“30 kW_t Thermal Cross Linear CSP System Test Unit” at RGPV , Bhopal

Principal Investigator

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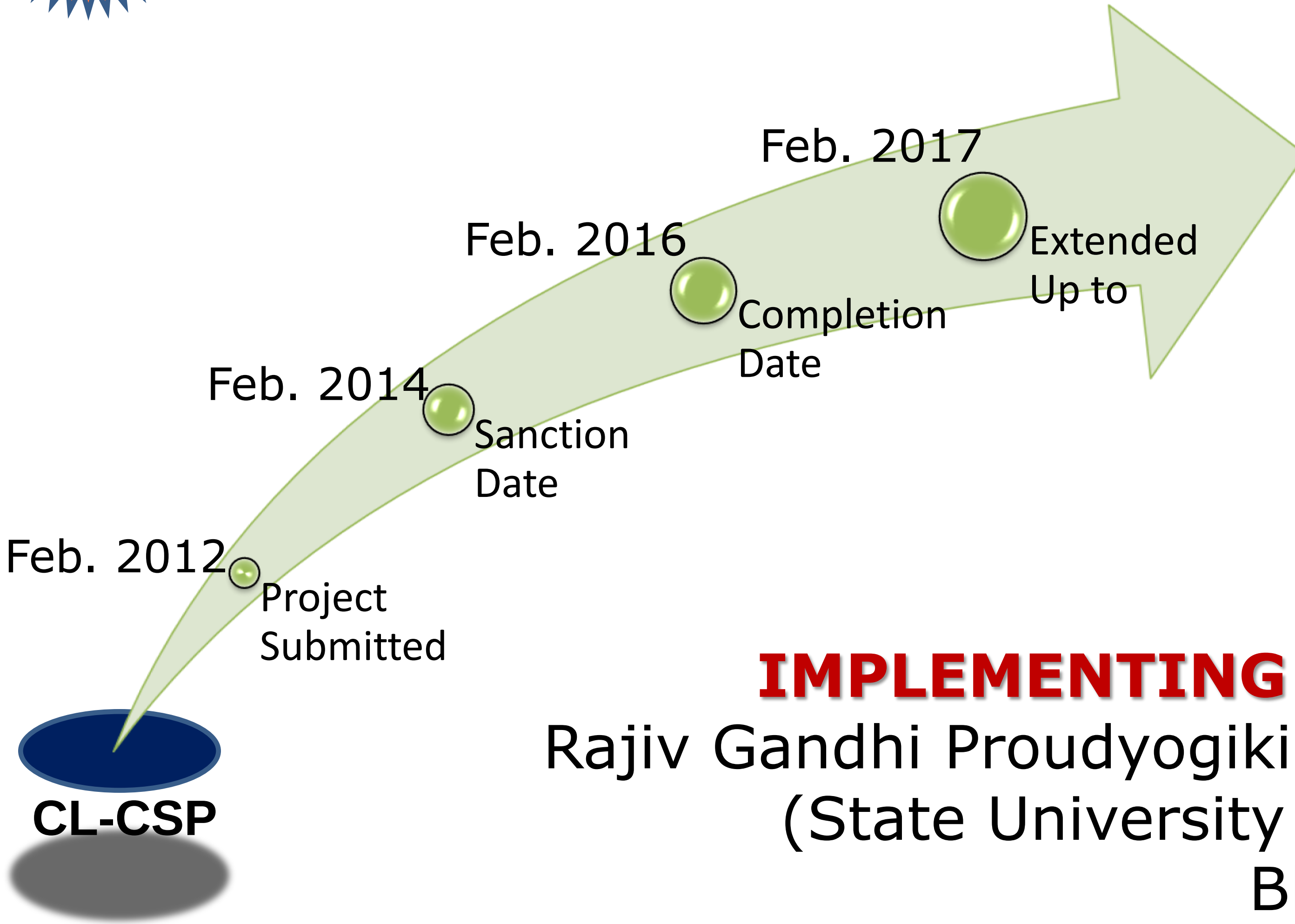
Name of Co-PI from other participating institution:

1. Prof. Yukata Tamaura , Prof. Emeritus Tokyo Institute of Technology, Tokyo, Japan & Representative Director, Solar Flame Cooperation
2. Mr. Rajendar Kaura, CMD, Bergen Group, Gurgaon
3. Dr. V.K Sethi, Ex-Director, UIT,RGPV,Bhopal, M.P.



IMPLEMENTING INSTITUTION

Rajiv Gandhi Proudyogiki Vishwavidyalya
(State University of Technology),
Bhopal, MP, India

INTRODUCTION

- To contribute in target of GOI , RGPV start a R&D project on a path breaking and innovative solar thermal technology with the collaboration with Tokyo institute of technology Japan.

- This Technology is known as Cross linear CSP (CL-CSP).

- This technology is amalgamation of two exiting solar thermal technology ie. Linear Fresnel and solar Tower.

- CL-CSP has virtues of both conventional Linear Fresnel and Tower technologies.

INTRODUCTION

- In this innovative and breakthrough CL-CSP technology temperature of 600 degree c will be achieved by concentrating solar to the receiver.

- The Heliostat use in this new technology is gyro type with E-W and N-S tracking facility, which is first time manufacture in world wide.

- The power consumption for operational of this tracking mechanism is very less.

INTRODUCTION

- This Technology may be substitution of coal for existing Thermal Power Plants during the day Time.

- As the Thermal to Thermal Conversation efficiency is 80%.

- This can also replace Fossil Fuels in Factories/industries and use for Hybrid Technology for CSP Plants.

IAI - Introduction

Industry Academic Interactive:

- To improve the quality of Tech Edu. on adequately to meet the needs of the industry & Society.
- To promote entrepreneurship in Tech. institution.
- To offer R & D, consultancy & testing services to solve industrial problems.
- To involve the working professionals in teaching & management of institutions
- CL-CSP -30 kW Project model is a endeavor & one of its kind attempt to bring academia & corporate fraternity on a single platform.

IAI - Introduction

MNRE, GoI, New Delhi

Rajiv Gandhi Proudyogiki Vishwavidyalaya, Bhopal.

Toyo Engineering and Solar Flame Corporation, Tokyo, Japan

Tokyo Institute of Technology, Japan.

Bergen Solar Power & Energy Ltd, Gurgaon

PROJECT OBJECTIVE

Broad Objective

Technology Demonstration of

Cross Linear – Concentrated Solar Power

in Indian conditions through a 30 kW-t Test Unit at RGPV, Bhopal

Specific Objectives

- Demonstrate High Temperature (>=600^0C) attainment of CL-CSP
- Optimize Simulation Technology of CL-CSP
- Utilize to develop 1 MW-e Test Plant and Commercial Plant of 20 MW size
- Strengthen Indian-Japanese technical collaboration
- An Industry – Academia joint venture project in true sense

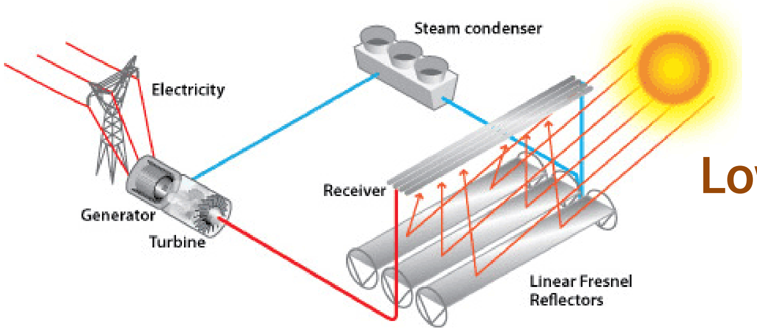
CL-CSP TECHNOLOGY

CL-CSP Technology

- Invented by Prof. Tamaura at Tokyo Institute of Technology
- Higher temperature around 600-700 degree C by applying linear focussing method
- Development of optical design of CL system and feasibility study for 20 MW pilot plant of the CL system has been completed
- Solar beam energy collected by CL is higher by nearly 20% as compared to Linear Fresnel.

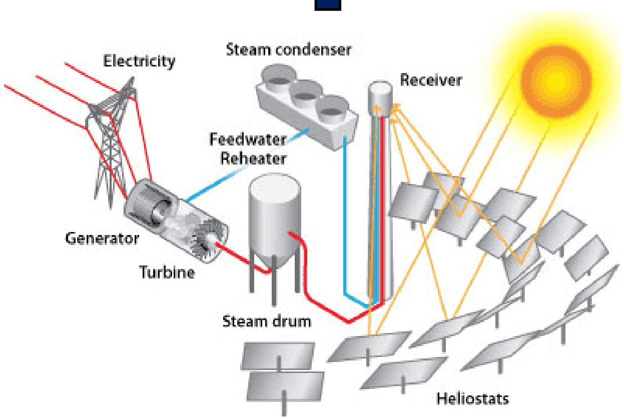
CL-CSP Technology

Linear Fresnel (LF) system



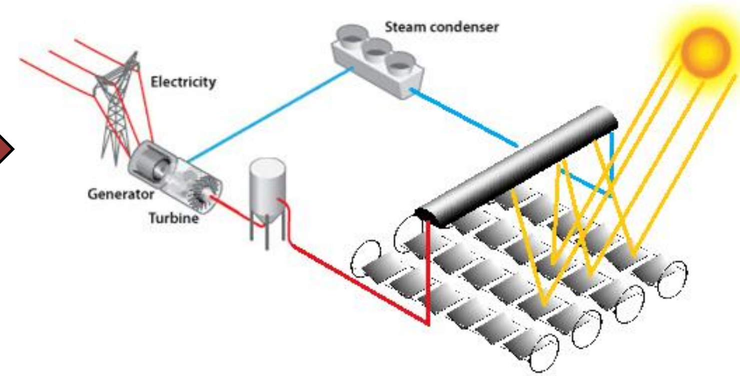
Low construction cost

Hybridization



High concentration
(High efficiency)

Central tower system



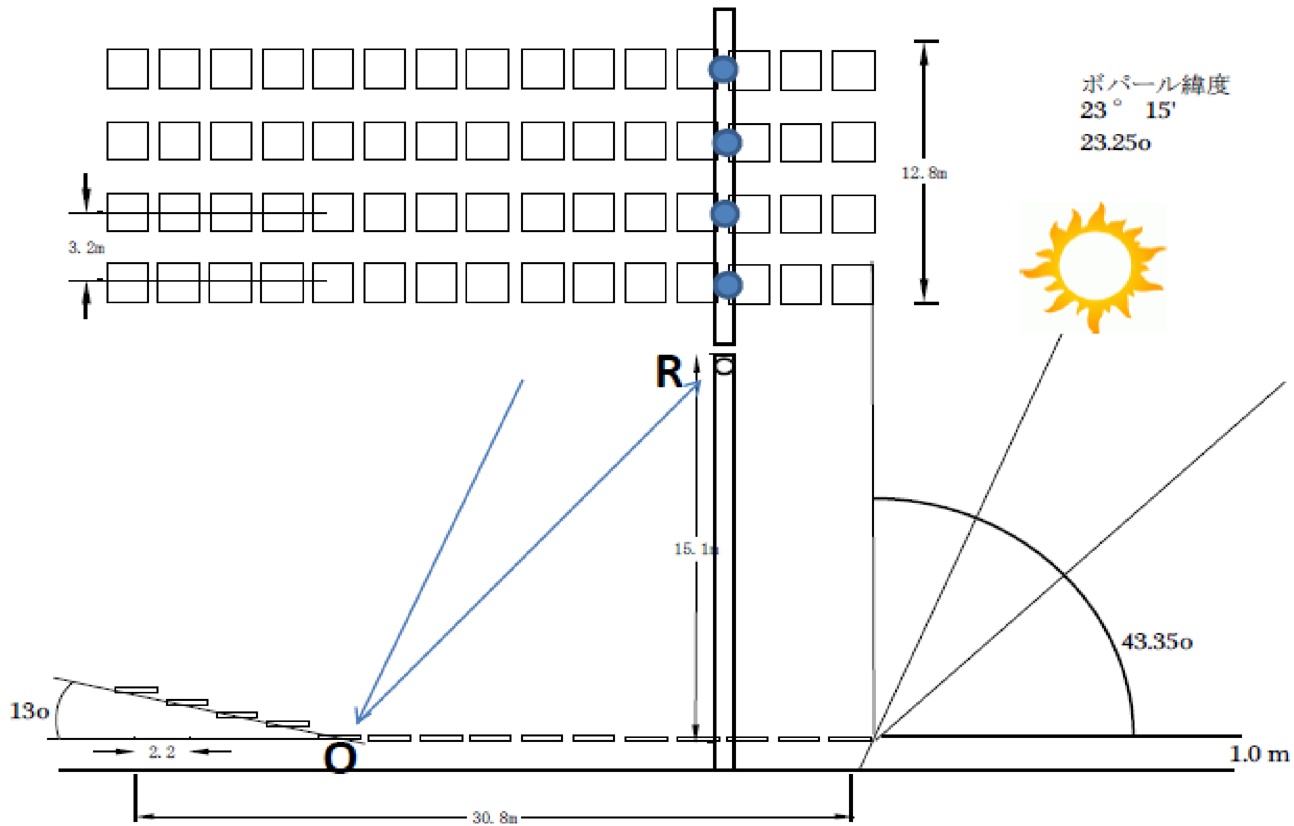
Cross Linear (CL) system

CL-CSP -COMPARISION

	Cross Linear	Tower, Trough, Linear Fresnel
Temperature	300-800 deg C	Tower: 1000 deg C Trough: 350 deg C Linear Fresnel: 450 deg C
Concentration	100-1000	Tower: 300-1000 Trough, Linear F <100
Thermal Fluid	Liquid: Water, Oil Gas: Air, Steam, CO_2	Tower: Stem, Molten Salt Trough: Oil, Steam, Molten Salt Linear Fresnel: Steam
CL Heliostat	Axis: 1.01 Control precision: Moderate or Low	Tower: 2.0/high precision Trough, Linear F: 1.0/middle precision
CL Receiver	Cavity, CPC , Pipes	Tower: cavity Trough: vacuum pipe Linear Fresnel: pipes, CPC, cavity

CL-CSP Technology

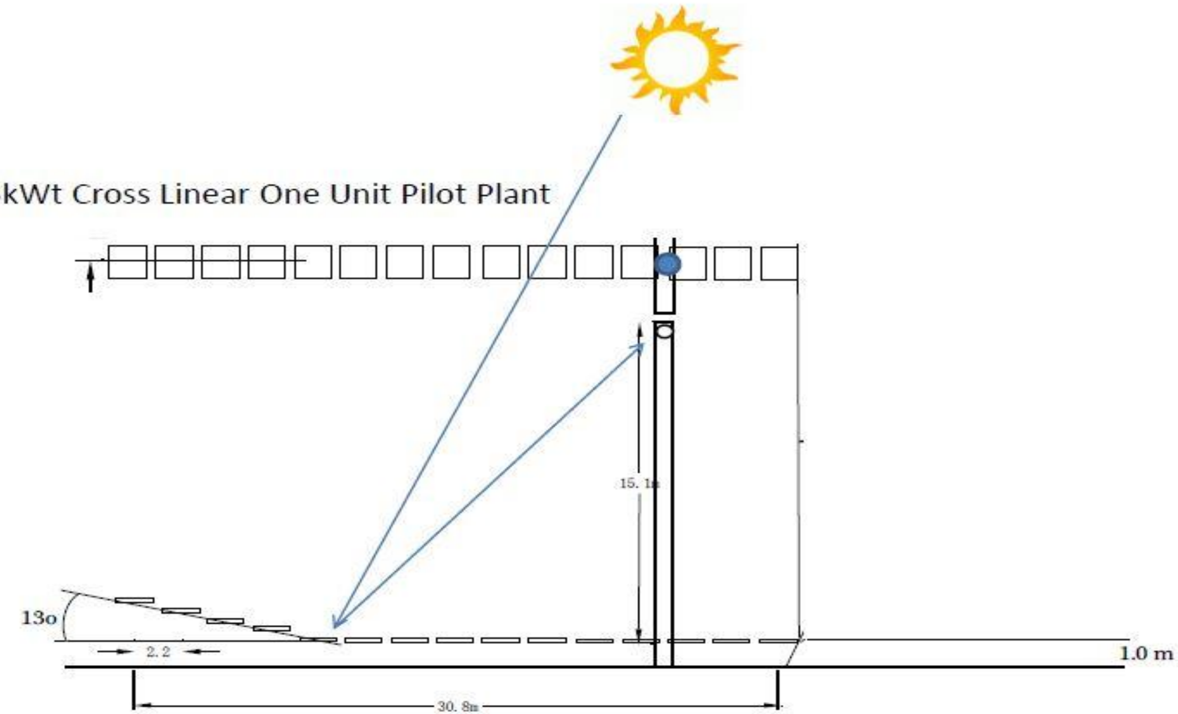
4 mirror lines



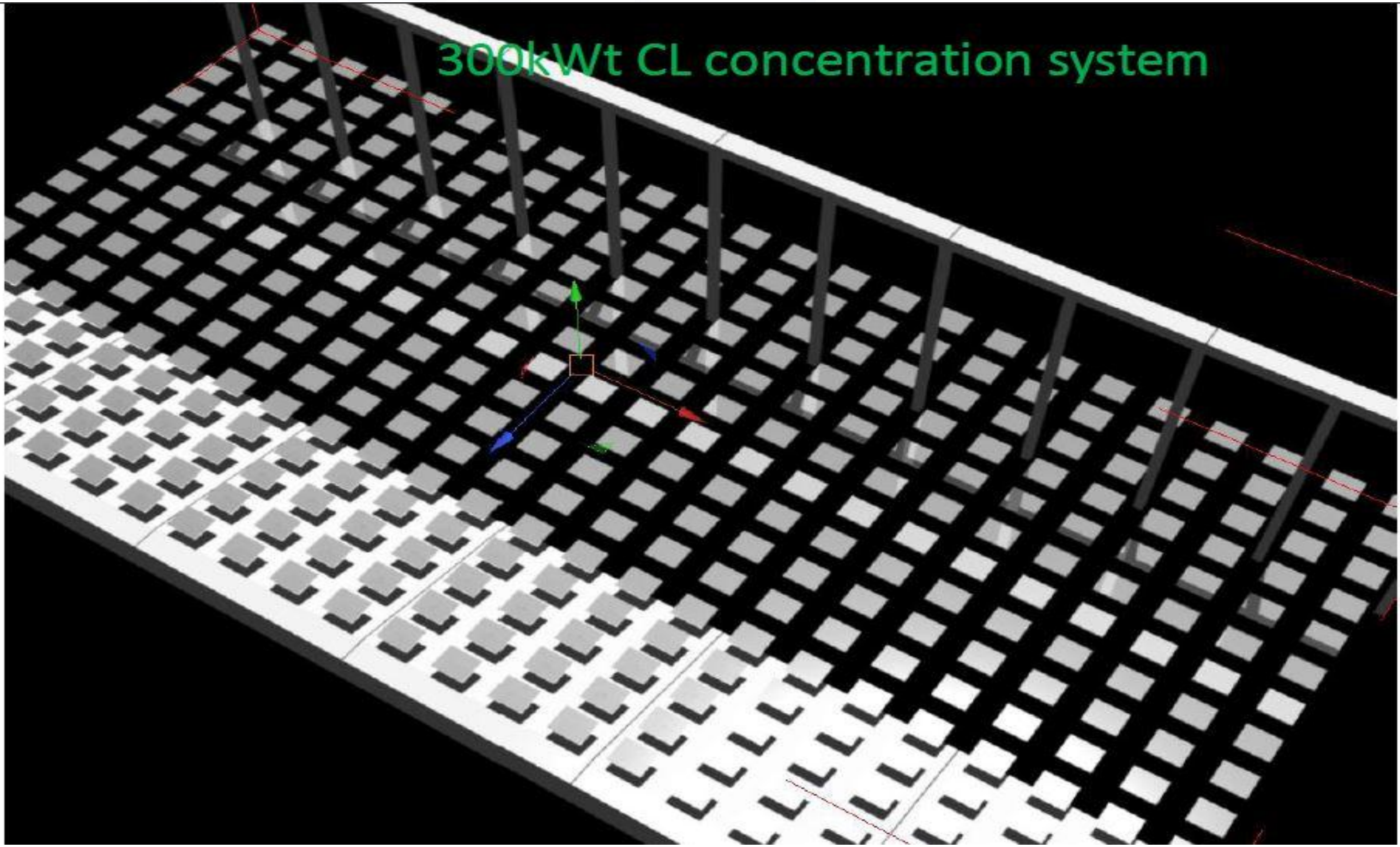
CL-CSP Technology

1 mirror line

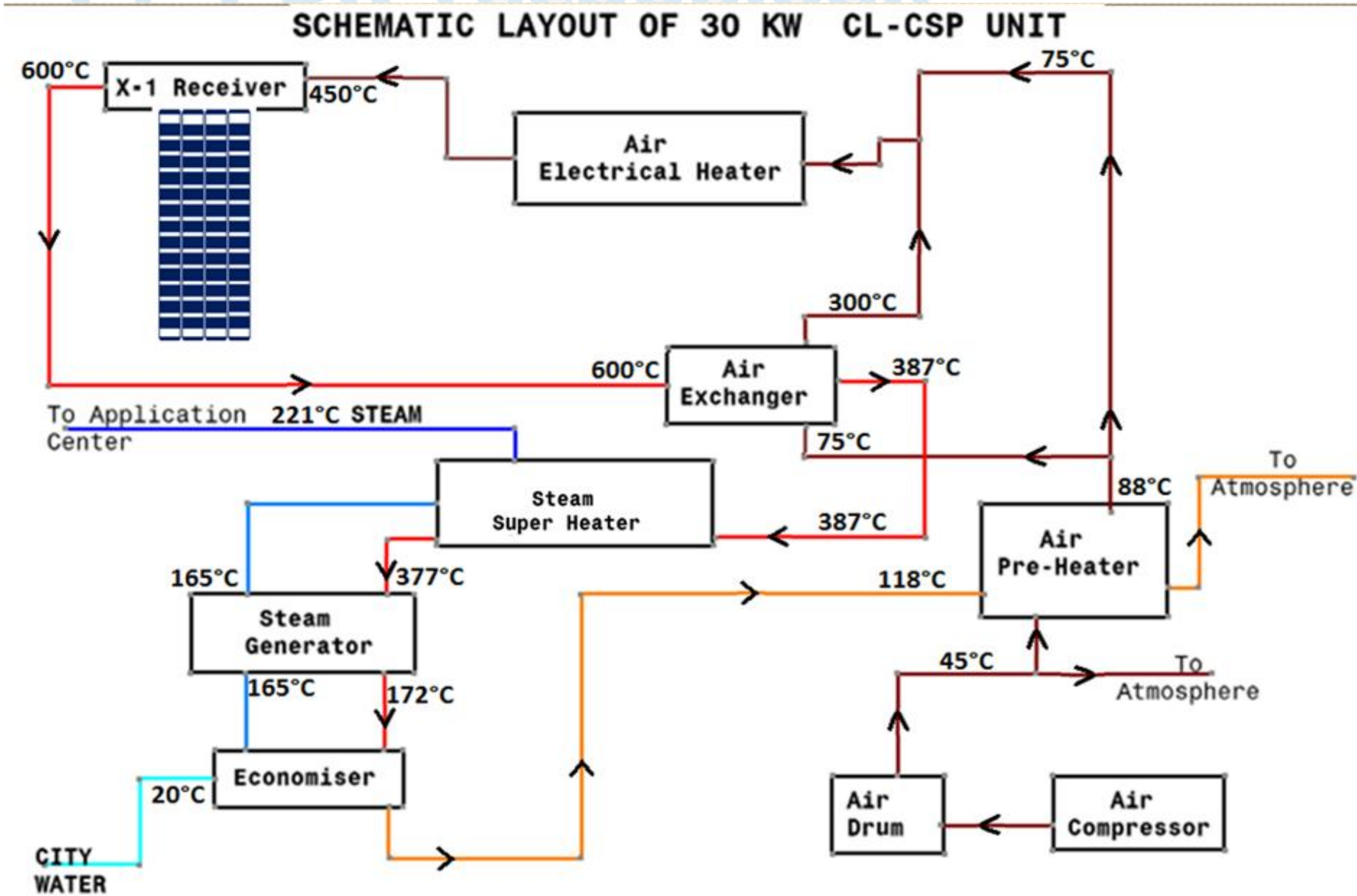
10-15kWt Cross Linear One Unit Pilot Plant



CL-CSP Technology



CL-CSP Technology



CL-CSP Technology

Features:

- It has virtues of both conventional Linear Fresnel and Tower technologies.
- It can provide very high temperatures (above 600 deg C), not possible with conventional methods.
- It is very cost effective and can easily be scaled up.
- It could prove to be an economical method of power generation.
- It can be employed as a substitutive of coal.

CL-CSP Technology

Features:

- It has higher optical efficiency (than Trough and Linear Fresnel) and thermal efficiency
- Trough and Linear Fresnel are one axial optical controlled, while CL is two axial optical controlled.
- CL can adjust mirror direction for higher concentration of sunlight with low cost and lesser optical loss
- Tower can provide high temperature with two axial optical control, but very costly. Also, the distance between receiver and mirror is huge which results in increased optical loss.

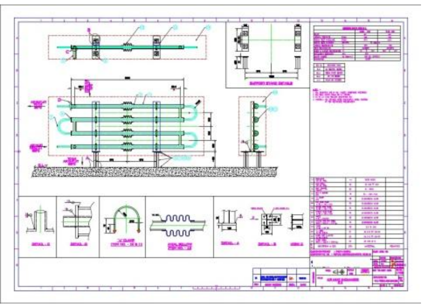
CL-CSP Technology

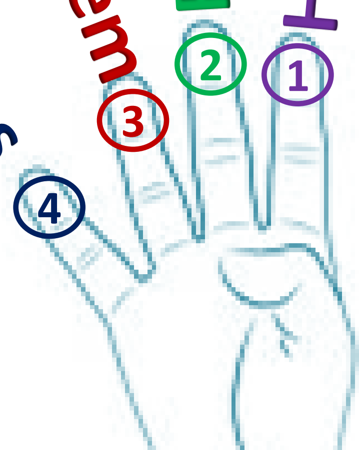
Features:

- CL, owing to high thermal efficiency, can help in establishing cost effective thermal storage system
- It is adaptable for high temperature requirement from steam turbine generators in case of hybrid power.
- Not only do these technologies help reduce global carbon emissions, but they also add some much-needed flexibility to the energy resource mix by decreasing our dependence on limited reserves and overseas sources of fossil fuels.

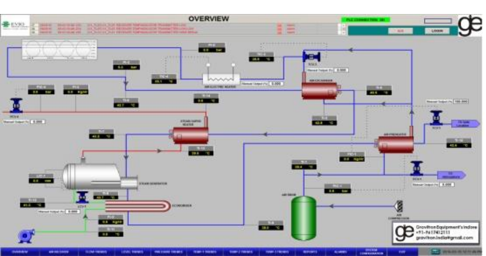
CL-CSP – MAJOR COMPONENTS

CL-CSP – Major Components





1. Heliostat
2. Receiver
3. Monitoring System
4. Heat Systems



Heliostat

A heliostat (from helios, the Greek word for sun, and stat, as in stationary) is a device that includes a mirror, usually a plane mirror, which turns so as to keep reflecting sunlight toward a predetermined target, compensating for the sun's apparent motions in the sky.

The target may be a physical object, distant from the heliostat, or a direction in space.

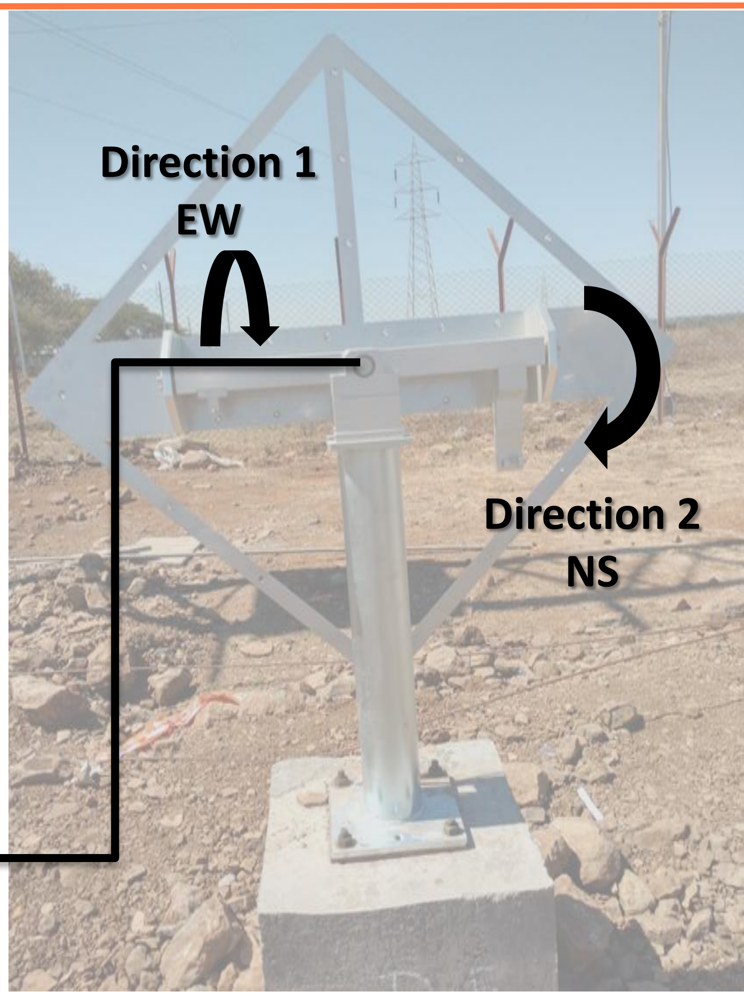
Heliostats - Specifications

Heliostat Type	: Gyro Type
Max Weight	: 70 Kg
Per Heliostat Consumption	: (1/60) Unit
Tracking System	: Dual Axis

Gyro Type Mechanism

- ➤ Easily Move in two Direction
- ➤ Height : Less then 1 meter
- ➤ Material : Cast Iron

Center of Rotation



Actuators

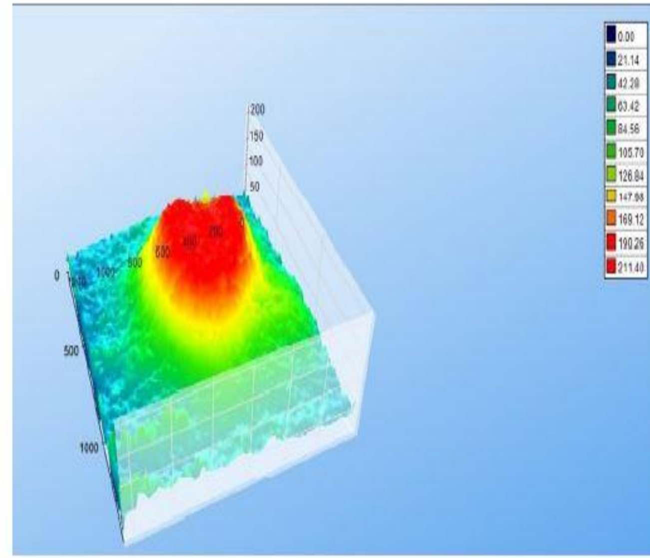
Quantity Per Heliostat	: 2 Nos.
Voltage Required	: 24 V
Max Load	: 90 kg
Current Type	: DC

Heliostat Assembly at Site

Heliostat working at Site

(2) A3 mirror concentration performance check from the image on the ceramics board screen placed on the ground.

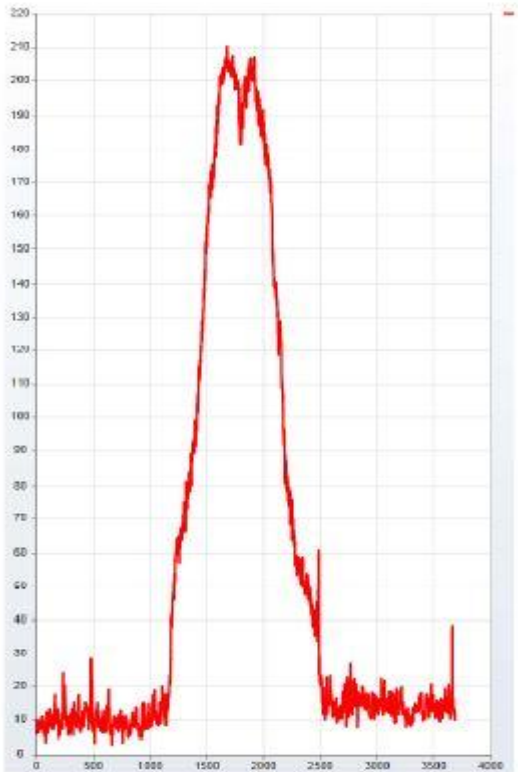
The test was carried out 8:30am using the ceramic board screen placed perpendicular toward sun position. The focal image was taken by the camera at lower sensitivity.



The analysis of the flux intensity showed that the highest flux area diameter is around 55cm which is smaller than 60cm of the 2ndary reflector.

Focal image flux is fairly uniform. A detail analysis was achieved using the ceramic board screen on the ground (see below).

Heliostat Working at Site



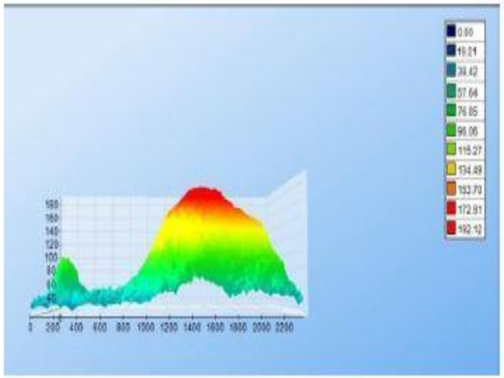
The focal image tested on the ground.

Image = Trapezoid; upper/lower bases =0.3

Upper base length = 55cm

The highest flux value was evaluated to be 5kW/m2 under the DNI=0.6kW/m2

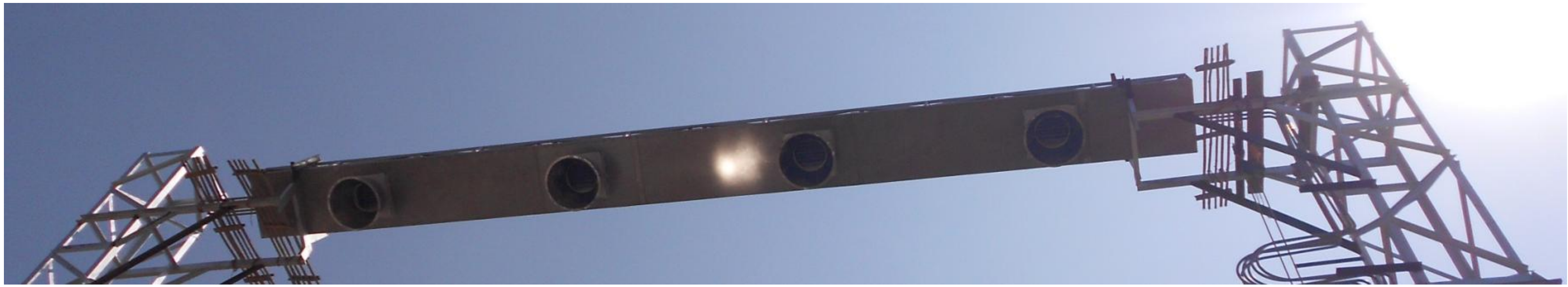
Concentration degree was evaluated to be 7 times from the calibration test.



CL-CSP - RECEIVER

Receiver at Site

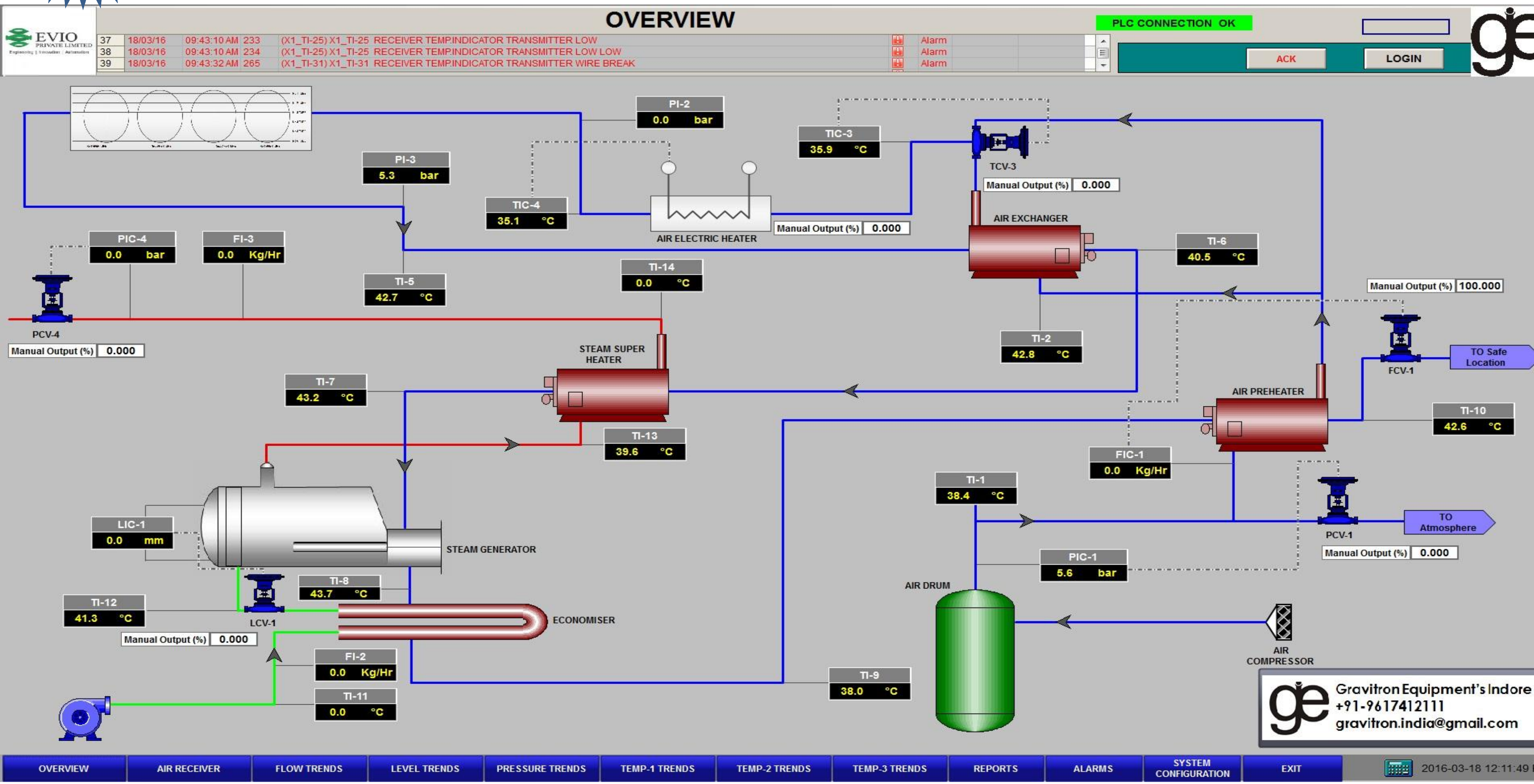
Focus On Receiver



CL-CSP - RECEIVER

Receiver
&
Heliostat
at Site

CL-CSP Project - Monitoring



CL-CSP COMPARISION

Equipments has installed at site

- Air Compressor
- Heat Exchanger
- Air Drum
- Economizer
- Steam Generator
- Steam Preheater
- Airpreheater
- Air Exchanger
- Air Electrical Heater
- All control and Instrumentation work
- Air Receiver

FIVE VITAL CONNECT OF THIS PROJECT

FIVE VITAL CONNECT OF THIS PROJECT

1. Connect to Knowledge Network

FIVE VITAL CONNECT OF THIS PROJECT

2. Connect to the Industries

FIVE VITAL CONNECT OF THIS PROJECT

3. Connect to the Society

FIVE VITAL CONNECT OF THIS PROJECT

4. Connect to National and Global Professional Societies

FIVE VITAL CONNECT OF THIS PROJECT

5. Connect to Local and Global Systems of Tech Education

CL-CSP – FUTURE SCOPE

CL-CSP –FUTURE SCOPE

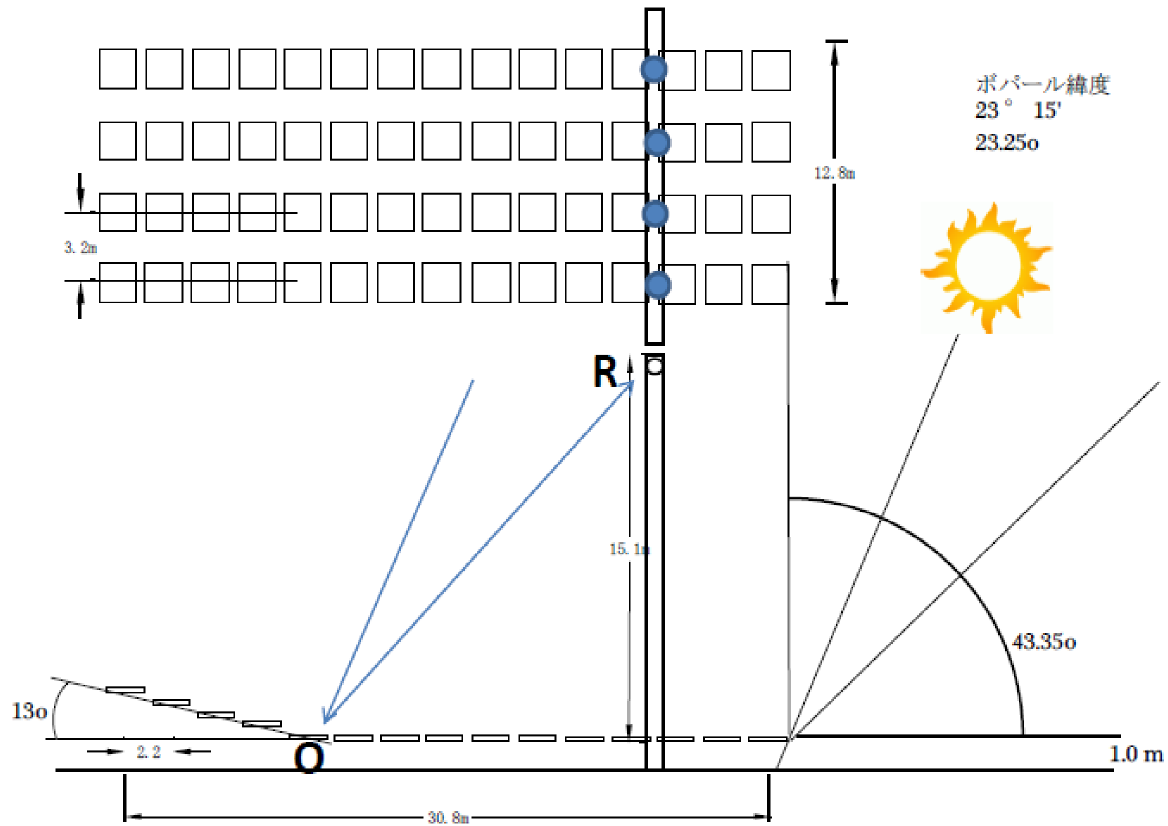
- **Application of steam:-** for this VAM RAC project has been submitted to MNRE.
- Hybridization with existing coal and gas fired power plant.
- Replacement of coal and diesel from low & medium range temp. required industry.
- Collection and analysis of data to reach this technology upto matured and commercial technology.

item(Solar Field)	figures(Design Point)
Mirror reflectivity	0.9
Receiver efficiency	0.6-0.8
Receiver spilege	0.05
cosine effect	0.85-0.95
Shadowing	0.07
Plant parts shadowing	0.05
Blocking	0.05
Total efficiency	0.366-0.574
DNI(kW/m2)	0.8

concentrated power/m2 mirror	0.293-0.459Wt
mirror number/mirror line	15
mirror size	1.5mx1.5m
mirror area/mirror line	33.75m2
concentrated power/ mirror line	9.89-15.5Wt
concentated power/ 4 mirror line	39.56-62.0kWt
heat loss in heat transmission	16.70%
recovered heat/ cell (4 mirror line)	33-52kWt
Optimizing heliostat number = 30kW/higher recovered heat(52kWt)	30/52x60=34 (35-55)

CL-CSP Technology(design point)

4 mirror lines



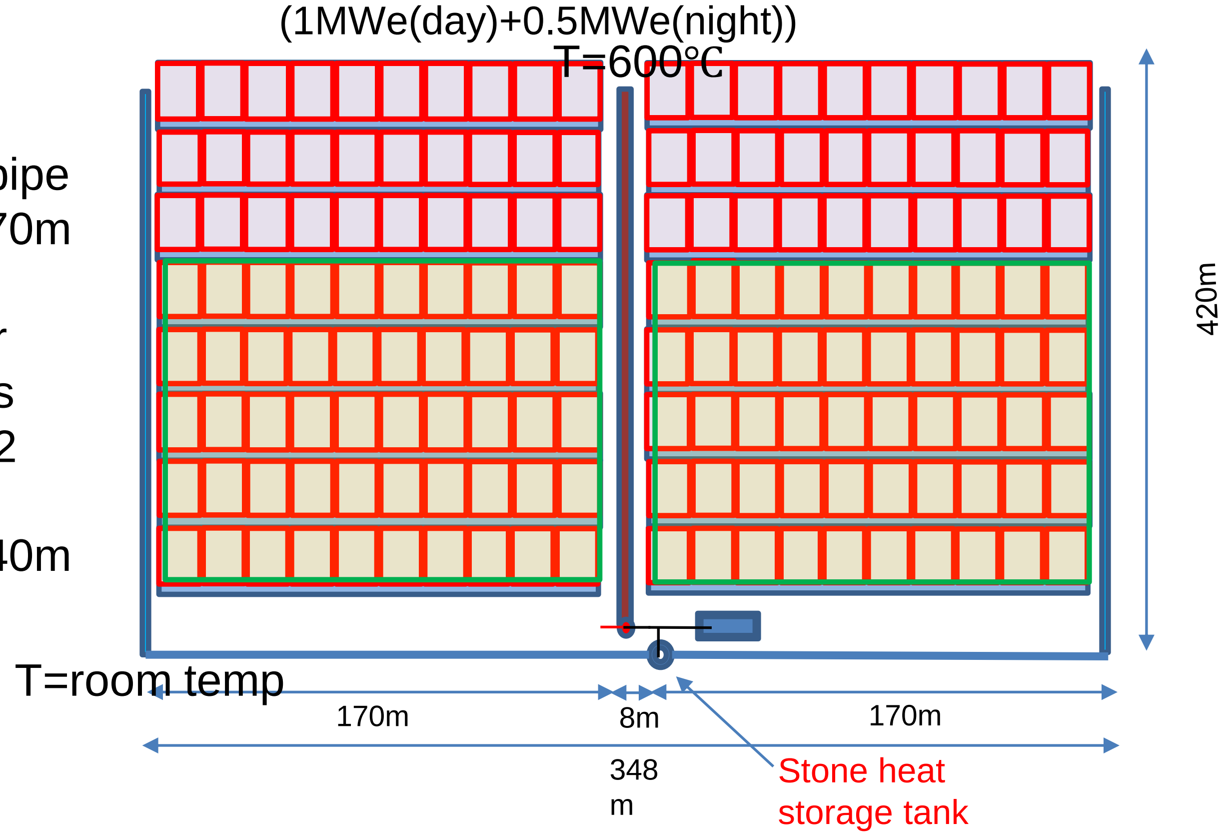
Target			
(air temp)	600℃		
(Power)	30kWt (pilot plant of R&D for CL-CSP scaled up)	500kWe (CSP plant)	1MWe(4MWt) (CSP Plant)
(Plant size/cell)	1	1x(8x19)	2x(8x19)
(Plant size/m x m)	15mx35m	420mx170m	420mx348m
(Receiver Lenght) Non up/down	15m	170m	170m
(Receiver Line number)	1	8	16
(Heliostat number)	<55	<7,600	<15,200
(Receiver height)	10～15m	10～15m	10～15m
(Stone storage number)	0	1	1
Test (30kW pilot plant) for **optimzing** the following items		—	—
heliostat number	40	—	—
receiver height	10m	—	—
Test (30kW pilot plant) for **receiver lengthning**	170m(Non up/down)	—	—
Design point of 30kW pilot plant		—	—
power	30kW	—	—
heliostat number	60	—	—
receiver length	15m		
receiver height	15m	—	—

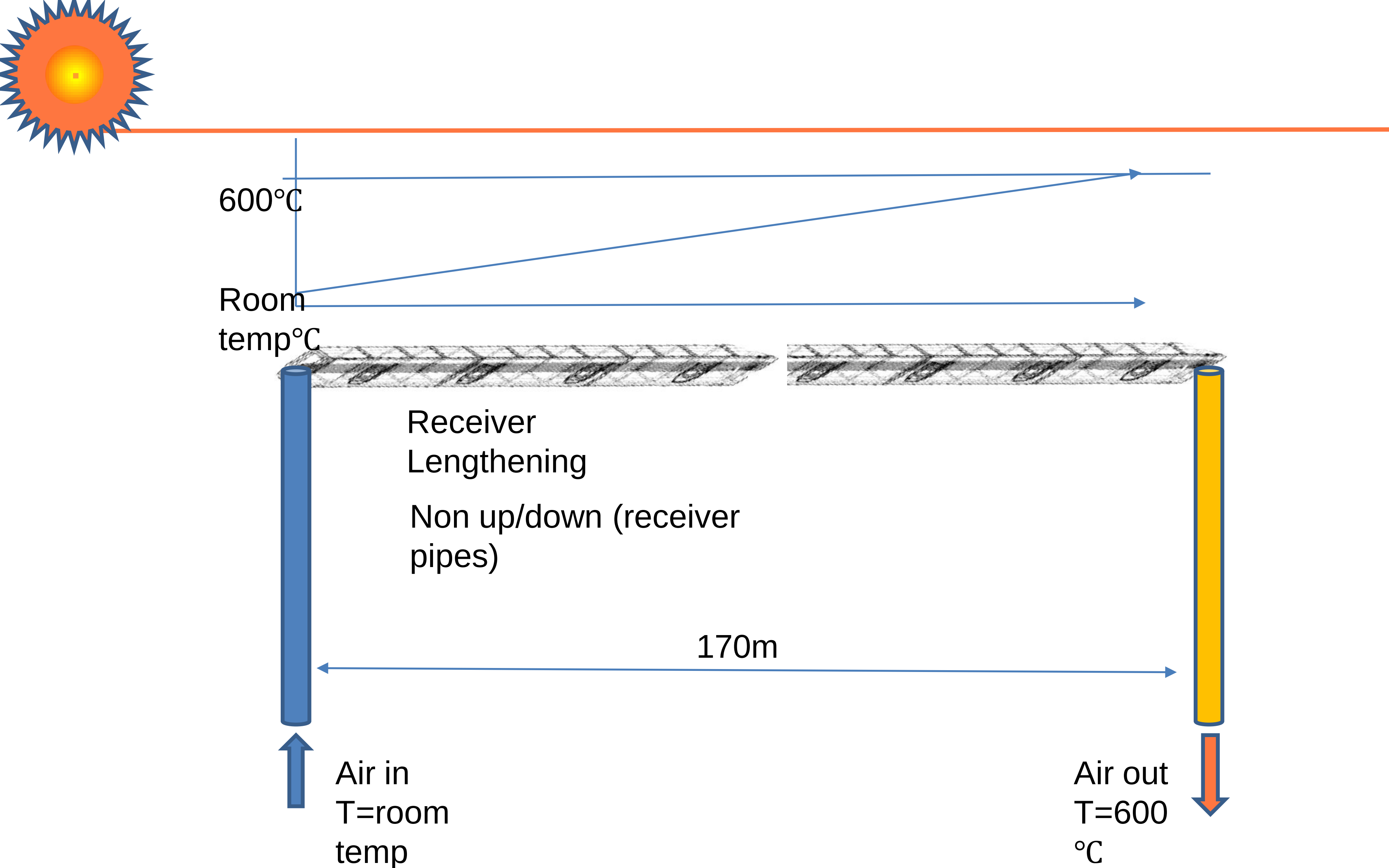
Lengthen Receiver pipe (Linear merit)

2MWe solar field (daytime =pow generation 8:00-16:00 8h)
1MWe solar field (daytime =pow generation +store; night time =pow generation16:00-0:00 8h)

Receiver pipe
Length=170m

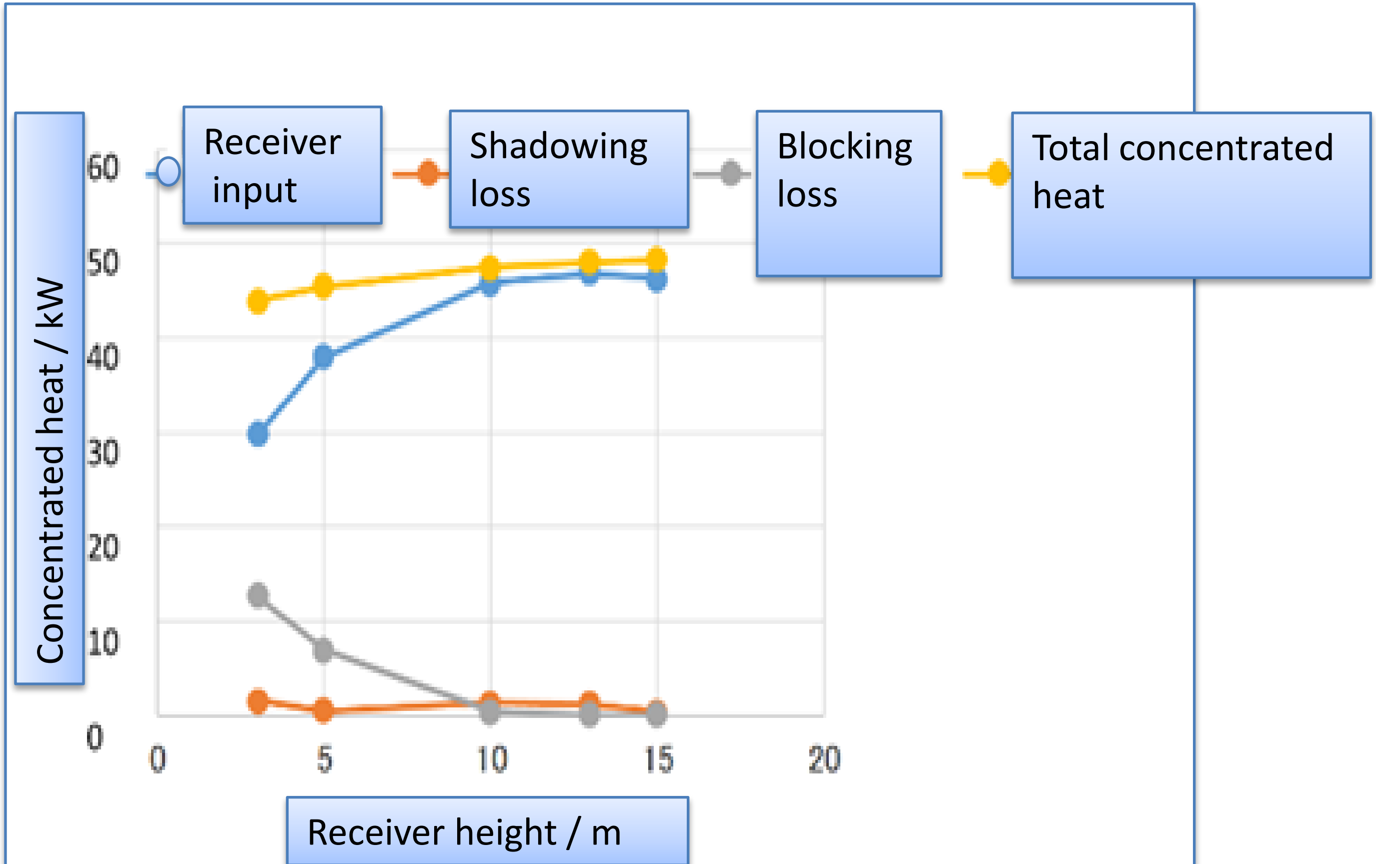
If the inner pressure is higher by 2 times
Length=340m





600℃
Room temp℃
Receiver Lengthening
Non up/down (receiver pipes)
170m
Air in T=room temp
Air out T=600 ℃

Field Optimization (reduce Rec height)

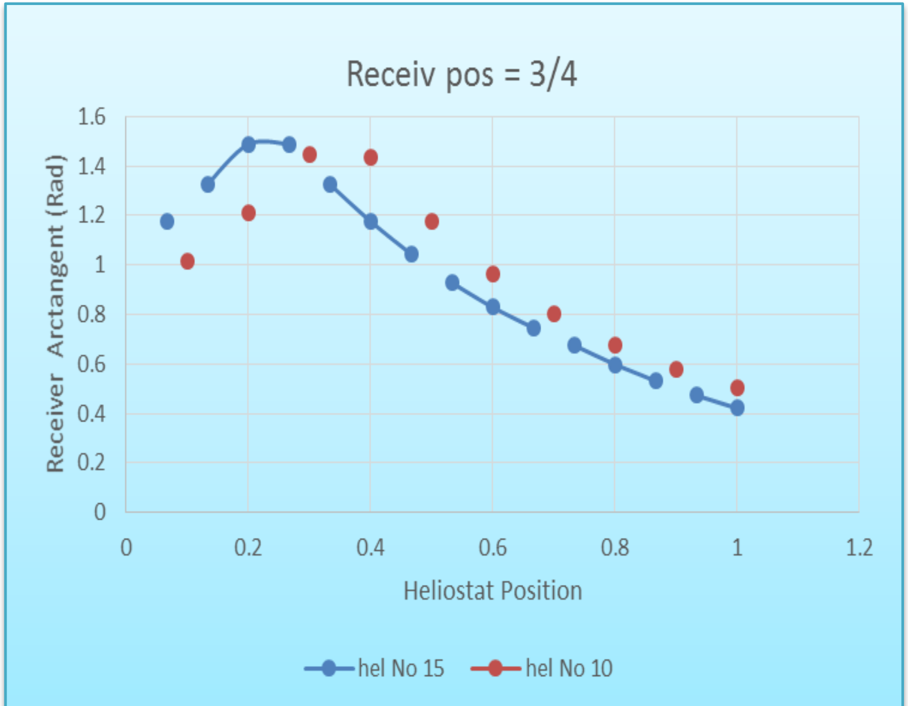


Variation (for Optimized field) of distance from Receiver at the position of HelNo=3/4 to the heliostat, focal length, and arc tangent for receiver height with the heliostat position number. HelNo=3/4 stands for that the receiver position is just middle between the heliostat number of 3 and 4.

Heliostat Number	normarized heliostat number	Distance from Receiver at the position of HelNo=3/4	Focal Length/ m	Arc Tangent for Receiver height
1	0.10	−6.25	11.79	1.01220
2	0.20	−3.75	10.68	1.21203
3	0.30	−1.25	10.08	1.44644
—	—	0(Receiver)	—	—
4	0.40	1.25	9.09	1.44644
5	0.50	3.75	9.75	1.21203
6	0.60	6.25	10.96	1.01220
7	0.70	8.75	12.55	0.85197
8	0.80	11.25	14.41	0.72664
9	0.90	13.75	16.43	0.62880
10	1.00	16.25	18.58	0.55165

Variation (for Design point) of distance from Receiver at the position of HelNo=3/4 to the heliostat, focal length, and arc tangent for receiver height (μin eq.1) with the heliostat position number. HelNo=3/4 stands for that the receiver position is just middle between heliostat number of 3 and 4.

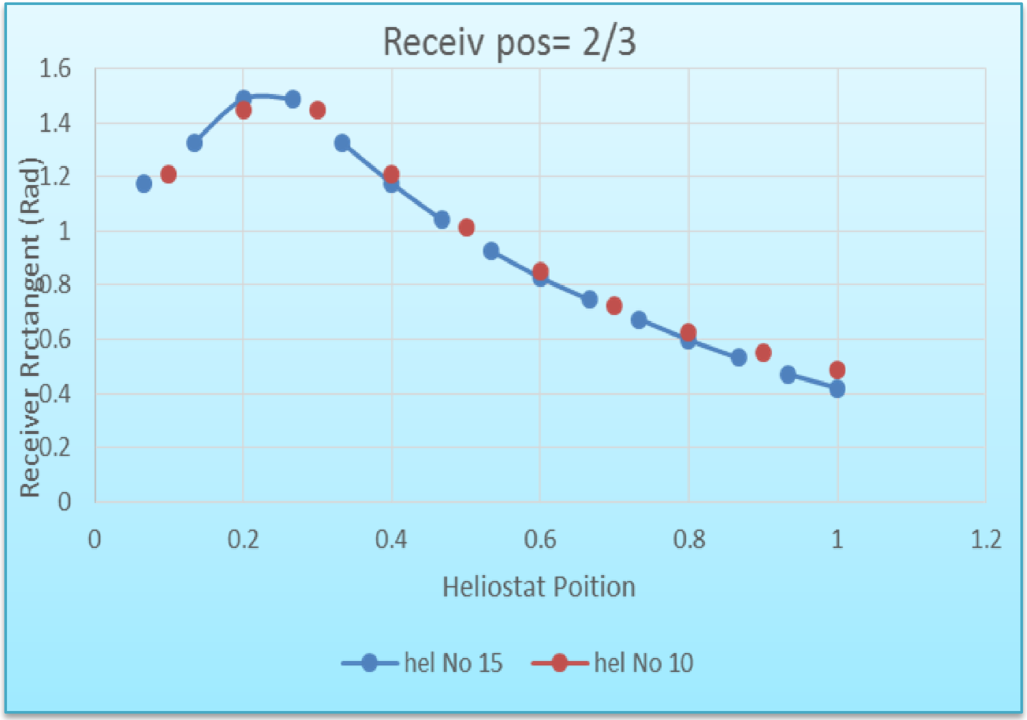
Heliostat Number	normarized heliostat number	Distance from Receiver at the position of HelNo=3/4	Focal Length/m	Arc Tangent for Receiver height
1	0.07	−6.25	16.25	1.17601
2	0.13	−3.75	15.46	1.32582
3	0.20	−1.25	15.05	1.48766
—	—	0(Receiver)	—	—
4	0.27	1.25	15.05	1.48766
5	0.33	3.75	15.46	1.32582
6	0.40	6.25	16.25	1.17601
7	0.47	8.75	17.37	1.04272
8	0.53	11.25	18.75	0.92730
9	0.60	13.75	20.35	0.82885
10	0.67	16.25	22.11	0.74542
11	0.73	18.75	24.01	0.67474
12	0.80	21.19	25.64	0.59818
13	0.87	23.62	27.40	0.53110
14	0.93	26.06	29.26	0.47233
15	1.00	28.49	31.22	0.42076



Relationships of the arc tangent and the normalized heliostat number between the reduced case of Table 2.2-22 (HelNo=3/4) (Curve with red circle; heliostat number=10) and the design point of Table 2.2-32 (HelNo=3/4) (Curve with blue circle; heliostat number=15)

Variation (for Optimized field) of distance from Receiver at the position of HelNo=2/3 to the heliostat, focal length, and arc tangent for receiver height (μin eq.1) with the heliostat position number HelNo=2/3 stands for that the receiver position is just middle between heliostat number of 2and 3.

Heliostat Number	normarized heliostat number	Distance from Receiver at the position of HelNo=2/3	Focal Length/ m	Arc Tangent for Receiver height
1	0.10	−3.75	10.68	1.21203
2	0.20	−1.25	10.08	1.44644
—	—	0(Receiver)	—	—
3	0.30	1.25	10.08	1.44644
4	0.40	3.75	10.68	1.21203
5	0.50	6.25	11.79	1.01220
6	0.60	8.75	13.29	0.85197
7	0.70	11.25	15.05	0.72664
8	0.80	13.75	17.00	0.62880
9	0.90	16.25	19.08	0.55165
10	1.00	18.75	21.25	0.48996

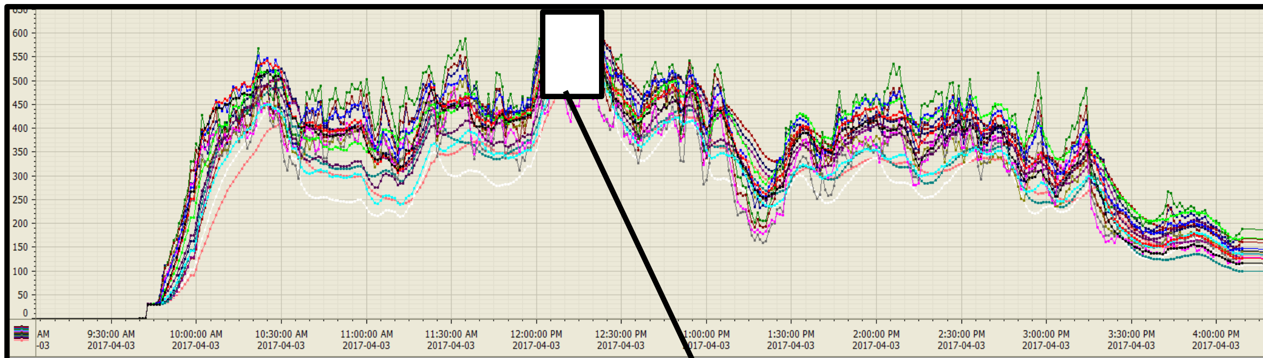


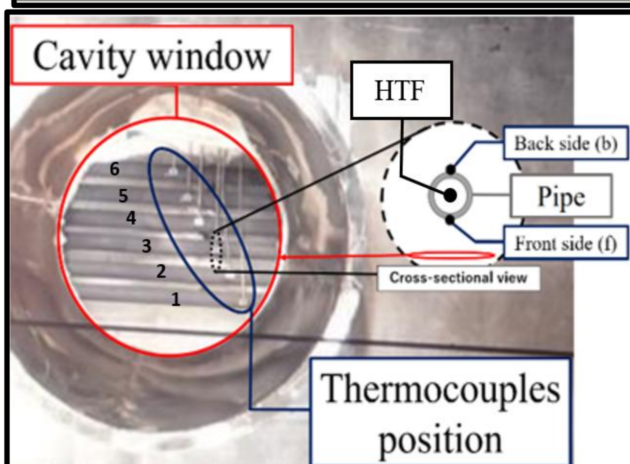
Relationships of the arc tangent and the normalized heliostat number between the reduced case of Table 2.2-32 (HelNo=2/3) (Curve with red circle; heliostat number=10) and the design point of Table 2.2-32 (HelNo=3/4) (Curve with blue circle; heliostat number=15)

The cosine factor calculated for the reduced case of the heliostat field reduced by 2/3 in the mirror line length, and lowered by 5m of the receiver height from 15m to 10m along with the receiver position shift at HelNo=2/3 under satisfying eq.1 of CL-CSP principle.

		Arc Tangent (rad)	-0.964	-1.176	-1.433	1.433	1.176	0.964	0.799	0.580
			Helostat Number							
Time	Solar altitude	Solar azimuth	No1	No2	No3	No4	No5	No6	No7	No9
6:00	-5.78	86.36	1.000	0.999	0.999	0.999	0.999	0.998	1.000	1.000
6:15	-2.25	87.85	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
6:30	1.41	89.33	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
6:45	4.67	90.82	1.000	0.999	0.999	0.999	0.999	0.999	1.000	1.000
7:00	8.05	92.31	0.999	0.998	0.998	0.998	0.998	0.998	1.000	1.000
7:15	11.46	93.82	0.998	0.997	0.996	0.996	0.997	0.995	0.999	1.000
7:30	14.88	95.37	0.997	0.995	0.993	0.993	0.995	0.991	0.999	1.000
7:45	18.29	96.96	0.995	0.992	0.989	0.990	0.992	0.987	0.999	1.000
8:00	21.7	98.61	0.994	0.990	0.985	0.986	0.990	0.982	0.998	1.000
8:15	25.09	100.33	0.992	0.987	0.980	0.981	0.987	0.976	0.998	0.999
8:30	28.47	102.15	0.990	0.983	0.975	0.976	0.983	0.969	0.997	0.999
8:45	31.82	104.09	0.988	0.979	0.970	0.971	0.979	0.962	0.996	0.999
9:00	35.15	106.16	0.985	0.975	0.964	0.965	0.975	0.955	0.996	0.999
9:15	38.43	108.41	0.983	0.972	0.958	0.959	0.972	0.947	0.995	0.999
9:30	41.68	110.86	0.981	0.967	0.952	0.953	0.967	0.940	0.995	0.999
9:45	44.87	113.57	0.978	0.963	0.946	0.947	0.963	0.932	0.994	0.999
10:00	47.99	116.58	0.976	0.960	0.940	0.941	0.960	0.925	0.993	0.999
10:15	51.02	119.97	0.974	0.956	0.935	0.936	0.956	0.918	0.993	0.999
10:30	53.95	123.82	0.972	0.952	0.929	0.930	0.952	0.911	0.992	0.999
10:45	56.74	128.23	0.970	0.949	0.925	0.925	0.949	0.905	0.992	0.999
11:00	59.35	133.32	0.968	0.946	0.920	0.921	0.946	0.899	0.991	0.998
11:15	61.74	139.21	0.967	0.944	0.916	0.917	0.944	0.894	0.991	0.998
11:30	63.83	146.01	0.965	0.941	0.913	0.914	0.941	0.890	0.991	0.998
11:45	65.57	153.8	0.964	0.940	0.911	0.912	0.940	0.887	0.990	0.998
12:00	66.86	162.54	0.964	0.939	0.909	0.910	0.939	0.885	0.990	0.998

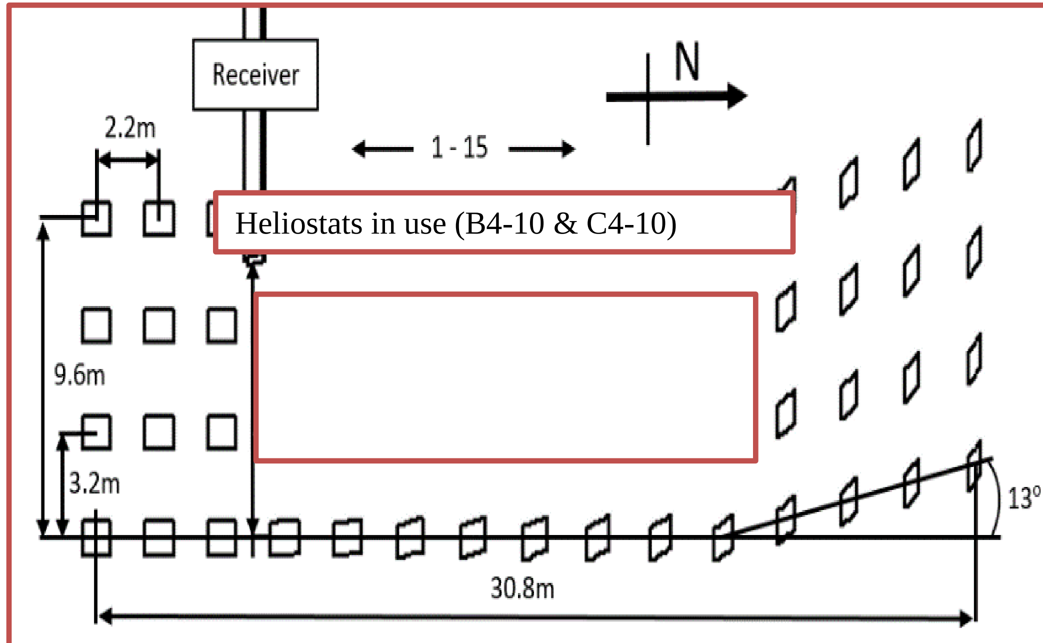
		Arc Tangent (rad)	-0.964	-1.176	-1.433	1.433	1.176	0.964	0.799	0.580
			Helostat Number							
Time	Solar altitude	Solar azimuth	No1	No2	No3	No4	No5	No6	No7	No9
6:00	-5.78	86.36	1.000	0.999	0.999	0.999	0.999	0.998	1.000	1.000
6:15	-2.25	87.85	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
6:30	1.41	89.33	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
6:45	4.67	90.82	1.000	0.999	0.999	0.999	0.999	0.999	1.000	1.000
7:00	8.05	92.31	0.999	0.998	0.998	0.998	0.998	0.998	1.000	1.000
7:15	11.46	93.82	0.998	0.997	0.996	0.996	0.997	0.995	0.999	1.000
7:30	14.88	95.37	0.997	0.995	0.993	0.993	0.995	0.991	0.999	1.000
7:45	18.29	96.96	0.995	0.992	0.989	0.990	0.992	0.987	0.999	1.000
8:00	21.7	98.61	0.994	0.990	0.985	0.986	0.990	0.982	0.998	1.000
8:15	25.09	100.33	0.992	0.987	0.980	0.981	0.987	0.976	0.998	0.999
8:30	28.47	102.15	0.990	0.983	0.975	0.976	0.983	0.969	0.997	0.999
8:45	31.82	104.09	0.988	0.979	0.970	0.971	0.979	0.962	0.996	0.999
9:00	35.15	106.16	0.985	0.975	0.964	0.965	0.975	0.955	0.996	0.999
9:15	38.43	108.41	0.983	0.972	0.958	0.959	0.972	0.947	0.995	0.999
9:30	41.68	110.86	0.981	0.967	0.952	0.953	0.967	0.940	0.995	0.999
9:45	44.87	113.57	0.978	0.963	0.946	0.947	0.963	0.932	0.994	0.999
10:00	47.99	116.58	0.976	0.960	0.940	0.941	0.960	0.925	0.993	0.999
10:15	51.02	119.97	0.974	0.956	0.935	0.936	0.956	0.918	0.993	0.999
10:30	53.95	123.82	0.972	0.952	0.929	0.930	0.952	0.911	0.992	0.999
10:45	56.74	128.23	0.970	0.949	0.925	0.925	0.949	0.905	0.992	0.999
11:00	59.35	133.32	0.968	0.946	0.920	0.921	0.946	0.899	0.991	0.998
11:15	61.74	139.21	0.967	0.944	0.916	0.917	0.944	0.894	0.991	0.998
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

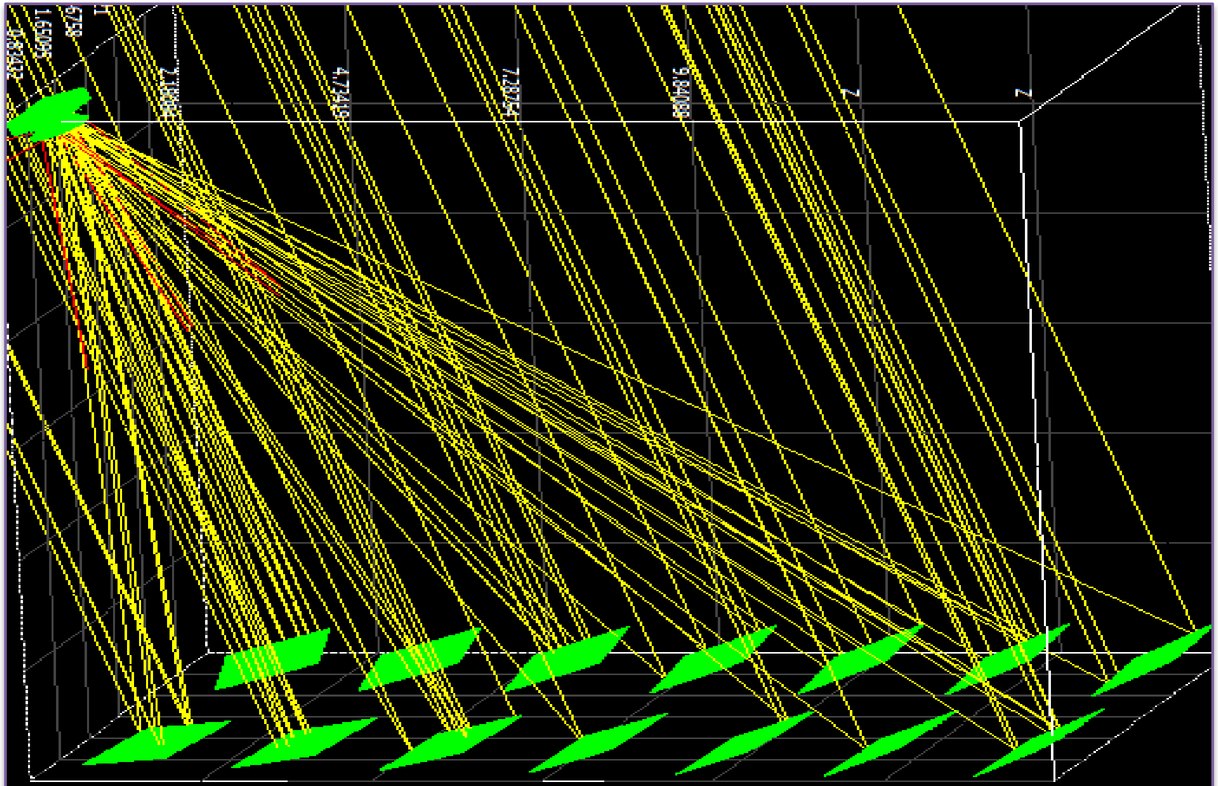




	Thermocouple's reading (K)		
	HTF	f	b
Pipe 1	819	798	853
Pipe 2	853	813	876
Pipe 3	877	863	878
Pipe 4	874	881	858
Pipe 5	803	861	868
Pipe 6	793	871	803

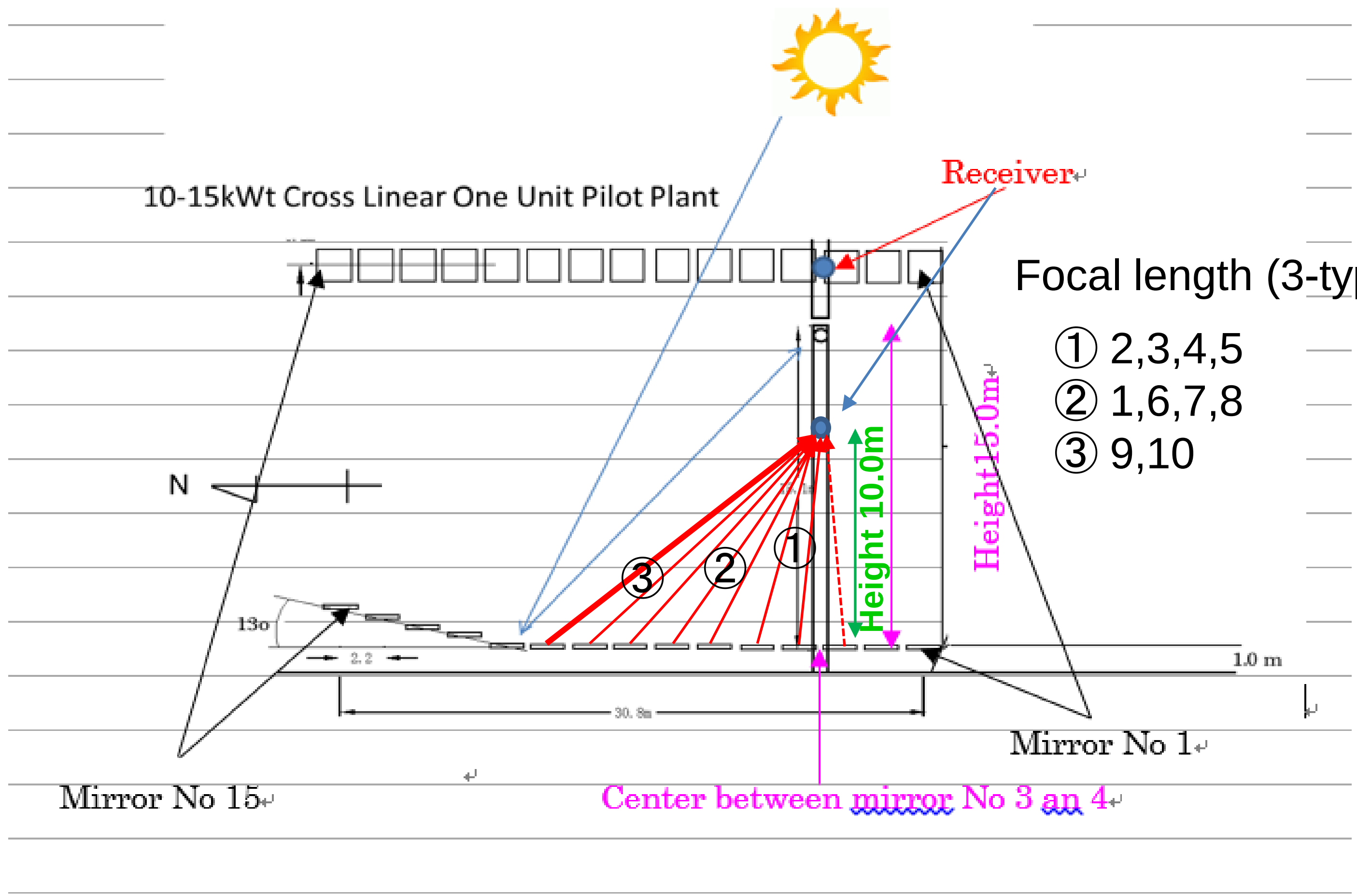
Measured temperature data on 3 April 2017 at RGPV, India


Receiver
N
2.2m
1 - 15
Heliostats in use (B4-10 & C4-10)
9.6m
3.2m
13°
30.8m



Ray tracing for 14 heliostats on 3 April 2017 at 12:15PM

Field Optimization (Reduce Hel. Number)

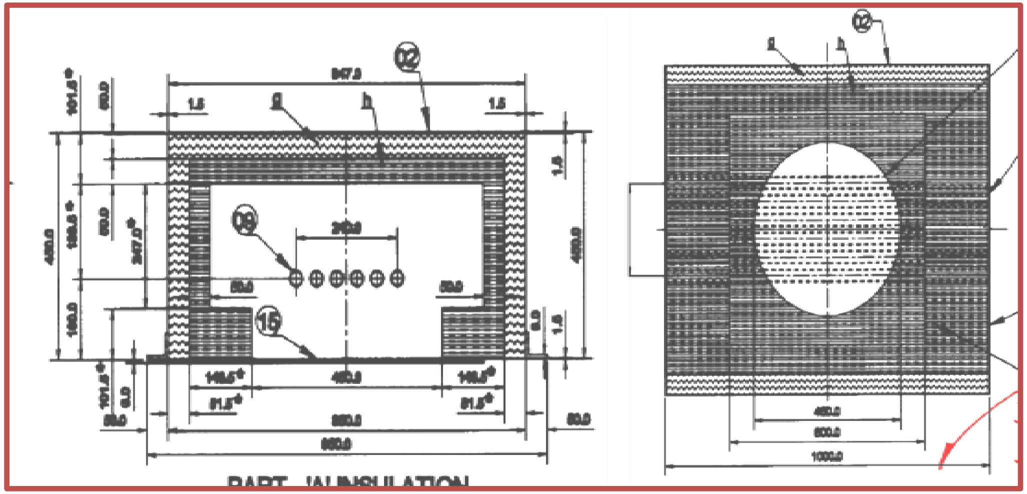


Focal length (3-types)

① 2,3,4,5
② 1,6,7,8
③ 9,10

$$Q = A_{Ap} \cdot [\alpha \cdot C \cdot E^{S} - \varepsilon \cdot \sigma \cdot T_{A}^{4} - U_{L} \cdot (T_{A} - T_{a})]$$

A_{Ap}; aperture area	
α ; average absorptivity of the absorber with respect to the solar spectrum	
C ; concentration factor	
E^{S} ; radiation density of the direct solar radiation (DNI)	
ε ; the average emissivity of the absorber with respect to the black body radiation at the absorber temperature T_A.	
σ ; the Stefan-Boltzmann constant	
U_L ; the heat loss coefficient due to convection and conduction.	



CAVITY LINEAR RECEIVER APPLIED FOR 30kWt PILOT PLANT OF CL-CSP

$$Q_c = A_{Ap} \cdot [\alpha \cdot C \cdot E^S - \psi \cdot \varepsilon \cdot \sigma \cdot T_A^4 - U_L \cdot (T_A - T_a)]$$

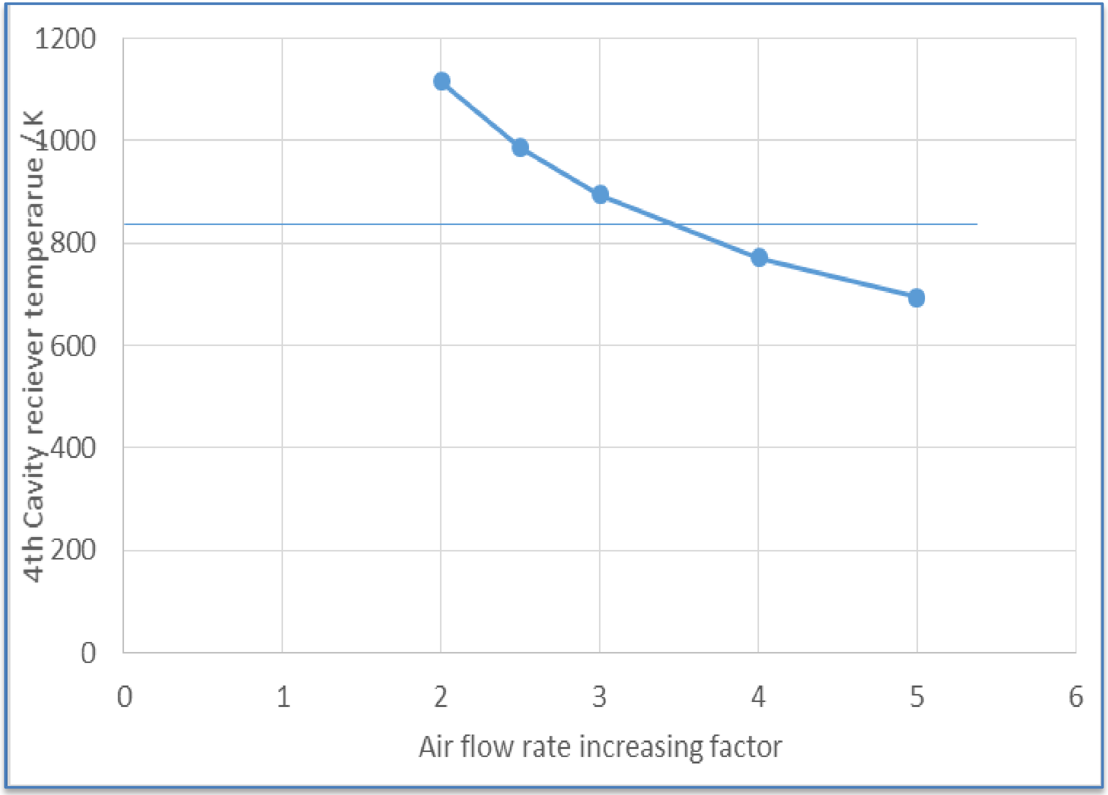
For the practical calculation of Qc of the 30kW CL-CSP pilot plant with A_{AP}= 0.16m^2, C=14.06 x 12 = 168.72 (theoretical), α=0.77, ε= 0.6, T_A = 875.5, U_L = 0.1, T_a = 318, andΨ=0.33, the heat transferred to the air fluid for the cavity receiver (Qc) of 6.705 kW, which is nearly equal to the recovered heat, was obtained.

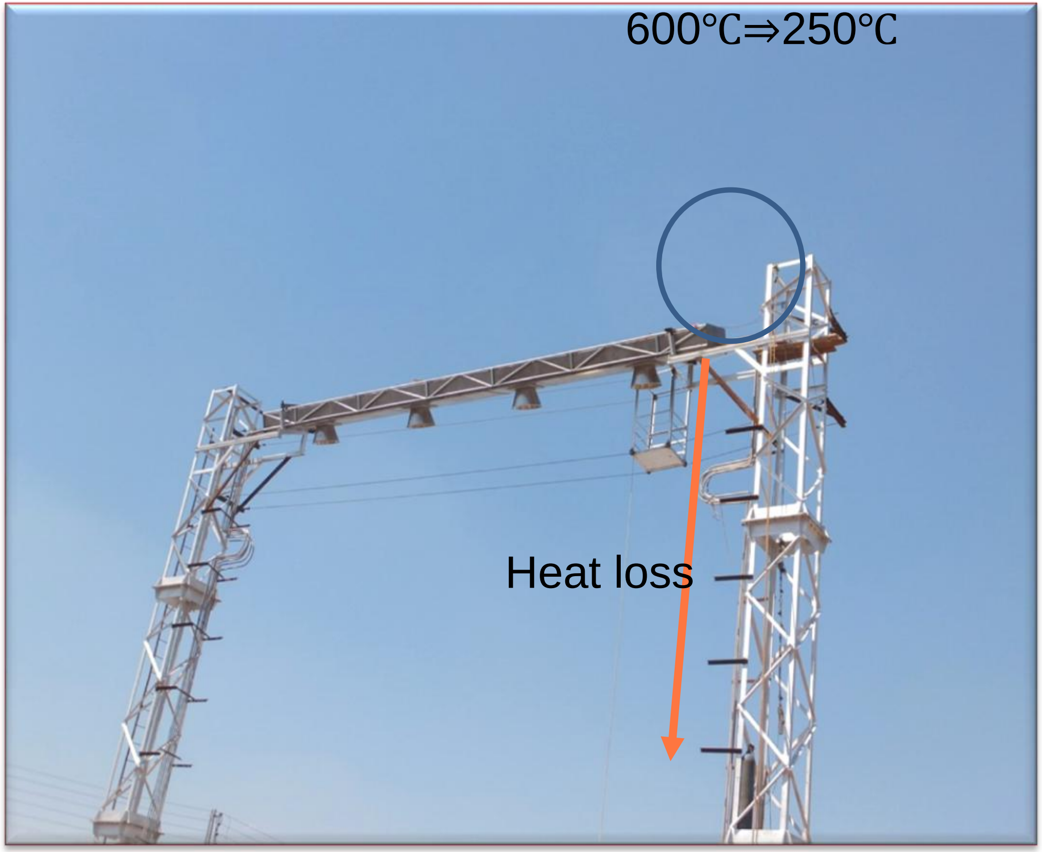
Revised 13/may 2017 in India by Prof.Tamaura

1	Receiver C Air FluidTemp	
	TI-15/℃	604
	TI-16/℃	601
	average temp/℃	602.50
2	Recovered heat /eq	1.110kW/kg*334kg/h*0.8*(602.5-40)/60/60*(3.4/6)
	kW	6.57
3	Input heat into receiver (input High case)/eq	12(1.5*1.5)*0.95(sp)*0.85(refc)*0.93(cosF)*0.8(DNI)
	kW	16.22
	Recovery efficiency (input High case)	0.405
4	Input heat into receiver (Low case)/eq	12(1.5*1.5)*0.95(sp)(0.8)*0.85(refc)(0.8)*0.93(cosF)*0.8(DNI)
	kW	10.38
	Recovery efficiency (input Low case)	0.632
5	Air flow /eq	334kg/h*0.2*(3.4/6atm)
	kg/h	37.85
6	Optimized field	
	Total capacity	(Recovered heat)X40/12/0.8
	kW	27.35
	rate from 30kW	0.91
7	Air specific weight 1.293kg/m^3(ntp)	

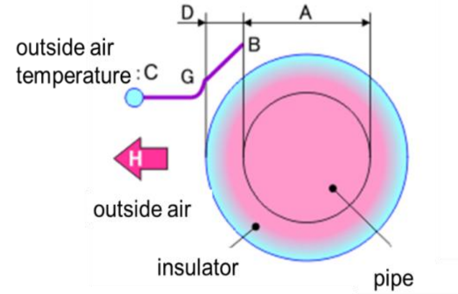
Boundary conditions and setting for ANSYS Fluent	Boundary conditions
Mass flow rate	333kg/h
Inlet air pressure	3.4atm
Inlet air temperature	313K-923K
Cavity air pressure	1atm
Glass window	Quartz glass 5mm
Insulator wall	Rockwool 100mm
Receiver pipe walls	System coupled
Image size (cm)	50
Total Power (W)	16925.6

4^{th} receiver Temp / air flow rate factor




600℃⇒250℃
Heat loss

A=pipe radius	0.03m
B=Inner pipe temp	600℃
C=ambient temp	40℃
D=insulator radius	0.3m
E=conduction coefficient	0.044W/Km
F=surface radiant	0.5
J=convection coefficient	11W/m2K
G=insulator surface temp	41.7648℃
K=convection heat loss	38.423W/m,
L=radiant	12.2681W/m
H=total heat loss/m	50.6911W/m



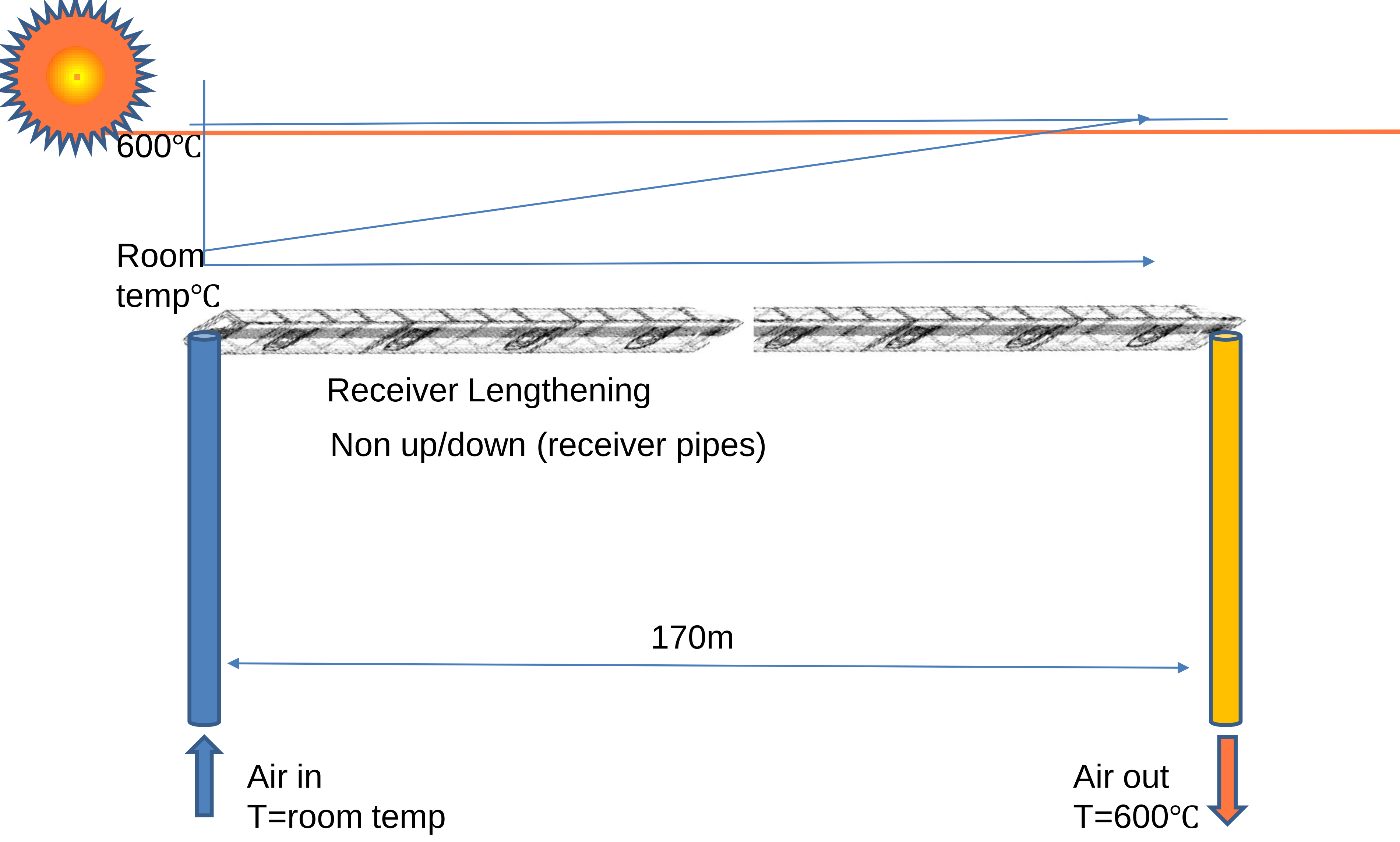
With the heat loss of 50.6911 W/m and the pipes length from the receiver to the ground level (20m), the total heat loss of the hot air (600℃) transfer from the receiver to the ground level steam generator is estimated to be 6.08kW.

$$\alpha = (A + 2 \times D) \times \pi$$

$$K = (G - C) \times J \times \alpha$$

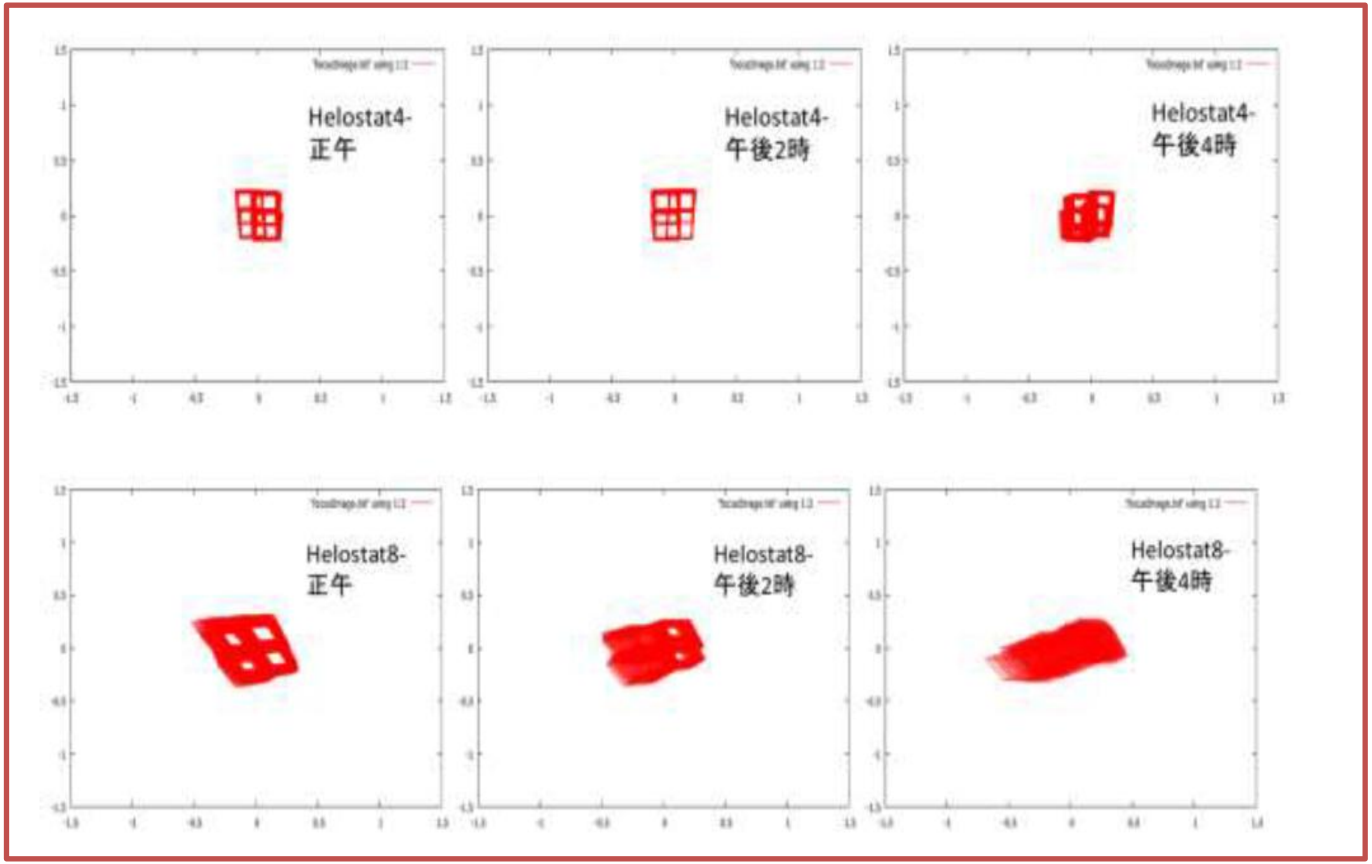
$$L = \left((G + 273.15)^4 - (C + 273.15)^4\right) \times F \times \sigma \times \alpha$$

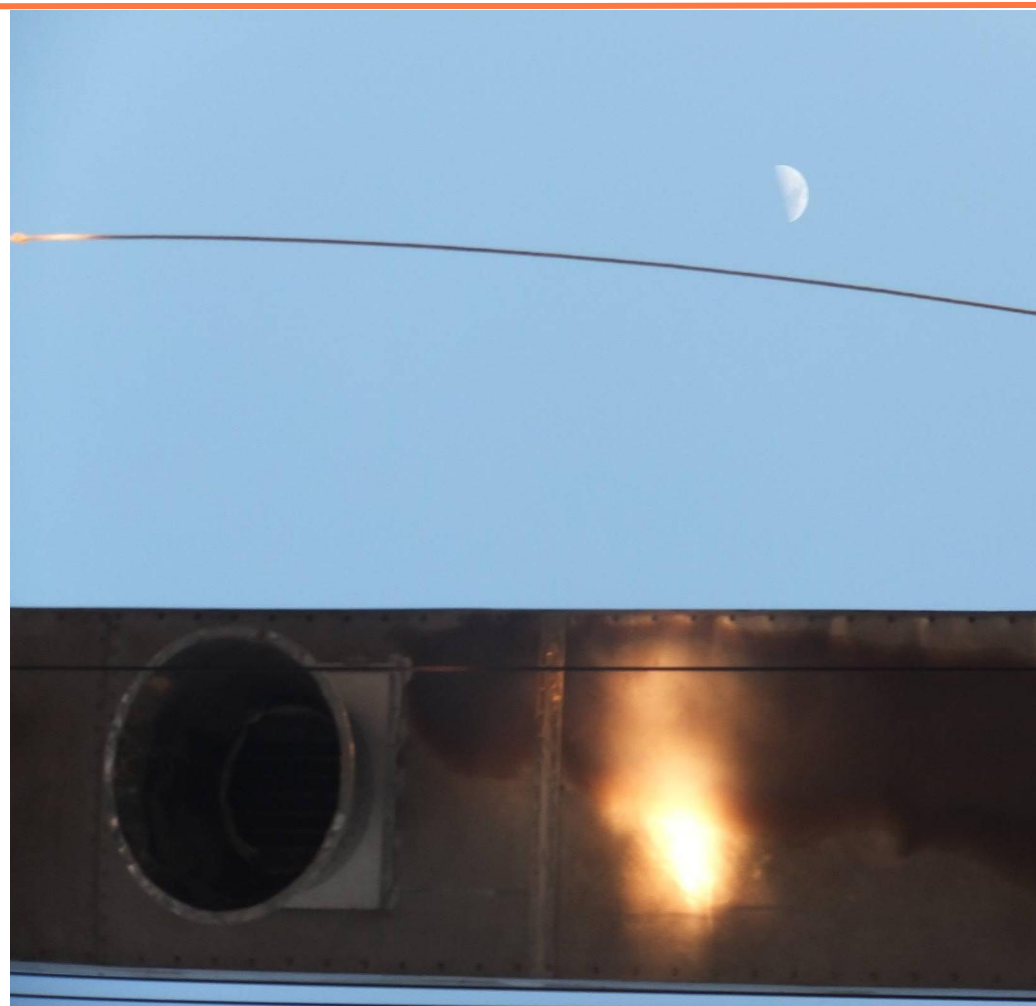
$$H = K + L = \frac{2 \times \pi \times E \times (B - G)}{\ln\left(\frac{A + 2 \times D}{A}\right)}$$

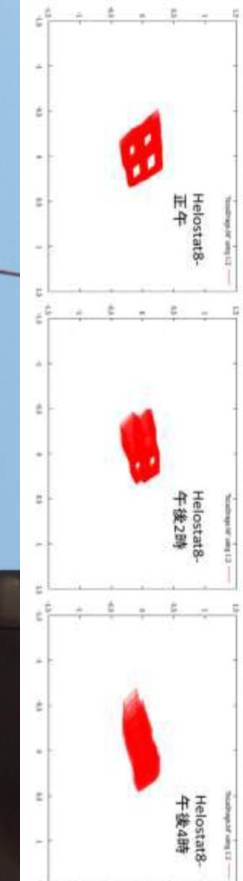

600℃
Room temp℃
Receiver Lengthening
Non up/down (receiver pipes)
170m
Air in
T=room temp
Air out
T=600℃

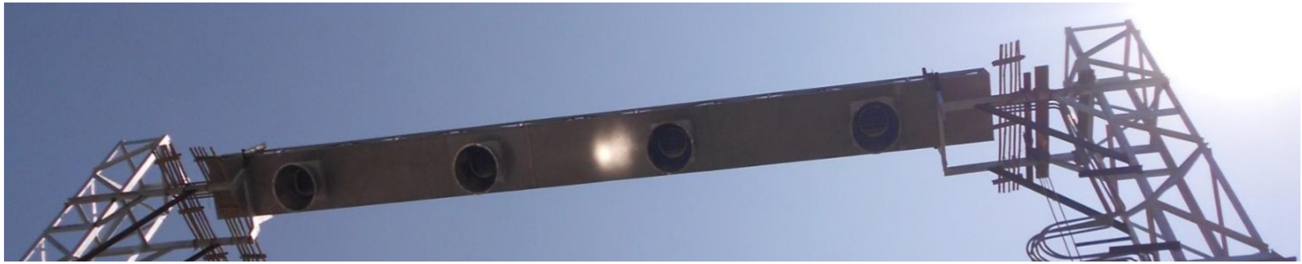
Examination on Simulation Errors

Comatic Error






Helostat8-正午
Helostat8-午後2時
Helostat8-午後4時



The future looks bright for Concentrated Solar Power

- **Storage, the CSP advantage:-Requirement of 24*7 Storage Technology in Solar thermal plants.**

- **Efforts to cut costs:-Investment cost is higher in present scenario.**

- **Higher temperatures can mean higher efficiencies:-More focus research is in deeded to enhance the temperature of solar thermal CSP technologies. As the temperature increases automatically the overall efficiency of the plant increases.**

- **Digital Glass can provide new ways to harvest sunlight.:- Also, the more R&D focus is to be required on the optical side of the Heliostat.**

Concentrated Solar Power Pros & Cons:-

Pros

- Carbon-free
- Can serve as a drop-in replacement for conventional fuels to make steam
- Operating costs are low
- Can utilize thermal storage to better match supply with demand
- High efficiency
- Scalable to the 100MW + level

Cons

- Intermittent
- Low energy density
- Construction/installation costs are high
- They require a considerable amount of space
- Manufacturing processes often create pollution
- Heavily location dependent
- Will involve significant transmission distances/losses

Conclusion

- The skin temperature of the Receiver pipes temp=645℃ using A lines—B lines(total number of mirrors=15) was obtained. This shows that the plant field with the installed heliostats has a potential to concentrate the solar heat to get the skin pipe temperature above 600℃.

- Air fluid temperature of 600 deg C was obtained, but the steam generation heat system at the ground can't be operated due to the heat loss (20.17% out of the 30kWt) between the receiver and the heat system at the ground. From this project we are not be able to generate the super heated steam due to the high ratio of the heat loss in the 600 deg C air from the receiver to the ground steam generation system.

Setting up a test unit of 30kWt Cross Linear CSP System at RGPV, Bhopal with the following objectives:-

a) **Demonstrate high temperature (>=600C) attainment from CL-CSP.**
Air fluid temp of 602degC was obtained, but the steam generation heat system at the ground can't be operated due to the heat loss (20.17% out of the 30kWt) between the receiver and the heat system at the ground.

b) **Optimize simulation technology of CL-CSP.**
The heliostat number was decreased from 60 to 40. The receiver height can be reduced to 10m from 15m in satisfaction for CL-CSP principle.

c)Utilize to develop 1MWe plant.

To save the heat loss from the receiver to the ground, the receiver lengthen with one span of 170m (1MWe) was designed.

d) Development of road map to bring down the tariff based on this technology to be competitive to solar PV plants considering scaling up and indigenization aspects of the technology.

This objective was setup in year 2011 when we submitted the project to MNRE. At that time, there was not too much difference in tariff of Solar PV and Solar Thermal. But in last five year big evolution in Solar PV technology it cost come down to less than convention thermal power plant cost. So we can't compare these to technology on tariff base but we can make CSP system more reliable and commercially viable .

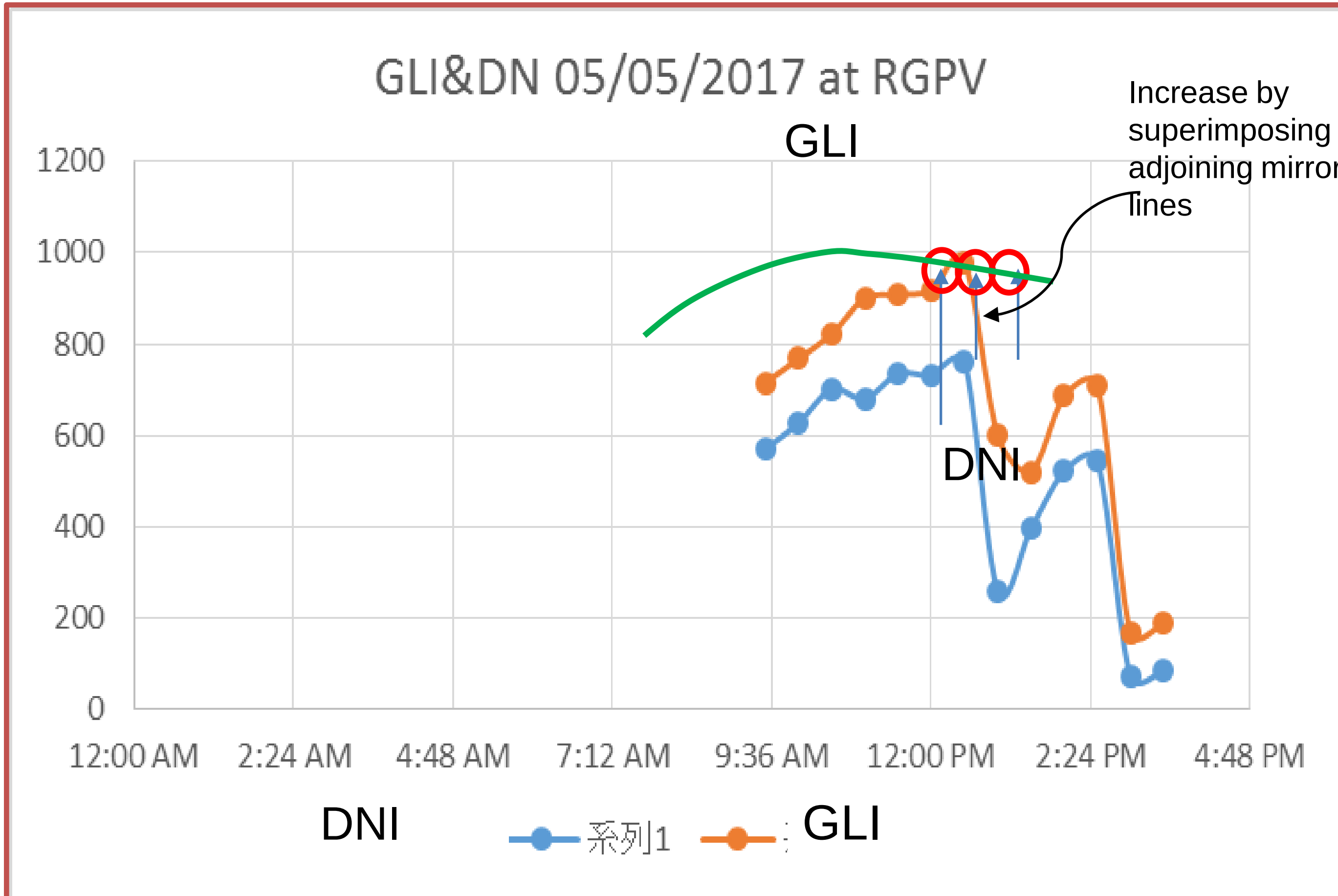
We were not be able to generate the super heated steam due to the high ratio (20%) of the heat loss in the 600deg C air from the receiver to the ground steam generation system.

For 30kW pilot plant, the heat loss ratio of the heat transfer pipes from the receiver to the ground heat system is 20.17% for 600deg C air (heat loss rate 20.17%=6.05/30kW).

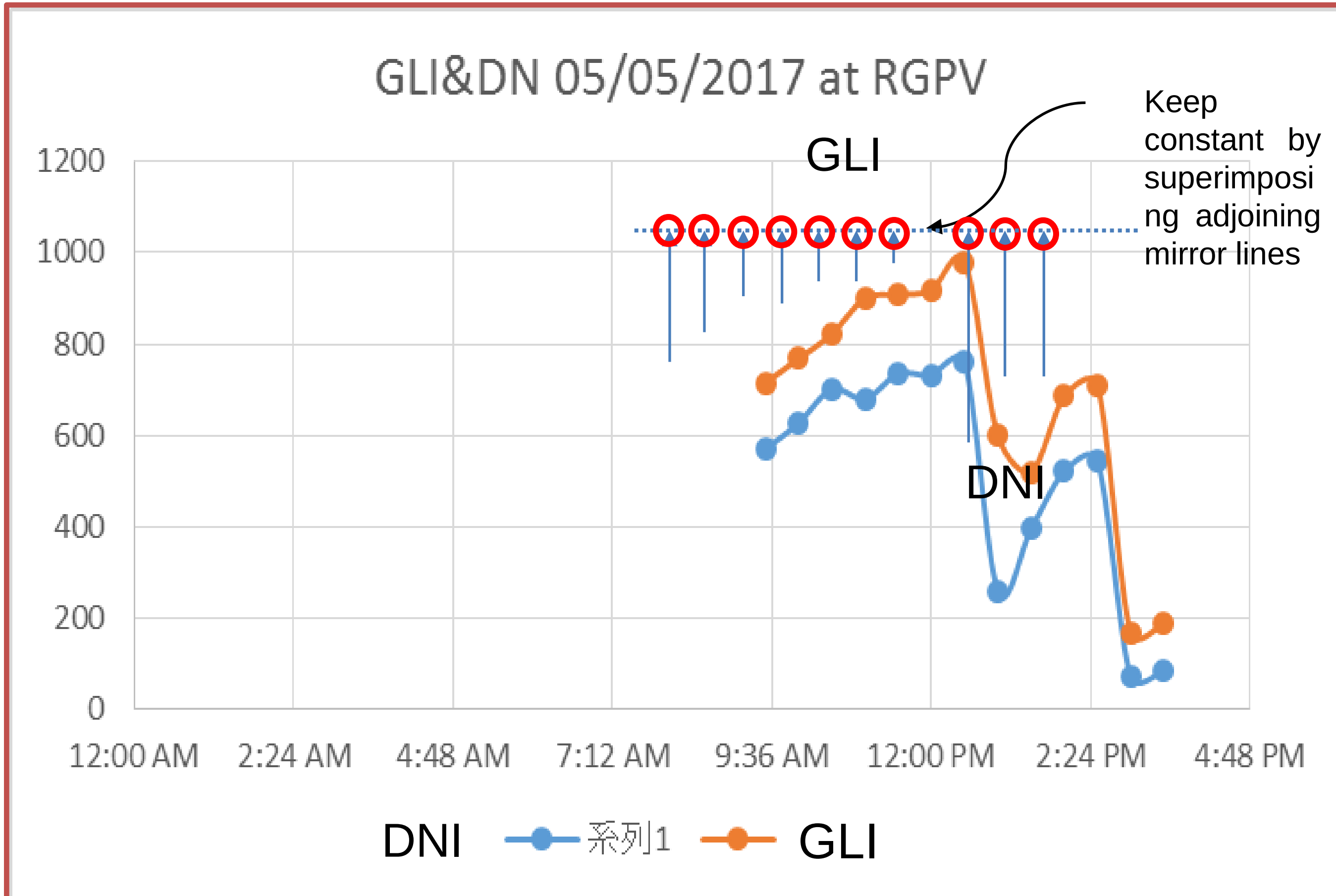
This can be solved by scaling up to 100-300kW using the one span receiver with a length of 170m.

We can't get the 600degC air continuously. To get the enough power for 30kW of the recovered heat at receiver A, we have to increase the flux of the concentrated beam more than 1.3 – 1.6 times. This suggests that we need the improvement of the mirror to get the higher concentration factor by 1.3 to 1.6 time.

For optimizing the 30kW pilot plant, we have to lower the existing receiver height of 15m to 10m.



GLI&DN 05/05/2017 at RGPV
GLI
Increase by superimposing adjoining mirror lines
1200
1000
800
600
400
200
0
DNI
12:00 AM
2:24 AM
4:48 AM
7:12 AM
9:36 AM
12:00 PM
2:24 PM
4:48 PM
DNI
系列1
GLI


GLI&DN 05/05/2017 at RGPV
GLI
DNI
Keep constant by superimposing adjoining mirror lines
1200
1000
800
600
400
200
0
12:00 AM
2:24 AM
4:48 AM
7:12 AM
9:36 AM
12:00 PM
2:24 PM
4:48 PM
DNI
系列1
GLI

30 kWt CROSS LINEAR-CONCENTRATED SOLAR POWER TECHNOLOGY BASED SOLAR THERMAL PROJECT AT RGPV ,BHOPAL,INDIA

Dr. Anil Kakodkar, Eminent Scientest

Dr. R. K Gosawami,Director-MNRE

Dr. H.P Garg, Sr. Solar Consultant, MNRE

Prof. R.B. Sharma, Director General- Amity University

UNIDO,CII & MNRE Visit

Dr. D. P. Agarwal, Ex-Chairman UPSE

Dr. Pramod Shrestha , National Consultant-Nepal

Prof. from Keney

MNRE officals Visit