THE USE OF OPEN CELL POLYURETHANE FOAMS IN AIR-TYPE SOLAR COLLECTORS AS THE HEAT ABSORBING ELEMENT

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ABSTRACT

After the energy crisis in early 1970's, the priority of alternative energy resources is expanded. There have been many researches, to increase the efficiency of solar energy utilization systems, for domestic and industrial usage since early 1980's up to now.

In many fields air-type solar collectors are applicable. They generally used in food industry to dry agricultural products, textile industry to dry fabrics and space heating. Drying grains (wheat, barley, maize, etc.), fruits (grape, fig, apricot etc.), vegetables, tea are examples for food industry. Greenhouse heating and hospital heating to obtain fresh air are examples of space heating. These examples show that improving their performance is indispensable for commercial acceptance.

In this study, the open-cell polyurethane foam as an absorber material, placed in a south facing, flat plate air-type solar collector at fixed tilt angle and effect of this material on collector efficiency has been investigated. The collector designed specially, in order to get maximum heat gain from the useful solar intensity falling on the glazing and insulated to loose minimum heat from collector case and transfer channels. Collector is tested under the regulations of ASHRAE 93-1986 standard named "Methods of Testing to Determine The Thermal Performance of Solar Collectors". Air passing through the collector has been provided by a fan. Tests are repeated with three air speeds 1.266 m/s, 1.5825 m/s and 1.899 m/s. Maximum average efficiency is calculated on 1.5825 m/s. Maximum average temperature difference of air between inlet and outlet sections observed on 1.266 m/s. Maximum outlet temperature that we get is on the same day with maximum average temperature difference.

ÖZET

1970'li yılların ilk yarısında patlak veren global enerji krizi sonrasında, alternatif enerji kaynaklarının önemi artmıştır. 1980'lerin başından itibaren evsel ve endüstriyel uygulamalarda kullanılan güneş enerjisi sistemlerinin verimlerinin arttırılması adına birçok araştırma yapılmıştır.

Hava akışkanlı güneş kollektörleri birçok alanda kullanılabilir. Genellikle gıda endüstrisinde tarımsal ürünlerin kurutulması, tekstil endüstrisinde kumaşların kurutulması ve mekanların ısıtılması için kullanılmaktadırlar. Hububatların (buğday, arpa, mısır, v.s.), meyvelerin (üzüm , incir, kayısı, v.s.) kurutulması gıda sektöründeki kullanımları için örnek teşkil etmektedir. Seraların ısıtılması ve hastanelerde temiz hava gereksiniminin karşılanması ise mekanların ısıtılmasına örnek olarak verilebilir. Verilen örnekler göstermektedir ki, hava akışkanlı güneş kollektörlerinin verimlerinin arttırılması ticari olarak kabul görmeleri açısından elzemdir.

Bu çalışmada; Güney'e bakan, sabit eğimli bir düzlemsel hava akışkanlı güneş kollektörü içerisine ısı yutucu eleman olarak yerleştirilen açık hücreli poliüretan köpük malzemenin, kollektör verimine etkileri incelenmiştir. Kollektör, üzerine düşen kullanılanılabilir güneş ışınımından maksimum ısı kazancı sağlanması için dizayn edilmiş ve kollektör kasası ile akış kanalından minimum ısı kaybı olması için yalıtım uygulanmıştır. Kollektör, ASHRAE 93-1986 "Güneş Kollektörlerinin Isıl Performanslarının Belirlenmesi İçin Test Yöntemleri" standardının gerekleri yerine getirilerek test edilmiştir. Kollektör içerisinden geçen hava bir fan marifeti ile sağlanmıştır. Testler 1.266 m/s, 1.5825 m/s ve 1.899 m/s olmak üzere üç farklı hava hızında tekrarlanmıştır. Maksimum ortalama kollektör verimi 1.5825 m/s'de gözlenmiştir. Giriş ve çıkış sıcaklıkları arasındaki maksimum sıcaklık farkı ve maksimum çıkış sıcaklığı aynı günde, 1.266 m/s'de gözlenmiştir.

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LIST OF SYMBOLS

Symbol	
A_c	collector area (m^2)
C_p	specific heat of the heat transfer fluid (J/kg.^oC)
k	thermal conductivity (W/m.^oC)
N	day number of the year
I_t	solar incidence over collector (W/m^2)
I_{sc}	solar constant (W/m^2)
I_n	terrestrial solar radiation normal to sun's rays (W/m^2)
I_h	terrestrial solar radiation on a horizontal surface (W/m^2)
T_a	ambient temperature (^oC)
T_i	inlet temperature (^oC)
T_o	outlet temperature (^oC)
T_p	absorber plate temperature (^oC)
ΔT	temperature difference between T_o and T_i
V_w	wind velocity (m/s)
V	air velocity in channel (m/s)
L	collector length (mm)
W	collector width (mm)
H	collector height (mm)
m	mass flow rate of the air (kg/s)
U_L	overall heat loss coefficient (W/m.^oC)
Q_u	useful energy delivered by collector (W)
F_R	heat removal factor, $0<F_R<1$, (dimensionless)
N/A	not available

Greek symbol

ρ	density (kg/m^3)
μ	viscosity (Pa.s)
ϕ	latitude (degrees)
δ	declination (degrees)
ω	hour angle (degrees)
θ	incidence angle (degrees)
θ_z	zenith angle (degrees)
α	altitude angle (degrees)
γ	azimuth angle (degrees)
γ_s	surface azimuth angle (degrees)
β	tilt angle (degrees)
τ	transmissivity (dimensionless)
α	absorptivity (dimensionless)
η	efficiency (%)

CHAPTER 1

INTRODUCTION

As we enter the 21st century, public awareness of the environmental damage that can come from using conventional energy sources, is reaching an all-time high. Although public approval for solar energy is high, there is some confusion over just how it can be used as a substitute or supplement for conventional energy sources such as coal, oil, gas, and nuclear. Though conventional fuel sources are typically used in only one way (combustion for the fossil fuels, reaction for nuclear), there are variety of ways in which the sun may be used to provide energy.

If examined in the broadest sense, most forms of energy ultimately owe their origin to the sun. The sun creates the air temperature differences which provide the air currents which make wind energy possible; it provides the light to grow the biomass fuels, such as wood and grain used to distill ethanol; it provides the moving force behind the Earth's water cycle, thus making hydroelectricity possible; even the fossil fuels began as vegetation long ago in the Earth's history. For simplicity, however, this fact sheet will dwell only on the use of solar energy in its strictest sense. In general, solar energy systems can be categorized as being one of two types: Thermal Systems, which use the sun's energy in the form of heat, and Light Utilizing Systems, which use the sunlight directly to provide energy or lighting. In this study we have worked on thermal utilization of solar intensity.

Active and passive solar energy systems are used to provide heat for thermal comfort in buildings (space heating) and water heating. Most space heating applications are in residences, but commercial buildings are heated with solar systems as well. Residential water heating is the most common application, but they are also effective for heating larger volumes of water for commercial purposes, such as for car washes, laundries, motels, beauty salons, public health facilities and even swimming pools. Active systems use mechanical equipment such as pumps and fans to regulate and distribute the energy collected from the sun. Like active systems, passive solar systems are used to provide space and water heating for buildings. Unlike active systems, they

do not use pumps or fans to store or distribute heat. Instead, they rely on the natural heat transfer forces of conduction, convection and radiation to distribute the heat collected.

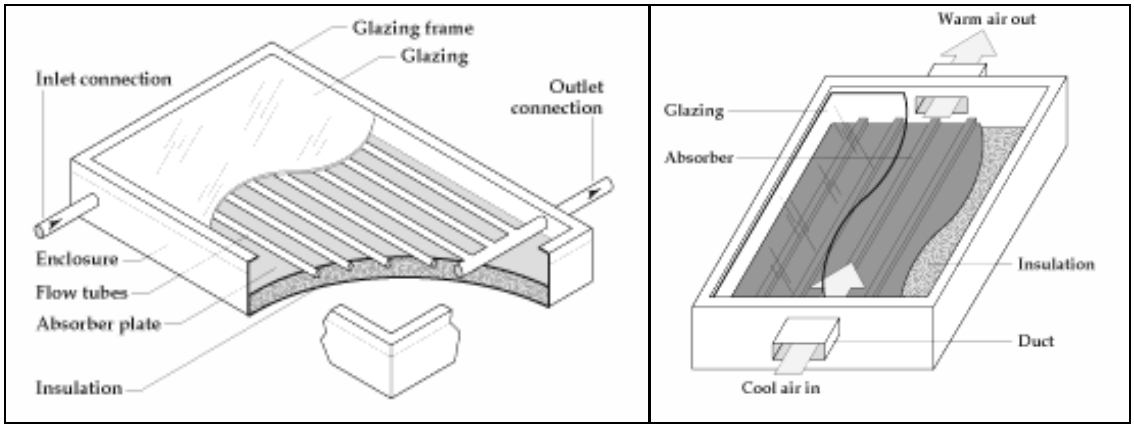
A typical thermal solar utilization system consists of one or more solar collectors, connected to a storage and distribution system. A solar collector is a device that utilizes the solar radiation to heat a fluid, which can than be used for suitable applications. Solar collectors may be classified according to their collecting characteristics, the way in which they are mounted (i.e., stationary or sun tracking), and the type of transfer fluid they employ. (Ashrae 1991)

(a)

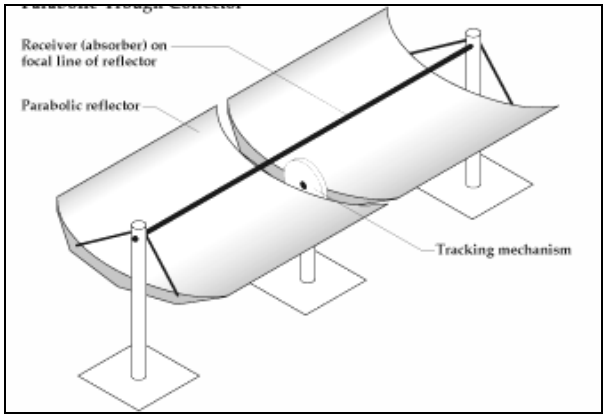
(b)

Figure 1.1. Flat plate and concentrating collectors.
(Source: Duffie and Beckman 1991)

A nonconcentrating or flat-plate collector (FPSC) is one in which the solar radiation absorbing surface is essentially flat and in which the aperture and the absorber are similar in area and geometry. A concentrating collector is one that usually contains reflectors or other optical means to concentrate the energy entering through the aperture to be incident upon a heat absorber of surface area smaller than the aperture.



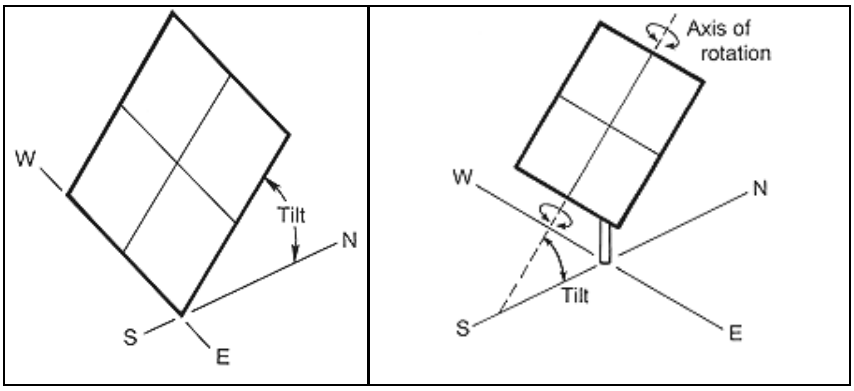
(a) Liquid type FPSC (b) Air type FPSC



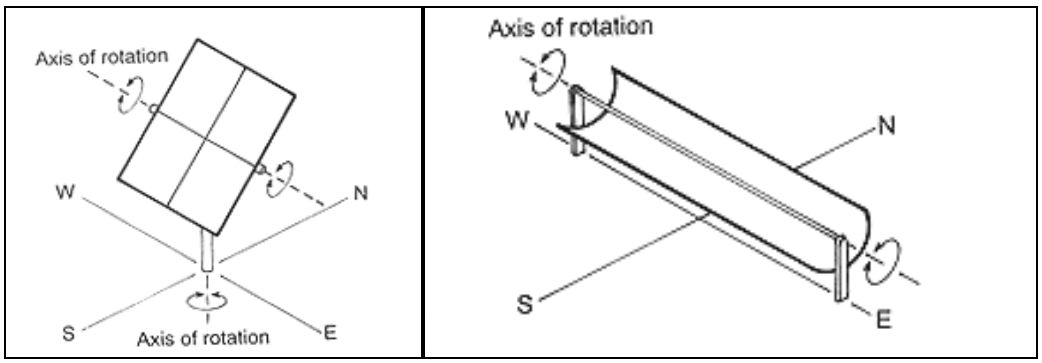
(c) Parabolic-trough collector

Figure 1.2. Schematic view of solar collector types.
(Source: Kalogirou 2004)

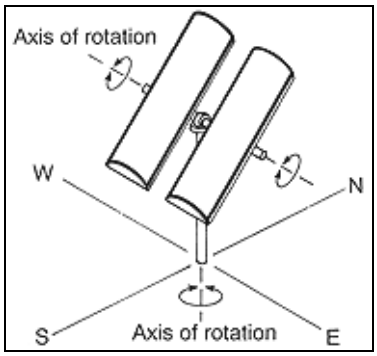
A solar collector can be mounted in a stationary position with a fixed azimuth and tilt angle (measured from the horizontal) or it may be adjustable as to tilt angle to follow the annual changes in solar declination; it may also be designed to track the sun in altitude and azimuth (azimuth mounting) or in its apparent daily rotation about the earth (polar or equatorial mounting).



(a) FPC facing south at fixed tilt (b) One-axis tracking FPC



(c) Two-axis tracking FPC (d) One-axis tracking Concentrating Collector



(e) Two-axis tracking Concentrating Collector

Figure 1.3. Categorization of solar collectors up to positioning.
(Source: Kalogirou 2004)

Liquid or gas fluids can be used as heat transfer medium. Commercially air is used for gas and water for liquid medium. Other fluids used for heat transfer will be discussed on relevant chapter.

Air-type solar collectors have a wide range of applications in the drying of agricultural products, space heating and air conditioning, industrial process heating (textile, paper, etc.) and greenhouse heating. Although, flat plate solar air heaters have reached near perfection and have proven commercial success in many domestic, agricultural and industrial applications all over the globe, improving their performance is essential for commercial acceptance.

In this thesis, the open cell polyurethane foam as an absorber material, placed in a south facing, flat plate air-type solar collector at fixed tilt angle and effect of this material on collector efficiency has been investigated. The collector designed specially in order to get maximum heat gain from the useful solar intensity falling on the glazing and insulated to loose minimum heat from collector case and transfer channels. Air passing through the collector has been provided by a fan.

CHAPTER 2

UTILIZATION OF SOLAR ENERGY

The sun is an average star of radius 0.7 million km and has a mass of about $2x10^{30}$kg. It radiates energy from an effective surface temperature of about 5760 K. From the fusion furnace of the sun, energy is transmitted radially, ie., outward as electromagnetic radiation called "solar energy" or sunshine. This electromagnetic spectrum, which comprises all the energy radiated by the sun, extends from gamma rays (of wavelength 10^{-10} cm and lower) to radio waves (of wavelength 10^{+5} cm and longer). The quantity of energy radiated by the sun can be estimated from a knowledge of the sun's radius and its surface temperature (assuming it to be black body) and this amount to a rate of about $3.8x10^{23}$ kW. (Duffie and Beckman 1991)

The earth is at about 150 million km from the sun and has a radius of about 6360 km. The total surface area of the earth is about 510 million km^2, of which only about 21% is land. The earth rotates round the sun in an elliptical orbit at a mean rate of about 30 km/s and at the same time revolves at a rate of 0.5 km/s. The earth's axis of rotation is tilted at 23.45° with respect to its orbit about the sun. This orientation is maintained by the earth in its orbital movement. This tilted position together with its daily rotation and yearly revolution accounts for the distribution of solar radiation over the earth's surface and the change in daylength. The constituents of the atmosphere up to 100 km are (by volume): Nitrogen - 78.08%, Oxygen - 20.95%, Argon - 0.93%, Water vapour - (0.1 to 2.8%), carbon dioxide - 0.0033% and traces of carbon monoxide, sulphur di oxide, ozone etc. depending on the location (whether it is an industrial location, farmland, etc.).

The intensity of solar radiation striking a horizontal surface is measured by a pyranometer. The instrument consists of a sensor enclosed in a transparent hemisphere that records the total amount of short-wave incoming solar radiation. That is, pyranometers measure "global" or "total" radiation: the sum of direct solar and diffuse sky radiation. Incoming (or down welling) longwave radiation is measured with a pyrgeometer. Outgoing (up welling) longwave radiation is measured in various ways, such as with pyrgeometers or with sensors that measure the temperature of the surface.

Table 2.1. Characteristics of the Earth and the Sun. (Duffie and Beckman 1991)

EARTH	
Mass (kg)	5.98E+24
Mass (Earth = 1)	1.00E+00
Equatorial radius (km)	6,378.14
Equatorial radius (Earth = 1)	1.00E+00
Mean density (gm/cm^3)	5.515
Mean distance from the Sun (km)	1.50E+08
Rotational period (days)	0.99727
Rotational period (hours)	23.9345
Orbital period (days)	365.256
Mean orbital velocity (km/sec)	29.79
Orbital eccentricity	0.0167
Tilt of axis (degrees)	23.45
Orbital inclination (degrees)	0
Equatorial escape velocity (km/sec)	11.18
Equatorial surface gravity (m/sec^2)	9.78
Visual geometric albedo	0.37
Mean surface temperature	15°C
Atmospheric pressure (bars)	1.013

SUN	
Mass (kg)	1.99E+30
Mass (Earth = 1)	332,830
Equatorial radius (km)	695,000
Equatorial radius (Earth = 1)	108.97
Mean density (gm/cm^3)	1.41
Rotational period (days)	25-36*
Escape velocity (km/sec)	618.02
Luminosity (ergs/sec)	3.83E+33
Magnitude (V_o)	-26.8
Mean surface temperature (°C)	6,000
Age (billion years)	4.5
Principal Chemistry of The Sun	
Hydrogen	92.10%
Helium	7.80%
Oxygen	0.06%
Carbon	0.03%
Nitrogen	0.01%
Neon	0.01%
Iron	0.00%
Silicon	0.00%
Magnesium	0.00%
Sulfur	0.00%
All others	0.00%

2.1. Sun - Earth Angles

It is common knowledge that the solar radiation received on the earth's surface is not constant. Most of the reasons for these variations could be explained by an understanding of the sun earth angle concepts. We observe in our daily life that the solar radiation on the earth's surface varies;

(i) during the day (from morning to noon and from noon to evening, with the maximum usually at noon). This is called hourly variations. This is due to the motion of the sun from east to west during the course of the day and is true for all locations.

(ii) daily, which is primarily due to the presence of clouds.

(iii) monthly (or seasonal variation), due to the location and the sun's position.

(iv) from location to location.

(v) depending on the orientation of the surface. ie, whether the surface receiving the radiation is placed horizontally or is tilted from the horizontal, etc. and

(vi) due to the presence of clouds. This could be seasonal in nature or even during the day and dependent on the location. For example, some locations at some time of the year have clouds in the afternoon, which reduces the afternoon solar radiation.

The factors (i), (iii), (iv) and (v) could be explained by a knowledge of the sun earth angles, while factors (ii) and (v) are discussed in section 2.2.4.

2.1.1. Basic Sun-Earth Angles

The position of a location on the earth's surface is known by the coordinates latitude and longitude. The sun's position in the sky is known by the hour angle and the declination. The relative position of the two at any given instant is known by the altitude and the azimuth angles.

Latitude (ϕ) is defined as the angular distance of a point (on the surface of the earth) from the equator. The angular distance could either be north or south of the equator. North latitudes are taken to be positive, while south latitudes are taken as negative.

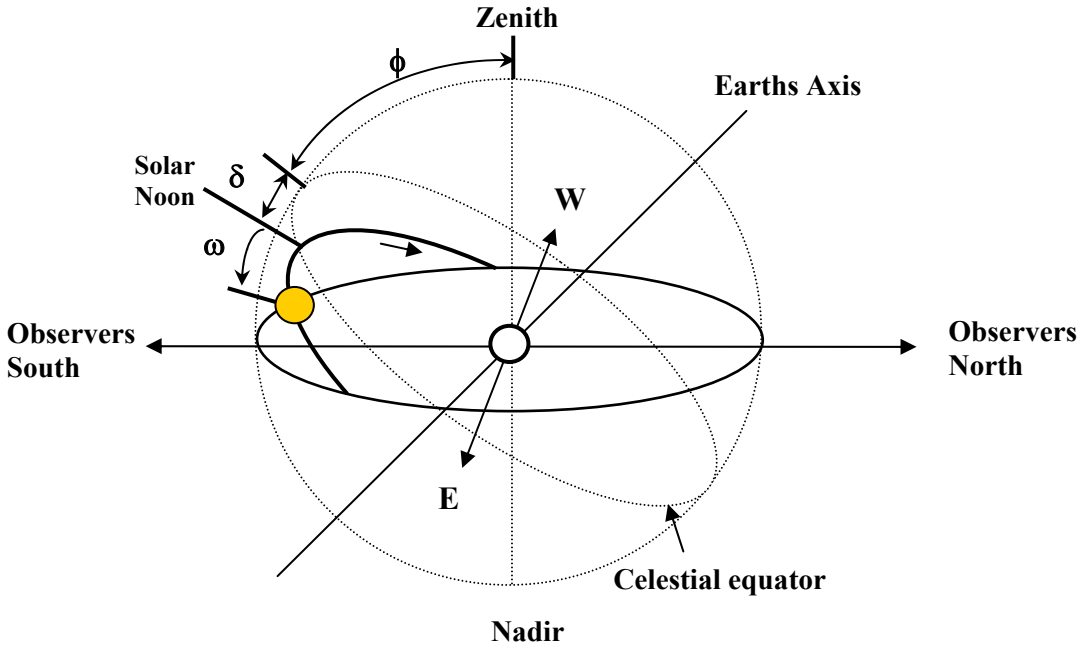


Figure 2.1. Solar angles, (ω, δ, ϕ)

Longitudes or Meridians are semi great circles passing through the poles of the earth. The zero (0) meridian passing through Greenwich near London is called the prime meridian by international agreement. The longitude angle can be defined as the angle between the prime meridian and the meridian passing through the location.

Hour angle, the angular displacement of the sun east or west of the local meridian due to rotation of the earth on its axis at 15^{o} per hour. It takes morning negative and afternoon positive values. At the solar noon it is zero, $\omega = 0$. (Figure 2.1)

Declination (δ) is the angular distance north (or south) of the equator of the point, when the sun is at its zenith. It can also be defined as the angle formed by the line extending from the centre of the sun to the centre of the earth and the projection of this line upon the earth's equatorial plane. When the sun is directly overhead at any location during solar noon, the latitude of that location gives the declination. This is shown clearly in Figure 2.1.

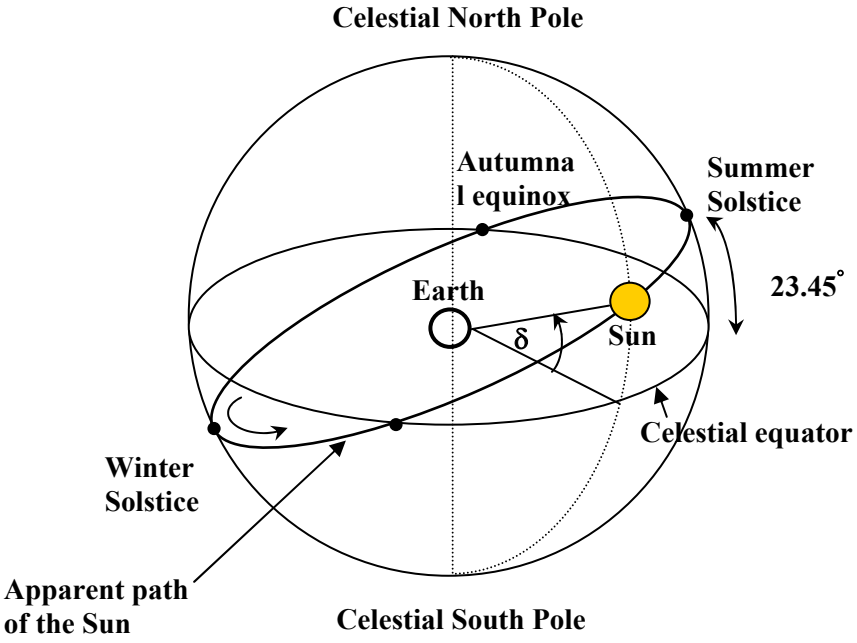


Figure 2.2. Sun path, equinox and solstices.

The declination of the sun varies daily (in fact, at every instant) and can be calculated from the following expression:

$$\delta = 23.45 \text{ SIN } \{360\ (284+N)/365\} \text{ degrees} \qquad (2.1)$$

where, N is the day number of the year. (Table 2.2) (Duffie and Beckman 1991)

Table 2.2. i^{th} Day of a year (N)

		For The Average Day of The Month	
Month	**N For i^{th} Day of Month**	**Date**	**N, Day of Year**
January	**i**	**17**	**17**
February	**31 + i**	**16**	**47**
March	**59 + i**	**16**	**75**
April	**90 + i**	**15**	**105**
May	**120 + i**	**15**	**135**
June	**151 + i**	**11**	**162**
July	**181 + i**	**17**	**198**
August	**212 + i**	**16**	**228**
September	**243 + i**	**15**	**258**
October	**273 + i**	**15**	**288**
November	**304 + i**	**14**	**318**
December	**334 + i**	**10**	**344**

The basic sun earth angles thus help in fixing the position of the sun and the location (on the earth's surface) clearly. The relationships between the two are known by knowledge of derived angles.

2.1.2. Derived Sun - Earth Angles

In addition to the above, the following derived angles are used to define the sun's position in relation to the surface.

The Incidence Angle (θ) on any surface is the angle between the sun's direct rays (I_b) and the normal to the surface.

The Zenith Angle (θ_z) is the incidence angle for a horizontal surface. ie. It is the angle between I_b and a line perpendicular to the horizontal surface at P as shown in Figure.2.3.

The Altitude Angle (α) is the angle on a vertical plane between I_b and the projection of the sun's rays on the horizontal plane (Figure 2.4).

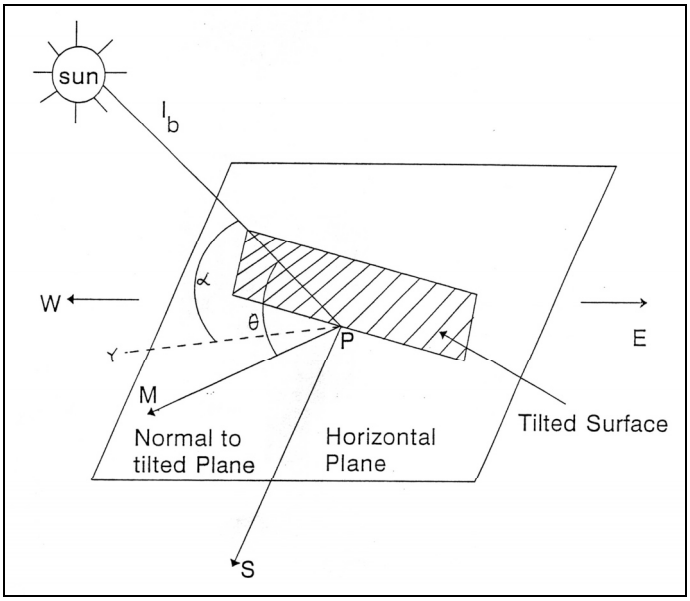


Figure 2.3. Incidence, altitude and altitude angle. The incidence angle has been shown for a tilted surface.

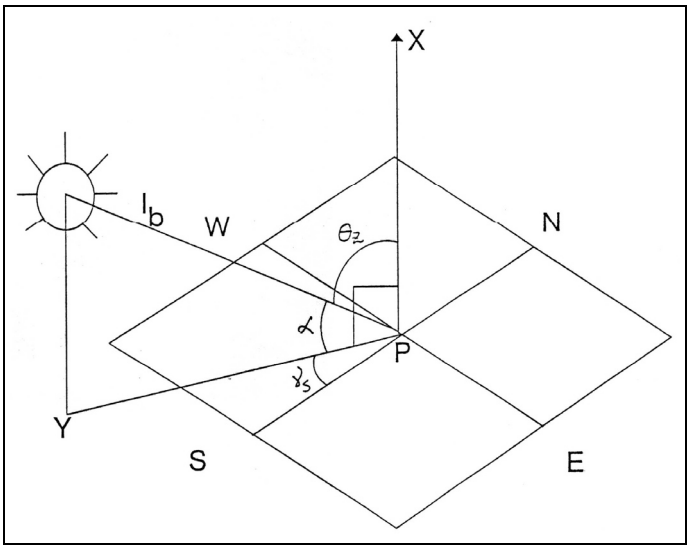


Figure 2.4. The zenith angle, altitude angle and the solar azimuth.

The Azimuth Angle (γ_s) is the angle on the horizontal plane measured from south to the horizontal projection of the sun's rays (I_b).

The Slope (β) or Tilt Angle is the angle the surface makes with the horizontal plane (Figure 2.5).

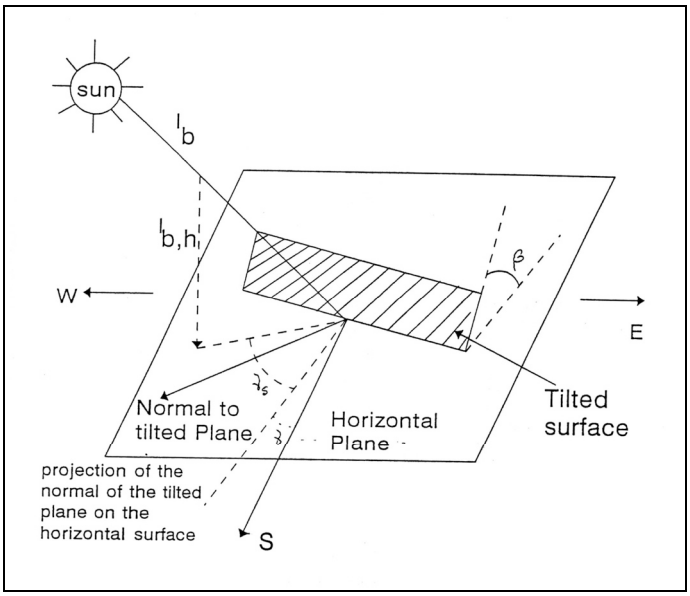


Figure 2.5. Tilt angle and azimuth angle for a non south facing tilted surface.

The Surface Azimuth Angle (γ) is the angle measured on the horizontal plane from due south to the horizontal projection of the normal to the surface (Figure 2.5). It is also given as the angle between the local meridian and the horizontal projection of the normal to the surface.

2.2. Solar Radiation

2.2.1. Extraterrestrial Solar Radiation (ETR)

Solar radiation outside of the earth's atmosphere is called extraterrestrial solar radiation. The extraterrestrial radiation on top of the earth's surface depends on many factors such as the distance, orientation, etc. As the earth makes an elliptical orbit round the sun, there is approximately a 6.6% variation in the amount of solar radiation received on top of the earth's atmosphere throughout the year. The solar constant (I_{sc}) is the total amount of electromagnetic energy of all wavelength that falls on a unit area normal to the sun in unit time at the top of the earth's atmosphere when the earth is at its mean distance (ie. average distance) from the sun. The concept of solar constant was first introduced by the French scientist Pouillet in 1837 and current accepted value of I_{sc} is 1367 W/m^2. (Duffie and Beckman 1991)

2.2.2. Spectral Distribution

The spectral distribution of the extraterrestrial radiation ranges from gamma rays to Radio waves as shown in Figure 2.6. The intensity of solar radiation has been drawn with respect to the wavelength and therefore, the area under the curve gives the total solar radiation covering the whole spectrum. Almost all the energy (98%) is concentrated in a narrow wavelength region from the ultraviolet to the infra red regions of the spectrum. The energy of the radio waves contributing to the solar radiation is negligible. The solar spectrum of interest could be divided into the following sections:

Radio	≥ 1 mm	Ultra violet	0.12 - 0.3 μm
Far infra red	10 μm - 1 mm	Extreme ultra violet	0.01 - 0.12 μm
Infra red	0.75 - 10 μm	Soft X rays	0.0001 - 0.01 μm
Visible	0.30 - 0.75 μm	Hard X rays	< 0.0001 μm

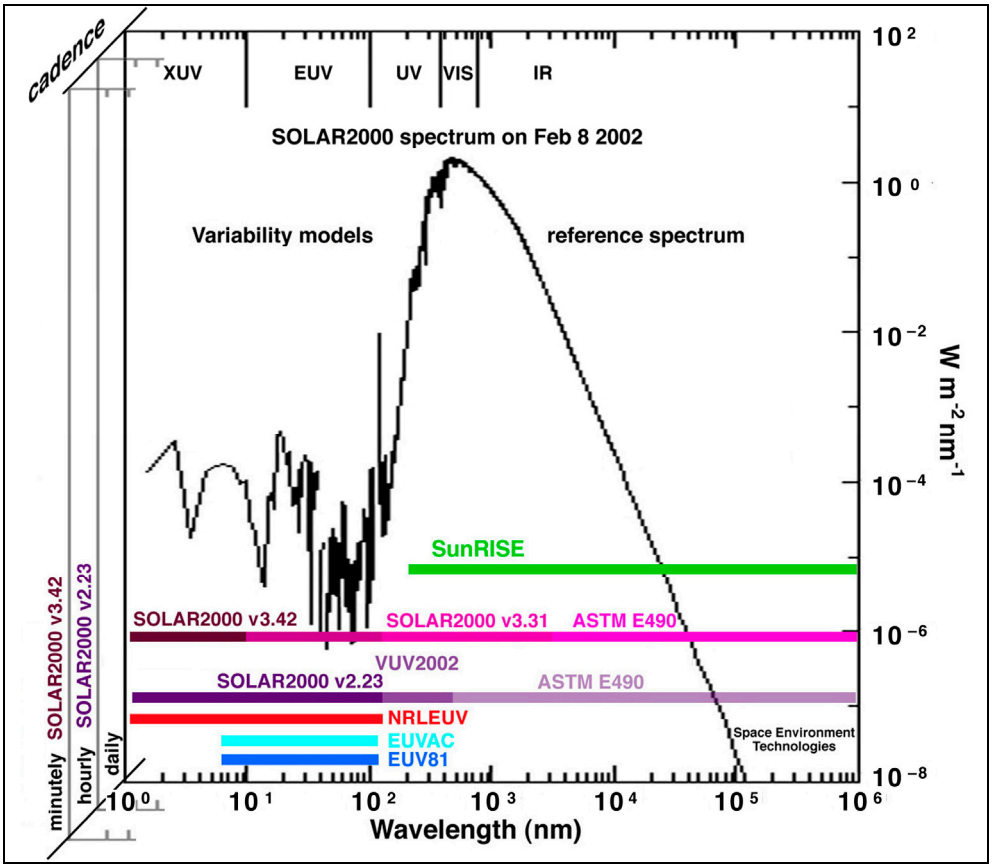


Figure 2.6. Solar Spectrum

(Source: Forson and Nazha 2003)

2.2.3. Intensity of Extraterrestrial Radiation

We have seen that ETR falling on a surface normal to the sun's rays at 1 AU (mean sun earth distance) is given by solar constant (I_{sc}). For other times when the sun earth distance is not equal to 1 AU, the intensity of sun's radiation on top of the earth's surface depends on the day and the intensity of the extra terrestrial solar radiation (ETR) on a surface *normal* to the sun's rays on any day is given by the following equation :

$$I_n = I_{sc} \{1 + 0.033 \text{ Cos } (360.n/365)\} \quad (2.2)$$

where, $1 < n < 365$, the day number of the year .

To calculate the ETR falling on a horizontal surface, the zenith angle has to be taken into account (Figure 2.4) as:

$$I_h = I_n \text{ Cos } (\theta_z) \quad (2.3)$$

2.2.4. Attenuation of Extraterrestrial Radiation

The intensity of the solar radiation falling on the earth's surface is influenced by a number of factors, classified as astronomical, geographical, geometrical, physical and meteorological.

Astronomical factors: The solar spectrum and the solar constant, sun earth distance variation, declination of the sun and the hour angle.

Geographical factors: Latitude, longitude and height above seal level.

Geometrical factors: Altitude, azimuth, tilt and surface azimuth angles.

Physical factors: Absorption and scattering in the atmosphere.

Meteorological factors: Cloudiness and albedo.

The atmosphere attenuates the extraterrestrial radiation (physical factor) by two significant phenomena:

(a) scattering by air molecules, water vapour and dust; and

(b) absorption by water vapour, ozone and carbon dioxide.

The actual composition and concentration of clean air varies with the geographical location, season and elevation. The normal composition of standard atmosphere is given in Table 2.3. The concentrations of the gases are highly variable and are not homogeneous.

Table 2.3. Atmosphere gases (Duffie and Beckman 1991)

Constituent gas	Content (% by volume)
Nitrogen (N_2)	78.084
Oxygen (O_2)	20.948
Argon (Ar)	0.934
Carbon dioxide (CO_2)	0.333
Neon (Ne)	$18.18 * 10^{-4}$
Helium (He)	$5.24 * 10^{-4}$
Krypton (Kr)	$1.14 * 10^{-4}$
Xenon (Xe)	$0.089 * 10^{-4}$
Hydrogen (H_2)	$0.5 * 10^{-4}$
Methanol (CH_2)	$1.5 * 10^{-4}$
Nitrous Oxide (N_2O)	$0.27 * 10^{-4}$
Ozone (O_3)	$0\text{-}12 * 10^{-4}$
Sulphur Dioxide	$0.001 * 10^{-4}$
Nitrogen Dioxide	$0.001 * 10^{-4}$
Ammonia (NH_2)	$0.004 * 10^{-4}$
Carbon monoxide	$0.19 * 10^{-4}$
Water vapour (H_2O)	$0\text{-}0.04 * 10^{-4}$
Nitric Oxide (NO)	$0.0005 * 10^{-4}$
Hydrogen Sulphate	$0.00005 * 10^{-4}$
Nitric Acid vapour	Traces

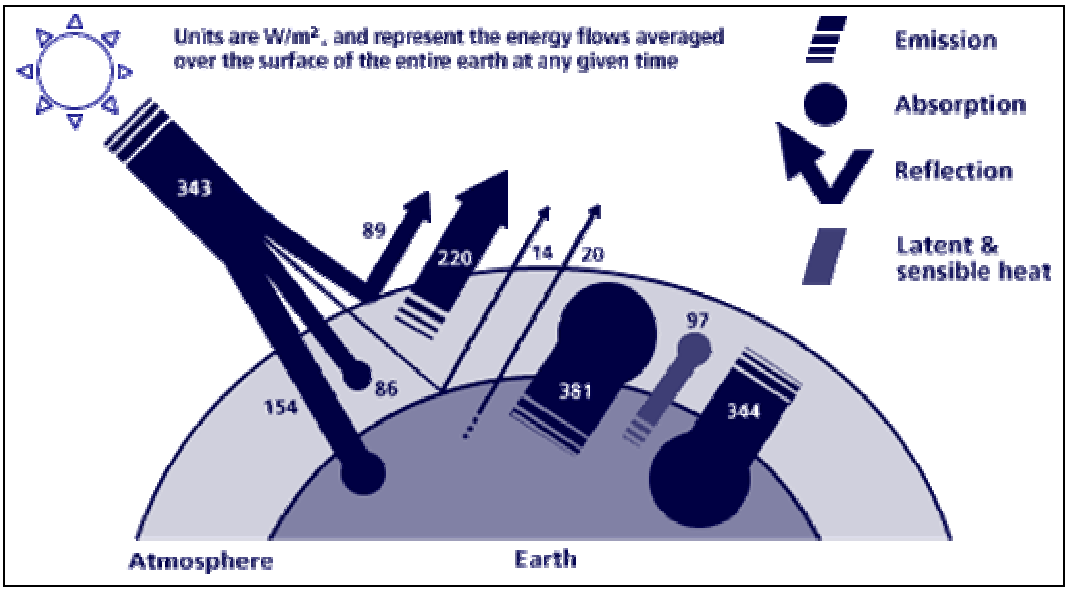


Figure 2.7. Solar Intensity on Earth.

(Source: Duffie and Beckman 1991)

Nitrogen and atomic oxygen absorb solar radiation continuously up to about 0.085μm. In addition, nitrogen and di atomic oxygen absorb solar radiation in a number of overlapping bands up to 0.2μm. This effectively curtails the solar radiation of wavelength less than 0.2 μm passing through the atmosphere and therefore, no solar radiation below 0.2μm reaches the surface of the earth.

Ozone also absorbs solar radiation below 0.2 μm and is a strong absorber between 0.2 and 0.3 μm, weaker between 0.3 and 0.35 μm, stronger in the visible region from 0.45 to 0.77 μm. Ozone is present in varying concentrations and depends on latitude and season and is concentrated more at the poles.

Water vapour present in the atmosphere contributes to the attenuation of solar radiation due to scattering and absorption. Water vapour scattering depends on perceptible water and is inversely proportional to the square of the wavelength. It absorbs solar radiation strongly in the infra red region at 0.82, 0.94, 1, 1.4 and 1.8 μm. Beyond 2.3 μm also, there is a strong absorption but the overall effect is very small at these wavelengths because the energy in this band region constitutes less than 5% of the total solar energy. The major source of water vapour is from the oceans and seas.

Carbon dioxide has a strong absorption band near 1.4 μm, 1.8 μm and above 2.6 μm. The sources of carbon dioxide are from plants, industrial flue gas emission and also from the variation of carbon dioxide solubility in the sea water.

Atmospheric aerosols, which are solid particles or liquid substances of radii 10A to 20 μm in suspension in air, also scatter the incoming radiation. Air molecules, whose sizes are very small as compared to the incoming wavelength of the solar radiation scatter according to the theory of Rayleigh, indicating that the scattering is proportional to λ^{-4}. Dust particles, which are of bigger sizes and vary from place to place depending on the season varies approximately as $\lambda^{-0.75}$. These are principally involved in the cloud forming process and are obtained from cosmic dust, meteorites, terrestrial marine origin, industrial and from combustion.

After absorption and scattering by the various constituents of the atmosphere, the major bandwidth of solar radiation which reaches the earth lies between 0.3 to 2.5 μm.

CHAPTER 3

SOLAR COLLECTORS

A solar collector is a device for intercepting incident solar radiation, converting this radiation to heat in a fluid, and delivering the heated fluid for use. If the surface on which solar radiation is absorbed has an area approximately equal to the area exposed to the sun's rays, the collector is of the nonconcentrating type. The solar absorbing surfaces in most nonconcentrating collectors are substantially flat or planar. Absorbing surfaces may also be of cylindrical shape, and unless associated with concentrating elements, they are included in this chapter.

The principal components of a flat-plate collector are a solar absorber, one or more flow passages for a heat transfer fluid, a layer of insulation below the absorber-flow channel assembly, a shallow box or a casing, and, one or two transparent covers. The absorber is usually a metal plate, or an assembly of metal sheets or plates forming a nearly continuous surface, coated with solar-absorbing substance such as a black paint, black porcelain enamel, or a metallic black oxide. Conduits within, or attached to, the absorber plate bring the heat transfer fluid into contact with the heated absorber plate and deliver the heated fluid to use. Transparent covers, usually tempered window glass, reduce thermal losses to the atmosphere by providing one or two stagnant air layers for suppression of convection loss. The opacity of glass to long wave radiation (above 5μm) emitted by the absorber surface reduces radiation loss as well. Insulation beneath the absorber and fluid passages inhibits downward heat loss, and the casing provides a rigid, protective structure for the entire collector assembly.

3.1. Types of Flate - Plate Collectors

Solar collectors may be divided into two main classifications based on the type of heat transfer fluid used. Liquid-heating collectors are used for heating water and nonfreezing aqueous solutions, and occasionally for nonaqueous heat-transfer liquids. Gas-heating collectors are employed as air heaters. The principal difference between the two types is the design of passages for heat-transfer fluid.

3.1.1. Heat Transfer Fluids for Solar Collectors

Heat transfer fluids carry heat from solar heat collectors to the heat storage tanks in solar heating (and cooling) systems. The fluids most commonly used are water, propylene glycol, ethylene glycol, and air. Less common fluids are synthetic hydrocarbons, paraffin hydrocarbons, aromatic refined mineral oils, refrigerants, and silicones.

When selecting a transfer fluid, you should consider the following criteria: the coefficient of expansion, viscosity, thermal capacity, freezing point, boiling point, and flash point. For example, in a cold climate, solar systems require fluids with low freezing points. Fluids exposed to high temperatures, as in a desert climate, should have a high boiling point. Viscosity and thermal capacity determine the amount of pumping energy required. A fluid with low viscosity and high specific heat is easier to pump, because it is less resistant to flow and transfers more heat. Other properties that help determine the effectiveness of a fluid are its corrosiveness and stability. The following are some of the most commonly used heat transfer fluids and their properties.

Air will not freeze or boil, and is non-corrosive. However, it has a very low heat capacity, and tends to leak out of collectors, ducts, and dampers.

Water is non-toxic and inexpensive. It has a high specific heat, and a very low viscosity, making it easy to pump. Unfortunately, water has a relatively low boiling point and a high freezing point. It can also be corrosive if the pH (acidity/alkalinity level) is not maintained at a neutral level. Water with a high mineral content (i.e., "hard" water) can cause mineral deposits to form in collector tubing and system plumbing.

Glycol/water mixtures have a 50/50 or 60/40 glycol-to-water ratio. Ethylene and propylene glycol are "antifreezes." Ethylene glycol is extremely toxic and should only be used in a double-walled, closed-loop system. You can use food-grade propylene glycol/water mixtures in a single-walled heat exchanger, as long as the mixture has been certified as non-toxic. Make sure that no toxic dyes or inhibitors have been added to it. Most glycols deteriorate at very high temperatures. You must check the pH value, freezing point, and concentration of inhibitors annually to determine whether the mixture needs any adjustments or replacements to maintain its stability and effectiveness.

Hydrocarbon oils have a higher viscosity and lower specific heat than water. They require more energy to pump. These oils are relatively inexpensive and have a low freezing point. The basic categories of hydrocarbon oils are synthetic hydrocarbons, paraffin hydrocarbons, and aromatic refined mineral oils. Synthetic hydrocarbons are relatively non-toxic and require little maintenance. Paraffin hydrocarbons have a wider temperature range between freezing and boiling points than water, but they are toxic and require a double-walled, closed-loop heat exchanger. Aromatic oils are the least viscous of the hydrocarbon oils.

Refrigerants/Phase Change Fluids, of which there are different kinds, are commonly used as the heat transfer fluid in refrigerators, air conditioners, and heat pumps. They generally have a low boiling point and a high heat capacity. This enables a small amount of the refrigerant to transfer a large amount of heat very efficiently. Refrigerants respond quickly to solar heat, making them more effective on cloudy days than other transfer fluids. Heat absorption occurs when the refrigerant boils (changes phase from liquid to gas) in the solar collector. Release of the collected heat takes place when the now-gaseous refrigerant condenses to a liquid again in a heat exchanger or condenser. For years chlorofluorocarbon (CFC) refrigerants, such as Freon, were the primary fluids used by refrigerator, air-conditioner, and heat pump manufacturers because they are nonflammable, low in toxicity, stable, non-corrosive, and do not freeze. However, due the negative effect that CFCs have on the earth's ozone layer, CFC production is being phased out as is the production of hydrochlorofluorocarbons (HCFC). The few companies that produced refrigerant-charged solar systems have either stopped manufacturing the systems entirely, or are currently seeking alternative refrigerants. Some companies have investigated methyl alcohol as a replacement for refrigerants.

Ammonia can also be used as a refrigerant. It is commonly used in industrial applications. Due to safety considerations it is not used in residential systems. The refrigerants can be aqueous ammonia, or a calcium chloride ammonia mixture.

Silicones have a very low freezing point, and a very high boiling point. They are non-corrosive and long-lasting. Because silicones have a high viscosity and low heat capacities, they require more energy to pump. Silicones also leak easily, even through microscopic holes in a solar loop. (Kalogirou 2004)

3.1.2. Liquid Type Solar Collectors

Figure 3.1 is a partially sectioned diagram of a typical flat-plate liquid solar collector. The drawing shows a commercially manufactured collector comprising a glass-cover metal box containing an absorber plate to which an array of tubes is attached and beneath which insulation is provided. Typical collector dimensions are 2 m by 1 m by 15 cm. the distance between glass covers is about 1 cm and the inner glass cover is usually about 2 cm above the absorber plate. 5-10 cm of insulation, such as heating-resistant fibrous glass, fills the space between the absorber plate and the bottom of the casing. Metal absorber plates, usually copper, steel, or aluminum, with tubing of copper in thermal conduct with the plates, are the most commonly used materials.

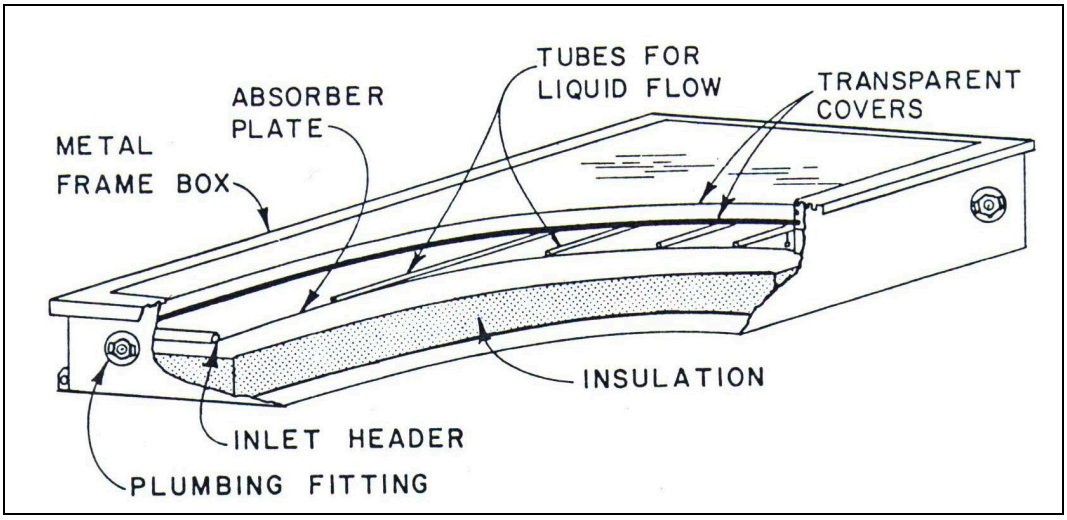


Figure 3.1. Sketch of Liquid Type Solar Collector
(Source: Altfelt and Leiner 1998)

Numerous variations on this design are illustrated in Figure 3.2. Most of the design differences are in the fluid conduits. Design A and E show tubing and headers inside the plate itself. This absorber is made by applying a tube pattern of stop-weld material to a metal or aluminum sheet, cold-welding another to it, and forming the tubing array by air inflation. Another absorber, shown in design F, comprises two sheets of steel, welded together at the edges and at 2 to 5 cm intervals. Expansion of the unwelded space by hydraulic pressure and attachment of inlet and outlet connections permits liquid flow between the plates.

A composite absorber, shown in design H, comprises copper tuber clamped into extruded aluminum fins which form an absorber plate. Mechanical pressure between fins and tubes is required for good thermal conduction from absorber surface to circulating liquid.

Several additional liquid-collector designs are sketched in Figure 3.2, all having essentially the same functional characteristics achieved various fabricating methods.

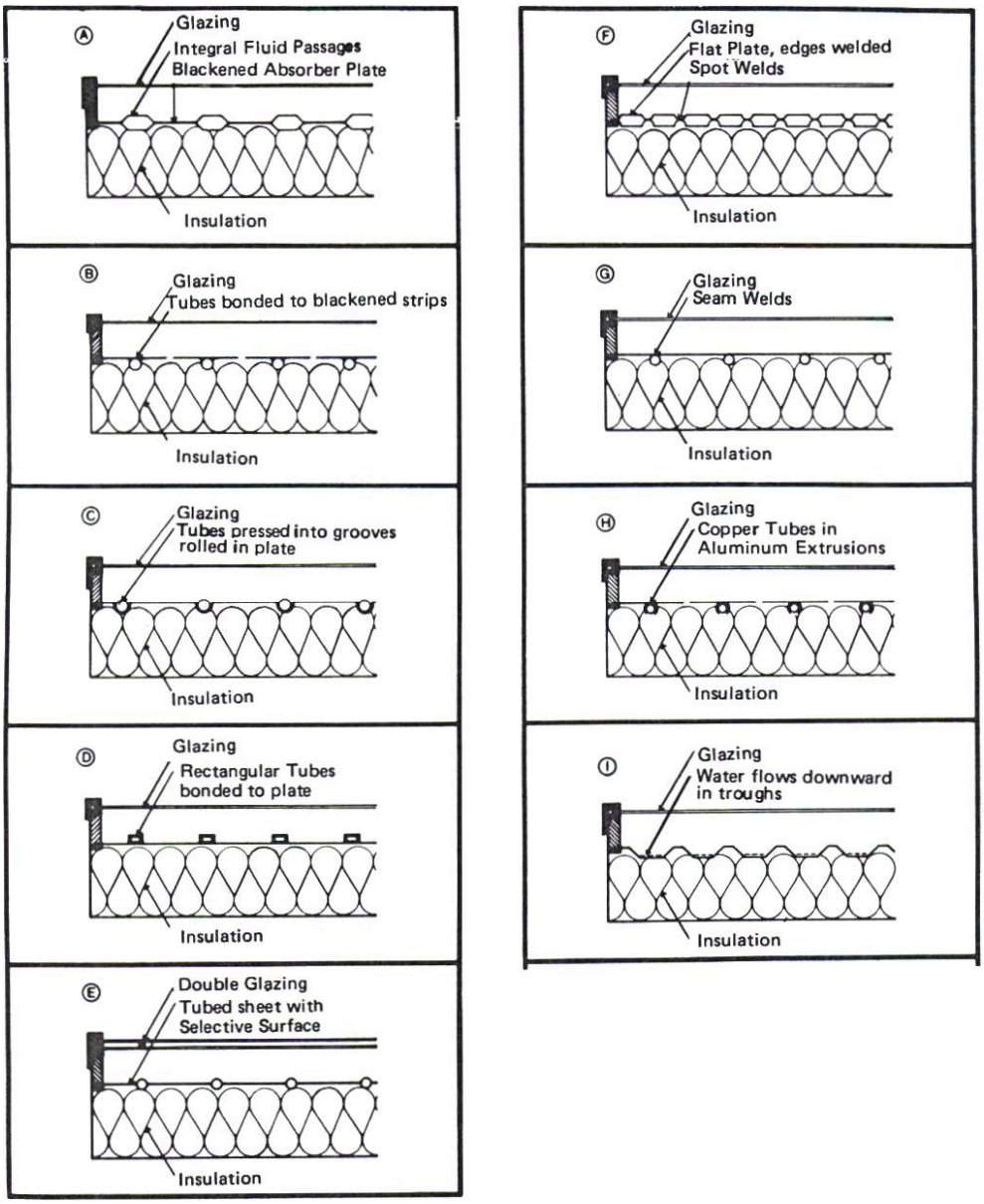


Figure 3.2. Various Designs for Liquid Type Solar Collector
(Source: Henden and Rekstand 2002)

3.1.2. Air Type Solar Collectors

Figure 3.3 is a perspective sketch of a typical air collector, and Figure 3.4 shows a longitudinal cross-sectional view of two collectors joined in series flow. The principal difference between air and liquid collectors is the size and configuration of the fluid conduits. The figure shows an air passage, about 1 cm high, beneath the absorber plate. For effective heat transfer, air flows below, and in contact with, the entire absorber surface. This design also has internal manifolds for air distribution to all collector panels in a close-fitting array.

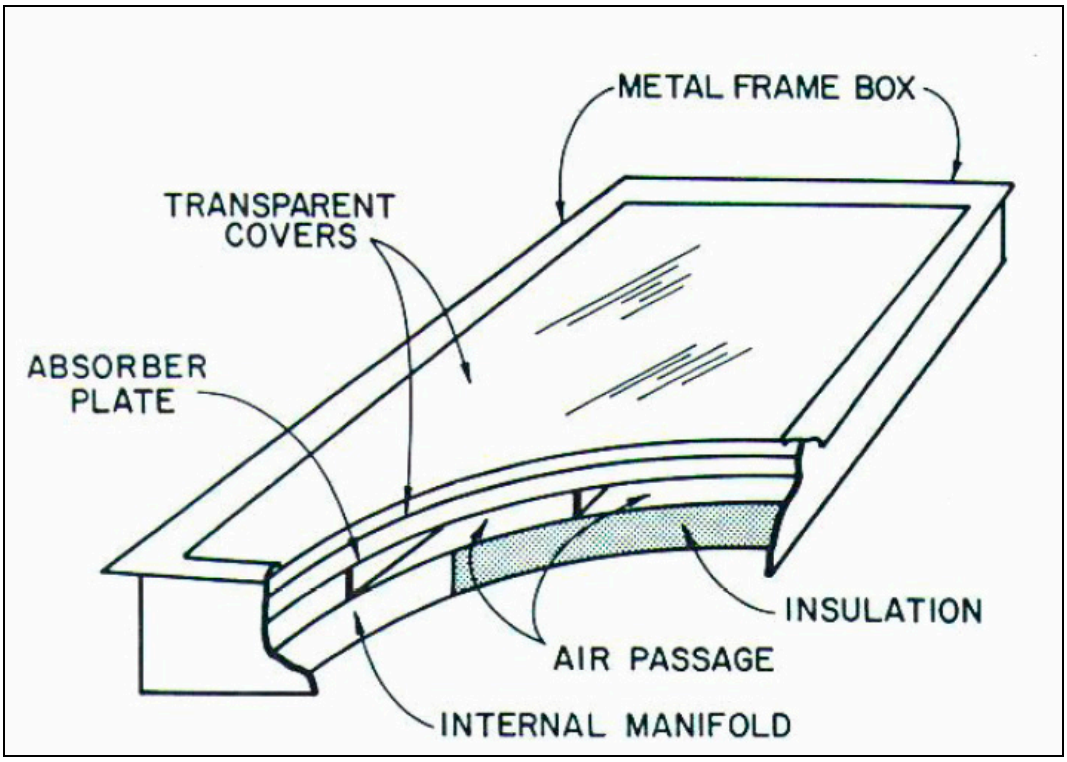


Figure 3.3. Sketch of Air Type Solar Collector
(Source: Altfelt and Leiner 1998)

The effects of material and construction of the absorber on the efficiency of the collectors have been widely reported in the literature.

Numerous variations in the design of collectors for heating air by solar energy are shown in Figure 3.5. Air can be passed in contact with black solar absorbing surfaces such as finned plates or ducts (A-C), several layers of metal screening, corrugated or roughened plates of various materials (B-D), and overlapped glass plated.

Flow may be straight through, serpentine, above, below, or on both sides of the absorber plate, or through a porous absorber material. (Hachemi 1999)

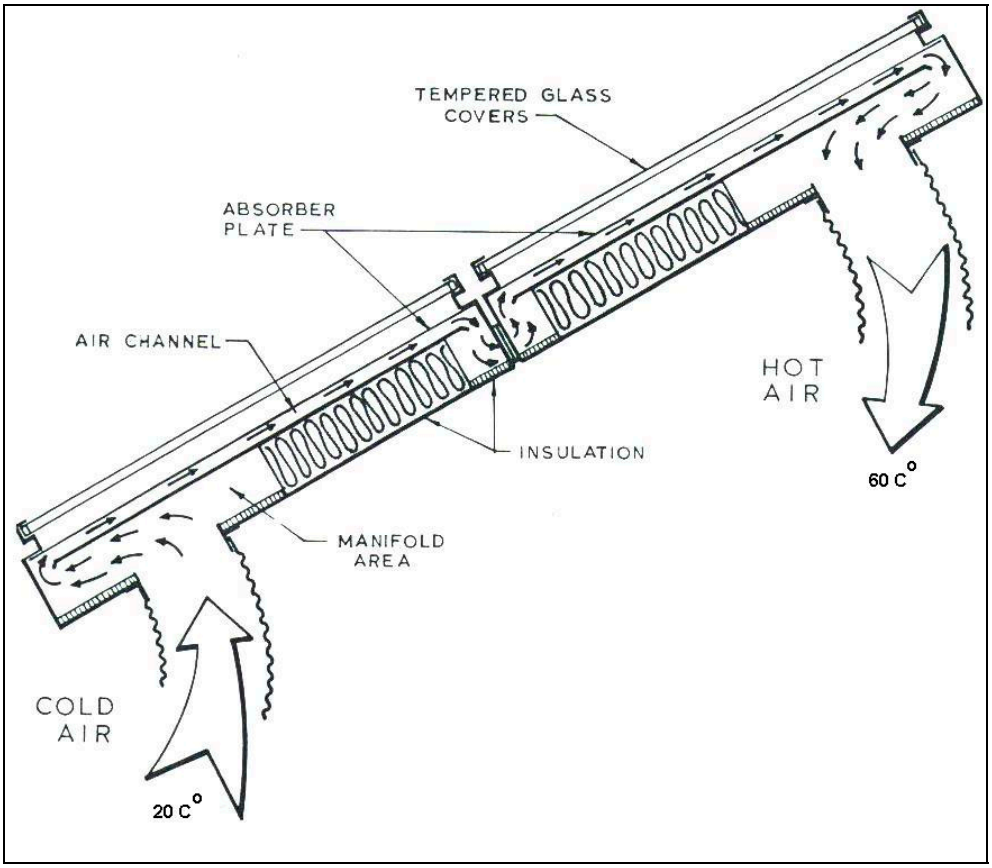


Figure 3.4. Air Type Solar Collectors in Series

(Source: Yeh and Lin 1997)

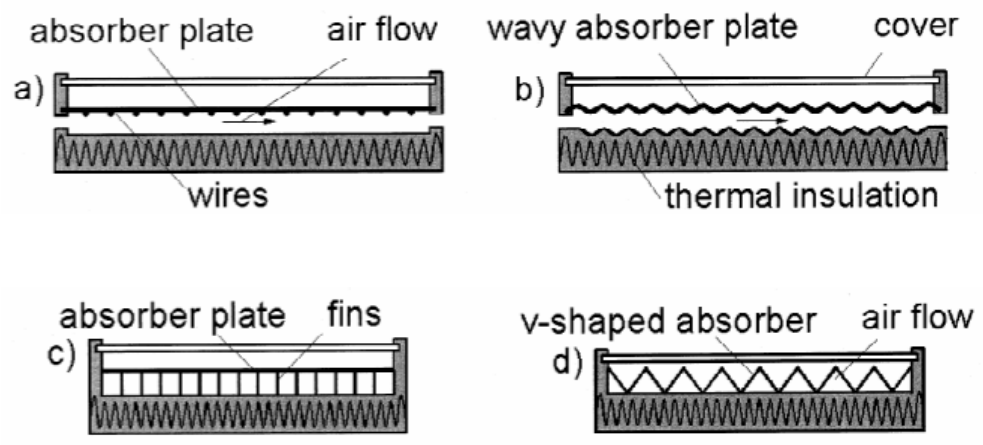


Figure 3.5. Various Designs for Air Type Solar Collector

(Source: Hachemi 1999)

3.2. Literature Survey on Air-Type Solar Collectors

Air solar collectors are a kind of heat exchangers that transform solar energy into heat. Usually, they are used for heating air in drying agricultural products and as an air heater in combination with auxiliary heaters for air conditioning of buildings.

In its simplest form, an air-type solar collector has a continuous passage beneath the absorber plate, through which air passed from one end of the collector to the other. Air comes in contact with the entire absorber surface so that the heat transfer area is maximized. (Bansal 1999)

As in the case of liquid collectors, materials used in the air collectors must be withstand stagnation temperatures without decomposition, melting, outgassing or other deterioration. Completely avoided, however, are high-temperature problems associated with the decomposition or phase change in the collector fluid, because air is sable at all attainable collector temperatures. There is, furthermore, no corrosion hazard, so mild steel can be used throughout the air collector. Freezing and boiling problems do not occur. (Momin and Saini 2002)

As with liquid collectors, air-type solar collector panels require suitable interconnections in parallel and series flow arrangements. The flow between panels may be through interconnecting ducts, between the edges of collector panels (Figure 3.4) or in and out of the bottom of the collector boxes. Manifolds with air inlets and outlets can be designed into the collector panels so that their placement side by side and end to end will form continuous passages (Figure 3.6).

Flat-plate solar air heaters can be used to dry a variety of agricultural products and food items such as,

- ✓ Fruits (Grapes ,figs ,bananas)
- ✓ Vegetables (Potatoes ,onions)
- ✓ Grains (Paddy ,wheat ,maize)
- ✓ Cash crops (Coffee ,walnut ,tobacco ,tea leaves)
- ✓ Spices (Ginger, garlic, chilies)
- ✓ Fish and meat

(Bhargava and Garg 1982)

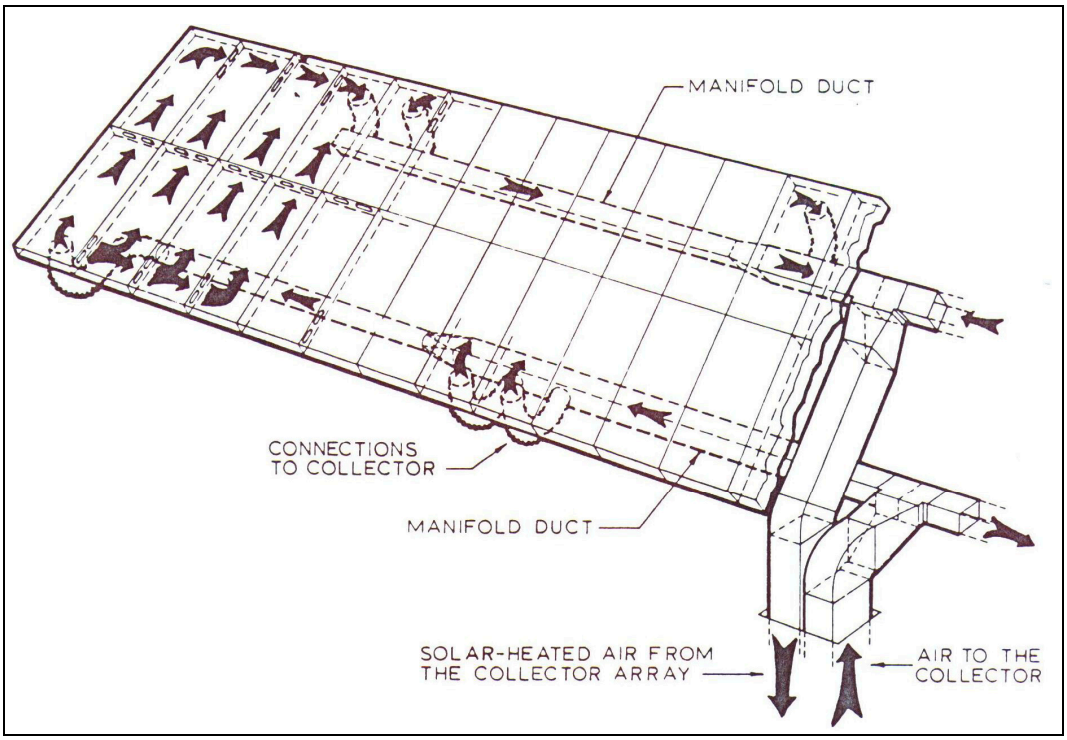


Figure 3.6. Typical arrangement of internally manifolded collector module in an array.

(Source: Biondi and Cicala 1988)

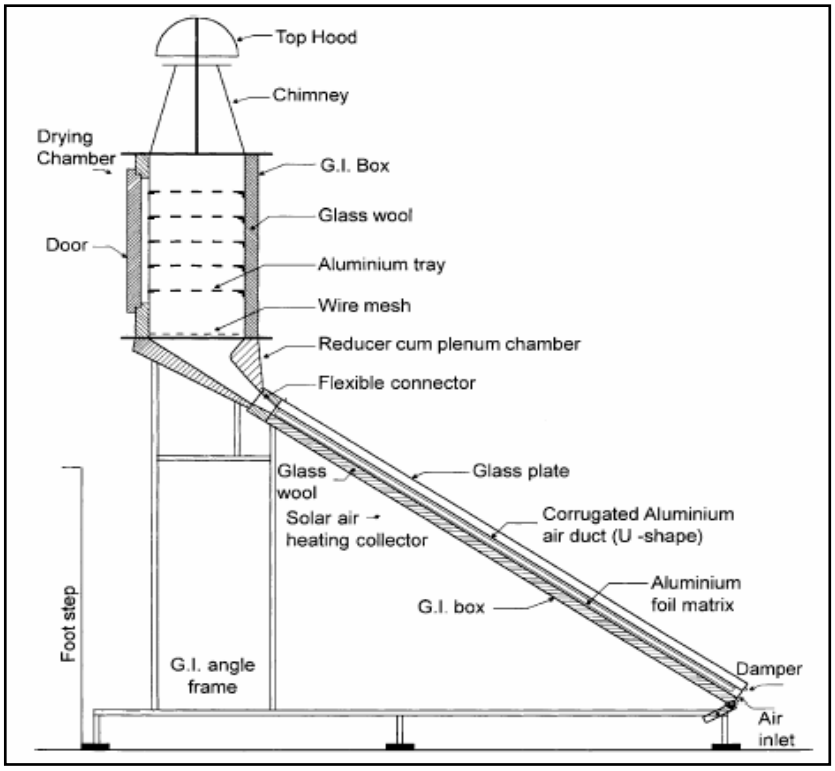


Figure 3.7. Air type solar collector setup for grape drying

(Source: Ekechukwu et al. 1999)

And other applications are,

- ✓ Space heating (Domestic & Agricultural)
- ✓ Leather drying
- ✓ Chemicals drying
- ✓ Lumber drying
- ✓ Fabric drying

(Choundhury and Anderson 1988)

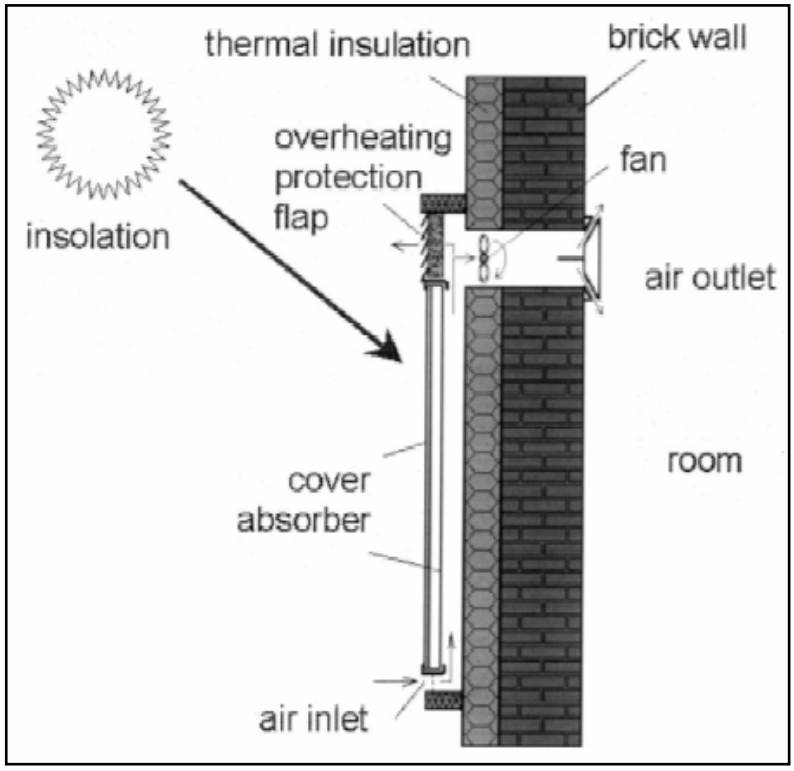


Figure 3.8. Air type solar collector setup for space heating
(Source: Choundhury et al. 1988)

Instead of passing all the air beneath the absorber plate, air flow may be both above and below the plate (Figure 3.9). Additional heat transfer surface is thus provided, thereby reducing the required temperature difference between plate and air, but the upward heat-loss coefficient is increased. The desirability of air flow o both sides of the absorber therefore depends on the application and, in particular, the temperature of operation relatively to that of the atmosphere.(Alkam and Al-Nimr 2001)

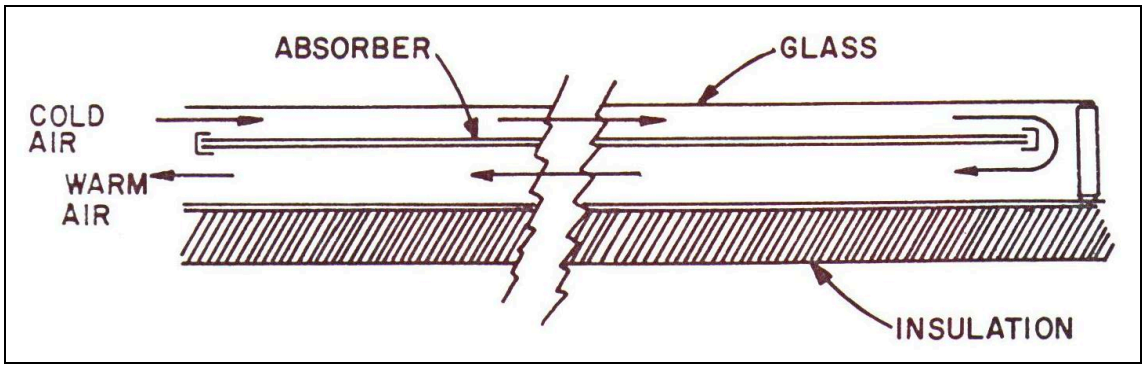


Figure 3.9. Double-pass air-type solar collector
(Source: Sophian and Daud 1999)

Numerous absorber plate designs have been used experimentally, and a few have been developed commercially. The differences between them involve principally the form of extended heat transfer surface and/or arrangements for producing additional air turbulence past the surface. The objective is the increase in the product of heat transfer coefficient and surface area, in order to minimize the difference in temperature between absorber plate and moving air. Some of the modifications are shown in Figure 3.10.

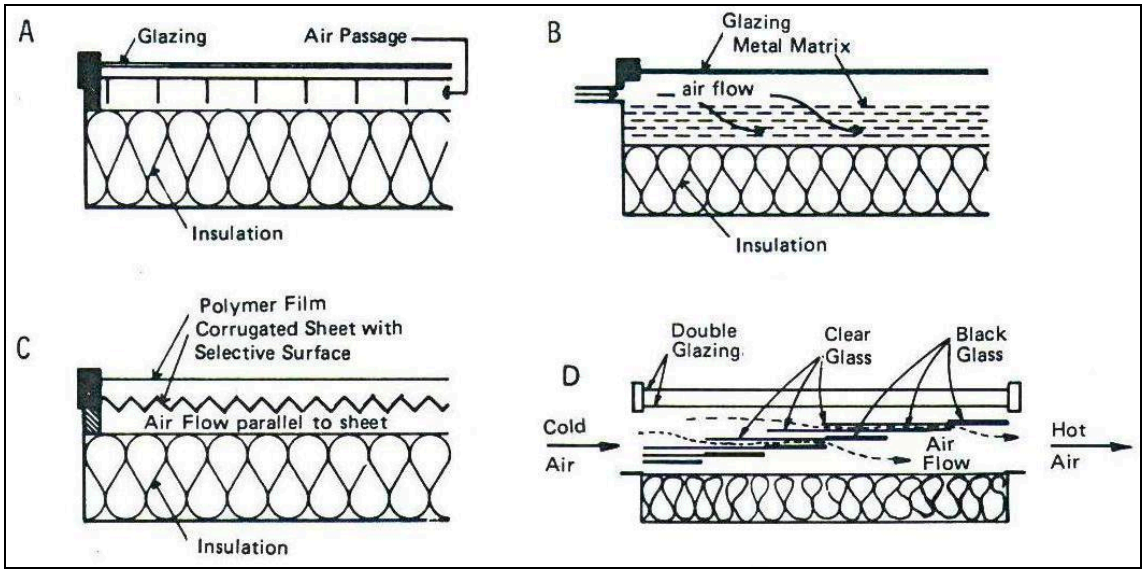


Figure 3.10. Absorber Types Used in Air-Type Solar Collector Applications
(Source: Yeh and Ho 1999)

Air-type flat-plate solar collectors have an important place among applications of solar energy system. The main part of air-type collectors is black absorber surface. Because of this, several investigations were made on this subject in order to increase efficiency of the collector and outlet temperature of fluid. It would be misleading to consider only the cost aspect of the design of a solar collector. High service costs increase total costs during the service life of solar collector. The most effective way to save energy is by increasing the efficiency in a solar collector by the heat transfer coefficient. Although they are widely used, their efficiencies are relatively low. In literature there are many researches, and it seems to be much more researches are going to be realized, in order to enlarge heat transfer area of Air-Type Flat Plate Solar Collectors. The aim of these investigations is to develop a more efficient absorber, to increase the amount of energy obtained, to decrease the cost of energy provided from sun, to store the energy and to use it continuously.

However, the disadvantages are the low density, the low thermal capacity and the small heat conductivity of air (Altfeld and Leiner 1998). Typical air solar collectors consist of a case, which holds a back insulation, an absorber and a transparent cover. The transparent cover reduces heat losses towards the front, meanwhile the air flows in between the absorber plate and the thermal insulation.

The effects of material and construction of the absorber on the efficiency of the collectors have been widely reported in the literature. Therefore, many configurations of the absorber plate have been designed to improve the heat transfer for the air flow in the passage. (Swartman and Ogunade 1966) proposed to modify the simple absorber flat plate for a solid matrix, (Choundhury and Anderson 1988) proposed a corrugated absorber, (Garg and Choundhury 1991) introduced the absorber plate with fins attached, (Parker and Lindley 1993) proposed a V-corrugated absorber plate, (Mohammad 1997) suggested a porous absorber plate, and (Kolb and Winter 1999) proposed a metal matrix absorber plate that improves the thermal performance. All the absorber plates proposed deal with clean new materials, implying high costs on the production of the very special absorber plates. (Henden et al. 2002) mentioned that the main barrier for large scale introduction of thermal solar systems is the high cost compared with conventional heating systems. The costs of the collector gain more importance, and the need of less expensive collectors is evident. Based on this idea, a rudimentary design of an air solar collector using convenient recyclable material for the absorber plate was built (Ekechukwu and Norton 1999). The thermal evaluation indicated that the efficiency of

this collector was very low (Toure 2001). Efficiency values about %70 for 3 m/s, %60 for 3.5 m/s and %48 for 4 m/s with polyurethane foam as heat absorbing element are obtained with the same experimental setup that we have used at our study. (Aydın 2005)

In general, the performance of a solar collector depends on the parameters which are listed as:

- ✓ Ambient conditions (T_a , V_w , I_o)
- ✓ Typology of the construction
- ✓ Choice of the materials
- ✓ Geometry (L, W, H, etc.)
- ✓ Characteristics of the working fluid (C_p , k , ρ , μ)
- ✓ Inlet temperature of the fluid (T_i)
- ✓ Flow rate (m)

  (Hegazy 1999)

The efficiency of a solar collector is defined as the ratio of the amount of useful heat collected to the total amount of solar radiation striking the collector surface during any time period.

Temperature difference between the outlet and the inlet temperatures depends on

- ✓ The level of insulation.
- ✓ The solar collector orientation.
- ✓ The dimensions of the collector.
- ✓ The transmittance of the cover material.
- ✓ The absorptance of the absorber surface.

  (Reddy and Gupta 1980)

3.3. General Principles

Under steady conditions, the useful heat delivered by a solar collector is equal to the energy absorbed in the metal surface minus the heat losses from the surface directly and indirectly to the surroundings. This principle can be stated in the relationship:

$$Q_u = A_c\left[I_t \cdot \tau \cdot \alpha - U_L\left(T_p - T_a\right)\right] \tag{3.1}$$

ABSORBED ENERGY = $A_c . I_t . \tau . \alpha$ (3.2)

EFFECTIVE HEAT LOSS = $A_c . U_L . (T_p - T_a)$ (3.3)

A diagrammatic representation of the terms in this relationship is shown in Figure 3.11.

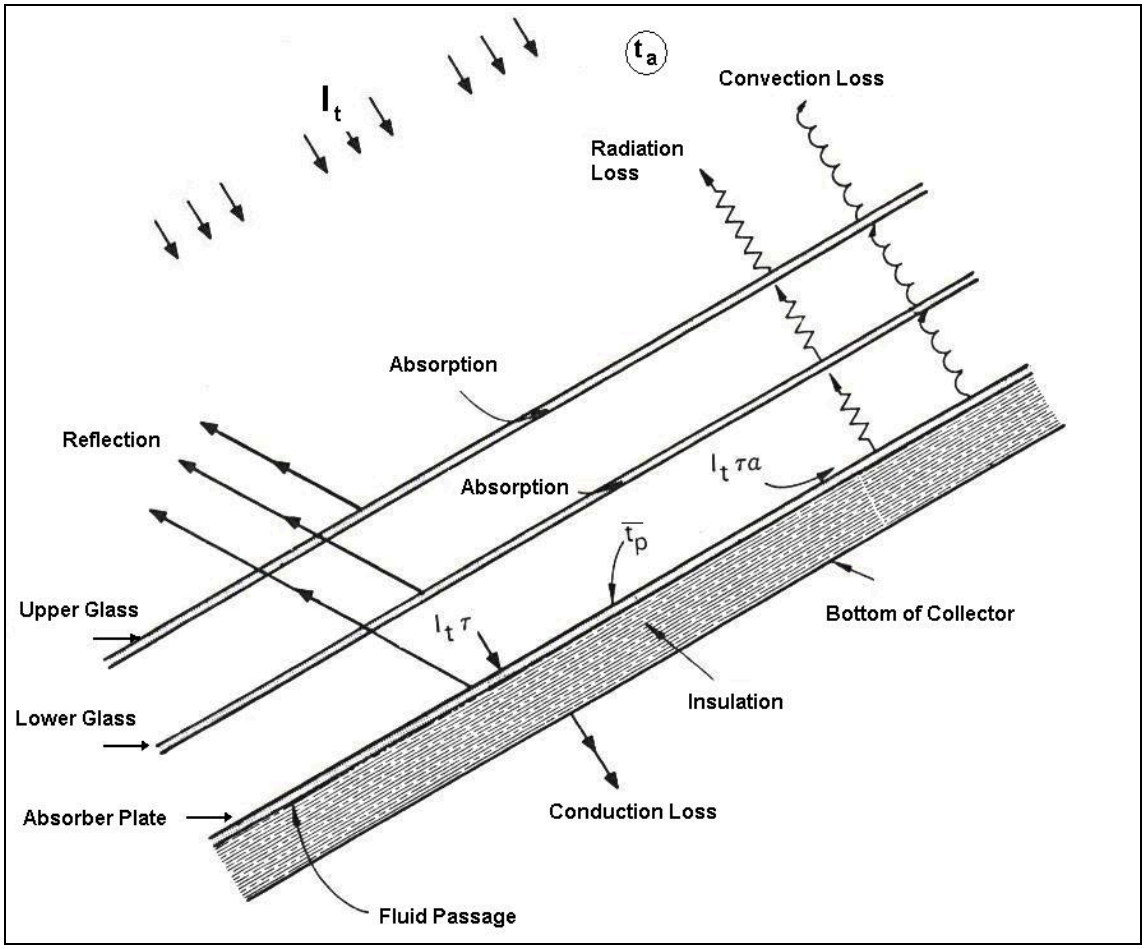


Figure 3.11. Definition sketch for Eq. 3.1.
(Source: Akhtar and Mullick 1999)

3.3.1. Heat Losses from Collector:

In order that the performance of a solar collector be as high as economically practical, design and operating factors that increase the value of $I_t . \tau . \alpha$ in Eq. (3.1) and

that reduce the value of $U_L.(T_p-T_a)$ are selected. The greater the energy absorption in the absorber surface and the lower the heat loss from the surface, the higher is the useful heat recovery. If an unglazed absorber plate is used as the collector, the heat loss coefficient to the atmosphere, U_L, of 30 to 60 $W/m^2.^oC$ is so large that an absorber temperature of 15 to 30 ^oC above atmospheric temperature is the maximum achievable under full solar radiation of 1000 W/m^2. Under these conditions, no useful heat is delivered from the collector because the heat loss is as large as the solar heat absorbed. When a fluid is circulated through the collector, useful heat output requires an even lower delivery temperature. Unless a low-temperature application is involved, such as swimming pool heating, heat losses must therefore be reduced.

To reduce the rate of radiation and convection loss, one or more transparent surfaces, such as glass, are placed above the absorber surface. One layer of glass can transmit as much as 92 % of the solar radiation striking it while greatly reducing the heat loss coefficient, U_L. This reduction is due to the suppression of convection loss by interposing a relatively stagnant air layer between absorber material and glass, and absorption of long-wave thermal radiation emitted by the hot metal absorber surface. The combined heat-loss coefficient can be reduced to 5-10 $W/m^2.^oC$ by the use of one glass cover. Similar benefits can be achieved by use of certain transparent plastic materials.

The heat-loss coefficient can be reduced further by using a second transparent cover with an air space between the two surfaces. Two convection barriers are then present, as well as two surfaces impending radiation loss. Coefficients in the range of 4-5 $W/m^2.^oC$ are then typically obtained.

Radiation losses can be decreased by other techniques, such as by reducing the radiation-emitting characteristics of the absorber. Thermal radiation emitted by the absorber plate may also be reduced by reflecting it downward from the lower glass cover by employing an infrared reflecting coating on the glass. A very thin, optically transparent layer of tin oxide or indium oxide deposited on the glass reflects thermal radiation back to the absorber material.

Heat losses can also occur from the side and back of the collector unless adequate insulation is used. Materials must be completely stable at the high temperatures occasionally encountered when the collector flow is interrupted. Fibrous glass wool with heat-resistant bonding agents are suitable types. The total R value of the

insulation should be at least 10 (0.57 $W/m^2.^oC$) for medium-temperature, flat-plate collectors.

The foregoing discussion has been concerned with methods for reducing U_L, the heat-loss coefficient. By so doing, the total heat loss is minimized and collector efficiency is increased. It is evident from Eq.3.1 that, losses also decrease as the difference between average plate temperature and air temperature increase. The ambient air temperature in an uncontrollable factor, but the fact that it varies with time and with geographic location means that collector efficiency also depends on these factors. It is also clear that a collector is more efficient at lower plate temperatures than high temperatures. But plate temperature depends on the temperature of the fluid being circulated in contact with the plate, the rate of fluid circulation, and the type of fluid. Fluid temperature depends on conditions elsewhere in the heat utilization system; whereas the other factors in Eq.3.1 depend on collector design, operating conditions, solar energy input, and atmospheric temperature. (Duffie and Beckman 1991)

3.3.2. Solar Energy Absorption

The first term in Eq.3.1 is the energy absorbed by the absorbing surface. The quantity depends on the solar incident on the tilted surface of the collector, which can be measured or derived from tables of averages. If based on horizontal readings, the values can be calculated for the proper collector position.

The transmissivity of the glazing, τ, is a function of the quality of the material, its thickness, its refractive index, and the angle at which solar radiation is reaches the surface. At normal incidence (Solar beam perpendicular to the surface), one sheet of ordinary window glass reflects about 8 % of the solar radiation. Two sheets of glass with an air space between them reflect about 15 %. Impurities in ordinary glass, principally iron, result in some radiation absorption; typically 3-mm glass absorbs 1 to 5 percent per sheet. Glass with iron content absorbs 1 to 2 percent per sheet, so at normal incidence the total transmission of two sheets of white glass can be approximately 80 %. The corresponding value of τ is, therefore 0.8 for this assembly. (Nield and Kuznetsov 1999)

Because beam radiation from the sun strikes a stationary collector at an angle that varies throughout the day and diffuse radiation is continuously received at all

angles, a weighted mean transmissivity is somewhat lower than this normal incidence value. An approximation for a single-glazed collector can be based on a 10 % average reflection loss and a suitable absorption loss dependent on glass quality. Assuming 2 % absorption, an effective all-day transmissivity, τ, is 0.85 to 0.88. In a collector with two covers of good quality, an average transmission coefficient of 0.75 to 0.77 is typically applicable.

The value of the transmission coefficients for plastic glazing depends on the type of the material used. Some plastics show transmissivities moderately higher than glass, whereas others have lower values.

Methods for reducing the reflectivity of glass surfaces have been developed. Thin metallic films formed by vapor deposition in vacuum are commonly used as lens coatings. By optical interference with certain wavelengths, reflectivity is reduced and transmission is increased. This process is too costly for solar collector application, but a cheaper method involving acid etching of the glass surface to produce a slightly porous silica surface has resulted in solar reflectivities as low as 2 % per sheet. Total transmissivity of a double-glazed collector can thereby be increased to values above 90.%. The cost effectiveness of this substantial improvement has not yet been demonstrated. (Ong 1995a)

The absorptivity, α, of the radiation-receiving surface depends on its chemical and physical properties and on the wavelength of the incident radiation. Surfaces that appear black have high absorptivity for the visible portion of the solar spectrum and are usually good absorbers for the infrared portion as well. Carbon black, numerous metal oxides, and most black paints have absorptivities above 0.95; that is, they absorb 95 percent of the solar radiation reaching the surface. (Ong 1995b)

The most common types of absorber surfaces are heat-resistant black paints, usually applied by spray, followed by curing with heat to vaporize all solvents and to secure permanence. These surfaces must be able to withstand temperatures of 150 to 200 ^{o}C in double glazed collectors without appreciable deterioration or out gassing. Black porcelain enamel, applied to steel as a frit and fused to the surface in a furnace, is also being used commercially. (Ashrae 1991)

3.3.3. Selective Surfaces for Reduction of Heat Loss

Most surfaces that are good absorbers for solar radiation are also good heat radiators. If, for example, a surface has an absorptivity of 0.95 for solar radiation, it normally radiates heat at a rate about 95 % of that emitted by a "perfect" radiator; that is, its emissivity is 0.95. Certain combinations of surfaces, however, are capable of absorbing solar radiation effectively, while at the same time radiating heat at a low rate. These combinations are known as selective surfaces. The most practical selective surfaces for solar collectors are composed of a very thin deposit of black metallic oxide or sulfide on a bright metal base. The black oxide coating is thick enough to act as a good solar absorber, with a solar absorptivity as high as 0.95, but it is essentially transparent to long-wave thermal radiation emitted by an object at a temperature of only a few hundred degrees. Bright metals have low emissivity for thermal radiation, typically about 0.1, so they are poor heat radiators and since the thin oxide coating is transparent to such radiation, the combination is a poor heat radiator. The radiation loss from this type of surface is therefore considerably lower than from a conventional, non-selective surface, so the overall heat loss coefficient, U_L, has a lower value when this type of surface is used.

The most successful and stable selective surface developed to date is made by electroplating a layer of nickel on the absorber plate, then electrodepositing a thin layer of chromium oxide on the nickel substrate. Nickel oxide coatings have also been used, but they are less resistant to moisture. Coatings of copper oxide on bright copper and nickel have similar properties, but temperature stability is limited. The most effective selective surfaces have solar absorptivities near 0.95 and emissivities near 0.1.

3.3.4. Optimum Tilt of Flat Plate Solar Collectors

This is governed principally by the objective which has to be clearly specified:

(a) whether the flat plate collector has to supply a load which is seasonal in nature. For example, solar collectors may be needed to supply only for heating a building in winter, which will necessitate the tilt of the collector to be the value for which the energy collection is maximum during the winter season alone

(b) whether the load is constant throughout the year.

The general thumb rule is:

For winter load, the tilt should be (latitude + 10^0) degrees and for year round use, the tilt = latitude.

The influence of other factors to the optimum tilt such as clearness index, diffuse fraction, etc., indicates that the optimum tilt could be given as a simple function of latitude and declination as:

$$\beta_{opt} = \phi + \tan^{-1}(-1.319 \tan \delta) \qquad (3.6)$$

(Sodha and Chandra 1994)

3.4. Collector Performance

3.4.1. Convenient Performance Equation

The principle design factors affecting collector performance are those related to heat-loss control and those involving the absorption of solar radiation. If the numerical values of all the terms in Eq.3.1 are known, the rate of useful heat recovery Q_u , can be calculated. In addition to the design characteristics of the collector, the three operating conditions – solar radiation, average plate temperature, and ambient temperature – must be known. With the exception of plate temperature, these terms can be measured in an operating collector or obtained from tables or charts for design purposes. Absorber plate temperature, however, is seldom known, nor it can be easily determined. It is affected by the other operating conditions, including the temperature of the fluid being supplied to the collector.

In an operating system composed of collector, storage and the space being heated, the temperature of the fluid in storage can be measured. When a system is being designed, storage temperature can be calculated or assumed until confirmed. This fluid is supplied directly to the collector, or indirectly via a heat exchanger, thereby affecting the absorber plate temperature in Eq.3.1. In a typical liquid collector, average plate temperatures are usually 5 to 10 ^oC above inlet liquid temperature, and in air collectors the temperature difference is 20 to 30 ^oC. For convenience, Eq.3.1 can be modified by

substituting inlet fluid temperature for the average plate temperature if a suitable correction factor is applied. (Hegazy 2000)

The resulting equation is,

$$Q_u = F_R \cdot A_C \left[I_t \cdot \tau \cdot \alpha - U_L \left(t_i - t_a \right) \right] \tag{3.4}$$

F_R is a correction factor or "heat removal factor" having a value between $0 < F_R < 1$, such that the useful heat recovery calculated by Eq. 3.4 is equal to that calculated by Eq. 3.1.

3.4.2. Heat Removal Factor

The heat removal factor, F_R, can be interpreted as the ratio of the heat actually delivered to that which would be delivered if the collector plate were at a uniform temperature equal to that of the entering fluid. This temperature equality would theoretically be possible if the fluid were circulated at such a high rate that there would be a negligible rise in its temperature as it passed through the collector and if the heat-transfer coefficient were so high that the temperature difference between the absorber surface and the fluid would be negligible. Under such circumstances, the value of F_R would be equal to "1".

In Eq. 3.4, the temperature of the inlet fluid is dependent on the characteristics of the complete solar heating system and the heat demand of the building. F_R, however, is affected only by the solar collector characteristics and the fluid type and flow rate through the collector.

3.4.3. Collector Efficiency Evaluation

Eq. 3.4 may be rewritten as efficiency of solar collection, that is, useful heat delivery divided by total solar radiation, by dividing both sides of the equation by I_t and by A_c. The result is Eq. 3.5:

$$\eta = \frac{Q_u}{I_t \cdot A_c} = F_R \cdot \tau \cdot \alpha - F_R \cdot U_L \cdot \frac{(T_i - T_a)}{I_t} \qquad (3.5)$$

For a specific collector operating at a constant fluid circulation rate, the values of A_c, F_R, τ, α and U_L are nearly constant. This is regardless of solar and temperature levels. Values of τ and α vary with angle of incidence of solar radiation on the plane of the collector, a fact recognized in a procedure outlined below). Assuming that they are constant, Eq. 3.5 represents a straight line on a graph of efficiency versus $(T_i - T_a)/I_t$. The properties of this line are an intercept (the intersection of the line with the vertical efficiency axis) equal to the numerical value of $(F_R . \tau . \alpha)$ an a "slope" of the line, that is, the vertical scale change divided by the horizontal scale change, equal to $(F_R . U_L)$. If experimental data on collector heat delivery at various temperatures and solar conditions are plotted on a graph, with efficiency as the vertical axis and $(T_i - T_a)/I_t$ as the horizontal axis, the best straight line through the data correlates collector performance with solar and temperature conditions. Intersection of the line with the vertical axis corresponds to the fluid inlet temperature being the same as the ambient temperature, where collector efficiency is zero. This condition corresponds to such a low radiation level or to such a high temperature of the fluid supply to the collector that heat losses are equal to solar absorption, no useful heat is delivered from the collector.

The linearity of Eq. 3.5 rests on the assumption that the values of $(F_R . \tau . \alpha)$ and $(F_R . U_L)$ are constant and independent of t_i, t_a, and I_t. Although the influence is small, F_R and U_L both depend slightly on collector temperature, represented by T_i. Since radiation loss is a function of the fourth power of the inlet and ambient temperatures, whereas convection loss is dependent on the first-power temperature difference, the heat-loss coefficient increases with rise in collector temperature and with temperature difference. A graph of efficiency versus $(T_i - T_a)/I_t$ therefore must curve slightly downward as the temperature difference/solar radiation ratio is increased. The magnitude of this effect, which is usually small enough, and in a portion of the collector operating range seldom encountered, that the linear assumption is adequate for practical design purposes.

In addition to recognition of the linear approximation, useful application of the equation requires determination and substitution of appropriate values of F_R, τ, α, and U_L. The values of F_R and U_L are affected by wind velocity across the collector and fluid velocity through the collector, so both of these flow rates must be known and specified. Wind velocity has a comparatively small effect on the efficiency of the glazed

collectors, and a “standard” 4.5 m/s wind speed is normally assumed for rating collector efficiencies. The value of F_R is not strongly dependent on flow rate in liquid collectors, but is particularly sensitive to flow rate in solar air collectors. The magnitude of the effect is indicated in a subsequent section on collector efficiency.

The value of the product $\tau . \alpha$ varies with the angle of the incidence of solar radiation on the collector, and is therefore dependent on the distribution of radiation between direct and diffuse and on the position of the sun relative to the collector surface. If known value of the product $\tau . \alpha$ is, as usual, for normal incidence radiation, it must be altered for other collector positions. When the equation is being used for collector design or for correlations of test results, performances at solar incident angles other than zero must be computed by using a value of $\tau . \alpha$ applicable to the particular angle prevailing. An “incident-angle modifier”, computed by use of data on transmission and absorption coefficients as functions of incident angle, can be used as factor by which $(\tau . \alpha)_n$, the $\tau . \alpha$ product at zero incident angle, is multiplied to obtain energy absorption rates at any solar angle, hence at any hour. To get that kind of chart ratios of measured collector efficiency at several solar angles, and with $T_i = T_a$, also provide this information. (Duffie and Beckman 1991)

Although the collector efficiency curve is not strictly linear, direct proportionality to $(T_i - T_a)/I_t$ is essentially obtained in the usual range of operation. Departure from linearity is significant only when conditions of temperature and solar radiation result in apparent efficiencies as low as 10 % to 15 %.

3.4.4. Correlation of Efficiency with Outlet and Average Collector Fluid Temperature

The convenient relationship, Eq. 3.5, correlating collector efficiency and operating conditions contains inlet temperature as an independent variable. For some applications, particularly those involving air collectors, average fluid temperature in the collector or the delivery temperature may be more useful. Figure 3.12 shows plots of the efficiency versus ratios of $\Delta T / I_t$ for a typical air-heating collector. On the outlet temperature basis, the intercept and the slope of the line are substantially greater than when correlated on the inlet temperature basis.

Use of the outlet-temperature curve, Figure 3.12, is particularly useful in evaluating air collectors for supply of heat at specific delivery temperatures for certain

processes or uses. A minimum air temperature for drying, for example, below which a solar air heater would not be operated, can be used in finding the abscissa for the appropriate curve of Figure 3.12. The efficiency of collection at a delivery temperature above ambient temperature can than be read. (Yeh and Ho 2002)

By correlating collector efficiency with delivery temperature, heat supply rate at specific delivery temperatures can be determined directly. The value and usefulness of heat depends on its actual temperature, so an outlet temperature parameter provides a fundamental basis for comparing liquid and air collectors on the same graph. Collector performance is sometimes reported at average fluid temperature, $(T_i+T_o)/2$; conversion to inlet or outlet temperature basis may be accomplished by use of some factors reported in literature.

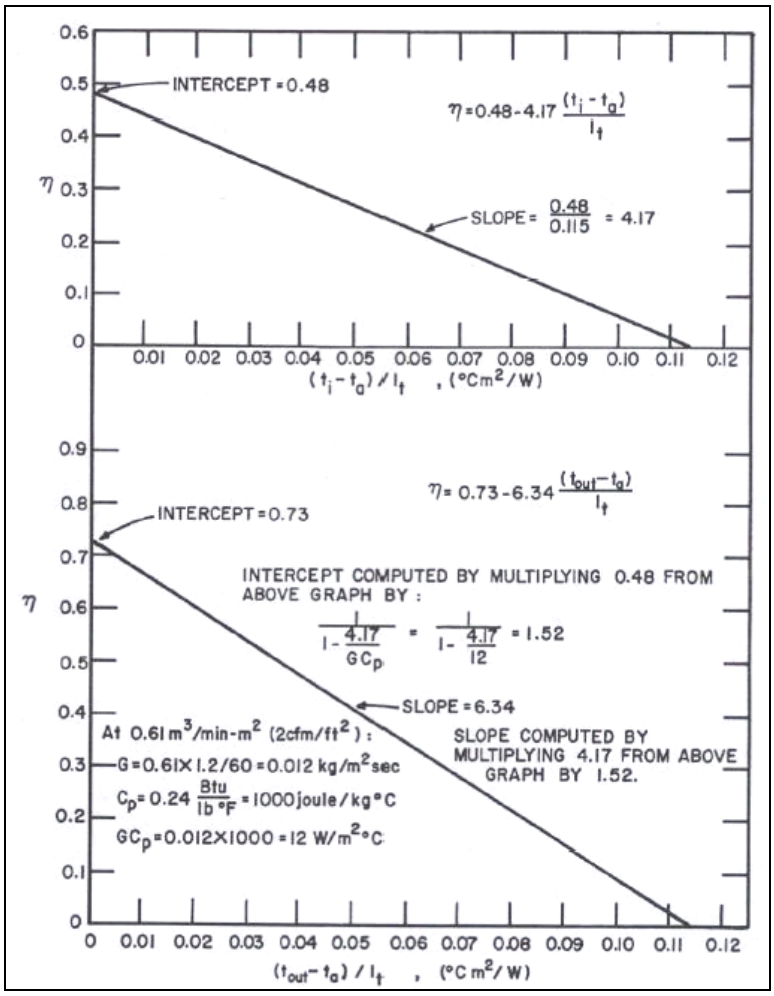


Figure 3.12. Efficiency of Typical Air Collector Correlation with Inlet and Outlet Temperatures.

(Source: Hachemi 1999)

3.4.5. Effect of Air Rate on Air –Type Solar Collectors

Because the heat transfer coefficient between absorber plate and air increases approximately as the eight-tenths power of the air velocity in the collector, there is a substantial efficiency advantage in employing relatively high air rates. But the higher the air rate, the greater are the pressure loss and the fan power requirement. Other configurations in the heat transfer zone could involve different air rates and pressure losses, but the trends are similar. The choice of most suitable air rate depends on the type of application and the trade-offs between power requirements and collector efficiency.

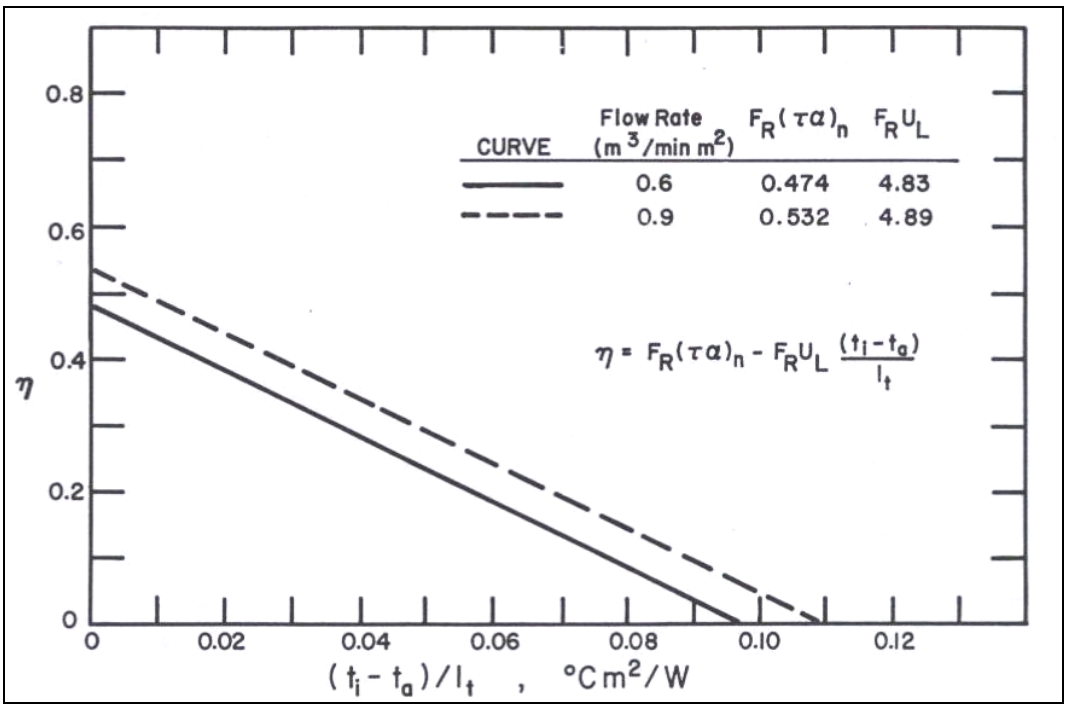


Figure 3.13. Air Collector Efficiencies at Different Flow Rates.

3.4.6. Comparison of Typical Collector Efficiencies

Figure 3.14 shows efficiencies of several types of collectors correlated with the "inlet parameter", $(T_i-T_a)/I_t$. These lines are the results of actual tests in which flow rate, solar radiation, and inlet, outlet, and ambient temperatures were measured. Collectors 3, 4 and 7 are seen to have the highest efficiencies, but final selection also depends on other factors such as the usual operating conditions, costs, and durability. Collector 4

appears to have the best performance if usually operated at conditions represented by the left-hand side of the graph. Such conditions are low inlet temperatures or high solar radiation. Near the right-hand side of the graph, where high inlet collector temperatures or low solar radiation prevail, collector 7 is more efficient than collector 4. It is evident that some collectors are better than others in certain temperatures and radiation ranges, whereas a reversal can occur at different conditions.

A graph such as that in Figure 3.15 for particular collector, when compared with others of similar type, can be used for identifying the best equipment. Collector manufacturers usually provide such data. Of equal value are reliable data on the quantities $F_R(\tau\alpha)_n$ and $F_R U_L$, where $(\tau\alpha)_n$ is the value of the transmissivity-absorptivity product at normal solar incidence angle. Knowledge of these two factors is equivalent to having the graphical relationship.

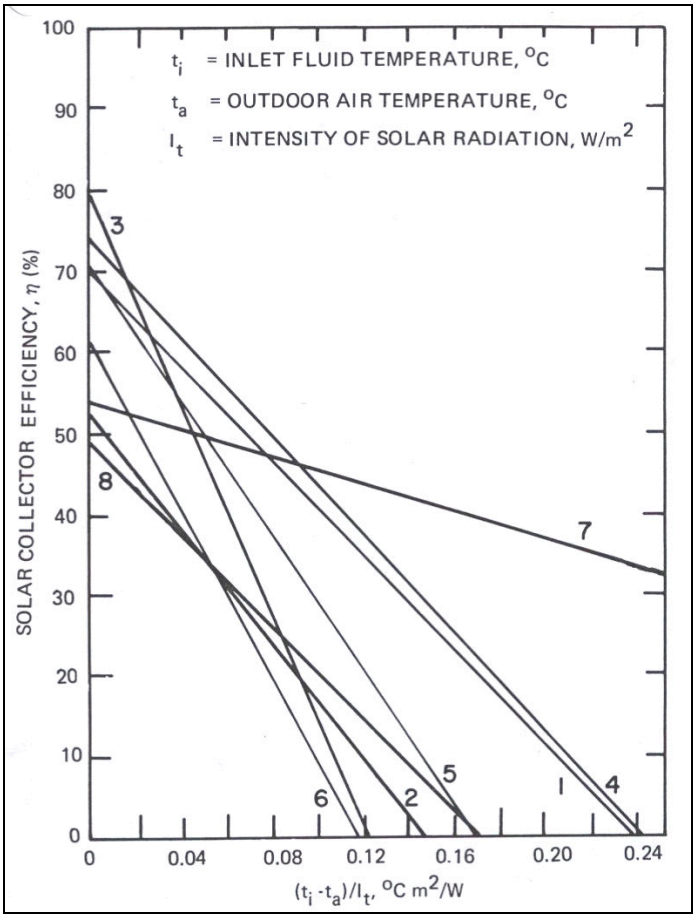


Figure 3.14. Solar Collector Efficiencies

(Source: Fleck and Meier 2002)

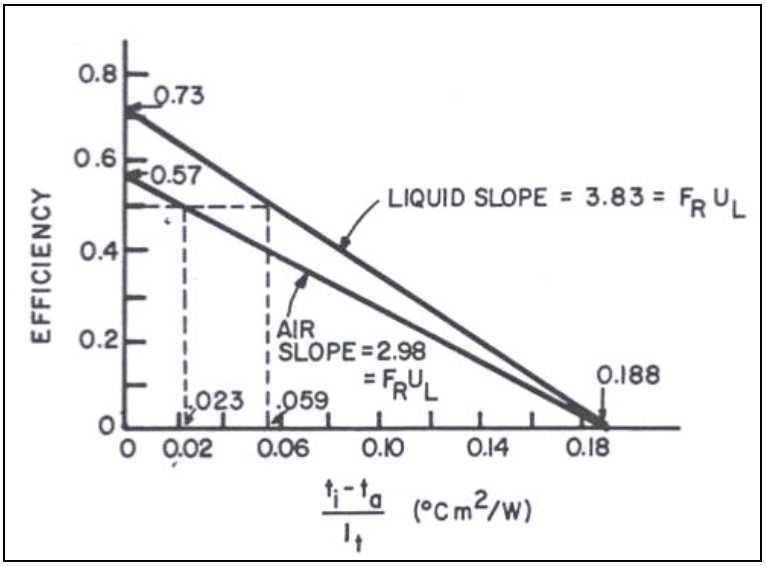


Figure 3.15. Results of Performance Calculations

Under effects of these studies, an air air-type solar collector was built and tested by using the ASHRAE 93-1986 standard named “Methods of Testing to Determine the Thermal Performance of Solar Collectors”. Performance of the collector observed and data obtained from data logger, are used to calculate and evaluate our collector efficiency. Effects of open-cell polyurethane foam on the thermal performance of an air-type solar collector are tested. Increment of the efficiency related to the porous media is presented and performance curves of collector are indicated. Factors, affect the performance, are discussed in future sections.

CHAPTER 4

EXPERIMENTAL SETUP

The experiments were conducted on the days of July, August and September in Manisa in Turkey. The collectors were located with 38.46 angles towards the south. The experiments were carried out at the same time periods between 11:00 and 15.00 of the days for 1.266 m/s, 1.5825m/s and 1.899 m/s of mass flow rates. The air flow through the collector was supplied by a radial fan and adjusted via a sliding valve located at the air inlet.

The experiments were carried out using three different mass flow rates and the sliding valve at the radial fan changed these rates. The velocity of the air was measured by an anemometer. The collectors were tested according to the ASHARE 93-86 standard. The incident solar radiation on collectors' inclined upper surface was measured with a HOBO pyranometer. Copper-Constantan thermocouples were placed at inlet and outlet flow channels of the collector. Temperature and solar radiation datum stored in a multifunctional data logger. The information about wind speed during the experiments, were kindly supplied by meteorology department in Manisa.

Figure 4.1. General Aspect of Experimental Setup

4.1. Parts of Experimental Setup

4.1.1. Air-Type Solar Collector

Air-type solar collector used in this project is designed to meet the regulations defined on ASHREA Standard 93-86 “Methods of Testing to Determine the Thermal Performance of Solar Collectors”. Basically our experimental setup consists of three main mechanical parts. First and the most important part is the collector itself. Second part is the inlet and outlet channels. Third part is the radial fan that provides air needed during experiments. Open-cell polyurethane foam that placed collector flow channel in order to increase heat transfer area is commercially used in HVAC applications as initial filter.

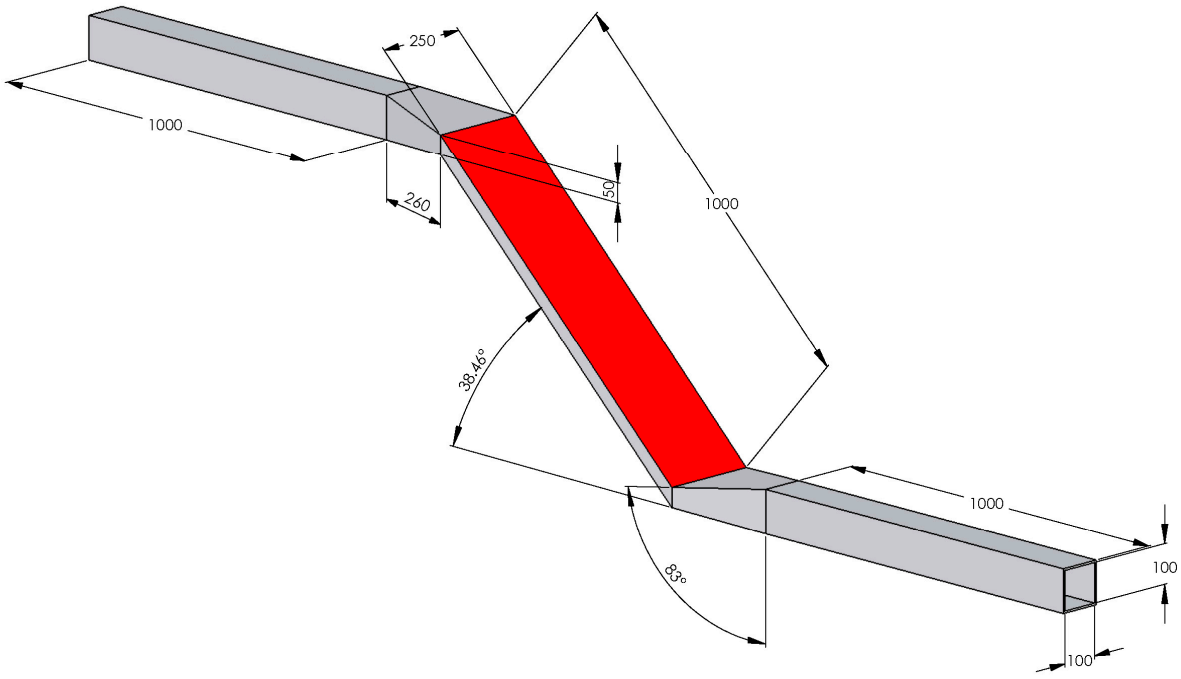


Figure 4.2. Technical Drawing of Experimental Setup

4.1.2. Radial Fan

Air needed for experiments is provided by a radial fan. An electrical motor drives the fan with a constant rational speed. Air speed can be varied by moving a sliding lid on the front side of the fan. This fan obtains 2820 revolutions per minute and has an energy consumption of 0.94 kW per hour. Maximum air speeds from 2 m/s to 6 m/s are measured by testing the radial fan, thus the range of air speed provided by fan is appropriate for our testing procedure.

Figure 4.3. Radial Fan

4.1.3. Open-Cell Polyurethane Foam

Open-cell polyurethane foam with a porosity of %85 was used as heat absorbing element. Porous disposition for increasing heat transfer surface area and black color for enhancing absorptivity of sun rays were the most effective factors in order to choose this material as heat absorbing element. This material can be found easily, because it is used as initial filter at HVAC applications. The polyurethane foam with this porosity has been chosen, because energy consumption of radial fan increases with bigger porosity ratios.

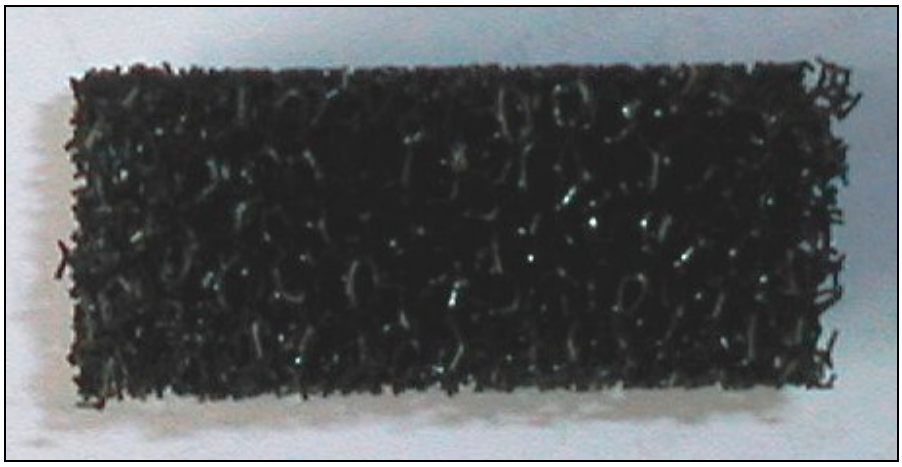


Figure 4.4. Open-Cell Polyurethane Foam

4.2. Measurement Equipment

4.2.1. Data Logging and Evaluating

In this study, ALHBORN – Almemo 2290-8 data logger is used to preserve temperature data (Figure 4.5). This data logger has five electrically measuring inputs with up to twenty measuring channels and two output sockets allow for connecting any Almemo output modules, printer or computer. Air inlet temperature, air outlet temperature and ambient temperature were measured with this data logger. All data have been measured every ten minutes in respect of the collector testing standard ASHRAE 93-1986.

Figure 4.5. ALHBORN / Almemo 2290-8 Data Logger

4.2.2. Temperature Measurements

Thermocouples and connectors (ZA 9020-FS NiCr-Ni), which are suitable for relevant temperature measurement range were used. Thermocouples have a range between -200 to 1370 ^{o}C and accuracy of ±(0.1 K ± %0.05 of measured value) (Ahlborn Manual). Data transfer from data logger to computer is realized by a RS232 interface.

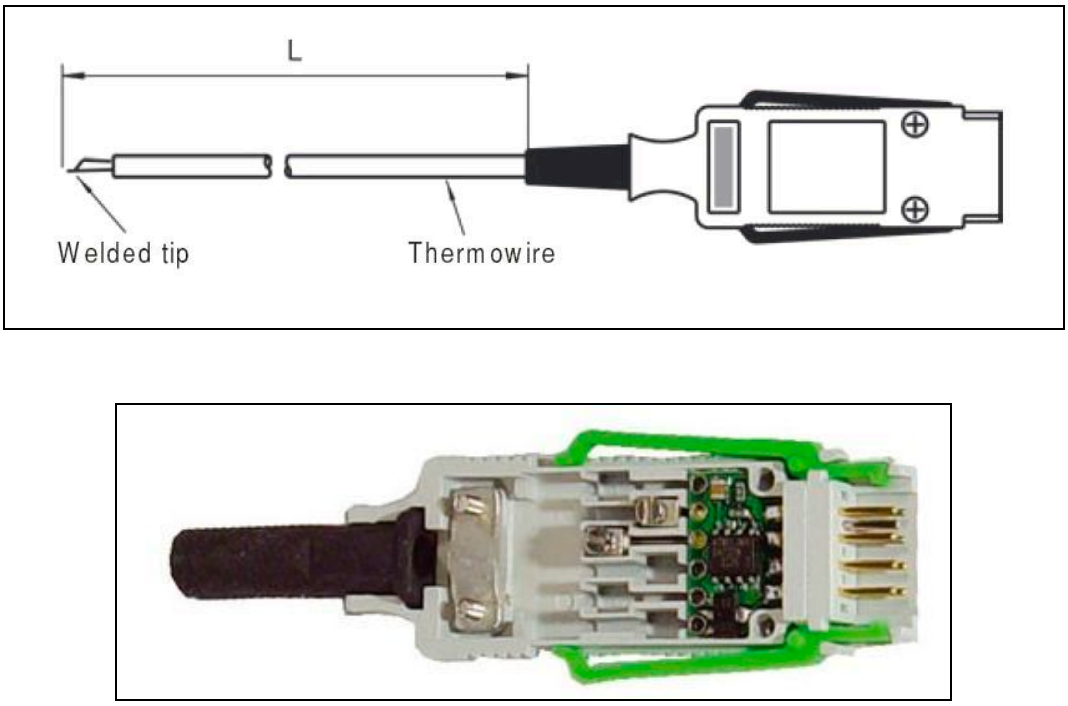


Figure 4.6. NiCr – Ni Thermocouple and Connector

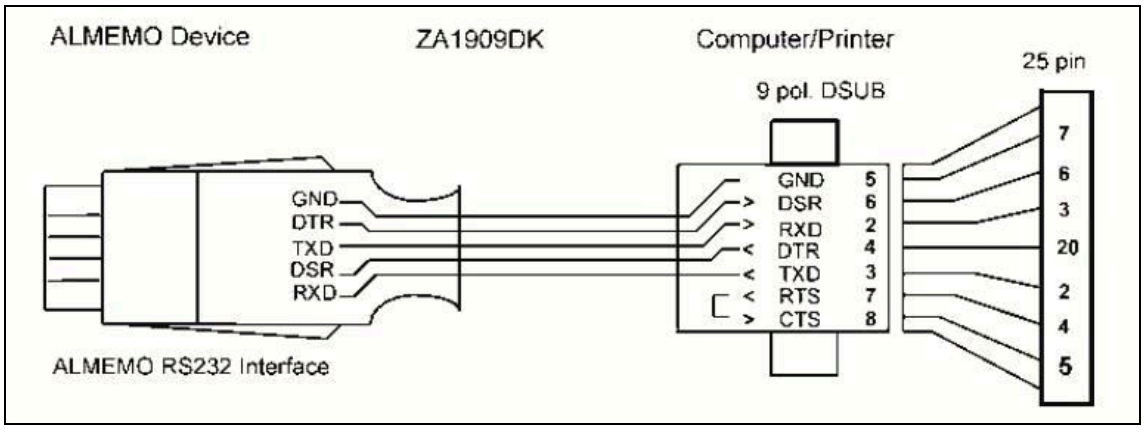


Figure 4.7. RS232 for Data Transfer

4.2.3. Flowmeter and Inlet Air Conditioning

In order to measure air speed, TESTO 401 V1 - anemometer was used (Figure 4.7). The anemometer has a range of 0 to 10m/s and accuracy of ±(0.1 m/s ± %0.05 of measured value) (Testo Manual), and this range was appropriate for our testing values. As well as it measures air velocity, the anemometer also measures temperature of air stream. Mass flow rate of air is calculated for each air speed value by considering the change of density for average air temperature.

In a flow channel with a square cross section area, maximum air speed is observed at midpoint. 2 m/s, 2.5 m/s and 3 m/s maximum air velocities have been measured and used at experiments. Correlation between maximum and average values of air speed at rectangular channel geometries has been reported by Purday (Purday 1949). At our experimental setup, maximum air stream velocity observed at the midpoint of the channel geometry has been measured and evaluated with the help of correlation below.

$$V_{av} = V_{max} \,.\, 0{,}6333 \qquad (4.1)$$

Thus average air velocities are calculated 1.266 m/s for 2 m/s, 1.5825 m/s for 2.5 m/s and 1.899 m/s for 3 m/s. These velocity values are being used at evaluation of experimental data.

Figure 4.7. TESTO 401 V1 - Anemometer

CHAPTER 5

RESULTS AND DISCUSSION

In this study, open-cell polyurethane foam with 85% porosity has been used as an absorbing element. Three different air speeds (1.266 m/s, 1.5825 m/s, 1.899 m/s) are being used on experimental investigation. At higher velocities, pressure loss increases relatively. 1.266 m/s of air velocity is the smallest value that can be obtained from the radial fan. Thus, we have chosen the smallest air velocities in order to overcome unwanted pressure drops.

When a comparison was made between different flow rates and with-without porous absorber, the days having approximately the same solar intensity were used. The radiation on inclined surface of the collector change in the range of 470.48 W/m^2 and 680.86 W/m^2 and it reaches maximum in the midday. In order to evaluate data, four zones have been established between these radiation values. Difference between the minimum and the maximum value of solar intensity on inclined surface is divided into four equal sections. Data at each zone have been evaluated separately in order to reach more accurate results.

- ✓ 1. ZONE 470.48 W/m^2 523.08 W/m^2
- ✓ 2. ZONE 523.08 W/m^2 575.67 W/m^2
- ✓ 3. ZONE 575.67 W/m^2 628.27 W/m^2
- ✓ 4. ZONE 628.27 W/m^2 680.86 W/m^2

Average values for efficiency, total solar intensity on collector area, inlet and outlet temperatures, and temperature difference between two edges of the collector are calculated in order to make a reliable comparison. Maximum and minimum values of these parameters are listed on Table 5.1.

Table 5.1. Maximum & Minimum Average Values on Experiments

Date	Average I_t (W/m^2)	Average Efficiency (η)	Average Temperature Difference	Average Ta (C^o)	Average Ti (C^o)	Average To (C^o)	Average V (m/s)	FULL/EMPTY	
9 August 2004	497.69	0.2637	7.36	23.08	25.08	32.44	1.899	EMPTY	Minimum Average ΔT
25 August 2004	680.20	0.3374	16.84	29.80	31.80	48.64	1.266	FULL	Maximum Average ΔT
20 July 2004	470.48	0.2433	7.73	24.15	26.15	33.88	1.5825	EMPTY	Minimum Average Efficiency
31 August 2004	640.47	0.3574	13.44	28.12	30.12	43.56	1.5825	FULL	Maximum Average Efficiency
20 July 2004	470.48	0.2433	7.73	24.15	26.15	33.88	1.5825	EMPTY	Minimum Average I_t
19 August 2004	680.86	0.3336	16.67	29.88	31.88	48.54	1.266	FULL	Maximum Average I_t
19 July 2004	476.21	0.2707	8.68	22.68	24.68	33.36	1.5825	EMPTY	Minimum Average Ti
19 August 2004	680.86	0.3336	16.67	29.88	31.88	48.54	1.266	FULL	Maximum Average Ti
9 August 2004	497.69	0.2637	7.36	23.08	25.08	32.44	1.899	EMPTY	Minimum Average To
25 August 2004	680.20	0.3374	16.84	29.80	31.80	48.64	1.266	FULL	Maximum Average To

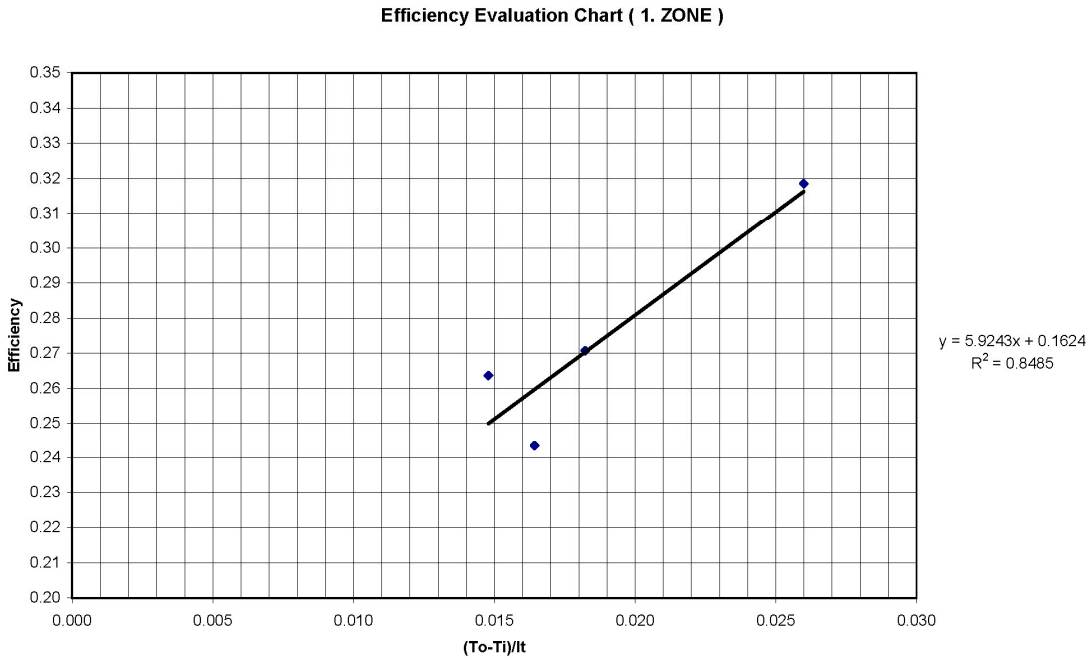
As known, the incident solar radiation is one of the most important parameters in the collector efficiency. We also know that increasing mass flow rate has a significant effect on collector efficiencies in the name of increment. As it is easily seen on the Table 5.1, we get maximum average ΔT is on 1.266 m/s and with open-cell polyurethane foam inside the collector. From the same table it seen that, minimum average ΔT we get is on 1.899 m/s and without foam in the collector. This behavior may be explained by longer constant times of air with the absorber surfaces inside the collector and visa versa. Maximum average efficiency is measured on 1.5825 m/s and with absorber in the collector. Evaluation of experimental data without classification of solar intensity on collector can be deceptive. For our investigation 1.Zone can not be taken into consideration, because data comes from these days are very irregular and not reliable. Increment of efficiency by rate of incident radiation level can be observed by charts (Figure 5.1. a, b, c, d).

Same evaluation for collector efficiencies is repeated for collectors' absorber characteristic. Charts on Figure 5.2 are drawn for collector efficiencies with and without open-cell polyurethane foam in flow channel. Slope of the line gives us the average collector efficiencies.

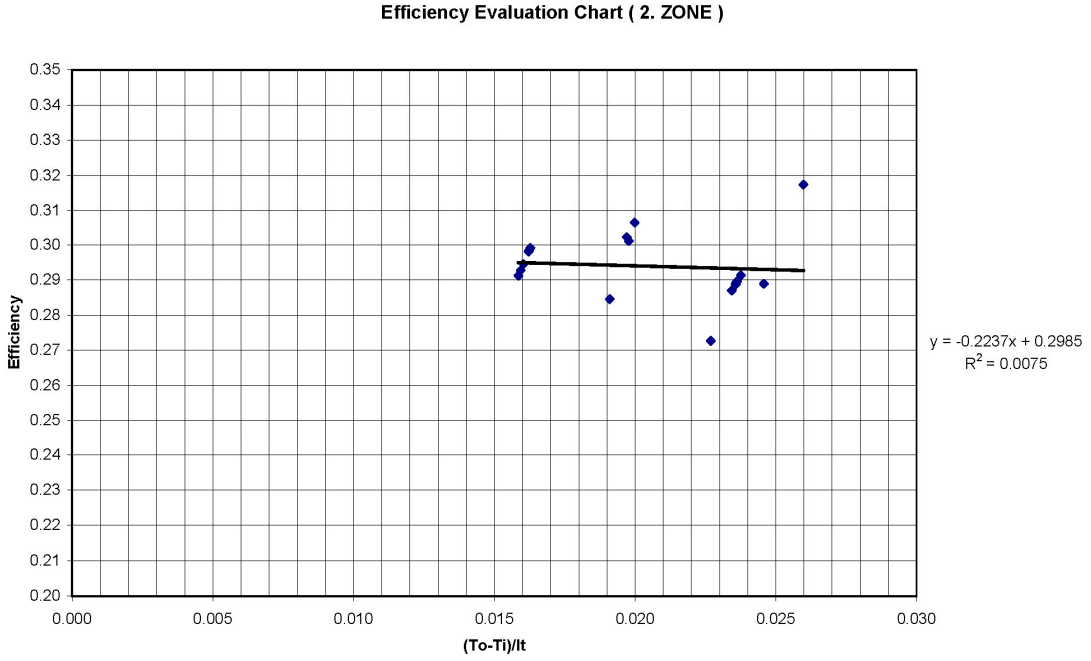
The average efficiencies and the average ΔT values versus average I_t for the same days are shown on Figure 5.3 and Figure 5.4 respectively. The zones denoted above can be seen on Figure 5.3, which the efficiencies of the collector under the same average incident radiation vary with the effect of air velocity and absorber characteristic. Average ΔT values for different air velocities can be easily seen on Figure 5.4 as imaginary inclined lines. Uppermost line represents the smallest air velocity 1.266 m/s, the one below it represents 1.5825 m/s and the lowest line represents 1.899 m/s. These results are similar with the ones reported in several studies at literature.

Table 5.2. Average Efficiency Values without Zone Segregation

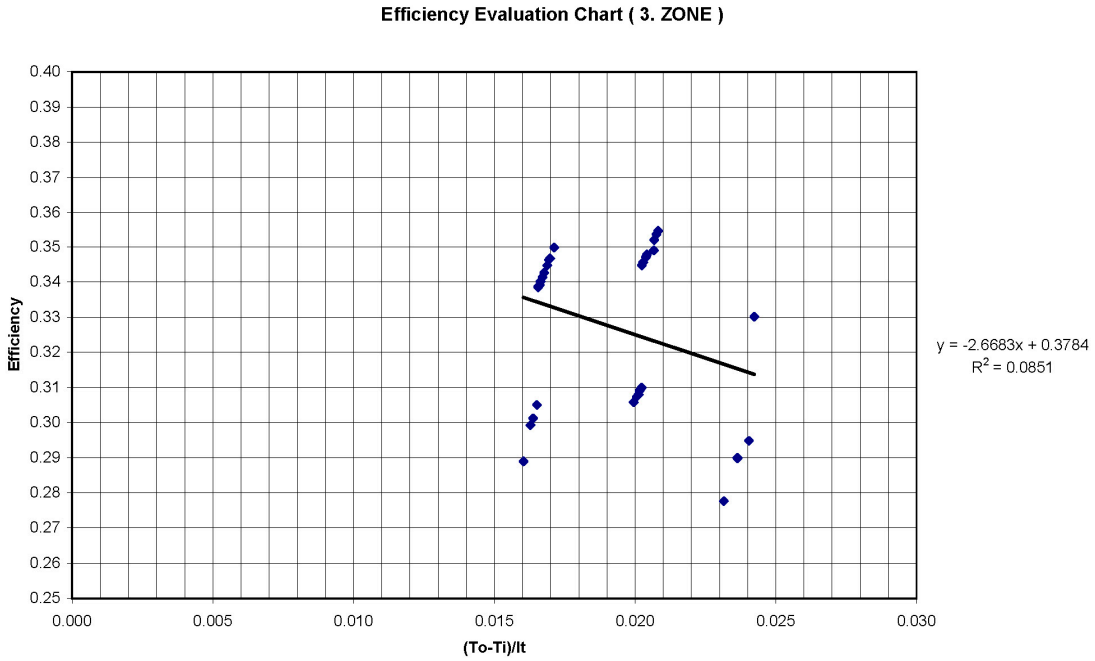
Average Efficiency	Without Zone Segregation
1.266 m/s EMPTY	0.2883
1.266 m/s FULL	0.3312
1.5825 m/s EMPTY	0.2965
1.5825 m/s FULL	0.3491
1.899 m/s EMPTY	0.2937
1.899 m/s FULL	0.3436


Efficiency Evaluation Chart (1. ZONE)
Efficiency
0.35
0.34
0.33
0.32
0.31
0.30
0.29
0.28
0.27
0.26
0.25
0.24
0.23
0.22
0.21
0.20
0.000
0.005
0.010
0.015
0.020
0.025
0.030
(To-Ti)/It
y = 5.9243x + 0.1624
R2 = 0.8485

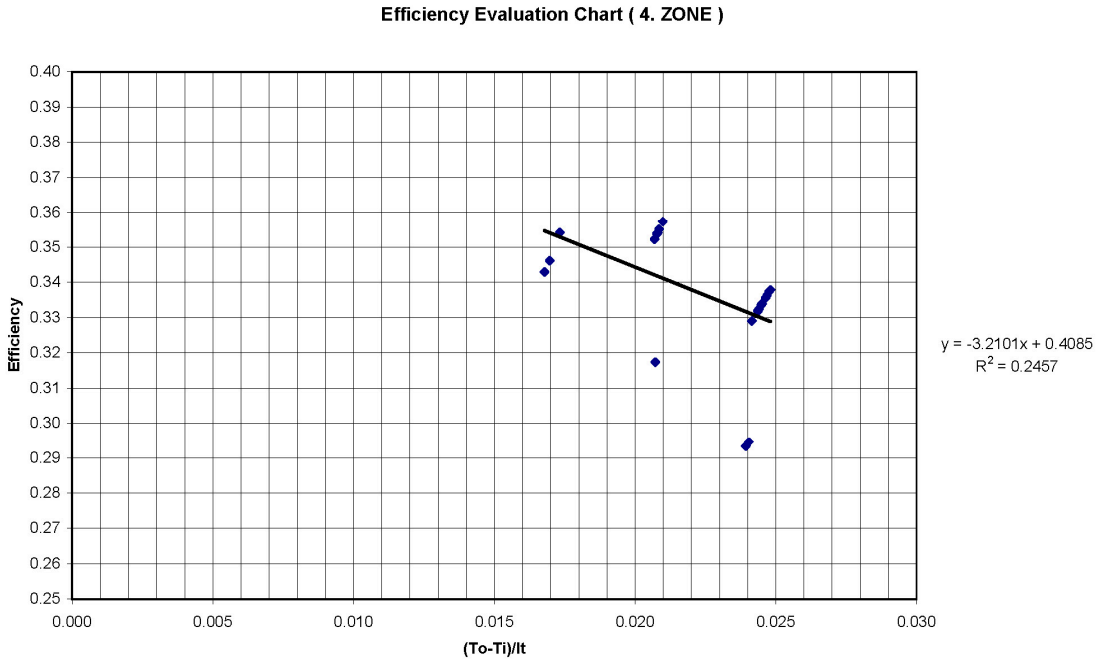
(a)


Efficiency Evaluation Chart (2. ZONE)
Efficiency
0.35
0.34
0.33
0.32
0.31
0.30
0.29
0.28
0.27
0.26
0.25
0.24
0.23
0.22
0.21
0.20
0.000
0.005
0.010
0.015
0.020
0.025
0.030
(To-Ti)/It
y = -0.2237x + 0.2985
R2 = 0.0075

(b)

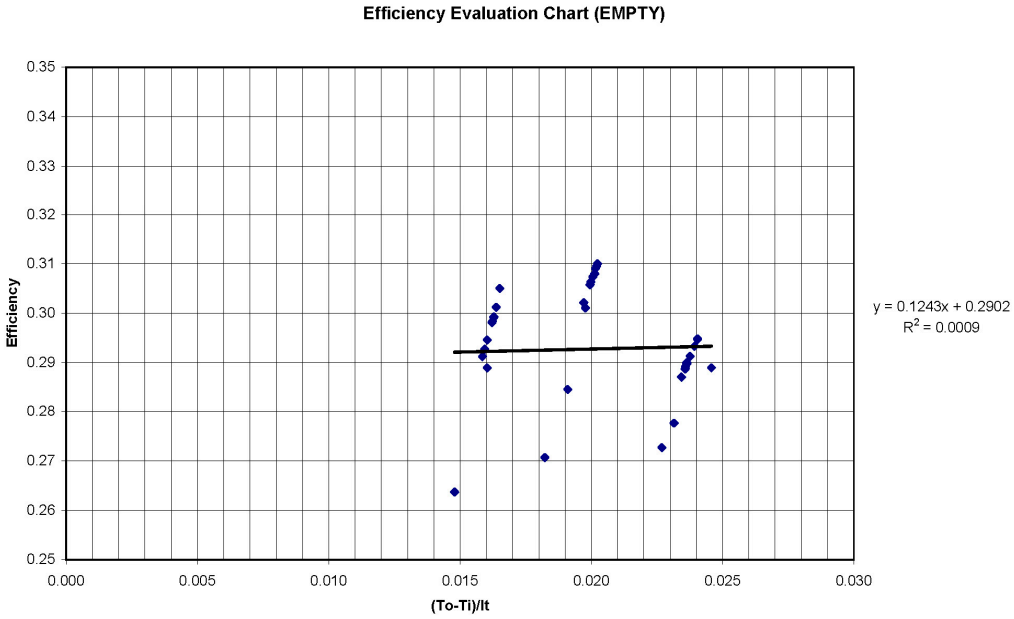


(c)

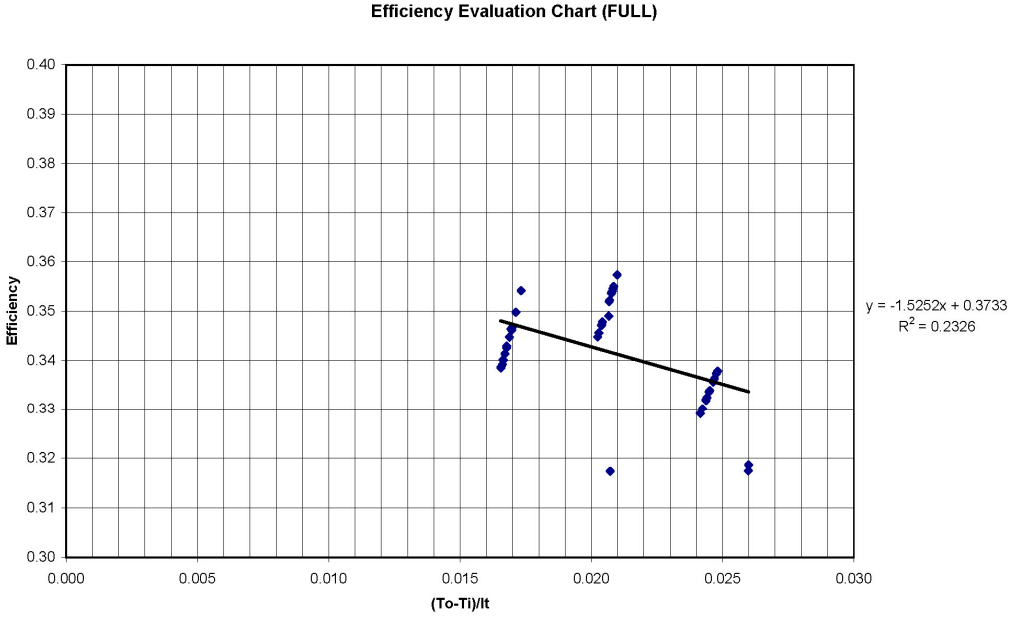


(d)

Figure 5.1. Efficiency Evaluation Charts a)1.Zone b)2.Zone c)3.Zone d)4.Zone



(a)



(b)

Figure 5.2. Efficiency Evaluation Charts for Absorber Characteristic

Table 5.3. Average Efficiency Values According to Zone Segregation

Average Efficiency	2.ZONE	3.ZONE	4.ZONE
1.266 m/s EMPTY	0.2867	0.2881	0.2940
1.266 m/s FULL	0.3174	0.3301	0.3340
1.5825 m/s EMPTY	0.2985	0.3083	-
1.5825 m/s FULL	-	0.3491	0.3491
1.899 m/s EMPTY	0.2952	0.2986	-
1.899 m/s FULL	-	0.3426	0.3542

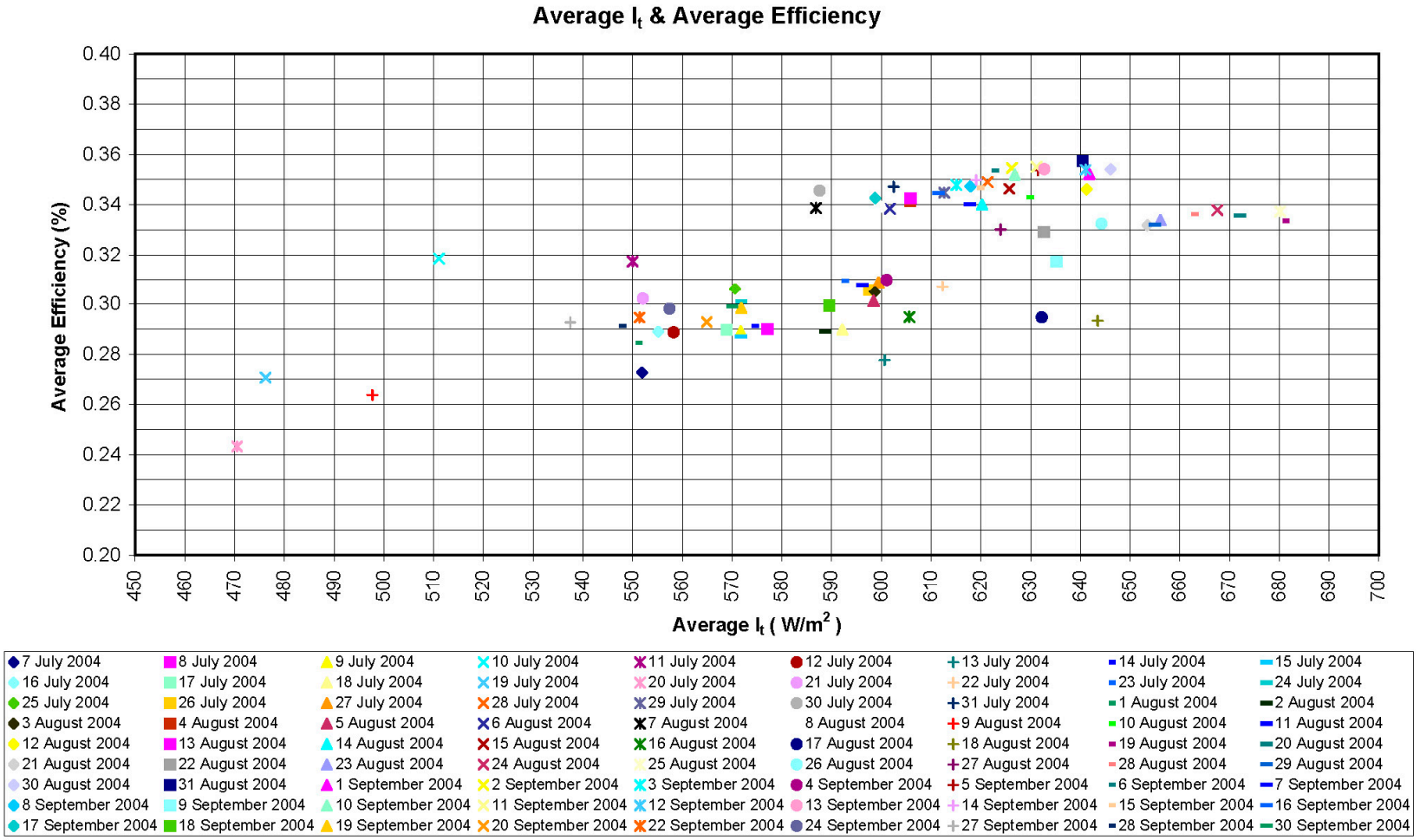


Figure 5.3. Graph of Average I_t versus Average Efficiency

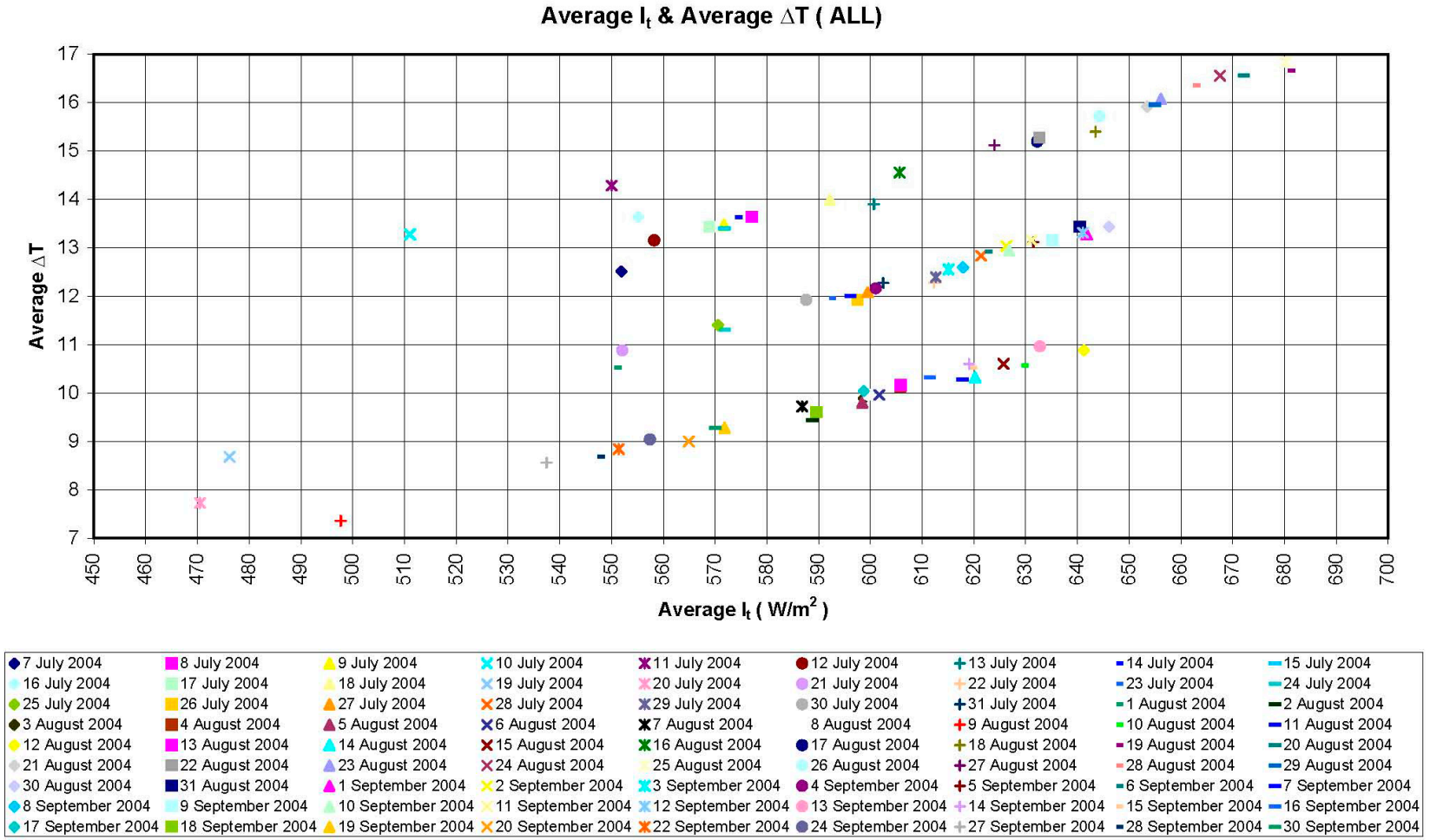


Figure 5.4. Graph of Average I_t versus Average ΔT

CHAPTER 6

CONCLUSIONS

From the interpretation of experimental data, we can classify our results in three groups. First, as it is expected, efficiency of an air-type solar collector increases with the increment of air velocity. But on the other hand, pressure drop and energy consumption of the system increases too. At higher air velocities, one of the most important disadvantages of air collectors comes out. Leakage out of acceptable limits can be very negative for collector efficiency. Second, open-cell polyurethane foam which placed into the collector as heat absorbing element has a positive effect on collector efficiency. On Table 6.1, the increment of efficiency due to foam placing can be observed easily. At some conditions we can not declare any opinion, because zone segregation has been formed for data evaluation, after all experiments completed. But especially for air velocity 1.266 m/s, augmentation of efficiency is very clear. When we compare with collector without polyurethane foam, for an air velocity of 1.266 m/s, increment of collector efficiency is 3.07 % at 2.zone, 4.2 % at 3.zone m/s and 4 % at 4.zone. The most important result that we obtained from the experiments is also seen on Table 6.2. Air type solar collector, used in this study is most efficient when it is operated at 1.899 m/s and open-cell polyurethane foam in collector. At the same chart it is seen that the worse efficiency is at 1.266 m/s and without absorbing material in collector.

Table 6.1. % of Efficiency Increments According to Zone Segregation

% Incerement	**2.ZONE**	**3.ZONE**	**4.ZONE**
1.266 m/s EMPTY	0.2867	0.2881	0.2940
1.266 m/s FULL	0.3174	0.3301	0.3340
% Change	**3.07**	**4.20**	**4.00**
1.5825 m/s EMPTY	0.2985	0.3083	-
1.5825 m/s FULL	-	0.3491	0.3491
% Change	**N/A**	**4.08**	**N/A**
1.899 m/s EMPTY	0.2952	0.2986	-
1.899 m/s FULL	-	0.3426	0.3542
% Change	**N/A**	**4.39**	**N/A**

The last comparison criterion is the temperature difference of process air between inlet ant outlet flow channels of the collector setup. The results are similar with other studies on literature. Lower the air velocity, higher the temperature difference and vice versa. This principle does not change when we place foam in the collector. We have seen that temperature difference increases with the foam in the collector. We have observed highest temperature difference, when the collector operates at 1.266 m/s and with foam in it. We also observed the lowest temperature difference, when the collector operates at 1.899 m/s and without foam placement.

Table 6.2. % of Temperature Differences According to Zone Segregation

Average ΔT	2.ZONE	3.ZONE	4.ZONE
1.266 m/s EMPTY	13.33	14.03	15.30
1.266 m/s FULL	14.29	15.12	16.19
% Change	**7.23**	**7.80**	**5.85**
1.5825 m/s EMPTY	11.03	12.07	-
1.5825 m/s FULL	-	12.61	13.27
% Change	**N/A**	**4.53**	**N/A**
1.899 m/s EMPTY	8.95	9.68	-
1.899 m/s FULL	-	10.22	10.96
% Change	**N/A**	**5.53**	**N/A**

After all results examined, it is obvious that open-cell polyurethane foam placed in an air-type solar collector, has a positive effect on collector efficiency. The question is that, we really want more efficient collectors or higher temperature differences? The answer of the question changes with the application, which collector will be used. First of all, the operating temperature range and air velocity should be determined.

The most difficult part of this investigation was evaluating raw experimental data. Finally zone approach is used in order to segregate data for reliable results. Four zones have been established, but this number can be increased for more accuracy. At literature, these kind of experimental studies on solar collector efficiencies are handled by at least two or more equal collectors. On future another collector can be settled up in order to confirm the results of this study. The open-cell polyurethane foam used in this study can be easily found commercially on market. But there is no other kind of foam available with much porosity for now. This study can be repeated with foams at different porosities, which has porosity much more than we have used.

Although the collector area is relatively smaller than reported ones, we think that data we get from the experiments will be useful for investigators work on this subject.

Finally it is necessary to declare that; if the relevant collector is integrated into a system, energy consumption of the fan has to be taken into consideration on overall energy balance.

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APPENDIX A

AVERAGE VALUES OF EXPERIMENTAL DATA

Table A.1. Average Data for July

Date	Average I_t (W/m^2)	Average Efficiency (η)	Average Temperature Difference	Average T_a (C^o)	Average T_i (C^o)	Average T_o (C^o)	V (m/s)	FULL/EMPTY	ZONE
7 July 2004	551.90	0.2727	12.52	24.88	26.88	39.40	1.266	EMPTY	2.ZONE
8 July 2004	577.12	0.2900	13.64	25.60	27.60	41.24	1.266	EMPTY	3.ZONE
9 July 2004	571.74	0.2891	13.48	25.28	27.28	40.76	1.266	EMPTY	2.ZONE
10 July 2004	511.06	0.3186	13.28	27.40	29.40	42.68	1.266	FULL	1.ZONE
11 July 2004	550.02	0.3175	14.29	25.03	27.03	41.32	1.266	FULL	2.ZONE
12 July 2004	558.24	0.2887	13.16	24.76	26.76	39.92	1.266	EMPTY	2.ZONE
13 July 2004	600.66	0.2776	13.91	27.64	29.64	43.54	1.266	EMPTY	3.ZONE
14 July 2004	574.14	0.2913	13.64	25.44	27.44	41.08	1.266	EMPTY	2.ZONE
15 July 2004	571.81	0.2870	13.40	25.36	27.36	40.76	1.266	EMPTY	2.ZONE
16 July 2004	555.13	0.2890	13.64	26.64	28.64	42.28	1.266	EMPTY	2.ZONE
17 July 2004	568.90	0.2897	13.44	25.24	27.24	40.68	1.266	EMPTY	2.ZONE
18 July 2004	592.16	0.2898	14.00	26.32	28.32	42.32	1.266	EMPTY	3.ZONE
19 July 2004	476.21	0.2707	8.68	22.68	24.68	33.36	1.5825	EMPTY	1.ZONE
20 July 2004	470.48	0.2433	7.73	24.15	26.15	33.88	1.5825	EMPTY	1.ZONE
21 July 2004	552.06	0.3022	10.88	24.52	26.52	37.40	1.5825	EMPTY	2.ZONE
22 July 2004	612.32	0.3073	12.28	27.20	29.20	41.48	1.5825	EMPTY	3.ZONE
23 July 2004	592.22	0.3096	11.96	26.20	28.20	40.16	1.5825	EMPTY	3.ZONE
24 July 2004	571.82	0.3011	11.31	25.94	27.94	39.25	1.5825	EMPTY	2.ZONE
25 July 2004	570.56	0.3063	11.40	25.16	27.16	38.56	1.5825	EMPTY	2.ZONE
26 July 2004	597.54	0.3058	11.92	26.60	28.60	40.52	1.5825	EMPTY	3.ZONE
27 July 2004	599.46	0.3090	12.08	26.60	28.60	40.68	1.5825	EMPTY	3.ZONE
28 July 2004	621.37	0.3490	12.84	27.80	29.80	42.64	1.5825	FULL	3.ZONE
29 July 2004	612.64	0.3448	12.40	27.12	29.12	41.52	1.5825	FULL	3.ZONE
30 July 2004	587.58	0.3456	11.92	26.00	28.00	39.92	1.5825	FULL	3.ZONE
31 July 2004	602.50	0.3471	12.28	26.72	28.72	41.00	1.5825	FULL	3.ZONE

Table A.2. Average Data for July

Date	Average I_t (W/m^2)	Average Efficiency (η)	Average Temperature Difference	Average T_a (C^o)	Average T_i (C^o)	Average T_o (C^o)	V (m/s)	FULL/EMPTY	ZONE
1 August 2004	550.80	0.2846	10.52	25.28	27.28	37.80	1.5825	EMPTY	2.ZONE
2 August 2004	588.77	0.2889	9.44	27.00	29.00	38.44	1.899	EMPTY	3.ZONE
3 August 2004	598.71	0.3051	9.88	26.58	28.58	38.46	1.899	EMPTY	3.ZONE
4 August 2004	605.82	0.3413	10.12	26.88	28.88	39.00	1.899	FULL	3.ZONE
5 August 2004	598.43	0.3012	9.80	26.60	28.60	38.40	1.899	EMPTY	3.ZONE
6 August 2004	601.70	0.3385	9.96	26.76	28.76	38.72	1.899	FULL	3.ZONE
7 August 2004	586.85	0.3387	9.72	26.00	28.00	37.72	1.899	FULL	3.ZONE
8 August 2004	599.68	0.3392	9.96	26.56	28.56	38.52	1.899	FULL	3.ZONE
9 August 2004	497.69	0.2637	7.36	23.08	25.08	32.44	1.899	EMPTY	1.ZONE
10 August 2004	629.41	0.3429	10.56	27.84	29.84	40.40	1.899	FULL	4.ZONE
11 August 2004	617.76	0.3401	10.28	27.40	29.40	39.68	1.899	FULL	3.ZONE
12 August 2004	641.26	0.3461	10.88	28.28	30.28	41.16	1.899	FULL	4.ZONE
13 August 2004	605.86	0.3426	10.16	26.80	28.80	38.96	1.899	FULL	3.ZONE
14 August 2004	620.26	0.3401	10.32	27.52	29.52	39.84	1.899	FULL	3.ZONE
15 August 2004	625.73	0.3463	10.60	27.64	29.64	40.24	1.899	FULL	3.ZONE
16 August 2004	605.63	0.2948	14.56	26.72	28.72	43.28	1.266	EMPTY	3.ZONE
17 August 2004	632.26	0.2947	15.20	28.00	30.00	45.20	1.266	EMPTY	4.ZONE
18 August 2004	643.48	0.2933	15.40	28.60	30.60	46.00	1.266	EMPTY	4.ZONE
19 August 2004	680.86	0.3336	16.67	29.88	31.88	48.54	1.266	FULL	4.ZONE
20 August 2004	672.14	0.3356	16.56	29.44	31.44	48.00	1.266	FULL	4.ZONE
21 August 2004	653.46	0.3318	15.92	28.76	30.76	46.68	1.266	FULL	4.ZONE
22 August 2004	632.66	0.3291	15.28	27.80	29.80	45.08	1.266	FULL	4.ZONE
23 August 2004	656.13	0.3339	16.08	28.84	30.84	46.92	1.266	FULL	4.ZONE
24 August 2004	667.56	0.3379	16.56	29.16	31.16	47.72	1.266	FULL	4.ZONE
25 August 2004	680.20	0.3374	16.84	29.80	31.80	48.64	1.266	FULL	4.ZONE
26 August 2004	644.25	0.3324	15.72	28.32	30.32	46.04	1.266	FULL	4.ZONE
27 August 2004	623.96	0.3301	15.12	27.56	29.56	44.68	1.266	FULL	3.ZONE
28 August 2004	662.55	0.3363	16.36	29.00	31.00	47.36	1.266	FULL	4.ZONE
29 August 2004	654.99	0.3320	15.96	28.76	30.76	46.72	1.266	FULL	4.ZONE
30 August 2004	646.09	0.3541	13.44	28.40	30.40	43.84	1.5825	FULL	4.ZONE
31 August 2004	640.47	0.3574	13.44	28.12	30.12	43.56	1.5825	FULL	4.ZONE

Table A.3. Average Data for September

Date	Average I_t (W/m^2)	Average Efficiency (η)	Average Temperature Difference	Average T_a (C^o)	Average T_i (C^o)	Average T_o (C^o)	V (m/s)	FULL/EMPTY	ZONE
1 September 2004	641.81	0.3522	13.28	28.20	30.20	43.48	1.5825	FULL	4.ZONE
2 September 2004	626.24	0.3546	13.04	27.52	29.52	42.56	1.5825	FULL	3.ZONE
3 September 2004	615.10	0.3479	12.56	27.16	29.16	41.72	1.5825	FULL	3.ZONE
4 September 2004	601.06	0.3100	12.16	26.56	28.56	40.72	1.5825	EMPTY	3.ZONE
5 September 2004	631.48	0.3538	13.12	27.72	29.72	42.84	1.5825	FULL	4.ZONE
6 September 2004	622.43	0.3536	12.92	27.40	29.40	42.32	1.5825	FULL	3.ZONE
7 September 2004	596.17	0.3080	12.00	26.52	28.52	40.52	1.5825	EMPTY	3.ZONE
8 September 2004	617.89	0.3473	12.60	27.32	29.32	41.92	1.5825	FULL	3.ZONE
9 September 2004	635.20	0.3174	13.16	27.88	29.88	43.04	1.5825	FULL	4.ZONE
10 September 2004	626.82	0.3520	12.96	27.56	29.56	42.52	1.5825	FULL	3.ZONE
11 September 2004	631.20	0.3551	13.16	27.68	29.68	42.84	1.5825	FULL	4.ZONE
12 September 2004	641.08	0.3539	13.32	28.20	30.20	43.52	1.5825	FULL	4.ZONE
13 September 2004	632.75	0.3542	10.96	27.76	29.76	40.72	1.899	FULL	4.ZONE
14 September 2004	619.07	0.3498	10.60	27.36	29.36	39.96	1.899	FULL	3.ZONE
15 September 2004	619.51	0.3467	10.52	27.36	29.36	39.88	1.899	FULL	3.ZONE
16 September 2004	611.48	0.3447	10.32	27.00	29.00	39.32	1.899	FULL	3.ZONE
17 September 2004	598.74	0.3427	10.04	26.48	28.48	38.52	1.899	FULL	3.ZONE
18 September 2004	589.56	0.2993	9.60	26.24	28.24	37.84	1.899	EMPTY	3.ZONE
19 September 2004	571.84	0.2984	9.28	25.48	27.48	36.76	1.899	EMPTY	2.ZONE
20 September 2004	564.92	0.2927	9.00	25.24	27.24	36.24	1.899	EMPTY	2.ZONE
22 September 2004	551.39	0.2946	8.84	24.56	26.56	35.40	1.899	EMPTY	2.ZONE
24 September 2004	557.42	0.2981	9.04	24.80	26.80	35.84	1.899	EMPTY	2.ZONE
27 September 2004	537.47	0.2927	8.56	24.00	26.00	34.56	1.899	EMPTY	2.ZONE
28 September 2004	547.54	0.2912	8.68	24.56	26.56	35.24	1.899	EMPTY	2.ZONE
30 September 2004	570.03	0.2991	9.28	25.48	27.48	36.76	1.899	EMPTY	2.ZONE

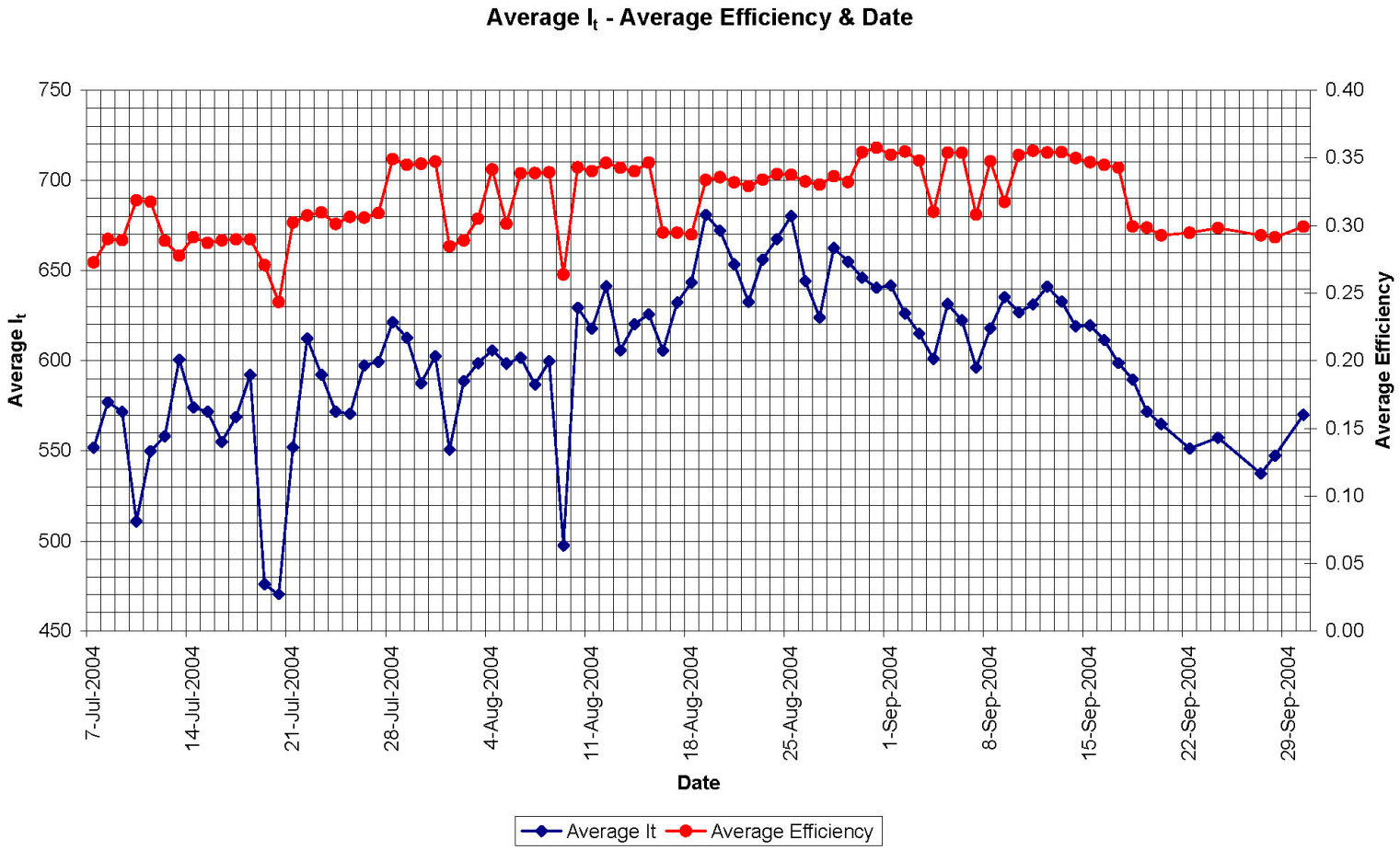

Figure A.1. Average It & Efficiency versus Experiment Days

APPENDIX B

MEASURED & CALCULATED DATA FOR JULY

Table B.1. Measured and Calculated Data for 07/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	-	07/07/2004	11:00	392.26	98	28	20	22	6	18.40	0.188
1.266	-	07/07/2004	11:10	363.00	91	28	20	22	6	18.40	0.203
1.266	-	07/07/2004	11:20	353.00	88	26	20	22	4	12.27	0.139
1.266	-	07/07/2004	11:30	445.25	111	33	21	23	10	30.05	0.270
1.266	-	07/07/2004	11:40	558.72	140	40	24	26	14	42.94	0.307
1.266	-	07/07/2004	11:50	418.32	105	33	20	22	11	33.74	0.323
1.266	-	07/07/2004	12:00	571.68	143	41	25	27	14	42.32	0.296
1.266	-	07/07/2004	12:10	576.72	144	41	25	27	14	42.32	0.294
1.266	-	07/07/2004	12:20	550.80	138	39	24	26	13	40.48	0.294
1.266	-	07/07/2004	12:30	635.76	159	45	28	30	15	45.39	0.286
1.266	-	07/07/2004	12:40	670.32	168	46	29	31	15	47.23	0.282
1.266	-	07/07/2004	12:50	635.04	159	45	28	30	15	45.39	0.286
1.266	-	07/07/2004	13:00	666.00	167	46	29	31	15	47.23	0.284
1.266	-	07/07/2004	13:10	694.80	174	48	31	33	15	46.00	0.265
1.266	-	07/07/2004	13:20	648.00	162	46	28	30	16	47.84	0.295
1.266	-	07/07/2004	13:30	648.00	162	46	28	30	16	47.84	0.295
1.266	-	07/07/2004	13:40	707.76	177	49	31	33	16	48.46	0.274
1.266	-	07/07/2004	13:50	687.60	172	48	30	32	16	49.07	0.285
1.266	-	07/07/2004	14:00	631.44	158	44	28	30	14	42.94	0.272
1.266	-	07/07/2004	14:10	563.04	141	40	24	26	14	42.94	0.305
1.266	-	07/07/2004	14:20	573.84	143	41	25	27	14	42.32	0.295
1.266	-	07/07/2004	14:30	440.64	110	33	20	22	11	34.96	0.317
1.266	-	07/07/2004	14:40	504.72	126	36	21	23	13	39.87	0.316
1.266	-	07/07/2004	14:50	514.08	129	37	22	24	13	39.26	0.305
1.266	-	07/07/2004	15:00	346.75	87	27	21	23	4	12.27	0.142

Table B.2. Measured and Calculated Data for 08/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	-	08/07/2004	11:00	504.00	126	36	22	24	12	36.80	0.292
1.266	-	08/07/2004	11:10	520.00	130	37	23	25	12	36.80	0.283
1.266	-	08/07/2004	11:20	530.40	133	38	23	25	13	39.87	0.301
1.266	-	08/07/2004	11:30	545.60	136	39	24	26	13	39.87	0.292
1.266	-	08/07/2004	11:40	557.60	139	40	25	27	13	39.87	0.286
1.266	-	08/07/2004	11:50	567.20	142	41	25	27	14	42.94	0.303
1.266	-	08/07/2004	12:00	576.00	144	41	26	28	13	39.87	0.277
1.266	-	08/07/2004	12:10	581.60	145	42	26	28	14	42.94	0.295
1.266	-	08/07/2004	12:20	588.00	147	42	26	28	14	42.94	0.292
1.266	-	08/07/2004	12:30	593.60	148	42	26	28	14	42.94	0.289
1.266	-	08/07/2004	12:40	599.20	150	43	27	29	14	42.94	0.287
1.266	-	08/07/2004	12:50	600.80	150	43	27	29	14	42.94	0.286
1.266	-	08/07/2004	13:00	606.40	152	43	27	29	14	42.94	0.283
1.266	-	08/07/2004	13:10	609.60	152	44	27	29	15	46.00	0.302
1.266	-	08/07/2004	13:20	608.80	152	43	27	29	14	42.94	0.282
1.266	-	08/07/2004	13:30	605.60	151	43	27	29	14	42.94	0.284
1.266	-	08/07/2004	13:40	604.00	151	43	27	29	14	42.94	0.284
1.266	-	08/07/2004	13:50	600.80	150	43	27	29	14	42.94	0.286
1.266	-	08/07/2004	14:00	596.00	149	43	26	28	15	46.00	0.309
1.266	-	08/07/2004	14:10	594.40	149	42	26	28	14	42.94	0.289
1.266	-	08/07/2004	14:20	586.40	147	42	26	28	14	42.94	0.293
1.266	-	08/07/2004	14:30	577.60	144	41	26	28	13	39.87	0.276
1.266	-	08/07/2004	14:40	569.60	142	41	25	27	14	42.94	0.302
1.266	-	08/07/2004	14:50	556.80	139	40	25	27	13	39.87	0.286
1.266	-	08/07/2004	15:00	548.00	137	39	24	26	13	39.87	0.291

Table B.3. Measured and Calculated Data for 09/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	-	09/07/2004	11:00	494.40	124	35	22	24	11	33.74	0.273
1.266	-	09/07/2004	11:10	506.40	127	36	22	24	12	36.80	0.291
1.266	-	09/07/2004	11:20	519.20	130	37	23	25	12	36.80	0.284
1.266	-	09/07/2004	11:30	531.20	133	38	24	26	12	36.80	0.277
1.266	-	09/07/2004	11:40	540.00	135	39	24	26	13	39.87	0.295
1.266	-	09/07/2004	11:50	549.60	137	39	24	26	13	39.87	0.290
1.266	-	09/07/2004	12:00	559.20	140	40	25	27	13	39.87	0.285
1.266	-	09/07/2004	12:10	566.40	142	40	25	27	13	39.87	0.282
1.266	-	09/07/2004	12:20	573.60	143	41	25	27	14	42.94	0.299
1.266	-	09/07/2004	12:30	582.40	146	42	26	28	14	42.94	0.295
1.266	-	09/07/2004	12:40	590.40	148	42	26	28	14	42.94	0.291
1.266	-	09/07/2004	12:50	601.60	150	43	27	29	14	42.94	0.285
1.266	-	09/07/2004	13:00	605.60	151	43	27	29	14	42.94	0.284
1.266	-	09/07/2004	13:10	612.80	153	44	27	29	15	46.00	0.300
1.266	-	09/07/2004	13:20	650.40	163	46	29	31	15	46.00	0.283
1.266	-	09/07/2004	13:30	628.80	157	45	28	30	15	46.00	0.293
1.266	-	09/07/2004	13:40	620.00	155	44	27	29	15	46.00	0.297
1.266	-	09/07/2004	13:50	608.00	152	43	27	29	14	42.94	0.282
1.266	-	09/07/2004	14:00	594.40	149	42	26	28	14	42.94	0.289
1.266	-	09/07/2004	14:10	593.60	148	42	26	28	14	42.94	0.289
1.266	-	09/07/2004	14:20	584.80	146	42	26	28	14	42.94	0.294
1.266	-	09/07/2004	14:30	571.20	143	41	25	27	14	42.94	0.301
1.266	-	09/07/2004	14:40	551.20	138	39	24	26	13	39.87	0.289
1.266	-	09/07/2004	14:50	539.20	135	39	24	26	13	39.87	0.296
1.266	-	09/07/2004	15:00	519.20	130	37	23	25	12	36.80	0.284

Table B.4. Measured and Calculated Data for 10/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	-	10/07/2004	11:00	498.80	125	42	27	29	13	39.87	0.320
1.266	-	10/07/2004	11:10	541.20	135	45	29	31	14	42.94	0.317
1.266	-	10/07/2004	11:20	585.20	146	48	31	33	15	46.00	0.314
1.266	-	10/07/2004	11:30	589.20	147	48	31	33	15	46.00	0.312
1.266	-	10/07/2004	11:40	602.00	151	49	31	33	16	49.07	0.326
1.266	-	10/07/2004	11:50	537.20	134	45	29	31	14	42.94	0.320
1.266	-	10/07/2004	12:00	548.40	137	45	29	31	14	42.94	0.313
1.266	-	10/07/2004	12:10	581.20	145	48	31	33	15	46.00	0.317
1.266	-	10/07/2004	12:20	538.00	135	45	29	31	14	42.94	0.319
1.266	-	10/07/2004	12:30	533.20	133	44	28	30	14	42.94	0.322
1.266	-	10/07/2004	12:40	500.40	125	42	27	29	13	39.87	0.319
1.266	-	10/07/2004	12:50	439.60	110	37	24	26	11	33.74	0.307
1.266	-	10/07/2004	13:00	442.00	111	37	24	26	11	33.74	0.305
1.266	-	10/07/2004	13:10	487.60	122	41	26	28	13	39.87	0.327
1.266	-	10/07/2004	13:20	468.40	117	40	26	28	12	36.80	0.314
1.266	-	10/07/2004	13:30	489.20	122	41	26	28	13	39.87	0.326
1.266	-	10/07/2004	13:40	554.00	139	46	29	31	15	46.00	0.332
1.266	-	10/07/2004	13:50	503.60	126	42	27	29	13	39.87	0.317
1.266	-	10/07/2004	14:00	511.60	128	42	27	29	13	39.87	0.312
1.266	-	10/07/2004	14:10	484.40	121	41	26	28	13	39.87	0.329
1.266	-	10/07/2004	14:20	503.60	126	42	27	29	13	39.87	0.317
1.266	-	10/07/2004	14:30	529.20	132	44	28	30	14	42.94	0.325
1.266	-	10/07/2004	14:40	453.20	113	39	25	27	12	36.80	0.325
1.266	-	10/07/2004	14:50	453.20	113	39	25	27	12	36.80	0.325
1.266	-	10/07/2004	15:00	402.00	101	35	23	25	10	30.67	0.305

Table B.5. Measured and Calculated Data for 11/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	-	11/07/2004	11:00	372.30	93	30	20	22	8	24.53	0.264
1.266	-	11/07/2004	11:10	445.90	111	34	20	22	12	36.80	0.330
1.266	-	11/07/2004	11:20	529.50	132	40	24	26	14	43.70	0.330
1.266	-	11/07/2004	11:30	550.80	138	41	25	27	14	42.94	0.312
1.266	-	11/07/2004	11:40	648.40	162	48	29	31	17	52.14	0.322
1.266	-	11/07/2004	11:50	700.40	175	53	32	34	19	58.27	0.333
1.266	-	11/07/2004	12:00	590.80	148	44	27	29	15	46.00	0.311
1.266	-	11/07/2004	12:10	606.00	152	45	27	29	16	49.07	0.324
1.266	-	11/07/2004	12:20	500.40	125	38	23	25	13	39.87	0.319
1.266	-	11/07/2004	12:30	575.60	144	43	26	28	15	46.00	0.320
1.266	-	11/07/2004	12:40	647.60	162	48	29	31	17	52.14	0.322
1.266	-	11/07/2004	12:50	598.80	150	45	27	29	16	49.07	0.328
1.266	-	11/07/2004	13:00	442.00	111	33	20	22	11	33.74	0.305
1.266	-	11/07/2004	13:10	598.64	150	45	27	29	16	49.07	0.328
1.266	-	11/07/2004	13:20	564.08	141	42	25	27	15	46.00	0.326
1.266	-	11/07/2004	13:30	596.08	149	45	27	29	16	49.07	0.329
1.266	-	11/07/2004	13:40	534.64	134	40	24	26	14	42.94	0.321
1.266	-	11/07/2004	13:50	415.60	104	32	20	22	10	30.67	0.295
1.266	-	11/07/2004	14:00	510.80	128	38	23	25	13	39.87	0.312
1.266	-	11/07/2004	14:10	500.40	125	38	23	25	13	39.87	0.319
1.266	-	11/07/2004	14:20	539.76	135	40	24	26	14	42.94	0.318
1.266	-	11/07/2004	14:30	611.44	153	46	28	30	16	49.07	0.321
1.266	-	11/07/2004	14:40	590.96	148	44	27	29	15	46.00	0.311
1.266	-	11/07/2004	14:50	543.60	136	41	25	27	14	42.94	0.316
1.266	-	11/07/2004	15:00	535.92	134	40	24	26	14	42.94	0.320

Table B.6. Measured and Calculated Data for 12/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	-	12/07/2004	11:00	436.00	109	31	20	22	9	27.60	0.253
1.266	-	12/07/2004	11:10	588.00	147	42	26	28	14	42.94	0.292
1.266	-	12/07/2004	11:20	576.00	144	41	26	28	13	39.87	0.277
1.266	-	12/07/2004	11:30	531.20	133	38	24	26	12	36.80	0.277
1.266	-	12/07/2004	11:40	609.60	152	44	27	29	15	46.00	0.302
1.266	-	12/07/2004	11:50	589.60	147	42	26	28	14	42.94	0.291
1.266	-	12/07/2004	12:00	560.80	140	40	25	27	13	39.87	0.284
1.266	-	12/07/2004	12:10	556.00	139	40	25	27	13	39.87	0.287
1.266	-	12/07/2004	12:20	556.00	139	40	25	27	13	39.87	0.287
1.266	-	12/07/2004	12:30	564.00	141	40	25	27	13	39.87	0.283
1.266	-	12/07/2004	12:40	564.00	141	40	25	27	13	39.87	0.283
1.266	-	12/07/2004	12:50	572.80	143	41	25	27	14	42.94	0.300
1.266	-	12/07/2004	13:00	573.60	143	41	25	27	14	42.94	0.299
1.266	-	12/07/2004	13:10	573.60	143	41	25	27	14	42.94	0.299
1.266	-	12/07/2004	13:20	572.80	143	41	25	27	14	42.94	0.300
1.266	-	12/07/2004	13:30	570.40	143	41	25	27	14	42.94	0.301
1.266	-	12/07/2004	13:40	570.40	143	41	25	27	14	42.94	0.301
1.266	-	12/07/2004	13:50	567.20	142	41	25	27	14	42.94	0.303
1.266	-	12/07/2004	14:00	564.00	141	40	25	27	13	39.87	0.283
1.266	-	12/07/2004	14:10	558.40	140	40	25	27	13	39.87	0.286
1.266	-	12/07/2004	14:20	556.80	139	40	25	27	13	39.87	0.286
1.266	-	12/07/2004	14:30	548.80	137	39	24	26	13	39.87	0.291
1.266	-	12/07/2004	14:40	541.60	135	39	24	26	13	39.87	0.294
1.266	-	12/07/2004	14:50	532.80	133	38	24	26	12	36.80	0.276
1.266	-	12/07/2004	15:00	521.60	130	37	23	25	12	36.80	0.282

Table B.7. Measured and Calculated Data for 13/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	-	13/07/2004	11:00	528.00	132	38	23	25	13	39.87	0.302
1.266	-	13/07/2004	11:10	566.40	142	40	25	27	13	39.87	0.282
1.266	-	13/07/2004	11:20	668.80	167	48	30	32	16	49.07	0.293
1.266	-	13/07/2004	11:30	688.00	172	49	30	32	17	52.14	0.303
1.266	-	13/07/2004	11:40	709.60	177	51	31	33	18	55.20	0.311
1.266	-	13/07/2004	11:50	684.80	171	49	30	32	17	52.14	0.305
1.266	-	13/07/2004	12:00	660.80	165	47	29	31	16	49.07	0.297
1.266	-	13/07/2004	12:10	669.60	167	48	30	32	16	49.07	0.293
1.266	-	13/07/2004	12:20	517.00	129	36	22	24	12	38.03	0.294
1.266	-	13/07/2004	12:30	469.00	117	30	21	23	7	20.73	0.177
1.266	-	13/07/2004	12:40	443.00	111	31	23	25	6	19.63	0.177
1.266	-	13/07/2004	12:50	371.00	93	30	20	22	8	25.76	0.278
1.266	-	13/07/2004	13:00	391.00	98	32	24	26	6	18.40	0.188
1.266	-	13/07/2004	13:10	407.00	102	34	25	27	7	22.69	0.223
1.266	-	13/07/2004	13:20	444.80	111	37	26	28	9	28.21	0.254
1.266	-	13/07/2004	13:30	711.20	178	51	31	33	18	55.20	0.310
1.266	-	13/07/2004	13:40	730.40	183	52	32	34	18	55.20	0.302
1.266	-	13/07/2004	13:50	561.00	140	39	25	27	13	38.34	0.273
1.266	-	13/07/2004	14:00	753.60	188	54	33	35	19	58.27	0.309
1.266	-	13/07/2004	14:10	756.00	189	54	33	35	19	58.27	0.308
1.266	-	13/07/2004	14:20	686.40	172	49	30	32	17	52.14	0.304
1.266	-	13/07/2004	14:30	680.00	170	49	30	32	17	52.14	0.307
1.266	-	13/07/2004	14:40	563.00	141	42	28	30	12	35.58	0.253
1.266	-	13/07/2004	14:50	700.00	175	50	31	33	17	52.14	0.298
1.266	-	13/07/2004	15:00	656.00	164	47	29	31	16	49.07	0.299

Table B.8. Measured and Calculated Data for 14/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	-	14/07/2004	11:00	512.00	128	37	23	25	12	36.80	0.288
1.266	-	14/07/2004	11:10	524.80	131	37	23	25	12	36.80	0.281
1.266	-	14/07/2004	11:20	536.00	134	38	24	26	12	36.80	0.275
1.266	-	14/07/2004	11:30	544.00	136	39	24	26	13	39.87	0.293
1.266	-	14/07/2004	11:40	557.60	139	40	25	27	13	39.87	0.286
1.266	-	14/07/2004	11:50	564.80	141	40	25	27	13	39.87	0.282
1.266	-	14/07/2004	12:00	574.40	144	41	25	27	14	42.94	0.299
1.266	-	14/07/2004	12:10	579.20	145	41	26	28	13	39.87	0.275
1.266	-	14/07/2004	12:20	586.40	147	42	26	28	14	42.94	0.293
1.266	-	14/07/2004	12:30	591.20	148	42	26	28	14	42.94	0.290
1.266	-	14/07/2004	12:40	595.20	149	43	26	28	15	46.00	0.309
1.266	-	14/07/2004	12:50	596.00	149	43	26	28	15	46.00	0.309
1.266	-	14/07/2004	13:00	600.00	150	43	27	29	14	42.94	0.286
1.266	-	14/07/2004	13:10	600.00	150	43	27	29	14	42.94	0.286
1.266	-	14/07/2004	13:20	597.60	149	43	26	28	15	46.00	0.308
1.266	-	14/07/2004	13:30	600.00	150	43	27	29	14	42.94	0.286
1.266	-	14/07/2004	13:40	598.40	150	43	27	29	14	42.94	0.287
1.266	-	14/07/2004	13:50	592.80	148	42	26	28	14	42.94	0.290
1.266	-	14/07/2004	14:00	588.80	147	42	26	28	14	42.94	0.292
1.266	-	14/07/2004	14:10	587.20	147	42	26	28	14	42.94	0.292
1.266	-	14/07/2004	14:20	581.60	145	42	26	28	14	42.94	0.295
1.266	-	14/07/2004	14:30	575.20	144	41	25	27	14	42.94	0.299
1.266	-	14/07/2004	14:40	568.00	142	41	25	27	14	42.94	0.302
1.266	-	14/07/2004	14:50	556.80	139	40	25	27	13	39.87	0.286
1.266	-	14/07/2004	15:00	545.60	136	39	24	26	13	39.87	0.292

Table B.9. Measured and Calculated Data for 15/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	-	15/07/2004	11:00	506.40	127	36	22	24	12	36.80	0.291
1.266	-	15/07/2004	11:10	520.80	130	37	23	25	12	36.80	0.283
1.266	-	15/07/2004	11:20	493.60	123	35	22	24	11	33.74	0.273
1.266	-	15/07/2004	11:30	587.20	147	42	26	28	14	42.94	0.292
1.266	-	15/07/2004	11:40	580.80	145	41	26	28	13	39.87	0.275
1.266	-	15/07/2004	11:50	593.60	148	42	26	28	14	42.94	0.289
1.266	-	15/07/2004	12:00	605.60	151	43	27	29	14	42.94	0.284
1.266	-	15/07/2004	12:10	604.00	151	43	27	29	14	42.94	0.284
1.266	-	15/07/2004	12:20	600.80	150	43	27	29	14	42.94	0.286
1.266	-	15/07/2004	12:30	592.80	148	42	26	28	14	42.94	0.290
1.266	-	15/07/2004	12:40	580.00	145	41	26	28	13	39.87	0.275
1.266	-	15/07/2004	12:50	621.60	155	44	28	30	14	42.94	0.276
1.266	-	15/07/2004	13:00	596.00	149	43	26	28	15	46.00	0.309
1.266	-	15/07/2004	13:10	560.00	140	40	25	27	13	39.87	0.285
1.266	-	15/07/2004	13:20	577.60	144	41	26	28	13	39.87	0.276
1.266	-	15/07/2004	13:30	548.00	137	39	24	26	13	39.87	0.291
1.266	-	15/07/2004	13:40	567.20	142	41	25	27	14	42.94	0.303
1.266	-	15/07/2004	13:50	548.80	137	39	24	26	13	39.87	0.291
1.266	-	15/07/2004	14:00	597.60	149	43	26	28	15	46.00	0.308
1.266	-	15/07/2004	14:10	599.20	150	43	27	29	14	42.94	0.287
1.266	-	15/07/2004	14:20	601.60	150	43	27	29	14	42.94	0.285
1.266	-	15/07/2004	14:30	597.60	149	43	26	28	15	46.00	0.308
1.266	-	15/07/2004	14:40	589.60	147	42	26	28	14	42.94	0.291
1.266	-	15/07/2004	14:50	587.20	147	42	26	28	14	42.94	0.292
1.266	-	15/07/2004	15:00	437.76	109	31	20	22	9	27.60	0.252

Table B.10. Measured and Calculated Data for 16/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	-	16/07/2004	11:00	402.56	101	34	21	23	11	35.18	0.350
1.266	-	16/07/2004	11:10	350.46	88	29	22	24	6	17.43	0.199
1.266	-	16/07/2004	11:20	303.10	76	27	20	22	5	14.68	0.194
1.266	-	16/07/2004	11:30	281.01	70	26	20	22	4	13.38	0.190
1.266	-	16/07/2004	11:40	251.01	63	26	21	23	3	10.04	0.160
1.266	-	16/07/2004	11:50	274.69	69	27	22	24	3	9.76	0.142
1.266	-	16/07/2004	12:00	459.94	115	39	24	26	14	41.47	0.361
1.266	-	16/07/2004	12:10	454.66	114	41	27	29	12	36.80	0.324
1.266	-	16/07/2004	12:20	549.38	137	46	29	31	15	46.21	0.336
1.266	-	16/07/2004	12:30	686.72	172	53	32	34	19	57.78	0.337
1.266	-	16/07/2004	12:40	756.18	189	58	35	37	21	63.94	0.338
1.266	-	16/07/2004	12:50	692.64	173	49	29	31	17	52.58	0.304
1.266	-	16/07/2004	13:00	516.22	129	37	22	24	13	38.57	0.299
1.266	-	16/07/2004	13:10	558.85	140	41	25	27	14	43.04	0.308
1.266	-	16/07/2004	13:20	599.10	150	43	26	28	15	45.27	0.302
1.266	-	16/07/2004	13:30	603.84	151	43	26	28	15	45.27	0.300
1.266	-	16/07/2004	13:40	587.26	147	43	26	28	15	45.27	0.308
1.266	-	16/07/2004	13:50	681.98	170	48	29	31	17	51.98	0.305
1.266	-	16/07/2004	14:00	753.02	188	54	33	35	19	58.68	0.312
1.266	-	16/07/2004	14:10	753.02	188	54	33	35	19	58.68	0.312
1.266	-	16/07/2004	14:20	743.55	186	54	33	35	19	58.68	0.316
1.266	-	16/07/2004	14:30	686.72	172	50	30	32	18	54.21	0.316
1.266	-	16/07/2004	14:40	629.89	157	44	27	29	15	47.51	0.302
1.266	-	16/07/2004	14:50	632.26	158	44	27	29	15	47.51	0.301
1.266	-	16/07/2004	15:00	670.14	168	48	29	31	17	51.98	0.310

Table B.11. Measured and Calculated Data for 17/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	-	17/07/2004	11:00	488.00	122	35	22	24	11	33.74	0.277
1.266	-	17/07/2004	11:10	497.60	124	36	22	24	12	36.80	0.296
1.266	-	17/07/2004	11:20	497.60	124	36	22	24	12	36.80	0.296
1.266	-	17/07/2004	11:30	531.20	133	38	24	26	12	36.80	0.277
1.266	-	17/07/2004	11:40	556.80	139	40	25	27	13	39.87	0.286
1.266	-	17/07/2004	11:50	593.60	148	42	26	28	14	42.94	0.289
1.266	-	17/07/2004	12:00	604.00	151	43	27	29	14	42.94	0.284
1.266	-	17/07/2004	12:10	588.00	147	42	26	28	14	42.94	0.292
1.266	-	17/07/2004	12:20	571.20	143	41	25	27	14	42.94	0.301
1.266	-	17/07/2004	12:30	575.20	144	41	25	27	14	42.94	0.299
1.266	-	17/07/2004	12:40	582.40	146	42	26	28	14	42.94	0.295
1.266	-	17/07/2004	12:50	582.40	146	42	26	28	14	42.94	0.295
1.266	-	17/07/2004	13:00	585.60	146	42	26	28	14	42.94	0.293
1.266	-	17/07/2004	13:10	591.20	148	42	26	28	14	42.94	0.290
1.266	-	17/07/2004	13:20	598.40	150	43	27	29	14	42.94	0.287
1.266	-	17/07/2004	13:30	600.00	150	43	27	29	14	42.94	0.286
1.266	-	17/07/2004	13:40	596.00	149	43	26	28	15	46.00	0.309
1.266	-	17/07/2004	13:50	590.40	148	42	26	28	14	42.94	0.291
1.266	-	17/07/2004	14:00	585.60	146	42	26	28	14	42.94	0.293
1.266	-	17/07/2004	14:10	588.00	147	42	26	28	14	42.94	0.292
1.266	-	17/07/2004	14:20	594.40	149	42	26	28	14	42.94	0.289
1.266	-	17/07/2004	14:30	579.20	145	41	26	28	13	39.87	0.275
1.266	-	17/07/2004	14:40	564.00	141	40	25	27	13	39.87	0.283
1.266	-	17/07/2004	14:50	544.80	136	39	24	26	13	39.87	0.293
1.266	-	17/07/2004	15:00	536.80	134	38	24	26	12	36.80	0.274

Table B.12. Measured and Calculated Data for 18/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	-	18/07/2004	11:00	491.20	123	35	22	24	11	33.74	0.275
1.266	-	18/07/2004	11:10	511.20	128	37	23	25	12	36.80	0.288
1.266	-	18/07/2004	11:20	521.60	130	37	23	25	12	36.80	0.282
1.266	-	18/07/2004	11:30	532.00	133	38	24	26	12	36.80	0.277
1.266	-	18/07/2004	11:40	542.40	136	39	24	26	13	39.87	0.294
1.266	-	18/07/2004	11:50	555.20	139	40	25	27	13	39.87	0.287
1.266	-	18/07/2004	12:00	568.00	142	41	25	27	14	42.94	0.302
1.266	-	18/07/2004	12:10	589.60	147	42	26	28	14	42.94	0.291
1.266	-	18/07/2004	12:20	600.80	150	43	27	29	14	42.94	0.286
1.266	-	18/07/2004	12:30	600.80	150	43	27	29	14	42.94	0.286
1.266	-	18/07/2004	12:40	612.00	153	44	27	29	15	46.00	0.301
1.266	-	18/07/2004	12:50	624.80	156	45	28	30	15	46.00	0.295
1.266	-	18/07/2004	13:00	612.00	153	44	27	29	15	46.00	0.301
1.266	-	18/07/2004	13:10	642.40	161	46	28	30	16	49.07	0.306
1.266	-	18/07/2004	13:20	633.60	158	45	28	30	15	46.00	0.290
1.266	-	18/07/2004	13:30	631.20	158	45	28	30	15	46.00	0.292
1.266	-	18/07/2004	13:40	634.40	159	45	28	30	15	46.00	0.290
1.266	-	18/07/2004	13:50	648.72	162	46	29	31	15	46.00	0.284
1.266	-	18/07/2004	14:00	631.20	158	45	28	30	15	46.00	0.292
1.266	-	18/07/2004	14:10	620.00	155	44	27	29	15	46.00	0.297
1.266	-	18/07/2004	14:20	632.00	158	45	28	30	15	46.00	0.291
1.266	-	18/07/2004	14:30	621.60	155	44	28	30	14	42.94	0.276
1.266	-	18/07/2004	14:40	611.20	153	44	27	29	15	46.00	0.301
1.266	-	18/07/2004	14:50	577.60	144	41	26	28	13	39.87	0.276
1.266	-	18/07/2004	15:00	558.40	140	40	25	27	13	39.87	0.286

Table B.13. Measured and Calculated Data for 19/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	-	19/07/2004	11:00	519.20	130	35	23	25	10	38.34	0.295
1.5825	-	19/07/2004	11:10	370.40	93	27	21	23	4	15.33	0.166
1.5825	-	19/07/2004	11:20	597.60	149	41	26	28	13	49.84	0.334
1.5825	-	19/07/2004	11:30	604.80	151	41	27	29	12	46.00	0.304
1.5825	-	19/07/2004	11:40	662.40	166	45	29	31	14	53.67	0.324
1.5825	-	19/07/2004	11:50	547.20	137	37	24	26	11	42.17	0.308
1.5825	-	19/07/2004	12:00	648.80	162	44	29	31	13	49.84	0.307
1.5825	-	19/07/2004	12:10	636.00	159	43	28	30	13	49.84	0.313
1.5825	-	19/07/2004	12:20	421.12	105	30	20	22	8	30.67	0.291
1.5825	-	19/07/2004	12:30	401.92	100	30	20	22	8	30.67	0.305
1.5825	-	19/07/2004	12:40	418.40	105	29	20	22	7	26.83	0.257
1.5825	-	19/07/2004	12:50	467.20	117	32	21	23	9	34.50	0.295
1.5825	-	19/07/2004	13:00	357.60	89	26	21	23	3	11.50	0.129
1.5825	-	19/07/2004	13:10	387.20	97	28	21	23	5	19.17	0.198
1.5825	-	19/07/2004	13:20	344.80	86	28	20	22	6	23.00	0.267
1.5825	-	19/07/2004	13:30	324.80	81	27	20	22	5	19.17	0.236
1.5825	-	19/07/2004	13:40	463.20	116	31	21	23	8	30.67	0.265
1.5825	-	19/07/2004	13:50	483.20	121	33	21	23	10	38.34	0.317
1.5825	-	19/07/2004	14:00	709.60	177	48	31	33	15	57.50	0.324
1.5825	-	19/07/2004	14:10	447.20	112	30	20	22	8	30.67	0.274
1.5825	-	19/07/2004	14:20	384.80	96	28	21	23	5	19.17	0.199
1.5825	-	19/07/2004	14:30	467.20	117	32	21	23	9	34.50	0.295
1.5825	-	19/07/2004	14:40	413.44	103	30	20	22	8	30.67	0.297
1.5825	-	19/07/2004	14:50	467.20	117	32	21	23	9	34.50	0.295
1.5825	-	19/07/2004	15:00	360.00	90	27	21	23	4	15.33	0.170

Table B.14. Measured and Calculated Data for 20/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	-	20/07/2004	11:00	282.24	71	26	21	23	3	11.50	0.163
1.5825	-	20/07/2004	11:10	243.84	61	26	20	22	4	15.33	0.252
1.5825	-	20/07/2004	11:20	240.00	60	25	20	22	3	11.50	0.192
1.5825	-	20/07/2004	11:30	261.12	65	25	20	22	3	11.50	0.176
1.5825	-	20/07/2004	11:40	297.60	74	26	21	23	3	11.50	0.155
1.5825	-	20/07/2004	11:50	291.84	73	26	21	23	3	11.50	0.158
1.5825	-	20/07/2004	12:00	366.72	92	29	20	22	7	26.83	0.293
1.5825	-	20/07/2004	12:10	453.12	113	30	21	23	7	27.60	0.244
1.5825	-	20/07/2004	12:20	581.76	145	39	27	29	10	37.57	0.258
1.5825	-	20/07/2004	12:30	677.76	169	47	32	34	13	47.92	0.283
1.5825	-	20/07/2004	12:40	532.80	133	36	26	28	8	32.20	0.242
1.5825	-	20/07/2004	12:50	758.40	190	51	35	37	14	52.90	0.279
1.5825	-	20/07/2004	13:00	595.20	149	41	29	31	10	37.19	0.250
1.5825	-	20/07/2004	13:10	714.24	179	48	34	36	12	47.54	0.266
1.5825	-	20/07/2004	13:20	532.80	133	36	26	28	8	32.20	0.242
1.5825	-	20/07/2004	13:30	532.80	133	36	26	28	8	32.20	0.242
1.5825	-	20/07/2004	13:40	522.00	131	36	24	26	10	38.34	0.294
1.5825	-	20/07/2004	13:50	519.60	130	36	24	26	10	38.34	0.295
1.5825	-	20/07/2004	14:00	591.36	148	41	27	29	11	43.32	0.293
1.5825	-	20/07/2004	14:10	451.20	113	30	21	23	7	27.60	0.245
1.5825	-	20/07/2004	14:20	460.80	115	32	22	24	7	27.22	0.236
1.5825	-	20/07/2004	14:30	405.12	101	28	20	22	6	23.00	0.227
1.5825	-	20/07/2004	14:40	487.68	122	33	22	24	9	32.97	0.270
1.5825	-	20/07/2004	14:50	541.44	135	36	26	28	8	32.20	0.238
1.5825	-	20/07/2004	15:00	420.48	105	30	20	22	8	30.67	0.292

Table B.15. Measured and Calculated Data for 21/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	-	21/07/2004	11:00	492.00	123	33	21	23	10	38.34	0.312
1.5825	-	21/07/2004	11:10	496.00	124	34	22	24	10	38.34	0.309
1.5825	-	21/07/2004	11:20	509.60	127	35	23	25	10	38.34	0.301
1.5825	-	21/07/2004	11:30	512.00	128	35	23	25	10	38.34	0.299
1.5825	-	21/07/2004	11:40	533.60	133	36	24	26	10	38.34	0.287
1.5825	-	21/07/2004	11:50	535.20	134	36	24	26	10	38.34	0.287
1.5825	-	21/07/2004	12:00	559.20	140	38	25	27	11	42.17	0.302
1.5825	-	21/07/2004	12:10	550.40	138	37	24	26	11	42.17	0.306
1.5825	-	21/07/2004	12:20	567.20	142	38	25	27	11	42.17	0.297
1.5825	-	21/07/2004	12:30	574.40	144	39	25	27	12	46.00	0.320
1.5825	-	21/07/2004	12:40	577.60	144	39	26	28	11	42.17	0.292
1.5825	-	21/07/2004	12:50	583.20	146	40	26	28	12	46.00	0.316
1.5825	-	21/07/2004	13:00	580.00	145	39	26	28	11	42.17	0.291
1.5825	-	21/07/2004	13:10	579.20	145	39	26	28	11	42.17	0.291
1.5825	-	21/07/2004	13:20	592.00	148	40	26	28	12	46.00	0.311
1.5825	-	21/07/2004	13:30	589.60	147	40	26	28	12	46.00	0.312
1.5825	-	21/07/2004	13:40	579.20	145	39	26	28	11	42.17	0.291
1.5825	-	21/07/2004	13:50	571.20	143	39	25	27	12	46.00	0.322
1.5825	-	21/07/2004	14:00	567.20	142	38	25	27	11	42.17	0.297
1.5825	-	21/07/2004	14:10	561.60	140	38	25	27	11	42.17	0.300
1.5825	-	21/07/2004	14:20	553.60	138	38	25	27	11	42.17	0.305
1.5825	-	21/07/2004	14:30	545.60	136	37	24	26	11	42.17	0.309
1.5825	-	21/07/2004	14:40	539.20	135	37	24	26	11	42.17	0.313
1.5825	-	21/07/2004	14:50	531.20	133	36	24	26	10	38.34	0.289
1.5825	-	21/07/2004	15:00	521.60	130	35	23	25	10	38.34	0.294

Table B.16. Measured and Calculated Data for 22/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	-	22/07/2004	11:00	560.80	140	38	25	27	11	42.17	0.301
1.5825	-	22/07/2004	11:10	570.40	143	39	25	27	12	46.00	0.323
1.5825	-	22/07/2004	11:20	579.20	145	39	26	28	11	42.17	0.291
1.5825	-	22/07/2004	11:30	578.40	145	39	26	28	11	42.17	0.292
1.5825	-	22/07/2004	11:40	576.80	144	39	26	28	11	42.17	0.292
1.5825	-	22/07/2004	11:50	596.00	149	40	26	28	12	46.00	0.309
1.5825	-	22/07/2004	12:00	605.60	151	41	27	29	12	46.00	0.304
1.5825	-	22/07/2004	12:10	616.00	154	42	27	29	13	49.84	0.324
1.5825	-	22/07/2004	12:20	631.20	158	43	28	30	13	49.84	0.316
1.5825	-	22/07/2004	12:30	653.60	163	44	29	31	13	49.84	0.305
1.5825	-	22/07/2004	12:40	688.80	172	47	31	33	14	53.67	0.312
1.5825	-	22/07/2004	12:50	679.20	170	46	30	32	14	53.67	0.316
1.5825	-	22/07/2004	13:00	694.40	174	47	31	33	14	53.67	0.309
1.5825	-	22/07/2004	13:10	650.40	163	44	29	31	13	49.84	0.306
1.5825	-	22/07/2004	13:20	631.20	158	43	28	30	13	49.84	0.316
1.5825	-	22/07/2004	13:30	629.60	157	43	28	30	13	49.84	0.317
1.5825	-	22/07/2004	13:40	625.60	156	42	28	30	12	46.00	0.294
1.5825	-	22/07/2004	13:50	622.40	156	42	28	30	12	46.00	0.296
1.5825	-	22/07/2004	14:00	617.60	154	42	27	29	13	49.84	0.323
1.5825	-	22/07/2004	14:10	603.20	151	41	27	29	12	46.00	0.305
1.5825	-	22/07/2004	14:20	595.20	149	40	26	28	12	46.00	0.309
1.5825	-	22/07/2004	14:30	588.80	147	40	26	28	12	46.00	0.313
1.5825	-	22/07/2004	14:40	579.20	145	39	26	28	11	42.17	0.291
1.5825	-	22/07/2004	14:50	572.80	143	39	25	27	12	46.00	0.321
1.5825	-	22/07/2004	15:00	561.60	140	38	25	27	11	42.17	0.300

Table B.17. Measured and Calculated Data for 23/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	-	23/07/2004	11:00	526.40	132	36	23	25	11	42.17	0.320
1.5825	-	23/07/2004	11:10	536.80	134	36	24	26	10	38.34	0.286
1.5825	-	23/07/2004	11:20	552.00	138	37	24	26	11	42.17	0.306
1.5825	-	23/07/2004	11:30	568.00	142	39	25	27	12	46.00	0.324
1.5825	-	23/07/2004	11:40	574.40	144	39	25	27	12	46.00	0.320
1.5825	-	23/07/2004	11:50	581.60	145	39	26	28	11	42.17	0.290
1.5825	-	23/07/2004	12:00	588.00	147	40	26	28	12	46.00	0.313
1.5825	-	23/07/2004	12:10	598.40	150	41	27	29	12	46.00	0.308
1.5825	-	23/07/2004	12:20	600.80	150	41	27	29	12	46.00	0.306
1.5825	-	23/07/2004	12:30	606.40	152	41	27	29	12	46.00	0.303
1.5825	-	23/07/2004	12:40	612.80	153	42	27	29	13	49.84	0.325
1.5825	-	23/07/2004	12:50	618.40	155	42	27	29	13	49.84	0.322
1.5825	-	23/07/2004	13:00	621.60	155	42	28	30	12	46.00	0.296
1.5825	-	23/07/2004	13:10	620.00	155	42	27	29	13	49.84	0.322
1.5825	-	23/07/2004	13:20	622.40	156	42	28	30	12	46.00	0.296
1.5825	-	23/07/2004	13:30	620.00	155	42	27	29	13	49.84	0.322
1.5825	-	23/07/2004	13:40	616.00	154	42	27	29	13	49.84	0.324
1.5825	-	23/07/2004	13:50	614.40	154	42	27	29	13	49.84	0.324
1.5825	-	23/07/2004	14:00	609.60	152	41	27	29	12	46.00	0.302
1.5825	-	23/07/2004	14:10	606.40	152	41	27	29	12	46.00	0.303
1.5825	-	23/07/2004	14:20	596.80	149	40	26	28	12	46.00	0.308
1.5825	-	23/07/2004	14:30	590.40	148	40	26	28	12	46.00	0.312
1.5825	-	23/07/2004	14:40	582.40	146	40	26	28	12	46.00	0.316
1.5825	-	23/07/2004	14:50	576.00	144	39	26	28	11	42.17	0.293
1.5825	-	23/07/2004	15:00	565.60	141	38	25	27	11	42.17	0.298

Table B.18. Measured and Calculated Data for 24/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	-	24/07/2004	11:00	512.80	128	35	23	25	10	38.34	0.299
1.5825	-	24/07/2004	11:10	524.80	131	36	23	25	11	42.17	0.321
1.5825	-	24/07/2004	11:20	550.40	138	37	24	26	11	42.17	0.306
1.5825	-	24/07/2004	11:30	555.20	139	38	25	27	11	42.17	0.304
1.5825	-	24/07/2004	11:40	560.80	140	38	25	27	11	42.17	0.301
1.5825	-	24/07/2004	11:50	572.80	143	39	25	27	12	46.00	0.321
1.5825	-	24/07/2004	12:00	607.20	152	41	27	29	12	46.00	0.303
1.5825	-	24/07/2004	12:10	618.40	155	42	27	29	13	49.84	0.322
1.5825	-	24/07/2004	12:20	572.80	143	39	25	27	12	46.00	0.321
1.5825	-	24/07/2004	12:30	577.60	144	39	26	28	11	42.17	0.292
1.5825	-	24/07/2004	12:40	601.60	150	41	27	29	12	46.00	0.306
1.5825	-	24/07/2004	12:50	597.60	149	41	26	28	13	49.84	0.334
1.5825	-	24/07/2004	13:00	615.20	154	42	27	29	13	49.84	0.324
1.5825	-	24/07/2004	13:10	707.60	177	48	31	33	15	57.50	0.325
1.5825	-	24/07/2004	13:20	614.40	154	42	27	29	13	49.84	0.324
1.5825	-	24/07/2004	13:30	611.20	153	41	27	29	12	46.00	0.301
1.5825	-	24/07/2004	13:40	537.60	134	36	25	27	9	34.12	0.254
1.5825	-	24/07/2004	13:50	619.20	155	42	27	29	13	49.84	0.322
1.5825	-	24/07/2004	14:00	620.80	155	42	27	29	13	49.84	0.321
1.5825	-	24/07/2004	14:10	621.60	155	42	28	30	12	46.00	0.296
1.5825	-	24/07/2004	14:20	621.60	155	42	28	30	12	46.00	0.296
1.5825	-	24/07/2004	14:30	497.60	124	35	26	28	8	29.52	0.237
1.5825	-	24/07/2004	14:40	500.80	125	37	24	26	11	41.40	0.331
1.5825	-	24/07/2004	14:50	460.00	115	34	24	26	7	28.37	0.247
1.5825	-	24/07/2004	15:00	416.00	104	32	24	26	6	22.62	0.217

Table B.19. Measured and Calculated Data for 25/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	-	25/07/2004	11:00	500.80	125	34	22	24	10	38.34	0.306
1.5825	-	25/07/2004	11:10	516.00	129	35	23	25	10	38.34	0.297
1.5825	-	25/07/2004	11:20	524.80	131	36	23	25	11	42.17	0.321
1.5825	-	25/07/2004	11:30	540.00	135	37	24	26	11	42.17	0.312
1.5825	-	25/07/2004	11:40	552.00	138	37	24	26	11	42.17	0.306
1.5825	-	25/07/2004	11:50	561.60	140	38	25	27	11	42.17	0.300
1.5825	-	25/07/2004	12:00	567.20	142	38	25	27	11	42.17	0.297
1.5825	-	25/07/2004	12:10	576.00	144	39	26	28	11	42.17	0.293
1.5825	-	25/07/2004	12:20	581.60	145	39	26	28	11	42.17	0.290
1.5825	-	25/07/2004	12:30	586.40	147	40	26	28	12	46.00	0.314
1.5825	-	25/07/2004	12:40	587.20	147	40	26	28	12	46.00	0.313
1.5825	-	25/07/2004	12:50	589.60	147	40	26	28	12	46.00	0.312
1.5825	-	25/07/2004	13:00	593.60	148	40	26	28	12	46.00	0.310
1.5825	-	25/07/2004	13:10	593.60	148	40	26	28	12	46.00	0.310
1.5825	-	25/07/2004	13:20	595.20	149	40	26	28	12	46.00	0.309
1.5825	-	25/07/2004	13:30	596.00	149	40	26	28	12	46.00	0.309
1.5825	-	25/07/2004	13:40	596.80	149	40	26	28	12	46.00	0.308
1.5825	-	25/07/2004	13:50	595.20	149	40	26	28	12	46.00	0.309
1.5825	-	25/07/2004	14:00	592.00	148	40	26	28	12	46.00	0.311
1.5825	-	25/07/2004	14:10	586.40	147	40	26	28	12	46.00	0.314
1.5825	-	25/07/2004	14:20	579.20	145	39	26	28	11	42.17	0.291
1.5825	-	25/07/2004	14:30	575.20	144	39	25	27	12	46.00	0.320
1.5825	-	25/07/2004	14:40	567.20	142	38	25	27	11	42.17	0.297
1.5825	-	25/07/2004	14:50	559.20	140	38	25	27	11	42.17	0.302
1.5825	-	25/07/2004	15:00	551.20	138	37	24	26	11	42.17	0.306

Table B.20. Measured and Calculated Data for 26/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	-	26/07/2004	11:00	531.20	133	36	24	26	10	38.34	0.289
1.5825	-	26/07/2004	11:10	533.60	133	36	24	26	10	38.34	0.287
1.5825	-	26/07/2004	11:20	547.20	137	37	24	26	11	42.17	0.308
1.5825	-	26/07/2004	11:30	562.40	141	38	25	27	11	42.17	0.300
1.5825	-	26/07/2004	11:40	576.00	144	39	26	28	11	42.17	0.293
1.5825	-	26/07/2004	11:50	584.00	146	40	26	28	12	46.00	0.315
1.5825	-	26/07/2004	12:00	591.20	148	40	26	28	12	46.00	0.311
1.5825	-	26/07/2004	12:10	604.80	151	41	27	29	12	46.00	0.304
1.5825	-	26/07/2004	12:20	609.60	152	41	27	29	12	46.00	0.302
1.5825	-	26/07/2004	12:30	615.20	154	42	27	29	13	49.84	0.324
1.5825	-	26/07/2004	12:40	624.00	156	42	28	30	12	46.00	0.295
1.5825	-	26/07/2004	12:50	625.60	156	42	28	30	12	46.00	0.294
1.5825	-	26/07/2004	13:00	627.20	157	43	28	30	13	49.84	0.318
1.5825	-	26/07/2004	13:10	623.20	156	42	28	30	12	46.00	0.295
1.5825	-	26/07/2004	13:20	624.00	156	42	28	30	12	46.00	0.295
1.5825	-	26/07/2004	13:30	628.80	157	43	28	30	13	49.84	0.317
1.5825	-	26/07/2004	13:40	623.20	156	42	28	30	12	46.00	0.295
1.5825	-	26/07/2004	13:50	623.20	156	42	28	30	12	46.00	0.295
1.5825	-	26/07/2004	14:00	620.80	155	42	27	29	13	49.84	0.321
1.5825	-	26/07/2004	14:10	615.20	154	42	27	29	13	49.84	0.324
1.5825	-	26/07/2004	14:20	603.20	151	41	27	29	12	46.00	0.305
1.5825	-	26/07/2004	14:30	598.40	150	41	27	29	12	46.00	0.308
1.5825	-	26/07/2004	14:40	592.00	148	40	26	28	12	46.00	0.311
1.5825	-	26/07/2004	14:50	584.00	146	40	26	28	12	46.00	0.315
1.5825	-	26/07/2004	15:00	570.40	143	39	25	27	12	46.00	0.323

Table B.21. Measured and Calculated Data for 27/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	-	27/07/2004	11:00	528.80	132	36	23	25	11	42.17	0.319
1.5825	-	27/07/2004	11:10	548.80	137	37	24	26	11	42.17	0.307
1.5825	-	27/07/2004	11:20	556.00	139	38	25	27	11	42.17	0.303
1.5825	-	27/07/2004	11:30	567.20	142	38	25	27	11	42.17	0.297
1.5825	-	27/07/2004	11:40	576.80	144	39	26	28	11	42.17	0.292
1.5825	-	27/07/2004	11:50	587.20	147	40	26	28	12	46.00	0.313
1.5825	-	27/07/2004	12:00	595.20	149	40	26	28	12	46.00	0.309
1.5825	-	27/07/2004	12:10	601.60	150	41	27	29	12	46.00	0.306
1.5825	-	27/07/2004	12:20	607.20	152	41	27	29	12	46.00	0.303
1.5825	-	27/07/2004	12:30	612.80	153	42	27	29	13	49.84	0.325
1.5825	-	27/07/2004	12:40	624.00	156	42	28	30	12	46.00	0.295
1.5825	-	27/07/2004	12:50	627.20	157	43	28	30	13	49.84	0.318
1.5825	-	27/07/2004	13:00	628.80	157	43	28	30	13	49.84	0.317
1.5825	-	27/07/2004	13:10	628.80	157	43	28	30	13	49.84	0.317
1.5825	-	27/07/2004	13:20	627.20	157	43	28	30	13	49.84	0.318
1.5825	-	27/07/2004	13:30	625.60	156	42	28	30	12	46.00	0.294
1.5825	-	27/07/2004	13:40	625.60	156	42	28	30	12	46.00	0.294
1.5825	-	27/07/2004	13:50	623.20	156	42	28	30	12	46.00	0.295
1.5825	-	27/07/2004	14:00	620.00	155	42	27	29	13	49.84	0.322
1.5825	-	27/07/2004	14:10	616.80	154	42	27	29	13	49.84	0.323
1.5825	-	27/07/2004	14:20	609.60	152	41	27	29	12	46.00	0.302
1.5825	-	27/07/2004	14:30	601.60	150	41	27	29	12	46.00	0.306
1.5825	-	27/07/2004	14:40	591.20	148	40	26	28	12	46.00	0.311
1.5825	-	27/07/2004	14:50	582.40	146	40	26	28	12	46.00	0.316
1.5825	-	27/07/2004	15:00	572.80	143	39	25	27	12	46.00	0.321

Table B.22. Measured and Calculated Data for 28/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	+	28/07/2004	11:00	534.40	134	36	24	26	10	42.59	0.319
1.5825	+	28/07/2004	11:10	601.60	150	41	27	29	12	51.11	0.340
1.5825	+	28/07/2004	11:20	584.80	146	40	26	28	12	51.11	0.350
1.5825	+	28/07/2004	11:30	560.80	140	38	25	27	11	46.85	0.334
1.5825	+	28/07/2004	11:40	681.60	170	46	30	32	14	59.63	0.350
1.5825	+	28/07/2004	11:50	662.40	166	45	29	31	14	59.63	0.360
1.5825	+	28/07/2004	12:00	706.40	177	48	31	33	15	63.89	0.362
1.5825	+	28/07/2004	12:10	628.00	157	43	28	30	13	55.37	0.353
1.5825	+	28/07/2004	12:20	645.60	161	44	29	31	13	55.37	0.343
1.5825	+	28/07/2004	12:30	656.80	164	45	29	31	14	59.63	0.363
1.5825	+	28/07/2004	12:40	615.20	154	42	27	29	13	55.37	0.360
1.5825	+	28/07/2004	12:50	538.40	135	37	24	26	11	46.85	0.348
1.5825	+	28/07/2004	13:00	703.20	176	48	31	33	15	63.89	0.363
1.5825	+	28/07/2004	13:10	707.20	177	48	31	33	15	63.89	0.361
1.5825	+	28/07/2004	13:20	702.80	176	48	31	33	15	63.89	0.364
1.5825	+	28/07/2004	13:30	710.40	178	48	31	33	15	63.89	0.360
1.5825	+	28/07/2004	13:40	700.00	175	48	31	33	15	63.89	0.365
1.5825	+	28/07/2004	13:50	615.20	154	42	27	29	13	55.37	0.360
1.5825	+	28/07/2004	14:00	688.00	172	47	30	32	15	63.89	0.371
1.5825	+	28/07/2004	14:10	704.00	176	48	31	33	15	63.89	0.363
1.5825	+	28/07/2004	14:20	406.40	102	30	20	22	8	34.08	0.335
1.5825	+	28/07/2004	14:30	707.60	177	48	31	33	15	63.89	0.361
1.5825	+	28/07/2004	14:40	620.80	155	42	27	29	13	55.37	0.357
1.5825	+	28/07/2004	14:50	503.20	126	34	22	24	10	42.59	0.339
1.5825	+	28/07/2004	15:00	349.44	87	30	23	25	5	21.30	0.244

Table B.23. Measured and Calculated Data for 29/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	+	29/07/2004	11:00	567.20	142	38	25	27	11	46.85	0.330
1.5825	+	29/07/2004	11:10	550.40	138	37	24	26	11	46.85	0.341
1.5825	+	29/07/2004	11:20	560.80	140	38	25	27	11	46.85	0.334
1.5825	+	29/07/2004	11:30	588.00	147	40	26	28	12	51.11	0.348
1.5825	+	29/07/2004	11:40	594.40	149	40	26	28	12	51.11	0.344
1.5825	+	29/07/2004	11:50	609.60	152	41	27	29	12	51.11	0.335
1.5825	+	29/07/2004	12:00	628.00	157	43	28	30	13	55.37	0.353
1.5825	+	29/07/2004	12:10	643.20	161	44	28	30	14	59.63	0.371
1.5825	+	29/07/2004	12:20	647.20	162	44	29	31	13	55.37	0.342
1.5825	+	29/07/2004	12:30	649.60	162	44	29	31	13	55.37	0.341
1.5825	+	29/07/2004	12:40	617.60	154	42	27	29	13	55.37	0.359
1.5825	+	29/07/2004	12:50	626.40	157	43	28	30	13	55.37	0.354
1.5825	+	29/07/2004	13:00	624.00	156	42	28	30	12	51.11	0.328
1.5825	+	29/07/2004	13:10	639.20	160	43	28	30	13	55.37	0.347
1.5825	+	29/07/2004	13:20	653.60	163	44	29	31	13	55.37	0.339
1.5825	+	29/07/2004	13:30	648.80	162	44	29	31	13	55.37	0.341
1.5825	+	29/07/2004	13:40	625.60	156	42	28	30	12	51.11	0.327
1.5825	+	29/07/2004	13:50	612.80	153	42	27	29	13	55.37	0.361
1.5825	+	29/07/2004	14:00	609.60	152	41	27	29	12	51.11	0.335
1.5825	+	29/07/2004	14:10	612.80	153	42	27	29	13	55.37	0.361
1.5825	+	29/07/2004	14:20	620.80	155	42	27	29	13	55.37	0.357
1.5825	+	29/07/2004	14:30	623.20	156	42	28	30	12	51.11	0.328
1.5825	+	29/07/2004	14:40	591.20	148	40	26	28	12	51.11	0.346
1.5825	+	29/07/2004	14:50	587.20	147	40	26	28	12	51.11	0.348
1.5825	+	29/07/2004	15:00	584.80	146	40	26	28	12	51.11	0.350

Table B.24. Measured and Calculated Data for 30/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	+	30/07/2004	11:00	523.20	131	36	23	25	11	46.85	0.358
1.5825	+	30/07/2004	11:10	538.40	135	37	24	26	11	46.85	0.348
1.5825	+	30/07/2004	11:20	544.80	136	37	24	26	11	46.85	0.344
1.5825	+	30/07/2004	11:30	561.60	140	38	25	27	11	46.85	0.334
1.5825	+	30/07/2004	11:40	571.20	143	39	25	27	12	51.11	0.358
1.5825	+	30/07/2004	11:50	576.80	144	39	26	28	11	46.85	0.325
1.5825	+	30/07/2004	12:00	588.00	147	40	26	28	12	51.11	0.348
1.5825	+	30/07/2004	12:10	593.60	148	40	26	28	12	51.11	0.344
1.5825	+	30/07/2004	12:20	596.00	149	40	26	28	12	51.11	0.343
1.5825	+	30/07/2004	12:30	604.80	151	41	27	29	12	51.11	0.338
1.5825	+	30/07/2004	12:40	609.60	152	41	27	29	12	51.11	0.335
1.5825	+	30/07/2004	12:50	612.00	153	42	27	29	13	55.37	0.362
1.5825	+	30/07/2004	13:00	615.20	154	42	27	29	13	55.37	0.360
1.5825	+	30/07/2004	13:10	615.20	154	42	27	29	13	55.37	0.360
1.5825	+	30/07/2004	13:20	614.40	154	42	27	29	13	55.37	0.361
1.5825	+	30/07/2004	13:30	612.80	153	42	27	29	13	55.37	0.361
1.5825	+	30/07/2004	13:40	610.40	153	41	27	29	12	51.11	0.335
1.5825	+	30/07/2004	13:50	607.20	152	41	27	29	12	51.11	0.337
1.5825	+	30/07/2004	14:00	604.80	151	41	27	29	12	51.11	0.338
1.5825	+	30/07/2004	14:10	600.80	150	41	27	29	12	51.11	0.340
1.5825	+	30/07/2004	14:20	596.00	149	40	26	28	12	51.11	0.343
1.5825	+	30/07/2004	14:30	586.40	147	40	26	28	12	51.11	0.349
1.5825	+	30/07/2004	14:40	577.60	144	39	26	28	11	46.85	0.324
1.5825	+	30/07/2004	14:50	568.00	142	39	25	27	12	51.11	0.360
1.5825	+	30/07/2004	15:00	560.80	140	38	25	27	11	46.85	0.334

Table B.25. Measured and Calculated Data for 31/07/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	+	31/07/2004	11:00	536.80	134	36	24	26	10	42.59	0.317
1.5825	+	31/07/2004	11:10	553.60	138	38	25	27	11	46.85	0.339
1.5825	+	31/07/2004	11:20	567.20	142	38	25	27	11	46.85	0.330
1.5825	+	31/07/2004	11:30	572.00	143	39	25	27	12	51.11	0.357
1.5825	+	31/07/2004	11:40	586.40	147	40	26	28	12	51.11	0.349
1.5825	+	31/07/2004	11:50	597.60	149	41	26	28	13	55.37	0.371
1.5825	+	31/07/2004	12:00	607.20	152	41	27	29	12	51.11	0.337
1.5825	+	31/07/2004	12:10	612.80	153	42	27	29	13	55.37	0.361
1.5825	+	31/07/2004	12:20	617.60	154	42	27	29	13	55.37	0.359
1.5825	+	31/07/2004	12:30	621.60	155	42	28	30	12	51.11	0.329
1.5825	+	31/07/2004	12:40	623.20	156	42	28	30	12	51.11	0.328
1.5825	+	31/07/2004	12:50	629.60	157	43	28	30	13	55.37	0.352
1.5825	+	31/07/2004	13:00	630.40	158	43	28	30	13	55.37	0.351
1.5825	+	31/07/2004	13:10	626.40	157	43	28	30	13	55.37	0.354
1.5825	+	31/07/2004	13:20	627.20	157	43	28	30	13	55.37	0.353
1.5825	+	31/07/2004	13:30	626.40	157	43	28	30	13	55.37	0.354
1.5825	+	31/07/2004	13:40	623.20	156	42	28	30	12	51.11	0.328
1.5825	+	31/07/2004	13:50	620.80	155	42	27	29	13	55.37	0.357
1.5825	+	31/07/2004	14:00	617.60	154	42	27	29	13	55.37	0.359
1.5825	+	31/07/2004	14:10	612.00	153	42	27	29	13	55.37	0.362
1.5825	+	31/07/2004	14:20	606.40	152	41	27	29	12	51.11	0.337
1.5825	+	31/07/2004	14:30	598.40	150	41	27	29	12	51.11	0.342
1.5825	+	31/07/2004	14:40	591.20	148	40	26	28	12	51.11	0.346
1.5825	+	31/07/2004	14:50	583.20	146	40	26	28	12	51.11	0.351
1.5825	+	31/07/2004	15:00	573.60	143	39	25	27	12	51.11	0.356

APPENDIX C

MEASURED & CALCULATED DATA FOR AUGUST

Table C.1. Measured and Calculated Data for 01/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	-	01/08/2004	11:00	533.60	133	36	24	26	10	38.34	0.287
1.5825	-	01/08/2004	11:10	543.20	136	37	24	26	11	42.17	0.311
1.5825	-	01/08/2004	11:20	564.00	141	38	25	27	11	42.17	0.299
1.5825	-	01/08/2004	11:30	576.80	144	39	26	28	11	42.17	0.292
1.5825	-	01/08/2004	11:40	584.80	146	40	26	28	12	46.00	0.315
1.5825	-	01/08/2004	11:50	614.40	154	42	27	29	13	49.84	0.324
1.5825	-	01/08/2004	12:00	651.20	163	44	29	31	13	49.84	0.306
1.5825	-	01/08/2004	12:10	703.20	176	48	31	33	15	57.50	0.327
1.5825	-	01/08/2004	12:20	703.20	176	48	31	33	15	57.50	0.327
1.5825	-	01/08/2004	12:30	656.80	164	45	29	31	14	53.67	0.327
1.5825	-	01/08/2004	12:40	705.60	176	48	31	33	15	57.50	0.326
1.5825	-	01/08/2004	12:50	740.80	185	50	33	35	15	57.50	0.310
1.5825	-	01/08/2004	13:00	700.80	175	48	31	33	15	57.50	0.328
1.5825	-	01/08/2004	13:10	584.80	146	40	26	28	12	46.00	0.315
1.5825	-	01/08/2004	13:20	573.60	143	39	25	27	12	46.00	0.321
1.5825	-	01/08/2004	13:30	456.00	114	35	23	25	10	38.34	0.336
1.5825	-	01/08/2004	13:40	422.40	106	27	21	23	4	15.33	0.145
1.5825	-	01/08/2004	13:50	437.76	109	30	21	23	7	26.83	0.245
1.5825	-	01/08/2004	14:00	378.88	95	28	20	22	6	23.00	0.243
1.5825	-	01/08/2004	14:10	407.20	102	26	20	22	4	15.33	0.151
1.5825	-	01/08/2004	14:20	433.36	108	29	21	23	6	23.00	0.212
1.5825	-	01/08/2004	14:30	393.12	98	27	20	22	5	19.17	0.195
1.5825	-	01/08/2004	14:40	403.36	101	28	21	23	5	19.17	0.190
1.5825	-	01/08/2004	14:50	450.72	113	36	23	25	11	42.17	0.374
1.5825	-	01/08/2004	15:00	550.40	138	37	24	26	11	42.17	0.306

Table C.2. Measured and Calculated Data for 02/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	-	02/08/2004	11:00	556.32	139	35	25	27	8	36.80	0.265
1.899	-	02/08/2004	11:10	515.36	129	35	25	27	8	36.80	0.286
1.899	-	02/08/2004	11:20	534.56	134	34	25	27	7	32.20	0.241
1.899	-	02/08/2004	11:30	580.64	145	36	26	28	8	36.80	0.254
1.899	-	02/08/2004	11:40	480.48	120	33	24	26	7	32.20	0.268
1.899	-	02/08/2004	11:50	403.52	101	30	23	25	5	23.00	0.228
1.899	-	02/08/2004	12:00	346.88	87	26	20	22	4	18.40	0.212
1.899	-	02/08/2004	12:10	556.00	139	36	25	27	9	41.40	0.298
1.899	-	02/08/2004	12:20	739.20	185	48	33	35	13	59.80	0.324
1.899	-	02/08/2004	12:30	644.80	161	41	29	31	10	46.00	0.285
1.899	-	02/08/2004	12:40	656.00	164	42	29	31	11	50.60	0.309
1.899	-	02/08/2004	12:50	676.00	169	43	30	32	11	50.60	0.299
1.899	-	02/08/2004	13:00	679.20	170	44	30	32	12	55.20	0.325
1.899	-	02/08/2004	13:10	732.00	183	47	32	34	13	59.80	0.327
1.899	-	02/08/2004	13:20	750.40	188	48	33	35	13	59.80	0.319
1.899	-	02/08/2004	13:30	756.40	189	49	33	35	14	64.40	0.341
1.899	-	02/08/2004	13:40	515.20	129	33	23	25	8	36.80	0.286
1.899	-	02/08/2004	13:50	450.40	113	29	20	22	7	32.20	0.286
1.899	-	02/08/2004	14:00	516.80	129	33	23	25	8	36.80	0.285
1.899	-	02/08/2004	14:10	754.20	189	48	33	35	13	59.80	0.317
1.899	-	02/08/2004	14:20	745.60	186	48	33	35	13	59.80	0.321
1.899	-	02/08/2004	14:30	744.80	186	48	33	35	13	59.80	0.321
1.899	-	02/08/2004	14:40	504.32	126	32	22	24	8	36.80	0.292
1.899	-	02/08/2004	14:50	488.16	122	34	24	26	8	36.80	0.302
1.899	-	02/08/2004	15:00	392.00	98	29	22	24	5	23.00	0.235

Table C.3. Measured and Calculated Data for 03/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	-	03/08/2004	11:00	539.20	135	35	24	26	9	41.40	0.307
1.899	-	03/08/2004	11:10	549.60	137	35	24	26	9	41.40	0.301
1.899	-	03/08/2004	11:20	557.60	139	36	25	27	9	41.40	0.297
1.899	-	03/08/2004	11:30	568.80	142	37	25	27	10	46.00	0.324
1.899	-	03/08/2004	11:40	579.20	145	37	26	28	9	41.40	0.286
1.899	-	03/08/2004	11:50	589.60	147	38	26	28	10	46.00	0.312
1.899	-	03/08/2004	12:00	598.40	150	38	27	29	9	41.40	0.277
1.899	-	03/08/2004	12:10	604.00	151	39	27	29	10	46.00	0.305
1.899	-	03/08/2004	12:20	615.20	154	40	27	29	11	50.60	0.329
1.899	-	03/08/2004	12:30	618.40	155	40	27	29	11	50.60	0.327
1.899	-	03/08/2004	12:40	620.80	155	40	27	29	11	50.60	0.326
1.899	-	03/08/2004	12:50	624.00	156	40	28	30	10	46.00	0.295
1.899	-	03/08/2004	13:00	625.60	156	40	28	30	10	46.00	0.294
1.899	-	03/08/2004	13:10	628.80	157	40	28	30	10	46.00	0.293
1.899	-	03/08/2004	13:20	626.40	157	40	28	30	10	46.00	0.294
1.899	-	03/08/2004	13:30	624.00	156	40	28	30	10	46.00	0.295
1.899	-	03/08/2004	13:40	622.40	156	40	28	30	10	46.00	0.296
1.899	-	03/08/2004	13:50	619.20	155	40	27	29	11	50.60	0.327
1.899	-	03/08/2004	14:00	619.20	155	40	27	29	11	50.60	0.327
1.899	-	03/08/2004	14:10	614.40	154	39	27	29	10	46.00	0.299
1.899	-	03/08/2004	14:20	612.80	153	39	27	29	10	46.00	0.300
1.899	-	03/08/2004	14:30	603.20	151	39	27	29	10	46.00	0.305
1.899	-	03/08/2004	14:40	598.40	150	38	27	29	9	41.40	0.277
1.899	-	03/08/2004	14:50	586.40	147	38	26	28	10	46.00	0.314
1.899	-	03/08/2004	15:00	577.60	144	37	26	28	9	41.40	0.287

Table C.4. Measured and Calculated Data for 04/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	+	04/08/2004	11:00	543.20	136	35	24	26	9	46.00	0.339
1.899	+	04/08/2004	11:10	556.00	139	36	25	27	9	46.00	0.331
1.899	+	04/08/2004	11:20	569.60	142	37	25	27	10	51.11	0.359
1.899	+	04/08/2004	11:30	579.20	145	37	26	28	9	46.00	0.318
1.899	+	04/08/2004	11:40	590.40	148	38	26	28	10	51.11	0.346
1.899	+	04/08/2004	11:50	598.40	150	38	27	29	9	46.00	0.308
1.899	+	04/08/2004	12:00	605.60	151	39	27	29	10	51.11	0.338
1.899	+	04/08/2004	12:10	613.60	153	39	27	29	10	51.11	0.333
1.899	+	04/08/2004	12:20	620.80	155	40	27	29	11	56.23	0.362
1.899	+	04/08/2004	12:30	625.60	156	40	28	30	10	51.11	0.327
1.899	+	04/08/2004	12:40	629.60	157	40	28	30	10	51.11	0.325
1.899	+	04/08/2004	12:50	630.40	158	41	28	30	11	56.23	0.357
1.899	+	04/08/2004	13:00	632.00	158	41	28	30	11	56.23	0.356
1.899	+	04/08/2004	13:10	633.60	158	41	28	30	11	56.23	0.355
1.899	+	04/08/2004	13:20	631.20	158	41	28	30	11	56.23	0.356
1.899	+	04/08/2004	13:30	631.20	158	41	28	30	11	56.23	0.356
1.899	+	04/08/2004	13:40	628.00	157	40	28	30	10	51.11	0.326
1.899	+	04/08/2004	13:50	622.40	156	40	28	30	10	51.11	0.328
1.899	+	04/08/2004	14:00	620.00	155	40	27	29	11	56.23	0.363
1.899	+	04/08/2004	14:10	616.80	154	40	27	29	11	56.23	0.365
1.899	+	04/08/2004	14:20	609.60	152	39	27	29	10	51.11	0.335
1.899	+	04/08/2004	14:30	601.60	150	39	27	29	10	51.11	0.340
1.899	+	04/08/2004	14:40	595.20	149	38	26	28	10	51.11	0.344
1.899	+	04/08/2004	14:50	585.60	146	38	26	28	10	51.11	0.349
1.899	+	04/08/2004	15:00	576.00	144	37	26	28	9	46.00	0.319

Table C.5. Measured and Calculated Data for 05/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	-	05/08/2004	11:00	533.60	133	34	24	26	8	36.80	0.276
1.899	-	05/08/2004	11:10	546.40	137	35	24	26	9	41.40	0.303
1.899	-	05/08/2004	11:20	558.40	140	36	25	27	9	41.40	0.297
1.899	-	05/08/2004	11:30	570.40	143	37	25	27	10	46.00	0.323
1.899	-	05/08/2004	11:40	579.20	145	37	26	28	9	41.40	0.286
1.899	-	05/08/2004	11:50	588.00	147	38	26	28	10	46.00	0.313
1.899	-	05/08/2004	12:00	595.20	149	38	26	28	10	46.00	0.309
1.899	-	05/08/2004	12:10	603.20	151	39	27	29	10	46.00	0.305
1.899	-	05/08/2004	12:20	609.60	152	39	27	29	10	46.00	0.302
1.899	-	05/08/2004	12:30	615.20	154	40	27	29	11	50.60	0.329
1.899	-	05/08/2004	12:40	619.20	155	40	27	29	11	50.60	0.327
1.899	-	05/08/2004	12:50	622.40	156	40	28	30	10	46.00	0.296
1.899	-	05/08/2004	13:00	624.80	156	40	28	30	10	46.00	0.295
1.899	-	05/08/2004	13:10	627.20	157	40	28	30	10	46.00	0.293
1.899	-	05/08/2004	13:20	627.20	157	40	28	30	10	46.00	0.293
1.899	-	05/08/2004	13:30	626.40	157	40	28	30	10	46.00	0.294
1.899	-	05/08/2004	13:40	621.60	155	40	28	30	10	46.00	0.296
1.899	-	05/08/2004	13:50	623.20	156	40	28	30	10	46.00	0.295
1.899	-	05/08/2004	14:00	612.80	153	39	27	29	10	46.00	0.300
1.899	-	05/08/2004	14:10	612.80	153	39	27	29	10	46.00	0.300
1.899	-	05/08/2004	14:20	606.40	152	39	27	29	10	46.00	0.303
1.899	-	05/08/2004	14:30	604.00	151	39	27	29	10	46.00	0.305
1.899	-	05/08/2004	14:40	589.60	147	38	26	28	10	46.00	0.312
1.899	-	05/08/2004	14:50	576.80	144	37	26	28	9	41.40	0.287
1.899	-	05/08/2004	15:00	567.20	142	36	25	27	9	41.40	0.292

Table C.6. Measured and Calculated Data for 06/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	+	06/08/2004	11:00	540.00	135	35	24	26	9	46.00	0.341
1.899	+	06/08/2004	11:10	548.80	137	35	24	26	9	46.00	0.335
1.899	+	06/08/2004	11:20	560.80	140	36	25	27	9	46.00	0.328
1.899	+	06/08/2004	11:30	570.40	143	37	25	27	10	51.11	0.358
1.899	+	06/08/2004	11:40	589.60	147	38	26	28	10	51.11	0.347
1.899	+	06/08/2004	11:50	584.80	146	38	26	28	10	51.11	0.350
1.899	+	06/08/2004	12:00	602.40	151	39	27	29	10	51.11	0.339
1.899	+	06/08/2004	12:10	623.20	156	40	28	30	10	51.11	0.328
1.899	+	06/08/2004	12:20	623.20	156	40	28	30	10	51.11	0.328
1.899	+	06/08/2004	12:30	622.40	156	40	28	30	10	51.11	0.328
1.899	+	06/08/2004	12:40	618.40	155	40	27	29	11	56.23	0.364
1.899	+	06/08/2004	12:50	622.40	156	40	28	30	10	51.11	0.328
1.899	+	06/08/2004	13:00	625.60	156	40	28	30	10	51.11	0.327
1.899	+	06/08/2004	13:10	622.40	156	40	28	30	10	51.11	0.328
1.899	+	06/08/2004	13:20	621.60	155	40	28	30	10	51.11	0.329
1.899	+	06/08/2004	13:30	620.80	155	40	27	29	11	56.23	0.362
1.899	+	06/08/2004	13:40	621.60	155	40	28	30	10	51.11	0.329
1.899	+	06/08/2004	13:50	625.60	156	40	28	30	10	51.11	0.327
1.899	+	06/08/2004	14:00	615.20	154	40	27	29	11	56.23	0.366
1.899	+	06/08/2004	14:10	609.60	152	39	27	29	10	51.11	0.335
1.899	+	06/08/2004	14:20	606.40	152	39	27	29	10	51.11	0.337
1.899	+	06/08/2004	14:30	600.80	150	39	27	29	10	51.11	0.340
1.899	+	06/08/2004	14:40	597.60	149	38	26	28	10	51.11	0.342
1.899	+	06/08/2004	14:50	589.60	147	38	26	28	10	51.11	0.347
1.899	+	06/08/2004	15:00	579.20	145	37	26	28	9	46.00	0.318

Table C.7. Measured and Calculated Data for 07/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	+	07/08/2004	11:00	526.40	132	34	23	25	9	46.00	0.350
1.899	+	07/08/2004	11:10	539.20	135	35	24	26	9	46.00	0.341
1.899	+	07/08/2004	11:20	548.80	137	35	24	26	9	46.00	0.335
1.899	+	07/08/2004	11:30	558.40	140	36	25	27	9	46.00	0.330
1.899	+	07/08/2004	11:40	569.60	142	37	25	27	10	51.11	0.359
1.899	+	07/08/2004	11:50	578.40	145	37	26	28	9	46.00	0.318
1.899	+	07/08/2004	12:00	584.00	146	38	26	28	10	51.11	0.350
1.899	+	07/08/2004	12:10	591.20	148	38	26	28	10	51.11	0.346
1.899	+	07/08/2004	12:20	597.60	149	38	26	28	10	51.11	0.342
1.899	+	07/08/2004	12:30	601.60	150	39	27	29	10	51.11	0.340
1.899	+	07/08/2004	12:40	604.80	151	39	27	29	10	51.11	0.338
1.899	+	07/08/2004	12:50	608.80	152	39	27	29	10	51.11	0.336
1.899	+	07/08/2004	13:00	609.60	152	39	27	29	10	51.11	0.335
1.899	+	07/08/2004	13:10	611.20	153	39	27	29	10	51.11	0.335
1.899	+	07/08/2004	13:20	610.40	153	39	27	29	10	51.11	0.335
1.899	+	07/08/2004	13:30	611.20	153	39	27	29	10	51.11	0.335
1.899	+	07/08/2004	13:40	612.00	153	39	27	29	10	51.11	0.334
1.899	+	07/08/2004	13:50	608.00	152	39	27	29	10	51.11	0.336
1.899	+	07/08/2004	14:00	603.20	151	39	27	29	10	51.11	0.339
1.899	+	07/08/2004	14:10	600.80	150	39	27	29	10	51.11	0.340
1.899	+	07/08/2004	14:20	592.80	148	38	26	28	10	51.11	0.345
1.899	+	07/08/2004	14:30	588.00	147	38	26	28	10	51.11	0.348
1.899	+	07/08/2004	14:40	580.00	145	37	26	28	9	46.00	0.317
1.899	+	07/08/2004	14:50	572.80	143	37	25	27	10	51.11	0.357
1.899	+	07/08/2004	15:00	562.40	141	36	25	27	9	46.00	0.327

Table C.8. Measured and Calculated Data for 08/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	+	08/08/2004	11:00	583.20	146	37	26	28	9	46.00	0.316
1.899	+	08/08/2004	11:10	543.20	136	35	24	26	9	46.00	0.339
1.899	+	08/08/2004	11:20	519.20	130	33	23	25	8	40.89	0.315
1.899	+	08/08/2004	11:30	576.00	144	37	26	28	9	46.00	0.319
1.899	+	08/08/2004	11:40	580.00	145	37	26	28	9	46.00	0.317
1.899	+	08/08/2004	11:50	580.80	145	37	26	28	9	46.00	0.317
1.899	+	08/08/2004	12:00	585.60	146	38	26	28	10	51.11	0.349
1.899	+	08/08/2004	12:10	596.00	149	38	26	28	10	51.11	0.343
1.899	+	08/08/2004	12:20	616.00	154	40	27	29	11	56.23	0.365
1.899	+	08/08/2004	12:30	606.40	152	39	27	29	10	51.11	0.337
1.899	+	08/08/2004	12:40	627.20	157	40	28	30	10	51.11	0.326
1.899	+	08/08/2004	12:50	570.40	143	37	25	27	10	51.11	0.358
1.899	+	08/08/2004	13:00	600.80	150	39	27	29	10	51.11	0.340
1.899	+	08/08/2004	13:10	633.60	158	41	28	30	11	56.23	0.355
1.899	+	08/08/2004	13:20	672.80	168	43	30	32	11	56.23	0.334
1.899	+	08/08/2004	13:30	651.20	163	42	29	31	11	56.23	0.345
1.899	+	08/08/2004	13:40	665.60	166	43	29	31	12	61.34	0.369
1.899	+	08/08/2004	13:50	636.80	159	41	28	30	11	56.23	0.353
1.899	+	08/08/2004	14:00	613.60	153	39	27	29	10	51.11	0.333
1.899	+	08/08/2004	14:10	595.20	149	38	26	28	10	51.11	0.344
1.899	+	08/08/2004	14:20	564.00	141	36	25	27	9	46.00	0.326
1.899	+	08/08/2004	14:30	591.20	148	38	26	28	10	51.11	0.346
1.899	+	08/08/2004	14:40	585.60	146	38	26	28	10	51.11	0.349
1.899	+	08/08/2004	14:50	612.00	153	39	27	29	10	51.11	0.334
1.899	+	08/08/2004	15:00	585.60	146	38	26	28	10	51.11	0.349

Table C.9. Measured and Calculated Data for 09/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	-	09/08/2004	11:00	508.80	127	33	23	25	8	36.80	0.289
1.899	-	09/08/2004	11:10	640.00	160	41	28	30	11	50.60	0.316
1.899	-	09/08/2004	11:20	652.80	163	42	29	31	11	50.60	0.310
1.899	-	09/08/2004	11:30	586.40	147	38	26	28	10	46.00	0.314
1.899	-	09/08/2004	11:40	581.60	145	37	26	28	9	41.40	0.285
1.899	-	09/08/2004	11:50	592.00	148	38	26	28	10	46.00	0.311
1.899	-	09/08/2004	12:00	660.00	165	42	29	31	11	50.60	0.307
1.899	-	09/08/2004	12:10	704.00	176	45	31	33	12	55.20	0.314
1.899	-	09/08/2004	12:20	590.40	148	38	26	28	10	46.00	0.312
1.899	-	09/08/2004	12:30	552.00	138	35	24	26	9	41.40	0.300
1.899	-	09/08/2004	12:40	420.00	105	27	21	23	4	18.40	0.175
1.899	-	09/08/2004	12:50	381.60	95	27	20	22	5	23.00	0.241
1.899	-	09/08/2004	13:00	384.80	96	27	20	22	5	23.00	0.239
1.899	-	09/08/2004	13:10	392.96	98	27	20	22	5	23.00	0.234
1.899	-	09/08/2004	13:20	485.12	121	31	21	23	8	36.80	0.303
1.899	-	09/08/2004	13:30	498.40	125	33	22	24	9	41.40	0.332
1.899	-	09/08/2004	13:40	419.20	105	27	20	22	5	23.00	0.219
1.899	-	09/08/2004	13:50	435.20	109	28	21	23	5	23.00	0.211
1.899	-	09/08/2004	14:00	376.80	94	26	20	22	4	18.40	0.195
1.899	-	09/08/2004	14:10	422.40	106	27	21	23	4	18.40	0.174
1.899	-	09/08/2004	14:20	377.60	94	26	20	22	4	18.40	0.195
1.899	-	09/08/2004	14:30	449.28	112	29	20	22	7	32.20	0.287
1.899	-	09/08/2004	14:40	375.20	94	26	20	22	4	18.40	0.196
1.899	-	09/08/2004	14:50	448.80	112	28	21	23	5	23.00	0.205
1.899	-	09/08/2004	15:00	506.88	127	33	22	24	9	41.40	0.327

Table C.10. Measured and Calculated Data for 10/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	+	10/08/2004	11:00	570.40	143	37	25	27	10	51.11	0.358
1.899	+	10/08/2004	11:10	583.20	146	37	26	28	9	46.00	0.316
1.899	+	10/08/2004	11:20	594.40	149	38	26	28	10	51.11	0.344
1.899	+	10/08/2004	11:30	604.00	151	39	27	29	10	51.11	0.339
1.899	+	10/08/2004	11:40	612.80	153	39	27	29	10	51.11	0.334
1.899	+	10/08/2004	11:50	623.20	156	40	28	30	10	51.11	0.328
1.899	+	10/08/2004	12:00	628.00	157	40	28	30	10	51.11	0.326
1.899	+	10/08/2004	12:10	637.60	159	41	28	30	11	56.23	0.353
1.899	+	10/08/2004	12:20	643.20	161	41	28	30	11	56.23	0.350
1.899	+	10/08/2004	12:30	648.80	162	42	29	31	11	56.23	0.347
1.899	+	10/08/2004	12:40	651.20	163	42	29	31	11	56.23	0.345
1.899	+	10/08/2004	12:50	653.60	163	42	29	31	11	56.23	0.344
1.899	+	10/08/2004	13:00	654.40	164	42	29	31	11	56.23	0.344
1.899	+	10/08/2004	13:10	655.20	164	42	29	31	11	56.23	0.343
1.899	+	10/08/2004	13:20	656.00	164	42	29	31	11	56.23	0.343
1.899	+	10/08/2004	13:30	655.20	164	42	29	31	11	56.23	0.343
1.899	+	10/08/2004	13:40	652.80	163	42	29	31	11	56.23	0.345
1.899	+	10/08/2004	13:50	648.80	162	42	29	31	11	56.23	0.347
1.899	+	10/08/2004	14:00	643.20	161	41	28	30	11	56.23	0.350
1.899	+	10/08/2004	14:10	640.00	160	41	28	30	11	56.23	0.351
1.899	+	10/08/2004	14:20	633.60	158	41	28	30	11	56.23	0.355
1.899	+	10/08/2004	14:30	624.80	156	40	28	30	10	51.11	0.327
1.899	+	10/08/2004	14:40	616.00	154	40	27	29	11	56.23	0.365
1.899	+	10/08/2004	14:50	607.20	152	39	27	29	10	51.11	0.337
1.899	+	10/08/2004	15:00	597.60	149	38	26	28	10	51.11	0.342

Table C.11. Measured and Calculated Data for 11/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	+	11/08/2004	11:00	556.00	139	36	25	27	9	46.00	0.331
1.899	+	11/08/2004	11:10	566.40	142	36	25	27	9	46.00	0.325
1.899	+	11/08/2004	11:20	579.20	145	37	26	28	9	46.00	0.318
1.899	+	11/08/2004	11:30	590.40	148	38	26	28	10	51.11	0.346
1.899	+	11/08/2004	11:40	600.80	150	39	27	29	10	51.11	0.340
1.899	+	11/08/2004	11:50	607.20	152	39	27	29	10	51.11	0.337
1.899	+	11/08/2004	12:00	616.80	154	40	27	29	11	56.23	0.365
1.899	+	11/08/2004	12:10	624.00	156	40	28	30	10	51.11	0.328
1.899	+	11/08/2004	12:20	628.80	157	40	28	30	10	51.11	0.325
1.899	+	11/08/2004	12:30	632.00	158	41	28	30	11	56.23	0.356
1.899	+	11/08/2004	12:40	636.80	159	41	28	30	11	56.23	0.353
1.899	+	11/08/2004	12:50	640.80	160	41	28	30	11	56.23	0.351
1.899	+	11/08/2004	13:00	643.20	161	41	28	30	11	56.23	0.350
1.899	+	11/08/2004	13:10	644.80	161	41	29	31	10	51.11	0.317
1.899	+	11/08/2004	13:20	644.80	161	41	29	31	10	51.11	0.317
1.899	+	11/08/2004	13:30	644.80	161	41	29	31	10	51.11	0.317
1.899	+	11/08/2004	13:40	640.00	160	41	28	30	11	56.23	0.351
1.899	+	11/08/2004	13:50	638.40	160	41	28	30	11	56.23	0.352
1.899	+	11/08/2004	14:00	636.80	159	41	28	30	11	56.23	0.353
1.899	+	11/08/2004	14:10	630.40	158	41	28	30	11	56.23	0.357
1.899	+	11/08/2004	14:20	624.00	156	40	28	30	10	51.11	0.328
1.899	+	11/08/2004	14:30	619.20	155	40	27	29	11	56.23	0.363
1.899	+	11/08/2004	14:40	608.00	152	39	27	29	10	51.11	0.336
1.899	+	11/08/2004	14:50	601.60	150	39	27	29	10	51.11	0.340
1.899	+	11/08/2004	15:00	588.80	147	38	26	28	10	51.11	0.347

Table C.12. Measured and Calculated Data for 12/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	+	12/08/2004	11:00	548.80	137	35	24	26	9	46.00	0.335
1.899	+	12/08/2004	11:10	561.60	140	36	25	27	9	46.00	0.328
1.899	+	12/08/2004	11:20	572.80	143	37	25	27	10	51.11	0.357
1.899	+	12/08/2004	11:30	583.20	146	37	26	28	9	46.00	0.316
1.899	+	12/08/2004	11:40	592.80	148	38	26	28	10	51.11	0.345
1.899	+	12/08/2004	11:50	603.20	151	39	27	29	10	51.11	0.339
1.899	+	12/08/2004	12:00	612.80	153	39	27	29	10	51.11	0.334
1.899	+	12/08/2004	12:10	619.20	155	40	27	29	11	56.23	0.363
1.899	+	12/08/2004	12:20	636.00	159	41	28	30	11	56.23	0.354
1.899	+	12/08/2004	12:30	647.20	162	42	29	31	11	56.23	0.347
1.899	+	12/08/2004	12:40	648.00	162	42	29	31	11	56.23	0.347
1.899	+	12/08/2004	12:50	654.40	164	42	29	31	11	56.23	0.344
1.899	+	12/08/2004	13:00	672.80	168	43	31	33	10	49.07	0.292
1.899	+	12/08/2004	13:10	720.80	180	46	29	31	15	77.18	0.428
1.899	+	12/08/2004	13:20	683.60	171	44	30	32	12	61.34	0.359
1.899	+	12/08/2004	13:30	684.80	171	44	30	32	12	61.34	0.358
1.899	+	12/08/2004	13:40	658.40	165	42	29	31	11	56.23	0.342
1.899	+	12/08/2004	13:50	670.40	168	43	30	32	11	56.23	0.335
1.899	+	12/08/2004	14:00	688.00	172	44	30	32	12	61.34	0.357
1.899	+	12/08/2004	14:10	720.80	180	46	31	33	13	67.98	0.377
1.899	+	12/08/2004	14:20	676.00	169	43	30	32	11	56.23	0.333
1.899	+	12/08/2004	14:30	648.80	162	42	29	31	11	56.23	0.347
1.899	+	12/08/2004	14:40	650.40	163	42	29	31	11	56.23	0.346
1.899	+	12/08/2004	14:50	648.80	162	42	29	31	11	56.23	0.347
1.899	+	12/08/2004	15:00	628.00	157	40	28	30	10	51.11	0.326

Table C.13. Measured and Calculated Data for 13/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	+	13/08/2004	11:00	543.20	136	35	24	26	9	46.00	0.339
1.899	+	13/08/2004	11:10	555.20	139	36	25	27	9	46.00	0.331
1.899	+	13/08/2004	11:20	567.20	142	36	25	27	9	46.00	0.324
1.899	+	13/08/2004	11:30	575.20	144	37	25	27	10	51.11	0.355
1.899	+	13/08/2004	11:40	583.20	146	37	26	28	9	46.00	0.316
1.899	+	13/08/2004	11:50	592.00	148	38	26	28	10	51.11	0.345
1.899	+	13/08/2004	12:00	600.80	150	39	27	29	10	51.11	0.340
1.899	+	13/08/2004	12:10	607.20	152	39	27	29	10	51.11	0.337
1.899	+	13/08/2004	12:20	614.40	154	39	27	29	10	51.11	0.333
1.899	+	13/08/2004	12:30	618.40	155	40	27	29	11	56.23	0.364
1.899	+	13/08/2004	12:40	625.60	156	40	28	30	10	51.11	0.327
1.899	+	13/08/2004	12:50	632.00	158	41	28	30	11	56.23	0.356
1.899	+	13/08/2004	13:00	634.40	159	41	28	30	11	56.23	0.355
1.899	+	13/08/2004	13:10	636.80	159	41	28	30	11	56.23	0.353
1.899	+	13/08/2004	13:20	636.80	159	41	28	30	11	56.23	0.353
1.899	+	13/08/2004	13:30	637.60	159	41	28	30	11	56.23	0.353
1.899	+	13/08/2004	13:40	635.20	159	41	28	30	11	56.23	0.354
1.899	+	13/08/2004	13:50	630.40	158	41	28	30	11	56.23	0.357
1.899	+	13/08/2004	14:00	625.60	156	40	28	30	10	51.11	0.327
1.899	+	13/08/2004	14:10	620.80	155	40	27	29	11	56.23	0.362
1.899	+	13/08/2004	14:20	612.80	153	39	27	29	10	51.11	0.334
1.899	+	13/08/2004	14:30	603.20	151	39	27	29	10	51.11	0.339
1.899	+	13/08/2004	14:40	596.80	149	38	26	28	10	51.11	0.343
1.899	+	13/08/2004	14:50	585.60	146	38	26	28	10	51.11	0.349
1.899	+	13/08/2004	15:00	576.00	144	37	26	28	9	46.00	0.319

Table C.14. Measured and Calculated Data for 14/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	+	14/08/2004	11:00	536.80	134	35	24	26	9	46.00	0.343
1.899	+	14/08/2004	11:10	557.60	139	36	25	27	9	46.00	0.330
1.899	+	14/08/2004	11:20	576.00	144	37	26	28	9	46.00	0.319
1.899	+	14/08/2004	11:30	586.40	147	38	26	28	10	51.11	0.349
1.899	+	14/08/2004	11:40	607.20	152	39	27	29	10	51.11	0.337
1.899	+	14/08/2004	11:50	615.20	154	40	27	29	11	56.23	0.366
1.899	+	14/08/2004	12:00	628.00	157	40	28	30	10	51.11	0.326
1.899	+	14/08/2004	12:10	612.80	153	39	27	29	10	51.11	0.334
1.899	+	14/08/2004	12:20	628.80	157	40	28	30	10	51.11	0.325
1.899	+	14/08/2004	12:30	624.00	156	40	28	30	10	51.11	0.328
1.899	+	14/08/2004	12:40	629.60	157	40	28	30	10	51.11	0.325
1.899	+	14/08/2004	12:50	648.80	162	42	29	31	11	56.23	0.347
1.899	+	14/08/2004	13:00	668.00	167	43	30	32	11	56.23	0.337
1.899	+	14/08/2004	13:10	660.00	165	42	29	31	11	56.23	0.341
1.899	+	14/08/2004	13:20	672.80	168	43	30	32	11	56.23	0.334
1.899	+	14/08/2004	13:30	668.00	167	43	30	32	11	56.23	0.337
1.899	+	14/08/2004	13:40	665.60	166	43	29	31	12	61.34	0.369
1.899	+	14/08/2004	13:50	641.60	160	41	28	30	11	56.23	0.351
1.899	+	14/08/2004	14:00	633.60	158	41	28	30	11	56.23	0.355
1.899	+	14/08/2004	14:10	624.80	156	40	28	30	10	51.11	0.327
1.899	+	14/08/2004	14:20	615.20	154	40	27	29	11	56.23	0.366
1.899	+	14/08/2004	14:30	604.00	151	39	27	29	10	51.11	0.339
1.899	+	14/08/2004	14:40	597.60	149	38	26	28	10	51.11	0.342
1.899	+	14/08/2004	14:50	595.20	149	38	26	28	10	51.11	0.344
1.899	+	14/08/2004	15:00	608.80	152	39	27	29	10	51.11	0.336

Table C.15. Measured and Calculated Data for 15/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	+	15/08/2004	11:00	538.40	135	35	24	26	9	46.00	0.342
1.899	+	15/08/2004	11:10	544.80	136	35	24	26	9	46.00	0.338
1.899	+	15/08/2004	11:20	552.80	138	36	24	26	10	51.11	0.370
1.899	+	15/08/2004	11:30	565.60	141	36	25	27	9	46.00	0.325
1.899	+	15/08/2004	11:40	572.80	143	37	25	27	10	51.11	0.357
1.899	+	15/08/2004	11:50	606.40	152	39	27	29	10	51.11	0.337
1.899	+	15/08/2004	12:00	606.40	152	39	27	29	10	51.11	0.337
1.899	+	15/08/2004	12:10	654.40	164	42	29	31	11	56.23	0.344
1.899	+	15/08/2004	12:20	650.40	163	42	29	31	11	56.23	0.346
1.899	+	15/08/2004	12:30	684.00	171	44	30	32	12	61.34	0.359
1.899	+	15/08/2004	12:40	674.40	169	43	30	32	11	56.23	0.333
1.899	+	15/08/2004	12:50	677.60	169	44	30	32	12	61.34	0.362
1.899	+	15/08/2004	13:00	675.20	169	43	30	32	11	56.23	0.333
1.899	+	15/08/2004	13:10	681.60	170	44	30	32	12	61.34	0.360
1.899	+	15/08/2004	13:20	642.40	161	41	28	30	11	56.23	0.350
1.899	+	15/08/2004	13:30	633.60	158	41	28	30	11	56.23	0.355
1.899	+	15/08/2004	13:40	640.00	160	41	28	30	11	56.23	0.351
1.899	+	15/08/2004	13:50	640.00	160	41	28	30	11	56.23	0.351
1.899	+	15/08/2004	14:00	659.20	165	42	29	31	11	56.23	0.341
1.899	+	15/08/2004	14:10	674.40	169	43	30	32	11	56.23	0.333
1.899	+	15/08/2004	14:20	656.00	164	42	29	31	11	56.23	0.343
1.899	+	15/08/2004	14:30	630.40	158	41	28	30	11	56.23	0.357
1.899	+	15/08/2004	14:40	624.00	156	40	28	30	10	51.11	0.328
1.899	+	15/08/2004	14:50	590.40	148	38	26	28	10	51.11	0.346
1.899	+	15/08/2004	15:00	568.00	142	37	25	27	10	51.11	0.360

Table C.16. Measured and Calculated Data for 16/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	-	16/08/2004	11:00	527.20	132	38	23	25	13	39.87	0.302
1.266	-	16/08/2004	11:10	536.80	134	38	24	26	12	36.80	0.274
1.266	-	16/08/2004	11:20	548.80	137	39	24	26	13	39.87	0.291
1.266	-	16/08/2004	11:30	556.80	139	40	25	27	13	39.87	0.286
1.266	-	16/08/2004	11:40	567.20	142	41	25	27	14	42.94	0.303
1.266	-	16/08/2004	11:50	572.80	143	41	25	27	14	42.94	0.300
1.266	-	16/08/2004	12:00	582.40	146	42	26	28	14	42.94	0.295
1.266	-	16/08/2004	12:10	592.00	148	42	26	28	14	42.94	0.290
1.266	-	16/08/2004	12:20	597.60	149	43	26	28	15	46.00	0.308
1.266	-	16/08/2004	12:30	606.40	152	43	27	29	14	42.94	0.283
1.266	-	16/08/2004	12:40	629.60	157	45	28	30	15	46.00	0.292
1.266	-	16/08/2004	12:50	635.20	159	45	28	30	15	46.00	0.290
1.266	-	16/08/2004	13:00	643.20	161	46	28	30	16	49.07	0.305
1.266	-	16/08/2004	13:10	628.00	157	45	28	30	15	46.00	0.293
1.266	-	16/08/2004	13:20	631.20	158	45	28	30	15	46.00	0.292
1.266	-	16/08/2004	13:30	629.60	157	45	28	30	15	46.00	0.292
1.266	-	16/08/2004	13:40	635.20	159	45	28	30	15	46.00	0.290
1.266	-	16/08/2004	13:50	642.40	161	46	28	30	16	49.07	0.306
1.266	-	16/08/2004	14:00	636.80	159	45	28	30	15	46.00	0.289
1.266	-	16/08/2004	14:10	642.40	161	46	28	30	16	49.07	0.306
1.266	-	16/08/2004	14:20	633.60	158	45	28	30	15	46.00	0.290
1.266	-	16/08/2004	14:30	611.20	153	44	27	29	15	46.00	0.301
1.266	-	16/08/2004	14:40	624.00	156	45	28	30	15	46.00	0.295
1.266	-	16/08/2004	14:50	617.60	154	44	27	29	15	46.00	0.298
1.266	-	16/08/2004	15:00	612.80	153	44	27	29	15	46.00	0.300

Table C.17. Measured and Calculated Data for 17/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	-	17/08/2004	11:00	587.20	147	42	26	28	14	42.94	0.292
1.266	-	17/08/2004	11:10	643.20	161	46	28	30	16	49.07	0.305
1.266	-	17/08/2004	11:20	580.00	145	41	26	28	13	39.87	0.275
1.266	-	17/08/2004	11:30	570.40	143	41	25	27	14	42.94	0.301
1.266	-	17/08/2004	11:40	623.20	156	45	28	30	15	46.00	0.295
1.266	-	17/08/2004	11:50	648.00	162	46	29	31	15	46.00	0.284
1.266	-	17/08/2004	12:00	680.00	170	49	30	32	17	52.14	0.307
1.266	-	17/08/2004	12:10	706.40	177	50	31	33	17	52.14	0.295
1.266	-	17/08/2004	12:20	680.80	170	49	30	32	17	52.14	0.306
1.266	-	17/08/2004	12:30	667.20	167	48	30	32	16	49.07	0.294
1.266	-	17/08/2004	12:40	644.80	161	46	29	31	15	46.00	0.285
1.266	-	17/08/2004	12:50	659.20	165	47	29	31	16	49.07	0.298
1.266	-	17/08/2004	13:00	651.20	163	47	29	31	16	49.07	0.301
1.266	-	17/08/2004	13:10	640.80	160	46	28	30	16	49.07	0.306
1.266	-	17/08/2004	13:20	645.60	161	46	29	31	15	46.00	0.285
1.266	-	17/08/2004	13:30	634.40	159	45	28	30	15	46.00	0.290
1.266	-	17/08/2004	13:40	640.80	160	46	28	30	16	49.07	0.306
1.266	-	17/08/2004	13:50	638.40	160	46	28	30	16	49.07	0.307
1.266	-	17/08/2004	14:00	633.60	158	45	28	30	15	46.00	0.290
1.266	-	17/08/2004	14:10	629.60	157	45	28	30	15	46.00	0.292
1.266	-	17/08/2004	14:20	656.00	164	47	29	31	16	49.07	0.299
1.266	-	17/08/2004	14:30	619.20	155	44	27	29	15	46.00	0.297
1.266	-	17/08/2004	14:40	579.20	145	41	26	28	13	39.87	0.275
1.266	-	17/08/2004	14:50	557.60	139	40	25	27	13	39.87	0.286
1.266	-	17/08/2004	15:00	589.60	147	42	26	28	14	42.94	0.291

Table C.18. Measured and Calculated Data for 18/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	-	18/08/2004	11:00	576.80	144	41	26	28	13	39.87	0.276
1.266	-	18/08/2004	11:10	605.60	151	43	27	29	14	42.94	0.284
1.266	-	18/08/2004	11:20	621.60	155	44	28	30	14	42.94	0.276
1.266	-	18/08/2004	11:30	634.40	159	45	28	30	15	46.00	0.290
1.266	-	18/08/2004	11:40	626.40	157	45	28	30	15	46.00	0.294
1.266	-	18/08/2004	11:50	610.40	153	44	27	29	15	46.00	0.301
1.266	-	18/08/2004	12:00	605.92	151	43	27	29	14	42.94	0.283
1.266	-	18/08/2004	12:10	633.92	158	45	28	30	15	46.00	0.290
1.266	-	18/08/2004	12:20	624.00	156	45	28	30	15	46.00	0.295
1.266	-	18/08/2004	12:30	655.20	164	47	29	31	16	49.07	0.300
1.266	-	18/08/2004	12:40	709.60	177	51	31	33	18	55.20	0.311
1.266	-	18/08/2004	12:50	704.00	176	50	31	33	17	52.14	0.296
1.266	-	18/08/2004	13:00	696.00	174	50	31	33	17	52.14	0.300
1.266	-	18/08/2004	13:10	692.00	173	49	31	33	16	49.07	0.284
1.266	-	18/08/2004	13:20	656.80	164	47	29	31	16	49.07	0.299
1.266	-	18/08/2004	13:30	668.00	167	48	30	32	16	49.07	0.294
1.266	-	18/08/2004	13:40	700.00	175	50	31	33	17	52.14	0.298
1.266	-	18/08/2004	13:50	680.00	170	49	30	32	17	52.14	0.307
1.266	-	18/08/2004	14:00	673.60	168	48	30	32	16	49.07	0.291
1.266	-	18/08/2004	14:10	656.00	164	47	29	31	16	49.07	0.299
1.266	-	18/08/2004	14:20	640.00	160	46	28	30	16	49.07	0.307
1.266	-	18/08/2004	14:30	622.40	156	44	28	30	14	42.94	0.276
1.266	-	18/08/2004	14:40	609.60	152	44	27	29	15	46.00	0.302
1.266	-	18/08/2004	14:50	601.60	150	43	27	29	14	42.94	0.285
1.266	-	18/08/2004	15:00	583.20	146	42	26	28	14	42.94	0.294

Table C.19. Measured and Calculated Data for 19/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	+	19/08/2004	11:10	628.85	157	45	28	30	15	51.11	0.325
1.266	+	19/08/2004	11:20	643.93	161	46	28	30	16	54.52	0.339
1.266	+	19/08/2004	11:30	655.84	164	47	29	31	16	54.52	0.333
1.266	+	19/08/2004	11:40	670.14	168	48	29	31	17	57.93	0.346
1.266	+	19/08/2004	11:50	674.90	169	48	30	32	16	54.52	0.323
1.266	+	19/08/2004	12:00	676.49	169	48	30	32	16	54.52	0.322
1.266	+	19/08/2004	12:10	677.28	169	48	30	32	16	54.52	0.322
1.266	+	19/08/2004	12:20	678.08	170	48	30	32	16	54.52	0.322
1.266	+	19/08/2004	12:30	679.66	170	49	30	32	17	57.93	0.341
1.266	+	19/08/2004	12:40	677.28	169	48	30	32	16	54.52	0.322
1.266	+	19/08/2004	12:50	677.28	169	48	30	32	16	54.52	0.322
1.266	+	19/08/2004	13:00	683.63	171	49	30	32	17	57.93	0.339
1.266	+	19/08/2004	13:10	689.99	172	49	30	32	17	57.93	0.336
1.266	+	19/08/2004	13:20	694.75	174	50	30	32	18	61.34	0.353
1.266	+	19/08/2004	13:30	698.72	175	50	30	32	18	61.34	0.351
1.266	+	19/08/2004	13:40	698.72	175	50	30	32	18	61.34	0.351
1.266	+	19/08/2004	13:50	700.31	175	50	31	33	17	57.93	0.331
1.266	+	19/08/2004	14:00	701.90	175	50	31	33	17	57.93	0.330
1.266	+	19/08/2004	14:10	703.48	176	50	31	33	17	57.93	0.329
1.266	+	19/08/2004	14:20	704.28	176	50	31	33	17	57.93	0.329
1.266	+	19/08/2004	14:30	697.13	174	50	30	32	18	61.34	0.352
1.266	+	19/08/2004	14:40	688.40	172	49	30	32	17	57.93	0.337
1.266	+	19/08/2004	14:50	677.28	169	48	30	32	16	54.52	0.322
1.266	+	19/08/2004	15:00	662.20	166	47	29	31	16	54.52	0.329
1.266	+	19/08/2004	11:10	628.85	157	45	28	30	15	51.11	0.325

Table C.20. Measured and Calculated Data for 20/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	+	20/08/2004	11:00	600.26	150	43	27	29	14	47.71	0.318
1.266	+	20/08/2004	11:10	616.94	154	44	27	29	15	51.11	0.331
1.266	+	20/08/2004	11:20	631.23	158	45	28	30	15	51.11	0.324
1.266	+	20/08/2004	11:30	643.14	161	46	28	30	16	54.52	0.339
1.266	+	20/08/2004	11:40	650.29	163	46	29	31	15	51.11	0.314
1.266	+	20/08/2004	11:50	655.84	164	47	29	31	16	54.52	0.333
1.266	+	20/08/2004	12:00	659.02	165	47	29	31	16	54.52	0.331
1.266	+	20/08/2004	12:10	662.20	166	47	29	31	16	54.52	0.329
1.266	+	20/08/2004	12:20	665.37	166	48	29	31	17	57.93	0.348
1.266	+	20/08/2004	12:30	670.14	168	48	29	31	17	57.93	0.346
1.266	+	20/08/2004	12:40	672.52	168	48	29	31	17	57.93	0.345
1.266	+	20/08/2004	12:50	675.69	169	48	30	32	16	54.52	0.323
1.266	+	20/08/2004	13:00	678.08	170	48	30	32	16	54.52	0.322
1.266	+	20/08/2004	13:10	682.05	171	49	30	32	17	57.93	0.340
1.266	+	20/08/2004	13:20	684.43	171	49	30	32	17	57.93	0.339
1.266	+	20/08/2004	13:30	687.60	172	49	30	32	17	57.93	0.337
1.266	+	20/08/2004	13:40	693.96	173	50	30	32	18	61.34	0.354
1.266	+	20/08/2004	13:50	698.72	175	50	30	32	18	61.34	0.351
1.266	+	20/08/2004	14:00	704.28	176	50	31	33	17	57.93	0.329
1.266	+	20/08/2004	14:10	706.66	177	50	31	33	17	57.93	0.328
1.266	+	20/08/2004	14:20	710.63	178	51	31	33	18	61.34	0.345
1.266	+	20/08/2004	14:30	705.87	176	50	31	33	17	57.93	0.328
1.266	+	20/08/2004	14:40	694.75	174	50	30	32	18	61.34	0.353
1.266	+	20/08/2004	14:50	684.43	171	49	30	32	17	57.93	0.339
1.266	+	20/08/2004	15:00	669.34	167	48	29	31	17	57.93	0.346

Table C.21. Measured and Calculated Data for 21/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	+	21/08/2004	11:00	580.41	145	41	26	28	13	44.30	0.305
1.266	+	21/08/2004	11:10	598.68	150	43	27	29	14	47.71	0.319
1.266	+	21/08/2004	11:20	614.56	154	44	27	29	15	51.11	0.333
1.266	+	21/08/2004	11:30	627.26	157	45	28	30	15	51.11	0.326
1.266	+	21/08/2004	11:40	636.79	159	45	28	30	15	51.11	0.321
1.266	+	21/08/2004	11:50	643.93	161	46	28	30	16	54.52	0.339
1.266	+	21/08/2004	12:00	647.11	162	46	28	30	16	54.52	0.337
1.266	+	21/08/2004	12:10	650.29	163	46	29	31	15	51.11	0.314
1.266	+	21/08/2004	12:20	651.87	163	47	29	31	16	54.52	0.335
1.266	+	21/08/2004	12:30	654.26	164	47	29	31	16	54.52	0.333
1.266	+	21/08/2004	12:40	656.64	164	47	29	31	16	54.52	0.332
1.266	+	21/08/2004	12:50	660.61	165	47	29	31	16	54.52	0.330
1.266	+	21/08/2004	13:00	663.78	166	47	29	31	16	54.52	0.329
1.266	+	21/08/2004	13:10	664.58	166	47	29	31	16	54.52	0.328
1.266	+	21/08/2004	13:20	667.75	167	48	29	31	17	57.93	0.347
1.266	+	21/08/2004	13:30	673.31	168	48	29	31	17	57.93	0.344
1.266	+	21/08/2004	13:40	675.69	169	48	30	32	16	54.52	0.323
1.266	+	21/08/2004	13:50	679.66	170	49	30	32	17	57.93	0.341
1.266	+	21/08/2004	14:00	680.46	170	49	30	32	17	57.93	0.341
1.266	+	21/08/2004	14:10	683.63	171	49	30	32	17	57.93	0.339
1.266	+	21/08/2004	14:20	686.02	172	49	30	32	17	57.93	0.338
1.266	+	21/08/2004	14:30	678.87	170	48	30	32	16	54.52	0.321
1.266	+	21/08/2004	14:40	666.96	167	48	29	31	17	57.93	0.347
1.266	+	21/08/2004	14:50	653.46	163	47	29	31	16	54.52	0.334
1.266	+	21/08/2004	15:00	639.96	160	46	28	30	16	54.52	0.341

Table C.22. Measured and Calculated Data for 22/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	+	22/08/2004	11:00	579.62	145	41	26	28	13	44.30	0.306
1.266	+	22/08/2004	11:10	593.12	148	42	26	28	14	47.71	0.322
1.266	+	22/08/2004	11:20	605.03	151	43	27	29	14	47.71	0.315
1.266	+	22/08/2004	11:30	621.70	155	44	27	29	15	51.11	0.329
1.266	+	22/08/2004	11:40	631.23	158	45	28	30	15	51.11	0.324
1.266	+	22/08/2004	11:50	635.99	159	45	28	30	15	51.11	0.321
1.266	+	22/08/2004	12:00	641.55	160	46	28	30	16	54.52	0.340
1.266	+	22/08/2004	12:10	635.99	159	45	28	30	15	51.11	0.321
1.266	+	22/08/2004	12:20	635.20	159	45	28	30	15	51.11	0.322
1.266	+	22/08/2004	12:30	636.79	159	45	28	30	15	51.11	0.321
1.266	+	22/08/2004	12:40	643.14	161	46	28	30	16	54.52	0.339
1.266	+	22/08/2004	12:50	644.73	161	46	28	30	16	54.52	0.338
1.266	+	22/08/2004	13:00	647.11	162	46	28	30	16	54.52	0.337
1.266	+	22/08/2004	13:10	651.08	163	47	29	31	16	54.52	0.335
1.266	+	22/08/2004	13:20	649.49	162	46	29	31	15	51.11	0.315
1.266	+	22/08/2004	13:30	643.93	161	46	28	30	16	54.52	0.339
1.266	+	22/08/2004	13:40	650.29	163	46	29	31	15	51.11	0.314
1.266	+	22/08/2004	13:50	642.35	161	46	28	30	16	54.52	0.340
1.266	+	22/08/2004	14:00	638.38	160	46	28	30	16	54.52	0.342
1.266	+	22/08/2004	14:10	637.58	159	46	28	30	16	54.52	0.342
1.266	+	22/08/2004	14:20	643.14	161	46	28	30	16	54.52	0.339
1.266	+	22/08/2004	14:30	639.96	160	46	28	30	16	54.52	0.341
1.266	+	22/08/2004	14:40	632.02	158	45	28	30	15	51.11	0.323
1.266	+	22/08/2004	14:50	621.70	155	44	27	29	15	51.11	0.329
1.266	+	22/08/2004	15:00	615.35	154	44	27	29	15	51.11	0.332

Table C.23. Measured and Calculated Data for 23/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	+	23/08/2004	11:00	581.21	145	42	26	28	14	47.71	0.328
1.266	+	23/08/2004	11:10	598.68	150	43	27	29	14	47.71	0.319
1.266	+	23/08/2004	11:20	614.56	154	44	27	29	15	51.11	0.333
1.266	+	23/08/2004	11:30	631.23	158	45	28	30	15	51.11	0.324
1.266	+	23/08/2004	11:40	639.96	160	46	28	30	16	54.52	0.341
1.266	+	23/08/2004	11:50	647.11	162	46	28	30	16	54.52	0.337
1.266	+	23/08/2004	12:00	651.08	163	47	29	31	16	54.52	0.335
1.266	+	23/08/2004	12:10	650.29	163	46	29	31	15	51.11	0.314
1.266	+	23/08/2004	12:20	654.26	164	47	29	31	16	54.52	0.333
1.266	+	23/08/2004	12:30	655.84	164	47	29	31	16	54.52	0.333
1.266	+	23/08/2004	12:40	659.81	165	47	29	31	16	54.52	0.331
1.266	+	23/08/2004	12:50	662.99	166	47	29	31	16	54.52	0.329
1.266	+	23/08/2004	13:00	663.78	166	47	29	31	16	54.52	0.329
1.266	+	23/08/2004	13:10	669.34	167	48	29	31	17	57.93	0.346
1.266	+	23/08/2004	13:20	672.52	168	48	29	31	17	57.93	0.345
1.266	+	23/08/2004	13:30	676.49	169	48	30	32	16	54.52	0.322
1.266	+	23/08/2004	13:40	680.46	170	49	30	32	17	57.93	0.341
1.266	+	23/08/2004	13:50	680.46	170	49	30	32	17	57.93	0.341
1.266	+	23/08/2004	14:00	684.43	171	49	30	32	17	57.93	0.339
1.266	+	23/08/2004	14:10	682.84	171	49	30	32	17	57.93	0.339
1.266	+	23/08/2004	14:20	685.22	171	49	30	32	17	57.93	0.338
1.266	+	23/08/2004	14:30	681.25	170	49	30	32	17	57.93	0.340
1.266	+	23/08/2004	14:40	674.11	169	48	29	31	17	57.93	0.344
1.266	+	23/08/2004	14:50	659.81	165	47	29	31	16	54.52	0.331
1.266	+	23/08/2004	15:00	645.52	161	46	28	30	16	54.52	0.338

Table C.24. Measured and Calculated Data for 24/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	+	24/08/2004	11:00	593.12	148	42	26	28	14	47.71	0.322
1.266	+	24/08/2004	11:10	611.38	153	44	27	29	15	51.11	0.334
1.266	+	24/08/2004	11:20	627.26	157	45	28	30	15	51.11	0.326
1.266	+	24/08/2004	11:30	638.38	160	46	28	30	16	54.52	0.342
1.266	+	24/08/2004	11:40	649.49	162	46	29	31	15	51.11	0.315
1.266	+	24/08/2004	11:50	656.64	164	47	29	31	16	54.52	0.332
1.266	+	24/08/2004	12:00	659.81	165	47	29	31	16	54.52	0.331
1.266	+	24/08/2004	12:10	662.20	166	47	29	31	16	54.52	0.329
1.266	+	24/08/2004	12:20	664.58	166	47	29	31	16	54.52	0.328
1.266	+	24/08/2004	12:30	666.96	167	48	29	31	17	57.93	0.347
1.266	+	24/08/2004	12:40	670.93	168	48	29	31	17	57.93	0.345
1.266	+	24/08/2004	12:50	673.31	168	48	29	31	17	57.93	0.344
1.266	+	24/08/2004	13:00	677.28	169	48	30	32	16	54.52	0.322
1.266	+	24/08/2004	13:10	682.05	171	49	30	32	17	57.93	0.340
1.266	+	24/08/2004	13:20	684.43	171	49	30	32	17	57.93	0.339
1.266	+	24/08/2004	13:30	688.40	172	49	30	32	17	57.93	0.337
1.266	+	24/08/2004	13:40	693.96	173	50	30	32	18	61.34	0.354
1.266	+	24/08/2004	13:50	695.54	174	50	30	32	18	61.34	0.353
1.266	+	24/08/2004	14:00	697.93	174	50	30	32	18	61.34	0.352
1.266	+	24/08/2004	14:10	698.72	175	50	30	32	18	61.34	0.351
1.266	+	24/08/2004	14:20	697.93	174	50	30	32	18	61.34	0.352
1.266	+	24/08/2004	14:30	692.37	173	49	30	32	17	57.93	0.335
1.266	+	24/08/2004	14:40	682.05	171	49	30	32	17	57.93	0.340
1.266	+	24/08/2004	14:50	669.34	167	48	29	31	17	57.93	0.346
1.266	+	24/08/2004	15:00	655.05	164	47	29	31	16	54.52	0.333

Table C.25. Measured and Calculated Data for 25/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	+	25/08/2004	11:00	610.59	153	44	27	29	15	51.11	0.335
1.266	+	25/08/2004	11:10	628.85	157	45	28	30	15	51.11	0.325
1.266	+	25/08/2004	11:20	643.14	161	46	28	30	16	54.52	0.339
1.266	+	25/08/2004	11:30	655.84	164	47	29	31	16	54.52	0.333
1.266	+	25/08/2004	11:40	663.78	166	47	29	31	16	54.52	0.329
1.266	+	25/08/2004	11:50	669.34	167	48	29	31	17	57.93	0.346
1.266	+	25/08/2004	12:00	672.52	168	48	29	31	17	57.93	0.345
1.266	+	25/08/2004	12:10	675.69	169	48	30	32	16	54.52	0.323
1.266	+	25/08/2004	12:20	678.08	170	48	30	32	16	54.52	0.322
1.266	+	25/08/2004	12:30	679.66	170	49	30	32	17	57.93	0.341
1.266	+	25/08/2004	12:40	681.25	170	49	30	32	17	57.93	0.340
1.266	+	25/08/2004	12:50	685.22	171	49	30	32	17	57.93	0.338
1.266	+	25/08/2004	13:00	689.19	172	49	30	32	17	57.93	0.336
1.266	+	25/08/2004	13:10	692.37	173	49	30	32	17	57.93	0.335
1.266	+	25/08/2004	13:20	695.54	174	50	30	32	18	61.34	0.353
1.266	+	25/08/2004	13:30	700.31	175	50	31	33	17	57.93	0.331
1.266	+	25/08/2004	13:40	705.07	176	50	31	33	17	57.93	0.329
1.266	+	25/08/2004	13:50	709.04	177	51	31	33	18	61.34	0.346
1.266	+	25/08/2004	14:00	709.84	177	51	31	33	18	61.34	0.346
1.266	+	25/08/2004	14:10	709.84	177	51	31	33	18	61.34	0.346
1.266	+	25/08/2004	14:20	708.25	177	51	31	33	18	61.34	0.346
1.266	+	25/08/2004	14:30	702.69	176	50	31	33	17	57.93	0.330
1.266	+	25/08/2004	14:40	692.37	173	49	30	32	17	57.93	0.335
1.266	+	25/08/2004	14:50	681.25	170	49	30	32	17	57.93	0.340
1.266	+	25/08/2004	15:00	665.37	166	48	29	31	17	57.93	0.348

Table C.26. Measured and Calculated Data for 26/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	+	26/08/2004	11:00	572.47	143	41	25	27	14	47.71	0.333
1.266	+	26/08/2004	11:10	587.56	147	42	26	28	14	47.71	0.325
1.266	+	26/08/2004	11:20	601.85	150	43	27	29	14	47.71	0.317
1.266	+	26/08/2004	11:30	616.94	154	44	27	29	15	51.11	0.331
1.266	+	26/08/2004	11:40	626.47	157	45	28	30	15	51.11	0.326
1.266	+	26/08/2004	11:50	630.44	158	45	28	30	15	51.11	0.324
1.266	+	26/08/2004	12:00	635.99	159	45	28	30	15	51.11	0.321
1.266	+	26/08/2004	12:10	640.76	160	46	28	30	16	54.52	0.340
1.266	+	26/08/2004	12:20	643.93	161	46	28	30	16	54.52	0.339
1.266	+	26/08/2004	12:30	644.73	161	46	28	30	16	54.52	0.338
1.266	+	26/08/2004	12:40	649.49	162	46	29	31	15	51.11	0.315
1.266	+	26/08/2004	12:50	653.46	163	47	29	31	16	54.52	0.334
1.266	+	26/08/2004	13:00	654.26	164	47	29	31	16	54.52	0.333
1.266	+	26/08/2004	13:10	656.64	164	47	29	31	16	54.52	0.332
1.266	+	26/08/2004	13:20	662.20	166	47	29	31	16	54.52	0.329
1.266	+	26/08/2004	13:30	665.37	166	48	29	31	17	57.93	0.348
1.266	+	26/08/2004	13:40	669.34	167	48	29	31	17	57.93	0.346
1.266	+	26/08/2004	13:50	671.72	168	48	29	31	17	57.93	0.345
1.266	+	26/08/2004	14:00	674.90	169	48	30	32	16	54.52	0.323
1.266	+	26/08/2004	14:10	676.49	169	48	30	32	16	54.52	0.322
1.266	+	26/08/2004	14:20	672.52	168	48	29	31	17	57.93	0.345
1.266	+	26/08/2004	14:30	666.96	167	48	29	31	17	57.93	0.347
1.266	+	26/08/2004	14:40	658.23	165	47	29	31	16	54.52	0.331
1.266	+	26/08/2004	14:50	644.73	161	46	28	30	16	54.52	0.338
1.266	+	26/08/2004	15:00	628.85	157	45	28	30	15	51.11	0.325

Table C.27. Measured and Calculated Data for 27/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	+	27/08/2004	11:00	557.39	139	40	25	27	13	44.30	0.318
1.266	+	27/08/2004	11:10	573.27	143	41	26	28	13	44.30	0.309
1.266	+	27/08/2004	11:20	588.35	147	42	26	28	14	47.71	0.324
1.266	+	27/08/2004	11:30	599.47	150	43	27	29	14	47.71	0.318
1.266	+	27/08/2004	11:40	609.79	152	44	27	29	15	51.11	0.335
1.266	+	27/08/2004	11:50	616.94	154	44	27	29	15	51.11	0.331
1.266	+	27/08/2004	12:00	620.11	155	44	27	29	15	51.11	0.330
1.266	+	27/08/2004	12:10	625.67	156	45	28	30	15	51.11	0.327
1.266	+	27/08/2004	12:20	628.05	157	45	28	30	15	51.11	0.326
1.266	+	27/08/2004	12:30	628.85	157	45	28	30	15	51.11	0.325
1.266	+	27/08/2004	12:40	633.61	158	45	28	30	15	51.11	0.323
1.266	+	27/08/2004	12:50	638.38	160	46	28	30	16	54.52	0.342
1.266	+	27/08/2004	13:00	639.96	160	46	28	30	16	54.52	0.341
1.266	+	27/08/2004	13:10	641.55	160	46	28	30	16	54.52	0.340
1.266	+	27/08/2004	13:20	647.11	162	46	28	30	16	54.52	0.337
1.266	+	27/08/2004	13:30	647.11	162	46	28	30	16	54.52	0.337
1.266	+	27/08/2004	13:40	648.70	162	46	28	30	16	54.52	0.336
1.266	+	27/08/2004	13:50	651.08	163	47	29	31	16	54.52	0.335
1.266	+	27/08/2004	14:00	649.49	162	46	29	31	15	51.11	0.315
1.266	+	27/08/2004	14:10	652.67	163	47	29	31	16	54.52	0.334
1.266	+	27/08/2004	14:20	651.08	163	47	29	31	16	54.52	0.335
1.266	+	27/08/2004	14:30	644.73	161	46	28	30	16	54.52	0.338
1.266	+	27/08/2004	14:40	624.88	156	45	28	30	15	51.11	0.327
1.266	+	27/08/2004	14:50	612.17	153	44	27	29	15	51.11	0.334
1.266	+	27/08/2004	15:00	568.50	142	41	25	27	14	47.71	0.336

Table C.28. Measured and Calculated Data for 28/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	+	28/08/2004	11:00	587.56	147	42	26	28	14	47.71	0.325
1.266	+	28/08/2004	11:10	606.62	152	43	27	29	14	47.71	0.315
1.266	+	28/08/2004	11:20	622.50	156	44	27	29	15	51.11	0.328
1.266	+	28/08/2004	11:30	635.99	159	45	28	30	15	51.11	0.321
1.266	+	28/08/2004	11:40	643.14	161	46	28	30	16	54.52	0.339
1.266	+	28/08/2004	11:50	651.87	163	47	29	31	16	54.52	0.335
1.266	+	28/08/2004	12:00	657.43	164	47	29	31	16	54.52	0.332
1.266	+	28/08/2004	12:10	658.23	165	47	29	31	16	54.52	0.331
1.266	+	28/08/2004	12:20	660.61	165	47	29	31	16	54.52	0.330
1.266	+	28/08/2004	12:30	666.17	167	48	29	31	17	57.93	0.348
1.266	+	28/08/2004	12:40	668.55	167	48	29	31	17	57.93	0.347
1.266	+	28/08/2004	12:50	672.52	168	48	29	31	17	57.93	0.345
1.266	+	28/08/2004	13:00	677.28	169	48	30	32	16	54.52	0.322
1.266	+	28/08/2004	13:10	679.66	170	49	30	32	17	57.93	0.341
1.266	+	28/08/2004	13:20	685.22	171	49	30	32	17	57.93	0.338
1.266	+	28/08/2004	13:30	683.63	171	49	30	32	17	57.93	0.339
1.266	+	28/08/2004	13:40	686.81	172	49	30	32	17	57.93	0.337
1.266	+	28/08/2004	13:50	687.60	172	49	30	32	17	57.93	0.337
1.266	+	28/08/2004	14:00	686.81	172	49	30	32	17	57.93	0.337
1.266	+	28/08/2004	14:10	694.75	174	50	30	32	18	61.34	0.353
1.266	+	28/08/2004	14:20	695.54	174	50	30	32	18	61.34	0.353
1.266	+	28/08/2004	14:30	682.05	171	49	30	32	17	57.93	0.340
1.266	+	28/08/2004	14:40	673.31	168	48	29	31	17	57.93	0.344
1.266	+	28/08/2004	14:50	655.84	164	47	29	31	16	54.52	0.333
1.266	+	28/08/2004	15:00	643.93	161	46	28	30	16	54.52	0.339

Table C.29. Measured and Calculated Data for 29/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.266	+	29/08/2004	11:00	579.62	145	41	26	28	13	44.30	0.306
1.266	+	29/08/2004	11:10	597.09	149	43	26	28	15	51.11	0.342
1.266	+	29/08/2004	11:20	612.17	153	44	27	29	15	51.11	0.334
1.266	+	29/08/2004	11:30	626.47	157	45	28	30	15	51.11	0.326
1.266	+	29/08/2004	11:40	635.20	159	45	28	30	15	51.11	0.322
1.266	+	29/08/2004	11:50	642.35	161	46	28	30	16	54.52	0.340
1.266	+	29/08/2004	12:00	645.52	161	46	28	30	16	54.52	0.338
1.266	+	29/08/2004	12:10	649.49	162	46	29	31	15	51.11	0.315
1.266	+	29/08/2004	12:20	653.46	163	47	29	31	16	54.52	0.334
1.266	+	29/08/2004	12:30	656.64	164	47	29	31	16	54.52	0.332
1.266	+	29/08/2004	12:40	658.23	165	47	29	31	16	54.52	0.331
1.266	+	29/08/2004	12:50	660.61	165	47	29	31	16	54.52	0.330
1.266	+	29/08/2004	13:00	664.58	166	47	29	31	16	54.52	0.328
1.266	+	29/08/2004	13:10	664.58	166	47	29	31	16	54.52	0.328
1.266	+	29/08/2004	13:20	672.52	168	48	29	31	17	57.93	0.345
1.266	+	29/08/2004	13:30	678.08	170	48	30	32	16	54.52	0.322
1.266	+	29/08/2004	13:40	682.84	171	49	30	32	17	57.93	0.339
1.266	+	29/08/2004	13:50	685.22	171	49	30	32	17	57.93	0.338
1.266	+	29/08/2004	14:00	686.81	172	49	30	32	17	57.93	0.337
1.266	+	29/08/2004	14:10	689.99	172	49	30	32	17	57.93	0.336
1.266	+	29/08/2004	14:20	686.02	172	49	30	32	17	57.93	0.338
1.266	+	29/08/2004	14:30	678.87	170	48	30	32	16	54.52	0.321
1.266	+	29/08/2004	14:40	667.75	167	48	29	31	17	57.93	0.347
1.266	+	29/08/2004	14:50	657.43	164	47	29	31	16	54.52	0.332
1.266	+	29/08/2004	15:00	643.14	161	46	28	30	16	54.52	0.339

Table C.30. Measured and Calculated Data for 30/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	+	30/08/2004	11:00	574.86	144	39	26	28	11	46.85	0.326
1.5825	+	30/08/2004	11:10	590.74	148	40	26	28	12	51.11	0.346
1.5825	+	30/08/2004	11:20	606.62	152	41	27	29	12	51.11	0.337
1.5825	+	30/08/2004	11:30	617.73	154	42	27	29	13	55.37	0.359
1.5825	+	30/08/2004	11:40	628.05	157	43	28	30	13	55.37	0.353
1.5825	+	30/08/2004	11:50	634.41	159	43	28	30	13	55.37	0.349
1.5825	+	30/08/2004	12:00	642.35	161	44	28	30	14	59.63	0.371
1.5825	+	30/08/2004	12:10	644.73	161	44	28	30	14	59.63	0.370
1.5825	+	30/08/2004	12:20	647.11	162	44	28	30	14	59.63	0.369
1.5825	+	30/08/2004	12:30	649.49	162	44	29	31	13	55.37	0.341
1.5825	+	30/08/2004	12:40	651.87	163	44	29	31	13	55.37	0.340
1.5825	+	30/08/2004	12:50	654.26	164	44	29	31	13	55.37	0.339
1.5825	+	30/08/2004	13:00	658.23	165	45	29	31	14	59.63	0.362
1.5825	+	30/08/2004	13:10	662.20	166	45	29	31	14	59.63	0.360
1.5825	+	30/08/2004	13:20	666.17	167	45	29	31	14	59.63	0.358
1.5825	+	30/08/2004	13:30	670.14	168	45	29	31	14	59.63	0.356
1.5825	+	30/08/2004	13:40	673.31	168	46	29	31	15	63.89	0.380
1.5825	+	30/08/2004	13:50	676.49	169	46	30	32	14	59.63	0.353
1.5825	+	30/08/2004	14:00	677.28	169	46	30	32	14	59.63	0.352
1.5825	+	30/08/2004	14:10	673.31	168	46	29	31	15	63.89	0.380
1.5825	+	30/08/2004	14:20	671.72	168	46	29	31	15	63.89	0.380
1.5825	+	30/08/2004	14:30	663.78	166	45	29	31	14	59.63	0.359
1.5825	+	30/08/2004	14:40	653.46	163	44	29	31	13	55.37	0.339
1.5825	+	30/08/2004	14:50	638.38	160	43	28	30	13	55.37	0.347
1.5825	+	30/08/2004	15:00	625.67	156	42	28	30	12	51.11	0.327

Table C.31. Measured and Calculated Data for 31/08/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	+	31/08/2004	11:00	570.09	143	39	25	27	12	51.11	0.359
1.5825	+	31/08/2004	11:10	585.18	146	40	26	28	12	51.11	0.349
1.5825	+	31/08/2004	11:20	601.06	150	41	27	29	12	51.11	0.340
1.5825	+	31/08/2004	11:30	612.97	153	42	27	29	13	55.37	0.361
1.5825	+	31/08/2004	11:40	621.70	155	42	27	29	13	55.37	0.356
1.5825	+	31/08/2004	11:50	626.47	157	43	28	30	13	55.37	0.354
1.5825	+	31/08/2004	12:00	631.23	158	43	28	30	13	55.37	0.351
1.5825	+	31/08/2004	12:10	635.20	159	43	28	30	13	55.37	0.349
1.5825	+	31/08/2004	12:20	638.38	160	43	28	30	13	55.37	0.347
1.5825	+	31/08/2004	12:30	641.55	160	44	28	30	14	59.63	0.372
1.5825	+	31/08/2004	12:40	645.52	161	44	28	30	14	59.63	0.370
1.5825	+	31/08/2004	12:50	647.11	162	44	28	30	14	59.63	0.369
1.5825	+	31/08/2004	13:00	651.87	163	44	29	31	13	55.37	0.340
1.5825	+	31/08/2004	13:10	655.84	164	45	29	31	14	59.63	0.364
1.5825	+	31/08/2004	13:20	660.61	165	45	29	31	14	59.63	0.361
1.5825	+	31/08/2004	13:30	663.78	166	45	29	31	14	59.63	0.359
1.5825	+	31/08/2004	13:40	666.17	167	45	29	31	14	59.63	0.358
1.5825	+	31/08/2004	13:50	670.14	168	45	29	31	14	59.63	0.356
1.5825	+	31/08/2004	14:00	670.93	168	46	29	31	15	63.89	0.381
1.5825	+	31/08/2004	14:10	670.93	168	46	29	31	15	63.89	0.381
1.5825	+	31/08/2004	14:20	667.75	167	45	29	31	14	59.63	0.357
1.5825	+	31/08/2004	14:30	661.40	165	45	29	31	14	59.63	0.361
1.5825	+	31/08/2004	14:40	651.08	163	44	29	31	13	55.37	0.340
1.5825	+	31/08/2004	14:50	638.38	160	43	28	30	13	55.37	0.347
1.5825	+	31/08/2004	15:00	626.47	157	43	28	30	13	55.37	0.354

APPENDIX D

MEASURED & CALCULATED DATA FOR SEPTEMBER

Table D.1. Measured and Calculated Data for 01/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	+	01/09/2004	11:00	564.53	141	38	25	27	11	46.85	0.332
1.5825	+	01/09/2004	11:10	581.21	145	39	26	28	11	46.85	0.322
1.5825	+	01/09/2004	11:20	595.50	149	40	26	28	12	51.11	0.343
1.5825	+	01/09/2004	11:30	609.00	152	41	27	29	12	51.11	0.336
1.5825	+	01/09/2004	11:40	618.53	155	42	27	29	13	55.37	0.358
1.5825	+	01/09/2004	11:50	627.26	157	43	28	30	13	55.37	0.353
1.5825	+	01/09/2004	12:00	631.23	158	43	28	30	13	55.37	0.351
1.5825	+	01/09/2004	12:10	635.99	159	43	28	30	13	55.37	0.348
1.5825	+	01/09/2004	12:20	639.17	160	43	28	30	13	55.37	0.347
1.5825	+	01/09/2004	12:30	642.35	161	44	28	30	14	59.63	0.371
1.5825	+	01/09/2004	12:40	644.73	161	44	28	30	14	59.63	0.370
1.5825	+	01/09/2004	12:50	647.11	162	44	28	30	14	59.63	0.369
1.5825	+	01/09/2004	13:00	647.90	162	44	28	30	14	59.63	0.368
1.5825	+	01/09/2004	13:10	651.08	163	44	29	31	13	55.37	0.340
1.5825	+	01/09/2004	13:20	654.26	164	44	29	31	13	55.37	0.339
1.5825	+	01/09/2004	13:30	659.02	165	45	29	31	14	59.63	0.362
1.5825	+	01/09/2004	13:40	663.78	166	45	29	31	14	59.63	0.359
1.5825	+	01/09/2004	13:50	669.34	167	45	29	31	14	59.63	0.356
1.5825	+	01/09/2004	14:00	678.87	170	46	30	32	14	59.63	0.351
1.5825	+	01/09/2004	14:10	683.63	171	46	30	32	14	59.63	0.349
1.5825	+	01/09/2004	14:20	683.63	171	46	30	32	14	59.63	0.349
1.5825	+	01/09/2004	14:30	674.11	169	46	29	31	15	63.89	0.379
1.5825	+	01/09/2004	14:40	661.40	165	45	29	31	14	59.63	0.361
1.5825	+	01/09/2004	14:50	649.49	162	44	29	31	13	55.37	0.341
1.5825	+	01/09/2004	15:00	632.02	158	43	28	30	13	55.37	0.350

Table D.2. Measured and Calculated Data for 02/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	+	02/09/2004	11:00	566.92	142	38	25	27	11	46.85	0.331
1.5825	+	02/09/2004	11:10	583.59	146	40	26	28	12	51.11	0.350
1.5825	+	02/09/2004	11:20	596.29	149	40	26	28	12	51.11	0.343
1.5825	+	02/09/2004	11:30	606.62	152	41	27	29	12	51.11	0.337
1.5825	+	02/09/2004	11:40	610.59	153	41	27	29	12	51.11	0.335
1.5825	+	02/09/2004	11:50	613.76	153	42	27	29	13	55.37	0.361
1.5825	+	02/09/2004	12:00	615.35	154	42	27	29	13	55.37	0.360
1.5825	+	02/09/2004	12:10	615.35	154	42	27	29	13	55.37	0.360
1.5825	+	02/09/2004	12:20	612.97	153	42	27	29	13	55.37	0.361
1.5825	+	02/09/2004	12:30	612.97	153	42	27	29	13	55.37	0.361
1.5825	+	02/09/2004	12:40	614.56	154	42	27	29	13	55.37	0.360
1.5825	+	02/09/2004	12:50	616.94	154	42	27	29	13	55.37	0.359
1.5825	+	02/09/2004	13:00	622.50	156	42	27	29	13	55.37	0.356
1.5825	+	02/09/2004	13:10	627.26	157	43	28	30	13	55.37	0.353
1.5825	+	02/09/2004	13:20	635.20	159	43	28	30	13	55.37	0.349
1.5825	+	02/09/2004	13:30	643.14	161	44	28	30	14	59.63	0.371
1.5825	+	02/09/2004	13:40	651.08	163	44	29	31	13	55.37	0.340
1.5825	+	02/09/2004	13:50	658.23	165	45	29	31	14	59.63	0.362
1.5825	+	02/09/2004	14:00	663.78	166	45	29	31	14	59.63	0.359
1.5825	+	02/09/2004	14:10	667.75	167	45	29	31	14	59.63	0.357
1.5825	+	02/09/2004	14:20	665.37	166	45	29	31	14	59.63	0.358
1.5825	+	02/09/2004	14:30	655.84	164	45	29	31	14	59.63	0.364
1.5825	+	02/09/2004	14:40	646.32	162	44	28	30	14	59.63	0.369
1.5825	+	02/09/2004	14:50	634.41	159	43	28	30	13	55.37	0.349
1.5825	+	02/09/2004	15:00	619.32	155	42	27	29	13	55.37	0.358

Table D.3. Measured and Calculated Data for 03/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	+	03/09/2004	11:00	555.01	139	38	25	27	11	46.85	0.338
1.5825	+	03/09/2004	11:10	570.89	143	39	25	27	12	51.11	0.358
1.5825	+	03/09/2004	11:20	582.80	146	40	26	28	12	51.11	0.351
1.5825	+	03/09/2004	11:30	589.94	147	40	26	28	12	51.11	0.347
1.5825	+	03/09/2004	11:40	597.88	149	41	26	28	13	55.37	0.370
1.5825	+	03/09/2004	11:50	603.44	151	41	27	29	12	51.11	0.339
1.5825	+	03/09/2004	12:00	605.82	151	41	27	29	12	51.11	0.337
1.5825	+	03/09/2004	12:10	604.23	151	41	27	29	12	51.11	0.338
1.5825	+	03/09/2004	12:20	605.03	151	41	27	29	12	51.11	0.338
1.5825	+	03/09/2004	12:30	604.23	151	41	27	29	12	51.11	0.338
1.5825	+	03/09/2004	12:40	606.62	152	41	27	29	12	51.11	0.337
1.5825	+	03/09/2004	12:50	609.00	152	41	27	29	12	51.11	0.336
1.5825	+	03/09/2004	13:00	612.17	153	42	27	29	13	55.37	0.362
1.5825	+	03/09/2004	13:10	617.73	154	42	27	29	13	55.37	0.359
1.5825	+	03/09/2004	13:20	623.29	156	42	27	29	13	55.37	0.355
1.5825	+	03/09/2004	13:30	632.02	158	43	28	30	13	55.37	0.350
1.5825	+	03/09/2004	13:40	638.38	160	43	28	30	13	55.37	0.347
1.5825	+	03/09/2004	13:50	645.52	161	44	28	30	14	59.63	0.370
1.5825	+	03/09/2004	14:00	653.46	163	44	29	31	13	55.37	0.339
1.5825	+	03/09/2004	14:10	655.05	164	44	29	31	13	55.37	0.338
1.5825	+	03/09/2004	14:20	654.26	164	44	29	31	13	55.37	0.339
1.5825	+	03/09/2004	14:30	645.52	161	44	28	30	14	59.63	0.370
1.5825	+	03/09/2004	14:40	635.20	159	43	28	30	13	55.37	0.349
1.5825	+	03/09/2004	14:50	621.70	155	42	27	29	13	55.37	0.356
1.5825	+	03/09/2004	15:00	608.20	152	41	27	29	12	51.11	0.336

Table D.4. Measured and Calculated Data for 04/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	-	04/09/2004	11:00	536.74	134	36	24	26	10	38.34	0.286
1.5825	-	04/09/2004	11:10	553.42	138	38	25	27	11	42.17	0.305
1.5825	-	04/09/2004	11:20	566.12	142	38	25	27	11	42.17	0.298
1.5825	-	04/09/2004	11:30	576.44	144	39	26	28	11	42.17	0.293
1.5825	-	04/09/2004	11:40	582.80	146	40	26	28	12	46.00	0.316
1.5825	-	04/09/2004	11:50	585.97	146	40	26	28	12	46.00	0.314
1.5825	-	04/09/2004	12:00	589.94	147	40	26	28	12	46.00	0.312
1.5825	-	04/09/2004	12:10	590.74	148	40	26	28	12	46.00	0.311
1.5825	-	04/09/2004	12:20	593.91	148	40	26	28	12	46.00	0.310
1.5825	-	04/09/2004	12:30	593.91	148	40	26	28	12	46.00	0.310
1.5825	-	04/09/2004	12:40	593.91	148	40	26	28	12	46.00	0.310
1.5825	-	04/09/2004	12:50	597.88	149	41	26	28	13	49.84	0.333
1.5825	-	04/09/2004	13:00	605.03	151	41	27	29	12	46.00	0.304
1.5825	-	04/09/2004	13:10	609.79	152	41	27	29	12	46.00	0.302
1.5825	-	04/09/2004	13:20	615.35	154	42	27	29	13	49.84	0.324
1.5825	-	04/09/2004	13:30	622.50	156	42	27	29	13	49.84	0.320
1.5825	-	04/09/2004	13:40	628.05	157	43	28	30	13	49.84	0.317
1.5825	-	04/09/2004	13:50	634.41	159	43	28	30	13	49.84	0.314
1.5825	-	04/09/2004	14:00	638.38	160	43	28	30	13	49.84	0.312
1.5825	-	04/09/2004	14:10	639.96	160	43	28	30	13	49.84	0.311
1.5825	-	04/09/2004	14:20	635.20	159	43	28	30	13	49.84	0.314
1.5825	-	04/09/2004	14:30	625.67	156	42	28	30	12	46.00	0.294
1.5825	-	04/09/2004	14:40	614.56	154	42	27	29	13	49.84	0.324
1.5825	-	04/09/2004	14:50	604.23	151	41	27	29	12	46.00	0.305
1.5825	-	04/09/2004	15:00	591.53	148	40	26	28	12	46.00	0.311

Table D.5. Measured and Calculated Data for 05/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	+	05/09/2004	11:00	577.24	144	39	26	28	11	46.85	0.325
1.5825	+	05/09/2004	11:10	593.12	148	40	26	28	12	51.11	0.345
1.5825	+	05/09/2004	11:20	605.03	151	41	27	29	12	51.11	0.338
1.5825	+	05/09/2004	11:30	613.76	153	42	27	29	13	55.37	0.361
1.5825	+	05/09/2004	11:40	622.50	156	42	27	29	13	55.37	0.356
1.5825	+	05/09/2004	11:50	626.47	157	43	28	30	13	55.37	0.354
1.5825	+	05/09/2004	12:00	625.67	156	42	28	30	12	51.11	0.327
1.5825	+	05/09/2004	12:10	622.50	156	42	27	29	13	55.37	0.356
1.5825	+	05/09/2004	12:20	622.50	156	42	27	29	13	55.37	0.356
1.5825	+	05/09/2004	12:30	620.11	155	42	27	29	13	55.37	0.357
1.5825	+	05/09/2004	12:40	622.50	156	42	27	29	13	55.37	0.356
1.5825	+	05/09/2004	12:50	623.29	156	42	27	29	13	55.37	0.355
1.5825	+	05/09/2004	13:00	627.26	157	43	28	30	13	55.37	0.353
1.5825	+	05/09/2004	13:10	632.02	158	43	28	30	13	55.37	0.350
1.5825	+	05/09/2004	13:20	639.96	160	43	28	30	13	55.37	0.346
1.5825	+	05/09/2004	13:30	647.90	162	44	28	30	14	59.63	0.368
1.5825	+	05/09/2004	13:40	655.84	164	45	29	31	14	59.63	0.364
1.5825	+	05/09/2004	13:50	662.99	166	45	29	31	14	59.63	0.360
1.5825	+	05/09/2004	14:00	666.96	167	45	29	31	14	59.63	0.358
1.5825	+	05/09/2004	14:10	669.34	167	45	29	31	14	59.63	0.356
1.5825	+	05/09/2004	14:20	664.58	166	45	29	31	14	59.63	0.359
1.5825	+	05/09/2004	14:30	656.64	164	45	29	31	14	59.63	0.363
1.5825	+	05/09/2004	14:40	643.14	161	44	28	30	14	59.63	0.371
1.5825	+	05/09/2004	14:50	629.64	157	43	28	30	13	55.37	0.352
1.5825	+	05/09/2004	15:00	616.14	154	42	27	29	13	55.37	0.359

Table D.6. Measured and Calculated Data for 06/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	+	06/09/2004	11:00	569.30	142	39	25	27	12	51.11	0.359
1.5825	+	06/09/2004	11:10	585.18	146	40	26	28	12	51.11	0.349
1.5825	+	06/09/2004	11:20	597.09	149	41	26	28	13	55.37	0.371
1.5825	+	06/09/2004	11:30	607.41	152	41	27	29	12	51.11	0.337
1.5825	+	06/09/2004	11:40	611.38	153	41	27	29	12	51.11	0.334
1.5825	+	06/09/2004	11:50	614.56	154	42	27	29	13	55.37	0.360
1.5825	+	06/09/2004	12:00	613.76	153	42	27	29	13	55.37	0.361
1.5825	+	06/09/2004	12:10	613.76	153	42	27	29	13	55.37	0.361
1.5825	+	06/09/2004	12:20	612.97	153	42	27	29	13	55.37	0.361
1.5825	+	06/09/2004	12:30	612.17	153	42	27	29	13	55.37	0.362
1.5825	+	06/09/2004	12:40	611.38	153	41	27	29	12	51.11	0.334
1.5825	+	06/09/2004	12:50	614.56	154	42	27	29	13	55.37	0.360
1.5825	+	06/09/2004	13:00	619.32	155	42	27	29	13	55.37	0.358
1.5825	+	06/09/2004	13:10	624.08	156	42	28	30	12	51.11	0.328
1.5825	+	06/09/2004	13:20	630.44	158	43	28	30	13	55.37	0.351
1.5825	+	06/09/2004	13:30	637.58	159	43	28	30	13	55.37	0.347
1.5825	+	06/09/2004	13:40	645.52	161	44	28	30	14	59.63	0.370
1.5825	+	06/09/2004	13:50	654.26	164	44	29	31	13	55.37	0.339
1.5825	+	06/09/2004	14:00	660.61	165	45	29	31	14	59.63	0.361
1.5825	+	06/09/2004	14:10	661.40	165	45	29	31	14	59.63	0.361
1.5825	+	06/09/2004	14:20	657.43	164	45	29	31	14	59.63	0.363
1.5825	+	06/09/2004	14:30	646.32	162	44	28	30	14	59.63	0.369
1.5825	+	06/09/2004	14:40	633.61	158	43	28	30	13	55.37	0.350
1.5825	+	06/09/2004	14:50	620.91	155	42	27	29	13	55.37	0.357
1.5825	+	06/09/2004	15:00	605.82	151	41	27	29	12	51.11	0.337

Table D.7. Measured and Calculated Data for 07/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	-	07/09/2004	11:00	554.21	139	38	25	27	11	42.17	0.304
1.5825	-	07/09/2004	11:10	570.89	143	39	25	27	12	46.00	0.322
1.5825	-	07/09/2004	11:20	585.18	146	40	26	28	12	46.00	0.314
1.5825	-	07/09/2004	11:30	593.12	148	40	26	28	12	46.00	0.310
1.5825	-	07/09/2004	11:40	601.06	150	41	27	29	12	46.00	0.306
1.5825	-	07/09/2004	11:50	605.03	151	41	27	29	12	46.00	0.304
1.5825	-	07/09/2004	12:00	605.82	151	41	27	29	12	46.00	0.304
1.5825	-	07/09/2004	12:10	605.03	151	41	27	29	12	46.00	0.304
1.5825	-	07/09/2004	12:20	606.62	152	41	27	29	12	46.00	0.303
1.5825	-	07/09/2004	12:30	609.79	152	41	27	29	12	46.00	0.302
1.5825	-	07/09/2004	12:40	604.23	151	41	27	29	12	46.00	0.305
1.5825	-	07/09/2004	12:50	612.17	153	42	27	29	13	49.84	0.326
1.5825	-	07/09/2004	13:00	625.67	156	42	28	30	12	46.00	0.294
1.5825	-	07/09/2004	13:10	524.04	131	36	24	26	10	38.34	0.293
1.5825	-	07/09/2004	13:20	639.96	160	43	28	30	13	49.84	0.311
1.5825	-	07/09/2004	13:30	647.90	162	44	28	30	14	53.67	0.331
1.5825	-	07/09/2004	13:40	629.64	157	43	28	30	13	49.84	0.317
1.5825	-	07/09/2004	13:50	687.60	172	47	30	32	15	57.50	0.335
1.5825	-	07/09/2004	14:00	501.01	125	34	23	25	9	34.50	0.275
1.5825	-	07/09/2004	14:10	626.47	157	43	28	30	13	49.84	0.318
1.5825	-	07/09/2004	14:20	591.53	148	40	26	28	12	46.00	0.311
1.5825	-	07/09/2004	14:30	599.47	150	41	27	29	12	46.00	0.307
1.5825	-	07/09/2004	14:40	635.20	159	43	28	30	13	49.84	0.314
1.5825	-	07/09/2004	14:50	510.54	128	35	23	25	10	38.34	0.300
1.5825	-	07/09/2004	15:00	531.98	133	36	24	26	10	38.34	0.288

Table D.8. Measured and Calculated Data for 08/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	+	08/09/2004	11:00	555.01	139	38	25	27	11	46.85	0.338
1.5825	+	08/09/2004	11:10	570.09	143	39	25	27	12	51.11	0.359
1.5825	+	08/09/2004	11:20	586.77	147	40	26	28	12	51.11	0.348
1.5825	+	08/09/2004	11:30	597.09	149	41	26	28	13	55.37	0.371
1.5825	+	08/09/2004	11:40	603.44	151	41	27	29	12	51.11	0.339
1.5825	+	08/09/2004	11:50	605.82	151	41	27	29	12	51.11	0.337
1.5825	+	08/09/2004	12:00	609.00	152	41	27	29	12	51.11	0.336
1.5825	+	08/09/2004	12:10	609.79	152	41	27	29	12	51.11	0.335
1.5825	+	08/09/2004	12:20	609.79	152	41	27	29	12	51.11	0.335
1.5825	+	08/09/2004	12:30	611.38	153	41	27	29	12	51.11	0.334
1.5825	+	08/09/2004	12:40	611.38	153	41	27	29	12	51.11	0.334
1.5825	+	08/09/2004	12:50	615.35	154	42	27	29	13	55.37	0.360
1.5825	+	08/09/2004	13:00	616.14	154	42	27	29	13	55.37	0.359
1.5825	+	08/09/2004	13:10	624.08	156	42	28	30	12	51.11	0.328
1.5825	+	08/09/2004	13:20	632.02	158	43	28	30	13	55.37	0.350
1.5825	+	08/09/2004	13:30	637.58	159	43	28	30	13	55.37	0.347
1.5825	+	08/09/2004	13:40	644.73	161	44	28	30	14	59.63	0.370
1.5825	+	08/09/2004	13:50	653.46	163	44	29	31	13	55.37	0.339
1.5825	+	08/09/2004	14:00	659.02	165	45	29	31	14	59.63	0.362
1.5825	+	08/09/2004	14:10	656.64	164	45	29	31	14	59.63	0.363
1.5825	+	08/09/2004	14:20	653.46	163	44	29	31	13	55.37	0.339
1.5825	+	08/09/2004	14:30	644.73	161	44	28	30	14	59.63	0.370
1.5825	+	08/09/2004	14:40	631.23	158	43	28	30	13	55.37	0.351
1.5825	+	08/09/2004	14:50	609.00	152	41	27	29	12	51.11	0.336
1.5825	+	08/09/2004	15:00	600.26	150	41	27	29	12	51.11	0.341

Table D.9. Measured and Calculated Data for 09/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	+	09/09/2004	11:00	574.06	144	39	26	28	11	42.17	0.294
1.5825	+	09/09/2004	11:10	592.32	148	40	26	28	12	46.00	0.311
1.5825	+	09/09/2004	11:20	605.03	151	41	27	29	12	46.00	0.304
1.5825	+	09/09/2004	11:30	615.35	154	42	27	29	13	49.84	0.324
1.5825	+	09/09/2004	11:40	619.32	155	42	27	29	13	49.84	0.322
1.5825	+	09/09/2004	11:50	621.70	155	42	27	29	13	49.84	0.321
1.5825	+	09/09/2004	12:00	624.88	156	42	28	30	12	46.00	0.294
1.5825	+	09/09/2004	12:10	625.67	156	42	28	30	12	46.00	0.294
1.5825	+	09/09/2004	12:20	622.50	156	42	27	29	13	49.84	0.320
1.5825	+	09/09/2004	12:30	622.50	156	42	27	29	13	49.84	0.320
1.5825	+	09/09/2004	12:40	623.29	156	42	27	29	13	49.84	0.320
1.5825	+	09/09/2004	12:50	625.67	156	42	28	30	12	46.00	0.294
1.5825	+	09/09/2004	13:00	632.02	158	43	28	30	13	49.84	0.315
1.5825	+	09/09/2004	13:10	639.96	160	43	28	30	13	49.84	0.311
1.5825	+	09/09/2004	13:20	648.70	162	44	28	30	14	53.67	0.331
1.5825	+	09/09/2004	13:30	655.84	164	45	29	31	14	53.67	0.327
1.5825	+	09/09/2004	13:40	666.17	167	45	29	31	14	53.67	0.322
1.5825	+	09/09/2004	13:50	673.31	168	46	29	31	15	57.50	0.342
1.5825	+	09/09/2004	14:00	680.46	170	46	30	32	14	53.67	0.315
1.5825	+	09/09/2004	14:10	680.46	170	46	30	32	14	53.67	0.315
1.5825	+	09/09/2004	14:20	672.52	168	46	29	31	15	57.50	0.342
1.5825	+	09/09/2004	14:30	661.40	165	45	29	31	14	53.67	0.325
1.5825	+	09/09/2004	14:40	648.70	162	44	28	30	14	53.67	0.331
1.5825	+	09/09/2004	14:50	630.44	158	43	28	30	13	49.84	0.316
1.5825	+	09/09/2004	15:00	617.73	154	42	27	29	13	49.84	0.323

Table D.10. Measured and Calculated Data for 10/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	+	10/09/2004	11:00	563.74	141	38	25	27	11	46.85	0.332
1.5825	+	10/09/2004	11:10	580.41	145	39	26	28	11	46.85	0.323
1.5825	+	10/09/2004	11:20	590.74	148	40	26	28	12	51.11	0.346
1.5825	+	10/09/2004	11:30	600.26	150	41	27	29	12	51.11	0.341
1.5825	+	10/09/2004	11:40	606.62	152	41	27	29	12	51.11	0.337
1.5825	+	10/09/2004	11:50	612.17	153	42	27	29	13	55.37	0.362
1.5825	+	10/09/2004	12:00	611.38	153	41	27	29	12	51.11	0.334
1.5825	+	10/09/2004	12:10	614.56	154	42	27	29	13	55.37	0.360
1.5825	+	10/09/2004	12:20	616.14	154	42	27	29	13	55.37	0.359
1.5825	+	10/09/2004	12:30	616.14	154	42	27	29	13	55.37	0.359
1.5825	+	10/09/2004	12:40	619.32	155	42	27	29	13	55.37	0.358
1.5825	+	10/09/2004	12:50	622.50	156	42	27	29	13	55.37	0.356
1.5825	+	10/09/2004	13:00	629.64	157	43	28	30	13	55.37	0.352
1.5825	+	10/09/2004	13:10	635.99	159	43	28	30	13	55.37	0.348
1.5825	+	10/09/2004	13:20	641.55	160	44	28	30	14	59.63	0.372
1.5825	+	10/09/2004	13:30	648.70	162	44	28	30	14	59.63	0.368
1.5825	+	10/09/2004	13:40	658.23	165	45	29	31	14	59.63	0.362
1.5825	+	10/09/2004	13:50	664.58	166	45	29	31	14	59.63	0.359
1.5825	+	10/09/2004	14:00	669.34	167	45	29	31	14	59.63	0.356
1.5825	+	10/09/2004	14:10	667.75	167	45	29	31	14	59.63	0.357
1.5825	+	10/09/2004	14:20	661.40	165	45	29	31	14	59.63	0.361
1.5825	+	10/09/2004	14:30	651.87	163	44	29	31	13	55.37	0.340
1.5825	+	10/09/2004	14:40	639.96	160	43	28	30	13	55.37	0.346
1.5825	+	10/09/2004	14:50	630.44	158	43	28	30	13	55.37	0.351
1.5825	+	10/09/2004	15:00	616.94	154	42	27	29	13	55.37	0.359

Table D.11. Measured and Calculated Data for 11/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	+	11/09/2004	11:00	571.68	143	39	25	27	12	51.11	0.358
1.5825	+	11/09/2004	11:10	568.50	142	39	25	27	12	51.11	0.360
1.5825	+	11/09/2004	11:20	601.06	150	41	27	29	12	51.11	0.340
1.5825	+	11/09/2004	11:30	610.59	153	41	27	29	12	51.11	0.335
1.5825	+	11/09/2004	11:40	596.29	149	40	26	28	12	51.11	0.343
1.5825	+	11/09/2004	11:50	618.53	155	42	27	29	13	55.37	0.358
1.5825	+	11/09/2004	12:00	620.91	155	42	27	29	13	55.37	0.357
1.5825	+	11/09/2004	12:10	619.32	155	42	27	29	13	55.37	0.358
1.5825	+	11/09/2004	12:20	621.70	155	42	27	29	13	55.37	0.356
1.5825	+	11/09/2004	12:30	621.70	155	42	27	29	13	55.37	0.356
1.5825	+	11/09/2004	12:40	620.91	155	42	27	29	13	55.37	0.357
1.5825	+	11/09/2004	12:50	624.88	156	42	28	30	12	51.11	0.327
1.5825	+	11/09/2004	13:00	628.85	157	43	28	30	13	55.37	0.352
1.5825	+	11/09/2004	13:10	637.58	159	43	28	30	13	55.37	0.347
1.5825	+	11/09/2004	13:20	646.32	162	44	28	30	14	59.63	0.369
1.5825	+	11/09/2004	13:30	656.64	164	45	29	31	14	59.63	0.363
1.5825	+	11/09/2004	13:40	666.17	167	45	29	31	14	59.63	0.358
1.5825	+	11/09/2004	13:50	674.11	169	46	29	31	15	63.89	0.379
1.5825	+	11/09/2004	14:00	677.28	169	46	30	32	14	59.63	0.352
1.5825	+	11/09/2004	14:10	675.69	169	46	30	32	14	59.63	0.353
1.5825	+	11/09/2004	14:20	666.96	167	45	29	31	14	59.63	0.358
1.5825	+	11/09/2004	14:30	656.64	164	45	29	31	14	59.63	0.363
1.5825	+	11/09/2004	14:40	647.90	162	44	28	30	14	59.63	0.368
1.5825	+	11/09/2004	14:50	632.82	158	43	28	30	13	55.37	0.350
1.5825	+	11/09/2004	15:00	616.94	154	42	27	29	13	55.37	0.359

Table D.12. Measured and Calculated Data for 12/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.5825	+	12/09/2004	11:00	582.80	146	40	26	28	12	51.11	0.351
1.5825	+	12/09/2004	11:10	597.88	149	41	26	28	13	55.37	0.370
1.5825	+	12/09/2004	11:20	609.00	152	41	27	29	12	51.11	0.336
1.5825	+	12/09/2004	11:30	619.32	155	42	27	29	13	55.37	0.358
1.5825	+	12/09/2004	11:40	624.08	156	42	28	30	12	51.11	0.328
1.5825	+	12/09/2004	11:50	628.85	157	43	28	30	13	55.37	0.352
1.5825	+	12/09/2004	12:00	631.23	158	43	28	30	13	55.37	0.351
1.5825	+	12/09/2004	12:10	630.44	158	43	28	30	13	55.37	0.351
1.5825	+	12/09/2004	12:20	630.44	158	43	28	30	13	55.37	0.351
1.5825	+	12/09/2004	12:30	631.23	158	43	28	30	13	55.37	0.351
1.5825	+	12/09/2004	12:40	632.82	158	43	28	30	13	55.37	0.350
1.5825	+	12/09/2004	12:50	635.99	159	43	28	30	13	55.37	0.348
1.5825	+	12/09/2004	13:00	641.55	160	44	28	30	14	59.63	0.372
1.5825	+	12/09/2004	13:10	648.70	162	44	28	30	14	59.63	0.368
1.5825	+	12/09/2004	13:20	655.05	164	44	29	31	13	55.37	0.338
1.5825	+	12/09/2004	13:30	662.20	166	45	29	31	14	59.63	0.360
1.5825	+	12/09/2004	13:40	670.93	168	46	29	31	15	63.89	0.381
1.5825	+	12/09/2004	13:50	678.87	170	46	30	32	14	59.63	0.351
1.5825	+	12/09/2004	14:00	683.63	171	46	30	32	14	59.63	0.349
1.5825	+	12/09/2004	14:10	682.05	171	46	30	32	14	59.63	0.350
1.5825	+	12/09/2004	14:20	674.11	169	46	29	31	15	63.89	0.379
1.5825	+	12/09/2004	14:30	665.37	166	45	29	31	14	59.63	0.358
1.5825	+	12/09/2004	14:40	651.87	163	44	29	31	13	55.37	0.340
1.5825	+	12/09/2004	14:50	637.58	159	43	28	30	13	55.37	0.347
1.5825	+	12/09/2004	15:00	620.91	155	42	27	29	13	55.37	0.357

Table D.13. Measured and Calculated Data for 13/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	+	13/09/2004	11:00	569.30	142	37	25	27	10	51.11	0.359
1.899	+	13/09/2004	11:10	583.59	146	38	26	28	10	51.11	0.350
1.899	+	13/09/2004	11:20	596.29	149	38	26	28	10	51.11	0.343
1.899	+	13/09/2004	11:30	607.41	152	39	27	29	10	51.11	0.337
1.899	+	13/09/2004	11:40	614.56	154	40	27	29	11	56.23	0.366
1.899	+	13/09/2004	11:50	616.94	154	40	27	29	11	56.23	0.365
1.899	+	13/09/2004	12:00	620.11	155	40	27	29	11	56.23	0.363
1.899	+	13/09/2004	12:10	621.70	155	40	27	29	11	56.23	0.362
1.899	+	13/09/2004	12:20	622.50	156	40	27	29	11	56.23	0.361
1.899	+	13/09/2004	12:30	623.29	156	40	27	29	11	56.23	0.361
1.899	+	13/09/2004	12:40	625.67	156	40	28	30	10	51.11	0.327
1.899	+	13/09/2004	12:50	628.85	157	40	28	30	10	51.11	0.325
1.899	+	13/09/2004	13:00	632.82	158	41	28	30	11	56.23	0.355
1.899	+	13/09/2004	13:10	639.17	160	41	28	30	11	56.23	0.352
1.899	+	13/09/2004	13:20	647.90	162	42	28	30	12	61.34	0.379
1.899	+	13/09/2004	13:30	656.64	164	42	29	31	11	56.23	0.343
1.899	+	13/09/2004	13:40	666.17	167	43	29	31	12	61.34	0.368
1.899	+	13/09/2004	13:50	672.52	168	43	29	31	12	61.34	0.365
1.899	+	13/09/2004	14:00	676.49	169	43	30	32	11	56.23	0.332
1.899	+	13/09/2004	14:10	674.90	169	43	30	32	11	56.23	0.333
1.899	+	13/09/2004	14:20	668.55	167	43	29	31	12	61.34	0.367
1.899	+	13/09/2004	14:30	658.23	165	42	29	31	11	56.23	0.342
1.899	+	13/09/2004	14:40	646.32	162	42	28	30	12	61.34	0.380
1.899	+	13/09/2004	14:50	632.02	158	41	28	30	11	56.23	0.356
1.899	+	13/09/2004	15:00	616.94	154	40	27	29	11	56.23	0.365

Table D.14. Measured and Calculated Data for 14/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	+	14/09/2004	11:00	569.30	142	37	25	27	10	51.11	0.359
1.899	+	14/09/2004	11:10	583.59	146	38	26	28	10	51.11	0.350
1.899	+	14/09/2004	11:20	593.91	148	38	26	28	10	51.11	0.344
1.899	+	14/09/2004	11:30	601.06	150	39	27	29	10	51.11	0.340
1.899	+	14/09/2004	11:40	602.65	151	39	27	29	10	51.11	0.339
1.899	+	14/09/2004	11:50	602.65	151	39	27	29	10	51.11	0.339
1.899	+	14/09/2004	12:00	601.85	150	39	27	29	10	51.11	0.340
1.899	+	14/09/2004	12:10	599.47	150	39	27	29	10	51.11	0.341
1.899	+	14/09/2004	12:20	599.47	150	39	27	29	10	51.11	0.341
1.899	+	14/09/2004	12:30	600.26	150	39	27	29	10	51.11	0.341
1.899	+	14/09/2004	12:40	602.65	151	39	27	29	10	51.11	0.339
1.899	+	14/09/2004	12:50	605.82	151	39	27	29	10	51.11	0.337
1.899	+	14/09/2004	13:00	612.17	153	39	27	29	10	51.11	0.334
1.899	+	14/09/2004	13:10	621.70	155	40	27	29	11	56.23	0.362
1.899	+	14/09/2004	13:20	632.02	158	41	28	30	11	56.23	0.356
1.899	+	14/09/2004	13:30	643.14	161	41	28	30	11	56.23	0.350
1.899	+	14/09/2004	13:40	655.05	164	42	29	31	11	56.23	0.343
1.899	+	14/09/2004	13:50	663.78	166	43	29	31	12	61.34	0.370
1.899	+	14/09/2004	14:00	668.55	167	43	29	31	12	61.34	0.367
1.899	+	14/09/2004	14:10	667.75	167	43	29	31	12	61.34	0.367
1.899	+	14/09/2004	14:20	658.23	165	42	29	31	11	56.23	0.342
1.899	+	14/09/2004	14:30	646.32	162	42	28	30	12	61.34	0.380
1.899	+	14/09/2004	14:40	631.23	158	41	28	30	11	56.23	0.356
1.899	+	14/09/2004	14:50	616.14	154	40	27	29	11	56.23	0.365
1.899	+	14/09/2004	15:00	597.88	149	38	26	28	10	51.11	0.342

Table D.15. Measured and Calculated Data for 15/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	+	15/09/2004	11:00	565.33	141	36	25	27	9	46.00	0.325
1.899	+	15/09/2004	11:10	579.62	145	37	26	28	9	46.00	0.317
1.899	+	15/09/2004	11:20	589.94	147	38	26	28	10	51.11	0.347
1.899	+	15/09/2004	11:30	597.88	149	38	26	28	10	51.11	0.342
1.899	+	15/09/2004	11:40	601.85	150	39	27	29	10	51.11	0.340
1.899	+	15/09/2004	11:50	602.65	151	39	27	29	10	51.11	0.339
1.899	+	15/09/2004	12:00	601.85	150	39	27	29	10	51.11	0.340
1.899	+	15/09/2004	12:10	600.26	150	39	27	29	10	51.11	0.341
1.899	+	15/09/2004	12:20	599.47	150	39	27	29	10	51.11	0.341
1.899	+	15/09/2004	12:30	599.47	150	39	27	29	10	51.11	0.341
1.899	+	15/09/2004	12:40	600.26	150	39	27	29	10	51.11	0.341
1.899	+	15/09/2004	12:50	605.03	151	39	27	29	10	51.11	0.338
1.899	+	15/09/2004	13:00	612.17	153	39	27	29	10	51.11	0.334
1.899	+	15/09/2004	13:10	622.50	156	40	27	29	11	56.23	0.361
1.899	+	15/09/2004	13:20	633.61	158	41	28	30	11	56.23	0.355
1.899	+	15/09/2004	13:30	645.52	161	41	28	30	11	56.23	0.348
1.899	+	15/09/2004	13:40	658.23	165	42	29	31	11	56.23	0.342
1.899	+	15/09/2004	13:50	666.96	167	43	29	31	12	61.34	0.368
1.899	+	15/09/2004	14:00	673.31	168	43	29	31	12	61.34	0.364
1.899	+	15/09/2004	14:10	669.34	167	43	29	31	12	61.34	0.367
1.899	+	15/09/2004	14:20	659.81	165	42	29	31	11	56.23	0.341
1.899	+	15/09/2004	14:30	646.32	162	42	28	30	12	61.34	0.380
1.899	+	15/09/2004	14:40	632.82	158	41	28	30	11	56.23	0.355
1.899	+	15/09/2004	14:50	619.32	155	40	27	29	11	56.23	0.363
1.899	+	15/09/2004	15:00	604.23	151	39	27	29	10	51.11	0.338

Table D.16. Measured and Calculated Data for 16/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	+	16/09/2004	11:00	555.01	139	36	25	27	9	46.00	0.332
1.899	+	16/09/2004	11:10	570.09	143	37	25	27	10	51.11	0.359
1.899	+	16/09/2004	11:20	581.21	145	37	26	28	9	46.00	0.317
1.899	+	16/09/2004	11:30	587.56	147	38	26	28	10	51.11	0.348
1.899	+	16/09/2004	11:40	591.53	148	38	26	28	10	51.11	0.346
1.899	+	16/09/2004	11:50	592.32	148	38	26	28	10	51.11	0.345
1.899	+	16/09/2004	12:00	590.74	148	38	26	28	10	51.11	0.346
1.899	+	16/09/2004	12:10	590.74	148	38	26	28	10	51.11	0.346
1.899	+	16/09/2004	12:20	590.74	148	38	26	28	10	51.11	0.346
1.899	+	16/09/2004	12:30	590.74	148	38	26	28	10	51.11	0.346
1.899	+	16/09/2004	12:40	593.12	148	38	26	28	10	51.11	0.345
1.899	+	16/09/2004	12:50	598.68	150	38	27	29	9	46.00	0.307
1.899	+	16/09/2004	13:00	607.41	152	39	27	29	10	51.11	0.337
1.899	+	16/09/2004	13:10	617.73	154	40	27	29	11	56.23	0.364
1.899	+	16/09/2004	13:20	628.85	157	40	28	30	10	51.11	0.325
1.899	+	16/09/2004	13:30	642.35	161	41	28	30	11	56.23	0.350
1.899	+	16/09/2004	13:40	654.26	164	42	29	31	11	56.23	0.344
1.899	+	16/09/2004	13:50	661.40	165	43	29	31	12	61.34	0.371
1.899	+	16/09/2004	14:00	665.37	166	43	29	31	12	61.34	0.369
1.899	+	16/09/2004	14:10	662.20	166	43	29	31	12	61.34	0.371
1.899	+	16/09/2004	14:20	652.67	163	42	29	31	11	56.23	0.345
1.899	+	16/09/2004	14:30	639.17	160	41	28	30	11	56.23	0.352
1.899	+	16/09/2004	14:40	624.08	156	40	28	30	10	51.11	0.328
1.899	+	16/09/2004	14:50	608.20	152	39	27	29	10	51.11	0.336
1.899	+	16/09/2004	15:00	590.74	148	38	26	28	10	51.11	0.346

Table D.17. Measured and Calculated Data for 17/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	+	17/09/2004	11:00	546.27	137	35	24	26	9	46.00	0.337
1.899	+	17/09/2004	11:10	560.56	140	36	25	27	9	46.00	0.328
1.899	+	17/09/2004	11:20	572.47	143	37	25	27	10	51.11	0.357
1.899	+	17/09/2004	11:30	578.03	145	37	26	28	9	46.00	0.318
1.899	+	17/09/2004	11:40	579.62	145	37	26	28	9	46.00	0.317
1.899	+	17/09/2004	11:50	583.59	146	38	26	28	10	51.11	0.350
1.899	+	17/09/2004	12:00	583.59	146	38	26	28	10	51.11	0.350
1.899	+	17/09/2004	12:10	583.59	146	38	26	28	10	51.11	0.350
1.899	+	17/09/2004	12:20	584.38	146	38	26	28	10	51.11	0.350
1.899	+	17/09/2004	12:30	583.59	146	38	26	28	10	51.11	0.350
1.899	+	17/09/2004	12:40	585.18	146	38	26	28	10	51.11	0.349
1.899	+	17/09/2004	12:50	589.15	147	38	26	28	10	51.11	0.347
1.899	+	17/09/2004	13:00	593.91	148	38	26	28	10	51.11	0.344
1.899	+	17/09/2004	13:10	601.06	150	39	27	29	10	51.11	0.340
1.899	+	17/09/2004	13:20	609.79	152	39	27	29	10	51.11	0.335
1.899	+	17/09/2004	13:30	624.88	156	40	28	30	10	51.11	0.327
1.899	+	17/09/2004	13:40	635.99	159	41	28	30	11	56.23	0.354
1.899	+	17/09/2004	13:50	643.14	161	41	28	30	11	56.23	0.350
1.899	+	17/09/2004	14:00	645.52	161	41	28	30	11	56.23	0.348
1.899	+	17/09/2004	14:10	643.14	161	41	28	30	11	56.23	0.350
1.899	+	17/09/2004	14:20	632.82	158	41	28	30	11	56.23	0.355
1.899	+	17/09/2004	14:30	621.70	155	40	27	29	11	56.23	0.362
1.899	+	17/09/2004	14:40	609.00	152	39	27	29	10	51.11	0.336
1.899	+	17/09/2004	14:50	595.50	149	38	26	28	10	51.11	0.343
1.899	+	17/09/2004	15:00	582.00	146	37	26	28	9	46.00	0.316

Table D.18. Measured and Calculated Data for 18/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	-	18/09/2004	11:00	536.74	134	35	24	26	9	41.40	0.309
1.899	-	18/09/2004	11:10	551.83	138	35	25	27	8	36.80	0.267
1.899	-	18/09/2004	11:20	563.74	141	36	25	27	9	41.40	0.294
1.899	-	18/09/2004	11:30	571.68	143	37	25	27	10	46.00	0.322
1.899	-	18/09/2004	11:40	574.06	144	37	26	28	9	41.40	0.288
1.899	-	18/09/2004	11:50	575.65	144	37	26	28	9	41.40	0.288
1.899	-	18/09/2004	12:00	576.44	144	37	26	28	9	41.40	0.287
1.899	-	18/09/2004	12:10	575.65	144	37	26	28	9	41.40	0.288
1.899	-	18/09/2004	12:20	575.65	144	37	26	28	9	41.40	0.288
1.899	-	18/09/2004	12:30	575.65	144	37	26	28	9	41.40	0.288
1.899	-	18/09/2004	12:40	578.03	145	37	26	28	9	41.40	0.287
1.899	-	18/09/2004	12:50	582.00	146	37	26	28	9	41.40	0.285
1.899	-	18/09/2004	13:00	589.15	147	38	26	28	10	46.00	0.312
1.899	-	18/09/2004	13:10	597.88	149	38	26	28	10	46.00	0.308
1.899	-	18/09/2004	13:20	606.62	152	39	27	29	10	46.00	0.303
1.899	-	18/09/2004	13:30	616.94	154	40	27	29	11	50.60	0.328
1.899	-	18/09/2004	13:40	625.67	156	40	28	30	10	46.00	0.294
1.899	-	18/09/2004	13:50	632.02	158	41	28	30	11	50.60	0.320
1.899	-	18/09/2004	14:00	632.82	158	41	28	30	11	50.60	0.320
1.899	-	18/09/2004	14:10	629.64	157	40	28	30	10	46.00	0.292
1.899	-	18/09/2004	14:20	620.91	155	40	27	29	11	50.60	0.326
1.899	-	18/09/2004	14:30	609.00	152	39	27	29	10	46.00	0.302
1.899	-	18/09/2004	14:40	595.50	149	38	26	28	10	46.00	0.309
1.899	-	18/09/2004	14:50	581.21	145	37	26	28	9	41.40	0.285
1.899	-	18/09/2004	15:00	564.53	141	36	25	27	9	41.40	0.293

Table D.19. Measured and Calculated Data for 19/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	-	19/09/2004	11:00	514.51	129	33	23	25	8	36.80	0.286
1.899	-	19/09/2004	11:10	528.80	132	34	24	26	8	36.80	0.278
1.899	-	19/09/2004	11:20	540.71	135	35	24	26	9	41.40	0.306
1.899	-	19/09/2004	11:30	548.65	137	35	25	27	8	36.80	0.268
1.899	-	19/09/2004	11:40	554.21	139	36	25	27	9	41.40	0.299
1.899	-	19/09/2004	11:50	557.39	139	36	25	27	9	41.40	0.297
1.899	-	19/09/2004	12:00	558.98	140	36	25	27	9	41.40	0.296
1.899	-	19/09/2004	12:10	560.56	140	36	25	27	9	41.40	0.295
1.899	-	19/09/2004	12:20	559.77	140	36	25	27	9	41.40	0.296
1.899	-	19/09/2004	12:30	562.15	141	36	25	27	9	41.40	0.295
1.899	-	19/09/2004	12:40	566.92	142	36	25	27	9	41.40	0.292
1.899	-	19/09/2004	12:50	571.68	143	37	25	27	10	46.00	0.322
1.899	-	19/09/2004	13:00	577.24	144	37	26	28	9	41.40	0.287
1.899	-	19/09/2004	13:10	585.18	146	38	26	28	10	46.00	0.314
1.899	-	19/09/2004	13:20	592.32	148	38	26	28	10	46.00	0.311
1.899	-	19/09/2004	13:30	601.85	150	39	27	29	10	46.00	0.306
1.899	-	19/09/2004	13:40	610.59	153	39	27	29	10	46.00	0.301
1.899	-	19/09/2004	13:50	613.76	153	39	27	29	10	46.00	0.300
1.899	-	19/09/2004	14:00	612.17	153	39	27	29	10	46.00	0.301
1.899	-	19/09/2004	14:10	609.79	152	39	27	29	10	46.00	0.302
1.899	-	19/09/2004	14:20	601.85	150	39	27	29	10	46.00	0.306
1.899	-	19/09/2004	14:30	588.35	147	38	26	28	10	46.00	0.313
1.899	-	19/09/2004	14:40	574.86	144	37	26	28	9	41.40	0.288
1.899	-	19/09/2004	14:50	558.98	140	36	25	27	9	41.40	0.296
1.899	-	19/09/2004	15:00	544.68	136	35	24	26	9	41.40	0.304

Table D.20. Measured and Calculated Data for 20/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	-	20/09/2004	11:00	504.19	126	32	23	25	7	32.20	0.255
1.899	-	20/09/2004	11:10	518.48	130	33	23	25	8	36.80	0.284
1.899	-	20/09/2004	11:20	530.39	133	34	24	26	8	36.80	0.278
1.899	-	20/09/2004	11:30	537.54	134	35	24	26	9	41.40	0.308
1.899	-	20/09/2004	11:40	543.10	136	35	24	26	9	41.40	0.305
1.899	-	20/09/2004	11:50	547.07	137	35	24	26	9	41.40	0.303
1.899	-	20/09/2004	12:00	549.45	137	35	25	27	8	36.80	0.268
1.899	-	20/09/2004	12:10	552.62	138	36	25	27	9	41.40	0.300
1.899	-	20/09/2004	12:20	555.80	139	36	25	27	9	41.40	0.298
1.899	-	20/09/2004	12:30	559.77	140	36	25	27	9	41.40	0.296
1.899	-	20/09/2004	12:40	562.95	141	36	25	27	9	41.40	0.294
1.899	-	20/09/2004	12:50	567.71	142	36	25	27	9	41.40	0.292
1.899	-	20/09/2004	13:00	574.06	144	37	26	28	9	41.40	0.288
1.899	-	20/09/2004	13:10	579.62	145	37	26	28	9	41.40	0.286
1.899	-	20/09/2004	13:20	590.74	148	38	26	28	10	46.00	0.311
1.899	-	20/09/2004	13:30	599.47	150	39	27	29	10	46.00	0.307
1.899	-	20/09/2004	13:40	606.62	152	39	27	29	10	46.00	0.303
1.899	-	20/09/2004	13:50	610.59	153	39	27	29	10	46.00	0.301
1.899	-	20/09/2004	14:00	609.00	152	39	27	29	10	46.00	0.302
1.899	-	20/09/2004	14:10	603.44	151	39	27	29	10	46.00	0.305
1.899	-	20/09/2004	14:20	590.74	148	38	26	28	10	46.00	0.311
1.899	-	20/09/2004	14:30	578.03	145	37	26	28	9	41.40	0.287
1.899	-	20/09/2004	14:40	565.33	141	36	25	27	9	41.40	0.293
1.899	-	20/09/2004	14:50	551.83	138	35	25	27	8	36.80	0.267
1.899	-	20/09/2004	15:00	534.36	134	34	24	26	8	36.80	0.275

Table D.21. Measured and Calculated Data for 22/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	-	22/09/2004	11:00	496.25	124	32	22	24	8	36.80	0.297
1.899	-	22/09/2004	11:10	509.75	127	33	23	25	8	36.80	0.289
1.899	-	22/09/2004	11:20	519.28	130	33	23	25	8	36.80	0.283
1.899	-	22/09/2004	11:30	525.63	131	34	24	26	8	36.80	0.280
1.899	-	22/09/2004	11:40	531.19	133	34	24	26	8	36.80	0.277
1.899	-	22/09/2004	11:50	535.95	134	34	24	26	8	36.80	0.275
1.899	-	22/09/2004	12:00	535.16	134	34	24	26	8	36.80	0.275
1.899	-	22/09/2004	12:10	535.16	134	34	24	26	8	36.80	0.275
1.899	-	22/09/2004	12:20	535.16	134	34	24	26	8	36.80	0.275
1.899	-	22/09/2004	12:30	536.74	134	35	24	26	9	41.40	0.309
1.899	-	22/09/2004	12:40	539.92	135	35	24	26	9	41.40	0.307
1.899	-	22/09/2004	12:50	545.48	136	35	24	26	9	41.40	0.304
1.899	-	22/09/2004	13:00	552.62	138	36	25	27	9	41.40	0.300
1.899	-	22/09/2004	13:10	558.98	140	36	25	27	9	41.40	0.296
1.899	-	22/09/2004	13:20	574.86	144	37	26	28	9	41.40	0.288
1.899	-	22/09/2004	13:30	585.18	146	38	26	28	10	46.00	0.314
1.899	-	22/09/2004	13:40	593.12	148	38	26	28	10	46.00	0.310
1.899	-	22/09/2004	13:50	597.88	149	38	26	28	10	46.00	0.308
1.899	-	22/09/2004	14:00	597.09	149	38	26	28	10	46.00	0.308
1.899	-	22/09/2004	14:10	592.32	148	38	26	28	10	46.00	0.311
1.899	-	22/09/2004	14:20	582.00	146	37	26	28	9	41.40	0.285
1.899	-	22/09/2004	14:30	570.09	143	37	25	27	10	46.00	0.323
1.899	-	22/09/2004	14:40	559.77	140	36	25	27	9	41.40	0.296
1.899	-	22/09/2004	14:50	545.48	136	35	24	26	9	41.40	0.304
1.899	-	22/09/2004	15:00	529.60	132	34	24	26	8	36.80	0.278

Table D.22. Measured and Calculated Data for 24/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	-	24/09/2004	11:00	466.87	117	32	21	23	9	41.40	0.355
1.899	-	24/09/2004	11:10	489.90	122	31	22	24	7	32.20	0.263
1.899	-	24/09/2004	11:20	503.40	126	32	23	25	7	32.20	0.256
1.899	-	24/09/2004	11:30	515.31	129	33	23	25	8	36.80	0.286
1.899	-	24/09/2004	11:40	531.98	133	34	24	26	8	36.80	0.277
1.899	-	24/09/2004	11:50	547.07	137	35	24	26	9	41.40	0.303
1.899	-	24/09/2004	12:00	554.21	139	36	25	27	9	41.40	0.299
1.899	-	24/09/2004	12:10	561.36	140	36	25	27	9	41.40	0.295
1.899	-	24/09/2004	12:20	561.36	140	36	25	27	9	41.40	0.295
1.899	-	24/09/2004	12:30	563.74	141	36	25	27	9	41.40	0.294
1.899	-	24/09/2004	12:40	570.89	143	37	25	27	10	46.00	0.322
1.899	-	24/09/2004	12:50	578.83	145	37	26	28	9	41.40	0.286
1.899	-	24/09/2004	13:00	573.27	143	37	26	28	9	41.40	0.289
1.899	-	24/09/2004	13:10	591.53	148	38	26	28	10	46.00	0.311
1.899	-	24/09/2004	13:20	595.50	149	38	26	28	10	46.00	0.309
1.899	-	24/09/2004	13:30	596.29	149	38	26	28	10	46.00	0.309
1.899	-	24/09/2004	13:40	601.06	150	39	27	29	10	46.00	0.306
1.899	-	24/09/2004	13:50	597.09	149	38	26	28	10	46.00	0.308
1.899	-	24/09/2004	14:00	605.03	151	39	27	29	10	46.00	0.304
1.899	-	24/09/2004	14:10	589.94	147	38	26	28	10	46.00	0.312
1.899	-	24/09/2004	14:20	585.97	146	38	26	28	10	46.00	0.314
1.899	-	24/09/2004	14:30	564.53	141	36	25	27	9	41.40	0.293
1.899	-	24/09/2004	14:40	558.98	140	36	25	27	9	41.40	0.296
1.899	-	24/09/2004	14:50	495.46	124	32	22	24	8	36.80	0.297
1.899	-	24/09/2004	15:00	535.95	134	34	24	26	8	36.80	0.275

Table D.23. Measured and Calculated Data for 27/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	-	27/09/2004	11:00	476.40	119	31	22	24	7	32.20	0.270
1.899	-	27/09/2004	11:10	493.87	123	32	22	24	8	36.80	0.298
1.899	-	27/09/2004	11:20	504.98	126	32	23	25	7	32.20	0.255
1.899	-	27/09/2004	11:30	509.75	127	33	23	25	8	36.80	0.289
1.899	-	27/09/2004	11:40	520.86	130	33	23	25	8	36.80	0.283
1.899	-	27/09/2004	11:50	528.80	132	34	24	26	8	36.80	0.278
1.899	-	27/09/2004	12:00	535.95	134	34	24	26	8	36.80	0.275
1.899	-	27/09/2004	12:10	539.13	135	35	24	26	9	41.40	0.307
1.899	-	27/09/2004	12:20	542.30	136	35	24	26	9	41.40	0.305
1.899	-	27/09/2004	12:30	545.48	136	35	24	26	9	41.40	0.304
1.899	-	27/09/2004	12:40	547.07	137	35	24	26	9	41.40	0.303
1.899	-	27/09/2004	12:50	552.62	138	36	25	27	9	41.40	0.300
1.899	-	27/09/2004	13:00	558.18	140	36	25	27	9	41.40	0.297
1.899	-	27/09/2004	13:10	562.15	141	36	25	27	9	41.40	0.295
1.899	-	27/09/2004	13:20	567.71	142	36	25	27	9	41.40	0.292
1.899	-	27/09/2004	13:30	571.68	143	37	25	27	10	46.00	0.322
1.899	-	27/09/2004	13:40	570.09	143	37	25	27	10	46.00	0.323
1.899	-	27/09/2004	13:50	567.71	142	36	25	27	9	41.40	0.292
1.899	-	27/09/2004	14:00	559.77	140	36	25	27	9	41.40	0.296
1.899	-	27/09/2004	14:10	557.39	139	36	25	27	9	41.40	0.297
1.899	-	27/09/2004	14:20	551.04	138	35	25	27	8	36.80	0.267
1.899	-	27/09/2004	14:30	539.92	135	35	24	26	9	41.40	0.307
1.899	-	27/09/2004	14:40	526.42	132	34	24	26	8	36.80	0.280
1.899	-	27/09/2004	14:50	512.13	128	33	23	25	8	36.80	0.287
1.899	-	27/09/2004	15:00	495.46	124	32	22	24	8	36.80	0.297

Table D.24. Measured and Calculated Data for 28/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	-	28/09/2004	11:00	480.37	120	31	22	24	7	32.20	0.268
1.899	-	28/09/2004	11:10	496.25	124	32	22	24	8	36.80	0.297
1.899	-	28/09/2004	11:20	512.92	128	33	23	25	8	36.80	0.287
1.899	-	28/09/2004	11:30	526.42	132	34	24	26	8	36.80	0.280
1.899	-	28/09/2004	11:40	537.54	134	35	24	26	9	41.40	0.308
1.899	-	28/09/2004	11:50	545.48	136	35	24	26	9	41.40	0.304
1.899	-	28/09/2004	12:00	555.01	139	36	25	27	9	41.40	0.298
1.899	-	28/09/2004	12:10	558.98	140	36	25	27	9	41.40	0.296
1.899	-	28/09/2004	12:20	563.74	141	36	25	27	9	41.40	0.294
1.899	-	28/09/2004	12:30	567.71	142	36	25	27	9	41.40	0.292
1.899	-	28/09/2004	12:40	572.47	143	37	25	27	10	46.00	0.321
1.899	-	28/09/2004	12:50	576.44	144	37	26	28	9	41.40	0.287
1.899	-	28/09/2004	13:00	576.44	144	37	26	28	9	41.40	0.287
1.899	-	28/09/2004	13:10	578.83	145	37	26	28	9	41.40	0.286
1.899	-	28/09/2004	13:20	584.38	146	38	26	28	10	46.00	0.315
1.899	-	28/09/2004	13:30	584.38	146	38	26	28	10	46.00	0.315
1.899	-	28/09/2004	13:40	578.03	145	37	26	28	9	41.40	0.287
1.899	-	28/09/2004	13:50	573.27	143	37	26	28	9	41.40	0.289
1.899	-	28/09/2004	14:00	566.12	142	36	25	27	9	41.40	0.293
1.899	-	28/09/2004	14:10	557.39	139	36	25	27	9	41.40	0.297
1.899	-	28/09/2004	14:20	548.65	137	35	25	27	8	36.80	0.268
1.899	-	28/09/2004	14:30	536.74	134	35	24	26	9	41.40	0.309
1.899	-	28/09/2004	14:40	522.45	131	34	24	26	8	36.80	0.282
1.899	-	28/09/2004	14:50	502.60	126	32	23	25	7	32.20	0.256
1.899	-	28/09/2004	15:00	485.93	121	31	22	24	7	32.20	0.265

Table D.25. Measured and Calculated Data for 30/09/2004

Air Velocity (m/s)	Absorber Material (+ / -)	Date	Hour	Total I_t Over Collector (W/m^2)	I_t Over Collector (W)	T_o	T_a	T_i	ΔT	Q_u (W)	Efficiency (η)
1.899	-	30/09/2004	11:00	497.04	124	32	23	25	7	32.20	0.259
1.899	-	30/09/2004	11:10	512.92	128	33	23	25	8	36.80	0.287
1.899	-	30/09/2004	11:20	528.01	132	34	24	26	8	36.80	0.279
1.899	-	30/09/2004	11:30	540.71	135	35	24	26	9	41.40	0.306
1.899	-	30/09/2004	11:40	552.62	138	36	25	27	9	41.40	0.300
1.899	-	30/09/2004	11:50	561.36	140	36	25	27	9	41.40	0.295
1.899	-	30/09/2004	12:00	569.30	142	37	25	27	10	46.00	0.323
1.899	-	30/09/2004	12:10	575.65	144	37	26	28	9	41.40	0.288
1.899	-	30/09/2004	12:20	581.21	145	37	26	28	9	41.40	0.285
1.899	-	30/09/2004	12:30	585.97	146	38	26	28	10	46.00	0.314
1.899	-	30/09/2004	12:40	588.35	147	38	26	28	10	46.00	0.313
1.899	-	30/09/2004	12:50	593.12	148	38	26	28	10	46.00	0.310
1.899	-	30/09/2004	13:00	595.50	149	38	26	28	10	46.00	0.309
1.899	-	30/09/2004	13:10	599.47	150	39	27	29	10	46.00	0.307
1.899	-	30/09/2004	13:20	600.26	150	39	27	29	10	46.00	0.307
1.899	-	30/09/2004	13:30	605.82	151	39	27	29	10	46.00	0.304
1.899	-	30/09/2004	13:40	604.23	151	39	27	29	10	46.00	0.305
1.899	-	30/09/2004	13:50	601.85	150	39	27	29	10	46.00	0.306
1.899	-	30/09/2004	14:00	598.68	150	38	27	29	9	41.40	0.277
1.899	-	30/09/2004	14:10	586.77	147	38	26	28	10	46.00	0.314
1.899	-	30/09/2004	14:20	576.44	144	37	26	28	9	41.40	0.287
1.899	-	30/09/2004	14:30	568.50	142	37	25	27	10	46.00	0.324
1.899	-	30/09/2004	14:40	555.80	139	36	25	27	9	41.40	0.298
1.899	-	30/09/2004	14:50	543.89	136	35	24	26	9	41.40	0.304
1.899	-	30/09/2004	15:00	527.22	132	34	24	26	8	36.80	0.279