CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION AND MOTIVATION

Photovoltaic devices are used in large scale in today's world scenario. The reason is that they are Environment friendly and give cheap electricity. Photovoltaic devices convert sunlight energy to electrical energy. They have a problem of corrosion which decreases the efficiency of its conversion of electricity. So, for this purpose, Environmental testing chamber is requiring to investigate and inspect the Photovoltaic Devices.

We want to investigate the photovoltaic cell which requires small Testing Chamber setup. So, cell will have very small components. We can get some components by manufacturing in CNC Milling machine, and, some components can purchase directly from market.

1.2 TESTING CHAMBER: AN INTRODUCTION TO RESEARCH AND BENEFITS

TESTING CHAMBER is beneficial for all types of photovoltaic cells.i.e. Organic, inorganic and any other. We inspect mostly the corrosion factor.i.e. a big obstacle for photovoltaic cell to convert sunlight into electricity. It means that it decreases efficiency of photovoltaic cell. We will use some methods to inspect the corrosion factor of photovoltaic cell .i.e. Humidity Freeze Test, Temperature Cycling Test. We will generate three parameters inside Chamber.i.e. Humidity, Temperature, Pressure. These parameters can be varied in limited scale according to our requirement.

1.3 APPLICATIONS & FEEDBACK

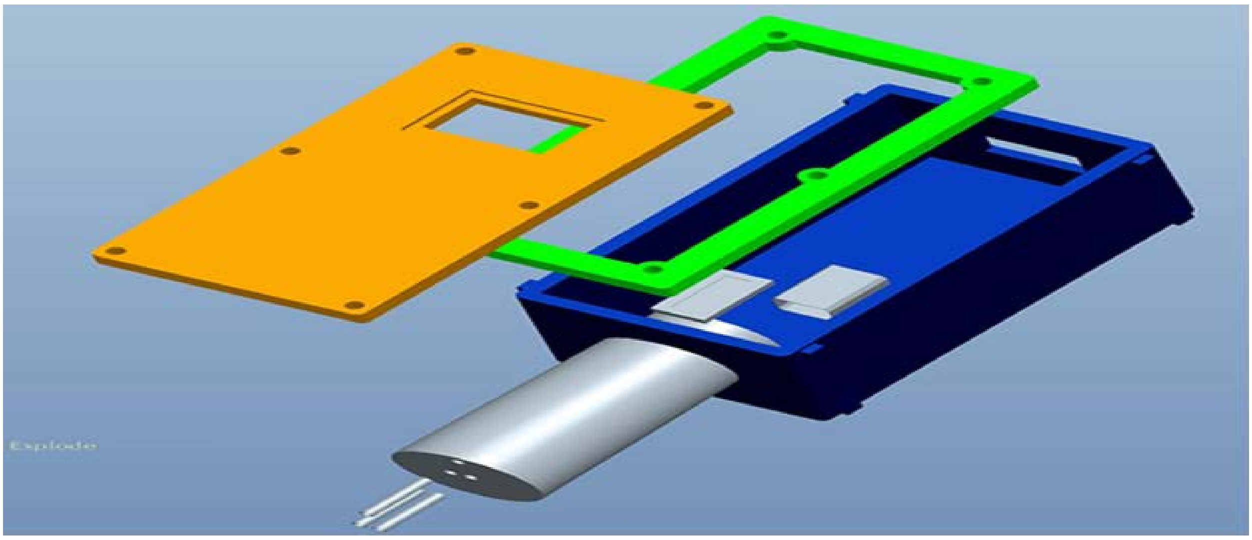
We can use Environmental Testing Chamber to test Photovoltaic devices prior to use. The means of evaluating is to find out the reliability and exact life time of photovoltaic cell. The main purpose is to lower the errors in Photovoltaic devices prior to use or Manufacturing. We can find out exact efficiency of photovoltaic cell with help of various tests to perform inside chamber. We can find out, in how much time, PV cell is able to perform work with maximum efficiency. This is main purpose of testing Photovoltaic cell.

1.4 ENVIORNMENTAL TESTING CHAMBER

Environmental testing chamber require to evaluating impact of environmental conditions on various devices. It also evaluates the durability of product. The testing will accomplish by artificially generating various parameters inside chamber. Environmental testing chamber has also a purpose to find out manufacturing flaws of various items. The environmental testing chamber consists of block with artificially generating various parameters to investigate various items degradation and total life time reliability of a testing product.

1.5 ENVIORNMENTAL TESTING CHAMBER FOR PHOTOVOLTAIC CELL

The main purpose for requisite Environmental Testing Chamber is to evaluate the efficiency of photovoltaic cell. Three parameters should be generated inside testing chamber for testing of Photovoltaic cell.i.e pressure, humidity, temperature. It is to evaluate the corrosion impact on photovoltaic cell because corrosion decreases efficiency of photovoltaic cell. It also evaluates the interconnect brakes of photovoltaic cell to investigate manufacturing of cell prior to use.



Environmental Testing Chamber with cold finger design

1.6 PHOTOVOLTAIC CELL

Photovoltaic cell converts sunlight into electricity directly by means of photovoltaic effect. It also named solar cell. With help of photovoltaic effect, we can generate current or voltage by incident sunlight rays fall on photovoltaic cell. International standards require for testing photovoltaic devices are IEC 61215, IEC 61646, and IEC 62106, IEC 61730.Photodiode is used to convert sunlight to current or voltage.

1.7 PHOTOVOLTAIC CELL FACTORS

Photovoltaic cell will investigate with help of four factors.

- Short Circuit current
- Open Circuit Voltage
- Power Efficiency
- Filler Factor

1.7.1 Short Circuit Current

The short circuit current will show by photovoltaic cell when both of its terminals are connected for current flow with zero resistance. By increasing light intensity, short circuit current will increase Short circuit current will increase if area of photovoltaic cell will increase.

$J_{sc} = I_{sc}/A$

J_{sc}= Short Circuit Current Density

I_{sc}= Short Circuit Current

A = Area

1.7.2 Open Circuit Voltage

Open circuit voltage will show when Photovoltaic cell will be disconnected from any circuit. It is a potential difference between two terminals of photovoltaic cell when no current flows in a circuit.

$$V_{oc} = \frac{kBT}{q} \ln \left(\frac{J_{sc}}{J_o} + 1 \right)$$

Voc = Output Current Voltage

1.7.3 Power Efficiency

The photovoltaic cell power efficiency equals to output power density by input power density.

$$\eta = \frac{J_m V_m}{P_s}$$

1.7.4 Filler Factor

It will show how much short circuit current and open circuit voltage utilized for maximum power.

$$FF = \frac{J_m V_m}{J_{sc} V_{oc}}$$

1.8 DIFFERENT COMPONENTS OF ENVIORNMENTAL TESTING CHAMBER FOR PHOTOVOLTAIC CELL

- Chamber

  Chamber should be small in size to test only one photovoltaic cell. There should be no interfere of outside environment towards inside environment. The chamber should be able to sustain temperature range of -40 to 90 °C.The chamber should be sealed from all sides so that no leakage or fluid permeability should happen.

- Bracket

  The photovoltaic cell will placed on bracket. The bracket is directly attach with face of cold finger design. The bracket should be placed inside chamber such that sunlight or artificial light from sun simulator directly fall on photovoltaic cell. The photovoltaic cell size should not be more than 2cm.

- Cold Finger Design

  The cold Finger design is required to attain low temperature inside chamber. The nitrogen will flow inside cold finger design with suitable pressure flow to attain low temperature of -40°C. Cold finger design contains nitrogen container from where nitrogen will flow to achieve requisite temperature. The design is accomplished such that photovoltaic cell should placed near to cold finger design, so that, cell will attain require temperature. The cold finger design should be tapered from outside so that nitrogen will not accumulated at the end of cold finger design. Sometimes bubbles are made inside cold finger nitrogen container which should be moved out from stainless steel pipe which connected at end of cold finger design.

- Heat Exchanger Mounting Element

  The heat exchanger is required to maintain temperature according to our requirement. The heating element is directly attached with heat exchanger. If we want to change temperature of photovoltaic cell then we varied temperature of heating element. Then heat exchanger change temperature in required surface area. If we want to lower temperature of photovoltaic cell then nitrogen will flow in cold finger design to lower temperature of photovoltaic cell as respect to heat exchanger.

- Humidifier

  The humidifier is used to maintain 85% relative humidity inside chamber. The hygrometer should also attached with humidifier to maintain require humidity inside chamber. The humidifier should be automatic because it should be placed inside chamber.

- Pressurized Air Tank

  The pressurized air tank is used to maintain pressure inside chamber is 100 psig/5931.5 mmHg.The pressurized air tank should be placed outside chamber

- Heat Exchanger

  Plate Heat Exchanger is very beneficial. It has high surface area to flow. It has high heat transfer rate as compare to other heat exchangers in these required conditions. Plate Heat exchanger is mostly use for low temperature applications. They are available in variable sizes. They are mostly used to handle clean fluids. Plate Type heat exchanger has high area density for heat transfer as compare to other heat exchangers. They will work with good efficiency. Due to compact size, plate heat exchanger has high cost. The cleaning of plate type heat exchanger is also very difficult.

1.9 PROBLEMS WITH INDUSTRY

The industry has a problem for making reliable photovoltaic devices. They made photovoltaic cells but they are unable to work in require estimated number of years. The main problem is for reliability. It means they don't know how many years it will become efficient. So, a Testing Chamber will require to evaluating the reliability of photovoltaic cell.

1.10 AIMS OF THIS RESEARCH

We want to made small and compact design testing setup for photovoltaic cell. There are setups available in market for photovoltaic panels but not for photovoltaic cells. Testing setups are made to minimize cost of photovoltaic cell by investigating efficiency of cell prior to use. Testing setups are designed to investigate the reliability of photovoltaic cell. The testing setup for photovoltaic cell has very little research background. We want to focus on photovoltaic cell testing chamber research due to increasing photovoltaic cell utilization day by day. We will investigate the corrosion effect in any kind of photovoltaic cell against impact of humidity, temperature and pressure.

1.11 OBJECTIVES OF RESEARCH

The objectives of the research consist of following as follows.

1.11.1 Design of a Testing chamber:

The design of Testing Chamber consists of Material Selection, Applicable Standards and the requisite relevant products available in market for testing setup

1.11.2 3D modeling of whole testing chamber setup in Pro-Engineer Software:

We should made the 3D-Modeling of parts which we want to manufacture .The fact is that these parts are not easily available from market. We also made the drawing sheets for these parts which show the required dimensions. The parts can be manufactured by using 3D modeling and Design criteria of Environmental Testing Chamber.

1.11.3 Design for manufacturing of cold finger design for maintaining low temperature inside testing chamber:

The Cold Finger is very important design for Environmental Testing Chamber Setup to maintain low temperature inside chamber. The liquid Nitrogen will flow inside Testing Chamber to maintain Temperature of -40 °C.

1.11.4 Study previous photovoltaic testing setups:

The previous research papers show that Environmental testing chamber setups are available in big sizes. These chambers are require for photovoltaic panel Testings. We very few research paper which shows work on small chambers with less than 1 meter size.

1.11.5 Investigate the suitable testing methods require for testing of photovoltaic cells in testing chamber:

Two types of tests are requiring for testing of photovoltaic cells. These tests are Humidity Freeze Test and Temperature Cycling Test. Three parameters should be generated with respect to varying time.

1.12 SCOPE AND LIMITATION

The Scope of the research consists of following as follows.

- Literature Survey
- Design of a Testing chamber
- 3D- Modeling
- Analysis of various parameter requirements inside chamber
- Discussion with Limitations
- Conclusion & Future Recommendation

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, we collect information about previous testing chamber setups, require testing methods and cold finger design. The information has been collected from various journal papers and conference papers.

2.2 VARIOUS TESTING CHAMBER SETUPS

THERMOTRON- Solar PV Testing (A White Paper) gives information for overview plan for designing of Environmental Testing Chamber for PV panels. This paper also gives requisite standards for PV testing.[4]. C.James Taylor focused automatic control of temperature and ventilation rate inside chamber by good programming and using software like Mat lab and Simulink. He selected Aluminum for chamber material.[1] Michael D.Kempe satisfactorily tested photovoltaic devices in accelerated stress chamber by using xenon arc lamp light for evaluation of 20 years exposure effect. It shows that the photovoltaic testing methods like standard IEC 61215 will not satisfactorily fulfill the 20 years sunlight exposure effect. The transmissivity and power efficiency during testing are largely focused.[11]. Suren A.Gevorgyan, Mikkel Jorgensen, Frederik C.Krebs made an atmosphere chamber under artificially generated vacuum conditions for polymer photovoltaic cells testing.[12] Sarah Kurtz and his companions investigate temperature varying factors and give analysis how long term and short term degradation of photovoltaic material occurs.[6]

2.3 REQUIRE TESTING METHODS INFORMATION

Suren A. Gevorgyan and his companions analyze long term degradation mechanism in organic photovoltaic devices. Four parameters are discussed and analyzed to find the degradation mechanism.i.e. Short Circuit Current, Open Circuit Voltage, Fill Factor, Power Conversion Efficiency. [9]. Olivier Haillant describes Sunlight, Humidity & Temperature test and their accelerated effects on Organic & polymeric PV devices. He also describes reliability and durability of a product. [5]. Tony Sample and his companions give analysis of damp heat test. The four parameters i.e. Short Circuit Current, Output Control Voltage, Filler Factor and Max.Pressure are discussed. [7]. Joseph Burdick, Jim Pruett, Elvira Beck give analysis of module Qualification Testing procedure for thin film crystalline photovoltaic modules. In this procedure, the requisite parameters for thin film crystalline photovoltaic modules are being analyzed.[2] R.G. ROSS and his companions describes the current & voltage corrosion analysis of thin-film Photovoltaic Modules.[3]. Mathew O.Reese,Suren A.Gevorgayn,Mikkel Jorgensen conduct various types of tests to evaluate the reliability of tests and to find out the operational accuracy of organic solar cells. The tests include thermal cycling testing, laboratory testing, outdoor testing, and shelf life testing etc. The tests consist of different chambers with various types of controlled environment conditions used.[10].Joule Thomson shows the cold finger design to maintain temperature of 80°K with 1W load. The analysis is focused on friction in inside heat exchanger of cold finger design with help of software like Fluint, Simulink and Mat lab. [8].

2.4 SUMMARY

This chapter gives brief information about various testing chamber setups which are existing nowadays. It also gives brief information about various testing principles which are requiring performing inside testing chamber.

CHAPTER 3

DESIGN SPECIFICATIONS

3.1 INTRODUCTION

We want to make a compact testing chamber for testing of photovoltaic cell. The design requirements consist of material selection according to our required parameters. It will show pressure, temperature and humidity limitations inside chamber. The size of chamber, control of corrosion effect and required insulation type are also discussed.

3.2 PARAMETERS TO CONSIDER INSIDE CHAMBER

Temperature, Humidity and pressure are three parameters which are generated in whole system. The three parameters will be generated inside chamber. These parameters should be generated inside enclosed space. The chamber will be completely insulated from outside environment, so that, there will be no variation in these parameters from outside environment.

3.3 DESIGN REQUIREMENTS FOR ENVIORNMENTAL TESTING CHAMBER

The design requirements are very important to investigate the specifications of material selection of other components of testing chamber. All components specifications depend upon design requirements for environmental testing chamber. The temperature range inside chamber will be largely varied. The maximum temperature should be attain is 90°C and minimum temperature should be attain as -40°C.The relative humidity should also be generated inside chamber. The maximum relative humidity should be generated inside chamber will be 85%.The maximum pressure will be attained inside chamber as 100psig or 5931 mmHg. The size of chamber is very small. It will be 100mm wide, 100mm height and 200mm length. The required insolation levels or solar light are 200 to 1000 wb/m².The chamber has a capacity to test only 1 photovoltaic cell at a time. The Table 1 shows all design criteria for required testing chamber setup.

Table 1

Temperature range	-40°C to 85°C
Relative Humidity	85%
Require Radiation Levels	(200 to 1000) Wb/m²
Test no. of PV cells	1
Required Pressure	100 psig(5931.5 mmHg)
Chamber Size	100mm (W), 100mm (H), 200mm (L).

3.4 MATERIAL SPECIFICATION FOR VARIOUS COMPONENTS

The material specification gives information about material selection of various components which are suitable for testing chamber setup. It depends upon how much temperature, pressure and relative humidity we want to attain inside testing chamber setup. It also depends upon how much insolation or radiation levels require for testing of chamber setups. The corrosion factor can also impact on material.

3.4.1 Material select for Chamber's Skin

Material should be selected on basis of good machinability and good corrosion resistance.

We select Aluminum Alloy 6020 because it has following characteristics.

- Excellent Machining
- High Corrosion Resistant

Aluminum Alloy has one limitation.i.e. It has high thermal conductivity, but, we control this drawback by select good insulation material. The table 2 shows material specification for chamber's skin.

Table 2

Type	**Aluminum Alloy 6020-T8**
Max. required Thickness	6.35mm or 0.25inch
Machinability	90%
Corrosion Rate	0.001 mg/mm² per hour

Thermal Conductivity	1190 BTU/Ft²/in/ hr
R-Value	0.61/in thickness
Standard Applicable	EN 515
Yield Strength	42ksi

3.4.2 Material select for Cold Finger design & Bracket

The material should be selected on basis of good thermal conductivity, good corrosion resistance and good machinability.

We select Copper-Nickel 90/10 due to following characteristics in it.

- Good Corrosion Resistance
- Good Heat Transfer
- Good bio fouling resistance
- Good Machinability

The Table 3 shows the specifications of Copper-Nickel 90/10 as follows.

Table 3

Type	**Copper-Nickel 90/10 (Annealed)**
Machinability	90%
Thermal Conductivity	2250 BTU/Ft²/in/ hr.
Brinell Hardness	70
Corrosion Resistance	0.0025 to 0.025mm/a
Annealing temperature Range	700 to 825°C

3.4.2.1 Cold Finger Design

The Cold Finger Design is utilized to maintain low temperature inside chamber. The design is such that it contains a liquid nitrogen container through which liquid nitrogen can flow inside chamber to maintain low temperature inside chamber. The design of cold finger will be discussed in next chapter. The table 4 will show design requirements for cold finger design.

Table 4

Inlet Diameter	45mm
Outlet Diameter	56mm
Length of Cold Finger Design	127mm
Refrigerant	Liquid Nitrogen
Tapering Angle	4° 95``

3.4.2.2 Bracket

The bracket size will be small. The Photovoltaic cell will placed inside bracket. Only one photovoltaic cell will placed inside this bracket. The table 5 will show considerable information about bracket.

Table 5

Bracket's Size	38mm Length, 20mm width, 5mm Height.
PV Cell's Size	34mm to 32mm
No of Photovoltaic Cell to place inside Bracket	1 Photovoltaic Cell

3.4.3 Material select for Glass Window Rubber Pads

We should select Rubber Pads for glass window to resist permeability of outward environment towards inward environment. We should select rubber pad which have very low gas permeability. The rubber pads should sustain requisite high and low temperature inside chamber. It should also have good pressure sustain capability. The size of rubber pads should be adjustable by considering chamber size and parameters limitations. We should need rubber pads with requirements which will show in table below.

Table 6

Temperature Range	-40°C to 90°C
Pressure Sustain Capability	1.75N/mm²
Hardness Required	70
Permeability to gas	0.01mm²
Size Range	Inside Diameter = 35mm Thickness = 1.7mm

We select Butyl O-Ring because it mostly matches the above requirements. The characteristics of Butyl O-Ring are shown in Table 7 below.

Table 7

Type	**Butyl O-Ring**
Temperature Range	-45°C to 121°C
Butyl O-ring hardness	65
Permeability to gas	0.015mm²
International Size Standards applicable	AS568B (-028 Size)
International size range available in market	Inside Diameter = 34.65 ± 0.33 Thickness = 1.78 ± 0.08

3.5 Type of Insulation Required

The require Insulation should have good high thermal resistance, low air permeability and low noise resistance. The Testing chamber should be isolated from outside environment. There should be no infiltration of outside environment to impact on inside chamber. The chamber should also be vibration free from outside enviornemnt.The insulation will be selected by considering following below parameters.

- High thermal resistance
- Air resistant
- Noise resistance.

The table 8 will show requirements of insulation type specifications. So, we select materials which are near to these specifications criteria.

Table 8

Thermal Conductivity	<5 BTU/hrFt°F
Water absorption	40%
R-Value	7
Temperature Range	90 to -40°C
Thickness Tolerance	2.54mm + 0.2mm

We selected Spray Foam Insulation (Polyurethane) for chamber's insulation. The Spray Foam Insulation specifications are nearer to above required specifications. The table 9 shows Specification for Spray Foam Insulation.

Table 9

Type	Spray Foam Insulation (Polyurethane)
R-Value	6.0/in
Water Absorption	65%
Thermal Conductivity	2 btu/hr ft °F at 200°F(93°C)
Thickness required	1inch
Permeability	0.2%
Air Absorption	99%

3.6 TYPE OF HEAT EXCHANGER REQUIRED

We require heat exchanger which has high heat transfer rate. The size of heat exchanger should not be greater than 35mm.We require that type of heat exchanger which has high area density for heat transfer. The heating element will also attach with heat exchanger which vary temperature according to our requirement. The heat exchanger will face two sources which have different temperatures. One source will be the Heating element and the other source will be the liquid nitrogen container which become near to heat exchanger. Due to flow of liquid nitrogen, we will get very low temperature i.e. below -20 °C. We will get controlled temperature for photovoltaic cell with help of heat exchanger. We will select the Plate Type Heat Exchanger to abide by the requisite conditions of Testing Chamber.

We should select that type of heat exchanger which match the following properties which shown below in Table 10.

Table 10

Rapid Heat Transfer rate	1.67°C/min
Refrigerant flow	Air
Require Area Density for heat transfer	6360mm²
Total Volume inside chamber	2097544.2 cu mm
Size of Heat Exchanger	H13mm, L23mm, W12.5mm

3.6.1 Plate Heat Exchanger

Plate Heat Exchanger has high surface area to flow. It has high heat transfer rate as compare to other heat exchangers in these required conditions. Plate Heat exchanger is mostly use for low temperature applications. They are available in variable sizes. They are mostly used to handle clean fluids. Plate Type heat exchanger has high area density for heat transfer as compare to other heat exchangers. They will work with good efficiency. Due to compact size, plate heat exchanger has high cost. The cleaning of plate type heat exchanger is also very difficult.

We will select plate heat exchanger type which should have following properties which show in Table 11.

Table 11

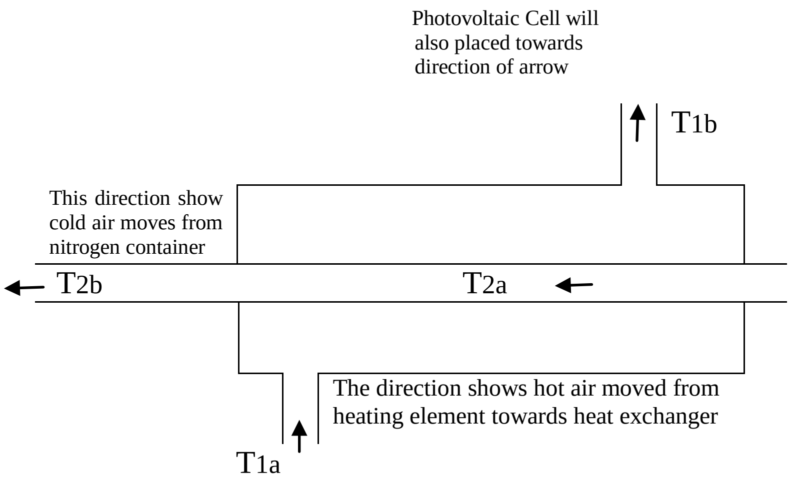
Rapid Heat Transfer rate	3°C/min
Refrigerant flow	Air
Require Area Density for heat transfer	6360mm²
Total Volume inside chamber	2097544.2 cu mm
Size of Heat Exchanger	H13mm, L23mm, W12.5mm

We can select Titanium Plate Heat Exchanger from China. The cost but can high by decreasing size of Heat Exchanger. This type of Heat Exchanger will follow some ASTM Standards also. The total specification of heat exchanger will show in table below. This type of heat exchanger will available in internet link as follow (http://www.alibaba.com/showroom/plate-heat-exchanger-price.html)

Table12

Name	Titanium Plate Heat Exchanger
Applicable Standard	ASTM F67, ASTM F136
Place of Origin	Shaanxi China (Mainland)
Size	Width: <135mm Thickness: 0.4 to 28mm

3.7 Heat Exchanger Requirement [13]



We used Plate Type Heat Exchanger. The flow arrangement in heat exchanger will be cross flow. We used air as refrigerant in Heat Exchanger.

For introducing large heat in heat exchanger from one side, we will start working of heating element. But for introducing lower temperature, we halt the heating element.

Heat Exchanger is attached with heating element. The Heating element will give high temperature at one end of the heat exchanger.i.e. max temperature will be 120ºC. Heat exchanger is also nearer to the cold finger design which has liquid nitrogen container and it creates lower temperature up to -40 ºC.

3.7.1 Air Properties at different temperature [15]

The dry air will use under very large temperature limitations. We require dry air refrigerant at high temperature till 120 ºC, and at cold temperature till -40 ºC. Dry air contains also large amount of nitrogen which is sustainable at very low temperature.

The properties of dry air at -40 ºC are
Density 1.6 kg/m³, Cp 1.0027kj/kg.k, Cv 0.72 kj/kg.k

The properties of dry air at 100 ºC are
Density 0.9413 kg/m³, Cp 1.0106kj/kg.k, Cv 0.7235 kj/kg.k,

3.7.2 Heat Exchanger Calculations

The required heat transfer rate by overall energy balance for hot air is,

$q = \dot{m}_h \, c_p (T2 - T1)$

q = Overall Heat Transfer Coefficient

$\dot{m}_h$ = Mass Flow Rate = 0.4 g/s

T_1 = Inlet Temperature = 120ºC = 120+273= 393K

T_2 = Outlet Temperature = 85 ºC = 85+273= 358K

Cp = 1.006 KJ/Kg.K

q = 0.4 g/s × 1.006 KJ/Kg.K × 65K

q = 26.16W

The required heat exchanger length may be obtained from equation as follows,

$q = UA \, \Delta T_{lm}$

$$\Delta T_{lm} = \frac{\Delta T_1 - \Delta T_2}{\ln \frac{\Delta T_1}{\Delta T_2}}$$

$\Delta T_1 = \Delta T_1$ is the temperature difference between two ends when hot air moves inside heat exchanger

$\Delta T_2 = \Delta T_2$ is the temperature difference between two ends when cold air moves inside heat exchanger

$\Delta T_1 = T_{1a} - T_{1b}$ = 120 ºC – (35 ºC) = 85 ºC = 358K

$\Delta T_2 = T_{2a} - T_{2b}$ = -35ºC – (5 ºC) = -40 ºC = 233K

$$\Delta T_{lm} = \frac{85\,ºC - (-40ºC)}{\ln \frac{85\,ºC}{-40ºC}} = \frac{358K - 233K}{\ln \frac{358K}{233K}} = \frac{125\,K}{0.43} = 18\,ºC$$

As $\dot{m}_c$ = 0.2 g/s

For the flow of cold water in pipe, Reynolds number will be calculated as follows

$$Re = \frac{4\,\dot{m}_c}{\pi\, D_i\, \mu}$$

Di = Inlet Diameter of pipe of Heat Exchanger = 0.003m

$$Re = \frac{4 \times 0.2\ g/s}{\pi \times 0.003m \times 225 \times 10^{-7}\ .\ N.s/m^2}$$

$$= \frac{1.2}{211.95} = 3774$$

As Reynolds Number greater than 2000, then, flow is turbulent.

$$Nu = 0.023\, Re^{4/5}\, Pr^{0.4}$$
$$= 0.023 \times 37744^{4/5} \times 0.7^{0.4}$$
$$= 95$$

Convection coefficient is computed as follow

As $k = 33.8 \times 10^{-3}$ W/m.K

$$hi = \frac{Nu\, k}{D} = \frac{95 \times 33.8 \times 10^{-3}\ W/m.K}{0.003m} = 1070\ W/m^2.k$$

For the flow of hot water in pipe, Reynolds number will be calculated as follows

As $D_0 = 0.005m$

$$Re = \frac{4\,\dot{m}h}{\pi\,(D0+Di)\,\mu} = \frac{4 \times 0.2\ g/s}{\pi \times (0.005+0.003)m \times 225 \times 10^{-7}\ .\ N.s/m^2}$$

$$Re = \frac{0.8 \times 10 \times 7}{5.652} = 1415$$

This flow is laminar. Assuming uniform temperature along inner surface of tube and perfectly insulated from outer surface. The convection coefficient of inner surface may be obtained as follow

.

$$h_0 = \frac{Nu\, k}{Do} = \frac{95 \times 33.8 \times 10^{-3}\ W/m.K}{0.005m} = 642\ W/m^2.k$$

The overall heat transfer coefficient is calculated as follow,

$$U = \frac{1}{(1/hi) + 1/h_o} = \frac{1}{(1/1070) + (1/642)}.$$
$$= \frac{1}{(0.0009) + (0.0016)}.$$
$$= 400\ W/m^2.k$$

The length of Heat Exchanger can be calculated as follows

$$L = \frac{q}{U \pi D_i \Delta T_{lm}}$$

$$= \frac{26.16W}{400W/m^2.k \times \pi \times 0.003m \times 291\ K}$$

$$= 0.023m = 23\ mm$$

3.8 Nitrogen Flow Calculation in cold finger container: [14]

The nitrogen container is placed inside of cold finger design to give low temperature inside chamber. Cold Finger design is placed inside of enclosed chamber. The chamber is completely insulated from outside environment.

We will find out the length of liquid nitrogen container and volumetric flow of liquid nitrogen.

For constant surface heat flux, the energy balance equation is as follows

$$A_s = L \times W = \frac{\dot{m}C_p (T_o - T_i)}{q_s}$$

L = Length of liquid Nitrogen Container = ?

w = Width of Container = 17mm

Cp = Constant Pressure of liquid Nitrogen at -40 ºC

To = Temperature of surrounding (Room Temperature) = 25 ºC

Ti = Temperature of Liquid Nitrogen Container = -40 ºC

qs = thermal conductivity or heat flux

The total heat transfer rate in cold finger is

$$q_s = \frac{-k (T_2 - T_1)}{X}$$

k = thermal conductivity of liquid nitrogen at -40 ºC = 20 × 10×-3 W/m.K

T2 = temperature at outlet (room temperature) = 25ºC = 298k

T1 = Temperature at inlet = -40 ºC = 233k

X = Length of cold finger = 136mm

$$q_s = \frac{k (T_2 - T_1)}{X}$$

$$= \frac{0.02\ W/m.K \times (298-233)k}{0.136m}$$

$$= 10\ W/m^2$$

$$L = \frac{\dot{m}C_p (T_o - T_i)}{q_s \times W} = \frac{0.2kg/s \times 1.042kj/kg.k \times (298-233)k}{10\ W/m^2 \times 0.017m}$$

L = 80 mm

We require 80 mm length of liquid nitrogen container to attain -40 º C temperatures.

The volumetric flow of liquid nitrogen container is as follows

The Reynold number is calculated as follow

$$Re = \frac{4\dot{m}}{\pi D \mu}$$

D = Diameter of Cold Finger = 56mm, ṁ = mass flow rate = 0.2kg/s

$\mu = 140 \times 10 \times -7\ Ns/m^2$

$$Re = \frac{4 \times 0.2 kg/s}{3.14 \times 0.056 m \times 140 \times 10 \times -7\ Ns/m^2}$$

$Re = 324970$

As $V = \frac{Re\ \nu}{L}$

V = Mean Velocity of liquid nitrogen in container

ν = Kinematic Viscosity = 0.000001 m^2/s

L = Length of liquid nitrogen container = 80 mm

$$V = \frac{Re\ \nu}{L} = \frac{324970 \times 0.000001\ m^2/s}{0.080 m} = 4.062\ m/s$$

$V = 4062\ mm/s$

As $Q = \frac{Re\ \nu\ A}{D_H}$

Q = Volumetric flow rate = ?

A = Area of liquid nitrogen container = 1360 mm^2

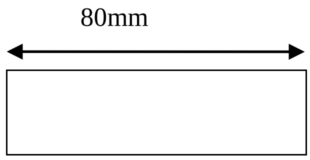
$$D_H = \text{Hydraulic Diameter} = \frac{4A}{P(\text{Wet Perimeter})} = \frac{4 \times 1360\ mm^2}{194 mm} = 28 mm$$

$$Q = \frac{324970 \times 0.000001\ m^2/s \times 0.00136\ m^2}{0.028 m} = 0.02\ m^3/s$$

So, the require volumetric flow in liquid nitrogen container is

$Q = 0.02\ m^3/s = 20\ mm^3/s$

The require length of nitrogen container is 80mm, and we require 20 mm^3/s for nitrogen flow.



3.9 TYPE OF HEATING ELEMENT & PIPE REQUIRE

3.9.1 Heating Element

The heating element should give temperature according to our required chamber's design requirement. We require a very small size of heating element. The heating element will start work when temperature is very low, and we will get high temperature with help of heating element.

3.6.1.1 Nichrome Heating Element

This type of heating element will be mounted below bracket. It will position on face of cold finger design. The required applicable temperature to maintain inside chamber with help of heating element should be near to 90°C. The length of heating element should not be greater than 20mm.The heating element will attach with heat exchanger. As we want to change temperature, the heating element will rise temperature of environment. After this, the heat exchanger will increase rate of heat flow according to our requirement and increase area density of heat exchange.The below figure shows require heating element for system setup.

The require heating element should have following size and temperature as shown in table below.

Table 13

Size	> than H15mm,W12mm
Applicable temperature	20 to 90°C

We should select a heating element which has considerable good temperature range as compare to our requirement. The product should follow the required applicable standards. The heating element should follow the properties which become nearer to properties which are shown in table below.

Table 14

Applicable Temperature Range	20 to 200°C
Surface Material	Nichrome
Standard	ISO 9001-2008
Hot zone length & spacing	10mm & 4.5mm respectively
Shank Spacing	6mm

The coil nichrome heating element is available which have good considerable temperature range. It is available in range of require size. This product is available on internet on website link (http://www.alibaba.com/product-gs/618615910/Coil_nichrome_heating_elements.htmlQuartz tube diameter: 10mm). The product's information shown in following below table.

Table 15

Name	Coil Nichrome heating elements
Model Number	ST-C013
Brand Name	Santian
Out dia	6.5-8mm
FOB Price	20-50$

3.6.2 Pipes

The pipes are required to flow nitrogen inside and outside testing chamber setup. The pipes are connected to the end of Cold Finger Design. Two pipes use for nitrogen flow. The third pipe also use which pushes out the bubbles which accumulate inside chamber. The pipes are made from martensitic stainless steel. The pipes diameter is 5mm and their length is 33mm.

3.7 PRESSSURIZED AIR TANK & HUMIDIFIER SELECTION

The Pressurized Air Tank and Humidifier are available in market in various sizes. Pressurized Air Tank will placed outside from testing chamber to maintain require pressure inside chamber. The humidifier will place inside chamber to maintain require relative humidity inside chamber.

3.7.1 Pressurized Air Tank

We want to maintain 100 psi or 5931.5 mmHg pressure inside testing chamber. The Pressurized Air Tank will tighted up to chamber such that no external environment will effect on inside chamber. The pressure relief valve will also attach to the chamber to regulate the required maintain pressure. The size of Pressurized Air Tank should not be greater than 1 meter. The require Pressurized Air tank can purchase from market which shown in below figure.

The Table 16 shows the desired specifications of pressurized air tank for testing chamber.

Table 16

Pressure	200psi
Tank Size	10’’ * 14’’
Weight	60Kg
Applicable Standard	ISO 11439

We get a Pressurized Air Tank which has specifications very near to desired requirements. The product will available in internet in website link (http://www.alibaba.com/product-gs/267663672/Air_Pressure_Tank.html)

The Table 17 shows specifications of this product which available in market.

Table 17

Name	Air Pressure Tank
Place of Origin	Zhejiang China (Mainland)
Size	Customized
FOB Price	US $ 50 / Piece

3.7.2 Humidifier

The humidifier will give 85% relative humidity inside testing chamber. The humidity should be maintained and controlled by humidifier. The humidifier will automatically switch off when it maintains required humidity level inside chamber. The humidifier will placed inside chamber. The size of humidifier is also small, so that, it will easily place inside chamber. It should be automatic. Hygrometer should also attach with it to maintain 85% relative humidity level. Size of humidifier should not be greater than 40mm height and 30mm length. The below figure shows humidifier available in market which meet our system design specifications.

We should select humidifier with following characteristics in it which show in table 18..

Table 18

Product size	20mm,15mm,30mm
Max.Humidity	100ml/ hr.
Type	Automatic

We get a humidifier which has following properties shown below in table 19. This product is available on internet in web link (http://www.alibaba.com/product-gs/499371197/Small_Humidifiers.html

Table 19

Name	Ultrasonic Humidifier
Voltage (V):	12
Place of Origin	China (Mainland)
Applicable Standards	ARI 630

3.11 SUMMARY

This chapter gives information about all design requirements of environmental testing chamber setup. All design requirements are made according to require temperature, humidity and pressure inside testing chamber. Material will be selected for chamber’s skin, bracket, and cold finger by considering requisite parameters impacts. This chapter also gives design information about products which we want to purchase from market. So, the design information of available requisite materials in market are also given in this chapter.

CHAPTER 4

Cold Finger Design

4.1 INTRODUCTION

The Cold Finger Design is require maintaining low temperature inside Testing Chamber. It is type of tube which become inserted and fixed inside Testing Chamber. The liquid nitrogen will flow inside tube to maintain low temperature inside Chamber. The heat Exchanger will be mounted on face of Cold Finger tube inside chamber to maintain required temperature towards required surface area. The bracket will also attach on face of Cold Finger design above to heat exchanger mounting element. The inner portion of Cold Finger Design contains Liquid Nitrogen container. The Liquid Nitrogen will flow inside and outside of Cold Finger Design with help of pipe. A motor will require to maintain continuous flow of liquid nitrogen inside and outside of Cold Finger Design. The Cold Finger design will be tapered at end of his body , so that, liquid nitrogen will not accumulate inside Cold Finger Design.

4.2 REFRIGERANT

Liquid Nitrogen will use as refrigerant. With help of liquid nitrogen, we can maintain low temperature inside chamber. i.e. -40°C. The motor will require maintaining continuous flow of liquid refrigerant according to our requirement.

4.3 MAIN OBJECTIVES OF COLD FINGER DESIGN

Cold Finger Design is made such that photovoltaic cell’s bracket, heating element and heat exchanger are directly attached at face of cold finger design. These three components should near to liquid nitrogen container, so that, we maintain low temperature of Photovoltaic Cell easily. The Design of Cold Finger should be such that liquid nitrogen will flow easily inside and outside chamber to maintain low temperature according to our requirement.

4.4 LIMITATIONS OF DESIGN

The bubbles will make inside chamber due to flow of liquid nitrogen. These bubbles can impact on system. To handle this problem, we made a hole with pipe extension at end of cold finger design on its above surface. The bubbles can easily come out from that hole.

4.5 TAPERING OF COLD FINGER

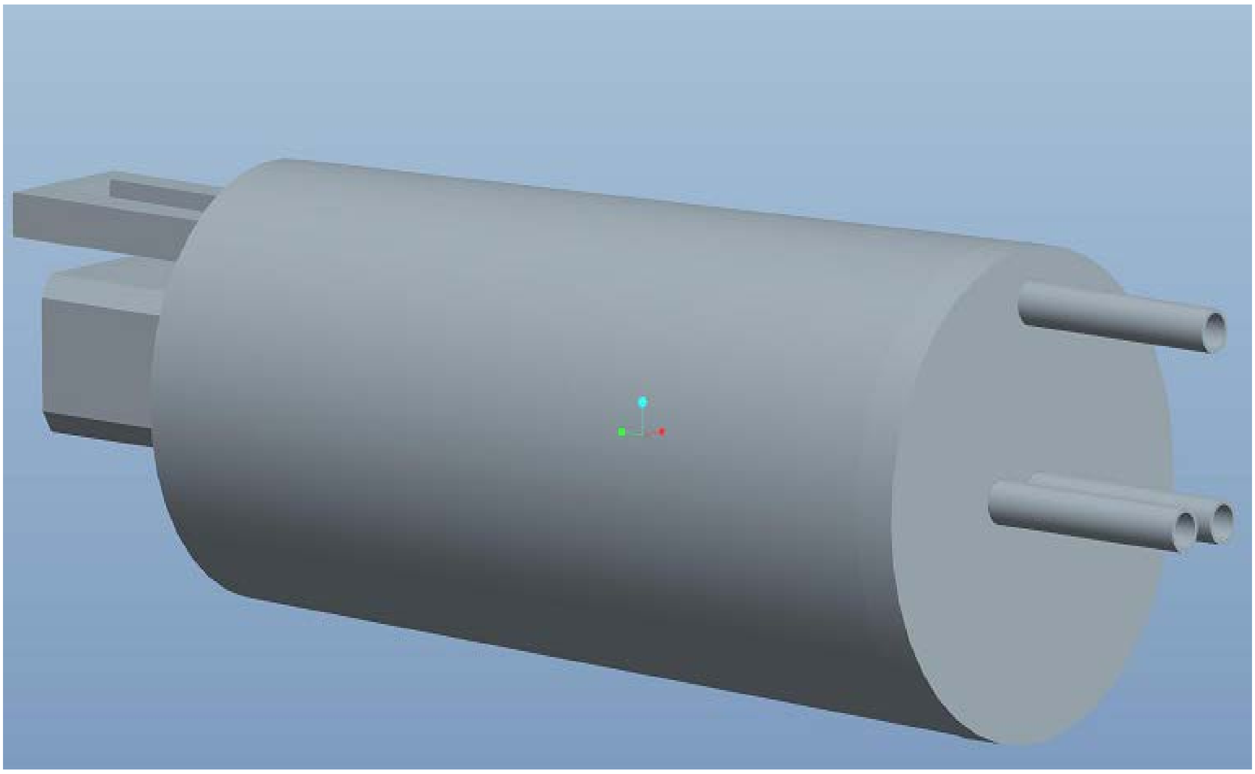
The Cold Finger Design will taper at end, so that, refrigerant will easily come out from chamber and it will not accumulate inside Cold Finger. The require taper angle to maintain flow of refrigerant is 4° 95``. The length of taper should be 127mm.

4.5.1 Size of Cold Finger

The cold Finger inner diameter is 45mm.The cold Finger outer diameter is 56mm. The length of Cold Finger Design is 127 mm. Cold Finger will fix and totally adjusted on inside of testing chamber.

4.6 SUMMARY

Cold Finger Design is very important in the designing of testing chamber. We will maintain low temperature with help of Cold Finger design for Photovoltaic Cell. The Cell will directly attach to the Cold Finger Design. Below Diagram shows the Cold Finger Design assembly.



Chapter 5

TESTING MEHODS

5.1 INTRODUCTION

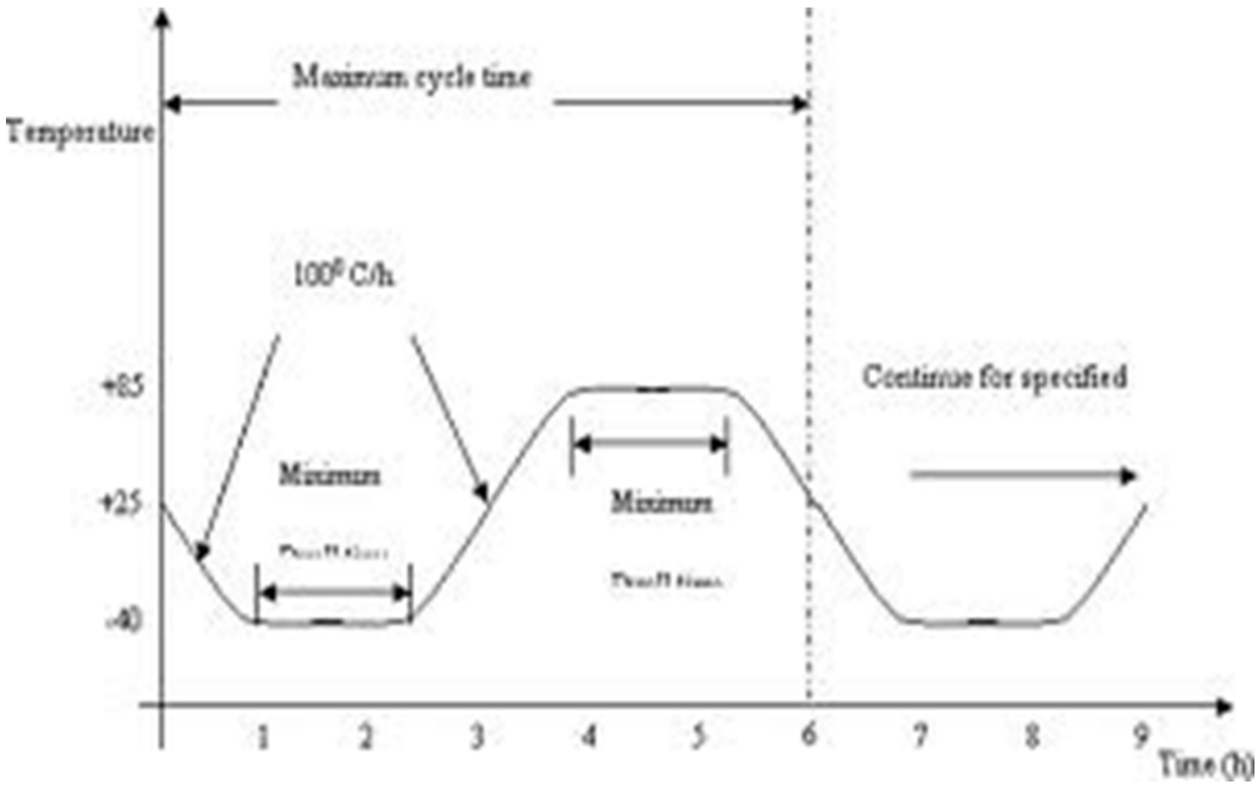
We perform tests to evaluate performance of Photovoltaic cell. Photovoltaic cells have large failures like corrosion and interconnect brakes. Photovoltaic cell is largely affected from Temperature and Humidity effects. With help of testing methods, we can judge the efficiency and reliability of Photovoltaic Cell. Corrosion factor is largely responsible to decrease efficiency of Photovoltaic Cell.

5.2 TEST OBJECTIVES

These tests are requiring investigating corrosion impact on Photovoltaic Cell. The Photovoltaic Cell reliability will be investigated by performing these tests. It means that, with help of these tests, we will know how much time the Photovoltaic Cell will be 100 percent efficient.

5.3 TEMPERATURE CYCLING TEST

The main work of this test is to check how much PV cell will sustain from repeated thermal stresses of different temperature variations. In this test, temperatures will high up to 85°C and drop to -40°C. The 85°C temperature will maintain for 10 min and then drop temperature to -40°C, it will also maintain for 10 minutes. This cycle will repeat for specified no. of cycles according to our own requirements. The temperature rate should not be increase to 100°C/hr. (i.e. 1.67°C/min).Each cycle will start when Environmental testing Chamber has attained normal temperature.(i.e.25°C)



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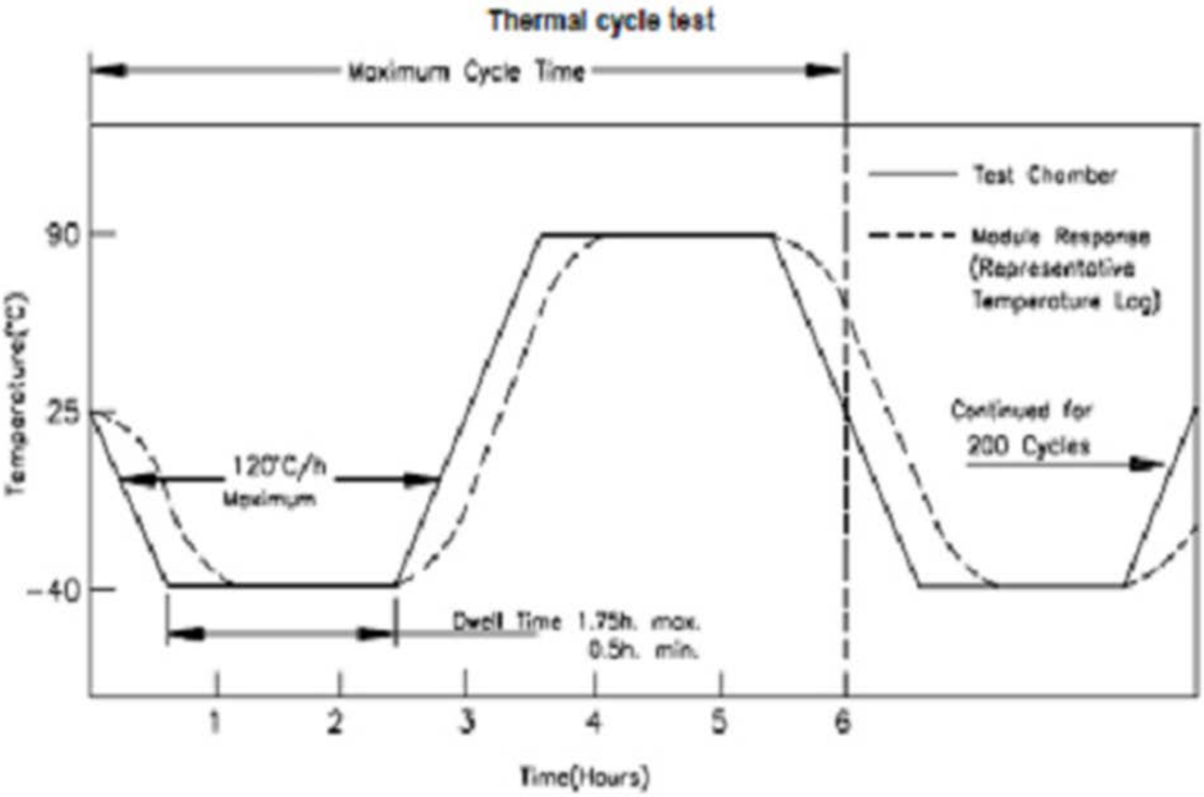
5.4 Humidity Freeze Test

Humidity Freeze Test is used to check how much humidity absorbs by PV Cell. We can also investigate how much corrosion effect will take place on PV Cell. In this test, we perform test for specified no.of cycles according to our own requirements. In each cycle, there are two sub-cycles.i.e. In first sub-cycle, we use controlled humidity level, and, in the second sub-cycle, we will not control humidity level. The first cycle has minimum dwell time of 1.75 hrs, and second sub cycle has maximum dwell time of 0.5 hrs. In first sub-cycle, we will attain 85% with tolerance of + 5% Relative Humidity. The temperature time scale for sub-cycles is 120°C/h max.These sub-cycles will repeat for specified no. of cycles according to our own requirements.



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5.5 SUMMARY

In this chapter, we discussed various testing methods which we want to perform in Testing Chamber. Two types of tests will discussed.i.e. Humidity Freeze test and Temperature Cycling Test. These tests are performs to investigate corrosion impact on Photovoltaic Cell.

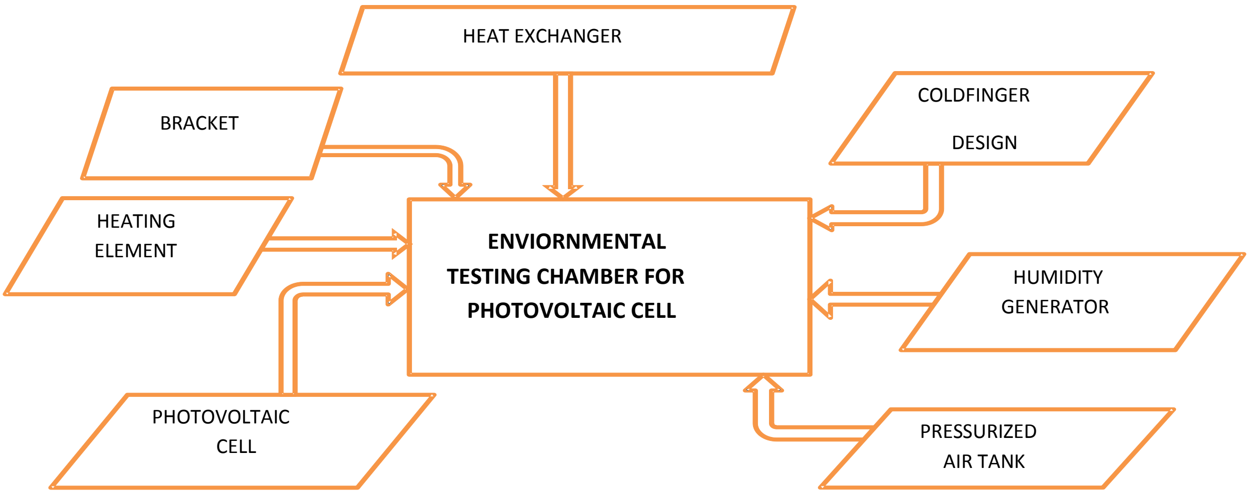
CHAPTER 6

System Component Diagram of Testing Chamber6.1

INTRODUCTION

The Flow Diagram of Environmental Testing Chamber will explain the require input and output parameters for designing of Photovoltaic Cell. The Input and Output parameters are very important because we design all components by considering these parameters. Flow Diagram gives brief view about whole Testing Chamber Input and Output parameters information.

YSTEM COMPONENT DIAGRAM OF TESTING CHAMBER



6.2 INPUT PARAMETERS OF TESTING CHAMBER COMPONENTS

The Input Parameters will be selected by considering design information of Testing Chamber setup. We assigned input parameters for various components of testing chamber setup. With help of Input Parameters, we can easily find out our require initial conditions in Testing Chamber.

6.3 OUTPUT PARAMETERS OF TESTING CHAMBER COMPONENTS

The Output Parameters will be selected by considering design information of Testing Chamber setup. We assigned output parameters for various components of testing chamber setup. With help of output Parameters, we can easily find out our require final conditions in Testing Chamber**.**

6.4 INPUT & OUTPUT PARAMETERS OF TESTING CHAMBER COMPONENTS

6.4.1 Chamber Input & Output Parameters

6.4.1.1 Input parameters

We should select material by considering some important input parameters for chamber. The Chamber should be air tight.i.e. there should be no leakage of air from testing chamber. The chamber should be totally sealed from outer environment. The chamber should also save from dust contamination. The Chamber should be light in weight. It should have small and compact design.

- Air Tight (No Leakage)
- Sealed
- Dust Free
- Corrosion Resistant
- No outside effect on inside parameters
- Light Weight & Compact Design

6.4.1.2 Output Parameters

Aluminum Alloy 6020 will be selected for chamber's skin. It has good corrosion resistance but it will not control heat transfer. For this purpose, Spray Foam Insulation will be used to control heat transfer from inside or outside environment. It will have following information given below.

- Aluminum Alloy 6020 is suitable for this purpose
- Dimensions = L 200mm, W 100mm, H 100mm
- Insulation = Spray Foam Insulation

6.4.2 Bracket Input & Output Parameters

6.4.2.1 Input parameters

Photovoltaic Cell will place easily inside bracket. The bracket will directly place near to Cold Finger, Heating Element and Heat Exchanger, so that, temperature variation can directly effect on Photovoltaic Cell. Bracket should be placed such that Sunlight will directly fall on Photovoltaic Cell. Their should be good heat transfer and Thermal Conductivity on bracket.

6.4.2.2 Output parameters

Bracket will Fixed and placed on face of Cold finger design and in down of Chamber's mirror. Only one photovoltaic cell will be placed inside bracket. The Cell has a direct temperature effect from various temperature variations. The other information about bracket are as follows

- Bracket Material: Copper-Nickel 90/10 Alloy
- Bracket's Size : 8mm Length, 20mm width, and 5mm height.
- PV Cell's Size : 34mm to 32mm

6.4.3 Heat Exchanger Input & Output Parameters

6.4.3.1 Input Parameters

We will select a heat exchanger which has high rate of heat transfer and gives more area density of heat flow. Some other information of heat exchanger are shown below.

- Surface Area req. for temperature change =6360
- Heat transfer rate require=1.67°C/min
- Type of heat transfer type=largely Convection
- Heating element & thermocouple also attached with heat exchanger

6.4.3.2 Output Parameters

Plate Type Heat Exchanger is best choice to obtain large heat transfer area and require large area density of heat transfer. Air will be used as refrigerant for Heat Exchanger.

6.4.4 Cold Finger Design

6.4.4.1 Input Parameters

Cold Finger Design will give cold temperature up to -40°C. Cold Finger Design should maintain good thermal conductivity & heat transfer towards whole inside chamber. Refrigerant will flow easily inside and outside cold finger design.

6.4.4.2 Output Parameters

We will use Liquid Nitrogen as Refrigerant. The Copper Alloy (Copper-Nickel 90/10) is used as material for cold finger design. Cold finger design should be tapered, so that, refrigerant will not accumulate inside cold finger design. Motor will use for refrigerant's continuous flow.

6.4.5 Humidifier Input & Output Parameters

The Chamber Temperature Range should be 90 to -40°C. The relative humidity maintains should be 85%. Air should be used as refrigerant. We should maintain 100 psi pressure inside chamber.

Refrigerant = Air

Maintain Fluid Pressure Inside Chamber = 100psig (5931.5 mmHg)

Maintain 85% relative humidity

6.4.6 Pressurized Air Tank Input & Output Parameters

6.4.6.1 Input Parameters

Pressurized Air Tank is to maintain 100 psig or 5931.5 mmHg pressure inside chamber.

6.4.6.2 Output Parameters

The size of pressurized air tank should not be greater than 1 meter. It will be placed outside chamber and connect chamber with a pipe. The size of pressurized air tank will be 10’’ * 14’’.The safety valve will also attach with pressurized air tank.

6.4.7 Heating Element Input & Output Parameters

6.4.7.1 Input Parameters

The heating element will directly attach to the heat exchanger. The heating element will place near to photovoltaic cell also. It should maintain maximum temperature limit 90 °C.

6.4.7.2 Output Parameters

The heating element has a small size. It will place near to bracket and heat exchanger. We will use nichrome heating element with temperature range of 20 to 90°C.

6.5 SUMMARY

This chapter explains the input and output parameters of testing chamber. All components of testing chamber will design by considering input and output parameters of all components of testing chamber setups.

Chapter 7

3-D MODELING

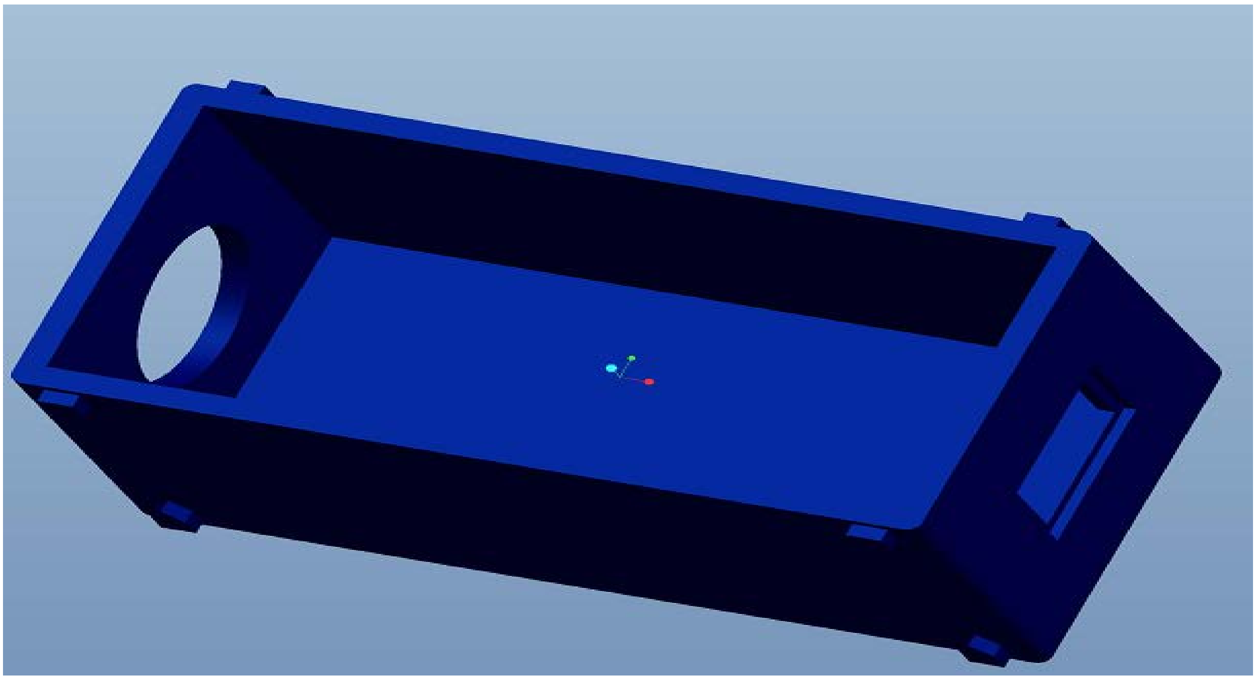
7.1 INTRODUCTION

The 3-d modeling of different components of testing chamber is made by using pro-engineering software. We make models of some components of testing chamber which we don’t want to purchase from market. We use this modeling to manufacture components by using CNC Milling Machine.

7.2 3-D MODELING OF VARIOUS COMPONENTS

7.2.1 3-D Modeling of Chamber

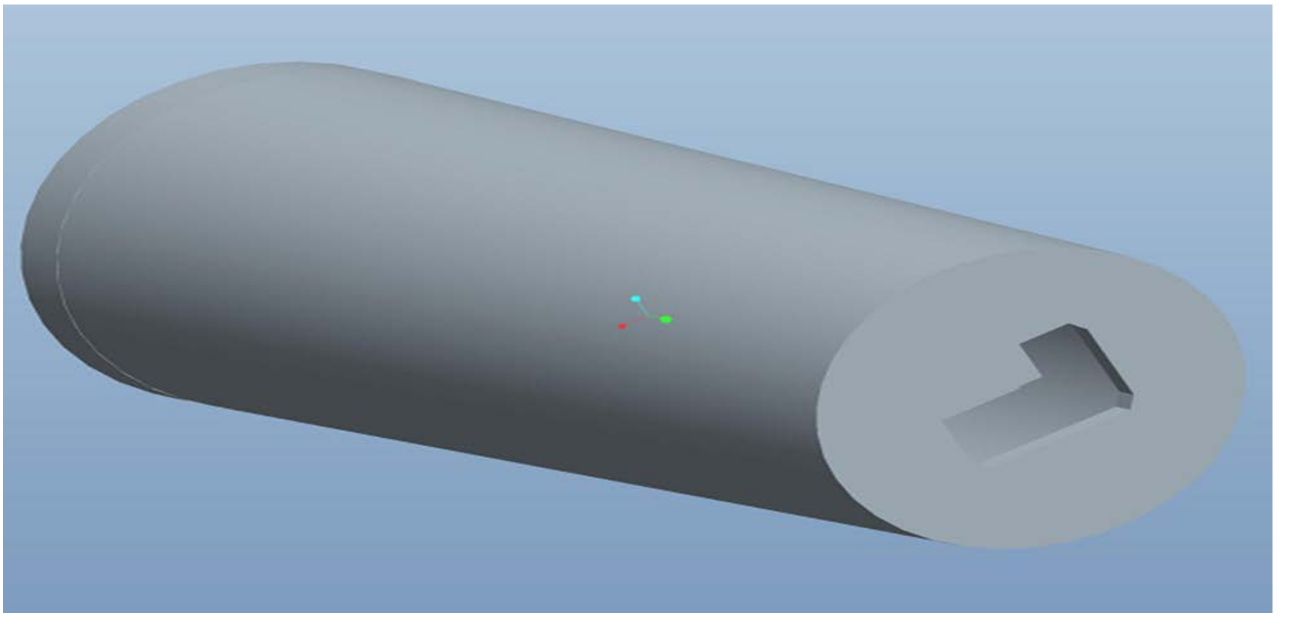
The Chamber is a simple rectangular design. One side of chamber shows circular shape in which cold finger tube will be inserted and fixed inside chamber. The other side shows rectangular cut in which mirror will be adjusted. The fact of rectangular cut is that light will come from mirror and directly strike to photovoltaic cell which placed inside chamber.



7.2.2 3-D Modeling of Cold Finger

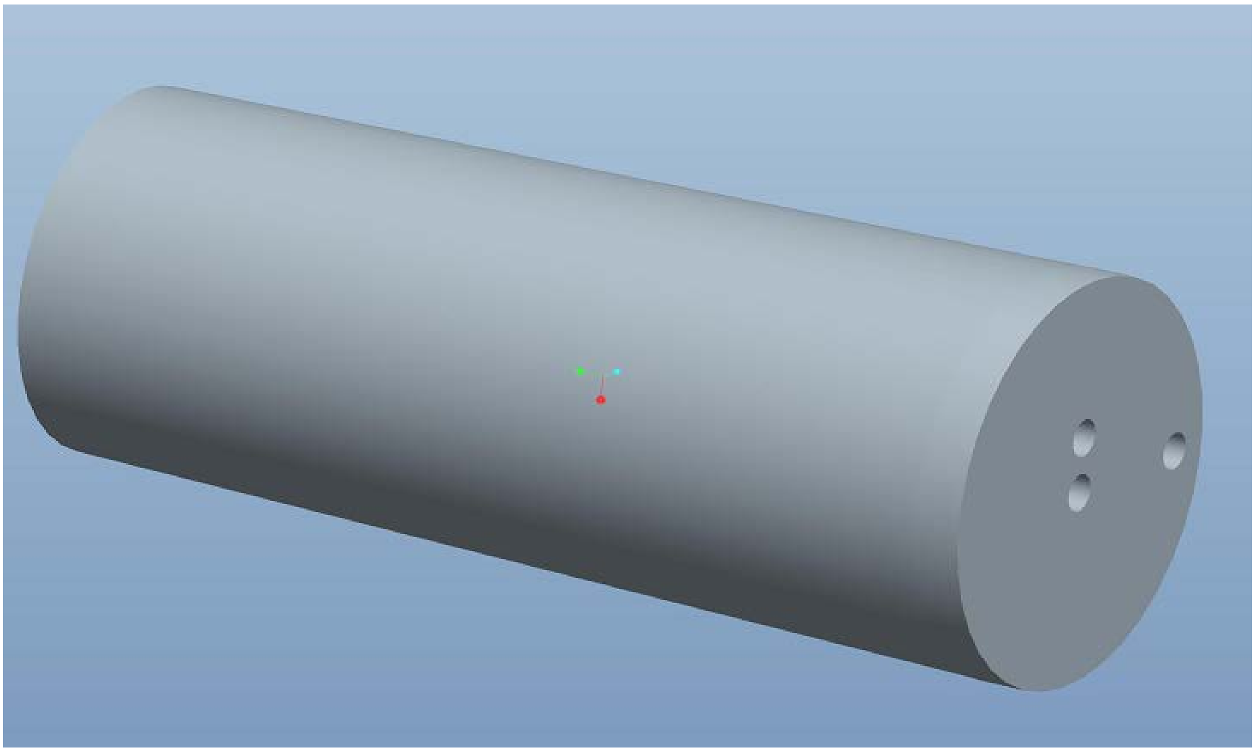
Cold Finger Design is made to maintain low temperature inside chamber. It is in shape of tube in which liquid nitrogen will flow to maintain require low temperature. It will be fixed inside chamber. The cold finger will place from that side of chamber from which circular cross-section side of chamber exists.

In front face of cold finger design, the bracket and heat exchanger will be mounted. The photovoltaic cell will be placed inside bracket. The front face of cold finger design is shown as follows.



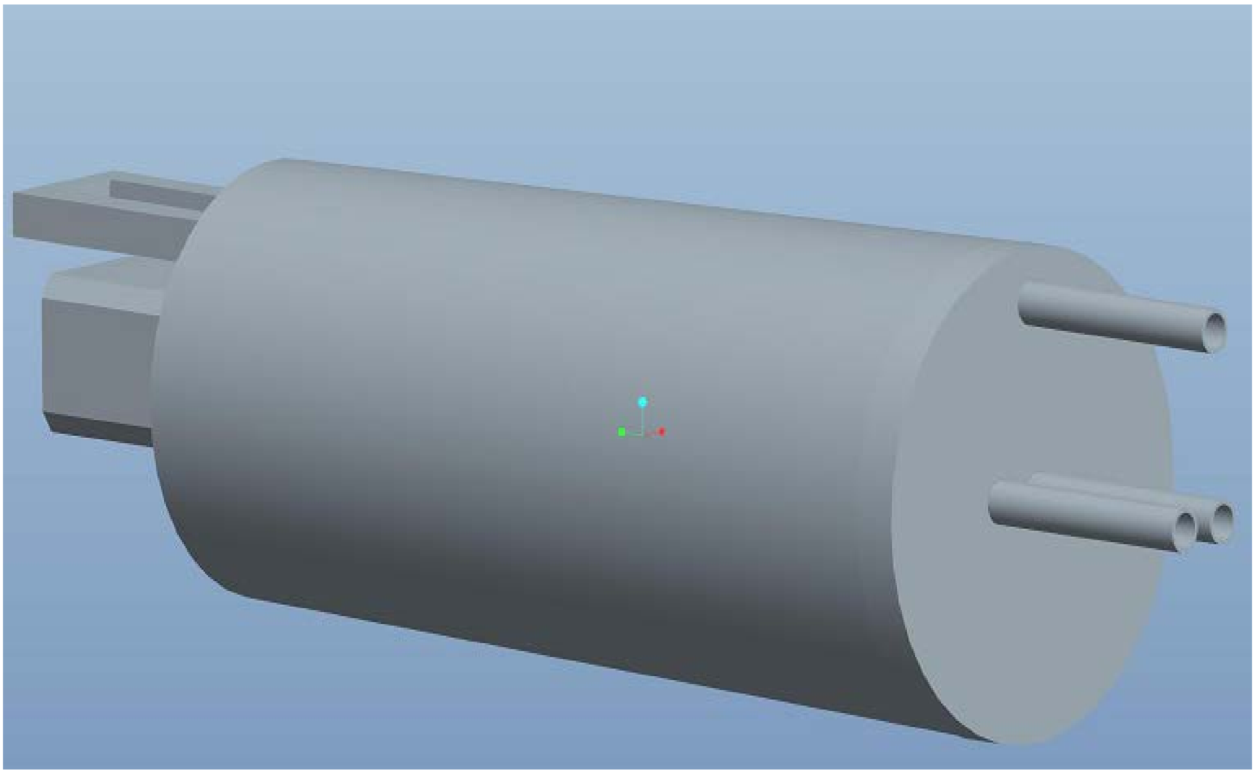
This is the front face of cold finger design. The bracket, heating element and heat exchanger are attach on this face of cold finger design.

The outer Face of Cold Finger design shows three holes. Two holes which are closer to each other show inside and outside flow of liquid nitrogen. The other hole is made to exhaust the air bubbles which made in nitrogen container. The nitrogen container will make inside Cold Finger Tube. The Outer face of Cold Finger Design is shown as follow.

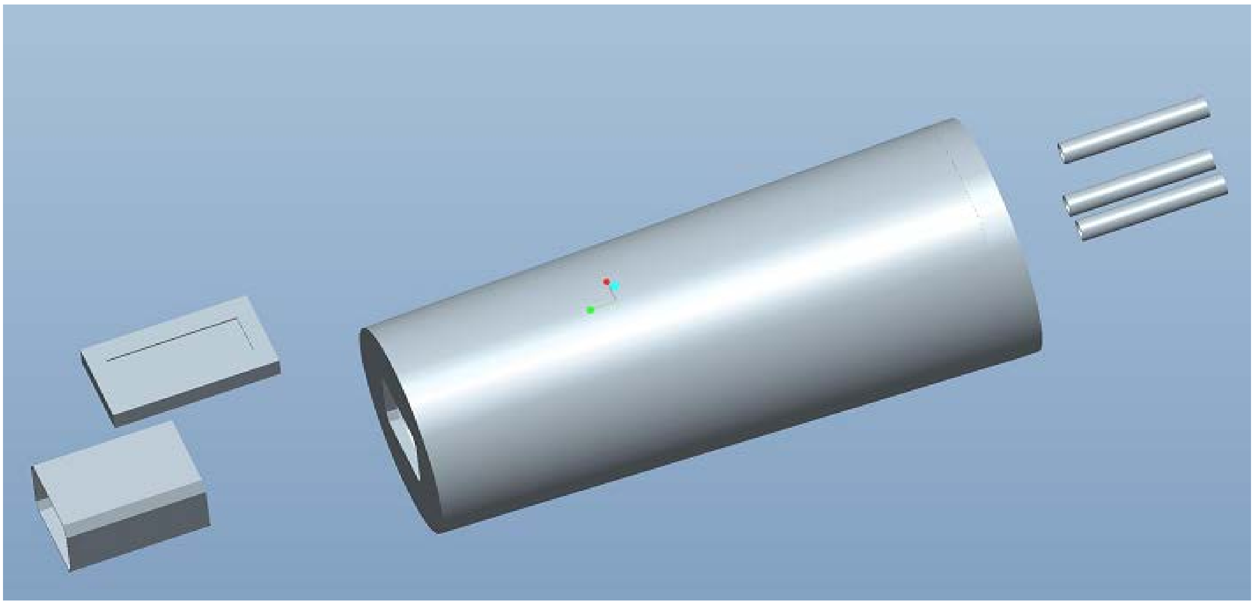


7.2.2.1 Assembly View of Cold Finger

The Assembly view gives very clear information about cold finger design. The Assembly view shows that how the cold finger will mount with other components.i.e. Bracket, Stainless Steel Pipes etc. The inner tube of Cold Finger Design contains the nitrogen container.

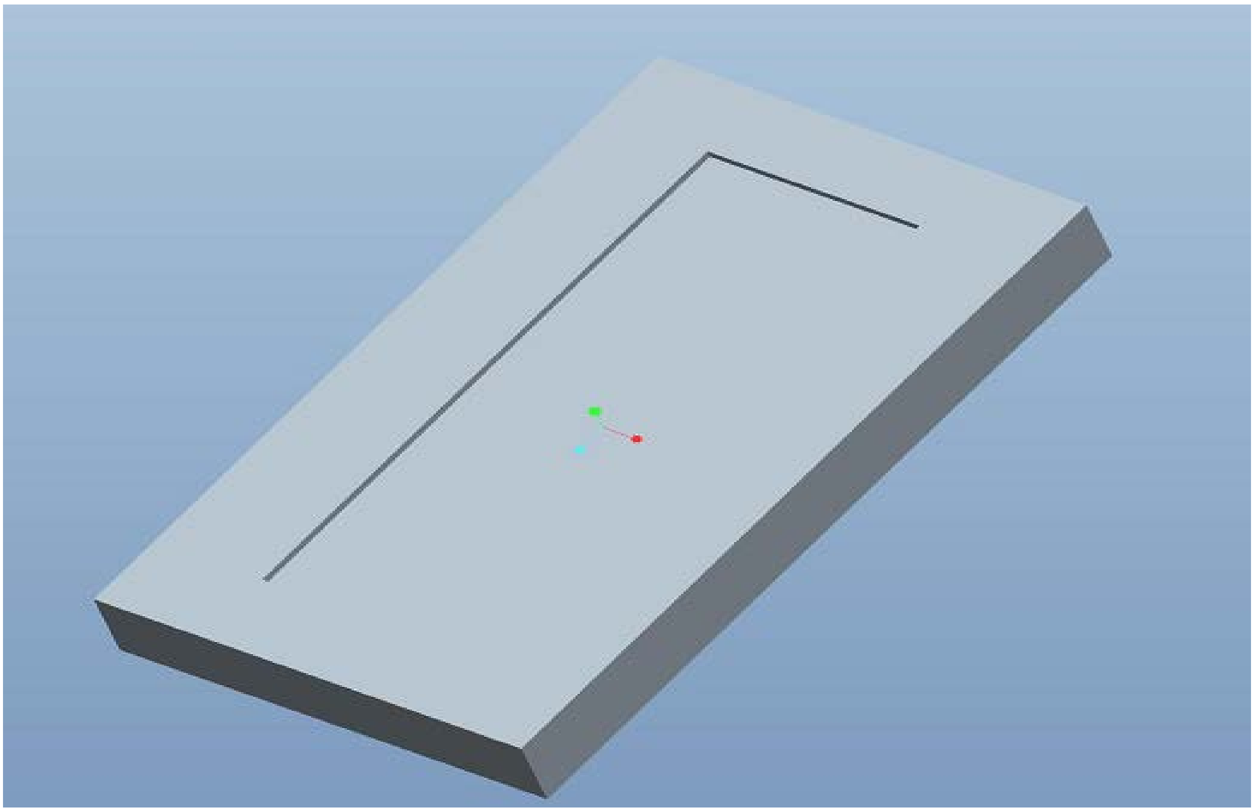


The Exploded View of Cold Finger design show the clear view how many individual components are fixed with cold Finger design. It explicit the placement of various components positions.



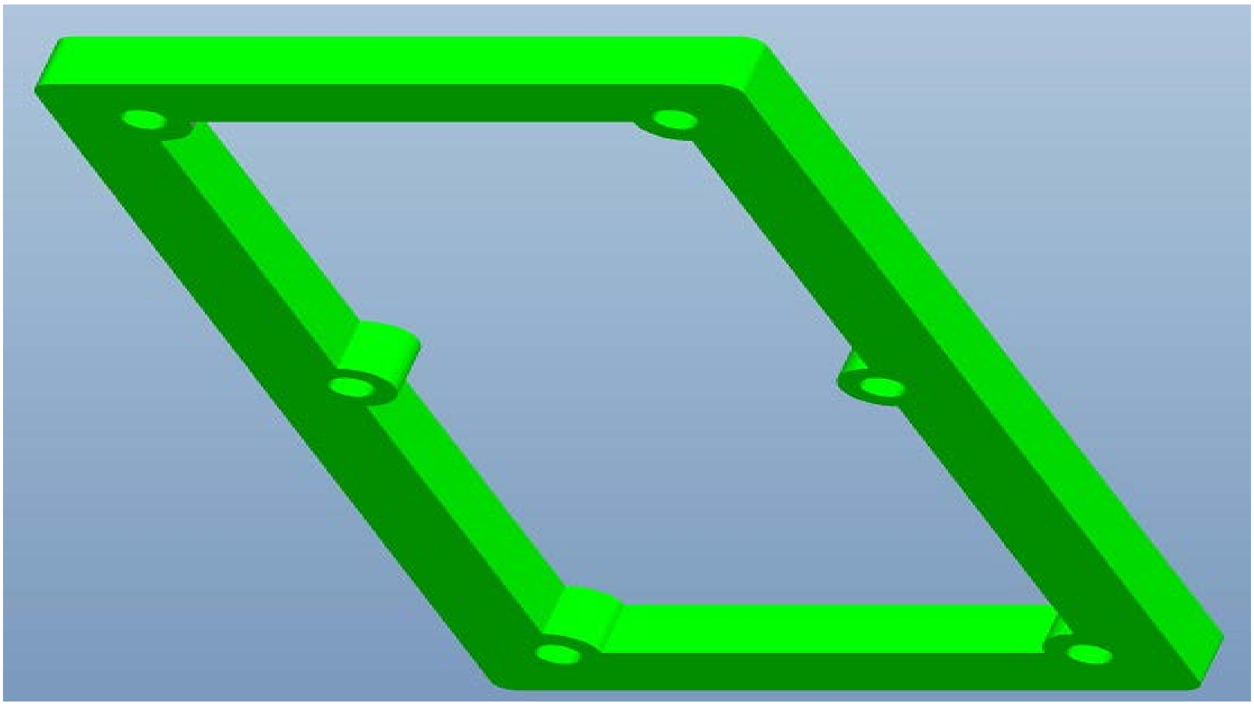
7.2.3 3-D Modeling of Bracket

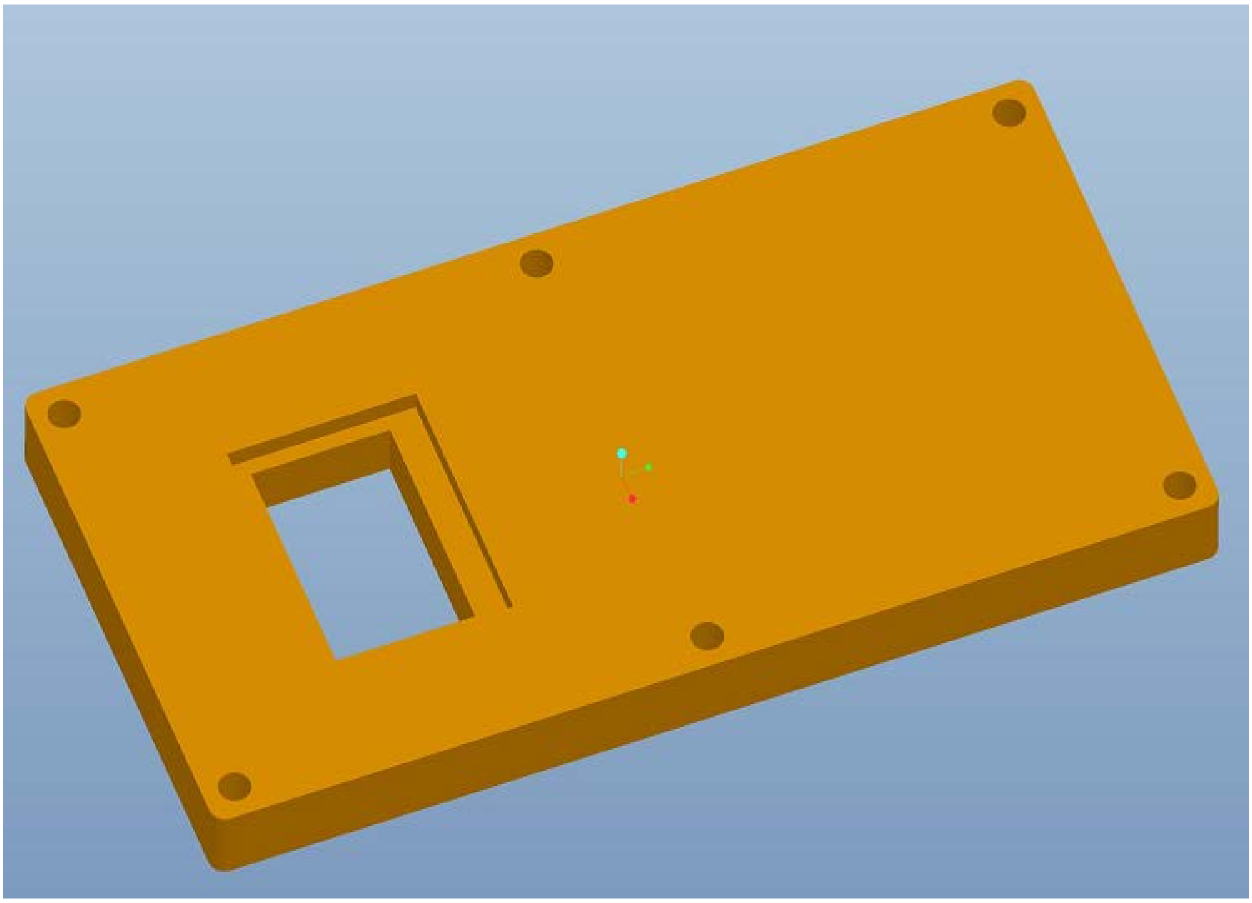
Bracket will attach on the face of the Cold Finger Design. The bracket contains the photovoltaic cell. The placement of photovoltaic cell is such that light will directly fall on the photovoltaic cell. The bracket contains one photovoltaic cell at a time. The below diagram shows its position near to cold finger.



7.2.4 3-D modeling of Chamber upper surface

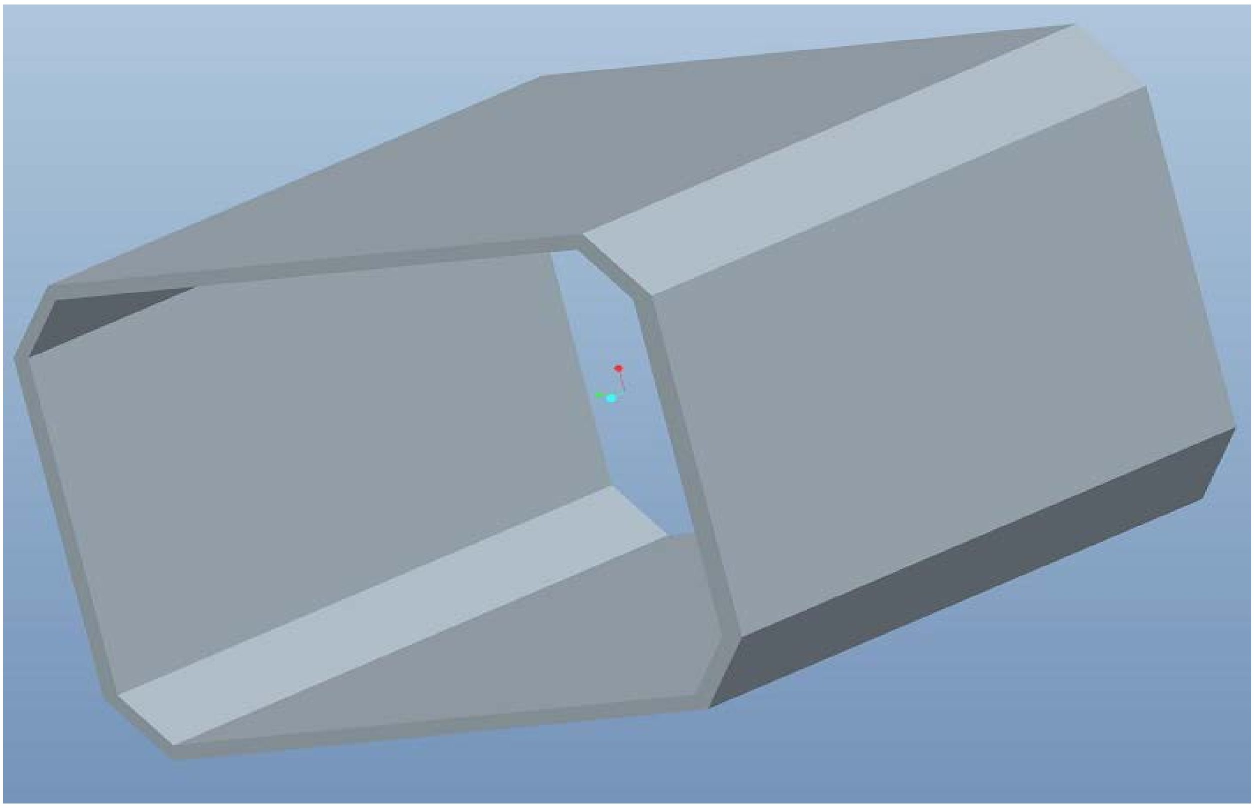
The upper surface of testing chamber has a mirror. The light will directly fall from this mirror towards photovoltaic cell, which is placed in bracket.





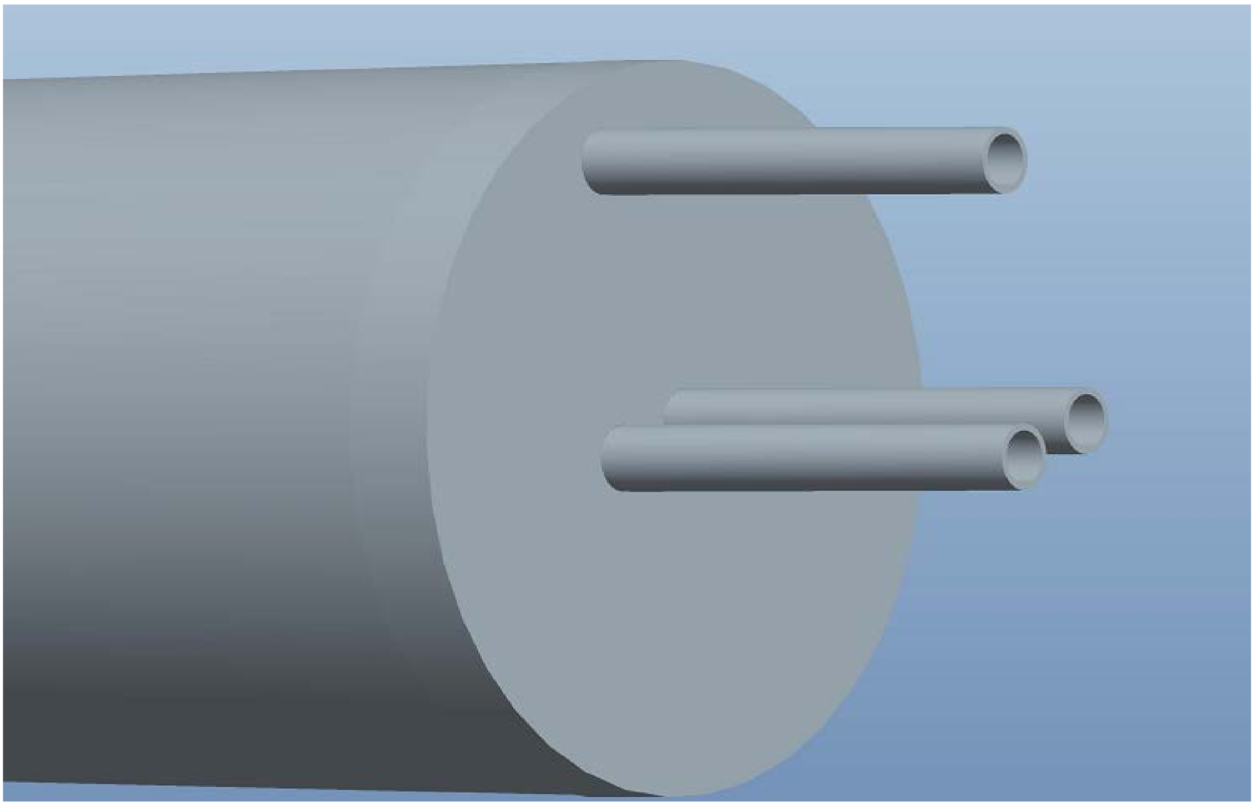
7.2.4 3-D modeling of heat exchanger mounting element

The heat exchanger and heating element are placed in this model. This model is shown below.



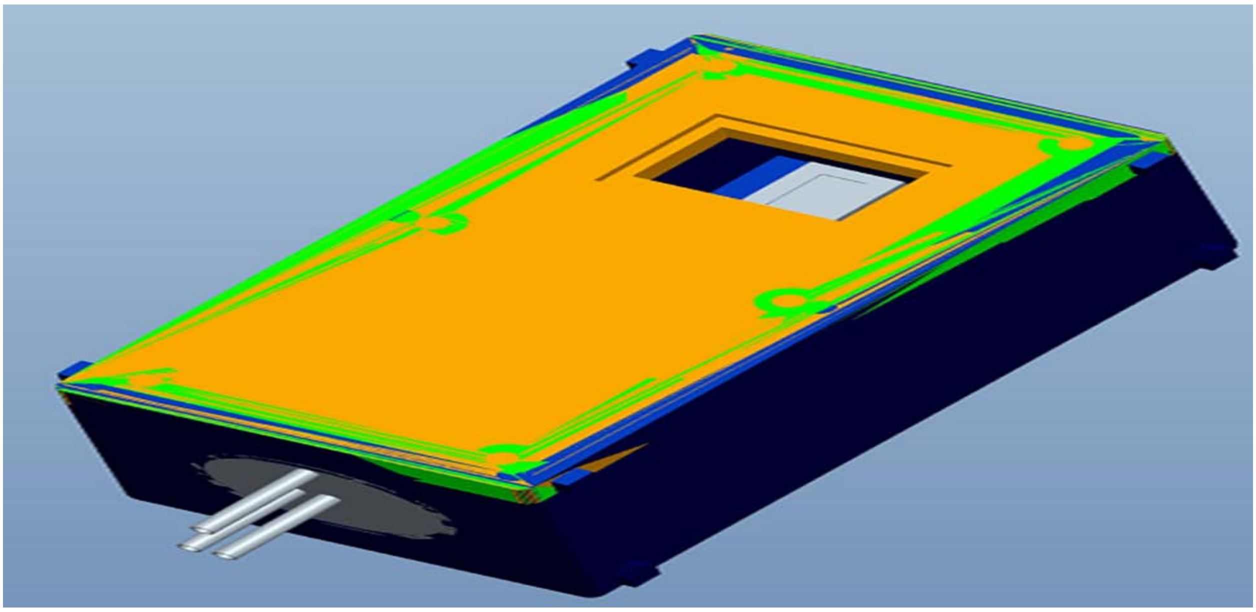
7.2.5 3-D modeling of stainless steel pipes for nitrogen flow

The two stainless steel pipes are directly attached to the nitrogen container to maintain nitrogen flow inside and outside chamber. The above pipe is made to put out the air bubbles which are made inside nitrogen container.The satinless steel pipes will fix at end face of cold finger design. Th below figure shows position of pipes.



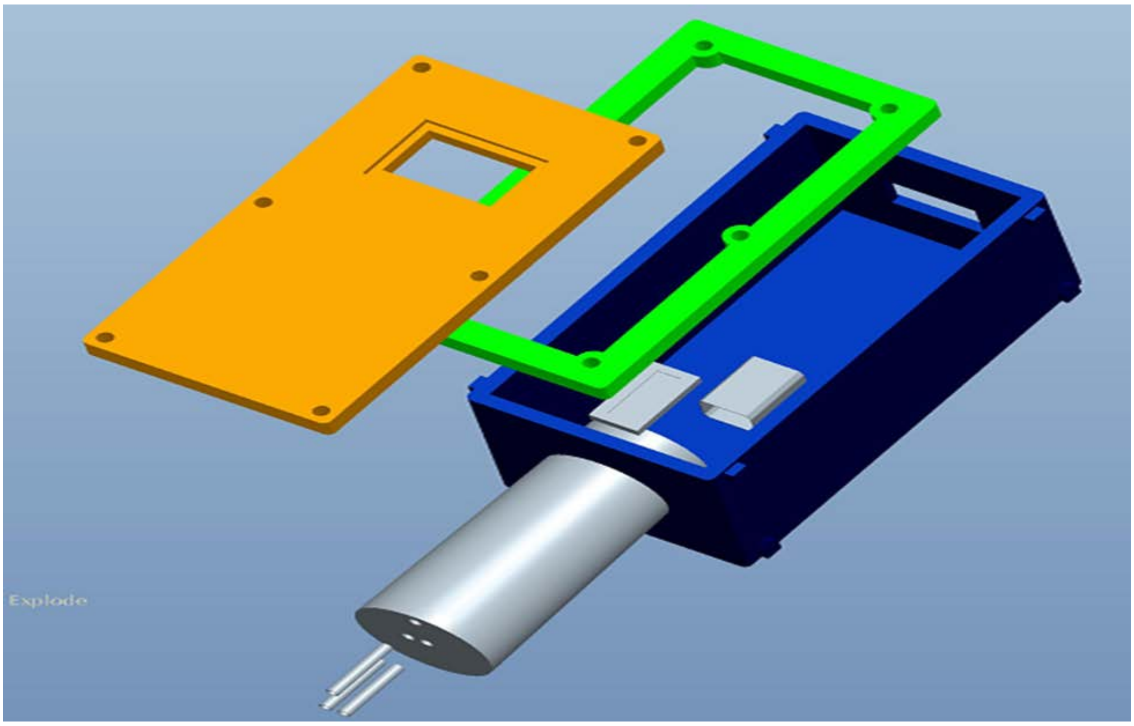
7.3 ASSEMBLY VIEW

The Assembly view of testing chamber shows that how all components of testing chamber are directly linked to each other. The below diagram shows the assembly view of the system.



7.4 EXPLODED VIEW

The exploded view of testing chamber show all components placement which we want to fabricate. The exploded view of testing chamber is shown as below.



7.5 SUMMARY

This chapter shows modeling of environmental testing chamber components. The modeling has been done to fabricate some components of Testing chamber easily. The components will be manufactured from CNC Milling Machine which available in SMME CNC Lab.

Chapter 8

CONCLUSIONS FROM RESEARCH WORK

9.1 REVIEW OF RESEARCH OBJECTIVES

We focused on design considerations of Testing Chamber setup. The heat exchangers calculations have been done to identify require specifications of heat exchanger. The objectives are limited to design and modeling setup of testing chamber. Some components like pressurized air tank, heating element, humidifier.etc will purchased from market for testing chamber. We identified the require materials which are suitable for testing chamber. The most important design is the design of cold finger. The cold finger will use to maintain low temperature inside chamber. With help of design consideration, we can find out the controlled parameters require by means of sensors and actuators. The liquid nitrogen container is placed inside cold finger design. Two testing methods are used to test photovoltaic cell. The photovoltaic cell would be tested to check corrosion and interconnect brakes in the cell. The photodiode will also use after manufacturing of Testing chamber to find out efficiency of photovoltaic cell. With help of Photodiode, we can first investigate efficiency of photovoltaic cell prior to testing. After various testing like humidity freeze test and damp heat test, photodiode again use to test various photovoltaic cell efficiency. The testing chamber is suitable for testing of any kind of Photovoltaic Cell.

9.2 MAJOR CONCLUSIONS OF RESEARCH STUDY

The design is used to test photovoltaic cell defects. We will inspect corrosion resistance and interconnect brakes in cell. We can use Environmental Testing Chamber to test Photovoltaic devices prior to use. The means of evaluating is to find out the reliability and exact life time of photovoltaic cell. The main purpose is to lower the errors in Photovoltaic devices prior to use or Manufacturing. We can find out exact efficiency of photovoltaic cell with help of various tests to perform inside chamber. We can find out, in how much time, PV cell is able to perform work with maximum efficiency. This is main purpose of testing Photovoltaic cell. During design, heat exchanger calculations are determined to identify heat exchanger’s require length and require heat transfer requirement. During design, main concentration is on cold finger design which contains nitrogen container which contain liquid nitrogen to flow inside chamber. We are not focused on controlled system which is require to vary temperature, pressure and humidity limitations. The photodiode will also use after manufacturing of testing chamber to find out efficiency of photovoltaic cell. With help of Photodiode, we can first investigate efficiency of photovoltaic cell prior to testing.

9.3 FUTURE RECOMMENDATIONS

We will manufacture a testing chamber by taking help of this design. We can enhance capacity of testing chamber by testing photovoltaic cells more than 1.The control system of testing chamber with sensors and actuators will made by taking consideration of this System. The Pressurized Air Tank is placed in outside environment. Some kind of nozzle pipe will use to maintain required pressure inside testing chamber. External Environment will not affect towards internal environment by using good fixing of pressurized Air Tank nozzle.

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[13] (Frank P. Incropera & David P. DeWitt) Fundamentals of Heat and Mass Transfer-Fifth Edition, Chapter 11 Heat Exchangers)

[14] (Frank P. Incropera & David P. DeWitt) Fundamentals of Heat and Mass Transfer-Fifth Edition, Chapter 8 Newton's Law of Cooling

[15] http://www.engineeringtoolbox.com/dry-air-properties-d_973.html

[16] THERMOTRON-Solar PV Testing (A White Paper)- July 2010 [4]

CRITIQUE:

1. This is a generalized type chamber and this chamber is not subjected to test photovoltaic devices. This chamber is only focused on control of temperature and airflow with automatic control.

2. The paper is the two decade old research for testing analysis for photovoltaic devices, but, gives good information for basic understanding of photovoltaic modules testing procedure. 1996. (National Renewable Energy Laboratory, Golden, CO, USA.)

3. The paper is the old one research and not discussed effects of other parameters like humidity effects, Pressure Effects.etc.

4. The white paper focuses on Photovoltaic panels but not on Photovoltaic cells but it is advantageous for basic knowledge to design Environmental testing chamber for Testing Photovoltaic devices.

5. The paper describes only effects of organic and polymeric type PV devices. The other types like Inorganic type PV devices are not discussed.

6. The paper focuses on sunlight limitations on different parts of world with respect to time

7. The paper gives good technical assessment data for accelerated parameters (Stress, Time) and ageing life with respect to light soaking effects but discussion is only limited to thin film PV modules.

8. The paper more focuses on friction inside heat exchanger, but, we cannot take generalized overview for cold finger design.

9. Article only focuses on organic type photovoltaic devices. Besides this, the degradation mechanism experimented by varying some parameters i.e. voltage, humidity but not all.

10. The Literature focus on multiple testing methods to evaluate the accuracies of conversion efficiency principle of organic solar cells only. Various types of testing chamber are used with various controlled conditions but not focused on a single testing setup.

11. The article not concentrates on other parameters to generate inside chamber other than irradiance level.

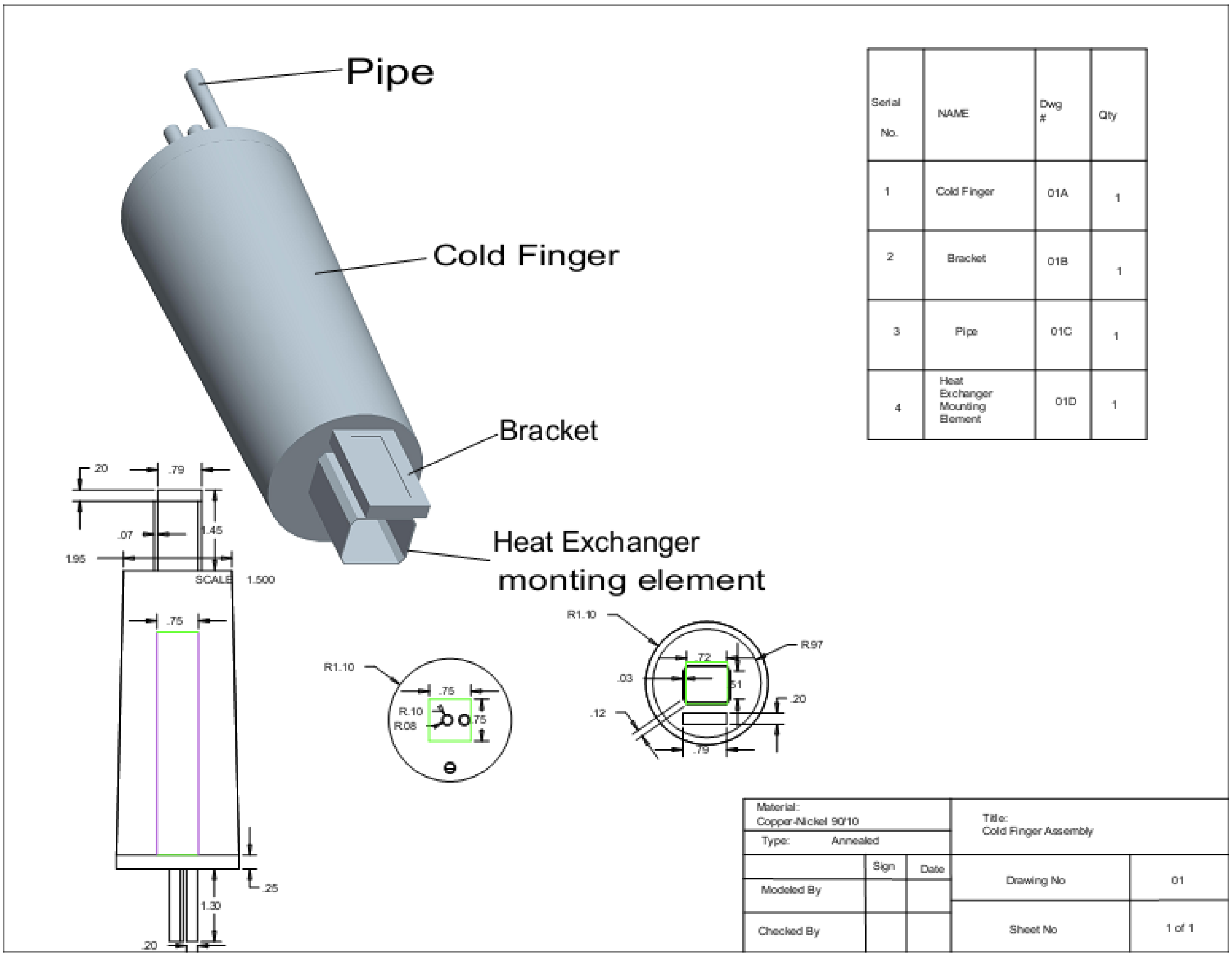
12. The controlled temperature is not maintained in this chamber like humidity, pressure.

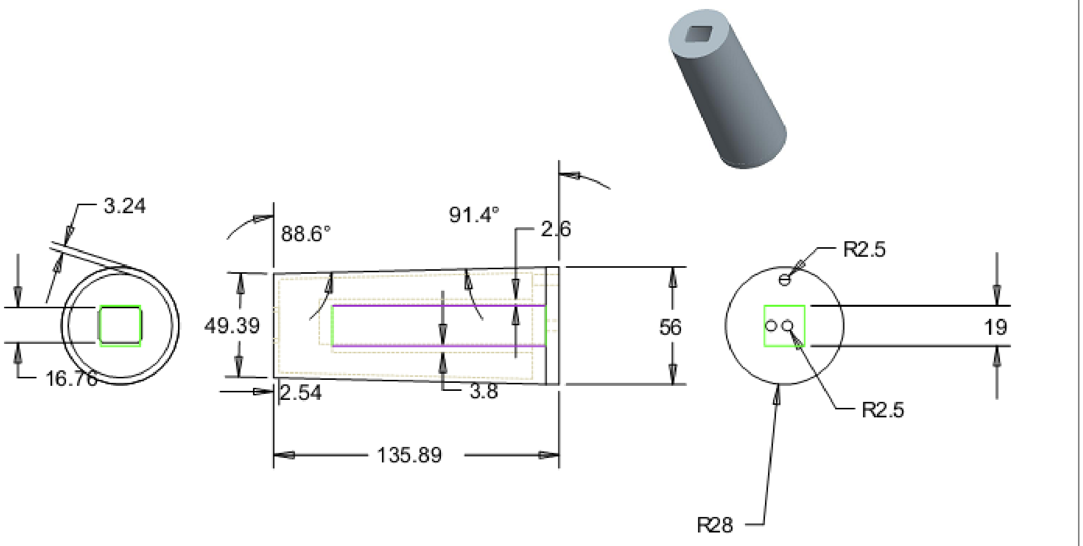
APPENDIX A

DRAWINGS

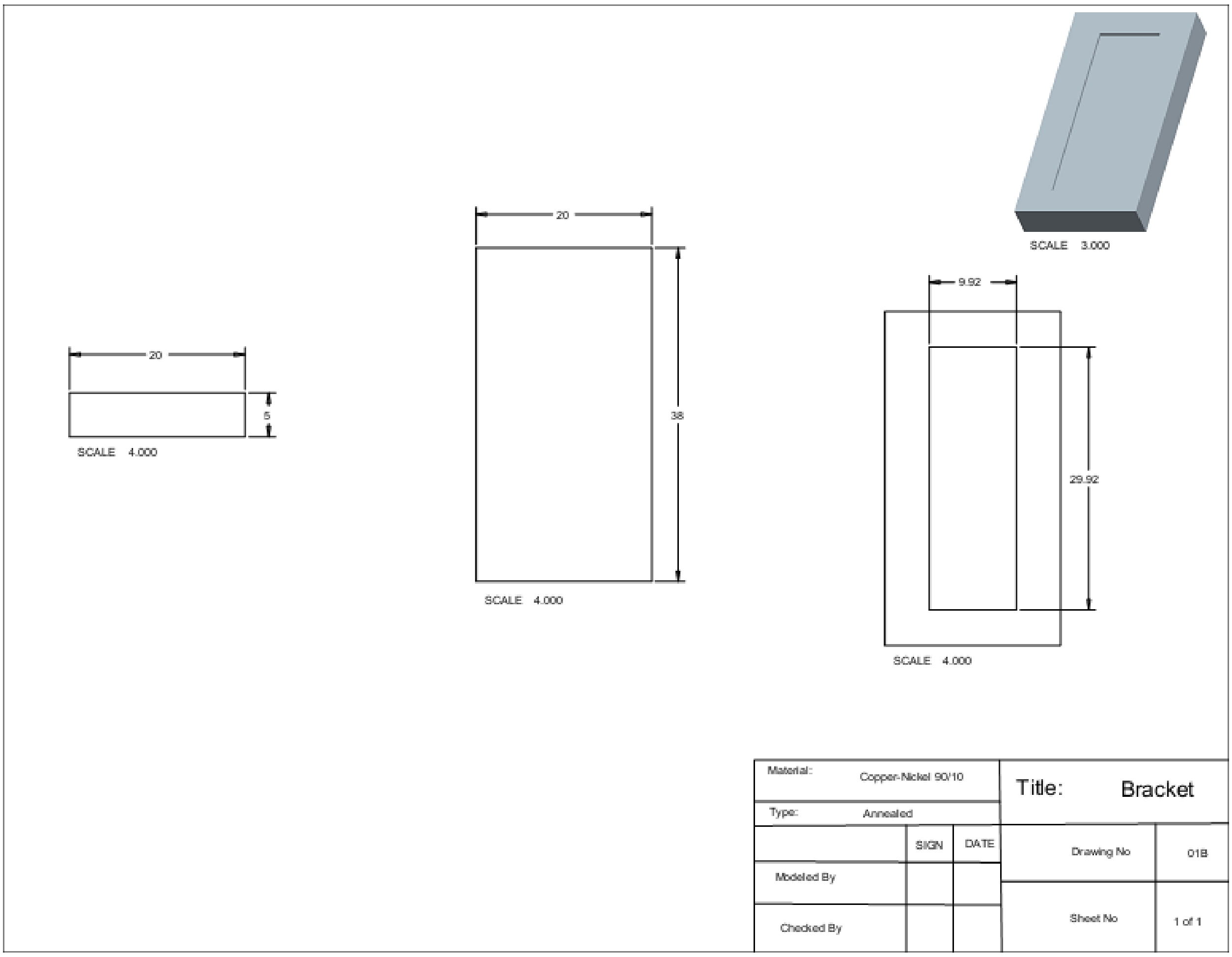
The dimensions are in mm.

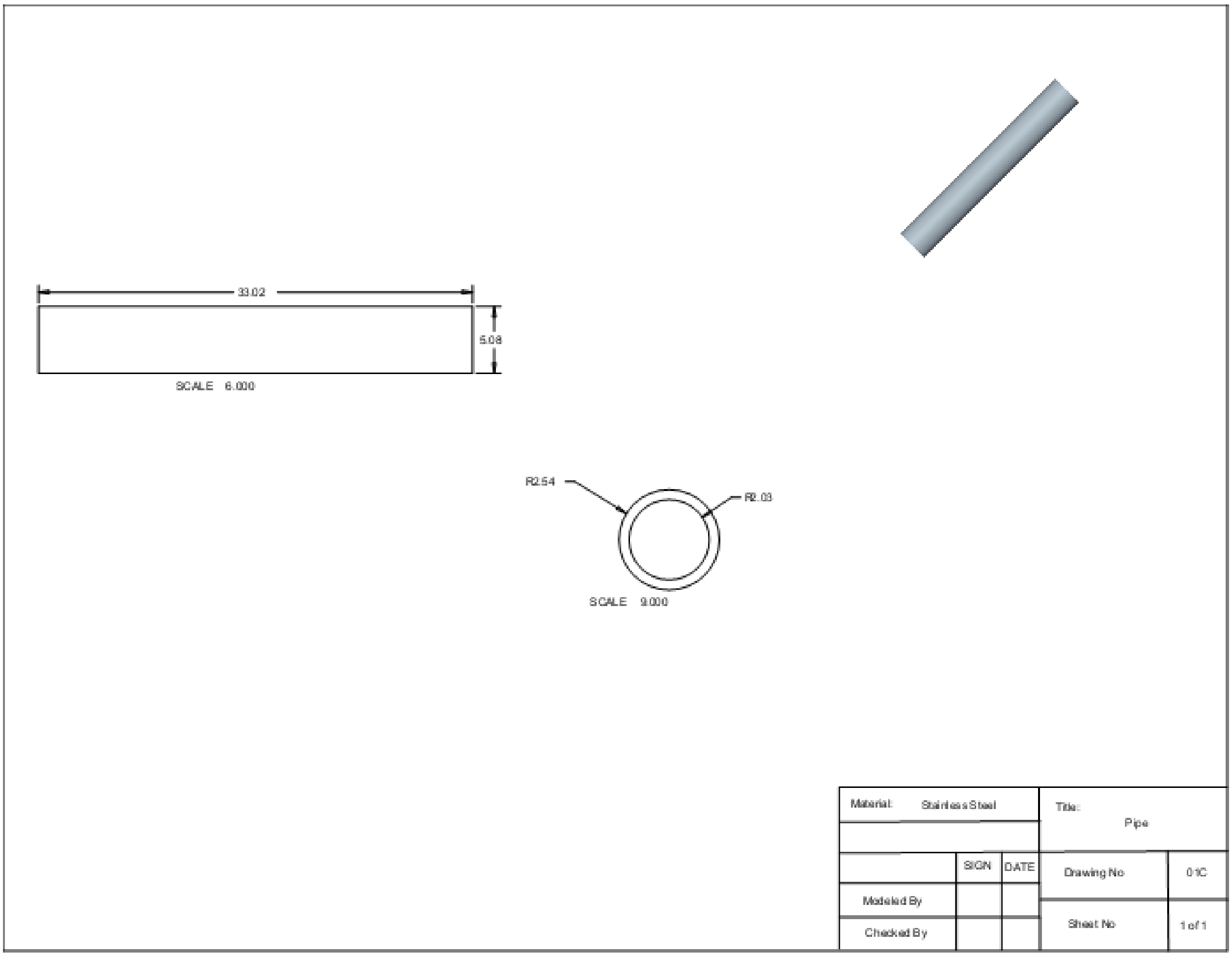
COLD FINGER DRAWING



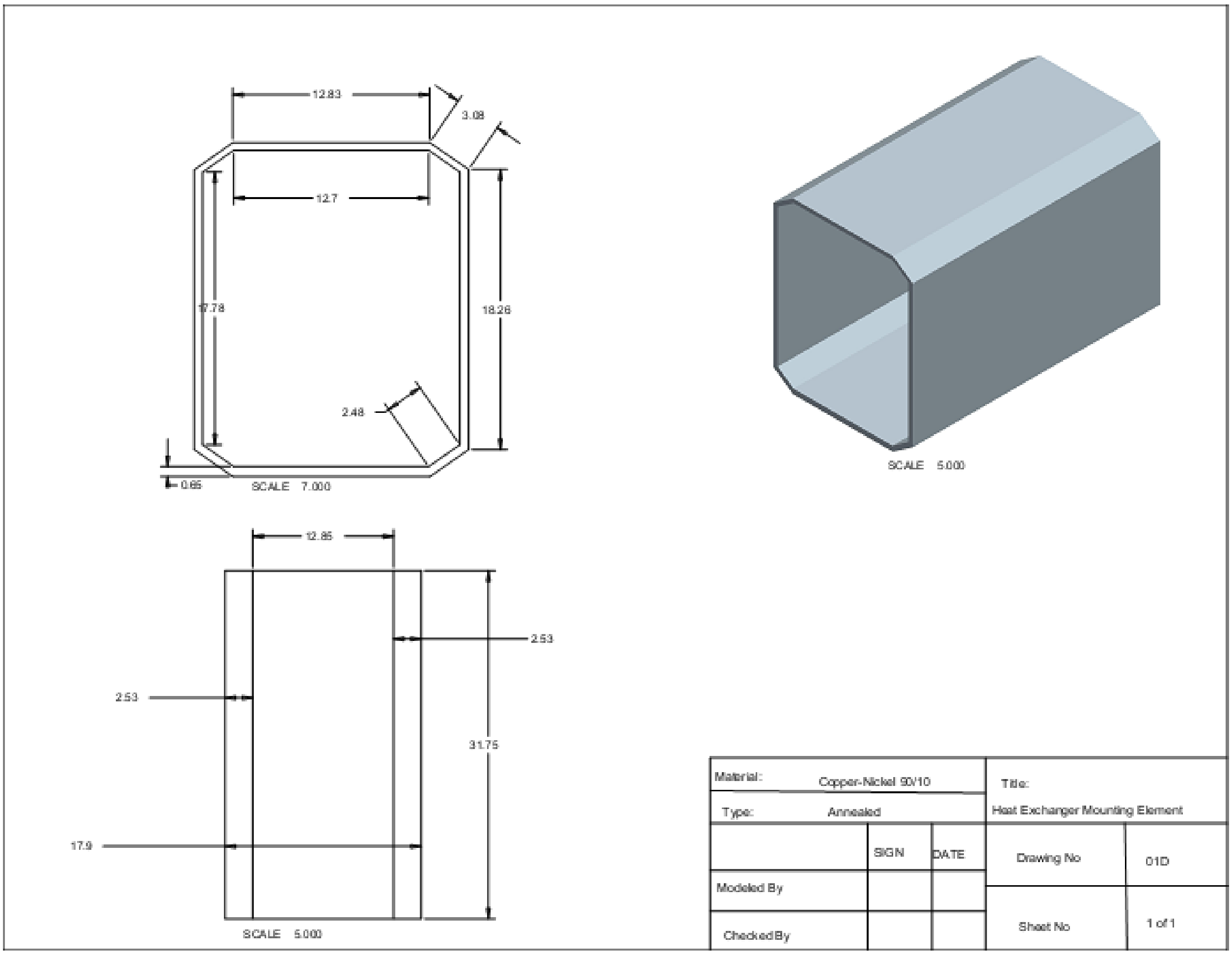


Material:: Copper-Nickel 90/10			Title: Cold Finger	
Type: Annealed				
	SIGN	DATE	Drawing No	01A
Modeled By			Sheet No	1 of 1
Checked By				

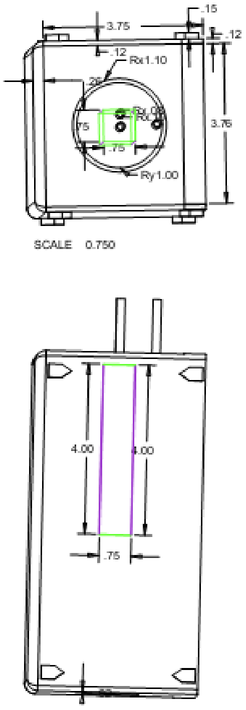

20
5
SCALE 4.000
20
38
SCALE 4.000
9.92
29.92
SCALE 4.000
SCALE 3.000
Material: Copper-Nickel 90/10
Type: Annealed
SIGN
DATE
Modeled By
Checked By
Title: Bracket
Drawing No 01B
Sheet No 1 of 1



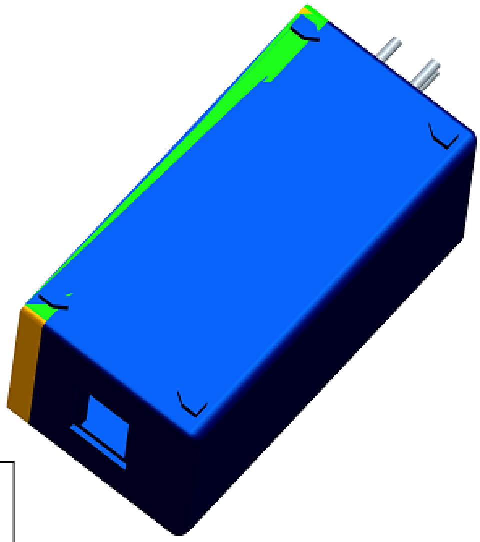
33.02
5.08
SCALE 6.000
R2.54
R2.03
SCALE 9.000
Material: Stainless Steel
SIGN
DATE
Modeled By
Checked By
Title: Pipe
Drawing No 01C
Sheet No 1 of 1


12.83
3.08
12.7
17.78
18.26
2.48
0.65
SCALE 7.000
SCALE 5.000
12.85
2.53
2.53
31.75
17.9
SCALE 5.000
Material: Copper-Nickel 90/10
Type: Annealed
Title:
Heat Exchanger Mounting Element
SIGN
DATE
Drawing No
01D
Modeled By
Sheet No
1 of 1
Checked By

CHAMBER DRAWING



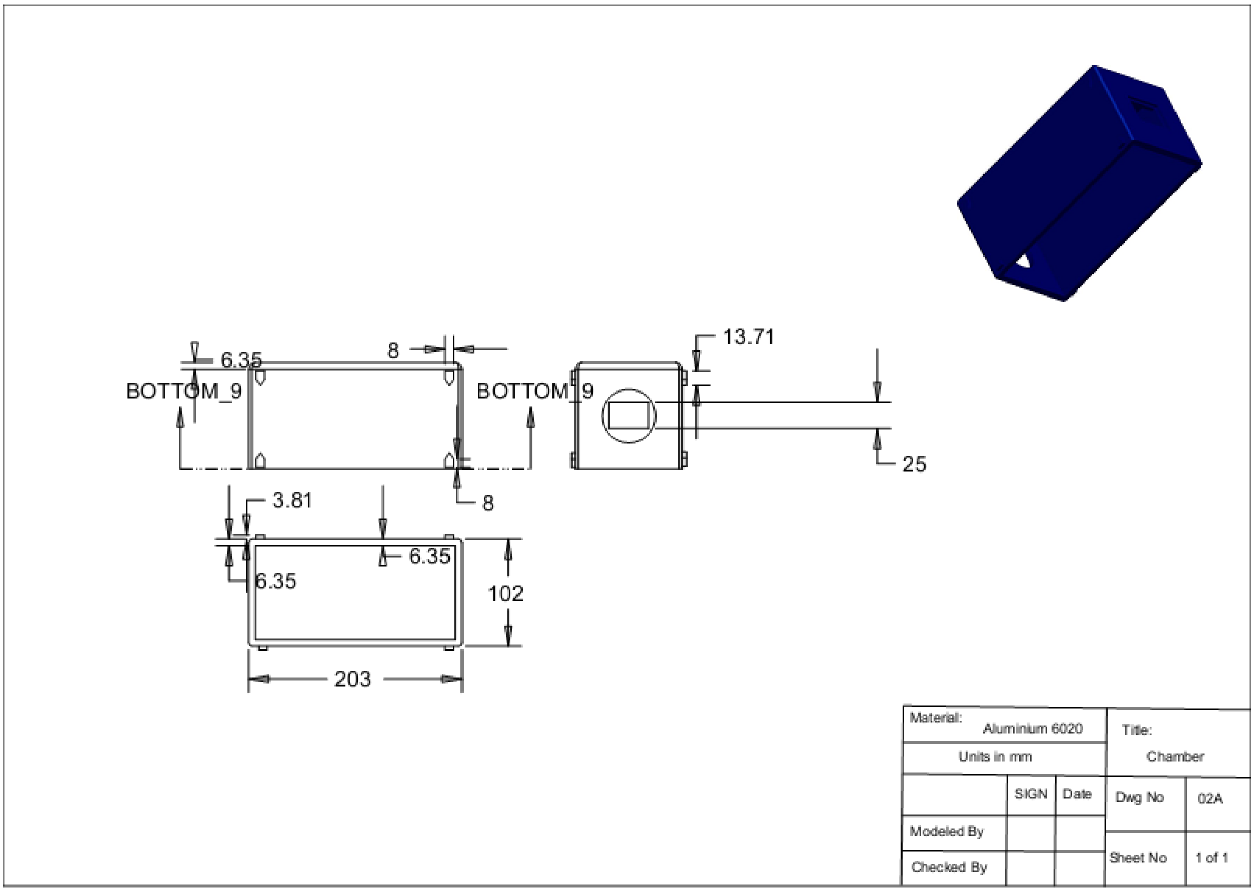
SCALE 0.750



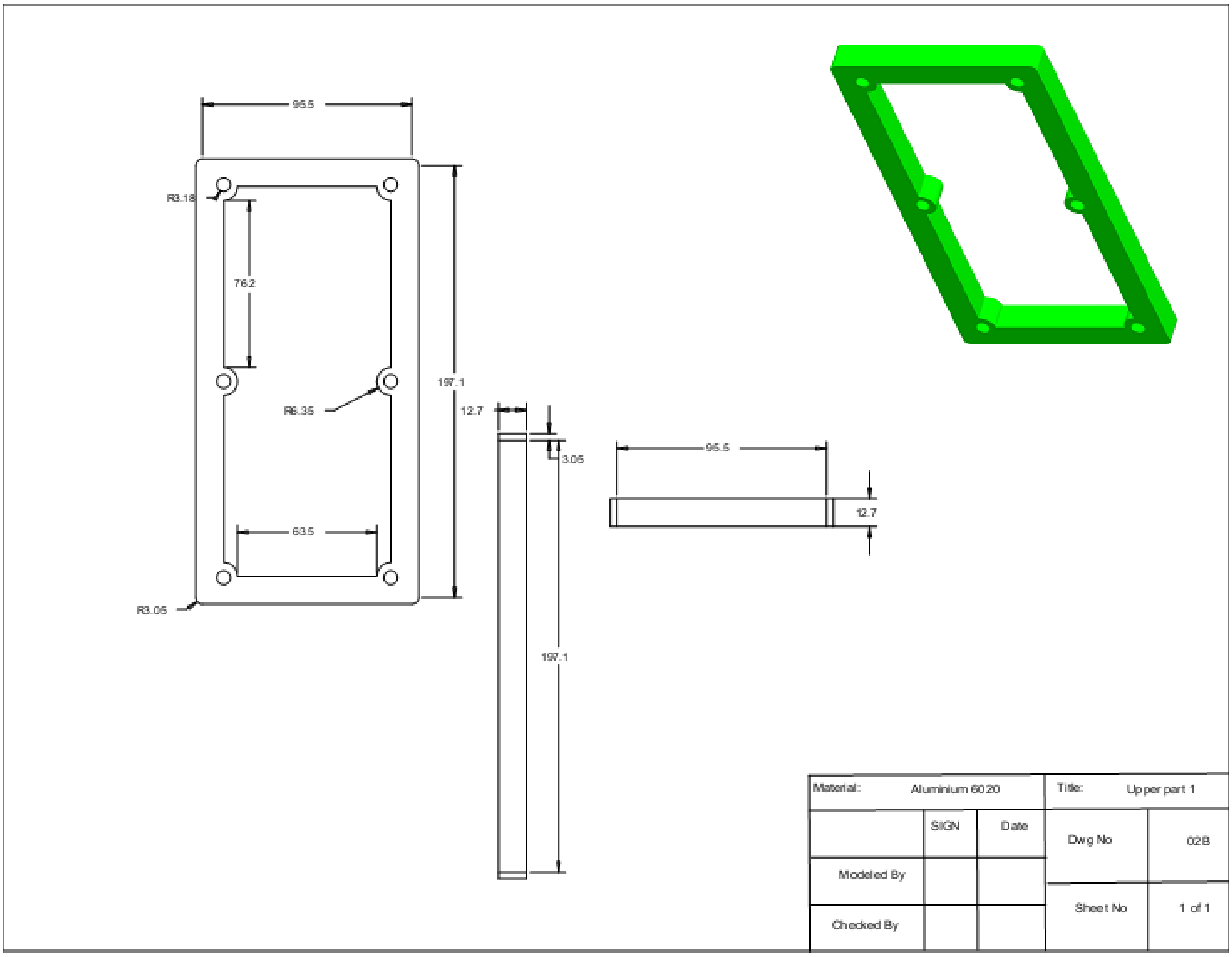
SCALE 1.000

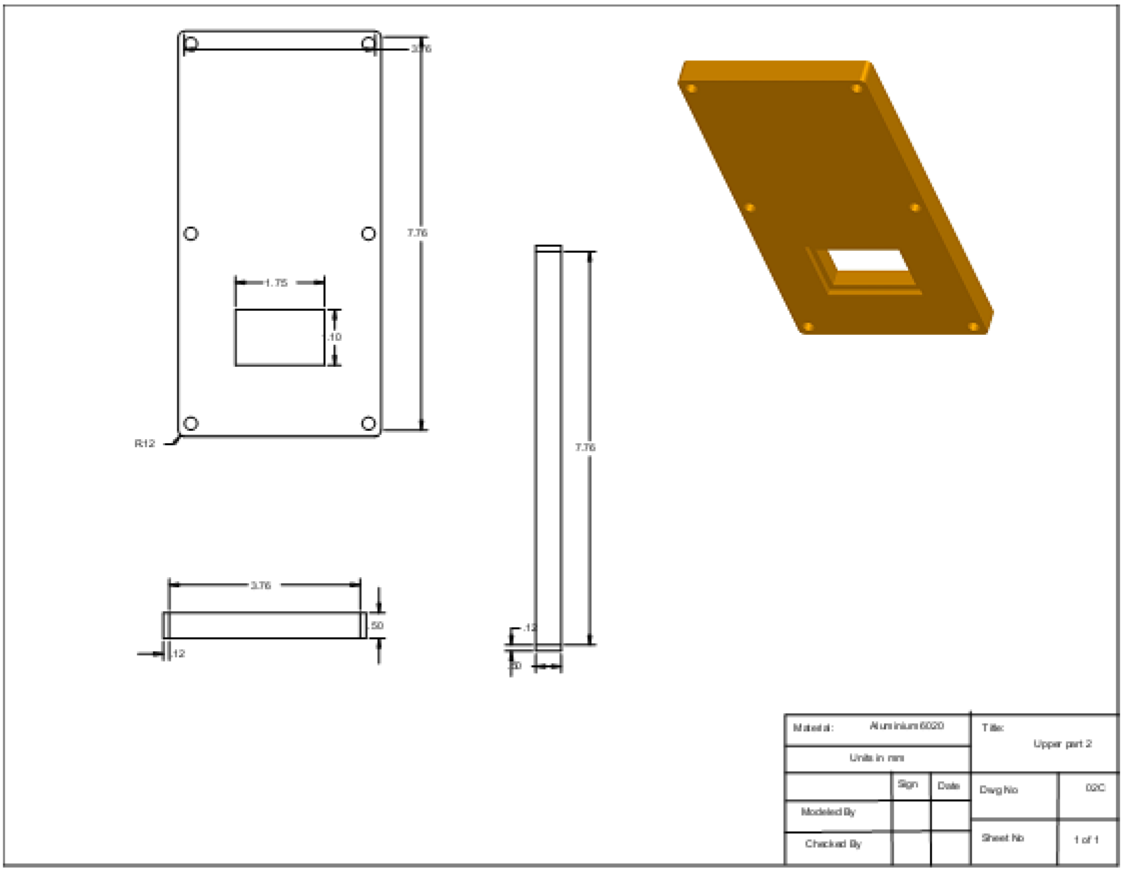
Sr#	Name	Dwg#	Qty
1	Chamber	02A	1
2	Upper part 1	02B	1
3	Upper part 2	02C	1
4	Cold finger	01	1

Material: Aluminium 6020			Title: Chamber Assembly	
Units in mm				
	SIGN	Date	Dwg No	02
Modeled By				
Checked By			Sheet No	1 of 1



6.35
8
BOTTOM_9
BOTTOM_9
13.71
25
8
3.81
6.35
6.35
102
203
Material: Aluminium 6020
Units in mm
Title: Chamber
SIGN
Date
Dwg No 02A
Modeled By
Checked By
Sheet No 1 of 1


95.5
R3.18
76.2
197.1
R6.35
12.7
3.05
95.5
12.7
63.5
R3.05
197.1
Material:
Aluminium 6020
Title:
Upper part 1
SIGN
Date
Dwg No
02B
Modeled By
Checked By
Sheet No
1 of 1


3.76
7.76
1.75
.10
R12
7.76
3.76
.50
.12
.12
Material:
Aluminium 6020
Title:
Upper part 2
Units in mm
Sign
Date
Dwg No
02C
Modeled By
Checked By
Sheet No
1 of 1