

List of Figures

Figure No	Title	Page
1.1	Classification of renewable energy resources [6]	3
1.2	Renewable energy potential worldwide [19]	5
1.3	Methods of solar energy utilization [22]	7
1.4	Spectral distribution of extra terrestrial radiation at mean sun-earth distance [26]	8
1.5	Extraterrestrial solar spectrum	9
1.6	Solar angle of incidence is a function of different solar angles	11
1.7	Different sun earth angles	12
1.8	Solar angle of incidence and slope of surface	13
1.9	Hour angles varies with time of the day	13
1.10	Position of sun in the sky	14
1.11	Various types of solar concentrator : (a) tubular diffuse collector, (b) tubular specular collector, (c) plane reflectors (V-trough), (d) multisectional flat collector, (e) compound parabolic collector (f) parabolic trough, (g) fresnel (h) central receiver. [37, 38]	16
1.12	Solar concentrating technology[39]	17
1.13	Solar parabolic trough concentrator[45]	20
1.14	Heat collecting element of PTCs[47]	21
1.15	Flux distribution in the plane of linear focusing concentrator extended from A to B [59]	25

1.16	Optical parameters of parabolic trough concentrator	26
1.17	Practical understanding of various heat transfer coefficient	27
1.18	Design specification of parabolic mirror reflector	31
1.19	Extended arc of parabola	32
1.20	Methods to store different types of energy [69]	34
1.21	Different methods of thermal energy storage [76]	37
2.1	Shows the cloudy under which the solar concentrating technology unable to focus the diffuse solar radiation	44
2.2	Shows the clean sky under which concentrated solar power performs well	45
2.3	Desirable properties of phase change material for effective storage of solar thermal energy [70]	46
2.4	Flow chart for the development of latent heat thermal energy storage unit under different stage [70]	47
2.5	Contribution of different solar concentrating technologies for power generation [100]	48
2.6	Flow chart of Methodology that was adopted for the present work	58
3.1	Basic design angles	60
3.2	Aperture parameters	60
3.3	Receiver parameters	61
3.4	Variation of concentration ratio with $\sigma = \frac{h}{f}$	66
3.5	schematic diagram of line concentrating parabolic trough concentrator at CERD, IIT (BHU), Varanasi	70
3.6	Line concentrating helical coil solar cavity receiver at CERD, IIT (BHU), Varanasi	71
3.7	Experimental set for steam generation using helical coil solar cavity receiver at CERD IIT (BHU), Varanasi	71
3.8	Schematic diagram of helical coil solar cavity receiver	72

3.9	Dimensions of copper helical coil absorber tube used in PTC	74
3.10	Photograph of circular magnetic needle to measure tilt angle of PTC	76
3.11	Photograph of vacuum vane rotary pump to create the vacuum at annulus	77
3.12	Photograph of vacuum gauge to measure vacuum pressure at annulus	77
3.13	Photograph of steam pressure gauge to measure steam pressure inside the helical coil	78
3.14	Photograph of hygrometer to measure relative humidity	78
3.15	Photograph of temperature indicator	79
3.16	Photograph of blackened helical coil receiver with thermocouple wire attached with it	80
3.17	Data monitoring station to measure environmental parameters at CERD IIT(BHU), Varanasi	81
3.18	Photograph of pyrliometer to measure beam radiation	81
3.19	Photograph of pyranometer to measure diffuse radiation	82
3.20	Variation of friction factor with Reynolds number for helical coil tube	87
3.21	Solar irradiation absorptions by receiver, 1 st glass cover, and the 2 nd glass cover	87
3.22	Pressure drop across the length of helical coil tube with the velocity of flow	89
4.1	Thermal resistance model for a cross section of a double glazing helical coil solar receiver	94
4.2	shows the heat gain and loss through parabolic trough concentrator	96
4.3	Schematic view of typical double glazing helical coil solar cavity receiver	96
4.4	Schematic diagram showing the system and heat transfer	116
4.5	Schematic diagram showing various possible heat transfers	117
4.6	Electrical analogy of various losses for the parabolic dish type cooker	117

4.7	Comparison of thermal efficiencies between the present work and the SNL test results	123
4.8	Variation of thermal efficiency of the present experimental setup with fluid temperature above ambient	125
5.1	Variation of ambient temperature with time of the day	129
5.2	Variation of direct solar radiation with time of the day	129
5.3	Variation of wind speed with time of the day	130
5.4	Variation of relative humidity with time of the day	130
5.5	Comparison of double glazing helical coil receiver with the horizontal tube receiver under the environmental conditions: solar radiation intensity range $600 - 900 W/m^2$ and the wind speed range $0.3 - 2.0 m/s$	131
5.6	Variation of heat loss with respect to vacuum pressure	134
5.7	Variation of useful energy and heat loss with vacuum pressure	134
5.8	Variation of heat loss coefficient with respect to wind speed	135
5.9	Variation of coiled tube Nusselt number with Reynolds number for different curvature ratio	137
5.10	Variation of coiled tube Nusselt number with Prandtl number	137
5.11	Variation of coiled tube Nusselt number with curvature ratio	138
5.12	Variation of Dean number with Reynolds number	138
5.13	Temperature distribution over the helical coil surface of receiver	139
5.14	shows the higher temperatures of helical coil receiver in comparison to the temperature of the glass cover and the ambient	140
5.15	shows the solar irradiation absorption by the lower and upper glass cover and the helical coil per unit length of receiver	141
5.16	Comparison of convective heat transfer coefficients for horizontal and helical coil receiver with respect to time of the day	142
5.17	Solar to thermal conversion efficiency as a function of time of the day for evacuated tube parabolic trough concentrator	143

5.18	Variation of inlet and outlet temperature of heat transfer fluid as a function of time of the day	145
5.19	Variation of exit fluid temperature as a function of inlet fluid temperature for the flow of thermal oil through the helical coil solar cavity receiver	145
5.20	Variation of helical coil receiver temperature as a function of time interval at different annulus pressures under the given conditions of solar radiation intensity and wind speed	147
5.21	Quality of vacuum degraded with glass cover temperature	148
5.22	Variation of solar radiation intensity with time of the day	150
5.23	Variation of temperature with time of the day	150
5.24	Variation of cooker temperature, ambient temperature and wind velocity with time of the day	151
5.25	Variation of side heat loss with time of day	152
5.26	Variation of heat loss from the side (W/s) with velocity (m/s) at 303 K ambient temperature	152
5.27	Variation of heat loss from side (W/s) with ambient temperature ($^{\circ}C$) at wind velocity= $1.2 m/s$ and cooker temperature= $84^{\circ}C$	153
5.28	Variation of heat loss from side (W/s) with cooking pot temperature ($^{\circ}C$) at wind velocity= $2.0 m/s$ and ambient temperature= $30^{\circ}C$	153
5.29	Variation of bottom heat loss (W/s) with time of the day	154
5.30	Variation of heat loss from top (W/s) with time of day	154
5.31	Variation of performance index and concentration ratio with time of the day	155
5.32	Variation of efficiency of cooking pot with time of the day	156