Receiver testing for a small-scale open solar-thermal Brayton cycle

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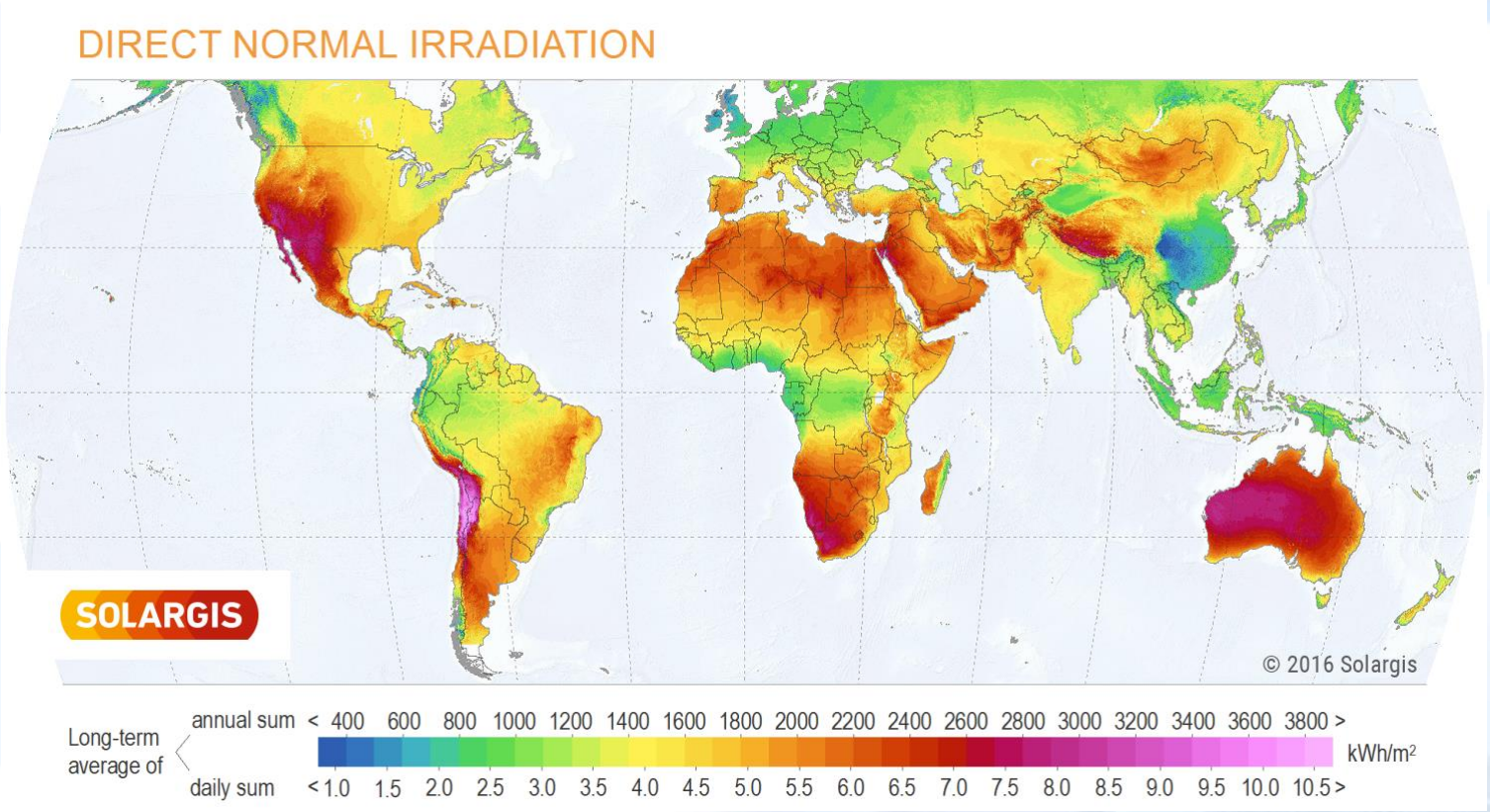
INTRODUCTION

Background

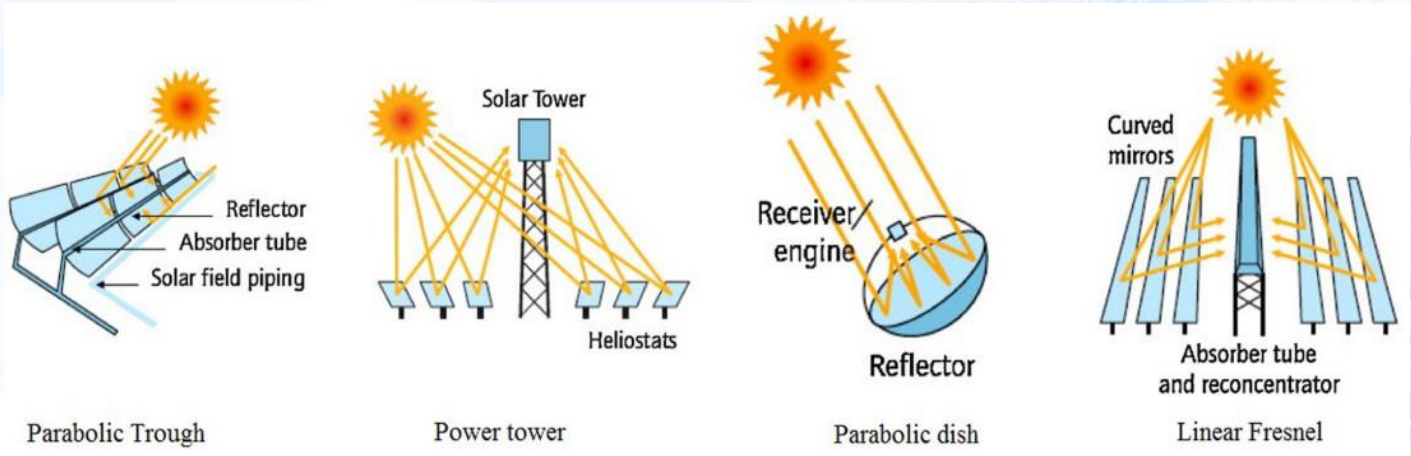


Long term average of direct normal solar irradiance (GeoModel Solar, 2016)

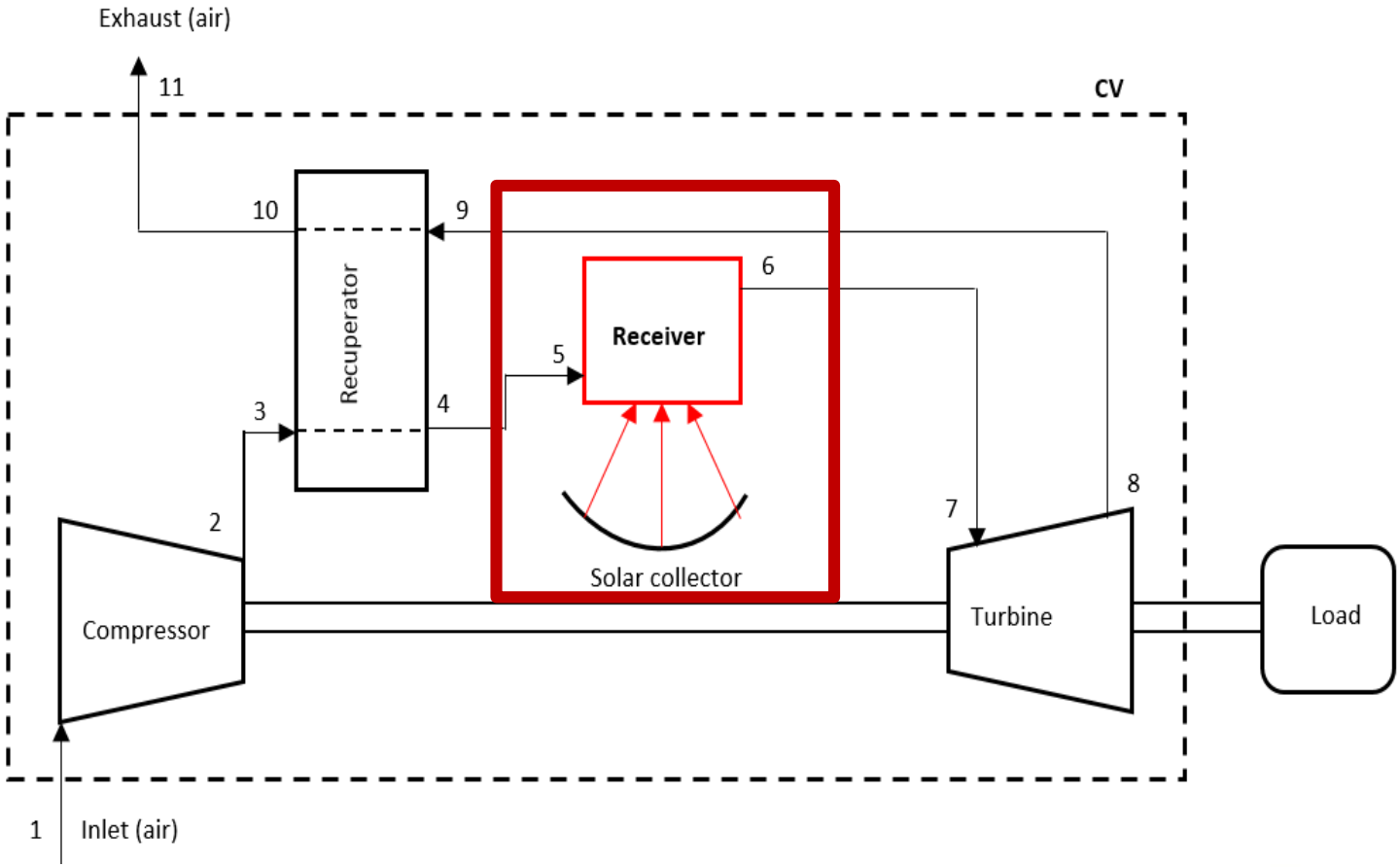
INTRODUCTION

Overview

- CSP technologies
  - Linear Fresnel
  - Parabolic Trough
  - Power tower
  - Parabolic dish
- Power cycles
  - Sterling
  - Rankine
  - Brayton

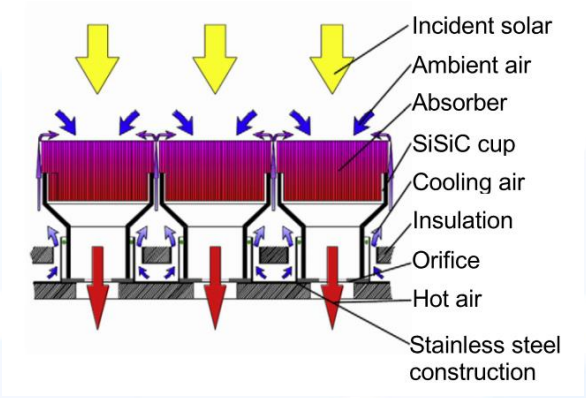


Solar Thermal Brayton Cycle

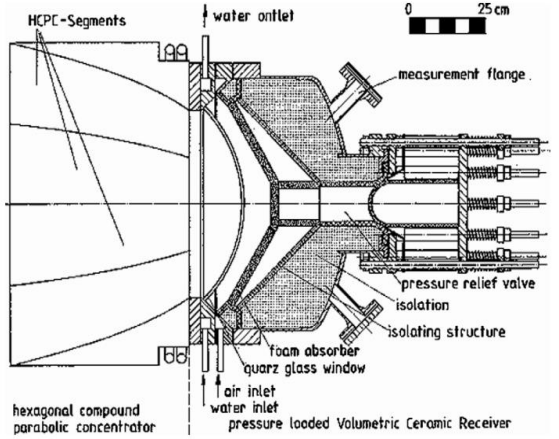


INTRODUCTION

Receivers

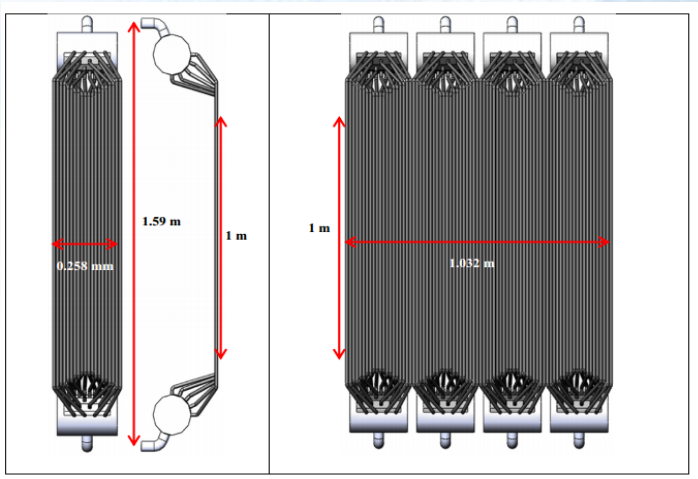


Open Volumetric



Closed Volumetric

Coiled tubular



Longitudinal tubular

INTRODUCTION

Proposed receiver

Problem and Objective

The aim of this investigation is to test the tubular receiver proposed by Dr Willem le Roux (CERG group) and determine the efficiency of said receiver and dish set-up.

Additional problems:

- South Africa needs to make use of the available DNI resource
- Rural areas need access to affordable electricity
- Efficiencies are too low
- Costs are too high
- Systems are too large

THE PROJECT

Background

- 4.8 meter diameter
- 2.18 meter focal length
- Concentration ratio: ±260 suns
- Dual-axis solar tracking system

Project Plan

- Construct solar dish receiver set-up
  - Structure and Dish
  - Receiver insulation
  - Thermocouples
  - Burner unit and gas installation
- Flux mapping (Lunar tests)
- Static/Angled receiver tests (without solar)
- Solar receiver tests
- Calculate receiver efficiency

NB: DNI and wind data during testing from Sauran and anemometer

METHODOLOGY

Optical Efficiency

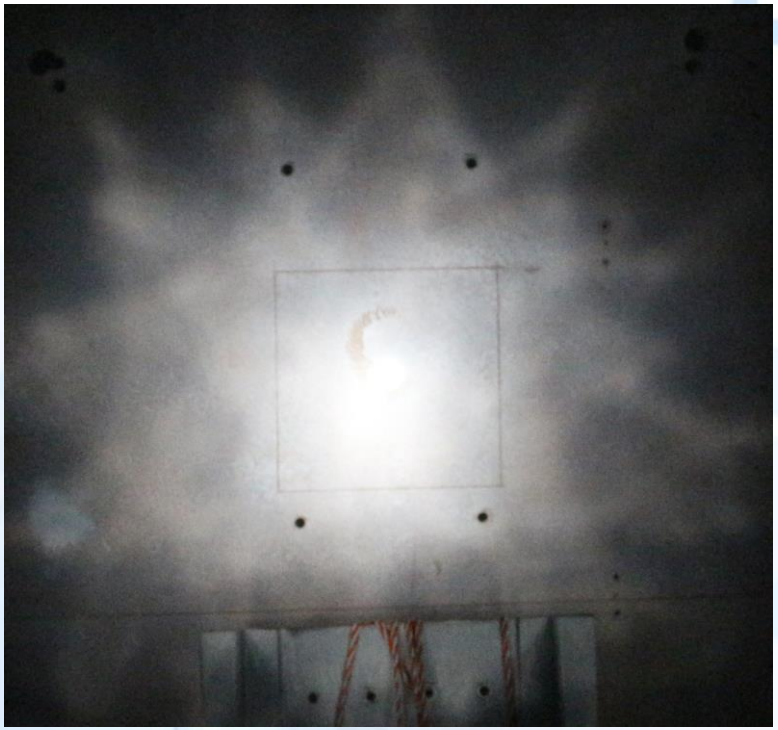
- Slope error
- Specularity error
- Tracking error

- Reflectance
- Spillage
- Shadowing

METHODOLOGY

Flux Mapping

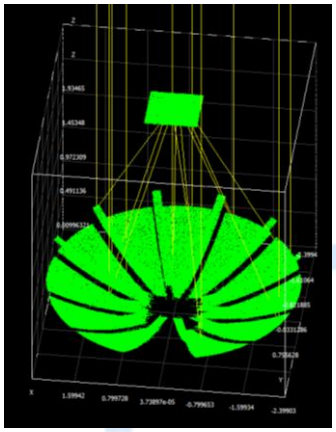
- Existing Methods:
  - CCD or CMOS camera
  - Radiometer
  - IR camera
  - Photographic Flux (PHLUX)



- Method used:

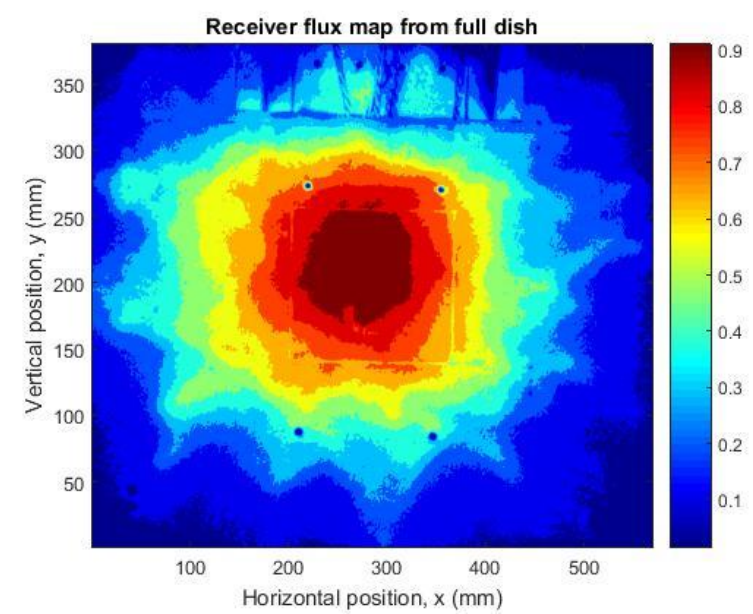
  LUNAR TEST: A DSLR camera and a flat white surface

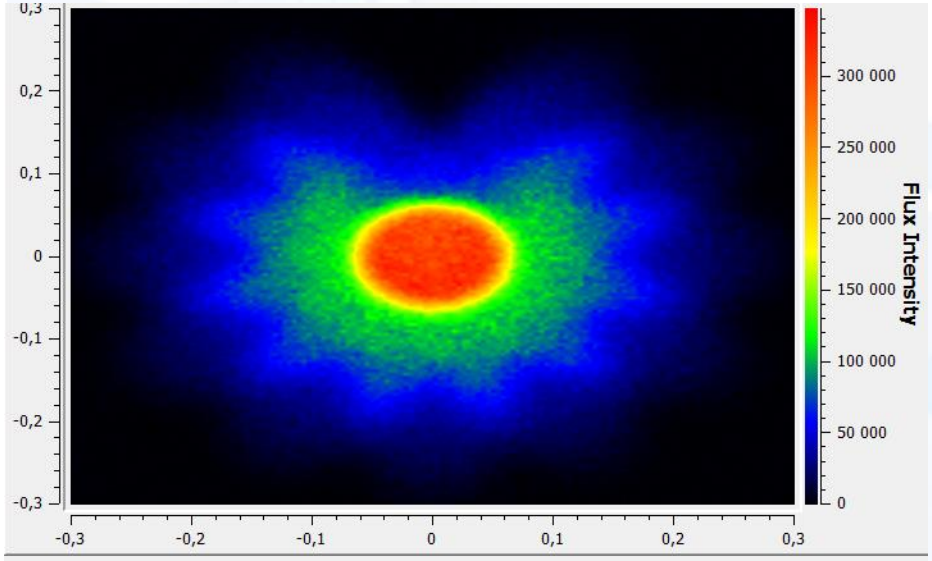
Results and Discussion



Flux Mapping

Lunar testing and SolTrace (Monte Carlo ray tracing software)

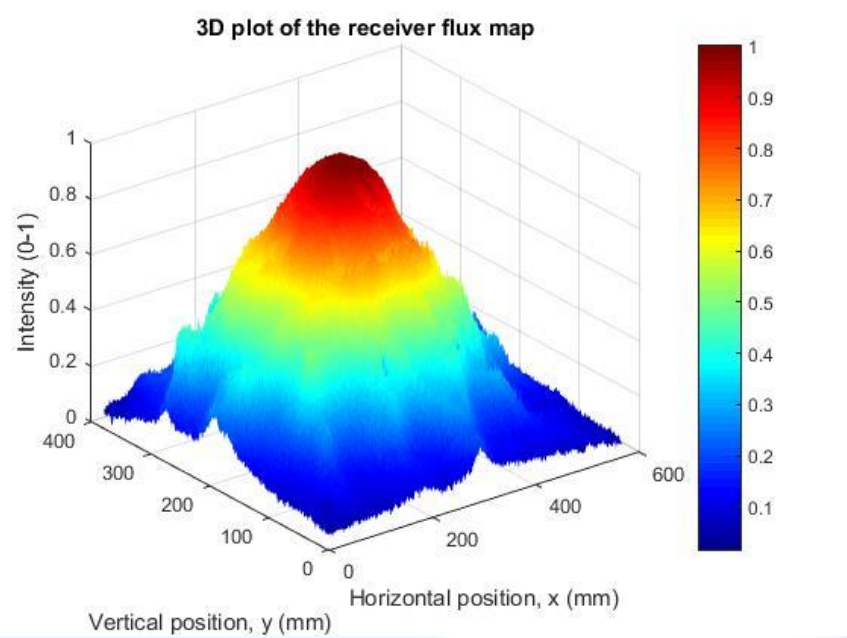


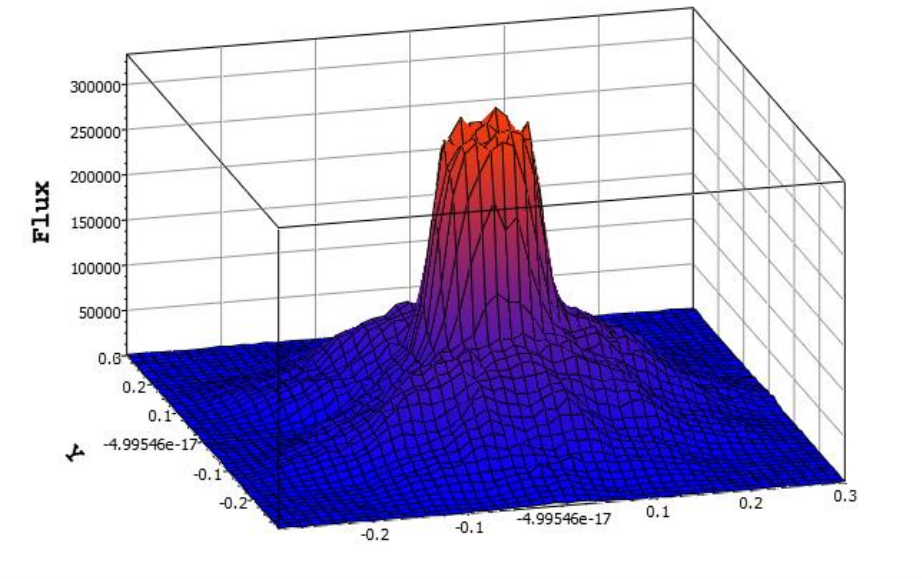


Spillage due to slope error and imperfect parabola at the edge of the dish

RESULTS AND DISCUSSION

Flux Mapping





METHODOLOGY

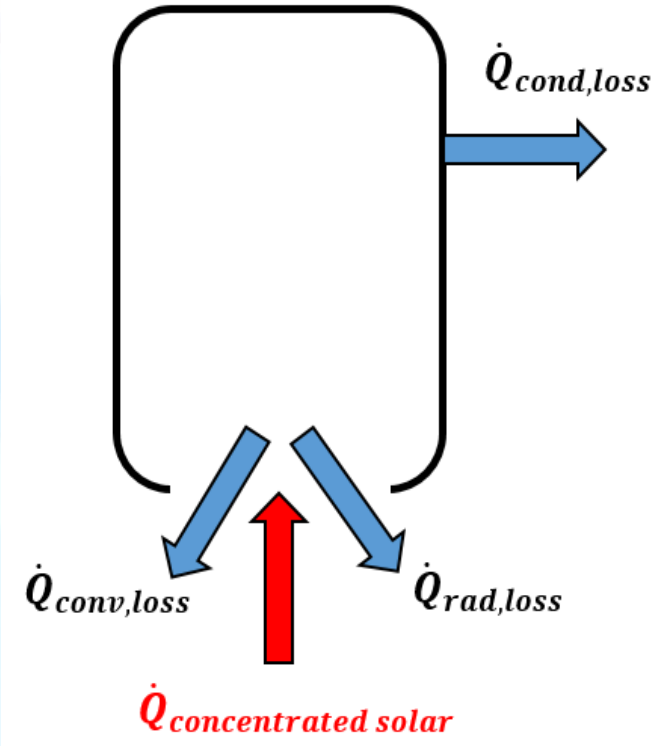
Static Testing

- Burner unit used to simulate hot air inlet

METHODOLOGY

Heat Losses

- Conduction
- Convection
- Radiation (main contributor)

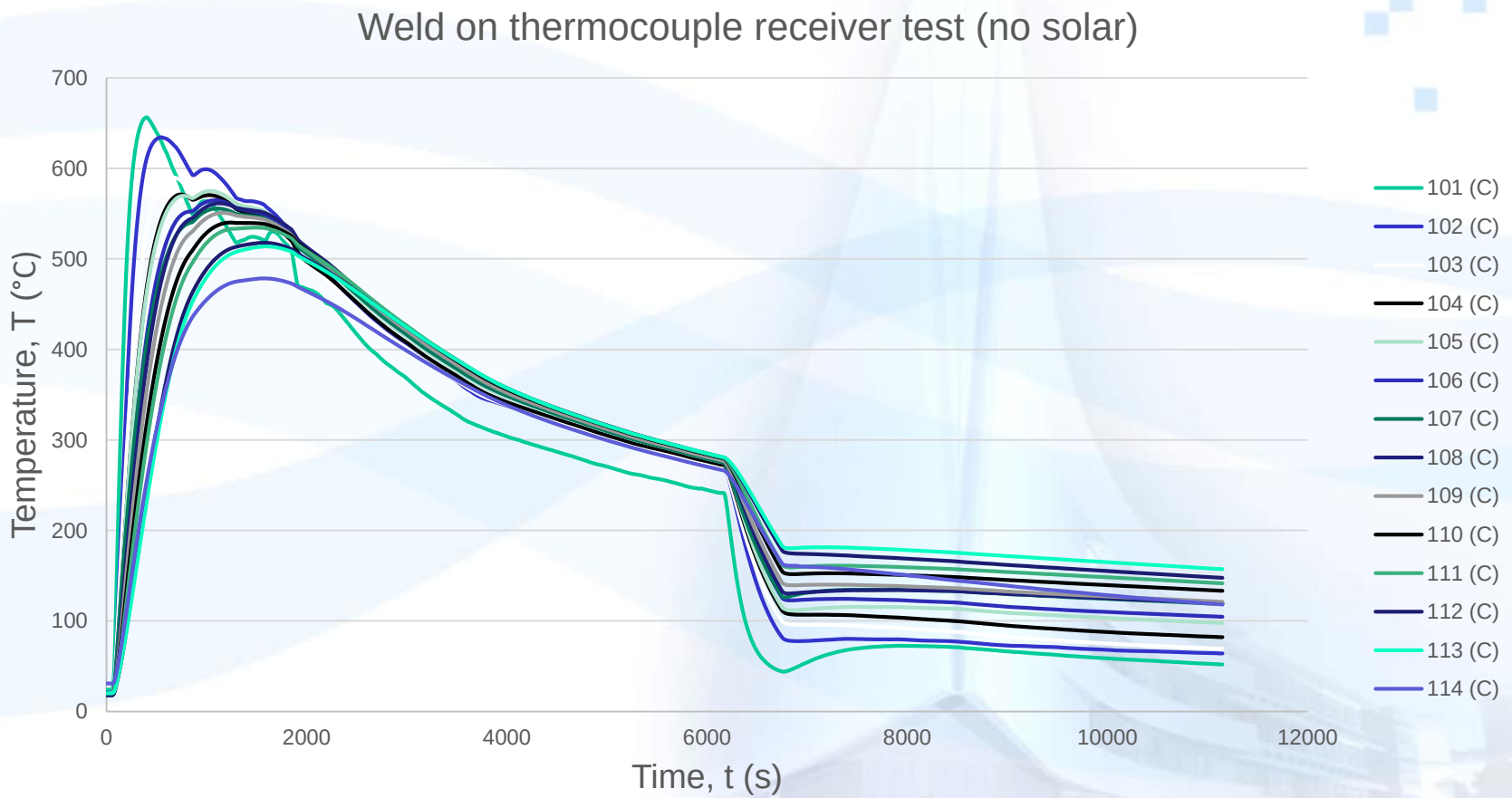


Efficiency

- $\dot{Q}_{losses} = \dot{Q}_{cond} + \dot{Q}_{conv} + \dot{Q}_{rad}$

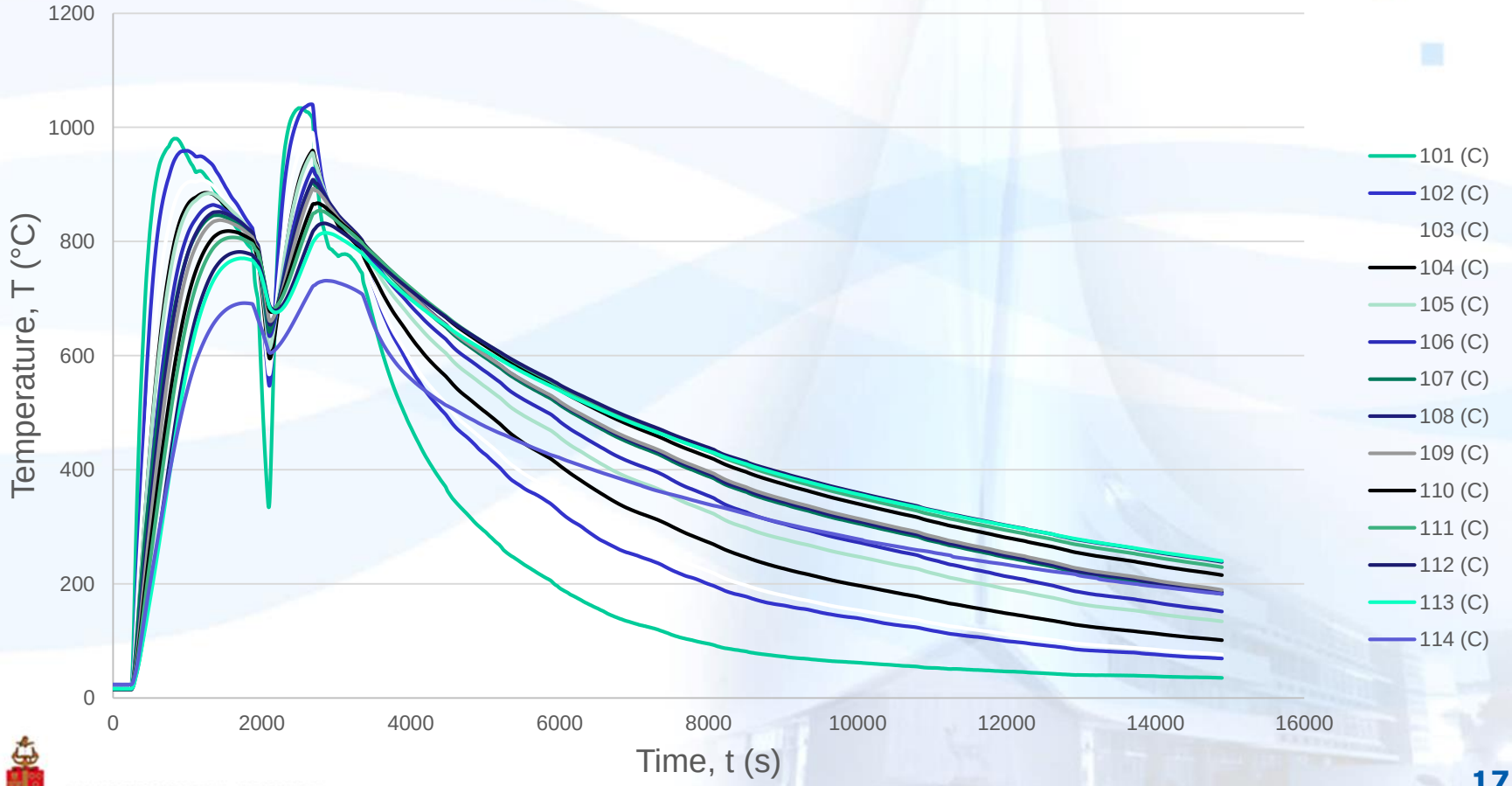
- $\eta_{receiver} = \dfrac{\dot{Q}_{receiver}}{\dot{Q}_{concentrated\ solar\ into\ receiver}} = \dfrac{\dot{m} c_p (T_{out} - T_{in})}{\eta_{dish} \dot{Q}_{solar}}$

Static Testing



Static Testing

Weld on thermocouple readings for a burner test with gas change over



Future Work

- Install 45kg gas bottles
- Angled receiver tests
- Solar exposed receiver tests

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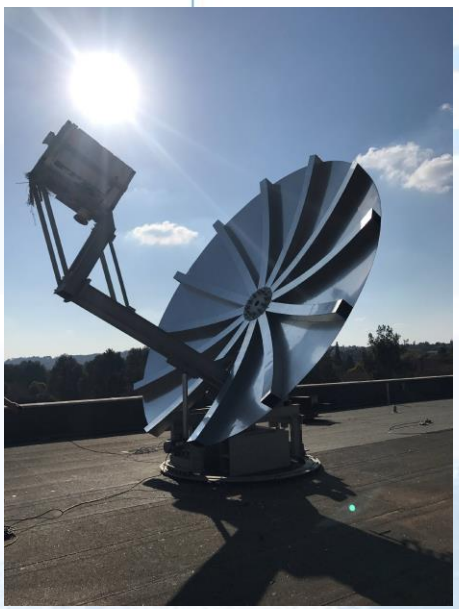
Solar Thermal Energy Research Group (STERG)

THANK YOU



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