International Journal Of Scientific & Engineering Research, Volume 7, Issue 7, July-2016
ISSN 2229-5518

CO2 EFFECT ON PARAPOLIC TROUGH

Increasing parabolic trough efficiency

Under Supervision

PhD. Mubarak Mustafa Muhammed

The Agriculture Engineering Emeritus Professor

Authors

Abdallah Hani

Abdelrhman Safwat

Abdelrhman Yasser

Ahmed Eid

Muhammed Abdelrhman

JUNE 26, 2016

AGRICULTURE EINGINERRING DEPATEMENT -FACUALTY OF AGRICULTURE - AIN SHAMS UNIVERSITY
Graduation Project 2016

Declaration

We declare that this work is the Original Work.

International Journal Of Scientific & Engineering Research, Volume 7, Issue 7, July-2016
ISSN 2229-5518

Contents:

Abstract

Solar energy is the hope to satisfy our needs from energy, in this paper we introduce a new technical to increase the efficiency of Parabolic Trough which shows good results.

Introduction

1.1. Parabolic trough

Parabolic trough at a plant near Harper Lake, California fig (1)

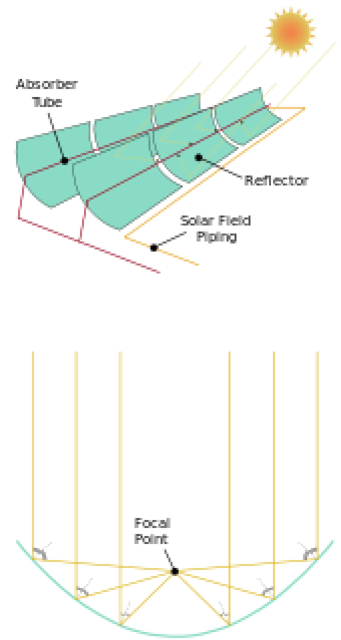
A **parabolic trough** is a type of solar thermal collector that is straight in one dimension and curved as a parabola in the other two, lined with a polished metal mirror. The energy of sunlight which enters the mirror parallel to its plane of symmetry is focused along the focal line, where objects are positioned that are intended to be heated. For example, food may be placed at the focal line of a trough, which causes the food to be cooked when the trough is aimed so the Sun is in its plane of symmetry. Further information on the use of parabolic troughs for cooking can be found in the article about solar cookers.

For other purposes, there is often a tube, frequently a **Dewar tube**, which runs the length of the trough at its focal line. The mirror is oriented so that sunlight which it reflects is concentrated on the tube, which contains a fluid which is heated to a high temperature by the energy of the sunlight. The hot fluid can be used for many purposes. Often, it is piped to a heat engine, which uses the heat energy to drive machinery or to generate electricity. This solar energy collector is the most common and best known type of parabolic trough. The paragraphs below therefore concentrate on this type.

Efficiency

The trough is usually aligned on a north-south axis, and rotated to track the sun as it moves across the sky each day. Alternatively, the trough can be aligned on an east-west axis; this reduces the overall efficiency of the collector due to cosine loss but only requires the trough to be aligned with the change in seasons, avoiding the need for tracking motors. This tracking method approaches theoretical efficiencies at the spring and fall equinoxes with less accurate focusing of the light at other times during the year. The daily motion of the sun across the sky also introduces errors, greatest at the sunrise and sunset and smallest at solar noon. Due to these sources of error, seasonally adjusted parabolic troughs are generally designed with a lower concentration acceptance product.

Heat transfer fluid (usually thermal oil – in our project was water) runs through the tube to absorb the concentrated sunlight. This increases the temperature of the fluid to some 400 °C. The heat transfer fluid is then used to heat steam in a standard turbine generator. The process is economical and, for heating the pipe, thermal efficiency ranges from 60-80%. The overall efficiency from collector to grid, i.e. (Electrical Output Power)/ (Total Impinging Solar Power) is about 15%, similar to PV (Photovoltaic Cells) but less than Stilling dish concentrators.



A diagram of a parabolic trough solar farm (top), and an end view of how a parabolic collector focuses sunlight onto its focal point.

Fig (2)

Problems

Despite the high heat it gains across the day, it losses it totally at night to be equal with the ambient temperature. Also it doesn't gain heat and losses heat very fast if the pipe is out the focal point. So we decided to try to increase Parabolic Trough's efficiency and decrease heat loss during night through CO2 (one of the greenhouse gasses)

Assessment Report from the **Intergovernmental Panel on Climate Change**, "*Atmospheric concentrations of carbon dioxide, methane and nitrous oxide are unprecedented in at least the last 800,000 years. Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid-20th century*".

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1.2. Greenhouse effect

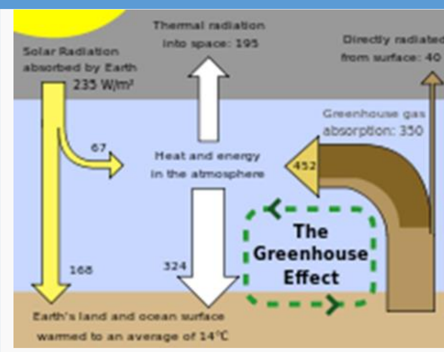
The **greenhouse effect** is the process by which radiation from a planet's atmosphere warms the planet's surface to a temperature above what it would be without its atmosphere.

If a planet's atmosphere contains radioactively active gases (i.e., greenhouse gases) the atmosphere will radiate energy in all directions. Part of this radiation is directed towards the surface, warming it. The downward component of this radiation – that is, the strength of the greenhouse effect – will depend on the atmosphere's temperature and on the amount of greenhouse gases that the atmosphere contains.

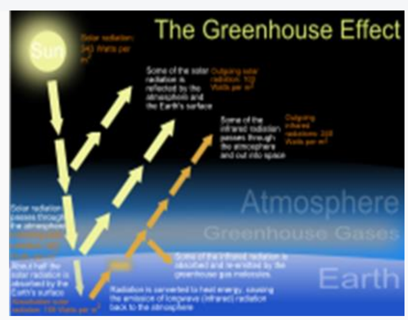
On Earth, the atmosphere is warmed by absorption of infrared thermal radiation from the underlying surface, absorption of shorter wavelength radiant energy from the sun, and convective heat fluxes from the surface. Greenhouse gases in the atmosphere radiate energy, some of which is directed to the surface and lower atmosphere. The mechanism that produces this difference between the actual surface temperature and the effective temperature is due to the atmosphere and is known as the greenhouse effect.

Earth's natural greenhouse effect is critical to supporting life. Human activities, primarily the burning of fossil fuels and clearing of forests, have intensified the natural greenhouse effect, causing global warming.

Greenhouse effect



A representation of the exchanges of energy between the source (the Sun), Earth's surface, the Earth's atmosphere, and the ultimate sink outer space. The ability of the atmosphere to capture and recycle energy emitted by Earth's surface is the defining characteristic of the greenhouse effect. Fig (3)



Another diagram of the greenhouse effect. Fig (4)

The mechanism is named after a faulty analogy with the effect of solar radiation passing through glass and warming a greenhouse. The way a greenhouse retains heat is fundamentally different, as a greenhouse works by reducing airflow and retaining warm air inside the structure.

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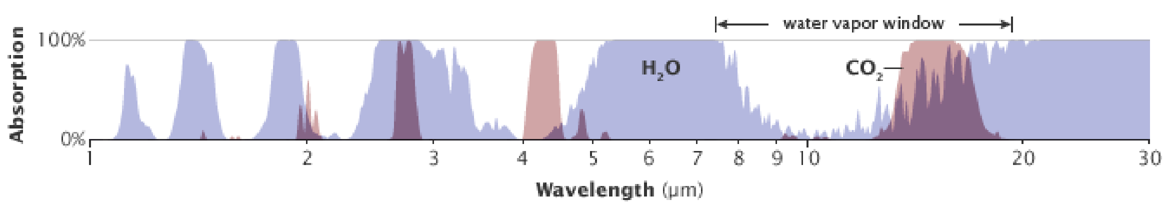
1.3. Greenhouse gases

Atmospheric gases only absorb some wavelengths of energy but are transparent to others. The absorption patterns of water vapor (blue peaks) and carbon dioxide (pink peaks) overlap in some wavelengths. Carbon dioxide is not as strong a greenhouse gas as water vapor, but it absorbs energy in wavelengths (**12-15 micrometers**) that water vapor does not, partially closing the "window" through which heat radiated by the surface would normally escape to space. (Illustration NASA, Robert Rohde)

By their percentage contribution to the greenhouse effect on Earth the four major gases are:

1. water vapor, **36–70%**
2. carbon dioxide**, 9–26%**
3. methane, **4–9%**
4. ozone, **3–7%**

It is not physically realistic to assign a specific percentage to each gas because the absorption and emission bands of the gases overlap (hence the ranges given above). The major non-gas contributor to Earth's greenhouse effect, clouds, also absorb and emit infrared radiation and thus have an effect on the radiative properties of the atmosphere.



Method

2.1Experimental System

Two experimental set-up are built one of them was a Parabolic Trough and the other with CO_2 injected in Parabolic Trough system still under case study. The modification of the parabolic trough by adding a Glass pipe injected by Carbon dioxide at the atmospheric pressure.

Fig (5). Photography picture of parabolic Trough without CO_2

Fig (6). Photography picture of parabolic Trough with CO_2

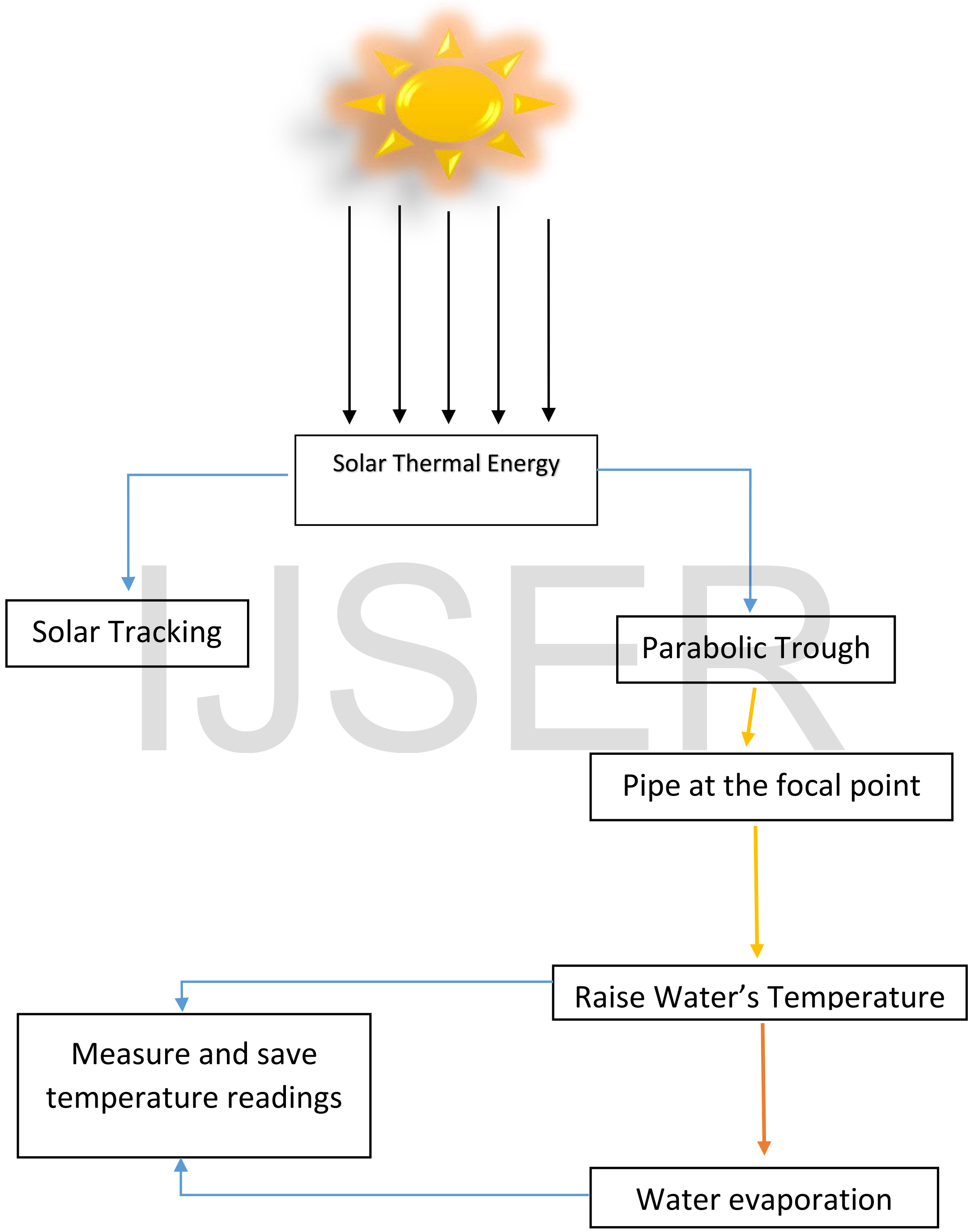


Fig (5). Schematic diagram the process of parabolic Trough

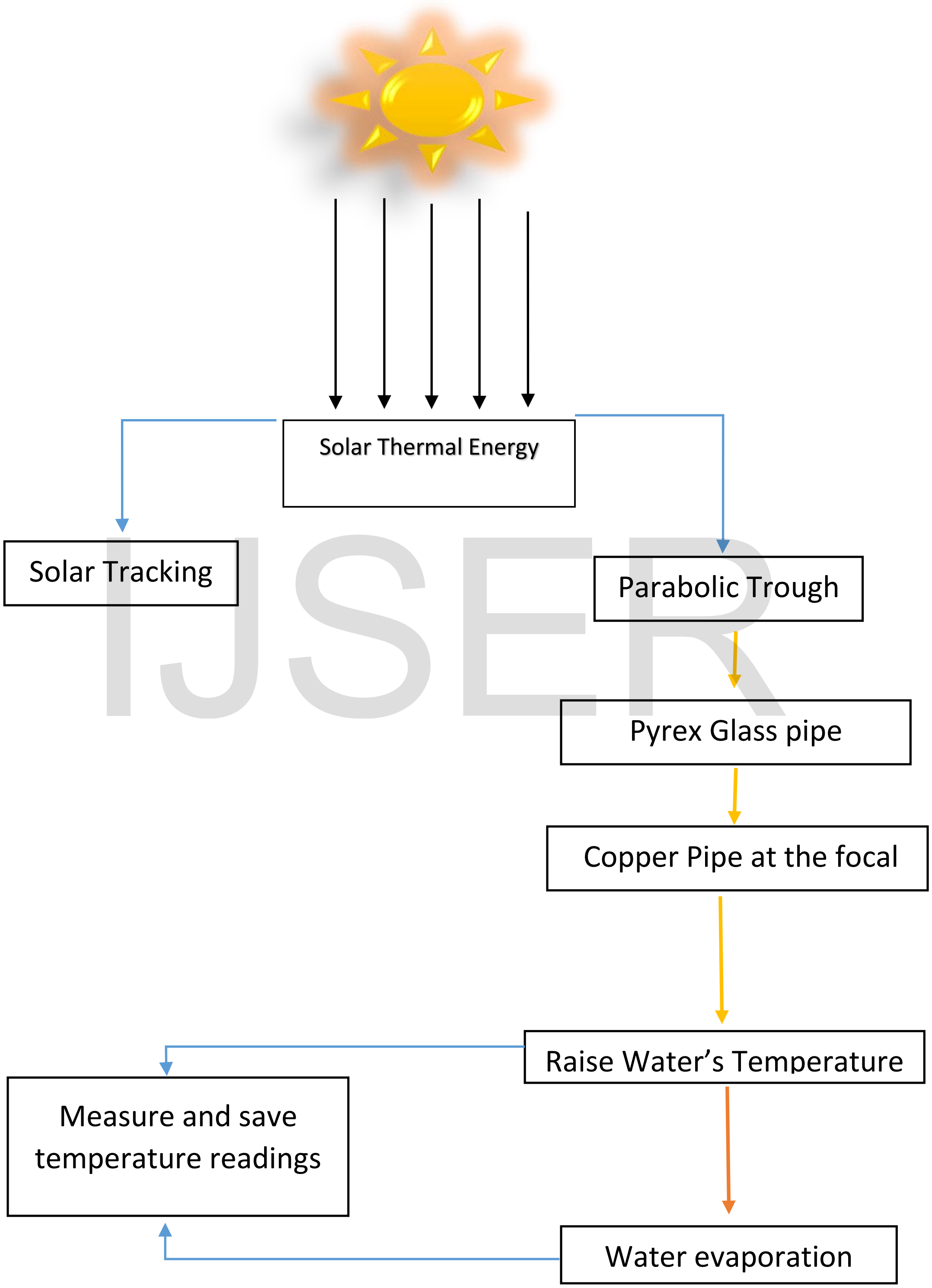


Fig (6). Schematic diagram the process of parabolic Trough with CO_2

2.2 Basic Components:

2.2.1. Parabolic trough solar collector

The Parabolic trough is solar concentrator, reflector and collector. It is manufactured from stainless steel (304) sheet 1.5 mm thickness and 2 m long, as showing in Fig. (7).

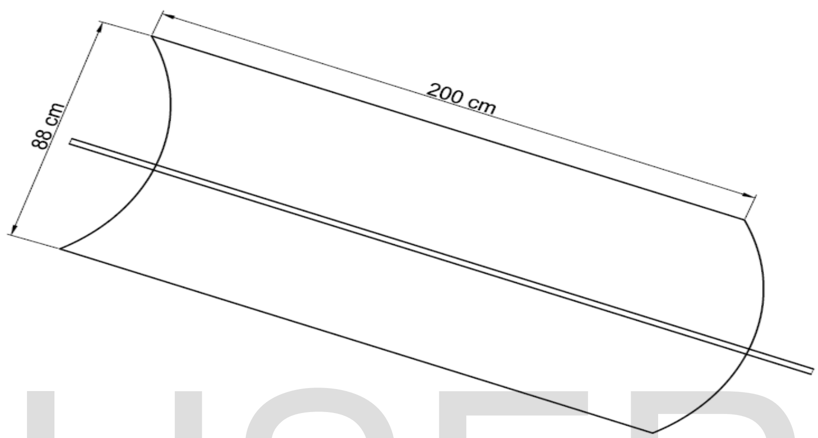


Fig.(7) : The dimensions of the parabolic trough

The pipe of 22 mm diameter is located at the focal line of the trough to collect the most of the reflected solar radiation. Figure (8) shows the incident on the surface of the trough and the reflected solar radiation on the focal pipe . It is painted by black color to absorb the highest amount of the solar energy.

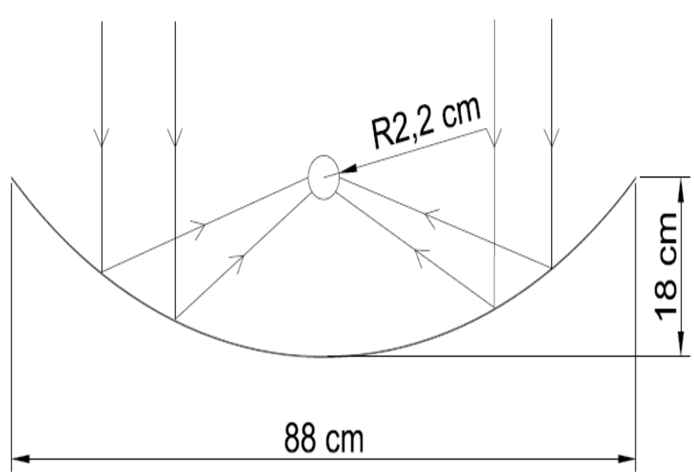


Fig. (8) : The incident on the surface of the trough and the reflected solar radiation on the focal pipe

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2.2.2 Thermal insulation

The external sides of the Glass pipe are thermally insulated by 25 mm thickness glass wool to minimize the thermal losses to the ambient.

2.2.3 A glass pipe

Which we used to trap CO_2 in in order to reserve some of heat.With diemensions (raduis 12 cm, Length 130 cm), Filled with CO_2 at atmosperic pressure.

2.2.4 Two Pressure release valves

Two pressure release valves are set to pressure equals to **1 bar (100 psi)** so if the pressure inside the pipe of CO_2 increased more than atmospheric pressure , PRV outlet Fig.(10) release the increased pressure so to make it equal to the atmospheric again , while the PRV inlet Fig(9) insert CO_2 gas if the pressure inside decreased .

Fig.(9) PRV inlet

Fig.(10) PRV outlet

2.2.5 Two pressure gauges

Two pressure guages are joined to the two PVRs to measure the pressure inside the CO_2 pyrex pipe and the pressure inside the Ballon (**CO_2 Reservoir)**.

2.2.6 CO_2 reservoir:

A ballon reservoir for CO_2 is selected so that its pressure is constant (**equals to the atmospheric pressure**) filled with **CO_2** .

2.3 Electric Components:

2.3.1 LDR sensors

Tracking is particularly important in solar energy collection systems that operate under concentrated sunlight.Two simple Light intensity sensors (LDR) as shown in Fig.(11) with ATmega32 microcontroller (Arduino UNO) are used to follow the sun during the day as the sunlight is prependicular on the two sensors all together. So they read the same value when the pipe is in the focal point.

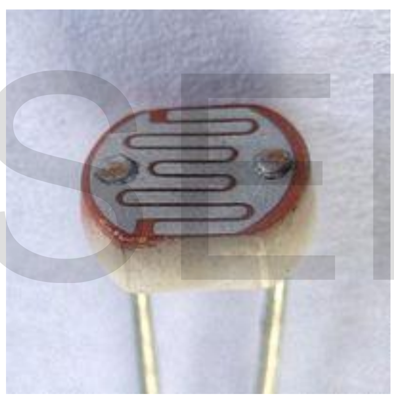


Fig. (11) LDR sensor

2.2.2 Two DC motors

Two motors Fig.(12) are used to control movement of the parabolic trough. The motor take the signal from the light intensity sensor circuit, they give the motor two signals one to make the motor move forward and the other to move backward pulling the wires and release it to move the **parabolic trough**.

Fig.(12) the motor.

The motor is selected as a simple motor work by a direct current (DC). Table (1) show the motor charactaristics

Table (1): Motor charactaristics:

current flow (I)	Voltage (V)	Armature resistance (R)	Angular speed (ωm)
10 Amp	24 Volts	0.1 Ω	958 radians/s

2.2.3DataLogger

Consists of SD Card Arduino Kit -Fig. (13) -and ATmega32 (Arduino UNO), ATmega32 reads temperature and LDR Value and store it in micro SD card every 10 seconds.

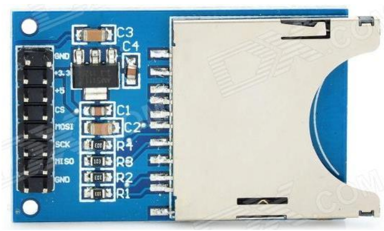


Fig. (13) SD Card Arduino Kit

2.2.4Temperature sensor

DS18B20 Temperature Sensor is used for measuring temperature of the selected location inside the parabolic trough system as showing in fig. (14). The temperature sensor is connected with the ATmega32 (Arduino UNO), which process the signals out of it and save to SD Card with the Celsius (Centigrade) temperature.

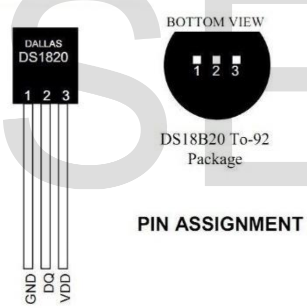


Fig . (12) DS18B20 sensor

The DS18B20 digital thermometer provides 9-bit to 12-bit Celsius temperature measurements and has an alarm function with nonvolatile user-programmable upper and lower trigger points. The DS18B20 communicates over a 1-Wire bus that by definition requires only one data line (and ground) for communication with a central microprocessor. In addition, the DS18B20 can derive power directly from the data line ("parasite power"), eliminating the need for an external power supply. Each DS18B20 has a unique 64-bit serial code, which allows multiple DS18B20s to function on the same 1-Wire bus. Thus, it is simple to use one microprocessor to control many DS18B20s distributed over a large area. Measures Temperatures from -55°C to +125°C.

2.2.5 ATmega32 (Arduino UNO)

It's the microcontroller Fig.(15) which where all process done, store LDR value and temperature on micro SD card every 10 seconds , and controls the two motors according the reading it gets from LDR sensors.

Fig. (15) Arduino Uno

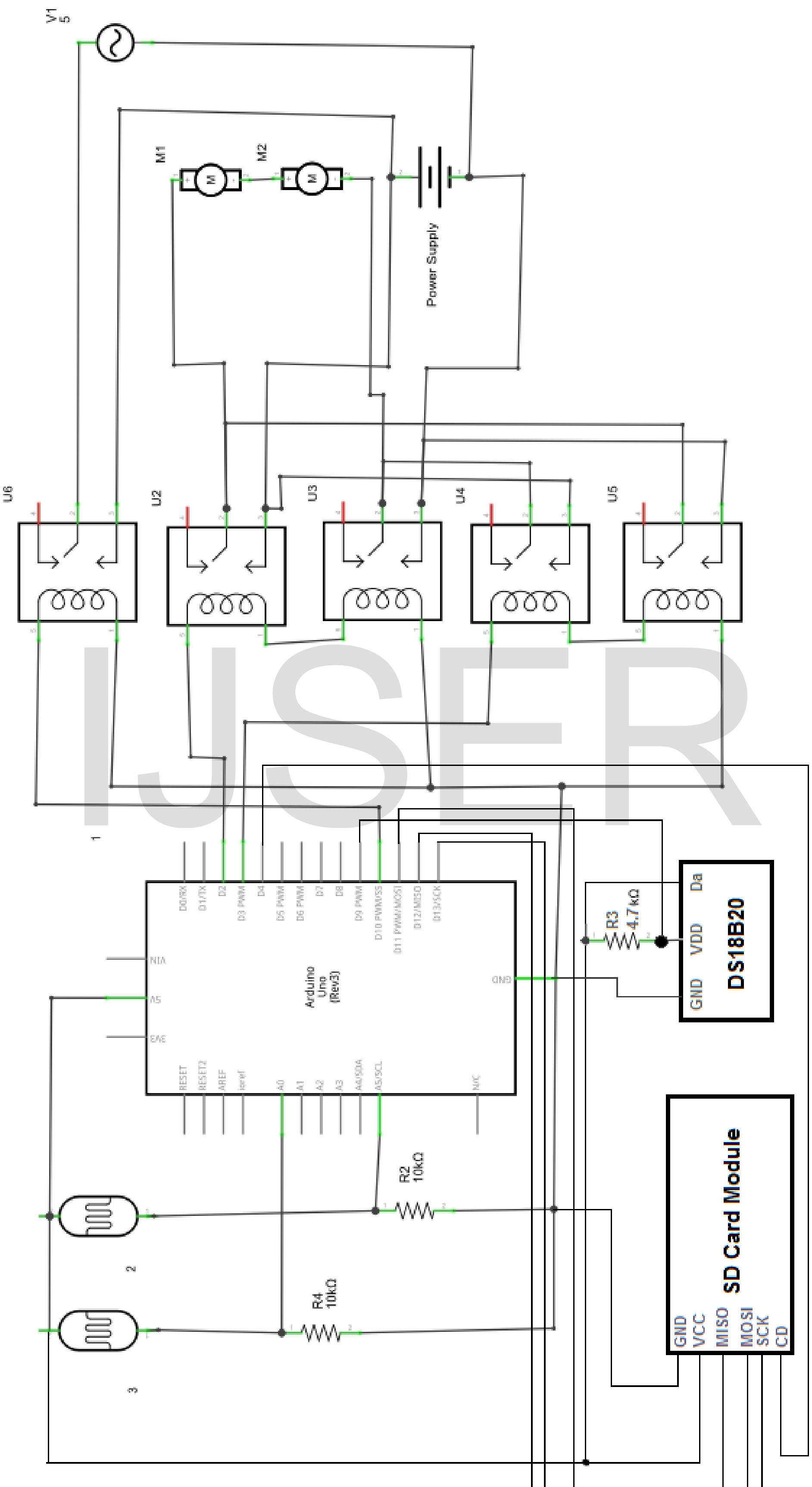


Fig. (16) Schematics for Project's Circuit

2.4 Software programs:

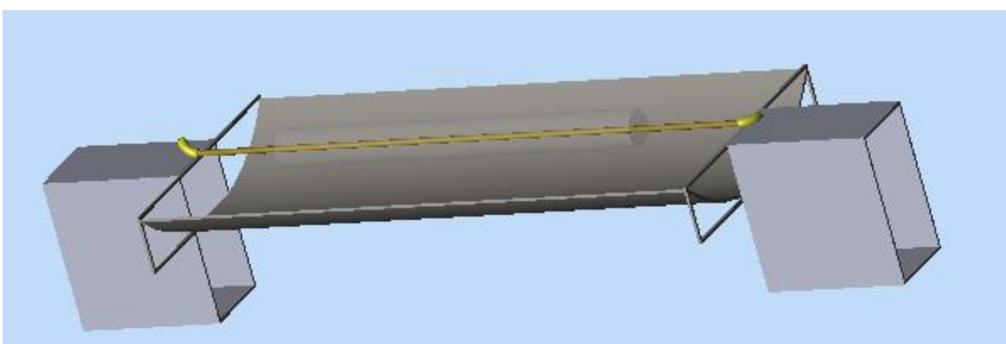
2.4.1 Edraw Max 8.2

Used in creating and designing project's circuit

2.4.2 Fritzing 0.9.2

Used in testing wiring and also in designing the project's circuit.

2.4.3 SolidWorks

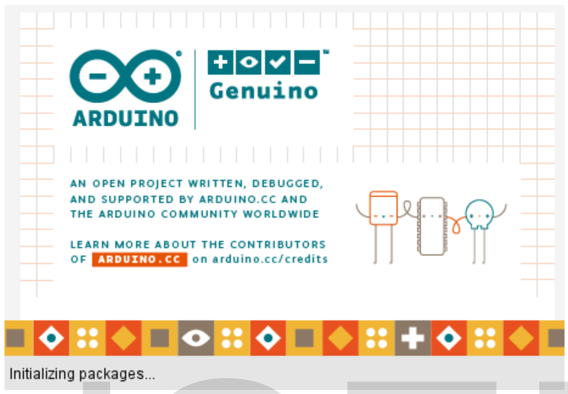


Used in designing the glass pipe and determine the amount of CO_2 required to be injected.

2.4.4 Excel 2013

Used in our calculations, getting charts and make comparisons.

2.4.5 IDE



An Arduino platform used in programming our microcontroller.

2.5 Mathematical Equations used:

Pressure inside the pipe (water/vapor pressure) p

The equation [edit]

$$\log_{10} p = A - \frac{B}{C+T}.$$

where p is the vapor pressure, T is temperature and A, B and C are component-specific constants.

The simplified form with C set to zero:

$$\log_{10} p = A - \frac{B}{T}$$

Example parameters [edit]

	A	*B*	*C*	*T* min. °C	*T* max °C
Water	8.07131	1730.63	233.426	1	100
Water	8.14019	1810.94	244.485	99	374
Ethanol	8.20417	1642.89	230.300	-57	80
Ethanol	7.68117	1332.04	199.200	77	243

The constants are given in °C and mmHg.

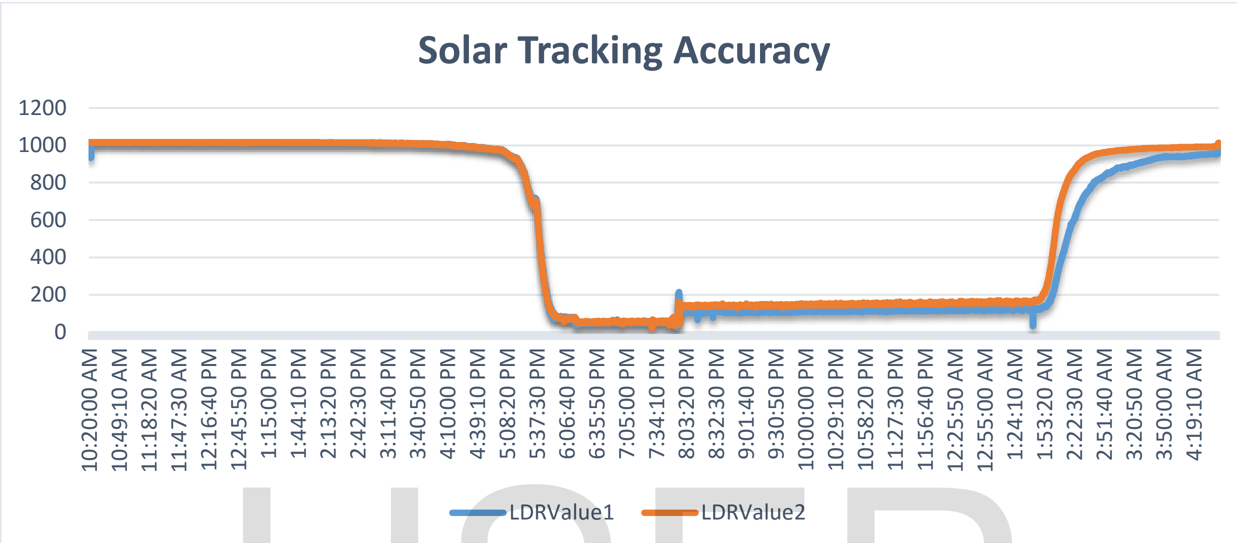
Efficiency:

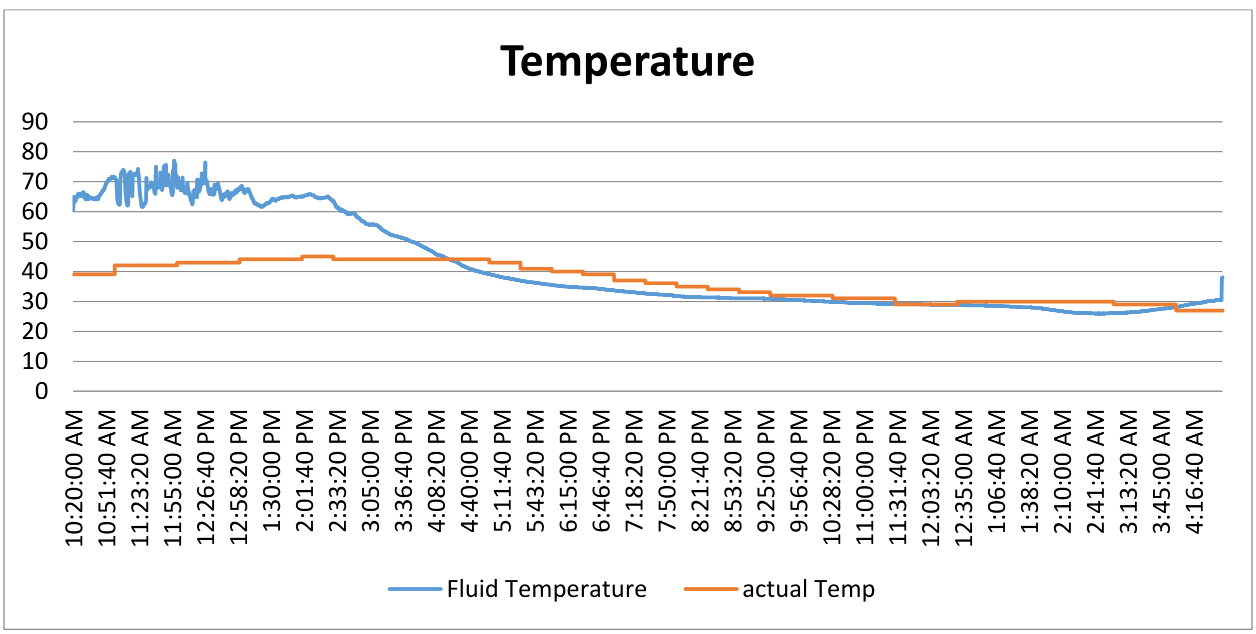
$$\eta = \frac{Averge\ temp.\ of\ fluid - actual\ temp}{actual\ temp}$$

Results

We made the device works for 5 days and nights for the Parabolic Trough without CO_2 and got this results:

Day 1 (15/5/2016):





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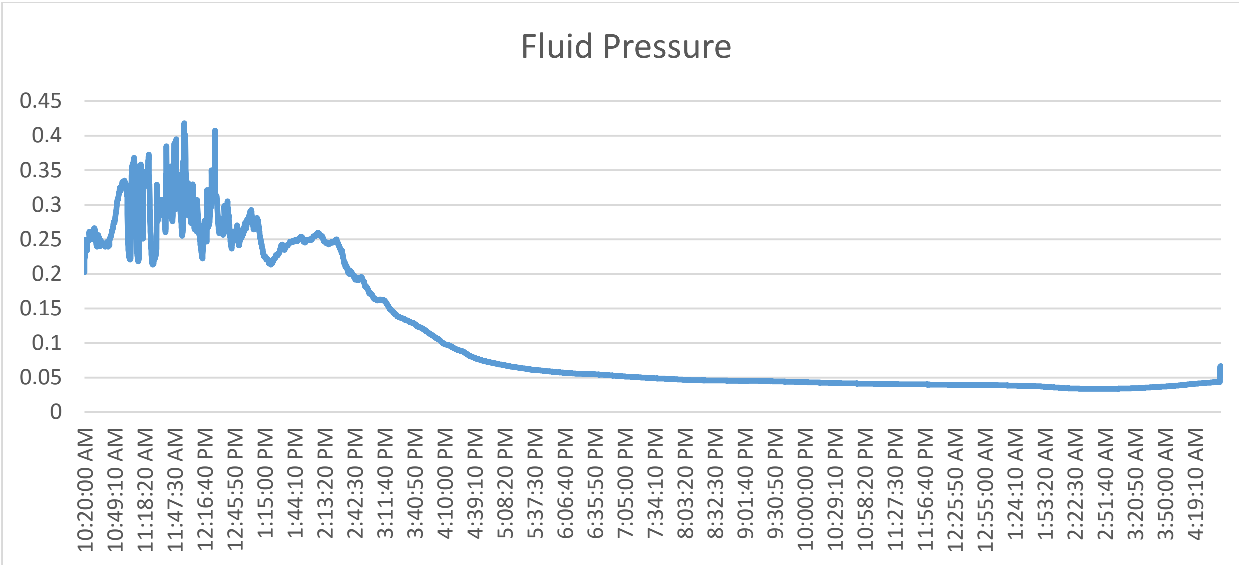
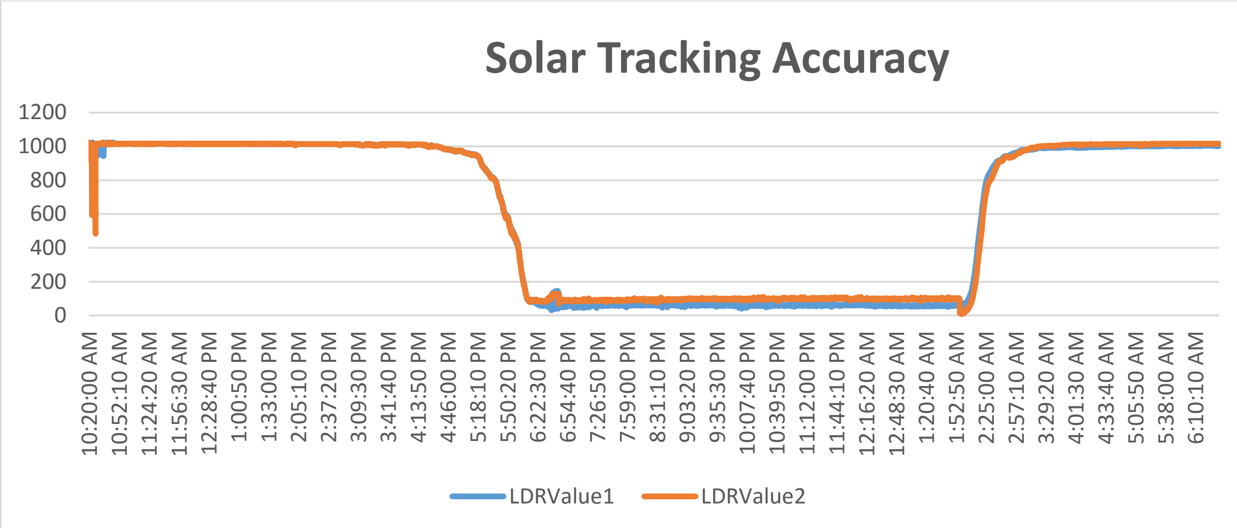
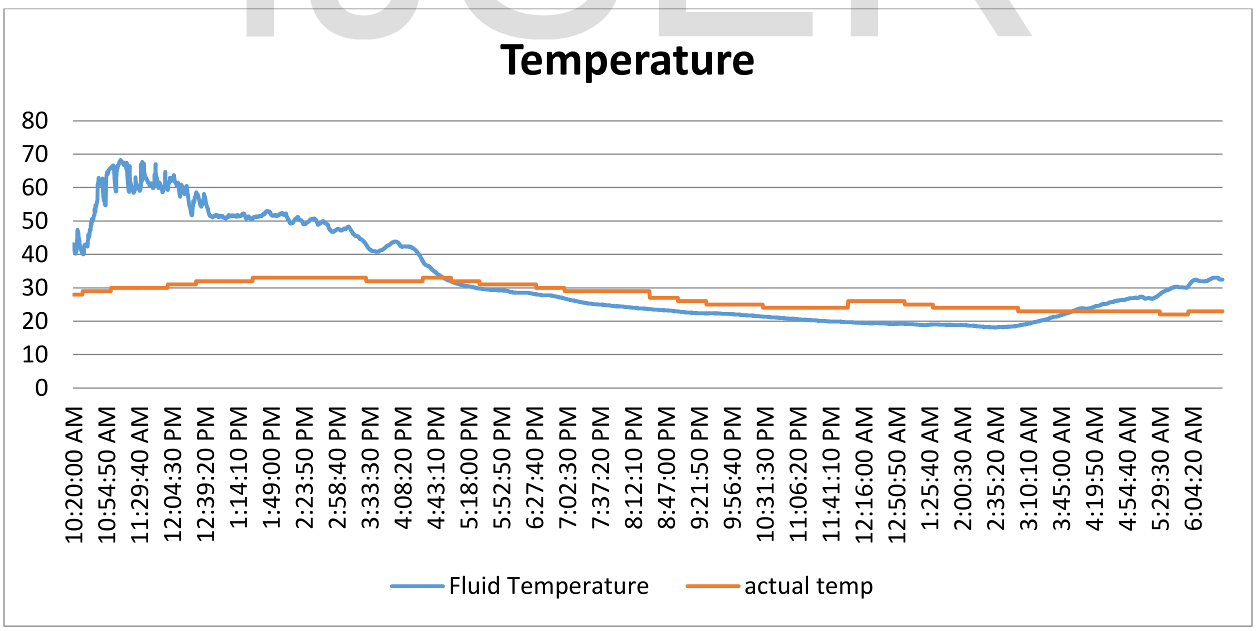


Max Temperature	77.00
Min Temperature	25.94
Average Temperature for Day	60.25
Average Temperature for night	30.45
Δ Temperature	51.06
Δ Average Temperature	29.80
Max pressure	0.41802
Min pressure	0.033394
Average pressure for Day	0.215792
Average pressure for night	0.04404
Δ pressure	0.384625
Δ Average pressure	0.171752

Day 2 (17/5/2016):





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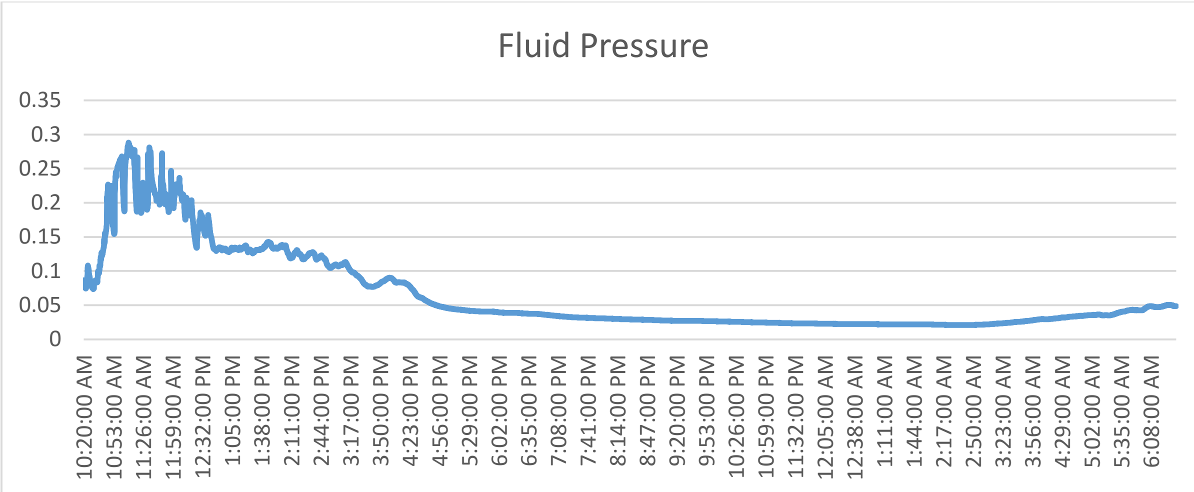
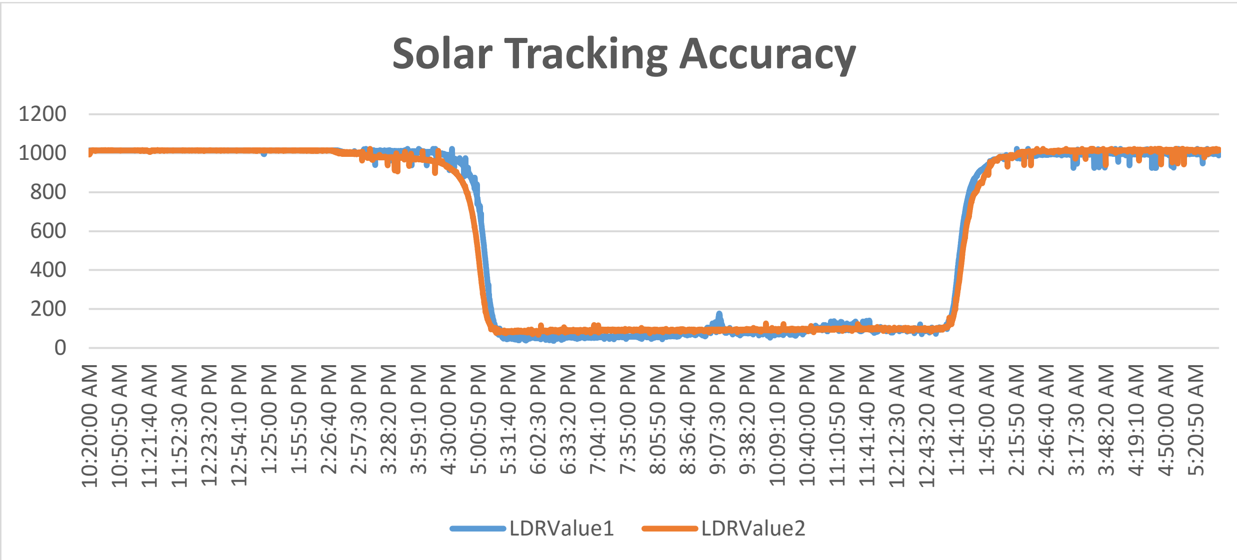
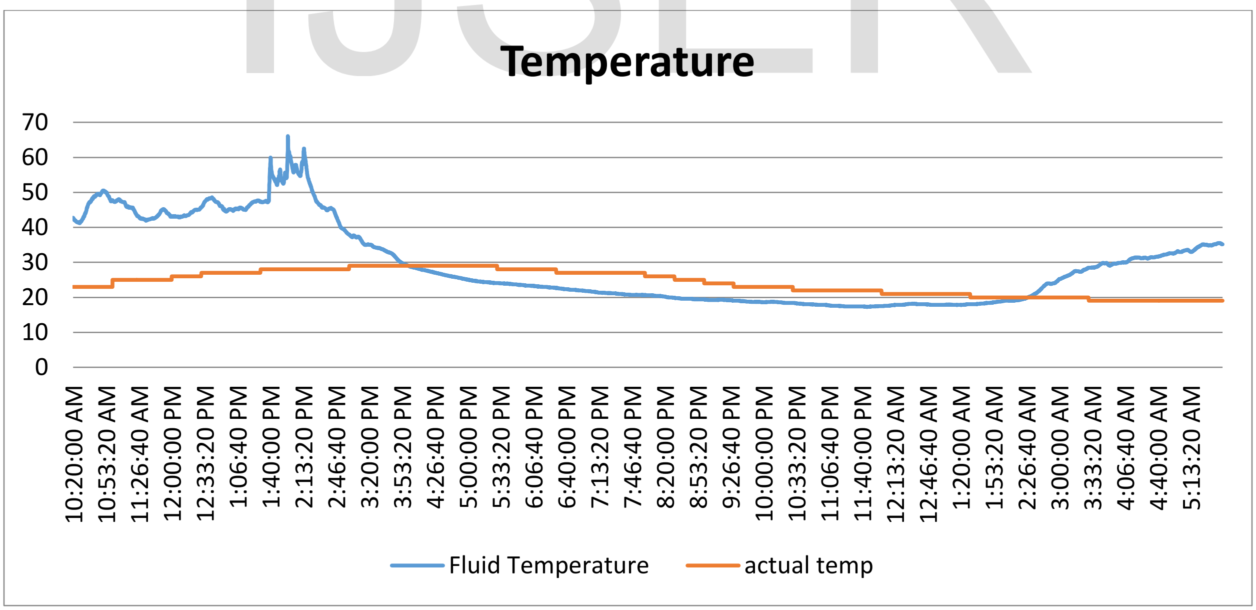
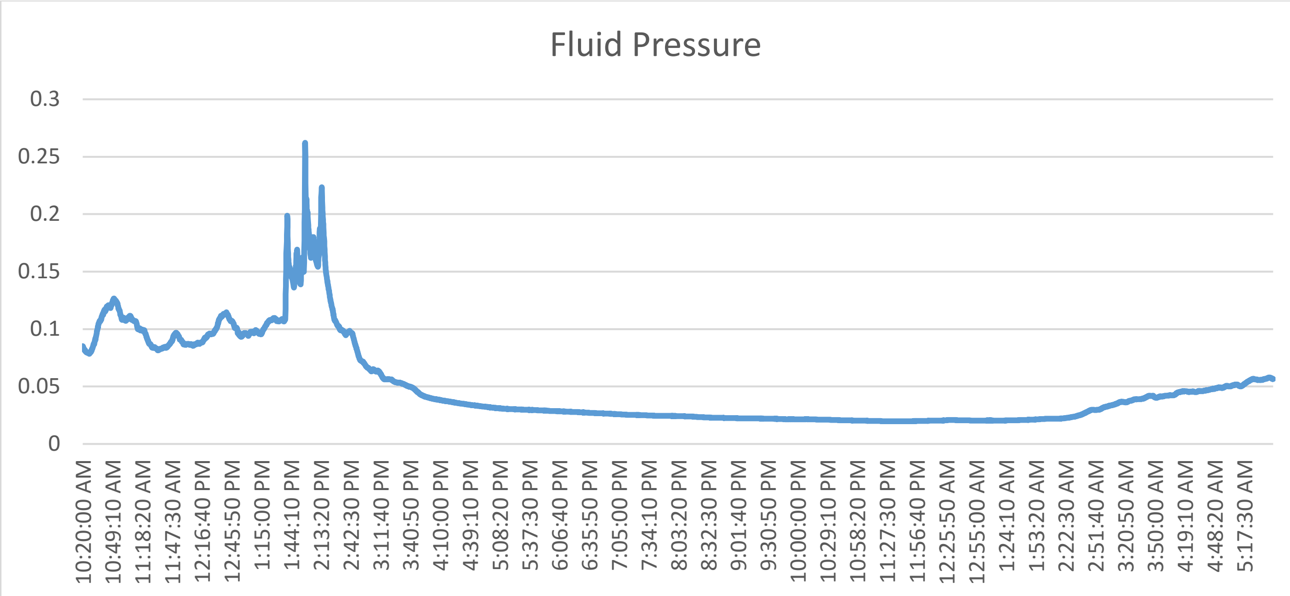


Max Temperature	68.25
Min Temperature	18.12
Average Temperature for Day	50.41
Average Temperature for night	23.63
Δ Temperature	50.13
Δ Average Temperature	26.79
Max pressure	0.288068
Min pressure	0.020713
Average pressure for Day	0.135095
Average pressure for night	0.029901
Δ pressure	0.267356
Δ Average pressure	0.105194

Day 3 (18/5/2016):

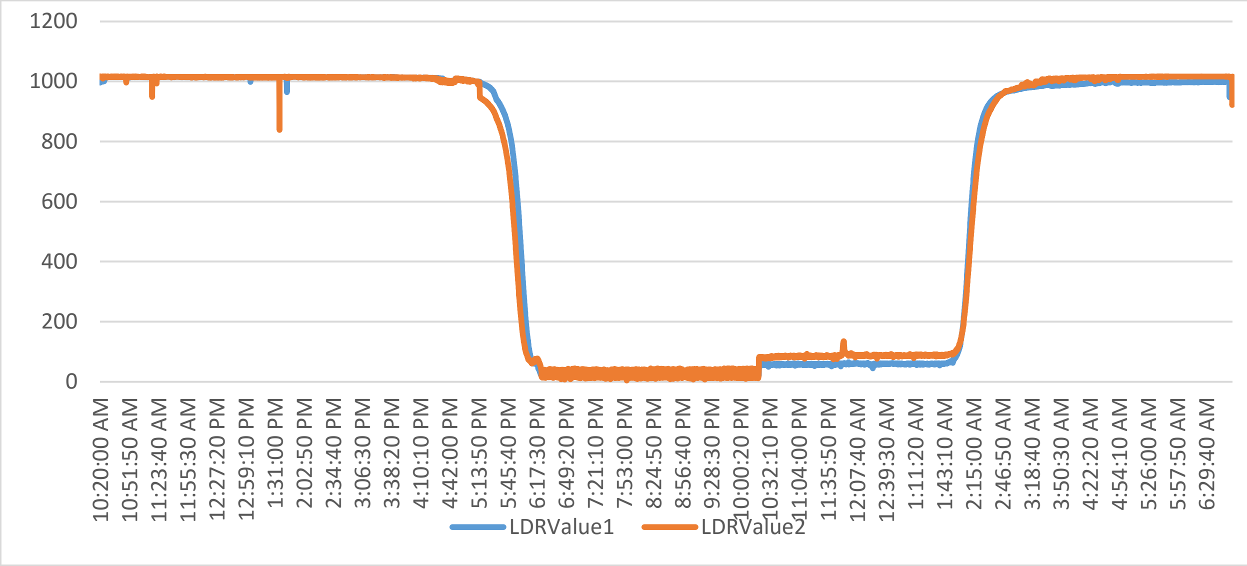


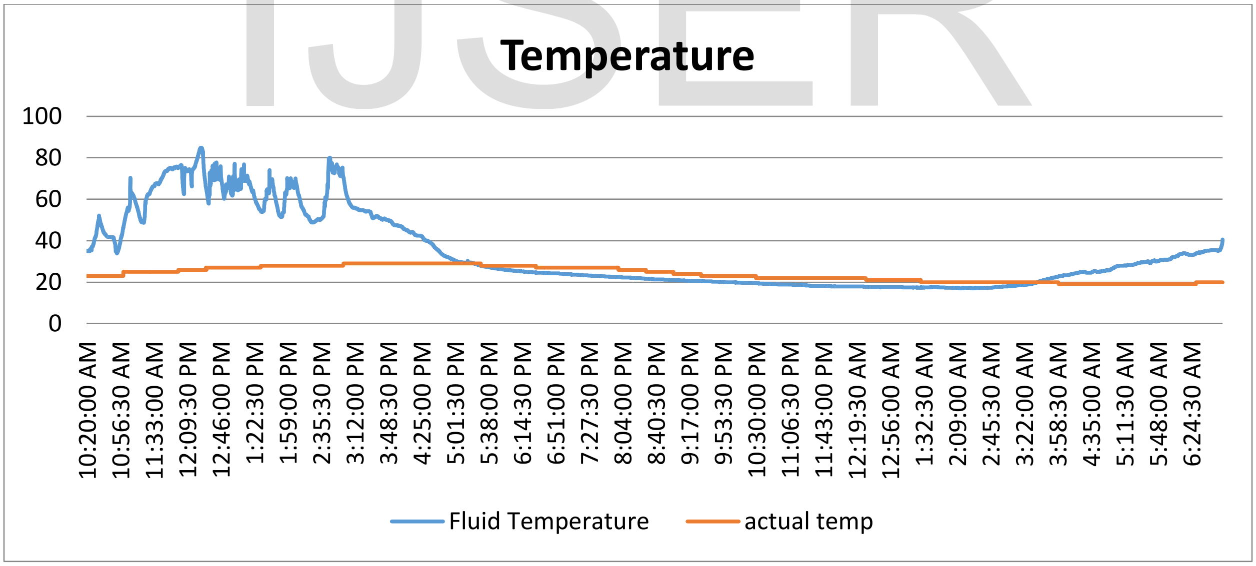


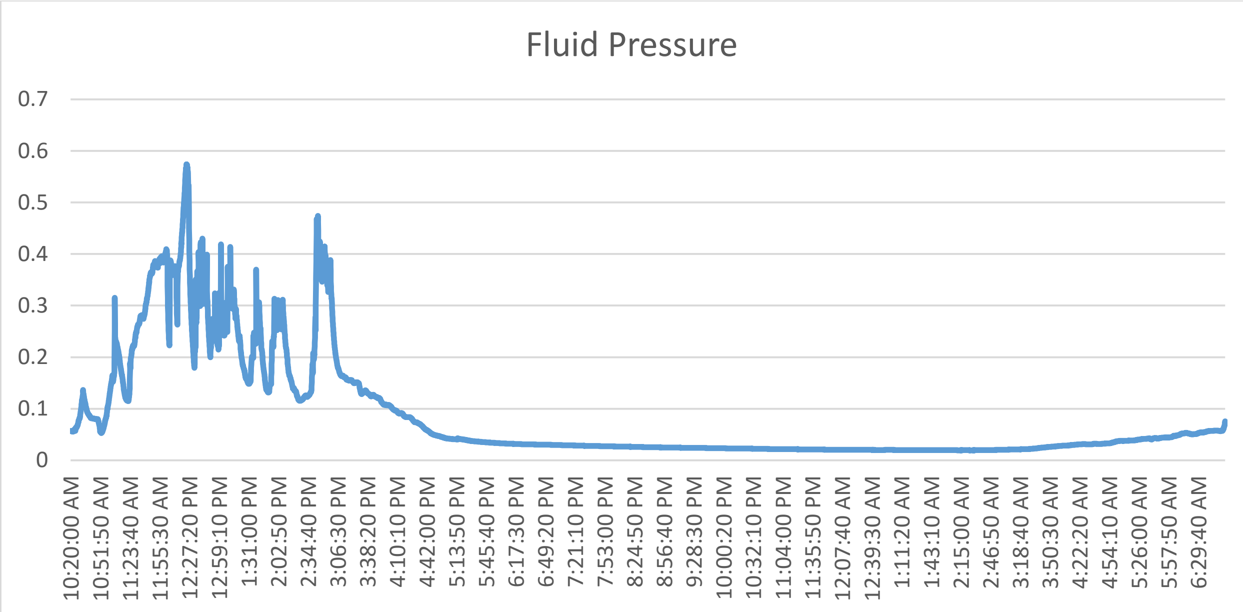


Max Temperature	66.12
Min Temperature	17.25
Average Temperature for Day	41.92
Average Temperature for night	21.52
Δ Temperature	48.87
Δ Average Temperature	20.40
Max pressure	0.262242
Min pressure	0.019605
Average pressure for Day	0.088795
Average pressure for night	0.026382
Δ pressure	0.242638
Δ Average pressure	0.062413

Day 4 (18/5/2016):







Max Temperature	84.87
Min Temperature	17.06
Average Temperature for Day	56.84
Average Temperature for night	22.56
Δ Temperature	67.81
Δ Average Temperature	34.29
Max pressure	0.574171
Min pressure	0.01937
Average pressure for Day	0.199057
Average pressure for night	0.028408
Δ pressure	0.554801
Δ Average pressure	0.170649

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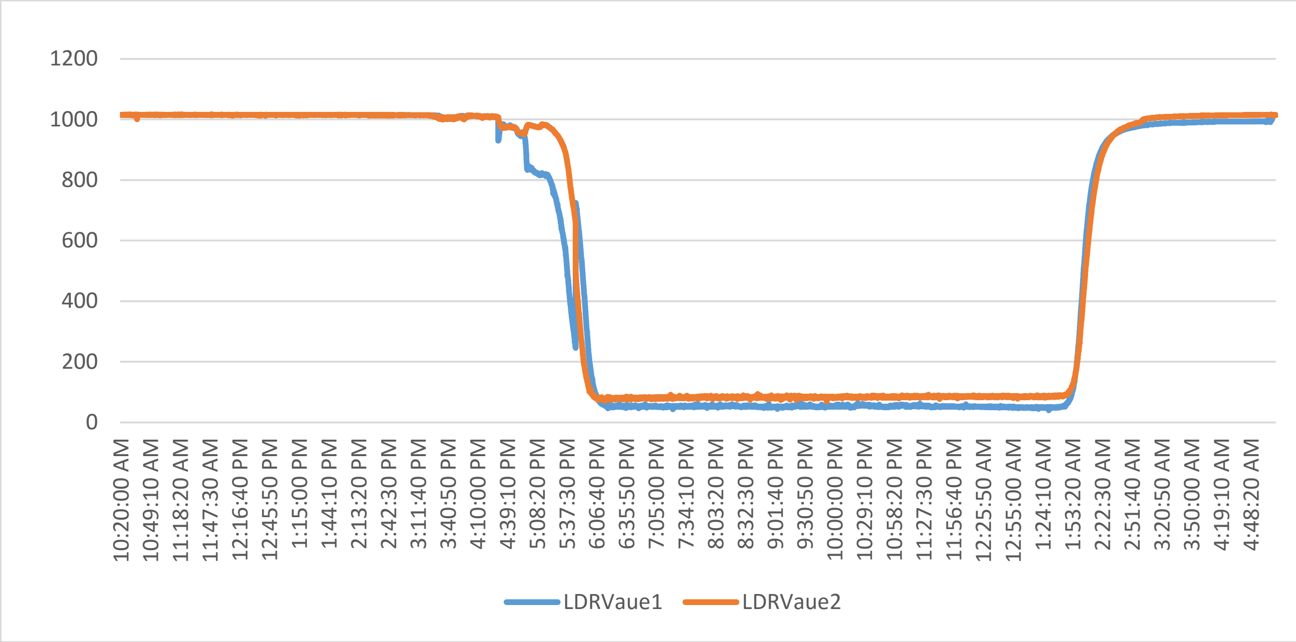
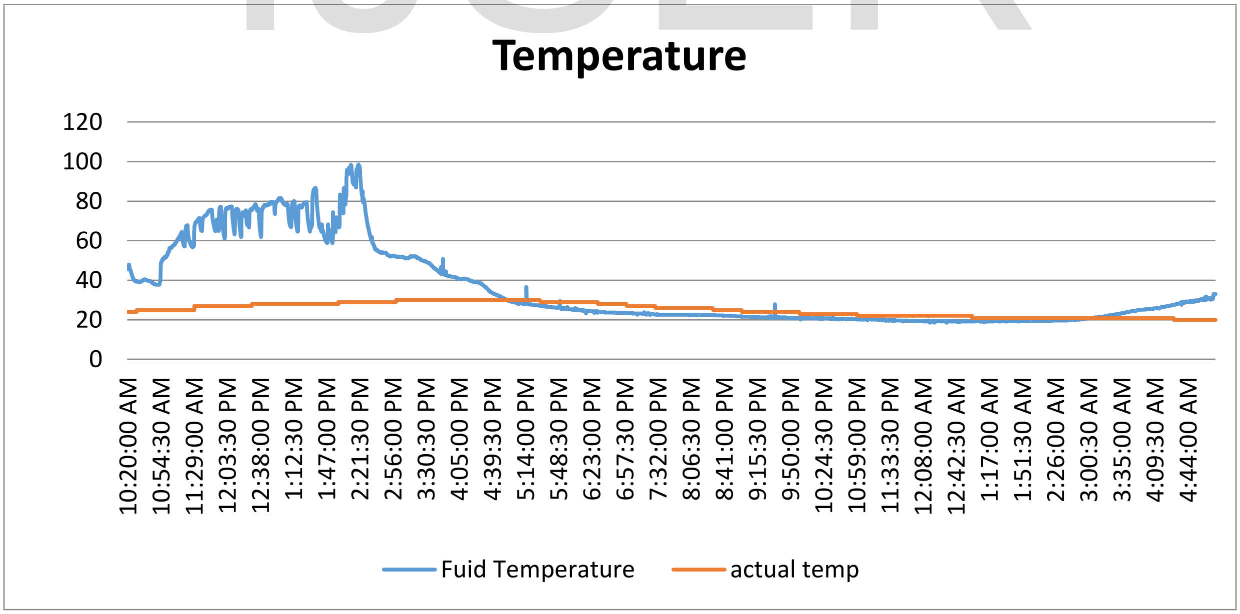
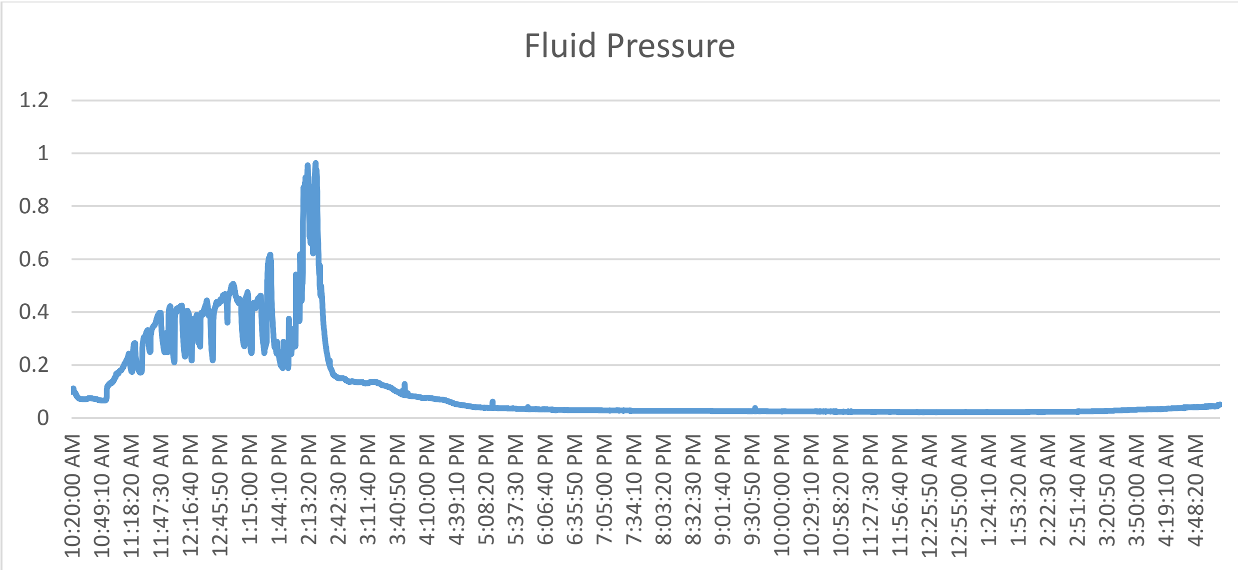
Day 5 (18/5/2016):







Max Temperature	98.62
Min Temperature	18.44
Average Temperature for Day	59.12
Average Temperature for night	22.40
Δ Temperature	80.18
Δ Average Temperature	36.71
Max pressure	0.96426
Min pressure	0.021134
Average pressure for Day	0.243204
Average pressure for night	0.027434
Δ pressure	0.943126
Δ Averages pressure	0.21577

Summery:

DAY	MAX TEMP	MIN TEMP	Δ T	AVERAGE
15/05/2016	77	25.94	51.06	41.24894
17/05/2016	68.25	18.12	50.13	32.45257
18/05/2016	66.12	17.25	48.87	29.06679
19/05/2016	84.87	17.06	67.81	33.64837
20/05/2016	98.62	18.44	80.18	36.73505
Average	78.972	19.362	59.61	34.630344

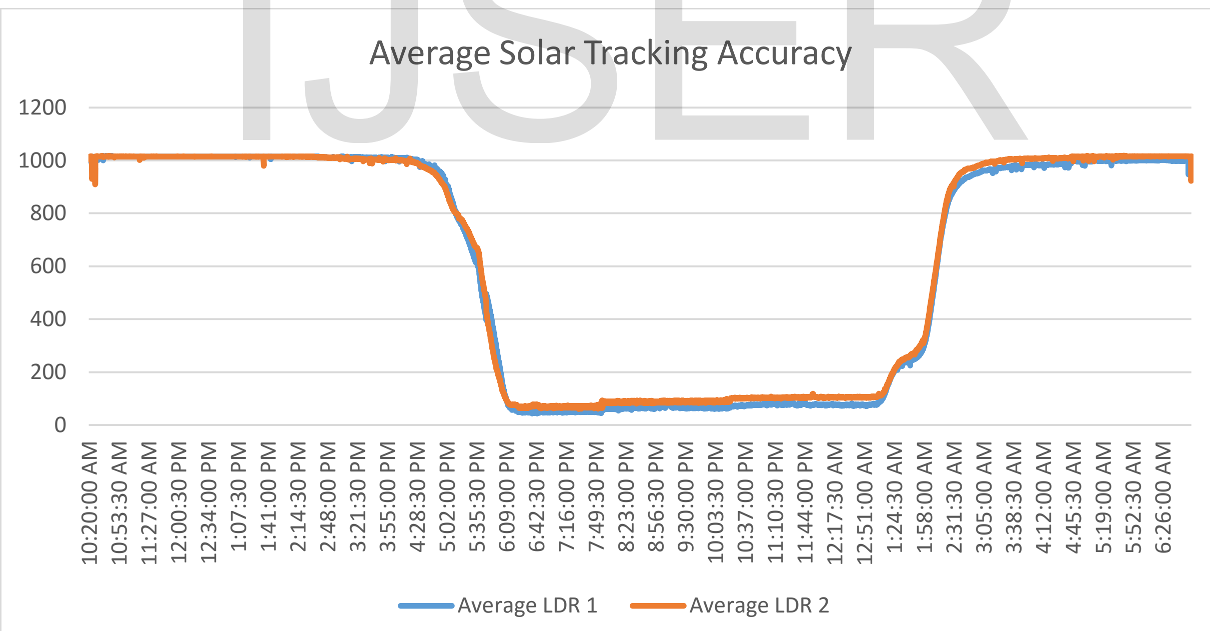
DAY	Average Temperature for Day	Average Temperature for night
15/05/2016	60.25	30.45
17/05/2016	50.41	23.63
18/05/2016	41.92	21.52
19/05/2016	56.84	22.56
20/05/2016	59.12	22.41
Average	53.708	24.114

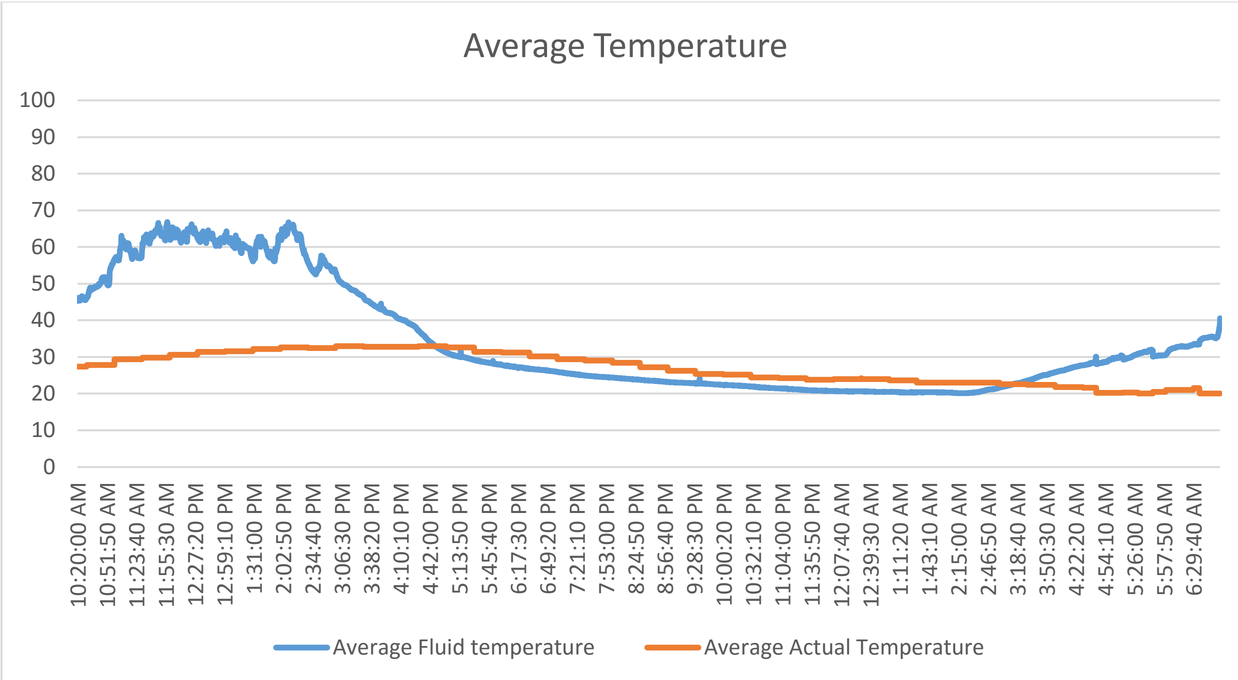
DAY	actual temp HI	actual temp lo
15/05/2016	45	30
17/05/2016	33	22
18/05/2016	29	20
19/05/2016	29	19
20/05/2016	30	19
Average	33.2	22

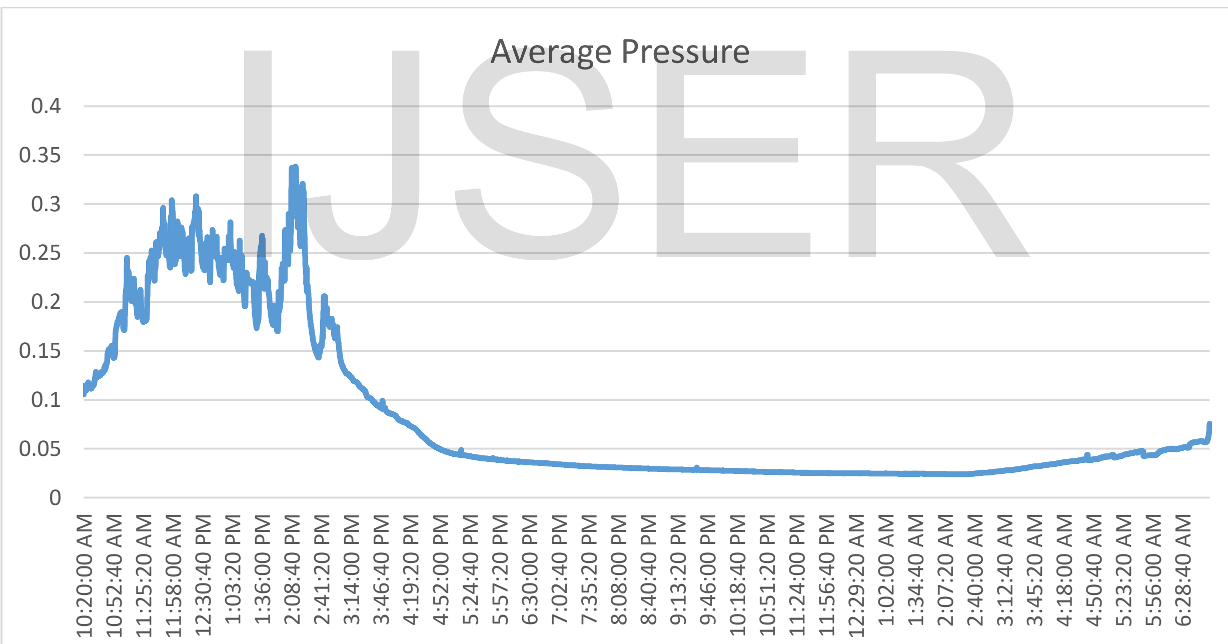
DAY	Max. pressure	Min Pressure	Δ p	AVERAGE
15/05/2016	0.418019701	0.033394355	0.384625347	0.225707028
17/05/2016	0.288068307	0.020712798	0.267355509	0.154390553
18/05/2016	0.262242486	0.019604738	0.242637749	0.140923612
19/05/2016	0.5741711	0.019369762	0.554801338	0.296770431
20/05/2016	0.964260112	0.021133912	0.9431262	0.492697012
Average	0.501352342	0.022843113	0.478509229	0.262097727

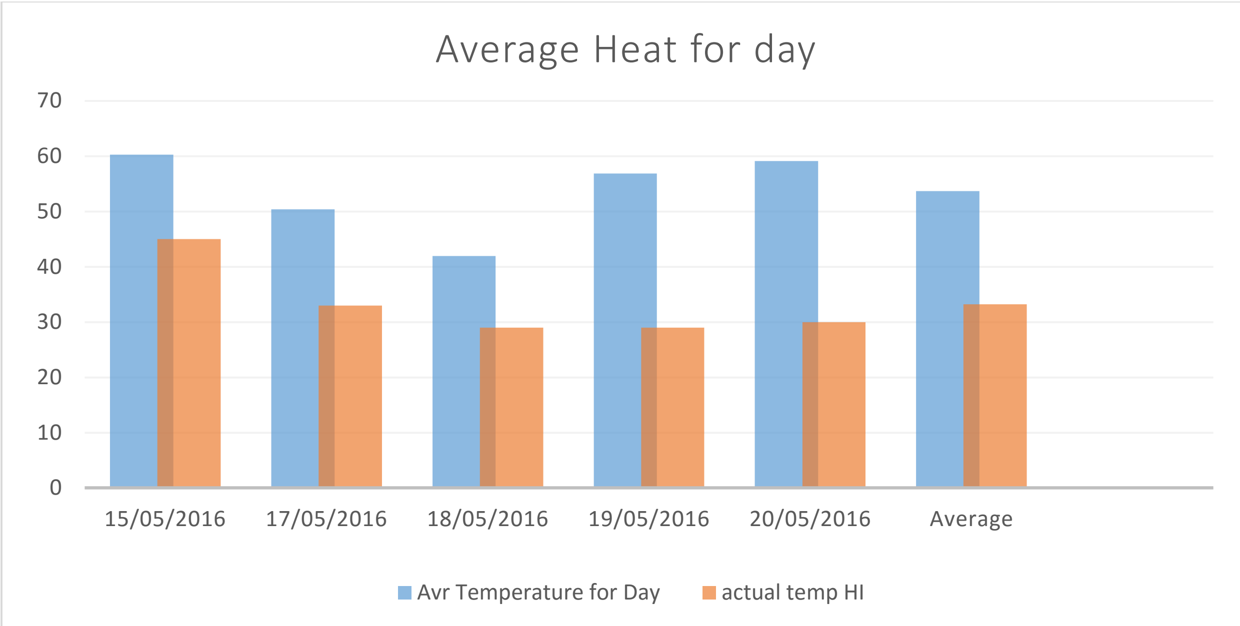
DAY	Average Pressure for Day	Average Pressure for night
15/05/2016	0.22	0.04
17/05/2016	0.14	0.03
18/05/2016	0.09	0.03
19/05/2016	0.2	0.03
20/05/2016	0.24	0.03
Average	0.178	0.032

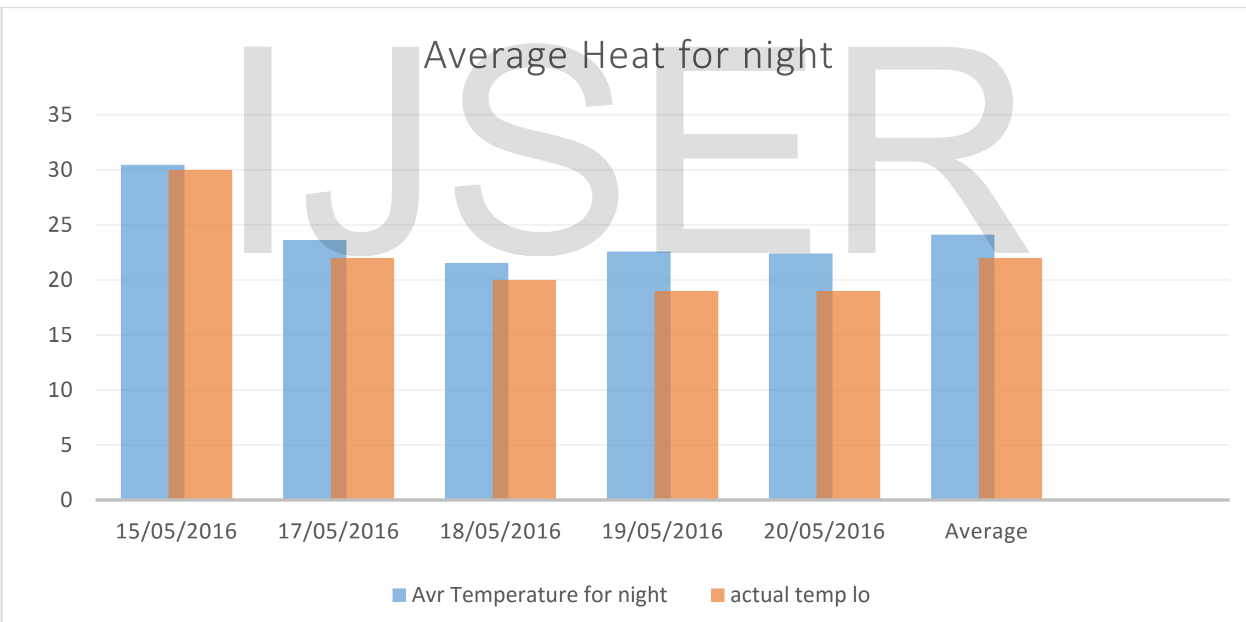
DAY	η for day	η for night
15/05/2016	33.89%	1.50%
17/05/2016	52.76%	7.41%
18/05/2016	44.55%	7.60%
19/05/2016	96.00%	18.74%
20/05/2016	97.07%	17.95%
Average	61.77%	9.61%

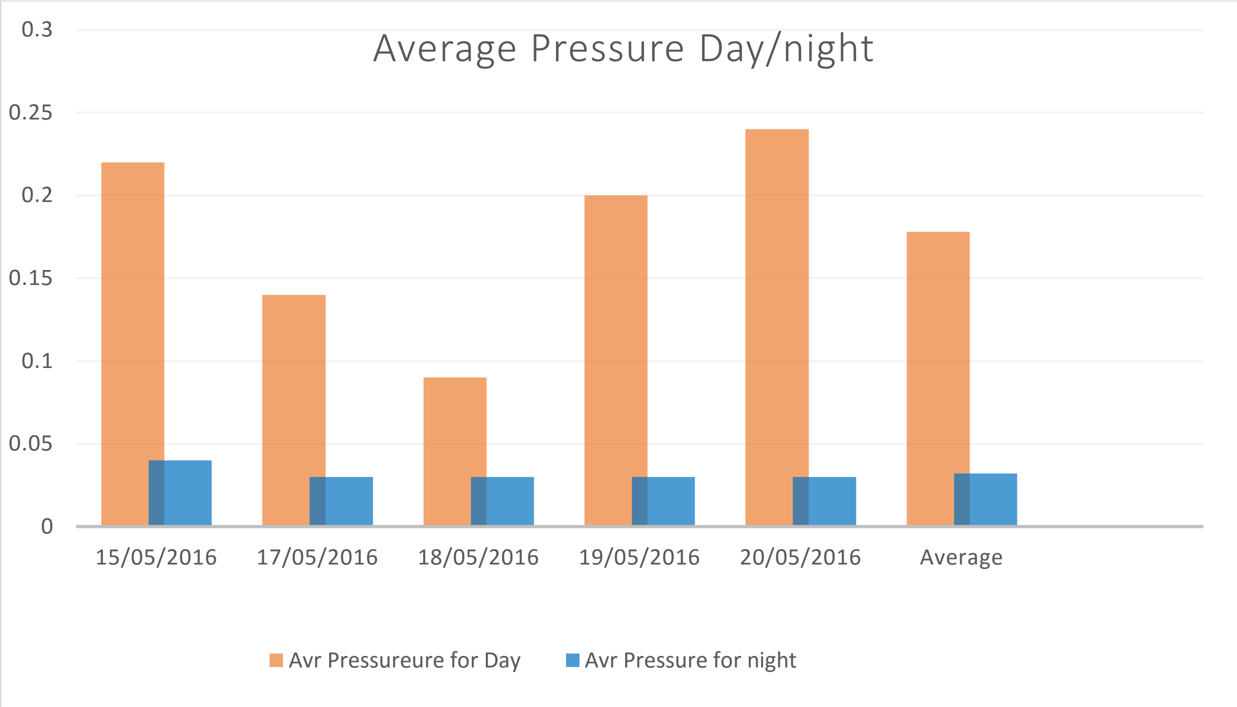


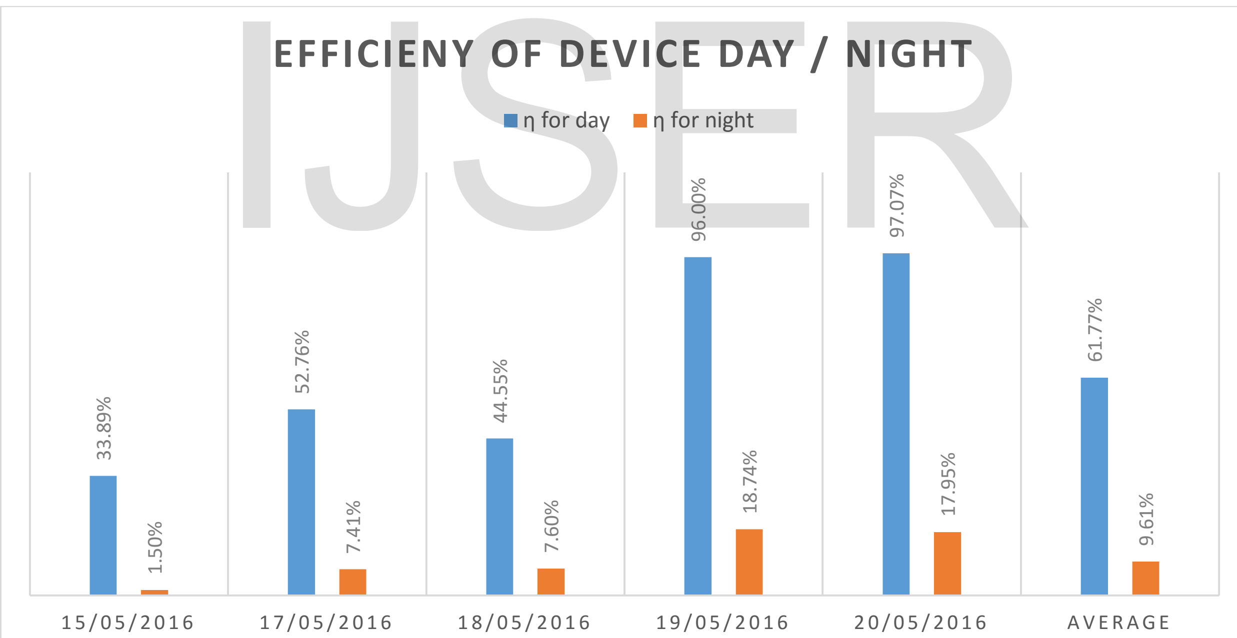

Average Temperature
100
90
80
70
60
50
40
30
20
10
0
10:20:00 AM
10:51:50 AM
11:23:40 AM
11:55:30 AM
12:27:20 PM
12:59:10 PM
1:31:00 PM
2:02:50 PM
2:34:40 PM
3:06:30 PM
3:38:20 PM
4:10:10 PM
4:42:00 PM
5:13:50 PM
5:45:40 PM
6:17:30 PM
6:49:20 PM
7:21:10 PM
7:53:00 PM
8:24:50 PM
8:56:40 PM
9:28:30 PM
10:00:20 PM
10:32:10 PM
11:04:00 PM
11:35:50 PM
12:07:40 AM
12:39:30 AM
1:11:20 AM
1:43:10 AM
2:15:00 AM
2:46:50 AM
3:18:40 AM
3:50:30 AM
4:22:20 AM
4:54:10 AM
5:26:00 AM
5:57:50 AM
6:29:40 AM
Average Fluid temperature
Average Actual Temperature


Average Pressure
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
10:20:00 AM
10:52:40 AM
11:25:20 AM
11:58:00 AM
12:30:40 PM
1:03:20 PM
1:36:00 PM
2:08:40 PM
2:41:20 PM
3:14:00 PM
3:46:40 PM
4:19:20 PM
4:52:00 PM
5:24:40 PM
5:57:20 PM
6:30:00 PM
7:02:40 PM
7:35:20 PM
8:08:00 PM
8:40:40 PM
9:13:20 PM
9:46:00 PM
10:18:40 PM
10:51:20 PM
11:24:00 PM
11:56:40 PM
12:29:20 AM
1:02:00 AM
1:34:40 AM
2:07:20 AM
2:40:00 AM
3:12:40 AM
3:45:20 AM
4:18:00 AM
4:50:40 AM
5:23:20 AM
5:56:00 AM
6:28:40 AM


Average Heat for day
70
60
50
40
30
20
10
0
15/05/2016
17/05/2016
18/05/2016
19/05/2016
20/05/2016
Average
Avr Temperature for Day
actual temp HI

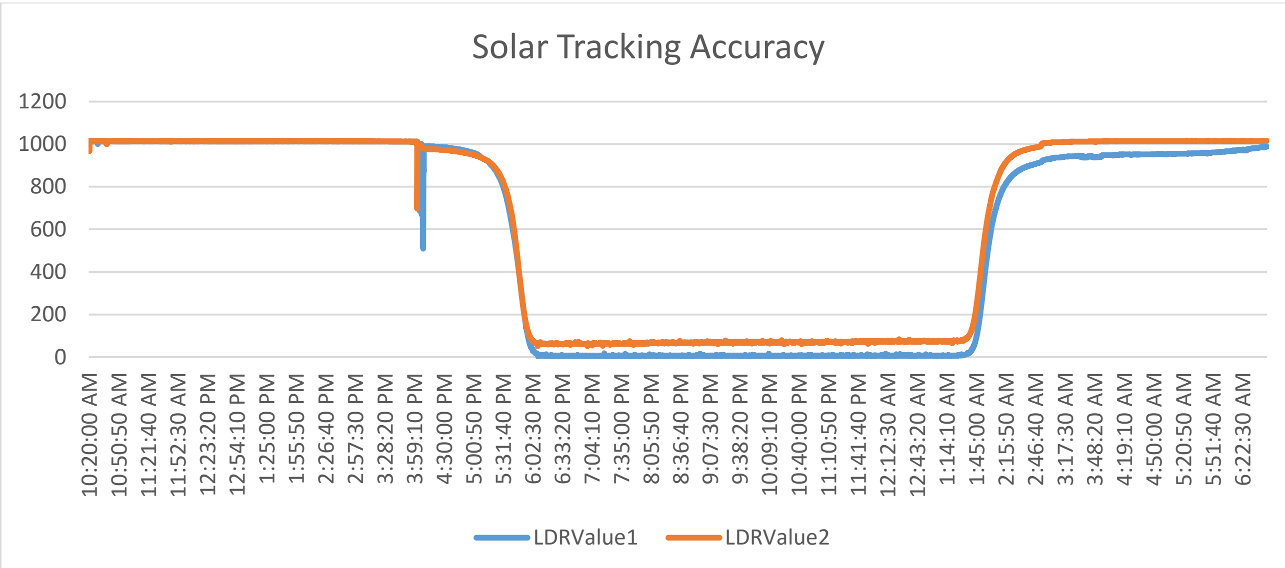

Average Heat for night
35
30
25
20
15
10
5
0
15/05/2016
17/05/2016
18/05/2016
19/05/2016
20/05/2016
Average
Avr Temperature for night
actual temp lo

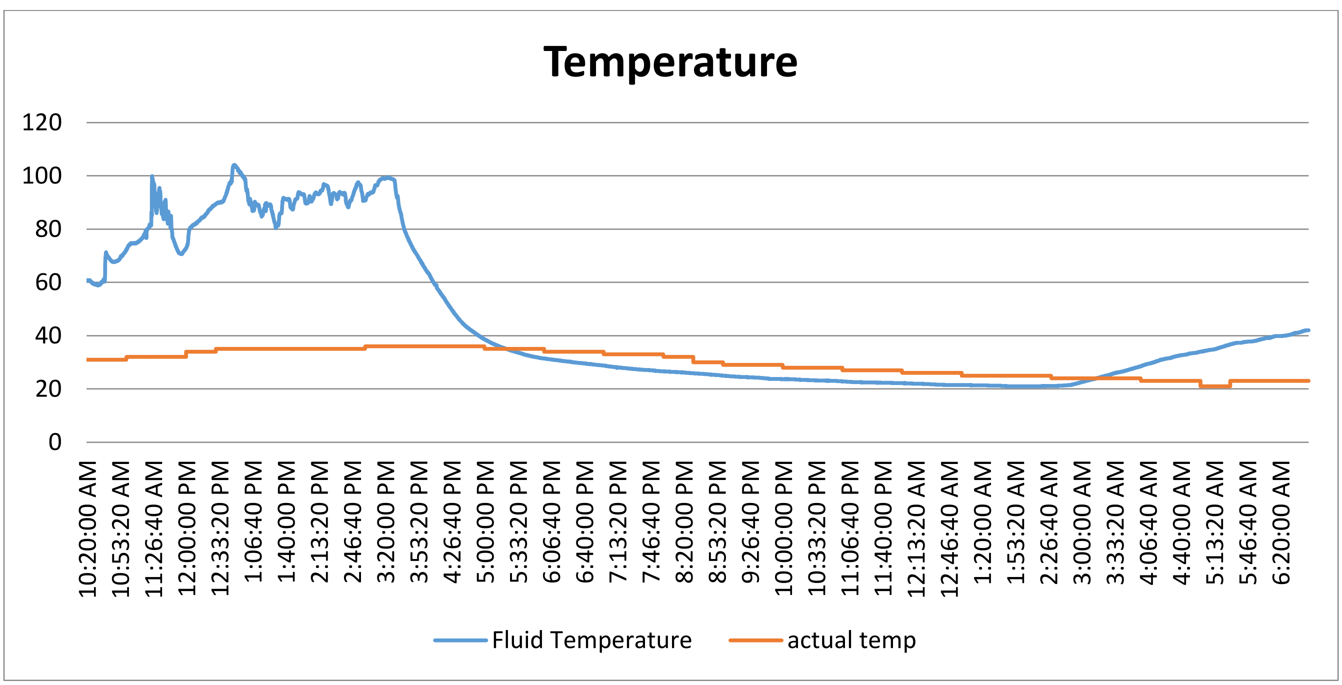

Average Pressure Day/night
0.3
0.25
0.2
0.15
0.1
0.05
0
15/05/2016
17/05/2016
18/05/2016
19/05/2016
20/05/2016
Average
Avr Pressureure for Day
Avr Pressure for night

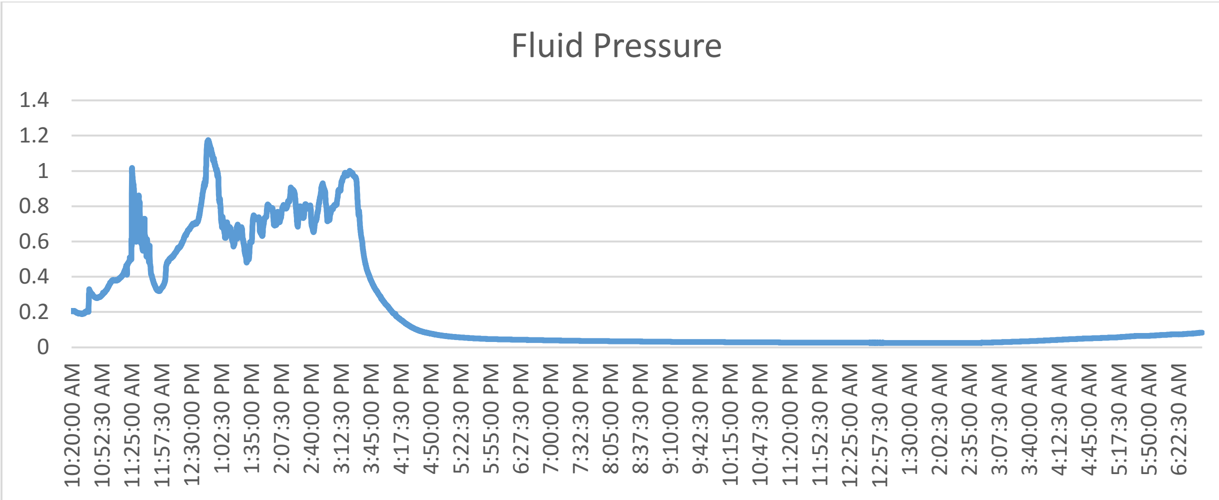

EFFICIENY OF DEVICE DAY / NIGHT
η for day
η for night
33.89%
1.50%
52.76%
7.41%
44.55%
7.60%
96.00%
18.74%
97.07%
17.95%
61.77%
9.61%
15/05/2016
17/05/2016
18/05/2016
19/05/2016
20/05/2016
AVERAGE

Then device works for 5 days and nights for the Parabolic Trough after injected by CO_2 and got this results:

<u>Day 1 (5/6/2016):</u>

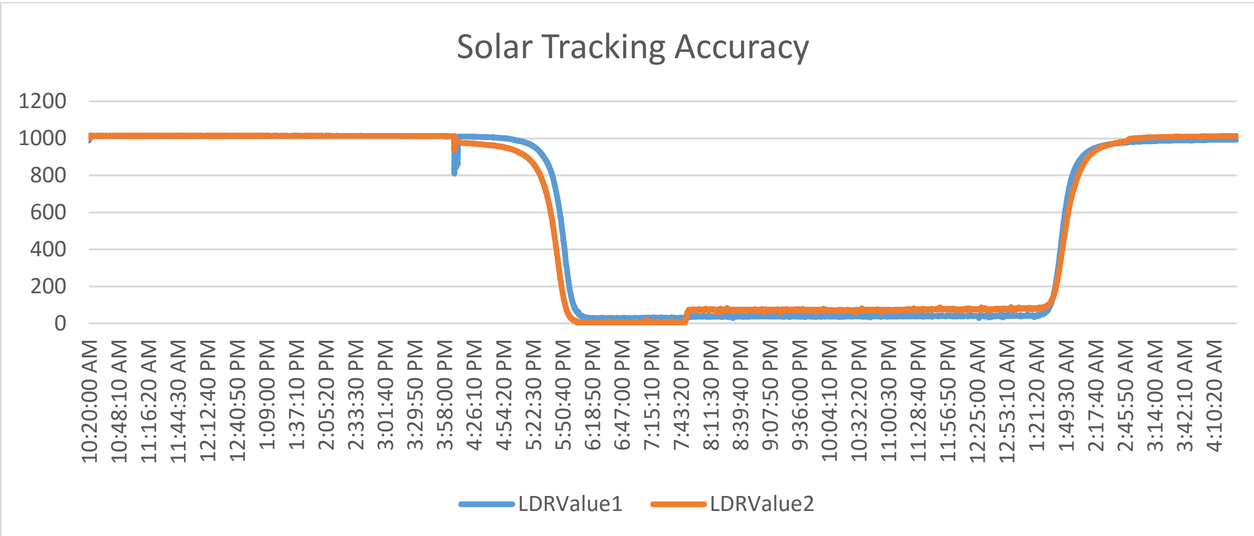


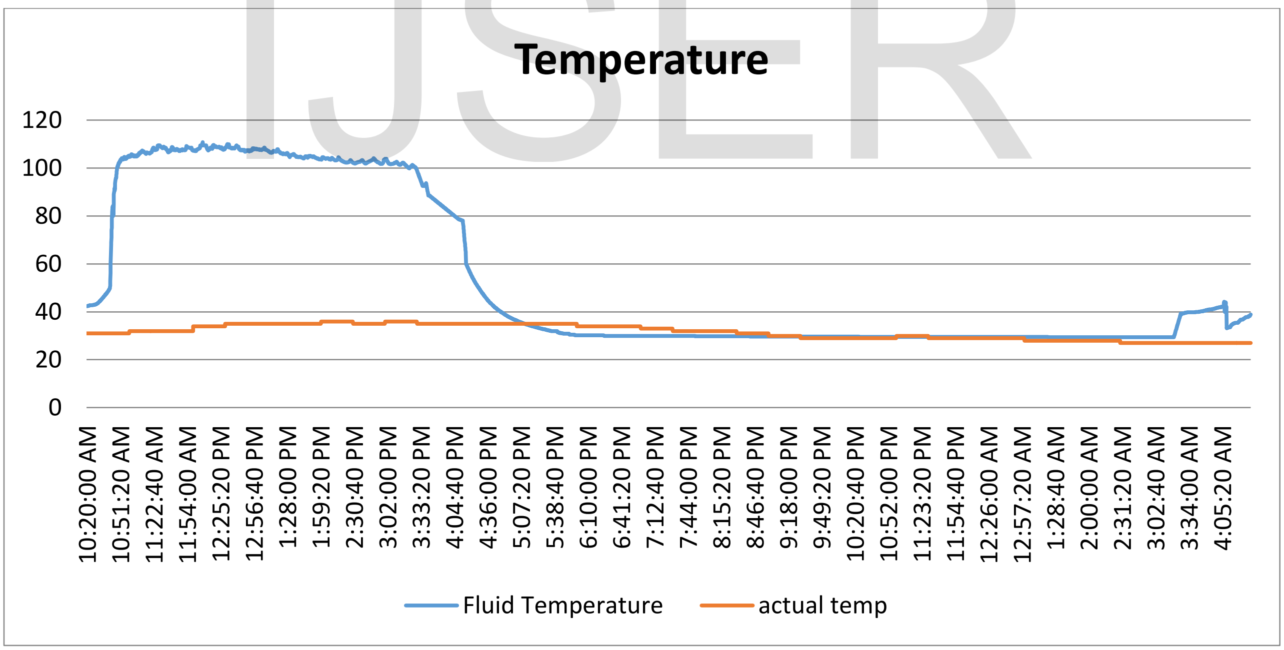


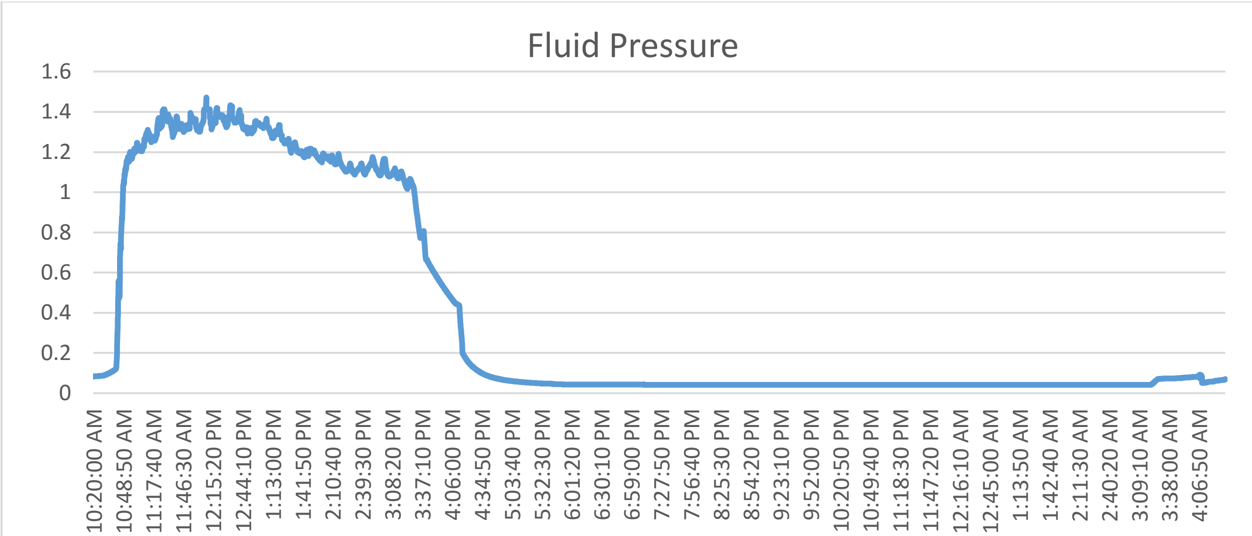


Max Temperature	104.12
Min Temperature	20.94
Average Temperature for Day	79.71
Average Temperature for night	25.59
Δ Temperature	83.18
Δ Average Temperature	54.13
Max pressure	1.175638
Min pressure	0.02469
Average pressure for Day	0.547675
Average pressure for night	0.033615
Δ pressure	1.150949
Δ Average pressure	0.51406

Day 2 (6/6/2016):

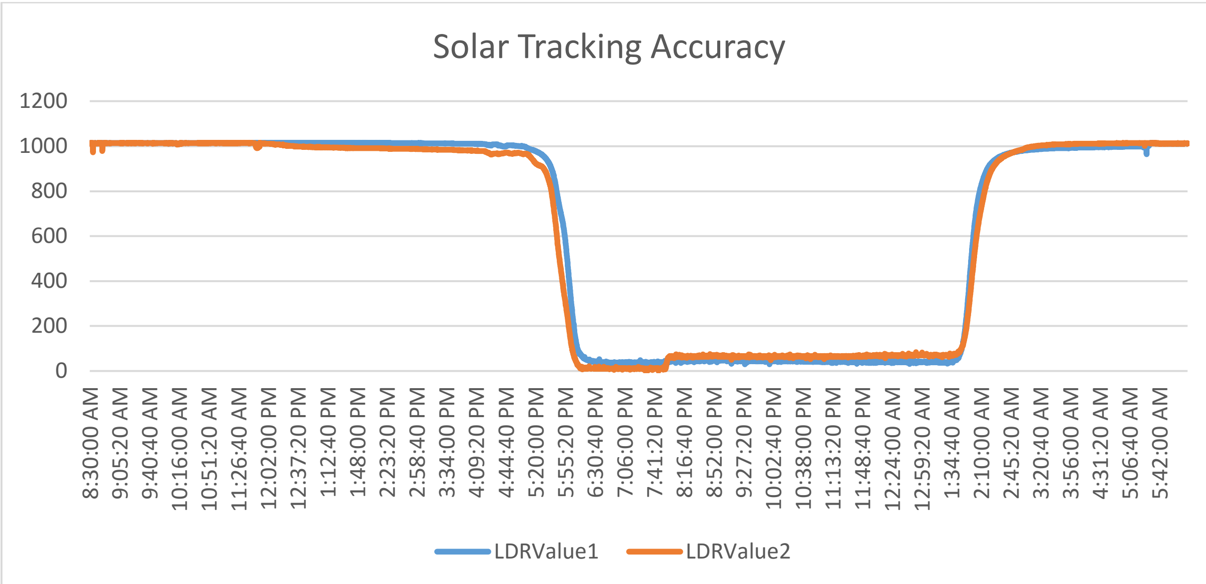

Solar Tracking Accuracy
1200
1000
800
600
400
200
0
10:20:00 AM
10:48:10 AM
11:16:20 AM
11:44:30 AM
12:12:40 PM
12:40:50 PM
1:09:00 PM
1:37:10 PM
2:05:20 PM
2:33:30 PM
3:01:40 PM
3:29:50 PM
3:58:00 PM
4:26:10 PM
4:54:20 PM
5:22:30 PM
5:50:40 PM
6:18:50 PM
6:47:00 PM
7:15:10 PM
7:43:20 PM
8:11:30 PM
8:39:40 PM
9:07:50 PM
9:36:00 PM
10:04:10 PM
10:32:20 PM
11:00:30 PM
11:28:40 PM
11:56:50 PM
12:25:00 AM
12:53:10 AM
1:21:20 AM
1:49:30 AM
2:17:40 AM
2:45:50 AM
3:14:00 AM
3:42:10 AM
4:10:20 AM
LDRValue1
LDRValue2

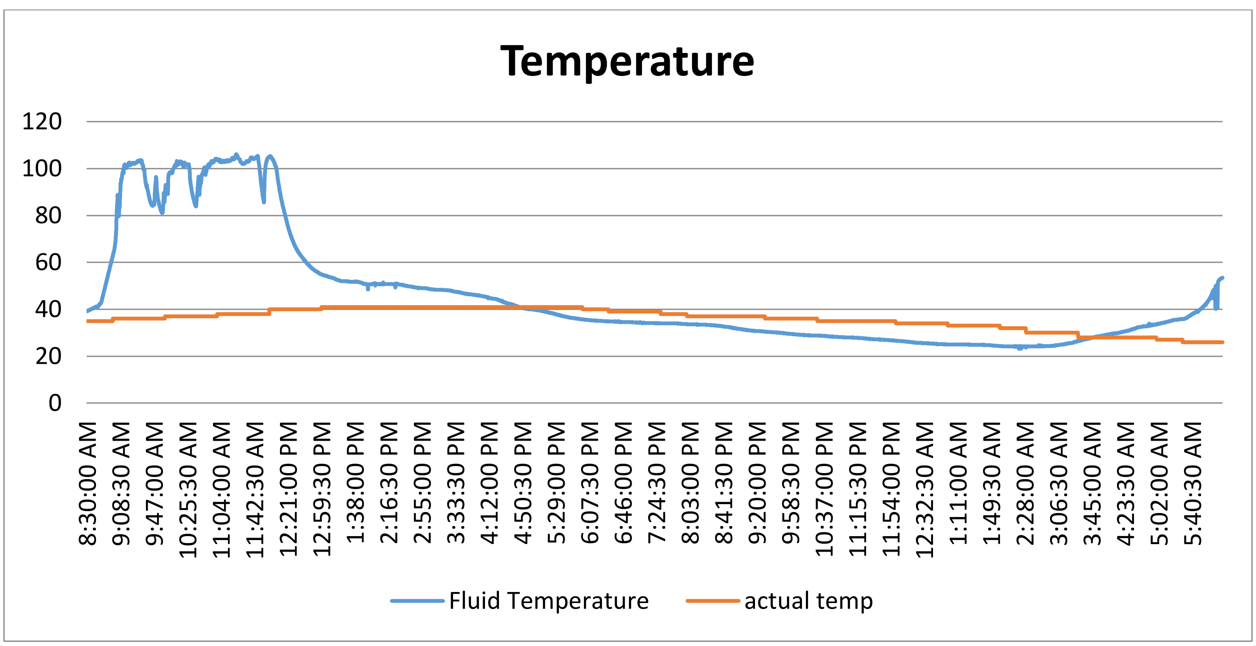

Temperature
120
100
80
60
40
20
0
10:20:00 AM
10:51:20 AM
11:22:40 AM
11:54:00 AM
12:25:20 PM
12:56:40 PM
1:28:00 PM
1:59:20 PM
2:30:40 PM
3:02:00 PM
3:33:20 PM
4:04:40 PM
4:36:00 PM
5:07:20 PM
5:38:40 PM
6:10:00 PM
6:41:20 PM
7:12:40 PM
7:44:00 PM
8:15:20 PM
8:46:40 PM
9:18:00 PM
9:49:20 PM
10:20:40 PM
10:52:00 PM
11:23:20 PM
11:54:40 PM
12:26:00 AM
12:57:20 AM
1:28:40 AM
2:00:00 AM
2:31:20 AM
3:02:40 AM
3:34:00 AM
4:05:20 AM
Fluid Temperature
actual temp

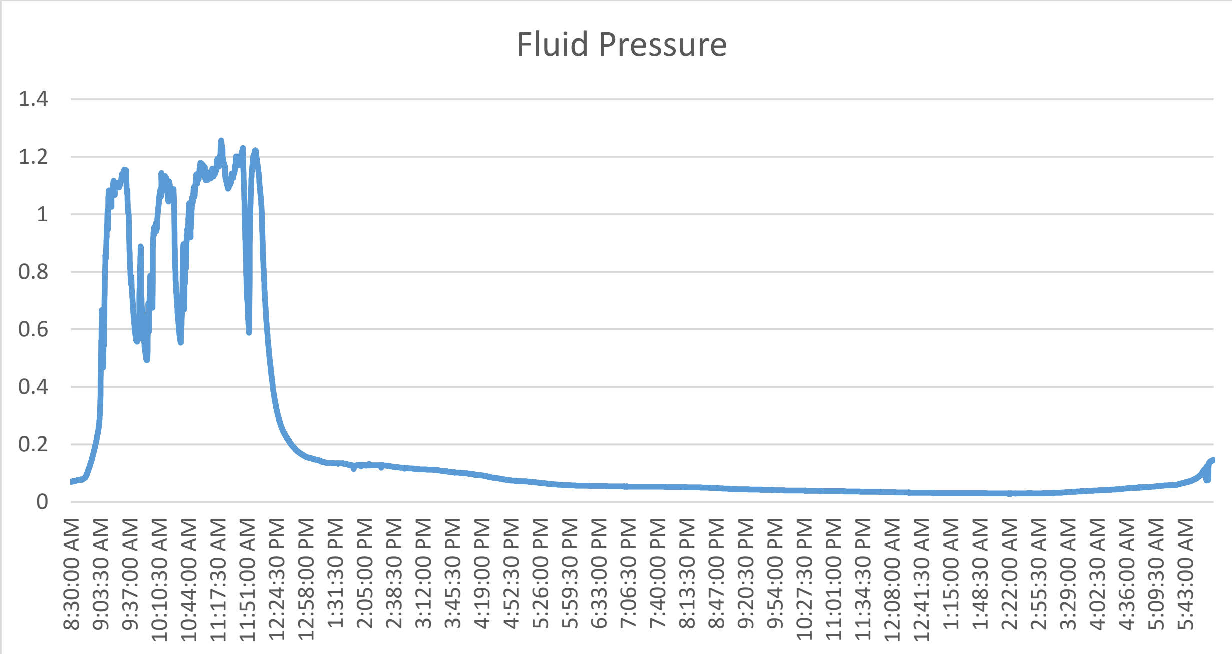


Max Temperature	110.80
Min Temperature	29.35
Average Temperature for Day	92.83
Average Temperature for night	30.86
Δ Temperature	81.45
Δ Average Temperature	61.96
Max pressure	1.472128
Min pressure	0.040763
Average pressure for Day	0.964365
Average pressure for night	0.045088
Δ pressure	1.431366
Δ Average pressure	0.919277

Day 3 (7/6/2016):

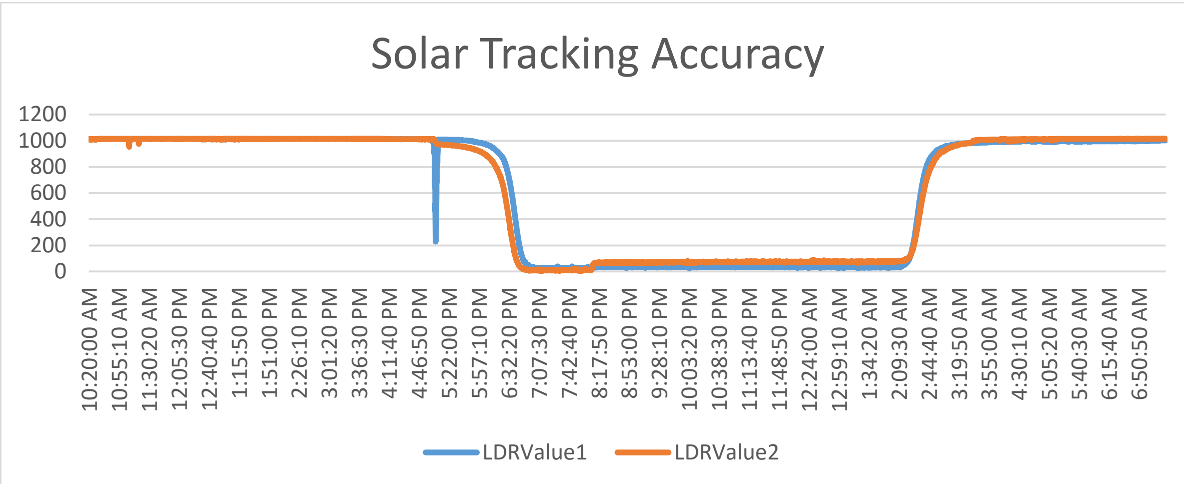

Solar Tracking Accuracy
1200
1000
800
600
400
200
0
8:30:00 AM
9:05:20 AM
9:40:40 AM
10:16:00 AM
10:51:20 AM
11:26:40 AM
12:02:00 PM
12:37:20 PM
1:12:40 PM
1:48:00 PM
2:23:20 PM
2:58:40 PM
3:34:00 PM
4:09:20 PM
4:44:40 PM
5:20:00 PM
5:55:20 PM
6:30:40 PM
7:06:00 PM
7:41:20 PM
8:16:40 PM
8:52:00 PM
9:27:20 PM
10:02:40 PM
10:38:00 PM
11:13:20 PM
11:48:40 PM
12:24:00 AM
12:59:20 AM
1:34:40 AM
2:10:00 AM
2:45:20 AM
3:20:40 AM
3:56:00 AM
4:31:20 AM
5:06:40 AM
5:42:00 AM
LDRValue1
LDRValue2

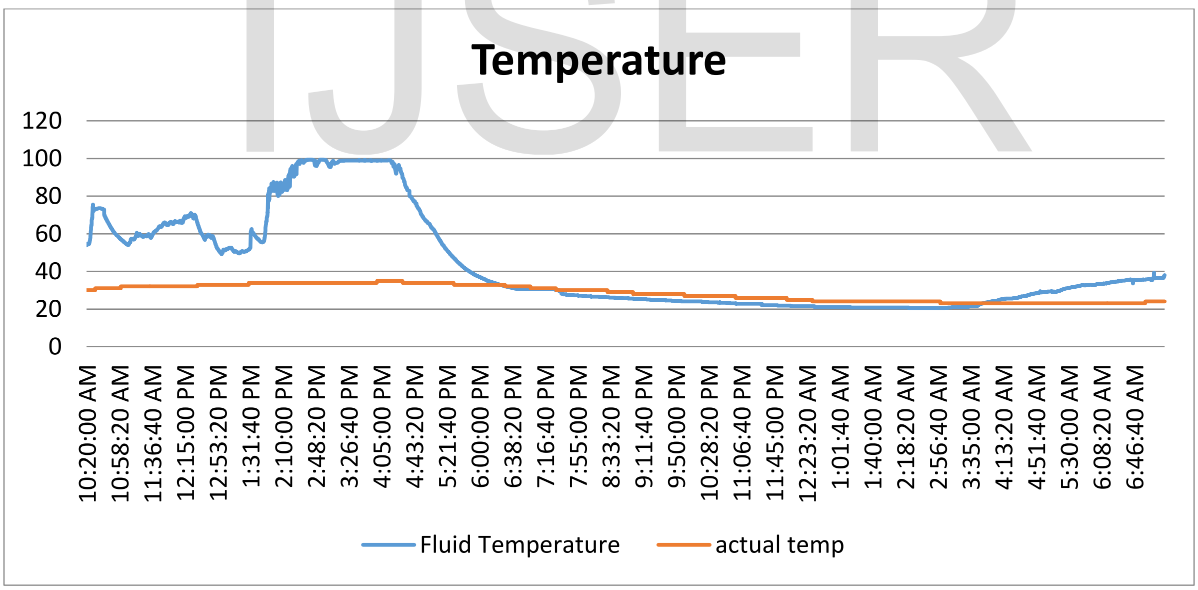

Temperature
120
100
80
60
40
20
0
8:30:00 AM
9:08:30 AM
9:47:00 AM
10:25:30 AM
11:04:00 AM
11:42:30 AM
12:21:00 PM
12:59:30 PM
1:38:00 PM
2:16:30 PM
2:55:00 PM
3:33:30 PM
4:12:00 PM
4:50:30 PM
5:29:00 PM
6:07:30 PM
6:46:00 PM
7:24:30 PM
8:03:00 PM
8:41:30 PM
9:20:00 PM
9:58:30 PM
10:37:00 PM
11:15:30 PM
11:54:00 PM
12:32:30 AM
1:11:00 AM
1:49:30 AM
2:28:00 AM
3:06:30 AM
3:45:00 AM
4:23:30 AM
5:02:00 AM
5:40:30 AM
Fluid Temperature
actual temp



Max Temperature	106.06
Min Temperature	23.12
Average Temperature for Day	74.82
Average Temperature for night	32.49
Δ Temperature	82.94
Δ Average Temperature	42.34
Max pressure	1.256097
Min pressure	0.028205
Average pressure for Day	0.547431
Average pressure for night	0.052146
Δ pressure	1.227892
Δ Average pressure	0.495285

Day 4 (8/6/2016):


Solar Tracking Accuracy
1200
1000
800
600
400
200
0
10:20:00 AM
10:55:10 AM
11:30:20 AM
12:05:30 PM
12:40:40 PM
1:15:50 PM
1:51:00 PM
2:26:10 PM
3:01:20 PM
3:36:30 PM
4:11:40 PM
4:46:50 PM
5:22:00 PM
5:57:10 PM
6:32:20 PM
7:07:30 PM
7:42:40 PM
8:17:50 PM
8:53:00 PM
9:28:10 PM
10:03:20 PM
10:38:30 PM
11:13:40 PM
11:48:50 PM
12:24:00 AM
12:59:10 AM
1:34:20 AM
2:09:30 AM
2:44:40 AM
3:19:50 AM
3:55:00 AM
4:30:10 AM
5:05:20 AM
5:40:30 AM
6:15:40 AM
6:50:50 AM
LDRValue1
LDRValue2


Temperature
120
100
80
60
40
20
0
10:20:00 AM
10:58:20 AM
11:36:40 AM
12:15:00 PM
12:53:20 PM
1:31:40 PM
2:10:00 PM
2:48:20 PM
3:26:40 PM
4:05:00 PM
4:43:20 PM
5:21:40 PM
6:00:00 PM
6:38:20 PM
7:16:40 PM
7:55:00 PM
8:33:20 PM
9:11:40 PM
9:50:00 PM
10:28:20 PM
11:06:40 PM
11:45:00 PM
12:23:20 AM
1:01:40 AM
1:40:00 AM
2:18:20 AM
2:56:40 AM
3:35:00 AM
4:13:20 AM
4:51:40 AM
5:30:00 AM
6:08:20 AM
6:46:40 AM
Fluid Temperature
actual temp

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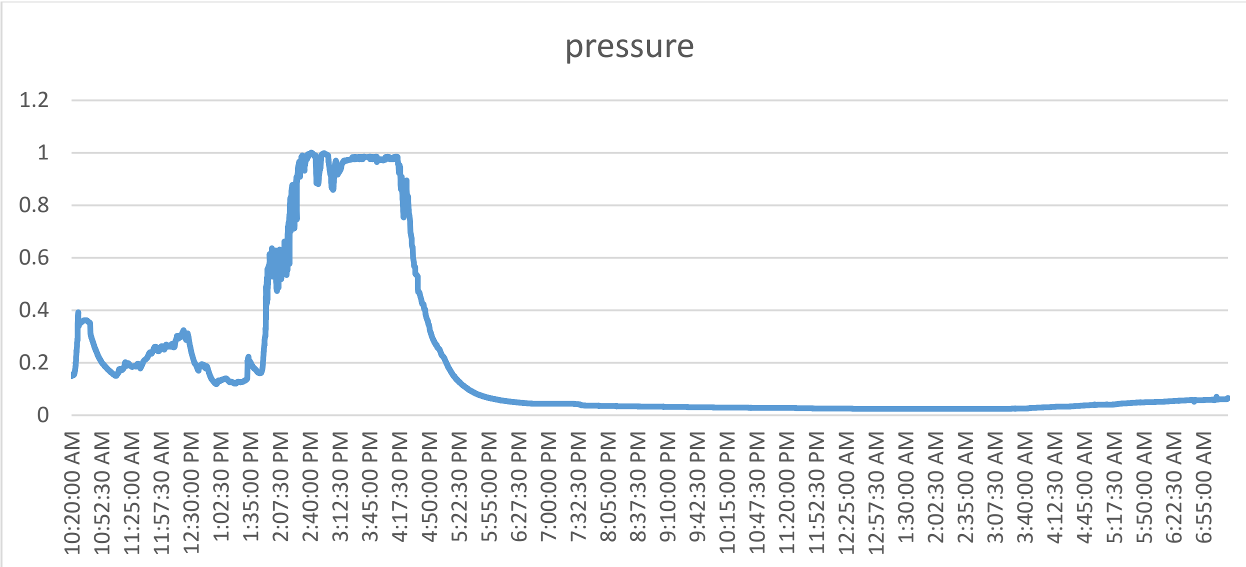
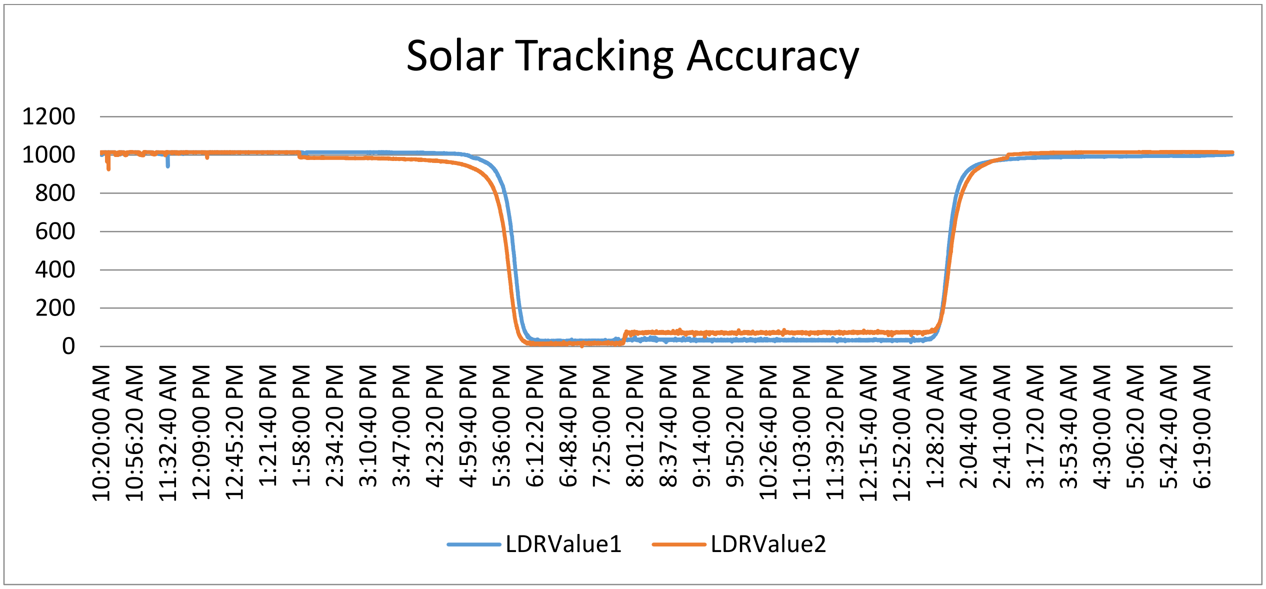
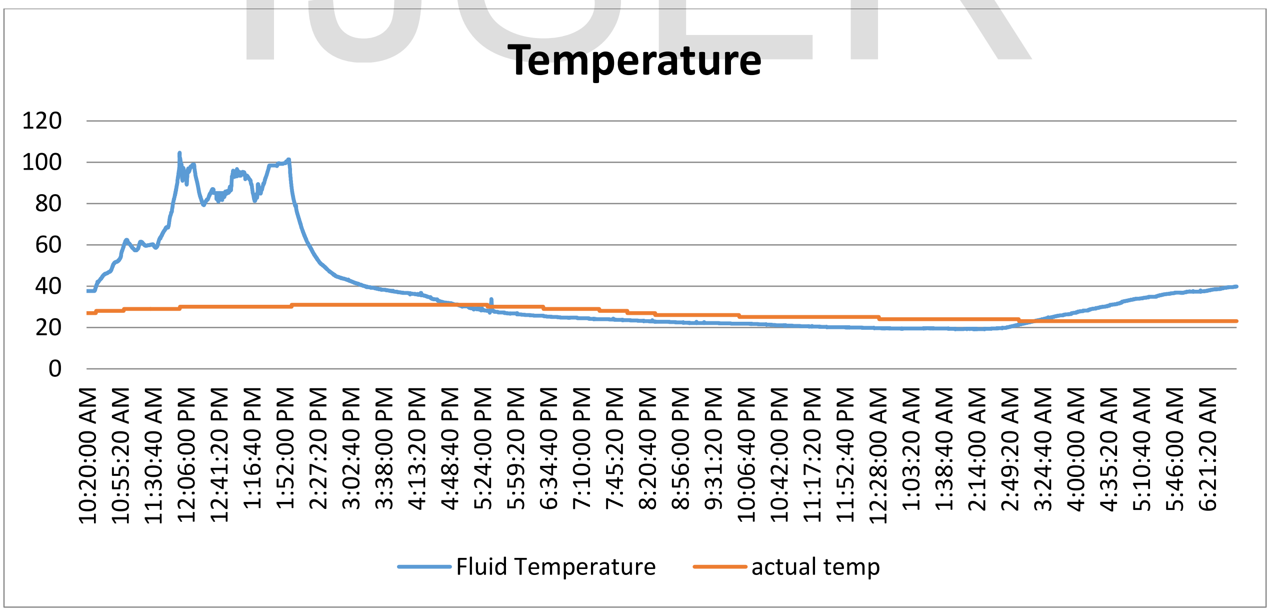
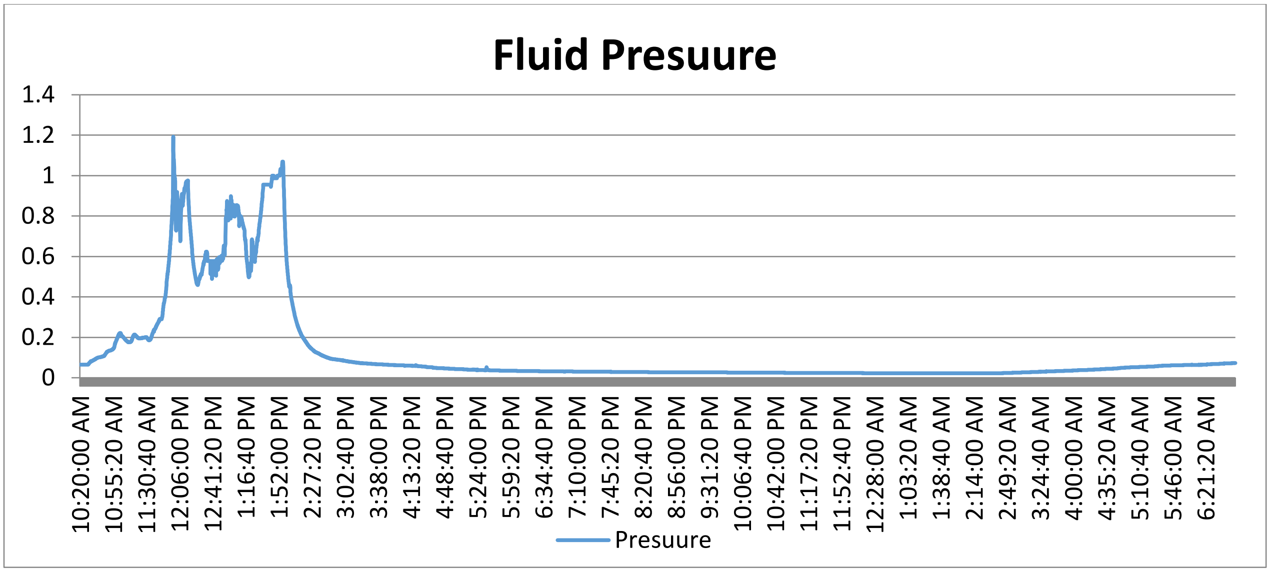


Max Temperature	99.50
Min Temperature	20.50
Average Temperature for Day	75.49
Average Temperature for night	26.51
Δ Temperature	79.00
Δ Average Temperature	48.97
Max pressure	1.001159
Min pressure	0.024028
Average pressure for Day	0.491615
Average pressure for night	0.039262
Δ pressure	0.977131
Δ Average pressure	0.452353

Day 5 (9/6/2016):


Solar Tracking Accuracy
1200
1000
800
600
400
200
0
10:20:00 AM
10:56:20 AM
11:32:40 AM
12:09:00 PM
12:45:20 PM
1:21:40 PM
1:58:00 PM
2:34:20 PM
3:10:40 PM
3:47:00 PM
4:23:20 PM
4:59:40 PM
5:36:00 PM
6:12:20 PM
6:48:40 PM
7:25:00 PM
8:01:20 PM
8:37:40 PM
9:14:00 PM
9:50:20 PM
10:26:40 PM
11:03:00 PM
11:39:20 PM
12:15:40 AM
12:52:00 AM
1:28:20 AM
2:04:40 AM
2:41:00 AM
3:17:20 AM
3:53:40 AM
4:30:00 AM
5:06:20 AM
5:42:40 AM
6:19:00 AM
LDRValue1
LDRValue2


Temperature
120
100
80
60
40
20
0
10:20:00 AM
10:55:20 AM
11:30:40 AM
12:06:00 PM
12:41:20 PM
1:16:40 PM
1:52:00 PM
2:27:20 PM
3:02:40 PM
3:38:00 PM
4:13:20 PM
4:48:40 PM
5:24:00 PM
5:59:20 PM
6:34:40 PM
7:10:00 PM
7:45:20 PM
8:20:40 PM
8:56:00 PM
9:31:20 PM
10:06:40 PM
10:42:00 PM
11:17:20 PM
11:52:40 PM
12:28:00 AM
1:03:20 AM
1:38:40 AM
2:14:00 AM
2:49:20 AM
3:24:40 AM
4:00:00 AM
4:35:20 AM
5:10:40 AM
5:46:00 AM
6:21:20 AM
Fluid Temperature
actual temp



Max Temperature	104.56
Min Temperature	19.19
Average Temperature for Day	61.10
Average Temperature for night	25.01
Δ Temperature	85.37
Δ Average Temperature	36.09
Max pressure	1.193499
Min pressure	0.02215
Average pressure for Day	0.32455
Average pressure for night	0.02839
Δ pressure	1.171349
Δ Average pressure	0.296161

Summery:

DAY	MAX TEMP	MIN TEMP	Δ T	AVERAGE
5/6/2016	104.12	20.94	83.18	62.53
6/6/2016	110.80	29.35	81.45	70.08
7/6/2016	106.06	23.12	82.94	64.59
8/6/2016	99.50	20.50	79	60.00
9/6/2016	104.56	19.19	85.37	61.875
Average	105.008	22.62	82.388	63.814

DAY	Average Temperature for Day	Average Temperature for night
5/6/2016	79.71	25.59
6/6/2016	92.83	30.86
7/6/2016	74.82	32.49
8/6/2016	75.49	26.51
9/6/2016	61.1	25.01
Average	76.789207	28.0920379

DAY	actual temp HI	actual temp lo
5/6/2016	36	25
6/6/2016	36	21
7/6/2016	42	26
8/6/2016	35	24
9/6/2016	32	22
Average	36.2	23.6

DAY	Max Pressure	Min Pressure	Δ p	AVERAGE
5/6/2016	1.175638141	0.024689531	1.15094861	0.600163836
6/6/2016	1.472128288	0.040762563	1.431365725	0.756445426
7/6/2016	1.256096606	0.028205077	1.227891529	0.642150841
8/6/2016	1.001158855	0.024028323	0.977130532	0.512593589
9/6/2016	1.193499	0.02215	1.71349	0.6078245
Average	1.219704178	0.027967099	1.300165279	0.623835638

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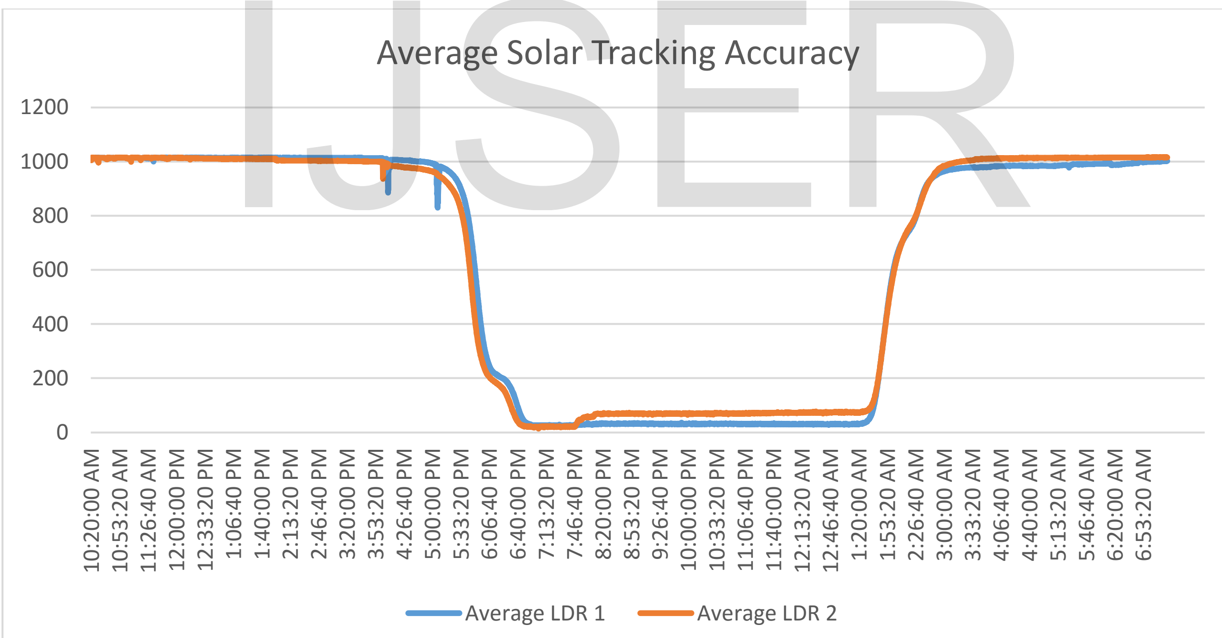
DAY	Average Pressure for day	Average Pressure for night
5/6/2016	0.55	0.03
6/6/2016	0.964364793	0.045087658
7/6/2016	0.547430896	0.052146196
8/6/2016	0.491614958	0.039261991
9/6/2016	0.32455	0.02899
Average	0.575127161	0.039820225

DAY	η day	η night
5/6/2016	121.42%	2.35%
6/6/2016	157.85%	46.97%
7/6/2016	78.15%	24.95%
8/6/2016	115.67%	10.47%
9/6/2016	90.94%	13.68%
Average	112.12%	19.03%



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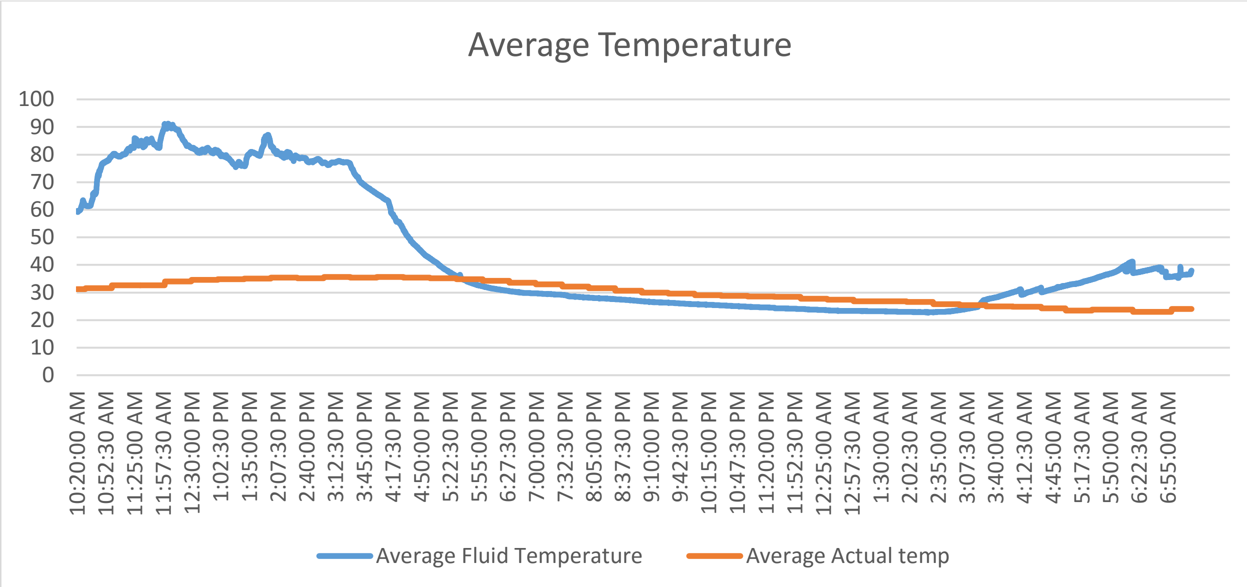

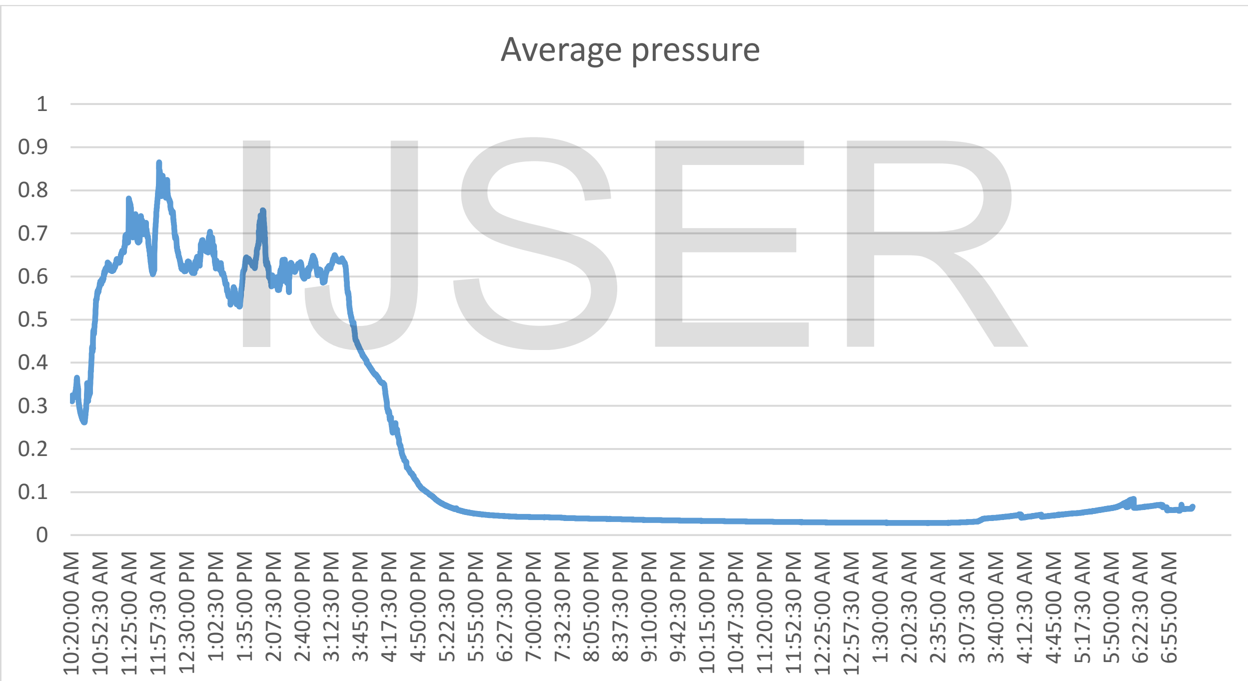

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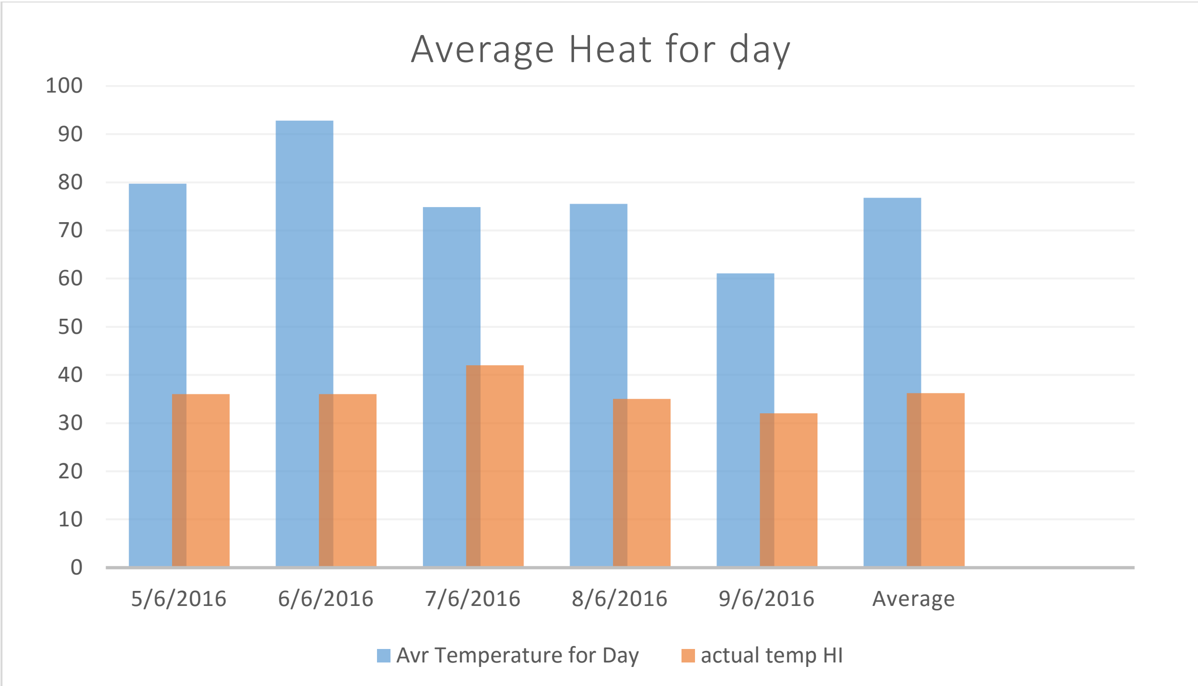

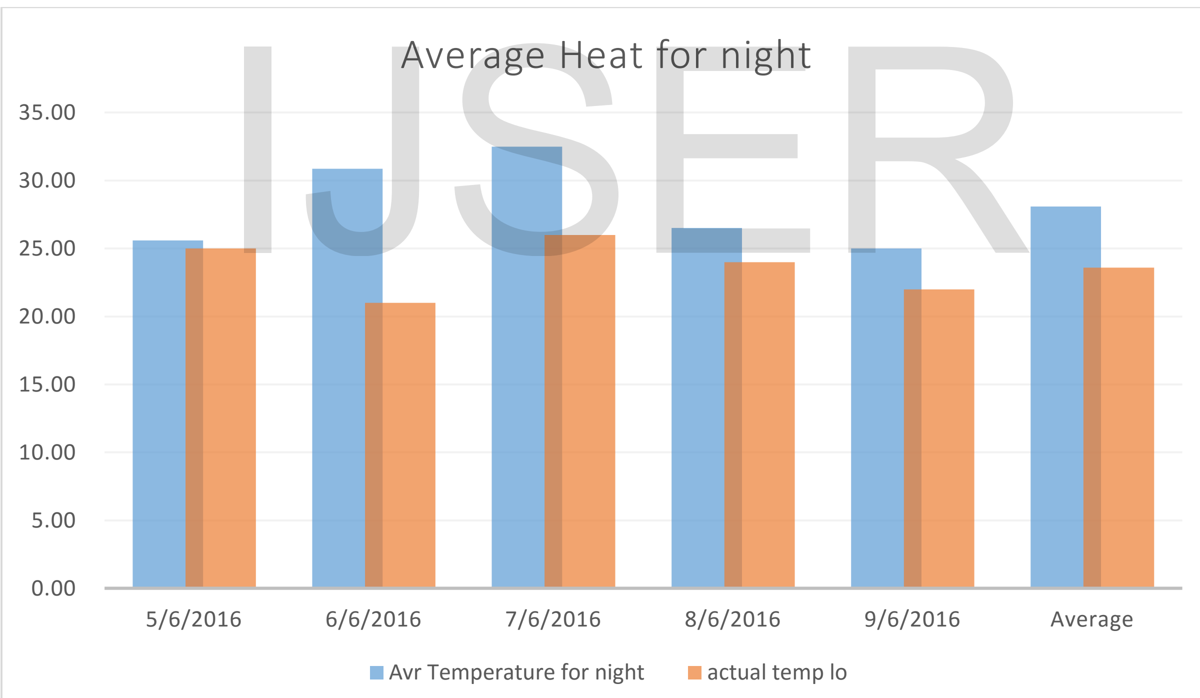

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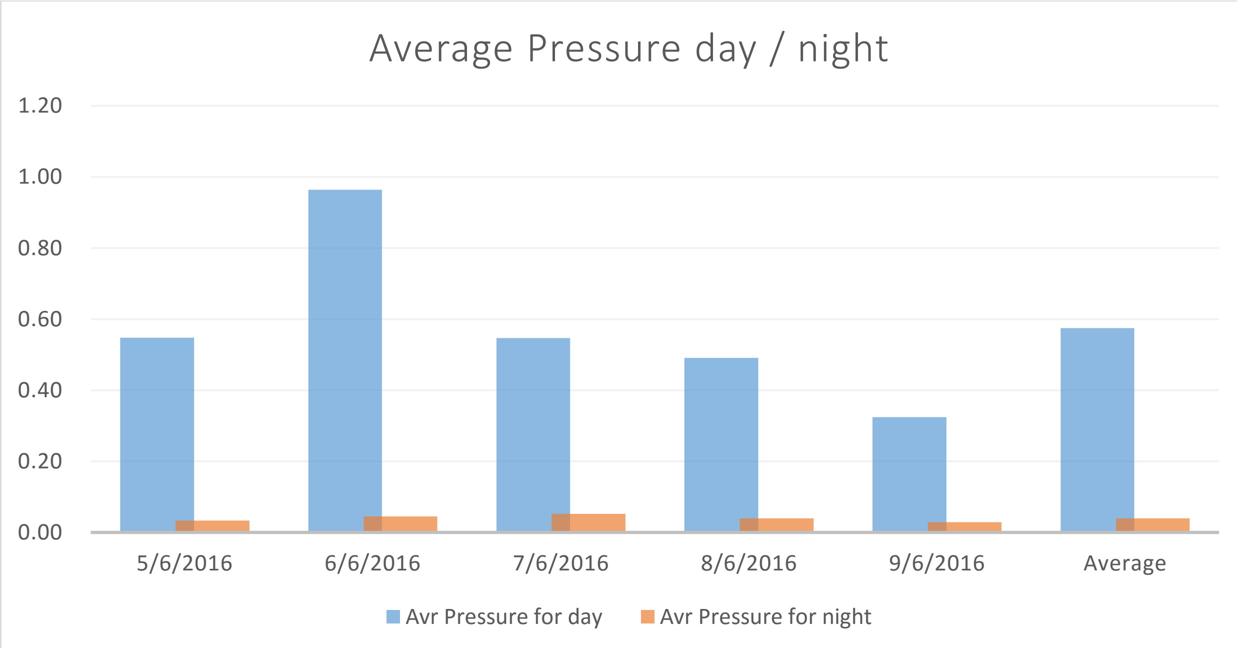
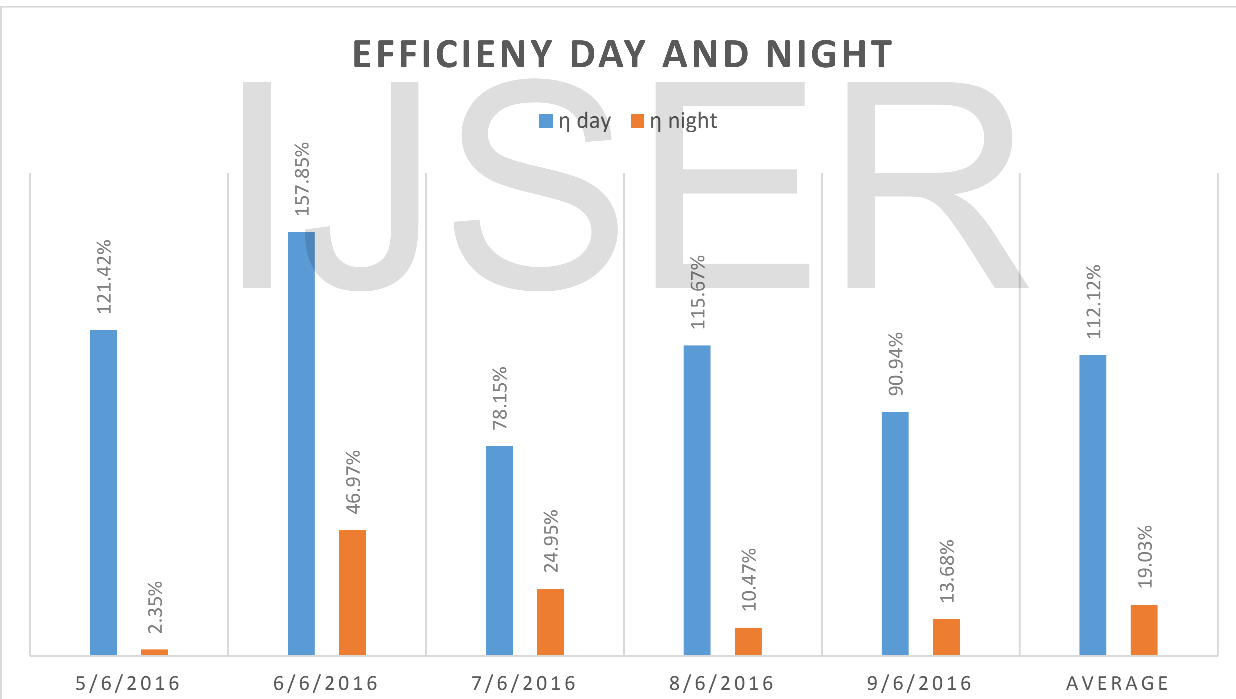
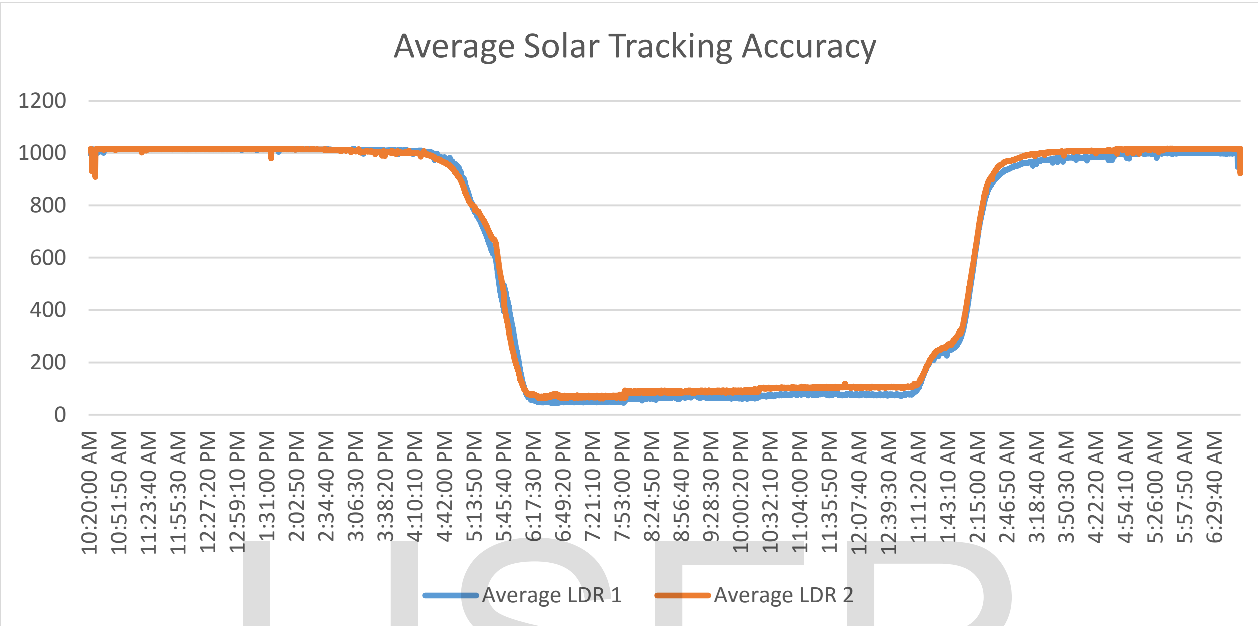




Discussion

1. First Experiment (Parabolic Trough):

1.1 Solar Tracking:

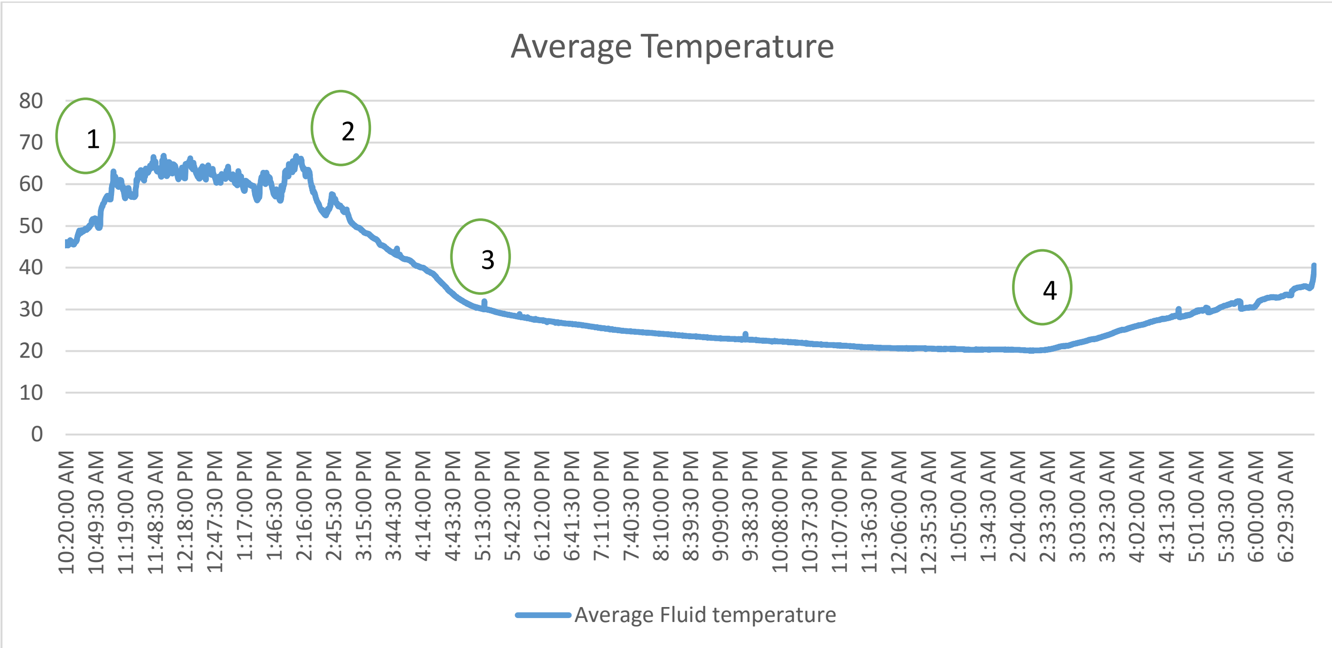


The solar Tracking - we have made - found to be very perfect in tracking the sunlight and in making the Parabolic Trough's pipe exactly at the focal point. And that is clearly appeared in the five days charts for the Solar Tracking Accuracy as the two lines – values of each LDR – seems to be coincides on each other all day. Then at night the motors shuts totally till the next sunrise.

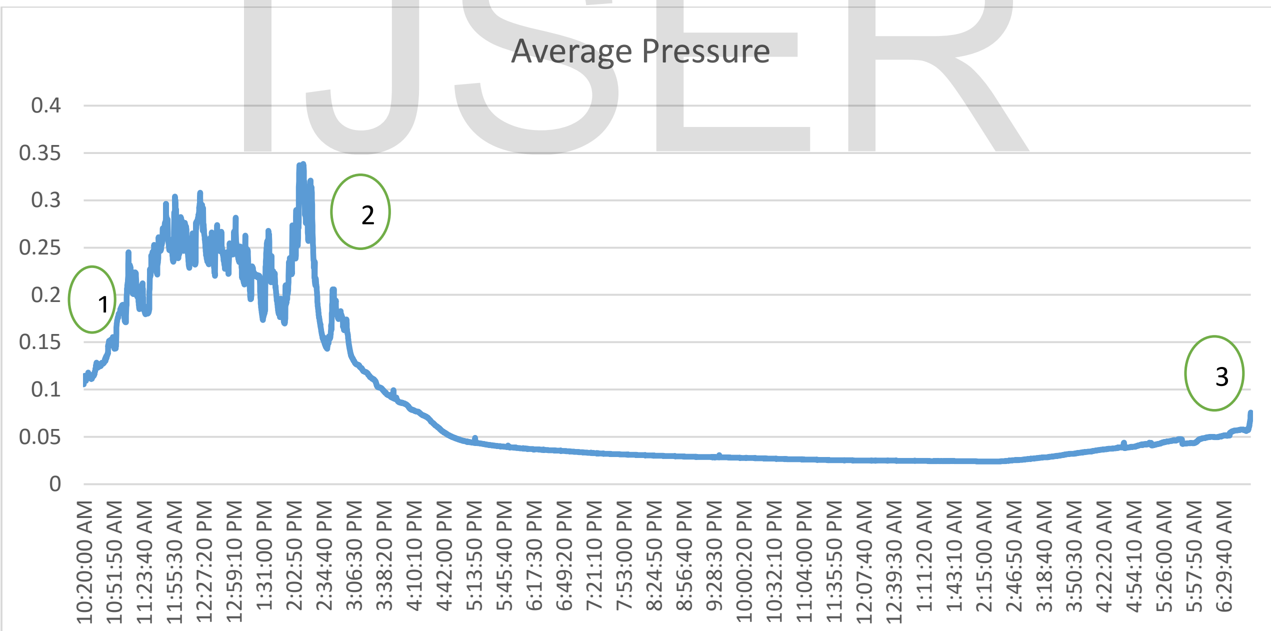
1.2 Temperature across the whole day:

We found from the five days charts that the temperature levels gained or lost by the Parabolic Trough are represented by **3 stages**:

1- **First stage (1-2):** Starting the day with average temperature **45.3** C (**10:20:00 AM**) then **it raises** to the top with Average Maximum Temperature **78.9 C** then **loss** its temperature **very quickly**.
2- **Second stage (2- 3):** The device starts to **loss** its temperature **very quickly** (**from approximately 2:00:00 PM**) after mid-day.
3- **Third stage (3-4):** still **losing** its temperature but **at lower rate** (and starts to cool the fluid inside as the pipe's material is red Copper) until the sunrises.



1.3 Pressure of the fluid across the whole day (bar):



We calculated the pressure according **Antoine's Pressure Equation** and found that the:

1- Pressure inside is **very hesitating** during daylight (from 1-2) with maximum pressure with Average Maximum pressure 0.5 bar.

2- Then the pressure decreases (2-3) till the temperature raises again with the sunrise.

Relationship between day and night (heat gained and lost):

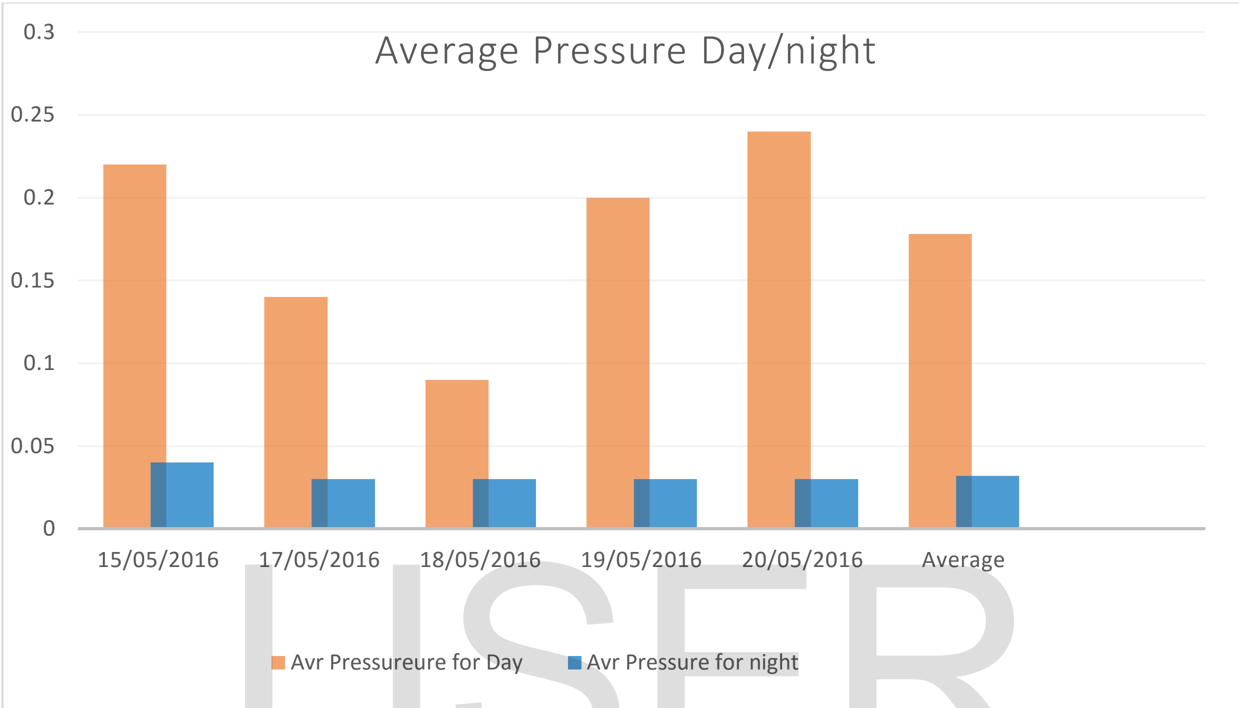


Chart (a)

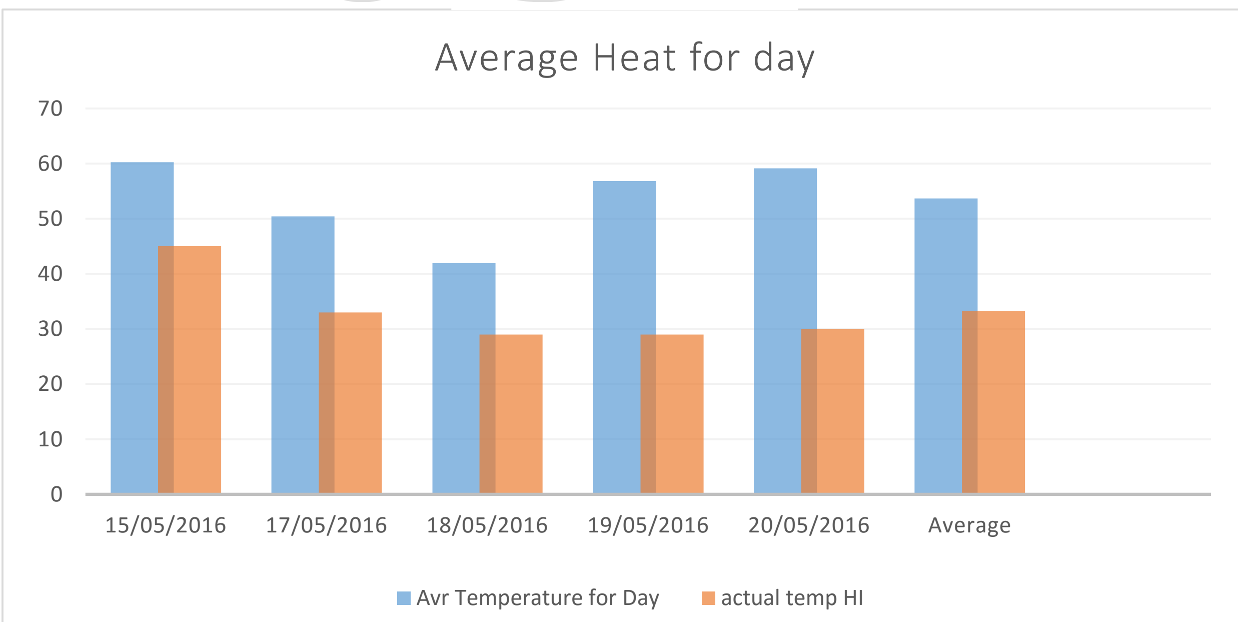


Chart (b)

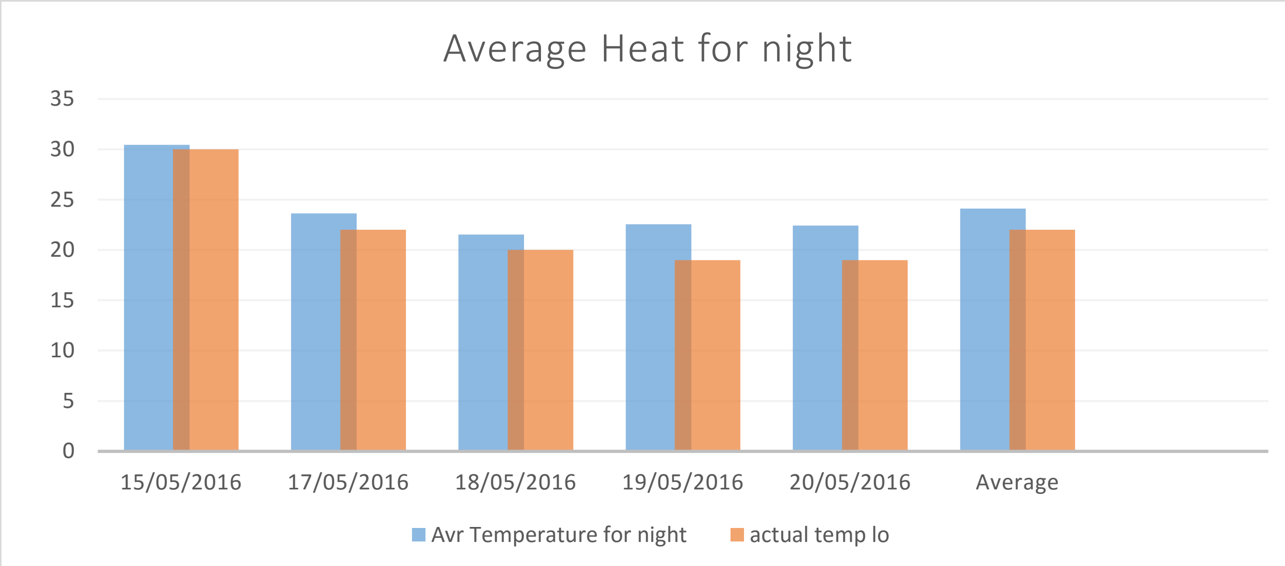
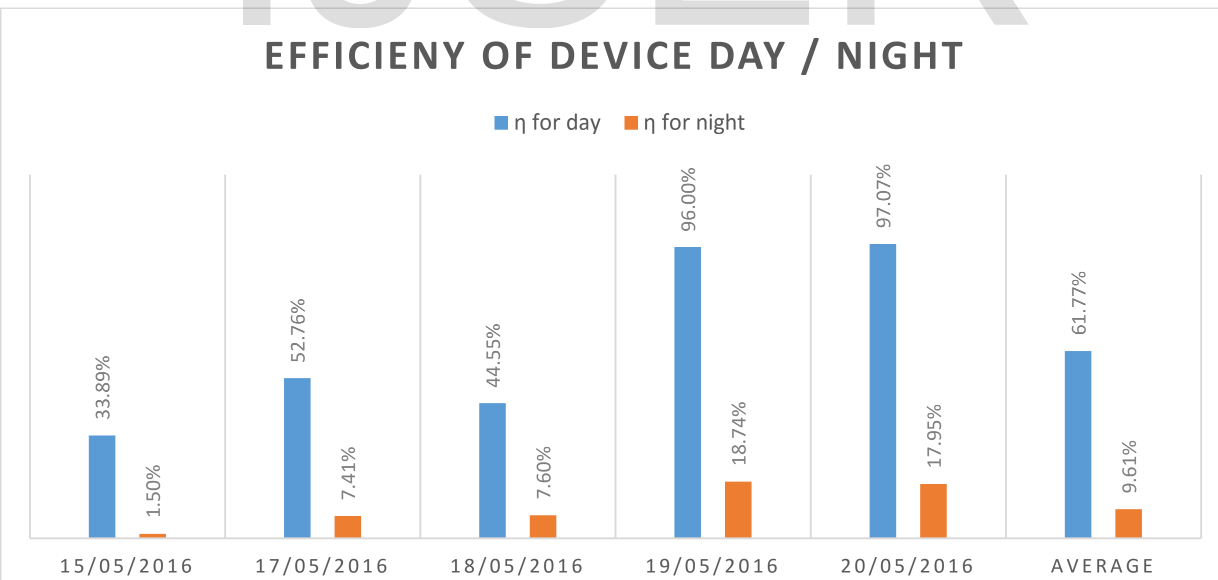


Chart (c)

It appears from chart (a) that the parabolic trough gains heat energy along the day time that exceeds the ambient temperature –chart (b) - , but it losses it totally through night (average heat approximately equals to actual Temp chart (c)) as the pipe plays as heat exchanger .

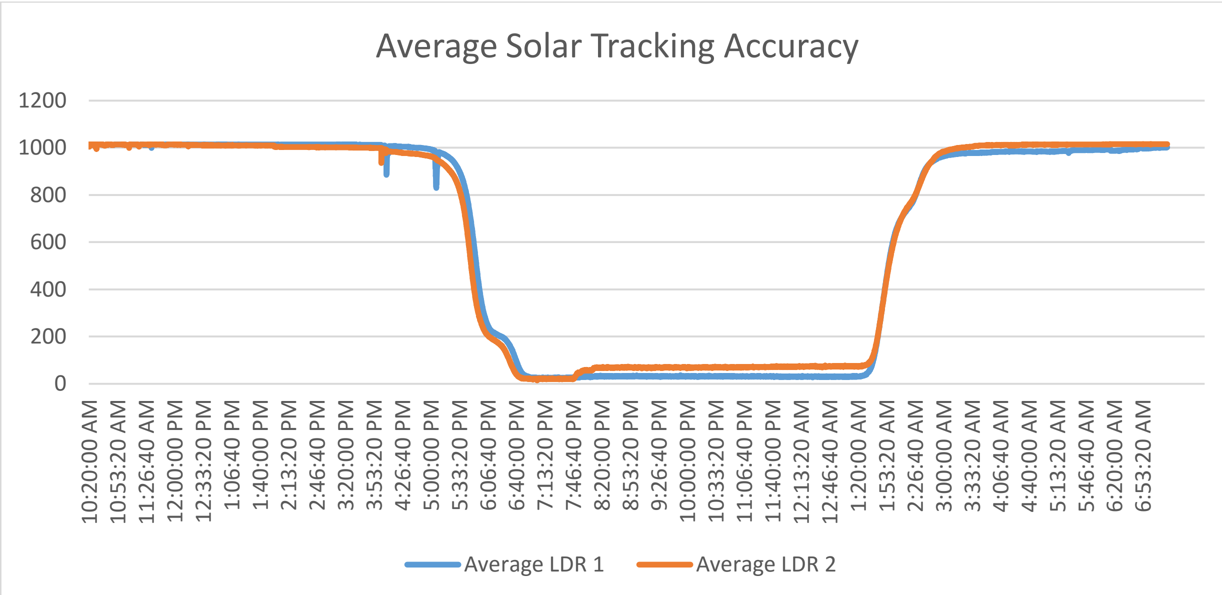
Efficiency of the device day and night:



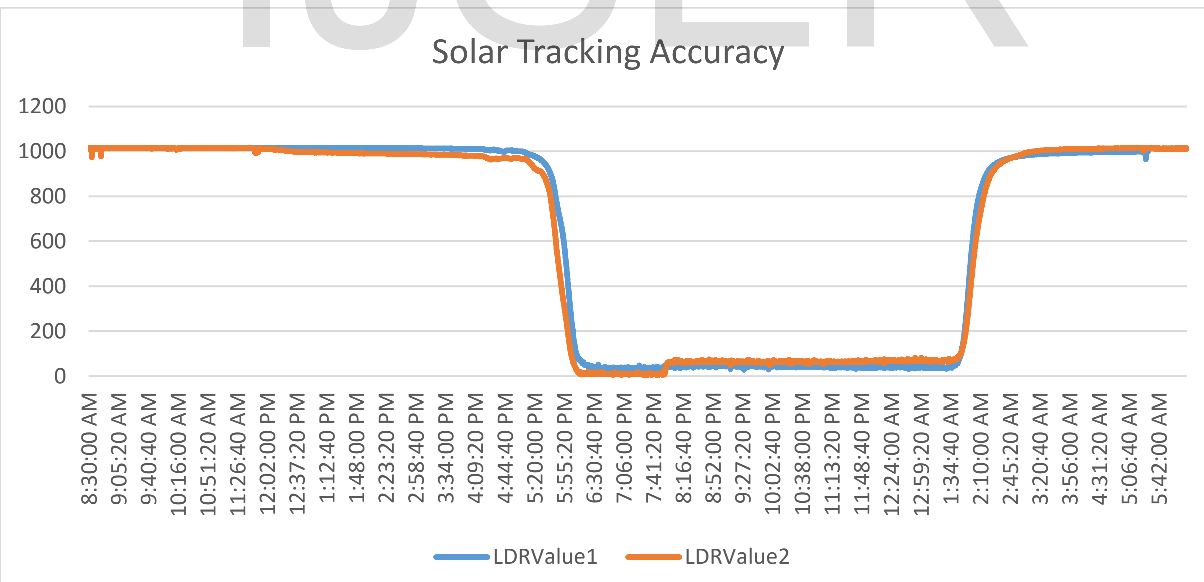
The Parabolic Trough showed average efficiency during day **by 61.7%** and by night showed average efficiency **by 9.61%.**

2. Second Experiment (Parabolic Trough injected by CO_2):

2.1 Solar Tracking:



Appears great work in tracking sunlight during daylight as the two lines (values of the two LDR) coincides on each other, except **a Failure** as a result of cutting wires of the track system in days 3 as it appears below:

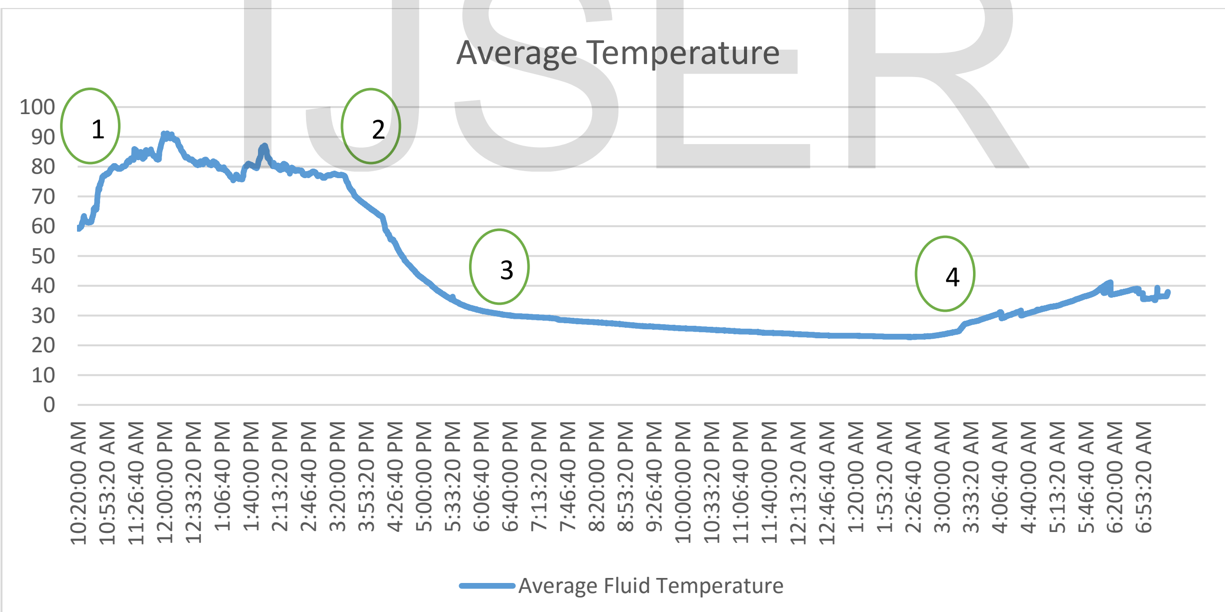


As it appears the wire fail at 12:05:00 PM but we repaired at next day early.

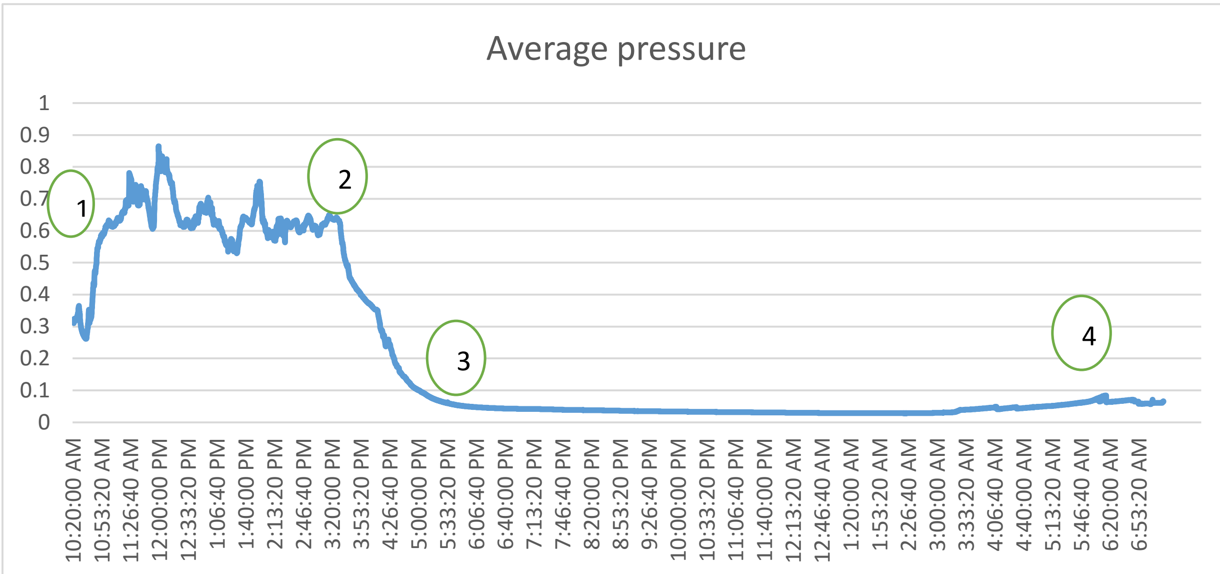
2.2 Temperature across the whole day:

We found from the five days charts that the temperature levels gained or lost by the Parabolic Trough with CO_2 are represented through four stages:

1- **First stage (1-2):** begin the day with average temperature **59.3 C** (**at 10:20:00 AM**) then **it raises to the top very quickly** with Average Maximum Temperature **105** C and appears to be **steady for long while** then starts to loss its temperature.
2- **Second stage (2- 3):** The device starts to **loss** its temperature (from approximately **4:00:00 PM**) after mid-day.
3- **Third stage (3-4):** the temperature **approximately steady** with **very slow rate** of **losing heat**.
4- **After (4)** [**approximately 3:00:00 AM**] the device starts to **collect** heat **by raising the ambient temperature** and also the first day light with **no need to make the pipe at the focal light** (appears very clearly in day 3 after Failure of the wires of the tracking system).



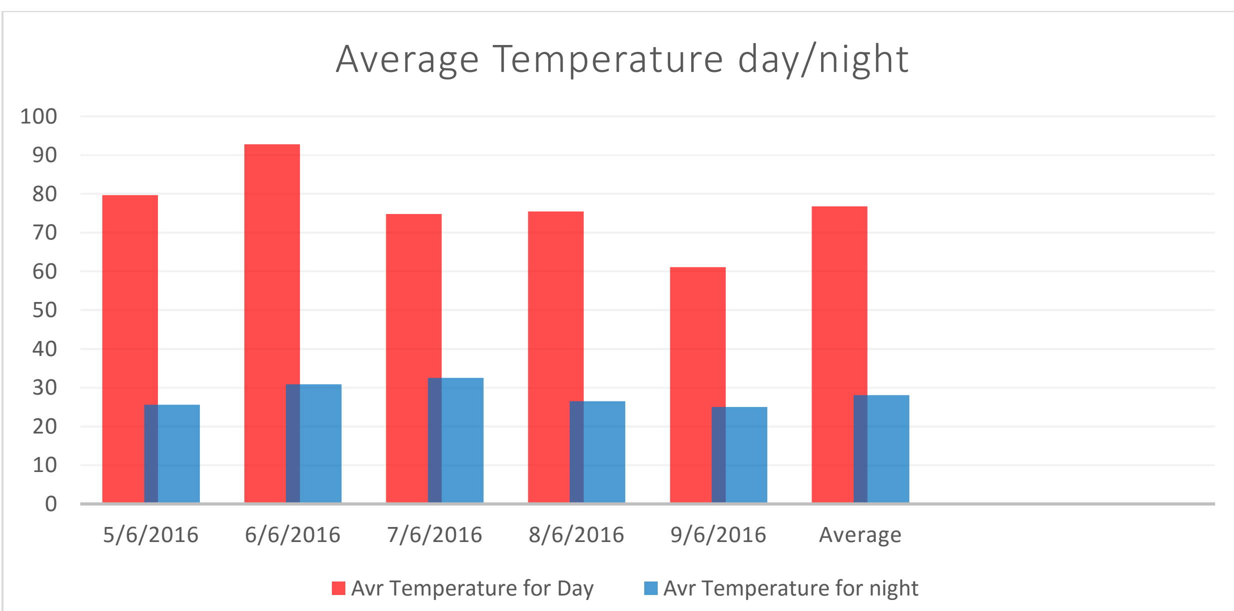
2.3 Pressure of the fluid across the whole day (bar):



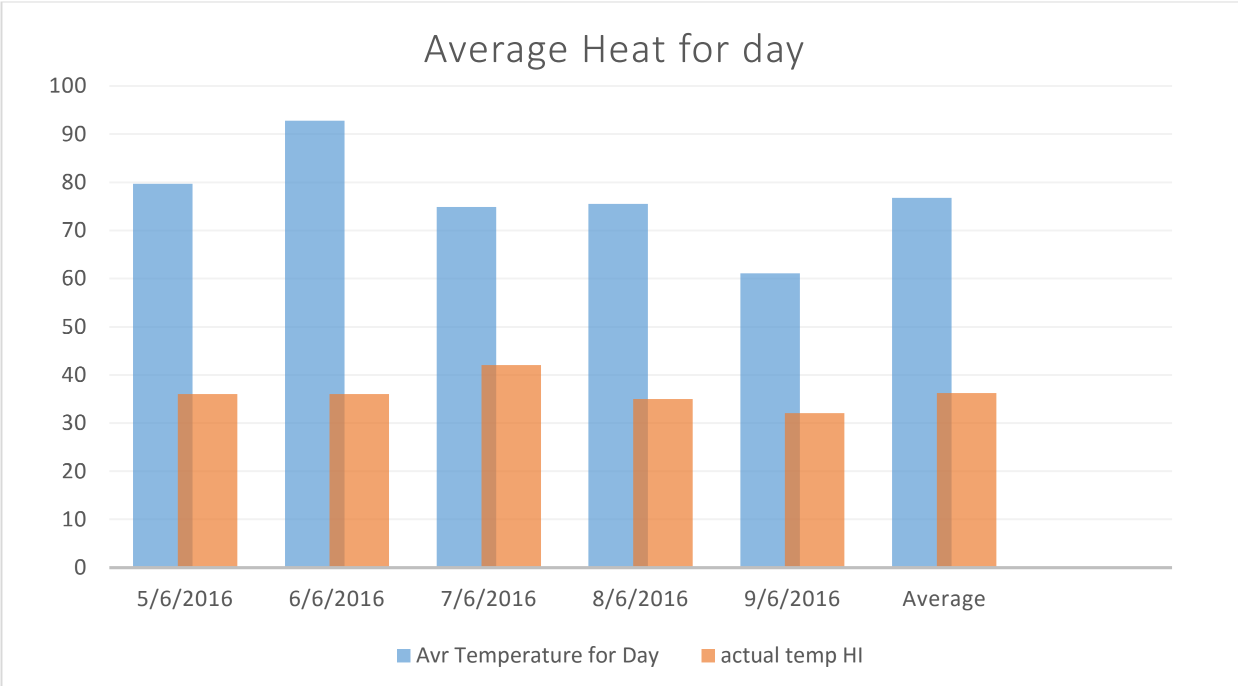
We Found that:

1- Pressure inside **raises very fast approximately steady** during **daylight (from 1-2)** with maximum pressure with **Average Maximum pressure 1.2 bar**.
2- Then the pressure **decreases (2-3).**
3- Then pressure became **steady** from (**3-4**) **till the temperature raises again.**

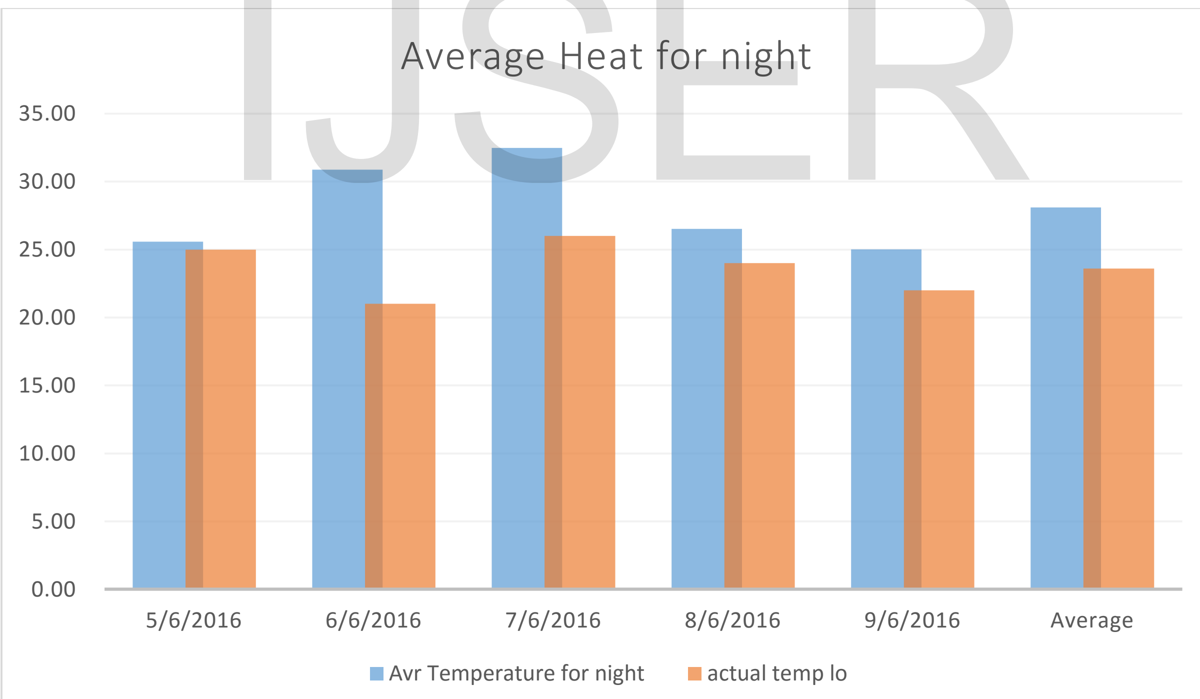
Relationship between day and night (heat gained and lost):



a



b

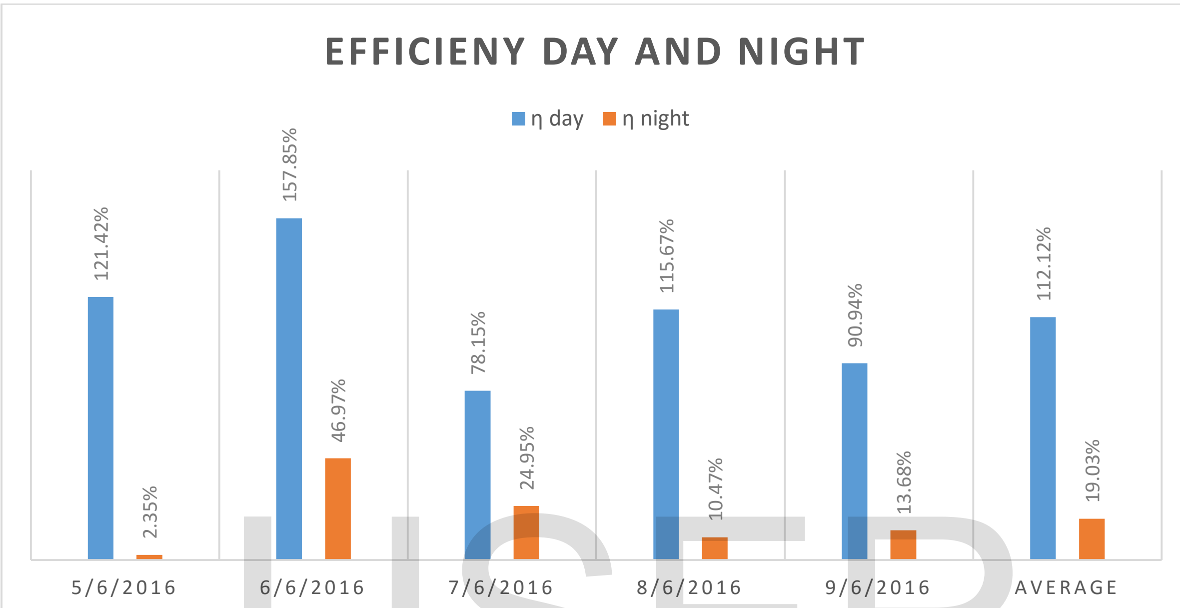


c

It appears from chart (a) that the parabolic trough with **CO_2 gains** heat energy along the day time that exceeds the ambient temperature **very much**, and then

losses heat –chart b- **but keep some heat during night** (chart (c)) as the pipe plays as heat exchanger. But after failure in day 3, it appears that the device **needs time to retain its temperature lost**.

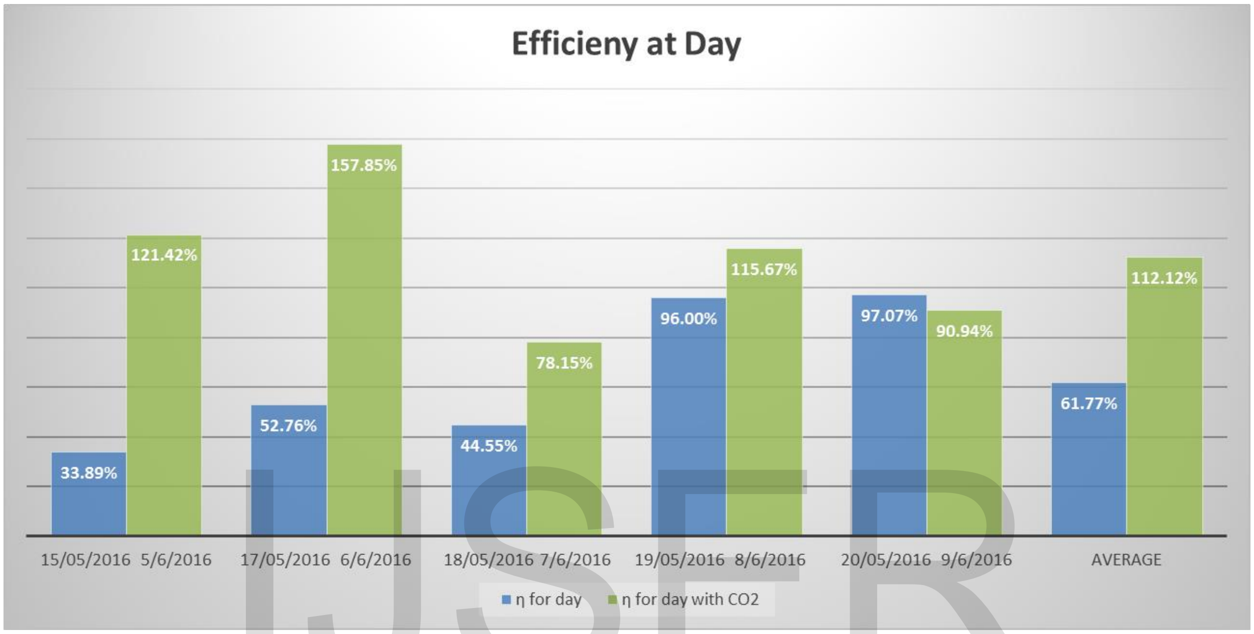
Efficiency of the device day and night:

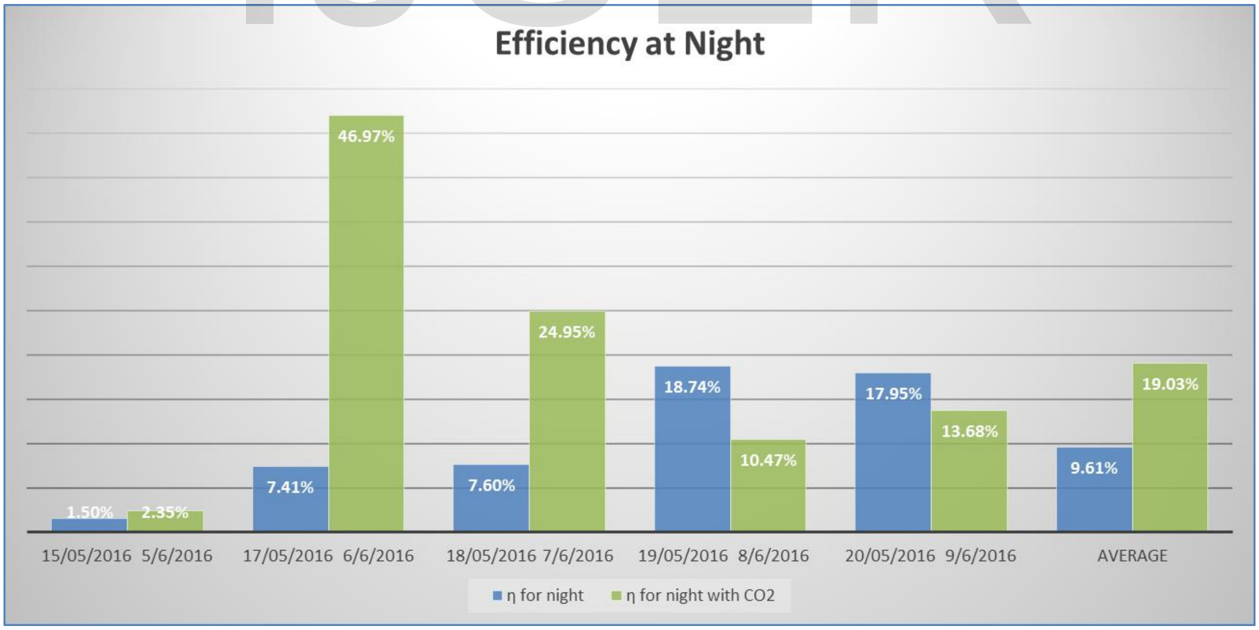


The Parabolic Trough with **CO_2 showed** average efficiency during day **by 112.12%** and by night showed average efficiency **by 19.03%.**

3. Comparison between device1 (Parabolic Trough) and device2 (Parabolic Trough injected by CO_2):

Using Carbon dioxide in our device increased the **parabolic average efficiency from 61.77% to 112.12% by day, also increased average efficiency from 9.61% to 19.03% by night.**

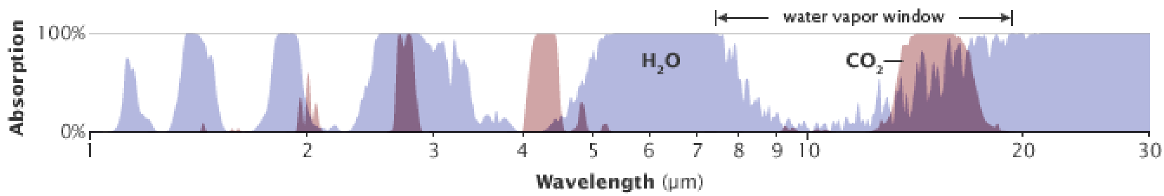




ALSO data shows that parabolic trough with **CO_2** have higher ability to absorb heat and lose it slower than the **normal** parabolic trough.

Conclusion

We can use **Carbon dioxide** to increase **parabolic trough** efficiency, as it traps a wavelength and absorbs energy in wavelengths **12-15 micrometers (NASA, Robert Rohde)**.



CO_2 increased the parabolic average efficiency 50.35% by day and 9.42% by night more than the normal parabolic trough despite of the Failure happened in day 3.

CO_2 have the ability to keep and save energy for some time and decrease the rate of loss of heat by night.

CO_2 have the ability to absorb more heat by day from those normal parabolic trough.

CO_2 have the ability to absorb heat by day even the pipe of the parabolic is not in the focal point as it absorbs energy in the wavelengths 12-15 micrometers.

Acknowledgement

We hope to thank **PhD. Mubarak Muhammed Mostafa – The Agriculture Engineering Emeritus professor** - for providing us with his knowledge without any hesitation.

We hope to thank **PhD. Essam Elsahar – The Agriculture Engineering Professor and the Head of the Agriculture Engineering Department –** for providing us with equipment.

We hope to thank **Dr. Zainab Mahmoud Hendy** – for providing us with the parabolic trough.

We hope to thank **Dr. Muhammed Fathy** – for encouraging us all the time.

And at last not least we hope to thank **Dr. Ashraf Abdelgalil** – for encouraging us all the time.

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