HIGH PERFORMANCE

SOLAR DISH CONCENTRATOR

FOR

STEAM GENERATION

1.0 INTRODUCTION

With the experience gained in the development of solar Heliodish Concentrators (9.0 meter Dia. X 6 nos.) during the period 1980-86 while working at BHEL and also looking at the target of 45000 meter sq. of dish concentrator area to be installed by 2017 in India, it is now intended to develop a 12.4 m Dia. Spherical or Parabolic Dish concentrator for steam generation at 300 degree or higher temperatures. Production of steam at such temperature is possible either by using solar line focusing collectors or solar point focusing collectors. Attainment of this temperature using line focusing collectors involves use of evacuated tube selectively coated absorbers. The overall efficiency available through this is around 30% in this temperature range. Alternatively an efficiency of about 70% is achievable by the use of the point focusing concentrating collectors without going in for evacuated tube selectively coated absorbers but with focally mounted single pass cavity receiver.

2.0 - DESCRIPTION OF THE DISH CONCENTRATOR

The Dish Concentrator for producing steam at 300°c and 10 bar pressure or even higher consists of the following main components.

- 2.1 Mirror Facets
- 2.2 Base Structure for mirror facets
- 2.3 Single pass cavity receiver
- 2.4 Two axis single board tracking and safety control
- 2.5 Control system for steam temperature and pressure
- 2.6 Circulation system consisting of Feed Water Pump Motor Assembly, Piping, Valves, Insulation etc.

Figure 1 presents the Dish Concentrator and Figure 2 presents a Schematic diagram for the total system .The Dish Concentrator is of 12.4 m dia., MS structure. The dish concentrator structure is made of mild steel radial beams which are 11 in no.. Mirror facets, 389 in nos. & rectangular in shape are mounted on the circular beams mounted on the radial beams. Each mirror facet has two degrees of freedom for alignment purpose. The Centre of the dish is joined to a torque tube which is mounted on a fork which in turn is mounted on the pedestal through an azimuth and elevation drive.

Figure-1(A) Dish Concentrator

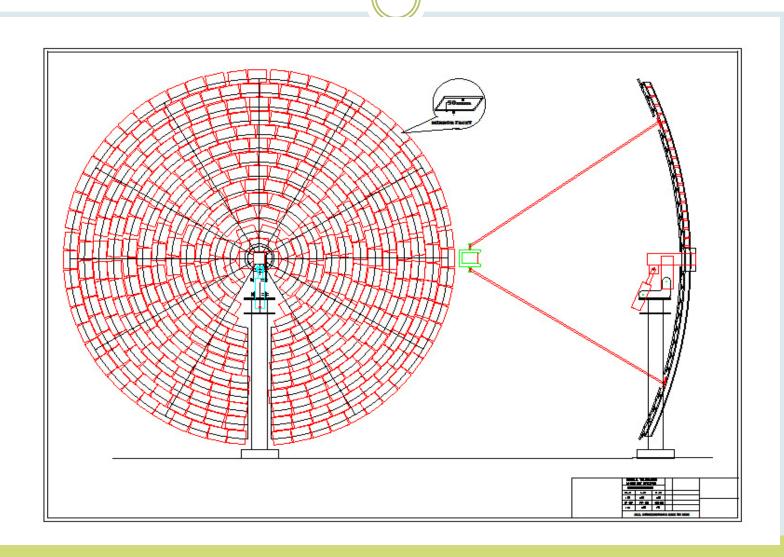


Figure-1(B) Dish Concentrator

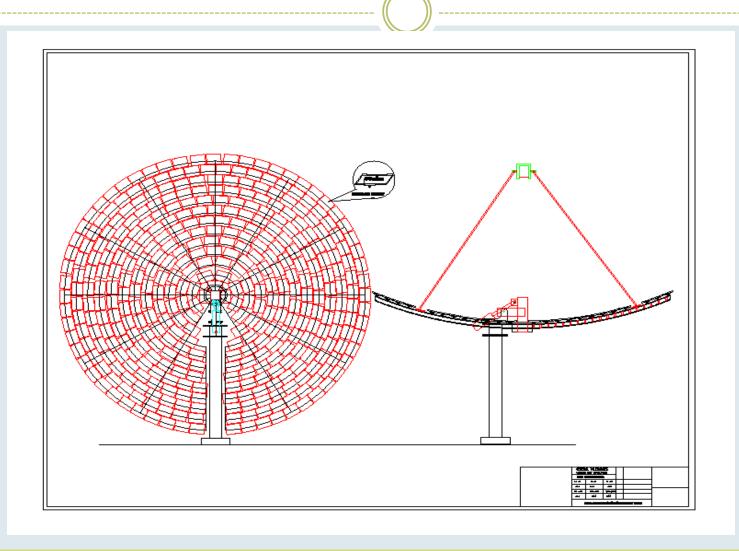
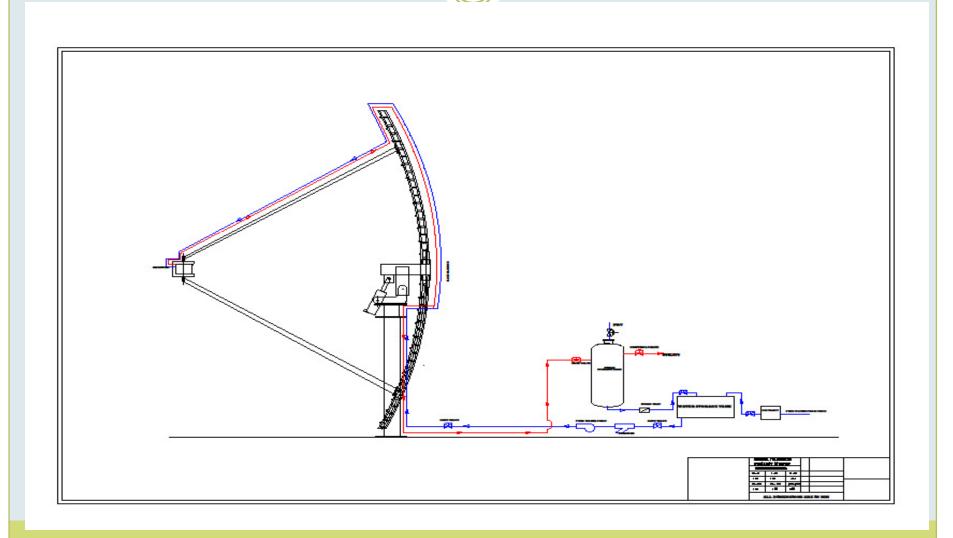


Figure-2 Schematic System Diagram of Dish Concentrator

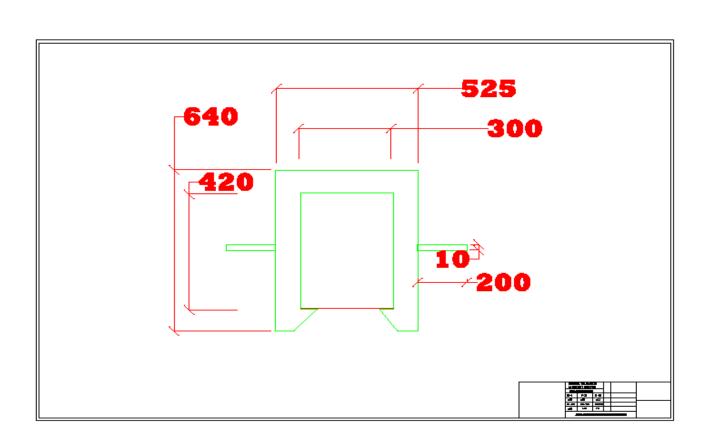


- The dish is operated between 5.0 m/sec and 10.0 m/sec. wind speed and starts stowing beyond this speed. At 14.0 m/sec and above, the Dish remains stationery in the horizontal position. The complete structure is balanced about the pivot point of the Fork mounted on the azimuth drive. The movement of the Dish in the azimuth is ±180° whereas in the elevation ± 120°. The dish has 105 m² effective reflecting area. The receiver is mounted at the focal point through a tripod structure.
- One millimeter thick mirror is mechanically deformed and is bonded to a spherically contoured Foam Glass/FRP substrate. All the mirrors in the circular rows of the Dish have same radius of curvature. The expected reflectance of the mirror is 0.95 and the surface slope error is less than 2 mrad.

3.0- DESCRIPTION OF THE RECEIVER

A cavity receiver as shown in fig - 3 is mounted at the focal point of the dish through a tripod structure. It forms the single pass steam boiler. The receiver is of 300mm ID and 420 mm long brazed helical coil housed inside a 525 mm ID and 640 mm long mild steel shell with back and front reflector plate. The front end is covered with graphite aperture plate to protect the receiver from sun walk up condition .The coil is, insulated with 9.5 mm thick ceramic insulation and 90.5 mm thick Rockwool insulation. The receiver is delivering a maximum of 97 kg/hr steam at 300°C and 10 bar pressure with solar DNI of 850 watts /m².

Figure 3- Receiver



4.0 **CONTROL SYSTEMS**

Since the input solar energy is variable from morning to evening and is also subjected to transients due to sudden cloud covers, the control philosophy has been developed taking such factor into consideration. In the control system, there are essentially two loops.

- Tracking control loop
- Steam control loop

4.1 TRACKING CONTROL LOOP

Two axis tracking has been carried out through two modes of operation such as memory mode and sun mode. Under memory mode of tracking, the microprocessor calculates accurate sun's position through a set of empirical equations which determine azimuth and elevation angles with respect to time. Through position feedback control loop, the computer gives necessary signals to the tracking motors to position the dishes.

During the sun tracking, the sun sensor output, one for elevation and another for azimuth on the same plane, feed the position error directly to a computer which drives the tracking motors to null the output of the sun sensor, thus tracking the sun. Since, the sun tracking operates on the premises of nulling the sensor, another signal is provided to the computer to generate insolation level, for changing over to memory mode of tracking when the insolation is insufficient for sun tracking during cloudy condition.

The solar tracking system employs an compatible single board computer and provides coarse tracking of the dish by using solar ephemeris data. An active shadow band sun sensor is used to control the system within < 0.7 mrad accuracy. The system utilizes positioning motors for both azimuth and elevation drive incorporating proper reduction gear. Maximum drive speed in azimuth and elevation movement is 600° per hour and 300° per hour respectively. The system also incorporates safety controls for the protection of receiver against burning and dish structure against high wind conditions.

4.2 STEAM CONTROL LOOP

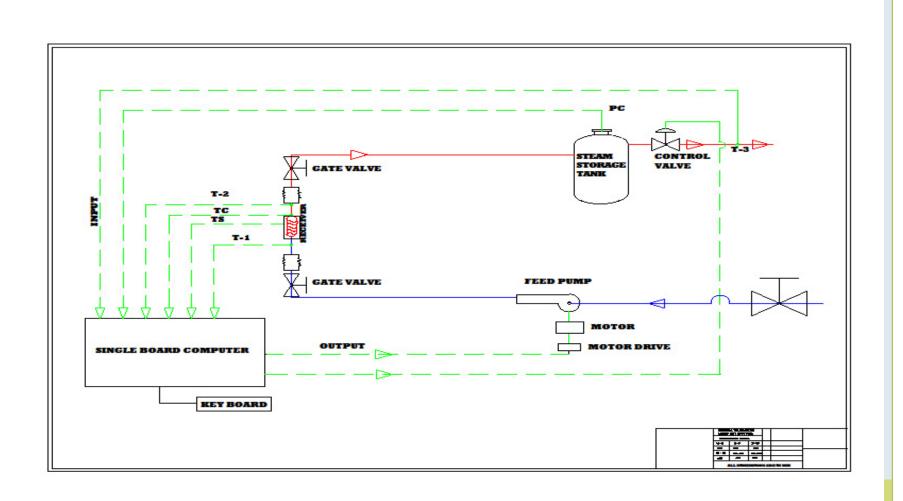
The steam temperature at the outlet of receiver is maintained by controlling water flow by varying the speed of feed water pump depending upon insolation level and the steam pressure in the total system is kept constant by controlling the steam flow in the utility line by the use of a control system.

5.0-INSTRUMENTATION AND MEASUREMENT SYSTEM

The measurement scheme provides avenue of acquisition of insolation data, temperatures, pressures and mass flow rate at various points necessary for the performance evaluation of the system .The schematic of instrumentation and measurement system has been shown in fig 4.



Figure 4- Instrumentation And Measurement System



6.0 SPECIFICATIONS OF SOLAR DISH CONCERTRATOR FOR STEAM GENERATION

Dish Structure	12.4 mtrs. Dia., MS Structure						
Reflecting surface	Faceted mirrors of rectangular shape 600x450 mm						
Total Reflecting Area	105 m ²						
Tracking system	Double axis, computer based and fine tuning by sun sensors						
Steam receiver	Cavity type , single pass						
Receiver coil	12 mm dia SS 347 tubing in the form of helical brazed coil						
Steam generation	300 °C temperature, 10 bar pressure or higher at 850 watts/m2 DNI.						

7.0 PREDICTED PERFOMANCE

The predicted performance of solar dish concentrator for steam generation for three typical days has been tabulated in Tables 1, 2 & 3

PREDICTED PERFOMANCE

02-05-12												
System Predicted Performance												
											Table No.	01
Site Details												
Latitude	2	8°4'										
Longitude	(-)7	77°12'										
Collector Area,m ²		105.0										
Heat Transfer Fluid		Water										
Parameters/Time*		8:00:00	9:00:00	10:00:00	11:00:00	12:00:00	13:00:00	14:00:00	15:00:00	16:00:00	17:00:00	Remarks
Hour angle	deg	-60	-45	-30	-15	0	15	30	45	60	75	
Declination angle	deg	15.510	15.510	15.510	15.510	15.510	15.510	15.510	15.510	15.510	15.510	
				C	oncentrator							
Direct Normal Irradiation	W/m²	545.95	761.15	802.36	847.49	852.56	875.50	838.09	832.82	775.75	412.50	7544.17
Optical Efficiency(mirror refrectivity,0.95 *		0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	
cavity Abosrbtance,0.95)= 0.90												
Solar thermal energy intercepted by	kW _{th}	51.59	71.93	75.82	80.09	80.57	82.73	79.20	78.70	73.31	38.98	712.9
Concentrator	-											
					Recevier							
Receiver effciency		0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	
Solar thermal energy intercepted by receiver	kWth	49.01	68.33	72.03	76.08	76.54	78.60	75.24	74.77	69.64	37.03	677.28
Ambient Temperature (Recevier inlet												
Temperature)	℃	27.24	27.13	27.31	26.45	27.92	28.79		29.80	29.89	29.89	
Recevier outlet Temperature	°C	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00		300.00	
Temperature rise, ΔT _{CF}	°C	272.8	272.9	272.7	273.6	272.1	271.2	270.5	270.2	270.1	270.1	
Heat gain by the receiver	kJ/h	176445.58	245996.07	259314.73	273900.29	275538.87	282952.85		269159.10		133315.88	2438200.3
Enthalpy of steam at 300 deg/ 10 bar	kJ/kg	2931	2931	2931	2931	2931	2931	2931	2931	2931	2931	
Steam flow rate	kg/h	60	84	88	93	94	97	92	92	86	45	
				n Flow Over a o								831.87
			Average Stea	ım Flow per ho	ur, kg/h							83

PREDICTED PERFOMANCE

20-06-12												
ystem Predicted Performance												
										Т	able No. ()2
Site Details												_
Latitude		28°4'										
Longitude	(-)77°12'										
Area of Concentrator ,m ²		105.0										
leat Transfer Fluid		Water										
Parameters/Time*		8:00:00		10:00:00	11:00:00				15:00:00			Remarks
Hour angle	deg	-60	1		-15			1	45			
Declination angle	deg	23.350	23.350	23.350	23.350	23.350	23.350	23.350	23.350	23.350	23.350	
				Conce	ntrator							
Direct Normal Irradiation	W/m²	278.5	636.7	813.4	947.7	1015.8		854.8	659.5	442.8	429.8	7062.5
Optical Efficiency(mirror refrectivity,0.95 *		0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	
avity Abosrbtance,0.95)= 0.90												
olar thermal energy intercepted by	kWth	26.3	60.2	76.9	89.6	96.0	92.9	80.8	62.3	41.8	40.6	667.4
Concentrator												
				Reco	evier							
leceiver effciency		0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	
olar thermal energy intercepted by	kWth	25.00	57.16	73.02	85.08	91.19	88.29	76.74	59.21	39.75	38.59	634.0
eceiver												
Ambient Temperature (Recevier inlet	ů	27.24	27.13	27.31	26.45	27.92	28.79	29.50	29.84	29.89	29.89	
'emperature)												
Recevier outlet Temperature	°C	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00	
emperature rise, ΔT _{CF}	°C	272.76	272.87	272.69	273.55	272.08	271.21	270.50	270.16	270.11	270.11	
leat gain by the receiver	kJ/h	90008.42	205775.07	262882.75	306287.16	328296.40	317857.37	276262.81	213143.81	143108.53	138907.06	2282529.4
	kJ/kg	2931	2931	2931	2931	2931	2931	2931	2931	2931	2931	
Enthalpy of steam at 300 deg/ 10 bar	IO/ Ng	2331	2331	2301	2331	2331						

Average Steam Flow per hour, kg/h

PREDICTED PERFOMANCE

					\mathbb{U}							
22-09-12												
System Predicted Performance												
										1	Table No.	03
Site Details												
Latitude	28	3°4'										
Longitude	(-)77	7°12'										
Area of Collector field,m ²		105.0										
Heat Transfer Fluid		Water										
Parameters/Time*		8:00:00	9:00:00	10:00:00	11:00:00	12:00:00	13:00:00	14:00:00	15:00:00	16:00:00	17:00:00	Pomovle
•	des			-30	-15		13:00:00		15:00:00		_	
Hour angle	deg	-60 -0.202		-0.202	-0.202		-0.202		-0.202			
Declination angle	deg	-0.202	-0.202		entrator	-0.202	-0.202	-0.202	-0.202	-0.202	-0.202	
Direct Normal Irradiation	W/m²	416.67	659.5	764.94	821.63	849.85	852.56	837.75	795.61	715.6	123.18	
Optical Efficiency(mirror refrectivity,0.95 *	VV/111	0.90		0.90			0.90					
cavity Abosrbtance,0.95)= 0.90		0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	
.,,												
Solar thermal energy incidence inside	kW _{th}											646.12
cavity	KVV (II	39.38	62.32	72.29	77.64	80.31	80.57	79.17	75.19	67.62	11.64	
					ceiver							
Receiver effciency		0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	
Solar thermal energy intercepted by	kW _{th}	37.4	59.2	68.7	73.8	76.3	76.5	75.2	71.4	64.2	11.1	613.82
receiver												
Ambient Temperature (Recevier inlet	°C	27.24	27.13	27.31	26.45	27.92	28.79	29.50	29.84	29.89	29.89	
Temperature)												
Recevier outlet Temperature	°C	300.00		300.00	300.00		300.00	300.00	300.00			
Temperature rise, ΔT _{CF}	°C	272.9		272.7	273.6		271.2	270.5	270.2		270.1	
Heat gain by the receiver	kJ/h	134663.58				274663.02		270752.42				2209743.8
Enthalpy of steam at 300 deg/ 10 bar	kJ/kg	2931		2931	2931	2931	2931	2931	2931	2931		
Steam flow rate	kg/h	46		84	91	94	94	92	88	79	14	
		T	otal Steam F	ow Over a da	ıy, kg							753.92
Average Steam Flow per hour, kg/h										75.39		

8.0 ECONOMIC PERFORMANCE:

S.NO.	Item	Quantity/Cost
1	System cost,Rs.	2939000.00
2	System Capacity, Steam Generation, Kg/Day	831.00
3	Total No. of days of operation per annum	250.00
4	Annual Steam Generation, Kg	207750.00
5	Dish Area meter sq.	105.00
6	Subsidy @ Rs.6000/meter sq.	630000.00
7	Accelerated Depreciation@35% of 80 % of cost,Rs.	822920.00
8	Interest @ 12% for 6 months on subsidy + Accelerated Dep., Rs.	87175.20
9	Total Initial Investment ,Rs	1573255.20
10	O&M cost @5% of system cost, Rs	146950.00
11	Calorific value of Diesel,kJ/kg	33600.00
12	Heat generated by Dish Concentrator, kJ/day	2414979.00
13	Heat generated by Dish Concentrator, kcal/day	577746.17
14	Diesel Saved Per Day	71.87
15	Diesel saved per annum, liters	17968.59
16	Annual value of Diesel saved @ Rs52	934366.88
17	Annual savings, Rs.	787416.88
18	Pay back, years	2.00

9.0 MARKET POTENTIAL

Solar Dish Concentrator can be used for the following Industrial / Commercial applications.

- Community cooking
- Hospitals
- Hospitalality sector
- Laundry
- Dairy
- Hostels / Guest houses
- Shale oil Extraction
- Process Steam
- Air Conditioning and Refrigeration
- Power Generation

10.0 DESIGN VALIDATION

 Design of Solar Dish Concentrator shall be validated by Software Company Tech Savvy Engineers, Noida and analytical work to be carried out by them is as follows:

A- Static Analysis:

- Analysis with Dead Weight.
- Analysis with respect to forces and loads.
- Deflections and stresses generated in the system.

B-CFD Analysis:

- Wind Load Calculations.
- Forces due to wind loads.
- Thermal Analysis of the system.

11.0 – Vendor List.

S.Nos.	Material /Items	Supplier
1	Thin Mirror	Asahi-India Glass Ltd. New Delhi
2	Mirror Substrate (Foam Glass)	Sun Refractories, Mumbai
3	Adhesives and Sealants	Sika India Pvt. Ltd., Malad West, Mumbai
4	Dual Axis Tracking Mechanism	GFC India, Coimbatore, Chennai
5	Concentrator, Structure and Receiver	Aman Engineering Associates, Bawana, Delhi
6	BOS AND I&C	Aman Engineering Associates, Bawana, Delhi

12.0 Costing

S.No.	Description	Weight,kg	Price,Rs.
1	Concentrator	3120	1173000
3	Receiver & Receiver Support structure	750	157000
2	Tracking Mechanism	350	400000
4	Fork and Padestal	1279	169000
5	Instrumentation		390000
6	BOS		135000
7	Consultancy Fee Rs. 1000/m2 (Dish Area)		115000
8	I&C		400000
9	Total	5499	2939000