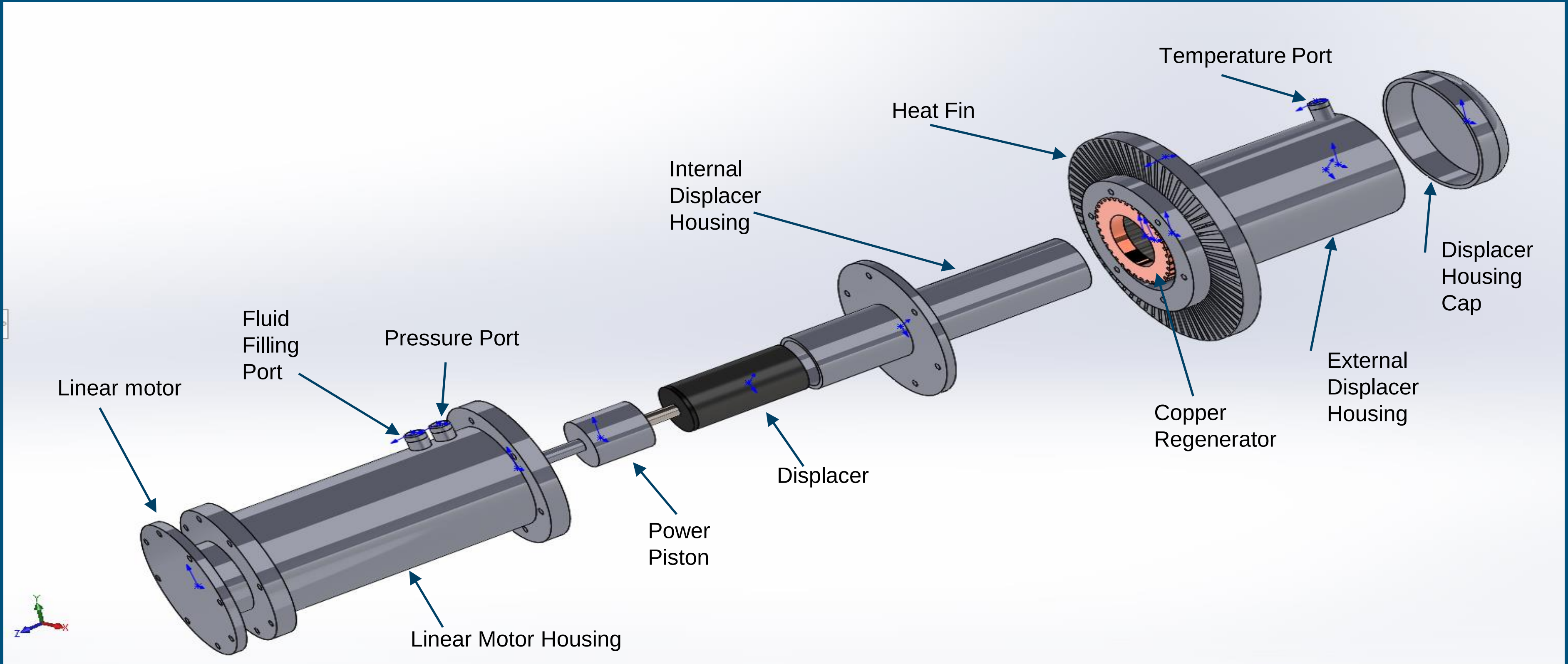
CAD Assembly



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Design Implementation

- Direct Drive Linear Motor (AC or DC pending cost analysis)
- Motor control (VFD or Power Supply with voltage potentiometer)
- Air or Helium working fluid (interchangeable)
- Regenerator material interchangeable (built as a cartridge)
- Thermocouple sensors (Arduino MEGA2560/Thermal Shield)
- Pressure sensor within main body (TBD)
- Data logging capability (Arduino MicroSD card Breakout Board)
- LCD display (Arduino 1602 Module)
- Lightweight polymer piston/displacer with stainless steel internal shaft
- Main housing aluminum/stainless tubing with flanged fittings

Project Strategy

- Reverse engineer existing FPSC
- Disassembly and testing
- Inner geometry dimensions
- Material selection
- Device functionality
- Use of existing motor drive to power upcoming prototypes

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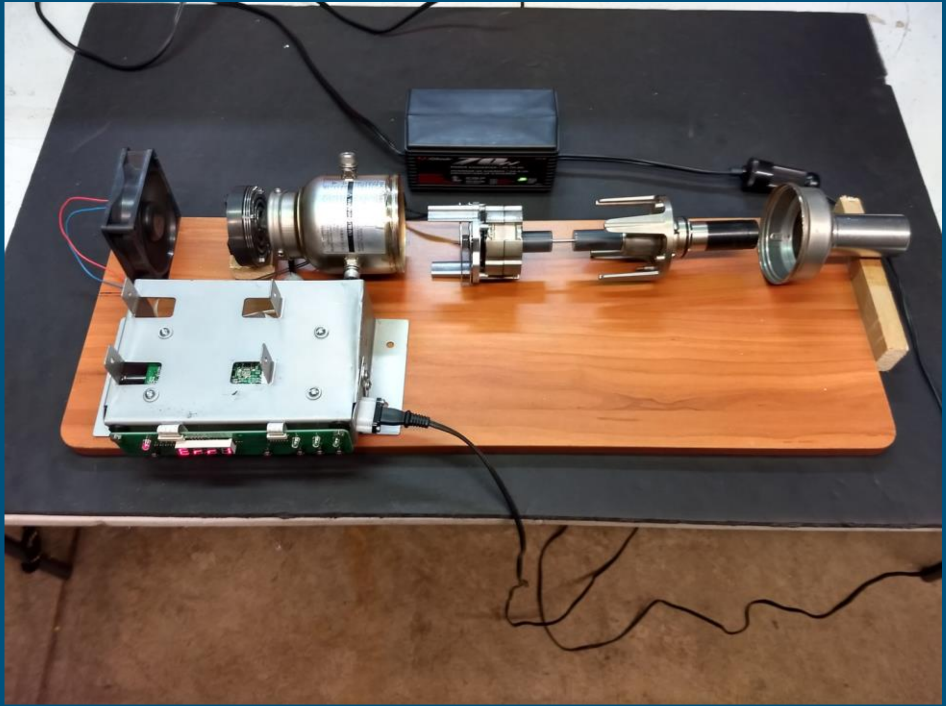
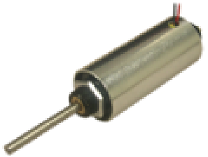
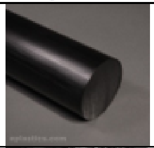
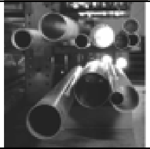
Manufacturing Strategy

- Parts requiring lathe machining: Engineering Fabrication Shop 98C
- Parts requiring CNC fabrication: Transmission Guitar Co.



Bill of Materials

- Purchase of these items pending final specification

Item #	Description/Source	Image	Est. Cost
1	DDLM-019-044-01 Direct Drive Linear Motor Actuator - Economy Series		$321.59
2	Voltage Regulator Speed Control Driver		$26.99
3	1.000" Dia. Black Acetal Rod (ABS)		$3.22/ft
4	SST-400 4" OD Stainless Steel Tubing		$36.50/ft

$388.20

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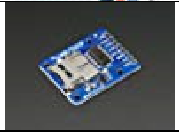
Items Purchased So far

- Obtained for reverse engineering, research, and testing
- Project total with current BOM estimate: $858.12

1	Envirocooler ActiVault 25L4C Cooler -A Jarden Life Science Brand-12V		$377.25
2	Schumacher PC-6 120AC to 6A 12V DC Power Converter		$16.53
3	MAX6675 Module + K Type Thermocouple Temperature Sensor Thermocouple		$6.99
4	Elegoo EL-KIT-008 Mega 2560		$59.99
5	Adafruit MicroSD card breakout board+ [ADA254]		$9.16

$469.92

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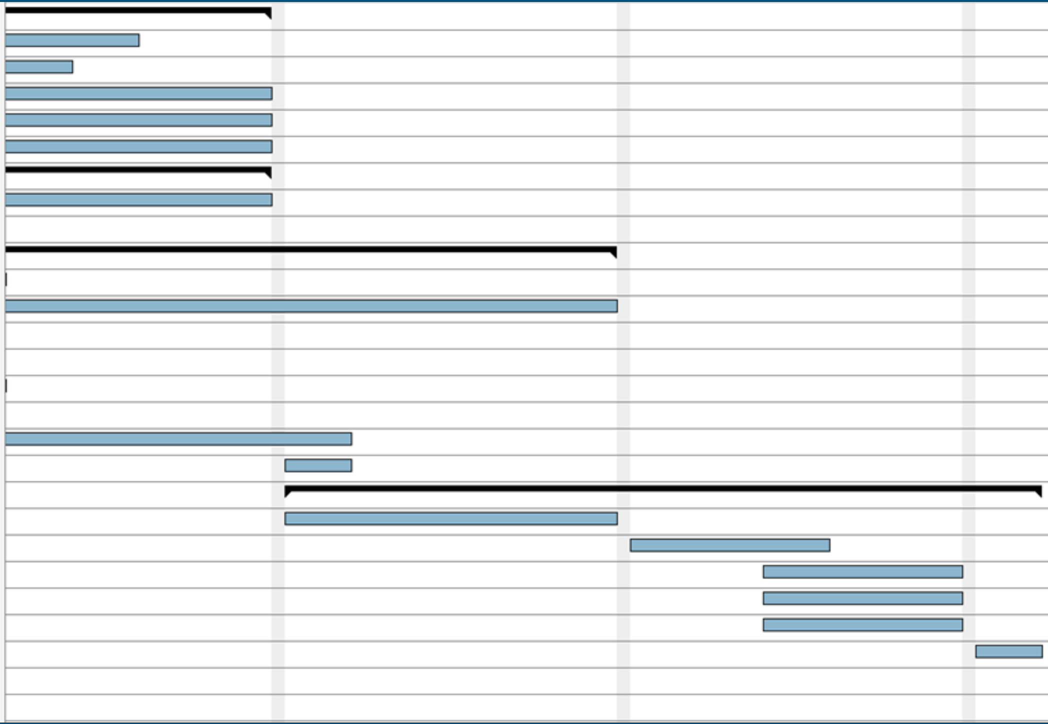
Gantt Chart

Material Purchasing	8/28/18	9/28/18
Motor	8/28/18	9/26/18
regenerator material	9/19/18	9/25/18
Rulon Seal	9/19/18	9/28/18
Cylinder Material	9/19/18	9/28/18
Heat Sink	9/19/18	9/28/18
Mathematical Modeling	9/14/18	9/28/18
Performance Benchmarks	9/14/18	9/28/18
Theoretical Performance	9/14/18	9/21/18
Technical Analyses	9/19/18	10/5/18
Stress analysis on pressurized cylinder	9/19/18	9/24/18
Cooler Space Existing Design Analysis	9/19/18	10/5/18
Motor/piston interface	9/19/18	9/21/18
Thermodynamic Analysis	9/19/18	9/24/18
Heat Transfer, COP, Power	9/19/18	9/24/18
Thermal Network	9/19/18	9/21/18
Expected Work and Volume correlati...	9/19/18	10/1/18
Advanced Shop Training	10/1/18	10/1/18
Manufacturing	10/1/18	10/15/18
Metal Bending: Heat Sink	10/1/18	10/5/18
Pressurized Cylinder	10/8/18	10/10/18
Drill: holes (cylinder)	10/10/18	10/12/18
Weld: Sealed Valve	10/10/18	10/12/18
Displacer	10/10/18	10/12/18
Lathe: threads	10/15/18	10/15/18
Arduino Code	10/22/18	10/29/18
Testing	11/1/18	11/2/18



Abdulrahman
Alazemi

Questions?

References

[1] Urieli, I. (2018). Chapter 3b - The First Law - Closed Systems - Stirling Ebdines (updated 7/5/2014). [online] Ohio.edu. Available at: https://www.ohio.edu/mechanical/thermo/Intro/Chapt.1_6/Chapter3b.html [Accessed 19 Sep. 2018].